# The Fifth Zeldovich Meeting

Monday, 12 June 2023 - Friday, 16 June 2023

# Book of Abstracts

# Contents

**Friday morning session / 1**

## Black-hole bomb and confined Penrose process

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We consider the decay of a particle with some energy E_0 > 0 inside the ergosphere of a black hole. After the first decay, one of particles with the energy E_1 < 0 falls towards a black hole while the second one with E_2 > E_0 moves in the outward direction. It bounces back from a reflecting shell and, afterwards, the process repeats. For radial motion of charged particles in the Reissner-Nordstom metric, the result depends strongly on a concrete scenario. In particular, an indefinitely large growth of energy inside a shell is possible that gives rise to a black-hole bomb. We also consider a similar multiple process with neutral particles in the background of a rotating axially symmetric stationary black hole. We demonstrate that, if particle decay occurs in the turning point, a black-hole bomb in this case is impossible at all. For a generic point inside the ergoregion, there is a condition for a black-hole bomb to exist. It relates the ratio of masses before and after decay and the velocity of a fragment in the center of mass frame.

**Friday afternoon session / 2**

## Warm Inflation using Irreversible Thermodynamical Approach

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We aim to study warm inflation via irreversible thermodynamics of open systems with matter creation/decay within Rastall theory of gravity. Interacting scalar field and radiation are assumed to be the components of cosmological fluid in a spatially flat FRW universe model. Considering the early universe as an open system and implementing the thermodynamics on the interacting cosmological fluid leads to modifying the standard formalism of the warm inflationary model, including the creation(decay) pressure, which is considered part of the energy-momentum tensor explicitly. Under slow-roll approximation, numerical solutions of the thermodynamical equations are obtained and represented graphically. By constraining the free model parameters, the theoretical predictions of the underlying model are compared with the Planck-2018 data.

**Thursday morning session / 3**

## Near field cosmology with constrained simulations: an overview

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Numerical simulations are the driving force behind much of the theoretical progress in our understanding of the formation of structure in the universe. Cosmological simulations must cover a large dynamical and mass range. A representative volume of the universe should be large, but this comes at the expense of the resolution. To overcome this problem we developed a new approach over the last two decades which consists of using observations of the nearby universe as constraints imposed on the initial conditions of the simulations.

The resulting constrained simulations successfully reproduce the observed structure within a few tens of megaparsecs around the Milky Way including the nearby well known clusters of galaxies. We have performed first constrained simulations within the CLUES project (Constrained Local UniversE simulations). More recently zoomed high resolution gasdynamical simulations allowed to study the formation of the Local Group in the right large scale environment, the HESTIA (High-resolution Environmental Simulations of The Immediate Area) project.

**Tuesday morning session / 5**

# Discoveries from FAST

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The Five-hundred-meter Aperture Spherical radio Telescope (FAST) has been in operation since early 2020. Largely motivated by the great Arecibo observatory, FAST now perches on the apex of sensitivity among centimeter-band radio instruments and will stay there until the advent of SKA. In a little three years, FAST data has facilitated more than 150 journal papers, including at least 7 on Nature, 2 on Science, 1 on Science Bulletin, and a few more on high-impact astronomy journals, such as Nature Astronomy. I will present a brief overview of FAST's discoveries so far, with particular emphasis on those that better reflects the unique advantages of this observatory. For example, the precise Zeeman measurement based on our novel HI Narrow Self-Absorption (HINSA) technique, the high quality HI images (~1% flux uncertainty), the world's first persistently active fast radio bursts (FRBs), etc. With these discoveries, I will also ponder upon the potential progresses to be made in terms of the better understanding the fundamental physical principles of the cosmos.

**Tuesday morning session / 6**

# Black hole induced star formation in the early universe

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In the local universe have been observed enhancements of star formation due to relativistic jets from accreting black holes (BHs). These BH "positive feedbacks" take place by the interaction of BH-jets with high-density molecular clouds, which leads to compression of the gas and subsequent enhancement of star formation. This BH-jet triggering mechanism of star formation must have been more important in the early universe, for two reasons. First, the global gas density in the universe evolves with redshift z as (1+z)^3, and at z = 30 the global gas density would be more than 10^4 times the global gas density in the local universe. Second, revently have been increasing indications that in the galaxies of the early universe massive BHs came first and grow faster than the stellar

populations. In this context, I propose that the rapidly growing BH seeds of the SMBHs of 10^9 M⊙ in quasars at z = 7 may have induced the formation of the first massive stars of Pop III.

**Friday afternoon session / 9**

## Anisotropic Strange Stars through Complexity Factor

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By using the gravitational decoupling method to create an exact solution to the field equations, this talk discusses the formulation of a charged anisotropic spherically symmetric strange star model. The initial decoupled system is split into Einstein-Maxwell and quasi-Einstein systems using minimal geometric modification. By employing the complexity factor to solve quasi-Einstein field equations, a well-known model for the isotropic spherical matter distribution is adopted with MIT bag equation of state incorporating electromagnetic field and generalize it to an anisotropic model. By visualizing metric functions, density, pressure, anisotropy parameter, energy requirements, and stability criterion for various strange star candidates, the physical viability of the resulting charged anisotropic solution is investigated. The generated model's physical acceptability is ensured by the fact that all physical aspects behave properly.

**Friday afternoon session / 10**

## An improved Zeldovich formula for the Cosmological Constant from Precanonical Quantum Gravity

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Within the precanonical quantization, which we will outline, the dynamics of quantum fields is controlled by the operator of the De Donder-Weyl Hamiltonian (DWH) whose classical version is derived from the Lagrangian. The operator ordering in the DWH operators of GR and its teleparallel equivalent, which is consistent with the diffeomorphism-invariant measure in the scalar product and the required (pseudo-)Hermicity, produces an exactly calculable constant addition, which is identified with the cosmological constant $\Lambda$. Its value corresponds to the Zeldovich-1968 formula in which the 6th degree of the proton mass is replaced by the square of the ultraviolet (inverse volume) scale $\aleph$ introduced by the precanonical quantization. This scale can be related to the scale of the mass gap of the quantum pure gauge theories of the Standard Model (IK-2017). This identification yields the observable value of $\Lambda$ up to approximately $3^2$ orders of magnitude error which is due to an error in the estimation of $\aleph$ from its relation to the mass gap. We also discuss how this error can be improved and how our approach leads to the "minimal acceleration" and derives its relation with $\sqrt{\Lambda}$ as anticipated in Milgrom's MOND.

**Wednesday afternoon session / 11**

## Relativistic Jets from all angles

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Due to their strong beaming, relativistic jets are overwhelmingly more likely to be detected from viewing angles close to their jet axis. This makes the angular structure of the jets (and in particular the under-energetic 'wings' of the jet) difficult to explore in the majority of jet powered transient events. Nonetheless, jets viewed mildly off-axis should be commonly detected and the resulting multiwavelength light-curves have unique features. I will show how these considerations can (i) explain peculiar behaviors seen in TDE jet light-curves, (ii) re-frame our understanding of commonly observed phenomena in GRB afterglows, such as X-ray plateaus and flares, (iii) puts strong constraints on GRB prompt emission, and (iv) sets tests and expectations for future observations. For jets viewed far off-axis I will show that there are different types of light-curves that could be observed (single or double peaked) and outline how the underlying jet structure can be robustly recovered from their observations. I will also discuss the connection with the recently discovered GRB 221009A, the brightest detected GRB to date by some margin, which has exhibited an intriguing and highly constraining afterglow evolution.

**Friday morning session / 12**

## Cosmology with Gamma-Ray Bursts

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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.

**Monday morning session / 13**

## The Imaging X-ray Polarimetry Explorer (IXPE) results from the first 1.5 years of observation

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The Imaging X-ray Polarimetry Explorer (IXPE) is a NASA-ASI Small Explorer mission selected on January 2017 and launched on $9^{th}$ December 2021. Three X-ray mirrors are coupled to three Detector Units clocked at 120° each one hosting a Gas Pixel Detector, sensitive to X-ray polarization designed, built tested, and calibrated by INAF and INFN institutes. Some dozens of celestial X-ray sources, from almost all the classes, were observed so far, and for more than a half IXPE detected significant polarization. Some unexpected results were found by IXPE and in this talk after an introduction to the mission I will describe the main Astrophysical achievements reached so far

**Tuesday afternoon session / 14**

## Pair-balance model for relativistic shocks and its application to astrophysical sources

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Among astrophysical objects whose emission originates from relativistic shocks are active galactic nuclei, gamma-ray bursts, and pulsar winds. Their exceptionally broad spectra are due to synchrotron and inverse Compton emission of accelerated leptons. Although these radiation processes are common in space, the relativistic shocks and shear flows possess an efficient feedback mechanism that sets them apart from other particle acceleration sites.
The feedback operates through inelastic collisions of high-energy inverse Compton photons with low-energy synchrotron photons, that create electron-positron pairs in a region where the flow's velocity is relativistic with respect to the photons' source. The pairs gain energy from the difference in flow's velocity. This constitutes the converter acceleration mechanism.
Whenever it is efficient, the converter acceleration reaches nonlinear saturation regime, where momentum transfer by high-energy photons keeps flow's velocity gradient at minimum necessary for converter acceleration to operate. The balance occurs when photons from the inverse Compton peak in the spectrum have barely enough energy to produce pairs with photons from the synchrotron peak. This balance condition predicts the positions of both synchrotron and inverse Compton peaks, and the ratio of their heights. The predictions are in line with recent observations of TeV emission from gamma-ray burst afterglows.

**Wednesday morning session / 15**

## Highlights of the Insight-HXMT X-ray Astronomy Satellite

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Insight-HXMT (hxmt.cn) is China's first X-ray astronomy satellite and was successfully launched on June 15th, 2017. It carries three sets of collimated X-ray instruments with large effective areas,

covering energy ranges of 1-15 keV, 5-30 keV, and 20-250 keV, respectively. In addition, it can also serve as an all-sky monitor for high energy sources between 0.2 to 3 MeV, such as bright pulsars and gamma-ray bursts. This talk will review some highlights of the scientific results of Insight-HXMT, including discoveries of the highest energy fundamental frequency of neutron star's cyclotron absorption feature from an accretion neutron star, the highest energy low frequency quasi-periodic oscillations from an accretion black hole which is evidence for a relativistic jet near the black hole, the first non-thermal X-ray burst associated with a fast radio burst and its identification with a magnetar, the brightest gamma-ray burst GRB 221009A, etc. Insight-HXMT has been performing well in orbit and is expected to operate for several more years. The observational program of Insight-HXMT is open world-wide.

**Wednesday morning session / 16**

## An electrodynamic process to extract the rotational energy of a Kerr black hole

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It has been thought for decades that rotating black holes (BHs) power the energetic gamma-ray bursts (GRBs) and active galactic nuclei (AGNs), but the mechanism that extracts the BH energy has remained elusive. This problem might be solved when the BH is immersed in an external magnetic field and ionized low-density matter. For a magnetic field parallel to the BH spin, the induced electric field accelerates electrons outward and protons inward in polar regions and vice versa in equatorial regions. For an antiparallel magnetic field, protons and electrons exchange their roles. The particles that are accelerated outward radiate off energy and angular momentum to infinity. The BH powers the process by reducing its energy and angular momentum by capturing polar protons and equatorial electrons that lead to net negative energy and angular momentum. The electric potential allows for negative energy states outside the BH ergosphere, so the latter does not play any role in this electrodynamical BH energy extraction process.

**Monday afternoon session / 17**

## A new channel for supermassive black hole formation

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Observations support the idea that supermassive black holes (SMBHs) power the emission at the center of active galaxies. However, contrary to stellar-mass BHs, there is a poor understanding of their origin and physical formation channel. In this article, we propose a new process of SMBH formation in the early Universe that is not associated with baryonic matter (massive stars) or primordial cosmology. In this novel approach, SMBH seeds originate from the gravitational collapse of fermionic dense dark matter (DM) cores that arise at the center of DM halos as they form. We show that such a DM formation channel can occur before star formation, leading to heavier BH seeds than standard baryonic channels. The SMBH seeds subsequently grow by accretion. We compute the evolution of the mass and angular momentum of the BH using a geodesic general relativistic disk accretion model. We show that these SMBH seeds grow to ~ 10^9–10^(10) Msun in the first Gyr of the lifetime of the Universe without invoking unrealistic (or fine-tuned) accretion rates.

**Monday morning session / 18**

## SRG/eROSITA all-sky survey: from solar flares and neutrino sources to cosmology

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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.

**Tuesday morning session / 19**

## Selected Studies of Cosmic and Gamma Rays with the MAGIC telescopes

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MAGIC is a ground-based Imaging Atmospheric Cherenkov Telescope (IACT) for very high energy gamma-ray measurements that has pioneered high-sensitivity measurements down to a few tens of GeV. It includes a system of double telescopes with a diameter of 17 m, separated by a distance of 85 m, operating in coincidence mode (stereo). The telescopes are located at an altitude of 2200 m above sea level in the European Northern Observatory *El Roque de los Muchachos* on the Canary Island of La Palma. In recent years, the MAGIC collaboration has developed innovative techniques that have increased the dynamic range and sensitivity of the telescopes to around 20 GeV and up to 100 TeV. These have expanded and greatly improved the capabilities of the instrument. In this report we want to focus on some selected observations of cosmic and gamma rays of galactic and extragalactic origin.

**Thursday morning session / 20**

## Influence of a plasma on the shadow of black holes

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If a black hole is seen against a backdrop of bright light sources, it forms as dark disc on the observer's sky, known as the "shadow" of the black hole. If one assumes that light rays are not influenced by a medium, i.e., if one assumes that they are lightlike geodesics of the spacetime metric, the boundary curve of the shadow can be analytically determined, provided that the spacetime is stationary and axisymmetric and that the Hamilton-Jacobi equation for lightlike geodesics separates. In this talk it

is discussed under which conditions such an analytical determination of the shadow is possible if the light rays are influenced by a non-magnetised pressure-less electron-ion plasma. Several examples are worked out, not only for black holes but also, for the sake of comparison, for some "black-hole impostors" such as wormholes. In particular, it is discussed if the boundary curve of the shadow can form "fishtails".
The talk is partly based on joined papers with Oleg Tsupko, Gennady Bisnovatyi-Kogan, Barbora Bezděková and Jiří Bičák.

**Tuesday afternoon session / 21**

## Hubble Tension challenge in the modern cosmology: possible solutions

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One of the problems in the modern cosmology is a so-called Hubble tension (HT), which is the difference between values of the present Hubble constant H0, measured by observation of the universe at redshift $z \leq 1$, and the same value measured by observations of a distant universe by observations of CMB fluctuations corresponding to $z \approx 1100$. We suggest that this Tension may be explained by deviation of the cosmological expansion from a standard ΛCDM model of a flat universe, due to the action of an additional variable component DEV during the post-recombination stage.
In order to maintain the almost constant DEV/DM energy density ratio during the whole time interval at $z < 1100$, it is necessary to allow the existence of a wide mass DM particle distribution.

**Friday morning session / 22**

## The spectral signatures of BHs versus NS

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In 2017 the work on the Comptonization (Sunyaev-Titarchuk) seen in the X-ray spectra of astrophysical sources was a candidate for the Nobel Prize in Physics. In this talk I provide all the details of the exciting prehistory of this topic and precise details of this discovery. The solution of this problem and its subsequent development and application to the spectra of accreting neutron star (NS) and black hole (BH) binaries reveals a lot of information on these objects. In particular, now we can unambiguously distinguish between a NS and a BH (Galactic or extragalactic) using correlations of their spectral indices vs mass accretion rate (or QPO frequency). I further demonstrate how we can determine a BH mass using this correlation

**Thursday morning session / 23**

## New quantum technologies and gravity

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As has been emphasized in the talk of Hansjoerg Dittus, the second quantum revolution enables new technologies which are not accessible through classical physics. These technologies are characterized by the engineering and manipulating of quantum states. In this talk the interface between these new technologies and the gravitational interaction is highlighted by considering a few topics: (i) a metrological triangle for gravity, (ii) two gravitational constants, (iii) Hong-Ou-Mandel interferometry in gravitational fields, and (iv) quantum imaging of the gravitational field.

**Tuesday morning session** / **24**

## Neutrino Telescope Baikal-GVD: Status and Nearest Future

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The progress in the construction and operation of the Baikal Gigaton Volume Detector in Lake Baikal is reported. The detector is designed for search for high energy neutrinos whose sources are not yet reliably identified. It currently includes over 3500 optical modules arranged on 98 strings, providing an effective volume of 0.6 km3 for cascades with energy above 1 PeV. We review the scientific case for Baikal-GVD, the construction plan, and first results from the partially built experiment, which is currently the largest neutrino telescope in the Northern Hemisphere and still growing up.

**Thursday morning session** / **25**

## Quantum sensing – the key technology for further gravitational experiments in space

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Progress in physics always has been stimulated by unexplained observations or experiments. Expressions like "dark matter" or "dark energy" might help to apply the present standard physical theories, but cannot explain their origin sufficiently. The situation of fundamental physics today still causes a lot of open questions, e.g. the theoretical inconsistency of quantum mechanics and General Relativity. Furthermore, there are observations which at least until now and after many years of studies, have not yet found any convincing explanation.
Therefore, we need better, i.e. more and more accurate measurement technology in order to detect even the most tiny effects acting on spacecraft which are our probes in deep space. It seems that those emerging technology must be based mainly on quantum optics able to explore the structure of spacetime in an new and unique way.
The presentation will report on the possibilities for future missions and space experiments in gravitational and quantum physics.

**Friday afternoon session** / **26**

## Development of semi-implicit numerical method on a moving grid for differentially rotating astrophysical MHD flows with self-gravity.

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We represent a numerical method for the simulation of 3D differentially rotating astrophysical MHD flows in cylindrical and spherical geometries. This approach belongs to the class of mixed Euler-Lagrange methods. The grid consists of rings which are rotating in a quasi-Lagrangian manner together with the background (differential and solid state) large-scale rotation, significantly reducing the numerical diffusion of the method associated with advection in the azimuthal direction. We use explicit Godunov-type scheme, while acoustic waves are treated in a semi-implicit way. This approach makes it possible to solve the equations of gas dynamics uniformly for wide range of Mach. The stability condition for the scheme does not depend on the speed of sound. This approach allows to simulate MHD differentially rotating flows like core collapse supernovae or accretion problems.

**Friday morning session / 27**

## Neutron Stars as Strong Field QED Laboratory

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Strong electromagnetic fields polarize the vacuum and electric fields produce charged pairs, the so-called Schwinger effect. The critical strength of electromagnetic fields, whose energy density equals to the rest mass of the charge, cannot be achieved in present laboratories. The critical electric fields enormously produce electron-positron pairs and the critical magnetic field has the lowest Landau level whose energy equals the rest mass of the charge and gives a measurable effect on the photon propagation.
I will address the physics in strong electromagnetic fields of neutron stars and advance methods to observe the vacuum polarization effects. Magnetars, the highly magnetized neutron stars, have magnetic fields stronger than the critical field and lead to measurable vacuum polarization effects such as the birefringence. A supercritical magnetic field in the Goldreich-Julian pulsar model induces a subcritical electric fields due to high spinning of neutron star, and hence the wrench effect of both electric and magnetic fields becomes significant in the propagation of light modes. The vacuum birefringence will be formulated to include the wrench effect and the X-ray polarimetry will be studied which can be measured in the future space telescopes, such as IXPE, e-XTP and Compton Telescope.

**Tuesday morning session / 28**

## Neutrino astronomy: IceCube results and the future of multimessenger searches

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In the course of the last decade, the IceCube Neutrino Observatory has marked the first milestones of neutrino astronomy, starting with the discovery and characterisation of the astrophysical neutrino flux. Astrophysical neutrinos are unique tracers of hadronic particle acceleration and could be the key to unveil the origin of high-energy cosmic rays. IceCube has been hunting for the sources of astrophysical neutrinos with a wide range of methods. Its realtime program which sends prompt alerts to the multimessenger community following the detection of interesting IceCube events, led in 2017 to the association of a high-energy neutrino and the flaring blazar TXS 0506+056. Subsequent archival searches found a burst of neutrinos from the same location five years earlier. More recently, improved searches for steady point-sources have produced evidence of neutrino emission from the nearby active galaxy NGC 1068. In this talk, I will focus on these and other IceCube neutrino astronomy results and outline the perspective for its near-future multi-messenger searches.

**Thursday afternoon session / 30**

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

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The knowledge of electromagnetic field of charged particles in the vicinity of a black hole is important for the study of many astrophysical phenomena, in particular of gamma-ray bursts and jets of supermassive black holes. In the present work we determine multipole coefficients of electromagnetic field for charged particle, radially falling into Schwarzschild black hole and consider the limit of approaching to the event horizon.

**Monday afternoon session / 31**

## Three arguable concepts

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We address i) the point-particle assumption inherent to non-quantum physics. It is singular and entails divergences. ii) In quantum mechanics (QM) EM plays an asymmetric role. It acts on QM fields, but the latter does not react back. We suggest a mutual action-reaction partnership between the two. By so doing, QM fields share their analyticity with EM fields and remove the singularities. iii) The conventional U1 symmetry leaves QM and EM invariant under a 'general' Lorentz gauge and causes the standard minimal coupling of QM to the EM 4-vector potential. One may, however, ask for invariance under the 'restricted' Lorentz gauge. This invites in the coupling to the derivatives of the vector potential and enlarges U1. We examine the Dirac electron in the context just dscribed. Without recourse to QED, we find that electron develops non-singular and distributed charge and current densities. The enlarged symmetry has its own constant of motion. The anomalous g-factor

of the so designed electron emerges, up to order (⊠/⊠)^2, as the constant of motion in agreement with the QED theorized and the laboratory measured values.

**Monday morning session / 32**

## Polarized light from accreting low mass X-ray binaries

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The polarized X-ray radiation emitted from an accreting low mass X-ray binary (LMXB) is expected to give information about the geometry of the region where the Comptonization occurs and about the spin of the accreting BH. Actually, first results obtained from IXPE seem to reveal that the scenario for LMXBs is more complicated than expected: the polarization properties seem to differ from what current models have predicted. Moreover, while there are hints that winds and the reflection component could have a role in the detected polarised light, the most interesting result reported until now is that the polarization angle of both BH and NS LMXB seems to be aligned with the radio jets.
I will summarize the principal characteristics of LMXBs in the light of the new IXPE results on polarization.

**Wednesday morning session / 33**

## The observation of GRB221009A from LHAASO

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LHAASO is a muti-purpose ground-based array of gamma-ray and cosmic-ray detectors in China, consisting of three detector arrays, the Water Cherenkov Detector Array (WCDA), the Kilo-meter squre Array ( KM2A) and the Wide Field of view Cherenkov Telescope Array (WFCTA). In this talk the observations of the brightest GRB 221009A by LHAASO including SEDs and light curves are to be presented.

**Wednesday afternoon session / 34**

## Probing neutrino-emitting blazars by high-resolution and high-energy observations

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Multimessenger studies of blazars combine electromagnetic emission from radio to gamma wavelengths, and neutrino detections up to petaelectronvolts. We demonstrate the synergy of the highest-resolution observations in the radio band and hard X-ray observations, and how they help us study sources of IceCube neutrinos. The radio VLBI technique is uniquely positioned in this space, as its resolution allows selecting beamed parsec-scale synchrotron emission, and neutrinos are likely to experience comparable beaming effects. Meanwhile, X-rays can be directly related to the neutrino production itself, and bring information about those processes. We present new insights on neutrino production in blazars, highlighting the role of electromagnetic observations in these results.

**Friday morning session / 35**

## Astrophysical searches for primordial black holes

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Interest to astrophysical evidence for primordial black holes formed in the early Universe from initial cosmological perturbation has increased after the discovery of coalescing binary black holes with masses more than dozen solar ones by gravitational-wave observatories. I will discuss the formation channels of merging binary black holes with a special focus on the possibility that some fraction of the observed binary black hole mergings can have the primordial origin.

**Friday morning session / 36**

## Black entropy, Weyl curvature, and Christodoulou-Ruffini irreducible mass

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In the context of reversible vs. irreversible transformations of a black hole, Christodoulou and Ruffini introduced the notion of irreducible mass, which is related to the event horizon area. The area of the event horizon was subsequently interpreted as the black hole entropy by Hawking and Bekenstein. Furthermore, Penrose conjectured the Weyl curvature hypothesis: the Weyl curvature is a density of gravitational entropy. However, implementing this idea is not so trivial with some drawbacks in the proposal of taking the square of the Weyl curvature as an entropy density being identified. In my talk, I will propose a solution to this issue through an appropriate combination of curvature quantities based only on the Weyl curvature (which therefore is not sensitive to the matter content of the spacetime and really constitutes a measure of the pure gravitational field), which exhibits a general applicability for all static and spherically symmetric black holes in general relativity independently on the matter field on their exterior. Our new formula for the gravitational entropy density allows us to provide some physical insights about the nature of black hole entropy, and of the Christodoulou-Ruffini irreducible mass, also putting our results in the perspective of modified gravity theories.

**Thursday afternoon session / 37**

# Quantum-gravitational corrections to the power spectrum for a closed universe

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We study the quantum-gravitational corrections to the power spectrum of a gauge-invariant inflationary scalar perturbations in a closed model of a universe. We consider canonical quantum gravity as an approach to quantizing gravity. This leads to the Wheeler-DeWitt equation, which has been studied by applying a semiclassical Born–Oppenheimer type of approximation. At the corresponding orders of approximation, we recover both the uncorrected and quantum-gravitationally corrected Schrödinger equations for the perturbation modes from which we calculate the quantum-gravitational corrections to the power spectrum in the slow-roll regime. The results are compared to the power spectra for the flat model of the universe.

**Tuesday afternoon session / 38**

# The Science Promise Now Being Realized After JWST's Decades of Challenges

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The James Webb Space Telescope is an astronomy mission that exceeds all others in capability. The first science results from JWST have already rewritten the science history books. JWST is astonishingly complex, yet it exceeds its requirements in essentially all areas. Its flawless launch and deployments are a testament to the engineering and management commitment of thousands of people in the US and in our partner nations, the European ESA and Canadian CSA, and of the support of policy-makers who funded this extraordinary mission through all its trials and tribulations. I will give a broad overview of the multi-faceted challenges that JWST faced and overcame, from birth 35 years ago, and of the early science results that challenge our understanding, particularly of the growth of galaxies in the early universe.

**Thursday afternoon session / 39**

# Symmetric periodic trajectories of charged particles in Gutsunaev–Manko spacetime

**Authors:** Ivan Kichigin[1]; Sergey Tegai[1]

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We consider the motion of charged particles in Gutsunaev–Manko spacetime, which is the exact solution of the Einstein–Maxwell field equations for a massive dipole. In the present work we study periodic orbits symmetric with respect to the equatorial plane. The spacetime is static and axially symmetric, therefore the problem is reduced to the motion in two-dimentional effective potential. We show that the Gutsunaev–Manko solution admits the same types of symmetric periodic trajectories as the classical magnetic dipole problem and study the stability of those trajectories.

**Monday afternoon session / 41**

## Breathing Fire: High-speed Ejecta from a Gamma-ray Binary

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If a rotation-powered (non-accreting) pulsar is in a binary with a high-mass star, then the collision of the relativistic pulsar wind with the stellar wind creates an intrabinary shock, generating high-energy radiation. In addition, the shocked pulsar and stellar winds can leave the binary and form a nebula whose properties should vary with the orbital phase. To search for such a nebula, we carried out multiple observations of the well known gamma-ray and X-ray high-mass binary LS 2883 with the Chandra X-ray observatory. In this eccentric binary ($e = 0.87$, $P_{\rm orb} = 3.4$ yr) a middle-aged pulsar B1259-63 orbits a fast-rotating Be star with an equatorial excretion disk. Our observations have unexpectedly shown X-ray emitting clumps, moving away from the binary in about the same direction and changing their shape and brightness. Presumably ejected near periastron passages, they reached projected velocities of about $0.1\,c$. I will discuss possible explanations of this remarkable phenomenon whose nature has not been fully understood yet.

**Friday afternoon session / 42**

## Magnetized advective accretion disks and their stability at higher acrretion rate: Theory and simulation

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An optically thin advective accretion disk appears to be indispensable to explain hard-state of black hole sources. Any transport of matter therein is assumed to be led by (modified) α-viscosity when the magnetic field is weak. We explore how large scale stronger magnetic field helps in transporting angular momentum, over α-viscosity based transport, depending on the field geometry. Interestingly, while above a critical accretion rate the accretion disk turns out to be thermally unstable, in the presence of stronger magnetic fields the disk regains its stability. We first establish this by theory and then explore the same by numerical simulation based on HARMPI. This increases the upper limit of accretion rate in optically thin flows, which has far reaching implications including explanation of ultra-luminous X-ray sources.

**Thursday afternoon session / 45**

## Exploring massive neutron stars towards mass gap: Constraining the high-density nuclear equation of state

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Due to the high-density nuclear matter equation of state (EOS) being as yet unknown, neutron stars (NSs) do not have a confirmed limiting "Chandrasekhar" type maximum mass. However,observations of NSs (PSR J1614-2230, PSR J0348+0432, PSR J0740+6620, PSR J0952−0607) indicate that NS's limiting mass, if there is any, could be well over $2M$ . On the other hand, there exists an observational mass gap between $2.5M$ and $5M$ , and the "massive NSs" are prime candidates to fill that gap. Several NS EOSs have been proposed using both microscopic and phenomenological approaches. In this project, we look at a class of phenomenological nuclear matter EOSs – relativistic mean field models – and see what kind of NS is formed from them. We compute the maximum mass supported by each model EOS to observe if the mass of the NS is indeed in the "massive" NS ($> 2M$ ) regime. Using tidal deformability constraints from gravitational wave observations, we place a further check on how physical the EOS used is. We also observe the effects of including exotic particles (hyperons, deltas) in the NS EOS and how that affects the NS mass. Finally, we look at how the NS's magnetic field affects its mass.

**Thursday morning session / 46**

## Black holes in alternative theories of gravity

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Black holes represent ideal laboratories to test Einstein's theory of general relativity and alternative theories of gravity. Alternative theories of gravity typically introduce additional degrees of freedom, among them most prominently a scalar field. Depending on the theory, the resulting black holes may then differ significantly from their counterparts in General Relativity. Possessing hair, such black holes might, for instance, be distinguished by their shadows or by their gravitational wave spectra.

**Tuesday morning session / 48**

## Extreme Universe through the eyes of MASTER Robots

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The Extreme Universe is the most powerful and fastest explosions in the Universe associated with the formation and transformation of relativistic stars.
For localization of gravitational-wave, neutrino and gamma-ray events, first of all, optical instruments of the 21st century are needed, which have outstanding technical characteristics: fast response, full robotization and high angular resolution. For example, the optical localization of these objects reduces the error box of neutrino, gamma and gravitational wave events by billion of times.

The latest results of the MASTER Global Robotic Network of Optical Robotic Telescopes are presented.

**Tuesday afternoon session / 49**

## 25 years of GRB/SNe: an overview

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25 years after the discovery of the first GRB/SN, SN1998bw remains the best observed example of this extraordinary class of events. Several other GRB/SNe have been discovered, allowing progress in determining their overall properties.
I will review some of the advances and outline the outstanding problems in this field.

**Thursday afternoon session / 50**

## Exploring second-order gravitational effects and the possibility for dark matter detection with the next generation of space-borne atomic standards of frequency and time

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General relativity (GR) and quantum theory form the basis of the modern physical picture of the universe. However, attempts to unify them inevitably lead to violations of the Einstein Equivalence Principle (EEP) which is the basis of GR. A promising kind of experiments to test the domain of validity of EEP is based on measuring the gravitational redshift. Recent progress in the stability and accuracy of atomic clocks, including those qualified for operation in space, provides for significant improvements of the accuracy of these measurements in the next 10 years, and also enables new kinds of experiments.

To assess the accuracy of such experiments and process their data, the current models of frequency and time transfer between two spacecraft in the Solar system, or a spacecraft and a ground station, need to be refined. We present such an improved model, which includes terms to order $c^{-4}$ and accounts for nonrelativistic Doppler compensation schemes, and use it to analyze the accuracy of EEP tests and PPN parameter measurements which can be performed in near-future space experiments in the Solar system. We also formulate the constraints on EEP violations predicted by fuzzy dark matter theories which can be achieved in such experiments.

**Friday afternoon session / 51**

## Astrophysical scenarios leading to gravitational wave modification

**Authors:** Monos Naidoo[1]; Nigel Bishop[1]; Petrus Van der Walt[1]

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Calculations of gravitational waves (GWs), both analytical and numerical, assume that they propagate from source to a detector on Earth in a vacuum spacetime. Whilst the average cosmological density of baryonic plus dark matter is small, a detected GW event may be a considerable distance away from its source, up to order 1 Gpc, and the quantity of intervening matter may not be negligible. Furthermore, there is the possiblity that the astrophysical environment of a source event may be such that the source is surrounded by a substantial amount of matter. As we enter into an era of precision GW measurements, it is important to quantify any effects due to the propagation of GWs through a non-vacuum spacetime

**Tuesday afternoon session / 52**

## The James Webb Space Telescope: status and science results

**Author:** Massimo Stiavelli[1]

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I will briefly describe the James Webb Space Telescope and its status. I will provide an overview of its major science results, or planned observations, in areas that will impact cosmology and fundamental physics.

**Monday morning session / 53**

## Relativistic Jets from Tidal Disruption Events

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Sw 1644 was one of the most surprising tidal disruption events (TDEs). Its prompt emission in soft gamma-rays triggered Swift. Later this was followed by X-ray and Radio afterglows. The energy implied by the radio afterglow increased by a factor of 10 over a period of a few hundred days, reaching an ultimate value of a few times $10^{52}$ erg. This is much higher than in other TDEs. Recently several TDEs have shown a delayed radio emission that began a few years after the event. I show that both events can be explained as relativistic jets viewed off-axis. This requires an initially relativistic jet with $10^{53}$ erg, making those events among the most energetic transient events. I will speculate on the origin of these events, as compared with regular TDEs that are significantly weaker, and on implications to other phenomena and in particular to the origin of Ultra High Energy Cosmic Rays.

**Monday afternoon session / 54**

## TBD

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online talk

**Friday morning session / 55**

## New developments in the inflationary scenario

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The present upper limit on the amount of tensor perturbations (primordial gravitational waves) generated during inflation, the tensor-to-scalar ratio r < 0.03, excludes many inflationary models popular in the past, like those with a power-law inflaton potential ('chaotic inflation'). However, a number of viable inflationary models still remain including the three one-parametric models: the pioneer $R^2$ one, the Higgs and the mixed $R^2$-Higgs models whose unambiguous target prediction is $r = 3(1 - n_s)^2 = 0.004$. New developments in these models are mostly related to their behaviour after inflation including creation and heating of usual matter. I consider one possibility of relating the purely geometrical $R^2$ model to realistic baryogenesis after inflation by adding three families of right-handed Majorana neutrinos with a large mass to the matter sector of the Standard Model. Another trend in the inflationary scenario is to think what was before inflation. This is natural since duration of the inflationary epoch was finite inside our past light-cone. I discuss different possibilities proposed historically with the main emphasis on isotropic bounce due to positive spatial curvature, or even in its absence, or alternatively, generic anisotropic singularity with curvature much exceeding that during the observable part of inflation.

**Thursday afternoon session / 59**

## Vacuum polarization around cosmic strings in anti-de Sitter spacetime

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Local properties of scalar, fermionic and electromagnetic vacua are discussed in the presence of cosmic string type topological defects. As important characteristics of the vacuum state we consider the expectation values of the squared fields, of the energy-momentum tensor and of the current density in the case of charged fields. The topological contributions are extracted from the vacuum expectation values and their asymptotic behavior is studied near the core of the defect and at large distances. The effects of the presence of branes are discussed and applications are described in braneworld models of the Randall-Sundrum type.

**Friday afternoon session / 60**

## Plausible detection of rotating magnetized neutron stars by their continuous gravitational waves

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In the past decades, several neutron stars (NSs), particularly pulsars, with mass $M > 2M_{\odot}$, have been observed. Hence, there is a generic question of the origin of massive compact objects. Here we explore the existence of massive, magnetized, rotating NSs by solving axisymmetric stationary stellar equilibria in general relativity using the Einstein equation solver for stellar structure XNS code. Such rotating NSs with magnetic field and rotation axes misaligned, hence with non-zero obliquity angle, can emit continuous gravitational waves (GW). We discuss the decay of the magnetic field due to Ohmic, Hall and Ambipolar diffusion, and decay of angular velocity, and obliquity angle with time due to angular momentum extraction by GW and dipole radiation, which determine the timescales related to the GW emission. Further, in the Alfv\'en timescale, a differentially rotating, massive proto-NS rapidly settles into a uniformly rotating, less massive NS due to magnetic braking and viscosity. These explorations suggest that detecting massive NSs is challenging and sets a timescale for detection. We calculate the signal-to-noise ratio of GW emission, which confirms that any detector cannot detect them immediately, but detectable by Einstein Telescope and Cosmic Explorer over months of integration time, leading to direct detection of NSs.

**Friday afternoon session / 61**

## A New Approach to Quantizing the General Relativity

**Author:** Abdel Nasser Tawfik[1]

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General theory and quantum mechanics are fundamentally very different theories with distinct formulations. Nevertheless, both of them claim to predict how Nature works! The everlasting battle for exploring and understanding the Universe and for privileging a consistent perception of reality is therefore awaiting a consolidator rather than a conqueror. This should be capable of either unifying those two different benchmarks or at least bringing one closer to the other! The latter describes the consolidating approach we are introducing here. We are not suggesting alternatives to GR. Also, we are not aiming at replacing QM by another theory. The present approach preserves the current versions of both theories. The applicability of GR and QM are solely enlarged so that sensical predictions become feasible at all scales. This was only possible, when finite gravitational fields are integrated in QM and quantum-mechanical aspects are then properly imposed on GR. We find that the additional curvatures that emerged with the quantization are associated with a maximal proper force, which is apparently related to the quantum-mechanical jumps characterizing the quantized metric tensor.

**Thursday afternoon session / 62**

## On quasinormal modes in 4D black hole solutions in the model with anisotropic fluid

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We consider a family of 4-dimensional black hole solutions
governed by natural number $q = 1, 2, 3, \dots$, which appear in the model with anisotropic fluid and the equations of state: $p_r = -\rho(2q-1)^{-1}$, $p_t = -p_r$, where $p_r$ and $p_t$ are pressures in radial and transverse directions, respectively, and $\rho > 0$ is the density. These equations of state obey weak, strong and dominant energy conditions. For $q = 1$ the metric of the solution coincides with that

of the Reissner-Nordstr\"om one. The global structure of solutions is outlined, giving rise to Carter-Penrose diagram of Reissner-Nordstr\"om or Schwarzschild types for odd $q = 2k+1$ or even $q = 2k$, respectively. Certain physical parameters corresponding to BH solutions
(gravitational mass, PPN parameters, Hawking temperature and entropy) are calculated. We obtain and analyse the quasinormal modes for a test massless scalar field in the eikonal approximation. For limiting case $q = +\infty$, they coincide with the well-known results for the Schwarzschild solution. We show that the Hod conjecture which connect the Hawking temperature and the damping rate is obeyed for all $q \geq 2$ and all (allowed) values of parameters.

**Wednesday afternoon session / 63**

## Radiative Penrose process: energy gain by a single radiating charged particle in ergosphere of rotating black hole

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We demonstrate an extraordinary effect of energy gain by a single radiating charged particle inside the ergosphere of a Kerr black hole in presence of magnetic field. We solve numerically the covariant form of the Lorentz-Dirac equation reduced from the DeWitt-Brehme equation and analyze energy evolution of the radiating charged particle inside the ergosphere, where the energy of emitted radiation can be negative with respect to a distant observer in dependence on the relative orientation of the magnetic field, black hole spin and the direction of the charged particle motion. Consequently, the charged particle can leave the ergosphere with energy greater than initial in expense of black hole's rotational energy. In contrast to the original Penrose process and its various modification, the new process does not require the interactions (collisions or decay) with other particles and consequent restrictions on the relative velocities between fragments. We show that such a Radiative Penrose effect is potentially observable and discuss its possible relevance in formation of relativistic jets and in similar high-energy astrophysical settings.

**Friday afternoon session / 64**

## Black hole extended thermodynamics

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We use certain compatibility conditions in the formalism of geometrothermodynamics and the non-extensivity property of black holes to argue that the corresponding fundamental equations should be given in terms of quasi-homogeneous functions. As a result, coupling constants in alternative theories of gravity, such as the cosmological constant, the Born-Infeld constant, etc., turn out to be thermodynamic variables, leading to extensions of classical black hole thermodynamics.

**Thursday afternoon session / 65**

## Gravity assist as a test of relativistic gravity

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We consider the gravity assist maneuver, that is, a correction of spacecraft motion at its passing near a planet, as a tool for evaluating the Eddington post-Newtonian parameters $\beta$ and $\gamma$, characterizing vacuum spherically symmetric gravitation fields in metric theories of gravity. We estimate the effect of variation in $\beta$ and $\gamma$ on a particular trajectory of a probe launched from the Earth's orbit and passing closely near Venus, where relativistic corrections slightly change the impact parameter of probe scattering in Venus's gravitational field. It is shown, in particular, that a change of $10^{-4}$ in $\beta$ or $\gamma$ leads to a shift of about 50 km in the probe's aphelion position.

**Wednesday afternoon session / 66**

## Supermassive PeVatron at the Galactic centre

**Author:** Arman Tursunov[1]

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A compact supermassive source SgrA*located at the center of our Galaxy has been observed at different wavelengths across the electromagnetic spectrum. It is the closest and largest in projection supermassive black hole candidate. At the same time, its particle acceleration capability related to the cosmic ray and neutrino messengers were not yet experimentally probed despite indirect indications of the existence of a PeVatron at the Galactic centre. In this talk, I will present a novel scenario of particle acceleration at the Galactic centre involving electromagnetic extraction of rotational energy from the central black hole. Modeling the black hole magnetosphere with the multiwavelength flaring activity of SgrA*, I will show that the maximum energy of accelerated protons may reach a few PeV at the source, contributing thus to the knee of the observed cosmic ray spectrum at the Earth's surface.

**Wednesday afternoon session / 67**

## Gamma-ray burst observations with the GRB IKI Follow up Network

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We present recent observations of gamma-ray bursts using the GRB IKI Follow up Network. In particular, we are discussing observations of the long duration GRB 221009A.The burst is the brightest one which registered almost all space-born gamma-ray detectors and saturated most of them. Besides of brightness it is usual GRB at low redshift of z=0.151 and due to its near vicinity both highest energy gamma photons ever detected and statistically significant multicolor optical afterglow as well

as late SN was detected. We present optical multicolor observations and evidence of SN. We discuss properties of the source and SN/GRB 221009A. of the source and SN/GRB 221009A.

**Thursday afternoon session / 68**

## Wormholes in a Friedmann universe

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We consider the generalized Tolman solution of general relativity, describing the evolution of a spherical dust cloud in the presence of an external electric or magnetic field. In such models, we study the possible existence of wormhole throats defined as spheres of minimum radius at a fixed time instant, and prove the existence of throats in the elliptic branch under certain conditions imposed on the arbitrary functions that are present in the solution. It is further shown that such dust clouds with throats can be inscribed into closed isotropic cosmological models filled with dust to form wormholes which exist for a finite period of time and experience expansion and contraction together with the corresponding cosmology. Explicit examples and numerical estimates are presented.

**Thursday afternoon session / 69**

## General radially moving references frames in the black hole background

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We consider general radially moving frames realized in the background of nonextremal black holes having causal structure similar to that of the Schwarzschild metric. In doing so, we generalize the Lemaître approach, constructing free-falling frames which are built from the reference particles with an arbitrary specific energy $e_0$ including $e_0 < 0$ and a special case $e_0 = 0$. The general formula of 3-velocity of a freely falling particle with the specific energy $e$ with respect to a frame with is presented. Using our radially moving frames, we consider also nonradial motion of test particles including the regions near the horizon and singularity. We also point out the properties of the Lemaître time at horizons depending on the frame and sign of particle energy.

**Monday morning session / 70**

## X-Ray Polarimetry: a new breakthrough in Relativistic Astrophysics

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At the beginning of X-Ray Astronomy Vitali Ginzburg stated that polarimetry would play a major role as a diagnostic in this domain. Experiments of Polarimetry were trailing after a few years the progresses of the discipline. But when Giacconi performed the revolution of the optics, polarimetry,

totally mismatched in sensitivity, was kept aside for almost 35 years.
The situation totally changed with the invention of detectors based on the photoelectric effect in gas.
The Imaging X-Ray Polarimetry Explorer, based on this technique, allowed to extend to polarimetry the break-through in sensitivity performed with the Einstein Satellite.
Data from IXPE, by introducing two new observational parameters are challenging many established views in Relativistic Astrophysics.

**Monday afternoon session / 72**

## TBD

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online talk

**Wednesday morning session / 73**

## Newborn Neutron Star Activities in Gamma-ray Burst

**Authors:** Chris Fryer[1]; Jorge Armando Rueda Hernandez[2]; L. M. Becerra[None]; Remo Ruffini[3]; Yu Wang[4]

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The collapse of the CO star forms a newborn neutron star (νNS) and triggers a supernova (SN) explosion. Mass and angular momentum are transferred to the νNS through fallback accretion. The energy from this accretion powers the gamma-ray burst prompt emission, while the synchrotron radiation fueled by the spinning νNS, explains the afterglow. Taking GRB 171205A as an example, we calculate the νNS's mass, angular momentum, and rotational evolution, fit the afterglow lightcurve, and determine that the SN explosion occurred within at most 7.36 hours before the GRB trigger.

**Tuesday morning session / 74**

## The Cerenkov Telescope Array in a multi-wavelength context

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The advent of the Cerenkov Telescope Array (CTA) will increase dramatically the number of detected very-high energy transients and will improve the accuracy of their variability timescale sampling. A number of facilities at lower energies are being designed and developed to guarantee accurate follow-up, identification, and monitoring of the counterparts to the TeV emitters. Within this framework, I will present a project for dedicated observational support of the CTA at radio, infrared and optical wavelengths, to be implemented as part of the "CTA Plus" program funded by the Italian Research Ministry under the EU PNRR aegis.

**Wednesday morning session / 75**

## TBD

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**Wednesday morning session / 78**

## Gaining understanding of gravitational wave emission in the earliest phases of long GRBs: sweeping frequencies and energetics

**Author:** Carlo Luciano Bianco[1]

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Due to the technical time delay, greater than $\sim$ 40 s, of the XRT instrument on board the Neil Gehrels Swift Observatory satellite, we are not able to observe the x-ray emission occurring less than $\sim$ 40 s after a gamma-ray burst (GRB) trigger time. A new strategy is indicated here of using the cosmological dilatation of time in the observer rest frame measured in high redshift GRBs to observe in the GRB cosmological rest-frame their earliest X-ray emission by Swift/XRT even less than 10 s after the trigger. We illustrate this procedure using 353 GRBs with well-defined cosmological redshift, based on the \textit{NASA-Swift GRB Table}. We compare and contrast the time delay between the trigger of the source and the first observation by Swift/XRT as measured in the observer frame (OTD) and the corresponding delay measured in GRBs' cosmological rest-frame (RTD). We consider as specific prototypes GRB 090423 at $z = 8.2$ with an RTD of 8.2~s, GRB 090429B at $z \sim 9.4$ with an RTD of 10.1~s, as well as the GRB 220101A at $z = 4.6$ with an RTD of 14.2~s. This opens a new possibility for probing the first episode of the binary-driven hypernova (BdHN) model linked to the origin and early appearance of the newborn neutron star ($\nu$NS) and the first clear manifestation of a transition from a Jacobi to a Maclaurin sequence prior to the onset of the GRB afterglow.

**Wednesday morning session / 79**

## Exploring the Progenitor of the Crab Nebula and Crab Pulsar: Insights from Binary-Driven Hypernovae

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We propose that the progenitor of the Crab Nebula and the Crab pulsar shares similarities with binary-driven hypernovae. The understanding of binary-driven hypernovae has revealed the crucial role played by the explosion of the supernova, as well as the hypercritical accretion of the supernova ejecta onto the binary companion neutron star (NS) and the newborn NS (νNS) in determining the dynamics of gamma-ray bursts (GRBs). The synchrotron emission resulting from the νNS-pulsar emission and the accreted supernova ejecta onto the νNS gives rise to X-ray afterglows. Notably, we find evidence that the X-ray afterglow luminosity of GRB 190114C, selected as a prototype binary-driven hypernova, when extrapolated to 1000 years, coincides with the presently observed emission of the Crab Nebula. To model the νNS, we employ the equilibrium sequence of Maclaurin spheroids. By ensuring that the νNS period extrapolated to 1000 years matches that of PSR B0531+21 (the Crab pulsar), we determine the initial spin of the νNS to be 0.9 ms. Subsequently, we track the evolution of the eccentricity, which manifests itself through the release of rotational and gravitational energy of the νNS-pulsar.

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## Limitations on the emitting particles spatial distribution and heating mechanism in relativistic jets

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Recent VLBI observations have revealed the AGNs with double- and triple-peaked transverse intensity profiles, particularly, M87 (Hada 2017, Walker et al. 2018) and 3C 273 (Bruni et al. 2021). There can be several reasons for such intensity profiles: (i) boosting and de-boosting of the emission from different parts of the jet; (ii) a spatial distribution of non-thermal electrons, which can be produced due to developing instabilities (e.g., McKinney 2006, Chatterjee 2019, Hardee & Eilek 2011, Nikonov et al. submitted), shear acceleration (Ostrowski 1990, 1998), Ohmic heating or equipartition (Lyutikov et al. 2005); (iii) a non-uniform structure of the jet; (iv) opacity effects (e.g., Zakamska et al. 2008). Many of these effects can contribute simultaneously (e.g. Gabuzda et al. 2021).

In presented work, we use magnetohydrodynamic semi-analytical models by Lyubarsky 2009 and Beskin et al. 2017 to explore the effect of stratified jet structure on the total intensity profiles. We show that double-peaked profiles appear either in the models with high maximal Lorentz factors or in optically thick conditions, and triple-peaked profiles in radio galaxies constrain the fraction of the emitting particles in a jet. The preferred models are the localization of non-thermal electrons at the jet edges and Ohmic heating.

**Thursday morning session / 82**

## Physics on the event horizon scale with millimetre and submillimetre interferometry

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Impressive progress has been achieved recently in studies addressing fundamental physical processes near the event horizon scale of putative cosmic black holes. The detection of gravitational waves, the near infrared interferometry measurements of relativistic stellar orbits and accretion disk hot spot motion in the Galactic Centre, and the millimetre interferometry imaging of the strong gravitational lensing on scales down to several Schwarzschild radii are presently the best evidence for the existence of black holes. These areas of study will continue to draw substantial attention in the coming years, as the results obtained until now still admit several alternative explanations featuring, for example, such exotic entities as wormholes and gravastars. In millimetre and submillimetre bands, significant advances in the sensitivity and resolution of interferometric measurements should enable the most stringent tests for discerning between black holes and their alternatives. These tests will include improved direct imaging of the event horizon scale at 86, 230, and 345 GHz, accurate polarimetric and Faraday rotation measurements, precise astrometric observations of the hot spot motion in the Galactic Centre, and detailed studies of the photon rings in a number of AGN. Current status and future prospects of these measurements will be discussed in this presentation.

**Friday morning session / 83**

## The transformation of the rotational energy of a Kerr BH

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We analyze the "ballistic method" of rotational energy extraction from an Kerr black hole (BH) by massive particle decay in the BH ergosphere pioneered by Roger Penrose. We focus on the negative energy counterrotating particles in-going to the horizon and evaluate the feedback on the BH irreducible mass (ΔMirr > |E1|). The change in irreducible mass is a function of the ratio of the particle mass μ1 to the mass of BH. In the limit μ1/M ⟶ 0, ΔMirr/|E1| ⟶ ∞, all the reduced extractable energy goes into the irreducible mass, resulting in high irreversibility.

**Wednesday afternoon session / 84**

## Constraining Supernova Ia progenitors by their locations in host galactic disc

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Over the past decade, substantial evidence has emerged supporting the presence of diverse progenitor channels leading to Type Ia Supernovae (SNe Ia). Among these channels, there are SNe Ia

originating from carbon-oxygen white dwarfs with sub-Chandrasekhar masses. These white dwarfs undergo detonation and explosion triggered by primary detonation in the helium shell, which has been accreted from a companion star. This double-detonation model predicts a correlation between the age of the progenitor system and the near peak brightness: the younger the exploding progenitors, the brighter the supernovae. Here, we present our recent achievements, demonstrating the validity of the anticipated correlation. To accomplish this, we studied the spatial distribution of nearby SNe Ia within host galactic discs and estimate the ages of their progenitor populations using various approaches, including the analysis of SNe light curve decline rates versus the vertical age gradients in discs, the distances from host spiral arms, and versus the stellar population properties in the star formation desert phenomenon and beyond.

**Wednesday afternoon session / 86**

## On direct and inverse Schwinger process in pair plasma

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We consider interaction between strong uniform electric field and electron-positron plasma. Depending on initial pair distirbution in momentum space pairs are either created or annihilated in external field. Accounding for back reaction of pairs on the electric field leads in the former case to damped plasma oscillations, while in the latter case to energy transfer from rest mass into internal energy of pairs.

**Thursday morning session / 87**

## Compact Star Merger as Progenitor of Low Redshift GRBs and the Occurrence Rates of Gravitational Sources and Kilonovae

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Bimodal distribution of duration of gamma-ray bursts (GRBs) has led to two progenitors; compact star mergers (two neutron stars, NSs or a NS and a black hole), for short GRBs (SGRBs),
and collapsars for long GRBs (LGRBs). It is expected that formation rate (FR) of LGRBs should be similar to the cosmic SFR, while that of SGRBs to be delayed relative to the SFR.
The localization of some LGRBs in star forming galaxies and some SGRBs away form such regions support this expectation. Also SGRBs are associated with gravitational wave (GW) sources and kilonovae.
However, several independent investigations of the FRs of LGRBs, using the Efron-Petrosian nonparametric method show a that is significantly larger than SFR at low redhifts.
I will review these results, present a new result on the FR of SGRBs, and show that decomposition of the FR of LGRBs into a SFR and low redshift components leads a low redshift
FR similar to that of SGRBs and delayed SFR. These suggest that low redshift LGRBs also have compact star mergers as progenitor increasing rate of the GW sources and kilonovae.
Recent discovery of association of a low redshift LGRB with a kilonova complements our findings.

**Friday morning session / 88**

## Probing episodes of phenomena associated with naturally produced GRB using X-ray free electron lasers

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Gamma-ray bursts (GRB) are the most energetic explosions that occur naturally in distant galaxies [1]. Their analysis facilitates the probing of early Universe and its expansion, the understanding of stellar evolution, the analysis of high energy phenomena and of the matter under extreme conditions [2, 3, 4]. GRBs constitute excellent natural laboratory settings to test the fundamental physics theories the properties of matter at data on matter-radiation interaction. This analysis enabled by the data acquisition Earth orbiting satellites may be complemented by experiments that can be conducted in a controlled manner in laboratories. The constant improvement of the X-ray free electron lasers facilities [5, 6] allow the realization of highly integrated projects [7, 8]. Experiments that would mimic the conditions in the outer galactic region and that can be conducted are: i) study of matter at extreme conditions, ii) analysis of matter dynamics at the atomic and molecular level employing pump-probe experiments on pulsed molecular supersonic beams, iii) study of electronic structure of matter under high magnetic fields, and iv) study the DNA mutations to test the hypothesis that GRB associated radiation with optimal intensities at the sea level could lead to bio-diversification [9].

**Thursday afternoon session / 89**

## Physics of quadrupolar compact astrophysical objects

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Theoretical and observational efforts are being pursued to understand and test general relativity. The ideal regime for such surveying involves the strong gravitational fields in the vicinity of the astrophysical black holes and compact objects, which are not directly accessible. Large international collaborations like the Event Horizon Telescope, and LISA, among many others, make access to a wide range of observational data. Mostly, it is assumed that astrophysical black holes are described by Kerr solution. However, others can also imitate a blackhole's properties, making it challenging when one tries to link the models to the observation. The black hole mimickers are currently of significant interest in the astrophysics communities. It appears essential to explore departures due to exercising relatively small parameters that can be taken as the additional physical degrees of freedom to the set-up and facilitate the link to the observational data with analytical and numerical approaches. This talk will present the construction of such an alternative background and be followed up by a recap on the physics and astrophysical properties that one expects to observe, using analytical and numerical methods and testing them with observational data.

**Friday afternoon session / 90**

## Revival of Descartes-Leibniz debate as a guide for a unification theory by removing singularities

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This paper revives the Descartes-Leibniz debate on the constant quantity of motion. This idea is based on keeping the total energy E=mc2 as a constant where the energy and the mass are independent of the form and speed even when the latter converges to the speed of light. With the increase of the speed, the object transforms the rest energy denoted here as the unexposed energy. The energy transformation process ends when the unexposed energy is completely transformed to an energy with a kinetic character denoted as exposed energy. This is used in the Lagrangian to derive the equations of motion. The exposed energy expresses the intensity of the field and is represented by another inherent characteristic: the energy state. At rest it is associated with the Schwarzschild radius for masses larger than Planck's mass. For smaller masses it is associated with the classical radius. The maximum energy state corresponds to the Plank length. The radii associated with different energy states are found using mcr=ah. The new model drops the elementary charge, the gravitational constant and unifies gravitation with electromagnetism. It leads to a new gravitation law with quantum character whose applicability limit is up to the Planck length.

**Wednesday afternoon session / 91**

## Analyses of QPOs in the background of deformed compact object

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Many Galactic black holes and neutron stars sources in Low-Mass X-Ray Binaries (LMXBs) exhibit quasi-periodic oscillations (QPOs) in the observed X-ray fluxes in their peaks. There are models of high frequency QPOs (HF QPOs) that relate this oscillatory motion to the properties of accretion disk formed in the vicinity of a compact object. Our interest is the study this phenomena in the black holes systems, since this HF QPO peaks are usually detected for a given source at constant frequencies ratio of small natural numbers, typically in a 3 : 2 ratio. In this work, we are considering a static and axially symmetric spacetime parametrized by a quadrupole and analyses the interplay between different parameters in this setup considering various HF QPO models.