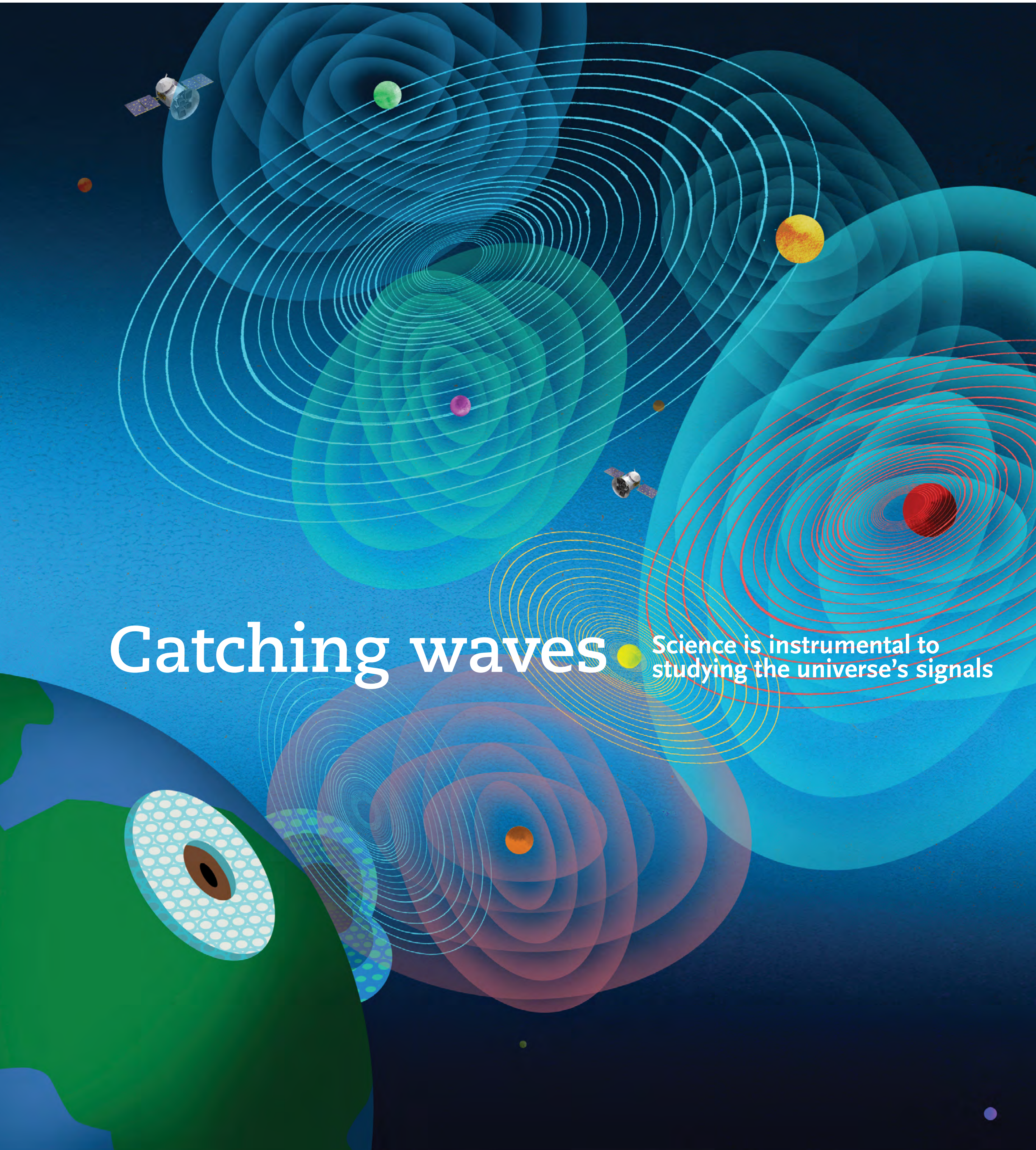
MIT

Science at MIT

Winter 2023 **Published twice yearly**



Catching waves

Science is instrumental to studying the universe's signals

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Scientists at the MIT Kavli Institute for Astrophysics and Space Research build customized experiments to study the universe: discovering exoplanets, characterizing the first stars and galaxies, and understanding environments with extreme gravity, such as black holes and neutron stars.

Illustration: Ellen Weinstein, www.ellenweinstein.com

SCHOOL OF SCIENCE
Massachusetts Institute of Technology

TABLE OF CONTENTS

Letter from the Dean

My fellow alumni and friends,

In this issue, we turn our gaze skyward. This last decade has been an explosive one for astrophysics and space research. Released in fall 2021, the National Academies' Decadal Survey on Astronomy and Astrophysics outlined the upcoming decade's most compelling science goals and set the funding priorities for national agencies such as NASA and NSF. Not surprisingly, scientists at MIT Kavli Institute (MKI) for Astrophysics and Space Research are playing key roles in projects and missions that have gotten the Astro2020 stamp of approval.

These scientists include veteran researchers, such as Deepto Chakrabarty '88, the new head in the Department of Physics (see page 6) and up-and-coming superstars such as Erin Kara, who was the keynote speaker for our breakfast talks speaker series. Thank you to those of you who could join us for our first in-person science talk in more than two years; and I hope we can continue the trend into the spring. On page 10, you can read more about how Erin's research elucidates the physics behind how black holes grow and affect their environments.

In a feature article on page 12, we introduce you to some new astronomical instrumentation MKI scientists are developing to study the unseen: from high-energy X-rays to light from the universe's first stars. Some instruments are already up and running in the desert of Chile; some are waiting to be incorporated into rockets to scan the sky. Others are in the planning stages and may take decades to start taking in data. A scientist's research journey can often be a long one — and supporters, such as Curt Marble '63 help launch those research dreams. On page 15, you can read about Curt's interest in supporting our MKI scientists. It gives me great pleasure to also acknowledge the research enabled in my own group through Curt's support and friendship.

In other philanthropic news, on page 20 you can read about the new MIT bionics center established by K. Lisa Yang's $24 million gift. At the helm is Ed Boyden, the Y. Eva Tan Professor in Neurotechnology at MIT, and Hugh Herr, professor of media arts and sciences at the MIT Media Lab. Ed is a renowned creator of tools to analyze and control the brain. Hugh is a pioneer in the development of bionic limbs to improve mobility for those with physical disabilities. Together with scientists including Nancy Kanwisher, an expert in perception and cognition, this team will develop new bionic interventions for our brains and bodies. On page 22, you can read about other scientific supporters, such as Barrie Zesiger who make it possible for our graduate students to devote themselves to the science that excites them and inspires us.

For an in-depth profile about one of our amazing graduate students who is looking at underpinnings of mind and machines, you can turn back to the beginning of the issue to read about the research of recent mathematics PhD recipient Juncal Arbelaiz. Doctorate in hand, Juncal is off to Princeton for a postdoc appointment to explore the reliability and robustness of artificial and biological interfaces.

Our life sciences program continues to thrive, in no small part due to the generous gift of Paul Schimmel whose transformative $50 million gift has provided funding for many graduate students across the Institute. The MIT Schimmel Family Program for Life Sciences still has opportunities for doubling the impact of Paul's gift. If that area of research speaks to your passions or interests, please do reach out to Amy Keating, our new head of the Department of Biology. You can read about Amy's research and her vision for an integrated and newly invigorated biological and life sciences program on page 8.

Interdisciplinarity and integration with life sciences is the life's work of Brandon Ogbunu, one of our two MIT Martin Luther King Jr. visiting scholars. On page 16, you can read about Brandon's research on protein evolution and his collaboration with Matt Shoulders in the Department of Chemistry. The MLK scholars program has been a wonderful way to grow our research partnerships — and most recently, our faculty.

I'm thrilled to share that Robert Gilliard, a recent MLK scholar who worked with inorganic chemist Kit Cummins (see last winter's *Science@MIT*), will join the Department of Chemistry as a fully tenured faculty member. I look forward to learning more about Robert and his research as he returns to the 'Tute this semester.

As we head into the spring, I hope these and other stories from the School of Science will continue to inspire you to set your sights on the stars.

With my very best wishes,

Dean Nergis Mavalvala PhD '97

Wiggling toward bio-inspired machine intelligence

Inspired by jellyfish and octopuses, PhD candidate Juncal Arbelaiz investigates the theoretical underpinnings that will enable systems to more efficiently adapt to their environments

Sandi Miller | Department of Mathematics

Juncal Arbelaiz is a native of Spain, where octopus is a common menu item. However, Arbelaiz appreciates octopus and similar creatures in a different way, with her research into soft-robotics theory.

More than half of an octopus' nerves are distributed through its eight arms, each of which has some degree of autonomy. This distributed sensing and information processing system intrigued Arbelaiz, who is researching how to design decentralized intelligence for human-made systems with embedded sensing and computation. At MIT, Arbelaiz is an applied math student who is working on the fundamentals of optimal distributed control and estimation.

She finds inspiration in the biological intelligence of invertebrates such as octopus and jellyfish, with the ultimate goal of designing novel control strategies for flexible, soft robots that could be used in tight or delicate surroundings, such as a surgical tool or for search-and-rescue missions.

"The squishiness of soft robots allows them to dynamically adapt to different environments. Think of worms, snakes, or jellyfish, and compare their motion and adaptation capabilities to those of vertebrate animals," says Arbelaiz. "It is an interesting expression of embodied intelligence — lacking a rigid skeleton gives advantages to certain applications and helps to handle uncertainty in the real world more efficiently. But this additional softness also entails new system-theoretic challenges."

> "As scientists, we are responsible to share our knowledge, to inform the public about scientific discovery and its impact."

In the biological world, the "controller" is usually associated with the brain and central nervous system — it creates motor commands for the muscles to achieve movement. Jellyfish and a few other soft organisms lack a centralized nerve center, or brain. Inspired by this observation, she is now working toward a theory where soft-robotic systems could be controlled using decentralized sensory information sharing.

"When sensing and actuation are distributed in the body of the robot and onboard computational capabilities are limited, it might be difficult to implement centralized intelligence," she says. "So, we need these sort of decentralized schemes that, despite sharing sensory information only locally, guarantee the desired global behavior. Some biological systems, such as the jellyfish, are beautiful examples of decentralized control architectures — locomotion is achieved in the absence of a [centralized] brain. This is fascinating as compared to what we can achieve with human-made machines."

A fluid transition to MIT

Her graduate studies at the University of Navarra in San Sebastian led to her working with MIT Professor John Bush in fluid dynamics. In 2015, he invited Arbelaiz to MIT as a visiting student to investigate droplet interactions. This led to their 2018 paper in *Physical Review Fluids*, and her pursuit of a PhD at MIT.

In 2018, her doctoral research shifted to the interdisciplinary Sociotechnical System Research Center, and is now advised by Ali Jadbabaie, the JR East Professor of Engineering and head of the Department of Civil and Environmental Engineering; and School of Engineering Associate Dean Anette Hosoi, who is the Neil and Jane Pappalardo Professor of Mechanical Engineering as well as an applied math professor. Arbelaiz also regularly works with Bassam Bamieh, associate director of the Center for Control, Dynamical Systems, and Computation at the University of California at Santa Barbara. She says that working with

Inspired by jellyfish and octopus, Juncal Arbelaiz is an applied math doctoral recipient who is working on the fundamentals of optimal distributed control and estimation. *Photo: Steph Stevens*

this team of advisors gives her the freedom to explore the multidisciplinary research projects she has been drawn to over the past five years.

For example, she uses system-theoretic approaches to design novel optimal controllers and estimators for systems with spatiotemporal dynamics, and to gain a fundamental understanding of the sensory feedback communication topologies required to optimally control these systems. For the soft-robotic applications, this amounts to ranking which sensory measurements are important to best trigger each of the "muscles" of this robot. Did the robot's performance degrade when each actuator only has access to the closest sensory measurements? Her research characterizes such a trade-off between closed-loop performance, uncertainty, and complexity in spatially distributed systems.

"I am determined to bridge the gap between machine autonomy, systems theory, and biological intelligence," she says.

Next chapter

A two-year Schmidt Science Fellowship, which funds young researchers to pursue postdoctoral studies in a field different from their graduate work, will let Arbelaiz further explore the intersection of biological and machine intelligence after graduation.

She plans to spend her postdoc time at Princeton University with Professor Naomi Leonard, and to work with researchers in systems biology, computer science, and robotics, to explore the reliability and robustness of biological and artificial ensembles. Specifically, she is interested in learning how biological systems efficiently adapt to different environments so that she can apply this knowledge to human-made systems, such as autonomous machines, whose vulnerability to noise and uncertainty creates safety issues.

"I foresee an unprecedented revolution approaching in autonomous and intelligent machines, facilitated by a fruitful symbiosis between systems theory, computation, and [neuro] biology," she says.

Paying it forward

Arbelaiz grew up in Spain acutely aware of the privilege of having access to a better education than her parents. Her father earned a degree in economics through independent study while working to support his family. His daughter inherited his persistence.

"The hardships my parents experienced made them cherish autodidactism, lifelong learning, and critical thinking," she says. "They passed on these values to me, so I grew up to be a curious and persevering person, enthusiastic about science and ready to seize every educational opportunity."

In a desire to pass this on to others, she mentors STEM students who lack guidance or resources. "I firmly believe that we should promote talent everywhere, and mentoring could be the key driver to encourage underrepresented minorities to pursue careers in STEM," she says.

An advocate for women in STEM, she was part of the executive committee of Graduate Women at MIT and MIT Women in Mathematics, and participates in various panels and workshops. She also runs live experiments for kids, such as at the MIT Museum's Girls Day events.

"As scientists, we are responsible to share our knowledge, to inform the public about scientific discovery and its impact, and to raise awareness about the value of research and the need to invest in it."

Arbelaiz also supports MIT's Covid-19 outreach efforts, including talks about the mathematical modeling of the virus, and translating into Basque her former mentor John Bush's MIT Covid-19 Indoor Safety app.

This interest in paying her STEM knowledge forward is something she credits to her MIT education. "MIT has been one of the best experiences of my life so far: it has brought enormous academic, professional, and personal growth," she says. "I share MIT's taste for collaborative and multidisciplinary research, the attraction to intellectual challenges, and the enthusiasm for advancing science and technology to benefit humankind."

Deepto Chakrabarty named head of the Department of Physics

High-energy astrophysicist to lead MIT School of Science physics community

School of Science

Professor Deepto Chakrabarty, principal investigator at the MIT Kavli Institute for Astrophysics and Space Research, has been named head of the Department of Physics, effective Aug. 29, 2022. Chakrabarty succeeds Peter Fisher, the Thomas A. Frank (1977) Professor of Physics, who has led the department since Nov. 13, 2013.

"Professor Chakrabarty will continue to provide strong leadership in high-energy astrophysics research working with his colleagues in the MIT Kavli Institute, and now, in his role at the head of physics, he will also enable the work of countless others," says Nergis Mavalvala, the Curtis (1963) and Kathleen Marble Professor of Astrophysics and the dean of the MIT School of Science. "As faculty lead of Physics 8.01, a required subject for all MIT undergraduates, over the past decade, Deepto has also had tremendous positive impact on the education of thousands of MIT students."

Deepto Chakrabarty has been named the new head of the Department of Physics. *Photo: Steph Stevens*

"I am deeply honored that I can continue the important work of the department. Peter Fisher's departmental leadership has been an inspiration" says Chakrabarty, who has been associate department head since 2020 and co-leader of the physics course 8.01 (Physics 1), a required subject for all MIT undergraduates, for the past eight years. "And with Dean Mavalvala at the helm of our school, MIT will continue to be the world leader in physics across the spectrum of research areas."

"Deepto's research in X-ray astronomy has provided a foundation for the field of high-energy astrophysics," says Fisher, who will begin his new role as the head of the Office of Research Computing and Data at the start of the year. "As former head of the astrophysics division within MIT and as a leader in current observational astrophysics techniques, Deepto has ensured that generations of past and current astrophysicists have deep and rigorous training. He has also served as associate department head for the last two years and comes well-prepared for his new role."
Chakrabarty's primary research interests are the physics and astrophysics of neutron stars. Specifically, he is a leader in the field in understanding millisecond pulsars, a type of fast-spinning neutron star formed in a binary system with an ordinary star. Gas pulled away from the surface of the companion star crashes onto the neutron star, spinning it up to rotation rates of hundreds of revolutions per second and emitting X-ray light in the process.

Physicists like Chakrabarty have shown that oscillations in the emitted X-ray light can be used to measure a pulsar's spin evolution and other key parameters. Such observations originally made with NASA's Rossi X-ray Timing Explorer earned Chakrabarty, and colleagues Tod Strohmayer of the NASA Goddard Space Flight Center and Rudy Wijnands of the University of Amsterdam, the Bruno Rossi Prize — the top award given by the High Energy Astrophysics Division of the American Astronomical Society.

Chakrabarty's current research uses NASA's Neutron Star Interior Composition Explorer (NICER), an X-ray astronomy instrument aboard the International Space Station built by NASA Goddard Space Flight Center and the MIT Kavli Institute. Recently, research scientist Dheeraj Pasham along with Chakrabarty, MIT Kavli Institute researchers, and other collaborators outside of MIT used NICER to trace the source of a bright blue cosmic explosion to the birth of a neutron star or black hole. This new evidence of X-ray pulses, every 4.4 milliseconds, over a span of 60 days, published in the journal *Nature Astronomy*, opens possibilities for finding more nascent black holes or neutron stars promptly in the wake of dying stars.

Chakrabarty completed his SB in physics at MIT in 1988. He subsequently earned his PhD in physics from Caltech in 1996, following two years at the Lawrence Berkeley National Laboratory as a staff physicist working on the Berkeley Automated Supernova Search. After receiving his doctorate, Chakrabarty returned to MIT in 1996 for a three-year postdoc appointment as a NASA Compton Gamma Ray Observatory Fellow, including a stint as a visiting fellow at Balliol College, Oxford University. In 1999, he became an assistant professor within the Department of Physics and was tenured in 2004.

> **"With Dean Mavalvala at the helm of our school, MIT will continue to be the world leader in physics..."**

Chakrabarty is a fellow of the American Physical Society and a legacy fellow of the American Astronomical Society. His other awards include an Alfred P. Sloan Research Fellowship, the Buechner Teaching Prize in Physics, and the inaugural 2017 *MITx* Prize for Teaching and Learning in MOOCs for his work on the 8.01x Mechanics Series. He recently chaired the panel "Compact Objects and Energetic Phenomena" of the Astro2020 Decadal Survey on Astronomy and Astrophysics, sponsored by the National Academy of Sciences.

Amy Keating named head of the Department of Biology

The computational structural biology researcher continues to serve the department and the MIT life sciences community

School of Science

Amy E. Keating, the Jay A. Stein (1968) Professor of Biology and a professor of biological engineering, has been named head of the Department of Biology, effective Aug. 15, 2022. She succeeds Alan Grossman, the Praecis Professor of Biology at MIT, who led the department since 2014.

"Professor Keating is a leading researcher in her field, employing computational techniques to understand how malfunction of proteins leads to disease," says Nergis Mavalvala, the Curtis (1963) and Kathleen Marble Professor of Astrophysics and the dean of the MIT School of Science.

In addition to leadership in her research — among other roles, she was recently the president of the Protein Society — she has served in key department leadership roles, including her most recent positions as associate department head and graduate officer. "In addition to her world-class research, Amy's teaching and service to the department, MIT, and the broader scientific community are exemplary," Mavalvala says.

> "I hope to create additional opportunities for MIT biology to maintain and grow our excellence in research, teaching, mentorship, and service."

Keating served on the search committee for the director of the Whitehead Institute for Biomedical Research as well as the selection committee for the dean of the School of Science. With Associate Professor Mary Gehring, Keating is co-director of the biology graduate program, and since 2012 she has been the co-PI with Professor Stephen Bell on the department's National Institutes of General Medical Sciences doctoral training grant.

"I look forward to continuing to work with the members of our department — students, faculty, and staff — to create a rich and diverse environment in which all our community members feel they belong and can thrive," says Keating, who is also a member of the Koch Institute for Integrative Cancer Research. "I hope to create additional opportunities for MIT biology to maintain and grow our excellence in research, teaching, mentorship, and service."

Keating's research focuses on interaction properties of proteins encoded in their sequences and structures. She investigates protein–protein interactions by integrating data from high throughput assays, structural modeling, and bioinformatics with biochemical and biophysical experiments.

Her research group studies proteins that regulate critical processes, such as cell death regulated by the Bcl-2 family of proteins. Keating has developed methods to reprogram the interaction between proteins, and applying these methods to Bcl-2 proteins has generated peptides that inhibit processes that keep cancer cells alive. Other areas of research include α-helical coiled-coil proteins and protein domains that bind to short linear motifs. For her research, Keating received a National Institutes of Health Transformative R01 grant designed to support innovative, high-risk, and unconventional research projects with the potential to transform a field of science.

"Amy's research has opened the door to using computational biology to address fundamental questions in protein–protein interactions, and to design peptide inhibitors with therapeutic impact," says Grossman. "Amy's interests and research fit well with the growing area of computational biology and are at the interface of several

Amy E. Keating, the Jay A. Stein (1968) Professor of Biology and a professor of biological engineering, has been named the new head of the Department of Biology.
Photo: Courtesy of the faculty

areas, including computation, biophysics, biochemistry, biological engineering, synthetic biology, and of course the MIT Schwarzman College of Computing. This is an area of strength that continues to increase in the department and at MIT."

Keating helped institute the department's professional development requirement for graduate students and she is deeply committed to providing opportunities for MIT graduate students outside of the Institute.

The brainchild of two bioengineering students, the graduate course 7.930[J] (Research Experience in Biopharma) exposes graduate students to industrial science and helps them develop the skills required to succeed in industry. In this subject, sponsored by Keating and Doug Lauffenburger, the Ford Professor of Engineering, and co-taught by Keating and Sean Clarke, a communications instructor and manager of biotech outreach within the Department of Biological Engineering, students participate in on-site research at local biopharmaceutical companies, where they both observe and participate in industrial science.

"It's really designed to demystify doing research in industry," says Keating. "The feedback we get suggests it's quite eye-opening in terms of changing some assumptions about what that life is like."

Keating has also played a significant role in the Department of Biology's diversity and outreach initiatives for graduate students, including providing research opportunities in her own lab through the Bernard S. and Sophie G. Gould MIT Summer Research Program in Biology.

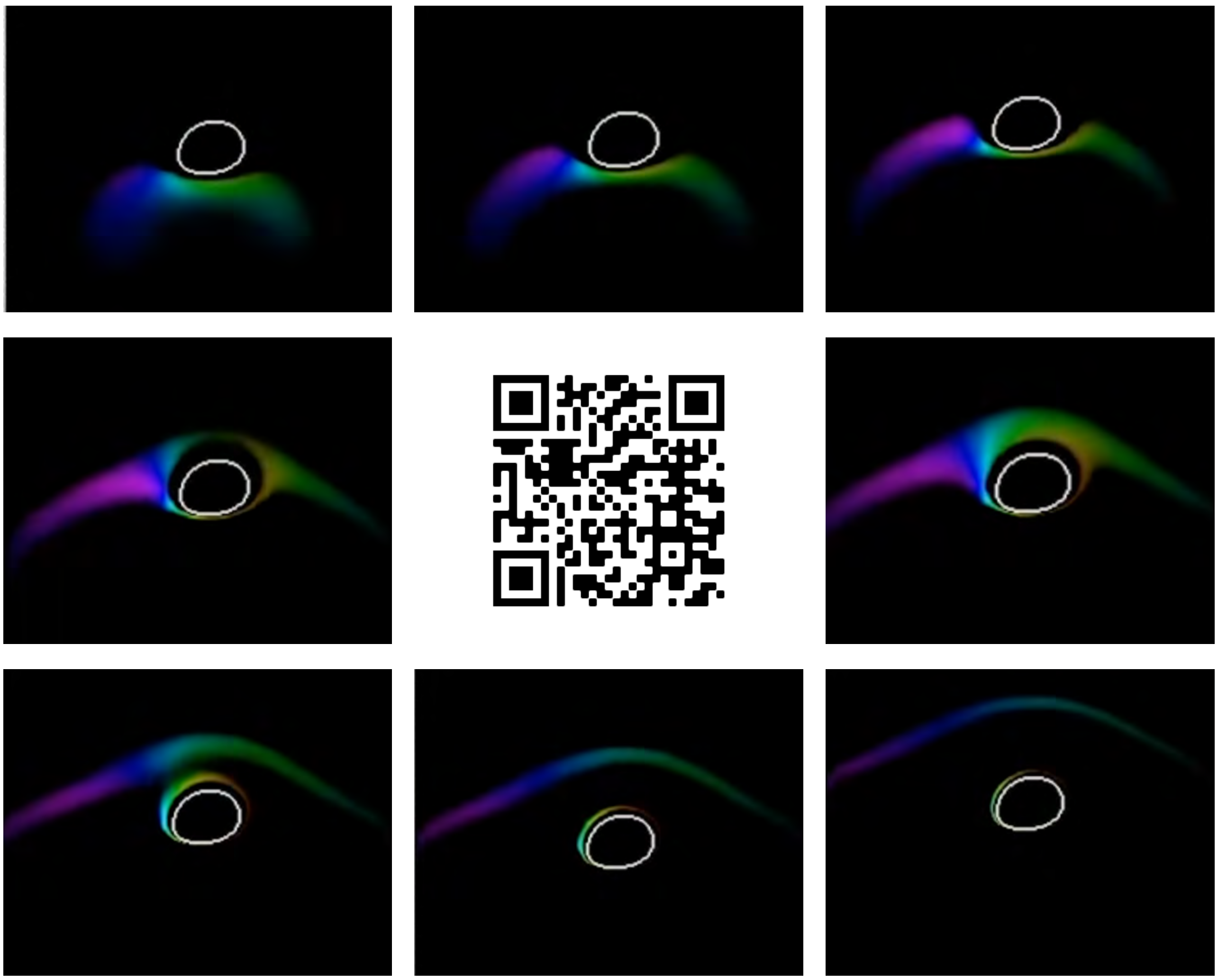
"She is a terrific teacher and mentor, and works tirelessly to recruit and support diverse and outstanding graduate students in the department," says Grossman.

Keating earned her doctorate from the University of California at Los Angeles and was introduced to protein biochemistry as a Helen Hay Whitney Postdoctoral Fellow working with professors Peter S. Kim of the Department of Biology and the Whitehead Institute for Biomedical Research and Bruce Tidor of MIT's Department of Biological Engineering. She joined the MIT Department of Biology as an assistant professor in 2002. Among her various awards, Keating recently received the Georgina Sweet Award for Women in Quantitative Biomedical Science as part of the Australian Research Council Laureate Fellowship program.

Press play

School of Science breakfast talks resume with the music of the cosmos

Markella Paradissis-Wagner | School of Science



Scan the QR code to hear Erin Kara and Kyle Keane's project, "Echoes of a black hole" on the MIT YouTube channel.

The role black holes play in the evolution of our universe is a large topic to ponder all before 9 a.m. But it's also an exciting one, especially for those who attended an early morning research talk given by Assistant Professor Erin Kara, Class of 1958 Career Development Assistant Professor of Physics and an astrophysics researcher in the MIT Kavli Institute for Astrophysics and Space Research.

Before the pandemic, the MIT School of Science breakfast talks were a regular series in which guests enjoyed breakfast and speaker presentations. The breakfast talk at the Samberg Conference Center on the bright, chilly morning of Oct. 20, 2022 was the first held in more than two years. Nergis Mavalvala, the Curtis (1963) and Kathleen Marble Professor of Astrophysics and dean of the School of Science welcomed guests back to campus and introduced Kara.

"I don't know of anyone of any age who isn't interested in black holes," Mavalvala said. Alumni, faculty, staff, and black hole fanatics of different ages packed the room, hooked on Kara's every word.

Kara began by expressing how working with her students and research group has been one of the greatest joys of her career at MIT. She then transitioned to her favorite astronomical image, an early Hubble deep field, depicting twinkling galaxies. In the middle of each galaxy lies a supermassive black hole a million to a billion times the mass of the sun.

Supermassive black holes are thought to be the only force that can unleash energy powerful enough to shape a high-mass galaxy. When materials are dumped into a black hole, the gravitational potential energy of the material is released, producing blazing radiation and relativistic jets punching from the black hole's center. A key component of Kara's research — as well as modern astrophysics — is to understand how the energy feedback process works in detail. Because the exchange takes place on such a small scale near the black hole's event horizon, Kara stated she needs to "zoom in to the innermost regions of black holes," — her main research interest.

Kara explained how reverberation mapping, a new technique to measure the inner workings of black holes, uses echoes of light bouncing off inflowing gas near the black hole to recreate what it looks like around the black hole. The process is akin to how bats echolocate in a dark cave: they internally measure the time delay of the sound reflecting off the wall and utilize it to establish the cave's space.

But mapping the data of an active black hole, the kind that determines how galaxies develop, is difficult. They appear as points of light on any data. Kara's goal is to reconstruct what she and her team believe it must look like on event horizon scales close to the black hole — and all they have to go off of are the photons' energy and when the photons hit the team's detector.

Furthermore, Kara's team built the detectors on NASA's Neutron star Interior Composition Explorer (NICER), a tool on the International Space Station (ISS) about the size of a washing machine. After communicating with the Monitor of All-sky X-ray Image, an instrument in the Japanese Experiment Module on the ISS, in 2018 NICER turned to face a stellar black hole in outburst every day for around a year.

Like supermassive black holes, stellar black holes produce jets. These phases only take several months — an outburst — where a supermassive black hole's outbursts span billions of years.

And the particular outburst NICER focused on was the brightest they had ever seen. Not only did it produce valuable data and an image displayed on the cover of *Nature*, but Kara's team measured the shortest reverberation light echoes recorded so far.

Music is also one of Kara's great passions. Her recent side project satisfies that curiosity of what it would be like to turn a black hole's light echoes into sound echoes — what it would sound like around a black hole. In partnership with Kyle Keane in the Department of Materials Science and Engineering, Ian Condry in the Department of Comparative Media Studies/Writing, and her collaborator Michal Dovciak at the Czeck Academy of Sciences, they converted these light echoes into sounds, which Kara played during her talk.

Everyone in the room froze, startled with delight, as a black hole visual simulation manifested onscreen and the shifting pitch of light echoes, the music of the cosmos, filled the room.

"I think it's amazing we can peer as far into such enigmatic objects," said Ila Fiete, a professor in the Department of Brain and Cognitive Science and an associate investigator at the McGovern Institute for Brain Research who attended the event. "A combination of physics and mathematics together with such amazing ingenuity and telescopes and infrastructure. I think it was beautiful. It was amazing."

Guests were eager to ask questions, such as how other frequencies affected the process of transfiguring light echoes into sound.

"It's like a rainbow of light, right?" Kara responded. "Light over all frequencies. If you were to play that, it would sound horrible. We wouldn't be able to pick out anything."

She described how her team addressed these challenges: While everything was based off real general and special relativity, they had to pick certain frequencies and increase the sound to create something they could hear.

Kara ended the talk with questions of her own: "How did the first supermassive black holes grow? We see these 10 billion solar mass black holes when the universe was less than a billion years old. How did they get so big so fast? Looking at those furthest black holes in X-rays is on the next frontier, and that's why we're hoping to launch this mission called AXIS."

AXIS (Advanced X-ray Imaging Satellite), a NASA Probe Mission Concept, was originally developed to serve as the lead high angular resolution X-ray mission of the 2020s, enhancing the X-ray resolution and spectroscopy work of the respected Chandra X-ray Observatory. AXIS was submitted to the Astro2020 Decadal Survey, and NASA intends to send it as a mission proposal in early 2023.

Kara notes that a project of this magnitude would require constructing large telescopes and international effort. "To probe the first black holes is really exciting stuff," Kara concluded.

If you build it…

The MIT Kavli Institute (MKI), led by Director Professor Robert Simcoe, equips people and laboratories to build customized experiments to study the universe. MKI's astronomical instrumentation experts work in three major areas: discovering exoplanets, characterizing the first stars and galaxies, and understanding environments with extreme gravity, such as black holes and neutron stars. In this issue of *Science@MIT*, we explore instruments led by MKI researchers that you might not yet know about.

It's outta here

While most — and perhaps all — galaxies have supermassive black holes at their centers, active galaxies are unique in that their supermassive black holes are actively gobbling up gas and dust from their surroundings. This process releases enormous amounts of energy and results in some of the most energetic phenomena in the universe.

Many of these active galaxies eject high-temperature plasma, or jets, at nearly the speed of light, producing X-rays in their magnetic fields. X-rays, like all forms of light, can be polarized. And just like polarized sunglasses can reduce glare on a sunny day, an X-ray polarimeter instrument can detect the glare of X-rays produced by plasma.

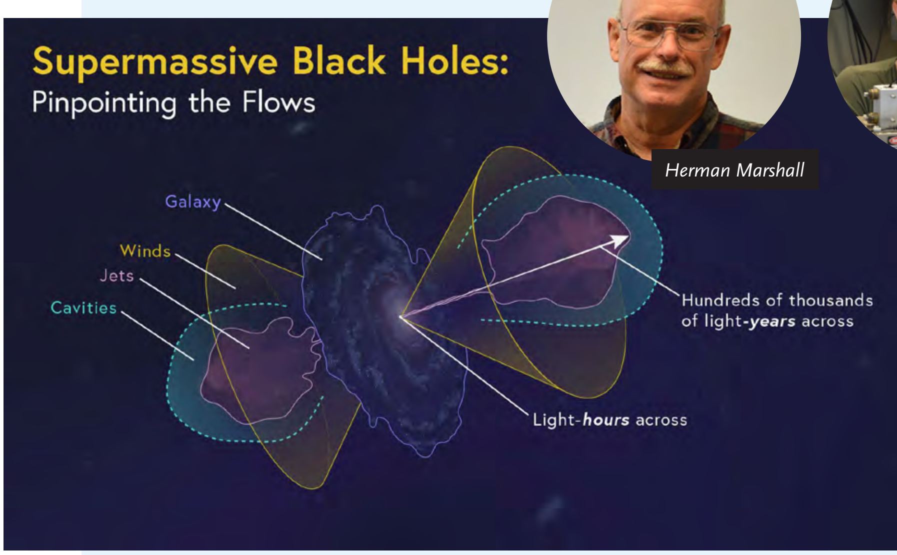
NASA recently approved a sounding rocket mission that will fly an MIT-built X-ray polarimeter to study a single active galaxy during the rocket's five minutes above the atmosphere. The mission's lead investigator, Herman L. Marshall, a MKI principal research scientist, has designed the astrophysics instrument to measure the polarization of the X-rays from these active galaxies in order to understand the structure and formation of these active galaxy jets.


Herman Marshall


Sarah Heine


Alan Garner

Dubbed the Rocket Experiment Demonstration of a Soft X-ray Polarimeter, the REDSoX Polarimeter uses advanced multilayer coated mirrors and high-efficiency diffraction gratings — technology also pioneered at MIT — to study the polarization of low-energy, or "soft," X-rays from active galaxies. The technique demonstrated by the REDSoX team, that includes MKI research scientist Sarah Heine and postdoc Alan Garner, will pave the way for future orbital missions using this MIT technology to study these fascinating objects.



Credit: NASA, ESA, Leah Hustak (STScI)

Future flight: Funded by NASA's Astrophysics Research and Analysis Program, the REDSoX Polarimeter is expected to launch in early 2027.

Watch for more about the detailed design of REDSoX and the lab where it will be built.

CHIME

Kiyoshi Masui

The Canadian Hydrogen Intensity Mapping Experiment, or CHIME, is an interferometric radio telescope located at the Dominion Radio Astrophysical Observatory in British Columbia, Canada. Though CHIME was designed to pick up radio waves emitted by hydrogen, the telescope is also sensitive to fast radio bursts.

Fast radio bursts (FRBs) are bright, brief flashes of light, registering in the radio band of the electromagnetic spectrum. The origins of these millisecond bursts are unknown, and their appearance is unpredictable. Since the first FRB was discovered in 2007, astronomers had only recorded around 140 bursts. Since CHIME began observing in 2018, the instrument has detected hundreds of FRBs emanating from different parts of the sky.

As a radio wave travels across space, any interstellar gas, or plasma, along the way can distort or disperse the wave's properties and trajectory. The degree to which a radio wave is dispersed tells how much gas it passed through, and can give clues to how far it has traveled from its source.

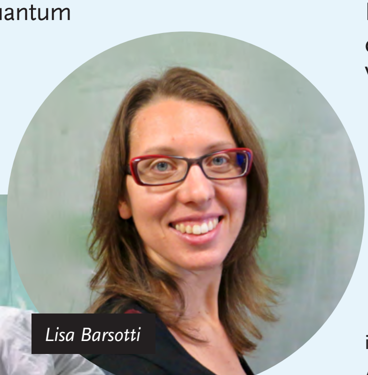
Most recently, Assistant Professor Kiyoshi Masui and others on the CHIME team, discovered the longest-lasting FRB, which was made up of a series regularly spaced bursts. The team suspects the signal might be from a rapidly spinning object, such as a pulsar or a magnetar. At MKI, Masui is building the correlator for an expanded network of radio telescopes across North America. This new network will pinpoint the exact sky locations where FRBs are triggered.

Ping me: CHIME has a large instantaneous field of view (200 square degrees) and broad frequency coverage (400-800 MHz). This is enabled by its digitally-driven design: it has no moving parts and points to many sky locations simultaneously using digital signal processing and a large computer cluster. These capabilities allow scientists to make a 3D map of hydrogen density — and, as a bonus, can provide information on fast, transient radio emissions.

Fourth wave technology

In 2015, the Advanced Laser Interferometer Gravitational-Wave Observatory (LIGO) made the first detection of gravitational waves from a binary black hole system. By the end of the second observing run (O2) in August 2017, the LIGO instruments and the Virgo interferometer in Italy recorded 11 gravitational-wave signals, including one from a binary neutron star merger. The third observing run (O3) started in April 2019, with improved LIGO and Virgo detectors and the addition of the Japanese KAGRA observatory in 2020.

Though O3 ended abruptly with the start of the pandemic, the MIT-designed instrumentation called a "quantum squeezer" was already tamping down the quantum noise generated by the vacuum fluctuations (zero-point energy) that enter the LIGO detectors. The reduced quantum noise in the interferometers contributed to increase the detection rate of gravitational-wave signals from approximately once per month in O2 to once per week in O3.



Lisa Barsotti

The last two years have seen major upgrades to LIGO and Virgo instruments, including the addition of a 300-meter-long filter cavity that optimally manipulates squeezed light before injection in the interferometers. These upgrades will help to make the most sensitive detectors yet, with a projected two-to three-fold increase in detection rate in the upcoming fourth observing run (O4) with respect to O3.

MKI Senior Research Scientist Lisa Barsotti has led the development of the LIGO quantum squeezer for over a decade. With the resulting upgraded technologies, coupled to other detector improvements, the LIGO Scientific Collaboration projects detecting binary star mergers at a distance of 160 to 190 megaparsecs in O4 (scheduled to start in March 2023, and last for one year), more than twice the distance reported in O1.

Using AI to squeeze more from the squeezer: With the addition of artificial intelligence, like that being developed at the National Science Foundation AI Institute for Artificial Intelligence and Fundamental Interactions, led by MIT's Laboratory for Nuclear Science, Barsotti and MIT graduate student Chris Whittle are working to enhance the performance of the quantum squeezer, both for Advanced LIGO, and for next-generation gravitational-wave detectors.

Cosmic Explorer

MathWorks Professor of Physics Matthew Evans is leading the U.S. efforts to develop Cosmic Explorer, a proposed next-generation gravitational-wave observatory, that will allow a full order of magnitude sensitivity improvement beyond Advanced LIGO.

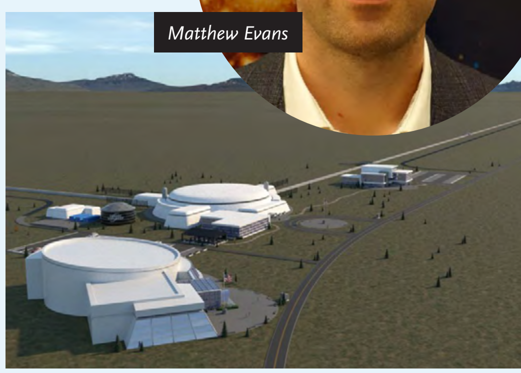
Like the current generation of observatories, Cosmic Explorer observatories will have an L-shaped geometry and a single interferometer. Although there are areas of detector technology where improvements will lead to increases in the bandwidth and sensitivity (such as a higher-performance quantum squeezer), the dominant improvement comes from the increased arm length; they will be five to 10 times that of the Advanced LIGO facilities!

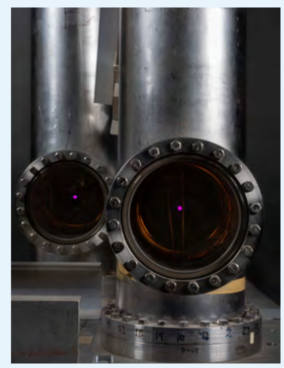
This means Cosmic Explorer will leap from only monitoring the nearby universe to surveying the entire universe for black hole and neutron star mergers. This increase will allow the observatories to peer further back in history and gravitational-wave signals from epochs when star formation was still in its infancy.

In addition to improved high-fidelity signals and greater redshift reach, Cosmic Explorer and next-generations of ground-based gravitational-wave observatories may allow researchers to detect dark or exotic matter around black holes, to test modified theories of gravity, or test astrophysical scenarios of compact-object formation and evolution.

Matthew Evans

National Academies approved: The National Academies' Astro2020 Decadal Survey, which sets the funding priorities for the next decade, resoundingly embraced Cosmic Explorer, stating that "gravitational wave astrophysics is one of the most exciting frontiers in science."





Museumworthy: Nobel Prize recipient Professor Rainer Weiss' original table-top LIGO prototype is on display at the newly relocated MIT Museum in Cambridge that opened in September 2022.

LLAMAS

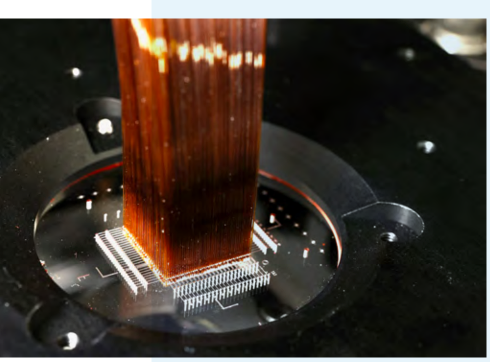
The Large Lenslet Array Magellan Spectrograph (LLAMAS) is a new 3D imager scheduled for 2023 installation at the 6.5-meter Magellan Telescopes at the Las Campanas Observatory in Chile. The design and construction of LLAMAS is being led by Professor Robert Simcoe and MKI principal research scientist Gabor Furesz.

LLAMAS injects starlight from the telescope into a fine grid of optical fibers, recording optical spectra with 6,000 colors at each of 2,400 discrete sky positions. These are used to reconstruct a 3D image of the sky with photon wavelength as the depth dimension.

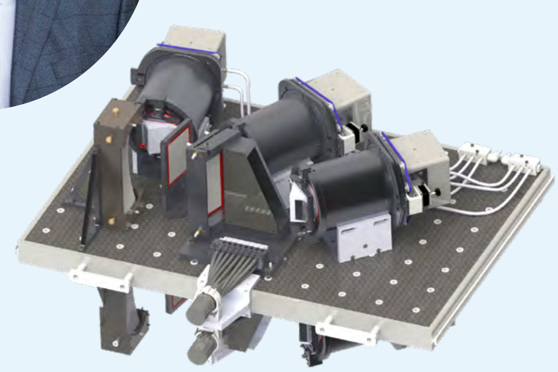
LLAMAS utilizes two primary subsystems: an bank of eight spectrographs that disperse and record the color traces for each fiber, and a micro-lens array that couples light between the telescope and fibers. To facilitate this technically challenging endeavor, the team cut and packaged more than 3,000 fibers at home during the Covid shutdown, and built a custom tool to align and bond each fiber to its correct position in the telescope focus, within a fine tolerance of a few microns.

Many key survey telescopes are being built in the Southern Hemisphere, including the Vera Rubin Observatory, the South-Pole Telescope, and the Atacama Large Millimeter/submillimeter Array. LLAMAS will work in concert with these observatories, providing MIT and other U.S. astronomers with wideband 3D views of the tens of thousands of sources these facilities will uncover.

Robert Simcoe



The microlens array with its 3,000 fibers.



An uncovered spectrograph unit, consisting of three independent spectrographs.

Basic building blocks to the stars

Curt Marble '63 funds instrumentation for astrophysics

Elizabeth Chadis | School of Science

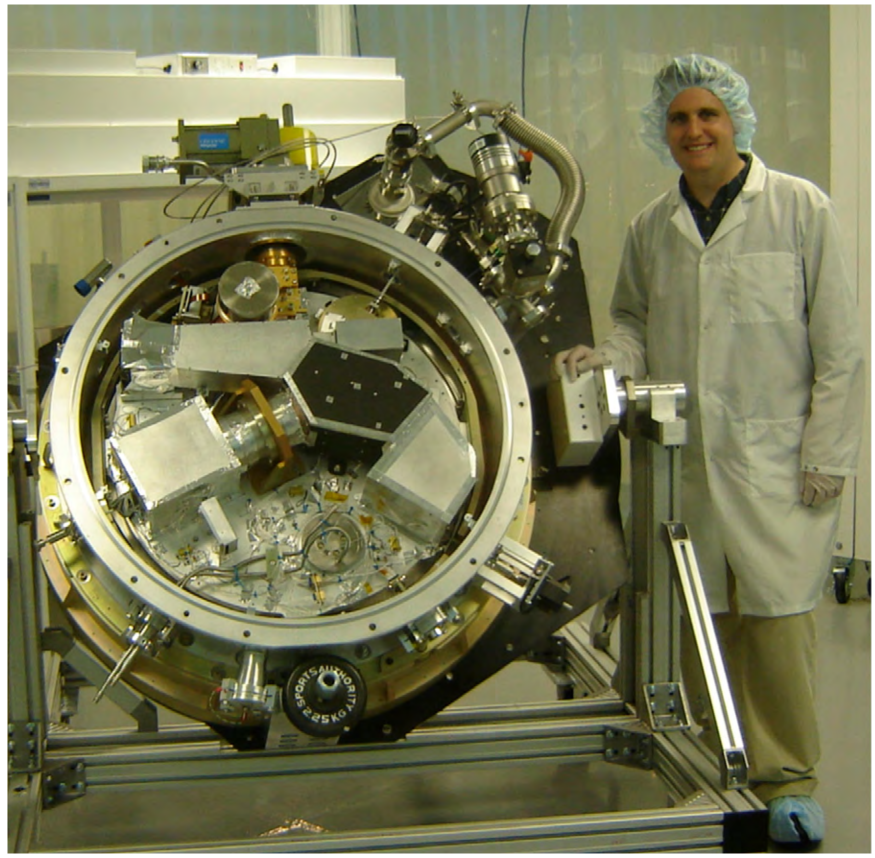
Curt Marble grew up in St. Petersburg, Florida and was in his own words, "a typical engineering kid who liked to take things apart." At MIT, Marble studied electrical engineering and then spent his career programming for computer-based medical information systems. After his retirement, Marble pursued his long-standing interests in cosmology and astrophysics and became engaged with the MIT Department of Physics. While there are many ways to support the work of the faculty and students, Marble decided to provide funds to support instrumentation projects. "I thought that a discretionary fund could provide the rapid and flexible means to support medium-sized projects or the seed funding for large ones," says Marble.

One of the early projects that Marble's instrumentation fund helped to complete was the development of FIRE, a fully cryogenic infrared spectrometer for the 6.5 meter Magellan telescopes at Las Campanas Observatory (LCO), in Chile. LCO is operated by a consortium of institutions, including MIT via MIT Kavli Institute for Astrophysics and Space Research and its director Robert Simcoe, the Francis L. Friedman Professor of Physics.

FIRE was designed and built by Simcoe and members of his lab who study the formation of the earliest stars and galaxies by constructing custom-built spectrometers for major astronomical observatories. FIRE classifies objects based on their infrared spectra and can determine how far away in time a cosmic object might be. Recently, the team used FIRE to identify the most distant known quasar, whose light was emitted when the universe was just 5 percent of its present age.

"Curt has been a wonderful partner for the faculty and students in physics, and supportive of our ambitions to explore the distant universe at the MIT Kavli Institute," says Simcoe. "His detailed questions about our methods and discoveries reveal an inquisitive spirit. His fund likewise enables us to unleash the technological creativity of our amazing research teams."

Professor Robert Simcoe, principal investigator, stands next to FIRE, the infrared spectrometer supported by the National Science Foundation and funded by the Curtis and Kathleen Marble instrumentation fund. *Photo: Courtesy of the faculty*



Simcoe's lab continues to work on development of instrumentation such as WINTER, a widefield camera mounted on a telescope that will survey the cosmos for infrared light. (Read about another MIT-made instrument, LLAMAS, on the facing page.)

Fortunately for MIT, Marble's interest isn't limited to the cosmos. He has invested in MIT's success in many different areas. He and his late wife, Kathy, created the Marble Center for Cancer Nanomedicine directed by Professor Sangeeta Bhatia within the Koch Institute for Integrative Cancer Research. The Marble Center is the first virtual nanomedicine center at MIT dedicated to tackling grand challenges in cancer detection, treatment, and monitoring with a focus on miniaturization and convergence — the blending of the life and physics sciences with engineering.

In addition, the Marbles contributed to the Green Center for Physics when it needed renovation and they have endowed an MIT presidential fellowship for graduate students and faculty chairs — including the funding for the professorship held by Nergis Mavalvala, the Curtis (1963) and Kathleen Marble Professor of Astrophysics and current dean of the School of Science.

"I believe in the importance of basic research, and MIT is among the best at getting that done," says Marble.

Brandon Ogbunu is a radical collaborator

MLK Visiting Professor "maximizes connection time" while studying protein evolution with MIT Chemistry

Phie Jacobs | School of Science

Brandon Ogbunu is an assistant professor in the Department of Ecology and Evolutionary Biology at Yale University. As part of the MLK Scholars program, Ogbunu is pursuing research at MIT with Professor Matthew Shoulders.
Photo: Steph Stevens

Learning has always come naturally to Brandon Ogbunu. When he was a child growing up in Manhattan, his mother, a teacher, instilled in him an appreciation for school, the sciences, and curiosity. At work, she taught mathematics, social studies, and special education. At home, she taught her son to embrace art, literature, and sports in addition to science, laying the groundwork for a well-rounded approach to learning that would inform the rest of his career.

Ogbunu grew up during the AIDS epidemic. Witnessing the devastating effects of the virus kindled an interest in disease. Although he describes himself as "a bit of an underachiever" in high school, he found his identity as a scholar during his time at Howard University. He majored in chemistry due to its reputation as the "central science" and voraciously read books on math, economics, and history to gain a more nuanced understanding of the topic. Toward the end of his undergraduate degree, Ogbunu learned more about the intersection between inequality and public health and began to consider how forces like poverty can drive the spread of diseases like HIV, tuberculosis, and malaria.

After graduating from Howard in 2002, he traveled to Kenya on a Fulbright fellowship. There, while studying the chemical ecology of malaria, he became captivated by evolution. "I fell in love with it as kind of a governing viewpoint on how the natural world works," he says.

When he returned to the United States, Ogbunu studied medicine at Yale, but found himself somewhat overwhelmed with career options. There were many ways to approach the problem of disease, but would he do so as a physician? An evolutionary biologist? A computer scientist? An economist? After his time in Kenya, he knew that whatever path he took, evolutionary reasoning — an approach to research that focuses on the practical applications of evolutionary theory — would have to be at the center of it.

It was then that Ogbunu took an interest in Professor Paul Turner's virology lab. Turner, a professor in the Yale Department of Ecology and Evolutionary Biology, had just published a paper that addressed virus evolution through the lens of game theory. "I was like, this is exactly the kind of lab I want to be in," Ogbunu recalls.

Ogbunu completed his PhD in microbiology in 2010. His dissertation revolved around a concept called "evolvability" — the capacity of organisms to evolve — in the context of infectious disease.

From there, Ogbunu decided to cultivate his interest in data science with a postdoctoral fellowship at the Broad Institute and Harvard University, where he studied population genetics under the supervision of Daniel Hartl.

It was during this postdoctoral training that Ogbunu first encountered professor of chemistry Matthew Shoulders, who at the time was a junior faculty member at MIT. The two scientists instantly hit it off. "We each gave each other a new language to describe the problems we were thinking about," Ogbunu says of their shared interest in protein evolution. "We could have a conversation with the person across the aisle. And I found that to be a model for the way that I collaborate in general."

After completing his postdoctoral training, Ogbunu taught for two years at Brown University, and in 2020, he joined the

Yale faculty as an assistant professor in the Department of Ecology and Evolutionary Biology.

Ogbunu's current research takes place at the intersection of evolutionary biology, genetics, and epidemiology. His lab uses experimental evolution, mathematical modeling, and computational biology to investigate disease across scales: from the biophysics of proteins involved in drug resistance, to the social determinants driving epidemics at the population level.

Ogbunu decided to apply for the Martin Luther King Jr. (MLK) Visiting Scholars and Professors program because, during his time at the Broad Institute, he grew to admire the interdisciplinary culture of MIT. "I believe in disciplines, and I believe in expertise," Ogbunu explains, "but I don't believe that you need to be relegated to any kind of singular domain. You should be able to think broadly." He also appreciated MIT's focus on the practical applications of scholarship. "Whatever it is you're making," he says, "be it literature, or poetry, or biomolecules — everybody likes to make things."

Creative intersections

At MIT, Ogbunu is working in the Department of Chemistry alongside Shoulders, whose lab focuses on understanding the mechanisms of protein folding and evolution. "I really try to maximize connection time," Ogbunu says of his day-to-day work at MIT. He spends his time collaborating with graduate students and postdocs in the Shoulders Laboratory, writing manuscripts and developing proposals with Shoulders himself, and attending meetings and seminars in various departments across campus.

Ogbunu is also embracing his artistic side through collaborations with fellow MLK Visiting Scholars. "The MLK Fellows are the most impressive people I've ever been around," he says. "The opportunity to be in a cohort with them is really truly an honor."

With Wasalu Jaco, widely known by his stage name Lupe Fiasco, Ogbunu has been exploring the relationship between rap and evolution and between music and data science. Ogbunu also hopes to collaborate with Eunice Ferreira, with whom he shares a passion for theater arts. In fact, Ogbunu was recently appointed to the board of the Catalyst Collaborative, a collaboration between MIT and Central Square Theater. He considers this appointment to be one of the great honors of his career.

"I like cutting-edge, provocative, and progressive ideas in a number of realms," Ogbunu says of his love for the arts. "I love creative intersections between science and society. And I love creative, cool people who are trying to make the world a better place."

Ogbunu's preferred creative outlet is writing. He has written for a number of publications, including *Scientific American*, *Undark*, and the *Boston Review*, and currently serves as an Ideas contributor at *WIRED* magazine. Ogbunu views science writing as part of the "scientific instrument," and he uses it as an avenue to explore new ideas. Much of his work also deals with issues of diversity, discrimination, and accessibility in science.

"I'm interested in influencing who gets to become a scientist," he says. "That's a very deep and important part of my identity." Ogbunu's mother, whom he identifies as his greatest inspiration, was extremely gifted, but it was difficult for a woman of her generation to pursue a career in science. Ogbunu wants to do his best to ensure that the opportunities that were unavailable to her are available to others. "Even in 2022 and beyond, there will be people who don't have access and don't have opportunity," he says. "I think their lack of access is a great shame for everyone."

In the future, Ogbunu would like to add "mechanistic depth" to his research by thinking about disease evolution on a more molecular level. He also plans to continue embracing his multidisciplinary approach to learning. "I want to lean into my multiplicity and no longer hide from it, and no longer apologize for it," he says. "I want to work in all these disciplines, but via radical collaboration. That's the thing that I pride myself on: the art of collaboration."

MIT launches new Office of Research Computing and Data

Professor Peter Fisher leads effort to grow and enhance computing infrastructure and services for MIT's research community

As the head of the Office of Research Computing and Data (ORCD) Professor Peter Fisher will lead the effort to grow and enhance computing infrastructure and services for MIT's research community. *Photo: Adam Glanzman*

As the computing and data needs of MIT's research community continue to grow — both in their quantity and complexity — the Institute has launched a new effort to ensure that researchers have access to the advanced computing resources and data management services they need to do their best work.

At the core of this effort is the creation of the new Office of Research Computing and Data (ORCD, pronounced "orchid"), led by Professor Peter Fisher, who stepped down as head of the Department of Physics to serve as the office's inaugural director. The office, which formally opened in September, builds on and replaces the MIT Research Computing Project, an initiative supported by the Office of the Vice President for Research, which contributed in recent years to improving the computing resources available to MIT researchers.

"Almost every scientific field makes use of research computing to carry out our mission at MIT — and computing needs vary between different research groups. In my world, high-energy physics experiments need large amounts of storage and many identical general-purpose CPUs, while astrophysical theorists simulating the formation of galaxy clusters need relatively little storage, but many CPUs with high-speed connections between them," says Fisher, the Thomas A. Frank (1977) Professor of Physics, who took up the mantle of ORCD director on Sept. 1.

"I envision ORCD to be, at a minimum, a centralized system with a spectrum of different capabilities to allow our MIT researchers to start their projects and understand the computational resources needed to execute them," Fisher adds.

Goods and services

The Office of Research Computing and Data will provide services spanning hardware, software, and cloud solutions, including data storage and retrieval, and offer advice, training, documentation, and data curation for MIT's research community. It will also work to develop innovative solutions that address emerging or highly specialized needs, and it will advance strategic collaborations with industry.

The exceptional performance of MIT's endowment last year has provided a unique opportunity for MIT to distribute endowment funds to accelerate progress on an array of Institute priorities. On the basis of community input and visiting committee feedback, MIT's leadership identified research computing as one such priority.

In his new role, Fisher reports to Maria Zuber, MIT's vice president for research, and coordinates closely with MIT Information Systems and Technology (IS&T), MIT Libraries, and the deans of the five schools and the MIT Schwarzman College of Computing, among others. He will also work closely with Provost Cynthia Barnhart.

"I am thrilled that Peter has agreed to take on this important role," says Zuber. "Under his leadership, I am confident that we'll be able to build on the important progress of recent years to deliver to MIT researchers best-in-class infrastructure, services, and expertise so they can maximize the performance of their research."

MIT's research computing capabilities have grown significantly in recent years. Ten years ago, the Institute joined with a number of other Massachusetts universities to establish the Massachusetts Green High-Performance Computing Center (MGHPCC) in Holyoke to provide the high-performance, low-carbon computing power necessary to carry out cutting-edge research while reducing its environmental impact. MIT's capacity at the MGHPCC is now almost fully utilized, however, and an expansion is underway.

Cuff comes to MIT

Over time, ORCD aims to recruit a staff of professionals, including data scientists and engineers, and system and hardware administrators, who will enhance, support, and maintain MIT's research computing infrastructure, and ensure that all researchers on campus have access to a minimum level of advanced computing and data management.

The first major appointment is the hiring of ORCD inaugural executive director, James Cuff, who will report to Fisher and to Mark Silis, MIT's vice president for IS&T.

"His true passion and experience reside in providing frictionless access to advanced research computing services while carefully managing budgets and teams to get the job done and delivered on time," says Fisher of Cuff, who joins ORCD with more than two decades of experience in incrementally complex research computing environments.

Over his 11 years at Harvard University, Cuff and his team designed and built Harvard's research computing organization from the ground up. He was one of the founding members of the MGHPCC design and build team; and more recently, Cuff served as an independent consultant working with technical startup companies covering many disparate aspects of advanced high-performance and scientific computing.

The need for more advanced computing capacity is not the only issue to be addressed. Over the last decade, there have been considerable advances in cloud computing, which is increasingly used in research computing, requiring the Institute to take a new look at how it works with cloud services providers and then allocates cloud resources to departments, labs, and centers. And MIT's longstanding model for research computing — which has been mostly decentralized — can lead to inefficiencies and inequities among departments, even as it offers flexibility.

The new research computing and data effort is part of a broader push to modernize MIT's information technology infrastructure and systems. "We are at an inflection point, where we have a significant opportunity to invest in core needs, replace or upgrade aging systems, and respond fully to the changing needs of our faculty, students, and staff," says Silis. "We are thrilled to have a new partner in the Office of Research Computing and Data as we embark on this important work."

New bionics center established at MIT with $24 million gift

Interdisciplinary research center funded by philanthropist Lisa Yang aims to mitigate disability through technologies that marry human physiology with electromechanics

Jennifer Michalowski | McGovern Institute for Brain Research

A deepening understanding of the brain has created unprecedented opportunities to alleviate the challenges posed by disability. Scientists and engineers are taking design cues from biology itself to create revolutionary technologies that restore the function of bodies affected by injury, aging, or disease — from prosthetic limbs that effortlessly navigate tricky terrain to digital nervous systems that move the body after a spinal cord injury.

With the establishment of the new K. Lisa Yang Center for Bionics, MIT is pushing forward the development and deployment of enabling technologies that communicate directly with the nervous system to mitigate a broad range of disabilities. The center's scientists, clinicians, and engineers will work together to create, test, and disseminate bionic technologies that integrate with both the body and mind.

The center is funded by a $24 million gift to MIT's McGovern Institute for Brain Research from philanthropist Lisa Yang, a former investment banker committed to advocacy for individuals with visible and invisible disabilities. Her previous gifts to MIT have also enabled the establishment of the K. Lisa Yang and Hock E. Tan Center for Molecular Therapeutics in Neuroscience, Hock E. Tan and K. Lisa Yang Center for Autism Research, Y. Eva Tan Professorship in Neurotechnology, and the endowed K. Lisa Yang Post-Baccalaureate Program.

> **"I am thrilled to support MIT on this major research effort to enable powerful new solutions that improve the quality of life for individuals who experience disability."**

"The K. Lisa Yang Center for Bionics will provide a dynamic hub for scientists, engineers, and designers across MIT to work together on revolutionary answers to the challenges of disability," says MIT president L. Rafael Reif. "With this visionary gift, Lisa Yang is unleashing a powerful collaborative strategy that will have broad impact across a large spectrum of human conditions — and she is sending a bright signal to the world that the lives of individuals who experience disability matter deeply."

To develop prosthetic limbs that move as the brain commands or optical devices that bypass an injured spinal cord to stimulate muscles, bionic developers must integrate knowledge from a diverse array of fields — from robotics and artificial intelligence to surgery, biomechanics, and design. The K. Lisa Yang Center for Bionics will be deeply interdisciplinary, uniting experts from three MIT schools: Science, Engineering, and Architecture and Planning. With clinical and surgical collaborators at Harvard Medical School, the center will ensure that research advances are tested rapidly and reach people in need, including those in traditionally underserved communities.

To support ongoing efforts to move toward a future without disability, the center will also provide four endowed fellowships for MIT graduate students working in bionics or other research areas focused on improving the lives of individuals who experience disability.

"I am thrilled to support MIT on this major research effort to enable powerful new solutions that improve the quality of life for individuals who experience disability," says Yang. "This new commitment extends my philanthropic investment into the realm of physical disabilities, and I look forward to the center's positive impact on countless lives, here in the U.S. and abroad."

The new K. Lisa Yang Center for Bionics at MIT, made possible by a $24 million gift from philanthropist Lisa Yang (center), will be led by Hugh Herr, professor of media arts and sciences at the MIT Media Lab (left) and Ed Boyden, the Y. Eva Tan Professor in Neurotechnology at MIT (right). *Photo: Caitlin Cunningham*

The center will be led by Hugh Herr, a professor of media arts and sciences at MIT's Media Lab, and Ed Boyden, the Y. Eva Tan Professor of Neurotechnology at MIT, a professor of biological engineering, brain and cognitive sciences, and media arts and sciences, and an investigator at MIT's McGovern Institute and the Howard Hughes Medical Institute.

A double amputee himself, Herr is a pioneer in the development of bionic limbs to improve mobility for those with physical disabilities. "The world profoundly needs relief from the disabilities imposed by today's nonexistent or broken technologies. We must continually strive toward a technological future in which disability is no longer a common life experience," says Herr. "I am thrilled that the Yang Center for Bionics will help to measurably improve the human experience for so many."

Boyden, who is a renowned creator of tools to analyze and control the brain, will play a key role in merging bionics technologies with the nervous system. "The Yang Center for Bionics will be a research center unlike any other in the world," he says. "A deep understanding of complex biological systems, coupled with rapid advances in human-machine bionic interfaces, mean we will soon have the capability to offer entirely new strategies for individuals who experience disability. It is an honor to be part of the center's founding team."

"The mobile prosthetics service fueled by the K. Lisa Yang Center for Bionics at MIT is an innovative solution to a global problem," says Julius Maada Bio, president of Sierra Leone. "I am proud that Sierra Leone will be the first site for deploying this state-of-the-art digital design and fabrication process. As leader of a government that promotes innovative technologies and prioritizes human capital development, I am overjoyed that this pilot project will give Sierra Leoneans (especially in rural areas) access to quality limb prostheses and thus improve their quality of life."

Together, Herr and Boyden will launch research at the bionics center with three other MIT faculty: assistant professor of media arts and sciences Canan Dagdeviren, Walter A. Rosenblith Professor of Cognitive Neuroscience Nancy Kanwisher, and David H. Koch (1962) Institute Professor Robert Langer. They will work closely with three clinical collaborators at Harvard Medical School: Marco Ferrone, an orthopedic surgeon; Matthew Carty, a plastic surgeon; and Nancy Oriol, faculty associate dean for Community Engagement in Medical Education.

"Lisa Yang and I share a vision for a future in which each and every person in the world has the right to live without a debilitating disability if they so choose," adds Herr. "The Yang Center will be a potent catalyst for true innovation and impact in the bionics space, and I am overjoyed to work with my colleagues at MIT, and our accomplished clinical partners at Harvard, to make important steps forward to help realize this vision."

Read more about the center's priorities, including the development of a mobile delivery system to ensure patients in medically underserved communities have access to prosthetic limb services, beginning in Sierra Leone.
yangtan.mit.edu/k-lisa-yang-center-for-bionics/

Championing the next generation

BCS graduate fellows and supporters celebrate students' roles in the research enterprise

Devan Monroe | Department of Brain and Cognitive Sciences

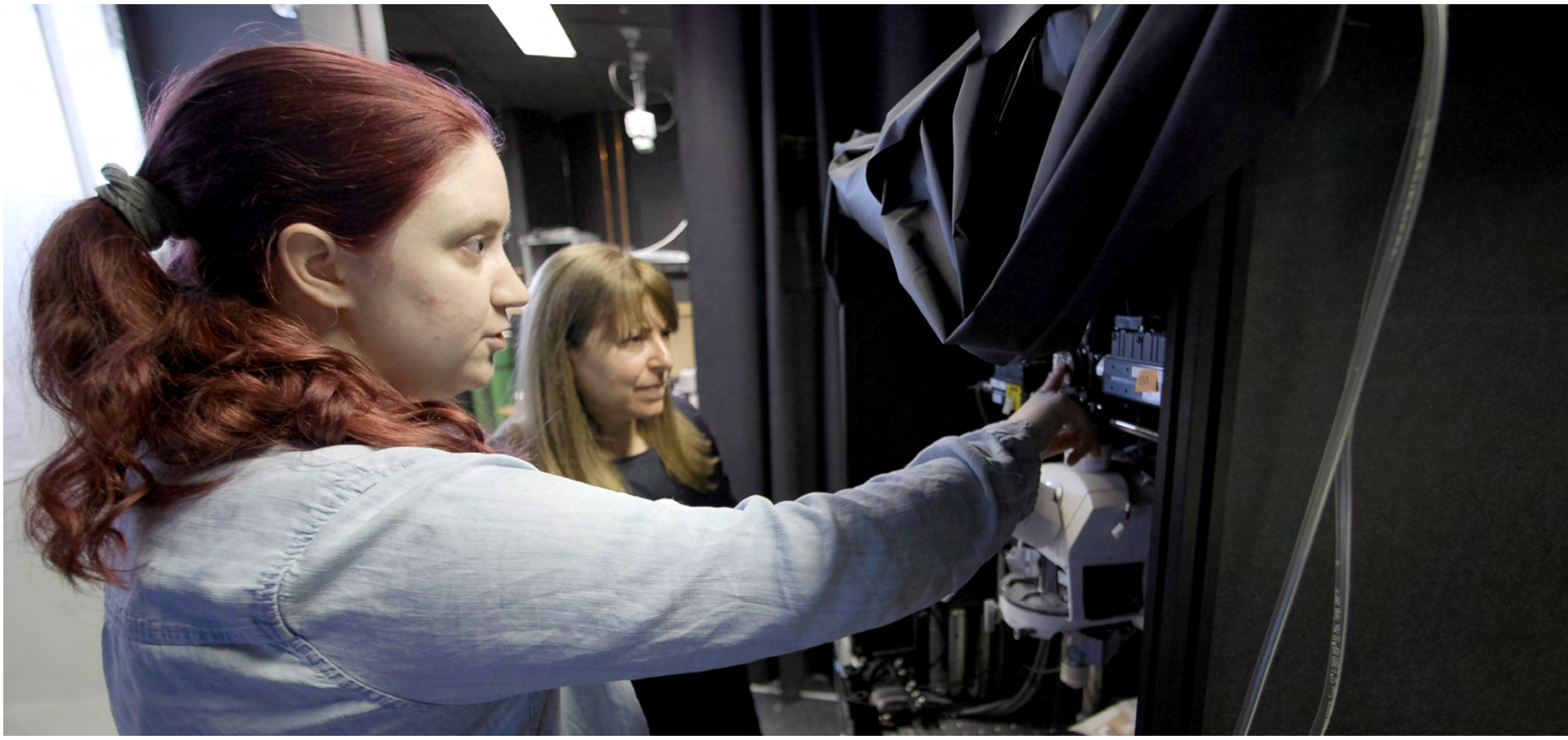
The Department of Brain and Cognitive Sciences (BCS) held its ninth annual Champions of the Brain Fellows event on Oct. 25, 2022. The virtual event celebrates BCS graduate students and those champions who make it possible for students to explore their scientific dreams and to drive the department's exciting research.

MIT Dean of Science Nergis Mavalvala provided opening remarks for the celebration, detailing the importance of fellowship support to attracting the top students and faculty.

"Graduate students, whether you're a physicist or a neuroscientist, are woven into the fabric of all the research that we do. They are partners in our thinking and really central to the research enterprise," said Mavalvala, the Curtis (1963) and Kathleen Marble Professor of Astrophysics.

Associate Professor Josh McDermott PhD '07 hosted the celebration. In his opening remarks, McDermott shared his personal experience as a graduate student in BCS as a past recipient of the Gerald J. (1964) and Marjorie J. Burnett Fellowship. He spoke about how the talent of BCS graduate students influenced his decision making when considering offers for faculty positions.

"When I was on the faculty job market and thinking about where to go to be a professor, the quality of the students here at MIT was a major factor in deciding that this is really where I needed to be. The students here are truly exceptional and it's such a privilege to work with them," said McDermott, who is also the associate department head and an associate investigator at the McGovern Institute for Brain Research. "Graduate fellowships are totally critical to MIT's innovation and excellence."



Kendyll Burnell is a third-year student studying the role of inhibition in adult plasticity in the lab of Professor Elly Nedivi at The Picower Institute for Learning and Memory. Burnell is supported by the Gerald J. (1964) and Marjorie J. Burnett Fellowship. *Photo: Endeavor Film*

The celebration featured the premiere of a video profile of BCS graduate student Fernanda de la Torre, who like McDermott was a recipient of the Gerald J. (1964) and Marjorie J. Burnett Fellowship, as well as a recipient of the prestigious Hubert J. P. Schoemaker (1976) fellowship. De la Torre also recently received the 2022 Paul and Daisy Soros Fellowship for New Americans. Fernanda's story as an undocumented child coming from Mexico to the United States to then seek better educational opportunities highlighted the resilience and tenacity of MIT graduate students, and the powerful support fellowships provide to young scientists.

The celebration continued with talks by three current graduate fellows, including Aída Piccato, a third-year student in Professor Mehrdad Jazayeri's lab supported by the James S. (1972) and Muguette Alder Fellowship. Piccato spoke about her work to understand the neural basis of memory strength, using multi-area neural recordings in non human primates. The second speaker, Sadie Zacharek, a third-year in Professor John Gabrieli's lab supported by the Irene T. Cheng (1978) Fellowship, discussed her project examining neural markers of treatment mechanism and predictions for treatment outcomes in social anxiety. The final student speaker was Kendyll Burnell, a third-year in Professor Elly Nedivi's lab supported by the Gerald J. (1964) and Marjorie J. Burnett Fellowship, presented her research on the role of inhibition in adult plasticity. Following a question-and-answer period with the graduate fellows, champions, faculty, and fellows were split into breakout rooms to allow for more intimate conversation.

The concluding segment of the celebration included prerecorded remarks from BCS Department Head Michale Fee, as well as remarks from Barrie R. Zesiger HM, MIT Corporation life member emeritus and a founder of Champion of the Brain Fellows.

Zesiger discussed the impact of supporting neuroscience research through the next generation of scientists. She also encouraged continued involvement and support from the audience.

"Graduate students are set up to be the entrepreneurs of most labs; and it's this entrepreneurship that can provide the rocket fuel for research for a better world," said Zesiger. "I want to multiply those of us who've given; I want us to give more, and I want us to find others who, of our friends, or colleagues [who wish to support BCS graduate students.]"

In closing, Fee emphasized the special, symbiotic relationship between graduate students and faculty.

Photo: Endeavor Film

"The word 'student' can imply a one-directional transfer of information: You're the student, and I'm the teacher. But the really wonderful thing about our graduate students, what I treasure the most, is what they have taught me," Fee said. "Students see scientific problems with fresh eyes, they think about things differently . . . With their new perspective, students can bring deep, old questions back to life. And being able to see our own research through these fresh, creative, unjaded eyes helps keep me enthusiastic."

Fee concluded: "By supporting our graduate students, you are helping to fire the engines of creativity in a promising young scientist, to enable them to do their best work in this extraordinary community of scholars. You are also supporting a legacy of faculty mentoring students, who then become mentors themselves — a generational cycle that is fundamental to advancing knowledge."

The annual Champions of the Brain Fellows honors those donors who commit $100,000 or more through an endowed, expendable, or corporate gift to support graduate students at the forefront of cutting-edge research in BCS.

To learn more about supporting BCS, visit bcs.mit.edu/give-bcs.

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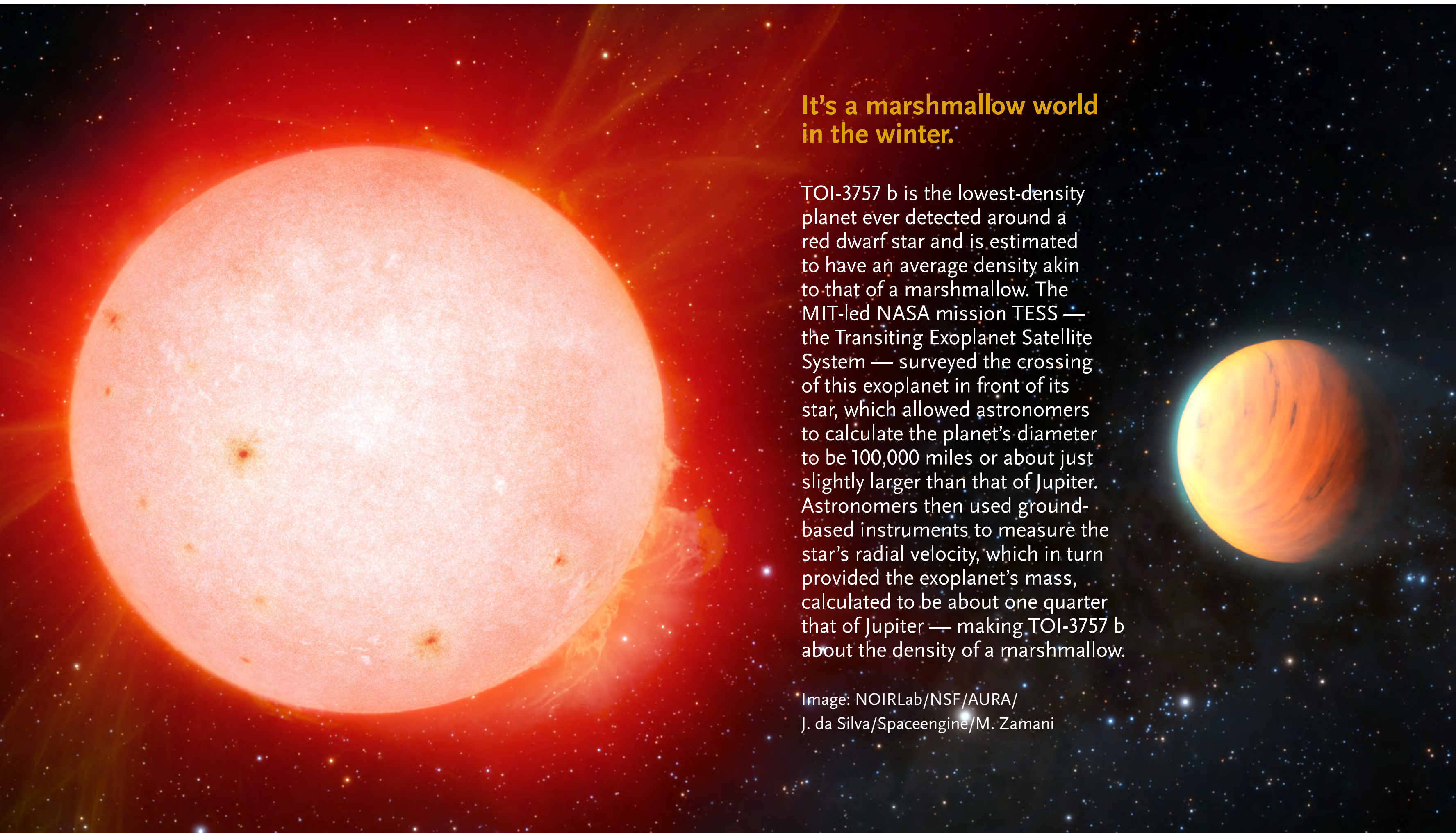

It's a marshmallow world in the winter.

TOI-3757 b is the lowest-density planet ever detected around a red dwarf star and is estimated to have an average density akin to that of a marshmallow. The MIT-led NASA mission TESS — the Transiting Exoplanet Satellite System — surveyed the crossing of this exoplanet in front of its star, which allowed astronomers to calculate the planet's diameter to be 100,000 miles or about just slightly larger than that of Jupiter. Astronomers then used ground-based instruments to measure the star's radial velocity, which in turn provided the exoplanet's mass, calculated to be about one quarter that of Jupiter — making TOI-3757 b about the density of a marshmallow.

Image: NOIRLab/NSF/AURA/
J. da Silva/Spaceengine/M. Zamani