

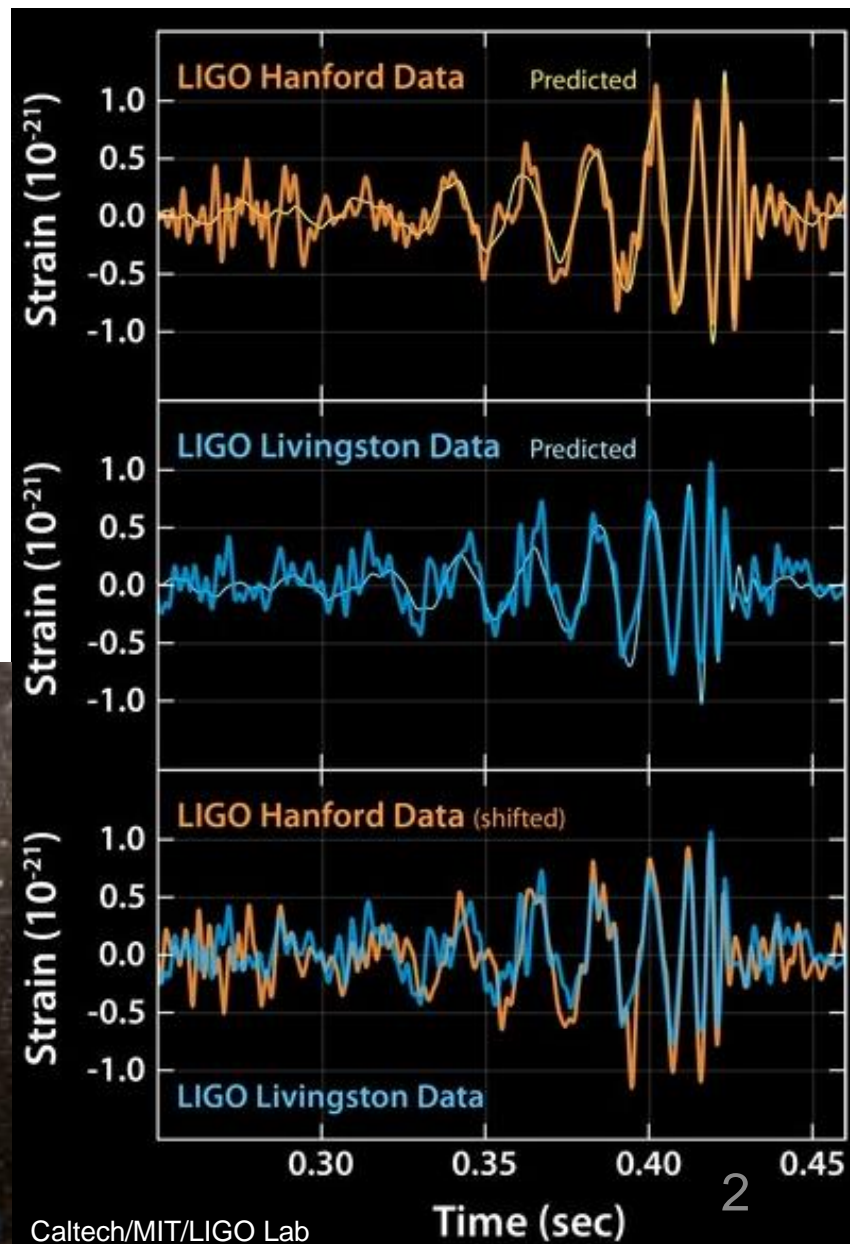
Recent News and Status of the KAGRA Gravitational Wave Telescope

Yuta Michimura

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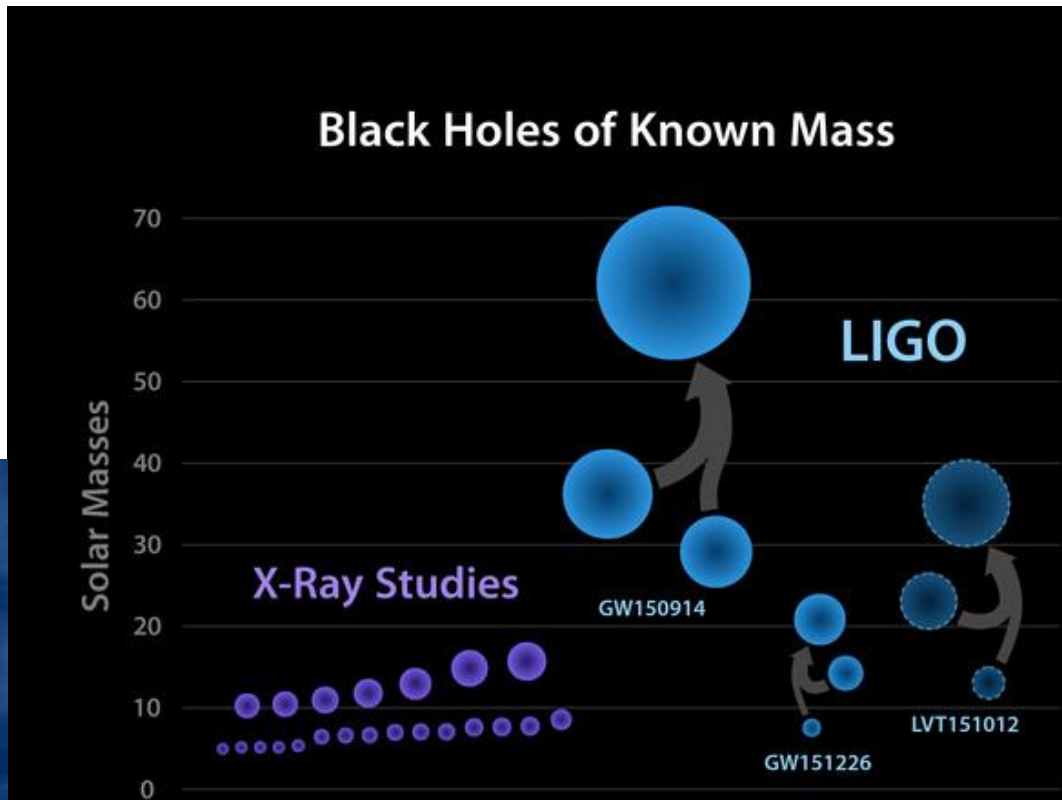
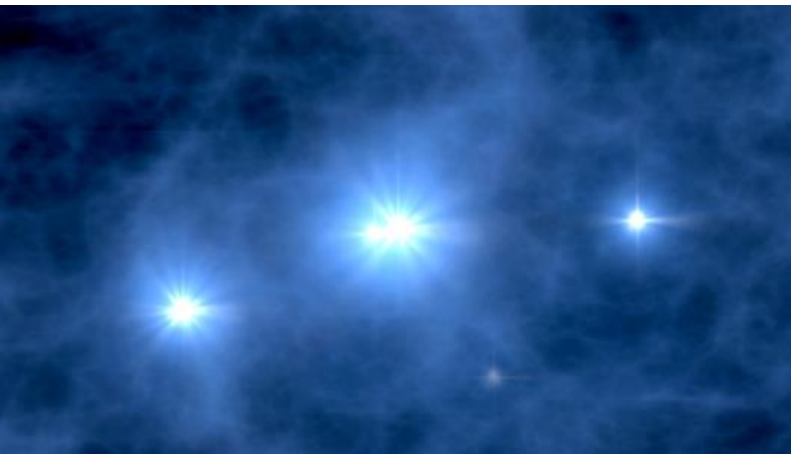
First Detection of GW

- Advanced LIGO detectors
- binary black hole mergers
 - GW150914
 - 36Msun & 29Msun
 - GW151226
 - 14Msun & 7.5Msun



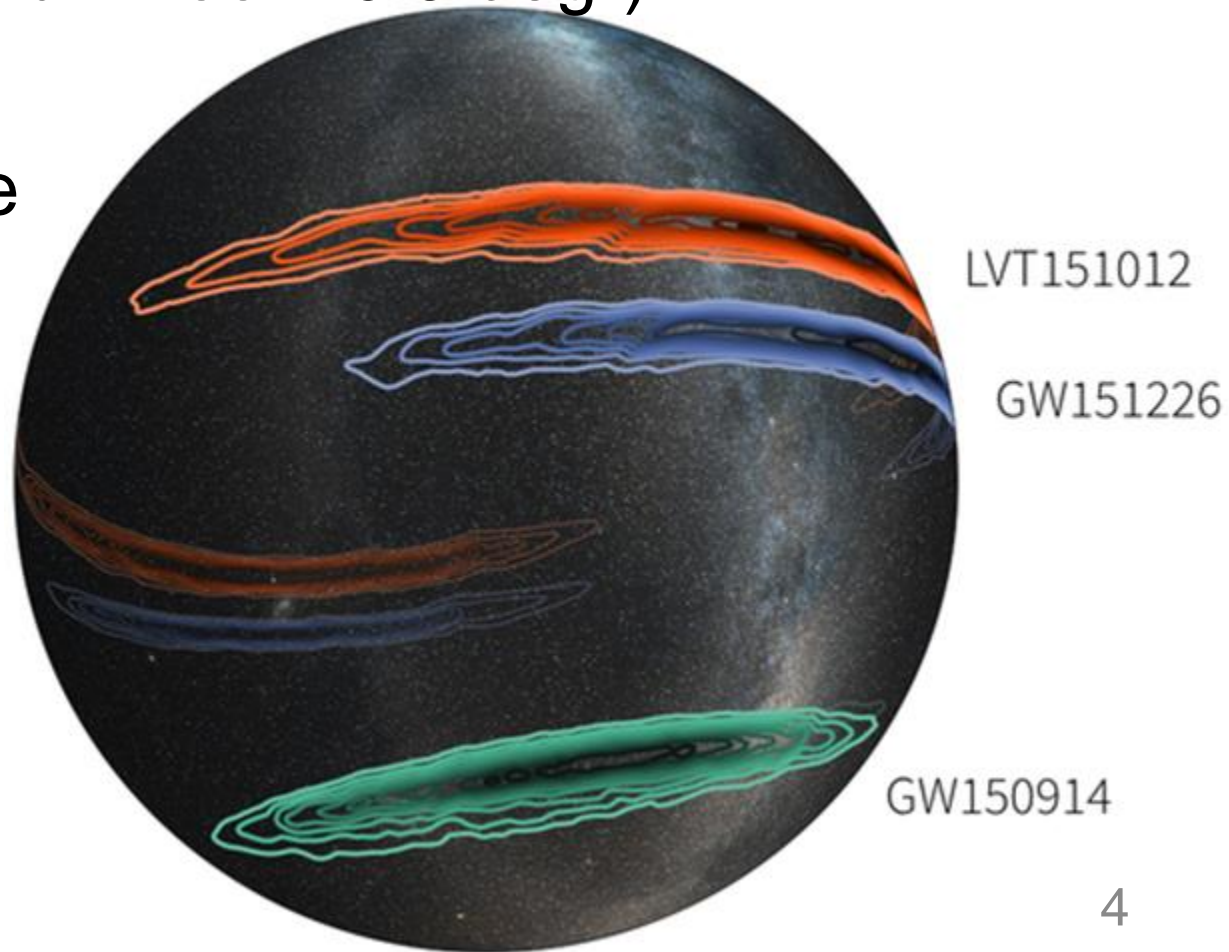
Where Do BBHs Came From?

- masses were heavier than expected
- usual stars can only be $\sim 10M_{\text{sun}}$ BHs
- still under discussion
 - primordial BHs?
 - from first stars?
 - from globular clusters?
 - etc.....



Sky Location

- sky location with 2 detectors has limitations within \sim hundreds of square-degrees (size of the full moon: 0.5 deg^2)
- need 3 or more detectors to localize better



Global Network of GW Detectors

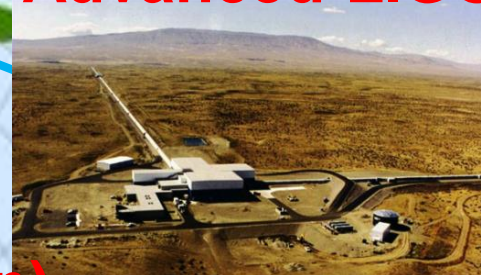
- upgrade/construction around the world



**Advanced LIGO
(preparing for O2)**



Advanced LIGO



**KAGRA
(construction)**



LIGO-India (approved)



KAGRA

- Large-scale **Cryogenic** Gravitational Wave Telescope (Nickname: KAGRA)
- constructed **underground** in Japan
- 60+ institutes, 200+ collaborators
- project started in 2010



PI:
Takaaki Kajita



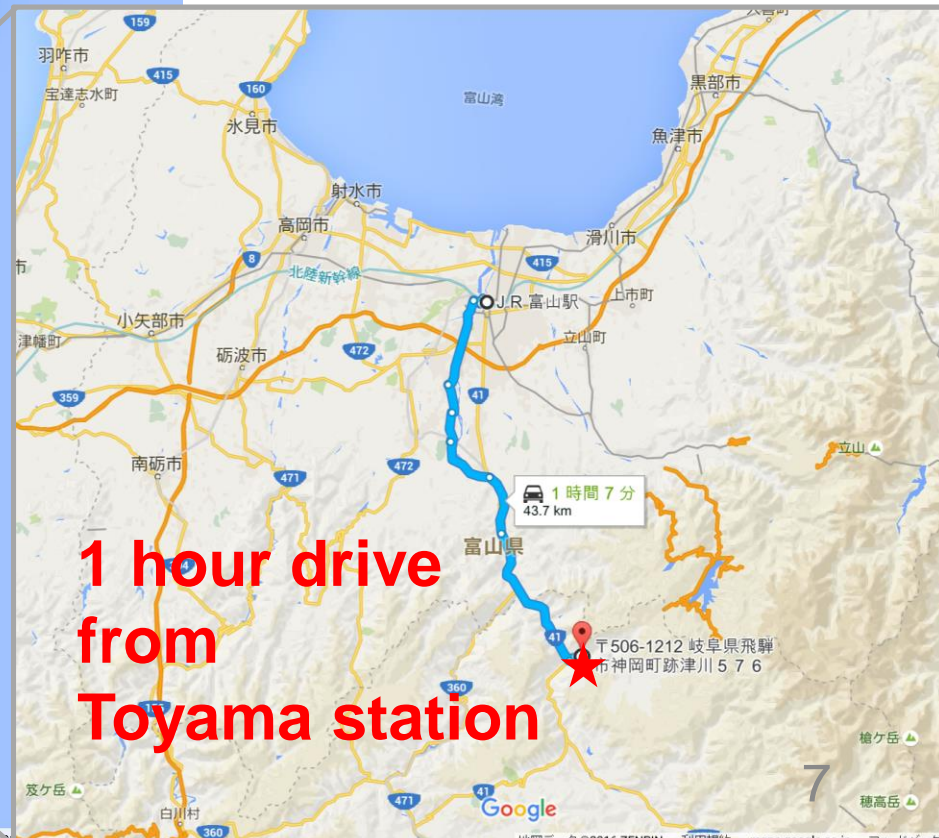
and many more...

Where's KAGRA?

- Kamioka mine, Gifu, Japan

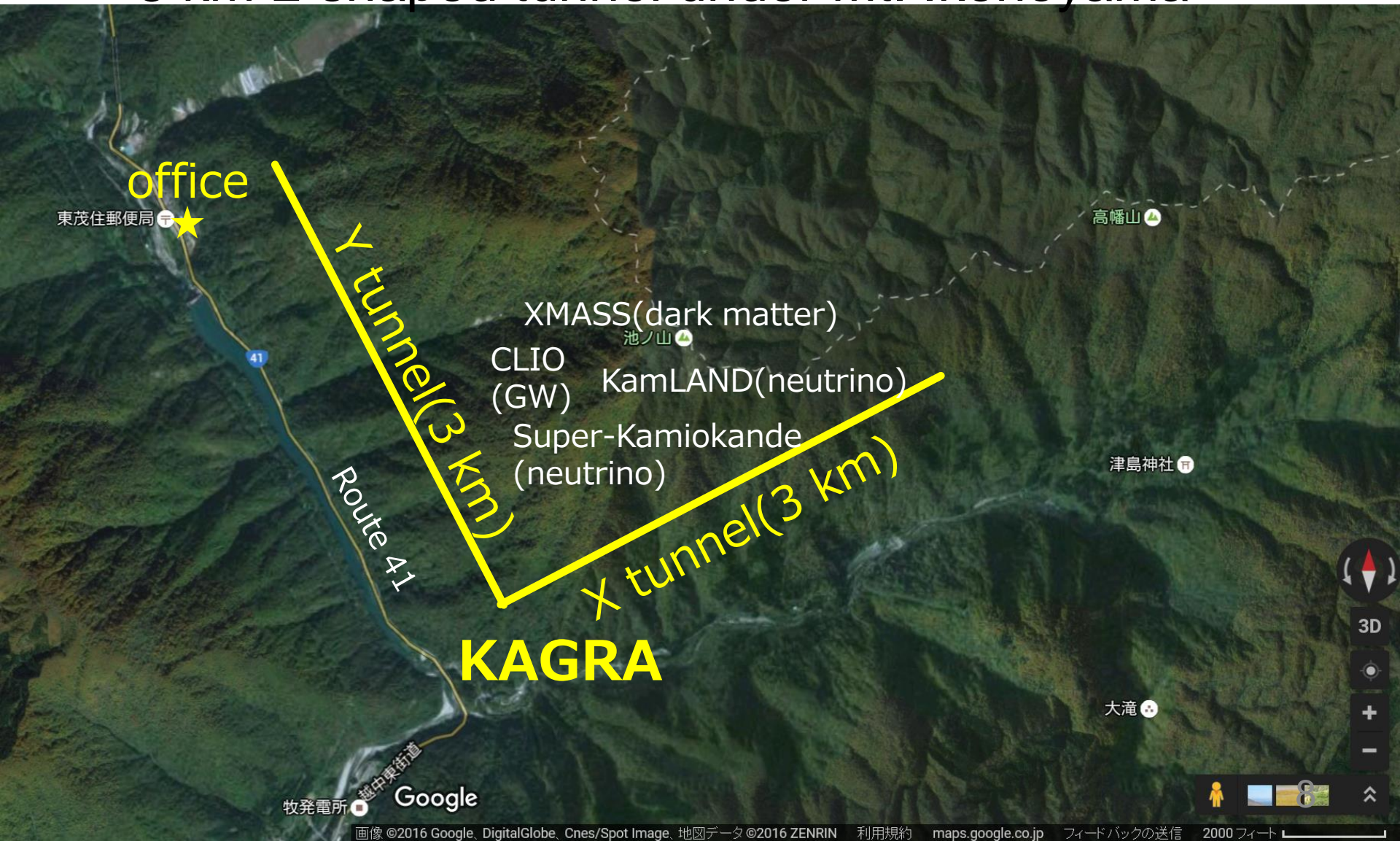


**2.5 hours from Tokyo
by Shinkansen**



Facilities Around Kamioka

- 3 km L-shaped tunnel under Mt. Ikenoyama



KAGRAトンネル

- 3 km vacuum pipe for each arm ($\sim 1e-7$ Pa)
- laser beam go back and forth



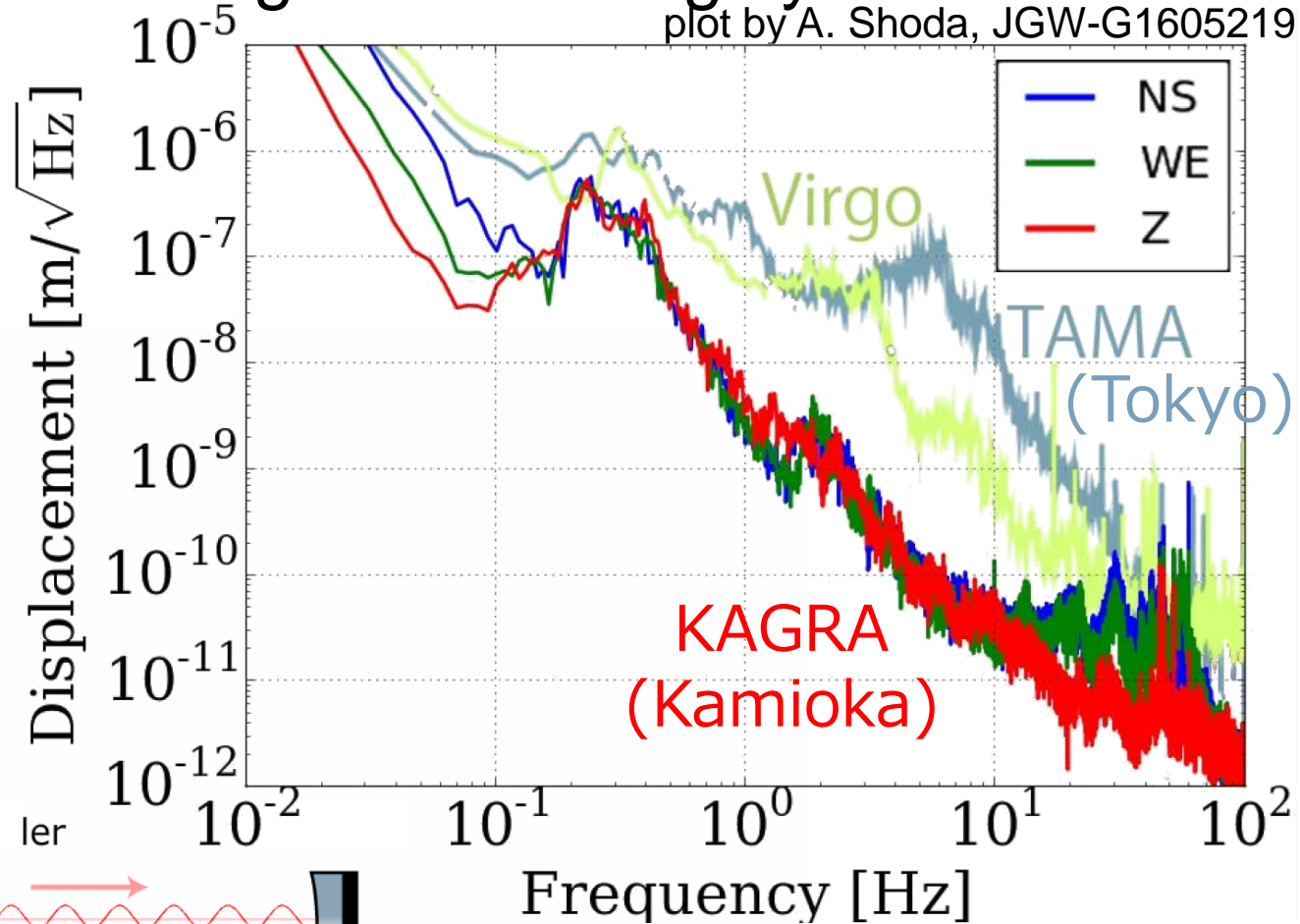
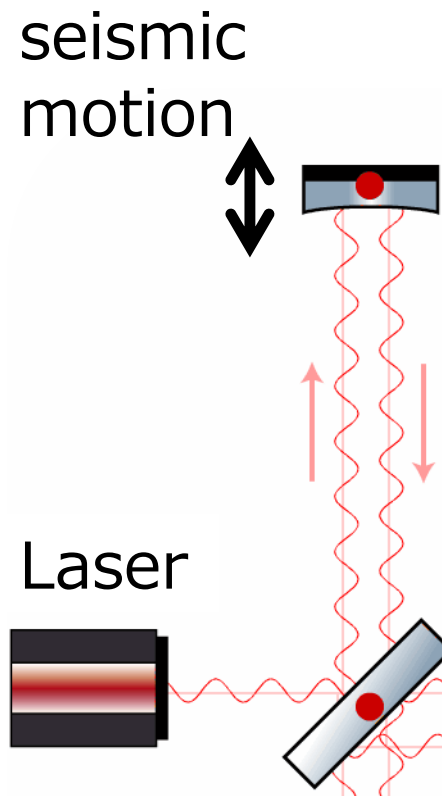
Working Underground is Tough

- helmet, work clothes, rubber boots, oximeter, electric bicycles, etc



Why Underground?

- seismic motion of mirrors will be noise source
- seismic noise underground is roughly 2 orders of magnitude smaller



Suspensions for Seismic Isolation

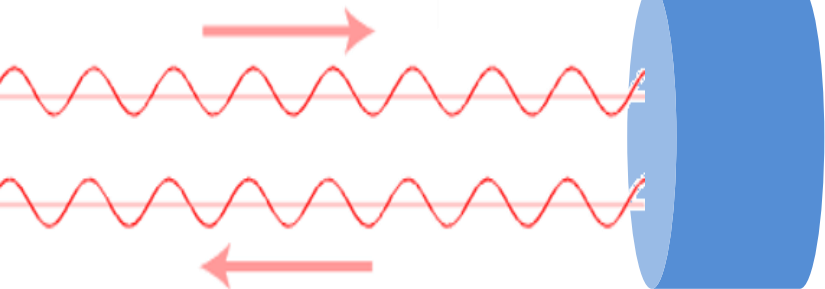
- suspend mirrors to reduce seismic noise



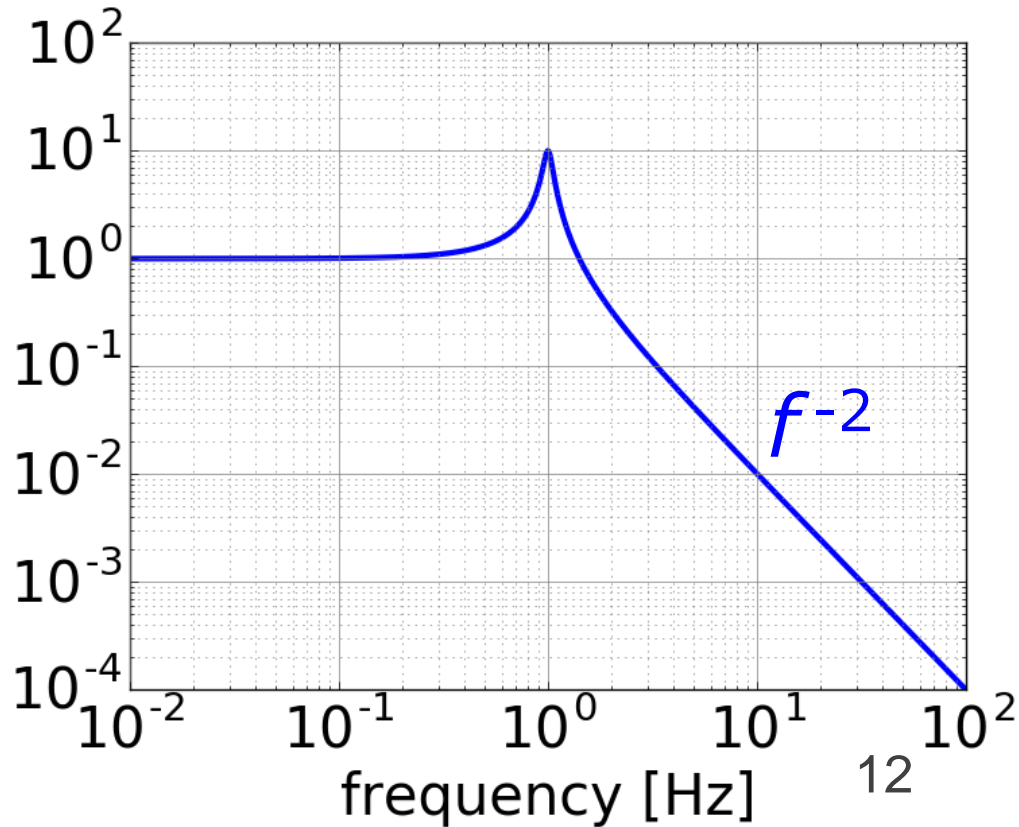
seismic motion



mirror motion

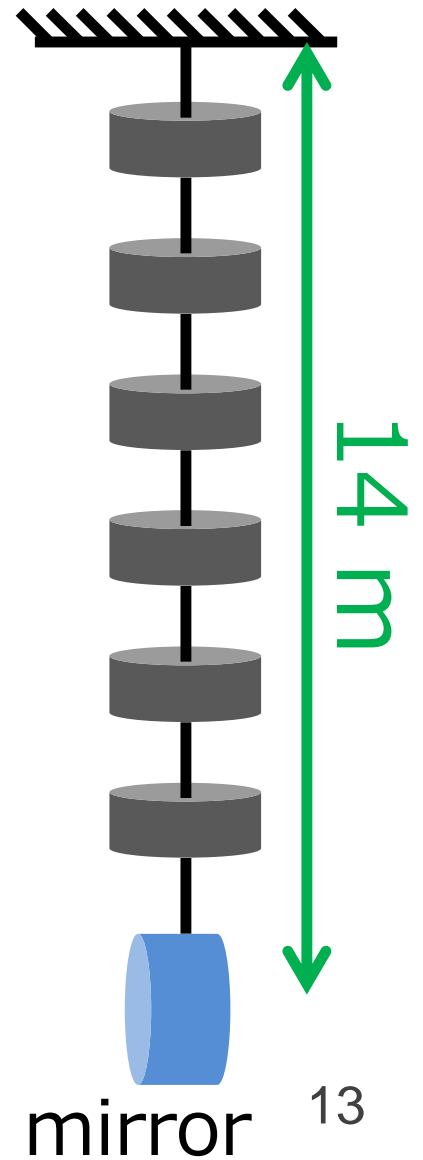
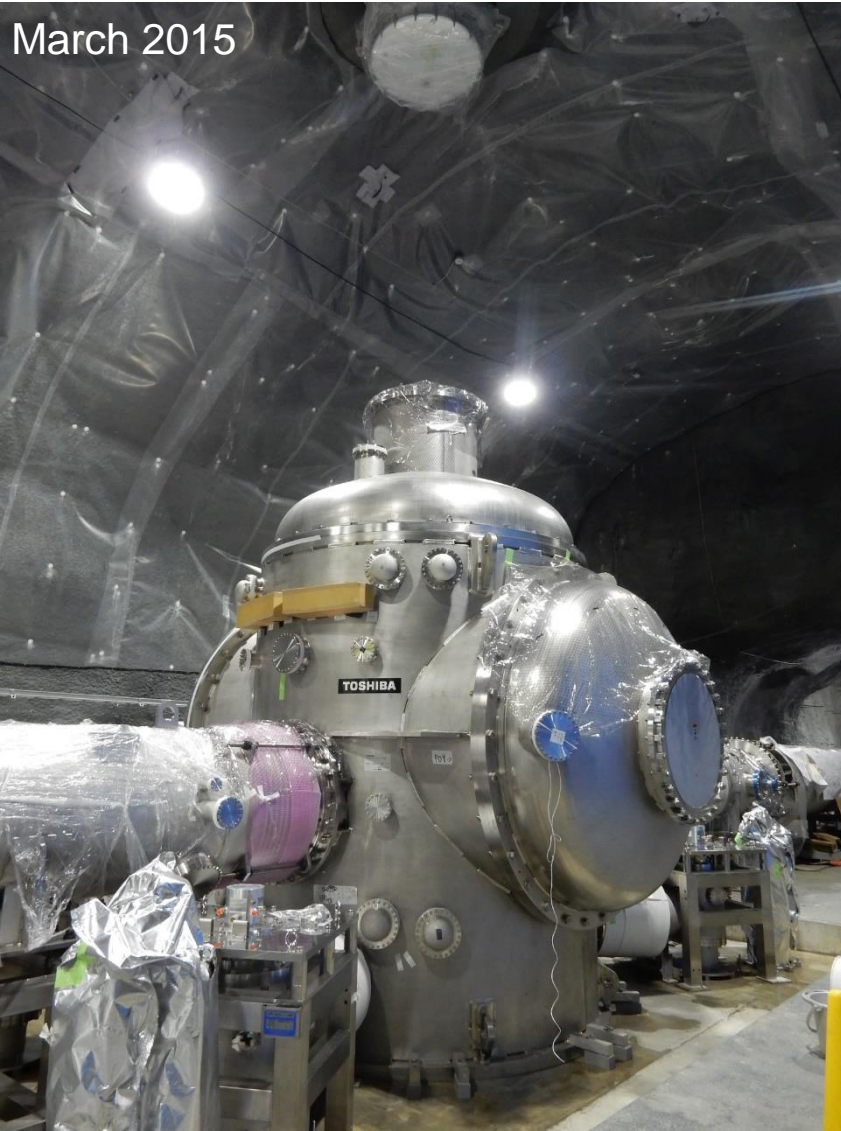


seismic suppression ratio

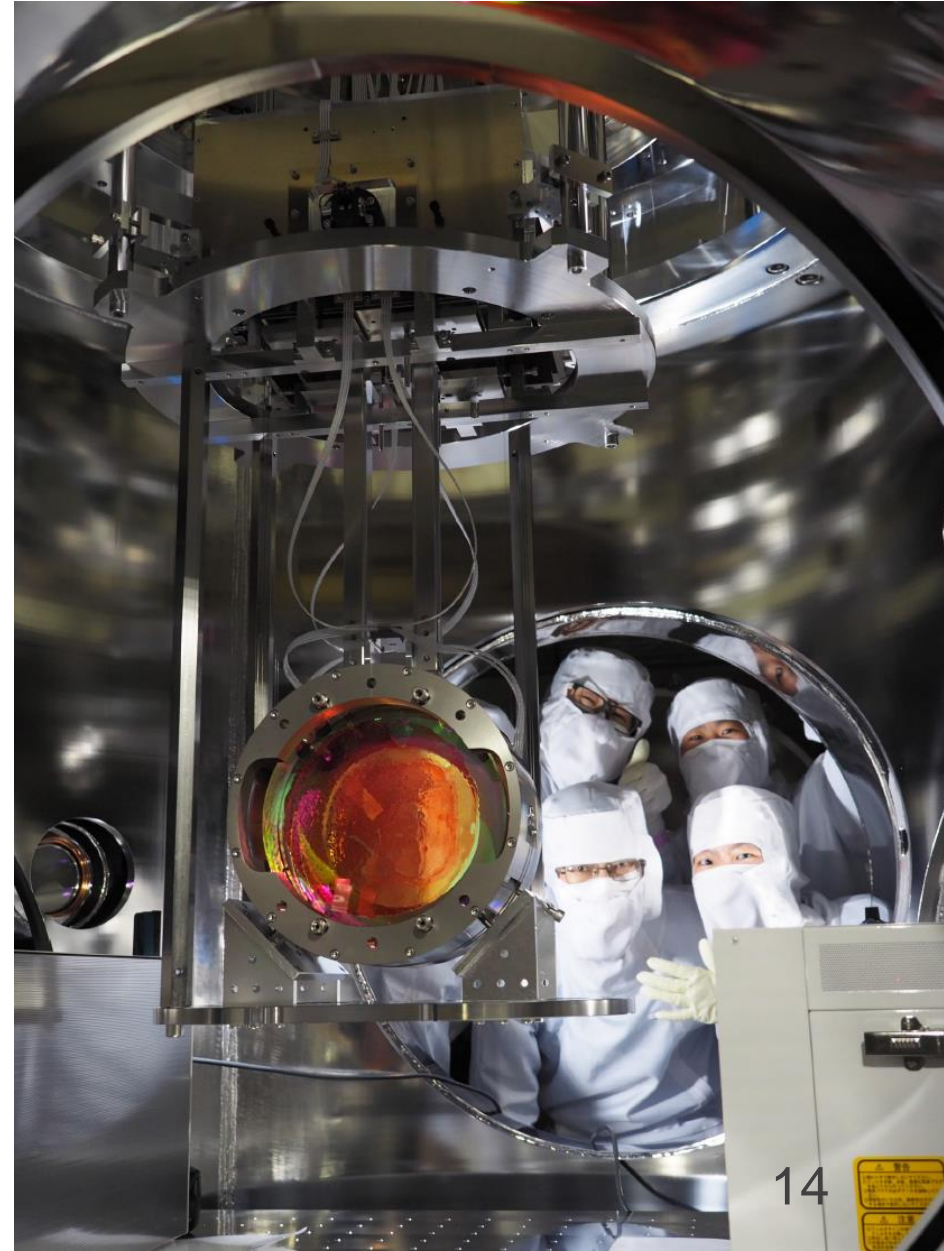
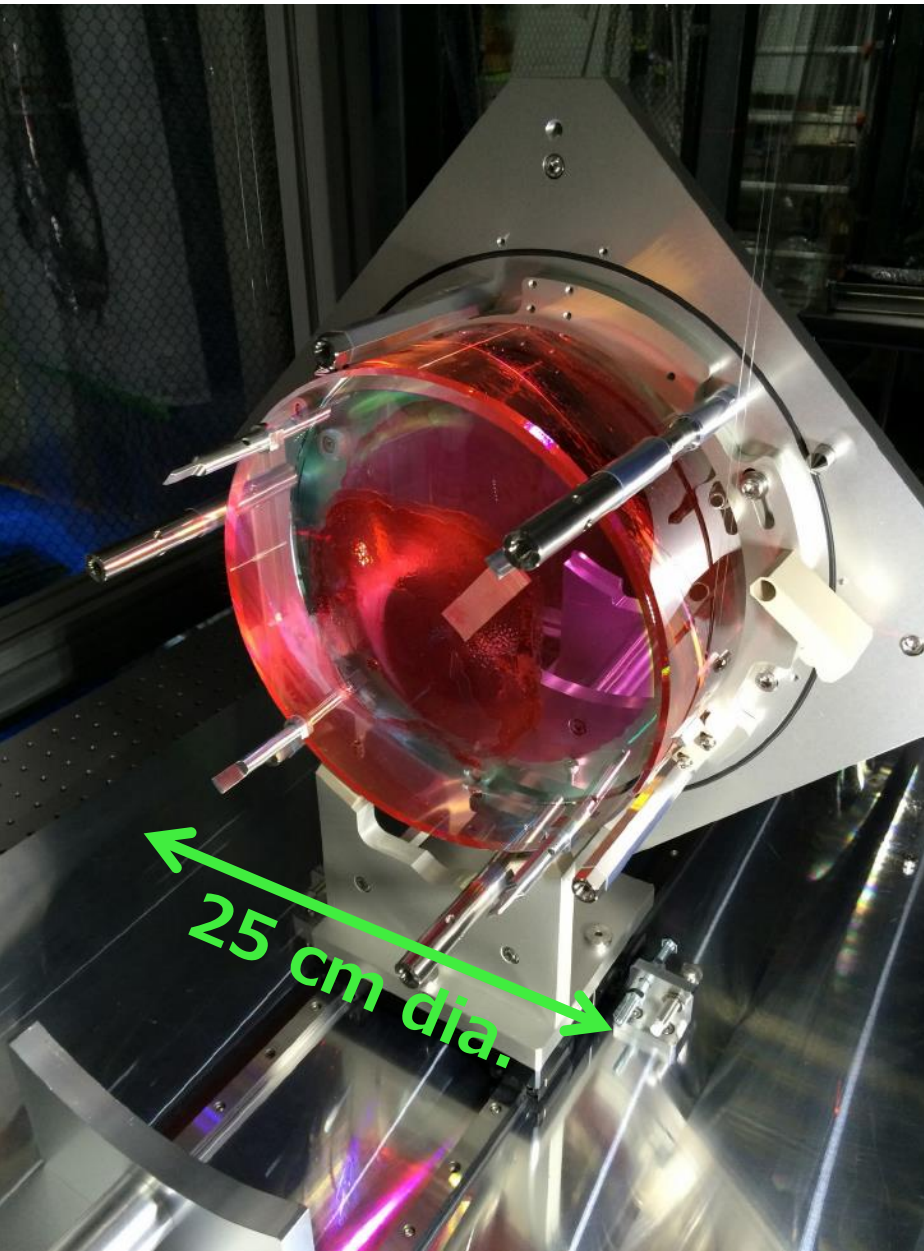


Vibration Isolation System

- 7-stage pendulum super attenuators

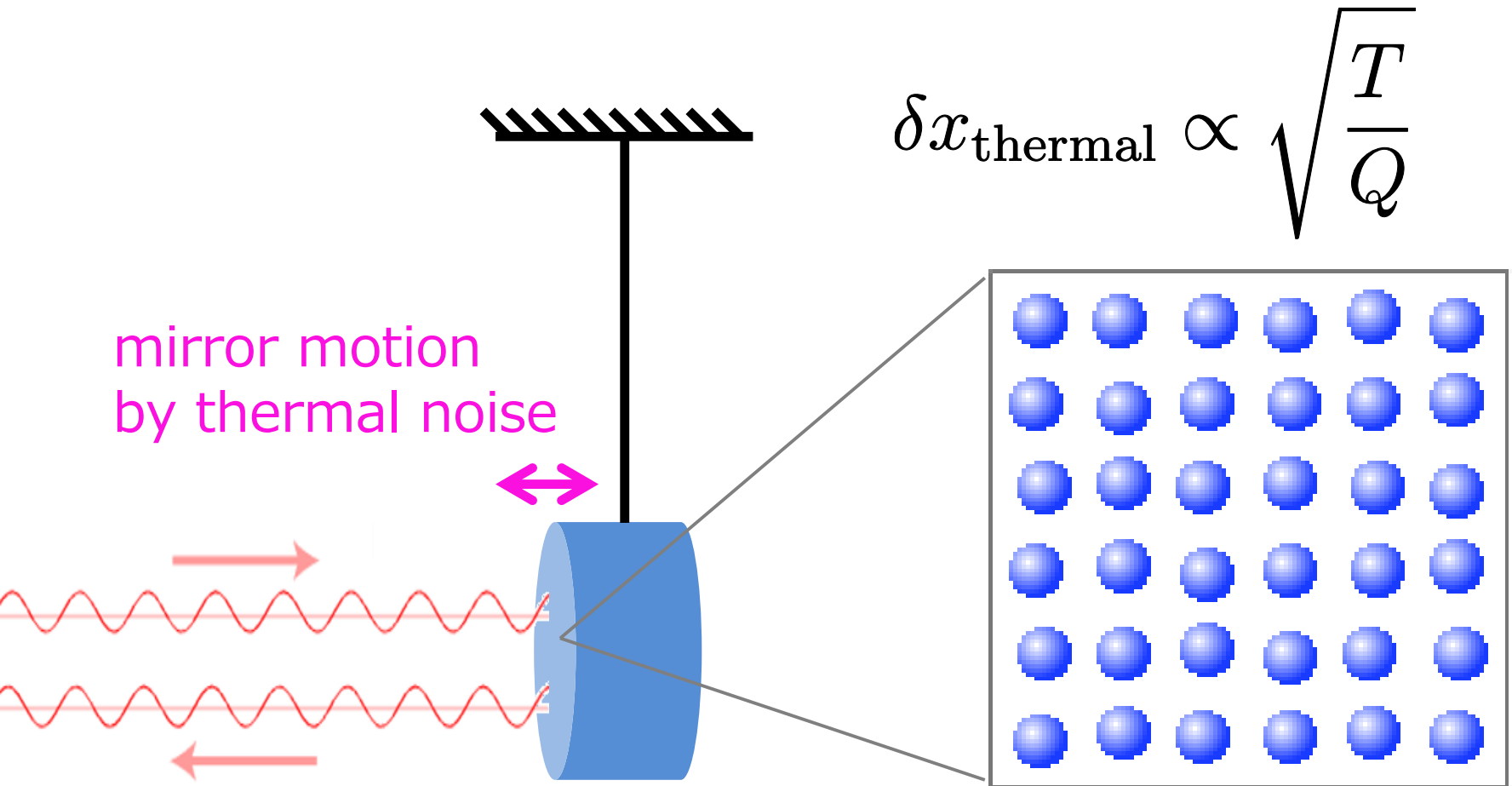


Room Temperature Suspension



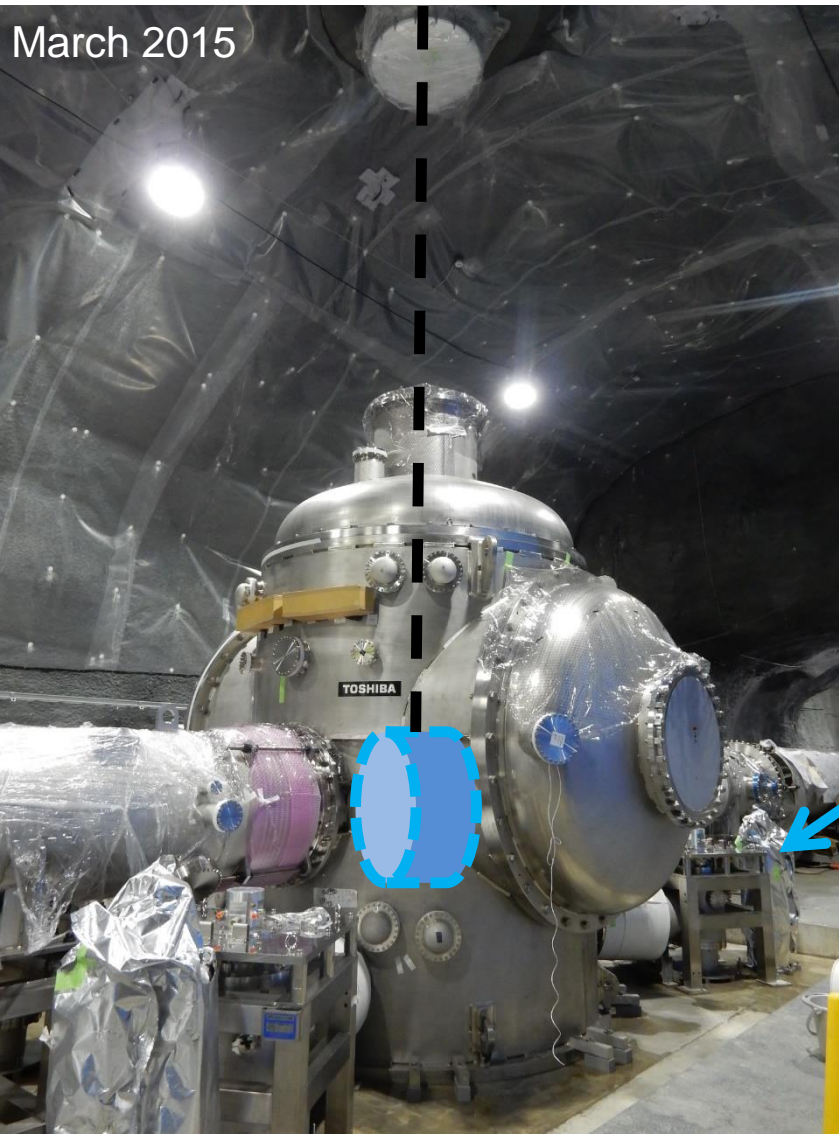
Thermal Noise

- Brownian motion of atoms creates thermal noise
- cool down mirrors to 20 K to reduce thermal noise



Cryostat

- developed cryocoolers with ultra-low vibration

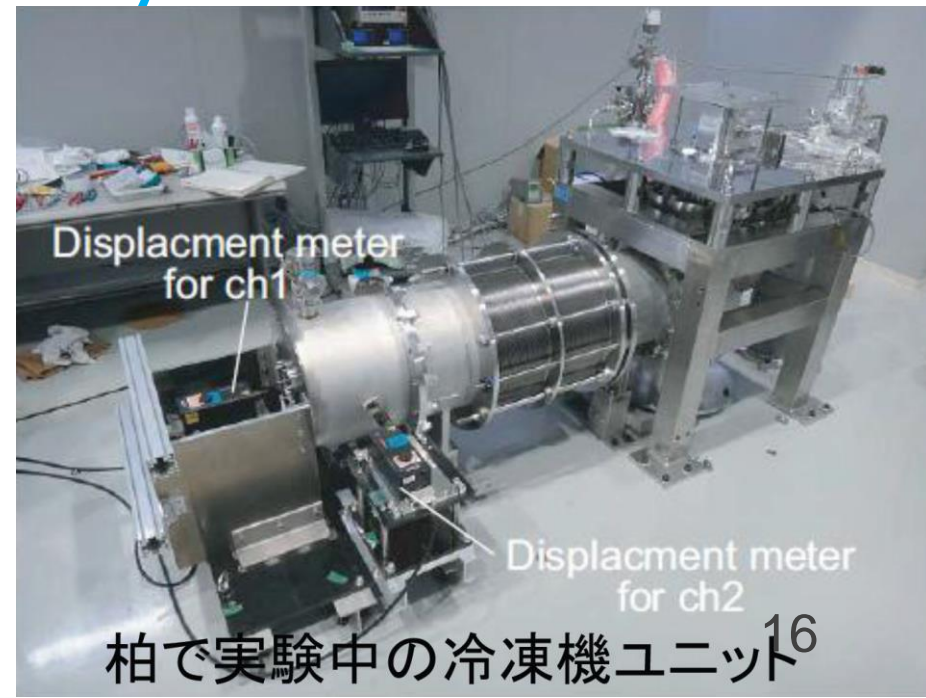


TOSHIBA
Leading Innovation >>>



JECC TORISHA Co.,Ltd.

cryocooler



柏で実験中の冷凍機ユニット¹⁶

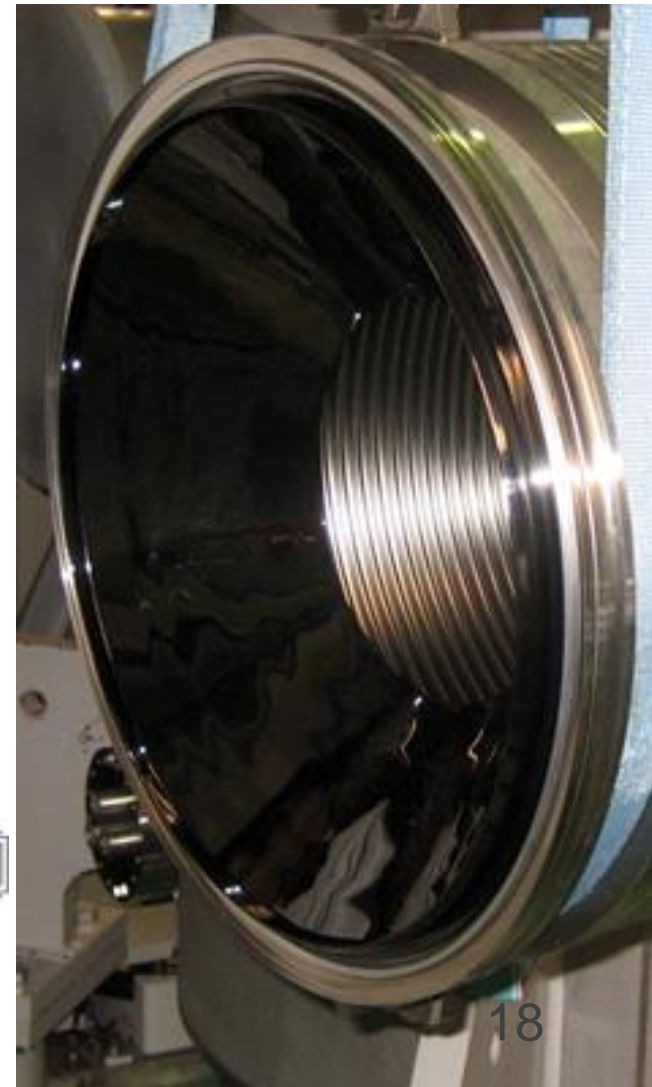
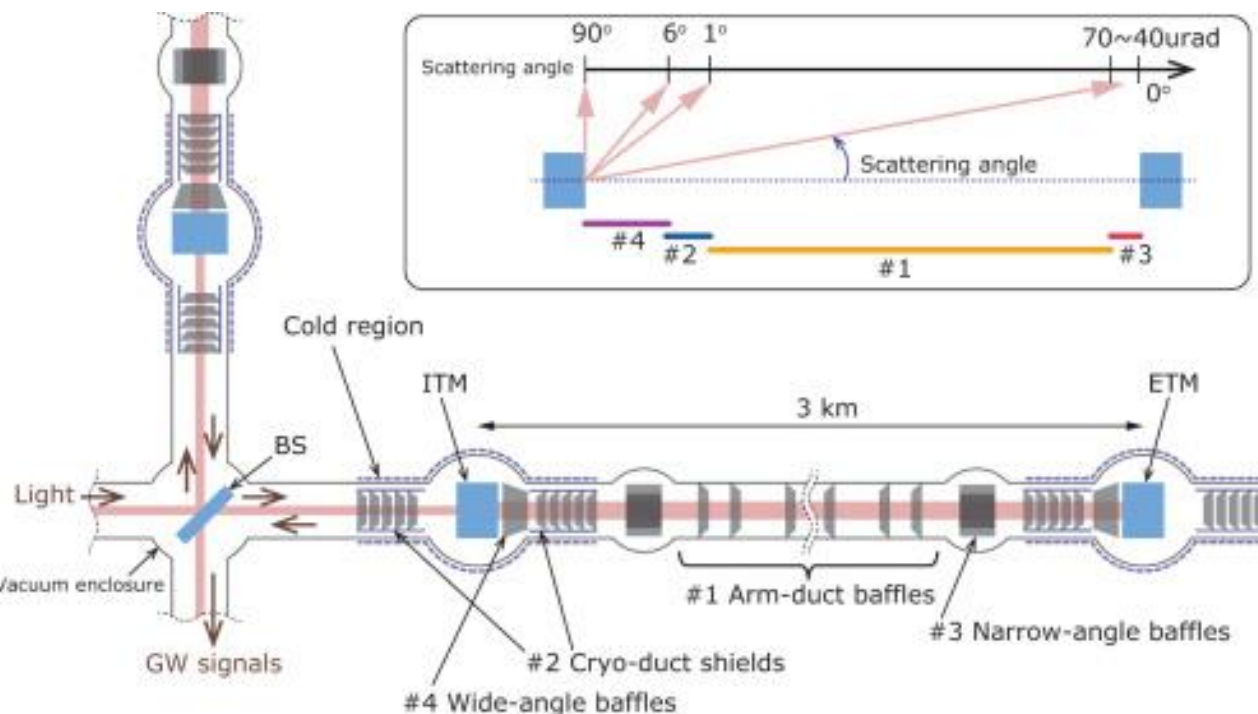
Inside the Cryostat



Optical Baffles

- for absorbing stray light and 300 K thermal radiation
- nickel-phosphorus-tungsten (NiPW) black coating

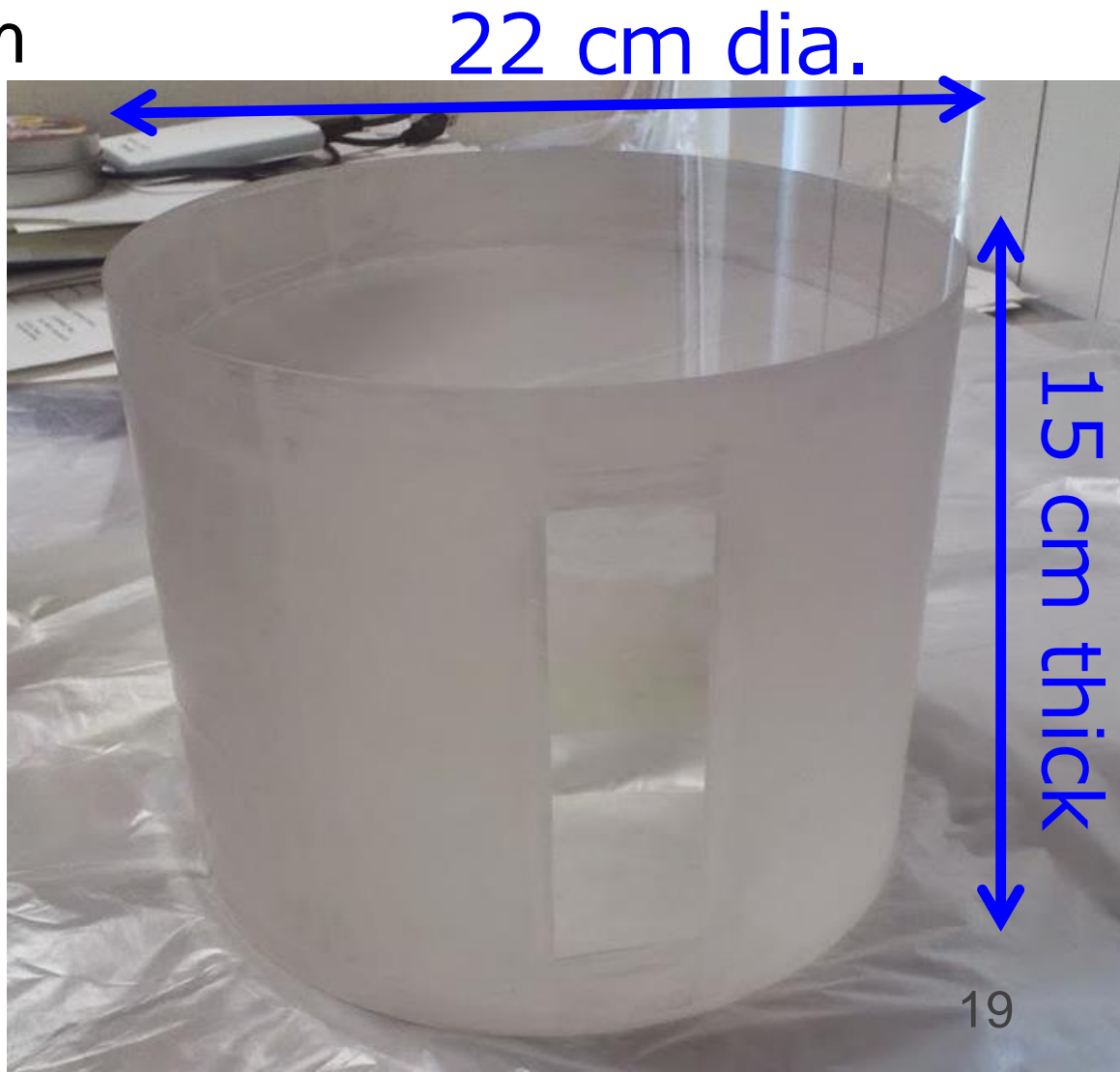
T. Akutsu+, Optical Materials Express 6, 1613 (2016)



Sapphire Mirror

- sapphire has high Q-value
- HR loss < 45 ppm
- absorption < 50 ppm/cm
- figure error < 0.5 nm rms

$$\delta x_{\text{thermal}} \propto \sqrt{\frac{T}{Q}}$$



Clean Environment

- ISO class 1 super clean booth



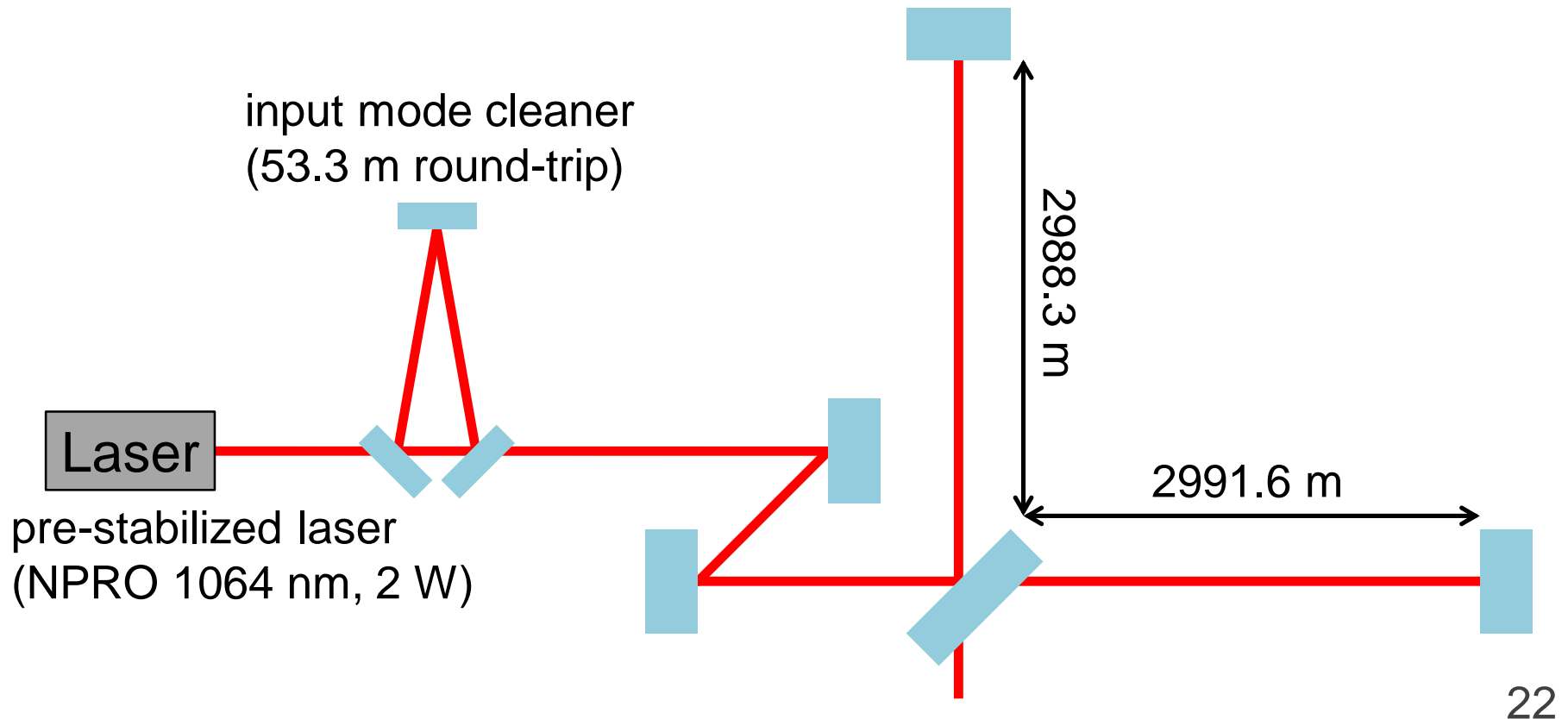
Recent News

- Nov 2015: inauguration of initial phase facility
- Mar-Apr 2016: First test runs with simplified 3-km Michelson configuration



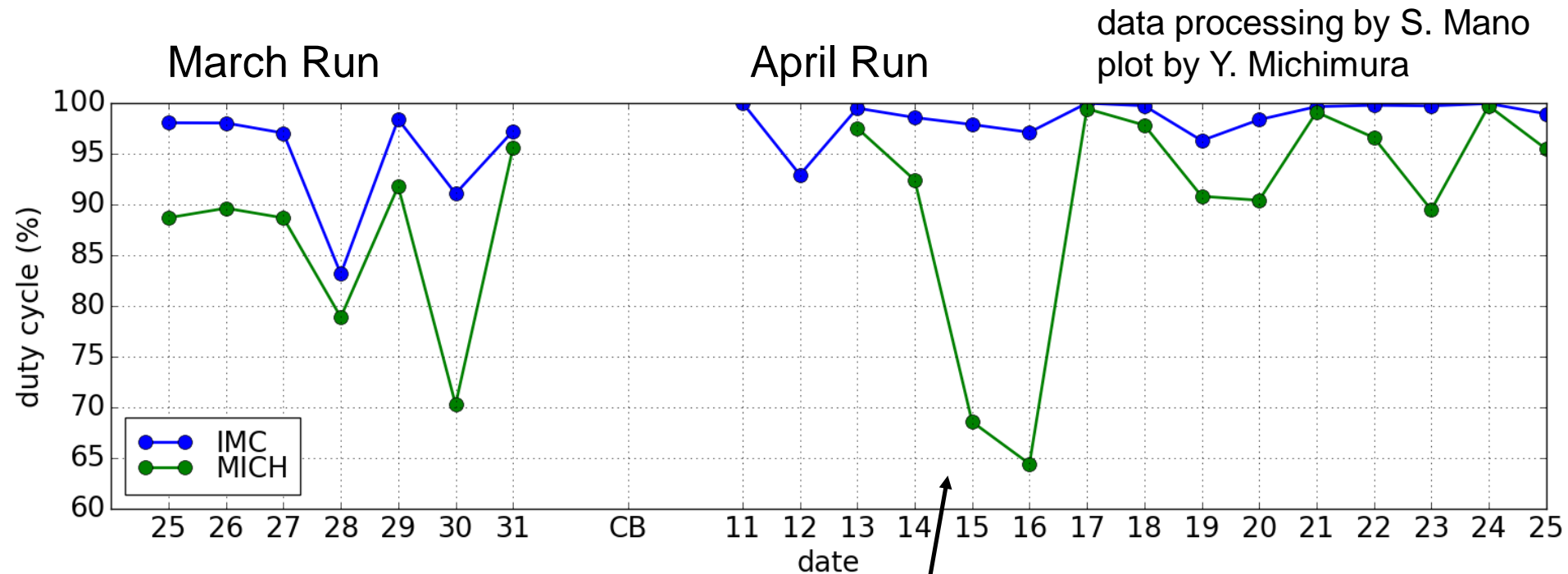
First Test Runs

- 3-km room temperature Michelson interferometer
- March 25 - 31 and April 11 - 25



Duty Factor

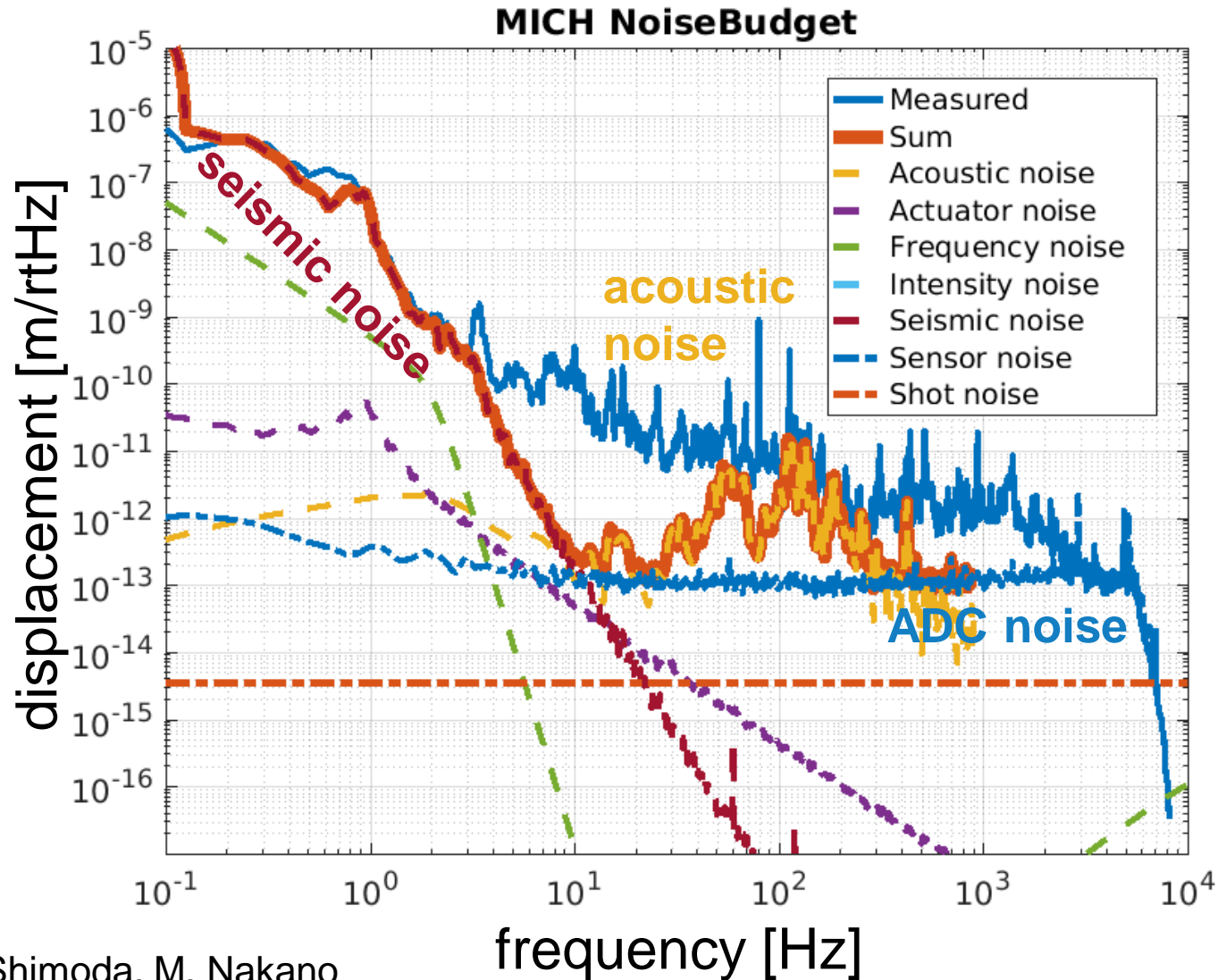
- 85.2 % for March run, 90.4 % for April run



Kumamoto Earthquake (7.0 Mw),
BS went wrong

Sensitivity

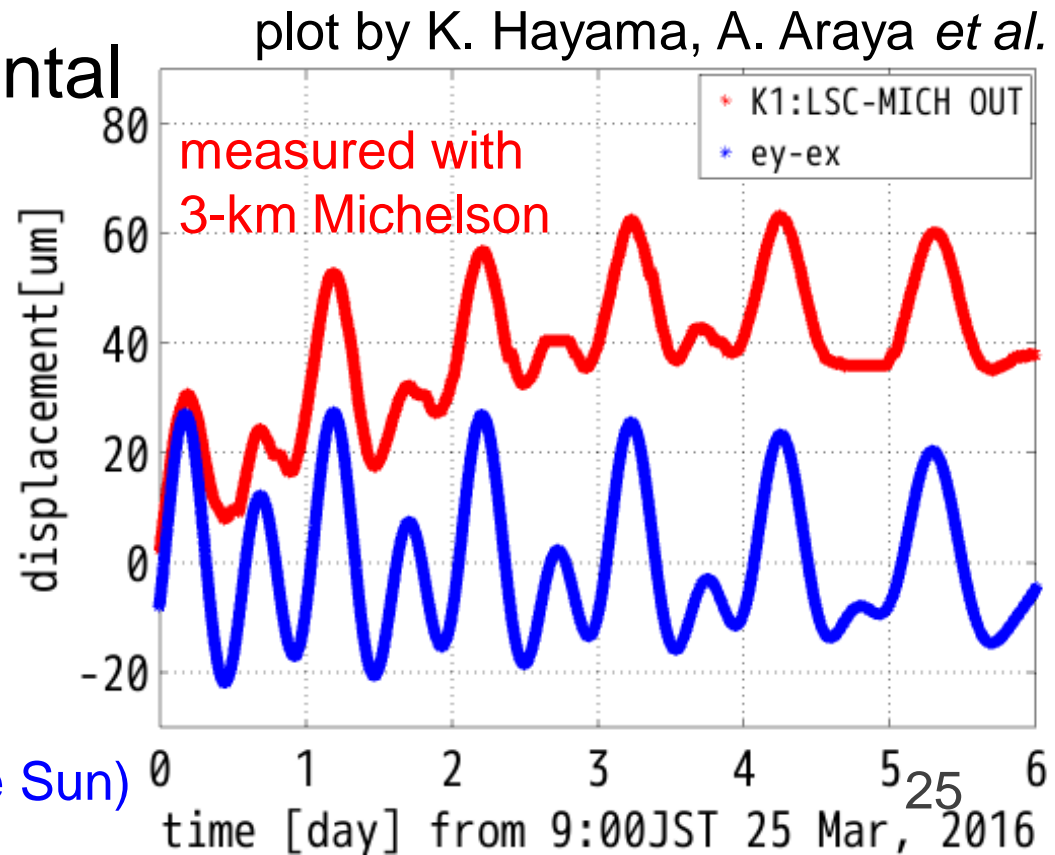
- not good, but the very first result for KAGRA



Test Run Results

- gained experience on 3-km interferometer operation
- observation shift and data transfer/management worked as expected
- acquired environmental data at KAGRA site
e.g. tidal length change of 3-km arms

prediction using GOTIC2 model
(tidal effect from the Moon and the Sun)



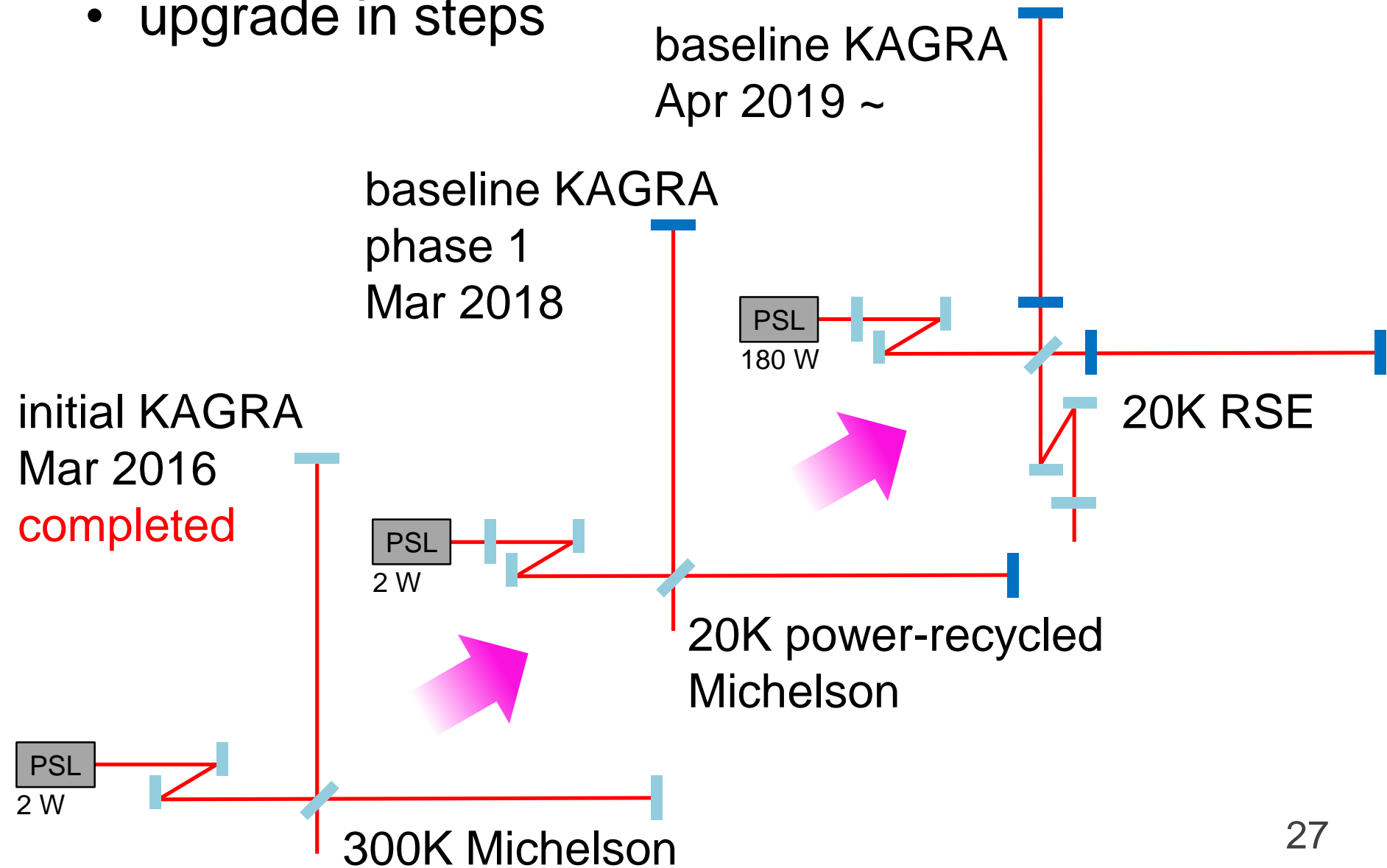
Data Transfer and Management

- real time transfer to **ICRR Kashiwa** and **Osaka City Univ.**
(~3 sec latency, ~ 200 MB/sec)
- delayed mirroring at **Academia SINICA, Taiwan** and **KISTI, Daejeon**
- 7.5 TB in total



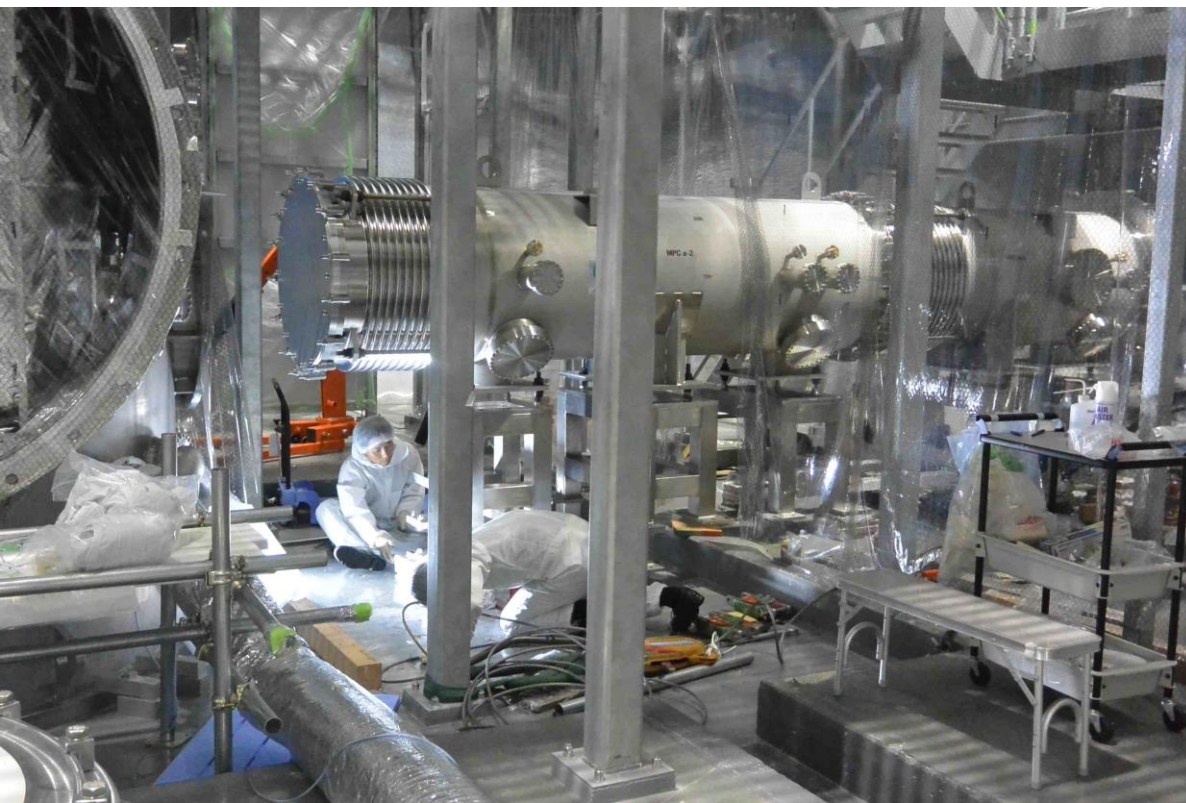
KAGRA Roadmap

- upgrade in steps



Recent Progress on Cryogenics

- cryogenic suspensions under development
- cryostat assembly on-going



photos from JGW-G1605315

Summary

- KAGRA is under construction at Kamioka, Japan
- Key features: **underground** and **cryogenic**
- First test runs with room temperature 3-km Michelson interferometer successfully completed on March 2016
- Cryogenic test run expected on March 2018
- Observation runs expected on ~ 2019