Multi-messenger Interfacing

Alessandra Corsi
William H. Miller III Department of Physics and Astronomy
Johns Hopkins University

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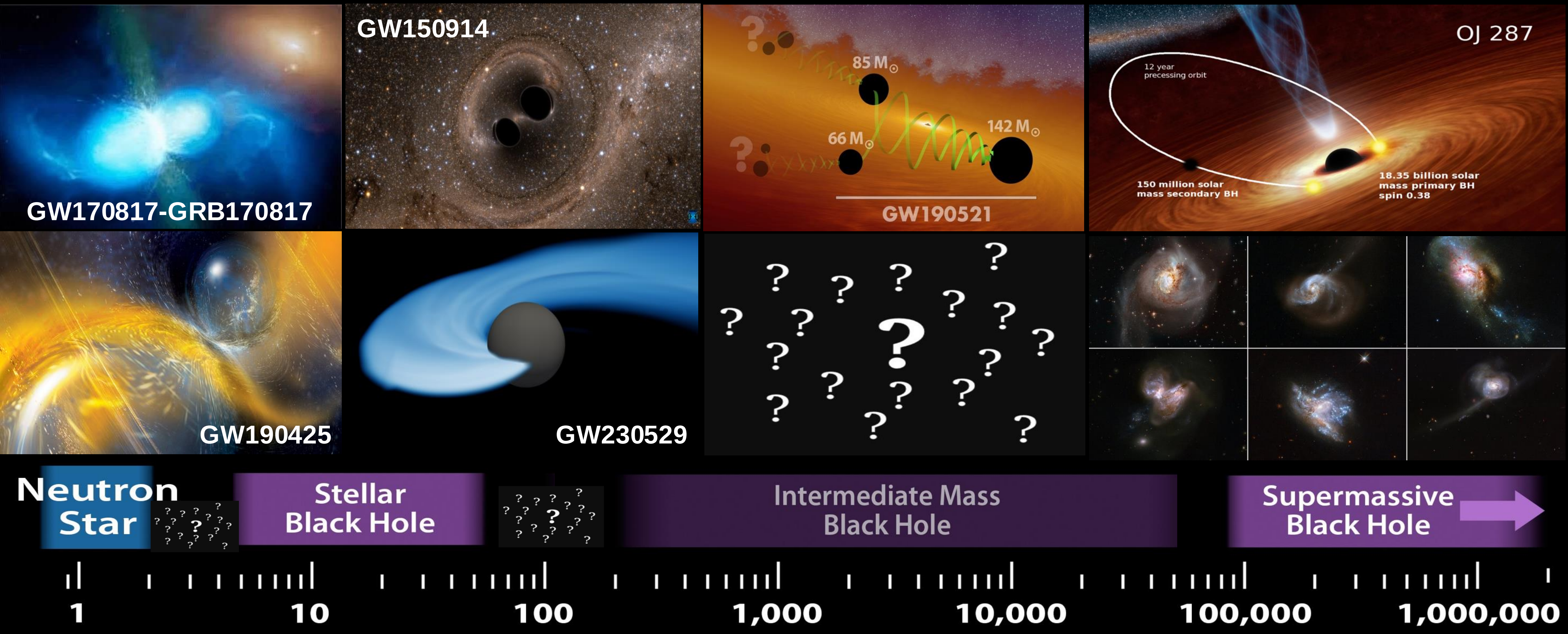
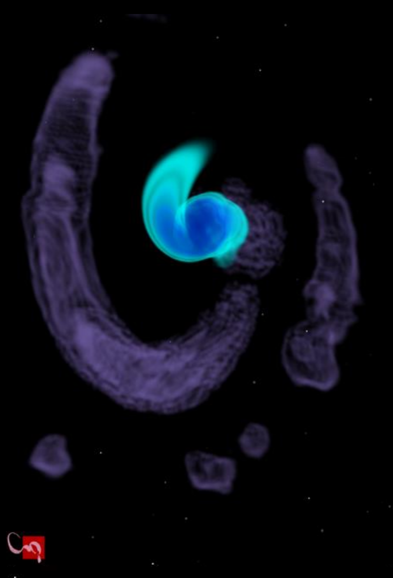
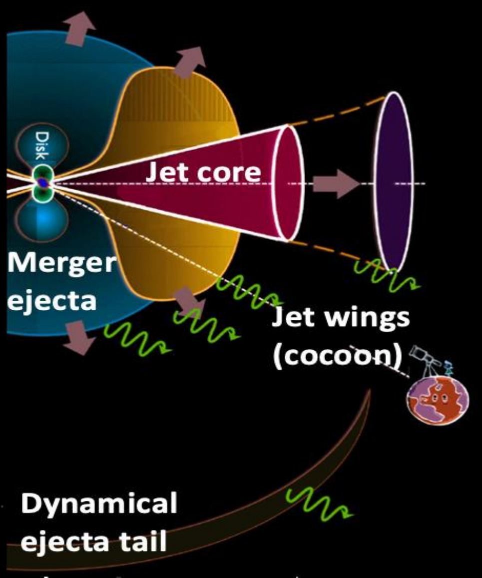
The mass spectrum of compact objects

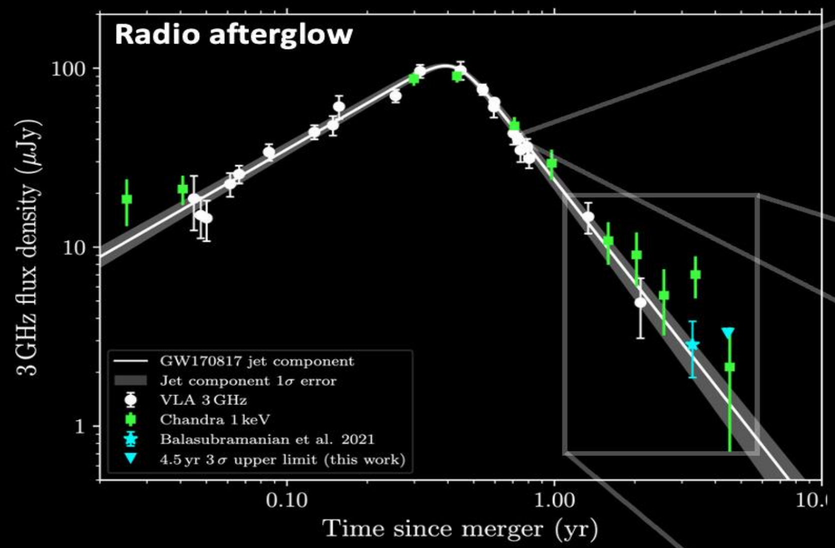


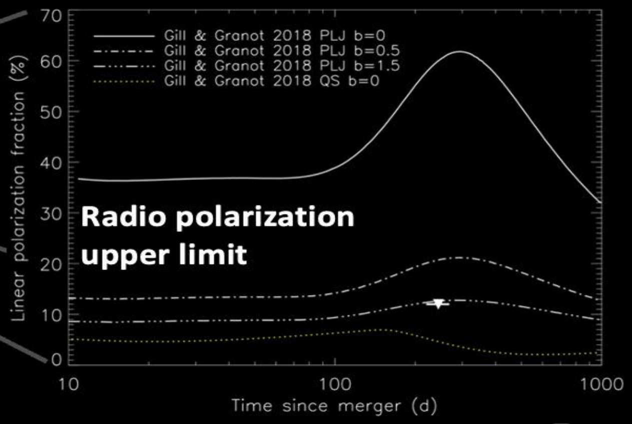
See also talks by:
- Thankful Cromartie (pulsars, this session)
- Joe Lazio (VLBI, Wednesday)
- Jessie Runnoe (nHz GW & EM counterparts, Wednesday)

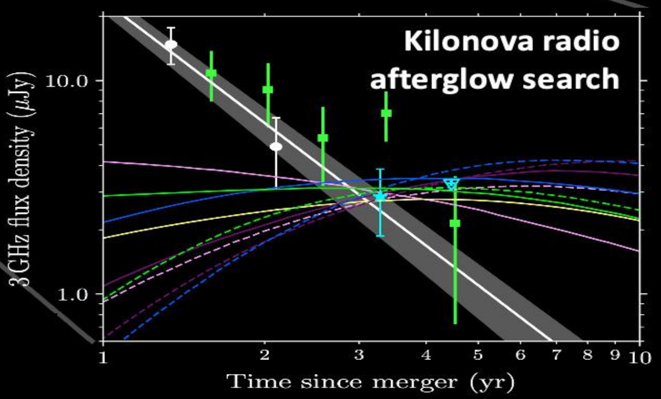
GW170817 (NS-NS @40 Mpc): The role of radio observations

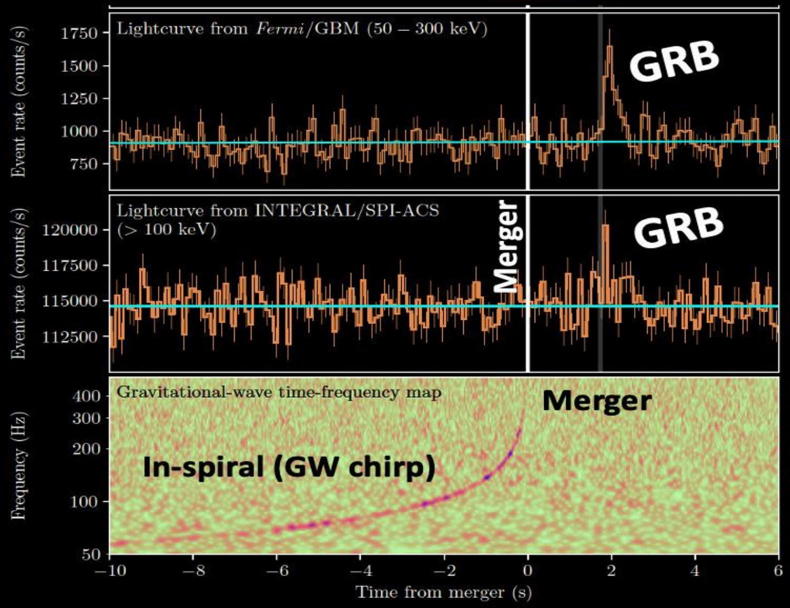


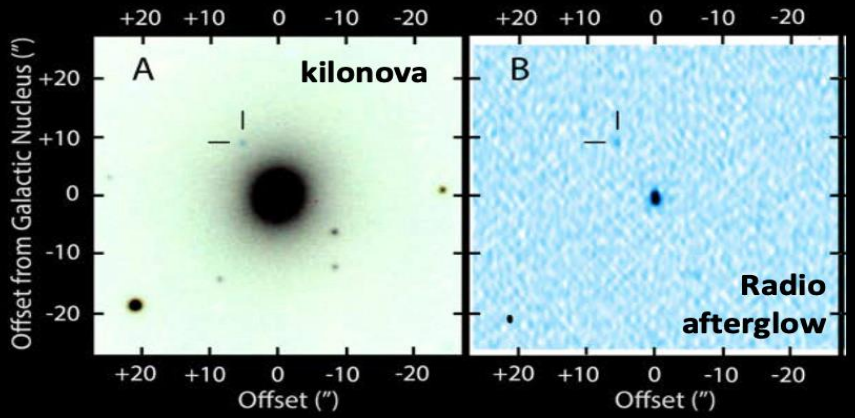


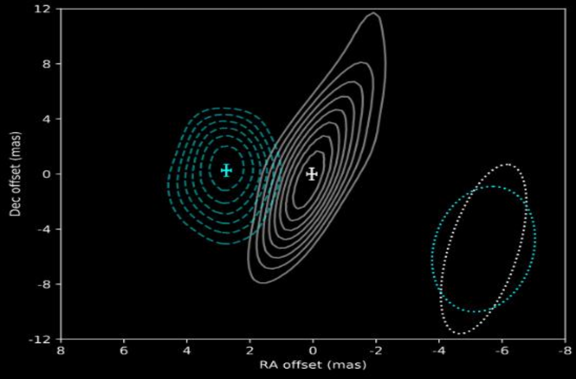








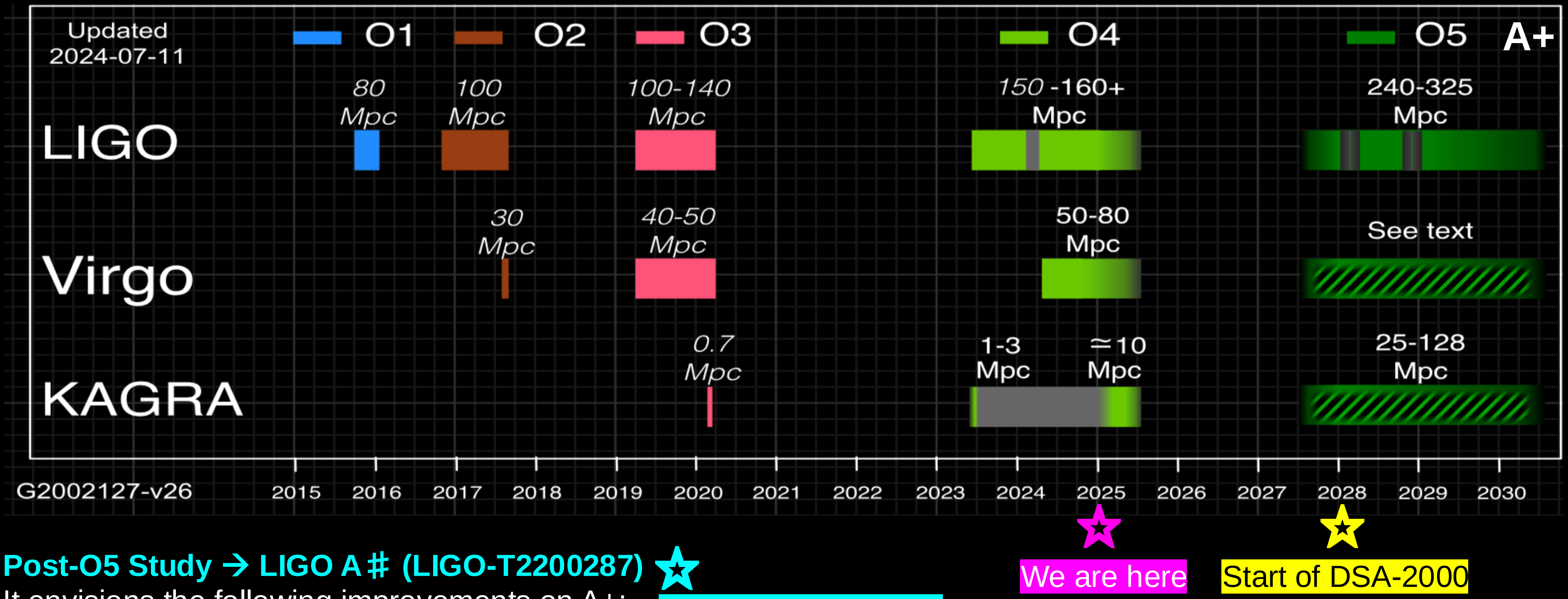




Superluminal motion

Abbott et al. 2017, Phys. Rev. Lett. 119, 161101
Abbott et al. 2017, ApJL, 848, L13
Balasubramanian, et al. 2022, ApJ, 938, 12
Corsi et al. 2018, ApJL, 861, L10
Hallinan, Corsi et al. 2017, Science, 358, 1579
Mooley et al. 2018, Nature, 561, 355

LIGO: Observing scenario and post-O5 era



Post-O5 Study → LIGO A♯ (LIGO-T2200287) ☆ ngVLA early science (2033-2038)

It envisions the following improvements on A+:

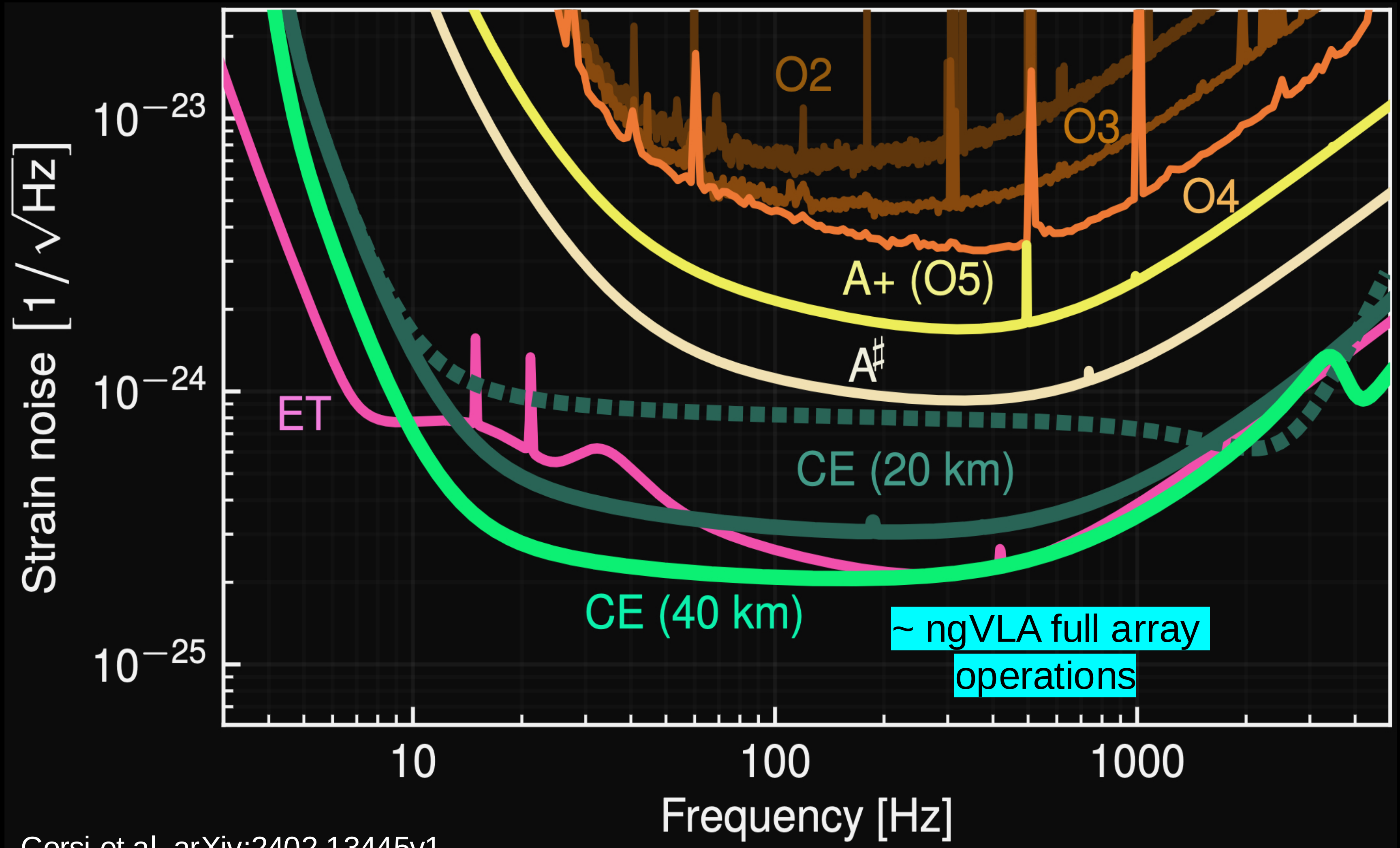
- 100 kg test masses;
- Higher stress (2x) test mass suspension fibers;
- Arm cavity power increased to 1.5 MW;
- Squeezing efficiency increased to 10 dB at high frequencies.
- Factor of ~2 reduction in coating thermal noise beyond A+

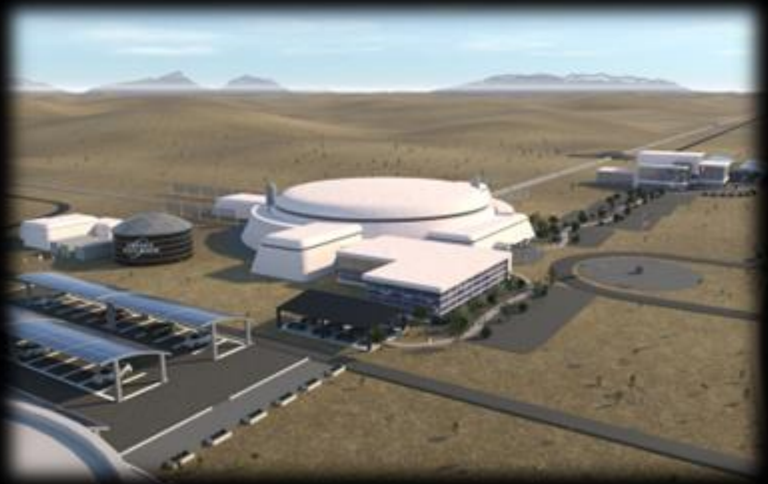
LIGO India (https://www.ligo-india.in/):

- Envisioned to start as an A+ detector (this is the current plan)
- Would be capable of A# hardware

Beyond A#: Cosmic Explorer and Einstein Telescope

10x better than LIGO A+





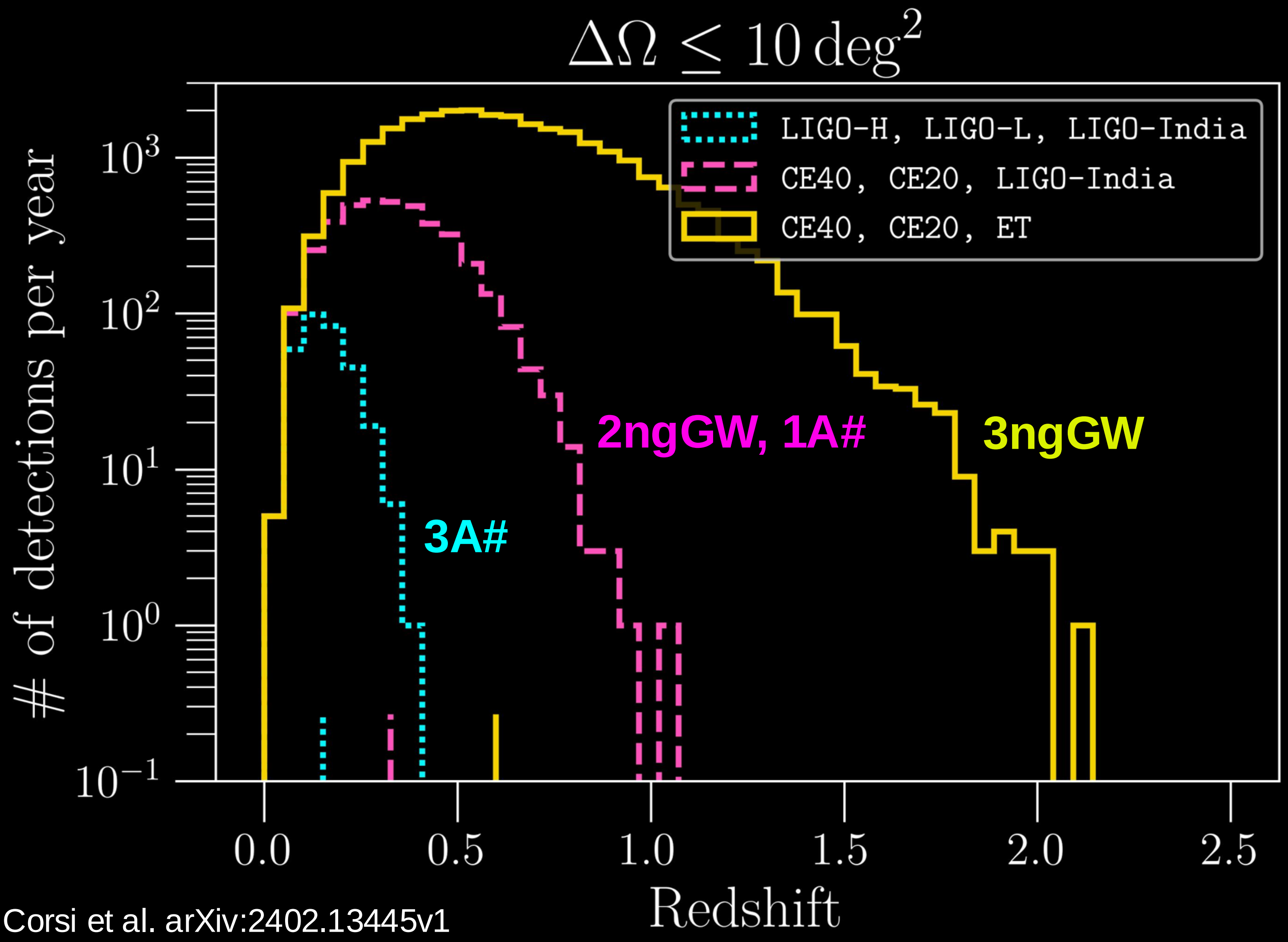
Networks recommended by the NSF MPSAC ngGW panel (unranked):

- CE40, ET, LIGO-India
- CE40, ET
- CE40, CE20, LIGO-India
- CE40, CE20

Corsi et al. arXiv:2402.13445v1
Evans et al. arXiv:2306.13745
Kalogera et al. 2024, https://www.nsf.gov/mps/phy/nggw/mpsac_nggw_subcommittee_report_2024-03-23.pdf

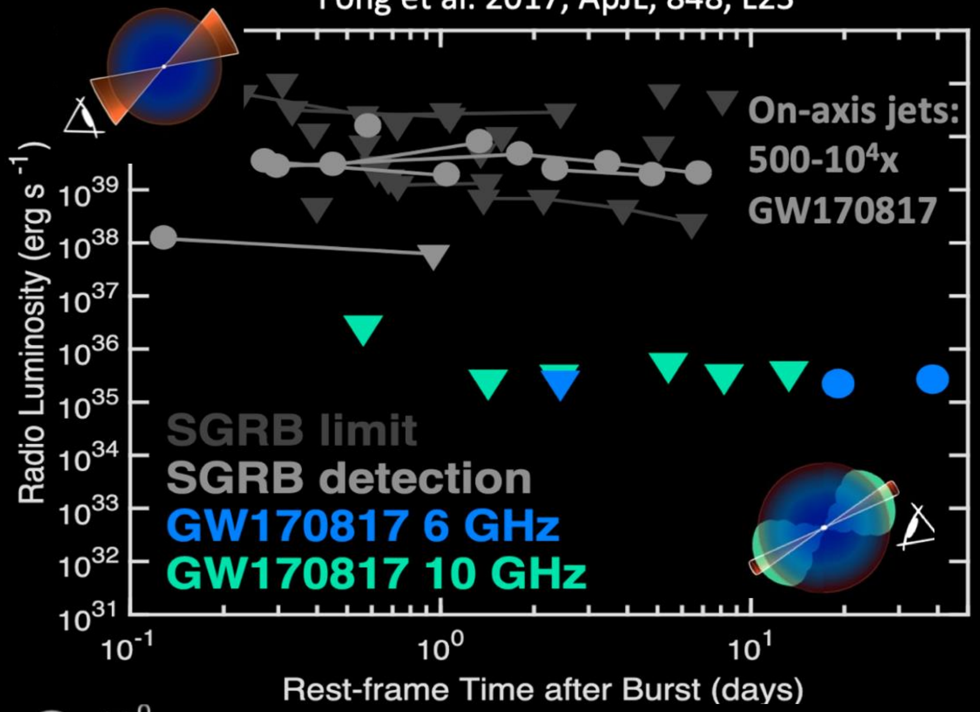
Radio ejecta of BNSs in the post-O5 era

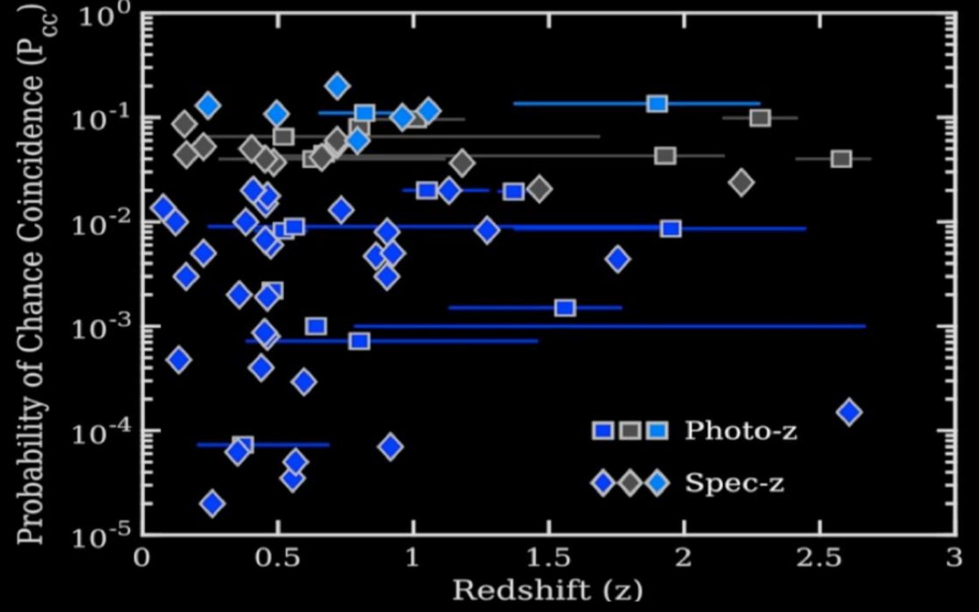
Assumed NS-NS rate: 320 Gpc^{-3} yr^{-1}
After O4a, 90% credible int.: 5-920 Gpc^{-3} yr^{-1}



Corsi et al. arXiv:2402.13445v1
Gupta et al. arXiv:2307.10421

Fong et al. 2017, ApJL, 848, L23





Fong et al. 2022 ApJ 940 56

The future of radio plus GW studies

Corsi et al., DSA-2000 science book
https://www.deepsynoptic.org/key-science

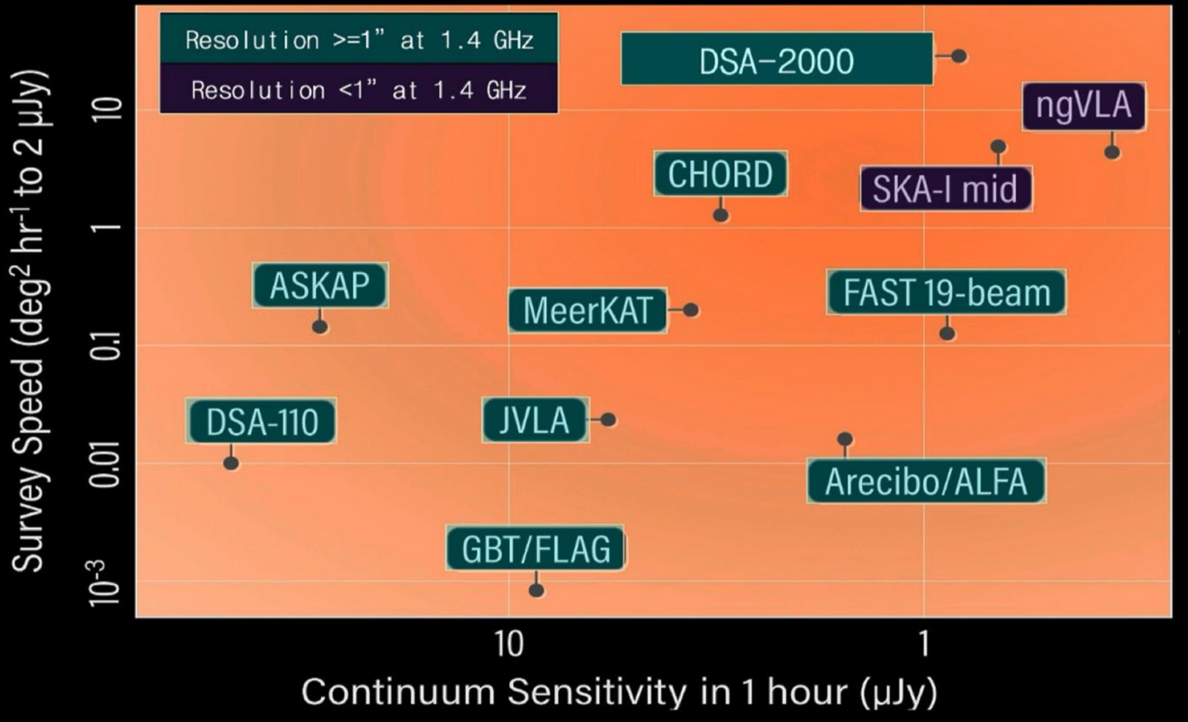
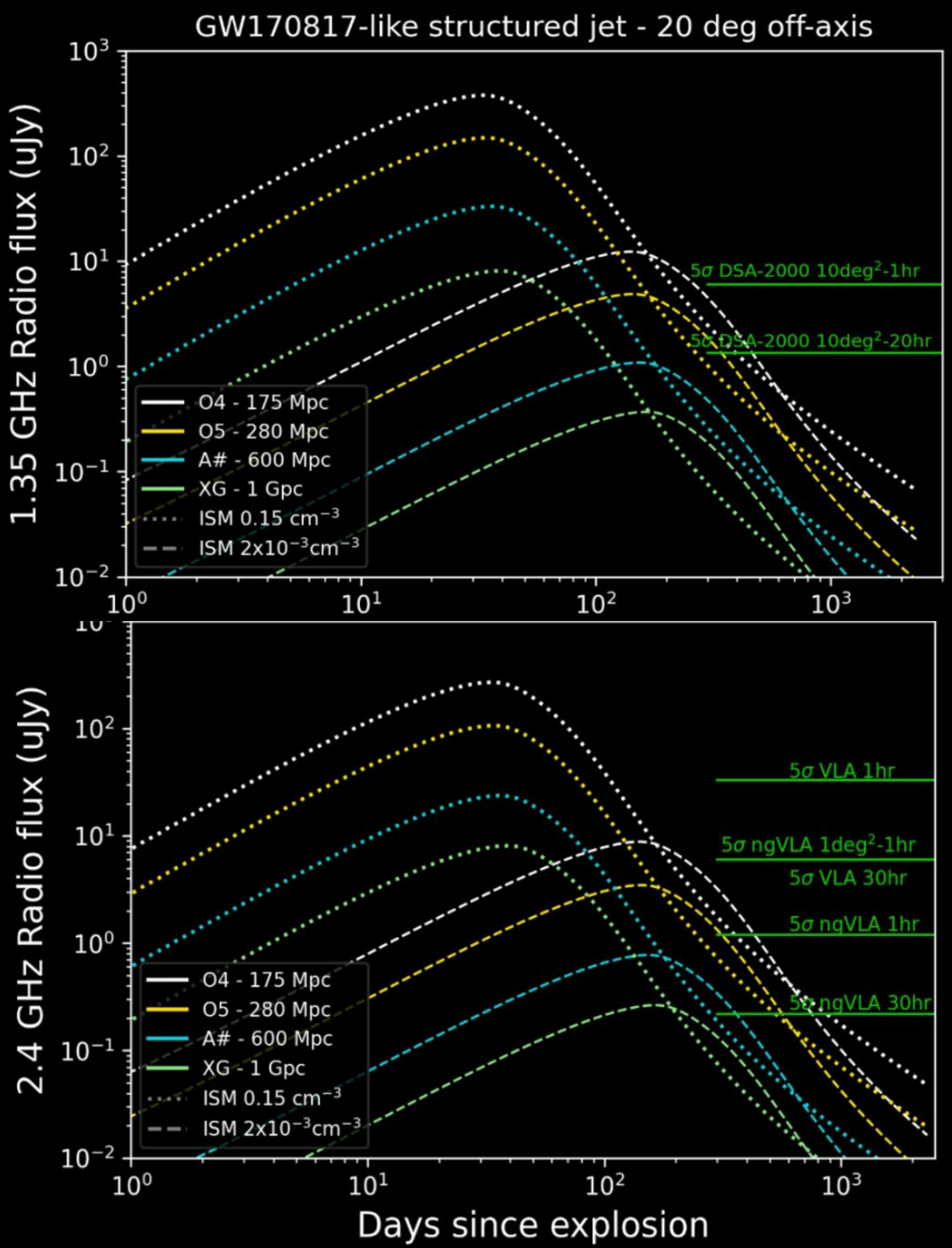
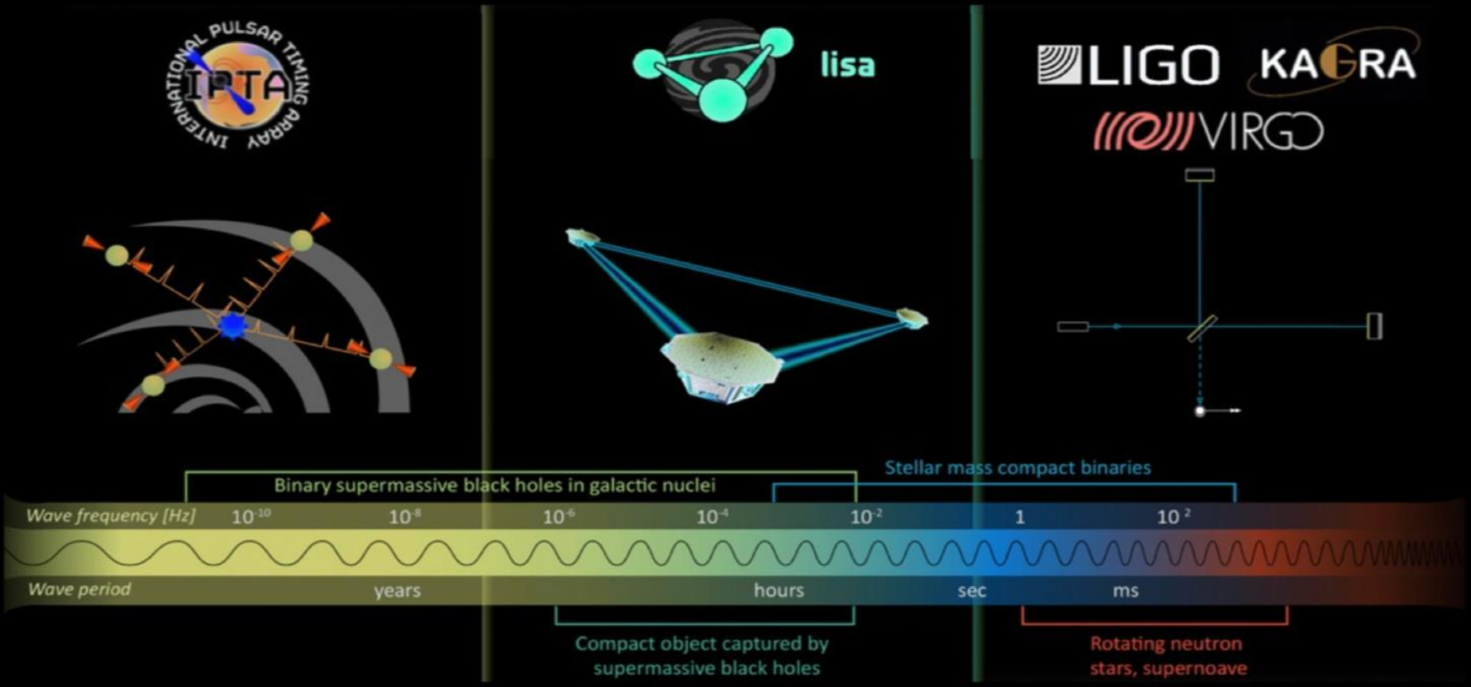
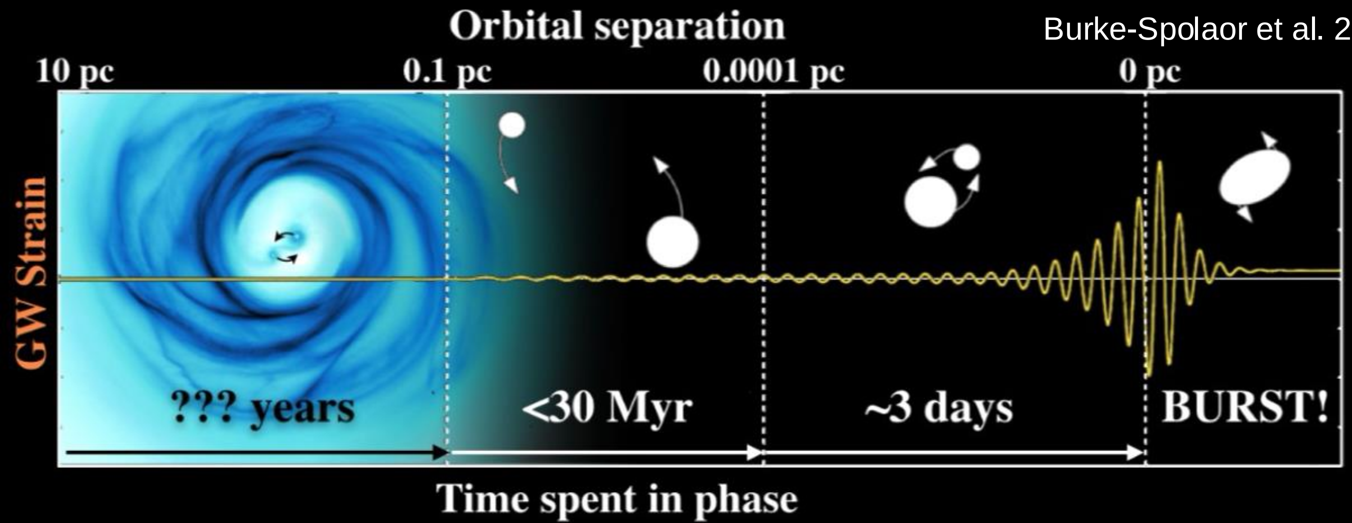


Figure adapted from
https://www.deepsynoptic.org/overview

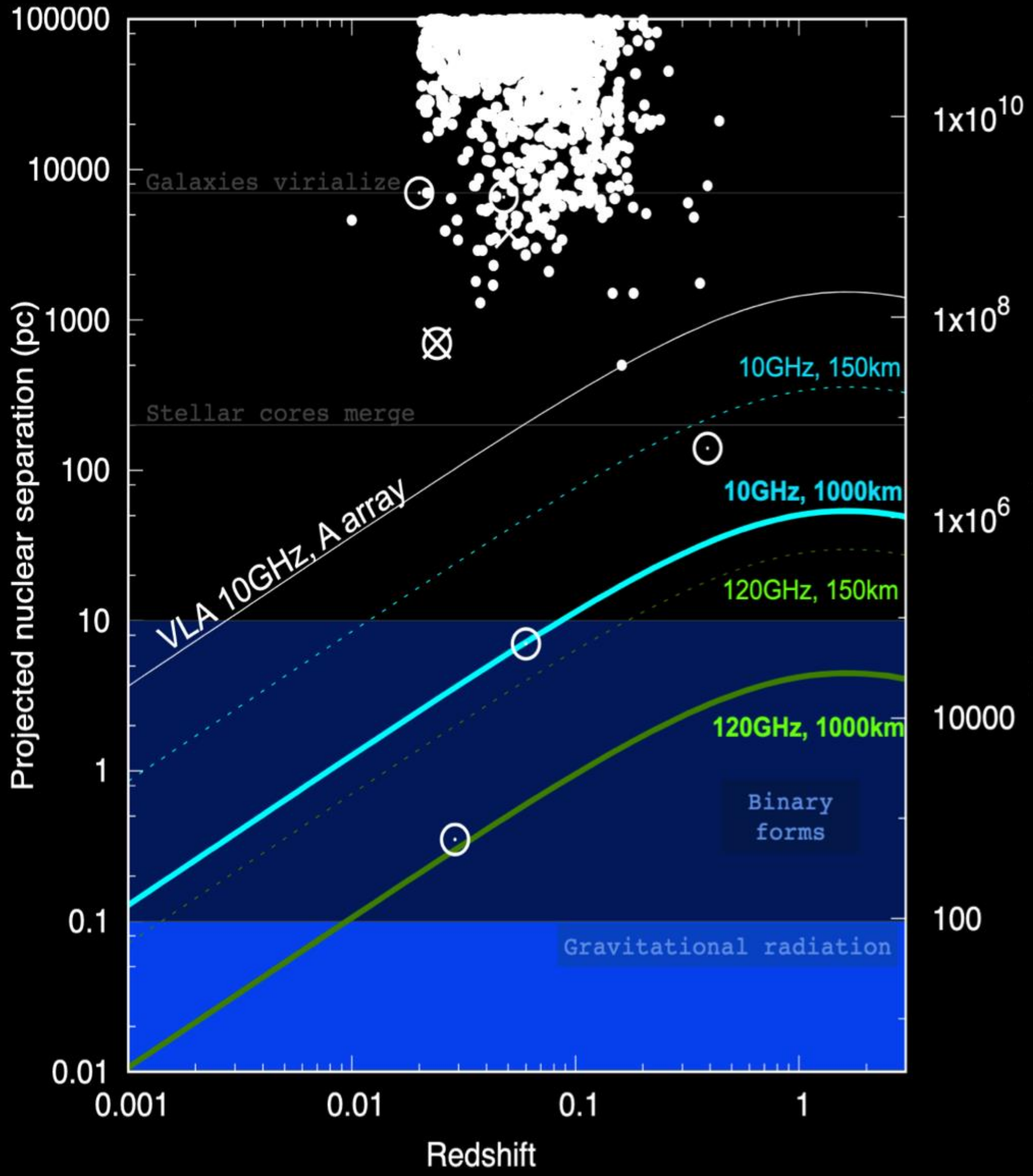


Radio plus GW studies of massive BH binaries





Burke-Spolaor et al. 2018



Conclusion and outlook

- LIGO-Virgo: direct measurements of GWs. Merging binary black holes, binary neutron stars, and black hole + neutron star systems have been observed - **‘a scientific revolution’.**

- **EM counterpart** discovered for GW170817. A lot more to learn in the future: we are yet to discover another EM+GW event.

- **Open questions:** Diversity of progenitors and outflows, nature of the merger remnants, merger dynamics for highest mass binary mergers, …

- O4 is on-going and plans underway to improve LIGO and Virgo sensitivities for O5 and beyond. **It is key that EM (radio) facilities progress in tandem.**

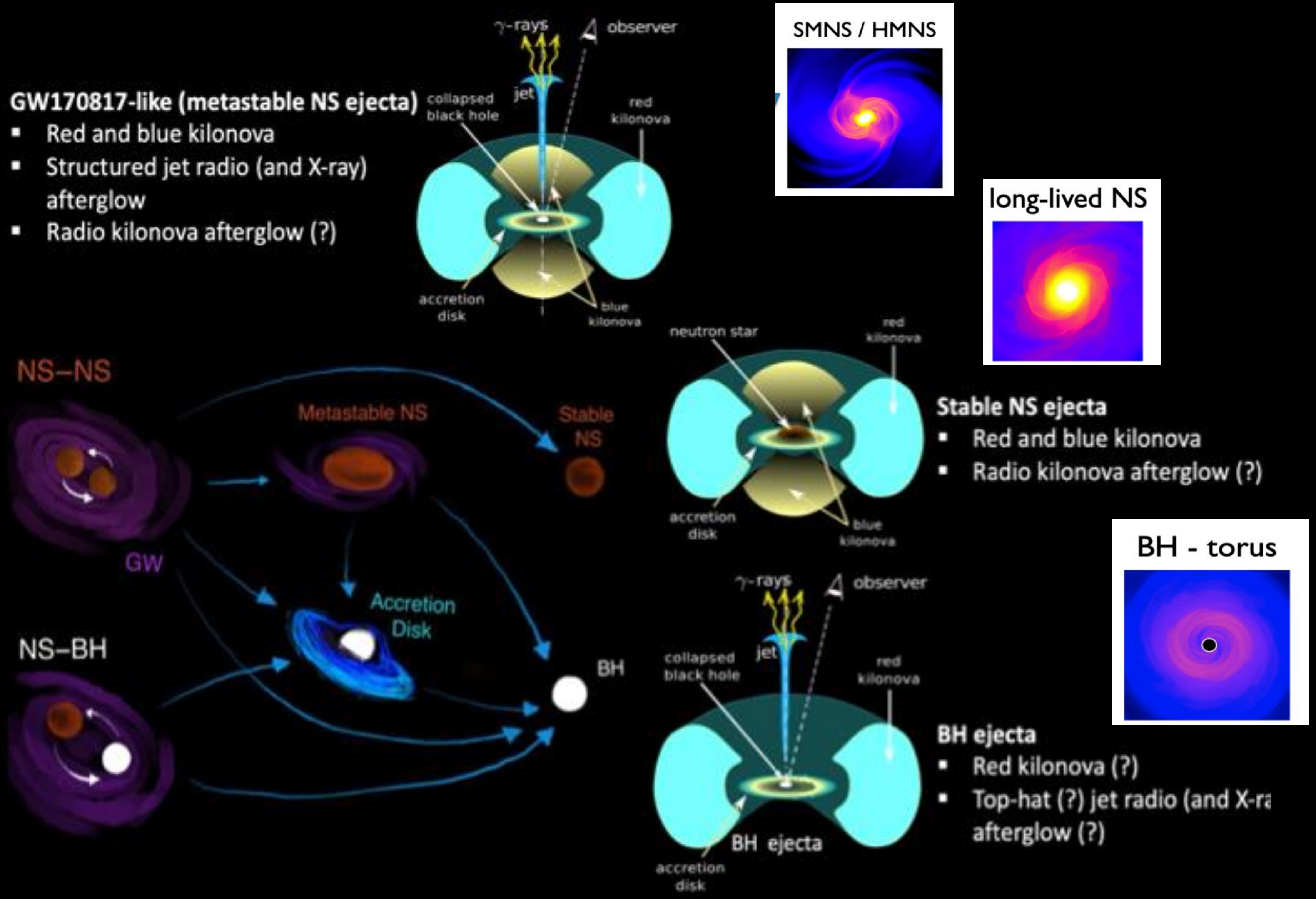
- **GW data analysis techniques must evolve** to discover new physics and increase computational efficiency in the ngGW era, as we transition from a trickle to a flood of detections.

- **PTAs / LISA enable exploration of high-mass end of BH binary systems.** With the ngVLA, potential for the next revolution in MMA!

The End

(Thanks for your attention!)

MMA of stellar-mass compact binaries: Key open questions



- What is the **mass distribution** of NS-NS and BH-NS binaries? (compare GW170817 with GW190425).
- **What are the properties of their outflows?** (geometry, energy and speed distribution, particle acceleration, magnetic field amplification, ISM density, …).
- **What is the nature of the merger remnant** (max NS mass and EoS of state of neutron matter)?