BERKELEY ASTRONOMY

UNIVERSITY OF CALIFORNIA AT BERKELEY
WINTER 2017

Astronomy in the News

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BERKELEY ASTRONOMERS SELECTED TO TAKE NEW SPACE TELESCOPE FOR A SPIN

By Robert Sanders, Media relations
November 21, 2017

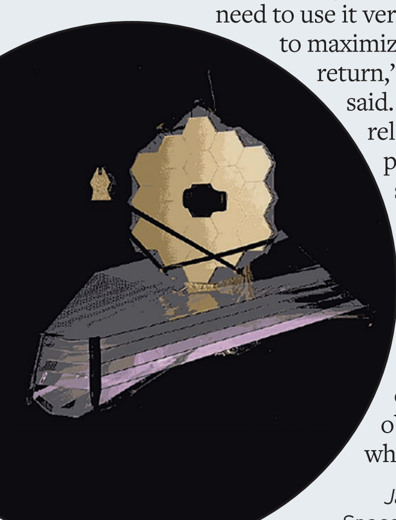
Berkeley astronomers, Imke de Pater and Daniel Weisz, have been chosen to lead two of the first 13 groups that will test the capabilities of NASA's advanced new successor to the Hubble Space Telescope, the James Webb Space Telescope.

From November 2019 until April 2020, these teams will scan objects near and far, ranging from planets in our solar system to planets around nearby stars, and from star systems in the Milky Way galaxy to galaxies at the edge of the universe.

"The diversity of science represented by these 13 teams is amazing," said Weisz, "we are definitely excited about this opportunity."

The teams are hoping for new discoveries, but they've also been selected because of promises to provide baseline information for future observers and computer software tools that those astronomers will need to make sense of their observations on the telescope.

"With the telescope's five-year lifetime, we need to use it very efficiently to maximize the return," Weisz said. "The early release science program is supposed to produce science-enabling results within five months of the observations, which in the astronomy world is basically yesterday."



James Webb Space Telescope, courtesy of NASA.

Letting astronomers rather than staff take the telescope for a test drive is a new concept for NASA, said de Pater. She and her team will focus on Jupiter, its moons Io and Ganymede and its faint rings, to see if they can capture fine detail against the bright background of Jupiter, which is actually too bright for the telescope to look at without filters.

"We will see if we can image the rings and get rid of the scattered light from Jupiter, which pushes the telescope's limits and really tests the capabilities of JWST," she said.

Weisz, who studies star systems, from globular clusters with millions of stars to galaxies in the local Universe, will take the long view. He is particularly interested in systems near enough that individual stars can be picked out and counted, which can tell astronomers about the history of the galaxy and ultimately the history of the universe.

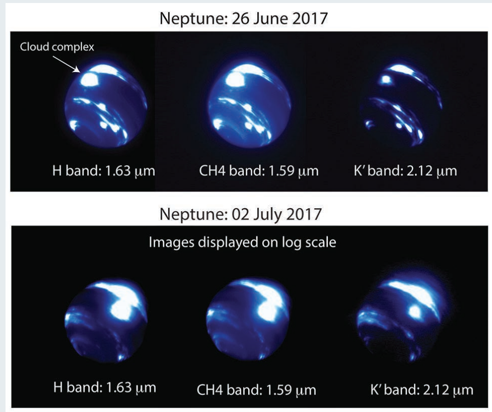
The James Webb telescope will be ideal for this, because its mirrors will be two and a half times the size of the mirror in the Hubble space telescope, effectively cutting the time it takes to collect data on a cluster or galaxy by a factor of 10. This allows detailed studies of the very faintest stars, some of which first started to glow when the universe was a baby more than 10 billion years ago.

"For studies of very faint stars in the Milky Way – our own galaxy – the JWST is going to be phenomenal," he said. "The telescope will do roughly in its five- to 10-year mission what Hubble has done in its 25-year mission for local galaxies."

During the 20 hours of telescope time allocated to his team, they will take images in both optical and infrared for a globular cluster in the Milky Way, a very faint, dark-matter-dominated dwarf galaxy that orbits the Milky Way and a close neighbor and traveling companion of the Milky Way, a galaxy at a distance of about 3 million light years.

By counting and determining the age of each star within within these galaxies, for example, he hopes to shed light on what happened early in the universe when stars first began to shine across the cosmos, the so-called epoch of reionization.

De Pater admits that two years is a long time to wait, but hopes to use the 28.9 allocated hours of observing time to measure the wind speeds in Jupiter's Great Red Spot,



Images of Neptune taken during twilight observing revealed an extremely large bright storm system near Neptune's equator (labeled 'cloud complex' in the upper figure), a region where astronomers have never seen a bright cloud. The center of the storm complex is ~9,000 km across, about 3/4 the size of Earth, or 1/3 of Neptune's radius. The storm brightened considerably between June 26 and July 2, as noted in the logarithmic scale of the images taken on July 2. (*N. Molter/I. de Pater, UC Berkeley/ C. Alvarez, W. M. Keck Observatory*)

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observe gases in the atmospheres of Io and Ganymede and see ripples left by comets in the rings around the planet.

"The idea is that for any solar system object, you have to assemble a mosaic of the planet or moon from multiple observations when everything is moving and rotating and changing. How do you do that?" de Pater said. "We have to develop the software so that astronomers can put their little postage stamps together into a map."

UC Berkeley research astronomer Michael Wong is one of the co-investigators on de Pater's team.

PUZZLING NEW SUPERNOVA MAY BE FROM STAR PRODUCING ANTIMATTER

By Robert Sanders, Media relations
November 9, 2017

An exploding star that continued to shine for nearly two years — unlike most supernovae, which fade after a few weeks — is puzzling astronomers and leading theorists, including UC Berkeley astrophysicist Daniel Kasen, to suggest that the event may be an example of a star so hot that it produces antimatter in its core.

Stars would have to be very massive to get this hot, Kasen said, which is why most astronomers assumed they existed, if at all, only in the early years of the universe.

But evidence that the star underwent repeated eruptions make "something along these lines seem most plausible," he said. Kasen, an associate professor of physics and of astronomy and a scientist at Lawrence Berkeley National Laboratory, is a coauthor of a paper describing the weird exploding star published this week in the British journal *Nature*.

"It is possible that this was the result of star so massive that it was capable of generating pairs of anti-electrons and electrons in its core," Kasen said. "That would cause the star to go through phases of violently instability, resulting in a series of bright eruptions."

Another co-author, Peter Nugent, a senior staff scientist in the Computational Research Division at Berkeley Lab and an adjunct professor of astronomy at UC Berkeley, helped lead observations of the exotic star explosion at the W.M. Keck Observatory in Hawaii.

"This is one of those head-scratcher type of events," he said. "At first we thought it was completely normal and boring. Then it just kept staying bright, and not changing, for month after month. Piecing it all together ... has started to shed light on what this could be. However, I'd really like to find another one."

The study was led by Iair Arcavi, a NASA Einstein postdoctoral fellow at UC Santa Barbara and Las Cumbres Observatory in Goleta, California.

GRADUATE STUDENT'S TWILIGHT OBSERVATIONS REVEAL HUGE STORM ON NEPTUNE

By Robert Sanders, Media relations
August 3, 2017

Spectacular sunsets and sunrises are enough to dazzle most of us, but to astronomers, dusk and dawn are a waste of good observing time. They want a truly dark sky. Not Ned Molter, a UC Berkeley astronomy graduate student. He set out to show that some bright objects can be studied just as well during twilight, when other astronomers are twiddling their thumbs, and quickly discovered a new feature on Neptune: A storm system nearly the size of Earth. "Seeing a storm this bright at such a low latitude is extremely surprising," said Molter, who spotted the storm complex near Neptune's equator during a dawn test run of twilight observing at W. M. Keck Observatory on Maunakea, Hawaii. "Normally, this area is really quiet and we only see bright clouds in the mid-latitude bands, so to have such an enormous cloud sitting right at the equator is spectacular." This massive storm system, which was found in a region where no bright cloud has ever been seen before, is about 9,000 kilometers in length, or one-third the size of Neptune's radius, spanning at least 30 degrees in both latitude and longitude. Molter observed it getting much brighter between June 26 and July 2. "Historically, very bright clouds have occasionally been seen on Neptune, but usually at latitudes closer to the poles, around 15 to 60 degrees north or south," said Imke de Pater, a UC Berkeley professor of astronomy and Molter's adviser. "Never before has a cloud been seen at or so close to the equator, nor has one ever been this bright." The discovery of Neptune's mysterious equatorial cloud complex was made possible by the new Keck Visiting Scholars Program, launched this summer, which gives graduate students and post-doctoral researchers experience working at the telescope, while contributing to Keck Observatory and its scientific community. "This result by Imke and her graduate student, Ned, is a perfect example of what we're trying to accomplish with the Keck Visiting Scholars Program," said Anne Kinney, chief scientist at Keck Observatory. "Ned is our first visiting scholar, and his incredible work is a testament to the value of this program. It's just been an outrageous success." Molter is one of eight scholars accepted into the program this year. His assignment during his six-week stay at the Observatory was to develop a more efficient method for twilight observing, making use of time that otherwise might not be used. Most observers in the Keck Observatory community peer deep into the night sky and cannot observe their targets during twilight. "Ned had never observed before, and he's very bright, so when Anne told me about the program, I knew he would be the perfect student for it," said de Pater. "Now that we've discovered this interesting cloud complex in Neptune, Ned has a running start on a nice paper for his Ph.D. thesis."

ASTRONOMERS STRIKE COSMIC GOLD

Robert Sanders, Media Relations
October 16, 2017

The first detection of gravitational waves from the cataclysmic merger of two neutron stars, and the observation of visible light in the aftermath of that merger, finally answer a long-standing question in astrophysics: Where do the heaviest elements, ranging from silver and other precious metals to uranium, come from?

Based on the brightness and color of the light emitted following the merger, which closely match theoretical predictions by University of California, Berkeley and Lawrence Berkeley National Laboratory physicists, astronomers can now say that the gold or platinum in your wedding ring was in all likelihood forged during the brief but violent merger of two orbiting neutron stars somewhere in the universe. This is the first detection of a neutron star merger by the Laser Interferometer Gravitational-Wave Observatory (LIGO) detectors in the United States and is the first time that light associated with a source of gravitational waves has been detected. "We have been working for years to predict what the light from a neutron merger would look like," said Daniel Kasen, an associate professor of physics and of astronomy at UC Berkeley and a scientist at Berkeley Lab. "Now that theoretical speculation has suddenly come to life."

Apart from black holes, neutron stars are the densest objects known in the universe. They are created when a massive star exhausts its fuel and collapses onto itself, compressing a mass comparable to that of the sun into a sphere only 10 miles across. The detection of a neutron star merger was surprising, because neutron stars are much smaller than black holes and their mergers produce much weaker gravitational waves than do black hole mergers. According to Berkeley professor of astronomy and physics Eliot Quataert, "We were anticipating LIGO finding a neutron star merger in the coming years but to see it so nearby – for astronomers – and so bright in normal light has exceeded all of our wildest expectations. And, even more amazingly, it turns out that most of our predictions of what neutron star mergers would look like as seen by normal telescopes were right!"

GENESIS OF THE ELEMENTS

While hydrogen and helium were formed in the Big Bang 13.8 billion years ago, heavier elements like carbon and oxygen were formed later in the cores of stars through nuclear fusion of hydrogen and helium. But this process can only build elements up to iron. Making the heaviest elements requires a special environment in which atoms are repeatedly bombarded by free neutrons. As neutrons stick to the atomic nuclei, elements higher up the periodic table are built. Where and how this process of heavy element production occurs has been one of the longest standing questions in astrophysics.

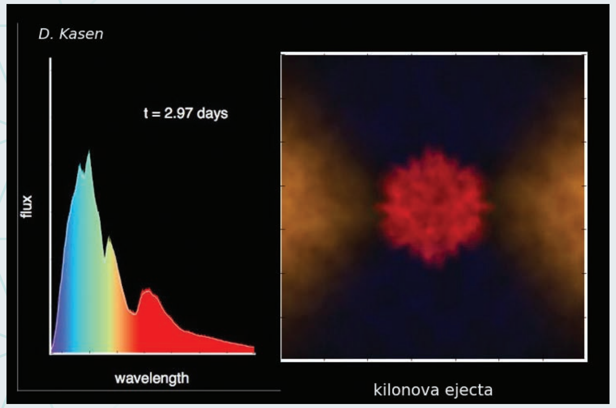
Speculation that astronomers might see light from such heavy elements traces back to the 1990s, but the idea had mostly been gathering dust until 2010, when Brian Metzger, then a freshly minted graduate student at UC Berkeley, now a professor of astrophysics at Columbia University, co-authored a paper with Quataert and Kasen in which they calculated the radioactivity of the neutron star debris and estimated its brightness for the first time.

"As the debris cloud expands into space," Metzger said, "the decay of radioactive elements keeps it hot, causing it to glow." Metzger, Quataert, Kasen and collaborators showed that this light from neutron star mergers was roughly one thousand times brighter than normal nova explosions in our galaxy, motivating them to name these exotic ashes "kilonovae." Jennifer Barnes, an Einstein postdoctoral fellow at Columbia, worked as a Berkeley graduate student with Kasen to make some of the first detailed predictions of what a kilonova should look like. "When we calculated the opacities of the elements formed in a neutron star merger, we found a lot of variation. The lighter elements were optically similar to elements found in supernovae, but the heavier atoms were more than a hundred times more opaque than what we're used to seeing in astrophysical explosions," said Barnes. "If heavy elements are present in the debris from the merger, their high opacity should give kilonovae a reddish hue." "I think we bummed out the entire astrophysics community when we first announced that," Kasen said. "We were predicting that a kilonova should be relatively faint and redder than red, meaning it would be an incredibly difficult thing to find. On the plus side, we had defined a smoking-gun – you can tell that you are seeing freshly produced heavy elements by their distinctive red color." That is just what astronomers observed.

A 'TREACHEROUS PREDICTION'

The August LIGO/Virgo discovery of a neutron star merger meant that "judgment day for the theorists would come sooner than expected," Kasen said. "For years the idea of a kilonova had existed only in our theoretical imagination and our computer models," he said. But as the data trickled in, one night after the next, the images began to assemble into a surprisingly familiar picture. On the first couple nights of observations, the color of the merger event was relatively blue with a brightness that matched the predictions of kilonova models strikingly well if the outer layers of the merger debris are made of light precious elements such as silver. However, over the ensuing days the emission became increasingly red, a signature that the inner layers of the debris cloud also contain the heaviest elements, such as platinum, gold and uranium. "Perhaps the biggest surprise was how well-behaved the visual signal acted compared to our theoretical expectations," Metzger noted. "No one had ever seen a neutron star merger up close before. Putting together the complete picture of such an event involves a wide range of physics – general relativity, hydrodynamics, nuclear physics, atomic physics. To combine all that and come up with a prediction that matches the reality of nature is a real triumph for theoretical astrophysics."

Three days after the merger and explosion, the bright blue glow from lighter elements in the outer polar regions is beginning to fade, giving way to the red glow from the heavier elements in the surrounding doughnut and spherical core. The red glow persisted for more than two weeks. (Dan Kasen image)



DISTANT GALAXY SENDS OUT 15 HIGH-ENERGY RADIO BURSTS

Robert Sanders, Media Relations
August 30, 2017

Breakthrough Listen, an initiative to find signs of intelligent life in the universe, has detected 15 brief but powerful radio pulses emanating from a mysterious and repeating source – FRB 121102 – far across the universe.

Fast radio bursts are brief, bright pulses of radio emission from distant but largely unknown sources, and FRB 121102 is the only one known to repeat: more than 150 high-energy bursts have been observed coming from the object, which was identified last year as a dwarf galaxy about 3 billion light years from Earth. Possible explanations for the repeating bursts range from outbursts from rotating neutron stars with extremely strong magnetic fields – so-called magnetars – to a more speculative idea: They are directed energy sources, powerful laser bursts used by extraterrestrial civilizations to power spacecraft, akin to Breakthrough Starshot's plan to use powerful laser

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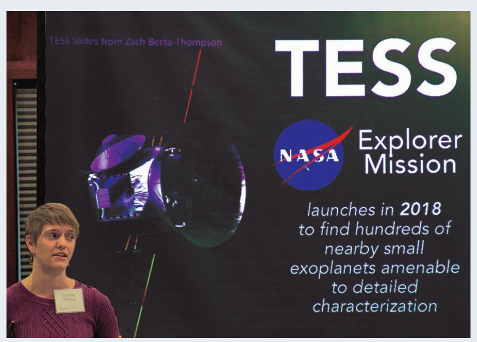
pulses to propel nano-spacecraft to our solar system's nearest star, Proxima Centauri. "Bursts from this source have never been seen at this high a frequency," said Andrew Siemion, director of the Berkeley SETI Research Center and of the Breakthrough Listen program.

First detected with the Parkes Telescope in Australia, fast radio bursts have now been seen by several radio telescopes around the world. FRB 121102 was discovered on Nov. 2, 2012, (hence its name) and in 2015 it was the first fast radio burst seen to repeat, ruling out theories of bursts' origins that involved the catastrophic destruction of the progenitor, at least in this instance. Regardless of FRB 121102's ultimate source, when the recently detected pulses left their host galaxy, our solar system was less than 2 billion years old, noted Steve Croft, a Breakthrough Listen astronomer at UC Berkeley. Life on Earth consisted only of single-celled organisms; it would be another billion years before even the simplest multi-cellular life began to evolve.

Astrophysics Roundtable

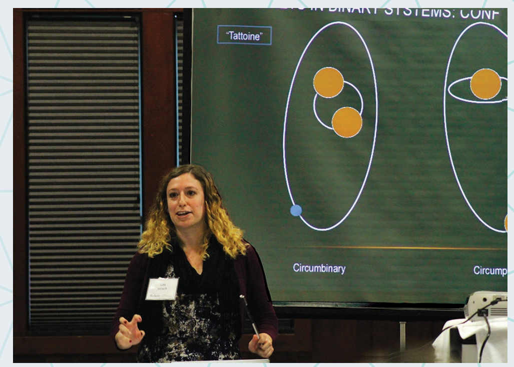
This fall's Astrophysics Roundtable focused on one of Astronomy's great strengths, *exoplanet research.*

The universe teems with planets - essentially every star harbors one if not multiple worlds, covering the full range from rocky moon-sized orbs to gas giants occupying orbits of once-unimaginable variety. From the thousands of planetary systems known researchers are piecing together the narrative of how they, and by extension the Earth, came to be.



Professor Courtney Dressing discusses TESS, the Transiting Exoplanet Survey Satellite mission.

This exciting event brought together new faculty hire Courtney Dressing with existing ones, Eugene Chiang and James Graham and highlighted the important work being done by postdocs and students. Discussing efforts by Berkeley astronomers to push into new discovery space using every possible tool, speakers covered Doppler spectroscopy, transit light curves, extreme adaptive optics imaging and massively parallel computation. Joining the faculty speakers were PhD student Lea Hirsch, Miller Postdoctoral Fellow Rebecca Jensen-Clem, and researcher Dan Werthimer.



Student Lea Hirsch spoke on solar-type stars having at least one binary companion.

Dr. Chiang concluded the discussion by touching on efforts to provide greater support for Berkeley astronomy graduate students and developing novel instrumentation that will enable researchers to glimpse another pale blue dot.

SACKLER LECTURE

Sandy Faber presented this year's annual Sackler lecture in November. Her talk, titled "Cosmic Knowledge and the Long-Term Strategy of the Human Race," discussed what she describes as the ultimate challenge to our species: How will we utilize the information afforded to us by modern astronomy, such as how the Galaxy was assembled, how the Sun and Earth were formed, and where the precious chemical elements that comprise our bodies came from, to answer questions about what's in store? For the first time in history, the human race is poised to use that knowledge of our cosmic past to predict our cosmic future.

Currently Professor Emerita of Astronomy & Astrophysics at UC Santa Cruz, Sandy Faber helped to discover dark matter in the universe, and, with UCSC colleagues Joel Primack and George Blumenthal, co-invented the standard paradigm for galaxy formation based on it. She led the team that discovered ubiquitous massive black holes at the centers of galaxies. She's helped to build and use some of the world's largest telescopes, including the twin 10-meter Keck giants on Mauna Kea and the Hubble Space Telescope, for which she and her graduate student/postdoc Jon Holtzman diagnosed the optical flaw. Currently she leads the CANDELS project, the largest galaxy survey yet with Hubble, which is revealing how infant galaxies formed 95% of the way back to the Big Bang.

The Raymond and Beverly Sackler Distinguished Lecturer in Astronomy is a free annual event made possible by an endowment from Raymond and Beverly Sackler in efforts to bring notable speakers to the Berkeley campus.

From the Chair's Desk

Campbell Hall, the Department of Astronomy's beautiful, safe, LEED-certified building, has been our happy home now for the past three years. Here we have enjoyed summer night observation parties via our much celebrated monthly Astro Nights; searched for extraterrestrial life from the 3rd floor offices of Breakthrough SETI; and continue to teach record numbers of astrophysics majors in our 1st floor classrooms.

This year, we welcome Courtney Dressing to our faculty ranks. Courtney is an observational astrophysicist specializing in the detection and characterization of extrasolar planets. Most exoplanet observers specialize in either planet detection by transits (analyzing the tell-tale dimming of starlight as a planet passes in front of its host star) or detection by radial velocities (analyzing the Doppler shifts of stellar absorption lines as a planet forces its host to revolve around their common center of mass). Courtney is an expert in both methods. By measuring planet radii through transits and planet masses by radial velocities, she characterizes these otherworldly worlds to zeroth order, starting humanity on the journey to understanding extrasolar planet compositions, formation histories, and potentials for harboring life. We are exceptionally fortunate that Courtney has joined our Department, as she is reinvigorating our graduate and undergraduate teaching and research programs in planetary science, and is attracting top postdoctoral talent.

...this has been a fruitful and exciting year for research for our group.

We continue to see an extremely high level of communication and coordination between administrators, staff, faculty, postdocs, students, and the public, in finalizing our decadal self-review. We have worked relentlessly on revamping curriculum to reflect current needs and industry trends, bringing in internationally-renowned speakers for our weekly Colloquium, CIPS, TAC, and Department Lunch seminars, and addressed issues ranging from faculty hiring needs to the use policy of the undergraduate research lab. Our appointed Astronomy Climate Advisors work tirelessly to raise awareness of issues related to gender equity and inclusion through one-on-one interventions, a Department-wide survey, and Town Hall discussions.

The level of dedication, enthusiasm, and scholarship characteristic to Astronomy is distilled in many of our departmental events. In particular, I encourage you attend to one of our monthly Astro Nights, a popular occasion for our immediate academic community, and also a laudable endeavor of outreach to the public. Envisioned, initiated, and run by our talented and enterprising group of graduate students (special thanks to Carina Cheng and Lea Hirsch), it features free public lectures from faculty, postdocs, and graduate students, followed by an opportunity to stargaze using the Treffers rooftop telescope with enthusiastic and knowledgeable student guides.

As you can see from various news developments in this issue, this has been a fruitful and exciting year for research for our group. I continue to be proud to serve as Chair of Astronomy, and look forward to what unfolds as we enter the new year.

Eugene Chiang

FACULTY AWARDS AND HIGHLIGHTS

An international team of 50 astronomers led by UC Berkeley Assistant Professor **Dan Weisz** has been selected to be among the first users of the James Webb Space Telescope (JWST), NASA's flagship mission that will launch in 2019. Their program, which focuses on measuring the properties of stars such as age and chemical composition in nearby galaxies, was one of thirteen programs selected out of 100 submitted as part of the call for Early Release Science with JWST. This was a very competitive selection process, with only 13 out of 106 programs chosen. Berkeley was the only institute to have two programs approved. **Imke de Pater's** program was the additional recipient of this honor.

Imke de Pater's JWST program is titled "ERS observations of the Jovian System as Demonstration of JWST's Capabilities for Solar System Science." **Dan Weisz's** program is titled: "The Resolved Stellar Populations Early Release Science Program."

Dan Weisz also received a 2017 Alfred P. Sloan Research Fellowship. This is a prestigious national award for early career researchers that is "in recognition of distinguished performance and a unique potential to make substantial contributions to their field." https://sloan.org/fellowships/

Aaron Parsons, lead investigator, and his team of researchers for the Hydrogen Epoch of Reionization Array (HERA) project were the recipients of $5.8 million in new funding from the Gordon and Betty Moore Foundation. The HERA project, led by UC Berkeley, will help build 110 new telescopes beyond the planned 240, creating a much more sensitive array able to detect faint radio signals at a wavelength of 21 centimeters. "Expanding HERA will help us map bubbles of ionization around early galaxies in our universe and will extend our ability to find the earliest signs of star formation in our universe," said Aaron Parsons.

In an exciting breakthrough this year, via the merging of neutron stars detected by the LIGO gravitational wave observatory, the predictions made 7 years ago by **Daniel Kasen,** former PhD students Brian Metzger (now faculty at Columbia) and Jennifer Barnes (now Einstein postdoctoral fellow at Columbia) and **Eliot Quataert** were confirmed. In their groundbreaking research, they theoretically predicted that debris flung out into space during the collision of two neutron stars would shine in a characteristic way. The ejected cloud of neutron star debris forms many of the heaviest elements in nature, including gold, platinum, uranium, and Berkelium. Radioactive heating from these and other elements keeps the debris hot, powering the light that was observed. The effects confirmed by the merger answered a long-standing question in astrophysics: where do the heaviest elements in nature come from? Not only did our Berkeley scientists correctly predict many properties of the light that was observed; they also played a key role interpreting the data from this unique event, their analysis published this year in Nature (see www.astro.berkeley.edu/news for more information).

Daniel Kasen was also named a Fellow of the American Physical Society this year.

ASTRO NIGHTS

Astro Night is a free stargazing and lecture event open to the public. The monthly event is usually held on the first Thursday of each month (during select months, as weather permits), starting with lecture and Q&A session, followed by guided stargazings using our fleet of telescopes, including our 17-inch roof-top telescope observatory. Members of the astronomy department are in attendance to answer any questions. Fall 2017 speakers included Gibor Basri, Jessica Lu, and Associate Project Astronomer Steve Croft. Spring talks will resume April 2018. Details can be found at http://astro.berkeley.edu/i/astro-night.

Welcome to our newest Graduate Students

The Astronomy community is excited to welcome our new graduate students to the department! Our 2017 first year cohort brings diverse backgrounds and broad research interests – we welcome them as they begin their graduate studies!

Jordan Fleming (Duke University): Jordan's research experience has been in structural acoustics, as he studied mechanical engineering prior to changing to physics. He is interested in cosmology, large-scale structure, dark matter, and galaxies.

Steven Giacalone (University of Chicago): Steven has worked on research involving transit timing variations in Kepler data, modeling planetary migration, and dust transport and magnetic fields in protoplanetary disks. He is interested in continuing to work in exoplanets and dynamics but finds most areas interesting.

Philipp Kempski (Oxford University): Philipp has worked on condensed matter theory as well as galactic outflows into dark matter halos. He is interested in continuing research in physics and cosmology using both analytic and computational models.

Casey Lam (MIT): Casey's prior research includes math theory, pulsars kicked out of the galactic disk, and primordial black holes. She is interested in continuing to research observational cosmology and black holes, but appreciates a data-driven approach to theoretical work.

Nathan Sandford (Pomona College): Nathan is interested in galaxy formation and evolution, and in stellar structure and evolution. He has previously worked on modeling metallicity gradients in spatially resolved galaxies, observations of near-Earth asteroids, and searching for gamma ray excess from dark matter annihilation.

Sarafina Nance (University of Texas-Austin): Sarafina is interested in theoretical and computational astrophysics on supernovae. Sarafina's research experience has been on stripped-envelope supernova progenitor models using the MESA code.

Spring 2018 Commencement

On May 16, 2017 the Departments of Astronomy and Physics held their joint commencement ceremony in Zellerbach Hall. The Department of Astronomy congratulates our 47 undergraduate students receiving their A.B. degrees, 4 graduate students who have completed their masters, and 7 Ph.D. recipients for the 2016-17 academic year. Dr. Lars Bildsten, Director of the Kavli Institute for Theoretical Physics and Gluck Professor of Theoretical Physics at the University of California, Santa Barbara, gave the commencement talk. Prior to the commencement ceremony, Astronomy awarded several prizes to graduating students during an an intimate celebration in Campbell Hall. We are proud of our students and are reminded of their amazing accomplishments as they take their knowledge out into the world. Congratulations to the Class of 2017!

2017 GRADUATE AWARDS

Mary Elizabeth Uhl Prize – for outstanding scholarly achievement by a graduate student finishing their dissertation in Astronomy or Physics, with a preference to Astronomy.
Eve Jihyun Lee
Katherine Rebecca de Kleer

2017 UNDERGRAD AWARDS

Commencement Speaker
Goni Halevi

Department Citation for Outstanding Scholarship
Leo Milos Pitelka Steinmetz

Dorothea Klumpke Roberts Prize – for outstanding scholarly achievement
Imad Pasha

Daniel Edward Wark Award – for astronomy majors in excellent academic standing
Magdelena Allen
Timothy Ross

OUTSTANDING GRADUATE STUDENT INSTRUCTOR AWARDS

Goni Halevi
Nicholas S. Kern
Wren A. Suess

M.A. DEGREES • FALL 2016

Dominic Ryan
Yunfan Zhang

SPRING 2017

Tom Zick

PH.D. DEGREES • FALL 2016

Francesca Maria Fornasini
Adviser: John Tomsick and Mariska T. Kriek
The faint, the poor, and the steady: studies of low-luminosity, metal-poor, and non-pulsating populations of high-mass X-ray binaries

SPRING 2017

Katherine Rebecca de Kleer
Adviser: Imke de Pater
Extreme Worlds of the Outer Solar System: Dynamic Processes on Uranus & Io

Nicholas Adam Hand
Adviser: Uros Seljak
Modeling galaxy clustering and redshift space distortion in Fourier space

Eve Jihyun Lee
Adviser: Eugene Chiang
The Late-Time Formation and Dynamical Signature of Small Planets

Sedona H. Price
Adviser: Mariska T. Kriek
Galaxies in the Young Universe: Structures, Masses, and Composition of Star-Forming Galxaies at z ~ 1.5-3

Isaac Steven Shivvers
Adviser: Alexei V. Filippenko
The Deaths of Massive Stars: Core Collapse Supernovae and Pre-Explosion Mass Loss

Dyas Utomo
Adviser: Leo Blitz
Molecular Clouds and Star Formation in Galaxies

RETIREMENTS – REINHARD GENZEL

Professor Reinhard Genzel retired this fall, after over two decades on campus as a faculty member at UC Berkeley. He was appointed to Astronomy in a joint appointment with his home department of Physics in fall 2011. A scholar of experimental astrophysics, infrared and submillimeter astronomy, Genzel's research contributed greatly to the understanding of the physical processes and the evolution of active galaxies; as well as to the development of novel instrumentation, including sensitive infrared spectrometers and imagers across the entire 1-1000mm band. He and his laboratory were the first to track the motions of stars at the center of the Milky Way and show that they were orbiting a very massive object, most likely a black hole.

He left campus in in 1986 to become Director of the Max Planck Institute for Extraterrestrial Physics, where he had been appointed an honorary Professor in 1988 at the Ludwig-Maximilian University. He returned to Berkeley in 1999.

Genzel is the recipient of many awards for his work, including Otto Hahn Medal of the Max-Planck Society Miller Fellowship, Shaw Prize of The Shaw Prize Foundation, Einstein Medal of the Albert-Einstein-Gesellschaft AEG, Newton Lacy Pierce Prize of the American Astronomical Society, Harvey Prize in the field of Science & Technology from the Israel Institute of Technology, and the Herschel Medal from the Royal Astronomical Society.

He continues to serve campus in his post-retirement appointment as professor of the graduate school.

IN MEMORIUM: HAROLD WEAVER

Harold Francis Weaver, a pioneer of radio astronomy who discovered the first microwave laser, or maser, in space, passed away peacefully in his Kensington, California, home on April 26 at the age of 99.

Weaver was a professor emeritus of astronomy, the founder of UC Berkeley's Radio Astronomy Laboratory and its director from 1958 until 1972 and a former chairman of the Department of Astronomy. He joined the UCB astronomy faculty in 1951.

Weaver founded the Radio Astronomy Laboratory in 1958. The lab dedicated its first telescopes in June 1962, in Hat Creek Valley in Northern California. Using the dish, Weaver and his colleagues discovered the first astrophysical maser – microwave amplification by stimulated emission or radiation, the radio equivalent of a laser – which had only been realized on Earth eight years earlier by the late UC Berkeley physicist and Nobel laureate Charles Townes. For decades, Weaver used the telescope to study other aspects of the interstellar medium and conducted large-scale surveys of interstellar hydrogen.

Among the many astronomers he mentored was Carl Sagan, whom he encouraged to explore his far-out ideas on the beginnings of life in the universe.

Weaver was born Sept. 25, 1917, in San Jose, where he lived with his parents above a spaghetti factory. After high school, as he was deciding whether to study astronomy or classics, Carmel poet Robinson Jeffers befriended him and encouraged his telescope building. Finally deciding to continue with astronomy, he went on to obtain his bachelor's degree in 1940 and his Ph.D. in 1942 in astronomy from UC Berkeley.

As an undergraduate taking a course in practical astronomy, he met his future wife, Cecile Trumpler, daughter of UC Berkeley astronomer Robert Trumpler. They married in 1939, before the elder Trumpler supervised Weaver's Ph.D. dissertation on peculiar stars, star clusters and stellar statistics.

Over Weaver's career, he published more than 70 professional papers. He retired in 1988, but remained very much involved in the department until nearly the end of his life.

"Harold was truly a giant in our Department of Astronomy," said colleague Alex Filippenko. "I will always remember his warm smile, his generosity and how he kept going with his research and other activities well into old age."

He is survived by his wife, Cecile, three children – Margot of Tucson, Arizona, Paul of Kensington and Kirk of Houston, Texas – six grandchildren and 11 great-grandchildren. He and his wife donated their home in Kensington to the university to be used after their deaths to fund the Trumpler-Weaver Endowed Professorship of Astronomy at UC Berkeley.

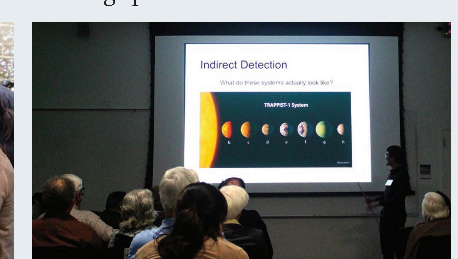
Evening with the Stars

The department hosted its annual Evening with the Stars event on March 23rd, featuring an engaging talk by Professor James Graham, Department Chair Eugene Chiang, and graduate students Jason Wang and Eve Lee.

The evening began with conversation and hors d'oeuvres as guests mingled with Astronomy department faculty members. Following the reception, Drs. Graham and Chiang, with Mr. Wang and Ms. Lee, described their efforts to detect, characterize, and understand the origins of extrasolar planets using specialized infrared instrumentation, large telescopes and adaptive optics. Their lively talk included demonstrations of the technologies underlying the direct imaging of planets.

After the lecture, guests enjoyed an extended opportunity to discuss the talk with the speakers and were treated to a tour of the Campbell Hall rooftop telescope and guided star gazing by graduate students Carina Cheng and Lea Hirsch.

Professor Aaron Parsons talks with guests of EWTS.



Grad student Jason Wang presents his research during the 2017 EWTS lecture.

**UNIVERSITY OF CALIFORNIA AT BERKELEY
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UPCOMING EVENTS

Evening with the Stars Spring 2018

Cal Day April 21, 2018

Commencement May 15, 2018

2017 Raymond and Beverly Sackler Distinguished Lecture in Astronomy Fall 2018

Astronomy Faculty Roundtable Fall 2018

Astro Night Public Lecture and Star Viewing April 2018; first Thursday of each month

Science @ Cal Monthly Lectures
3rd Saturday of each month
UC Berkeley location changes each month
Visit http://scienceatcal.berkeley.edu

Newsletter Credits: *Marissa Dominguez, Lochland Trotter, Robert Sanders, Eugene Chiang.*
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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!