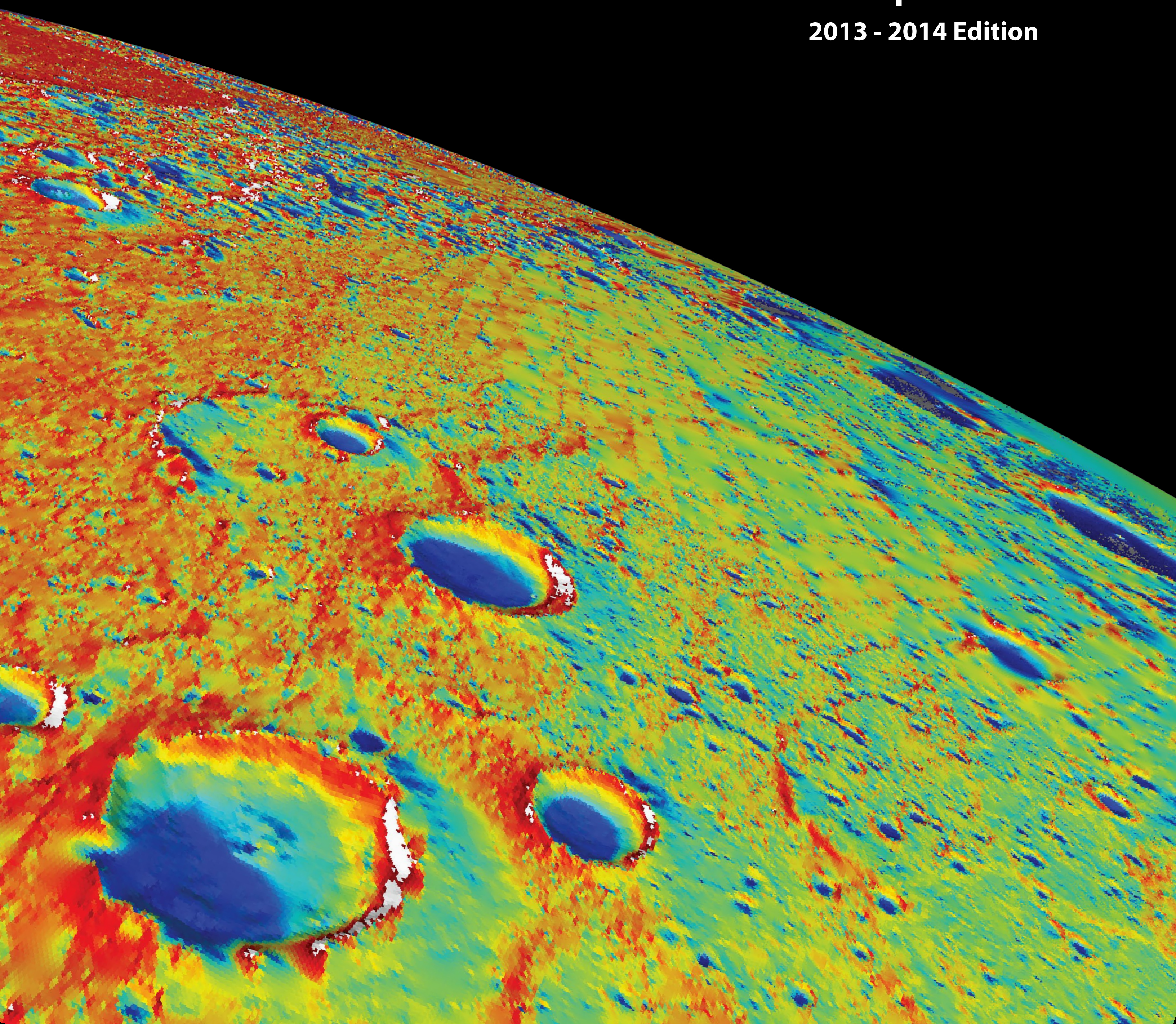
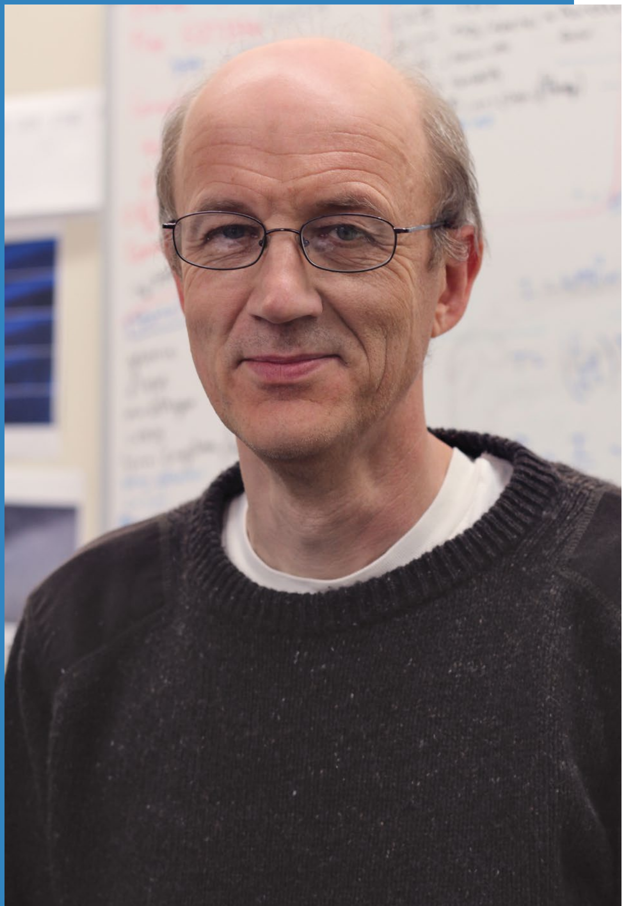
UCLA

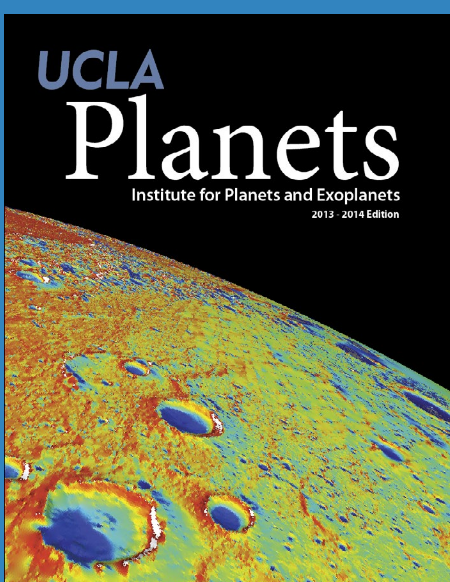
Planets

Institute for Planets and Exoplanets

2013 - 2014 Edition







Cover:
Thermal model of the north polar region of Mercury. Recently discovered permanently shadowed regions within impact craters (blue) remain at temperatures low enough to harbor ice deposits.

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A Note from the Director

UCLA's Institute for Planets and Exoplanets (iPLEX) was founded in late 2011 with seed funding provided by Dean of Physical Sciences Joseph Rudnick and Vice Chancellor for Research James Economou. Our main goal is to establish UCLA as the best place in the world to study planets in all their diversity. We target both our planetary neighbors in the solar system and exoplanets found in orbit around other stars. Studies of planets and exoplanets are complementary. Examining exoplanets gives the context needed to properly interpret the content and layout of our solar system, while observing the nearby solar system provides the detailed knowledge we need to understand distant planets of other stars.

As you will see from this booklet, iPLEX brings together experts from a wide range of backgrounds, studying a staggering variety of topics. This intellectual breadth distinguishes planetary science from most other endeavors. We use techniques ranging from laboratory studies of isotopes and meteorites to theoretical calculations, and collect data from the world's largest ground-based telescopes and from spacecraft spread across the solar system. Planetary science captures the imagination and enthusiasm of UCLA students, some of whom are featured in these pages. We are keen to develop untapped opportunities for expansion of planetary science in undergraduate and graduate programs, and to reach out to the wider world.

This booklet showcases only a small fraction of the planet-related science underway at UCLA.

David Jewitt

David Jewitt
iPLEX Director

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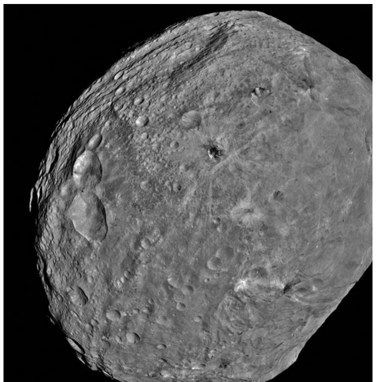

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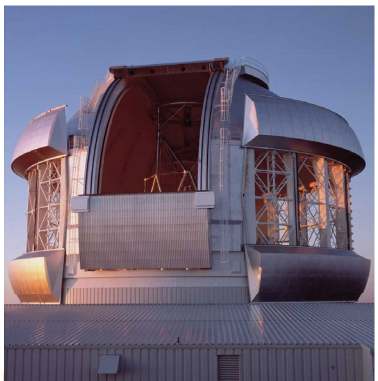

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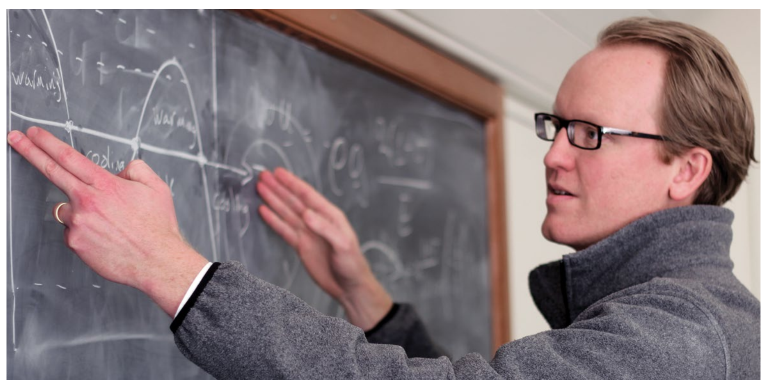

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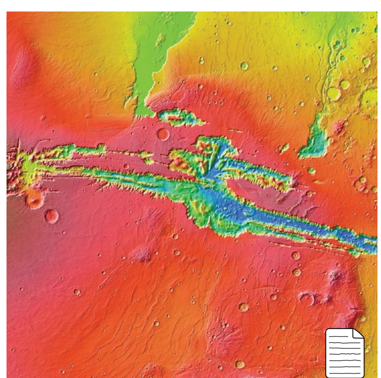

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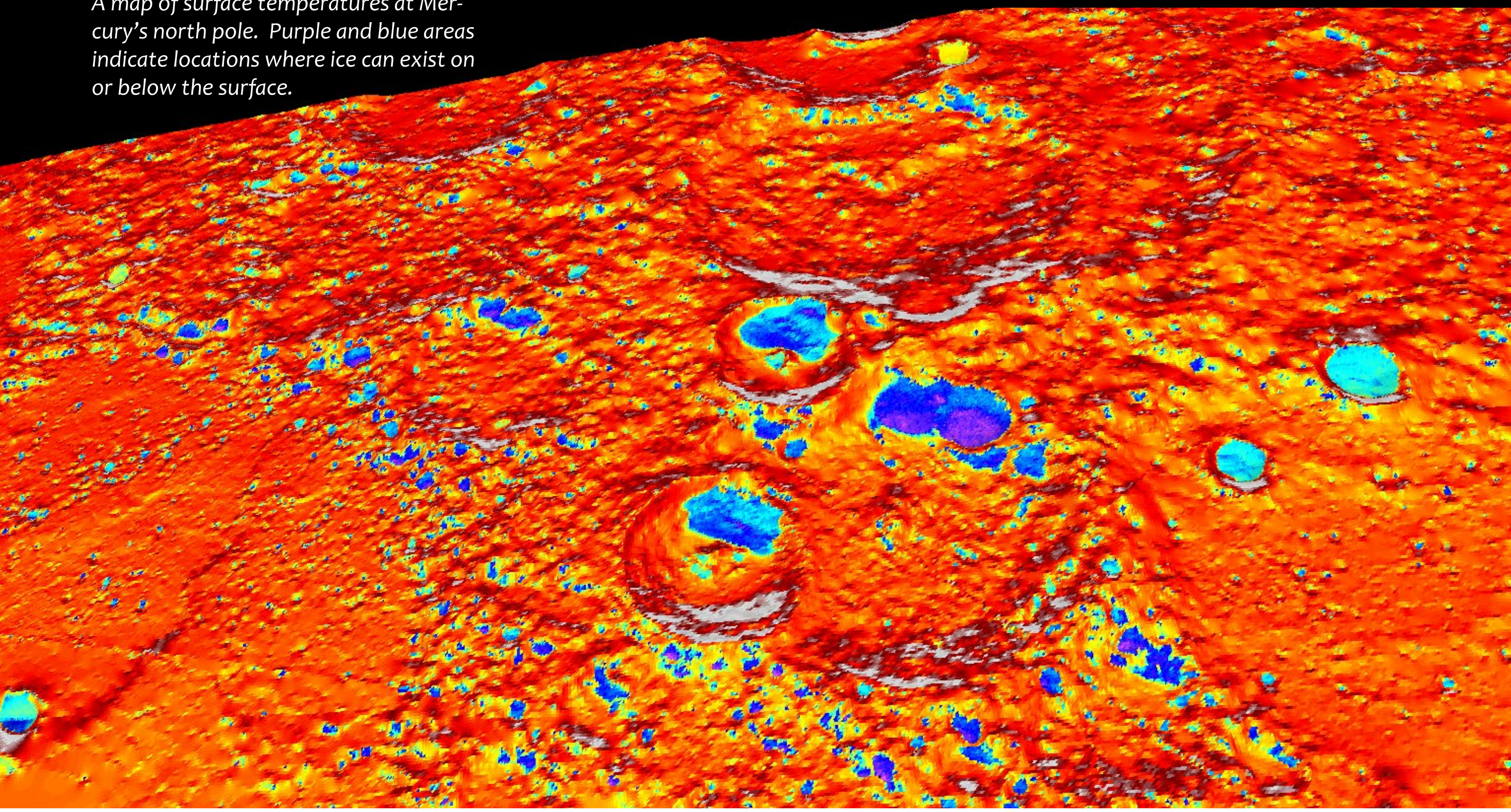
Icy Mercury

Surface temperatures on Mercury reveal extensive ice deposits in polar regions



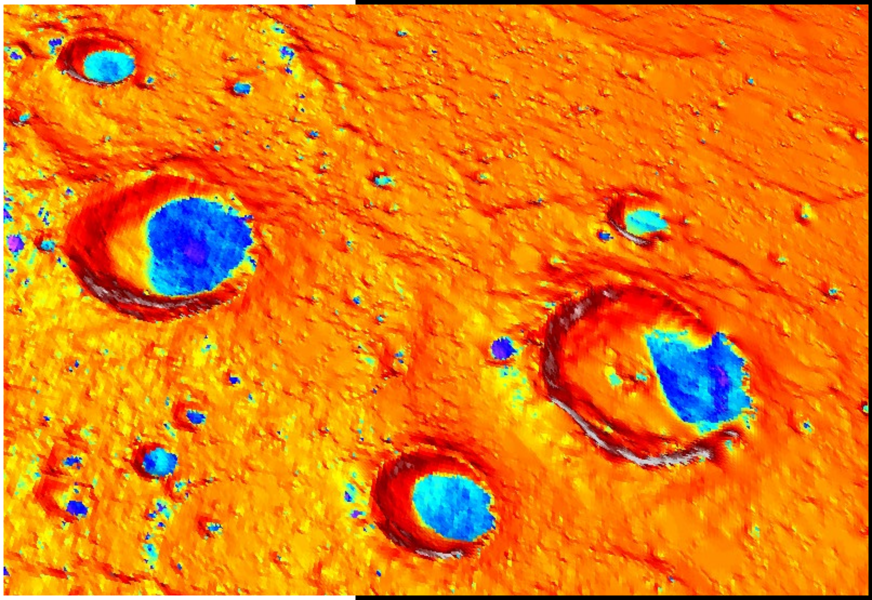
A map of surface temperatures at Mercury's north pole. Purple and blue areas indicate locations where ice can exist on or below the surface.

On a tour of water ice deposits in the solar system, the planet Mercury would seem an unlikely stop. Twice as close to the Sun as Earth, Mercury is constantly roasting at oven-like temperatures. Nevertheless, scientists analyzing data from NASA's MESSENGER spacecraft have confirmed earlier work showing that small areas in the polar regions of Mercury are able to escape the scorching sunlight and remain downright frigid. Using topographic data from NASA's MESSENGER mission, UCLA Professor David Paige and his team have crafted the first accurate computer model of temperatures at the poles of Mercury. They have successfully pinpointed extremely cold places near Mercury's north pole where frozen water can be found on or below the surface.

"Mercury is the innermost planet in the solar system, and, arguably, it's among the least explored," said Paige. "The surface exhibits the most extreme range of temperatures of any body we know of in the solar system." Within a single polar crater on Mercury, there are spots that reach temperatures above 500 degrees Fahrenheit within sight of areas cold enough to freeze and preserve water for billions of years. These "natural freezers" exist within the shadowed areas of polar-crater rims, never experiencing direct sunlight due to the low angle of the Sun near the poles, Paige said.

Paige, a self-described "professional ice finder," has studied the poles of planetary bodies in the solar system from Mercury all the way to Pluto. His most recent research, presented on NASA TV in November 2012, sheds light on the long-standing issue of ice on Mercury. In the early 1990s, scientists were surprised to find areas near Mercury's poles that were unusually bright when observed with radar from Earth, an indication that ice might be present on the scalding world. Paige's thermal model identified cold spots on Mercury, almost perfectly matching the locations where ice was inferred from radar and MESSENGER observations.

But ice was not the only substance MESSENGER scientists found on Mercury. Scientists were surprised to find unusually dark deposits above polar ice within permanently shadowed craters. Paige believes these newly discovered black deposits are a thin crust of lingering organic material brought to the planet over the past several million years by the impact of water-rich asteroids and comets. "The stuff we find covering the ice is darker than the rest of Mercury, which is already a really dark planet. That's amazing," Paige said. "At the very least, it means there is something out of the ordinary going on inside these permanently shadowed areas where the ice has accumulated."



A surface temperature map of craters in the north polar region of Mercury. The two largest craters are approximately 25 km in diameter. Blue and purple areas are cold enough to harbor surface or subsurface ice deposits.

Comets and asteroids periodically crash into Mercury, bringing water ice and a diverse cocktail of organic material to the planet. In the searing daytime heat of Mercury, the only place water and organics can survive without evaporating into space is within permanently shadowed craters at the poles. In the warmest parts of the shadowed areas, the water evaporates away, leaving behind the hardier organic molecules that stick around at higher temperatures. This organic coating becomes black when exposed at the surface, in some cases covering subsurface ice deposits and protecting them from evaporation.

The presence of bright ice and dark organics on Mercury's surface presents a mystery for MESSENGER scientists. Every time a large comet or asteroid collides with Mercury, a huge swath of the planet becomes covered in a layer of dirt and dust kicked up during the impact. For the water ice and black organic layers to have remained exposed as they appear today, the deposits must have either formed recently in the planet's history or be maintained by new water brought to Mercury by smaller, more frequent impacts of icy bodies.

Planetary scientists remain puzzled as to why the extensive water ice deposits have been preserved on Mercury while corresponding permanently shadowed regions on the Moon remain relatively dry. Paige, the principal investigator of the Diviner Lunar Radiometer experiment onboard NASA's Lunar Reconnaissance Orbiter, created his thermal model of Mercury using data he has collected from the Moon. Since the crater-scarred landscapes of both bodies have comparable temperatures and conditions at the poles, one might expect the two bodies to have the same amount of ice. The large discrepancy remains a mystery that may only be solved through future research.

Understanding how water ice and organics arrived on Mercury may help scientists determine the conditions necessary for sustaining life on other planets. "Billions of years ago, the Earth acquired a layer of water and other volatile material that formed atmospheres, oceans and even the first organic molecules that started life," Paige said. "Uncovering the origin of the surface material at the poles of Mercury is a very important problem. It is essential to understanding the origins of life and the potential habitability of planetary systems around other stars."

David Paige is a professor in the Earth and Space Sciences department.

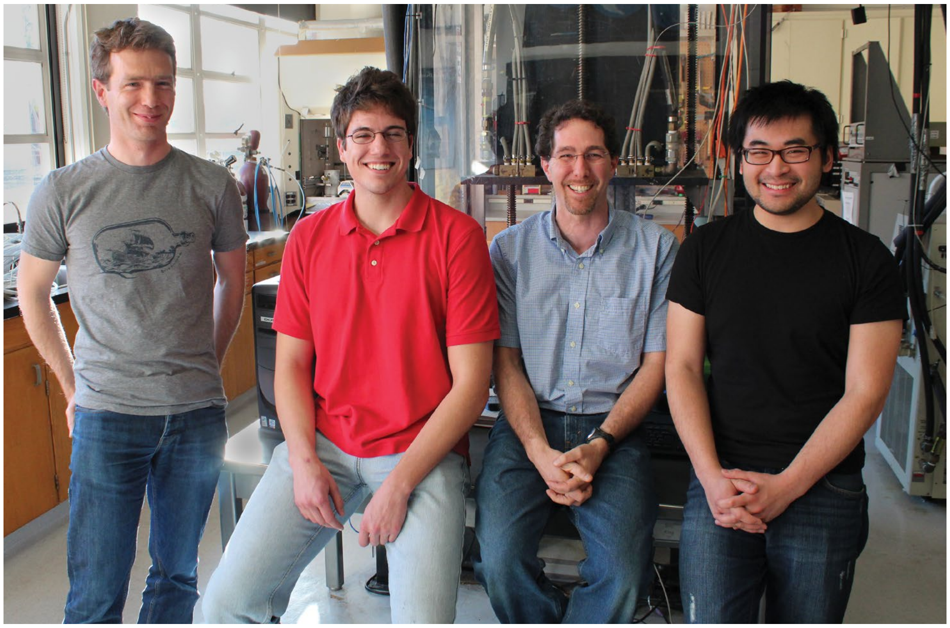
Putting a spin on fluid dynamics

Scientists from UCLA's SPINLab simulate planetary interiors with rotating experiments

The Simulated Planetary Interiors Laboratory, known more fondly as the SPINLab, is a state-of-the-art fluid dynamics research facility among only a handful of such unique labs in the world. Funded by the National Science Foundation, the group is led by Associate Professor Jonathan Aurnou, who has dedicated over ten years of his life to building functional models of planetary cores and atmospheres.

The daily routine for Jon, his graduate students, post-doctoral scholars and researchers involves spinning large, heat-driven containers of water or liquid metal in order to understand the fundamental physics of rotating bodies. "We are interested in explaining how strongly turbulent systems, like planetary cores and planetary atmospheres, organize into planetary-scale magnetic fields, jet systems, and vortices," said Aurnou.

The primary device used in the lab, a rotating magnetic convection device (RoMag), is a fluid-filled cylinder that to Aurnou represents "a parcel of fluid inside a planetary core." "The idea is to study all the ingredients that are involved in planetary core convection and dynamo generation in their simplified state," said Jonathan Cheng, a fourth-year graduate student with Aurnou. Dynamos, large-scale magnetic fields generated from the motions of an electrically conducting fluid, are known to exist within planets, stars and even galaxies. Yet the detailed physics of these natural dynamos remain largely mysterious.



The SPINLab team. From Left to Right: Michael Le Bars, Alex Grannan, Jonathan Aurnou, and Jonathan Cheng.

The Earth has a very organized magnetic field, created by convective motions in its rapidly rotating molten metal core, but other bodies such as Uranus and Neptune, the ice giants, and Jupiter and Neptune, the gas giants, have much "messier" dynamos, Aurnou said. In his lab, however, Aurnou is more concerned with studying the underlying dynamics of fluid systems than reproducing these dynamos. "I know there are dynamos. There are dynamos all over the solar system and on just about every star," Aurnou said. "I'm interested not so much in building a dynamo in my laboratory, but instead in building experiments that allow me to better understand the fundamental physics that underlie dynamo processes."

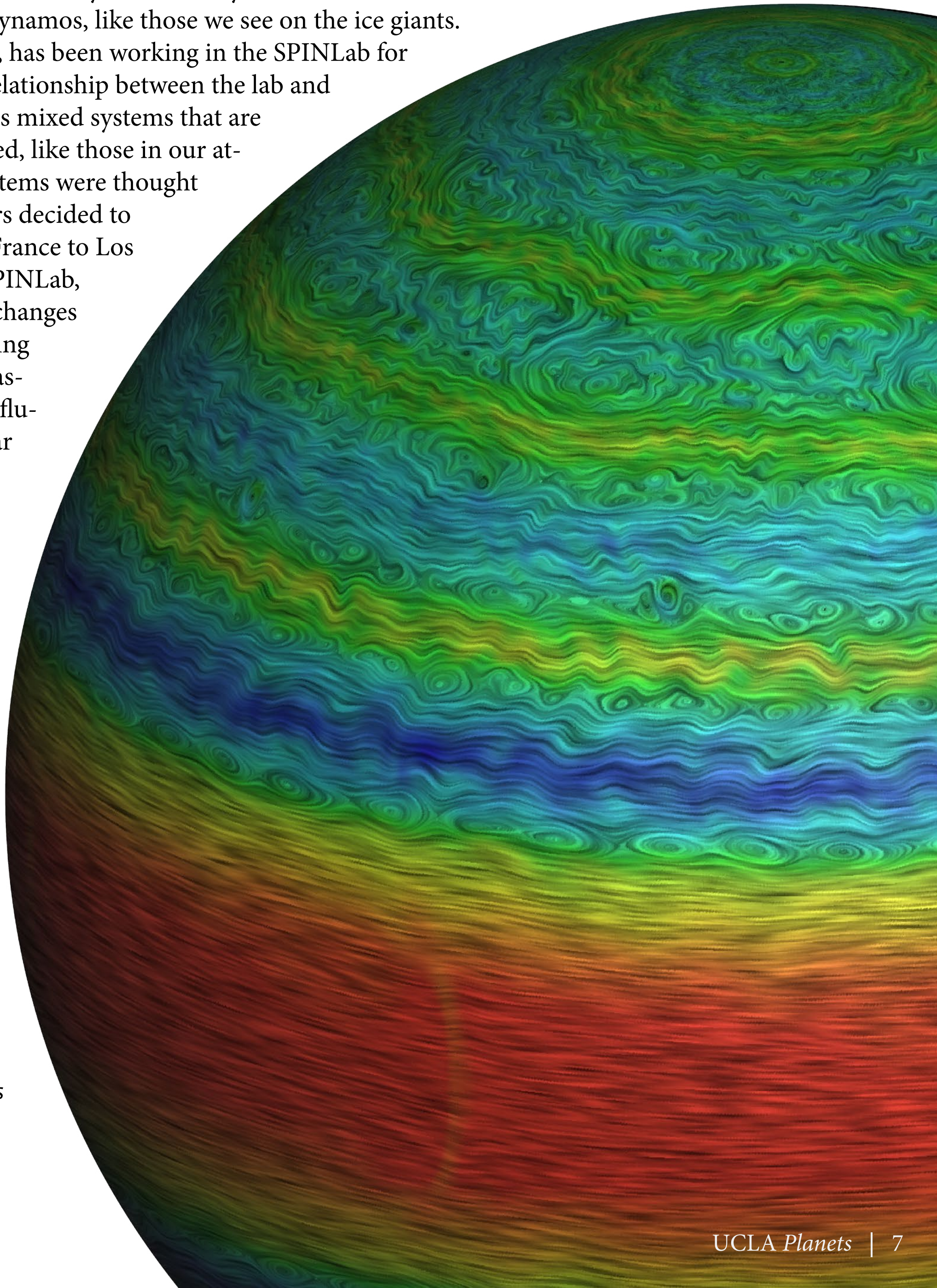
spinlab SIMULATED PLANETARY INTERIORS LAB UCLA

Jonathan Aurnou is an associate professor in the Earth and Space Sciences department.

And fundamentals have proved successful so far for the SPINLab. Using RoMag, the team has been able to show drastic differences in rotating convection systems that are metal versus those that are water. In water experiments, rapidly rotating systems become turbulent much faster than numerical models had predicted. The interpretation is that planets with deep-water layers can easily break down into turbulent systems that create disordered dynamos, like those we see on the ice giants.

Marie-Curie fellow Michael Le Bars, has been working in the SPINLab for a year, taking part in a long-standing relationship between the lab and French researchers. Le Bars investigates mixed systems that are partially convecting and partially layered, like those in our atmosphere, oceans, and stars. These systems were thought to be well understood, but when Le Bars decided to ship his experiments all the way from France to Los Angeles and try rotating them in the SPINLab, the results were surprising. "Rotation changes everything," said Le Bars. One interesting result was the production of "inverse cascades" that create columns of spinning fluid that cut across stratified layers similar to the Great Red Spot on Jupiter.

The fluid dynamics of most turbulent systems studied in the SPINLab are simply too complex for even the most advanced supercomputers to model or predict, but Aurnou and his team realize the importance of combining the two approaches. They hope to build bridges between experimental and computational methods in order to determine "how to make models that better describe the examples we see in nature."



A two-dimensional simulation of wind flow and turbulence within the atmosphere of a gas giant like Jupiter or Saturn.

An artist interpretation of an asteroid being broken apart. Image Credit: NASA/JPL/Caltech

Asteroids around other stars

Researchers analyze pulverized extrasolar asteroids using light from distant stars

When a Sun-like star reaches the end of its lifetime, it blows off its outer layers in a sustained stellar windstorm, leaving behind an Earth-sized, ultra-dense "white dwarf" star. Astronomers thought they knew what to expect from these celestial leftovers, but were puzzled over a decade ago when they found that a large fraction of observed white dwarfs emit more infrared light than predicted. Most white dwarf stars are composed of hydrogen and helium, but spectral measurements of some stars revealed puzzling signals from heavier elements such as calcium.

To UCLA Professor **Michael Jura**, the presence of additional elements indicated that the stellar atmospheres of these white dwarf stars were contaminated from an outside source. Many scientists hypothesized that the interstellar medium, a cosmic soup of stray particles inhabiting the space between stars, was responsible for this stellar pollution. Jura thought the answer might instead lie with extrasolar asteroids. "It was a mystery. A number of these stars had been known for quite a few years, but nobody knew quite why they were polluted," he said. Jura believes that the stellar contamination occurs when an asteroid perturbed out of its normal orbit plummets towards its parent star and is violently ripped to shreds by gravitational forces. Starlight from the white dwarf is consequently absorbed by the newly created disk of dust and debris left over from the shattered asteroid. The dusty ring encircling the star re-radiates the starlight as infrared light that is invisible to the human eye but can be measured by specialized telescopes on Earth.

The swirling cloud made from atomized asteroids does more than absorb light; it eventually becomes part of the star itself. "What is particularly important is that this disk doesn't just orbit the star, but that it slowly accretes onto the star," said Jura. Bits of asteroid falling into the white dwarf star contaminate the stellar atmosphere with heavier elements that wouldn't ordinarily be present. "Because we have these dust disks which are broken-up asteroids, we have a tool for measuring the elemental composition of extrasolar asteroids," he said.

To figure out what these asteroids were made of before they were destroyed, Jura and his graduate student **Siyi Xu** use data taken from the Hubble and Spitzer space telescopes. They also observe using the Keck telescopes on the big island of Hawaii a few nights every year. So far, they have detected 19 different elements heavier than helium in their white dwarf measurements.

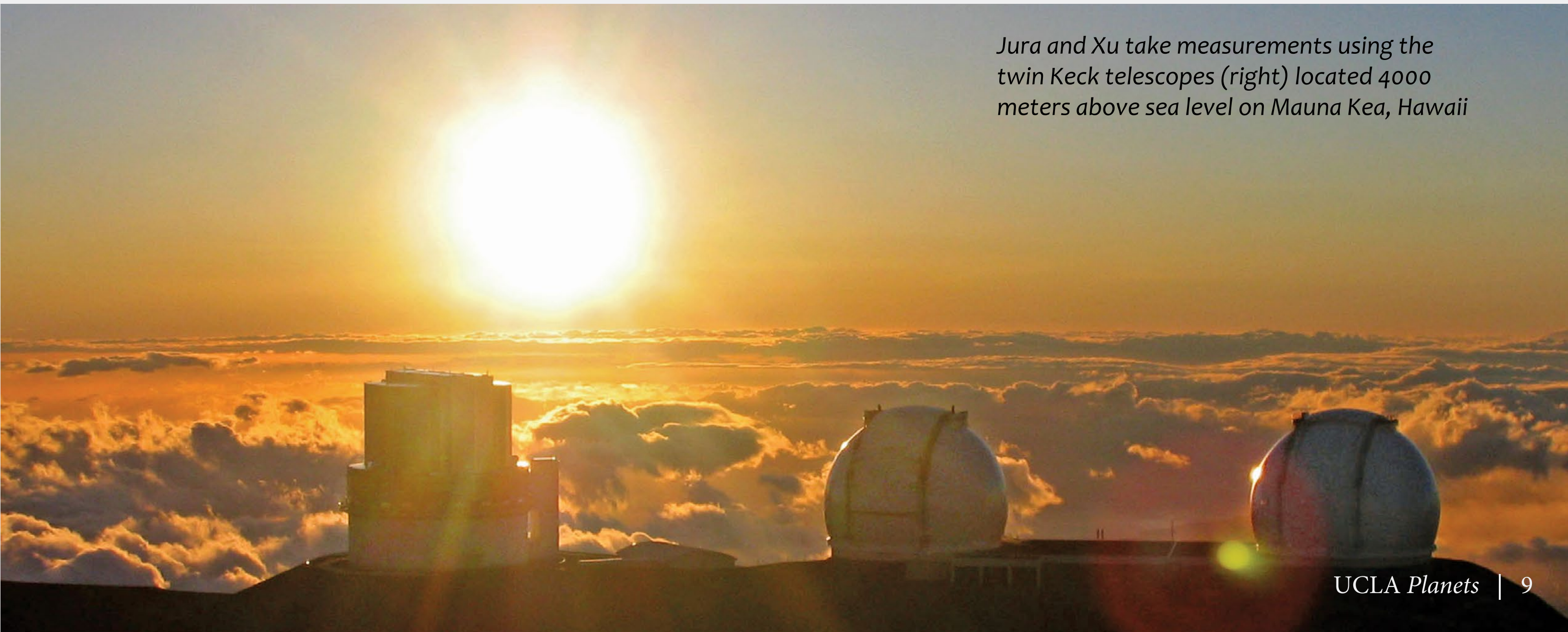
Mike Jura is a professor in the Physics and Astronomy department.

"We find the compositions of extrasolar asteroids are quite similar to meteorites in our own solar system. For one particular star, GD 362, the best match is mesosiderite, a type of stony-iron meteorite," said Xu. Oddly enough, Xu is able to measure traces of certain elements in meteorites vaporized by distant stars more easily than scientists studying intact meteorites in their labs. "It is very hard to measure the bulk composition of a meteorite in a lab without destroying it completely," Xu said. "Since the asteroid is already broken up for us, we can measure all of the abundances and make a comparison."

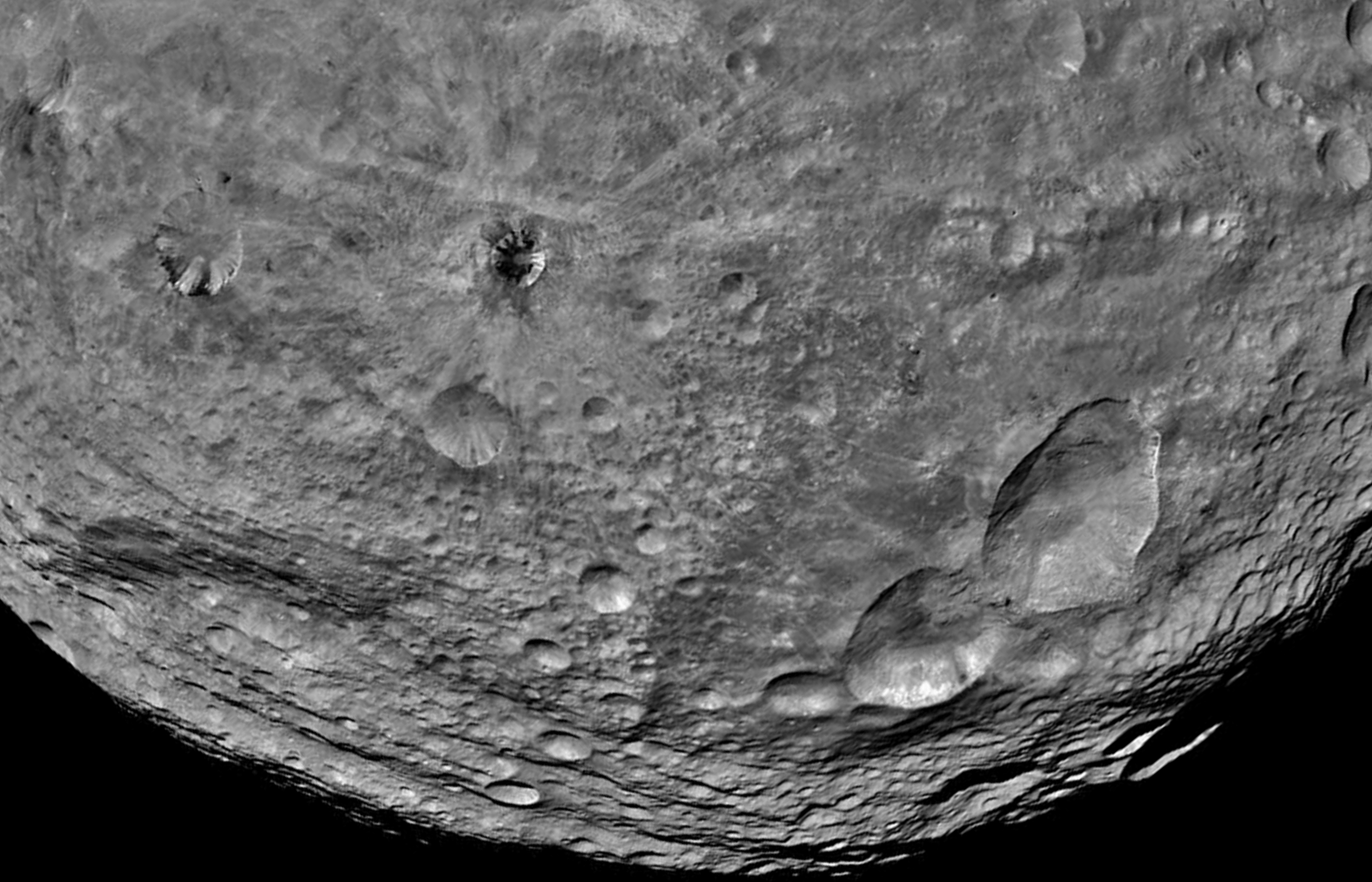
Siyi Xu is a third-year graduate student in the Physics and Astronomy department.

Determining the composition of extrasolar asteroids may help scientists understand how Earth-like exoplanets around stars are formed. "We picture that when rocky planets form, they build up from nearby chunks of orbiting rock and debris," Jura said. "In our own solar system, that process was somewhat inefficient, so we have asteroids left over." Our solar system is one of many planetary systems with surplus building blocks left behind from planet formation; scientists estimate that nearly 30% of white dwarf star systems have extrasolar asteroid populations.

Previously, astronomers have only been able to guess the composition of asteroids in other star systems based on what they have learned about asteroids closer to home. "We think they are probably the original suite of asteroids that formed when the star was forming planets," Jura said. "It's just plain fun to think that you can actually figure out what these other planetary systems are made out of."



Jura and Xu take measurements using the twin Keck telescopes (right) located 4000 meters above sea level on Mauna Kea, Hawaii



Vesta in the Light of Dawn

Graduate student Jennifer Scully gets up close and personal with the asteroid Vesta

On September 27th, 2007, NASA's Dawn spacecraft left Earth and began a multi-year journey to two of the largest objects in the solar system's main asteroid belt. The first stop on its interplanetary roadtrip was the asteroid Vesta. Dawn reached the Arizona-sized chunk of primordial rock in 2011, providing scientists with the first close-up view of the asteroid's ancient surface.

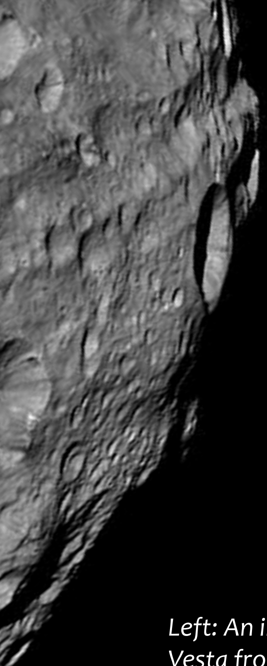
A leftover remnant from the formation of the solar system over four billion years ago, Vesta may be similar in composition to the larger bits of celestial debris that originally came together to form the inner planets. Scientists studying our planet's origins hope that Vesta will reveal clues about our past that have long been erased by plate tectonics and weathering on Earth.

"Studying Vesta is like going back to the beginning of the solar system," said Jennifer Scully, a third-year UCLA graduate student working on the Dawn mission. "It is kind of like a fossil of the sort of bodies that were around that combined to make the Earth," she said. Scully, the lead mapper for two large areas on Vesta, makes geological maps of the asteroid's surface in order to interpret the history of different features and formations.

What she has found so far has been surprising. "We discovered a lot of things that were unexpected at Vesta," she said. Grayscale and color images taken by Dawn's framing camera show a remarkable range of shades on the surface of Vesta, featuring both very bright and very dark material. "It's very colorful," said Scully. "We think the dark material is residue from meteorites called carbonaceous chondrites that have hit the surface."

Data from Dawn's instruments including the camera's seven color filters, a spectrometer, and a neutron detector help scientists characterize surface deposits and divide Vesta into areas depending on age, composition, and morphology. But sometimes this close-up view of Vesta raises more questions than answers.

"We found both straight and sinuous gully features and I'm investigating what sort of flow(s) formed them," said Scully. Whether or not some of the gully



features could have been carved by molten rock is under investigation. "The team has not found any definitive features of volcanism," Scully said. "There could have been activity early on, but the evidence has been wiped clean by billions of years of impacts."

Evidence of many of these impacts is preserved on Vesta's surface in the form of craters. These craters range in size from being so small that Dawn's camera can barely resolve them to being so large that they have diameters nearly as big as Vesta. The two largest impact basins on the asteroid, named Veneneia and Rheasilvia, are found in Vesta's southern hemisphere. Scully is one of many Dawn scientists who are working to connect these impact basins with structures in Vesta's northern hemisphere. "The current understanding is that each of these large impacts sent shock waves through Vesta, which formed large-scale ridges and depressions on the opposite side," said Scully.

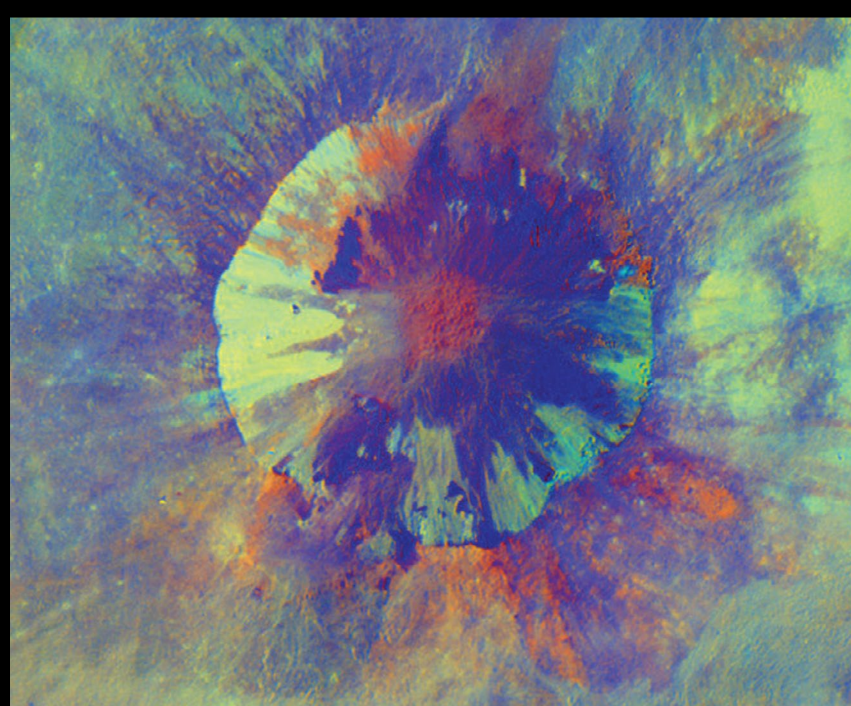
The Dawn spacecraft does not only examine the surface of an asteroid, it can also give scientists clues about its internal structure. "From the way the gravity pulls on the spacecraft you can tell about the internal layers and the size of the core," said Scully. From examining how Vesta's gravitational field tugs on Dawn, scientists believe that Vesta has a distinct crust, mantle, and core like Earth.

Left: An image obtained of the asteroid Vesta from NASA's Dawn spacecraft from a distance of 3,200 miles. Image Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

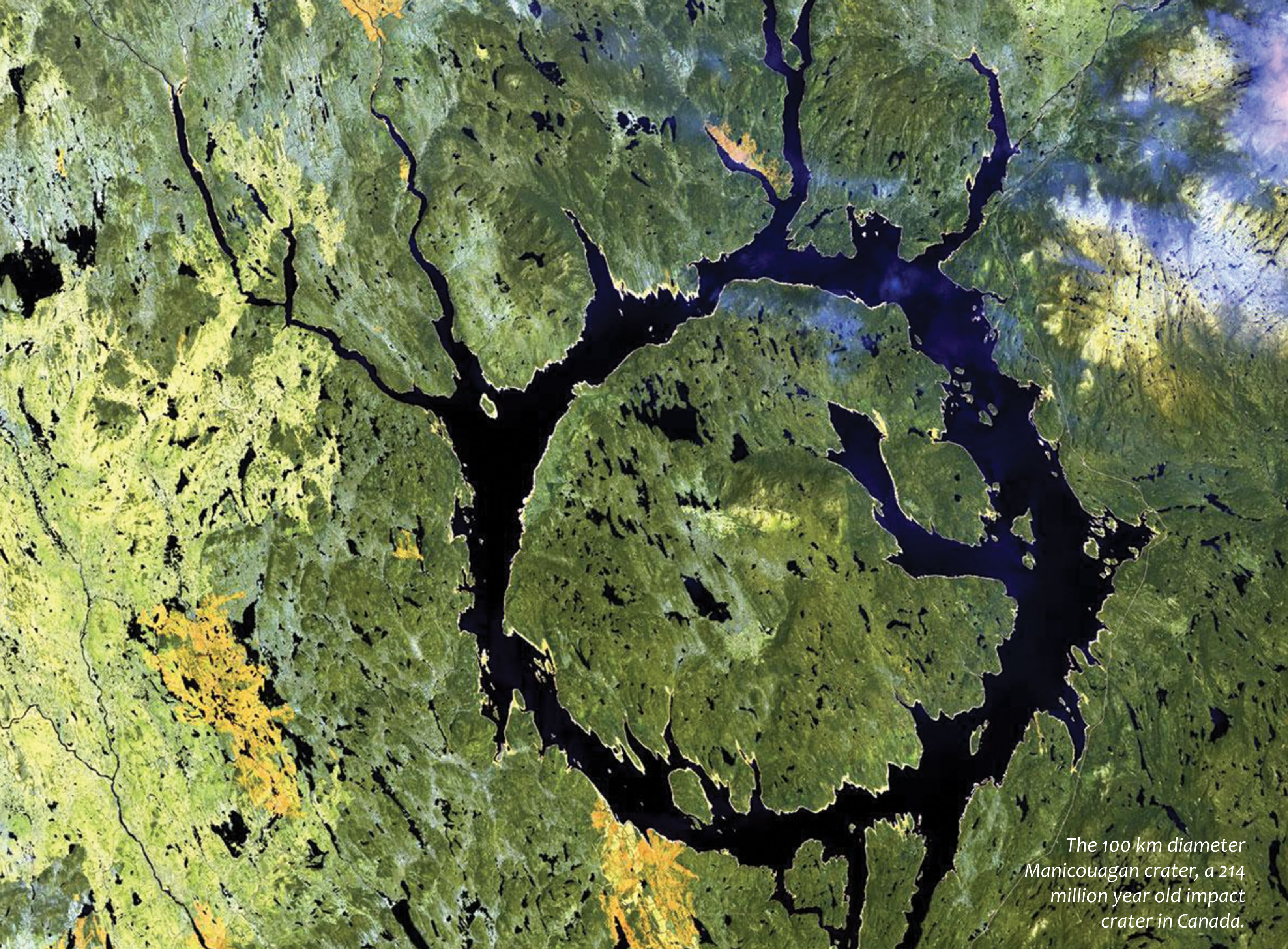
The same is likely not true for the asteroid Ceres, Vesta's younger cousin and the next and final stop for the Dawn spacecraft. After remaining in orbit around Vesta for one year, the Dawn spacecraft took its leave in September of 2012 to begin a three-year journey to Texas-sized Ceres, the largest object in the main asteroid belt located between Mars and Jupiter. Unlike Vesta, scientists think Ceres may harbor large amounts of water ice under its surface. Because Ceres is wetter than Vesta, it will present a whole new set of questions. Scully looks forward to directly comparing the data collected from the two asteroids when the spacecraft arrives at Ceres in 2015.

For Scully, the decision to come to UCLA and work with Professor Christopher Russell was a "no brainer." "Getting to work on an actual active mission is pretty awesome. You get to meet a lot of people and really see how a team works," she said. In addition to her work on the geology of Vesta, Scully helped create an online system called Asteroid Mappers where citizen scientists can identify features on Vesta using real data collected by Dawn.

Jennifer Scully is a third-year graduate student in the Earth and Space Sciences department.



False color view of Cornelia crater on Vesta. Different colors indicate areas of different physical properties or composition. Image Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/JHUAPL



The 100 km diameter Manicouagan crater, a 214 million year old impact crater in Canada.

Decoding Solar System History

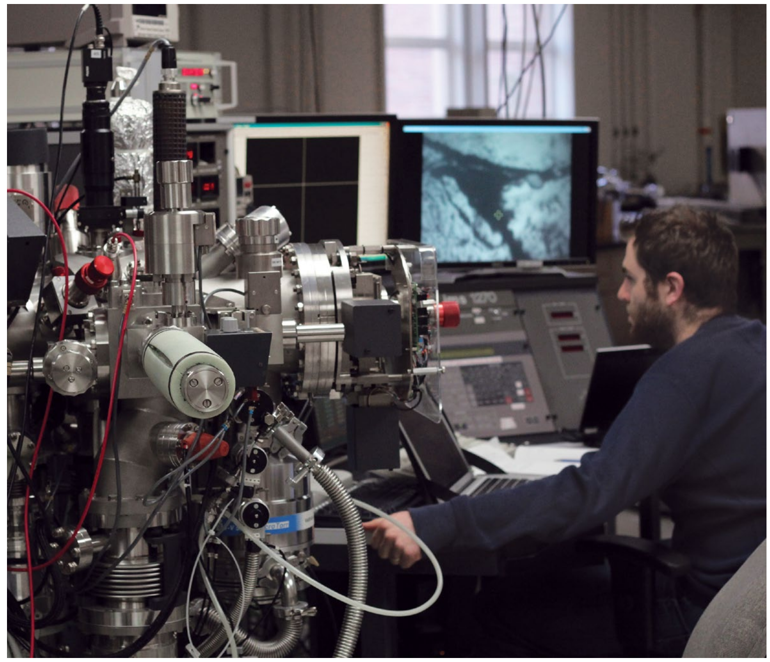
Some of the oldest minerals on Earth may hold clues about the early solar system

The answer to one of the great mysteries of our solar system's history may lie within a grain no wider than a single strand of human hair. Scientists have long known that the mineral zircon is very hardy. "Zircon tends to stick around for a long time," said Beth Ann Bell, a fifth-year UCLA graduate student who studies these tiny grains. And she's not kidding about zircon's longevity – the samples she studies are 3.8 to 3.9 billion years old. The Earth itself is 4.5 billion years old.

With their advisor, UCLA Professor Mark Harrison, Bell and her colleagues study individual zircon grains to better understand a critical and highly controversial event in our solar system's history known as the Late Heavy Bombardment (LHB). During the LHB, which occurred between 3.8 and 4.1 billion years ago, a very large number of craters formed on the surface of the Moon. Analysis of the craters and lunar samples have led some scientists to suggest that the objects that crashed into the Moon were numerous and came from far away, possibly beyond the orbit of Jupiter. "The whole inner solar system should have been impacted and evidence of the LHB should be detectable anywhere, even on Earth" said Matthew Wielicki, also a fifth-year graduate student. But scientists are still uncertain if the LHB actually happened at all. "There is much debate among planetary scientists as to whether the lunar samples from NASA's Apollo mission are giving us the full picture of what was happening at that time," said Wielicki.

To better understand the LHB, Wielicki and Bell analyze zircons on Earth in an attempt to determine whether any of the objects that formed the Moon's craters also impacted our planet. Like tiny little clocks, zircons can record the timing of an impact event by the heat signatures it leaves behind. Some recorded features, known as shock features, are diagnostic of an impact and can cause a grain to appear as though it was shattered. However, such telltale signs do not always develop, and scientists must instead investigate subtler signs, like the ratios of radioactive elements inside the zircon.

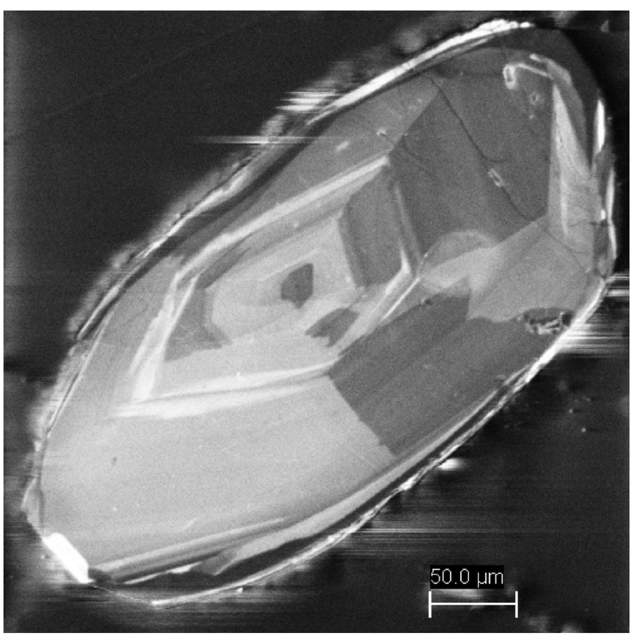
To study element ratios within their zircon grains, Bell and Wielicki use a unique device called a **Secondary Ion Mass Spectrometer (SIMS)**, located at UCLA. "With many techniques you must pulverize your sample, essentially destroying it, in order to study it," said Bell. With the SIMS, samples are left intact and shot with a beam of energized atoms, or ions, and analyzed in tiny patches. The SIMS can peer into a grain "one atomic layer at a time," allowing them to study multiple heating events in a single zircon, said Wielicki.



Located at UCLA, the Secondary Ion Mass Spectrometer (SIMS) is one of a few such instruments in the world used for scientific endeavors.

Cosmic impacts aren't the only events in Earth's history that could produce heat signatures in zircon grains. Using the SIMS, Bell and Wielicki hope to be able to distinguish between zircon grains that have been affected by a meteor impact and those that have been heated by "some other event, like mountain building or volcanism, all which were occurring on Earth during the LHB timeframe."

Because of efficient weathering and erosion processes, there are no impact craters on Earth which date back to the LHB, so Wielicki works to develop the tools necessary to understand impact-heated zircon grains using zircons from more recent impact events. Bell then tests the validity of those tools on LHB-age zircons whose history is unknown. "The rocks where we find ancient samples are sedimentary, which means they were once older rocks that eroded, and then turned into the sandstone we see today," said Bell, "we don't know what types of rock they originally grew in."



The internal structure of a zircon grain that is almost 4 billion years old.

"We are cornering two parts of a three-fold approach to pin down the LHB," said Wielicki. The third piece of their approach involves studying zircons from other inner solar system objects. "The real excitement comes when we apply our analytical tools to samples from objects like Vesta," said Wielicki. Vesta, the target of NASA's Dawn mission, is a large asteroid located in the inner solar system that has been cold for a very long time. Wielicki said, "If we see any heating signal in Vesta's zircons, we know it must be from an impact."

For Bell and Wielicki, the picture is far from complete. The LHB, which occurred just before the onset of life on Earth, could have ties to the origins of life. It is unclear, however, if impacts would have acted as "life frustrators," slowing life's development, or if they actually delivered the "building blocks" for life, said Wielicki. "Understanding the timing of the LHB may help answer some of the questions about life on Earth, but first we need a better understanding of the impact history for the inner solar system," he said.

Planetary Portraits

The Gemini Planet Imager will reveal planets around young stars

Most planet-hunting astronomers infer the existence of extrasolar planets by monitoring tiny changes in the parent stars. With the recently assembled Gemini Planet Imager (GPI), UCLA Assistant Professor Michael Fitzgerald intends to capture images of these extrasolar planets directly.

Scheduled to go online at the Gemini South Observatory in Chile in late 2013, GPI will be able to detect planets in newly formed systems where traditional detection methods would be likely to fail. Sensitive at infrared wavelengths, GPI targets young planets, which are warmer than their more evolved counterparts in other systems. "When planets form they are initially large and are slowly contracting, releasing their gravitational energy in the form of heat and cooling off as they get older," Fitzgerald said. "We need to look at young systems because that's when their planets are warmest and therefore brightest in the infrared."

Above and Below: The Gemini South Observatory in Chile where the GPI instrument will be installed later this year. Image Credits: Copyright NeelonCrawford/Polar Fine Arts, Gemini Observatory and National Science Foundation

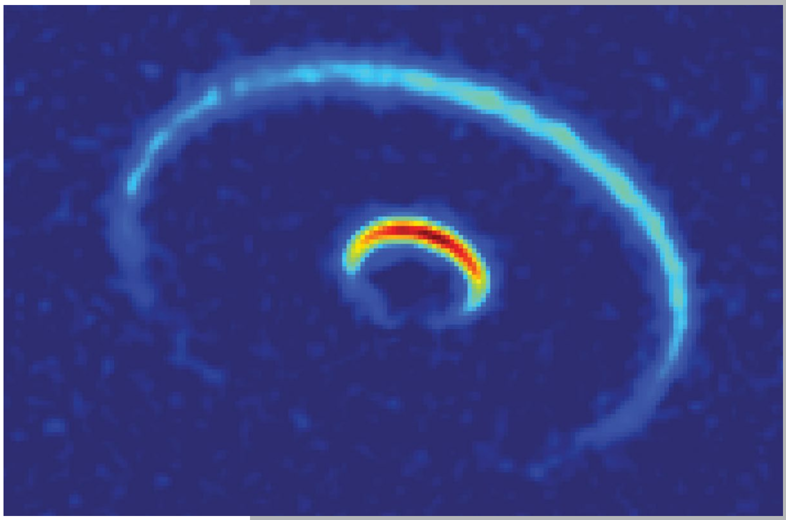
Using a method based on pioneering work by UCLA Professor Ben Zuckerman, the GPI Exoplanet Survey Team has identified and catalogued over 900 nearby young stars that are promising candidates for planet imaging. They hope to image 600 of these stars and expect to find roughly fifty new planets. The type of planets most likely to be revealed by GPI are Jupiter-sized gas giants that formed less than one hundred million years ago and are located many Earth-Sun distances away from their parent star.

But the search won't be easy. "Stars are a million times brighter than the planets we are looking for, and these are the biggest and brightest planets that we expect to see," Fitzgerald said. The GPI experiment utilizes several state-of-the-art innovations to image these elusive planets including a special coronograph that blocks out light from the parent star in order to make the planet more easily visible, and a unique deformable mirror that helps to compensate for atmospheric distortion.

The best picture astronomers can hope for will show an extrasolar gas giant as a single point of light. "The planet will not be spatially resolved," Fitzgerald said. "We'll see a dot." Yet the GPI instrument can glean a surprising amount of information from a tiny speck of light. Fitzgerald and his colleagues will be able to analyze the composition of these far-off planets using a spectrograph built by UCLA Professor James Larkin, and perhaps even more importantly, they'll be able to directly image their associated circumstellar disks.

"A lot of these systems are young – the planets have only recently formed and there are a lot of leftover planetesimals which collide and produce debris disks," Fitzgerald said. Scattered light from the dusty cloud surrounding the star has a distinct polarization signature that can be separated from the unpolarized starlight by using special filters. "If we just look at the intensity of the polarized light, the dust jumps out," Fitzgerald said. The shape and position of stellar disks around new stars may help scientists like Fitzgerald better understand the formation of our own solar system. "There is a lot of diversity in the debris disks we see. Some of them are rings, some are very extended, a few show interesting asymmetry, and some are even offset from the star due to gravitational perturbations from a planet," Fitzgerald said. The structure of dusty disks may also provide clues about the orbital dynamics of distant planets. "The highlight for the Gemini Planet Imager will be looking at the systems where you have both a disk and a planet, because you can immediately put constraints on the orbit of the planet," Fitzgerald said. "If you see a nice, symmetric disk, you wouldn't expect a planet to be plowing through it."

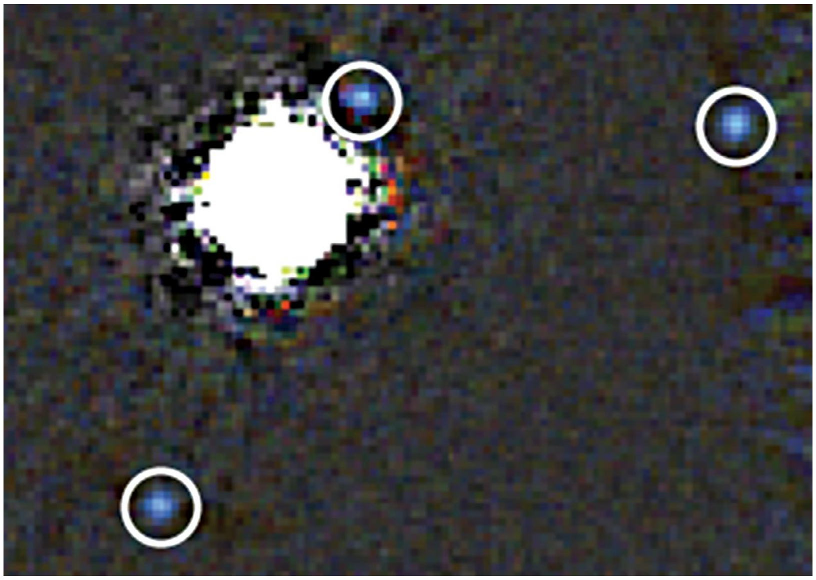
Fitzgerald, who came to UCLA in 2010, is also collaborating with scientists at NASA's Jet Propulsion Laboratory in Pasadena, California to develop a way to make precision radial velocity measurements using infrared rather than visible light. He hopes the technique will help to find planets around young, energetic stars that are too active to yield accurate results in optical wavelengths, and low mass stars which are optically faint. Fitzgerald has enjoyed forming new interdisciplinary collaborations in his search for extrasolar planets as a member of iPLEX. "Having iPLEX and integrating all of the departments in terms of exoplanet studies is definitely the way of the future," he said.



A simulation of dust rings around a star as they may appear through the Gemini Planet Imager. The morphology of the rings shows an offset from the star, indicating the effects of hidden planets.

Image Credit: Chris Johnson, UCLA

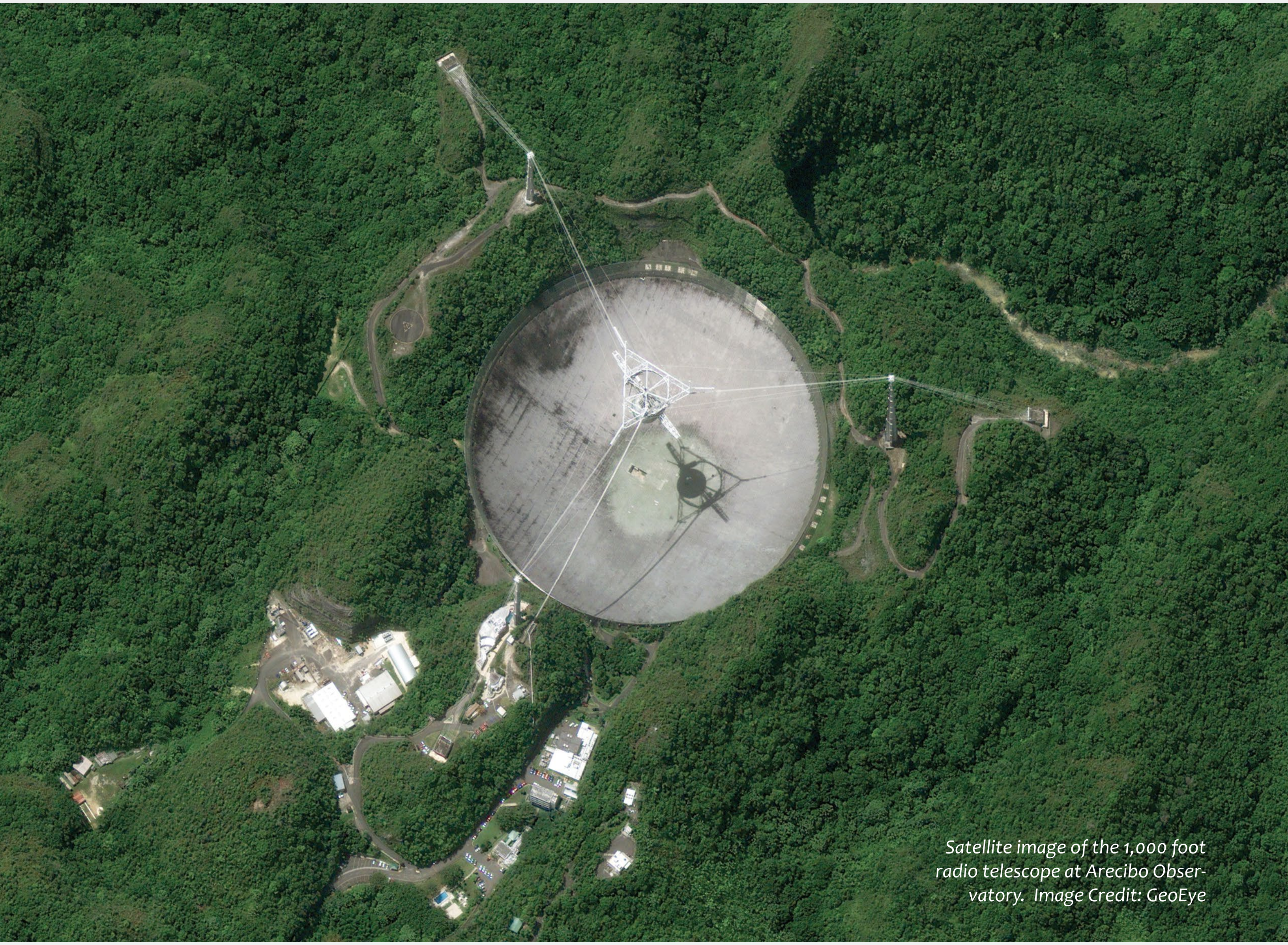
Michael Fitzgerald is an assistant professor in the Physics and Astronomy department.



A simulation showing how GPI might identify planets around another star. The star's light is blocked by a coronograph, and the star's three planets are represented as blue dots circled in white.

Tracking Asteroids

Graduate students use radar to track asteroids and predict hazards



Satellite image of the 1,000 foot radio telescope at Arecibo Observatory. Image Credit: GeoEye

Every year, UCLA graduate student Shantanu Naidu makes a pilgrimage to Arecibo Observatory, a uniquely constructed 300-meter radio telescope on the island of Puerto Rico. His goal: to determine the shape, spin, orbit, and other physical properties of Near Earth Asteroids (NEAs). These large chunks of rock left over from the formation of the solar system orbit around the Sun while remaining relatively close to Earth.

Observing asteroids with radio waves is a far cry from the traditional picture of nocturnal astronomers and mountaintop telescope domes housing fragile mirrors and lenses. Since the wavelengths they employ are far outside the visible light spectrum, radar observations can take place as easily during the day as they can at night. Likewise, the measurements are not affected by weather because the long wavelength radio waves can easily penetrate cloud layers in Earth's atmosphere.

Naidu bounces radio waves off his targets and examines the reflected signal to reveal the shape of asteroids that would normally appear as "unresolved points of light" through optical telescopes. Radio telescopes can both resolve and track these elusive objects. Radar observations taken from Arecibo over the course of a few hours contain hundreds to thousands of pixels with surface resolutions as fine as 7.5 meters.

One of Naidu's primary goals is to determine a precise orbit for each NEA he studies. At Arecibo, Naidu can pinpoint the position of an asteroid with an uncertainty of only

"NASA wants to catalog the orbits of as many Near Earth Asteroids as possible so we can predict if any asteroid is going to collide with the Earth and take countermeasures."

a few tens of meters, a remarkable feat given that the majority of these objects are more than ten million kilometers from Earth. The precision of an asteroid's orbit is important because NEAs occasionally come close to Earth as they orbit around the Sun. Scientists want to be able to identify any asteroid that could be a potential hazard decades or centuries before impact. "NASA wants to catalog the orbits of as many Near Earth Asteroids as possible so we can predict if any asteroid is going to collide with the Earth and take countermeasures," said Naidu. Radar measurements of NEAs enable Naidu and his colleagues to derive orbits for the objects far more accurately than any other method. With a single additional observation, the time interval for reliable trajectory predictions can be improved by a factor of 5 to 10, allowing scientists to chart the position of asteroids over the course of hundreds of years rather than decades.

Radar measurements help provide advanced warning for incoming asteroids, but only a tiny fraction of NEAs are currently being studied. Naidu and his colleagues have observed roughly four hundred of these nearby asteroids, but scientists estimate that 20,000 NEAs with diameters greater than 100 meters exist in the solar system.

Arecibo radar image of a Near Earth Asteroid taken during its close approach to Earth in February 2012. The asteroid is about 2.3 km in diameter. Image Credit: S. Naidu

When Naidu observes an asteroid for the first time using radar, he hopes to hit the jackpot and see not just one object, but two or three. What originally appears to be a single asteroid could instead be an asteroid binary, two asteroids that orbit each other like moons orbiting a planet. "When we observe, we see that one in every six asteroids larger than 200 meters has a moon around it, so we know that binaries form a significant portion of the NEAs," said Naidu. "Fifteen years ago, we didn't even know that binaries existed."

Fourth-year graduate student Julia Fang works to model the "orbital architecture" of these complex multi-asteroid systems. She creates computational models to predict how radiation from the Sun or a close encounter with the gravitational field of a planet could change the orbital paths of a multi-asteroid system. She hopes to recreate the history of these complicated systems in order to understand what processes might be responsible for producing their current orbits. "Asteroids provide clues about the orbital history of the planets and how they evolved," said Fang.

Both Naidu and Fang are advised by UCLA Professor Jean-Luc Margot, one of the world's foremost experts in high-precision radar observations of asteroids. Additional information about the UCLA radar program is available at: http://radarastronomy.org.

Shantanu Naidu is a third-year graduate student in the Earth and Space Sciences department.

Julia Fang is a fourth-year graduate student in the Physics and Astronomy department.

Stormy Titan

Professor Jonathan Mitchell predicts weather on Saturn's icy moon

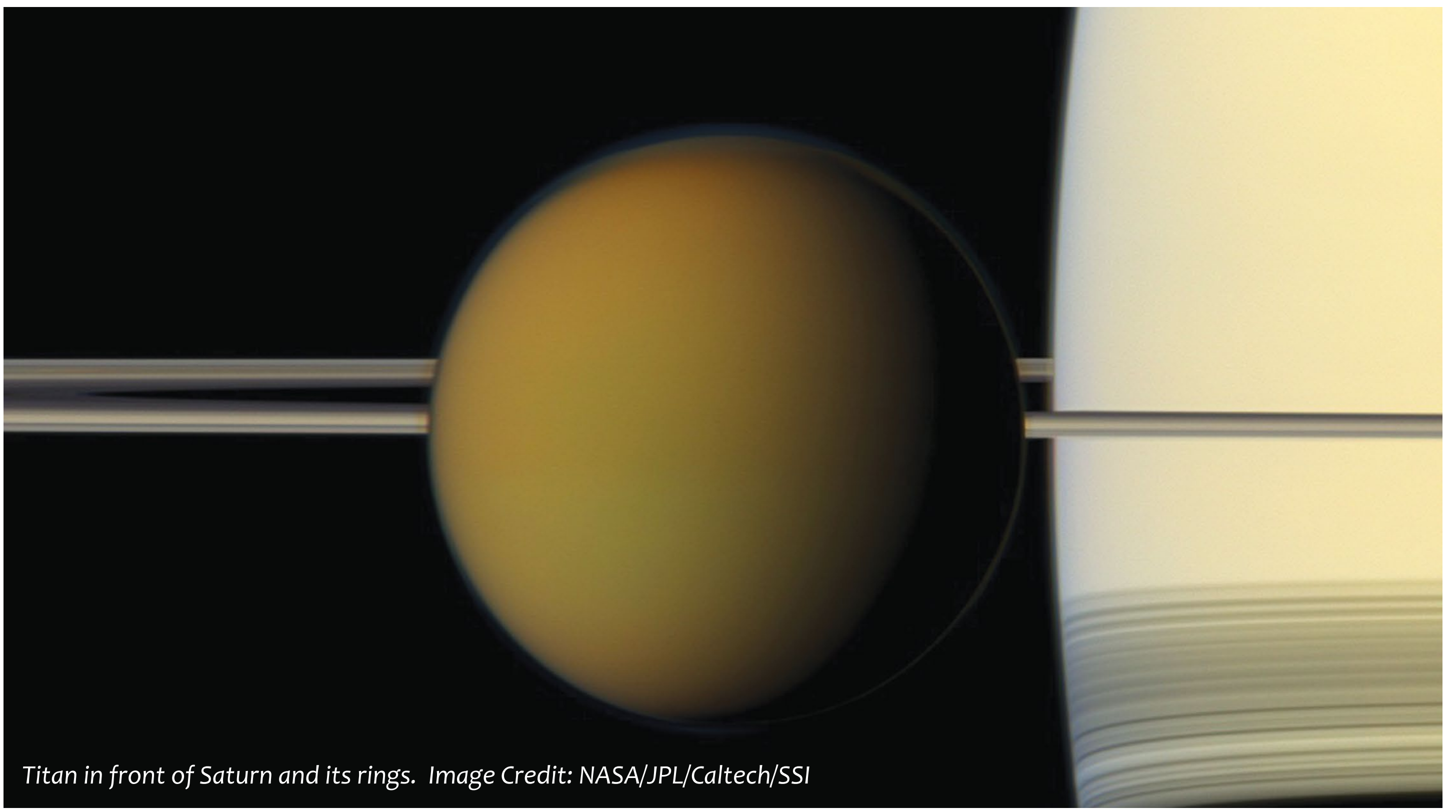
Saturn's largest moon, Titan, is an icy world dominated by extensive sand dunes at the equator, methane-filled lakes near the poles, and vast networks of dry riverbeds in between. Wrapped in a nitrogen atmosphere thicker than Earth's, Titan is an ideal test bed for studying planetary climate models for UCLA Assistant Professor Jonathan Mitchell.

"Titan is probably the most Earth-like place in the solar system in terms of its very active weather cycle," said Mitchell. But a weather forecaster on chilly Titan would be more likely to predict a liquid methane downpour than the water-based showers we are accustomed to on Earth. "Titan is too cold for water to play a role in the weather. Instead, it rains and hails methane, the natural gas we use as fuel for our stoves," Mitchell said.

So is Titan a veritable tinder box, an enormous gas leak ready to catch fire at the slightest spark? Not at all, said Mitchell. "You might worry about it exploding, but all the oxygen is locked up into water. If you wanted a lighter that you could carry around on Titan, then you'd carry around a flint with a little vial of oxygen because there is plenty of methane in the air and the limiting ingredient is the oxygen for combustion."

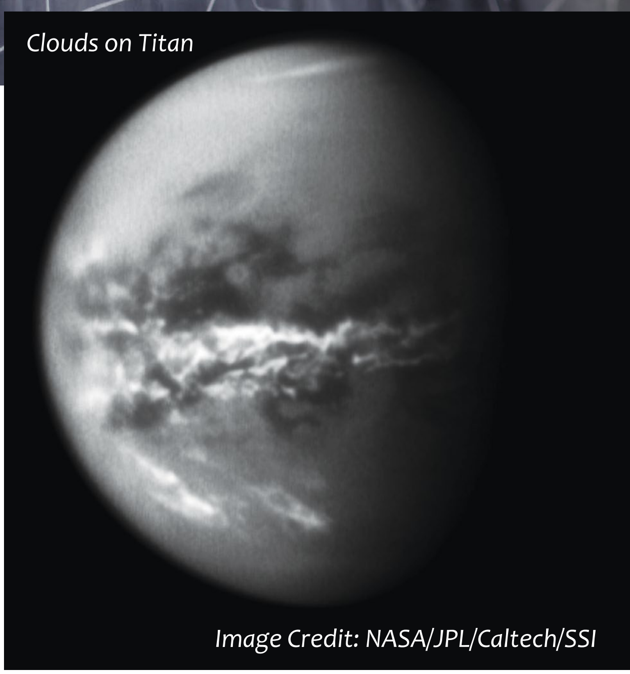
Titan has surface temperatures nearly 300 degrees Fahrenheit below zero (-180° Celsius). Water makes up about half the solid body by mass, and where you would expect to find a rocky crust on a terrestrial planet like Earth, Titan's surface layers are composed mainly of ice. "Water is essentially Titan's rock," said Mitchell. "These temperatures are so far beyond the realm of human experience that they're hard to even grasp."

Despite the frigid conditions, Titan's climate patterns are technically quite tropical, Mitchell said. "On Earth, we have a certain temperature difference between the equator and the poles which gives rise to vastly different climates on the surface, like tropical islands versus Antarctica," he said. "On Titan, this temperature difference is essentially erased, which makes its climate all tropics." The subzero weather results from the fact that Titan spins more slowly than Earth, taking sixteen days to complete a full rotation, and also because of its smaller size. While Titan is larger than Mercury and is the second largest moon in the solar system, it is still less than half the size of Earth.



Titan in front of Saturn and its rings. Image Credit: NASA/JPL/Caltech/SSI

To be able to understand and predict weather patterns on Titan, Mitchell and his colleagues rely on observations from NASA's Cassini spacecraft that help them improve their computer simulations. "We're looking at the visible and near-infrared images of Titan to survey cloud features and find interesting spatial patterns from the evolution of storms," Mitchell said. Because Cassini can only take



Clouds on Titan

Image Credit: NASA/JPL/Caltech/SSI

Jonathan Mitchell is an assistant professor in the Earth and Space Sciences department.

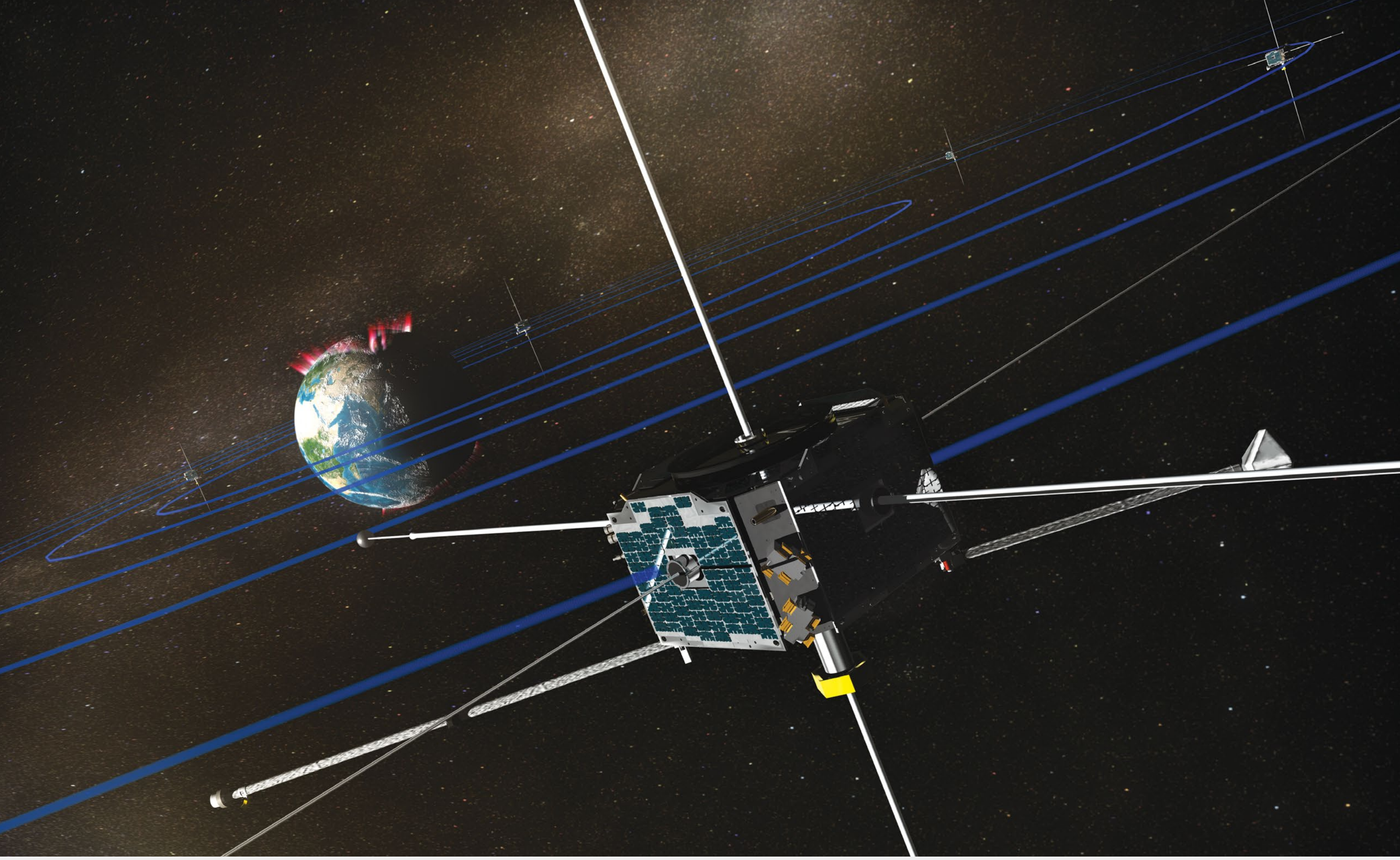
measurements at Titan during its regular flyby once every few weeks, an accurate computer model is critical to understanding weather patterns on the icy body.

Mitchell's research may help explain a curious phenomenon called super-rotation, which causes Titan's atmosphere to circle the planet at speeds higher than expected. "Super-rotation means that the atmosphere as a whole is spinning faster than the planetary surface," Mitchell said. "This is puzzling because we typically think an atmosphere gains its momentum from friction with the surface."

Since coming to UCLA in 2009, Mitchell has expanded his work to include Earth's ancient climate, which he hopes will help him to better predict how regional climates will change as the planet warms over the next century. "We've essentially nailed the problem of anthropogenic greenhouse gases warming the planet," Mitchell said. "The much harder question is: what will be the resulting impacts?"

Mitchell grew up in rural Iowa where incessant gazing at the stars as a small child led to the occasional tripping injury. "I've always been curious, and that's what made me a scientist," Mitchell said. "I was destined to be looking up." As a graduate student at the University of Chicago, Mitchell originally studied cosmology and gravitational lensing. But after a few years, he switched fields to study the physics of climate on Earth and other planets. "Cassini was arriving at Saturn about that time so I decided to take a pit stop at Titan, and I haven't really left since," he said.

Mitchell, who enjoys singing in small group ensembles in his spare time, has found a home at UCLA. "Academically, I just can't imagine a better fit for me. I have very broad interests and UCLA is a place where you can really expand and learn."



Exploring Earth's Magnetosphere

Scientists study magnetic fields around the Earth to forecast space weather

The Sun is a veritable force in our solar system. It emits a tremendous amount of heat and energy, called the solar wind, which constantly blows and buffets the planets at a velocity almost two thousand times faster than the average jet plane. Akin to an invisible shield, the Earth's magnetic field deflects most of the solar wind, but it happens often that the magnetic fields of the Earth and Sun briefly and directly come into contact with one another.

When the fields connect, part of Earth's magnetic field "peels away from the sunward side and drapes around the back of the planet," said sixth-year graduate student, Christine Gabrielse. The backside of Earth's magnetic field, or magnetotail, is "squeezed from the outside as a result of the peel back," she said. Eventually, two points on the interior of the Earth's magnetic field meet in what is called a near-Earth reconnection, releasing a great deal of energy that flows toward Earth. "These powerful phenomena, known as substorms, can create more than picturesque auroras", Gabrielse said. "They can damage spacecraft or astronauts, or even ground-based systems." On March 13th, 1989, one such storm caused a legendary power outage in Canada's Quebec province that left more than three quarters of a million people without power for nearly twelve hours.

While scientists had studied substorms for years, many questions remained regarding these space weather events. Proposed by UCLA Professor Vassilis Angelopoulos, NASA's Time History of Events and Macroscale Interactions During Substorms (THEMIS) mission was designed to answer some of these questions.

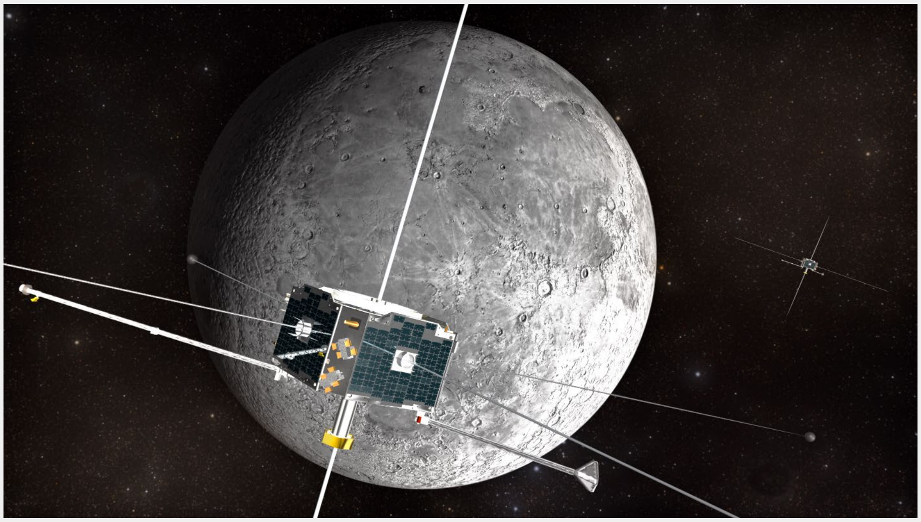
Launched in February 2007, the mission consisted of five identical satellites deployed to critical locations around Earth. Unprecedented at the time, THEMIS allowed scientists to track the flow of energy around Earth and determine how and where substorms initiate. "The spacecraft gave us five pinholes in the magnetic curtain we are trying to see through," said Drew Turner, an assistant researcher at UCLA working on the THEMIS mission.

From their unique orbits, engineered to simultaneously provide five key perspectives of the vast space environment, the spacecraft quickly solved the questions they'd set out to answer. "In 2008, THEMIS repeatedly showed that reconnection happens in the magnetotail first, activating a substorm," said Gabrielse. With its primary goal accomplished, THEMIS set new objectives. Splitting the satellites into two groups, three continued to orbit Earth, while two were sent to the Moon as a 'new' mission called Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS). "The extension to ARTEMIS was quite miraculous," said Turner. "The spacecraft were not equipped with the ability to maneuver out of their orbit. The THEMIS engineers and operators sent satellites to the Moon by way of tiny puffs of rocket fuel."

Using "the most comprehensive plasma instruments we've sent to the Moon," the two ARTEMIS satellites are now busy determining the rock types on its surface, said Turner. The satellites detect small variations in the Moon's particle and electric fields allowing them to distinguish between different materials. "It's a natural way of detecting surface composition from afar," said Turner. In addition, the satellites are improving substorm research by studying the Earth's space environment from their entirely new viewpoint near the Moon. "With the two spacecraft at the Moon we can test what's happening on the other side of the reconnection," said Shanshan Li, a fifth-year UCLA graduate student. "We can start to form a three-dimensional substorm model of Earth's space environment."

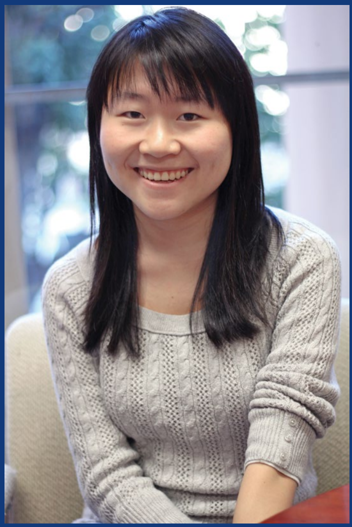
The THEMIS satellites that have remained in orbit around Earth are "scientific goldmines," according to Turner. Coordinating observations with the Van Allen Probes, a pair of recently launched NASA satellites, they were able to detect a previously unknown layer of charged particles surrounding Earth. Turner said, "in a huge and complex system, my bread and butter is combining as many satellites' data as I can to get as complete a global picture as possible."

With the Sun approaching a period of increased activity, the media have begun to report space weather more often. "It's good to see that society is taking an interest," said Turner. "We've become increasingly dependent on



Above: The ARTEMIS spacecraft at the Moon. Left: The THEMIS spacecraft in orbit around the Earth. Image Credit: SVS/NASA

space-based assets," said Turner. "Even something as simple as using an ATM will most often result in a satellite-relayed signal at some point." Since large space storms can have huge societal impacts, it is important to be able to see them coming. "Just like meteorologists want to be able to forecast a storm on Earth, we want to be able to predict a storm in space," said Gabrielse. "Ultimately, our aim is to determine what's going on in the Sun-Earth environment and try to better understand it."



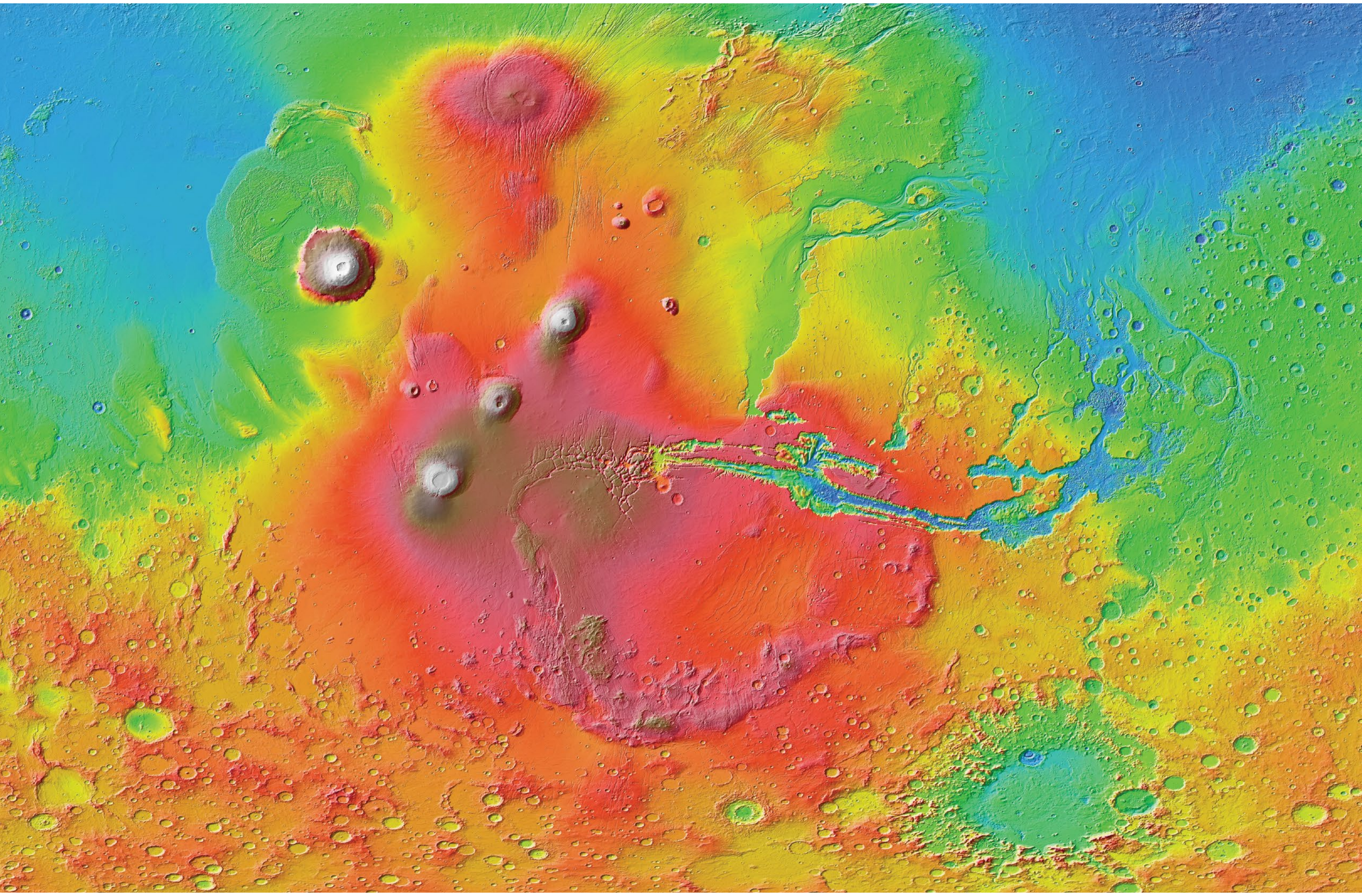
Shanshan Li is a fifth-year graduate student in the Earth and Space Sciences department.

Drew Turner is an assistant researcher in the Earth and Space Sciences department.

Christine Gabrielse is a sixth-year graduate student in the Earth and Space Sciences department.

An Earthly Perspective on Planets

Professor An Yin uses his experience on Earth to study the geology of other worlds



A topographic false-color map of Mars including some of the largest volcanoes and the largest canyon in the solar system. Image Credit: NASA/JPL/Caltech/Arizona

Few people can claim that their children learned to walk in the forests of Yosemite National Park. Professor An Yin, who has spent much of his 26 years at UCLA conducting fieldwork in Tibet, the Himalayas, and California, can. Having spent his graduate career investigating remote areas of Glacier National Park, Yin's mountaineering experience equipped him for the challenging Asian fieldwork and tectonic research that earned him the Donath Medal from the Geological Society of America. "It was a frontier in an area that was not explored before, despite it being on Earth," said Yin. "Knowing almost nothing about this large area, I tried to make a synthesis." Nowadays, Yin spends less time in Tibet and the Himalayas, making only two trips a year, usually to drop off graduate students to conduct their own fieldwork. Instead, he has directed his interest toward the fledgling field of research known as planetary geology.

In 2008, Yin began applying his Earth geology expertise to landscapes he observed on other planets. "Having limited data to create a tectonic story in large areas of Asia gave me the know-how to explore planet-related problems," Yin said. "The process turns out to be quite similar." In his early days of Tibetan research Yin used satellite images to estimate locations of faults before going into the field; similarly, he uses satellite images to understand planetary geology from afar. Images today, however, provide more clues about the geology. "High-resolution images have revolutionized mapping and geologic interpretation," said Yin. "We still can't determine composition, but we can say for certain how much and in what manner a feature is offset from its original position."

To explain the features he observes on Mars, Yin has developed a theory that invokes a one-plate tectonic system. Unlike Earth, which has 15 major tectonic plates that move continuously and are responsible for forming mountains and oceans, Mars has only one plate that moves very slowly. Moving at a pace 1000 times slower than those on Earth, Mars' tectonic plate produces plate-boundary features like volcanoes and faults that materialize in a relatively small area and grow very large. Maps of Mars show that almost all its prominent features are confined to just one-third of the planet. Among these features are the colossal Tharsis Montes, three volcanoes so large they could fit 32 of Earth's three-mile-high Andean volcanoes into the volume they occupy.

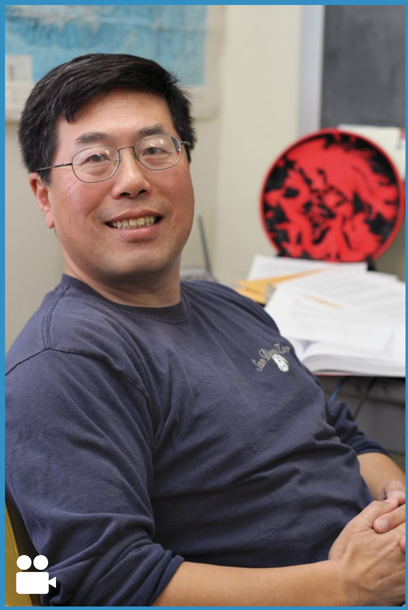
Although Mars' features are grander, they share many characteristics with Earth's terrain. This observation led Yin to contemplate the underlying processes that create the two planets' surfaces. For not only Mars, but for many planetary bodies, the differences in these processes may be the result of their individual "evolutionary paths," said Yin.

Piecing together the story of how a planet's geology has changed over time requires Yin to use all the resources at his disposal. "The problem with planetary geology is that you see a static image," he said, "the history is harder to show." One way of revealing the history is by observing it. In Yin's laboratory, he and his graduate students design sandbox experiments to reveal how faults, mountains, and valleys develop. While these experiments are intended to mimic natural conditions, they do not represent the exact history of any process, and act more as a guide to help determine whether their basic assumptions are correct.

From these experiments, Yin has determined that the histories of Mars and Earth are quite similar, differing only in their rates of evolution. "Mars is smaller and has less heat, so the driving engine is not as powerful as Earth's," said Yin. Although Mars and Earth appear to be quite similar, other planetary bodies may have very dissimilar evolutionary paths.

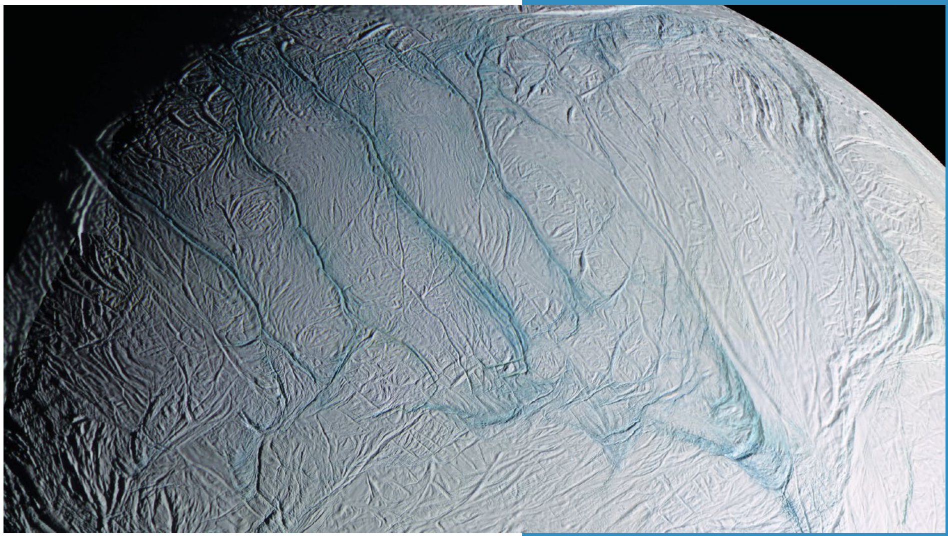
Yin's newest foray into planetary science involves Enceladus, an icy moon of Saturn. He interprets the famous "Tiger Stripes" that periodically eject water vapor from its south pole as a product of the movement of the moon's icy shell, and prefers to call them "Horsetails," after a Himalayan feature they so closely mimic. While Yin can decipher portions of Enceladus' history from its surface features, it remains unclear whether there is a global or localized ocean beneath the icy surface. "This is an actively debated subject," said Yin, "but for now I can only tell the story of what happened."

From the otherworldly geology he's studied thus far, Yin has learned that "the planetary world is something that defies common sense in many respects. We have an idea of how a planet should develop and what it should look like, and we find exception after exception after exception." Yin hopes that his continued interdisciplinary approach to planetary geology will result in observing "overlapping parts of commonality" between planets that could reveal more about planetary evolution as a whole.



An Yin is a professor in the Earth and Space Sciences department.

An image of the "Tiger Stripes" on Enceladus. Image Credit: NASA



Alumni Profile: Ashwin Vasavada

MSL Deputy Project Scientist Ashwin Vasavada answers questions about his work

As Deputy Project Scientist of NASA's Mars Science Laboratory, Ashwin Vasavada works with other mission scientists at the Jet Propulsion Laboratory in Pasadena, CA to decide where the Curiosity rover will next travel on Mars. Vasavada, who received a B.S. in Geophysics and Space Physics from UCLA in 1992, describes what it is like to command a rover on Mars and gives advice to aspiring planetary scientists.

What inspired you to study planetary science and Mars in particular?

The late 1970s and early 1980s are sometimes referred to as the Golden Age of planetary exploration. NASA landed its first spacecraft on Mars, and the twin Voyagers began a 'grand tour' of the outer solar system. I remember being fascinated as a young kid by the pictures from these missions, especially those taken from the surface of Mars, as if one were standing right there and looking out at eye level. It was amazing to me that there were entire other worlds out there, exotic, but yet familiar, with rocks and soil and sky. Even though I grew up with the space shuttle, I never wanted to be an astronaut. It was these robotic probes that really took my imagination.

What is your favorite image returned by Curiosity so far?

Probably my favorite images are the distant panoramas of Mt. Sharp, the 3-mile-high mountain that is the main scientific target for Curiosity. It's a gorgeous mountain, with canyons carved into its slopes by wind and water. The foothills form layered buttes, like the badlands in the Dakotas. You can follow ancient stream beds uphill until they wind around some corner between sheer walls. If we're fortunate, we'll be there in a year or so, dwarfed by those hills.

The base of Mt. Sharp, the Curiosity rover's final destination on Mars.
Image Credit: NASA/JPL/Caltech/MSSS

What has been the most exciting part of working on the MSL mission?

After ten years working on MSL, I've had practically every emotion. There's a deep satisfaction in working with a group of talented people who are at the top of their game. JPL has the best engineers around, and they give it their all to help us scientists conduct our experiments on other planets. In 2008, we had to make the difficult decision to delay our launch by two years. The complexity of the rover was proving too challenging for our schedule, and Mars only comes around every two years for a launch. That was tough, but fortunately NASA stuck with it. Given all the great media coverage, you might think I would say that the landing was the most exciting. But actually, the moment I will never forget is the launch of Curiosity from Cape Canaveral. Only then, staring at this massive rocket and hearing it thunder to the sky, did I fully grasp that we little humans were hurling a one-ton emissary to another planet. And my family and close friends were there with me, watching along.

> "Only then, staring at this massive rocket and hearing it thunder to the sky, did I fully grasp that we little humans were hurling a one-ton emissary to another planet."

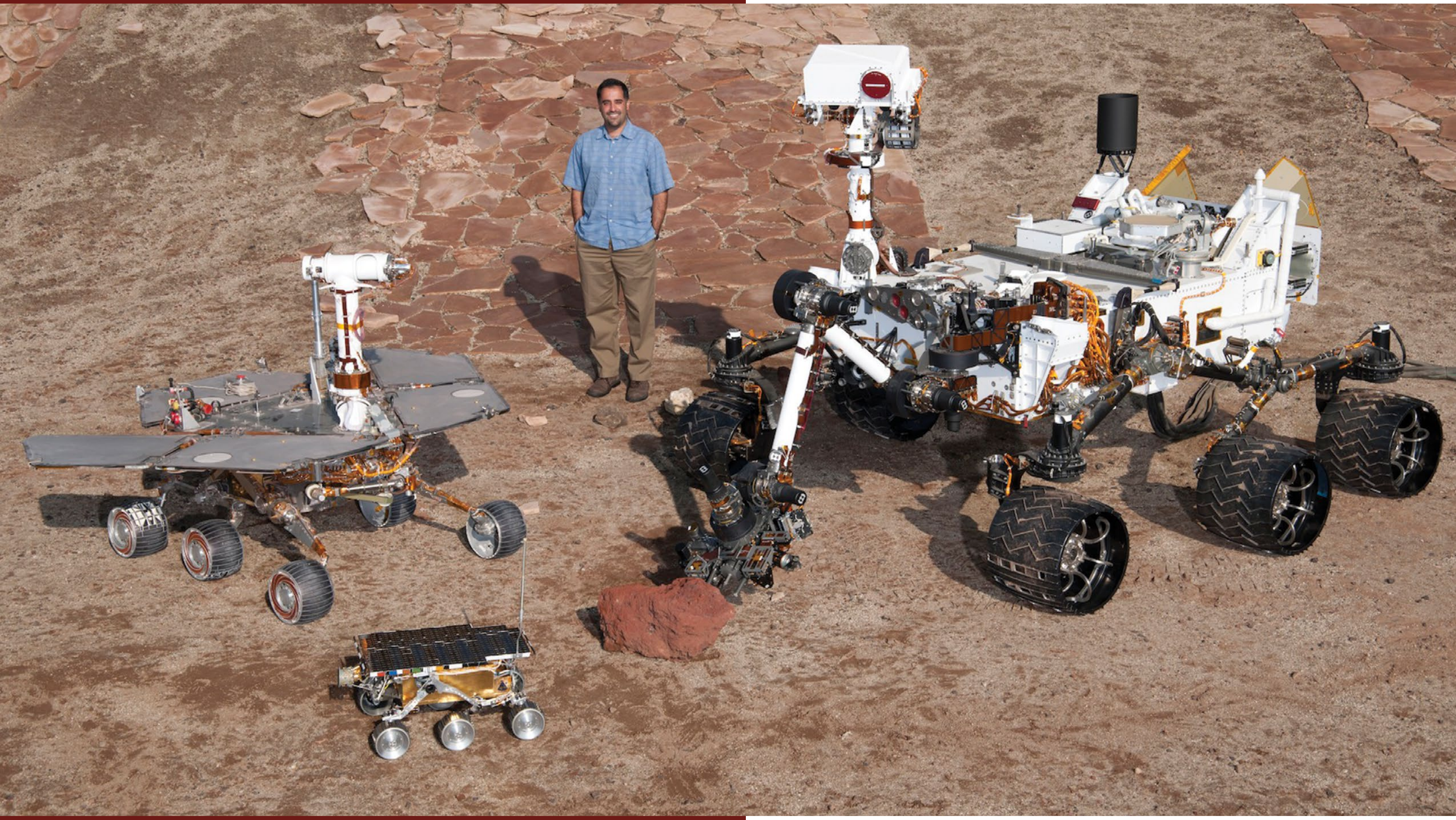
Ashwin Vasavada next to a model of the Curiosity rover (right). Curiosity is about the size of a small car and is the largest rover to land on Mars so far.

What was your best experience at UCLA?

Attending UCLA couldn't have worked out better for me. Like many students, I wasn't exactly sure where I was headed when I arrived. I chose UCLA because, of the schools that gave me admission, it alone excelled in both the sciences and the arts. I was seriously contemplating a career in music back then, and UCLA gave me the chance to continue to perform alongside music majors while studying science. Grad school at Caltech was five years locked in a laboratory, so I'm so grateful that at UCLA I had the classic college experience--weeknights studying hard, then playing in the marching band at the Rose Bowl on Saturday!

What advice would you give to aspiring planetary scientists?

Probably my favorite piece of advice is to not let the 'planetary' distract from the 'scientist'. Many young scientists want to immediately join the current, big mission, almost like running away to the circus. And like the circus, it's exciting, but somewhat career-limiting! My advice would be to find a research topic you love, maybe even in Earth science, since that's often where the state of the art resides. Dive into it for graduate school and a few postdocs, and let NASA come knocking on your door to ask you to join the next mission, because you're now the expert. Stay focused on being the best scientist you can be.



Hao Cao

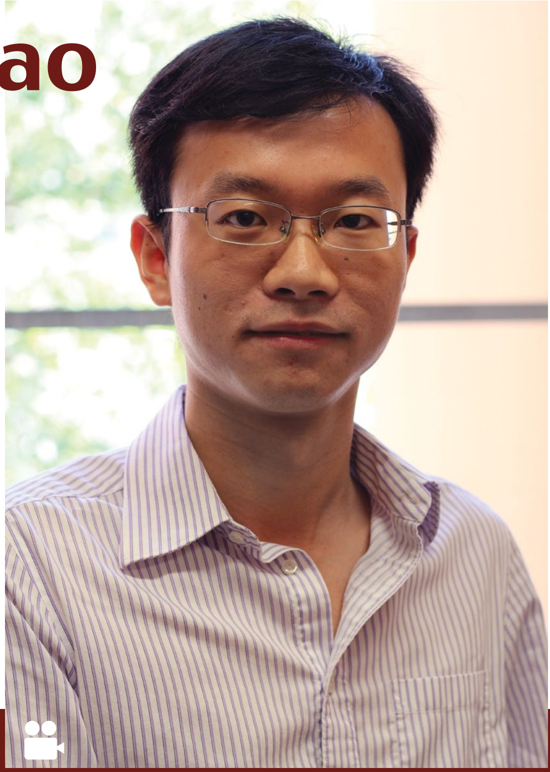
Long ago, scientists discovered that when a compass points north on Earth, it is not actually pointing to the North Pole. The axis of Earth's magnetic field is tilted away from the axis that the planet spins about. Every planet in our solar system with a magnetic field follows this rule, except one: Saturn.

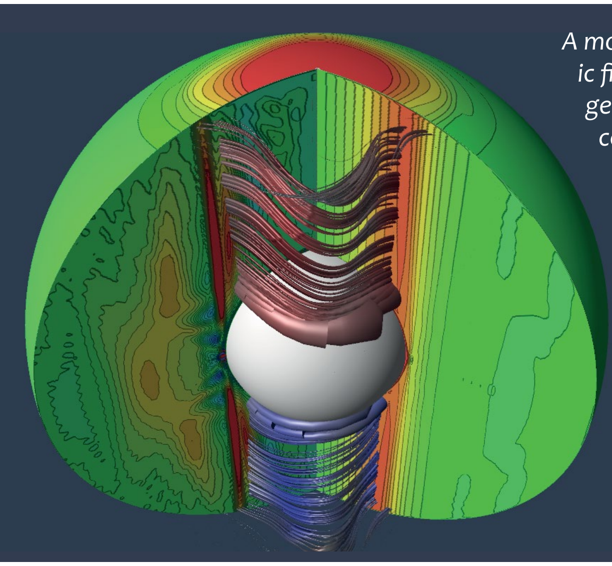
When fourth-year graduate student Hao Cao came to UCLA, his advisor, Professor Chris Russell, presented him the opportunity to study data from NASA's Cassini mission. Arriving at Saturn in 2004, Cassini has been orbiting the planet ever since, measuring Saturn's magnetic field, among many other things. Cao wondered, "What does the magnetic field tell us about Saturn?"

To answer that question, Cao needed to determine how Saturn's magnetic field is generated. The sixth planet from the Sun, Saturn is a gas giant composed primarily of hydrogen, the simplest and most abundant of elements in the universe. Inside Saturn, where pressure is a million times greater than at Earth's surface, hydrogen is thought to exist as liquid metal. The turbulent motions of this electrically conductive hydrogen are what give rise to the magnetic field of Saturn. But metallic hydrogen is also responsible for producing the tilted magnetic field on Jupiter. Cao knew he had to look deeper.

He began contemplating the rocky core that may exist deep in the heart of Saturn, which could shape the metallic hydrogen layer that lies above it. "Zonal winds that move across the planet could reach deep inside the planet and influence the shape of the magnetic field being generated by the metallic hydrogen layer," said Cao. As a result of these interactions, Cao has produced the best size estimate of Saturn's core to date. Twice the size and ten times the mass of Earth, but only 1/5th the size of Saturn, this core is the first to be assessed using magnetic field data.

Recently, Cao has begun trying to explain Mercury's puzzling asymmetric magnetic field using information from NASA's MESSENGER spacecraft. "When you study a place like Saturn or Mercury, there are many things you learn for the first time," said Cao. Beyond magnetic field research, Cao is interested in many aspects of planetary science. "Dynamo studies are only part of understanding planets. Formation, internal structure, and dynamics are all related – it's not an isolated problem," he said.





A model of the magnetic field (wire-like lines) generated in Saturn's conducting, metallic hydrogen interior.

Recent PhDs 2011-2013

Chris Crockett
US Naval Observatory; Freelance science writer

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Jessica Watkins

For third-year UCLA graduate student **Jessica Watkins**, the "big picture goal" has always been to travel to space as an astronaut. To achieve her dream meant intense physical training (she was part of Stanford's 2008 international collegiate rugby championship team) and earning a Ph.D. in a research area relevant to space. Beginning her education as a mechanical engineer, she soon realized it wasn't for her. Turning to a course bulletin for inspiration, she found classes about planets and atmospheres in Stanford's Geological and Environmental Sciences department that would prove to suit her well.

Presently, Watkins works with her advisor, UCLA Professor An Yin, to understand massive landslides in Mars' Valles Marineris, a network of canyons the size of the continental United States. Using images and data from NASA's Mars Reconnaissance Orbiter and satellite images of Earth for comparison, she attempts to determine whether the cause of Martian landslides is tectonic activity, flowing water, glaciers, or something else. Accordingly, Watkins is trying to determine if any of the minerals in her landslides are hydrated, or wet. Although she is not studying the astrobiological aspects of the minerals, she said her work is "one small study that could tell us a lot," including information about the habitability of Mars.

Watkins also examines landslides up close to understand how to best interpret images of Mars' landslides. During a recent field investigation of a Mars-like landslide in Death Valley National Park, Watkins was surprised that some of her preliminary image interpretations were incorrect. "There are many things about other planets that we might not be able to truly understand just from images," she said. "Being able to walk around and get your hands on it really makes a difference."

Left: Blackhawk Landslide in Lucerne Valley, CA. The region shown is 2 km across. Right: A landslide in Ius Chasma on Mars, about 30 km in length. Image Credits: Google Earth and NASA/JPL/MSSS

That's what drew Watkins to planetary geology. "UCLA merges geology and planetary science really well," she said. "I can use my Earth geology background to study other planets." This summer, Watkins will collaborate with Mars Science Laboratory (MSL) scientists at the Jet Propulsion Laboratory (JPL) in Pasadena, California in hopes of improving our understanding of Mars' surface. In retrospect, Watkins realizes she has always been interested in Mars. "My earliest memory of being interested in Mars was in fifth grade," she said. "We had to make illustrated books – I wrote mine on Marty the Martian."

Raquel Nuno

Raquel Nuno works to construct a water-cooled data center for computational modeling. The completed facility connects 3000 computers and has 1 million gigabytes of data storage.

> "Teachers were very important in shaping my interests and career goals. I would like to have that sort of positive impact on other students."

When Raquel Nuno isn't hunting for atmospheric water vapor on Mars, she's constructing a massive super computer in the basement of UCLA's Geology building. Nuno, a recent UCLA graduate with an interest in planetary science, analyzes data collected by NASA's two Viking spacecraft that orbited Mars from 1976-1980. She hopes to pinpoint areas where excess water vapor in the Martian atmosphere might trigger the formation of Recurring Slope Lineae, mysterious dark streaks that appear on crater rims and canyon walls during the warmest Martian seasons. These features, first observed by NASA's Mars Reconnaissance Orbiter in 2010, may indicate the presence of flowing liquid water beneath Mars' surface. "We think Recurring Slope Lineae could mean there is current hydrological activity on Mars," said Nuno. "The question we are trying to answer is: where is this water coming from?" To locate potential water sources, Nuno and her advisor, Professor David Paige, have been looking for areas on Mars where the water content in the air is higher than average. Nuno presented her results during a talk at the American Astronomical Society's Division of Planetary Science meeting in Reno, NV in October of 2012.

Nuno, who moved to the United States from Portugal at age eleven, is the first person in her family to earn a college degree. Her unlikely path to planetary science began when she joined the United States Air Force out of high school, working as a medical laboratory technologist. While in the military, Nuno took classes at six different colleges and universities before enrolling as an undergraduate student at UCLA, her "favorite so far." Nuno hopes to pursue a career in academia and she hopes to inspire the next generation of scientists and researchers through teaching. "Teachers were very important in shaping my interests and career goals," she said. "I would like to have that sort of positive impact on other students."

Hubble postdoctoral fellow and soon-to-be Assistant Professor at Massachusetts Institute of Technology, Hilke Schlichting is no stranger to traveling long distances. On a daily basis, Schlichting ventures three-to-five billion miles from Earth to the Kuiper Belt, a primordial ring of icy bodies in the outer reaches of our solar system. "I'm interested in all aspects of planet formation," said Schlichting. "Our solar system provides an opportunity to study it in a way that we cannot study elsewhere."

Of course, Schlichting does all her space traveling from the comfort of her office at UCLA. Using data from the nearly 1500 Kuiper Belt Objects (KBOs) scientists have identified since 1992, Schlichting studies size distribution, especially for objects larger than 100 km across. Objects of this size, including the well-known dwarf planet, Pluto, are important because "planet formation never proceeded to completion for these bodies," said Schlichting. "It's an ideal laboratory for testing planet formation theories."

No one knows exactly how planets form. "We know there is a gaseous disk that surrounds a star or stars in the beginning," said Schlichting, "but we can't observe the early stages of formation because the gas blocks our view." To predict exactly what happens in the early stages of planet formation, Schlichting creates models that try to reproduce the distribution of objects observed in the Kuiper Belt. From her models she has learned that planet formation goes through a phase called "runaway growth," a time when a relatively small fraction of the total mass coalesces very quickly into large objects. "The model matches the large KBOs, which are frozen in the runaway growth phase," she said.

Schlichting has also conducted research to identify very small objects in the Kuiper Belt. "The objects are too small to reflect much sunlight back to Earth," said Schlichting. Instead, she observes a large number of background stars in hopes that a small object will pass in front of one of the stars, thereby blocking out some of the starlight. Seeing these ephemeral objects is rare, and Schlichting has detected only two from an immense data set that was collected by Hubble Space Telescope over a period of more than 16 years.

In July 2013, Schlichting, her husband, and her Alaskan malamute, Amir, will leave sunny California to brave the shores of the Atlantic in Boston, Massachusetts. "Amir is such a California dog," Schlichting said. "He won't even go outside if it's raining." Regardless of 100-pound Amir's reluctance to brave the elements, Schlichting looks forward to continuing to solve the mysteries of planetary formation at her new institute. "I've learned many things from UCLA's Department of Earth & Space Sciences that I never would have learned in an astrophysics department. It has been a very stimulating place," she said. "Moving to Boston will be quite a challenge, hopefully in a good way."

> "I've learned many things from UCLA's Department of Earth and Space Sciences... it has been a very stimulating place."

Life on Mars?

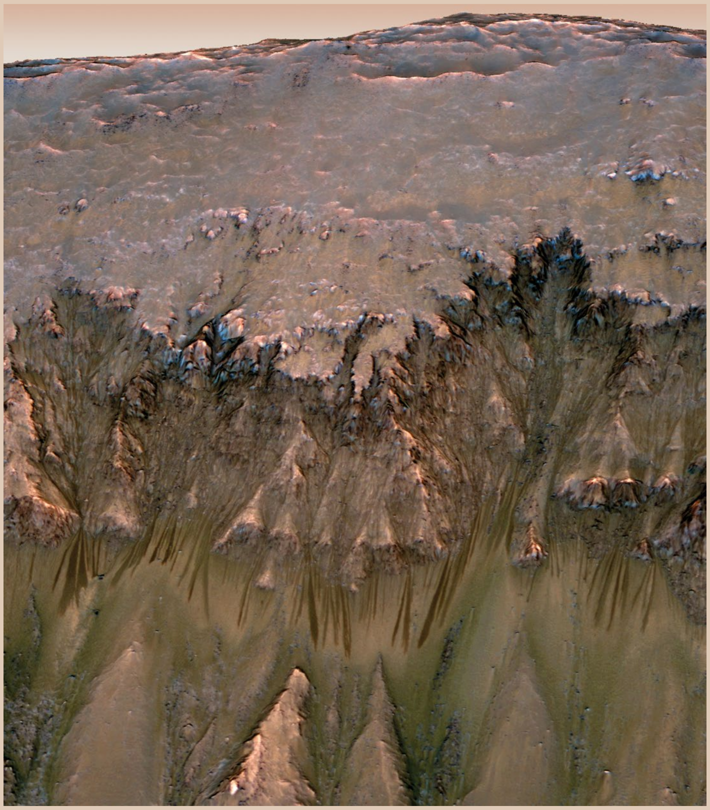
During an iPLEX meeting at UCLA, scientists discuss whether life can survive on Mars

In February 2013, more than 50 of the world's leading Mars scientists gathered in UCLA's historic Royce Hall to discuss if life could currently survive on the red planet. The iPLEX-hosted conference consisted of three-dozen talks over two days that covered widely ranging topics, from current liquid water activity on Mars to NASA's planetary protection policies. "The habitability of Mars is a pressing issue because we plan to send humans there in the next century," said conference co-organizer, UCLA Professor David Paige. "To do that in a responsible way, we should take into account that there could be an indigenous biosphere on Mars."

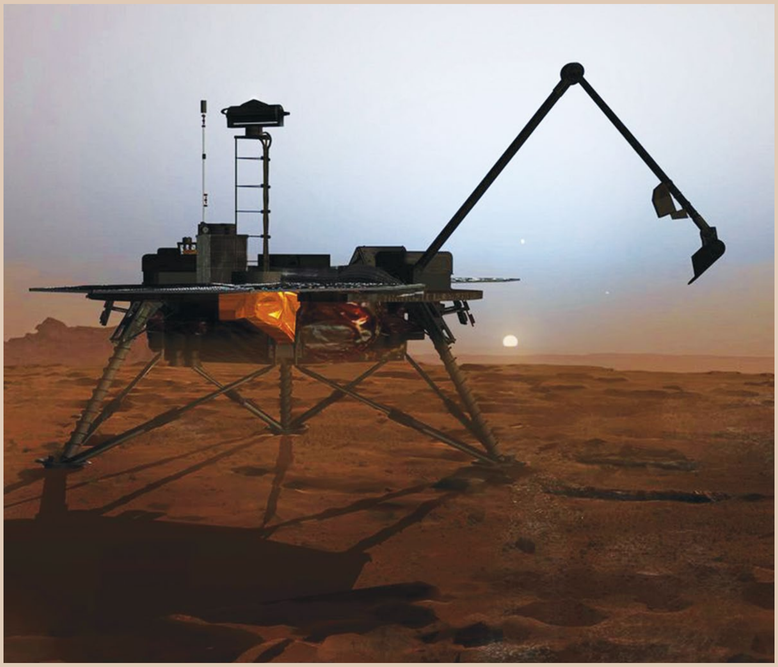
Life is nearly everywhere on Earth, but that's not the case for inhospitable Mars. University of Florida Professor Andrew Schuerger, an astrobiologist and speaker at the conference, listed 17 separate environmental hazards that could impede the development of microbial life on the surface of Mars. Topping the list were microbe-frying ultraviolet light, sub-zero temperatures, and an oxygen-less atmosphere. Nonetheless, Schuerger and his colleagues have made it their mission to find bacteria that can survive in the harshest environments on Earth and determine whether the tiny microorganisms could grow in Mars-like conditions. The search has lead to the discovery of several hypobarophiles, microorganisms that can live in extremely cold and oxygen-deprived environments.

Yet even the sturdiest of hypobarophiles would shrivel without a source of liquid water, said Schuerger. Although the Martian surface is dry, evidence suggests that water exists beneath the surface, according to University of Arizona Professor Alfred McEwen. First discovered by NASA's Mars Reconnaissance Orbiter in 2011, Recurring Slope Lineae (RSL) are dark streaks that slowly creep down sun-facing crater rims and canyon walls during the Martian spring and summer. Flowing water mixed with Martian salts found just beneath the planet's surface may be responsible for the finger-like patterns, though the source of the water is still unknown. "Given the seasonality and temperature dependence, we think briny water is the best candidate to have formed these features," said McEwen. While the formation of RSL may look remarkably like running water on Earth, McEwen is quick to emphasize that on Mars, the trickle of briny water takes weeks to flow downhill and behaves more like "maple syrup oozing downslope."

Liquid water below Mars' surface may not only be salty, it may also contain perchlorate, a molecule toxic to most kinds of life. The recent discovery of perchlorate on Mars during an experiment onboard the NASA's Phoenix



A color-enhanced image of the inside rim of Newton Crater on Mars. The dark streaks, called Recurring Slope Lineae (RSL) are each less than 5 meters wide and may represent current subsurface liquid water activity. Image Credit: NASA/JPL/University of Arizona



An artist concept of the Phoenix lander on the surface of Mars. In 2008, scientists were surprised to find that the substance perchlorate was present in the Martian soil. Image Credit: NASA/JPL/Caltech

lander in 2008 was discussed in detail at the conference. "Perchlorate is a double-edged sword," said Paige. "It is a reactive molecule that destroys organics, yet we find a variety of organisms on Earth that, in fact, use it to survive."

Solving the puzzle of whether life could survive in the harsh and varied environments of Mars requires a community of scientists from many disciplines, said Paige. "Many types of scientists are involved, from researchers who study orbital images to biologists who grow microorganisms in petri dishes, and everyone in between," he said. "To get such a diverse community together was a lot of fun."

The conference, sponsored by iPLEX, the NASA Astrobiology Institute and the UK Centre for Astrobiology, is the first iPLEX meeting to be open to virtual participants. Nearly 50 participants watched the conference online, asking speakers questions via webchat. Nine talks were given remotely by speakers located as far away as the United Kingdom, Hungary and Russia. All conference talks were recorded and can be streamed for free on the iPLEX website.

iPLEX Conferences

The Institute for Planets and Exoplanets (iPLEX) hosts several conferences on the UCLA campus every year that cover a diverse array of planetary science topics. iPLEX conferences attract researchers from all over the world, fostering scientific collaborations at UCLA and providing students with the opportunity to interact with top scientists in their fields. For more information about past or upcoming conferences, visit the iPLEX website at http://planets.ucla.edu/meetings.

iPLEX Conferences 2012-2013	
June 12-13, 2012	Ices and Organics in the Inner Solar System
February 4-6, 2013	The Present-Day Habitability of Mars
June 26-28, 2013	Connecting Theory to Experiments in Geophysical and Astrophysical Fluid Dynamics

Meteorite Museum

Nearly 50,000 years ago, an asteroid fragment slammed into Earth approximately forty miles east of what is now Flagstaff, Arizona. Upon impact, the celestial projectile shattered into thousands of pieces and created a mile-wide hole now known as Meteor Crater. A 357-pound chunk of that original asteroid now stands center stage in the new UCLA Meteorite Museum.

The Canyon Diablo meteorite was donated to UCLA by philanthropist William Andrews Clark, Jr. upon his death in 1934, becoming one of the first specimens entered into the UCLA Meteorite Collection. While originating from sporadic donations and purchases, it has been Professor John Wasson and researcher Alan Rubin who have spent decades building the collection to its 1500-specimen count

today. Together, they have made the collection one of the most extensive in the world, but only recently have these unique bits of our solar system's history been on display for visitors to admire. "For many years, we've collected beautiful exhibit specimens, but kept them locked in an inaccessible cabinet," Rubin said. "It's nice to put them on display for other people to see."

Those expecting the museum to be filled with rows of indistinguishable black rocks may be surprised to learn that there are many types of meteorites, ranging from metallic to stony and everything in between. More than one exhibit emphasizes chondrites, a type of meteorite that is a subject of "endless fascination," according to Rubin. "Chondrites are composed of thousands or millions of tiny spherules, called chondrules." While each chondrule tells a different story, they are still very much a mystery. "It appears that chondrules formed from clumps of dust in the solar nebula, the gas and dust cloud that was here before the planets and asteroids formed, and were zapped in a way that is still unknown," Wasson said.

Not all the exhibits display rocks of extraterrestrial origin, however. One exhibit showcases a collection of melted tektites and Libyan desert glass that formed as a result of meteor impacts. Another exhibit offers tips on how to correctly identify meteorites. Rubin, a world expert in meteorite identification, receives phone calls nearly every day from meteorite-hunting hopefuls. While real specimens occasionally come across his desk, the vast majority of these objects come from Earth. The exhibit, entitled "Meteorwrongs," features some of the more interesting Earthly samples Rubin has accumulated over the years.

Wasson and Rubin hope that the museum will help educate the next-generation of meteorite researchers. "The museum will be a wonderful teaching resource," Wasson said. "Our goal is to make it the world's best scientifically-oriented meteorite museum." Open to the public weekdays from 9am – 4pm, the museum is located in Geology 3697. The museum, still incomplete, will have mounted informational tablets in its final configuration.

The UCLA Meteorite Museum is supported by the Department of Earth and Space Sciences and the Institute for Planets and Exoplanets. Those interested in providing financial support to the UCLA Meteorite Collection should visit http://giving.ucla.edu/meteorites/.

Outreach

UCLA's Explore Your Universe
November 2013

This free and annual public event features hundreds of hands-on science activities appropriate for kids and adults alike, from creating fossils and launching rockets to seeing a UCLA planetarium show. In 2012, more than 3000 participants flocked to UCLA's campus to join in the all-day science exhibition. Come participate in this year's event in November!

The UCLA Institute for Planets and Exoplanets assists in hosting several large outreach events for the general public every year. The two most popular events are Explore Your Universe, held every November, and International Observe the Moon Night, held each Fall. These and other events are designed to bring the exciting world of planetary research to the local community and to help educate the next generation of UCLA planetary scientists. For more information about upcoming iPLEX outreach events, please visit our website at: http://planets.ucla.edu/outreach/.

International Observe the Moon Night
October 12, 2013

During this event, held every year in the Fall when the Moon can be viewed in the First Quarter phase, participants can interact with scientists from various NASA lunar missions and view the Moon through powerful telescopes. The event is free to the public and happens concurrently in many other locations. Last year, participants gathered at 577 separate locations in 49 countries to view the Moon.

An artist interpretation of colliding planets. Image Credit: Lynette Cook for Gemini Observatory/AURA

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Institute for Planets and Exoplanets

The Institute for Planets and Exoplanets (iPLEX) is an academic consortium bridging the interests of UCLA faculty, researchers and students in the departments of Earth and Space Sciences, Physics and Astronomy, and Oceanic and Atmospheric Sciences. Our goal is to promote and advance planetary science research by means of interdisciplinary collaboration. Research in the planetary sciences at UCLA spans many topics, including, but not limited to planetary system formation, growth and structure, physics of interiors, planetary geology, atmospheres and oceans, primitive bodies, extrasolar planet detection, magnetic fields, and circumstellar debris disks. Current iPLEX membership at UCLA includes 28 faculty members, 31 postdoctoral researchers and research scientists, and 45 graduate students across three UCLA departments. Since its launch in 2011, fourteen students have earned Doctorate degrees in planetary science-related fields.

In addition to fostering collaborations between departments at UCLA, we aim to develop inter-institutional partnerships, both at the individual and institutional level. One way we attempt to achieve this is through hosting conferences and workshops, which draw planetary scientists from worldwide locations to the UCLA campus and provide researchers and students alike with the opportunity to collaborate on current planetary science (see pages 30-31). Additionally, iPLEX and scientists at NASA's Jet Propulsion Laboratory (JPL) in Pasadena are discussing an institutional partnership that should create numerous research opportunities and benefit JPL and UCLA alike.

Furthermore, iPLEX is interested in sharing the fascinating world of planetary science with local and national communities and schools. Our education and public outreach program includes annual events during which students and their families can come to UCLA to participate in hands-on planetary science activities, from making their own comets to seeing a UCLA planetarium show to observing the Moon with powerful telescopes (see page 33). In addition, iPLEX is helping to build a meteorite museum at UCLA that will be free and accessible to members of the public (see page 32).

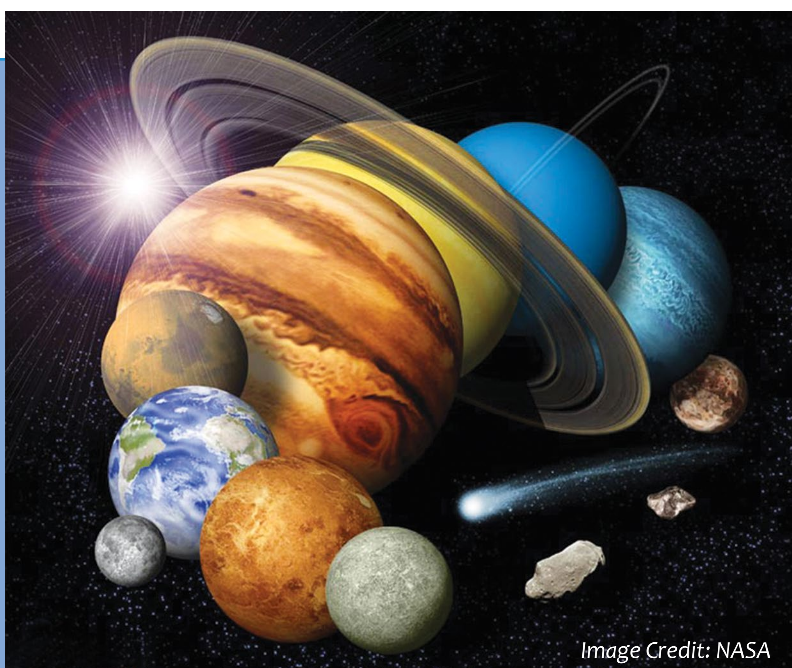

Image Credit: NASA

Support iPLEX

Donations to UCLA's Institute for Planets and Exoplanets can be made through our website: http://giving.ucla.edu/planets. Your tax-deductable charitable donation will support the interdisciplinary and collaborative research initiatives of world-class scientists to explore our universe, expand our knowledge of planetary systems, and make new and important discoveries. In addition, your generosity will promote education and public outreach programs designed to bring planetary research to the community and inspire the next generation of UCLA planetary scientists. We thank you for your support.

planets.ucla.edu

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An artist interpretation of a small Kuiper Belt Object. Image Credit: NASA/ESA/G. Bacon