



Future Plans for KAGRA Facility

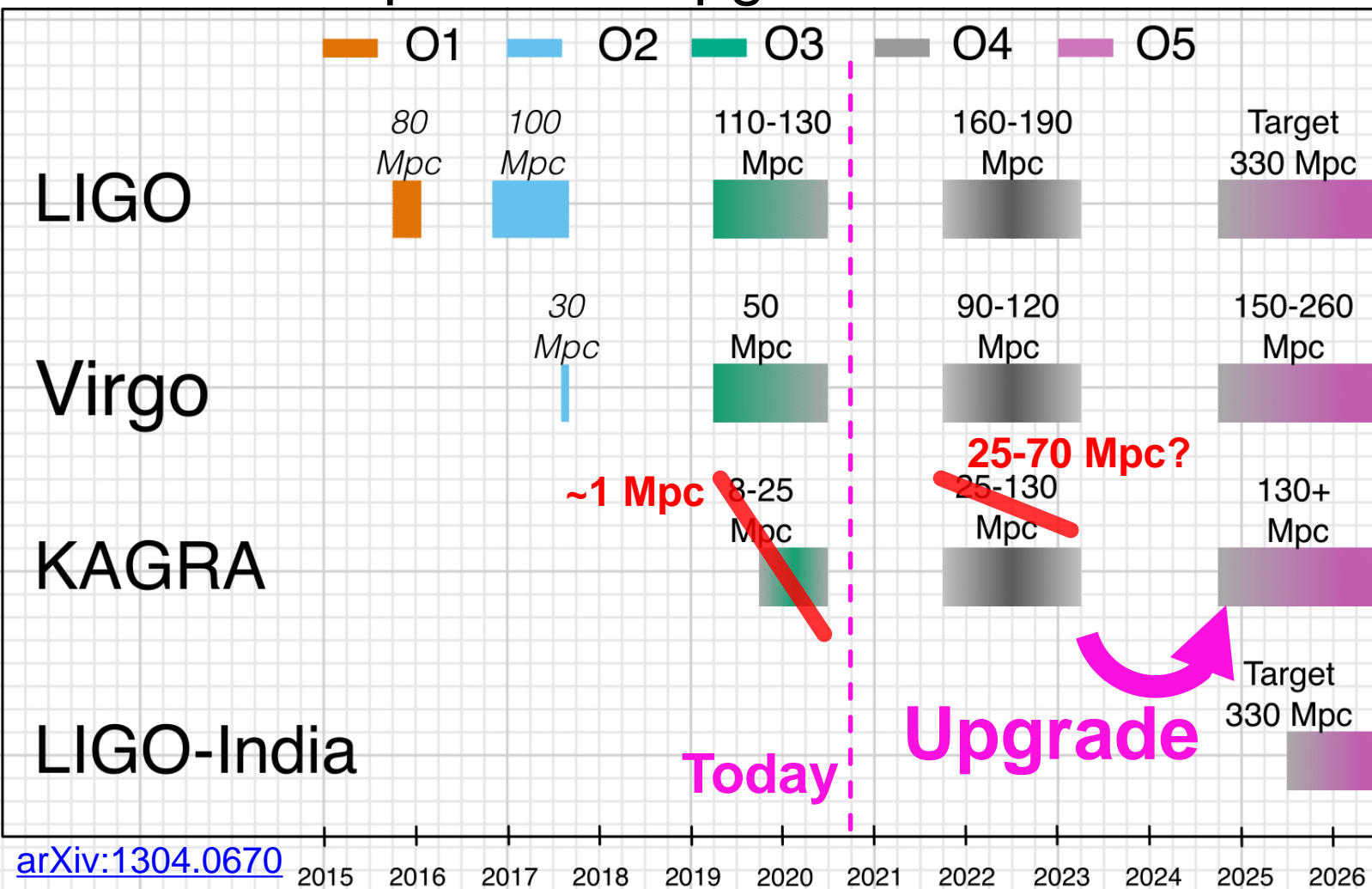
Yuta Michimura

Department of Physics, University of Tokyo

for the KAGRA Collaboration

Observing Scenario

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



Upgrading KAGRA is Tricky

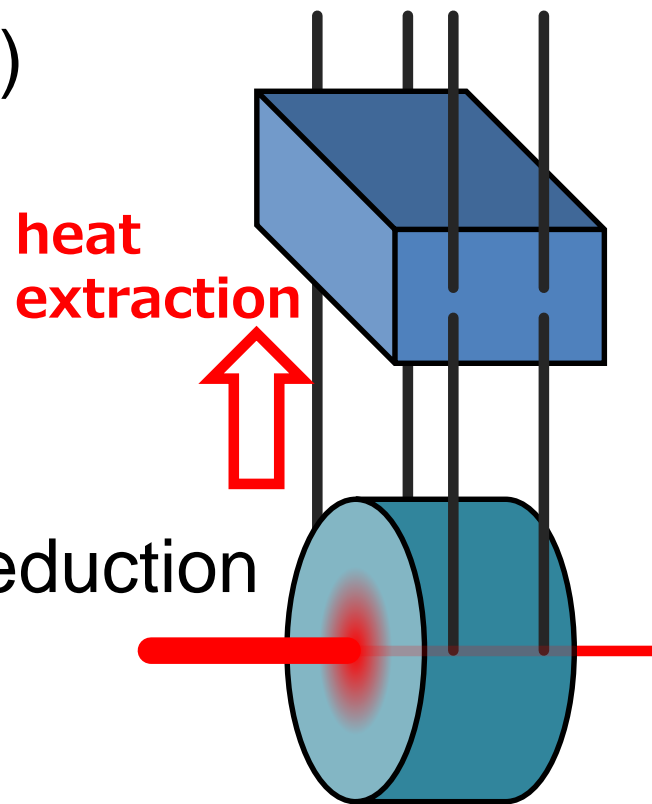
- Only **cryogenic** interferometer among 2G
- Not trivial to do both
 - high power (**400 kW** on mirror)
 - low temperature (**20 K**)

- Sapphire fibers to extract heat
thinner and longer
for suspension thermal noise reduction



Dilemma

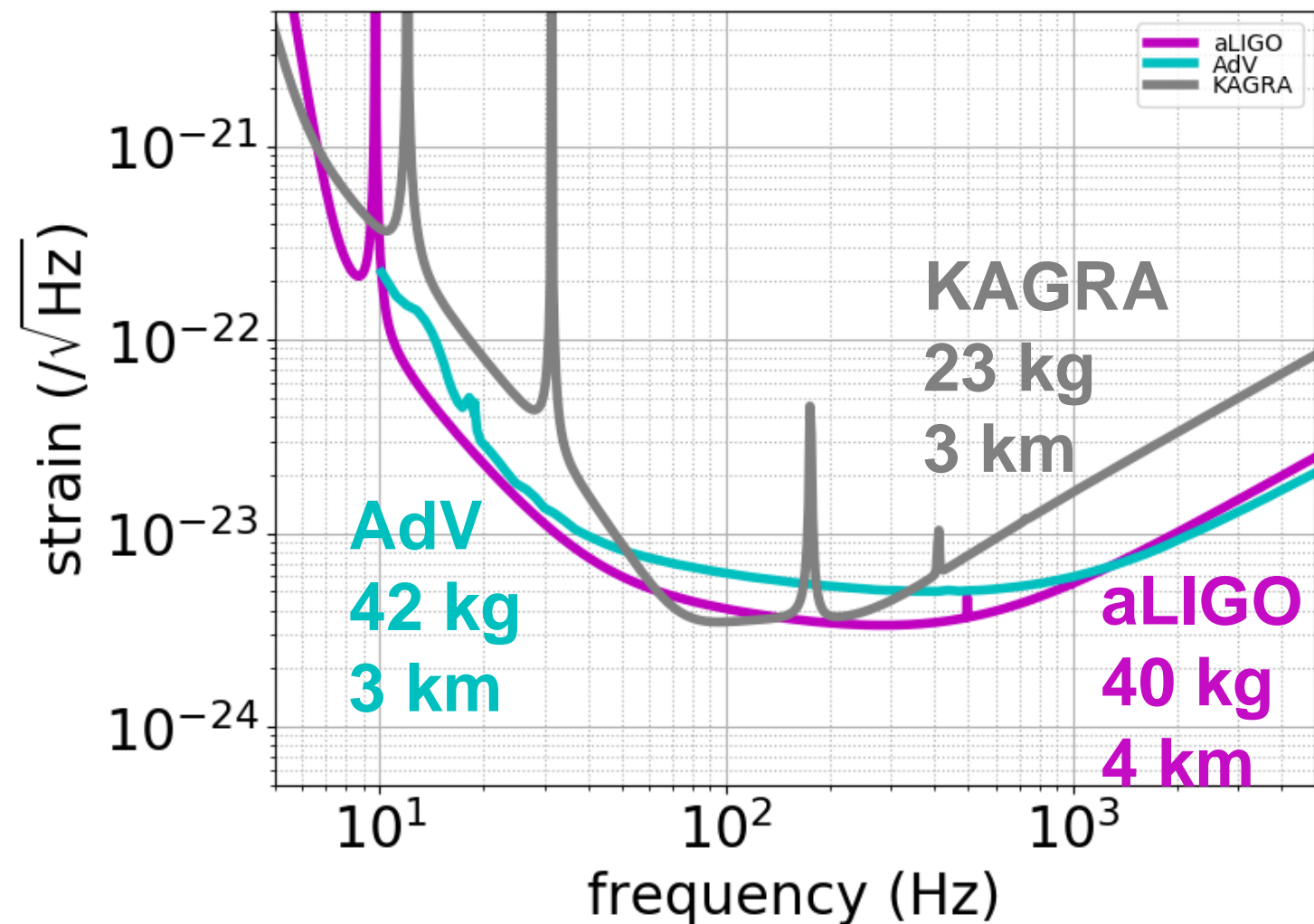
thicker and shorter
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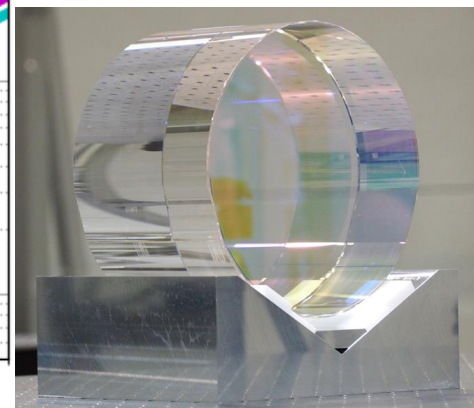
Y. Michimura+, [PRD 97, 122003 \(2018\)](#)

2G Sensitivity Comparison

- Not good at low freq. because of **thick and short fiber** (35 cm, ϕ 1.6 mm) to extract heat, and **lower mass**

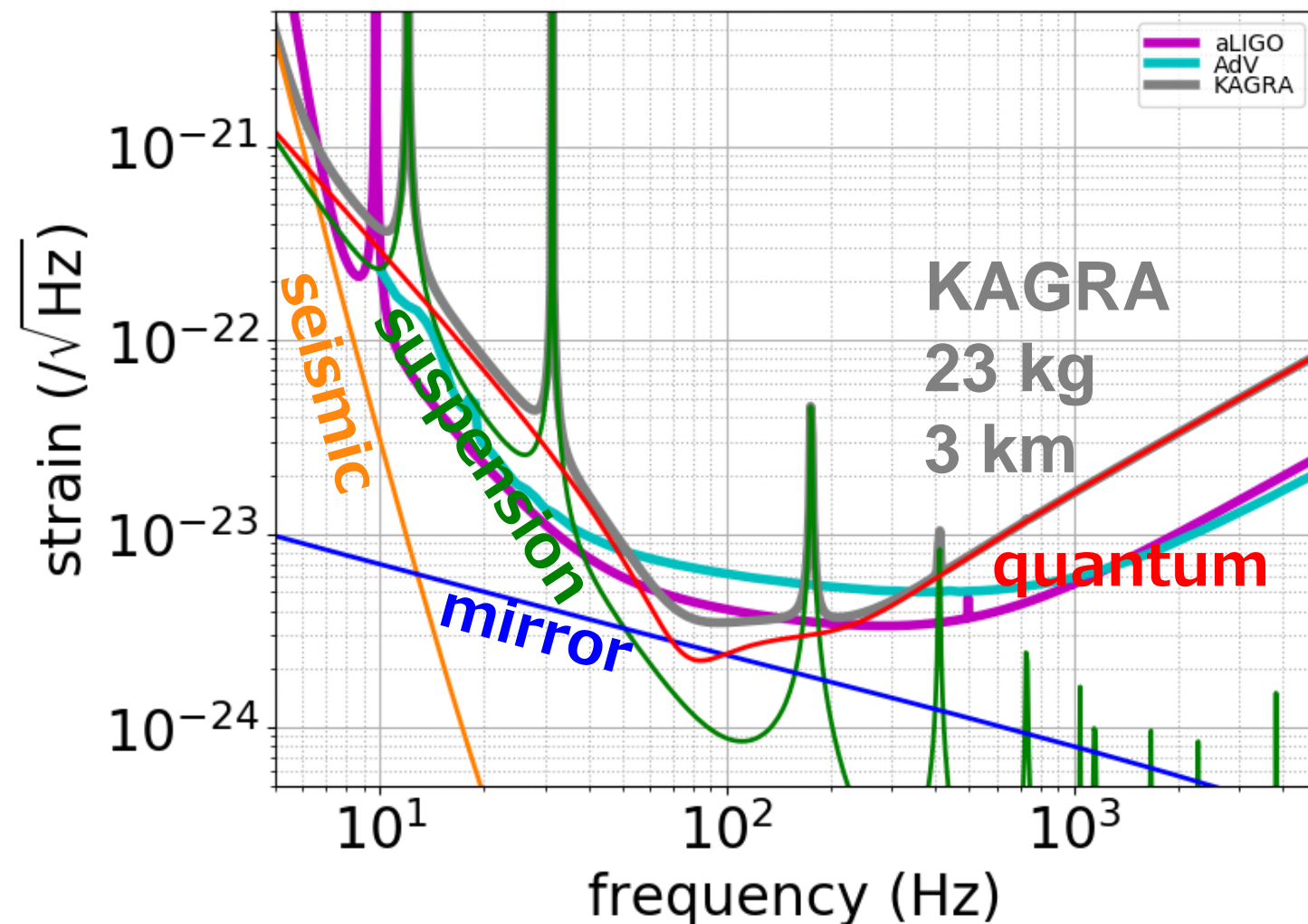


23 kg was the largest available sapphire mirror

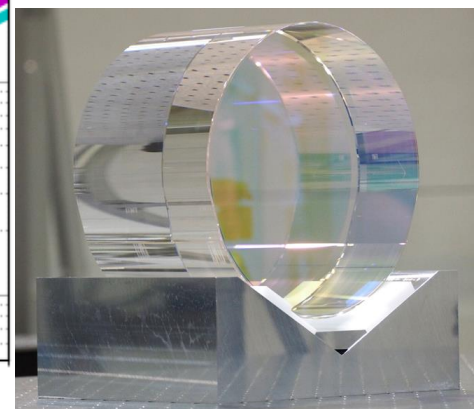


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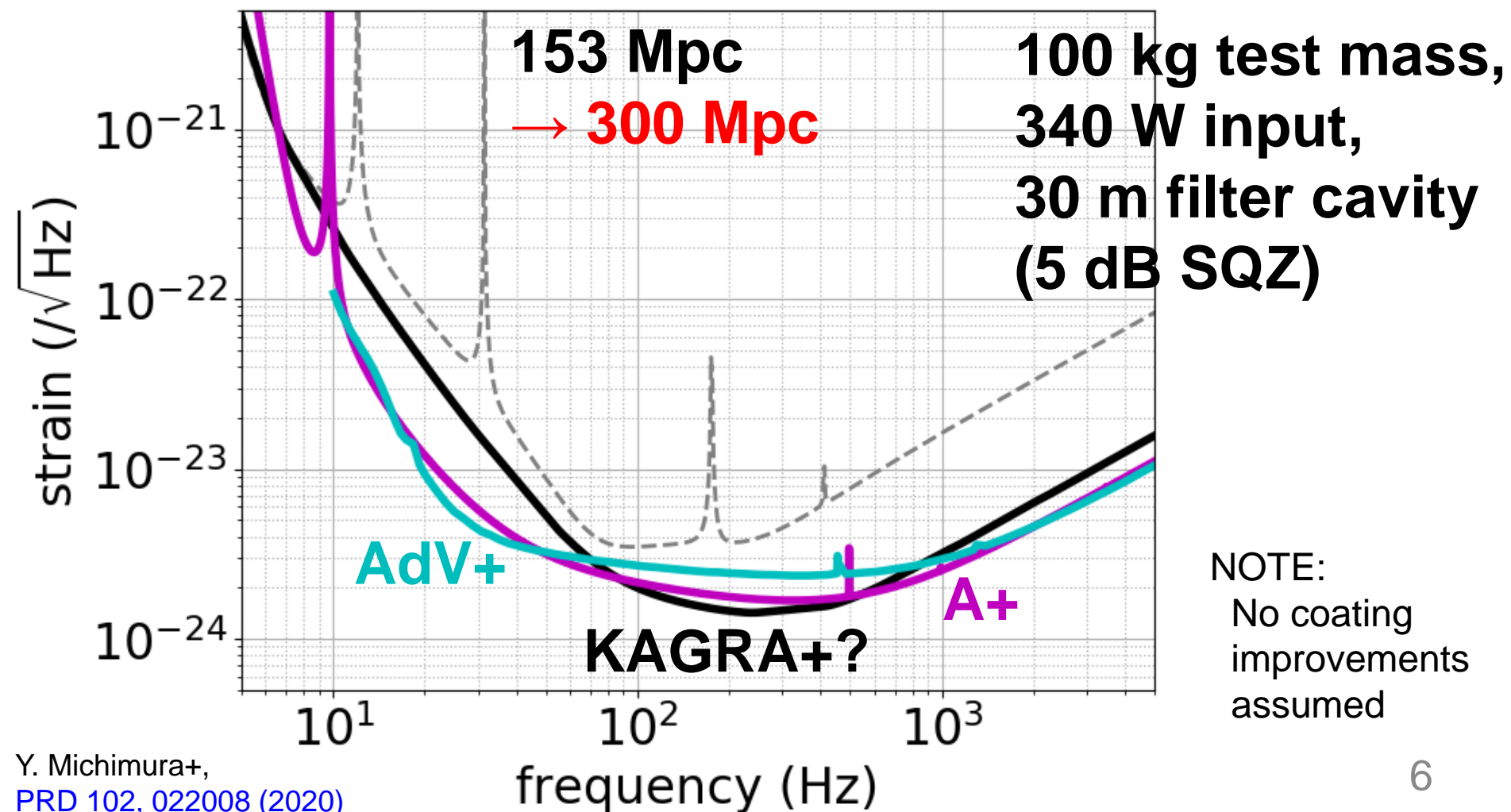


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Upgrade Plan for KAGRA?

- **Twofold broadband** sensitivity improvement possible with multiple upgrade technology



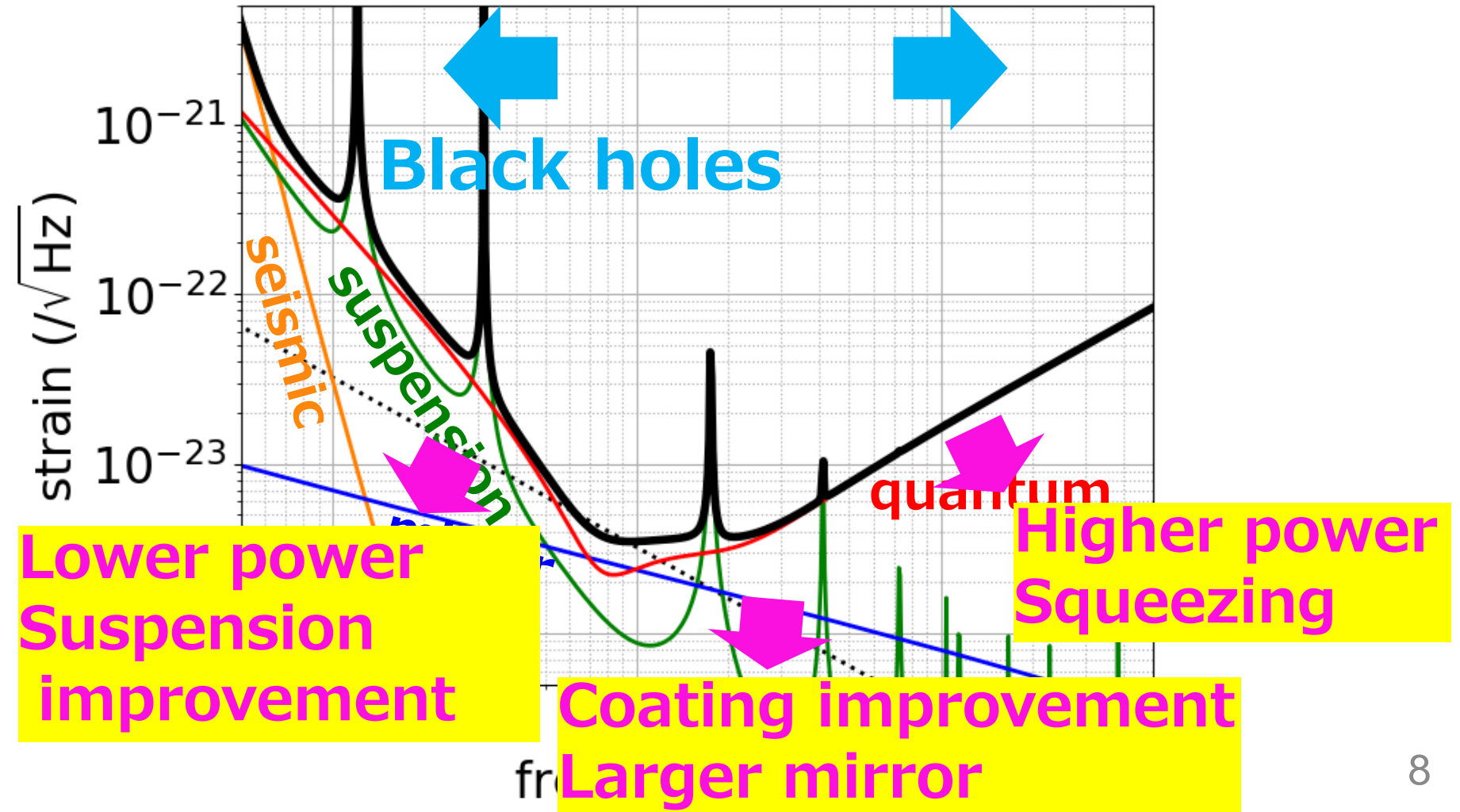
Technologies for the Upgrade

- 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

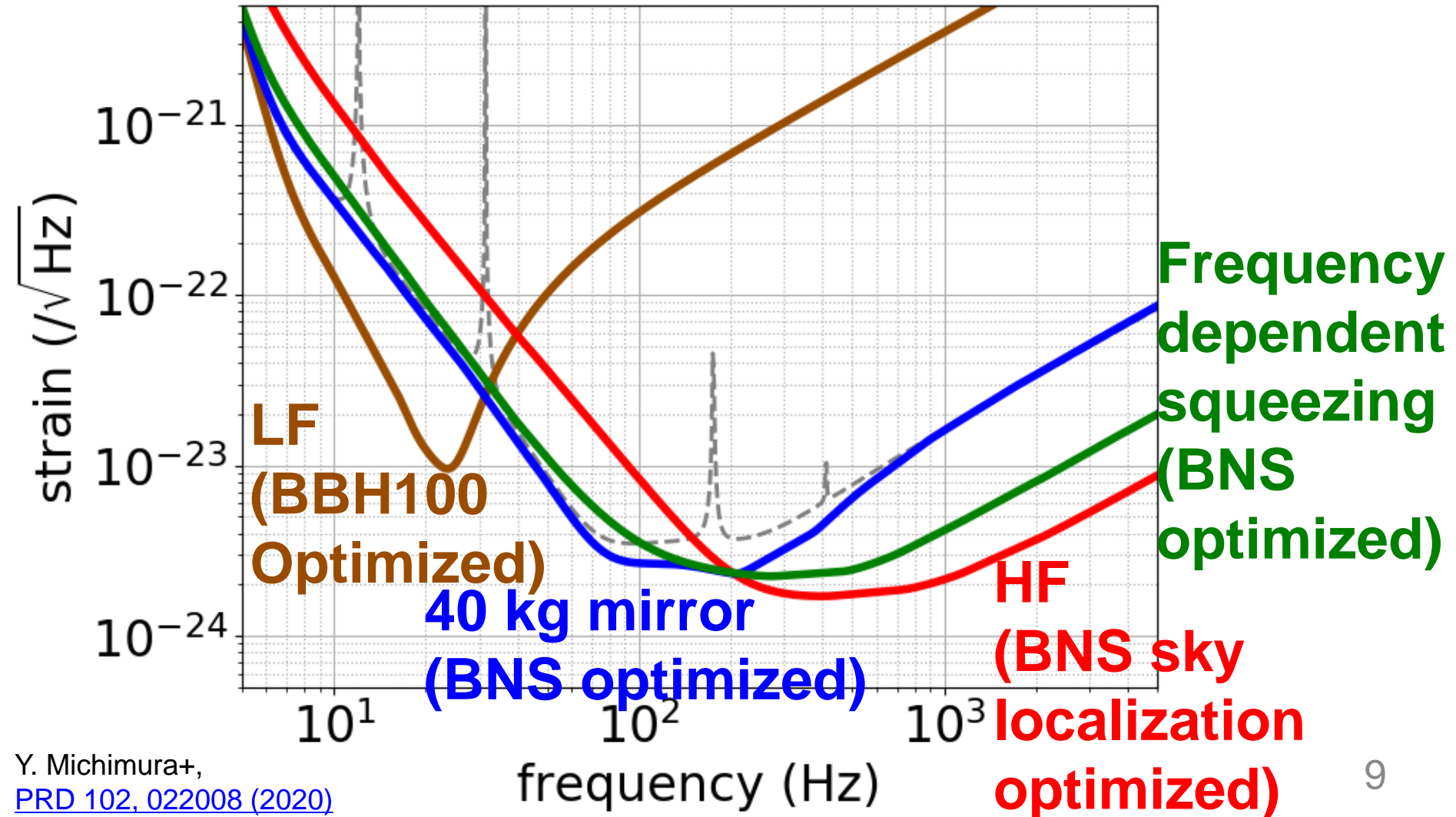
- Different technologies improve sensitivity in different bands

Neutron stars



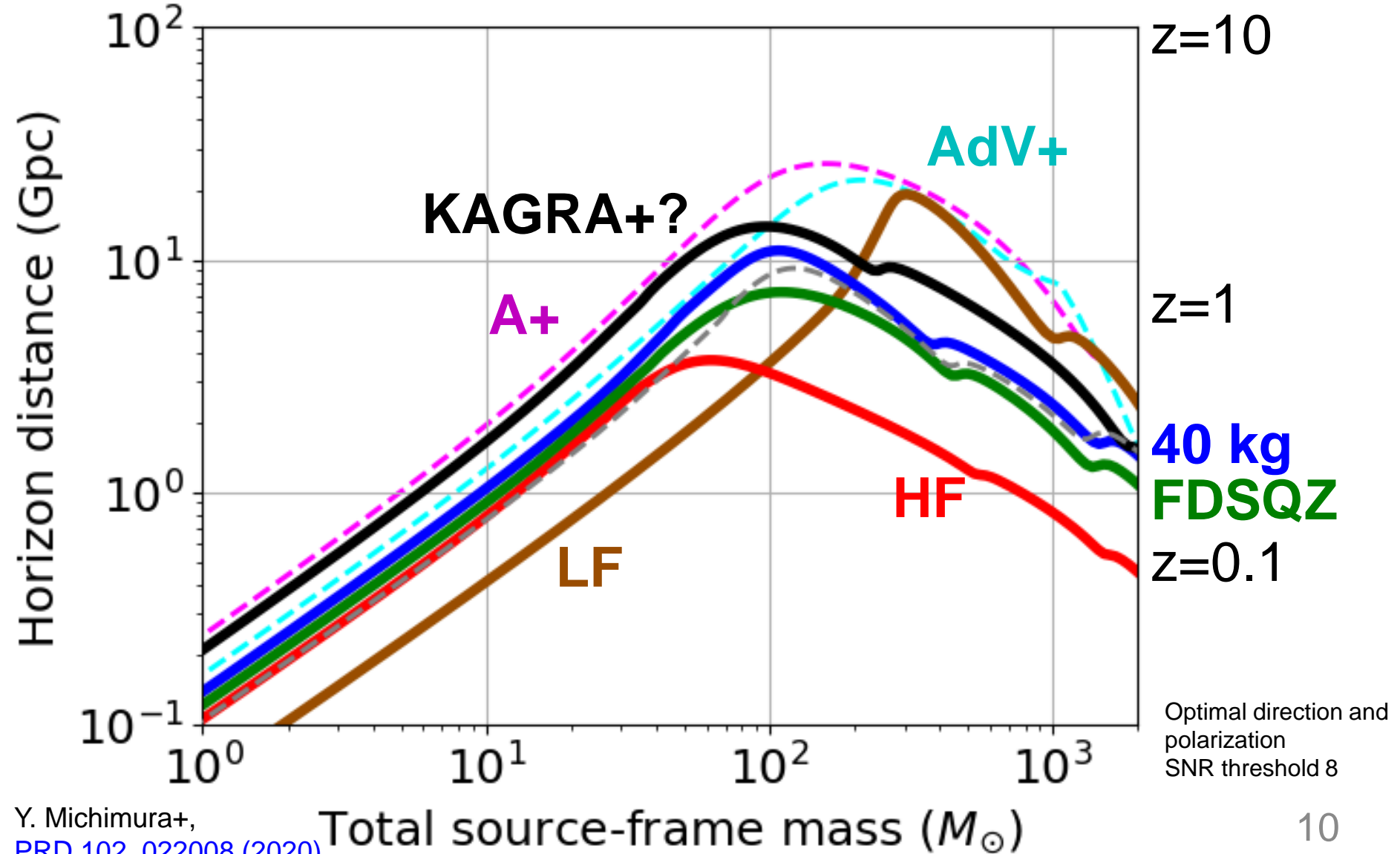
Possible Near Term Upgrade Plans

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



Horizon Distance Comparison

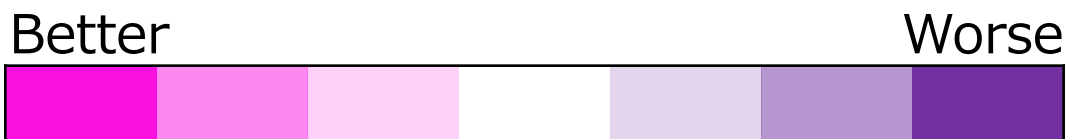
- Hard to beat A+ with horizon distance



(Selected) Science Comparison

- Sensitivity improvement in different bands give different science cases

	LF	40kg	FDSQZ	HF	Longer
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	+			-	+



+100% +50% +15% -15% -50% -100%

* Compared with bKAGRA, assumed A+ and AdV+ Network

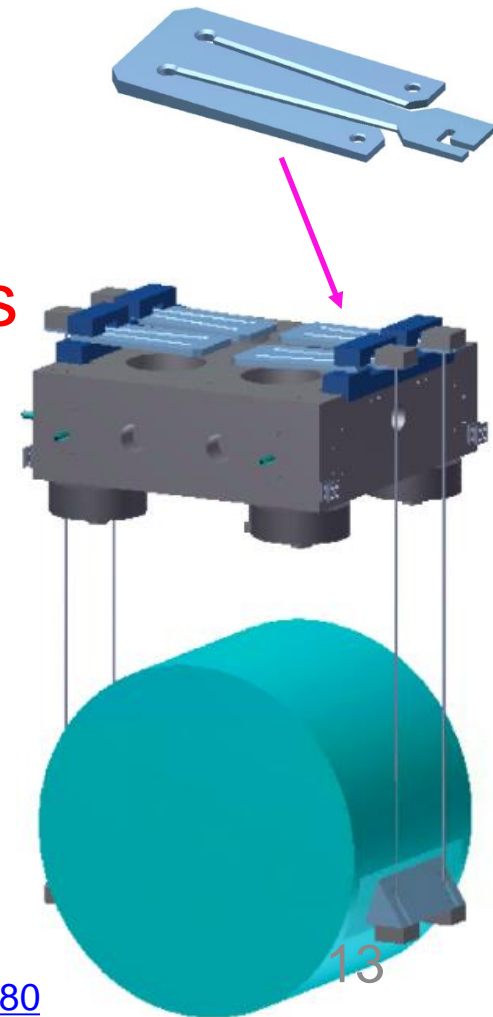
* Summarized by A. Nishizawa *et al.* [arXiv:2008.02921](https://arxiv.org/abs/2008.02921)

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 overcome 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**



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)
- **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

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**)