Kyoto University
2018 Autumn

# KYOTO U
# Research News

# What does Kyoto University stand for today?

We live in an era of increasing melding of science, technology, and the political-economy. The merging of these broad forces appears to happen effortlessly. Yet as we stand on the verge of a new world in which we may abdicate many of our responsibilities to 'artificial intelligence', can we say with confidence that this future Earth will have the best interests of humanity, and of human society, at heart?

This University strives for a new cross-curricular harmony among the humanities and the sciences. Not merely an updated liberal arts ideal, but rather a rethinking of the nature of humanity and of society itself.

Globalism and multilateralism have bred great advances. However forces of self-centrism and exclusion — at the heart of our democratic world — threaten the very core of our value system.

Science does not exist in a moral vacuum. We must not lose sight of the role scholarship must play in shaping a better future for all. And at the forefront of this endeavor must be the human sciences — the humanities and social sciences — constantly asking and forever seeking the path of our moral compass.

Is this the true future we seek for human society? Is this what we aim for as the dominant species on this planet? Are we certain that we, as humans, are being true to the spirit of our humanity?

These are the questions we must constantly ask. And it is the answers we find that will guide our University and our society into the future.

Juichi Yamagiwa, President

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**On the cover**

A *bijin-ga* (traditional woodblock print beauty portrait) design of a *'tsuki-mi'* autumn moon-viewing scene, featuring motifs of the telescope and mathematical inquiry described in the first two articles, pages 3–11. (Trais/Fujiwara)

*Welcome to the latest issue of our magazine, now entering its third year of publication. In this first section you will find two in-depth pieces from the Sciences: first on the development of the new 3.8M Telescope; and secondly spotlighting the newest faculty member of maths institute RIMS, as she seeks to understand the common theoretical architectures lying at the heart of all computer languages.*

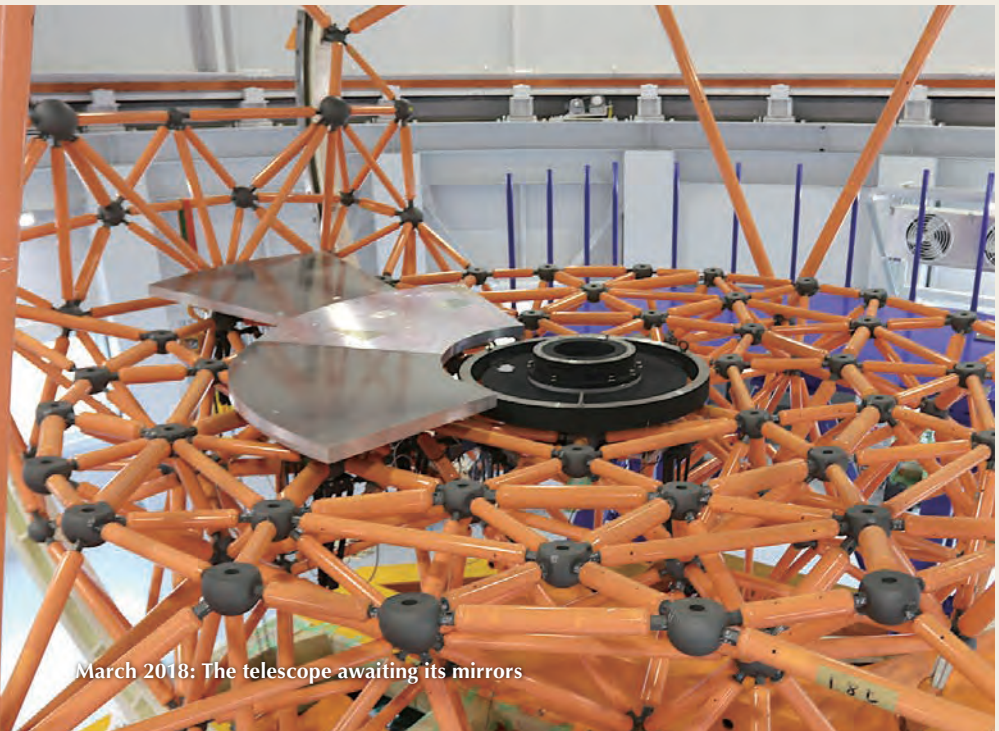


# The high-tech astronomy of *Seimei*

## Building East Asia's newest and largest telescope

Human knowledge, like the universe, is constantly expanding. And now our ability to observe the heavens is about to expand even further.

In 2006 **Kyoto University, Nagoya University, the National Astronomical Observatory of Japan** (NAOJ), and **Nano-Optonics Energy Inc** began an over decade-long project to construct the largest telescope in East Asia. The "Okayama 3.8M Telescope", recently nicknamed *Seimei* after the historical *onmyoji* and astrologer, will finally aim for the stars in late 2018. But it's not just its sheer size that's impressive: equipped with innovative new technologies, Seimei will be unrivaled in its speed and accuracy as it combs the cosmos.



March 2018: The telescope awaiting its mirrors

### Bridging the skies

East Asia has until now lacked a multipurpose, optical infra-red telescope with a diameter larger than 2.5 meters. This gap in terrestrial astronomy's ability to gather high-quality data around the globe meant that if a cosmic phenomenon — such as a massive stellar explosion — were to suddenly appear over this hemisphere, crucial first records would be lost.

Initial observations of giant stellar events are critical for researchers, but their rarity and unpredictability require constant, careful monitoring of the night sky. So this blindspot over Asia has been a planet-scale weakness.

# Backstage at the lab

For the telescope itself, it's not just about being bigger and better; this new scope heralds a coming generation of high tech eyes on the sky. And what better place to put it than the **Okayama Astrophysical Observatory** in west Japan, home to an historical 188 cm telescope that — when completed in 1960 — was also the largest in Asia.

The Okayama Observatory, managed by NAOJ, working together with leading telescope technology developers at Kyoto University and Nagoya University, formed a team with the common goals of increasing the efficiency of construction as well as the movement and capture speed of the telescope itself.

The final hurdle was project funding, which is often difficult to surmount in Japan due to a lack of philanthropic traditions. Fortunately one KyotoU graduate thought differently, leading to Nano-Optonics Energy Inc contributing over a third of the project's total cost. And so with all the pieces in place, in 2006 the 3.8M telescope project was formally launched.

## Next-gen tech

"Three key technologies define this telescope," explains Masaru Kino of KyotoU's Graduate School of Science. "Its quick-slewing mount, segmented mirror design, and the mirror grinding itself. We have focused on improving speed and accuracy, since we plan to specialize in observing short-lived astronomical phenomena."

*Superflares* are one such event type. Similar to our sun's flares, these occur on distant stars with many times the energy level. *Gamma-ray bursts* are another target, consisting of violent eruptions of radiation from massive stars. And then there are *black hole binaries*, where a black hole and an ordinary star orbit each other. Each of these is extremely difficult to observe, as they only last for a brief period of time.

To make such observations with any accuracy, the telescope needs to be moved quickly. This is where the quick-slewing mount comes in: made of light-weight materials, the telescope's striking lattice structure — considerably shorter than its 188 cm predecessor — can be readily rotated by just one or two people.

The additional leading edge technologies are to be found in the telescope's heart. Mirrors for observatory telescopes aren't made from ordinary glass. In order to capture the night sky with the utmost precision,

March 2018: Project team member Masaru Kino explaining Seimei's groundbreaking design

the highest possible quality glass must be used, which becomes a limiting factor on total size.

The 3.8M teams's radical solution was to break up the mirror into 18 petal-like segments. Previous segmented designs have used hexagons.

"These 'petal' segments are a world's first, and as a result we expect to obtain higher optical performance than with existing designs," Kino says.

The 18 mirror petals are laid out in two concentric rings — six on the inside and twelve outside — with each segment weighing about 70 kg. These are then mounted onto individual actuators that control the mirrors' orientation with nano-scale accuracy. So when the telescope has been reoriented — or even when the dome is opened and wind pressure necessitates minute recalibration — each segment readjusts accordingly.

Finally, there are the mirrors themselves. Typically the high grade glass used in telescope mirrors is ground and polished in a slow and meticulous process taking up to one year.

Kino states, "We succeeded in developing a new method that grinds the mirrors at higher speed but with extreme precision, up to a point just short of the final processing step." This resulted in a reduction of time to just one month.

An additional benefit of this new technology development is that it is scalable. Initial plans for Seimei actually intended it to be much bigger. However, building a medium-sized scope has dramatically reduced costs and resulted in significant weight reduction.

Now that the technology baseline has been established, building further advanced telescopes will take considerably less time. And in fact plans to build a successor near the equator in Indonesia are already in the making.

## From the drawing board to the future

Like many groundbreaking scientific endeavors, the Okayama 3.8M Telescope took a dedicated team over a decade to complete. Even after the project got its start in 2006, the mirror grinding technology was only perfected in 2012. Public funding was first acquired in 2015, allowing for completion of the telescope, with additional funding obtained in 2016 for building the dome on the grounds of the Okayama Observatory. In the fall of 2017 a public call for a nickname was announced, resulting in over 1,000 responses coming in from across the globe, leading to an announcement in April 2018 of the name Seimei.

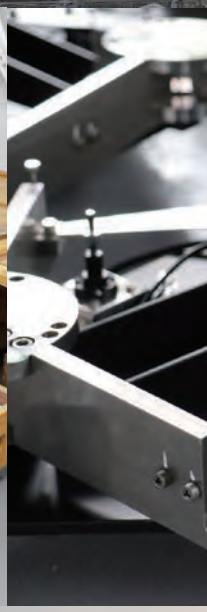
The drive and curiosity of the researchers who have made this possible are as boundless as the universe to which they lift their eyes. In the coming months and years — as Seimei's mirrors reflect the heavens — these dedicated stargazers hope to discover and understand the most elusive phenomena of the cosmos, while blazing a new path for those who will follow.

Seimei's official website (in Japanese) is at www.kusastro.kyoto-u.ac.jp/psmt

July 2018: The mirrors in place at last!

# Backstage at the lab

March 2018: With the dome opened, Seimei is in position to scan the heavens; the name also means 'life' in Japanese, a reference to the hope that the telescope may also assist in the search for life elsewhere in the cosmos

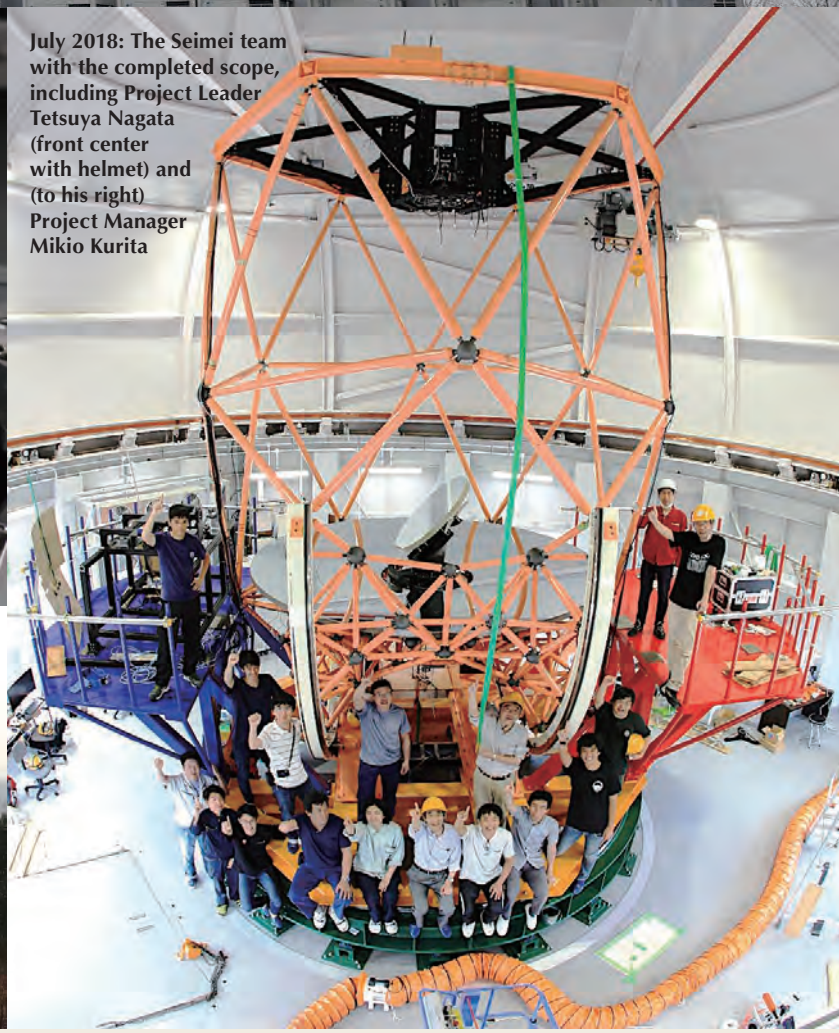


March 2018:
Kino unwraps a mirror segment

March 2018: The exterior of the dome housing Seimei

March 2018: An actuator for controlling an individual segment

March 2018: Other facilities at the Okayama Astrophysical Observatory complex



July 2018: The Seimei team with the completed scope, including Project Leader Tetsuya Nagata (front center with helmet) and (to his right) Project Manager Mikio Kurita

# Understanding the machines, Kyoto style

## Melding mathematics and informatics to comprehend and improve the black box

**Koko Muroya** (Assistant Professor, RIMS) × **Masahito Hasegawa** (Professor, RIMS) × **Atsushi Igarashi** (Professor, Graduate School of Informatics)

### A first for RIMS

**Hasegawa:** Welcome to Kyoto! How are you adjusting to your new environment and life here?

**Muroya:** Thank you! Everything is still new for me, but I'm gradually getting used to it and I've found that it's very peaceful.

**Igarashi:** Let's each take a moment to explain our research.

**Hasegawa:** I do primarily theoretical work. But over the course of my career I've interacted with groups working on software theory, mathematical logic, algorithms, and programing languages, all of which were popular in the 1970s. **RIMS**, the **Research Institute for Mathematical Sciences**, has gone through many changes over its long history. Today, my **computer science** group and that of Kazuhisa Makino — working on **discrete optimization algorithms** — are two major research foci at the institute.

But speaking of history, we have a milestone right here: the first female faculty member at RIMS!

**Igarashi:** Is that so? Congratulations!

**Muroya:** Yes, that's me, and it's why I'm a little nervous. In this day and age it's a little rare that a department has no women in its faculty.

**Hasegawa:** We've been trying for some time now. Igarashi-sensei, how about at the School of Informatics?

**Igarashi:** Too few. We have over one hundred faculty members between the six departments. Among these, only a handful are female researchers.

**Muroya:** Looking at ratios, adding one female faculty member to RIMS would probably put the numbers at about the same level then.

### A European approach

**Hasegawa:** Honestly though, you have a brilliant record and we've been really looking forward to having you join us. Europe leads in **software and number theory research**, so we are eager to recruit scholars who have experience there. I worked extensively at Edinburgh, and Muroya-sensei is working in the UK.

**Muroya:** Computer science in Europe is very different from in the United States. **Complexity theory** is more popular in North America.

**Hasegawa:** That's right. Europe and the US go about solving problems in different ways. I agree that Japan follows a more European approach in this area.

## *Tools crossing the divide*

**Igarashi:** I focus on **programming languages**, and specifically **tool development**. Often when programming I feel ashamed that my code ends up having so many bugs. I must always push myself to code better, but on the flip side, I blame cumbersome tools, which motivates me to invent something more user-friendly.

Programming languages are tools that human beings manipulate, so they should have cognitive aspects. But the real technical problems still lie at the mathematical level, so I aim to develop tools that are comprehensible to both humans and computers.

**Hasegawa:** I really see what you mean. As a mathematician I can't help but compare mathematics to programming. And thinking theoretically, I assume that people struggle with coding because the theories behind them are not clear.

What I like about mathematics is that it never gets old: only upgraded. Results from ten or twenty years ago can be still highly useful today. But computer science evolves incessantly; what's popular today can be old news tomorrow. Both the slow-pace of mathematics and the fast-pace of computer science are equally significant, so I seek to balance my life between the two.

Programming languages become useless with major software upgrades, which constantly annoys me. I must always be calm and professional about it!

## *Computing theories*

**Igarashi:** As a child I picked up BASIC — thanks to my parents working for an electronics manufacturer — but when I enrolled in the **University of Tokyo** I wasn't really sure what to study. Then I learned about the **Department of Information Science**, and fueled by a belief that computers would play a pivotal role in the future, I decided to join the department and work on program language theories, taking a mathematical approach.

**Muroya:** I also graduated from that same department at UTokyo! My father was a software engineer and had a huge Mac at home. He didn't teach me to code and I wasn't really interested, so in my first year at the department I was really intimidated by the **C language** —but somehow survived the curriculum.

The department included fields such as **optimization**, **construction**, and **numerical calculation**. I thought that optimization would change over time, and be worth studying, so I focused on theories that would help me capture their essence in mathematics.

You could say I study **programming theory** because I don't write code.

**Hasegawa:** It takes so much time to write stylish code using smart algorithms, so I'm happy to leave that to truly talented people. Theories may take years to get used to, but once you master the basics and applications, you can apply them repeatedly and learn to explain them to others in plain

*Koko Muroya*

*Masahito Hasegawa*

language. That's why I have devoted my life to studying theories.

**Igarashi:** Good theories and their results live on and on, don't they?

**Hasegawa:** Yes indeed.

**Muroya:** Good theories don't go out of style!

**Hasegawa:** On the other hand, even if you develop a really spectacular program, it will eventually become obsolete.

**Hasegawa:** Programming used to require professional skills, but the trend is changing and now it's becoming everyone's job. In mathematics, linear algebra and calculus are taught in the same way worldwide, with textbooks and teaching approaches being nearly universal.

**Igarashi:** Meanwhile in our field of informatics, trends are replaced at such a fast pace that there's no time to settle down and establish a common approach.

**Muroya:** Right. Textbooks explaining important principles quickly become obsolete.

Speaking of which, I recall during my days at the University of Tokyo that instructors would say, "This is your homework," with just some keywords on a slide, and nothing else. What to do with them depended on us.

**Hasegawa:** Interesting.

**Muroya:** If anything it improved our net-searching skills! Most of the information that we need is available on the internet, including new languages. Online information is more up-to-date than textbooks.

**Igarashi:** That might be unique to our field. For instance, when students studying physics and mechanical engineering work on an assignment, they might go to the library for basic information.

**Muroya:** And they probably have standard textbooks.

**Hasegawa:** The basics in many fields don't change dramatically, after all.

**Igarashi:** Another unique aspect of our field is that the most up-to-date information is uploaded by volunteers, and it is really accurate.

**Muroya:** There's a vast amount of information available online which gives us the freedom to pick out just what we need. There are actually some textbooks on programming theory out there, but the bottom line is it's all about independent thinking.

## *Koko's approach*

**Hasegawa:** Hold on— Muroya-sensei hasn't talked about her research yet!

**Muroya:** All of this fascinating talk made me forget too!

My research isn't about fixing code, but rather more about what I want to do with programs, and what I can do with tasks. For example, if there are some muddy tasks lying ahead of you, I aim to give advice on how to fix them using a broad approach.

**Machine learning** and **probabilistic programming** are not so clear-cut. What matters to me the most is that I offer better viewpoints, and assist with revising programs so that users feel happy and enjoy the increased convenience.

**Hasegawa:** Are you trying to expand the possibilities of programming languages by offering new insights?

**Muroya:** Not exactly the possibilities per se. My interests go deeper to the level of theories. I am looking for a unifying viewpoint that can be applied to different languages. I am not sure if applying this viewpoint to heavy hitting languages makes sense, but I want see what lies at the root level.

**Igarashi:** Such as finding commonly shared structures.

**Muroya:** Yes, exactly.

**Hasegawa:** Revolutionize programming languages at the root level?

**Muroya:** That would be spectacular. The reality is that people overlook the roots because they lie at such a deep level. My goal is to dig out all potential errors and clean the mess.

## *Bugs in the machine*

**Igarashi:** I am more into the language itself. Errors frustrate me. Now that I teach, I find that some students can pick it up by themselves, while others need more attention. So hearing a student say, "I finally get it!" makes me really happy.

**Muroya:** Learning programming is kind of like understanding the feelings of computers, isn't it? If you write code but it doesn't work well, you fix the bugs and then say, "Is this what you want?" You have to put yourself in the computer's shoes. There are not many strategies to tackle programming, so it's like completing a puzzle with only a limited number of pieces.

**Igarashi:** I also look into **program validation**, trying to verify their accuracy. What particularly challenges me is detecting the cause of errors after seeing an error message. This is probably a technology that many would really like to have, but it is something that cannot be completed overnight. Where to start is even a challenge.

Error messages are usually really terrible, and often misleading. A number of studies have tried to simplify them, but there hasn't been a definitive one yet. And there are hundreds of approaches to squashing such bugs.

**Hasegawa:** This problem is not limited to computer sciences either. In every scientific field, I don't think there is ever a theory that deals with errors in a systematic way.

**Muroya:** Errors can be limitless. Anything and everything can cause then.

**Igarashi:** How you approach errors is a reflection of your interests as a researcher.

**Muroya:** At a basic level, our job is to explain how certain languages form specific kinds of structures when analyzed theoretically. The rest of the job is in the hands of researchers who use the languages.

## *Trendiness at KyotoU*

**Hasegawa:** Scholars at the Graduate School of Informatics prefer their own approaches, and don't care about what's popular. That's why they are here at Kyoto University: to be independent thinkers. It also means that Kyoto University can be slow in catching up with the latest trends.

**Igarashi:** Yes, for instance we are lacking in the study of IT security. We have just one affiliated researcher who specializes in encryption, but that's it.

Recently-enrolled undergrads are always surveyed, and until three or four years ago a large percentage said that they wanted to develop **video games**. But we don't teach this! More importantly, *what* kind of game you develop is more challenging than the process of developing the games themselves, which actually requires more artistic than programming skills.

Students now, however, are much more interested in **artificial intelligence**. Most of the recent survey responses include keywords such as AI, VR, and AR.

**Hasegawa:** The students are certainly more sensitive to trends than we are!

**Igarashi:** I wonder how deeply they know about these trends though. I teach an entry-level course on GUI programming, and there was a student who was not challenged enough by the assignments, so as part of the graphical user interface design I was teaching he added a function for recognizing handwritten numbers. I hadn't covered that, but he seems to have picked up the basics himself in high school.

**Muroya:** As the number of useful libraries increases, it becomes easier to begin coding. You can practically get by in this field just by combining the right libraries.

**Igarashi:** And we also want to train our students to make those libraries themselves!

**Muroya:** If you want to combine libraries, you can search for them, plug them in, and get started. Most likely you'll fail on your first try, but that is when you really start to work. After failing a few more times, you begin looking into the whole program, and trying to see how it all works.

**Hasegawa:** You are officially in our field when you realize that programs aren't just black boxes!

**Muroya:** Right! People enter our field feeling fear about what's inside the black box. I was one of those people. But then you join us as you start to want to understand what's inside. Some opt for controlling programs, while others choose to analyze them.

*Atsushi Igarashi*

# Cutting edge

www.kyoto-u.ac.jp/cutting-edge/

*In this second section you can read a sampling of some of the latest scholarship from KyotoU. And in addition to numerous examples from the natural sciences, we are pleased to present a recent paper from Education on the hot topic of testing, with more output coming in the future from the humanities and social sciences.*

## High achievement not always based on high student initiative

What is the key to high student achievement in the sciences?

For years, researchers have pored over data to develop theories on how to maximize a given student's potential. One way to understand the landscape of international education is to analyze standardized tests, such as the Program for International Student Assessment, or PISA.

PISA is conducted by the Organization for Economic Co-operation and Development, OECD, to evaluate the academic performance of 15-year-olds across the globe in the areas of science, math, and literacy. The test is unique in that it assesses creativity, by requiring the students to apply their knowledge in practical contexts.

However, few studies of PISA scores and data among various countries have successfully answered questions regarding regional differences, in particular higher scores from East Asia compared to the West.

Writing in *Comparative Education Review*, Jeremy Rappleye of Kyoto University's Graduate School of Education explains that this discrepancy originates from different core concepts of learning: while in the West the focus is on learning as 'self-fulfillment', in the East the emphasis is on 'self-overcoming'.

"Learning based on self-fulfillment allows students to be independent experimenters, taking the initiative in their pursuit of knowledge and education," explains Rappleye. "Today this is considered the dominant concept of learning, and many East Asian countries are redesigning their education systems in this direction. But our PISA analysis shows something different."

With his colleague Hikaru Komatsu, Rappleye compared PISA-Science test scores with the degree of student initiative in science classes. They looked at conditions such as how often students are allowed to design their own experiments, or given a chance to choose the direction of their investigations.

"Previous education studies commonly focused on economic factors such as per capita GDP or education spending. Our analysis uniquely focuses on the science classes themselves," Komatsu states.

"Interestingly, we discovered that countries allowing more student initiative in science classes tended to have lower science PISA scores."

The team developed their findings by expanding on the common 'self-overcoming' learning paradigm, which assumes that until students complete their learning, they risk being confined to their own incomplete understanding of the topic, and that guidance and enforcement are essential in order to expand each student's understanding.

"Our findings challenge the currently dominant idea of education and learning, putting into question the direction of education reform happening in many countries today," concludes Rappleye. "We think it is vital to rethink these ideas, before we begin to degrade today's academic achievements."

## How does HIV escape cellular booby traps?

Human immunodeficiency virus — HIV — is believed to have evolved from a simian immunodeficiency virus, or SIV, that originated in chimpanzees. How SIV made the species jump has remained a mystery, since human bodies possess a defense mechanism that should prevent such infections. Tetherin, a crucial protein for this protection, acts as a sticky pad on the surface of infected cells, preventing them from releasing nascent virus particles.

In this evolutionary battle, viruses have developed their own arsenal of proteins as a countermeasure. For example, Vpu, an HIV accessory protein that targets tetherin, allows HIV to escape and spread.

An international team led by Kei Sato and Yoshio Koyanagi of Kyoto University

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# Visualizing danger from songbird warning calls

Watch out! Snake!

The moment you hear this, you cannot help but imagine a slithering creature, as your body prepares for a possible attack. In human conversation, hearing a particular word (eg 'snake') can cause a listener to retrieve a specific mental image, even if there is nothing in the field of vision.

This cognition was once thought to be unique to humans. Now it turns out that songbirds have a similar ability.

A study in *PNAS* reveals that a small songbird, the Japanese tit (*Parus minor*), can retrieve a visual image of a predator from specific alarm calls, providing the first evidence that nonhuman animals can 'see' a reference to certain vocalizations.

"The Japanese tit produces particular alarm calls when, and only when, encountering a predatory snake," explains Toshitaka Suzuki at the Center for Ecological Research, Kyoto University, and author of this study.

Using audio playback of calls and a short stick cut from a tree branch, the researcher discovered that simply hearing snake-specific calls causes the birds to perceive an otherwise inanimate object as a real snake.

In the experiment, snake-specific alarm calls were played while the birds approached a stick being moved in a serpentine fashion — up a tree trunk or along the ground. The birds notably did not respond to the same stick when hearing other calls, or if the stick's movement was not snake-like, indicating that, before seeing a real snake, they retrieve a snake image from specific alarm calls, causing them to become more sensitive to objects resembling snakes.

"With a snake's image in mind, tits can efficiently search out a snake regardless of its spatial position," says Suzuki.

Upon encountering a real snake, the birds typically make a close approach, hovering over it and spreading their wings and tail, as if to deter the snake from attacking. The birds in this study likewise made an approach, but did not exhibit such distraction behavior.

"They may have realized that the stick was not a real snake once they got close enough."

Suzuki was inspired by his previous work showing that the Japanese tit alters its response to snake-specific alarm calls depending on circumstances. If such alarms are heard while in a nest cavity, the birds immediately flee as if to evade an attack. In contrast, when outside the nest, they look at the ground near the nesting tree as if searching for a snake.

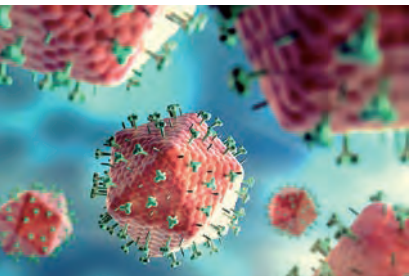
"These birds do not respond to the calls in a uniform way, but appear to retrieve a snake image and then decide how to deal with the predator according to the circumstance," he explains.

Over the last three decades, field biologists have revealed that many animals, such as monkeys and meerkats, produce specific calls for specific types of food or predators.

"Retrieval of mental images may also be involved in other animal communication systems," adds Suzuki. "Uncovering cognitive mechanisms for communication in wild animals can give insights into the origins and evolution of human speech." ■

set out to test whether the evolution of Vpu could have aided SIV in making the leap to humans. Their study, published in the journal *Cell Host and Microbe*, helps explain how HIV came into our world.

"We used an immunodeficient mouse model with a reconstituted human immune system, established through the transplantation of human blood-forming stem cells," explains Koyanagi. This design, he adds, allowed for both SIV and HIV infection to be studied in the mice.



Using reverse genetics to engineer several HIV strains with different Vpu mutants, the team investigated which Vpu function was key for successful virus infection.

"Vpu can inhibit immune signaling pathways in the cell and degrade tetherin," states Sato. "The Vpu variant responsible for downregulating tetherin was the most important property of Vpu for HIV."

They also found that returning tetherin to normal levels could suppress virus replication, suggesting that a minimal number of tetherin molecules can combat HIV.

Interestingly, SIV could not effectively infect human blood cells in the mouse model. But when SIV Vpu was endowed with properties resembling HIV Vpu — namely, anti-tetherin activity — blood cell infection did occur.

Sato concludes, "From an evolutionary standpoint, our study suggests that a gain-of-function ability in Vpu to overcome human tetherin allowed SIV to infect a new host: us." ■

# What a handsome schnoz!

Is big beautiful? In the case of the male proboscis monkey, it appears to be all in the nose.

In research published in *Science Advances*, an international research team has found evidence supporting both male-male competition and female choice as factors in the evolution of the enlarged male nose.

What's more, nasal enlargement modifies the male's call, possibly as an audible clue to attractiveness. These results are the first in primate research that evaluate unique masculine characteristics with morphology, acoustics, and socioecology.

"In animals, males often have exaggerated physical traits as a consequence of sexual selection. But you can't get any odder than the long, drooping nose of the proboscis monkey," explains Hiroki Koda of Kyoto University's Primate Research Institute and first author of the study.

"And although this unique feature has long been admired, explanations for its evolution and its ecological roles have remained unclear."

Among primates, larger noses with prominent sexual dimorphism are only seen in this species. Theoretically, exaggerated male traits could serve as advertising competitiveness to other males or to attract females.

To test their hypothesis, the team conducted morphological measurements and behavioral observations on monkeys both in captivity and in their natural habitat. They tested correlations between features such as body mass, facial characteristics, testicular volume, vocalizations, and the number of harem females in the observed groups.

"We found strong correlation between the size of an enlarged nose with physical strength — indicated by body mass — and reproductive ability — indicated by testis size," describes Koda. "The number of harem females was larger as well. To put it simply, the large nose appears to act as a 'badge' of strong male characteristics."

Their acoustic analyses also suggested that nasal enlargement systematically modified the resonance properties of male vocalizations, making their voices lower when attracting a female.

"We were quite surprised to find such a clear relationship between nose size and attractive characteristics," says lead author Ikki Matsuda. "Not only did we find physical correlation, our results showed correlation to the auditory component in attracting a mate."

The group expects their results to be a promising contribution to evolutionary theory, with new perspectives on audiovisual coevolution of exaggerated male traits, sure to be of broad relevance to the field of biology.

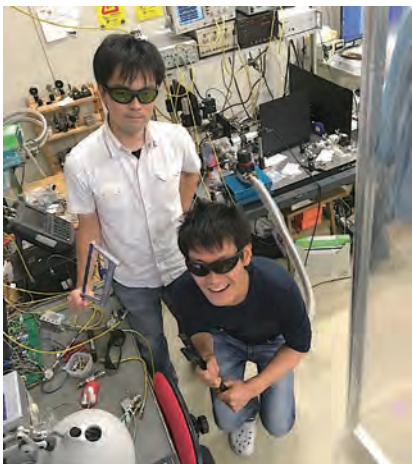
They hope to expand their research to assess the cognition of males and females for enlarged noses, and to determine how an enlarged male nose ecologically contributes to mating success in the social systems of proboscis monkeys. ■

# Electro-mechano-optical NMR detection

An international research project led by Kazuyuki Takeda of Kyoto University and Koji Usami of the University of Tokyo has developed a new method of light detection for nuclear magnetic resonance — NMR — by up-converting NMR radio-frequency signals into optical signals.

This new detection method — appearing in the journal *Optica* — has the potential to provide more sensitive analysis compared with conventional NMR. Its possible utilization in higher-accuracy chemical analysis, as well as in magnetic resonance imaging — MRI — technology, are also of interest.

NMR is a branch of spectroscopy where scientists measure the spin of an atom's nucleus in order to determine its identity. Atomic nuclei subjected to a magnetic field induce radio-frequency signals in a detector circuit. Since different atoms cause signals at different frequen-



# Twisting graphene into spirals

It's probably the smallest spring you can imagine.

Researchers from Kyoto University and Osaka University report for the first time in the *Journal of the American Chemical Society* the successful synthesis of hexa-peri-hexabenzo [7]helicene, or 'helical nanographene'.

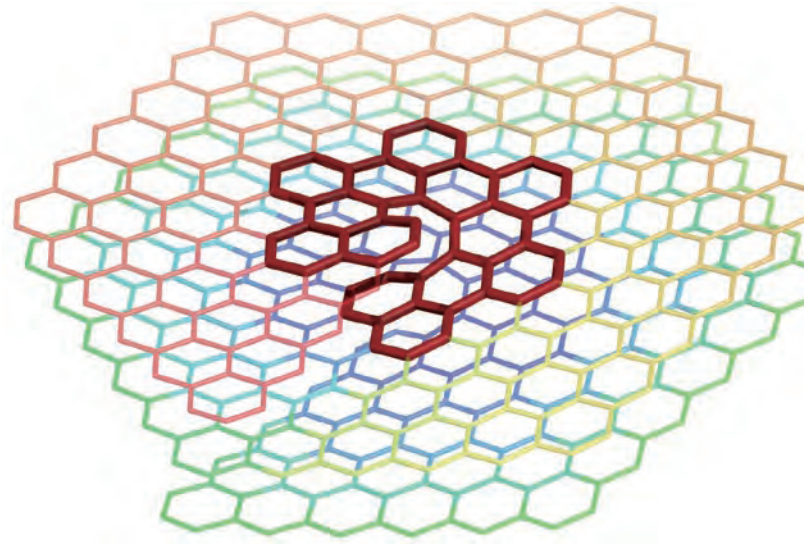
These graphene constructs previously existed only in theory, so successful synthesis offers promising applications from nanoscale induction coils to molecular springs for use in nanomechanics.

Graphene — a hexagonal lattice of single layer carbon atoms exhibiting outstanding charge and heat transport properties — has garnered extensive research and development interest.

Helically twisted graphenes have a spiral shape. Successful synthesis of this type of graphene could have major applications, but its model compounds have never been reported. And while past research has gotten close, resulting compounds have never exhibited expected properties.

"We processed some basic chemical compounds through step-by-step reactions, such as McMurry coupling, followed by stepwise photocyclodehydrogenation and aromatization," explains first author Yusuke Nakakuki. "We then found that we had synthesized the foundational backbone of helical graphene."

The team confirmed the helicoid nature of the structure through X-ray crystallography, also finding both clockwise and counter-clockwise nanographenes. Further tests showed that the electronic structure and photoabsorption properties of this compound are much different from previous ones.



"This helical nanographene is the first of its kind," concludes lead author Kenji Matsuda. "We will try to expand its surface area and make the helices longer. I expect to find many new physical properties as well."

cies, scientists can use this information to determine the compounds contained in a sample. The most well-known application of this is in MRI-based imaging, such as in fMRI scans.

"NMR is a very powerful tool, but its measurements rely on amplification of electrical signals at radio-frequencies. That pulls in extra noise and limits the sensitivity of our measurements," explains Takeda. "So we developed an experimental NMR system from scratch, which converts radio-frequency signals into optical ones."

The principle behind this 'up-conversion' is a new hybrid quantum conversion technology. The team worked to integrate this system into NMR, eventually building a device that connects electronics to mechanics, and then to optics. The material linking all three systems is an elastic membrane of silicon nitride.

"We constructed a capacitor by vacuum-depositing a metal layer onto the silicon nitride membrane," explains co-author Usami. Using this with an inductor, they built a resonator to detect NMR signals, and next constructed an optical cavity using the metal layer as a mirror.

"The incoming electric NMR signal shakes the membrane, causing motion that is detected by an optical interferometer."

The team believes that the success of this optical detection can push the spectroscopy method even further, with the hope that this increased accuracy in detection and characterization of materials can be utilized in multiple scientific disciplines.

Takeda concludes, "Various methods for optical NMR detection have been reported, and while some are highly sensitive, they have so far lacked widespread applicability. Our new scheme has proven to be both versatile and applicable to a wide range of materials."

# Studying the human impact on sea urchin abundance

Sea urchin populations are more sensitive to human activities than previously believed, according to a half-century long observational study.

Researchers found that changing water temperature and algal blooms strongly affected sea urchin populations, and even caused some abnormal development of their larvae. The research is published in the journal *Ecological Indicators*.

Continuous long-term monitoring is important for detecting ecological changes and understanding their causes. Sea urchins are ecological drivers that can affect the dynamics of whole communities, thanks to their extensive eating of seaweed and large population fluctuations. They are also commonly found in shallow water and therefore subject to human influences, yet few long-term studies focus on their population health.

Between 1963 and 2014, researchers studied the dynamics of three common species of sea urchins in a fixed area off of Hatakejima (pictured), a marine reserve in southern Japan, making this the longest running study of its kind.

Each year the team conducted a survey of the area, and between 1983 and 2008, six surveys were taken of the entire coast. The three species showed similar overall trends, with large numbers in the 1960s and 1970s, abrupt declines in the late 1970s and early 1980s, and a recovery toward the late 1990s.

The scientists, from several Japanese institutes, found that red tide – another term for algal bloom – along with warm winter ocean temperatures and sea currents is related to the abundance and species richness of these three most common varieties. Each species was affected by different factors, and in one case, red tides were linked to abnormal development, providing a rare connection between larval and post-larval ecology of an intertidal animal – one that is in water at high tide and out of water at low tide – over a long term.

Tomoyuki Nakano of Kyoto University said: "Our study is the longest of its kind into sea urchin populations, and demonstrates the importance of monitoring impacts of environmental stressors and addressing the mechanisms of changes in the abundance of not only sea urchins but other marine creatures."

The team conclude that because human impacts will continue to affect marine invertebrates, long-term studies like this one will be invaluable in understanding ecological changes. Combining these observations with experimental approaches will shed light on connections among environmental factors. ■

# Capturing t Yanbaru wh

The critically endangered Yanbaru whiskered bat, *Myotis yanbarensis*, has been caught for the first time on Okinawa Island since its discovery 22 years ago. Kyoto University doctoral student Jason Preble succeeded in the capture on the night of 20 February, during a survey in the Yanbaru Forest in the north of Okinawa's main island.

The rare bat species was first discovered in the subtropical Yanbaru Forest in 1996, when two specimens were collected. It was later observed on a few occasions on the islands Tokunoshima and Amami-Oshima, but no sightings were reported again on Okinawa Island.

This small, tree-dwelling bat, endemic to these islands, thus became a serious conservation concern and was declared 'critically endangered' — the highest risk level — by both the Japanese Ministry of Environment and the International Union for the Conservation of Nature.

On 20 February 2018 at 20:05, Preble captured one male Myotis yanbarensis weighing 4.9 g and apparently in good health. Three nights later he caught a second male bat weighing 5.2 g. Upon release, he tracked these individuals using VHF transmitters. A third male was also caught four days later. The captures took place in the former United States military Northern Training Area, facilitated by a high-tech

# he rare iskered bat

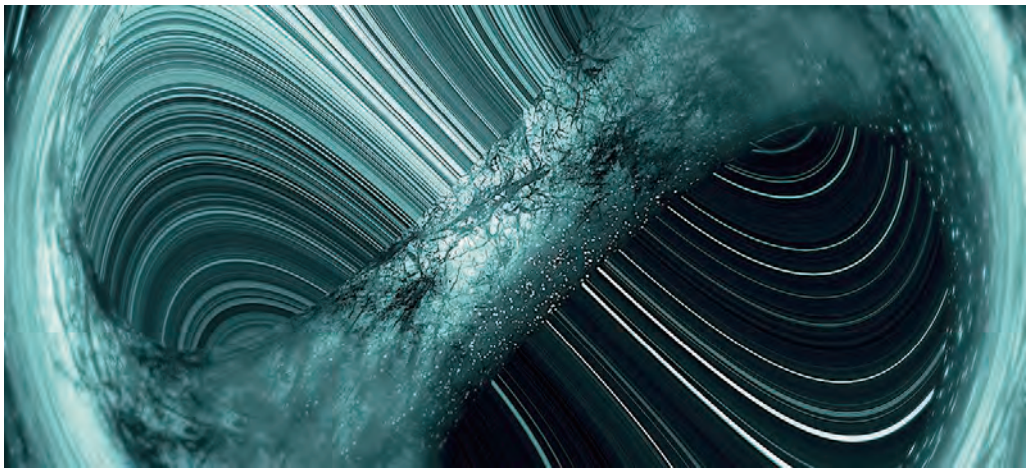
acoustic lure that broadcasts synthesized bat calls.

Moreover, Preble was able to record the bat's echolocation call, vital data that was previously unreported.

This large area of forest was returned to Japan in December 2016, and Kyoto University's Island Bat Research Group, led by Christian Vincenot, was among the first teams to be granted access by the Ministry of Environment, Okinawa Forestry Office, and Aha Dam authority.

The presence of the Yanbaru whiskered bat indicates that this zone, which was off limits for over a half-century, may have served as an unintended wildlife sanctuary. This discovery revives hope for conservation of this rare species, while also suggesting that Myotis yanbarensis may be range-restricted to a small part of the Yanbaru Forest and therefore may continue to be at risk of local extinction.

Extreme caution is therefore advised in the management of this area, which is currently a candidate for UNESCO Natural Heritage status. Bats are often highly sensitive to infrastructure development, as seen in the steep decline in endangered populations following the construction in 2013 of a new airport runway over bat caves on Ishigaki island, also in the Okinawan archipelago. ■



# Using geometry and qubits to build real universes

Researchers at Kyoto University's Yukawa Institute for Theoretical Physics have announced the discovery of a new geometric formula for computing an amount of quantum information of quantum bits.

The conjecture, published in *Nature Physics* and established by Koji Umemoto and Tadashi Takayanagi, can be regarded as a generalization of the black hole entropy "Bekenstein-Hawking" formula, providing a new tool for studying the deep connections between gravity and the quantum realm.

In physics, quantum mechanics explains the basic laws of micro-phenomena. The smallest discrete unit of information of this scale is called a quantum bit, or qubit. Recently, scientists have been actively exploring new conjectures to link quantum mechanics with general relativity, with projects such as 'It from Qubit' facilitating this inquiry.

String theory is a promising framework unifying the two principles, with theorists working to show how universes with gravity can emerge from quantum bits.

The team conducted geometrical calculations in gauge/gravity correspondence to derive various properties that match quantum values. The properties were then confirmed to precisely agree with known values in quantum information theory.

The final published formula shows that an amount of information shared by two objects A and B — especially in mixed states, called "entanglement of purification" — is equal to the cross-sectional area of a tunnel connecting the two in a gravitational universe.

Takayanagi states that to understand the origins of the universe, researchers must comprehend the basic laws of micro-universes — ie a quantum theory of gravity. Deriving the fundamentals of spacetime from quantum bits provides a crucial step toward achieving that goal.

The team intends to further explore the deep connections between gravity and quantum information, as their formula is only the gateway to a new region of inquiry. ■

# KyotoU today

*Kyoto University's myriad operations span multiple campuses around the city of Kyoto, numerous offices, research facilities, and other operations around the country, and dozens of centers, liaison offices, and field stations across the globe. In this final section you can sample some of the latest developments, spanning student life, industry outreach, and overseas activities.*

## KURNe: research news in motion

Communicating the scholarship of Kyoto University via video has grown from individual lab projects to online courses on the edX platform, and further to the already vast archive of lectures and other original content offered by OCW, KyotoU's 'OpenCourseWare' hub.

First inaugurated in 2016, the University's official YouTube channel now features short research videos as part of its *Kyoto U Research News Express — KURNe* — series: each episode being in English, under two minutes, and featuring a popular story from the 'Cutting edge' section of this magazine.

Each news-like episode begins with an introduction by the series' host, then moving to a brief overview by the featured researcher. The host segments are filmed at Kyoto University's traditional Yoshida Izumidono seminar house, lending the series a *wa* aesthetic, characteristic of the city of Kyoto. Researchers are interviewed at their offices, labs, or a locale of their choosing.

These shorts are mainly the work of two people: Raymond K Terhune of the Office of Global Communications, and Ryohei Oka, an undergraduate intern from the Faculty of Economics. Raymond writes the scripts, conducts the interviews, and directs, with Ryohei hosting and editing.


The series has attracted the interest of academics and communicators around Japan, in part because of its catchy look in spite of the minimal production cost. New episodes are planned monthly for the current academic year, through March 2019.

As a showcase for cooperation between talented students and university communicators, the production team hopes that this effort will inspire other institutions to tap new and vital sources of innovative ideas to propel science communication into the future.

All episodes of KURNe are online at: tiny.cc/kurne

# News from overseas centers

## Bangkok ASEAN Center

www.oc.kyoto-u.ac.jp/overseas-centers/asean/en/

KyotoU's research footprint in Southeast Asia is both diverse and long-standing, ranging from the humanities and social sciences to the natural sciences and applied fields. In 2017 alone, over 100 projects funded by JSPS Kakenhi grants were carried out in the ASEAN region, a majority reflecting and responding to contemporary issues.

Atop this strong base, the University's ASEAN Center is opening a new horizon for contributions to society, in part by actively promoting the United Nations' Sustainable Development Goals, which seek to address the world's most pressing challenges.

This comes as a natural extension of the Center's vigorous support for the Japan-ASEAN Science, Technology and Innovation Platform — JASTIP — aiming to promote sci-tech cooperation centered on sustainable development research.

In turn this has led to the January 2018 hosting in Kyoto of a roundtable on "Shaping New Horizons for Japan-ASEAN Science and Technology Cooperation towards the UN SDGs", inviting counterpart institutions from the region together with Japan's science ministry MEXT. Further, the ASEAN Center is working to identify and map how KyotoU contributes to the SDGs through its research activities in Southeast Asia, in collaboration with the ASEAN Network Committee.

Given its history of commitment to the region, the ASEAN Center continually supports the University and its researchers in their critical role of implementing the UN's goals.

## Heidelberg European Center

www.oc.kyoto-u.ac.jp/overseas-centers/eu/en/

The SDGs are a hot topic in Europe as well.

A matching fund agreement was signed on 17 April 2018 between Kyoto University and the German Academic Exchange Service (DAAD). This new "DAAD-Kyoto University Partnership Program towards SDGs 2019–2020" supports early-career researchers in both countries to take part in short-term stays, deepening their research networks in view of the SDGs.

Five Kyoto University researchers took part in a two-week pilot program in Germany during 2017, with advisory help provided by the Kyoto University Research Administration office (KURA) and the University's European Center, resulting in the start of much fruitful collaboration.

"I want to deepen relationships with German researchers, and acquire funding to invite them to Kyoto," says Tsubasa Watanabe, assistant professor at the Institute for Integrated Radiation and Nuclear Science. He visited the German Cancer Research Center (DKFZ) and European Molecular Biology Laboratory (EMBL), where he pursued a novel cancer treatment method.

"My trip expanded my possibilities for future research in Germany," explains Shoma Ishikawa, a doctoral student investigating cell aging at the Graduate School of Biostudies. He met with a team at Cologne University's Cluster of Excellence on aging-associated diseases, CECAD.

Such positive outcomes will surely encourage a new round of young investigators in both countries to apply for Kyoto-DAAD support, fulfilling the hopes of the University's European Center as it continues to support the next generation of leaders in joint scholarship.

## Science with industry:

# Mining answers from the data mountain

"The race is on."

As always, JB Brown speaks animatedly, ideas flying and crashing, his hands at one moment gesturing, and at another careening across his laptop keyboard. Yet his eyes remain steady, almost looking past us, as he describes the coming revolution in computational drug discovery.

"Everyone in academia and industry is in this quest to find small molecules," he continues. "Antibodies are huge, comprised of maybe thousands of atoms, while small molecules might be just 50 or 60."

Antibody-based therapies — such as **anti-PD-1 cancer immunotherapy**, developed by **Tasuku Honjo** of Kyoto University — have been highly successful in many cases. But the costs associated with testing and applying them are prohibitive, limiting their wide-scale application.

"Once an antibody has been found to be useful, it has to be grown in an animal's body and then isolated."

All of this costs money, and limits availability. But a small molecule — that performs the same task by binding to a receptor on a cell — could change all that.

"Factories could be designed to make these small molecules on a mass scale."

Brown, an American, has earned advanced degrees in informatics from KyotoU, and spends much of his time grappling with medical data. He has also developed tools for advanced data analysis and the evaluation of AI algorithms, but today we're discussing the area of his work most closely tied to industry: **bioinformatics**.

"Companies have amassed huge amounts of data, but they don't know what to do with it." For example, matching a sample of 100 proteins in the human body — that may be associated with a particular disease — with 20,000 candidate compounds yields two million data points.

"But how do you make sense of that much data? This is where my platform comes in." By applying fundamental knowledge of biochemistry, Brown has been able to show that working with a much smaller dataset can actually yield results more quickly and accurately.

And smaller datasets mean greatly reduced costs for testing. Plus Brown sees his method as having applications for finding new targets for older drugs.

"A key concept here is **polypharmacology**: drugs performing multiple functions."

Currently in talks with several pharma companies, Brown's eyes sparkle in anticipation of a bright future for smarter healthcare.

See statlsi.med.kyoto-u.ac.jp/~jbbrown

## *So tell us... what do you do and how did you get to Japan?*

### "How do our circadian clock and metabolism interface?"

**Jean-Michel Fustin**
Adjunct Lecturer, Graduate School of Pharmaceutical Sciences
orcid.org/0000-0002-6200-6075

Originally from Belgium. Came to KyotoU in 2008 as a JSPS postdoctoral fellow; Adjunct Lecturer from 2014. Current recipient of Kakenhi (Grant-in-Aid) *Kaitaku* from JSPS.

### "How do bacteria infect us and how do our bodies respond?"

**Minsoo Kim**
Associate Professor, *Hakubi* scholar in molecular and cell physiology
www.hakubi.kyoto-u.ac.jp/eng/02_mem/06kim.shtml

Originally from South Korea. Came to UTokyo in 1996 as a PhD candidate. Following graduation and faculty promotions, came to KyotoU in 2015 as an Associate Professor. Current recipient of Kakenhi *Kiban C* from JSPS, and also private foundation funding.

### "How can we improve how we teach and learn?"

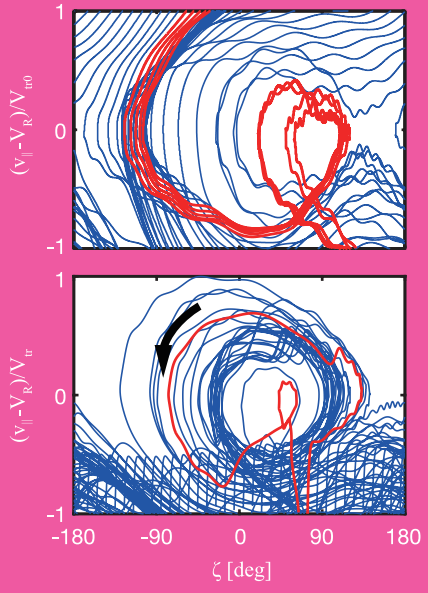
**Emmanuel Manalo**
Professor of educational psychology, Graduate School of Education
cogpsy.educ.kyoto-u.ac.jp/en/member/Emmanuel_Manalo.htm

Originally from New Zealand. First visited Japan and Kyoto in 1998. Previously at Waseda University. Professor at KyotoU since 2014. Current recipient of Kakenhi *Kiban A* from JSPS.

*JSPS = Japan Society for the Promotion of Science*
*Kakenhi Kaitaku = Grant-in-Aid for Challenging Research (Pioneering)*
*Kakenhi Kiban = Grant-in-Aid for Scientific Research (A, B, or C)*

Presenting her professor (Yoshiharu Omura, Research Institute for Sustainable Humanosphere, Uji Campus) with a cushion with her thesis printed on it ignited an impromptu scientific meeting

During a December 2016 trip to Kagoshima with a group of laboratory colleagues to watch the Arasé Geospace Probe launch: "I relish the thought of studying the Arasé data and comparing them with my simulations"




Tracking particle velocities in space: the red spiral movement cannot be approximated, but it is through this movement that sudden acceleration occurs; this work has earned Ms Kubota many academic awards worldwide, resulting in the KyotoU President's Award for 2017

Ms Kubota's favorite lunch is a sandwich from Tamaki-Tei bakery, across from the entrance to the Uji campus

**Yuiko Kubota** (3rd Year Doctoral, Graduate School of Engineering)

# Capturing a single particle in limitless space

## Awarded *Honorable Mention for an Outstanding Woman Researcher*

**"I intuitively thought: space!"**

When searching for a major, this was the image that came to Yuiko Kubota's mind.

"Earth's magnetic field causes highly energetic charged plasma particles to engulf the planet in radiation belts. Astronauts or artificial satellites passing through these belts can experience great injury and damage. To safely develop space, it is essential that we learn the mechanisms of belt formation, such as the causes of fluctuations in their size."

Ms Kubota focuses on electromagnetic waves generated by low energetic charged plasma particles that exist in larger volumes than radiation belt particles.

"Such waves cause a few special particles to accelerate, which then form radiation belts." By proving this, Ms Kubota earned KyotoU's Honorable Mention for Outstanding Women Researchers.

"Thirty years ago 'approximation' methods — averaging particle movements across the whole — were the norm. But with today's supercomputers, we can track individual particles precisely, while quantitatively confirming changes in the entire belt as well. This much more closely matches observed data."

Next she is developing a simulator to evaluate the entire range of the belts.

"I would be delighted if this research can play even a small role in the development of geophysics. Our methods are very new, but the advantage is that we can explain phenomena that no one has yet confirmed. Even prominent professors discuss this with me not as a student, but as a fellow scientist, which really makes me glad to have continued with my work."

"The diversity of Kyoto University's academic environment means that everyone is enthusiastically pursing all sorts of study. I respect them very much, and I want very much to keep pace with them."

Almost as if in waves of particles, highly individual scholars gather at this University, and stimulated by her interactions with colleagues and at conferences, Ms Kubota moves forward energetically. As she accelerates to the top of her field, she shows no signs of slowing down.

Artwork by Kyoto University students, combined with artistic scenes as glimpsed by researchers.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**Art Studio Suisai Tokidoki Pen**
**Masa'aki Kuwahara** (1st year Doctoral, Graduate School of Letters)
Watercolor, *Yukibaré no Asa* (*Fine Morning after a Snowfall*)

The tense, cool mood of the words brought to mind a snowy scene I saw at the foot of Mt Kongo, when headed out at dawn in winter last year, evoking the unique atmosphere of the chill air, clean and pure, sparkling and refreshing. 25 January 2017; Kamogami, Gosé, Nara

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**Music Research Society Instrumentalists**
**Keisuké Iizuka** (2nd Year, Faculty of Law)

**Title: *Préludes*, book 1 no 10, *La cathédrale engloutie***
**Composer: Claude Debussy**

Depicting a cathedral, submerged in the ocean, rising up and then disappearing once again into the depths. The low echo of the cathedral bell — vague yet firm, vibrating in the taut air — reminds me of a quavering voice from a tin can phone.

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**Tin can telephone**

I saw today
at a planetarium
Some artificial stars

Along the night's white line
his muffled voice
Sped straight to me

I found today
A new moon

And into the black of night
My voice verily returned

**Kamifusen Shira'aé** (2nd Year, Faculty of Letters)

I used to play with these phones as a child. I was mystified by how my voice could travel along that thin string without falling off.



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