KAGRA SCIENTIFIC CONGRESS: COLLABORATORS' INFORMATION EXCHANGE 2021/MAY 1

# KSC Newsletter

Issue 8

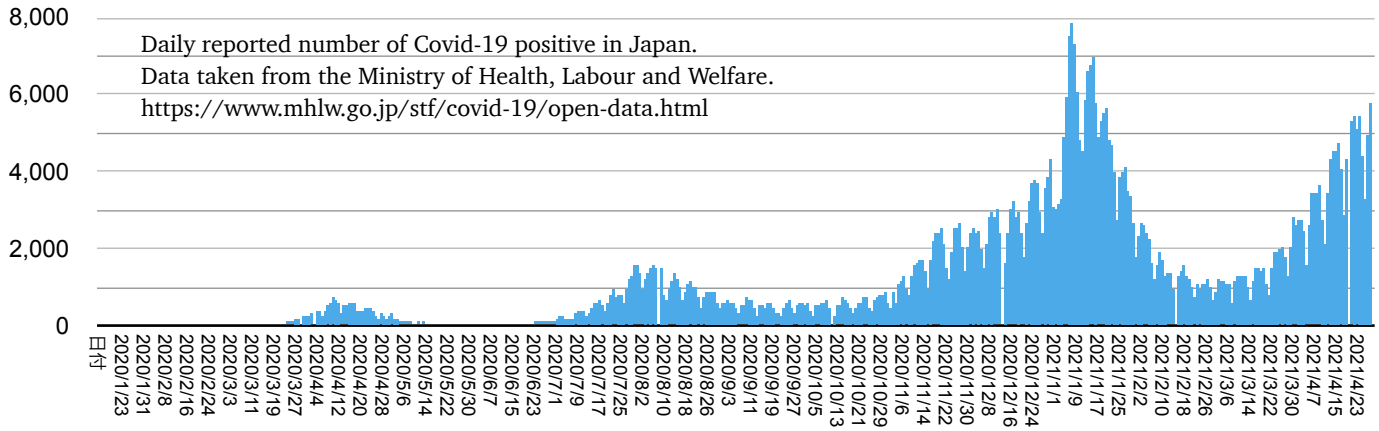
## Towards New Phase

We are still confronting with the war to COVID-19 and its variants. In most regions in the world (except China and Taiwan), we still have to spend our time scared of corona infection, avoiding contact with people as much as possible, having less conversation, and living a life that restrains movement. Academic meetings, workshops, seminars and classes have been made online. All the experiments and installations are under restricted environment. We know criticizing unreliable governments can not solve these problems.

But let's think differently. Epidemics have hit humankind many times in history. Human beings have confronted it and managed to overcome it. Newton had to spent two years returning to the countryside when the city of London was closed due to plague outbreak. At this time, he summarized the calculus method and got the idea of the inverse square law of gravity. Newton himself later recalled in his autobiography that "the last two years have been the pinnacle of his life's imagination." It is a "creative vacation".

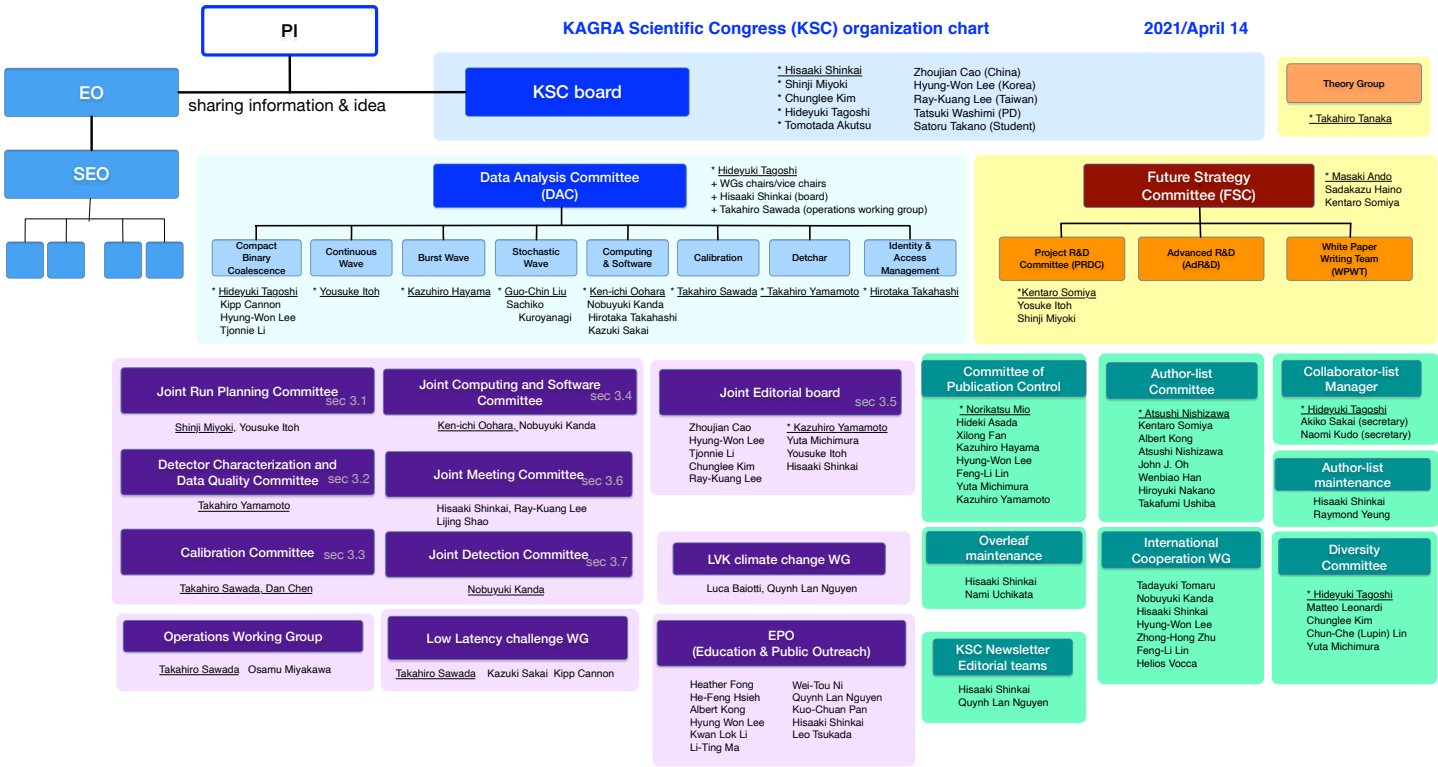
## From O3a, O3b, O3GK to O4

The third observation period (O3a/b) of LIGO and Virgo was terminated by COVID-19 on March 27, 2020, while KAGRA passed the joining condition of 1 Mpc sensitivity in binary neutron star on March 26 and went into the observing mode in April. KAGRA once decided to make solo observation, but someone noticed that GEO600 in Germany was in operation as Astrowatch with the sensitivity 1.2 Mpc. We therefore organized KAGRA+GEO combinational operation from April 7 to 21, 2020, under the LIGO-Virgo-KAGRA (LVK) collaboration, which was named O3GK later. We were operating KAGRA until summer with the expectation of O3c, but it was the fighting period against the earthquakes in Nagano and Gifu prefectures in Japan. The experiment groups started repairing and installing facilities in September, and are now rushing for O4, which is supposed to start in the summer 2022 (more than a half year delay from the original LVK plan).
Meanwhile, from October 2020, KAGRA's authorship as the LVK-collaboration papers started for O3b data analysis. We established Joint Editorial Board and started assigning our reviewer for each paper, and we are required to check the drafts which come almost every week.



# Organization New Committees in KSC

We are still under construction. In the past year, we newly created many committees in KSC. **Future Strategy Committee (FSC)** was proposed for our future design after O5, and set up with three subgroups, Project R&D, Advanced R&D, and White Paper Writing Team. The chair of FSC is Masaki Ando (U Tokyo). **Theory Group** was formed with 30+ members with the chair Takahiro Tanaka (Kyoto U).
Recently, Calibration group was split into two, a group at site (**SEO-CAL**; chair: Dan Chen from NAOJ) and a group under Data Analysis Committee (**DAC-CAL**; chair: Takahiro Sawada from Osaka City U). The former works for creating C00, while the latter is responsible for C10. The half members of Committee of Publication Control (CPC) and Author-list Committee were changed in September 2020, the chair of CPC is Norikatsu Mio (U Tokyo) and the chair of Author-list comm is Atsushi Nishizawa (U Tokyo).
For joint organization as LVK network, we started **Joint Editorial Board** for organizing LVK papers with the chair Kazuhiro Yamamoto (U Toyama). We also assigned **Operations Working Group** and **Low Latency Working Group**, Takahiro Sawada (Osaka City U) took both chairs. For managing the author-list with LV, **Author-list maintenance** group was also started.




KAGRA has 439 collaborators (as of April 29, who filed O3 commitment form), but sometimes we are lacking human resources for organization. We expect your active contributions for any works together with researches.

This year, we have the election of KSC board in August. The current board chair, Hisaaki Shinkai (Osaka Inst. Tech), will complete the two terms of four years. For the next two years, we will start O4 and make real observations. We expect new board members who will lead us on more amazing phase.

Hisaaki Shinkai

KAGRA site

# From March 2020 to March 2021

Takashi Uchiyama, ICRR

At the KAGRA site in Kamioka, Hida City, Gifu Prefecture, Japan, spring comes later than in Tokyo. I delivered photos of the cherry blossoms blooming on the KAGRA site on April 3rd in 2020 and March 31st in 2021 to KAGRA collaborators and I would like to review the events of KAGRA over the past year.

First of all, I would like to introduce the climate of Kamioka over the past year [1]. The biggest impact on KAGRA was the heavy rain in July. In Kamioka, it rained more than 660 mm, which was more than double the normal amount, during a month of this July. In particular, 178 mm of rainfall was recorded during the three days from July 6th to 8th. Due to this rain, the optical fiber for high-speed internet connected to the research facilities in KAGRA, including KAGRA, was sometimes disconnected. High-speed internet was restored on July 14th, about a week later.

Kamioka is a region with a lot of snow in Japan. This winter snow began on December 15th with the first snowfall. What was different from usual was that the amount of snowfall reached 90 cm at once in the three days following the first snowfall. This was about twice as much snow as in December of normal years. The amount of snowfall after December was about the same as normal in January, but it was relatively small in February and March. Probably because of this, the amount of underground spring water due to the thaw that has increased since around March does not seem to be particularly large compared to the average year, and it is already on a downward trend. Due to the measures established so far and the efforts of the underground management staff, the situation where the laboratory is contaminated by spring water has not occurred.

Next, I comment on the impact of the COVID-19 pandemic on KAGRA. As is well known, limiting activity is effective in preventing the spread of the new coronavirus. Since KAGRA is a facility of the University of Tokyo (U Tokyo), we are working under the policy of U Tokyo. Here is a brief introduction to the activity restrictions set by U Tokyo.

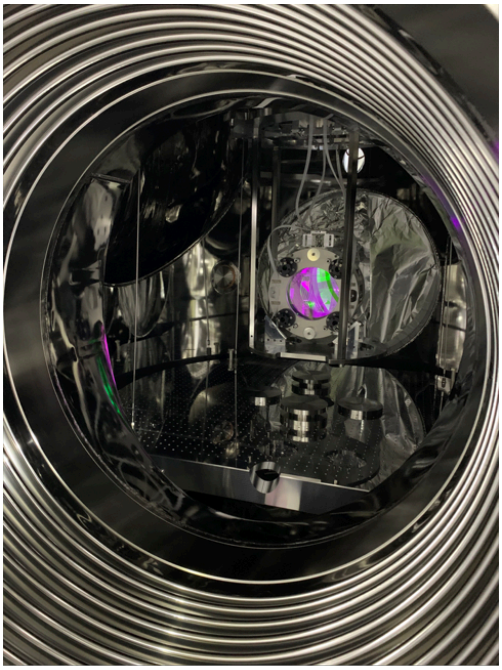


Figure 1: Vibration Isolation System waits for upgrade for O4.

U Tokyo has set activity restriction from level 0 (Normal operation) to 4 (All on-campus activities suspended in principle) according to the situation of corona sickness [2]. Activity restrictions began at level 1 on April 3rd, 2020 and were raised to level 2 the next day. After that, in response to the Japanese government issuing a state of emergency on April 7th, the University of Tokyo also raised the activity restrictions to level 3 (Maximum restrictions) from April 8th. Even in April 2021, this level 3 is the maximum level of activity restrictions actually set. The Level 3 period lasted until the end of May, after which it was gradually lowered to Level 0.5 (Minimum restrictions) on July 13. It returned to level 1 in January 2021, but never to level 0. As of April 2021 at the time of writing this manuscript, the activity limit is level 0.5.

By the way, KAGRA conducted the first international joint observation O3GK for KAGRA from April 7th to 21st. For observations, please refer to KSC news letter No.7 (2020 April) [3]. You can see that this observation was made most of the time under the strong activity limitation of Level 3. As a result, it became impossible to call collaborators from the outside, and observations were carried out with a minimum shift system by local staff. After O3GK was finished, we put the interferometer in "Suspend mode" and focused on maintaining it. It continued until June 1st when the activity restriction level was relaxed to 2.

From June 1st, the interferometer was returned and the measurements necessary for writing a treatise were proceeded. From mid-July, when the activity limit level was lowered to 0.5, an interferometer control experiment (RSE experiment) using the RSE configuration will begin as part of the work toward O4. Researchers began to come to KAGRA little by little, but efforts to prevent the spread of infection continued, such as limiting the number of people in the control room to three.

The RSE experiment continued until mid-October, but the interferometer was shut down, triggered by a legal inspection of KAGRA's electrical equipment accompanied by a power outage on October 14. The vacuum chambers have been opened to the atmosphere, and the ducts connecting the chambers have also been removed so that you can see the inside as shown in Fig. 1. The refurbishment and upgrade work for O4 has begun in earnest. Researchers, contractors, and staff supporting research activities have returned to KAGRA as before, while paying attention to preventing the spread of infection. These days at most more than 30 people go to the mine. And the work for O4 is still going on without sending out infected people and without closing KAGRA.

I should comment the time of O3GK once again and report the earthquake swarms that occurred around KAGRA at that time [4]. From April 22nd, the day after O3GK ended, earthquakes with these epicenters located only a few tens of kilometers southeast of KAGRA began to occur frequently. The frequency of related earthquakes was 67 in April, 102 in May, 13 in June, 43 in July, 4 in August, and 5 in September. On May 19, 42 earthquakes were recorded in just one day, and at 13:12 that day there was an earthquake with a maximum magnitude of 5.4. It has also been reported on KAGRA's klog [5]. Considering that the area usually has only 3 to 6 earthquakes a month, it is clear that it was an unusual few months.

At the end of March 2020, KAGRA's sensitivity reached 1 Mpc as the observable range of gravitational waves emitted during neutron binary coalescence, which was a condition for joinig to O3. Immediately after that, after a one-week engineering run, we did O3GK for two weeks. From the next day, several months of earthquake swarms began. Looking back, it's easy to see that O3GK was done in a miraculous time frame. I would like to thank all the collaborators for their efforts to realize O3GK.

I introduce two other works underway in Kamioka from a different perspective. One is a new research building (new building) called the International Center for Elementary Particles in Space, which is currently under construction. Figure 2 shows the image of the expected completion. It is scheduled to be completed in November 2021 near the data analysis building of the KAGRA observatory, next to the Kamioka Observatory for Cosmic Ray Research, the host organization of Super-Kamiokande (SK). The new building is a building with 4 floors above ground and 1 basement floor, and not only laboratories, but also rooms such as a large hall, exhibition space, SK server room, nap room area, coworking lounge, and reception meeting room will be constructed. The large hall on the 1st floor, the nap room on the 4th floor on the top floor, and the coworking lounge will also be available to KAGRA collaborators, so please look forward to it. The second is Hyper-Kamiokande (HK) [6]. HK is a neutrino detector that is a larger version of Super-Kamiokande. Its construction has begun in another mine, about 10 km from KAGRA [7]. The experiment is scheduled to start in 2027.

Figure 2: Planned image of the International Center for Elementary Particles in Space

Last but not least, writing an article that looks back on such a year will highlight unusual things such as the weather, earthquakes, and above all, the COVID-19 pandemic. However, I would like to emphasize that the true "Update of KAGRA site" is created by the daily efforts toward O4. Please take a look at klog [8], where articles are posted almost every day.

We ask for the continued cooperation and support of all collaborators for the success of KAGRA and the development of gravitational wave astronomy.

Reference

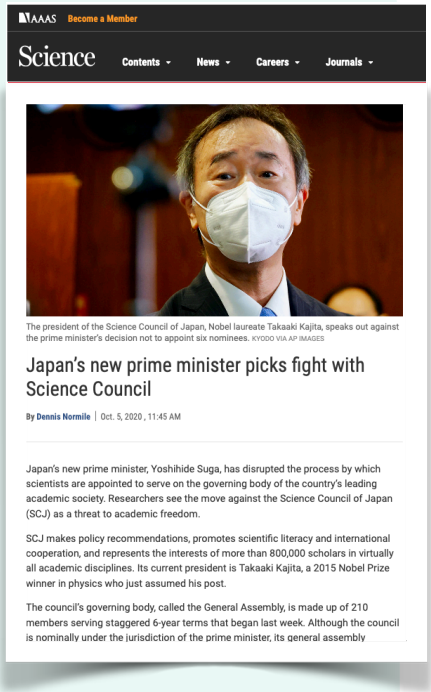
[1] https://www.data.jma.go.jp/obd/stats/etrn/index.php
[2] https://www.u-tokyo.ac.jp/covid-19/en/policies/index.html#id01
[3] KSC Newsletter No.7 (2020 April), https://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/DocDB/ShowDocument?docid=11619
[4] http://www.jma-net.go.jp/gifu/shosai/jishin/gaikyo/pdf/632_09_jishin.pdf
[5] https://klog.icrr.u-tokyo.ac.jp//?r=14402
[6] http://www.hyper-k.org/en/index.html
[7] http://www.hyper-k.org/en/news/news-20201014.html
[8] https://klog.icrr.u-tokyo.ac.jp/osl/?

## Politics

Science Council of Japan is an independent body of the government and consults with the government from a scientific standpoint.

Our PI, **Takaaki Kajita**, became the president of the SCJ, October 1, 2020. This was a great news for us, but for him, the tasks revealed too heavy, since on that day, one big political problem was scooped.

Prime Minister Yoshihide Suga refused to approve 6 new SCJ members without opening reasons. This was against the statements of the previous PMs to keep the independence of SCJ, and also breaks the law. The law on SCJ states that "appointments shall be made on the basis of a recommended list," but the PM Suga has interpreted this broadly to mean that he has the right to appoint. All of us concern that political intervention in academia leads to the destruction of society, culture and democracy.


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 is nominally under the jurisdiction of the prime minister, its general assembly

Seven months has passed, but the government has never spoken to the processes of the selection of people. Newspapers say this is because the six scholars in question had expressed opposition to contentious security legislation enacted in 2015 by Suga's predecessor, Shinzo Abe.


thejapantimes

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.

The ruling Liberal Democratic Party (LDP) is pressing for reform of the Science Council, and Kajita-san has to respond to them, thought it is likely to exchange the problem. In April, SCJ concluded that the current status as a national agency is "appropriate" and "it is difficult to find a positive reason to change." SCJ also calls PM Suga to put things right as he is the only individual empowered to do so. Six scholars have formally requested the government to disclose the information.

Keep watching the next.

EPO

# EPO Activities in Taiwan

Albert Kong (National Tsing Hua University)

Since the establishment of the KAGRA EPO working group, Taiwan has actively participated in discussion of EPO activities of gravitational wave science. Our team consists of academic staffs and students from National Tsing Hua University and National Cheng Kung University. At this stage, we help review the science summaries of LVK scientific publications and translate them into traditional Chinese.

To kick off the first systematic gravitational wave outreach activities in Taiwan, we just put in an outreach proposal to the Ministry of Science and Technology. The main focus of the proposal is to integrate art and technology to introduce gravitational wave science. To this end, our KAGRA EPO team is working with the College of Arts at National Tsing Hua University. Our ultimate objective is to create some artworks inspired by gravitational wave science so that general public can appreciate the beauty of science. In this newsletter, we introduce two concepts of our artwork.

The first interactive artwork is called “Listening the ripples of gravitational waves”. This is inspired by the fact that the frequency of gravitational wave of a merging stellar mass black hole system is about several hundred hertz and this can be heard by human being. Furthermore, the frequency and amplitude depend on the mass ratio of the system. This artwork is an indoor display in a dark area. Figure 1 shows the concept design of the artwork. The artwork consists of a rotating LED rod in the ceiling. The rod is made of LED strip lights that can produce chasing effects controlled by an Arduino system. Two spectators will stand under two ends of the rod where a weight scale will measure the weights and compute the mass ratio. With this information together with some simple assumptions, our system will determine an approximate gravitational wave signal and the spectators will watch a sound and light show of the rotating LED rod with sounds produced by the corresponding gravitational wave signal.

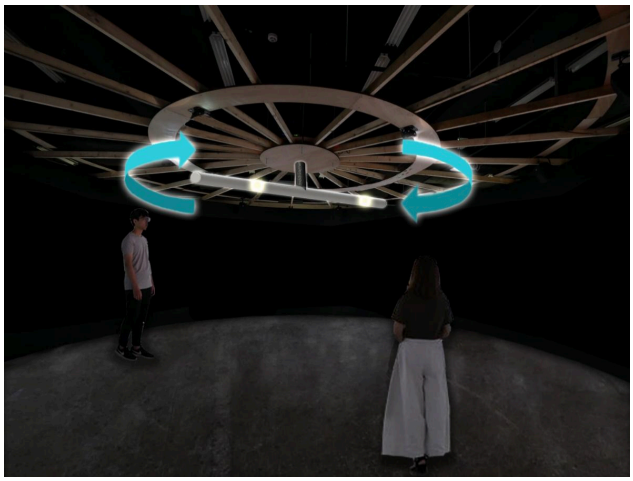


Figure 1: The concept design of “Listening the ripples of gravitational waves” (credit: College of Arts/NTHU)

The second technology inspired artwork is an interactive gravitational wave catalogue. The central piece of the artwork is a touch screen desk (Figure 2). When a spectator touches the screen, an animated moving gravitational wave illustration inspired by real detections is projected onto the desk. The spectators will need to download a mobile app and use the phone as a gravitational wave “detector”. The touch screen desk and the phone are connected with Bluetooth and internet. When the phone approaches to the moving gravitational wave, spectator can scoop the gravitational wave. A successful “detection” will respond with vibration and sounds associated with the gravitational wave signal from the phone. All the information of the gravitational wave signal will display on the phone. The information can be stored in the phone so that spectator can study in more detail in the future.

The interactive touch screen desk consists of an array of non-contact capacitive control interface controlled by an Arduino system (Figure 3). By combining with the gyroscope of the mobile phone, the capacitive control can sense the location and motion of the phone, and trigger a “detection”. Information of the gravitational wave signal will be sent to the mobile phone via internet.

Figure 2: The design concept of the interactive gravitational wave detection (credit: College of Arts/NTHU)

Figure 3: A non-contact capacitive control interface panel used in another art project (credit: College of Arts/NTHU)

This project will be combined with lecture series and other exhibits to introduce gravitational wave science. While the proposal is still under review, we have already started preparation and some art students are interested in working with us to develop the artworks. If such science and technology artworks can be realised, we are happy to share our works to a greater community and hopefully we can invite some of you to visit us in the near future. Moreover, since the whole setup of the artworks is quite simple, it is also possible to lend our artworks to overseas institutes.


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

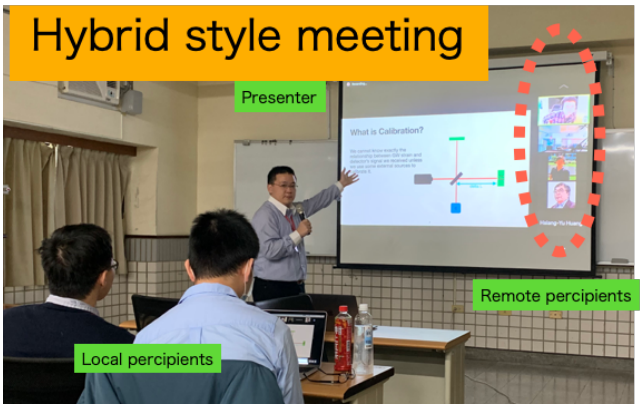
One of the activities of EPO group is to publish “Science Summary” of LVK papers. The articles are with real figures of published paper, together with glossaries. KAGRA EPO contributes its translations to Japanese, Chinese (both simplified and traditional), and Korean. The contents are at undergrad level, but sometime educational even for researchers. KAGRA EPO needs more volunteers of translators and proof readers.

KIW 7

# The 7th KAGRA International Workshop

The 7th KAGRA international workshop (KIW) was held on 18-20 December 2020 in National Central University, Taoyuan City, Taiwan. This workshop is one of the important conferences to discuss the science of KAGRA gravitational wave experiment. However, KIW focuses not only on the KAGRA experiment, but also encompasses other gravitational wave experiments, gravitational wave sciences, and multi-messenger astronomy.


In this workshop, we employed the hybrid style meeting. Local Taiwan people attended National Central University and overseas people joined the online conference system. The unique point of this workshop is parallel sessions. We separated the sessions to experiment, analysis and theory.




There are 242 participants from 20 regions!

We encouraged researchers of both experiment and theory, especially of young generations, to make contributions and exchange the ideas at this conference.

This workshop covered various topics related to gravitational observation; development and characterization of the current and future detector, data analysis, and recent observational results (the results of O3a, from April 2019 to September 2019 by LIGO and Virgo). Finally, the total number of participants of this meeting was 242 from 20 regions. This number is the largest in the previous workshop and three times larger.

Yuki Inoue

Workshop Report

## Highlights of the 30th Midwest Relativity Meeting

Grant Mathews, University of Notre Dame

The 30th annual Midwest Relativity meeting 2020 was sponsored by the University of Notre Dame, Center for Astrophysics. It took place from October 22-24, 2020. A special thanks for the hard work of putting together this workshop is due to the Local Organizing Committee comprised of Grant Mathews, Lan Nguyen, Arielle Phillips, In-Saeng Suh, Atul Kedia, Miguel Correa, Luca Boccioli, Xilu Wang, and the Scientific Organizing Committee consisting of Grant Mathews – U. Notre Dame, David Garfinkle – Oakland Univ, John Friedman – U. Wisc. Milwaukee, Brett Bolen – Grand Valley State Univ., and Nicholas Yunes – the University of Illinois at Urbana Champaign.

Although we were required to conduct the meeting virtually, it was a huge success. The meeting was attended by over 150 participants representing not just the Midwest, but around North America, South America, Europe, Asia, and even Antarctica.

There were 85 talks spread across 14 sessions over three days. Sessions encompassed a broad range of interesting recent developments in the field including the physics of neutron stars and black holes; gravitational lensing; and gravitational waves both theoretical and observational including updates on the LIGO-Virgo-KAGRA collaboration as well as many talks on LISA. Perhaps, the largest number of talks were on the topic of binary neutron-star mergers and black-hole mergers. There were also lively sessions on the puzzle of the black hole mass gap and the GW190521 event.

There was an excellent key-note talk in the session on relativistic supernovae given by NSF Gravity Program Director, Pedro Marronetti on the topic of gravity waves from core-collapse supernovae. Other highlights included interesting sessions on cosmology, quantum gravity, and relativistic fluid dynamics.

This year's Blue Apple award for the best student presentation was given to Lindsay DeMarchi from Northwestern University for her excellent talk on Multi-Messenger Observations of TZOs.

The next Midwest Relativity 2021 meeting will be hosted by the University of Illinois at Urbana Champaign.

## KAGRA MEETING SCHEDULE

Since KAGRA is now attending LVK meetings, which are held March and September, KSC board decided to reduce our face-to-face (F2F) meeting to twice a year. We skip Spring F2F this year, but one-day short telecon in May. Such telecon may be organized when an agenda arises.

**KAGRA telecon, May 12, 2021.** Starts 18:00 JST. Only for collaborators.
**The 8th KAGRA International Workshop, July 7-9, 2021.** Online style. Open to all.
Hosted by KASI, Daejeon, Korea. **http://kiw8.org** Presentation Registration by May 31.

**The 27th KAGRA Face-to-Face meeting, August, 2021.** Online style. Only for collaborators

**LVK collaboration meeting, September 2021.** Maybe in the second week. Online style. Only for collaborators.

**The 28th KAGRA Face-to-Face meeting, December, 2021.** Only for collaborators

**LVK collaboration meeting, March 2022.** Only for collaborators

**The 9th KAGRA International Workshop**, at Beijing Normal U, China, **Spring 2022.** Open to all.

Newly Joined

## Department of Earth Science and Astronomy, The University of Tokyo

We are pleased to have joined the KAGRA collaboration in the face-to-face meeting held in the summer of 2020. Unfortunately, we met online, not in person due to the COVID-19 pandemic. We are looking forward to meeting in person someday, and hope that we will continue to contribute to the KAGRA collaboration.

Our research group is on the Komaba campus of the University of Tokyo, close to Shibuya, Tokyo. Most of the students on the Komaba campus are first- and second-year undergraduate students of the university. They learn liberal arts and will major in law, economics, literature, science, engineering, agriculture, medical science, and so on when they will be third- and fourth-year undergraduate students. Because faculty in the Komaba Astro group teach students with such a wide variety of backgrounds, we specialize in various astronomical fields, such as planets (including exoplanets), stars (including the Sun), and galaxies. Out of five faculty and three postdocs, two faculty (Ataru Tanikawa, Shin'ichirou Yoshida), and one postdoc (Alessandro A. Trani) have joined the KAGRA collaboration.

Ataru Tanikawa

Ataru Tanikawa studies binary black hole formation in isolated binaries and star clusters including open clusters and globular clusters. He hopes that he will make clear the origin of binary black holes observed by the current gravitational wave observatories and that he will also utilize gravitational wave observations to understand the cosmic star formation history and star cluster dynamics. Additionally, he is interested in astronomical transients related to the thermonuclear explosion of white dwarfs, such as type Ia supernovae and tidal disruption events. These transients are also promising gravitational wave sources for space-borne gravitational wave observatories.

Shin'ichirou Yoshida is interested in equilibria, oscillations, and stability of compact stars, which are closely related to gravitational astronomy. Rotation of these objects and the existence of a magnetic field may especially affect the spectrum and the detectability of gravitational waves from these stars. He numerically constructs equilibrium models of compact stars by taking into account these features and studies the characteristic oscillations and stability.

Shin'ichirou Yoshida

Alessandro Trani

Alessandro A. Trani develops numerical tools to study the dynamics of few-body systems composed of massive stars, planets, and black holes. He applies these models to reveal the details of the pathways to the formation of gravitational wave events, such as three-body encounters in stellar clusters, and triple systems in the field. In this way, he aims to elucidate the origin of merging binary black holes. We provide individual photos of the three people. It is difficult to take a group photo due to this pandemic situation.

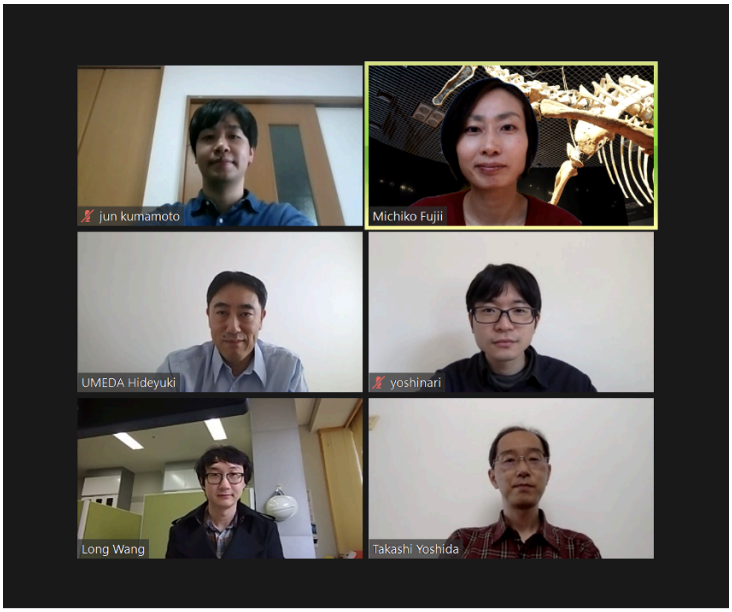
As described above, we are theoretical astrophysicists. We are happy if our studies are helpful for gravitational wave observers. We have not yet seen the KAGRA collaboration members. We are looking forward to seeing you in person with a peaceful feeling after this pandemic.

Ataru Tanikawa 🍏

Newly Joined

## GW group at the Department of Astronomy, The University of Tokyo

It is our great pleasure to join KAGRA Collaboration. The Department of Astronomy at the University of Tokyo is one of the oldest astronomy departments in Japan. The research topics cover a wide range of astronomy, from planets to cosmological structure formation. This time, two theoretical groups joined the collaboration. We work on theoretical and numerical studies of the formation and evolution of binary black holes (BBHs). We focus on two formation channels of BBHs; 1. BBH formation from massive Pop. III stars and 2. BBH formation in dense star clusters. We are theoretically estimating the distribution of BBHs observable in future observations and hope to understand the formation processes of BBHs.



Zoom photo of our group. We currently work remotely.

Currently, two faculty members (Michiko Fujii, Hideyuki Umeda), three postdocs (Takashi Yoshida, Jun Kumamoto, Long Wang), and two students (Naoto Yoshinari, Kotaro Hijikawa) are in the collaboration. But, our department has more than 20 new students every year. We hope that new members will participate in our group in the future.

Michiko Fujii

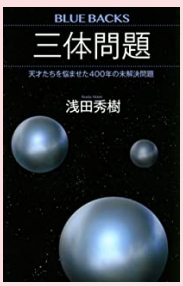
## BOOKS BY KAGRA COLLABORATORS


**Dictionary of Relativity and Universe** (Soutairon to Uchuu no Jiten, in Japanese)
Chief Editors: Masaki Ando & Tetsuya Shiromizu
Editors: Hideki Asada, Akihiro Ishibashi, Tsutomu Kobayashi, Hisaaki Shinkai, Jiro Soda, Keisuke Taniguchi
(Asakura Shoten Publishing, 2020)
10,000 JPY, 420 pages

Contributors from KAGRA (LIGO) collaborators: Akito Araya, Kunihito Ioka, Yosuke Itoh, Takaaki Kajita, Keita Kawabe, Kazuaki Kuroda, Sachiko Kuroyanagi, Kazunori Kohri, Yasufumi Kojima, Ayaka Shoda, Yuichiro Sekiguchi, Kentaro Somiya, Hideyuki Tagoshi, Takahiro Tanaka, Ataru Tanikawa, Keisuke Taniguchi, Kenichi Nakao, Hiroyuki Nakano, Yuta Michimura, Ryo Yamazaki, Kazuhiro Yamamoto, Jun'ichi Yokoyama, Shin'ichiro Yoshida

**"Neutrino and Gravitational Wave" are totally explained in one book**
Kazunori Kohri
(Beret Publication, 2021)
1800 JPY, 280 pages


**Three body problem**
Hideki Asada
(Kodansha Publishing, 2021)
1100 JPY, 264 pages



## New Group Gravitational Wave Physics and Astronomy / Data Science Group at Tokyo City University

Tokyo City University (TCU) is located in the Tokyo area, Japan. TCU has three campuses: Setagaya, Todoroki, and Yokoyama. The Research Center for Space Science（宇宙科学研究センター）in Advanced Research Laboratories（総合研究所）at Todoroki campus was established on September 1st, 2020. I joined this center and formed the Gravitational Wave Physics and Astronomy/Data Science Group. Gravitational Wave Physics and astronom`y are listed as one of the main research topics of this center. After I joined this center, MOU between ICRR and TCU was established and signed on October 27th, 2020.


My group is expected to contribute to the research of gravitational-wave physics and multi-messenger astronomy as the KAGRA member by using information technology, such as artificial intelligence, machine learning, and advanced signal processing techniques, etc.

Currently, three fourth-year undergraduate students at the department of computer science joined my group. Some third-year undergraduate students at the department of computer science and at the department of intelligent systems will join soon. They plan to study and develop the analysis method with machine learning and/or advanced signal processing techniques, such as Hilbert-Huang transform. They are also interested in the development of computer systems and software, data management systems, and access management works.

I hope that they will be able to be active in these fields of research. And I would like to develop this group as one of the KAGRA data analysis active groups.

Hirotaka Takahashi 🍏

## WE HEAR THAT . . .

**Hirotaka Takahashi** moved from Nagaoka University of Technology to Tokyo City University as a Professor, September 2020.
**Marc Eisenmann** moved from LAPP to NAOJ as a Postdoctoral researcher, November 2020.
**Keiko Kokeyama** moved from ICRR to Cardiff University as a research associate, January 2021.
**Masayuki Nakano** moved from ICRR to Caltech as a Postdoctoral researcher, March 2021.
**Chang-Hee Kim** moved from KASI to KAIST as a Postdoctoral researcher, March 2021.
**Tomohiro Yamada** moved from ICRR to KEK as a Ph.D. researcher, April 2021.
**Yutaka Shikano** moved from Keio University to Gunma University as an Associate Professor, April 2021.
**Takahiro Yamamoto** moved from Kyoto University to Nagoya University as a Postdoctoral researcher, April 2021.
**Zhao Yuhang** moved from NAOJ to ICRR as a Postdoctoral researcher, April 2021.
**Naoki Aritomi** moved from University of Tokyo to NAOJ for Project research fellow, April 2021.
**Congratulations!** If you have other news, please notice them to the editors.

**Ayaka Shoda** moved to instrument company in Tokyo, February 2020.
**Yoshihisa Obayashi** moved to UT Information Technology Center, March 2021.
**We miss you.** Thank you for your long contributions for the KAGRA collaboration.

New Group

## Department of Physics, National Cheng Kung University

In December last year, we, the Department of Physics at National Cheng Kung University (NCKU), successfully joined KAGRA! We would like to express our gratitude to all the KAGRA Scientific Collaboration (KSC) members again for the support and their continuous efforts in maintaining KAGRA as a friendly community for new members and also an excellent place for science explorations. Thanks to the invitation from the editors of the KSC Newsletter, we have the chance to let the KSC members know our city, our university, and our research group deeper through this article.

NCKU is located in a beautiful city, Tainan, which is in the southern part of Taiwan. If you ask a Taiwanese about the impressions of Tainan, “wonderful food” will definitely be one of them. Established in 1931 November (with the original name as the Tainan Technical College), NCKU is reaching the 90th anniversary this year. In this long period of history, NCKU has been among the top-tier universities as well as an important cornerstone of education in Taiwan. The Department of Physics was found later in 1946. Since then, we have been steadily expanding in terms of research and education. Currently, we have 35 full-time faculty members, 201 undergraduate students, and 120 postgraduate students. Our research interests cover a wide variety of topics in Physics, including Multi-Messenger Astronomy, of course.

Figure 1: Kwan-Lok Li (left), Hwei-Jang Yo (top-right), and Chen-Hsun Ma (bottom-right)

The KAGRA research group at NCKU is relatively young and we now have three core members, Prof. Kwan-Lok Li (the group leader), Prof. Hwei-Jang Yo, and Mr. Chen-Hsun Ma (master student). Prof. Li is an astronomer working on multi-messenger observations on compact objects. The focus of his research has been on understanding the origin of high-energy emission in variable and transient. Besides, his team is currently building a 0.5-m robotic telescope for the electromagnetic counterpart searches for gravitational-wave events. Prof. Yo is a theoretical physicist in gravitational-wave physics, in particular, binary black holes and neutron stars coalescence, gravitational wave template construction, and alternate theories of gravity. His team has just shown theoretically how the eccentricity of a binary can affect the localization of a compact binary coalescence (CBC) gravitational-wave event. Mr. Ma is currently working on an X-ray observation of the galaxy NGC 1559. He is looking for an interesting class of X-ray systems called ultraluminous X-ray sources (ULXs), which are good candidates for intermediate-mass black holes (IMBHs). He will continue his research for IMBHs with the upcoming KAGRA observations.

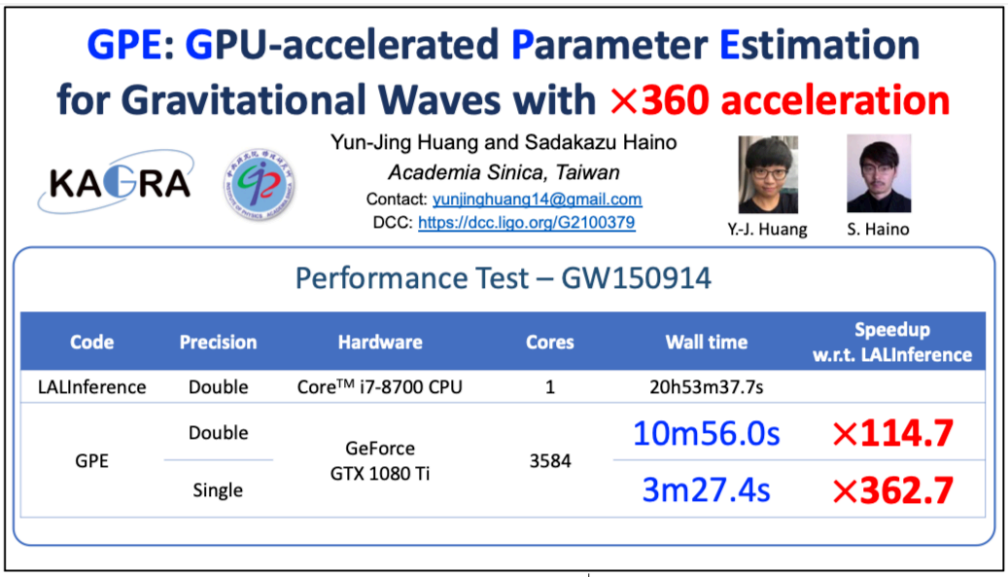
In the future, we hope to make contributions to KSC in the following areas. First, we plan to use innovative ways, like Fintech (e.g., ARIMA), Hilbert-Huang transform, and deep learning to find new gravitational wave events. We actually have started the project with the KAGRA institute members, NTHU (Taiwan), CNU (Korea), and UNIST (Korea), since 2019. We also aim for a quicker and hopefully more accurate way to constrain the localization of a gravitational-wave event using machine-learning techniques. Besides projects for new methods, we plan to build a gravitational waveform template library for eccentric mergers, which is possible in some CBC formation channels. The template library will be helpful in discovering new eccentric systems in the future.

Kwan-Lok Li (Ray) 🍏

Poster Award at LVK March

# How to turn 2k US$ gaming PC into super computer for gravitational wave data analysis

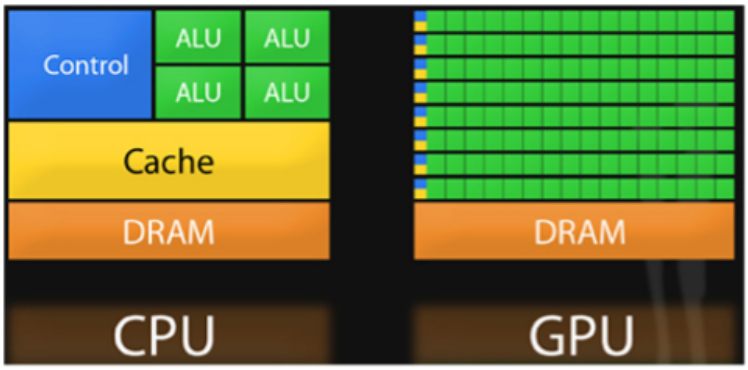
Yun-Jing Huang (Academia Sinica) was awarded the best poster of data analysis at the LVK meeting March 2021. **Congratulations!** The editor asked Yun-Jing to explain his research.




Yun-Jing Huang
(Academia Sinica, Taiwan)

Gravitational wave parameter estimation is a very time-consuming process. It may take several days to several weeks to extract the source parameters from a single detected gravitational wave signal. In light of the multi-detection era the LIGO-Virgo-KAGRA network is now entering, an acceleration of this process is in demand.

Graphics Processing Units (GPUs) are designed with thousands of arithmetic logic units (ALUs), which is in contrast to CPUs, where there are usually only less than ten ALUs. This arithmetic intensive design makes GPUs suitable for graphics rendering or algorithms that involve highly repetitive computations, and may demonstrate a performance that is hundreds or thousands of times faster than a CPU-equivalent algorithm. By equipping a desktop PC with one GPU, we may be able to spend just 2k US$ to achieve a performance that is only attainable by using thousands of CPUs from a CPU cluster.




The program GPE (GPU-accelerated Parameter Estimation), developed by Yun-Jing Huang and Dr. Sadakazu Haino from Institute of Physics, Academia Sinica, is a highly accelerated parameter estimation program for gravitational wave compact binary coalescence signals. GPE uses GPU to parallelize the frequency-domain waveform calculations and the prior sampling portion of the nested sampling algorithm. GPE can achieve a performance 360 times faster than LIGO's parameter estimation program – LALInference, while producing consistent results. By using one GPU, the fast speedup can lower the computation time for the parameter estimation of a GW150914-type event from 21 hours down to only three and a half minutes.

The benefits of GPE are not limited to the acceleration of the data analysis process of real events. Statistical studies that require running parameter estimation on large number of simulated events can benefit greatly from GPE. In addition, EM follow-up procedures require fast and accurate production of sky localization areas, and if GPE can be optimized to produce confidence regions within a few minutes or even a few seconds, it would increase the probability of observing an EM counterpart and provide us with rich results. 🍏

## KITP Scholar Award

Lan Quynh Nguyen (Univ. of Notre Dam) received a Kavli Institute for Theoretical Physics (KITP) Scholar Award, which will allow her to pursue her research on dark matter and gravitational waves in the institute's collaborative and interdisciplinary environment. She will conduct theoretical aspects of using gravitational waves to observe dark matter, at KITP's campus at the University of California Santa Barbara.

**Congratulations!**

https://physics.nd.edu/news/physics-professor-wins-prestigious-kitp-scholar-award/

## KAGRA COLLABORATION ARTICLES

An arm length stabilization system for KAGRA and future gravitational-wave detectors
KAGRA collaboration (author-list 2018)
Class. Quant. Grav. 37 (2020) 035004 [arXiv:1910.00955]
https://iopscience.iop.org/article/10.1088/1361-6382/ab5c95

Overview of KAGRA : KAGRA science
KAGRA collaboration (author-list 2018 + 2019 +3)
Prog. Theor. Exp. Phys. (2020) ptaa120 [arXiv:2008.02921]
https://doi.org/10.1093/ptep/ptaa120

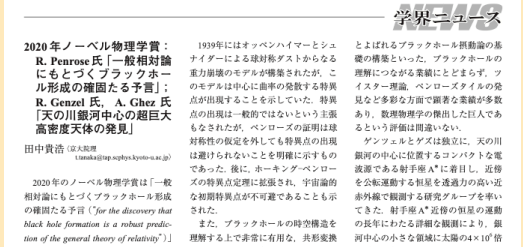
Overview of KAGRA : Detector design and construction history
KAGRA collaboration (author-list 2018)
Prog. Theor. Exp. Phys. (2020) ptaa125
https://doi.org/10.1093/ptep/ptaa125

Overview of KAGRA : Calibration, detector characterization, physical environmental monitors, and the geophysics interferometer
KAGRA collaboration (author-list 2018)
Prog. Theor. Exp. Phys. (2020) ptab018 [arXiv:2009.09305]
https://doi.org/10.1093/ptep/ptab018

Vibration isolation systems for the beam splitter and signal recycling mirrors of the KAGRA gravitational wave detector
KAGRA collaboration (author-list 2019)
Class. Quant. Grav. 38 (2020) 065011
https://iopscience.iop.org/article/10.1088/1361-6382/abd922

## NOBEL PRIZE FOR BLACK HOLE RESEARCH

The Royal Swedish Academy of Sciences awarded the Nobel Prize in Physics 2020 to Roger Penrose "for the discovery that black hole formation is a robust prediction of the general theory of relativity" and to Reinhard Genzel and Andrea Ghez "for the discovery of a supermassive compact object at the centre of our galaxy".



学界ニュース NEWS

2020年ノーベル物理学賞：R. Penrose氏「一般相対論にもとづくブラックホール形成の確固たる予言」；R. Genzel氏，A. Ghez氏「天の川銀河中心の超巨大高密度天体の発見」

田中貴浩（京大院理 t.tanaka@tap.scphys.kyoto-u.ac.jp）

2020年のノーベル物理学賞は「一般相対論にもとづくブラックホール形成の確固たる予言（"for the discovery that black hole formation is a robust prediction of the general theory of relativity"）」とよばれるブラックホール摂動論の基礎の構築といった，ブラックホールの理解につながる業績にとどまらず，ツイスター理論，ペンローズタイルの発見など多彩な方面で顕著な業績が多数あり，数理物理学の模範とした巨人であるという評価は間違いない．

1939年にはオッペンハイマーとシュナイダーによる球対称ダストからなる重力崩壊のモデルが構築されたが，このモデルは中心に曲率の発散する特異点が出現することを示していた．特異点の出現は一般的ではないという主張もなされたが，ペンローズの証明は球対称性の仮定を外しても特異点の出現は避けられないことを明確に示すものであった．後に，ホーキング-ペンローズの特異点定理に拡張され，宇宙論的な初期特異点が不可避であることも示された．

また，ブラックホールの時空構造を理解する上で非常に有用な，共形変換

ゲンツェルとゲズは独立に，天の川銀河の中心に位置するコンパクトな電波源である射手座A*に着目し，近傍を公転運動する恒星を透過力の高い近赤外線で観測する研究グループを率いてきた．射手座A*近傍の恒星の運動の長年にわたる詳細な観測により，銀河中心の小さな領域に太陽の$4\times10^6$倍

**Hisaaki Shinkai** wrote an article for the web magazine Ronza 論座 by Asahi Newspaper (Oct 13, 2020), and also for 天文教育(Astronomy Education, 2020 Nov). **Takahiro Tanaka** wrote an article for the JPS magazine (2021 Jan).

論座 RONZA

「ブラックホール」でまとめたノーベル物理学賞

理論家ペンローズの並外れた業績と、「謎」を「実在」に転換させた長年の天文観測

真貝寿明　大阪工業大学教授（相対性理論、宇宙物理学、天文学史）

https://webronza.asahi.com/science/articles/2020101000005.html

## Left KAGRA

Ayaka Shoda, National Astronomical Observatory in Japan


It has been almost half a year since I left academia. I appreciate KSC newsletter editors giving me a chance to write another letter to you all. After working on Torsion-bar GW Antenna at the graduate school of the University of Tokyo, I joined KAGRA as a VIS member at NAOJ. It was so fruitful and precious that I have worked on the design and the construction of the vibration isolation system for power recycling mirrors as a team leader. I am thankful for KAGRA members, especially NAOJ and VIS members. It was so exciting when the first PR mirror was installed. I would also never forget that I dropped the PR3 mirror. Even after such a big accident, no one blamed me and everyone helped me to deal with it. And every experience in this almost ten years makes me confident that I can continue to work on any development.

After giving birth, my life was drastically changed, and I decided to shift my career. Now I am working as a researcher at a company in Tokyo where we manufacture 3D profiling instruments using a laser beam. It is a kind of serendipity that I am still measuring the distance with optics. I am now leading an R&D project to develop a new instrument. The system itself is brand new to me (for example, I am learning non-linear optics and nano-photonics these days). It is very interesting to learn new physics, techniques, and instruments. I feel very lucky that I could somehow jump into a new research field at this age. I will try my best to complete a project.

I am looking forward to another opportunity for us to collaborate again as we are both working on precision measurements. And I am also looking forward to hearing the good news that KAGRA catches GW signals directly. See you again, soon!

## Farewell KAGRA

Yoshihisa Obayashi, ICRR, University of Tokyo

Hello, I'm Yoshi Obayashi. I'm really pity to leave KAGRA. I'm now starting public relations job at the UT Information Technology Center. I'd like to recall the recent communication activities in KAGRA.

The publicity of the gravitational wave detectors including KAGRA rapidly grew up in 2015 - 2017, just before I join, thanks to all GW scientists' efforts and Nobel prizes to our PI Prof. Kajita in 2015 and LIGO leaders in 2017. So, when I started job in KAGRA in the end of 2017, I realized my task was not just KAGRA to be known but to be understood and loved by the people all over the world.

We started several KAGRA SNS channels: facebook.com/kagra.pr, twitter.com/kagra_pr and instagram.com/kagra.observatory in early 2018. They were initially unofficial channels "by KAGRA fans" but now all are official by KAGRA EPO. We've continuously posted our achievements, events information, beautiful scenes of Kamioka town and so on in a hybrid style of Japanese and English. The facebook page has 526 followers and the twitter has 1,795 now. Some posts on Facebook got more than 3k views. On the other hand, the Instagram page is still under development and has only three posts and 58 followers. I hope someone to grow up the Instagram page.

We welcomed many science reporters, photographers and television crews from Japan and oversea. They seemed really impressed by our huge underground instruments and scientists domesticating the delicate equipments. Consequently, large numbers of great articles and programs have been published and broadcast. Find (imperfect) international coverage list in the end of this report.

We created some PR materials. Collaborating with Iwanami Audio-Visual Media, we produced KAGRA's promotion video and it's online: youtu.be/x7LHXTtGei0. (click right video)


We produced also stunning graphic images collaborating with CG designer Rey Hori. Photographer Enrico Sacchetti took ultra high-resolution pictures and provided us for various usage.

We held a lot of public communication events like public lectures, science café, and public open-days. Even though these events were basically for the local residents, some audiences were from quite distant cities. All the public open days of underground facility got applicants more than double of the capacity. In 2020, the open day under Covid-19 pandemic was held online. We got 1700+ live views and 8000+ archive views from the world. See sites.google.com/g.ecc.u-tokyo.ac.jp/sk-kagra-online-open-days

My three+ years in KAGRA were truly lovely period for me. The detector construction was completed and the joint observation with GEO600 has successfully performed even under the pandemic. There's no doubt that KAGRA scientists' tireless efforts made these achievement. I'm very happy that I could help KAGRA and its scientists' activities and achievements known by the world. I believe KAGRA achieve higher sensitivity soon and I'm looking forward to hear that it find multiple astronomical spectacles. Thank you for your everything!


- Nature News Jan. 2, 2019, "Japan's pioneering detector set to join hunt for gravitational wave" https://www.nature.com/articles/d41586-018-07867-z
- UTokyo Focus Apr. 18, 2019, "Tunnel of wonders" https://www.u-tokyo.ac.jp/focus/en/features/z0508_00111.html
- Scientific American Nov. 1, 2019, "Inside the World's First Underground Gravitational-Wave Detector" https://www.scientificamerican.com/article/inside-the-worlds-first-underground-gravitational-wave-detector/
- Symmetry Oct. 29, 2020, "Japan's KAGRA searches the sky for gravitational waves" https://www.symmetrymagazine.org/article/japans-kagra-searches-the-sky-for-gravitational-waves
- Nature Video Feb. 14, 2020, "Inside Japan's big physics" https://www.nature.com/articles/d41586-020-00417-6

## NEW COLLABORATORS (*=NEW GROUP)

[April 11, 2020-April 28, 2021]

Aoyama Gakuin University
- Kaori Obayashi

Chungnam National University
- Sangin Kim

High Energy Accelerator Research Organization (KEK)
- Shinichiro Michizono

Instituto de Fisica Teorica
- Santiago Jaraba

Korea Astronomy and Space Science Institute (KASI)
- Soonkyu Je

Nagaoka University of Technology
- De Silva M. M. Laththuwahandi
- Kohei Shiota

National Astronomical Observatories, Chinese Academic of Sciences
- Lijun Gou
- Yun-Long Zhang
- Chunyang Zhao

National Astronomical Observatory of Japan (NAOJ)
GW Science Project
- Marc Eisenmann
- Michael Page

National Astronomical Observatory of Japan (NAOJ) Kamioka Branch
- Dan Chen
- Satoru Ikeda

National Central University
- Putu Wira Hadiputrawan
- Tsung-Chieh Ho
- Miftahul Ma'arif

*National Cheng Kung University
- Chen-Hsun Ma
- Hwei-Jang Yo

National Institute of Technology, Nagaoka College
- Naoto Aoki
- Ryota Onezawa
- Odonchimed Sodtavilan

National Taiwan Normal University
- Chung-Hao Liao
- Avani Patel
- Ya-Qi Wang

National Tsing Hua University
- Huali Chen
- He-Feng Hsieh
- Li-Ting Ma
- Surojit Saha
- Inhyeok Song
- Martin Spinrath
- Shu-Wei Yeh

National Yang Ming Chiao Tung University
- Hong-Yin Chen
- Li-Cheng Yang

Niigata University
- Chiaki Hirose
- Naoki Koyama
- Tomoyuki Kusaka
- Mizuki Nakagawa
- Mihiro Toyoshima

Osaka City University
- Yuya Fujimoto
- Isamu Fukunaga
- Ryo Kato
- Taisei Kiyota
- Mahoro Matsuyama
- Nozomi Morisue
- Mayuki Sekiya
- Kota Tomita

Tamkang University
- Yu-Ting Chang
- Ching Chun Huang
- Yu Syue Huang
- Ting Yu Shih

The University of Tokyo
* Department of Astronomy
- Michiko Fujii
- Kotaro Hijikawa
- Jun Kumamoto
- Hideyuki Umeda
- Long Wang
- Takashi Yoshida
- Naoto Yoshinari

The University of Tokyo
*Department of Earth Science and Astronomy, College of Arts and Sciences
- Ataru Tanikawa
- Alessandro Alberto Trani
- Shin'ichirou Yoshida

The University of Tokyo
Department of Physics
- Hiroki Chiyoda
- Hiroki Fujimoto
- Shogo Mizumura
- Masaya Ono
- Yuka Oshima

The University of Tokyo
Institute for Cosmic Ray Research (ICRR), KAGRA Observatory
- Renichi Chiba
- Hirofumi Kibukawa
- Masahide Tamaki

The University of Tokyo
Research Center for the Early Universe (RESCEU)
- Reiko Harada
- Soichiro Kuwahara
- Daiki Watarai

Tokyo Institute of Technology
- Homare Abe
- Kaido Suzuki
- Takanori Suzuki

Ulsan National Institute of Science and Technology (UNIST)
- Sinwoo Kim
- Jae Ho Lee

University of Notre Dame
- Atul Kedia
- Grant Mathews

University of Toyama
- Takahiro Iguchi
- Misato Seo

Collaboration-list committee made their mailing address kagraros@icrr.u-tokyo.ac.jp; ros from a roster.
If your affiliation address (or email) changes: Contact to kagraros@icrr.u-tokyo.ac.jp
If your group has new members: Contact to kagraros@icrr.u-tokyo.ac.jp
If you have a nice photo: Let the KSC Newsletter share them.

If your neighbor is planning to join KAGRA collaboration: Please suggest to check out our wiki FAQ
http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA/KSC/FAQ

## RECENT KAGRA STATUS TALKS

| meeting/conferences | | speaker | JGWdoc |
|---|---|---|---|
| 14th International Conference on Gravitation, Astrophysics and Cosmology | Aug. 2020 | Nobuyuki Kanda | [JGW-G2011805] |
| LVK 2020 September meeting | Sep. 2020 | Hisaaki Shinkai | [JGW-G2011989] |
| JPS meeting | Sep. 2020 | Masayuki Nakano | [JGW-G2011986] |
| KIW 7 | Dec. 2020 | Hisaaki Shinkai | [JGW-G2012314] |
| SPIE 2020 conference | Dec. 2020 | Shinji Miyoki | [JGW-P2012257] |
| LVK 2021 March meeting | Mar. 2021 | Yuta Michimura | [JGW-G2112616] |
| JPS meeting | Mar. 2021 | Takaaki Yokozawa | [JGW-G2012296] |
| ASJ meeting | Mar. 2021 | Tomotada Akutsu | [JGW-G2012276] |

## FROM EDITORS

We appreciate many contributors again for this issue.
We are always calling editorial volunteers, and we also want your posts and/or leaks of information.
Please send your inquiries the current editorial staff.

Hisaaki Shinkai (OIT) hisaaki.shinkai at oit.ac.jp
Quynh Lan Nguyen (UND) lnguyen3_at_nd.edu

**KSC Newsletter (yes, it's free)**

this issue
No. 8 (2021/05) [**JGW-L2112871**] https://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/DocDB/ShowDocument?docid=12871
back numbers
No. 7 (2020/04) [**JGW-L1911619**] https://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/DocDB/ShowDocument?docid=11619
No. 6 (2019/12) [**JGW-L1911020**] https://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/DocDB/ShowDocument?docid=11020
No. 5 (2019/8) [**JGW-L1910543**] https://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/DocDB/ShowDocument?docid=10543
No. 4 (2019/4) [**JGW-L1910057**] https://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/DocDB/ShowDocument?docid=10057
No. 3 (2018/12) [**JGW-M1809350**] https://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/DocDB/ShowDocument?docid=9350
No. 2 (2018/8) [**JGW-L1808559**] https://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/DocDB/ShowDocument?docid=8559
No. 1 (2018/4) [**JGW-L1808122**] https://gwdoc.icrr.u-tokyo.ac.jp/cgi-bin/DocDB/ShowDocument?docid=8122