LISA science

LGWA synergies and multi messenger perspective

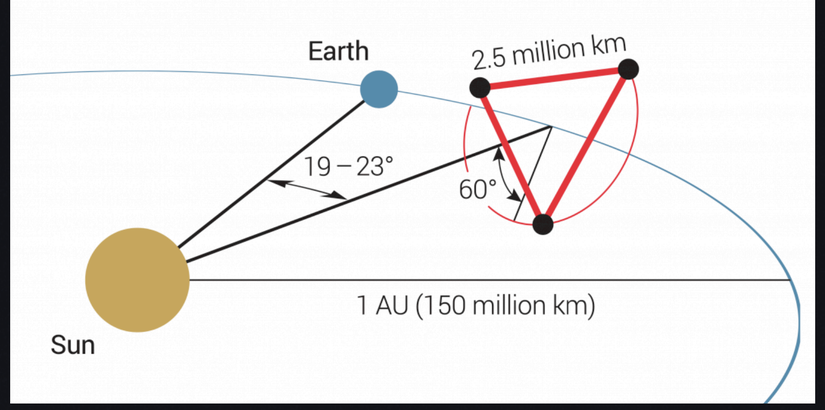
Alessandra De Rosa

INAF ISTITUTO NAZIONALE DI ASTROFISICA
IAPS ISTITUTO DI ASTROFISICA E PLANETOLOGIA SPAZIALI

LGWA meeting 2026

LISA

project status





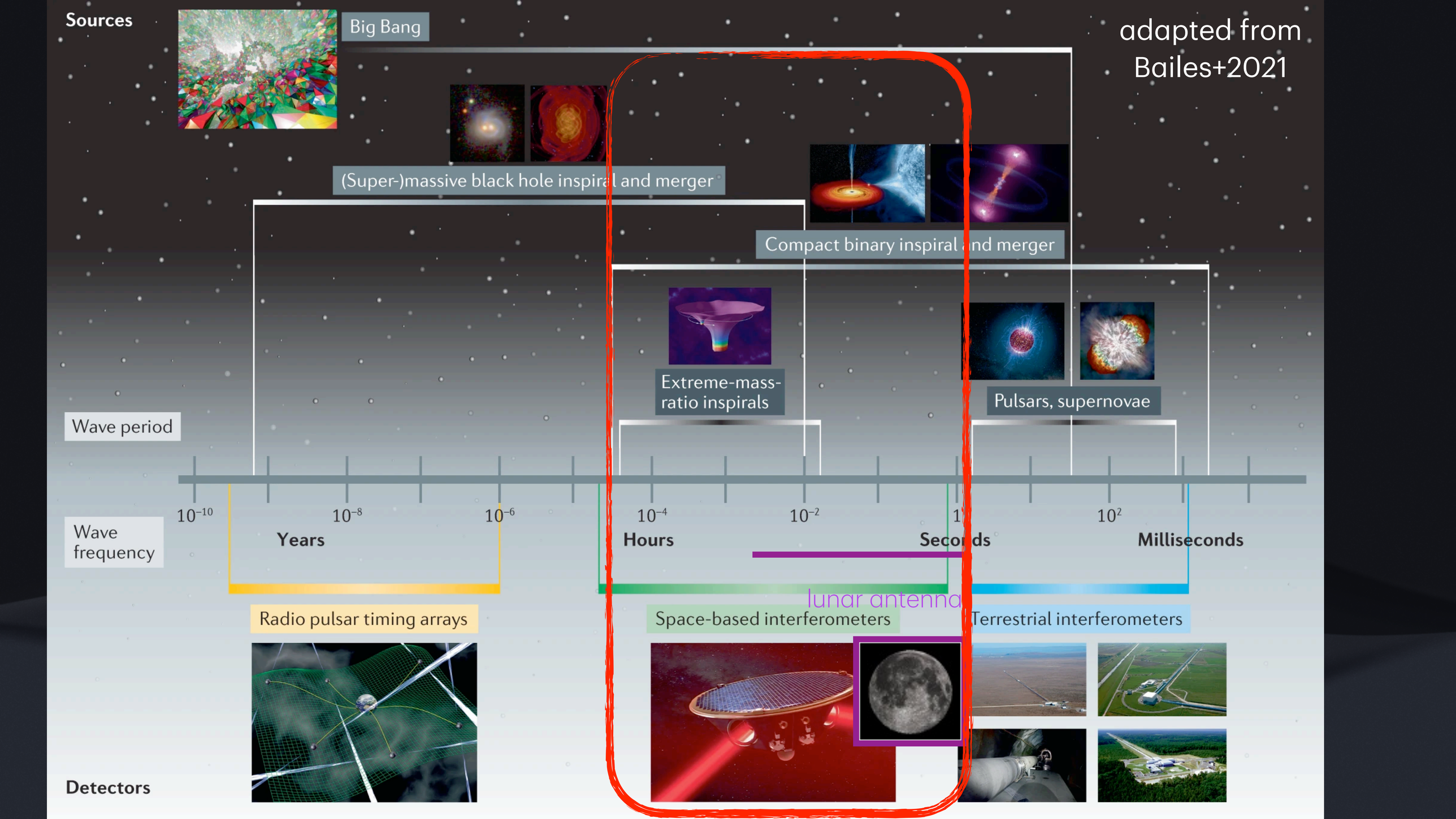
LISA is a large-scale space mission designed to detect gravitational waves in the mHz domain (0.1 mHz-0.1 Hz). It will be the first space-based gravitational wave observatory.

LISA will consist of three spacecraft separated by 2.5 million km in a triangular formation, following Earth about 50 million km in its orbit around the Sun.

The LISA launch is expected in 2035

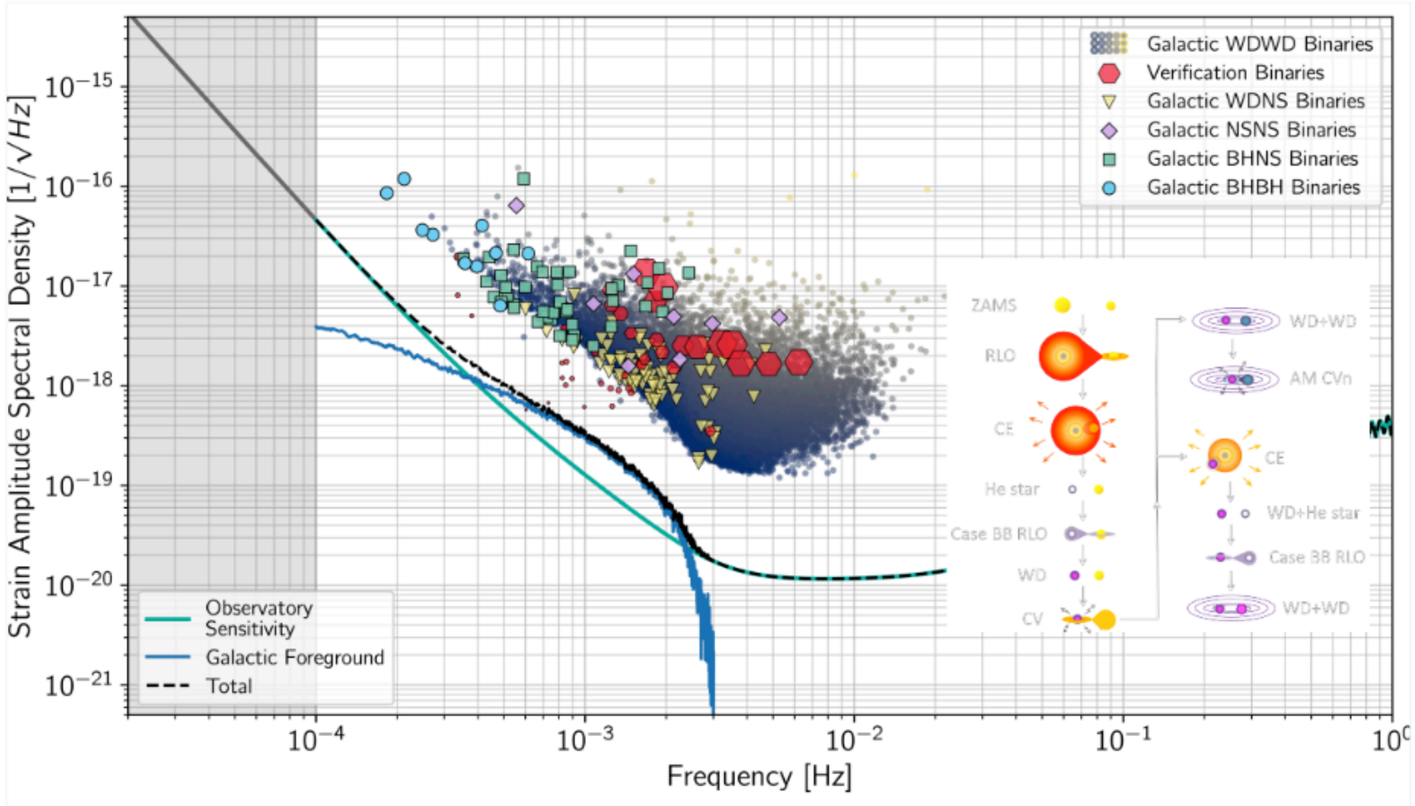
The LISA Consortium is a large international collaboration that combines the resources and expertise from scientists in many countries all over the world. Together with ESA, its member states, and NASA, the LISA Consortium is working to bring the LISA Mission to fruition.

LISA science projects


Sources
Big Bang
adapted from Bailes+2021
(Super-)massive black hole inspiral and merger
Compact binary inspiral and merger
Extreme-mass-ratio inspirals
Pulsars, supernovae
Wave period
Wave frequency
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^{2}
Years
Hours
Seconds
Milliseconds
lunar antenna
Radio pulsar timing arrays
Space-based interferometers
Terrestrial interferometers
Detectors

LISA science - Compact binaries

GW Astrophysics



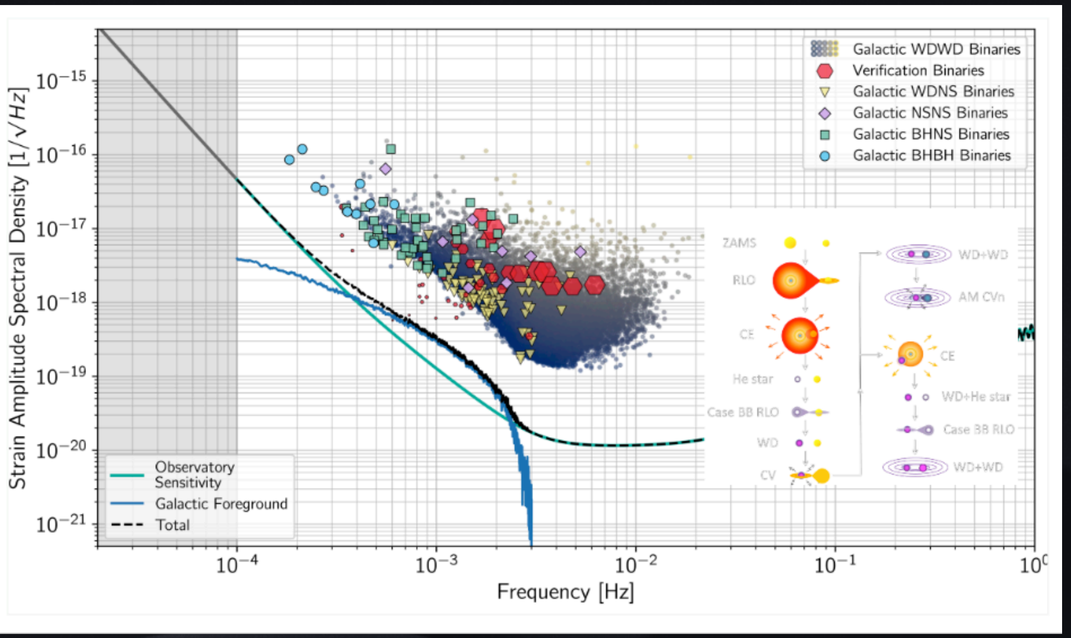
Source	N	N^{detected}
WD+WD	$\sim 10^8$	6,000–10,000
NS+WD	$\sim 10^7$	100–300
BH+WD	$\sim 10^6$	0–3
NS+NS	$\sim 10^5$	2–100
BH+NS	$\sim 10^4 - 10^5$	0–20
BH+BH	$\sim 10^6$	0–70

Stellar compact binaries will be the most numerous GW sources in the LISA band; many are invisible in EM while some will be multi-messenger sources.

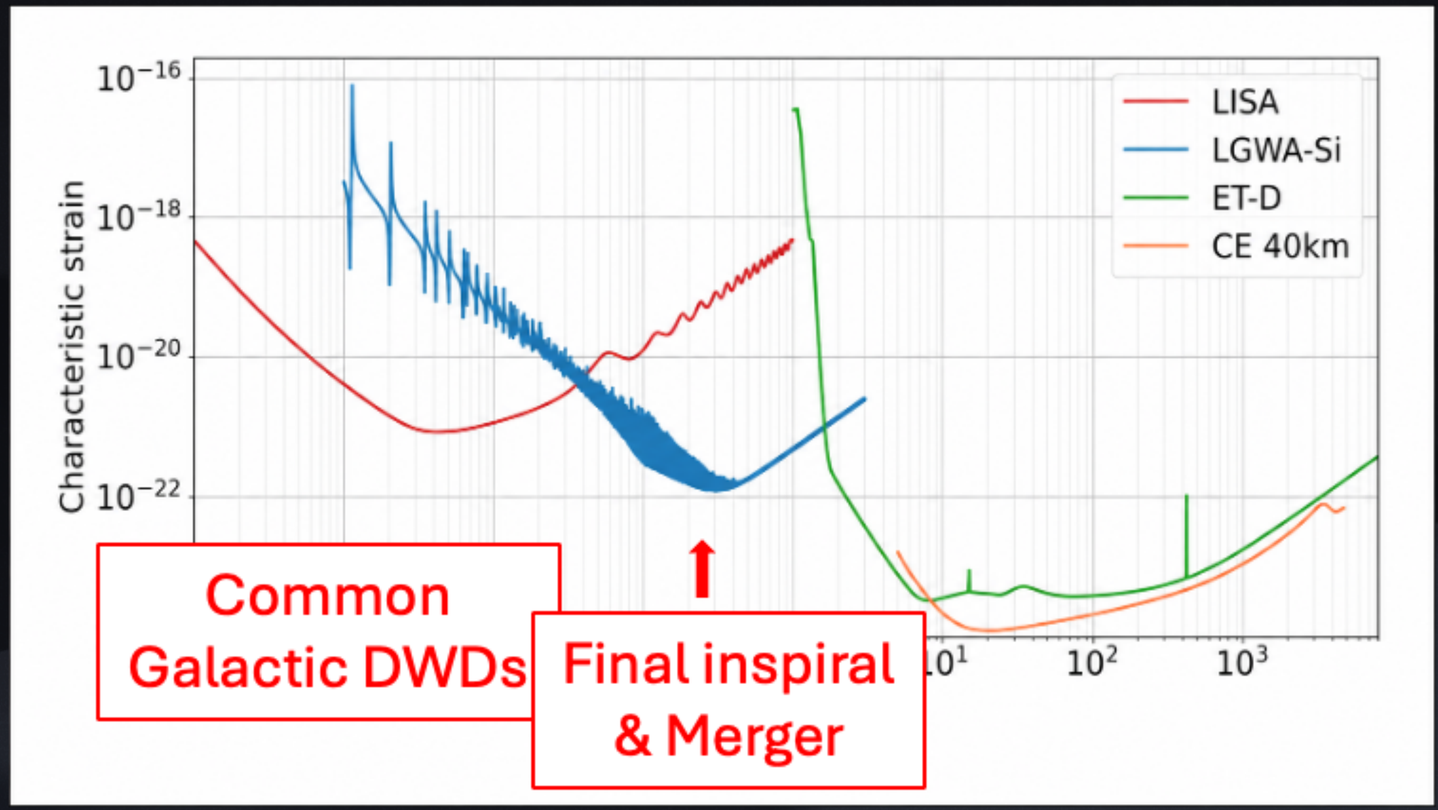
LISA Definition Study Report

LISA & LGWA science - Compact binaries

GW Astrophysics



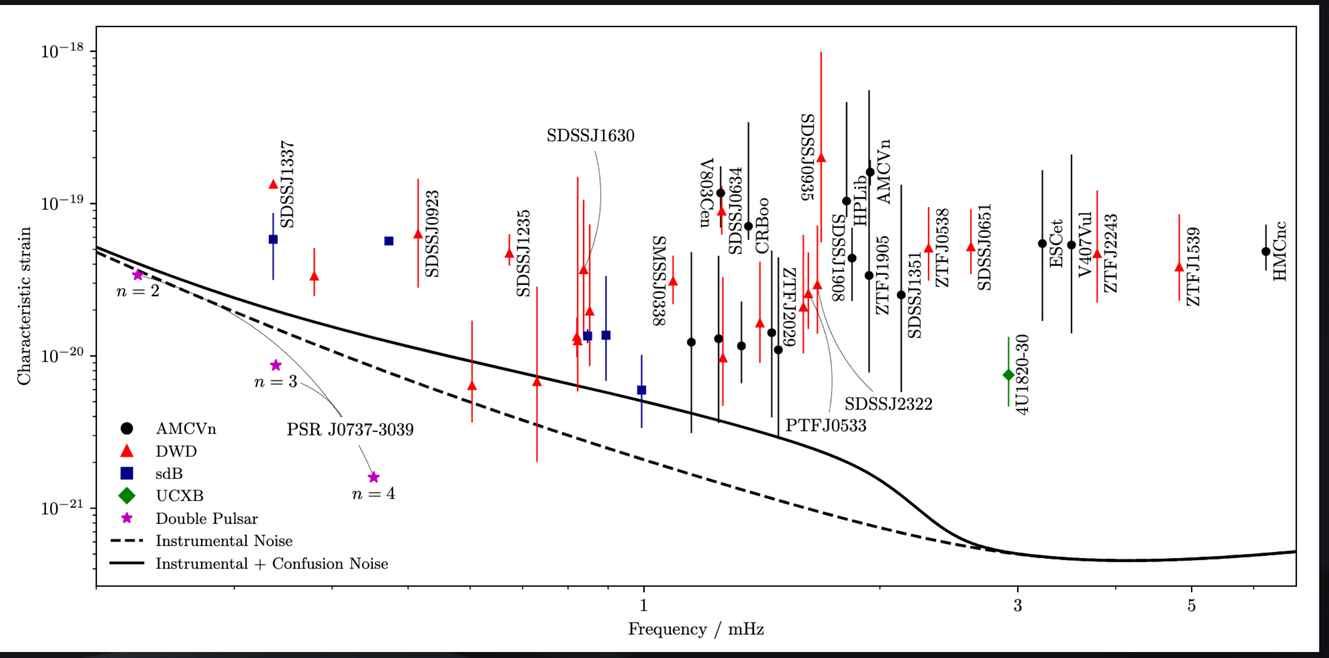
binary synthesis model predicts 2-200 double WDs in the Milky Way with orbital periods of less than 200 seconds. LISA and LGWA observing different evolutionary phases



LISA Definition Study Report
Amaro-Seoane+23
Bortolas+25 in LGWA WP 2025

LISA & LGWA science - Compact binaries

EM+GW Astrophysics



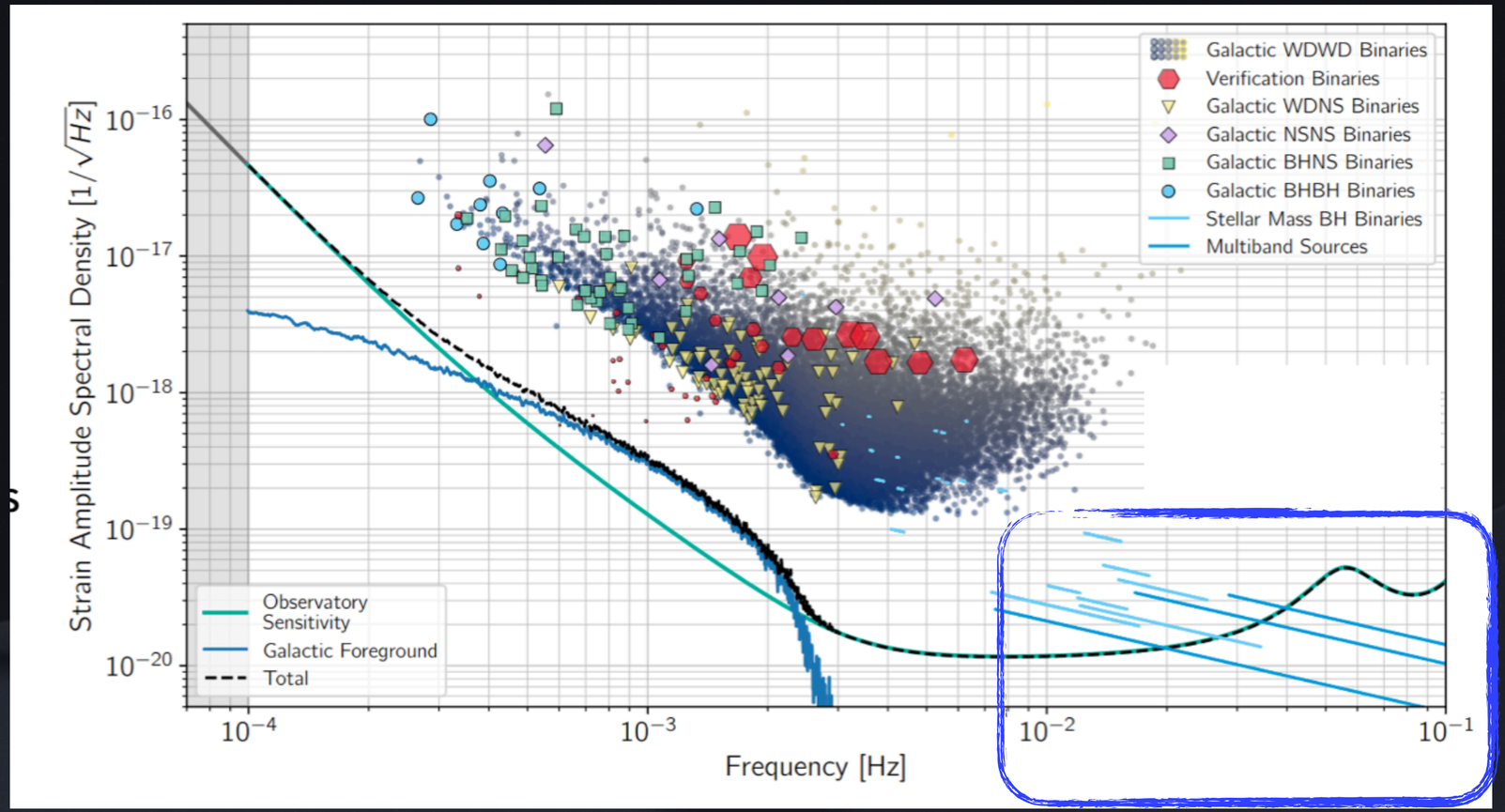
Finch+2023

Coordinated EM observations help distinguish detached from interacting systems and reveal their accretion states, complementing LISA's precise GW-derived orbital parameters.

Together, EM and GW data provide a complete and unbiased census of Galactic compact binaries, essential for understanding their formation and evolution.

LISA science - stellar mass BH binaries

multi-band sources

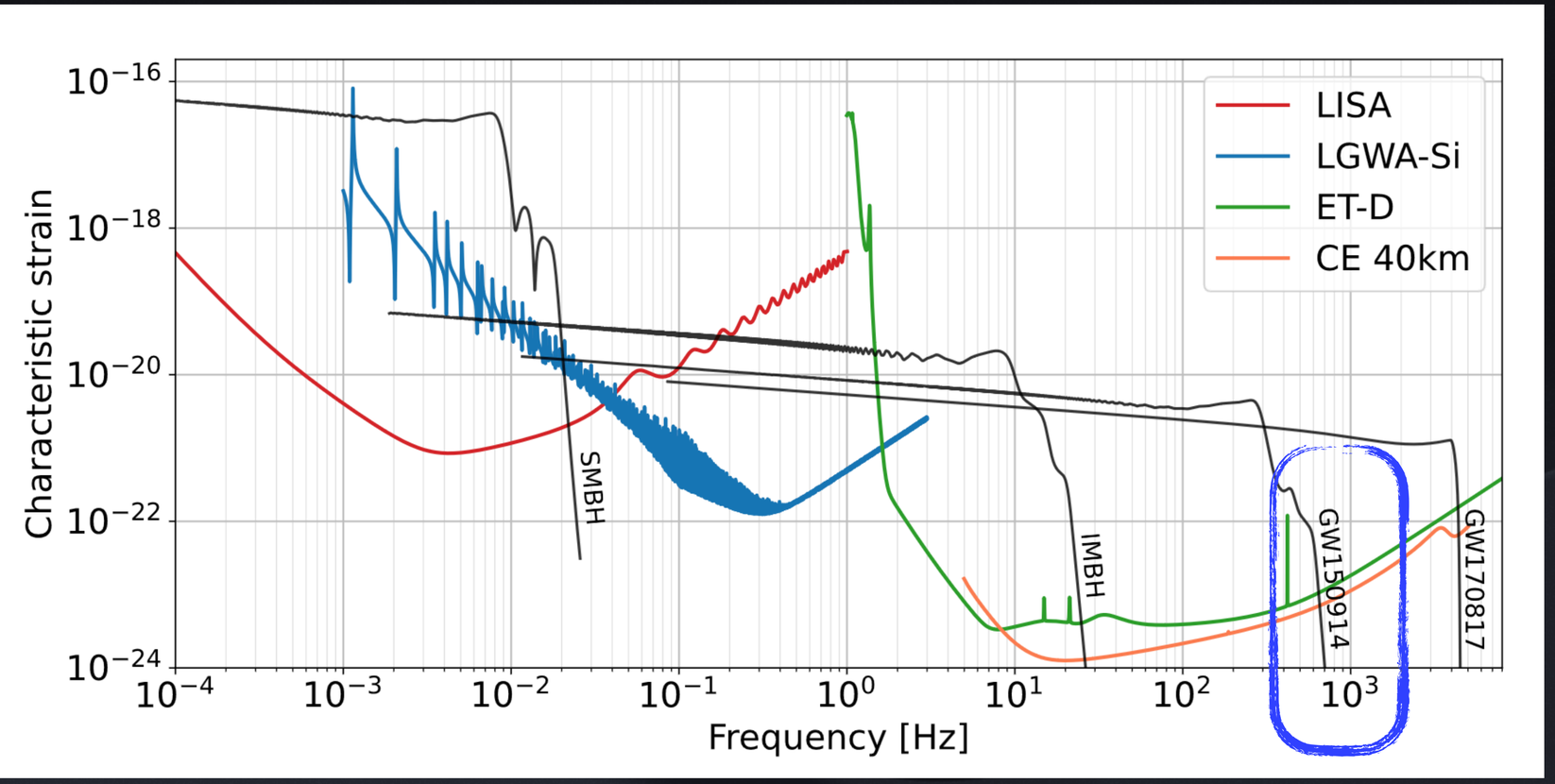


GW150914-like binaries a few years prior to their coalescence. The inferred sky position and time to coalescence will inform ground-based GW detectors and EM observatories to enable GW multi-band and multi-messenger observations

LISA Definition Study Report

LISA & LGWA science - stellar mass BH binaries

multi-band sources

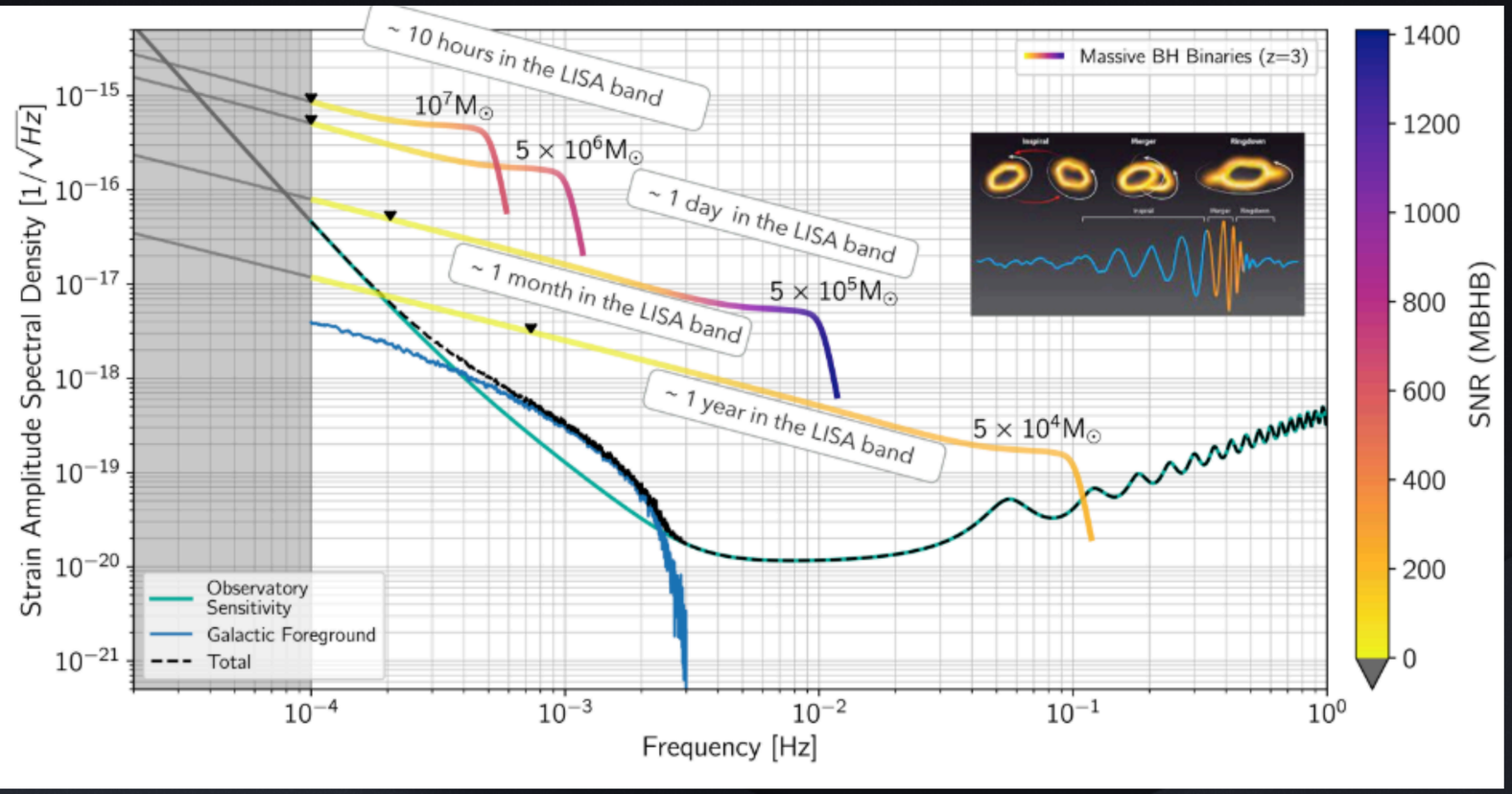


GW150914
- 5 yr before at 0.016 Hz—> LISA
- 1 day before the merger 0.26 Hz—> LGWA
- at merger—> CE

LGWA WP, Harms+25

LISA: Science - Growth and merger of MBH

GW domain



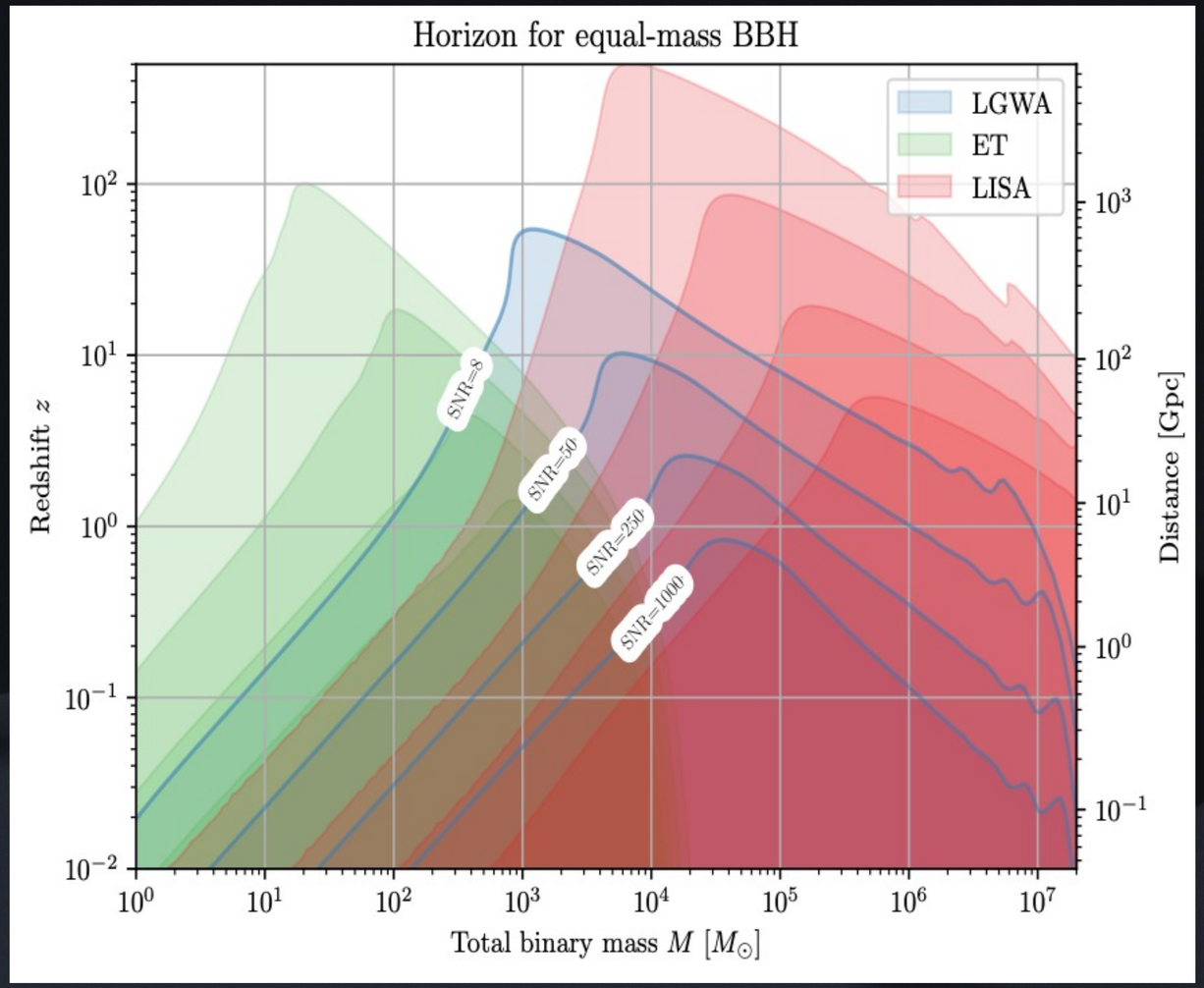
MBH binaries become detectable by LISA weeks/days/hours before the merger, depending on BHM and redshift, and become quiescence shortly after coalescence, forming a class of transient sources

(in contrast to the continuous sources such as Galactic binaries)

LISA Definition Study Report
Amaro-Seoane+23

BH population in the GW domain

ET & LGWA & LISA

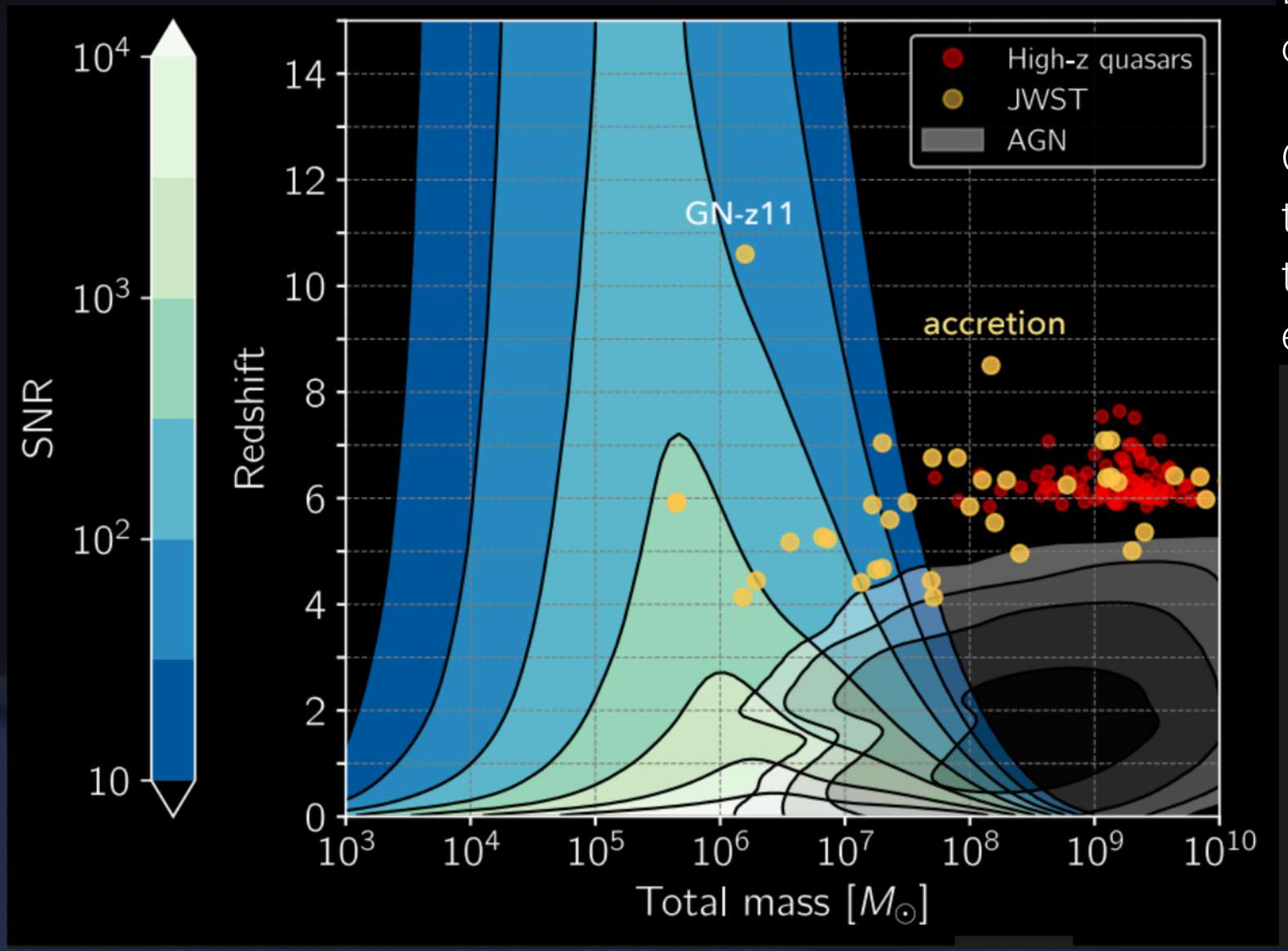


Mass range <u>coordinated multi-band GW</u> observations (ET, CE LGWA in LISA's mission lifetime) are possible, with LISA having the capability to first follow the early inspiral of IMBHs, and tracking the merger phase.
This unique combination will allow precise measurements out to z ~ 5

<u>not only coordinated observation</u>: multiband observations ET+LGWA+LISA would detect the inspiral, merger and ringdown of BH binaries out to redshift z ~ 10 —> BH population

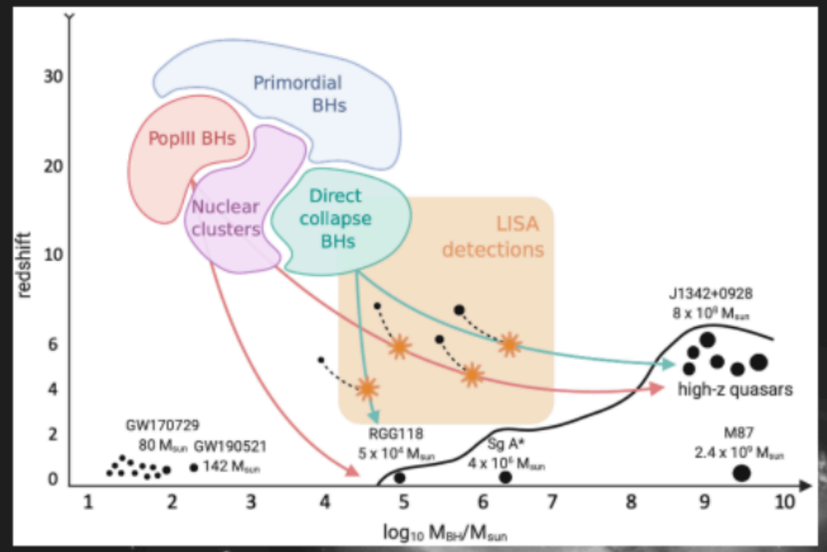
Valiante+21, Jani+19, LGWA+25

massive BH population in the MM domain



LISA will explore the low-mass tail of the MBH mass function.

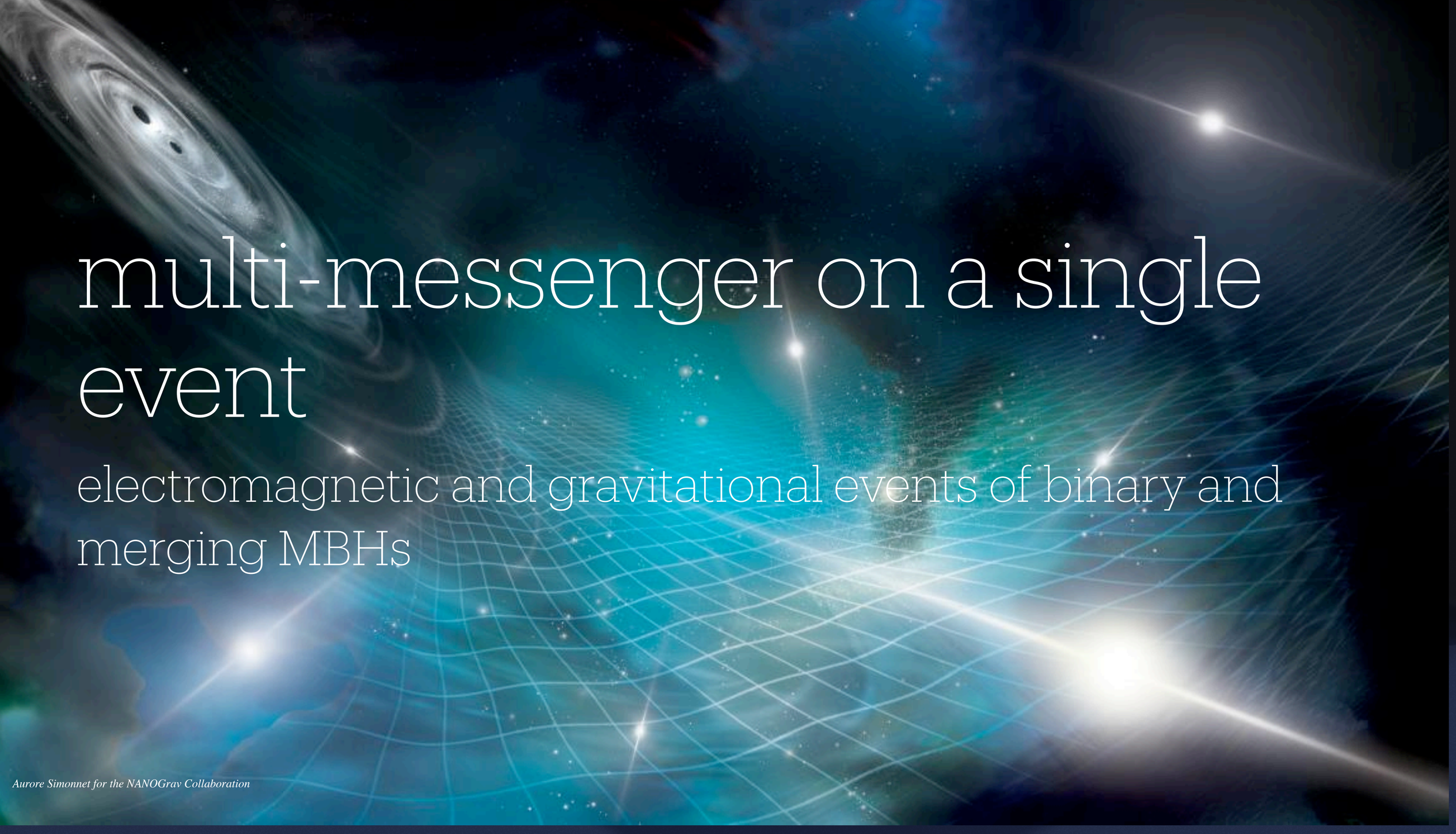
GW+EM view of MBH will allow us to understand how AGN are triggered, how MBH grow and evolve



future/current EM facilities for MBH

a not complete overview

	Description	**Observatories/Missions**
BH population	Measure SMBH masses in distant and nearby galaxies using high-resolution (image/spec) infrared and optical data.	JWST, E-ELT, SDSS-V
BH Growth	Study SMBH growth through X-ray emission, accretion processes, and transient events. High-z QSO	Athena, XRISM, Euclid, LSST, ROMAN, eXTP
Host Properties and Coevolution	Understand the relationship between SMBHs and their host galaxies, including dark matter distribution.	DESI, Euclid, ROMAN, JWST, SKA



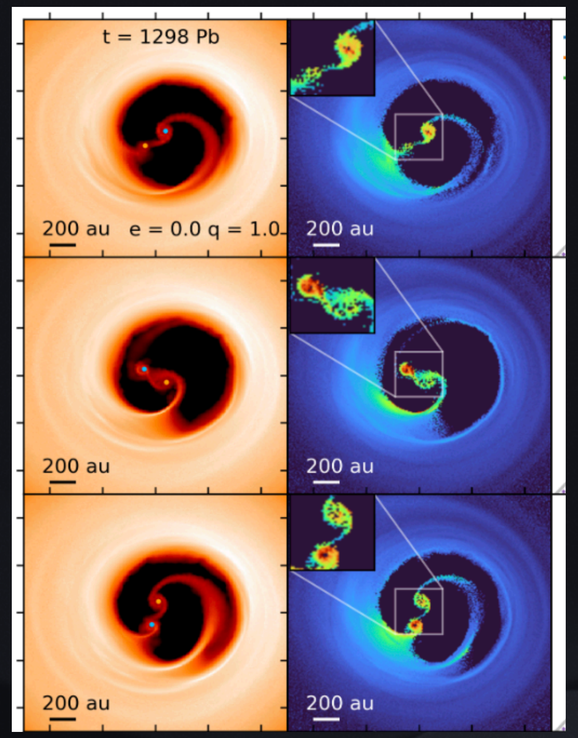
multi-messenger on a single event

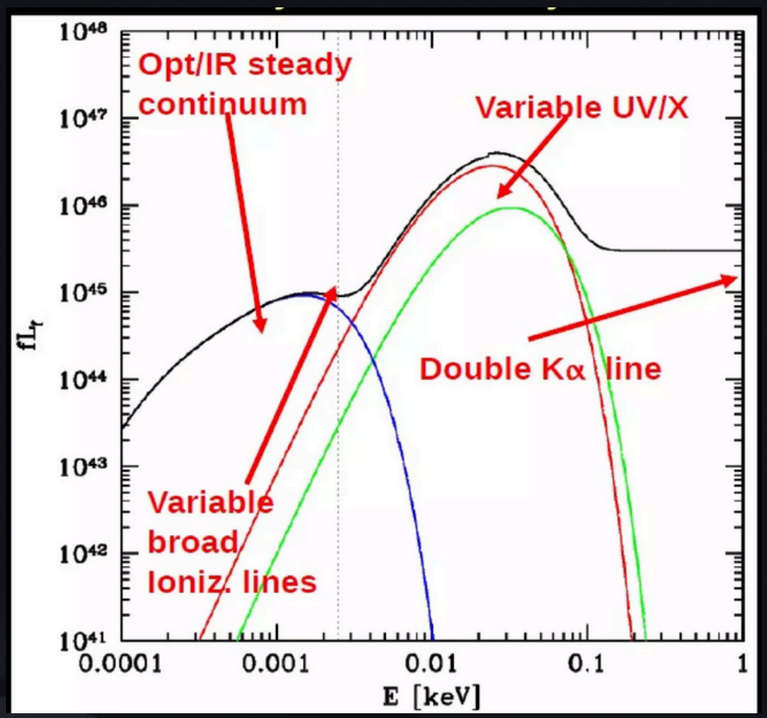
electromagnetic and gravitational events of binary and merging MBHs

Aurore Simonnet for the NANOGrav Collaboration

EM of accretion disc and corona in SMBH binaries

final stage of mergers



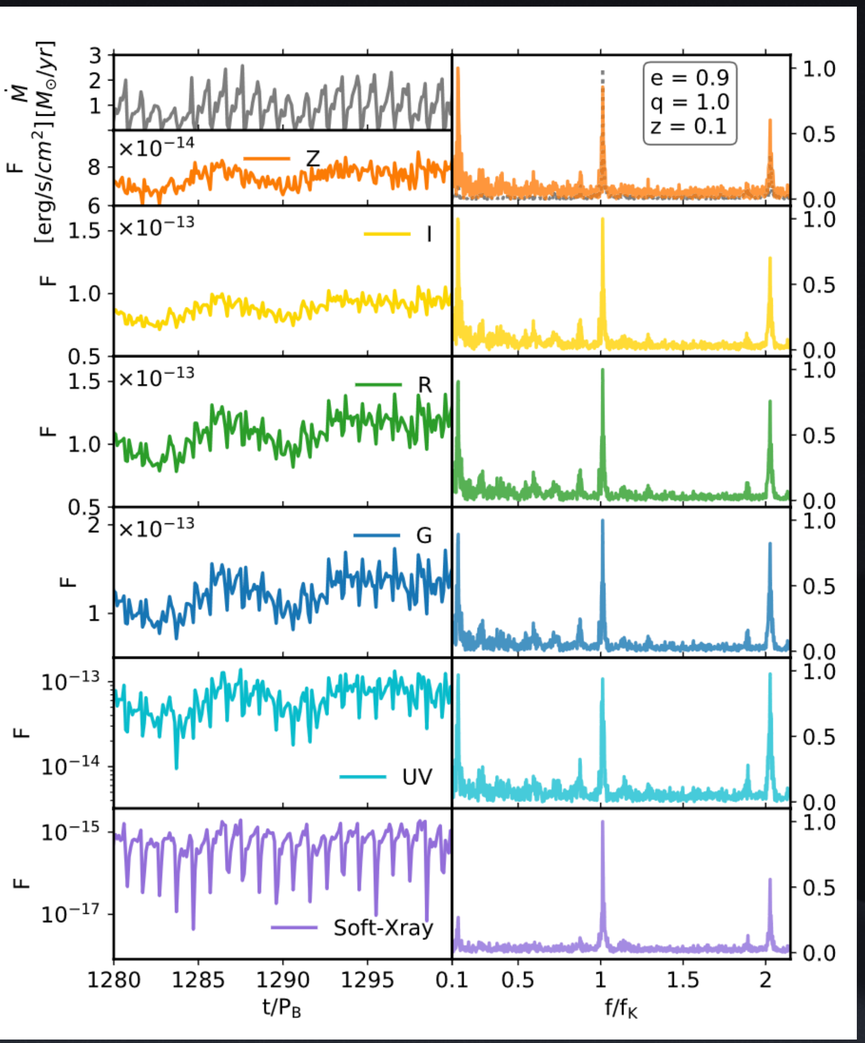


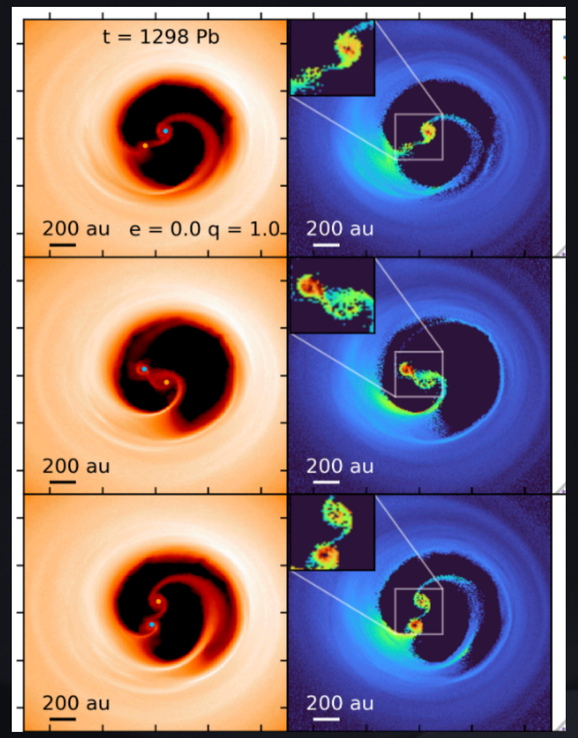
Richness of states: the flow pattern depends on BH mass, q, BH spin, and assumed geometry

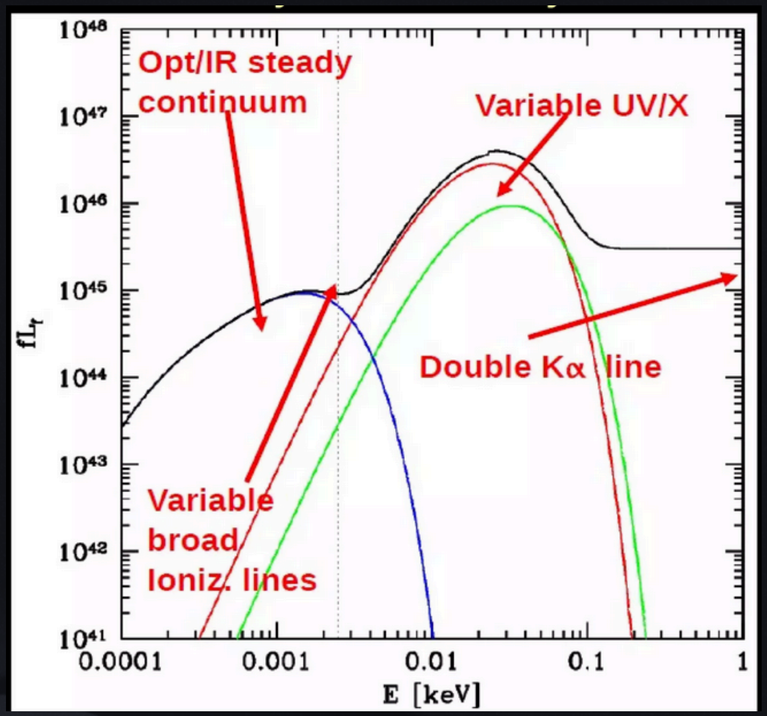
Cocchiararo+24, Farris+15,17; Tang+18; D'Orazio+18,D'Ascoli+18, Bowen+18, Roeding+11, Sesana+12, Franchini+24,, Severgnini+20, Serafinelli+20

EM of accretion disc and corona in SMBH binaries

final stage of mergers







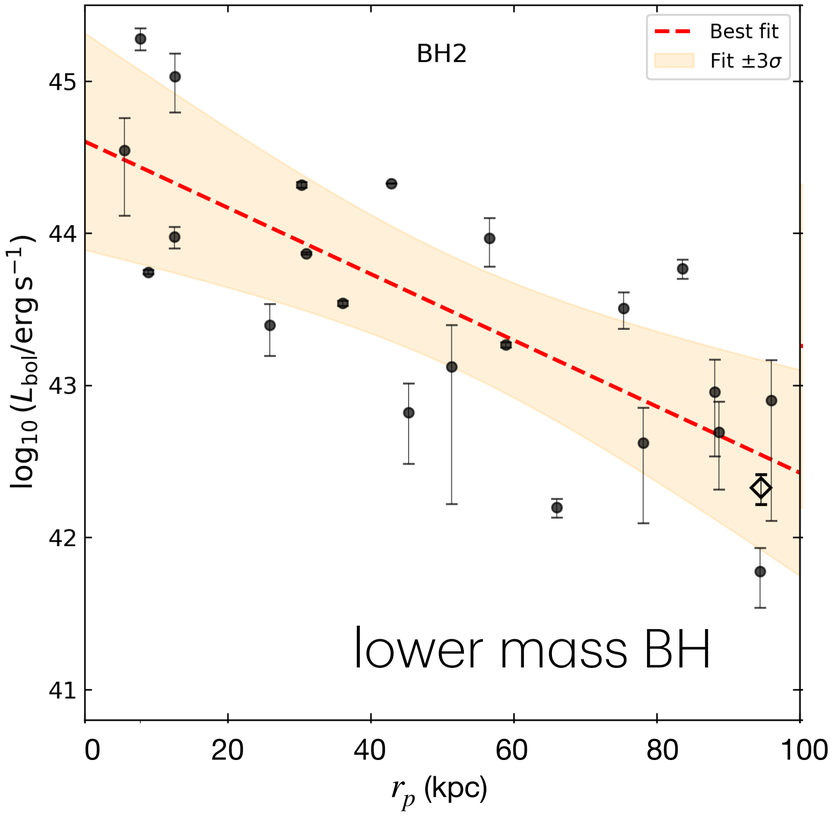
Richness of states: the flow pattern depends on BH mass, q, BH spin, and assumed geometry

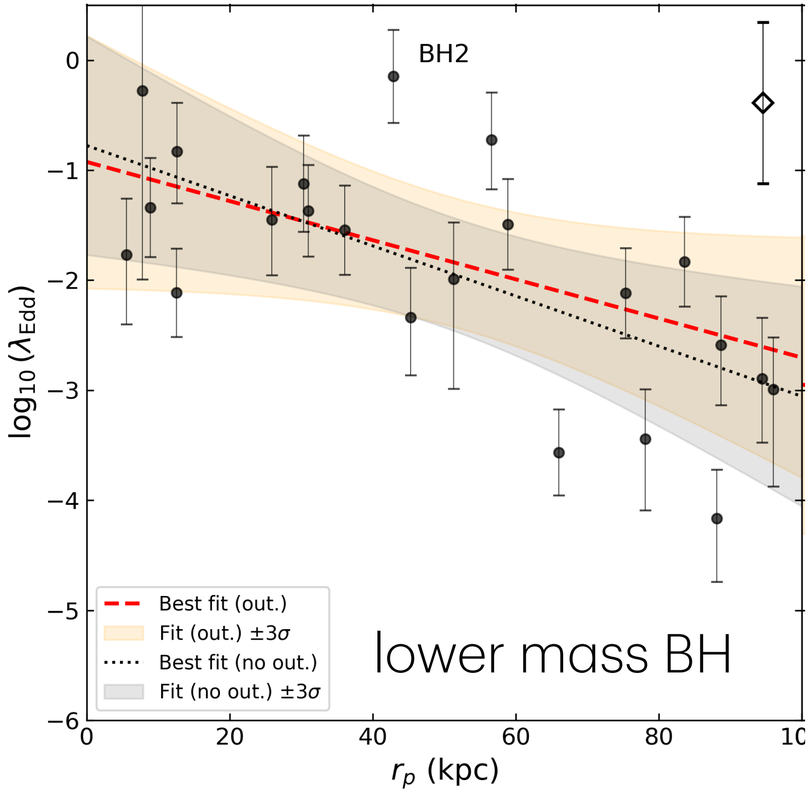
significant variability of a factor of ≈2 in the optical and of ≈10 in UV and X-rays.

Cocchiararo+24, Farris+15,17; Tang+18; D'Orazio+18,D'Ascoli+18, Bowen+18, Roeding+11, Sesana+12, Franchini+24,, Severgnini+20, Serafinelli+20

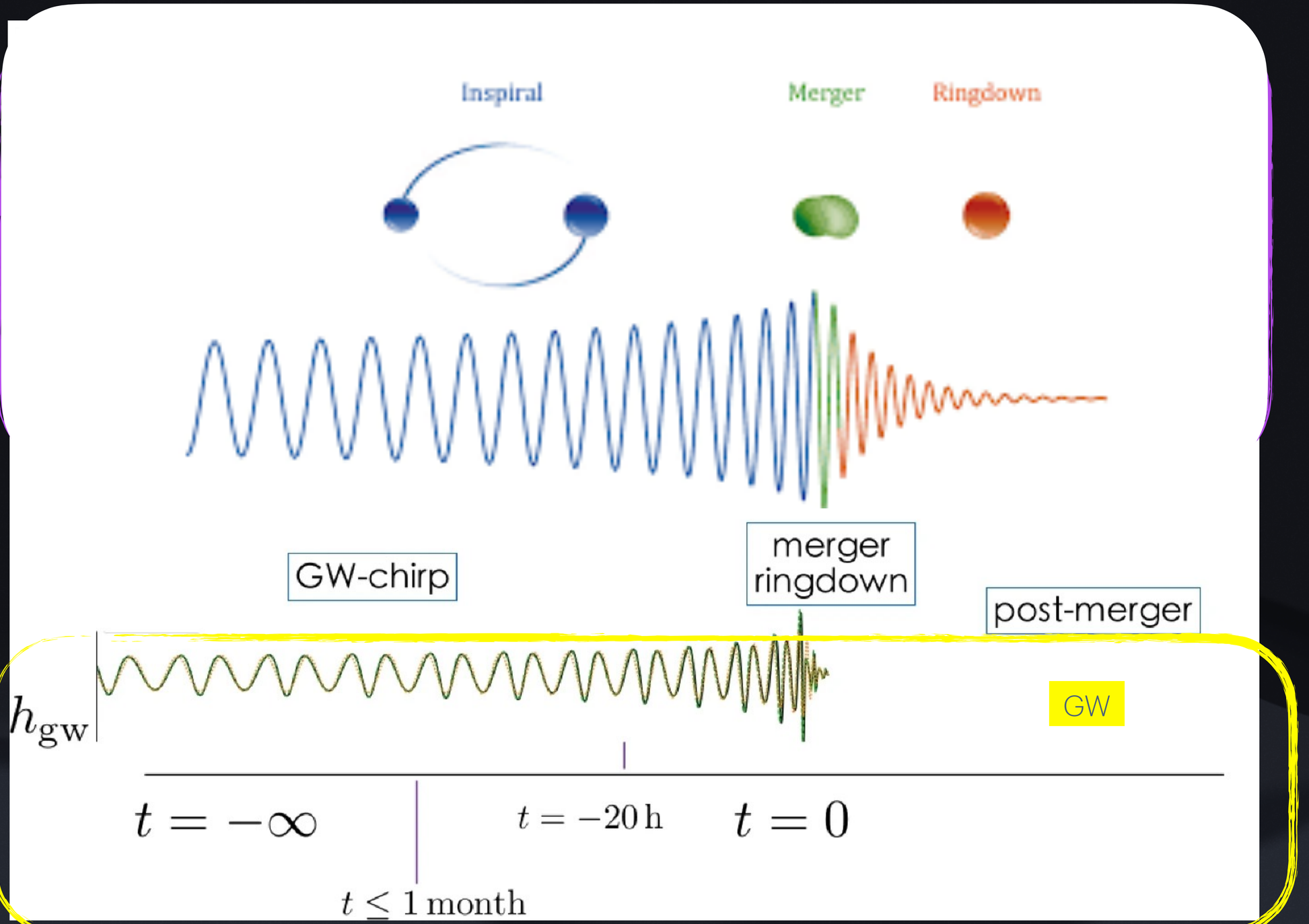
AGN triggering vs mergers: X-ray view of dual AGN

- Statistical evidence of correlation between Lbol(BH2) and Lambda_Edd(BH2) vs separations
- In minor mergers the less massive SMBH may be more powered the more it gets closer to its (more massive) companion (in agreement with numerical simulations, Capelo+2015).

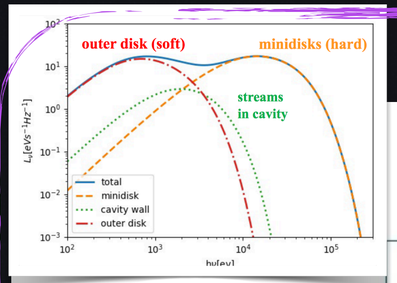


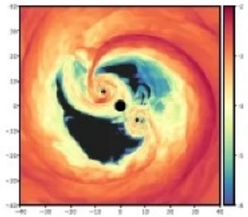


PhD Battistini, ADR+2026, A&A, 710, 232


Inspiral
Merger
Ringdown
GW-chirp
merger
ringdown
post-merger
$h_{\rm gw}$
GW
$t = -\infty$
$t = -20\,\mathrm{h}$
$t = 0$
$t \leq 1\,\mathrm{month}$

EM

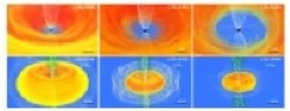




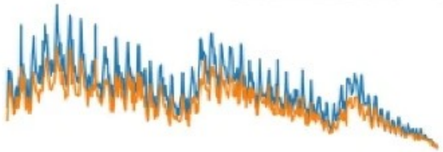
merger

inspiral

post-merger



L_X





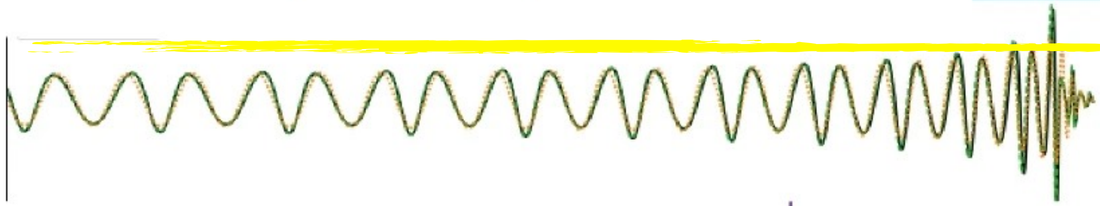
Disc re-brightening ? Jet?

$t = -\infty$ $t = -20\,\mathrm{h}$ $t = 0$

GW-chirp

merger
ringdown

post-merger



h_{gw}

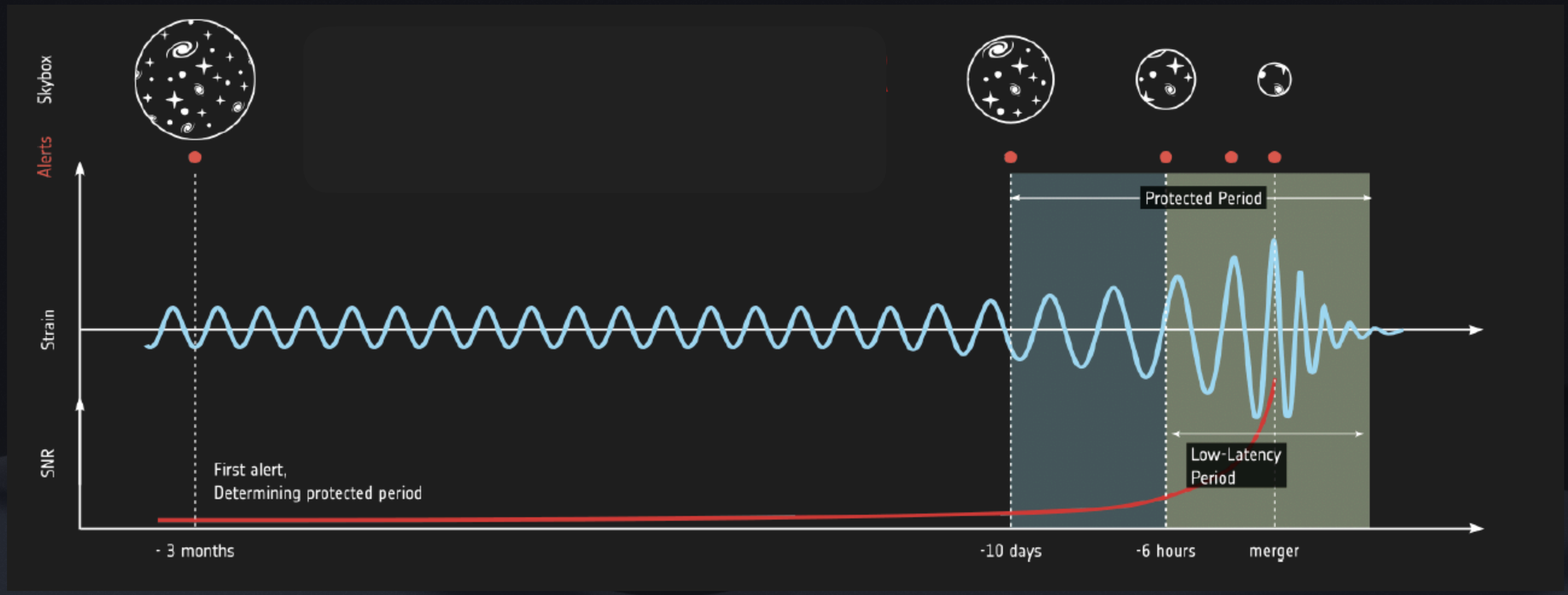
GW

$t = -\infty$ $t = -20\,\mathrm{h}$ $t = 0$

$t \leq 1\,\mathrm{month}$

LISA alerts and multi messenger

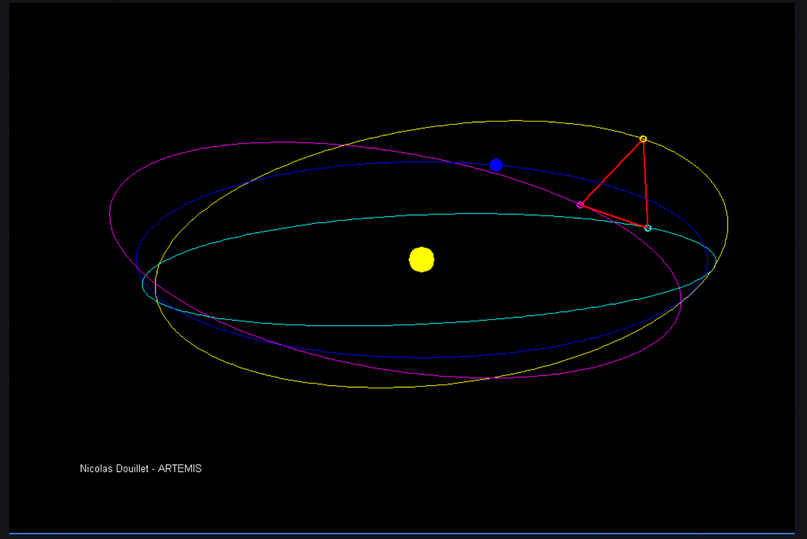
Low-Latency pipeline



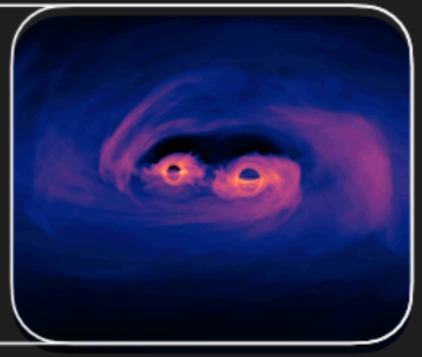
protected period of quasi-realtime data (outside the nominal 8 hr)

GW localization with LISA

following GW events from MBH mergers with EM observatories

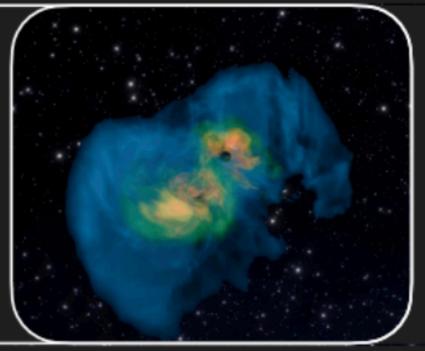


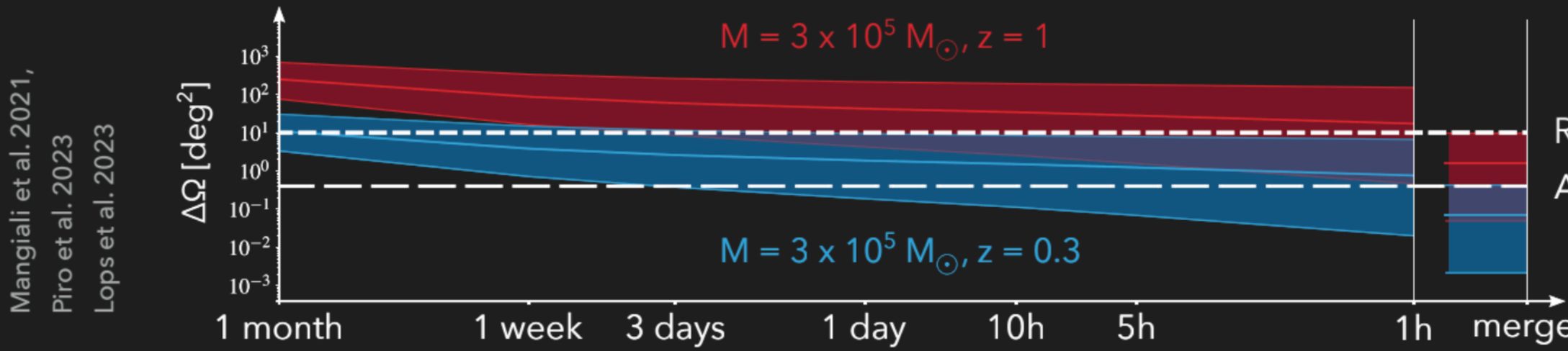
Current simulations a 4 hours (Athena) response time and 5″ Angular resolution (HEW) instead of 12 hours and 9″



Afterglow emission

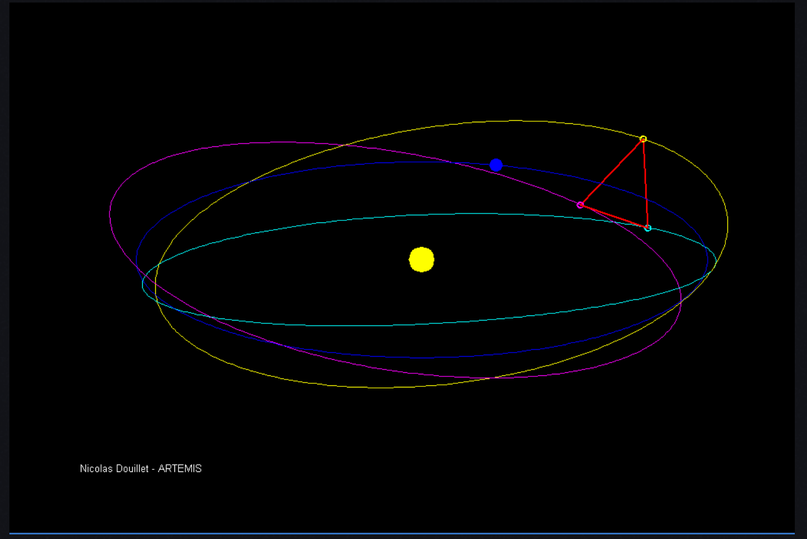
- At merger localisation within ~0.1 deg² or better is possible for the LISA binaries out to z~3



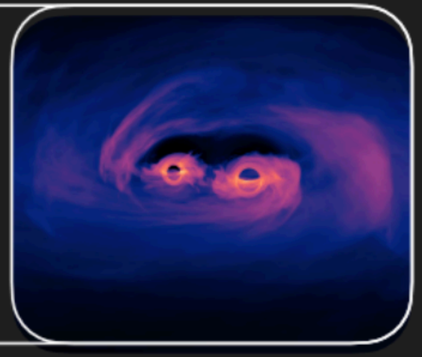


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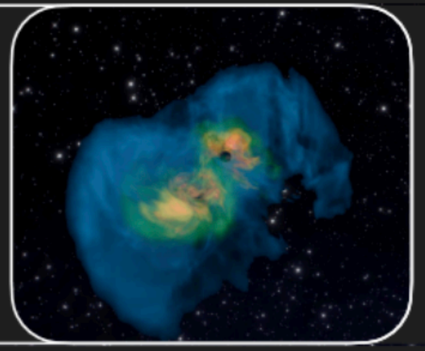


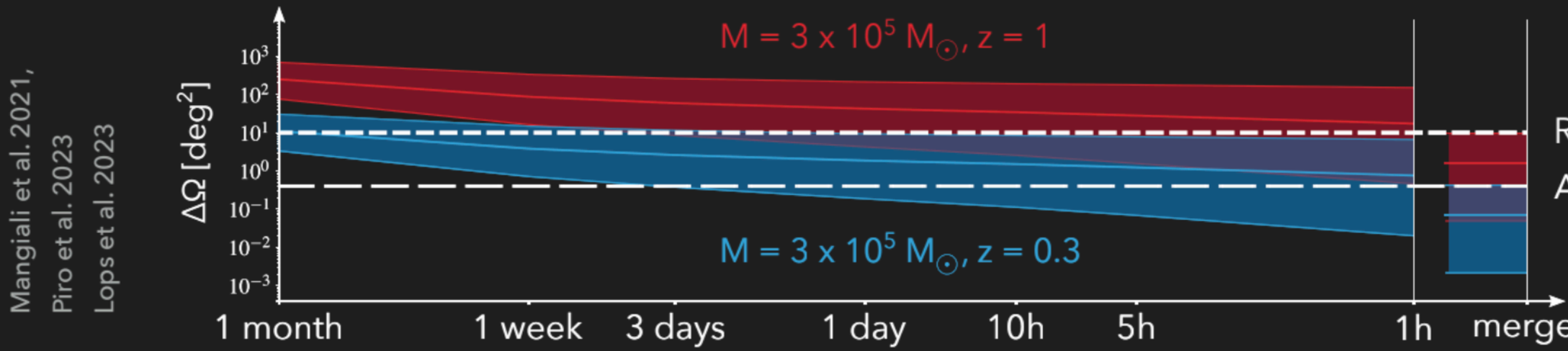
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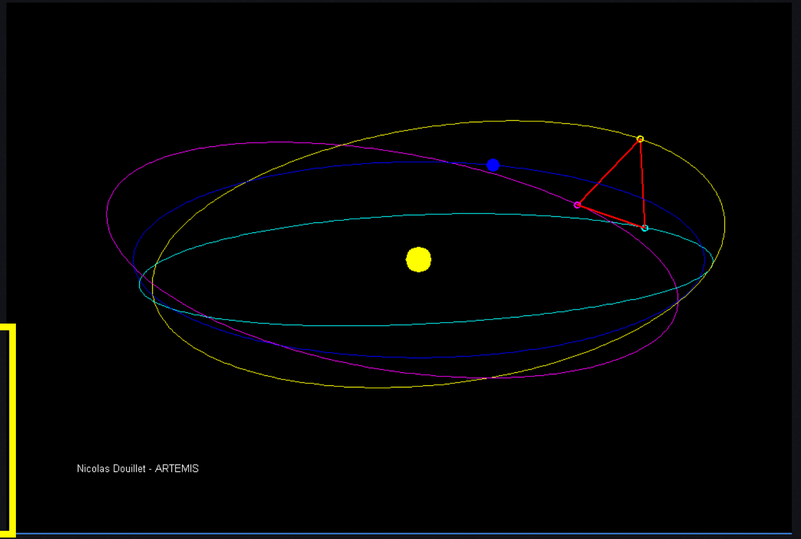
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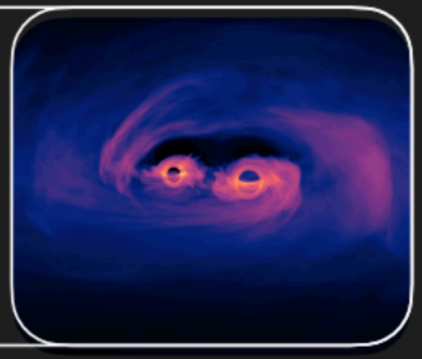
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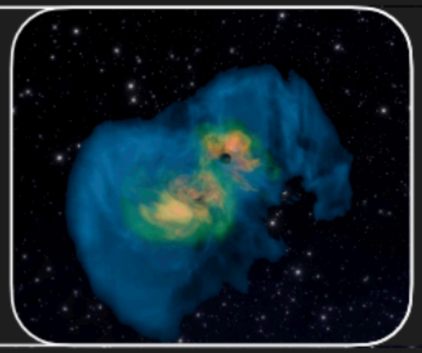
LISA-TAIJI network still represents a considerable localization advantage x10

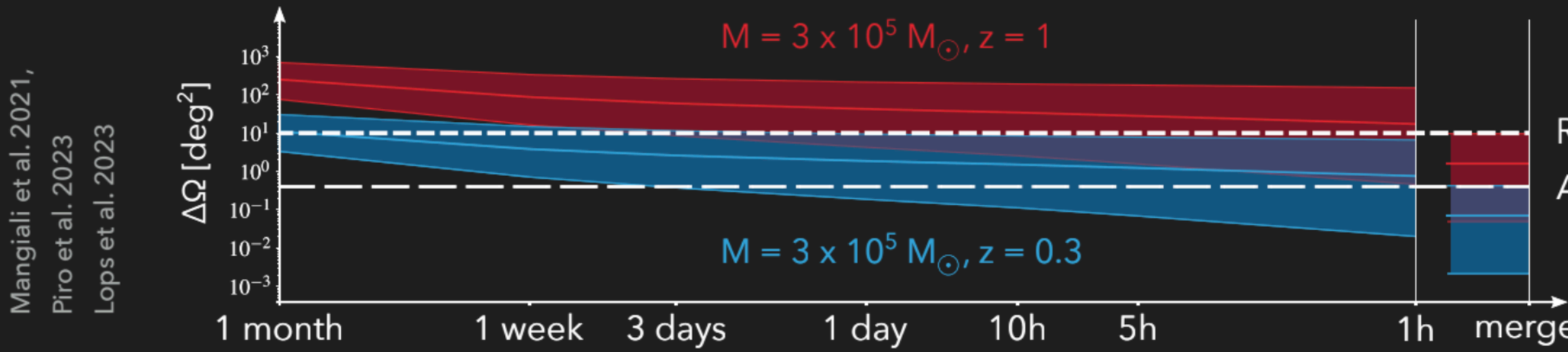
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Afterglow emission

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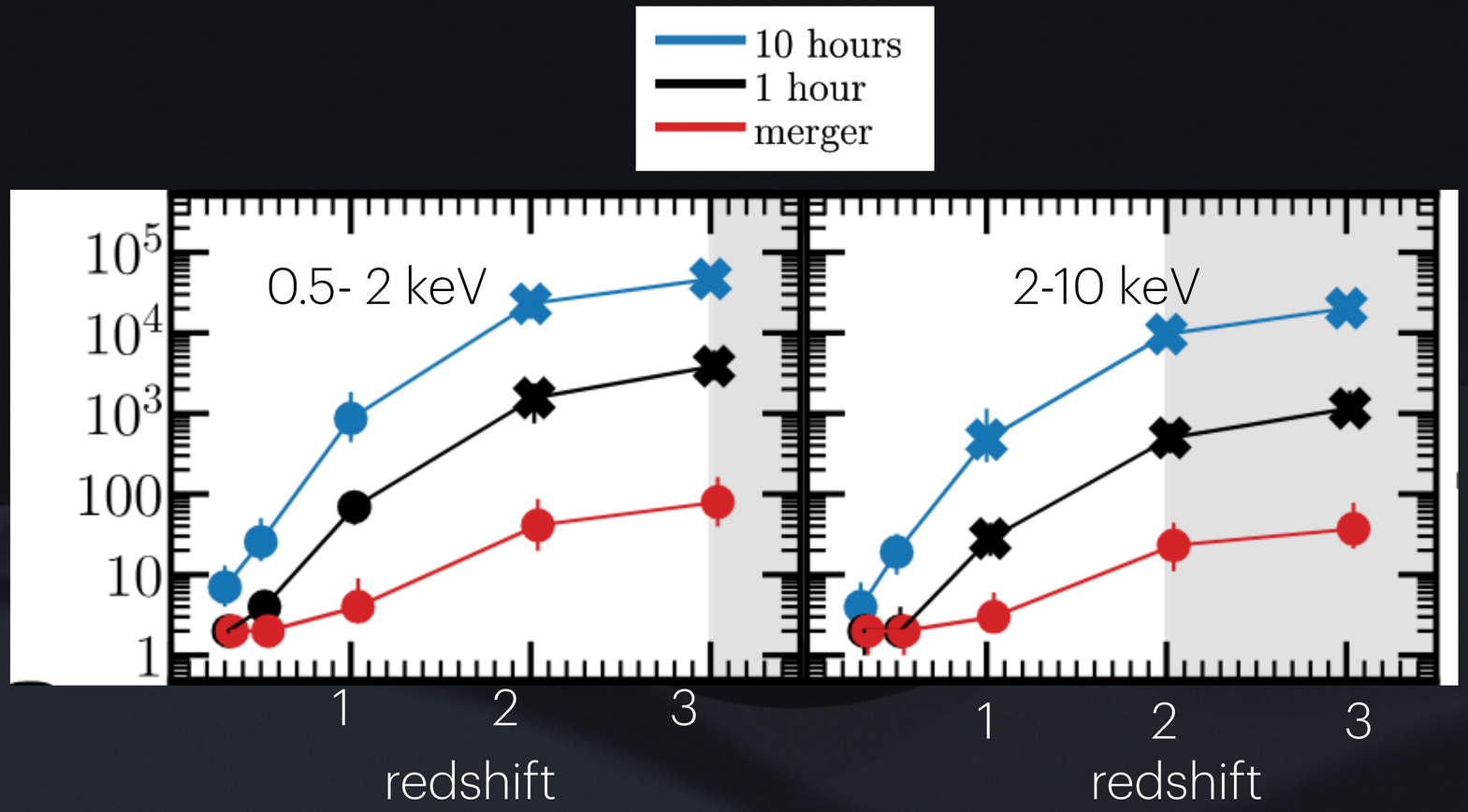




GW localization with LISA

following GW events from MBH mergers with X-ray EM observatories

MBH accrete at Eddington limit with neutral absorption
log(NH/cm-2)=21.5 M(BH)=3e6 Msun



inspira phase hundreds potential hosts especially at high-z

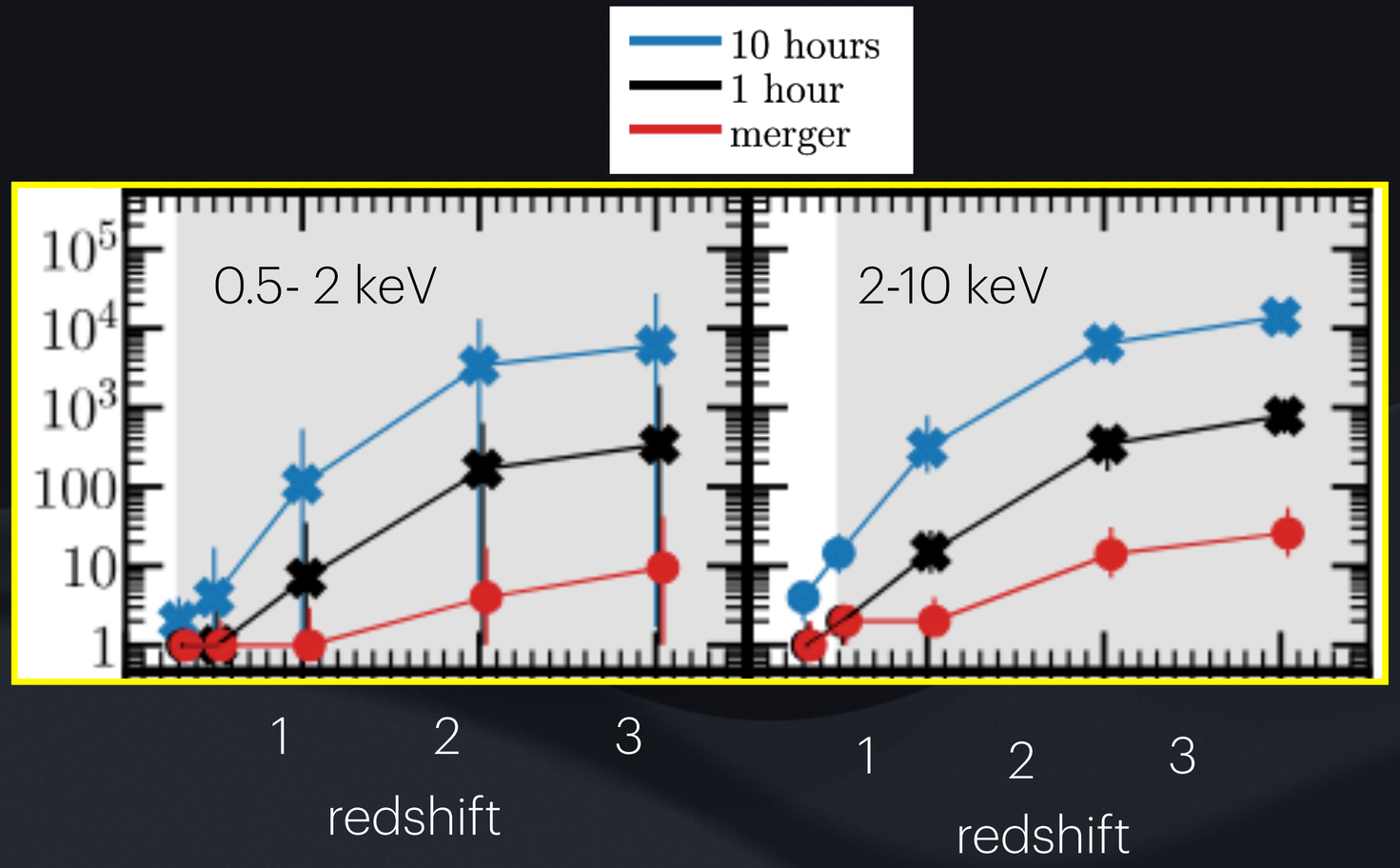
at merger X-ray AGNs in the LISA error-box is < 10 at z < 1

Lops+2023

GW localization with LISA

following GW events from MBH mergers with X-ray EM observatories

MBH accrete at Eddington limit with neutral absorption
log(NH/cm-2)=23 M(BH)=3e6 Msun



AGN Host

If log(NH/cm-2)=23, more sources with X-ray fluxes falling below the detection limit

Lops+2023

Astrophysics LISA Science Projects

How can the community be engaged?

- *Dual and binary AGN* - Alessandra De Rosa, Leonid Gurvits, David Izquierdo-Villalba, Kunyang Li
- *Environment of MBH mergers* - Nianyi, Chen, John Regan, Sean McGee
- *EMRI catalogs* - Elisa Bortolas, Matteo Bonetti, Luca Broggi, Alessandro Trinca
- *Waveform parameter space (with wavWG)* - Luca Broggi, Lucio Mayer, Sean McWilliams, Marta Volonteri
- *Data standard and DDPC-friendly catalogs* - Laurentiu Caramete, Golam Shaifullah, Tristan Bruel, David Izquierdo-Villalba
- *Comparing UCB catalogues for LISA with existing observations* - Alexey Bobrick, Simone Scaringi, Silvia Toonen
- *Extending UCB catalogs to include mass-transferring systems (e.g. AM CVns, CVs, UCXBs, etc.)* - Thomas Kupfer, Simone Scaringi, Nathan Steinle
- *Dynamical binaries in the Galaxy and Local Volume* - Sara Rastello, Manuel Arca Sedda, Tristan Bruel, Cristiano Ugolini
- *Extragalactic DWD foreground* - Valeriya Korol, Mauro Pieroni, Gijs Nelemans
- *LISA triples and CBPs* - Camilla Danielski, Nicola Tamanini, Silvia Toonen
- *Updatable predictions for stBBH in LISA* - Riccardo Buscicchio, Alexandre Toubiana
- *Updating the astroWG LRR (2025)*: Compact binaries - Thomas Kupfer, Thomas Tauris, Tassos Fragos
- *Updating the astroWG LRR (2025)*: Massive black holes - Elisa Bortolas, Melanie Habouzit, Pedro Capelo Alessandra De Rosa coordinates MM chapter
- *Updating the astroWG LRR (2025): EMRIs* - Pau Amaro-Seoane, Lorenz Zwick, Saavik Ford, Alejandro Torres Orjuela, Verónica Vázquez-Aceves

Thank you!