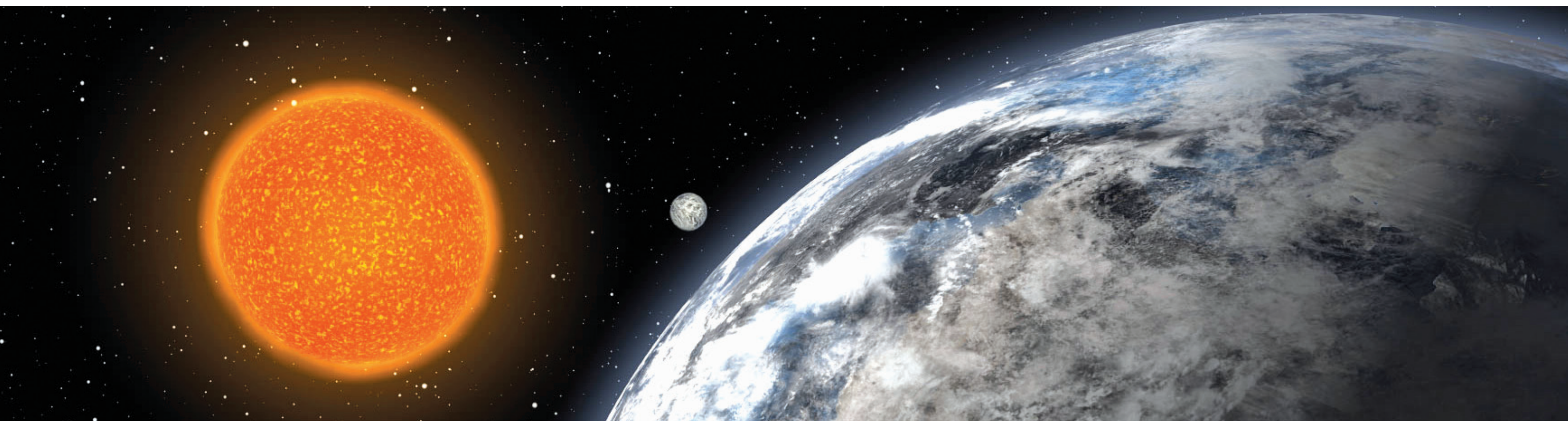
# CarnegieScience

The Newsletter of the Carnegie Institution for Science

SUMMER 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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LETTER FROM THE INTERIM CO-PRESIDENTS
JOHN MULCHAEY AND YIXIAN ZHENG

# Welcome Eric D. Isaacs, Carnegie's 11th President!

Please join us in welcoming Dr. Eric D. Isaacs as Carnegie Science's 11th president. Our board of trustees unanimously appointed him on May 10. Eric joins us from the University of Chicago. As he takes the helm, we will return to our scientific research and continue directing our departments at the Observatories and Embryology. Our tenure as interim co-presidents has been particularly fulfilling as we learned so much more about both the breadth of Carnegie science and our business operations.

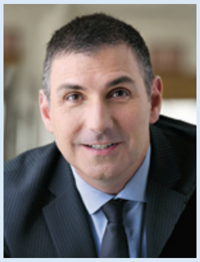
We also served as members of the presidential search committee. We are grateful for the vigilance, dedication, and care that the other search members—trustees Michael Duffy, Sandy Faber, Steve Fodor, Suzanne Nora Johnson, and Cristián Samper—took to ensure that Carnegie Science was able to attract the strongest candidates possible.

Eric has been the Executive Vice President for Research, Innovation and National Laboratories and the Robert A. Millikan Distinguished Service Professor of Physics at the University of Chicago. He directly oversaw Argonne National Laboratory and Fermi National Accelerator Laboratory for the U.S. Department of Energy's Office of Science. Additionally, he presided over the university's partnership with the Giant Magellan Telescope project, of which Carnegie is a founding partner. He has also served on the board of the Marine Biological Laboratory at Woods Hole, which is affiliated with the university.

Eric's research interests are in condensed matter physics and quantum materials. He has a Ph.D. in physics from MIT and a bachelor's degree from Beloit College. From 2014 to 2016, he served as provost at the University of Chicago. Prior to that he was director of Argonne National Laboratory for five years, where he had been since 2003, with a joint appointment to the physics department. He also worked at Bell Laboratories for 15 years.

The scope of Eric's research expertise and management is a great match for Carnegie as it spans the life and physical sciences, including astronomy. In addition, he is experienced in computing and data science, which is essential to advancing Carnegie's research programs. As a proven leader managing large, complex organizations and partnerships, we could not be happier with this choice.

The candidate pool was particularly strong, and Eric represented the best mix of all the qualities, skills, and experience that we were seeking. We are confident that he will lead with strength, vision, and innovation and that Carnegie's scientific programs will flourish as we continue our second century of pioneering research.



**John Mulchaey and Yixian Zheng**
*Interim Co-presidents*

Carnegie's Allan Spradling

# Carnegie's Allan Spradling Awarded the 23rd March of Dimes and Richard B. Johnson, Jr., MD Prize in Developmental Biology

**Allan C. Spradling,** director emeritus of Carnegie's Department of Embryology, has been awarded the 23rd March of Dimes and Richard B. Johnson, Jr., MD Prize in Developmental Biology as "an outstanding scientist who has profoundly advanced the science that underlies our understanding of prenatal development and pregnancy."

Department director and Carnegie interim co-president Yixian Zheng remarked, "Allan is a legend in developmental biology. We are all delighted by this well-deserved recognition of Allan's groundbreaking research."

Spradling's decades of scientific accomplishments cover a broad spectrum of advancements. Since the early 20th century, the fruit fly *Drosophila melanogaster* has been used as the model organism for understanding genetics. Spradling and colleagues have developed this fly into a model for linking classical genetics with specific physiological processes for understanding human biology.

More recently Spradling has been known for his work on stem cells in living tissues and the "niches" or specialized microenvironments in which stem cells grow and change, which has helped guide mammalian stem cell research. Lately, Spradling's group has concentrated on understanding how oocytes (young eggs) are made, a fundamental process that underlies embryonic development.

Spradling has been awarded many prizes, appointments, and accolades for his work. The March of Dimes Prize has been awarded annually since 1996 to honor investigators whose research has profoundly advanced the science that underlies the understanding of birth defects. The March of Dimes Foundation created the prize as a tribute to Dr. Jonas Salk shortly before his death in 1995. Dr. Salk received foundation support for his work on the polio vaccine.

The prize includes a cash award of $150,000 and a silver medal cast by Tiffany & Co. in the design of the Roosevelt dime, in recognition of President Franklin Delano Roosevelt founding the organization in 1938 with a mission to conquer polio.

Spradling received the award in May at the annual meeting of the Pediatric Academic Societies in Toronto, Canada, where he presented a talk. ■

## TRUSTEE NEWS

# Carnegie Trustees Sandra Faber and Mary-Claire King Receive Prestigious Awards

**Former Carnegie fellow and current trustee Sandra Faber** was selected to receive the 2018 American Philosophical Society's Magellanic Premium Medal. The medal is the nation's oldest for scientific achievement. It was established in 1786. It is awarded from time to time "to the author of the best discovery or most useful invention related to navigation, astronomy, or natural philosophy..."

Faber is the University of California, Santa Cruz, University Professor of Astronomy and Astrophysics and has been a Carnegie trustee since 1985. Her pioneering research on the formation and evolution of galaxies, the evolution of structure in the universe, and concepts such as the "Great Attractor" and "cold dark matter" has gained her world acclaim. She is also a leading authority on telescopes and astronomical instrumentation.

**Carnegie trustee Mary-Claire King** was awarded a 2018 Dan David Prize of the Dan David Foundation in Tel Aviv. It "recognizes and encourages innovative and interdisciplinary research that cuts across traditional boundaries and paradigms. It aims to foster universal values of excellence, creativity, justice, democracy, and progress and to promote the scientific, technological, and humanistic achievements that advance and improve our world."

King is the American Cancer Society Professor in the Department of Medicine and the Department of Genome Sciences at the University of Washington. She is a world leader in human genetics and is known best for her research on the BRCA1 gene involved in breast and ovarian cancer. ■

# Synthesizing Elusive TITANIC NITRIDE

A team of experimental and computational scientists led by Carnegie's Tim Strobel and Venkata Bhadram have synthesized a long sought-after form of titanium nitride, $Ti_3N_4$, which has promising mechanical and optoelectronic properties—the combination of electronics and light.

Standard titanium nitride (TiN), with a one-to-one ratio of titanium and nitrogen, exhibits a crystal structure resembling that of table salt—sodium chloride, or NaCl. It is a metal with abrasive properties and used for tool coatings and electrode manufacturing. Titanium nitride with a three-to-four ratio of titanium and nitrogen, called titanic nitride, has remained elusive, despite theoretical predictions of its existence and the fact that nitrides with this ratio have been identified for the other members of titanium's group on the period table, including zirconium.

Strobel and Bhadram's team—with Carnegie's Hanyu Liu and Rostislav Hrubiak, as well as Vitali B. Prakapenka of the University of Chicago, Enshi Xu and Tianshu Li of George Washington University, and Stephan Lany of the National Renewable Energy Laboratory—undertook the challenge. Their work is published in *Physical Review Materials*.

They created $Ti_3N_4$ in a cubic crystalline phase using a laser-heated diamond anvil cell, which was brought to about 740,000 times normal atmospheric pressure (74 gigapascals) and about 4000°F (2500 K). Advanced X-ray and spectroscopic tools confirmed the crystalline structure, and theoretical model-based calculations allowed them to predict the thermodynamic nature and physical properties of $Ti_3N_4$.

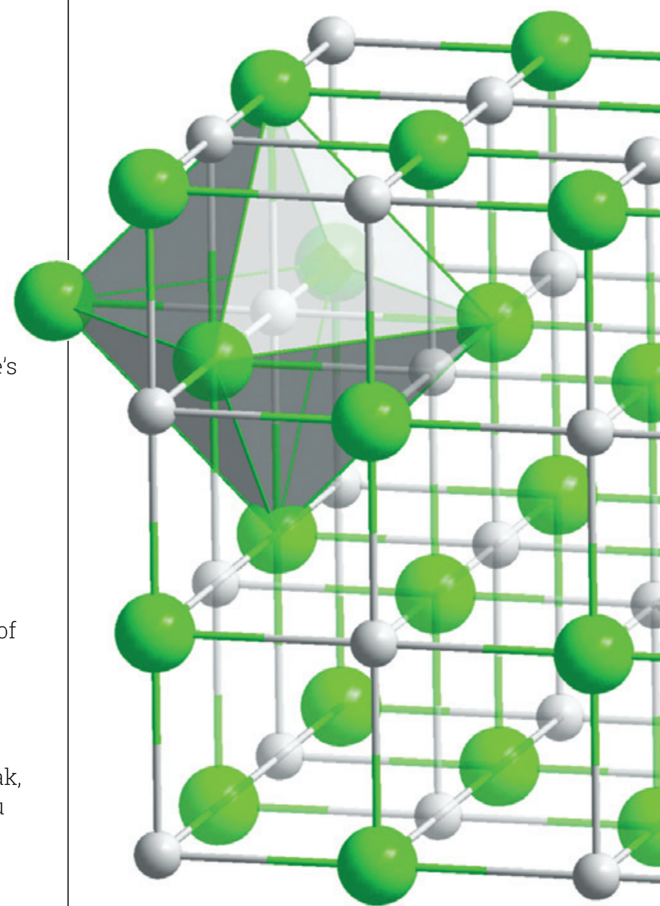
Table salt-like TiN is metallic, meaning it can conduct a flow of electrons that makes up a current. But cubic $Ti_3N_4$ is a semiconductor, which means that it can have its electrical conductivity turned on and off. This possibility is tremendously useful in electronic devices. Titanium-based semiconductors are particularly popular as catalysts for solar water-splitting reactions to produce hydrogen, a clean renewable-energy.

This ability to switch conductivity on and off is possible because some of a semiconductor's electrons can move from lower-energy insulating states to higher-energy conducting states when subjected to an input of energy. The energy required to initiate this leap is called a band gap. The band gap for cubic $Ti_3N_4$ is larger than expected based on previous model predictions. Furthermore, like metallic TiN, $Ti_3N_4$ is expected to exhibit excellent mechanical and wear resistance properties.

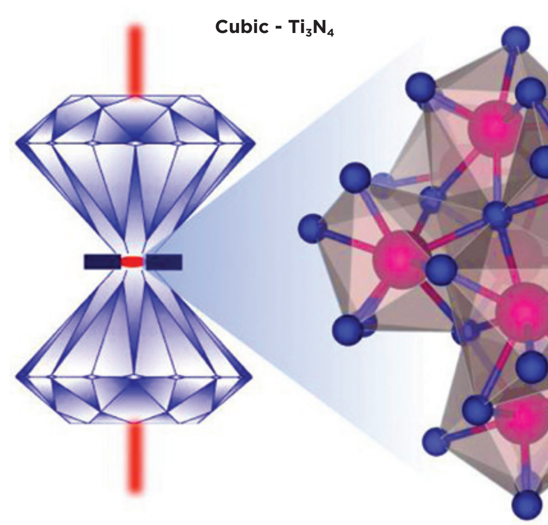
"To our knowledge this is the first experimental report on semiconducting titanium nitride," said lead author Bhadram. "We believe that this work will stimulate further experimental and theoretical efforts to design new ways to scale up the synthesis of $Ti_3N_4$ at ambient pressure." ■

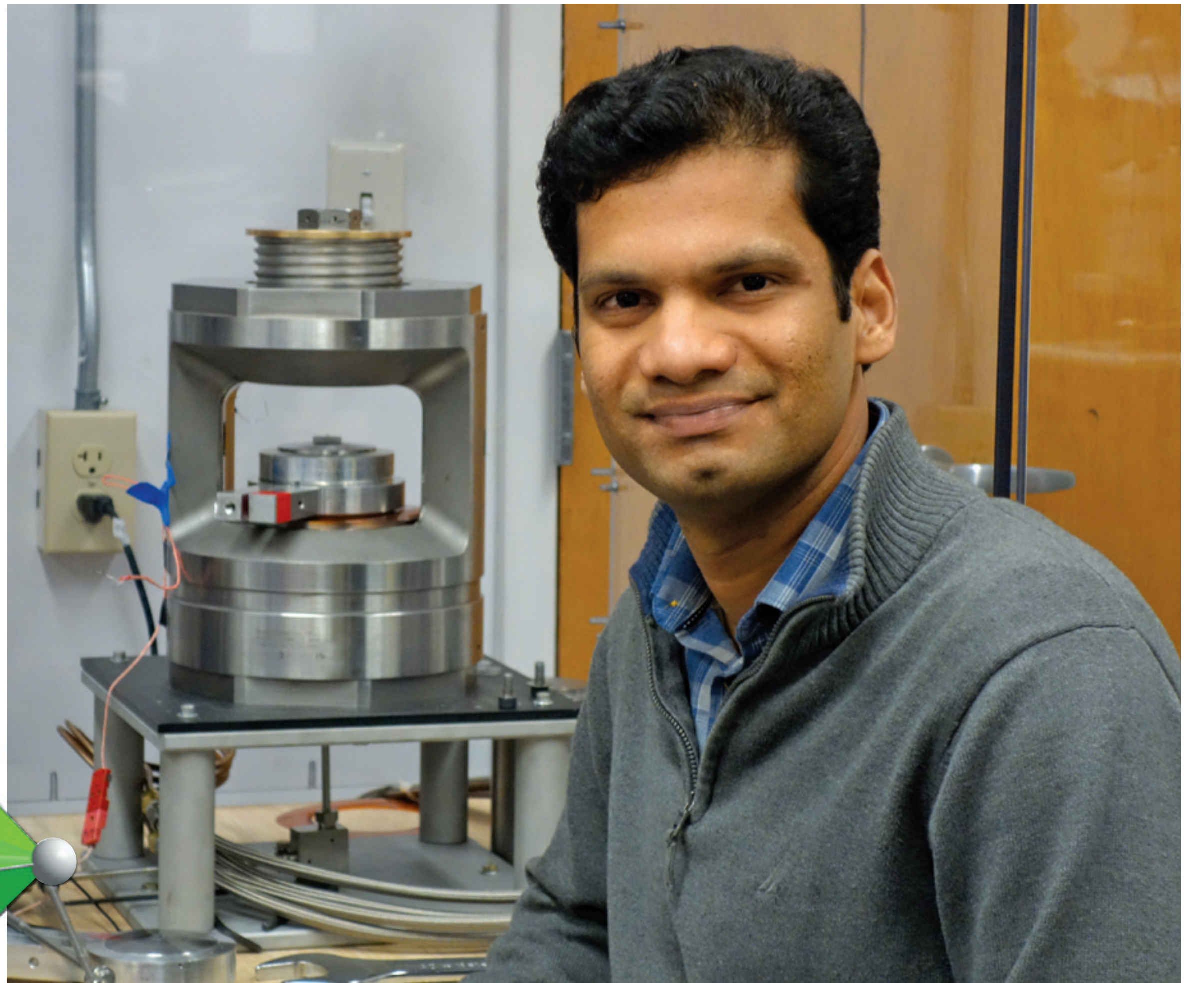
**SUPPORT:**
Energy Frontier Research in Extreme Environments Center (EFree), an Energy Frontier Research Center (EFRC) funded by the U.S. Department of Energy (DOE), Office of Science, supported this work.

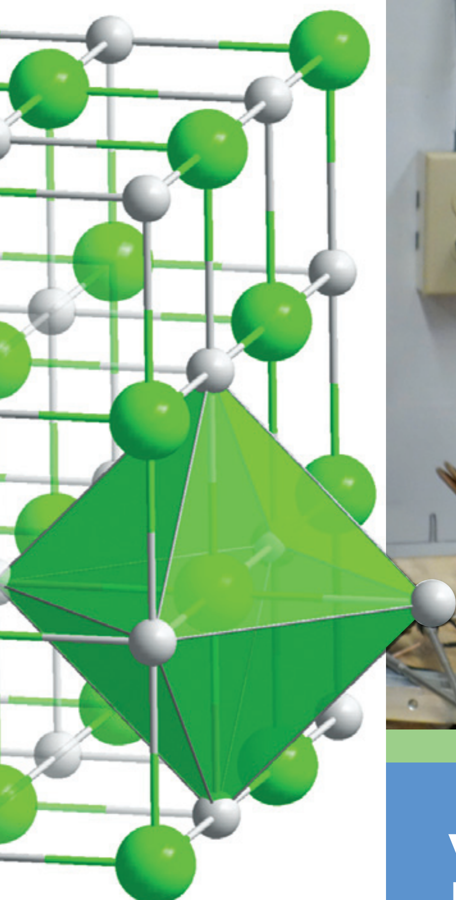
Portions of this work were performed at GeoSoilEnviroCARS and HPCAT, Advanced Photon Source, Argonne National Laboratory. The National Science Foundation–Earth Sciences and DOE–GeoSciences supports GeoSoilEnviroCARS.

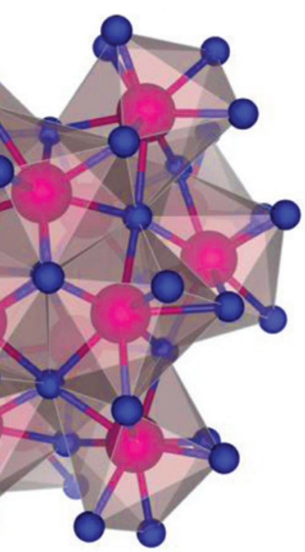


The structure of sodium chloride, table salt (above), is compared to the new, cubic form of titanium nitride, called titanic nitride (below) with its three-to-four ratio. The latter can be synthesized under extreme pressures and temperatures in a laser-heated diamond anvil cell, illustrated on its left.
*Images courtesy Wiki and Venkata Bhadram*









# **Venkata Bhadram** Receives Ninth Postdoctoral Innovation and Excellence Award

Strobel lab postdoctoral researcher Venkata Bhadram was lead author on the study and the most recent recipient of Carnegie's Postdoctoral Innovation and Excellence (PIE) Award. PIE Award recipients receive a cash prize for their exceptionally creative approaches to science, strong mentoring, and contributing to the sense of campus community. The PIE Awards are made through nominations from the departments and are chosen by the Office of the President.

According to Strobel, Bhadram "is one of the best young scientists in high-pressure research and is poised to become a world leader in the field." Bhadram started his postdoc in the Energy Frontier Research in Extreme Environments Center (EFree), which uses extreme pressure and temperature conditions to advance energy science.

By the end of his postdoc, Bhadram will have published over six important papers. He was the first to discover titanium pernitride ($TiN_2$) and cubic titanic nitride ($Ti_3N_4$), promising materials for technological applications. He was also the first to discover a rock salt-type modification of $ZnSiP_2$, a possible use in multijunction solar cell applications, which allow absorption of a broader range of wavelengths. Bhadram performed the first photocatalytic water-splitting measurements on novel zinc-manganese oxide solid solutions in the structure to break hydrogen and oxygen apart using light, to possibly produce clean hydrogen-burning fuel, among other accomplishments.

Bhadram is eager to learn new experimental and theoretical methods. He was a key developer of the 250-ton Paris-Edinburgh press used for recovering cubic millimeters of samples from experiments. The team developed their own custom assemblies and anvil designs and now perform routine high-pressure runs.

Bhadram also lectures, including an excellent and accessible introductory lecture on solid-state physics. He regularly volunteers to work with visiting students, from high school to postdoctoral levels. ■

# Smoking Gun: Forming an Ultracompact Dwarf Galaxy

**To unravel the formation history of an irregularly shaped galaxy,** Carnegie's François Schweizer, Dan Kelson, and Edward Villanueva, with colleagues, observed the late-stage merging galaxy NGC 7727 using the Hubble Space Telescope and the du Pont and Magellan Clay telescopes at Carnegie's Las Campanas Observatory. This galaxy is relatively bright with two unequal tails formed by gravitational tidal processes. Interestingly, it has surprisingly little gas, which rotates in the opposite direction to the rotation of the stars. It also has two bright internal knots called nuclei. They appear close by astronomical standards, only some 1,600 light years apart. Although similar in distance from us, the nuclei are very different otherwise.

Except for the presence of a second nucleus, this galaxy shares many properties with other recent merger remnants. The researchers compared its "Nucleus 2" with well-studied ultracompact dwarf (UCD) galaxies. They suggest it may be the best case yet for a recently formed, massive UCD that resulted from the tidal stripping of a gas-rich disk galaxy.

Ultracompact dwarf galaxies are unusually dense, contain old stars, and are brighter and more massive than the Milky Way's biggest spherical stellar clusters called globular clusters. They are also much more compact than typical dwarf galaxies. The researchers imaged the object and took light intensity measurements and spectroscopy of NGC 7727. When light from a celestial object is split into its constituent color spectra, astronomers can discern chemistry, temperature, speed, and more.

The primary nucleus of NGC 7727, dubbed Nucleus 1, has old red stars. It is "red and dead" and lacks any signs of an active central black hole. Nucleus 2, previously thought to be a Milky Way foreground star, by contrast is very compact, bright, and appears to have had recent, active star formation in addition to older stars. It also contains a central source of X-ray emission, suggesting a black hole.

Although Nucleus 2 shares many properties with UCDs, it also features some that are distinctly different: it is more massive and has a unique post-starburst spectrum and a blue tidal stream—blue stars are young. Most of its stars formed over 10 billion years ago, but some 35% appear to have formed between 0.5 and 1.8 billion years ago perhaps in two different starburst sessions. In combination, these properties suggest that Nucleus 2 is the clearest case yet of a recently formed UCD.

The researchers conclude that Nucleus 2 formed recently as a UCD through a merger and continues being stripped, meaning it is currently evolving.

Schweizer remarked: "Astronomers believe that extended star-formation histories or the presence of tidal streams would be powerful, 'smoking guns' for UCDs forming as nuclei stripped of their host galaxies. Only a few such signatures have been found to date. Uniquely, Nucleus 2 features both of these smoking-gun signatures, which might mean that NGC 7727 experienced one or maybe two mergers during the past few billion years. The most recent merger involved a gas-rich disk companion, the host galaxy of Nucleus 2, and began about 2 billion years ago. Now Nucleus 2 orbits within NGC 7727 like the naked pit of a peach stripped of its flesh." ■

1

❶ This illustration shows an ultracompact dwarf galaxy (enlarged 20x) in comparison to the Milky Way.

*Image courtesy European Southern Observatory*

2

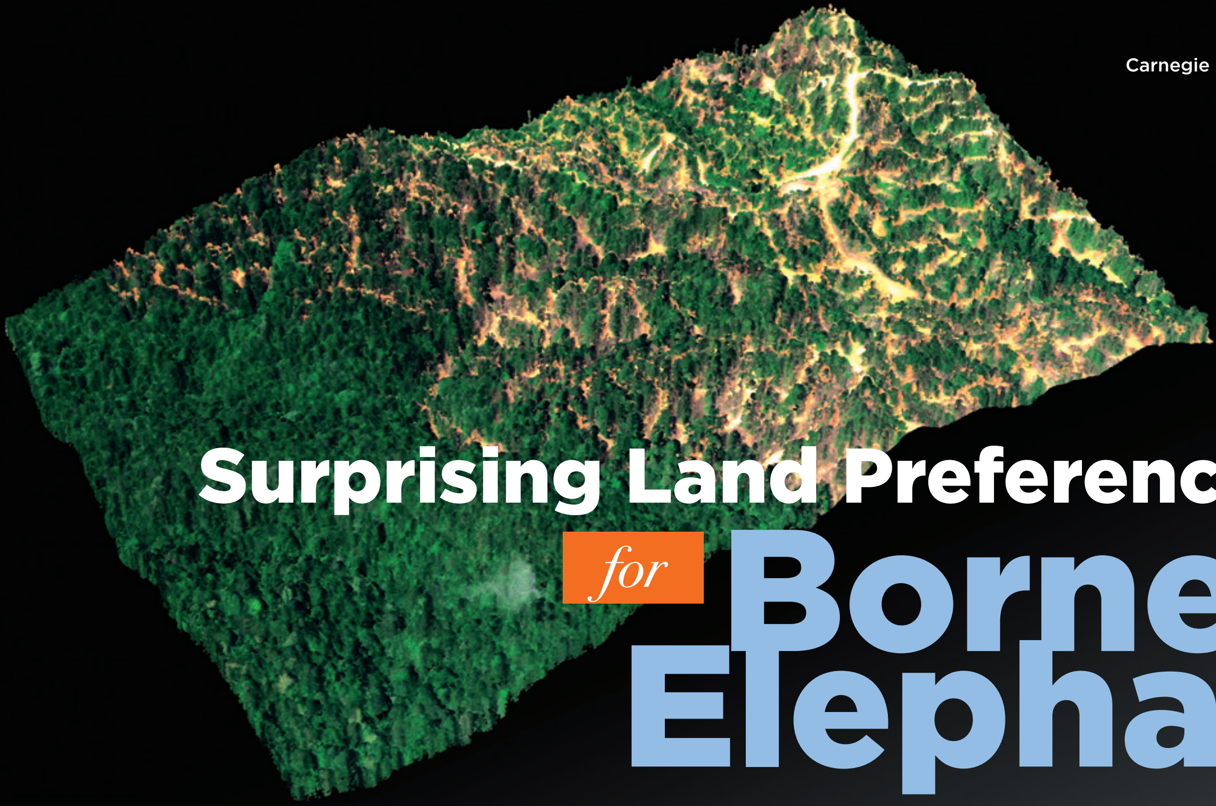
❷ Carnegie's François Schweizer, Dan Kelson, and Edward Villanueva, with colleagues Patrick Seitzer (University of Michigan) and Bradley Whitmore (Space Telescope Science Institute), imaged the irregularly shaped galaxy NGC 7727 (left) and took light intensity measurements and spectroscopy using the Hubble Space Telescope and the du Pont and Magellan Clay telescopes at Carnegie's Las Campanas Observatory to understand its formation history. The close-up image on the right shows the two nuclei. The smaller, bright one was mistaken for a star in the Milky Way for many years.

*Images courtesy Ivanhoe Girls' Grammar School Astronomy Club, Samuel Carbone (Trinity College), Travis Rector, and Australian Astronomical Observatory (left) and François Schweizer (right).*

3

❸ Carnegie's Dan Kelson (left) and François Schweizer (right) were coauthors on the study.

*Image courtesy Cindy Hunt*



This image is an oblique 3-D view of the rainforest in Sabah produced via instrumentation on the flying Carnegie Airborne Observatory.
*Image courtesy Carnegie Airborne Observatory*

# Surprising Land Preference *for* Borneo's Elephants

**The future survival of Bornean elephants may depend on degraded forests.**
A new study, published in the journal *Biological Conservation,* finds that forests of surprisingly short stature are ideal for these mammoth beasts.

"Our study indicates that forests with a mean canopy height of 43 feet (13 meters) were those most utilized by Bornean elephants. These forests are consistent with degraded landscapes or those recovering from previous logging, or clearance," remarked lead author Luke Evans, a postdoctoral researcher at Carnegie and Danau Girang Field Centre, Cardiff University, in Sabah, Malaysia, on the island of Borneo. "The study utilized GPS tracking data from 29 individual elephants that were collared across Sabah, providing high-resolution, multiyear data."

The study paired the GPS tracking data for each elephant with airborne laser-based images of forests in Sabah, providing high-resolution 3-D maps of forest canopy height and structure.

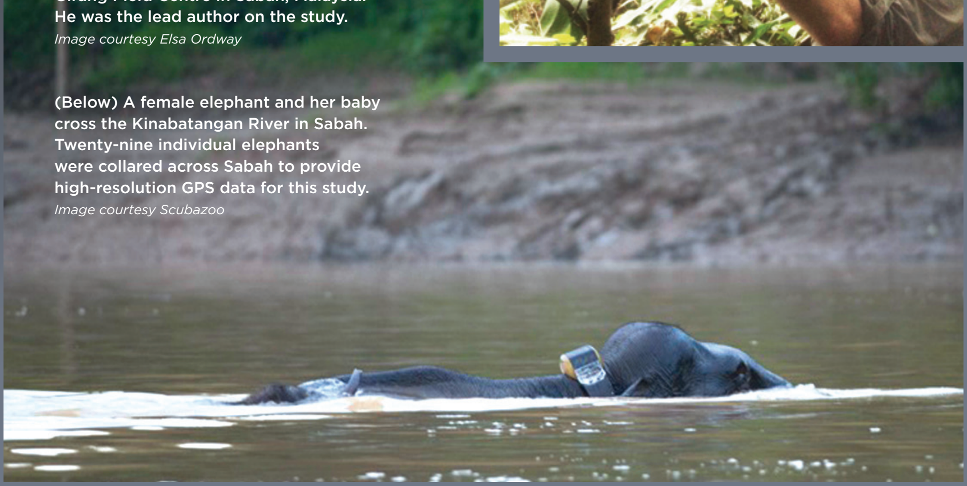
Carnegie coauthor Greg Asner explained how the Carnegie Airborne Observatory enabled these findings: "Our mapping of Sabah's forests is unique in that it provides accurate and detailed spatial information on forest structure. Combined with the GPS telemetry data for the elephants, the connection between relatively low-statured tree canopies and elephant habitat emerged in a way that was previously unknown."

"The danger is that a large proportion of these lower-stature forest habitats could be prime candidates for conversion to large-scale agriculture before their importance is fully realized," added coauthor Benoît Goossens of Danau Girang Field Centre and advisor for the Sabah Wildlife Department.

"The hope is that this study will reinforce the importance of protecting habitats perceived as 'low-quality,' rather than merely solely old-growth, high-carbon, forests," Goossens concluded.

The project is part of an ongoing effort—funded by the Rainforest Trust and spearheaded by the Sabah Forestry Department—to increase totally protected areas in Sabah to 30% of total land area.

"These new findings, when combined with our previous work on forest carbon, orangutan habitat, and upcoming tree biodiversity results, will be a unique combination of studies to help Sabah achieve its conservation goals," Asner remarked. ■



(Right) Luke Evans is a postdoctoral researcher at Carnegie and the Danau Girang Field Centre in Sabah, Malaysia. He was the lead author on the study.
*Image courtesy Elsa Ordway*

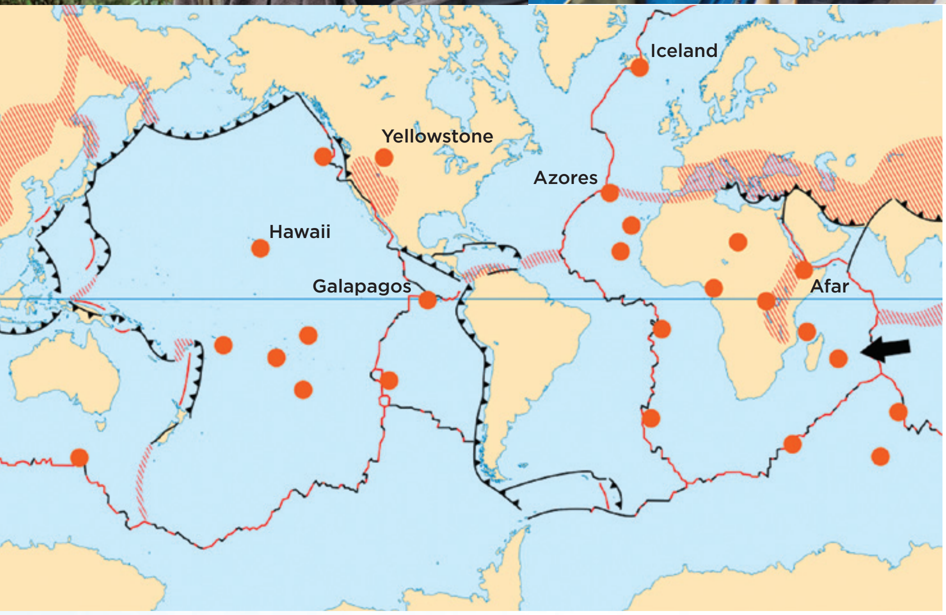
(Below) A female elephant and her baby cross the Kinabatangan River in Sabah. Twenty-nine individual elephants were collared across Sabah to provide high-resolution GPS data for this study.
*Image courtesy Scubazoo*

*Text courtesy Sabah Wildlife Department, Danau Girang Field Centre, and Cardiff University.*



Carnegie's Bradley Peters (left), Rick Carlson (middle), and Mary Horan conducted the research, published in *Nature*.

*Images courtesy Bradley Peters, Matt Scott, and Mary Horan*




Réunion Island is east of Madagascar in the Indian Ocean (black arrow). The hot spot that formed the island comes from an unusually primitive deep source. Lines depict plate boundaries, while shaded areas are plant boundary zones. Orange points are prominent hot spots.

*Image adapted from Wiki Commons*

Réunion marks the present-day location of the hotspot that **66 MILLION YEARS AGO** erupted the Deccan Traps flood basalts—volcanic rocks—that cover most of India and may have contributed to the extinction of the dinosaurs.

This fieldwork photo from Réunion Island shows the flank of the Cirque de Cilaos, looking out towards the Indian Ocean.

*Image courtesy Bradley Peters*

# Modern Volcanism and Earth's Birth

Plumes of hot magma from the volcanic hotspot that formed Réunion Island in the Indian Ocean rise from an unusually primitive deep source, according to new work from Carnegie's Bradley Peters, Richard Carlson, and Mary Horan, along with James Day of the Scripps Institution of Oceanography. *Nature* published their work.

Réunion marks the present-day location of the hotspot that 66 million years ago erupted the Deccan Traps flood basalts—volcanic rocks—that cover most of India and may have contributed to the extinction of the dinosaurs. Flood basalts and other hotspot lavas are thought to originate from different portions of Earth's deep interior than most volcanoes at Earth's surface. Studying this material may help scientists understand our planet's evolution.

The heat from Earth's formation melted much of the planet, separating Earth into two layers as denser iron sank toward the center, creating the core and leaving the silicate-rich mantle floating above.

Over the next 4.5 billion years, deep portions of the mantle rose, melted, and then separated again by density, creating the crust and changing the chemical composition of Earth's interior. As crust sinks into the interior—a phenomenon that occurs today along the boundary of the Pacific Ocean—the mantle slowly stirs these materials, with their distinct chemistry, back into the deep planet.

But not all of the mantle is well blended. Some older patches still exist, like poorly mixed cake batter. Analysis of the chemical compositions of Réunion Island volcanic rocks indicate that their source material is different from other, better-mixed parts of the modern mantle.

The team revealed that Réunion lavas originate from regions of the mantle that were isolated from the broader, well-blended mantle. These isolated pockets were formed within the first 10% of Earth's history.

They used new data on isotopes, elements that have the same number of protons but a different number of neutrons. Sometimes, the number of neutrons in the nucleus makes an isotope unstable; to gain stability, the isotope releases energetic particles during radioactive decay. This process alters its number of protons and neutrons, transforming it into a different element. The team's study harnesses this process to provide a fingerprint for the age and history of distinct mantle pockets.

Samarium-146 is one such unstable, or radioactive, isotope with a half-life of only 103 million years. It decays to the isotope neodymium-142. Although samarium-146 was present when Earth formed, it became extinct very early in Earth's infancy. Neodymium-142 provides a good record of Earth's earliest history, up to when all the samarium-146 transformed into neodymium-142.

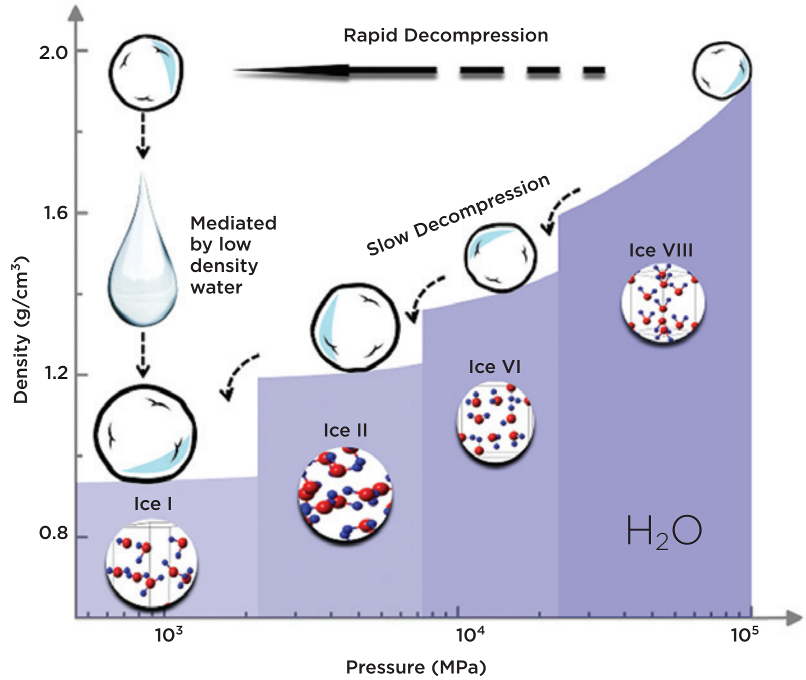
Differences in the abundances of neodymium-142 compared to other isotopes of neodymium could only have been generated by chemical changes of the mantle in the first 500 million years of Earth's 4.5 billion-year history.

The ratio of neodymium-142 to neodymium-144 in Réunion volcanic rocks, with results from lab-based mimicry and modeling studies, indicate that despite billions of years of mantle mixing, Réunion plume magma likely originates from a preserved pocket of the mantle that experienced a compositional change caused by large-scale melting of Earth's earliest mantle.

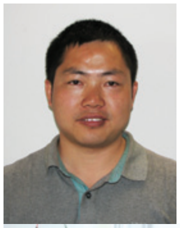
The team's findings could also help explain the origin of dense regions at the boundary of the core and mantle called large low shear velocity provinces (LLSVPs) and ultralow velocity zones (ULVZs), reflecting the unusually slow speed of seismic waves as they travel through these deep mantle regions. These regions may be relics of early melting events.

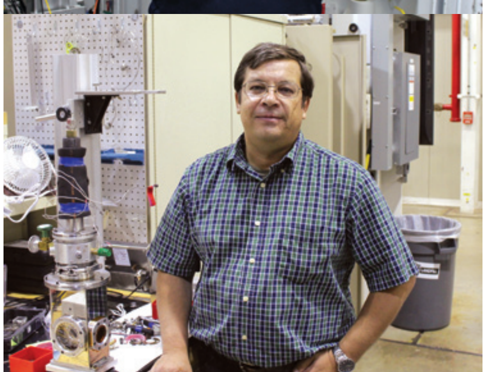
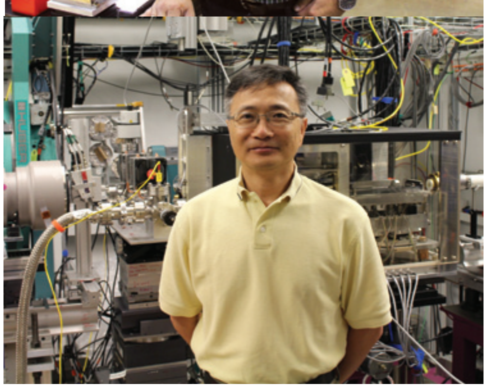
"The mantle differentiation event preserved in these hotspot plumes can both teach us about early Earth geochemical processes and explain the mysterious seismic signatures created by these dense deep-mantle zones," said lead author Peters. ■

**SUPPORT:**
The National Geographic Society (NGS 8330-07), the Geological Society of America (GSA 10539-14), and a generous personal donation from Dr. R. Rex provided funding for fieldwork for this study. Carnegie Institution for Science provided support for laboratory work.




The illustration at right shows how rapid decompression is the key to observing low-density liquid water. Low-density water mediates the rapid decompression transition from ice-VIII to ice Ic.
*Image courtesy Chuanlong Lin and Guoyin Shen*



Carnegie high-pressure geophysicists (from top) Chuanlong Lin, Jesse Smith, Stanislav Sinogeikin, and Guoyin Shen found evidence of the long-theorized, difficult-to-see low-density liquid water.
*Images courtesy HPCAT*

# FOUND: LOW-DENSITY LIQUID WATER

**Water makes up more than 70% of our planet and some 60% of our bodies. But it has strange properties compared to most other liquids. The solid form is less dense than the liquid form—that's why ice floats. Water's peculiar heat capacity profile has a profound impact on ocean currents and climate, and it can remain liquid at extremely cold temperatures.**

In addition to ordinary water and steam, there are at least 17 forms of water ice and two proposed forms of supercooled liquid water.

New work from Carnegie high-pressure geophysicists Chuanlong Lin, Jesse Smith, Stanislav Sinogeikin, and Guoyin Shen found evidence of the long-theorized, difficult-to-see low-density liquid water. *Proceedings of the National Academy of Sciences* published their work.

The normal density of water is one gram of water molecules per each cubic centimeter. Studies of anomalies in water's behavior have indicated the existence of liquid water with both lower and higher densities than this standard. But observing these phenomena experimentally has been difficult.

Every molecule has a chart indicating how its bulk molecular structure changes under different temperature and pressure conditions; it is called a phase diagram. The parts of the phase diagram where low-density water is thought to occur are notoriously difficult to explore—"water's no-man's land" because they require a series of very specific, very difficult conditions.

But the Carnegie team was able to observe low-density water as an intermediate phase using a newly developed rapid-decompression technique to turn the high-pressure crystalline phase ice-VIII to the diamond-like ice Ic at temperatures between about -207 and -163°F (140 and 165 K).

Sophisticated X-ray analysis confirmed the observation of the low-density liquid water phase, which only lasted for about half a second at -163°F (165 K). When ice-VIII was decompressed at moderate speeds, it formed other phases of ice, indicating that the speed of decompression is key to observing the low-density liquid water phase.

"Our newly developed, very fast decompression method was the key to this exciting observation of low-density liquid water as an intermediate between two crystalline phases," Shen explained. ■

**SUPPORT:**
The U.S Department of Energy (DOE) Basic Energy Sciences Division of Materials Sciences and Engineering supported this research under Award DE-FG02-99ER45775. DOE National Nuclear Security Administration supports HPCAT operation under Award No. DE-NA0001974. The Advanced Photon Source is a User Facility operated for the DOE Office of Science by Argonne National Laboratory under Contract No. DE-AC02-06CH11357.

# Arthur Grossman Receives Human Frontier Science Program Grant

Plant scientist Arthur Grossman was part of a team awarded a three-year grant from the International Human Frontier Science Program Organization. The group will use an integrated approach to investigate how light and metabolic signals control photosynthesis in algae.

Senior scientist Arthur Grossman of Carnegie's Department of Plant Biology was part of a team* awarded a three-year grant, with $100,000 for each year, from the International Human Frontier Science Program (HFSP) Organization. The team will use an integrated approach to investigate how light and metabolic signals control photosynthetic processes in algae.

HFSP's collaborative research grants are given for projects that address "complex mechanisms of living organisms." The program only supports "cutting-edge, risky projects" conducted by globally distributed teams.

HFSP announced 31 winning teams. There were 771 submitted proposals representing more than 50 different countries.

Grossman has been studying algae for years. Algae dominate the oceans, produce half of the oxygen we breathe, and are important to the Earth's ecology, human health, and nutrition. They are used as food, fuel, health care, and cosmetics, among other purposes. Despite the pervasiveness of algae there is much that scientists don't know about them.

Grossman stated, "This new HFSP grant brings together a unique set of investigators to develop a holistic view of photosynthetic control that spans metabolism to epigenetics and mathematical modeling. Interactions among the participants, with their diverse intellectual orientations, will surely reveal many surprises."

Grossman is a pioneer in studying a broad range of topics about algae. His research has been important for understanding basic mechanisms in photosynthetic organisms as well as their evolution. He has investigated metabolic processes and the acclimation of algae and cyanobacteria (blue-green algae) to changing environmental conditions; the diversity of photosynthetic microbes in hot spring mats; molecular mechanisms associated with coral bleaching; the management of light energy by photosynthetic marine microbes; and the identification of novel genes associated with photosynthetic function, among other topics.

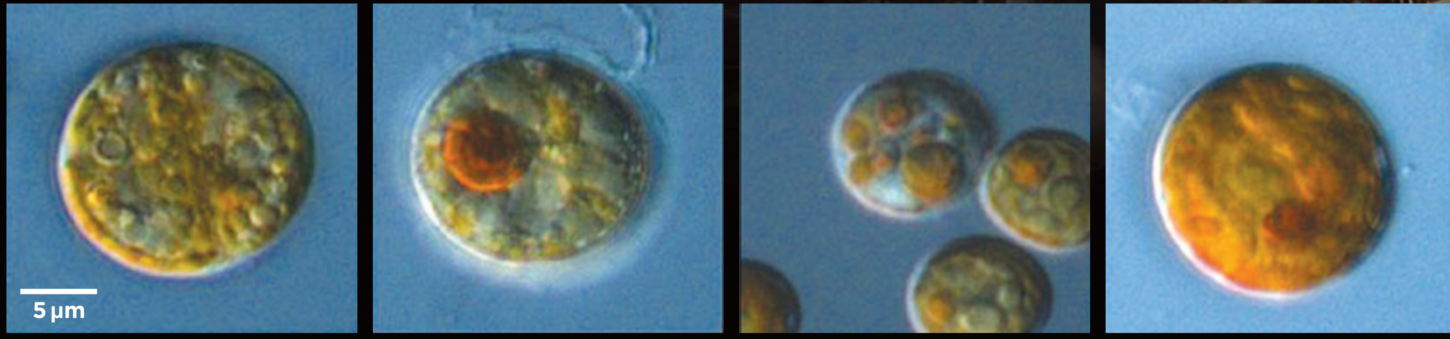
Grossman has been a Carnegie staff scientist since 1982 and professor by courtesy at Stanford University. Over the years, he has received many awards and accolades for his research. ■

**COLLABORATORS:**

***Other team members include Dimitris Petroutsos of the Institute of Biosciences and Biotechnologies in France, Chuan He of the University of Chicago, and Zoran Nikoloski of the Max Planck Institute of Molecular Plant Physiology in Potsdam, Germany.**

This series of images shows groups of the algae *Symbiodinium* that share common ancestry. The organism forms an endosymbiotic partnership—one organism living within the other—with coral and is needed for coral survival.

*Image modified from Xiang et al., 2013*



# Four New Carnegie Venture Grants

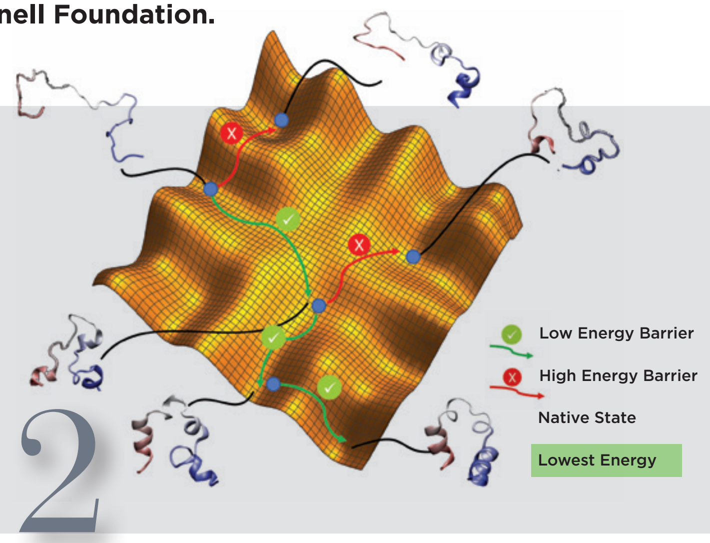
**Four new Carnegie Venture Grants have been awarded, following the second call for 2017 proposals. Grant projects ignore conventional boundaries by bringing together researchers from different backgrounds with fresh eyes to explore new questions. Each grant provides $100,000 for investigations that are likely to grow in unexpected ways. Proposals are chosen by the Office of the President. Grants are generously supported, in part, by trustee Michael Wilson and his wife Jane and by the Ambrose Monell Foundation.**

1

## Detecting Signs of Life

One Venture Grant was awarded to astronomer **Andrew McWilliam** of the Observatories and Hubble postdoctoral fellow **Johanna Teske** to detect molecules important to the emergence of life on Earth-sized exoplanets.

*Image courtesy NASA*




2

## Materials Science Applied to Biological Protein Folding

A second Venture Grant is for materials physicists **Tim Strobel**, **Ron Cohen**, and **Li Zhu**, all of the Geophysical Laboratory, to collaborate with Plant Biology's proteomics facility director **Shouling Xu** to apply recently developed materials physics methods to the biological problem of understanding protein folding. The mechanisms of protein folding are vital to life and to understanding diseases.

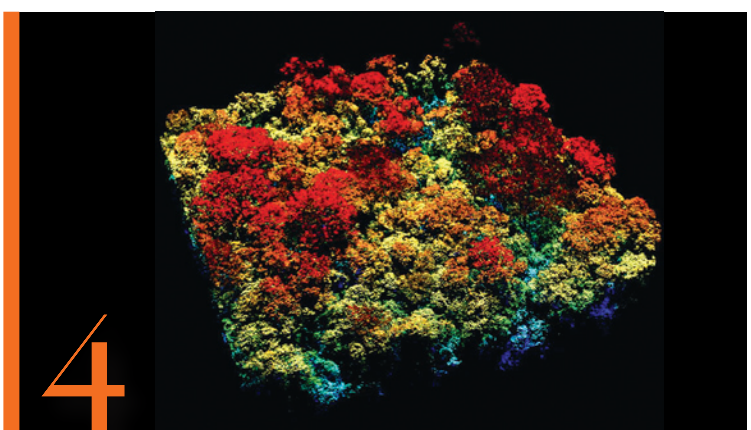
*Image courtesy Li Zhu*

3

## A "Gene Gun" for Genetic Manipulation

A third Venture Grant was awarded to a project between plant biologists **Zhiyong Wang** and global ecologists **Joe Berry** and **Jennifer Johnson**, with **Karlheinz Merkle** of Stanford University, to develop a new "gene gun." The objective is to deliver biomolecules deep into plant cells that then participate in reproduction, for the purpose of genetic manipulation.

*Image courtesy Zhiyong Wang*



4

## Measuring Photosynthesis at Large Scales

A fourth Venture award was made for a collaboration among instrument designer **Nick Konidaris** of the Observatories and global ecologists **Greg Asner**, **Joe Berry**, and **Ari Kornfeld**. It will allow measurements of photosynthesis to be coupled with structural characteristics of plants to scale up leaf-level understanding to canopy and regional processes. ■

*Image courtesy Carnegie Airborne Observatory*

Rebecca Albright was a Carnegie postdoctoral fellow in Ken Caldeira's lab before joining the California Academy of Sciences.
*Image courtesy California Academy of Sciences*

This photo shows the site of the coral reef flat study at One Tree Island in Australia's Great Barrier Reef.
*Image courtesy Aaron Takeo Ninokawa, UC-Davis*

An experimental plume of carbon dioxide-enriched seawater marked with a purple dye tracer flows across a coral reef flat in Australia's Great Barrier Reef. This study is the first ocean-acidification experiment on a natural coral reef community and provides evidence that near-future ocean acidification projections predict severely depressed coral reef growth.
*Image courtesy Aaron Takeo Ninokawa, UC-Davis*

# Shown: Acidification from $CO_2$ Slows Coral Growth

**Ocean acidification** will severely impair coral reef growth before the end of the century if carbon dioxide emissions continue unchecked, according to new research on Australia's Great Barrier Reef by Carnegie's Ken Caldeira and the California Academy of Sciences' Rebecca Albright.

Their work, published in *Nature,* is the first ocean acidification experiment in which seawater was made acidic by the addition of carbon dioxide and then allowed to flow across a natural coral reef community. The acidity of the seawater was increased to reflect end-of-century projections of unabated carbon dioxide emissions.

Two years ago, Caldeira and Albright, then at Carnegie, published a landmark study providing evidence that ocean acidification is already slowing coral reef growth.

In that work, they made a coral reef's seawater chemistry more alkaline—essentially giving the reef an antacid—and demonstrated that the coral's ability to construct its architecture improved. It was the first time that seawater chemistry was experimentally manipulated in a natural coral reef environment.

Then and now, they altered seawater chemistry surrounding One Tree Island off the coast of Australia. But this time they increased the acidity by adding carbon dioxide to that seawater.

"Last time, we made the seawater less acidic, like it was 100 years ago, and this time, we added carbon dioxide to the water to make it more acidic, like it could be 100 years from now," Caldeira explained.

Burning fossil fuel releases carbon dioxide into the atmosphere. It is well established that these emissions are the culprit of global climate change, and that global warming has a negative impact on coral reefs. Atmospheric carbon is also absorbed into the ocean and remains there for millennia.

A chemical reaction between the seawater and absorbed carbon emissions produces carbonic acid, which is corrosive to coral reefs, shellfish, and other marine life. Reefs are especially vulnerable, because their skeletons are constructed by accreting calcium carbonate, called calcification. As the surrounding water becomes more acidic, calcification becomes more difficult.

"Our findings provide strong evidence that ocean acidification caused by carbon dioxide emissions will severely slow coral reef growth in the future unless we make steep and rapid reductions in greenhouse gas emissions," said first author Albright.

Furthermore, the team showed how acidification affects natural coral reefs on an ecosystem scale, not just in terms of individual organisms or species as other studies have done.

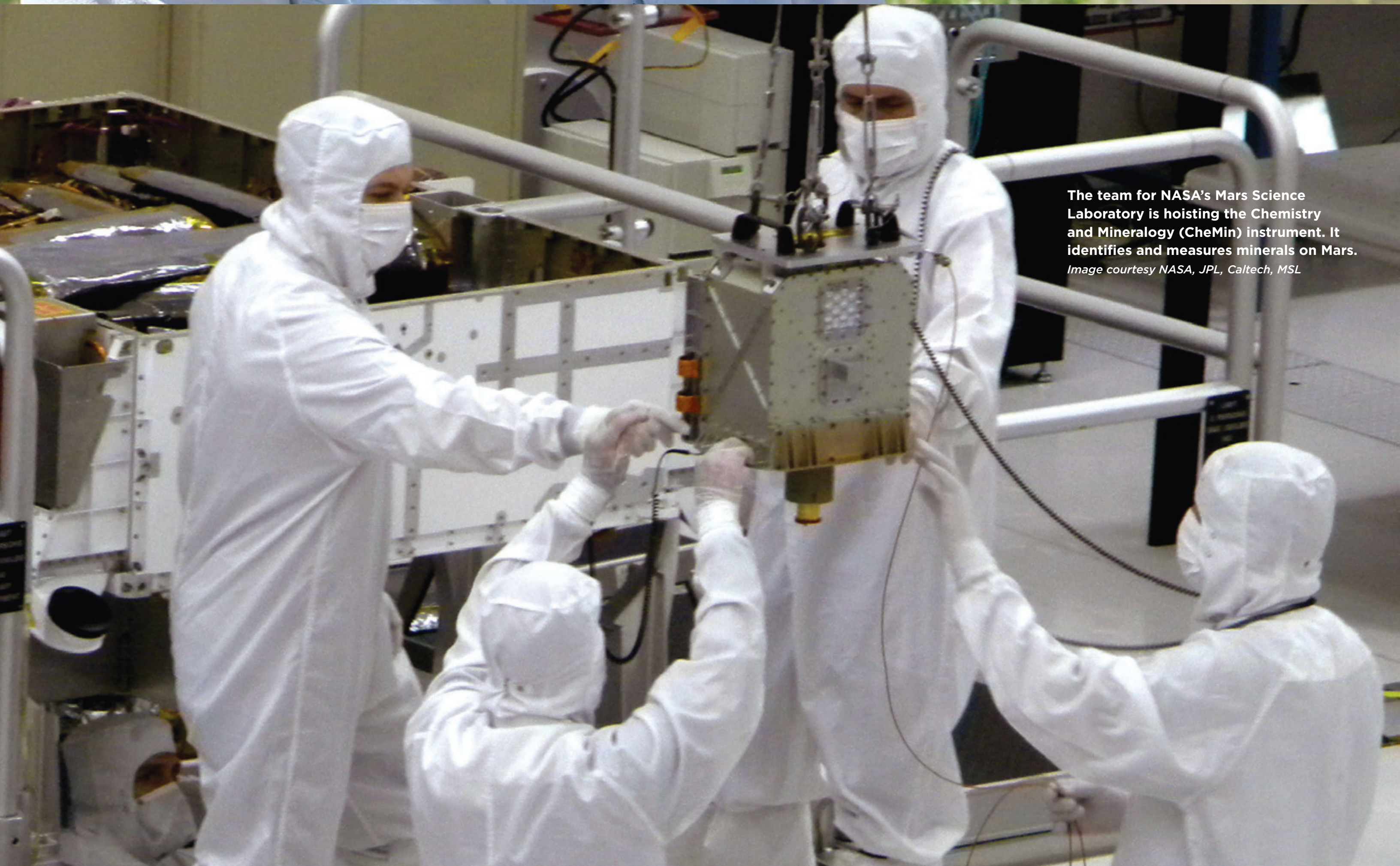
This approach is crucial to understanding the full scope and complexity of ocean acidification's impact, as well as to predicting how acidification will affect the coastal communities that depend on these ecosystems.

"Coral reefs offer economic opportunities to their surrounding communities from fishing and tourism," Caldeira said. "But for me the reef is a beautiful and diverse outpouring of life that we are harming with our carbon dioxide emissions. For the denizens of the reef, there's not a moment to lose in building an energy system that doesn't dump its waste into the sky or sea." ■

**COLLABORATORS:**
**Other members of the research team were Carnegie's Yui Takeshita, David Koweek, and Yana Nebuchina; Aaron Ninokawa and Jordan Young of UC-Davis; Kennedy Wolfe of the University of Sydney; and Tanya Rivlin of the Hebrew University of Jerusalem.**

# MOST-VIVID PICTURE OF MARTIAN MINERALOGY

Shaunna Morrison is a Carnegie postdoctoral researcher and program manager for the open-access Deep-Time Data Infrastructure (DTDI) project. She works with Bob Hazen on mineral network analysis and mineral ecology and evolution, in addition to the Mars Science Laboratory mission.
*Image courtesy Shaunna Morrison*



The team for NASA's Mars Science Laboratory is hoisting the Chemistry and Mineralogy (CheMin) instrument. It identifies and measures minerals on Mars.
*Image courtesy NASA, JPL, Caltech, MSL*

# YET

**A team of scientists led by Carnegie's Shaunna Morrison and including Bob Hazen** has revealed the mineralogy of Mars at an unprecedented scale. It will help them understand the planet's geologic history and habitability. Their findings are published in two *American Mineralogist* papers.

Minerals form from novel combinations of elements facilitated by geological activity, including volcanoes and water-rock interactions. Understanding the mineralogy of another planet, such as Mars, could allow scientists to understand the forces that shaped their formation in that location.

An instrument on NASA's Mars Curiosity Rover called the Chemistry and Minerology X-Ray Diffraction instrument, or CheMin, is the first tool of its kind ever to operate on another planet. But there are limitations to how much it can tell scientists about the Red Planet's minerals—how they formed and what they can illuminate about Martian history.

Morrison found a way to glean more information from the CheMin data, which paints a detailed picture of the minerals the rover encountered.

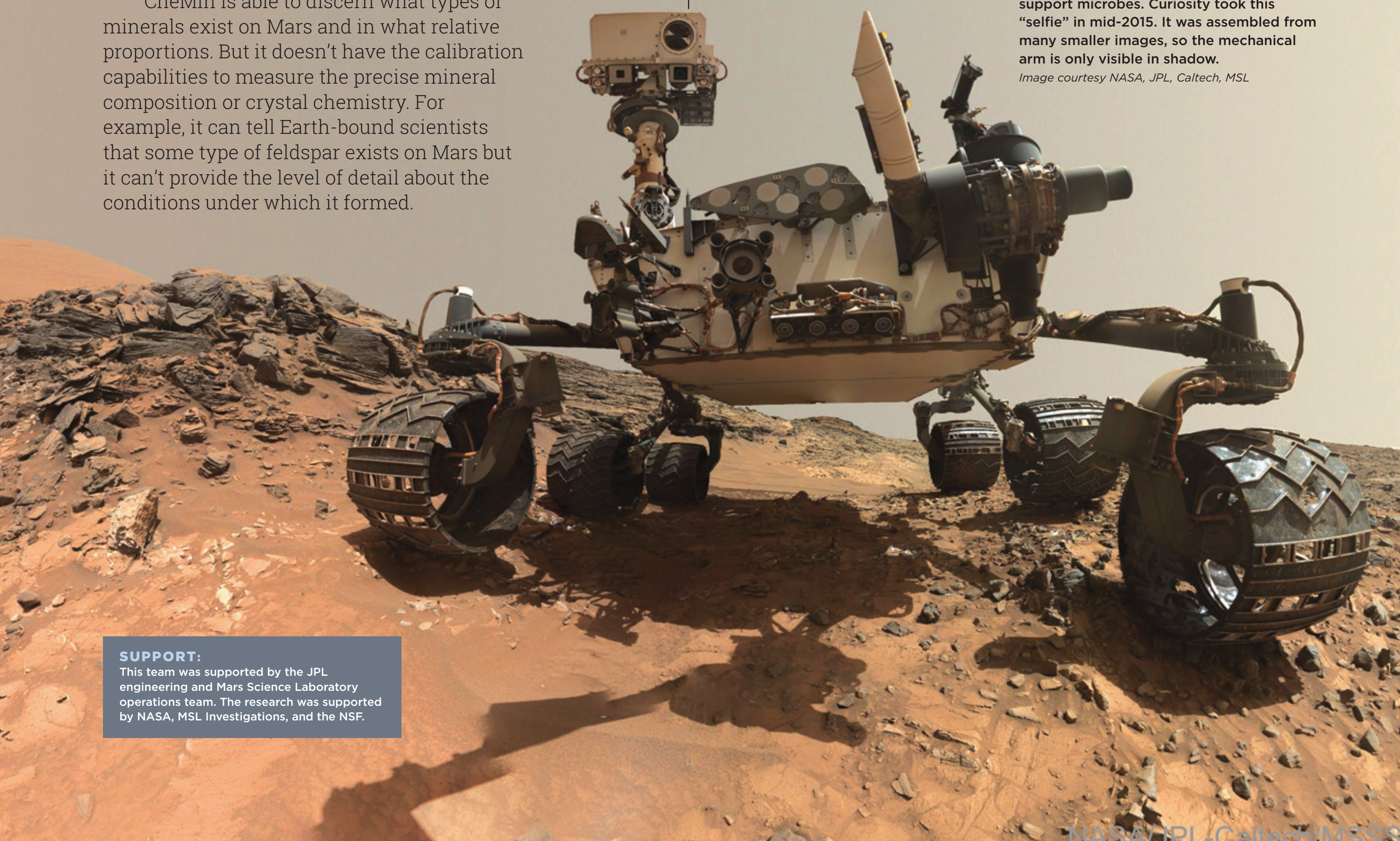
CheMin is able to discern what types of minerals exist on Mars and in what relative proportions. But it doesn't have the calibration capabilities to measure the precise mineral composition or crystal chemistry. For example, it can tell Earth-bound scientists that some type of feldspar exists on Mars but it can't provide the level of detail about the conditions under which it formed.

Crystals, by definition, have a long-range repetitive structure. The smallest unit of the geometry of this crystal lattice is called the unit cell, comprised of repeating atomic units. Morrison realized that because the unit cell dimensions are known for minerals found in the 13 samples CheMin took of the soils, sandstones, and formations of Mars' Gale crater, she could use them as a key to unlock more information.

"I scoured the literature, gathering and analyzing thousands of measurements of both mineral compositions and unit cell dimensions and then determined a mathematical connection between them," Morrison explained. "Once this relationship was established, it could be used to glean much more detail about the minerals in the Martian samples taken by CheMin."

For example, CheMin was able to measure that Mars' Gale crater contains the minerals feldspar and olivine. By using Morrison's connection between unit cells and compositions, the team was able to determine how the composition of feldspar varies between the different sampling locations, which can offer information about its igneous origins. The percentage of magnesium found in olivine samples ranges from 52% to 72%, which when compared with Martian meteorites may offer information about aqueous alteration of the material.

"Thanks to Shaunna's creative approach, we have improved CheMin's resolution by an order of magnitude," Hazen explained. "The result is the most vivid picture yet of the mineralogy of another planet." ■



NASA's Mars Science Laboratory mission Curiosity is the biggest and most varied rover sent to Mars. It launched in November 2011 and landed in August of 2012. It investigates whether Mars has had the environmental conditions necessary to support microbes. Curiosity took this "selfie" in mid-2015. It was assembled from many smaller images, so the mechanical arm is only visible in shadow.
*Image courtesy NASA, JPL, Caltech, MSL*

**SUPPORT:**
This team was supported by the JPL engineering and Mars Science Laboratory operations team. The research was supported by NASA, MSL Investigations, and the NSF.

# HABITABILITY OF PROXIMA b NOW IN QUESTION

**A team of astronomers led by Carnegie's Meredith MacGregor and Alycia Weinberger detected a massive stellar flare, a radiation explosion, from the closest star to our own Sun, Proxima Centauri, last March. This finding, published by *The Astrophysical Journal Letters*, raises questions about the habitability of our Solar System's nearest exoplanetary neighbor, Proxima b, which orbits Proxima Centauri.**

MacGregor, Weinberger, and their colleagues—David Wilner of the Harvard-Smithsonian Center for Astrophysics and Adam Kowalski and Steven Cranmer of the University of Colorado, Boulder—discovered the enormous flare when they reanalyzed observations taken last year by the Atacama Large Millimeter/submillimeter Array (ALMA), a radio telescope made up of 66 antennas.

At peak luminosity the flare was 10 times brighter than our Sun's largest flares observed at similar wavelengths. Stellar flares have not been well studied at the wavelengths detected by ALMA, especially around stars of Proxima Centauri's type, called M dwarfs, the most common in our galaxy.

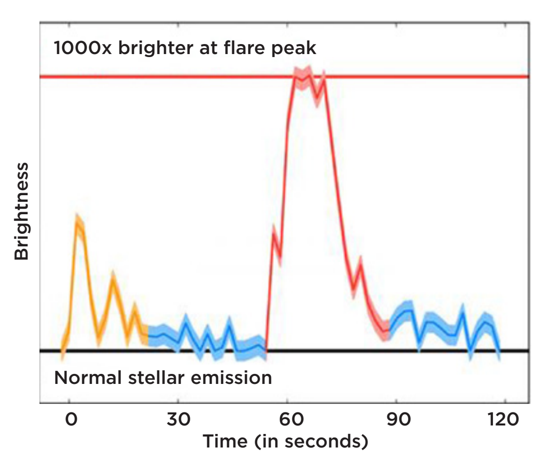
"March 24, 2017, was no ordinary day for Proxima Cen," said lead author MacGregor.

The flare increased Proxima Centauri's brightness 1,000 times over 10 seconds. This was preceded by a smaller flare; taken together, the whole event lasted fewer than two minutes of the 10 hours that ALMA observed the star between January and March of last year.

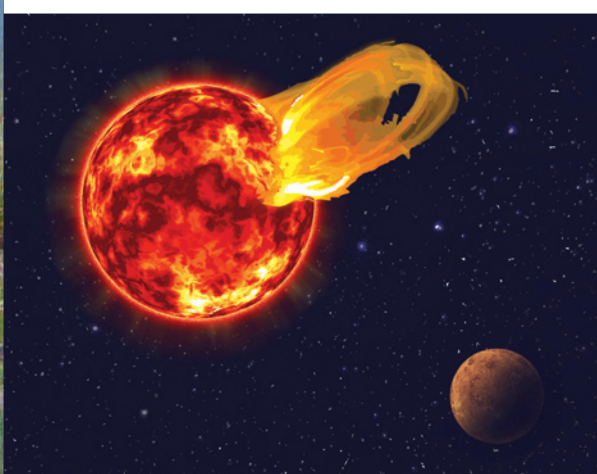
Stellar flares happen when a shift in the star's magnetic field accelerates electrons to speeds approaching that of light. These electrons interact with the highly charged plasma making up most of the star, causing an eruption with emissions across the entire electromagnetic spectrum.

"It's likely that Proxima b was blasted by high-energy radiation during this flare," MacGregor explained, adding that it was already known that Proxima Centauri experienced regular, although smaller, X-ray flares. "Over the billions of years since Proxima b formed, flares like this one could have evaporated any atmosphere or ocean and sterilized the surface, suggesting that habitability may involve more than just being the right distance from the host star to have liquid water."

A November paper that also used ALMA data interpreted its average brightness, which included the light output of both the star and the flare together, as being caused




This graph shows the brightness of Proxima Centauri as observed by ALMA over the two minutes of the event on March 24, 2017. The massive stellar flare is shown in red, with the smaller earlier flare in orange, and the enhanced emission surrounding the flare that could mimic a disk in blue. At its peak, the flare increased Proxima Centauri's brightness by 1,000 times. The shaded area represents uncertainty.
*Image courtesy Meredith MacGregor*



This artist's impression of a flare from Proxima Centauri is modeled after the loops of glowing hot gas seen in the largest solar flares. An artist's impression of the exoplanet Proxima b is shown in the foreground. Proxima b orbits its star 20 times closer than the Earth orbits the Sun. A flare 10 times larger than a major solar flare would blast Proxima b with 4,000 times more radiation than the Earth gets from solar flares.
*Image courtesy Roberto Molar Candanosa/Carnegie Institution for Science, NASA/SDO, NASA/JPL*

National Science Foundation postdoctoral fellow Meredith MacGregor studies debris disks to understand planetary system evolution. She arrived at the Department of Terrestrial Magnetism in September 2017 with her Ph.D. from Harvard. She stands at the Very Large Array Radio Telescope in New Mexico—a different array from the one used in the study.
*Image courtesy Meredith MacGregor*

"...habitability may involve more than just being the right distance from the host star to have liquid water."

by multiple disks of dust encircling Proxima Centauri, not unlike our own Solar System's asteroid and Kuiper belts. The authors of that study said that the presence of dust pointed to the existence of more planets or planetary bodies in the stellar system.

But when this team looked at the ALMA data as a function of observing time, instead of an overall average, they saw the transient explosion of radiation emitted from Proxima Centauri for what it truly was.

"There is now no reason to think that there is a substantial amount of dust around Proxima Cen," Weinberger said. "Nor is there any information yet that indicates the star has a rich planetary system like ours." ■

**SUPPORT:**
A National Science Foundation (NSF) Astronomy and Astrophysics Postdoctoral Fellowship supported this research in part, under Award No. 1701406.

ALMA is a partnership of the European Southern Observatory (ESO) (representing its member states), NSF (U.S.), and National Institutes of Natural Sciences (Japan), together with the National Research Council (Canada), National Security Council and Academia Sinica Institute of Astronomy and Astrophysics (Taiwan), and Korea Astronomy and Space Science Institute (Republic of Korea), in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, Associated Universities, Inc. (AUI)/National Radio Astronomy Observatory (NRAO), and National Astronomical Observatory of Japan. NRAO is a NSF facility operated under cooperative agreement by AUI.

# Carnegie's Spreading Outreach!

Prior to the filmed forum, Origins researchers and guests spent the day discussing fundamental research questions.



Several Carnegie scientists participated in this filmed Origins panel discussion. Plant Biology's Devaki Bhaya is talking. Other Carnegie scientists include Plant Biology's Arthur Grossman (right of Bhaya) and Geophysical Laboratory's Andrew Steele (far right).

**Carnegie has sponsored the Capital Science Evening Lectures, open to the public at the Administration Building, for nearly three decades now.** Other long-standing lectures include the Broad Branch Road Campus Neighborhood Lecture Series in Washington, D.C., and the Carnegie Astronomy Lecture Series sponsored by the Observatories in Pasadena. Now, public lectures are expanding to the Department of Embryology in Baltimore and Plant Biology in Stanford. Our outreach is spreading!

Another new initiative, made possible by the generous support of the Carnegie Corporation of New York and valued advice from Judge David Tatel and Dr. Edie Tatel, is the Science & Society project. Carnegie Science recently presented a series of discussion forums, filmed for broadcast, on origins-related questions in Washington, D.C.

How and when did life originate on Earth? How many other Earth-like planets are in our Solar System and the universe? Are we alone? Questions like these about our origins and the possibility of life elsewhere have intrigued people since the beginning of history. The topics addressed include planet formation and habitability, Earth's journey towards life, life beyond Earth, and the philosophical and theological consequences of discovering life elsewhere.

The Origins events consisted of a panel of experts, including more than a dozen Carnegie researchers who helped plan and participate in the program. Experts discussed the subjects in front of an invitation-only audience who participated with questions. The subsequent video series highlight the importance of the discovery science process. They emphasize how scientists think about fundamental questions and how science is an ongoing data-based debate. ■

The invitation-only audience gets settled before the Origins panel discussion starts.

CARNEGIE ORIGINS

# ROCKY OR GASSY SUPER-EARTHS?

**This artist's rendition shows a system with three super-Earth exoplanets.**
*Image courtesy European Southern Observatory*

**A star about 100 light years away in the Pisces constellation, GJ 9827, hosts what may be one of the most massive and dense super-Earth planets detected to date, according to research led by Carnegie's Johanna Teske. These objects provide evidence to help astronomers better understand how such planets form.**

The GJ 9827 star hosts a trio of planets, discovered by NASA's exoplanet-hunting Kepler/K2 mission, and all three are slightly larger than Earth. The Kepler mission determined this size to be most common in the galaxy with periods between a few and several hundred days.

Intriguingly, no planets of this size exist in our Solar System, making scientists particularly curious about conditions under which they form and evolve.

One important key to understanding a planet's history is to determine its composition. Are these super-Earths rocky like our planet? Or do they have solid cores surrounded by large, gassy atmospheres?

To determine their composition, scientists need to measure mass and radius, which allows them to determine bulk density.

When quantifying planets this way, astronomers have noticed a trend: planets with radii greater than about 1.7 times that of Earth have a gassy envelope, like Neptune, and those with smaller radii are rocky, like Earth.

Some researchers have proposed that this difference is caused by photoevaporation, which strips planets of their surrounding envelope of so-called volatiles—substances like water and carbon dioxide that have low boiling points. This could create smaller-radius planets, but more information is needed.

This is why GJ 9827's three planets are special; with radii of 1.64 (planet b), 1.29 (planet c), and 2.08 (planet d), they span this dividing line between a rocky, super-Earth and somewhat gassy, sub-Neptune planets.

Teams of Carnegie scientists, including coauthors Steve Shectman, Sharon Wang, Paul Butler, Jeff Crane, and Ian Thompson, have been monitoring GJ 9827 with their Planet Finder Spectrograph (PFS), so they were able refine the masses of the three planets with data in hand, rather than with new observations.

"Usually, if a transiting planet is detected, it takes months if not a year or more to gather enough observations to measure its mass," Teske explained. "Because GJ 9827 is a bright star, we happened to have it in the catalog of stars that Carnegie astronomers have been monitoring for planets since 2010. This was unique to PFS."

The spectrograph was developed by Carnegie scientists and mounted on the Magellan Clay telescope at Carnegie's Las Campanas Observatory.

The PFS observations indicate that planet b is roughly eight times the mass of Earth, which would make it one of the most massive and dense super-Earths yet discovered. The masses for planet c and planet d are estimated to be about two and a half and four times that of Earth respectively, although the uncertainty is very high.

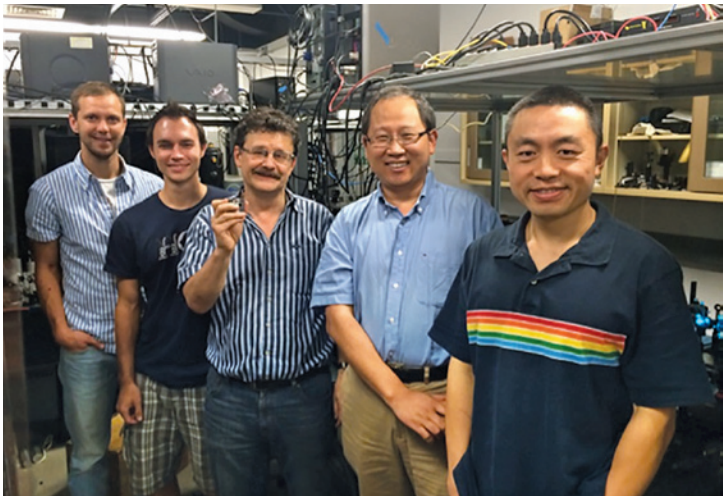
This information suggests that planet d has a significant volatile envelope and leaves open the question of whether planet c has a volatile envelope or not. But the better certainty on the mass of planet b suggests that that it is roughly 50% iron.

"More observations are needed to pin down the compositions of these three planets," Wang said. "But they do seem like some of the best candidates to test our ideas about how super-Earths form and evolve, potentially using NASA's upcoming James Webb Space Telescope."

Angie Wolfgang, a National Science Foundation postdoctoral fellow from the Pennsylvania State University, is also a coauthor on the paper. ■

**Johanna Teske (left) and Jeff Crane work on the Planet Finder Spectrograph in 2016. It is installed at Carnegie's Las Campanas Observatory in Chile on the Magellan Clay telescope.**
*Image courtesy Johanna Teske*

**SUPPORT:**
The National Science Foundation supported this work. This research made use of the NASA Exoplanet Archive, which is operated by the California Institute of Technology (Caltech) under contract with NASA under the Exoplanet Exploration Program. This research has also made use of the Exoplanet Follow-up Observation Program website, which is operated by Caltech under contract with NASA under the Exoplanet Exploration Program.



Members of the Goncharov lab shown (from left) are Sergey Labonov, Nicholas Holtgrewe, Alexander Goncharov, Xiaojia Chen, and Haidon Zhang. Goncharov holds a diamond anvil cell, shown up close (at right, top).
*Image courtesy Alexander Goncharov*

# The Case of the Missing Xenon

The case of the missing xenon is a problem that's stumped geophysicists for decades. New work from an international team including Carnegie's Alexander Goncharov and Hanyu Liu, and Carnegie alumni Elissaios Stavrou and Sergey Lobanov, is chasing down the solution, which they published in *Physical Review Letters*.

The mystery stems from meteorites, which retain a record of our Solar System's earliest days. One type, called carbonaceous chondrites, contains some of the most primitive known samples of Solar System material, including a lot more xenon than is found in our own planet's atmosphere.

"Xenon is one of a family of seven elements called the noble gases, some of which, such as helium and neon, are household names," explained lead author Stavrou, now at Lawrence Livermore National Laboratory (LLNL). "Their name comes from a kind of chemical aloofness; they normally do not combine, or react, with other elements."

Because xenon doesn't play well with others, its deficiency in Earth's atmosphere—even in comparison to other, lighter noble gases, like krypton and argon—is difficult to explain. Theoretical predictions tell us that those lighter gases should be even more depleted than xenon.

The research team, which also included Yansun Yao of the University of Saskatchewan, Joseph Zaug of LLNL, and Eran Greenberg and Vitali Prakapenka of the University of Chicago, focused their attention on the idea that the missing xenon might be found deep inside the Earth, specifically hidden in compounds with nickel and especially iron, which forms most of the planet's core.

Although xenon doesn't form compounds under ambient conditions, under the extreme temperatures and pressures of planetary interiors it isn't quite so aloof.

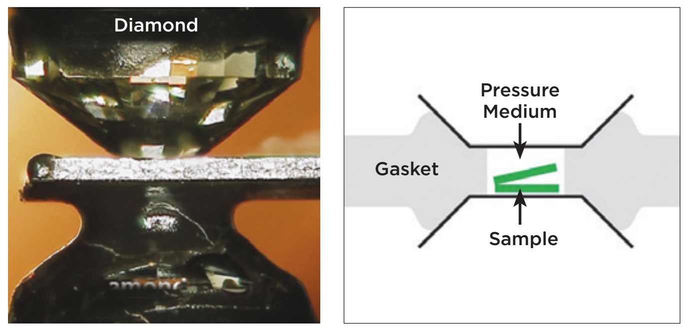
"When xenon is squashed by extreme pressures, its chemical properties are altered, allowing it to form compounds with other elements," Lobanov explained.

Using a laser-heated diamond anvil cell, the researchers mimicked the conditions found in the Earth's core and employed advanced spectroscopic tools to observe how xenon interacted with both nickel and iron.

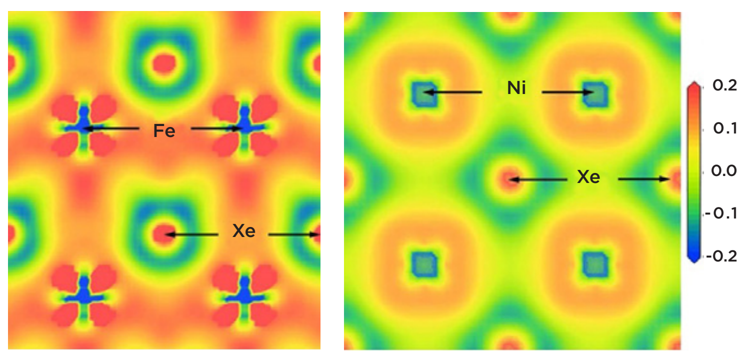
They found that xenon (Xe) and nickel (Ni) formed $XeNi_3$ under nearly 1.5 million times normal atmospheric pressure (150 gigapascals) and at temperatures of above about 2200°F (1200°C or 1500 K). At nearly 2 million times normal atmospheric pressure (200 gigapascals) and at temperatures above about 3000°F (1700°C or 2000 K), they synthesized the complex xenon/iron (Fe) compound $XeFe_3$.

"Our study provides the first experimental evidence of previously theorized compounds of iron and xenon existing under the conditions found in the Earth's core," Goncharov said. "However, it is unlikely that such compounds could have been made early in Earth's history, while the core was still forming, and the pressures of the planet's interior were not as great as they are now."

The researchers are investigating whether a two-stage formation process could have trapped xenon in Earth's early mantle and then later incorporated it into $XeFe_3$ when the core separated and the pressure increased. But more work remains to be done. ■




This close-up of a diamond anvil cell, with the diagram, shows how samples are squeezed between two diamonds to pressures mimicking the Earth's interior.
*Image courtesy Alexander Goncharov*




The application of extreme pressure dramatically affects the chemical properties of xenon, so that it stops acting aloof and interacts with iron and nickel. This illustration shows how the changes in the electromagnetic properties of xenon (Xe), iron (Fe), and nickel (Ni) under these intense pressures allow for the formation of $XeFe_3$ and $XeNi_3$.
*Image courtesy the research team*

**SUPPORT:**
Part of this work was performed under the auspices of the U.S. Department of Energy (DOE) by Lawrence Livermore National Security, LLC. DARPA; the Deep Carbon Observatory; the Army Research Office; the Natural Sciences and Engineering Research Council of Canada; a Chinese Academy of Sciences visiting professorship for senior international scientists; the National Natural Science Foundation of China; the Ministry of Education and Science of Russian Federation; and the Energy Frontier Research Center funded by the DOE, Office of Science, Basic Energy Sciences (BES) supported this work.

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# DC STEM Network to Share $1 Million Award in STEM Coalition Challenge

**(Right) Educators are using a variety of materials to make something functional, an exercise called making, at the 3rd Annual DC STEM Summit held at Carnegie's headquarters in Washington, D.C.**
*Image courtesy Jessica Kerpez, CASE*

The DC STEM Network is one of eight groups to win the US2020's 2018 STEM Coalition Challenge. The Challenge was a nationwide competition for communities to increase hands-on STEM mentoring and maker-centered learning to underrepresented students. The winners were announced at the Bay Area Maker Faire in San Mateo, CA. The DC STEM Network will receive a share of a $1 million award to support further innovative, STEM-based learning for Washington, D.C., students.

The Network was selected from 92 applications from 35 states, representing more than 1,800 nonprofits, companies, school districts, and local government partners. The Network is a collaboration between Carnegie Science's education arm, the Carnegie Academy for Science Education (CASE), and the D.C. Office of the State Superintendent of Education (OSSE). The Network's mission is to unite community partners in a sustainable collective effort to design, guide, and advocate for transformative STEM learning opportunities for all D.C. students.

Washington, D.C., is a hub for STEM jobs—behind only Silicon Valley in the number of STEM-related employment opportunities. The core of the Network's mission is preparing D.C. students to fill those jobs. In addition to managing the annual DC. STEM Fair, the DC STEM Network guides students through hands-on STEM and maker programs as well as summer STEM internships.

Winners were selected based on factors including their potential for impact; approach to partnership building; creative engagement strategies; and sustainability planning. All eight winners will share the $1 million prize for financial support, consulting, and staff funding for two years.

Marlena Jones, director of the DC STEM Network, remarked, "The DC STEM Network is thrilled to join this cohort of outstanding STEM partners to increase access to making and mentoring in the District of Columbia." ■

**Katia Grigoriants (left) is the strategic partnership manager for the Carnegie Academy for Science Education (CASE). Marlena Jones (right) is the acting director for CASE and the director of the DC STEM Network.**
*Image courtesy Blonde Photography*