KAGRA status and prospect

Takafumi Ushiba on behalf of the KAGRA Collaboration

Institute for Cosmic Ray Research, UTokyo, Japan

Gravitational Waves

New eyes to observe the Universe

K. Kokeyama JGW-G1808116

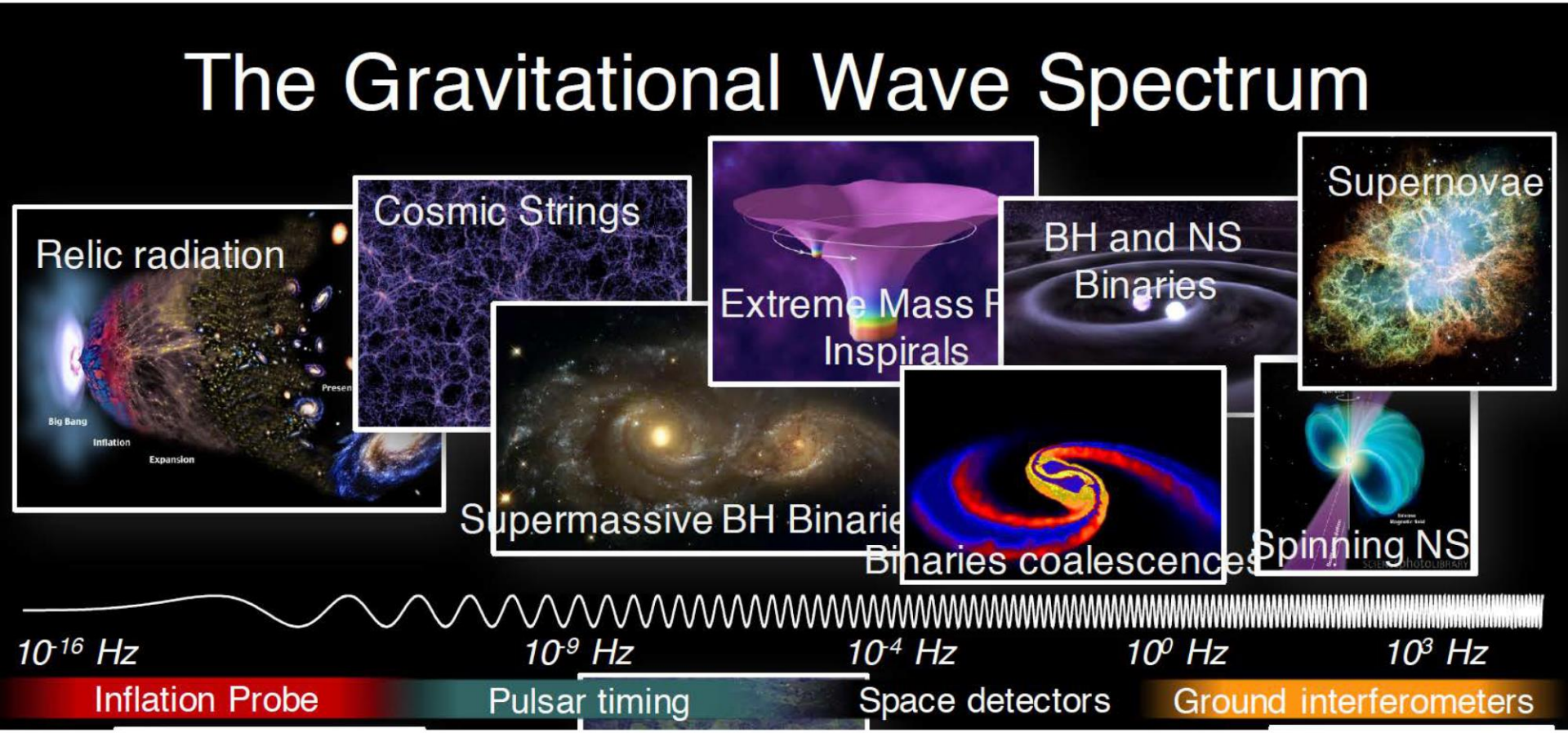


Figure: M Evans

Fruitful sciences with GWs

- Fundamental physics:
  — Verification of GR in strong gravity and drastic dynamics
  — Equation of states of neutron stars
  — etc.

- Astrophysics:
  — Mass distribution of black holes
  — Progenitors of Gamma Ray Bursts
  — etc.

- Comology:
  — Direct observation before CMB era
  —etc.

Current Observable GW bands

Currently only high-frequency GWs have been directly detected by LIGO and Virgo.

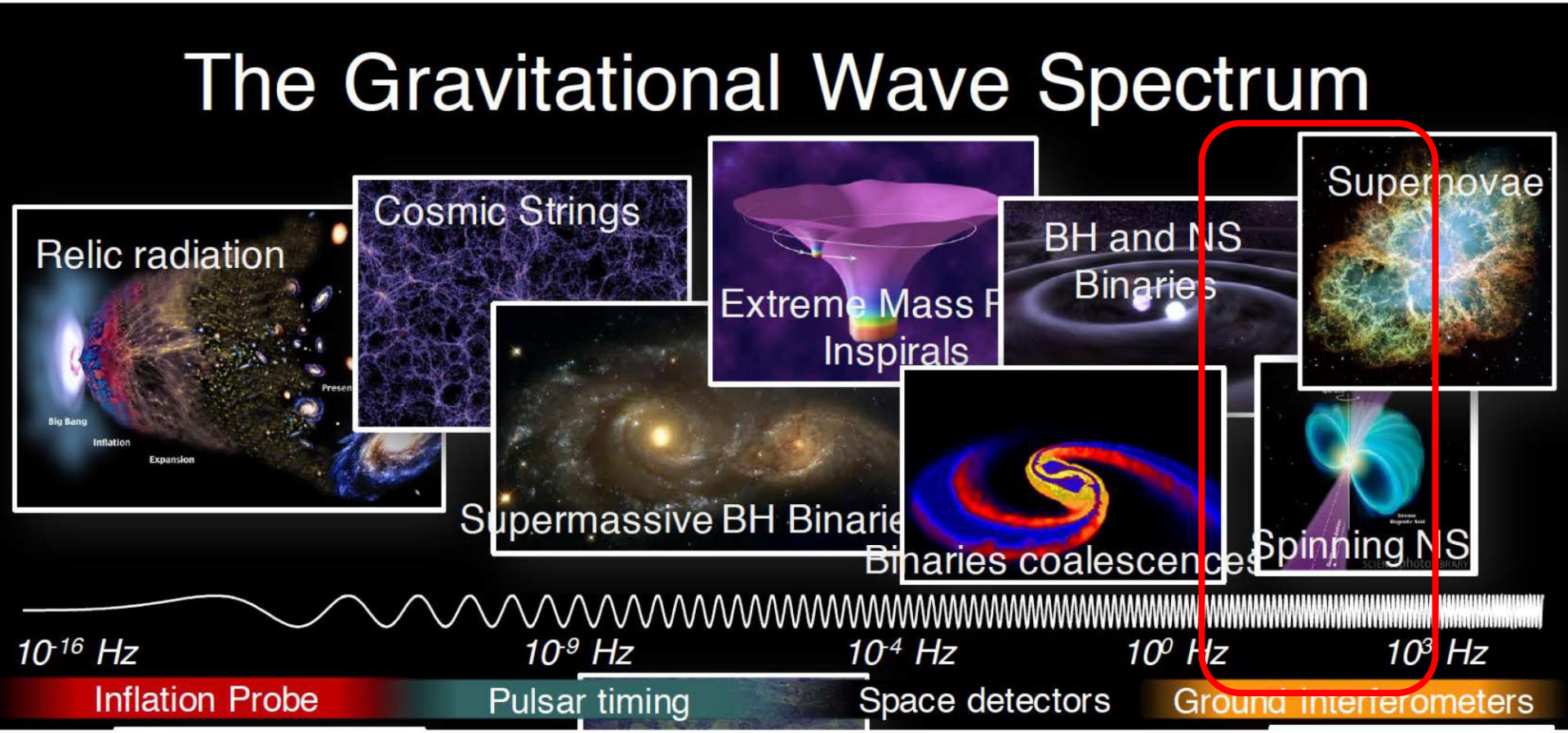
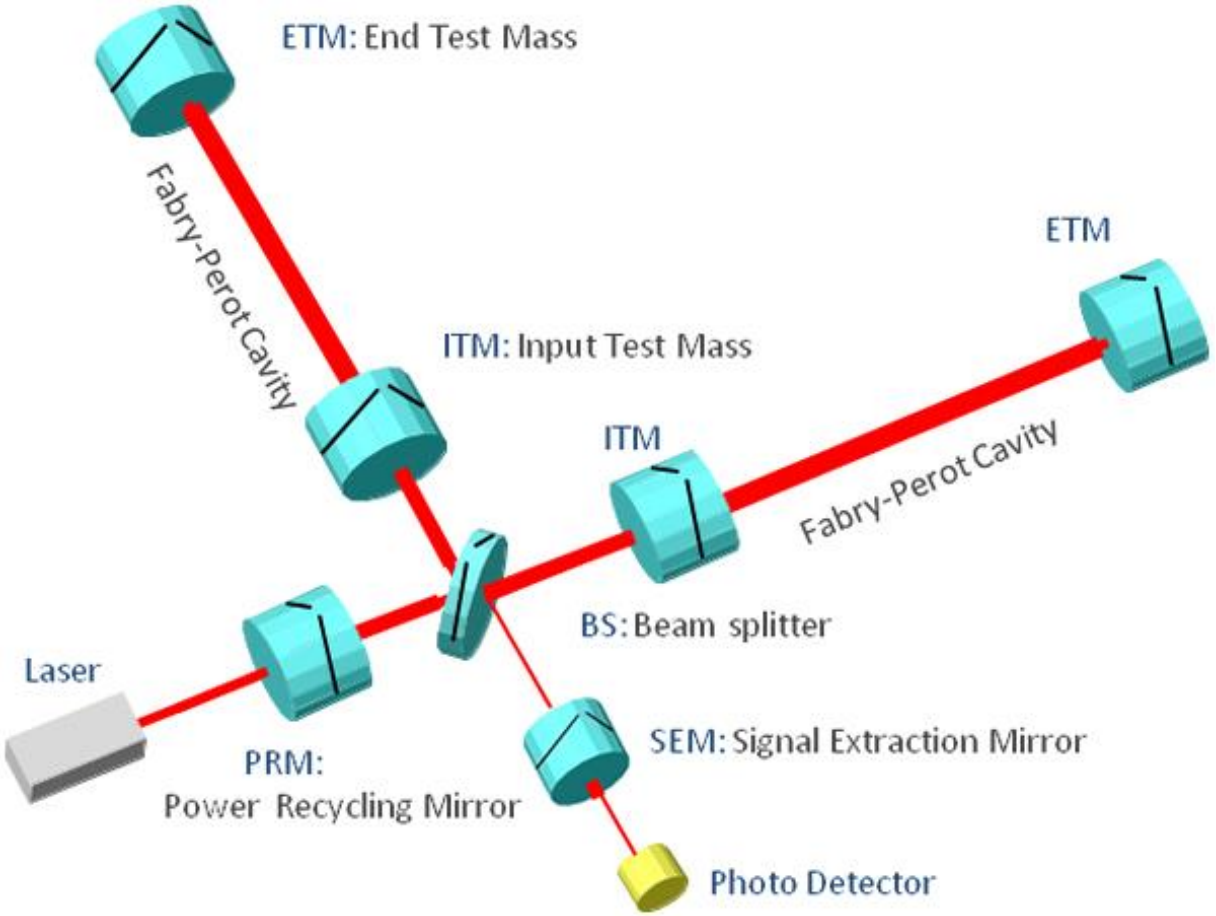


Figure: M Evans

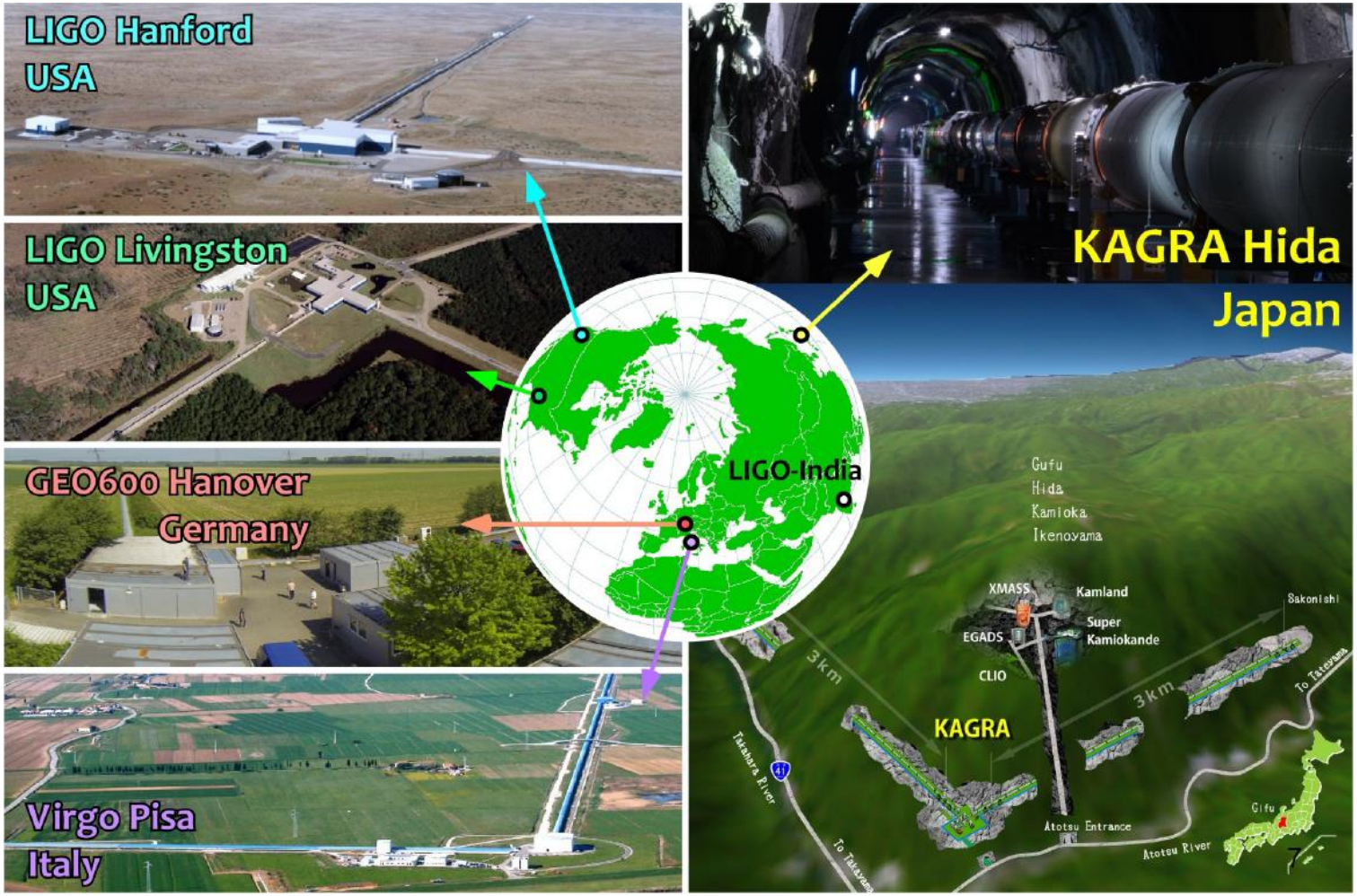
Next generation GWDs and space GWDs will expand the window of GWs

Interferometric GW detector

Fabry-Perot Michelson Interferometers with recycling technique



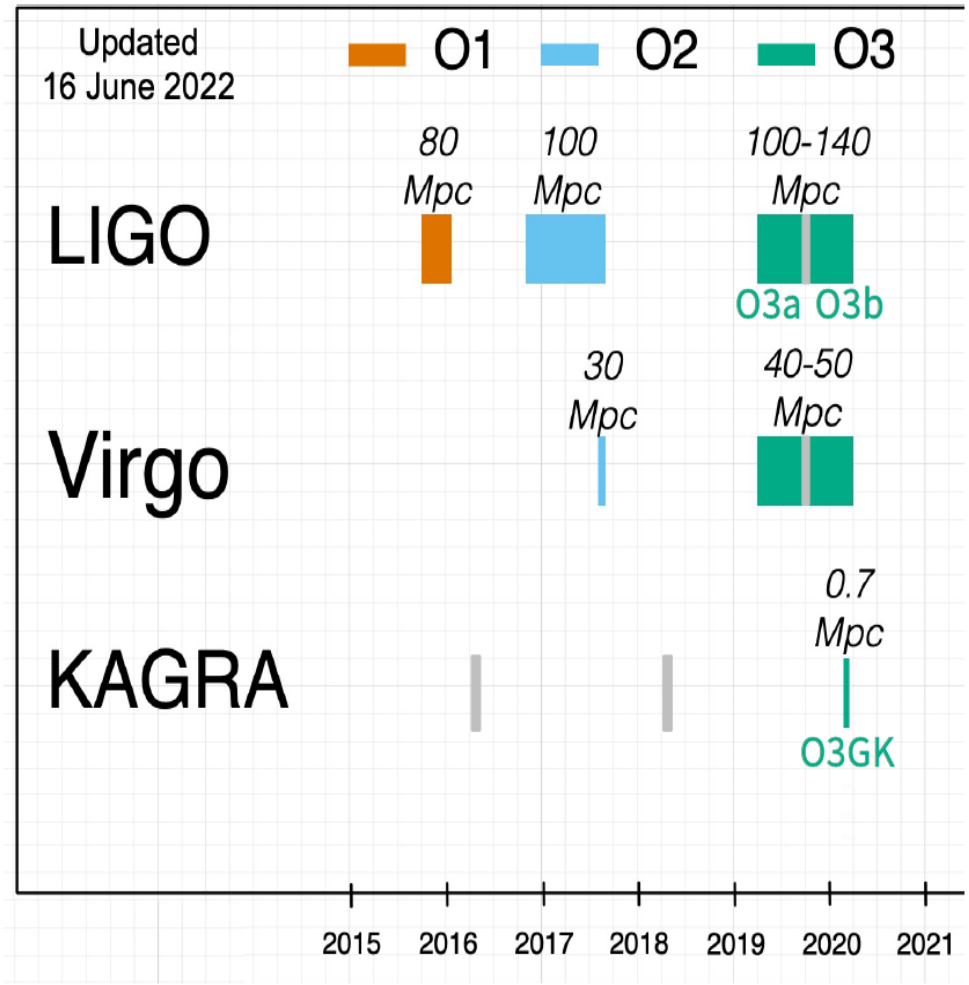
Global network of GW detectors



Improvement of confidence in direction, duty cycle, sky coverage, and so on.

Past observing run

T. Sawada, JGW-G2214421-v7



1st Observing Run (O1)
2015. 9 - 2016. 1

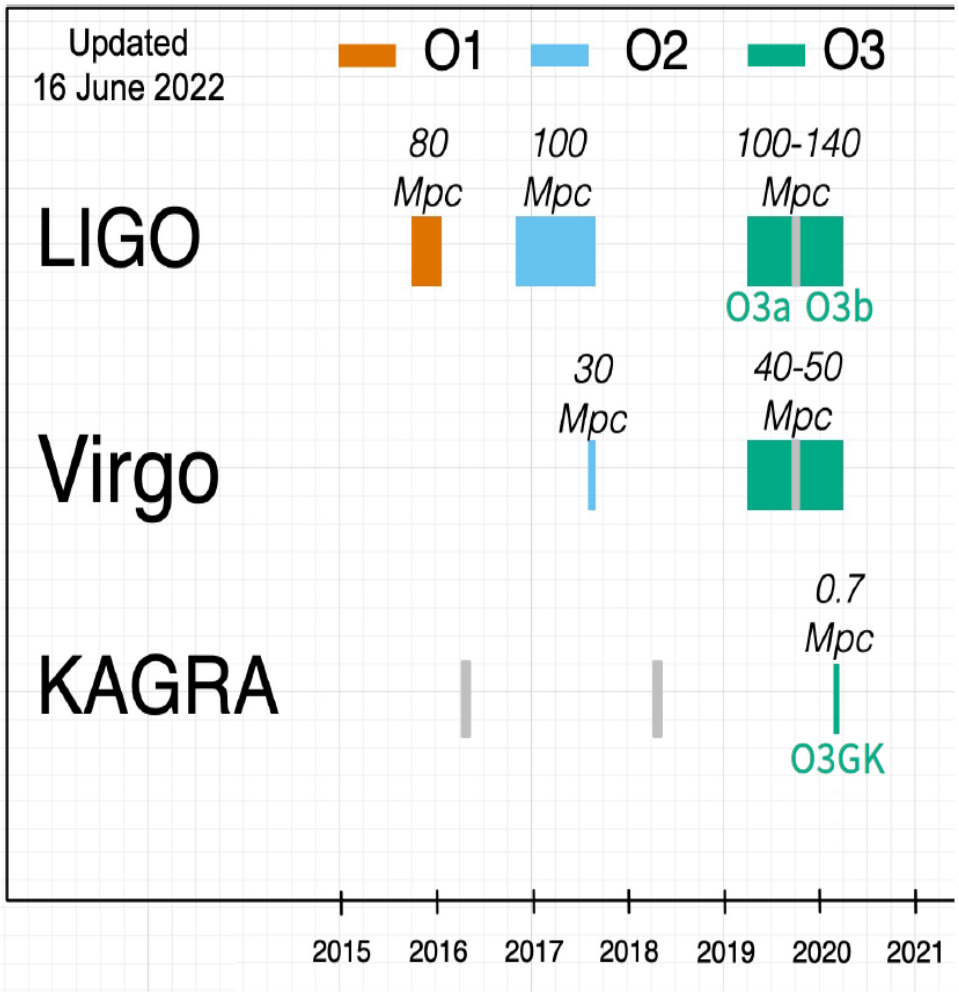
- LIGO only
- GW150914: First direct detection of GWs – binary black hole merger (BH-BH)

2nd Observing Run (O2)
2016. 11 - 2017. 8

- First LIGO only, Virgo from August 1st onwards
- GW170814: First triple-detector GW detection
- GW170817: First binary neutron star merger detection (NS-NS)
- Birth of multi-messenger astronomy with GW

Past observing run

T. Sawada, JGW-G2214421-v7



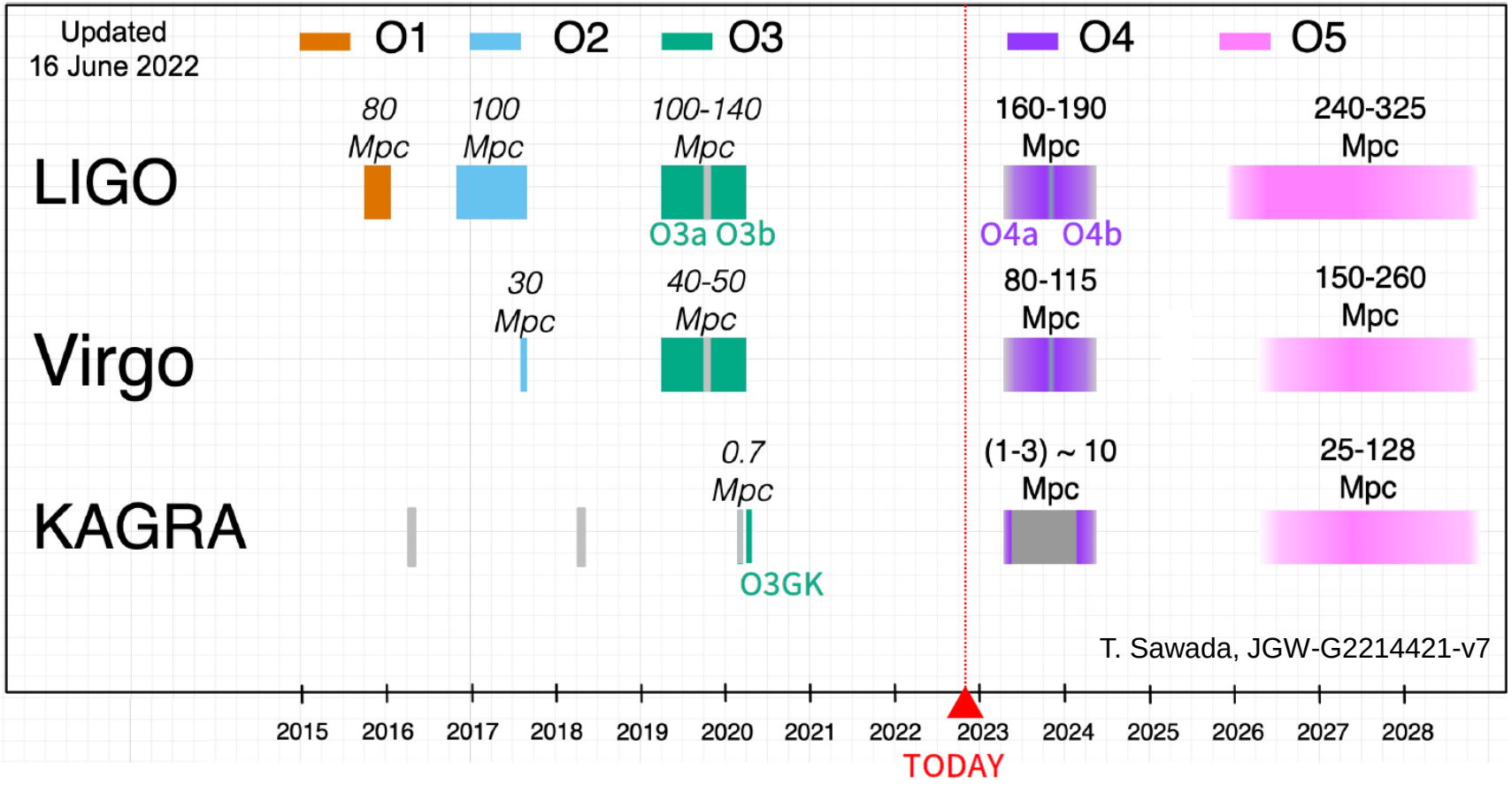
3rd Observing Run (O3)

- 2019. 4 - 2020. 3 (O3a, O3b)
  - LIGO+Virgo
  - Initially planned to complete at the end of April 2020,

    but due to a COVID-19 disaster, it ended in March 2020.
- 2020. 4 (O3GK)
  - GEO+KAGRA

Plan of next observing run

Planned from March, 2023 and up-to-date plan will be announced soon.



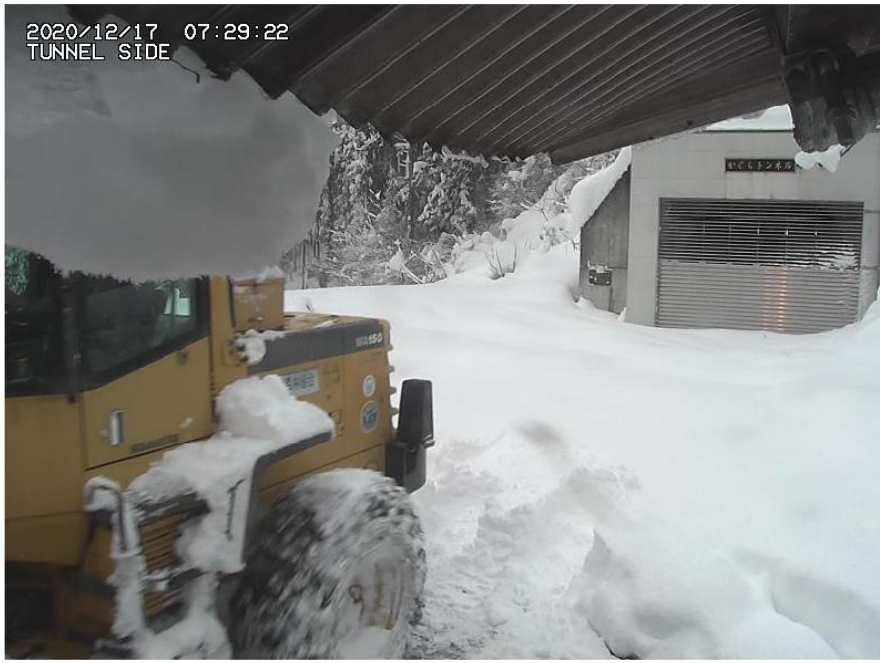
We finished installation work except for OMC
and are now starting the commissioning of the interferometer.

KAGRA

KAGRA site

90cm snow in one night

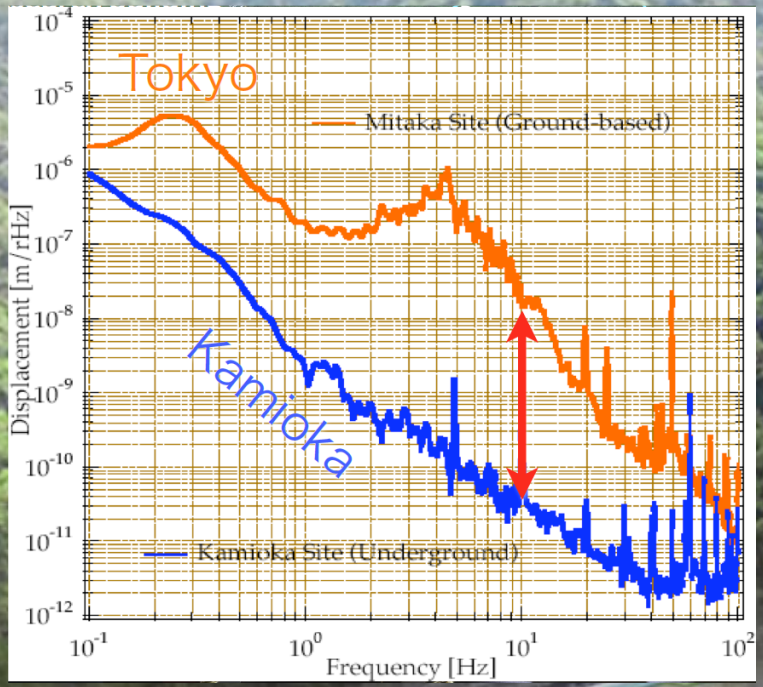
KAGRA entrance

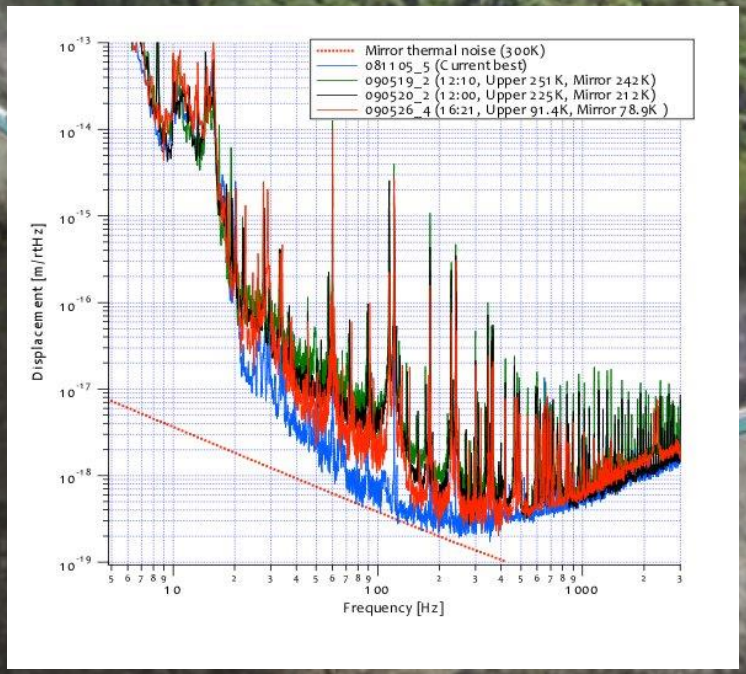


KAGRA entrance in winter season

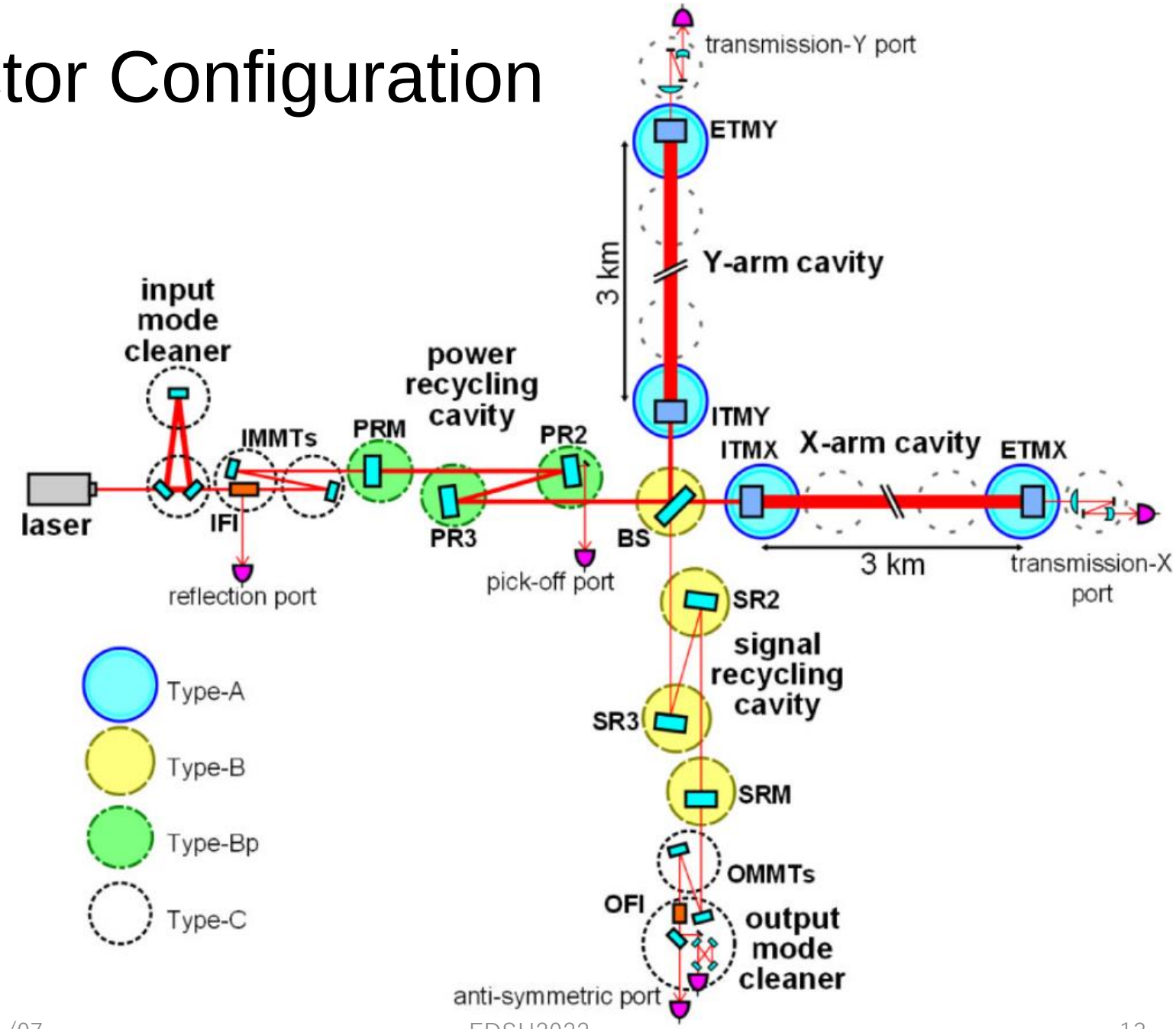
KAGRA site around BS

Key features of KAGRA



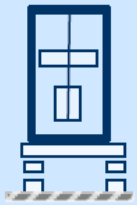


Detector Configuration

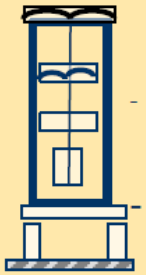


Suspensions

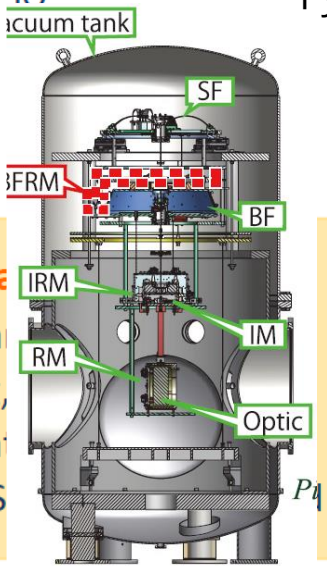
bKAGRA configuration
- Cryogenic test masses
- 3 km arm cavities
- RSE with power recycling

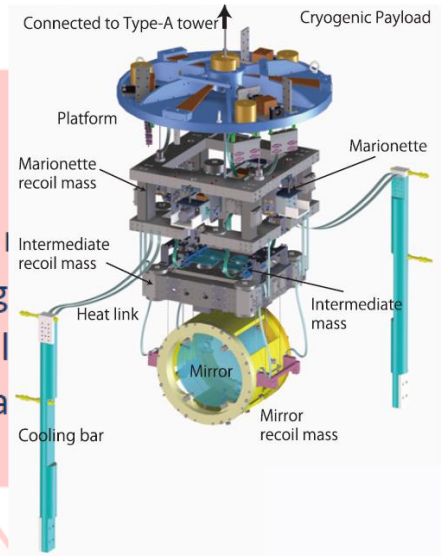


Type-C system
- Mode cleaner
  Silica, 0.5kg, 290K
- Stack + Payload

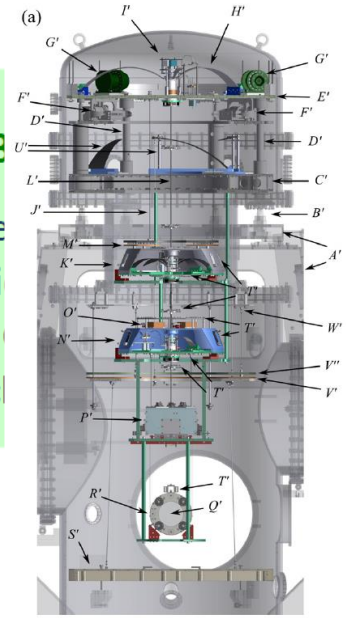


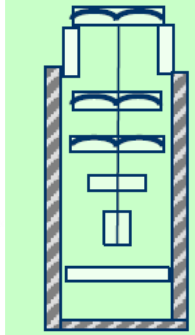
Type-Bp pa
- Test mass a
  Silica, 10kg,
- Seismic isola
  Table + GAS





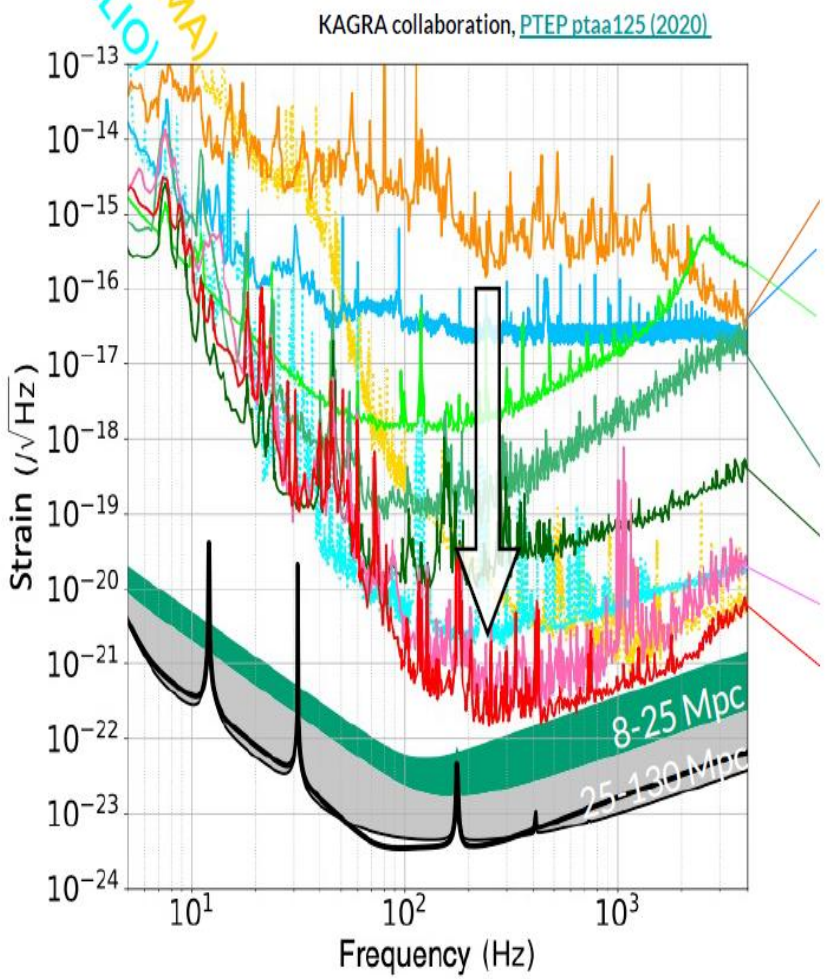
Type-B
- Core
  Sili
- IP +
- Stac





History of KAGRA

Evolution of Sensitivity Curve



T. Sawada, JGW-G2214421-v7

2010 Funded by MEXT Japan
2012 Started Construction
2016 Test Operation @ room temp. (iKAGRA)
2018 Cryogenic Test Operation (bKAGRA)
2019/8 FPMI

2019/10 Joined Research MoA with LIGO-Virgo

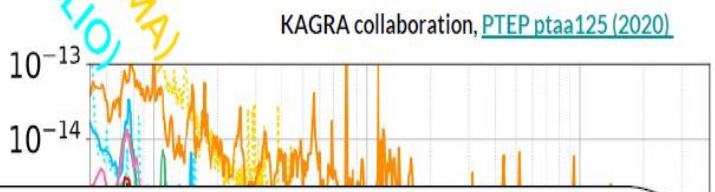
2019/11 FPMI
2019/12 FPMI
2020/2 PRFPMI
2020/3 PRFPMI

2020/3 Joined O3 PRFPMI @ room temp.
2020/4 Observation O3GK

FPMI = Fabry-Perot Michelson Interferometer
PRFPMI = Power Recycling Fabry-Perot Michelson Interferometer

History of KAGRA

Evolution of Sensitivity Curve



T. Sawada, JGW-G2214421-v7

Joint Research MoA with LIGO-VIRGO
Signed on Oct. 4, 2019

2010 Funded by MEXT Japan
2012 Started Construction
2016 Test Operation @ room temp. (iKAGRA)
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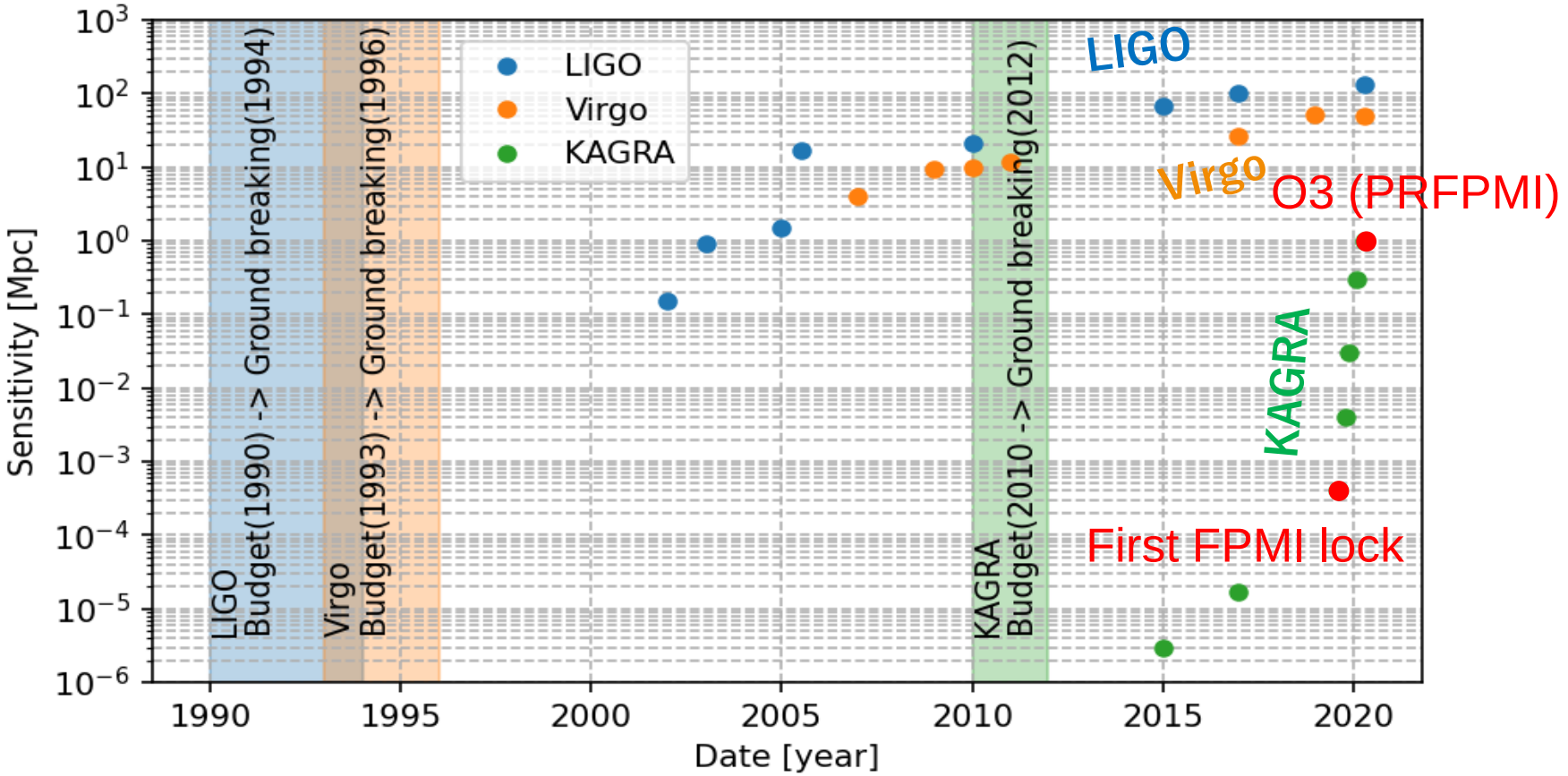
2020/4 Observation O3GK

FPMI = Fabry-Perot Michelson Interferometer
PRFPMI = Power Recycling Fabry-Perot Michelson Interferometer

Sensitivity history of KAGRA

J. Yokoyama, JGW-G2214090-v2

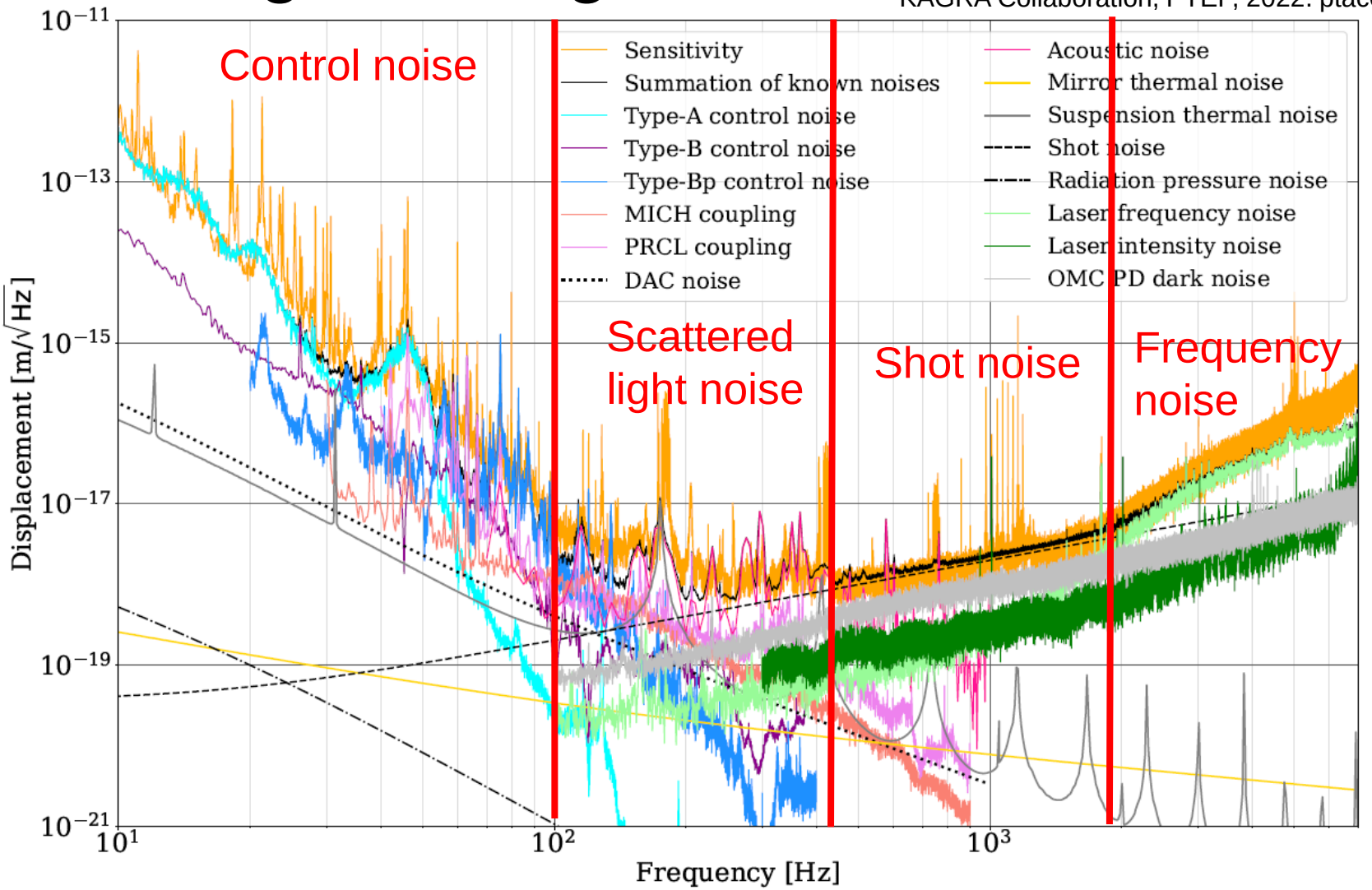


Thanks to the experience in LIGO and Virgo,

our senisitivity improvement speed is quite high.

Noise budget during O3GK

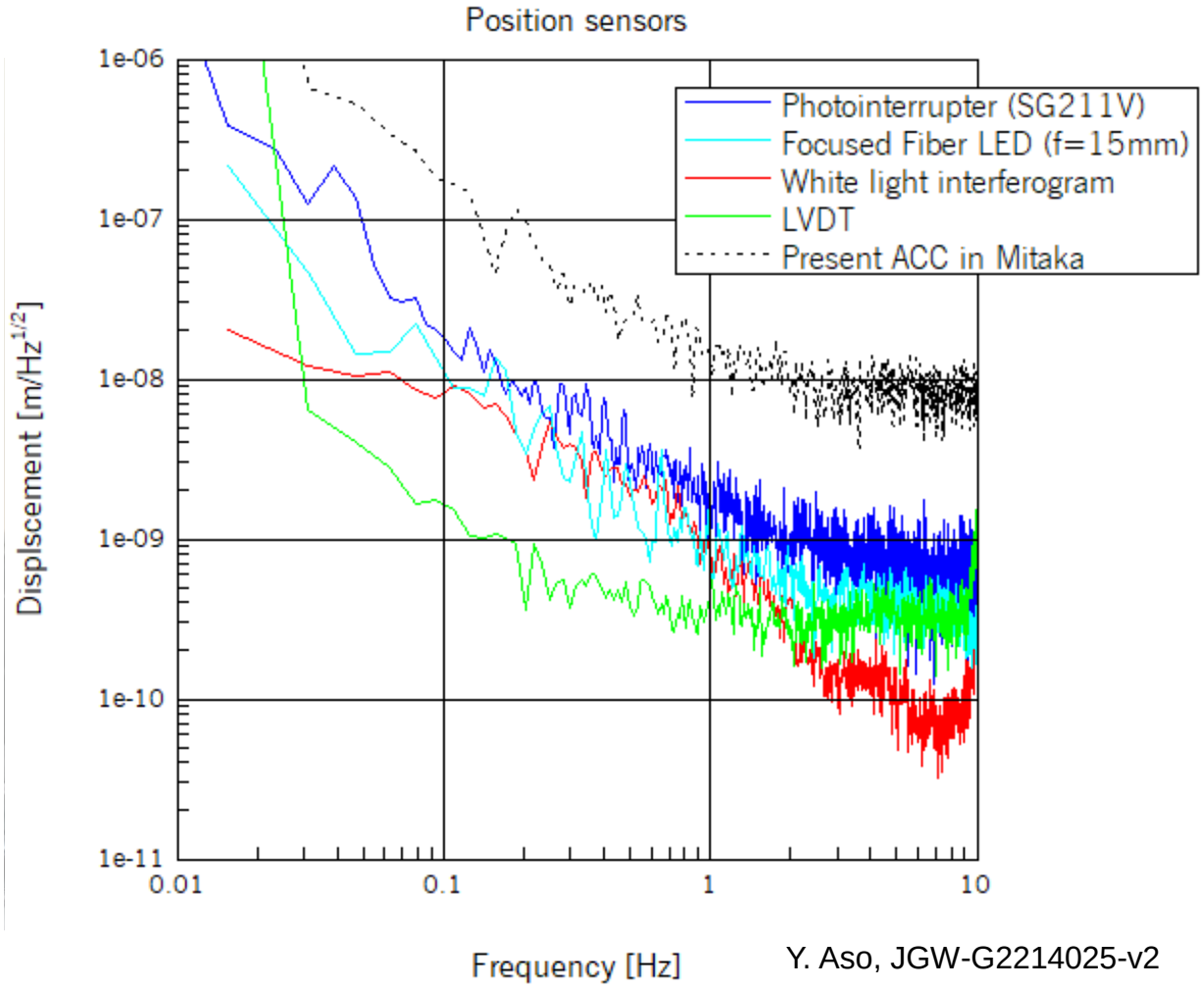
KAGRA Collaboration, PTEP, 2022. ptac093



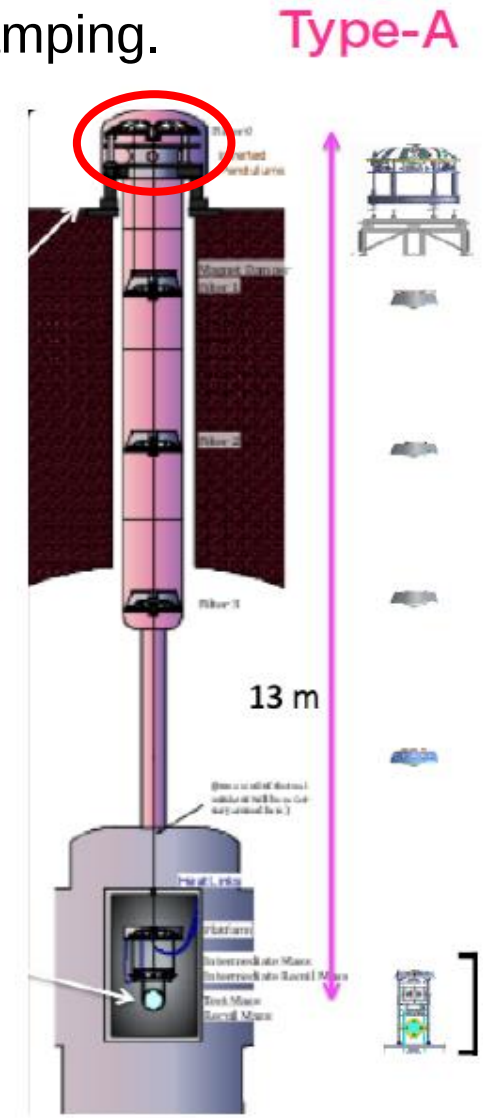
We identified dominant noise sources in all observation band

Suspension update for low frequency

Update of inertial sensors for better inertial damping.



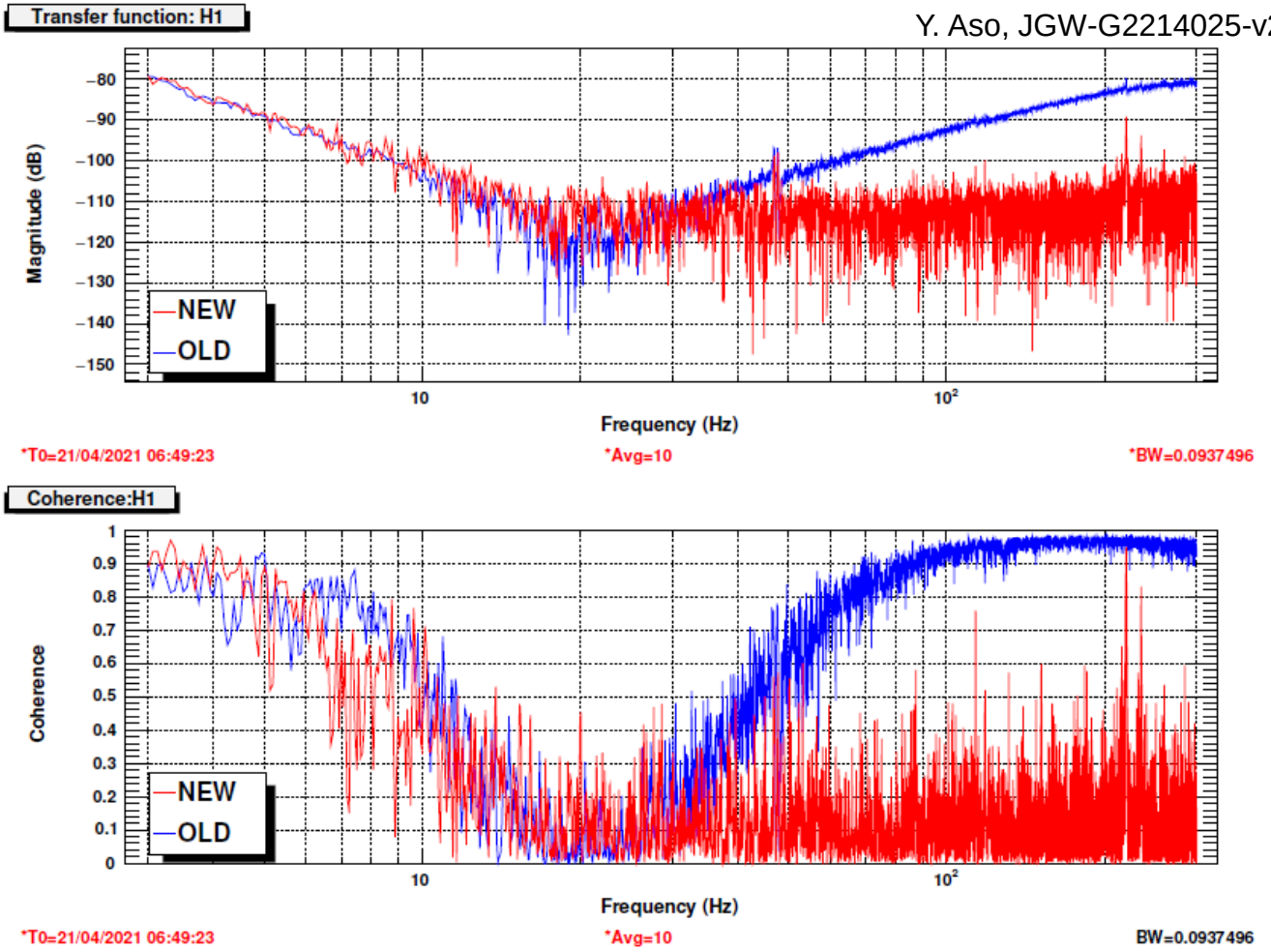
Y. Aso, JGW-G2214025-v2

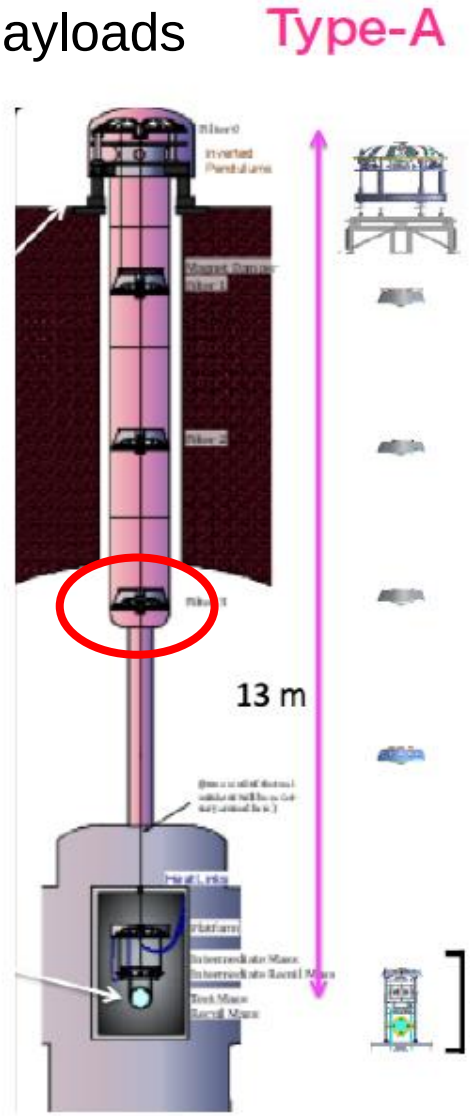


Suspension update for low frequency

Update of sensors and actuators on cryogenic payloads

Y. Aso, JGW-G2214025-v2

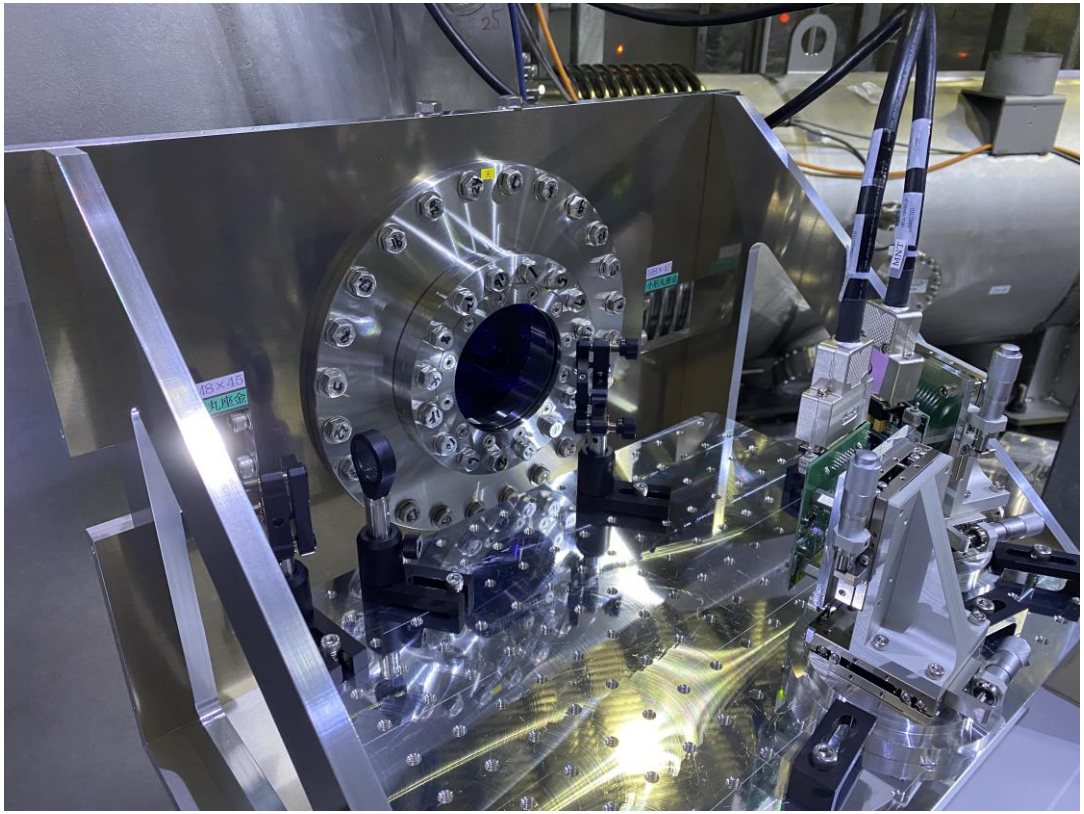




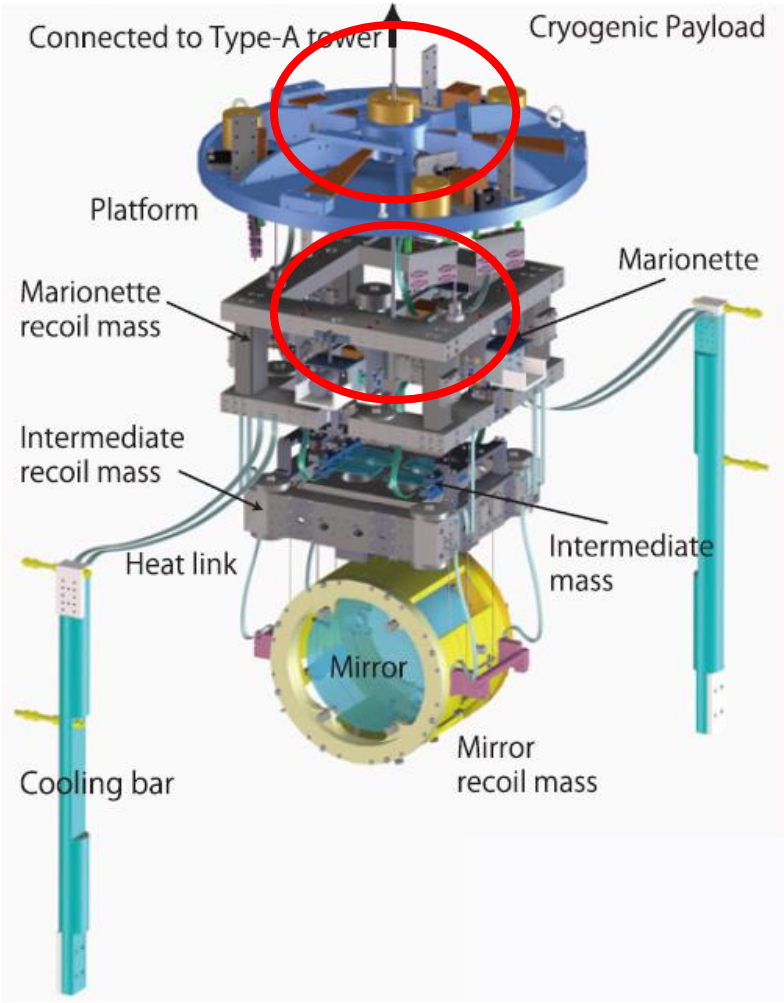
Reduction of cross-coupling in LVDTs

Suspension update for low frequency

Added new optical levers for better angular sensing.

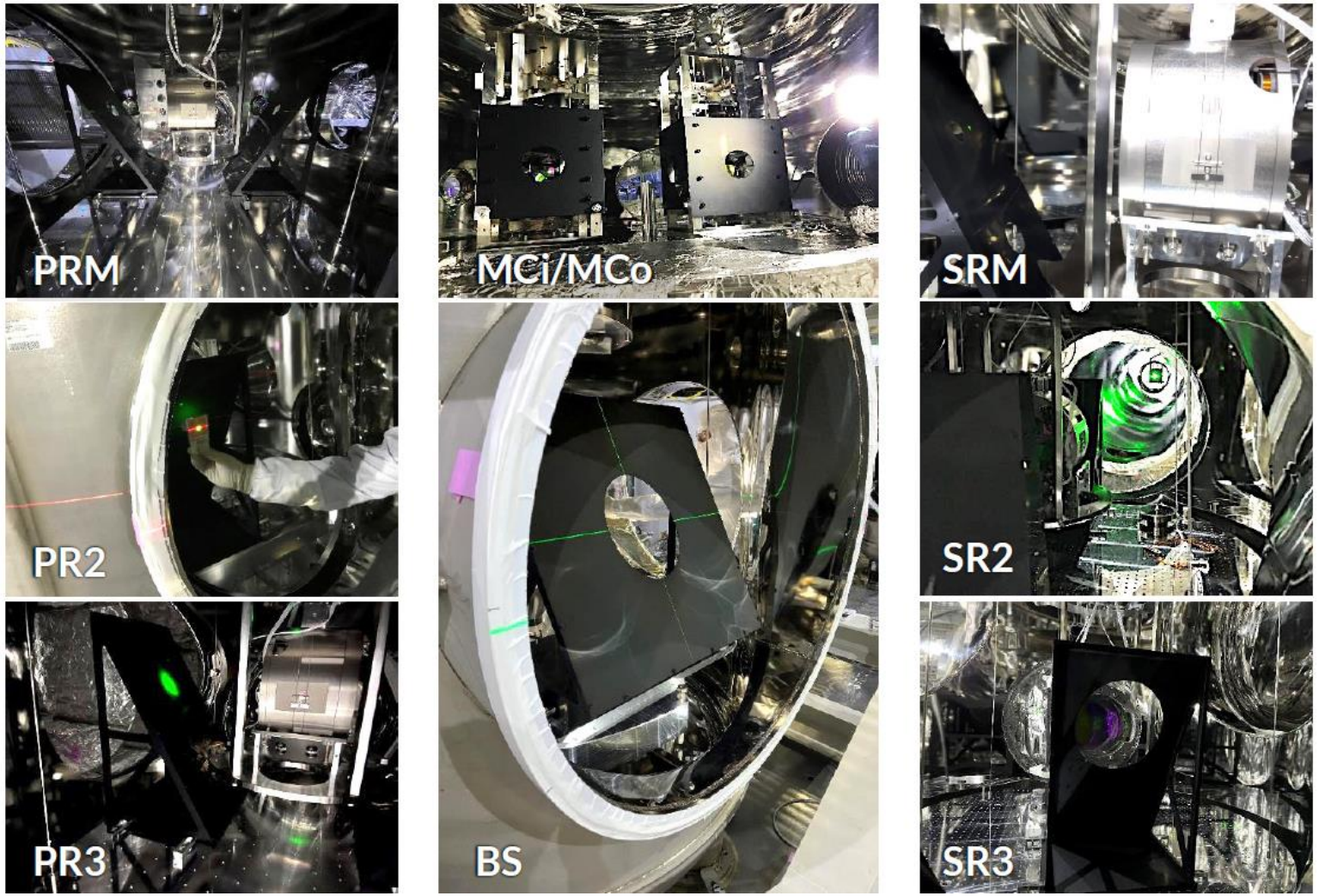


T. Yokozawa, JGW-G2214400-v3



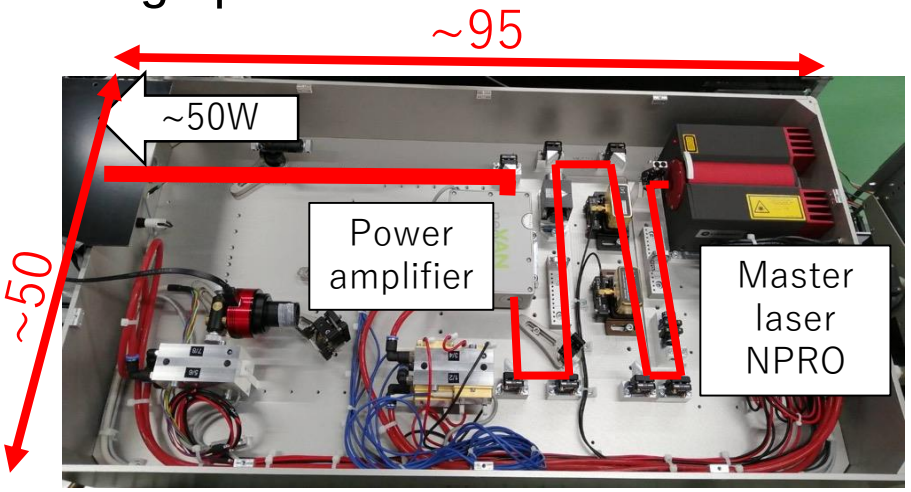
Baffle installation for middle frequency

Installed many baffles around central area mirrors

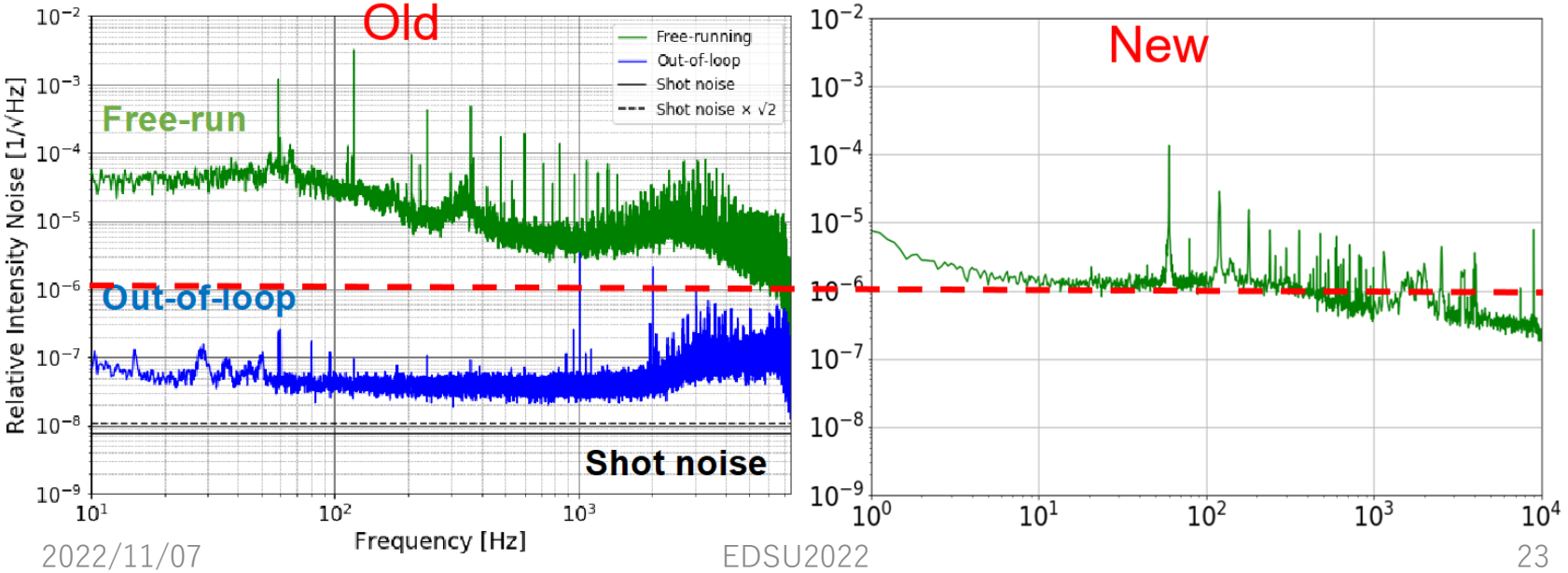


High power laser for high frequencies

Installed new high power laser with better intensity noise.



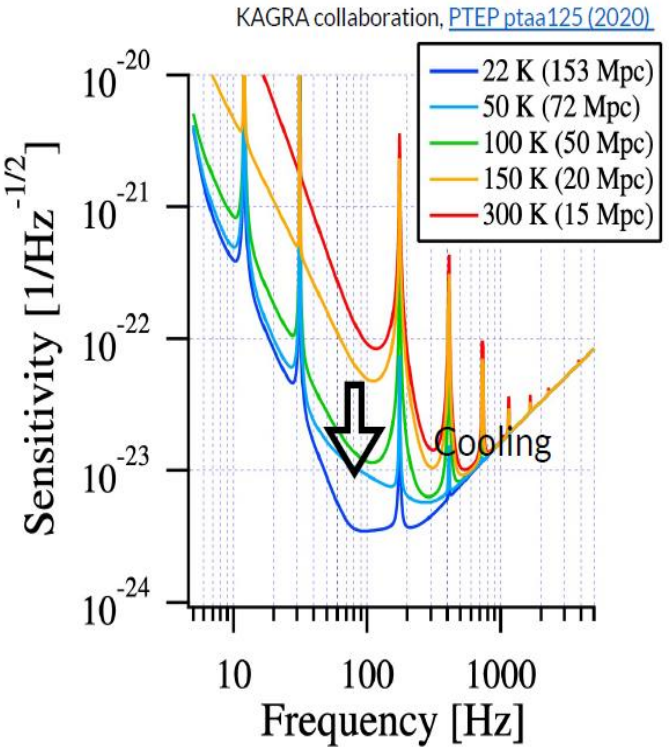
Y. Aso, JGW-G2214025-v2



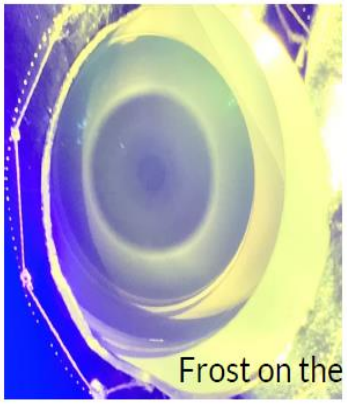
Updates of vacuum and cryogenics

Achievement of cryogenic mirrors are important for better sensitivity.

We want to reduce thermal noise by cooling the mirror, but..



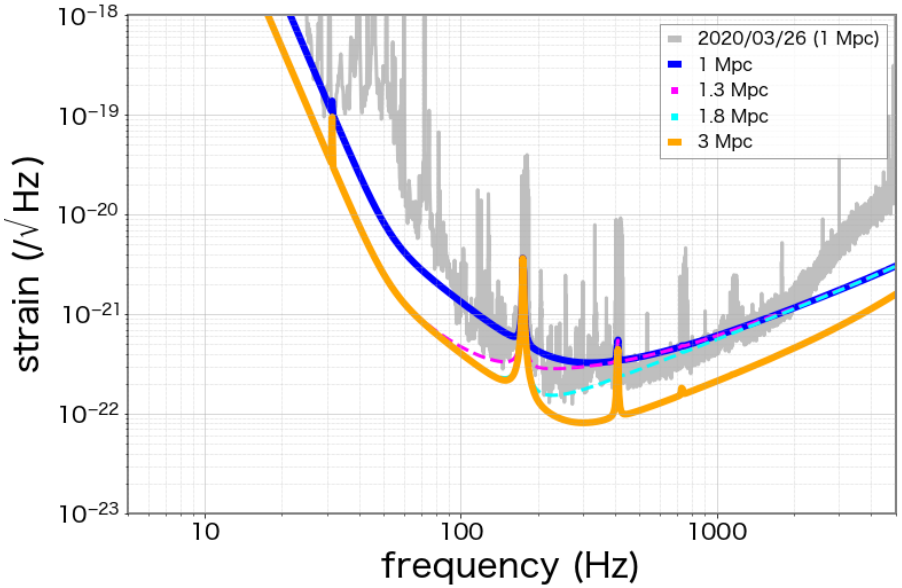
Problems occurred in the preparations for O3



- Additional vacuum pumps
  - 12 more ion-pumps
  - 10 more turbo molecular pumps
- Better vacuum
- Avoid molecular adsorption on mirrors during cooling
- Defrosting heaters

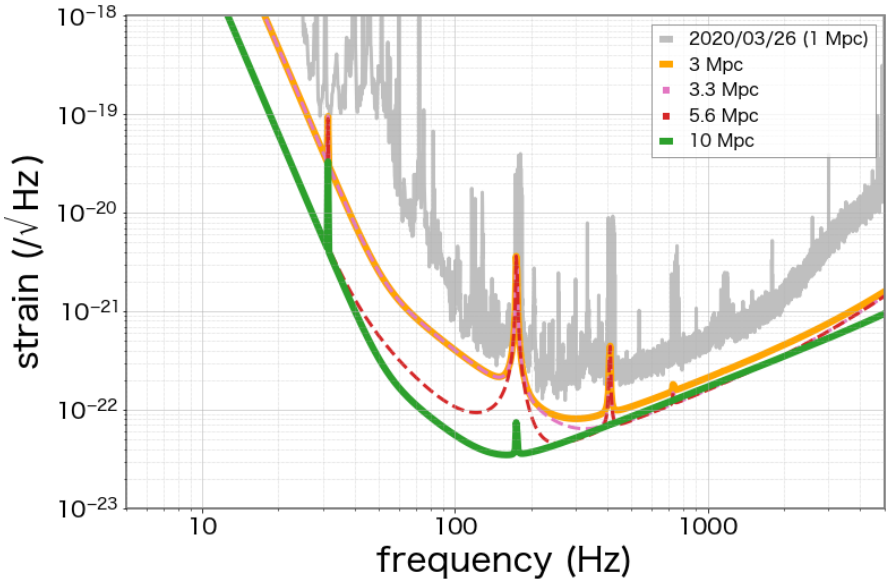
Expected sensitivity toward O4

O4a



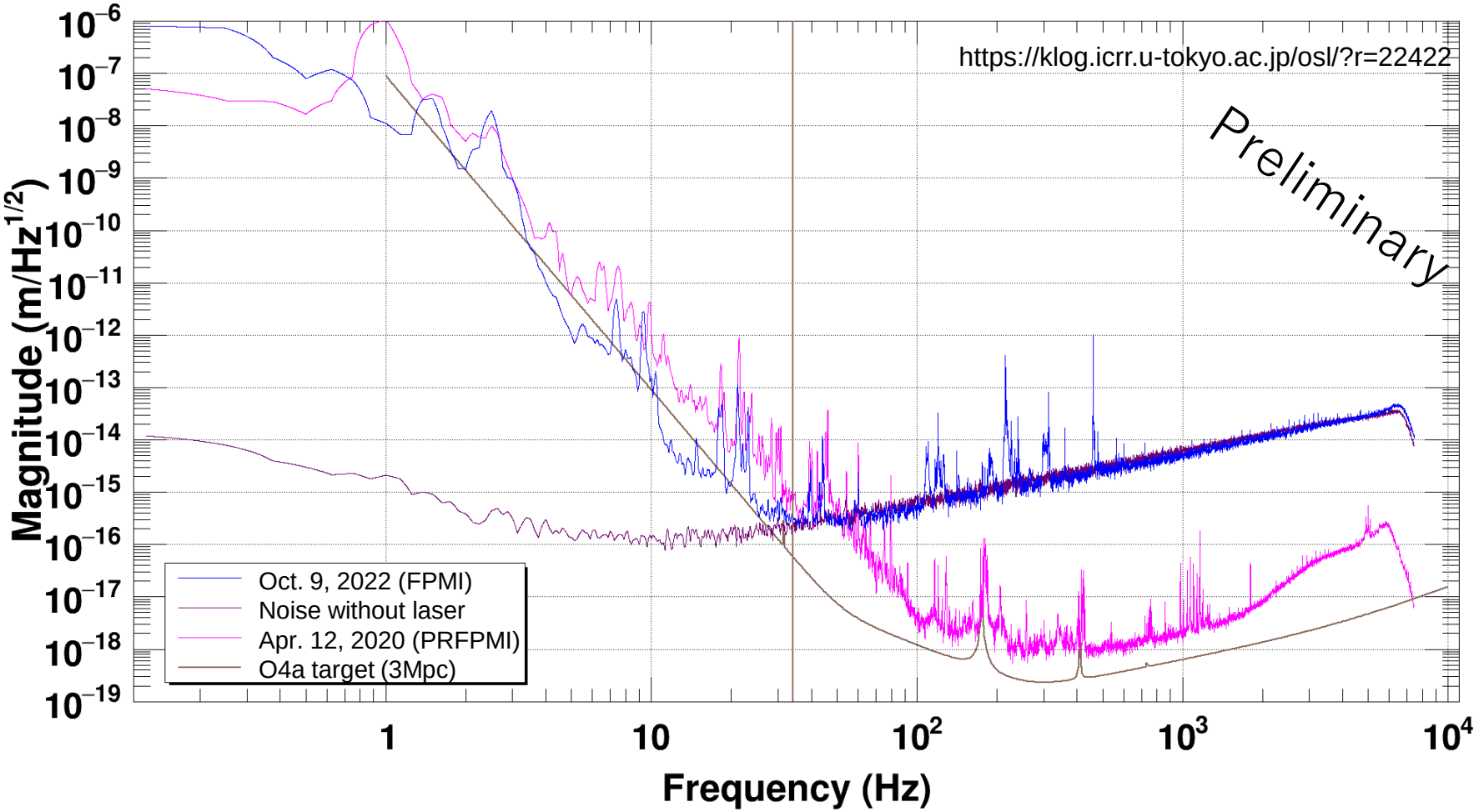
O4b

H. Yuzurihara



We aimed to achieve 1 – 3 Mpc at the beginning of O4 (O4a) and 3 -10 Mpc at the end of O4 (O4b).
To achieve them, we plan to have relatively longer commissioning break between O4a and O4b compared with LIGO and Virgo.

Current sensitivity with FPMI configuration



We have already seen some noise reduction at low frequencies.
higher noise at high frequencies is due to the configuration difference and can be reduced when we will achieve PRFPMI.

Summary

- LIGO-Virgo-KAGRA Collaboration has been started.
- KAGRA couldn’t join O3 observing run with LV due to COVID19 pandemic but had an observing run, O3GK, with GEO600 in April, 2020.
- Next observing run, O4, planned to start from March, 2023.
- KAGRA will join O4 with better sensitivity than O3GK
- Installation works were finished and commissioning was just started.