Future Plans for KAGRA Facility

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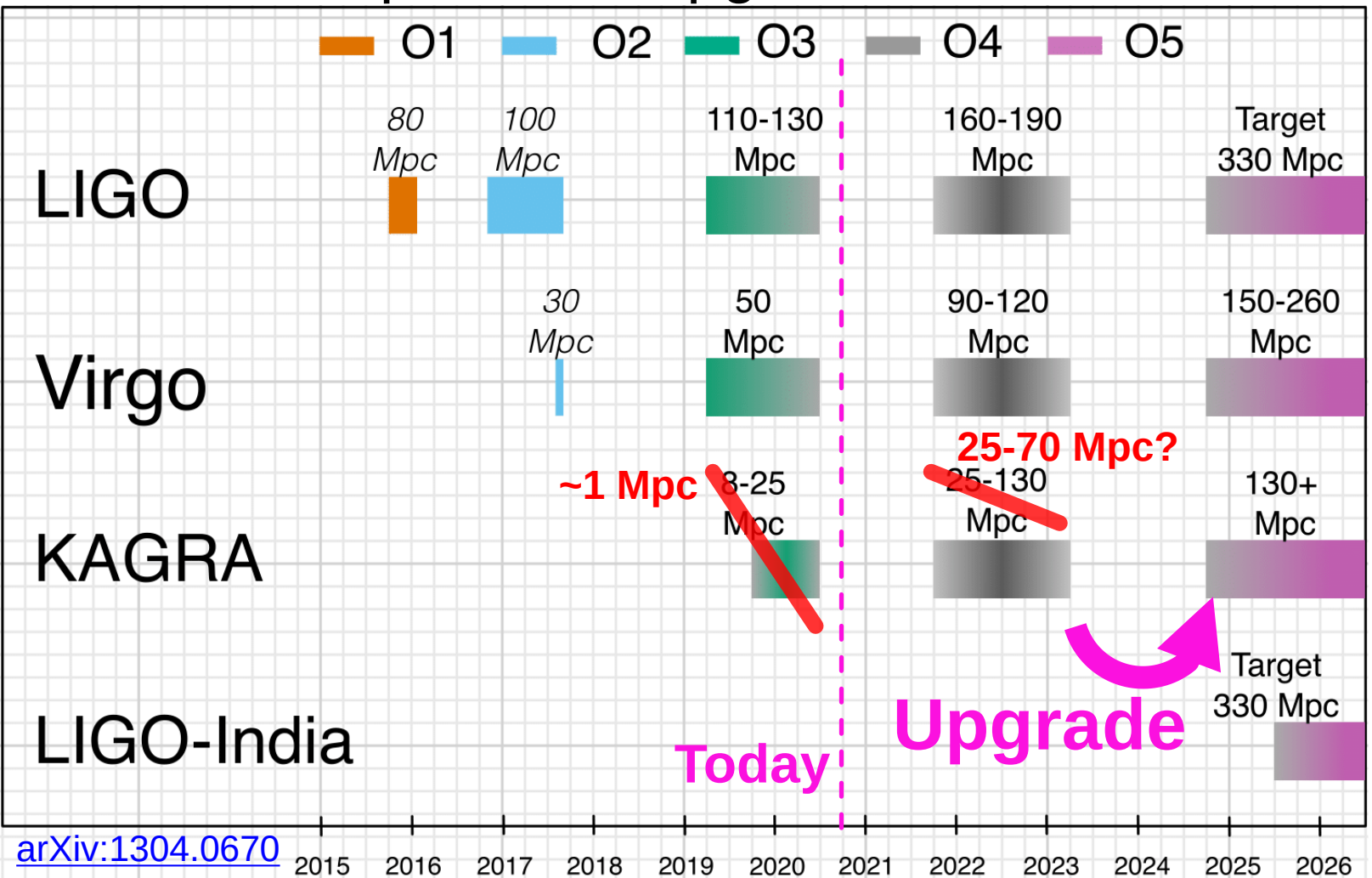
for the KAGRA Collaboration

Observing Scenario

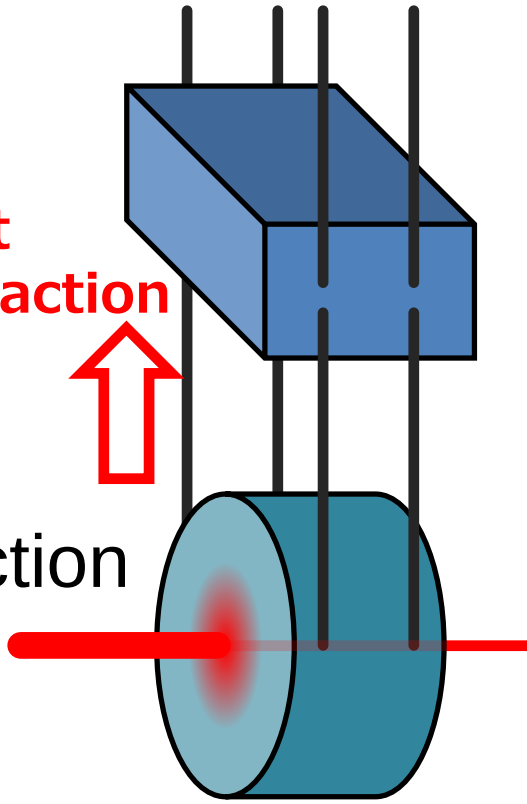
- Achieving the designed sensitivity is already tough
- But the plan is to upgrade KAGRA for O5



arXiv:1304.0670

Upgrading KAGRA is Tricky

- Only cryogenic interferometer among 2G
- Not trivial to do both
  - high power (400 kW on mirror)
  - low temperature (20 K)



- Sapphire fibers to extract heat

thinner and longer
for suspension thermal noise reduction

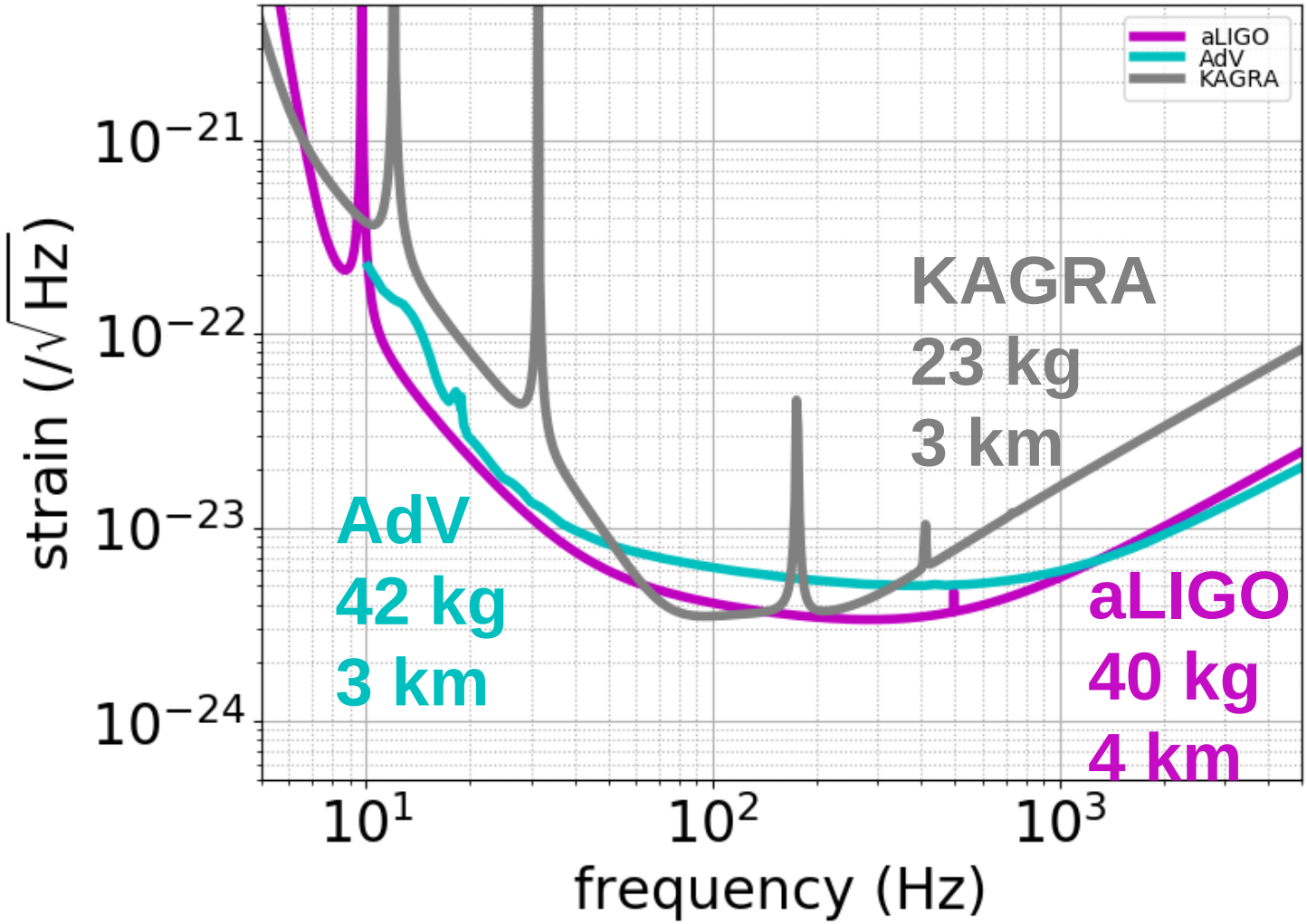
Dilemma

thicker and shorter
for heat extraction

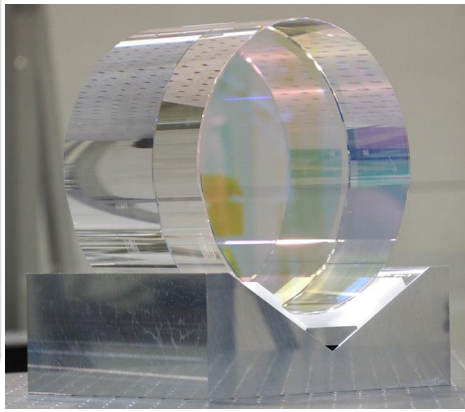
Y. Michimura+, PRD **97**, 122003 (2018)

2G Sensitivity Comparison

- Not good at low freq. because of thick and short fiber (35 cm, φ1.6 mm) to extract heat, and lower mass



23 kg was the largest available sapphire mirror



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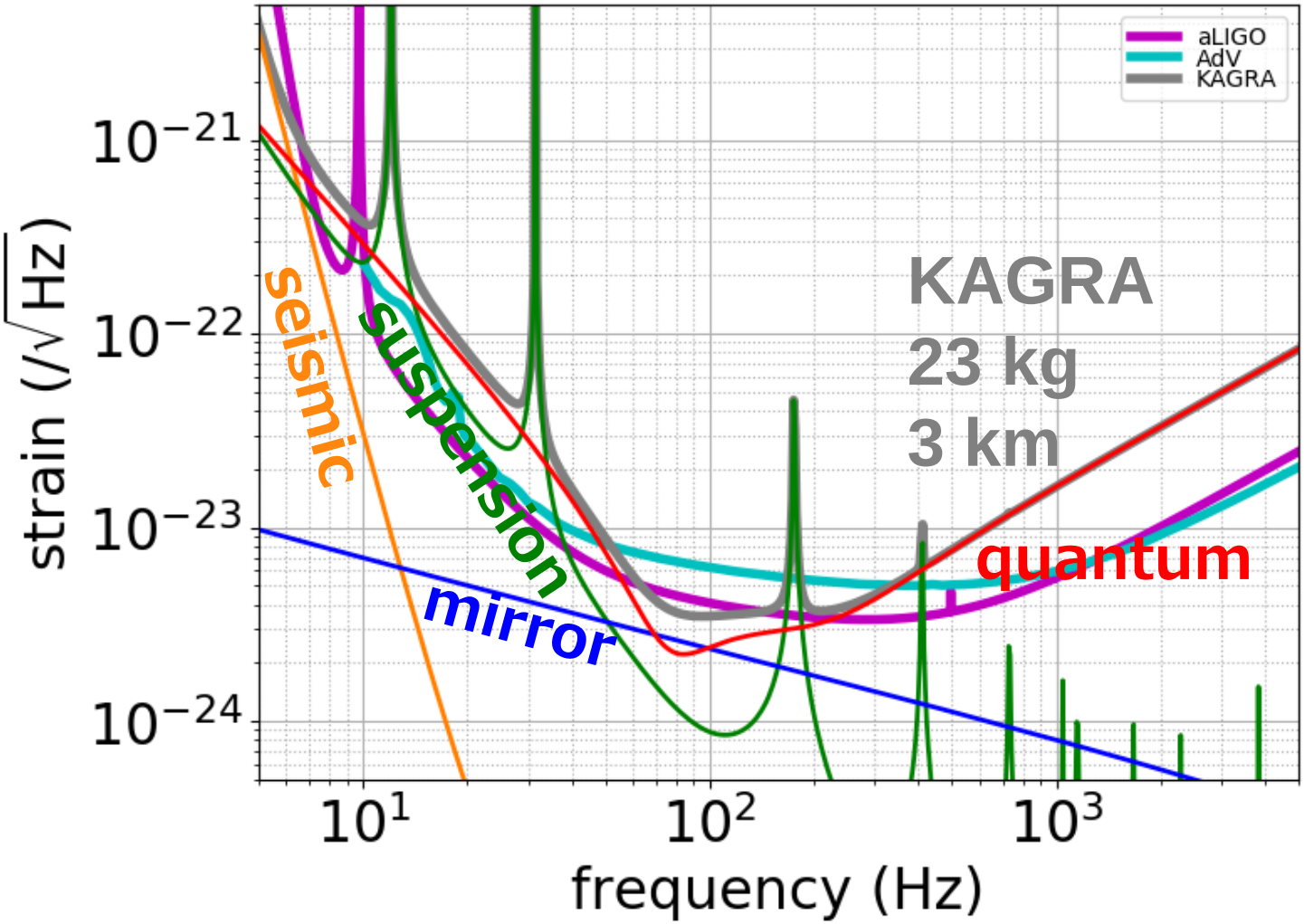

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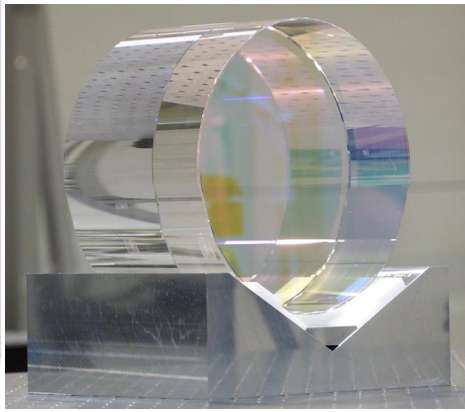
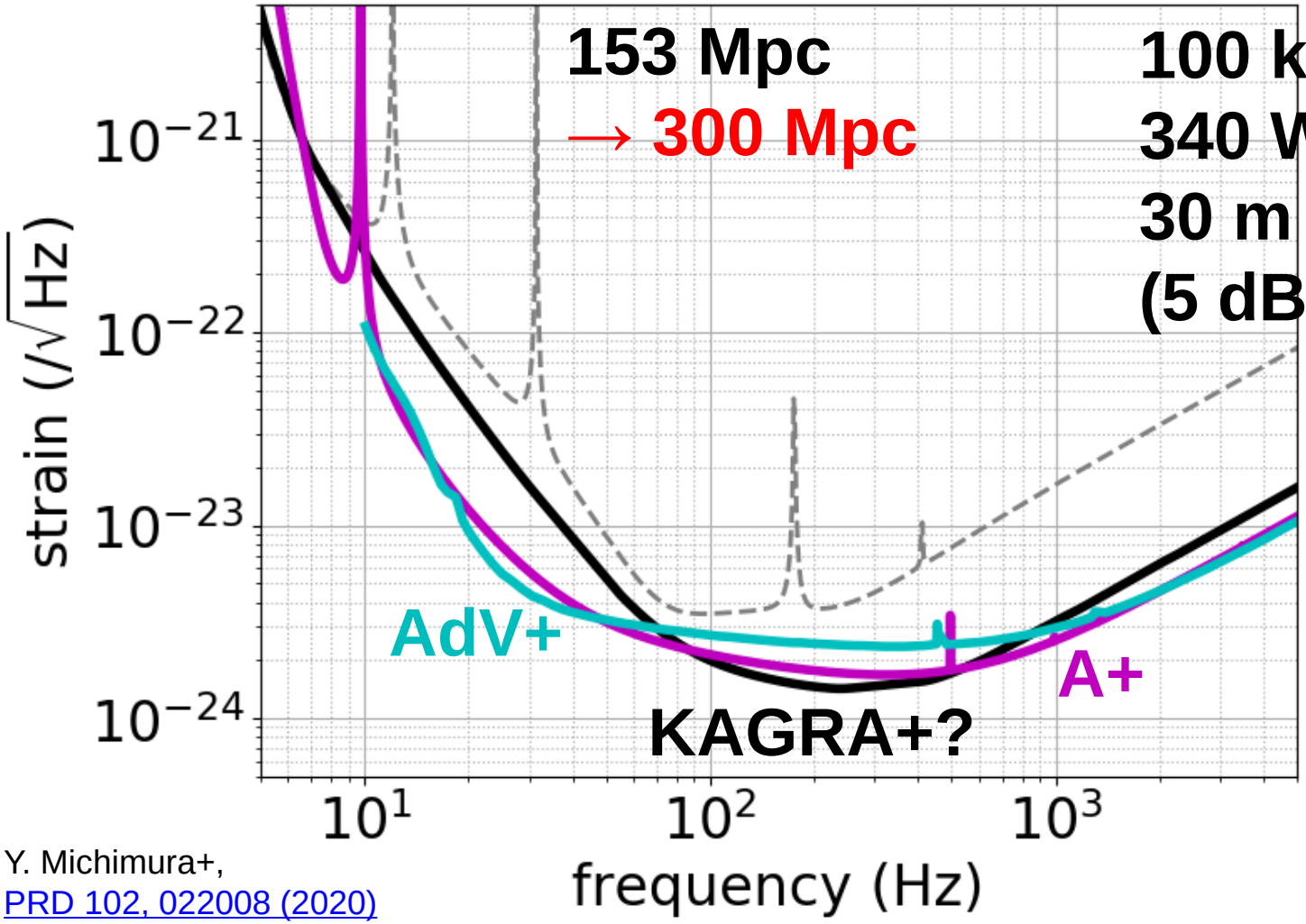


Upgrade Plan for KAGRA?

- Twofold broadband sensitivity improvement possible with multiple upgrade technology



NOTE:
No coating improvements assumed

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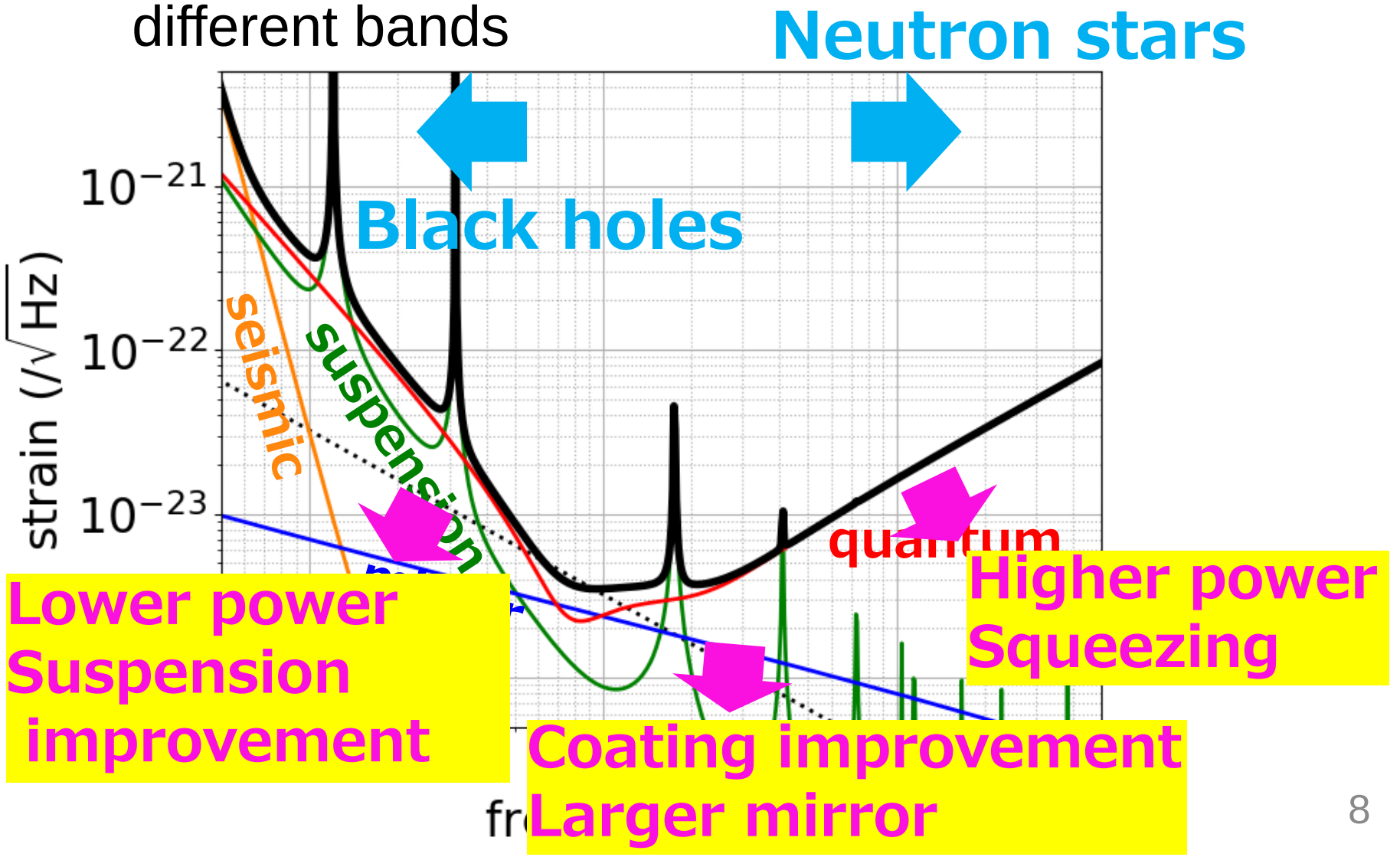
PRD 102, 022008 (2020)

Technologies for the Upgrade

- Broadband improvement is favorable so that we don't miss any science
- Combination of multiple technologies necessary to do broadband improvement
  - Larger sapphire test mass and its suspension
  - Higher power laser
  - Frequency dependent squeezing
- Upgrade should be done in steps
- What to implement first depends on scientific scenarios and technical feasibility

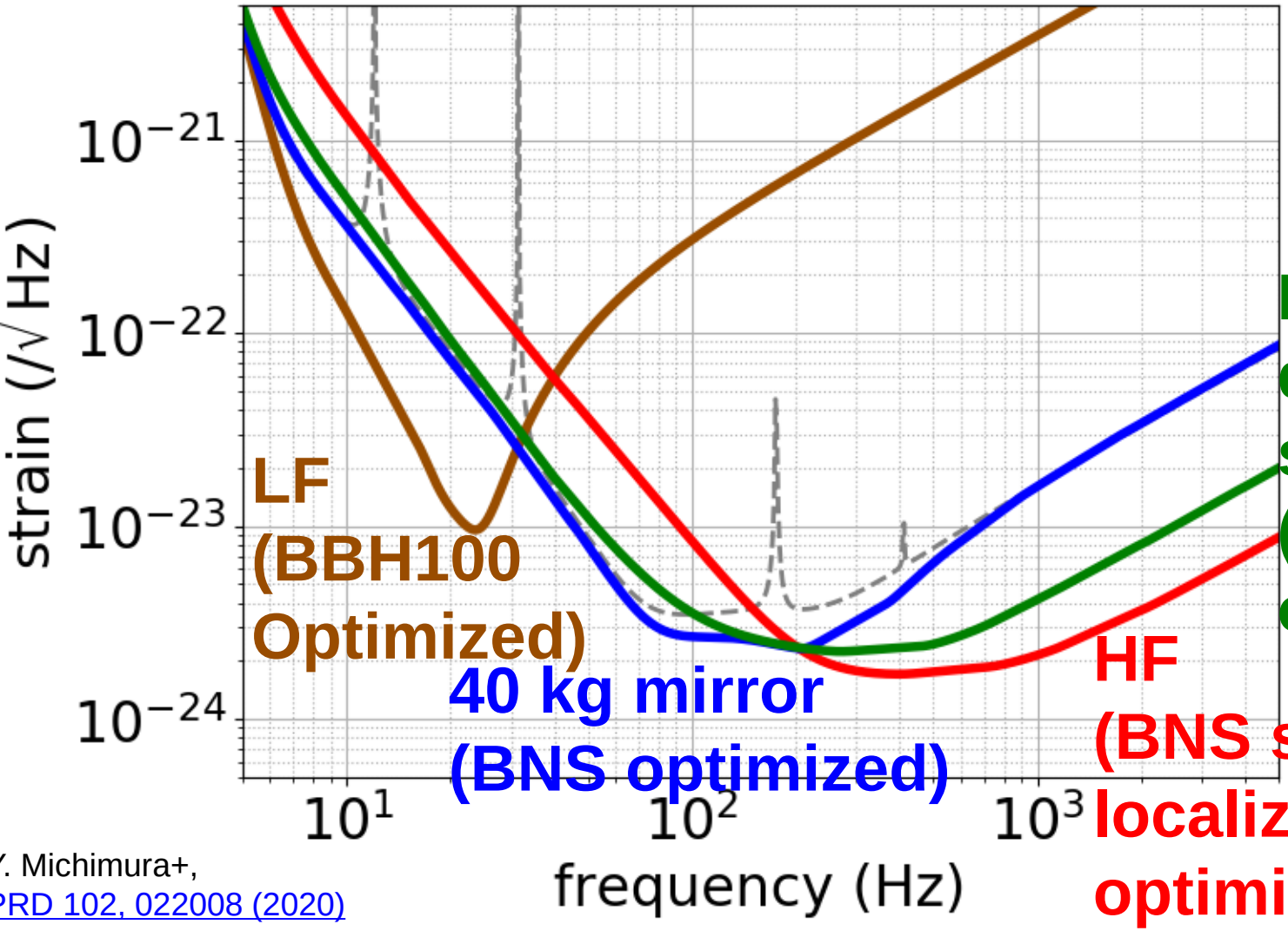
Options for Near Term Upgrade

- Different technologies improve sensitivity in different bands



Possible Near Term Upgrade Plans

- Based on technical feasibility, facility and budget constraints (~5 years, ~$5M)



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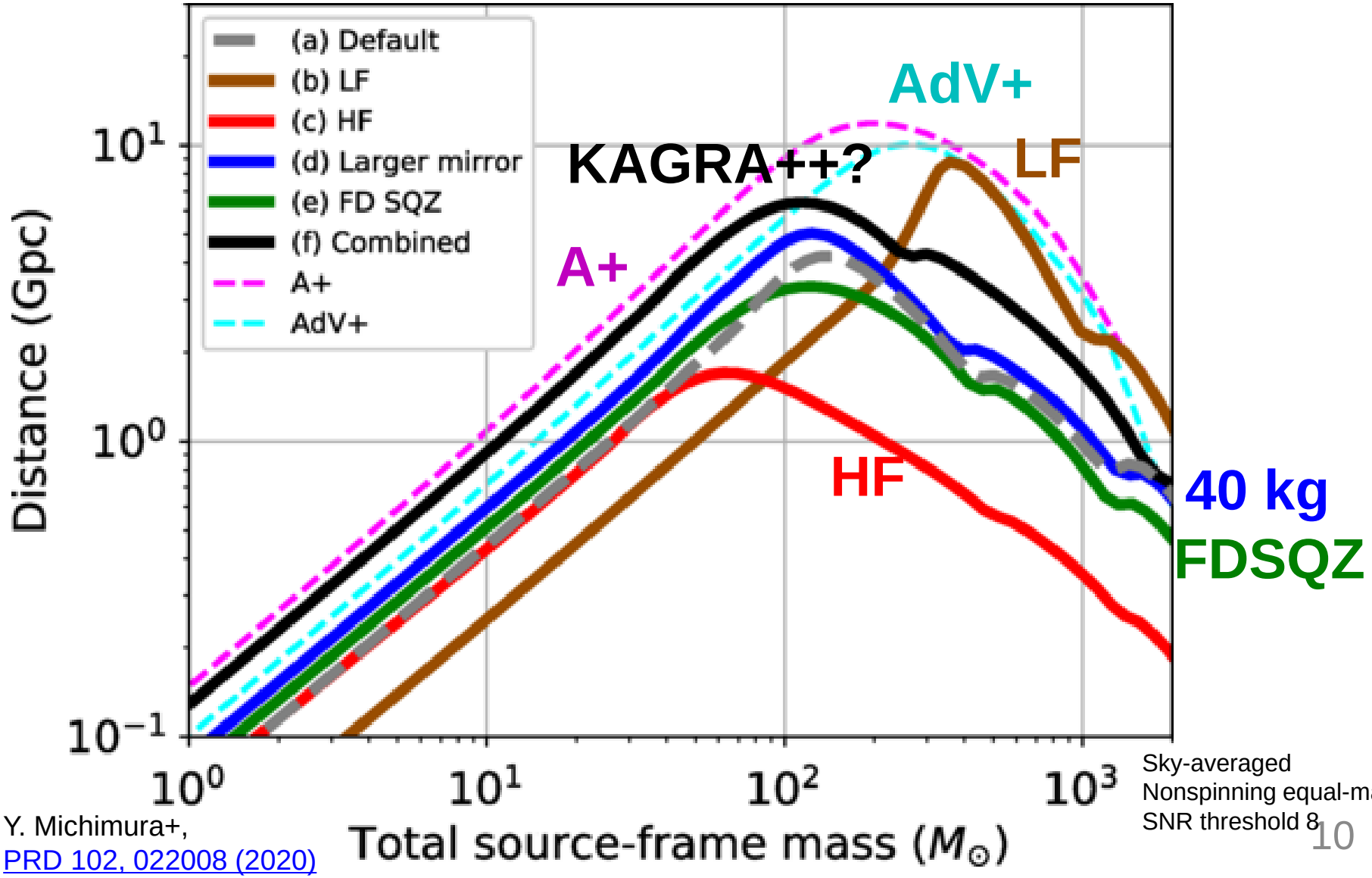
Detection Ranges

- Hard to beat A+ with horizon distance



Sky-averaged
Nonspinning equal-mass
SNR threshold 8

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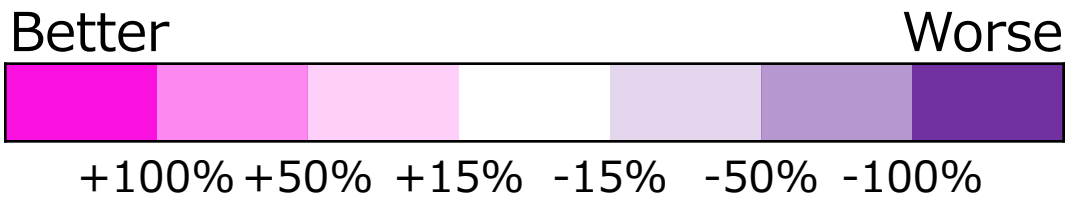
(Selected) Science Comparison

- Sensitivity improvement in different bands give different science cases

	LF	40kg	FDSQZ	HF	K++
IMBH event rate					
NS event rate					
NS tidal deformability					
Hubble constant by BBH					
Hubble constant by BNS					
GW polarization test					
Stellar-mass BH spectroscopy					
IMBH spectroscopy					



* Compared with bKAGRA, assumed A+ and AdV+ Network
* Summarized by A. Nishizawa *et al.* arXiv:2008.02921

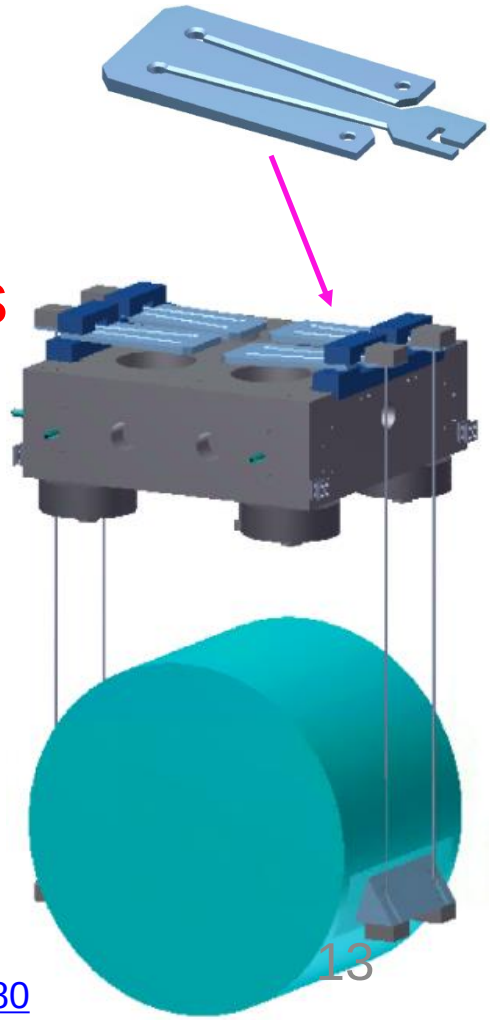
Effective Progression of Upgrades?

- **Low frequency** is uncertain since many low frequency excess noises exist
- **40 kg mirror** would be feasible but even larger mirror is required for longer term
- **Higher power laser** and **frequency dependent squeezing** are attractive in terms of feasibility
- **HF** plan has better sensitivity than A+ and AdV+ at high frequencies

- **Higher power laser** → **Squeezing** → **Frequency dependent squeezing** → **Larger mirror** might be an effective progression

Still Many Other Challenges

- Many other challenges still remain to be overcame to achieve design sensitivity
  - Detuning of signal recycling cavity
  - Homodyne detection
  - Larger thermal resistance
  - Mechanical loss of sapphire blades
    3.6e-5 measured, while 7e-7 required
  - No sapphire mirror spares
    2 out of 12 met absorption requirement
    - measured ~30 ppm/cm
    - requirement for ITM was 50 ppm/cm
  - Inhomogeneity of sapphire ITM refractive index
  - ITM birefringence



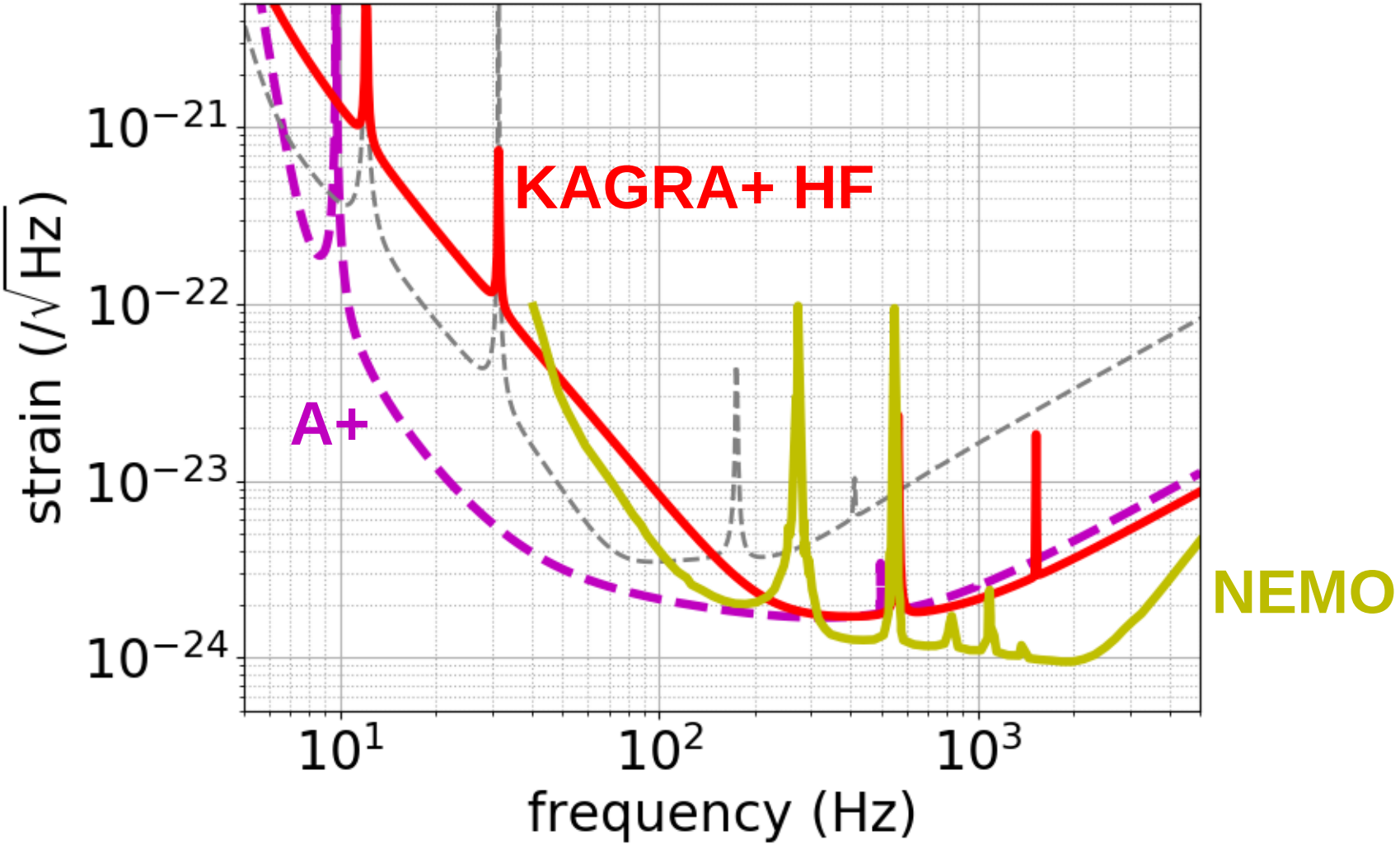
T. Yamada
JGW-G1910180

Discussion History

- **March 2017**: Semi-officially started the discussion
- **May 2017**: Upgrade plans first presented outside of KAGRA at GWADW2017 at Hamilton Island (JGW-G1706485)
- **December 2018**: Future Planning Committee formulated (Chair: Sadakazu Haino)
- **June 2019**: Birefringence observed
- **August 2019**: First version of the white paper summarized (JGW-M1909590)
- **2020**: Discussions to establish Future Strategy Committee to further organize the activities for upgrade implementation

KAGRA+ HF and NEMO

- What KAGRA can do with ~5years, ~$5M, within current 3 km facility (NEMO: 4 km, ~$100M)



Summary

- KAGRA requires different approach for the upgrade due to its cryogenic operation
- Twofold sensitivity improvement (300 Mpc) is feasible by combining multiple technologies
- What to implement first depends on scientific scenarios and technical feasibility
- KAGRA HF upgrade seems to be most attractive for the first step
- But there are still many practical challenges

- Other options is to do HF upgrade with extreme RSE and long SRC scheme (next Kentaro's talk)