What Gravitational Waves Can Tell Us About the Universe (A Partial List)

Gravitational waves are an entirely new way to probe the universe

Physics

- Is General Relativity the correct theory of gravity?
- How does matter behave under extreme gravity?
- What is the equation of state of neutron stars?

Astrophysics & Astronomy

- What powers short gamma ray bursts, the brightest events in the universe?
- How do stars explode?
- How many stellar mass black holes are there in the universe?
- Do intermediate mass black holes exist?

Cosmology

- Can we detect primordial gravitational waves?
- What is the value of the Hubble constant?
- Do primordial black holes exist?

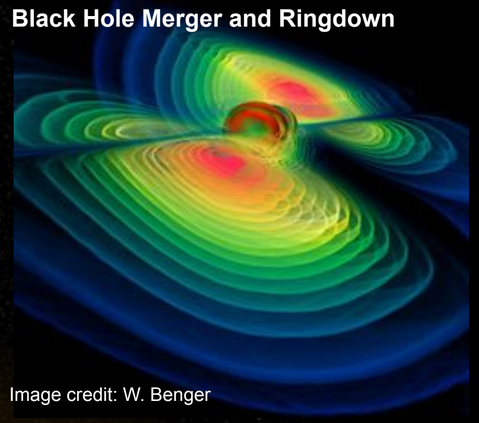


Image credit: W. Benger

Image credit: NASA

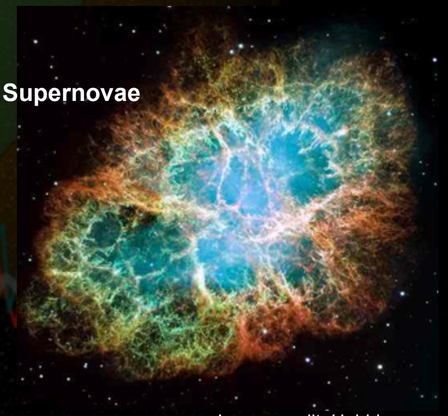
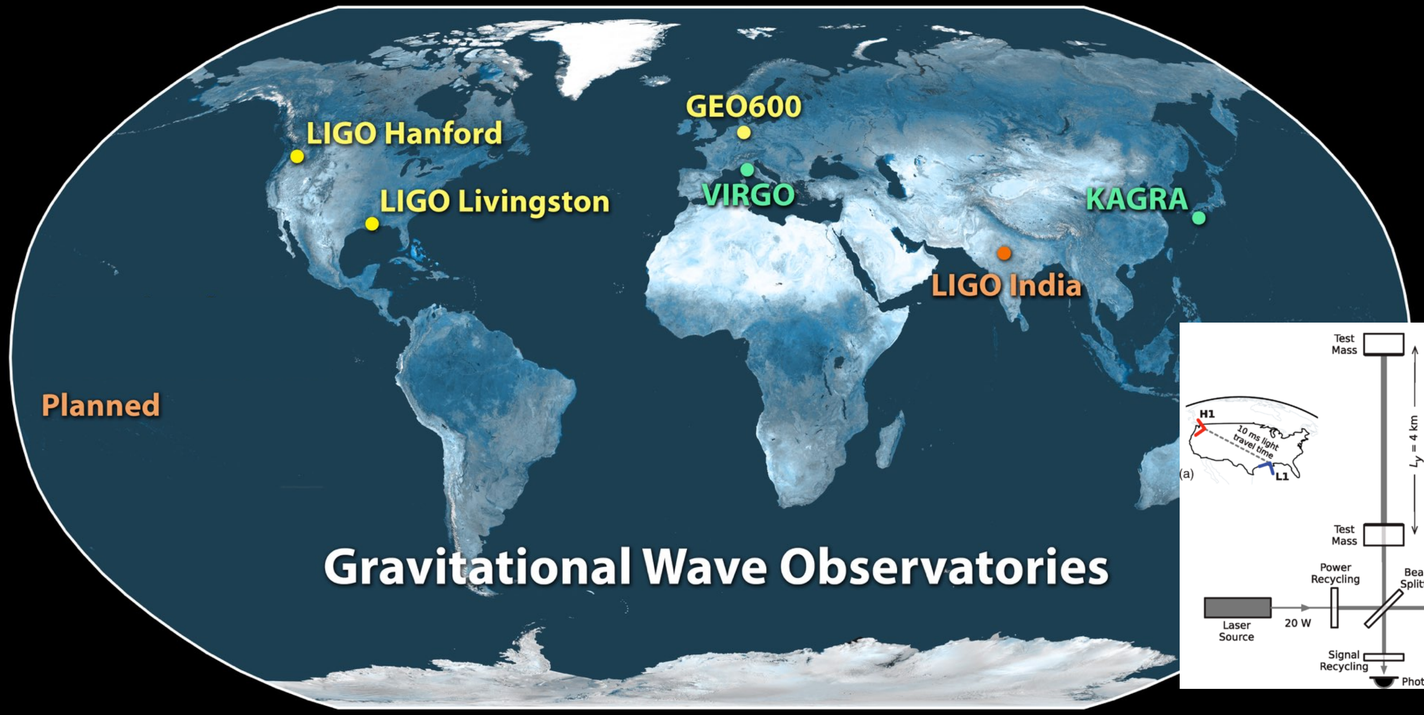
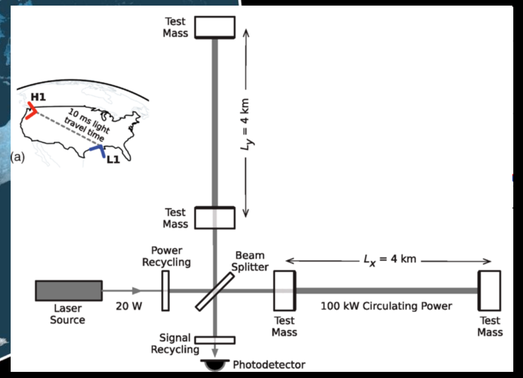
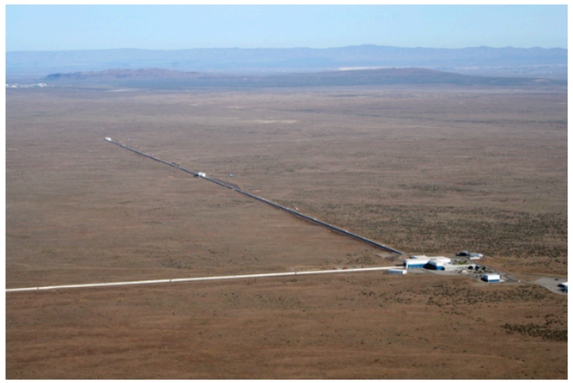


Image credit: Hubble

LIGO and the International Gravitational Wave observatory Network







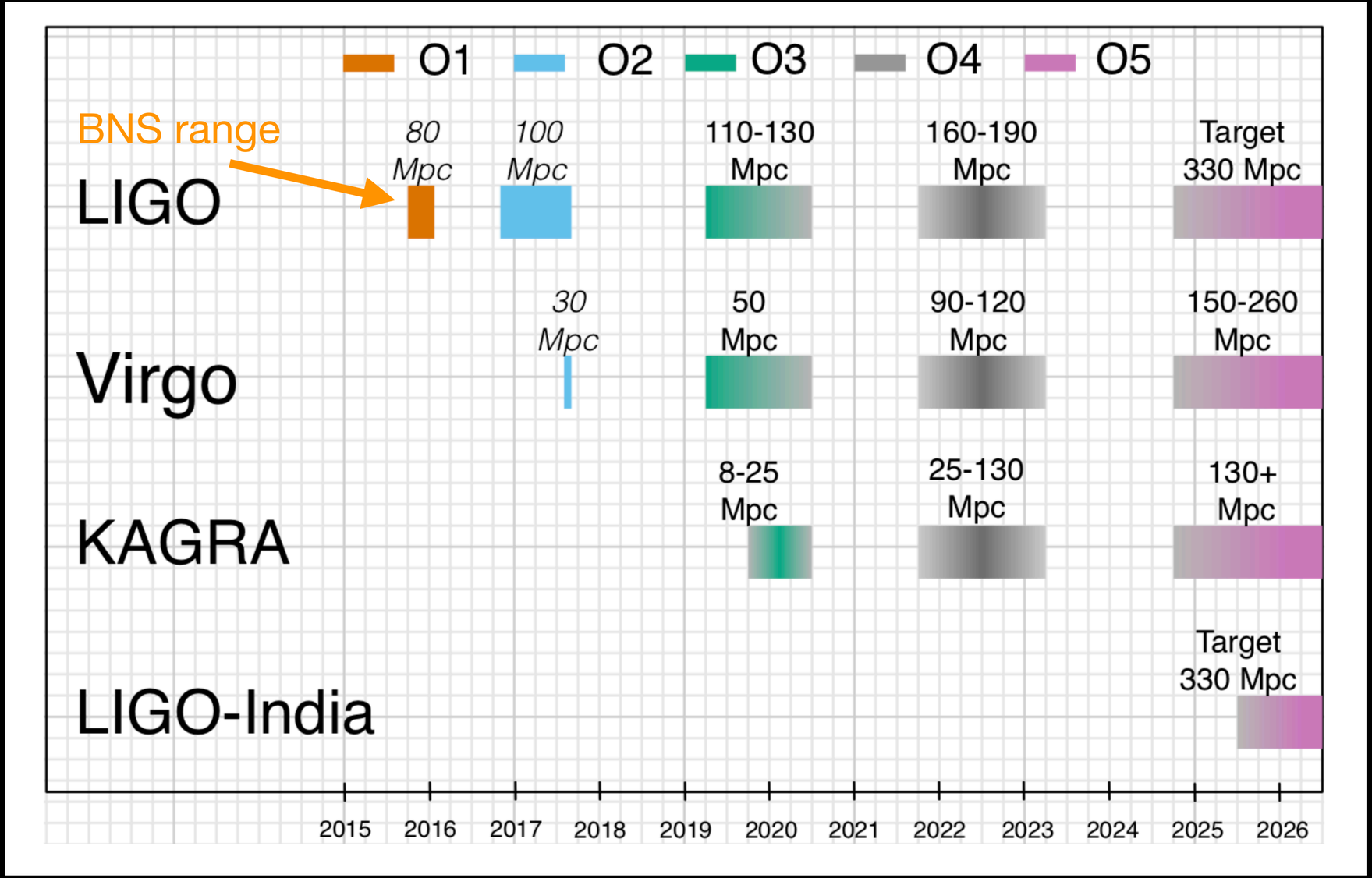
LIGO Hanford (WA)

LIGO Livingston (LA)

Virgo (Italy)

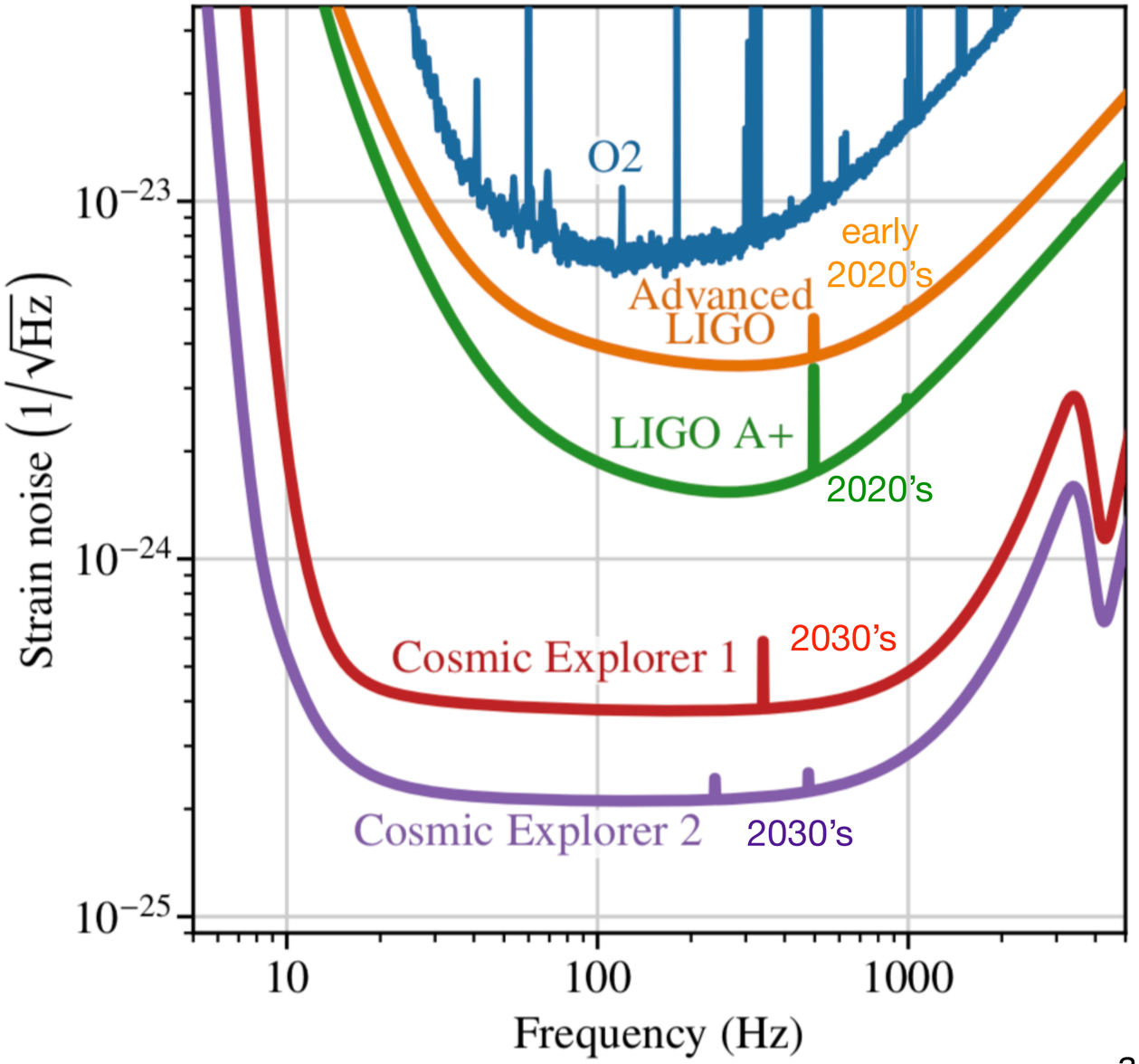
GEO600 (Germany)

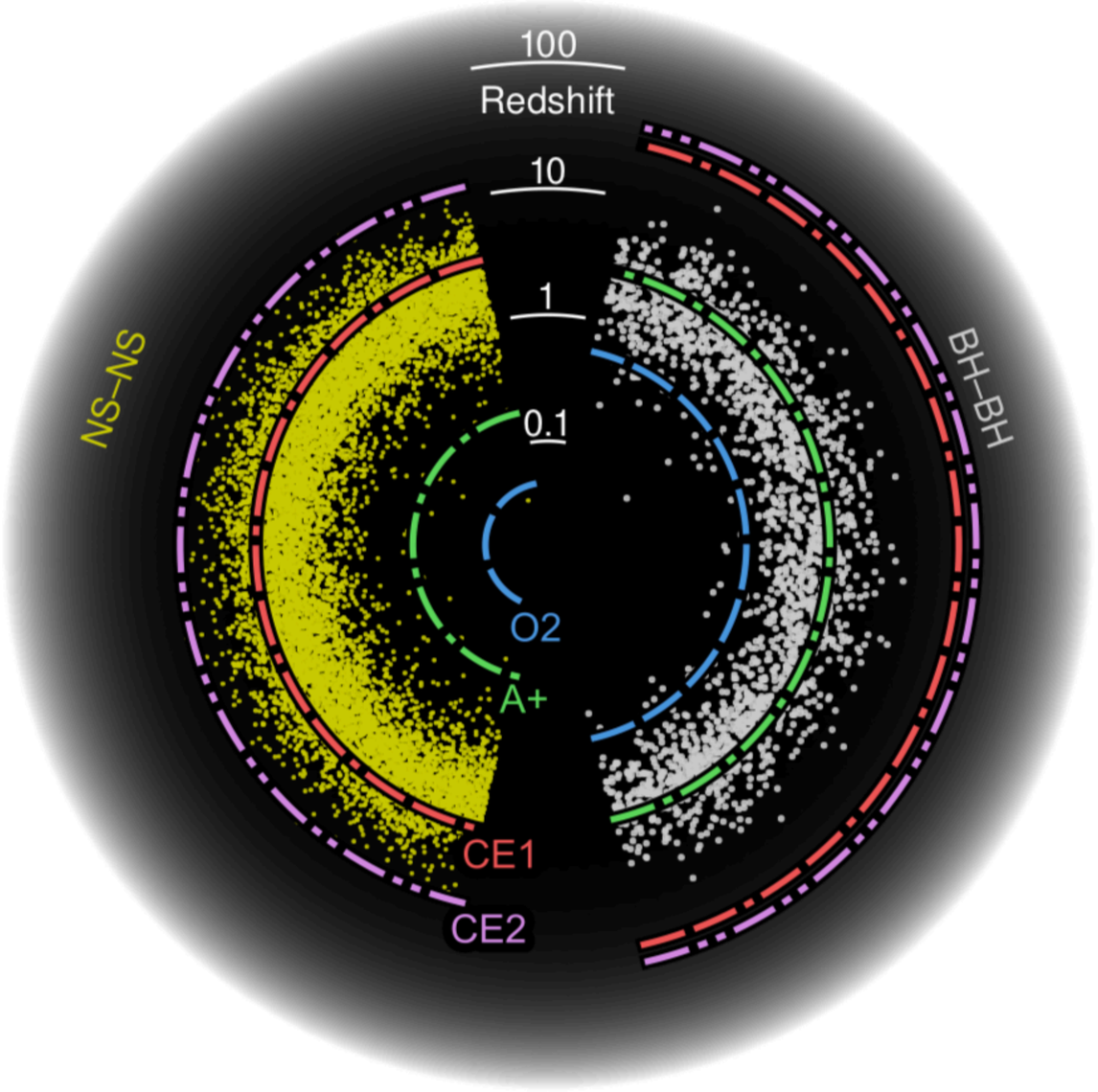
Prospects for Observing and Localizing Gravitational-Wave Transients with Advanced LIGO and Advanced Virgo and KAGRA — arxiv.org:1304.0670



Next run not before August 2022; Upcoming schedule update in November

https://www.ligo.org/scientists/GWEMalerts.php





arXiv:1903.04615

The Future for Multi-Messenger Astrophysics

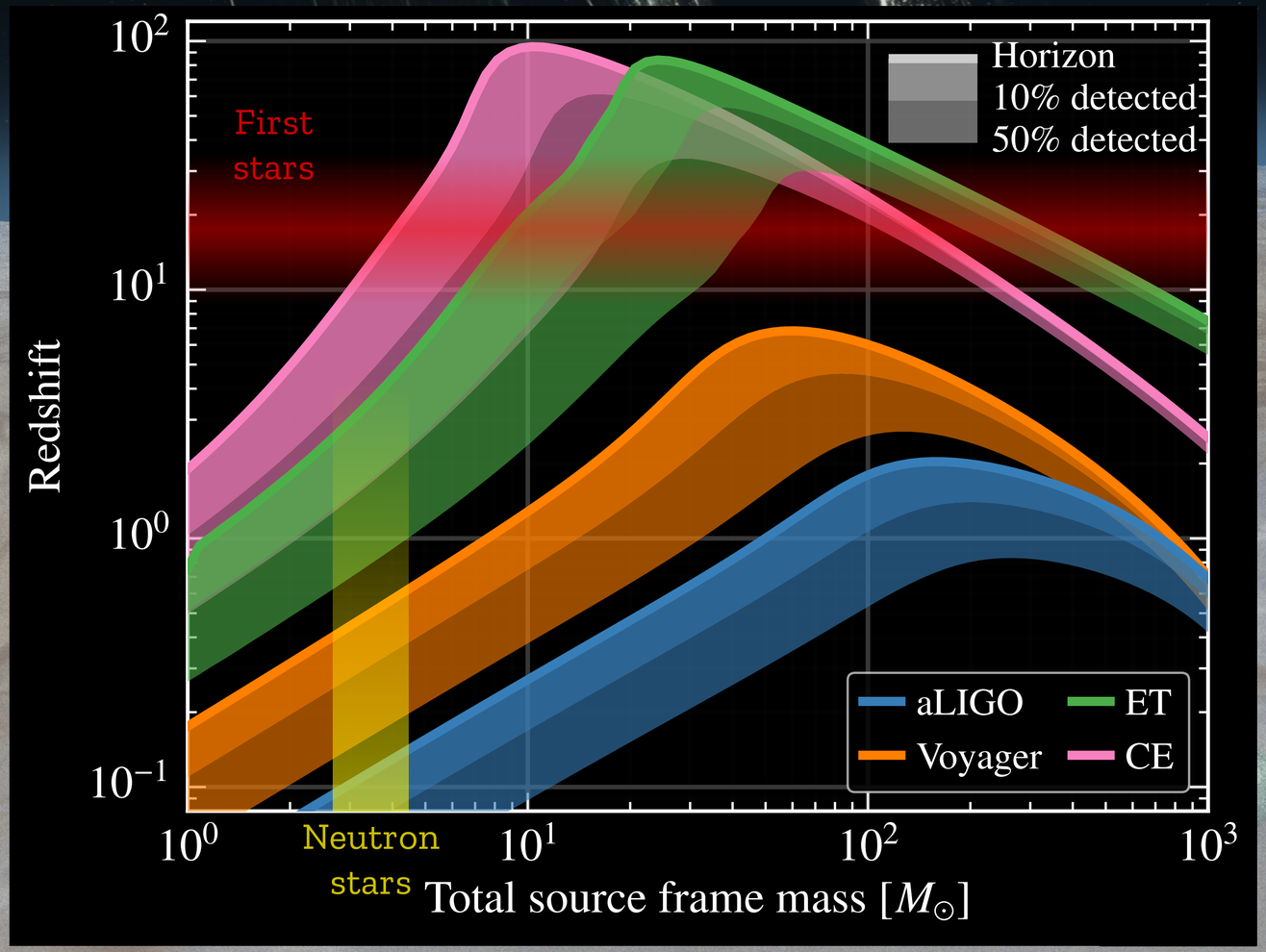


Table 1: Expected detections per year (N), number detected with a resolution of < 1, < 10 and < 100 sq. deg. (N_1, N_{10} and N_{100}, respectively) and median localization error (M in sq. deg.), in a network consisting of LIGO-Hanford, LIGO-Livingston and Virgo (HLV), HLV plus KAGRA and LIGO-India (HLVKI) and 1 Einstein Telescope and 2 Cosmic Explorer detectors (1ET+2CE).

Network	N	N_1	N_{10}	N_{100}	M
HLV	48	0	16	48	19
HLVKI	48	0	48	48	7
1ET+2CE	990k	14k	410k	970k	12

arXiv:1903.09277

Formation and evolution of compact binaries
Heavy element nucleosynthesis
Jet physics
Cosmology
Multi-band gravitational wave astronomy

Gravitational Wave Periods

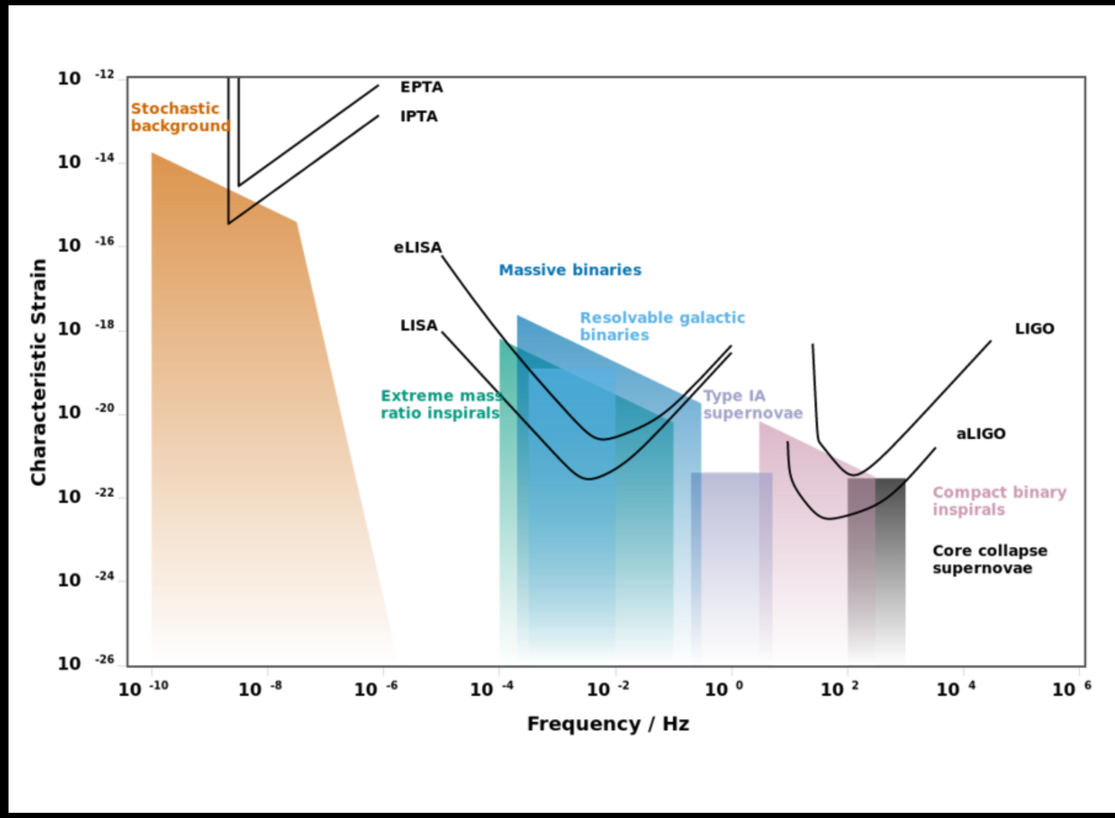
Milliseconds

Minutes to Hours

Years to Decades

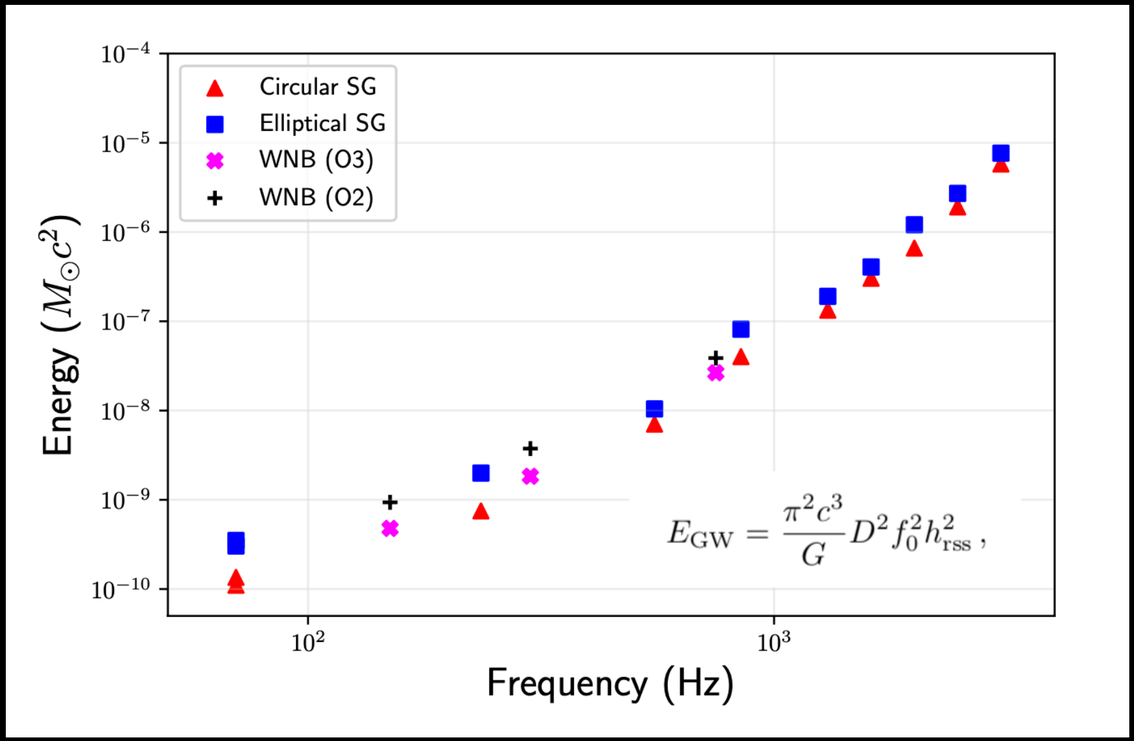
Billions of Years

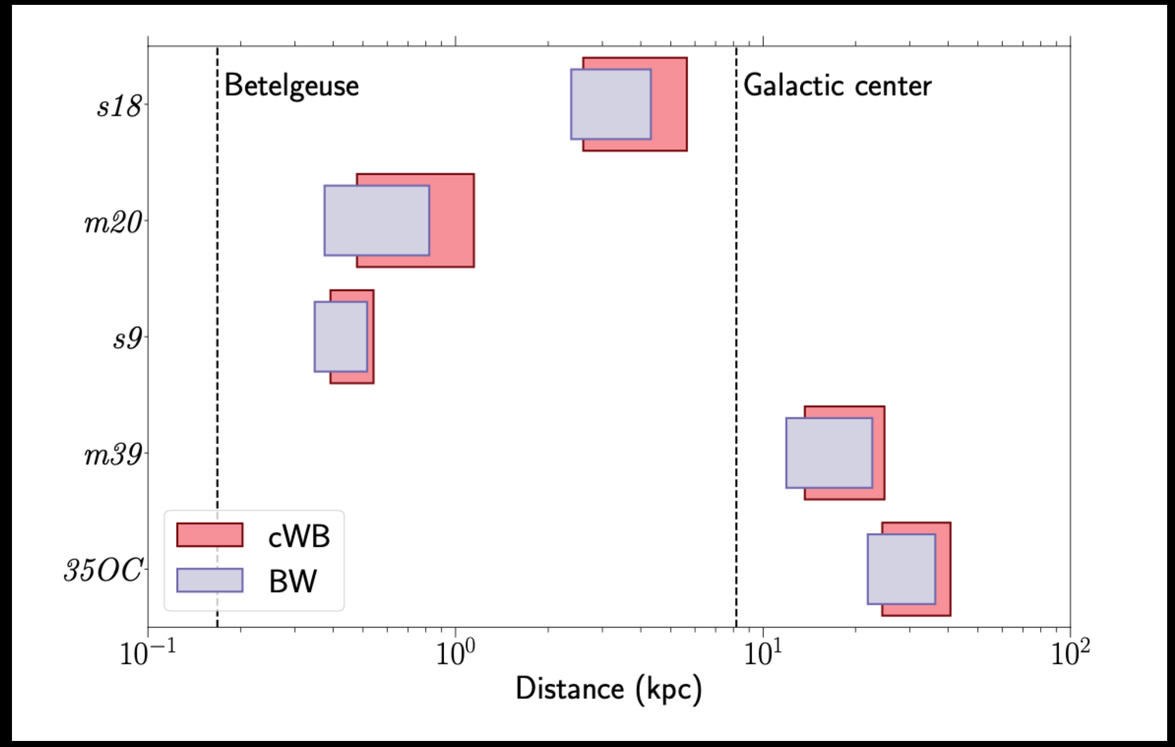
LIGO/Virgo LISA Pulsar Timing Array Cosmology Probes



Burst all-sky: the "Ears Wide Open" approach

All-sky search for short gravitational-wave bursts in the third Advanced LIGO and Advanced Virgo run
arXiv:2107.03701





GW energy in short pulses from the galactic center, detectable with 50% probability.

Function of frequency and waveform.

Distance scaling: $\mathbf{E_{GW} \propto D^2}$

(so, *need ~3x10⁶ more E_{GW} for a signal from the Virgo Cluster to be detectable*)

E.G. sensitive to galactic supernovae:
Core Collapse Supernovae numerical simulations:
E_{GW} up to $10^{-7}\ M_\odot c^2$