XVII Marcel Grossmann Meeting - Pescara
Multi-Messenger parallel session, 12 July 2024

How to do multi-messenger forecasts in the Einstein Telescope era: addressing present and future challenges

Ulyana Dupletsa

in collaboration with

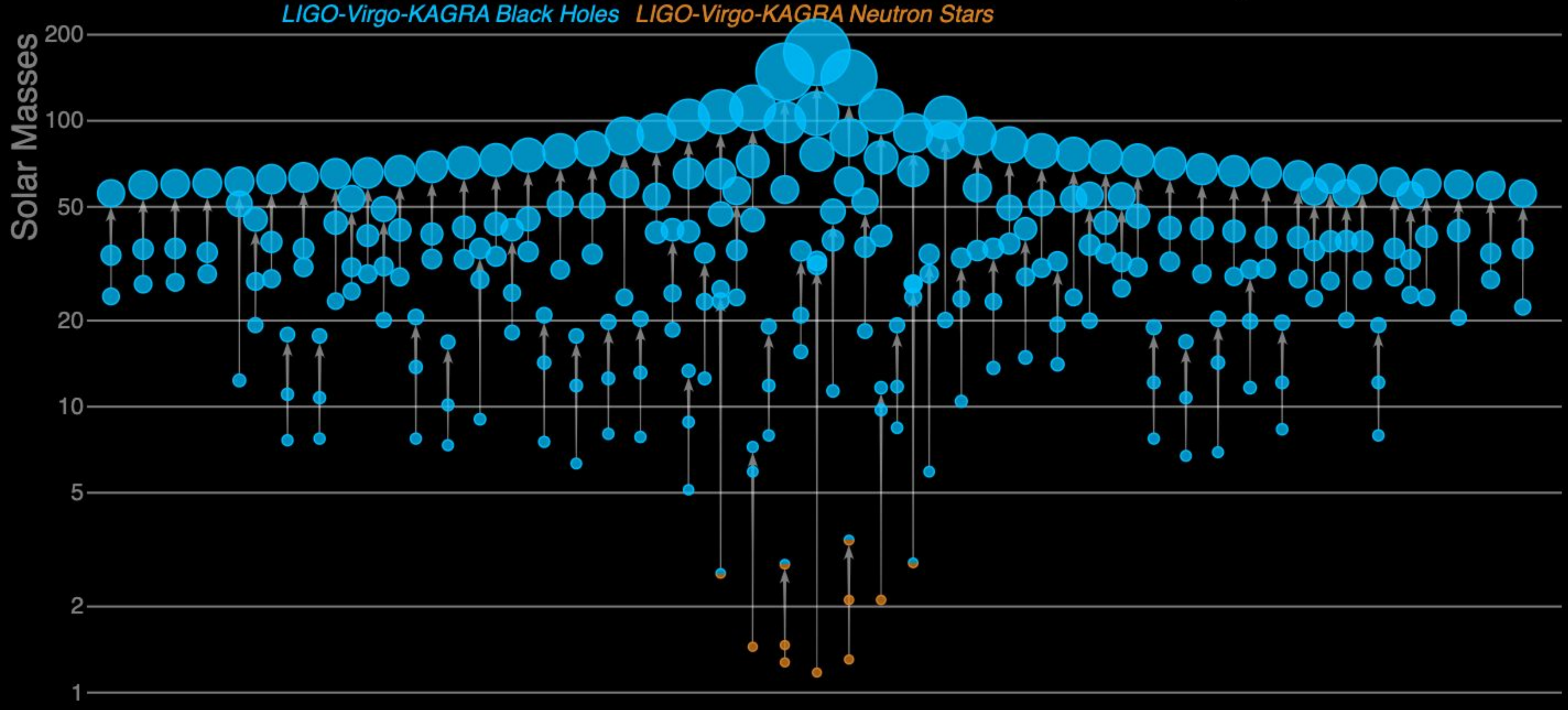
Marica Branchesi, Biswajit Banerjee, Stefano Foffa, Jan Harms, Nandini Hazra, Francesco Iacovelli, Eleonora Loffredo, Michele Mancarella, Michele Maggiore, Michela Mapelli, Niccolò Muttoni, Samuele Ronchini, Filippo Santoliquido, Jacopo Tissino

GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

INFN

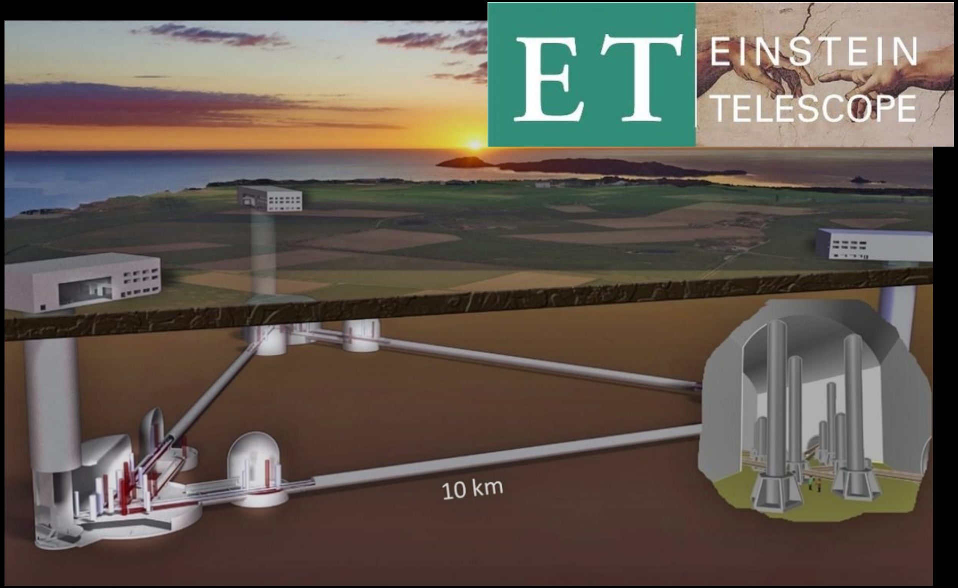
EINSTEIN TELESCOPE

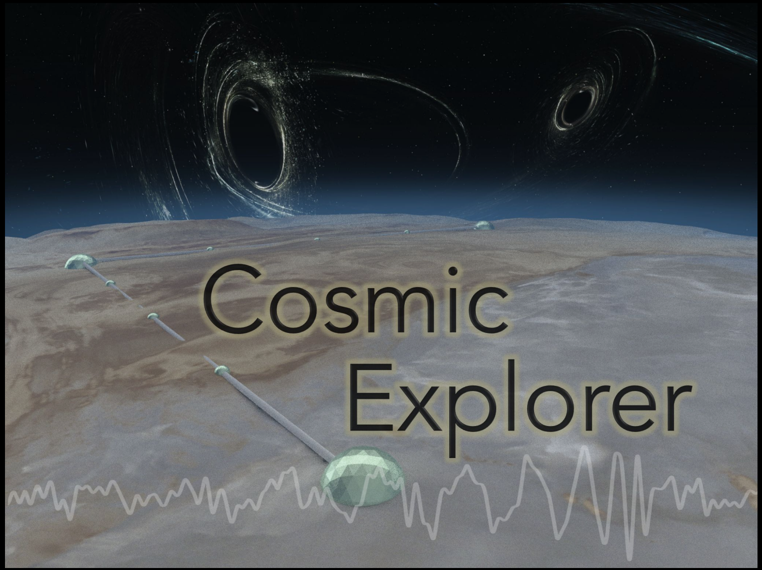
Masses in the Stellar Graveyard



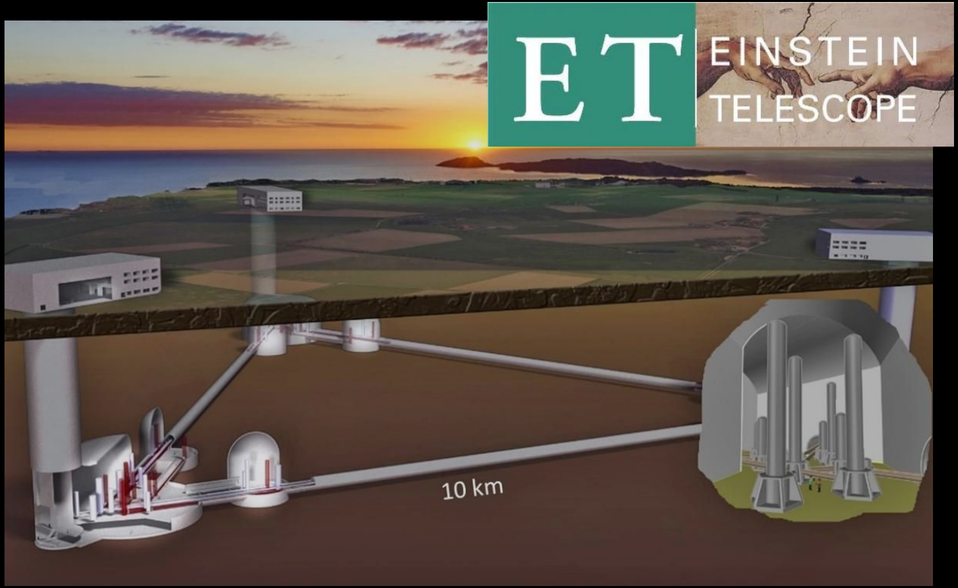
LIGO-Virgo-KAGRA | Aaron Geller | Northwestern

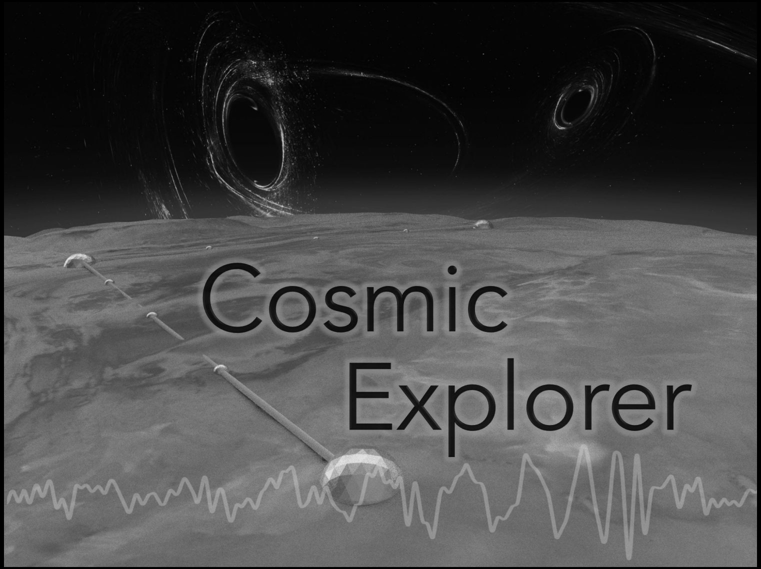
Next-generation ground-based GW detectors





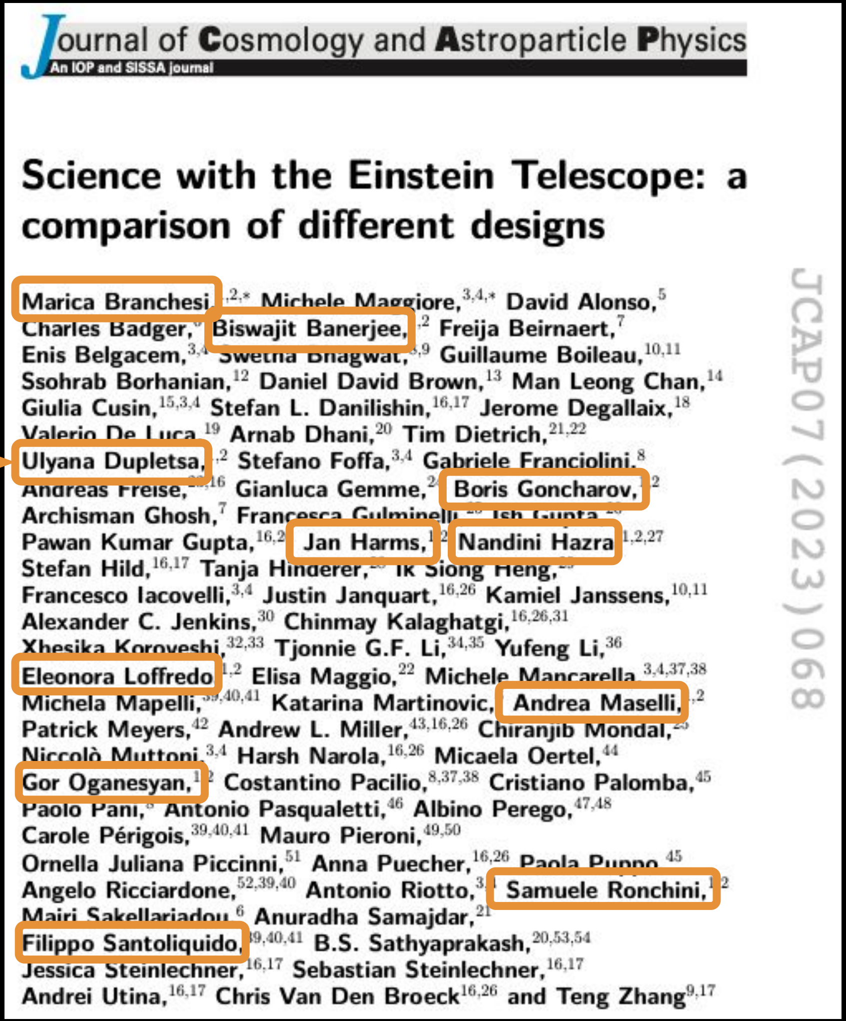
Next-generation ground-based GW detectors





- 1e5 BBHs
- 1e5 BNSs

[Maggiore et al., 2020]


Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Science with the Einstein Telescope: a comparison of different designs

Marica Branchesi,[1,2,*] Michele Maggiore,[3,4,*] David Alonso,[5]
Charles Badger,[6] Biswajit Banerjee,[1,2] Freija Beirnaert,[7]
Enis Belgacem,[3,4] Swetha Bhagwat,[8,9] Guillaume Boileau,[10,11]
Ssohrab Borhanian,[12] Daniel David Brown,[13] Man Leong Chan,[14]
Giulia Cusin,[15,3,4] Stefan L. Danilishin,[16,17] Jerome Degallaix,[18]
Valerio De Luca,[19] Arnab Dhani,[20] Tim Dietrich,[21,22]
Ulyana Dupletsa,[1,2] Stefano Foffa,[3,4] Gabriele Franciolini,[8]
Andreas Freise,[16] Gianluca Gemme,[24] Boris Goncharov,[1,2]
Archisman Ghosh,[7] Francesca Gulminelli, Ish Gupta,
Pawan Kumar Gupta,[16,26] Jan Harms,[1,2] Nandini Hazra,[1,2,27]
Stefan Hild,[16,17] Tanja Hinderer, Ik Siong Heng,
Francesco Iacovelli,[3,4] Justin Janquart,[16,26] Kamiel Janssens,[10,11]
Alexander C. Jenkins,[30] Chinmay Kalaghatgi,[16,26,31]
Xhesika Koroveshi,[32,33] Tjonnie G.F. Li,[34,35] Yufeng Li,[36]
Eleonora Loffredo,[1,2] Elisa Maggio,[22] Michele Mancarella,[3,4,37,38]
Michela Mapelli,[39,40,41] Katarina Martinovic, Andrea Maselli,[1,2]
Patrick Meyers,[42] Andrew L. Miller,[43,16,26] Chiranjib Mondal,
Niccolò Muttoni,[3,4] Harsh Narola,[16,26] Micaela Oertel,[44]
Gor Oganesyan,[1,2] Costantino Pacilio,[8,37,38] Cristiano Palomba,[45]
Paolo Pani,[8] Antonio Pasqualetti,[46] Albino Perego,[47,48]
Carole Périgois,[39,40,41] Mauro Pieroni,[49,50]
Ornella Juliana Piccinni,[51] Anna Puecher,[16,26] Paola Puppo,[45]
Angelo Ricciardone,[52,39,40] Antonio Riotto,[3,4] Samuele Ronchini,[1,2]
Mairi Sakellariadou,[6] Anuradha Samajdar,[21]
Filippo Santoliquido,[39,40,41] B.S. Sathyaprakash,[20,53,54]
Jessica Steinlechner,[16,17] Sebastian Steinlechner,[16,17]
Andrei Utina,[16,17] Chris Van Den Broeck[16,26] and Teng Zhang[9,17]

JCAP07(2023)068

Science Reference Paper for the **CoBA study**

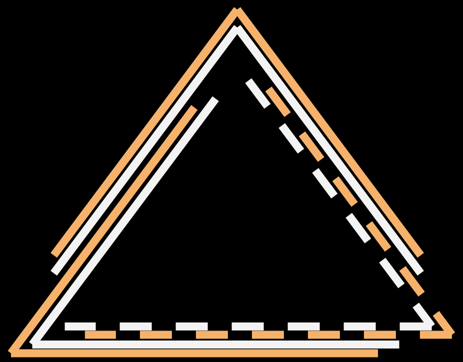
Work coordinated by **Marica Branchesi** and **Michele Maggiore**

(arXiv:2303.15923)

G S
S I

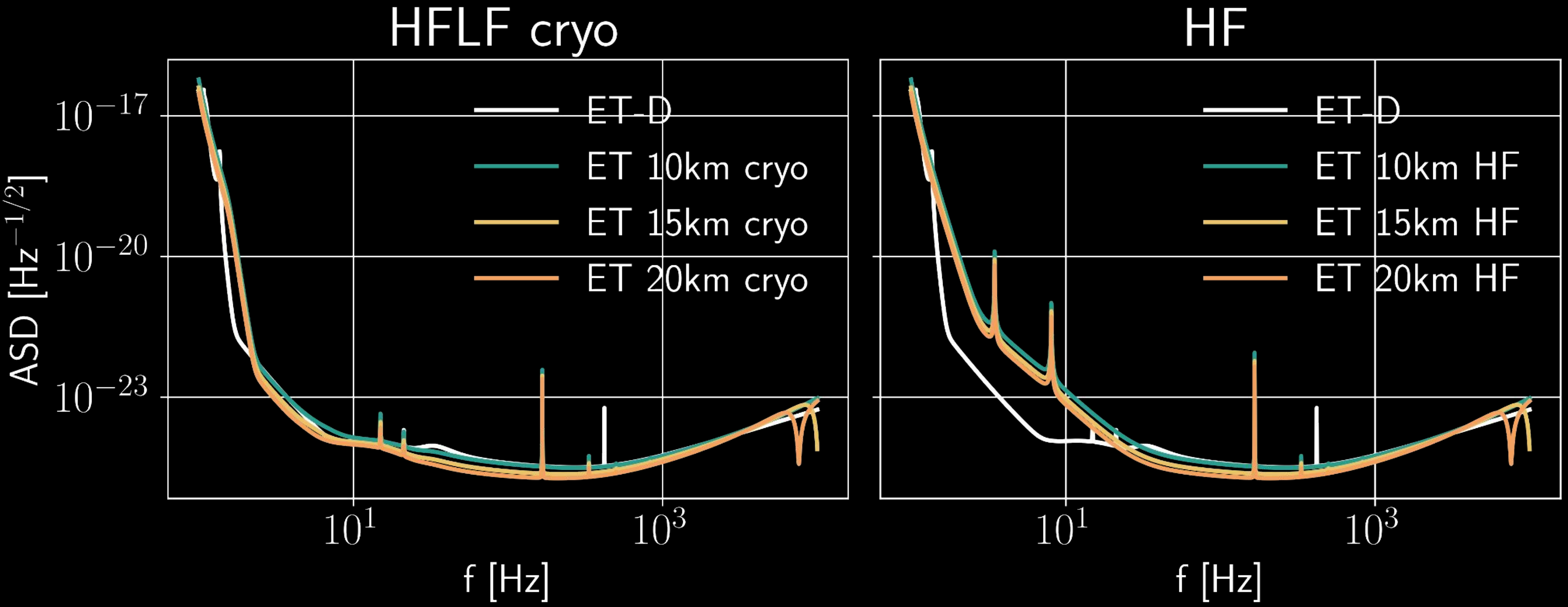
JCAP 07 (2023) 068

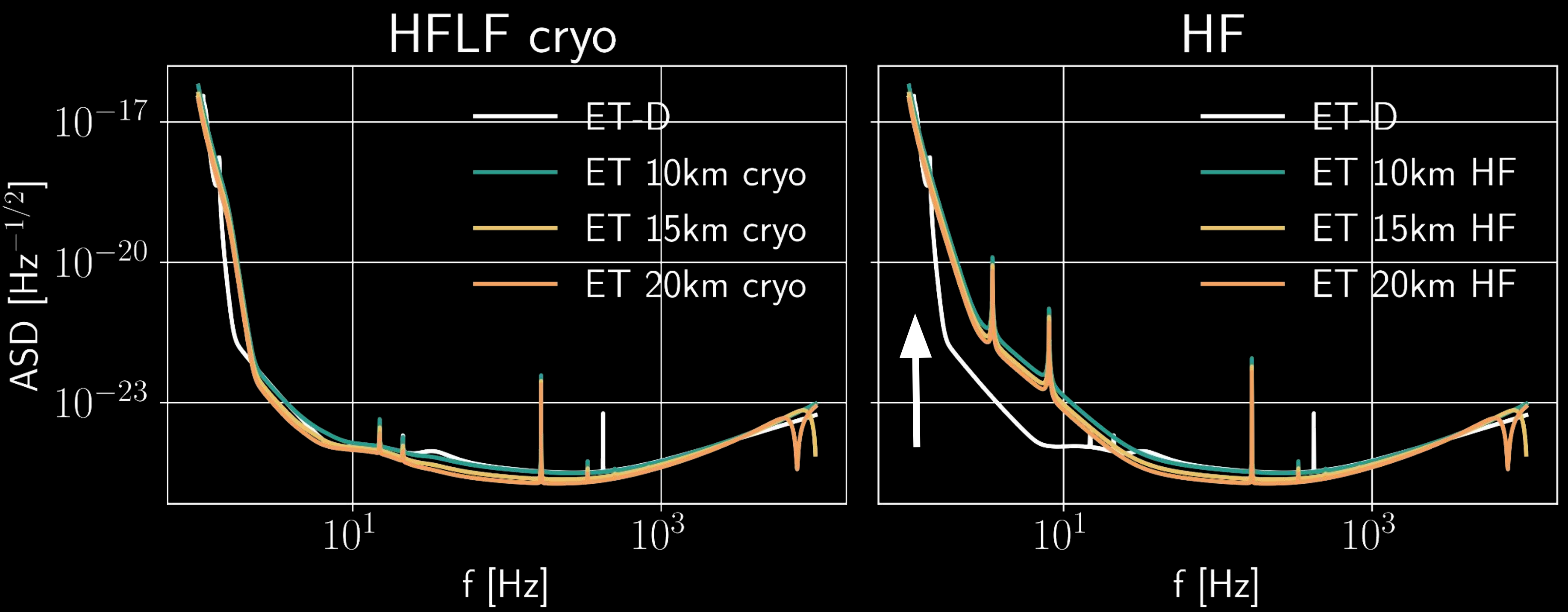
Reference Design of ET



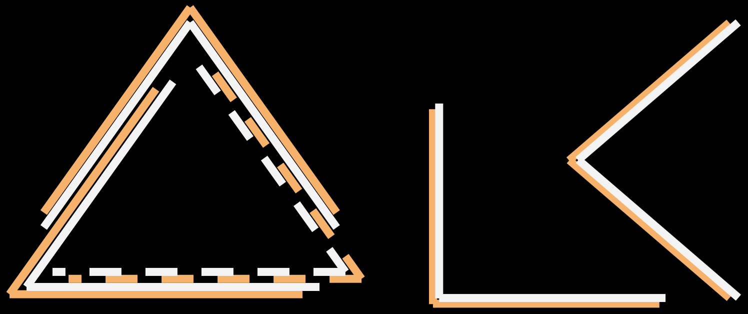
The reference ET configuration consists of:

- Triangular shape
- 10 km arms
- 3 nested detectors in xylophone configuration: HF + HFLF (cryogenic)


HFLF cryo
HF
ASD [Hz$^{-1/2}$]
10^{-17}
10^{-20}
10^{-23}
10^{1}
10^{3}
f [Hz]
ET-D
ET 10km cryo
ET 15km cryo
ET 20km cryo
ET 10km HF
ET 15km HF
ET 20km HF


HFLF cryo
HF
ASD [Hz$^{-1/2}$]
10^{-17}
10^{-20}
10^{-23}
10^{1}
10^{3}
f [Hz]
ET-D
ET 10km cryo
ET 15km cryo
ET 20km cryo
ET 10km HF
ET 15km HF
ET 20km HF

Different Configurations



- Changes in geometry: triangle vs 2L, different arm lengths
- Role of the low frequency instrument: what happens if we have only the HF part?

- **Triangle, 10 km arms (reference design)**
- **2L, 15 km arms, at 45º**
- **Triangle, 15 km arms**
- **2L, 20 km arms, at 45º**

From LVK parameter estimation to forecasts for ET

From signals to parameters

$$d = n + h(\vec{\theta}_{\mathrm{true}})$$

From signals to parameters

$$d = n + h(\vec{\theta}_{\rm true})$$

$$p(\vec{\theta}|d) \propto \mathcal{L}(\vec{\theta}|d)\pi(\vec{\theta})$$

From signals to parameters

$$d = n + h(\vec{\theta}_{\mathrm{true}})$$

$$p(\vec{\theta}|d) \propto \mathcal{L}(\vec{\theta}|d)\pi(\vec{\theta})$$

$$\mathcal{L}(d|\vec{\theta}) \propto \exp\left[-\frac{1}{2}\langle d - h(\vec{\theta})|d - h(\vec{\theta})\rangle\right]$$

From signals to parameters

$$d = n + h(\vec{\theta}_{\rm true})$$

$$p(\vec{\theta}|d) \propto \mathcal{L}(\vec{\theta}|d)\pi(\vec{\theta})$$

$$\mathcal{L}(d|\vec{\theta}) \propto \exp\left[-\frac{1}{2}\langle d - h(\vec{\theta})|d - h(\vec{\theta})\rangle\right]$$

matched-filtering

takes into account the
sensitivity of the detector!

From signals to parameters

$$d = n + h(\vec{\theta}_{\mathrm{true}})$$

$$p(\vec{\theta}|d) \propto \mathcal{L}(\vec{\theta}|d)\pi(\vec{\theta})$$

$$\mathcal{L}(d|\vec{\theta}) \propto \exp\left[-\frac{1}{2}\langle d - h(\vec{\theta})|d - h(\vec{\theta})\rangle\right]$$

matched-filtering

takes into account the sensitivity of the detector!

Forecasts for 3G Detectors

- Fisher matrix codes are **particularly useful to study the performance of future GW observatories**
- **Computationally convenient**: we can easily study entire populations (~1e5 events): each event takes fraction of a second to complete, which is to compare with full PE softwares as **Bilby** that take order of days to process a GW event

Fisher Matrix Primer

$$\mathcal{L}(d|\vec{\theta}) \propto \exp\left[-\frac{1}{2}\langle d - h(\vec{\theta})|d - h(\vec{\theta})\rangle\right]$$

$$h(\vec{\theta}) = h_0 + \Delta\theta^i h_i$$

expand around the true value at first order

$$\mathcal{L}(d|\vec{\theta}) = \exp\left[-\frac{1}{2}\Delta\theta^i\langle h_i|h_j\rangle\Delta\theta^j\right]$$

Fisher Matrix Primer

$$\mathcal{L}(d|\vec{\theta}) \propto \exp\left[-\frac{1}{2}\langle d - h(\vec{\theta})|d - h(\vec{\theta})\rangle\right]$$

$$h(\vec{\theta}) = h_0 + \Delta\theta^i h_i$$

expand around the true value at first order

$$\mathcal{L}(d|\vec{\theta}) = \exp\left[-\frac{1}{2}\Delta\theta^i \langle h_i|h_j\rangle \Delta\theta^j\right]$$

Gaussian Likelihood

Fisher Matrix

Fisher Matrix Primer

$$\mathcal{L}(d|\vec{\theta}) \propto \exp\left[-\frac{1}{2}\langle d - h(\vec{\theta})|d - h(\vec{\theta})\rangle\right]$$

$$h(\vec{\theta}) = h_0 + \Delta\theta^i h_i$$

expand around the true value at first order

$$\mathcal{L}(d|\vec{\theta}) = \exp\left[-\frac{1}{2}\Delta\theta^i \langle h_i|h_j\rangle \Delta\theta^j\right]$$

Gaussian Likelihood

Fisher Matrix

$$\Delta\theta^i = \theta^i - \theta^i_{\mathrm{inj}}$$

gwbench

S. Borhanian,
2021

GitLab link

GWFAST

F. Iacovelli,
M. Mancarella, et al.
2022

GitHub link

TiDoFM

Li et al.
2022

GitHub link

GWFish

U. Dupletsa, J. Harms,
et al.
2022

GitHub link

GWFISH

gwbench

S. Borhanian,
2021

GitLab link

GWFAST

F. Iacovelli,
M. Mancarella, et al.
2022

GitHub link

TiDoFM

Li et al.
2022

GitHub link

GWFish

U. Dupletsa, J. Harms, et al.
2022

GitHub link

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Science with the Einstein Telescope: a comparison of different designs

Marica Branchesi,[1,2,*] Michele Maggiore,[3,4,*] David Alonso,[5]
Charles Badger,[6] Biswajit Banerjee,[1,2] Freija Beirnaert,[7]
Enis Belgacem,[3,4] Swetha Bhagwat,[8,9] Guillaume Boileau,[10,11]
Ssohrab Borhanian,[12] Daniel David Brown,[13] Man Leong Chan,[14]
Giulia Cusin,[15,3,4] Stefan L. Danilishin,[16,17] Jerome Degallaix,[18]
Valerio De Luca,[19] Arnab Dhani,[20] Tim Dietrich,[21,22]
Ulyana Dupletsa,[1,2] Stefano Foffa,[3,4] Gabriele Franciolini,[8]
Andreas Freise,[23,16] Gianluca Gemme,[24] Boris Goncharov,[1,2]
Archisman Ghosh,[7] Francesca Gulminelli,[25] Ish Gupta,[20]
Pawan Kumar Gupta,[16,26] Jan Harms,[1,2] Nandini Hazra,[1,2,27]
Stefan Hild,[16,17] Tanja Hinderer,[28] Ik Siong Heng,[29]
Francesco Iacovelli,[3,4] Justin Janquart,[16,26] Kamiel Janssens,[10,11]
Alexander C. Jenkins,[30] Chinmay Kalaghatgi,[16,26,31]
Xhesika Koroveshi,[32,33] Tjonnie G.F. Li,[34,35] Yufeng Li,[36]
Eleonora Loffredo,[1,2] Elisa Maggio,[22] Michele Mancarella,[3,4,37,38]
Michela Mapelli,[39,40,41] Katarina Martinovic,[6] Andrea Maselli,[1,2]
Patrick Meyers,[42] Andrew L. Miller,[43,16,26] Chiranjib Mondal,[25]
Niccolò Muttoni,[3,4] Harsh Narola,[16,26] Micaela Oertel,[44]
Gor Oganesyan,[1,2] Costantino Pacilio,[8,37,38] Cristiano Palomba,[45]
Paolo Pani,[8] Antonio Pasqualetti,[46] Albino Perego,[47,48]
Carole Périgois,[39,40,41] Mauro Pieroni,[49,50]
Ornella Juliana Piccinni,[51] Anna Puecher,[16,26] Paola Puppo,[45]
Angelo Ricciardone,[52,39,40] Antonio Riotto,[3,4] Samuele Ronchini,[1,2]
Mairi Sakellariadou,[6] Anuradha Samajdar,[21]
Filippo Santoliquido,[39,40,41] B.S. Sathyaprakash,[20,53,54]
Jessica Steinlechner,[16,17] Sebastian Steinlechner,[16,17]
Andrei Utina,[16,17] Chris Van Den Broeck[16,26] and Teng Zhang[9,17]

JCAP07(2023)068

Science Reference Paper for the **CoBA study**

Work coordinated by Marica Branchesi and Michele Maggiore

(arXiv:2303.15923)

G S
S I

JCAP 07 (2023) 068

Contents

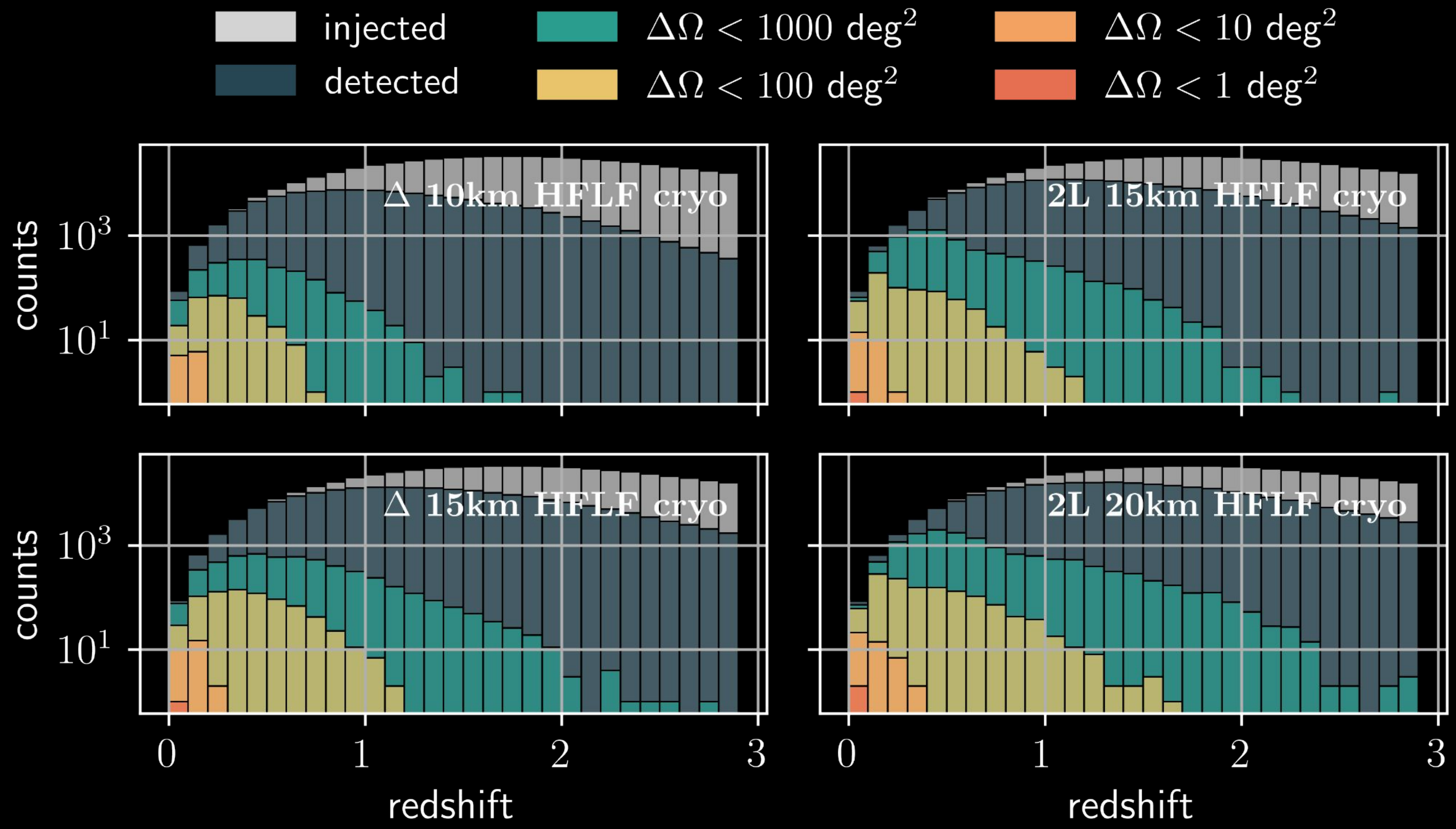
Contents

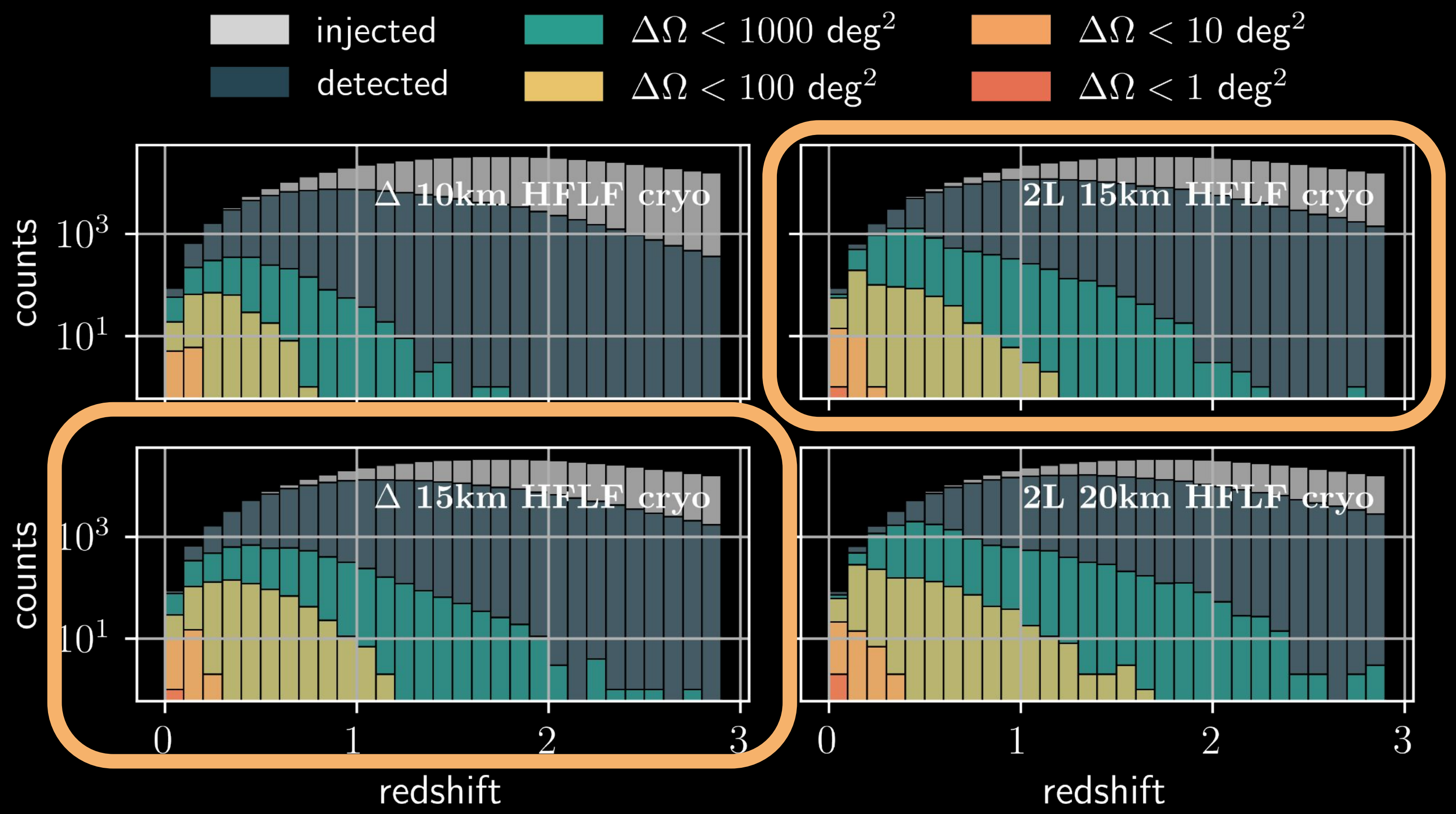
Starting Assumptions

- **IMRPhenomD_NRTidalv2**
- The BNS population was obtained using **MOBSE** (isolated binaries) with a local merger rate of 250 Gpc^{-3} yr^{-1} (to compare to the LVK result of 10-1700 Gpc^{-3} yr^{-1}
- 1 year of observations

Multi-Messenger Astronomy

Sky Localization


injected
detected
ΔΩ < 1000 deg²
ΔΩ < 100 deg²
ΔΩ < 10 deg²
ΔΩ < 1 deg²
Δ 10km HFLF cryo
2L 15km HFLF cryo
Δ 15km HFLF cryo
2L 20km HFLF cryo
counts
10³
10¹
0
1
2
3
redshift


injected
detected
$\Delta\Omega < 1000$ deg^2
$\Delta\Omega < 100$ deg^2
$\Delta\Omega < 10$ deg^2
$\Delta\Omega < 1$ deg^2
Δ 10km HFLF cryo
2L 15km HFLF cryo
Δ 15km HFLF cryo
2L 20km HFLF cryo
counts
10^3
10^1
0
1
2
3
redshift

Full (HFLF cryo) sensitivity detectors								
$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs				BNSs with $\Theta_v < 15^\circ$			
	Δ10	Δ15	2L 15	2L 20	Δ10	Δ15	2L 15	2L 20
10	11	27	24	45	0	1	2	5
40	78	215	162	350	8	22	20	33
100	280	764	644	1282	26	74	68	133
10000	2112	5441	7478	13482	272	632	1045	1725

Full (HFLF cryo) sensitivity detectors								
$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs				BNSs with $\Theta_v < 15^\circ$			
	Δ10	Δ15	2L 15	2L 20	Δ10	Δ15	2L 15	2L 20
10	11	27	24	45	0	1	2	5
40	78	215	162	350	8	22	20	33
100	280	764	644	1282	26	74	68	133
10000	2112	5441	7478	13482	272	632	1045	1725

Full (HFLF cryo) sensitivity detectors								
$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs				BNSs with $\Theta_v < 15^\circ$			
	Δ10	Δ15	2L 15	2L 20	Δ10	Δ15	2L 15	2L 20
10	11	27	24	45	0	1	2	5
40	78	215	162	350	8	22	20	33
100	280	764	644	1282	26	74	68	133
10000	2112	5441	7478	13482	272	632	1045	1725

HF sensitivity detectors								
$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs				BNSs with $\Theta_v < 15^\circ$			
	Δ10	Δ15	2L 15	2L 20	Δ10	Δ15	2L 15	2L 20
10	0	1	5	5	0	0	2	2
40	4	10	20	47	0	5	6	17
100	14	53	76	144	7	33	35	64
10000	145	548	1662	3378	80	336	672	1302

Full (HFLF cryo) sensitivity detectors								
$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs				BNSs with $\Theta_v < 15^\circ$			
	Δ10	Δ15	2L 15	2L 20	Δ10	Δ15	2L 15	2L 20
10	11	27	24	45	0	1	2	5
40	78	215	162	350	8	22	20	33
100	280	764	644	1282	26	74	68	133
10000	2112	5441	7478	13482	272	632	1045	1725

HF sensitivity detectors								
$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs				BNSs with $\Theta_v < 15^\circ$			
	Δ10	Δ15	2L 15	2L 20	Δ10	Δ15	2L 15	2L 20
10	0	1	5	5	0	0	2	2
40	4	10	20	47	0	5	6	17
100	14	53	76	144	7	33	35	64
10000	145	548	1662	3378	80	336	672	1302

Full (HFLF cryo) sensitivity detectors								
$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs				BNSs with $\Theta_v < 15^\circ$			
	Δ10	Δ15	2L 15	2L 20	Δ10	Δ15	2L 15	2L 20
10	**11**	27	24	45	0	1	2	5
40	**78**	215	162	350	8	22	20	33
100	**280**	764	644	1282	26	74	68	133
10000	**2112**	5441	7478	13482	272	632	1045	1725

HF sensitivity detectors								
$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs				BNSs with $\Theta_v < 15^\circ$			
	Δ10	Δ15	**2L 15**	**2L 20**	Δ10	Δ15	2L 15	2L 20
10	0	1	**5**	**5**	0	0	2	2
40	4	10	**20**	**47**	0	5	6	17
100	14	53	**76**	**144**	7	33	35	64
10000	145	548	**1662**	**3378**	80	336	672	1302

Full (HFLF cryo) sensitivity detectors								
$\Delta\Omega_{90\%}$ [deg^2]	**All orientation BNSs**				**BNSs with $\Theta_v < 15^\circ$**			
	Δ10	**Δ15**	**2L 15**	**2L 20**	**Δ10**	**Δ15**	**2L 15**	**2L 20**
10	11	27	24	45	**0**	1	2	5
40	78	215	162	350	**8**	22	20	33
100	280	764	644	1282	**26**	74	68	133
10000	2112	5441	7478	13482	**272**	632	1045	1725

HF sensitivity detectors								
$\Delta\Omega_{90\%}$ [deg^2]	**All orientation BNSs**				**BNSs with $\Theta_v < 15^\circ$**			
	Δ10	**Δ15**	**2L 15**	**2L 20**	**Δ10**	**Δ15**	**2L 15**	**2L 20**
10	0	1	5	5	0	0	**2**	**2**
40	4	10	20	47	0	5	**6**	**17**
100	14	53	76	144	7	33	**35**	**64**
10000	145	548	1662	3378	80	336	**672**	**1302**

Pre-Merger Alerts

detections within $z<1.5$

The importance of pre-merger alerts

Pre-merger detections are critical to detect the prompt/early multi-wavelength emission in order to:

- Probe the central engine of GRBs, and in particular to understand the jet composition, the particle acceleration mechanism, the radiation and energy dissipation mechanisms (VHE prompt CTA/ET synergy)
- To probe the structure of the outer sub-relativistic ejecta, early UV emission

[**B. Banerjee** et al., *Astronomy&Astrophysics* 678 (2023) A126]

Full (HFLF) cryo sensitivity detectors							
Configuration	$\Delta\Omega_{90\%}$	All orientation BNSs			BNSs with $\Theta_v < 15^\circ$		
	[deg^2]	30 min	10 min	1 min	30 min	10 min	1 min
Δ10 km	10	0	1	5	0	0	0
	100	10	39	113	2	8	20
	1000	85	293	819	10	34	132
	All detected	905	4343	23597	81	393	2312
Δ15 km	10	1	5	11	0	1	1
	100	41	109	281	6	14	36
	1000	279	806	2007	33	102	295
	All detected	2489	11303	48127	221	1009	4024
2L 15 km	10	0	1	8	0	0	0
	100	20	54	169	2	7	26
	1000	194	565	1399	23	73	199
	All detected	2172	9598	39499	198	863	3432
2L 20 km	10	2	4	15	1	1	2
	100	39	118	288	7	19	47
	1000	403	1040	2427	47	128	346
	All detected	4125	17294	56611	363	1588	4377

Full (HFLF) cryo sensitivity detectors							
Configuration	$\Delta\Omega_{90\%}$	All orientation BNSs			BNSs with $\Theta_v < 15^\circ$		
	[deg^2]	30 min	10 min	1 min	30 min	10 min	1 min
Δ10 km	10	0	1	5	0	0	0
	100	10	39	113	2	8	20
	1000	85	293	819	10	34	132
	All detected	905	4343	23597	81	393	2312
Δ15 km	10	1	5	11	0	1	1
	100	41	109	281	6	14	36
	1000	279	806	2007	33	102	295
	All detected	2489	11303	48127	221	1009	4024
2L 15 km	10	0	1	8	0	0	0
	100	20	54	169	2	7	26
	1000	194	565	1399	23	73	199
	All detected	2172	9598	39499	198	863	3432
2L 20 km	10	2	4	15	1	1	2
	100	39	118	288	7	19	47
	1000	403	1040	2427	47	128	346
	All detected	4125	17294	56611	363	1588	4377

HF sensitivity detectors							
Configuration	$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs			BNSs with $\Theta_v < 15^\circ$		
		30 min	10 min	1 min	30 min	10 min	1 min
Δ10 km	100	0	0	0	0	0	0
	1000	0	0	4	0	0	1
	All detected	0	3	317	0	0	26
Δ15 km	100	0	0	2	0	0	0
	1000	0	0	10	0	0	4
	All detected	2	8	891	0	1	84
2L 15 km	100	0	0	0	0	0	0
	1000	0	0	7	0	0	3
	All detected	0	7	743	0	1	69
2L 20 km	100	0	0	3	0	0	0
	1000	0	0	13	0	0	6
	All detected	2	11	1535	0	1	146

HF sensitivity detectors							
Configuration	$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs			BNSs with $\Theta_v < 15^\circ$		
		30 min	10 min	1 min	30 min	10 min	1 min
Δ10 km	100	0	0	0	0	0	0
	1000	0	0	4	0	0	1
	All detected	0	3	317	0	0	26
Δ15 km	100	0	0	2	0	0	0
	1000	0	0	10	0	0	4
	All detected	2	8	891	0	1	84
2L 15 km	100	0	0	0	0	0	0
	1000	0	0	7	0	0	3
	All detected	0	7	743	0	1	69
2L 20 km	100	0	0	3	0	0	0
	1000	0	0	13	0	0	6
	All detected	2	11	1535	0	1	146

HF sensitivity detectors							
Configuration	$\Delta\Omega_{90\%}$ [deg^2]	All orientation BNSs			BNSs with $\Theta_v < 15^\circ$		
		30 min	10 min	1 min	30 min	10 min	1 min
Δ10 km	100	0	0	0	0	0	0
	1000	0	0	4	0	0	1
	All detected	0	3	317	0	0	26
Δ15 km	100	0	0	2	0	0	0
	1000	0	0	10	0	0	4
	All detected	2	8	891	0	1	84
2L 15 km	100	0	0	0	0	0	0
	1000	0	0	7	0	0	3
	All detected	0	7	743	0	1	69
2L 20 km	100	0	0	3	0	0	0
	1000	0	0	13	0	0	6
	All detected	2	11	1535	0	1	146

No localized pre-merger detections!

Applications to Cosmology

Cosmology: ET + VRO

See Eleonora’s talk!

- Joint GW-kilonova detections!
- 1 year of observations
- 115 joint detections for 2L-20km-cryo
- Dependence on BNS merger rate normalization

VERA C. RUBIN
OBSERVATORY

Cosmology: ET + VRO

HFLF cryogenic		
Configuration	$\Delta H_0/H_0$	$\Delta\Omega_M/\Omega_M$
Δ10 km	0.009	0.832
Δ15 km	0.007	0.303
2L 15 km	0.006	0.370
2L 20 km	0.004	0.243

HF only		
Configuration	$\Delta H_0/H_0$	$\Delta\Omega_M/\Omega_M$
Δ10 km	0.065	1.23
Δ15 km	0.057	1.86
2L 15 km	0.066	1.31
2L 20 km	0.031	1.22

Dramatic reduction of joint detections without LF in both cases!

Conclusions

- All the triangular and 2L geometries that have been investigated can be the baseline of a **superb 3G detector**, that will allow to improve by orders of magnitude compared to 2G detectors
- The **2L-15km-45º configuration** in general offer a better scientific return with respect to the Δ-10km, and has a similar performance on all parameters (for both BBHs and BNSs) to the **Δ-15km**
- The **low frequency sensitivity** is crucial for exploiting the full potential of ET. In the HF-configuration only, independently of the chosen geometry, several scientific targets would be lost or significantly diminished
- **Data analysis** for the next-generation poses a great **challenge**

Thank You!

ulyana.dupletsa@gssi.it

GSSI