

University of California, Berkeley  
 Department of Astronomy  
 Hearst Field Annex MC 3411  
 Berkeley, CA 94720-3411

## Upcoming Events:

### Science@Cal Monthly Lectures

3<sup>rd</sup> Saturday of each month  
 11:00 a.m.  
 UC Berkeley Campus location changes each month  
 Consult website for details <http://scienceatcal.berkeley.edu/lectures>

### Evening with the Stars

TBA Fall 2014  
 Please see the Astronomy website for more information  
<http://astro.berkeley.edu>

### 2015 Raymond and Beverly Sackler Distinguished Lecture in Astronomy

Carolyn Porco, Space Science Institute  
 Public lecture: Wednesday, Jan 28  
 Joint Astronomy/Earth Planetary Sciences Colloquium: Thursday, Jan 29  
 Please see the Astronomy website for more information  
<http://astro.berkeley.edu>



## Astronomy T-Shirts

### All-American Astros

The Annual Departmental T-Shirt Design Contest continues to provide distraction from the rigors of astrophysics and an opportunity to explore hidden artistic and creative talents.

Last year's winner "Baseball", was submitted by graduate student, Adam Morgan. His All-American design, as well as limited numbers of previous designs, are available for purchase online: <http://qmorgan.dyndns.org/tshirts/>

Cost is \$16 plus shipping for the most recent design and \$14 for previous year's

designs. Purchases can be made via PayPal using a credit or debit card.

The design contest for 2014-15 will be announced in fall 2014, with the winning design selected and printed in time for Cal Day in April 2015. All Astronomy Department students, staff, faculty, postdocs, and researchers are welcome to submit their designs for consideration.

The winning design is determined by departmental vote. More information can be found on the department website, <http://astro.berkeley.edu>.



Banner photographs, L-R: 1. Sather Gate, University of California, Berkeley, 2. Keck Telescopes, Laser Guide Star, 3. Graduate student Ryan Foley and Professor Alex Filippenko in Keck II Control Room, 4. Katzman Automatic Imaging Telescope (KAIT), Lick Observatory, 5. The full moon above one of the CARMA antennae.

Banner photography provided by Laurie Hatch ([www.lauriehatch.com](http://www.lauriehatch.com)), Keck Observatory, and Steve Croft.

Design: Lisa Krieshok, [lisa@krieshok.com](mailto:lisa@krieshok.com)

### Astronomy News 2014 University of California, Berkeley

Newsletter Contributors: Imke de Pater, Rayna Helgens, Lochland Trotter, Barbara Hoversten, Mariska Kriek, Josh Bloom, Geoff Marcy, Marc Davis.

Newsletter photography and graphics: Steve Croft, Laurie Hatch ([www.lauriehatch.com](http://www.lauriehatch.com)), STUDIOS Architectural Design, Lochland Trotter, Rayna Helgens, Michael Masahiro Yano, PNAS Editorial ([pnas@nas.org](mailto:pnas@nas.org)).

## BERKELEY ASTRONOMY



University of California | 2014

### From the Chair's Desk...



The Astronomy Department is a vibrant, evolving community. It's hard to fully capture all that is happening here in a few brief paragraphs, but I'll attempt to provide some highlights! Our faculty continue to receive recognition at the

highest levels for their research and teaching. This is conveyed not only through prizes and awards, but also by the sheer number of invitations to conferences, workshops, and summer schools. This year I call out in particular the **2014 Distinguished Teaching Award, the most prestigious teaching award on our campus, which was presented to Professor Eugene Chiang.** With numerous students commenting on Eugene's "passion" for teaching, "being an engaging lecturer, a captivating speaker, passionate, persuasive", and as "if telling a story", it's clear the award is well-deserved (see page 3).

A paper authored by our graduate student Erik Petigura, together with former postdoc Andrew Howard (now a Professor at University of Hawaii) and Professor Geoff Marcy, has won the Cozzarelli Prize from the National Academy of Sciences. Their paper, titled *The prevalence of Earth-size planets orbiting Sun-like stars*, was judged the top physical and mathematical sciences paper published in the Proceedings of the National Academy of Sciences in 2013. (see page 4 for a featured article)

With the numerous astronomical observations and surveys, whether from space or the ground, the sheer volume of data is growing at an ever increasing rate – perhaps to be compared to the accelerated expansion of our universe? Professor Josh Bloom was a

co-PI on the founding grant for the Berkeley Institute for Data Science (BIDS) to bring together scientists with diverse backgrounds, yet all dealing with "Big Data" (see page 2). He is also on the management council that oversees the Large Synoptic Survey Telescope. This past summer Bloom again organized the annual Python Language Bootcamp, an immensely popular three-day summer workshop with >200 attendees. His semester-long graduate-level course "Python Computing for Data Science" included more than 30 PhD-candidates from departments across campus, the largest graduate-level class taught by the astronomy department.

In this newsletter we also feature our most recently hired Assistant Professor, Mariska Kriek, a co-PI on a large survey of faint galaxies, carried out with the revolutionary multi-object near-infrared spectrograph MOSFIRE on the 10-m Keck telescope (page 3).

To continue our theme of "flying astronomers" we write about the SOFIA airborne observatory on page 3.

In October we hosted our annual *Raymond and Beverly Sackler Distinguished Lecture in Astronomy*, a public talk which featured Dr. David Spergel from Princeton University. In this free public lecture Dr. Spergel discussed the role of ongoing and future Cosmic Microwave Background (CMB) observations and described how the combination of large-scale structure, supernova and CMB data could be used to address questions such as: What happened during the first moments of the big bang? What is the dark energy? What were the properties of the first stars? Our undergraduate, graduate, and postdoctoral programs continue to thrive. In 2013 and 2014 we conferred 26 and 29 Bachelors degrees in Astronomy, respectively. Four students were awarded their Ph.D. in 2013, and five in 2014 (see page 5). Several new students from across the country joined our graduate program both years. Over two dozen postdoctoral fellows worked in the department, including those holding

the Friends of Astrophysics Postdoctoral Fellowship and many other coveted prize fellowships.

In addition to the rigorous research they pursue, our students and postdocs also find time to get involved in other interesting career-building and public outreach activities. Matt George, Adam Morgan, and Chris Klein joined the Insight Data Science Fellows Program (<http://insightdatascience.com>).

This is a 6-week program that brings together PhDs with science backgrounds to learn the methods and tools of Data Science. The main objective of the program is to form smallish teams and work on an interested data science application. At the end of the program the teams present to local tech companies looking to hire data scientists. It has a very good placement rate, and it's an invaluable networking opportunity.

I'd like to conclude this letter by talking about New Campbell Hall – our new home that will have an enormous impact on virtually all we do, every day. Construction of New Campbell Hall is on schedule and proceeding as planned. We will start moving into the new building on 22 September, 2014

*Continued on page 2*

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*Chair's Desk from page 1*

(see page 5 for recent photos and progress). It's exciting to see the new building take shape. We most eagerly await a piece of art for the dome in the lobby of the new building (see page 5). We are happy to report that all the design features that promise to facilitate research collaboration, enhance teaching and learning, and engage the public are incorporated in the building. There will be numerous open interaction spaces for informal meetings and discussions to bring together those involved in theory, instrumentation, observations, and numerical modeling. The marvelous suspended pedestrian bridge on the south side of the building, linking New Campbell Hall with Le Conte Hall, will fulfill a long-standing dream to promote interaction between astronomers and experimental physicists. On both sides of the bridge, open areas will be available for relaxed, informal discussions; other glassed-in rooms nearby will provide more private settings to meet. The building's roof will feature both inside and outside spaces. Inside, a fully equipped

room will serve both as boardroom and as an intimate space for small lectures. This enclosed space will open up on another space with floor to ceiling windows, offering sweeping views of the Bay. The outside upper deck will house one of the building's highlights – a new state-of-the-art rooftop observatory to be used for teaching and public outreach events.

The Undergraduate Teaching Laboratory, where students get hands-on experience in optical, infrared and radio astronomy, add tremendous value to a student's education. As stated by an External Review Committee, our flagship courses where students get this experience is "highly regarded beyond the confines of Berkeley." The UG Teaching Lab is featured prominently in the new building. In addition to a cluster of computers, it will have direct access to the optical and radio telescopes on the roof of new Campbell Hall, as well as computer links to Leuschner Observatory's optical/infrared and radio telescopes. The new lab will provide all the components needed to learn about the statistical nature of astronomical signals, the filtering effects of instrumentation, noise and errors, data analysis and display,

report writing, presentation, and teamwork. However, to maintain and upgrade these facilities, we seek donors for our Student Observatory Fund, an endowed fund that will enable our students, the astronomers of the future, to have full observational capabilities covering the entire visible-to-radio wavelength range. Your gifts are welcome – and essential – to realize our vision. We gratefully acknowledge the commitment of all those who demonstrate their support with a contribution or a pledge.

If you would like to learn more about how you can contribute, please contact me at [imke@berkeley.edu](mailto:imke@berkeley.edu) or call the department at 510-643-5040.

*Imke de Pater is a planetary scientist, specializing in radio and infrared observations of planets, including their magnetic fields, satellites and ring systems. During her term as Chair she managed to publish her second textbook: Lissauer, J.J., and I. de Pater, 2013. Fundamental Planetary Science. Physics, Chemistry and Habitability. Cambridge University Press, pp. 583.*

## Newly created Berkeley Institute for Data Science

The rapidly increasing importance of data-intensive and data-driven approaches at Berkeley has led to the establishment of the Berkeley Institute for Data Science (BIDS), a collaborative effort supported by the Gordon and Betty Moore Foundation and the Alfred P. Sloan Foundation. The new 5-year, \$37.8 million initiative was announced in late 2013. BIDS will be an intellectual home for data science on campus, if not nationwide and internationally. It will help researchers harness the full potential of the data-rich world that today characterizes all fields of science and discovery, including astronomy. It will build on existing campus strengths to facilitate and enhance the development and application of cutting-edge data science techniques in the biological, social, physical and engineering sciences. There will be more than a dozen data science Fellows employed at all levels (staff, post-docs and faculty). The center will offer enhanced trainings for undergrads and graduate students, including bootcamps and hack-a-thons. The goal is to accelerate the

pace of scientific discovery, with implications for our understanding of the universe, climate and biodiversity research, seismology, neuroscience, human behavior and many other areas. The Institute officially kicked off



*Astronomy Faculty 2014.*

in December 2013 with a star-studded day of talks, panel discussions, and a "data science faire." BIDS will open its doors in the newly renovated wing of Doe Library in Fall 2014. Astronomy Professor, Joshua Bloom, is a co-PI on the Berkeley Institute for Data Science founding grant and one of the members of the BIDS team. Prof. Saul Perlmutter is the PI of the grant.

## Professor Marc Davis to Retire

Marc Davis, renowned Cosmologist and Physicist, has announced his retirement from UC Berkeley this year. Since 1981, Davis has held dual appointments in Astronomy and Physics, punctuating his time as a professor and researcher by serving as chair of the Astronomy department from 1988-1992. In addition to his work at Berkeley, Davis served as lead Principal Investigator on the ambitious DEEP2 Redshift Survey, studying the properties and clustering of galaxies. He was instrumental in the DEFW collaboration, which established the validity of the "cold dark matter" theory that is now cited as the accepted explanation for the formation of galaxies. His work has garnered wide recognition and a long list of awards, including the Gruber Prize, the Heineman Prize, and an Honorary PhD from the University of Chicago.

## DEPARTMENT OF ASTRONOMY UNIVERSITY OF CALIFORNIA BERKELEY

*The Department of Astronomy wishes to thank the alumni, parents, students, faculty, staff and friends who so generously support us!*

Please return this form with your check to:  
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- The New Campbell Hall Student Observatory Fund  
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Please make your check for the Department of Astronomy payable to UC Regents.

In addition to my donation, a matching gift form from my employer:

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You can also donate to the Astronomy Department online at:  
<http://givetocal.berkeley.edu/search/?s=astronomy>

*A portion of all gifts is used to defray the costs of administering the funds. All gifts are tax-deductible, as prescribed by law.*

## GIVING OPPORTUNITIES

As state funding has declined over the past decade, the Astronomy Department has increasingly relied on the generosity of alumni and friends to maintain excellence in research and teaching. Your support will ensure that Berkeley Astronomy continues to thrive in the years to come. We invite you to make a gift to one of our funding priorities, listed below, or to a priority of your choice:

### Student Observatory Fund

The new Student Observatory Fund is a vitally important investment in our future. It will sustain our new teaching observatory on the rooftop of New Campbell Hall and also upgrade our undergraduate lab and associated telescope facilities for our majors. See page 4 for further details.

### Friends of UC Berkeley Astronomy

This unrestricted fund gives the department Chair the flexibility to allocate spending and resources on the highest priorities and new opportunities that arise. The fund supports important initiatives that benefit both students and faculty, including mentorship programs, conferences, technology upgrades, department activities and much more.

### New Campbell Hall

Though the building itself has been funded, additional donations are needed for programmatic and facility enhancements. The new building will play a key role in inspiring and educating the next generation of astronomers.

### Research

Until the Student Observatory Fund is fully funded, it remains our highest priority. We realize, however, that some of our donors are inspired to give to research. Please contact us if you would like to explore the option of supporting a faculty member or a specific line of research.

### INCREASING THE IMPACT OF YOUR GIFT

#### Corporate Matching Gift Program

Many employers of all sizes will match your gifts to UC Berkeley. Consult the employer matching-gift search page: <http://givetocal.berkeley.edu/browse/?u=172> for further details.

#### Endowment Matching Programs:

Endowments created for student support can be named in recognition of the donor or another honoree and may be eligible for matching through the following programs:

- The Graduate Fellowship Matching Program for gifts of \$50K or more pledged over five years.
- The William and Grace Ford Undergraduate Scholarship Matching Program for endowments of \$100K

For further information, please contact:  
Lochland Trotter, [lochland@berkeley.edu](mailto:lochland@berkeley.edu), 510-643-5040

## 2013/14 AWARDS

### MARY ELIZABETH UHL PRIZE

The Mary Elizabeth Uhl Prize is awarded each year to a graduate student for outstanding scholarly achievement.

#### 2014: Mike McCourt (advisor Eliot Quataert)

Mike's thesis includes many original contributions to our understanding of the physics of galaxy cluster plasmas. For example, he developed an analytical and numerical understanding of how thermal instabilities regulate the rate at which cold gas flows to small radii, fueling star formation and black hole growth in the centers of clusters. This likely provides a key to understanding why cluster plasmas have the properties they do. Mike will be an ITC postdoctoral Fellow at Harvard.

#### 2014: Chat Hull (advisor Carl Heiles and Dick Plambeck)

Chat Hull's research is focused on polarization measurements of the radio continuum and spectral lines to learn more about star formation in molecular clouds. Before starting as a Jansky Fellow at Harvard, he will be taking a cross-country road trip across the northern U.S. and southern Canada, hoping he will arrive at Harvard when the first snow falls.

#### 2013: Jonnie Pober (adviser Don Backer and Aaron Parsons)

Jonnie initially worked with Professor Don Backer on PAPER: Precision Array for Probing the Epoch of Reionization. When Backer passed away in 2010, new faculty member Aaron Parsons essentially became Don's successor and as a result, became Jonnie's advisor. Jonnie received a NSF Astronomy and Astrophysics Postdoctoral Fellowship, which he took to the University of Washington. Pober completed his Ph.D. in 2013 and is currently a NSF Astronomy and Astrophysics Postdoctoral Fellow at the University of Washington, Department of Physics.

### DOROTHEA KLUMPKE ROBERTS PRIZE IN ASTRONOMY

Outstanding scholarly achievement by an upper-level undergraduate student.

#### 2014: Rea Kolbl

Rea will be attending Stanford University in the fall for Applied Physics, researching condensed matter. Rea is a double major in Astrophysics and Physics, and is engaged in research with Geoff Marcy. Rea has created a sophisticated spectroscopic technique that

detects unseen neighboring stars near a much brighter primary star. She discovered over 60 binary stars in the Kepler database.

#### 2014: Caleb Levy

Will be graduating in Fall 2014 and will apply to graduate school for Mathematics–functional analysis.

Caleb is a double major in Astrophysics and Applied Math. He's currently engaged in research with Phillip Marcus, a professor in the department of Mechanical Engineering. Last summer he worked on a project to figure out how energy flows in protoplanetary disks using ray tracing.

#### 2013: Andrew Vanderburg

Andrew was recipient of the 2013 Dorothea Klumpke Roberts prize. As an astronomy student at Berkeley, Vanderburg's research ranged from improving the precision of radial velocity measurements taken at Keck to using externally dispersed interferometry to measure high resolution infrared spectra. Andrew is currently a graduate student at Harvard University.

### ROBERT J. TRUMPLER GRADUATE STUDENT AWARD

The Robert J. Trumpler Graduate Student Excellence Award recognizes academic excellence in the field of Astronomy. This award is given to one or more high achieving graduate students in recognition of academic excellence as well as outreach.

#### 2014: Garrett (Karto) Keating

Karto's thesis research involves intensity mapping of CO at high redshifts ( $z \sim 5$ ), with CARMA. He is using over a 1000 hrs on the Hubble Deep 'Goods-North' field, achieving sensitivities that are of interest for current cosmological models. This research involves not only astronomy—but also a very high level of statistical and instrumental analysis.

#### 2014: James Gold McBride

James McBride is fascinated by galactic evolution and structure. He has worked on the observational effect of magnetic fields in galaxy and star formation, the starburst phenomenon, AGN and angular momentum transport therein, cooling flows in clusters of galaxies, and the interaction of radio jets with the intercluster medium. He studies these through a variety of observations including full-Stokes VLBI mapping of OH megamasers.

#### 2013: Chat Hull

Chat was an observational astronomer whose research focused on polarization from protostellar disks. He completed his Ph.D. in 2014.

### OUTSTANDING GRADUATE STUDENT INSTRUCTOR AWARD

This award provides campus-wide recognition of excellence in teaching by Graduate Student instructors.

2014: Sedona Price, Lauren Weiss, and Drummond Fielding

2013: Ryan Turner and Katherine de Kleer

### DEPARTMENT CITATION

The Departmental Citation is a prestigious award given to an undergraduate in recognition for his or her distinguished undergraduate work. The Committee on Prizes initiated the Departmental Citation plan in 1955 with the approval and support of the Chancellor.

#### 2014: Kevin Yu

Kevin is a double major with Astrophysics and Physics. His research has involves a comparison of the relationship between stellar and dynamical masses of simulated galaxies to observations. He will begin work as a Software Engineer at FiveStars Loyalty Inc., in SF

#### 2013: Peter Blanchard

Peter had a superb academic record as a double major in astronomy and physics. He began working with Professor Alex Filippenko in searching for supernovae using KAIT, was upgraded to using the Nickel 1-meter telescope at Lick Observatory remotely from Evans Hall and ultimately was allowed to work on the 3-meter Shane telescope at Lick Observatory. He is currently attending Harvard University to get his graduate degree.

### UNDERGRADUATE STUDENT COMMENCEMENT SPEAKER

#### 2014: Skylar Kerzner

Skylar was a double major in Astrophysics and Physics and will start grad school this fall at UC San Diego, where he will pursue his interests in Artificial Intelligence and Brain-Computer interfaces through a PhD program in Cognitive Science.

#### 2013: Peter Blanchard

Peter was an Astrophysics and Physics double major and has since gone on to Harvard where he is pursuing his graduate degree.

## Professor Imke de Pater takes flight with NASA's SOFIA aircraft



NASA's SOFIA (Stratospheric Observatory for Infrared Astronomy) is a project dedicated to observing the infrared universe through the use of a flying observatory. Key scientific goals of SOFIA are to study the dynamics and chemistry of interstellar matter, formation and evolution of stars, the composition, structure, and evolution of comets, and planetary atmospheres and surfaces through observations between 0.3 and 1600 mm.

Observations over this wavelength range can be accomplished because SOFIA can reach altitudes of 41,000 feet, placing those onboard above the terrestrial water vapor layer which is blocking most of the incoming light at infrared – submillimeter wavelengths. Additionally, because the observatory is in an airplane, it can go to specific sites to observe transient phenomena and specific events, such as occultations of stars by asteroids, moons and planets.

The SOFIA aircraft, a modified Boeing 747-SP, houses and transports a German-built 2.5 meter, 17-ton telescope, along with onboard consoles astronomers and mission staff use to monitor data collected from the telescope during flight. In addition to the pilot, co-pilot and flight engineer, there is the mission director, science flight planner, two telescope operators, instrument operators, and security guards. SOFIA's Educational and Public Outreach Program is extremely active,

and regularly invite teachers and educators to join the flight.

Imke de Pater had the good fortune to fly with SOFIA in early May 2014 in order to observe the planet Jupiter. Each of the two flights was 10 hours long - taking off and landing at NASA's Armstrong Flight Research Center in Palmdale, CA, and were dedicated to observations conducted with the Faint Object infraRed CAmera for the SOFIA Telescope (FORCAST), a dual-channel mid-infrared camera and spectrograph sensitive from 5-40  $\mu\text{m}$ . The observations, overall, were very successful, and the team is working hard to reduce and analyze the data. Although observing with SOFIA is much more flexible than with the Hubble Space Telescope, it is very strict compared to ground-based observations. Placement of the telescope at the side of the airplane requires specific flight "tracks" that zig-zag across the Pacific Ocean and inland areas in order to observe particular objects.

## UC-Wide collaboration underway: MOSFIRE Deep Evolution

Mariska Kriek, our most recently hired astronomy professor is co-PI on a major new faint galaxy survey being undertaken at the 10-meter Keck I Telescope on Mauna Kea, Hawaii. This survey, called the MOSFIRE Deep Evolution Field (MOSDEF) survey, will exploit the new capabilities of a recently-completed multi-object near infrared spectrograph MOSFIRE. Using this new spectrograph, the MOSDEF survey will target 2,000 extremely distant galaxies, lying 9 to 12 billion light years away. MOSDEF will result in more than an order of magnitude

improvement over existing galaxy surveys at a similar distance.

With these data in hand, the team will study the stellar and gaseous content of galaxies when the Universe was only 1.5-4.5 billion years old. Professor Kriek will lead the study of the stellar content, and the motions of the stars and gas in these distant galaxies. Both these probes provide powerful clues to how galaxies grow and build up their stellar mass over cosmic time.

MOSDEF is a UC-wide collaboration;

additional co-PIs include Alison Coil from UC San Diego, Alice Shapley from UCLA, and Naveen Reddy, Brian Siana, and Bahram Mobasher from UC Riverside. Together they have been awarded a total of 47 observing nights on the Keck I Telescope for the survey, which will be executed over 4 years. The team just completed their second observing semester and is currently analyzing the first data. They have also been awarded a \$975,000 grant from the National Science Foundation, which will be divided among the four campuses.

## Professor Eugene Chiang Receives 2014 Distinguished Teaching Award

On March 13th 2014, Chancellor Nicholas Dirks announced faculty member Dr. Eugene Chiang as a recipient of the 2014 Distinguished Teaching Award. Dr. Chiang has been a professor with the Astronomy

department since 2001 and currently serves as director of the Berkeley Center for Integrative Planetary Science. His research focuses on theoretical astrophysics, with an emphasis on understanding the



origin of planetary systems, both extra-solar and solar. Dr. Chiang is an active member within the campus community: In addition to acting as head Graduate Advisor for the Astronomy Department,

he serves on multiple committees which include the Berkeley Committee on Undergraduate Scholarships, Honors, and Financial Aid and is the Astronomy Liaison and Co-I for the Berkeley Science and Diversity program. On April 23rd the campus honored Dr. Chiang's excellence



in teaching with a public ceremony: in attendance were members of the chancellor's office, the department, Dr. Chiang's family and colleagues, and many of his undergraduate and graduate students.

## Astronomers answer key question: How common are habitable planets?

NASA's Kepler space telescope, now crippled and its four-year mission at an end, nevertheless provided enough data to answer its main research question: How many of the 200 billion stars in our galaxy have potentially habitable planets?

Based on a statistical analysis of all the Kepler observations, astronomers at UC Berkeley and University of Hawaii, Manoa now estimate that one in five stars like the sun have planets about the size of Earth and a surface temperature conducive to life.



Given that about 20 percent of stars are sun-like, the researchers say, that amounts to several tens of billions of potentially habitable, Earth-size planets in the Milky Way Galaxy.

"When you look up at the thousands of stars in the night sky, the nearest sun-like star with an Earth-size planet in its habitable zone is probably only 12 light years away and can be seen with the naked eye. That is amazing," said UC Berkeley graduate student Erik Petigura, who led the analysis of the Kepler data.

Petigura has been doing research under the supervision of professor Geoff Marcy, UC Berkeley professor of astronomy. "Erik is an absolutely brilliant graduate student in our department. He brings deep insights about astrophysics and planetary science to his research. I can't imagine anyone else doing the monumental analysis of the Kepler data that Erik accomplished," Marcy said.

"The primary goal of the Kepler mission was to answer the question, 'What fraction of the Sun-like stars have Earth-size planets at lukewarm temperatures so that water would not be frozen into ice or vaporized into steam, but remain a liquid, because liquid water is now understood to be the prerequisite for life?'" Marcy said. "Until now, no one knew exactly how common potentially habitable planets were around sun-like stars in the galaxy."

"It's been nearly 20 years since the discovery of the first extrasolar planet around a normal star. Since then, we have learned that most stars have planets of some size orbiting them, and that Earth-size planets are relatively common in close-in orbits that are too hot for life," said Andrew Howard, a former UC Berkeley post-doctoral fellow who is now on

the faculty of the Institute for Astronomy at the University of Hawaii. "With this result, we've come home, in a sense, by showing that planets like our Earth are relatively common throughout the Milky Way Galaxy."

Petigura, Howard, and Marcy published their analysis and findings in Proceedings of the National Academy of Sciences in November 2013. Their paper, titled *The prevalence of Earth-size planets orbiting Sun-like stars* was judged the top physical and mathematical sciences paper and was awarded the Cazzarelli Prize for 2013.

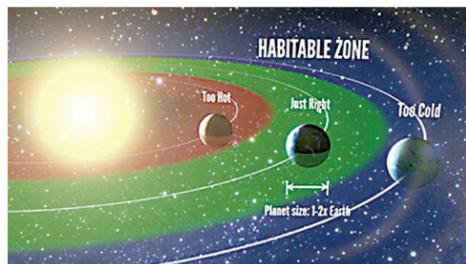
### Earth-size may not mean habitable

"For NASA, this discovery is vitally important, because future missions will try to take an actual picture of a planet, and the size of the telescope they have to build depends on how close the nearest Earth-size planets are," Howard said. "An abundance of planets orbiting nearby stars simplifies such follow-up missions."

The team cautioned that Earth-size planets in orbits about the size of Earth's are not necessarily hospitable to life, even if they reside in the habitable zone around a star where the temperature is not too hot and not too cold.

"Some may have thick atmospheres, making it so hot at the surface that DNA-like molecules would not survive. Others may have rocky surfaces that could harbor liquid water suitable for living organisms," Marcy said. "We don't know what range of planet types and their environments are suitable for life."

However Howard, Marcy and their colleagues provide hope that many such planets actually are rocky and could support liquid water. They reported that one Earth-size planet



The field of view of the Kepler space telescope, located in the constellation Cygnus, just above the plane of the Milky Way Galaxy. Kepler made precise measurements of the brightnesses of 156,000 stars for four years.

discovered by Kepler – albeit, a planet with a likely temperature of 2,000 Kelvin, which is far too hot for life as we know it – is the same density as Earth and most likely composed of rock and iron, like Earth.

"This gives us some confidence that when we

look out into the habitable zone, the planets Erik is describing may be Earth-size, rocky planets," Howard said.

### Transiting planets

NASA launched the Kepler space telescope in 2009 to look for planets outside the solar system that cross in front of, or transit, their stars, which causes a slight diminution – about one hundredth of 1 percent – in the star's brightness. From among the 150,000 stars imaged every 30 minutes for four years, NASA's Kepler team reported more than 3,000 planet candidates. Many of these are much larger than Earth – ranging from large planets with thick atmospheres, like Neptune, to gas giants like Jupiter – or in orbits so close to their stars that they are roasted.

To sort them out, Petigura and his colleagues are using the Keck telescopes in Hawaii to obtain spectra of as many stars as possible. This will help them determine each star's true brightness and calculate the diameter of each transiting planet, with an emphasis on Earth-diameter planets.

Independently, Petigura, Howard and Marcy focused on the 42,000 stars that are like the sun or slightly cooler and smaller, and found 603 candidate planets orbiting them. Only 10 of these were Earth-size, that is, one to two times the diameter of Earth and orbiting their star at a distance where they are heated to lukewarm temperatures suitable for life. The team's definition of habitable is that a planet receives between four times and one-quarter the amount of light that Earth receives from the sun.

### A census of extrasolar planets

Petigura rigorously subjected his planet-finding algorithms to a battery of tests in order to measure how many habitable zone, Earth-size planets they missed. Petigura actually introduced fake planets into the Kepler data in order to determine which ones his software could detect and which it couldn't.

"What we're doing is taking a census of extrasolar planets, but we can't knock on every door. Only after injecting these fake planets and measuring how many we actually found could we really pin down the number of real planets that we missed," Petigura said.

Accounting for missed planets, as well as the fact that only a small fraction of planets are oriented so that they cross in front of their host star as seen from Earth, allowed them to estimate that 22 percent of all sun-like stars in the galaxy have Earth-size planets in their habitable zones.

All of the potentially habitable planets found in the team's survey are around K stars, which

*Continued on page 5*

## NEW CAMPBELL HALL UPDATE

We are happy to report construction of the new Campbell Hall is on schedule and proceeding as planned. Our move into the new building is slated for September 2014 and we simply cannot wait to settle in and start making use of the building's state-of-the-art classrooms, remote observing labs, and newly built roof-top observatory, which will house a new 17 inch Dall-Kirkham Astrograph telescope.



## DON'T FORGET—THE STUDENT OBSERVATORY FUND IS NOW ACTIVE!

This fund was established to support the upgrade of our undergraduate lab and telescopes used by our astrophysics majors, and to maintain the New Campbell Hall Rooftop Observatory. The fund also supports our off-site Leuschner Observatory, which is used for undergraduate teaching and research. For more information on how you can support the Student Observatory Fund or discuss how you can contribute to new Campbell Hall, please contact Lochland Trotter at 510-643-5040 or, lochland@berkeley.edu.

### Habitable planets? from page 4

are cooler and slightly smaller than the sun, Petigura said. But the researchers' analysis shows that the result for K stars can be extrapolated to G stars like the sun. Had Kepler survived for an extended mission, it would have obtained enough data to directly detect a handful of Earth-size planets in the habitable zones of G-type stars.

"If the stars in the Kepler field are representative of stars in the solar neighborhood, ... then the nearest (Earth-size) planet is expected to orbit a star that is less than 12 light-years from Earth and can be seen by the unaided eye," the researchers wrote in their paper. "Future

## Artist Chosen to create new artwork for Campbell Hall

Mungo Thomson has been commissioned to create a new installation in the dome located in the lobby on the first floor of Campbell Hall. The ceiling dome marks the entrance to the building and will greet visitors with a moving image of the wonder and magnificence inspired by the study of astronomy.

### About Mungo Thomson

Mungo Thomson is a Los Angeles-based artist whose work explores mass culture, cosmology, and reception with economy and wit. He has been described as a perceptual artist who works with language and context rather than light and space. His work addresses the voids that exist within culture—the gaps, pauses, digressions and mistakes that surround material production, institutional space, and everyday life. He has had solo exhibitions, projects and performances at The High Line, New York; SITE Santa Fe; The Times Museum, Guangzhou, China; The Aspen Art Museum, Aspen; The Hammer Museum, Los Angeles; The Kadist Art Foundation, Paris, France; and GAMeC, Bergamo, Italy, among others.



instrumentation to image and take spectra of these Earths need only observe a few dozen nearby stars to detect a sample of Earth-size planets residing in the habitable zones of their host stars."

In January, the team reported a similar analysis of Kepler data for scorched planets that orbit close to their stars. The new, more complete analysis shows that "nature makes about as many planets in hospitable orbits as in close-in orbits," Howard said.

The research was funded by UC Berkeley and the National Science Foundation, with the assistance of the W. M. Keck Observatory and NASA.

## CONGRATULATIONS to our recent PhD's!

### May 2013

#### Jonathan Pober

Adviser: Aaron Parsons  
*Overcoming the Challenges of 21cm Cosmology*  
Pober is a NSF Astronomy and Astrophysics Fellow at the University of Washington in the Department of Physics.

### December 2013

#### Adam Miller

Adviser: Joshua Bloom  
*Time-Domain Studies as a Probe of Stellar Evolution*  
Miller is a Hubble Fellow at the Jet Propulsion Laboratory in Pasadena, California.

#### Yookyung Noh

Adviser: Joanne Cohn  
*The Largest Structure to the Smallest Collapsed Object in the Universe*

#### Joshua Hajime Shiode

Adviser: Eliot Quataert  
*The Evolution and Stability of Massive Stars*  
Shiode is a John Bahcall Public Policy Fellow at the American Astronomical Society in Washington DC.

### May 2014

#### Adam Nolan Morgan

Adviser: Joshua Bloom  
*Classification, Follow-up, and Analysis of Gamma-ray Bursts and their Early-time NIR/Optical Afterglows*  
Adam will be participating in a 6 week Insight Data Science Fellows Program.

#### Christopher Robert Klein

Adviser: Joshua Bloom  
*Improving RR Lyrae Distance Indicators Through Instrumentation, Observation, and Calibration*  
Chris will be participating in a 6 week Insight Data Science Fellows Program.

#### Charles Lindsay Hopkins Hull

Advisers: Carl Heiles and Richard Plambeck  
*From Cores to Envelopes to Disks: A Multi-scale View of Magnetized Star Formation*  
Chat will be a Jansky and SMA fellow at Harvard.

#### Michael Kingsley McCourt Jr.

Adviser: Eliot Quataert  
*Gas Dynamics in Galaxy Clusters*  
Mike will be an ITC Fellow at Harvard, working on the hot plasma in galaxy clusters and in the galactic center.

### December 2014

#### Matthew Richard George

Advisers: Uros Seljak and David Schlegel  
*Galaxies and Dark Matter in Group Halos*  
Matt will be participating in a 6 week Insight Data Science Fellows Program.