Status and Recent Developments in Gravitational Wave Experiments

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Gravitational Waves

Scale of Effect Vastly Exaggerated

LIGO/R. Hurt

When massive objects accelerate, the curvature of space changes. This change travels out at the speed of light as gravitational waves

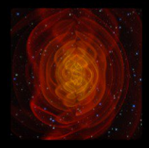
Colliding neutron stars and black holes are some the best sources of detectable gravitational waves

SXS

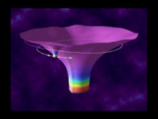
Gravitational Wave Spectrum

Big Bang

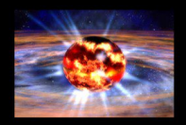
Supermassive Black Hole Binary Merger



Compact Binary Inspiral & Merger



Extreme Mass-Ratio Inspirals



Pulsars, Supernovae

age of the universe

Wave Period

years

hours

seconds

milliseconds

10^{-16} 10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 1 10^{2}

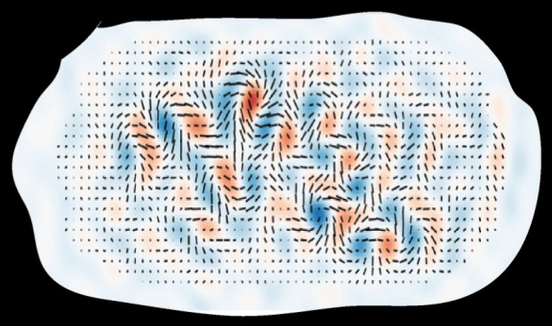
Wave Frequency

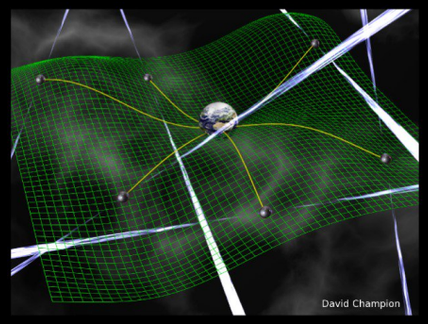
CMB Polarization

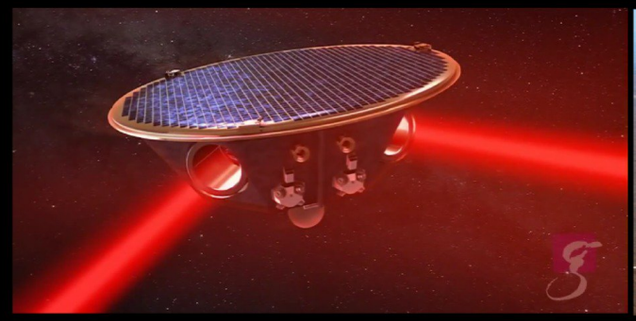
Radio Pulsar Timing Arrays

Space-based interferometers

Terrestrial interferometers







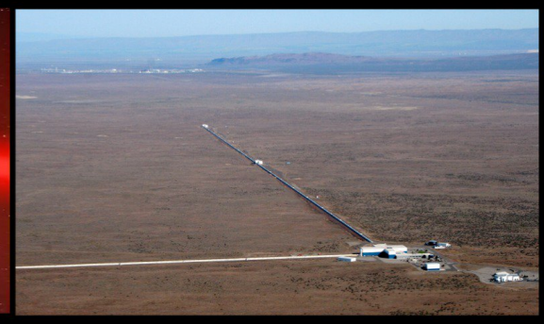
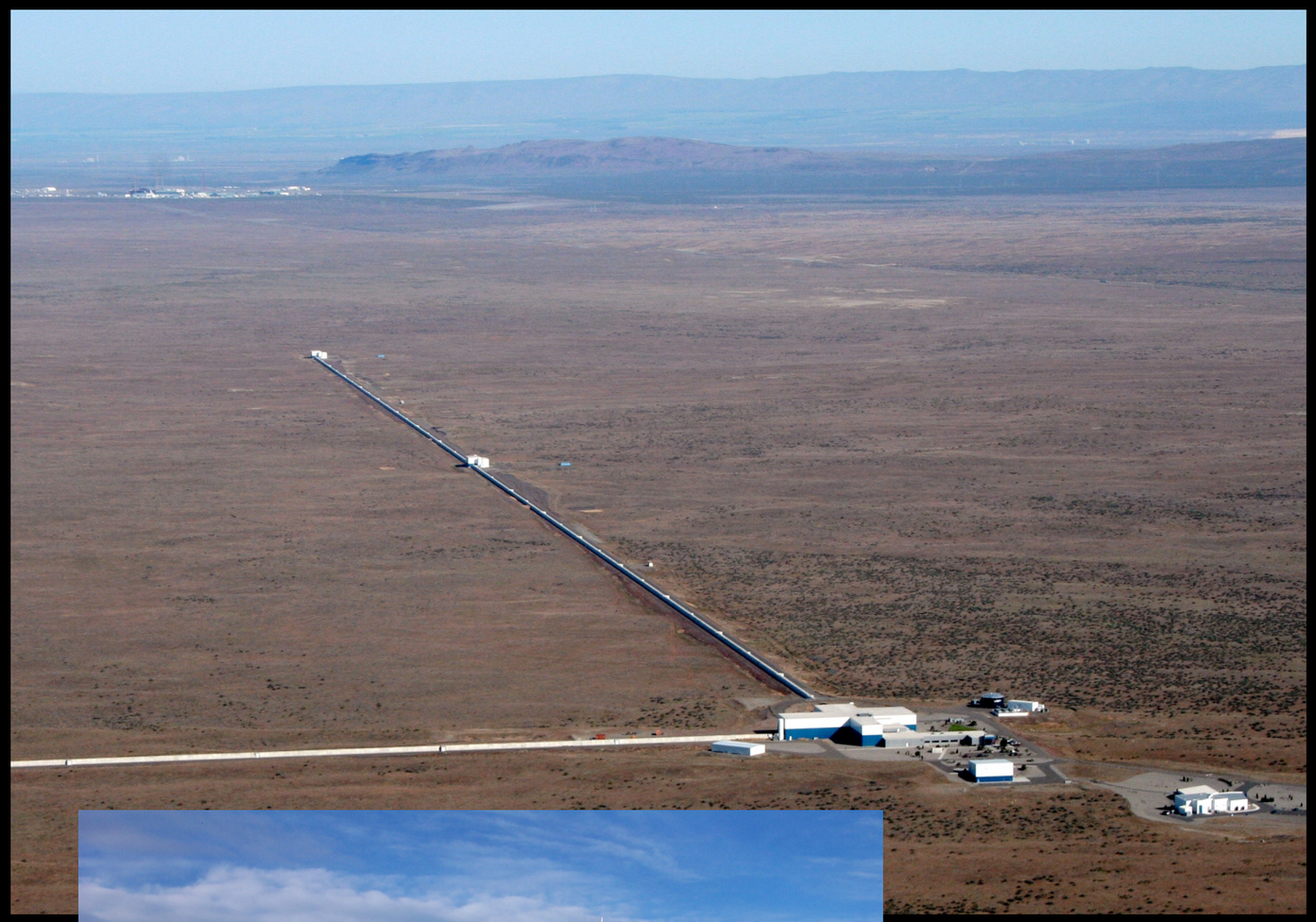


Image credit: Karan Jani/Georgia Tech

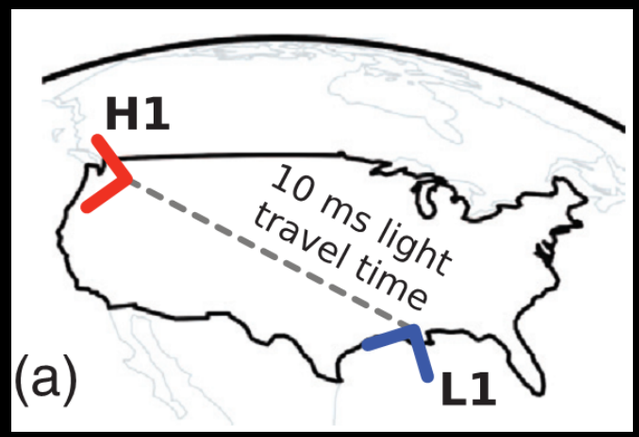
LIGO

Laser Interferometer Gravitational-wave Observatory

LIGO-Hanford



LIGO-Livingston



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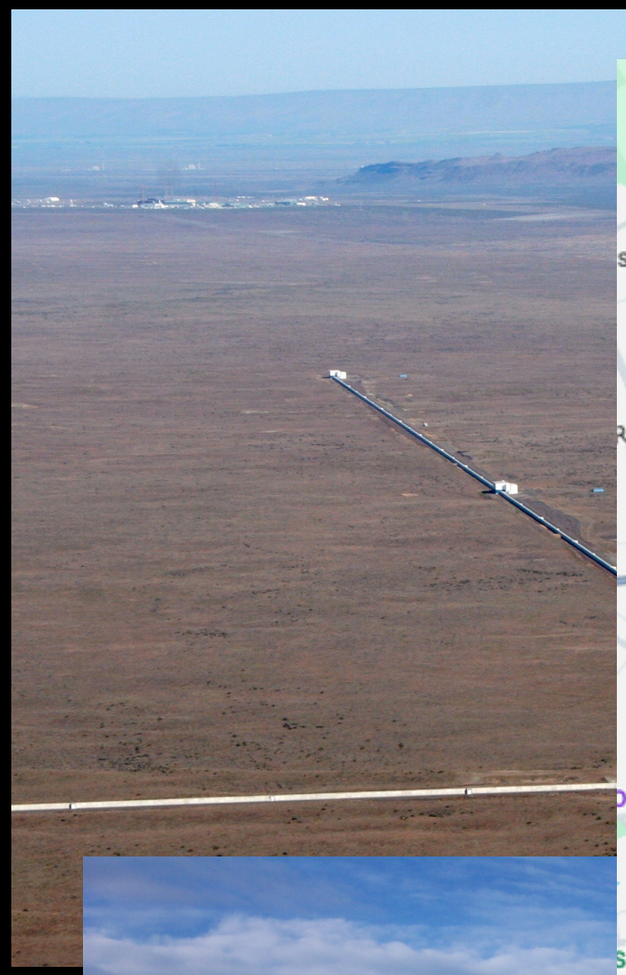
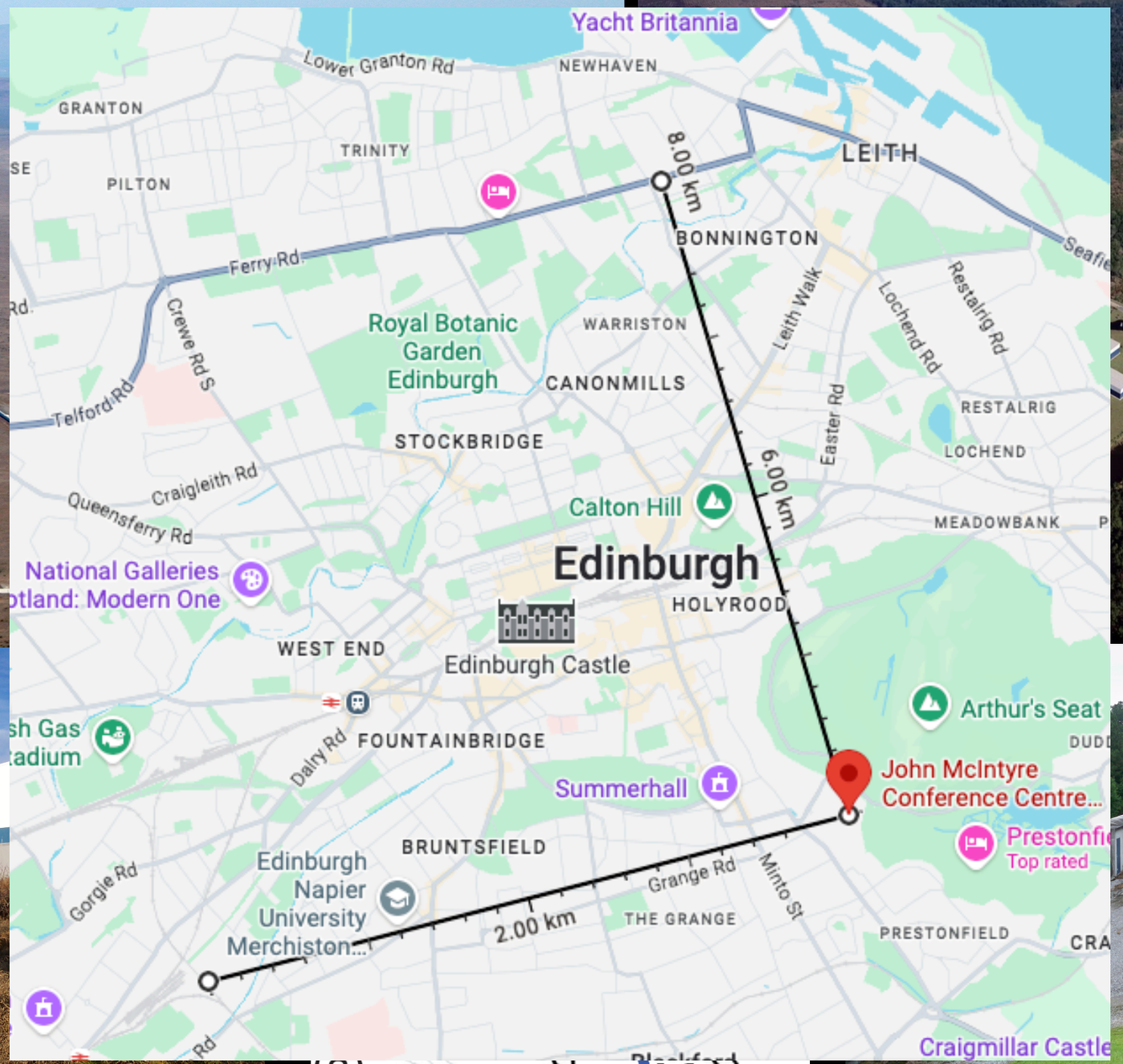
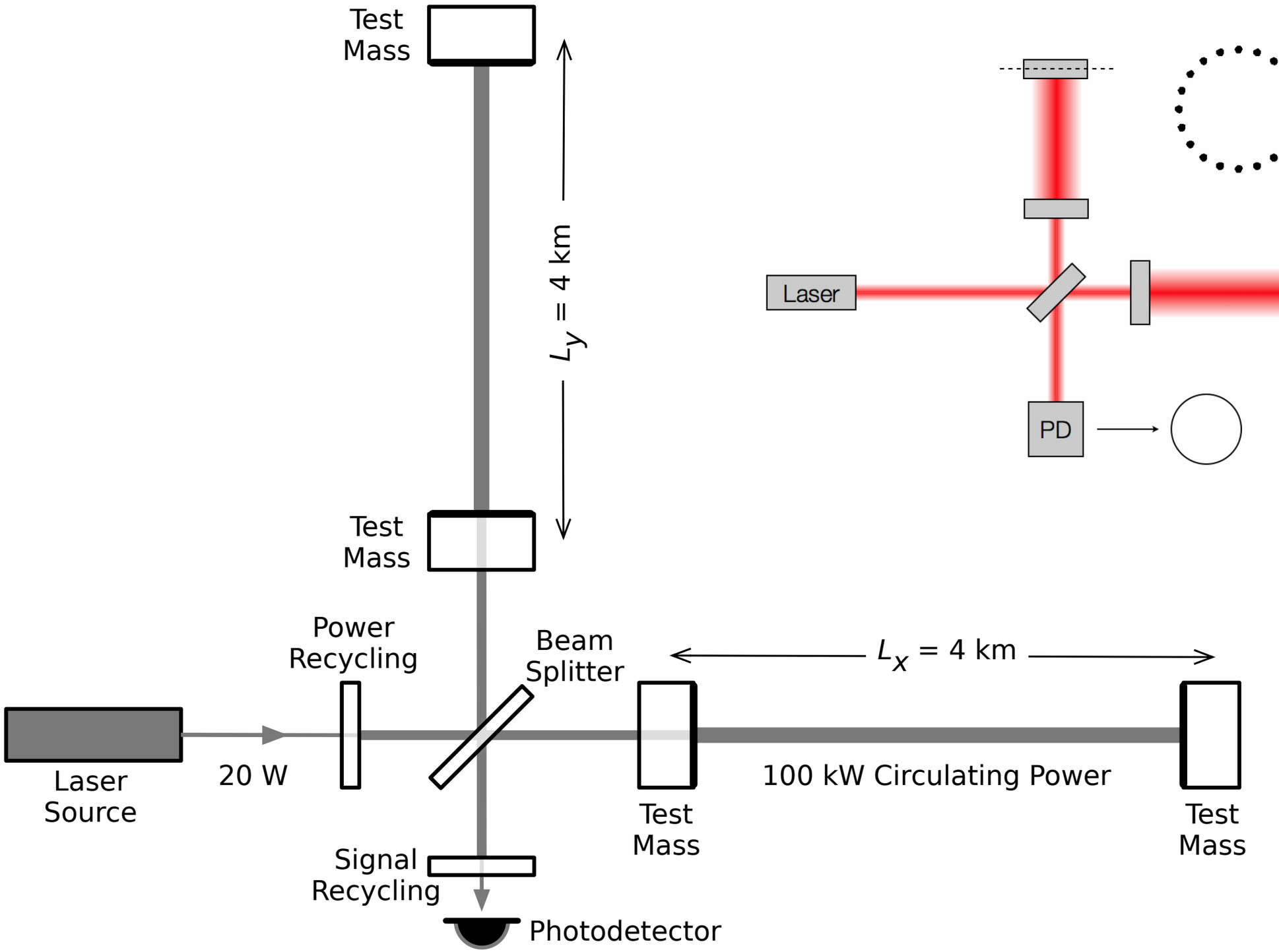




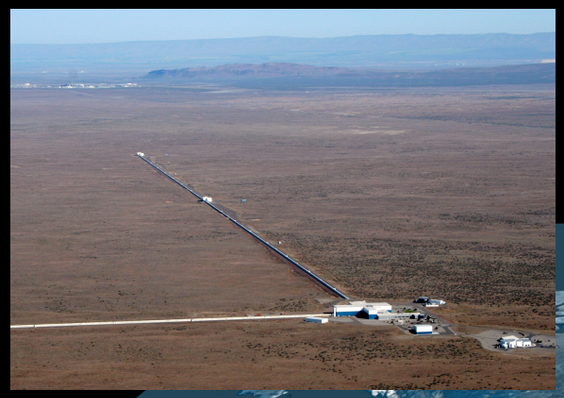
LIGO-Livingston

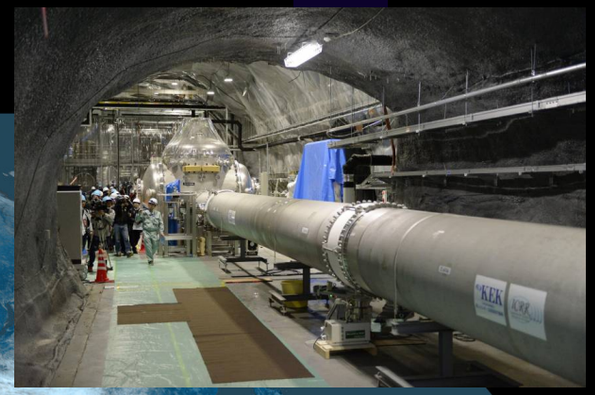
The basics of a GW Interferometer



B. P. Abbott et al., PRL 116, 131103 (2016)

Global Network





LIGO Hanford

GEO600

LIGO Livingston

Virgo

KAGRA

Operat

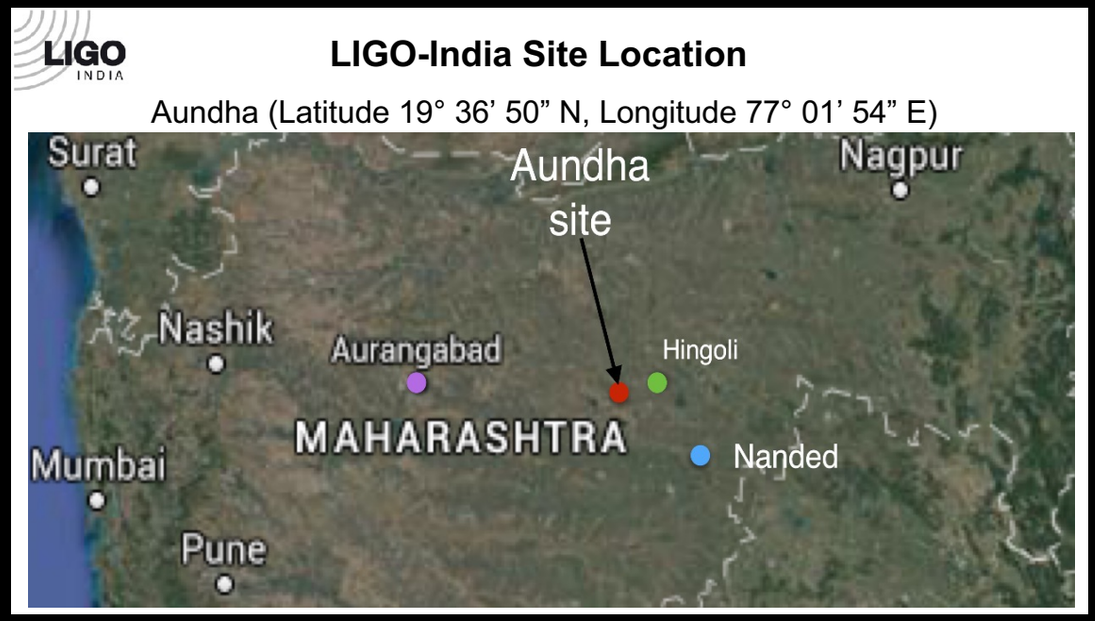
Planne

LIGO India

Gravitational Wave Observatories

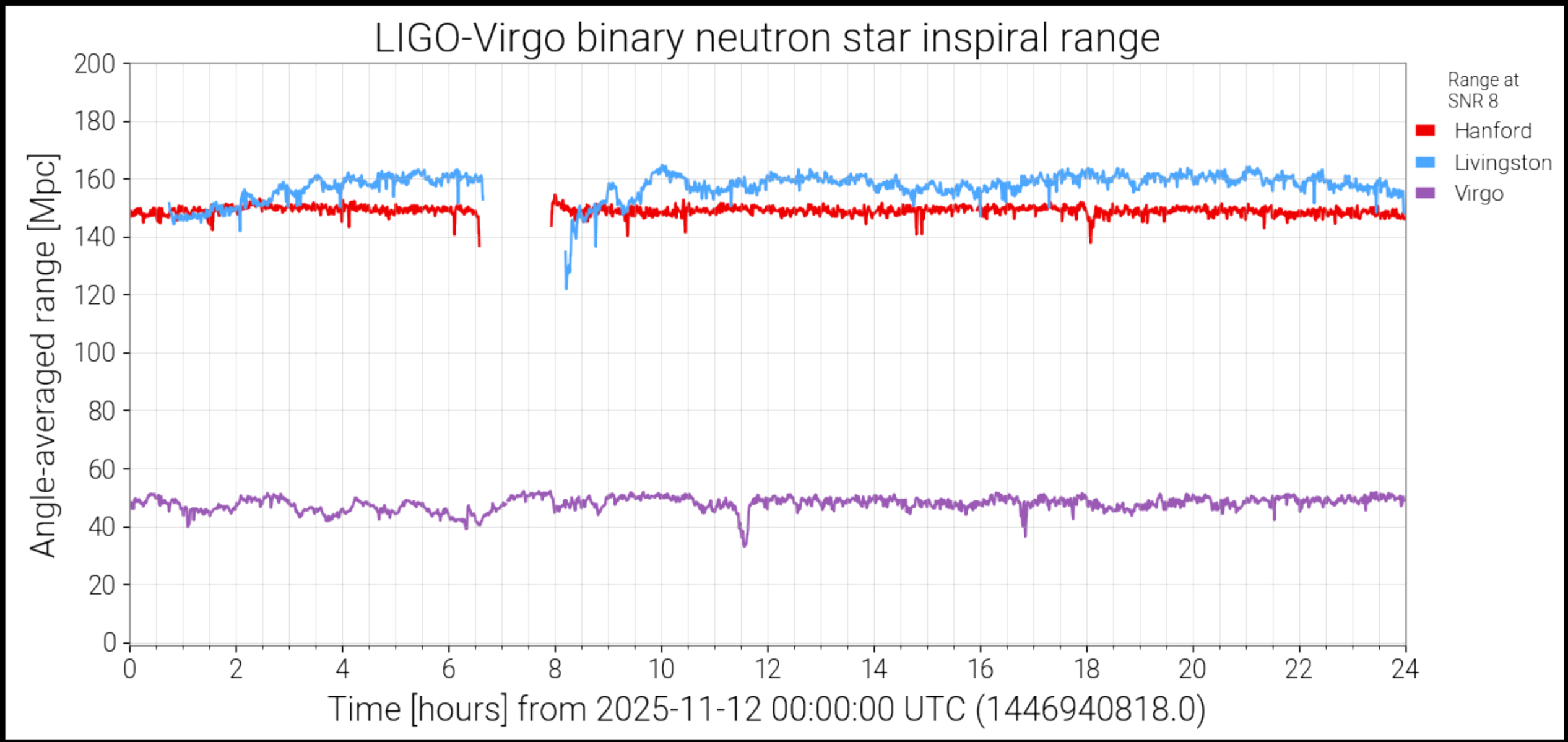
LIGO India

- LIGO India is being built as the Advanced LIGO configuration.
- Expected to be operational in 2030 with starting sensitivity of 100-120 Mpc
- Construction is starting now



(Conceptual ariel view of LIGO India Observatory)

Sensitivity

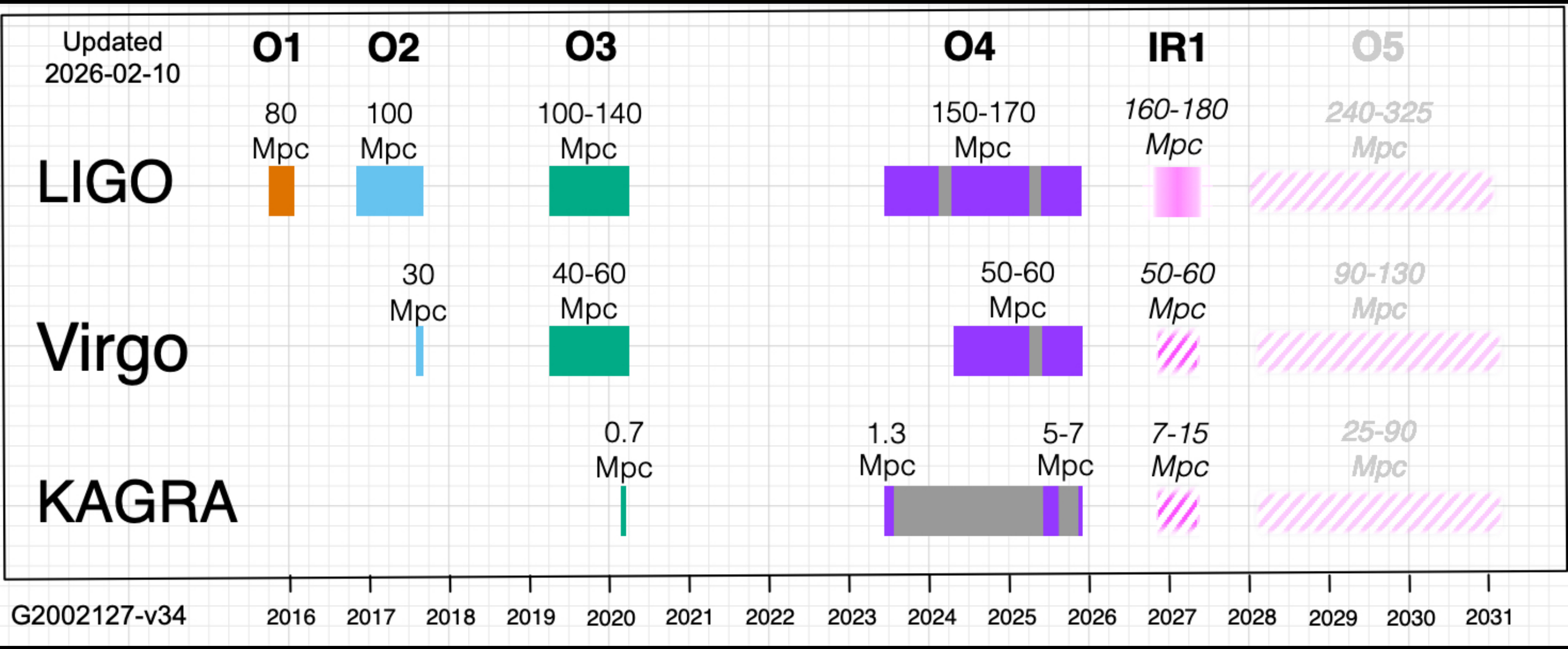


12th November 2025

Public Summary Pages: https://gwosc.org/detector_status/

Observing Run Plan

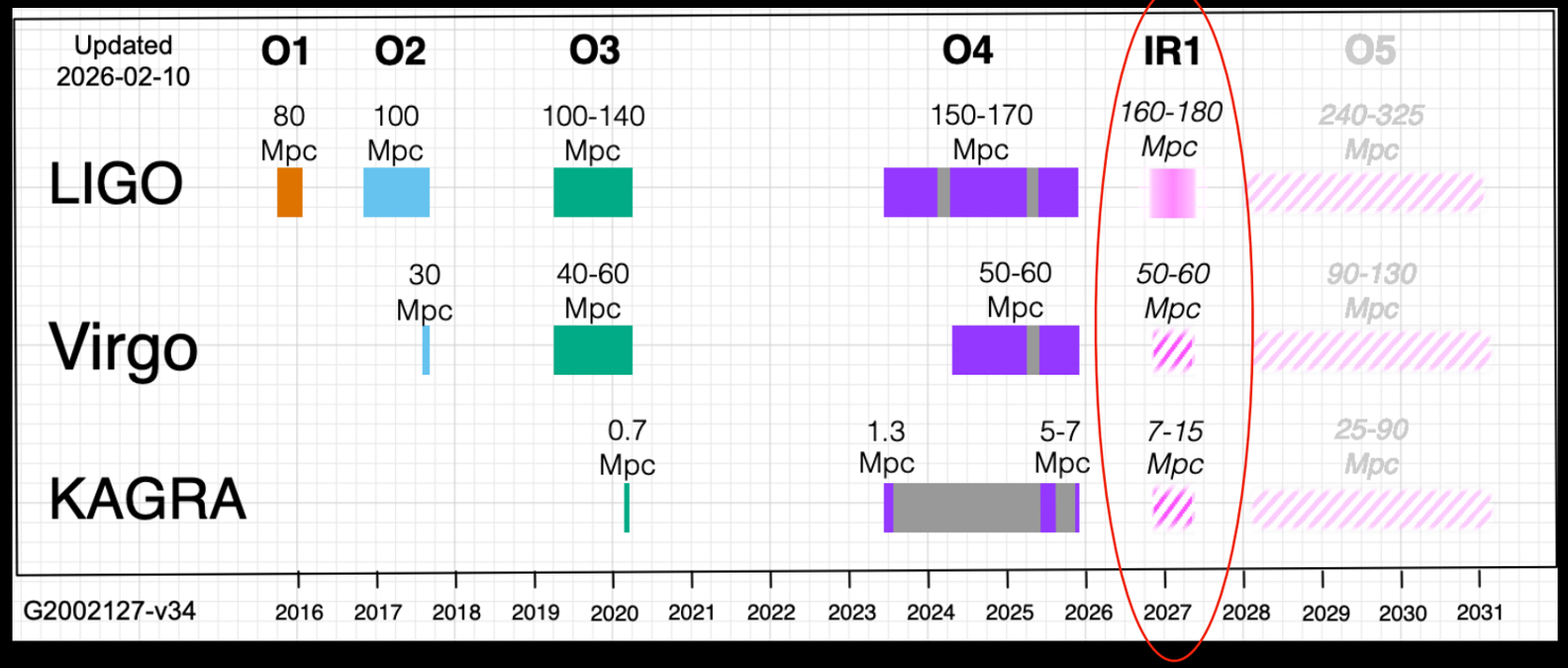
https://observing.docs.ligo.org/plan/



GW observations: 3 | 8 | 79 | 128 (so far been released)

218 GW events and counting

IR1



- Over the next year the LIGO, Virgo and KAGRA collaborations are merging into the International Gravitational Wave Network - IGWN

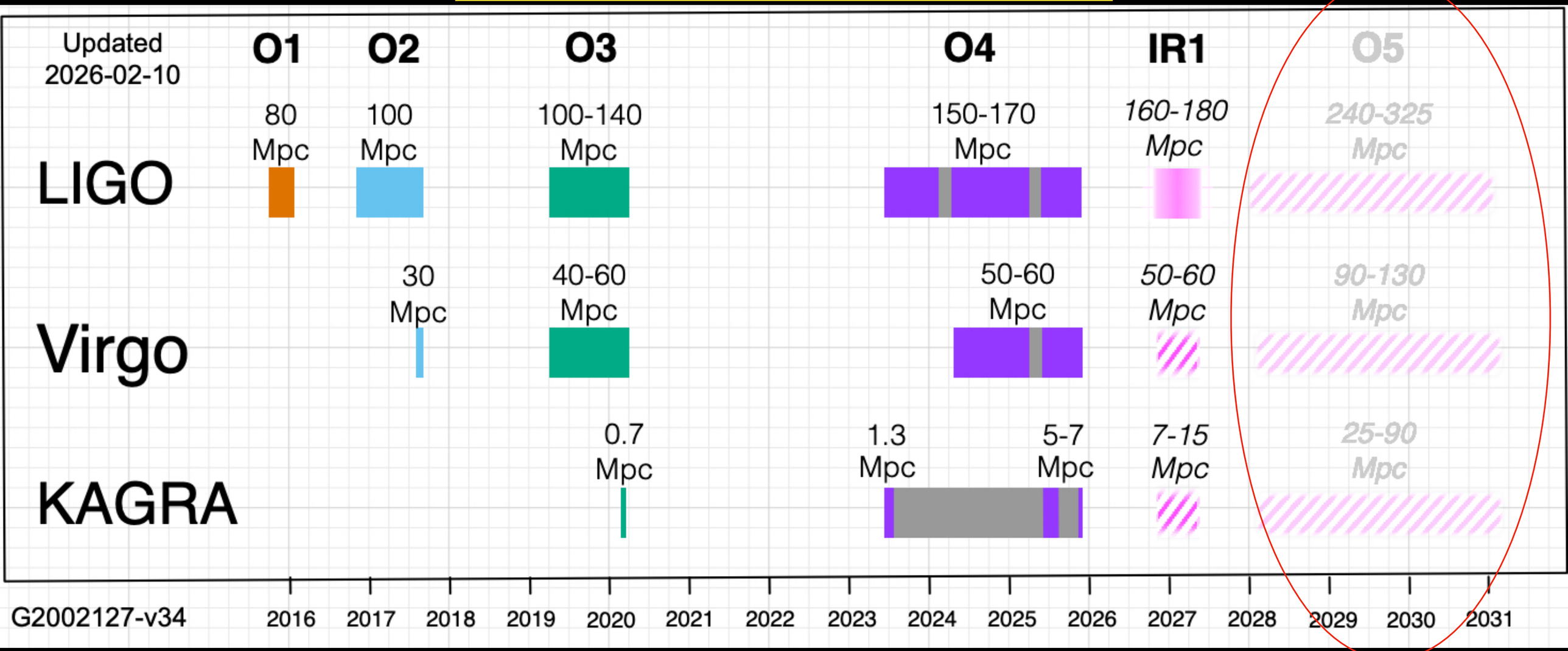
- IR1 (intermediate run 1) is due to start toward the end of October, lasting 6 months

- Not expecting significant sensitivity improvements in IR1 relative to O4, i.e. detections every few days

- Main drivers for IR1:
  - overlap with Rubin
  - commission hardware upgrades (being installed now)

O5

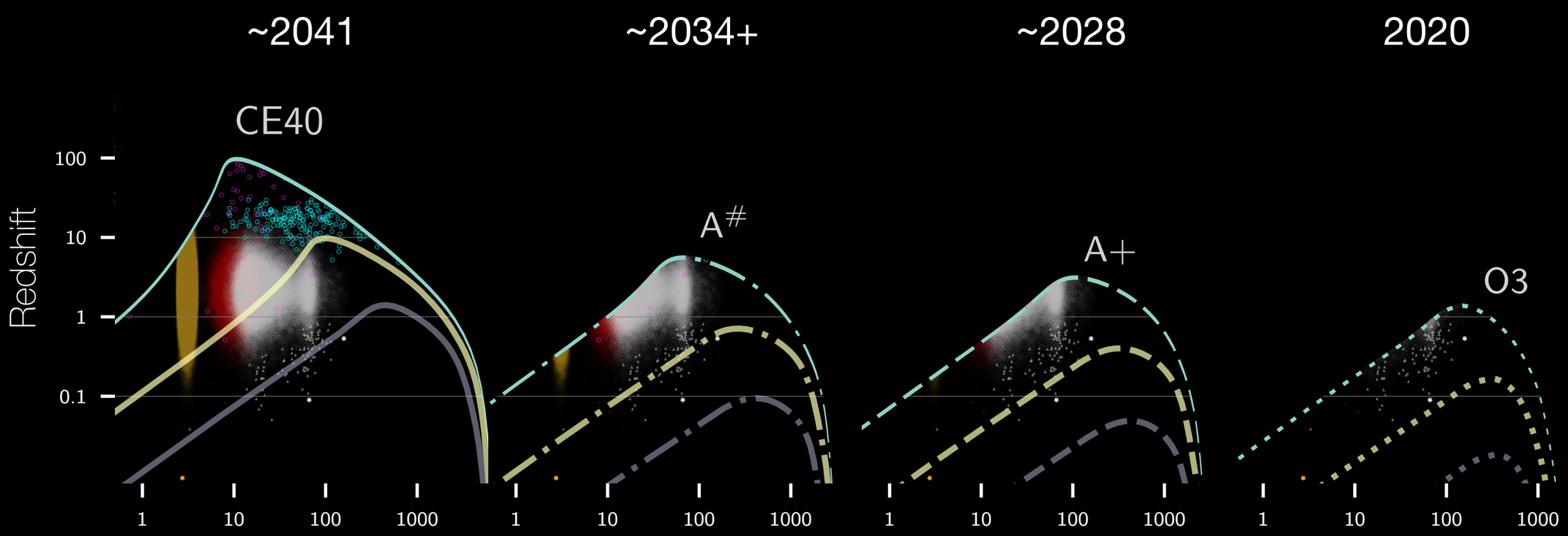
https://observing.docs.ligo.org/plan/



Plans for O5 remain uncertain, likely a run starting in 2028 for 2-3 years

Double the sensitivity compared to current detectors, so expecting a few detections per day

Ground based detectors over the next 15 years



Lines denote signal to noise (SNR) thresholds:

- purple - SNR = 1000
- yellow - SNR = 100
- cyan - SNR = 8

ArXiv: 2306.13745

Third Generation Telescopes

Cosmic Explorer - USA

40 and 20 km L-shaped surface observatory

Improvements (compared to today):

- Arm power - 1.5MW (750 kW)
- Test mass - 320 kg (40 kg)
- Test mass suspension length - 1.6m (4 m)

Construction projected to start mid 2030s

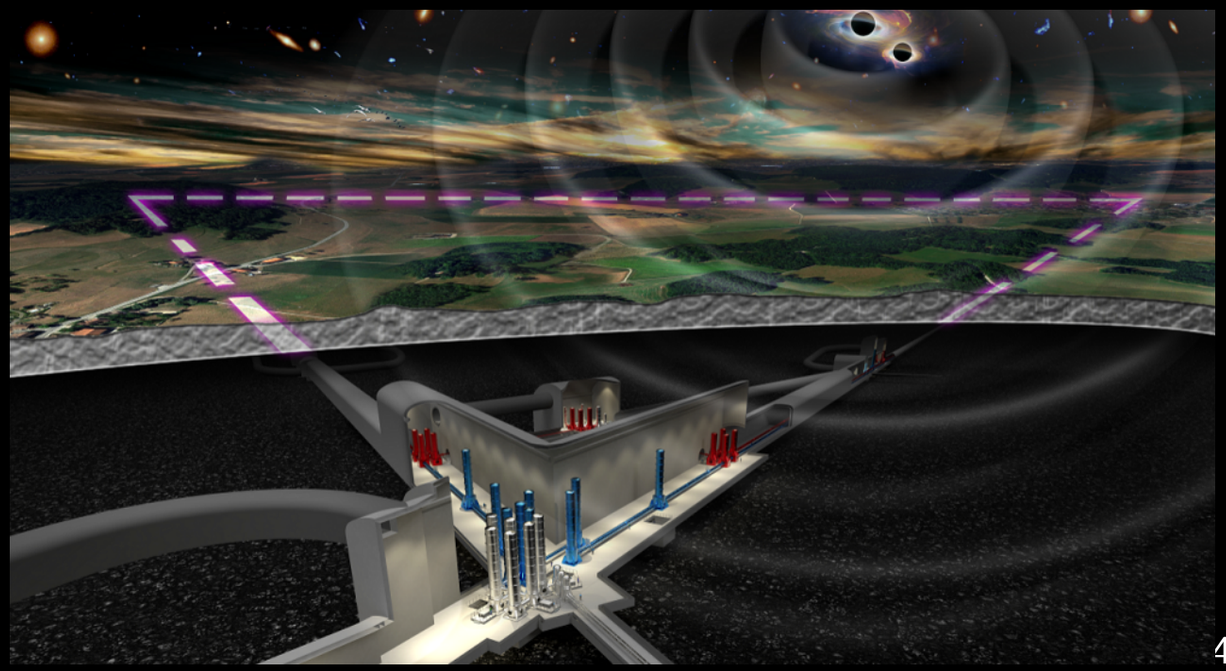
Einstein Telescope - Europe

10 km triangle configuration underground

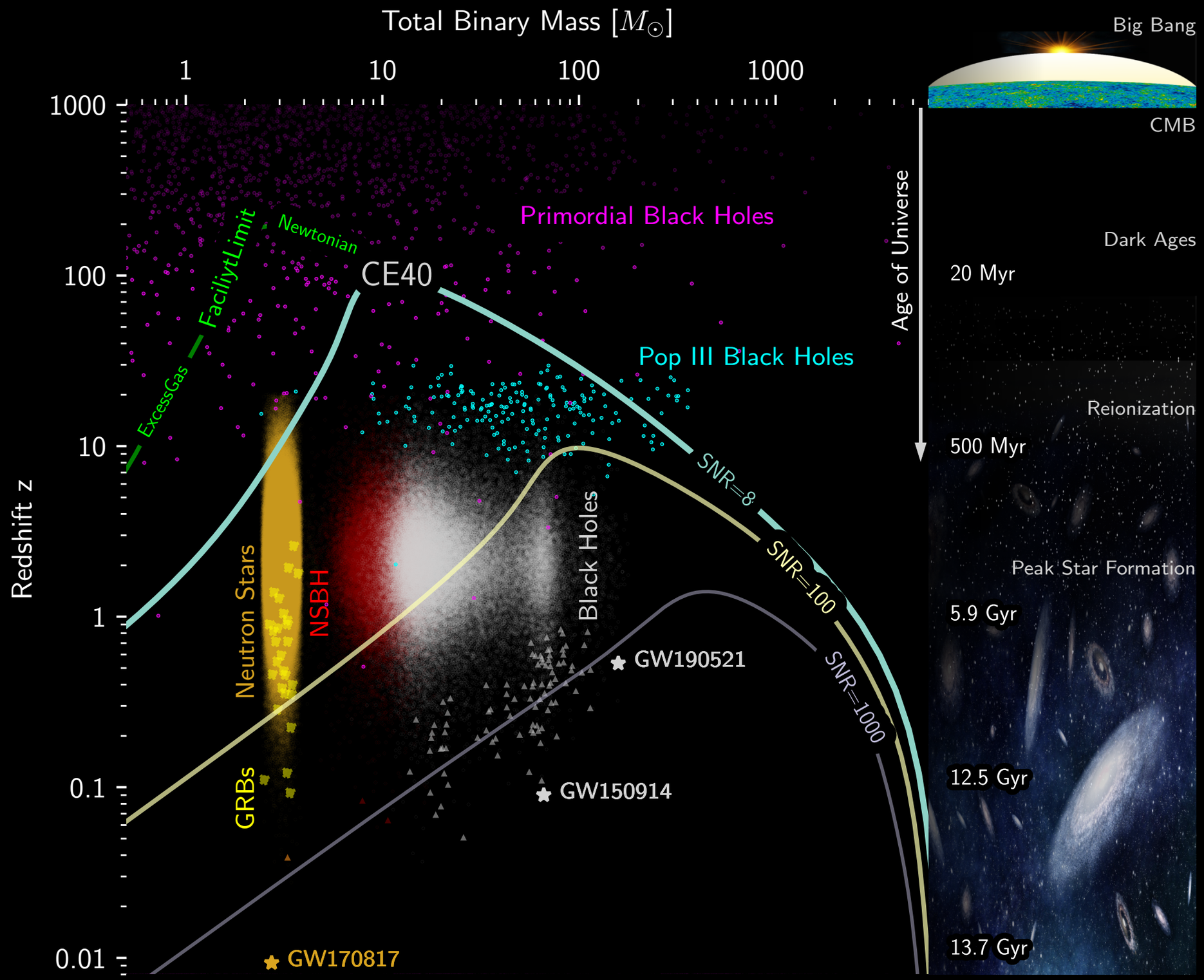
New technologies (for example):

- cryogenic system to cool some of the main optics to 10 – 20K
- new quantum technologies to reduce light fluctuations

Construction projected to start in 2030s



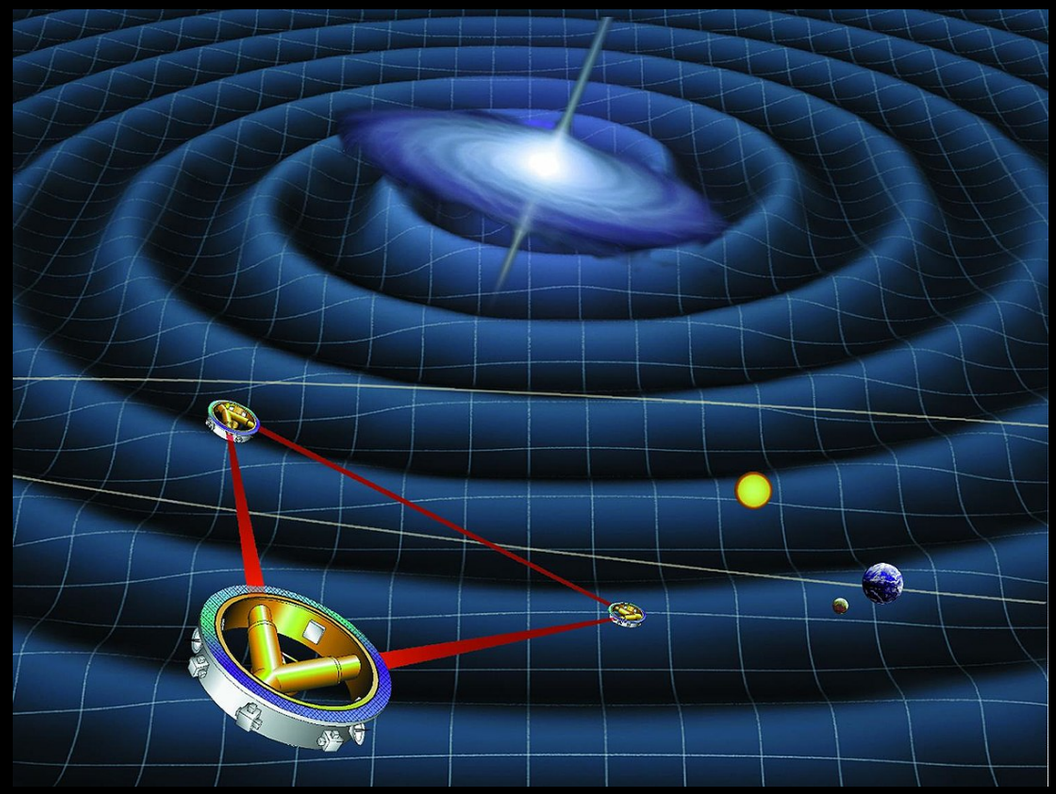
Third Generation Sensitivity

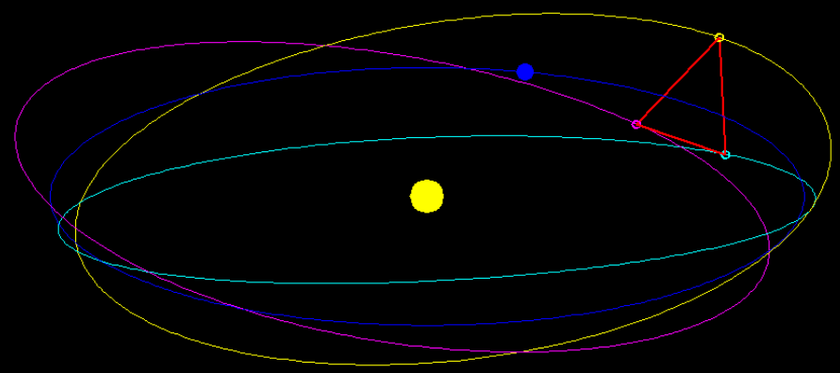


ArXiv: 2306.13745

LISA

- Sensitive to the region 10^{-4} to 10^{-1} Hz
- Three satellites in equilateral triangle
  - Arms - 2.5 million km
  - LISA behind the Earth by ~50 million km
- LISA pathfinder demonstrated key technologies
- Formally adopted by ESA January 2024
- Launch expected August 2035
- Sources include:
  - Merging massive black hole binaries
  - Extreme mass ratio inspirals
  - Galactic binaries
  - Inspiral of stellar mass black holes (merger could be observed by ground based detectors)





ArXiv:2402.07571

Back to the GW Spectrum

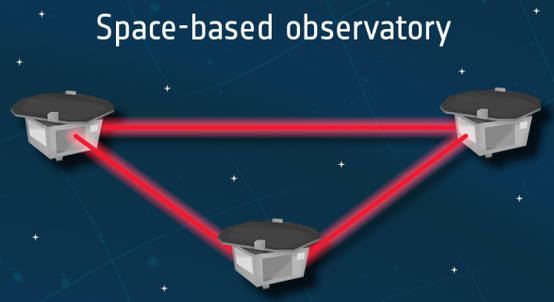
THE SPECTRUM OF GRAVITATIONAL WAVES

esa

Observatories & experiments

Ground-based experiment

Space-based observatory



Pulsar timing array

Cosmic microwave background polarisation

Timescales

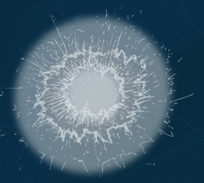
milliseconds — seconds — hours — years — billions of years

Frequency (Hz)

100 — 1 — 10^{-2} — 10^{-4} — 10^{-6} — 10^{-8} — 10^{-16}

Cosmic fluctuations in the early Universe

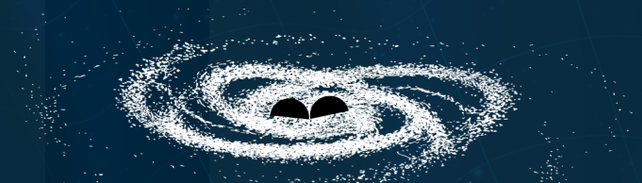
Cosmic sources



Supernova

Pulsar

Compact object falling onto a supermassive black hole



Merging supermassive black holes

Merging neutron stars in other galaxies

Merging stellar-mass black holes in other galaxies

Merging white dwarfs in our Galaxy

#lisa

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Questions?