CarnegieScience

The Newsletter of the Carnegie Institution for Science

FALL 2018

EMBRYOLOGY ▫ GEOPHYSICAL LABORATORY ▫ GLOBAL ECOLOGY ▫ THE OBSERVATORIES ▫ PLANT BIOLOGY ▫ TERRESTRIAL MAGNETISM ▫ CASE: CARNEGIE ACADEMY FOR SCIENCE EDUCATION

On the Inside

CARNEGIE SCIENCE

CARNEGIE INSTITUTION FOR SCIENCE

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Intellectual courage. Unfettered curiosity. Scholarly independence.

More than a century ago, the Carnegie Institution for Science was founded to provide exceptional researchers with the resources to take intellectual risks and pursue knowledge at the forefront of discovery.

The scientists who were the first beneficiaries of Andrew Carnegie's vision would not recognize the universe that we know today—a cosmos made up primarily of dark matter and dark energy. They would be equally astounded by our increasingly nuanced understanding of life down to the molecular scale. Nevertheless, after decades of transformative discovery, those first Carnegie researchers would immediately recognize the fundamental principles that guide our work today.

The wide-ranging work featured in this issue of *Carnegie Science* demonstrates the continuing power of our first principles to inspire and support collaborative, cross-disciplinary, potentially world-changing research.

In an ambitious attempt to map and monitor the world's coral reefs, Carnegie's Reefscape Project has forged a powerful new collaboration with Paul G. Allen Philanthropies, Planet Labs Inc., University of Queensland, and the Hawai'i Institute of Marine Biology. This effort, which relies on high-resolution satellite imagery and will use artificial intelligence, will help us to monitor changes in global reef health in real time, with the goal of finding ways to preserve these fragile, crucial ecosystems.

As we work to understand and protect this planet's ecological systems, we also are training new generations of scientists to lead this effort in the future. We are very proud to showcase important new climate research led by former Carnegie postdoctoral fellow Summer Praetorius, who is now with the U.S. Geological Survey (USGS). The exceptional work of our postdocs is central to the Carnegie Institution's international reputation.

Looking even further ahead, Carnegie is working to bring the excitement of scientific exploration to schoolchildren through the prize-winning BioEYES program, cocreated by Carnegie Department of Embryology scientist Steven Farber. In this program, elementary and high school students gain new insights into genetics and biology by studying the development of live zebrafish from single cells to free-swimming larvae.

This issue also highlights Carnegie's continuing eminence in astronomy and our scientists' ability to wield scientific instruments, and the data they generate, to explore the universe. Carnegie postdoctoral fellow Jaehan Bae was part of an international team that took a new look at archival data from the Atacama Large Millimeter/submillimeter Array (ALMA), an installation of 66 radio telescopes in the Atacama Desert of northern Chile, to find evidence of "baby planets" in the giant rotating disc of gas and dust surrounding a newly formed star. By studying the swirls and eddies inside the gaseous disc, they pinpointed the locations of two planets roughly the size of Jupiter—perhaps the youngest exoplanets ever detected.

As I read this issue, I was impressed once again by the talent and creativity of Carnegie researchers, and by the ways in which our unique organizational structure makes it possible for us to stay nimble as we pursue exciting investigative pathways. As we move forward together, I know that the extraordinary people of the Carnegie Institution will continue to fulfill our responsibility to conduct the best science, at the highest level, and to make sure that our doors remain open to everyone who has a compelling new idea and the skill to pursue it.

Eric D. Isaacs

Eric D. Isaacs
President

Carnegie Trustee Emeritus Samuel Bodman Dies

Former Secretary of Energy in the George W. Bush administration and a Carnegie trustee from 2009 until 2013, Samuel Bodman died at the age of 79 after a lengthy illness on September 7, 2018, in El Paso, Texas.

Before serving as Energy Secretary, Bodman served as Deputy Secretary of the Treasury and Deputy Secretary of Commerce.

Born in Chicago in 1938, Bodman went on to receive a B.S. in Chemical Engineering from Cornell in 1961 and a Ph.D. from MIT in 1965. He then taught at MIT until 1970 and worked at a venture capital firm, later joining Fidelity Investments. In 1987 he was appointed Chairman and CEO of a specialty chemical company, Cabot Corporation. He was a member of the American Academy of Arts and Sciences and the National Academy of Engineering.

Bodman joined the Carnegie board in 2009 and, with his background in engineering and finance, served as a valuable member of the Budget and Operations and Finance Committees.

Bodman is survived by his wife Diane Bodman, three children, two stepchildren, and numerous grandchildren. ■

The Real Deal

Douglas Koshland knew that BioEYES was the "real deal" when he heard about it from an unexpected source. Having worked alongside BioEYES founder and Carnegie staff scientist Steve Farber at Carnegie's Department of Embryology, Doug had heard about this hands-on science education program and the impact it was making on the lives of underserved students throughout Baltimore. Yet it was a conversation with a local teacher that prompted Doug to get involved.

This first-grade teacher, who worked in a public school serving some of the most underprivileged students in Baltimore, heard about BioEYES through her students, whose siblings in 4th and 5th grades were participating in BioEYES during the day and sharing what they learned with their families each night. With two kids of his own, Doug knew that it requires something truly special to elicit such excitement from young children. After that, he began to philanthropically support the program, and has since been impressed by how they use scientific methodology to assess BioEYES strengths.

Doug recognizes the immediate impact that comes from fostering an enthusiasm for science in students and training teachers to conduct and develop engaging scientific curricula; BioEYES will be the first step for many on the path to science, technology, engineering, and mathematics (STEM) careers. Just as important, though, is how BioEYES cultivates a life-long love of science for many others—students who will one day shape society as science-literate politicians, educators, and voters.

Although Doug left Carnegie Science in 2010, he remains invested in BioEYES as a donor and advisory committee member. "It's money well spent because it's work done well," he explained. "Carnegie hires amazing people like Steve that you'd want to support." Doug cites programs like the Capital Science Evening lectures and the Carnegie Academy for Science Education (CASE)'s First Light as examples of how Carnegie makes an amazing impact beyond the work being done in laboratories. "If you want to be involved with people who are doing something good, keep an eye on Carnegie and you'll discover something innovative and inspiring to support." ■

(Above) Young zebrafish are entirely clear and are used to observe fish development in detail. Adult zebrafish are shown at top. Images courtesy Marnie Halpern and Jeremy Hayes

(Left) BioEYES cofounder Steve Farber talks to students about the development of zebrafish at the 2018 USA Science & Engineering Festival in Washington, D.C.

First-Ever Global and Dynamic Map of Coral Reefs

Carnegie scientist Greg Asner and the Reefscape Project play a crucial role in a new partnership that's responding to the crisis of the declining health of coral reefs. The project will develop global maps and monitoring systems using satellite imagery and big data processing. Less than a quarter of the world's reefs are mapped or monitored using visual assessment from scuba and light aircraft or, in some places, lower-resolution satellite images.

A new collaboration with Paul G. Allen Philanthropies, Planet Labs Inc., Carnegie, University of Queensland, and the Hawai'i Institute of Marine Biology is taking on one of the world's most intractable challenges: to develop tools to support, inform, and inspire critical conservation measures to save our diminishing coral reefs.

The partnership will provide the first-ever seamless mosaic of high-resolution satellite imagery of the world's coral reefs and engage with the global coral reef science and management communities to deliver accurate reef maps and see how they are changing. The mosaic, maps, and eventual change-detection system will be made available to conservationists, planners, and policymakers.

"We need to know what is occurring in this hidden world of shallow coral reefs if we have any hope to save them," said Art Min, vice president of impact for Paul Allen, "Coral reefs cover less than 1% of the ocean surface, and yet nearly 1 billion people and 25% of all marine life depend on them."

Asner and his team will use artificial intelligence combined with field-based observations to guide calibrations of Planet's 3.7-meter resolution satellite data to account for atmospheric effects, glare, reflectivity, and other features that make it difficult to penetrate the ocean's surface for mapping—all of which will allow scientists from the University of Queensland to classify the reefs. The Carnegie team will also build a novel coral reef-monitoring system using daily Planet satellite data to

PARTNERS:

PAUL G. ALLEN PHILANTHROPIES

Paul G. Allen Philanthropies

Microsoft cofounder and philanthropist Paul G. Allen was deeply committed to ocean health and had a growing portfolio of programs targeted at the protection of the marine ecosystem.

TO LEARN MORE VISIT:

PAULALLEN.COM OR PGAPHILANTHROPIES.ORG.

planet

Planet Labs Inc.

Planet is an integrated aerospace and data analytics company that operates history's largest fleet of Earth-imaging satellites, collecting a massive amount of information about our changing planet. Planet is driven by a mission to image all of Earth's landmass every day, and make global change visible, accessible, and actionable.

TO LEARN MORE VISIT:

PLANET.COM AND FOLLOW ON TWITTER AT @ PLANETLABS

1 Coral reefs are among the most diverse ecosystems in the world, and many economies depend on them. They also help to buffer shorelines, protecting them from erosion. However, they are in danger of disappearing from an onslaught of different threats. The new partnership will build the first-ever coral reef-monitoring system to detect where reefs are changing, so action can be taken to mitigate effects.
Image courtesy Greg Asner/Divephoto.org

2 Carnegie scientists Robin Martin (left) and Greg Asner (right) are collecting data on the properties of corals, which will be combined with satellite data to construct global and dynamic maps of coral reefs.
Image courtesy Chris Balzotti

3 The new coral reef-monitoring system uses Planet satellite data. Planet imagery can be used to map shallow coral reefs. This image shows Mo'orea, French Polynesia.
Image courtesy Planet Labs Inc.

SUPPORT:
Leonardo DiCaprio Foundation, the Nature Conservancy, and Paul G. Allen Philanthropies provided support.

detect changes in coral reefs such as bleaching or destruction from coastal development. The Carnegie change-detection and alert system will be the first of its kind and will propel a global effort to slow and reverse coral reef losses.

"Where there is effort, there is hope," Asner said. "I'm tired of only seeing negative news about coral reefs. I want to focus on resilience as well as danger to highlight efforts, such as ours, to understand, manage, and conserve reef systems. Our new coral reef-monitoring system made possible in this project will be the first to detect where reefs are changing, and to direct action to mitigate losses."

In its first year, the partnership plans to produce the global mosaic, a global community engagement plan, and five site-based maps to validate the new image processing and mapping methodology. The pilot sites were chosen to represent a variety of reef types and health from across the globe where field verification data are readily available. They are Heron Island, Great Barrier Reef, Australia; Mo'orea, French Polynesia; Lighthouse Reef, Belize; West Hawaii Island, Hawaii; and Karimunjawa, Indonesia.

"Seeing change is the first step in taking responsibility for it," said Andrew Zolli, vice president for global impact initiatives at Planet. "By putting the most complete, up-to-date picture of the world's corals in the hands of scientists, conservationists, and communities, we hope to accelerate action on the coral crisis before it's too late."

Once the five sites are mapped and methodology refined, the partnership intends to scale the benthic and geomorphic mapping to regions in 2019 and then the entire globe in 2020. Also, in 2019 the use of artificial intelligence will be applied to detect changes on the reefs and alert conservationists and governments to the situation so that resources can be immediately engaged.

Greg Asner and Robin Martin have accepted senior positions at Arizona State University, where Asner will establish a new Center for Global Discovery and Conservation Science, and Martin will be an associate professor. They are eager to keep connections open with the many colleagues at Carnegie with whom they have collaborated on both coral work and their mapping efforts. ■

The Remote Sensing Research Centre, University of Queensland

The Remote Sensing Research Centre uses remotely sensed data, fieldwork, and spatial models to measure, map, and monitor biophysical properties in terrestrial, atmospheric, and aquatic environments to better understand and manage the Earth's environments and resources.

TO LEARN MORE VISIT:
SEES.UQ.EDU.AU/REMOTE-SENSING-RESEARCH-CENTRE

Hawai'i Institute of Marine Biology

The mission of the Hawai'i Institute of Marine Biology (HIMB) is to conduct multidisciplinary research and education in all aspects of tropical marine biology. HIMB continues to be a world leader in research to understand and conserve tropical marine ecosystems. HIMB is an independent research unit within the School of Ocean Earth Science and Technology (SOEST) at the University of Hawai'i, Mānoa.

TO LEARN MORE VISIT:
HIMB.HAWAII.EDU/ABOUT-US/

What Makes Diamonds Blue?

Blue diamonds, like the world-famous Hope Diamond, formed up to four times deeper in the Earth's mantle than most other diamonds, according to new work published on the cover of *Nature*. The discovery received wide media attention.

The research group, including Carnegie's Steven Shirey, Emma Bullock, and Jianhua Wang, determined that blue diamonds form at least as deep as the transition zone between the upper and lower mantle, or between 255 and 410 miles (410 and 660 kilometers) below the surface. Several of the samples even showed clear evidence that they came from deeper than 410 miles, meaning they originated in the lower mantle. By contrast, most other gem diamonds come up from between 93 and 124 miles (150 and 200 km).

"These so-called type IIb diamonds are tremendously valuable, making them hard to get access to for scientific research purposes," explained lead author Evan Smith of the Gemological Institute of America, adding, "and it is very rare to find one that contains inclusions, which are tiny mineral crystals trapped inside the diamond."

Inclusions are remnants of the minerals from the rock in which the diamond crystallized; they can tell scientists about the conditions under which the diamond formed.

Type IIb diamonds owe their blue color to the element boron, which is mostly found on the Earth's surface. But analysis of the trapped mineral grains in 46 blue diamonds examined over two years indicate that they crystallized in rocks that exist only under the extreme pressure and temperature conditions of the Earth's lower mantle.

So how did the boron get down there if it is an element known for residing predominately in the shallow crust?

According to the group's hypothesis, it came from seafloor that was conveyed down into the Earth's mantle when one tectonic plate slid beneath another, a process known as subduction.

The new study proposes that boron from the Earth's surface was incorporated into water-rich minerals like serpentine, which crystallized during geochemical reactions between seawater and the rocks of the oceanic plate. This reaction between rock and water is a process called serpentinization and can extend deep into the seafloor, even into the oceanic plate's mantle portion.

The group's discovery reveals that the water-bearing minerals travel far deeper into the mantle than previously thought, which indicates the possibility of a super-deep hydrological cycle.

"Most previous studies of super-deep diamonds had been carried out on diamonds of low quality," Shirey said. "But between our 2016 finding that the world's biggest and most-valuable colorless diamonds formed from metallic liquid deep inside Earth's mantle and this new discovery that blue diamonds also have super-deep origins, we now know that the finest gem-quality diamonds come from the farthest down in our planet." ■

COAUTHORS AND SUPPORT:

Other coauthors on the paper are Stephen Richardson of University of Cape Town, Fabrizio Nestola of University of Padua, and Wuyi Wang of the Gemological Institute of America.

A Gemological Institute of America Liddicoat Postdoctoral Research Fellowship, the Deep Carbon Observatory, and the European Research Council supported this research.

❶ This photo shows a blue, boron-bearing diamond with dark fragments of a mineral called ferropericlase, which were examined as part of this study. This gem weighs 0.03 carats.
Image courtesy Evan Smith/ Gemological Institute of America

❷ This larger, blue, boron-bearing diamond contains mineral fragments that were examined as part of this study. This gem weighs 3.81 carats and is 1.26 centimeters long.
Image courtesy Robison McMurtry/ Gemological Institute of America

The August cover of the journal *Nature* featured the paper revealing the super-deep origin of blue diamonds, on which Evan Smith of the Gemological Institute of America is lead author and Carnegie's Steven Shirey (middle), Emma Bullock (left), and Jianhua Wang (right) are coauthors.

PACIFIC OCEAN'S EFFECT ON ARCTIC WARMING

New research, led by former Carnegie postdoctoral fellow Summer Praetorius, shows that changes in the heat flow of the northern Pacific Ocean may have a larger effect on the Arctic climate than previously thought. The August 7, 2018, issue of *Nature Communications* published the findings.

(Above) Former Carnegie postdoctoral fellow Summer Praetorius was lead author on the study.
Image courtesy Summer Praetorius

The Arctic is experiencing larger and more rapid increases in temperature from global warming more than any other region, with sea ice declining faster than predicted. This effect, known as Arctic amplification, involves many positive feedback mechanisms in polar regions.

What has not been well understood is how sea surface temperature patterns and oceanic heat flow from Earth's different regions, including the temperate latitudes, affect these polar feedbacks. This new research suggests that the importance of changes occurring in the Pacific may have a stronger impact on Arctic climate than previously recognized.

Paleoclimate records show that climate change in the Arctic can be very large and can happen rapidly. During the last deglaciation, there were two episodes of accelerated Arctic warming—with temperatures increasing by 15°C in Greenland over the course of decades. The events were accompanied by rapid warming in the midlatitude North Pacific and North Atlantic Oceans.

Because of these past changes, the research team* modeled a series of ocean-to-atmosphere heat flow scenarios for the North Pacific and the North Atlantic. They used the National Center for Atmospheric Research's Community Earth System Model (CESM) to assess the impacts to the Arctic's surface temperature and climate feedbacks.

Praetorius, who was at Carnegie at the time of the research and is now with the U.S. Geological Survey (USGS), explained, "Since there appeared to be coupling between abrupt Arctic temperature changes and sea surface temperature changes in both the North Atlantic and North Pacific in the past, we thought it was important to untangle how each region may affect the Arctic differently in order to provide insight into recent and future Arctic changes."

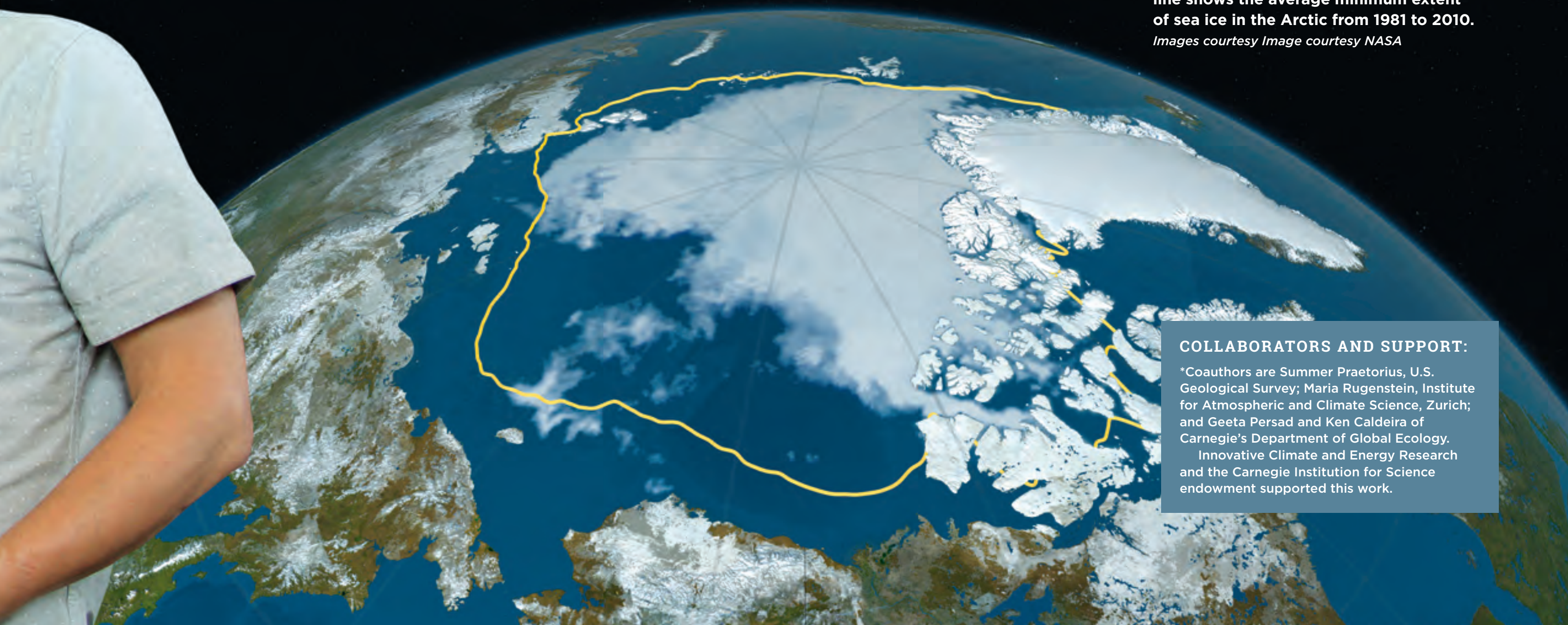
The researchers found that both cooling and warming anomalies in the North Pacific resulted in greater global and Arctic surface air temperature anomalies than the same perturbations modeled for the North Atlantic. Until now, this sensitivity had been underappreciated.

The scientists also found that the strong global and Arctic changes depended on the magnitude of water vapor transfer from the midlatitude oceans to the Arctic. Warm moist air carried poleward towards the Arctic can lead to more low-lying clouds that trap warmth near the surface. The poleward movement of heat and moisture drive the Arctic's sea ice retreat and low-cloud formation, amplifying Arctic warming.

The so-called ice-albedo feedback causes retreating ice and snow, leading to greater warming through increasing absorption of solar energy on darker surfaces.

In recent years, the Arctic has experienced an even greater accelerated warming. The unusually warm ocean temperatures in the Northeast Pacific paralleled the uptick in Arctic warming, possibly signaling a stronger link between these regions than generally recognized.

"While this is a highly idealized study, our results suggest that changes in the Pacific Ocean may have a larger influence on the climate system than generally recognized," remarked Carnegie coauthor Ken Caldeira. ■



This image shows the extent of Arctic sea ice in September 2016. The yellow line shows the average minimum extent of sea ice in the Arctic from 1981 to 2010.
Images courtesy Image courtesy NASA

COLLABORATORS AND SUPPORT:

*Coauthors are Summer Praetorius, U.S. Geological Survey; Maria Rugenstein, Institute for Atmospheric and Climate Science, Zurich; and Geeta Persad and Ken Caldeira of Carnegie's Department of Global Ecology.

Innovative Climate and Energy Research and the Carnegie Institution for Science endowment supported this work.

New Venture Grant and Postdoctoral Innovation & Excellence Awards

A NEW VENTURE GRANT has been awarded to the Geophysical Laboratory's Dionysis Foustoukos and Sue Rhee of the Department of Plant Biology, with colleague Costantino Vetriani of Rutgers University, for their project *Deciphering Life Functions in Extreme Environments*.

Carnegie Science Venture Grants bring together cross-disciplinary researchers with fresh eyes to explore unusual questions. Each grant provides $100,000 support for two years and are generously supported, in part, by trustee Michael Wilson and his wife Jane and the Ambrose Monell Foundation.

Foustoukos, Rhee, and Vetriani have teamed up to integrate microbial physiology, genomics, and metabolic network modeling with high-pressure and temperature experimentation to understand gene regulation in response to changing environmental conditions of microorganisms that live in the extreme environments of deep-sea hydrothermal vents without sunlight, limited nutrients, and in extreme pressure and temperature conditions.

Their objective is to unravel how microorganisms interact with each other and the environment. Foustoukos's high-pressure experimental results will be compared to genomic studies and genome databases from the Rhee lab to reconstruct the metabolic network models of these microorganisms. The team hopes to better understand how environmental factors and physiology of these organisms shape the evolution of the deep biosphere.

Dionysis Foustoukos (top left) and Sue Rhee (top right) will study how high-pressure adapted organisms at deep-sea hydrothermal vents (above) interact with each other and the environment. They hope to better understand how environmental factors and physiology shape the evolution of the deep biosphere.
Images courtesy Dionysis Foustoukos and Robin Kempster

Maria Drout

10TH & 11TH POSTDOCTORAL INNOVATION & EXCELLENCE AWARDS

Recipients of the Postdoctoral Innovation and Excellence (PIE) Awards are given a cash prize for their exceptionally creative approaches to science, strong mentoring, and contributing to the sense of campus community. These awards are made through nominations from the departments and are chosen by the Office of the President.

Observatories' NASA Hubble Postdoctoral Fellow Maria Drout received the tenth such award. Drout was one of four Carnegie astronomers who, along with colleagues from U.C.-Santa Cruz, provided the first-ever glimpse of two neutron stars colliding in August 2017. She was first author on a *Science* paper, which measured the changing light from that merger to shed light on the origin of the heaviest elements in the universe. The discovery was widely covered by the media.

Among her many outreach activities, Drout is dedicated to providing graduate students in technical and scientific fields with the communication skills that they will need throughout their careers, as evidenced by initiatives such as Astrobites.com and the Communicating Science Workshop series (ComSciCon). Her expertise in this arena was flawlessly executed during the many media interviews she conducted for the neutron star merger discovery.

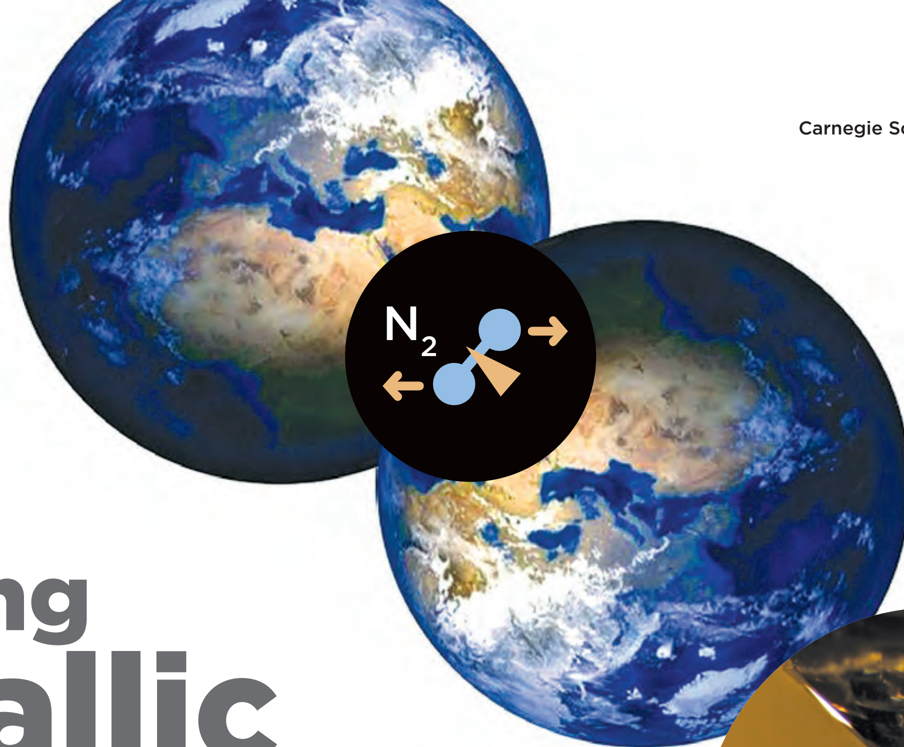
Ethan Greenblatt

Drout joined the faculty in the Department of Astronomy and Astrophysics at the University of Toronto in September 2018.

Ethan Greenblatt, a senior postdoctoral associate at the Department of Embryology, was awarded the eleventh PIE Award. Greenblatt has made a major impact on biological science, particularly with his research identifying genetic factors underlying fragile X syndrome, the most common cause of autism.

Greenblatt's research revealed that defects in the cell's ability to create unusually large proteins was at work in the disorder. He investigated the *FMR1* gene believed to be essential for controlling the last stages of the gene's protein-making. This research required him to develop innovative methods, including adapting a protocol originally developed by former Embryology staff member Nick Ingolia.

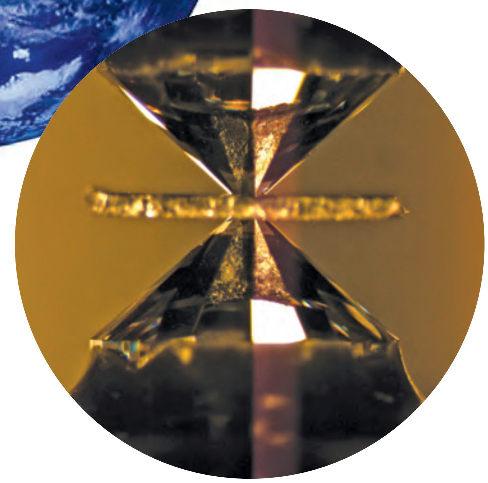
Greenblatt regularly contributes to the sense of community at the department and to the greater Baltimore community. His consistent commitment to this Carnegie trainee community has resulted in his serving on their behalf in discussions with administrative staff on different issues. He has been at Carnegie since 2012. ■



Nitrogen is the dominant gas in Earth's atmosphere, where it is most commonly bonded with itself in diatomic N_2 molecules. The new research indicates that it becomes a metallic fluid when subjected to the extreme pressure and temperature conditions found deep inside the Earth and other planets.
Image courtesy Alexander Goncharov

Creating Metallic Nitrogen

New work from a team led by Carnegie's Alexander Goncharov confirms that nitrogen, the dominant gas in Earth's atmosphere, becomes a metallic fluid when subjected to the extreme pressure and temperature conditions found deep inside the Earth and other planets. *Nature Communications* published the findings.



Nitrogen is one of the most common elements in the universe and is crucial to life on Earth. In living organisms it is a key part of both the nucleic acids that form genetic material and the amino acids that make up proteins. It comprises nearly 80% of the Earth's atmosphere.

But what about how nitrogen behaves in the intense pressure and high temperatures found inside a planet?

"Nitrogen could get into the Earth's mantle when one tectonic plate slides beneath another, a process called subduction, and could even make its way into the iron-rich core as an impurity," explained Carnegie's Shuqing Jiang, the paper's lead author. "Or it could be a remnant from Earth's formation that didn't escape via volcanic activity to form the proto-atmosphere in Earth's babyhood."

In Earth's atmosphere, nitrogen is most commonly bonded with itself in so-called diatomic, N_2, molecules. Calculations indicate that at extreme pressures and temperatures, nitrogen should transform the diatomic molecule from an insulating state (unable to conduct electricity) to a metallic fluid polymer (able to conduct electricity) comprised of atoms linked by complex molecular bonds.

Previous experiments showed evidence of diatomic nitrogen molecules disassociating and changing states under extreme pressures and temperatures, but researchers needed to explore a greater range of conditions.

Goncharov and the team—which also included Carnegie's Fuhai Su; University of Chicago's Nicholas Holtgrewe; GFZ German Research Centre for Geosciences' Sergey Lobanov; Howard University's Mohammad Mahmood; and University of Edinburgh's Stewart McWilliams—set out to further probe these extreme-condition transitions using a laser-heated diamond anvil cell.

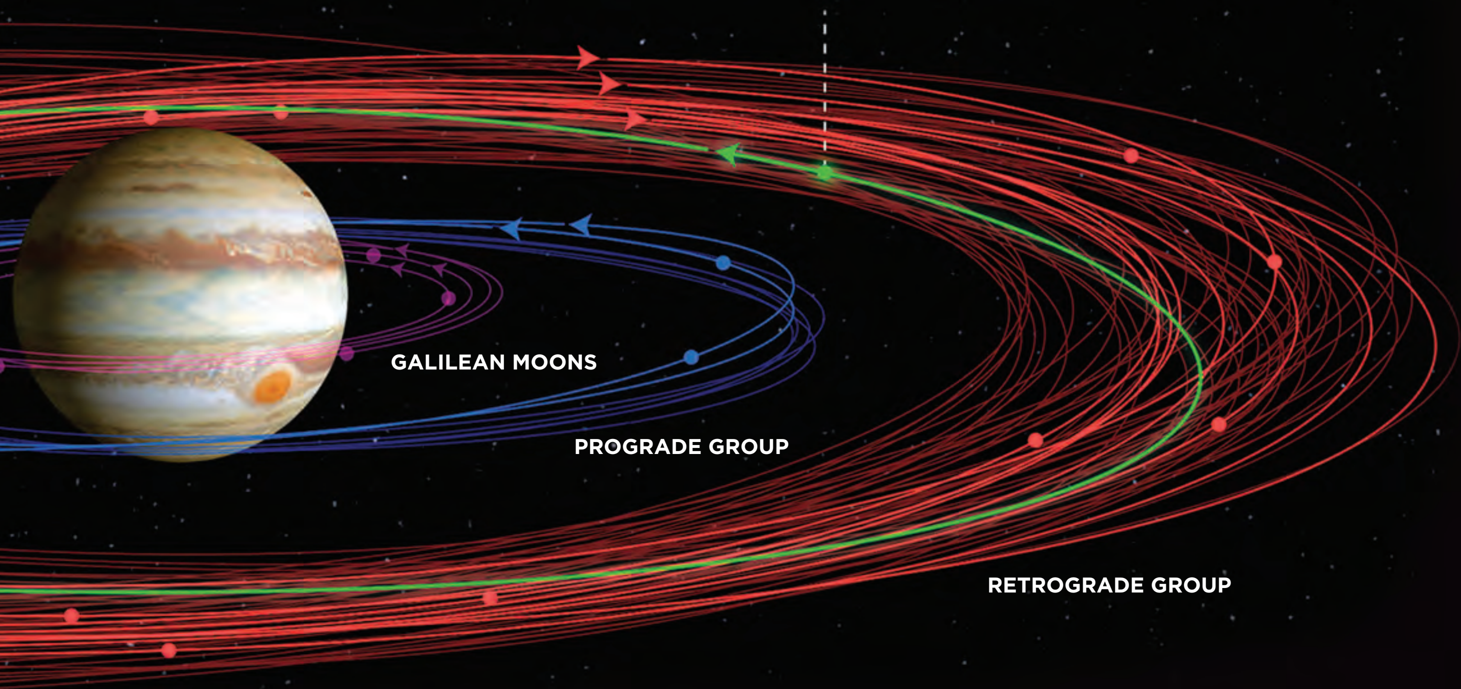
They found that the temperature at which nitrogen transitions from insulating to metallic decreases as the pressure increases, starting at about 1,180,000 times normal atmospheric pressure (120 gigapascals) and 4928°F (2720°C; 3000 K).

"This means that, theoretically, nitrogen would remain in its diatomic state in the Earth's mantle but would disassociate into a fluid metal in or just above the core, which potentially has implications for our understanding of the planet's deep nitrogen cycle," said Lobanov, who was at Stony Brook University when the research was conducted.

Added Holtgrewe, "Our findings could inform the efforts to create forms of energetic nitrogen polymers as well as superconducting, metallic states of a sister diatomic molecule, hydrogen or H_2, which could revolutionize the energy sector if reliably synthesized." ■

Alex Goncharov is holding a diamond anvil cell chamber (above). Above Alex is a close up of a diamond anvil cell. A sample is squeezed between the two diamond tips to pressures equivalent to those in the deep Earth.
Images courtesy Alex Goncharov and Dave Mao

SUPPORT:
The National Science Foundation, the Army Research Office, the Deep Carbon Observatory, the National Natural Science Foundation of China, the Chinese Academy of Science, the Education and Physical Science Research Council, and the British Council Researcher Links Programme supported this work.



New Moons of Jupitor Discovered—ONE ODDBALL

The two moons orbiting in the same direction of Jupiter's orbit, the prograde group, are shown in blue. The orbits of nine outer moons moving in the opposite direction, retrograde, are shown in red. The oddball, Valetudo, has an orbit that crosses the outer group and is at risk for head-on collisions.
Image courtesy Roberto Molar Candanosa

Twelve new moons orbiting Jupiter have been found, 11 "normal" outer moons and one "oddball" moon. This brings Jupiter's total number of known moons to a whopping 79, the most of any planet in our Solar System. The discovery was widely covered by the media.

A team led by Carnegie's Scott S. Sheppard first spotted the moons in the spring of 2017 while they were on the hunt for a possible massive planet far beyond Pluto.

In 2014 this same team found the object with the most distant known orbit in our Solar System and was the first to realize that an unknown massive planet at the fringes of our Solar System could explain the similarity of the orbits of several small extremely distant objects. This putative planet is sometimes called Planet X or Planet Nine. University of Hawaii's Dave Tholen and Northern Arizona University's Chad Trujillo are also part of the team.

"Jupiter just happened to be in the sky near the search fields where we were looking for extremely distant Solar System objects, so we were serendipitously able to look for new moons around Jupiter while at the same time looking for planets at the fringes of our Solar System," Sheppard said.

Gareth Williams at the International Astronomical Union's Minor Planet Center used the team's observations to calculate orbits for the newly found moons. "It takes several observations to confirm an object actually orbits around Jupiter," Williams said. "So the whole process took a year."

Two Groups of New Moons

Nine of the new moons are part of a distant outer swarm of moons that orbit the planet in the opposite direction of Jupiter's spin rotation (retrograde). These distant retrograde moons are grouped into at least three distinct orbital groupings and are thought to be the remnants of three once-larger parent bodies that broke apart during collisions with other bodies. The newly discovered moons take about two years to orbit Jupiter.

Two of the new discoveries are part of a closer, inner group of moons that orbit in the same direction as the planet's rotation (prograde). These moons all have similar orbital distances and angles of inclinations around Jupiter and so are thought to also be fragments of a larger moon that broke apart. These two newly discovered moons take a little less than a year to orbit Jupiter.

The Oddball

"Our other discovery is a real oddball and has an orbit like no other known Jovian moon," Sheppard explained. "It's also likely Jupiter's smallest known moon, being less than one kilometer in diameter."

This new oddball moon is more distant and more inclined than the inner group of moons, and it takes about one and a half years to orbit Jupiter. So, unlike the closer-in group of moons, this new oddball prograde moon has an orbit that crosses the outer moons orbiting in the opposite direction.

As a result, head-on collisions are much more likely to occur between the oddball and the outer moons, orbiting in the opposite direction.

"This is an unstable situation," said Sheppard. "Head-on collisions would quickly break apart and grind the objects down to dust. It's possible the various orbital moon groupings we see today were formed in the distant past through this same mechanism.

The team thinks this small oddball moon could be the last-remaining remnant of a once-larger inner group of moons that formed some of the outer moons during past head-on collisions. The name Valetudo has been proposed for it, after the Roman god Jupiter's great-granddaughter, the goddess of health and hygiene.

Early Solar System Dynamics

Understanding the complex influences that shaped a moon's orbital history can teach scientists about our Solar System's early years.

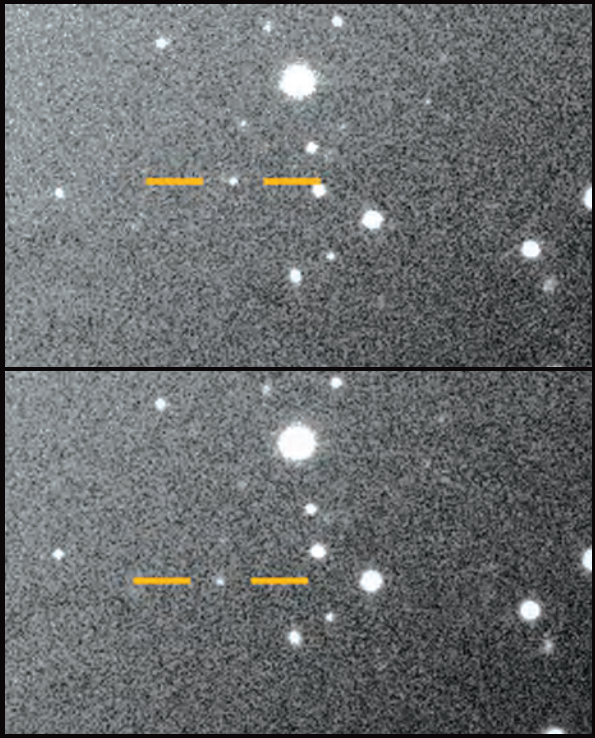
For example, the discovery that these new moons are still abundant suggests the collisions that created them occurred after the era of planet formation, when the Sun was still surrounded by a rotating disk of gas and dust that formed the planets.

Because of their sizes—one to three kilometers—these moons are more influenced by surrounding gas and dust. If these raw materials had still been present when Jupiter's first generation of moons collided to form its current clustered groupings of moons, the drag exerted by any remaining gas and dust on the smaller moons would have been sufficient to cause them to spiral inwards toward Jupiter. Their existence shows that they were likely formed after this gas and dust dissipated.

Confirming the Moons

The initial discovery of most of the new moons was made on the Blanco 4-meter telescope at Cerro Tololo Inter-American Observatory in Chile, operated by the National Optical Astronomical Observatory of the United States. The telescope recently was upgraded with the Dark Energy Camera, making it a powerful tool for surveying the night sky for faint objects. Several telescopes were used to confirm the finds, including the 6.5-meter Magellan telescope at Carnegie's Las Campanas Observatory in Chile; the 4-meter Discovery Channel telescope at Lowell Observatory in Arizona; and the 8-meter Subaru telescope, the University of Hawaii's 2.2-meter telescope, and the 8-meter Gemini North telescope, all in Hawaii. NASA's Jet Propulsion Laboratory confirmed the calculated orbit of the unusual oddball moon in 2017 to double-check its location prediction during the 2018 recovery observations to make sure the new interesting moon was not lost. ■

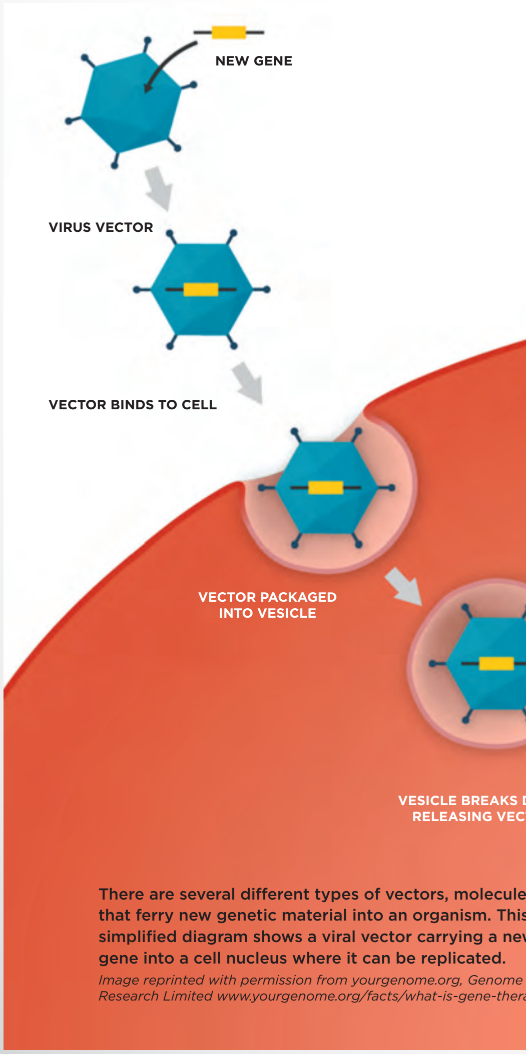
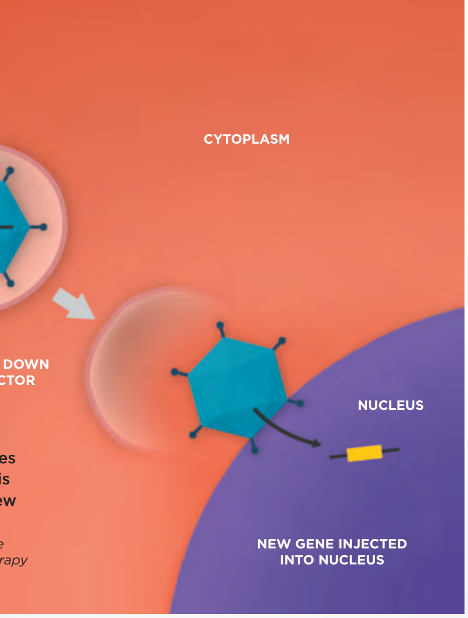
These are images of the oddball moon Valetudo from the Magellan telescope in May 2018. The moon can be seen moving relative to the steady-state background of distant stars. Jupiter is not in the field but is off to the upper left.
Image courtesy Scott Sheppard



Carnegie's Scott Sheppard
Image courtesy Roberto Molar Candanosa

SUPPORT:
A NASA Planetary Astronomy grant partially funded this research, including data gathered with the 6.5-meter Magellan telescope. This project used data obtained with the Dark Energy Camera, which was constructed by the Dark Energy Survey-collaborating institutions. Observations were partly obtained at Cerro Tololo Inter-American Observatory, operated by the National Optical Astronomical Observatory, operated by the Association of Universities for Research in Astronomy under contract with the National Science Foundation.

NEW TOOL for Female Reproductive Genetics

There are several different types of vectors, molecules that ferry new genetic material into an organism. This simplified diagram shows a viral vector carrying a new gene into a cell nucleus where it can be replicated.

Image reprinted with permission from yourgenome.org, Genome Research Limited www.yourgenome.org/facts/what-is-gene-therapy

The fruit fly *Drosophila melanogaster* is a powerful model organism for studying animal and human development and disease, and there are many tools to genetically modify its cells. One tool is called the Gal4/UAS two-component activation system. This tool is a biochemical method used to study gene expression—the process of turning on a gene—and gene function. Although it has been a mainstay of *Drosophila* genetics for twenty-five years, it only functions effectively in nonreproductive cells, not in egg-producing cells. It has not been known why. Now, Carnegie's Steven DeLuca and Allan Spradling have discovered why, and they have developed a new tool that can work in both cell types. *Genetics* published the research in June 2018.

The *GAL4* gene is a transcription factor. Transcription factors encode proteins that turn on genes. The Gal4 protein recognizes an activator (called UAS), which can activate a gene of interest. A special version of UAS (called UASp) was made at the Department of Embryology in 1998 to work during egg-cell development. But the fact that different tools are needed for nonreproductive cells and egg-forming cells has been a major limitation.

Steven DeLuca is a Howard Hughes Medical Institute postdoctoral fellow in the Spradling lab.

The original UAS, called pUASt is a vector—a molecule that ferries foreign genetic material into another cell—and it contains a promotor called Hsp70. As the name suggests, promotors are bits of DNA that initiate or promote gene activation. Researchers have developed several varieties to improve its expression. The promotor is a member of a family of proteins in most organisms that are important for protein folding and for protecting cells from stress. Protein-folding mechanisms are vital to life and to understanding diseases.

DeLuca and Spradling studied the differences between the UASp and UASt promoters. Their research agreed with previous reports that UASt worked better than UASp in all nonreproductive tissues while UASp worked better in the female egg-producing system.

They also looked at why UASt was weakly expressed in the female reproductive system. The evidence indicated that noncoding RNA molecules (called piRNA) orchestrated the suppression that limited UASt.

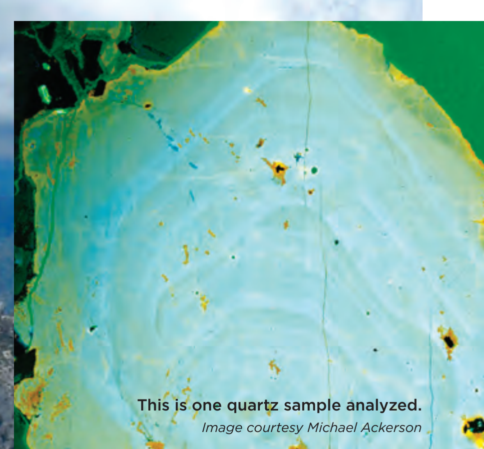
They then looked at where these UASt-piRNAs originated and what was happening and then attempted to create a new version of the UAS vector that works well in both the nonreproductive cells and the egg-producing system.

DeLuca explained, "We hypothesized that Hsp70 piRNAs might recognize UASt RNA to initiate piRNA silencing. To prevent Hsp70 piRNAs from recognizing UASt RNA, we trimmed down the UASt vector's nucleotides—basic units of DNA and RNA—to be shorter than a single piRNA. We went from 213 nucleotides to 19 nucleotides. We named this shortened variant 'UASz,' because we hoped it would be the last one anyone would make!"

The scientists found that UASz was expressed about four times higher than UASp at all stages in the egg-producing system. ■

SUPPORT:
The Helen Hay Whitney Foundation and Howard Hughes Medical Institute, in addition to Carnegie, supported this work.

Yosemite Granite Tells a Different Story About Earth's Geology



This is one quartz sample analyzed.
Image courtesy Michael Ackerson

Yosemite's half dome is a spectacular display of granite.
Image courtesy National Park Service/Don Wood, www.nature.nps.gov/geology/geologic_wonders/index.cfm

Lead author Michael Ackerson (above) was a Carnegie postdoctoral fellow from 2015 to November 2017. He is now at Rensselaer Polytechnic Institute. Carnegie staff scientist Bjørn Mysen (top) was also part of the team.
Images courtesy Michael Ackerson and Bjørn Mysen

A team of scientists including Carnegie's Michael Ackerson, now at Rensselaer Polytechnic Institute, and Bjørn Mysen revealed that granites from Yosemite National Park contain minerals that crystallized at much lower temperatures than previously thought possible. This finding upends scientific understanding of how granites form and what they can teach us about our planet's geologic history. *Nature* published the work.

Granites solidified from volcanic processes, forming igneous rocks mostly comprised of the minerals quartz and feldspar.

"Granites are the ultimate product of the processes by which our planet separated into layers, and they are key to understanding the formation of the continental crust," Ackerson said. "Minerals from granites record almost all of our planet's history, from 4.4 billion years ago to today."

So understanding the conditions under which granites form is important to geoscientists trying to unravel the processes that have shaped the Earth.

Until now, the prevailing wisdom was that the minerals that comprise granite crystallize as the molten rock cools to temperatures between about 1200 and 1300°F (650 and 700°C). Below these temperatures, the granites were thought to be completely crystallized.

It was previously known that under certain conditions some of granites' minerals could solidify at lower temperatures. So the team, which also included Nicholas Tailby of the American Museum of Natural History and Bruce Watson of Rensselaer Polytechnic Institute, used lab analysis to determine the temperatures of granite crystallization from Yosemite National Park granites.

The team employed a technique called titanium-in-quartz thermometry. By measuring the amount of titanium dissolved in the quartz crystals, the team determined the temperatures at which it crystallized within the Earth when the granites formed 90 million years ago.

They demonstrated that quartz crystals in samples of a body of granite body called the Tuolumne Intrusive Suite in Yosemite crystallized at temperatures between 885 and 1042°F (474 and 561°C), up to 200° cooler than previously thought possible for granite.

"These granites tell a different story," Ackerson added. "And it could rewrite what we think we understand about how Earth's continents form."

These findings could influence our understanding of the conditions in which the Earth's crust first formed during the Hadean and Archean Eons. They could also explain some recent observations about the temperature at which volcanic magmas exist before eruption and the mechanisms through which economically important ore deposits form. ■

SUPPORT:
NASA Astrobiology Institute supported this work.

This is a seagrass bed off the California Channel Islands. Such beds are important for marine life food and shelter. They also help fight seabed erosion, filter pathogens from the water, and absorb carbon dioxide during photosynthesis.
Image courtesy Claire Fackler, Channel Islands National Marine Sanctuary, NOAA

Can Seagrass Help Fight Ocean Acidification?

Seagrass meadows could play a limited, localized role in alleviating ocean acidification in coastal ecosystems, according to new work led by Carnegie's David Koweek and including Carnegie's Ken Caldeira, published in *Ecological Applications.*

Human-induced carbon dioxide emissions are the driving force behind global climate change. This atmospheric carbon dioxide is also absorbed into the ocean where chemical reactions with the seawater produce carbonic acid, which is corrosive to marine life, particularly shellfish that construct their shells and exoskeletons out of calcium carbonate.

Seagrasses provide an important source of food and shelter for marine animals, help fight seabed erosion, and filter bacterial pathogens from the water. They also take up carbon dioxide during photosynthesis.

Research had demonstrated that California's coastal estuaries and bays are experiencing ocean acidification. So the team tested the theory that carbon dioxide uptake by seagrass meadows could buffer the pH of local ocean water and help fight short-term effects of acidification.

They combined data from seagrass meadows in Tomales Bay, a Marin County, California, inlet, with sophisticated modeling tools that accounted for factors including the amount of seagrass within the meadow, seasonal variation in photosynthetic activity, nighttime respiration, water depth, and tidal currents.

"Local stakeholders, such as California's shellfish industry, want to know whether seagrass meadows may help to counteract ocean acidification," Koweek said. "Our results suggest that California seagrass meadows will likely offer only limited ability to counteract ocean acidification over long periods."

On average, the computer simulations predicted that the seagrass meadows would turn back the clock on ocean acidification a few decades, a small offset to the more than 150 years of acidification, which is happening more quickly with increasing fossil fuel emissions.

However, there were times when their models show that seagrass meadows were able to offer much greater buffering. These happened during periods when low tides occurred during the day, when photosynthesis was active. Koweek and Caldeira say that these offer important opportunities.

This level of buffering could make an impact in aquaculture or in natural shellfish communities where marine organisms are able to align their calcification activity with the seagrass buffering periods.

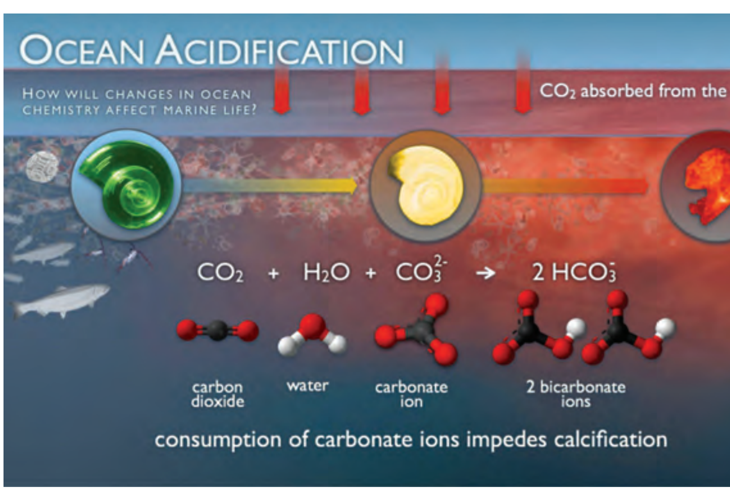
"We are starting to understand that some marine organisms, such as blue mussels, are actually able to shift the time of day in which they do most of their calcification. If other organisms are able to do the same, then even brief windows of significant ocean acidification buffering by seagrass meadows may bring substantial benefits to the organisms that live in them," Koweek said.

Koweek and Caldeira are grounded in their optimism for solutions to stop ocean acidification around the world.

"Of course, the only way to truly fight ocean acidification is to rapidly and permanently reduce the rate at which we are spewing carbon dioxide emissions into the sky," Caldeira noted.

Koweek added, "However, seagrass meadows are a critical part of California's coastline. Although our results indicate that seagrass meadows along the California coast are not likely to offer long-term buffering to fight ocean acidification, their enduring role as habitat for marine organisms, protectors against sea-level rise, and magnets of biodiversity should be more than enough reason to restore and protect these iconic ecosystems." ■

Carnegie postdoctoral researcher David Koweek was lead author on the study.
Image courtesy David Koweek



Atmospheric carbon dioxide is absorbed into the ocean where chemical reactions with the seawater produce carbonic acid, which is corrosive to marine life.
Image courtesy NOAA

SUPPORT AND COLLABORATORS:

The paper's other coauthors are Richard Zimmerman of Old Dominion University; Kathryn Hewett, Brian Gaylord, and John. J. Stachowicz of University of California, Davis; Sarah Giddings of University of California, San Diego's Scripps Institution of Oceanography; Kerry Nickols of California State University, Northridge; Jennifer Ruesink of University of Washington; and Yuichiro Takeshita of the Monterey Bay Aquarium Research Institute.

This work is a contribution of the Seagrass Ocean Acidification Amelioration Workshop of the Bodega Marine Laboratory, financial support for which was provided by California Sea Grant and the Coastal & Marine Sciences Institute of the University of California, Davis. The National Science Foundation provided partial support.

Plasma-Spewing Quasar Unveils Young Universe

Carnegie's Eduardo Bañados led a team that found a quasar with the brightest radio emission ever observed in the early universe spewing out a jet of extremely fast-moving material.

Bañados' discovery was followed up by Emmanuel Momjian of the National Radio Astronomy Observatory, which allowed the team to see with unprecedented detail the jet shooting out of a quasar that formed within the universe's first billion years. Quasars contain enormous black holes accreting matter at the centers of massive galaxies.

The findings, published in two papers in *The Astrophysical Journal*, will allow astronomers to better probe the young universe during an important period of transition to its current state.

This newly discovered quasar, called PSO J352.4034–15.3373, is one of a rare breed that doesn't just swallow matter into the black hole; it also emits a jet of plasma traveling at speeds approaching that of light. This jet makes it extremely bright in the frequencies detected by radio telescopes. Although quasars were identified more than 50 years ago by their strong radio emissions, we now know that only about 10% of them are strong radio emitters.

What's more, quasars contain enormous black holes accreting matter at the centers of massive galaxies of the universe, taking 13.7 billion years to reach Earth. P352-15 is the first quasar with clear evidence of radio jets seen within the first billion years of the universe.

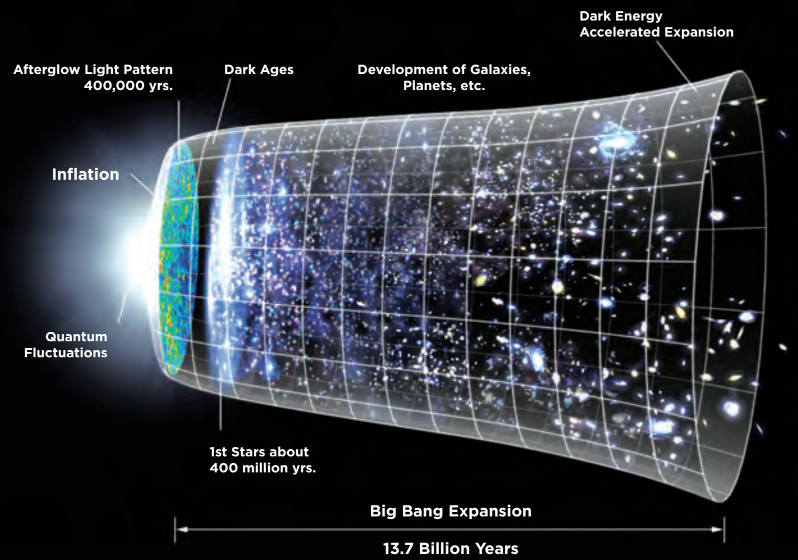
"There is a dearth of known strong radio emitters from the universe's youth, and this is the brightest radio quasar at that epoch by an order of magnitude," Bañados said.

"This is the most detailed image yet of such a bright galaxy at this great distance," Momjian added.

The Big Bang started the universe as a hot soup of extremely energetic particles that were rapidly expanding. As the particles expanded, they cooled and coalesced into neutral hydrogen gas, which left the universe dark, without any luminous sources, until gravity condensed matter into the first stars and galaxies. About 800 million years after the Big Bang, the energy released by these first galaxies caused neutral hydrogen to get excited and lose an electron, or ionize, a state that the gas has remained in since that time.

It's highly unusual to find radio jet-emitting quasars such as this one from the period just after the universe's lights came back on.

"The jet from this quasar could serve as an important calibration tool to help future projects penetrate the dark ages and perhaps reveal how the earliest galaxies came into being," Bañados concluded. ■



The universe formed some 13.7 billion years ago with the Big Bang. The team found a plasma-spewing quasar with the brightest radio emission ever observed, dating to 13 billion years ago when the universe was in its infancy.
Image courtesy NASA/WMAP Science Team

An artist's conception of a radio jet spewing out fast-moving material from the newly discovered quasar.
Image courtesy Robin Dienel, Carnegie Institution for Science

(Below) Eduardo Bañados is the Carnegie-Princeton Fellow at the Observatories.
Image courtesy Cindy Hunt

SUPPORT AND COLLABORATORS:

The European Research Council funded this research in part. This paper includes data gathered with Carnegie's 6.5-meter Magellan telescopes located at Las Campanas Observatory in Chile.

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

The Pan-STARRS1 (PS1) surveys and the PS1 public science archive have been made possible through contributions by the Institute for Astronomy; University of Hawaii; Pan-STARRS Project Office; Max-Planck Society and its participating institutes; Max Planck Institute for Astronomy, Heidelberg; Max Planck Institute for Extraterrestrial Physics, Garching; Johns Hopkins University; Durham University; University of Edinburgh; Queen's University Belfast; Harvard-Smithsonian Center for Astrophysics; Las Cumbres Observatory Global Telescope Network Inc.; National Central University of Taiwan; Space Telescope Science Institute; NAS; National Science Foundation; University of Maryland; Eötvös Loránd University; Los Alamos National Laboratory; and the Gordon and Betty Moore Foundation.

This is an artist's impression of protoplanets forming around a young star.
Image courtesy NRAO/AUI/NSF; S. Dagnello

NEW WAY TO FIND BABY EXOPLANETS

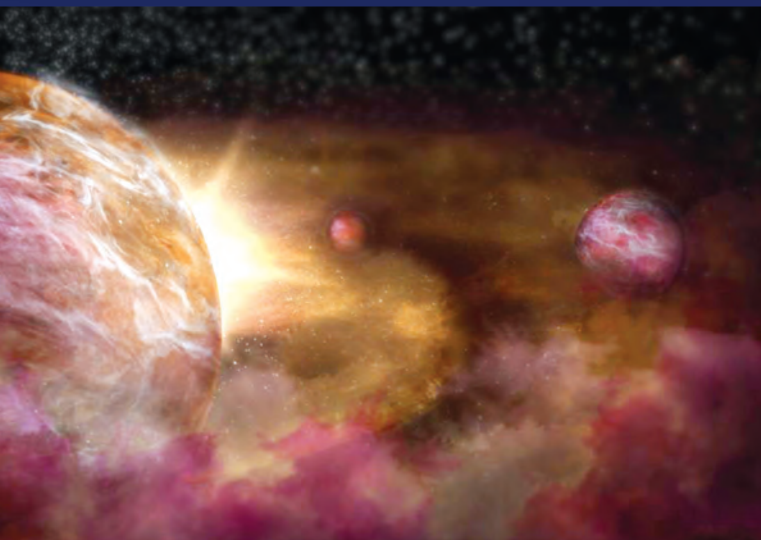
New work from an international team of astronomers including Carnegie postdoctoral fellow Jaehan Bae used archival radio telescope data to develop a new method for finding very young extrasolar planets. Of the thousands of exoplanets discovered by astronomers, only a handful are in their formative years. The new technique successfully confirmed the existence of two previously predicted Jupiter-mass planets around the star HD 163296. The *Astrophysical Journal Letters* published their work.

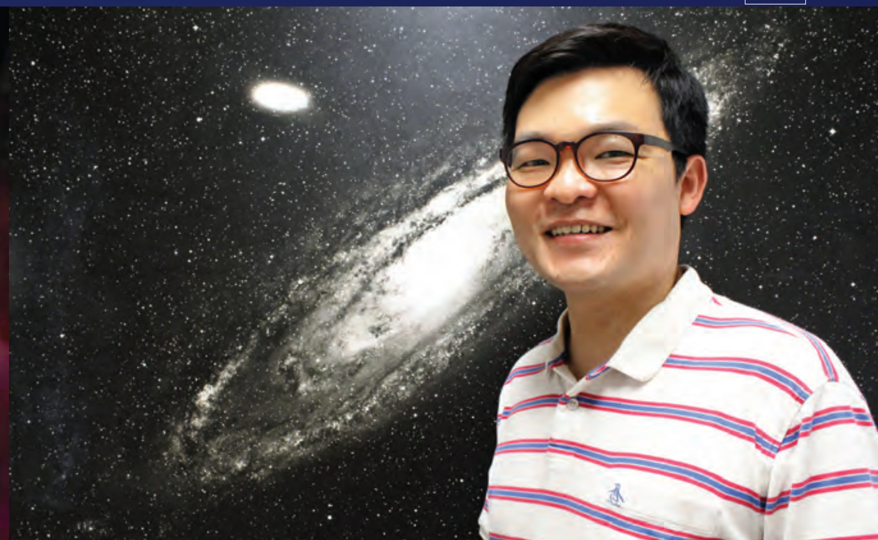
Young stars are surrounded by rotating disks of gas and dust, from which planets are formed. Finding more baby planets will help astronomers answer the many outstanding questions about planet formation, including the process by which our own Solar System evolved.

The 60-odd radio telescope antennae of the Atacama Large Millimeter/submillimeter Array (ALMA) have been able to image these disks with never-before-seen clarity.

The research team—including lead author Richard Teague and coauthor Edwin Bergin of the University of Michigan, Tilman Birnstiel of the Ludwig Maximilian University of Munich, and Daniel Foreman-Mackey of the Flatiron Institute—used archival ALMA data to demonstrate that anomalies in the velocity of the gas in these rotating protoplanetary disks can be used to indicate the presence of giant planets.

SUPPORT:
A grant from the NASA supported this research. The NASA High-End Computing Program, through the NASA Advanced Supercomputing Division at Ames Research Center Computing, provided resources.
ALMA is a partnership of European Southern Observatory (ESO) (representing its member states), National Science Foundation (USA), and National Institutes of Natural Sciences (Japan), together with National Research Council (Canada), National Science Council of Taiwan and Academia Sinica Institute of Astronomy and Astrophysics (Taiwan), and Korea Astronomy and Space Science Institute (Korea), in cooperation with Chile. The Joint ALMA Observatory is operated by ESO, Associated Universities, Inc./National Radio Astronomy Observatory (NRAO), and National Astronomical Observatory of Japan. The NRAO is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc. Tilman Birnstiel acknowledges funding from the European Research Council (ERC) under the European Unions Horizon 2020 Research and Innovation program under grant agreement No. 714769.





Jaehan Bae has been the Rubin Postdoctoral Fellow at Terrestrial Magnetism since September 2017.
Image courtesy Roberto Molar Candanosa

Other techniques for finding baby planets in the disks surrounding young stars are based on observations of the emission coming from a disk's dust particles. But dust only accounts for 1% of a disk's mass, so the team decided to focus instead on the gas that comprises 99% of a young disk.

Their new technique focuses on the motion of the gas, probing radial pressure gradients in the gas to see the shape of the perturbations—like swirls and eddies—allowing astronomers to make a more-precise determination of the masses and locations of planets embedded in the disk.

Their new method successfully confirmed the previously predicted existence of two Jupiter-mass planets around HD 163296. They orbit at distances of 83 and 137 times the distance between the Sun and the Earth, but the host star is much brighter than the Sun.

"Although dust plays an important role in planet formation and provides us invaluable information, it is the gas that accounts for 99% of protoplanetary disks' mass. It is therefore crucial to study kinematics, or motion, of the gas to better understand what is happening in the disks we observe," explained Bae.

"This method will provide essential evidence to help interpret the high-resolution dust images coming from ALMA. Also, by detecting planets at this young stage we have the best opportunity yet to test how their atmospheres are formed and what molecules are delivered in this process," said lead author Teague. ■

The Atacama Large Millimeter/submillimeter Array (ALMA) is located on the Chajnantor plains in Chile, nearly 16,000 feet (5,000 meters) above sea level.
Image courtesy NRAO/AUI/NSF

Staff Scientist Emeritus, Astronomer John Graham, Dies

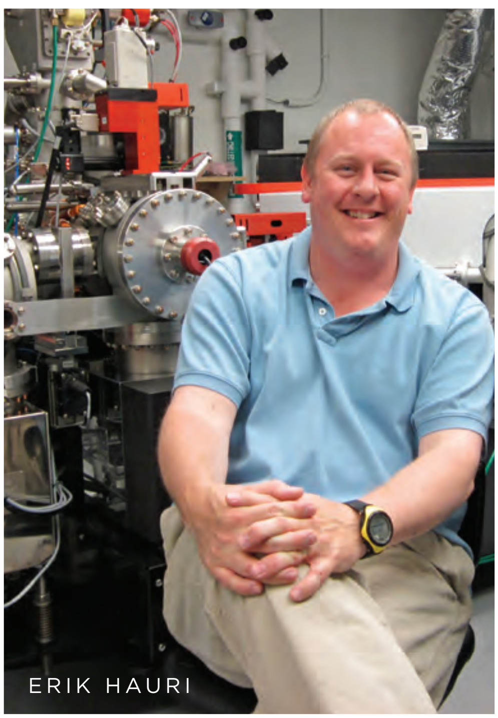
JOHN GRAHAM

John A. Graham, Carnegie's staff scientist emeritus of the Department of Terrestrial Magnetism, died of a brain tumor on Thursday, September 13, 2018, in his home in Washington, D.C.

He was born on July 28, 1939, and went on to receive his Ph.D. from the Australian National University in 1964. Prior to joining Carnegie, he was an astronomer at the Cerro Tololo Inter-American Observatory in Chile. He was hired as staff scientist in Astronomy in 1985 and retired in April 2002. His research mostly focused on star formation in the Milky Way and in external galaxies.

Graham was active in numerous astronomical societies over the years, including the American Astronomical Society, where he was vice president between 1984 and 1986 and secretary between 2003 and 2009. He was a long-time member, and a board director, of the Astronomical Society of the Pacific. Concurrent with his work at Carnegie, he served as a program director for the Division of Astronomical Sciences at the National Science Foundation from 2000 to 2001. ■

Geochemist Erik Hauri, Who Found Lunar Water, Dies at 52



ERIK HAURI

Image courtesy Steve Jacobsen, Northwestern University

Carnegie geochemist at the Department of Terrestrial Magnetism, Erik Hauri, upended our understanding of the Moon's formation. He died Wednesday, September 5, 2018, in North Potomac, MD, from cancer. He was 52.

He was born April 25, 1966, in Waukegan, Illinois. Hauri worked tirelessly to understand how planetary processes affect the chemistry of the Earth, Moon, and other objects, and to understand the origin and evolution of planetary bodies. Hauri joined Carnegie as a staff scientist in 1994. He focused on water, believing that understanding its origin and distribution among the celestial bodies would help unravel the evolution of the Solar System.

Scientists believed that the Moon was depleted in water because of its violent formation. In 2008, Hauri and team revealed that tiny beads of lunar volcanic glass collected during the Apollo missions contained water. They later found water in the lunar interior, and that the Moon's mantle contained as much water as our own and that the lunar water supply originated from Earth.

These results challenged long-held beliefs about the Moon's formation. Today scientists are trying to reconcile a wet Moon with Moon formation theories.

"Erik's dedication to advancing the capabilities of modern instrumentation allowed him to disprove a 40-year-old assumption that the Moon contained no water," said Richard Carlson, director of the Department of Terrestrial Magnetism. "His insight into these questions will be sorely missed."

Hauri, the first in his family to attend college, received a B.S. in geology and marine science with honors from the University of Miami in 1988 and a Ph.D. in geochemistry from the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution in four years, 1992. He received numerous recognitions for his work.

Hauri is survived by his wife, Tracy; his children, Kevin, Matthew, and Michaela; his father, Larry Hauri; sister, Stacy Mariano; brother, Roger Hauri; and their families.

Hauri requested that in lieu of flowers, donations be made in support of the Merle A. Tuve Fellowship fund, which supports visiting scientists for short stays. ■

See carnegiescience.edu/ErikHauri to donate to this fund.

Carnegie's Las Campanas Observatory in Chile has some of the darkest skies and best viewing conditions found anywhere, and astronomers remain vigilant in keeping light pollution to a minimum.
Image courtesy Yuri Beletsky

A group of astronomers presented the case against light pollution to Chilean authorities.

Las Campanas Astronomers Take On Light Pollution

A group of astronomers from Carnegie's Las Campanas Observatory (LCO) including Mark Phillips and Guillermo Blanc, along with Miguel Roth from the Giant Magellan Telescope Organization, recently presented the case against light pollution to Chilean authorities.

Combating light pollution is not about demanding complete darkness. It is about illuminating human spaces well, Blanc explained. He reported on the effects of light from cities, highways, and mines near the nation's biggest astronomical observatories.

Experts from diverse fields ranging from biology, astronomy, and medicine to architecture, urban planning, and design presented their light pollution concerns with a goal of reviewing and improving the state of Chile's public policies on the matter.

Of particular concern for astronomy at Las Campanas and nearby La Silla is the Algarrobo highway. Blanc suggested downward-facing lights with limited emissions that are monochromatic, such as filtered and "amber"-colored LEDs, would improve the situation.

Other presentations included details about how seabird populations, particularly fledglings, are affected by artificial lights, the impact of light pollution on human sleep cycles, and how our circadian rhythms are altered by shifting sleep schedules.

The nation's first lighting-related regulations date to 1998, and they apply only to northern Chile, to mitigate negative effects on astronomical observations. In 2012 a new ordinance was created, which considered additional concerns such as limits on the intensity of emitted light, the angle of emission, and the wavelength range allowed.

The discussion was part of the inaugural International Day of Light as proclaimed by UNESCO for which there were events planned around the world. The Chilean program was organized by national science and technology agencies and other groups to draw attention to problems caused by light pollution.

"This event was the product of a long-term relationship between the international observatories in Chile, including Las Campanas, and the Chilean government to work on the protection of the Atacama Desert as a natural laboratory for astronomical research," Blanc said. "It shows Carnegie's commitment to have a positive social and environmental impact in LCO's host country." ■

Embryology Goes to Washington

In July, members of the Department of Embryology showed off some of their science to Congressional members and Capitol Hill staff at the Celebrate Life Sciences Fair. The Zheng lab, Halpern lab, and BioEYEs science outreach program led demonstrations with zebrafish, jellyfish, and coral. They also chatted with policymakers about the importance of federal science funding. Over 120 visitors attended, including three members of Congress. ■

Terrone Jasper discusses the BioEYES science outreach program. It uses zebrafish to teach students and teachers about development, genetics, and more.

Over 120 visitors attended the Capitol Hill event that emphasized the importance of federal funding on science.
Images courtesy Miriam Alexander-Kearns

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FALL 2018

Capital Science Evening Lectures

Live Streaming, Live Tweets, and Archived for Later Viewing!

The Washington, D.C., Capital Science Evening Lectures are all free and open to the public. Registration is required. They feature some of the most extraordinary researchers of our time. Many of these events are webcast live and/or recorded. The lectures are held at 1530 P St., NW, and are listed at right.

For details see https://carnegiescience.edu/events


1


2

TUESDAY, SEPTEMBER 18, 2018 - 6:30 PM

Shining a Light on Gravitational Waves

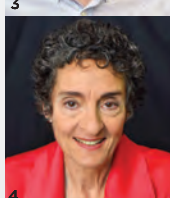
DR. MARIA DROUT[1]
Assistant Professor, Department of Astronomy & Astrophysics, University of Toronto; Research Associate, Carnegie Observatories, Carnegie Institution for Science

DR. TONY PIRO[2]
Staff Scientist, Carnegie Observatories, Carnegie Institution for Science

DR. BEN SHAPPEE[3]
Assistant Professor, University of Hawaii

Registration opens on August 18 **#SWOPETEAM**


3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WEDNESDAY, OCTOBER 3, 2018 - 6:30 PM

What Can the Developing Brain Teach Us About Alzheimer's Disease?

DR. CARLA SHATZ[4]
Sapp Family Provostial Professor & Professor of Biology and Neurobiology, Stanford University; David Starr Jordan Director, Stanford Bio-X James H. Clark Center; Kavli Prize Laureate

Registration opens on September 3 **#DEVELOPINGBRAIN**

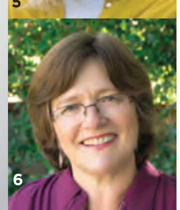

5

WEDNESDAY, OCTOBER 17, 2018 - 6:30 PM

Restoring and Protecting Earth's Wild Beauty

KRISTINE MCDIVITT TOMPKINS[5]
Cofounder, Tompkins Conservation; Carnegie Medal of Philanthropy recipient

Registration opens on September 17 **#WHYPARKS**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THURSDAY, DECEMBER 6, 2018 - 6:30PM

The Big Ones - The Natural Disasters That Have Shaped Our Science and Our Culture

DR. LUCY JONES[6]
Founder and Chief Scientist, Dr. Lucy Jones Center for Science and Society

Registration opens on November 6 **#THEBIGONES**