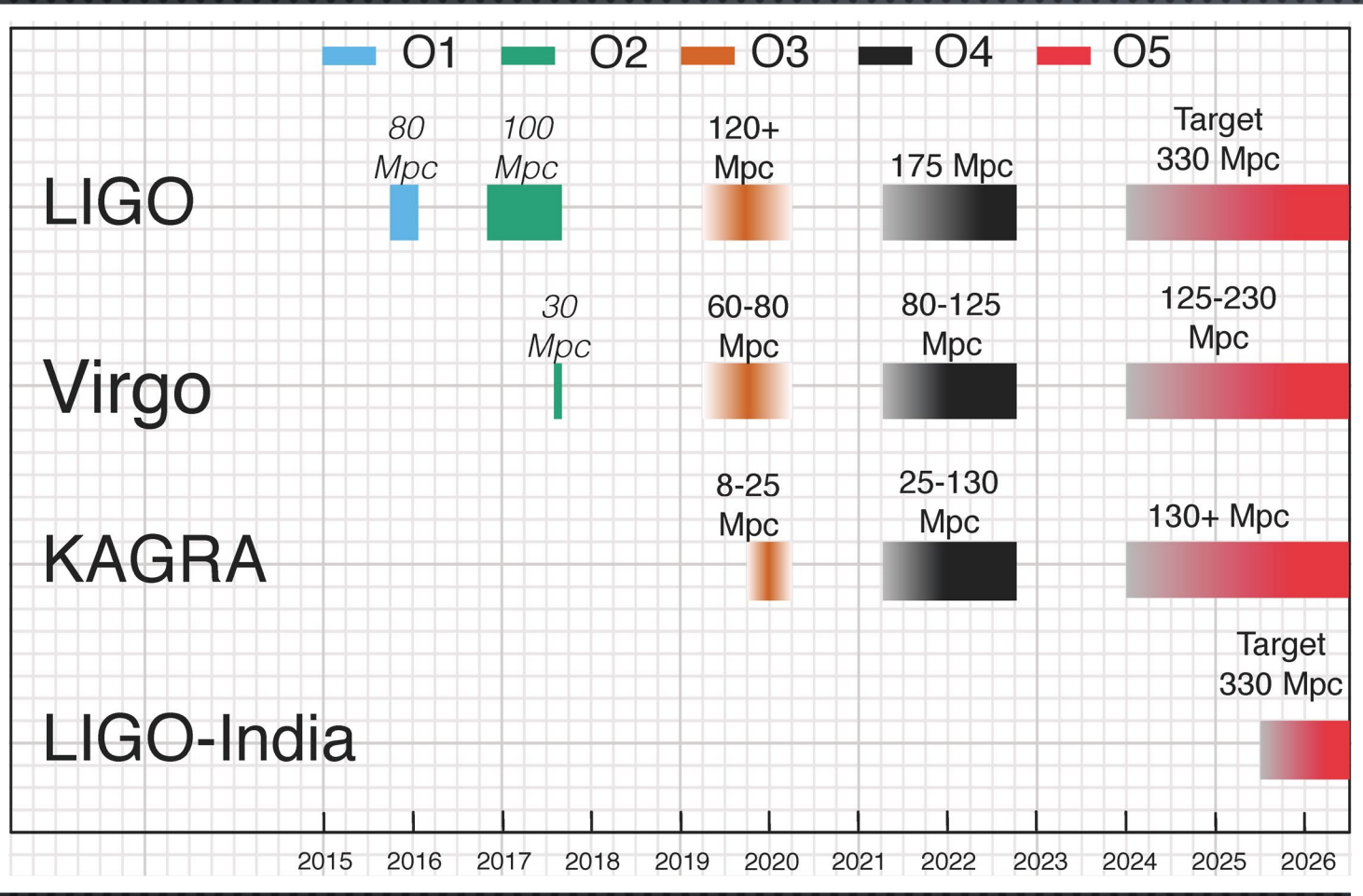
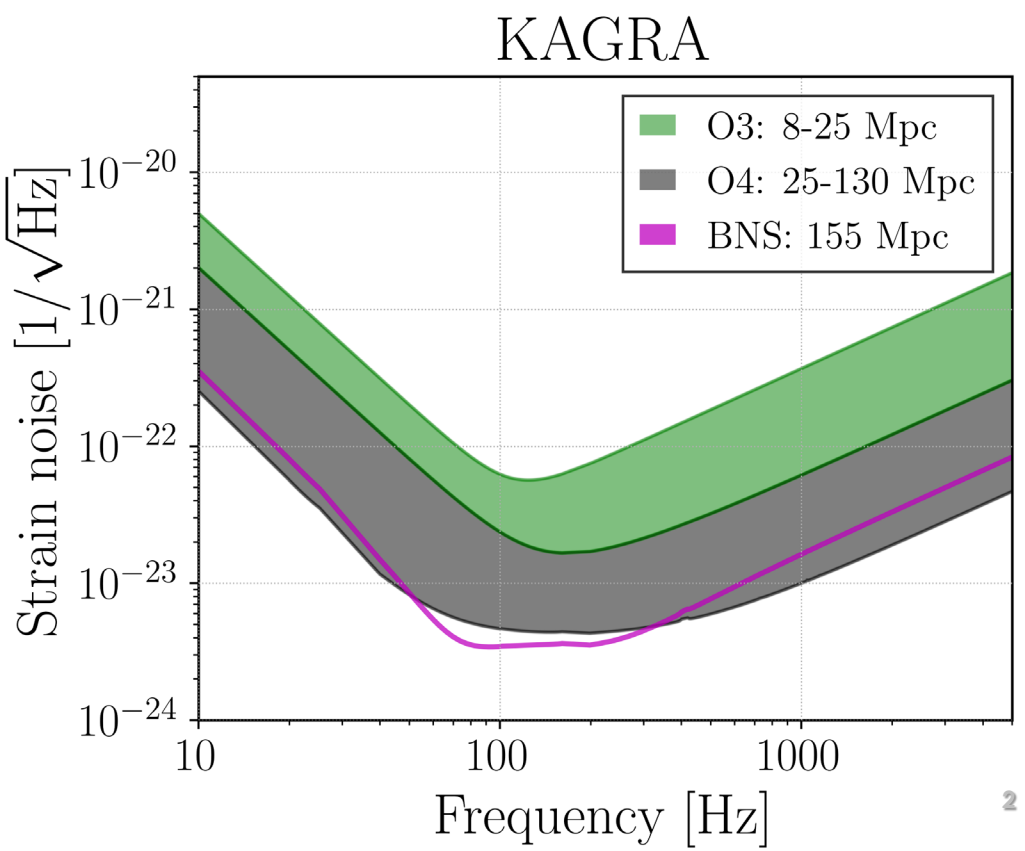
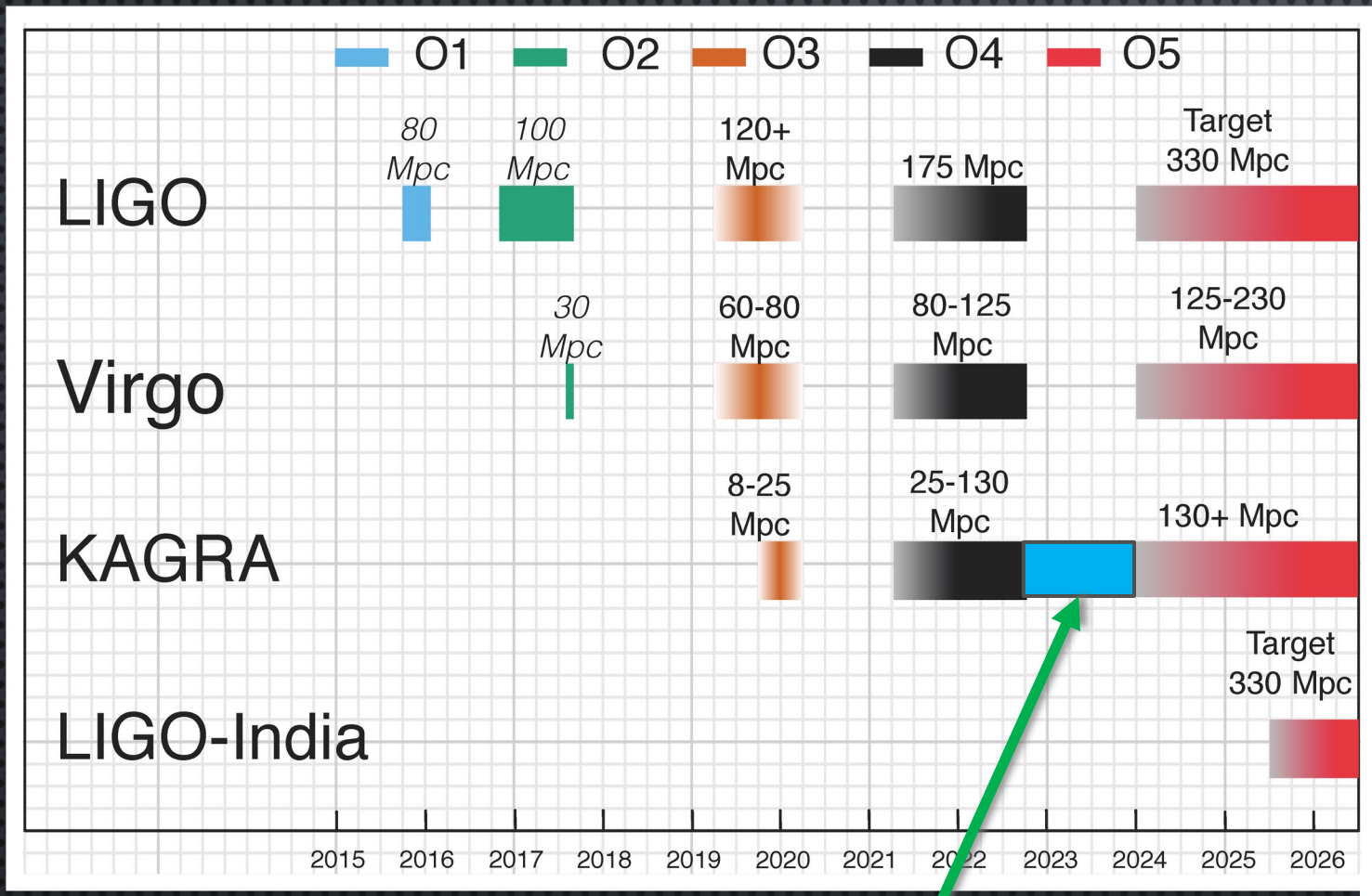
# KAGRA Upgrade Plan

2019/5/9@LIGO PAC

National Astronomical Observatory of Japan
Yoichi Aso
On Behalf of The KAGRA Collaboration


O1
O2
O3
O4
O5
LIGO
80 Mpc
100 Mpc
120+ Mpc
175 Mpc
Target 330 Mpc
Virgo
30 Mpc
60-80 Mpc
80-125 Mpc
125-230 Mpc
KAGRA
8-25 Mpc
25-130 Mpc
130+ Mpc
LIGO-India
Target 330 Mpc
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026


KAGRA
O3: 8-25 Mpc
O4: 25-130 Mpc
BNS: 155 Mpc
Strain noise $[1/\sqrt{\text{Hz}}]$
$10^{-20}$
$10^{-21}$
$10^{-22}$
$10^{-23}$
$10^{-24}$
10
100
1000
Frequency [Hz]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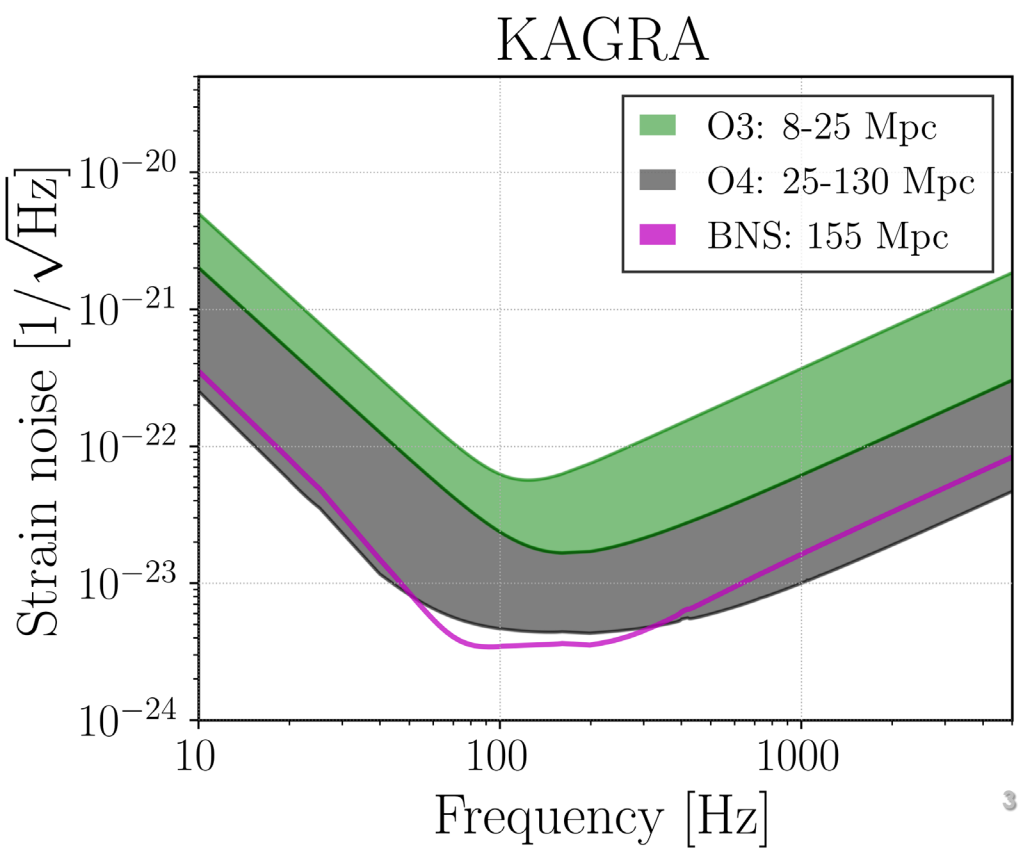
Upgrade !?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Frequency [Hz]

# Historical Background

- No official platform to discuss KAGRA upgrade until recently
  - PI wanted people to focus on the realization of the baseline KAGRA
    - Limited resource
    - Need to fulfill the commitments to the funding agency
- Unofficial activities for upgrade still existed

# Unofficial technical studies of KAGRA upgrade

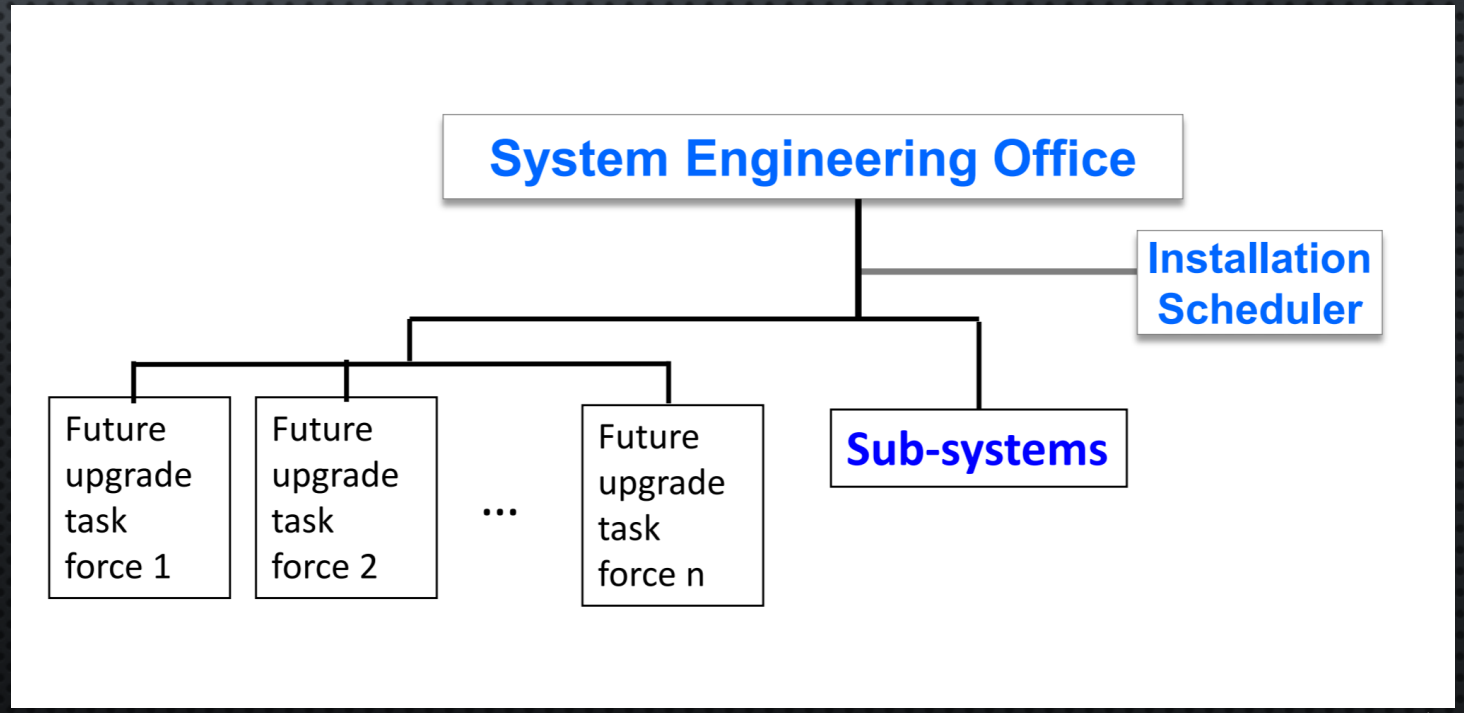
- Proposal for the discussion: 2017 March F2F meeting
  - JGW-G1706398
- Discussions at KAGRA International Workshops
- Presentations at Japan Physics Society meetings
- Satellite meeting:  2017 Dec. 4th @TITECH
http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/LCGT/Meeting/f2f/2017Dec/Sateite
- KAGRA upgrade document tree
  - JGW-E1809314

# Kajita-san's presentation@F2F in August 2018

- JGW-G1808915
- Officially presented PI's vision on the future upgrade scheme of KAGRA
- Recognized the need for starting the discussion of upgrade

## Funding scheme:

Each group proposing an upgrade item should obtain grant by themselves

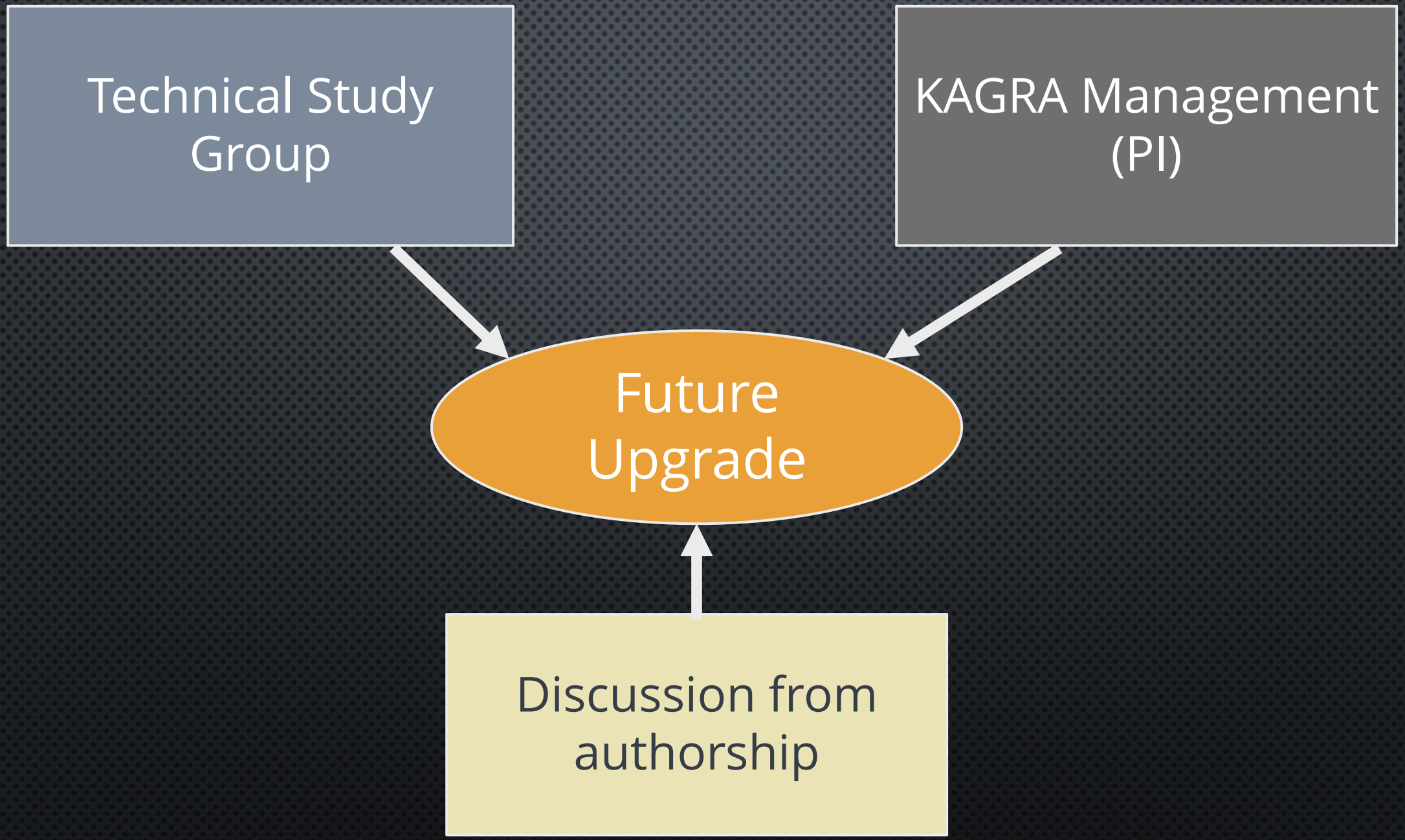


# Discussion from another viewpoint: Authorship

- KAGRA wants to join O3: Authorship becomes a serious matter
- What are counted as contributions to warrant authorship ?
  - KAGRA authorship policy JGW-M1503490
  - "Contributions for research and development activities authorized by the project are also included"
- Problem: No procedure to authorize an R&D by the project existed

- We need to establish a process to recognize important R&Ds for KAGRA upgrade
- To assess the importance of an R&D, we need a reference frame
  - A white paper on KAGRA upgrade plan

- This issue was raised at the F2F in May 2018


Technical Study Group
KAGRA Management (PI)
Future Upgrade
Discussion from authorship

Technical Study Group

KAGRA Management (PI)

Future Upgrade

# Needed to develop a unified framework

Discussion from authorship

# Proposal to set up two committees under KSC

- Future Planning Committee (FPC)
  - Manage the discussion of KAGRA future upgrade plan
  - Produce a white paper for future upgrade

- Project R&D Committee (PRDC)
  - KAGRA Project R&D is an official R&D of KAGRA to be counted towards authorship
  - PRDC manages the selection of the Project R&Ds
    - Judgement is made based on the white paper by the FPC

- Approved at the F2F meeting in Dec. 2019

FPC released the first draft of the white paper recently: JGW-M1909590

# Funding Scheme

Basic direction given by the PI

- Each group responsible for an upgrade item should obtain funding for the upgrade work
- Especially, contributions from outside Japan is important
- One example
  - Backup laser (60W) for O3 and 140W laser for O4
  - Academia Sinica (Taiwan) will procure commercial amplifiers (neoVAN-4S-HP) JGW-G1910052
  - The funding comes from Taiwan

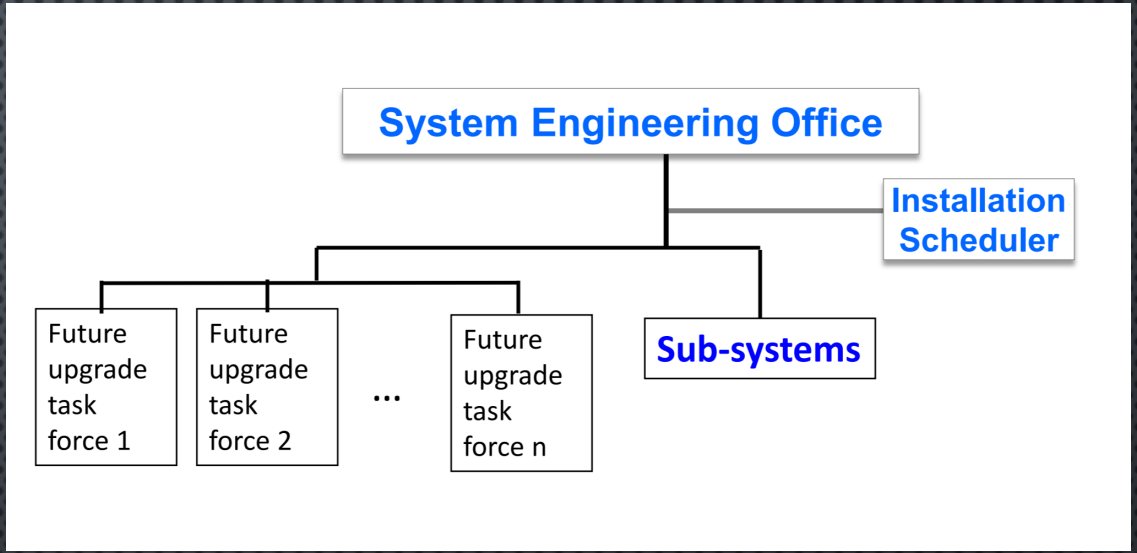
Aso's personal opinion

- KAGRA project as a whole should still seek for a large funding from MEXT
- In fact, we are applying for another Tokusui (~5MUSD)

# Organization, Management

## Basic idea given by Kajita-san

- A task force for each upgrade item
- SEO manages the overall upgrade




Aso's personal opinion

- A vast improvement in the project management is necessary for the upgrade
- Implementing standard engineering management practices is important
  - Need to hire dedicated engineers for this
- Need to find a practical compromise
  - Available resources
  - KAGRA people's mindset for the project

# Overview of the upgrade white paper

JGW-M1909590

- List up scientific targets
- List up potential technologies to be adopted for upgrade
  - Score the significance and feasibility of each technology
- List up 4 candidates for upgrade
  - Low frequency optimization (LF)
  - Heavier mirror (40kg)
  - Frequency dependent squeezing (FDsq)
  - High frequency optimization (HF)

Recommendations

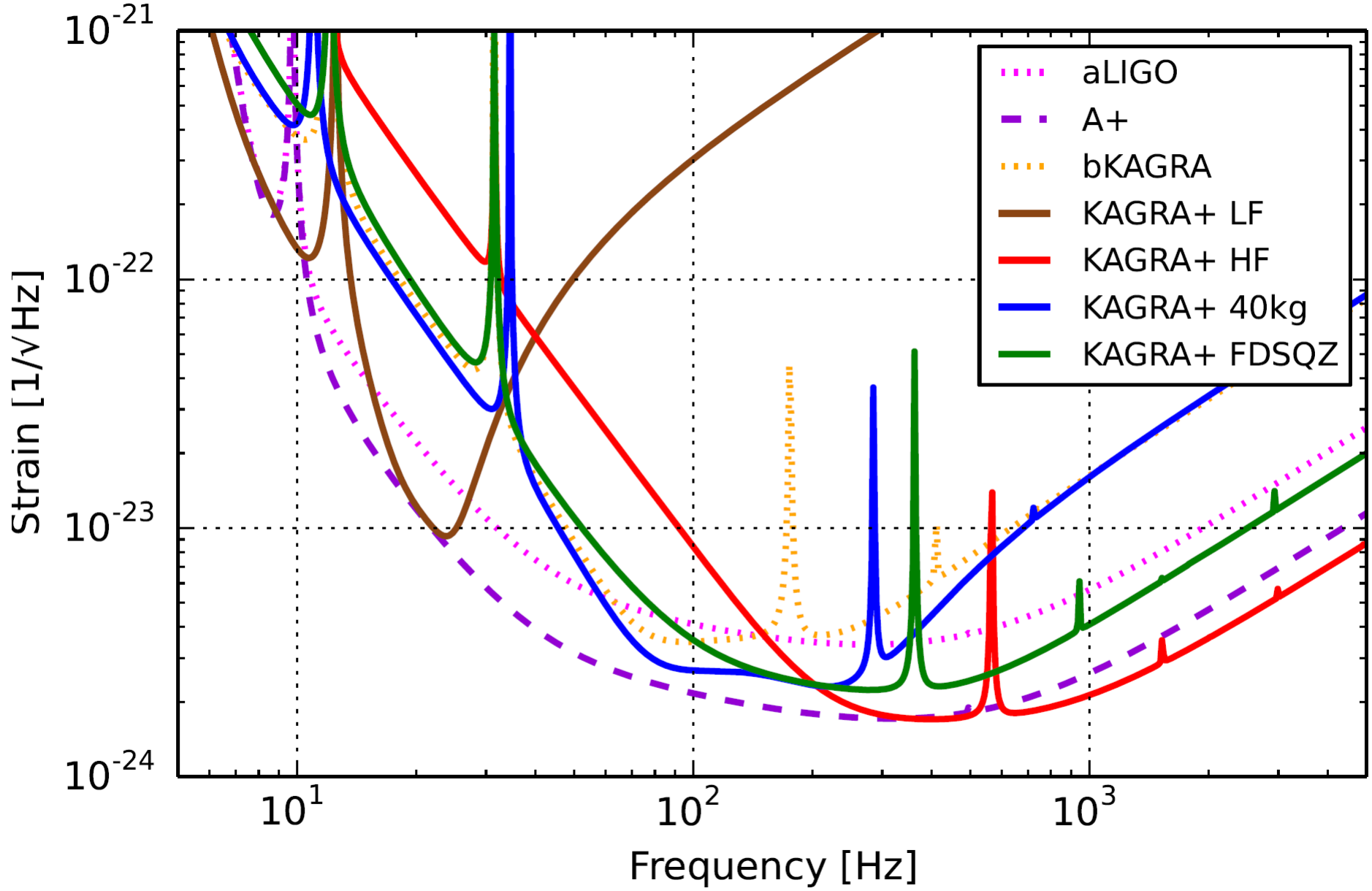
- HF & FDsq for 5 year upgrade (after O4)
- Continue R&D on LF and 40kg for longer term upgrade

# Parameters for candidate upgrade options

| | **bKAGRA** | **LF** | **HF** | **40kg** | **FDsq** |
|---|---|---|---|---|---|
| detuning angle (deg) | 3.5 | 28.5 | 0.1 | 3.5 | 0.2 |
| homodyne angle (deg) | 135.1 | 133.6 | 97.1 | 123.2 | 93.1 |
| mirror temperature (K) | 22 | 23.6 | 20.8 | 21.0 | 21.3 |
| SRM reflectivity (%) | 84.6 | 95.5 | 90.7 | 92.2 | 83.2 |
| fiber length (cm) | 35.0 | 99.8 | 20.1 | 28.6 | 23.0 |
| fiber diameter (mm) | 1.6 | 0.45 | 2.5 | 2.2 | 1.9 |
| mirror mass (kg) | 22.8 | 22.8 | 22.8 | 40 | 22.8 |
| input power at BS (W) | 673 | 4.5 | 3440 | 1500 | 1500 |
| maximum detected squeezing (dB) | 0 | 0 | 6.1 | 0 | 5.2 (FC) |

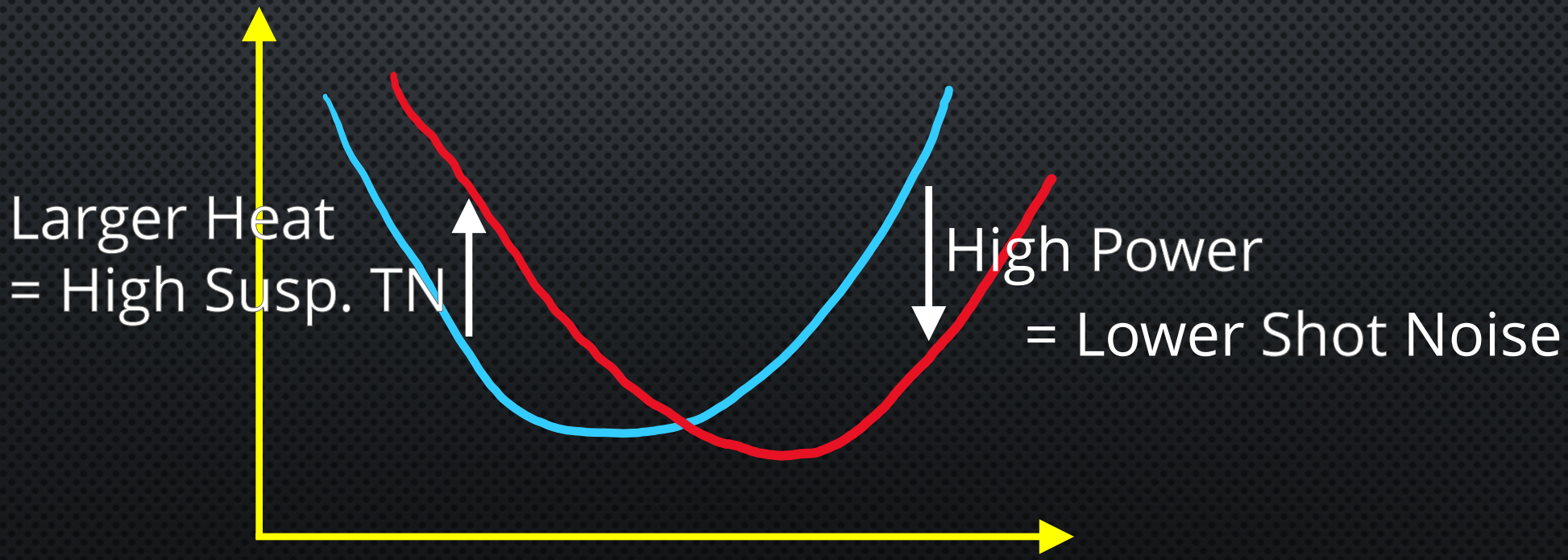
Table 25: Detector parameters for the upgrade options.

# Comparison of noise curves



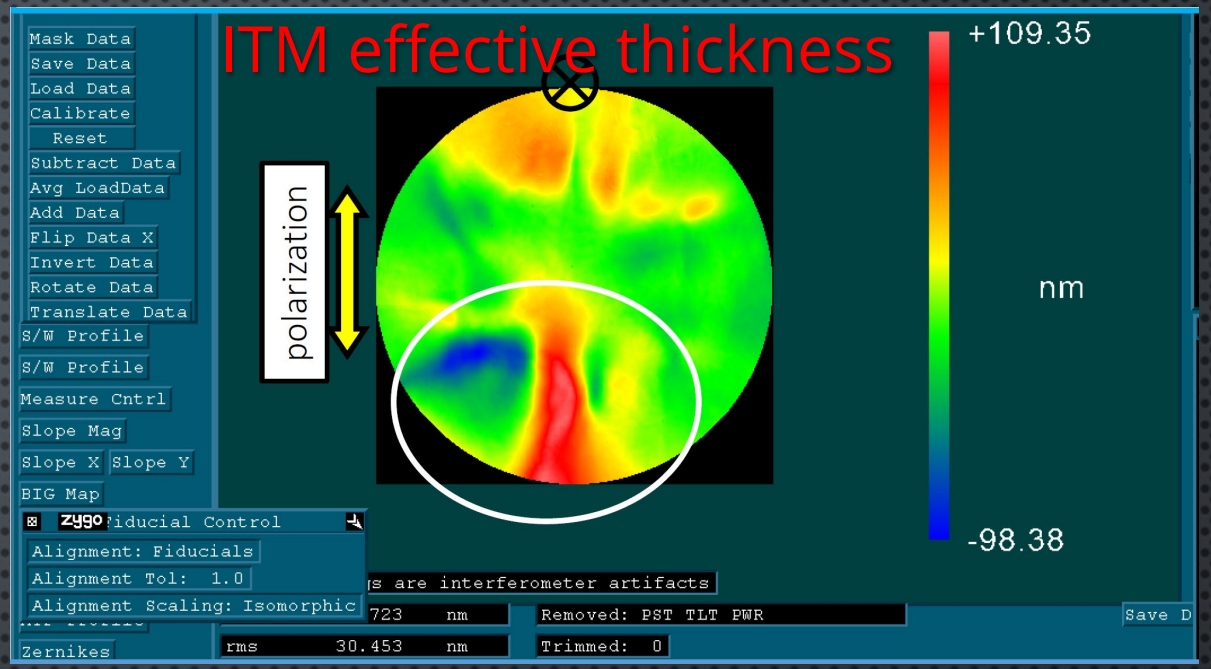
# Peculiar issues with KAGRA upgrade

- Trade-off between high power and low suspension thermal noise
  High power => Large heat in the mirror
  => Thicker sapphire fiber => Larger suspension thermal noise
- Broad band improvement is more difficult than aLIGO / aVirgo
- We need to choose between high frequency and low frequency

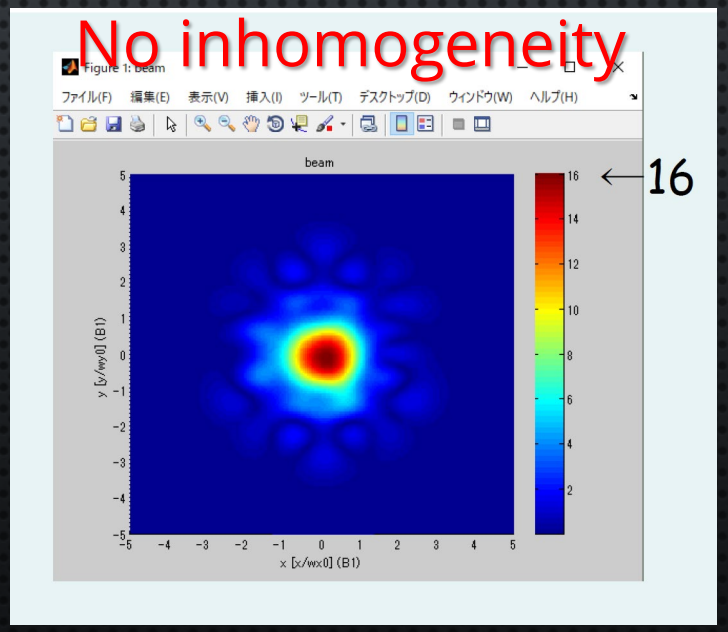


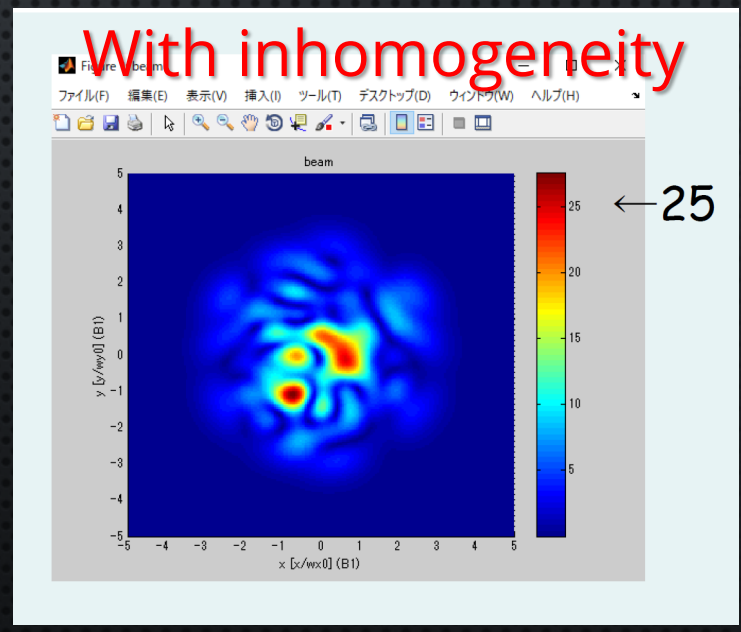
# ITM inhomogeneity risk

- Large inhomogeneity in ITM transmission phase
- Caused by the use of wrong polarization during correction polish (IBF)
- Expected increase of shot noise
- WFS signal may be distorted
- Other adverse effects may exit
- Need a strategy to make new mirrors

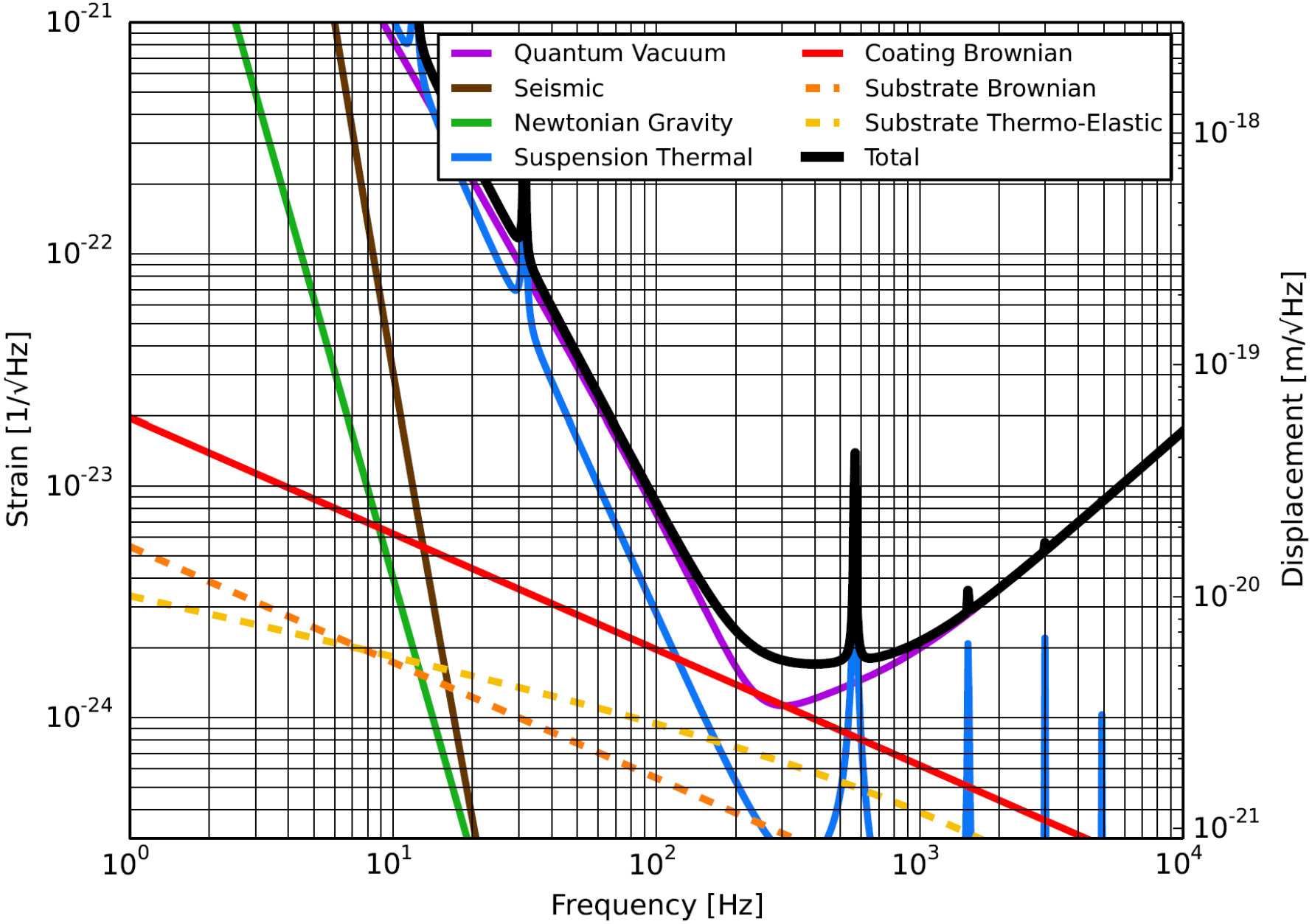



## Simulated AS port beam shape

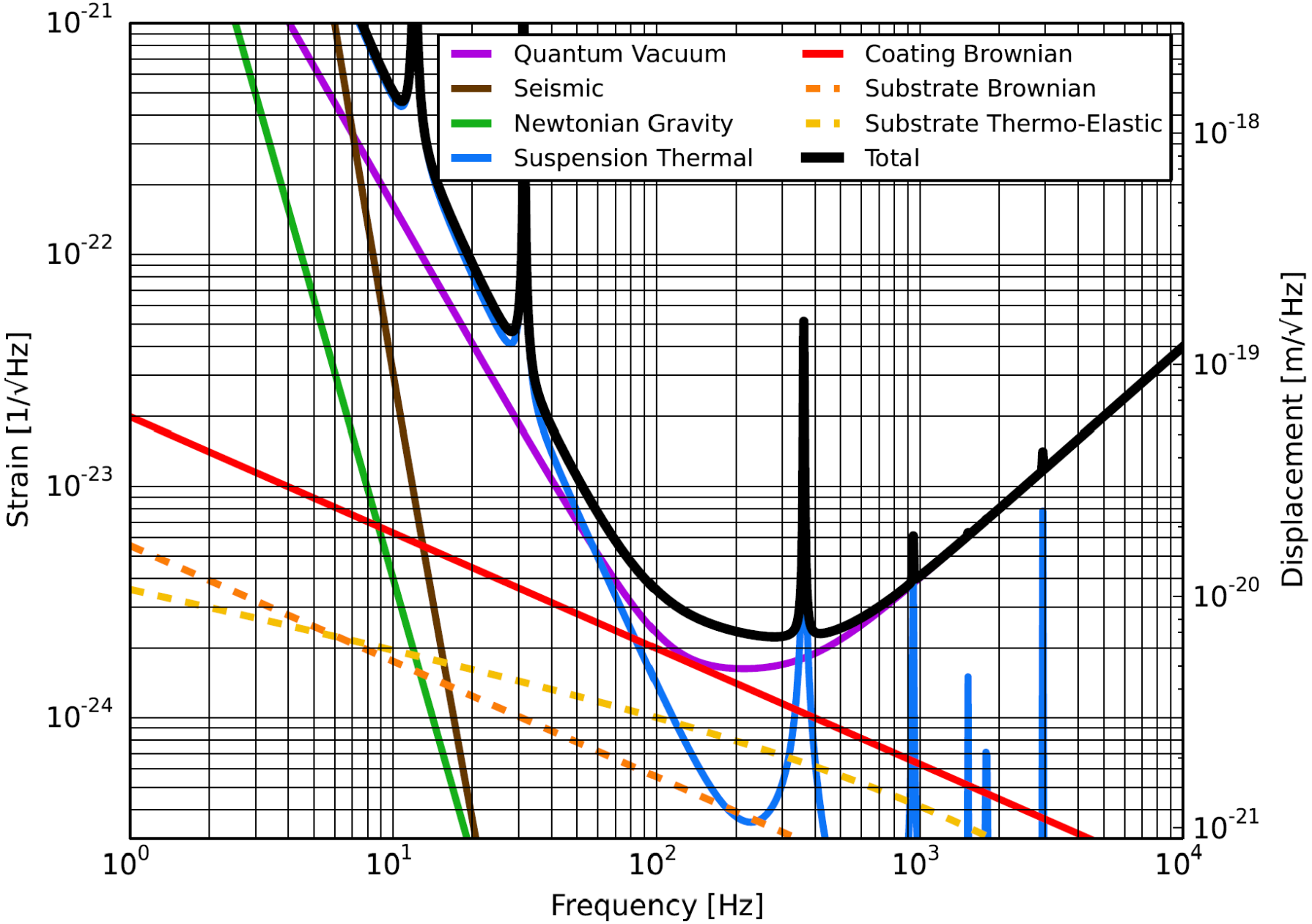


# KAGRA+ (HF)


Quantum Vacuum
Seismic
Newtonian Gravity
Suspension Thermal
Coating Brownian
Substrate Brownian
Substrate Thermo-Elastic
Total
Strain [1/√Hz]
Displacement [m/√Hz]
Frequency [Hz]
10^-21
10^-22
10^-23
10^-24
10^-18
10^-19
10^-20
10^-21
10^0
10^1
10^2
10^3
10^4

# KAGRA+ (FDSQZ)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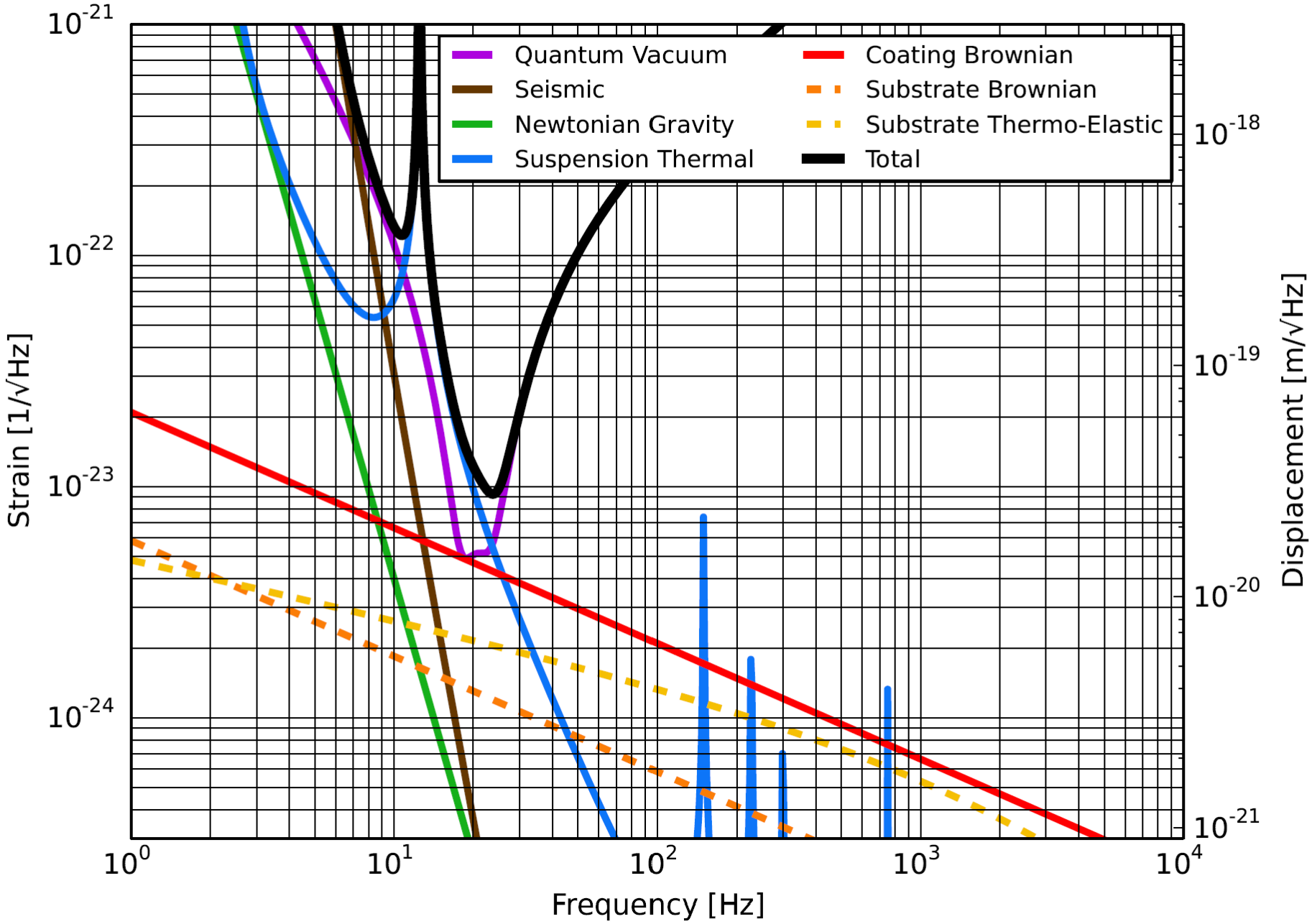
10^1
10^2
10^3
10^4

# KAGRA+ (LF)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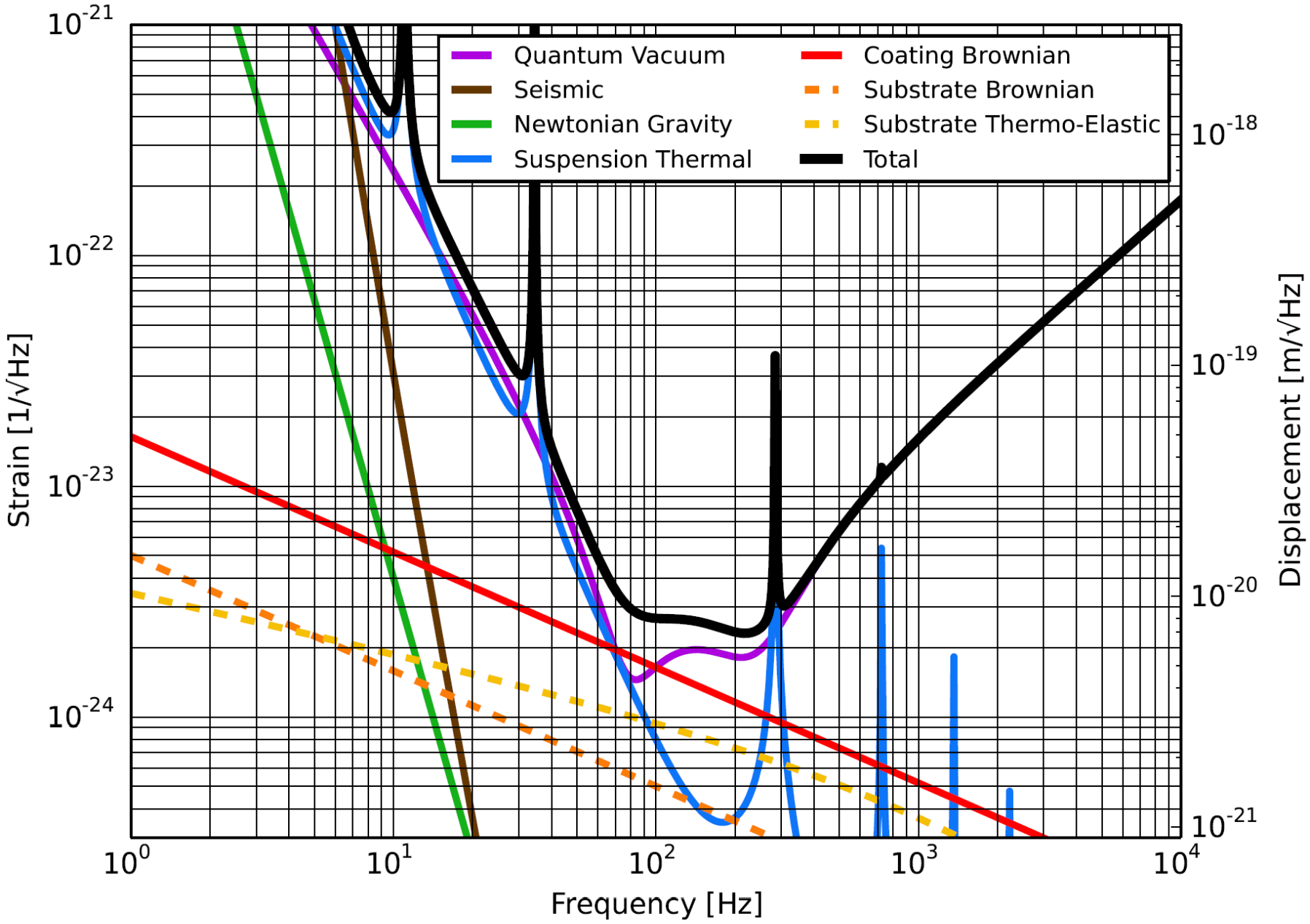
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