KAGRA Status Report

The 10th East Asian Meeting on Astronomy
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on behalf of KAGRA Collaboration

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Introduction

- Gravitational Wave was Predicted in 1916
- First observation by LIGO/Virgo(2015)
- Open a new window for observing the universe

Selected for a Viewpoint in *Physics*
PRL **116,** 061102 (2016) PHYSICAL REVIEW LETTERS week ending 12 FEBRUARY 2016

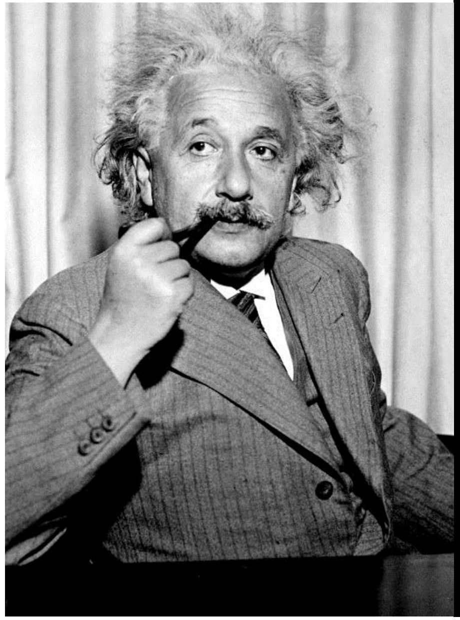
Observation of Gravitational Waves from a Binary Black Hole Merger

B. P. Abbott *et al.**
(LIGO Scientific Collaboration and Virgo Collaboration)

(Received 21 January 2016; published 11 February 2016)

On September 14, 2015 at 09:50:45 UTC the two detectors of the Laser Interferometer Gravitational-Wave Observatory simultaneously observed a transient gravitational-wave signal. The signal sweeps upwards in frequency from 35 to 250 Hz with a peak gravitational-wave strain of 1.0×10^{-21}. It matches the waveform predicted by general relativity for the inspiral and merger of a pair of black holes and the ringdown of the resulting single black hole. The signal was observed with a matched-filter signal-to-noise ratio of 24 and a false alarm rate estimated to be less than 1 event per 203 000 years, equivalent to a significance greater than 5.1σ. The source lies at a luminosity distance of 410^{+160}_{-180} Mpc corresponding to a redshift $z = 0.09^{+0.03}_{-0.04}$. In the source frame, the initial black hole masses are $36^{+5}_{-4} M_\odot$ and $29^{+4}_{-4} M_\odot$, and the final black hole mass is $62^{+4}_{-4} M_\odot$, with $3.0^{+0.5}_{-0.5} M_\odot c^2$ radiated in gravitational waves. All uncertainties define 90% credible intervals. These observations demonstrate the existence of binary stellar-mass black hole systems. This is the first direct detection of gravitational waves and the first observation of a binary black hole merger.

DOI: 10.1103/PhysRevLett.116.061102



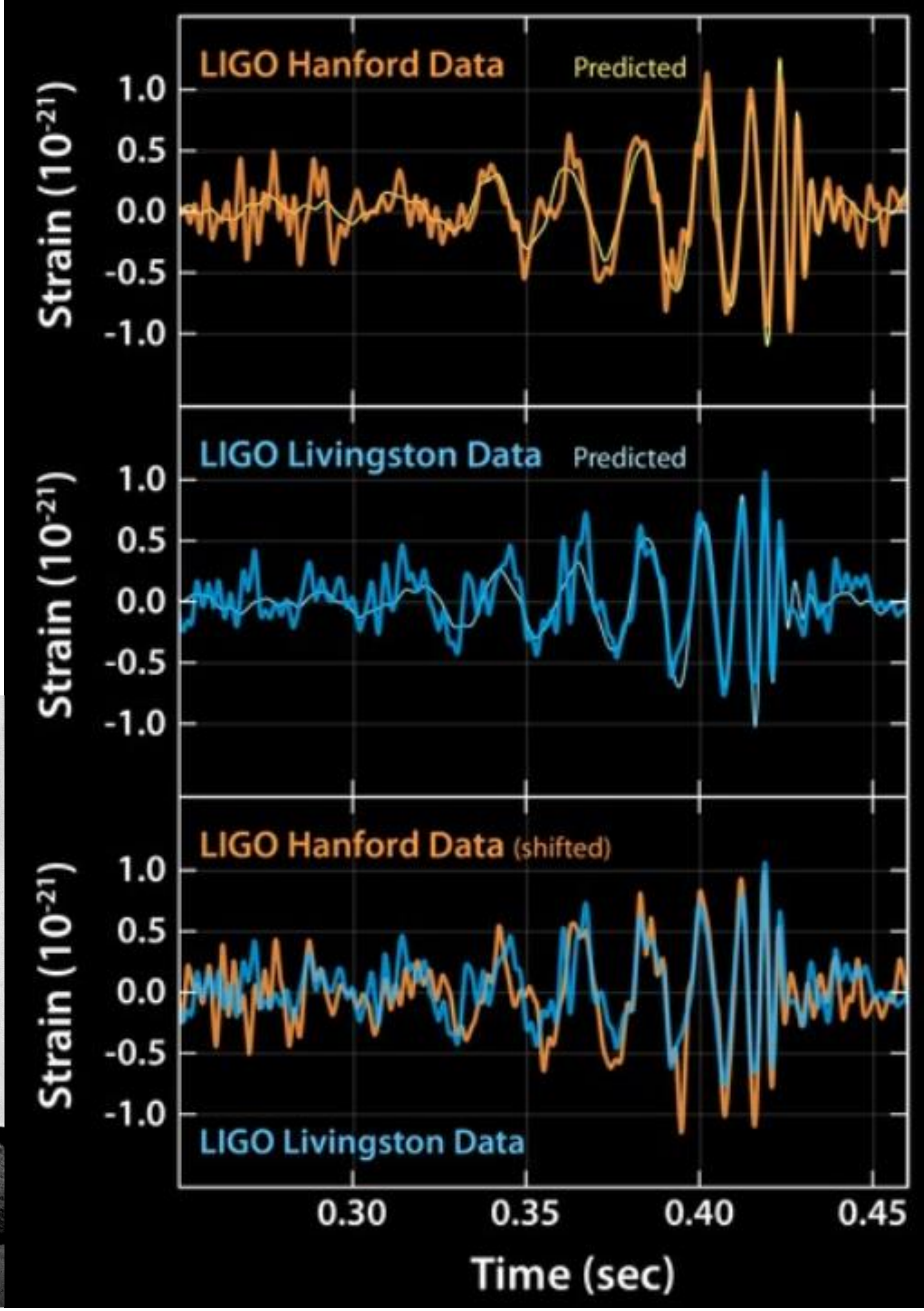
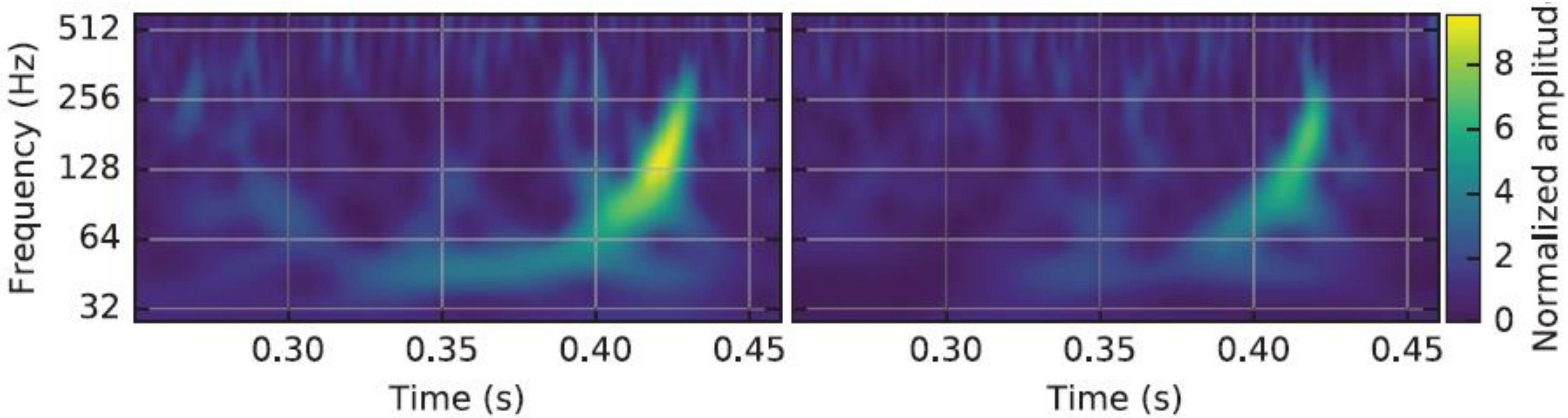


Image Credit: Caltech/MIT/LIGO Lab

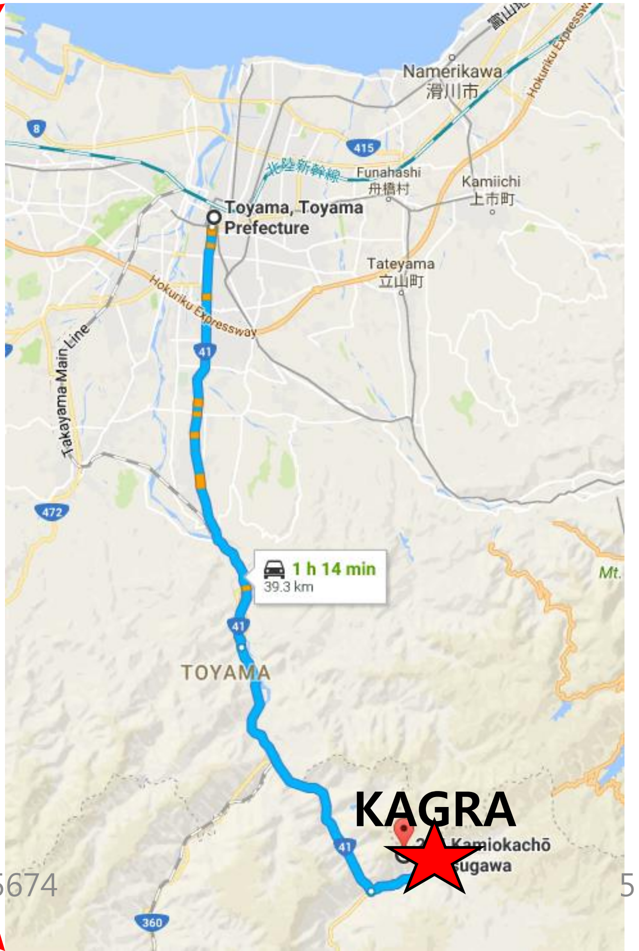
Introduction

- $M_1 = 36^{+5}_{-4}\mathrm{M}_\odot,\ M_2 = 29^{+4}_{-4}\mathrm{M}_\odot,\ M_f = 62^{+4}_{-4}\mathrm{M}_\odot$
- $d = 410^{+180}_{-160}\mathrm{Mpc} \approx 1.34 \times 10^9\mathrm{ly}$



Project Overview

- Unique *underground* and *cryogenic* interferometer of 3km
- Location: Mt. Ikenoyama, Toyama, Japan

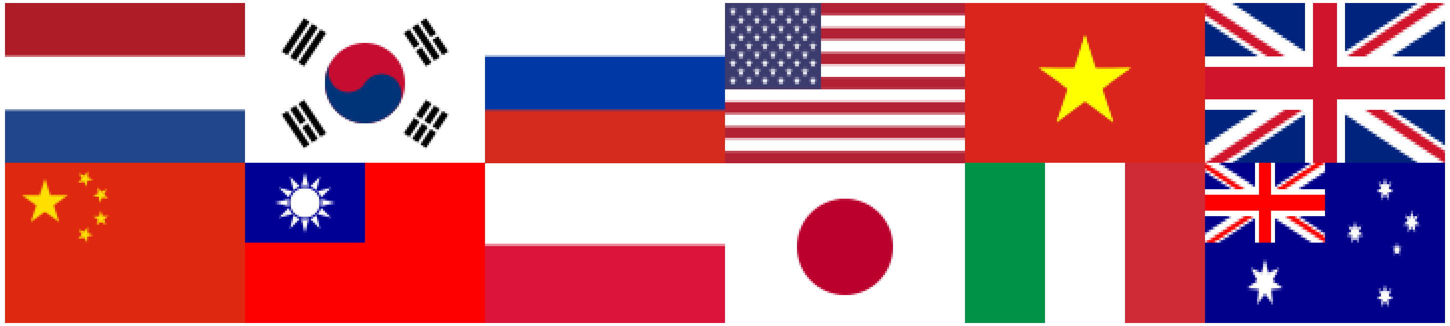


Project Overview

Image Credit: K. Kokeyama

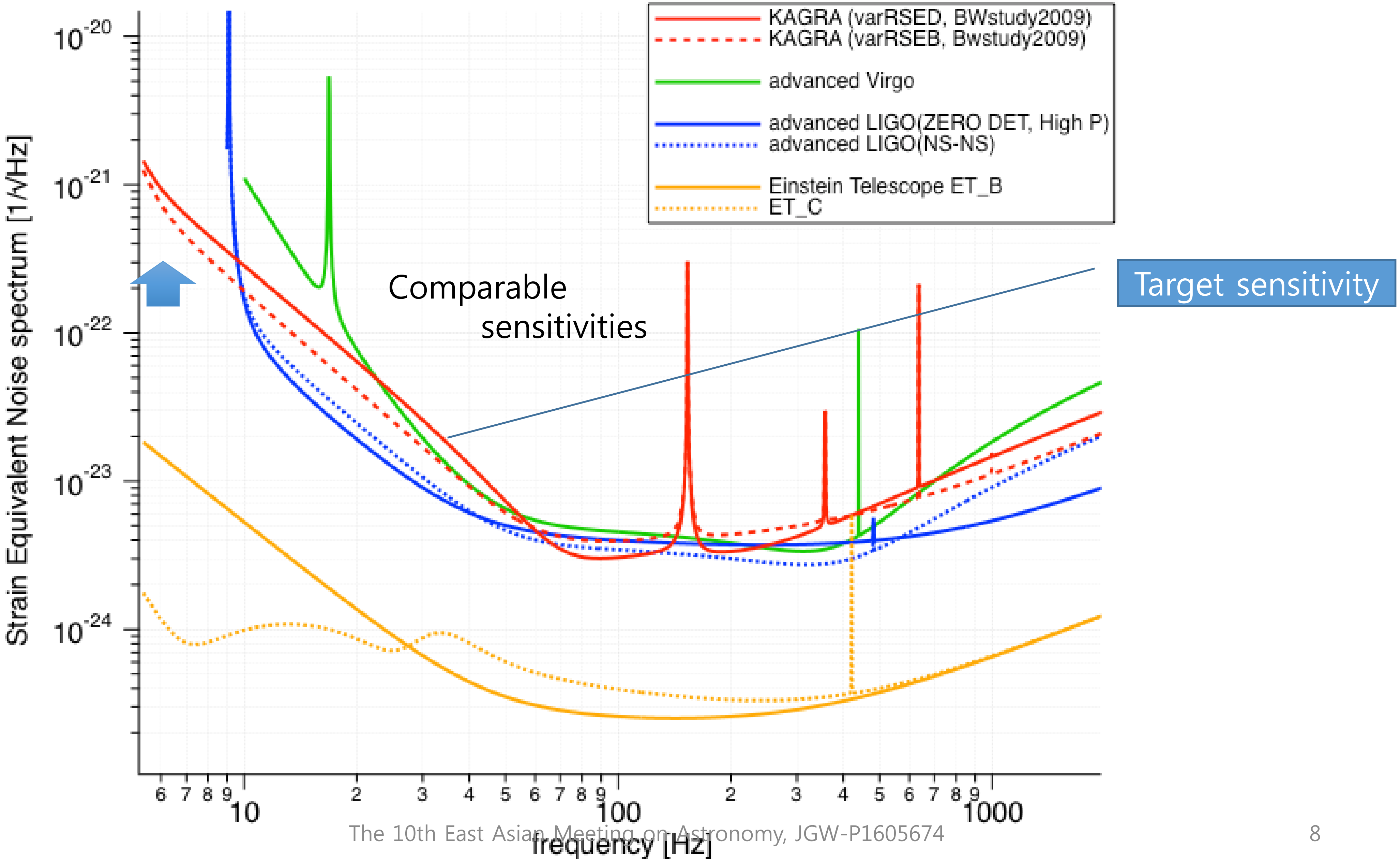
Project Overview(International Collaboration)

- Korea, China, Taiwan, Vietnam, Italy, US, Australia, Russia, UK, Netherlands, Poland



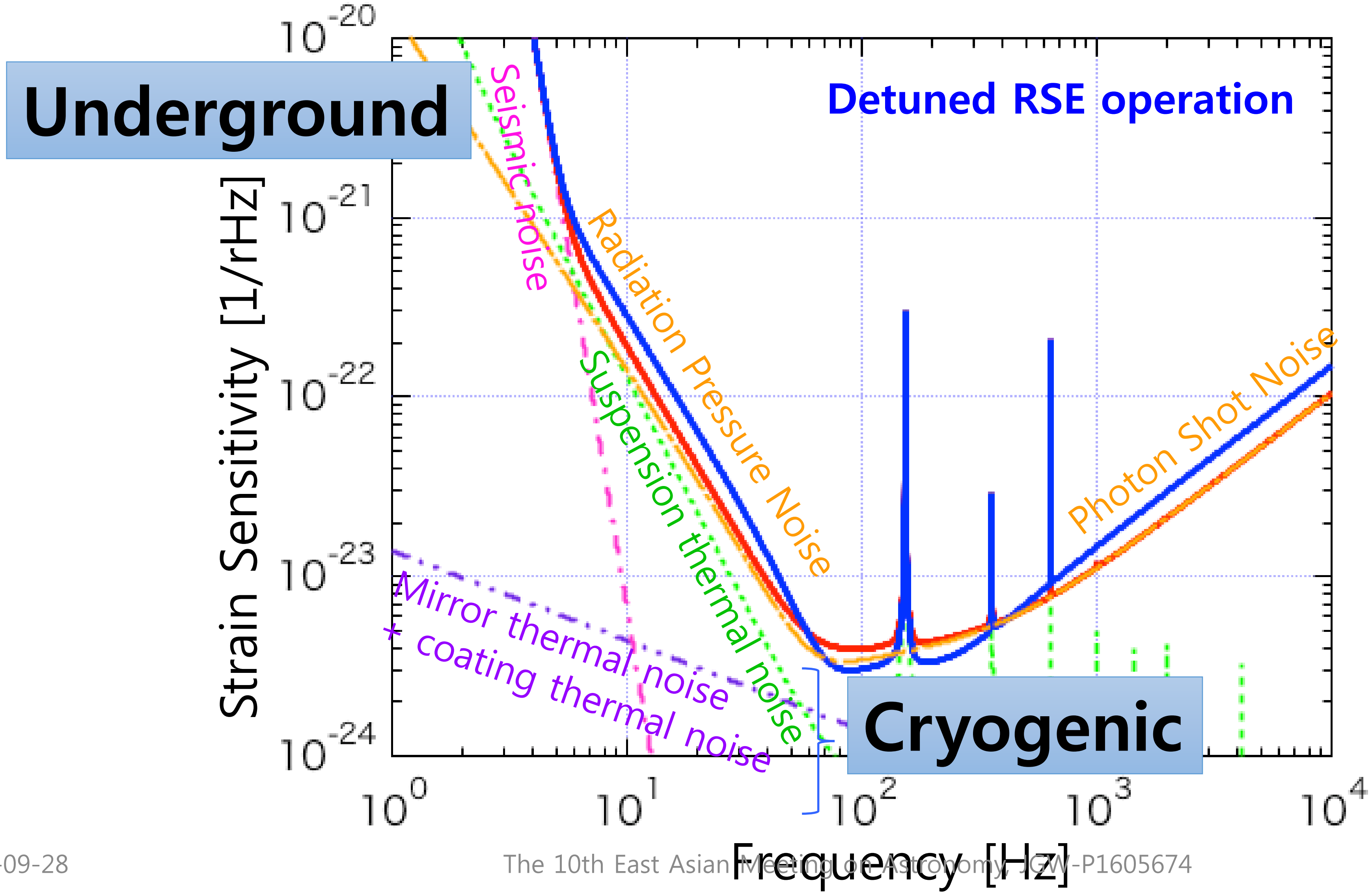
- Currently, 12 countries including Japan

Sensitivities of 2nd & 3rd Generation GW Telescopes



Noise Budget of KAGRA

h ~ factor x 10^{-24} [/√Hz] for observation band



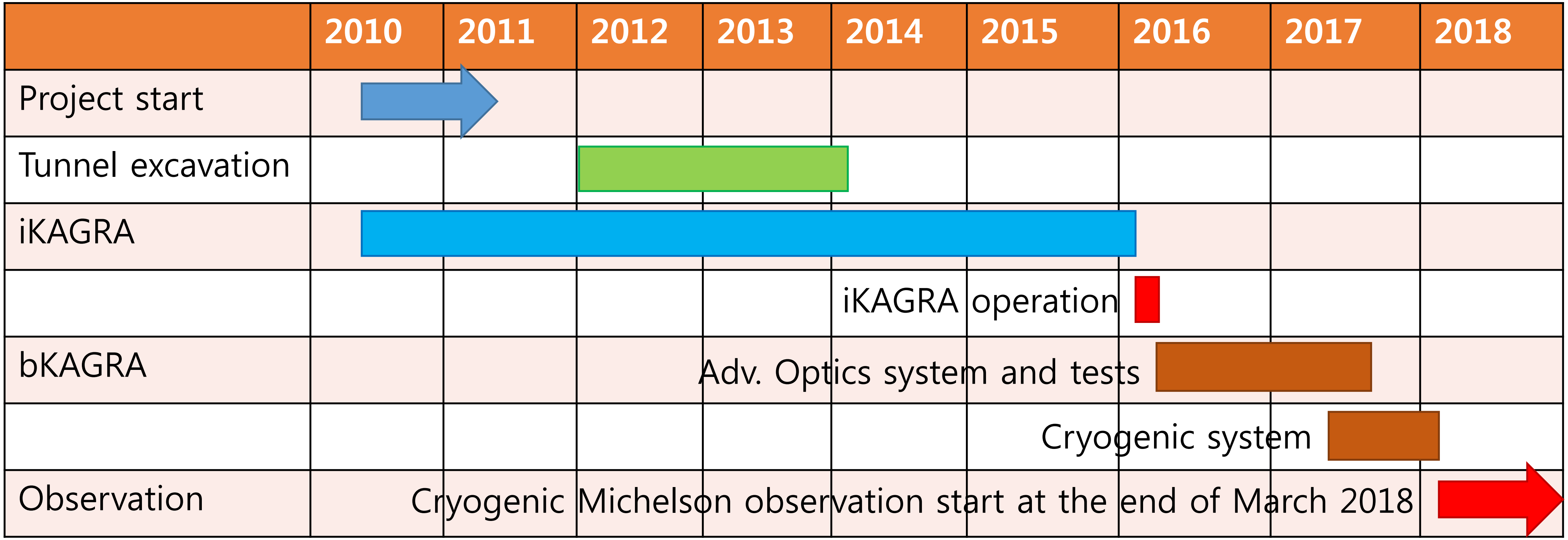

Cryogenic Mirror System
Features in
KAGRA
Underground

Data Storage and Software

- ICRR(University of Tokyo)
- Osaka City University
  (latency ~3seconds)
- Korea Institute of Science and Technology Information(KISTI, Korea)
- Academia Sinica(Taiwan)

- Software
  - KAGALI

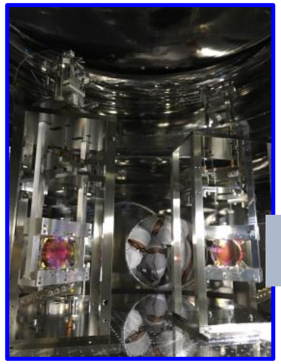
Overall Schedule

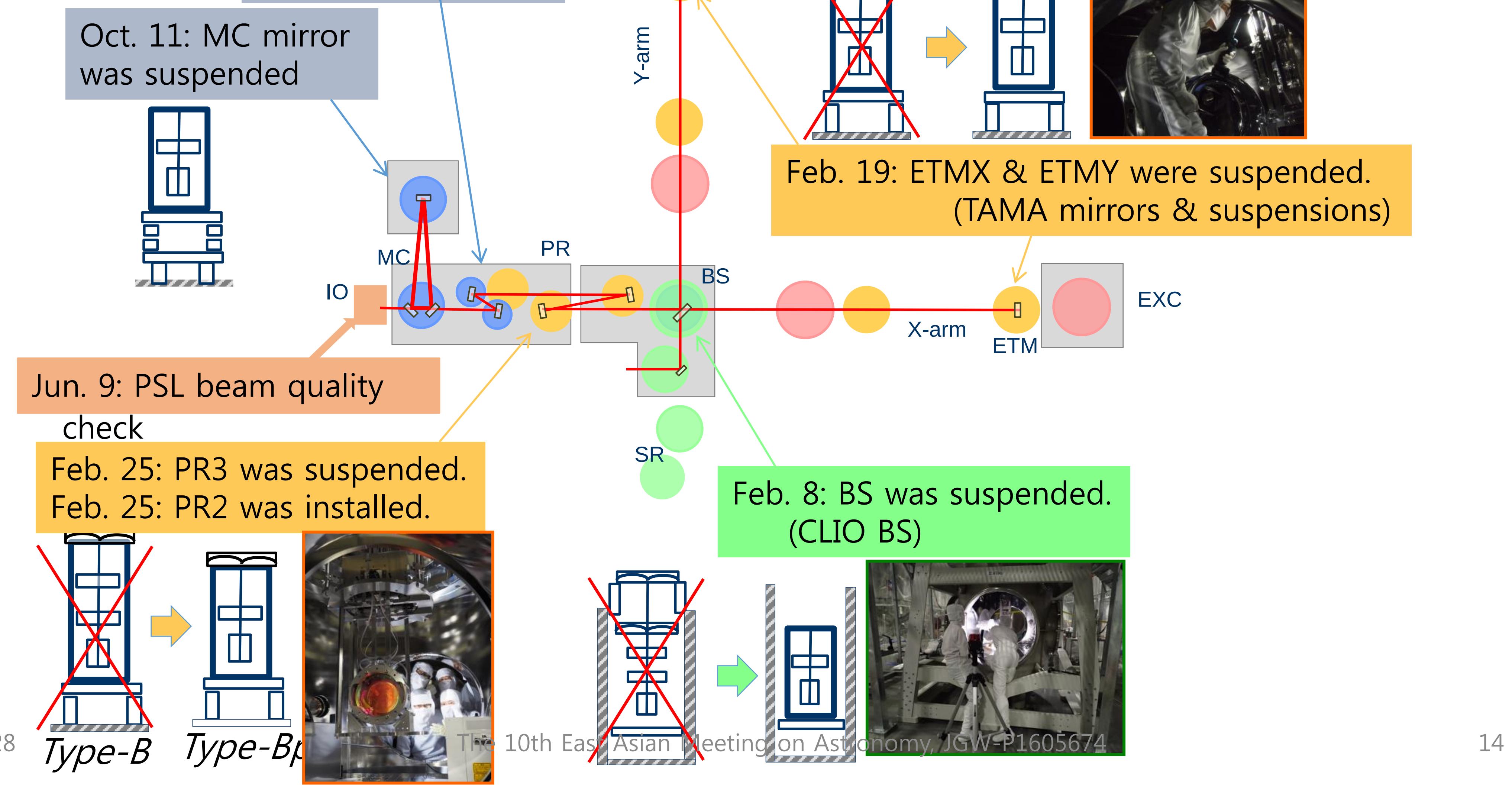


Scientific Goals

- Astrophysics
  - Radiation from compact/massive objects
  - Multi-messenger astronomy
  - Black hole, Neutron star, Supernovae, GRB, etc…
  - New window for observing the universe
- Physics
  - Test of general relativity in strong field
- Cosmology
  - Cosmic background of GW
  - Galaxy and star evolution

iKAGRA commissioning milestones





Mar. 25: iKAGRA operation was started.

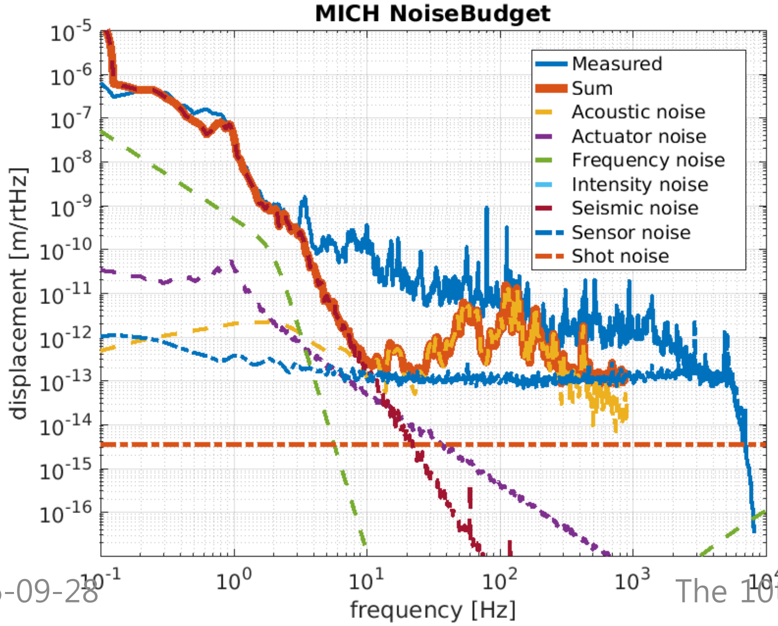
iKAGRA 1st run: Mar. 25 - 31, 2016

iKAGRA 2nd run: Apr. 11 - 25, 2016

Typical Sensitivity

$6 \times 10^{-16}\,\mathrm{Hz}^{-1/2} @ 100\,Hz$

plot by T. Shimoda
M. Nakano, Y. Michimura



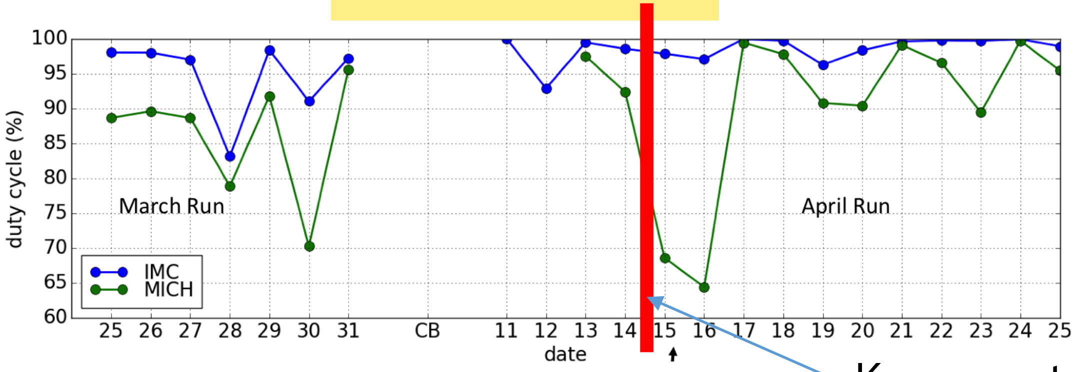
Duty Factor

1st run: 85.2%

2nd run: 90.4%

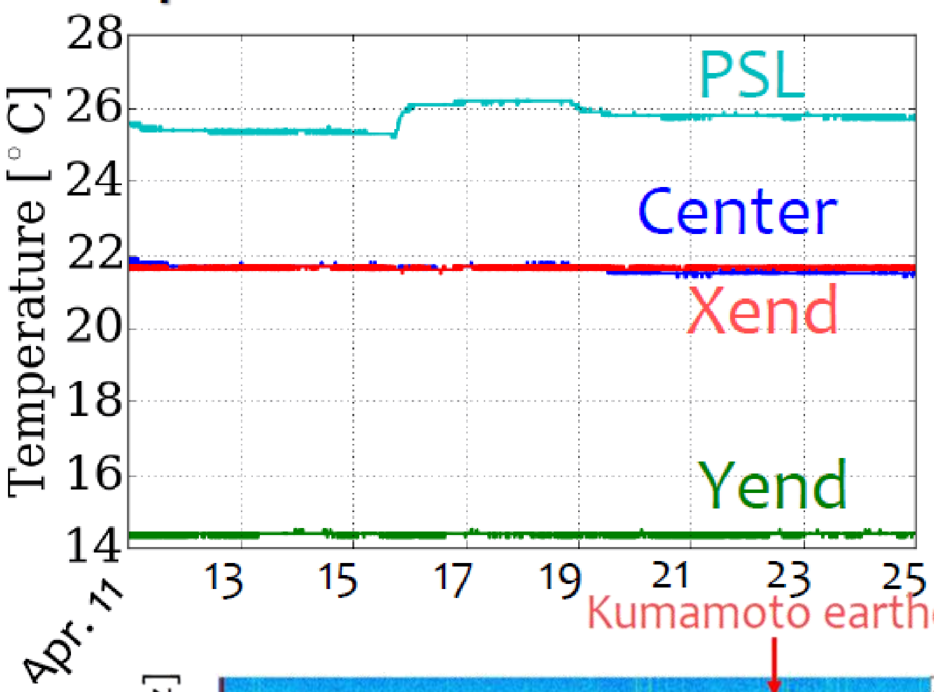
Injection test -> Yokozawa

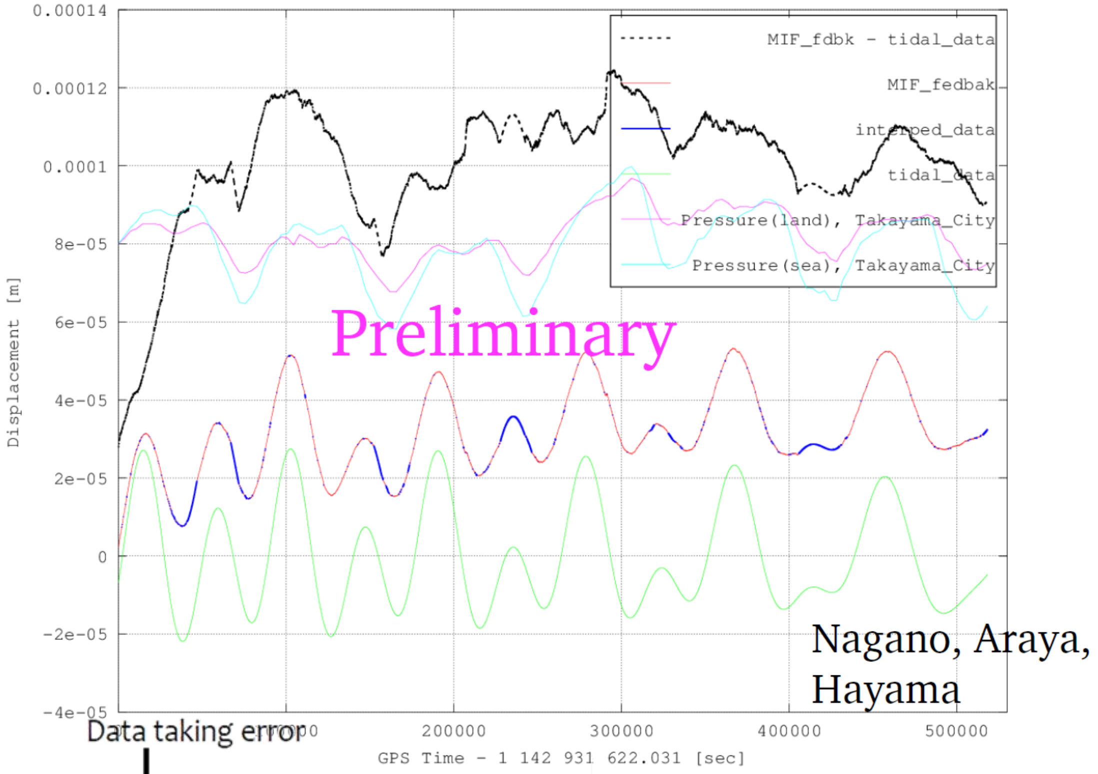
Detector Characterization -> Hayama

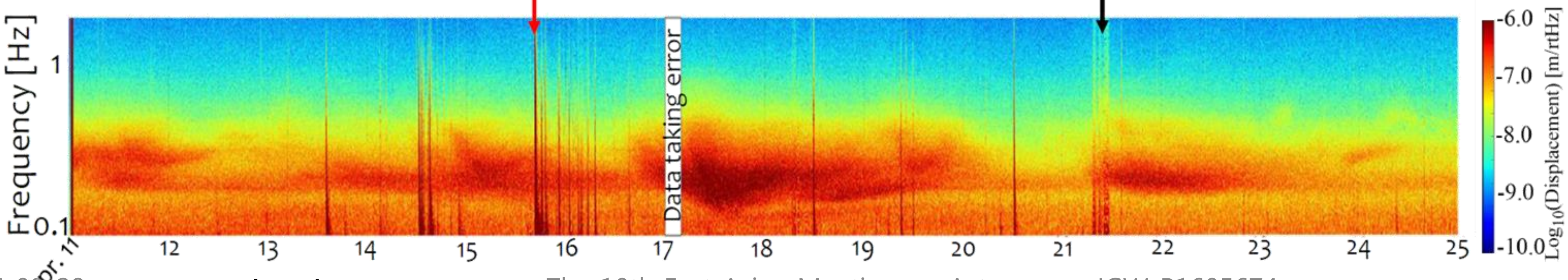


Kumamoto earthquake

Environment during iKAGRA







A. Shoda

iKAGRA Operation

Short Commissioning(4/12)
- Actuator gain calib. Peaks added
- Mci feedback added for IMC
- ETMX/Y coil balance modified
- Guardian bug fix(4/13)

First Run(3/25-31)
- Mid fringe lock
- Lost lock every ~30min.
- Alignment adjusted manualy
- Calib. Done off0line
- PMC re-locked manually
- GVs close to IXA/IYA closed
- PR2-BS duct open
- EX/Y coil balance sign incorrect

Commissioning Break(4/1-10)
- Changed oplev
- IMC servo topology changed
- PR2-BS duct was connected
- BVs close to IXA/IYA were opened

Second Run(4/11-25)
- Longer lock duration
- More stable IMC

Learning from iKAGRA

Required time and manpower is more than expected
Task assignment is not clear

Learn how to lock long beam line
Bug fixes for some control system
Obtain site specific information

It works!

Toward bKAGRA

Based on the experience of iKAGRA, we plan to proceed bKAGRA in 3 steps.

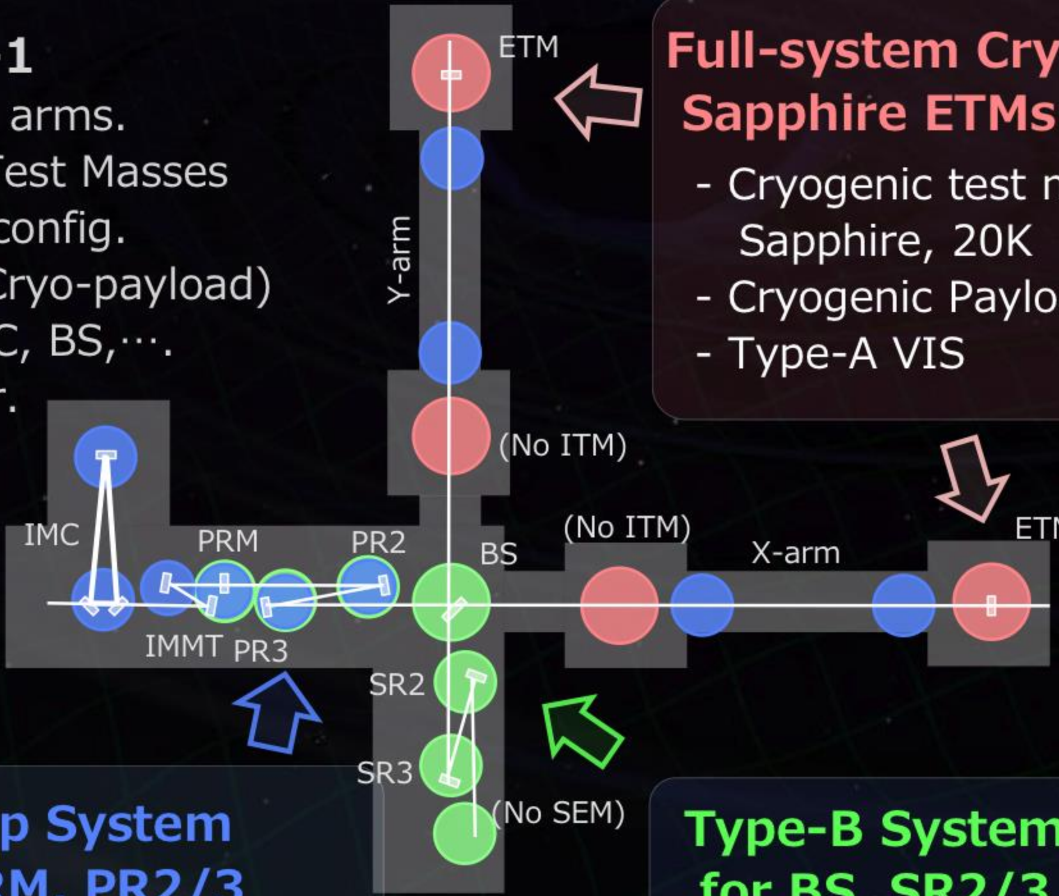
Phase-1 : Operation of a 3km cryogenic Michelson interferometer (-2018. 3).

Phase-2 : Operation with full configuration: cryogenic and RSE (2018.4 – 2019 1Q??)

Phase-3 : Commissioning and Observation run (2019 2Q ??-)

bKAGRA Phase-1 (- 2018.3)

bKAGRA Phase-1
- PRMI with 3 km arms.
- Cryogenic End Test Masses suspended full config. (Type-A VIS +Cryo-payload)
- Final VIS for PRC, BS,⋯.
- Low laser power.



Full-system Cryogenic Sapphire ETMs


- Cryogenic test masses Sapphire, 20K
- Cryogenic Payload
- Type-A VIS

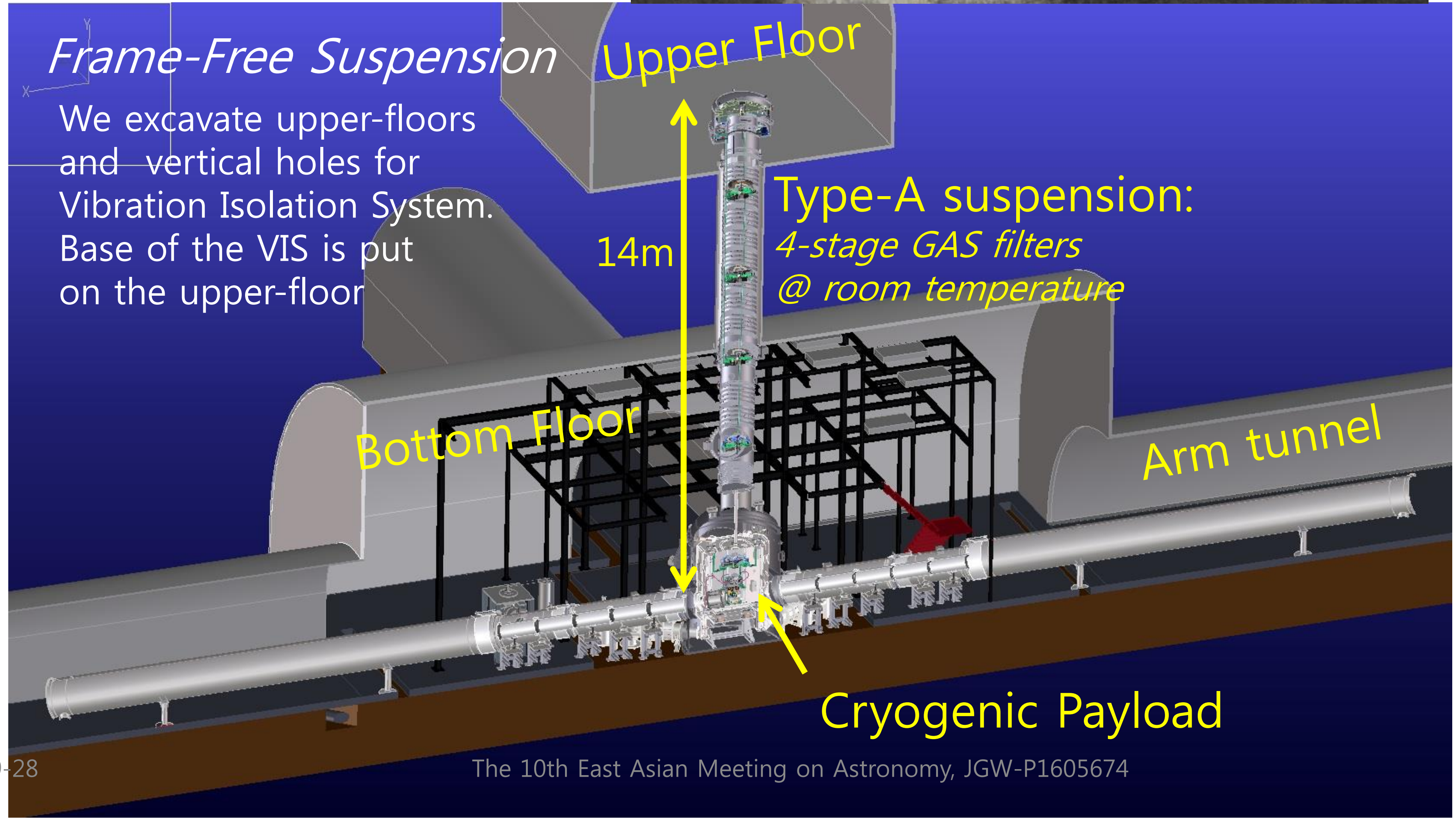
Type-Bp System for PRM, PR2/3


- Final Config.
- Room temp., 300K
- Power Recycling implementation is TBD

Type-B System for BS, SR2/3


- Final config.
- Room temp., 300K
- No SRM

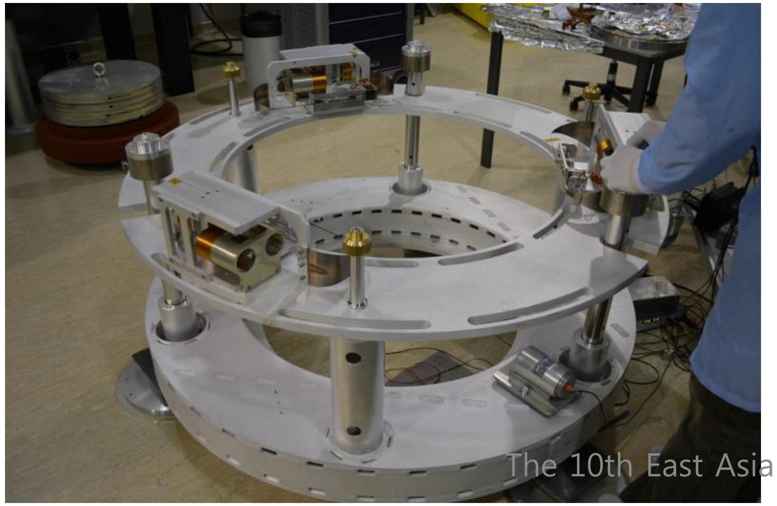
Main Mirror Suspension



We have already rushed toward bKAGRA

X-end cryostat assembly

Inverted pendulum for Type-A suspension

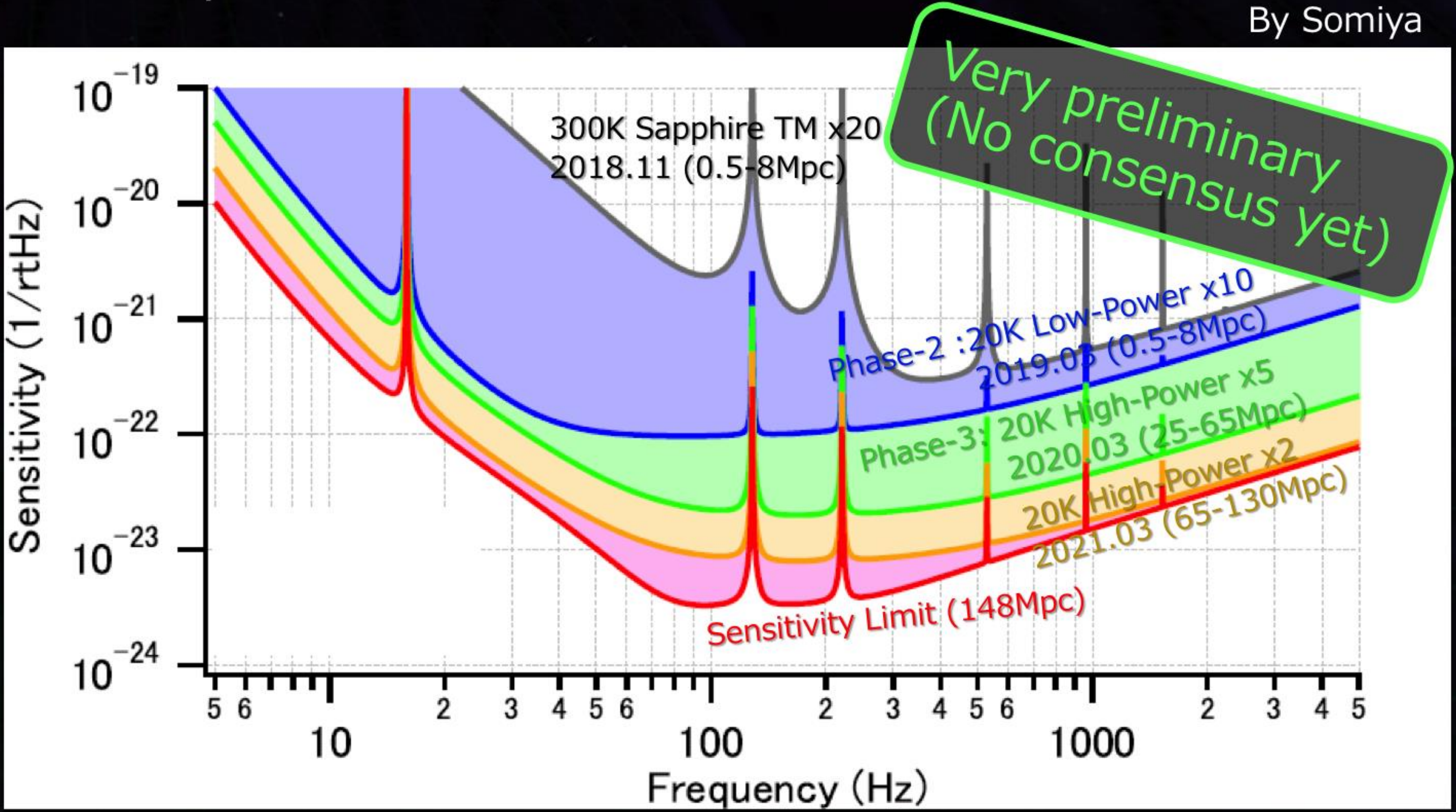


Vacuum chamber for Type-A

Sensitivity Prediction

- Not a promise or consensus. Just for reference

By Somiya



Participation of Korean Group

- Join from 2011 via Korean Gravitational-Wave Group(KGWG)
- KGWG
  - PI: Prof. Hyung Mok Lee(Seoul National University)
  - Participations: Device, Detector Characterization, Data Analysis
  - Institutes: Seoul National University, Hanyang University, Sogang University, Korea University, Myeongji University, Pusan National University, Inje University, KISTI, NIMS, KASI

- Sejong University for GPU-data analysis

Summary

- KAGRA is a new 2nd generation GW interferometer under construction in Japan.
- Cryogenic mirror system and underground site are the most advanced features in KAGRA.
- iKAGRA test operation was done in March/Apr. 2016. We learned a lot of issues from this experience toward bKAGRA.
- bKAGRA will be proceeded in 3 steps. First phase will be cryogenic Michelson and first run must be done by Mar. 2018.
- bKAGRA phase-2 will be full configuration and will start around 2019.
- We will be a part of global GW observation network around then and will lead new age of GW physics and astronomy together.