大型低温重力波望遠鏡 KAGRAの現状

Takashi Uchiyama on behalf of the KAGRA Collaboration
Institute for Cosmic Ray Research, UTokyo, Japan

Based on T. Ushiba JGW-G2214503-v7

Current Observable GW bands

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

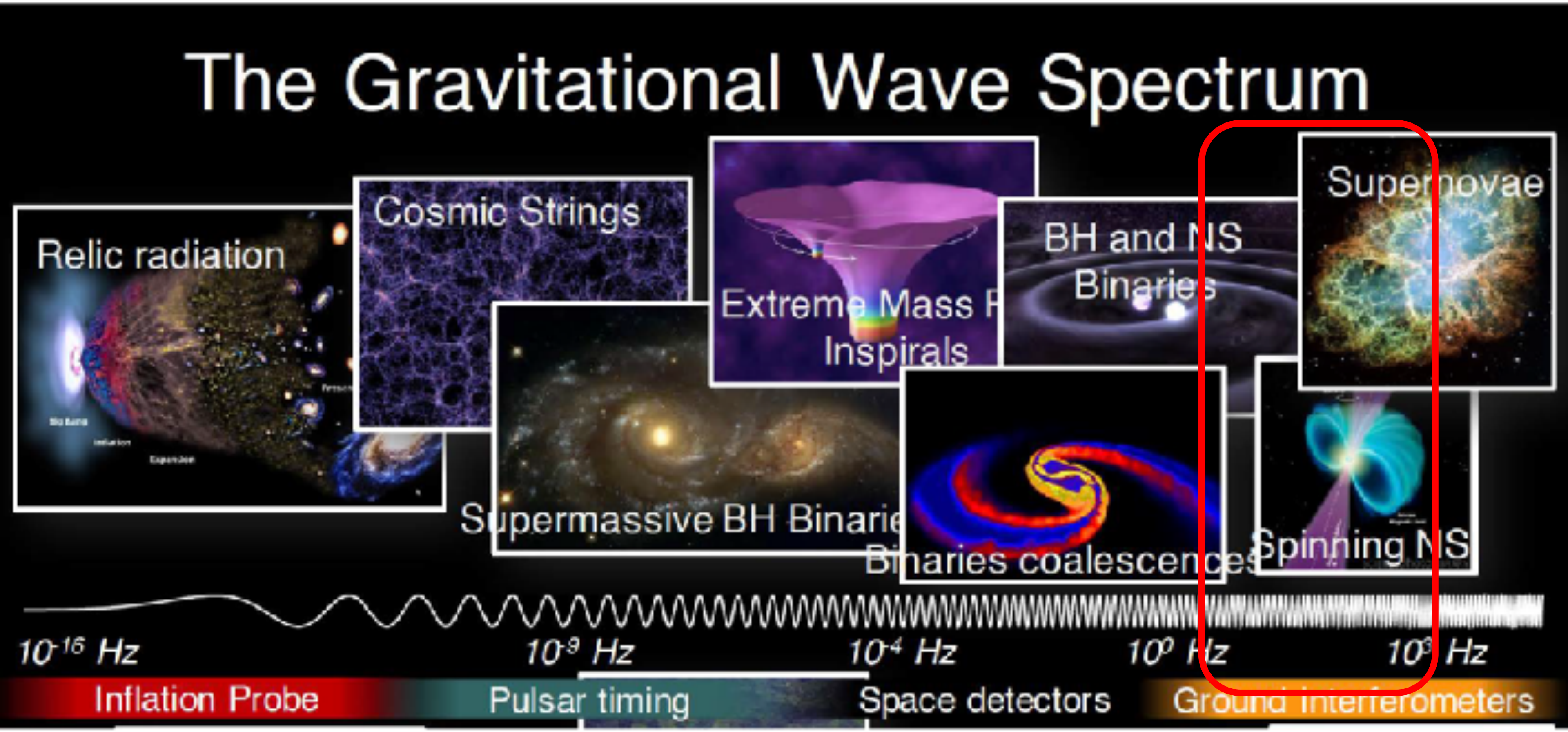
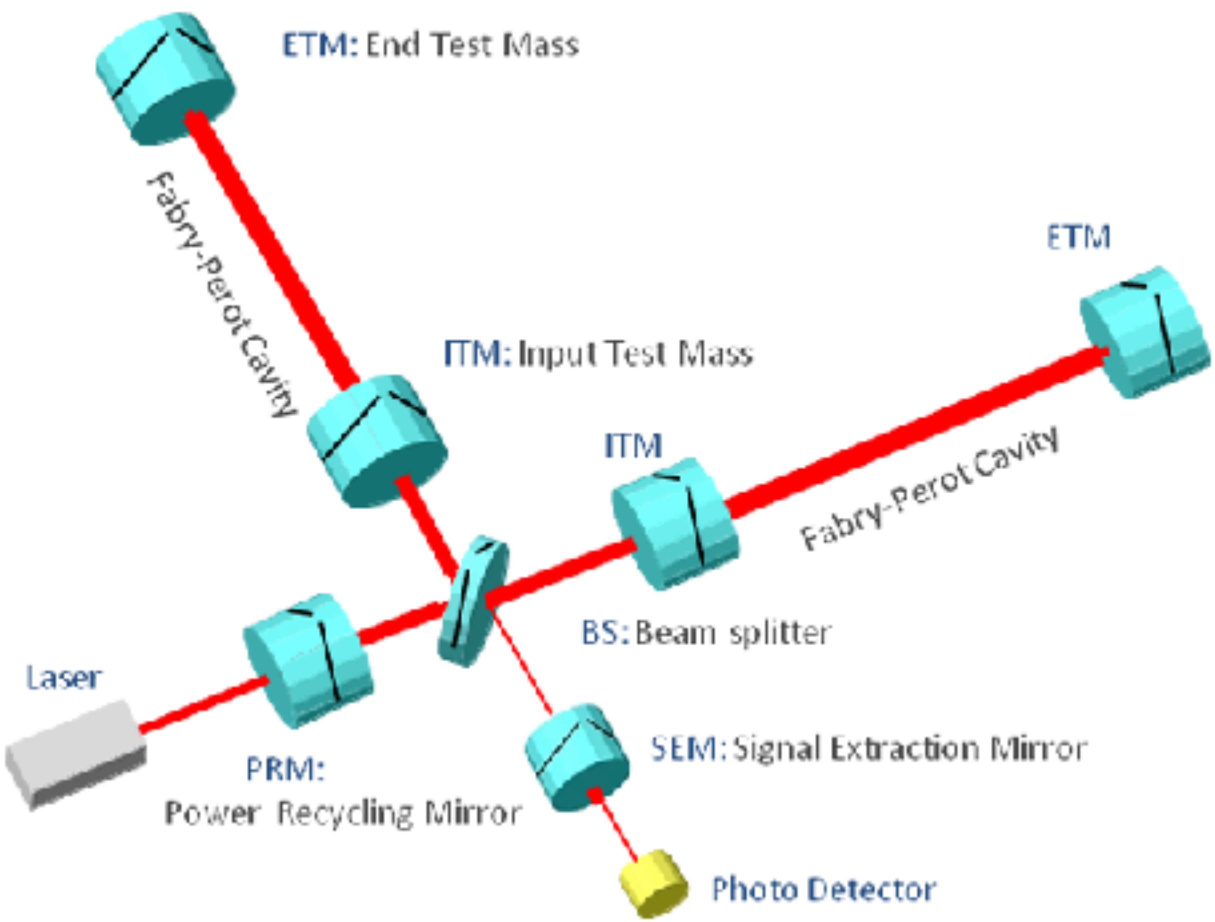


Figure: M Evans

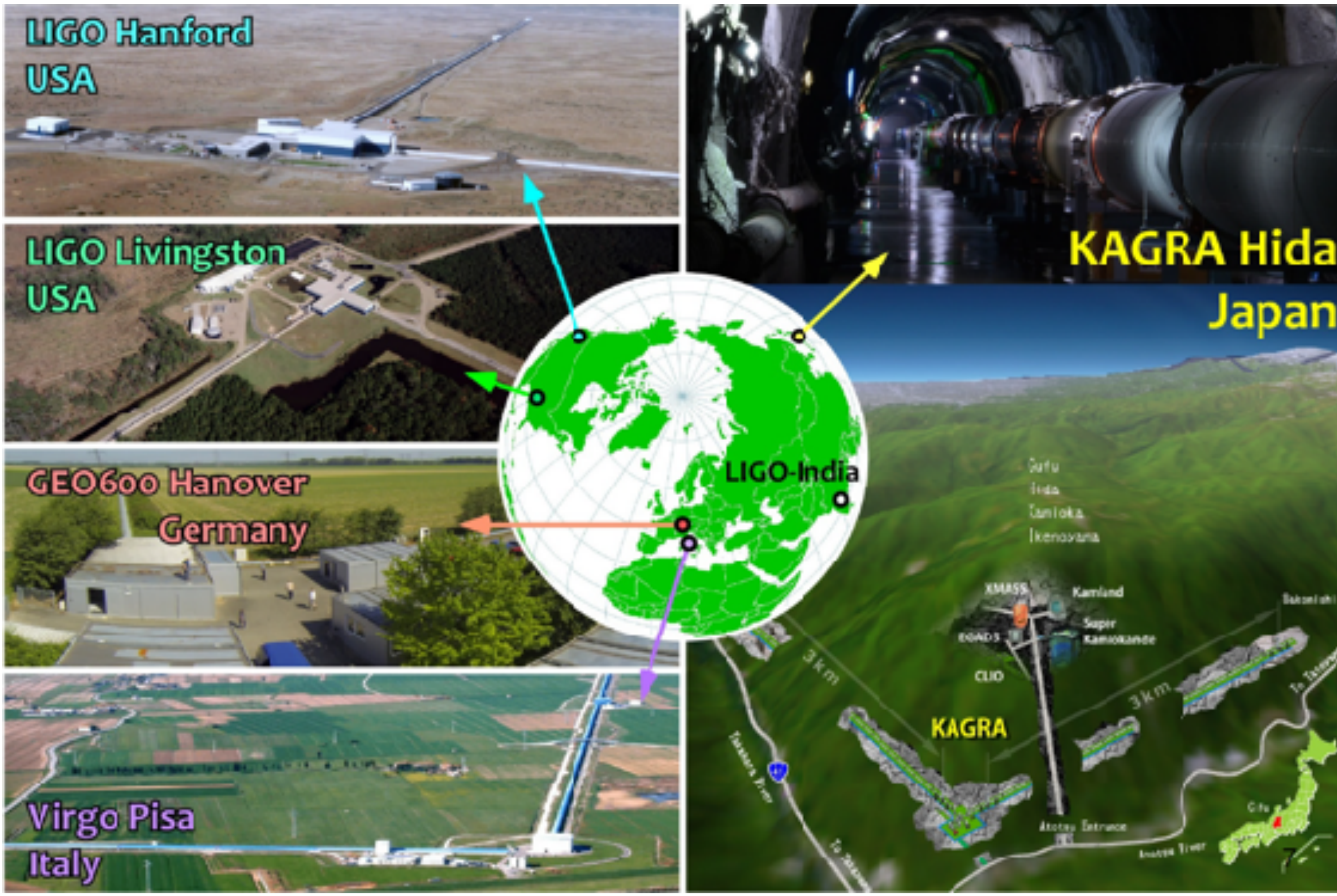
Next generation GWDs and space GWDs will expand the window of GWs

Interferometric GW detector

Fabry-Perot Michelson Interferometers with recycling technique



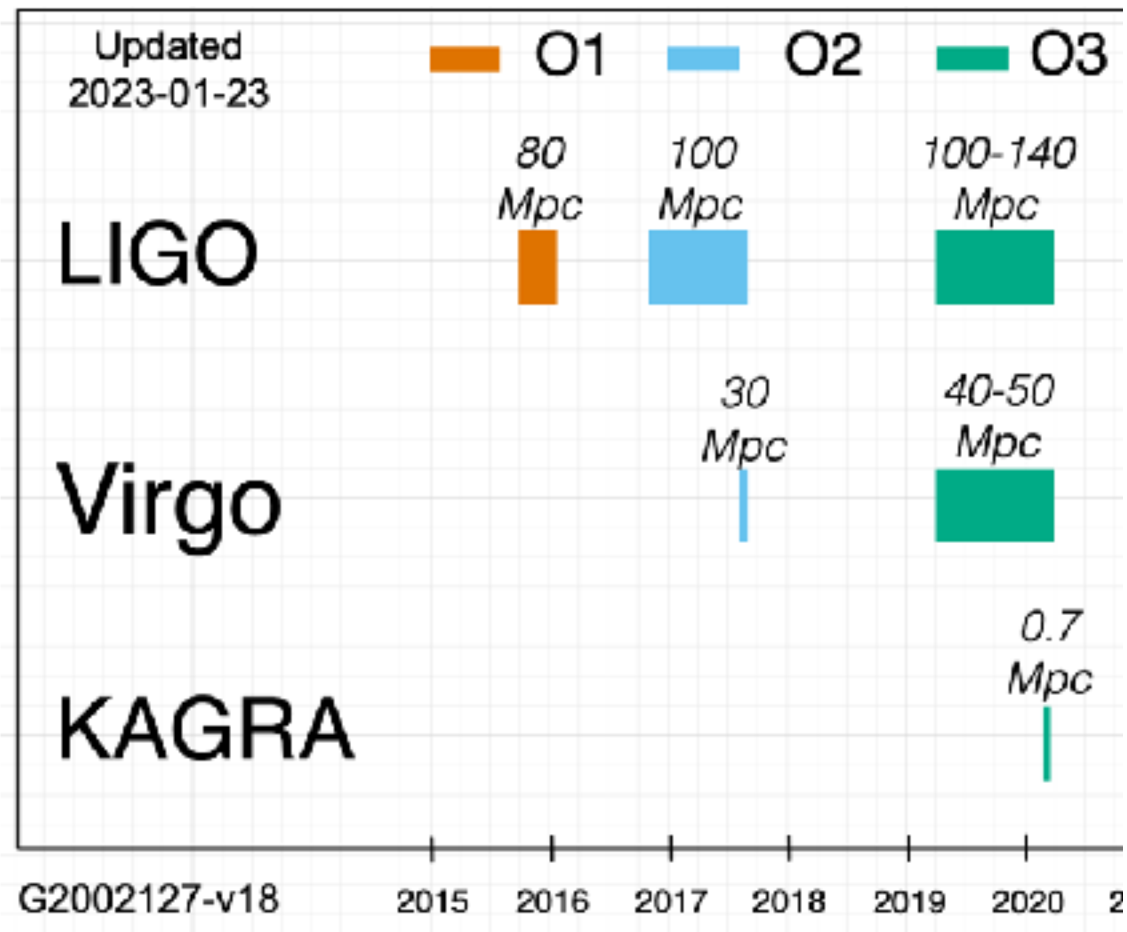
Global network of GW detectors



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

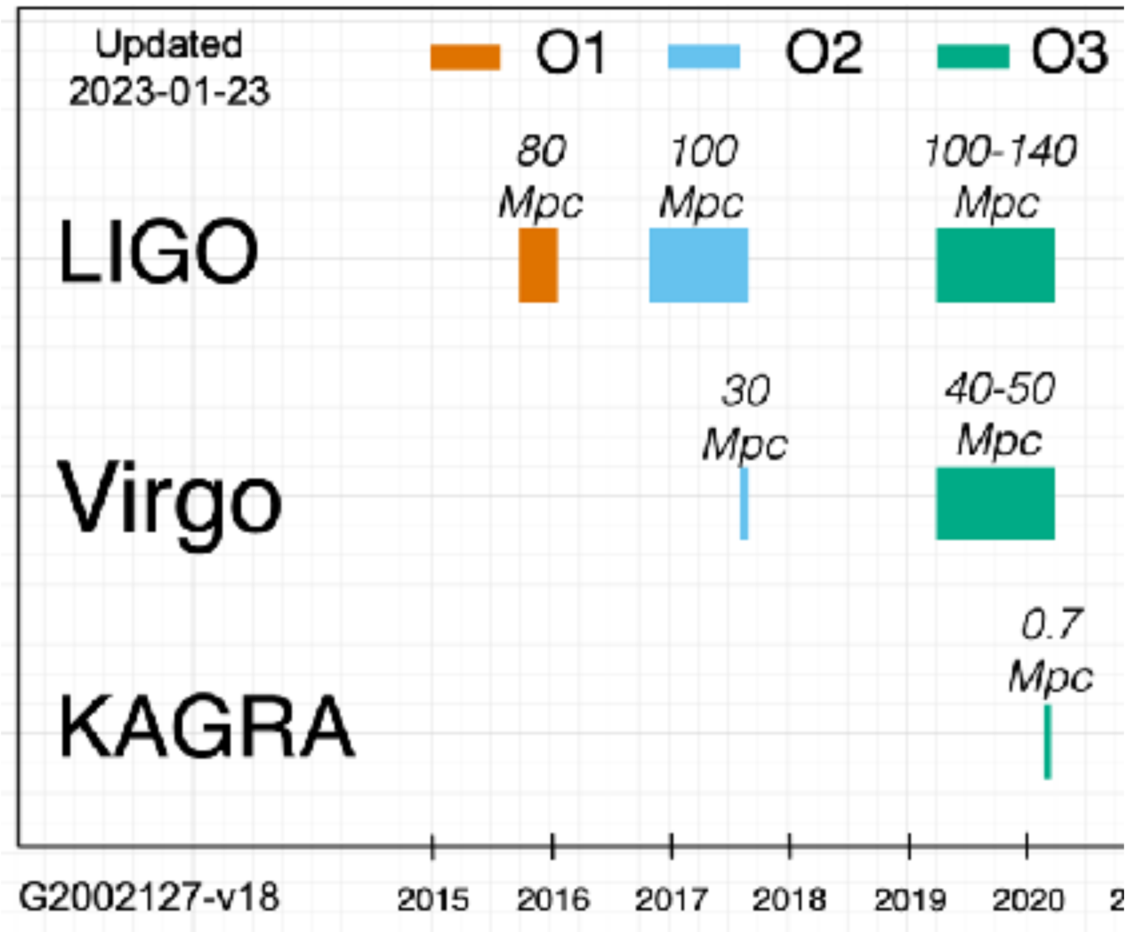
- LIGO only
- **GW150914**: First direct detection of GWs – binary black hole merger (BH-BH)

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

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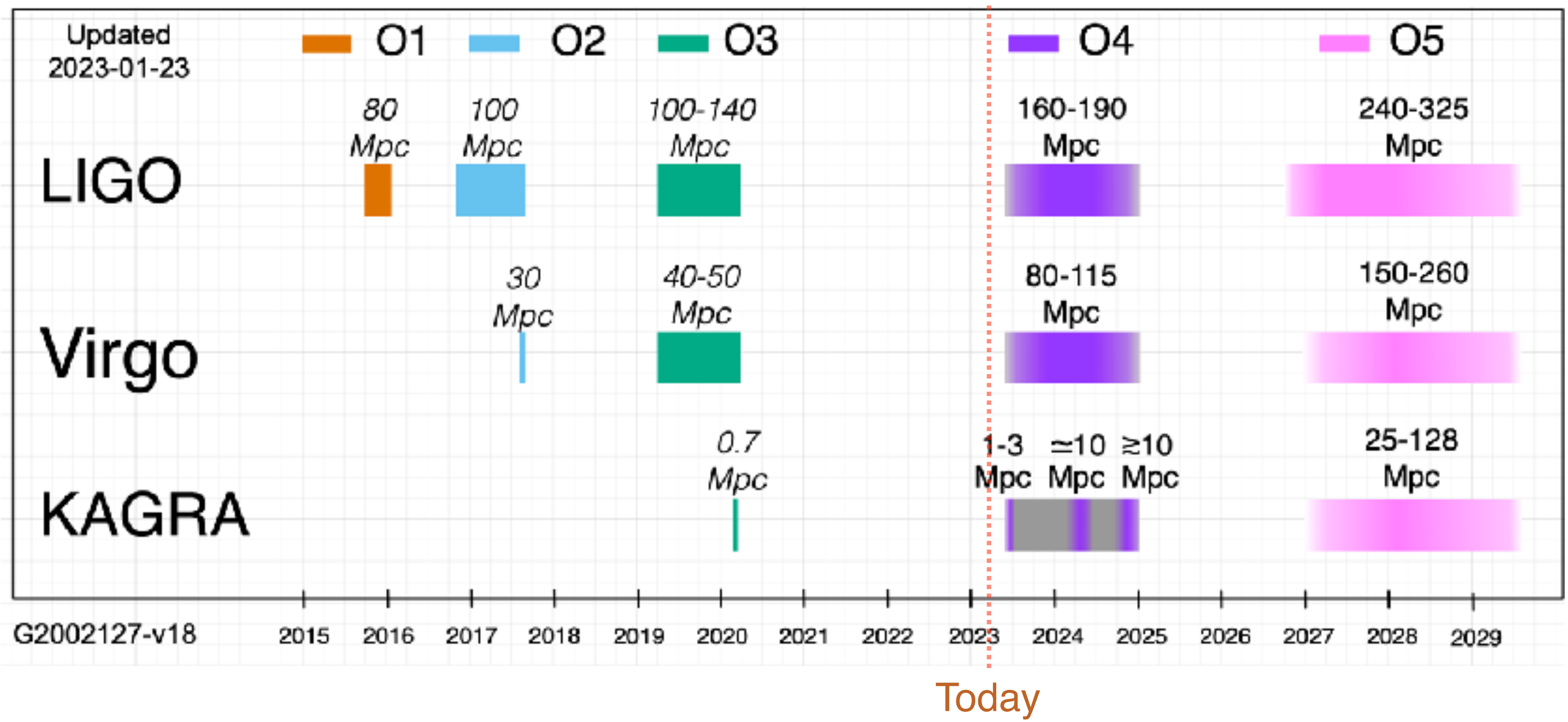
Plan of next observing run O4

Planned from 24 May 2023.

18 months for observing.



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

KAGRA

KAGRA site

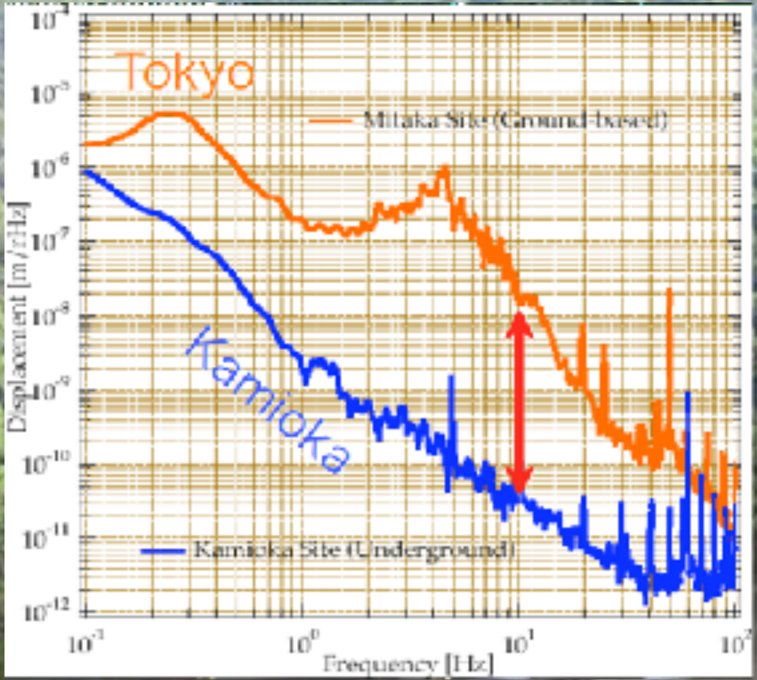
90cm snow in one night

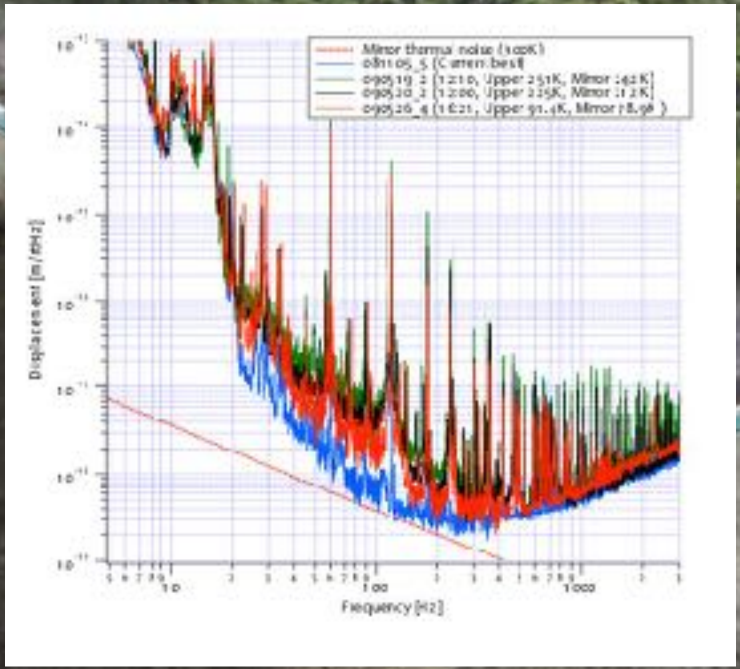
KAGRA entrance

KAGRA entrance in winter season

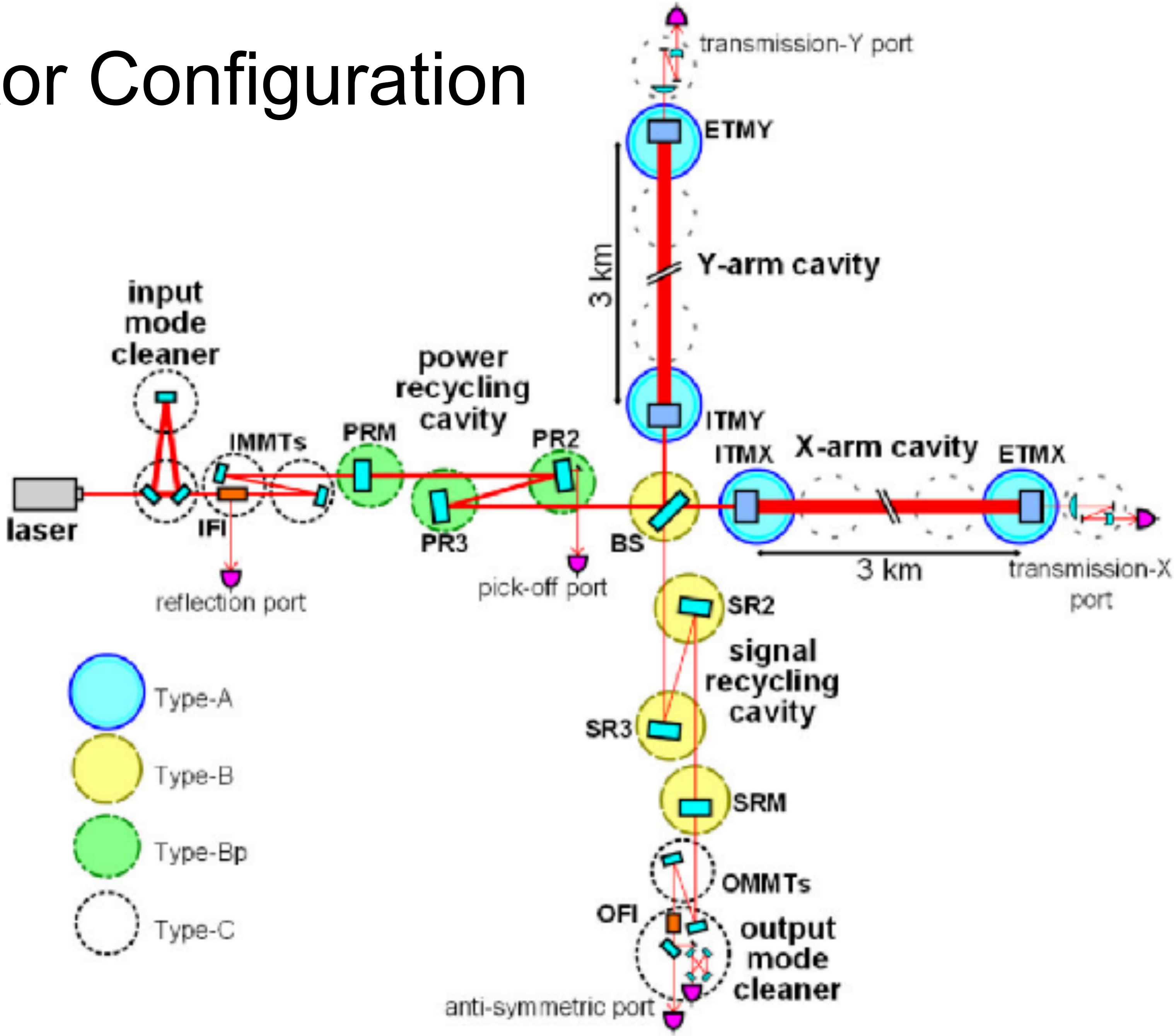
KAGRA site around BS

Key features of KAGRA





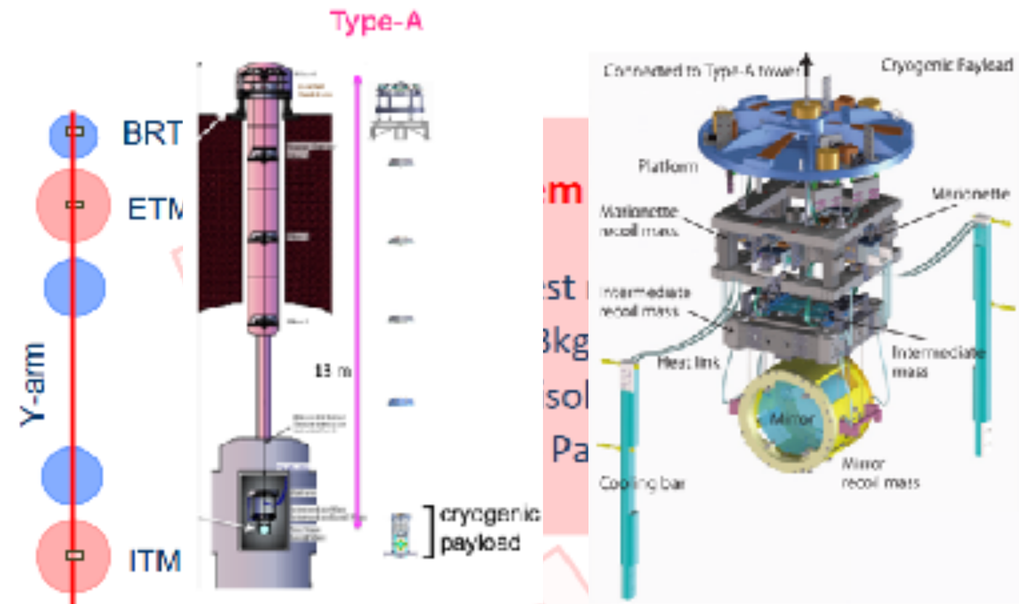
Detector Configuration

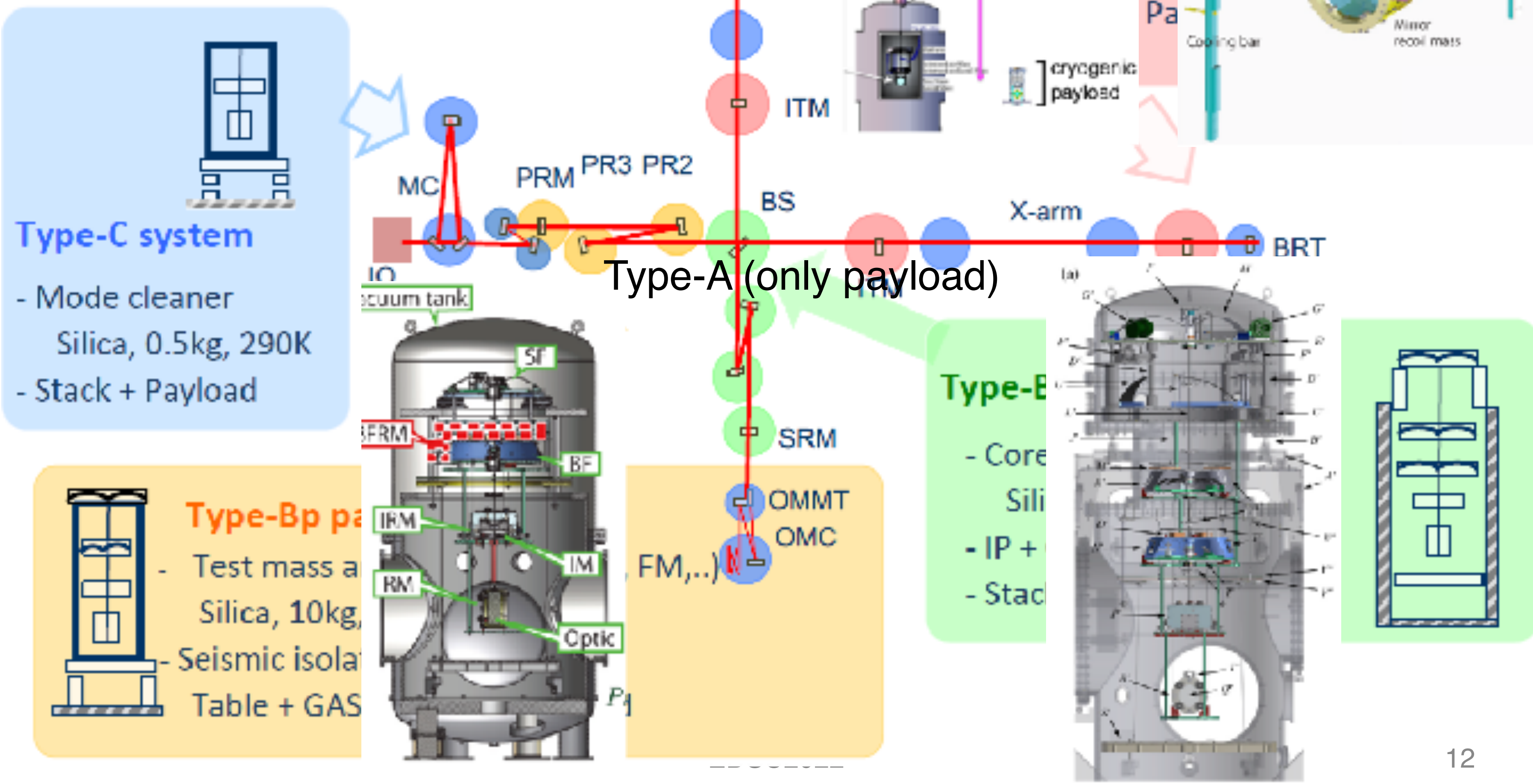


Suspensions

bKAGRA configuration

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

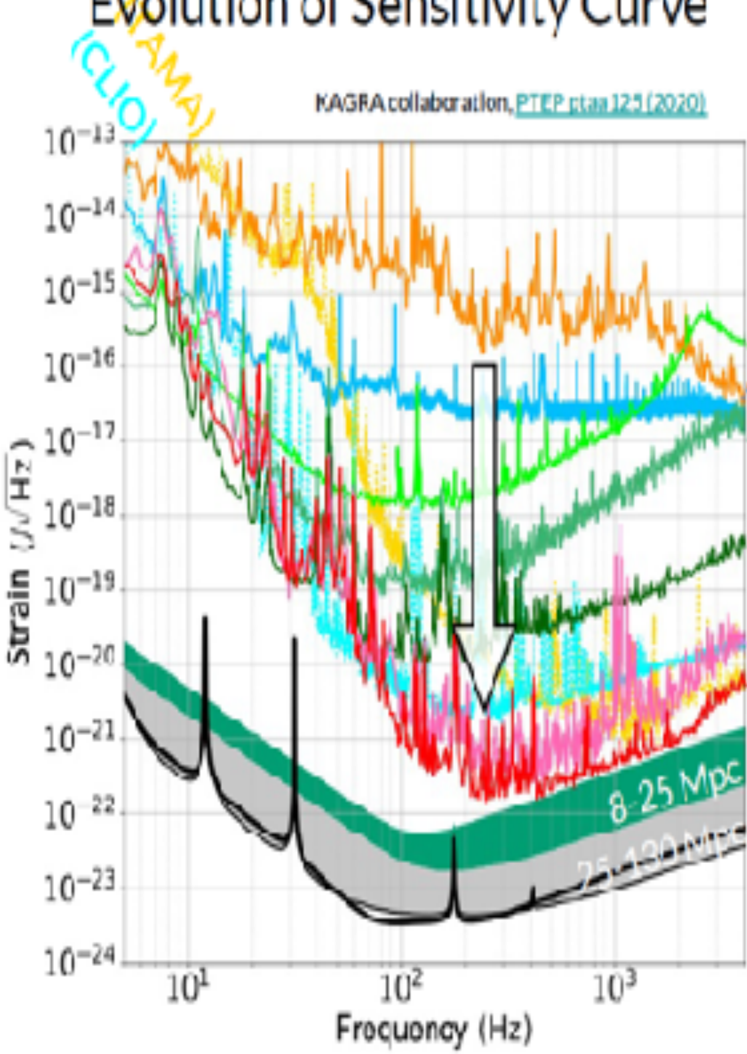




History of KAGRA

Evolution of Sensitivity Curve

T. Sawada, JGW-G2214421-v7

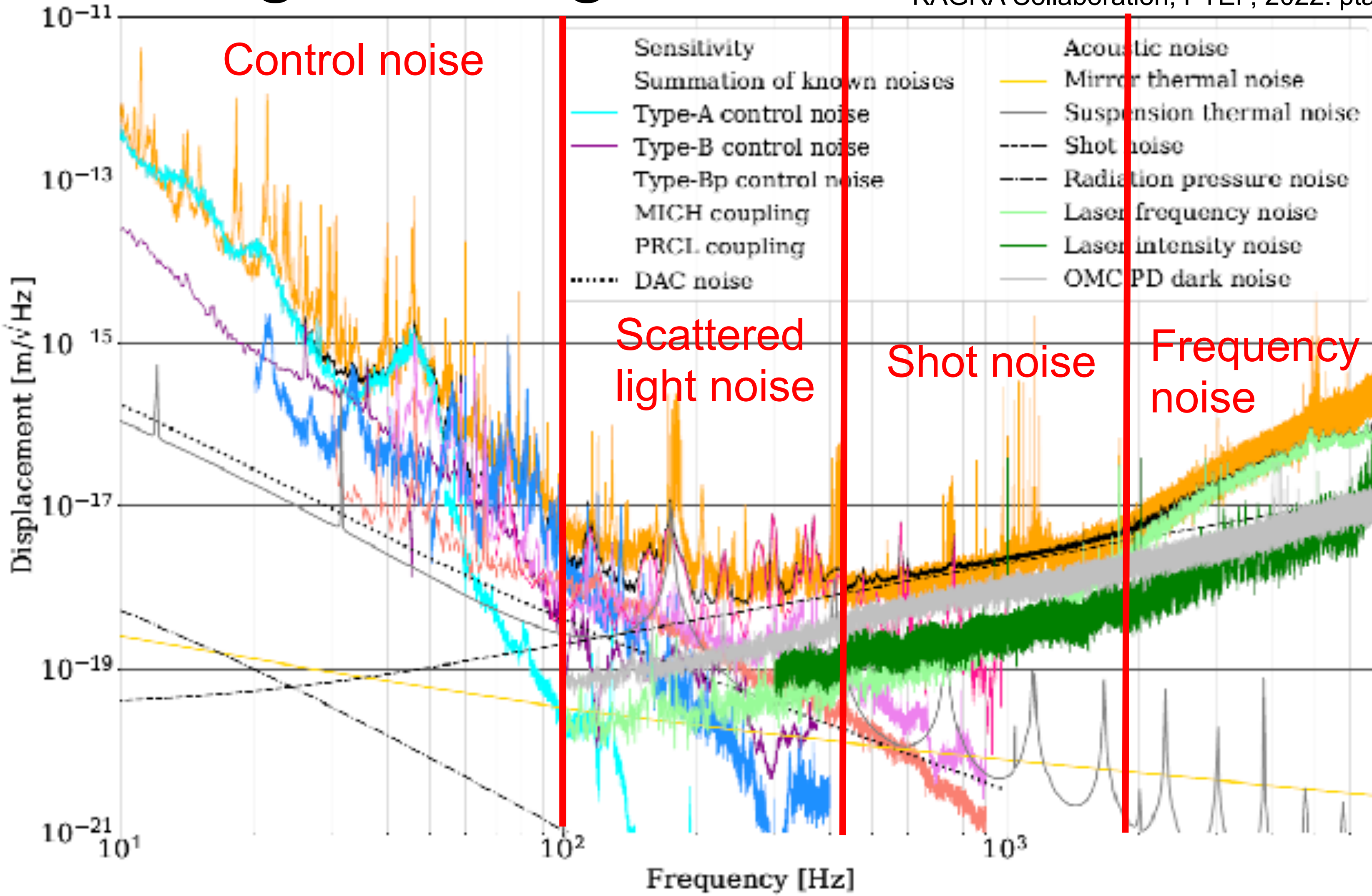


2010 Funded by MEXT Japan
2012 Started Construction
2016 Test Operation @ room temp. (iKAGRA)
2018 Cryogenic Test Operation (bKAGRA)
2019/8 FPMI
2019/10 Joined Research MoA with LIGO-Virgo
2019/11 FPMI
2019/12 FPMI
2020/2 PRFPMI
2020/3 PRFPMI
2020/3 Joined O3 PRFPMI @ room temp.
2020/4 Observation O3GK

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

Noise budget during O3GK

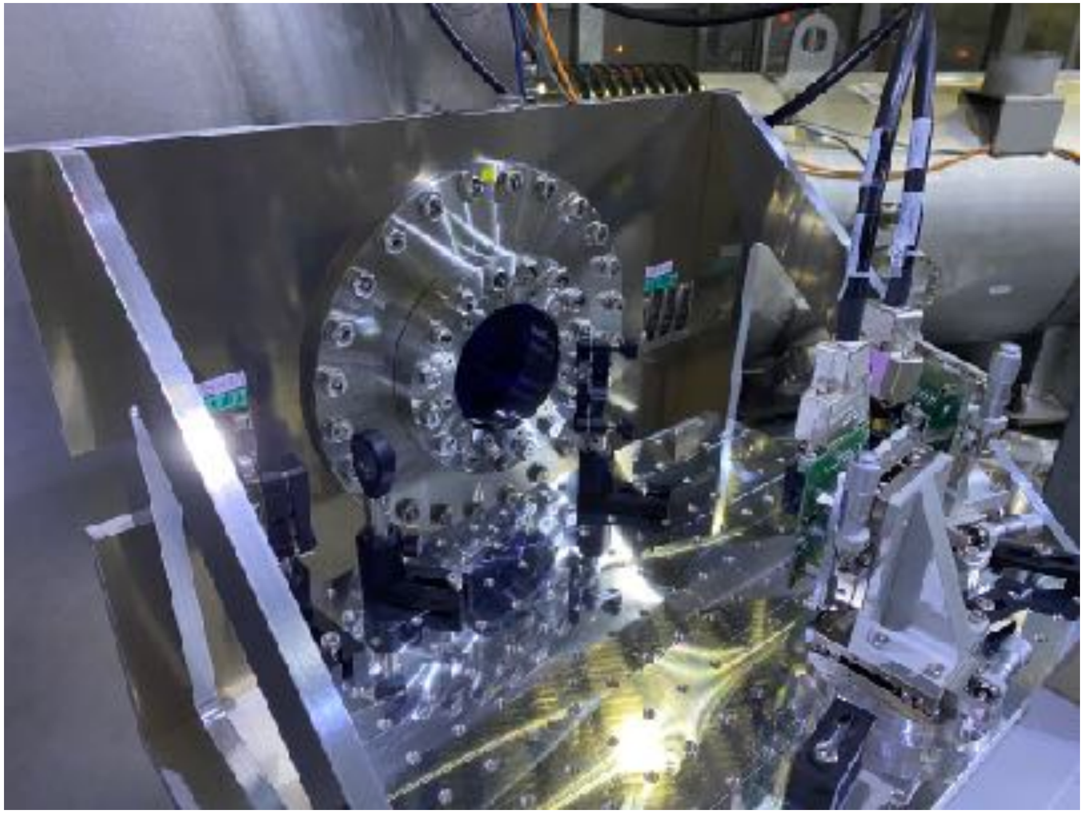
KAGRA Collaboration, PTEP, 2022. ptac093



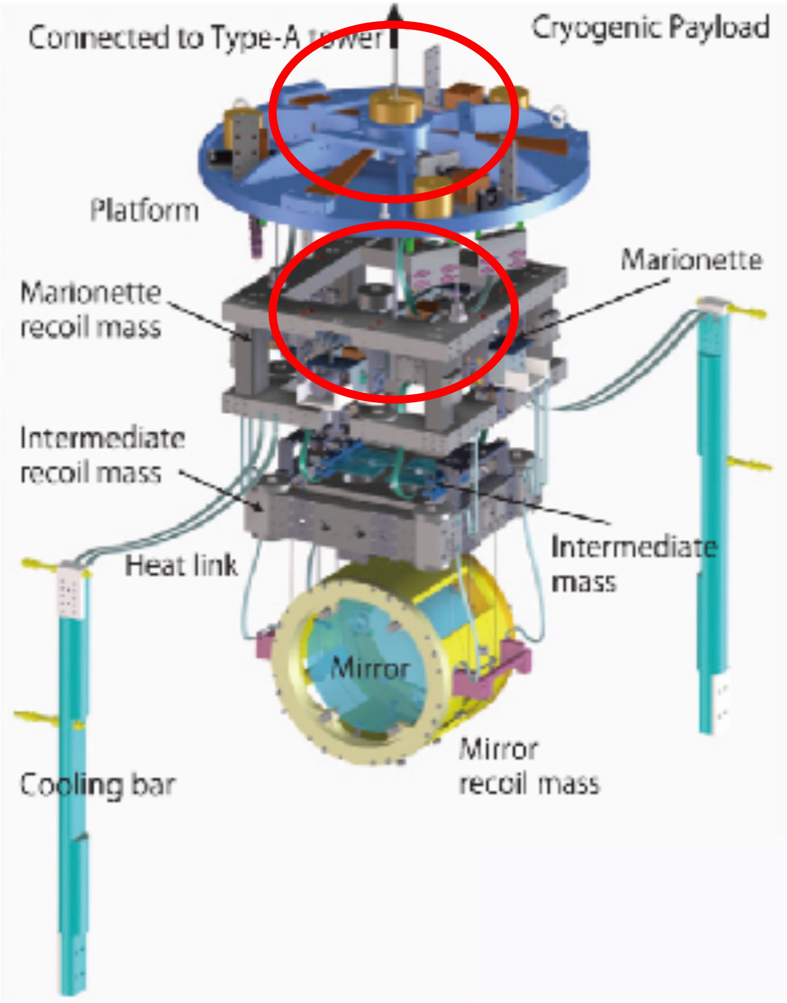
We identified dominant noise sources in all observation band

Suspension update for low frequency

Added new optical levers for better angular sensing.



T. Yokozawa, JGW-G2214400-v3

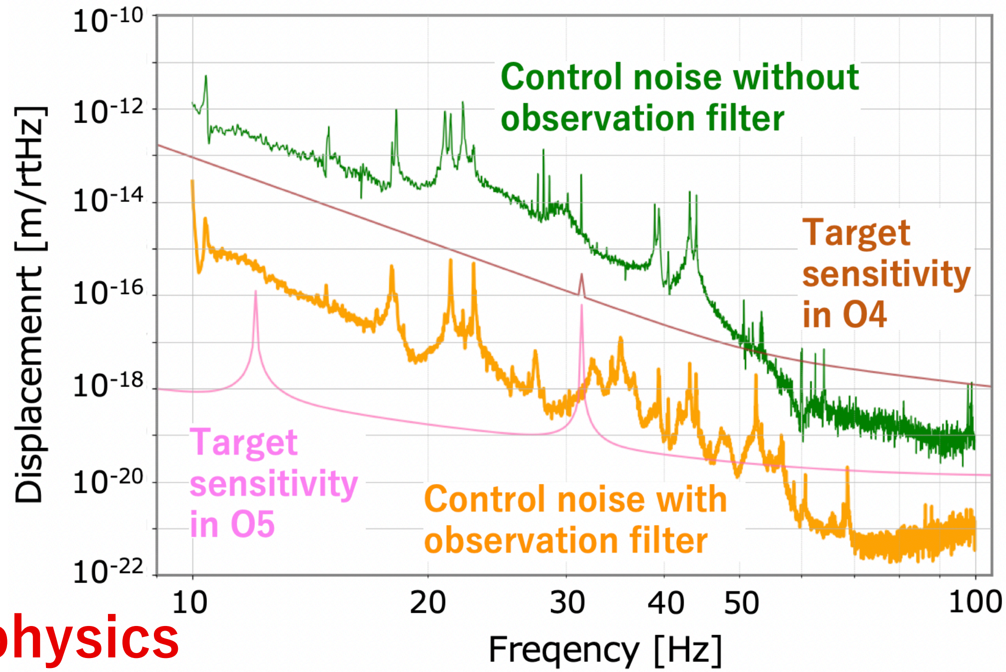


Conclusion and Future Work

Conclusion

With my newly designed control, the control noise was reduced by 2~3 orders of magnitude while maintaining stable operation of the interferometer for a long time

Target sensitivity for KAGRA's next observation is cleared (at low frequency)



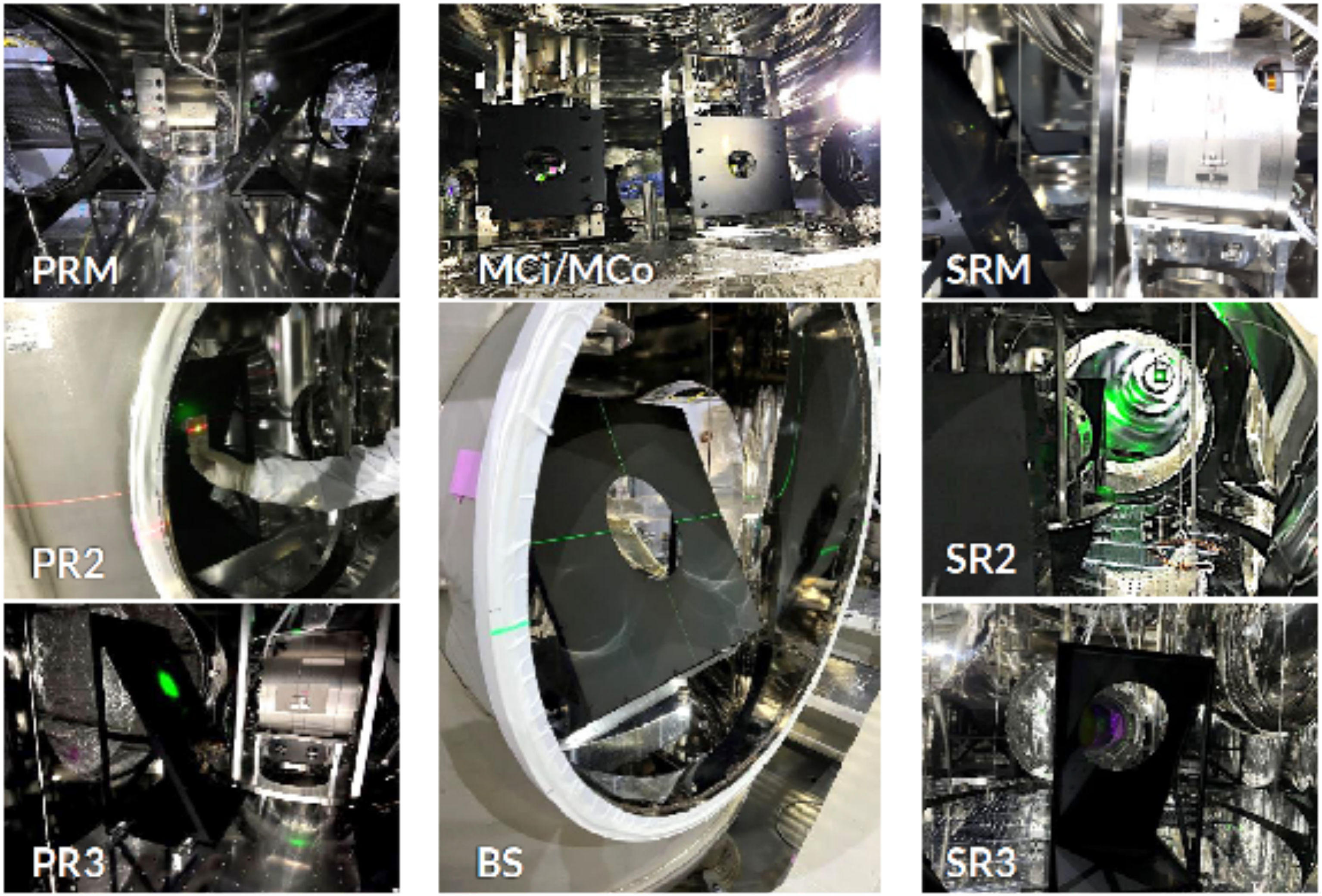
Future Work

Developing a new control method and reducing the control noise to achieve the final target sensitivity of KAGRA → **Contribution to GW physics**

M. Tamaki, JGW-G2314804-v4

Baffle installation for middle frequency

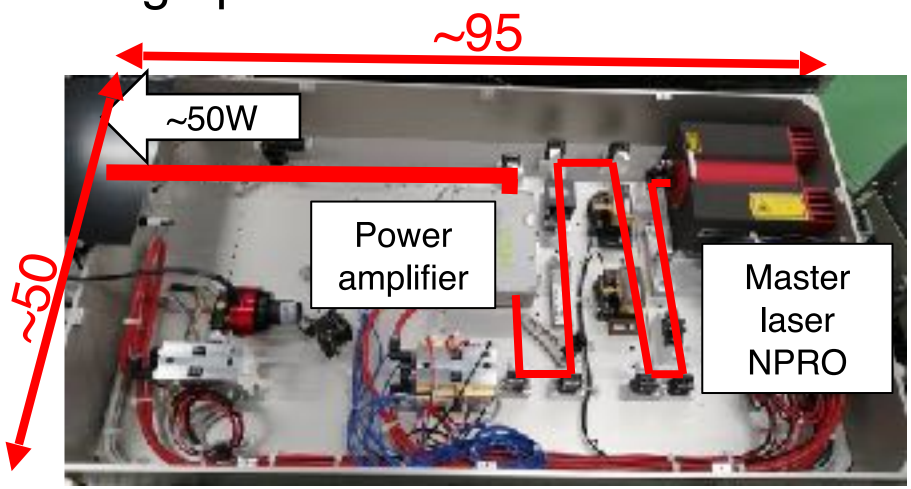
Installed many baffles around central area mirrors



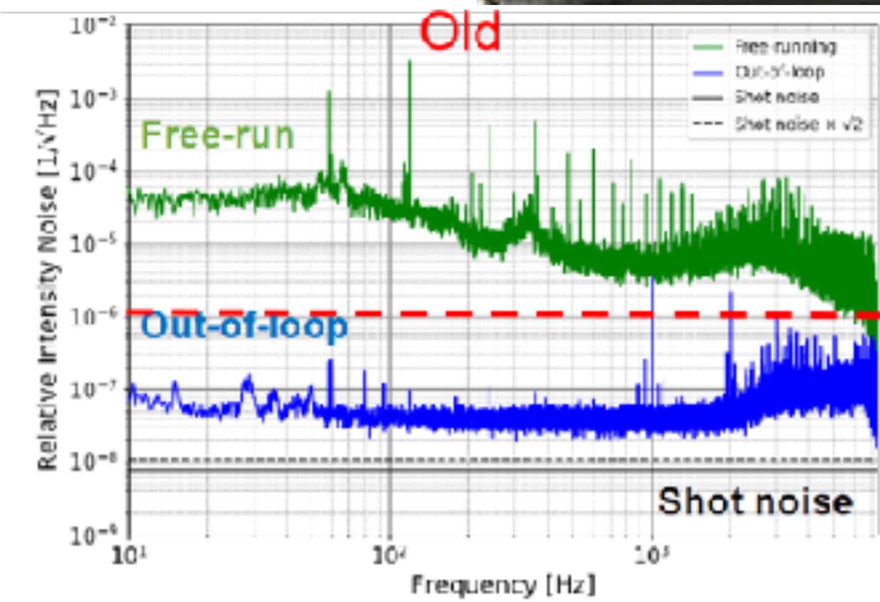
T. Sawada, JGW-G2214421-v7

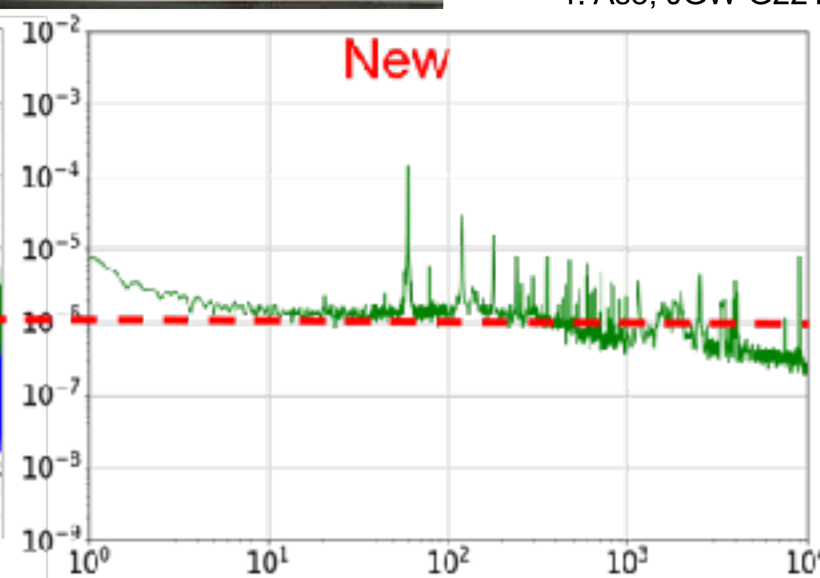
High power laser for high frequencies

Installed new high power laser with better intensity noise.



Y. Aso, JGW-G2214025-v2



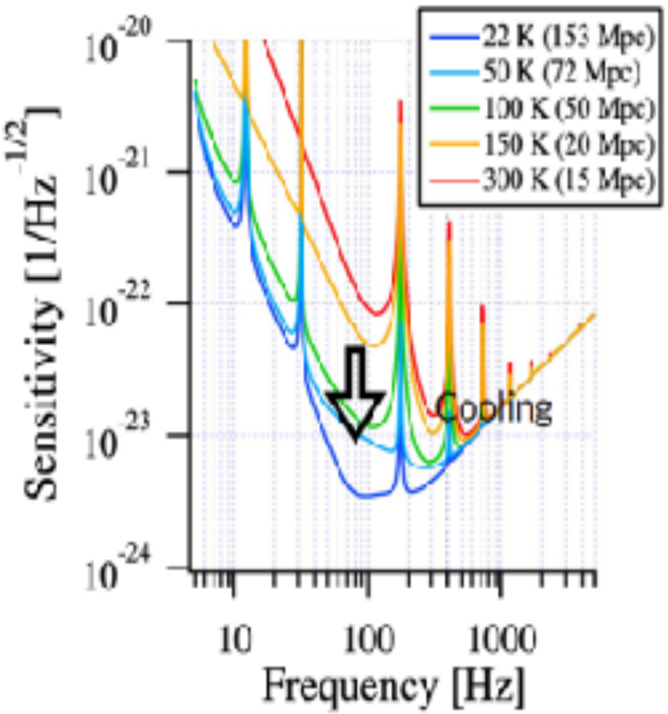


Updates of vacuum and cryogenics

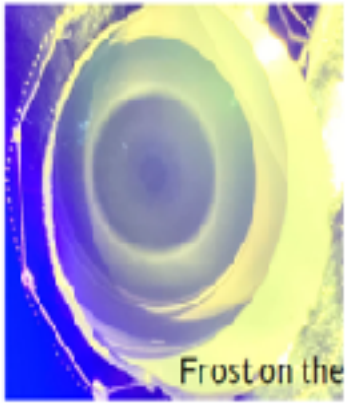
Achievement of cryogenic mirrors are important for better sensitivity.

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

KAGRA collaboration, PTEP ptaa125 (2020)



Problems occurred in the preparations for O3

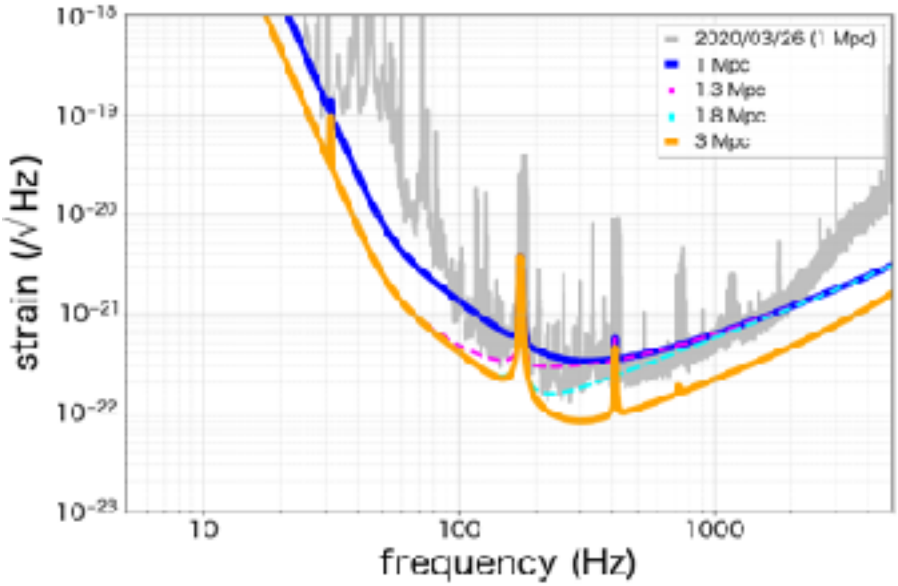


- Additional vacuum pumps
  - 12 more ion-pumps
  - 10 more turbo molecular pumps
- Better vacuum
- Avoid molecular adsorption on mirrors during cooling
- Defrosting heaters

T. Sawada, JGW-G2214421-v7

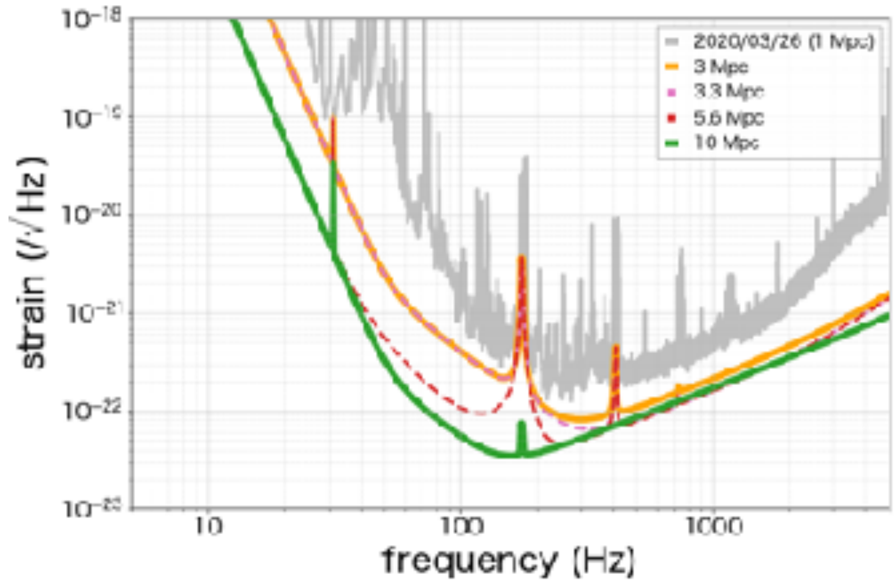
Expected sensitivity toward O4

O4a

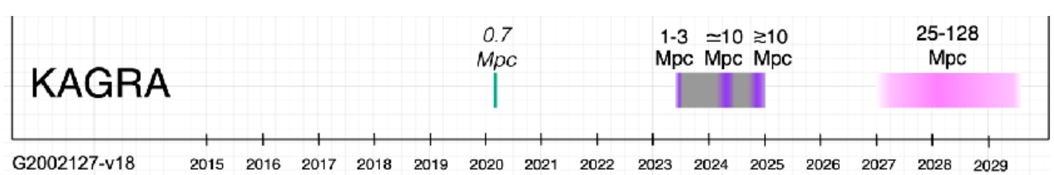


O4b

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.



KAGRA関係共同利用研究

	研究課題	査定額
G1	大型低温重力波望遠鏡に関する研究 (XII)	¥300,000
G3	高性能極低温鏡制御系の開発	¥500,000
G4	大型低温重力波望遠鏡(KAGRA)の低温懸架系の研究	¥200,000
G5	KAGRA実験に向けた伝導冷却の方法の高度化	¥300,000
G6	KAGRAにおけるレーザー強度安定化のためのR&D	¥400,000
G7	重力波望遠鏡KAGRAの測定感度向上 に資する雑音低減および極微小散乱光計測技術の開発III	¥450,000
G9	KAGRAにおける環境由来のノイズ削減に関する研究	¥200,000
G10	KAGRA検出器における注入試験による環境雑音評価手法の研究	¥150,000
G11	機械学習・深層学習を用いたノイズ 特徴の分析と干渉計診断への応用 (II)	¥350,000
G12	重力波検出の信頼性向上のための突発性雑音データ解析システムの構築	¥200,000
G13	重力波望遠鏡における電磁波散乱・ 伝搬シミュレーション X	¥100,000
G14	高性能サファイア鏡懸架系の開発	¥250,000
G15	KAGRAの制御と自動運転	¥300,000
G16	KAGRAデータ転送・保管系の構築 (8)	¥400,000
G17	KAGRAデータを低遅延国際重力波探 索網へ組み込むための共同研究推進(2)	¥200,000
G18	重力波探索のための望遠鏡診断システムの構築(II)	¥250,000
G19	KAGRAを用いたモデル化されていない突発性重力波探査	¥200,000
G22	KAGRA望遠鏡の高感度化のための雑 音源同定ツール開発	¥200,000
G23	熱雑音を用いた新たな重力波望遠鏡 の較正手段の開発	¥200,000
全１９課題		¥5,150,000

Published papers in this Year

- KAGRA Collaboration First joint observation by the underground gravitational-wave detector, KAGRA with GEO600
- Unsupervised learning architecture for classifying the transient noise of interferometric gravitational-wave detectors
- Performance of the KAGRA detector during the first joint observation with GEO 600 (O3GK)
- Response of the underground environment of the KAGRA observatory against the air pressure disturbance from the Tonga volcano eruption on January 15th, 2022
- A laser interferometer accelerometer for vibration sensitive cryogenic experiments
- Vibration analysis of KAGRA cryostat at cryogenic temperature
- Input optics systems of the KAGRA detector during O3GK
- Estimation of Newtonian noise from KAGRA cooling system
-

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 on 24 May 2023.
- KAGRA will join O4 with better sensitivity than O3GK
- Commissioning is ongoing.