BERKELEY ASTRONOMY

UNIVERSITY OF CALIFORNIA AT BERKELEY
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Astronomy in the News

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AI HELPS TRACK DOWN MYSTERIOUS COSMIC RADIO BURSTS

September 10, 2018 - Bob Sanders, Media Relations

Artificial intelligence is invading many fields, most recently astronomy and the search for intelligent life in the universe, or SETI. Researchers at Breakthrough Listen, a SETI project led by the University of California, Berkeley, have now used machine learning to discover 72 new fast radio bursts from a mysterious source some 3 billion light years from Earth.

Fast radio bursts are bright pulses of radio emission mere milliseconds in duration, thought to originate from distant galaxies. The source of these emissions is still unclear, however. Theories range from highly magnetized neutron stars blasted by gas streams from a nearby supermassive black hole, to suggestions that the burst properties are consistent with signatures of technology developed by an advanced civilization.

"This work is exciting not just because it helps us understand the dynamic behavior of fast radio bursts in more detail, but also because of the promise it shows for using machine learning to detect signals missed by classical algorithms," said Andrew Siemion, director of the Berkeley SETI Research Center and principal investigator for Breakthrough Listen, the initiative to find signs of intelligent life in the universe.

Breakthrough Listen is also applying the successful machine-learning algorithm to find new kinds of signals that could be coming from extraterrestrial civilizations.

While most fast radio bursts are one-offs, the source here, FRB 121102, is unique in emitting repeated bursts. This behavior has drawn the attention of many astronomers hoping to pin down the cause and the extreme physics involved in fast radio bursts.

The AI algorithms dredged up the radio signals from data were recorded over a five-hour period on Aug. 26, 2017, by the Green Bank Telescope in West Virginia. An earlier analysis of the 400 terabytes of data employed standard computer algorithms to identify 21 bursts during that period. All were seen within one hour, suggesting that the source alternates between periods of quiescence and frenzied activity, said Berkeley SETI postdoctoral researcher Vishal Gajjar.

UC Berkeley Ph.D. student Gerry Zhang and collaborators subsequently developed a new, powerful machine-learning

Data comes from the Green Bank Telescope in West Virginia, pictured above. Photo by Jenya Chernoff

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Green Bank Telescope, by Jenya Chernoff

algorithm and reanalyzed the 2017 data, finding an additional 72 bursts not detected originally. This brings the total number of detected bursts from FRB 121102 to around 300 since it was discovered in 2012.

"Whether or not FRBs themselves eventually turn out to be signatures of extraterrestrial technology, Breakthrough Listen is helping to push the frontiers of a new and rapidly growing area of our understanding of the Universe around us," he added.

ENIGMATIC 'LUNAR SWIRLS' LINKED TO MOON'S VOLCANIC PAST

September 7, 2018 - Bob Sanders, Media Relations

Lunar swirls, beautiful features of the moon that are found on no other body in the solar system, may be caused by the interaction some 3 billion years ago between erupting lava and the moon's strong magnetic field.

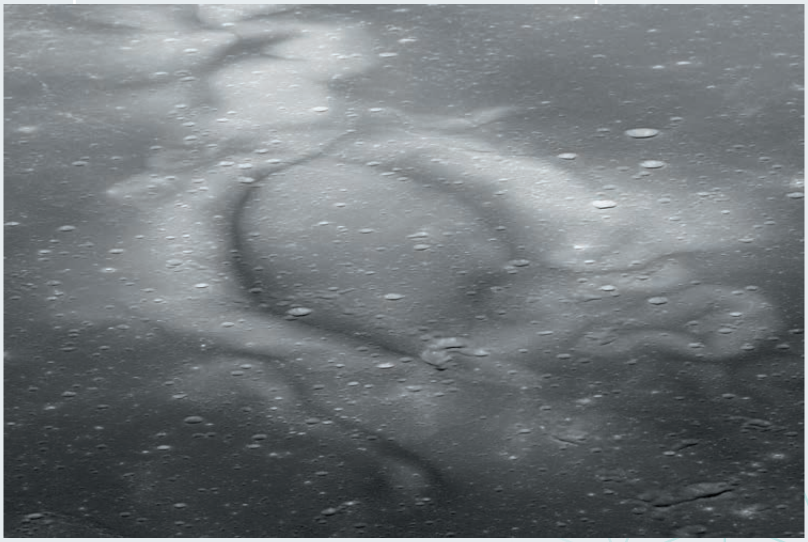
The new theory of how these swirls formed, which gives clues about the moon's thermal and magnetic history, comes from a collaboration between Douglas Hemingway, a Miller postdoctoral fellow at UC Berkeley, and Sonia Tikoo, a professor of planetary science at Rutgers University. Their results were published this week in the Journal of Geophysical Research.

The swirls, a popular telescope target of amateur astronomers, are bright, cloud-like patches that snake across portions of the moon's surface. The most famous, called Reiner Gamma, is about 40 miles long. Lunar swirls are located in areas with powerful, localized magnetic fields, as discovered by moon-orbiting satellites like Lunar Prospector, which carried sensitive magnetometers to chart the surface magnetic fields remaining today.

Lunar swirls called Reiner Gamma photographed from the Lunar Reconnaissance Orbiter by its Narrow Angle Camera. (NASA/GSFC/ASU)

Hemingway and Tikoo worked with what is known about the intricate geometry of lunar swirls and the strengths of associated magnetic fields, and developed mathematical models for what underground geologic structures might be generating the magnetic fields. A key insight of the work is that moon rocks can become highly magnetic when heated more than 600 degrees Celsius in an oxygen-free environment, something that doesn't happen on the oxygen-filled Earth.

Recent research by Tikoo showed that the moon's magnetic field persisted much longer than people thought after its birth 4.5 billion years ago, overlapping with a period of major volcanic activity about 3 billion years ago.



Lunar swirls called Reiner Gamma photographed from the Lunar Reconnaissance Orbiter by its Narrow Angle Camera. (NASA/GSFC/ASU)

LOOKING FOR WATER IN JUPITER'S GREAT RED SPOT

August 29, 2018 - Bob Sanders, Media Relations

Scientists have for the first time detected water clouds deep inside Jupiter's Great Red Spot – a centuries-old storm larger than planet Earth – allowing them to put tighter limits on the total amount of water in the planet. The estimates bring scientists closer to reconstructing the history of Jupiter, in particular, whether it formed where it is today, five times farther from the sun than Earth, or much farther from the sun and later migrated to its present location.

"Based upon all the exoplanets now known, it appears as if planets may form at a different place and then migrate in and/or out to where we see them today," said Imke de Pater, a UC Berkeley professor of astronomy and a co-author of a report that appeared this month in the Astronomical Journal. "So what happened in our solar system? Did Jupiter form beyond where Neptune is today?"

The report's conclusions

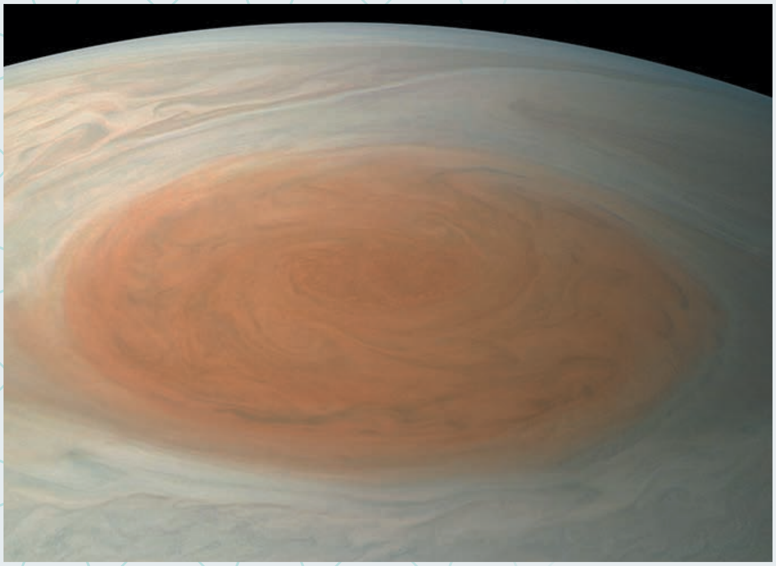


Image of Jupiter's Great Red Spot, a storm bigger than Earth, created by Björn Jónsson using data from the JunoCam imager on NASA's Juno spacecraft. (2017)

are based on measurements of the thermal radiation leaking from the depths of the Great Red Spot made by de Pater and astronomer Mike Wong using telescopes at the Keck Observatory and NASA's Infrared Telescope Facility (IRTF), both in Hawaii. The 5-micron infrared radiation measurements displayed the chemical signature of water above the planet's deepest clouds. "I say that we very likely found a water cloud," said lead author Gordon Bjoraker, an astrophysicist at NASA's Goddard Space Flight Center.

ZAPPING HYDROGEN GAS WITH 168 LASERS TURNS IT INTO A METAL

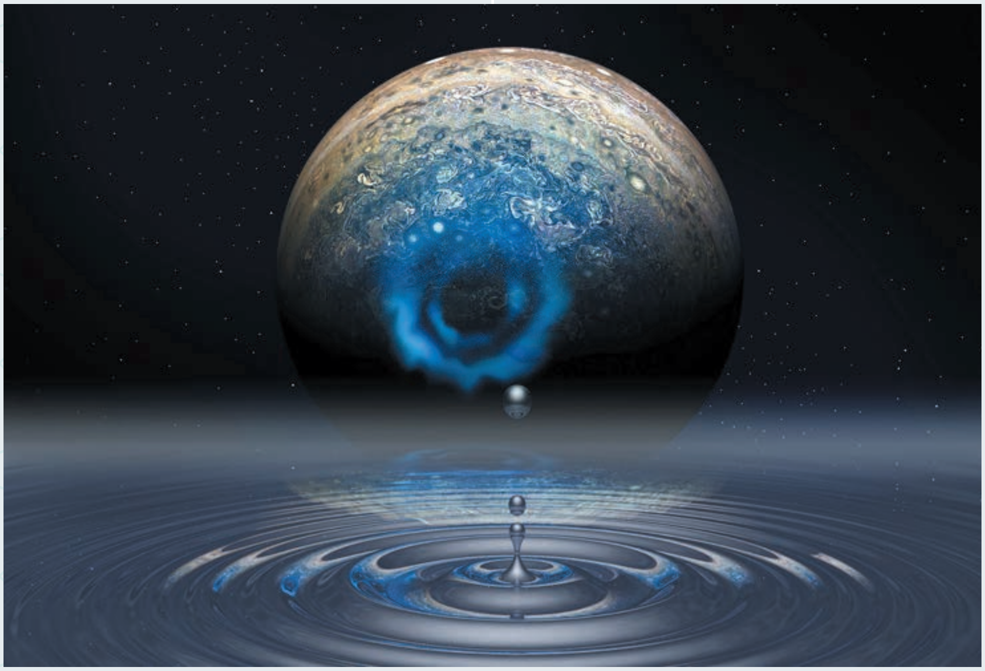
August 20, 2018 - Bob Sanders, Media Relations

Scientists have bombarded hydrogen with 168 powerful laser beams – part of the world's largest laser, the National Ignition Facility at Lawrence Livermore National Laboratory – to reproduce what happens to the gas under the intense pressures at the cores of giant planets. What they saw confirms predictions that if you keep hydrogen cool enough while pounding on it with six million times atmospheric pressure – twice the pressure at the center of the Earth – the hydrogen turns into a shiny metal.

"It's like squeezing air and turning it into a shiny, light version of liquid mercury. Although exotic at Earth's surface, metallic hydrogen is the main material inside most giant planets and stars," said Raymond Jeanloz, a UC Berkeley professor of astronomy and of earth and planetary science and a co-author of the research.

The team's optical measurements of the so-called insulator-to-metal transition in fluid hydrogen resolved discrepancies in previous experiments and established new benchmarks for calculations used to construct planetary models. Livermore Lab physicist Peter Celliers was the lead author of the paper, which was published this week in the journal Science.

"These results are a true experimental tour de force and are particularly important because they provide a very stringent test on the different varieties of numerical simulations that one can use to predict the properties of planetary constituents at high pressure — necessary to model the internal structure and evolutionary processes of Jupiter and Saturn," said Marius Millot, a physicist at LLNL and co-author of the paper.



Unraveling the properties of fluid metallic hydrogen at the National Ignition Facility could help scientists unlock the mysteries of Jupiter's formation and internal structure. (Image courtesy of Mark Meamber/LLNL)

BLACK HOLES RULED OUT AS UNIVERSE'S MISSING DARK MATTER

October 2, 2018 - Bob Sanders, Media Relations

For one brief shining moment after the 2015 detection of gravitational waves from colliding black holes, astronomers held out hope that the universe's mysterious dark matter might consist of a plenitude of black holes sprinkled throughout the universe.

UC Berkeley physicists have dashed those hopes.

Based on a statistical analysis of 740 of the brightest supernovas discovered as of 2014, and the fact that none of them appear to be magnified or brightened by hidden black hole "gravitational lenses," the researchers concluded that primordial black holes can make up no more than about 40 percent of the dark matter in the universe. Primordial black holes could only have been created within the first milliseconds of the Big Bang as regions of the universe with a concentrated mass tens or hundreds of times that of the sun collapsed into objects a hundred kilometers across.

The results suggest that none of the universe's dark matter consists of heavy black holes, or any similar object, including massive compact halo objects, so-called MACHOs.

Dark matter is one of astronomy's most embarrassing conundrums: despite comprising 84.5 percent of the matter in the universe, no one can find it. Proposed dark matter candidates span nearly 90 orders of magnitude in mass, from ultralight particles like axions to MACHOs.

"I can imagine it being two types of black holes, very heavy and very light ones, or black holes and new particles. But in that case one of the components is orders of magnitude heavier than the other, and they need to be produced in comparable abundance. We would be going from something astrophysical to something that is truly microscopic, perhaps even the lightest thing in the universe, and that would be very difficult to explain," said lead author Miguel Zumalacárregui, a Marie Curie Global Fellow at the Berkeley Center for Cosmological Physics.

"We are back to the standard discussions. What is dark matter? Indeed, we are running out of good options," said Uroš Seljak, a UC Berkeley professor of physics and astronomy and BCCP co-director. "This is a challenge for future generations."

Miguel Zumalacárregui image

The analysis is detailed in a paper published Oct. 1 in the journal Physical Review Letters. BCCP is a joint research and education initiative between UC Berkeley and Lawrence Berkeley National Laboratory. Seljak is a Berkeley Lab faculty scientist.

Breakthrough Listen

Breakthrough Listen, the global initiative to seek signs of intelligent life in the universe, in partnership with the South African Radio Astronomy Observatory (SARAO), announced the beginning of a major new program with the MeerKAT telescope. The MeerKAT survey will examine a million individual stars – 1,000 times the number of targets in any previous search – in the quietest part of the radio spectrum, monitoring for signs of extraterrestrial technology. With the addition of MeerKAT's observations, Listen will operate 24 hours a day, seven days a week, in parallel with other surveys.

Photo credit: SKA South Africa

"Collaborating with MeerKAT will significantly enhance the capabilities of Breakthrough Listen ", said Yuri Milner, founder of the Breakthrough Initiatives. "This is now a truly global project."

Built and operated by the South African Radio Astronomy Observatory (SARAO), and inaugurated in July 2018, MeerKAT is a powerful array of 64 radio antennas in the remote Karoo Desert of South Africa. By partnering with SARAO, Breakthrough Listen gains access to one of the world's premier observing facilities at radio wavelengths. Signals from the 64 dishes (each 13.5 meters in diameter) are combined electronically to yield an impressive combination of sensitivity, resolution and field of view on the sky.

MeerKAT also serves as a precursor for the Square Kilometre Array, which will expand and enhance the current facility in the coming decades, eventually spanning a million square meters across South Africa and Australia to create by far the world's largest radio telescope.

FREE MONTHLY LECTURES AND STAR GAZING: ASTRO NIGHTS!

Astro Night is a free stargazing and lecture event open to the public starting late spring, throughout summer, and early fall. It is usually held on the first Thursday of each month, as weather permits, starting with a lecture and Q&A session, followed by guided stargazings using our fleet of telescopes--including our 17-inch rooftop telescope observatory. Members of our department are on site to answer any questions.

This recent series of Astro Night lectures featured, among others, Professor Alex Filippenko, SETI Chief Scientist Dan Werthimer, PhD student Stephen Ro, and screening of a documentary film about high school students searching for pulsars using radio astronomy data from West Virginia's Green Bank Telescope.

Spring talks will resume in April 2019. Details can be found at http://astro.berkeley.edu/i/astro-night.

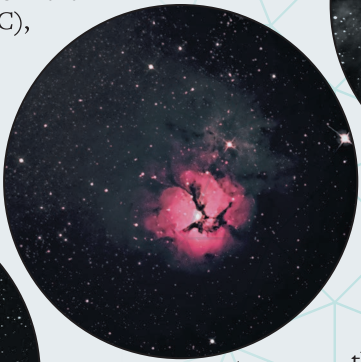
Undergraduate Spotlight: Costas Soler

Meet Costas Soler, a senior, double majoring in Astrophysics and Marine Science. He submitted these beautiful photos taken on the roof of Campbell Hall on his personal 8-inch reflector telescope, part of a tiny robotic/computerized observatory that he's been putting together for the past 2 years. Says Soler: "It's designed to efficiently capture 'pretty pictures,' to help make astronomy and exploration a little more accessible to everyone." Check out the photos, as well as his notes, below:

COMA GALAXY CLUSTER

This is the Coma Cluster, ~320 million light years away, and I read that it weighs in at ~10^14 solar masses! To capture this from Campbell, I used a light pollution filter, and gathered 5 hours of data. I also had to use a second guiding telescope to correct for errors in the telescope's motor mount. Since I used my monochrome CCD (cooled to -20 C), I also set up a filter wheel to cycle through the red, green, and blue filters necessary to render this in color. It was definitely a challenge, but very much worth the work!

Rossette Nebula



Triffid Nebula

LAGOON NEBULA

This is a gigantic "stellar nursery." See that star cluster in the middle of that blazing red cloud? There, the cloud collapsed under its own gravity. As gas squished together, pressures increased, temperatures skyrocketed, and nuclear fusion began to take place. Once that happened, stars were born.

Veil Nebula

Lagoon Nebula

Coma Galaxy Cluster

VEIL NEBULA

This strikes me as one of the Universe's masterpieces, a "Supernova Remnant." It's what's left over when a giant star supernovas at the end of its life. These explosions are so powerful that they often outshine entire galaxies, as well as produce all the heavy elements - including the iron in your blood. Though we don't always catch supernovae as they happen, we often find their tattered remains of oxygen (blue) and hydrogen (pink-red).

TRIFFID NEBULA

This is a conglomeration of 3 types of nebula - a Reflection nebula (blue), an emission nebula, and an absorption nebula. The emission nebula emits the light that my telescope connected, primarily through blackbody radiation. It's tinged red by hydrogen emissions. The blue part is much cooler, made of hydrogen, but doesn't get hot enough to emit light. Rather, it reflects incident light - much like clouds on Earth. The mysterious dark streaks are absorption nebulae. These are cold dust lanes, probably soot left over from supernovae in the remote past.

ROSETTE NEBULA

This is another stellar nursery. This monochrome image shows only a map of hydrogen in this area - fuel for new stars. Some have already formed from this massive fuel reserve, including the cluster at the center.

NEW AND NOTEWORTHY

Faculty member **Eliot Quataert** was elected to the American Academy of Arts and Sciences (AAAS) in spring 2018. AAAS is a time-honored, prestigious society that convenes leaders in academic, business and government sectors to solve critical national and global challenges. Quataert is a theoretical astrophysicist with interests in a variety of problems, including black holes, stellar physics, plasma astrophysics, and galaxy formation.

Eve Lee, who received her PhD in Astrophysics in spring 2017 under advisor Eugene Chiang, was appointed Assistant Professor of Physics at McGill University in fall 2019.

Assistant Professor **Dan Weisz** was named Hellman Fellow for his project: Uncovering the Origin of the Elements. Weisz studies fossil relics of the first stars and galaxies. With support from a Hellman Fellowship, he will use the Keck and Hubble Space Telescopes to explore the genesis of elements in the periodic table.

PhD student **Kareem El-Badry**, who studies under Eliot Quataert and Dan Weisz, was awarded the Price Prize by Ohio State University for his research topic: "Dwarf galaxies as laboratories for astrophysics and cosmology." The Price Prize is awarded annually to graduate students doing excellent research in areas related to cosmology and astrophysics.

PhD student **David Khatami**, who studies under Dan Kasen, was awarded an NSF Fellowship. Khatami works with Kasen on developing and testing theoretical models of energetic transients such as supernovae, kilonovae, compact object mergers, and tidal disruption events.

Associate Professor **Aaron Parsons**, PI of the Hydrogen Epoch of Reionization Array (HERA) project, announces that HERA was awarded $7.2M by the NSF Mid-Scale Innovations Program for 5 years, to observe with its fully constructed 350-element array. HERA is a radio telescope dedicated to observing large scale structure during and prior to the epoch of reionization.

Professor **Alex Filippenko** had some exciting findings published in a recent issue of The Astrophysical Journal. These latest results strongly support a surprising conclusion that Filippenko and other collaborators first reported several years ago: the Universe is now expanding significantly faster than expected, even after taking dark energy into account! The discrepancy, if real, may indicate that dark energy is actually growing stronger with time, or that dark matter interacts with light in unanticipated ways, or (perhaps most likely) that there is a new, very light, fundamental subatomic particle such as a neutrino that affects the expansion of the Universe.

Professor **Jessica Lu** was honored with the Prytanean prize, awarded to outstanding women junior faculty members.

2017-2018 Commencement Information

PH.D. DEGREES 2017-2018

(Includes non-Astronomy graduates with advisors in the Department of Astronomy)

Zaki Ali
Advisor: Aaron Parsons
"Observing the Epoch of Reionization: Power Spectrum Limits and Commissioning Next Generation 21cm Experiments"

Jennifer Lynn Barnes
Advisor: Dan Kasen
"Electromagnetic Signatures of Transients from Compact Object Mergers"

Kaylan Burleigh
Advisor: Peter Nugent
A Monte Carlo Method for Identifying Imaging Systematics in Galaxy Surveys 2016

Drummond Fielding
Advisor: Eliot Quataert
Interplay of Galactic Winds and Circumgalactic Media

Daniel Goldstein
Advisor: Peter Nugent
Foundations of Strongly Lensed Supernova Cosmology

Chelsea Harris
Advisor: Peter Nugent
One Shell, Two Shell, Red Shell, Blue Shell: Numerical Modeling to Characterize the Circumstellar Environments of Type I Supernovae

Aaron Lee
Advisers: Chris McKee, Richard Klein
"Star and Planet Formation Through Cosmic Time"

Phuongmai Ngoc Truong
Advisors: Leo Blitz & Adrian Lee
"High-Resolution Velocity Fields of Low-Mass Disk Galaxies: CO Observations, Rotation Curves and Mass Modeling"

Melanie Renee Veale
Advisors: Chung-Pei Ma, Martin White
"One Bird, Several Stones: Investigating Massive Galaxies via Stellar Kinematics , Environment, and Quasar Demographics"

Jason Wang
Advisers: James Graham and Paul Kalas
"Footage of Other Worlds: Unveiling the Dynamical Architecture of Young Exoplanetary Systems"

2017-18 GRADUATE AWARDS

Uhl Award For outstanding scholarly achievement by a graduate student close to finishing his/her dissertation in Astronomy or in Physics with preference to Astronomy
Danny Goldstein and **Jason Wang**

Trumpler Award In recognition of academic excellence and outstanding record of involvement in the department or wider astronomical community. Anyone post-qual is eligible.
Carina Cheng

OUTSTANDING GSI AWARDS:

Benjamin Stahl (Physics) and **Robert Citron** (EPS)

2017-18 UNDERGRAD AWARDS

Commencement speaker
Haynes Stephens

Department Citation for "outstanding scholarship." The recipient of this award needs to have maintained a grade point average of 3.5 in the department.
Samantha Wu

Klumpke-Roberts for "outstanding scholarly achievement"
Timothy "Willie" Ross and **Ben Jeffers**

WARK award for astro majors in excellent academic standing
Nijaid Arrendondo and **Robert Pascua**

THE DISTINGUISHED ASTRONOMY LECTURE AT UC BERKELEY: FROM THE ACCELERATING UNIVERSE TO ACCELERATING SCIENCE

This year's Distinguished Astronomy Lecturer (formerly Sackler Lecture) was **Robert P. Kirshner** of Harvard University. Robert P. Kirshner leads the science program at the Gordon and Betty Moore Foundation, served on the astronomy faculty at Harvard for 30 years, and was elected President of the American Astronomical Society in 2004. He moved to the Moore Foundation in 2015. His work with students developing the use of supernovae to trace cosmic expansion was a fundamental contribution that helped lead to the discovery of cosmic acceleration in 1998. Kirshner was awarded the National

Academy's 2014 Watson Medal and the 2015 Wolf Prize in Physics. His award-winning book "The Extravagant Universe: Exploding Stars, Dark Energy, and the Accelerating Universe" in available in 6 languages. His lecture detailed the mission of the UC Berkeley and Gordon and Betty Moore Foundation to accelerate scientific discovery, and the way scientists are working to learn more about the nature of dark energy. This talk summarized the present state of knowledge and looked ahead to new ways to use infrared observations of supernovae to improve the our grip on dark energy.

Getting To Know

A Q&A WITH OUR NEWEST MEMBER OF THE ASTRONOMY FACULTY COURTNEY DRESSING

You are an observational astronomer. Can you describe what this means for a wider audience? How would you describe your day to day job?

My job includes teaching classes, advising students, conducting research, describing the results of our research, and preparing proposals for telescope time or funding to pursue new research investigations.

The unusual part of my job happens in the middle of the night when my students and I use telescopes to study stars and the planets that orbit them. Most recently, I've used the 3-m Shane Telescope at Lick Observatory near San Jose to determine which of the stars observed by the NASA Kepler mission have stellar companions and the IRTF in Mauna Kea to determine the properties of stars hosting planets detected by K2. My group also conducts observations with space-based observatories like Kepler/K2, Spitzer, and the newly launched Transiting Exoplanet Survey Satellite (TESS).

What drew you to this field? Also, if you could have any other job, what would you choose to be?

I read and watched lots of science fiction while growing up. I loved reading fictional stories about exploring distant planets and I was deeply curious about whether we might someday detect life elsewhere in the galaxy. I was fascinated by space exploration and frequently visited the National Air & Space Museum. I also checked out nearly every space book in our local library. At the time, exoplanets had barely been discovered and none were anywhere close to habitable. The situation is very different today!

(left to right: Graduate students Andrew Mayo, Professor Dressing, Steven Giacalone, Jordan Fleming)

We've discovered thousands of planets and astronomers are actively designing instruments to detect signs of life on other planets. My father and his work as an environmental scientist played a large role in my interest in pursuing a career in science. He and I did dozens of science experiments together over the years and he

encouraged me to pursue a PhD. My high school astronomy teacher Lee Ann Hennig and my mom's cousin, Anne Martt (a rocket scientist at United Space Alliance), also inspired my early interest in space exploration and astronomy. I love working with students so I could also see myself teaching primary or secondary school. I would also enjoy working at a science museum or running a bakery.

What are some of your favorite past times/ hobbies outside of Astronomy?

Outside of work, I enjoy running, hiking, reading, cooking, attending local events in my fun Oakland neighborhood, spending time with friends, and playing with my adorable mutt. I'm a fairly serious baker (hence the back-up career plan) and I've made space-themed treats for a variety of events. I also have baked two 3-tier wedding cakes during graduate school.

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UPCOMING EVENTS

Evening with the Stars
Spring 2019

Cal Day
April 13, 2019

Astro Night Public Lecture and Star Viewing
April 2019
(first Thursday of each month)

Commencement
Spring 2019

Newsletter Credits:
Marissa Dominguez, Robert Sanders

Support Berkeley Astronomy

On behalf of the faculty, students, and staff we extend our greatest thanks to our friends and donors for helping to preserve and enhance the scholarship, teaching, and research excellence of the Berkeley Astronomy Department.

Berkeley Astronomy is home to world-renowned scientists and researchers and is universally regarded as one of the top astronomy departments in the world. Our award winning faculty and outstanding students are engaged in some of the most fascinating research today–from studying the relationship between planets and moons in our solar system, to discovering new planets, galaxies, and black holes, to creating a road map for exploring the structure of the Universe.

As a friend of the department, you already know the important role private funding has in supporting our endeavors toward excellence. Over the past decade, state funding has continued to decline and the Astronomy Department has increasingly relied on the generosity of our alumni and friends to maintain our mission of award-winning teaching and research. Without the support of our extended family, we would be unable to maintain our standard of providing the best resources for our faculty, researchers and students.

We invite you to make a gift to any of the following funds, each a critical component in the investment of our future. Visit http://give.berkeley.edu/#astronomy to make an online gift, or use the enclosed envelope.

Student Observatory Fund assists with the purchase and maintenance of the latest instrumentation and teaching observatories managed by the Astronomy Department. The fund also provides support for the department's upper-division undergraduate laboratory course - the capstone experience for all astronomy majors.

Friends of Astronomy Fund supports all facets of the department's program budget, from research travel for students, to recruitment of top faculty, to the day-to-day material needs of the classrooms and teaching labs.

Graduate Student Support Fund directly benefits our students. Funding for fellowships is a top priority in the department, as a full year fellowship can cost more than $35,000 and will only continue to increase. Offering student support is one of our best tools for attracting the brightest and most promising students.

Thank you for your generosity!

Did you know–many employers match gifts to UC Berkeley? To discuss matching or other opportunities to support Astronomy at Berkeley, contact Maria Hjelm, Director of Development and College Relations, mhjelm@berkeley.edu.

GO BEARS!