Seventeenth Marcel Grossmann Meeting

Sunday, 7 July 2024 - Friday, 12 July 2024

Aurum, the ‘Gabriele d’Annunzio’ University and ICRANet

Book of Abstracts

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Probing deviations to Kerr geometry with extreme mass-ratio inspirals

Author: Shailesh Kumar[1]

[1] *Indian Institute of Technology Gandhinagar*

Corresponding Author: shaileshkumar.1770@gmail.com

One of the primary research aims of the Laser Interferometer Space Antenna (LISA) mission is to comprehensively map the Kerr spacetime, a fundamental pursuit in the realm of general relativity. To achieve this goal, it is essential to develop precise tools capable of discerning any deviations from the Kerr geometry. Extreme mass-ratio inspirals (EMRIs) stand out as particularly promising sources for probing the spacetime metric, offering profound insights into the gravitational phenomena. In this direction, we analyze a deformed Kerr geometry, being the central source of an EMRI system, with an inspiralling object that exhibits eccentric equatorial motion. We conduct a leading order post-Newtonian analysis and examine the deviations in gravitational wave fluxes and phase, emerging at two post-Newtonian order. Our findings evaluate the detectability of these deviations through gravitational wave dephasing, highlighting the pivotal role of LISA observations in advancing our understanding of spacetime geometry.

Wormholes, energy conditions and time machines / 2

Harmonic Oscillator with Time as a Dynamical Variable

Author: Hou Yau[1]

[1] *San Francisco State University*

Corresponding Author: hyau@mail.sfsu.edu

We find that a field with oscillations of matter in proper time has the properties of a zero-spin bosonic field. A particle observed in this field is a proper time oscillator. Neglecting all quantum effects, a proper time oscillator can mimic a point mass at rest in general relativity. The spacetime outside a 'stationary' proper time oscillator is a Schwarzschild field.

First stars and their remnants as dark matter probes / 3

The Identification of Supermassive Dark Star Candidates in JWST Data

Author: Jillian Paulin[1]

Co-authors: Katherine Freese [2]; cosmin ilie

[1] *University of Pennsylvania*

[2] *University of Texas- Austin*

Corresponding Author: jpaulin@sas.upenn.edu

Early James Webb Space Telescope (JWST) observations defied expectations from the standard ΛCDM model of cosmology. There is an overabundance of very massive, high-redshift galaxies and quasars when the universe was only a few hundred million years old. Supermassive Dark Stars (SMDS) offer a potential solution to this paradox. They are candidates for the first stars in the universe, alongside

Population III stars. SMDS are distinguished from Population III stars in that they are cooler and much puffier, and are powered by dark matter (DM) annihilations rather than nuclear fusion. SMDS can grow to be 10 million times the mass of the sun, and shine 1 billion times as bright as the sun. At the end of their lives, SMDS directly collapse into black holes, offering an explanation for the surprising amount of high-redshift quasars observed. We have identified the first SMDS candidates from the JWST Advanced Deep Extragalactic Survey (SMDS): JADES-GS-z13-0, JADES-GS-z12-0, and JADES-GS-z11-0.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 4

On the uniqueness of ΛCDM-like evolution for homogeneous and isotropic cosmology in General Relativity

Authors: B. Mishra[None]; Daniele Gregoris[1]; Saikat Chakraborty[None]

[1] *Jiangsu University of Science and Technology*

Corresponding Author: danielegregoris@libero.it

The Λ-ColdDarkMatter model, despite being in well agreement with many observational datasets at the background level, exhibits a growth of perturbations troubled by some inconsistencies: the H_0 and σ_8 tensions. Adopting a theoretical perspective, this opens the question about the possibility of having a cosmological model, based on other than a cosmological constant and a pressureless dark matter degrees of freedom, whose background cosmic history is as in ΛCDM. Tuning the novel degrees of freedom can potentially resolve the issues arising at the perturbation level. Therefore, in my talk I will discuss some models with cosmographic jerk parameter j=1 all along their evolutions (as from the statefinder diagnostic, this is enough for reproducing the ΛCDM at the background level, but for very specific models with deceleration parameter q=1/2). Our class of models will be based on interactions in the dark sector in which dark energy is accounted for by either a non-ideal fluid or a canonical scalar field, while we maintain the assumptions of general relativity as the gravitational theory, and of homogeneity and isotropy as in the usual Friedman scenario. By applying dynamical system techniques, I will show that coupled fluid-fluid models with non-phantom fluids or coupled quintessence models with power law and exponential potentials can never reproduce a cosmological evolution similar to that of the ΛCDM. Hence, assuming those tensions to be a genuine manifestation of some cosmological effects, we may need to resolve them by invoking some different extensions of the current standard model. My talk will be based on Phys. Lett. B 842 (2023) 137962, 2208.04596 [gr-qc].

Dark matter detection / 5

Who knows what dark matter lurks in the heart of M87: The shadow knows, and so does the ringdown.

Authors: Ramin Daghigh[1]; Gabor Kunstatter[2]

[1] *Metropolitan State University*

[2] *University of Winnipeg*

Corresponding Author: ramin.daghigh@metrostate.edu

We calculate the effect of dark matter on the ringdown waveform and shadow of supermassive black holes at the core of galaxies. Our main focus is on the supermassive black hole at the core of M87, which is large enough to allow for viable observational data. We compare the effects of a dark matter spike to those expected from a galactic halo of the same mass. Our calculation for the halo starts from the Hernquist density function and assumes anisotropic pressure that is zero in the radial direction. The resulting Tolman-Oppenheimer-Volkoff equations allow the corresponding metric to be obtained analytically in closed form. The geometry of the anisotropic dark matter spike is the same as that obtained in [ApJ 940 33 (2022)] under the assumption of isotropy. The effect of the spike is orders of magnitude more significant than the halo as long as the distribution scale of the latter is within a few orders of magnitude of the value expected from observations. Our results indicate that the impact of the spike surrounding M87* on the ringdown waveform may in principle be detectable. Finally, we point out the somewhat surprising fact that existing Event Horizon Telescope observations of black hole shadows are within an order of magnitude from being able to detect, or rule out, the presence of a spike.

Gravitational instantons and black holes / 6

Calculating quasinormal modes of extremal and non-extremal Reissner-Nordström black holes with the continued fraction method

Authors: Jodin Morey[1]; Ramin Daghigh[2]; Michael Green[2]

[1] *University of Minnesota*

[2] *Metropolitan State University*

Corresponding Author: ramin.daghigh@metrostate.edu

We use the numerical continued fraction method to investigate quasinormal mode spectra of extremal and non-extremal Reissner-Nordström black holes in the low and intermediate damping regions. In the extremal case, we develop techniques that significantly expand the calculated spectrum from what had previously appeared in the literature. This allows us to determine the asymptotic behavior of the extremal spectrum in the high damping limit, where there are conflicting published results. Our investigation further supports the idea that the extremal limit of the non-extremal case, where the charge approaches the mass of the black hole in natural units, leads to the same vibrational spectrum as in the extremal case despite the qualitative differences in their topology. In addition, we numerically explore the quasinormal mode spectrum for a Reissner-Nordström black hole in the small charge limit.

Black hole formation, evolution and the black hole mass gap / 7

New instanton on a warped Kerr spacetime

Author: Reinoud Slagter[1]

[1] *ASFYON, Astronomisch Fysisch Onderzoek Nederland*

Corresponding Author: info@asfyon.com

We find an exact time-dependent instanton solution on a vacuum Kerr-like warped spacetime in conformal dilaton gravity. The antipodal boundary condition on the hypersurface of a Klein bottle $\sim \mathbb{C}^1 \times \mathbb{C}^1$ is used to describe the Hawking particles. We used the Hopf fibration to get S^2 as the black hole horizon, where the centrix is not in a torus but in the Klein bottle. The twist fits very well with the antipodal identification of the point on the horizon. No "cut and past" is necessary, so the Hawing particles remain pure without instantaneous information transport.
A local observer passing the horizon will not notice a central singularity in suitable coordinates.
The black hole paradoxes are also revisited in our new black hole model.
A connection is made with the geomeric quantization of $\mathbb{C}^1 \times \mathbb{C}^1 \sim S^3$ by considering the symplectic 2-form.
Remarkably, the metric solution results from a first-order PDE, allowing the connection with self-duality.

The model can be easily extended to the non-vacuum situation by including a scalar field. Both the dilaton and the scalar field can be treated as quantum fields as we approach the Planck era.

Latest results from Galactic center observations / 8

General formulae for the periapsis shift of a quasi-circular orbit in static spherically symmetric spacetimes and the strong energy condition

Authors: Tomohiro Harada[1]; Takahisa Igata[2]; Hiromi Saida[3]; Yohsuke Takamori[4]

[1] *Rikkyo University*

[2] *Gakushuin University*

[3] *Daido University*

[4] *NIT Wakayama*

Corresponding Author: harada@rikkyo.ac.jp

We study the periapsis shift of a quasi-circular orbit in general static spherically symmetric spacetimes. We derive two formulae in full order with respect to the gravitational field, one in terms of the gravitational mass m and the Einstein tensor and the other in terms of the orbital angular velocity and the Einstein tensor. These formulae reproduce the well-known ones for the forward shift in the Schwarzschild spacetime. In a general case, the shift deviates from that in the vacuum spacetime due to a particular combination of the components of the Einstein tensor at the radius r of the orbit. The formulae give a backward shift due to the extended-mass effect in Newtonian gravity. In general relativity, in the weak-field and diffuse regime, the active gravitational mass density, ρA=(ϵ+pr+2pt)/c2, plays an important role, where ϵ, pr and pt are the energy density, the radial stress and the tangential stress of the matter field, respectively. We show that the shift is backward if ρA is beyond a critical value ρc□2.8×10−15g/cm3(m/M□)2(r/a.u.)−4, while a forward shift greater than that in the vacuum spacetime instead implies ρA<0, i.e. the violation of the strong energy condition, and thereby provides evidence for dark energy. We obtain new observational constraints on ρA in the Solar System and the Galactic Centre.

Inflation: perturbations, initial singularities and emergent universes / 9

Revisiting compaction functions for primordial black hole formation

Authors: Tomohiro Harada[1]; Chul-Moon Yoo[2]; Yasutaka Koga[2]

[1] *Rikkyo University*

[2] *Nagoya University*

Corresponding Author: harada@rikkyo.ac.jp

Shibata and Sasaki [Phys. Rev. D 60, 084002 (1999)] introduced the so-called compaction function. Since then, it has been empirically established that the maximum value of this function (or its volume-averaged counterpart) in the long-wavelength solutions gives a very robust threshold of primordial black hole formation. In this paper, we show that in spite of initial intention, the Shibata-Sasaki compaction function cannot be interpreted as the ratio of the mass excess to the areal radius in the constant-mean-curvature slice of their choice but coincides with that in the comoving slice up to a constant factor depending on the equation of state. We also discuss the gauge (in)dependence of the legitimate compaction function, i.e., the ratio of the mass excess to the areal radius, in the long-wavelength solutions.

Black holes in alternative theories of gravity / 10

Banados-Silk-West effect with finite forces near different types of horizons: general classification of scenarios

Authors: Hryhorii Ovcharenko[1]; Oleg Zaslavskii[2]

[1] *V. N. Karazin Kharkiv National University*

[2] *Kharkov V. N. Karazin National University*

Corresponding Author: zaslav@ukr.net

If two particles move towards a black hole and collide in the vicinity of the horizon, under certain conditions their energy Ec.m. in the center of mass frame can grow unbounded. This is the Banados-Silk-West (BSW) effect. Usually, this effect is considered for extremal horizons and geodesic (or electrogedesic) trajectories. We study this effect in a more general context, when both geometric and dynamic factors are taken into account. We consider generic axially symmetric rotating black holes. The near-horizon behavior of metric coefficients is determined by three numbers p, q, k that appear in the Taylor expansions for different types of a horizon. This includes nonextremal, extremal and ultraextremal horizons. We also give general classification of possible trajectories that include so-called usual, subcritical, critical and ultracritical ones depending on the near-horizon behavior of the radial component of the four-velocity. We assume that particles move not freely but under the action of some unspecified force. We find when the finiteness of a force and the BSW effect are compatible with each other. The BSW effect implies that one of two particles has fine-tuned parameters. We show that such a particle always requires an infinite proper time for reaching the horizon. Otherwise, either a force becomes infinite or a horizon fails to be regular. This realizes the so-called principle of kinematic censorship that forbids literally infinite Ec.m. in any act of collision. The obtained general results are illustrated for the Kerr-Newman-(anti-)de Sitter metric used as an example. The description of diversity of trajectories suggested in our work can be of use also in other contexts, beyond the BSW effect. In particular, we find the relation between a force and the type of a trajectory.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 12

Evidence for 3XMM J185246.6+003317 as a massive magnetar with a low magnetic field

Authors: Jaziel Coelho[1]; Jonas Pereira[2]; Rafael de Lima[3]

[1] *UFES*

[2] *Nicolaus Copernicus Astronomical Center (CAMK)*

[3] *Universidade do Estado de Santa Catarina (UDESC)*

Corresponding Author: rafael.lima@udesc.br

3XMM J185246.6+003317 is a transient magnetar located in the vicinity of the supernova remnant Kes\,79. So far, observations have only set upper limits to its surface magnetic field and spindown, and there is no estimate for its mass and radius. Using ray-tracing modelling and Bayesian inference for the analysis of several light curves spanning a period of around three weeks, we have found that it may be one of the most massive neutron stars to date. In addition, our analysis suggests a multipolar magnetic field structure with a subcritical field strength and a carbon atmosphere composition. Due to the time-resolution limitation of the available light curves, we estimate the surface magnetic field and the mass to be $\log_{10}(B/\mathrm{G}) = 11.89^{+0.19}_{-0.93}$ and $M = 2.09^{+0.16}_{-0.09}$~$M_\odot$ at 1σ confidence level, while the radius is estimated to be $R = 12.02^{+1.44}_{-1.42}$ km at 2σ confidence level. They were verified by simulations, i.e., data injections with known model parameters, and their subsequent recovery. The best-fitting model has three small hot spots, two of them in the southern hemisphere. These are, however, just first estimates and conclusions, based on a simple ray-tracing model with anisotropic emission; we also estimate the impact of modelling on the parameter uncertainties and the relevant

phenomena on which to focus in more precise analyses. We interpret the above best-fitting results as due to accretion of supernova layers/interstellar medium onto 3XMM J185246.6+003317 leading to burying and a subsequent re-emergence of the magnetic field, and a carbon atmosphere being formed possibly due to hydrogen/helium diffusive nuclear burning. Finally, we briefly discuss some consequences of our findings for superdense matter constraints.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 13

Shocked advective flows around black holes and associated observational signatures

Authors: Chandra Bahadur Singh[None]; Toru Okuda[1]

Co-author: Ramiz Aktar [2]

[1] *Hokkaido University of Education*

[2] *National Tsing Hua University*

Corresponding Author: chandrasingh@ynu.edu.cn

Low angular momentum flows around black holes are likely to form standing shocks during the accretion processes. The shocks possibly encounter instabilities leading to various observational signatures associated with inflows and outflows. In our work, we address a range of issues like flaring in under-luminous Sgr A* with supermassive black hole and outflow properties in super-accretors like SS 433 and ultraluminous X-ray sources with stellar-mass black holes.

References:

1. T. Okuda , C.B. Singh, R. Aktar, 2023, MNRAS, 522, 1814.
2. T. Okuda , C.B. Singh C.B., R. Aktar, 2022, MNRAS, 514, 5074.
3. C.B. Singh, T. Okuda, R. Aktar, 2021, RAA, 21, 134.
4. T. Okuda, C.B. Singh, 2021, MNRAS, 503, 586.

Theories of gravity: alternatives to the cosmological and particle standard models / 14

Gravity versus Quantum Particle Dynamics

Author: Otto Kong[1]

[1] *National Central University*

Corresponding Author: otto@phy.ncu.edu.tw

The question of compatibility between our theory of gravity, more or less along the line of General Relativity, and basic notions of quantum physics has been a major concern. We focus, in particular, on an exact Weak Equivalence Principle and the notion of the momentum observable for a particle as a vector quantity with an invariant magnitude as given through the metric. Contrary to the problems in the Schr\"odinger wavefunction representation, we give a formalism of quantum mechanics in curved spacetime through the Heisenberg picture, supplemented by a noncommutative geometric perspective, that maintains the features. Quantum particle dynamics should be seen as one on a quantum, noncommutative, geometric model of spacetime with a metric that defines the inner product between vectors as observables as well as the inner product for the vector space of states in the Schr\"odinger picture. Then, quantum gravity is about quantum spacetime. We also

address the Relativity Principle with quantum reference frame transformations.
(Refs: Class. Quantum Grav. 41, 085013; NCU-HEP-k102 to be published;
Results Phys. 31, 105033)

Loop quantum gravity: cosmology and black holes / 15

Status of Birkhoff's theorem in polymerized semiclassical regime of Loop Quantum Gravity

Authors: Jerzy Lewandowski[1]; Luca Cafaro[2]

[1] *Uniwersytet Warszawski*

[2] *University of Warsaw*

Corresponding Author: l.cafaro@uw.edu.pl

The collapse of a spherically symmetric ball of dust has been intensively studied in Loop Quantum Gravity (LQG). From a quantum theory, it is possible to recover a semiclassical regime through a polymerization procedure. In this setting, general solutions to the Polymerized Einstein Field Equations (PEFE) will be discussed both for the interior and the exterior of the dust cloud. Exterior solutions are particularly interesting since they may lead to a semiclassical version of the Birkhoff's theorem. It is seen that if time independence of the vacuum is imposed, there exists a class of solutions depending on two parameters. Nevertheless, the possibility of more intricate time dependent solutions is not ruled out completely.
A second approach to study semiclassical spacetimes is by considering an Oppenheimer-Snyder model. Namely, one glues the portion of spacetime containing dust with the vacuum part by matching the extrinsic curvatures. In this way, one gets a metric tensor for the vacuum which can be compared to the one obtained previously.
Although these two methods are completely independent from each other, the results we obtained are in perfect agreement.

Experimental graviation / 16

Detecting single gravitons with quantum sensing

Authors: Germain Tobar[1]; Sreenath Manikandan[2]; Thomas Beitel[3]; Igor Pikovski[3]

[1] *Stockholm University*

[2] *Nordita*

[3] *Stevens Institute of Technology*

Corresponding Author: germain.tobar@fysik.su.se

The quantization of gravity is widely believed to result in gravitons – particles of discrete energy that form gravitational waves. But their detection has so far been considered impossible, in particular Dyson recently analysed whether observing single graviton exchange between matter and gravitational waves is even possible in principle. Here we show that single graviton exchange can be observed in realistic, albeit challenging laboratory experiments. We show that stimulated and spontaneous single-graviton processes can become relevant for massive quantum acoustic resonators and that stimulated absorption can be resolved through continuous sensing of quantum jumps. In analogy to the discovery of the photo-electric effect for photons, such signatures can provide the first experimental evidence of the quantization of gravity.

Emission mechanisms in gamma-ray bursts / 17

Magnetically dominated outflow in GRB 080916C?

Author: Gregory Vereshchagin[1]

Co-authors: Damien Begue [2]; Liang Li [3]

[1] *ICRANet*

[2] *Bar Ilan University*

[3] *ICRANet, Piazza della Repubblica 10, I-65122 Pescara, Italy*

Corresponding Author: veresh@icra.it

One of the main arguments in favour of magnetically dominated outflows is the absence of photospheric component in their broad-band time-resolved spectra, with such notable example as GRB 080916C. Detection of subdominant thermal component in this GRB is actually consistent with the photosphere of ultrarelativistic baryonic outflow, deep in the coasting regime. Therefore, the magnetic dominance of the outflow is not required for the interpretation of this GRB.

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 18

Tests for the expansion of the Universe

Author: Martín López-Corredoira[1]

[1] *Instituto de Astrofísica de Canarias*

Corresponding Author: martin@lopez-corredoira.com

The standard interpretation of the redshifts of galaxies is that they are due to the expansion of the universe plus peculiar motions, but there are other explanations, such as the "tired light" hypothesis, which assumes that the photon loses energy owing to some unknown photon-matter process or photon-photon interaction when it travels some distance. Different observational tests give different results, although none of them so far provides a strong proof in favour of a static universe. The discussion on anomalous redshifts is also inconclusive.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 19

Underestimation of Hubble constant error bars: a historical analysis

Author: Martín López Corredoira[1]

[1] *Instituto de Astrofísica de Canarias*

Corresponding Author: martin@lopez-corredoira.com

The aim of this analysis of a historical compilation of Hubble-Lemaître constant (H0) values in the standard cosmological model is to determine whether or not the stated error bars truly represent the dispersion of values given. For this analysis, a chi-squared test was executed on a compiled list of past measurements. It was found through statistical analyses of the data (163 data points measured between 1976 and 2019), that the chi^2 values (between 480.1 and 575.7) have an associated

probability that is very low: Q = 1.8E-33 for a linear fit of the data vs. epoch of measurement and Q = 1.0E-47 for the weighted average of the data. This means that either the statistical error bars associated with the observed parameter measurements have been underestimated or the systematic errors were not properly taken into account in at least 15-20% of the measurements.

The fact that the underestimation of error bars for H0 is so common might explains the apparent 4.4-sigma discrepancy formally known today as the Hubble tension. Here we have carried out a re-calibration of the probabilities with the present sample of measurements and we find that x-sigmas deviation is indeed equivalent in a normal distribution to the x_eq.sigmas deviation, where x_eq. =0.83x^0.62. Hence, the tension of 4.4-sigma, estimated between the local Cepheid-supernova distance ladder and cosmic microwave background (CMB) data, is indeed a 2.1-sigma tension in equivalent terms of a normal distribution, with an associated probability P(> x_eq.) = 0.036 (1 in 28). This can be increased to an equivalent tension of 2.5-sigma in the worst cases of claimed 6-sigma tension, which may in any case happen as a random statistical fluctuation.

Theories of gravity: alternatives to the cosmological and particle standard models / 20

Alternative cosmologies

Author: Martín López Corredoira[1]

[1] *Instituto de Astrofísica de Canarias*

Corresponding Author: martin@lopez-corredoira.com

The present-day standard model of cosmology, Lambda-CDM, gives us a representation of a cosmos whose dynamics is dominated by gravity (general relativity) with a finite lifetime, large scale homogeneity, expansion and a hot initial state, together with other dark elements necessary to avoid certain inconsistencies with observations. There are however some models with characteristics that are close to those of the standard model but differing in some minor aspects: different considerations on CP violation, inflation, number of neutrino species, quark-hadron phase transition, baryonic or non-baryonic dark-matter, dark energy, nucleosynthesis scenarios, large-scale structure formation scenarios; or major variations like an inhomogeneous universe, Cold Big Bang, varying physical constants or gravity law, different solutions of Friedmann-Lemaître-Robertson-Walker like zero-active mass (also called "R_h=ct") and Milne, and cyclical models, the more distant quasi-steady-state cosmology, plasma cosmology, or universe models as a hypersphere, to the most exotic cases including static models with non-cosmological redshifts of galaxies.

None of the alternative models has acquired the same level of development as Lambda-CDM in offering explanations of available cosmological observations. One should not, however, judge any theory in terms of the number of observations that it can successfully explain (ad hoc in many cases) given the much lower level of development of the alternative ones.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 21

The cosmological observations for a novel and efficient model of dark energy

Author: Tonatiuh Matos[1]

[1] *Centro de Investigación y de Estudios Avanzados del IPN*

Corresponding Author: tonatiuh.matos@cinvestav.mx

It is a fact that the universe lives on a gravitational wave background (GWB), which is extra space–time energy that is not contained in Einstein's field equations. In a previous work, this energy is

treated as a property of space–time and not as a source. With this in mind, a new model was developed that incorporates this energy to explain the current accelerated expansion of the universe where the GWB was incorporated by extending Einstein's equations to $R - 1/2Rg + (2\pi^2/\lambda^2)g = {}^2T$, where λ is the Compton wavelength of the cosmological scale graviton. In the present talk, we show that this extended form agrees very well with the observations of cosmic chronometers, baryon acoustic oscillations, and Pantheon SN Type Ia, reproducing the observational data with a $\Delta\chi^2 = 3.26$ in favour of the current model compared to the ΛCDM. The favoured values by these observations are $\Omega_m = 0.311 \pm 0.065$, $H_0 = 68.3 \pm 1.4 km\, s^{-1} Mpc^{-1}$, and $\Omega_k = 0.001 \pm 0.011$. We also find that this model fits excellently with the observed cosmic microwave background and mass power spectrum data, if $H_0 = 68 km\, s^{-1} Mpc^{-1}$. We conclude that this model is an excellent alternative to explain the accelerated expansion of the universe without incorporating the cosmological constant or some type of extra matter.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 22

Relativistic viscous accretion flow model for black hole sources with XMM–Newton observations

Author: Santabrata Das[1]

Co-author: Anuj Nandi [2]

[1] *Indian Institute of Technology Guwahati*

[2] *URSC, ISRO*

Corresponding Author: sbdas@iitg.ac.in

We develop a model formalism to study the structure of a relativistic, viscous, optically thin, advective accretion flow around a rotating black hole in presence of radiative coolings. We use this model to examine the physical parameters of four black hole Ultra-luminous X-ray sources (BH-ULXs), namely mass ($M_{\rm BH}$), spin ($a_{\rm k}$) and accretion rate ($\dot{m}$), respectively. While doing this, we adopt a recently developed effective potential to mimic the spacetime geometry around the rotating black holes. We solve the governing equations to obtain the shock induced global accretion solutions in terms of $\dot{m}$ and viscosity parameter (α). Using shock properties, we compute the Quasi-periodic Oscillation (QPO) frequency ($\nu_{\rm QPO}$) of the post-shock matter, when the shock front exhibits Quasi-periodic variations. We also calculate the bolometric luminosity ($L_{\rm bol}$) of the entire disc for these shock solutions. Utilizing $\nu_{\rm QPO}$ and $L_{\rm bol}$, we constrain BH-ULXs mass by varying their spin ($a_{\rm k}$) and accretion rate ($\dot{m}$). We find that NGC6946 X−1 and NGC5408 X−1 seem to accrete at sub-Eddington accretion rate provided their central sources are rapidly rotating, whereas IC342 X−1 and NGC1313 X−1 can accrete in sub/super-Eddington limit irrespective to their spin values.

Astrophysics with gravitational waves / 23

Dynamical tidal Love numbers of Kerr-like compact objects

Author: Sumanta Chakraborty[1]

Co-authors: Elisa maggio [2]; Paolo Pani [3]; Michela Silvestrini [4]

[1] *Indian Association for the Cultivation of Science*

[2] *AEI*

[3] *Sapienza University of Rome*

[4] *INFN Naples*

Corresponding Author: sumantac.physics@gmail.com

We develop a framework to compute the tidal response of a Kerr-like compact object in terms of its reflectivity, compactness, and spin, both in the static and the frequency-dependent case. Here we focus on the low-frequency regime, which can be solved fully analytically. We highlight some remarkable novel features, in particular: i) Even in the zero-frequency limit, the tidal Love numbers (TLNs) depend on the linear-in-frequency dependence of the object's reflectivity in a nontrivial way. ii) Intriguingly, the static limit of the frequency-dependent TLNs is discontinuous, therefore the static TLNs differ from the static limit of the (phenomenologically more interesting) frequency-dependent TLNs. This shows that earlier findings regarding the static TLNs of ultracompact objects correspond to a measure-zero region in the parameter space, though the logarithmic behavior of the TLNs in the black hole limit is retained.

Quantum gravity phenomenology / 25

Distinguishing Jordan and Einstein frames in gravity through entanglement

Author: Sumanta Chakraborty[1]

Co-authors: Anupam Mazumdar ; Ritapriya Pradhan

[1] *Indian Association for the Cultivation of Science*

Corresponding Author: sumantac.physics@gmail.com

In general relativity, the use of conformal transformation is ubiquitous and leads to two different frames of reference, known as the Jordan and the Einstein frames. Typically, the transformation from the Jordan frame to the Einstein frame involves introducing an additional scalar degree of freedom, often already present in the theory. We will show that at the quantum level, owing to this extra scalar degree of freedom these two frames exhibit subtle differences that the entanglement between two massive objects can probe.

Theories of gravity: alternatives to the cosmological and particle standard models / 26

Dust models in Einstein-Gauss-Bonnet gravity

Author: Shavani Naicker[1]

Co-authors: Byron Brassel [2]; Sunil Maharaj [1]

[1] *University of KwaZulu-Natal (South Africa)*

[2] *Durban University of Technology*

Corresponding Author: shavaninaicker10@gmail.com

Abstract: Dust is considered to be the simplest form of matter composed of pressureless, radiation and is abundant in galaxies, clusters and superclusters in a cosmological context. It has also been shown that stars are encompassed by these radiating pressureless particles which make up the atmosphere of the star. The gravitational behaviour of these pressureless fluid distributions are investigated in Einstein-Gauss-Bonnet (EGB) gravity in the presence of an electromagnetic field. The EGB field equations are generated for this system in arbitrary dimensions. It was found that the governing equation for this static charged dust configuration is classified as an Abel differential equation of the second kind; a complicated nonlinear differential equation. These are difficult to solve in general however we demonstrate a method that reduces the nonlinear differential equation to a simpler form enabling exact solutions to be found. This process of finding exact solutions to the governing equations in any gravitational field theory represents a foundation for analysing the

gravitational dynamics of astrophysical objects. Furthermore, we demonstrate that the charged dust model obtained is physically well behaved in a region at the centre, and dust spheres can be generated. It can be observed that the higher order curvature terms influence the dynamics of charged dust and the gravitational behaviour which is distinct from general relativity.

Wormholes, energy conditions and time machines / 27

Avoiding Singularities with Propagating Torsion

Author: Luca Fabbri[1]

[1] *University of Genova*

Corresponding Author: luca.fabbri@unige.it

We consider the torsional completion of the theory of gravity in which torsion is a propagating axial-vector field: we show how this changes the energy conditions leading to the singularity formation being avoided. We discuss how the same construction possesses regular matter distributions even in the case of a single particle. We give a brief discussion also about the localization of such matter distribution.

Large scale structure and dark energy / 28

Dispersion in the Hubble-Lemaitre constant measurements from gravitational clustering

Author: Swati Gavas[1]

Co-authors: Jasjeet Bagla [1]; Nishikanta Khandai [2]

[1] *Indian Institute of Science Education and Research Mohali, India*

[2] *National Institute of Science Education and Research, India*

Corresponding Author: swatigavas47@gmail.com

Measurements of the Hubble-Lemaitre constant H_0 require us to estimate the distance and recession velocity of galaxies independently. Gravitational clustering that leads to the formation of galaxies and the large scale structure leaves its imprints in the form of peculiar velocities of galaxies. In general, it is not possible to disentangle the peculiar velocity component from the recession velocities of galaxies, and this introduces an uncertainty in the determination of H_0. We use cosmological N-body simulations to quantify the impact of peculiar velocities on the estimation of H_0. We consider observers to be located in dark matter halos and target galaxies to be distributed amongst dark matter halos. We compute the distribution of the estimated value of H_0 across all such observers in the simulation, and we study the distribution as a function of distance from the observer. We find that the dispersion of this distribution is large at small scales, and it diminishes as we go to large separations, reaching the level of the quoted statistical error in Planck and SH0ES measurements well beyond 135 Mpc and 220 Mpc respectively. Measurements at smaller scales are susceptible to errors arising from peculiar motions and this error can propagate to measurements at larger scales in the distance ladder. Notably, we observe a weak negative correlation between the local overdensity around an observer and the deviation of the local and the global value of H_0. We show that deviations more significant than 5% of the global values can be encountered frequently at scales of up to 40 Mpc, and this is considerably larger than the statistical errors on local estimates.

Black holes in alternative theories of gravity / 29

Black hole thermodynamics and boundary terms

Author: Marek Liška[1]

Co-authors: David Kubiznak [2]; Robie A. Hennigar [3]

[1] *Institute of Theoretical Physics, Charles University, Prague*

[2] *Perimeter Institute*

[3] *Departament de Física Quántica i Astrofísica, Institut de Ciéncies del Cosmos, Universitat de Barcelona*

Corresponding Author: liska.mk@seznam.cz

I discuss sensitivity of black hole thermodynamics to certain boundary terms in the action. While boundary terms cannot affect the classical gravitational dynamics, they apparently influence both the black hole entropy and temperature. Remarkably, this behaviour is confirmed by two standard approaches to black hole thermodynamics; the covariant phase space (Iyer-Wald) and the Euclidean grandcanonical ensemble (Brown-York). In my talk, I introduce our findings on the example of 4D scalar-tensor Einstein-Gauss-Bonnet gravity. I also comment on other cases that may display similar behaviour, in particular on thermodynamics of regular black hole solutions.

Quantum gravity phenomenology / 30

The role of gravitational energy in the quantum gravity phenomenology

Author: Marek Liška[1]

Co-author: Ana Alonso-Serrano [2]

[1] *Institute of Theoretical Physics, Charles University, Prague*

[2] *Institut für Physik, Humboldt-Universität zu Berlin*

Corresponding Author: liska.mk@seznam.cz

Since the seminal work of Jacobson, it has been known that the equations governing gravitational dynamics can be reconstructed from thermodynamics of local causal horizon. Remarkably, it is even possible to recover low energy quantum phenomenological corrections to gravitational dynamics from thermodynamics. In vacuum, the only possible such corrections are quadratic in Weyl tensor. These contributions take the form of the time component of the Bel-Robinson tensor, which satisfies many of the properties expected from a measure of the quasi-local gravitational energy. In my talk, I show how this candidate expression for the gravitational energy enters the thermodynamics of local causal horizons and whether one should ultimately expect it to affect the gravitational dynamics. Notably, such effects would provide a quantum signature in the vacuum gravitational dynamics.

Theories of gravity: alternatives to the cosmological and particle standard models / 31

Modeling of Charged Compact Star in f (Q) gravity

Author: Muhammad Azam[1]

Co-author: Muhammad Awais [1]

[1] *University of Education, Lahore.*

Corresponding Author: azam.math@ue.edu.pk

This study focuses on constructing physical model of spherically
symmetric systems incorporating electromagnetic fields within the
framework of f (Q) gravity. To achieve this, we derive the field equations corresponding to f (Q) gravity in the presence of anisotropic matter, and then connect the interior space-time with the exterior Reissner
Nordstrom metric to determine the constants inherent in the model.
In our approach, we adopt an electrical charge distribution characterized by s(r) = Kr3, where K represents the intensity of the charge to
manifest the charged properties of matter distributions. To ensure the
physical viability of our solution, we rigorously examine the stability
using causality conditions. Subsequently, we apply these developed
model to study certain well-known compact objects, such as LMC X-
4. The analysis involve plotting various physical parameters against
fixed values incorporated in the model, facilitated by computational
software like Mathematica.

Massive white dwarfs and related phenomena / 32

The origin and characteristics of massive white dwarfs

Author: Lilia Ferrario[1]

[1] *The Australian National University*

Corresponding Author: lilia.ferrario@anu.edu.au

Our understanding of the mass distribution of white dwarfs remains elusive, yet it stands as a fundamental aspect of these stellar remnants that mark the final stage of the majority of stars' lifecycles. Unravelling this distribution requires untangling the influences of the initial mass function, star formation history, and stellar evolution. The latter can be significantly altered by the presence of a close companion star, leading to complex phases of interaction, mass loss, and merging. Coalescing white dwarfs give rise to some of the most energetic and spectacular phenomena observed in the universe.

Increasing evidence suggests that a significant portion of massive white dwarfs originates from binary mergers rather than single-star evolution. The population of massive white dwarfs is generally old and with kinematic properties consistent with those of stars belonging to the Galactic thick disc and halo. The merger scenario is also strongly supported by the presence of strong magnetic fields and rapid rotation rates.

White dwarfs in close binaries are also sources of low- frequency gravitational waves. Therefore, some of the progenitors of these merging binaries will be detectable with the space-based gravitational wave observatory LISA, which will 'hear' thousands of them millions of years before they merge.

In this presentation, I will provide an overview of our current understanding of massive white dwarfs and their characteristics (e.g., mass, atmospheric composition, magnetic field, age) and I will emphasise the critical role that massive white dwarfs play in numerous exotic and powerful astrophysical phenomena.

Wormholes, energy conditions and time machines / 33

Properties of dynamical regular black holes in semiclassical gravity

Author: Ioannis Soranidis[1]

Co-author: Sebastian Murk [2]

[1] *Macquarie University*

[2] *Okinawa Institute of Science and Technology*

Corresponding Author: ioannis.soranidis@students.mq.edu.au

Regular black holes have become a popular alternative to the singular mathematical black holes predicted by general relativity as they circumvent mathematical pathologies associated with the singularity while preserving crucial black hole features such as the trapping of light. Based on the assumption that semiclassical gravity is valid in the vicinity of their apparent horizons, we examine the behavior of the null energy condition and study the trajectories of particles entering and exiting the trapped spacetime region throughout its evolution. We find that the null energy condition is always violated in the vicinity of the outer horizon while being satisfied in the vicinity of the inner horizon, which implies that the trapped spacetime region (as determined from the behavior of null geodesic congruences) is effectively separated into an NEC-violating and an NEC-non-violating domain. We show that quantum effects are more dominant close to the outer apparent horizon and become more pronounced towards the final stages of the evaporation process. In addition, we demonstrate that there is a unique way for particles to escape the trapped region on an ingoing geodesic, thus offering a natural resolution to the information loss paradox. Lastly, we highlight the physical implications of these results and outline how the parameters of various theoretical models are constrained by current and future observational data (e.g. through light rings).

Absolute stability of strange quark matter: from dark matter to stellar evolution / 35

A new model of compact stellar objects with dark matter as its component

Author: Shyam Das[1]

Co-author: Farook Rahaman

[1] *Malda College*

Corresponding Author: dasshyam321@gmail.com

In this paper, we develop a new model representing a spherically symmetric dark matter fluid sphere that could describe compact stellar objects. We consider that the compact star contains two regions namely, an isotropic inner core region with constant density and an anisotropic outer region with a specific realistic equation of state. We solve the system of field equation by assuming a particular density profile along
with prescribing a linear equation of state. With this, we solved the Einstein field equations. The obtained solutions are well-behaved and physically acceptable which represent equilibrium and stable matter configuration by satisfying the Tolman–Oppenheimer–Volkoff (TOV) equation. The interior solutions matched with the de Sitter metric at the core boundary and with the exterior Schwarzschild solution at the surface boundary. This solution is found to satisfy some well-known physical conditions e.g., energy conditions, causality conditions, and stability conditions for representing a stellar compact star. Considering a particular compact star EXO 1785-248 with its recently observed mass and radius, we analyzed the physical viability of the model by analyzing our solutions.

Black hole formation, evolution and the black hole mass gap / 36

A new channel to form near- and sub-solar-mass black holes and naked singularities

Author: Chandrachur Chakraborty[1]

Co-author: Sudip Bhattacharya [2]

[1] *Manipal Centre for Natural Sciences, MAHE, INDIA*

[2] *Tata Institute of Fundamental Research, Mumbai 400005, India*

Corresponding Author: chandrachurchakraborty@gmail.com

Existence of naked singularities is a topical and fundamental issue of physics. The formation mechanism of such objects, particularly those with near-solar-mass, is not yet clear. Since, recent gravitational wave events have suggested the existence of near-solar-mass collapsed objects which cannot be formed via stellar evolution, here we investigate a likely formation channel, and especially if a near-solar-mass cosmic object can be transmuted into a Kerr naked singularity by capturing primordial dark matter particles. If the dynamical ejecta is small during the transmutation, the said cosmic object could be transmuted to a Kerr naked singularity. On the other hand, if the dynamical ejecta is large, the same will be transmuted to a sub-solar mass Kerr BH. We show that many white dwarfs could transmute into Kerr naked singularities or a sub-solar mass Kerr BHs (depending on the amount of dynamical ejecta), while neutron stars may not, and mention plausible observational implications (https://arxiv.org/abs/2401.08462).

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 37

Horizon-penetrating form of parametrized metrics for static and stationary black holes

Author: Luciano Rezzolla[1]

[1] *Institute for Theoretical Physics, Frankfurt, Germany*

Corresponding Author: rezzolla@itp.uni-frankfurt.de

The Rezzolla-Zhidenko (RZ) and Konoplya-Rezzolla-Zhidenko (KRZ) frameworks provide an efficient ap- proach to characterize agnostically spherically symmetric or stationary black-hole spacetimes in arbitrary metric theories. In their original construction, these metrics were defined only in the spacetime region outside of the event horizon, where they can reproduce any black-hole metric with percent precision and a few parameters only. At the same time, numerical simulations of accreting black holes often require metric functions that are regular across the horizon, so that the inner boundary of the computational domain can be placed in a region that is causally disconnected from the exterior. We present a novel formulation of the RZ/KRZ parametrized metrics in coordinate systems that are regular at the horizon and defined everywhere in the interior. We compare the horizon-penetrating form of the KRZ and RZ metrics with the corresponding forms of the Kerr metric in Kerr-Schild coordinates and of the Schwarzschild metric in Eddington-Finkelstein coordinates, remarking the similarities and differences. We expect the horizon-penetrating formulations of the RZ/KRZ metrics to represent new tools to study via simulations the physical processes that occur near the horizon of an arbitrary black hole.

Gravitational kHz waves - LIGO-Virgo-KAGRA / 38

Listening to the long ringdown: a novel way to pinpoint the equation of state in neutron-star cores

Author: Luciano Rezzolla[1]

[1] *Institute for Theoretical Physics, Frankfurt, Germany*

Corresponding Author: rezzolla@itp.uni-frankfurt.de

Multimessenger signals from binary neutron star (BNS) mergers are promising tools to infer the largely unknown properties of nuclear matter at densities that are presently inac- cessible to laboratory experiments. The gravitational waves (GWs) emitted by BNS merger remnants, in particular, have the potential of setting tight constraints on the neutron- star equation of state (EOS) that would complement those coming from the late inspiral, direct mass-radius measurements, or ab-initio dense-matter calculations. To explore this possibility, we perform a representative series of general-relativistic simulations of BNS systems with EOSs carefully constructed so as to cover comprehensively the high-density regime of the EOS space. From these simulations, we identify a novel and tight correla- tion between the ratio of the energy and angular-momentum losses in the late-time portion of the post-merger signal, i.e., the "long ringdown", and the properties of the EOS at the highest pressures and densities in neutron-star cores. When applying this correlation to post-merger GW signals, we find a significant reduction of the EOS uncertainty at densities several times the nuclear saturation density, where no direct constraints are currently avail- able. Hence, the long ringdown has the potential of providing new and stringent constraints on the state of matter in neutron stars in general and, in particular, in their cores.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 39

Extended emission" from fallback accretion onto merger remnants

Author: Luciano Rezzolla[1]

[1] *Institute for Theoretical Physics, Frankfurt, Germany*

Corresponding Author: rezzolla@itp.uni-frankfurt.de

Using a set of general-relativistic magnetohydrodynamics simulations that include proper neutrino transfer, we assess for the first time the role played by the fallback accretion onto the remnant from a binary neutron-star merger over a timescale of hundreds of seconds. In particular, we find that, independently of the equation of state, the properties of the binary, and the fate of the remnant, the fallback material reaches a total mass of � 10−3 ��, i.e., about 50% of the unbound matter, and that the fallback accretion rate follows a power-law in time with slope ~ �−5/3. Interestingly, the timescale of the fallback and the corresponding accretion luminosity are in good agreement with the so-called "extended emission" observed in short gamma-ray bursts (GRBs). Using a simple electromagnetic emission model based on the self-consistent thermodynamical state of the fallback material heated by r-process nucleosynthesis, we show that this fallback material can shine in the gamma- and X-rays with luminosities � 1048 erg/s for hundreds of seconds, thus making it a good and natural candidate to explain the extended emission in short GRBs. In addition, our model for the emission by the fallback material reproduces well and rather naturally some of the phenomenological traits of the extended emission, such as its softer spectra with respect to the prompt emission and the presence of exponential cutoffs in time. Our results clearly highlight that fallback flows onto merger remnants cannot be neglected and the corresponding emission represents a very promising and largely unexplored avenue to explain the complex phenomenology of GRBs.

Inflation: perturbations, initial singularities and emergent universes / 40

Raychaudhuri equation invariance in the presence of inflation-type fields

Author: GOUTAM MANNA[1]

Co-authors: Debashis Gangopadhyay [2]; Arijit Panda [3]

[1] *Prabhat Kumar College, Contai*

[2] *Sister Nivedita University, Kolkata*

[3] *Raiganj University, Raiganj*

Corresponding Author: goutammanna.pkc@gmail.com

We demonstrate that the Raychaudhuri equation remains unchanged for certain solutions of scalar fields ϕ that have a non-canonical Lagrangian of the form $\mathcal{L}(X, \phi) = -V(\phi)F(X)$, with $X = \frac{1}{2}g_{\mu\nu}\nabla^{\mu}\phi\nabla^{\nu}\phi$ and $V(\phi)$ represents the potential. There are several solutions available for both homogeneous and inhomogeneous fields, which are reminiscent of inflation scenarios. Further, the existence of primordial inhomogeneities is provided by the quantum fluctuations that may exhibited by these inflaton-type solutions.

Massive white dwarfs and related phenomena / 41

The massive fast spinning white dwarf in the HD 49798/RX J0648.0–4418 binary

Author: Sandro Mereghetti[None]

Corresponding Author: sandro.mereghetti@inaf.it

I will review the properties and discuss some of the puzzling aspects of the unique binary system composed by the luminous hot subdwarf HD 49798 and a white dwarf of 1.220(8) solar masses and spin period of 13.2 s. This is one of the few massive white dwarfs with a dynamically measured mass and the one with the shortest spin period. It emits pulsed X-rays with a very soft spectrum, powered by accretion from the tenuous stellar wind of its companion of sdO spectral type. The current level of mass accretion cannot provide enough angular momentum to explain the precisely measured spin-up rate (71.9(6) nanoseconds per year), which is instead best interpreted as the result of the radial contraction of this young white dwarf. The higher mass transfer rate expected during the future evolutionary stages of HD 49798 will drive the white dwarf above the Chandrasekhar limit, but the final fate, a type Ia SN explosion or the collapse to a millisecond pulsar, is uncertain.

Dark energy and the accelerating universe / 42

Violation of NEC in $f(\bar{R}, \bar{T})$ gravity within a non-canonical theory using the modified Raychaudhuri equation

Author: GOUTAM MANNA[1]

Co-authors: Arijit Panda [2]; Debashis Gangopadhyay [3]

[1] *Prabhat Kumar College, Contai*

[2] *Raiganj University, Raiganj*

[3] *Sister Nivedita University, Kolkata*

Corresponding Author: goutammanna.pkc@gmail.com

In this work, we construct the Raychaudhuri equation in $f(\bar{R}, \bar{T})$ gravity in the context of a non-canonical theory, which is the K-essence theory. We solved the modified Raychaudhuri equation for the additive form of $f(\bar{R}, \bar{T})$, which is $f_1(\bar{R}) + f_2(\bar{T})$. In this solution, we use two distinct scale factors to generate two kinds of $f(\bar{R}, \bar{T})$ solutions. The ongoing debate between Fisher et. al. and Harko et. al. in 2020 regarding the additive form of $f(\bar{R}, \bar{T})$ provides resolution within the modified $f(\bar{R}, \bar{T})$ gravity theory. By doing a viability test and examining energy conditions, we found that in the first scenario, the null energy condition (NEC) is violated between two places where the NEC is met. Furthermore, we found that this violation of the NEC has a symmetrical characteristic throughout the phase transition. These findings suggest that bouncing events may occur as a consequence of symmetrical violations of the NEC during the universe's expansion. In addition, this model indicates that resonant-type quantum tunneling might occur when the NEC is broken. The findings of the NEC violation using the power law of scale factor may have empirical significance in current observations. In the second solution, our model shows that the strong energy requirement is broken but the NEC and weak energy criteria are satisfied. The effective energy density drops but remains positive, although the effective pressure and equation of state parameters are negative. This shows that the cosmos is growing rapidly and is dominated by dark energy.

Absolute stability of strange quark matter: from dark matter to stellar evolution / 43

Schwinger process in hot electrospheres of strange stars

Author: Mikalai Prakapenia[1]

Co-author: Gregory Vereshchagin [2]

[1] *ICRANet-Minsk, B. I. Stepanov Institute of Physics*

[2] *ICRANet*

Corresponding Authors: veresh@icra.it, nikprokopenya@gmail.com

We present a series of numerical simulations of the pair creation process in the electrosphere of strange star using the Vlasov–Maxwell equations. The mechanism of pair creation in the electrosphere of compact objects is revisited, paying attention to evaporation of electrons and acceleration of electrons and positrons, which were previously not addressed in the literature.

Astrophysics with gravitational waves / 44

Chameleon-induced signatures in polarization of gravitational waves

Author: Murli Manohar Verma[1]

[1] *University of Lucknow*

Corresponding Author: sunilmmv@yahoo.com

The chameleon-induced polarization modes of gravitational waves (GWs) are explored in f(R) gravity arising due to scalar field. The chameleon mechanism works strongly in high density regions where mass of the scalar field particle becomes high and the oscillations of the scalar field sharply increase. This produces enhanced scalar modes in addition to the tensor modes of polarization in gravitational waves. It is shown that this approach can be significantly used to distinguish the Lambda CDM models from modified gravity models subject to detection of all modes in future GWs detections.

Theories of gravity: alternatives to the cosmological and particle standard models / 45

Modified gravity model without dark matter and dark energy

Author: Murli Manohar Verma[1]

[1] *University of Lucknow*

Corresponding Author: sunilmmv@yahoo.com

We explore a model in modified $f(R)$ gravity where the modification in geometrical part of the Einstein-Hilbert action leads to complete elimination of the need for dark matter and dark energy, both. This is specifially obtained by the scalar fields induced in the Einstein's gravity whose dynamical oscillations account for the effects (otherwise attributed to dark matter and dark energy in standard Lambda CDM model) throughout the evolution of the universe, and is found to be strongly influlential at the epochs of structure formation. The parameters such as mass of scalar fields in this model are constrained by observations and cosmological considerations.

Unveiling neutrino secrets through cosmology: current status and future developments / 46

Gravitational Influence on the Quantum Speed Limit in Neutrino-Antineutrino Oscillations

Author: Abhishek Jha[1]

Co-authors: Banibrata Mukhopadhyay [1]; Mayank Pathak [1]; Mriganka Dutta [1]; Subhashish Banerjee [2]

[1] *Indian Institute of Science*

[2] *Indian Institute of Technology Jodhpur*

Corresponding Author: kjabhishek@iisc.ac.in

We investigate the quantum speed limit (QSL) during the time evolution of neutrinos and antineutrinos under the influence of a gravitational field. We derive an analytical expression for the four-vector gravitational potential in the underlying Hermitian Dirac Hamiltonian using the Boyer-Lindquist coordinates. This gravitational potential leads to an axial vector in the Dirac equation in curved spacetime, contributing to the effective mass matrix of the neutrino-antineutrino systems. Our findings indicate that the gravitational field, depending on its strength, significantly influences the transition probabilities in both one- and two-flavor neutrino-antineutrino oscillations. While the former corresponds to neutrino-antineutrino oscillation, the latter is for flavor oscillations as well. We then apply the expression for transition probabilities between states to analyze the Bures angle, which quantifies the closeness between the initial and final states of the time-evolved flavor state. We use this concept to probe the QSL for the time-continuous evolution of the initial flavor neutrino state. Finally, we discuss the implications of entanglement in neutrino-antineutrino oscillations in the vicinity of a spinning primordial black hole.

First stars and their remnants as dark matter probes / 47

Compatibility of JWST results with exotic halos

Author: Luca Visinelli[1]

[1] *Shanghai Jiao Tong University*

Corresponding Author: luca.visinelli@sjtu.edu.cn

The James Webb Space Telescope (JWST) is unveiling astounding results on the composition and evolution of the cosmo at very high redshifts. In this talk, I develop a UV luminosity function model for high-redshift galaxies, considering parameters such as the stellar formation rate, dust extinction, and halo mass function, calibrated at $z = 4$-7. Testing the model against higher redshifts suggests a negligible role of dust extinction very early on, prompting a modification of the stellar formation rate to incorporate a larger fraction of luminous objects per massive halo. I discuss some exotic explanations of this effect. Based on https://arxiv.org/abs/2403.13068

Strong electromagnetic and gravitational field physics: From laboratories to early Universe / 48

Broken energy degeneracy in non-uniform magnetic field: Faster quantum speed limit

Author: Srishty Aggarwal[1]

Co-authors: Arindam Ghosh [1]; Banibrata Mukhopadhyay [1]; Subhashish Banerjee [2]

[1] *Indian Institute of Science*

[2] *Indian Institute of Technology Jodhpur*

Corresponding Author: srishtya@iisc.ac.in

When charged fermions gyrate within a uniform magnetic field, their energy undergoes quantization into discrete levels known as Landau levels, a phenomenon termed Landau quantization. This effect finds diverse applications, ranging from the quantum Hall effect and the de Haas Van Alphen effect to the formation of super-Chandrasekhar white dwarfs. In a uniform magnetic field, Landau levels exhibit degeneracy due to the overlap of spin-up fermions in lower energy levels with spin-down fermions in the adjacent higher energy levels.
Our investigation focuses on the two-dimensional motion of relativistic cold electrons amidst spatially varying magnetic fields. We observe that the degeneracy of Landau levels, that arises in constant magnetic fields, lifts out in the presence of variable fields, with the energy levels of spin-up and spin-down electrons aligning in intriguing ways depending on the field's nature of change. We propose an experimental setup for achieving non-uniform magnetic fields in laboratory settings.
Utilizing the spatially growing magnetic field, we aim to attain a higher quantum speed limit,the faster transition speed between the quantum states, for electrons. This advancement holds significant promise for accelerating quantum information processing, particularly in the realm of quantum computing. Furthermore, we determine the critical magnetic field that bridges the gap between non-relativistic and relativistic regimes, employing the Bremermann-Bekenstein bound to constrain the maximal rate of information production.

Neutrinos in the multi-messenger era / 49

Towards future multi-messenger detections of core-collapse supernovae harbouring choked jets

Author: Angela Zegarelli[1]

Co-authors: Dafne Guetta [2]; Imre Bartos [3]; Silvia Celli [4]; Silvia Gagliardini [5]

[1] *Ruhr Universität, Bochum*

[2] *Ariel University, Ariel*

[3] *University of Florida*

[4] *Sapienza University & INFN-Roma1*

[5] *Ariel University, Sapienza Università di Roma*

Corresponding Author: angela.zegarelli@astro.ruhr-uni-bochum.de

Over the last decade, the scenario of choked jets embedded in core-collapse supernovae (CCSNe) has attracted careful attention. The extended stellar envelopes of red supergiant (RSG) and blue supergiant (BSG) stars, both progenitors of Type II SNe, may constitute a challenge to the launch of a powerful jet able to burrow through their envelopes. As the jet carves its way through them, it dissipates its energy in a double-shock structure that forms at its head. The hot head material spills sideways, forming a cocoon that engulfs the jet and collimates it. If before choking the jet crossed a significant fraction of the stellar envelope, the cocoon is energetic enough to break out of the star, releasing ultraviolet (UV) and optical (O) emissions lasting over a few days. For a proper characterisation of RSGs and BSGs, the identification of both these electromagnetic signals is of paramount

importance, because of the low probability for gamma rays to emerge.
I here discuss prospects in measuring UV emission, in view of the launch in 2026 of the satellite ULTRASAT which will operate in the UV band, complementing the performances of the currently active optical telescope ZTF. Furthermore, choked jets are also extremely interesting within the growing field of multi-messenger astronomy, being considered as possible contributors to the astrophysical diffuse neutrino flux, not yet associated with any existing source. In this regard, I discuss the possibility of exploiting multi-messenger detection on how to set multi-messenger observations among UV/O/neutrino telescopes optimising combined detections between different facilities.

Strong electromagnetic and gravitational field physics: From laboratories to early Universe / 50

Novel resummations for strong field (S)QED

Authors: César García-Pérez[1]; Diego Mazzitelli[2]; Sebastián Franchino-Viñas[3]; Ulises Wainstein-Haimovichi[4]; Vincenzo Vitagliano[1]

[1] *Università di Genova*

[2] *Centro Atómico Bariloche*

[3] *Helmholtz-Zentrum Dresden-Rossendorf*

[4] *Universidad de La Plata*

Corresponding Author: safranchino@gmail.com

There are several quantum phenomena that can be described in a semiclassical approach, such as the Hawking effect, Schwinger pair production and the Casimir effect.
In this talk we will focus on the role of resummations in this framework, which are necessary if one wants to access the nonperturbative regime. We will give a general overview of results valid for quantum fields in curved spacetime and in electromagnetic backgrounds, including some recent novelties as well.
Partly based on https://arxiv.org/abs/2312.16303 .

Black holes in alternative theories of gravity / 51

Some words about gravitational entropy and Penrose's Weyl curvature conjecture

Authors: Daniele Gregoris[1]; Yen Chin Ong[2]

[1] *Jiangsu University of Science and Technology*

[2] *Yangzhou University*

Corresponding Author: danielegregoris@libero.it

Many notions of entropy have been formulated in Physics, from thermodynamics to statistical mechanics and information theory. Bekenstein and Hawking, relying on completely different physical arguments than each other's, pioneered the idea of *gravitational* entropy claiming that the gravitational field of an empty space
black hole as Schwarzschild comes with an entropy equal to one fourth of its horizon area. In the cosmological context, Penrose has instead conjectured that the Weyl curvature should serve as a measure of gravitational entropy proposing the so-called Weyl curvature hypothesis. However, implementing consistently all those ideas is not a trivial task, with drawbacks in the literature proposal of considering the square of the Weyl tensor as an appropriate entropy density being identified. In my talk, I will propose a solution to this issue by introducing an appropriate combination of curvature quantities based only on the Weyl curvature, which therefore is not sensitive to the matter

content and really constitutes a measure of the *pure gravitational field*, exhibiting a general applicability to all static and spherically symmetric black holes in general relativity independently of the matter field in their exterior. Physical insights about the nature of black hole entropy will be provided, also putting our results in the perspective of modified gravity theories. My talk will be based on PRD 105, 104017 (2022).

Neutrinos in the multi-messenger era / 52

Neutrino fluxes from different classes of galactic sources

Author: Silvia Gagliardini[1]

[1] *Ariel University, Sapienza Università di Roma*

Corresponding Author: silviagagliardini@hotmail.com

We estimate the neutrino flux from different kinds of galactic sources and compare it with the recently diffuse neutrino flux detected by IceCube. We find that the flux from these sources may contribute to ~20% of the IceCube neutrino flux. Most of the sources selected in this work populate the southern hemisphere, therefore a detector like KM3NeT could help in resolving the sources out of the observed diffused galactic neutrino flux.

Neutrinos in the multi-messenger era / 53

Low- and High-energy Neutrinos from SN 2023ixf in M101

Authors: Aurora Langella[1]; Dafne Guetta[None]; SIlvia Gagliardini[None]

[1] *INFN Naples*

Corresponding Author: alangella@na.infn.it

Supernova (SN) 2023ixf in M101 is the closest SN explosion observed in the last decade. Therefore, it is a suitable test bed to study the role of jets in powering the SN ejecta. With this aim, we explored the idea that high-energy neutrinos could be produced during the interaction between the jets and the intense radiation field produced in the SN explosion and eventually be observed by the IceCube neutrino telescope. The lack of detection of such neutrinos has significantly constrained both the fraction of stellar collapses that produce jets and/or the theoretical models for neutrino production. Finally, we investigated the possibility of detecting low-energy neutrinos from SN 2023ixf with the Super- and Hyper-Kamiokande experiments, obtaining, in both cases, subthreshold estimates.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 54

Study of the relativistic accretion flow around Kerr-Taub-NUT black hole with shocks

Author: GARGI SEN[1]

Co-authors: Debaprasad Maity [1]; Santabrata Das [1]

[1] *Indian Institute of Technology Guwahati*

Corresponding Author: g.sen@iitg.ac.in

We investigate the properties of relativistic accretion flow in a Kerr-Taub-NUT (KTN) spacetime in presence or absence of shock waves. This spacetime, characterized by the spin parameter or Kerr parameter ($a_{\rm k}$) and the gravitomagnetic charge or NUT parameter (n), can represent either a black hole or a naked singularity depending on the suitable choice of their values. By solving the relevant governing equations, we examine the behavior of accretion flows within the black holes regime. We find that the ingoing subsonic flows from the outer edge experience centrifugal repulsion, leading to the formation of discontinuous shock transitions under appropriate relativistic conditions. The resulting post-shock region exhibits higher entropy compared to the pre-shock flow, indicating a preference for shock-induced solutions. Post-shock compression heats and densifies the flow, forming a post-shock corona (PSC) that emits high-energy radiation through the reprocessing of soft photons via inverse Comptonization. The properties of the PSC, characterized by shock location (r_s), compression ratio (R), shock strength (S), and the dynamics of PSC is controlled by the flow parameters, namely energy ($calE$) and angular momentum (λ) of the flow. We identify the effective region of the parameter space in $\lambda - calE$ plane for shock and observe that shock forms for wide range of flow parameters. Moreover, we find that $a_{\rm k}$ and n act oppositely in determining the shock parameter space. Furthermore, considering free-free emissions, we calculate the disc luminosity and find that global shock solutions are energetically favored due to their relatively higher luminosity compared to shock-free solutions.

First stars and their remnants as dark matter probes / 55

Detectability of Supermassive Dark Stars with the Roman Space Telescope

Author: Saiyang Zhang[None]

Co-authors: Katherine Freese [1]; cosmin ilie

[1] *University of Texas- Austin*

Corresponding Author: szhangphys@utexas.edu

Supermassive dark stars (SMDS) are luminous stellar objects formed in the early Universe at redshift $z \sim 10 - 20$, made primarily of hydrogen and helium, yet powered by dark matter.
We examine the capabilities of the Roman Space Telescope (RST), and find it able to identify $\sim 10^6 M_\odot$ SMDSs at redshifts up to $z \sim 14$. With a gravitational lensing factor of $\mu \sim 100$, RST could identify SMDS as small as $\sim 10^4 M_\odot$ at $z \sim 12$ with $\sim 10^6$s exposure.
Differentiating SMDSs from early galaxies containing zero metallicity stars at similar redshifts requires spectral, photometric, and morphological comparisons. With only RST, differentiation of SMDS, particularly those formed via adiabatic contraction with $M \geq 10^5 M_\odot$ and lensed by $\mu \geq 100$, is possible due to their distinct photometric signatures from the first galaxies. Those formed via dark matter capture can be differentiated only by image morphology: i.e. point object (SMDSs) vs. extended object (sufficiently magnified galaxies).
By additionally employing James Webb Space Telescope (JWST) spectroscopy, we can identify the HeII $\lambda 1640$ absorption line, a "smoking gun" for SMDS detection. Although RST doesn't cover the required wavelength band (for $z_{\rm emi} \geq 10$), JWST does, hence the two can be used in tandem to identify SMDS.
The detection of SMDS would confirm a new type of star powered by dark matter and may shed light on the origins of the supermassive black holes powering bright quasars observed at $z \geq 6$.

Inflation: perturbations, initial singularities and emergent universes / 56

Fuzzy dark matter and Primordial blackholes

Author: Govindarajan Thupil[1]

[1] *Inst of Mathematical Sciences, Krea University*

Corresponding Author: thupilrg@gmail.com

Novel proposal is made for candidate Fuzzy dark matter.Interestingly it has connections to primordial black holes which can seed supermassive black hole and play critical role in galaxy formation.

Emission mechanisms in gamma-ray bursts / 57

Unveiling GRB prompt emission physics through empirical correlations

Author: Alessio Mei[1]

[1] *GSSI*

Corresponding Author: alessio.mei@gssi.it

Gamma-ray bursts (GRBs) are the brightest sources in the Universe.
They appear as gamma-ray flashes, with a spectrum that peaks around a few hundred keV . The prompt spectra of GRBs were historically characterised through the phenomenological Band function, composed of two power laws smoothly connected around the peak. Because of the broad spectral shape, GRB spectra seem consistent with non-thermal radiative processes, and the leading interpretation invokes synchrotron emission from relativistic electrons. In this framework, the Band function fails to describe an intrinsically complex synchrotron spectrum featuring spectral breaks in the X-ray/gamma-ray energy range. In this work, for the first time, we test the impact of physical models in understanding the physics of prompt emission through the well-known GRB prompt empirical correlations. We analyse a sample of GRBs with measured redshift observed by Fermi. We fit this dataset with two functions: a phenomenological Band function, and a physical synchrotron model. We compare our results with the established Epeak-Liso empirical correlation, the Yonetoku relation. We find that in our sample the Epeak-Liso relation is less tight when the synchrotron model is used. Interestingly, the spectral cooling strength appears to drive the specific GRB position in the Yonetoku relation plane. GRBs in an intermediate cooling state show a tighter correlation even concerning the results obtained from the fit with a Band function. Finally, we present the correlations between the characteristic synchrotron frequencies and the energetics/luminosity of GRBs in our sample.
These new findings suggest a possible connection between the prompt empirical correlations and the physical mechanisms inside the jet which drive the main gamma-ray emission.

Theories of gravity: alternatives to the cosmological and particle standard models / 58

A TDiff invariant scalar field theory: breaking and restoring the symmetry

Authors: Antonio L. Maroto[1]; Darío Jaramillo Garrido[1]; Prado Martín-Moruno[1]

[1] *Universidad Complutense de Madrid (UCM)*

Corresponding Author: djaramil@ucm.es

We reflect on the possibility of breaking the diffeomorphism (Diff) invariance in the gravitational couplings of matter down to only transverse diffeomorphisms (TDiff), and study the consequences on a scalar field theory. We then explore the possibility of restoring the full Diff invariance preserving the locality of the theory by the introduction of an additional vector field. From the equivalent fluid description, we find that the reformulation with the full symmetry allows us to find the expression for the effective speed of sound of general TDiff models. This result provides us with physically

reasonable conditions that should be satisfied by the coupling functions. We finally consider some particular cases of interest, such as adiabatic models, constant equation of state models, or models presenting different gravitational domains (characterized by the focusing or possible defocusing of time-like geodesics), which could be used to unify the dark sector.

Cosmic Insights from Big Data: How Machine Learning is Decoding the Universe / 59

ML4GW: An AI-based pipeline for Real-time Gravitational Wave Analysis

Author: Erik Katsavounidis[1]

[1] *MIT*

Corresponding Author: kats@mit.edu

Deep learning algorithms have excelled in various domains. Despite this success, few deep-learning models have seen full end-to-end deployment in gravitational-wave searches, both in real-time and on archival data. In particular, there is a lack of standardized software tools for quick implementation and development of novel AI ideas. We address this gap by developing the ML4GW and HERMES libraries. We show how these libraries enhance efficiency and AI model robustness in the context of a broad range of gravitational wave analyses with an emphasis on real-time application, scalability to heterogeneous computing resources, and streamlining the training to deployment cycles for machine learning models. Building on this toolkit, we present specific end-to-end searches in archival data from the O3 LIGO-Virgo-KAGRA observing run. These searches include A-frame, a low-latency machine learning pipeline for compact binary sources of gravitational waves, DeepClean, a deep learning-based denoising scheme for astrophysical gravitational waves, GWAK, a semi-supervised AI strategy to identify unmodeled gravitational wave transients, and AMPLFI, a pipeline for deep learning-based parameter estimation. In addition, we discuss how such pipelines can lead to latency improvements for multi-messenger targets. Finally, we show how ML4GW and HERMES can quickly integrate the plethora of deep learning based algorithms being developed for gravitational wave identification across the broader astrophysics community.

GRB-SN connection / 60

Systematics and Biases in Observations of Supernovae Associated with Gamma-Ray Bursts

Author: Sergey Belkin[1]

Co-author: Alexei Pozanenko [2]

[1] *Monash University*

[2] *Space Research Insitute (IKI)*

Corresponding Author: sergey.belkin@monash.edu

Detection, observation, and description of supernovae associated with gamma-ray bursts are currently topical tasks in the field of transient phenomena. However, there is a certain pool of factors that can complicate or even make it impossible to identify a supernova in the light curve of a gamma-ray burst. And even if a supernova signature has been detected, further steps to determine its parameters can introduce their own uncertainties and systematic errors, which can affect the quality, for example, of the supernova light curve and the determination of its parameters. In this talk, we will discuss the selective effects influencing the possibility of detecting a supernova associated with a gamma-ray burst and estimating its parameters. We will also discuss possible options for their consideration and minimisation. It can contribute to increasing the statistics of detected supernovae

with gamma-ray bursts and help approach the answer to questions such as "*Why aren't all long GRBs accompanied by SNe?*" and "*Do SN-GRBs and type SN Ic belong to the same general sample?*".

Wormholes, energy conditions and time machines / 61

A geodesically complete ring wormhole

Authors: Juan Carlos Del Águila Rodríguez[1]; Tonatiuh Matos[2]

[1] *Universidad Autónoma Metropolitana*

[2] *Centro de Investigación y de Estudios Avanzados del IPN*

Corresponding Author: jdelaguila@fis.cinvestav.mx

In this talk the possible geodesic completeness of an electromagnetic dipole wormhole is studied in detail. The space-time contains a curvature singularity, and belongs to a class of solutions to the Einstein-Maxwell equations with a coupled scalar field that can be allowed to be phantom or dilatonic. Specifically, a numerical analysis is performed to examine congruences of null geodesics that are directed toward the singularity. The results found here show that, depending on the strength of the coupling between the scalar and electromagnetic fields, the wormhole can be either geodesically incomplete or complete. The latter case is the most physically interesting since it provides an explicit example in which a curvature singularity does not necessarily imply geodesic incompleteness.

Loop quantum gravity: cosmology and black holes / 62

The universality of the diagonal model, or the Abelianization of the Gauss constraint in Loop Quantum Cosmology

Author: Matteo Bruno[1]

Co-author: Giovanni Montani [2]

[1] *Sapienza Università di Roma*

[2] *ENEA*

Corresponding Author: matteo.bruno@uniroma1.it

In this talk, we aim to discuss the abelian features of Loop Quantum Cosmology, demonstrating that the Gauss constraint can be recast into three abelian constraints.
We begin the discussion by considering nondiagonal Bianchi models, illustrating their deep connection with the diagonal case. Specifically, we show that the Hilbert space of these models factorizes into spaces that are isomorphic to the canonical Hilbert space of LQC.
Subsequently, we investigate the introduction of gauge freedom, presenting a set of abelian constraints that are equivalent to the Gauss constraint. This reveals that the previously defined Hilbert space is the gauge-invariant one, and the abelianization of the quantum theory emerges as a general result within the minisuperspace framework.

Loop quantum gravity / 63

A (not) new geometric approach to Ashtekar variables and symmetry reduction

Author: Matteo Bruno[1]

[1] *Sapienza Università di Roma*

Corresponding Author: matteo.bruno@uniroma1.it

We will present a mathematical formulation of Ashtekar variables using the language of differential topology, aligning as closely as possible with the mathematical description of Yang-Mills theories. This approach illuminates the similarities while highlighting the differences between the two.
Additionally, within this framework, we can properly discuss the imposition of symmetries at the classical level and offer a quantization that adheres to the Loop Quantum Gravity prescriptions.
As an application, we will construct the classical cosmological sector of General Relativity using Ashtekar variables without invoking the minisuperspace. This cosmological sector has a set of constraints that mirror those in LQG, leading naturally to a quantization in terms of spin-network states.

Gamma-ray bursts and AGNs with machine learning / 64

GRB Redshift Classifier Using Supervised Machine Learning

Author: Maria Dainotti[1]

Co-authors: Agnieszka Pollo [2]; Shubham Bhardwaj [3]

[1] *National Astronomical Observatory of Japan*

[2] *National Centre for Nuclear Research*

[3] *SOKENDAI/National Astronomical Observatory of Japan*

Corresponding Author: shubham.bhardwaj@grad.nao.ac.jp

Gamma-ray bursts (GRBs) have been observed at very high redshifts, up to 9.4, and can be a crucial astrophysical object for studying the evolutionary history of the universe. However, the rapid dimming of their afterglows, combined with the constrained availability of telescope time, poses challenges in promptly observing these events. This difficulty is particularly pronounced for high-redshift GRBs, resulting in a limited number of observed GRBs with accurately determined redshifts and an even smaller subset of high-redshift GRBs. To address these observational challenges, rapid and efficient follow-up mechanisms are essential to perform spectroscopy on GRBs before their optical afterglows fade beyond detectable limits, ensuring comprehensive spectrum coverage. To facilitate this, we propose the development of a binary classifier using supervised machine learning (ML) techniques. This classifier is designed to quickly and accurately differentiate between low- and high-redshift GRBs, enabling more targeted and efficient use of telescope time for high-redshift observations.

Latest results from Galactic center observations / 65

New insights into the population of young, massive stars near Sagittarius A*

Author: Eulalia Gallego Cano[1]

[1] *IAA-CSIC*

Corresponding Author: lgc@iaa.es

Prior studies have revealed the presence of young massive stars in the central 0.5 pc of the Galactic Centre, prompting questions about their properties and formation in the immediate vicinity of the

massive black hole Sagittarius A. *Intriguingly, the shape of the initial mass function (IMF) in this region appears to deviate from the standard Salpeter/Kroupa law. However, our knowledge of the stellar population in this challenging environment remains limited due to extreme extinction and crowding, which pose a steep hurdle to the photometric classification of stars. Spectroscopic data are available only for comparably bright sources. In this talk, we present the results of our latest study, where we employed intermediate band (IB) near-infrared imaging with the aim of enhancing our understanding of the number and distribution of young, massive stars in this region. In agreement with previous studies, but going significantly beyond them, we found a core-like distribution of late-type stars. In contrast, the density of the early-type stars increases steeply towards the black hole. The analysis revealed a top-heavy IMF for young stars within about 0.4 pc of Sagittarius A.* A standard IMF may suffice at greater distances, indicating diverse star formation mechanisms at work. Additionally, we demonstrate how intermediate band photometry can serve to determine metallicities, with around 6% of the late-type stars in our sample exhibiting metal-poor characteristics.

Gravitational instantons and black holes / 66

Testing black hole with electromagnetic perturbations

Author: Bobir Toshmatov[1]

[1] *New Uzbekistan University*

Corresponding Author: b.toshmatov@newuu.uz

It is a well-known fact that light rays do not follow the null geodesics of spacetime, instead, they propagates along the null geodesics of the effective spacetime. In my presentation, we discuss the construction of the effective spacetime by studying the electromagnetic perturbations of black holes in general relativity coupled with nonlinear electrodynamics. Additionally, we explore the possibilities of distinguishing between the types of charge (electric or magnetic) of black holes by studying the motion of photons around generic black holes within the framework of general relativity coupled with nonlinear electrodynamics. Furthermore, we demonstrate the effectiveness of electromagnetic perturbations in testing the accuracy of black hole solutions in general relativity coupled with non-linear electrodynamics.

Black holes in alternative theories of gravity / 67

How Relic Black Holes , in the early universe allow Torsion to form a Cosmological constant, and set restrictions on Relic Black holes in terms of a quantum number n as specified

Author: Andrew Beckwith[1]

[1] *Chongqing University, physics*

Corresponding Author: rwill9955b@gmail.com

Our idea is to state that a particular set of values and reformulation of initial conditions for relic black holes, as stated in this manuscript , will enable using the idea of Torsion to formulate a cosmological constant and resultant Dark Energy. Relic Planck sized black holes will allow for a spin density term which presents an opportunity to modify a brilliant argument given as to cancelling Torsion as given by de Sabbata and Sirvaram, Erice 1990 . The 1990 de Sabbata and Sirvaram article claims that Torsion cancels Cosmological vacuum energy whereas our formulation leads to a left over cosmological constant 10^-121 times vacuum energy . Meantime speculation given by Corda replaces traditional firewalls in relic Black holes with a different formulation are included. This revised Black hole formulation uses the idea of a quantum number n, which ties into our own Cosmological constant and early universe Dark Energy values.

Low frequency gravitational waves: sciences and detections / 68

Detection of Exotic Compact Objects with Extreme Mass Ratio Inspirals and mini-EMRIs

Author: Huaike Guo[1]

[1] *University of Chinese Academy of Sciences*

Corresponding Author: guohuaike@ucas.ac.cn

I will discuss the detection of exotic compact objects, such as primordial black holes, boson stars, etc, with gravitational waves from a binary system where the mass ratio is extremely small (or large), and show that such exteme mass ratio inspirals and mini-EMRIs are ideal systems for detection of very light exotic compact objects, and that they serve as important targets for space-based and terrestrial gravitational wave detectors.

Low frequency gravitational waves: sciences and detections / 70

An Exact One-Body Approach to the Binary Problem in General Relativity

Author: Dingfang Zeng[None]

Corresponding Author: dfzeng2000@icloud.com

To precisely model or solve the binary problem in general relativity is a formidable challenge for both astronomy and gravitational physics. We will provide an exact one-body approach for the conservative part of such a problem, which applies to the whole three stages of the binary merger process. It utilizes a rotating gravitational field comprising two joined patches as the background for the two participants of merger process, whose rotational speed is determined by the energy balance condition at infinity when the dissipation effect of gravitational wave radiation is considered. Taking the quadrupole radiation as the source of dissipation, our method yields gravitational waveforms of binary merger events highly coincident with those of EOB+NR+BHPT(Effective One Body method, Numerical Relativity, Black Hole Perturbation Theory), but with all features directly traceable to the inner structure of black holes.

Neutrinos in the multi-messenger era / 71

Are X-rays the new γ-rays in neutrino astronomy?

Author: Imre Bartos[1]

[1] *University of Florida*

Corresponding Author: imrebartos@gmail.com

The production mechanism of astrophysical high-energy neutrinos is not yet understood. A common assumption is that beamed relativistic outflows (jets) driven by accreting black holes are needed to accelerate particles to such high energies to produce high-energy neutrinos. Indeed, the first astrophysical high-energy neutrino source candidate identified by IceCube at a significance level of >3σ was a blazar – an AGN with an accreting supermassive black hole that drives a relativistic jet directed towards Earth. Recently, IceCube discovered strong evidence that Seyfert galaxies also emit neutrinos, which appears unrelated to jet activity. I will show that the neutrino–hard X-ray flux ratio of the blazar TXS 0506+056 is consistent with neutrino production in a γ-obscured region near the central supermassive black hole, with the X-ray flux corresponding to reprocessed γ-ray

emission with flux comparable to that of neutrinos. Similar neutrino–hard X-ray flux ratios were found for three of IceCube's Seyfert galaxies, raising the possibility of a common neutrino production mechanism that may not involve a strong jet. I will discuss how future observations could test the jet origin of blazar neutrinos.

Inflation: perturbations, initial singularities and emergent universes / 72

Big Bang Nucleosynthesis constraints on $f(T, \mathcal{T})$ gravity

Author: SAI SWAGAT MISHRA[1]

Co-authors: Ameya Kolhatkar [1]; Pradyumn Kumar Sahoo [1]

[1] *BITS PILANI, Hyderabad Campus*

Corresponding Author: saiswagat009@gmail.com

Big Bang Nucleosynthesis provides us with an observational insight into the very early Universe. Since this mechanism of light element synthesis comes out of the standard model of particle cosmology which follows directly from General Relativity, it is expected that any modifications to GR will result in deviations in the predicted observable parameters which are mainly, the neutron-to-proton ratio and the baryon-to-photon ratio. We use the measured neutron-to-proton ratio and compare the theoretically obtained expressions to constrain two models in the framework of $f(T, \mathcal{T})$ gravity. The theoretically constrained models are then tested against observational data from the Hubble dataset and the ΛCDM model to explain the accelerated expansion of the Universe.

Quantum gravity phenomenology / 73

Quantum gravity effects in spacetimes with a fundamental length scale

Authors: Paul Davies[1]; Philip Tee[1]

[1] *Arizona State University*

Corresponding Author: ptee2@asu.edu

It is a longstanding conjecture that spacetime is emergent from an unknown substructure on an ultramicroscopic scale. While there are many competing models of this sort, a generic question is whether the existence of a fundamental length has any observable consequences. To investigate this, we have examined various quantum field effects within the framework of one such model: Doubly Special Relativity. Here, a type of spacetime discreteness, or pixelation, is reconciled with special relativity by introducing curvature into momentum space. The upshot is that the quantum vacuum is made dispersive, thereby affecting the propagators needed to calculate a variety of quantum field processes, such as the Davies-Fulling-Unruh effect and Hawking Radiation.

Wormholes, energy conditions and time machines / 74

GUP Corrected Casimir Wormholes in symmetric teleparallel Gravity

Author: Pradyumn Sahoo[1]

[1] *BITS-Pilani, Hyderabad Campus*

Corresponding Author: pksahoo@hyderabad.bits-pilani.ac.in

We have systematically presented the effect of the Generalized Uncertainty Principle (GUP) in Casimir wormhole space-time in the recently proposed modified gravity, the so-called symmetric teleparallel gravity, or $f(Q)$ gravity. We consider two famous GUP models, such as the Kempf, Mangano, and Mann (KMM) model and the Detournay, Gabriel, and Spindel (DGS) model, in this study. Also, to find the solutions, we assumed two different $f(Q)$ forms and obtained analytic as well as numerical solutions under the effect of GUP. Besides this, we investigate the solutions with three different redshift functions under an anisotropic fluid located at the throat. Further, we analyzed the obtained wormhole solutions with energy conditions, especially null energy conditions (NEC) at the wormhole's throat, and encountered that some arbitrary quantity disrespects the classical energy conditions at the wormhole throat of radius r_0. Later, the ADM mass and the volume integral quantifier are also discussed to calculate the amount of exotic matter required near the wormhole throat. Additionally, we show the behavior of the equation of state parameters under the effect of GUP.

Neutrinos in the multi-messenger era / 75

High-Energy Neutrinos and Photons from NGC 1068

Author: Enrico Peretti[1]

[1] *CNRS*

Corresponding Author: enrico.peretti.science@gmail.com

The IceCube neutrino observatory recently found an excess of TeV neutrinos at a significance of 4.2 σ associated to NGC 1068, one of the most well known nearby Seyfert galaxies.
NGC 1068 was already known as a gamma-ray emitter in the GeV band, whereas only upper limits in the flux were found in the TeV band.
Interestingly, the neutrino flux is about two orders of magnitude larger than the gamma-ray upper limits at the same energies thereby suggesting an optically thick hadronic source.
In my talk, I will review and discuss the possible sites for particle acceleration and their contribution to the multi-messenger flux of NGC 1068.

Gamma-ray bursts and AGNs with machine learning / 76

Gamma-ray Bursts as Distance Indicators by a Statistical Learning Approach

Author: Maria Dainotti[None]

Co-author: Aditya Narendra [1]

[1] *Jagiellonian University*

Corresponding Author: aditya.narendra@doctoral.uj.edu.pl

Gamma-ray bursts (GRBs) can be probes of the early universe, but currently, only 26% of GRBs observed by the Neil Gehrels Swift Observatory GRBs have known redshifts (z) due to observational limitations. To address this, we estimated the GRB redshift (distance) via a supervised statistical learning model that uses optical afterglow observed by Swift and ground-based telescopes. The inferred redshifts are strongly correlated (a Pearson coefficient of 0.93) with the observed redshifts, thus proving the reliability of this method. The inferred and observed redshifts allow us to estimate the number of GRBs occurring at a given redshift (GRB rate) to be 8.47-9 yr−1Gpc−1 for 1.9<z<2.3.

Since GRBs come from the collapse of massive stars, we compared this rate with the star formation rate highlighting a discrepancy of a factor of 3 at z<1.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 77

Revealing the spectro-polarimetric insights of black hole X-ray binaries with IXPE and Prospects of XPoSat

Author: Seshadri Majumder[1]

Co-authors: Ankur Kushwaha [2]; Swapnil Singh [2]; Kiran Jayasurya [2]; Santabrata Das [1]; Anuj Nandi [3]

[1] *Indian Institute of Technology Guwahati*

[2] *U. R. Rao Satellite Centre, Bangalore*

[3] *URSC, ISRO*

Corresponding Author: seshadrimajumder7@gmail.com

We present the results of a comprehensive spectro-polarimetric analysis of nine black hole X-ray binaries namely Cyg X$-$1, 4U 1630$-$47, 4U 1957+115, Cyg X$-$3, LMC X$-$1, LMC X$-$3, Swift J1727.8$-$1613, Swift J151857.0$-$572147 and GX 339$-$4 using quasi-simultaneous IXPE, NICER and NuSTAR observations. Polarimetric measurements with IXPE confirm the detection of a significant degree of polarization varying in the range of $1.44-21.41\%$ ($2-8$ keV) for all the sources in different spectral states (LHS, HIMS, SIMS, HSS) except LMC X$-$1. The energy-dependent polarization study imparts a significant ($>4\sigma$) increase of polarization degree with energy up to $\sim 11\%$ (25%) for 4U 1630$-$47 (Cyg X$-$3) whereas marginal ($<2\sigma$) variation is observed for rest of the sources. A detailed spectro-polarimetric study ($2-8$ keV) and broad-band spectral analysis ($0.7-60$ keV) using the high quality IXPE, NICER and NuSTAR observations further corroborates the detection of polarization from model-dependent approach and reveals the morphologies of distinct spectral states, respectively. In addition, we find a significant correlation between the spectro-polarimetric parameters, tightly connected to the spectral states of the sources. Based on the obtained results, we infer the disc-jet-corona geometry of the sources in different spectral states and the possible origin of the polarized emissions. Finally, we discuss the prospects of India's first X-ray polarimetric mission, XPoSat in the context of IXPE results.

Mid-frequency gravitational waves (0.1-10 Hz): sources and detection methods / 78

Multiband Gravitational Wave Observations at the Low to Middle and High Frequencies.

Author: Yuetong Zhao[None]

Co-authors: Wei-Tou Ni ; Youjun Lu [1]

[1] *National Astronomical Observatories of China*

Corresponding Author: ytzhao@bnu.edu.cn

The ground-based gravitational wave (GW) observations discover a population of merging stellar binary black holes (BBHs), which could also be detected by the space-based low-frequency GW detectors, such as LISA, Taiji and Tianqin, in their early inspiral stages. The middle-frequency GW band, a missing link between the high-frequency and low-frequency band, is an important piece for multiband GW observations of stellar BBHs. There are several different proposed detectors (e.g. DECIGO, AMIGO, BBO and LGWA) for the middle-frequency band. We investigate the multiband GW detections of stellar BBHs and demonstrate the advantages of such observations in improving the localization and parameter estimations of the sources. We generate mock samples of BBHs by considering different formation models as well as the merger rate density constrained by the current observations (GWTC-3). We specifically consider the astrodynamical middle-frequency interferometer GW observatory (AMIGO) in the middle-frequency band and estimate that it may detect 21–91 BBHs with signal-to-noise ratio $\varrho \geq 8$ in a 4-yr observation period. The multiband observations by the low-frequency detectors⊠LISA and Taiji) and the middle-frequency detector (AMIGO) may detect 5–33 BBHs with $\varrho_{\rm LT} \geq 5$ and $\varrho_{\rm AMI} \geq 5$, which can evolve to the high-frequency band within 4 yr and can be detected by CE and ET. The joint observations of LISA-Taiji-AMIGO-ET-CE can also lead to an improvement of the localization and the measurement precision of the chirp mass by a factor of ~120, ~2.4×10^5, ~1.8×10^4, or ~1.2×10^4, and ~5.5×10^4, ~16, ~120, or ~5, comparing with those by CE-ET, AMIGO, LISA-Taiji, or LISA-Taiji-AMIGO.

Dark matter halos: its nature, modeling & tracers / 79

The observed halo shapes suggest that dark matter deviates from the collisionless cold dark matter paradigm

Author: Jorge Sanchez Almeida[1]

[1] *Instituto de Astrofísica de Canarias*

Corresponding Author: jos@iac.es

In the standard cosmological model the dark matter (DM) particles are collisionless and, because of this very nature, they develop halos with the characteristic central cusp known as NFW profile. Real galaxies do not show NFW profiles but, rather, have a DM mass distribution with a central plateau or core, characteristic of self-gravitating systems in thermodynamic equilibrium (SA+20). Within the standard model, the collisionless DM reaches equilibrium through baryon-driven processes able to transform the overall potential from cusp to core (Governato+10). Such mechanism becomes inoperative for galaxies with few stars (stellar mass <10^6 Msun; Penarrubia+12), thus, finding cores in these galaxies would indicate that the DM is not collisionless, reflecting the much sought-after and currently unknown true nature of the DM (whether it is fuzzy, self-interacting, warm, or else). Measuring the DM distribution in these tiny galaxies through traditional dynamical indicators is impossible, but we have developed a tool to constrain the distribution of DM from the stellar photometry alone. Cores in the stellar distribution are very common, and they turn out to be inconsistent with NFW potentials because the phase-space distribution function to match them has to be negative (SA+23). I will put forward the arguments leading to this conclusion, and then apply the technique to six observed Ultra Faint Dwarf galaxies, with stellar masses between 10^3 and 10^4 Msun. They show stellar cores incompatible with NFW potentials, which suggests the DM to deviate from the collision-less cold dark matter paradigm. This result still requires to be put on a solid statistical basis, but the needed data will be available soon provided by the new generation of deep imaging surveys such as the LSST-Vera Rubin Observatory or the Euclid satellite.

Governato+10, Nat, 463, 203
Penarrubia+12, ApJL, 759, L42,
Sanchez Almeida+20, A&A Letters, 642, 14
Sanchez Almeida+23, ApJ, 954, 153

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 80

Study of mass outflow rates from magnetized accretion disk around rotating black holes

Authors: Camelia Jana[1]; Santabrata Das[2]

[1] *Indian Institute of Technology, Guwahati*

[2] *Indian Institute of Technology Guwahati*

Corresponding Author: camelia_jana@iitg.ac.in

We develop a framework to study the properties of mass outflows from a relativistic, viscous, magnetized, advective accretion flow around a rotating black hole (BH). While doing so, we assume that the disk is mainly threaded by the toroidal component of magnetic field and consider synchrotron radiation as the main cooling mechanism within the accretion disk. With this, we self consistently solve the coupled accretion-ejection equations and obtain the shock-induced global inflow-outflow solutions in the steady state. Using this model, we estimate mass outflow rate ($R_{\dot{m}}$, the ratio of outflow to inflow mass flux) by varying the model parameters, such as plasma-β (ratio of gas pressure to magnetic pressure), accretion rate ($\dot{m}$), viscosity($\alpha_{\rm B}$) and black hole spin ($a_{\rm k}$). We observe that $R_{\dot{m}}$ increases as the magnetic activity inside the disk is increased. Specifically, we find that a maximum $\sim$ 30% of accreted matter can be ejected for a Kerr black hole ($a_{\rm k} = 0.99$), whereas for Schwarzschild black hole it is $\sim$ 24%. Finally, we discuss the implication of this formalism in explaining the kinetic jet power commonly observed from black hole sources.

Black holes in alternative theories of gravity / 82

The Classical Point Particle Singularity: An Illusion in GR and Elsewhere!

Author: Yousef Sobouti[1]

Co-author: Haidar Sheikhahmadi [2]

[1] *Institute for Advanced Studies in Basic Sciences - Zanjan*

[2] *School of Astronomy, Institute for Research in Fundamental Sciences (IPM)*

Corresponding Author: sobouti@iasbs.ac.ir

Singularities in Newton's gravity, in general relativity (GR), in Coulomb's law, and elsewhere in classical physics, stem from two ill conceived assumptions that, a) there are point-like entities with finite masses, charges, etc., packed in zero volumes, and b) the non-quantum assumption that these point-like entities can be assigned precise coordinates and momenta. In the case of GR, we argue that the classical energy-momentum tensor in Einstein's field equation is that of a collection of point particles and is prone to singularity. In compliance with Heisenberg's uncertainty principle, we propose replacing each constituent of the gravitating matter with a suitable quantum mechanical equivalent, here a Yukawa-ameliorated Klein-Gordon (YKG) field. YKG fields are spatially distributed entities. They do not end up in singular spacetime points nor predict singular blackholes. On the other hand, YKG waves reach infinity as 1 r□^−(□±□ □)□. They create non-Newtonian and non-GR gravity forces that die out as □−1 instead of □−2. This feature alone is capable of explaining the observed flat rotation curves of spiral galaxies, and one may interpret them as alternative gravities, dark matter paradigms, etc. There are ample observational data encapsulated in the Tully-Fisher relation to support these conclusions.

Black holes in alternative theories of gravity / 83

Dynamics of scalar fields in the nonlinear σ-models in the Eddington inspired Born-Infeld gravity

Author: Bakhodir Kayumov[1]

Co-author: Bobir Toshmatov [2]

[1] *School of Humanities and Natural Sciences, New Uzbekistan University*

[2] *New Uzbekistan University*

Corresponding Author: b.kayumov@newuu.uz

In our presentation, we demonstrate the spacetime properties of a monopole within nonlinear σ-models in Eddington inspired Born-Infeld gravity. Specifically, we investigate characteristic circular orbits of test particles and photons, including circular null geodesics, marginally bound orbits, and stable circular orbits, as influenced by spacetime parameters. Additionally, we discuss the dynamics of a massless scalar field, covering quasinormal frequencies in both low and high energy regimes, their time evolutions, and the stability of the configuration against scalar perturbations.

Theories of gravity: alternatives to the cosmological and particle standard models / 84

Structure formation in shift-symmetric Galileon models

Author: Francesco Pace[1]

[1] *University of Torino*

Corresponding Author: francesco.pace@unito.it

In this talk I will present the evolution of perturbations in a sub-class of Horndeski models characterised by shift symmetry, considering a very general parametrisation of the background. I will show how the free background parameters affect the evolution of the perturbations and present results on the halo mass function and how we can use it to distinguish these models from the standard LCDM cosmology.

GRB-SN connection / 85

Deciphering the distance and the nature of GRB 210704A

Authors: Alan Watson[1]; Brendan O'Connor[2]; Eleonora Troja[3]; Nathaniel Butler[4]; Peter Veres[5]; Rosa Leticia Becerra Godinez[6]; Simone Dichiara[7]

[1] *UNAM*

[2] *George Washington University*

[3] *NASA/GSFC*

[4] *Arizona State University*

[5] *University of Alabama in Huntsville*

[6] *Università degli Studi di Roma, Tor Vergata*

[7] *UMD/NASA-GSFC*

Corresponding Author: rosa.becerra@roma2.infn.it

GRB 210704A is a burst of intermediate duration (T90~1-4 s) followed by a fading afterglow and an optical excess that peaked about 7 days after the explosion. Its properties, and in particular those of the excess, do not easily fit into the well established classification scheme of GRBs as being long or short.

In this talk, I will present multi-wavelength observations of the GRB and its counterpart, observed up to 160 days after the burst. I also present three possible scenarios to explain our multi-frequency observations and considering the diverse estimated distance values: a neutron star merger, a collapsing massive star, and an atypical explosion possibly hosted in a cluster of galaxies. We find that traditional kilonova and supernova models do not match well the properties of the optical excess, leaving us with the intriguing suggestion that this event was an exotic high-energy merger.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 86

Tests of General Relativity with black hole X-ray data

Authors: Askar Abdikamalov[1]; Cosimo Bambi[2]

[1] *New Uzbekistan University*

[2] *Fudan University*

Corresponding Author: a.abdikamalov@newuu.uz

General Relativity has been extensively tested within the weak-field regime across various experiments. Recent years have seen significant progress in exploring the strong-field domain, now made possible through gravitational waves, X-ray data, and radio images of supermassive black holes like SgrA*and M87*. In this talk, I will discuss recent efforts to test General Relativity using black hole X-ray data, utilizing the NKBB and RELXILL_NK models. These models are employed for thermal and reflection spectra analysis from black hole accretion disks, respectively, to test the Kerr black hole hypothesis.

Inflation: perturbations, initial singularities and emergent universes / 87

A non-singular universe out of Hayward black hole

Author: Michał Bobula[1]

[1] *University of Wrocław*

Corresponding Author: michal.bobula@uwr.edu.pl

We construct a (quantum mechanically) modified model for the Oppenheimer-Snyder collapse scenario where the exterior of the collapsing dust ball is a Hayward black hole spacetime and the interior is a dust Friedmann-Robertson-Walker cosmology. This interior cosmology is entirely determined by the junction conditions with the exterior black hole. It turns out to be non-singular, displaying a power-law contraction which precedes a de Sitter phase or, reversely, a power-law expansion followed by a de Sitter era. We also analyse the global causal structure and the viability of the model.

Theories of gravity: alternatives to the cosmological and particle standard models / 88

The Classical Point Particle Singularity: An Illusion in GR and Elsewhere!

Author: Yousef Sobouti[1]

Co-author: Haidar Sheikhahmadi [2]

[1] *Institute for Advanced Studies in Basic Sciences - Zanjan*

[2] *School of Astronomy, Institute for Research in Fundamental Sciences (IPM)*

Corresponding Author: sobouti@iasbs.ac.ir

Singularities in Newton's gravity, in general relativity (GR), in Coulomb's law, and elsewhere in classical physics, stem from two ill conceived assumptions that, a) there are point-like entities with finite masses, charges, etc., packed in zero volumes, and b) the non-quantum assumption that these point-like entities can be assigned precise coordinates and momenta. In the case of GR, we argue that the

classical energy-momentum tensor in Einstein's field equation is that of a collection of point particles and is prone to singularity. In compliance with Heisenberg's uncertainty principle, we propose replacing each constituent of the gravitating matter with a suitable quantum mechanical equivalent, here a Yukawa-ameliorated Klein-Gordon (YKG) field. YKG fields are spatially distributed entities. They do not end up in singular spacetime points nor predict singular blackholes.
On the other hand, YKG waves reach infinity as $r^{-1-(\pm)}$. They create non-Newtonian and non-GR gravity forces that die out as $^{-1}$ instead of $^{-2}$. This feature alone is capable of explaining the observed flat rotation curves of spiral galaxies, and one may interpret them as alternative gravities, dark matter paradigms, etc. There are ample observational data encapsulated in the Tully-Fisher relation to support these conclusions.

Gravitational lensing, shadows and photon rings / 90

Constraining spherically symmetric metrics by the gap between photon rings

Authors: Fabio Aratore[1]; Oleg Tsupko[2]; Volker Perlick[None]

[1] *Università degli studi di Salerno*

[2] *ZARM, Bremen University, Germany*

Corresponding Author: faratore@unisa.it

Gravitational lensing of luminous matter that surrounds a black hole or some other sufficiently compact object produces an infinite sequence of images. Besides the direct (or primary) image, it comprises demagnified and deformed replicas of the original known as photon rings which are progressively nearing the boundary of the socalled shadow.
We present analytical approximation formulas for higher-order photon rings for an asymptotically flat, static, spherically symmetric spacetime that admits a photon sphere. We consider an emission ring in the equatorial plane and an observer at arbitrary inclination far away from the center. Fixing the emission radius and leveraging the strong deflection limit, which provides an analytical logarithmic approximation for the deflection angle, we find the deformed shape of higher-order photon rings in the form of a polar equation on the observer's screen.
In particular, we use the relative separation between two neighboring photon rings, which we call "gap parameter", for characterizing the underlying spacetime. We obtain an analytical expression for the gap parameter of higher-order photon rings for metrics of the considered class that may depend on multiple parameters.
The advantage of using this quantity is in the fact that, to within the assumed approximations, it is independent of the mass of the central object (or of some other characteristic parameter if the mass is zero) and of the distance of the observer. Measurements of the gap parameter, which may become possible in the near future, will restrict the spacetime models that are in agreement with the observations. Even without knowledge of the emission radius, it will conclusively rule out some metrics.
We exemplify our calculations of the gap parameter with the Schwarzschild, Reissner-Nordstrom, Janis-Newman-Winicour and Ellis wormhole metrics.

Machine learning in astronomy: AGN, transient events, cosmology and others / 91

Prompt GRB recognition through waterfalls and deep learning

Authors: Eric Burns[None]; Michela Negro[1]; Nicolò Cibrario[2]

[1] *Louisiana State University*

[2] *Università degli Studi di Torino / INFN-To*

Corresponding Author: ericburns@lsu.edu

Gamma-ray Bursts (GRBs) are one of the most energetic phenomena in the cosmos, whose study probes physics beyond the reach of laboratories on Earth. Yet, our quest to fully unravel the origin of these events and comprehend their underlying physics is far from complete. Central to this pursuit is the rapid classification of GRBs to guide follow-up observations and analysis across the electromagnetic spectrum and beyond.
In this talk I will present a compelling approach which lays the groundwork for a new and robust GRB prompt classification. Leveraging self-supervised deep learning, we pioneer a novel and previously unexplored data product: GRB *waterfalls*.

Experimental graviation / 92

The progress of G measurement at HUST

Author: Qing Li[1]

Co-authors: Xin Li [1]; Ruiqi Liu [1]; Tong Huang [1]

[1] *Huazhong University of Science and Technology*

Corresponding Author: qingli@hust.edu.cn

This work introduces the experimental progress of the measurement of gravitational constant G at Huazhong University of Science and Technology. We intend to carry out the measurement with the silicon spheres. The surface separation between the spheres is measured with the laser interferometry with an uncertainty of less than 0.1 um. The expected uncertainty of G is better than 10ppm.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 93

Vacuum Energy from Qubit Entropy

Author: Gonçalo Quinta[1]

[1] *Instituto de Telecomunicações*

Corresponding Author: goncalo.quinta@tecnico.ulisboa.pt

We develop a non-conventional description of the vacuum energy in quantum field theory in terms of quantum entropy. Precisely, we show that the vacuum energy of any non-interacting quantum field at zero temperature is proportional to the quantum entropy of the qubit degrees of freedom associated with virtual fluctuations. We prove this for fermions first and then extend the derivation to quanta of any spin. We also argue that essentially the same results are valid in the interacting case in the mean-field approximation and when the background is curved and static.

Large scale structure and dark energy / 94

Gravitational collapse of dark matter in presence of dark energy

Author: PRIYANKA SAHA[1]

Co-author: Dipanjan Dey [2]

[1] *Phd scholar, IIT Kanpur*

[2] *Dalhousie University, Canada*

Corresponding Author: sahapriyanka335@gmail.com

We propose a model of the gravitational collapse of dark matter in the presence of dark energy, modeled by quintessence or phantom-like scalar fields. This work is based on the principles of general relativity up to virialization. We have chosen a spherical patch that starts to collapse gravitationally, as occurs in top-hat collapse. It is observed that although the dark matter sector collapses, the dark energy sector maintains a profile that is almost similar to the dark energy profile for the background expanding FLRW universe, given suitable model parameters. It is noted that in order to formulate the problem in the general relativistic setting, one requires an external generalized Vaidya spacetime to be matched with the internal spherical patch whose dynamics are guided by the FLRW metric. It is shown that almost all collapses are accompanied by some flux of matter and radiation in the generalized Vaidya spacetime. Some spherical regions of the Universe are observed not to collapse but to expand eternally, producing void-like structures. Whether a spherical region will collapse or expand depends on the initial values of the system and other model parameters. The evolution of the over-dense region will change if the scalar field is non-minimally coupled to the dark matter. Here we focus on algebraic coupling, where the interaction Lagrangian is independent of the derivatives of the scalar field. Our investigation reveals that an increase in the coupling strength causes dark energy to cluster with dark matter at a certain cosmological scale where the influence of dark energy cannot be ignored. This phenomenon arises from the specific nature of the non-minimal coupling considered in our work. As this work shows that collapsing structures must emit some form of radiation, this may be taken as an observational signature of our proposal.

Low frequency gravitational waves: sciences and detections / 96

Ground testing of release impulse for the aluminum test mass based on the compound pendulum

Author: Lingling Yang[1]

Co-author: Xin Li [1]

[1] *□□□□□□□□□□□1037□□□□□□□□□□*

Corresponding Author: 1240649564@qq.com

In the space gravitational wave detection program, the locking and releasing of test mass is one of the key technologies. The test mass is locked in during the launch phase of the spacecraft and then released during the scientific exploration phase, allowing it to go into free fall. Among them, the residual release impulse of the test mass is required to be in the order of magnitude of 10-5 kg m/s, so that the test mass can be trapped by the electrostatic feedback control. Based on the above content, a compound pendulum is built to measure the release impulse of the test mass. The test mass is locked by two thimbles in the opposite positions, and the release impulse is obtained by the swing of the pendulum. When the aluminum test mass is locked and released by the aluminum and the stainless steel thimbles, the release impulse and its uncertainty are in the order of magnitude of 10-5 kg m/s and 10-7 kg m/s, respectively. The double-thimble locking and releasing experiment based on the compound pendulum provides a feasible measurement scheme for the test of the release impulse in Tianqin project.

Quantum gravity phenomenology / 97

Wave function of the universe in the presence of trans-Planckian censorship

Author: Vikramaditya Mondal[1]

[1] *Indian Association for the Cultivation of Science*

Corresponding Author: psvm2345@iacs.res.in

The wave function for a closed de Sitter universe has been computed, demanding consistency with the recently proposed Trans-Planckian Censorship Conjecture (TCC). We extend the Einstein-Hilbert action to contain a complex-valued term which provides an exponentially decaying weight for the geometries violating TCC in the Lorentzian path integral sum while working in the minisuperspace approach to quantum cosmology. This postulated modification suppresses the probability of evolution of the universe into configurations that violate TCC. We show that due to the presence of this suppression factor, the Hubble rate of the universe at the end of the inflation gets subdued and assumes a value less than what is expected classically. Moreover, the consequences of this quantum gravity motivated correction in the primordial power spectrum are discussed as well.

Strong electromagnetic and gravitational field physics: From laboratories to early Universe / 98

Non-linear media in weakly curved spacetime: optical solitons and probe pulses for gravimetry

Authors: Alessio Belenchia[None]; Daniel Braun[None]; Dennis Rätzel[1]; Felix Spengler[None]

[1] *Humboldt Universität zu Berlin*

Corresponding Author: dennis.raetzel@zarm.uni-bremen.de

That light propagating in a gravitational field gets frequency-shifted is one of the basic consequences of any metric theory of gravity rooted in the equivalence principle. At the same time, also a time dependent material's refractive index can frequency-shift light propagating in it. The mathematical analogy between the two effects is such that the latter has been used to study the optical analogue of a black-hole spacetime. Here, we combine these two effects by showing that light propagation in non-linear media in the presence of a moving refractive index perturbation can lead to a gravity-dependent blueshift. We find that the predicted blueshift surpasses the gravitational redshift even if the medium is considered to be perfectly stiff. In realistic scenarios, by far the strongest frequency shift arises due to the deformation of the dielectric medium and the corresponding photoelastic change of refractive index. This has the potential to facilitate optical sensing of small gravity gradients.

High energy astrophysics / 99

SRG/eROSITA catalogue of X-ray active SDSS dwarf galaxies

Author: Sergei Bykov[1]

Co-authors: Marat Gilfanov [2]; Rashid Sunyaev [3]

[1] *Max Planck Institute for Astrophysics*

[2] *MPA, Garching & IKI, Moscow*

[3] *Space Research Institute (IKI) of the Russian Academy of Sciences, Max Planck Institute for Astrophysics and Institute for Advanced Study, Princeton*

Corresponding Author: sdbykov@mpa-garching.mpg.de

We present a sample of 99 dwarf galaxies (stellar mass < 10^9.5 M☉) with X-ray activity in their central regions. The sample was obtained from a match of the SRG/eROSITA X-ray catalogue in the eastern galactic hemisphere with the MPA-JHU SDSS catalogue. The obtained matches were cleaned rigorously with the help of external optical catalogues to increase the purity of the sample. This work is the largest study of this kind - X-ray activity in ≈85 per cent of matched dwarfs was not reported before. The majority of X-ray active dwarfs are identified as star-forming galaxies. However, the X-ray luminosity of 82 objects cannot be explained by the collective emission of X-ray binaries, rendering them strong candidates for dwarf galaxies with an active accreting black hole in their centre. We find that the fraction of AGN among dwarf galaxies drops from ~2*10^-2 at L_X ~ 10^39 erg/s to ~(2 - 4) · 10^-4 at L_X ~ 10^41 erg/s and increases with the stellar mass of the host galaxy. We serendipitously discovered sources with unexpected properties. We report on a tidal disruption event (TDE) candidate in a dwarf galaxy, a massive black hole in a dwarf galaxy with a soft thermal spectrum, a luminous dwarf galaxy with an obscured X-ray spectrum and a few other peculiar sources. We found three Ultra-luminous X-ray (ULX) source candidates and a sample of X-ray bright galaxy pairs, in four of which both members shine in X-rays.
https://arxiv.org/abs/2310.00303

Dark energy and the accelerating universe / 100

Cosmology on a gravitational wave background

Author: Tonatiuh Matos[1]

[1] *Centro de Investigación y de Estudios Avanzados del IPN*

Corresponding Author: tonatiuh.matos@cinvestav.mx

There is no doubt that we live in a Gravitational Wave Background (GWB). In this talk we start from this hypothesis and show that if we take into account the energy generated by the GWB we have to extend Einstein's equations with a term $2\pi^2/\lambda^2$, where λ is the Compton wave length of the graviton of the size of the observable universe. We call this model Compton Mass Dark Energy (CMaDE). With these equations we study the corresponding cosmology and using the SimpleMC code we find that this model fits the Pantheon + BAO + CC data better than the LCDM model. Then, using the same values for the parameters, using the CLASS code we compared this model to the CMB data and found excellent agreement with the CMB and MPS profiles. We conclude that the CMaDE model is an excellent candidate to explain the accelerated expansion of the universe, without cosmological constants, extra matter or modifications of Einstein's equations. Ref: arXiv:2303.07111 and MNRAS 529, 3013, (2024).

Black hole formation, evolution and the black hole mass gap / 103

Primordial Black Hole Dark Matter from Warm Natural Inflation

Author: Grant Mathews[1]

Co-authors: MIguel Correa [2]; Mayukh Gangopadhyay ; Nur Jaman [3]

[1] *University of Notre*

[2] *University of Notre Dame*

[3] *IISERKOL*

Corresponding Author: gmathews@nd.edu

In recent work [1,2] we have shown that within the natural warm inflationary paradigm (WNI) observational constraints on the primordial power spectrum from the cosmic microwave background (CMB) can be satisfied without going beyond the Planck scale of the effective field theory. Moreover, WNI can inevitably provide perfect conditions for the production of primordial black holes (PBHs) in the golden window of black-hole mass range where it can account for all of the the dark matter content of the universe while satisfying observational constraints. In this talk we review the contributions from this form of dark matter to the gravitational wave background, and the prospects for this PBH dark matter to merge into early seeds of galaxy formation and super-massive black holes at high redshift.

[1] M. Correa, M. R. Gangopadhyay, N. Jaman, G. J. Mathews, Phys. Lett. B835, 137510 (2022).
[2] M. Correa, M. R. Gangopadhyay, N. Jaman, G. J. Mathews,
Phys. Rev. D 109, 063539 (2024)

*Work at the University of Notre Dame supported by the U.S. DOE under nuclear theory grant DE-FG02-95-ER40934

Modeling of binary neutron star and black hole-neutron star mergers, and of their electromagnetic counterparts / 104

Binary neutron star mergers with a crossover to quark mater: Comparing the QHC19 and QHC21 equations of state

Authors: Grant Mathews[1]; Hee Il Kim[2]; InSaeng Suh[3]; Wei Sun[4]

[1] *University of Notre*

[2] *Sogang University*

[3] *Oak Ridge National Laboratory*

[4] *University of Notre Dame*

Corresponding Author: gmathews@nd.edu

In previous work [1] it was shown that a crossover transition from hadronic to quark matter during the merger of neutron stars can lead to interesting observational consequences in the emergent gravitational radiation. In particular, the increased pressure in the crossover density region ($2-5$ times the nuclear saturation density) can lead to an extended duration of high frequency ($\sim 2-3$ kHz) gravitational wave emission during the post merger epoch. However, that study was based upon the QHC19 formulation of the crossover equation of state. More recently, the updated QHC21 version has been developed based upon the NICER observations suggesting larger radii for neutron stars. In this talk we will discuss new simulations of neutron-star mergers based upon the QHC21 EoS. In comparison with the previous results we find that the long duration post-merger gravitational-wave emission is even more pronounced in the QHC21 EoS. Prospects for the detection of the GW emission in the spectral density function via current and future GW observatories is discussed.

[1] A. Kedia,1 H. I. Kim, I.-S. Suh, and G. J. Mathews, Phys. Rev. D 106, 103027 (2022).

Strong electromagnetic and gravitational field physics: From laboratories to early Universe / 106

Electromagnetic memory in arbitrary curved spacetimes

Authors: SUSMITA JANA[1]; Shankaranarayanan S[2]

[1] *IIT BOMBAY*

[2] *IIT Bombay*

Corresponding Author: susmitajana@iitb.ac.in

The gravitational memory effect and its electromagnetic (EM) analog are potential probes in the strong gravity regime. In the literature, this effect is derived for static observers at asymptotic infinity. While this is a physically consistent approach, it restricts the spacetime geometries for which one can obtain the EM memory effect. To circumvent this, we evaluate the EM memory effect for comoving observers (defined by the 4-velocity u_{μ}) in arbitrary curved spacetimes. Using the covariant approach, we split Maxwell's equations into two parts—projected parallel to the 4-velocity u_{μ} and into the 3-space orthogonal to u_{μ}. Further splitting the equations into 1 + 1 + 2-form, we obtain the acceleration vector of the comoving observer located in a two-dimensional (2D) surface orthogonal to the direction of propagation of the EM waves. We refer to this expression as the master equation for the EM memory in an arbitrary curved spacetime. The master equation corresponding to the acceleration of the comoving observer in the 2D surface provides a physical understanding of the contribution to the EM memory. For instance, the leading order contribution only requires information about the total energy density of the EM field, while the subleading contributions contain information about the spacetime geometry and the other components of the energy-momentum tensor of the EM field. To our knowledge, this is the first time a transparent and easily applicable final expression for electromagnetic memory has been derived for a general curved spacetime. We then obtain EM memory for specific spacetime geometries and demonstrate the advantages of our approach.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 107

Simulating magnetically arrested advective accretion flow (MA-AAF) around black holes: Explaining ULXs in hard states

Author: Rohan Raha[1]

Co-authors: Koushik Chatterjee [2]; Banibrata Mukhopadhyay [3]

[1] *Indian Institute of Science, Bangalore*

[2] *University of Maryland*

[3] *Indian Institute of Science*

Corresponding Author: raharohan@iisc.ac.in

An optically thin advective accretion disk appears to be indispensable in explaining the hard spectral state of black hole sources. We explore, with the help of general relativistic magnetohydrodynamic (GRMHD) simulations, how a large scale stronger magnetic field helps in transporting angular momentum in disk and outflow/jet, depending on the field geometry and plasma-β parameter, basically by underlying magnetic shear, along with the spin parameter of the black hole. In the present work, we propose a general advective, sub-Eddington, disk-outflow model in the presence of large-scale strong magnetic fields. We start from a magnetized torus around a Kerr black hole and simulate how the accretion disk evolves in time. We also investigate how it can produce jets and outflows via the possible Blandford-Znajek and Blandford-Payne processes. The underlying model simulation based on HARMPI exhibits an outflow efficiency up to 10, depending on black hole spin and magnetic field strength. This, in turn, is able to explain the observed luminosity of Ultra Luminous X-ray sources (ULXs) in their hard states. This model can, in general, explain any bright, hard state of stellar mass black hole sources and their high luminosity without incorporating super-Eddington accretion rates. Total energy, due to matter and magnetic field, is responsible for such high luminosity.

High energy astrophysics / 108

Multiwavelength pulsations and surface temperature distribution in the middle-aged pulsar B1055-52

Author: Armin Vahdat[1]

Co-authors: Bettina Posselt [2]; George Pavlov [3]

[1] *University of Tübingen*

[2] *University of Oxford*

[3] *The Pennsylvania State University*

Corresponding Author: mv.armin@gmail.com

We explore the X-ray emission from PSR B1055−52 using observations from XMM-Newton taken in 2019 and 2000. Traditional models of neutron star atmospheres fail to adequately describe the phase-integrated X-ray emission of this pulsar. Instead, our findings suggest a dual blackbody model with differing temperatures and areas, supplemented by a nonthermal power-law component, fits best. Our analysis reveals significant phase-related variations in the thermal emission, indicating a nonuniform temperature distribution across the neutron star's surface, potentially due to combined internal and external heating. Additionally, we observe distinct high pulse fractions (60%–80%) in the 0.7–1.5 keV range and identify a potential second hot spot at lower energies, supporting the hypothesis of an orthogonal rotator geometry and an asymmetrically aligned magnetic field. In this talk, I will present these findings in detail and discuss their implications for our understanding of neutron star structure and magnetic field dynamics.

Dark matter halos: its nature, modeling & tracers / 109

A natural explanation of the VPOS from multistate Scalar Field Dark Matter

Authors: Tonatiuh Matos[1]; Tula Bernal[2]

[1] *Centro de Investigación y de Estudios Avanzados del IPN*

[2] *Universidad Autonoma Chapingo*

Corresponding Author: tonatiuh.matos@cinvestav.mx

Observations with the Gaia satellite have confirmed that the satellite galaxies of the Milky Way are not distributed as homogeneously as expected. The same occurs in galaxies such as Andromeda and Centaurus A, where satellite galaxies around their host galaxies have been observed to have orbits aligned perpendicular to the galactic plane of the host galaxy. This problem is known for the Milky Way as Vast Polar Structure (VPOS). The Scalar Field Dark Matter Field (SFDM), also known as Ultralight-, Fuzzy-, BEC-, Axion-dark matter, proposes that dark matter is a scalar field, which in the non-relativistic limit follows the Schr\"odinger equation coupled to the Poisson equation. Although the scalar field here is classical, the Schr\"odinger equation contains a ground state and excited states as part of its nature.

In this talk, we show that such quantum character of the SFDM can naturally explain the VPOS observed in galaxies. By taking into account the ground and the first excited states only, we can fit the rotation curves of the galaxies in a very simple way, and with the best-fit parameters obtained, we can explain the VPOS. We do this with particular galaxies, such as the Milky Way, Andromeda, Centaurus A, and six other galaxies whose satellites have been observed. From this result, it follows that the multistate SFDM is not distributed homogeneously around the galaxy and therefore explains the VPOS distribution of satellite galaxies. According to this result, this could be a generalized characteristic of galaxies in the Universe. Finally, we also show how the scale of each galaxy depends on a parameter that is determined by the final temperature of the scalar field of the galaxy halo under study. This explains why different galaxies with SFDM give different values of the mass of the scalar field.

Quantum gravity phenomenology / 110

The Physics on a Gravitational Wave Background

Authors: Tonatiuh Matos[1]; Eric S. Escobar-Aguilar[2]

[1] *Centro de Investigación y de Estudios Avanzados del IPN*

[2] *Departamento de Fisica, Universidad Autonoma Metropolitana Iztapalapa*

Corresponding Author: e.escobar@xanum.uam.mx

It is a fact that the universe lives on a gravitational wave background (GWB). In this talk we start from this hypothesis. Due to the GWB, space-time is fluctuating in such a way that it locally resembles a lake with small waves and therefore quantum particles cannot follow geodesic trajectories, but rather follow stochastic trajectories. In the present talk, we begin by adding a stochastic term to the trajectories of quantum particles and derive the corresponding field equations of a quantum particle. Surprisingly we arrive at the Klein-Gordon equation in curved space-time. Since in the proper limit this equation reduces to a Schrödinger equation, this leads to the following relevant result: the Schrödinger equation can be a direct consequence of the fact that the universe lives in a GWB

Gravitational lensing, shadows and photon rings / 111

Semiclassical lensing and Radiative Lense Equations

Author: claudio coriano[1]

[1] *Universita del Salento*

Corresponding Author: claudio.coriano@le.infn.it

We present phenomenological analysis of photon lensing in an external gravitational background in the case of photons and neutrinos, and propose a method to incorporate radiative effects in the classical lens equations. The study is performed for a Schwarzschild metric, generated by a point-like source, and expanded in the Newtonian potential at first order. We use a semiclassical approach, where the perturbative corrections to scattering, evaluated at one-loop in the Standard Model, are compared with the Einstein formula for the deflection using an impact parameter formulation. For this purpose, we use the renormalized expression of the graviton/fermion/fermion vertex presented in previous studies. We show the agreement between the classical and the semiclassical formulations, for values of the impact parameter bh of the neutrinos of the order of bh~20, measured in units of the Schwarzschild radius. The analysis is then extended with the inclusion of the post Newtonian corrections in the external gravity field, showing that this extension finds application in the case of the scattering of a neutrino/photon off a primordial black hole. The energy dependence of the deflection, generated by the quantum corrections, is then combined with the standard formulation of the classical lens equations. We illustrate our approach by detailed numerical studies, using as a reference both the thin lens and the nonlinear Virbhadra-Ellis lens.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 112

Conformal Backreaction, Chiral and Conformal Anomalies in The Early Universe

Corresponding Author: claudio.coriano@le.infn.it

Conformal Field Theory in momentum space allows to investigate effective actions related to the Trace Anomaly of the Stress energy Tensor in great detail. The resulting action is nonlocal and

can be investigated in general metric backgrounds. The method of reconstruction of the action is worked out, in our analysis, both around flat spacetime and for general backgrounds, by comparing the conformal constraints of flat space with the variational solution of the trace anomaly functional. We present explicit examples of this comparison for the conformal case. We extend the method to the analysis of the effective action for the chiral gravitatonal anomalies, as well as for parity odd trace anomalies. We discuss the physical implications of these results in early universe cocosmology and the evolution of chiral asymmetries in chiral plasmas

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 113

Dark Gravity confronted with Supernovae, Baryonic Oscillations and Cosmic Microwave Background data

Author: Frederic Henry-couannier[1]

[1] *cppm*

Corresponding Author: henry@cppm.in2p3.fr

Dark Gravity is a natural extension of general relativity
in presence of a flat non dynamical background. Matter and radiation
fields from its dark sector, as soon as their gravity dominates over our side fields gravity, produce a constant acceleration law of the scale factor. After a brief reminder of the Dark Gravity theory foundations the confrontation with the main cosmological probes is carried out. We show that, amazingly, the sudden transition between the usual matter dominated decelerated expansion law a(t) ∝ t2/3 and this
accelerated expansion law a(t) ∝ t2 predicted by the theory should
be able to fit the main cosmological probes (SN,BAO, CMB and age
of the oldest stars data) but also direct H0 measurements with two
free parameters only : H0 and the transition redshift.

Black holes in alternative theories of gravity / 114

Strong interactions and Bekenstein – Hawking black hole entropy

Author: Hristu Culetu[None]

Corresponding Author: hculetu@yahoo.com

All particles created through the Hawking process have to be generated in the collapsing object. The black hole internal states should be related to the precollapsed state (a one-to-one correspondence between the internal state and precollapse configuration).
The baryons that formed the initial collapsing star cannot reappear since all their rest energy has been carried away by the thermal radiation. Therefore, the Hagedorn temperature should have been reached before the end of collapse of the star, and hadrons decayed as quarks and gluons, as a consequence of deconfinement. We assume that the BH entropy, which counts the internal microstates, should depend on the strong interaction fundamental scale. Inside the quark star formed after deconfinement, we assume there exists negative pressure $p = -B = -\epsilon$ (B - the bag constant, ϵ - the energy density) at zero chemical potential in vacuum, related to the confinement process, akin to inside hadrons, where a strong gravity model is proposed.
The Bekenstein black hole entropy expression is adjusted separately for $m > m_P$ and for $m < m_P$, where $m_P = 10^{-5}g$ is the Planck mass. We found that black holes with $m < m_P$ will not evaporate, an old idea expressed by V. Mukhanov in 1986.

Inflation: perturbations, initial singularities and emergent universes / 115

Eternal Inflation and a Geodesically Complete Universe

Author: Damien Easson[1]

[1] *Arizona State University*

Corresponding Author: easson@asu.edu

I will discuss eternal inflation and the key role that inflation plays in resolving cosmological singularities. I will describe how proposed no-go theorems, such as the famous theorem of Borde, Guth and Vilenkin (BGV) are circumvented or obviated. Our exploration encompasses eternal inflating, loitering, and bouncing models, shedding light on the critical aspects that underpin geodesic completeness and the constraints energy conditions in General Relativity impose on such spacetimes. Ignoring the intractable subtleties introduced by quantum considerations, such as rare tunneling events and Boltzmann brains, we will argue that the universe need not have a beginning or an end.

Theories of gravity: alternatives to the cosmological and particle standard models / 116

Generalized K-essence inflation in Jordan and Einstein frames

Authors: Orlando Luongo[1]; Tommaso Mengoni[2]

[1] *University of Camerino, Physics Division*

[2] *University of Camerino*

Corresponding Author: tommaso.mengoni@unicam.it

We here explore a specific class of scalar field, dubbed quasi-quintessence which exhibits characteristics akin to ordinary matter. Specifically, we investigate under which conditions this fluid can mitigate the classical cosmological constant problem. We remark that, assuming a phase transition, it is possible to predict inflationary dynamics within the metastable phase triggered by the symmetry breaking mechanism. During this phase, we study inflationary models incorporating this cancellation mechanism for vacuum energy within the context of quasi-quintessence. There, we introduce four novel potentials, categorized into two main groups, i.e., the Starobinsky-like and symmetry breaking paradigms. Afterwards, we consider two distinct cases, the first without coupling with the curvature, while the second exhibiting a Yukawa-like interacting term. Hence, we compute the inflationary dynamics within both the Jordan and Einstein frames and discuss the objective to unify old with chaotic inflation into a single scheme. We therefore find the tensor-to-scalar ratio and the spectral terms and conclude that the most suited approach involves the Starobinsky-like class of solution. Indeed, our findings show that small field inflationary scenarios appear disfavored and propose de facto a novel technique to reobtain the Starobinsky potential without passing through generalizations of Einstein's gravity. Last but not least, we conjecture that vacuum energy may be converted into particles by virtue of the geometric interacting term and speculate about the physics associated with the Jordan and Einstein frames.

Cosmic backgrounds from radio to far-IR / 117

Using Planck maps for a systematic search of ultra-bright high-z strongly lensed galaxies

Author: Matteo Bonato[1]

[1] *INAF-IRA*

Corresponding Author: matteo.bonato@inaf.it

Thanks to its all-sky coverage, the Planck mission had the unique capability of detecting the brightest strongly lensed high-z galaxies in the sky. The combination of boosted luminosity and stretching of images offers a unique opportunity to pierce into their internal structure and dynamics via high-resolution follow-up observations. It becomes possible to reach spatial resolutions of tens of pc and measure feedback-driven molecular outflows. Resolved imaging and kinematics of early galaxies is the most direct and powerful way to learn about the complex physical processes governing galaxy formation and evolution and to discriminate among competing scenarios. In this talk, I will present such a scientific exploitation of Planck maps and the chance of a systematic search of strongly lensed galaxies in those data.

Theories of gravity: alternatives to the cosmological and particle standard models / 118

Does dark energy really revive using DESI 2024 data?

Authors: Marco Muccino[1]; Orlando Luongo[2]; Youri Carloni[3]

[1] *INFN*

[2] *University of Camerino, Physics Division*

[3] *University of Camerino*

Corresponding Author: youri.carloni@unicam.it

In this work, we investigate the impact of the Dark Energy Spectroscopic Instrument (DESI) 2024 data on dark energy scenarios. Specifically, we analyze three typologies of models, the first in which the cosmic speed up is related to thermodynamics, the second associated with Taylor expansions of the barotropic factor, whereas the third based on ad hoc dark energy parameterizations. In this respect, we perform Monte Carlo Markov chain analyses, adopting the Metropolis-Hastings algorithm, of 12 models. To do so, we first work at the background, inferring a posteriori kinematic quantities associated with each model. Afterwards, we obtain early time predictions, computing departures on the growth evolution with respect to the model that better fits DESI data. We find that the best model to fit data \emph{is not} the Chevallier-Polarski-Linder (CPL) parametrization, but rather a more complicated log-corrected dark energy contribution. To check the goodness of our findings, we further directly fit the product, $r_d h_0$, concluding that $r_d h_0$ is anticorrelated with the mass. This treatment is worked out by removing a precise data point placed at $z = 0.51$. Surprisingly, in this case the results again align with the ΛCDM model, indicating that the possible tension between the concordance paradigm and the CPL model can be severely alleviated. We conclude that future data points will be essential to clarify whether dynamical dark energy is really in tension with the ΛCDM model.

Wormholes, energy conditions and time machines / 119

Gravitational Field Propulsion Techniques

Author: Gary Stephenson[1]

[1] *Seculine Consulting*

Corresponding Author: seculine@gmail.com

Two broad sets of classes of gravitational field propulsion techniques are investigated: classical general relativity field propulsion, and the quantum manipulation of spacetime. Classical approaches in this paper include a Forward Coil, which concentrates an acceleration field in the center of the coil, the use of wormholes, and a tokamak plasma quadrupole oscillator, creating gravitational waves

which can then rectified via quadrupole rectification. Classes of quantum approaches include the direct stimulation of graviton emission, and the stimulation of metamaterials to engineer the quantum vacuum. A nomenclature is suggested to categorize these classes.

Multi-messenger astronomy with gravitational waves / 120

Bayesian parameter estimation of continuous gravitational waves from known pulsars

Author: Anjana Ashok[1]

Co-authors: Maria Alessandra Papa [2]; Pep Covas Vidal [2]; Reinhard Prix [2]

[1] *Max Planck Institute for Gravitational Physics (AEI), Hannover*

[2] *Max Planck Institute for Gravitational Physics*

Corresponding Author: anjana.ashok@aei.mpg.de

Continuous gravitational wave (CW) searches targeted at known pulsars utilize electromagnetic observations of the sources to infer the phase-evolution parameters of the gravitational wave signal. We present a new method to perform Bayesian estimation of the amplitude parameters of a CW signal. The method leverages the well-established CW detection statistic, the F-statistic, and modern stochastic samplers to build Bayesian posteriors of the unknown signal parameters. After testing the method, we apply it on putative gravitational wave signals from PSR J1526-2744, a recently-discovered milli-second pulsar.

Experimental graviation / 121

Measuring a novel form of gravitomagnetism with hierarchical triple systems

Author: Lorenzo Iorio[1]

[1] *MIM*

Corresponding Author: lorenzo.iorio@libero.it

In hierarchical triple systems, the inner binary can be considered as a rotating matter ring with respect to the distant, outer companion. As such, the orbital angular momentum of the former induces an own gravitomagnetic field which may be orders of magnitude larger than that due to the individual spin angular momenta of the binary's components.The resulting gravitomagnetic orbital precessions may reach a considerable fraction of the Schwarzschild-like, gravitoelectric ones. Potential scenarios able, in principle, to allow for a measurement of such an effect are the so-called circumbinary exoplanets and triple systems like PSR J0337+1715 made of a tight pulsar-white dwarf pair orbited by a further, distant white dwarf. A major source of systematic bias is given by the competing classical precessions due to the quadrupolar term of the multipolar expansion of the Newtonian potential of a massive ring modeling the largest contribution to the overall gravitational field experienced by the distant companion.

Loop quantum gravity / 122

A better space of generalized connections

Authors: José A. Zapata[1]; Juan Orendain[2]

[1] *Universidad Nacional Autónoma de México*

[2] *Case Western Reserve University, USA.*

Corresponding Author: zapata@matmor.unam.mx

Given a base manifold M and a Lie group G, we define $\widetilde{calA}_M$ a space of generalized G-connections on M with the following properties:

- The space of smooth connections $calA_M^\infty = \sqcup_\pi calA_\pi^\infty$ is densely embedded in $\widetilde{calA}_M = \sqcup_\pi \widetilde{calA}_\pi^\infty$; moreover, in contrast with the usual space of generalized connections, the embedding preserves topological sectors.
- $\widetilde{calA}_M$ is a homogeneous diffeological covering space for the standard space of generalized connections of loop quantization $\bar{calA}_M$.
- $\widetilde{calA}_M$ is a measurable space that can be constructed as an inverse limit of of spaces of connections with a cutoff, much like $\bar{calA}_M$. At each level of the cutoff, a Haar measure, a "BF measure" and heat kernel measures can be defined. For compact gauge groups and for each topological sector, the Haar measure has finite volume and induces a measure in the inverse limit.
- The topological charge of generalized connections on closed manifolds $Q = \int Tr(F)$ in 2d, $Q = \int Tr(F \wedge F)$ in 4d, etc, is defined.
- The space of generalized connections on a manifold that is subdivided can be calculated in terms of the spaces of generalized connections associated to the pieces. This property holds even when the subdivision generates corners. Thus, spaces of boundary connections can be computed from spaces of connections associated to faces.
- The soul of our generalized connections is a notion of higher homotopy parallel transport defined for smooth connections. We recover standard generalized connections by forgetting its higher levels.

Gravitational instantons and black holes / 123

Energy formula, surface geometry and energy extraction for Kerr-Sen black hole

Author: PARTHA PRATIM PRADHAN[1]

[1] *HIRALAL MAZUMDAR MEMORIAL COLLEGE FOR WOMEN*

Corresponding Author: pppradhan77@gmail.com

We evaluate the surface energy~($calE_s^\pm$), rotational energy~($calE_r^\pm$) and electromagnetic energy~($calE_{em}^\pm$) for a Kerr-Sen black hole~(BH) having the event horizon~($calH^+$) and the Cauchy horizon~($calH^-$). Interestingly, we find that the sum of these three energies is equal to the mass parameter i.e. $calE_s^\pm + calE_r^\pm + calE_{em}^\pm = calM$. Moreover in terms of the scale parameter ~($\zeta_\pm$), the distortion parameter~($\xi_\pm$) and a new parameter~($\sigma_\pm$) which corresponds to the area~($calA_\pm$), the angular momentum ~(J) and the charge parameter~(Q), we find that the mass parameter in a compact form
$calE_s^\pm + calE_r^\pm + calE_{em}^\pm = calM = \frac{\zeta_\pm}{2}\sqrt{\frac{1+2\,\sigma_\pm^2}{1-\xi_\pm^2}}$
which is valid through all the horizons ($calH^\pm$). We also
compute the equatorial circumference and polar circumference which is a gross measure of the BH surface deformation. It is shown that when the spinning rate of the BH increases, the equatorial circumference increases while the polar circumference decreases. We show that there exist two classes of geometry separated by $\xi_\pm = \frac{1}{2}$ {in} Kerr-Sen BH. In the regime $\frac{1}{2} < \xi_\pm \leq \frac{1}{\sqrt{2}}$, the Gaussian curvature is negative and there exist \emtwo polar caps on the surface. While for $\xi_\pm < \frac{1}{2}$, the Gaussian

curvature is positive and the surface will be an oblate deformed sphere. Furthermore, we compute the exact expression of rotational energy that should be extracted from the BH via Penrose process. The maximum value of rotational energy which is extractable should occur for extremal Kerr-Sen BH i.e.
$calE_r^+ = \left(\frac{\sqrt{2}-1}{2}\right)\sqrt{2calM^2 - Q^2} = \left(\sqrt{2}-1\right)\sqrt{\frac{J}{2}}$.

Astrophysics with gravitational waves / 124

Observability of spin precession in the presence of a black-hole remnant kick

Author: Angela Borchers[1]

Co-authors: Frank Ohme [1]; Jannik Mielke [1]; Shrobana Ghosh [1]

[1] *Max Planck Institute for Gravitational Physics (Albert Einstein Institute)*

Corresponding Author: aborchers001@gmail.com

Remnants of binary black-hole mergers can gain significant recoil or kick velocities due to the anisotropic emission of gravitational waves, which may leave a characteristic imprint in the observed signal. So far, only one gravitational-wave event supports a non-zero kick velocity: GW200129_065458. This signal is also the first to show evidence for spin-precession. For most other gravitational-wave observations, spin orientations are poorly constrained as this would require large signal-to-noise ratios, unequal mass ratios or inclined systems. We investigate whether the imprint of the kick can help to extract more information about the spins. We perform an injection and recovery study comparing binary black-hole signals with significantly different kick magnitudes, but the same spin magnitudes and spin tilts. To exclude the impact of higher signal harmonics in parameter estimation, we focus on equal-mass binaries that are oriented face-on. We find that signals with large kicks necessarily include large asymmetries, and these give more structure to the signal, leading to more informative measurements of the spins and mass ratio. Our results also complement previous findings that argued precession in equal-mass, face-on or face-away binaries is nearly impossible to identify. In contrast, we find that in the presence of a remnant kick, even those signals become more informative and allow determining precession with signal-to-noise ratios observable already by current gravitational-wave detectors.

High energy astrophysics / 125

Constraining scalar-Gauss-Bonnet gravity with binary pulsars

Author: Kalin Staykov[1]

[1] *Sofia University*

Corresponding Author: kstaykov@phys.uni-sofia.bg

The orbital decay of binary pulsars is a very precise tool for testing general relativity and modified theories of gravity and for constraining the existence of additional neutron star charges. The orbital decay has been used for constraining scalar-tensor theories (STT) decades ago. In the present talk we demonstrate that the same simple methodology used for constraining STT can be applied to scalar-Gauss-Bonnet (sGB) gravity as well. At first, we demonstrate the applicability of the method used for STT by comparing it against results obtained by statistical methods. Following that we proceed towards driving constraints on Einstein-dilaton Gauss-Bonnet gravity.
In addition, we make use of the fact that in sGB gravity the maximal allowed neutron star mass, as well as the minimal allowed black hole mass, are parameter-dependent and, by imposing the contemporary observational limits on the neutron star and black hole masses, we set additional constraints on the parameter space of the theory.

Neutrinos in the multi-messenger era / 126

On the outflows driven by choked jets

Author: Matteo Pais[1]

Co-authors: Tsvi Piran [2]; Ehud Nakar [3]

[1] *INAF - Osservatorio Astronomico di Padova (OAPD)*

[2] *The Hebrew University*

[3] *Tel Aviv University*

Corresponding Author: matteo.pais@inaf.it

Many stripped-envelope supernovae (SNe) present a signature of high-velocity material responsible for broad absorption lines in the observed spectrum. These include SNe associated with long gamma-ray bursts (LGRBs), low-luminosity GRBs (llGRBs), and SNe not associated with GRBs. It was recently suggested that this high-velocity material originates from a cocoon driven by a relativistic jet. In LGRBs, this jet breaks out successfully from the stellar envelope, while the jet is choked in llGRBs and SNe that are not associated with GRBs. Here, we use numerical simulations to explore the velocity distribution of an outflow driven by a choked jet and its dependence on the jet and progenitor properties. We find that in all cases where the jet is not choked too deep within the star, the outflow carries a roughly constant amount of energy per logarithmic scale of proper velocity over a wide range of velocities, which depends mostly on the cocoon volume at the time of its breakout. This is a universal property of jet-driven outflows, which does not exist in outflows of spherically symmetric explosions or when the jets are choked very deep within the star. We, therefore, conclude that choked jets (not too deep) provide a natural explanation for the fast material seen in the early spectra of stripped-envelope SNe that are not associated with LGRBs and that properties of this material could reveal information on the otherwise hidden jets.

Dark matter halos: its nature, modeling & tracers / 127

Collisionless relaxation of galaxy clusters and the dark wave (if it exists).

Author: Alexander Milovanov[1]

[1] *ENEA National Laboratory, Centro Ricerche Frascati, Frascati, Italy*

Corresponding Author: alexander.milovanov@enea.it

This paper reports a stochastic theory of gravitational relaxation based on a Lévy-fractional Klein-Kramers equation with self-consistent entropy term. The use of fractional derivatives in this equation is motivated with nonequilibrium phase-space dynamics breaking the restrictive assumptions of Gaussianity, lack of correlation and nearness to virialized state. Astrophysical applications of the theory concern gravitational evolution of galaxy clusters with non-minimally coupled cold dark matter. One hard result pertaining to the statistical model is that position correlations between galaxies are attracted by the power law r^{-7/4}, which approximates the canonical scaling r^{-1.8} found in observations. The kinetic description, considered in this paper's work, is compatible with an idea that the relaxation of galaxy clusters to virialized state could be collisionless and mediated by hypothetical "dark waves", collective excitations of the coupled baryonic-dark matter system driven by the variation of local curvature on suitably small spatial scales.

Reference:

A. V. Milovanov, Stochastic theory of gravitational relaxation and Lévy-fractional Klein-Kramers equation, Europhys. Lett. EPL **140** (2022) 59001.

High energy astrophysics / 128

Testing a Lepto-Hadronic Two-Zone Model with Extreme High-Synchrotron Peaked BL Lacs and Track-like High-Energy Neutrinos

Author: Edilberto Aguilar-Ruiz[1]

Co-authors: Antonio Galván-Gámez [2]; Nissim Fraija Cabrera [2]

[1] *Instituto de radioastronomia y astrofísica, UNAM*

[2] *Instituto de astronomía, UNAM*

Corresponding Author: e.aguilar@irya.unam.mx

Numerous studies suggest that high-energy (HE) neutrinos and ultra-high-energy (UHE) cosmic rays could originate from extremely high-synchrotron peaked (EHSP) BL Lacs, which have been identified as effective particle accelerators. Due to the discovery of HE-neutrinos by the IceCube telescope, these hypotheses may shortly have the opportunity to be tested. In this work, we use a two-zone leptohadronic model to explain the spatial coincidence of three EHSP BL Lac: 1RXS J09462.5+010459, 1ES 1101-232, and 3HSP J095507.9+355101 with the arrival of track-like neutrinos. Our results for 1RXS J09462.5+010459 and 1ES 1101-232 indicate that the model accurately describes the electromagnetic emission and neutrino events without increasing the fluxes in the measured bands. In addition, the X-ray flaring state of 3HSP J095507.9+355101 can be explained by our model, but the measured ultraviolet flux during the neutrino arrival time window cannot be explained. For all cases, the broadband emission and neutrino arrival are better described by hard proton distributions ≈1.5. Finally, the proton luminosity required to explain the neutrino fluxes is slightly higher than the Eddington limit with a photopion efficiency of ≈0.1 for non-flaring state cases. On the other hand, for the flaring state of 3HSP J095507.9+355101, the proton luminosity must be higher than the Eddington limit at least by one order of magnitude, even if the photopion efficiency reaches unity.

Theories of gravity: alternatives to the cosmological and particle standard models / 129

Reconstructing cosmological dynamics from quantum communication between particle detectors

Author: Alessio Lapponi[1]

Co-authors: Orlando Luongo [2]; Stefano Mancini [2]

[1] *Scuola Superiore Meridionale (SSM), Largo San Marcellino 10, 80138 Napoli, Italy*

[2] *University of Camerino, Physics Division*

Corresponding Author: alessio.lapponi-ssm@unina.it

Particle detector models have been recently proven to be an effective mean to know how curved spacetimes affect quantum systems. For example, particles generated by the Unruh effect could be detected by an accelerating system and can provide a reliable communication of quantum messages, usually prevented by the no-cloning theorem. Motivated by this fact, we propose a quantum communication protocol between harmonic oscillators detectors undergoing a cosmological expansion. We see that the maximum rate of classical information they exchange is dependent on the barotropic factor of the cosmological fluids and on the coupling between the field and the scalar curvature. Consequently, we can extract information of the cosmic dynamics studying how these detectors communicate. Further, we establish a necessary condition to achieve a quantum capacity greater than zero. Because of the no-cloning theorem, it finally turns out that maximally symmetric metrics do not lead to a reliable communication of quantum messages between particle detectors and, so, alternative cosmological spacetimes could instead exhibit more detectable outcomes.

Multi-messenger astronomy with gravitational waves / 130

Multi-Messenger Astrophysics with future GRB space missions

Author: Lorenzo Amati[1]

[1] *INAF - OAS Bologna*

Corresponding Author: lorenzo.amati@inaf.it

The huge luminosity, the redshift distribution extending at least up to z~10 and the association with the explosive death of very massive stars make long GRBs extremely powerful probes for investigating the early Universe (pop-III stars, cosmic re-ionization, SFR and metallicity evolution up to the "cosmic dawn") and measuring cosmological parameters. At the same time, as demonstrated by the GW170817 event, GRBs are a key electromagnetic counterpart of gravitational waves produced by NS-NS and NS-BH merging events. GRB space mission projects for the next decade aim at fully exploiting these unique potentialities of the GRB phenomenon, thus providing an ideal synergy with the very large astronomical facilities of the future (e.g., ELT, CTA, SKA, Athena) and, in particular, with the Einstein Telescope (ET). For instance, the THESEUS mission, under study by ESA as candidate M7 for a launch in 2037, by providing an unprecedented combination of X-/gamma-ray monitors, on-board IR telescope and spacecraft autonomous fast slewing capabilities, would be a wonderful machine for the detection, multi-wavelength characterization and redshift measurement of any kind of GRBs and many classes of X-ray transients. Thanks to these unprecedented capabilities and a perfectly matched timeline with ET, this mission would thus provide at least several tens, and likely more than one hundred, EM counterparts to GW detections, thus greatly enhancing the scientific return of ET for multi-messenger astrophysics and cosmology, as well as extreme and fundamental physics with GRBs.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 131

GRB cosmology with next-generation GRB observatories

Author: Lorenzo Amati[1]

[1] *INAF - OAS Bologna*

Corresponding Author: lorenzo.amati@inaf.it

The huge luminosity, the redshift distribution extending at least up to z~10 and the association with the explosive death of very massive stars make long GRBs (i.e., those lasting up to a few minutes) potentially extremely powerful probes for shedding light on main open issues in our understanding of the early Universe: star formation rate evolution up to the first generation of stars (pop–III), cosmic reionization, luminosity function and metallicity evolution of primordial galaxies up to the "cosmic dawn". At the same time, the correlation between radiated energy and spectral photon peak energy ("Amati relation" is under intensive investigations for "standardizing" GRBs and using them for measuring cosmological parameters, investigating the nature and evolution of "dark energy" and testing non-standard cosmological models. I will also
report on the status, concepts and expected performances of space mission projects (e.g., THESEUS) aiming at fully exploiting these potentialities of the GRB phenomenon, also in synergy with the large e.m. facilities of the future like LSST, ELT, TMT, SKA, CTA, ATHENA

Repeating transients in galactic nuclei: confronting observations with theory / 132

Quasi Periodic Eruptions as EMRIs counterparts

Author: Alessia Franchini[1]

[1] *University of Zurich*

Corresponding Author: alessia.franchini@uzh.ch

Quasi Periodic Eruptions (QPEs) are a puzzling X-ray phenomena recently discovered in a number of sources with similar properties.
In this talk, I am going to present a theoretical model that is able to reproduce their phenomenology in at least 4 sources. The QPEs arise from impacts between an Extreme Mass Ratio Inspiral (EMRI) object and a rigidly precessing TDE-like accretion disc.
Since there seems to be a hint of correlation between some of the sources properties and TDEs host galaxy properties, modelling QPEs might eventually improve our understanding of the TDE demographics.

Wormholes, energy conditions and time machines / 133

Galactic Wormholes and Black Holes

Author: Chiranjeeb Singha[1]

[1] *Inter-University Centre for Astronomy and Astrophysics*

Corresponding Author: chiranjeeb.singha@gmail.com

This work explores the environmental influences on wormholes. Specifically, two classes of wormholes are considered: the Damour-Solodukhin and braneworld types. I will discuss the Damour-Solodukhin wormhole at the galactic center. Our results suggest that galactic Damour-Solodukhin wormholes are more stable than isolated ones under linear scalar perturbation. This enables the identification of galactic parameters independently from gravitational wave measurements. Additionally, the impact of the galactic environment on photon spheres, innermost stable circular orbits, and shadow radii is analyzed. Furthermore, the study introduces galactic black holes modeled in pure Lovelock gravity, with implications for gravitational wave observations and Hawking temperature calculations, indicating a quenching effect by the galactic halo.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 134

Parity violation in the trace anomaly

Authors: Jérémie Quevillon[1]; Roman Zwicky[2]; Rémy Larue[3]

[1] *LAPth*

[2] *Edinburgh University*

[3] *LPSC*

Corresponding Author: remy.larue@lpsc.in2p3.fr

The trace anomaly is the breaking of Weyl ($\sim$ scale) invariance upon quantisation of a theory, and occurs in a gauge and/or gravitational background. The presence of the parity violating Pontryagin densities $R\tilde{R}$ and $F\tilde{F}$ in the trace anomaly could have far reaching phenomonological consequences, and have been the subject of debates over the past decade.

In our latest work (arXiv:2309.08670) we investigate in a model-independent manner the presence of parity violating contributions to the trace anomaly. We show that the finiteness of the gauge,

diffeomorphism and Lorentz anomalies can be used to constrain the generic form of the energy-momentum tensor, both with and without explicit breaking of the Weyl symmetry.
The main result is that any theory compatible with dimensional regularisation cannot admit a parity violating trace anomaly.
We also address the question of the R-term in the trace anomaly, and argue that it is unambiguous contrary to common claims.

AMS-02 experiment at the International Space Station / 135

Unique Properties of Daily Proton Fluxes up to 100 GV

Author: Francesco Faldi[1]

[1] *INFN - Perugia*

Corresponding Author: francesco.faldi@cern.ch

The precision measurement of daily proton fluxes with AMS during twelve years of operation in the rigidity interval from 1 to 100 GV is presented. The proton fluxes exhibit variations on multiple time scales. From 2014 to 2018, we observed recurrent flux variations with a period of 27 days. Shorter periods of 9 days and 13.5 days are observed in 2016. The strength of all three periodicities changes with time and rigidity. Unexpectedly, the strength of 9-day and 13.5-day periodicities increases with increasing rigidities up to ~10 GV and ~20 GV respectively. Then the strength of the periodicities decreases with increasing rigidity up to 100 GV.

Cosmic Insights from Big Data: How Machine Learning is Decoding the Universe / 136

DeepGraviLens: a multi-modal architecture for classifying gravitational lensing data

Author: Nicolò Oreste Pinciroli Vago[1]

Co-author: Piero Fraternali [2]

[1] *Politecnico di Milano, INAF*

[2] *Politecnico di Milano*

Corresponding Author: nicolooreste.pinciroli@polimi.it

Gravitational lensing is the relativistic effect generated by massive bodies, which bend the space-time surrounding them. It is a deeply investigated topic in astrophysics and allows validating theoretical relativistic results and studying faint astrophysical objects that would not be visible otherwise. In recent years Machine Learning methods have been applied to support the analysis of the gravitational lensing phenomena by detecting lensing effects in data sets consisting of images associated with brightness variation time series. However, the state-of-the-art approaches either consider only images and neglect time-series data or achieve relatively low accuracy on the most difficult data sets. This paper introduces DeepGraviLens, a novel multi-modal network that classifies spatio-temporal data belonging to one non-lensed system type and three lensed system types. It surpasses the current state of the art accuracy results by $\approx 3\%$ to $\approx 11\%$, depending on the considered data set. Such an improvement will enable the acceleration of the analysis of lensed objects in upcoming astrophysical surveys, which will exploit the petabytes of data collected, e.g., from the Vera C. Rubin Observatory.

Gravitational instantons and black holes / 137

Entropy Product Function and Central charges in NUT Geometry

Corresponding Author: pppradhan77@gmail.com

We define an entropy product function (EPF) for Taub-Newman-Unti-Tamburino(TNUT) black hole(BH) following the prescription suggested by Wu et al. [PRD 100, 101501(R) (2019)].
The prescription argues that a generic four-dimensional TNUT spacetime might be expressed in terms of three or four different types of thermodynamic hairs. They can be defined as the Komar mass($M = m$), the angular momentum($J_n = mn$), the gravitomagnetic charge ($N = n$), the dual (magnetic) mass ($\tilde{M} = n$). Taking this prescription and
using the EPF, we derive the central charges of dual CFT (conformal field theory) via Cardy's formula. Remarkably, we find that for TNUT
BH there exists a relation between the central charges and EPF as $c = 6\left(\frac{\partial calF}{\partial calN_i}\right)$,
where $calF$ is EPF and $calN_i$ is one of the integer-valued
charges i.e. the NUT charges(N) or any new conserved charges(J_N).
We reverify these results by calculating the exact values of different thermodynamic parameters. We define the EPF $calF$ from the first law of thermodynamics of both horizons. Moreover, we write the first laws of both the horizons for left-moving and right-moving sectors.
Introducing the B\'{e}zout's identity, we show that for TNUT BH one
can generate more holographic descriptions described by a pair of integers (a, b). More holographic pictures have
a great significance in understanding the holographic nature of quantum gravity. Furthermore, using the EPF we derive the central charges for Reissner-Nordstr\"{o}m-NUT(RNNUT) BH, Kerr-Taub-NUT~(KNUT) BH and Kerr-Newman-NUT~(KNNUT) BH proved that they are equal in both
sectors provided that the EPF is mass-independent(or universal).

Unveiling neutrino secrets through cosmology: current status and future developments / 138

Relic Neutrino Background from Cosmic Ray Reservoirs

Authors: Alessandro Granelli[1]; Andrea Giovanni De Marchi[2]; Filippo Sala[3]; Jacopo Nava[4]

[1] *University of Bologna and INFN*

[2] *Andrea Giovanni De Marchi*

[3] *UNIBO*

[4] *Unibo*

Corresponding Author: alessandro.granelli@unibo.it

The existence of a relic neutrino backgorund (RνB) is a major prediction of the standard cosmological model, but its detection is one of the hardest tasks in neutrino physics. The main challenge arises because of its extremely low energy, as a consequence of its low temperature $T_\nu \simeq 1.67 \times 10^{-4}$ eV. The most promising experimental technique to detect the RνB is that of neutrino capture in tritium, as proposed for PTOLEMY, althoug the actual sensitivity to RνB remains uncertain. An intriguing detection possibility is that a fraction of the RνB has larger kinetic energies compared to that of the diffuse background. For instance, upscatterings of ultra-high-energy (UHE) cosmic rays (CRs) off the RnuB can accelerate relic neutrinos to UHE. In the case of large neutrino overdensities in the regions of space where the UHECRs-RνB interactons take place, the flux of boosted RnuB can be sizeable enough to imprint signals at terrestrial facilities that look for UHE neutrinos. We discuss such possibility concentrating on galaxy clusters that act as CR-reservoirs. The long trapping times of UHECRs make this flux larger than that of RνB up-scattered by UHECRs en route to Earth. We find that IceCube excludes RνB overdensities larger than $\sim 10^{10}$ in galaxy clusters, and that future PUEO, RNO-G, GRAND and IceCube-Gen2 will test values down to $\sim 10^8$. Moreover, the flux of RνB boosted in this way exhibits a peculiar flavour composition, thus being distinguishable from other astrophysical UHE neutrino fluxes.

High energy astrophysics / 139

Probing cosmic sources with AstroSat

Author: Sudip Bhattacharyya[1]

[1] *Tata Institute of Fundamental Research*

Corresponding Author: sudip@tifr.res.in

AstroSat is a multiwavelength astronomy satellite with a suite of instruments facilitating simultaneous observations of cosmic objects in the optical, ultraviolet, soft X-ray, and hard X-ray ranges. The capabilities of these science payloads include a large collection area, high time resolution, excellent imaging, and hard X-ray polarization. *AstroSat* has observed varieties of cosmic sources, including accreting black holes, neutron stars, and white dwarfs. We will give a quick overview of the *AstroSat* instruments and highlight some of their main scientific results.

Dark energy and the accelerating universe / 142

Neutron stars with a dark-energy core from the Chaplygin gas

Author: Juan Z. Pretel[1]

Co-authors: Mariana Dutra [2]; Sergio Duarte [1]

[1] *Centro Brasileiro de Pesquisas Físicas*

[2] *ITA*

Corresponding Author: juan04manuel91@gmail.com

As a potential candidate for the late-time accelerating expansion of the Universe, the Chaplygin gas and its generalized models have significant implications to modern cosmology. In this study we explore the effects of dark energy on the internal structure of a neutron star composed of two phases, which leads us to wonder: Do stable neutron stars have a dark-energy core? To address this question, we focus on the radial stability of stellar configurations composed by a dark-energy core — described by a Chaplygin-type equation of state (EoS) — and an ordinary-matter external layer which is described by a hadronic EoS. We examine the impact of the rate of energy densities at the phase-splitting surface, defined as $\alpha = \rho_{\rm dis}^{-}/\rho_{\rm dis}^{+}$, on the radius, total gravitational mass, oscillation spectrum and tidal deformability. The resulting mass-radius diagrams are notably different from dark energy stars without a common-matter crust. In particular, we found that both the mass and the radius of the maximum-mass configuration decrease as α becomes smaller. Furthermore, we compare our theoretical predictions with several observational mass-radius measurements and tidal deformability constraints. The analysis of the normal oscillation modes reveals that there are two regions of instability on the $M(\rho_c)$ curve when α is small enough indicating that the usual stability criterion $dM/d\rho_c > 0$ still holds for rapid phase transitions. Nevertheless, this is no longer true for the case of slow transitions.

AMS-02 experiment at the International Space Station / 143

The Layer 0 upgrade of the AMS-02 experiment on the ISS: status and perspectives

Author: yaozu jiang[1]

[1] *Istituto Nazionale di Fisica Nucleare (INFN) - Sezione di Perugia, I-06123 Perugia, Italy*

Corresponding Author: yaozu.jiang@pg.infn.it

In the end of 2026, the AMS-02 experiment on the International Space Station will undergo a major upgrade of its apparatus: a double layer of microstrip silicon sensors, for a total area of ~ 7 m^2 and almost doubling the total area of the microstrip silicon tracker, called Layer 0 (L0) will be installed on top of the current flying apparatus.
In this talk we'll present briefly the design and the major technological challenges and innovations related to the AMS-L0 upgrade.
We'll discuss how the upgrade will improve the physics capabilities of the experiment, in particular in terms of acceptance (i.e. collected statistics).
We'll conclude with a brief review of the results, obtained mainly with a large Beam Test campaign at CERN, with the prototypes and with some first flight microstrip silicon sensor models.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 144

A model independent consistency test between cosmological expansion history and perturbation growth

Author: Matteo Martinelli[1]

[1] *INAF - Osservatorio Astronomico di Roma*

Corresponding Author: matteomartinelli85@gmail.com

In this talk I will present a method devised to test the consistency between the background expansion and the evolution of cosmological perturbations. Such a test can be performed in a model independent way thanks to machine learning techniques and it will allow the detection of possible failures of the standard cosmological model, providing a direction to explore with alternative theoretical models.
The results I will present highlight how such a technique will require a data sensitivity not available in current data, but that could be reached by upcoming Stage IV surveys. Nevertheless, the analysis of current data provides hints of some discrepancy between the two sectors, possibly related to the S8 tension.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 145

High-energy corrections to the CGHS model: a systematic procedure

Authors: Shankaranarayanan Subramaniam[1]; Susobhan Mandal[1]; TAUSIF PARVEZ[1]

[1] *IIT Bombay*

Corresponding Author: toushif.parvez@gmail.com

The knowledge of what entered them is completely lost as black holes evaporate. This contradicts the unitarity principle of quantum mechanics and is referred to as the information loss paradox. Understanding the end stages of black hole evaporation is key to resolving this paradox. As a first step, we need to have exact models that can mimic 4-D black holes in General relativity in classical limit and have a systematic way to include high-energy corrections. While there are various models in the literature, there is no systematic procedure by which one can study high-energy corrections. In this talk, we obtain Callan, Giddings, Harvey, and Strominger (CGHS) — a (1+1)-D — model from 4-D scalar-tensor theory action. We then show that 4-D Horndeski action — the most general scalar-tensor theory that does not lead to Ostrogradsky ghosts — can systematically provide a route to include terms relevant at the end stages of black hole evaporation. We discuss some of the interesting

features of the corrected CGHS model and obtain Hawking flux. We compare our results with other works.

Black holes in alternative theories of gravity / 146

Distinguishing Signature of Kerr-MOG Black Hole and Naked Singularity via Lense-Thirring Effect

Author: PARTHA PRATIM PRADHAN[1]

[1] *HIRALAL MAZUMDAR MEMORIAL COLLEGE FOR WOMEN*

Corresponding Author: pppradhan77@gmail.com

We examine the geometrical difference between non-extremal black hole(NXBH), extremal black hole(XBH) and naked singularity(NS) via Lense-Thirring(LT) effect in spinning modified-gravity(MOG). For NXBH, we find that the LT frequency (Ω_{LT}) is proportional to the angular-momentum($J = a\,calM$) parameter or spin parameter(a) i.e. $\Omega_{LT} \propto J$ or $\Omega_{LT} \propto a$[where $calM = M(1+\alpha)$ is ADM mass, α is MOG parameter and M is Komar mass] and is inversely proportional to the cubic value of radial parameter i.e. $\Omega_{LT} \propto \frac{1}{r^3}$.
For XBH ($a^2 = \frac{G_N^2 calM^2}{1+\alpha}$), we find LT frequency is proportional to the angular-momentum parameter i.e. $\Omega_{LT} \propto \frac{1}{\sqrt{1+\alpha}}$ and is inversely proportional to the cubic value of radial parameter i.e. $\Omega_{LT} \propto \frac{1}{r^3}$. While for NS, we find $\Omega_{LT} \propto \frac{calM^3}{J^3}$ and $\Omega_{LT} \propto \frac{\left[r-\left(\frac{\alpha}{1+\alpha}\right)\frac{G_N calM}{2}\right]}{\sqrt{1+\left(\frac{\alpha}{1+\alpha}\right)\frac{G_N^2 calM^2}{a^2}}}$ in the limit $\theta = 0$ and $a = \frac{J}{calM} >> r$. It depends both on the angular momentum parameter and MOG parameter~α.

AMS-02 experiment at the International Space Station / 147

Properties of Cosmic Deuterons Measured by the Alpha Magnetic Spectrometer

Author: Diego Gomez Coral[1]

[1] *Instituto de Física, UNAM*

Corresponding Author: dgomezco@fisica.unam.mx

Precision measurements of the cosmic ray D flux are presented as function of rigidity from 1.9 to 21 GV, based on 21 million D nuclei. We observed that over the entire rigidity range D exhibit nearly identical time variations with p, ^{3}He, and ^{4}He fluxes. Above 4.5 GV, the D/^{4}He flux ratio is time independent and its rigidity dependence is well described by a single power law ∝ R^{Δ} with $\Delta_{D/\ He}$ = −0.108 ± 0.005. This is in contrast with the ^{3}He/^{4}He flux ratio for which we find $\Delta_{^3He/\ He}$ = −0.289 ± 0.003. The significance of $\Delta_{D/\ He}$ > $\Delta_{^3He/\ He}$ exceeds 10 σ. In addition, we found that above ~ 13 GV the rigidity dependence of D and p fluxes is identical with a D/p flux ratio of 0.027 ± 0.001. These unexpected observations show that contrary to expectations, cosmic deuterons have a sizeable primary-like component.

Gravitational lensing, shadows and photon rings / 148

Shadows of rotating hairy Kerr black holes coupled to time periodic scalar fields with a nonflat target space”

Author: Galin Gyulchev[1]

[1] *Sofia University ”St. Kliment Ohridski”*

Corresponding Author: gyulchev@phys.uni-sofia.bg

We study the shadows cast by rotating hairy black holes with two non-trivial time-periodic scalar fields having a non-flat Gaussian curvature of the target space spanned by the scalar fields. Such black holes are a viable alternative to the Kerr black hole, having a much more complicated geodesic structure and resulting shadows. We investigate how a nontrivial Gauss curvature alters the pictures for different amounts of scalar hair around the black holes, quantified by a normalized charge. Our results indicate that for high charge values near the boson star limit, chaotic shadows with multiple small, disconnected components appear across all Gaussian curvatures. With moderately large scalar hair and corresponding normalized charge, chaotic behavior persists, but a dominant shadow component forms, significantly influenced by Gaussian curvature. For example, in flat target space, highly chaotic shadows develop a large central region as Gaussian curvature increases, even with heavy scalar hair. At lower normalized charge values, the shadows resemble those of Kerr black holes, with minimal impact from Gaussian curvature.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 149

Luminous, magnetar-powered supernovae

Author: Achille Fiore[1]

[1] *Goethe Universität Frankfurt am Main*

Corresponding Author: fiore@physik.uni-frankfurt.de

Superluminous supernovae are a class of exceedingly bright transients whose luminosity cannot be comfortably explained by the standard 56Ni-decay picture. The quest for an alternative scenario has pointed at the contribution of a nascent millisecond magnetar and/or at the interaction of the supernova ejecta with a circumstellar medium surrounding the progenitor star; however, some of the observed photometric and spectroscopic features of many superluminous supernovae are seemingly reminiscent of a 56Ni-decay contribution. I present the results of the spectrophotometric observational campaigns of a sample of hydrogen-poor superluminous supernovae collected with the ePESSTO+ and/or NUTS2 and/or ZTF collaborations, discuss the observational data in the framework of the magnetar and the circumstellar-interaction scenario and, in some cases, I suggest the possible contribution of 56Ni.

Exploring the Universe with strong gravitational lensing / 150

Overview of Strong Lensing related research with Euclid

Author: Raphael Gavazzi[1]

[1] *Laboratoire d’Astrophysique de Marseille*

Corresponding Author: raphael.gavazzi@lam.fr

I will briefly summarize ongoing activities related to Strong Gravitational lensing, and illustrate a few very recent results of strong lensing events uncovered in the Euclid ERO data.

The Euclid mission: current status, results from early observations, and future prospects / 151

Weak gravitational lensing in the A2390 cluster of galaxies of the ”A Glimpse Into Euclid's Universe Through a Giant Magnifying Lens” ERO program

Authors: Hakim Atek[1]; Raphael Gavazzi[2]

[1] *IAP*

[2] *Laboratoire d'Astrophysique de Marseille*

Corresponding Author: raphael.gavazzi@lam.fr

I will present recent lensing results in the massive lensing cluster A2390 which has been observed as part of the Euclid Early Release Observations. The goal is to showcase the weak and strong lensing capabilities of the imaging data of the Euclid satellite.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 152

Combining galaxy catalogs and gravitational wave data to infer cosmological parameters

Author: Matteo Tagliazucchi[1]

[1] *University of Bologna*

Corresponding Author: matteo.tagliazucchi2@unibo.it

Gravitational waves (GWs) from the coalescence of compact binaries are among the most promising cosmological probes. Their signal can be used to study the late-time cosmic expansion of the Universe independently from other known cosmological probes and without the need for an intermediate calibrator. However, this is only possible if the binary redshift is known.
Different methods have been proposed to include redshift information in the inference process, from the direct detection of electromagnetic counterparts (”bright sirens”) to the use of statistical properties inferred either from a catalog of possible hosts or from spectral features in the source-frame mass distribution of the GW population (”dark sirens”).
In this talk, I will present CHIMERA, a code that combines the use of spectral features and galaxy catalogs within a hierarchical Bayesian framework to fully exploit multi-messenger information and simultaneously infer cosmological and GW population parameters from dark siren events.
We tested the code on a set of simulated O4 and O5 GW events, along with a complete mock galaxy catalog, to assess its improvements over previous approaches. I will discuss the results obtained, focusing on the importance of an accurate galaxy catalog and providing a new forecast on the precision of the Hubble constant measurement, showing that such a method can achieve a few percent error in H_0 using $\mathcal{O}(100)$ well-localized GW events while correctly marginalizing the population parameters.

Theories of gravity: alternatives to the cosmological and particle standard models / 153

Entanglement entropy in quantum black holes

Authors: Alessio Belfiglio[1]; Orlando Luongo[2]; Stefano Mancini[2]; sebastiano tomasi[3]

[1] *Università di Camerino*

[2] *University of Camerino, Physics Division*

[3] *università degli studi di camerino*

Corresponding Author: sebastiano.tomasi@unicam.it

We discuss the entanglement entropy for a massive Klein-Gordon field in two Schwarzschild-like quantum black hole spacetimes, also including a nonminimal coupling term with the background scalar curvature. To compute the entanglement entropy, we start from the standard spherical shell discretisation procedure, tracing over the degrees of freedom residing inside an imaginary surface. We estimate the free parameters for such quantum metrics through a simple physical argument based on Heisenberg uncertainty principle, along with alternative proposals as asymptotic safety, trace anomaly, and graviton corpuscular scaling. Our findings reveal a significant decrease in entropy compared to the area law near the origin for the quantum metrics. In both scenarios, the entanglement entropy converges to the expected area law sufficiently far from the origin. We then compare these results to the entropy scaling in regular Hayward and corrected-Hayward spacetimes to highlight the main differences with such regular approaches.

Theories of gravity: alternatives to the cosmological and particle standard models / 154

Thoughts on Spacetime Models and Cosmological Constant: Gravitation and Electromagnetism

Author: Lalaonirina Rakotomanana[1]

[1] *IRMAR*

Corresponding Author: lalaonirina.rakotomanana-ravelonarivo@univ-rennes.fr

Cosmology is mainly based on the *Friedmann's equations* assuming Isotropy and Homogeneity of the Einstein spacetime, starting from the Friedmann-Lemaître-Robertson Walker metric. Introduction of an ad hoc Cosmological Constant allows to model phenomenologically the so-called *Dark Energy* for explaining the acceleration of the Universe expansion discovered by Riess et al. and Permutter et al. in 1998.

Considering an Einstein-Cartan vacuum spacetime, this work focus on the influence of *electromagnetic background* field on this accelerated Universe expansion. In addition to metric and torsion (generated by independent connection), we study the influence of the compatibility of both of them with the *volume-form*, needed to correctly define any Lagrangian of the vacuum.

The action including **Einstein-Palatini** (extended version of Hilbert-Einstein Lagrangian) and **Yang-Mills** Lagrangians is considered all along the study. Application of rigorous *Variation Procedure* allows us to derive an extended system of fields equations : (1) Maxwell, (2) Einstein-Maxwell and (3) additionally a linking third relation giving what we called « **Distortion of the spacetime** ». This (third-order) distorsion tensor is expressed explicitly and is generated by a particular component of the background electromagnetic wave : the **Chern-Simmons** current which is constituted by Magnetic Helicity and Spin Angular Momentum of the wave.

Beyond the classical assumption of Perfect Fluid filling Universe, electromagnetic background clearly induces Anisotropy (and eventually Inhomogeneity) of the Spacetime which precludes any easy derivation of a sufficiently tractable extended Friedmann's equations in such a case. Nevertheless, assuming that if only the trace torsion-vector is considered, the integral curves of the vector field might be suggested as the tangent field of *giant filaments*, and confirming that the two major forces remain the gravitation and magnetic forces. By the way, considering a volume-form compatible with metric and connection (with torsion) permits to obtain strikingly action similar to that of *Brans-Dicke* action.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 155

Electromagnetic field of a charged particle, asymptotically approaching Schwarzschild black hole

Authors: Alexander Garkun[1]; Alexander Gorbatsievich[2]; Gregory Vereshchagin[3]; Stanislav Komarov[4]

[1] *Institute of Applied Physics, National Academy of Sciences of Belarus, 16 Academic Str, 220072 Minsk, Belarus*

[2] *Belarusian State University; Institute of Applied Physics, National Academy of Sciences of Belarus, 16 Academic Str, 220072 Minsk, Belarus*

[3] *ICRANet, Piazza della Repubblica, 10, 65122 Pescara, Italy; ICRA, Dipartimento di Fisica, Sapienza Universit\‘a di Roma, Piazzale Aldo Moro 5, I-00185 Rome, Italy; INAF — IAPS, Via del Fosso del Cavaliere, 100, 00133 Rome, Italy*

[4] *Belarusian State University*

Corresponding Author: staskomarov@tut.by

The electromagnetic field of a particle moving in the vicinity of a Schwarzschild black hole is calculated. The energy emitted by the particle is calculated using the multipole expansion approach. The particle is considered as it approaches the event horizon of the black hole. The electromagnetic field of this particle is calculated in the limit of the event horizon approach. It is shown that the electromagnetic field in this case tends to be spherically symmetric. The astrophysical applications of the results obtained are discussed.

High energy astrophysics / 156

Overview of SRG/eROSITA results in the Eastern Galactic hemisphere

Author: Marat Gilfanov[1]

[1] *MPA, Garching & IKI, Moscow*

Corresponding Author: gilfanov@mpa-garching.mpg.de

After more than two years of scanning the sky the eROSITA X-ray telescope aboard SRG orbital observatory produced the best ever X-ray maps of the sky and discovered more than three million X-ray sources, of which about 20% are stars with active coronas in the Milky Way, and most of the rest are galaxies with active nuclei, quasars and clusters of galaxies. eROSITA detected over 10^3 sources that changed their luminosity by more than an order of magnitude, including about a hundred tidal disruption events. Two tidal disruption events are associated with IceCube neutrinos. SRG/eROSITA samples of quasars and galaxy clusters will make it possible to study the large-scale structure of the Universe at z~1 and measure its cosmological parameters. I will review some of the SRG/eROSITA results in the Eastern Galactic hemisphere.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 157

Towards a new model-independent calibration of Gamma-Ray Bursts

Author: Arianna Favale[1]

Co-authors: Maria Dainotti [2]; Adrià Gómez-Valent [3]; Marina Migliaccio [1]

[1] *University of Rome Tor Vergata*

[2] *National Astronomical Observatory of Japan*

[3] *INFN, Sezione di Roma 2, Università di Roma Tor Vergata*

Corresponding Author: favalearianna@gmail.com

Low-redshift observations play a crucial role in constraining cosmological parameters but current data on baryon acoustic oscillations and Supernovae of Type Ia (SNIa) cover up to $z \sim 2.5$. Gamma-Ray Bursts (GRBs) stand out as one of the most promising observables as they exhibit characteristics that suggest they are potentially standardizable candles. This allows their use to extend the distance ladder beyond SNIa. However, GRB correlations are still challenging due to the spread in their intrinsic properties. In this work, we propose an innovative and cosmology-independent method of calibration of the three-dimensional Dainotti relation, the fundamental plane relation between the peak prompt luminosity, the rest-frame end time of the plateau phase, and its corresponding luminosity. We employ state-of-the-art data on Cosmic Chronometers (CCH) at $z < 2$ and use the Gaussian Processes reconstruction tool. We select 20 long GRBs in the range $0.553 \leq z \leq 1.96$ from the Platinum sample, which consists of well-defined GRB plateau properties that obey the fundamental plane relation. We verify that the choice of priors on the parameters of the Dainotti relation and the modelling of CCH uncertainties and covariance have negligible impact on our results. Moreover, we consider the case in which the redshift evolution of the physical features of the plane is accounted for. We find that CCH allows us to identify a sub-sample of GRBs that adhere even more closely to the fundamental plane relation, with an intrinsic scatter of $\sigma_{int} = 0.20^{+0.03}_{-0.05}$ obtained when evolutionary effects are considered. In an epoch in which we strive to reduce uncertainties on the GRB correlations variables to tighten constraints on cosmological parameters, we have found a novel model-independent approach to pinpoint a sub-sample that can represent a valuable set of standardizable candles. This allows us to extend the cosmic distance ladder presenting a new catalogue of calibrated luminosity distances up to $z = 5$.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 158

Cosmic chronometers to calibrate the ladders and measure the curvature of the Universe. A model-independent study

Author: Arianna Favale[1]

Co-authors: Adrià Gómez-Valent [2]; Marina Migliaccio [1]

[1] *University of Rome Tor Vergata*

[2] *INFN, Sezione di Roma 2, Università di Roma Tor Vergata*

Corresponding Author: favalearianna@gmail.com

We use the state-of-the-art data on cosmic chronometers (CCH) and the Pantheon+ compilation of supernovae of Type Ia (SNIa) to test the constancy of the SNIa absolute magnitude, M, and the robustness of the cosmological principle (CP) at $z < 2$ with a model-agnostic approach. We do so by reconstructing $M(z)$ and the curvature parameter $\Omega_k(z)$ using Gaussian Processes. Moreover, we use CCH in combination with data on baryon acoustic oscillations (BAO) from various galaxy surveys (6dFGS, BOSS, eBOSS, WiggleZ, DES Y3) to measure the sound horizon at the baryon-drag epoch, r_d, from each BAO data point and check their consistency. Given the precision allowed by the CCH, we find that $M(z)$, $\Omega_k(z)$ and $r_d(z)$ are fully compatible (at $< 68\%$ C.L.) with constant values. This justifies our final analyses, in which we put constraints on these constant parameters under the validity of the CP, the metric description of gravity and standard physics in the vicinity of the stellar objects, but otherwise in a model-independent way. If we exclude the SNIa contained in the host galaxies employed by SH0ES, our results read $M = (-19.314^{+0.086}_{-0.108})$ mag, $r_d = (142.3 \pm 5.3)$ Mpc and $\Omega_k = -0.07^{+0.12}_{-0.15}$, with $H_0 = (71.5 \pm 3.1)$ km/s/Mpc (68% C.L.). These values are independent from the main data sets involved in the H_0 tension, namely, the cosmic microwave background and the first two rungs of the cosmic distance ladder. If, instead, we also consider the SNIa in the host galaxies, calibrated with Cepheids, we measure $M = (-19.252^{+0.024}_{-0.036})$ mag, $r_d = (141.9^{+5.6}_{-4.9})$ Mpc, $\Omega_k = -0.10^{+0.12}_{-0.15}$ and $H_0 = (74.0^{+0.9}_{-1.0})$ km/s/Mpc. At present, the error bars provided by this model-agnostic approach are still too large to arbitrate the tension. With the advent of upcoming surveys, the proposed method can serve both as a discriminator of models beyond the ΛCDM and as an independent means of testing the calibration of the direct and inverse cosmic distance ladders.

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 159

Auto-stabilized Electron

Author: Munawar Karim[1]

[1] *Namibia University of Science and Technology*

Corresponding Author: mkarim@icloud.com

We propose a theory to explain the mechanism that stabilizes an electron. We show that the intrinsic divergences that occur in quantum electrodynamics can be removed by casting it within general relativity. The infinities are compensated by the curvature created by the intense energy density of the electromagnetic field in the vicinity of the electron. Using the concept of hydrostatic stability we find that the outward and inward pressures balance at a radius of (√alpha/4pi)xPlanck length. The resulting electron mass is 10^17 GeV. Details of the theory and calculations and results will be presented.

Modeling of binary neutron star and black hole-neutron star mergers, and of their electromagnetic counterparts / 160

The Collimation of Relativistic Jets in Late Post-Neutron Star Binary Merger Simulations

Author: Matteo Pais[1]

[1] *INAF - Osservatorio Astronomico di Padova (OAPD)*

Corresponding Author: matteo.pais@inaf.it

The gravitational waves from the binary neutron star merger GW170817 were accompanied by a multiwavelength electromagnetic counterpart, which confirms the association of the merger with a short gamma-ray burst (sGRB). The afterglow observations implied that the event was accompanied by a narrow, ~5°, and powerful, ~1e50 erg, jet. We study the propagation of a Poynting flux-dominated jet within the merger ejecta (kinematic, neutrino-driven, and magnetorotational instability turbulence-driven) of a neutrino-radiation-GRMHD simulation of two coalescing neutron stars. We notice that a postmerger low-density/low-pressure polar cavity, which arose due to angular momentum conservation, is crucial to letting the jet break out. At the same time, the ejecta collimates the jet to a narrow opening angle. The collimated jet has a narrow opening angle of ~4°-7° and an energy of 1e49-1e50 erg, in line with the observations of GW170817 and other sGRBs. Furthermore, we run a set of 2.5D high-resolution cylindrical RHD simulations where we inject a narrow, powerful jet into the post-merger phase of the BNS for different opening angles, luminosities, and times after the merger. We explore the case of an early launch of the jet at 0.1 s and a late launch at 1 s after the merger; the latter is consistent with the time delay of ≈ 1.74 s observed between GW 170817 and GRB 170817A.

Theories of gravity: alternatives to the cosmological and particle standard models / 161

Particle production in inflationary regimes

Authors: Alessio Belfiglio[1]; Orlando Luongo[2]; Stefano Mancini[2]

[1] *Università di Camerino*

[2] *University of Camerino, Physics Division*

Corresponding Author: alessio.belfiglio@unicam.it

We investigate inflationary particle production, focusing in particular on the role of inflaton fluctuations and the corresponding geometric particle production arising from spacetime perturbations. We analyze both small and large-field models, in agreement with experimental observations, also discussing nonminimal coupling to the scalar curvature of spacetime. Geometric production is then compared to the widely studied mechanism of gravitational particle production, with particular emphasis on ultralight spectator scalar fields, which have been recently proposed as plausible dark matter candidates. The "geometric" particle density for such fields is computed assuming instantaneous reheating into a radiation dominated era, showing that the presence of inhomogeneities may have relevant effects on particle production mechanisms. Possible implications for primordial entanglement generation are also debated.

Inflation: perturbations, initial singularities and emergent universes / 162

Distinguishing bounce and inflation via quantum signatures from cosmic microwave background

Authors: S. Mahesh Chandran[1]; Shankaranarayanan S[1]

[1] *IIT Bombay*

Corresponding Author: maheshchandran14895@gmail.com

Cosmological inflation is a popular paradigm for understanding Cosmic Microwave Background Radiation (CMBR); however, it faces many conceptual challenges. An alternative mechanism to inflation for generating an almost scale-invariant spectrum of perturbations is a *bouncing cosmology* with an initial matter-dominated contraction phase, during which the modes corresponding to currently observed scales exited the Hubble radius. Bouncing cosmology avoids the initial singularity but has fine-tuning problems. Taking an *agnostic view* of the two early-universe paradigms, we propose a quantum measure — Dynamical Fidelity Susceptibility (DFS) of CMBR — that distinguishes the two scenarios. Taking two simple models with the same power-spectrum, we explicitly show that DFS behaves differently for the two scenarios. We discuss the possibility of using DFS as a distinguisher in the upcoming space missions. [Ref: arXiv:2405.08543]

Gravitational lensing, shadows and photon rings / 163

A seven Parameter Kerr-Newman-like Metric

Author: Francisco Frutos-Alfaro[1]

[1] *Escuela de Fisica, Universidad de Costa Rica*

Corresponding Author: francisco.frutos@ucr.ac.cr

In this contribution a new metric with seven parameters is found.
The metric possess the following features: mass, rotation, charge,
magnetic dipole, massive quadrupole, octupole, and hexadecapole.
These spacetime is versatile and realistic for representing compact objects like neutron stars. It has several astrophysical applications, for
example to study the chaotic behavior of geodesics or the gravitational
lens effect. The spacetime was found using the Kerr-Newman metric
as seed metric, the other parameters were included approximately up
to the second order. This metric is a solution to the Einstein-Maxwell
equations by expanding in a Taylor series up to the second order in
the perturbative parameters.

High energy astrophysics / 164

Supermassive black holes: magnetosphere, energy extraction, and high-energy radiation

Author: Arman Tursunov[1]

[1] *Max Planck Institute for Radio Astronomy*

Corresponding Author: atursunov@mpifr-bonn.mpg.de

Magnetic fields in regions of strong gravity play a crucial role in the explanation of various astrophysical phenomena, such as e.g. the formation and collimation of relativistic jets observed in black hole systems of different mass scales. In this presentation, I will discuss the influence of magnetic fields on dynamical environments of supermassive black holes from both theoretical and observational perspectives. In particular, I will present a new solution to a black hole magnetosphere, which can be related to jet launching/switching-off scenarios, two new black hole energy extraction mechanisms of high efficiency, and related cosmic ray acceleration scenario. I will describe the multiwavelength and multimessenger predictions of the new mechanisms and discuss the observational implications of theoretical predictions for various known supermassive black hole candidates, including the closest one, Sagittarius A*, located at the center of our Galaxy.

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 165

Extended Theories of Electro-Magnetism for astrophysics and cosmology

Author: Alessandro D.A.M. Spallicci[1]

[1] *Université d'Orléans - Centre National de la Recherche Scientifique*

Corresponding Author: spallicci@cnrs-orleans.fr

Benetti M., Bentum M.-J., Bonetti L., Capozziello S., Dib A., Djeghloul N., dos Santos Filho L.R., Ellis J., Helayël-Neto J.A., Lämmerzahl C., López-Corredoira M., Mavromatos N.E., Perlick V., Randriamboarison O., Retinò A., Sakharov A.S., Sarkisyan-Grinbaum E.K.G., Sarracino G., Spallicci A.D.A.M., Vaivads A.

The ad-hoc dark Universe compatible to GR, faces the lack of experimental evidence and of identified candidate particles in the SM. Meanwhile, going beyond GR is also not observationally supported. Sice photons remain the main messengers of the cosmos, we analyse whether Generalised Theories of Electro-Magnetism induce a reinterpretation impacting cosmology. The SME induces a mass to a photon [1,2], the only SM free massless particle, compatible to the upper limits by FRBs [3-5] and solar wind [6,7]. The photons either SME or massive of the de Broglie-Proca type or non-linear of the Born-Infeld, Heisenberg-Euler type and even Maxwellian undergo a frequency shift in presence of EM and/or LSV backgrounds [8]. This shift, added to expansion redshift determines new cosmological scenarios, e.g., without recurring to the accelerated expansion [9-11] and possibly dark matter. Finally, we have applied the Heisenberg principle to cosmological scales, reading the Hubble-Humason-Lemaître constant as quantum measurement and reinterpreting the tension accordingly [12,13].

[1] 2017, Phys. Lett. B, 764, 203
[2] 2018, Eur. Phys. J. C, 78, 811
[3] 2016, Phys. Lett. B, 757, 548
[4] 2017, Phys. Lett. B, 768, 32
[5] 2017, Adv. Space Res., 59, 736
[6] 2016, Astropart. Phys., 82, 49
[7] 2024, arXiv:2205.02487 [hep-ph] to appear in Eur. Phys. J. Plus

[8] 2019, Eur. Phys. J. C, 79, 590
[9] 2021, Eur. Phys. J. C, 81, 4
[10] 2022, Eur. Phys. J. Plus, 137, 253
[11] 2022, Eur. Phys. J. Plus, 137, 1386
[12] 2020, Found. Phys. 50, 893
[13] 2022, Found. Phys. 52, 23

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 166

Diffusive interactions between photons and electrons, an application to cosmology

Author: Louis Marmet[1]

[1] *York University, Toronto*

Corresponding Author: lmarmet@yorku.ca

The last century has seen tremendous improvements in our understanding of electromagnetism. An important discovery was made by Einstein in 1916, who combined thermodynamics and atomic physics to predict stimulated emission. The quantization of Maxwell's Equations yielded a powerful tool, Quantum Electrodynamics, which produced extremely accurate predictions as well as explained a large variety of optical phenomena that were discovered and studied during the late 20th century.

In order to understand the details of light-propagation over cosmological distances, it is important to consider every effect that can modify the properties of light. In the 1970s and 80s, the development of the laser triggered a series of important experiments on radiative optical forces, atomic cooling, the dipole force, quantum standing wave, superimposed traveling waves, and ponderomotive forces on electrons.

I will discuss these processes and describe how they affect light propagation in intergalactic space through a 'stimulated transfer process'. Specifically, diffusive properties of electron-photon interactions produce a global energy loss of the photons that appears as a redshift. Although the photon redshift is very small, an Atom-Interferometer can detect small changes in energy as a result of the interactions. I will discuss how the energy change can be measured through the momentum given to the atoms.

Based on the average number density of electrons in intergalactic space and the interaction cross section of the stimulated transfer process, an approximate value of the Hubble constant can be derived from fundamental optics theory, supporting the idea that a more complete understanding of light-matter interactions leads to a very different interpretation of the universe.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 167

Vacuum dynamics in the Universe: implications on the cosmological tensions

Author: Joan Solà Peracaula[1]

[1] *Universitat de Barcelona*

Corresponding Author: sola@fqa.ub.edu

The possibility that the vacuum energy density (VED) could be time dependent in the expanding Universe is intuitively more reasonable than just a rigid cosmological constant for the entire cosmic history. The framework of the running vacuum model (RVM) is a remarcable example, in which the VED appears as a power series of the Hubble rate, H(t), and its derivatives. The RVM contributes to alleviate the cosmological tensions with the data, and at a more fundamental level it also helps to smooth out certain hardcore aspects of the cosmological constant problem. Finally, a very recent extensions of the RVM, in which the dark energy (DE) is a composite system made of running vacuum energy and an entity X called "phantom matter" (which is radically different from phantom DE, since the former produces positive pressure, like ordinary mattter, rather than the negative one produced by the latter) has proven capable to yield an excellent fit to the cosmological data. Such a fit, in addition, is compatible with the observed quintessence-like behavior around our time (as reported by the DESI Collaboration). In my talk, I will discuss some of these theoretical aspects of the VED and also some successful phenomenological implications.

Strong electromagnetic and gravitational field physics: From laboratories to early Universe / 168

Renormalizing the vacuum energy in cosmological spacetime: a new approach to the cosmological constant problem

Author: Joan Solà Peracaula[1]

Co-author: Cristian Moreno Pulido [2]

[1] *Universitat de Barcelona*

[2] *University of Barcelona*

Corresponding Author: sola@fqa.ub.edu

Phenomenological studies in the last few years have provided significant support to the idea that the vacuum energy density (VED) is a running quantity with the cosmological evolution. Such a running actually helps in alleviating the cosmological tensions afflicting the ΛCDM. The theoretical studies backing up this approach go under the name of "running vacuum model" (RVM). Using this framework, based on quantum field theory (QFT) in curved spacetime, one can show that the properly renormalized VED in FLRW spacetime can be freed from fine tuning troubles and the vacuum dynamics proves to be a smooth power series of the Hubble rate H and its time derivatives. The calculation is performed using a new version of the adiabatic renormalization procedure, which leads to a cosmic evolution with the value of H, i.e. ρ_vac(H). As a result the "cosmological constant" Λ appears here as the nearly sustained value of 8πG(H)ρ_vac(H) around (any) given epoch H, where G(H) is the gravitational coupling, which runs very mildly (logarithmically). The VED evolution between points H and H_0 of the cosmic history reads δρvac(H)~ν_eff m_Pl^2(H^2−H_0^2) (where the coefficient |νeff|≪1) and m_Pl is the Planck mass. The effective coefficient ν_eff receives contributions from all the quantized matter fields and can be explicitly computed in QFT. Remarkably, there also exist higher powers of H which can trigger inflation in the early universe. Finally, the equation of state (EoS) of the running vacuum receives also quantum corrections from bosons and fermion fields, shifting its value from -1. The striking consequence is that the EoS of the quantum vacuum may nowadays appear as quintessence, as DESI has reported. But the ultimate source of the dynamics stems from the running QFT vacuum, not from fundamental quintessence fields.

Dark energy and the accelerating universe / 169

A dynamical systems formulation for inhomogeneous LRS-II spacetimes

Authors: Amare Abebe[1]; Peter Dunsby[2]; Rituparno Goswami[3]; Saikat Chakraborty[4]

[1] *North-West University*

[2] *University of Cape Town*

[3] *University of KwaZulu-Natal*

[4] *The Institute for Fundamental Study, Naresuan University, Thailand*

Corresponding Author: saikat.ch@nu.ac.th

I will introduce a dynamical system formulation for inhomogeneous LRS-II spacetimes using the covariant 1+1+2 decomposition approach, that we recently proposed in 2404.01161. Our approach describes the LRS-II dynamics from the point of view of a comoving observer. Promoting the covariant radial derivatives of the covariant dynamical quantities to new dynamical variables and utilizing the commutation relation between the covariant temporal and radial derivatives, we have been able to show that it is possible to construct an autonomous system of first-order ordinary differential equations along with some purely algebraic constraints. I will talk about some interesting features in the LRS-II phase space with dust, one of them being that the homogeneous solutions constitute an invariant submanifold. For the particular case of LTB, I show that it is possible to recover some previously known results. The talk will be based on our recent work 2404.01161.

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 170

Useful Predictions from the 5D Vacuum Equation

Author: Detlef Hoyer[1]

[1] *TU Hamburg, Germany*

Corresponding Author: d.hoyer@hamburg.de

Abstract. Since the work of Kaluza it has been known that Maxwell's equations are mathematically a subset of the Ricci curvature tensor in five dimensions. In the present paper a complete set of equations for the 5D Ricci curvature tensor is described that reproduces both the 4D Einstein gravitational equations and the equations of electromagnetism. The fifth row and column of 5x5 matrices of the Ricci tensor result in new parameters capable of generating 4D stress-energy-momentum tensors. We recall that using 5D vacuum equation no additional 5D stress-energy-momentum tensor is required. Solutions of the 5D vacuum equation $R_{\mathrm{i\ j=0}}$ have been given the term 'induced matter theory.' A special feature of this theory is the occurrence of a scalar force field which is capable of generating mass. Three important exact solutions are addressed: the solution of the 5D vacuum equation for a charged mass, solutions without charges and electromagnetism but with gravity and the scalar field, and a static two mass solution also known as the '1-body metric.' Finally, geodesic motion trajectories in 4D-spacetime are calculated numerically using gravitational and scalar mass density components. Results are discussed and further work on more trajectory differences between the use of 4D and 5D formulations under electromagnetic influence is outlined.

Gravitational instantons and black holes / 171

Accretion flows around spinning compact objects in the post-Newtonian regime

Author: Samik Mitra[1]

Co-authors: Elham Nazari ; Santabrata Das [1]; Shahram Abbassi [2]

[1] *Indian Institute of Technology Guwahati*

[2] *University of Western Ontario*

Corresponding Author: m.samik@iitg.ac.in

We present the structure of a low angular momentum accretion flows around rotating compact objects incorporating relativistic corrections up to the leading post-Newtonian order. To begin with, we formulate the governing post-Newtonian hydrodynamic equations for the mass and energy-momentum flux without imposing any symmetries. However, for the sake of simplicity, we consider the flow to be stationary, axisymmetric, and inviscid. Toward this, we adapt the polytropic equation of state (EoS) and analyze the geometrically thin accretion flow confined to the equatorial plane. The spin-orbit effects manifest themselves in the disk structure. This is a relativistic interaction between the body's spin and the motion of fluid elements inside the gravitational potential of the body. In the present analysis, we focus on global transonic accretion solutions, where a subsonic flow enters far away from the compact object and gradually gains radial velocity as it moves inwards. Thus, the flow becomes supersonic after reaching a certain radius, known as the critical point. For a better understanding of the transonic solutions, we classify the post-Newtonian equations into semi-relativistic (SR), semi-Newtonian (SN), and non-relativistic (NR) limits and compare the accretion solutions and their corresponding flow variables. With these, we find that SR and SN flow are in good agreement all throughout, although they deviate largely from the NR ones. Interestingly, the density profile seems to follow the profile $\rho \propto r^{-3/2}$ in the post-Newtonian regime. The present study has the potential to connect Newtonian and GR descriptions of accretion disks.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 172

New insights in the realm of the Gamma-ray Burst - Supernovae correlations

Author: Maria Dainotti[1]

Co-authors: Biagio De Simone [2]; Khadir M. Islam [3]; Kenzaburo Kawaguchi [4]; Takashi Moriya [1]; Tomoya Takiwaki [5]; Nozomu Tominaga [6]; Anjasha Gangopadhyay [7]

[1] *National Astronomical Observatory of Japan*

[2] *Università degli Studi di Salerno*

[3] *University of Constantine 1*

[4] *Kumamoto University*

[5] *SOKENDAI; NAOJ*

[6] *NAOJ*

[7] *Hiroshima University*

Corresponding Author: b.desimone1@studenti.unisa.it

Gamma-Ray Bursts (GRBs) are very energetic cosmological transients. Long GRBs are usually associated with Type Ib/c Supernovae (SNe), and we refer to them as GRB-SNe. Since the associated SN for a given GRB is observed only at low redshift, a possible selection effect exists when we consider intrinsically faint sources which cannot be observed at high redshift. Thus, it is important to explore the possible relationships between GRB and SN parameters after these have been corrected for astrophysical biases due to the instrumental selection effects and redshift evolution of the variables involved. So far, only GRB prompt emission properties have been checked against the SNe Ib/c properties without considering the afterglow (AG). This work investigates the existence of relationships among GRB's prompt and AG and associated SN properties. We investigate 91 bidimensional correlations among the SN and GRB observables before and after their correction for selection biases and evolutionary effects. As a result of this investigation, we find hints of a new correlation with a Pearson correlation coefficient > 0.50 and a probability of being drawn by chance < 0.05. This correlation is between the luminosity at the end of the GRB optical plateau emission and the rest-frame peak time of the SN. According to this relation, the brightest optical plateaus are accompanied by the largest peak times. This correlation is corrected for selection biases and redshift evolution and may provide new constraints for the astrophysical models associated with the GRB-SNe connection.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 173

On how BAO shape the late-time solutions to the H_0 tension, and the wXCDM

Author: Adrià Gómez-Valent[1]

[1] *Institut de Ciències del Cosmos, Universitat de Barcelona*

Corresponding Author: agomezvalent@icc.ub.edu

In this talk I will first review the late-time phenomenology required to solve the Hubble tension, making especial emphasis on the pivotal role played by the data on baryon acoustic oscillations (BAO) in the building of the inverse distance ladder. I will show, in particular, how the angular (2D) and anisotropic (3D) BAO data, despite being obtained from the same parent catalogues of tracers, lead to completely different solutions. While 3D BAO calls for a phantom-like transition in the effective dark energy (DE) density at z<0.15, accompanied by a growth of the absolute magnitude of supernovae in the same redshift range, 2D BAO requires negative values of the effective DE density at z>1.5-2. This is a clear manifestation of the existing tension between the 2D and 3D BAO data sets, which could be hinting at the presence of unaccounted for systematic or underestimated uncertainties in one or both data sets. I will quantify this tension employing a model-independent method. Finally, I will discuss a model called wXCDM with a transition from a phantom matter phase to quintessence at $z \sim 1.5$ that allows to solve the H_0 and growth tensions very efficiently when angular BAO is used in the analysis. In Bayesian terms, this model is strongly preferred over its competitors and might also explain the existence of unexpectedly massive galaxies at $z = 5 - 10$, as unveiled by the James Webb Space Telescope.

Repeating transients in galactic nuclei: confronting observations with theory / 174

Observations of repeating nuclear transients

Author: Thomas Wevers[1]

[1] *Space Telescope Science Institute*

Corresponding Author: twevers@stsci.edu

The deployment of large sky surveys are enabling the characterization of the transient night sky in unprecedented detail. Among other things, such surveys are revealing novel modes of variability around supermassive black holes which are incompatible with the behaviour of active galactic nuclei.

This includes quasi-periodic X-ray eruptions, or QPEs, which repeat on timescales of hours-days and have so far been observed exclusively at X-ray wavelengths, but whose origin remains debated (although many different theoretical models exist to explain their broad properties).

On longer timescales (10s-1000s of days), optical and X-ray surveys are discovering sources exhibiting repeated flares consistent with the tidal disruption events (TDEs) of stars by SMBHs, which are likely partial stripping events of stellar objects on bound, highly eccentric orbits.

Although they occur on vastly different timescales, and their properties are far from homogeneous, evidence is emerging that these two classes of objects may be closely related.
I will present an overview of the observational properties of these repeating nuclear transients, highlight their similarities and differences, and present the current evidence for a connection between QPEs and TDEs and its implications.

Black holes in alternative theories of gravity / 175

Observing naked singularities by the Event Horizon Telescope

Authors: Galin Gyulchev[1]; Petya Nedkova[1]; Stoytcho Yazadjiev[1]; Valentin Deliyski[1]

[1] *Sofia University*

Corresponding Author: pnedkova@phys.uni-sofia.bg

Horizonless compact objects may produce phenomenological features which distinguish them observationally from black holes. In particular, the images of the accretion disks around them possess a characteristic morphology including a series of central bright rings instead of a black hole shadow. We demonstrate how the central ring structure arises relating it to the behavior of the deflection angle on the scattering geodesics and the light ring structure of the spacetime. Focusing on two classes of reflective naked singularities we further discuss whether the central rings can be observed by the present and near-future Event Horizon Telescope (EHT) arrays. While they may be hard to be distinguished by the current capacities, the next-generation EHT will be able detect them as qualitative deviations in the image morphology.

Machine learning in astronomy: AGN, transient events, cosmology and others / 176

Neural network time-series classifiers for gravitational-wave searches in single-detector periods

Author: Agata Trovato[1]

[1] *University of Trieste - INFN sezione Trieste*

Corresponding Author: agata.trovato@units.it

The search for gravitational wave signals in the data collected by the current ground-based interferometers is a complex problem, especially when only one detector operates. Modern deep learning approaches could contribute to find a solution. I'll discuss the detection problem and present the work detailed in https://iopscience.iop.org/article/10.1088/1361-6382/ad40f0 where we investigate the performance of neural network classifiers based on three types of architectures: convolutional neural network, temporal convolutional network, and inception time. The last two architectures are specifically designed to process time-series data. We apply the trained classifiers to LIGO data from the O1 science run, focusing specifically on single-detector times. We find a promising candidate on 2016-01-04 12:24:17 UTC compatible with a black hole merger with masses 50 $M_\odot$ and 24 $M_\odot$.

Black holes in alternative theories of gravity / 177

Black holes in a modified gravity: Hawking radiation and cosmological implications

Authors: Banibrata Mukhopadhyay[1]; Panchajanya Dey[1]

[1] *Indian Institute of Science*

Corresponding Author: bm@iisc.ac.in

There are observations supporting the plausible modification to Einstein gravity, while the exact theory of gravity in the strong field regime is

indeed under debate. We obtain a new black hole solution in an f(R)-gravity-based modified gravity. Such a black hole evaporates faster by Hawking radiation compared to that in the Einstein gravity, i.e. the Kerr black hole.
One of its implications is in the consideration of primordial black holes (PBHs) as dark matter. The exact constituents of dark matter are a big puzzle, where PBHs are argued to be a potential candidate. The faster evaporation of PBHs in the modified gravity puts a strict constraint on contributing PBHs to dark matter. This further widens the debate of the origin on dark matter.

Slowly rotating pulsars / 178

What is the true nature of PSR J0901-4046?

Author: Banibrata Mukhopadhyay[1]

Co-authors: Nirupam Roy [1]; A R Rao [2]

[1] *Indian Institute of Science*

[2] *Tata Institute of Fundamental Research*

Corresponding Author: bm@iisc.ac.in

The radio pulsar PSR J0901-4046 exhibits very slow rotation with a spin period 76 s, which is unusually low for a neutron star. Typically the spin period of radio pulsars ranges 1.4 ms to 23.5 s, when they are divided into various sub-classes, e.g. transient, millisecond pulsar, magnetar. The question arises, is PSR J0901-4046 really a neutron star? In fact, the spin period 76 s more corroborates with a moderately spinning white dwarf. We plan to examine the true nature of PSR J0901-4046 assuming it having a complicated magnetic fields and based on its position with respect to the death line in the $P-\dot{P}$ plane. We argue that the source seems to be more plausibly a highly magnetized white dwarf, lying close to the white dwarf, AR Scorpii, in the $P-\dot{P}$ plane.

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 179

Square root gauge theory and its applications

Author: Eduardo Guendelman[1]

[1] *Ben Gurion University*

Corresponding Author: guendel@bgu.ac.il

We study the effects that a $\sqrt{-F_{\mu\nu}F^{\mu\nu}}$ in the action can have and we find,

1. Combined with a Maxwell term $-F_{\mu\nu}F^{\mu\nu}$ it gives a confining behavior.
2. adding a ¨mass term¨$A_\mu A^\mu$, a source genrates a Coulomb component with asymptotic strength independent of the charge at the source, the gauge fields produce a cloud of charge, so as to get always the same asymptotic Coulomb solution .
3. A scale invariant, generally coordinate invariant theory can be constructed by introducing both 1. a dilaton field ϕ, 2 a metric independent measure Φ constructed out of non metric degrees of freedom, ¨the measure fields, term $-F_{\mu\nu}F^{\mu\nu}$, $\sqrt{-F_{\mu\nu}F^{\mu\nu}}$, ¨$A_\mu A^\mu$, while $\sqrt{-F_{\mu\nu}F^{\mu\nu}}$, ¨$A_\mu A^\mu$ couple to Φ , $-F_{\mu\nu}F^{\mu\nu}$ couples to $\sqrt{-g}$. The dilaton field ϕ can have

kinetic terms that couple to the different measures and exponential potentials that couple to the different measures.

After ssb of scale symmetry, bag like structures are found inside the bag there is a high vacuum energy and free gauge particles and outside there is a low vacuum energy and a confinement phase, or alternatively, inside the bag there is a high vacuum energy and free gauge particles and outside there is a low vacuum energy and a phase allowing the asymptotic Coulomb solution independent of the charge at origin , One can envision a picture where QCD suffers a confinement/ deconfinement phase transition, while QED suffers a transition from a regular massless photons phase to a phase which allows the source independent asymptotic Coulomb solutions, the cosmological consequences of the Coulomb solution will be discussed.

1. In these theories wormholes can ¨hide¨ charge by directing the gauge flux to the other universe, so for an external observer, some intrinsically charged object may appear neutral.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 180

Planckian discreteness in cosmology: Brownian motion of dark matter particles

Author: Arad Nasiri[1]

[1] *Imperial College London*

Corresponding Author: a.nasiri21@imperial.ac.uk

Quantum gravity has yet remained elusive from an observational standpoint. In this talk, I will discuss Swerves, a proposal within quantum gravity phenomenology that predicts testable effects in cosmological data. Motivated by considerations in Causal Set Theory, a discrete approach to quantum gravity, we have formulated the covariant Brownian motion of free particles around their geodesics. At the level of the Fokker-Planck equation, this approach provides the unique generally covariant extension to the Boltzmann equation for free particles. When applied to dark matter particles, it results in dynamical warming at late times, which suppresses the matter power spectrum at small scales. Thus, the model shows potential for alleviating the S_8 tension.

High energy astrophysics / 181

Nonlinear nature of black hole IGR J17091−3624

Authors: Banibrata Mukhopadhyay[1]; Anindya Guria[1]

[1] *Indian Institute of Science*

Corresponding Author: bm@iisc.ac.in

Extracting nonlinear nature of astrophysical systems, particularly from observed data, has long been considering for various kinds of sources. Accretion disks around compact objects are one of them. Our group has been working on it for more than two decades: for GRS 1915+105, Sco X-1, Cyg X-1,2,3, IGR J17091−3624, etc. Sources exhibit sometimes chaotic/deterministic and sometimes stochastic nature. Interestingly, GRS 1915+105, depending on its temporal class, exhibits both. IGR J17091−3624, on the other hand, has been argued to be twin of GRS 1915+105 due to their similar "heartbeat" pattern in lightcurves

and high-frequency QPOs, for quite sometime. However, the former is a very faint noise-dominated source, exhibited stochastic nature in timeseries by earlier studies, which further challenged its twin status of GRS 1915+105. We employ several denoising techniques to mitigate noise effects and employ methods like Autoencoder, Principal Component Analysis (PCA), Singular Value Decomposition (SVD), and Correlation Integral (CI) to isolate the deterministic signatures. We find signs of determinism in IGR J17091−3624 after denoising, thus supporting the hypothesis of it being similar to GRS 1915+105, even as a dynamical system. Our findings not only shed light on the complex nature of IGR J17091-3624, but also pave the way for future research employing noise-reduction techniques to analyze non-linearity in observed dynamical systems.

Multi-messenger astronomy with gravitational waves / 183

Hierarchical inference of cosmological and astrophysical population properties from gravitational wave observations and galaxy catalogs

Author: Matteo Tagliazucchi[1]

[1] *University of Bologna*

Corresponding Author: matteo.tagliazucchi2@unibo.it

Gravitational waves (GWs) from compact binary coalescences are standard sirens that can probe the cosmic expansion history of the late-time Universe once the binary chirp mass-redshift degeneracy is broken. Methods for injecting redshift information into the inference process range from the direct detection of electromagnetic counterparts ("bright sirens") to the use of statistical properties inferred either from a catalog of possible hosts or from spectral features in the source-frame mass distribution ("dark sirens").
In this talk, I will present CHIMERA, a code that combines these methods within a hierarchical Bayesian framework to constrain cosmological and GW population parameters simultaneously. I will discuss the constraints obtained with this code on a set of simulated O4 and O5 GW events and a complete galaxy catalog, showing that a percentage-level measurement of H0 can be obtained with $\mathcal{O}(100)$ well-localized GW events and a spectroscopic galaxy catalog, while correctly marginalizing the population assumptions. I will then describe the technical improvements we are developing to address the computational limits of the code and to accommodate the large amount of GW data coming from 3G detectors, such as the Einstein Telescope and LISA. Finally, I will briefly present the blinded mock data challenge we are conducting between CHIMERA and similar codes for hierarchical Bayesian inference using GW data and galaxy catalogs to assess possible computational limitations or systematic effects.

Absolute stability of strange quark matter: from dark matter to stellar evolution / 184

Strange stars and strange quark planets

Author: Yong-Feng Huang[1]

[1] *Nanjing University*

Corresponding Author: hyf@nju.edu.cn

Strange-quark matter (SQM) may be the true ground state of hadronic matter. In this case,the observed pulsars may actually be strange stars, but not neutron stars. According to the SQM hypothesis, the existence of a hydrostatically stable sequence of SQM stars has been predicted, ranging from 1

to 2 solar mass strange stars, to smaller strange dwarfs and even strange planets. While gravitational wave (GW) astronomy is expected to open a new window to the universe, it will shed new light on the search for SQM stars. We show that due to their extreme compactness, strange planets can spiral very close to their host SSs without being tidally disrupted. We thus can try to identify strange quark objects by searching for close-in pulsar planets. Additionally, Like inspiraling neutron stars or black holes, a merging strange star-strange planet system would serve as new sources of GW bursts, producing strong GWs at the final stage. The events occurring in our local universe can be detected by GW detectors, such as Advanced LIGO and the future Einstein Telescope. This effect provides a unique probe to SQM objects and is hopefully a powerful tool for testing the SQM hypothesis.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 185

Massive, magnetized neutron stars as mass gap objects

Author: Zenia Zuraiq[1]

Co-authors: Banibrata Mukhopadhyay [2]; Fridolin Weber [3]

[1] *Indian Institute of Science, Bangalore*

[2] *Indian Institute of Science*

[3] *San Diego State University*

Corresponding Author: zeniazuraiq@iisc.ac.in

Based on: Phys. Rev. D 109, 023027 (2024), arXiv:2311.02169

Neutron stars (NSs) can have core densities several times that of the nuclear saturation density. One of the open questions in NS physics is the unknown high-density nuclear matter equation of state (EOS). By considering a number of proposed, phenomenological relativistic mean-field EOSs, we construct theoretical models of NSs. Based on our selected models, we find that the emergence of exotic matter at these high densities restricts the masses of NSs to $\simeq 2.2 M_{\odot}$. However, on introducing a magnetic field to the star, along with a model anisotropy, we find that the star's mass increases significantly, placing it within the observational mass gap that separates the heaviest NSs from the lightest black holes. We propose that gravitational wave observations, like GW190814, and other potential candidates within this mass gap, may actually represent massive, magnetized NSs.

Massive white dwarfs and related phenomena / 186

Simulating magnetized white dwarfs by time evolution: Chandrasekhar limit and beyond

Author: Zenia Zuraiq[1]

Co-authors: Achal Kumar [2]; Alexander J. Hackett [3]; Banibrata Mukhopadhyay [4]

[1] *Indian Institute of Science, Bangalore*

[2] *University of Florida*

[3] *CEICO, Institute of Physics of the Czech Academy of Sciences*

[4] *Indian Institute of Science*

Corresponding Author: zeniazuraiq@iisc.ac.in

We explore in detail the time-dependent simulation for the evolution of the magnetized main sequence (MS) stars to magnetised white dwarfs (WDs) using the Cambridge Stellar evolution code:

STARS. In order to do so, we have appropriately modified the said code by introducing magnetic effect and cooling. We investigate further the possible existence of stable, massive, super-Chandrasekhar WDs, inferred from the observations of peculiar over-luminous type Ia supernovae (such as SNLS-03D3bb). Magnetic fields greatly contribute to the existence of massive WDs, both through classical and quantum effects, as shown by our group's previous theoretical calculations. In this work, we explore the classical effects of magnetic fields on the structure of the MS stars, the evolution of the star on the HR diagram and finally, WDs. We investigate the stability of magnetic WDs, both below and above the Chandrasekhar limit. We obtain the possibility of existence of super-Chandrasekhar WDs and new mass limit(s), depending on the magnetic field geometry, mass accretion from its companion and cooling rates.

Black hole formation, evolution and the black hole mass gap / 187

Observations of binary black holes in the pair-instability mass gap.

Author: Sergey Klimenko[1]

[1] *University of Florida*

Corresponding Author: klimenko@phys.ufl.edu

Most observed binary black hole (BBH) mergers belong to the stellar-mass BBH population produced by the collapse of isolated stars. A pair-instability supernova (PISN) mechanism prevents the formation of black holes from the stellar collapse with mass greater than 50 and less than 120 solar masses. Any BBH merger with a component black hole in the PISN mass gap is likely to originate from an alternative formation channel. In this talk, we discuss detections of the high-mass BBH systems and present the observational evidence for BBH events in the PISN gap, including the GW190521 event, which was firmly established as an outlier to the stellar-mass BBH population if the PI mass gap begins at or below 65 solar masses.

Wormholes, energy conditions and time machines / 188

Ellis-Bronnikov wormholes in slow rotation

Author: Fech Scen Khoo[None]

Co-authors: Bahareh Azad [1]; Jose Luis Blázquez-Salcedo [2]; Jutta Kunz [1]

[1] *University of Oldenburg*

[2] *Universidad Complutense de Madrid*

Corresponding Author: fech.scen.khoo@uni-oldenburg.de

It has been long known that the static Ellis-Bronnikov wormholes of GR are radially unstable. Here we study the radial perturbations of these wormholes in slow rotation up to second order. We find that rotation can potentially stabilize the unstable mode of the static wormholes.

Wormholes, energy conditions and time machines / 189

Spectrum of quasinormal modes of rapidly rotating Ellis-Bronnikov wormholes

Author: Jose Luis Blázquez-Salcedo[1]

Co-authors: Bahareh Azad [2]; Burkhard Kleihaus [2]; Fech Scen Khoo [2]; Francisco Navarro-Lérida [1]; Jutta Kunz [2]; Luis Manuel González Romero [1]

[1] *Universidad Complutense de Madrid*

[2] *Oldenburg University*

Corresponding Author: jlblaz01@ucm.es

In this talk we will present the first study of the spectrum of quasinormal modes of rotating Ellis-Bronnikov wormholes. We compute the spectrum using a spectral decomposition of the metric perturbations on a numerical background. We study the dependence of the modes on the angular momentum and show that rotation breaks the triple isospectrality of the symmetric and static wormhole.

Cosmic Insights from Big Data: How Machine Learning is Decoding the Universe / 190

Using cGANs for Anomaly Detection: Hunting for Gravitational Lensing Systems in Euclid

Author: Ruby Pearce-Casey[1]

[1] *The Open University*

Corresponding Author: ruby.pearce-casey@open.ac.uk

We present a proof of concept for an alternative method of strong gravitational lens finding using a conditional Generative Adversarial Network (*cGAN*). We use Early Release Observation (*ERO*) images of the Perseus Cluster from Euclid, covering 0. 57sq.degrees on the sky, and the network is based on the *pix2pix* architecture with an adapted *U-Net* generator. We train our model to predict Euclid's *NISP-H* band flux ($1.54 - 2.00m$) from a combination of the filters *NISP-J*, *NISP-Y* and *VIS* band ($0.55 - 1.54m$) in 40,000 cut-outs from the Perseus Cluster which are 20×20 arcseconds in size. We test the *cGAN* on 5,000 cut-outs from the Perseus cluster, 10% of which contain a simulated strong gravitational lens painted into the cut-out based on SIE/Singular Isothermal Ellipsoid and PEMD/Power Law Ellipse Mass Density mass profiles. Candidate gravitational lenses and cut-outs with a gravitational lens painted in were deliberated excluded from the model's training data set such that gravitational lensing systems remain unknown to the network. We find that the *cGAN* can accurately predict the *NISP-H* band flux of the cut-outs from the Perseus cluster. However, the model fails to predict the *NISP-H* band flux of the cut-outs containing the simulated gravitational lenses, with a larger difference between the prediction of the model and ground truth for lenses with extended arcs and Einstein rings, suggesting that the *cGAN* can be used as an anomaly detector for an alternative method of lens finding.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 191

Update on anomalies and cosmological tensions from the latest data sets

Author: Javier de Cruz Pérez[1]

[1] *Universidad Complutense de Madrid*

Corresponding Author: jadecruz@ucm.es

The persistence in some of the tensions and anomalies that affect the standard model of cosmology, like the H_0-tension, the σ_8-tension and the lensing anomaly, has motivated the study of alternative models capable of dealing with them. We re-analyze some of the most common extensions of the ΛCDM model in addition to other more theoretically motivated models in light of different combinations of the most recent data sets, including the Planck PR4 and the DESI BAO 2024, in order to see whether it is possible to alleviate the tensions aforementioned. The use of statistical criteria allows us to compare the performance of the different models under study.

Causal set theory / 192

Do causal sets have symmetries?

Author: Christoph Minz[1]

[1] *ITP, Universität Leipzig*

Corresponding Author: christoph.minz@itp.uni-leipzig.de

Causal sets are locally finite, partially ordered sets (posets), which are considered as discrete models of spacetime. On the one hand, causal sets corresponding to a spacetime manifold are commonly generated with a random process called sprinkling. This process keeps only a discrete set of points of the manifold and their causal relations (loosing the spacetime symmetries in each sprinkle).
On the other hand, the main conjecture of causal set theory is that given an ensemble of causal sets there is a corresponding spacetime manifold and the continuum symmetries of it are like all manifold properties "reconstructible" from the partial orders of all the causal sets in the ensemble. But most generic finite posets have very few layers ("instances of time") in contrast to sprinkles with many layers in a sufficently large spacetime region.
In a recent project, I investigated the automorphism groups of (finite) posets in order to identify and classify their symmetries systematically. The comparison of local symmetries of generic posets (including Kleitmann-Rothschild orders) with sprinkled causal sets may help us to find posets that can serve as discrete spacetime models in causal set theory.
In the discussion of the results, we use the representation of posets as Hasse diagrams. I developed some simple tools (available for LaTeX and online) that will be explained alongside.

GRB-SN connection / 193

GRB/SN Connections and Understanding Transient Engines

Author: Chris Fryer[1]

[1] *Los Alamos National Laboratory*

Corresponding Author: fryer@lanl.gov

Although astronomers quickly identified stellar implosion as the dominant progenitor of long-duration gamma-ray bursts, the exact mechanism that produces the high angular momenta in the progenitor that is required to produce gamma-ray bursts. The properties of the supernovae associated with these bursts (currently believed to be primarily/all type Ic supernovae) provide key insight into the nature of these progenitors and here we review the progenitor scenarios that match this observational constraint. With these models, we can also study the connection between normal gamma-ray bursts, low-luminosity gamma-ray bursts and asymmetric supernovae.

Causal set theory / 194

Planckian discreteness in cosmology: Brownian motion of dark matter particles

Author: Arad Nasiri[1]

[1] *Imperial College London*

Corresponding Author: a.nasiri21@imperial.ac.uk

Quantum gravity has yet remained elusive from an observational standpoint. In this talk, I will discuss Swerves, a proposal within quantum gravity phenomenology that predicts testable effects in cosmological data. Motivated by considerations in Causal Set Theory, a discrete approach to quantum gravity, we have formulated the covariant Brownian motion of free particles around their geodesics. At the level of the Fokker-Planck equation, this approach provides the unique generally covariant extension to the Boltzmann equation for free particles. When applied to dark matter particles, it results in dynamical warming at late times, which suppresses the matter power spectrum at small scales. Thus, the model shows potential for alleviating the S_8 tension.

Inflation: perturbations, initial singularities and emergent universes / 195

Unification: inflation and dark epochs from multi-field theory

Author: Eduardo Guendelman[1]

[1] *Ben Gurion University*

Corresponding Author: guendel@bgu.ac.il

A two scalar field model that incorporates non Riemannian Measures of integration or usually called Two Measures Theory (TMT) is introduced, in order to unify the early and present universe. In the Einstein frame a K-essence is generated and, as a consequence for the early universe, we can have Inflation and then subsequent early and present present dark epochs with consistent generation of dark energy (DE), dark matter (DM) and stiff matter. The scale invariance is introduced and then is spontaneously broken from the integration of the degrees of freedom associated with the modified measures. The resulting effective potentials and K-essence in the Einstein frame produce three flat regions corresponding to the different epochs mentioned before. For the first flat region we can obtain an inflationary universe. Also assuming this first plateau, we study the inflation in the framework of the slow-roll approximation,which brings us to an easy transition transition to the first DE region. In this scenario under the slow roll approximation we obtain a linear combination that is a constant. The corresponding cosmological perturbations in our model are determined and we also obtain the different constrains on the parameter-space from the Planck data.The slow roll approximation can be arranged so that the transition from inflation to the next flat region can be achieved without problems.

In the following flat regions, representing the Early Dark Energy and Late Dark Energy periods, DE and also the DM, which do not need to be introduced separately, they are instead a result of a K-essence induced by the multi measures, multi field theory.Therefore the scalars generate both the DE and the DM . Also a stiff matter component, which decays very fast, is automatically generated from the K-essence theory from two scalar fields.

Latest results from Galactic center observations / 196

The NIR to X-ray variability of Sgr A*: temporal asymetry and the importance of relavistic effects

Author: Sebastiano von Fellenberg[1]

[1] *MPIfR*

Corresponding Author: sfellenberg@mpifr-bonn.mpg.de

I will present an overview of temporal variability studies of Sgr A*, discussing several observables, such as the flux distribution, the SED, the PSD and (higher order) structure functions, and will give an overview of how these are typically modelled in observational studies. A particular focus will be put on the temporal symmetry of Sgr A*, which as a new and useful observable for the study of astronmical time series.

Black holes in alternative theories of gravity / 197

Does no-hair theorem fail in the modified theories of gravity?

Authors: Alan Sunny[1]; Semin Xavier[2]; Shankaranarayanan Subramaniam[2]

[1] *Department of Physics, Indian Institute of Technology Bombay, Mumbai 400076, India*

[2] *IIT Bombay*

Corresponding Author: seminxavier@iitb.ac.in

The no-hair conjecture asserts that all black holes in general relativity (GR) coupled to any matter must be Kerr–Newman type. The three independent externally observable classical parameters— mass, electric charge, and angular momentum — uniquely determine all the information about the matter that formed into a black hole. However, the conjecture fails in some cases where the matter sources are described by non-linear field equations.

This raises a few questions: Is the no-hair theorem a feature of gravity or GR? Are there other types of rotating black hole solutions besides Kerr's, which are specific to GR? If yes, which category of modified gravity theories support and how do they differ from the Kerr solution in GR? This talk addresses the no-hair conjecture in the $f(R)$ gravity. We show this by explicitly constructing multiple slow-rotating black hole solutions, up to second order in rotational parameter, for a class of $f(R)$ models. We analytically show that multiple vacuum solutions satisfy the field equations up to the second order in the rotational parameter. In other words, we show that the multiple vacuum solutions depend on arbitrary constants, which depend on the coupling parameters of the model. Hence, our suggests that the no-hair theorem for modified gravity theories merits extending to include the coupling constants. We discuss the kinematical properties of these black hole solutions and compare them with slow-rotating Kerr solutions, which are the rotating black hole solutions in GR. Specifically, we show that the circular orbits for the black holes in $f(R)$ are smaller than that of Kerr. This implies that the inner-most stable circular orbit for black holes in $f(R)$ is smaller than Kerr's; hence, the shadow radius might also be smaller, which will have implications for observations of black holes

Exploring the Universe with strong gravitational lensing / 198

Time delay cosmography with galaxy clusters with a new strong lensing tool

Author: Giorgia Di Rosa[1]

[1] *University of Ferrara*

Corresponding Author: giorgia.dirosa@unife.it

In recent years, the precision of the Hubble constant (H_0) measurements has significantly improved, revealing some discrepancy between the estimates inferred from local and early-universe probes. This tension might be ascribed to the presence of unknown systematic effects or some deviation from the current cosmological model (flat ΛCDM), thus pointing to the need of new physics. Adding new independent and complementary techniques to measure H_0 could provide crucial insights into unveiling the origin of this tension.
Strong gravitational lensing (SL) of time-varying sources offers such an opportunity. As recently demonstrated in a spectacular fashion in the case of the strongly lensed "supernova Refsdal" by a massive galaxy cluster, a robust modeled mass distribution of the lens and a measurement of the time-delays of multiple images of the supernova (SN) can be used to provide competitive and independent constraints on the Hubble constant and other geometrical cosmological parameters.
In the effort to exploit time-delay cosmography on cluster scale, I will show the first results from the SL analysis of two galaxy clusters with multiply lensed quasars, based on a new SL modeling tool called Gravity.jl (credit: M. Lombardi). The availability of time delay measurements among quasar images in these clusters, in combination with the high computing performance and flexibility of this SL tool, provide an opportunity to test a number of possible systematics in the measurement of the Hubble constant. I will also discuss the prospects of using Gravity.jl in the new era of high-quality and high-volume strong lensing data.

Low frequency gravitational waves: sciences and detections / 199

Linear dynamics and gravitational waves in gravitational quantum field theory

Authors: Da Huang[1]; Yong Tang[2]; Yong-Liang Ma[3]; Yu-Feng Zhou[4]; Yuan-Kun Gao[2]; Yue-Liang Wu[5]

[1] *National Astronomical Observatories, Chinese Academy of Sciences*

[2] *University of Chinese Academy of Sciences*

[3] *Nanjing University*

[4] *Institute of Theoretical Physics, Chinese Academy of Sciences*

[5] *UCAS*

Corresponding Author: dahuang@bao.ac.cn

The gravitational quantum field theory is a gauge formulation of the gravity dynamics based on the inhomogeneous spin gauge symmetry, which leads to the generalized Einstein equation. In order to test this theory, we linearize the dynamic equations of gravitational interaction by keeping terms up to the leading order in the dual gravigauge field. We then apply the linearized dynamic equations into two particular gravitational phenomena. Firstly, we consider the linearized equations in the absence of source fields, which is shown to have five physical propagating polarizations as gravitational waves, i.e., two tensor modes, two vector modes, and one scalar, instead of two tensor polarizations in the general relativity. Secondly, we examine the Newtonian limit in which the gravitational fields and the matter source distribution are weak and static. By deriving the associated Poisson equation, we obtain the exact relation of the fundamental interaction coupling in the gravidynamics with the experimentally measured Newtonian constant. We also make use of non-relativistic objects and relativistic photons to probe the Newtonian field configurations. In particular, the experiments from the gravitational deflection of light rays and the Shapiro time delay can place stringent constraints on the linearized gravidynamics in the gravitational quantum field theory.

High energy astrophysics / 200

First light of the Einstein Probe mission

Author: Francesco Coti Zelati[None]

Corresponding Author: cotizelati@ice.csic.es

The launch of the Einstein Probe mission in January 2024 has marked a significant leap forward in the exploration of the transient X-ray Universe. Led by the Chinese Academy of Sciences and in collaboration with the European Space Agency, the Max Planck Institute for Extraterrestrial Physics and the French space agency, the mission consists of two instruments: the Wide-field X-ray Telescope, equipped with cutting-edge lobster-eye Micro-Pore Optics, ideal for detecting new transient phenomena; and the Follow-up X-ray Telescope, designed for sensitive follow-up observations of newly discovered transients. To maximize the scientific output of the mission, the Einstein Probe consortium has been structured in six independent science topical panels. In this talk, I will highlight our active involvement in the consortium, particularly our activities related to the panel focused on Compact Stellar Objects. I will outline insights into our ongoing and upcoming initiatives, from target preparation for performance verification observations to submissions of observing proposals and the development of state-of-the-art pipelines to systematically characterise the X-ray spectral and timing properties of newly discovered transients.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 201

Matter ejections behind the highs and lows of a transitional millisecond pulsar

Author: Francesco Coti Zelati[None]

Corresponding Author: cotizelati@ice.csic.es

In this talk, I will describe the results of the most extensive multiwavelength observational campaign ever carried out on the prototype of the class of transitional millisecond pulsars, PSR J1023+0038. The campaign aimed to find an explanation once and for all for the peculiar variability pattern shown by the source during its current active X-ray state. The results of the data analysis indicate that this phenomenology is due to changes in the innermost region of the accretion disc. These changes trigger the emission of discrete mass ejections, which occur on top of a compact jet, as testified by the detection of at least one short-duration millimetre flare at the high-to-low mode switch. The pulsar is subsequently re-enshrouded, completing the picture of the mode switches.

Strong electromagnetic and gravitational field physics: From laboratories to early Universe / 202

Magnon-antimagnon pair production by magnetic field inhomogeneities and the bosonic Klein effect

Authors: Tiago Adorno[1]; Dmitri Gitman[2]; Sergei Gavrilov[3]

[1] *Xi'an Jiaotong-Liverpool University*

[2] *Department of Physics, Tomsk State University, Russia, P.N. Lebedev Physical Institute, Russia, and Institute of Physics, University of Sao Paulo, Brazil.*

[3] *Department of Physics, Tomsk State University, Russia, and Department of General and Experimental Physics, Herzen State Pedagogical University of Russia, Russia*

Corresponding Author: tiago.adorno@xjtlu.edu.cn

Similar to Dirac models of nanostructures, low-energy excitations in spin systems –magnons– can be described in terms of effective field theories. The theory describing antiferromagnets can be mapped into scalar massless electrodynamics with an external electromagnetic potential. Here, we consider the case of a constant inhomogeneous magnetic field applied to an antiferromagnet, whose characteristic magnetic moment plays the role of the electric charge, and magnons and antimagnons differ by the sign of the magnetic moment. In the framework of the effective description, we discuss

how vacuum instability (the Schwinger effect) due to magnon-anti magnon production arises in this context. In particular, we show how to use the strong field QED with x-steps developed by the authors (SPG and DMG) to study magnon-anti magnon pair production characteristics by magnetic field inhomogeneities. Finally, we will examine specific examples and investigate the impact of the external field inhomogeneity on magnon pair production.

Gravitational lensing, shadows and photon rings / 204

Geometry of trapped photon region in the phase space of Kerr-Newman and Kerr-Sen spacetime

Author: Karim Mosani[1]

[1] *Ruhr University (Bochum), Germany*

Corresponding Author: kmosani2014@gmail.com

In Einstein's general relativity, extremely strong gravity can trap light. In a spacetime admitting a singularity, we say that light (or a "photon") is trapped if it neither escapes to spatial infinity nor falls into the singularity. Null geodesics govern the trajectories of light. In the Schwarzschild spacetime with positive mass M, there exist (unstable) circular orbits of trapped photons at the Schwarzschild radius $r = 3M$, outside the black hole horizon at $r = 2M$. These orbits fill a three-dimensional submanifold of topology $S^2 \times \mathbb{R}$ called the photon sphere of the Schwarzschild spacetime. In general, a region in spacetime that is a union of all trapped null geodesics is called the Trapped Photon Region (TPR) of spacetime. In this talk, we will consider the Kerr-Newman and Kerr-Sen spacetime and see that, unlike the TPR of Schwarzschild spacetime, the TPR in such spacetimes is not a submanifold of the spacetime in general. However, the lift of TPR in the phase space is a five-dimensional submanifold. This result has applications in various problems in mathematical relativity (This work is an extension of a similar result but in Kerr spacetime by Cederbaum and Jahns- 2019).

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 205

Electromagnetic Oscillation in Cold Plasma in Higher Dimensional Spacetime

Author: Dibyendu Panigrahi[1]

[1] *Netaji Nagar Day College, Kolkata 700092*

Corresponding Author: dibyendupanigrahi@yahoo.co.in

The Einstein–Maxwell and the electrodynamical equations are written for a (d+1)-dimensional FRW-like spacetime in the presence of plasma with the help of a wellknown (3 + 1) decomposition formalism given by Thorne and Macdonald. Actually this work is the generalisation of earlier one by Holcomb and Tajima[2].

We have studied the propagation of an electromagnetic wave in cold plasma in higher dimensional spacetime in the presence of an ambient and homogeneous magnetic field, both parallel and perpendicular to the wave propagator[4]. We assume the plasma medium to be cold so that the pressure can be neglected when considering the particle equation of motion.

In the presence of an external magnetic field many interesting oscillation modes manifest themselves. A simplified Appleton–Hartree type of solution generalized to higher dimensions is obtained in curved spacetime. Only a selected range of frequencies are available for propagation here for the case of the magnetic field parallel to the propagation vector. The permittivity-tensor where the dielectric constant scalar transforms into the second rank tensor. The refractive index of the plasma medium is also studied. The cyclotron frequency was calculated which decays with time where

dependance of dimensions was also observed. There is no fixed resonant frequency as in the Newtonian case and it changes with time. Again, the condition of evanescent wave was discussed. It is also found that the propagation of the electromagnetic wave is more restricted in higher dimensions than the usual 4D. The well-known phenomenon of Farday rotation is also studied which has interestingly many important astrophysical implications.
The dispersion relations were discussed for both ordinary and extraordinary wave when the magnetic field is perpendicular to the propagation vector.
References:
1. K A Holcomb and T Tajima, Phys. Rev.D 40 (1989) 3809
2. D Panigrahi and S Chatterjee, JCAP08 (2008) 032

Loop quantum gravity: cosmology and black holes / 206

Quantum Impulsive Null Geometries

Author: Wolfgang Wieland[1]

[1] *FAU Erlangen Nuremberg*

Corresponding Author: wolfgang.wieland@fau.de

Gravitational waves propagate at the speed of light. If we take an ultra-short distributional pulse of gravitational radiation, the resulting wavefront will move along a co-dimension one light-like (null) surface in spacetime. The question of how to describe the quantum geometry of such impulsive null initial data is an important physical problem shared across different approaches. In my presentation, I report on three new results on this frontier. First, a new mathematical technique is introduced to characterize the phase space of the radiative modes of impulsive null initial data at the full non-perturbative level. Second, we take the description to the quantum level, using a non-perturbative polymer quantization familiar from Loop Quantum Gravity. Third, an immediate physical implication is found: in the model, the Planck luminosity separates the eigenvalues of the radiated power. Below the Planck power, the spectrum of the radiated power is discrete. Above the Planck power, the spectrum is continuous and the resulting physical states contain caustics that can spoil the semi-classical limit. The bound depends on the Barbero–Immirzi parameter, which sets the fundamental scale in Loop Quantum Gravity relative to the Planck scale. The talk is based on arXiv:2402.12578, arXiv:2401.17491, arXiv:2104.05803.

Loop quantum gravity / 207

Simplicial Graviton from Selfdual Ashtekar Variables

Author: Wolfgang Wieland[1]

[1] *FAU Erlangen Nuremberg*

Corresponding Author: wolfgang.wieland@fau.de

Selfdual gravity is a reformulation of general relativity on the phase space of an SL(2,C) gauge theory. As pointed out by Abhay Ashtekar in the mid 1980ies, this reformulation lead to a remarkable simplicity of Hamiltonian GR. Using selfdual variables, the constraints simplify and assume the simplest possible polynomial form. In this talk, I lay out a new non-perturbative lattice approach for selfdual gravity. Three results will be discussed. First of all, I explain how to introduce a local kinematical phase space at the lattice sites. At each lattice site, a set of constraints is found that replace the generators of hypersurface deformations in the continuum. The second and most intriguing result is that the discretized constraints close under the Poisson bracket. The resulting reduced phase space describes the two radiative modes at the discretized level. As consistency check, I apply the construction to gravity in three-dimensions. In this way, the established spin-network representation

of three-dimensional gravity is recovered from a local quantisation of space. The talk is based on arXiv:2305.01803

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 208

Constraining the photon mass: from the lab to the atmosphere and beyond

Author: Pedro Malta[None]

Corresponding Author: pedrocmalta@gmail.com

The de Broglie-Proca theory, which endows the photon with a small, but finite rest mass, is the simplest extension of Maxwell's electrodynamics. Over the last hundred years its consequences have been investigated both theoretically and experimentally with ever tighter upper bounds being set. In this talk we discuss recent limits/sensitivities on the photon mass from laboratory-based experiments, as well as using atmospheric phenomena on Earth. We also briefly discuss limits obtained from Doppler-tracking data of the Cassini spacecraft and the potential for tests at astrophysical scales.

Inflation: perturbations, initial singularities and emergent universes / 209

Primordial black holes as Dark matter, gravitational radiation as Dark energy (P.W.Anderson): experimentally and observationally tested unified approach to Planck-scale physics and Big Bang cosmology, early Large-scale structure and Two-stage accelerated expansion of the Universe

Author: Victor Borsevici[1]

[1] *Free International University of Moldova (ULIM)*

Corresponding Author: borsevici@mail.ru

Recent remarkable discoveries, such as Einstein's gravitational waves, "impossible early" galaxies and quasars, 2D photon Bose-Einstein condensate with rest energy etc. provide a solid experimental and observational basis for "fiery marriage of general relativity with quantum theory" (J.Wheeler). Consecutively, in a physical logic, nature inspire us that primordial black holes (PBHs) represent 2D spherical photon condensates trapped in their own gravitational fields. Such a physical model inevitably leads to the remarkable equation that directly connects Compton wavelength of condensed light (quantum theory) with geodesical length (general relativity): λsm=2πRs , Rs-gravitational radius of black hole. Figuratively speaking, Spacetime tells condensed Light quanta how to curve; condensed Light quanta tells Spacetime how to quantize.
Relying only on the well-established physical laws one can easily find the numerous quantized characteristics (mass, rest energy, size, entropy, temperature, amount of quantum information etc.) and simple but very important laws that govern birth, growth and death of PBHs. We find that two-particle emission (both outside black hole, accompanied with gravitational radiation) remove so-called "information loss" problem.
Moving backwards alone the "arrow of time" we find the "graininess-spacetime" consisting of 3D Planck condensed photons. However, after Big Bang, by the end of Planckian era (at about 50πTp) we already find continuum spacetime with gravitational radiation (dark) energy density Ωλ=0.6777…
To this very early important moment the first stage of accelerated expansion of the Universe had practically finished. Recent second stage of accelerated expansion is caused by remarkable growth of gravitational radiation (DE) as a result of intense (compare modern Ωλ estimations with the early 0.6777…) merger processes between current BPHs background (DM) and supermassive black holes in

the active galactic nuclei (AGN). Note that modern DM represents asteroid-mass microscopic PHBs which emit “unsolved” diffuse hard X-ray with peak at 30keV and hard cut-off 511keV/2.

Exploring the Universe with strong gravitational lensing / 210

Time-delay cosmography as an independent and competitive cosmological probe

Author: Ana Acebron[1]

[1] *Instituto de Física de Cantabria (IFCA)*

Corresponding Author: anaacebronmunoz@gmail.com

The percent precision achieved on the values of the cosmological parameters defining the expansion rate and the geometry of the Universe has recently revealed some tension between the measurements of the value of the Hubble constant (H0) from local and early-Universe cosmological probes. The best strategy forward today is to develop independent and complementary techniques to measure H0, and assess a tension that signals new physics beyond the standard cosmological model.

Using time delays of time-varying sources, such as supernovae (SNe) or quasars, that are strongly lensed by galaxy clusters grants such an opportunity. Known as time-delay cosmography, this single-step method is fully independent from other probes, and as such, can play a crucial role in helping to clarify the current Hubble tension problem.

In this talk, I will review recent developments and current efforts in time-delay cosmography with galaxy- and cluster-scale systems. Remarkably, the relative error on the inferred value of H0 from a single (galaxy or cluster) strong lensing system is similar and demonstrates the complementarity of the two techniques. I will finally highlight novel ideas aimed at enhancing the power of time delays in lens clusters by probing the member galaxies. Such studies are paving the way for using a statistically significant sample of these rare lensing configurations, that will be discovered in forthcoming surveys, like the LSST and Euclid, as a competitive cosmological probe.

Gravitational instantons and black holes / 211

Multi-Black Hole Gravitational Field

Authors: Eliska Klimesova[1]; Martin Zofka[2]

[1] *Institute of Theoretical Physics, Charles University Prague, Czech Republic*

[2] *Institute of Theoretical Physics, Charles University, Prague*

Corresponding Author: klimesova.ell@gmail.com

We shall discuss a system consisting of three extremally charged black holes moving in their own gravitational and electromagnetic fields. Based on a method by Ferrell & Eardley for an arbitrary number of holes, we take the exact static Majumdar-Papapetrou spacetime, and perturb it by giving the holes small velocities.

Suprisingly, the complicated equations can be reduced to a classical mechanics problem with a Lagrangian determining the motion of the black hole system, which is given as an integral over the spatial variables. The issue is to evaluate the integral explicitly. This has been done for two holes so far—we extend it by adding a third one. We compare the motion of the third black hole to that of a test particle in the field of the two remaining holes. What remains is the self-force due to the third black hole acting on itself.

Gamma-ray bursts and AGNs with machine learning / 212

Pseudo Redshifts of Gamma-Ray Bursts with a Plateau Phase

Author: Yong-Feng Huang[1]

Co-author: Chen Deng [1]

[1] *Nanjing University*

Corresponding Author: hyf@nju.edu.cn

The X-ray afterglow of many gamma-ray bursts (GRBs) exhibits a plateau phase, which may be related to continued activities of the central engine. It has been found that there exists a so-called L–T–E correlation for these GRBs, which involves three key parameters, i.e., the isotropic gamma-ray energy Eiso of the prompt phase, the end time Ta of the plateau phase, and the corresponding X-ray luminosity Lx. In our recent study, we found that the L–T–E correlation can be used to derive a pesudo redshift for GRBs with a plateau phase. Based on the large sample of GRBs with such a pesudo redshift, statistical analysis is carried.

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 213

Lessons from Stuekelberg theory in Cosmology.

Author: Govindarajan Thupil[1]

[1] *Inst of Mathematical Sciences, Krea University*

Corresponding Author: thupilrg@gmail.com

Abstract: Stueckelberg solved the problem of gauge invariance
in massive
QED by a new mechanism which is precursor for Abelian Higgs.
It has several implications in Cosmology and we will discuss few of
them.

Strong electromagnetic and gravitational field physics: From laboratories to early Universe / 214

A study of scalar quantum electrodynamics in de Sitter spacetime

Author: Ehsan Bavarsad[1]

[1] *Department of Physics, University of Kashan, 8731753153, Kashan, Iran*

Corresponding Author: e.bavarsad@gmail.com

The aim of this study is to explore some features of the nonperturbative, one-loop, regularized effective Lagrangian of scalar quantum electrodynamics (QED) in a uniform electric field background with constant energy density in the Poincare patch of 2-dimensional de Sitter spacetime (dS_2). Particularly, the electric permittivity of the vacuum, and the equation of state of the created Schwinger scalars have been investigated.

Gravitational lensing, shadows and photon rings / 215

Polarized image of equatorial emission in horizonless spacetimes

Authors: Galin Gyulchev[1]; Petya Nedkova[2]; Stoytcho Yazadjiev[2]; Valentin Deliyski[3]

[1] *Sofia University "St. Kliment Ohridski"*

[2] *Sofia University*

[3] *Sofia University "st. Kliment Ohridski"*

Corresponding Author: valentin.deliyski@gmail.com

We study the linear polarization from the accretion disk around horizonless compact objects. Previous works have shown that these spacetimes can have significantly different lensing properties from black holes. In particular, their relativistic images can exibit a qualitatively new ring structure, inside what would be the shadow region. We search for characteristic signatures which could distinguish these spacetimes from black holes by their polarization properties. To do this, we apply a simplified model of a magnetized fluid ring orbiting in the equatorial plane. We find that for low inclinations, the direct images show a very similar polarization structure to black holes but the intensity of the strongly lensed indirect images can grow up to an order of magnitude compared to that of the Schwarzschild back hole. We also show that the polarization intensity of the new ring structure is significant compared to that of the Schwarzschild black hole and the twist of the polarization vector of these central images is significantly different for the considered spacetimes. Thus while it can be difficult to distinguish horizonless spacetimes from black holes by means of the polarization of their direct images, the strongly lensed indirect images and the qualitatively new central ring structure provide characteristic signatures which can serve as probes for horizonless objects.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 216

Study of Spectral State Transitions in Black Hole Binaries

Author: Soumen Mondal[1]

[1] *Jadavpur University, Kolkata, India*

Corresponding Author: soumenjuphysics@gmail.com

The aim of our work is to study the origin of the spectral transitions of transient black hole binaries. In this work, we find signatures of spectral state transition (hard to soft state) while studying the radiative shock for the accretion flow. The gradient of the energy dissipation curve shows a sudden break for certain critical flow parameters when the post-shock dissipation is maximum. This particular feature is common to all spins, and the transitions are well observed. We have identified all the critical flow parameters for different black hole spins. With the dissipation, the inner edge of the disk or the geometry of the post-shock corona reduces progressively and attains a minimum for maximum dissipation. The spin enhances the maximum dissipation further. Using the exact general relativistic framework, we therefore systematically study the various dynamical properties of radiative/dissipative shocks in accretion flows to understand the observed phenomena, namely, the variation of the hard intensity emitted from the evolving Comptonizing medium, the spectral transitions, and their entanglement with the inner edge of the disk, etc. The results presented here might be useful in finding the variation of the hardness ratio and could be a first step to procuring the "q" diagram theoretically.

High energy astrophysics / 217

On the properties of dissipative shocks in the relativistic accretion flows

Author: Soumen Mondal[1]

[1] *Jadavpur University, Kolkata, India*

Corresponding Author: soumenjuphysics@gmail.com

In this work, we study the properties of dissipative shocks for fully relativistic accretion flows around spinning black holes. In an accretion flow harbouring a dissipative shock (formally known as radiative shock), a significant portion of the thermal energy may get released from the post-shock corona. A stellar-mass black hole may therefore emit hard X-rays from the inner edge of the disc. If the bulk energy loss is significant, post-shock pressure drops, and shock moves forward towards the black hole compressing the size of the post-shock corona, resulting an enhancement of the corona temperature and compression ratio. The dynamical properties of the radiative shocks are therefore systematically investigated to understand accurately the radiative loss processes, temporal variations, and the spectral properties. We notice that the range of flow parameters (e.g. energy and angular momentum) responsible for the formation of 'shocks in accretion (SA)' is identical for both the cases of standing and dissipative
shocks. The spin of the black hole enhances the dissipation further. We estimate the maximum energy release, which is observed close to 100 per cent in the extreme cases. This could be useful in explaining various observed phenomena namely the formation and the systematic evolution of quasi-periodic oscillations, and the time lags in between hard and soft X-ray photons (e.g. XTE J1550−564, GRO J1655−40, etc.) during their outbursts.

Micro-Hertz gravitational waves (0.1-100 μHz): sources and detection methods / 218

Detectability of gas-rich E/IMRI's in LISA band: observable signature of transonic accretion flow.

Author: Soumen Mondal[1]

[1] *Jadavpur University, Kolkata, India*

Corresponding Author: soumenjuphysics@gmail.com

Real extreme/intermediate-mass ratio inspiral (E/IMRI) systems are likely to contain large accretion discs which could be as massive as the central supermassive black hole. Therefore, contrary to its ideal model, a real E/IMRI system contains a third important component: the accretion disc. We study the influence of these discs on the emitted gravitational wave (GW) profile and its detectability through proposed LISA observation. We use a semirelativistic formalism in the Kerr background for the case of transonic accretion flow which is a potential candidate to describe the accretion flows around active galactic nuclei. The hydrodynamic drag of the discs modified the motion of the companion as a result of the emitted wave changes in amplitude and phase. We found that these changes are detectable through the last few years of observation by LISA (in some cases as small as 6 months) for EMRIs residing within redshift $z = 1$ from the detector and for the accretion rate of the primary black hole of the order of one Eddington rate. These choices of parameter values are consistent with real systems. The drag effect and hence the detectability of the emitted GW is sensitive to the hydrodynamical model of the disc. Therefore, we vary the disc parameters, accretion rate, and duration of observation of E/IMRIs, and find that in comparison with other disc models, transonic solution
of fers relati vely better observ able signatures in detecting the gas-rich E/IMRI's within the LISA band. Such observations will help one to probe the nature of the accretion flow and verify various paradigms of accretion physics.

Low frequency gravitational waves: sciences and detections / 219

Eccentric orbits in disk-embedded EMRIs : Orbital evolution and observability trend in LISA.

Author: Soumen Mondal[1]

[1] *Jadavpur University, Kolkata, India*

Corresponding Author: soumenjuphysics@gmail.com

The purpose of this work is to study the orbital evolution under the combined effect of disk-drag and GW-emission for E/IMRIs endowed with accretion disk. We study the dependence of disk-torque and GW-torque on the orbital parameters of compact companions. We employ a semi-relativistic technique to study E/IMRI dynamics evolving under most general elliptical-orbits in the equatorial plane and assume natural transonic disk in the Kerr space-time around a supermassive black-hole (SMBH). To conduct an accurate investigation, we fix the disk attributes and alter orbital-parameters, mass-ratio of E/IMRIs and spin of SMBH. We notice that high-eccentric orbits with smaller semi-major axis exhibit a more prominent impact of accretion-drag on the companion-dynamics. The magnitude of disk-torque is greater and almost one order higher in retrograde-spins than prograde spins. We identify the best-fitted orbital parameters, which can potentially enhance detectability of accretion-disk effect on the observed GW-signal. Prioritizing such orbital-configuration, we obtain substantial impact on the dephasing for maximum disk-torque and high signal-to-noise-ratio (SNR) in emitted signals. Employing a threshold-SNR (> 8), we finally identify the detectability trend of those systems in LISA-band. A key aspect of our findings is the ability to constrain the orbital parameters by GW-detection and estimate orbital-ellipticity or other orbital characteristics by comparing two SNRs. Hence, the study will be important in understanding the orbital-evolution, predicting orbital-configuration, and finding detectability for such gas-rich E/IMRIs. The predictions of E/IMRI formation pathways from ground and more certainly from future space-borne detectors, would also be possible from the likelihood of such eccentric-E/IMRIs in the sky.

Astrophysics with gravitational waves / 220

Conservation, Non-conservation Laws and Gravitational Energy-momentum in General Relativity

Author: Zhaoyan Wu[1]

[1] *Jilin University*

Corresponding Author: zyw@jlu.edu.cn

We show that because in a curved spacetime parallel transportations of (r,s)- tensors with r+s>0 depend on paths, one cannot add up (r,s)-tensors at different points to get a definite sum (r,s)-tensor when r+s>0. However, when restricted to an infinitesimal spacetime region, one still can add up (r,s)-tensors at different points to get a definite sum (r,s)-tensors, if neglecting higher order infinitesimals. Due to these sound facts from geometry, we cannot talk about the sum of (r,s)- tensors distributing on a finite or infinite hypersurface, nor the net increase of (r,s)-tensors in a finite or infinite spacetime region, if r+s>0; but we still can talk about the sum of (r,s)-tensors distributing on an infinitesimal hypersurface element, or the net increase of (r,s)-tensor in an infinitesimal spacetime region, when neglecting higher order infinitesimals. Therefore, denoting by ⊠ the flux density (r+1,s)- tensor field of (r,s)- tensor Q, the conservation law of Q in curved spacetime can only be "the covariant divergence of ⊠ vanishes everywhere". It reads, "the net increase of tensor Q in any infinitesimal 4-dimensional neighborhood is zero".

In particular, matter energy-momentum P is a (1,0)-tensor, denote its flux density field by T. The conservation law for P in GR cannot be anything else but "the covariant divergence of T vanishes everywhere". It reads, the net increase of matter energy-momentum in any infinitesimal spacetime region is zero. This means matter fields and matter particles exchange energy-momentum with each other, but not with anything else including gravitational field.

Force, or interaction in physics, always means exchange of energy-momentum. Now that the gravitational field does not exchange energy-momentum with matter fields and matter particles. So,

gravitational field does not carry energy- momentum, it is not a force field, and gravity is not a natural force.

Gamma-ray bursts and AGNs with machine learning / 221

Revisiting the Spectral-Energy Correlations of GRBs with {\it Fermi} Data I:\\ Model-wise Properties

Authors: Liang Li[1]; Liang Li[1]

[1] *ICRANet, Piazza della Repubblica 10, I-65122 Pescara, Italy*

Corresponding Author: liang.li@icranet.org

Gamma-ray bursts (GRBs) exhibit a diversity of spectra. Several spectral models (e.g., Band, cutoff power-law, and blackbody) and their hybrid versions (e.g., Band+blackbody) have been widely used to fit the observed GRB spectra. Here, we attempt to collect all the bursts detected by {\it Fermi}-GBM with known redshifts from July 2008 to May 2022, motivated to (i) provide a parameter catalog independent from the official \emph{Fermi}/GBM team and (ii) achieve a "clean" model-based GRB spectral-energy correlation analysis. A nearly complete GRB sample was created, containing 153 such bursts (136 long gamma-ray bursts and 17 short gamma-ray bursts). Using the sample and by performing detailed spectral analysis and model comparisons, we investigate two GRB spectral-energy correlations: the cosmological rest-frame peak energy ($E_{\rm p,z}$) of the νF_ν prompt emission spectrum correlated with (i) the isotropic-bolometric-equivalent emission energy $E_{\gamma,\rm iso}$ (the Amati relation), and (ii) the isotropic-bolometric-equivalent peak luminosity $L_{\rm p,iso}$ (the Yonetoku relation). From a linear regression analysis, a tight correlation between $E_{\rm p,z}$ and $E_{\gamma,\rm iso}$ (and $L_{\gamma,\rm iso}$) is found for both the Band-like and CPL-like bursts \textcolor{red}{(except for CPL-like burst $E_{\rm p,z}$-$E_{\gamma,\rm iso}$ correlation)}. More interestingly, the CPL-like bursts do not fall on the Band-like burst Amati and Yonetoku correlations, suggesting distinct radiation processes, and pointing towards the fact that these spectral-energy correlations are tightly reliant on the model-wise properties.

Emission mechanisms in gamma-ray bursts / 222

A Cosmological Fireball with Sixteen-Percent Gamma-Ray Radiative Efficiency

Authors: Alberto J.Castro Tirado[1]; Asaf Peer[2]; Bing Zhang[3]; Felix Ryde[4]; Kim Page[5]; Liang Li[6]; P.N. Bhat[7]; Peter Veres[7]; Sylvain Guiriec[None]; Yang Wu[8]

[1] *Instituto de Astrofisica de Andalucia (IAA-CSIC), PO Box 03004, 18008 Granada, Spain*

[2] *Department of Physics, Bar-Ilan University, Ramat-Gan 52900, Israel*

[3] *Department of Physics and Astronomy, University of Nevada, Las Vegas, NV 89154, USA*

[4] *Department of Physics, KTH Royal Institute of Technology, and the Oskar Klein Centre for Cosmoparticle Physics, 10691 Stockholm, Sweden*

[5] *School of Physics and Astronomy, University of Leicester, University Road, Leicester LE1 7RH, UK*

[6] *ICRANet, Piazza della Repubblica 10, I-65122 Pescara, Italy*

[7] *Center for Space Plasma and Aeronomic Research, University of Alabama in Huntsville, Huntsville,AL,USA*

[8] *ICRANet, Piazza della Repubblica 10, 65122 Pescara, Italy*

Corresponding Author: liang.li@icranet.org

Gamma-ray bursts (GRBs) are the most powerful explosions in the universe. How efficiently the jet converts its energy to radiation is a long-standing problem and it is poorly constrained. The standard model invokes a relativistic fireball with a bright photosphere emission component. A definitive

diagnosis of GRB radiation components and measurement of GRB radiative efficiency require prompt emission and afterglow data with high-resolution and wide-band coverage in time and energy. Here we report a comprehensive temporal and spectral analysis of the TeV-emitting bright GRB 190114C. Its fluence is one of the highest of all GRBs detected so far, which allows us to perform a high-resolution study of the prompt emission spectral properties and their temporal evolution down to a timescale of about 0.1 s. We observe that each of the initial pulses has a thermal component contributing $\sim 20\%$ of the total energy, the corresponding temperature and the inferred Lorentz factor of the photosphere evolve following broken power-law shapes. From the observation of the non-thermal spectra and the light-curve, the onset of afterglow corresponding to the deceleration of the fireball is considered at ~ 6~s. By incorporating the thermal and the non-thermal observations, as well as the photosphere and the synchrotron radiative mechanisms, we can directly derive the fireball energy budget with little dependence on hypothetical parameters and to measure a $\sim 16\%$ radiative efficiency for this GRB. With the fireball energy budget derived, the afterglow microphysics parameters can also be constrained directly from the data.

Black hole formation, evolution and the black hole mass gap / 223

Spins of primordial black holes in a matter-dominated era

Author: Daiki Saito[None]

Co-authors: Chulmoon Yoo ; Tomohiro Harada [1]; Yasutaka Koga

[1] *Rikkyo University*

In this talk, I will discuss the probability distribution of the spins of primordial black holes (PBHs) formed in a matter-dominated universe. For this evaluation, I focus on cosmological perturbations that follow a Gaussian distribution and examine their linear-order effects on the tidal torque they generate. By the time the fluid gravitationally collapses to form a PBH, nonlinear effects become significant. To account for these effects, I apply the Zel'dovich approximation. I also use peak theory, which describes the behavior of the Gaussian field, to evaluate the probability distribution of PBH spins. Additionally, I propose a threshold for fluctuations necessary for PBH formation based on the magnitude of the resulting spins.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 224

Polarization-corrected light propagation in gravitational fields

Author: Sebastian Murk[1]

Co-authors: Daniel Terno [2]; Rama Vadapalli [2]

[1] *Okinawa Institute of Science and Technology (OIST)*

[2] *Macquarie University*

Corresponding Author: sebastian.murk@oist.jp

The propagation of electromagnetic waves in vacuum is commonly modeled within the geometric optics approximation according to which light rays follow null geodesics. This is a sensible model whenever the wavelength is much smaller than the characteristic length scale of the medium through which it propagates since distinct wave phenomena such as diffraction are negligible in this case. However, in general the dynamical evolution of electromagnetic waves depends on the photon polarization and deviates from that of a null geodesic, which is often referred to as the gravitational spin Hall effect. We use a perturbative approach based on the Newman-Penrose formalism to numerically model trajectories of null tetrads and analyze the consequences of the gravitational spin Hall

effect for solar system observations. In addition, we describe the properties of polarization-corrected photon trajectories in Schwarzschild spacetimes.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 225

Particle Creation in a Linear Gravitational Wave Background

Author: Tanmoy Chakraborty[1]

Co-author: Parthasarathi Majumdar [1]

[1] *Indian Association for the Cultivation of Science*

Corresponding Author: tanmoy123physics@gmail.com

Inspired by the pioneering 1968 work of L Parker, demonstrating matter quanta production in a dynamical spacetime background, we consider production of scalar quanta in a gravitational wave background. Choosing the spacetime to be a flat spacetime perturbed linearly by a linear gravitational wave, we show that scalar particles may indeed be produced in a perturbative manner. Our formulation is valid for any linear gravitational wave background profile, and is by no means restricted to monochromatic plane waves, in contrast to much of the earlier work on this topic. Thus, our work is directly applicable to gravitational wave signals from compact binary coalescence detected at LIGO, where they are of a pulsed character rather than monochromatic plane waves. We also briefly outline generalizing our approach for photon creation in a gravitational wave background. In this aspect, irrespective of the astrophysical nature of the binary merger sourcing the gravitational wave signal, one expects the dynamical nature of the spacetime to produce all species of light particles. Thus, any binary coalescence is in effect a source of multi-messenger astrophysics.

Latest results from Galactic center observations / 226

Non-thermal lobe of the Milky Way powered by the Galactic Center outflows

Author: Heshou Zhang[1]

Co-authors: Gabriele Ponti [1]; Ettore Carretti [2]; Ruo-Yu Liu [3]; Mark Morris [4]; Marijke Haverkorn [5]; Nicola Locatelli [1]; Xueying Zheng [6]; Felix Aharonian [7]; Hai-Ming Zhang [3]; Yi Zhang [6]; Giovanni Stel [1]; Andrew Strong [6]; Micheal Yeung [6]; Andrea Merloni [6]

[1] *INAF - OA Brera*

[2] *INAF - IRA*

[3] *Nanjing University*

[4] *UCLA*

[5] *Radboud University Nijmegen*

[6] *MPE*

[7] *Dublin Institute for Advanced Studies*

Corresponding Author: heshou.zhang@inaf.it

The large-scale structures such as Fermi Bubbles and eROSITA Bubbles provide a unique opportunity to study our Milky Way. However, the nature and origin of these large structures are still under debate. In this talk, I will present the identification of several kpc-scale magnetised structures based on their polarized radio emission and their gamma-ray counterparts, which can be interpreted as the radiation of relativistic electrons in the Galactic magnetic halo. These non-thermal structures extend far above and below the Galactic plane and are spatially coincident with the thermal X-ray emission from the eROSITA Bubbles. The morphological consistency of these structures suggests a common

origin, which can be sustained by Galactic outflows driven by the active star-forming regions located at 3 – 5 kpc from the Galactic Centre. These results reveal how X-ray-emitting and magnetised halos of spiral galaxies can be related to intense star formation activities and suggest that the X-shaped coherent magnetic structures observed in their halos can stem from galaxy outflows.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 227

Cosmology with quasars: what we are after

Author: Elisabeta Lusso[1]

[1] *Università di Firenze, Dipartimento di Fisica e Astronomia/INAF-Arcetri*

Corresponding Author: elisabeta.lusso@unifi.it

I will review what the perspectives of quasars in the context of observational cosmology are and I will present recent measurements of the expansion rate of the Universe based on a Hubble diagram of quasars detected up to the highest redshift ever observed (z~7.5). A deviation from the ΛCDM model emerges at higher redshift, with a statistical significance of ~4σ. If an evolution of the dark energy equation of state is allowed, data suggest a dark energy density increasing with time. I will finally show that the synergy amongst multi-wavelength facilities (current and future) will provide the needed sample statistics to obtain constraints on the observed deviations from the standard cosmological model which will rival and complement those available from the other cosmological probes.

AMS-02 experiment at the International Space Station / 228

Unique Properties of Secondary Cosmic Rays: Results from the Alpha Magnetic Spectrometer

Author: Nikita Belyaev[1]

[1] *MIT*

Corresponding Author: nbelyaev@cern.ch

We present high-statistics measurements of the secondary cosmic rays Lithium, Beryllium, Boron, and Fluorine based on 11.5 years of AMS data. The unexpected rigidity dependence of the secondary cosmic ray fluxes and their ratios to the primary cosmic rays such as Li/C, Be/C, B/C, Li/O, Be/O, B/O, F/Si and P/Si are discussed. The systematic comparison with the latest GALPROP cosmic ray model is also presented.

AMS-02 experiment at the International Space Station / 229

Unique Properties of Primary Cosmic Rays measured by the Alpha Magnetic Spectrometer

Author: Meeran Zuberi[1]

[1] *Massachusetts Institute of Technology*

Corresponding Author: meeran.zuberi@cern.ch

We present high-statistics measurements of primary cosmic rays, including Proton, Helium, Carbon, Oxygen, Neon, Magnesium, Silicon, Sulfur, Iron, and Nickel, based on 11.5 years of AMS data. The data reveals, with high accuracy, that there are only three distinct classes of primary elements. Additionally, we provide a systematic comparison with the latest GALPROP cosmic ray model.

Black hole formation, evolution and the black hole mass gap / 230

Electric and magnetic fields of a charged ring in the vicinity of Kerr black hole

Authors: Alexander Garkun[1]; Alexander Gorbatsievich[2]; Gregory Vereshchagin[3]; Stanislav Komarov[4]

[1] *Institute of Applied Physics, National Academy of Sciences of Belarus, 16 Academic Str, 220072 Minsk, Belarus*

[2] *Belarusian State University; Institute of Applied Physics, National Academy of Sciences of Belarus, 16 Academic Str, 220072 Minsk, Belarus*

[3] *ICRANet, Piazza della Repubblica, 10, 65122 Pescara, Italy; ICRA, Dipartimento di Fisica, Sapienza Universit\'a di Roma, Piazzale Aldo Moro 5, I-00185 Rome, Italy; INAF — IAPS, Via del Fosso del Cavaliere, 100, 00133 Rome, Italy*

[4] *Belarusian State University; Institute of Applied Physics, National Academy of Sciences of Belarus, 16 Academic Str, 220072 Minsk, Belarus; ICRANet-Minsk, National Academy of Sciences of Belarus, 68-2 Nezavisimosti Ave., 220072 Minsk, Belarus*

Corresponding Author: staskomarov@tut.by

Electric and magnetic fields of a charged ring located in the vicinity of Kerr black hole are computed with multipole decomposition. Lines of force of electric and of magnetic fields in the ZAMO frame are presented and analyzed for different positions of the ring and selected values of the Kerr parameter. Special attention is paid to the case when position of the ring approaches the event horizon. Astrophysical applications are discussed.

AMS-02 experiment at the International Space Station / 231

On the origin of the spectral features observed in the cosmic ray spectrum

Authors: Sarah Recchia[1]; Stefano Gabici[2]

[1] *INAF-Brera*

[2] *Université Paris Cité, CNRS, Astroparticule et Cosmologie*

Corresponding Author: sarah.recchia@inaf.it

Recent measurements revealed the presence of several features in the cosmic ray spectrum. In particular, the proton and helium spectra exhibit a spectral hardening at ≈ 300 GV and a spectral steeping at ~ 15 TV, followed by the well known knee-like feature at ~ 3 PV. The spectra of heavier nuclei also harden at ~ 300 GV, while no claim can be currently done about the presence of the ~15 TV softening, due to low statistics. In addition, the B/C ratio seems to become rather flat at ~ 1 TeV/n.
We present a novel scenario for cosmic ray sources and transport in the Galaxy that may explain such features. The proposed model is based mainly on two assumptions. First, in the Galactic disk, where magnetic field lines are mainly oriented along the Galactic plane, particle scattering is assumed to be very inefficient. Therefore, the transport of cosmic rays from the disk to the halo is set by the magnetic field line random walk induced by large scale turbulence. Second, we propose that the spectral steepening at ~ 15 TV is related to the typical maximum rigidity reached in the

acceleration of cosmic rays by the majority of supernova remnants, while we assume that only a fraction of sources, contributing to ~ 10 – 20% of the cosmic ray population, can accelerate particles up to ~ PV.
We show that, within this framework, it is possible to reproduce the proton and helium spectra from GV to multi-PV, and the p/He ratio, the spectra of cosmic ray from lithium to iron, the pbar flux and the pbar/p ratio and the abundance ratios B/C, B/O, C/O, Be/C, Be/O, Be/B. We also discuss the 10Be/9Be ratio in view of the recent AMS-02 preliminary measurements.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 232

Properties of low angular momentum general relativistic MHD flows around black holes

Author: Samik Mitra[1]

Co-author: Santabrata Das [1]

[1] *Indian Institute of Technology Guwahati*

Corresponding Author: m.samik@iitg.ac.in

In this work, we investigate the global structure of shock-induced general relativistic magneto-hydrodynamic (GRMHD) accretion flows around a Kerr black hole, where the disk is threaded by the radial (b^r) and the toroidal (b^ϕ) magnetic fields. In doing so, we consider an advective, axisymmetric, and optically thin accretion flow that is confined in the disk mid-plane. In addition, we adopt the relativistic equation of state and obtain the trans-magnetosonic accretion solutions in the ideal MHD limit. In a magnetized flow, the inflowing matter experiences centrifugal repulsion and an additional barrier due to the magnetic pressure that eventually causes a discontinuous shock transition of the flow variables following the necessary shock conditions. With this, we examine the shock dynamics with the variation of radial magnetic flux (Φ) and the iso-rotation parameter (F) rather than the local magnetic fields (b^r, b^ϕ). However, the shock properties and dynamics of the post-shock corona (PSC) are largely driven by the radial magnetic flux (Φ), whereas the effect of F is less significant. It is worth mentioning that the toroidal magnetic field jumps significantly across the shock front, resulting in a highly magnetized PSC. We further identify the effective region of the parameter space for standing fast-MHD shocks and observe that shock forms for a wide range of flow parameters, namely energy (E), angular momentum (L), and radial magnetic flux (Φ), respectively. Meanwhile, we observe that the shocked GRMHD flow fails to achieve the Magnetically Arrested Disk (MAD) state in the mid-plane, yet it sustains a 'SANE' (Standard And Normal Evolution) flux. Finally, we discuss the astrophysical importance of low-angular momentum accretion flows in the realm of GRMHD.

Dark energy and the accelerating universe / 233

On Thermodynamic Stability of the Variable Generalised Chaplygin gas

Author: Dibyendu Panigrahi[1]

Co-author: Sujit Kumar Chatterjee [2]

[1] *Netaji Nagar Day College*

[2] *New Alipore College, Kolkata 700053*

Corresponding Authors: chat_sujit1@yahoo.com, dibyendupanigrahi@yahoo.co.in

A cosmological model with a new variant of Chaplygin gas obeying an equation of state(EoS), $p = -\frac{B}{\rho}$ where $B = B_0 a^n$[1], is investigated in the context of its thermodynamical behaviour. Here B_0 and n are constants and a is scale factor. We show that the equation of state of this 'Variable Chaplygin gas' (VGCG) can describe the current accelerated expansion of the universe. Following standard thermodynamical criteria we mainly discuss the classical thermodynamical stability of the model and find that the new parameter, n introduced in VGCG plays a crucial role in determining the stability considerations and should always be negative[2]. Moreover the positivity of thermal capacity at constant volume c_V as also the validity of the third law of thermodynamics are ensured in this case. For the particular case $n = 0$ the effective equation of state reduces to CDM model in the late stage of the universe while for $n < 0$ it mimics a phantom-like cosmology which is in broad agreement with the present SNe Ia constraints like VGCG model.The thermal equation of state is discussed and the EoS parameter is found to be an explicit function of temperature only. Further for large volume the thermal equation of state parameter is identical with the caloric equation of state parameter when T ⟶0.
We further observe that although the earlier model of Lu[3] explains many of the current observational findings of different probes it fails the desirable tests of thermodynamical stability. Our model is very general in the sense that many of earlier works in this field may be obtained as a special case of our solution.

References:
1. Guo Zong-Kuan, Zhang Yuan-Zhong: *Phys. Lett.***B645**, 326 (2007)
2. D. Panigrahi and S. Chatterjee: *Gen. Relativity Gravit.* **49**, 35(2017)
3. J. Lu: *Phys. Lett.* **B680**, 404 (2009)

Experimental graviation / 234

Testing Local Lorentz Invariance with the LAGEOS II satellite

Author: David Lucchesi[1]

Co-authors: Massimo Visco [2]; Roberto Peron [2]; Giuseppe Pucacco [3]; Luciano Anselmo [4]; Massimo Bassan [3]; Marco Cinelli [2]; Alessandro Di Marco [2]; Marco Lucente [2]; Carmelo Magnafico [2]; Carmen Pardini [4]; Feliciana Sapio [2]

[1] *INAF/IAPS Tor Vergata and INFN ROMA2*

[2] *IAPS-INAF*

[3] *INFN Roma Tor Vergata*

[4] *ISTI-CNR*

Corresponding Author: david.lucchesi@inaf.it

The Preferred Frame Effects (PFE), in the framework of the Parametrized-Post Newtonian (PPN) formalism, valid in the weak-field and slow-motion (WFSM) limit of General Relativity (GR), are described by the three parameters α1, α2 and α3, all equal to zero in GR and in tensor-scalar theories of gravity. A test of PFE is equivalent to a test of Local Lorentz Invariance (LLI), which represents a pillar of GR. In essence, LLI states that the result of any local (in space and time) non-gravitational test experiment is independent of the speed of the free-falling apparatus in which the experiment is conducted.
We present, in the WFSM limit of GR, a measurement of the parameter α1 based on the analysis of the orbital residuals of the passive geodetic satellite LAGEOS II over a time interval of approximately 28 years. LAGEOS II is very well tracked through the powerful Satellite Laser Ranging (SLR) technique. We considered the possible existence of PFE due to the motion of the Earth-Sun-satellite system with respect to the Cosmic Microwave Background radiation and analyzed the effects on the satellite's longitude.
It is important to stress that LLI is well tested in high-energy physics experiments but is much more difficult to test in the gravitational context, both in the weak-field regime and in the strong- or quasi-strong-field regime. In the weak-field regime, the best results in constraining the parameters α1 and α2 were obtained through the Lunar Laser Ranging (LLR) technique.
The result we obtained is in line with a null value for the α1 parameter and improves the constraint obtained with LLR. Therefore, this improved limit for the PPN parameter constrains further the possible existence vector-tensor theories of gravity.

This research activity is conducted as part of the SaToR-G experiment, financed by the National Institute of Nuclear Physics.

Fast radio bursts / 235

The nebular origin of the persistent radio emission of FRB

Author: Gabriele Bruni[1]

Co-author: Luigi Piro [1]

[1] *INAF - IAPS*

Corresponding Author: gabriele.bruni@inaf.it

Fast Radio Bursts (FRBs) are millisecond-duration, bright extragalactic bursts, whose produc- tion mechanism is still unclear. Recently, a persistent radio source (PRS) of non-thermal origin was discovered to be physically associated to two of the repeating FRB sources. These two sources have unusually large Rotation Measure (RM) values, likely tracing a dense magneto- ionic medium, consistent with a synchrotron radiation originating from a nebula surrounding the FRB source. Recent theoretical arguments predict that, if the observed RM mostly arises from the PRS region, there should be a simple relation between the luminosity of the PRS and the RM. We recently reported the detection of a third, less luminous PRS associated with the nearby FRB20201124A, significantly expanding the predicted relation into the low luminosity − low RM regime (<1000 rad/m2). These findings support the idea that the PRS is generated by a nebula in the FRB environment, and that most FRBs do not show a PRS because of a weaker magneto-ionic medium.

Astrophysics with gravitational waves / 237

Why CGW is yet to be detected from isolated magnetized rotating neutron stars?

Authors: Banibrata Mukhopadhyay[1]; Mayusree Das[1]

[1] *Indian Institute of Science*

Corresponding Author: bm@iisc.ac.in

There are evidences for neutron stars (NSs) with the rotational frequency of several 100th of Hz and moderate magnetic fields, though magnetars are slowly spinning. Hence, if their magnetic and rotating axes are misaligned (nonzero obliquity angle), hence they are pulsars, then they should be potential sources for continuous gravitational waves (CGWs), along with their electromagnetic emissions. However, so far we have not detected a single NS by CGW. In this talk, based on our ApJ 955, 19 (2023), I will address the physical implausibility of detecting CGWs from isolated NSs. I will explore the decays of magnetic field, angular velocity, and obliquity angle with time, due to the Hall, Ohmic, ambipolar diffusion and angular momentum extraction by GW and dipole radiation, which determine the timescales related to the GW emission.
Further, in the Alfvén timescale, a differentially rotating, massive proto-NS rapidly loses angular momentum to settle into a uniformly rotating, less massive compact objects due to magnetic braking and/or viscous drag.
These explorations suggest that the detection of NSs is challenging and sets a timescale for detection. We calculate the signal-to-noise ratio of GW emission, which confirms that any detector may not detect them immediately, but they may detectable by Einstein Telescope, Cosmic Explorer over months of integration time, leading to direct detection of NSs. Basically, the fast

decay of the obliquity angle, that makes isolated NSs practically
undetectable by CGW.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 238

A neural networks method to search for long transient gravitational waves

Author: Francesca Attadio[1]

Co-authors: Cristiano Palomba [2]; Marco Serra [2]

[1] *Roma Sapienza, Virgo group*

[2] *INFN Roma, Virgo group*

Corresponding Author: francesca.attadio@uniroma1.it

I will illustrate a new method to search for long transient gravitational wave signals, like those expected from fast spinning newborn magnetars, in interferometric detector data.
Because of the fast frequency variation of these signals, matched filter techniques used for standard semi-periodic persistent signals are computationally unfeasible.
We explored a different approach by means of machine learning paradigms, with the goal of a fast and inexpensive procedure
We develop a classifier that is able to discriminate between the presence or absence of a signal in time-frequency maps.
To help with the classification task, we also developed a denoiser, i.e., a model able to reduce the noise of the time-frequency map while preserving at best the track of the signal.
We have studied the performance of both networks with simulated colored noise, according to the design noise curve of LIGO interferometers.
Simulated long transient signals from newborn magnetars, have been generated and added to the detector noise.
I will show that the combination of the two neural network models is crucial to increasing the chance of detection.
In addition, I will demonstrate that our method is robust with respect to changes in the exponent of the power law describing the time evolution of the signal frequency.
To conclude, our results highlight the computationally low cost of this method to generate triggers for long transient signals and lay the foundations for further improvements to perform systematic searches.

Dark matter halos: its nature, modeling & tracers / 239

The Baryonic Mass Estimates of the Milky Way Halo in the form of High Velocity Clouds

Author: Noraiz Tahir[1]

Co-authors: Francesco De Paolis [2]; Martín López-Corredoira [3]

[1] *Department of Physics, School of Natural Sciences (SNS), National University of Science and Technology (NUST), H12, Islamabad, Pakistan*

[2] *Department of Mathematics and Physics "Ennio De Giorgi", University of Salento, Via per Arnesano, 73100, Lecce, Italy; INFN, Sezione di Lecce, Via per Arnesano, 73100, Lecce, Italy; INAF, Sezione di Lecce, Via per Arnesano, 73100, Lecce, Italy*

[3] *Departamento de Astrofisica, Universidad de La Laguna, E-38205, Tenerife, Spain and Instituto de Astrofisica, de Canarias, La Laguna, E-38205, Tenerife, Spain*

Corresponding Author: noraiz.tahir@sns.nust.edu.pk

The halo of our Galaxy is populated with a significant number of high-velocity clouds (HVCs) moving with a speed up to 500 km/s. It is suggested that these HVCs *might* contain a non-negligible fraction of the missing baryons. We aim to estimate the baryonic mass of the Milky Way halo in the form of HVCs to constrain a fraction of missing baryons in the form of these clouds. Such findings would substantially help in studying our Galaxy's halo dynamics. Here we summarise our estimates on the baryonic mass of the Milky Way halo in HVCs. We estimate that the total mass of the Milky Way halo resulted to be $\sim (7 \pm 2) \times 10^9 M_\odot$ in the form of HVCs and compact high-velocity clouds (CHVCs).

Micro-Hertz gravitational waves (0.1-100 μHz): sources and detection methods / 240

Probing ultralight fields with inspiral gravitational waves

Author: Jun Zhang[1]

[1] *International Center for Theoretical Physics Asia-Pacific*

Corresponding Author: zhangjun@ucas.ac.cn

Gravitational waves provide a unique probe to physics in strong gravity regime and dark sector of our universe. In this talk, we will discuss the effects of ultralight fields on binary inspirals, assuming the fields are significantly excited by neutron stars or black holes in the binaries. We will report on a search for axion-like particles by analyzing the gravitational waves from the binary neutron star inspiral GW170817. We will also investigate the prospect of probing ultralight fields with multi-band gravitational wave observations.

Micro-Hertz gravitational waves (0.1-100 μHz): sources and detection methods / 242

Parameter Inference on supermassive black holes for the sub-mHz gravitational wave mission ASTROD-GW

Authors: Gang Wang[1]; Renjie Wang[2]

[1] *Shanghai Astronomical Observatory, CAS*

[2] *HIAS, UCAS*

Corresponding Author: wangrenjie@ucas.ac.cn

The future space-borne gravitational wave(GW) missions will be able to detect abundant gravitational wave signals in the micro-Hz band. The gravitational wave mission, ASTROD-GW can bridge the gap between the millihertz and nanohertz bands and has a great potential to detect the supermassive black hole binary coalescence events. A large number of galactic binaries will continuously emit GW signals below ~10 mHz. The GW signals from enormous unresolved sources become a confusion noise. The ASTROD-GW mission will face serious foreground, and the spectrum of foreground noise will even exceed the instrumental noise in some frequency bands. We investigate the detectability of sub-mHz GW missions to detect supermassive black hole binaries and evaluate the effect of foreground noise on the detection of supermassive black hole binaries. ASTROD-GW can detect extremely distant events of supermassive black hole binaries with unprecedented precision. The parameter accuracy is reduced by about an order of magnitude due to foreground noise. With the fitted model of foreground spectra, we examine the parameters determination of the foreground from the simulated observation data. In the optimistic assumption, if the foreground could be well modeled and characterized, the foreground noise may be subtracted from the data and the PSD of residuals would be around two orders lower than the original data. If this could be achievable, the estimation of supermassive black hole binaries will be greatly improved.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 243

An Optical Gamma-Ray Burst Catalogue with Measured Redshift PART I: Data Release of 535 Gamma-Ray Bursts and Colour Evolution

Author: Maria Dainotti[1]

Co-authors: Biagio De Simone [2]; Ridha Fathima Mohideen Malik [3]; Vibhavasu Pasumarti [4]; Navonil Saha [5]; Delina Levine [6]; Bruce Gendre [7]; Daisaburo Kido [8]; Alan Watson [9]; Rosa Leticia Becerra Godinez [10]; Sergey Belkin [11]; S. Desai [4]; A. C. C. do E. S. Pedreira [9]; U. Das [12]; Liang Li [13]; Sam Oates [14]; S. B. Cenko [15]; Alexei Pozanenko [16]; A. Volnova [17]; Y. D. Hu [18]; A. J. Castro-Tirado [19]; N. B. Orange [20]; Takashi Moriya [1]; Nissim Fraija [21]; Y. Niino [8]; E. Rinaldi [22]; Nathaniel Butler [23]; J. d. J. G. González [9]; A. S. Kutyrev [24]; W. H. Lee [9]; X. Prochaska [25]; E. Ramirez-Ruiz [25]; M. Richer [9]; M. H. Siegel [26]; K. Misra [27]; Andrea Rossi [28]; C. Lopresti [29]; U. Quadri [30]; L. Strabla [30]; N. Ruocco [31]; S. Leonini [32]; M. Conti [32]; P. Rosi [32]; L. M. T. Ramirez [32]; S. Zola [33]; I. Jindal [34]; L. Chan [35]; M. Fuentes [36]; G. Lambiase [37]; K. K. Kalinowski [38]; W. Jamal [39]; R. Kumar [40]

[1] *National Astronomical Observatory of Japan*

[2] *Università degli Studi di Salerno*

[3] *Universite Cote D'Azur, University of Rome "Tor Vergata"*

[4] *Indian Institute of Technology Hyderabad*

[5] *Zentrum für Astronomie der Universität Heidelberg, Indian Institute of Science Education and Research Kolkata*

[6] *California Institute of Technology*

[7] *University of Western Australia*

[8] *University of Tokyo*

[9] *Universidad Nacional Autónoma de México*

[10] *Università degli Studi di Roma, Tor Vergata*

[11] *Monash University*

[12] *National Institute of Science Education and Research Bhubaneswar*

[13] *ICRANet, Piazza della Repubblica 10, I-65122 Pescara, Italy*

[14] *University of Birmingham*

[15] *NASA Goddard Space Flight Center, University of Maryland*

[16] *Space Research Insitute (IKI)*

[17] *Space Research Institute of the Russian Academy of Sciences (IKI)*

[18] *Instituto de Astrofísica de Andalucía (IAA-CSIC), INAF - Osservatorio Astronomico di Brera*

[19] *Instituto de Astrofísica de Andalucía (IAA-CSIC), Universidad de Málaga*

[20] *OrangeWave Innovative Science, Etelman Observatory Research Center*

[21] *Instituto de Astronomia, UNAM*

[22] *Interdisciplinary Theoretical and Mathematical Sciences (iTHEMS) Program - RIKEN*

[23] *Arizona State University*

[24] *NASA Goddard Space Flight Center, University of Maryland*

[25] *UCO/Lick Observatory, University of California*

[26] *Pennsylvania State University*

[27] *ARIES*

[28] *Istituto Nazionale di Astrofisica (INAF)*

[29] *GAD-Gruppo Astronomia Digitale*

[30] *Osservatorio Bassano Bresciano*

[31] *Osservatorio Astronomico "Nastro Verde"*

[32] *Montarrenti Observatory*

[33] *Astronomical Observatory, Jagiellonian University*

[34] *Indian Institute of Technology Kharagpur*

[35] *Assets High School, Honolulu*

[36] *University of Michigan*

[37] *Universitá di Salerno, INFN-Napoli*

[38] *Aarhus University, Jagiellonian University*

[39] *Lebanese International University*

[40] *Indian Institute of Technology Kanpur*

Corresponding Author: ridhafathima273@gmail.com

We present the largest optical photometry compilation of Gamma-Ray Bursts (GRBs) with measured redshifts (z). Our dataset includes 64813 observations of 535 events (including upper limits) from 28 February 1997 to 18 August 2023. We introduce *grbLC*, a user-friendly web tool for visualising photometry, coordinates, redshift, host-galaxy extinction, and spectral indices for each event in our database. Additionally, we have integrated a Gamma-ray Coordinate Network (GCN) scraper within *grbLC* to automate the collection of magnitudes from GCN circulars. The web tool also includes a Python package for uniformly investigating colour evolution in GRBs. We compute the optical spectral indices of 138 GRBs, and craft a novel procedure to infer the presence of colour evolution in GRBs. By providing a standardised format and a centralised repository for optical photometry, our web-based archive represents a significant step towards unifying various community efforts to collect GRB photometric data. This comprehensive catalogue facilitates population studies by offering light curves (LCs) with improved coverage, as it aggregates data from multiple ground-based observatories and the *Swift* satellite. Consequently, these LCs can be employed to train future LC reconstructions, for an extended inference of the redshift. The data gathering also allows us to fill orbital gaps in the *Swift* observations, particularly at critical points in the LCs, such as the end of the plateau emission or the identification of jet breaks.

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 244

Torsion electrodynamics and the axial vector spin–torsion coupling effects in the framework of the Poincaré gauge theory of gravity

Author: Mariia Trukhanova[1]

Co-authors: Pavel Andreev [2]; Yuri Obukhov [3]

[1] *Lomonosov Moscow State University, Faculty of Physics, Department of theoretical physics*

[2] *Lomonosov Moscow State University, Faculty of Physics, Department of general physics*

[3] *Theoretical Physics Laboratory, Nuclear Safety Institute, Russian Academy of Sciences*

Corresponding Author: podarovskayamariya@gmail.com

Based on the Poincare gauge theory of gravity with the most general Lagrangian quadratic in curvature and torsion, we investigate the axial vector torsion-spin coupling. The dynamical equations for the so-called "electric" $\mathcal{E}_a$ and "magnetic" $\mathcal{B}^a$ components of the torsion variable are obtained in the general form, where the helicity density and spin density of the electromagnetic with scalar and vector potentials $\phi, \vec{A}$ are the sources of these fields
\begin{align}
\vec{\nabla}\cdot\vec{\mathcal E} - \mu^2\varphi - \lambda\partial_t(\partial\alpha) &=
-\,{\frac{\chi}{\mu_0}}\,\vec{A}\cdot\vec{B},\\
\vec{\nabla}\times\vec{\mathcal B} -{\frac 1{c^2}}\partial_t\vec{\mathcal E} + \mu^2\vec{\alpha}
+ \lambda\vec{\nabla}(\partial\alpha) &= -\,\chi\varepsilon_0\left(\phi\vec{B}
+ \vec{E}\times\vec{A}\right).
\end{align}The modified Maxwell's equations for the electromagnetic field are derived, where the sources are dependent on the torsion field potentials $\varphi, \vec{\alpha}$
\begin{align}
\vec{\nabla}\cdot\vec{E} &= 2\chi c\,\vec{\alpha}\cdot\vec{B}
- \chi c\,\vec{A}\cdot\vec{\mathcal B},\\
\vec{\nabla}\times\vec{B} - {\frac 1{c^2}}\partial_t\vec{E} &=

{\frac{2\chi}{c}}\left(\varphi\vec{B} + \vec{E}\times\vec{\alpha}\right) -
{\frac{\chi}{c}}\left(\phi\vec{\mathcal B} + \vec{\mathcal E}\times\vec{A}\right).
\end{align}It has been shown that the source of the "electric" component of the torsion variable is the helicity density of the electromagnetic field $\sim \vec{A}\cdot\vec{B}$. Such a configuration can be implemented in electromagnetic systems with a non-trivial topology. The source of the vortex "magnetic" component of the torsion variable generated by the spin density of the electromagnetic field $\sim \phi\vec{B}+\vec{E}\times\vec{A}$. The rotation of the polarization plane of the electromagnetic wave, in the uniform torsion field $(\varphi,\vec{\alpha}) = const$, is predicted. When a wave passes through the axial vector torsion field region, an orthogonal component of the electric field strength occurs. The polarization plane of the electomagnetic wave rotates, and the angle of rotation is proportional to the coupling constant and value of the potential φ of the axial vector torsion field $|\gamma| = \frac{\chi\varphi h}{c}$. The physical meaning of the polarization plane rotation may specify the process of photons generation during their interaction with axial vector bosons.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 245

Numerical models of GRB central engines and challenges with observations

Authors: Agnieszka Janiuk[1]; Joseph Saji[2]

[1] *Center for Theoretical Physics, PAS*

[2] *Center for Theoretical Physics, Polish Academy of Sciences*

Corresponding Author: agnes@cft.edu.pl

I will review the recent developments of GR MHD numerical simulations of GRB central engines.
I will also present some multi-messenger observational challenges still unsolved by these models.

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 246

Galactic rotation curves in the light of extended theories of electromagnetism

Authors: Abedennour Dib[1]; Alessandro D.A.M. Spallicci[2]; Nazim Djeghloul[3]

[1] *LPC2E*

[2] *Université d'Orléans - Centre National de la Recherche Scientifique*

[3] *Oran 1 University*

Corresponding Author: abedennour.dib@cnrs-orleans.fr

Electromagnetism is one of the pillars of modern physics and until very recently was nature's sole messenger. The avenue of multi-messenger astronomy in the recent year is opening a whole new world of observations and promises great advances for science, but nonetheless still relies on electromagnetic waves as a core component.
Extended theories of electromagnetism impact thus directly our observations and interpretations of astrophysical phenomena as they modify the core ingredient in our measurements. Extended models where non-linear interactions (notably photon-background EM field) occur, exhibit a violation of the conservation of their energy momentum tensor, regardless of the nature of the model (massive , SME, Non-linear etc). Said violations hints towards the loss of translational symmetry and by extension that frequencies are not necessarily conserved. This lead us to describe what we will call frequency shifts that are usually due to the passage of a radiation in an external non-

dynamical electromagnetic field. These effects while very small on a local scale, could lead to non negligible effects on larger ones.
In this presentation, we will consider these effects on a galactic scale and attempt to shed a new light on the issue of excess velocities in galaxies, and offer an alternative/complementary description to the dark matter/modified gravity paradigms. We will notably highlight a correlation between additional velocities and magnetic fields within galaxies and then derive a path from modified Maxwellian models to a contribution of magnetic origin to the observed velocities for galaxies. We will conclude by discussing two possible mechanisms that would explain such a contribution.

Loop quantum gravity / 247

Quantum-reduced loop gravity: New perspectives on the kinematics and dynamics

Author: Ilkka Mäkinen[1]

[1] *National Centre for Nuclear Research, Poland*

Corresponding Author: ilkka.makinen@ncbj.gov.pl

We present a systematic approach to the kinematics of quantum-reduced loop gravity, a model originally proposed by Alesci and Cianfrani as an attempt to probe the physical implications of loop quantum gravity. In order to implement the quantum gauge-fixing procedure underlying quantum-reduced loop gravity, we introduce a master constraint operator on the kinematical Hilbert space of loop quantum gravity, representing a set of gauge conditions which classically constrain the densitized triad to be diagonal. On one hand, the standard Hilbert space of quantum-reduced loop gravity can be recovered as a space of solutions of the master constraint operator, while on the other hand the master constraint approach provides a useful starting point for considering various possible generalizations of the standard construction. We also examine the dynamics of certain simple quantum states of geometry in the framework of quantum-reduced loop gravity. In particular, we show that the Hamiltonian which governs the dynamics of a state consisting of a single six-valent node bears a close formal resemblance to the Hamiltonian constraint of Bianchi I models in loop quantum cosmology.

Experimental graviation / 249

The status of the GINGER project

Author: Matteo Luca Ruggiero[1]

[1] *Università di Torino, INFN - LNL*

Corresponding Author: matteoluca.ruggiero@unito.it

Large frame Ring Laser Gyroscopes which operate based on the Sagnac effect, are highly sensitive instruments used to measure angular velocity relative to fixed stars. The GINGER (Gyroscopes IN GEneral Relativity) project plans to build an array of three large Ring Laser Gyroscopes, firmly attached to the Earth. GINGER aims to detect General Relativity effects and potential Lorentz Violation in the gravitational field, once it achieves a sensitivity of 10^{-9} or better of Earth's rotation rate. Since the array is anchored to the Earth's crust, it will also yield valuable data for geophysical studies. The project is currently being developed as part of the multi-component observatory called Underground Geophysics at Gran Sasso (UGSS). Sensitivity is crucial for determining the instrument's significance in fundamental science. Recent advancements in sensitivity measurements, achieved with a prototype RLG named GINGERINO, suggest that GINGER should reach a sensitivity level of 1 part in 10^{11} of Earth's rotation.

Dark matter detection / 250

The Galileo for Science Project (G4S_2.0): Domain Wall Dark Matter and Atomic Clocks

Author: Alessandro Di Marco[1]

Co-authors: Feliciana Sapio [1]; Massimo Visco [1]; David Lucchesi [1]; Marco Cinelli [1]; Emiliano Fiorenza [1]; Carlo Lefevre [1]; Pasqualino Loffredo [1]; Marco Lucente [1]; Carmelo Magnafico [1]; Roberto Peron [1]; Francesco Santoli [1]; Francesco Vespe [2]

[1] *IAPS-INAF*

[2] *ASI-CGS*

Corresponding Author: alessandro.dimarco1@inaf.it

G4S_2.0 (Galileo for Science) is an ongoing project funded by the Italian Space Agency (ASI) and carried out by the Center for Space Geodesy (ASI-CGS) in Matera, the Istituto di Astrofisica e Planetologia Spaziali (IAPS/INAF) in Rome, and the Politecnico di Torino (POLITO). The project's goal is to address several intriguing challenges, including Fundamental Physics measurements using the European Galileo Global Navigation Satellite System (GNSS).
One aspect of the project focuses on updating the current constraints on ultralight scalar field dark matter (ULDM) in the form of topological galactic Domain Walls (DWs).
The ultralight scalar within the DW may interact with certain degrees of freedom of the Standard Model (SM) of particle physics. This interaction is typically described an effective low-energy lagrangian density that takes into account the couplings between ultralight dark matter and the SM.
In a simplified scenario, the ultralight dark matter of the DW could interact only with a single degree of freedom of the SM, such as the electron Dirac field. In such a scenario, if a DW were to interact with the onboard atomic clock of a Galileo satellite, it could cause a temporary shift in the fundamental electron mass, resulting in a glitch in the nominal operating frequency of the target atomic clock. This glitch would theoretically propagate throughout the entire Galileo clock network, providing a detectable pattern.

We will give an overview of the assumptions regarding Dark matter and DW, as well as the activities conducted at IAPS-INAF in Rome, which are essential for constraining the presence of DW dark matter and its potential interaction with the SM sector. Specifically, we will discuss the updated results regarding the statistical properties of the global Galileo Rubidium (Rb) - Passive Hydrogen Maser (PHM) clock network and its ability to detect a possible Domain Wall signal.

Present and future of cosmic microwave background observations / 251

ComPACT: Combined ACT+Planck galaxy cluster catalogue

Author: Svetlana Voskresenskaia[1]

Co-authors: Alex Meshcheryakov [2]; Natalya Lyskova [2]

[1] *Higher School of Economics (HSE)*

[2] *Space Research Institute Russian Academy of Science*

Corresponding Author: savoskresenskaya@edu.hse.ru

Galaxy clusters are the most massive gravitationally bound systems consisting of dark matter, hot baryonic gas and stars. They play an important role in observational cosmology and galaxy evolution studies. We develop a deep learning model for segmentation of Sunyaev-Zeldovich (SZ) signal on ACT+Planck intensity maps and construct a pipeline for microwave cluster detection in the ACT footprint. The proposed model allows us to identify previously unknown galaxy clusters, i.e. it is capable of detecting SZ sources below the detection threshold adopted in the published galaxy clusters catalogues (such as ACT DR5 and PSZ2). In this paper, we use the derived SZ signal map to

considerably improve a cluster purity in the extended catalogue of Sunyaev-Zeldovich objects from Planck data (SZcat) in the ACT footprint. From SZcat, we create a new microwave galaxy cluster catalogue (ComPACT), which includes 2,962 SZ objects with cluster purity conservatively estimated as ⍰ 74-84 per cent. We categorise objects in the catalogue into 3 categories, based on their cluster reliability. Within the ComPACT catalogue, there are ⍰ 977 new clusters with respect to the ACT DR5 and PSZ2 catalogues.
nasa.ads: https://ui.adsabs.harvard.edu/abs/2024MNRAS.tmp.1272V/abstract

New frontier of multi messenger astrophysics: follow up of electromagnetic transient counterpart of gravitational wave sources / 252

GW and multi-messenger astronomy: lessons learned from the first three LVK observing runs

Author: Barbara Patricelli[None]

Corresponding Author: barbara.patricelli@pi.infn.it

The era of Gravitational Wave (GW) Astronomy started on 2015, with the first observation of GWs from the merger of a binary black hole (BBH) system by Advanced LIGO. Two years later, the detection of GWs from a binary neutron star (NS-NS) merger by the Advanced LIGO and Advanced Virgo network and of the associated electromagnetic (EM) signals marked the birth of multi-messenger astronomy with GWs, opening a new chapter in the study of the universe.
Besides these two ground-breaking discoveries, the LIGO, Virgo and KAGRA (LVK) collaboration reported the detection of dozens of binary coalescences during the first three observing runs, including mergers between BHs, NSs and mixed NS-BHs. These GW observations allowed us to infer some properties of the NS and BH populations, such as the mass distributions and the merger rates, and to better understand the astrophysics of binary mergers and the origin of these systems.
This talk will give an overview of the GW and multi-messenger observations during the first three LVK observing runs and of their astrophysical implications.

New frontier of multi messenger astrophysics: follow up of electromagnetic transient counterpart of gravitational wave sources / 254

Lesson learnt in 04 and future perspective

Author: Giacomo Principe[1]

Co-author: LIGO-Virgo-KAGRA collaboration

[1] *University of Trieste*

Corresponding Author: giacomo.principe@ts.infn.it

The fourth observing run (O4) of LIGO-Virgo-KAGRA is now ongoing, relying on the most sensitive network of gravitational-wave interferometers to date. In this talk, I will highlight in a multi-messenger context some of the most recent astrophysical findings and their implications for massive-star evolution, supernova theory, compact binary populations, and the search of electromagnetic and cosmic-ray counterparts of gravitational-wave sources. In addition, I will discuss the future perspectives of the field in view of the forthcoming gravitational wave observations.

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 255

Interaction between electromagnetism and gravitation from unified geometric framework

Author: Nazim Djeghloul[1]

[1] *Oran 1 University*

Corresponding Author: ndjeghloul@gmail.com

An alternative formulation of classical electromagnetism relying on torsion in metrically flat spacetime in four dimensions is presented. Unification with gravitation is then obtained as a direct consequence of the extension to the more general case of metrically curved spacetime. A propagating equation for the electromagnetic potential is derived and discussed. In the same context, it is also shown that a second kind of photon can be predicted (which could be the so-called "Dark Photon") and how it can be distinguished from the known photon in presence of gravitation.

Modeling of binary neutron star and black hole-neutron star mergers, and of their electromagnetic counterparts / 256

Atomic inputs and opacity numerical estimation concerning early-stage kilonova ejecta

Author: Matteo Bezmalinovich[1]

Co-author: Sergio Cristallo [1]

[1] *INAF - Osservatorio Astronomico d'Abruzzo*

Corresponding Author: matteo.bezmalinovich@inaf.it

In the Universe, the nucleosynthesis beyond iron group elements occurs thanks to neutron capture processes. In the context of the multi-messenger astronomy, the observation of the electromagnetic (EM) counterpart of the GW170817 event, known as kilonova (KN), provided evidence that the coalescence of binary neutron stars systems is a favourable stellar site hosting the rapid neutron capture process (r-process). The luminosity of a KN, a quasi-thermal EM transient powered by the radioactive decay of unstable heavy neutron rich isotopes, mainly depends on the thermal energy produced during the element nucleosynthesis and on the plasma ejecta opacity. However, to better understand KN spectra, a detailed knowledge of atomic inputs is required. Modelling the ejecta opacity points to the necessity of overcoming uncertainties in opacity calculations arising from often oversimplified atomic structure models. In this framework, by means of the relativistic atomic code package grasp2018, we present numerical results of selected light r-process nuclei at different ionisation states of interest for the early-stage KN ejecta, which have been performed to estimate plasma opacity values. Finally, we highlight the importance of having more and accurate atomic inputs to better address the opacity estimation.

Theories of gravity: alternatives to the cosmological and particle standard models / 257

Asymptotically Schwarzschild solutions in $f(R)$ extension of General Relativity

Authors: Federico Scali[1]; Oliver Fabio Piattella[1]

[1] *University of Insubria - Department of Science and high Technology and INFN (National Institute for Nuclear Physics) section Milan*

Corresponding Author: fscali@studenti.uninsubria.it

We consider the gravitational field outside a static, spherically symmetric source in the context of a general $f(R)$ extension of General Relativity. We study the modified Einstein equations (EE), which involve the two free potentials of the metric together with $f(R)$ and its derivative $\phi = \frac{\partial f}{\partial R}$, without making any preliminary assumption on f as a function of the scalar curvature. Instead, we do require complete agreement with the usual Schwarzschild solution far from the source and minimal regularity of both the potentials and ϕ as functions of the coordinates.
Under these conditions we are able to perturbatively solve the modified EE, explicitly compute the leading correction to the Schwarzschild line element and retrieve a posteriori the corresponding $f(R)$. This is non analytical in $R = 0$ and depends on two parameters: a universal coupling c_1 and an integer number $n \geq 2$, which determines the order of the correction.

In the second part of the work, we firstly compute the parametrized post Newtonian parameters for the modified Schwarzschild line element: while γ agrees by construction with the strict Cassini bound for every n, the constraint on β from the precession of Mercury places a severe upper bound on c_1 for $n = 2$. We then compute the leading correction to the gravitational redshift and use observations of the sunlight gravitational redshift to set numerical upper bounds on c_1 at varying n. The corrections to the bending of light from a distant star by the Sun, to the precession of Mercury and to the Shapiro delay are also computed.

The result is a class of $f(R)$ theories built from a purely bottom-up approach and compatible with the local tests. This result can also help constraining exact $f(R)$ models working in Cosmology, since it provides the correct local limit.

Theories of gravity: alternatives to the cosmological and particle standard models / 258

The effects of intrinsic spin of matter in relativistic cosmology

Author: Paulo Luz[1]

[1] *CENTRA, Instituto Superior Técnico*

Corresponding Author: paulo.luz@tecnico.ulisboa.pt

We discuss general solutions of the Einstein-Cartan theory sourced by a cosmological perfect fluid composed of particles with intrinsic spin. In the considered model, the metric tensor is described by a general FLRW solution, however, the Weyl tensor might not vanish. The coupling between the intrinsic spin and the Weyl tensor excludes spatially closed solutions, and the universe must either be flat or open. In the open case, it is shown that the magnetic part of the Weyl tensor verifies a wave equation, such that, in a dynamic universe, the intrinsic spin of matter leads to the generation and emission of gravitational waves. The properties of these waves are discussed, with an emphasis on their decay rate at late time. Lastly, we discuss that, in the considered cosmological model, the intrinsic spin of matter contributes to a positive accelerated expansion of the universe.

First stars and their remnants as dark matter probes / 259

The Formation of Supermassive Black Holes from Pop III.1 Protostars powered by Dark Matter Annihilation

Author: Jonathan Tan[1]

[1] *Chalmers Univ. & Univ. of Virginia*

Corresponding Author: jctan.astro@gmail.com

The origin of supermassive black holes (SMBHs) is a key open question for contemporary astrophysics and cosmology. Here we discuss the predictions of a model of SMBH formation from Pop III.1 protostars, i.e., metal-free stars forming in locally isolated dark matter minihalos, where dark matter annihilation has a chance to alter the structure of the star allowing growth to supermassive scales (Banik, Tan & Monaco 2019; Singh, Monaco & Tan 2023). The model predicts that all SMBHs have already formed by z ~ 25 with a spatial distribution that is initially relatively unclustered. We also present predictions for SMBH occupation fractions, host galaxy properties, frequency of binary AGN and the gravitational wave background from this SMBH population. These predictions are compared to latest results from HST, JWST and pulsar timing array observations.

AMS-02 experiment at the International Space Station / 260

Spectra of Cosmic Rays escaping from star clusters

Authors: Giovanni Morlino[1]; Pasquale Blasi[2]

[1] *Italian National Institute for Astrophysics (INAF)*

[2] *GSSI*

Corresponding Author: giovanni.morlino@inaf.it

Cosmic ray acceleration inside compact star clusters has recently received much attention, mainly because of the detection of gamma ray emission from some of such astrophysical sources. Here we focus on the acceleration of nuclei at the wind termination shock and we investigate the role played by proton energy losses and spallation reactions of nuclei, especially downstream of the shock. We show that for a rather generic choice of the mean gas density in the cavity excavated by the cluster wind, the spectrum of He nuclei is systematically harder than the spectrum of hydrogen, in a manner that appears to be qualitatively consistent with the observed and yet unexplained phenomenon of discrepant hardening. We also find that the spallation reactions of heavier nuclei are likely to be so severe that their spectra become very hard and with a low normalization, meaning that it is unlikely that heavy nuclei escaping star clusters can provide a sizeable contribution to the spectrum of cosmic rays at the Earth.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 261

Understanding the Nature of the Optical Emission in Gamma-Ray Bursts

Author: Rosa Leticia Becerra Godinez[1]

Co-authors: Alain Klotz [2]; Alan Watson [3]; Dafne Guetta [4]; Fabio De Colle [5]; Jean-Luc Atteia [6]

[1] *Università degli Studi di Roma, Tor Vergata*

[2] *IRAP*

[3] *Universidad Nacional Autónoma de México*

[4] *Ariel University, Ariel*

[5] *UNAM*

[6] *IRAP - CNRS/UPS/CNES*

Corresponding Author: rosa.becerra@roma2.infn.it

We collected the optical light curve data of 227 gamma-ray bursts (GRBs) observed with the TAROT, COATLI, and RATIR telescopes. These consist of 133 detections and 94 upper limits. We constructed

average light curves in the observer and rest frames in both X-rays (from {\itshape Swift}/XRT) and in the optical. Our analysis focused on investigating the observational and intrinsic properties of GRBs. Specifically, we examined observational properties, such as the optical brightness function of the GRBs at $T = 1000$ seconds after the trigger, as well as the temporal slope of the afterglow.
We also estimated the redshift distribution for the GRBs within our sample. Of the 227 GRBs analysed, we found that 116 had a measured redshift. Based on these data, we calculated a local rate of $\rho_0 = 0.2$ Gpc^{-3} yr^{-1} for these events with $z < 1$.
To explore the intrinsic properties of GRBs, we examined the average X-ray and optical light curves in the rest frame.
We use the {\scshape afterglowpy} library to generate synthetic curves to constrain the parameters typical of the bright GRB jet, such as energy ($\langle E_0 \rangle \sim 10^{53.6}$~erg), opening angle ($\langle \theta_{\rm core} \rangle \sim 0.2$~rad), and density ($\langle n_0 \rangle \sim 10^{-2.1}$ cm^{-3}). Furthermore, we analyse microphysical parameters, including the fraction of thermal energy in accelerated electrons ($\langle \epsilon_e \rangle \sim 10^{-1.37}$) and in the magnetic field ($\langle \epsilon_B \rangle \sim 10^{-2.26}$), and the power-law index of the population of non-thermal electrons ($\langle p \rangle \sim 2.2$).

High energy astrophysics / 262

Synchrotron radiation as the origin of spectral cutoff in ultraluminous X-ray sources

Author: Tanuman Ghosh[1]

[1] *Inter-University Centre for Astronomy and Astrophysics*

Corresponding Author: tanuman.ghosh@iucaa.in

Ultraluminous X-ray sources are the X-ray binaries with X-ray luminosity exceeding the Eddington limit of a 10 solar mass black hole. Recent consensus is that these sources are powered mainly by super-Eddington accretion onto stellar-mass compact objects. An increasing number of discovered pulsating ULXs further advocate a possible scenario that neutron stars dominate a significant fraction of the ULX population. Modern X-ray observatories have confirmed that most ULXs, if not all, show a characteristic spectral cutoff around 10 keV. Such a finding warrants a generalized physical origin explaining the cutoff. We discuss a novel theoretical model that can explain this X-ray spectral cutoff with the underlying physics of synchrotron radiation. The velocity distribution of the plasma particles, the emission angle of the radiation, and the magnetic field strength are the primary factors determining the cutoff energy. Depending on the velocity distribution of the particles, a semi-relativistic plasma with a high-latitude angle or a highly relativistic plasma with emission close to the orbital plane of the electron can adequately explain this cutoff. We discuss how the cutoff appears analytically from the properties of Bessel functions using stationary-phase approximations. We also discuss the congruence between the theoretical model and the data for some ULXs and investigate the physical parameters in these sources. As a corollary, we find that if this new model explains the origin of such characteristic spectral cutoff in these sources, most ULXs are neutron stars.

New frontier of multi messenger astrophysics: follow up of electromagnetic transient counterpart of gravitational wave sources / 263

Neutron star binaries in star clusters: a radio-optical synergy to test fundamental physics and general relativity

Author: Mario Cadelano[1]

[1] *University of Bologna*

Corresponding Author: mario.cadelano@unibo.it

Millisecond pulsars (MSPs) are fast-spinning neutron stars formed in binary systems through mass-accretion from a companion star. A large fraction are found in star clusters, such as globular clusters, whose high stellar densities create a collisional environment in which 2 and 3-body gravitational interactions are promoted. These interactions are responsible not only for the formation of a large population of neutron star binaries and MSPs, but also for the production of a wealth of exotic systems not predicted by standard evolutionary models. Among these, the long-sought MSP orbiting a black hole is considered one of the holy grails of pulsar astronomy. Indeed, its discovery would open the door to unprecedented tests of fundamental physics and general relativity, and would allow the investigation of the precursors of several gravitational wave events.

Here I will present the discovery of the first MSP orbiting a companion in the mass-gap between neutron stars and black-holes. By exploiting the synergy between high-precision radio timing observations with MeerKAT and high-resolution optical observations with the Hubble Space Telescope, we discovered in the inner regions of the cluster NGC1851 a binary system consisting of a neutron star orbiting a mass-gap object: either a low-mass black-hole or a high-mass neutron star. I will discuss the formation mechanisms of such an exotic binary, the implications for gravitational wave astrophysics, and follow-up tests of general relativity.

Finally, I will show how we are capitalising on the synergy between MeerKAT and dedicated James Webb and Hubble Space Telescope observations to characterise compact binaries that are likely to host a supermassive neutron star. The characterisation of these systems and the determination of the neutron star masses can be used to constrain the equation-of-state of ultra-dense matter, which is one of the still open and most debated questions in fundamental physics.

The Euclid mission: current status, results from early observations, and future prospects / 264

Constraining Cosmological Parameters Combining 2- and 3-Point Correlation Functions: First Step Towards the Future Euclid Dataset

Author: Massimo Guidi[1]

[1] *University of Bologna*

Corresponding Author: massimo.guidi@uniroma3.it

For galaxy clustering, constraining cosmological parameters using the three-point correlation function, despite being pivotal, has historically been limited by the computational cost of modelling. Here, we introduce a new emulator developed within the framework of a Euclid Preparation Key-Project activity, which substantially accelerates MCMC evaluation. For the first time in a simulation study, we present then constraints on cosmological parameters by combining two- and three-point statistics. As a result, we will also present an overview of the future perspectives and ongoing activities on cosmological parameters inference analyses from lower- and higher-order correlation functions in configuration space focusing on the BAO scale regime as a potential powerful tool to disentangle and investigate cosmological models.

Machine learning in astronomy: AGN, transient events, cosmology and others / 265

Accelerating Likelihood Exploration to Constrain Cosmological Parameters Using 2- and 3-Point Correlation Functions Emulators

Author: Massimo Guidi[1]

[1] *University of Bologna*

Corresponding Author: massimo.guidi@uniroma3.it

Constraining cosmological parameters for galaxy clustering analyses using the three-point correlation function, despite being pivotal, has historically been limited by the high computational cost of modelling. Here, we introduce a new emulator, based on a convolutional neural network, developed within the framework of a Euclid Preparation Key-Project activity, which substantially accelerates Monte Carlo Markov Chains evaluation making a cosmological analysis feasible. As a result, we will also present how different applications of the new emulator can shed light on disentangling and investigating cosmological models in view of future survey datasets.

Exploring the Universe with strong gravitational lensing / 266

A new era of strong gravitational lensing by galaxy clusters

Author: Pietro Bergamini[1]

[1] *Università degli Studi di Milano*

Corresponding Author: pietro.bergamini@inaf.it

The advent of a new generation of observational facilities, such as the James Webb Space Telescope (JWST) and the Euclid space telescope, has just inaugurated a new era of discoveries that are destined to revolutionize all fields of astrophysics, including strong gravitational lensing by galaxy clusters. The JWST's spectrophotometric data, of unprecedented spatial resolution and sensitivity, have allowed us to increase by at least an order of magnitude the number of multiple images included in the lens models. Furthermore, extensive area surveys such as the Euclid's Wide Survey and the Legacy Survey of Space and Time (LSST) will increase the number of known cluster lenses by several orders of magnitudes. In parallel to observations, state-of-the-art gravitational lensing software exploiting the computing power of the most modern machines are being developed to fully exploit the enormous amount of available data.
During my talk, I will outline the groundbreaking advancements underway in the field of strong gravitational lensing, culminating in the development of the most sophisticated and accurate lens models to date. Furthermore, I will illustrate how these cutting-edge lens models are opening new windows of inquiry into some of the biggest challenges of modern astrophysics, ranging from the studies of the first stellar complexes that have appeared in the Universe to the detailed mapping of the dark matter distribution in clusters, in the effort to advance our understanding on the nature of dark matter.

Dark energy and the accelerating universe / 267

A new era of the fine structure constant measurements in the early universe

Author: Dinko Milaković[1]

[1] *Institute for Fundamental Physics of the Universe*

Corresponding Author: dmilakov@sissa.it

In some modern theories, fields of the Standard Model of particle physics are allowed to interact with dark matter and dark energy. Such interactions, if they exist, may give rise to temporal evolution of the fine structure constant (α) or its spatial variations. Consequently, stringent constraints on such theories can be placed by searching for any possible α variation. Recent advancements in astronomical instrumentation and a newly developed spectral analysis tool based on Artificial Intelligence (AI) allow for unprecedented precision in measuring the value of α from newly acquired astronomical spectra.

I will present major developments based on the high-resolution spectrograph ESPRESSO (mounted on the Very Large Telescope) and on the new AI spectral modelling tool, AI-VPFIT. The former provided the highest quality data yet and the latter provided a tool for objective, robust, and reproducible measurements derived from spectroscopic data. Combined, these advancements allowed us to identify and quantify several new systematic effects important for α (and similar) measurements, associated both with the astrophysical objects (e.g. non-terrestrial isotopic abundances) and with the measurement process (e.g. model non-uniqueness). More importantly, they also allowed us to remove them, ushering a new era of fundamental physics measurements in the early universe.

Fast radio bursts / 268

Multi-messenger and multi-wavelength constraints on FRB progenitors and emission mechanisms

Author: Alex Cooper[1]

[1] *University of Oxford*

Corresponding Author: alexander.cooper@physics.ox.ac.uk

Follow-up observations are crucial to our understanding of fast radio bursts (FRBs), and have enabled studies of their host galaxies and persistent counterparts. As FRB localizations become routine, multi-wavelength simultaneous & post-burst observations will allow us to begin to constrain and characterise the progenitors and the emission mechanisms powering FRBs. In this talk, I will present recent theoretical & observational work undertaken to predict optical and radio counterparts to FRBs in magnetar and merger progenitor frameworks.

In the former, I will discuss our post-burst observations of FRB 200428 from Galactic magnetar SGR 1935+2154, which provides strong evidence against the afterglow expected within the synchrotron maser shock model. In the latter, I will briefly discuss a new mechanism for producing FRB-like bursts in neutron star mergers, before detailing prospects for detecting gravitational wave, kilonova, and radio afterglow counterparts. I will conclude by presenting stringent new optical constraints on the association between GW190425 and FRB190425.

Loop quantum gravity: cosmology and black holes / 269

Regular black holes and their relationship to polymerized models and mimetic gravity

Authors: Hongguang Liu[1]; Kristina Giesel[1]; Parampreet Singh[2]; Stefan Weigl[1]

[1] *FAU Erlangen-Nürnberg*

[2] *Louisiana State University*

Corresponding Author: liuhongguang@outlook.com

In this talk we present the analysis of the embedding of a large class of generalized LTB models in effective spherically symmetric spacetimes. We introduce a reconstruction algorithm that allows, for a large class of models, to construct from a given metric in Schwarzschild-like coordinates the corresponding effective spherically symmetric model, its dynamics as a 1+1-dimensional field theory, as well as a corresponding covariant Lagrangian of extended mimetic gravity in four dimensions. Such a reconstruction allows us to obtain Lagrangians of extended mimetic gravity models for black hole models with a regular center, e.g. of Bardeen and Hayward, as well as for effective LQG-inspired models. Moreover, the reconstruction allows us to extend static regular black hole models to exact general non-marginally bound inhomogeneous dust collapse solutions. For effective LQG-inspired models, within this formalism we can investigate and view the physical properties of the models,

such as the existence of weak shell-crossing singularities and shock solutions, from a novel perspective. Concrete examples with standard LQC and an asymmetric bouncing model inspired by Thiemann regularized LQC in the LTB sector will be discussed.

Slowly rotating pulsars / 270

A mechanism for coherent radio emission from ultra-long period magnetars

Author: Alex Cooper[1]

[1] *University of Oxford*

Corresponding Author: alexander.cooper@physics.ox.ac.uk

The nature of recently discovered ultra-long period radio transients is uncertain. If these sources are neutron stars, their long periods strongly challenge rotation-powered emission models. In this talk, I will present a new model of radio emission from ultra-long period magnetars, in which crustal stresses power magnetospheric twists, which dissipate to produce coherent radio emission. I will introduce the possible driving forces behind emission including: plastic flow, thermoelectric gradients and past starquakes, and discuss how twist-generated curvature or inverse-Compton scattered photons may naturally reproduce the observed properties of known sources. I will detail our predictions of the pulse profiles and multi-wavelength counterparts of these long period radio transients. I will conclude by discussing new theoretical deathlines and 'active zones', in which more long period sources could be discovered.

Cosmic Insights from Big Data: How Machine Learning is Decoding the Universe / 271

Causal discovery in astrophysics

Author: Mario Pasquato[1]

[1] *IASF Milano (INAF)*

Corresponding Author: mario.pasquato@gmail.com

Causal discovery techniques have been introduced in the context of machine learning with the goal of finding and constraining causal relations between variables. Multiple algorithms for this task are available, amounting to different operational definitions of causal relations based directly on observational data. These tools have found wide application in disciplines that have limited access to experimental manipulation, such as economics or epidemiology. However, in physics, even in a purely observational context such as astrophysics, causality has historically been understood exclusively in the context of a theoretical framing of some sort: astrophysics describes causal relations through theoretical models and, more recently, simulations. Data-driven causal techniques could prove complementary to this approach, but as of now have virtually never been applied to astronomical data.
I will show through concrete examples that a data driven approach to causal questions in astrophysics is viable and useful for resolving long standing issues. Moreover, I will discuss critically how it meshes with theoretical understanding, arguing that this is a major area for development of machine learning in astrophysics.

AMS-02 experiment at the International Space Station / 273

The role of electron capture decay in the precision era of Galactic cosmic-ray data

Authors: David Maurin[None]; Manuela Vecchi[None]; Marta Borchiellini[None]

Corresponding Author: m.borchiellini@rug.nl

Electron capture (EC) decay relies on attachment and stripping cross-sections, that in turn, depend on the atomic number of the nucleus. We revisit the impact of EC decay in the context of the high-precision cosmic-ray fluxes measured by the AMS-02 experiment. We derive the solution of the steady-state fluxes in a 1D thin disk model including EC decay. We compare our results with relevant elemental and isotopic fluxes and evaluate the impact of this process, given the precision of recent AMS-02, ACE-CRIS, SuperTIGER, and Voyager data. We find this impact to be at the level or larger than the precision of recently collected data for several species, e.g. $_{31}$Ga and $_{33}$As, indicating that EC decay must be properly taken into account in the calculation.

Black holes in alternative theories of gravity / 274

Scalarized Black Hole Solutions in Modified Theories

Author: Zakaria Belkhadria[1]

[1] *Università di Cagliari/ Université de Genève/ INFN/GWSC*

Corresponding Author: zakaria.belkhadria@unica.it

This presentation delves into the study of 'hairy' black holes within the framework of Einstein scalar Maxwell gravity and Einstein scalar Gauss-Bonnet theories, with a focus on revealing new scalarized black hole solutions. We revisit established scalarization phenomena and venture into new solution territories, particularly highlighting the blend of linear and non-linear scalarization in Einstein Scalar Maxwell gravity. Our goal also includes the identification of new scalarized black hole solutions in Gauss-Bonnet theory with a Maxwell field, while outlining their observational significance. Our approach leverages numerical techniques to scrutinize asymptotically flat, spontaneous, and non-linear scalarized black holes in the Einstein-Maxwell-Scalar model, with a keen emphasis on the horizon radii and scalar field intensities. We culminate with an analysis of how scalarization sources shape the horizon area. Our research enhances the comprehension of black hole scalarization and paves the way for continued investigation in this exciting field.

Present and future of cosmic microwave background observations / 275

Early Universe with CMB B-mode and observational challenges

Author: Susanna Azzoni[1]

[1] *Princeton*

Corresponding Author: sazzoni@princeton.edu

The large-scale B-mode polarization of the Cosmic Microwave Background (CMB) holds immense potential for revealing high-energy physics from the early Universe. Detecting this signature would likely indicate the emission of primordial gravitational waves following the Big Bang, providing crucial insights into the physics that created them. However, observing this faint signal is extremely challenging due to the interference from B-mode-emitting Galactic foregrounds and the need for meticulous control over instrumental systematics. In this talk, I will outline the impact of these challenges on our observations, focusing on current and upcoming CMB experiments. I will also

introduce innovative methods for foreground removal and discuss the characterization of various instrumental effects on the final cosmological signal.

Exploring the Universe with strong gravitational lensing / 276

Gravity.jl: a fast software for strong gravitational lens modeling

Author: Davide Abriola[1]

[1] *Università degli Studi di Milano*

Corresponding Author: davide.abriola@unimi.it

Strong gravitational lensing by galaxy clusters is one of the most powerful tools to accurately probe the dark matter mass distribution in the densest regions of such structures, where multiple images are formed, and to test the currently accepted ΛCDM cosmological paradigm. Present and future observational facilities, such as the Euclid space telescope and the Vera Rubin observatory, are expected to observe thousands of massive galaxy clusters, increasing by more than an order of magnitude the number of known systems. Therefore, given the huge amount of data acquired, a software capable of performing both accurate and fast lensing analyses is required to investigate the structure of these systems, to constrain the values of the cosmological parameters and to study high-redshift sources.

In my talk, I will present Gravity.jl, a new Julia-based strong lensing modeling software. In contrast with previous codes, Gravity.jl combines an unprecedented speed with a wide variety of sampling techniques. I will show how Gravity.jl works and how it has been applied in currently-studied clusters. I will conclude by presenting several ongoing analysis that would not be possible without such a flexible code, as well as the cosmological analyses this software allows.

Modeling of binary neutron star and black hole-neutron star mergers, and of their electromagnetic counterparts / 277

Prospects for multi-messenger observations of binary neutron star mergers in the fourth LIGO-Virgo-KAGRA observing run

Author: Barbara Patricelli[None]

Corresponding Author: barbara.patricelli@pi.infn.it

On August 17, 2017, the joint detection of GW170817 and GRB 170817A opened the era of multi-messenger astronomy with gravitational waves (GWs) and provided the first direct probe that at least some binary neutron star (BNS) mergers are progenitors of short gamma-ray bursts (S-GRBs). Since then, no other joint BNS/S-GRB observations have been reported. On May 2024 the fourth LVK observing run (O4) has started, and it will last at least until February 2025: many other GW detections are expected in the next months, and possibly this will lead to another multi-messenger event.
In this talk I will present a comprehensive study on the expected joint GW and electromagnetic (EM) observations of BNS mergers in O4. This work combines accurate population synthesis models with simulations of the expected GW signals and the associated S-GRBs. We consider different assumptions about the GRB jet structure and we estimate the expected joint GW and EM detection rates with Fermi, Swift, INTEGRAL and SVOM. The comparison of the theoretical predictions of this work with the O4 observations will be key to probe the physics of BNSs, as well as the BNS/S-GRB association and the GRB jet structure.

Repeating transients in galactic nuclei: confronting observations with theory / 278

Accretion and Ejection onto Supermassive Black Holes: A Comparative Study of Persistent and Transient X-ray Sources

Author: Francesco Tombesi[1]

[1] *Tor Vergata University of Rome*

Corresponding Author: francesco.tombesi@roma2.infn.it

This preliminary study aims to explore the contrasting X-ray signatures of accretion and ejection processes in supermassive black holes, focusing on both persistent active galactic nuclei (AGN) and transient sources, such as tidal disruption events (TDEs), quasi-periodic eruptions (QPEs), and quasi-periodic outflows (QPOuts). We will examine the continuum emission characteristics, comparing black body radiation from the accretion disk and power-law emissions from the corona. The analysis will include absorption features, highlighting the differences between slower warm absorbers and ultra-fast outflows (UFOs) observed in both soft (0.5-2 keV) and hard X-ray (2-10 keV) bands. Additionally, we will investigate the potential impact of orbiting compact objects on the accretion disk structure, the existence of two-phase disks, and clumpy outflows. This study is still under development, aiming to elucidate the underlying physics of accretion and ejection in these varied astrophysical environments. We intend to pose open questions to stimulate discussion and inspire new research directions.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 279

Electromagnetic interactions near the black hole horizon

Author: Fabiano Feleppa[1]

Co-authors: Nava Gaddam [2]; Nico Groenenboom [3]

[1] *University of Salerno and INFN, Salerno*

[2] *International Centre for Theoretical Sciences, Tata Institute for Fundamental Sciences, Bengaluru 560089, Karnataka, India*

[3] *Institute for Theoretical Physics and Center for Extreme Matter and Emergent Phenomena, Utrecht University, 3508 TD Utrecht, The Netherlands*

Corresponding Author: ffeleppa@unisa.it

In this talk, I will describe a theory for scalar QED near the black hole event horizon. In particular, I will show how to compute the electromagnetic eikonal S-matrix from elastic $2 \longrightarrow 2$ scattering of charged particles exchanging soft photons in the black hole eikonal limit. The resulting ladder resummation agrees perfectly with the result from the first quantised formalism developed by 't Hooft, whereas the field-theoretic formulation allows for a computation of a wider range of amplitudes. Some possible applications of the formalism developed here will be also discussed.

Wormholes, energy conditions and time machines / 280

Kerr-like Wormhole

Authors: Juan Carlos Del Águila Rodríguez[1]; Tonatiuh Matos[2]

[1] *Universidad Autónoma Metropolitana*

[2] *Centro de Investigación y de Estudios Avanzados del IPN*

Corresponding Author: tonatiuh.matos@cinvestav.mx

In 2006 we proposed the conjecture that rotating wormholes might be stable, while static ones might not be. In this talk we present an exact solution of the Einstein-Phantom Field equations similar to the Kerr solution. It is singular in a ring around the throat, but this singularity is geodesically complete and cannot be touched by null geodesics, our conclusion is that the singularity is not in causal contact with the rest of the universe, giving rise to a new form of Cosmic Censorship. The solution has several exotic behaviors that we explain in this talk.

Repeating transients in galactic nuclei: confronting observations with theory / 281

Dynamics of the candidate SMBH-IMBH system ASASSN-20qc exhibiting a quasiperiodic UFO

Author: Michal Zajaček[1]

[1] *Masaryk University*

Corresponding Author: michal.zajacek31@gmail.com

The recently reported transient event ASASSN-20qc (Pasham et al., 2024), which was revealed first by the optical outburst and then the delayed soft X-ray emission, was shown to exhibit a quasiperiodic ultrafast outflow. I will show using analytical as well as numerical calculations (see also the contribution by Petra Sukova) that such a behaviour is consistent with the intermediate-mass black hole (IMBH, mass range~100-10000 Solar masses) orbiting the supermassive black hole (SMBH) on an inclined orbit. The remaining puzzle is the origin and the likelihood of such systems. Using the typical characteristics and the history of dense nuclear star clusters, I will analyze the dynamical origin of such an IMBH. It is also plausible that the IMBH is a remnant core of a tidally dissolving stellar cluster. In that case, the optical TDE-like outburst ASASSN-20qc would be a direct consequence of the IMBH-star binary break-up in the vicinity of the SMBH, i.e. it would be the manifestation of the final stages of the dissolution of a star cluster hosting an IMBH. I will provide estimates of the rates of such events in the nearby Universe.

Neutrinos in the multi-messenger era / 282

Neutrino Oscillations in Extreme Astrophysical Laboratories: Insights from GRBs

Author: Gibran Morales[1]

Co-author: Nissim Fraija [2]

[1] *IRyA-UNAM*

[2] *IA-UNAM*

Corresponding Author: gibranmr@gmail.com

Astronomy has entered a new era of multi-messenger observation with the early detection of neutrinos from SN1987A and the recent discovery of gravitational waves. Neutrinos serve as an effective detection channel for various astrophysical sources. This research focused on neutrino propagation through multiple media, including central engines within gamma-ray bursts (GRBs) and environments with strong magnetic fields. We studied how these neutrinos interact with and are affected by their surroundings. Our findings show that neutrino propagation highly depends on the medium's properties, such as density profiles and magnetic fields. In environments with non-isotropic density distributions, we demonstrated that neutrino propagation is essential in understanding the energy extraction mechanisms at work near GRB central engines.
Furthermore, our findings indicate that neutrino oscillation probabilities can vary significantly with

changes in propagation latitude and energy, allowing for potential differentiation between GRB progenitors. The implications of our studies extend beyond theoretical understanding. They pave the way for multi-messenger astrophysics, aiding in identifying the sources of observed neutrino flux. These findings are crucial for the future of neutrino astronomy and the development of next-generation neutrino detectors, and they promise to enhance our ability to investigate the universe's most energetic events.

Latest results from Galactic center observations / 283

Dynamical Coupling of Keplerian Orbits in Post Newtonian Gravity: From Galactic Center to Compact Planetary Systems.

Author: Myank Singhal[1]

Co-authors: Jaroslav Haas [1]; Ladislav Subr [1]

[1] *Astronomical Institute, Charles University*

Corresponding Author: myanksinghal1999@gmail.com

This work investigates the long-term evolution of two bodies in nearby initially coplanar orbits around a central dominant body, perturbed by a fourth body on a distant Keplerian orbit. Previous works on this setup enforced circular orbits by adding a spherical potential of extended mass. This results in a long-term coherent evolution with nearly coplanar orbits experiencing only small inclination oscillations. This work extends the previous research by (i) considering post-Newtonian corrections to the gravity of the central body, either instead of or in addition to the potential of extended mass and (ii) relaxing the requirement of strictly circular orbits. In this work, we tested the applicability with a system scaled to the orbits of S-stars; we consider the clockwise disc to represent the perturbing body, with post-Newtonian corrections to the gravity of Sagittarius A* playing the role of damping potential. Considering post-Newtonian corrections, even stellar-mass central bodies in compact planetary systems can allow for the coupled evolution.

Mineral detection of dark matter and neutrinos / 284

Analyzing right-handed neutrino dark matter with electron recoil events

Author: Santiago Collazo[1]

Co-authors: Carlos Raúl Argüelles [2]; Soroush Shakeri [3]

[1] *Instituto de Astrofísica de La Plata*

[2] *La Plata National University & ICRANet*

[3] *ICRANet-Isfahan, IUT*

Corresponding Author: scollazo@fcaglp.unlp.edu.ar

We present theoretical estimations of the event rates for the interaction between a right-handed neutrino dark matter with an electron bound to a Xenon atom. Motivated by recent results on dark matter in cosmological and astrophysical contexts, we study a fermionic dark matter candidate with a mass of 200 keV as a case of example. The interaction occurs through an effective electromagnetic model where the output is standard-model particles. This mechanism allows right-handed neutrinos to couple with standard-model particles with the interchange of W or Z bosons. Based on a previous result and with the aim of improving it, we incorporate the ionization form factor that arises from the interaction of the fermionic candidate with a bound electron. In addition, we compute the sensitivity curves for different direct detection experiments that could potentially detect such phenomena. Our

numerical framework is extensible to other dark matter particle masses in the sub-MeV range and for other materials.

Low frequency gravitational waves: sciences and detections / 285

Gravitational wave asteroseismology of charged strange stars in the Cowling approximation

Author: José Domingo Arbañil Vela[1]

Co-authors: César Flores [2]; César Lenzi [3]; Juan Pretel [4]

[1] *Universidad Privada del Norte*

[2] *Universidade Estadual da Região Tocantina do Maranhão*

[3] *Instituto Tecnológico de Aeronáutica*

[4] *Centro Brasileiro de Pesquisas Físicas*

Corresponding Author: jd.arbanil@gmail.com

In this work we study, within the framework of Cowling approximation, the effect of the electric charge on the gravitational wave frequency of fluid oscillation modes of strange quark stars. For this purpose, the dense matter of the stellar fluid is described by the MIT bag model equation of state (EoS), while for the electric charge profile, we consider that the electric charge density is proportional to the energy density. We find that the gravitational wave frequencies change with the increment of electric charge; these effects are more noticeable at higher total mass values. We obtain that the f-mode is very sensitive to the change in the electric charge of the star. Furthermore, in the case of the p_1 mode, the effect of the electric charge is not very significant. Our results reveal that the study of the fundamental pulsation mode of an electrically charged compact star is very important to distinguish whether compact stars could contain electric charge.

Multi-messenger astronomy with gravitational waves / 287

Studies on multi-messenger astrophysics with the GW-Universe Toolbox

Author: Shu-Xu Yi[1]

[1] *Institute of High Energy Physics, Chinese Academy of Sciences*

Corresponding Author: sxyi@ihep.ac.cn

The GW-Universe Toolbox is a software package designed to simulate observations of various types of gravitational wave (GW) source populations using a wide range of GW detectors, including ground-based and space-based laser interferometers, as well as pulsar timing arrays. In its recent development, the GW-Universe Toolbox has been upgraded to enable the simulation of joint observations of gamma-ray burst (GRB) prompt emissions and GW chirps from binary neutron star mergers. In this talk, we will first introduce the software and then discuss its application to several astrophysical problems, including the population study of compact binary mergers, sub-threshold joint observations, and constraints on GW velocity.

Repeating transients in galactic nuclei: confronting observations with theory / 288

Quasi-Periodicities and Jet Precession in AGN Perturbed by Black Hole Companions

Author: Sean Ressler[1]

Co-authors: Bart Ripperda [2]; Huan Yang [3]; Luciano Combi [4]; Xinyu Li [5]

[1] *Canadian Institute for Theoretical Astrophysics*

[2] *Princeton University/Flatiron Institute*

[3] *Perimeter Institute/University of Guelph*

[4] *Perimeter Institute*

[5] *Tsinghua University*

Corresponding Author: seanmressler@gmail.com

Detecting and interpreting electromagnetic counterparts to binary black hole mergers will require a detailed understanding of the complex plasma dynamics governing the surrounding accretion flow, particularly for binaries including at least one supermassive black hole. Quasi-periodicities observed in active galactic nuclei (AGN) may already provide a clue as to how a secondary black hole in such a system may appear observationally. In this talk I will present an exciting and computationally efficient new way to simulate binary black hole accretion in gravitational wave-emitting systems relevant for LISA and pulsar timing arrays. Specifically, I will summarize the results of simulating a smaller mass companion black hole colliding with an established AGN accretion disk. We find that quasi-periodicities appear in both the unbound outflow rate (which could correspond to small "flares" in the light curve) and in the precession of the primary black hole disk/jet caused by spin-orbit coupling. Our results are relevant for the prospect of confirming the existence of secondary black holes in AGN systems and for studying systems like OJ 287 where there is already a strong case for a secondary companion.

Micro-Hertz gravitational waves (0.1-100 μHz): sources and detection methods / 289

Micro-Hertz Gravitational Waves (0.1-100 ⊠Hz): Overview of Sources and Detection Methods

Author: Wei-Tou Ni[1]

Co-author: Gang Wang [2]

[1] *State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Innovation Academy for Precision Measurement Science and Technology, Chinese Academy of Sciences, Wuhan 430071, China*

[2] *Shanghai Astronomical Observatory, CAS*

Corresponding Author: weitou@gmail.com

Micro-Hertz Gravitational Waves (0.1-100 ⊠Hz): Overview of Sources and Detection Methods

Wei-Tou Ni and Gang Wang

The micro-Hz GW (Gravitational Wave) band, ranging from 0.1 to 100 ⊠Hz, occupies a crucial intermediate gap between the PTA (Pulsar Timing Array) GW detection band (0.03—100 nHz) and the sensitive bands of space missions like LISA/Taiji/TianQin (0.1 mHz—1 Hz). This frequency range is abundant with potential GW sources. The primary scientific objectives within this band include the detection of GWs from supermassive BH (Black Hole) binary inspiral and coalescence events spanning masses of 10^5-10^10 solar masses, as well as GWs emitted during the inspiral phase of intermediate-mass BH coalescence and intermediate BH binaries falling into supermassive BHs. Detection of micro-Hz GWs will provide opportunities to study the BH co-evolution with the galaxies, to test general relativity and beyond-the Standard-Model theories, to explore the micro-Hz stochastic GW background and so on. Great advances in both scientific goals and detection methods have accumulated since MG16. We here give an overview for this parallel session.

Future innovations in gamma-ray astronomy / 290

The Compton Spectrometer and Imager mission

Author: Francesco Fenu[1]

[1] *Agenzia Spaziale Italiana*

Corresponding Author: francesco.fenu@asi.it

The Compton Spectrometer and Imager (COSI) is a NASA Small Explorer (SMEX) satellite mission planned to fly in 2027. It has the participation of institutions in the US, Europe and Asia and aims at the construction of a gamma ray telescope for observations in the 0.2-5 MeV energy range. It will cover the full sky with a 120×120 degrees^2 field of view, excellent energy resolution, imaging capability and sensitivity to polarization. It consists of an array of germanium strips detectors cooled to cryogenic temperatures with millimeter position resolution for gamma-ray interactions, surrounded by an active BGO shield to reduce background contamination. Goals of COSI are: the study of the electron-positron 511 keV annihilation emission in the Galaxy, mapping the emission from galactic element formation, exploring the polarization in the gamma rays and the detection of transient sources in multimessenger campaigns. In this work we present the mission, its scientific goals and its design.

Mid-frequency gravitational waves (0.1-10 Hz): sources and detection methods / 291

Mid-frequency Gravitational Waves (0.1-10 Hz): Overview of Sources and Detection Methods

Authors: Youjun Lu[None]; Wei-Tou Ni[1]

[1] *State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Innovation Academy for Precision Measurement Science and Technology, Chinese Academy of Sciences, Wuhan 430071, China*

Corresponding Author: weitou@gmail.com

Mid-frequency Gravitational Waves (0.1-10 Hz): Overview of Sources and Detection Methods

Youjun Lu and Wei-Tou Ni

The mid-frequency GW (Gravitational Wave) band (0.1-10 Hz) between the LIGO-Virgo-KAGRA detection band and LISA-TAIJI/TIANQIN detection band is rich in GW sources. In addition to the intermediate BH (Black Hole) Binary coalescence, GWs can also come from the inspiral phase of stellar-mass coalescence and from compact binaries falling into intermediate BHs. Detecting mid-frequency GWs enables us to study the compact object population, to test general relativity and beyond-the Standard-Model theories, to explore the stochastic GW background, to give early alert for GW observations of these sources at high frequency band and for electromagnetic searches for their counterpart, and so on. Great advances in both scientific goals and detection methods have accumulated since MG16. We here give an overview for this parallel session.

Neutrinos in the multi-messenger era / 292

Online event reconstruction and classification in KM3NeT

Author: Alessandro Veutro[1]

Co-authors: Angela Zegarelli [2]; Damien Dornic [3]; Emidio Giorgio [4]; Emmanuel Le Guirriec [3]; Francesco Filippini [5]; Giulia Illuminati ; Godefroy Vannoye [3]; Juan Palacios González [6]; Jérome De Favereau [7]; Massimo Mastrodicasa [8]; Mathieu Lamoureux [7]; Sebastien Le Stum [3]; Silvia Celli [9]; Vincent Cecchini [6]

[1] *INFN sezione di Roma1*

[2] *Ruhr Universität, Bochum*

[3] *Centre de Physique des Particules de Marseille*

[4] *INFN - Laboratori nazionali del sud*

[5] *INFN - sezione Bologna*

[6] *Instituto de Física Corpuscular, Valencia*

[7] *Université catholique de Louvain*

[8] *Sapienza Università di Roma and INFN-Roma*

[9] *Sapienza University & INFN-Roma1*

Corresponding Author: alessandro.veutro@roma1.infn.it

KM3NeT is the next generation deep-sea neutrino telescopes currently under construction in the Mediterranean Sea. It is composed of two water-Cherenkov neutrino detectors: ARCA and ORCA, located at two sites, south-est of Portopalo di Capo Passero (Italy) and close to Toulon (France), respectively. One of the main scientific goals of KM3NeT is to observe cosmic neutrinos and investigate their sources following a multi-messenger approach, i.e. by combining coincident detection from different telescopes.

The combination of an extended field of view and a high duty cycle is crucial for detecting and informing other telescopes about interesting neutrino candidates in a very short time. For this purpose, an efficient online framework can provide, in real time and for each event, reconstructed physical variables, like visible energy and arrival direction.
Furthermore, in order to search for neutrino signal, a high background rejection power is needed and deep learning techniques provide promising results.
The flexibility and the low amount of information required as input make Graph Neural Networks (GNNs) the perfect candidate to perform real-time event selection in parallel with the event reconstruction processes.

In this talk, the status of the KM3NeT online framework and the event reconstruction and classification algorithms will be presented.

Cosmic Insights from Big Data: How Machine Learning is Decoding the Universe / 293

Leveraging Transfer Learning for Astronomical Image Analysis

Author: Stefano Cavuoti[1]

Co-authors: Demetra De Cicco [2]; Lars Doorenbos [3]; Gianluca Sasanelli [2]; Olena Torbaniuk [4]; Massimo Brescia [2]; Giuseppe Longo [2]; Pablo Márquez-Neila [3]; Maurizio Paolillo [2]; Raphael Sznitman [3]; Crescenzo Tortora [1]

[1] *INAF - Astronomical Observatory of Capodimonte Napoli*

[2] *University of Napoli "Federico II"*

[3] *AIMI, ARTORG Center, University of Bern*

[4] *University of Bologna*

Corresponding Author: stefano.cavuoti@gmail.com

This presentation explores some applications of transfer learning in astronomical image analysis, focusing on the usage of a pretrained network (EfficientNet) as a feature extractor. We discuss methods for identifying active galactic nuclei, extracting physical parameters, and detecting anomalies in time series data. Additionally, we present some potential future applications, demonstrating the versatility of this approach, even without a training phase.

Micro-Hertz gravitational waves (0.1-100 μHz): sources and detection methods / 294

Design and evaluation of ASTROD-GW mission orbit with inclined configurations

Authors: Gang Wang[1]; Wei-Tou Ni[2]; Wei-Tou Ni[3]

[1] *Shanghai Astronomical Observatory, CAS*

[2] *State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Innovation Academy for Precision Measurement Science and Technology, Chinese Academy of Sciences, Wuhan 430071, China*

[3] *Innovation Academy of Precision Measuremnt Sciencs and Technology of Chinese Academy of Sciences*

Corresponding Authors: weitou@gmail.com, wei-tou.ni@wipm.ac.cn

ASTROD-GW is designed to observe gravitational waves in the micro-Hz frequency band, employing three spacecraft near the Sun–Earth Lagrange points L3, L4, and L5 to form triangular interferometers with a 2.6 AU arm length. Benefiting from the relative gravitational stabilities of the Lagrange points in 30 years, the mission orbit can remain stable for more than 10 years. The antenna pattern of interferometer will remain (largely) constant to a source if the orbits of three spacecraft stay in the ecliptic plane. To improve the angular resolution to the sources, we twist the orbital formation to be slightly inclined with ecliptic plane, resulting in a half-year precession antenna pattern.

In this talk, we report a set of 10-year ASTROD-GW mission orbits obtained from numerical ephemeris framework which including cases with inclination angles of 0° (no inclination), 0.5°, 1.0°, 1.5°, 2.0°, 2.5°, and 3.0°. Additionally, we calculate the path mismatches of the first- and second-generation time delay interferometry configurations for the different inclinations and compare their capabilities for suppressing laser frequency noise.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 295

Disk-Outflow Symbiosis in GRMHD Simulations: Explaining ULXs in Hard State

Author: Mayank Pathak[1]

Co-author: Banibrata Mukhopadhyay [2]

[1] *Joint Astronomy Programme, Department of Physics, Indian Institute of Science, Bengaluru, Karnataka, India*

[2] *Department of Physics, Indian Institute of Science, Bengaluru, Karnataka, India*

Corresponding Author: mayankpathak@iisc.ac.in

Ultraluminous X-ray sources (ULXs) have captivated researchers for decades due to their exceptionally high luminosities and unique spectral characteristics. Some of these sources defy expectations by exhibiting super-Eddington luminosities with respect to stellar mass sources even in their low-hard state. Numerical steady-state calculations suggest that ULXs in this state can be explained as highly magnetized advective accretion sources around stellar-mass black holes. To explore this further, we employ GRMHD simulations using the publicly available code, BHAC (Black Hole Accretion Code), to model the behavior of highly magnetized advective accretion flows around a black hole. Our simulations demonstrate that such systems can indeed produce the intense luminosities observed in ULXs. Additionally, we validate that the magnetic fields required for these high emissions are of the order of 10^7 Gauss, consistent with previous numerical steady-state findings.

Micro-Hertz gravitational waves (0.1-100 μHz): sources and detection methods / 296

Investigating the detectability of galactic double white dwarfs and confusion noise for the micro-Hz gravitational wave missions

Authors: Gang Wang[1]; Zhen Yan[1]; Bin Hu[2]; Wei-Tou Ni[3]; Wei-Tou Ni[4]

[1] *Shanghai Astronomical Observatory, CAS*

[2] *Beijing Normal University*

[3] *State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Innovation Academy for Precision Measurement Science and Technology, Chinese Academy of Sciences, Wuhan 430071, China*

[4] *Innovation Academy of Precision Measuremnt Sciencs and Technology of Chinese Academy of Sciences*

Corresponding Author: gwang@shao.ac.cn

A large number of galactic binary systems emit gravitational waves (GW) continuously with frequencies below ~10 mHz. The LISA mission could identify tens of thousands of binaries over years of observation and will be subject to the confusion noise around 1 mHz yielded by the unresolved sources. Beyond LISA, there are several missions have been proposed to observe GWs in the sub-mHz range where the galactic foreground is expected to be overwhelming the instrumental noises. In this talk, we report our investigation on the detectability of sub-mHz GW missions to detect the galactic double white dwarf (DWD) binaries and evaluate the confusion noise produced by the undistinguished DWDs. This confusion noise could also be viewed as a stochastic GW foreground and be effectively observed in the sub-mHz band. The parameter determinations for the modeled foreground are examined by employing different detector sensitivities and population models. By assuming the determined foregrounds could be subtracted from the data, we evaluate the residuals which are expected to have power spectral densities two orders of magnitude lower than the originals data.

Modeling of binary neutron star and black hole-neutron star mergers, and of their electromagnetic counterparts / 297

A covariant approach to relativistic large-eddy simulations

Authors: Thomas Celora[1]; Greg Comer[2]; Nils Andersson[3]; Ian Hawke[3]; Marcus Hatton[3]

[1] *Institute of Space Sciences (ICE-CSIC)*

[2] *Saint Louis University*

[3] *University of Southampton*

Corresponding Author: thomas.celora@gmail.com

The first detection of a binary neutron star merger has made sharp reality the long-standing paradigm that these cosmic fireworks are exciting laboratories for extreme physics. To get the most out of observations, however, we need accurate modelling of the merger dynamics via numerical relativity simulations. In this respect, the large amount of numerical work carried out over the last decade has allowed us to obtain a robust, but broad-brush, picture of the merger dynamics. Current simulations are in fact far from resolving the full range of scales involved, particularly because of the development of turbulence in the merger remnant. This has motivated recent efforts towards adapting the large-eddy simulation strategy to the relativistic setting relevant for binary mergers. Despite the impressive results that such efforts have already delivered, however, all the practical implementations so far are problematic in that they break covariance. In this talk, I will discuss a theoretical framework that allows us to overcome said limitations, and go on to present a practical implementation of the first fully-covariant filtering strategy in relativity.

Fast radio bursts / 298

A quantitative framework to study: Two-screen scattering effects in FRBs

Author: Sachin Pradeep Etakkepravan Thulicheri[1]

[1] *University of Bonn / Max-Planck-Institut für Radioastronomie*

Corresponding Author: sachinpradeepet@gmail.com

Fast Radio Bursts are known to exhibit scintillation and scattering phenomena , often attributed to the interaction of multiple screens. A common argument is that two screens, when appearing "pointlike" to each other, scintillate on both scales. This condition is commonly invoked to constrain scattering to FRB host galaxies. In this study, we explore this regime through simulations, revealing that two scales of scintillation persists even with the screens partially resolve each other.

The project's primary goal is to understand the appearance of the pulse when the screens resolve each other. The dynamic spectra of the pulse in this context unveil two distinct scales of scintillation, contradicting the argument the scattered image formed by the first screen should be unresolved by the second screen to observe 2-screen diffractive scintillation, commonly used to set an upper limit on the host screen distance from the FRB source.

Our investigation has revealed that as the screens resolve each other , the scintillation pattern changes along the scattering tail, a phenomenon absent when the screens remain unresolved. Our study also shows how specific FRB structures can arise from particular image distributions within the scattering screen. Additionally, we investigate the alterations in observables, such as modulation index, scintillation time scale, and bandwidth, as the screens resolve. We also demonstrate through simulations that the quenching phenomenon can be used to locate the host galaxy screen, thereby probing the host galaxy ISM at AU scales.

The work also introduces a new theoretical model and a novel simulation tool to study multi-screen scattering, which can be easily adapted to study images arising from gravitational lensing and microlensing from CGM clouds.

Multi-messenger astronomy with gravitational waves / 299

Speed of Gravity and Cosmology Constraints from Binary Neutron Stars using Time Delays between Gravitational Waves and Short Gamma-ray Bursts.

Author: Leonardo Iampieri[1]

Co-authors: Francesco Pannarale [2]; Simone Mastrogiovanni [3]

[1] *Sapienza, Università di Roma*

[2] *Sapienza – University of Rome & INFN*

[3] *Italian Institute of nuclear physics Rome (INFN)*

Corresponding Author: leonardo.iampieri@uniroma1.it

The landmark detection of a gravitational wave (GW) from the Binary Neutron Star Merger (BNS) GW170817 and its electromagnetic counterparts allowed us to study the Universe in a totally new way. Among the several discoveries made possible by GW170817, we can find the tightest constraints on the speed of gravity and the first measure of the Hubble constant (H0). Both these two measures were possible thanks to several assumptions that might not be granted with future detections. In fact, the speed of gravity was measured using agnostic assumptions on the prompt-time delay between the GW and the short Gamma-ray burst (sGRB), while the measure of H0 was possible thanks to the identification of the source host galaxy. In this talk, I will discuss how by relaxing the assumptions on GW-sGRB prompt time delay and identification of host galaxy still permits to infer the speed of gravity and H0 with populations of GW sources. By simulating populations of GW-sGRB detections with future observing runs, we find that: (i) it will be possible to jointly fit the GW-sGRB prompt-time delay distribution together with the speed of gravity and (ii) it will be possible to measure the Universe expansion even if the case that the source host galaxy is not observe. In particular, the latter result is made possible thanks to a new technique that I explored able to assign a redshift to the source using the GW-sGRB observed time delay.

Neutrinos in the multi-messenger era / 300

Neutrino real-time follow-ups with KM3NeT

Authors: Alessandro Veutro[1]; Angela Zegarelli[2]; Damien Dornic[None]; Emidio Giorgio[None]; Emmanuel Le Guirrec[None]; Francesco Filippini[None]; Giulia Illuminati[None]; Godefroy Vannoye[None]; Jerome De Favereau de Jeneret[None]; Juan Palacios Gonzalez[None]; Massimo Mastrodicasa[3]; Mathieu Lamoureux[None]; Sebastien Le Stum[None]; Silvia Celli[4]; Vincent Cecchini[5]

[1] *INFN sezione di Roma1*

[2] *Ruhr Universität, Bochum*

[3] *Sapienza Università di Roma and INFN-Roma*

[4] *Sapienza University & INFN-Roma1*

[5] *IFIC Valencia - CSIC*

Corresponding Author: massimo.mastrodicasa@roma1.infn.it

KM3NeT is a deep-sea research infrastructure comprising two water-Cherenkov neutrino telescopes being constructed in the Mediterranean Sea: ARCA in Italy, aiming at identifying and studying TeV-PeV astrophysical neutrino sources, and ORCA in France, designed to study the intrinsic properties of neutrinos in the few-GeV range. KM3NeT is also able to detect MeV-scale neutrinos expected at core-collapse supernovae. Given the complementary energy ranges they are optimised for, both telescopes can be used to explore neutrino astronomy from a few MeV to a few PeV, although their different primary goals. The KM3NeT observatory takes an active role in the real-time multi-messenger searches, which allow to study transient phenomena by combining information from the simultaneous observation of complementary cosmic messengers with different observatories. A key aspect to increase the discovery potential of transient sources and refine the localization of poorly localized triggers, such as gravitational waves, is the real-time distribution of alerts when potentially interesting events are detected. In this context, the KM3NeT real-time analysis framework is continuously reconstructing all ARCA and ORCA events, performing follow-ups of external alerts received from other multi-messenger instruments and searching for core-collapse supernova events. The selection of a sample of interesting events to send alerts to the external multi-messenger community is still under definition. This contribution deals with the latest results of the real-time follow-ups of external alerts with the KM3NeT real-time analysis framework.

Gravitational lensing, shadows and photon rings / 301

Shape of higher-order photon rings in image of Schwarzschild black hole

Author: Oleg Tsupko[1]

[1] *ZARM, Bremen University, Germany*

Corresponding Author: tsupkooleg@gmail.com

Higher-order photon rings can be expected to be detected in a more detailed image of the black hole found in future observations. These rings are lensed images of the luminous matter surrounding the black hole and are formed by photons that loop around it. We have succeeded to derive an analytical

expression for the shape of the higher-order rings in the form that is most convenient for application: the explicit equation of the curve in polar coordinates. The formula describes the apparent shape of the higher-order image of the circular ring with the given radius around Schwarzschild black hole as viewed by distant observer with an arbitrary inclination. For the derivation, the strong deflection limit of the gravitational deflection is used. Our formula is a simple and efficient alternative to the numerical calculation of ray trajectories, with the main application to studying the shape of $n = 2$ and $n = 3$ photon rings.

Inflation: perturbations, initial singularities and emergent universes / 302

Scale-invariant inflation: theoretical predictions and observational constraints

Authors: Chiara Cecchini[1]; Mariaveronica De Angelis[2]; Massimiliano Rinaldi[1]; Sunny Vagnozzi[1]; William Giaré[2]

[1] *University of Trento*

[2] *University of Sheffield*

Corresponding Author: mdeangelis1@sheffield.ac.uk

There is solid theoretical and observational motivation behind the idea of scale invariance as a fundamental symmetry of Nature. We consider a recently proposed classically scale-invariant inflationary model, quadratic in curvature and featuring a scalar field nonminimally coupled to gravity. We go beyond earlier analytical studies, which showed that the model predicts inflationary observables in qualitative agreement with data, by solving the full two-field dynamics of the system – this allows us to corroborate previous analytical findings and set robust constraints on the model's parameters using the latest CMB data from Planck and BICEP/Keck. We demonstrate that scale-invariance constrains the two-field trajectory such that the effective dynamics are that of a single field, resulting in vanishing entropy perturbations and protecting the model from destabilization effects. We derive tight upper limits on the non-minimal coupling strength, excluding conformal coupling at high significance. We demonstrate an overall insensitivity to initial conditions. We argue that the model predicts a minimal level of primordial tensor modes set by r > 0.003, well within the reach of next-generation CMB experiments. These will therefore provide a litmus test of scale-invariant inflation, and we comment on the possibility of distinguishing the model from Starobinsky and α-attractor inflation.

Loop quantum gravity: cosmology and black holes / 303

Relational dynamics in group field theory with the Page-Wootters formalism

Author: Andrea Calcinari[1]

Co-author: Steffen Gielen [1]

[1] *University of Sheffield*

Corresponding Author: andrea.calcinari@hotmail.it

A common criticism to deparametrised quantum gravity formalisms, where a time variable is selected before quantisation, is that covariance seems to be lost. In this talk, I will resolve this concern for the group field theory (GFT) approach to quantum gravity thanks to the equivalence between the Dirac quantisation scheme and the Page-Wootters (PW) formalism — applied here to quantum gravity for the first time. By defining cosmological Dirac observables that evolve with respect to a dynamical clock, which is an internal *quantum* degree of freedom, I will show that the relational dynamics emerging from this "post-quantum time" framework coincide with the classical deparametrisation

procedure of GFT cosmology, proving that quantisation and the choice of the clock commute. I will finally comment on the interpretation that the PW formalism suggests in terms of "synchronised" quantum geometry states. This construction works for any number of group field modes, and can generalise the PW formalism to the multi-fingered time scenario, typical of systems with multiple Hamiltonian constraints.

High energy astrophysics / 304

INTEGRAL: 20 years of hard X-ray surveys and Background measurements

Author: Roman Krivonos[1]

[1] *Space Research Institute (IKI), Moscow, Russia*

Corresponding Author: krivonos@cosmos.ru

The INTEGRAL hard X-ray surveys have proven to be of fundamental importance. In more than twenty years of operation, the INTEGRAL observatory has given us a sharper view of the hard X-ray sky, and provided the triggers for many follow-up campaigns from radio frequencies to gamma-rays. In addition to conducting a census of hard X-ray sources across the entire sky, INTEGRAL has carried out unique observations of the Galactic X-ray background and large-scale cosmic X-ray background, which will without question be included in the annals of X-ray astronomy as one of the mission's most salient contribution to our understanding of the hard X-ray sky.

Gravitational lensing, shadows and photon rings / 305

The Optical Appearance of a Black Hole

Author: Muhammad Ali Raza[1]

[1] *COMSATS University Islamabad, Lahore Campus*

Corresponding Author: maliraza01234@gmail.com

Since the first theoretical proposition of a black hole solution, it has been one of the most investigated questions that what would be the appearance of a black hole. There have been hundreds of black hole solutions in various frameworks for which studies are available dealing with the optical images of these black hole models. Currently, we call it the black hole shadow as it turns out due to the absence of light from the photon sphere. We still can visualize the boundary of the shadows in the form of a ring of light that essentially is a region where photons are trapped in circular orbits. From such orbits, if they are unstable, the photons will either fall into the black hole or will scatter away to the eye of an observer. Since the discovery of the images of supermassive black holes M87*and Sgr A* detected by the EHT collaborations, the study related to the shadows has got a massive boost. The images of M87*and Sgr A* also provided some additional data related to the size of the black holes, their distance from the Earth and their mass. This data is sufficient to draw a comparative analysis for the theoretical models of the black holes. The comparison of the black hole shadows with the image size of M87*and Sgr A* helps us to find the values of the parameters of the black holes for which that particular black hole model is either M87*or Sgr A*. Such an analysis based on the data for M87*and Sgr A* would also be useful in testing the gravity theories. In addition, the existence of any plasma distribution around the black hole can also be tested.

Wormholes, energy conditions and time machines / 306

End-state of gravitational collapse of scalar and vector fields: Strong naked singularities

Authors: Karim Mosani[1]; Koushiki Bhattacharyya[2]

Co-authors: Jay Verma Trivedi [1]; Pankaj S Joshi [1]; Tapobroto Bhanja [3]

[1] *International Centre for Space and Cosmology, School of Arts and Sciences,Ahmedabad University*

[2] *Ahmedabad University*

[3] *International Centre for Cosmology and PDPIAS, Charotar University of Science and Technology*

Corresponding Author: koushiki.malda@gmail.com

In this presentation, I will discuss about the unhindered gravitational collapse of spatially homogeneous (SH) scalar fields ϕ with a potential $V_s(\phi)$, as well as vector fields $\tilde{A}$ with a potential $V_v(B)$ where $B = g(\tilde{A}, \tilde{A})$ and g is the metric tensor. If the past end-point of a causal geodesic is a singularity, then this singularity is said to be naked. Such a singularity is strong if the volume of an object vanishes when it approaches the singularity. I will discuss our results that for both scalar and vector fields, classes of potentials exist that give rise to black holes or naked singularities. I will also discuss about the classes of potentials, as well, for which the resultant singularities are strong. There is a non-zero subset of such potentials where the resultant singularities are both naked and strong. This talk is based on Phys. Rev. D **108**, 044049, 2023.

The SVOM mission in the time-domain era / 307

The mission project THESEUS in the Multi-Messenger Astronomy golden era

Author: Giulia Stratta[1]

[1] *Goethe University Frankfurt*

Corresponding Author: stratta@physik.uni-frankfurt.de

Recent breakthrough discoveries in multi-messenger astronomy include the first identifications of cosmological neutrino and gravitational wave sources. Among these are well-known gamma/X-ray transient sources such as active galactic nuclei and gamma-ray bursts. Several more identifications are expected over the next decade. However, it will only be in the second half of the 2030s that statistically significant samples will become available, thanks to the anticipated one order of magnitude increase in sensitivity of next-generation neutrino and gravitational wave detectors that will be operational by then. By that time, gamma/X-ray surveyors like THESEUS will play a crucial role in detecting and accurately localizing the gamma/X-ray counterparts, enabling multi-band follow-up campaigns and detailed source characterization. In this talk, I will introduce the THESEUS mission concepts and the main achievements expected during this multi-messenger astronomy golden era.

ANTARES – 15 years of multi-messenger astronomy in the sea / 308

Beyond ANTARES: the future of neutrino telescopes, a short review

Author: Vincent Cecchini[1]

[1] *IFIC Valencia - CSIC*

Corresponding Author: vincent.cecchini@gmail.com

The observation of neutrinos of cosmic origin opens a whole new field for neutrino astrophysics. This quest has been paved by pioneering experiments in the second half of the 20th century and is now at the dawn of a new era thanks to numerous new proposals.

In this talk, I will review the continuation of neutrino astronomy following the ANTARES era by providing an overview of some of the planned Cherenkov-based neutrino detectors.

The designs of the KM3NeT neutrino telescope, currently under construction in the Mediterranean Sea, as well as other promising neutrino telescopes such as Baikal-GVD, IceCube-Gen2, P-ONE, and TRIDENT, will be described, and their main scientific objectives will be presented.
Additionally, I will briefly address some alternative detection methods suitable for the observation of extremely high-energy neutrinos, including radio detection and air-shower imaging.

Cosmic Insights from Big Data: How Machine Learning is Decoding the Universe / 309

LEMON: Modelling strong gravitational lenses in a finger snap

Author: Crescenzo Tortora[1]

[1] *INAF - Osservatorio Astronomico di Capodimonte*

Corresponding Author: crescenzo.tortora@inaf.it

New wide-field astronomical surveys are opening a new window on the Universe, by collecting data for extraordinarily vaste samples of galaxies. Strong gravitational lenses are rare astronomical events, whose actual number will increase of more than 100 times thanks to the unique data from the Euclid wide survey or the Rubin LSST observations. After finding such 100,000 strong lenses, they need to be modelled. It is therefore absolutely necessary to develop techniques which can allow to estimate precise galaxy lens and source model parameters and their uncertainties in a finger snap.

For this reason we have developped a machine learning code based on Bayesian Neural Networks, named LEMON (LEns MOdelling with Neural networks), and started to implement it within the Euclid Strong lensing pipeline, to complement the more standard and more time consuming lens modelling approaches. I will present our latest developments. We have trained the network on a sample of Euclid-like mock lenses. We model the lens using both a SIE and a power-law, characterized by the Einstein radius, the axis ratio and the position angle, and the power-law slope for the latter model. With respect to the previous version of the code we will also determine the light parameters of the lens galaxy, i.e. effective radius, Sérsic index and total magnitude. I will discuss the performance of the code, the application to real data and introduce future developments and applications.

Experimental graviation / 310

Perspectives of measuring the gravitational attraction of ultra-relativistic particle beams: A potential new testbed for gravitational theory

Authors: Christian Pfeifer[1]; Daniel Braun[2]; Dennis Rätzel[3]; Felix Spengler[None]; Marta Maria Marchese[4]; Stefan Nimmrichter[4]

[1] *ZARM - University of Bremen*

[2] *University of Tübingen*

[3] *Humboldt Universität zu Berlin*

[4] *University of Siegen*

Corresponding Author: dennis.raetzel@zarm.uni-bremen.de

The Newtonian law of non-relativistic gravity has been tested in many laboratory experiments with very high precision. In contrast, the gravitational field of ultra-relativistic matter, dominated by kinetic energy and stresses, has not been measured directly. I will examine the gravitational field of moving source masses in general relativity and scalar-tensor theory. The latter serves as an example to show that ultra-relativistic source velocities can enhance the difference of the gravitational effect on gravity sensors predicted by theories of modified gravity and general relativity significantly. This makes new regimes of gravitational theory accessible for tests, in principle. I will then report on perspectives to detect the gravitational attraction due to proton bunches at the Large Hadron Collider (LHC). Bounds on the necessary sensitivity will be given and compared with abilities of state-of-the-art optomechanical sensors. Due to the length of the LHC's proton beam of 27 kilometers, correlated measurements with many detectors could facilitate the measurement. I will shortly dicuss the possibility to coherently couple sensors to achieve the optimal scaling with their number.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 311

Vibrating ring around black hole

Author: Martin Kološ[1]

[1] *Institute of Physics, Silesian University in Opava*

Corresponding Author: martin.kolos@physics.slu.cz

A thin circular structure vibrating in the central plane of a black hole will be investigated. This circular ring (string loop) can be considered a simplified model for thin magnetic flux tubes (in plasma physics), and connections to accreting fluid structures around the black hole will be demonstrated. The stability of the string loop and the frequencies of its vibrational modes will be provided and compared with the vibrational modes of thick toroidal fluid structure around black holes, which is the standard analytical model for the temporal properties of accretion flow.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 312

Magnetar Giant Flares

Author: Eric Burns[None]

Corresponding Author: ericburns@lsu.edu

Magnetars were discovered as soft gamma-ray repeaters by gamma-ray burst monitors. Their most energetic events are giant flares, seen as a bright, short flash followed by an exponentially-decaying periodic tail. There have been 3 such events seen in the Milky Way and Large Magellanic Cloud in ~60 years of observing. When these events occur in nearby galaxies their tail emission is undetectable, and they appear as short gamma-ray bursts. We have now identified 6 extragalactic magnetar giant flares, allowing for the first population studies on rates and host galaxy types, providing key information in the quest to understand their progenitors. We will discuss recent results and on-going work.

Cosmic Insights from Big Data: How Machine Learning is Decoding the Universe / 313

Strengthening leverage of Astroinformatics in inter-disciplinary Science

Author: Massimo Brescia[1]

[1] *Department of Physics - University Federico II of Napoli*

Corresponding Author: massimo.brescia@unina.it

Most domains of science are experiencing a paradigm shift due to the advent of a new generation of instruments and detectors which produce data and data streams at an unprecedented rate.
The scientific exploitation of these data, namely Data Driven Discovery, requires interoperability, a massive and optimal use of Artificial Intelligence methods in all steps of the data acquisition, processing and analysis, the access to large and distributed computing HPC facilities, the implementation and access to large simulations and interdisciplinary skills that usually are not provided by standard academic curricula. Furthermore, in order to cope with this data deluge, most communities have leveraged on solutions and tools originally developed by large corporations for purposes other than scientific research, and accepted compromises to adapt them to their specific needs. Through the presentation of several astrophysical use cases, we show how the data driven based solutions could represent the optimal playground to achieve the multi-disciplinary methodological approach.

Gravitational lensing, shadows and photon rings / 314

Shadows of supermassive dark compact objects at galaxy centers

Authors: Carlos Raúl Argüelles[1]; Florencia Vieyro[2]; Joaquin Pelle[3]

[1] *Universidad Nacional de La Plata*

[2] *IAR & CONICET*

[3] *FAMAF & CONICET*

Corresponding Author: carlosarguelles80@hotmail.com

Current images of the supermassive black hole (SMBH) candidates observed at the center of our Galaxy and M87, have opened an unprecedented era to study both, gravity in its strong regime and the very nature of the relativistic sources. Very-long-baseline interferometry (VLBI) data show images consistent with a central black hole as predicted by General Relativity (GR). However, it is important to consider whether similar images can be obtained from other kinds of well-motivated dark compact objects without abandoning the Einstein theory of Gravity. It has been recently shown that by modeling the dark matter (DM) halos as a self-gravitating system of neutral fermions within GR, they can harbor very dense fermionic cores at their centers, which can mimic spacetime signatures of a BH. Such dense and horizonless cores of DM can satisfy the constraints imposed by observations, i.e. to be supermassive and compact and to lack a hard surface.
In this talk we show the resulting relativistic images of the fermionic cores under the assumption that photons are emitted from standard α discs which are self-consistently solved in the current DM framework.
We repeat the imaging analysis for different DM particle masses and viewing angles. Remarkably, the disk around the DM core casts a shadow surrounded by a ring-like feature of the lensed photons that resembles that expected in the BH scenario.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 315

Non-minimal coupling, negative null energy, and effective field theory

Author: Eleni-Alexandra Kontou[1]

[1] *King's College London*

Corresponding Author: eleni.kontou@kcl.ac.uk

Even classical scalar fields, non-minimally coupled with the curvature, can violate energy conditions such as the null energy condition. In the context of quantum field theory, non-minimally coupled scalars can obey lower bounds, known as quantum energy inequalities, but these are always state dependent. In this talk I will discuss classical and quantum bounds on the null energy and consider possible violations. Further, I will examine the conformal transformation between Jordan and Einstein frames both classically and semiclassically. Finally, I will comment on extensions of this work and connections with self-interacting fields.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 316

The fast variability properties of Galactic black hole binaries: An explanation of soft/hard time lag

Author: Broja G. Dutta[1]

Co-author: Sandip K. Chakrabarti [2]

[1] *Rishi Bankim Chandra College (WB State University)*

[2] *Indian Centre for Space Physics*

Corresponding Author: brojadutta@gmail.com

The fast variability properties of Galactic black holes binaries can be satisfactorily explained by considering multiple physical mechanisms, such as Comptonization, reflection, variation in accretion geometry, focusing due to gravitational bending, and the effect of disk-jet connections. The nature of variability i.e., soft/hard time lag in Black Hole Transients, is complex due to the interplay of multiple nonlinear physical mechanisms. In the Propagatory shock Oscillation Solution (POS) scenario, the observed QPO frequency gives out the location of shock i.e., the size of the Comptonizing region. The frequency drifting implies the geometrical variation of the Comptonizing region, i.e., a radial movement of the shock front. This drifting is triggered by the cooling of the post-shock region due to the variation in Keplerian and Sub-Keplerian accretion rates. We have studied a few Galactic Black hole transients e.g., GRS 1915+105, XTEJ 1550-564, GX 339-4, H 1743-322, XTE J1650-500 etc. and found that the evolution of QPOs is independent of inclination because the shock movement depends on the accretion rates and not the inclination. However, the time lag evolution changes sign when the accretion rate and disk geometry vary for both high and low inclination sources. We conclude that the origin of soft/hard lag can be satisfactorily explained by the these changes in the accretion geometry result in alterations in the dominant physical mechanisms of the governing accretion dynamics.

ANTARES – 15 years of multi-messenger astronomy in the sea / 317

Physics beyond the standard model with the ANTARES neutrino telescope

Author: Chiara Poirè[1]

[1] *Università degli studi di Salerno - INFN Napoli*

Corresponding Author: cpoire@unisa.it

Neutrinos can be used to probe a vast number of physics phenomena, as in the case of searches for dark matter candidates in astrophysical objects. Dark matter particles can accumulate in massive astrophysical bodies and annihilate into Standard Model particles that can yield neutrinos. To detect neutrinos, large arrays of light sensors located at great depth and in a large volume of transparent material are needed. The ANTARES neutrino telescope has operated for 15 years in the Mediterranean Sea starting in 2007. Neutrino events collected by this telescope have been used to test the Weakly Interacting Massive Particle (WIMP) hypothesis for dark matter in the Galactic Centre, the Sun, the center of the Earth.
Beyond the hypothesis of WIMP dark matter particle, also secluded dark matter models in which dark matter annihilates into mediators which subsequently decay into Standard Model particles, have been investigated. A neutrino telescope can perform searches for other physics signals beyond the Standard Model, and ANTARES has also searched for heavy nuclearites and magnetic monopoles. In this talk an overview of the results achieved by ANTARES in indirect dark matter searches, searches for heavy nuclearites and magnetic monopoles is given.

Machine learning in astronomy: AGN, transient events, cosmology and others / 318

Detection of Gravitational Waves from Repetitive Magnetar Bursts Using Autoencoder-Based Denoising and Stacking

Author: Hugo EInsle[1]

[1] *Université Côte d'Azur*

Corresponding Author: hugo.einsle@oca.eu

Unmodeled gravitational-wave signals from magnetars are expected to be weak and challenging to detect in LIGO-Virgo-KAGRA data. We introduce a new method to denoise and stack signals from repetitive magnetar bursts, such as the 2020 SGR 1935+2154 burst storm which produced 217 bursts in 1120 seconds. Our method involves identifying bursts in electromagnetic data and searching for corresponding gravitational signals in time-frequency (TF) maps. We use autoencoders to denoise the gravitational data for each burst and stack the denoised TF-maps to increase the significance of a potential repetitive signal. Results on simulated data showed that the detection statistic of both stacked synthetic signals and background noise both evolve logarithmically with the number of stacked TF-maps, signals detection statistic evolving 54% faster, demonstrating the method's effectiveness. We will present the method for denoising and stacking, and the detection perfomances on both simulated and real data based on synthetic signals.

Wormholes, energy conditions and time machines / 319

Casimir Wormholes with Temperature and Charge

Author: Remo Garattini[1]

[1] *Università degli Studi di Bergamo*

Corresponding Author: remo.garattini@unibg.it

We describe the connection between a traversable wormhole and the Casimir effect. With the help of an equation of state we also discuss different forms of solutions related to the Casimir source. The effect of including an electromagnetic field and a temperature to the original energy density are also discussed.

Fast radio bursts / 320

Shedding light on the FRB phenomenon using Italian radiotelescopes

Author: Davide Pelliciari[1]

Co-authors: Gianni Bernardi [2]; Maura Pilia [3]; Paolo Esposito [4]; Andrea Geminardi [5]

[1] *University of Bologna (UniBo) - IRA/INAF (Bologna)*

[2] *INAF - Istituto di Radio Astronomia (Bologna)*

[3] *INAF - Osservatorio Astronomico di Cagliari*

[4] *University School for Advanced Studies IUSS Pavia*

[5] *INAF - Osservatorio Astronomico di Cagliari, University School for Advanced Studies IUSS Pavia*

Corresponding Author: davide.pelliciari@inaf.it

Fast radio bursts (FRBs) are bright millisecond radio transients observed at extragalactic distances, whose origin is still highly debated. In this presentation, I summarize the key findings from two recent studies that leverage observations conducted with the Northern Cross radio telescope at 408 MHz, aimed at shedding light on the enigmatic FRB phenomenon. We investigated how prevalent magnetars such as SGR J1935+2154 are within FRB progenitors. We conducted a long monitoring on a sample of 7 star-forming nearby galaxies (< 12 Mpc). We do not report any FRB candidate coming from the selected galaxies, allowing us to place stringent upper limits on the event rate per magnetar. We also exploit the Northern Cross in a long multiwavelength monitoring of FRB 20220912A, one of the most active repeaters known. During 6 months of observations, we report 16 new bursts from the source at 408 MHz. We show that the burst energy distribution resembles the one of another hyperactive repeater, hinting for a similar emission mechanism. We also report no detections at 1.4 GHz from observations conducted with the Medicina 32-m single dish. We find that FRB 20220912A has shown a decline of 4 orders of magnitude in its bursting activity at 1.4 GHz over a one year time scale compared to literature observations, while remaining active at 408 MHz.

Multi-messenger astronomy with gravitational waves / 321

Multi-messenger Astronomy: The Benefit and Contribution of TianQin

Author: En-Kun Li[1]

[1] *Sun Yat-sen University*

Corresponding Author: lienk@mail.sysu.edu.cn

TianQin, a space-based gravitational wave (GW) detector scheduled for launch in the mid-2030s, promises groundbreaking insights into the Universe. Operating in the milli-Hertz band, TianQin can detect a diverse array of sources, including double white dwarfs (DWDs), massive black hole binaries (MBHBs), stellar-mass black hole binaries (SBHBs), extreme mass ratio inspirals (EMRIs), and the stochastic gravitational wave background (SGWB). In this report, we will focus on the benefit and contribution of TianQin to multi-messenger astronomy. With the help of the electromagnetism (EM)detection data from Gaia early data release 3 and Zwicky Transient Facility, we have confirmed 2/5 new potential DWDs as GW candidates for TianQin/LISA, which can be used as verification binaries for TianQin/LISA [2302.02802]. If the GW from an MBHB passes near some massive objects, such as massive galaxies, the strong lensing of the gigantic black hole on the GWs, together with the redshift of the lensing, can give strong constraints on the cosmology parameters [2304.10435]. The merger of MBHBs can result in strong EM radiation, so the near real-time data transmission and the near real-time data analysis of the GW with TianQin make the follow-up EM detections possible, and the MBHBs become a potential multi-messenger source [2309.06910]. Using the sky localization error box determined by the detected SBHB GW signals, one can weigh the galaxies and then get the redshift information of the SBHBs. Adopting the source's angular diameter distance

obtained from GW and the redshift from the galaxies catalogue, one can constrain the parameters of cosmology [2110.05224]. The stripped mass from the white dwarf accreted by the central black hole produces periodic X-ray burst signals1, and these systems can be treated as some EMRIs. Thus, these events may be another type of multi-messenger source. The combined detection can provide more information on the system [2307.08231].

Repeating transients in galactic nuclei: confronting observations with theory / 322

Tidal Disruption Events and Their Connections to Repeating Nuclear Transients

Author: Taeho Ryu[1]

[1] *Max Planck Institute for Astrophysics*

Corresponding Author: tryu@mpa-garching.mpg.de

Tidal disruption events (TDEs) are one of the most dramatic nuclear transients in which a star is destroyed by the intense tidal force of supermassive black holes in a few hours, generating a flare luminous enough to outshine the entire host galaxy. Since its first detection in the 1990s, the number of detected events have been steadily growing thanks to ongoing surveys and telescopes, such as Pan-STARRS, ATLAS, and ASAS-SN, reaching approximately one hundred. The number will dramatically growth by the observations of future transient surveys such as LSST and ULTRASAT. Early TDE candidates are mostly characterized by a single peak in luminosity. However, as more TDEs have been observed, a few surprises have emerged. One notable surprise is the observation of repeated nuclear transients with a range of peak-to-peak timescales, including quasi-periodic eruptions. Although the origin of such events have not been confirmed, some may have close correlations with TDEs. In this talk, I will review the theory of TDEs, focusing on the types of TDEs that can produce repeating flares.

Dark matter halos: its nature, modeling & tracers / 323

Stellar streams embedded in a fermionic dark matter halo

Author: Santiago Collazo[1]

Co-authors: Carlos Raúl Argüelles [2]; Martín Mestre [1]

[1] *Instituto de Astrofísica de La Plata*

[2] *La Plata National University & ICRANet*

Corresponding Author: scollazo@fcaglp.unlp.edu.ar

For the first time in the literature, a dark matter (DM) halo model based on first physical principles such as (quantum) statistical mechanics and thermodynamics is used to try to reproduce 6D phase-space observations in stellar streams. We model both DM haloes, the one of the progenitor and the one of its host with a spherical self-gravitating system of neutral fermions which accounts for the effects of particles escape and fermion degeneracy, the latter causing a high-density core at the center of the halo. Full baryonic components for each galaxy are also considered. We analyze cold streams (such as GD-1) as well as the Sagittarius (Sgr) stream. For the later we use a spray algorithm with ~10^5 particles to generate the Sgr tidal debris which evolves in the combined gravitational potential of the host-progenitor system, to then make a direct comparison with the full phase-space data of the stream. We repeat this kind of simulations for different parameter setups of the fermionic model with special attention to test different DM halo morphologies allowed by the physics. We find that both allowed profiles, i.e. polytropic or power law-like, can fit the essential features of the stellar debris. Additionally, in the case of the polytropic halo, and thanks to the dense and compact fermion-core, it can provide a good alternative to the black hole scenario in SgrA*. Finally we show that both

models fail to reproduce the exact phase-space distribution of stars through the end of the leading arm of the Sgr stream, conclusion which is shared by former analysis using spherically symmetric haloes.

Causal set theory / 324

The Causal Set Path Integral and an Emerging Continuum

Author: Steven Carlip[1]

[1] *University of California at Davis*

Corresponding Author: carlip@physics.ucdavis.edu

Causal set theory offers a simple and elegant picture of discrete physics. Unfortunately, though, the vast majority of causal sets do not look anything like continuum spacetimes, and must be excluded if the theory is to describe our actual universe. I will summarize recent results that show that almost all non-manifoldlike causal sets are, in fact, extremely strongly suppressed in the gravitational path integral. This does not quite yet demonstrate the emergence of a continuum—we don't understand enough about the remaining unsuppressed causal set—but it is an important step forward.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 325

X-ray polarization from magnetar sources

Author: Roberto Taverna[1]

[1] *Dipartimento di Fisica e Astronomia - Università degli Studi di Padova*

Corresponding Author: roberto.taverna@unipd.it

The launch of the IXPE telescope in late 2021 finally made polarization measurements in the 2-8 keV band a reality, more than 40 years after the pioneering observations of the OSO-8 satellite. In the first two years of operations, IXPE targeted more than 60 sources, including four magnetars, neutron stars with magnetic fields in the petaGauss range. In this presentation I will summarize the IXPE main findings and discuss their implications for the physics of ultra-magnetized neutron stars. Polarimetric observations confirmed theoretical predictions, according to which X-ray radiation from magnetar sources is highly polarized, up to ~80%, the highest value detected so far. This provides an independent confirmation that magnetars are indeed endowed with a super-strong magnetic field and that the twisted magnetosphere scenario is the most likely explanation for their soft X-ray emission. Polarization measurements allowed us to probe the physical conditions of the star's outermost layers, showing that the cooler surface regions are in a condensed state, with no atmosphere on top. Although no smoking-gun of vacuum QED effects was found, the phase-dependent behavior of the polarization angle strongly hints that vacuum birefringence is indeed at work in magnetar magnetospheres.

Future innovations in gamma-ray astronomy / 327

GammaTPC: A Next-Generation MeV Gamma-Ray Instrument

Authors: Bahrudin Trbalic[1]; Tom Shutt[2]

[1] *Stanford University*

[2] *SLAC*

Corresponding Author: bahrudin@stanford.edu

Exploring the mid-range γ-ray regime (0.1-50 MeV) remains a significant challenge in astrophysics due to the lack of sensitive instruments in this energy band. To address this gap, we propose the GammaTPC, a novel MeV γ-ray instrument concept utilizing a liquid argon (LAr) time projection chamber (TPC). This instrument aims to achieve an all-sky survey capability with a large effective area, extensive field of view, and high sensitivity to polarization. The GammaTPC promises pointing and energy resolution comparable to or exceeding current missions, such as AMEGO, by using a novel charge readout architecture (GAMPiX).

The GammaTPC concept leverages the benefits of a TPC, such as fine spatial resolution and effective background reduction, to enhance the detection of Compton and pair production events. Additionally, GammaTPC's ability to measure electron recoil tracks significantly enhances angular resolution and polarization detection. Its large area and the use of inexpensive active material, liquid argon, make it a cost-effective solution for high-sensitivity γ-ray observations.

Preliminary Monte Carlo simulations indicate that GammaTPC will significantly surpass the sensitivity of existing instruments, offering a transformative leap in γ-ray astronomy. This development promises to fill the observational gap in the mid-range γ-ray band and open new windows for studying cosmic phenomena, including relativistic jets, nuclear processes, and potential dark matter signatures, thereby advancing our understanding of the universe.

A NICER view of extreme gravity from the International Space Station / 328

First Detection of Soft-Lag in GRS 1915+105 at HFQPO during Soft State: A Multi-Mission Approach

Author: Broja G. Dutta[1]

Co-authors: Prajjwal Majumder [2]; Anuj Nandi [3]

[1] *Rishi Bankim Chandra College (WB State University), Naihati, North 24 Parganas*

[2] *Rishi Bankim Chandra College (WB State University), Naihati, West Bengal 743165, India*

[3] *Space Astronomy Group, ISITE Campus, U. R. Rao Satellite Centre, Bangalore 560037, India*

Corresponding Author: brojadutta@gmail.com

The Galactic X-ray black hole candidate GRS 1915+105 exhibits high-frequency quasi-periodic oscillations (HFQPOs) at ~ 67 Hz only during the radio-quiet 'softer' variability classes. We have studied the long-term X-ray variability from 1996 to 2017 using observations from RXTE, AstroSat, NuSTAR and NICER. AstroSat observations reveal the first detection of a soft-lag for higher energy photons (6-25 keV) relative to soft photons (3-6 keV), associated with the ~ 67 Hz HFQPO, in the range from 0.40 to 1.68 milliseconds. We find a consistent lag-energy correlation, where the soft-lag increases with energy, peaking at ~18 keV across all variability classes (δ, ω, κ, and γ). An extensive study of the γ variability class reveals an evolution of HFQPOs from ~ 69 Hz to 66 Hz and then up to 71 Hz. We observed a transition from hard to soft lag using the RXTE and AstroSat observations. Broadband spectral analysis indicates a higher bolometric flux with a lower electron temperature (kTe) of the corona during observations without HFQPO. We confirmed from the NICER/NuSTAR observations that the observed soft-lag could be due to the presence of a reflection mechanism in accretion dynamics.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 329

Accretion processes around compact objects

Author: Banibrata Mukhopadhyay[1]

[1] *Indian Institute of Science*

Corresponding Author: bm@iisc.ac.in

I will first plan to review the accretion phenomenology and underlying models, mostly for a black hole. I will attempt to touch upon, how over the decades with the evolution of observations with newer data, newer models are proposed to explain them: standard Shakura-Sunyaev Keplerian disk, advective sub-Keplerian disk, magnetically arrested (advective) disk, etc. Finally, I will aim to uncover two particular issues: QPOs and ULXs, based on one of the modern accretion theories.

Massive white dwarfs and related phenomena / 330

Super-Chandrasekhar white dwarfs

Author: Banibrata Mukhopadhyay[1]

[1] *Indian Institute of Science*

Corresponding Author: bm@iisc.ac.in

Over more than a decade, along with my group members I have been exploring the possible violation of Chandrasekhar mass-limit significantly and possible new mass-limit(s). They are indirectly supported by some observations of peculiar type Ia supernovae. The potential reasons behind such a violation could be magnetic field, modified gravity, noncommutative spacetime etc. Many other groups also, following our initiation, showed similar violation based on alternate physics. I will attempt to review this topic and its evolution, based on the single degenerate scenario.

Mid-frequency gravitational waves (0.1-10 Hz): sources and detection methods / 331

Updates on the ZAIGA project

Author: Dongfeng Gao[None]

Corresponding Author: dfgao@apm.ac.cn

ZAIGA (the Zhaoshan long-baseline Atom Interferometer Gravitation Antenna) is a proposed underground long-baseline atom interferometer (AI) facility, aiming for experimental research on gravitation and related problems. It includes gravitational wave detection (ZAIGA-GW), dark matter detection (ZAIGA-DM), high-precision test of the equivalence principle of micro-particles (ZAIGA-EP), clock-based gravitational red-shift measurement (ZAIGA-CE-R), rotation measurement and gravitomagnetic effect (ZAIGA-RM and ZAIGA-GG).

In this talk, we will report the current status of the ZAIGA project, including the brief overview, the environment and infrastructure design, and the development on key unit technologies.

References:

1 Mingsheng Zhan et al., ZAIGA: Zhaoshan Long-baseline Atom Interferometer Gravitation Antenna, Int. J. Mod. Phys. D 29, 1940005 (2020)
[2] Wei Zhao, Xitong Mei, Dongfeng Gao, Jin Wang, and Mingsheng Zhan, Ultralight scalar dark

matter detection with ZAIGA, Int. J. Mod. Phys. D 31, 2250037 (2022).
[3] Pre-research report of the ZAIGA project, not published.

Slowly rotating pulsars / **332**

The current observational landscape of ultra-long period transients

Author: Kaustubh Rajwade[1]

[1] *University of Oxford*

Corresponding Author: kaustubh.rajwade@physics.ox.ac.uk

Ultra-long period (ULP) radio transients are one of the most recent mysteries in compact object astrophysics. Theories suggest that these could be slowly spinning neutron stars or white dwarfs. However, the confirmation of either (or both) would be a giant leap toward understanding the evolution of compact objects and the physics of coherent radio emission. This has led to large-scale image-plane searches for this emerging population at various radio facilities around the globe. In this talk, I will give a brief overview of the observational constraints we have on the currently known population of ULP transients. I will go over the various search techniques and selection biases that exist in archival searches and provide a description of new image-domain techniques being used to discover this new population. I will also briefly discuss the various observed properties of the sources and compare them to some of the other similar astrophysical phenomena. I will conclude by presenting a new ULP transient discovery with the LOFAR telescope and an outlook toward the future of this exciting emerging field.

Black holes in alternative theories of gravity / **333**

The canonical ensemble of a self-gravitating matter thin shell in asymptotically AdS

Author: Tiago Fernandes[1]

Co-authors: Francisco Gandum [2]; José Sande Lemos [2]

[1] *IST, CENTRA, GRIT*

[2] *IST. CENTRA, GRIT*

Corresponding Author: tiago.vasques.fernandes@tecnico.ulisboa.pt

We construct the canonical ensemble of a matter thin shell in asymptotically AdS using the Euclidean path integral approach.
We impose spherical symmetry, the Hamiltonian and momentum constraints, the hot AdS regularity conditions and the asymptotic behaviour of AdS on the metrics summed in the path integral and obtain the reduced action, which can be regarded as a generalized free energy. We then perform the zero loop approximation, i.e. the path integral is given solely by the contribution of the stationary points of the action. We obtain the equations of stationarity and stability in general, showing that stability is guaranteed if the gravitational radius increases as temperature increases and if the shell is mechanically stable. We show this system can be described as a particular case of a system only dependent on the gravitational radius although one looses the mechanical stability condition.
We use a specific equation of state for the shell and find five solutions for the shell, with two solutions being stable: one with no shell, i.e. hot AdS; and one with a shell.
We obtain the thermodynamic quantities of the ensemble, the mean energy, the mean

pressure and the entropy, which in this case corresponds to the entropy of the shell.
The ensemble is thermodynamically stable if the heat capacity is positive, while the mechanical stability cannot be described by thermodynamic variables of the system.
We compare the two stable solutions and the stable black hole solution of Hawking and Page in the context of phase transitions and determine the favorable solution for fixed temperatures, by analyzing which solution has the lowest free energy.

Repeating transients in galactic nuclei: confronting observations with theory / 334

qUFOs as the key observational feature of SMRIs

Author: Petra Suková[1]

Co-authors: Francesco Tombesi [2]; Vladimír Karas ; Dheeraj Pasham [3]; Michal Zajaček [4]

[1] *Astronomical Institute of the CAS*

[2] *Tor Vergata University of Rome*

[3] *Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, MA, USA*

[4] *Masaryk University*

Corresponding Author: petra.sukova@asu.cas.cz

Recently, a previously quiescent nearby galactic nucleus, ASASSN-20qc, went to an outburst during which it has shown quasioperiodic ultra-fast outflows (qUFOs) with changing column density every cca 8 days. Different physical mechanisms have been proposed to explain such behaviour, with the most promising scenario being the smaller, probably intermediate-mass black hole, orbiting the primary supermassive black hole at the distance of about a hundred gravitational radii of the primary (see also the talk by Michal Zajacek). The secondary black hole is punching through the accretion flow launching fast outflowing blobs of gas ($\sim 0.3c$), which are causing repeating absorption events. We will examine the potential launching mechanisms of UFOs and show GRMHD simulation for the SMRI (Small Mass Ratio Inspiral) scenario. We will discuss the importance of observing UFOs and their variability in large sky surveys.

ANTARES – 15 years of multi-messenger astronomy in the sea / 335

Searches for Diffuse and Galactic neutrino emissions with ANTARES telescope

Author: Théophile Cartraud[1]

[1] *APC*

Corresponding Author: cartraud@apc.in2p3.fr

The ANTARES neutrino telescope has collected data from February 2007 until its shutdown in February 2022. The full ANTARES dataset, including both track-like and shower-like events, has been used to search for both a diffuse, and a galactic neutrino flux. The latter being either evaluated agnostically through the contribution of the Galactic ridge with a single power law, or by evaluating different models of galactic emission.
This talk will review the results of these analyses, which revolve around two kinds of methods. First, a Bayesian counting approach for both the diffuse and galactic ridge analysis is presented. Second, a frequentist likelihood analysis is applied for phenomenological models such as KRA-γ, CRINGE or Fermi-LAT $_0$, but also toy-models modelling the Galactic Ridge analysis

Strong electromagnetic and gravitational field physics: From laboratories to early Universe / 336

Adiabatic regularization for massive and massless spin-1 fields

Author: Javier Marañón González[1]

Co-author: Jose Navarro-Salas [2]

[1] *Universidad de Valencia / IFIC*

[2] *University of Valencia-IFIC (CSIC)*

Corresponding Author: jmarag@ific.uv.es

The adiabatic regularization method is likely the most direct and intuitive subtraction scheme for FLRW cosmologies. The method requires one to start with a nonvanishing mass, but massless theories can be studied by taking the massless limit at the end of the calculations. In fact, the conformal anomaly for scalar fields was first derived with the adiabatic method by taking the massless limit. For spin-1, however, this limit changes the number of degrees of freedom, so it cannot be performed directly.

In this work, we show a direct approach that begins with the canonical quantization of a massive Proca field in FLRW. We give the details of the construction and show that, in the massless limit, the renormalized stress-energy tensor of the Proca field is closely related to that of a minimally coupled scalar field.

Bibliography: [DOI 10.1103/PhysRevD.108.125001]

Galactic and extragalactic magnetars: recent observations and theoretical progress / 337

Magnetars in the Infrared

Author: Bettina Posselt[1]

Co-authors: George Pavlov ; Jeremy Hare ; Oleg Kargaltsev

[1] *University of Oxford*

Corresponding Author: bettina.posselt@physics.ox.ac.uk

Most of our knowledge about magnetars and pulsars is based on high-energy or radio observations. Due to the faintness of neutron stars in the infrared and the limited availability of space missions covering the wavelengths between millimeter wavelengths and the visible light, infrared studies of these compact objects are sparse. Yet, there is a lot of discovery potential at these wavelengths. The recently launched JWST allows us to probe the physics of magnetars and their environments with deep infrared observations.
A particularly interesting example is the bright magnetar 4U 0142+61 for which Wang et al 2007 reported an infrared excess, based on Spitzer observations, that was interpreted as a passive disk. Our JWST observing campaign measured the infrared emission of 4U 0142+61 over a wider wavelength range than has been previously possible. This presentation will summarize our surprising results, discuss their implications for the infrared emission process, and put them into perspective with respect to other infrared observations of neutron stars.

A NICER view of extreme gravity from the International Space Station / 338

Determining the spin-down power of the radio-quiet isolated neutron star RX J0806.4-4123

Author: Bettina Posselt[1]

Co-authors: Frank Haberl ; George Pavlov ; Wynn Ho

[1] *University of Oxford*

Corresponding Author: bettina.posselt@physics.ox.ac.uk

We present the strategy, analysis, and results of our four-year timing program of RX J0806.4-4123 with NICER. RX J0806.4-4123 belongs to the group of radio-quiet X-ray thermal isolated neutron stars (XTINSs) that are located between the rotation-powered pulsars and the magnetars in the P-Pdot diagram. The slowly rotating XTINSs constitute a key population to learn about the structure, physics and population diversity of neutron stars. RX J0806.4-4123 is close (~250pc) and shows interesting multiwavelength properties that seemingly deviate from those of similar neutron stars. The spin-down power is a critical parameter in the physical interpretation of the multiwavelength findings. We will also discuss a simple and universal method for estimating the uncertainties of frequency and its derivative based on the Z^2_K statistics (K is the number of Fourier harmonics).

Causal set theory / 339

Measuring spatial distances in causal sets via causal overlaps

Author: Marián Boguñá[1]

[1] *Universitat de Barcelona*

Corresponding Author: marian.boguna@ub.edu

We introduce a new approach to measuring proper distances between space-like separated events in Minkowski spacetimes of any dimension. Interestingly, this approach allows us to measure distances up to the Planck scale with arbitrary precision. It also enables us to define reference frames and evaluate some kinematic quantities along time-like paths.

GRB-SN connection / 340

Magnetars as Powering Sources of Gamma-Ray Burst Associated Supernovae

Author: Amit Kumar[1]

[1] *University of Warwick, UK*

Corresponding Author: amit.kumar.3@warwick.ac.uk

The era of long gamma-ray bursts (LGRBs) and supernovae (SNe) connections started with the discovery of the first direct temporal and spatial connection of GRB 980425 and SN 1998bw. This field has evolved enormously over the last two decades, with more than fifty LGRBs and SNe association events. The association of a SN with a GRB can be seen as a late-time bump in the optical/NIR light curves after fading the afterglow nearly 2-3 days after the burst. Numerous studies suggest that LGRBs and stripped-envelope SNe share similarities in their progenitors and host environments to some extent. Another probable contributing factor to these events' diversity in observed properties could be the underlying powering mechanism, where spin-down millisecond magnetars are one of the most popular powering sources for these events. Internal plateau, extended emission, precursor and flaring activities in GRBs also support the underlying magnetars as power sources. Furthermore,

different magnetar properties, such as the initial spin period, magnetic field, and central engine activity duration, can give rise to different transient types and properties of the transients within the same class. Hence, investigating the characteristics of the central engine powering sources and comparing them across various types of transients can provide valuable insights into the distinct properties of transients (for details, see Kumar, A., et al. 2024, MNRAS, in press, arXiv:2403.18076). My talk will aim to provide a comprehensive overview of the spin-down millisecond magnetars as powering sources for GRB-SNe and the potential of magnetars with varying characteristics to give rise to a diverse array of transient events, which is crucial to understanding how the life of stars ends differently.

High energy astrophysics / 341

On the probing of non-homogeneous magnetic fields in radio supernovae

Author: Mile Karlica[1]

Co-authors: Claes Ingvar Björnsson [2]; Miroslava Vukčević [3]; Rahim Moradi [4]

[1] *ICRANet*

[2] *Stockholm University*

[3] *Astronomical Observatory of Belgrade*

[4] *ICRANet and ICRA-Sapienza*

Corresponding Author: mile.karlica@icranet.org

Observations and numerical simulations indicate that non-homogeneous magnetic fields are ubiquitous in astrophysical settings. However, in most models of astrophysical non-thermal radiation they are not treated as non-homogeneous. Here we present our analysis of non-homogeneous magnetic field of radio supernovae. Flat topped radio spectra around synchrotron self-absorption frequency points to a non-singular value of magnetic field. Building upon that, we present a numerical scheme to solve the integral equation related to synchtron self-absorption using two different inverse methods present in scipy Python library: LSMR (an iterative method) and NNLS (non-negative least square). We present the limitations of LSMR as a method which works well only with smooth magnetic field distribution functions, while NNLS works well only in the cases of the singular or discrete magnetic field value. We open the discussion about the influence of non-homogeneous magnetic fields on the radiation spectra of other known astrophysical phenomena.

Gravitational kHz waves - LIGO-Virgo-KAGRA / 342

Compact Binary Coalescences Observed by the LIGO-Virgo-KAGRA Collaboration during the First Three Observing Runs

Author: Lorenzo Piccari[1]

[1] *Sapienza University of Rome, INFN*

Corresponding Author: lorenzo.piccari@uniroma1.it

The first detection of a gravitational-wave signal emitted by a compact binary coalescence was achieved by the network of two LIGO detectors on September 14, 2015. The event, labelled GW150914, is associated with a binary black hole merger. It ushered the era of GW astronomy, offering a new way to probe our Universe.
Since then, during its first three observing runs, the LIGO-Virgo-KAGRA (LVK)
Collaboration uncovered 89 more gravitational-wave signals, collected in the Gravitational Waves Transient Catalogs (GWTCs).

These signals are all generated by compact binary coalescence sources, mostly BBHs, with a handful compatible with the presence of at least one neutron star in the coalescing binary. Among these events, there are two further outstanding ones.
1) GW170817, the first detected signal compatible with the coalescence of two neutron stars, and the only case of multi-messenger detection involving a GW signals to date.
2) GW190521, the binary black hole merger with the highest total mass
ever detected (150 $M_\odot$).
In this talk, I will provide an overview of these and other relevant observational results obtained by the LVK Collaboration during the first three observing runs.

AMS-02 experiment at the International Space Station / 343

The AMS-02 experiment on the International Space Station

Author: Mercedes Paniccia[1]

Co-author: Manuela Vecchi

[1] *University of Geneva (Switzerland)*

Corresponding Author: mercedes.paniccia@cern.ch

In twelve years on the International Space Station, AMS has collected more than 230 billion cosmic rays up to energies of multi-TeV. The precision of the magnetic spectrometer enables us to present data to an accuracy of ~1%. Explicitly, the high energy data on elementary particles (electrons, positrons, antiprotons, and protons) requires new sources of explanation. The data on nuclei and isotopes show characteristic energy dependence not predicted by any theory. The comprehensive AMS data requires a new model of the cosmos. In this contribution I will highlight the latest AMS results.

AMS-02 experiment at the International Space Station / 344

Summary of the AMS results and their interpretation

Author: Manuela Vecchi[None]

Co-author: Mercedes Paniccia [1]

[1] *University of Geneva (Switzerland)*

Corresponding Author: m.vecchi@rug.nl

In this talk, I will summarize the results presented during the Parallel session focused on the AMS-02 experiment on the International Space Station, together with their interpretation. In particular, I will discuss the latest flux measurements. The precision of AMS-02 results revealed unexpected phenomena that challenged conventional theoretical models. I will also give a brief overview of the phenomenological works presented during the session, which describe cosmic-ray origin and propagation within the Galaxy.

Black holes in alternative theories of gravity / 345

Regular multi-horizon Lee-Wick black holes

Author: Nicolò Burzillà[1]

Co-authors: Breno Loureiro Giacchini [2]; Leonardo Modesto [3]; Tibério de Paula Netto [4]

[1] *INFN, Rome 2 Tor Vergata*

[2] *Institute of Theoretical Physics, Faculty of Mathematics and Physics, Charles University*

[3] *Università di Cagliari*

[4] *Departamento de Fisica, ICE, Universidade Federal de Juiz de Fora*

Corresponding Author: nburzilla@outlook.it

We present a detailed analysis of the static spherically symmetric solutions of a sixth-derivative gravity model with complex conjugate poles (Lee-Wick gravity) in the effective delta source approximation. The solutions exhibit an interesting structure that depends on the real and imaginary part of the Lee-Wick mass $\mu = a + ib$. In particular, because of the oscillating behavior of the metric that depends on the ratio b/a, a rich structure of horizons is present.
This multi-horizon structure generates a sequence of mass gaps, and consequently, multiple regimes for black hole sizes (horizon position gaps) are present. In what concerns the thermodynamics of these objects, the oscillation of the Hawking temperature determines the presence of multiple mass scales for the remnants of the evaporation process and may permit the existence of cold black hole remnants with zero Hawking temperature~T and quasi-stable intermediate configurations with $T \approx 0$ and a long evaporation lifetime. For the sake of generality, we consider two families of solutions, one with a trivial shift function and the other with a non-trivial one (dirty black hole).

This talk is based on the paper 2308.12810 published in JCAP 11 (2023) 067.

GRB-SN connection / 346

Broad-line type Ic SN 2020bvc. Signatures of an off-axis gamma-ray burst afterglow

Author: Luca Izzo[1]

[1] *INAF-Naples and DARK/NBI*

Corresponding Author: luca.izzo@inaf.it

In this talk, I will present and discuss the evidence for an off-axis jet in the nearby broad-lined SN 2020bvc. Particular attention will be devoted to the modeling of the multi-wavelength late-time emission detected from this event, and on the signatures of cocoon emission in the very early spectra of this event.

New frontier of multi messenger astrophysics: follow up of electromagnetic transient counterpart of gravitational wave sources / 347

Kilonovae host galaxies

Author: Luca Izzo[1]

[1] *INAF-Naples & DARK/NBI*

Corresponding Author: luca.izzo@inaf.it

I will review the properties of kilonova host galaxies, focusing in particular on kilonovae detected from their associated gamma-ray burst component. A special consideration will be devoted to the physical properties of KNe, such as the offset from their hosts, and considerations on their formation channels.

Latest results from Galactic center observations / 348

Multi-wavelength view of the Galactic Center outflows

Author: Heshou Zhang[1]

Co-authors: Gabriele Ponti [1]; Ettore Carretti [2]; Ruo-Yu Liu [3]; Mark Morris [4]

[1] *INAF - OA Brera*

[2] *INAF - IRA*

[3] *Nanjing University*

[4] *UCLA*

Corresponding Author: heshou.zhang@inaf.it

The large-scale structures such as Fermi Bubbles and eROSITA Bubbles provide a unique opportunity to study our Milky Way. However, the nature and origin of these large structures are still under debate. In this talk, I will present the identification of several kpc-scale magnetised structures based on their polarized radio emission and their gamma-ray counterparts, which can be interpreted as the radiation of relativistic electrons in the Galactic magnetic halo. These non-thermal structures extend far above and below the Galactic plane and are spatially coincident with the thermal X-ray emission from the eROSITA Bubbles. The morphological consistency of these structures suggests a common origin, which can be sustained by Galactic outflows driven by the active star-forming regions located at 3 – 5 kpc from the Galactic Centre. These results reveal how X-ray-emitting and magnetised halos of spiral galaxies can be related to intense star formation activities and suggest that the X-shaped coherent magnetic structures observed in their halos can stem from galaxy outflows.

ANTARES – 15 years of multi-messenger astronomy in the sea / 349

15 Years of Transient and Multi-Messenger Astronomy with the ANTARES Neutrino Telescope

Author: Sergio Alves Garre[1]

[1] *Instituto de Física Corpuscular (CSIC-UV)*

Corresponding Author: salves@ific.uv.es

The water Cherenkov neutrino telescope ANTARES was a 0.01 km3 volume
detector located in the Mediterranean Sea which aimed at the detection of high-energy cosmic neutrinos, specially those of Galactic origin. It operated from 2007 until the beginning of 2022, accumulating more than 15 years of data. Its advantageous location allowed ANTARES to explore the Southern Sky, including the Galactic Centre with a high duty cycle while benefiting from an excellent angular resolution due to the Mediterranean water properties.

The coincident detection of the neutrino candidate IC170922A with flaring blazar TXS 0506+056 on 2017 constitutes one of the most important achievement of the multi-messenger astronomy and made clear the necessity of constant collaboration between different observatories and the benefits of constraining neutrino signal in time. ANTARES has actively participated in the search for transient neutrino signal playing an important role inside the multi-messenger community. In this talk we will briefly review all the transient analyses, results and contribution done by ANTARES during its 15 years of operation to the field of multi-messenger astronomy.

Unveiling neutrino secrets through cosmology: current status and future developments / 350

Robust neutrino mass weighing with high redshift mass maps

Author: Frank Qu[None]

Corresponding Author: jq247@cantab.ac.uk

CMB lensing provides a powerful way to measure the mass of the neutrinos. Traditional analyses of CMB lensing can suffer from biases in neutrino mass constraints if the wrong dark energy model or parametrization is assumed. In this talk, I will present a method to remove low-redshift contributions from CMB lensing mass maps, enhancing their sensitivity to high-redshift structures and becoming robust to low-redshift modelling. This is achieved by subtracting appropriately scaled galaxy density maps, effectively nulling the low-redshift structure through a model-insensitive procedure similar to delensing. This results in a high-redshift-only mass map that can uniquely probe the growth of structure at very high redshifts while also providing powerful constraints on neutrino mass.

Astrophysics with gravitational waves / 351

Detectability of exotic object mergers by current generation gravitational wave detectors

Author: Shrobana Ghosh[1]

Co-author: Mark Hannam [2]

[1] *Max Planck Institute for Gravitational Physics, AEI Hannover*

[2] *Cardiff University*

Corresponding Author: shrobana.ghosh@aei.mpg.de

Over the last decade the international network of gravitational wave detectors (LIGO-Virgo-KAGRA) have detected close to a hundred compact binary mergers. All observations have been consistent with mergers of black holes or neutron stars, but some have been posited as signals generated by the merger of exotic stars. The signal from any compact binary merger would look like that emitted by the merger of two black holes at leading order. Any deviations would be small and very sensitive to the underlying model of formation. We consider a more generic compact-binary waveform model, which allows us to make qualitative statements about the detectability of exotic mergers with current gravitational wave data analyses, and the identification of deviations from the black hole hypothesis.

Causal set theory / 352

Entropy and the Vacuum State in Causal Set Theory

Author: Joshua Jones[1]

[1] *Dublin Institute for Advanced Studies*

Corresponding Author: jjones@stp.dias.ie

One of the best known interactions between quantum field theory and general relativity is the way that horizons gain an associated entropy, given by an area law. Entanglement entropy is a particularly promising candidate as the source of this entropy, and providing an explanation for black hole entropy as entanglement entropy was one of the initial motivations behind the formulation of causal set theory. To understand entanglement entropy in causal set theory, we must be able to define quantum fields upon the causal set, and the Sorkin-Johnston prescription provides a means of doing so. We will go over the details of how we can use this prescription to define a vacuum state.

We will also give a covariant definition of entropy suitable for use within causal set theory, and go on to explain why the Sorkin-Johnston vacuum state must necessarily be pure. Finally we will show how this entropy formula can be leveraged to perform calculations of entanglement entropy within the causal set that would be intractable in continuum theories.

Massive white dwarfs and related phenomena / 353

On the possible common origin of pulsar pairs: B0834+06 and B1742-30.

Authors: Karen Gigoyan[1]; Valeri Hambaryan[2]

[1] *NAS RA Byurakan Astrophysical Observatory after V. A. Ambartsumian*

[2] *1) Astrophysikalisches Institut und Universitaets-Sternwarte Jena, 2) Byurakan Astrophysical Observatory.*

Corresponding Author: karengigoyan@bao.sci.am

Astrometric data presented in ATNF Pulsar Catalogue have enabled us to determine the trajectories through
the Galactic potential for different kick-velocity models of pulsars.
The system was disrupted ~0.2-0.8 Myr ago, which must correspond to the true age of at least one of the pulsars.
The implied pulsar birth velocities are consistent with the high velocities of neutron stars in general.
The consistency between our derived kinematic age and the spin-down age of one of the pulsars and similarity of the tangential velocities of pulsars are remarkable.

Gamma-ray bursts and AGNs with machine learning / 354

Deep learning techniques to detect and localize Gamma-ray Bursts in sky maps and time series acquired by the AGILE and COSI space missions.

Author: Nicolò Parmiggiani[1]

Co-authors: Alessandro Rizzo [2]; Alessandro Ursi [3]; Alex Ciabattoni [1]; Ambra Di Piano [1]; Andrea Bulgarelli [1]; Andreas Zoglauer [4]; Antonio Macaluso [5]; Carlotta Pittori [6]; Elisabetta Cavazzuti [3]; Gabriele Panebianco [1]; John Tomsick [4]; Luca Castaldini [1]; Marco Tavani [7]; Riccardo Falco [1]; Valentina Fioretti [1]

[1] *INAF/OAS Bologna*

[2] *INAF*

[3] *ASI*

[4] *Space Sciences Laboratory at the University of California, Berkeley*

[5] *German Research Center for Artificial Intelligence GmbH (DFKI)*

[6] *INAF/OAR Roma*

[7] *INAF/IAPS Roma*

Corresponding Author: nicolo.parmiggiani@inaf.it

AGILE is a high-energy astrophysics space mission launched in 2007 which terminated the operations in 2024. Its payload is comprised of the Gamma-Ray Imaging Detector (GRID), the SuperAGILE X-ray detector, the Mini-Calorimeter (MCAL), and an AntiCoincidence System (ACS).

Over the past few years, the AGILE Team has developed deep learning (DL) models to analyze sky maps and time series acquired by AGILE detectors.

The first method developed is designed to detect Gamma-Ray Bursts (GRBs) in the GRID sky maps above 100 MeV. The model detected 21 GRBs from an input list. We developed an additional DL model to localize GRBs in sky maps.

Then, we implemented a method to perform anomaly detection on time series data generated by the AGILE ACS to identify GRBs. The DL model detected 72 GRBs, 15 of which for the first time in the AGILE data.

We implemented a new deep neural network to predict the expected background count rates of the ACS based on the orbital and attitude parameters of the AGILE satellite. The difference between predicted and acquired count rates in the ACS data is used to detect GRBs.

We determine the p-value distribution for all DL models to evaluate the statistical significance of the detected GRBs.

Moreover, we are developing Quantum Deep Learning (QDL) models to compare them with the classical ones. The goal is to figure out how to exploit the quantum computer features.

Finally, we are developing DL models for the COSI space mission starting from the know-how acquired with AGILE. The first model aims to localize the GRBs using the count rates of the anticoincidence BGO panels and another model aims to predict the BGO background rate expected as a function of the orbital and attitude parameters to detect GRBs when the acquired rate exceeds the predicted one.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 355

Multifrequency polarimetry of High-Synchrotron Peaked blazars probes the shape of their jets

Author: Filippo Bolis[1]

Co-authors: Emanuele Sobacchi [2]; Fabrizio Tavecchio [3]

[1] *DiSAT, Università dell'Insubria and INAF – Osservatorio Astronomico di Brera*

[2] *Gran Sasso Science Institute and INAF – Osservatorio Astronomico di Brera*

[3] *INAF – Osservatorio Astronomico di Brera*

Corresponding Author: filippo.bolis@inaf.it

Multifrequency polarimetry is emerging as a powerful probe of blazar jets, especially due to the advent of the Imaging X-ray Polarimetry Explorer (IXPE) space observatory.
We study the polarization of High-Synchrotron Peaked (HSP) blazars, where both optical and X-ray emission can be attributed to synchrotron radiation from a population of non-thermal electrons. We adopt an axisymmetric stationary force-free jet model, where the electromagnetic fields are determined by the jet shape. In particular, the jet geometry is defined by the pressure profile of the external medium confining the jet. When jets are confined by a windy-like medium, they acquire a quasi-parabolic shape. In this case, the X-ray polarization degree is Pi_X ~ 15–40%, and the optical polarization degree is Pi_O ~ 5–20%. The polarization degree is strongly chromatic, as Pi_X/Pi_O ~ 2–5. The chromaticity is due to the softening of the electron distribution at high energies, and is much stronger than for a uniform magnetic field.
The Electric Vector Position Angle (EVPA) is aligned with the projection of the jet axis on the plane of the sky. These results compare very well with multifrequency polarimetric observations of HSP blazars. Instead, when the jet is nearly cylindrical, the polarization degree is large and weakly chromatic (we find Pi_X ~ 70% and Pi_O ~ 60%), close to the expected values for a uniform magnetic field. The EVPA is perpendicular to the projection of the jet axis on the plane of the sky. We also provide analytical approximated formulae, valid for small viewing angles, for both the polarization degree and the EVPA as a function of the spectral-index.
The polarization degree is highly chromatic unlike the EVPA. The polarization degree and the EVPA may be less sensitive to the specific particle acceleration process (e.g., magnetic reconnection or shocks) than previously thought.

The Euclid mission: current status, results from early observations, and future prospects / 356

Mask R-CNN for the Automated Detection of Bright Gravitational Arcs in Euclid Galaxy Clusters

Authors: Ana Acebron[1]; Claudio Grillo[2]; Giuseppe Angora[3]; Lorenzo Bazzanini[4]; Marco Lombardi[2]; Mario Radovich[5]; Massimo Brescia[6]; Massimo Meneghetti[7]; Matteo Maturi[8]; Piero Rosati[4]; Pietro Bergamini[2]

[1] *Departamento de Física Moderna Santander*

[2] *Universita' degli Studi di Milano*

[3] *INAF Napoli*

[4] *Universita' degli Studi di Ferrara*

[5] *INAF Padova*

[6] *Università di Napoli Federico II*

[7] *INAF Bologna*

[8] *Universität Heidelberg*

Corresponding Author: bzzlnz@unife.it

In the era of big data, developing robust methods for the autonomous extraction of information from vast multi-dimensional datasets is pivotal. This work focuses on utilizing a region-based convolutional neural network (Mask R-CNN) to automatically detect bright arcs produced by strong gravitational lensing in galaxy clusters, specifically for the upcoming Euclid survey. These kinds of events offer a powerful tool for probing the mass distribution of galaxy clusters and the large-scale structure of the universe. To replicate the observational conditions expected from Euclid, we used downgraded Hubble Space Telescope images of real galaxy clusters. We trained the network by simulating strong lensing events on these clusters, leveraging high-precision lensing models of 10 massive galaxy clusters within a redshift range of $0.2 < z < 0.6$. A training set of 4000 2'x2' images was generated by injecting Sersic sources near the caustic lines of each galaxy cluster. Our model achieves high completeness in the simulated test images, successfully recovering all the brightest arcs. The Mask R-CNN's training procedure involves direct processing of full-field images, circumventing the need for pre-extracted cutouts. The successful application of this method demonstrates the feasibility of using advanced neural network architectures to enhance the detection of astrophysical phenomena. Our approach is well-suited to handle the massive amounts of data expected from next-generation telescopes, showcasing the potential of deep learning to significantly advance the field of astrophysics.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 357

Reconstructing Dark Energy

Author: Arman Shafieloo[1]

[1] *Korea Astronomy and Space Science Institute*

Corresponding Author: arman.shafieloo@gmail.com

Reconstructing the expansion history of the universe and properties of dark energy have been among the main goals of physical cosmology. I will discuss about reconstructing dark energy in light of most recent cosmological observations including DESI-2024 BAO observations, Union3 supernova compilation and Planck CMB data.

Gravitational kHz waves - LIGO-Virgo-KAGRA / 358

Advancements in Encoding Gravitational-wave Sky Localizations: Virtual Observatory Standards and New Challenges for the Einstein Telescope

Author: Giuseppe Greco[1]

[1] *INFN-Perugia*

Corresponding Author: giuseppe.greco@pg.infn.it

The International Virtual Observatory Alliance (IVOA) plays a crucial global role in establishing technical standards necessary for realizing the Virtual Observatory (VO). Our discussion focuses on the extensive adoption of the Multi-Order Coverage map (MOC) data structure for encoding the localization regions of gravitational wave sources detected by the LIGO, Virgo, and KAGRA (LVK) collaborations. Through practical demonstrations, we will illustrate how the adoption of this standard facilitates planning and interoperability in multi-messenger activities across a network of telescopes.
In the era of the Einstein Telescope (ET), hundreds of thousands of alerts will need to be combined in real-time with the electromagnetic facilities available at that time. We present the latest advancements in expanding MOCs to handle spatial and temporal information simultaneously, highlighting their potential to manage the substantial data stream.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 359

Modelling neutron star magnetic fields

Author: Brynmor Haskell[1]

[1] *Nicolaus Copernicus Astronomical Center, PAS*

Corresponding Author: bhaskell@camk.edu.pl

The magnetic field of a neutron star plays a key role in its evolution and the dynamics of the emission, both electromagnetic and gravitational. Nevertheless the field configuration of these stars is still highly uncertain. In this talk I will review the main issues involved in modelling the magnetic field, and recent advances.

Black hole formation, evolution and the black hole mass gap / 360

Gravitational wave echos from physical black holes

Author: Yu-Song Cao[1]

[1] *Beijing University of Technology*

Corresponding Author: caoyusong15@mails.ucas.ac.cn

In this talk I will show that the theoretical model of physical black holes predict that gravitational wave echos acoompanies with all the black hole merger events in real world. The first part of my talk will be introducing the concept of physical black holes, highlighting that all the black holes in observed in astronomy should be discribed by dynamical, horizonless and singular free metric. Then I will introduce the how gravitational wave echos in physical black models and demonstrate its characters. At last I will compare our model with other mechanisms also predicting gravitational wave echos and show the echo signals predicted by our model has distinctive character over other models.

First stars and their remnants as dark matter probes / 362

Observational Puzzles and Prospectives: Growing Supermassive Black Holes at z >6

Author: Andreea Petric[1]

[1] *Space Telescope Science Institute*

Corresponding Author: apetric@stsci.edu

JWST's discoveries of black holes with masses ~ 108M⊠ when the Universe was less than 5% of its current age challenge our understanding of star and black hole formation. The leading hypothesis to explain these observations is the inflowing of a large amount of gas directly onto the SMBH from galaxy-wide scales while maintaining gas stability against star formation. However, alternatives in which the initial seeds are already massive either because they formed from dark-matter powered stars or as direct collapse black holes can successfully explain a wide range of observations. In this talk, I will discuss multiwavelength and multi-messenger observations from current and planned missions (e.g., JWST, Nancy Grace Roman, and the Square Kilometer Array) and their potential to distinguish between the various theories about the origins of supermassive black holes at z > 6.

ANTARES – 15 years of multi-messenger astronomy in the sea / 363

An overview on neutrino astronomy

Author: Luigi Antonio Fusco[1]

[1] *Università di Salerno and INFN*

Corresponding Author: lfusco@unisa.it

High-energy neutrinos can convey a significant amount of information on the mechanisms at play in astrophysical environments. Neutrino telescopes have been designed to study such signals, detecting the Cherenkov photons induced in deep waters or ice by the charged products of the neutrino interaction. The physics case for neutrino telescopes will be reviewed in this contribution, providing an overview on the most relevant results in the field.

Inflation: perturbations, initial singularities and emergent universes / 364

Quantum Geometric Models for Early Universe Cosmology

Author: Peter Schupp[1]

[1] *Constructor University*

Corresponding Author: pschupp@constructor.university

We revisit basic problems of classical Friedmann-Lemaître cosmology that motivate the idea of cosmological inflation in light of modern ideas on quantum geometry. Classical cosmology assumes the validity of General Relativity with its smooth Riemannian spacetime geometry at all scales, even below the Planck scale where quantum-gravitational effects are expected to dominate. We argue that models that take the quantum geometry of spacetime below the Planck scale into account are quite generically not affected by the horizon problem of classical cosmology. A slight adjustment of the quantization prescription of quantum field theory leads to a toy model with appropriate symmetries

and expected effects of quantum geometry, including fuzzy light cones and non-locality. Preliminary computations show that such models may be relevant not only for the horizon problem but also for the flatness problem.

Present and future of cosmic microwave background observations / 365

Can the Topology of the Universe Affect the CMB?

Author: Javier Carrón Duque[1]

[1] *Instituto de Física Teórica (IFT-CSIC)*

Corresponding Author: javier.carron@csic.es

Cosmic Microwave Background (CMB) observations traditionally assume an isotropic and homogeneous infinite Universe. However, a growing number of large-scale anomalies and dipoles in the literature suggest the need to revisit these assumptions. A physically well-motivated explanation for these anomalies is the impact of the Universe's topology. Even in a flat Universe, the topology can introduce anisotropic correlations in the CMB. In this talk, I will present the recent and ongoing work of the COMPACT collaboration on the observational effects of the Universe's topology. I will discuss the specific, testable predictions for the CMB, focusing on how advancements in data analysis and future polarization measurements can reveal the global shape of the Universe.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 366

Exploring the behaviour of long gamma-ray bursts with intrinsic afterglow correlations

Author: Samantha Oates[1]

[1] *Lancaster University*

Corresponding Author: s.r.oates@lancaster.ac.uk

We present a correlation observed in the afterglows of long duration Gamma-ray Bursts (GRBs) between the initial luminosity and average afterglow decay rate. We will show how this correlation, initially found at optical and X-ray wavelengths, is observed across the electromagnetic spectrum from the GeV to the radio. This correlation does not depend on the presence of specific light curve features and is potentially applicable to all long GRB afterglows. We will also discuss this correlation in the context of other GRB correlations. We will also explore the implications and whether the correlation is consistent with the expectations of the standard afterglow model.

A NICER view of extreme gravity from the International Space Station / 367

Following up SMBH binaries candidates with NICER to search for periodic variability.

Author: Dusán Tubín[1]

[1] *Leibniz Institute for Astrophysics Potsdam*

Corresponding Author: dtubin@aip.de

Supermassive black hole binaries (SMBHBs) represent the latest stage in the hierarchical growth of massive galaxies through major mergers. In these systems, accretion onto the black holes is expected to form two individual accretion disks around each black hole, fed by a larger circumbinary disk. Consequently, the X-ray and UV emission from these systems is expected to vary regularly, with periods comparable to that of the binary orbit. We searched the eROSITA all-sky scans for quasi-periodic signals in extragalactic sources that exhibit an 'up-down-up-down' or 'down-up-down-up' profile in their flux light curve, in the 0.2 – 2.3 keV band, indicating potential periodic variability. Despite the six-month cadence of the eROSITA observations, higher cadence monitoring programs are required to populate the light curves sufficiently to confirm or rule out their binary SMBH nature. In this talk, I will present preliminary results on the most promising candidates and their extensive NICER monitoring campaigns to confirm or reject their tentative periodicity. We will also estimate the detection rate of SMBHBs based on our searches for periodicity in the X-ray light curves and compare this to theoretical predictions.

Loop quantum gravity: cosmology and black holes / 368

Rainbow Black hole from quantum gravitational collapse

Author: Yaser Tavakoli[1]

Co-authors: Ali Parvizi [2]; Jerzy Lewandowski [1]; Tomasz Pawlowski [2]

[1] *University of Warsaw*

[2] *University of Wrocław*

I will present the quantum evolution of scalar field modes on a quantum spacetime of a collapsing, homogeneous dust ball. Without field backreaction, quantum gravity resolves classical singularities, causing a bounce on the collapse background. Including backreaction, the emergent dressed geometry becomes mode-dependent, resembling a radiation fluid. I will examine the semiclassical dynamics of this mode-dependent background, noting that backreaction accelerates the bounce compared to a dust-only scenario. Additionally, matching interior and exterior regions at the dust boundary reveals a rainbow black hole geometry in the exterior spacetime.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 369

The Quantum Perspectives of Kerr Black Hole Formation and Evaporation

Author: Jun Nian[1]

[1] *International Centre for Theoretical Physics Asia-Pacific, University of Chinese Academy of Sciences*

Corresponding Author: nianjun@ucas.ac.cn

Black holes are fascinating objects in nature. Although they are introduced as classical solutions in general relativity, their intrinsic nature should be quantum, which manifests during the black hole formation and evaporation processes. If string theory is claimed to be a quantum gravity candidate, it should be able to provide a consistent picture and elucidate some perspectives for black hole formation and evaporation. In this talk, we will focus on rotating Kerr black holes. On the one hand, we will show through a toy model that Kerr black holes can emerge naturally from the Virasoro minimal string theory. On the other hand, we use a field-theoretic approach to compute the time evolution of entanglement entropy between an evaporating Kerr black hole and its Hawking quanta, i.e., the Page curve, which provides a new resolution to the long-standing black hole information paradox. This talk is based on my recent papers, 2312.14287 and 2210.06762, and some work in progress.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 370

Proper-time flow equation and non-local truncations in quantum gravity

Author: Emiliano Maria Glaviano[1]

Co-author: Alfio Maurizio Bonanno [1]

[1] *INFN, INAF, Unict*

Corresponding Author: emiliano.glaviano@inaf.it

Functional flow equations based on proper-time (PT) regulators have attracted much interest in recent years because of their effectiveness in various non-perturbative situations, for example the exploration of the ordered phase in a scalar theory or non-perturbarive quantum gravity. In this talk in particular we study the flow of the non-local truncation in quantum gravity and we focus in particular on the Polyakov effective action for a non-minimally coupled scalar field on a two dimensional curved space. We show that it is possible to explicitly integrate the flow of all the local and non-local operator terms up to k=0 and recover effective action without the integration of the conformal anomaly. We also present the structure of the non-local term in the effective action in d=4 for Einstein gravity.

Quantum gravity phenomenology / 371

Scalar Perturbations of Regular Black Holes from Non-Singular Collapse Models in Asymptotic Safety

Authors: Alfio Bonanno[1]; Andrea Spina[2]; Antonio Panassiti[3]

[1] *INFN-INAF-Università di Catania*

[2] *INFN-Università di Catania*

[3] *Università di Catania*

Corresponding Author: andreaspina99@gmail.com

We investigate the massless scalar field perturbations, including the quasinormal modes spectrum and the ringdown waveform, of regular black hole spacetimes derived within the Asymptotic Safety program. In particular, we discuss the stability of a new class of AS black holes recently derived dynamically within a non-singular model of collapse and explore the possibility of detecting signatures of the horizon structure with high-order overtones.

Theories of gravity: alternatives to the cosmological and particle standard models / 372

Repulsive gravity in regular black holes

Author: Orlando Luongo[1]

[1] *University of Camerino, Physics Division*

Corresponding Author: orlando.luongo@unicam.it

We evaluate the effects of repulsive gravity using first order geometric invariants for regular black holes. We compare the repulsive regions with the predictions got from singular solutions. Notable characteristics and pathologies of regular black holes are thus emphasised. To heal the potential

incompleteness of regular solutions, we construct alternative regular solutions. Implications and physical consequences of our results, as well as the inclusion of novel spacetimes are discussed in detail. Particular attention is devoted to the comparison of such solutions with quasi-periodic oscillations from astronomical sources.

Latest results from Galactic center observations / 373

Spectroscopic Observations of the Milky Way Nuclear Star Cluster

Author: Anja Feldmeier-Krause[1]

[1] *University of Vienna*

Corresponding Author: anja.krause@univie.ac.at

The Galactic centre region consists of the nuclear stellar disk (NSD), a flat, rotating stellar structure, and the nuclear star cluster (NSC), the densest concentration of stars in the Galaxy.
The NSC and NSD are distinct structures of the Milky Way, but also connected to the larger Milky Way structures, e.g. via the inflow and outflow of gas, and the infall of star clusters.
Our knowledge of the larger Milky Way structures, Galactic disc, bulge and halo, has expanded in recent years through surveys and dedicated missions. But, due to high foreground extinction, the NSC and NSD are inaccessible for these surveys, and they miss an important piece for our understanding of the Milky Way's formation and evolution, leaving us with many unanswered questions, such as:
How did the NSC assemble within the NSD and the other larger structures of the Milky Way? What is NSC's history of mass accretion and star formation, can we identify distinct events?

In this talk I will present spectroscopic observations of the NSC and inner NSD, resulting in >2,500 stellar spectra, and measurements of their line-of-sight velocity and overall metallicity. These data can constrain dynamical models of the Galactic centre, which inform us about the mass distribution, dynamical structure and evolution of the NSC.

Gravitational instantons and black holes / 374

Analyzing Shadows of Naked Singularities and Black Holes

Authors: Aray Muratkhan[1]; Saken Toktarbay[2]

Co-authors: Aiazhan Orazymbet [1]; Hernando Quevedo [3]; Madina zhakipova [1]

[1] *Al farabi Kazakh National University*

[2] *Al-Farabi Kazakh National University*

[3] *Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México*

Corresponding Authors: saken.yan@yandex.com, arai12@mail.ru

We investigate the shadows produced by naked singularity spacetimes. Most analytical solutions for black hole shadows have focused on scenarios where the geodesic equations for photons. We examine the spherical null naked singularity metric, which is a spherically symmetric solution to Einstein's equations. Additionally, we consider a static, axially symmetric singular solution of the vacuum Einstein equations that can describe the gravitational field outside a mass distribution with a quadrupole moment, and which also lacks an event horizon. This spacetime is marked by the presence of naked singularities. Theoretical studies indicate that shadows can be cast not only by black holes but also by other compact objects such as naked singularities and boson stars. We provide an analytical calculation of the shadows for both types of naked singularity spacetimes and compare

them with the shadow of a Schwarzschild static black hole. Our findings indicate that these shadows can serve as mimics for black holes.

Loop quantum gravity / 375

Numerical analysis of the volume operator in loop quantum gravity

Authors: Haida Li[1]; Hongguang Liu[2]

[1] *South China University of Technology*

[2] *FAU Erlangen-Nürnberg*

Corresponding Author: liuhongguang@outlook.com

In loop quantum gravity (LQG), the volume operator plays a crucial role in the study of quantum geometry and quantum dynamics. However, the effect of the volume operator is studied only for some simple cases. In this talk, we introduce a numerical algorithm that can give the matrix elements of the volume operator on arbitrary valent gauge-variant and gauge-invariant spin network states and their corresponding coherent states. Moreover, we propose an improved version of the Giesel-Thiemann semiclassical perturbation theory of the volume operator, which gives the correct semiclassical approximation to the matrix elements and the gauge invariant expectation values. Our numerical algorithm verifies the result and links the full quantum evaluation to the semiclassical results. Based on this analysis, we implement an algorithm for the computation of the matrix elements of the Hamiltonian operator with the Lorentzian term on arbitrary spin network states and for the computation of its semiclassical expectation value on the corresponding coherent states. This opens the possibility to study the genuine full quantum dynamics in LQG.

Causal set theory / 376

Recent work in Causal Set Theory

Author: Yasaman Yazdi[1]

[1] *Dublin Institute for Advanced Studies*

Corresponding Author: ykyazdi@stp.dias.ie

I will give an overview of recent work in causal set theory and the status of the field.

Navigating science and philosophy: exploring limits / 377

Integrating philosophy into science education - Enhancing critical reasoning and understanding of General Relativity in school curricula

Author: Sara Mattiello[1]

[1] *Università degli Studi di Torino*

Corresponding Author: sara.mattiello@unito.it

The relationship between philosophy and science has historically been characterized by a deep interconnection between the empirical construction of reality and theoretical frameworks. Physics, as an epistemologically autonomous discipline with its own experimental scientific method, has its roots in philosophical reflection on natural phenomena. However, in today's educational system, science teaching—including the teaching of modern science—often struggles to design curricula that truly reflect the processes of experimental sciences, also neglecting the significant contribution of philosophy to the birth of science. This oversight is paradoxical, considering that students, from their early years of schooling, frequently pose questions that touch upon the great domains of knowledge.

Following studies that investigate the relationship between phylogenesis and ontogenesis, this contribution seeks to explore whether and how the dialogical-philosophical approach, from the early years of schooling, can contribute to the construction of scientific knowledge. In order to increasingly integrate the foundations of General Relativity into school curricula, the use of the philosophical approach could indeed stimulate the critical reasoning skills necessary for investigating abstract physical phenomena.

Gravitational lensing, shadows and photon rings / 378

Least model-dependent strong lensing properties of galaxy clusters

Author: Jenny Wagner[1]

[1] *Bahamas Advanced Study Institute and Conferences*

Corresponding Author: thegravitygrinch@gmail.com

Strong gravitational lenses are massive cosmic objects, like galaxies or galaxy clusters, which can map an extended background source, like a galaxy, into several highly distorted and magnified images. Analysing the properties of those images yields important information about the distribution of the deflecting mass and the background source. Common approaches to reconstruct the source or the deflecting mass distribution model the *global* properties of the source and the lens. They obtain a consistent description of the entire configuration by refining the model until it matches the observation to a predefined precision.

In contrast, this talk shows a different approach to infer *local* properties of the gravitational lens and to reconstruct the source only using the properties of the multiple images without assuming a lens or a source model. The approach can be applied to galaxy or galaxy-cluster lenses in the same way and yields the maximum information all lens models agree upon. Showcasing two example lenses, I highlight
1) how to obtain a smoothness scale for dark matter with it from only three multiple images in a newly discovered cluster and
2) how to identify and resolve limits of lens models that may lead to highly unrealistic dark matter properties.

References:
- Lens method overview: https://arxiv.org/abs/1906.05285
- Examples: https://arxiv.org/abs/2207.01630 and https://arxiv.org/abs/2306.11779

More information about me:
Dr. Jenny Wagner
Bahamas Advanced Study Institute & Conferences
https://thegravitygrinch.blogspot.com
https://en.wikipedia.org/wiki/Jenny_Wagner

Strong electromagnetic and gravitational field physics: From laboratories to early Universe / 379

Pair Production in Charged Black Holes: Monodromy Approach

Author: Chiang-Mei Chen[1]

[1] *National Central University, Taiwan*

Corresponding Author: cmchen@phy.ncu.edu.tw

In this talk I will firstly review the Schwinger effect in charged black holes and then introduce a remarkable alternative approach by using the monodromy. The explicit elaboration of monodromy and the model calculations seem to reveal evidences that the monodromy can provide a practical technique to study the spontaneous pair production in general black holes and electromagnetic fields.

Inflation: perturbations, initial singularities and emergent universes / 380

Bubble universe from flat spaces

Author: Eduardo Guendelman[1]

[1] *Ben Gurion University*

Corresponding Author: guendel@bgu.ac.il

We show by matching two flat spaces one in Minkowski coordinates (empty space) and the other in Minkowski coordinates after a special conformal transformation (also empty space) through a bubble with positive and constant surface tension, that the motion of the bubble is hyperbolic. If the surface tension is very big the initial size of the bubble is as small as we wish, so that we can indeed obtain an infinite universe out of empty spaces. The induced space in the bubble is de Sitter type.

Large scale structure and dark energy / 381

Luminosity distance dispersion in Swiss-cheese cosmology as a function of the hole size distribution

Authors: Thippayawis Cheunchitra[None]; Andrew Melatos[1]

[1] *University of Melbourne*

Corresponding Author: tcheunchitra@student.unimelb.edu.au

The luminosity distance-redshift (D_L-z) relation of Type Ia supernovae (SNe Ia) yields evidence for a nonzero cosmological constant, i.e. 'dark energy'. SNe Ia analyses typically involve fitting the D_L and z to the functional form derived theoretically from the homogeneous and isotropic Friedmann-Lemaitre-Robertson-Walker (FLRW) metric. However, the metric in the epoch relevant to SNIa measurements deviates appreciably from FLRW due to gravitational clumping of mass into large-scale structures like filaments and voids, whose size distribution spans many orders-of-magnitude. Each line of sight to a SNe Ia passes through a random sequence of structures, so D_L differs stochastically from one line of sight to the next. Such dispersion in D_L may be dominated by a few large voids or many small voids, partly depending on the probability density function of the void size. In

this work, we calculate the D_L dispersion in a Lemaitre-Tolman-Bondi Swiss-cheese universe with a power-law hole size distribution, as a function of the lower cut-off and logarithmic slope.

Dark matter detection / 382

Ultralight scalar and axion dark matter detection with long-baseline atom interferometers

Author: Wei Zhao[1]

[1] *Shandong University of Aeronautics*

Corresponding Author: zhaowei164@mails.ucas.ac.cn

The detection of dark matter is a challenging problem in modern physics.
We provide a proposal to detect the coupling of ultralight scalar dark matter to quarks and gluons as well as the coupling of ultralight axion dark matter to gluons with long-baseline atom interferometers. The ultralight scalar and axion dark matter could induce the oscillation of the nuclear charge radii and then oscillate the atomic transition frequency by interacting with quarks and gluons. We calculate the differential phase shift caused by the scalar and axion dark matter in long-baseline atom interferometers and give the proposed constraints on the scalar dark matter coupling parameters d_g and $d_{\hat{m}}$ as well as the axion dark matter coupling parameter $1/f_a$. Our results are expected to improve existing bounds and complement bounds from other experiments in the future.

Slowly rotating pulsars / 383

Analysing pulsar timing noise with a Kalman filter to test the two-component pulsar model

Authors: Andrew Melatos[1]; Nicholas O'Neill[2]; Patrick Meyers[3]

[1] *University of Melbourne*

[2] *The University of Melbourne*

[3] *California Institute of Technology*

Corresponding Author: noneill@student.unimelb.edu.au

Pulsar timing noise is the stochastic deviation of the pulse arrival times of a pulsar away from their long term trend. In the standard two-component crust-superfluid neutron star model, timing noise can be explained as the perturbation of the two components by irregular torques. Interactions between the crust and superfluid cause these perturbations to decay exponentially with a characteristic relaxation timescale, similar to post-glitch relaxation. In this research we assume the two-component model, then use a Kalman filter to track the pulsar frequency over time and produce a Bayesian posterior for the two-component model parameters given the data. Our method is reliable on simulated data, which we show through individual and large-scale Monte Carlo tests. We also show a representative example with a real pulsar, in which physical properties of the star including the relaxation timescale are efficiently measured. Our measurements of neutron star properties may lead to information about their equation of state and the crust-superfluid interaction and also provide evidence for or against the two-component model.

Dark matter halos: its nature, modeling & tracers / 384

Thermodynamics sheds light on the nature of dark matter galactic halos

Author: Andrés Aceña[1]

Co-authors: Argelia Bernal [2]; Juan Barranco [3]; Ericsson López [4]

[1] *Universidad Nacional de Cuyo, Mendoza, Argentina*

[2] *University of Guanajuato-Mexico*

[3] *University of Guanajuato-México*

[4] *Observatorio Astronómico de Quito*

Corresponding Author: jbarranc@fisica.ugto.mx

In spherical symmetry, the gravitational potential of galaxies and their halos are univocally derived from the rotational velocity profile. Thousands of galaxies are well-fitted by a universal velocity profile and thus, the gravitational profile is well known. By considering that dark matter can be treated either as an ideal gas, a Fermi, or a Bose gas, we found that only the latter can generate such a gravitational profile with a decreasing temperature profile if the mass of the boson is below 20,eV/c^2. If we demand that the sound speed is less than the speed of light, a lower bound on the boson's mass is obtained.

Dark matter halos: its nature, modeling & tracers / 385

Bayesian analysis for rotational curves with l-boson stars as a dark matter component

Authors: Argelia Bernal Bautista[1]; Atalia Navarro-Boullosa[1]; J. Alberto Vázquez[2]

[1] *Universidad de Guanajuato*

[2] *ICF-UNAM*

Corresponding Author: bernal.a@ugto.mx

Using Low Brightness Surface Galaxies (LBSG) rotational curves we inferred the free parameters of l-boson stars as a dark matter component. The l-boson stars are numerical solutions to the non-relativistic limit of the Einstein-Klein-Gordon system, the Schrödinger-Poisson (SP) system. These solutions are parametrized by an angular momentum number $l = (N - 1)/2$ and an excitation number n. We perform a bayesian analysis by modifying the SimpleMC code to perform the parameter inference, for the cases with $l = 0$, $l = 1$ and multi-states of l-boson stars. We used the Akaike information criterion (AIC), Bayesian information criterion and the Bayes factor to compare the excited state (l=1) and the multi-state case with the ground state (l=0) as the base model due to its simplicity. We found that the data in most galaxies in the sample favors the multi-states case and that the scalar field mass tends to be slightly bigger than the ground state case.

Black holes in alternative theories of gravity / 386

Black holes at a crossroads during the late stages of evaporation in quadratic gravity

Authors: Alfio Bonanno[1]; Samuele Marco Silveravalle[2]

[1] *INAF Catania*

[2] *SISSA*

Corresponding Author: sm.silveravalle@gmail.com

By studying quantum fields on classical curved spacetimes, Gibbons and Hawking managed to derive the thermodynamical properties of black holes, while making at the same time the first robust prediction of a semiclassical theory of gravity. Nevertheless, they quickly realized that black hole evaporation leads to sudden bursts of energy and loss of information. It can be argued that these phenomena happen in the final stages of evaporation, where the semiclassical approximation needs to be refined with the inclusion of quantum corrections also for the gravitational part of the theory. A natural way to describe gravity at high energies is to add quadratic curvature terms to the Einstein-Hilbert action, *i.e.* quadratic gravity. At the cosmological level it is known that its classical solutions can give rise to a model of inflation that matches observations strikingly well, while in an astrophysical context, at small masses, it allows for the possibility of non-Schwarzschild black holes. These solutions have very peculiar properties, due to the presence of a massive spin-2 particle which corresponds to a ghost at quantum level. The branch of non-Schwarzschild solutions crosses the one of Schwarzschild ones at a specific mass which could be between the one of an asteroid and the Planck mass, depending from the value of a slightly constrained free parameter. Nonetheless, we expect standard formation processes to create standard black holes, which could reach such small masses only at the late stages of their evaporation. Through the analysis of their dynamical stability, of their thermodynamical properties and the nature of their singularity, we investigate what could happen to a black hole who has reached this crossing point. While this investigation might not solve the problem of the endpoint of evaporation, it can shed a light on the directions it might take during its last moments.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 387

Boson stars and their relatives in semiclassical gravity

Authors: Alberto Diez-Tejedor[1]; Argelia Bernal[1]; Darío Núñez[2]; Juan Barranco[1]; Juan Carlos Degollado[3]; Miguel Alcubierre[2]; Miguel Megevand[4]; Olivier Sarbach[5]

[1] *University of Guanajuato-México*

[2] *UNAM-México*

[3] *ICF-UNAM, México*

[4] *Instituto de Física Enrique Gaviola, CONICET.*

[5] *IFM-Universidad Michoacana de San Nicolas de Hidalgo, México*

Corresponding Author: jbarranc@fisica.ugto.mx

We construct boson star configurations in quantum field theory using the semiclassical gravity approximation. Restricting our attention to the static case, we show that the semiclassical Einstein-Klein- Gordon system for a single real quantum scalar field whose state describes the excitation of N identical particles, each one corresponding to a given energy level, can be reduced to the Einstein-Klein-Gordon system for N complex classical scalar fields. Particular consideration is given to the spherically symmetric static scenario, where energy levels are labeled by quantum numbers n, l, and m. When all particles are accommodated in the ground state n ¼ l ¼ m ¼ 0, one recovers the standard static boson star solutions, that can be excited if $n \neq 0$. On the other hand, for the case where all particles have fixed radial and total angular momentum numbers n and l, with $l \neq 0$, but are homogeneously distributed with respect to their magnetic number m, one obtains the l-boson stars, whereas when l ¼ m ¼ 0 and n takes multiple values, the multistate boson star solutions are obtained. Further generalizations of these configurations are presented, including the multi-l multistate boson stars, that constitute the most general solutions to the N-particle, static, spherically symmetric, semiclassical real Einstein-Klein-Gordon system, in which the total number of particles is definite. In spite of the fact that the same spacetime configurations also appear in multifield classical theories, in semiclassical gravity, they arise naturally as the quantum fluctuations associated with the state of a single field describing a many-body system. Our results could have potential impact on direct detection experiments in the context of ultralight scalar field/fuzzy dark matter candidates.

Gravitational instantons and black holes / 388

Non-perturbative quantum gravity denounces singular Black Holes

Author: Anna Tokareva[1]

[1] *Hangzhou Institute for Advanced Study & ICTP-AP Centre Beijing/Hangzhou*

Corresponding Author: tokareva@ucas.ac.cn

Although General Relativity predicts the presence of a singularity inside of a Black Hole, it is not a complete theory of gravity. A real structure of a Black Hole interior near an expected singularity depends on the UV completion of gravity. In this paper, we establish that the question whether singular spherically symmetric solutions are absent is governed by the functional form of a non-perturbative graviton propagator. We explicitly show in a framework of a ghost-free infinite derivative gravity that for the graviton propagator of an exponential form favored by the unitarity a singularity is not possible unless an unphysical situation when the total mass of the Black Hole is infinite is considered.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 389

Entanglement Harvesting in Accelerated Systems: Field Temperature and Boundary Effects

Authors: Dipankar Barman[1]; Subhajit Barman[2]; Bibhas Ranjan Majhi[1]

[1] *Indian Institute of Technology Guwahati*

[2] *ndian Institute of Technology Guwahati*

Corresponding Author: dipankar1998@iitg.ac.in

Quantum entanglement harvesting (EH) in the relativistic setup has recently attracted much attention. The formulation studies the possibility of two uncorrelated Unruh-DeWitt detectors getting entangled over time due to the effects of quantum vacuum fluctuations, depending on the motion and the background spacetimes. We investigate the effects of field temperature $T^{(f)}$ on EH between two uniformly accelerated detectors. Field temperature suppresses EH for lower accelerations. However, after a critical acceleration, temperature has opposite effect. Multiple critical points are in the $(1+3)$ dimension, and a single critical point is in the $(1+1)$ dimension. We also consider the presence of multiple reflecting boundaries on EH. We observe that the reflecting boundaries can cause suppression or enhancement of entanglement, depending on different physical parameters.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 390

Magnetorotational Dynamos in Turbulent Accretion Disks

Author: Tushar Mondal[1]

Co-author: Pallavi Bhat [2]

[1] *International Centre for Theoretical Sciences, Tata Institute of Fundamental Research, Bangalore, India*

[2] *ICTS - TIFR*

Corresponding Author: tushar.mondal@icts.res.in

Understanding the intricate network of nonlinear interactions crucial for the development and sustenance of turbulence induced by magnetorotational instability (MRI) has proven challenging. A large-scale dynamo, generating dominant azimuthal magnetic fields, emerges as a pivotal component of this turbulence. Direct numerical simulations of MRI dynamo have revealed statistical self-organization into large-scale cyclic dynamics. However, comprehending the underlying physics of these statistical states and assessing their astrophysical significance present theoretical hurdles. Through our newly developed direct statistical simulations, we have successfully identified several new dynamo mechanisms responsible for generating different components of large-scale magnetic fields. In this talk, I will delve into the fundamental physics associated with the dynamo cycle and elucidate the properties and implications of the resulting cyclic patterns within turbulent accretion disks.

References

1 Mondal T., Bhat P., Phys. Rev. E 108, 065201 (2023).

High energy astrophysics / 391

Stochastic and secular anomalies in measurements of pulsar braking indices

Author: Andrés Vargas[1]

Co-author: Andrew Melatos [2]

[1] *Research Fellow, The University of Melbourne*

[2] *University of Melbourne*

Corresponding Author: a.vargas@unimelb.edu.au

Stochastic (i.e. the achromatic component of timing noise unrelated to interstellar propagation) and secular variations in the spin frequency ν of a rotation-powered pulsar complicate the interpretation of the measured second derivative of the spin frequency $\ddot{\nu}$, and hence the braking index, n, in terms of a power-law spin-down torque $\propto \nu^{n_{\rm pl}}$. Both categories of variation can lead to measurements of $\ddot{\nu}$ which yield anomalous braking indices, i.e. $|n| = |\nu\ddot{\nu}/\dot{\nu}^2| \gg 1$, where the overdot symbolizes a derivative with respect to time. In this talk, I will discuss the following three key results. First, the combined effect of stochastic and secular deviations from pure power-law spin down on measurements of $\ddot{\nu}$ and its implications in observationally constraining n. Second, how the variance of $\ddot{\nu}$ (or equivalently n) satisfies a falsifiable, analytical result derived from first principles. We quantify said variance through analytic calculations, Monte Carlo simulations involving synthetic data from a phenomenological model, and modern Bayesian techniques. Third, how the variance of $\ddot{\nu}$ may be applied to real astronomical situations to predict or interpret the measured braking index n.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 392

Estimation of neutron star mass and radius from the high-frequency QPOs in GRB 200415A

Author: Hajime Sotani[1]

[1] *RIKEN*

Corresponding Author: sotani@yukawa.kyoto-u.ac.jp

Neutron stars are one of the most suitable environments for probing physics under extreme states. For example, the quasi-periodic oscillations (QPOs) observed in a giant flare occurred in a strongly magnetized neutron star (magnetar), are carrying crucial information for extracting the neutron star properties. To theoretically explain the observed QPOs in GRB 200415A, we systematically examine the crustal torsional oscillations, neglecting the magnetic effects. We find that the observed QPOs can be identified with several overtones of crustal oscillations, for well selected combination of the nuclear saturation parameters. Thus, we can inversely constrain the neutron star mass and radius for GRB 200415A by comparing them to the values of nuclear saturation parameters obtained from terrestrial experiments. We impose further constraints on the neutron star mass and radius while the candidate neutron star models are consistent with the constraints obtained from the other astronomical and experimental observations.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 393

A novel approach to estimate magnetars' age and magnetic fields

Author: Tushar Mondal[1]

[1] *International Centre for Theoretical Sciences, Tata Institute of Fundamental Research, Bangalore, India*

Corresponding Author: tushar.mondal@icts.res.in

Magnetars are slowly rotating, young, and isolated neutron stars with surface dipole magnetic fields exceeding the quantum electrodynamic magnetic field limit. They exhibit highly energetic behavior, as in the case of soft-gamma repeaters (SGRs) and anomalous X-ray pulsars (AXPs). Recently, they have been studied with paramount interest by almost every modern X-ray telescope. Despite the success, the traditional picture of magnetars has been challenged by the discovery of low-field magnetar, SGR 0418+5729. It remains mysterious over the decades to interpret the evolutionary stage (or age) of such a puzzling source within the magnetar paradigm. Unlike ordinary radio pulsars, the characteristic age is not a reliable indicator for the true age of a magnetar. Here we provide a novel approach to estimate the realistic age of a magnetar. The methodology simultaneously accounts for the surface dipole magnetic field measurement as well. The previous studies for such field measurement are either based on an orthogonal vacuum rotator model or based on a force-free plasma-filled magnetospheric model of pulsars. In general, a real pulsar should be an oblique rotator surrounded by a plasma-filled magnetosphere with particle acceleration gaps to generate pulsar high-energy emissions. In this framework, we solve the self-consistent time evolution for magnetars, including the current state-of-the-art magnetic field decay mechanisms. The rotational period of magnetars increases over time due to the extraction of angular momentum by gravitational-wave radiations, magnetic dipole radiations, and particle winds. These torques also change the obliquity angle between the magnetic and rotation axes. In the peculiar case of SGR 0418+5729, we find a dipolar magnetic field of 1.0×10^14 G and a realistic age of 18 kyr; both are consistent within the magnetar paradigm.

References

1 Mondal T., 2021, ApJ Letters, 913, L12

Gravitational kHz waves - LIGO-Virgo-KAGRA / 394

Supernova gravitational waves and protoneutron star asteroseismology

Author: Hajime Sotani[1]

[1] *RIKEN*

Corresponding Author: sotani@yukawa.kyoto-u.ac.jp

Supernova gravitational waves are the next candidates to those from the compact binary mergers. The gravitational waves generally depend on the supernova models, such as the progenitor mass and equation of state (EOS) for a higher-density region. So, even if one succeeds in detecting them in the future, it may be difficult to extract physical information from them. Up to now, the supernova gravitational waves have mainly been studied via numerical simulations. From such simulations, the gravitational wave signals are shown, whose frequencies increase from a few hundred hertz to kilo-hertz. On the other hand, the origin of this signal has been unclear. To understand the gravitational wave signals appearing in numerical simulations, we are studying them with the approach of asteroseismology. In particular, using the numerical data of simulations we prepare the protoneutron star models and determine the specific oscillation modes on each time step. Then, we successfully identify the gravitational wave signals come from the fundamental oscillations of protoneutron stars. In this talk, we also show the recent progress in supernova gravitational waves with asteroseismology.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 395

On the matter density discrepancy.

Author: Ziad Sakr[1]

[1] *USJ-IRAP-ITP*

Corresponding Author: sakr@thphys.uni-heidelberg.de

We investigate whether there are evidences for the existence of a new tension on the matter density parameter, independent or in relation with the Hubble or the matter fluctuation parameter tension, and that using a combination of multiple probes in a model independent approach where we relax most of the calibration parameters related to the aforementioned discrepancies.

Loop quantum gravity: cosmology and black holes / 396

Viability of loop quantum cosmology at the level of bispectrum

Authors: Roshna K[1]; V Sreenath[2]

[1] *National Institute of Technology Karnataka, Surathkal, India*

[2] *National Institute of Technology Karnataka*

Corresponding Author: roshnak.217ph005@nitk.edu.in

Observations by Planck indicate that CMB anisotropies are consistent with predictions of nearly Gaussian primordial perturbations as the one generated in slow roll inflation. On the other hand, loop quantum cosmology (LQC) generates a non-Gaussian bispectrum. In particular, calculations of primordial bispectrum generated in LQC shows that the non-Gaussianity function $f_{\rm NL}(k_1,\, k_2,\, k_3)$ is highly scale dependent and oscillatory at long wavelengths and is nearly scale invariant as in slow roll at small scales. In this talk, we discuss the viability of such a non-Gaussian bispectrum in the light of observations by Planck. More specifically, we model the bispectrum generated in LQC and compute its imprints on the CMB bispectrum. We then show that the CMB bispectrum generated in LQC though non-Gaussian, due to its highly oscillatory nature, is similar to that generated in slow roll inflation and hence consistent with the observations by Planck.

ANTARES – 15 years of multi-messenger astronomy in the sea / 397

ANTARES: 15 years of cosmic neutrino source searches

Author: Giulia Illuminati[None]

Corresponding Author: giulia.illuminati@bo.infn.it

ANTARES, an observatory for high-energy neutrinos located below the surface of the Mediterranean Sea, finished its observational mission in February 2022 after operating for 15 years. Positioned strategically in the Northern hemisphere and equipped with exceptional angular resolution, it was well-suited for its main goal: identifying the sources of cosmic neutrinos, particularly in surveying the southern celestial sphere for galactic neutrino objects.

Numerous searches aimed at identifying neutrino sources were performed using ANTARES data. This involved scrutinizing the sky for events consistent with the point-source hypothesis, without bias from electromagnetic observations, as well as targeting astrophysical catalogs provided by multi-messenger experiments. Additionally, ANTARES employed a stacking method, grouping similar astrophysical objects to establish constraints on neutrino emissions from various source classes. Moreover, to enhance discovery potential, joint analyses with IceCube were conducted.

These searches performed throughout ANTARES' entire lifespan have yielded noteworthy findings, which are summarised in this contribution.

Neutrinos in the multi-messenger era / 398

Probing the origin of cosmic neutrinos in the multi-messenger era: results from ANTARES

Author: Giulia Illuminati[None]

Corresponding Author: giulia.illuminati@bo.infn.it

The high-energy neutrino observatory ANTARES concluded its 15-year observational campaign in February 2022. Among is primary goals was the identification of the sources of cosmic neutrinos.

Throughout its operational lifespan, ANTARES conducted multiple searches aimed at detecting steady and transient neutrino sources using different methods, such as inspecting for possible neutrino emission from the astrophysical objects described in multi-messenger catalogs. Moreover, starting in 2009, ANTARES has been involved in a rich real-time program which included searching for neutrinos in coincidence with promising transient astrophysical events, as well as triggering electromagnetic follow-up observations of interesting neutrino candidates by sending alert messages to the astronomical community.

An overview of the findings obtained through these research approaches over the full lifetime of ANTARES is provided in this presentation.

Emission mechanisms in gamma-ray bursts / 399

Evidence for cocoon emission in GRB 171205A

Author: Luca Izzo[1]

[1] *INAF-Capodimonte & DARK/NBI*

Corresponding Author: luca.izzo@inaf.it

In this talk, I will present and discuss evidence for cocoon emission in the early afterglow emission phases of the nearby GRB-SN 171205A. Special attention will be given to the multi-wavelength analysis, and to modeling of the cocoon component.

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 400

Finding upper bounds on the Bopp length in Bopp-Podolsky theory

Author: Volker Perlick[None]

Corresponding Author: volker.perlick@zarm.uni-bremen.de

The Bopp-Podolsky theory is a gauge-invariant and Lorentz-invariant theory of electromagnetism that introduces a new hypothetical constant of Nature with the dimension of a length, called the Bopp length. The theory was introduced by Bopp in 1940, and independently by Podolsky in 1942, in order to cure the infinite field energies of point charges. If one sets the Bopp length equal to zero one recovers the standard Maxwell vacuum theory. In this talk I discuss several methods of how to give upper bounds on the Bopp length on the basis of experiments and observations with present or future technologies. It is demonstrated that the strictest bounds are provided by atomic spectroscopy.

Gravitational lensing, shadows and photon rings / 401

Gravitational lensing by wormholes

Author: Volker Perlick[None]

Corresponding Author: volker.perlick@zarm.uni-bremen.de

In this talk I consider the propagation of light rays, either in vacuum or in a non-magnetised pressureless plasma, in axially symmetric and stationary spacetimes that describe wormholes. Among other things, I discuss the necessary and sufficient conditions for separability of the Hamilton-Jacobi equation (i.e., for the existence of a Carter constant) which allows complete integrability. For the case that this condition is satisfied, I demonstrate how the photon region and the shadow can be analytically determined. I also discuss the necessary and sufficient condition for light rays to stay in the equatorial plane and the bending angle for such light rays.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 402

Investigating the connection between the X-ray plateaus and flares in Gamma-ray Bursts light curves

Author: Hüsne Dereli-Bégué[1]

Co-authors: Asaf Pe'er [2]; Damien Begue [2]; Felix Ryde [3]

[1] *Bar-Ilan University*

[2] *Bar Ilan University*

[3] *Department of Physics, KTH Royal Institute of Technology, and the Oskar Klein Centre for Cosmoparticle Physics, 10691 Stockholm, Sweden*

Corresponding Author: husnedereli@gmail.com

Gamma-ray bursts (GRBs) are one of the most energetic explosions known in the Universe. Even though many GRBs have been observed since their discovery more than 50 years ago, and despite the success of the "fireball" model, there are still many open questions and unexplained observations. The origin of the plateau phase observed in the early X-ray light curve of GRBs (up to thousands of seconds) has been debated since its discovery in 2005. In our recent paper, we show that the observed plateau phase can be explained within the classical GRB model by considering an expanding stellar shell with initial jet Lorentz factors of tens. In the early study, while we excluded any flare feature, in this study, we fit the Swift-XRT light curves (including flares and plateaus) of several GRBs by using the MultiNest fitting method and considering theoretical afterglow models (Wind & ISM). In this talk, I will discuss if there is any link between the plateaus and flares seen in the vast majority of the early X-ray light curves of GRBs, and its origin is still a debated topic. Our discussion is carried out in the environments of the GRBs in the fireball model.

Emission mechanisms in gamma-ray bursts / 403

Numerical Simulation of Photospheric Emission in Gamma-Ray Bursts

Author: Hirotaka Ito[1]

[1] *RIKEN*

Corresponding Author: hirotaka.ito@riken.jp

We explore the properties of photospheric emission in gamma-ray bursts (GRBs) based on relativistic hydrodynamical simulations and Monte Carlo radiation transfer calculations. Our simulations confirm that photospheric emission gives rise to correlations between the spectral peak energy and luminosity that agree with the observed Yonetoku, Amati, and Golenetskii correlations. It is also shown that the spectral peak energy and luminosity correlate with the bulk Lorentz factor. However, synthetic spectral shapes tend to be narrower than those observed, suggesting the need for an additional physical process to provide non-thermal broadening. Furthermore, polarization analysis shows that while the degree of polarization is low for the jet core emission ($\Pi < 4\%$), it increases with viewing angle outside the core and can reach $\Pi \sim 20\%–40\%$ in extreme cases. This implies that typical GRBs have systematically lower polarization compared to X-ray-rich GRBs and X-ray flashes. Our simulations also indicate significant temporal variation in the polarization position angle ($\Delta\psi \sim 90°$), which is compatible with observations. A notable energy dependence of the polarization property is another characteristic feature found, with the position angle difference among different energy bands reaching ~90°.

The SVOM mission in the time-domain era / 404

The new SOXS instrument for the ESO NTT: overview and status of the project

Author: Paolo D'Avanzo[1]

[1] *INAF - Osservatorio Astronomico di Brera*

Corresponding Author: paolo.davanzo@inaf.it

SOXS (Son Of X-Shooter) will be a unique spectroscopic facility built by an international consortium for the ESO-NTT 3.6-m telescope in La Silla (Chile). The design foresees a single-object, high-efficiency spectrograph with a resolution-slit product of ~ 4,500, capable of simultaneously observing the complete spectral range 350 - 2000 nm with a good sensitivity and with imaging capabilities in

the visible band (ugrizY). It is designed to observe all kind of transients and variable sources discovered by different surveys with a highly flexible schedule maintained by the consortium, based on the Target of Opportunity concept. SOXS is going to be a fundamental spectroscopic partner for any kind of imaging survey, becoming one of the premier transient follow-up instruments in the Southern hemisphere.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 405

Cosmic clocks and cosmic chronometers: constraining the Hubble parameter now and then

Author: Elena Tomasetti[1]

[1] *University of Bologna*

Corresponding Author: elena.tomasetti2@unibo.it

Constraining the expansion history of the Universe with new and complementary approaches is crucial now that we are in the age of precision cosmology, where managing systematic effects and increasing the accuracy of the measurements is essential.

In this talk, I will present how the ages of the oldest objects in our Universe can shed light on its expansion history, both in the local Universe and at high redshift. At z=0, we analyse the ages of the oldest globular clusters, which naturally place a lower limit on the current age of the Universe and, in turn, an upper limit on H_0. In our work, we study a sample of globular clusters in the Milky Way, deriving their physical properties via full-spectrum-fitting (FSF). They show estimations of cluster masses and metallicities [Z/H] that align very well with literature values, along with slightly higher age estimates. We complement FSF with the analysis of relevant spectral indices, that prove to be useful diagnostics in identifying spurious solutions. In the end, selecting the tail of oldest objects of our sample, we can obtain an upper limit on H_0.

At higher redshift, we benefit from the quality of the VLT/MUSE spectroscopic data and analyse spectra and photometry of a selected sample of massive and passive galaxies at high S/N, deriving their physical properties via FSF. We then apply the cosmic chronometers method, and from the analysis of their differential ageing in redshift, we derive a new, cosmology-independent, measurement of the Hubble parameter at z$\sim$0.55, taking into account both statistic and systematic effects.

Latest results from Galactic center observations / 406

Galactic Heartbeat: are the Milky Way's Nuclear Star Cluster and Disc part of the same structure?

Author: Francisco Nogueras Lara[1]

[1] *ESO*

Corresponding Author: francisco.noguerasIara@eso.org

The innermost regions of most galaxies are characterised by the presence of extremely dense nuclear star clusters, which sometimes appear alongside larger stellar structures known as nuclear stellar discs. Understanding the relationship between nuclear star clusters and nuclear stellar discs is challenging due to the large distances to other galaxies, which limits their analysis to integrated light. In this context, the Milky Way's centre, which hosts both structures, serves as a unique template to understand their relationship and formation scenarios. Using photometric, metallicity, and kinematic catalogues, we analysed the connection between these two Galactic centre components and

studied their stellar populations. We detected kinematic and metallicity gradients along the line of sight, suggesting a smooth transition between the nuclear stellar disc and cluster. Our results indicate that these two Galactic centre components might be part of the same structure, with the Milky Way's nuclear stellar disc being the extended edge of the nuclear star cluster.

Black holes in alternative theories of gravity / 407

Testing alternative spacetimes by fitting both the hot-spot data of Sgr A*, and high-frequency quasi-periodic oscillations observed in AGNs and microquasars

Author: Misbah Shahzadi[1]

Co-authors: Martin Kološ [2]; Zdenek Stuchlik [3]

[1] *COMSATS University Islamabad, Pakistan*

[2] *Institute of Physics, Silesian University in Opava*

[3] *Silesian University in Opava, Czech Republic*

Corresponding Author: misbahshahzadi51@gmail.com

We explore the class of stationary, axisymmetric, and asymptotically flat spacetimes describing charged black holes in general relativity combined with nonlinear electrodynamics, or reflecting the influence of dark matter, or in so-called parameterized dirty Kerr spacetimes, and test them using the observational data of both hot-spot and the high-frequency quasi-periodic oscillations detected in active galactic nuclei and microquasars. We show that the orbital frequencies as well as positions of the hot-spots orbiting the considered black holes fit the observed positions and periods of the flare orbits, and give relevant constraints on the parameters of the considered black hole spacetimes and the gravity or other theories behind such modified spacetimes. We demonstrate which spacetimes provide the best fit for high-frequency quasi-periodic oscillation data and could be fruitful for future exploration.

Gravitational kHz waves - LIGO-Virgo-KAGRA / 408

Status and future perspectives of the electromagnetic follow-up of gravitational wave sources

Author: Maria Grazia Bernardini[1]

[1] *INAF - Osservatorio Astronomico di Brera*

Corresponding Author: maria.bernardini@inaf.it

The search and characterization of the electromagnetic counterparts of gravitational wave emitters requires the collaborative efforts of researchers with both theoretical and observational expertise extending over the full range of the electromagnetic spectrum. The lessons learned from the first two observing runs of the advanced interferometers and the successful story of the detection of the afterglow and kilonova after the binary neutron star merger GW 170817 motivated astrophysicists across Europe to gather together to facilitate the access to top observing facilities and to guarantee an effective team organization. In this talk we review the main results accomplished the European community in this field up to the present observing run (O4), and the challenges that have to be addressed to meet the improved sensitivity of the third generation interferometers.

High energy astrophysics / 409

X-ray emission from isolated neutron stars: latest results from XMM-Newton, NICER and eROSITA

Author: Michela Rigoselli[1]

[1] *INAF*

Corresponding Author: michela.rigoselli@inaf.it

The X-ray spectra of isolated neutron stars (INSs) typically include a thermal component, that comes from the cooling surface, and a non-thermal component, produced by highly-relativistic particles accelerated in the stellar magnetosphere. Hot spots from returning currents can also be detected.

Middle-aged pulsars exhibit a mixture of these components, but other flavours of INSs, that show a large variety of physical parameters (such as spin period, magnetic field and age) emit only thermal X-rays. These stars are usually detected either by large serendipitous datasets from pointed X-ray observations or from searches in the data of all-sky surveys.

The connection between these thermally-emitting INSs, the ordinary pulsars, and the new emergent class of pulsars characterized by a long period, that do not show X-ray emission despite their large magnetic field, is one of the current challenges in the study of neutron stars.

In this contribution I will review the latest results on several objects belonging to various INS classes, such as the XDINS RX J1856.5-3754, the enigmatic Calvera, the long period PSR J0250+5854 and the new thermal INS candidates, obtained with the X-ray observatories XMM-Newton, NICER and eROSITA.

Latest results from Galactic center observations / 410

X-ray echoes and the structure of molecular clouds in the Galactic Center

Author: Giovanni Stel[1]

Co-authors: Francesco Haardt [2]; Gabriele Ponti [3]; Mattia Sormani [2]

[1] *Osservatorio di Brera - Università dell'Insubria*

[2] *Università degli Studi dell'Insubria*

[3] *INAF Osservatorio Astronomico di Brera*

Corresponding Author: giovanni.stel@inaf.it

Molecular clouds in the Galactic Center reprocess radiation from past outbursts, generating a strong Fe Kα fluorescent line (6.4 keV). Reflecting the radiation that reaches them as mirrors, these clouds retain the historical activity of their illuminating sources. Studying this echo radiation provides crucial information about the source, the clouds' properties, and the relative geometry between the clouds and the illuminating source. We examined fluorescence in molecular clouds near Sgr A*, specifically in the Circumnuclear Disk and the Sgr A complex, located within 15 arcminutes of the SMBH.

In the Circumnuclear Disk, we detected a signal generated by the outburst of the magnetar SGR J1745-2900 (which happened in April 2013). Using the known luminosity of this outburst and the measured X-ray intensity, we estimated the mean hydrogen column density of the Circumnuclear Disk. In the Sgr A complex, the fluorescence is most probably due to Sgr A*'s flaring activity over the past few hundred years, as suggested by multiple studies. Thanks to 25 years of XMM-Newton observations of the Galactic Center, we were able to track the interaction of the wavefront of this past energetic event with the molecular cloud distribution. By analyzing the evolving signal, we

reconstructed a 3D map of the molecular cloud distribution and studied the internal structure of the Sgr A complex.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 411

Spontaneous breaking of diffeomorphism invariance in conformally reduced quantum gravity

Author: Gabriele Giacometti[1]

Co-authors: Alfio Maurizio Bonanno [2]; Dario Zappalà [3]; Salvatore Plumari [4]

[1] *UniCT*

[2] *INFN, INAF, Unict*

[3] *Istituto Nazionale di Fisica Nucleare- Sez. Catania*

[4] *Dipartimento di Fisica e Astronomia, Università di Catania*

Corresponding Author: gabriele.giacometti@phd.unict.it

We study the spontaneous breaking of diffeomorphism invariance using the proper-time non-perturbative flow equation in quantum gravity. In particular, we analyze the structure of the UV critical manifold of conformally reduced Einstein-Hilbert theory and study the occurrence of a non-trivial minimum for the conformal factor at Planckian energies. We argue that our result can be interpreted as the occurrence of a dynamically generated minimal length in quantum gravity.

First stars and their remnants as dark matter probes / 412

An Overview of Dark Stars

Author: Paolo Gondolo[1]

[1] *University of Utah*

Corresponding Author: paolo.gondolo@utah.edu

"Dark stars" are a theoretical class of celestial objects powered by dark matter annihilation rather than nuclear fusion. I will review the conditions in the early universe conducive to the formation of dark stars, covering the theoretical basis of dark matter annihilation as an energy source. I will discuss the expected properties of dark stars, including their size, luminosity, lifespan, and spectral signatures. I will also address the observational challenges and opportunities for detecting dark stars, including possible candidates identified by the James Webb Space Telescope (JWST).

Causal set theory / 413

Fluctuations and Correlations in Causal Set Theory

Authors: Heidar Moradi[1]; Miguel Zilhão[2]; Yasaman Yazdi[3]

[1] *University of Kent*

[2] *University of Aveiro*

[3] *Dublin Institute for Advanced Studies*

Corresponding Author: hm490@kent.ac.uk

We study the statistical fluctuations (such as the variance) of causal set quantities, with particular focus on the causal set action. To facilitate calculating such fluctuations, we develop tools to account for correlations between causal intervals with different cardinalities. We present a convenient decomposition of the fluctuations of the causal set action into contributions that depend on different kinds of correlations. This decomposition can be used in causal sets approximated by any spacetime manifold M. Our work paves the way for investigating a number of interesting discreteness effects, such as certain aspects of the Everpresent Λ cosmological model.

IXPE observations and multiwavelength opportunities / 414

Theoretical implications of IXPE polarimetric measurements for blazars

Author: Fabrizio Tavecchio[None]

Corresponding Author: fabrizio.tavecchio@inaf.it

I will review the theoretical implications of the IXPE and multifrequency polarimetric measurements of the emission from blazars. In particular, for highly-synchrotron peaked BL Lacs current measurements show a strong frequency-dependency of the degree of polarization, commonly attributed to a stratified emission region, possibly associated to shock acceleration. I will discuss this interpretation, together with possible alternatives.

Cosmic backgrounds from radio to far-IR / 415

The Epoch of Reionisation through the low-frequency radio lens

Author: Adélie Gorce[1]

[1] *CNRS IAS*

Corresponding Author: adelie.gorce@universite-paris-saclay.fr

About a billion years after the Big Bang, the Epoch of Reionisation saw the first light sources in the Universe slowly ionise the primordial atoms of the surrounding IGM. Learning about this distant epoch has the potential of unveiling crucial information about the formation of the first stars, galaxies, and early black holes, which sourced it.
One particularly promising probe of this epoch is the cosmological signal from the 21cm spectral line of neutral hydrogen. However, its observation remains elusive: Attempted measurements are still plagued with foregrounds and systematics, whilst modelling uncertainties prevent us from extracting precise constraints from existing and forthcoming datasets.

In this talk, I will describe what the high-redshift 21cm signal can tell us about the history of our Universe and of its first luminous objects. I will present the analysis, observational, and instrumental strategies developed all around the world to access this elusive signal. These considerable efforts have led to significant progress in recent years, including the first claimed detection of the global, sky-averaged 21cm signal and ever lower upper limits on the power spectrum of its spatial fluctuations by SKA precursors and pathfinders. I will then focus on the improvements we can expect with the SKA and namely on the potential of 21cm intensity maps to constrain the Epoch of Reionisation.

Neutrinos in the multi-messenger era / 416

Physics results of KM3NeT and update on the construction phase

Author: Simone Biagi[1]

[1] *INFN - LNS*

Corresponding Author: biagi@infn.it

KM3NeT is a multi-site underwater detector, designed to detect and study cosmic neutrinos and their sources in the Universe, and improve the measurement of the neutrino oscillation parameters. Two neutrino telescopes are under construction in the Mediterranean Sea, ARCA (Portopalo di Capo Passero, Italy) and ORCA (Toulon, France), optimized respectively for neutrinos in the energy range of 1 TeV-100 PeV and 10 GeV-10 TeV. The construction of both detectors is well under way, with 27 and 18 Detection Units active in ARCA and ORCA respectively. In this talk, I will report the main physics results obtained with ARCA and ORCA, in their partial configurations, and an overview of the expected performances of the full detectors will be given. The KM3NeT alert system will be discussed, in the context of a multi-messenger approach. The main technological efforts carried on in the last years will be described, which paved the way to the current mass construction phase.

A NICER view of extreme gravity from the International Space Station / 417

Thermonuclear X-ray bursts with NICER

Author: Gaurava K. Jaisawal[1]

[1] *DTU Space, Technical University of Denmark*

Corresponding Author: gaurava@space.dtu.dk

Type-I X-ray bursts are powered by the unstable thermonuclear burning of accreted hydrogen and helium material on the surface of a neutron star (NS) in low-mass X-ray binary systems. They typically last for tens to hundreds of seconds, depending on the fuel composition. Among the observed bursts, approximately 20% of them are powerful enough to lift the NS photosphere tens to hundreds of kilometers above the surface. Studying these events provides crucial information about nuclear processes, the interaction between the burst and accretion disk, and constraints on NS physical parameters such as spin and compactness. Thanks to the unprecedented timing and spectral sensitivity of NICER (Neutron Star Interior Composition Explorer) in the soft X-ray range, thermonuclear X-ray bursts from several sources have been detected in the last seven years. This talk will highlight these interesting findings observed by NICER.

Repeating transients in galactic nuclei: confronting observations with theory / 418

EMRI+TDE=QPE: Star-Disc Interaction around Massive Black Holes and Quasi-Periodic Eruptions

Author: Itai Linial[1]

Co-author: Brian Metzger [2]

[1] *Columbia University/Institute for Advanced Study*

[2] *Columbia University/Flatiron Institute*

Corresponding Author: itailinial@gmail.com

Quasi-periodic eruptions (QPEs) are an emerging class of high amplitude bursts of X-ray radiation, repeating on a hours-day timescale, recently discovered near the central supermassive black holes

(SMBHs) of a few low-mass galaxies. I will briefly review our current theoretical understanding of QPEs, and will focus on a scenario involving a main-sequence star repeatedly colliding with an accretion flow feeding the SMBH. I will demonstrate how this model naturally reproduces the observed period, luminosity, emission temperature, duration, occurrence rate of QPEs, as well as the association between QPEs and other types of transients occurring around SMBHs. I will also discuss the implications of the observations and of our model for probing the dynamics around SMBHs, accretion physics around SMBHs, the rate of extreme mass ratio inspirals (EMRIs), and the discovery prospects of related repeating nuclear transients.

Mid-frequency gravitational waves (0.1-10 Hz): sources and detection methods / 420

The progenitors of Type Ia Supernovae: a clear-cut case for the Lunar Gravitational Wave Antenna

Author: Nando Patat[1]

Co-authors: Enrico Cappellaro [2]; Jan Harms [3]; Marica Branchesi [3]; Stefano Benetti [2]

[1] *European Southern Observatory*

[2] *INAF-OAPD*

[3] *GSSI*

Corresponding Author: fpatat@eso.org

Despite of the key role of Type Ia Supernovae in cosmology and after decades of research, the nature of their progenitors remains unclear. None of the results obtained so far is sufficiently conclusive and, in some cases, the findings appear to be even in contradiction. Moreover, observations have shown that about 30% of the discovered SNe Ia largely deviate from the properties of 'normal' thermonuclear events, such as peak luminosity, light curve morphology and spectral features. The rising era of GW astronomy opens a new avenue for obtaining independent and direct insights to the SN~Ia progenitors' nature, which remains one of the burning, open questions in modern astrophysics. In my talk I will present the problem and its possible solution in connection to the foreseen GW detectors in the deci-Hz region. In particular, I will describe and discuss the case of the Lunar Gravitational Waves Antenna, which carries the promise of answering this fundamental question.

Latest results from Galactic center observations / 422

S-stars & G-stars orbiting a fermionic dark matter core

Authors: Carlos Raúl Argüelles[1]; Eduar Becerra-Vergara[2]; Jorge Armando Rueda Hernandez[3]; Martín Mestre[4]; Remo Ruffini[5]; Valentina Crespi[6]

[1] *Universidad Nacional de La Plata*

[2] *Universidad Industrial de Santander*

[3] *ICRANet*

[4] *Instituto de Astrofísica de La Plata*

[5] *ICRANet, ICRA, INAF*

[6] *Instituto de Astrofisica de La Plata*

Corresponding Author: carlosarguelles80@hotmail.com

The observations of the so-called S-stars together with the dust-enshrouded objects, the G-stars, can help to further corroborate Einstein's General Relativity theory and to better constrain the nature of the supermassive black hole (SMBH) candidate, SgrA. *In recent years, a novel dark matter (DM) model for galaxy haloes has been developed, the Ruffini-Argüelles-Rueda (RAR) model. It consists of*

self-gravitating fermions in hydrostatic and thermodynamic equilibrium, that develop a dense and degenerate core which is the central region of a continuous distribution of a more extended DM halo. In the case of the Milky way, for particle masses in the range 56–390 keV/c², the core can successfully explain the dynamics of the S-stars, leading to an alternative interpretation of Sgr A to that of a Supermassive Black Hole (BH). Simultaneously, the extended halo agrees with the galaxy rotation curve data. In this talk we show how well such DM solutions can explain the astrometric data of the G-stars and S-stars, and compare with the BH paradigm. For the parameter space exploration of the different models, we use a Markov Chain Monte Carlo (MCMC) sampler and then perform a quantitative comparison via Bayes factors.

Slowly rotating pulsars / 423

Evolution of the long-period pulsars with fallback discs

Author: Ali Arda Gençali[1]

Co-author: Ünal Ertan [1]

[1] *Sabancı University*

Corresponding Author: gencali@sabanciuniv.edu

Recently discovered long-period pulsars (LPPs), namely PSR J0901−4046 (76 s), GLEAM-X J162759.5−523504.3 (1091 s), and GPM J1839−10 (1318 s), have rotational periods much longer than those of radio pulsars and other isolated neutron star populations. LPPs exhibit transient pulsed-radio epochs with unusual and variable pulse shapes, similar to the radio behaviors of rotating radio transients (RRATs) and few radio emitting anomalous X-ray pulsars (AXPs) and soft-gamma repeaters (SGRs). The long-term evolutions of LPPs and their evolutionary connections with other isolated neutron star populations provide a significant test for the models. In the earlier applications of the fallback disc model to AXPs/SGRs, the simulations indicated that some of these sources with relatively strong dipole moments could evolve to long periods of LPPs. In this work, we have shown through numerical analysis that the properties of the three LPPs could be achieved by the neutron stars evolving with fallback discs and the dipole fields of conventional strength ($\sim$ a few 10^{12} G on the surface of the star).

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 424

Blandford-Znajek power as a strong-gravity signature

Author: Filippo Camilloni[1]

[1] *Goethe University Frankfurt*

Corresponding Author: camilloni@itp.uni-frankfurt.de

The Blandford-Znajek (BZ) mechanism is an electromagnetic manifestation of the Penrose process that currently constitutes the best theoretical candidate to explain the launching of relativistic jets by black holes.
In this talk we offer a modern review about the BZ mechanism and the analytic construction of black hole magnetospheres. Higher order perturbative corrections are crucial in order to produce results that are complementary to numerical simulations when the black hole is in the high-spin regime, and can potentially predict new features about the non-perturbative structure of the BZ theory. Moreover, we show by means of an explicit example that these perturbative corrections depend in a non-degenerate manner on the underlying theory of gravity considered, enabling one to use the BZ power emitted as a strong-gravity signature to test General Relativity against alternative theories of gravity on future horizon-scale observations.

Mineral detection of dark matter and neutrinos / 425

Paleo-detectors for cosmic rays

Author: Lorenzo Apollonio[1]

Co-authors: Alessandro Veutro [2]; Claudio Galelli [3]; Federico Maria Mariani [1]; Lorenzo Caccianiga [4]; Paolo Magnani [1]

[1] *UniMi & INFN*

[2] *Università di Roma La Sapienza*

[3] *Laboratoire Univers et Théories, Observatoire de Paris, Université PSL, Université Paris Cité*

[4] *INFN*

Corresponding Author: lorenzo.apollonio@unimi.it

The paleo-detector technique proposes to use long-age minerals, which have been exposed to an enormous flux of particles, as astroparticle detectors. Some of these particles should have interacted with mineral nuclei, generating linear defects in the crystalline structure in the form of tracks. The paleo-detectors have been proposed to detect dark matter and neutrinos, using minerals found well deep in the ground, shielded by the cosmic rays. These studies take advantage of the enormous exposure, even to these rare events, that can be acquired through age with a small amount of material. We propose to use the paleo-detectors as cosmic rays detectors. Since the cosmic rays can be shielded, we can find optimal exposure windows during which the minerals were exposed to the flux and then shielded. We take as example the dessication of the Mediterranea Sea during the Messinian (~ 6 Myr ago). After the dessication, several evaporites were formed, exposed to the flux of cosmic rays (for ~ 300 kyr) and then submerged again. The large amounts of tracks expected is enough to measure the variation of 1% of the flux, making this technique optimal to identify a potential transient events happened during the exposure window.

Cosmic backgrounds from radio to far-IR / 426

Extragalactic sources background from radio to sub-millimetre wavelengths

Author: Luigi Toffolatti[1]

[1] *Ballarin*

Corresponding Author: ltoffolatti@uniovi.es

We review the contribution of undetected extragalactic sources to the cosmic microwave background (CMB) radiation, from radio to sub-millimetre wavelengths. As demostrated by very recent analyses, Active Galactic Nuclei (AGN) is the dominant population in this frequency
range, at least down to the $\simeq$ mJy flux density level in source number counts. As for this, number counts of extragalactic sources are well determined at cm wavelengths down to very faint flux levels thanks to many very recent deep and large-area surveys. On the other hand, at mm wavelengths, observations of number counts of extragalactic sources are mainly provided by CMB experiments, capable to detect only very bright sources, down to many tens of mJy, at best. Therefore, an accurate modeling of number counts of extragalactic sources is needed to correctly predict the extragalactic background light (EBL) and the contaminant signal produced by extragalactic sources in CMB anisotropy (all-sky) maps. We discuss here how to model AGN number counts and, at the same time, we present the results obtained by a recent successful cosmological evolution model of AGNs at radio/microwave frequencies.

Dark energy and the accelerating universe / 427

Dark Energy in 2024

Author: Benjamin L'Huillier[1]

[1] *Sejong University*

Corresponding Author: lhuillier.benjamin@gmail.com

In this talk, I will review the state of the art of dark energy in light of the early Stage IV surveys results.

The Euclid mission: current status, results from early observations, and future prospects / 428

Euclid Near-Infrared Instrument (NISP): imaging pipeline development and preliminary results on instrument performances

Author: Matteo Correnti[1]

Co-authors: Andrea Bonchi [2]; Fabiana Faustini [1]; Gianluca Polenta [2]; Ronaldo da Silva [1]

[1] *INAF/OAR - ASI/SSDC*

[2] *ASI/SSDC*

Corresponding Author: matteo.correnti@inaf.it

Euclid is an ESA survey mission designed to understand the origin of the Universe's accelerating expansion using weak gravitational lensing and redshift clustering as main probes. Very high image quality is required for galaxy shape measurements, while accurate photometry at visible and near-infrared wavelengths and near-infrared spectroscopy are needed to measure photometric and spectroscopic galaxy redshifts.

Within the Euclid Science Ground Segment, the near-infrared imaging (NIR) processing function has the task to reduce all the images produced by the near-infrared instrument (NISP) in photometric mode. Starting from Level 1 raw frames, the NIR pipeline produces individual images and stacked mosaics in Y, J, and H bands accounting for instrumental effects, subtracting the sky background, performing both astrometric and photometric calibrations, and providing all the information needed for catalogue production such as PSF, variance, weights, and quality flags.

Here, after an overview of the pipeline design, I will present the current status of the NIR processing function development. Moreover, I will provide a brief overview of the instrument performances, obtained from the analysis of the commissioning data and of the first scientific imaging observations, collected during Euclid first ten months of operation.

High energy astrophysics / 429

Non-thermal radiation due to CR transport in the magnetic halo of the Milky Way

Author: Heshou Zhang[1]

Co-authors: Gabriele Ponti [1]; Ettore Carretti [2]; Ruo-Yu Liu [3]; Mark Morris [4]; Marijke Haverkorn [5]; Nicola Locatelli [1]; Xueying Zheng [6]; Felix Aharonian [7]; Hai-Ming Zhang [3]; Yi Zhang [6]; Giovanni Stel [1]; Andrew Strong [6]; Micheal Yeung [6]; Andrea Merloni [6]

[1] *INAF - OA Brera*

[2] *INAF - IRA*

[3] *Nanjing University*

[4] *UCLA*

[5] *Radboud University Nijmegen*

[6] *MPE*

[7] *Dublin Institute for Advanced Studies*

Corresponding Author: heshou.zhang@inaf.it

The large-scale structures such as Fermi Bubbles and eROSITA Bubbles provide a unique opportunity to study our Milky Way. However, the nature and origin of these large structures are still under debate. In this talk, I will present the identification of several kpc-scale magnetised structures based on their polarized radio emission and their gamma-ray counterparts, which can be interpreted as the radiation of relativistic electrons in the Galactic magnetic halo. These non-thermal structures extend far above and below the Galactic plane and are spatially coincident with the thermal X-ray emission from the eROSITA Bubbles. Multi-wavelength spectral energy distribution analyses have revealed that both thermal and non-thermal extended structures can be explained by Galactic outflows driven by the active star-forming regions located at 3 – 5 kpc from the Galactic Centre. These results reveal how X-ray-emitting and magnetised halos of spiral galaxies can be related to intense star formation activities.

Latest results from Galactic center observations / 430

An X-ray View of the Galactic Center: present and past Sgr A* high-energy activity

Author: Andrea Goldwurm[1]

[1] *APC-Paris & CEA/IRFU-Saclay*

Corresponding Author: andrea.goldwurm@cea.fr

I will present a review on the X-ray emission coming from the Galactic Center (GC), and in particular from the Central Molecular Zone, established from the results that have been obtained in the last 20 years with Chandra, XMM-Newton, INTEGRAL and other space observatories operating in the range 1-200 keV.
I will focus in particular on the emission that the GC super Massive Black Hole, Sgr A*, radiates presently in these energies, both persistently and in flaring mode, and on the results that indicate its higher activity in the past.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 431

Evolutionary Links Between the Isolated Neutron Star Populations

Author: Ali Arda Gençali[1]

Co-author: Ünal Ertan [1]

[1] *Sabancı University*

Corresponding Author: gencali@sabanciuniv.edu

We have investigated the evolutionary links between the isolated neutron star populations namely radio pulsars (RPs), anomalous X-ray pulsars (AXPs), soft gamma repeaters (SGRs), dim isolated neutron stars (XDINs), high-magnetic-field RPs (HBRPs), central compact objects (CCOs), rotating radio

transients (RRATs), and long-period pulsars (LPPs) in the fallback disc model. The results of our simulations can be summarized as follows: (1) These diverse populations emerge as a natural outcome of their evolutions with different initial conditions (initial period, disc mass, and the magnetic dipole moment). (2) Each population has evolutionary connections with at least one other population. (3) HBRPs with relatively strong magnetic dipole moments evolve into AXP/SGR and eventually become LPPs in their late phases of evolution. (4) No evolutionary links exist between persistent AXP/SGRs and RRATs, XDINs, and CCOs. (5) Evolutionary curves of known RRATs which have the highest estimated birth rate pass through a large fraction of the RPs during the initial phases, while a small fraction of the RRAT curves traces the region of all known XDINs. This implies that a significant fraction of RPs are evolving into the RRAT properties, and that a small fraction of RRATs are progenitors of the XDINs. These results provide concrete support to the ideas proposing evolutionary connections between the neutron star families to account for the ‘’birth-rate problem”, the discrepancy between the cumulative birth rate estimated for these systems and the core-collapse supernova rate.

Astrophysics with gravitational waves / 432

Dissipative effects in matter and metric perturbations: formal analysis

Author: David Díaz-Guerra[1]

Co-authors: Conrado Albertus [1]; M. Ángeles Pérez-García [1]; Prasanta Char [1]

[1] *Universidad de Salamanca*

Corresponding Author: ddiazgue@usal.es

Compact objects are usually described using the perfect fluid formalism. However, in astrophysical processes out of local equilibrium, dissipative effects become important to realistically describe the dynamics of the system.
In this work, we present for the first time the gauge-invariant non-spherical perturbations in a dissipative self-gravitating fluid in spherical symmetry. For this we use the Gerlach-Sengupta formalism to work with gauge-invariant metric perturbations, and the Gundlach-Martín-García approach to transform the tensor perturbation equations into scalar equations.
We calculate the dynamics of the dissipative contributions, e.g. bulk viscosity, heat flux, and anisotropic stress, using the Müller-Israel-Stewart equations in the gauge-invariant formalism.

We obtain the set of field equations for the evolution of matter and metric perturbations in the polar and axial sectors. In the former, we find two wave equations sourced by the anisotropic contributions, and the evolution of all matter perturbations for radiative modes ($l \geq 2$). In the latter, we find one wave equation coupled to the evolution of matter perturbations. Finally we comment on the contribution of dissipative effects in the lower-order multipoles ($l = 0, 1$) for both sectors.

Wormholes, energy conditions and time machines / 433

Wormhole restrictions from quantum energy inequalities

Author: Eleni-Alexandra Kontou[1]

[1] *King's College London*

Corresponding Author: eleni.kontou@kcl.ac.uk

It is known that all wormholes violate classical energy conditions, non-negativity constraints on contractions of the stress-energy tensor. Since these conditions are violated by quantum fields, it was believed that wormholes can be constructed in the context of semiclassical gravity. But negative

energies in quantum field theory are not without restriction: quantum energy inequalities (QEIs) control renormalized negative energies averaged over a geodesic. Thus, QEIs provide restrictions on the construction of wormholes. First, I will briefly discuss both 'short' and 'long' (without causality violations) wormhole solutions in the context of semiclassical gravity. Then I will present constraints on the Maldacena, Milekhin and Popov 'long' wormhole from the smeared and the doubled smeared null energy condition.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 434

Assessing the significance of CMB anomalies with cosmological gravitational waves

Author: Giacomo Galloni[1]

[1] *University of Ferrara*

Corresponding Author: giacomo.galloni@unife.it

Since the very first observations, the Cosmic Microwave Background (CMB) has revealed on large scales unexpected features known as anomalies, which challenge the standard Λ cold dark matter (ΛCDM) cosmological model. One of these is the hemispherical power asymmetry, i.e. a difference in the average power on the two hemispheres centered around (l, b) = (221, −20), which shows a relatively high level of significance. Another is the lack-of-correlation, where the measured two-point angular correlation function of CMB temperature anisotropies is compatible with zero, differently from the predictions of the standard model. These anomalies could indicate a deviation from the standard model, unknown systematics, or simply a rare realization of the model itself. In this talk, I will investigate the physical origin of these anomalies, leveraging the potential information provided by the cosmological gravitational wave background (CGWB) detectable by future gravitational wave (GW) interferometers. In particular, I will analyze both constrained and unconstrained realizations of the CGWB to study the extent of information that GWs can offer. Indeed, the CGWB represents a unique window to explore the early universe and I will show that it can be used in combination with CMB data to shed light on the CMB anomalies.

Gravitational kHz waves - LIGO-Virgo-KAGRA / 435

Continuous wave and long-transient signals from newborn magnetars: status and prospects for detection

Author: Simone Dall'Osso[1]

[1] *Sapienza Universita' di Roma*

Corresponding Author: sim.dall@gmail.com

The search for continuous wave (CW) sources represents a new frontier of gravitational wave astronomy. The current and future LVK science runs may eventually reach the required sensitivities for the first detection of a rotating, distorted NS. At the same time, increasing efforts are being devoted to the search of long-transient signals (a few hours long) from newly born magnetars, a special class of NS expected to have particularly fast rotation and large mass quadrupole. Long transients bear some resemblance to CW signals, while posing specific challenges in terms of data analysis and of observing strategies, which strongly require a multi-messenger approach. I will review the current status and the outlook of such efforts, with special emphasis on their synergies with electromagnetic observations, the new ideas they have inspired and their potential for breakthrough discoveries.

Theories of gravity: alternatives to the cosmological and particle standard models / 436

Linear perturbations in Horndeski models with spatial curvature

Author: Serena Gambino[1]

Co-authors: Filippo Vernizzi [2]; Francesco Pace [3]

[1] *Scuola Superiore Meridionale Via Mezzocannone, 4 80138 Napoli - Italy CF: 95315120634*

[2] *IPhT, Paris-Saclay*

[3] *University of Torino*

Corresponding Author: s.gambino@ssmeridionale.it

This work aims to investigate the impact of spatial curvature in modified gravity models, specifically within the Horndeski framework. Typically overlooked in the literature due to the spatial flatness assumed in the ΛCDM model, this study aims to fill this gap. The ΛCDM model, rooted in General Relativity (GR), is in good agreement with observational data, but faces problems with cosmological parameters such as H0, σ8 and, more recently, Alens (the amplitude of the weak lensing signal from CMB photons). These discrepancies motivate the exploration of models beyond ΛCDM, such as the Horndeski model, the most comprehensive scalar tensor theory with second-order equations of motion.
My research is progressing in several stages, the topic of this talk will be to outline the theoretical results obtained: field equations for a curved Horndeski model derived using the effective field theory of dark energy. I will then show how these equations are implemented in the Einstein-Boltzmann code hi_CLASS to compute cosmological observables in order to study the influence of spatial curvature on the CMB anisotropy power spectrum and the matter power spectrum. Subsequently, a statistical analysis using the MCMC code MontePython will constrain the cosmological parameters by comparing observational and computed data.
The critical finding I want to highlight is that spatial curvature significantly modifies the equations of motion, introducing couples with the α-parameters of the Horndeski model. In particular, the spatial derivatives in the scalar perturbation equations gain an additional +3K term and new terms appear, showing that spatial curvature multiplies the scalar perturbation π and α functions. For gravitational waves, the derivative term receives a +2K addition. These modifications suggest that ignoring spatial curvature could miss crucial insights and potential solutions to the tensions in the ΛCDM model.

Theories of gravity: alternatives to the cosmological and particle standard models / 437

Breaking the baryon-dark matter degeneracy in a model-independent way through the Sunyaev-Zeldovich effect

Authors: Anna Chiara Alfano[1]; Marco Muccino[2]; Orlando Luongo[3]

[1] *Scuola Superiore Meridionale*

[2] *INFN*

[3] *University of Camerino, Physics Division*

Corresponding Author: a.alfano@ssmeridionale.it

We propose a model-independent Bézier parametric interpolation to alleviate the degeneracy between baryonic and dark matter abundances by means of intermediate-redshift data. To do so, we first interpolate the observational Hubble data to extract cosmic bounds over the (reduced) Hubble constant, h0, and interpolate the angular diameter distances, D(z), of the galaxy clusters, inferred from the Sunyaev-Zeldovich effect, constraining the spatial curvature, Ωk. Through the so-determined Hubble points and D(z), we interpolate uncorrelated data of baryonic acoustic oscillations bounding the baryon (ωb = h^2_0Ω_b) and total matter (ωm = h^2_0Ω_m) densities, reinforcing the constraints on h0 and Ωk with the same technique. Instead of pursuing the usual treatment to fix ωb via the value obtained from the cosmic microwave background to remove the matter sector degeneracy, we here interpolate the acoustic parameter from correlated baryonic acoustic oscillations. The results of our Monte Carlo–Markov chain simulations turn out to agree at 1−σ confidence level with the flat ΛCDM model. While our findings are roughly suitable at 1−σ with its non-flat extension too, the Hubble constant appears in tension up to the 2−σ confidence level. Accordingly, we also reanalyze the Hubble tension with our treatment and find our expectations slightly match local constraints.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 438

Theoretical Modelling of Gamma-Ray Burst 090510

Author: Joseph Saji[1]

Co-authors: Agnieszka Janiuk [2]; Maria Dainotti [3]; Shubham Bhardwaj [4]

[1] *Center for Theoretical Physics, Polish Academy of Sciences*

[2] *Center for Theoretical Physics, PAS*

[3] *National Astronomical Observatory of Japan*

[4] *SOKENDAI/National Astronomical Observatory of Japan*

Corresponding Author: josephpsaji@gmail.com

Gamma-ray bursts observed in high energies allow the investigation of the emission processes of these still puzzling events. Here, we investigate the peculiar GRB 090510, a short GRB with an indication of plateau emission observed by the Fermi-LAT within the context of general relativistic magnetohydrodynamic code (HARM) to infer the jet opening angle, the energetics, the Lorentz Gamma factor, the structure and variability of the jet, and the progenitor parameters of the compact binary. We tested the 2D and 3D models and estimated the time scale of variability. The predicted energetics and the jet opening angle are in general agreement with observed values when we consider that the jet opening angles also evolve with redshift. This work establishes a basis for ongoing exploration, which will further align the theoretical model simulations with observations.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 439

X-ray approach to the magnetar-FRB connections using NICER

Author: Teruaki Enoto[1]

[1] *Kyoto University*

Corresponding Author: enoto.teruaki.2w@kyoto-u.ac.jp

The NICER (Neutron star Interior Composition ExploreR) X-ray telescope on the International Space Station can provide a powerful approach to the magnetar and FRB connections using its large effective area and prompt follow-up observation of transients. Our NICER magnetar and magnetosphere (M&M) science collaboration has observed several transient magnetars and FRB-related phenomena. We detected X-ray enhancement associated with giant radio pulses, a phenomenon similar to FRBs, from the Crab pulsar, performed follow-up observations of the Galactic magnetar SGR 1935+2154 after it produced an FRB burst in 2020, and in 2022, and discovered twin glitches before and after the FRB from the same source, SGR 1935+2154. Here, we review these NICER observations and related X-ray observations.

Slowly rotating pulsars / 440

Ultra-long Period Radio Sources - Are they Magnetars?

Author: Zorawar Wadiasingh[1]

Co-authors: Paz Beniamini [2]; Jeremy Hare [3]; Kaustubh Rajwade [4]; George Younes [5]; Dimitrios Skiathas [6]; Constantinos Kalapotharakos [7]; Alexander van der Horst [8]

[1] *University of Maryland College Park / NASA GSFC*

[2] *Open University of Israel*

[3] *NASA GSFC / CUA*

[4] *University of Oxford*

[5] *NASA GSFC / UMBC*

[6] *NASA GSFC / University of Patras*

[7] *NASA GSFC*

[8] *George Washington University*

Corresponding Author: zwadiasingh@gmail.com

In this talk I will make the case that ultra-long period radio pulsars are magnetically powered neutron stars, or magnetars in the broadest sense of the term. Although they appear very different observationally from X-ray magnetars, I will argue they host strong magnetar-like fields. This will encompass arguments from many directions, including source densities, energetics, the physics of how coherent radio emission works in normal pulsars, and observational constraints. The existence of such objects opens an exciting new avenue of possibilities, which I will briefly discuss, including unexplored evolutionary tracks for neutron stars, extragalactic detections of these objects in nearby galaxies, and the possibility some will be involved in binary neutron star mergers. These sources, as ultra-long period magnetars, may also be closely linked with periodic windowing of activity seen in some extragalactic repeating fast radio bursts.

Micro-Hertz gravitational waves (0.1-100 μHz): sources and detection methods / 442

Probing supermassive black hole binaries in micro-Hertz band with satellite orbital resonances

Authors: Peng Xu[1]; Minghui Du[1]; Qiong Deng[2]

[1] *Institute of Mechanics, Chinese Academy of Sciences*

[2] *Lanzhuo University*

Corresponding Author: xupeng@imech.ac.cn

Coalescing supermassive black hole binaries (SMBHBs) are the primary source candidates for low frequency gravitational wave (GW) detections, which could bring us deep insights into galaxy evolutions over cosmic time and violent processes of spacetime dynamics. Promising candidates had been found based on optical and X-ray observations, which claims for new and ready-to-use GW detection approaches before the operations of space-borne antennas. We show that, satellite orbit resonance effects in satellite laser ranging systems, intersatellite ranging systems and lunar ranging systems could serve as probes of coalescing SMBHBs in the micro-Hertz band. Lasting and characteristic imprints caused by such resonances in the residual distances or accelerations from such ranging measurements are studied, and the detection SNR is analyzed with both the current and future improved ranging precisions. For SLR missions, within redshift $z \sim 1$, the threshold SNR = 5 requires 1–2 years of accumulated data for the current precision and months of data for improved precision, which are workable for the data processing. Such a detection scheme could fulfill the requirement of a tentative SMBHB probe during the preparing stage of LISA and Taiji, and it requires no further investment to any new and advanced facilities. It is also worthwhile to look back and

re-process the archived data from the past decades, in where resonant signals from SMBHBs might be hidden.

Exploring the Universe with strong gravitational lensing / 443

Cosmic chronometers and time delay cosmography: a new synergy to constrain the expansion history of the Universe

Author: Elena Tomasetti[1]

Co-author: Piero Rosati [2]

[1] *University of Bologna*

[2] *Universita' degli Studi di Ferrara*

Corresponding Author: elena.tomasetti2@unibo.it

In the era of precision cosmology, where the accuracy of observational probes and the rigorous control of systematic uncertainties are of paramount importance, exploring the synergies among different methods can play a key role. Typically this is done on a global level and the results from different probes, coming from various datasets, are combined to increase the precision of the cosmological constraint. Here instead we report the first attempt for a self-consistent probe combination, where different methods are applied on the same sample.
In particular, we want to exploit the synergy of two complementary approaches - time delay cosmography (TDC) and cosmic chronometers (CC) - whose combination can boost their precision in constraining cosmological parameters and their robustness against systematic effects. Given a lens galaxy cluster, TDC allows estimates of H_0 based on time delays between the multiple images of time-varying sources strongly lensed by the cluster; at the same time, CC can constrain the differential time evolution of the Universe as traced by the most massive and passive galaxies, members of the same lens cluster and other lens clusters in close-by redshift bins.
In particular, I will show the preliminary results of an ongoing pilot project, focusing on the galaxy cluster MACS J1149.5+2223 (z=0.54), for which TDC has already produced constraints on H_0 thanks to the presence of the multiply imaged SN 'Resfdal'. Here, instead, we want to apply the CC method benefiting from the exquisite quality of VLT/MUSE spectra available for its member galaxies and for those of its redshift-neighbours SDSS J1029+2623 (z=0.59) and SDSS J2222+2745 (z=0.49). Finally, the combination of their results will allow us to test the power of this joint analysis.

ANTARES – 15 years of multi-messenger astronomy in the sea / 444

The ANTARES adventure

Author: Marco Circella[1]

[1] *Circella*

Corresponding Author: marco.circella@ba.infn.it

ANTARES was the first neutrino telescope that operated in the deep sea for more than 15 years. From its location in the northern hemisphere, it long represented the largest detector world-wide with a privileged view towards the Galactic center, providing valuable results in a variety of investigations. It also served as a long-term, real-time, high-bandwidth facility for sea and Earth science measurements. A slender design of the apparatus, featuring several innovative solutions, was instrumental for ensuring success in the installation in the deep sea and even, when needed, maintenance of the apparatus, paving the way towards the next generation of deep-sea detectors. In this talk, we will review the main design choices of ANTARES and we will illustrate the exciting adventure of its construction and operation.

Present and future of cosmic microwave background observations / 445

Component separation of CMB polarization data

Author: Alessandro Carones[1]

[1] *SISSA*

Corresponding Author: alessandro.carones@roma2.infn.it

Upcoming experiments of the Cosmic Microwave Background (CMB) will reach unprecedented sensitivity to polarization, thus allowing to target the first detection of primordial CMB B-modes and possibly shed new light on reionization history, cosmic birefringence, neutrino masses, and large-scale CMB anomalies. However, accurate measurements of the CMB polarization require exquisite control of Galactic and extragalactic foreground contamination, thus pointing to the need for the application of robust component separation techniques. In this talk, I will provide an overview of the approaches adopted to reconstruct a cleaned CMB polarization signal together with future perspectives for the optimization of the different methodologies.

Fast radio bursts / 446

The Italian perspective of the science of fast radio bursts: past and present efforts, the future

Author: Matteo Trudu[1]

[1] *INAF - Cagliari*

Corresponding Author: trudumatteo@outlook.com

One of the most enigmatic challenges in contemporary time domain radio astronomy is understanding the nature of fast radio bursts (FRBs). These millisecond-duration, highly coherent radio flashes predominantly originate from beyond our Galaxy.
In this presentation, I will review the extensive efforts of the Italian research community in uncovering the origins and physical mechanisms behind FRBs, since the early days to this field to the present era, particularly focusing on multi-frequency campaigns aimed at FRB sources. Additionally I will discuss Italy's significant role in the forthcoming Canadian Hydrogen Observatory and Radio-transient Detector (CHORD) telescope. With its expansive field of view and real-time detection and precise localisation capabilities, CHORD promises to revolutionise our understanding of these mysterious cosmic phenomena.

Large scale structure and dark energy / 447

On the optimal extraction of the Alcock Paczynski signal from voids

Author: Giulia Degni[1]

[1] *Università Roma Tre*

Corresponding Author: giulia.degni@uniroma3.it

Cosmic voids, large under-dense regions in the Universe, serve as promising laboratories for extracting cosmological information. They offer opportunities to explore deviations from ΛCDM and provide insights into dark energy and modification of gravity. Upcoming surveys like Euclid will enable detailed void analyses, allowing access to a huge number of voids. Voids' significance lies

in their spherically symmetric property when stacked, becoming standard spheres. However, observationally, they exhibit two types of distortions crucial for extracting cosmological information: redshift-space distortions (RSD), caused by galaxy velocities, and geometrical distortions, arising from the use of incorrect cosmological models when converting observed redshifts into distances (Alcock-Paczynski test). Current RSD models are insufficient for smaller voids. A new technique, utilizing a reconstruction method based on the Zel'dovich approximation, extends analyses to smaller voids and enhances the precision of parameter constraints.

Multi-messenger astronomy with gravitational waves / 448

PyGRB: A matched filtering triggered gravitational-wave search pipeline

Author: Sebastian Gómez Lopez[1]

[1] *La Sapienza Università di Roma*

Corresponding Author: sebastian.gomezlopez@uniroma1.it

(pdf version attached)

Ever since the observation of GW170817 provided evidence for binary neutron star mergers as sources of gravitational waves and other transient emissions such as short gamma-ray bursts, the development of electromagnetically informed gravitational-wave analysis pipelines has gained relevance in the astrophysics community [2, 1, 3, 4]. In this talk, I will illustrate the most recent implementation of PyGRB, a coherent gravitational-wave search that uses matched filtering and targets the time and sky locations of electromagnetic transients, typically short gamma-ray bursts. The coherent matched filtering implementation for a multidetector network will be shown in detail, highlighting differences with respect to typical all-sky coincident searches. Finally, performance measurements and test runs will be shown as proof of concept for its usage.

References
1 I. W. Harry and S. Fairhurst. A coherent triggered search for single spin compact binary coalescences in gravitational wave data. Class. Quant. Grav., 28:134008, 2011.
[2] Ian W. Harry and Stephen Fairhurst. A targeted coherent search for gravitational waves from compact binary coalescences. Phys. Rev. D, 83:084002, 2011.
[3] A. R. Williamson, C. Biwer, S. Fairhurst, I. W. Harry, E. Macdonald, D. Macleod, and V. Predoi. Improved methods for detecting gravitational waves associated with short gamma-ray bursts. Phys. Rev. D, 90(12):122004, 2014.
[4] Andrew Robert Williamson. Gravitational waves with gamma-ray bursts. PhD thesis, Cardiff U., Cardiff University, 2016.

Gravitational lensing, shadows and photon rings / 449

Gravitational Lensing in the Kerr Spacetime: The Standard Observer

Author: Torben Frost[1]

[1] *Kavli Institute for Astronomy and Astrophysics - Peking University*

Corresponding Author: torben.frost@pku.edu.cn

The Kerr spacetime is one of the most relevant spacetimes in contemporary astrophysics and describes the spacetime of a rotating black hole. When light rays pass by or are emitted in the close vicinity of a Kerr black hole they are gravitationally lensed and this leads to characteristic lensing

features on the sky of a distant observer. While it is a common assumption that the observer is located at a large distance from the black hole and therefore static, in real astrophysical settings this is not necessarily the case. However, when the observer is located at a finite distance from the black hole he is commonly dragged along by the black hole which also impacts the observable lensing features.
In this talk, we will now analyse what such an observer will see. For this purpose, we will assume that we have a standard observer (sometimes also called Carter observer) in the domain of outer communication outside the photon region. First, we will introduce an orthonormal tetrad and reparameterise the constants of motion of the lightlike geodesics using latitude-longitude coordinates on the observer's celestial sphere. Then we will derive and discuss the angular radius of the shadow of the black hole in dependence on the celestial longitude. In the next step, we will then characterise the different types of motion and analytically solve the equations of motion using elementary and Jacobi's elliptic functions as well as Legendre's elliptic integrals. Finally, we will use the analytic solutions to write down a lens equation and to derive the redshift and the travel time, and discuss the results. We will also discuss the implications for the observation of different types of light sources.

IXPE observations and multiwavelength opportunities / 450

IXPE observations of supernova remnants

Author: Riccardo Ferrazzoli[1]

[1] *INAF-IAPS*

Corresponding Author: riccardo.ferrazzoli@inaf.it

Supernova remnants (SNRs) are among the most important sources of non-thermal X-rays in the sky and likely contributors to Galactic cosmic rays and represent ideal targets to showcase the capabilities of the Imaging X-ray Polarimetry Explorer (IXPE) in performing spatially-resolved X-ray polarimetry.
For the first time, we can determine the turbulence level (through the measurement of polarization degree) and the orientation (through polarization direction) of the magnetic field near the shocks, where particle acceleration occurs.
IXPE reported so far the results of the observations of four SNRs: Cas A, Tycho, SN 1006 and RX J1713.7-3946.
These objects exhibit a wide range of characteristics, including dynamical age, spectral composition of emission, and progenitor type.
Aptly, they revealed significantly different results among them in terms of magnetic field properties and morphology, providing unexpected insights and shedding light on the particle acceleration mechanisms in astrophysical shocks.

High energy astrophysics / 451

Multimessenger Gravitational Lensing in Black Holes Spacetimes

Author: Torben Frost[1]

[1] *Kavli Institute for Astronomy and Astrophysics - Peking University*

Corresponding Author: torben.frost@pku.edu.cn

Usually, when we talk about gravitational lensing we either speak of gravitational lensing of light or gravitational waves. However, in the presence of a black hole also massive particles like neutrinos can be gravitationally lensed. While nowadays most neutrino detectors are not sensitive enough to resolve neutrino events with an angular resolution that is high enough so that we can completely

resolve the resulting lensing features, they still have the potential to provide supplementary information to more conventional lensing observations.
Therefore, in this talk, we will now discuss how gravitational lensing of massive particles can provide this additional information. For this purpose, we will treat the massive particles as test masses and assume two simple black hole spacetimes from general relativity: The Schwarzschild spacetime and the so-called Newman-Unti-Tamburino (NUT) spacetime. Using the lens equation and the travel time in terms of the time coordinate and the proper time we will illustrate which differences occur compared to light rays and how they may contribute to correctly characterising black hole spacetimes in the context of a multimessenger approach.

GRB-SN connection / 452

Can single massive stars be LGRB progenitors?

Author: Arpita Roy[1]

[1] *Australian National University*

Corresponding Author: arpita.roy1016@gmail.com

In this talk, we will discuss the origins of Long-duration Gamma-Ray Bursts (LGRBs). Typically associated with Type-Ic Supernovae, LGRBs are linked to massive stars. However, it remains unclear whether the progenitors are in binary systems or are effectively single stars. Our emphasis will be on single-star pathways. Our emphasis will be on single-star pathways. Specifically, we will explore which mass ranges, metallicities, and rotation rates favor LGRB production. The metallicity evolution of these stars, in connection to observed LGRB metallicity evolution, is not well understood, making it difficult to conclude if single stars are the major LGRB production channel irrespective of metallicities. Additionally, the evolutionary paths of massive stars ($M > 10\ M_\odot$) remain substantially uncertain. These stars begin their lives as main sequence O stars, but depending on their masses, rotation rates, and metallicities, they can pass through a wide range of evolutionary states. This leads to various possible surface compositions, spectral classifications, and end products, such as core-collapse SN, Pair-Instability SN (PISN), Pulsational Pair-Instability SN (PPISN), and Black Holes. We will present models of massive stars within a mass range of 10−150 MSun, with a mass resolution of ΔM = 10 MSun, and rotation rates (v/v_crit) from 0 to 0.6, with a velocity resolution of Δ(v/v_crit) = 0.1. We will discuss the possible metallicity and rotation rate distributions from our models that may be favorable for producing LGRB candidates, considering observed LGRB rates and their metallicity evolution. Our primary focus will be on exploring whether Chemically Homogeneous Evolution (CHE) could be a major channel for LGRB production.

Fast radio bursts / 453

Detection and localisation of the highly active FRB 20240114A with MeerKAT

Author: Jun Tian[None]

Corresponding Author: jun.tian@manchester.ac.uk

Fast radio burst (FRB) sources show a wide range of repetition rates, with some being able to emit hundreds and even thousands of bursts within hours. This provides a valuable opportunity for studying their burst morphology in detail, investigating their polarisation properties, localising the source to (sub)arcsecond precision, identifying its host galaxy, and searching for any associated persistent radio source (PRS). Here we present the MeerKAT observation of a new, highly active repeater FRB 20240114A, which was initially discovered by CHIME and reported to enter a period of high activity in 2024 January. We detect 62 bursts within 2hr of observation, with 44 in the UHF-band (544-1088MHz) and 18 in the L-band (856-1712MHz), confirming the high activity of the FRB source. Using the brightest burst in the sample, we measure a structure maximising dispersion measure (DM) and a Faraday rotation measure (RM). We find the bursts are band limited with a fractional bandwidth of ~10% and show frequency downward drifting, similar to other repeaters. We also perform the first interferometric localisation of the FRB source, allowing us to confidently identify its host galaxy. Interestingly, this host is classified as a dwarf star-forming galaxy, and contributes a large DM, suggesting the potential existence of a PRS. Based on the simple relation between the PSR luminosity and the RM from the FRB local environment, we derive a flux density for the PRS potentially associated with FRB 20240114A, which can be detected with continuum observations.

A NICER view of extreme gravity from the International Space Station / 454

The Masses and Radii of Neutron Stars Observed by NICER

Author: Sharon Morsink[1]

[1] *University of Alberta*

Corresponding Author: morsink@ualberta.ca

The dense interiors of neutron stars provide a window to the nature of cold matter at densities above nuclear that complements precision laboratory nuclear experiments. The uncertain physics at high density leads to a range of possible equations of state (EOS). Since each potential EOS allows a different neutron star mass and radius curve, observations of many neutron star masses and radii provide an important input that can constrain the supranuclear EOS. Pulse-profile modeling is a technique that uses the gravitationally-lensed X-ray flux emitted from hot spots on the neutron star's surface to infer its mass and radius. Since the pulsars have a strong gravitational field and rotate rapidly, general relativity is a crucial ingredient in this analysis. In this talk, I will give an overview of how the NICER Lightcurve Working Group infers the radius and mass of a neutron star, along with the latest results and the planned future observations of other pulsars.

Fast radio bursts / 455

Understanding Fast Radio Bursts sources: theoretical challenges and new ideas

Author: Simone Dall'Osso[1]

[1] *Sapienza Universita' di Roma*

Corresponding Author: sim.dall@gmail.com

Over 15 years after their discoveries, fast radio bursts (FRBs) still elude our understanding, despite the outstanding progress we have witnessed both observationally and theoretically. The huge luminosities of FRBs, and the apparent dichotomy between one-offs and repeaters, are just some of the theoretical challenges posed by such events. Among the countless proposed interpretations of FRBs, several authors have suggested that (at least some) their sources may be related to the cosmic population of magnetars. Observations lend some support to this hypothesis, as the galactic magnetar SGR 1935+215 is the only known astrophysical source from which FRB-like radio flares have been observed in the past few years. I will summarize the main advantages, and some shortcomings, of magnetar-based FRB models and will introduce a new idea that holds the potential to overcome (at least some of) the main shortcomings, explain at once the rare repeaters and the numerous one-off sources, and even bridge the gap between the apparent paucity of FRBs from local magnetars and their comparatively large all-sky rate.

Massive white dwarfs and related phenomena / 456

EXPLORING COMPACT OBJECT GRAVITATIONAL FIELDS WITHIN EINSTEIN'S GENERAL RELATIVITY FRAMEWORK

Authors: Amina Sadu[1]; Saken Toktarbay[1]

[1] *Al-Farabi Kazakh National University*

Corresponding Author: saduamina2003@gmail.com

In this research, we examine the gravitational behavior of dense astronomical bodies, specifically white dwarfs and neutron stars, using Einstein's gravitational theories. We explore the effects of deviations from spherical symmetry by applying a simplified mathematical model, incorporating the quadrupole moment to a first-order approximation 1.
Focusing on the interiors of white dwarfs, we use the Salpeter equation of state [2] to study how these stars maintain equilibrium between gravitational pull and internal pressure. We also compare the Chandrasekhar and Salpeter equations of state for ideal fluid solutions in general relativity to understand their influence on spherical objects.
This study provides new insights into the balance of forces within dense stars, enhancing our understanding of celestial mechanics under extreme conditions. Our future work will extend this analysis to non-spherically symmetric objects by adding parameters and refining the model for more accurate descriptions of complex geometries. This will improve our understanding of how different equations of state affect the properties and evolution of astrophysical objects in the universe.

High energy astrophysics / 457

Protoneutron star dynamos and magnetar formation

Authors: Alexis Reboul-Salze[1]; Jérôme Guilet[2]; Matteo Bugli[3]; Paul Barrère[2]; Raphaël Raynaud[4]

[1] *AEI*

[2] *CEA*

[3] *UniTO*

[4] *UPCité*

Corresponding Author: raphael.raynaud@cea.fr

Magnetars are isolated young neutron stars that exhibit the most intense magnetic fields known in the Universe and are characterized by a wide variety of high-energy emissions. The birth of rapidly rotating magnetars is also a promising scenario to power outstanding explosive transients. The formation process of these objects, as well as the origin of their ultra-strong magnetic fields, remains an open question, but the amplification of magnetic fields by MHD instabilities inside protoneutron stars seems inevitable. I will review the different dynamo scenarios that can explain magnetar formation, focusing on recent progress achieved with 3D-MHD HPC simulations, and discuss them in light of various observational constraints.

The SVOM mission in the time-domain era / 458

The SVOM mission for the study of the transient high-energy sources

Author: Andrea Goldwurm[1]

[1] *APC-Paris & CEA/IRFU-Saclay*

Corresponding Author: andrea.goldwurm@cea.fr

On behalf of the SVOM collaboration, I will present the science objectives, characteristics and status of the Chinese-French Space-based multi-band astronomical Variable Objects Monitor mission, expected to put in orbit, at the end of June 2024, a spacecraft carring four instruments, working in a range from visible to gamma-ray frequencies, in order to observe transient and variable high-energy sources.
With the capability to autonomously point the narrow field telescopes on the the transient events detected by the large field instruments, and supported by a near-real time alert system and a battery of ground telescopes, SVOM is dedicated to the time domain astronomy and particularly to the study of Gamma-Ray Bursts.

Present and future of cosmic microwave background observations / 459

CMB probes of fundamental physics: current status and future prospects

Author: Nicola Bartolo[1]

[1] *Physics and Astronomy Department*

Corresponding Author: bartolo@pd.infn.it

The Comic Microwave Background is one of the most powerful cosmological observables, allowing to probe a variety of phenomena, from the Early Universe and high energy physics at scales never achievable in earth facilities, to the evolution of the Universe at much recent epochs. In this talk I will provide an overview of signatures of new fundamental physics, for which the CMB can play the role of a privileged laboratory as a test-bed for scenarios beyond the standard model of particle physics and of cosmology. I will consider, e.g, early universe physics (inflation), including primordial gravitational waves and primordial non-Gaussianty, cosmic birefringence, and axions in cosmology.

Mid-frequency gravitational waves (0.1-10 Hz): sources and detection methods / 460

Arm-Locking Frequency Noise Suppression for Astrodynamical Middle-Frequency Interferometric Gravitational Observatory

Authors: Jun Nian[1]; Wei-Tou Ni[2]

[1] *International Centre for Theoretical Physics Asia-Pacific, University of Chinese Academy of Sciences*

[2] *Innovation Academy of Precision Measuremnt Sciencs and Technology of Chinese Academy of Sciences*

Corresponding Author: nianjun@ucas.ac.cn

For space gravitational wave (GW) detection, arm locking is a proposal useful in decreasing the frequency noise of the laser sources for current developing space missions LISA and Taiji/TianQin. In this talk, we discuss the application of arm locking to the Astrodynamical Middle-frequency Interferometric Gravitational Observatory (AMIGO) to decrease the frequency noise of laser sources. For AMIGO, the arm-locking technique can suppress the laser frequency noise by three orders of magnitude. The advantage of this is to make the auxiliary noise assignment for AMIGO easier and more relaxed. For the first-generation time-delay interferometry (TDI) configuration, the laser frequency noise contribution is already below the core noise contribution. For the simple Michelson TDI configuration (X0), the arm locking makes the acceleration-thrust scheme, the delay-line scheme, or the combined scheme easier to implement. Within a relatively short period of less than a day (compared to less than twenty days for LISA/Taiji), the Doppler frequency pulling can be efficiently reduced to within $\pm$ 0.001 Hz and does not affect the mission duty cycle much.

Inflation: perturbations, initial singularities and emergent universes / 461

Mixmaster Universe in a 2D non-commutative GUP framework

Authors: Giovanni Montani[1]; Sebastiano Segreto[2]

[1] *ENEA*

[2] *Università degli Studi di Roma "La Sapienza"*

Corresponding Author: sebastiano.segreto@uniroma1.it

In this work, we examine the dynamical aspects of the cosmological Mixmaster model within the framework of a non-commutative Generalized Uncertainty principle (GUP) theory.
The theory is formulated classically by introducing a well-defined symplectic form that differs from the ordinary one, thereby inducing a deformation of the Poisson brackets.
We first investigate the behavior of the Bianchi I and Bianchi II models using Misner variables. Then, we study the Bianchi IX model in the Mixmaster approximation, which is well-known for accurately reproducing the dynamics of the point-particle Universe approaching the cosmological singularity.
We derive the corresponding Belinsky-Khalatnikov-Lifshitz (BKL) map and explore its resulting features, shaped by the effects of the non-commutative GUP scheme.

Cosmic backgrounds from radio to far-IR / 462

Cosmoglobe DR2: Global analysis of the microwave and infrared sky

Author: Ingunn Kathrine Wehus[1]

[1] *University of Oslo*

Corresponding Author: i.k.wehus@astro.uio.no

Two lessons learned from Planck was the importance of global analysis of instrumental, astrophysical and cosmological parameters as well as the usefulness of joint analysis of multiple datasets for component separation purposes. These lessons has been further developed into a coherent pipeline for global analysis of multiple datasets by BeyondPlanck and Cosmoglobe, which has been successfully applied to joint end-to-end analysis of raw data from WMAP and Planck LFI. The recent Cosmoglobe Data Release 2 generalizes this to the infrared spectrum, performing a reanalysis of the COBE-DIRBE raw data, supported by Planck HFI, WISE, Gaia and COBE-FIRAS. Expanding the upper frequency range of the Cosmoglobe Sky Model from 1 to 240 THz requires a drastically altered thermal dust model, as well as adding models for starlight, CII line emission and dynamical Zodical light emission. This global analysis leads to the strongest constraints on the cosmic infrared background (CIB) spectrum from DIRBE published to date. I will give an introduction to global analysis before presenting our latest results.

Present and future of cosmic microwave background observations / 463

Commander4 – massively parallel end-to-end Bayesian CMB analysis

Author: Hans Kristian Eriksen[1]

[1] *University of Oslo*

Corresponding Author: h.k.k.eriksen@astro.uio.no

I will present a recently funded Open Science ERC AdG program that aims to implement a single massively parallel end-to-end framework called "Commander4" for the joint analysis of past, present and future CMB experiments. This framework will build on the existing Commander code that was used by Planck for component separation, and subsequently generalized by the BeyondPlanck and Cosmoglobe projects to derive new state-of-the-art frequency maps for Planck LFI, WMAP and DIRBE. However, the existing code only scales well up to O(100) computing cores. Commander4 aims to improve this scaling to O(100,000) cores, as required for next-generation experiments such as Simons Observatory and LiteBIRD. The first application of this new code, however, will be a re-analysis of the raw uncalibrated Planck HFI time-ordered data, and this will be organized as part of the larger Cosmoglobe effort. All interested parties are warmly invited to join this work, both on the Commander4 framework itself and Planck HFI.

Gravitational kHz waves - LIGO-Virgo-KAGRA / 464

Neutrino counterpart of kHz GW sources

Authors: Alessandro Veutro[1]; Fulvio Ricci[1]; IRENE DI PALMA[2]; Marco Drago[1]; Melissa Lopez[3]; Pablo Cerda-Duran[4]

[1] *Universita' di Roma La Sapienza, I-00185 Roma, Italy*

[2] *INFN AND SAPIENZA UNIVERSITY OF ROME*

[3] *Institute for Gravitational and Subatomic Physics (GRASP), Department of Physics*

[4] *Departamento de Astronomia y Astrofisica, Universitat de Valencia,*

Corresponding Author: irene.dipalma@uniroma1.it

Multimessenger astrophysics provides unique and valuable insights into the properties and processes of the physical universe. The recent discovery of gravitational waves and high energy cosmic neutrinos, marked the beginning of a new era of the multimessenger astronomy. These new messengers, along with electromagnetic radiation and cosmic rays, give new insights into the most extreme energetic cosmic events. Among them supernovae explosion is one of the challenging targets of this new astronomical approach. We developed a machine learning algorithm to further improve the detectability of such type of source. Prospects for a third generation gravitational wave detector will be presented.

The Euclid mission: current status, results from early observations, and future prospects / 465

Extended forecasts for Euclid in combination with other cosmological probes

Author: Giampaolo Benevento[1]

[1] *INFN Roma II*

Corresponding Author: benevent@roma2.infn.it

The future Euclid space satellite mission will offer an invaluable opportunity to constrain modifications to general relativity at cosmic scales.I will present forecasts for extended cosmological scenarios such as k-mouflage gravity and the Transitional Planck Mass model, considering spectroscopic and photometric primary probes by Euclid alone and in combination with other probes. In particular the cross-correlation between the photometric Euclid probes and the CMB temperature and lensing, will be especially relevant for extended models that have modified growth of structure compared to the standard Lambda-Cold Dark Matter scenario. Our forecasts suggest that Euclid alone will

significantly improve constraints on modified gravity parameters compared to current data. When combined with CMB observations, the sensitivity to deviations from GR increases substantially, allowing to constrain extra-parameters that are unconstrained with present data.

Cosmic backgrounds from radio to far-IR / 466

Cosmic Infrared Background: the good and the bad and the good

Author: Abhishek Maniyar[1]

[1] *Stanford University, USA*

Corresponding Author: amaniyar@stanford.edu

The cosmic infrared background (CIB) is sourced by the dusty star-forming galaxies throughout the Universe and spans a wide range of redshifts. Its measurements are thus a powerful tool to map the star formation at high redshifts and understand the connection between the host dark matter halos with the galaxies residing in them. Also, in synergy with the cosmic microwave background (CMB), the CIB acts as a powerful cosmological probe with applications ranging from constraining primordial non-Gaussianity to dark energy. Finally, despite being an excellent astrophysical and cosmological probe, CIB acts as a foreground for the CMB and line intensity mapping studies. In this talk, I will explore both of these sides and discuss the possibilities of converting the CIB from a foreground to a signal.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 467

Beyond Early Dark Energy: an EFT-based approach to cosmological tensions

Author: Giampaolo Benevento[1]

[1] *INFN Roma II*

Corresponding Author: benevent@roma2.infn.it

The Transitional Planck Mass (TPM) model is a useful application of the Effective Field Theory of Dark Energy and Modified Gravity, characterized by a step-like transition in the Planck Mass at cosmological scales. This transition, occurring during the radiation era, has shown efficacy in mitigating the Hubble tension. It achieves this by decreasing the sound horizon as detected by Cosmic Microwave Background (CMB) probes, offering a compelling alternative to Early Dark Energy (EDE) models.In this presentation, I will explore constraints on the TPM model derived from a comprehensive dataset encompassing Cosmic Microwave Background, Baryon Acoustic Oscillations, Large Scale Structure, and Type Ia supernovae observations. These datasets indicate a preference for approximately a 5% shift in the effective Planck mass (less than 10% at a 2σ level) when incorporating a prior based on local H0 measurements. I will discuss the goodness of fit to each dataset and the limiting factors to the performances of the model.
The TPM model exhibits unique characteristics that distinguish it from classic EDE. The transition in the Planck mass is not constrained to happen at a very specific time, avoiding the coincidence problem found in EDE.
There is also an interesting anti-correlation between the values of the S8 and H0 parameters, which could be exploited to relieve different cosmological tension at the same time.
Additionally, I will present recent advancements, including new constraints derived from the latest Type Ia supernovae catalogs.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 468

Charting the CCSN-GRB Spectrum: Non-Spinning Black Hole-Driven Jets in the LSST Epoch

Author: Justin Bopp[1]

Co-author: Ore Gottlieb [2]

[1] *CUNY Graduate Center*

[2] *Tel Aviv University/CIERA*

Corresponding Author: justinbopp@gmail.com

GRB jets are launched from rapidly spinning black holes (BHs), anchored by a strong magnetic field, a process known as the Blandford–Znajek (BZ) mechanism. However, most BHs from core collapse are likely born slowly spinning, raising the question of what type of transients emerge in those cases. With the upcoming launch of LSST, it is imperative to map the wide spectrum of transients from core-collapse supernovae (CCSNe) to GRBs. To bridge the underlying physics of the collapsing star and observations, we perform a suite of 3D general-relativistic magnetohydrodynamics (GRMHD) collapsar simulations, which extend from the self-consistent jet launching by an accreting BH to the breakout from the star. We show that even non-spinning BHs produce collimated outflows through a combination of the Blanford-Payne (BP) mechanism from magnetized blobs in the BH accretion disk, and the BZ mechanism via the BH accreting plasma. Such outflows could be the origin of low-luminosity GRBs or fast-blue optical transients. The jets unbind the star, generating a luminous signal observable by LSST. This work marks the first step of mapping the physics of various collapsars on the spectrum between CCSNe and GRBs to observations.

A NICER view of extreme gravity from the International Space Station / 469

NICER discoveries of repeating extragalactic nuclear transients

Author: Dheeraj Pasham[1]

Co-authors: Francesco Tombesi [2]; Michal Zajaček [3]; Petra Suková [4]

[1] *MIT*

[2] *Tor Vergata University of Rome*

[3] *Masaryk University*

[4] *Astronomical Institute of the CAS*

Corresponding Author: p.dheerajreddy@gmail.com

A new subclass of transients spatially coincident with centers of galaxies have been uncovered in the past few years. One of the leading hypothesis for these repeaters is that they could be driven by objects orbiting massive black holes. I will give an overview of how NICER's large effective area and excellent maneuverability have been instrumental in making these discoveries.

A NICER view of extreme gravity from the International Space Station / 470

Searches for gravitational waves from pulsars

Authors: Cristóbal Espinoza[1]; Wynn Ho[None]; Zaven Arzoumanian[2]

[1] *Universidad de Santiago de Chile*

[2] *NASA Goddard Space Flight Center*

Corresponding Author: cristobal.espinoza.r@usach.cl

Pulsars are promising sources of gravitational waves (GWs). While asymmetric mass distributions will produce continuos GWs, sudden relocations of small fractions of the internal neutron superfluid could produce transient GW emission. Such rearrangements are believed to be responsible for rapid accelerations in rotation, known as glitches, which have been observed in hundreds of pulsars. The search for pulsar generated signals in gravitational wave data is highly simplified by the use of precise knowledge of the rotational pulsar phase. Thus there has been a historical collaboration between pulsar observatories and gravitational wave astronomers. NICER regularly monitors several X-ray pulsars which are good candidates for GW emission. One of them is PSR J0537-6910, a highly energetic pulsar that exhibits large and frequent spin-up glitches. Not only glitches could be generating GWs in this pulsar but also r-mode oscillations in its interior. We will summarise our observations of this pulsar and the GW searches that we have done targetted at the emission generated by the aforementioned processes.

Black holes in alternative theories of gravity / 471

Embeding LTB models in mimetic gravity and exact spherically symmetric solutions

Authors: Hongguang Liu[1]; Kristina Giesel[1]; Parampreet Singh[2]; Stefan Weigl[1]

[1] *FAU Erlangen-Nürnberg*

[2] *Louisiana State University*

Corresponding Author: liuhongguang@outlook.com

In this talk we present the analysis of a large class of extended mimetic gravity Lagrangians, which allow the embedding of the Lemaître-Tolman-Bondi (LTB) models in spherically symmetric spacetimes. Using the LTB embedding, we are able to completely decouple the dynamics along the radial direction and obtain exact solutions of the modified Friedmann equations. Moreover, we introduce a reconstruction algorithm that allows, for a large class of models, to construct from a given metric in Schwarzschild-like coordinates the corresponding dynamics as a 1+1-dimensional field theory, as well as a corresponding extended mimetic gravity Lagrangian in four dimensions. Such a reconstruction allows us to obtain Lagrangians of extended mimetic gravity models for black hole models with a regular center, e.g. of Bardeen and Hayward, as well as for effective loop quantum gravity inspired models. Moreover, the reconstruction allows us to extend static black hole models to general non-marginally bound inhomogeneous dust collapse solutions of the corresponding theory.

Latest results from Galactic center observations / 472

The formation and stability of a cold disc made out of stellar winds in the Galactic Centre

Author: Diego Calderón[1]

Co-authors: Christopher Russell [2]; Jorge Cuadra [3]

[1] *University of Hamburg*

[2] *University of Delaware*

[3] *Universidad Adolfo Ibañez*

Corresponding Author: calderon@hs.uni-hamburg.de

The discovery of a cold (~10,000 K) disc-like structure around the super-massive black hole at the centre of the Milky Way, Sagittarius A*(Sgr A*), has challenged our understanding of the gas dynamics and thermodynamic state of the plasma in its immediate vicinity. State-of-the-art simulations do not agree whether or not such a disc can indeed be a product of the multiple stellar wind interactions taking place in the region. This work aims to constrain the conditions for the formation of a cold disc as a natural outcome of the system of mass-losing stars orbiting around Sgr A*, and to investigate if such a disc is a transient or a long-lasting structure. We conduct a set of hydrodynamic simulations of the observed Wolf-Rayet (WR) stars feeding Sgr A* using the adaptive mesh-refinement grid-based code Ramses. We focus on the impact of the unusual, H-poor composition of the plasma emanating from the WR stars. The simulations show that more realistic chemical compositions of the plasma affect the radiative cooling enough to impact the properties of the medium and, as a consequence the rate at which material inflows onto Sgr A*. We have identified that the formation of a cold disc due to the action of the stellar winds is possible only for certain chemical compositions that are consistent with the current observational constraints. However, it is not possible to reproduce all the properties of the observed disc, since the inclination of the observed and simulated discs do not align perfectly. We conclude that the hypothesis of the stellar winds forming a cold disc around Sgr A* is feasible but might require additional ingredients that have not been included in the model yet (e.g. inflow material from the mini-spiral).

Latest results from Galactic center observations / 473

Star Formation in the Inner Parsecs of the Galactic Center

Author: Nadeen Sabha[None]

Corresponding Author: nadeen.sabha@uibk.ac.at

Our Galactic Center (GC) is the closest and most accessible galactic nucleus, which provides us with the unique opportunity to conduct resolved star formation studies in extreme environments. Despite the need for very high gas densities to overcome the tidal field of the supermassive black hole Sgr A*, and induce gravitational collapse, there is evidence for star formation taking place at the heart of the Milky Way: Several bipolar CO outflows, masers and compact radio continuum sources, that display characteristics similar to those associated with newly formed low-mass stars, have been found in the central parsecs. Furthermore, the molecular content of the GC circumnuclear disk, located at a distance of ≥ 2 pc from Sgr A*, represents one of the largest reservoirs of dense molecular gas in the inner few parsecs and even within its cavity dense clumps of molecular material can be found.

In this talk I will review the observational hints of ongoing star formation in the inner few parsecs, and discuss them in light of our recently obtained mid-infrared observations from space with the JWST's MIRI integral field unit and from ground with the VLT's VISIR instrument. This study represents the first high-resolution imaging and spectral datasets taken in the mid-infrared which aims at tackling the question of whether or not star formation is indeed taking place in the tidally stressed environment of our Galactic Nucleus.

Latest results from Galactic center observations / 474

Galactic center G objects as dust-enshrouded stars near the supermassive black hole

Author: Michal Zajaček[1]

[1] *Masaryk University*

Corresponding Author: michal.zajacek31@gmail.com

In this talk, I revisited the model of a dust-enshrouded star orbiting a low-luminosity galactic nucleus (Zajacek et al., 2014, 2016, 2017). Although it is quite challenging for dust to survive in hot X-ray-emitting plasma surrounding supermassive black holes (SMBHs), now we have an observational evidence that compact dusty objects or G objects can approach the SMBH in the Galactic center (Sgr A*) on the scale of a few 1000 gravitational radii. Since there are about ten G objects in the Galactic center, it is more likely that they are dust-enshrouded stars whose gaseous-dusty envelopes are stable within the corresponding tidal (Hill) radii of the order of a few astronomical units. Such a length-scale is consistent with their infrared broad-band spectral energy distributions. Broad emission lines, such as in particular Br-gamma recombination line, can be interpreted to arise within the accretion stream from the circumstellar envelopes forming a compact disc that is truncated by the stellar magnetic field. Alternatively, they could also be associated with circumstellar accretion-disc outflows. In comparison with the line origin in the photoionized envelopes that can generally be tidally perturbed, the scenario involving the circumstellar accretion-disc inflow or outflow can ensure that the line luminosity is rather stable. I speculate about the origin of dust-enshrouded stars (young stellar objects or binary mergers) as well as prospects to detect their signs around other low-luminosity galactic nuclei.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 475

Prospects in dark energy cosmology through the calibrated Ep,I-Eiso correlation

Authors: Ester Piedipalumbo[1]; Marek Demianski[2]; Lorenzo Amati[3]

[1] *Department of Physics "E. Pancini", University of Naples Federico II*

[2] *Institute for Theoretical Physics, University of Warsaw, Pasteura 5, PL-02-093 Warsaw, Poland; Department of Astronomy, Williams College, Williamstown, MA 01267, USA*

[3] *INAF-IASF, Sezione di Bologna, via Gobetti 101, I-40129 Bologna, Italy*

Corresponding Author: ester@na.infn.it

Using a new sample consisting of 264 GRBs with measured redshifts and spectra, we applied different techniques to calibrate the Ep,I-Eiso correlation against the type Ia SN data to build a calibrated GRB Hubble diagram. We tested the possible redshift dependence of the correlation and its effect on the Hubble diagram to investigate the tension with the flat ΛCDM model and the dark energy equation of state.

Gravitational lensing, shadows and photon rings / 476

Can relativistic effects explain galactic dynamics without dark matter?

Author: Filipe Costa[1]

Co-author: José Natário [2]

[1] *CAMGSD - Instituto Superior Técnico, Universidade de Lisboa*

[2] *CAMGSD - IST Universidade de Lisboa*

Corresponding Author: lfilipecosta@tecnico.ulisboa.pt

In a growing number of recent works, it has been claimed that "gravitomagnetism"/frame-dragging and/or non-linear general relativistic effects can play a leading role in galactic dynamics, partially or totally replacing dark matter. Using the 1+3 "quasi-Maxwell" formalism (and generalizing it for null geodesics), we show, on general grounds, such hypothesis to be impossible. We demonstrate that (i) the observed gravitational lensing effects rule out any galactic model (linear or non-linear) based on gravitomagnetism, and (ii) non-linear contributions to the gravitational field actually weaken gravitational attraction, thereby only aggravating the need for dark matter. I shall also briefly dissect the misunderstandings at the origin of the recently proposed relativistic "galactic" models, most notably the Balasin-Grumiller solution, which serves as an archetypal example for the two key observations above.

High energy astrophysics / 477

Moving corona and the relativistic broad iron emission line

Author: Yuan Feng[1]

Co-authors: Shuang-Nan Zhang ; Ye-Fei Yuan [2]

[1] *USTC*

[2] *University of Science and Technology of China*

Corresponding Author: yfyuan@ustc.edu.cn

Iron fluorescence emission lines from X-ray binaries and active galactic nuclei are important diagnostic tools for studying the physical processes near the event horizon of both the stellar-mass black holes in X-ray binaries and the supermassive black holes in active galactic nuclei. In this work, we investigate the line profile of the relativistic broad iron lines from the cool accretion disk of a black hole due to the asymmetric illumination of a moving corona, which moves away from the disk with a relativistic velocity. Both the off-axis location and the radial velocity of the moving corona are considered. Our results clearly show that the illumination and the line profile are dependent on the position and velocity of the corona, since the disk region below the corona receives more flux, which is the most important factor affecting the line profiles. As expected, if the corona is close to the receding part of the rotating disk, the red peak is enhanced, while the blue peak is weakened in the broad line profile, and the central energy of the emission line is low. Conversely, if the corona is close to the approaching part of the disk, the blue peak is strong and the central energy of the emission line is high, even higher than the intrinsic energy of the emission line. Due to the beaming effect of the moving corona, the corona with high velocity illuminates the outer region of the disk, which leads to the red peak disappearing and there being only one blue peak in the profile of the emission line.

Unveiling neutrino secrets through cosmology: current status and future developments / 478

Cosmological limits on the neutrino mass sum for beyond-ΛCDM models

Author: Helen Shao[1]

Co-authors: Blake Sherwin [2]; Frank Qu [2]; Jahmour Givans [3]; Jo Dunkley [4]; Mathew Madhavacheril [5]

[1] *Princeton university*

[2] *University of Cambridge*

[3] *Center for Computational Astrophysics*

[4] *Princeton University*

[5] *University of Pennsylvania*

Corresponding Author: helenshao0904@gmail.com

Cosmic neutrinos are a subdominant part of the cosmological dark matter whose main cosmological effect is to suppress the small-scale clustering. This has enabled an upper limit on the sum of their masses to be placed from astronomical data, with at most 2\% of the dark matter composed of neutrinos at 95\% confidence, or $\Sigma m_\nu < 0.12$ eV. This bound assumes that the cosmological model is ΛCDM, where dark energy is a cosmological constant, the spatial geometry is flat, and the primordial fluctuations follow a pure power-law. Here I present updates on how the mass limit degrades if we relax these assumptions. We use data from \textit{Planck} and SDSS, augmented with new gravitational lensing measurements from the Atacama Cosmology Telescope and the new sample of Type Ia supernovae from the Pantheon+ survey. We find the neutrino mass limit is stable to most model extensions, degrading the limit by less than 10\%. The broadest bound is $\Sigma m_\nu < 0.23$ eV at 95\% confidence for a model with dynamical dark energy, although this scenario is not statistically preferred over the simpler \lcdm\ model. We further explore how our bounds vary when supplementing our datasets with the latest DESI measurements

Mineral detection of dark matter and neutrinos / 479

Towards a prototype paleo-detector for supernova neutrino and dark matter detection

Author: Emilie LaVoie-Ingram[1]

[1] *University of North Florida*

Corresponding Author: emiliemarie000@gmail.com

Using ancient minerals as paleo-detectors is a proposed experimental technique expected to transform supernova neutrino and dark matter detection. In this technique, minerals are processed and closely analyzed for nanometer scale damage track remnants from nuclear recoils caused by supernova neutrinos and possibly dark matter. These damage tracks present the opportunity to directly detect and characterize the core-collapse supernova rate of the Milky Way Galaxy as well as the presence of dark matter. Current literature presents theoretical estimates for these potential tracks, however, there is little research investigating the experimental feasibility of this technique. At the University of North Florida, we have contributed to the field by searching for and analyzing these damage tracks in prototype detectors constructed from selected minerals, including: halite, Muscovite mica, and Phlogopite mica. Our research characterizes the applicable backgrounds in these prototype detectors. We have employed non-destructive techniques, including laser confocal and atomic force microscopy to identify and characterize damage tracks in the minerals. Chemical etching and plasma etching of target minerals is used to enhance the detectability of these damage tracks at the expense of altering some of their geometrical attributes. With the use of an etching rate model and automatic track detection via Python, damage track lengths are reconstructed. Our data is compared to current theoretical predictions to pursue the practical implementation of paleo-detectors as local core-collapse supernova neutrino and dark matter detectors.

This research will be continued at the University of Michigan starting August 2024. Progress from the current Michigan team will be provided, as well as a discussion of the exciting next steps ahead.

Navigating science and philosophy: exploring limits / 480

Time Electron Theory

Author: Syed Munim Qadri[1]

[1] *Independent Researcher*

Corresponding Author: noobmomin399@gmail.com

Alternate Theory of Time along with numerical proof.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 481

Paving the way for GRB cosmology with the Dainotti correlation

Author: Aleksander Lenart[1]

[1] *Astronomical Observatory, Jagiellonian University in Kraków*

Corresponding Author: lenart.a.lenart@gmail.com

Despite decades of research, cosmology still lacks reliable probes to study the Universe in the intermediate redshift regime (from $z = 1$ up to $z = 1100$). Very few astronomical objects observed at such high distances can be standardized. We present the case of Gamma-Ray Bursts (GRBs, $z < 9.4$). For these sources, the observational luminosity distance can be derived using an empirical log-linear relation between the luminosity at the end of the plateau phase (L_a), rest-frame time at the end of the plateau (T^*_a), and peak luminosity (L_{peak}). This relation was first formulated by Dainotti et al. (2016) as:
$\log_{10} L_a = a \times \log_{10} T^*_a + b \times \log_{10} L_{peak} + c$.
Although this correlation has been shown to result from the intrinsic physics of the sources rather than observational effects, applying it to cosmological computations remains challenging. We still face the issue of pinpointing a coherent set of events. A reliable fitting method must properly account for selection bias and redshift evolution. We demonstrate that the raw data of the GRB sample is significantly affected by these effects and how to correct this data. Additionally, we present a circularity-free method for fitting the cosmological model based on a de-evolving procedure developed by Efron & Petrosian (1992). We discuss possible choices of probes with uniform properties, making them standardizable. Lastly, we present our results of fitting cosmological parameters and propose potential developments for the future.

Emission mechanisms in gamma-ray bursts / 482

Bethe-Heitler constraints on proton synchrotron models for GRBs.

Author: Damien Begue[1]

[1] *Bar Ilan University*

Corresponding Author: cayley38@gmail.com

GRB spectra seem to be well fitted by models based on marginally fast-cooled synchrotron radiation. This observation challenges the synchrotron process as a viable mechanism as it leads to (too) large emission radii and (too) large bulk Lorentz factors. To overcome this difficulty, it was proposed that proton could be the particles radiating synchrotron emission. I will show that if protons are indeed at the origin of GRB emission, electron-positron pair creation by the Bethe-Heitler process could also be efficient, leading to the creation of an additional spectral component which takes the form of a sub-dominant power-law with well-defined characteristics. I will argue that such power-law might have already been observed.

Emission mechanisms in gamma-ray bursts / 483

Physics of GRB afterglows: general principles and application to notable GRBs

Author: Evgeny Derishev[1]

[1] *Institute of Applied Physics, Nizhny Novgorod, Russia*

Corresponding Author: derishev@appl.sci-nnov.ru

GRB afterglows are powered by emission from relativistic collisionless shocks. The converter acceleration mechanism, which is specific just for relativistic shocks, makes them efficient emitters and at the same time modifies the shock structure. As a result, the shock balances itself within a region in the parameter space that can be estimated analytically or evaluated numerically with a good precision. This constitutes the pair balance model for relativistic shocks, which allows one to predict afterglow spectra from the first principles.

To test the pair balance model one needs an afterglow where both the synchrotron and inverse Compton (TeV) components are observed simultaneously. Then one can resolve degeneracy inherent to the general synchrotron-self-Compton framework and determine the parameters of the emitting region.

Two notable examples of simulataneous X-ray and TeV observations are GRB 190114C (early afterglow, few minutes since the trigger) and GRB 190829A (late afterglow, beginning from 10 hours after the trigger). Although two GRBs belong to fairly distant evolutionary stages, their parameters (determined from broad-band spectra) fit nicely into predictions of pair-balance model of relativistic shocks.

Gamma-ray bursts and AGNs with machine learning / 484

GRB optical and X-ray plateau properties classifier using unsupervised machine learning

Author: Shubham Bhardwaj[1]

Co-authors: Aditya Narendra [2]; Agnieszka Pollo [3]; Anish Kalsi [4]; Enrico Rinaldi [5]; Maria Dainotti [6]; Sachin Venkatesh [7]

[1] *SOKENDAI/National Astronomical Observatory of Japan*

[2] *Jagiellonian University*

[3] *National Centre for Nuclear Research*

[4] *Delhi Technological University*

[5] *Interdisciplinary Theoretical and Mathematical Science Program*

[6] *National Astronomical Observatory of Japan*

[7] *Georgia Institute of Technology*

Corresponding Author: shubham.bhardwaj@grad.nao.ac.jp

The division of gamma-ray bursts (GRBs) into different classes, other than the 'short' and 'long', has been an active field of research. We investigate whether GRBs can be classified based on a broader set of parameters, including prompt and plateau emission ones. Observational evidence suggests the existence of more GRB subclasses, but results so far are either conflicting or not statistically significant. The novelty here is producing a machine-learning-based classification of GRBs using their observed X-rays and optical properties. We used two data samples: the first, composed of 203 GRBs, is from the Neil Gehrels Swift Observatory (Swift/XRT), and the latter, composed of 134 GRBs, is from the ground-based Telescopes and Swift/UVOT. Both samples possess the plateau emission (a flat part of the light curve happening after the prompt emission, the main GRB event). We have applied the Gaussian mixture model (GMM) to explore multiple parameter spaces and subclass combinations to reveal if there is a match between the current observational subclasses and the statistical classification. With these samples and the algorithm, we spot a few microtrends in certain cases, but

we cannot conclude that any clear trend exists in classifying GRBs. These microtrends could point towards a deeper understanding of the physical meaning of these classes (e.g. a different environment of the same progenitor or different progenitors). However, a larger sample and different algorithms could achieve such goals. Thus, this methodology can lead to deeper insights in the future.

High energy astrophysics / 485

Highlights and discoveries from SRG/ART-XC

Author: Alexander Lutovinov[1]

[1] *Space Research Institute (IKI)*

Corresponding Author: aal@iki.rssi.ru

An overview of highlights and discoveries from Mikhail Pavlinsky ART-XC telescope on board the SRG observatory is presented. Since 2019 SRG/ART-XC has conducted several full all sky surveys as well as a deep survey of our Galaxy. As a result, we obtained the catalogue of hard X-ray sources detected at the all sky, which includes more than one and a half thousand objects, most of them are active galactic nuclei. Hundreds of new objects have been detected during all sky and galactic surveys, including the microquasar SRGA J043520.9+552226/AT2019wey, slowly rotating neutron stars, Swift J1727.8-1613 - the brightest object in the X-ray sky of 2023. In February 2024 SRG/ART-XC discovered a new accreting millisecond pulsar demonstrating quasi regular X-ray bursts and effects of the GR in its pulse profile. We also obtained detailed X-ray light curves of the supernova SN2023ixf and the most powerful gamma-ray burst, GRB221009A. At this moment SRG/ART-XC continues the all sky surveys.

Machine learning in astronomy: AGN, transient events, cosmology and others / 486

Convolutional Neural Network and Soprano: computing numerically expensive models in the blink of an eye

Authors: Damien Begue[1]; Hüsne Dereli-Bégué[2]; Narek Sahakyan[3]

[1] *Bar Ilan University*

[2] *Bar-Ilan University*

[3] *ICRANet-Armenia*

Corresponding Author: cayley38@gmail.com

I will discuss the use of machine learning and more specifically of convolutional neural network (CNN) to enable fitting of blazar (or other objects) SEDs with numerically costly models. In particular, I will describe the necessary ingredients, the numerical approach and tools, the setup of the neural network and the training steps. Finally, I will discuss future plans and improvements.

IXPE observations and multiwavelength opportunities / 487

X-ray polarimetry of GRB 221009A

Author: Alberto Manfreda[1]

[1] *INFN Napoli*

Corresponding Author: alberto.manfreda@na.infn.it

We present the Imaging X-ray Polarimetry Explorer (IXPE) observation of the gamma-ray burst (GRB) 221009A, which reached Earth on October 9, 2022. Although IXPE was not originally designed for this purpose, the exceptional brightness of GRB 221009A allowed it to observe the afterglow emission even after almost 60 hours, providing the first constraints on the X-ray polarization in the 2-8 keV energy band. Additionally, IXPE performed simultaneous polarimetry of the GRB prompt emission by capturing its echo in the form of halo-rings of dust-scattered photons. These results offer insights into the GRB jet opening angle and viewing angle, as well as the properties of the emission region.

Navigating science and philosophy: exploring limits / 488

The unity of time

Author: Claus Laemmerzahl[1]

[1] *University of Bremen*

Corresponding Author: claus.laemmerzahl@zarm.uni-bremen.de

In this talk various definitions and realizations of time are considered and compared. These realizations are clocks based on kinematics and dynamics, on electromagnetic and gravitational interactions, on classical and quantum systems. Conditions are stated for which all these time scales coincide. Furthermore, the issue of the synchronization of clocks will be treated. Finally, the importance of the definition of time for the new Système International will be outlined.

Slowly rotating pulsars / 489

X-ray emission from isolated neutron stars: latest results from XMM-Newton, NICER and eROSITA

Author: Michela Rigoselli[1]

[1] *INAF*

Corresponding Author: michela.rigoselli@inaf.it

The X-ray spectra of isolated neutron stars (INSs) typically include a thermal component, that comes from the cooling surface, and a non-thermal component, produced by highly-relativistic particles accelerated in the stellar magnetosphere. Hot spots from returning currents can also be detected.

Middle-aged pulsars exhibit a mixture of these components, but other flavours of INSs, that show a large variety of physical parameters (such as spin period, magnetic field and age) emit only thermal X-rays. These stars are usually detected either by large serendipitous datasets from pointed X-ray observations or from searches in the data of all-sky surveys.

The connection between these thermally-emitting INSs, the ordinary pulsars, and the new emergent class of pulsars characterized by a long period, that do not show X-ray emission despite their large magnetic field, is one of the current challenges in the study of neutron stars.

In this contribution I will review the latest results on several objects belonging to various INS classes, such as the XDINS RX J1856.5-3754, the enigmatic Calvera, the long period PSR J0250+5854 and the new thermal INS candidates, obtained with the X-ray observatories XMM-Newton, NICER and eROSITA.

Emission mechanisms in gamma-ray bursts / 490

Theory of photon scattering in shearing plasma: Applications to GRBs

Author: Mukesh Kumar Vyas[1]

Co-author: Asaf Pe'er [1]

[1] *Bar Ilan University, Ramat Gan, Israel*

Corresponding Author: mukeshkvys@gmail.com

We investigate the photon analogue of Fermi acceleration where a photon scatters within the shearing layers of a relativistic plasma and produces power-law-shaped spectra at high energies. It is an alternative to existing explanations of power law spectra such as synchrotron process or inverse Comptonization. Among several potential applications of this phenomenon, I will describe its application to Gamma-ray bursts (GRBs) jets where we explain the high energy spectra of the GRB prompt phase. I will briefly touch upon other applications to the work in Active Galactic nuclei (AGNs) jets as well as in accretion discs around black holes.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 491

The lightest neutron star formed from a binary system

Authors: Shurui Zhang[1]; Jorge Armando Rueda Hernandez[2]; Rodrigo Negreiros[3]

[1] *ICRANet-UNIFE & USTC*

[2] *ICRANet*

[3] *Catholic Institute of Technology*

Corresponding Author: zhangsr@mail.ustc.edu.cn

The exceptionally low mass $0.77^{+0.2}_{-0.17}M_{\odot}$ inferred of the central compact object (CCO) XMMU J173203.3−344518 within the SNR HESS J1731−347, of age ≈ 4.5 kyr, challenges the standard core-collapse scenario of NS formation. The observed (likely post-AGB) star of $\approx 0.6M_{\odot}$, at 0.3 pc from XMMU J1732, also within the SNR, enriches the scenario. To address this puzzle, we advance the possibility that the gravitational collapse of a rotating iron core of an evolved star can produce a light NS. We estimate the structure of the rotating pre-SN iron core of $\approx 1.2M_{\odot}$ and examine its gravitational collapse. We show that the angular momentum conservation during the collapse of an iron core rotating at $\approx 45\%$ of the Keplerian limit leads to an $\approx 0.9M_{\odot}$ stable newborn NS. Assuming magnetic dipole radiation for a 10^{11} G field, the CCO must rotate relatively slowly with the upper limit of its rotation frequency being ≈ 530 Hz. Thus, the CCO mass and radius measurement probes the non-rotating NS mass-radius relation in the low-mass region. We show that a canonical NS thermal evolution agrees with the XMMU J1732 observed surface temperature of $\approx 2 \times 10^6$ K, assuming 4.5 kyr as its age. We propose the pre-SN evolved star, likely an ultra-stripped core of $\approx 4.2M_{\odot}$, formed a tidally locked binary of ≈ 1.43 days orbital period with the post-AGB star. The SN produces a mass loss of $\approx 3M_{\odot}$, imparting a kick velocity < 670 km s^{-1}, disrupting the binary. This scenario agrees with the observed projected offset of 0.3 pc between XMMU J1732 and IRAS 17287−3443. Therefore, our findings support the possibility of CCOs originating in binaries, the relevant role of rotation in core-collapse events, and the CCO XMMU J1732 being the lightest NS ever observed.

Dark energy and the accelerating universe / 492

Ruling Out New Physics at Low Redshift as a solution to the H_0 Tension

Author: Ryan Keeley[1]

[1] *UC Merced*

Corresponding Author: rkeeley@ucmerced.edu

What has everyone so excited about the H0 tension is the potential for discovering new physics, such as the physics of dark energy. In particular, the question of new physics explanations for this tension are often divided into whether the new physics plays a role at high redshift or low redshift. In this talk, I will make the case that there can be no low-redshift solution to the H0 tension. To robustly answer this question, I used a very flexible parametrization for the dark energy equation of state, w(z), such that every cosmological distance still allowed by the data exists within this prior volume. To then answer whether there exists a satisfactory solution to the H0 tension within this comprehensive parameterization, I constrained the model using different partitions of the Planck, eBOSS/SDSS DR16 BAO, Pantheon SN and SH0ES H0 datasets. When constrained by just the CMB+H0 datasets, there exists a set of w(z) which yields high H0 values, but these w(z) functions are ruled out by the SN and BAO datasets. In other words, the constraint from CMB+SN+BAO datasets does not allow for high H0 values and converges around w(z)=-1. I will also talk about how this story changes when replacing the eBOSS/SDSS BAO constraint with the DESI BAO constraint

Latest results from Galactic center observations / 494

Update on Dusty Sources and Candidate Young Stellar Objects in the S-cluster

Authors: Florian Peißker[1]; Maria Melamed[2]; Michal Zajaček[3]; Myank Singhal[4]; Vladimír Karas[None]

[1] *Ph1, University of Cologne, Germany*

[2] *University of Cologne*

[3] *Masaryk University*

[4] *Astronomical Institute, Charles University*

Corresponding Author: melamed@ph1.uni-koeln.de

The Galactic Center provides a unique opportunity to observe galactic cores, objects in the close proximity to a supermassive black hole (SMBH), and star formation channels that exhibit imprints of this peculiar environment. This habitat hosts, in addition to the SMBH Sgr A*, a surprisingly young cluster with the so-called S-stars. These stars orbit the SMBH on timescales of a few years with thousands of km/s. While the presence of high-velocity stars in the S-cluster already imposes a variety of scientific questions, the observation of several bright L-band emission sources has resulted in a rich discussion of their nature. The detection of a prominent Doppler-shifted Brγ line accompanies most of these sources that seem to be embedded in a dusty envelope. With the radiative-transfer model HYPERION, we find strong indications of the presence of a stellar low-mass population embedded in the S-cluster. We revisit this intriguing cluster and its dusty members that orbit the supermassive black hole Sgr A* on bound Keplerian trajectories. Among these cluster members, there is one source that initiated the studies of this analysis: G1.We find that the flux density of G1 in the NIR and MIR resembles a spectral energy distribution of a Class I YSO, which contributes to the “Paradox of Youth”.

GRB-SN connection / 495

On the gravitational collapse and the formation of compact-object binaries from binary-driven hypernovae

Author: Laura Marcela Becerra Bayona[1]

Co-authors: Chris Fryer [2]; Jorge Armando Rueda Hernandez [3]; Remo Ruffini [4]

[1] *Universidad Industrial de santander*

[2] *Los Alamos National Laboratory*

[3] *ICRANet*

[4] *ICRANet, ICRA, INAF*

Corresponding Author: laura.marcela.becerra@gmail.com

The binary-driven hypernova (BdHN) model proposes long gamma-ray bursts (GRBs) originate in binaries composed of a carbon-oxygen (CO) star and a neutron star (NS) companion. The CO collapse triggers the GRB. It generates a newborn NS (νNS) and a supernova (SN) that accretes onto the NS and the νNS. This accretion process, which is highly super-Eddington, rapidly transfers mass and angular momentum to the stars.

In this work, we investigate the binary parameters that determine whether the νNS or the NS companion undergoes gravitational collapse into a BH during the accretion process, weather quark deconfinement can occur and whether the system remains gravitationally bound forming NS-NS or NS-BH binaries.To this end, we use smooth hydrodynamic simulations to model the expansion of the SN material in the gravitational field of the NS and the νNS. We employ up-to-date nuclear equations of state (EOS) to describe the NS interior and calculate the structural evolution in full general relativity using an adapted version of the RNS code.

The existence of bound systems predicts an evolutionary connection between the long and short GRB populations. BdHNe I, the most compact (about five minutes orbital period) and energetic, show prompt BH formation. These systems form NS-BH binaries with merger timescales on the order of tens of kiloyears due to gravitational-wave emission. BdHNe II form NS-NS binaries with a wider range of merger timescales. In summary, our findings uncover the physical mechanisms responsible for BdHN and offer insight into the potential results of such catastrophic events in binary systems.

Neutrinos in the multi-messenger era / 496

Observational-data rich future in multimessenger astrophysics

Author: Zsuzsa Marka[1]

[1] *Columbia University*

Corresponding Author: zsuzsa@astro.columbia.edu

With the proliferation new and more sensitive detector technologies, coincident observation of triggers for two or more messengers (gravitational-waves, electromagnetic, neutrinos) will become increasingly frequent. I will discuss implications and unmet needs for the observational-data rich future when low-latency subthreshold triggers will be publicly available for several messenger types and coincidences will be regularly observed. In this new era, proper statistical evaluation of coincidences will be a key requirement for confirming detection claims, commending additional observations, and enabling comprehensive multimessenger astronomy in general. In my talk joint observations of gravitational-waves and neutrinos and their follow-up will serve as a use case.

Machine learning in astronomy: AGN, transient events, cosmology and others / 497

Machine Learning to Boost Multimessenger Astrophysics

Author: Zsuzsa Marka[1]

[1] *Columbia University*

Corresponding Author: zsuzsa@astro.columbia.edu

Gravitational-wave detections and open public alerts enabled prompt multimessenger studies for the global community. There is an ongoing effort to assimilate and invent machine learning techniques that will allow faster and more confident detections. Better characterized detections of more gravitational-wave events thereby will expand multimessenger science. I will highlight trailblazing efforts from the intersection of Data Science and Astrophysics for the development of more efficient methods for gravitational-wave discovery.

Mid-frequency gravitational waves (0.1-10 Hz): sources and detection methods / 498

Artificial Precision Timing Array: bridging the decihertz gravitational-wave sensitivity gap with clock satellites

Author: Szabolcs Marka[1]

[1] *Columbia University*

Corresponding Author: sm2375@columbia.edu

Gravitational-wave astronomy has achieved remarkable progress over the past decades, detecting waves across a wide range of frequencies. However, the band around one Hz remains unexplored. This band is vital for studying some of the most fascinating sources, including intermediate-mass binary black hole mergers, early inspiralling compact binaries, and possibly cosmic inflation. The Artificial Precision Timing Array (APTA), a new detector concept based on pulsar timing principles, aims to access this intriguing band. APTA aims to use precision-clock-carrying satellites that emit pulsing signals towards a central point. This talk will discuss the APTA concept and the clock precision required for its successful detection of gravitational waves. With advancements in clock technology anticipated within the next decade, APTA could detect a wide range of astrophysical sources, opening a new research area focused on designing and constructing gravitational-wave detectors based on pulsar timing principles.

Astrophysics with gravitational waves / 499

Lessons, promises, and innovations in synergistic gravitational-wave science

Author: Szabolcs Marka[1]

[1] *Columbia University*

Corresponding Author: sm2375@columbia.edu

The discovery of gravitational waves and their synergistic signatures has opened immense opportunities for astrophysics. Significant advancements in gravitational-wave detector technology, both on Earth and in space, along with progress in electromagnetic and neutrino observatories, have rapidly expanded our understanding of the cosmos. In

this talk, I will explore how this wholistic approach has emerged, leading to deep understanding and unexpected breakthroughs. I will share cohesive narratives that highlight the lessons, promises, and innovations from gravitational-wave astrophysics. Emphasizing the scientific impact, I will discuss the results of seamlessly integrating data from gravitational-wave, neutrino, and electromagnetic observatories, including AGN environments and hierarchical mergers.

Black holes in alternative theories of gravity / 500

Hairy black holes in extended Einstein-Maxwell-scalar theories with magnetic charge and kinetic couplings

Author: Kitaro Taniguchi[1]

Co-authors: Shinta Takagishi [1]; Ryotaro Kase [1]

[1] *Tokyo University of Science*

Corresponding Author: 1222708@ed.tus.ac.jp

We study static and spherically symmetric black hole (BH) solutions in extended Einstein- Maxwell-scalar theories which is classified in a subclass of the $U(1)$ gauge-invariant scalar-vector- tensor theories. The scalar field is coupled to the vector field, which has electric and magnetic charges. We investigate modifications to the Reissner-Nordstr¨om solution focusing on the three types of scalar-vector interactions, including derivative couplings. We solve the field equations analytically in two asymptotic regions which are the vicinity of the BH horizon and the spatial infinity, and clarify the condition for the existence of scalar hair. To understand the behaviors of solutions in intermediate scales, the field equations are integrated numerically for concrete models with different types of couplings. We find new hairy BH solutions with scalar hair in the presence of magnetic charge and kinetic coupling. The magnetic charge plays an important role in distinguishing hairy BH solutions originated from three types of different interactions at a large coupling limit.

Black hole formation, evolution and the black hole mass gap / 501

Initial Conditions and Evolution for Spherically Symmetric Collapse

Authors: Elly Bayona[1]; Hernando Quevedo[1]; Miguel Alcubierre[2]

[1] *National Autonomous University of Mexico*

[2] *Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de Mexico*

Corresponding Author: elly.bayona@correo.nucleares.unam.mx

Spherical collapse in general relativity has been studied with different methods, especially by using a priori given equations of state that describe the collapsing matter as a perfect fluid. We propose an alternative perspective, in which the initial density of the perfect fluid is given as a polynomial function of the radial coordinate that is regular everywhere inside the fluid. We then solve the corresponding differential equations, including the TOV equilibrium condition, using a 4-th order Runge-Kutta method and obtain a consistent model with a central perfect-fluid core surrounded by dust. Then, we analyze numerically the evolution of these initial conditions using the Ollinsphere code and obtain as a result a dynamical process in which the dust implodes into the central core to form a collapsed configuration. The density and pressure of the resulting matter distribution satisfy the standard physical conditions. The model is also consistent with the Buchdahl limit and the speed of sound conditions, even by using realistic values of compact astrophysical objects such as neutron stars.

New frontier of multi messenger astrophysics: follow up of electromagnetic transient counterpart of gravitational wave sources / 502

ET-WST synergy for next generation gravitational wave multi-messenger observations

Authors: Sofia Bisero[1]; Susanna Vergani[1]; Marica Branchesi[2]; Eleonora Loffredo[2]; Nandini Hazra[2]; Ulyana Dupletsa[2]

[1] *GEPI, Observatoire de Paris, Université PSL, CNRS*

[2] *Gran Sasso Science Institute*

Corresponding Author: sofia.bisero@obspm.fr

The Einstein Telescope (ET), third generation gravitational wave (GW) interferometer, will explore a large volume of the universe, detecting up to 10^5 binary neutron star system mergers (BNS) per year, beyond redshift z ~ 3. This will clearly revolutionize GW multi-messenger (MM) astrophysics. A significant amount of electromagnetic (EM) counterpart candidates will be provided by optical-NIR photometric observations within the large GW signal error regions: the bottleneck of GW MM science will be to gather the spectroscopic data required to discriminate against EM counterpart candidates, identifying and characterizing them. New observational strategies will be necessary and they have to be prepared well in advance of ET operations.
I will present the results of the work that I am carrying out within the Wide-field Spectroscopic Telescope (WST) science team and the MM division of the ET Observational Science Board to assess the impact of next generation Integral-Field Spectroscopy (IFS) and Multi-Object Spectroscopy (MOS) on the detection, identification and characterisation of the EM counterparts of ET BNS.

Exploring the Universe with strong gravitational lensing / 503

New constraints on the density profiles of subhaloes with gravitational imaging

Author: Giulia Despali[1]

[1] *DIFA, University of Bologna*

Corresponding Author: giulia.despali@unibo.it

Strong gravitational lensing is one of the most promising methods for studying the nature of dark matter. It allows one to detect low-mass dark haloes within the haloes of lens galaxies and along their line of sight, providing a quantitative test of the Cold Dark Matter (CDM) paradigm in a halo mass regime and distances that are not accessible to any other technique. So far, two detections of dark perturbers in strong lensing systems have been reported. Both perturbations are extremely compact, posing potential challenges to the CDM model. I will present a new analysis of the two detections, including constraints on the density profiles and a comparison to CDM predictions derived from hydrodynamical simulations. I will then discuss upcoming promising optical and radio observations that may allow us to push the detection limits to lower masses and obtain a larger statistical sample. These are being used to set new constraints on cold, warm and fuzzy dark matter.

IXPE observations and multiwavelength opportunities / 504

Synergies between IXPE and MAGIC observations of blazars

Author: Elisa Prandini[1]

[1] *Padova University and INFN Padova*

Corresponding Author: elisa.prandini@unipd.it

MAGIC is an imaging atmospheric Cherenkov telescope that has been observing very high energy gamma rays above 100 GeV for over 20 years. Thanks to its location and low energy threshold, MAGIC is particularly well-suited for observing blazars. Its observation strategy combines the monitoring of a few selected sources with the observation of new targets, often triggered by Target of Opportunity (ToO) events. Past multi-wavelength observations have highlighted the complexity of blazars, both in their temporal and spectral evolution. MAGIC has significantly contributed to this understanding with precise spectral measurements at the highest energies and detailed studies of variability timescales. A particularly relevant aspect still under investigation is the jet structure and the acceleration mechanism. The opening, with IXPE, of the new observational window of X-ray polarimetry marks a significant step forward in understanding these objects. In this contribution, I will provide an overview of blazars observed by MAGIC that are of particular interest to IXPE, highlighting recent results and possible future observational strategies and targets. Special emphasis will be placed on the studies of the two blazars Mkn 421 and Mkn 501, which involve joint observations by MAGIC and IXPE.

Loop quantum gravity: cosmology and black holes / 505

Black hole explosions in loop quantum gravity

Author: Francesco Fazzini[1]

[1] *University of New Brunswick*

Corresponding Author: e5bgr@unb.ca

Effective models of gravitational collapse in loop quantum gravity for the Lemaître-Tolman-Bondi spacetime predict that collapsing matter reaches a maximum finite density, bounces, and then expands outwards. I explain how in the marginally bound case, shell-crossing singularities commonly occur for inhomogeneous initial profiles of the dust energy density; this is the case in particular for all profiles that are continuous and of compact support, including configurations arbitrarily close to the Oppenheimer-Snyder model. When a shell-crossing singularity occurs, it is necessary to seek weak solutions to the dynamics; I argue that weak solutions typically develop shock waves. I will conclude by showing numerical simulations where shock waves arise in weak solutions of Lemaître-Tolman-Bondi effective equations written in generalized Painlevé-Gullstrand coordinates, both for marginally bound and unbound configurations.

Machine learning in astronomy: AGN, transient events, cosmology and others / 507

Gamma-proton identification based on multi-model ensemble algorithm

Author: Jie Li[1]

[1] *University of South China*

Corresponding Author: 20222004110209@stu.usc.edu.cn

Identifying gamma-rays and rejecting the background of cosmic ray hadrons are crucial for very-high-energy gamma-ray observation and relevant scientific research. Based on the simulated data from the square kilometer array (KM2A) of LHAASO, eight high-level features are extracted for the gamma/hadron classification. Machine-learning (ML) models, including logistic regression, support vector machines, decision trees, random forests, XGBoost, CatBoost and deep neural networks (DNN), are constructed and trained using datasets of four energy bands ranging from 10^{12}eV to

10^{16}eV, and finally fused using the stacking integration algorithm. To comprehensively assess the classification ability of each model, the accuracy, F1 score, precision, recall and AUC value of the ROC curve are used. The results show that the ML methods have a significant improvement on particle classification in LHAASO-KM2A, particularly in the low-energy range. Among these methods, XGBoost, CatBoost and DNN achive a higher classification accuracy than decision trees and random forests, while the fusion model exhibits the highest accuracy. The ML methods provide a useful and alternative method for gamma/hadron identification.

Absolute stability of strange quark matter: from dark matter to stellar evolution / 508

Superfluid dark stars

Authors: Fabrizio Nesti[None]; Lorenzo Cipriani[None]; Massimo Mannarelli[None]; Silvia Trabucco[None]

Corresponding Author: lorenzo.cipriani@graduate.univaq.it

We present a superfluid dark star model consisting of relativistic dark bosons with two-body self-interaction. The obtained masses, radii, and tidal deformability depend in a simple way on the boson mass and interaction strength. We report first results on binary mergers: the distinctive amplitude and frequency of the emitted gravitational waves are well within reach of terrestrial interferometers.

Emission mechanisms in gamma-ray bursts / 509

Discovering early high- and very-high-energy gamma-rays from compact binary mergers in the era of 3G GW detectors

Author: Biswajit Banerjee[1]

Co-authors: Gor Oganesyan [1]; Marica Branchesi [1]

[1] *Gran Sasso Science Institute (GSSI)*

Corresponding Author: biswaphy90@gmail.com

The origin of the prompt emission in gamma-ray bursts (GRBs) remains debated. Our understanding is primarily derived from wide-field telescopes that operate within the 10 keV-10 MeV range. However, capturing early emissions at higher energies (above 100 GeV) is challenging because of the time required for slewing of the telescopes. I will discuss multi-messenger observational strategies aimed at detecting early VHE emissions from compact binary mergers, particularly in the context of third-generation gravitational wave detectors such as the Einstein Telescope (ET) and Cosmic Explorer (CE). With the proposed exceptional low-frequency sensitivity, it becomes feasible to detect and pinpoint gravitational wave events during the inspiral phase, providing an early warning alert for electromagnetic facilities. I will further discuss the physical mechanisms responsible for generating VHE counterparts via the synchrotron self-Compton model in the leptonic scenario, as well as external inverse Compton emission, as potential candidates in the 10 GeV - 10 TeV energy band (very-high-energy gamma-rays; VHE). Additionally, I will briefly discuss the recent discovery of the GeV component from a compact binary merger, GRB 211211A, and its implications for the possibility of GeV to sub-TeV emissions from these sources. Furthermore, I will highlight the detection of the second component of GRB 221009A and its potential impact on our understanding of VHE prompt emissions.

Quantum gravity phenomenology / 510

Constraints on quantum spacetime-induced decoherence from neutrino oscillations

Authors: Giulia Gubitosi[1]; Vittorio D'Esposito[1]

[1] *University of Naples Federico II*

Corresponding Author: vittorio.d.esp@gmail.com

We investigate the implications of decoherence induced by quantum spacetime properties on neutrino oscillation phenomena. We develop a general formalism where the evolution of neutrinos is governed by a Lindblad-type equation and we compute the oscillation damping factor for various models that have been proposed in the literature. Furthermore, we discuss the sensitivity to these effects of different types of neutrino oscillation experiments, encompassing astrophysical, atmospheric, solar, and reactor neutrino experiments. By using neutrino oscillation data from long-baseline reactors and atmospheric neutrino observations, we establish stringent constraints on the energy scale governing the strength of the decoherence induced by stochastic metric fluctuations.

Gravitational lensing, shadows and photon rings / 511

Extended source effect with thin light bundles

Author: Nezihe Uzun[1]

[1] *Polish Academy of Sciences, Center for Theoretical Physics*

Corresponding Author: neziheu@gmail.com

Geometric optics limit is considered to be a good-enough approximation for the calculation of distances and image distortions in curved spacetime. It is usually assumed that spherical waves are emitted from a point source and we observe a section of the wavefront. In the geometric optics limit, this section is represented by a thin bundle of rays. Accordingly, the intensity profile on the transverse, observational screen is homogeneous. In this talk, we outline the analogies between the paraxial ray optics of the Newtonian theory and the thin bundles in general relativity. We then propose a method adapted from the paraxial wave optics of the Newtonian theory in order to study the extended source effect. The idea is to use phase space methods and symplectic symmetries to superpose two bundles initiated from an extended source. We explore the possibility of obtaining inhomogeneous intensity profiles on the transverse plane associated with the fundamental Gaussian mode. We observe that their form is preserved throughout the propagation in curved spacetime on account of the symplectic symmetries of the phase space. Finally, we show that the caustics can be avoided with this method.

Gamma-ray bursts and AGNs with machine learning / 512

Evidence of mini-jet emission in a large emission zone from a magnetically-dominated gamma-ray burst jet

Author: Shu-Xu Yi[1]

[1] *Institute of High Energy Physics, Chinese Academy of Sciences*

Corresponding Author: sxyi@ihep.ac.cn

The second brightest GRB in history, GRB230307A provides an ideal laboratory to study the details of GRB prompt emission thanks to its extraordinarily high photon statistics and its single broad

pulse overall shape characterized by an energy-dependent fast-rise-exponential-decay (FRED) profile. Here we demonstrate that its broad pulse is composed of many rapidly variable short pulses, rather than being the superposition of many short pulses on top of a slow component. Such a feature is consistent with the picture of many mini-jets due to local magnetic reconnection events in a large emission zone far from the GRB central engine, as envisaged in the internal-collision-induced magnetic reconnection and turbulence (ICMART) model, but raises a great challenge to the internal shock models that attribute all variability components to collisions among different shells. Since relativistic mini-jets demand strong magnetization in the outflow, this work provides strong evidence for a Poynting-flux-dominated jet composition of this bright GRB.

A NICER view of extreme gravity from the International Space Station / 513

How General Relativistic Effects Modify Spectral-Timing Properties of Accreting Black Holes

Author: Guglielmo Mastroserio[1]

[1] *Università degli Studi di Milano*

Corresponding Author: mgullik@gmail.com

Black holes are among the most challenging objects to study in the universe since nothing can escape from their event horizon. Fortunately, these objects leave traces by imposing their extreme gravitational pull on the surrounding matter as it falls into the black hole. Spectral-timing analysis has become very popular for studying accreting black holes and inferring the geometrical structure of these systems. It combines the analysis of X-ray spectral and timing features produced in the innermost region of accreting black holes, allowing us to characterize properties such as mass and spin, and to shed light on the interplay between the corona, the jet, and the accretion disk. NICER is the perfect instrument to perform such analysis due to its extraordinary timing capabilities and fine spectral resolution. I will overview the most recent results derived from the spectral-timing analysis of accreting black holes using NICER observations.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 514

Magnetar outbursts and beyond

Author: Alice Borghese[1]

[1] *INAF/Astronomical Observatory of Rome*

Corresponding Author: alice.borghese@gmail.com

Magnetars are the strongest magnets we know of, with magnetic fields reaching values up to 10^15 G at the surface. Transient activity in the X-/gamma ray regime is the birthmark of magnetars. Their radiative variability includes short, explosive events from milliseconds to hundreds of seconds (i.e., bursts and giant flares) and longer-lived outbursts (weeks to months). In this talk, I will review the results obtained from a systematic analysis of outbursts, focusing on a few specific events. Then, I will finish with some considerations on magnetar-like activity from other classes of neutron stars and the possible evolutionary links between different neutron star families.

The SVOM mission in the time-domain era / 515

The SVOM Core Program

Author: Susanna Vergani[1]

[1] *CNRS - Observatoire de Paris*

Corresponding Author: susilandia@gmail.com

SVOM (Space-based multi-band astronomical Variable Objects Monitor) is a Sino-French mission launched in June 2024. Its Core Program is dedicated to the detection and study of Gamma-Ray Bursts (GRBs). I will show how the set of SVOM instruments as well as the observing strategy compare with previous mission, and present how SVOM allows new discovering space and how it will improve GRB studies.

Navigating science and philosophy: exploring limits / 516

the conceptual tension between relativity and quantum mechanics

Author: Giovanni Amelino-Camelia[1]

[1] *Università Federico II di Napoli*

Corresponding Author: gac0000@gmail.com

I observe that some of the challenges faced by quantum-gravity research can be traced back to the conceptual tension between relativity and quantum mechanics

Quantum gravity phenomenology / 517

quantum mechanics relativity and gravity

Author: Giovanni Amelino-Camelia[1]

[1] *Università Federico II di Napoli*

Corresponding Author: gac0000@gmail.com

I observe that some of the key challenges faced by quantum-gravity research, and particularly by quantum-gravity phenomenology, can be traced back to grey area of our understanding of the interface between quantum mechanics and special relativity

Historical supernovae / 518

Astronomy before the telescope

Author: Costantino Sigismondi[1]

Co-authors: Andrea Brucato [2]; John B. Jandoc [3]; Laura Manfrini [4]; Paolo De Vincenzi [2]; Paolo Ochner [5]; Tiziana Pompa [4]

[1] *ICRA Sapienza and ICRANET Pescara*

[2] *Sapienza University of Rome*

[3] *Lyceum Galileo Ferraris, Rome*

[4] *Lyceum Galileo Galilei, Pescara, Italy*

[5] *University of Padova and Astrophysical Observatory of Asiago*

Corresponding Author: sigismondi@icra.it

To study the historical galactic Supernovae it is necessary the knowledge of the observations made with the naked eye. Within 2' of theoretical angular accuracy in daytime and 1' in nightime, the astronomical observations made before Tycho were conducted artistically, depending on the skills, the techniques available and the inspiration of the astronomers.
Galileo Galilei stands in between the two periods, having contributed to the (Super)Nova of Kepler of 1604 with visual observations and discussions. Five years later, in 1609, Galileo started the glorious season of discoveries at the telescope.
We will discuss on 1) Relative and absolute stellar positions 2) Timing accuracy 3) Low contrast observations: Comets and Aurorae 4) The nature of written accounts 5) Unwritten testimonies (archaeoastronomy).
With these items we prepare an examen on a) Historical Galactic Supernovae written accounts.
b) Solar activity in the ancient times (Aurorae and Sunspots reports).
c) Lunar features identifications.

Historical supernovae / 519

Relativistic particles from the Sun

Author: Costantino Sigismondi[1]

Co-authors: Paolo Ochner [2]; Maria Dal Pian [3]

[1] *ICRA Sapienza and ICRANET Pescara*

[2] *University of Padova and Astrophysical Observatory of Asiago*

[3] *Lyceum Brocchi, Bassano del Grappa, Italy*

Corresponding Author: sigismondi@icra.it

The particles ejected from the Sun during some particularly powerful eruptions (X-ray flare class X) reach the Earth in twenty minutes, immediately after the photons that carry the image and information of the event.
The speed of the most energetic protons of the solar wind is measurable from the images of C3 coronagraph of SOHO SOlar and Heliospheric Observatory and from the X-ray and proton tracks of the GOES 16 and 18 satellites. Their kinetic energy is E=$mc^2(\gamma - 1)$,
where γ is the Lorentz factor.
From the assumption of equipartition of the energy $1/2m \cdot v^2 = 3/2KT$ we also derive the equivalent thermodynamic temperature in the blasting zone, of the order of 10^{10} K.
Data from the M9.75 class flare on June 8, 2024 at 1:24 UT are taken into account to study these particles, which are protons. Their average velocity is $v \sim c/7$ and their kinetic energy is $E \sim 10$ MeV.
By cross-correlating the data of the GOES 16 and 18 satellites, maximum velocities between $v = 0.23$ c and $v = 0.38$ c are found, with kinetic energies of protons between 27 and 81 MeV. The presence of particles with $E100$ MeV and the possibility to detect particles with $E500$ MeV with the GOES satellite, implies α-particles ejected from the Sun, or Cosmic Rays.
The effects on the Earth's magnetosphere and atmosphere of such Solar Proton Events are discussed, as well as the biological threats, in order to extend these considerations to galactic Supernovae or galactic Gamma-Ray Bursts.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 520

Vacuum selection in qft

Author: Daniele Colosi[1]

[1] *Universidad Nacional Autónoma de México*

Corresponding Author: dcolosi@enesmorelia.unam.mx

In this talk we show that the relevant physical information in the construction of a vacuum state is encoded in the selection of a Lagrangian subspace of the space of complexified solutions. In particular we show the existence of a one-to-one correspondence between vacuum states for qft in curved spacetime and Lagrangian subspace. This result implies a unification of a general notion of amplitude and vacuum state as well as a proposal for vacuum selection. Moreover we will briefly comment on the quantization of evanescent modes of the field (modes with energy smaller than the mass) based on the appropriate identification of the corresponding Lagrangian subspace, and mention some of the latest results obtained in this area.

Mineral detection of dark matter and neutrinos / 521

Mineral Detection of Dark Matter and Neutrinos

Author: Alexey Elykov[1]

[1] *Karlsruhe Institute of Technology (KIT)*

Corresponding Author: alexey.elykov@kit.edu

With Dark Matter still eluding detection a window has opened for new ideas in the field. One such idea is to utilize the advent of modern microscopy and computational techniques to read out nm and μm-sized damage features produced by interactions of Dark Matter and neutrinos with nuclei of minerals. Natural minerals should have accumulated these minute features over Myrs, allowing us to use them as "paleo-detectors". The enormous exposure of such paleo-detectors could provide them with sensitivity that rivals that of modern direct detection experiments. Uniquely, paleo-detectors could be used to probe the distribution of Dark Matter in our Galaxy and the evolution of neutrino fluxes from various sources over our Galaxy's lifetime. Natural or artificially produced minerals could also be used as directionally sensitive detectors for studying reactor neutrinos and Dark Matter-induced interactions on laboratory timescales. This talk will outline the state of the newly emerging and interdisciplinary research field of mineral-based detectors.

Quantum field theory in curved spacetimes and perturbative quantum gravity / 522

Vacuum instability and Black Hole Evaporation

Author: Michael Florian Wondrak[None]

Co-authors: Heino Falcke ; Walter D. van Suijlekom

Corresponding Author: m.wondrak@astro.ru.nl

This talk presents a new avenue to black hole evaporation using a heat-kernel approach in the context of effective field theory analogous to deriving the Schwinger effect. Applying this method to an uncharged massless scalar field in a Schwarzschild spacetime, we show that spacetime curvature takes a similar role as the electric field strength in the Schwinger effect. We interpret our results as local pair production in a gravitational field and derive a radial production profile. The resulting emission peaks near the unstable photon orbit. Comparing the particle number and energy flux to the Hawking case, we find both effects to be of similar order. However, our pair production mechanism itself does not explicitly make use of the presence of a black hole event horizon and might have cosmological implications.
The presentation is based on Phys. Rev. Lett. 130 (2023) 221502.

Fast radio bursts / 523

Fast Radio Bursts: the CHIME Revolution

Author: Juan Mena-Parra[1]

[1] *University of Toronto*

Corresponding Author: juan.menaparra@utoronto.ca

Fast radio bursts (FRBs) are enigmatic millisecond-duration pulses of radio light observed across cosmological distances. Their origins and emission mechanisms remain unclear, making FRBs one of the most intriguing new mysteries in astrophysics. The Canadian Hydrogen Intensity Mapping Experiment (CHIME), with its specialized real-time transient-search engine (CHIME/FRB), has emerged as the leading facility for FRB detection, revolutionizing the field unprecedented detection rates and increasing the known sample by an order of magnitude. This extensive new sample has already enabled detailed studies of the statistical properties of the FRB population as well as of individual events with unique characteristics. We are currently enhancing CHIME's capabilities to include very-long-baseline interferometry (VLBI) through the CHIME/FRB Outriggers program. This large-scale initiative aims to deploy CHIME-like outrigger telescopes at continental baseline distances, working in tandem with CHIME to precisely pinpoint FRB locations using VLBI. This precision is essential for identifying host galaxies, studying source environments, and enabling the use of FRBs as cosmological probes. In this talk, I will provide an overview of CHIME/FRB's most recent results, present the CHIME/FRB Outriggers program, and report on its status.

Gravitational kHz waves - LIGO-Virgo-KAGRA / 524

How are the LVK gravitational wave searches doing, and where are they headed?

Author: Prathamesh Joshi[1]

[1] *Pennsylvania State University*

Corresponding Author: ppj5075@psu.edu

During the fourth observing run of the LVK collaboration, we have already seen large improvements in the results produced by the search pipelines in low-latency. We have reached new levels of sensitivity and reliability. In the quest to detect every gravitational wave out there, we are now more ready than ever to participate in the next multimessenger event. During this fourth observing run, we have seen the first glimpse of results from unmodeled or burst searches. As we start getting high-latency offline results, we will begin to explore gravitational waves from new parameter spaces. In the future, we are looking to incorporate precession and higher order modes of gravitational waves in these searches. These advancements will play a crucial role in obtaining a better scientific understanding of some of the biggest mysteries of the universe. In this talk, I will give an overview of the current status and performance of search pipelines, and what the future holds for them.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 525

Introducing Bayesian Model Averaging to include model uncertainty in our cosmological parameters' estimates

Author: Simone Paradiso[1]

[1] *University of Waterloo*

Corresponding Author: simone.paradiso@uwaterloo.ca

In this talk I am presenting Bayesian Model Averaging, a well established statistical technique that offers a principled approach to model uncertainty marginalization in a Bayesian context.Specifically, this talk goes through the two recent papers I published in which I describe an implementation of such methodology for Cosmological analyses with 1) an application to the early dark energy as a possible solution to the Hubble tension and 2) a broad application to some notorious tensions arising from the CMB and LSS datasets, as the number of neutrino species, the Dark Energy equation of state and the curvature of the Universe. In this talk I will present results from the application of BMA to the last publicly available Planck data and BAO measurements from BOSS and eBOSS.

Present and future of cosmic microwave background observations / 526

The cosmological analysis of Planck LFI raw data from Beyond-Planck and Beyond

Author: Simone Paradiso[1]

[1] *University of Waterloo*

Corresponding Author: simone.paradiso@uwaterloo.ca

In this talk I will present cosmological results from the recent work carried on by the BeyondPlanck collaboration: a Bayesian end-to-end analysis of Planck LFI raw data. This novel approach allowed to seamlessly go through all the steps of a classical CMB analysis pipeline in an integrated framework: commander3. Cosmological results we produced are therefore naturally marginalized over all the model parameters' uncertainty, including instrumental parameters and foreground residual from component separation. The final CMB analysis includes a high multipole likelihood, based on full-sky foreground cleaned maps produced by imprinting constrained CMB realizations in the masked region of the sky, and a large scale map-based CMB likelihood that for the first time implements a sampled based computation of a noise covariance matrix that accounts for all the uncertainty sources propagated in the analysis pipeline. The effort from the BeyondPlanck community is being carried on in the much wider Cosmoglobe project, whose goals are being presented during this very conference.

New frontier of multi messenger astrophysics: follow up of electromagnetic transient counterpart of gravitational wave sources / 527

How to do multi-messenger forecasts in the Einstein Telescope era: addressing present and future challenges

Author: Ulyana Dupletsa[1]

[1] *GSSI, INFN*

Corresponding Author: ulyana.dupletsa@gssi.it

Next-generation gravitational-wave detectors will be able to explore a broad range of science case studies. Evaluating their detection and parameter-estimation capabilities is a mandatory step in the planning process. We will start by discussing currently available data analysis tools that allow us to do forecasts. In particular, we will talk about GWFish, a software that simulates gravitational-wave detector networks and calculates measurement uncertainties based on the Fisher matrix approximation. We will then present the results obtained with GWFish on the scientific perspectives for different designs for the Einstein Telescope (ET), the European next-generation gravitational-wave observatory. The talk will overview the impact of different detector geometries and sensitivities, focusing on the multi-messenger capability of ET operating in synergy with electromagnetic observatories, where localization capabilities have a crucial role, especially for sending pre-alerts for detecting prompt and early emissions.

Low frequency gravitational waves: sciences and detections / 528

Using mHz gravitational waves to catch galactic center mergers of supermassive dark matter cores

Authors: Carlos Raúl Argüelles[1]; Jorge Armando Rueda Hernandez[2]; Jose Fernando Rodriguez Ruiz[3]; Remo Ruffini[4]

[1] *La Plata National University & ICRANet*

[2] *ICRANet*

[3] *Universidad Industrial de Santander*

[4] *ICRANet, ICRA, INAF*

Corresponding Author: jorge.rueda@icra.it

There is an open debate about whether some galactic centers (including Sgr A*) could actually be supermassive dark matter cores made of fermions with masses in the range of 60-350 keV. We discuss the possibility of pinpointing mergers of such cores using mHz gravitational waves with the forthcoming space-based interferometers and assess the consequences of the possible outcomes from the physical and astrophysical viewpoint.

Gamma-ray bursts and AGNs with machine learning / 529

A Stochastic Approach to Reconstruct Gamma-Ray-burst Light Curves

Author: Maria Dainotti[1]

Co-authors: Aditya Narendra [2]; Agnieszka Pollo [3]

[1] *National Astronomical Observatory of Japan*

[2] *Jagiellonian University*

[3] *National Centre for Nuclear Research*

Corresponding Author: aditya.narendra@doctoral.uj.edu.pl

Gamma-ray bursts (GRBs), as they are observed at high redshift (z = 9.4), are vital to cosmological studies and investigating Population III stars. To tackle these studies, we need correlations among relevant GRB variables with the requirement of small uncertainties on their variables. Thus, we must have good coverage of GRB light curves (LCs). However, gaps in the LC hinder the precise determination of GRB properties and are often unavoidable. Therefore, extensive categorization of GRB LCs remains a hurdle. We address LC gaps using a stochastic reconstruction, wherein we fit two preexisting models (the Willingale model; W07; and a broken power law; BPL) to the observed LC, then use the distribution of flux residuals from the original data to generate data to fill in the temporal gaps. We also demonstrate a model-independent LC reconstruction via Gaussian processes. At 10% noise, the uncertainty of the end time of the plateau, its correspondent flux, and the temporal decay index after the plateau decreases by 33.3%, 35.03%, and 43.32% on average for the W07, and by 33.3%, 30.78%, 43.9% for the BPL, respectively. The uncertainty of the slope of the plateau decreases by 14.76% in the BPL. After using the Gaussian process technique, we see similar trends of a decrease in uncertainty for all model parameters for both the W07 and BPL models. These improvements are essential for the application of GRBs as standard candles in cosmology, for the investigation of theoretical models, and for inferring the redshift of GRBs with future machine-learning analyses.

Machine learning in astronomy: AGN, transient events, cosmology and others / 530

Deep Learning for Identification and Characterization of Ca II Absorption Lines: A Multi-Task CNN Approach

Author: yang liu[None]

Corresponding Author: 20222008110515@stu.usc.edu.cn

Quasar absorption line is a powerful tool for studying the universe, enabling us to probe distant gas, dust, and galaxy formation and evolution. However, detecting Ca II absorbers is particularly challenging, requiring significant time and effort. Existing deep learning methods often produce a high number of false positives and still require extensive manual verification, achieving an precision of only 20.3%. To address this issue, we propose a multi-task convolutional neural network (CNN) architecture. We compare three different CNN structures and find that the ResNet-CBAM model, which incorporates residual modules and an attention mechanism, performs best. Results demonstrate that the ResNet-CBAM model achieves an accuracy of 99.53% in detecting Ca II absorbers. Additionally, it excels in predicting critical parameters such as equivalent width (EW) and full width at half maximum (FWHM), with correlation coefficients of 0.964 and 0.849, respectively. Furthermore, it exhibits excellent generalization ability, boosting detection precision on new data from a mere 20.3% to 90.5%, significantly reducing the need for manual inspection and paving the way for automated Ca II absorber search. In real-world applications on SDSS Data Release 7 (DR7) and DR12, our model successfully identified 743 known Ca II absorbers and discovered potential candidates in approximately 400 spectra.

Emission mechanisms in gamma-ray bursts / 531

Kerr black hole energy extraction, irreducible mass feedback, and the effect of the captured particles charge

Authors: Jorge Armando Rueda Hernandez[1]; Remo Ruffini[2]

[1] *ICRANet*

[2] *ICRANet, ICRA, INAF*

Corresponding Author: jorge.rueda@icra.it

We analyze the extraction of the rotational energy of a Kerr black hole (BH) endowed with a test charge and surrounded by an external test magnetic field and ionized low-density matter. For a magnetic field parallel to the BH spin, the electric field accelerates electrons outward(inward) and protons inward(outward) in a region around the BH poles(equator). For zero net charge, the polar region comprises roughly 60 degrees from the polar axis and the equatorial 30 degrees from the equator. We recall the system has axial and equatorial reflection symmetry. Polar(equatorial) protons(electrons) that can be captured by the BH have positive(negative) energy and angular momentum. We show that a gain of positive charge makes the polar region shrink and the equatorial region enlarge. Thus, the BH could experience a cyclic behavior for an isotropic particle density. Starting from a zero charge, it accretes more polar protons than equatorial electrons, gaining net positive charge, energy, and angular momentum. Then, the shrinking(enlarging) of the polar(equatorial) region makes it accrete more equatorial electrons than polar protons, gaining net negative charge, energy, and angular momentum. In this phase, the BH rotational energy is extracted. The extraction process continues until the new enlargement of the polar region reverses the situation, and the cycle repeats. We show that the process produces a relatively low increase of the BH irreducible mass compared to gravitational mechanisms like the Penrose process. Hence, it provides a first step towards electrodynamical, efficient mechanisms for extracting the BH rotational energy. Consequences in the context of gamma-ray bursts are discussed.

Slowly rotating pulsars / 532

The puzzling X-ray source in RCW 103

Author: Alice Borghese[1]

[1] *INAF/Astronomical Observatory of Rome*

Corresponding Author: alice.borghese@gmail.com

1E 161348-5055 (1E 1613), the source at the center of the supernova remnant RCW103, has defied any easy classification since its discovery, owing to its long-term variability from months to years and a periodicity of 6.67 hr with a variable light curve profile across different flux levels. On June 2016, 1E 1613 emitted a magnetar-like millisecond burst of hard X-rays, accompanied with a factor ~100 brightening in the persistent soft X-ray emission. The duration and spectral decomposition of the burst, the discovery of a hard X-ray tail in the spectrum, and the long-term outburst history (from 1999 to 2016 July) suggest that 1E 1613 is an isolated magnetar and the periodicity of 6.67 hr is the rotational spin period, making 1E 1613 the slowest magnetar ever. During this talk I will review the properties of this source, focusing on the last outburst and the mechanism required to slow it down till a such long period.

Gravitational lensing, shadows and photon rings / 533

Light bending around a gravitating object immersed in a moving medium

Author: Barbora Bezdekova[1]

Co-authors: Oleg Tsupko [2]; Christian Pfeifer [3]

[1] *Charles University*

[2] *ZARM, Bremen University, Germany*

[3] *ZARM - University of Bremen*

Corresponding Author: baja@etranslator.biz

A well-known effect confirmed by astrophysical observations is the light deflection in the gravitational field. In the recent years, the Hamiltonian formalism has been frequently applied in analytical studies to discuss how a medium that surrounds the gravitating object changes the light bending compared to the absence of the medium. Within this formalism, the medium is usually regarded as a cold plasma. However, in a cold plasma the light motion is independent of the medium velocity. Correspondingly, any difference of a medium from the cold plasma model will manifest itself in the appearance of a deflection angle dependence on the medium velocity. In our recent work we considered that a more general medium surrounds a spherically symmetric object and analyzed the deflection angles. Two particular examples of the medium were discussed, i.e., the radially falling and rotating ones. Results obtained in these settings will be presented. Furthermore, I will discuss additional findings derived when an axially symmetric object in a moving medium was considered instead.

IXPE observations and multiwavelength opportunities / 534

IXPE observations of the Crab and othe PWNe: a critical review

Author: Niccolo' Bucciantini[1]

[1] *INAF - Osservatorio di Arcetri*

Corresponding Author: niccolo.bucciantini@inaf.it

With the IXPE satellite a new observational window has opened for the study of the physical properties of Pulsar Wind Nebulae. For the first time we are able to directly map the magnetic field geometry in the inner regions of these systems, where our current theoretical models place the site of particle acceleration. I will review the current status of X-ray polarimetry in PWNe, in the context of the canonical PWN picture, and how it relates to information from other wavelengths. Implications for the physics of acceleration, and the role of turbulence, will be also discussed.

Extended theories of electromagnetism and their impact on laboratory experiments and astrophysical observations / 535

Archimedes: how much does the vacuum weigh?

Author: Annalisa Allocca[1]

[1] *Università "Federico II" di Napoli - INFN sez. di Napoli*

Corresponding Author: annalisa.allocca@unina.it

The cosmological constant problem enfolds one of the most long-standing issues in physics: the incompatibility between Quantum Field Theory and General Relativity. Within this background, the Archimedes experiment aims to investigate the relationship between zero-point quantum fluctuations of the electromagnetic field and gravity. Using a highly sensitive suitably designed beam-balance, Archimedes will measure the force exerted by gravitational field on samples hanging from the balance arms. Vacuum energy is modulated inside the samples by exploiting superconductive transition, which turns them in a stack of Casimir cavities, expelling not-allowed EM modes. If vacuum energy interacts with gravity, an upward force will act on the samples and could be interpreted as the missing weight of the ejected EM modes, in similarity with the Archimedes buoyancy of fluid. The expected signal in torque generated with this modulation is of the order of $10^{-13} Nm/\sqrt{Hz}$. To minimize environmental disturbances, Archimedes is installed in the SarGrav Laboratories at the Sos-Enattos site, in Sardinia (Italy) which is seismically very quiet and, for this reason, candidate for hosting the third-generation Gravitational Waves detector Einstein Telescope. The tilt sensitivity of Archimedes prototype, installed in the same laboratory, is currently thermal-noise limited, and has been measured to be below $10^{-12} Nm/\sqrt{Hz}$ in the frequency band 20 mHz - 70 mHz, which makes it one of the most sensitive beam-balance in the world in this frequency range. Besides demonstrating the correctness of the design, measurements on the prototype also showed that it is capable to investigate other kind of fundamental physics aspects, such as the interaction with dark B-L photons. The final setup of the Archimedes experiment is now fully installed, the first sensitivity measurement in vacuum is expected by the end of 2024, while the final measurement of the vacuum fluctuations' weight is forecast to be performed within 2026.

Gamma-ray bursts and AGNs with machine learning / 536

Optimising a stochastic pulse-avalanche model of GRB light curves with a genetic algorithm

Authors: Anastasia Tsvetkova[1]; Cristiano Guidorzi[2]; Filippo Frontera[3]; Giuseppe Angora[4]; Lisa Ferro[2]; Lorenzo Amati[5]; Lorenzo Bazzanini[6]; Manuele Maistrello[2]; Massimo Brescia[7]; Mattia Bulla[2]; Piero Rosati[6]; Romain Maccary[2]

[1] *University of Cagliari*

[2] *University of Ferrara*

[3] *University of Ferrara and INAF-OAS Bologna*

[4] *INAF Napoli*

[5] *INAF - OAS Bologna*

[6] *Universita' degli Studi di Ferrara*

[7] *Department of Physics - University Federico II of Napoli*

Corresponding Author: frrlsi@unife.it

The light curves (LCs) of long gamma-ray bursts (GRBs) show a wide variety of morphologies, which current LC simulation models based on the internal shock paradigm still fail to fully reproduce. The reason is that, despite the recent significant advance in understanding the energetics and dynamics of long GRBs, the nature of their inner engine, how the relativist outflow is powered, and the dissipation mechanisms are still not understood. This limits our ability to describe and simulate those transients properly. A promising way to gain insights is modelling GRB LCs as the result of a common stochastic process. In the BATSE era, a stochastic pulse avalanche model was proposed by Stern et al. (1996) and tested by comparing ensemble-average properties of simulated and real LCs. Using machine learning, we optimised the model parameters by exploiting the genetic algorithm's capability to explore the parameter space thoroughly. We revived this model by applying it to two independent and complementary datasets, BATSE and Swift/BAT. In this contribution, we describe our optimisation algorithm, showing the results obtained on both datasets. Such a technique could be extended to different and more physically-grounded GRB light curve models. Moreover, the model allows us to simulate realistic LCs as they will be seen by upcoming detectors, which is fundamental to test light curve triggering algorithms in a realistic way and properly characterise next-generation high-energy instruments.

New frontier of multi messenger astrophysics: follow up of electromagnetic transient counterpart of gravitational wave sources / 537

Perspectives for kilonovae detections with the next-generation multi-messenger observatories

Authors: Eleonora Loffredo[1]; Nandini Hazra[2]; Ulyana Dupletsa[2]

[1] *Osservatorio Astronomico d'Abruzzo - INAF*

[2] *Gran Sasso Science Institute*

Corresponding Author: eleonora.loffredo@inaf.it

The detection of the gravitational wave (GW) signal GW170817 and the electromagnetic (EM) signal AT2017gfo confirmed the association between binary neutron star (BNS) mergers and kilonovae (KNe) and showed the potential of joint detection to unveil the nature of neutron stars and the nucleosynthesis of heavy elements in the Universe. The next-generation GW interferometers, such as the Einstein Telescope (ET), are unprecedented resources to enhance the chances of detecting EM counterparts significantly enlarging the horizon of detectable BNS mergers, and dramatically improving the source parameter estimation. Starting from BNS merger populations based on population synthesis codes, we compute the number of detected mergers and estimate the source parameters for different configurations of ET operating alone or in a network of present or next-generation GW detectors. We compute the KN emission associated with the BNS merger population for two different nuclear equations of state, and considering the influence of black hole prompt collapse on the kilonova signal. Furthermore, we include the emission from the afterglows of short gamma-ray bursts. In the talk, I will discuss the perspectives for KNe detections with ET observing in synergy with the Vera Rubin Observatory, taking into account the present uncertainties on the rate of BNS mergers, neutron star mass distribution, and nuclear equation of state.

Massive white dwarfs and related phenomena / 538

On the optical transient of double white dwarf mergers

Authors: Jaziel Coelho[1]; Jorge Armando Rueda Hernandez[2]; Manoel Felipe Sousa[3]

[1] *UFES*

[2] *ICRANet*

[3] *National Institute for Space Research (INPE)*

Corresponding Author: jorge.rueda@icra.it

Double white-dwarf (DWD) mergers are relevant astrophysical sources expected to produce massive, highly-magnetized WDs, supernovae (SNe) Ia, and neutron stars (NSs). There are expected to be numerous sources in the sky, but none have been yet detected, evading the most advanced transient surveys (e.g., The Zwicky Transient Facility - ZTF). We characterize the optical transient from DWD mergers, leaving as a central remnant a stable (sub-Chandrasekhar) WD. The expansion and cooling of the merger's dynamical ejecta emits an optical transient peaking at 1-10 d post-merger, with luminosities of 10^{40}-10^{41} erg s^{-1}. We present light-curves, spectra, and color evolution of the transient. These properties, with the estimated rate of DWD mergers, are consistent with the absence of detection, e.g., by ZTF. More importantly, we show that the Legacy Survey of Space and Time (LSST) of the Vera C. Rubin Observatory will likely detect a few/several hundred per year.

Cosmic backgrounds from radio to far-IR / 539

Observer motion and boosting effects of the cosmic background spectrum at high multipoles, solutions and perspectives

Author: Tiziana Trombetti[1]

[1] *INAF*

Corresponding Author: tiziana.trombetti@inaf.it

The peculiar motion of an observer relative to an ideal reference frame at rest with respect to the cosmic background produces boosting effects which modify and transfer at higher multipoles the frequency spectrum of the isotropic background. To mitigate the computational effort needed for accurate theoretical predictions, I present analytical solutions of a linear system able to evaluate the spherical harmonic expansion coefficients for (analytical or semi-analytical) backgrounds, also extended to generic tabulated functions. Owing to the dipole spectrum frequency dependence and to precise inter-frequency calibrations, it will be possible to constrain (or even detect) the tiny imprints in the background spectrum from a variety of cosmological and astrophysical processes.

The SVOM mission in the time-domain era / 540

The SVOM Mission and Perspectives for Multi-messenger Astronomy

Author: Rachel Hamburg[1]

[1] *CNRS/IJCLab*

Corresponding Author: rachel.hamburg@ijclab.in2p3.fr

The recently launched SVOM (Space-based multi-band astronomical Variable Objects Monitor) mission is a French-Chinese collaboration dedicated to the study of high energy transients, particularly gamma-ray bursts (GRBs). Boasting sensitivity from gamma-ray to optical wavelengths, SVOM will have the ability to promptly localize GRBs to arcminute precision and provide rapid optical follow-up from both space and ground components. Science operations will begin in a few months, providing the exciting opportunity to make joint observations with the gravitational-wave (GW) detectors

LIGO, Virgo, and KAGRA in their fourth observing run (O4). During O4, SVOM will utilize all its instruments to perform multi-wavelength follow-up of neutron star mergers in order to detect and characterise their electromagnetic counterparts. In this talk, we will present an overview of the SVOM mission and its current strategies to search for prompt GRB, afterglow, and kilonova signals from GWs.

Astrophysics with gravitational waves / 541

An Effective Field Theory Approach to Gravitational and Electromagnetic Love Numbers of Magnetars

Authors: Kent Yagi[1]; Siddarth Ajith[1]

[1] *University of Virginia*

Corresponding Author: sa4fb@virginia.edu

Effective field theory methods have been used in a multitude of applications in gravitational theory, and recent efforts employ such techniques to study tidal interactions. The tidal deformability of stars presents exciting opportunities to analyze both nuclear and gravitational physics due to its dependence on the interior physics of stellar bodies. Information about tidal deformability is encoded in gravitational wave signals sourced by stars, so furthering our understanding of tidal interactions is crucial to probe the fundamental physics that can be observed from gravitational systems. Magnetar systems have been studied in a perturbative framework in general relativity, but the effects of coupled tidal field and magnetic field interactions have not been thoroughly explored. We employ the conventional neutron star perturbation techniques in conjunction with an effective action description of magnetized, tidally-deformed stars to study electromagnetic and gravitational Love numbers. We find that there are new Love numbers from the coupling of electromagnetic and gravitational fields, and this effective action approach can break ambiguities in Love number definitions. These interactions may have a measurable effect in double magnetar systems which could be observed with gravitational waves. This work studies tidal interactions of an Einstein-Maxwell system, and it can be extended to study other vector-tensor gravitational theories that are composed of less familiar fields.

Absolute stability of strange quark matter: from dark matter to stellar evolution / 542

On quark deconfinement in the accreting neutron stars of binary-driven hypernovae

Authors: Alessandro Drago[1]; Giuseppe Pagliara[None]; Jorge Armando Rueda Hernandez[2]; Laura Marcela Becerra Bayona[3]

[1] *University of Ferrara*

[2] *ICRANet*

[3] *Universidad Industrial de santander*

Corresponding Author: laura.marcela.becerra@gmail.com

In the binary-driven hypernova (BdHN) scenario, long gamma-ray bursts (GRBs) originate in a binary system composed of a carbon-oxygen (CO) star and a neutron star (NS) companion in close orbit. The collapse of the CO star generates a newborn NS (νNS) at its center and a type Ic supernova (SN) explosion. Part of the SN ejecta is accreted onto the NS companion and onto the νNS by fallback. The accretion process occurs at hypercritical (highly super-Eddington) rates, transferring mass and angular momentum to the stars. We here assess whether or not quark deconfinement can occur either in the νNS or in the NS companion during the hypercritical accretion process.

Experimental graviation / 543

Simulation strategies for the characterization of realistic radiation-pumped dispersion force-driven nanoscale parametric amplifiers

Author: Fabrizio Pinto[1]

[1] *Izmir University of Economics*

Corresponding Author: fabriziopinto2013@gmail.com

Nano-electromechanical systems (NEMS), electrostatically driven at their resonance frequency and parametrically pumped by time-dependent dispersion forces, are theoretically expected to display remarkable gain, sensitivity, resolution, and tunability properties. This author previously discussed employing nanodevices of this novel class as sensors to measure non-gravitational accelerations in such applications as SmallSats, in which spacecraft mass and volume limits are particularly stringent. This author also previously proposed modulating dispersion forces not by varying the interboundary gap width, which adds subsystem mass, complicates device design, and introduces mechanical vibration disturbances, but by back-illuminating a fixed semiconducting surface. Although both such dispersion force approaches have been experimentally demonstrated in the past, no experiment studying dispersion force-driven parametric amplifiers has yet been reported. Furthermore, no simulations of the dynamical behavior of such highly non-linear systems in non-inertial reference frames have appeared in the literature, even in the pump-off state, that is, under static dispersion force conditions. In this paper, we report the first results on such simulations in non-inertial frames, including a comparison between numerical results and a generalized theory of resonance in non-linear one-dimensional (1D) oscillators. In order to enhance the ability of our model to describe the multiphysics nature of our approach and to facilitate future experimentation, dispersion forces with non-ideal materials are introduced for the first time and a block diagram for nanodevice testing with laboratory instrumentation is presented.

Multi-messenger astronomy with gravitational waves / 544

Gravitational-wave cosmology with large-scale structure correlations

Author: Sayantani Bera[1]

[1] *University of the Balearic Islands*

Corresponding Author: sayantani.bera@uib.eu

The standard sirens in the gravitational wave (GW) astronomy provide us with a direct measure of the cosmological distances independent of the cosmic distance ladder. When accompanied by an electromagnetic counterpart, it can also provide a redshift measurement, thus offering a new avenue to probe the cosmic expansion rate today, also known as the Hubble constant H0. However, the majority of the detected GW events, which are binary black hole mergers, are observed without any electromagnetic counterpart. Such sources with unknown redshifts, known as the 'dark sirens', can also be used to infer H0, by making use of the clustering properties of these sources with respect to the observed galaxies and the underlying dark matter distribution. In this talk, I will discuss how the angular clustering between gravitational-wave standard sirens and galaxies allows an inference of H0, regardless of whether the true host galaxies of any of these sirens are present in the galaxy catalog. Moreover, the constraints are not biased by the galaxy catalog incompleteness which has been one of the concerning issues of the current state-of-the art methods in gravitational wave cosmology with dark sirens. With a realistic mock galaxy catalog and a set of GW events distributed within 1 Gpc simulated with coloured Gaussian noise of the Advanced LIGO and Advanced Virgo detectors operating at O4 sensitivity, we show that our method is able to reliably extract the cosmological expansion rate. As the expected number of binary black holes grows with the current and future observing runs, this technique will be imperative for any unbiased cosmological inference using GWs

Quantum gravity phenomenology / 545

A classical field treatment of gravitational fluctuation forces: From the space-time foam to neutron star merger interactions

Author: Fabrizio Pinto[1]

[1] *Izmir University of Economics*

Corresponding Author: fabriziopinto2013@gmail.com

In this presentation, we discuss a treatment of Casimir-Polder gravitational fluctuation forces based on a classical general relativistic gravitational field framework. In analogy with the acoustic Casimir effect, we analyze the interaction between high density neutron star surfaces within a bath of classical gravitational waves. We extend a previously published treatment of the interaction of gravitationally polarizable particles within a zero-point gravitational field, also including mixed gravitational-electrodynamical potentials. Finally, we consider the exploitation of "fluctuations of fluctuation forces" on very short time-scales as possible magnification strategies in the detection of such interactions on an elementary particle scale, such as in neutron-neutron and neutron-wall scattering processes. The epistemological implications of our findings in the search for unique quantum gravity signatures are explored.

New frontier of multi messenger astrophysics: follow up of electromagnetic transient counterpart of gravitational wave sources / 546

Fully calibrated lanthanide atomic data for 3D kilonova modeling

Authors: Andreas Flörs[1]; Ricardo Fereirra da Silva[2]; Luke Shingles[1]; Christine Collins[1]; Jorge Sampaio[2]; José Manuel Pires Marques[2]; Gabriel Martínez-Pinedo[1]

[1] *GSI Helmholtzzentrum für Schwerionenforschung*

[2] *LIP, Lisboa, Portugal*

Corresponding Author: floersandreas@gmail.com

With the detection of multiple neutron-star merger events in the last few years, the need for a more comprehensive understanding of nuclear and atomic properties has become increasingly important. Despite our current understanding, there are still large discrepancies in the opacities obtained from different codes and methods. These discrepancies lead to variations in the location and strength of absorption and emission features in radiative transfer models and prevent a firm identification of r-process products. To address this issue, we developed an optimisation technique for energy levels and oscillator strengths consistent with available experimental data. With this novel method, we can increase the accuracy of calculations while reducing the computational cost, finally making it possible to apply the method to all lanthanides instead of focusing on single ions.

We will report on converged large-scale atomic structure calculations of all singly and doubly ionised lanthanides with greatly improved transition wavelength accuracy compared to previous works. The impact of our new atomic data set on realistic 3D radiative transfer calculations and prospects of r-process signature identification will be investigated.

This work is supported by the European Research Council (ERC) under
the European Union's Horizon2020 research and innovation programme
(ERC Advanced Grant KILONOVA No.885281)

The Euclid mission: current status, results from early observations, and future prospects / 547

Near Infrared Spectro-Photometer instrument performances and capabilities

Author: Eduardo Medinaceli[1]

[1] *INAF-OAS*

Corresponding Author: eduardo.medinaceli@inaf.it

ESA's mission Euclid launched in July 2023 was fully commissioned and since early 2024 is performing its nominal survey. Euclid performs an extra galactic survey (0<z<2) using visible and near-infrared light. To detect infrared radiation is equipped with the Near-Infrared Spectro-Photometer (NISP) instrument sensible in the 0.9-2 μm range. The NISP instrument will be extensively described, including its complete optical system that allows to perform spectrometry (using a Blue and Red Grisms) and photometry (using YE 0.95-1.21μm, JE 1.17-1.57μm, and HE 1.52-2.02μm filters); its focal plane array (0.56 deg2 FoV) composed of 16 Teledyne's HAWAII-2RG with a total of 64 Mpx, with a 0.3 arcsec/px resolution; and the data reduction approach implementing with the on-board processing to derive the signal and mitigate the downlinked data load to ground.
NISP capabilities will be described using examples of in-flight calibration results that enabled science results already achieved with the early release data what will be partially touch in this presentation

Exploring the Universe with strong gravitational lensing / 548

Strong gravitational lensing at the radio wavelengths

Author: Cristiana Spingola[1]

[1] *INAF - Istituto di Radioastronomia*

Corresponding Author: cristiana.spingola@inaf.it

Current small scale cosmological controversies are coming down to the precision level of observations. The key point is whether a better understanding of baryonic physics, dark matter physics, or both is required to address these challenges. In this talk, I will describe how interferometric observations of strong gravitational lenses in the radio domain are uniquely contributing to address these small scale cosmological issues up to high redshift.

Absolute stability of strange quark matter: from dark matter to stellar evolution / 549

Cosmological constraints on macroscopic dark matter

Author: Luca Caloni[1]

Co-author: Massimiliano Lattanzi [2]

[1] *University of Ferrara*

[2] *INFN Ferrara*

Corresponding Author: luca.caloni@unife.it

The nature of dark matter is still a mystery. The possibility exists that dark matter is not made of elementary particles, but instead of "macroscopic" objects. In this class of scenarios, dubbed "macro

DM", the small interaction rates of dark matter are achieved through a small number density, as opposed to a small cross section. Examples of macro DM include clumps of strange quark matter ("strangelets"), or primordial black holes. In our talk, after briefly reviewing the phenomenology of macro DM, we will discuss current constraints and prospects for future experiments.

Absolute stability of strange quark matter: from dark matter to stellar evolution / 550

4D-TExS: A new 4D lattice-QCD equation of state with extended density coverage

Author: Claudia Ratti[1]

Co-authors: Ahmed Abuali ; Attila Pasztor ; Hitansh Shah ; Johannes Jahan ; Micheal Kahangirwe ; Paolo Parotto ; Seth Trabulsi ; Szabolcs Borsanyi

[1] *University of Houston*

Corresponding Author: cratti@uh.edu

Although calculations of QCD thermodynamics from first-principle lattice simulations are limited to zero net-density due to the fermion sign problem, several methods have been developed to extend the equation of state (EoS) to finite values of the $B,\ Q,\ S$ chemical potentials. Taylor expansion around $\mu_i = 0$ $(i = B,\ Q,\ S)$ enables to cover with confidence the region up to $\mu_i/T = 2.5$. Recently, a new method has been developed to compute a 2D EoS in the $(T,\ \mu_B)$ plane. It was constructed through a T-Expansion Scheme (TExS), based on a resummation of the Taylor expansion, and is trusted up to densities around $\mu_B/T = 3.5$. We present here the new 4D-TExS EoS, a generalization of the TExS to all 3 chemical potentials, offering a larger coverage than the 4D Taylor expansion EoS. After explaining the basics of the T-Expansion Scheme and how it is generalized to multiple dimensions, we will present results for thermodynamic observables as functions of temperature and all chemical potentials. This equation of state can be used to study the cosmological evolution around the QCD phase transition era.

Absolute stability of strange quark matter: from dark matter to stellar evolution / 551

Strange quark matter as dark matter

Authors: Alessandro Drago[1]; Claudia Ratti[2]; Francesco Di Clemente[3]; Marco Casolino[4]; Massimilano Lattanzi[5]

[1] *University of Ferrara*

[2] *University of Houston*

[3] *INFN Sezione di Ferrara*

[4] *INFN e Università di Roma Tor Vergata*

[5] *INFN sezione di Ferrara*

Corresponding Author: fdiclemente@fe.infn.it

Forty years ago, Witten suggested that dark matter could be composed of macroscopic clusters of strange quark matter. This idea was very popular for several years, but it dropped out of fashion once lattice QCD calculations indicated that the confinement/deconfinement transition, at small baryonic chemical potential, is not first order, which seemed to be a crucial requirement in order to produce large clusters of quarks. We revised both the conditions under which strangelets can be produced in the Early Universe and the many phenomenological implications of their existence. We discusses the limits on their mass distribution and a possible and simple scheme for their production alongside with the most promising techniques to detect this type of objects.

Quantum gravity phenomenology / 552

Planck-scale effects in the propagation of high-energy particles from astrophysical sources

Author: Giulia Gubitosi[1]

[1] *University of Naples Federico II*

Corresponding Author: giulia.gubitosi@unina.it

I review the phenomenology of Planck-scale effects influencing the propagation of high-energy particles from astrophysical sources.
I discuss the interplay between Planck-scale effects and the universe expansion, and present possible methods to constrain such effects using observations.

Navigating science and philosophy: exploring limits / 553

Some ramifications from the choice of clocks in canonical classical and quantum cosmology

Author: Parampreet Singh[1]

Co-author: Kristina Giesel [2]

[1] *Louisiana State University*

[2] *FAU Erlangen-Nürnberg*

Corresponding Author: psingh@lsu.edu

To address the problem of time in canonical quantum gravity, one strategy is to use relational observables which results in the use of reference fields or clocks. We explore various ramifications of these clocks in the classical as well as quantum setting. First we show the way the choice of clocks is tied to gauge fixing and gauge invariant variables in the classical cosmological perturbation theory. Second, we discuss the way choice of clocks influences the loop quantization of inflationary spacetimes. Our results point to various subtleties in the use of the reference fields both in the classical and quantum theory.

The Euclid mission: current status, results from early observations, and future prospects / 554

The Euclid Mission

Author: Kerry Paterson[1]

[1] *Max-Planck-Institut für Astronomie*

Corresponding Author: paterson@mpia.de

The ESA *Euclid* mission will conduct an extragalactic survey over about 14 000 deg2 of extragalactic sky. The two instruments onboard, VIS and the Near-Infrared Spectrometer and Photometer (NISP), will provide high-resolution optical imaging, as well as near-infrared imaging and spectroscopy over the survey footprint. In addition to accurate weak lensing and clustering measurements that probe structure formation over half of the age of the Universe, its primary probes for cosmology, these exquisite data will enable a wide range of legacy science. In this talk I will present an overview of

the Euclid mission, provide an update on the current status of the mission, present results from the Early Release Observations and discuss legacy science within Euclid.

Future innovations in gamma-ray astronomy / 555

Envisioning the Future of Gamma-Ray Astronomy in Space: Overview of NASA's FIG SAG Effort

Author: Paolo Coppi[1]

Co-authors: Chris Fryer [2]; C. Michelle Hui [3]; Milena Crnogorcevic [4]; Tiffany Lewis [5]; Marcos Santander [6]; Zorawar Wadiasingh [7]

[1] *Yale University*

[2] *Los Alamos National Laboratory*

[3] *Marshall Space Flight Center*

[4] *Stockholm University*

[5] *Michigan Technological University*

[6] *University of Alabama*

[7] *Goddard Space Flight Center*

Corresponding Author: paolo.coppi@yale.edu

As current space-based gamma-ray instruments such as Fermi begin to show their age, it is time to think about the next generation and the overall future of gamma-ray astronomy in space. To help start the process, NASA has commissioned the Future Innovations in Gamma-Rays (FIG) Science Activity Group (SAG) to collect information and publish a report identifying future gamma-ray science opportunities and priorities, the detector technology development and investment needed to realize those priorities, and the complementary investments in areas such as theoretical modeling and machine learning needed to fully exploit the data collected by next-generation instruments. The goal is to produce a document by the end of 2024 that will be useful to the broader, international gamma-ray community. We welcome input from anyone interested in the future of gamma-ray astronomy. I will give an overview of the FIG SAG process and how you can provide your input. I will also give a brief overview of the lessons we have learned thus far.

Gravitational kHz waves - LIGO-Virgo-KAGRA / 556

Improving Low-Frequency sensitivity of gravitational wave detectors. A new compact, seismic attenuation system for the Einstein Telescope

Authors: Massimiliano Razzano[1]; Francesco Fidecaro[None]; Lorenzo Bellizzi[None]; Federico De Santi[None]; Alessio Fiori[None]; Luca Muccillo[None]; Maria Antonietta Palaia[None]; Lucia Papalini[None]; Barbara Patricelli[None]; Michele Vacatello[None]

[1] *University of Pisa and INFN-Pisa*

Corresponding Author: massimiliano.razzano@unipi.it

Third generation ground-based gravitational wave detectors will broaden our view of the Universe. In the meantime, upgrade programs as Virgo_nEXT are planned to boost the sensitivity of existing detectors such as Advanced Virgo in the post-O5 time frame. In particular, improving the sensitivity at low frequencies will enable the detection of coalescences of higher mass black holes and allow more precise early warning for binary neutron star mergers, increasing the number of expected multimessenger observations. In this scenario, designing a new generation seismic attenuation system

is crucial to achieve higher sensitivity at low frequencies with respect to current interferometers. We present a new concept for a compact seismic attenuation mechanical filter that has the potential to reduce the size of current super attenuator systems, a result that could bring a leap in the sensitivity at low frequencies of gravitational-wave detectors and significant reduction in the underground civil work for the future Einstein Telescope.

Fast radio bursts / 557

Constraints on FRB emission in the aftermath of GRBs

Author: Barbara Patricelli[None]

Co-authors: Maria Grazia Bernardini [1]; Matteo Ferro [1]

[1] *INAF - Osservatorio Astronomico di Brera*

Corresponding Author: barbara.patricelli@pi.infn.it

The physical origin of Fast Radio Bursts (FRBs) is still unknown. Many models consider magnetars as possible FRB sources, supported by the observational association of FRBs with the galactic magnetar SGR 1935+2154. Magnetars are also thought to be the source of the power of a fraction of Gamma Ray Bursts (GRBs), opening the possibility that the two extreme phenomena have a common progenitor.

In this talk we present a new, systematic search for GRB-FRB association, using the most updated catalog of FRBs observed with the Canadian Hydrogen Intensity Mapping Experiment (CHIME) instrument, and the sample of all GRBs detected by Swift so far. We also show, using a synthetic population of FRBs associated to Swift GRBs, how likely it is to have a joint detection with current and future radio facilities.

With our analysis we only recovered two, low significant, possible GRB-FRB associations already reported in literature; however the absence of any unambiguous association so far between Swift GRBs and FRBs cannot exclude that the two populations are connected, given the characteristics of current GRB and FRB detectors. In the next decade, with new generations of GRB and FRB detectors there will be a higher probability to detect joint GRB-FRB events, if any.

Massive white dwarfs and related phenomena / 558

High-energy emission in SGRs/AXPs

Authors: Manuel Malheiro[1]; Ronaldo Lobato[2]

Co-authors: Jaziel Goulart Coelho [3]; Jorge Armando Rueda Hernandez [2]

[1] *Instituto Tecnológico de Aeronáutica*

[2] *ICRANet*

[3] *UTFPR*

Corresponding Author: vieira.lobato@gmail.com

In this work, we investigate the high-energy emission in SGRs/AXPs, neutron stars with extreme magnetic field, named magnetars. The observed high-energy emission in the X-rays and gamma-ray bands are explained. The outer gap accelerator model considers the generation of high-energy emission far away from the surface of the star in a combination of curvature radiation and inverse Compton scattering. The high-energy emission is constrained by employing the death-lines, the condition for pair-production and the generation of hard X and soft gamma rays. From the point of the death-lines and death-zones obtained here by the outer gap model the SGRs/AXPs should not emit

hard X-rays, since they are below the death-line, in disagreement with the observations: SGRs/AXPs are characterized by short and intense burst in the hard X-rays (few hundred keV). The reason for the absence of hard X-Ray emission in the outer gap model, is the low magnetic field strength at the light cylinder, which is too far away from the star's surface in comparison to millisecond γ-rays pulsars.

Massive white dwarfs and related phenomena / 559

Cooling Dynamics of Massive and Hot White Dwarfs: Exploring Instability and Type Ia Supernova Implications

Author: Sílvia Nunes[1]

Co-authors: José Domingo Arbañil Vela [2]; Manuel Malheiro [3]

[1] *Rio de Janeiro State University (UERJ)*

[2] *Universidad Privada del Norte*

[3] *Instituto Tecnológico de Aeronáutica*

Corresponding Author: silvianunesss@gmail.com

White dwarfs are potentially the remnants of the oldest entities in the universe. They typically evolve from stars in the asymptotic giant branch, boasting initially high temperatures and masses that can reach up to $10^8[K]$ and $1.41M_\odot$, known as the Chandrasekhar mass limit. A recent study by Nunes, Arbañil, and Malheiro in 2021 delved into the dynamics of these massive stars, particularly their structure and stability under temperature effects. This research reveals a region in which hot white dwarfs nearing the Chandrasekhar limit suggest a potential consequence: the cooling process could induce instability, rendering previously stable stars unstable due to radial effects. Exploring these effects, we actively investigate the potential for the cooling of a massive star to induce instability, leading to collapse and culminating in a type Ia supernova. Through this endeavor, we aspire to provide novel insights into the evolutionary trajectory of isolated white dwarfs.

Massive white dwarfs and related phenomena / 560

Estimating the optical/infrared magnitudes of ultra-slow radio pulsars as white dwarfs

Author: Sarah Villanova Borges[1]

[1] *University of Wisconsin Milwaukee*

Corresponding Author: villanovaborges@gmail.com

On June 9th, we received the news of the passing of Professor Manuel Malheiro. Malheiro was not only a colleague and advisor, but also a friend. This presentation covers our last work together and represents my homage to him.
The lack of isolated neutron stars~(NSs) rotating slower than 11 s led to the postulate of a maximum limit for their rotation period. However, the discovery of radio pulsars with periods around 1000 s challenges this hypothesis. To solve this seemingly problematic observations, two main path can be taken. The first is to classify them as neutron stars and modify the standard theories to fit them. The second is to model them as white dwarf~(WD) pulsars. In this second scenario, we would expect a photosphere emitting in optical/infrared ranges.
Following this idea, I estimate the optical and infrared magnitudes of GLEAM-X J1627-5235 and GPM J1839-10 as white dwarf pulsars. The model consist of a photosphere and a dusty disk. Based on these estimates, I discuss the feasibility of observations by current and future facilities.

Spectral and temporal properties of accretion flows and jets around compact objects and the theoretical models / 561

Ivestigate AGN feeding & feedback in nearby universe

Author: Khashayar Kianfar[1]

[1] *Instituto Tecnológico de Aeronáutica*

Corresponding Author: khashayar.kianfar@gmail.com

As the last student of Prof. Malheiro I would like to talk about him and present my work which he was involved in his last year of his life:

The study of Active Galactic Nuclei (AGN) has garnered significant attention due to their structures and dynamic behaviors. Understanding AGN feedback mechanisms and their impact on host galaxies is of paramount importance. In this context, the TWIST sample, consisting exclusively of AGN galaxies in the nearby universe. Our primary aim is to investigate cold molecular outflows and AGN feedback through CO (2-1) observations using the Atacama Large Millimeter/submillimeter Array (ALMA).

It should be noted that several objects within our TWIST sample have already been the focus of extensive research in past years. In the following section, we will summarize these prior studies, highlighting their key findings and results to provide a comprehensive understanding of the existing literature.

For this preliminary study, we employ the three-dimensional kinematic modeling tool, 3D-Barolo. We utilize its default mode, which predicts initial values for the model parameters automatically. While these initial guesses may not be the most accurate, they offer a broad overview of the kinematic features, setting the stage for more refined models. The data for this study are in the form of cleaned data cubes with a spectral resolution of 30km/s.

Massive white dwarfs and related phenomena / 562

Mass limits of the extremely fast-spinning white dwarfs

Author: Edson Otoniel da Silva[1]

Co-authors: Fridolin Weber [2]; Jaziel Goulart Coelho [3]; Manuel Malheiro [4]

[1] *Universidade Federal do Cariri*

[2] *San Diego State University*

[3] *UTFPR*

[4] *Instituto Tecnológico de Aeronáutica*

Corresponding Author: edson.otoniel@ufca.edu.br

We explore the stability of this rapidly rotating WD using a modern equation of state (EoS) that accounts for electron–ion, electron–electron, and ion–ion interactions. For this EoS, we determine the mass density thresholds for the onset of pycnonuclear fusion reactions and study the impact of microscopic stability and rapid rotation on the structure and stability of WDs, considering them with helium, carbon, oxygen, and neon. From this analysis, we obtain a minimum mass and maximum mass for stable WDs, like is the case of the CTCV J2056−3014 with range of the mass of 0.56 $M_{\odot}$ - 1.38 $M_{\odot}$. If the mass of CTCV J2056−3014 is close to the lower mass limit, its equatorial radius would be on the order of 10^{4} km due to rapid rotation. Such a radius is significantly larger than that of a nonrotating WD of average mass (0.6 $M_{\odot}$), which is on the order of 7×10^{3} km.

Black holes in alternative theories of gravity / 563

Holography of new 3d conformal higher spin theories for low spins

Author: Iva Lovrekovic[1]

[1] *TU Wien*

Corresponding Author: iva.lovrekovic@gmail.com

We study asymptotic symmetries for 3d Chern-Simons theory as a gauge theory of so(3,2), sl_4 and sl_5 algebras. For the near horizon boundary conditions we present solutions from several projectors from Chern-Simons to the metric formulation. These solutions are generalized BTZ solutions for our theories. We also study the classification according to so(3,2) one parameter subgroups and classify obtained solutions.

Wormholes, energy conditions and time machines / 564

Wormholes geometries in f(R,T^2) gravity satisfying the energy conditions

Authors: Nailya Ganiyeva[1]; Francisco Lobo[2]; João Luís Rosa[3]

[1] *Instituto de Astrofísica e Ciências do Espaço, University of Lisbon*

[2] *Science Faculty of the University of Lisbon*

[3] *University of Gdansk*

Corresponding Author: fslobo@fc.ul.pt

In this work we analyze traversable wormhole spacetimes in the framework of a covariant generalization of Einstein's General Relativity known as energy-momentum squared gravity. Here, we show that a wide variety of wormhole solutions for which the matter fields satisfy all the energy conditions, namely the null, weak, strong and dominant energy conditions, exist in this framework, without the necessity for a fine-tuning of the free parameters that describe the model. For that purpose, we derive the junction conditions for the theory, and we prove that a matching between two spacetimes must always be smooth, i.e., no thin-shells are allowed at the boundary. Finally, we use these junction conditions to match the interior wormhole spacetime to an exterior vacuum described by the Schwarzschild solution, thus obtaining traversable localized static and spherically symmetric wormhole solutions satisfying all energy conditions for the whole spacetime range.

Black hole formation, evolution and the black hole mass gap / 565

Illustris-TNG simulated central black mass and Galaxy properties correlations with a Machine Learning approach

Author: Imani Dindy[1]

[1] *CUNY Graduate Center*

Corresponding Author: imani.l.dindy@gmail.com

Observationally, it is well established that the masses of central black holes are tightly correlated with galaxy properties, most notably the bulge's velocity dispersion. Cosmological hydrodynamical

simulations can capture most of these correlations, but it is yet not understood why this occurs. To gain greater insight into central black hole growth we use machine learning algorithms to study the relationship between central black hole mass and other galaxy properties at z=0 in the TNG simulations. We find that the central black hole mass can be accurately predicted with just a few galaxy properties only if the central black hole mass is above a resolution dependent value. For those black holes we find a simple formula that predicts their mass within a mean absolute error of 1.14\%, 0.95\% and 0.68\% for TNG 50, 100 and 300 respectfully. We are also able to construct intuitive equations for both 100 and 300 boxes that estimates black hole mass well when used in the box it is trained on.

Loop quantum gravity: cosmology and black holes / 566

Revisiting light propagation over quantum Universe

Author: Tomasz Pawłowski[1]

Co-author: Aliasghar Parvizi [1]

[1] *University of Wrocław, Faculty of Physics and Astronomy*

Corresponding Author: tomasz.pawlowski@uwr.edu.pl

One of principal aspects in which the effects of quantum gravity are hoped to manifest itself through possible modification to a dispersion relation of electromagnetic (e-m) waves. By combining (i) the symmetry reduced approaches to spacetime quantization, including loop quantum cosmology or geometrodynamics framework, and (ii) the (extension of the) Born-Oppenheimer approximation of interacting fields, one can build a reliable though still quasi-phenomenological model for a description of propagation of the e-m radiation over a cosmological spacetime. The past works employing such approach indicated a pathological behavior - superluminal propagation at low energies. We reexamine the approach via systematic studies (using indicated method) of e-m wave propagation over a flat quantum Friedmann-Lemaitre-Robertson-Walker Universe using a synthesis of analytical and numerical methods. It turns out, that (i) the e-m wave propagation agrees with the one predicted by general relativity in the low energy limit, and (ii) loop quantum effects actually suppress the modifications to the dispersion relation in comparison with those predicted, where the geometry is quantized via geometrodynamics.

Historical supernovae / 567

Fitting the Crab Supernova with a Gamma-Ray Burst

Authors: Remo Ruffini[1]; Costantino Sigismondi[2]

[1] *ICRANet Pescara*

[2] *ICRA Sapienza and ICRANET Pescara*

Corresponding Authors: ruffini@icra.it, sigismondi@icra.it

A panorama of the current historiography on the Supernova of 1054 is outlined. Shklovsky (1968), and Murdin (1985) show how the interpretation of this phenomenon converged on a Su-pernova event. Here we reconsider the historical data, assuming a Gamma-Ray Burst (GRB) as its source. A Supernova correlated with the GRB explains well the fading time observed by the an-cient Chinese astronomers, in daytime and in night time, while the GRB power-law explains the present X-rays and GeV emission of the Crab. On the ground of recent understanding of the first episode of binary driven Hypernova GRB (BDHN GRB) in terms of the collapse of a ten solar masses core, we propose the possible identification of the real Supernova event at earlier time than Chinese chronicles. This work allows a new understanding of the significance of historical astronomical observations, including

a fireball, due to gamma-rays air shower observation, and a plague of acute radiation syndrome, documented with several thousands of victims in the Eura-sian area (Egypt, Iraq and Siria).

Astrophysics with gravitational waves / 568

On the maximum mass and stability of differentially rotating neutrons stars

Author: Dorota Rosinska[1]

Co-authors: Pablo Cerda-Duran [2]; Pawel Szewczyk [1]

[1] *OA, University of Warsaw*

[2] *University of Valencia*

Corresponding Author: rosinska@gmail.com

The dynamical stability of differentially rotating neutron stars
is of paramount importance in understanding the fate of the post-merger remnant of binary neutron stars mergers and the formation of black holes during core collapse supernovae. We study systematically
the dynamical stability of differentially rotating neutron stars for a broad range of masses, rotation rates and degrees of differential rotation. We pay particular attention to quasi-toroidal configurations that are outside the parameter space region explored in previous works. We estimate the limits of the region of stability against quasi-radial perturbations by performing an extensive set of numerical simulations. We find that some of the stability criteria proposed in the past are not sufficient nor necessary to determine stability if differential rotation is present and propose a new more general criterion. We show that massive configurations, up to 2.5 times the maximum mass of a non-rotating neutron stars could be temporary stabilised by differential rotation. They are important source of gravitational waves.

Gravitational kHz waves - LIGO-Virgo-KAGRA / 569

GEO 600 - Very High Frequency

Author: James Lough[1]

[1] *Max Planck Institute for Gravitational Physics/Leibniz University Hannover*

Corresponding Author: james.lough@aei.mpg.de

GEO 600 has been operating as a gravitational wave detector routinely since before the advanced detector era in mode known as “astrowatch”. While exploring new technologies in large scale interferometry we keep the detector in an operational state allowing for calibrated data production. Technology highlights pioneered at GEO at high frequencies include the application of squeezing. That and other new techniques we’ve been exploring will be used in our next phase of operations going to very high frequencies, extending the frequency range of observational data to 100s of kHz. We report on the ongoing activities at the GEO 600 gravitational wave detector.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 570

Protoneutron star dynamos and magnetar formation

Authors: Alexis Reboul-Salze[1]; Jérôme Guilet[2]; Matteo Bugli[3]; Paul Barrère[2]; Raphaël Raynaud[4]

[1] *AEI*
[2] *CEA*
[3] *UniTO*
[4] *UPCité*

Corresponding Author: raphael.raynaud@cea.fr

Magnetars are isolated young neutron stars that exhibit the most intense magnetic fields known in the Universe and are characterized by a wide variety of high-energy emissions. The birth of rapidly rotating magnetars is also a promising scenario to power outstanding explosive transients. The formation process of these objects, as well as the origin of their ultra-strong magnetic fields, remains an open question, but the amplification of magnetic fields by MHD instabilities inside protoneutron stars seems inevitable. I will review the different dynamo scenarios that can explain magnetar formation, focusing on recent progress achieved with 3D-MHD HPC simulations, and discuss them in light of various observational constraints.

Monday plenary session / 571

Updates on pulsar discoveries and timing with MeerKAT

Corresponding Author: federico.abbate@inaf.it

Pulsar observations have been an important target for MeerKAT having two Large Survey Projects (MeerTIME and TRAPUM) dedicated to them. This has led to the discovery of more than 200 new pulsars within globular clusters, unidentified Fermi sources, the Magellanic clouds and the Galactic disk. These discoveries have pushed the boundaries of our knowledge of the pulsar properties. Furthermore, the timing of the known pulsars has led to numerous measurements of neutron star masses, further tests of General Relativity, large population studies of pulsars, important results on the properties of globular clusters and exciting results on the timing of pulsar for the search of low-frequency gravitational waves.

Thursday plenary session / 572

Cosmology and fundamental physics with next-generation GRB observatories

Corresponding Author: lorenzo.amati@inaf.it

The huge luminosity, the redshift distribution extending at least up to z~10 and the association with the explosive death of very massive stars make long GRBs extremely powerful probes for investigating the early Universe (pop-III stars, cosmic reionization, SFR and metallicity evolution up to the "cosmic dawn") and measuring cosmological parameters. At the same time, GRBs are expected to be the most prominent electromagnetic counterpart of gravitational-wave sources like NS-NS and NS-BH merging events, and to be associated with neutrino emission. Moreover, the combination of extreme distances, huge number of photons emitted over wide photon energy range and the variability down to few ms makes these phenomena a promising tool for performing tests of fundamental physics like Lorentz Invariance Violation (LIV). I review the status, concepts and expected performances of space mission projects, as THESEUS, aiming at fully exploiting these unique potentialities of the GRB phenomenon, thus providing an ideal synergy with the large e.m. facilities of the future like LSST, ELT, TMT, SKA, CTA, ATHENA in the e.m. domain, advanced second generation (2G++) and third generation (3G) GW detectors and future large neutrino detectors (e.g., Km3NET).

Thursday plenary session / 573

Dark matter in galactic structure

Corresponding Author: carguelles@fcaglp.unlp.edu.ar

The nature of dark matter (DM) is one of the most relevant questions in modern astrophysics. I will present a brief overview of recent results that inquire into a possible fermionic quantum nature of the DM particles, focusing mainly on the interconnection between the microphysics of the neutral fermions and the macrophysical structure of galactic halos. I will show how such an interconnection when analyzed through a first principle physics model based on statistical mechanics and thermodynamics of self-gravitating fermions, leads to a richer core-halo structure for the DM halos than the one obtained from N-body simulations. I will discuss the many distinct applications of such a fermionic model both on halo scales -including morphology constraints from rotation curves and stellar streams- all the way to galaxy center scales -including the case of SgrA* and supermassive BH formation-. In particular I will highlight the possibility that the Milky Way center harbors a dense DM fermion-core instead of a supermassive black hole (SMBH), as well as the role of baryons and the possibility to cause an induced collapse into a massive BH. Further details of each application will be given in different parallel sessions of this Meeting.

Tuesday plenary session / 574

On the Quantum Nature of the Coulombic Interaction

Corresponding Author: ashtekar.gravity@gmail.com

The interface between Quantum Information and Quantum Field Theory –especially Quantum Gravity – is emerging as a forefront area of fundamental physics. But there is some tension between the way the basic concepts are commonly understood by the two communities. In particular, are the Coulombic modes' of the gravitational field sourced by quantum matter quantum mechanical? They are not registered in the usual Hilbert spaces Hgrav (and Hph) of gravitons (and photons) that know only about theradiative modes'. Will the proposed experiments directly test the quantum nature of the radiative aspects' orCoulombic aspects'? The talk will examine such elementary yet fundamental issues by drawing on an exactly soluble, non-perturbative quantum gravity model that is especially well-suited for this purpose.

Monday plenary session / 575

Exploring uncharted horizons of astrophysical binary black holes

Corresponding Author: campanellimanuela@gmail.com

In this talk, we will explore the theoretical foundations of binary black holes and the revolutionary simulations in numerical relativity that have deepened our understanding of these objects. We will also showcase the remarkable achievements in observational astronomy made possible by gravitational wave observations, which have not only confirmed the existence of binary black holes but have also provided invaluable information about their characteristics, such as mass, spin, and environment. Additionally, we will discuss the potential for electromagnetic observations of binary black hole mergers and the insights they can offer, especially concerning gravitational wave recoils predicted by numerical relativity simulations.
Looking ahead, we will address the exciting prospects made possible by upcoming astronomical

facilities, advanced gravitational wave observatories, and space missions like LISA. These advancements will enable us to penetrate further into the cosmos and uncover even more intriguing binary black hole systems. It cannot be overstated how important theoretical calculations are in bridging observational data with the underlying physics. We will delve into the challenges associated with these calculations, from the intricacies of computational methods to the complexities of understanding the physics underlying these phenomena. Furthermore, we will highlight ongoing efforts to develop modern computational tools that will enhance our understanding and improve the accuracy of binary black hole modeling, with a particular focus on simulating accreting supermassive binary black holes and their behavior and interactions.

Friday plenary session / 576

KAGRA, LIGO, VIRGO observations

Corresponding Author: marta.colleoni@uib.eu

After the first groundbreaking observation of gravitational waves emitted by the collision of two black holes on 14 September 2015, the LIGO-Virgo-KAGRA network has completed three successful observing runs yielding nearly a hundred events. All detections were compatible with short transients emitted by the coalescence of compact binaries composed of black holes and/or neutron stars. The first half of the fourth observing run, which took place from May 2023 to January 2024, brought 81 new high-confidence gravitational wave candidates. This number has been steadily increasing since the LIGO and Virgo interferometers have resumed observations after a mid-run break of a few months. The ongoing run has already made new and fascinating discoveries. The talk will summarise the main observational results obtained by the current network of gravitational wave detectors until now.

Wednesday plenary session / 577

Repeating Transients from Centers of Galaxies as Extreme Mass Ratio Binaries

Corresponding Author: dheeraj@space.mit.edu

Extreme Mass Ratio binaries are systems containing a massive black hole (>10,000 Msolar) and a closely orbiting smaller object (0.1-1000 Msolar). If the companion is also a compact object they can produce gravitational waves potentially detectable with the space-based detectors that will start operating in the next decade. The identification of electromagnetic counterparts of such gravitational wave emitters will transform our understanding of supermassive black hole growth, probe dark energy, and put fundamental constraints on gravity. I will present an overview of the various flavors of repeating transients in galactic centers that we have identified using multi-wavelength studies of several classes of astrophysical transients including stellar tidal distribution events, outbursts from active galactic nuclei (AGN), quasi-periodic eruptions, and quasi-periodic outflows, as seen for the first time by our group. I will also present state-of-the-art general relativistic hydrodynamic simulations of objects embedded in accretion disks around supermassive black holes as a potential model to unify various flavors of repeating transients. I will argue that in some cases these repeating transients could be double compact object binaries with direct implications for multi-messenger astronomy. I will end by highlighting the prospects they hold for the coming decade.

Public lectures / 578

The Mystery of Dark Matter in the Universe

Corresponding Author: ktfreese@utexas.edu

The ordinary atoms that make up the known universe, from our bodies and the air we breathe to the planets and stars, constitute only 5% of all matter and energy in the cosmos. The remaining 95% is made up of a recipe of 25% dark matter and 70% dark energy, both nonluminous components whose nature remains a mystery. Freese will recount the stories of the dark matter puzzle, starting with the discoveries of visionary scientists from the 1930s who first proposed its existence, to Vera Rubin in the 1970s whose observations conclusively showed its dominance in galaxies, to the deluge of data today from underground laboratories, satellites in space, and the Large Hadron Collider. Theorists contend that dark matter most likely consists of new fundamental particles; the best candidates include WIMPs (weakly interacting massive particles), axions, light or fuzzy dark matter, or even primordial black holes. Billions of them pass through our bodies every second without us even realizing it, yet their gravitational pull is capable of whirling stars and gas at breakneck speeds around the centers of galaxies, and bending light from distant bright objects. In this talk Freese will provide an overview of this cosmic cocktail, including the evidence for the existence of dark matter in galaxies. She will also talk about Dark Stars, early stars powered by dark matter, that may have already been discovered by the James Webb Space Telescope. Solving the dark matter mystery will be an epochal moment in humankind's quest to understand the universe.

Tuesday plenary session / 579

Collapsar/Magnetar Progenitors and their relation to Gamma-ray Bursts and Hypernovae

Corresponding Author: fryer@lanl.gov

In the late 1998, SN 1998bw, the supernova associated with GRB 980425, catapulted the collapsar engine (caused by the collapse of a massive rotating star to a black hole) to the top of the list of proposed engines for these cosmic explosions. Another engine argues that the collapse of a massive star to a magnetar could also produce these GRBS. The rarity of these events argues that only a small subset of massive stars create collapsars or magnetars with jets sufficiently strong to produce GRBs. In general, the difficulty lies in making stars with sufficiently high angular momentum to activate the collapsar disk or magnetar engines. The progenitor scenarios and their engines make different predictions for the properties of the GRB properties (durations, strengths, environments) and their associated hypernovae and broad-lined supernovae. Here we review the strengths and weaknesses of both engines and progenitor scenarios, comparing their predictions to observables. These comparisons will constrain the possible engines/progenitors and we will discuss these constraints.

Wednesday plenary session / 580

Fresh results (and surprises) from the James Webb Space Telescope

Corresponding Author: adriano.fontana@inaf.it

In less than two years since the release of the first data, the James Webb Space Telescope has revolutionised our knowledge and understanding of the Universe. Thanks to its unprecedented collecting area and IR sensitivity, JWST has allowed us to study the atmosphere of exo-planeets, stellar populations in nearby galaxies and galaxies and AGNs up to z~15 . In my talk I will review the status of the field, describe some of the latest results, first touching a couple of high impact results on exoplanets and resovled nearby stellar populations, and then focusing in particular on those related to the evolution of galaxies and AGNs in the first Gyr after the Big Bang. For these, the emerging picture is extremely exciting, as it combines confirmations - with galaxies showing an evolution off their rest frame properties as we approach the Big Bang - and surprises, like the slower-than-expected evolution of galaxies beyond z~10 and the large fraction of AGNs that are being detected. I will conclude with the potential impact of these discoveries on the fundamental physics and cosmology.

Thursday plenary session / 581

Experimental Studies of Black Holes: Status & Prospects

Corresponding Author: arichter@mpe.mpg.de

More than a century ago, Albert Einstein presented his general theory of gravitation. One of the predictions of this theory is that not only particles and objects with mass, but also the quanta of light, photons, are tied to the curvature of space-time, and thus to gravity. There must be a critical mass density, above which photons cannot escape. These are black holes. It took fifty years before possible candidate objects were identified by observational astronomy. Another fifty years have passed, until we finally can present detailed and credible experimental evidence that black holes of 10 to 1010 times the mass of the Sun exist in the Universe. Three very different experimental techniques have enabled these critical experimental breakthroughs. It has become possible to investigate the space-time structure in the vicinity of the event horizons of black holes. I will summarize these interferometric techniques, and discuss the spectacular recent improvements achieved with all three techniques. In conclusion, I will sketch where the path of exploration and inquiry may lead to in the next decades.

582

Electromagnetic-gravitational perturbations of Kerr-Newman black holes

Corresponding Author: elena.giorgi@columbia.edu

Black hole solutions in General Relativity are parametrized by their mass, spin and charge. In this talk, I will motivate why the charge of black holes adds interesting dynamics to solutions of the Einstein equation thanks to the interaction between gravitational and electromagnetic radiation. Such radiations are solutions of a system of coupled wave equations with a symmetric structure which allows to define a combined energy-momentum tensor for the system. Finally, I will show how this physical-space approach is resolutive in the most general case of Kerr-Newman black hole, where the interaction between the radiations prevents the separability in modes.

Thursday plenary session / 583

General Relativity meets Geodesy

Corresponding Author: eva.hackmann@zarm.uni-bremen.de

The intersection of General Relativity and geodesy represents a new frontier in Earth sciences. A major task of geodesy is to determine the gravity field of the Earth, e.g. to monitor mass variations. Due to recent advancements in high precision clock comparison, General Relativity introduced an

entirely new measurement concept to geodesy based on the gravitational redshift. We present the basics of a genuinely general relativistic framework for geodesy, generalising the traditional (post-)Newtonian geodetic concepts. Moreover, we outline the exciting applications of clocks on ground and in space for gravity field recovery, reference systems, synchronisation, and tests of General Relativity.

Tuesday plenary session / 584

Fast Radio Bursts

Corresponding Author: vkaspi@physics.mcgill.ca

TBD

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TBD

Corresponding Author: roy.patrick.kerr@gmail.com

TBD

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The nonlinear stability of slowly rotating Kerr black holes

Corresponding Author: seri@math.princeton.edu

The full proof of the nonlinear stability of Kerr consists of five papers, three written in collaboration with Jeremie Szeftel, one in collaboration with Elena and Jeremie Szeftel and another supporting paper authored by Dawei Shen. In my lecture I will describe the main architecture of the proof as well as some of the most important consequences.

Friday plenary session / 587

Current status of DECIGO and B-DECIGO

Corresponding Author: kentaro.komori@phys.s.u-tokyo.ac.jp

DECIGO (DECi-Hertz Gravitational-wave Observatory) and B-DECIGO are interferometric satellites expected to be launched in Japan around the 2030s targeting the observation of gravitational waves (GWs) from 0.1 Hz to 10 Hz. These missions will unveil populations of intermediate-mass black hole mergers, provide frequent opportunities to localize the host galaxy of a binary neutron star before its merger, and ultimately, directly observe stochastic GWs originating from cosmic inflation. In this talk, the current status of DECIGO and B-DECIGO is presented along with their basic configurations. Additionally, key components that have been studied so far are reported, such as sensitivity trade-offs and theoretical and experimental demonstrations of intersatellite formation flying.

Thursday plenary session / 588

Black holes in alternative gravity theories

Corresponding Author: jutta.kunz@uni-oldenburg.de

In our quest towards a theory of gravity beyond General Relativity black holes with their strong gravitational fields represent an important testing ground. Among the numerous alternative theories of gravity much work in recent years has focused on a set of scalar-tensor theories, where the scalar field couples to higher curvature terms. The properties of the resulting black holes in such theories may differ distictly from those of the Schwarzschild and Kerr black holes as, for instance, revealed by their shadows or their gravitational wave spectra.

Tuesday plenary session / 589

Testing Gravity and quantum mechanics

Corresponding Author: claus.laemmerzahl@zarm.uni-bremen.de

General Relativity and quantum mechanics are both universally applicable theories and are most important for our present understanding of matter, space and time. Clearly, both theories have to be tested as good as possible. In this talk an overview is given of recent tests of both theories like the Equivalence Principle, equivalence of active and passive gravitational mass, the redshift, the linearity of quantum mechanics, Bell inequality. Due to a lack of the combined understanding of General Relativity and quantum mechanics we lay emphasis on quantum tests exploring the structure of space-time and of the gravitational interaction. This concerns tests using clocks, atoms and photons and also includes many particle systems and entanglement.

Wednesday plenary session / 590

Extreme Universe

Corresponding Author: lipunov2007@gmail.com

We will talk about the emergence of new sciences such as “Gravitational-wave astronomy”, “Neutrino extragalactic astronomy”, “Transient radio astronomy”, “Fast Transient X-ray Astronomy”.

Tuesday plenary session / 591

Establishing an Evolutionary Picture of Fast Radio Bursts (FRBs)

Corresponding Author: dili@nao.cas.cn

Human’s perception and philosophy of the cosmos depend on our collective sensors. Modern optical sky surveys in the 20th century gave rise to the concept of dynamic Universe, one mysterious manifestation of which is fast radio bursts (FRBs). Look like a radio pulse from a neutron star, the FRBs can be 20 orders of magnitude brighter and, if exist, can be seen as far as redshift of z=10,

together with the presumed first generation of galaxies and supermassive blackholes. Showing potential for breakthroughs in astrophysics, the discovery of FRBs was awarded the 2023 Shaw's prize in astronomy. We built the largest radio telescope, namely, the Five-hundred-meter Aperture Spherical radio Telescope (FAST), which has been leading the field of characterizing repeating FRBs ever since the inception of FAST's operation in 2020. With close to 100 FAST-based FRB papers, including 5 on Naturand 2 on Science, we started to reveal the evolution of repeating FRBs. We manage to characterize the environment and potentially the age of an active FRB with a single physical parameter, namely, sigma_RM, which can be derived from observation and reflects the complexity of the plasma enshrouding the FRBs. We are also working on a next generation FRB machine, namely Cosmic Antennae (CA), the aim of which is to increase the discovery rate by orders of magnitude over all current radio telescopes.

Tuesday plenary session / 592

Hunting dark matter with the XENON experiments

Corresponding Author: lindner@mpi-hd.mpg.de

A brief reminder of the case for particle dark matter and general search strategies will be followed by a description of the XENON dark matter program. The main part of the talk will cover details about the currently running XENONnT detector, the latest results and an outlook on future plans.

Monday plenary session / 593

BIack Holes and Massive Galaxies in the Early Universe

Corresponding Author: felix.mirabel@cea.fr

Recent observations with the JWST and ALMA have identified at z > 10 massive star forming galaxies of up to 1011 solar masses that are already quench at z > 3. The very early formation and rapid evolution of massive galaxies produced great surprise, because it is difficult to reconcile with standard ΛCDM predictions. I will show that BH-jet feedback accelerated the formation and evolution of massive galaxies. Since the diameter of the Universe decreases with redshift z as 1/(1+z), the global gas density of the Universe increases with redshift, positive BH-feedback becoming a relevant mechanism in the early Universe. In this context, the existence of massive star formation galaxies at z > 10 that are already quench at z > 3 is not surprising. If the SMBHs of more than 107 solar masses found in quasars up to z = 7 result from rapidly growing BH seeds, I will conclude that BH-jet feedback enhanced the formation and growth of the first stars and galaxies at cosmic dawn.

Monday plenary session / 595

The science of EPTA (European Pulsar Timing Array)

Corresponding Author: andrea.possenti@inaf.it

A Pulsar Timing Array (PTA) exploits the remarkable rotational stability of a sample of the rapidly spinning "recycled" pulsars in order to provide the possibility to search for gravitational waves (GWs) in the ultra-long period range, between few months to few decades. Therefore, by acting as galactic-scale GW detectors, the PTAs can explore a portion of the GW spectrum which is not charted by other already operating or planned instruments. The most recent results of the efforts of the various

PTA teams are very intriguing, showing the first evidence for a detection, still to be corroborated by additional results. The talk will report on the foundations, the status, and the perspectives of these experiments, with particular focus on the case of the European Pulsar Timing Array (EPTA) contributions, resulting from more than two decades of available pulsar observations, as well as parallel theoretical and analysis developments

Thursday plenary session / 596

Recent results from IceCube

Corresponding Author: chraab@icecube.wisc.edu

IceCube is a cubic kilometer neutrino observatory at the geographic South Pole whose sensitivity from PeV down to GeV, or MeV using a special DAQ, has spawned a diverse scientific program. It discovered and continues to characterize the astrophysical neutrino flux, recently identifying a galactic component. To resolve it further, IceCube has found a 4.2σ excess from the direction of NGC 1068 and continues to target a variety of source candidates, both above and below 1 TeV. IceCube maintains several programs for real-time alerts and follow-ups. The background of events caused by particles from cosmic ray air showers in itself enables the study of cosmic ray and neutrino physics, in particular neutrino oscillations. IceCube further makes significant efforts towards physics beyond the Standard Model such as searching for quantum gravity. This talk highlights results since the previous Marcel Grossmann meeting in 2021 and provides an outlook on prospects for the planned high-energy extension IceCube-Gen2.

Wednesday plenary session / 597

Lesson about gravity from black-hole imaging

Corresponding Author: rezzolla@itp.uni-frankfurt.de

I will briefly discuss how the first images of the supermassive black holes M87*and Sgr A* were obtained by the EHT collaboration. In particular, I will describe the theoretical aspects that have allowed us to model the dynamics of the plasma accreting onto the black hole and how the comparison between the theoretical images and the observations on a broad range of frequencies has allowed us to deduce the presence of supermassive black holes and to extract information about the accretion process. In addition, I will describe the lessons we have learned from these imaging process about strong-field gravity and alternatives to black holes.

Friday plenary session / 598

The Einstein Telescope project: a third generation of Gravitational Wave detector on the Earth.

In the field of gravitational wave (GW) detection, groundbreaking discoveries like those made by the LIGO, Virgo, and KAGRA collaborations signify the culmination of extensive interdisciplinary efforts spanning various research fields. These detectors grapple with numerous noise sources that undermine their sensitivity. To surmount these challenges, we are exploring strategies that harness novel technologies and innovative approaches. The development of third-generation GW interferometers, epitomised by the Einstein Telescope (ET) project, underscores a monumental experimental

endeavour.
In this talk, we will offer an overview of the new experimental challenges facing ET and the strategies proposed to achieve the ambitious advancements in sensitivity. By overcoming these challenges, we aim to unlock unparalleled opportunities to explore the Universe through gravitational waves.

Friday plenary session / 599

AI in the Cosmos: Application of neural networks for modeling multiwavelength and multimessenger data from blazar observations

Corresponding Author: narek@icra.it

The integration of Artificial Intelligence (AI) into astronomy and astrophysics marks a transformative era in the exploration of the Universe, enhancing the analysis of vast data sets with unparalleled efficiency and precision. AI is revolutionizing the usability of observational data, expanding our understanding of various cosmic phenomena. Blazar research particularly benefits from the application of AI. In this talk, I will present a pioneering effort in employing a Convolutional Neural Network (CNN) for the efficient modeling of blazar emissions. Blazars are among the most powerful extragalactic sources, emitting across the entire electromagnetic spectrum, from radio to very high-energy gamma-ray bands. As significant sources of non-thermal radiation, blazars are frequently monitored by various telescopes, leading to the accumulation of substantial multi-wavelength data over different time periods. Also, over the years, the complexity of models of blazar emission has dramatically increased which hinders parameter exploration and makes data interpretation through model fitting challenging. By training the CNN on lepton-hadronic emission models generated for a set of models computed with the kinetic code SOPRANO, which considers the interaction of initial and all secondary particles, the resultant CNN can accurately model the radiative signatures of electron/proton interactions in relativistic jets. This CNN-based approach significantly reduces computational time, thereby enabling fitting to multi-wavelength (photons) and multi-messenger (neutrinos) datasets. The adoption of this AI-driven methodology enables self-consistent modeling of blazar emissions, offering profound insights into their underlying physics and potentially uncovering new astrophysical phenomena. I will present and discuss several results where these networks have been used to model multi-wavelength, multi-temporal data from blazar observations.

Monday plenary session / 600

Do we understand cosmic structure growth? Insights from new CMB lensing measurements with the Atacama Cosmology Telescope

Corresponding Author: bds30@damtp.cam.ac.uk

One of the most powerful tests of our cosmological model is to verify the predicted growth of large-scale structure with time. Intriguingly, many recent measurements have reported small discrepancies in such tests of structure growth ("the S8 tension"), which could hint at systematic errors or even new physics. Motivated by this puzzling situation, I will present new determinations of cosmic structure growth using CMB gravitational lensing measurements from the Atacama Cosmology Telescope (ACT). These ACT DR6 CMB lensing measurements allow us to directly map the dark matter distribution in projection out to high redshifts; new cross-correlations of CMB lensing with unWISE galaxies also allow us to probe the matter tomographically. I will discuss the implications of our lensing results for the validity of our standard cosmological model as well as for key cosmological parameters such as the neutrino mass and Hubble constant.

Thursday plenary session / 601

IXPE re-shapes astrophysics through the lens of X-ray polarimetry

Corresponding Author: paolo.soffitta@iaps.inaf.it

In the early 1960s, as X-ray Astronomy was beginning to take shape, the critical role of X-ray polarimetry became apparent. By 2001, significant progress had been made, demonstrating the effective use of the photoelectric effect in gas as a breakthrough technique in Astrophysics. It wasn't until 2021 that an observatory with the required sensitivity utilizing the photoelectric effect could be launched. The Imaging X-ray Polarimetry Explorer (IXPE), a NASA-ASI SMEX mission, became the first Small Explorer mission equipped with three telescopes. Here, I will explore the earliest efforts in this field, the enabling technologies the IXPE mission's objectives and significant findings in its first two and half years. Highlights include Supernova Remnants, insights into acceleration processes, understanding the inner structures of compact objects like Black Holes and Neutron Stars, and Active Galactic Nuclei. I will look to future opportunities from IXPE's results.

Public lectures / 602

Thirty Meter telescope – India's participation

Corresponding Author: annapurni.iia@gmail.com

In Late 2014 India joined the International consortium for building and operating next generation mega ground based optical and infrared astronomy facility known as the "Thirty Meter telescope (TMT) International Observatory (TIO). India's in-kind contributions include Primary mirror Segment Support Assembly (SSA), Actuators, Edge Sensors, Primary mirror Segment Polishing, Observatory Software (OSW) and Telescope Control Software (TCS), M1/M2/M3 segment coating plants and Science Instruments. India is participating in the first light science instrument WFOS and leading the effort for the second-generation instrument HROS – a high resolution spectrograph. I will present the science goals and the current status of the activities.

Friday plenary session / 604

Unleashing the scientific potential of LISA

Corresponding Author: daniele.vetrugno@unitn.it

LISA is considered by a growing part of the relevant scientific community to be one of the most exciting and impacting observatories from space in the next 30 years. The scientific case it carries with it is enormous, ranging from the supermassive black holes to the Galactic binaries' astrophysics via cosmology and fundamental physics. Not to mention its invaluable discovery potential. Added to this, is the complexity of the almost unprecedented technological challenge. To fulfill its promises, the observatory will have to measure to picometer level the distance between free-falling test masses (TMs) on a baseline of 2.5 million kilometers, by using laser interferometry. Furthermore, it must be able to maintain TMs as inertial references at the sub-femto-g level in terms of the relative acceleration between them. Those performances will depend on the design of the Optical Metrology System (OMS) and Gravity Reference System (GRS), this last one being for a large part a legacy of LISA Pathfinder (LPF), but also on a complex interaction between the LISA subsystems and the entire satellite surrounding them, and on crucial in-orbit operations, calibrations, and instrument noise characterizations, some of them only possible downstream of the Time Delay Interferometry observable calculations. In this talk, we will describe the LISA mission, its design and performances,

and the critical in-orbit operations needed to achieve them. We will also give an update of the project status and what's ahead of us in the next few years.

Friday plenary session / 605

Searching for Nanohertz Gravitational Waves with Pulsar Timing Arrays

Corresponding Author: vigeland@uwm.edu

Pulsar timing arrays are sensitive to low-frequency gravitational waves with periods of months to decades. They do so by precisely timing a collection of millisecond pulsars, whose extremely stable rotation makes them ideal for measuring perturbations in spacetime. Gravitational waves induce correlations in the pulse arrival times that follows a characteristic pattern known as the Hellings-Downs curve. Recently, pulsar timing array experiments around the world published the first evidence of nanohertz gravitational waves in the form of a gravitational wave background. In this talk, I will discuss how pulsar timing arrays detect gravitational waves, describe recent results from the NANOGrav collaboration and the International Pulsar Timing Array (IPTA) collaboration, and discuss future prospects for finding nanohertz gravitational waves from a variety of sources.

Wednesday plenary session / 606

Can AI Understand Our Universe?

Corresponding Author: yu.wang@icranet.org

ChatGPT has been a highly discussed topic recently, capturing the attention of both professionals and the general public. It has sparked conversations about the impact of artificial intelligence (AI) on the world. As physicists and astrophysicists, we are interested in whether large language models (LLMs) can accurately analyze scientific data and produce valid physics results. In this article, we fine-tune the generative pre-trained transformer (GPT) model using astronomical data. We demonstrate a single model's ability to understand multiple astronomical data sets, exemplified by its classification of astrophysical phenomena, distinction between types of gamma-ray bursts (GRBs), deduction of the redshift of quasars, and estimation of black hole (BH) parameters. We consider this a successful test, proving the LLM's efficacy in scientific research. This shift moves us from specialized knowledge in various areas to an integrated understanding, offering deeper and more connected insights into how the natural world works. It signals the start of a new phase in scientific research.

Monday plenary session / 607

Progress of Taiji Program and Nature of Gravity & Spacetime

Corresponding Author: ylwu@itp.ac.cn

Taiji is a Chinese space mission to detect gravitational waves with frequencies covering the range of 0.1mHz to 1.0Hz by utilizing a triangle of three spacecrafts in orbit around the Sun, which aims to probe the super (intermediate) mass black hole merges and extreme (intermediate) mass ratio inspirals, to study the most challenging issues concerning the origin and evolution of massive black holes and universe, and to explore the nature of gravity and spacetime as well as dark side of the universe. In this talk, I am going to introduce briefly Taiji's mission, scientific objectives and payload

design, and present a brief report on Taiji's roadmap with the testing result of Taiji-1, the current status of Taiji-2 and the prospection of Taiji-3. I will also bring a discussion on the nature of gravity and spacetime beyond the general relativity and Riemannian geometry, which enables to establish gravitational quantum field theory (GQFT) to combine consistently the general relativity and quantum field theory, and to unify all basic forces within the framework of GQFT.

Wednesday plenary session / 608

Fermi/eRosita Bubbles as relics of the past activity of the Galaxy's central black hole

Corresponding Author: hyang@phys.nthu.edu.tw

The eROSITA X-ray satellite has revealed two gigantic bubbles extending to ~80° above and below the Galactic center (GC). The morphology of these 'eROSITA bubbles' bears a remarkable resemblance to the Fermi bubbles previously discovered by the Fermi Gamma-ray Space Telescope and its counterpart, the microwave haze. The physical origin of these striking structures has been intensely debated; however, because of their symmetry about the GC, they probably originate from some energetic outbursts from the GC in the past. In this talk, I will review important progress made over the years in terms of understanding their physical origin, and show that the Fermi/eROSITA bubbles likely originate from past activity of the GC black hole, Sgr A. *I will discuss the implications of this result, and how it may provide insights into evolution history of Sgr A* and our own Galaxy.

Wednesday plenary session / 609

The Einstein Probe mission

Corresponding Author: wmy@nao.cas.cn

Launched on January 9th, 2024, the Einstein Probe (EP) is a space X-ray observatory designed to detect mainly high-energy transient and variable sources in the universe. It aims at detecting such sources at unprecedented sensitivity and spatial resolution in the soft X-ray band and performing quick onboard follow-up observations in X-rays. EP carries two instruments, a wide-field X-ray telescope (WXT) to monitor the soft X-ray sky in 0.5-4keV with a 3600 square-degree field-of-view, and a narrow-field follow-up X-ray telescope (FXT) in 0.3-10keV. The WXT is an imaging telescope making use of novel X-ray focusing technology of lobster-eye micro-pore optics. Transient alerts can be downlinked quickly to ground to trigger follow-up observations at multi-wavelengths. The Einstein Probe is a project led by the Chinese Academy of Sciences in collaboration with ESA, MPE and CNES. Since its launch, the satellite has been in the commissioning phase, during which a series tests on the spacecraft and the instruments, and in-orbit calibration are carried out. During this phase a number of X-ray transients have been detected by EP and extensively followed up and studied by the EP science team and by the wider community. This talk will introduce the mission, its status, the instrument performance and preliminary results of the transient sources detected.

Tuesday plenary session / 610

Highlights of Insight-HXMT Results and the Future eXTP Mission

Corresponding Author: zhangsn@ihep.ac.cn

In this talk will first review some highlights of the scientific results of Insight-HXMT,China's first X-ray astronomy satellite launched on June 15th, 2017. I will then introduce the future mission eXTP (enhanced X-ray Timing and Polarimetry), planned for launch around 2028, to explore the physics under the extreme conditions of gravity, magnetism and density by making precise observations of black holes and neutron stars with simultaneous X-ray timing, spectroscopy and polarimetry.

Thursday plenary session / 611

Dark matter direct detection with PandaX experiment

Corresponding Author: nzhou@sjtu.edu.cn

Located at the China Jinping Underground Laboratory, the PandaX experiment employs xenon as a target to detect rare physics signals, such as dark matter and neutrinos. The PandaX-4T, the latest generation detector featuring a 4-ton xenon target volume, commenced data collection in 2020. One of our objectives is to unravel the nature of dark matter by investigating various potential signatures. In this talk, I will present the most recent results of the dark matter search using the PandaX-4T physics run data, and also give a brief overview of the future prospects of the PandaX experiment.

Friday plenary session / 612

Inertial sensor for TianQin project

Corresponding Author: zhouzb@hust.edu.cn

TianQin is a Chinese space-borne gravitational wave detector proposed in 2014, and aims to detect gravitational waves in the frequency range of 1mHz ~ 1 Hz, with three earth orbiting satellites with an orbital radius of about 105 km forming an equilateral triangle with side length 1.7×105 km. The free falling test masses are used as inertial references to provide measurement points for intersatellite laser interferometry, and also to guide the micro-thrusters control the spacecrafts to follow up them. The residual acceleration noise in the direction of the sensitive axis (intersatellite link) must be not exceed 10-15 m/s2/Hz1/2 within the detection band for TianQin. In this talk, firstly I will introduce the TianQin mission, and then present the requirement analysis and preliminary design of inertial sensor, finally give current progresses and its verification on the ground and in flight.

Dark matter halos: its nature, modeling & tracers / 613

Gaia DR3: rotation curve of the Milky Way and the infall epoch of dwarfs

Author: Francois Hammer[1]

[1] *Paris-Observatory GEPI*

Corresponding Author: francois.hammer@obspm.fr

The ESA Gaia astrometric mission has revolutionized our understanding of the Milky Way (MW) by providing six-dimensional phase-space measurements of its stars. Utilizing the third data release (Gaia DR3), we have derived a precise MW rotation curve (RC) extending up to 26.5 kpc. For the first time, we detect a Keplerian decline in the RC from 19 to 26.5 kpc. We estimate the MW dynamical mass to be 2.06 ^{+0.24}_{-0.13} x 10^11 Msun. I'll discuss this result in the context of other mass estimates as well as in comparison to other spiral galaxies showing flat rotation curves.
Gaia DR3 also provides accurate values of the orbital energy for most dwarfs lying within 150 kpc from the Milky Way center. Satellite orbital energy anti correlates with their infall time since the Galaxy assembled its mass through the cosmic epoch and thus cannot bind high orbital energy objects at early epochs. Dwarf orbital energies are found 10 times (4 times) larger than those of the Gaia-Sausage-Enceladus (Sgr infall) events, respectively. It is very unlikely that most dwarfs entered the halo 8-10 Gyr ago, while the tension is alleviated if most of them arrived less than 3 Gyr ago. This late fall of dwarfs may affect estimates of their mass content as well as it prevents to determine the Milky Way mass from their orbital motions.

614

Fast Radio Bursts and the CHIME/FRB Project

Corresponding Author: vkaspi@physics.mcgill.ca

Fast Radio Bursts are millisecond-duration bursts of radio waves arriving generally from cosmological distances. Their nature remains unknown. Here I will review the latest on what is known about this mysterious phenomenon, concentrating on what has been learned from the CHIME telescope, a digital radio telescope operating in Canada, that offers an unprecedented view of the FRB population.

Black holes in alternative theories of gravity / 615

Quasinormal modes of rapidly rotating black holes

Author: Fech Scen Khoo[None]

Corresponding Author: fech.scen.khoo@uni-oldenburg.de

We present the spectrum of quasinormal modes of rapidly rotating black holes. We apply a spectral decomposition on the perturbations of the metric and other dynamical fields. We compare our results with the modes computed using other methods, study the accuracy of our calculations, and investigate the application of our method to black holes in alternative theories of gravity.

Current status of the H_0 and growth tensions: theoretical models and model-independent constraints / 616

On the statistical assumption on the distance moduli of Supernovae Ia and its impact on the determination of cosmological parameters

Author: Maria Dainotti[1]

[1] *National Astronomical Observatory of Japan*

Corresponding Author: mariagiovannadainotti@yahoo.it

Type Ia Supernovae (SNe Ia) are considered the most reliable standard candles and they have played an invaluable role in cosmology since the discovery of the Universe's accelerated expansion. During the last decades, the SNe Ia samples have been improved in number, redshift coverage, calibration methodology, and systematics treatment. These efforts led to the most recent "Pantheon" (2018) and "Pantheon +" (2022) releases, which enable to constrain cosmological parameters more precisely than previous samples. In this era of precision cosmology, the community strives to find new ways to reduce uncertainties on cosmological parameters. To this end, we start our investigation even from the likelihood assumption of Gaussianity, implicitly used in this domain. Indeed, the usual practice involves constraining parameters through a Gaussian distance moduli likelihood. This method relies on the implicit assumption that the difference between the distance moduli measured and the ones expected from the cosmological model is Gaussianly distributed. In this work, we test this hypothesis for both the Pantheon and Pantheon + releases. We find that in both cases, this requirement is not fulfilled, and the actual underlying distributions are a logistic and a Student's t distribution for the Pantheon and Pantheon + data, respectively. When we apply these new likelihoods fitting a flat ΛCDM model, we significantly reduce the uncertainties on the matter density ΩM and the Hubble constant H0 of ~ 40%. As a result, the Hubble tension is increased at > 5 σ level. This boosts the SNe Ia power in constraining cosmological parameters, thus representing a huge step forward to shed light on the current debated tensions in cosmology.
This analysis has also been extended to the GRBs and BAO, and results show a decrease in terms of cosmological parameters when these probes are added.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 617

GRB cosmology with other probes

Corresponding Author: mariagiovannadainotti@yahoo.it

Cosmological models and their parameters are widely debated, especially about whether the current discrepancy between the values of the Hubble constant, H 0, obtained by Type Ia supernovae (SNe Ia) and the Planck data from the cosmic microwave background radiation could be alleviated when alternative cosmological models are considered. Thus, combining high-redshift probes, such as gamma-ray bursts (GRBs) and quasi-stellar objects (QSOs, or quasars), together with baryon acoustic oscillations and SNe Ia is important to assess the viability of these alternative models and whether they can cast further light on the Hubble tension. In this work, for GRBs, we use a three-dimensional relation between the peak prompt luminosity, the rest-frame time at the end of the X-ray plateau, and its corresponding luminosity in X-rays: the 3D Dainotti fundamental plane relation. Regarding QSOs, we use the Risaliti-Lusso relation among the UV and X-ray luminosities for a sample of 2421 sources. We correct both the QSO and GRB relations by accounting for selection and evolutionary effects with a reliable statistical method. We here use both the traditional Gaussian likelihoods ([illegible]) and the new best-fit likelihoods ([illegible]) to infer cosmological parameters of nonflat Lambda cold dark matter (ΛCDM) and flat wCDM models. We obtain for all the parameters reduced uncertainties, up to 35% for H 0, when applying the new [illegible] likelihoods in place of the Gaussian ones. Our results remain consistent with a flat ΛCDM model, although with a shift of the dark energy parameter w toward w < -1 and a curvature density parameter toward Ω k < 0.

Future innovations in gamma-ray astronomy / 618

Crystal Eye: A Wide Field of View Instrument for Studying Astrophysical MeV Photons

Author: Ivan De Mitri[1]

[1] *Gran Sasso Science Institute (GSSI) and INFN*

Corresponding Author: ivan.demitri@gssi.it

Crystal Eye represents an innovative space-based all-sky monitor designed to observe photons in the 30 keV to 50 MeV range. Utilizing a novel detection technique, this instrument features enhanced localization capabilities compared to current instruments, made possible by new materials and sensors. Its primary scientific objective is to detect electromagnetic signals from extreme phenomena in the universe. To support multi-messenger studies, the satellite will provide alerts to both space and ground-based experiments. Currently, a full-scale model of the Crystal Eye detector is under design and construction. Additionally, a smaller prototype is being prepared for a two-month mission aboard the Space Rider (ESA) in a low Earth orbit during 2025-2026. This work presents the instrument setup, along with sensitivity and performance calculations derived from Monte Carlo simulations of the complete detector configuration and prototype tests.

Future innovations in gamma-ray astronomy / 619

Status and future prospects of MeV astronomy

Observation of cosmic gamma-rays in the MeV range have long been considered both promising and challenging. The challenges directly result from the physics of the photon-matter interaction at these energies, being dominated by incoherent Compton scattering, forming a global minimum in photon-matter cross-section without an option of building focusing optics. The non transparency of the atmosphere to these photons requires telescopes to be placed into space where charged particles produce abundant detector background. Despite all these odds, pioneering work of Compton GRO and the still ongoing INTEGRAL has proven some of the promises but also the challenges. This talk will outline a selection of what we have reached, where we are headed in the near future with, e.g., NASA's COSI small satellite mission, and some dreams being pursued for the future.

Gamma ray bursts relationships in multi-wavenths as cosmological tools / 620

GRBs: what do we know today that we did not know 10 years ago?

Corresponding Author: asaf.peer@biu.ac.il

In this talk, I will highlight some of the recent and most exciting theoretical and observational development in gamma-ray bursts (GRBs) that occured in the past decade, alongside some new open questions that I anticipate would be at the forefront of GRB reserch in the next decade. In particular, I will discuss our current state of knowledge on: (1) jet structure, which became evident following GRB/GW170817; (2) the on-going debate about the orign of TeV emission, as was seen in few GRBs; (3) The ~10 MeV emission line seen in the BOAT GRB 221009A, and its implication on the prompt emission physics; (4) polarization measurements that show discrepancy between theory and data; and finally (5) indication that in many GRBs, the Lorentz factor is only a few tans, rater than few hundreds.

IXPE observations and multiwavelength opportunities / 621

Evidence of the past activity of the Black Hole at the center of our Galaxy by X-Ray polarimetry

Author: Enrico Costa[1]

[1] *Istituto di Astrofisica e Planetologia Spaziali, INAF*

The first spectral images of the environment surrounding SgrA*suggested the co-existence of thermalized plasma with extended regions showing the typical spectrum of a "cold" matter irradiated by a flux of hard X-Ray. In 2002 E.Churazov, R.Sunyaev and S.Sozonov proposed to measure the polarization of this reflected component in the brightest molecular cloud around the Galactic Center, SgrB2, to derive the distance of the source and the evidence of a brightening a few centuries ago. Since then the polarimetry of the molecular clouds has been one of the clue in mission proposals. The fast changes in the emission detected with Chandra on one side confirmed the reflection but on the other side forced to a frequent rethinking of the targets. In view of the IXPE launch the target chosen by a team lead by F. Marin was the Sgr A cloud. A long observation in 2022 gave the evidence of reflection from a source compatible with SgrA*, corresponding to a flare occurred around 200 years ago. This is only a start but these observations are heavily time demanding.

IXPE observations and multiwavelength opportunities / 622

Imaging X-ray Polarimetry Explorer (IXPE) observations of Radio-Loud AGN

Author: Eileen Meyer[1]

[1] *University of Maryland Baltimore County (UMBC)*

Corresponding Author: meyer@umbc.edu

Imaging X-ray Polarimetry Explorer (IXPE), the first dedicated astrophysics mission for X-ray polarimetry, has now completed its 2-year prime mission phase, increasing the number of X-ray polarization detections from one to a few dozen, with significant consequences for our understanding of high-energy astrophysical objects. Radio-loud AGN are one of the prime source classes for IXPE, and I will review the insights we have gained so far from IXPE, often in concert with complimentary observations with e.g. Swift, NuSTAR, XMM, and optical and radio telescopes. The opening of the first General Observer period in early 2024 promises to expand on these discoveries to new source classes and science questions for jetted AGN.

Latest results from Galactic center observations / 623

HP2 sessions summary

Author: Michal Zajaček[1]

[1] *Masaryk University*

Corresponding Author: michal.zajacek31@gmail.com

This talk presents a summary of both sessions on the Galactic Center.

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Magnetized Supermassive Stars and Hypermassive Black Holes

Using general relativity, we study the equilibirum and stability of stars with quasi-spherical symmetry involving random transverse magnetic fields (RTMF) within an extremely wide mass range including magnetized supermassive stars of millions or ten millions of solar masses. Among others, such magnetized

massive stars in proper mass ranges would most likely be the progenitors of black holes within the forbidden mass zone as reported by several LIGO/Virgo observations due to the suppression of electron-positron pair instabilities and would also be the progenitors of magnetars by empirical reasoning. Separately, we present the study on self-similar dynamic formation of hypermassive black holes (HMBHs – 10 to 1000 billion solar masses or even higher) and supermassive black holes (SMBHs – millions to billions of solar masses) within giant mass reservoirs in the Universe including the early universe. Pertinent observations and analyses are discussed.

Emission mechanisms in gamma-ray bursts / 626

A different interpretation of GRB spectra: backscattering model to explain keV-MeV and proton-synchrotron for TeV emission

Corresponding Author: asaf.peer@biu.ac.il

In this talk, I will present two recent models for explaining the observed GRB spectra.
As a GRB jet drills its way through the collapsing star, it traps a baryonic "cork" ahead of it. If the jet does not cross this cork, but rather photons that are emitted deep in the flow (e.g., by pair annihilation) are scattered by the cork, an observer close to the jet axis will see these photons due to light abberation. I will show that this model has several advantages, such s its ability to naturally explain both the high and low energy spectral slopes, the observed temporal peak evolution, the delay of the soft photons and the E_pk-Eiso ("Amati") relation, among others.

The Euclid mission: current status, results from early observations, and future prospects / 627

Unveiling the darkness: Cosmology Through Euclid satellite

Corresponding Author: lmbmgh@unife.it

The current standard model of cosmology successfully describes a variety of measurements, but the nature of its main components, dark matter and dark energy, remains unknown. The Euclid mission will provide high-resolution optical imaging, along with near-infrared imaging and spectroscopy, covering approximately 14,000 square degrees of extragalactic sky. Euclid is optimized for two powerful and complementary probes: weak gravitational lensing and galaxy clustering. These are among the most sensitive tools for investigating dark energy and gravity on cosmological scales.
One of Euclid's primary goals is to constrain the dark energy equation of state, aiming for a figure of merit (FoM) greater than 400. Additionally, it seeks to measure the growth-index factor with a 1-sigma uncertainty of 0.02. The high-quality data from Euclid will also address the Hubble constant (H0) debate, as its primary probes will provide state-of-the-art constraints on the cosmological parameters of the baseline flat ΛCDM model, significantly reducing uncertainties on all these parameters. Euclid will also enhance our ability to test extensions of the standard cosmological model, such as improving constraints on the sum of neutrino masses. In this talk, I will highlight Euclid's key cosmological science cases and discuss the benefits of cross-correlating Euclid data with CMB observations to tighten parameter constraints and minimize systematic effects.

Latest results from Galactic center observations / 628

The Parsec to Sub-Parsec Scale Environment

Corresponding Author: ciurlo@astro.ucla.edu

The galactic black hole is not very active at present, but at about 1 pc there is a large reservoir of material that will eventually trigger a more intense phase of activity. Smaller-scale processes can also accrete material onto the black hole producing short peaks in activity. Here, I present the structure and dynamics of the interstellar medium from the parsec to sub-parsec scale and how each component potentially contributes to the accretion flow and trace the influence of the black hole on stars and clouds. In particular, I will highlight the unexpected presence of molecular hydrogen in the central parsec (where the strong UV field is supposed to dissociate it) and the unveiling of several dust-enshrouded objects, orbiting close to the central black hole. The latter include the "G objects", likely the dusty product of binary mergers, and X7 a tidally stretching gas cloud possibly ejected by a stellar collision.

Wednesday plenary session / 629

Map of the entire Sky in X-rays and its variability over time

Corresponding Author: rsyunyaev@gmail.com

This map contains information about the diffuse emission of the halo of our Galaxy, millions of accreting supermassive black holes, half a million stars with active coronae, and 50,000 clusters of galaxies filled with dark matter and diffuse hot gas. It demonstrates strong variability of X-ray sources on different time scales from the giant explosions in our Galaxy and the Tidal Disruptions of stars near supermassive black holes in Active Galactic nuclei. This map was created using the data of the whole sky scans by SRG Orbital Observatory with eRosita and ART-XC X-Ray grazing incidence telescopes aboard. SRG works on the halo orbit around the second Lagrange point similar to the orbit of the James Webb Telescope 1.5 Mln km away from the Earth.

Monday plenary session / 630

Bi-twistors: an extension of twistor theory for general space-times

Corresponding Author: rpenroad@gmail.com

Twistor theory was initially developed to describe the geometry of Minkowski space-time in terms of its null geodesics. The natural generalization to curved space-times requires the ubiquitous existence of α-surfaces, this requiring the Weyl curvature to be anti-self-dual, which for a real space-time implies conformal flatness. A bi-twistor, however, incorporates both a twistor and a dual-twistor, together with their canonical commutation relations, and the role of the α-surfaces is simply replaced by that of null geodesics, which are ubiquitous in any space-time. Accordingly, bi-twistor theory can be developed so as to apply to space-times generally.

High energy astrophysics / 631

Two decades of gamma-ray astronomy with INTEGRAL

Author: Sandro Mereghetti[None]

Corresponding Author: sandro.mereghetti@inaf.it

The ESA INTEGRAL satellite, devoted to high resolution spectroscopy coupled to good imaging capabilities over a wide field of view in the 15 keV - 10 MeV range, was launched in October 2002. After more than two decades, its four instruments are still working well, and they provide unique capabilities in the study of high-energy phenomena.
In this talk I will give a brief overview of the main science achievements obtained with INTEGRAL. These include important topics which were among the original motivation of this mission, as well as unexpected discoveries and significant results in unanticipated fields of current astrophysics.

Galactic and extragalactic magnetars: recent observations and theoretical progress / 632

Nonlinear vacuum electrodynamic lensing on magnetars

Co-authors: A. Talkhat ; Medeu Abishev [1]; Tursynbek Yernazarov [2]

[1] *Al Farabi Kazakh National University*

[2] *al-Farabi Kazakh National University*

Corresponding Author: abishevme@gmail.com

We study numerically a combined gravitational and nonlinear magnetic lensing effect on electromagnetic flux. A magnetar with a dipole magnetic field and background gravitational field is considered to deflect the light rays which passed through its magnetosphere. We assume a square wave front as a grid with the dynamic step. At the nodes of this grid, the rays enter perpendicularly into the cubic area, which covers the main magnetic lensing region with a magnetar at the center. On the basis of general relativity (GR) and nonlinear vacuum electrodynamics, the distribution of rays by the deflection angle in the combined field of the magnetar was obtained. On the basis of the analysis of the obtained data, it is possible to assert that the magnetic field distorts the result of gravitational lensing. Therefore, the magnetar is regarded as a gravitational-magnetic lensing object, wherein the magnetic field induces axial distortion within 10e-6. These results are expected to be detectable by modern instruments.

Emission mechanisms in gamma-ray bursts / 633

Diffusion spectra and equitemporal surfaces of ultrarelativistic shell radiation as applied to gamma-ray bursts

Author: Aksana Kurhuzava[None]

Corresponding Author: kuppory@gmail.com

Large-scale cosmic emissions of explosive energy that occur during the explosions of certain supernovae or the merger of compact objects are called gamma-ray bursts. We study the radiation of the ultrarelativistic shell in the diffusion approximation, which takes place at the initial stage of a gamma-ray burst. We get the effective temperature, instantaneous and time-integrated spectra for the different distribution of the initial internal energy of the shell. The resulting time-integrated emission spectra of the shell photosphere contain a Band component and a thermal component. Also we considered the types of the equitemporal surfaces with a different type of the movement of the shell.

Theories of gravity: alternatives to the cosmological and particle standard models / 634

Status of Electromagnetic Accelerating Universe

Corresponding Author: paul.h.frampton@gmail.com

To describe the dark side of the Universe, we adopt a novel approach where dark energy is explained as an electrically charged majority of dark matter. Dark energy, as such, does not exist. The Friedmann equation at the present time coincides with that in a conventional approach, although the cosmological "constant" in the Electromagnetic Accelerating Universe (EAU) Model shares a time dependence with the matter component. Its equation of state is $\omega \equiv P/\rho \equiv -1$ within observational accuracy.

Navigating science and philosophy: exploring limits / 635

Time is entropy: A geometric proof

Author: Hernando Quevedo[1]

[1] *National Autonomous University of Mexico*

Corresponding Author: quevedo@nucleares.unam.mx

We use the formalism of geometrothermodynamics to associate a Riemannian manifold called equilibrium space to any thermodynamic system. In the case of an ideal gas, we show that quasi-static thermodynamic processes correspond to geodesics in the equilibrium space. Interpreting time as the affine parameter along geodesics, we show that the entropy of the ideal gas is linearly proportional to time, and the second law of thermodynamics determines the arrow of time.

Monday plenary session / 636

TBD

Corresponding Author: ruffini@icra.it

Tuesday plenary session / 637

TBD

Corresponding Author: mkramer@mpifr-bonn.mpg.de

Friday plenary session / 638

An overview of INAF's involvement in observational facilities

Author: Roberto Ragazzoni[1]

[1] *INAF*

Public lectures / 639

TBD

Author: Wendy Freedman[1]

[1] *University of Chicago*

Corresponding Author: wfreedman@uchicago.edu