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Astronomy in the News

ASTRONOMERS MAY HAVE DETECTED A 'DARK' FREE-FLOATING BLACK HOLE

By Robert Sanders, June 10, 2022

If, as astronomers believe, the death of large stars leave behind black holes, there should be hundreds of millions of them scattered throughout the Milky Way galaxy. The problem is, isolated black holes are invisible.

Now, a team led by University of California, Berkeley, astronomers has for the first time discovered what may be a free-floating black hole by observing the brightening of a more distant star as its light was distorted by the object's strong gravitational field — so-called gravitational microlensing.

The team, led by graduate student Casey Lam and Jessica Lu, a UC Berkeley associate professor of astronomy, estimates that the mass of the invisible compact object is between 1.6 and 4.4 times that of the sun. Because astronomers think that the leftover remnant of a dead star must be heavier than 2.2 solar masses in order to collapse to a black hole, the UC Berkeley researchers caution that the object could be a neutron star instead of a black hole. Neutron stars are also dense, highly compact objects, but their gravity is balanced by internal neutron pressure, which prevents further collapse to a black hole.

Whether a black hole or a neutron star, the object is the first dark stellar remnant — a stellar "ghost" — discovered wandering through the galaxy unpaired with another star.

"This is the first free-floating black hole or neutron star discovered with gravitational microlensing," Lu said. "With microlensing, we're able to probe these lonely, compact objects and weigh them. I think we have opened a new window onto these dark objects, which can't be seen any other way."

Determining how many of these compact objects populate the Milky Way galaxy will help astronomers understand the evolution of stars — in particular, how they die — and of our galaxy, and perhaps reveal whether any of the unseen black holes are primordial black holes, which some cosmologists think were produced in large quantities during the Big Bang.

The analysis by Lam, Lu and their international team has been accepted for publication in *The Astrophysical Journal Letters.* The analysis includes four other microlensing events that the team concluded were not caused by a black hole, though two were likely caused by a white dwarf or a neutron star. The team also concluded that the likely population of black holes in the galaxy is 200 million — about what most theorists predicted.

SAME DATA, DIFFERENT CONCLUSIONS

Notably, a competing team from the Space Science Institute (STScI) in Baltimore analyzed the same microlensing event and claims that the mass of the compact object is closer to 7.1 solar masses and indisputably a black hole. A paper describing the analysis by the STScI team, led by Kailash Sahu, has been accepted for publication in The Astrophysical Journal.

Continued on page 2

Astronomers may have discovered the first free-floating black hole in the Milky Way galaxy, thanks to a technique called gravitational microlensing. With new observations, they hope to find many more such ghost stars. This image was captured from a video by Roxanne Makasdjian and Alan Toth, microlensing animations from Casey Lam and Sean Terry, UC Berkeley's Moving Universe Lab, and image data courtesy of the OGLE collaboration. Additional images courtesy of the National Science Foundation and NASA. You can watch the video by navigating to: astro.berkeley.edu/astronomers-may-have-detected-a-dark-free-floating-black-hole/

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Both teams used the same data: photometric measurements of the distant star's brightening as its light was distorted or "lensed" by the super-compact object, and astrometric measurements of the shifting of the distant star's location in the sky as a result of the gravitational distortion by the lensing object. The photometric data came from two microlensing surveys: the Optical Gravitational Lensing Experiment (OGLE), which employs a 1.3-meter telescope in Chile operated by Warsaw University, and the Microlensing Observations in Astrophysics (MOA) experiment, which is mounted on a 1.8-meter telescope in New Zealand operated by Osaka University. The astrometric data came from NASA's Hubble Space Telescope. STScI manages the science program for the telescope and conducts its science operations.

Because both microlensing surveys caught the same object, it has two names: MOA-2011-BLG-191 and OGLE-2011-BLG-0462, or OB110462, for short.

While surveys like these discover about 2,000 stars brightened by microlensing each year in the Milky Way galaxy, the addition of astrometric data is what allowed the two teams to determine the mass of the compact object and its distance from Earth. The UC Berkeley-led team estimated that it lies between 2,280 and 6,260 light years (700-1920 parsecs) away, in the direction of the center of the Milky Way Galaxy and near the large bulge that surrounds the galaxy's central massive black hole.

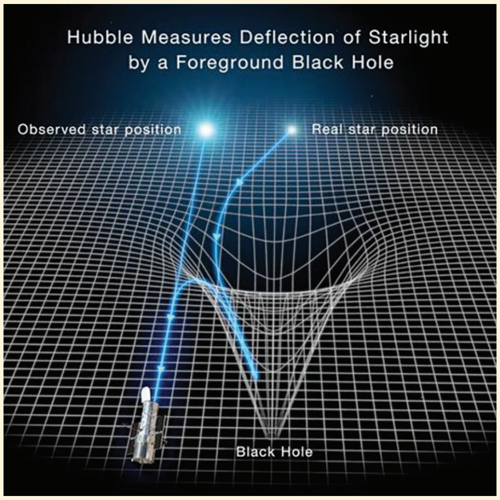
The STScI group estimated that it lies about 5,153 light years (1,580 parsecs) away.

LOOKING FOR A NEEDLE IN A HAYSTACK

Lu and Lam first became interested in the object in 2020 after the STScI team tentatively concluded that five microlensing events observed by Hubble — all of which lasted for more than 100 days, and thus could have been black holes — might not be caused by compact objects after all.

Lu, who has been looking for free-floating black holes since 2008, thought the data would help her better estimate their abundance in the galaxy, which has been roughly estimated at between 10 million and 1 billion. To date, star-sized black holes have been found only as part of binary star systems. Black holes in binaries are seen either in X-rays, produced when material from the star falls onto the black hole, or by recent gravitational wave detectors, which are sensitive to mergers of two or more black holes. But these events are rare.

"Casey and I saw the data and we got really interested. We said, 'Wow, no black holes. That's amazing,' even though there should have been," Lu said. "And so, we started looking at the data. If there were really no black holes in the data, then this wouldn't match our model for how many black holes there should be in the Milky Way. Something would have to change in our understanding of black holes — either their number or how fast they move or their masses."



This illustration shows how the gravity of a black hole warps spacetime and bends the light of a distant star so that its position is shifted as seen from Earth. This deflection, captured by the Hubble Space Telescope (left foreground), and the associated brightening of the star allow astronomers to discover these otherwise invisible, free-floating objects and calculate their mass and velocity. (Illustration credit: NASA, ESA, STScI, Joseph Olmsted)

When Lam analyzed the photometry and astrometry for the five microlensing events, she was surprised that one, OB110462, had the characteristics of a compact object: The lensing object seemed dark, and thus not a star; the stellar brightening lasted a long time, nearly 300 days; and the distortion of the background star's position also was long-lasting.

The length of the lensing event was the main tipoff, Lam said. In 2020, she showed that the best way to search for black hole microlenses was to look for very long events. Only 1% of detectable microlensing events are likely to be from black holes, she said, so looking at all events would be like searching for a needle in a haystack. But, Lam calculated, about 40% of microlensing events that last more than 120 days are likely to be black holes.

"How long the brightening event lasts is a hint of how massive the foreground lens bending the light of the background star is," Lam said. "Long events are more likely due to black holes. It's not a guarantee, though, because the duration of the brightening episode not only depends on how massive the foreground lens is, but also on how fast the foreground lens and background star are moving relative to each other. However, by also getting measurements of the apparent position of the background star, we can confirm whether the foreground lens really is a black hole."

According to Lu, the gravitational influence of OB110462 on the light of the background star was amazingly long. It took about one year for the star to brighten to its peak in 2011, then about a year to dim back to normal.

Read the rest of the article here: https://news.berkeley.edu/2022/06/10/astronomers-may-have-detected-a-dark-free-floating-black-hole/

THE ULTIMATE FATE OF A STAR SHREDDED BY A BLACK HOLE

By Robert Sanders, July 11, 2022

In 2019, astronomers observed the nearest example to date of a star that was shredded, or "spaghettified," after approaching too close to a massive black hole.

That tidal disruption of a sun-like star by a black hole 1 million times more massive than itself took place 215 million light years from Earth. Luckily, this was the first such event bright enough that astronomers from the University of California, Berkeley, could study the optical light from the stellar death, specifically the light's polarization, to learn more about what happened after the star was torn apart.

Their observations on Oct. 8, 2019, suggest that a lot of the star's material was blown away at high speed — up to 10,000 kilometers per second — and formed a spherical cloud of gas that blocked most of the high-energy emissions produced as the black hole gobbled up the remainder of the star.

Earlier, other observations of optical light from the blast, called AT2019qiz, revealed that much of the star's matter was launched outward in a powerful wind. But the new data on the light's polarization, which was essentially zero at visible or optical wavelengths when the event was at its brightest, tells astronomers that the cloud was likely spherically symmetric.

"This is the first time anyone has deduced the shape of the gas cloud around a tidally spaghettified star," said **Alex Filippenko**, UC Berkeley professor of astronomy and a member of the research team.

The results support one answer to why astronomers don't see high-energy radiation, such as X-rays, from many of the dozens of

If a star (red trail) wanders too close to a black hole (left), it can be shredded, or spaghettified, by the intense gravity. Some of the star's matter swirls around the black hole, like water down a drain, emitting copious X-rays (blue). Recent studies of these so-called tidal disruption events suggest that a significant fraction of the star's gas is also blown outward by intense winds from the black hole, in some cases creating a cloud that obscures the accretion disk and the high-energy events happening within. (Image credit: NASA/CXC/M. Weiss) tidal disruption events observed to date: The X-rays, which are produced by material ripped from the star and dragged into an accretion disk around the black hole before falling inward, are obscured from view by the gas blown outward by powerful winds from the black hole.

"This observation rules out a class of solutions that have been proposed theoretically and gives us a stronger constraint on what happens to gas around a black hole," said UC Berkeley graduate student **Kishore Patra**, lead author of the study. "People have been seeing other evidence of wind coming out of these events, and I think this polarization study definitely makes that evidence stronger, in the sense that you wouldn't get a spherical geometry without having a sufficient amount of wind. The interesting fact here is that a significant fraction of the material in the star that is spiraling inward doesn't eventually fall into the black hole — it's blown away from the black hole."

POLARIZATION REVEALS SYMMETRY

Many theorists have hypothesized that the stellar debris forms an eccentric, asymmetric disk after disruption, but an eccentric disk is expected to show a relatively high degree of polarization, which would mean that perhaps several percent of the total light is polarized. This was not observed for this tidal disruption event.

"One of the craziest things a supermassive black hole can do is to shred a star by its enormous tidal forces," said team member Wenbin Lu, UC Berkeley assistant professor of astronomy. "These stellar tidal disruption events are one of very few ways astronomers know the existence of supermassive black holes at the centers of galaxies and measure their properties. However, due to the extreme computational cost in numerically simulating such events, astronomers still do not understand the complicated processes after a tidal disruption."

A second set of observations on Nov. 6, 29 days after the October observation, revealed that the light was very slightly polarized, about 1%, suggesting that the cloud had thinned enough to reveal the asymmetric gas structure around the black hole. Both observations came from the 3-meter Shane telescope at Lick Observatory near San Jose, California, that is fitted with the Kast spectrograph, an instrument that can determine the polarization of light over the full optical spectrum. The light becomes polarized — its electrical field vibrates primarily in one direction — when it scatters off electrons in the gas cloud.

"The accretion disk itself is hot enough to emit most of its light in X-rays, but that light has to come through this cloud, and there are many scatterings, absorptions and reemissions of light before it can escape out of this cloud," Patra said. "With each of these processes, the light loses some of its photon energy, going all the way down to ultraviolet and optical energies. The final scatter then determines the polarization state of the photon. So, by measuring polarization, we can deduce the geometry of the surface where the final scatter happens."

Patra noted that this deathbed scenario may apply only to normal tidal disruptions — not "oddballs," in which relativistic jets of material are expelled out the poles of the black hole. Only more measurements of the polarization of light from these events will answer that question.

"Polarization studies are very challenging, and very few people are well-versed enough in the technique around the world to utilize this," he said. "So, this is uncharted territory for tidal disruption events."

Patra, Filippenko, Lu and UC Berkeley researcher Thomas Brink, graduate student Sergiy Vasylyev and postdoctoral fellow Yi Yang reported their observations in a paper that has been accepted for publication in the journal Monthly Notices of the Royal Astronomical Society.

Read the rest of this article here: https://news.berkeley.edu/2022/07/11/the-ultimate-fate-of-a-star-shredded-by-a-black-hole/

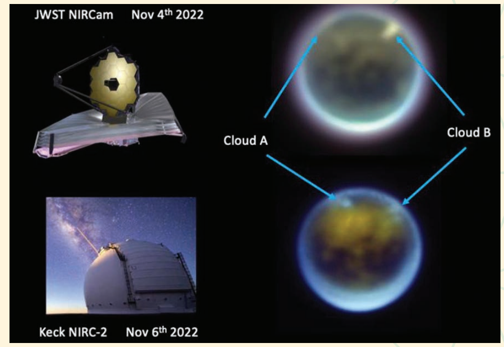
Profs. Wenbin Lu and Joshua Bloom also co-authored a well-publicized work on a remarkable tidal disruption event ("A very luminous jet from the disruption of a star by a massive black hole"; Andreoni et al., Nature, 612, 430 2022). Very much like the TDE J1644+57 studied by Bloom et al. in 2011, the event dubbed AT2022cmc appears to be explained by a relativistic jet launched during the black hole mass feeding process.

WEBB SPACE TELESCOPE, KECK TEAM UP TO STUDY SATURN'S MOON TITAN

By Robert Sanders, December 1, 2022

The James Webb Space Telescope (JWST) has turned its infrared cameras on Saturn's moon Titan, giving astronomers another eye on the largest and one of the most unusual moons in the solar system.

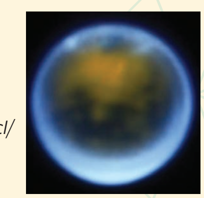
The only satellite with a dense atmosphere, it's also the only world besides Earth that has standing bodies of liquid on its surface, including rivers, lakes and seas — though the liquid is thought to be methane, ethane and other hydrocarbons that are toxic to humans.



Evolution of clouds on Titan over 30 hours between Nov. 4 and Nov. 6, as seen by near-infrared cameras on the James Webb Space Telescope (top) and Keck Telescope. Titan's trailing hemisphere seen here is rotating from left (dawn) to right (evening) as seen from Earth and the sun. Cloud A appears to be rotating into view, while Cloud B appears to be either dissipating, or moving behind Titan's limb. Clouds are not long-lasting on Titan or Earth, so those seen on Nov. 4 may not be the same as those seen on Nov. 6. (Image credit: NASA/STScI/Keck Observatory/Judy Schmidt)

The new observations, combined with those from Earth-bound telescopes, will help astronomers understand the weather patterns on Titan in advance of a NASA mission to the moon, called Dragonfly, that is scheduled for launch in 2027. A multirotor lander, Dragonfly will assess the habitability of Titan's unique environment, investigate the moon's unusual chemical stew, and search for signatures of water-based or hydrocarbon-based life.

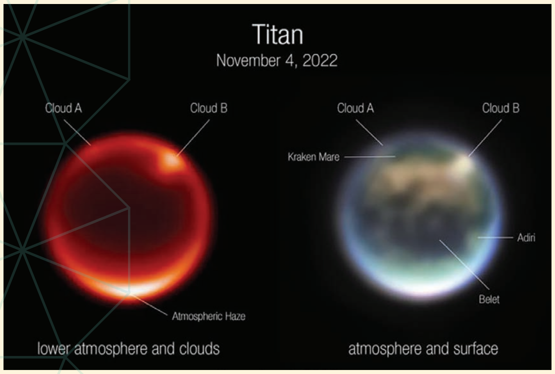
Astronomers have observed Titan for decades, since before the Voyager encounter in 1980. Over approximately the past 25 years, they focused powerful ground-based and orbital telescopes on the satellite, complementing observations by NASA's Cassini mission to Saturn, which observed Titan between 2004 and 2017. University of California, Berkeley, astronomer Imke de Pater led many Titan observations using high-resolution adaptive optics on the Keck Telescopes in Hawai'i.



A Keck telescope image of Titan taken on Nov. 7, 2022, showing bright clouds in the Northern Hemisphere at 11 o'clock and 1 o'clock. (Image credit: NASA/STScI/Keck Observatory/Judy Schmidt)

After the JWST imaged Titan on Nov. 4, the telescope's Titan team saw what looked like two clouds in the atmosphere. Titan team lead Conor Nixon quickly emailed de Pater and Katherine de Kleer — a UC Berkeley Ph.D. who is now an assistant professor of planetary science and astronomy at the California Institute of Technology — to help confirm the clouds and track their movement with the Keck Telescope.

A series of Keck images taken about 30 and 54 hours later showed similar clouds — likely the



Saturn's moon Titan captured by the James Webb Space Telescope's NIRCam instrument on Nov. 4, 2022. The left image, taken through a 2.12-micron filter, shows clouds and lower atmospheric haze. The right image is a color composite using four filters. Kraken Mare is thought to be a methane sea; Belet is composed of dark-colored sand dunes; Adiri is a bright feature. (Image credit: NASA, ESA, CSA, A. Pagan [STScI]. Science: JWST Titan GTO Team)

same ones — but slightly displaced because of the moon's rotation relative to Earth.

"We were concerned that the clouds would be gone when we looked at Titan one and two days later with Keck, but to our delight there were clouds at the same positions, looking like they might have changed in shape," said de Pater, a UC Berkeley Professor of the Graduate School.

THE POWER OF JWST

Though the quality of the JWST and Keck images may look about the same to the untrained eye, de Pater noted that JWST has instruments that can measure aspects of Titan's atmosphere that Keck cannot, complementing one another. In particular, JWST's infrared spectroscopic capability allows it to pinpoint the altitudes of clouds and hazes with much better accuracy.

"By using spectrometers on JWST together with the optical image quality with Keck, we get a really complete picture of Titan," she said, such as the heights of clouds, the atmosphere's optical thickness, and the elevation of haze in the atmosphere.

In particular, at wavelengths where Earth's atmosphere is opaque — that is, Titan cannot be seen from any Earth-based telescope — JWST can observe and provide information on the lower atmosphere and surface.

Read the rest of this article at: https://news.berkeley.edu/2022/12/01/webb-space-telescope-keck-team-up-to-study-saturns-moon-titan/

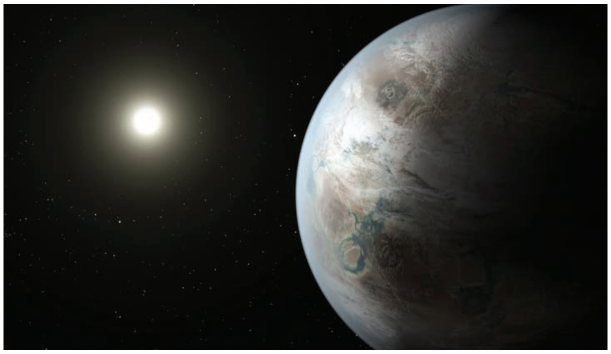
Keen to learn more? You can read "Berkeley astronomers to put new space telescope through its paces" and many other articles about research in our department on our website at astro.berkeley.edu/news

AI reveals unsuspected math underlying search for exoplanets

By Robert Sanders, May 24, 2022

Artificial intelligence (AI) algorithms trained on real astronomical observations now outperform astronomers in sifting through massive amounts of data to find new exploding stars, identify new types of galaxies and detect the mergers of massive stars, accelerating the rate of new discovery in the world's oldest science.

But AI, also called machine learning, can reveal something deeper, University of California, Berkeley, astronomers found: unsuspected connections hidden in the complex mathematics arising from general relativity — in particular, how that theory is applied to finding new planets around other stars.



Artist's concept of a sun-like star (left) and a rocky planet about 60% larger than Earth in orbit in the star's habitable zone. Gravitational microlensing has the ability to detect such planetary systems and determine the masses and orbital distances, even though the planet itself is too dim to be seen. (Image credit: NASA Ames/JPL-Caltech/T. Pyle)

In a paper appearing in the journal Nature Astronomy, Joshua Bloom and his graduate student Keming Zhang describe how an AI algorithm developed to more quickly detect exoplanets when such planetary systems pass in front of a background star and briefly brighten it — a process called gravitational microlensing — revealed that the decades-old theories now used to explain these observations are woefully incomplete.

Read the full article here: https://news.berkeley.edu/2022/05/24/ai-reveals-unsuspected-math-underlying-search-for-exoplanets

News and Noteworthy

Prof. **Alex Filippenko** was awarded the American Astronomical Society's 2022 Education Prize.

Brianna Franklin, Undergraduate Advisor, received the Team Advising Innovation Award alongside her counterparts in Physics, for the new Discovery program (led by Prof. **Eugene Chiang**).

Prof. **Chung-Pei Ma**, the Judy Chandler Webb Professor in Physical Sciences, was elected to the National Academy of Sciences. Prof. Ma was also joined by Emeritus Prof. **Imke de Pater** and Adjunct Prof. **Richard Klein** in being named as a Fellow of the American Astronomical Society.

Prof. **Raffaella Margutti** was named as Finalist of the 2022 Blavatnik National Awards for Young Scientists.

In December 2021, Graduate student **Sarafina Nance** was selected as Forbes "30 Under 30" in Science.

To stay up to date with Astronomy news, check our website at: astro.berkeley.edu/news

Alex Filippenko, professor of astronomy, UC Berkeley (courtesy of Steve McConnell)

Message from the Chair

While remaining ever vigilant on the health front, we thankfully returned in 2022 to the semblance of pre-pandemic department life: in-person classes, in-person seminars, and (perhaps most important) in-person causal interactions. It has been wonderful to see so many students, postdocs, faculty and staff working together towards our common mission of scientific excellence, teaching, and mentorship. Herein you'll read about some of the great scientific results of the hard work of our members.

It was wonderful to take part in the first in-person graduation ceremony in many years in May 2022 (Prof. **Fiona Harrison** from Caltech was our distinguished speaker), where we graduated an astounding 48 undergraduates: indeed in the latest survey of astronomy programs by the American Physical Society, Berkeley Astronomy had the second largest number of graduating bachelors in the country. Our major continues to grow. This may partly be a reaction to amazing very public news of the successful launch of JWST late last year but I would like to think it is also due to the reputation of our faculty and courses as providing a challenging but foundational educational experience. Regardless, the growth of the major will be supported by the new MPS Scholars program as well as the new Physics and Astronomy DiscoveryProgram.

Just as new students and postdoctoral scholars arrived (and departed), the department also saw changes in the personnel. After decades of service to our department **Frank Latora** retired and we were very thankful to hire the very excellent **Dirk Wright** into a similar role. Dirk is working as the technical lead in the undergraduate laboratories and Leuschner observatory. We also welcomed Associate MPS Dean **Collette Patt**'s Diversity team to Campbell Hall, which serves as the headquarters for the new MPS Scholars Program. Prof. **Eliot Quataert**, former chair, officially stepped down from his position at Berkeley as he took up a permanent position at Princeton–we were all sad to see him leave but are happy to learn that he plans to visit the department periodically. Starting in January 2023, Dr. **Luke Zoltan Kelly** will join our department as a new adjunct professor. Prof. Kelley is a theorist, working at the interface of compact objects, time-domain transients, and galaxy evolution. His primary focus is multi-messenger astrophysics with low-frequency gravitational waves (GWs) produced by supermassive black-hole binaries. As we were going to press we learned of the passing of Emeritus Professor **Leo Blitz**. Leo joined our faculty in 1996 and served as the director of the Radio Astronomy Laboratory for a decade. He will be missed.

New plaudits and accolades of our members continued in 2022 of course. Prof. **Alex Filippenko** was awarded the American Astronomical Society's 2022 Education Prize–it is hard to go anywhere in this world without running into someone who took (and loved) Alex's C10 class! **Brianna Franklin**, Undergraduate Advisor, received the Team Advising Innovation Award alongside her counterparts in Physics, for the new Discovery program (led by Prof. **Eugene Chiang**). Prof. **Chung-Pei Ma**, the Judy Chandler Webb Professor in Physical Sciences, was elected to the National Academy of Sciences. Prof. Ma was also joined by Emeritus Prof. **Imke de Pater** and Adjunct Prof. **Richard Klein** in being named as a Fellow of the American Astronomical Society. Prof. **Raffaella Margutti** was named as Finalist of the 2022 Blavatnik National Awards for Young Scientists. In December 2021, Graduate student **Sarafina Nance** was selected as Forbes "30 Under 30" in Science.

The rising cost of living in the Bay Area continues to be a real strain to our members. Many of the graduate students, postdoctoral scholars, and research staff (across the entire UC) went on strike for six weeks, following months of stalled contract negotiations. Now that the UC and the represented workers have settled on a contract, we all hope to return together and foster a vibrant research and teaching community in our Department. I am extremely hopeful for 2023 on many fronts.

Let me close by thanking all of you for your continued interest in and support of the work we do in Berkeley Astronomy. It has been a great honor for me to have served as Chair of this department for the past 2+ years. I wish you all the best for the new year.

Josh Bloom, Chair

New Faculty Highlight: Wenbin Lu

Questions by Andrea Antoni

1. What draws you to transient and high-energy astrophysics?

"The rapid development of observing facilities in this field. Progress in astronomy largely depends on innovations in observations."

2. When/why did you decide to pursue astrophysics? Did you consider other fields?

"When I was an undergraduate student, I considered lab physics and chemistry. I went to hear some colloquium talks in the astronomy department of my undergraduate university and got attracted by the large number of open questions in astronomy, especially new ones provided by recent observations in the past few years. I feel that these open questions provide more opportunities for young people to make some progress."

3. What do you enjoy most about doing astrophysics?

"Making predictions and seeing how they are either falsified or verified."

4. What skill/practice are you hoping to improve the most this year in your job?

"Teaching. Finding ways to educate students efficiently!"

5. What has been your biggest failure and what did you learn from it?

"During graduate school, I put way too much time in a research field that did not have many new, exciting opportunities. If given another chance, I would have abandoned that research field early on and switched to other fields that have more opportunities. The lesson is to keep an eye on developing research fields."

6. Who was your biggest role model when you were growing up and what did you admire about them?

"Albert Einstein. The deep thinking and creative thought experiments."

7. What are your favorite activities to do during your free time?

"Hiking and rock climbing."

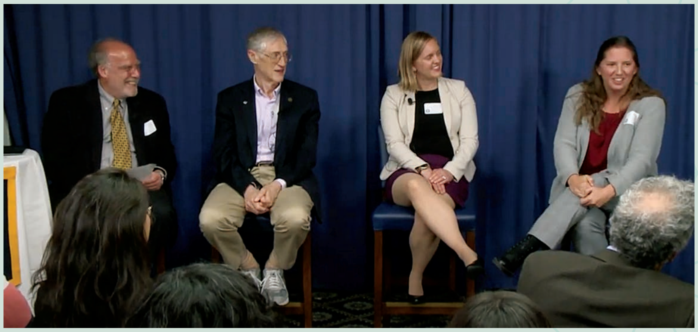
Research Fellows and Postdocs

Dr. Boryana Hadzhiyska is a postdoctoral fellow with the Miller Institute and Berkeley Lab. Their research blends the distinct fields of cosmology, galaxy formation, particle physics, and statistics to reveal the answers to some of the most puzzling enigmas of our Universe: dark matter, dark energy, and neutrinos. In particular, Dr. Hadzhiyska compares predictions from powerful numerical simulations with observations from cutting-edge galaxy experiments, jointly analyze early Universe probes (e.g., cosmic microwave background) and galaxy observations, and develop analytical approaches, in an effort to provide competitive constraints on galaxy formation and cosmology. Building healthy relationships with our peers and the wider community is integral to science, and Boryana devotes many efforts to community service, mentoring, and outreach.

Dr. Damya Souami is a Fulbright Fellow. She arrived at UC Berkeley in November and will be staying until the end of June. She has just been selected for a CNRS researcher position in LESIA, Observatoire de Paris and is a member of the Gaia DPAC (Data Processing and Analysis Consortium) and the DART Investigation team. Damya tackles both dynamical and observational aspects of planetary sciences and specializes in the use of stellar occultations to physically characterize solar system objects. Dr. Souami has led successful occultation campaigns by the (sub-km sized) near-Earth asteroids Apophis and Didymos, thus marking the beginning of a new era in the study of these populations and in the use of this observational method. In 2021, she organized and led the largest ground observational campaign of the Neptune system combining both a rare occultation event by Neptune as well as Adaptive Optics imaging of the planet and its rings. This is the first large scale observational campaign since Voyager-2 in 1989 to study both Neptune's rings and arcs as well as the upper atmosphere of the planet.

Dr. Sean Terry is a postdoctoral scholar working on the Keck All-sky Precision Adaptive Optics (KAPA) project, which is a major upgrade to the Keck-1 telescope. KAPA will deliver significantly increased image quality and sky coverage through the addition of multiple laser guide stars (four), a faster real-time controller computer, and infrared tip-tilt sensing. He also studies gravitational microlensing targets through high resolution imaging with Keck and Hubble Space Telescope (HST). Some of these targets may be rare isolated black holes (BHs), and high resolution imaging is a powerful tool to measure the small astrometric deflection of the background star due to the massive lens object (e.g., BHs). Dr. Terry is currently monitoring a promising microlensing BH candidate. This candidate has one of the longest microlensing timescales ever observed and could be an isolated BH with a mass 10 times that of the Sun. There is also evidence of binarity; meaning the lens system could be two non-interacting BHs or a BH and non-interacting star/white dwarf. If the binary lens interpretation is correct, this system would have very important implications for 'pre-merger' gravitational wave sources in the LIGO/VIRGO era.

Dr. J. J. Zanazzi is a 51 Pegasi b fellow, who just arrived at UC Berkeley in the Fall of 2022. His research lies at the intersection of orbital and fluid mechanics, and seeks to understand the extraordinary diversity of exoplanetary system architectures we observe. Currently, he is examining how transition disks (protoplanetary disks with "holes") can mold the orbits of forming exoplanets, and how eccentric disks shepard dust which later form planets. He is also examining how massive planets gravitationally tug their host star, causing them to flicker like a faulty light bulb.



James Webb Space Telescope Event in Washington D.C.

A number of faculty held a lively forum in October 2022 at the National Press Club, in Washington, D.C. just as new results from JWST were being released. Profs. Jessica Lu and Courtney Dressing — along with JWST Project Scientist, Berkeley Alum and Nobel Laureate John Mather — discussed the history of the project and importance of JWST for UC Berkeley science. Professor and Mathematical and Physical Sciences Dean Steven Kahn moderated the forum, which was introduced by Chair Bloom. Watch this lively conversation offered by the MPS Development Office here: www.youtube.com/watch?v=2ng7bcOzuas

2021-2022 Commencement Information

The Department of Astronomy held its first in-person commencement since Spring 2019. The Astronomy Spring 2022 Commencement honored the class of 2022 and invited back graduates from Fall 2019-Spring 2021 to celebrate their accomplishments.

DEGREES CONFERRED 2022:
48 Astrophysics BAs
5 Astrophysics MAs
2 Astrophysics PhDs

PRIZES & AWARDS:

Department Citation
Yilun Ma

Dorothea Klumpke Roberts Prize
Kush Maheshwari

Mary Elizabeth Uhl Prize
Philipp Kempski

Daniel Edward Wark Award
Fira Fatmasiefa
Angela Cheng

Robert J. Trumpler Award
Nathan Sandford

Outstanding Graduate Student Instructor Awards
Maude Gull
Caleb Harada

Welcome to our Newest Group of Graduate Students!

Emiko Gardiner (*Engineering Science + Physics, University of Virginia*) is wrapping up research in massive star formation, specifically modeling ionization in massive protostellar outflow simulations, with their undergraduate research advisors Prof. Jonathan Tan and Prof. Jan Staff. Next semester, they begin work with Adjunct Prof. Luke Kelley on predicting anisotropy in the gravitational wave background (GWB). They expect these predictions to be pertinent to highly anticipated GWB and continuous wave observations in the near future!

Natalie LeBaron (*Physics, University of California Santa Barbara*) worked under Prof. Philip Lubin in classical and machine learning based pipelines for large scale time domain astronomy. She is now currently joint advised by Prof. Joshua Bloom and Prof. Raffaela Margutti working on multimessenger transient astronomy observation and classification. She is a Berkeley fellow and BAIR Scholar.

Anna Pusack's (*Astronomy + Astrophysics, University of Colorado Boulder; Philosophy + East Asian Studies, Dickinson College*) previous research was on the near-Sun dust environment via dust impacts on Parker Solar Probe with David Malaspina as well as researchers at SSL (including Stuart Bale and Marc Pulupa). Anna is currently working with Jessica Lu in the Moving Universe Lab (MULab) looking at young nuclear star clusters in the center of the Milky Way using James Webb data.

Eli Wiston (*Physics, University of Pennsylvania*) is interested in observational time-domain astronomy, in particular understanding high energy transient phenomena. He is planning to work with Prof. Raffaella Margutti on the radio side of her group's multimessenger approach to these transients. Outside of research, Eli is passionate about teaching and public outreach, helping with Astro Movie Night, volunteering with Be a Scientist, and planning to work to improve astronomy's accessibility by sonifying astrophysical data.

Getting to Know Astronomy

Q&A with graduating senior James Sunseri

1. What is your research focus at Cal? Will this be your focus going into graduate school?

"My research is primarily focused on numerical astrophysics. I love developing software packages and algorithms to analyze numerical simulations that help us better understand the universe. My current work is focused on using large-scale cosmological magnetohydrodynamical simulations to better understand the impacts of baryonic feedback on the Cosmic Web. I also work with simulations of the interstellar medium to better understand turbulence and magnetic fields. I plan to continue working on theory-based numerical work in graduate school with a focus in cosmology, general relativity, and magnetohydrodynamics."

2. What has been the most rewarding thing you have done as an undergrad in the Department of Astronomy?

"The most rewarding thing I have done in my time at UC Berkeley has been sharing my knowledge with others through teaching. As a first-generation student, I feel a moral obligation to share my hard-earned knowledge with others. I am incredibly proud of all the students I have mentored and taught over the years through the Python DeCal, Astro C10, and ULAB. When I started teaching the Python DeCal, we had less than 10 students and now the class is self-sustaining and a staple of the Astronomy curriculum."

3. What advice would you give future Astrophysics majors?

"I would like to tell future Astronomy majors that it is okay to take a random-walk on your path to success. It is hard not to compare ourselves to others, but I urge you not to; people come from wildly different backgrounds so making a direct comparison is impossible. What I find matters most is pursuing what you love. If you don't know what that is yet, keep exploring! I was most fulfilled at Berkeley when I was digging down rabbit holes that I found interesting, not because they were easy to do or because someone told me to, but because I thought it was fascinating."

Free Astronomical Instrumentation Summer School: AstroTech

This past summer, 30 undergraduate and graduate students participated in a week of hands-on optics lab experience as part of the Astro Tech summer school. A team of instructors, including UC Berkeley professor Jessica Lu, helped students explore how to build instruments used to observe the Universe.

Students worked with optics, mechanical structures, detectors, calibration hardware, electronics, and software. AstroTech also focuses on making the instrumentation builders community more inclusive and supportive of those from groups currently underrepresented in the field. AstroTech is funded by the Heising-Simons Foundation and the National Science Foundation and is co-led by UC Berkeley and the Institute for Scientist and Engineering Educators. AstroTech 2023 takes place July 17–21. The application deadline is February 16, 2023.

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Supporting Astronomy

Friends of Astronomy Fund directly supports all facets of the department's operations from research to instruction, recruitment of top faculty and staff, to the day-to-day technology and supply needs in the classrooms and teaching labs.

The Astronomy Equity and Inclusion Programs and Initiatives Fund supports efforts such as expanding undergraduate research and professional development opportunities for underrepresented students, expansion of our student orientation programs and colloquia, demystifying the career paths of astronomers. With your support, we can broaden opportunities for underrepresented students, improve representation among faculty, and postdocs, and expand mentoring to all students as they progress towards degree completion.

Graduate Student Support Fund assists efforts to cover the necessary resources for graduate students. Funding fellowships is a top priority in the department, as a full year fellowship can cost more than $40,000 and will only continue to increase. Offering student support is one of our best tools for attracting the brightest and most promising students.

Student Observatory Fund assists with the 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.

Gifts to any of these funds can be directed to:
astro.berkeley.edu/astronomy-fans/make-a-gift

New Giving Opportunity

Join us in making an impact!

Many employers will match your gifts to UC Berkeley. To discuss matching or other opportunities to support Astronomy at Berkeley, contact Ryan Guasco, Associate Development Director (rguasco@berkeley.edu, or via phone at 510-599-8698)

Thank you for your supporting the future of Berkeley Astronomy!

GO BEARS!