

KAGRA Gravitational Wave Project in the 2030's and Mult Messenger Astronomy

*CTAO LST sub-Array Inauguration,
La Palma, October 16, 2026*

*Takaaki Kajita,
for the KAGRA collaboration
ICRR, Univ. of Tokyo*



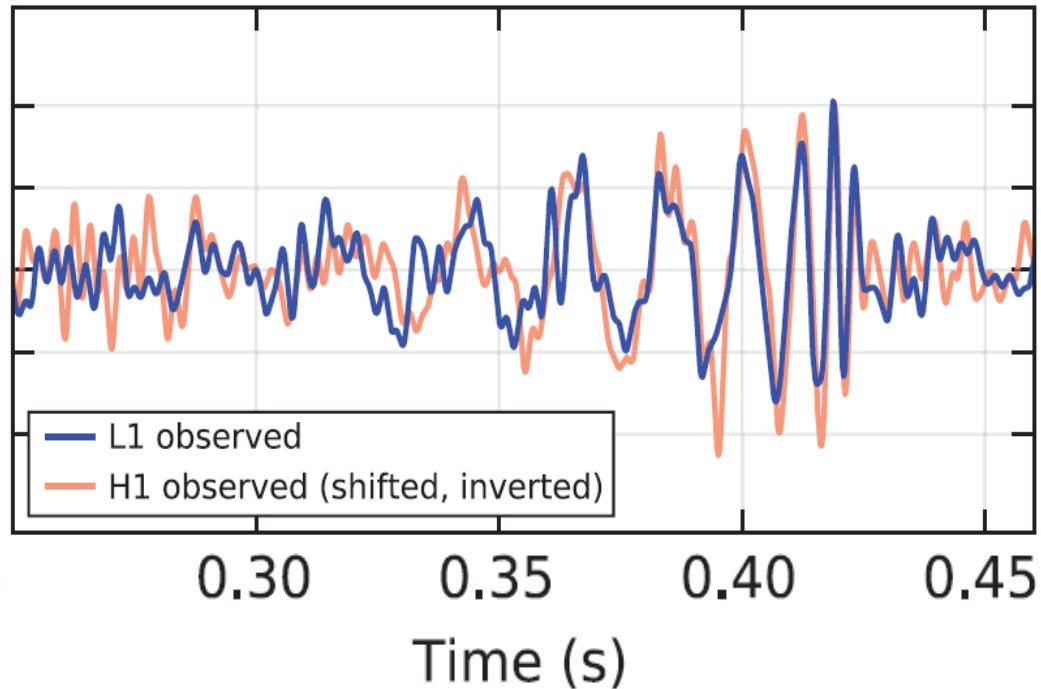
Outline

- *Introduction*
- *The KAGRA Project*
- *Gravitational Wave Network*
- *KAGRA in the 2030's*
- *Summary*

Introduction

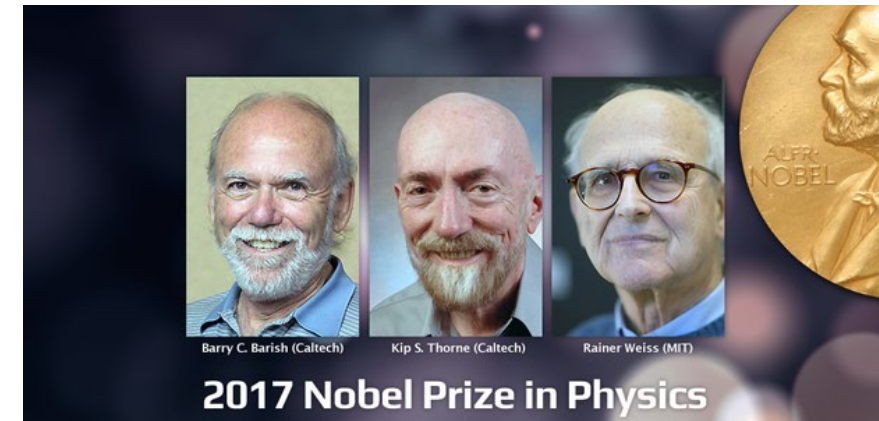
The first detection of GW (GW150914)

LIGO Scientific Collaboration and Virgo Collaboration, PRL, **116**, 061102 (2016)



✓ On Sep. 14, 2015, LIGO observed the signal with the 2 laser interferometers. Data told us that 2 blackholes of $36 M_{\text{Sun}}$ and $29 M_{\text{Sun}}$, respectively, merged at the distance of 1.3 Billion light-years.

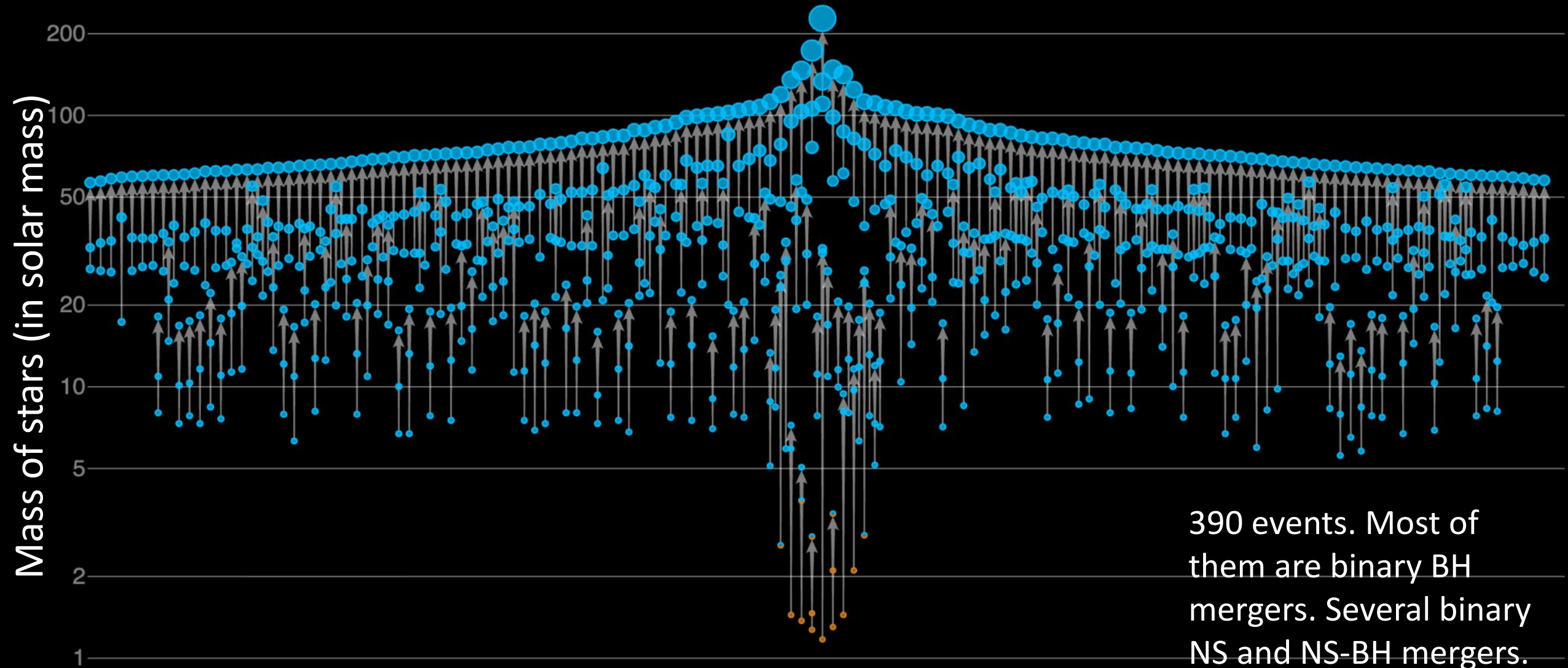
✓ *Great discovery!*



LIGO-Virgo observation summary (until Jan, 2025)

<https://ligo.org/gwtc-5-0-updated-ligo-virgo-kagra-catalog-sets-new-records-in-precision-gravitational-wave-astronomy/>

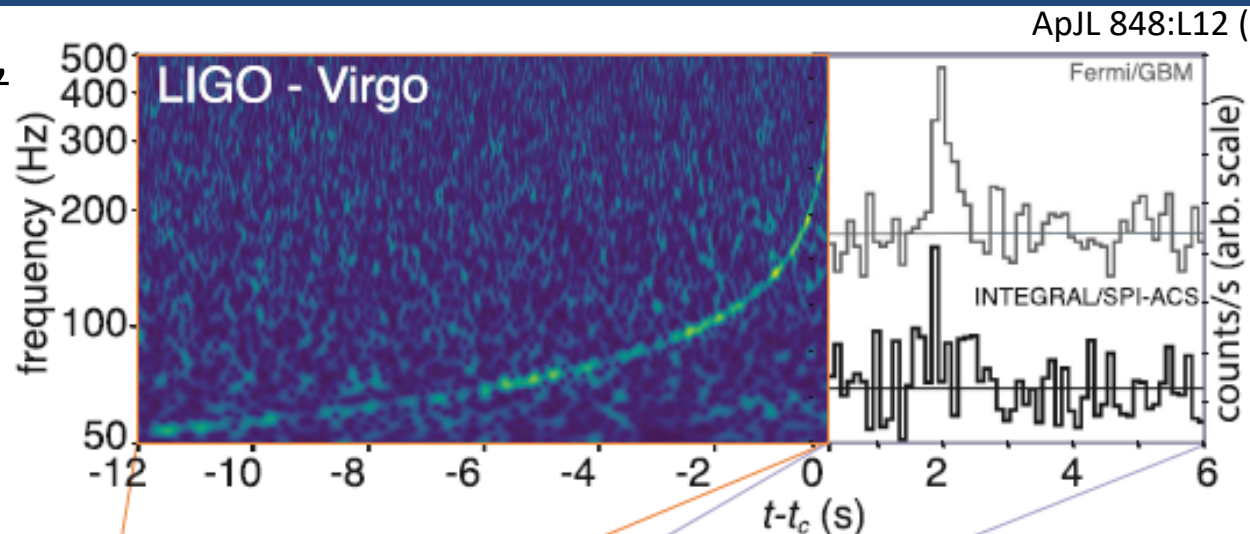
LIGO-Virgo-KAGRA Black Holes LIGO-Virgo-KAGRA Neutron Stars



LIGO-Virgo-KAGRA | Aaron Geller | Northwestern

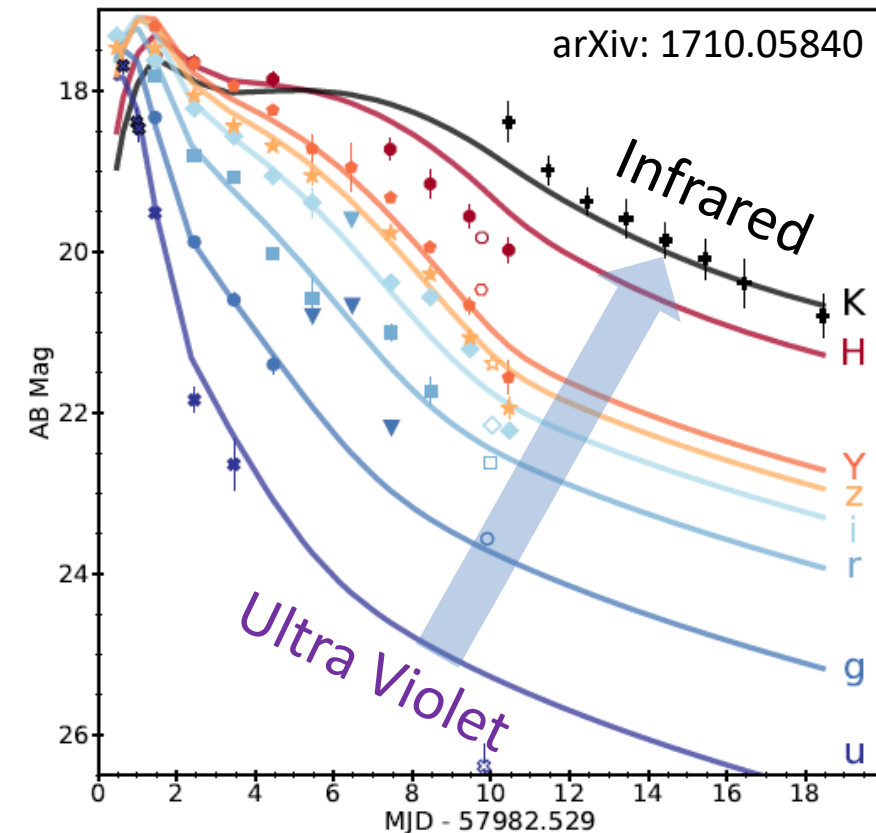
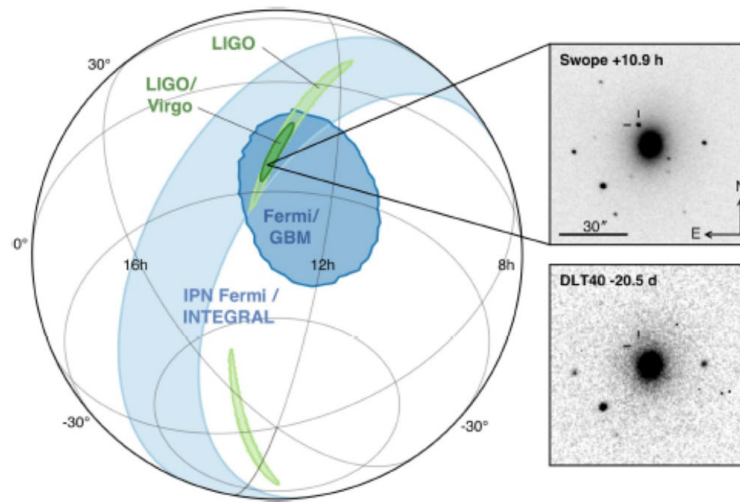
Binary Neutron Star Merger and Multi-messenger astronomy with GW

Aug. 17,
2017



ApJL 848:L12 (217)

Pointing the binary neutron star merger event by LIGO and Virgo and the discovery of the optical counterpart



Consistent with heavy metals (gold, platinum, ..) generation!



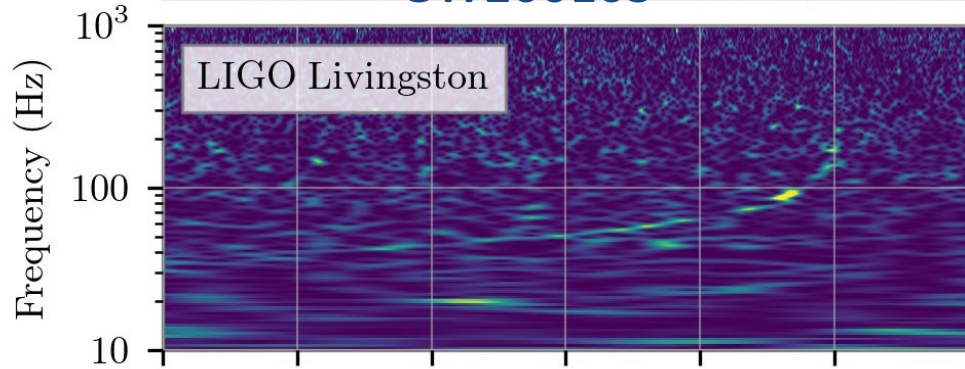
Next: simultaneous observation of GW and TeV gamma rays

Some interesting events

GW200105 and GW200115: neutron star - black hole mergers

GW200105

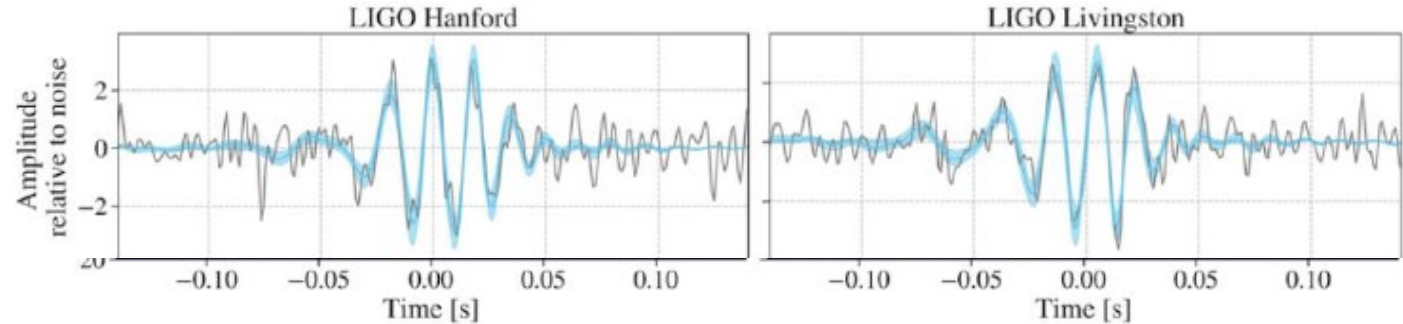
arXiv:2106.15163



GW200105: $8.9^{+1.2}_{-1.5} M_{\odot}$ and $1.9^{+0.3}_{-0.2} M_{\odot}$
GW200115: $5.7^{+1.8}_{-2.1} M_{\odot}$ and $1.5^{+0.7}_{-0.3} M_{\odot}$
(But no EM counterparts identified.)

GW231123: The most massive BH binary detected through GWs

arXiv:2507.08219

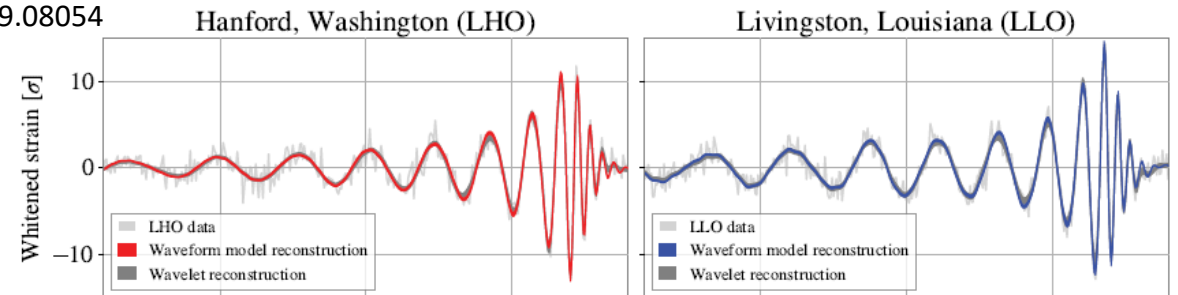


- Masses: $137^{+23}_{-18} M_{\odot}$ and $101^{+22}_{-50} M_{\odot}$
("forbidden" mass range (60-130 $M_{\odot}$)?)
- High spins: $0.9^{+0.10}_{-0.19}$ and $0.80^{+0.20}_{-0.52}$
- ➔ hierarchical mergers?

GW250114: Highest significance event

- Signal to noise ratio: 80
- ➔ Consistent with GR
- ➔ Confirmation of the Hawking's area law

arXiv: 2509.08054



The KAGRA project

KAGRA collaboration

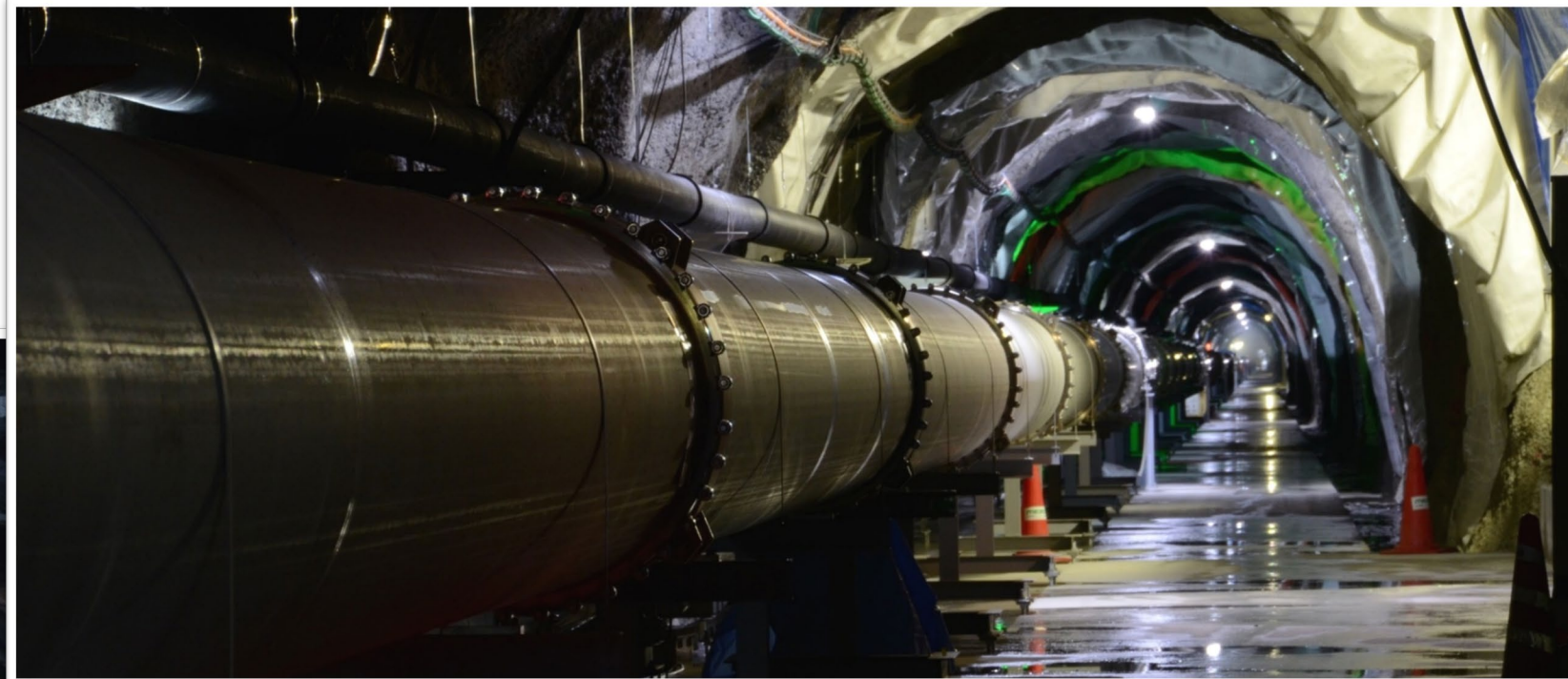


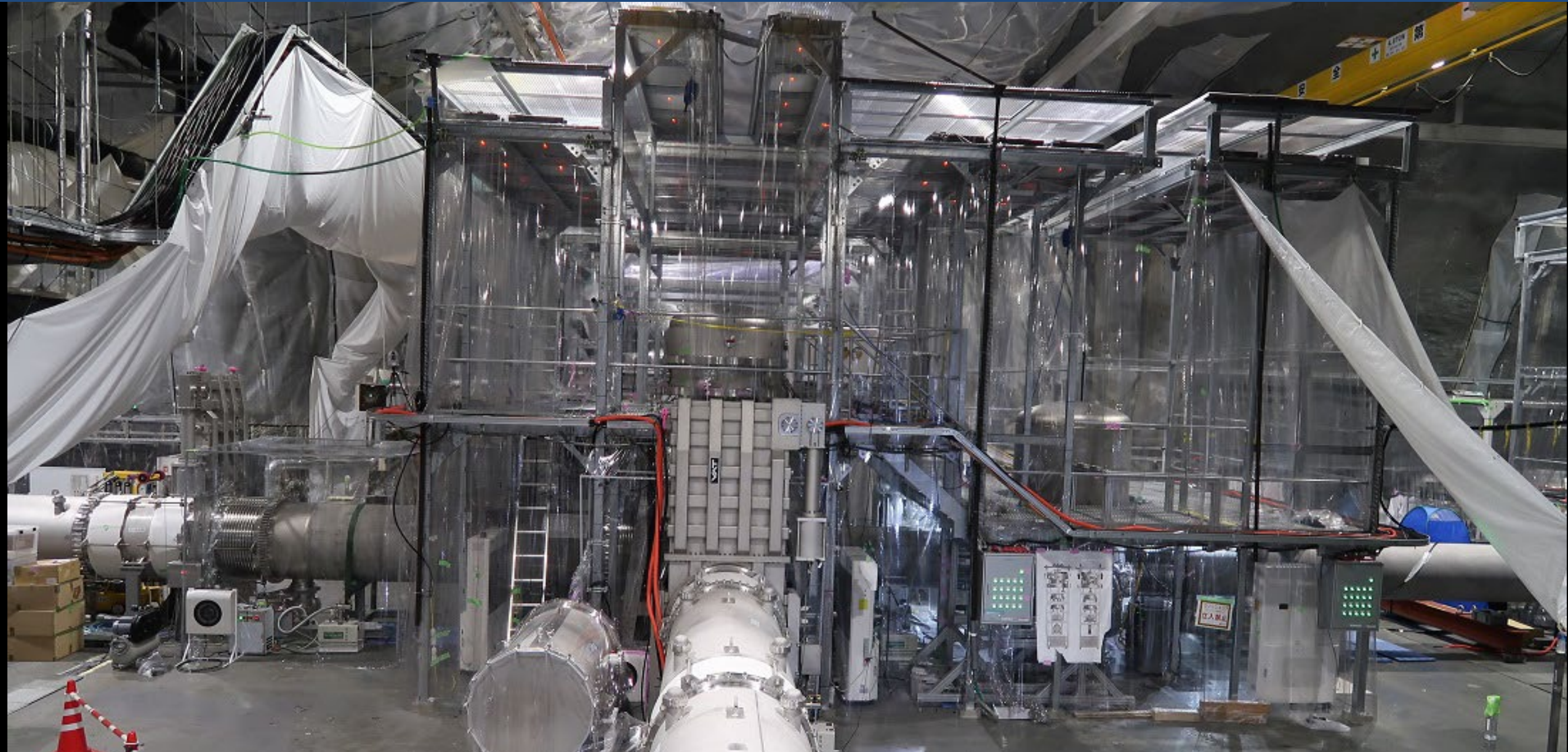
9 countries/regions, ~160 authors
(and ~450 collaborators)

Location of KAGRA (construction started in 2010)



3km long vacuum tubes (Feb. 2015)





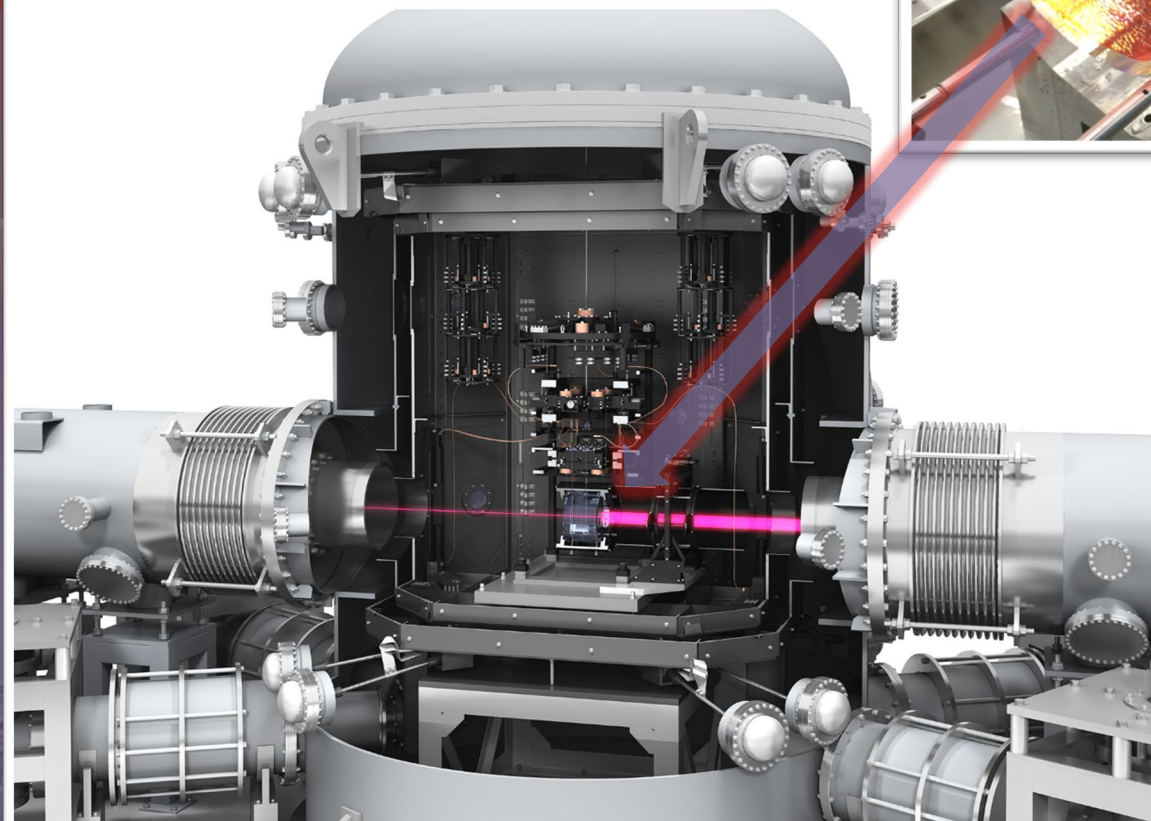
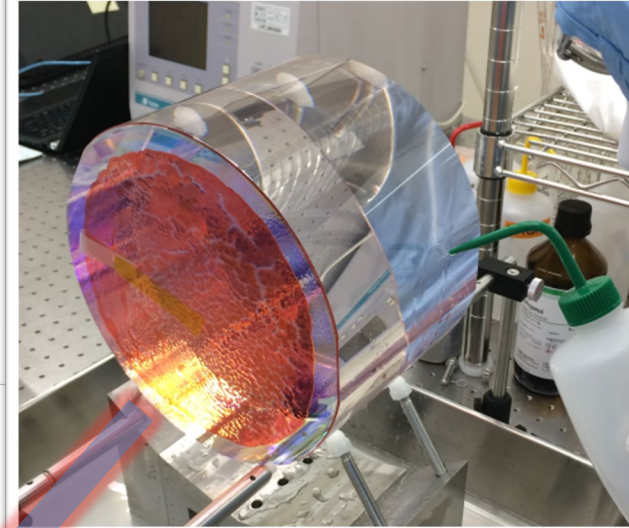
Mirror, Cryogenic System, Vibration Isolation System



Installing
vibration
isolation system

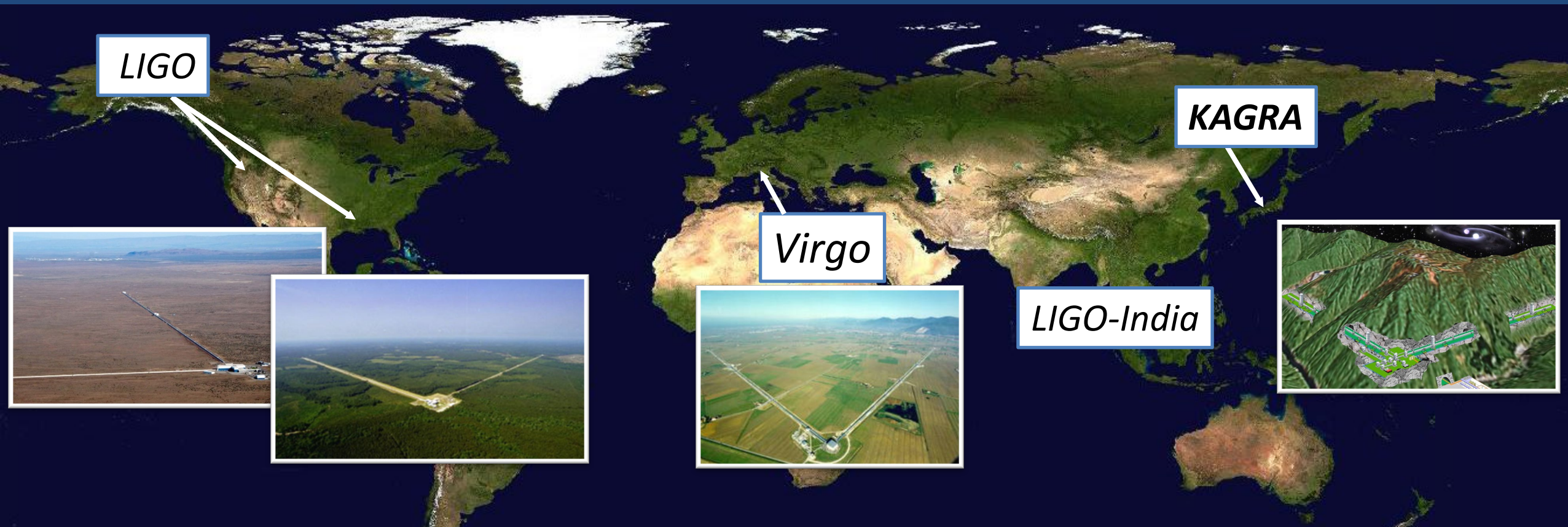


Preparing cryogenic mirror
(22cm(ϕ), 15cm (t), 23kg)
➔ To the KAGRA site



Gravitational Wave Network

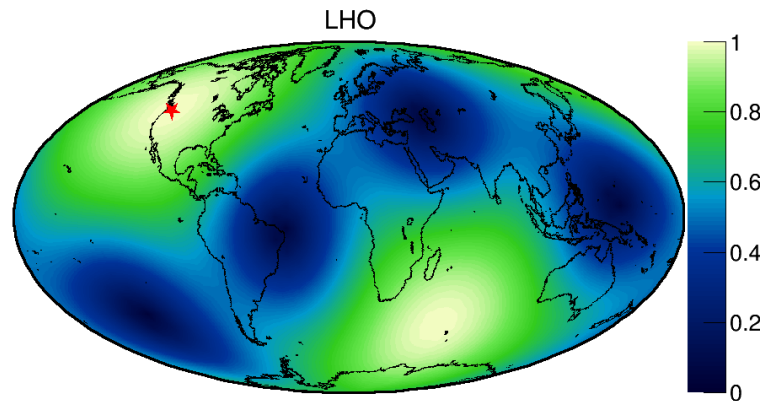
Joining the global GW network



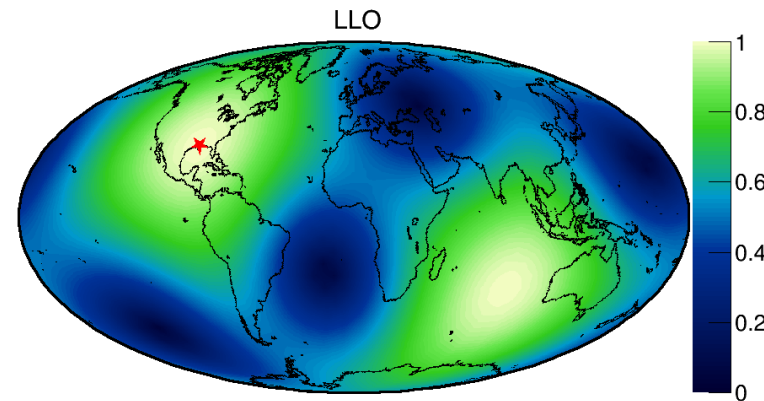
- ◆ KAGRA joined the network observation with LIGO and Virgo in 2020. We are working together, namely, we observe GWs simultaneously and analyze the data as a team.
- ◆ In September 2026, LVK signed a new MoA to work closer forming IGWN (International Gravitational Wave observatory Network). IGWN will be fully operational in 2028.

Importance of Global GW Network: Detector antenna patterns

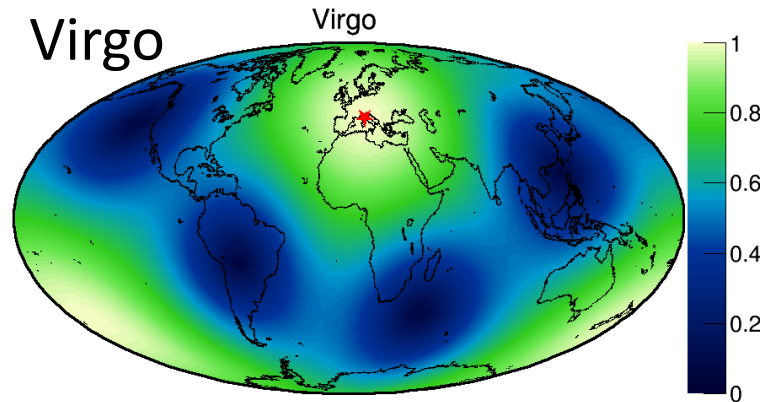
LIGO (Hanford)



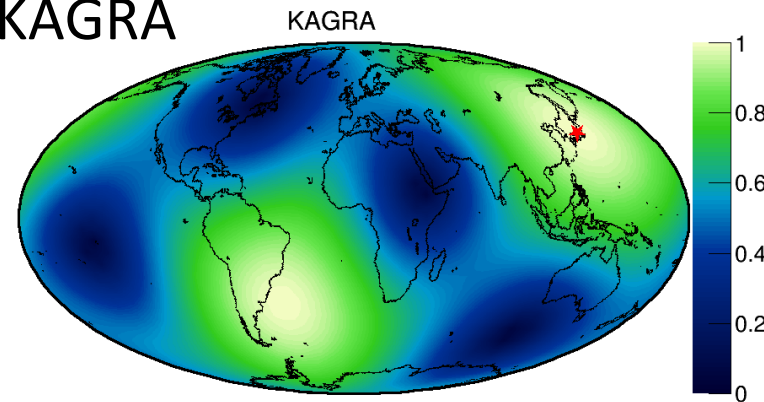
LIGO (Livingston)



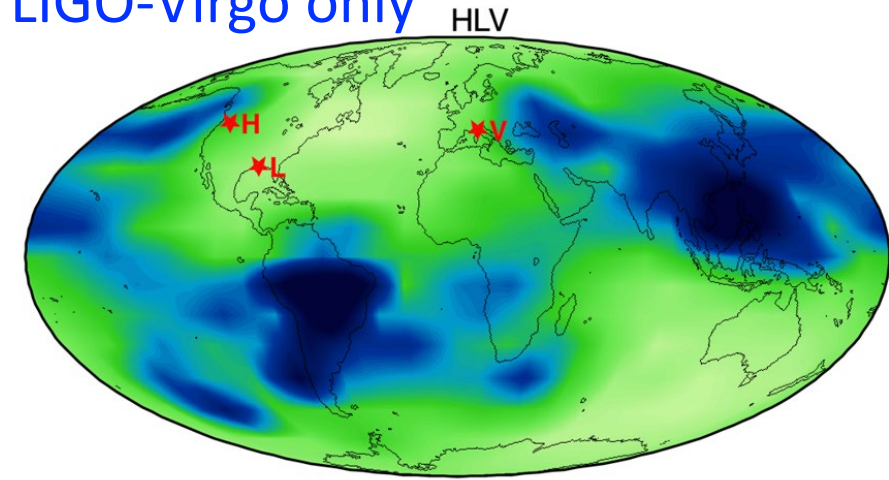
Virgo



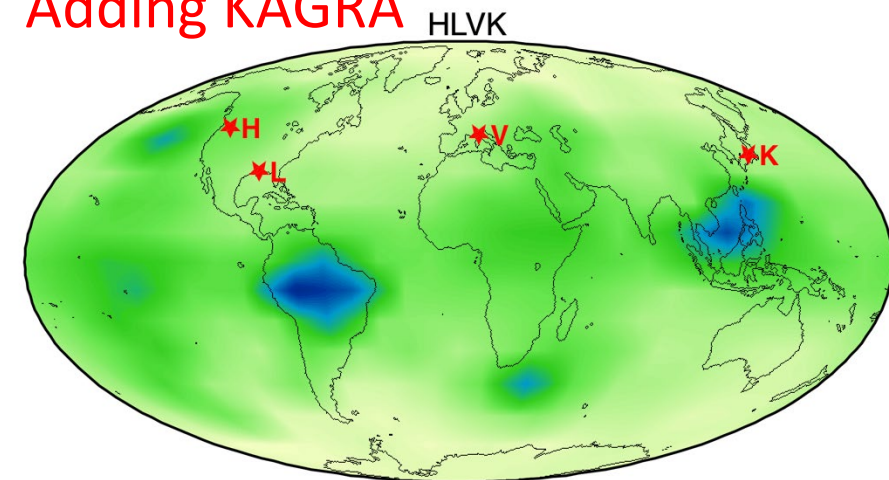
KAGRA



LIGO-Virgo only

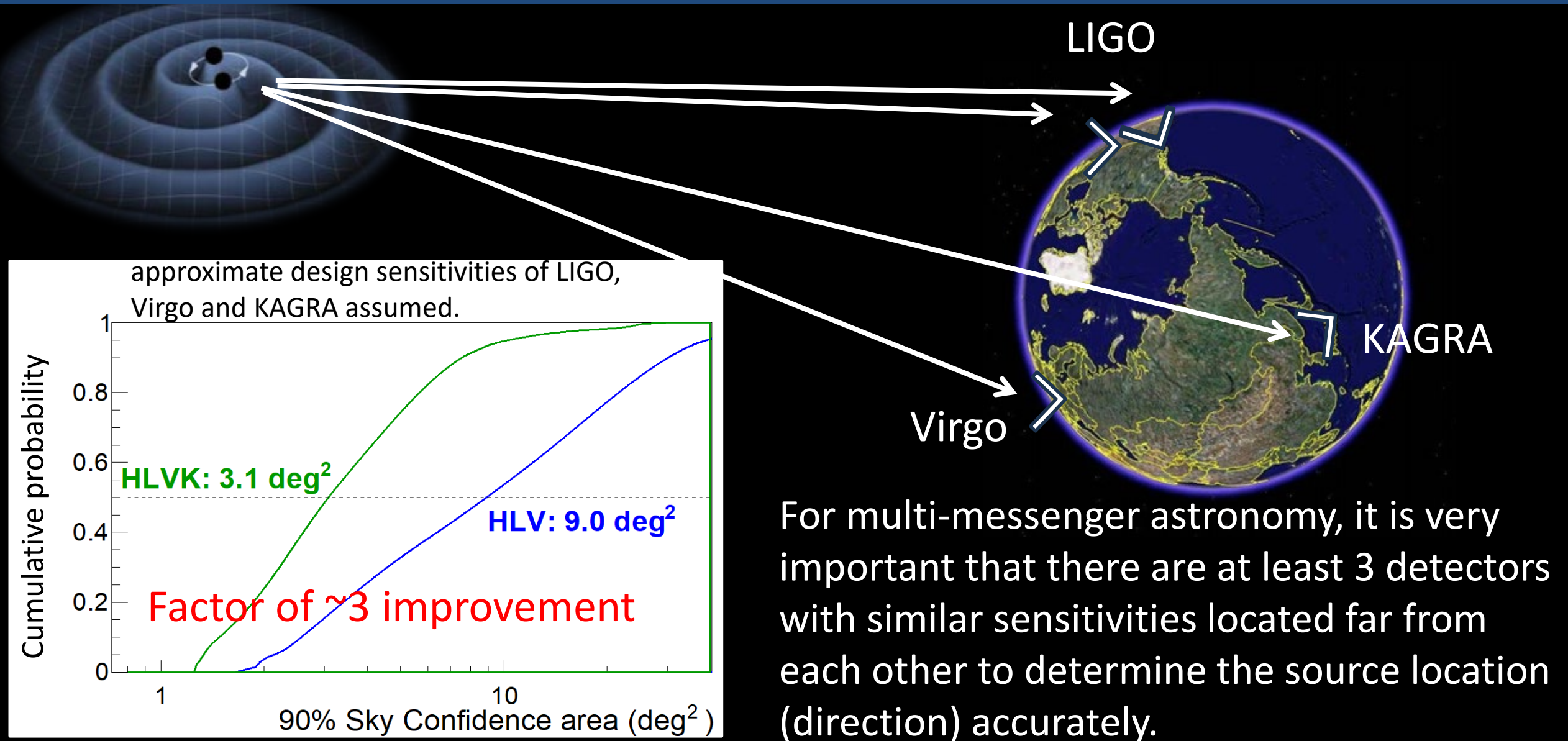


Adding KAGRA



KAGRA is complementary in the sensitive direction to other detectors.

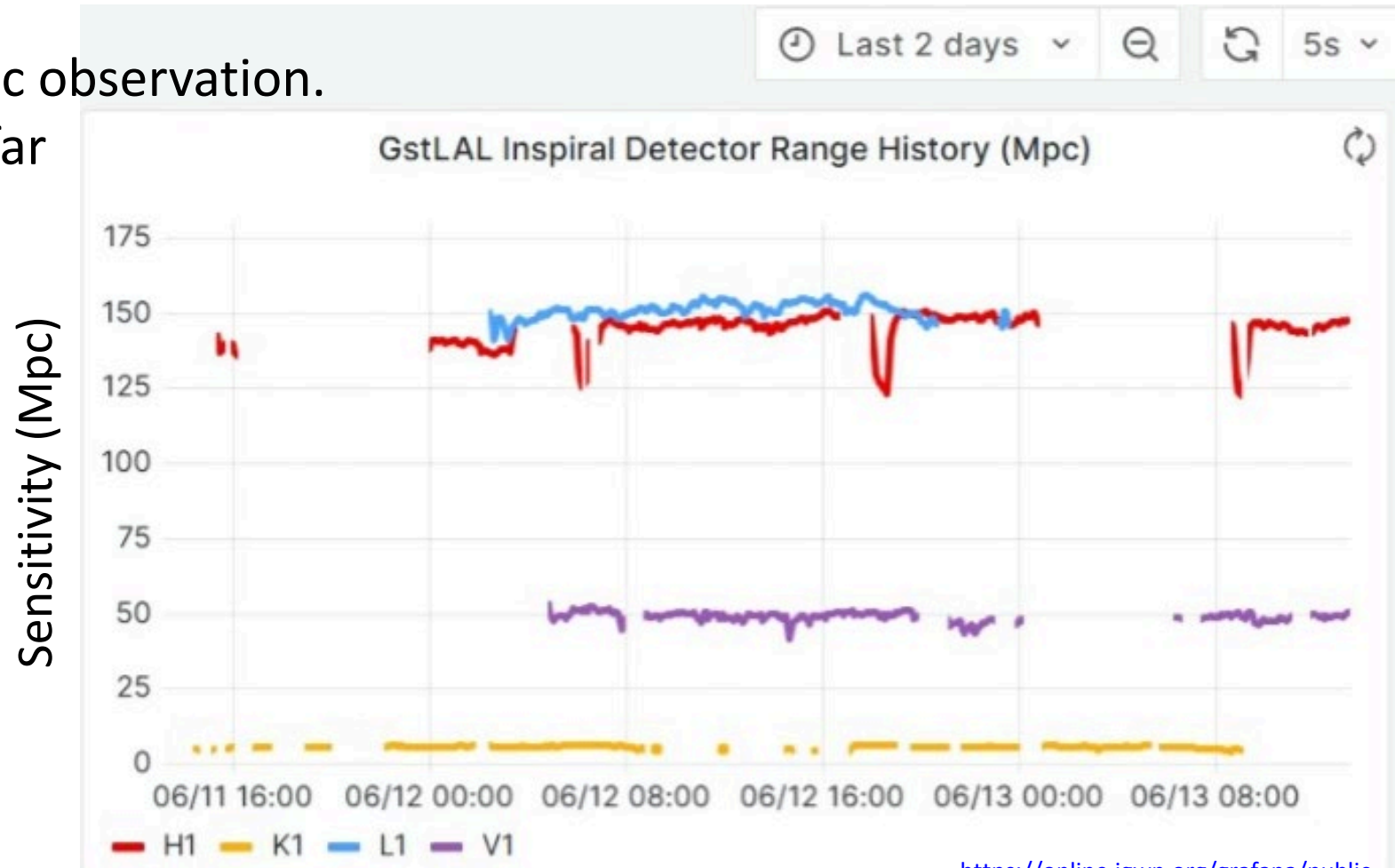
Importance of Global GW Network: Pointing accuracy



4th LIGO-Virgo-KAGRA Observation (O4)

- ✓ O4a started on May 24, 2023. (KAGRA joined O4a. But the sensitivity was not good. Stopped the observation in a month and started the improvement work.
- ✓ (Noto earthquake ...)
- ✓ On June 11, KAGRA joined the O4c observation.
- ✓ The best sensitivity of KAGRA so far was 7.5 Mpc.
- ✓ O4c observation concluded on Nov. 18, 2025.

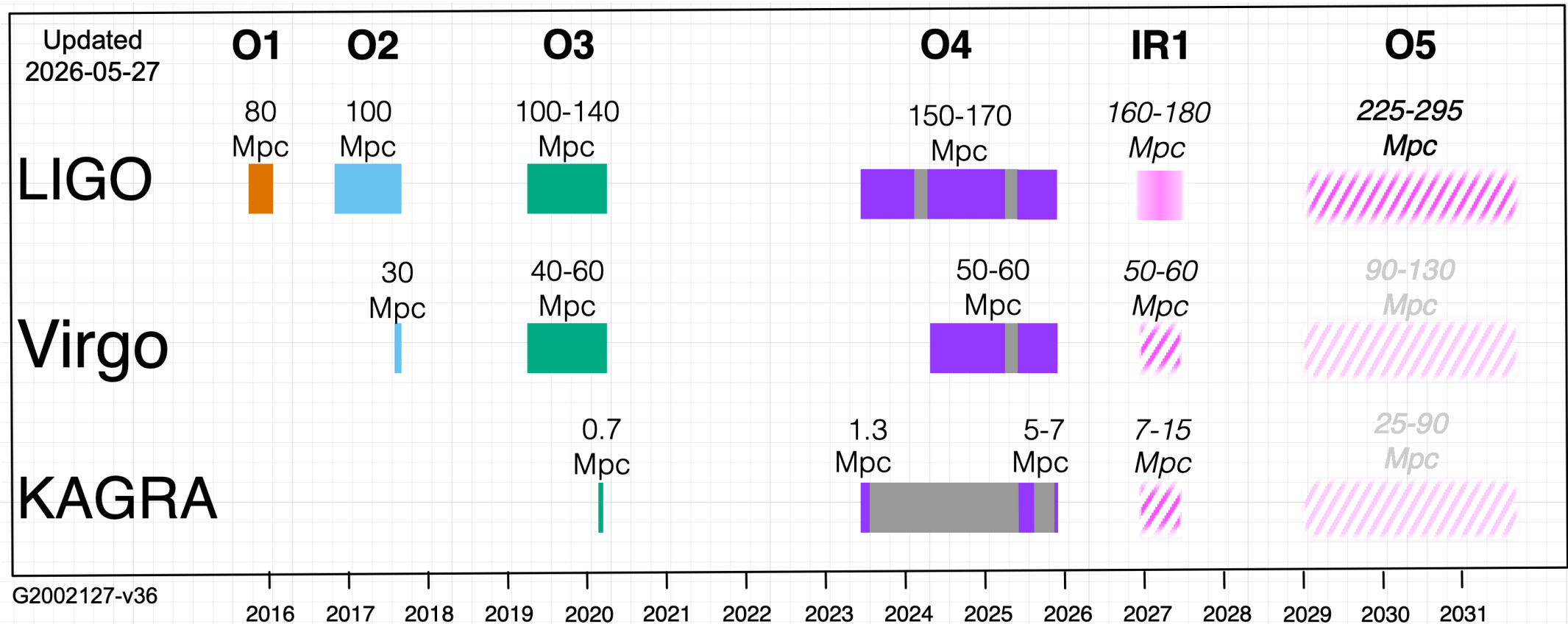
Status of
LIGO/Virgo/KAGRA
around June 11, 2025



<https://online.igwn.org/grafana/public-dashboards/1a0efabe65384a7287abfcc1996e4c4d?orgId=1&refresh=5s&from=now-2d&to=now>

KAGRA in the 2030's

LVK observation plan



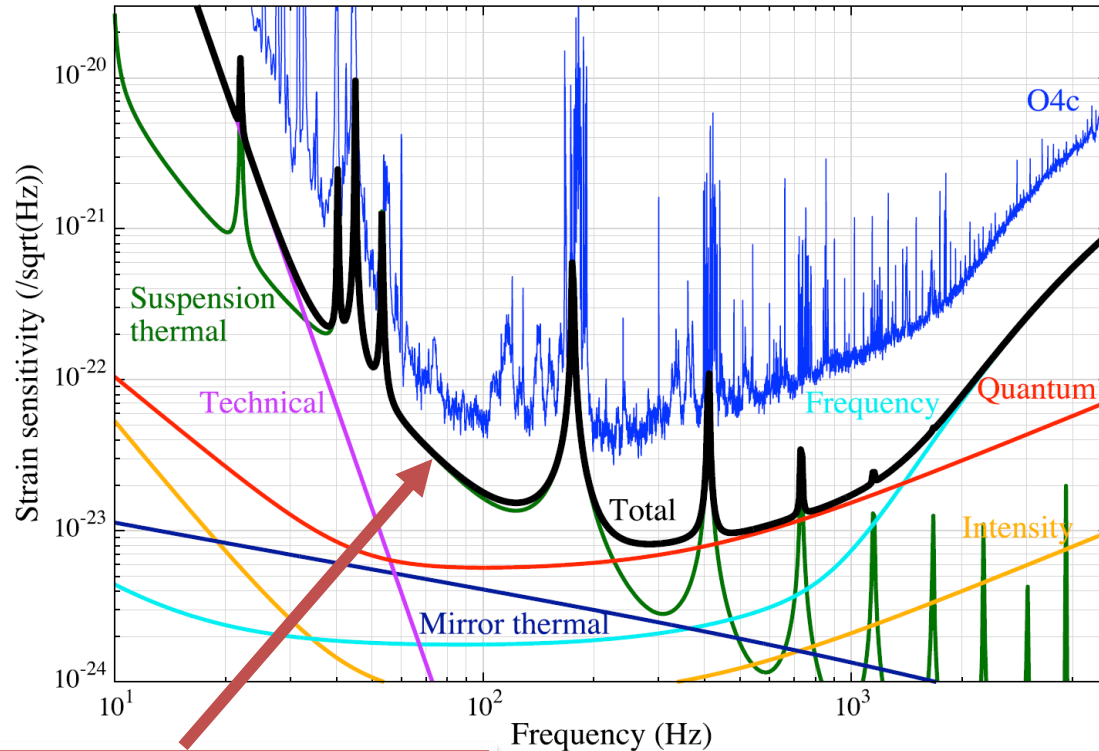
<https://observing.docs.ligo.org/plan/>

- ✓ After O4, LVK are upgrading their detectors, will have a half year run starting around end of 2026, and will start the O5 observation around 2029 with improved sensitivities.
- ✓ What will be the KAGRA's plan?

KAGRA in O5

At the beginning of O5:

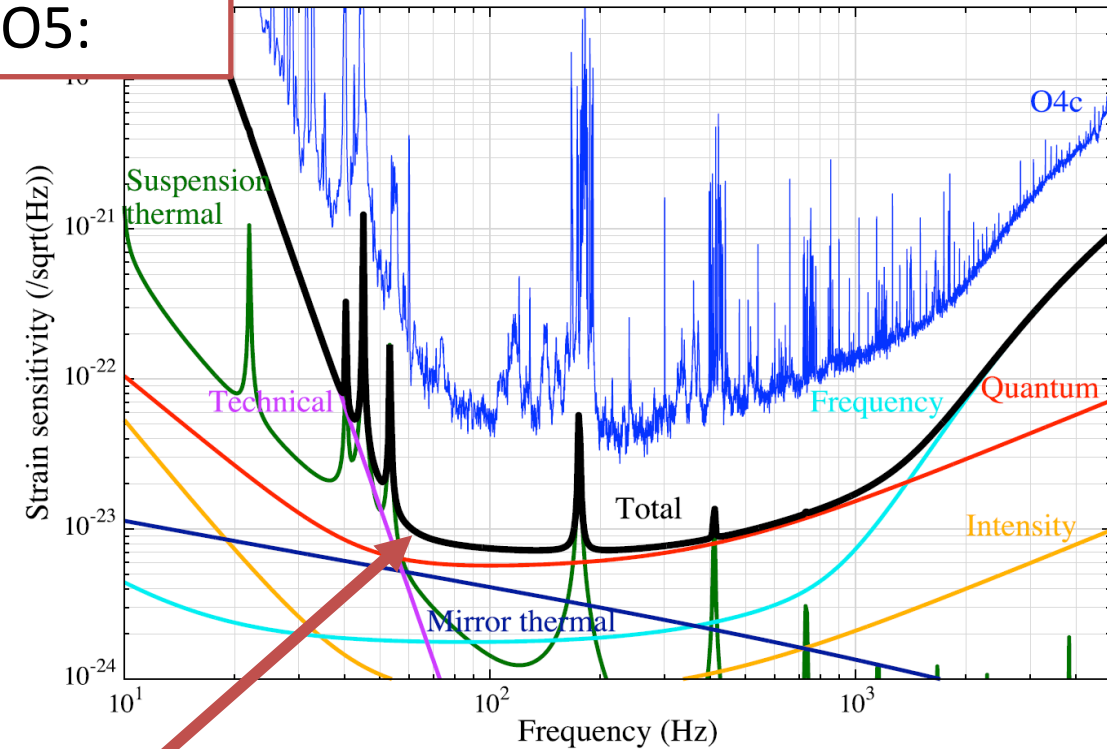
- Better ITMs
- Signal recycling technology
- Higher laser power
- Reduction of various noises, ...



BNS range: 33 Mpc

At the later stage of O5:

- better sapphire suspension fibers

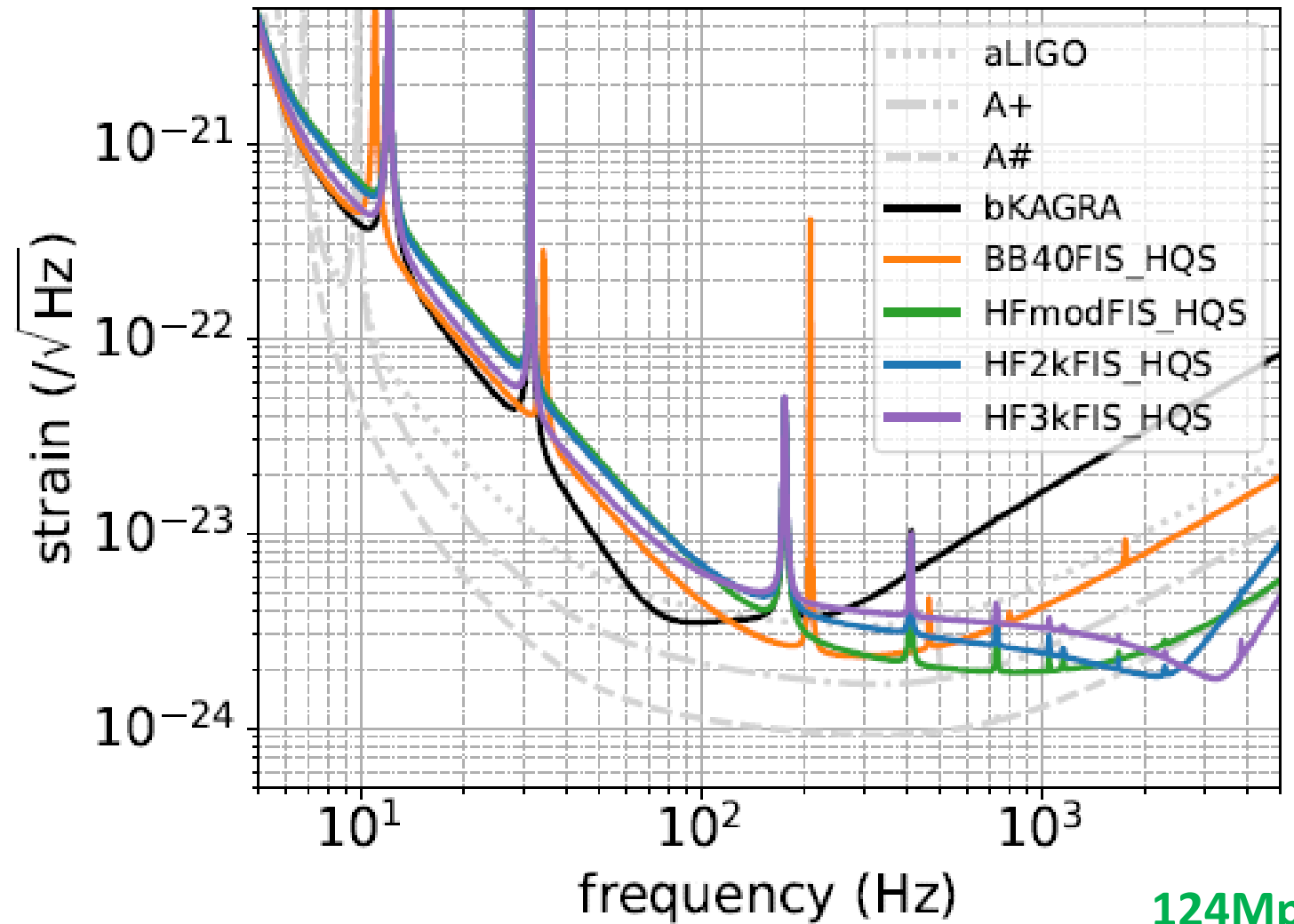


BNS range:
upto 74 Mpc

Note: Sensitivity can be improved further by squeezing → ~90Mpc

KAGRA after O5

- LIGO: “A#” upgrade program after O5. A# aims to increase the sensitivity over A+ (O5 configuration) by a factor of 2.
- Virgo has plans to upgrade the sensitivity similar to LIGO’s A#.
- LIGO-India will join.
- KAGRA has been discussing future plans. Cryogenic sapphire mirrors are very good for high laser power operation. → Possible upgrade with higher sensitivity in the kHz band.

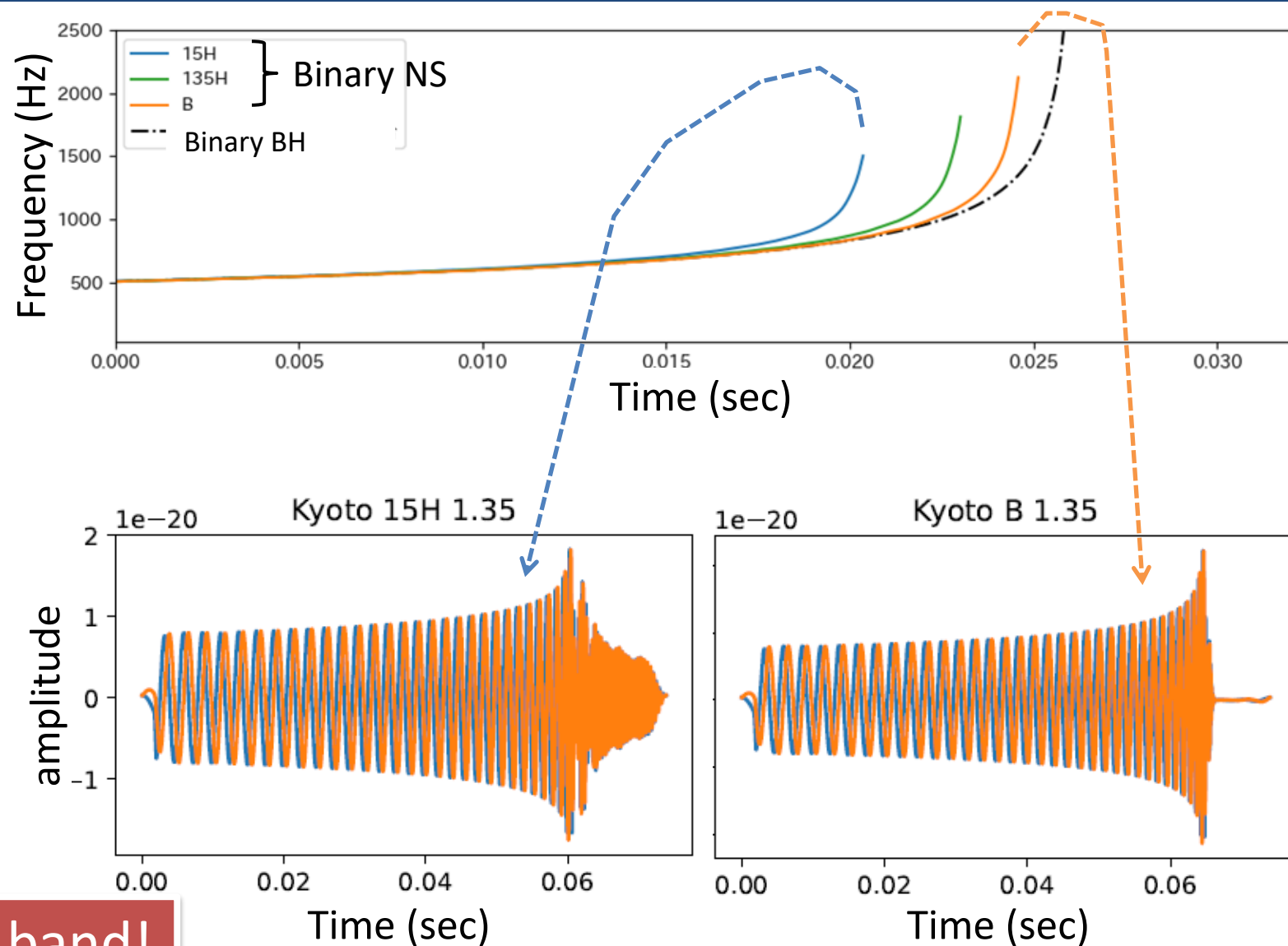


KAGRA collaboration, arXiv:2508.03392v1 [gr-qc]

124Mpc
BNS range: 103Mpc
100Mpc

Gravitational waves in the kHz band

- One of the important scientific topics is to understand the neutron stars better.
 - We would like to understand the equation of state of the neutron stars better.
 - We would like to know if a supermassive neutron stars exist after the merger of binary neutron stars.
 - We would like to know if particles are accelerated (TeV gamma rays!).

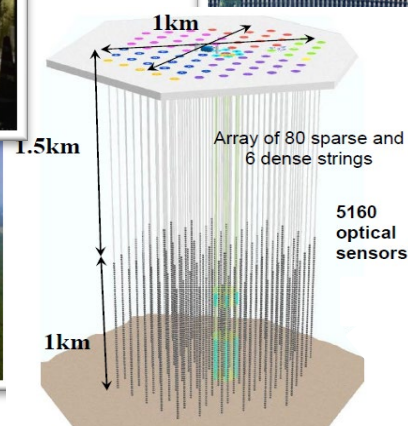
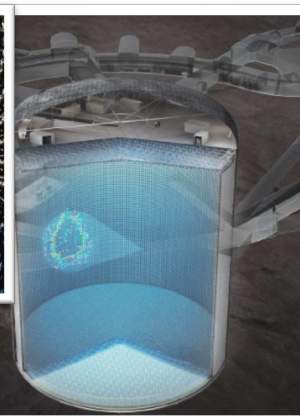
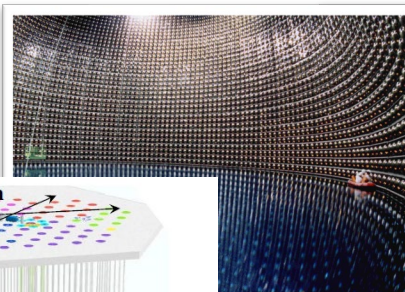
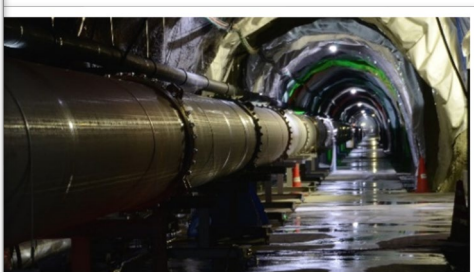


Gravitational waves in the kHz band!

Supernova and multi-messenger astronomy

SN1987A

If a supernova explodes at the center of the Milky Way...



Hyper-K will start the operation in 2028

+Gamma ray
(CTAO, ...)

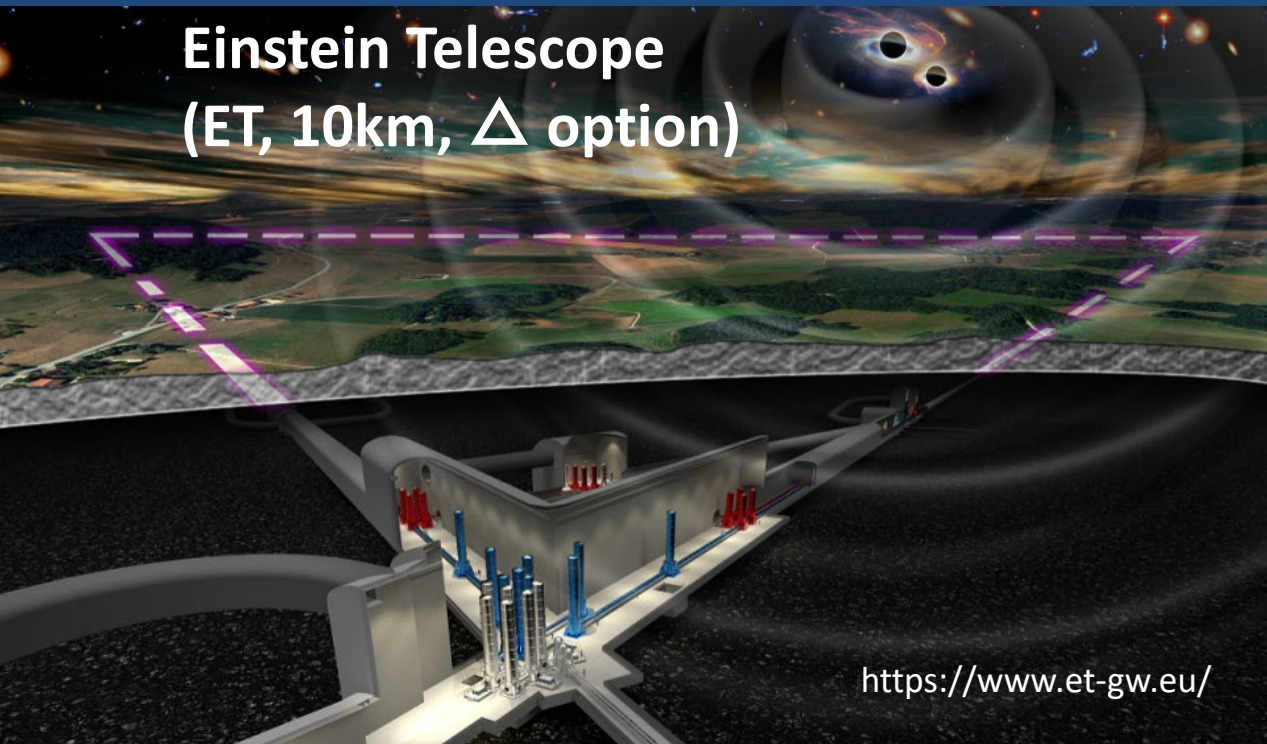
Gravitational waves

Neutrinos

+optical
observations,
+ Simulations

Truly understand supernovae!

Future ground based GW detectors



- ✓ Since the present generation of ground-based GW detectors have been so successful, colleagues in USA and Europe are planning the next generation GW interferometers.
- ✓ These interferometers will have extremely high sensitivities.
- ✓ KAGRA's features and experience could be useful for the future GW detectors (ET).

Summary

- Gravitational wave astronomy is a new and exciting scientific field. Many more fundamental discoveries will be ahead of us.
- KAGRA is a unique gravitational wave detector with cryogenic mirrors and the underground site.
- Around 2030, KAGRA plans to begin observing GWs and contributing to the WG astronomy.
- In O6 and later, KAGRA plans to improve the sensitivity in the kHz band and uniquely contribute to the development of the GW and multi-messenger astronomy.
- We look forward to working together with CTAO!