Introduction of KAGRA, Status of KAGRA

- Underground and Cryogenic interferometric 3 km gravitational-wave detector at Kamioka, Japan

(c) KAGRA Collaboration / Rey.Hori

Hisaaki Shinkai (Osaka Inst. Tech.)

KAGRA Scientific Congress, board chair
on behalf of KAGRA collaboration

JGW-G2012314

Why Shinkai talks instead of Kajita-san?

Science Council of Japan vs Prime Minister Suga

Kajita-san became the head of SCJ, October 1, 2020. On that day, one big political problem was scooped; PM Suga refused to approve 6 new SCJ members without opening reasons.

the japan times

NATIONAL

Suga meets science council chief amid furor over rejected nominees

Takaaki Kajita, head of the Science Council of Japan, speaks to reporters at the Prime Minister's Office Friday after meeting Prime Minister Yoshihide Suga. | KYODO

KYODO

SHARE Oct 16, 2020

Prime Minister Yoshihide Suga met with the president of the Science Council of Japan on Friday amid mounting criticism over the premier's decision to block six scholars from joining the government advisory body.

Takaaki Kajita said they discussed "the future of the council" but Suga did not provide an explanation for why he refused to appoint the nominees last month.

AAAS Become a Member

Science Contents News Careers Journals

The president of the Science Council of Japan, Nobel laureate Takaaki Kajita, speaks out against the prime minister's decision not to appoint six nominees. KYODO VIA AP IMAGES

Japan's new prime minister picks fight with Science Council

By Dennis Normile | Oct. 5, 2020 , 11:45 AM

Japan's new prime minister, Yoshihide Suga, has disrupted the process by which scientists are appointed to serve on the governing body of the country's leading academic society. Researchers see the move against the Science Council of Japan (SCJ) as a threat to academic freedom.

SCJ makes policy recommendations, promotes scientific literacy and international cooperation, and represents the interests of more than 800,000 scholars in virtually all academic disciplines. Its current president is Takaaki Kajita, a 2015 Nobel Prize winner in physics who just assumed his post.

The council's governing body, called the General Assembly, is made up of 210 members serving staggered 6-year terms that began last week. Although the council

SCJ is an independent body of the government and consults with the government from a scientific standpoint. The government has never spoken to the selection of people.
Newspapers say this is because the SCJ continues to express its opposition to military research.

This political problem continues 2.5 months already and no progresses for solution.

nature

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EDITORIAL · 06 OCTOBER 2020

Why *Nature* needs to cover politics now more than ever

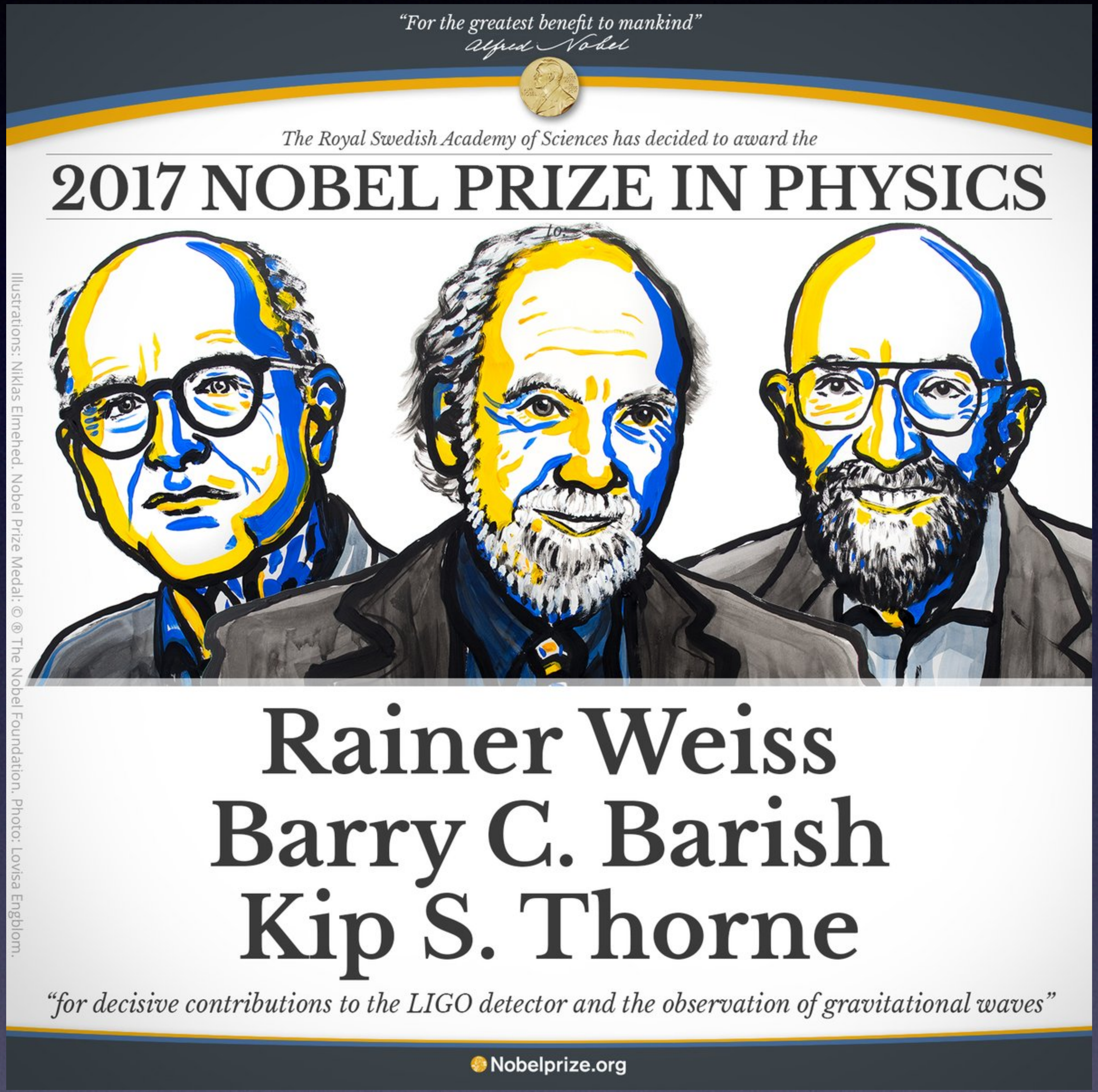
Science and politics are inseparable — and *Nature* will be publishing more politics news, comment and primary research in the coming weeks and months.

First Detection (2015 Sep 14)

2017 Nobel Prize

Feb 2016, LIGO announced the first detection of GW (GW150914). The source was Binary BH.

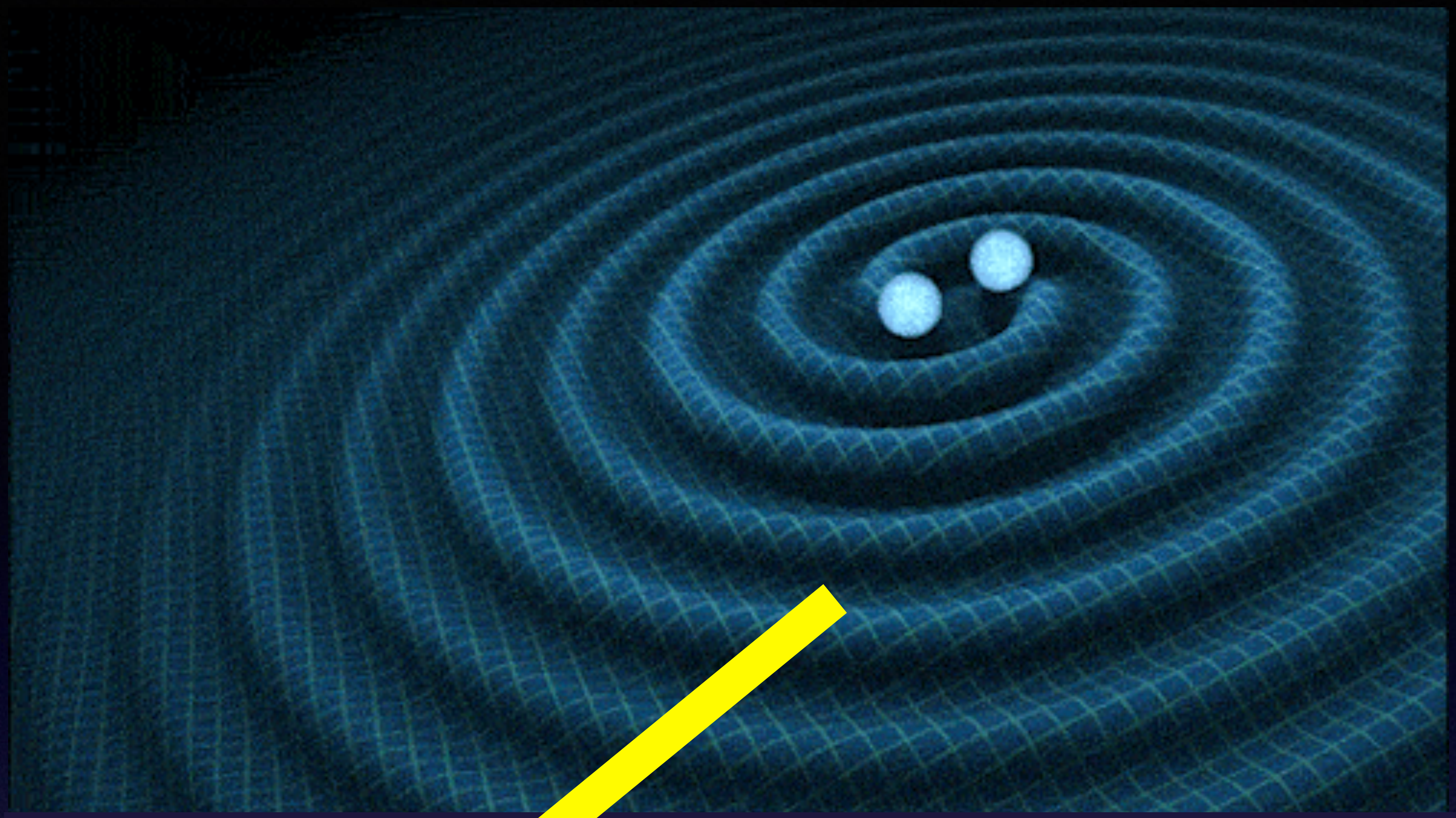
Oct 2017, LIGO/Virgo announced the first GW detection from Binary NSs (GW170817).

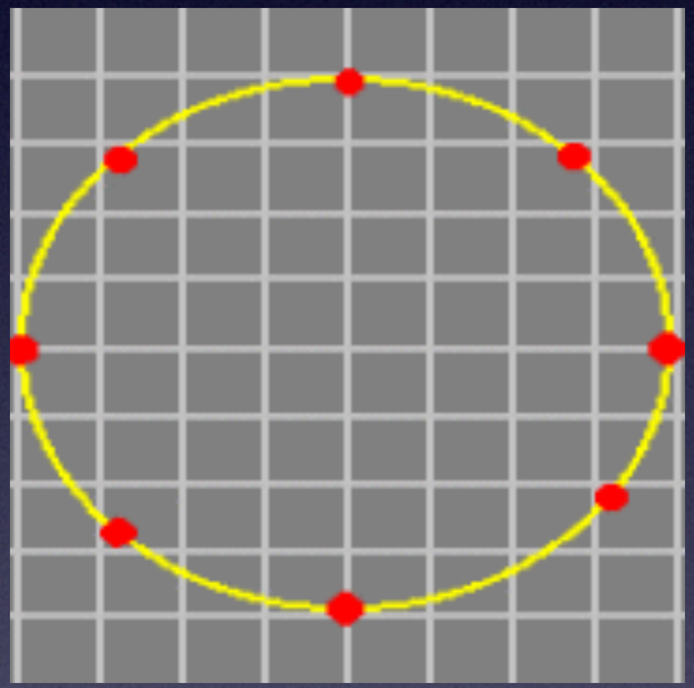


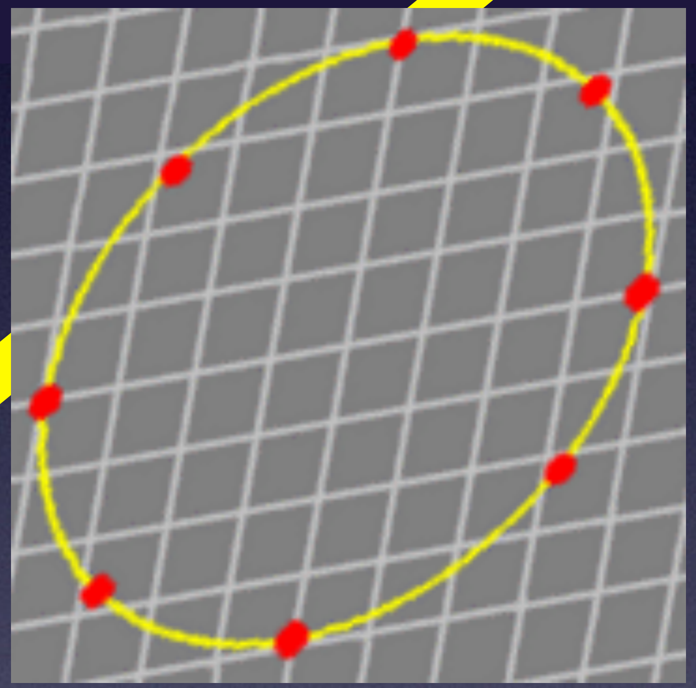
Oct 2017, Royal Swedish academy of science announced the physics prize goes to GW project.

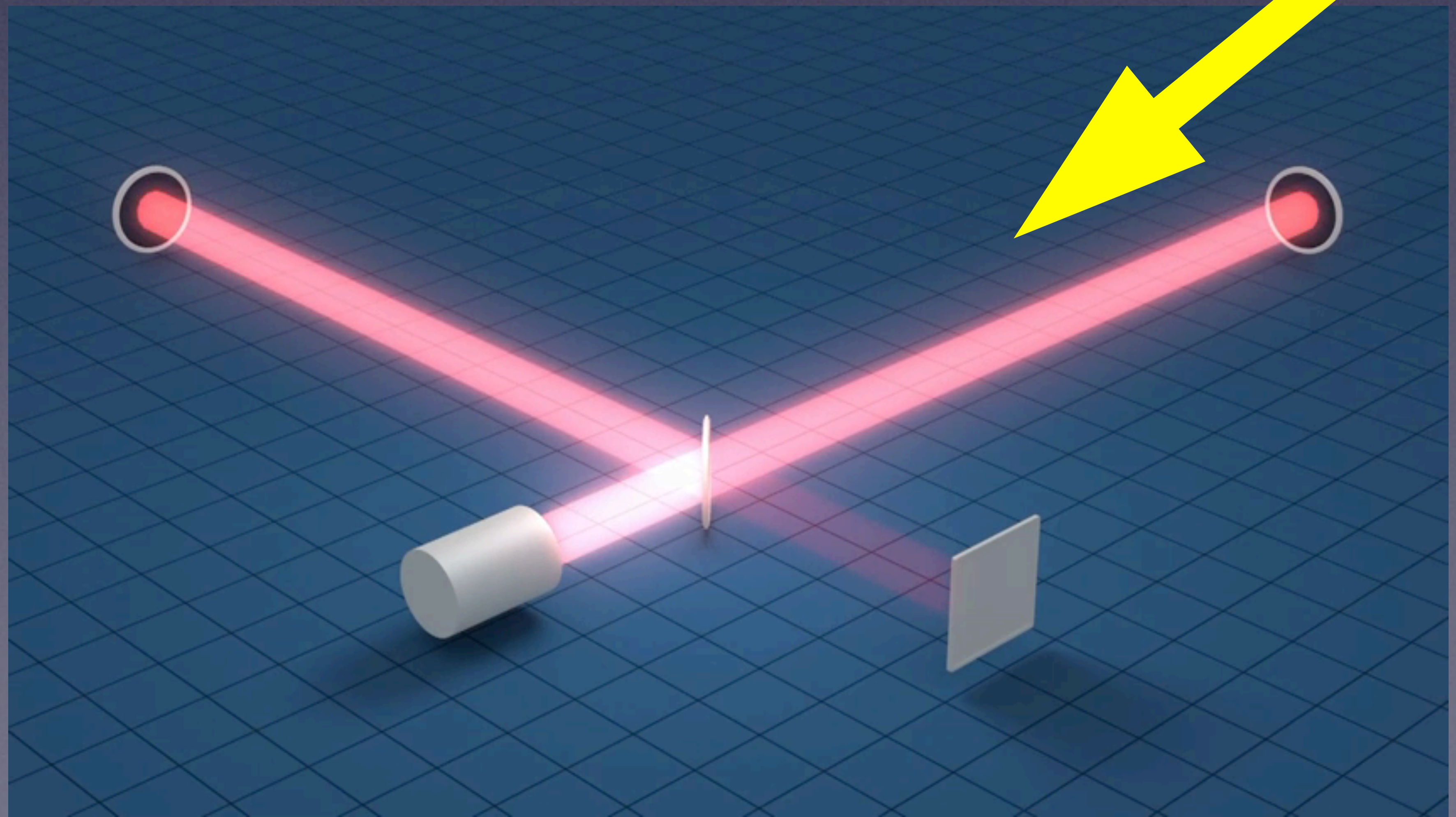
Gravitational Wave

from binary BH-BH, NS-NS, BH-NS









重力波の波源 (GW sources)

http://gwcenter.icrr.u-tokyo.ac.jp

supernovae

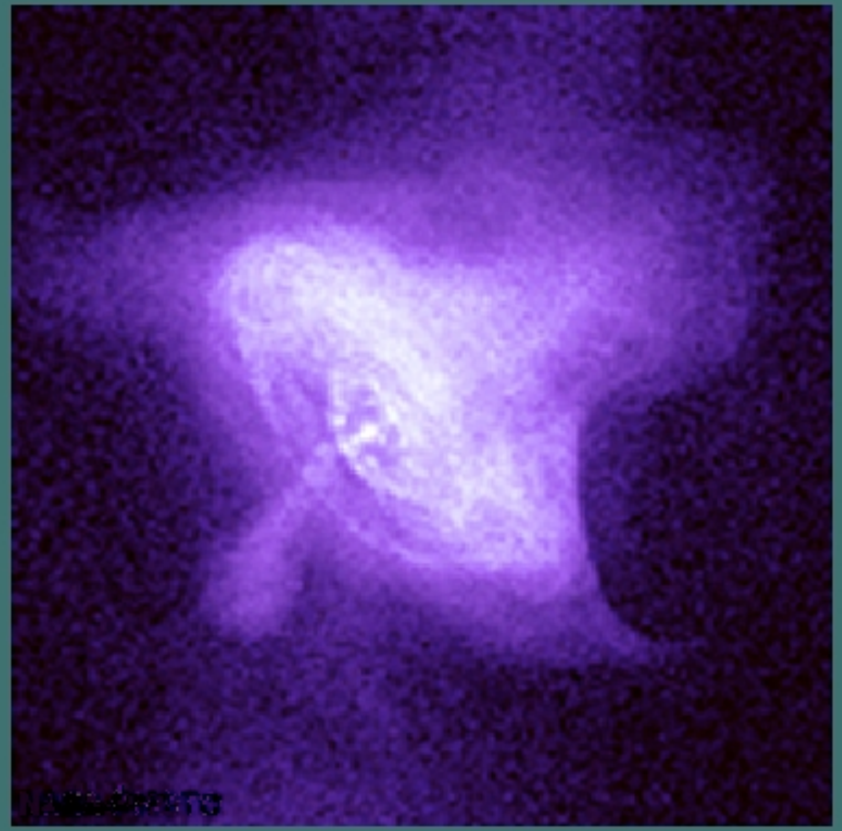
超新星爆発（写真出典:NASA）

予測が難しい

hard to predict

pulsars

パルサー（写真出典:NASA）

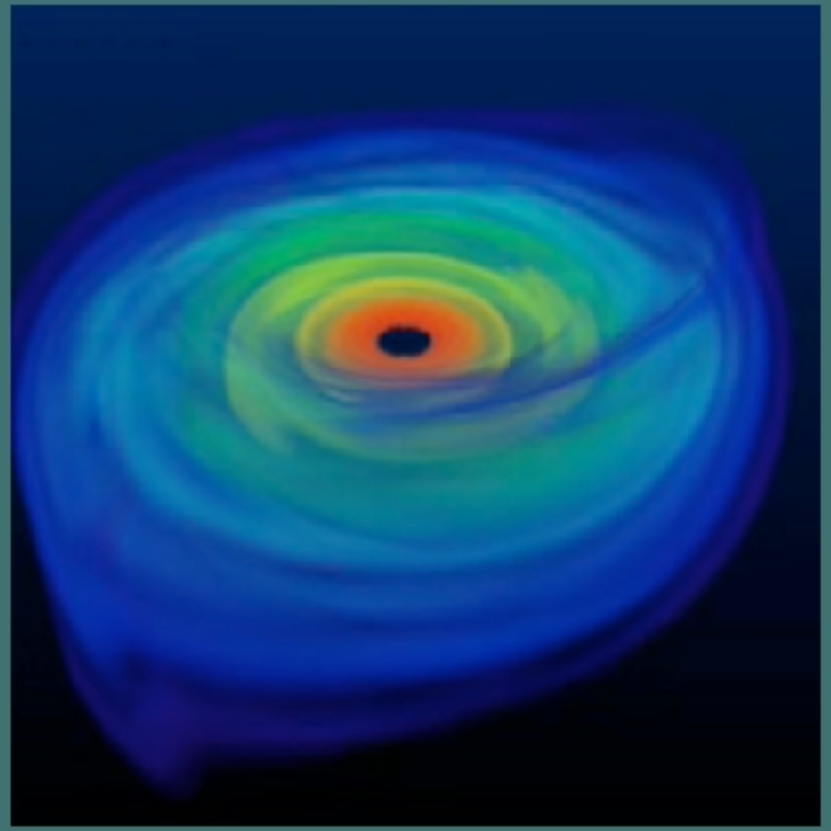


振幅が小さい

too small amplitude

black hole

ブラックホール（想像図）



振幅が小さい

too small amplitude

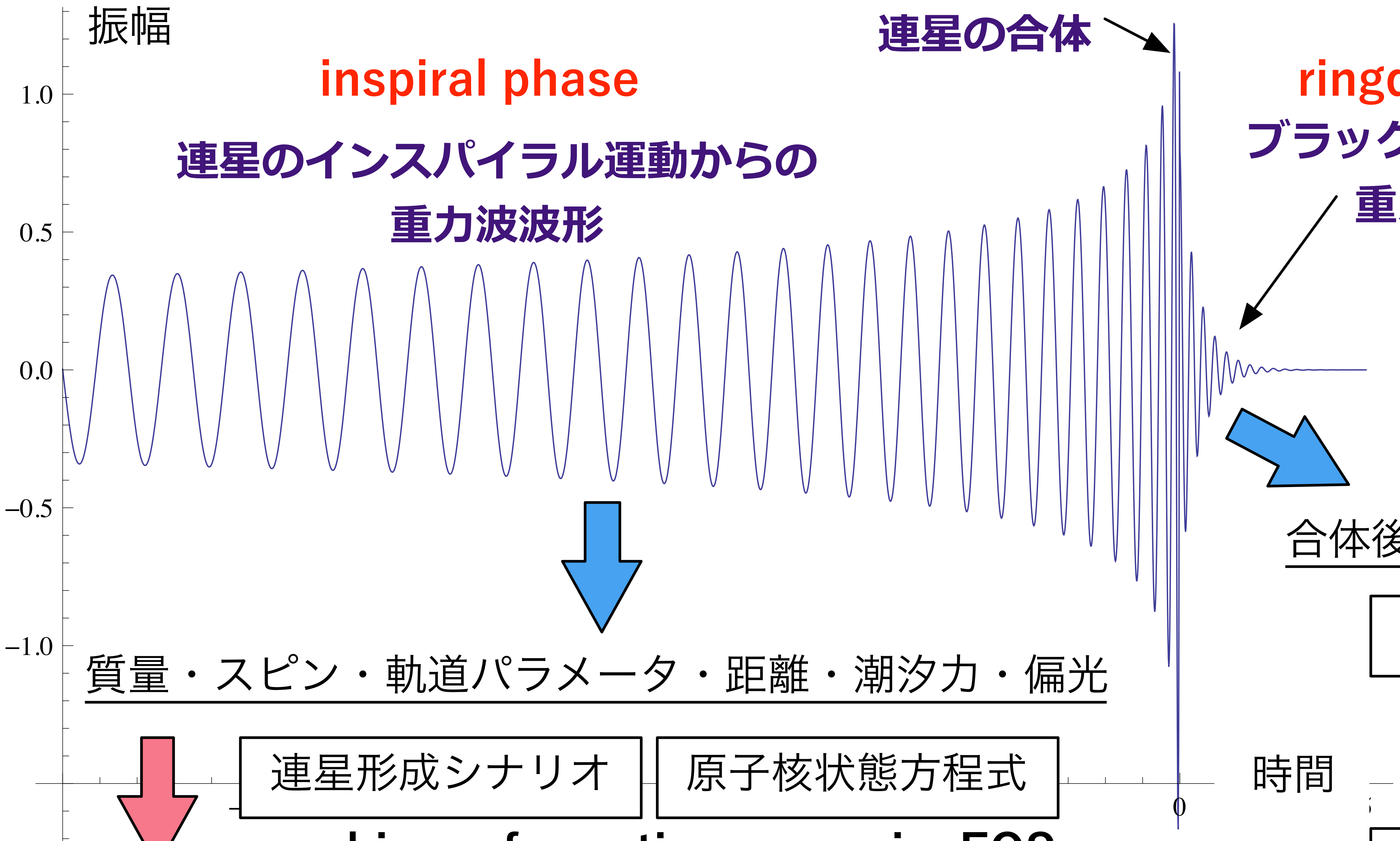
binary neutron stars

連星中性子星合体（想像図）

連星合体

binary coalescence

What we can learn from GW?



merger phase
連星の合体

inspiral phase
連星のインスパイラル運動からの重力波波形

ringdown phase
ブラックホール形成の重力波波形

質量・スピン・軌道パラメータ・距離・潮汐力・偏光

連星形成シナリオ	原子核状態方程式

binary formation scenario, EOS

統計

statistics

宇宙論パラメータ	銀河形成シナリオ

cosmological parameters, galaxy formation scenario

合体後の質量・角運動量

重力理論の検証

test of GR

究極理論の構築

unified theory

What kind of technology we need?

LIGO: The Laser Interferometer Gravitational-Wave Observatory

Alex Abramovici, William E. Althouse, Ronald W. P. Drever, Yekta Gürsel, Seiji Kawamura, Frederick J. Raab, David Shoemaker, Lisa Sievers, Robert E. Spero, Kip S. Thorne, Rochus E. Vogt, Rainer Weiss, Stanley E. Whitcomb, Michael E. Zucker

The goal of the Laser Interferometer Gravitational-Wave Observatory (LIGO) Project is to detect and study astrophysical gravitational waves and use data from them for research in physics and astronomy. LIGO will support studies concerning the nature and nonlinear dynamics of gravity, the structures of black holes, and the equation of state of nuclear matter. It will also measure the masses, birth rates, collisions, and distributions of black holes and neutron stars in the universe and probe the cores of supernovae and the very early universe. The technology for LIGO has been developed during the past 20 years. Construction will begin in 1992, and under the present schedule, LIGO's gravitational-wave searches will begin in 1998.

Einstein's general relativity theory describes gravity as due to a curvature of space-time (1). When the curvature is weak, it produces the familiar Newtonian gravity that governs the solar system. When the curvature is strong, however, it should behave in a radically different, highly nonlinear way. According to general relativity, the nonlinearity creates black holes (curvature produces curvature without the aid of any matter), governs their structure, and holds them together against disruption (2). Inside a black hole, the curvature should nonlinearly amplify itself to produce a space-time singularity (2), and near some singularities the nonlinearity should force the curvature to evolve chaotically (3). When an object's curvature varies rapidly (for example, because of pulsations, colli-

The authors are the members of the LIGO Science Steering Group. A. Abramovici, W. E. Althouse (Chief Engineer), R. W. P. Drever, S. Kawamura, F. J. Raab, L. Sievers, R. E. Spero, K. S. Thorne, R. E. Vogt (Director), S. E. Whitcomb (Deputy Director), and M. E. Zucker are with the California Institute of Technology, Pasadena, CA 91125. Y. Gürsel is at the Jet Propulsion Laboratory, Pasadena, CA 91109. D. Shoemaker and R. Weiss are at the Massachusetts Institute of Technology, Cambridge, MA 02129.

SCIENCE • VOL. 256 • 17 APRIL 1992 325

Science 256 (1992) 325

vibration control

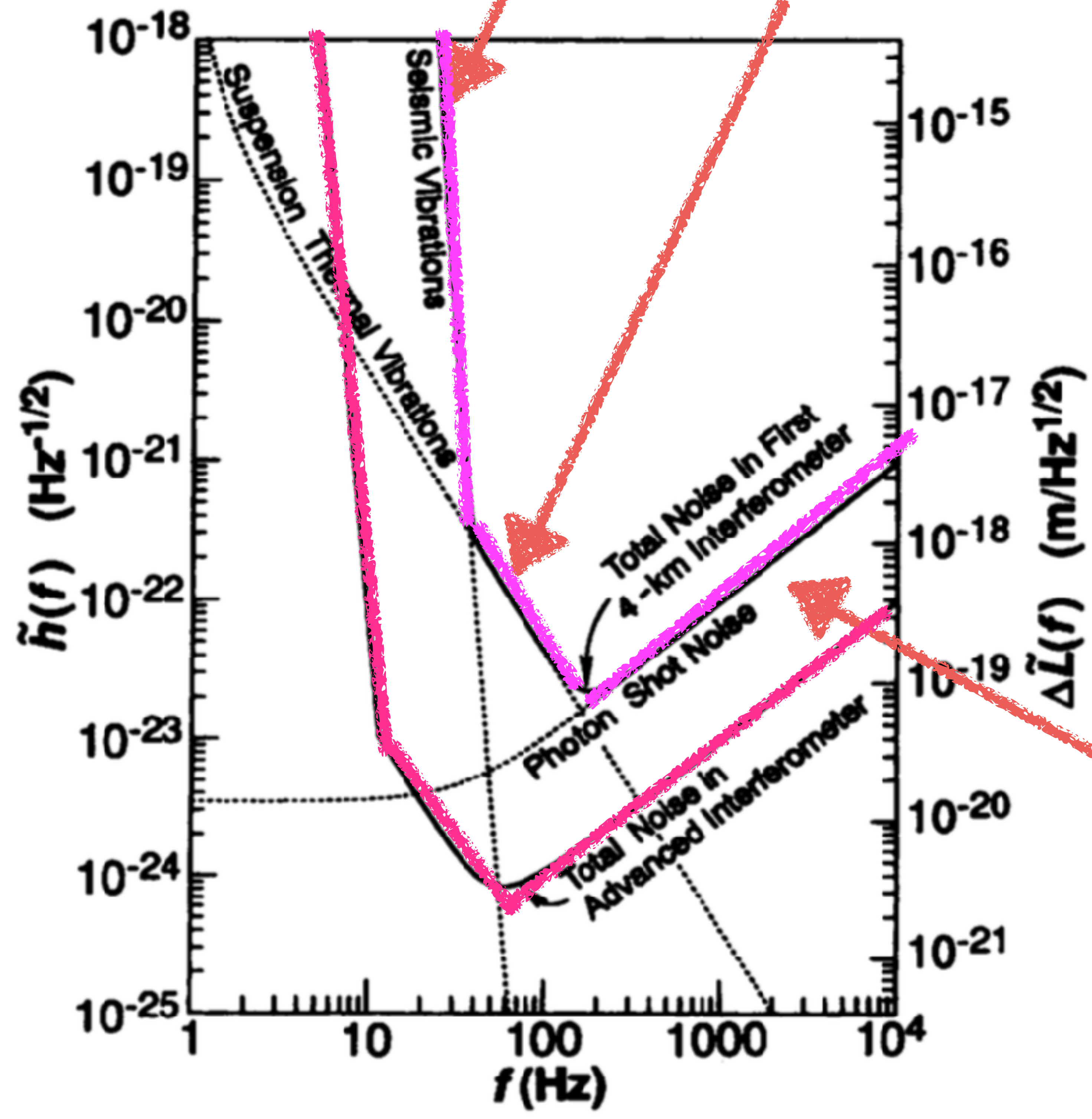
地面振動

(seismic noise)

熱雑音

(thermal noise)

thermal control



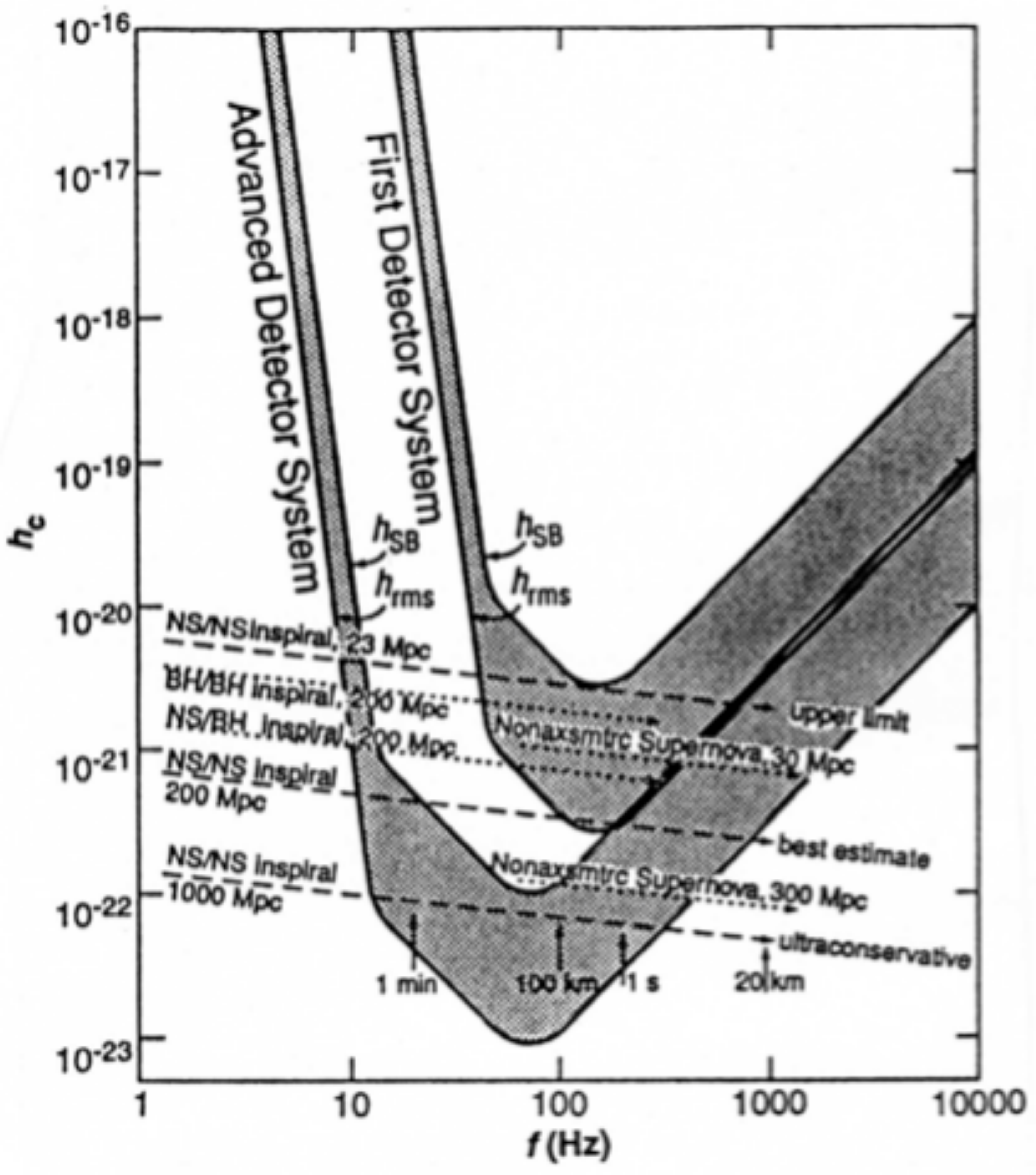
散射雑音

(shot noise)

high-power laser

Fig. 7. The expected total noise in each of LIGO's first 4-km interferometers (upper solid curve) and in a more advanced interferometer (lower solid curve). The dashed curves show various contributions to the first interferometer's noise.

What kind of technology we need?



Science 256 (1992) 325

vibration control

地面振動

(seismic noise)

熱雑音

(thermal noise)

thermal control

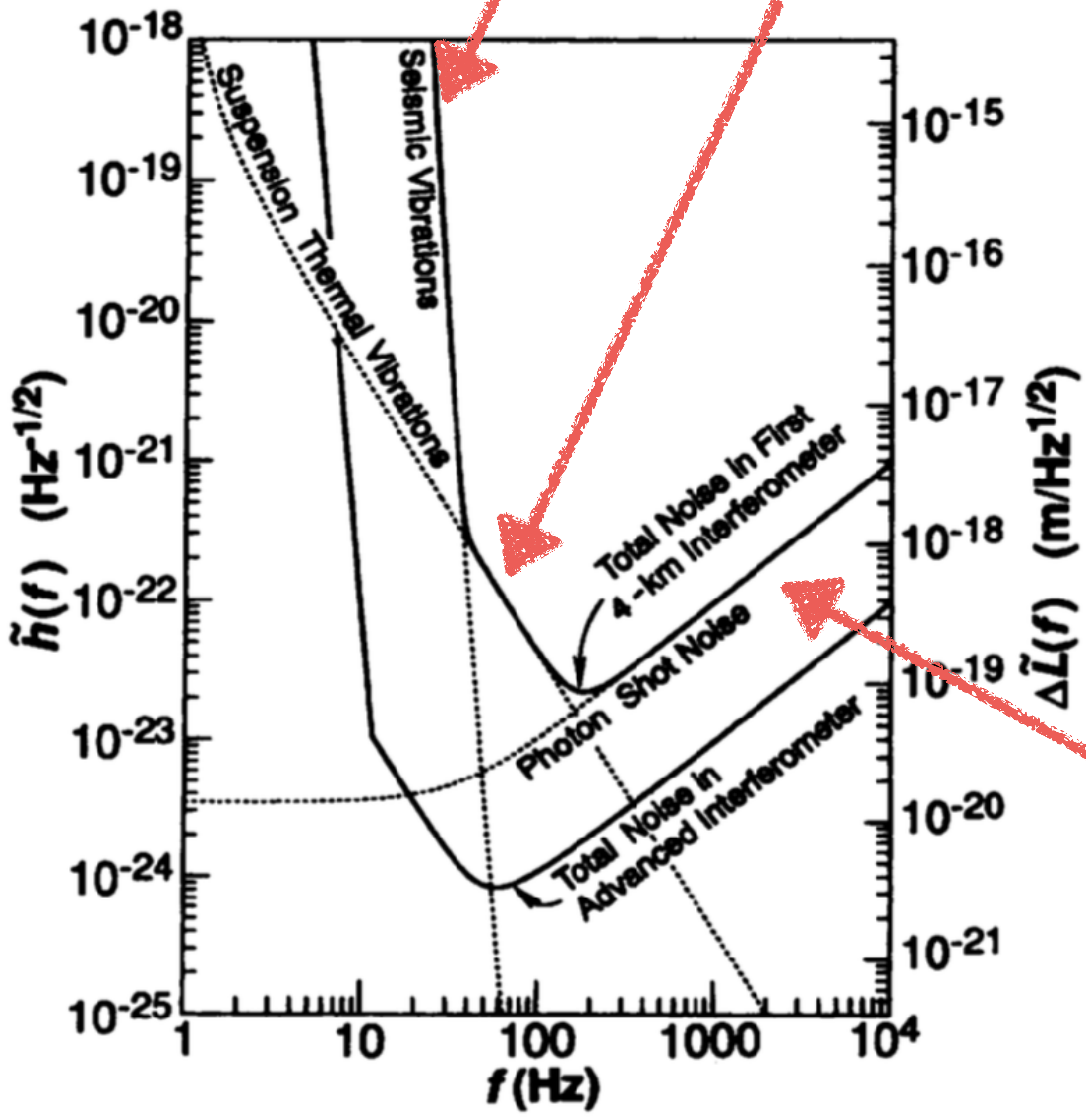


Fig. 7. The expected total noise in each of LIGO's first 4-km interferometers (upper solid curve) and in a more advanced interferometer (lower solid curve). The dashed curves show various contributions to the first interferometer's noise.

散射雑音

(shot noise)

high-power laser

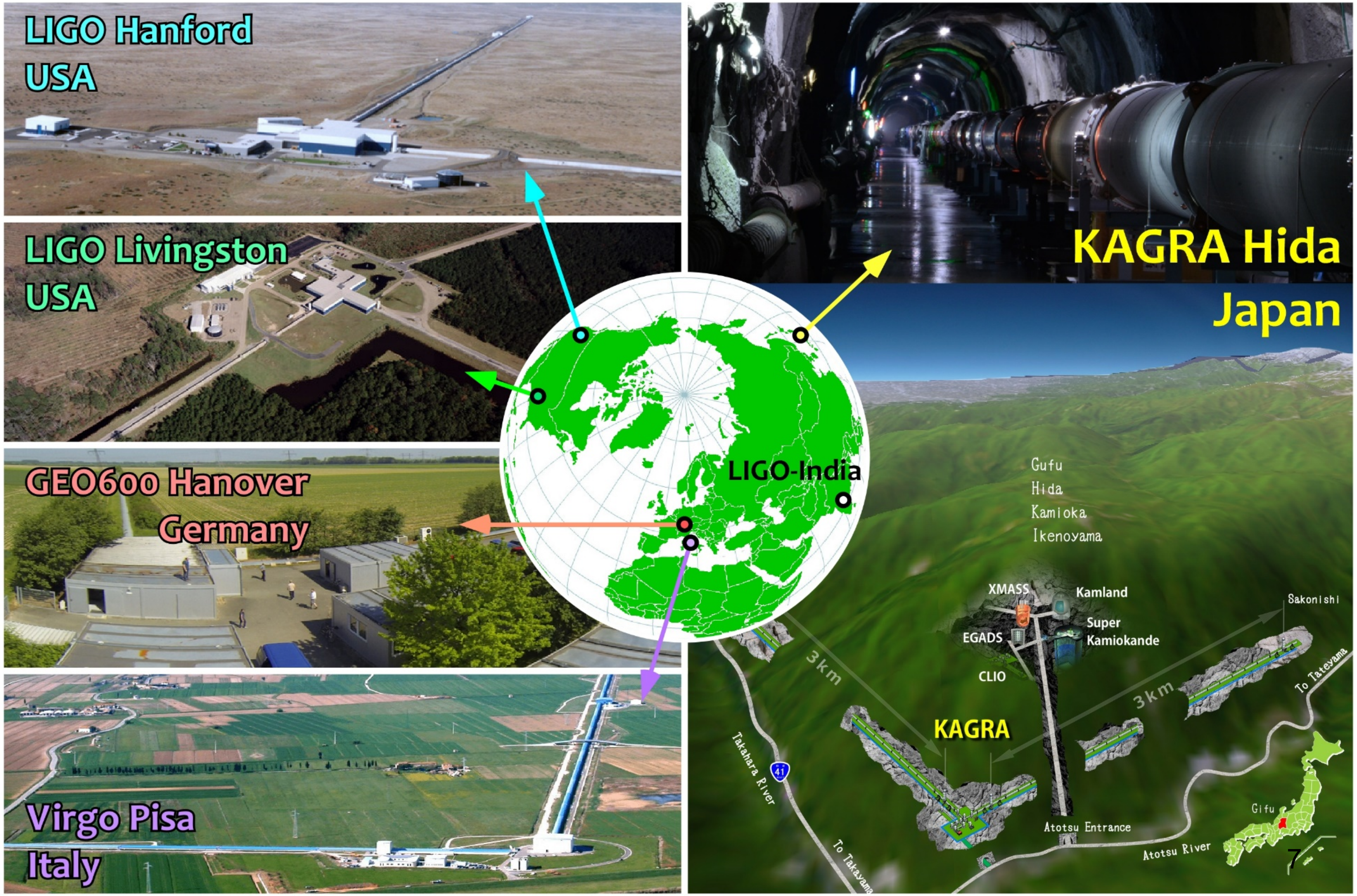
GW International Network

4 km

4 km

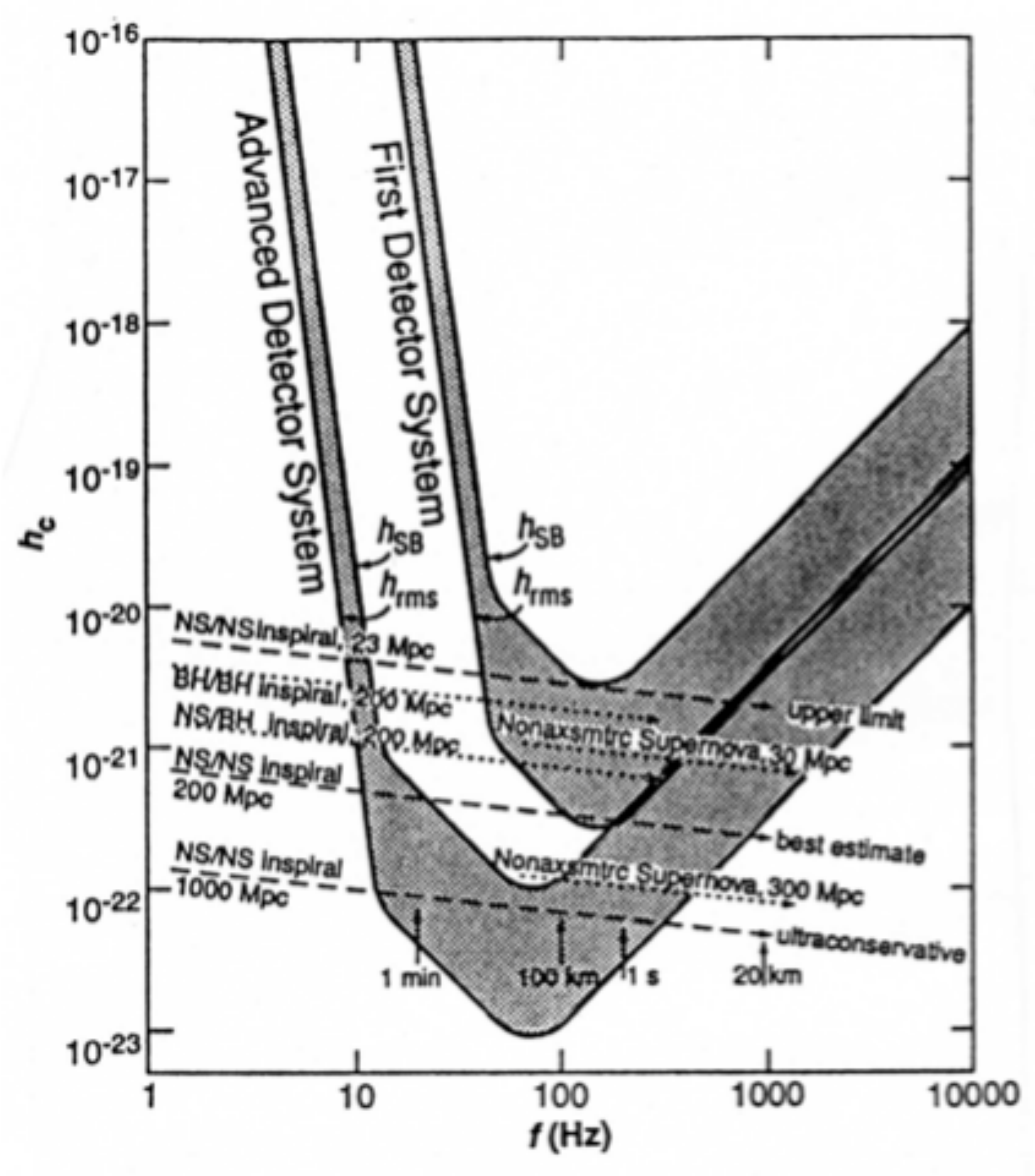
600 m

3 km



3 km

Sensitivity Curve



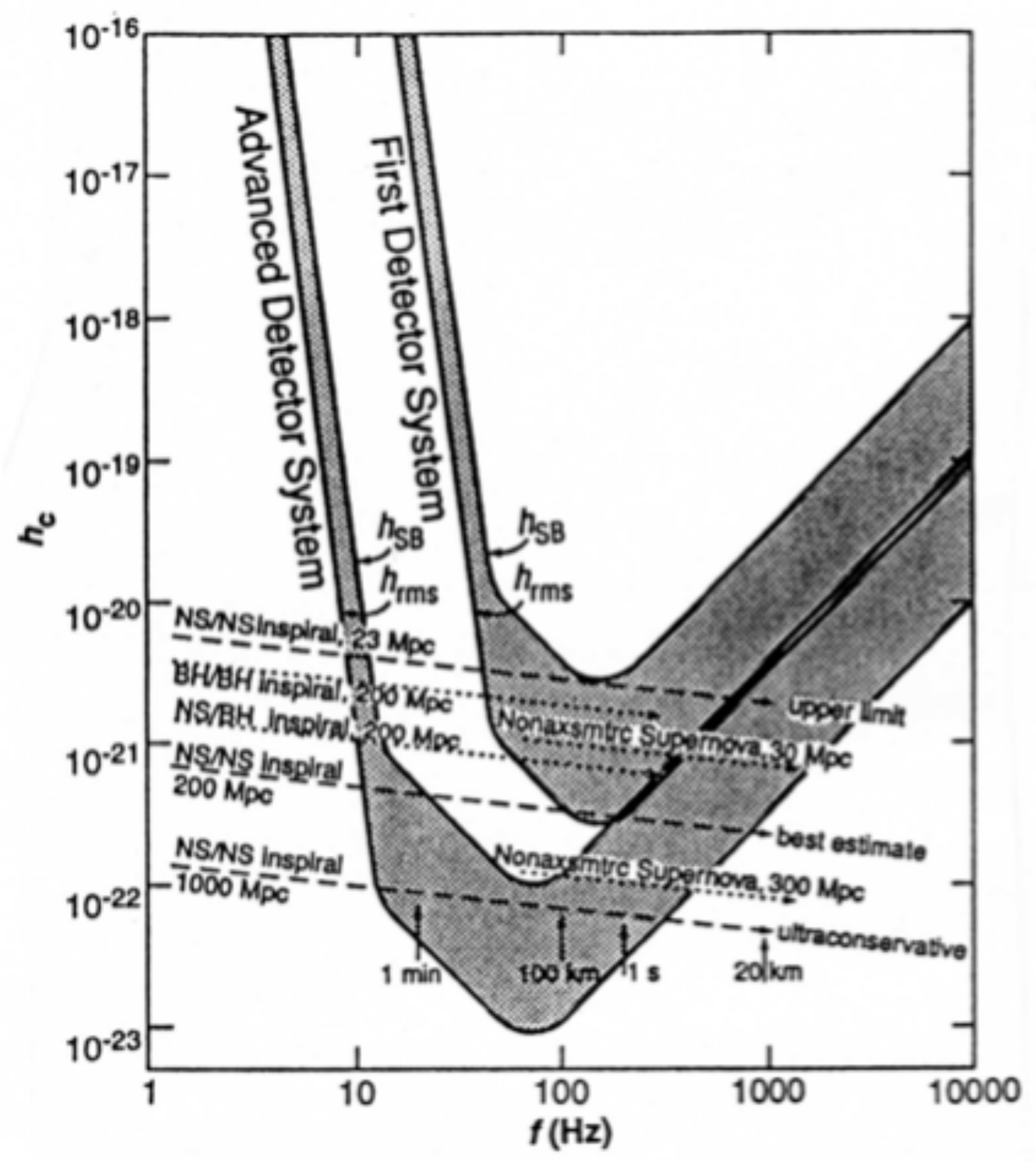
Science 256 (1992) 325

amplitude of GW $h(t) \propto \frac{1}{r}$ **1/ distance**

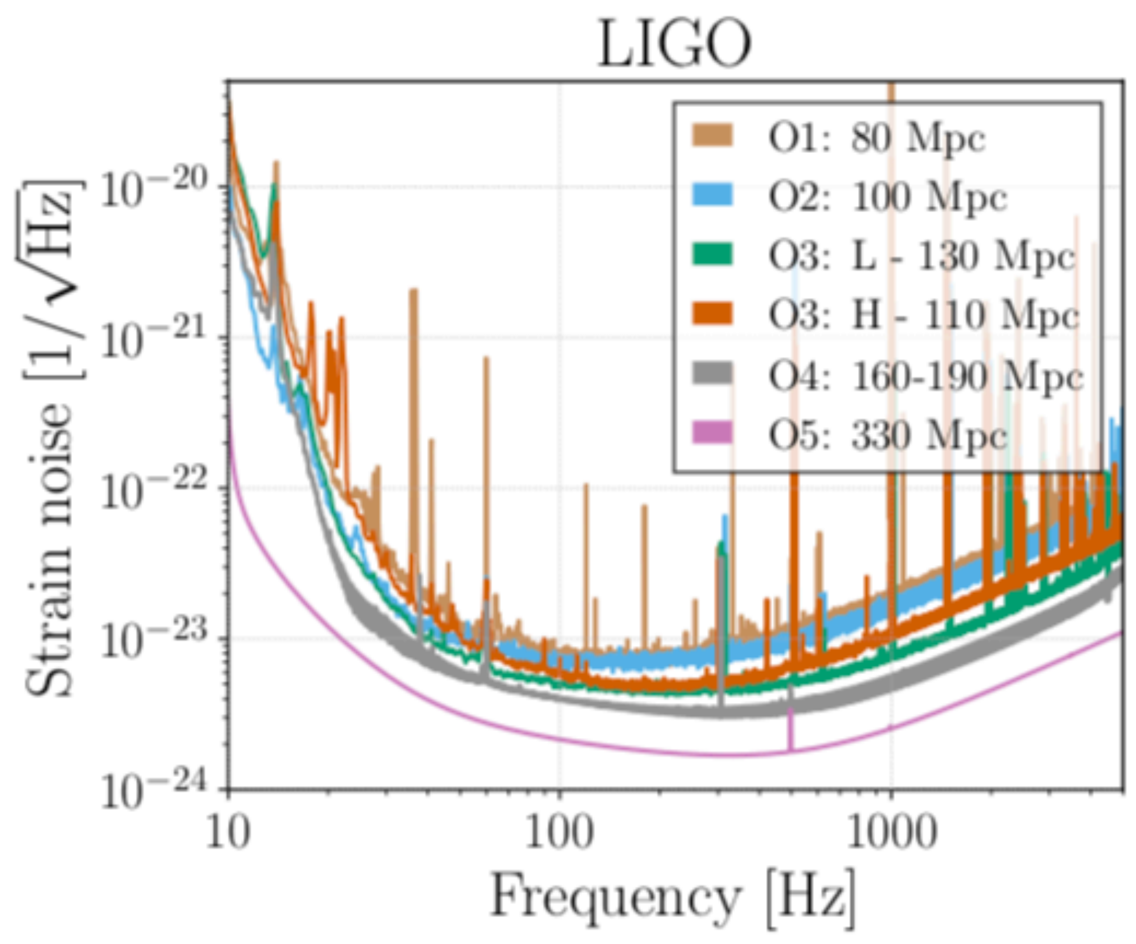
if we improve one-order of magnitude of the sensitivity,
then the observational volume of the Universe **become 10^3 times larger.**

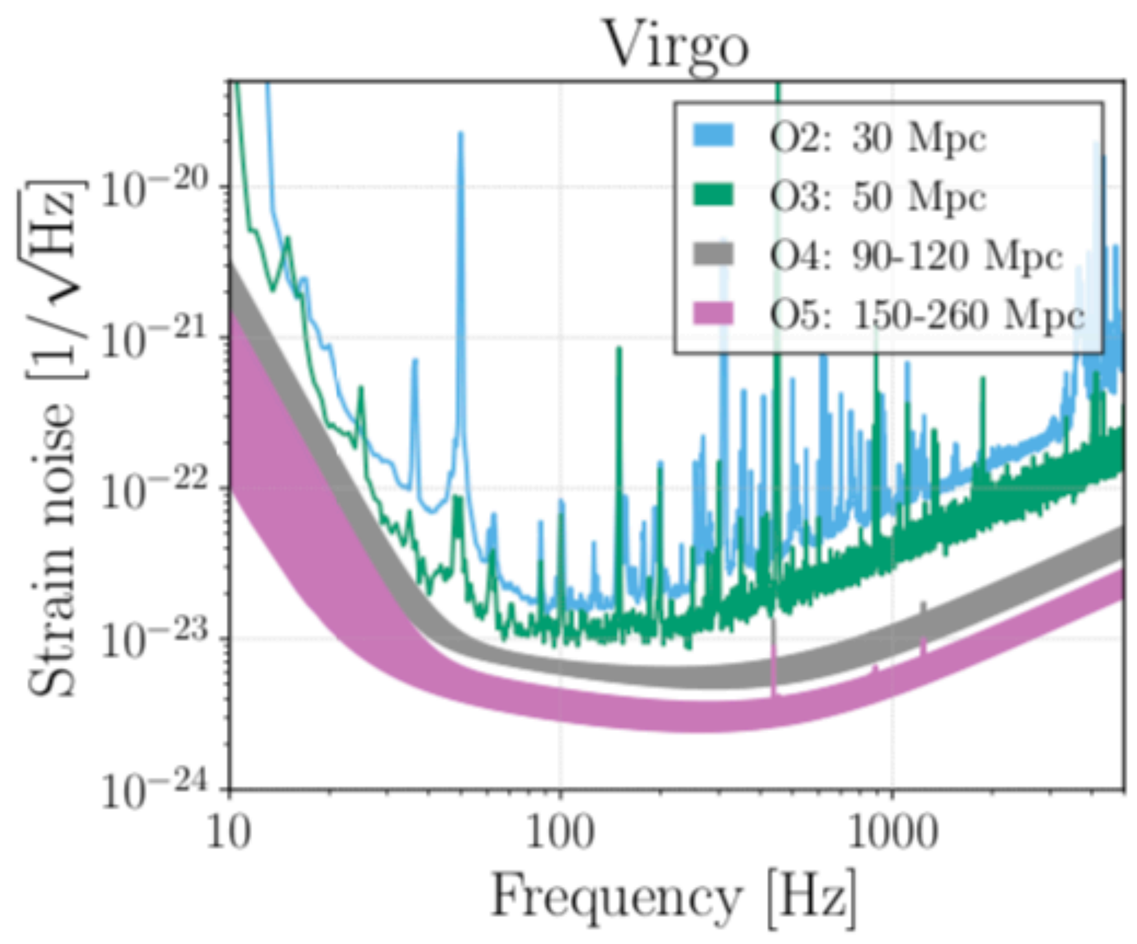
O1 (2015/9/12 - 2016/1/19) LIGO
Update
O2 (2016/11/30 - 2017/8/25) LIGO+Virgo
Update
O3a (2019/4/1 - 2019/9/30) LIGO+Virgo
O3b (2019/10/1 - 2020/3/27) LIGO+Virgo + KAGRA
Update
O4 (2022?)

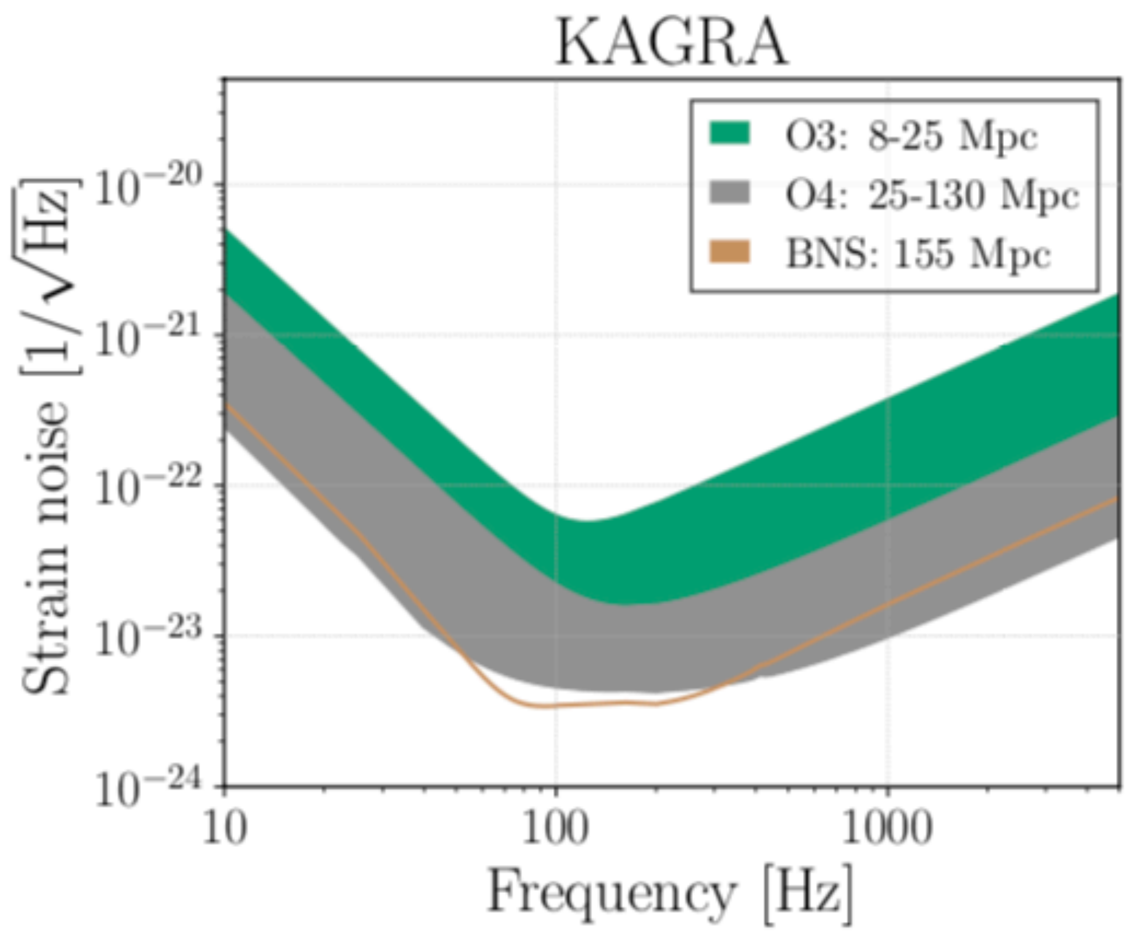
Sensitivity Curve



Science 256 (1992) 325



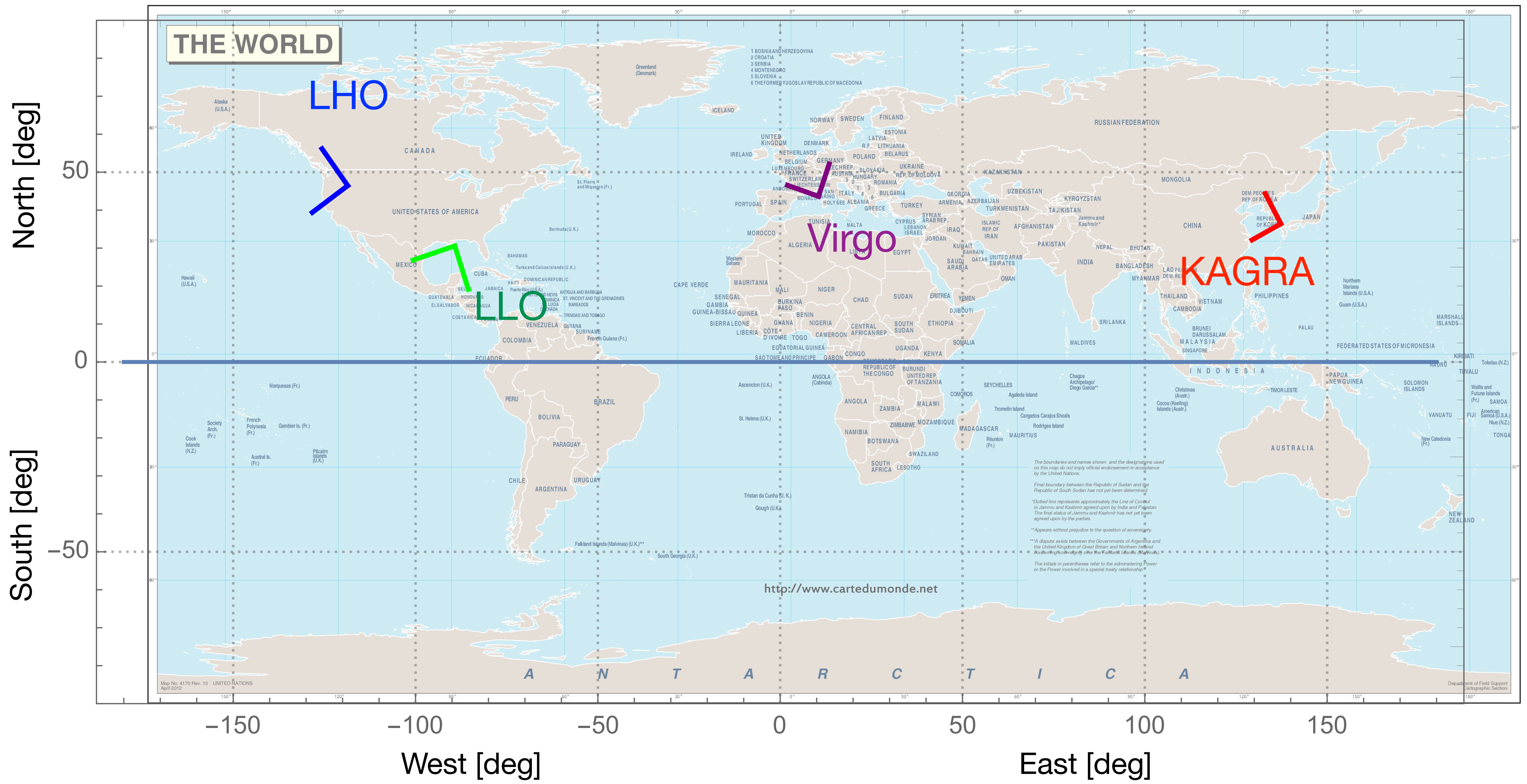


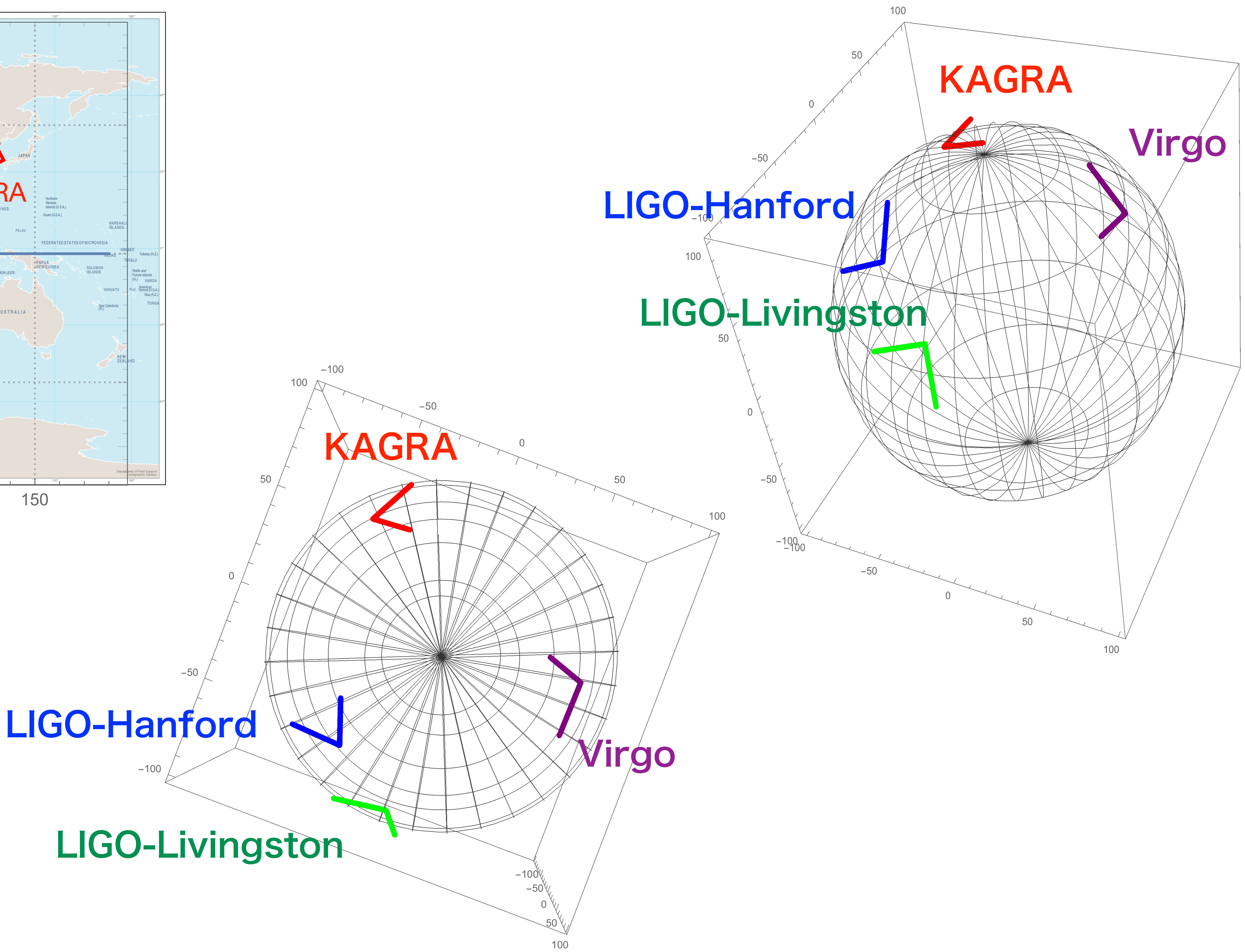


Binary NS range

LVK collaboration, Living Rev Relativ (2020) 23:3
https://link.springer.com/article/10.1007/s41114-020-00026-9
[1304.0670ver2020Jan]

Fourth 2nd generation detector on the Earth





more precise GW source localization

more certain GW source parameters

more chances to hunt GW events

more information of GW polarization

more ideas for GW researches

more man power

KAGRA (Kamioka Gravitational-Wave Observatory)

Mozumi control office. (15 min)

Toyama City (60 min)

http://gwcenter.icrr.u-tokyo.ac.jp/en/

1000m under the summit of the Mt.

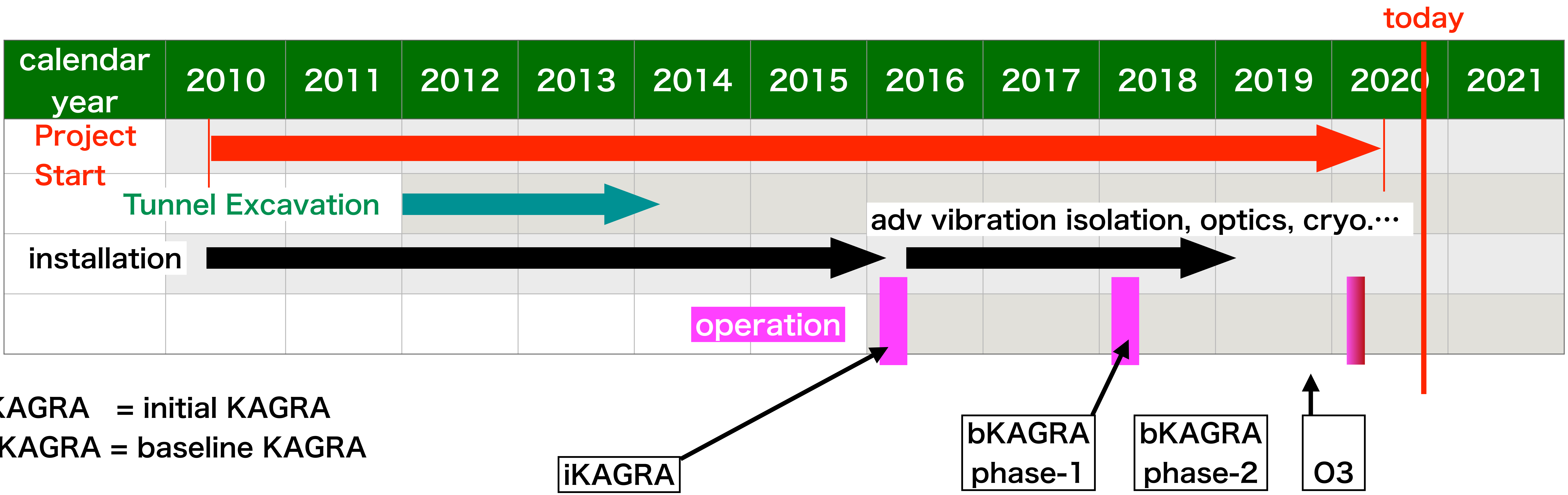
358m above the sea level.

（大型低温重力波望遠鏡）

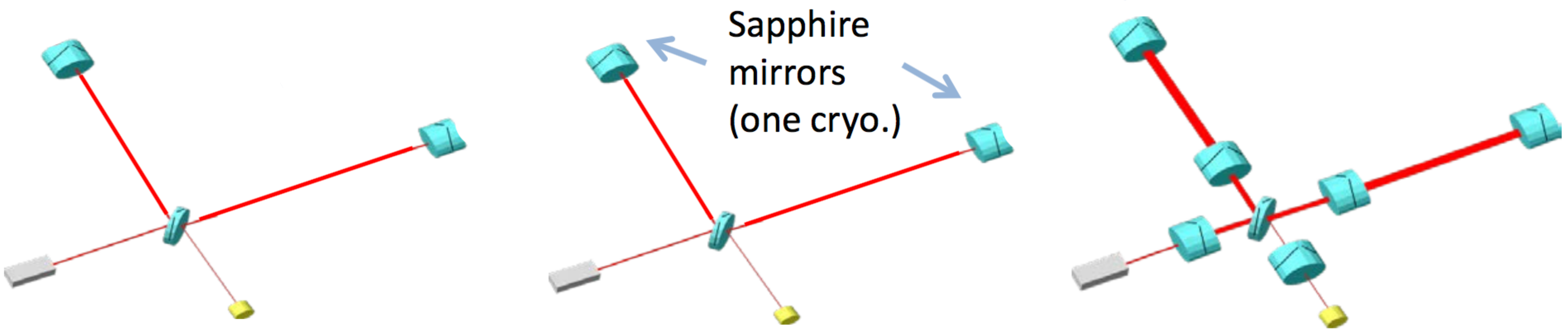
former name LCGT = large cryogenic gravitational telescope

named by public naming contest, 神楽（かぐら）dance music in front of Gods

Brief History of KAGRA



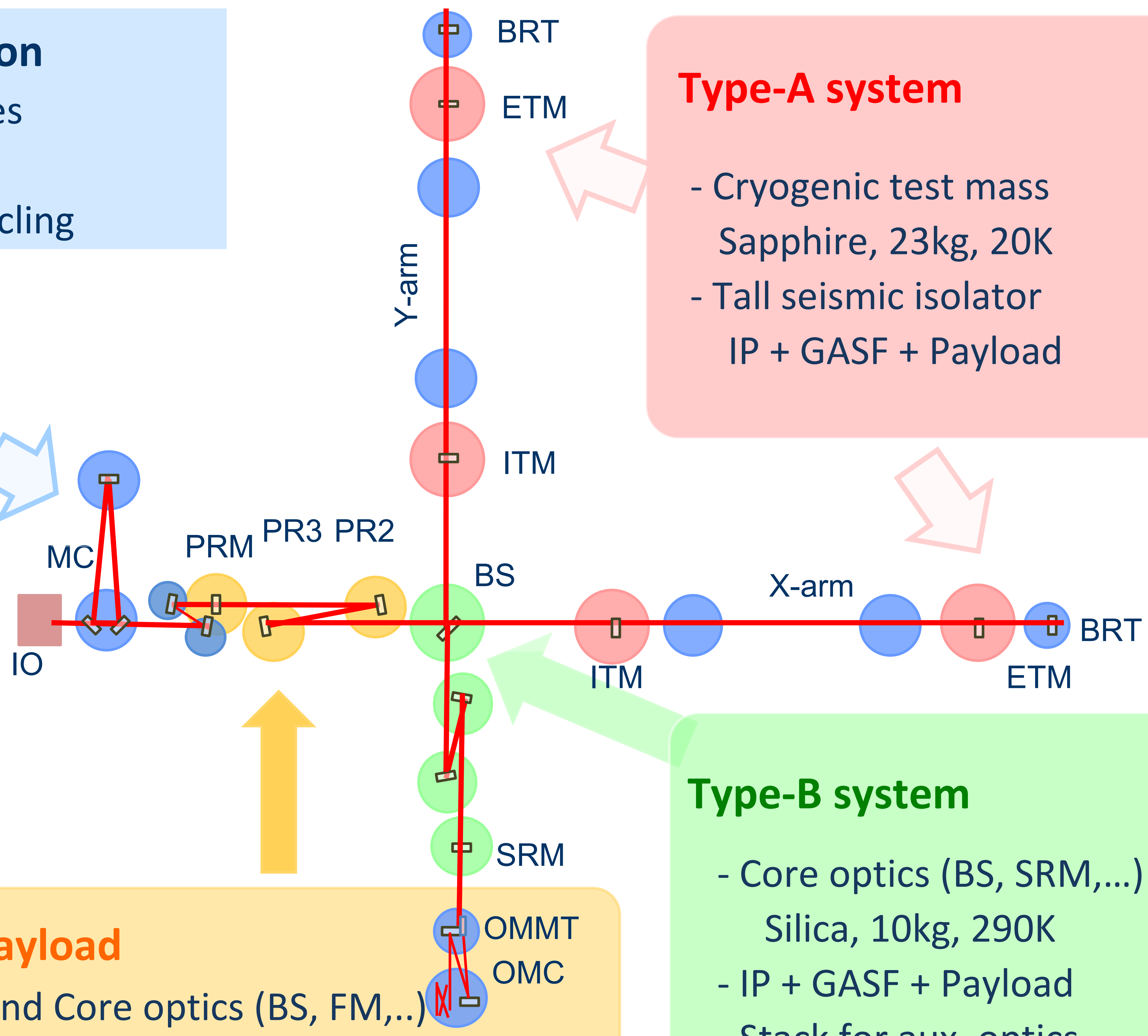
iKAGRA = initial KAGRA
bKAGRA = baseline KAGRA



[arXiv:1712.00148]   [arXiv:1901.03569]

KAGRA suspension systems

bKAGRA configuration
- Cryogenic test masses
- 3 km arm cavities
- RSE with power recycling

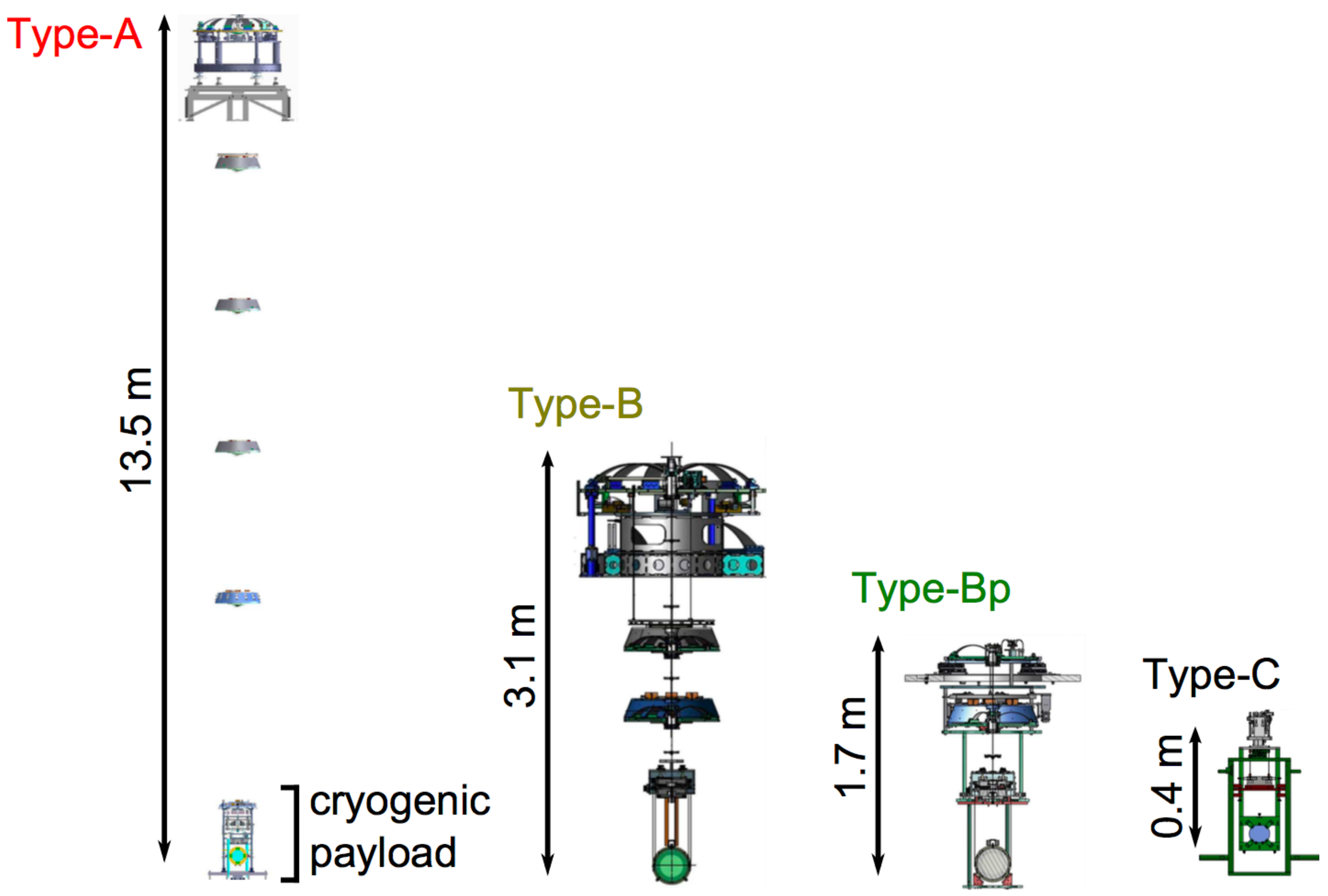


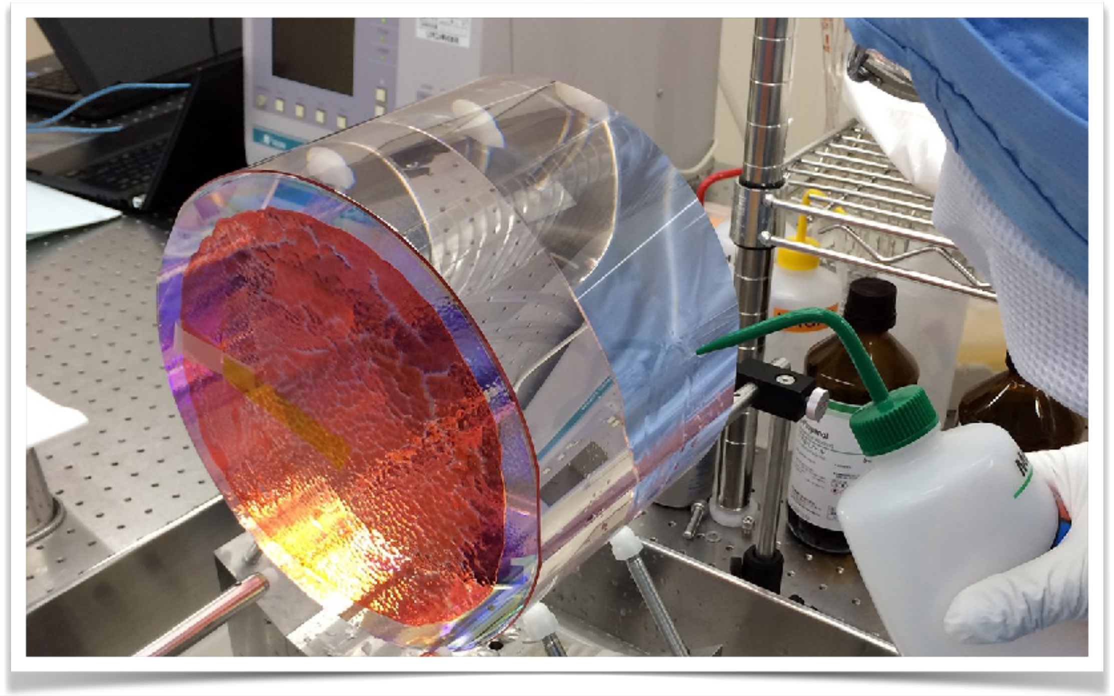
Type-A system
- Cryogenic test mass
  Sapphire, 23kg, 20K
- Tall seismic isolator
  IP + GASF + Payload

Type-C system
- Mode cleaner
  Silica, 0.5kg, 290K
- Stack + Payload

Type-B system
- Core optics (BS, SRM,…)
  Silica, 10kg, 290K
- IP + GASF + Payload
- Stack for aux. optics

Type-Bp payload
- Test mass and Core optics (BS, FM,..)
  Silica, 10kg, 290K
- Seismic isolator
  Table + GASF + Type-B Payload





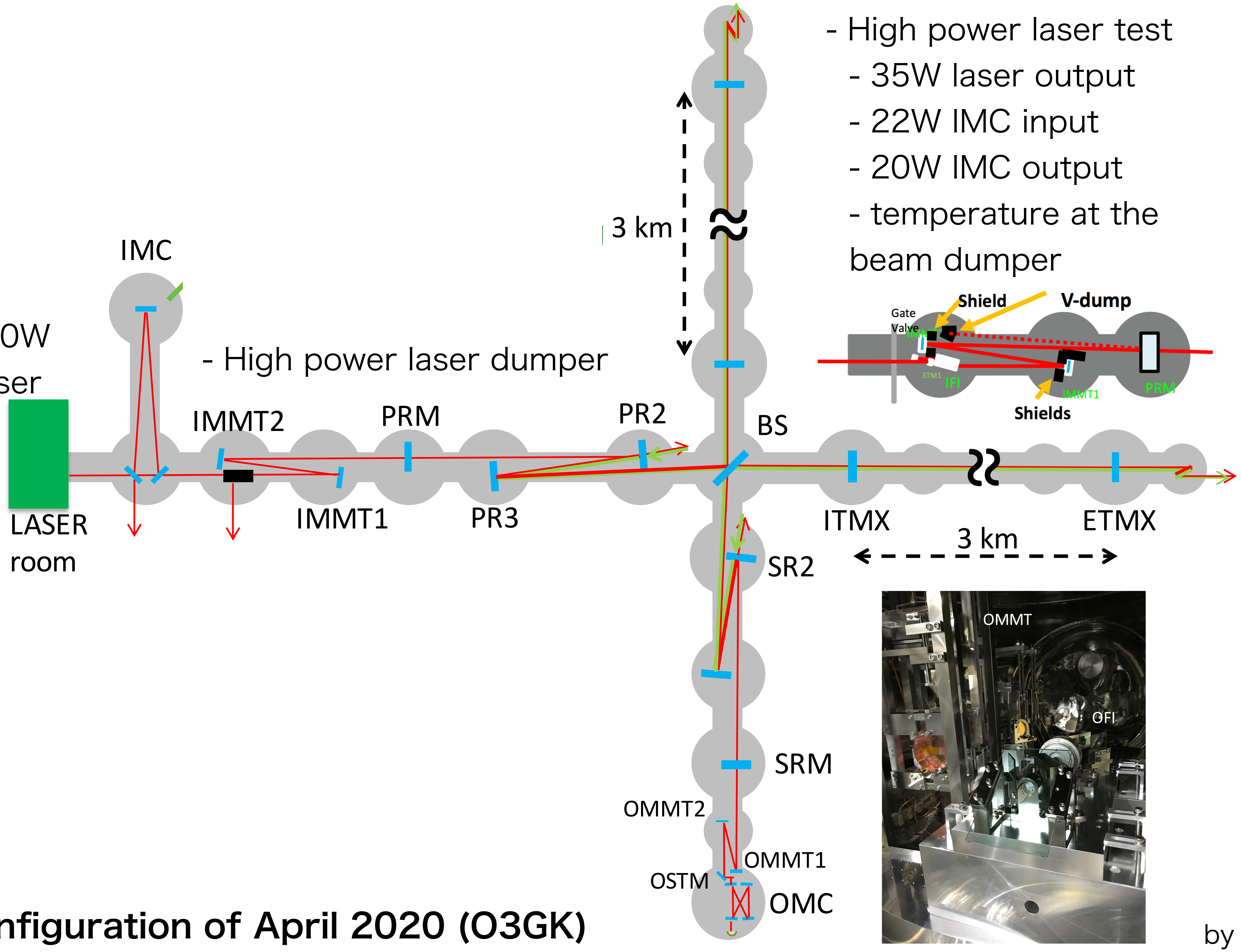
as the configuration of April 2020 (O3GK)

Laser, Input-Output Optics, Auxiliary optics

- 40W Laser

- High power laser dumper

- High power laser test
  - 35W laser output
  - 22W IMC input
  - 20W IMC output
  - temperature at the beam dumper

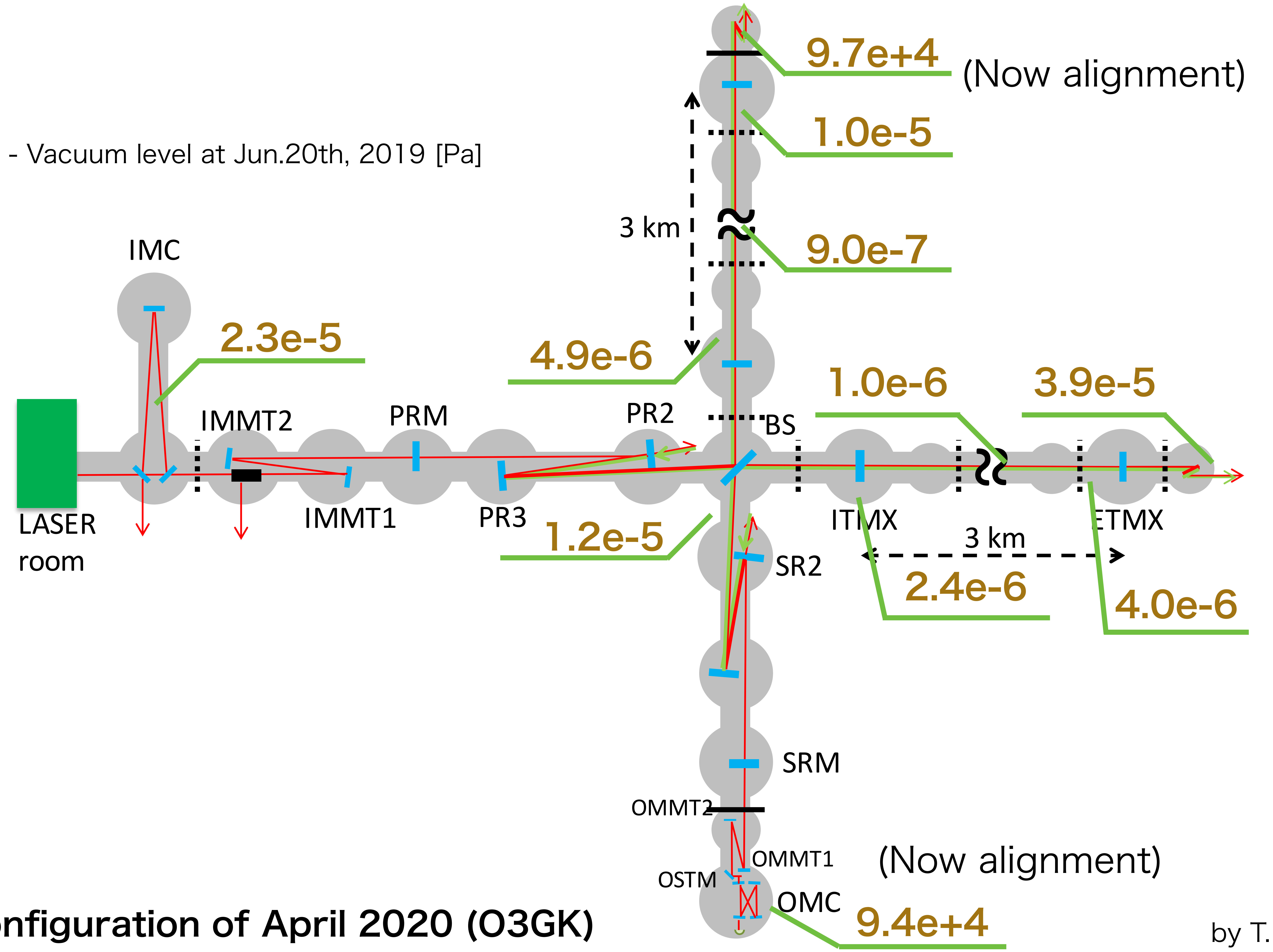


by T. Yokozawa

as the configuration of April 2020 (O3GK)

Vacuum & Facilities

- Vacuum level at Jun.20th, 2019 [Pa]

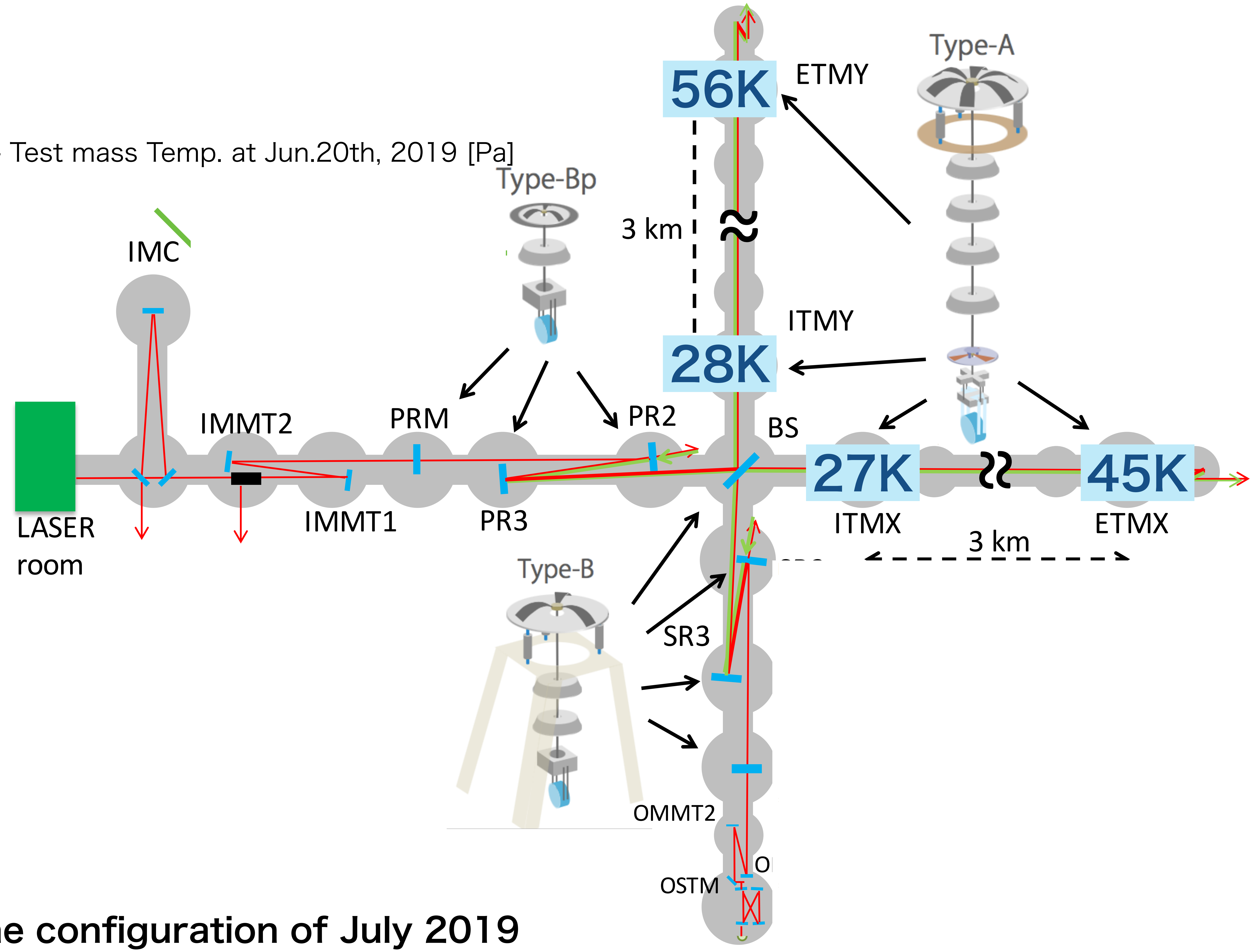


as the configuration of April 2020 (O3GK)

by T. Yokozawa

Cryogenic, Vibration Isolation, Mirrors

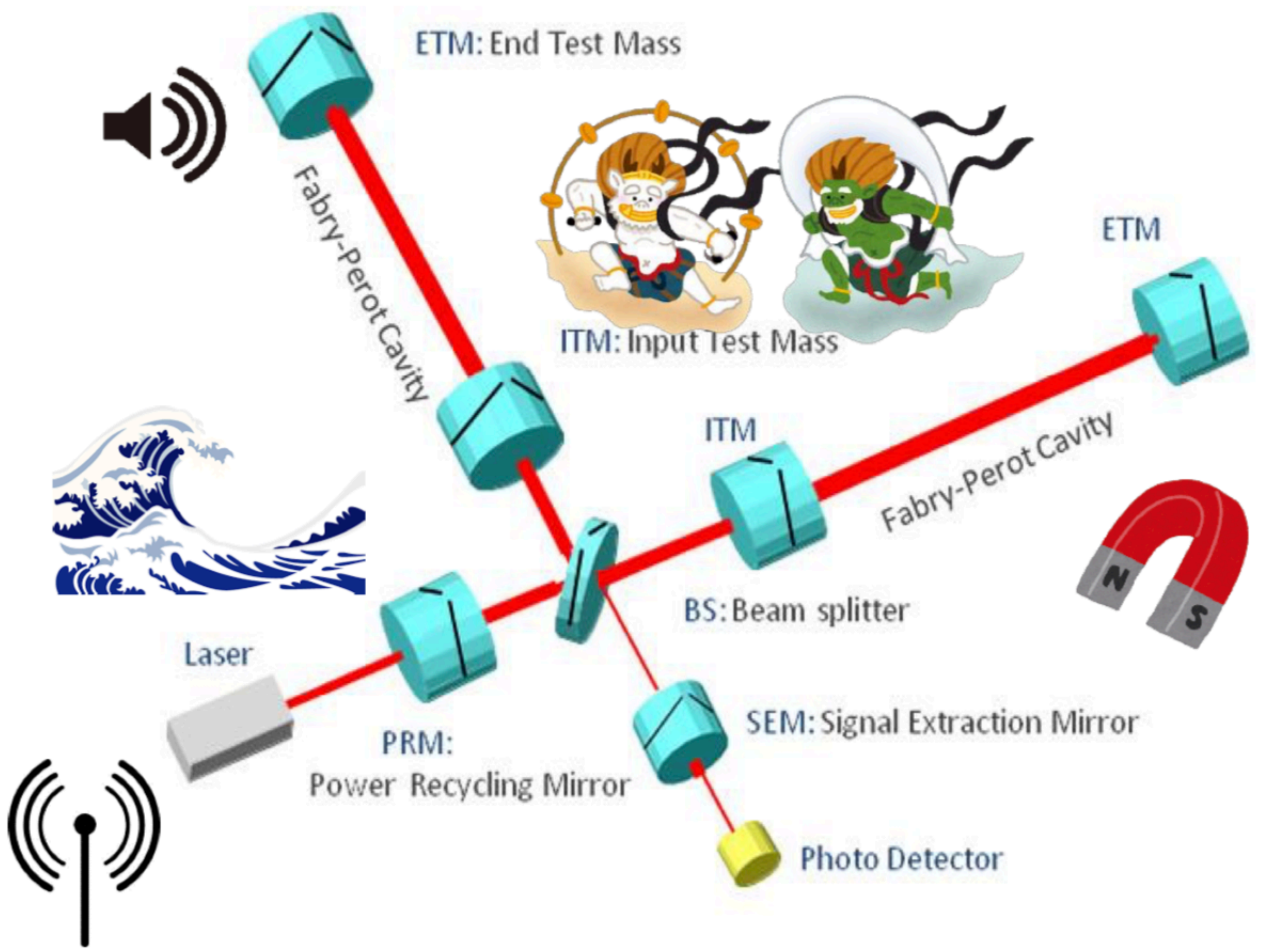
- Test mass Temp. at Jun.20th, 2019 [Pa]

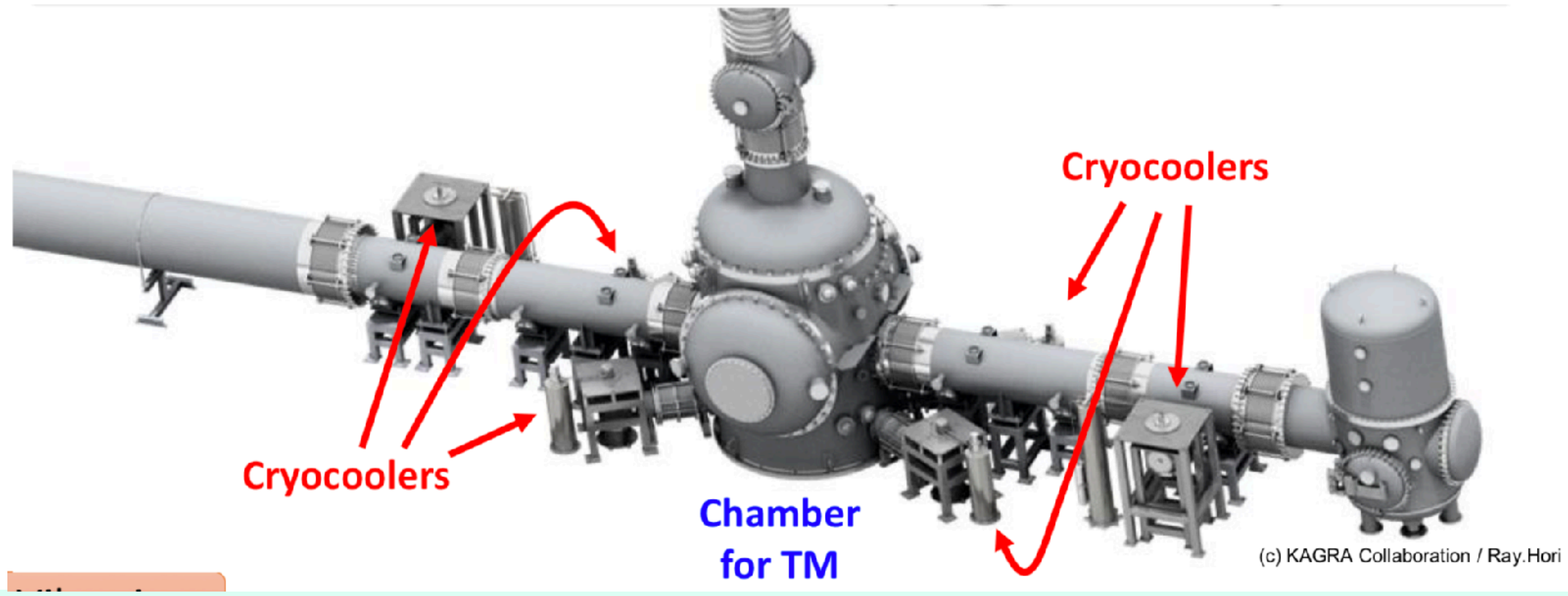


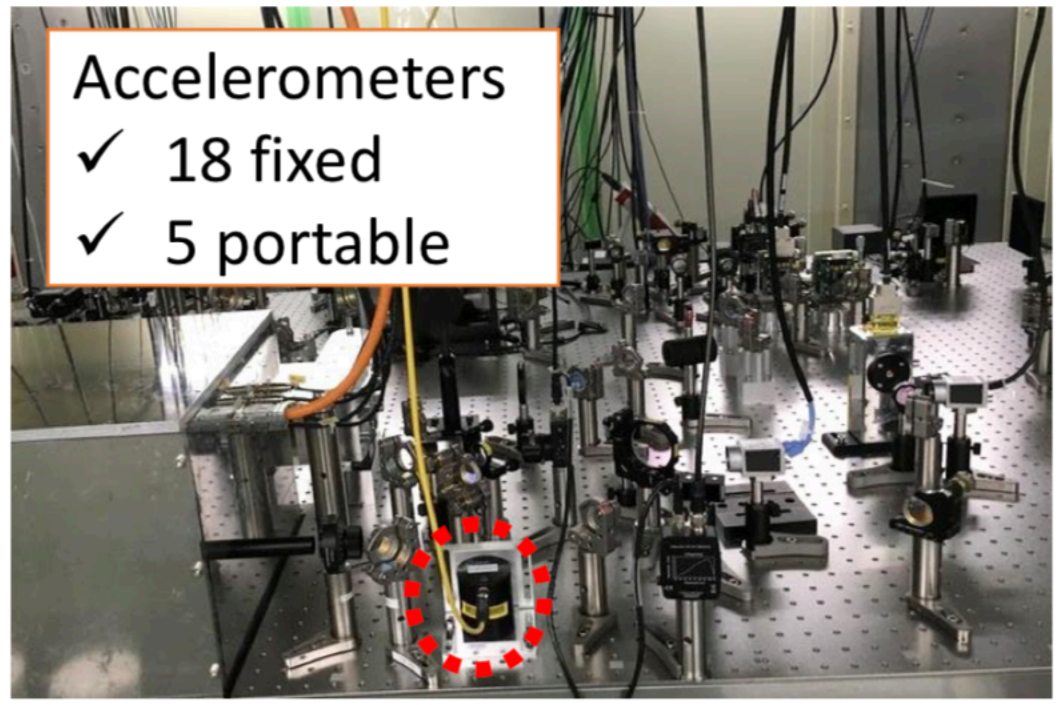
as the configuration of July 2019

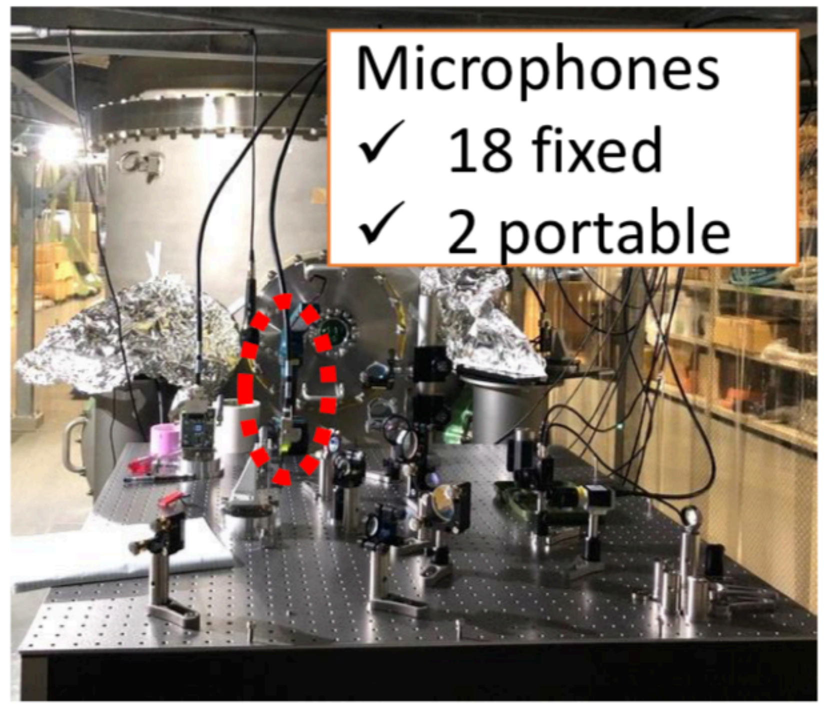
by T. Yokozawa

Physical environment monitors









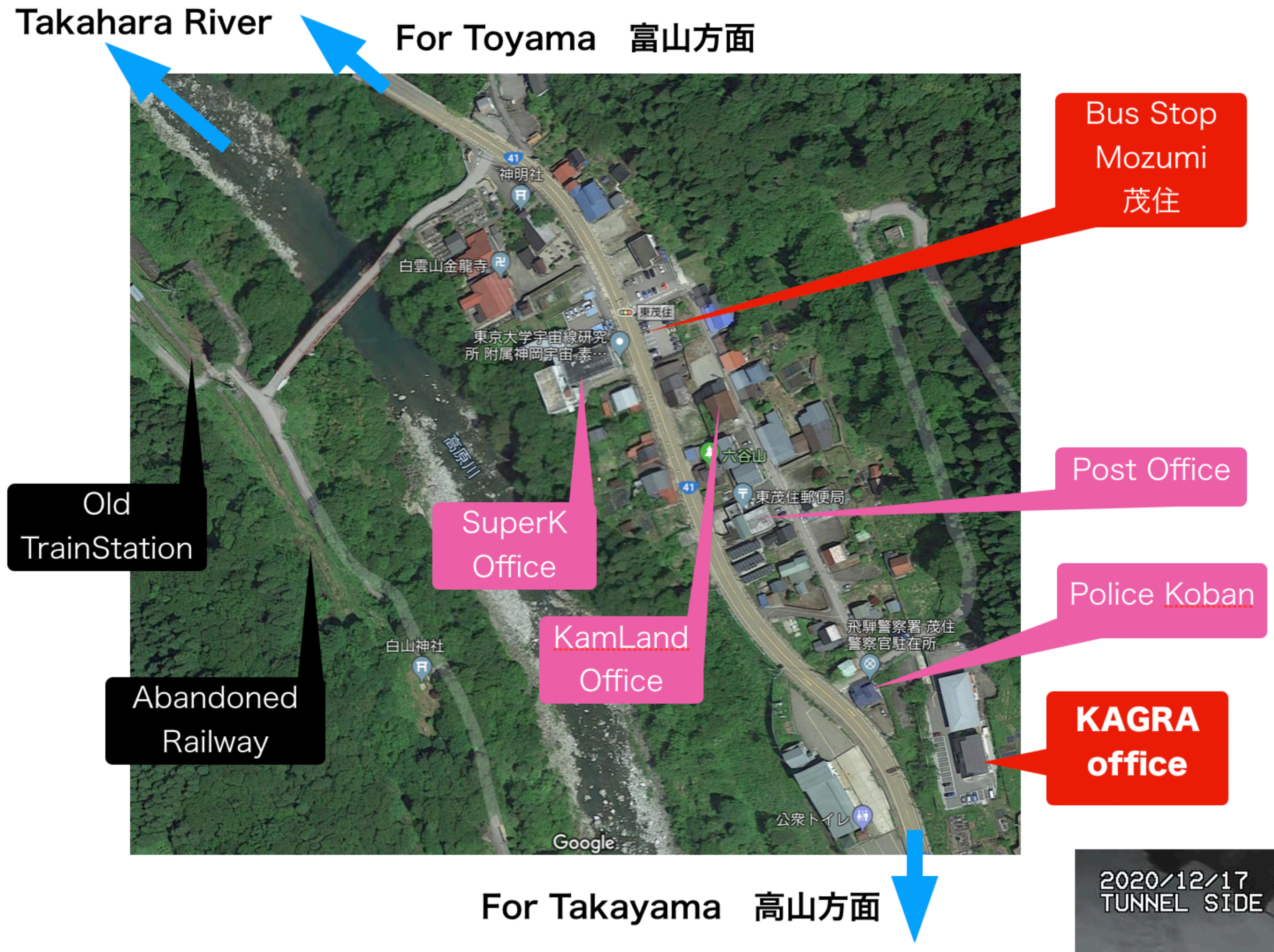
Magnetometers
- ✓ 2 fixed
- ✓ 3 portable

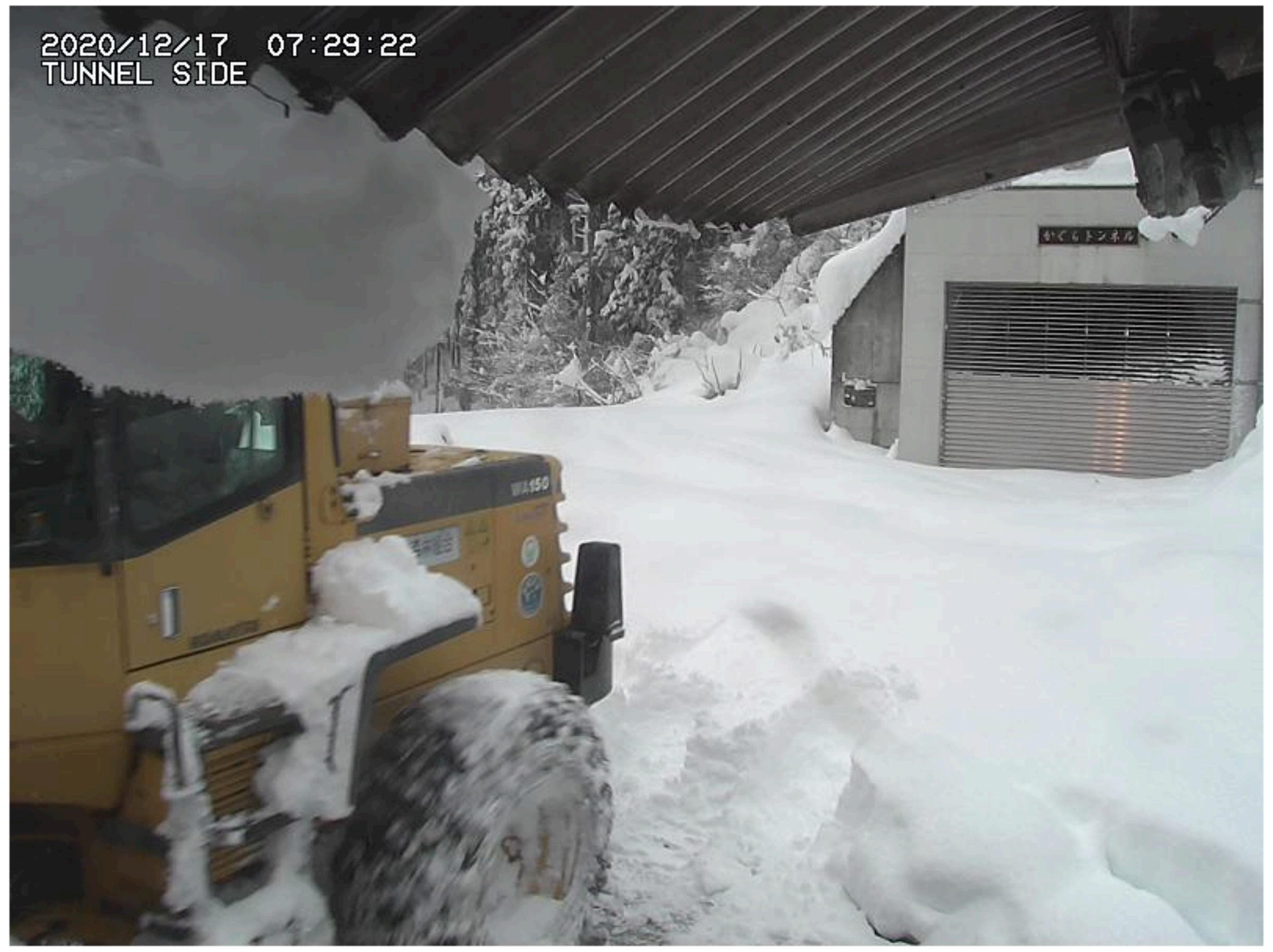
Other sensors :
- ◆ Radio frequency recover (1)
- ◆ DC power monitor (1)
- ◆ Temperature & humidity sensors (69)
- ◆ Vacuum gauges (11)

by T. Washimi

KAGRA (Kamioka Gravitational-Wave Observatory)

KAGRA (Kamioka Gravitational-Wave Observatory)

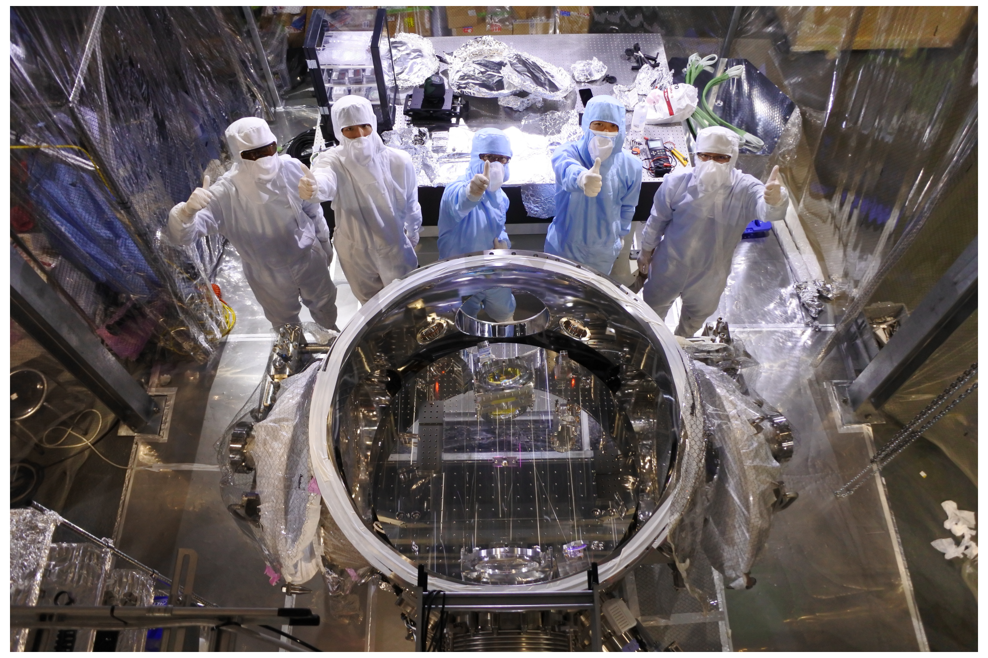




90cm snow in one night, Dec 17 2020

http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA/KSC#newsletter

(Right) Photon Calibrator X-end installation completed. July 25. [JGW-G1809009]
In photo, Takaaki Yokozawa, Yuki Inoue, Takahiro Yamamoto, and Chihiro Kozakai.



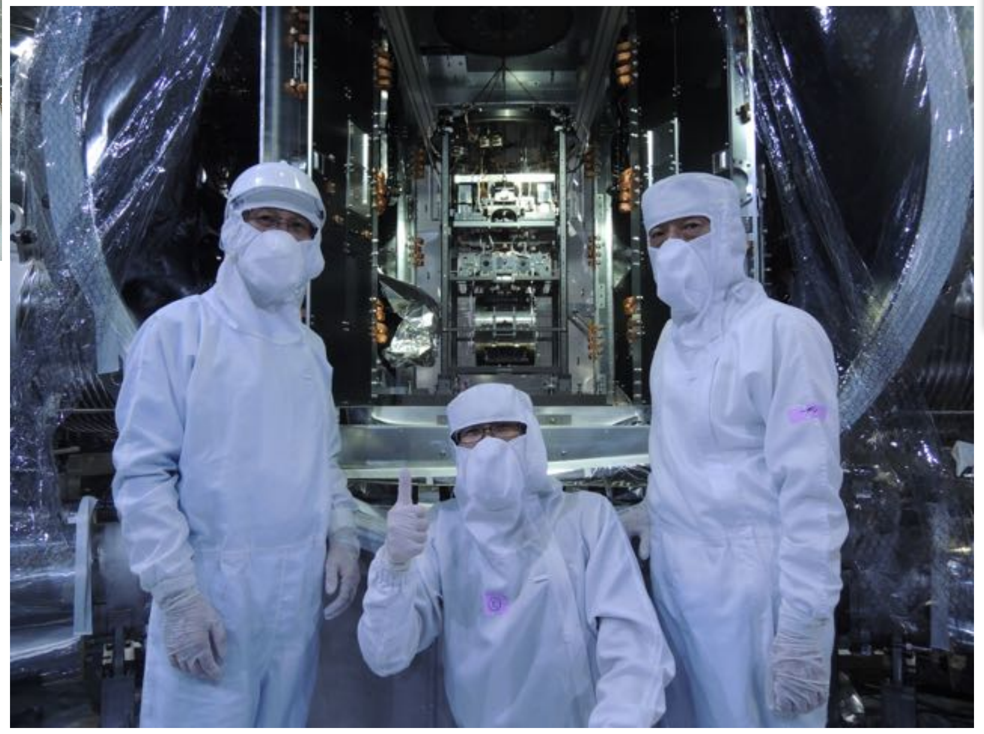
(Left) Installed the BRT part on the TMS-VIS in the EXT chamber at the X-end! [klog 06342].
In photo, Fumihiro Uraguchi, Koji Nagano, Kunihiko Hasegawa, Kenta Tanaka, Naoki Kita, and Tomotada Akutsu.

We did it! in 2018

(Right) SR3 Installation, July 20. [klog 05569]
Panwei Huang, Naoatsu Hirata, Terrence Tsang, Fabian Peña, Mark Barton, Ryohei Kozu, and Enzo Tapia. (plus Guiguo observing)

(Above) OMC installation succeeded, October 18. [klog 06612]
In photo, Sotatsu Otabe, Kohei Kusayanagi, Hiraku Sasaki, and Kentaro Somiya.

(Right) Nov. 9, the last installation of cryogenic payload was completed. The photo at Y-front was distributed in [kagra 02500].
In photo, Masahiro Takahashi, Takayuki Tomaru and Sakae Araki.



Editors thank Takaaki Yokozawa for his suggestions of photos.

KSC Newsletter

Issue 4

Einstein Telescope and KAGRA signed agreement

to collaborate on the development of the common technologies

The 5th KAGRA International Workshop (KIW5) was held at Perugia, Italy. The third day of the workshop was named "The first KAGRA-Virgo-3G Detectors Workshop (KV3G)", where we discussed the project of Einstein Telescope (ET), one of the key gravitational-wave observatory plans in the future. The nascent ET collaboration (it will be formulated in April 2019) plans to construct a triangle-shape 10 km-armed laser-interferometer underground, and with cryogenic technology. Its core technologies match with our experiences.

On February 16, 2019, at the gorgeous Sala dei Notari (hall of Notari), our PI, Takaaki Kajita, and the ET steering board chairmen, Michele Punturo and Harald Lück, signed a letter of intent to collaborate on the development of third generation detectors. The scope of the letter is quite general (see JGW-M1909820), but we believe it becomes a certain step forward for both of us.
KIW5 and KV3G workshop had more than a hundred of participants. The meeting continued from the early morning to the late evening, but we enjoyed a small historical old city area, Perugia chocolates, and environment of AC Perugia (Perugia Calcio). We thank LOC members, especially Helios Vocca

Contents of this issue

KSC Newsletter

Issue 6

KAGRA joined International GW Network

Signed up LIGO-Virgo-KAGRA MoA for joint observation

On October 4, 2019, KAGRA held a ceremony to mark the completion of the detector. The ceremony was in the site, and after the play of the music of *kagura* (the traditional Shinto-style ritual music) by local children's musical group, Takaaki Kajita, our PI, pushed a button with U Tokyo Executive Vice President Kohei Miyazono to demonstrate the detector in motion. In the evening of the day, the signing ceremony of a memorandum of agreement (MoA) on a research collaboration between KAGRA, LIGO and Virgo were held.

This MoA makes KAGRA an equal partner of LIGO and Virgo, and once KAGRA satisfied the criteria for joining observation then all the scientific achievements will be presented as LIGO-Virgo-KAGRA collaboration. KAGRA is definitely close to the production phase after the ten-year construction and installation period.

bove) Pose for photos after signing a MoA. (from left) EGO vice esident Christian Olivetto, Virgo spokesperson Jo van den Brand, AGRA principal investigator Takaaki Kajita, LIGO Executive Director avid Reitze, KSC board chair Hisaaki Shinkai, and KAGRA vice PI asatake Ohashi. At ANA Crowne Plaza hotel Toyama, October 4, 019. [Photo courtesy of Hida City]

ight above) The ceremony at the site. Playing *kagura* music by local rine musicians. (Right below) Takaaki Kajita and U Tokyo Vice esident Kohei Miyazono switched on the green button, and it locked. hotos courtesy of H. Oobayashi.]

KSC Newsletter

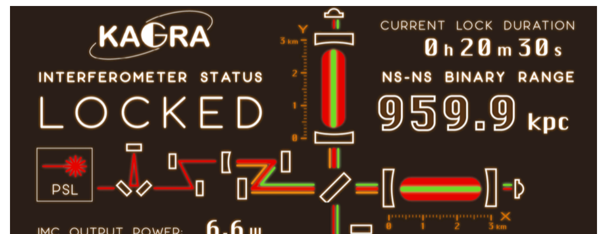
Issue 7

KAGRA entered the observing mode!

We are operating at Mpc-level finally

After we signed to the memorandum of agreement (MoA) [JGW-M1910663] [JGW-M1910664], with LIGO/Virgo in October, our target has been concentrated to join to Observation 3 (O3) of LIGO/Virgo. The requirements [JGW-M1910813] are to improve the sensitivity of the detector over 1 Mpc in binary neutron-star range, and to clear the readiness checklists of data flows/calibrations/organization. When we first locked the detector on August 23, 2019, the sensitivity was 0.4 kpc. In order to reach our target (10 Mpc), the team so far made great efforts for commissioning and noise-hunting.

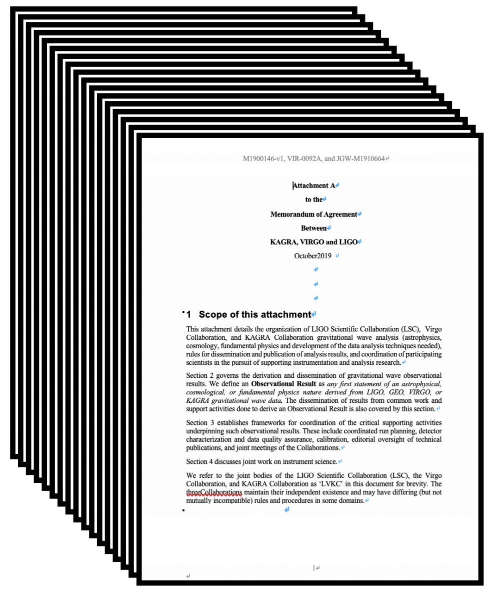
The planned date for starting observation was postponed a couple of times. We made engineering run in December, then went back to the commissioning. After the announce of the first lock of the power recycling system on January 26 [klog12639] and OMC readout ready [klog12763], our sensitivity started recording the number as we graphed below



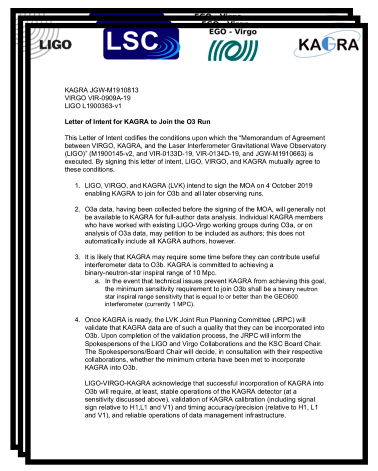
Joint Research MoA signed LIGO-Virgo-KAGRA

October 4, 2019 @ Ceremony of MoA signing

main part (10 pages)
Concept, Definitions, Purposes

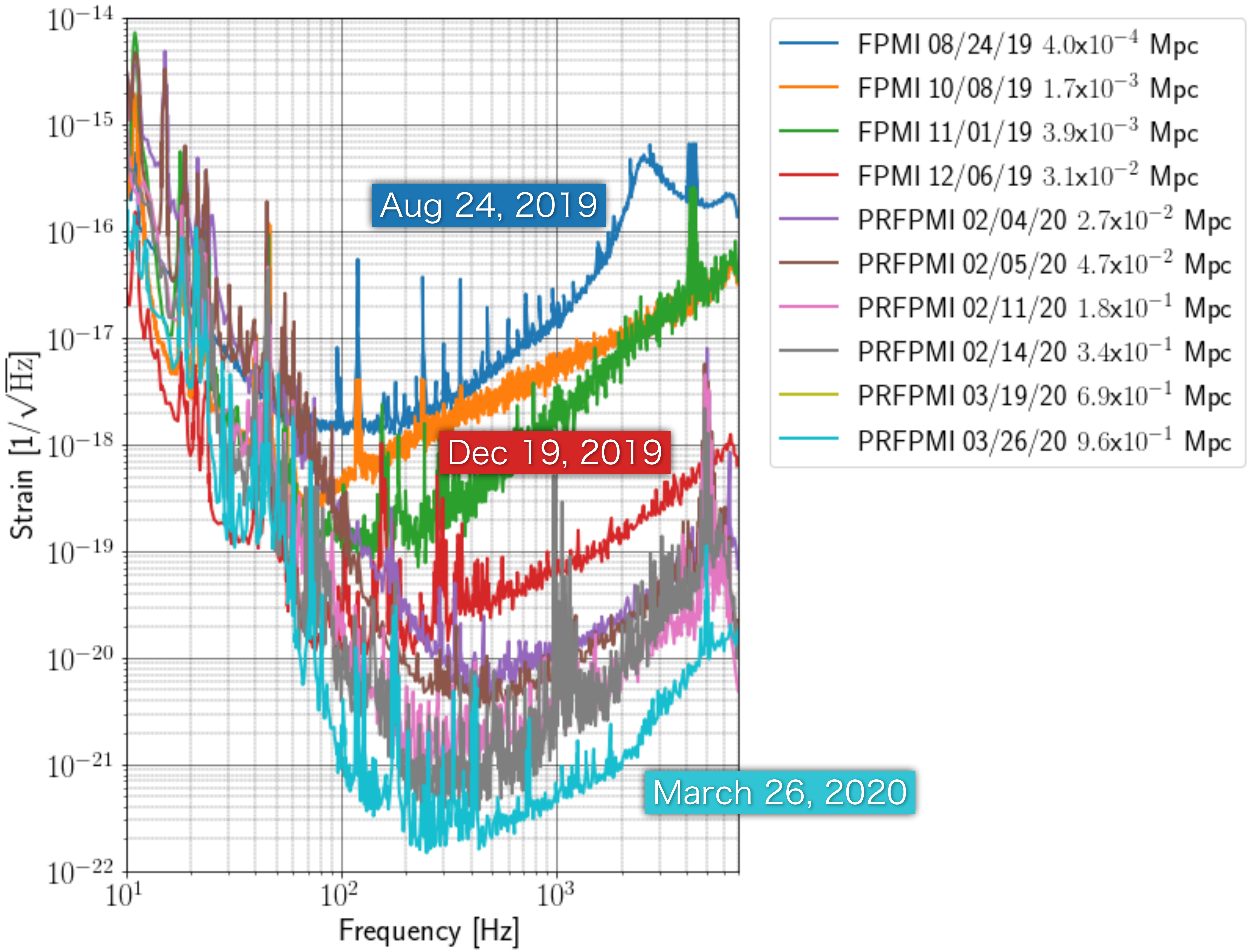


Appendix A (17 pages)
Organizations, Procedures

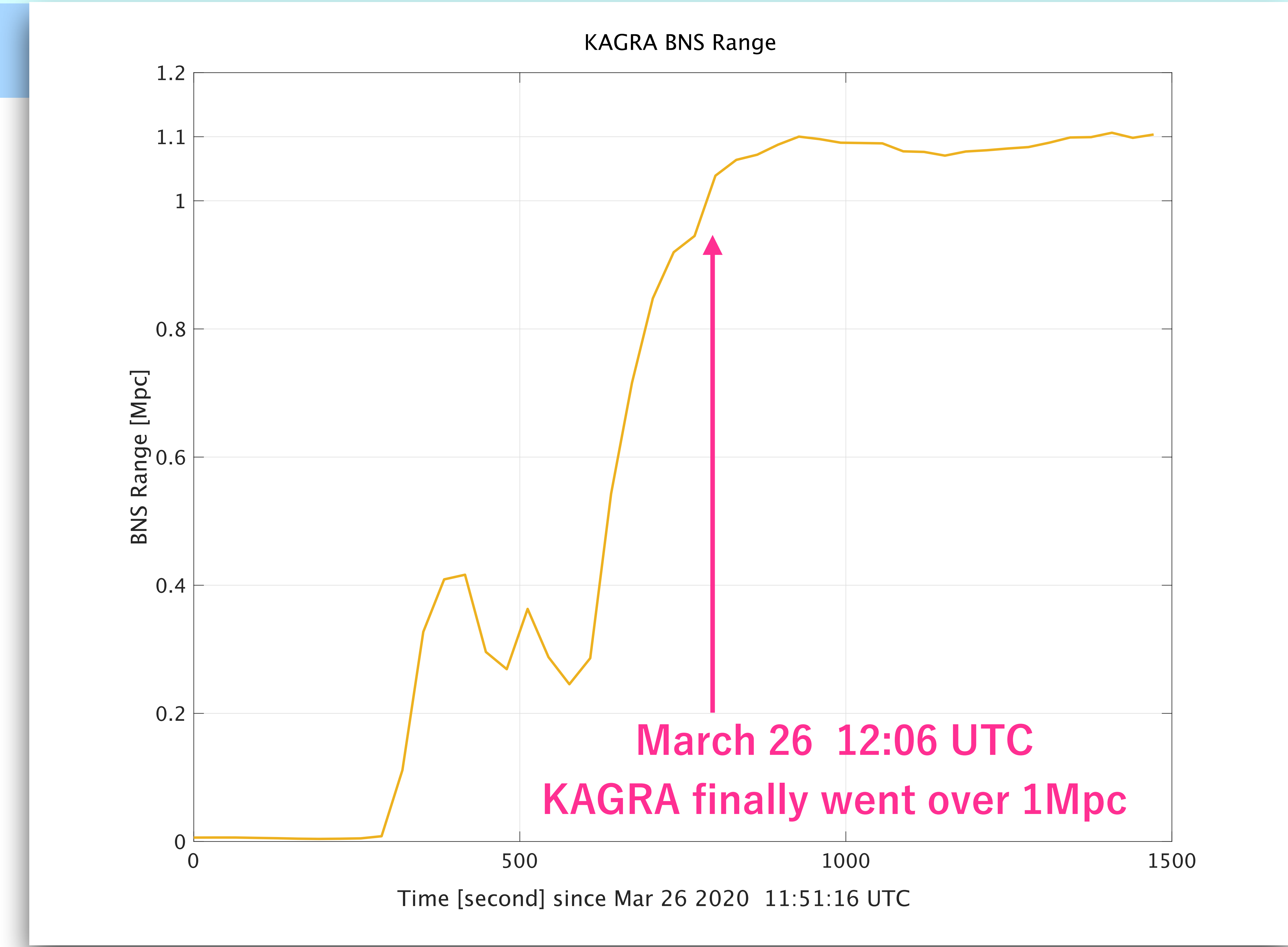


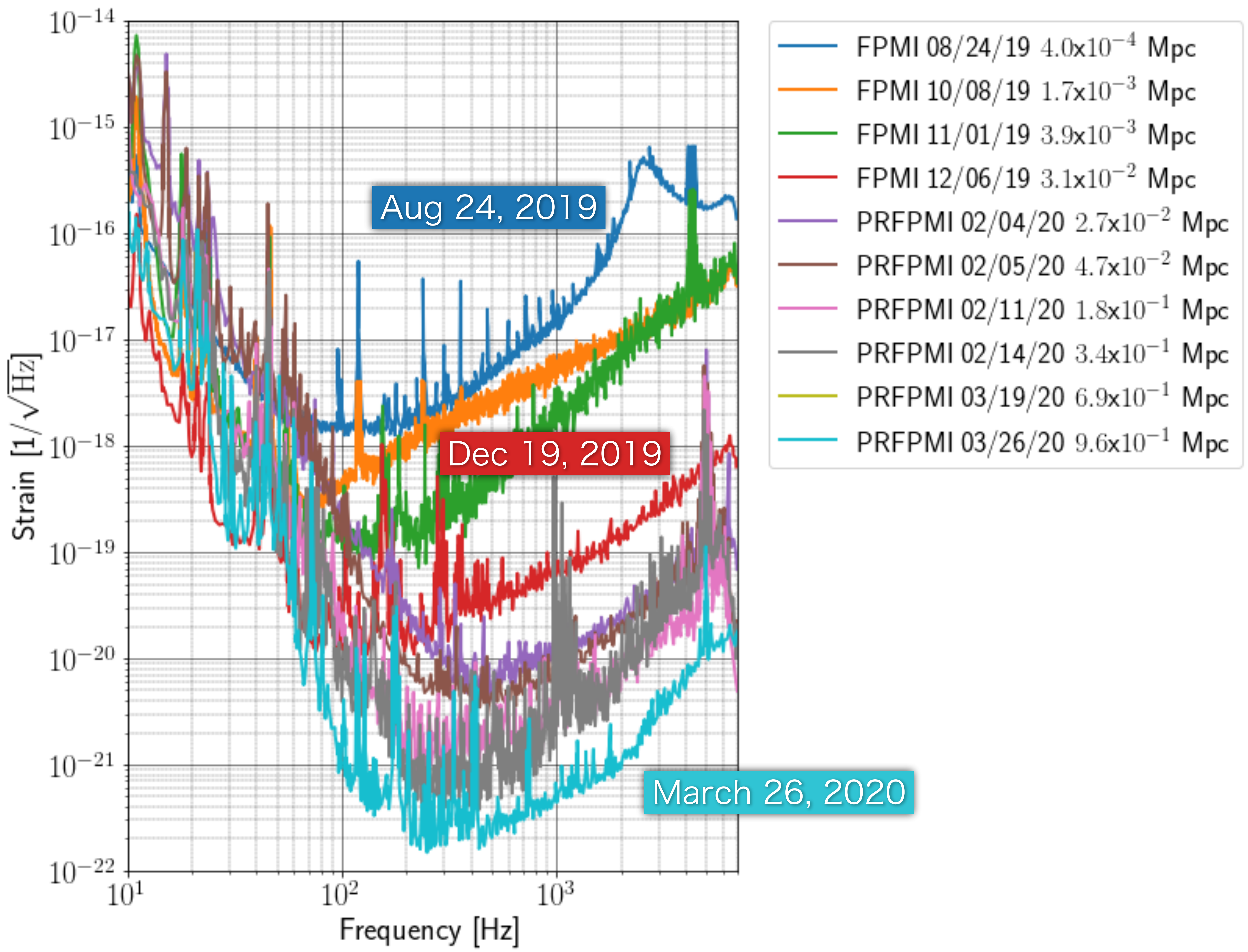
Letter of Intent (3 pages)
KAGRA's Join to O3

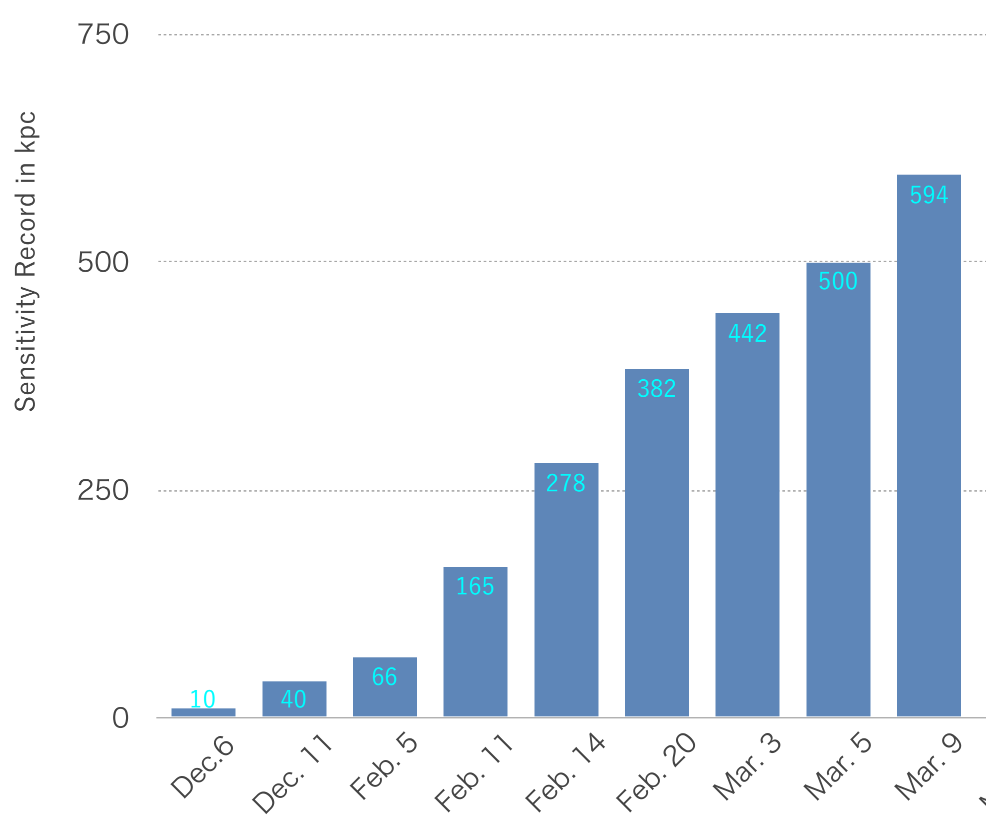
＊ 1 Mpc (BNS) is required to join the observation.



＊ Finally, over 1 Mpc in the end of March 26, 2020.





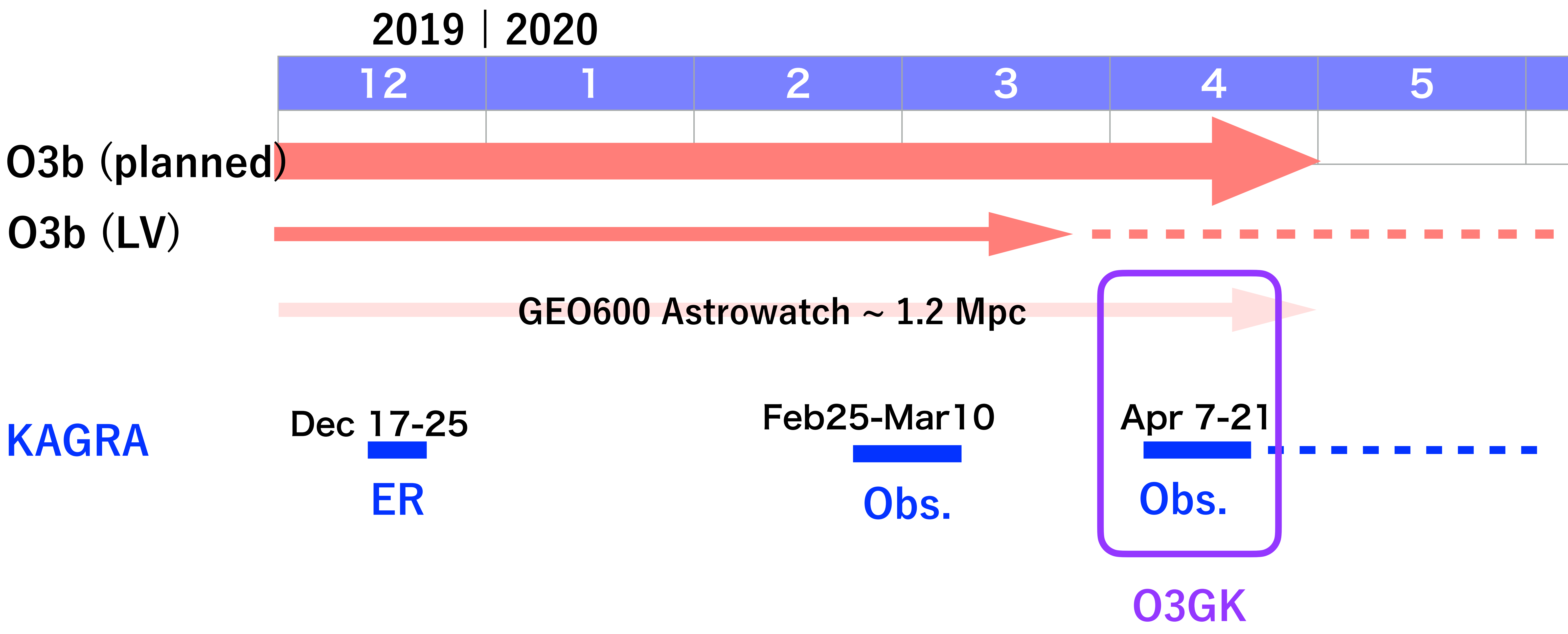


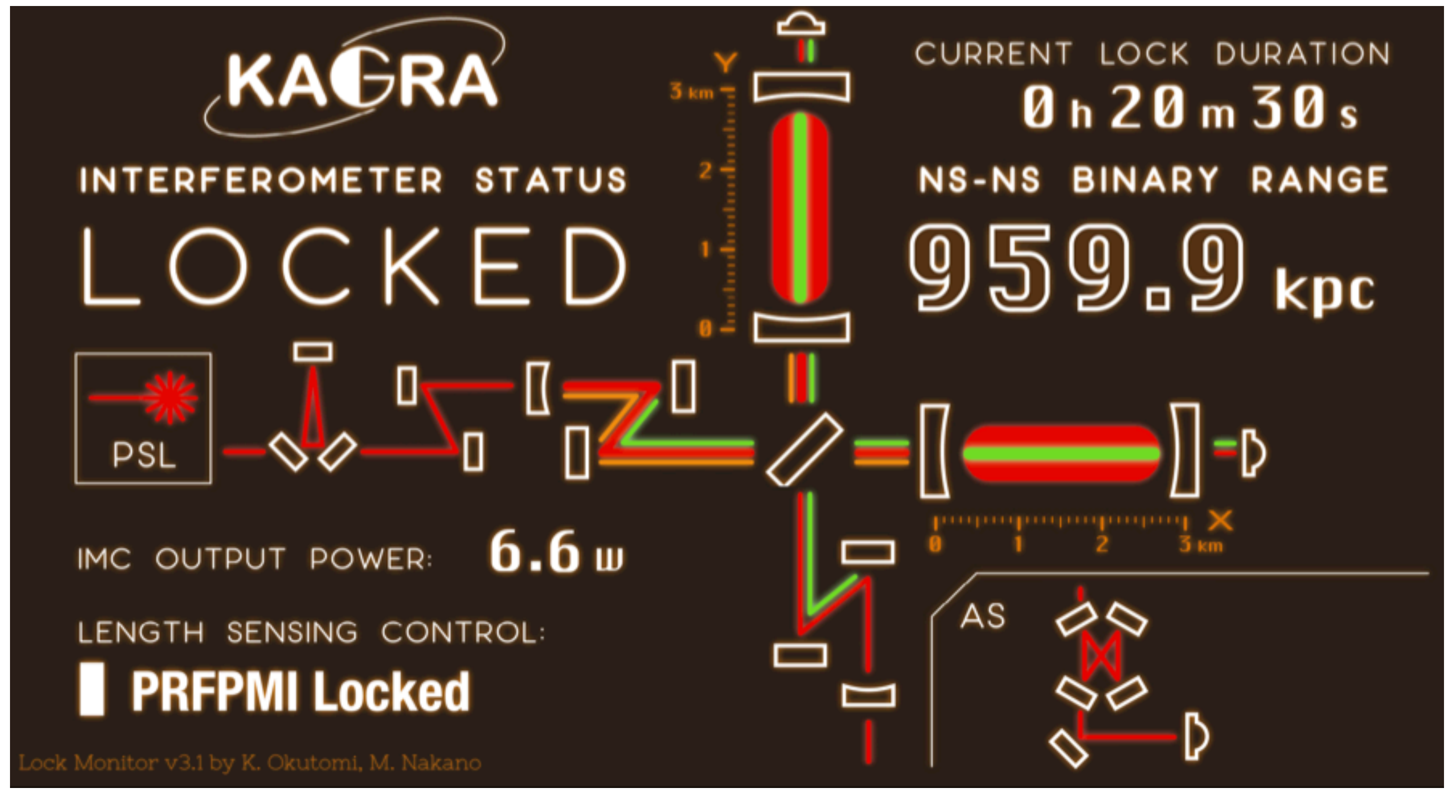
* **Power-Recycling FPMI** **Observation in April**

* **Frosting of Mirrors** due to incompleteness of vacuum

→ not go to 20K, but 250K

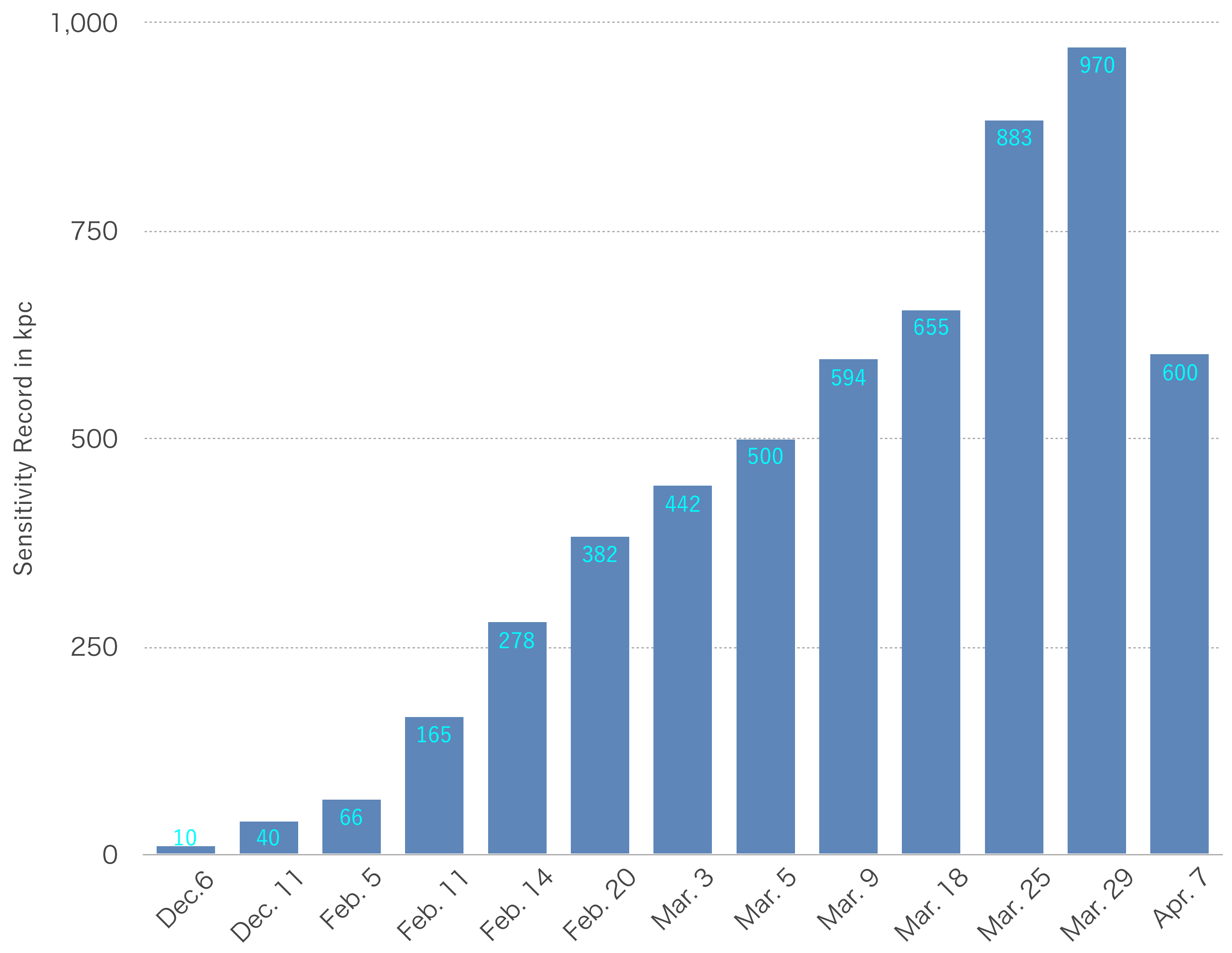
O3b, O3GK, and after that





March 29, 2020

* O3GK observation paper plan
(LVK paper)



KAGRA collaboration

Statistics of KAGRA collaboration
(December 11, 2020)

	collaborators	Institutions, Groups
Japan	277	67
Taiwan	64	8
China	63	15
Korea	38	17
Italy	20	5
USA	10	5
Australia	5	1
Hong Kong	5	1
India	3	2
France	2	2
Spain	2	1
Poland	2	1
UK	2	2
Russia	1	1
Germany	1	1
Vietnam	1	1
total	495	129

http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA

KAGRA collaboration

KAGRA

112groups, 14 countries/regions

410+ active members

+50-40 since Mar 2020.

Default-author list 2018+2019

has 243 names.

Organize Face-to-Face meeting
3 times (April/August/Dec) / year

F2F Aug. 2020 @ online, Japan

F2F Dec. 2020 @ NCU, Taiwan

Organize International Workshop
twice / year

KIW7 Dec. 2020 @ NCU, Taiwan

KIW8 July 2021 @ Daejeon, Korea

KIW9 ?? 2021 @ Beijing China

http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA

KAGRA collaborators in Taiwan

Academia Sinica
- Cheng-Yi Chiang
- Yu-Kuang Chu
- ***Sadakazu Haino**
- Yun-Jing Huang
- Hsiang-Yu Huang
- Feng-Kai Lin
- Ling-Wei Luo
- Darkhan Tuyenbayev

Industrial Technology Research Institute
- ***Sheng-Jui Chen**
- Sheau-Shi Pan

National Applied Research Laboratories
- ***Chun-Yu Lin**

National Chiao Tung University
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- Hong-Yin Chen
- Chia-Jui Chou
- Yi-Hsuan Huang
- Sheng-Hong Lai
- Hans Brynner Lao
- Yu-Hsuan Lo
- ***Yi Yang**

National Cheng Kung University
- Kwan Lok Li

National Central University
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- Hsuan-Yu Chu
- ***Yuki Inoue**
- ***Chia Ming Kuo**
- Hong Lin Lin
- Harn Fung Pang

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- Huali Chen
- Chao-Qiang Geng
- Yao-Chin Huang
- ***Albert Kong**
- Hao-Jui Kuan
- ***Ray-Kuang Lee**
- En-Tzu Lin
- Bo-Han Lin
- Jhih-Rong Lu
- ***Kuo-Chuan Pan**
- Surojit Saha
- Martin Spinrath
- Chien-Ming Wu
- Hsun-Chung Wu
- Shu-Rong Wu
- Tsung Ju Yang
- Shu-Wei Yeh

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- Guo-Zhang Huang
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- Han-Shiang Kuo
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- Mei-Ting Lin
- Jie-Shiun Tsao
- Wei-Ren Xu
- Hong Zhang

Tamkang University
- Yu-Ting Chang
- ***Chian-Shu Chen**
- Hong-Yu Chou
- Chia-Hsuan Hsiung
- Hui-Chih Huang
- Ching Chun Huang
- Yu Syue Huang
- ***Guo Chin Liu**
- Kin-Wang Ng
- Alessandro Parisi
- Ting Yu Shih

64 collaborators as of Dec 12, 2020. * KSC contact person

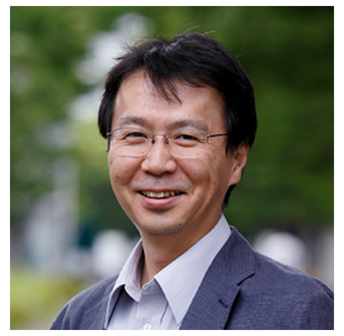
Organization of KAGRA

Takaaki Kajita
(PI)

Masatake Ohashi
(vice PI)

Shinji Miyoki
(SEO proj. manager)

PI
Executive Office
System Engineering Office
sharing information & idea
KAGRA Scientific Congress (KSC) organization chart
KSC board
* Hisaaki Shinkai
* Shinji Miyoki
* Chunglee Kim
Hideyuki Tagoshi
Tomotada Akutsu
Zhoujian Cao (China)
Hyung-Won Lee (Korea)
Ray-Kuang Lee (Taiwan)
Tatsuki Washimi (PD)
Satoru Takano (Student)
Data Analysis Committee (DAC)
Theory Group
Future Strategy Committee (FSC)
LVK committees
KAGRA committees



Hideyuki Tagoshi
(DAC chair)

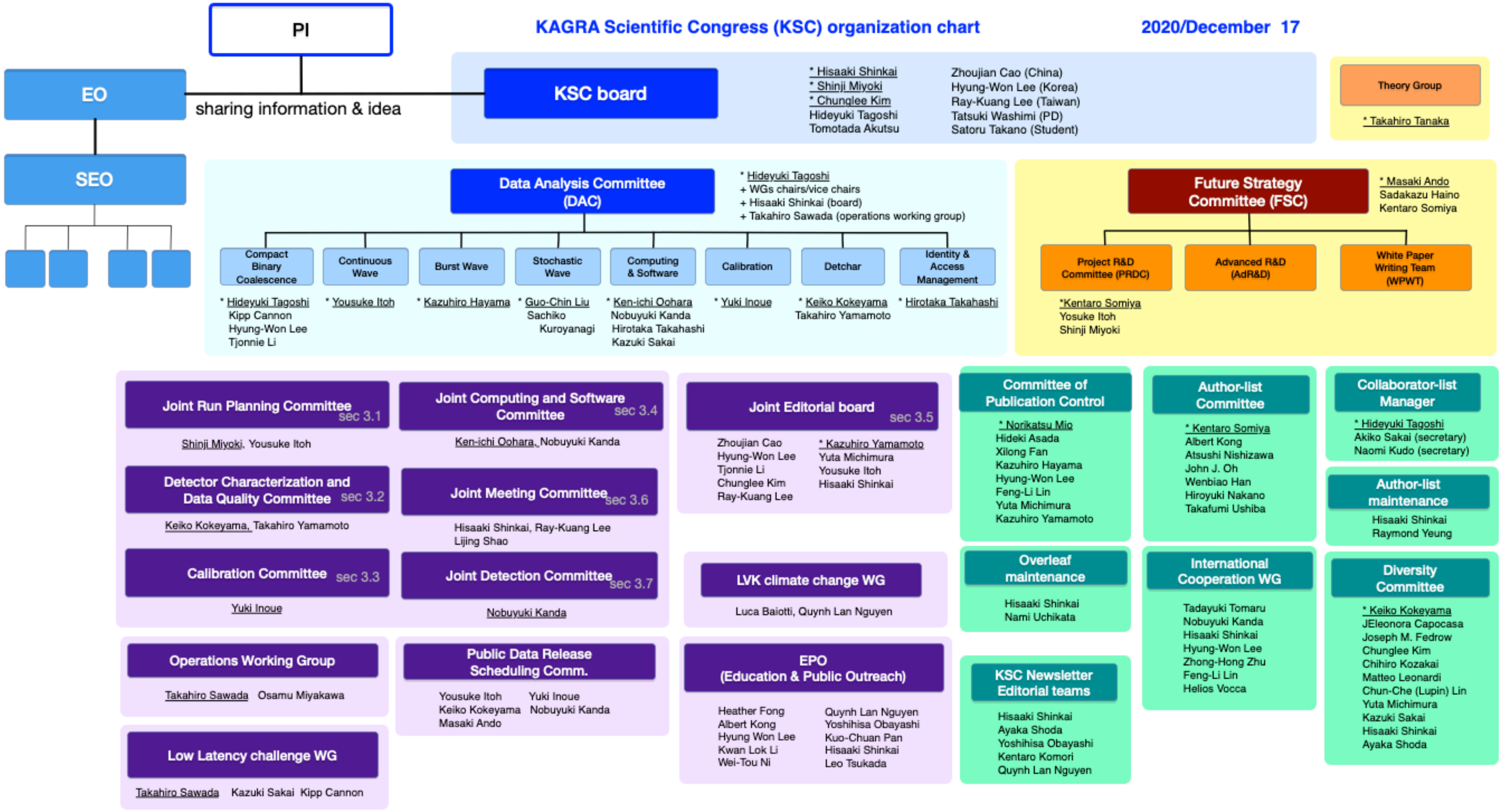
Takahiro Tanaka
(Theory chair)

HS
(KSC chair)

Masaki Ando
(FSC chair)

http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA/KSC

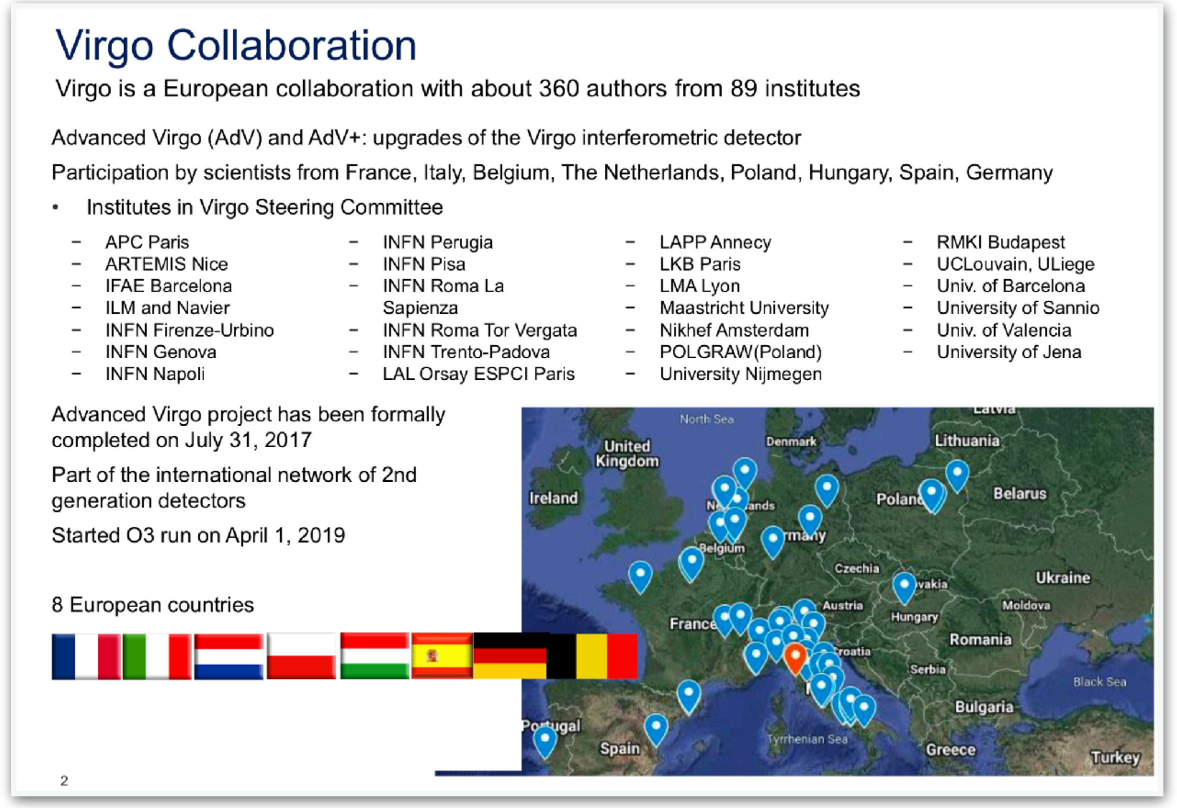
Organization of KSC（KAGRA Scientific Congress）



http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA/KSC

International GW network （国際重力波観測ネットワーク）

LIGO | VIRGO | KAGRA



LIGO	Virgo	KAGRA
1330 members	465 members	410 members
860 authors	360 authors	240 authors
101 groups	96 groups	115 groups
20 countries	8 countries	14 regions

Science Summary as of LVK-outreach

KAGRA

LSC LIGO Scientific Collaboration

News | Detections | Our science explained | Multimedia | Educational resources | For researchers | About the LSC | LIGO Lab | Observing Plans

Intro to LIGO & Gravitational Waves | Science Summaries | Popular Articles | Frequently Asked Questions | Magazine | Advanced LIGO

SUMMARIES OF LSC SCIENTIFIC PUBLICATIONS

We now feature, for each new research article, a summary written for the general public. Simply click on any of the titles for an online version, or on the '[flyer]' links for a downloadable file in PDF format. Translations into several languages are also available for some of these summaries. Where not noted separately, translations can be accessed through their language acronyms (e.g. 'es' for Spanish, also see details in the sidebar) or from the top of the English online versions.

LATEST DETECTIONS

GWTC-2 (Oct 28, 2020)

Catalog paper summarizing previous and new detections from the O3a observing run:

GWTC-2: An Expanded Catalog Of Gravitational-Wave Detections [flyer]

Also in: Bengali [bn] | Catalan [ca] | Chinese (simplified) [zh-Hans] | Chinese (traditional) [zh-Hant] | French [fr] | German [de] | Greek [el] | Hindi [hi] | Italian [it] | Japanese [ja] | Korean [ko] | Polish [pl] | Spanish [es] .

Companion papers:

- The population properties of compact objects following LIGO/Virgo Run O3a [flyer] | [it] | [ja] | [zh-Hant]
- Testing General Relativity with Gravitational Waves from the first half of the LIGO-Virgo 3rd Observing Run [flyer] | [fr] | [de] | [it] | [ja] | [ko] | [pl] | [zh-Hant]
- Searching for hidden gravitational waves produced by gamma-ray burst events in O3a [flyer] | [de] | [it] | [ja] | [ko] | [pl] | [zh-Hant]

GW190521 (Sep 2, 2020)

GW190521: The Most Massive Black Hole Collision Observed To Date [flyer]

Also in: Blackfoot [bla] | Catalan [ca] | Chinese (traditional) [zh-Hant] | Dutch [nl] | French [fr] | Galician [gl] | German [de] | Greek [el] | Hindi [hi] | Hungarian [hu] | Italian [it] | Japanese [ja] | Korean [ko] | Marathi [mr] | Polish [pl] | Spanish [es]

LOOKING DOWN A DETECTOR ARM

Visitors at LIGO Hanford Observatory gaze down the site's X arm. Half of the 4-kilometer length of the arm is visible in the photo. (Credit: LIGO Laboratory)

TRANSLATIONS: LANGUAGE KEYS

For most summaries, we list the available translations by their ISO 639-1 / ISO 639-2 keys, as listed below. Translations are a volunteer effort and different sets of languages are available for each summary. You can search for the key of your language, in square brackets – for instance [fr] for French – on this page to find all science summaries that have been translated into it.

- **[bla]**: Blackfoot (Siksiká)
- **[bn]**: Bengali (Bangla)

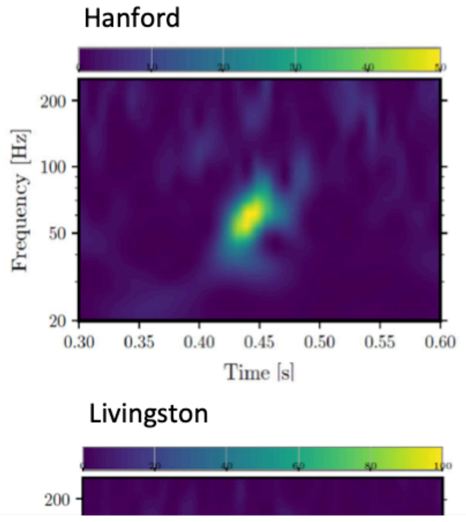
LSC LIGO Scientific Collaboration VIRGO

GW190521: 迄今測量到最大質量的黑洞碰撞

我們觀察到了什麼？

在2019年5月21日，先進雷射干涉重力波天文台 (Advanced LIGO) 與先進處女座干涉儀 (Advanced Virgo) 觀測到一對異乎尋常的黑洞合併所產生的重力波信號。該信號名為 GW190521。比起迄今為止觀察到的任何其他雙黑洞合併系統，GW190521的持續時間都更短，並在更低的頻率處達到峰值。

一般而言，來自雙黑洞合併系統的重力波信號在 Advanced Virgo 和 Advanced LIGO 的靈敏頻帶中持續的時間會與其總質量成反比。而



LSC LIGO Scientific Collaboration VIRGO

從 LIGO 和 Virgo 第三次前半段聯合觀測看緻密星體的族群特性

典型的黑洞是什麼樣的？它們數量有多少？黑洞的數量是否隨著宇宙的演化而改變？我們可以利用重力波去了解雙黑洞的形成嗎？

LIGO和Virgo天文台的第三次聯合觀測 (O3) 已經結束，而第二個重力波觀測目錄 (GWTC-2) 也隨之發布，其中收集許多在O3前半段(稱為O3a)發現的重力波事件。與之前的目錄GWTC-1比較，重力波事件的數量增加了四倍。我們在第一個目錄發現新穎且獨特的重力波系統，並就我們以電磁波觀測所認識的黑洞，針對其起源提出了新的問題，而第二個目錄則根據重力波族群的特性揭示新觀點，

黑洞有兩個物理特徵：質量和自旋……洞系統的特徵還取決於黑洞自旋……星軌道平面的方向以及我們與黑……離。因重力波以光速傳送，我們……離得到在黑洞合併時的宇宙年齡。

LSC LIGO Scientific Collaboration VIRGO

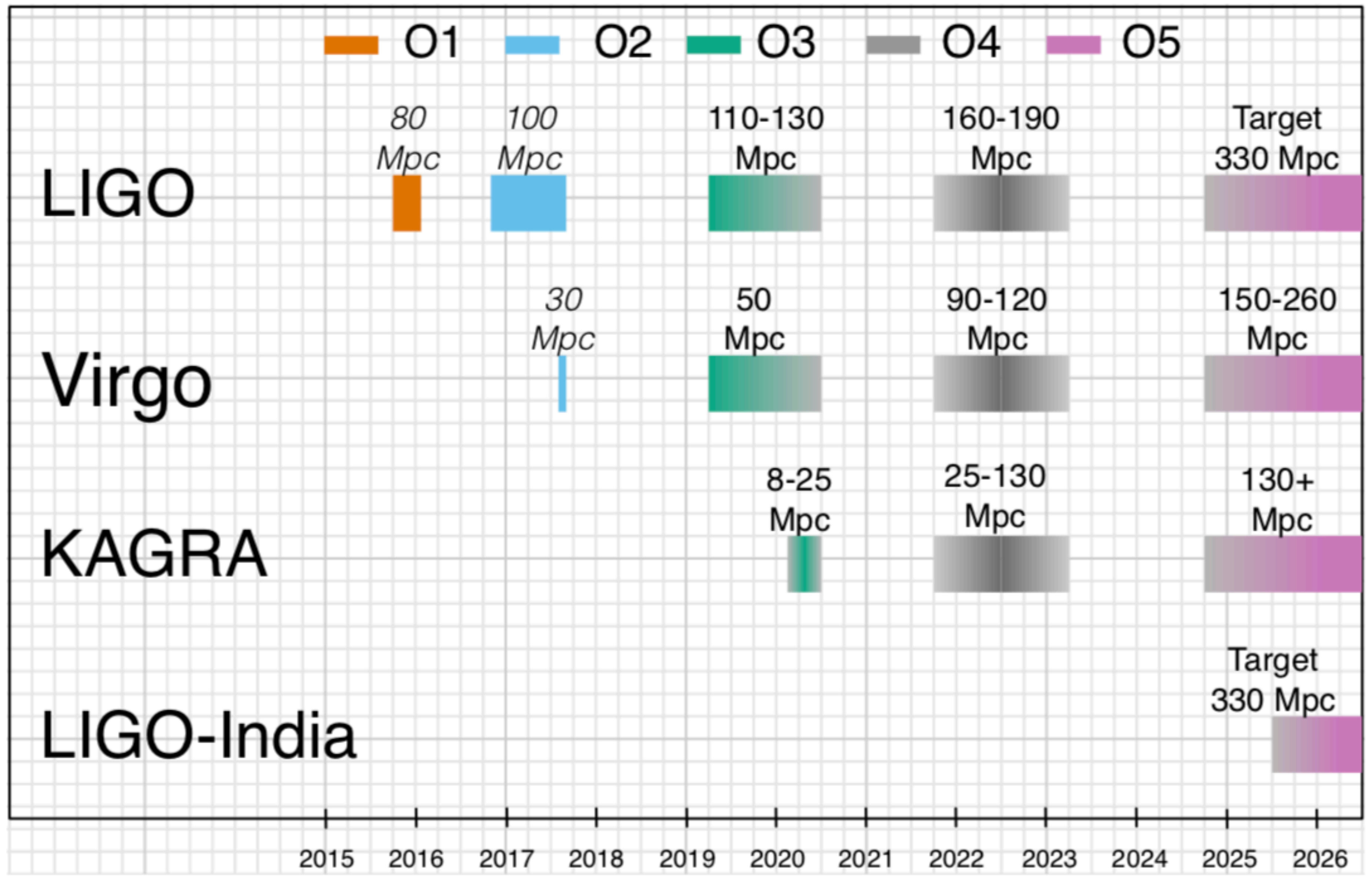
GWTC-2：重力波源的擴展目錄

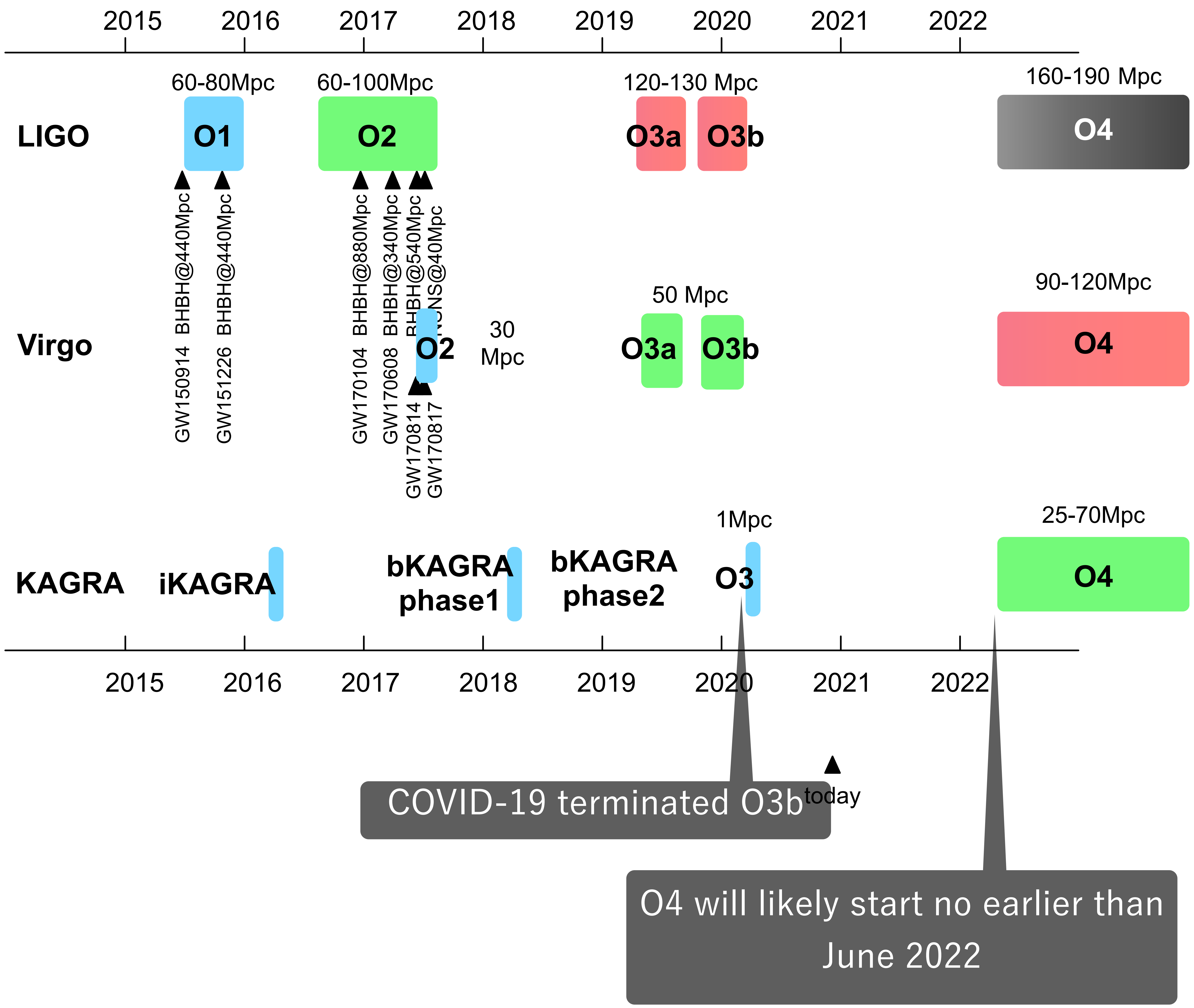
我們發表了新的LIGO和Virgo重力波源目錄（GWTC-2或"Gravitational-Wave Transient Catalog 2"），當中使用了從2015年的首次觀測到O3a（第三期觀測的前半期）收集到的所有數據。O3a的實際運行日期為2019年4月1日至10月1日，期間偵測到39個新的重力波源，加上在GWTC-1中列出的11個已確認事件，使GWTC-2中的重力波事件總數達到了50個。在O3a中發現的天體涵蓋了相當廣泛的天文物理性質，它們也分別與雙黑洞（BBH）、雙中子星（BNS）和中子星黑洞（NSBH）合併事件的理論模型非常吻合。

值得注意的是，O3a中偵測到的重力波事件數量比前兩個觀測期（O1和O2）所找到的總和還要高出三倍以上。Virgo探測器更是首次連同另外兩個LIGO探測器全程參與了O3a。在整個O3a觀測行動中，97%的觀測時間有至少一個探測器在運作，而有約82%的時間有至少兩個探測器在運作。此外，一些特別有趣的事件也在O3a被發現，當中包括：史上第二次觀測到與雙中子星合併吻合的重力波事件；第一批具有明顯不同質量對的事件；以及總質量約為太陽質量150倍的重量級雙黑洞。在此摘要中，我們將解構LIGO和Virgo在O3a中被大幅提升的觀測能力，以及這些重力波事件對天體物理學領域的重大意義。

https://www.ligo.org/science/outreach.php

Target Sensitivity & Schedule





"Scenario Paper" [1304.0670ver2020Jan]

LVK collaboration, Living Rev Relativ (2020) 23:3

https://link.springer.com/article/10.1007/s41114-020-00026-9

Big Project selection in Japan

SciTech Research Selection Comm. (MEXT) : Roadmap 2020 (Sep. 2020)

List for final selection : 15 KAGRA is in the list.

MEXT is accepting public comments.

Final decision was made in the end of September.

physics, astronomy

- ✓ **KAGRA (ICRR)**
- ✓ Subaru (NAOJ)
- ✓ ALMA (NAOJ)
- ✓ Super B-factory (KEK)
- ✓ J-PARC (KEK)
- ✓ LiteBIRD (JAXA)
- ✓ Super-Kamiokande (ICRR)

Grade A Importance, Community's approval,
Core Institutes, Joint research system
Plan's appropriate

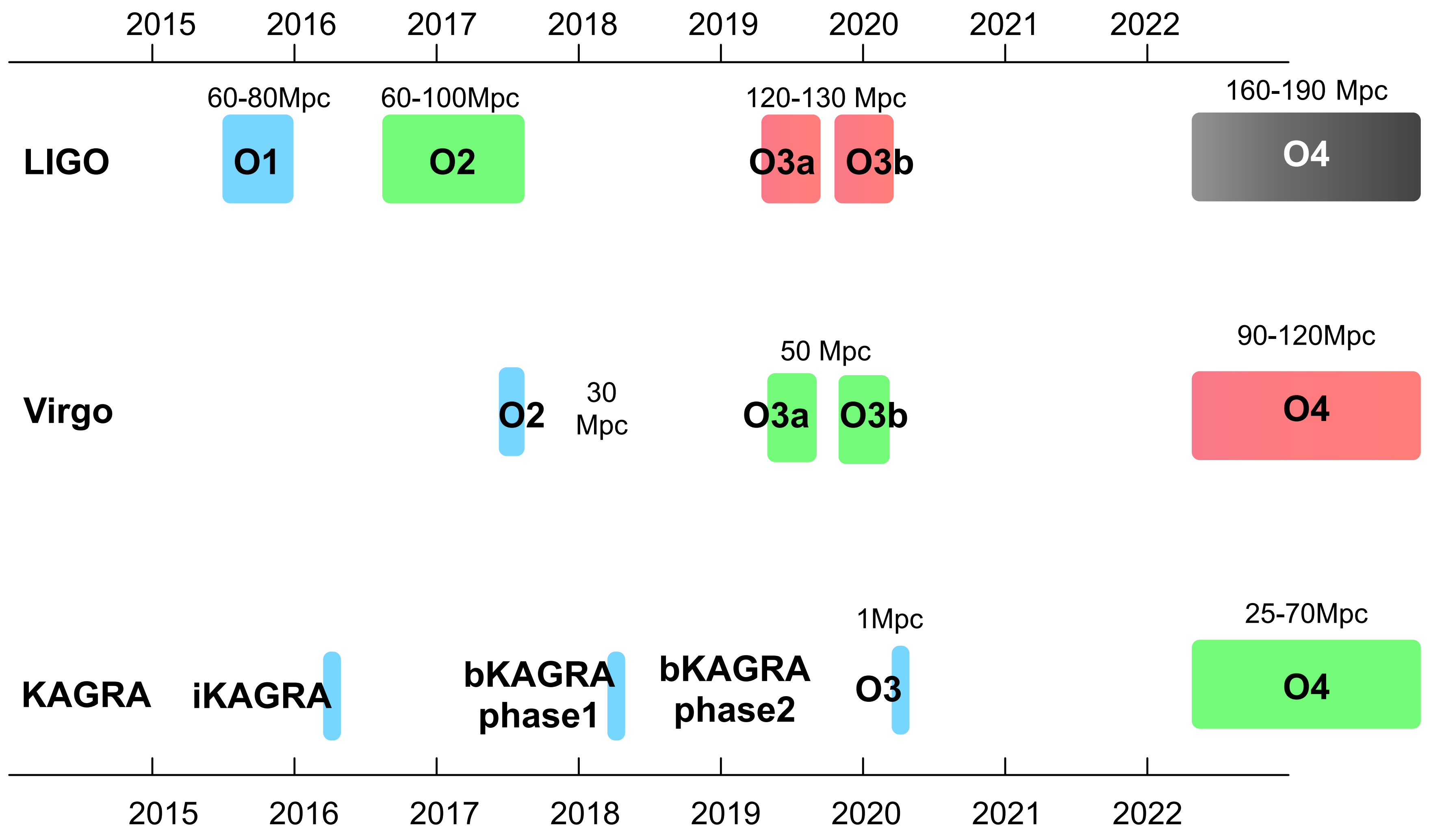
Grade A Emergency, Strategy, Supports from general

KAGRA project (operation) budget: 2023Apr-2034Mar

Toward O4

KAGRA

* **Target Sensitivity 25 - 130 Mpc**
* Recent estimate: **80 Mpc at most?**
  due to heat absorption of sapphire mirrors
  by reducing laser noise, low-f noise, then it goes better more.



- [x] less than 100K
- [ ] dual recycling
  - [x] lock trials by the end of September
- [ ] suspension noise control for low freq.
  - [x] one-order reduced in July
- [ ] de-frosting mirrors
- [ ] de-frosting windows for oplev light

x20 sensitivity at mid-freq.

June 2022
O4 ready

commissioning

Summer 2021

repair & installation

October 2020

- Cryo-Payload repairing
- ETMY tower repairing
- install laser beam baffles
- Cryocoolers replacement (CRY)
- Intensity noise reduction system (IOO)

- DGS/AEL upgrade (DGS/AEL)
- Stray light around IOO (AOS)
- Suspension frame modification (AOS, VIS)
- Temperature monitors (VIS)
- and more

Overview of KAGRA: reviews in PTEP 2020

ACCEPTED MANUSCRIPT

Overview of KAGRA : Detector design and construction history

T Akutsu, M Ando, K Arai, Y Arai, S Araki, A Araya, N Aritomi, Y Aso, S Bae, Y Bae ... Show more

Progress of Theoretical and Experimental Physics, ptaa125, https://doi.org/10.1093/ptep/ptaa125

Published: 17 August 2020 **Article history** ▾

published PTEP 2020
KAGRA history

https://doi.org/10.1093/ptep/ptaa125

arXiv: 2005.05574

ACCEPTED MANUSCRIPT

Overview of KAGRA: KAGRA science

T Akutsu, M Ando, K Arai, Y Arai, S Araki, A Araya, N Aritomi, H Asada, Y Aso, S Bae ... Show more

Progress of Theoretical and Experimental Physics, ptaa120, https://doi.org/10.1093/ptep/ptaa120

Published: 12 August 2020 **Article history** ▾

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published PTEP 2020
KAGRA Science

https://doi.org/10.1093/ptep/ptaa120

arXiv: 2008.02921

* Overview of KAGRA : Calibration, detector characterization, physical environment, and geophysics interferometer
submitted PTEP 2020

in preparation

* Overview of KAGRA : Noise Budget
* Overview of KAGRA : Data transfer and management
* Overview of KAGRA : Data analysis methods
* Overview of KAGRA : Future plans

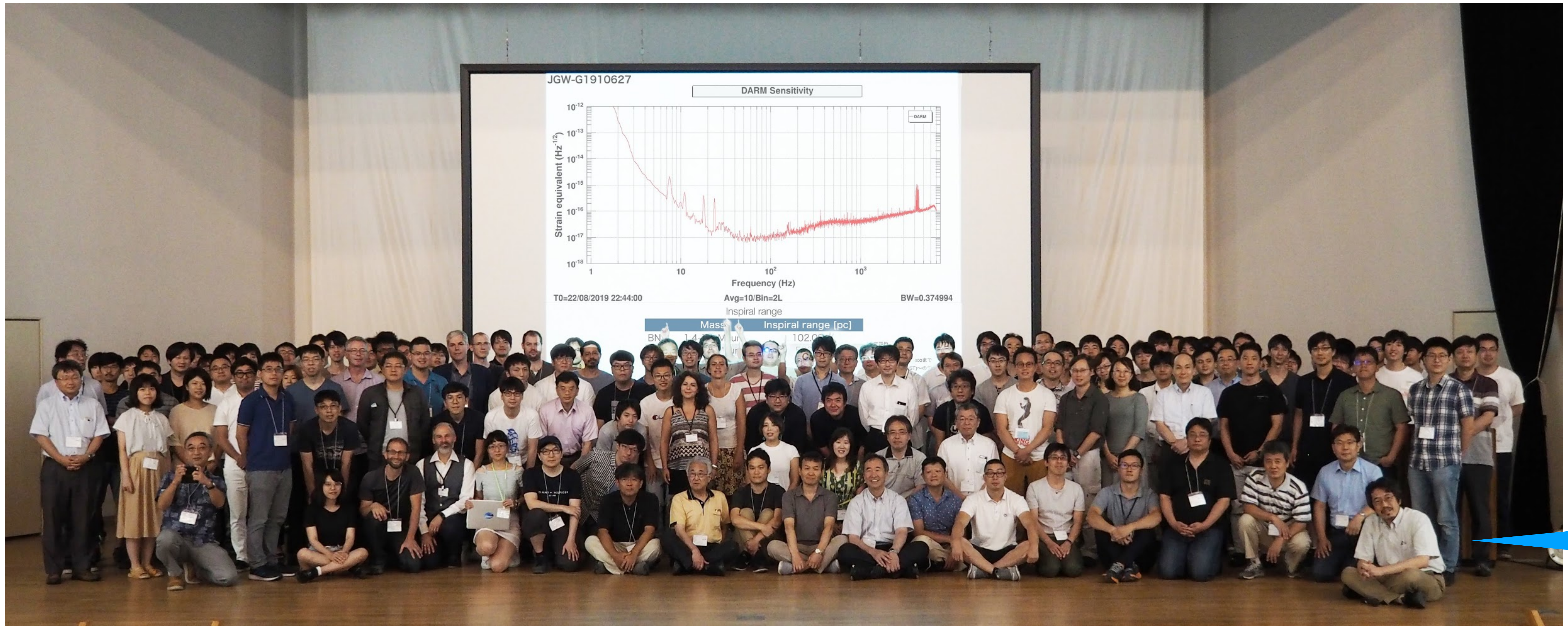
Status of KAGRA: Summary

"O3"
- KAGRA finally joined in April, two-week observation run.
- O3GK publication plan is ongoing.

Detector
- Repairs and Installations from October, 2020
- LVK O4 is planned to start June 2022.

Budget
- KAGRA is in the final list of Japan MEXT Roadmap 2020

Science
- LVK joint publications started October 2020 on O3b.



If you are planning to join, please contact to your nearest KAGRA collaborators, or consult below FAQ.

http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA/KSC/FAQ