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Astronomy in the News

STELLAR EXPLOSION IN 1054 C.E. MAY HAVE BEEN A THIRD FLAVOR OF SUPERNOVA

By Robert Sanders, Media relations, June, 2021

Astronomers have found convincing evidence that supernovae come in a third flavor, powered by a long-suspected explosive mechanism that may explain a bright supernova humans observed 1,000 ago and that birthed the beautiful Crab Nebula.

The evidence is an exploding star observed in 2018, the first that fits all six criteria for a hypothesized type of supernova called an electron-capture supernova.

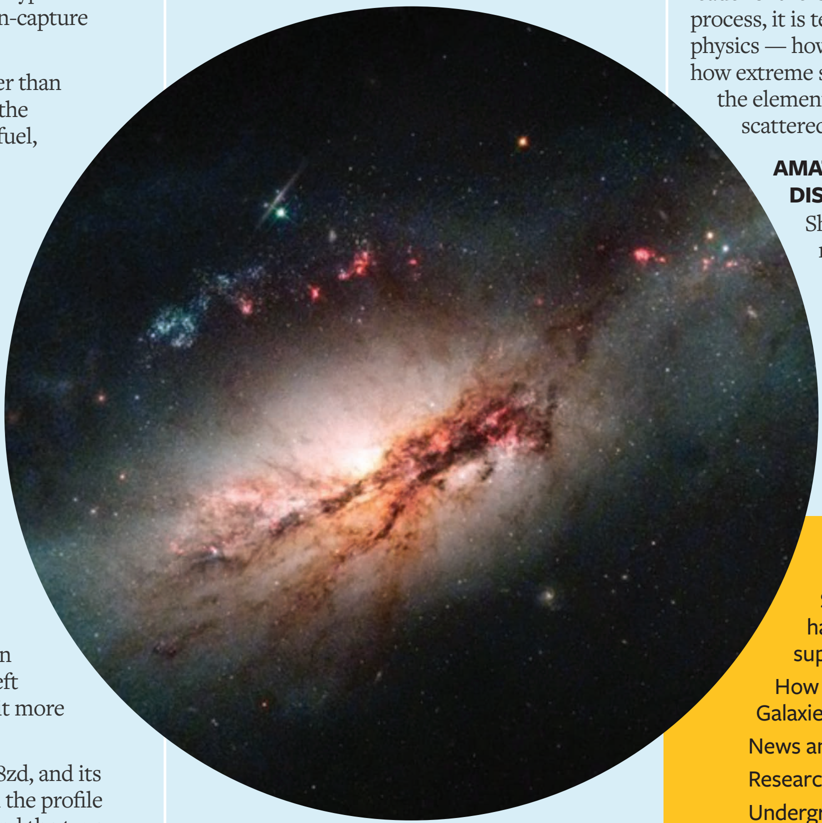
Large stars — red supergiants bigger than about 10 of our suns — collapse in the center when their cores run out of fuel, causing the outer layers to explode and leaving behind a neutron star or black hole. Stars less massive than about eight of our suns and that have a companion star likely contract initially to a white dwarf, which then pulls matter onto itself from the adjacent star until it experiences a runaway thermonuclear explosion that blows it to smithereens.

Stars between 8 and 10 solar masses theoretically should explode in a different way. Their immense internal pressure would force electrons to fuse with atomic nuclei, causing a sudden drop in electron pressure that precipitates a collapse and subsequent explosion of the surrounding layers. What's left behind would be a neutron star a bit more massive than our sun.

The 2018 supernova, called SN 2018zd, and its progenitor star, respectively, match the profile of an electron-capture supernova and the type of massive star that would undergo such an explosion. The bright supernova observed around the world in 1054 C.E., which was visible during the day for 23 days, had characteristics reminiscent of SN 2018zd — in particular, a very long-lasting glow that made it visible at night for nearly two years — suggesting that it, too, was an electron-capture supernova.

"This is the best known case for this interesting category of supernovae that is in between the mass range for the exploding white dwarf and the iron core of a massive star that collapses and then rebounds and leads to an explosion, the so-called core-collapse supernovae," said Alex Filippenko, a professor of astronomy at the University of California, Berkeley. "This study significantly increases our understanding of the final stages of stellar evolution."

Filippenko and a team of astronomers led by Daichi Hiramatsu, a graduate student at UC Santa Barbara and Las Cumbres Observatory (LCO), a worldwide network of robotic optical telescopes, reported the findings on June 28th, 2021 in the journal *Nature Astronomy.* They are members of the Global Supernova Project, a worldwide team of scientists that uses dozens of telescopes on Earth and in space to observe supernovae.



A Hubble Space Telescope image of the starburst galaxy NGC 2146 showing the position of the supernova SN 2018zd (large white dot on right), which was first detected in 2018. The stellar explosion is a smoking gun for the existence of electron-capture supernovae, a third type of exploding star. (Composite image courtesy of NASA/STScI/J. DePasquale and Las Cumbres Observatory)

"The term Rosetta Stone is used too often as an analogy when we find a new astrophysical object, but in this case, I think it is fitting. This supernova is literally helping us decode thousand-year-old records from cultures all over the world," said Andrew Howell, a staff scientist at LCO, adjunct professor of physics at UC Santa Barbara and leader of the Global Supernova Project. "In the process, it is teaching us about fundamental physics — how some neutron stars get made, how extreme stars live and die, and about how the elements we're made of get created and scattered around the universe."

AMATEUR ASTRONOMER'S DISCOVERY

Shortly after the supernova was noticed by amateur astronomer Koichi Itagaki in Japan, team member Schuyler Van Dyk, Filippenko's former postdoctoral fellow and a senior research scientist at the California Institute of Technology, was able to obtain a Hubble Space

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Telescope image of the supernova. He compared this with earlier Hubble Space Telescope images of that area of the sky and positively identified the progenitor star in the galaxy NGC 2146, about 31 million light years from Earth.

"It's great when we have both pre-explosion and post-explosion Hubble images, because we can confidently pinpoint which star exploded from the exact location of the supernova," Van Dyk said.

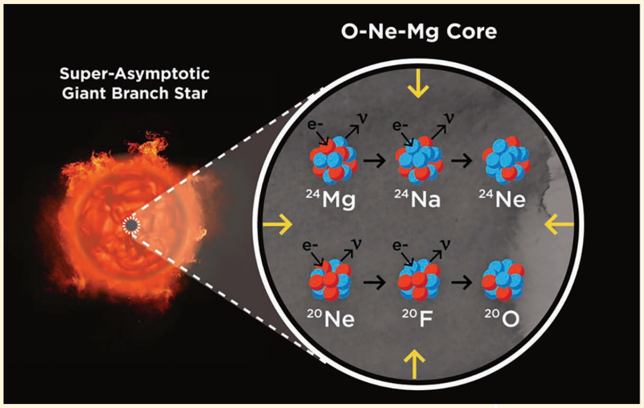
"That was one of the key components that had never been done for other candidate electron-capture supernovae — they had never had a viable identified progenitor star, the star that explodes," Filippenko said.

The identity of the progenitor star allowed the team to compare both the star and supernova characteristics with those predicted by team member Ken'ichi Nomoto of the Kavli Institute for the Physics and Mathematics of the Universe, at the University of Tokyo. He first hypothesized this type of supernova in 1980.

Based on models by Nomoto and other astronomers, such stars should have a lot of mass — between 8 and 10 solar masses — but lose much of it before exploding, and this shed mass should be of an unusual chemical composition, rich in helium, carbon and nitrogen, but low in oxygen. The electron-capture supernova explosion should be weak, about 10 times less energetic than a core-collapse supernova; have little radioactive fallout, primarily radioactive nickel; and have lots of neutron-rich elements, such as oxygen, neon and magnesium, in the core.

That is what they found. The progenitor star was a massive super-asymptotic, giant branch (SAGB) star — that is, an old, bloated red giant, the largest diameter star possible. Observations showed that it had shed a significant fraction of its mass before the explosion, and the gas surrounding the pre-explosion star matched the expected chemical composition. The explosion was relatively weak for a Type II supernova, produced little radioactive nickel, and showed strong emission lines of a neutron-rich element, stable nickel.

The brightening and dimming of the supernova over time resembled that of several other unusual supernovae that have been categorized as Type II-P because their light output first plateaus and then drops to a very low level about 100 days after the explosion. This faintness is due to the dearth of radioactive nickel.



A super-asymptotic giant branch star (left) and its core (right) made up of oxygen (O), neon (Ne) and magnesium (Mg). These bloated stars are the end state of stars in a mass range of about 8 to 10 solar masses. The core is supported by electron (e-) pressure, but when it becomes dense enough, neon and magnesium start to eat up electrons (so called electron-capture reactions), reducing the core pressure and inducing a core-collapse supernova explosion. In the process, sodium (Na) and fluorine (F) are also produced, along with lots of neutrinos (ν). (Graphic courtesy of S. Wilkinson; Las Cumbres Observatory)

The new discoveries shed light on some mysteries of the 1054 C.E. supernova, which exploded within the Milky Way Galaxy and was famously mentioned in Chinese and Japanese records. The resulting remnant — the Crab Nebula — has been studied in great detail, and the supernova has been the best candidate for an electron-capture supernova. The new result increases the confidence that SN 1054 was an electron-capture supernova, the team argues.

This hypothesis also explains why that supernova was relatively bright, compared to expectations based on early models of electron-capture supernovae: Its luminosity was probably artificially enhanced by the supernova ejecta colliding with material cast off by the progenitor star, as was seen in SN 2018zd.

"People have speculated that the Crab Nebula supernova was an electron-capture supernova, but I think SN 2018zd makes that association stronger," Filippenko said. "We have now come to the realization that an electron-capture supernova may make itself more noticeable for a longer time than would have been anticipated just based on the initial theory 40 years ago."

Filippenko and the team hope to find more examples of this third flavor of supernova that need to be relatively nearby for astronomers to be able to identify each one's progenitor star, which is typically faint, and record the long-term glow from the ejecta.

Read the full article here: https://news.berkeley.edu/story_jump/stellar-explosion-in-1054-c-e-may-have-been-a-third-flavor-of-supernova/

HOW FAST IS THE UNIVERSE EXPANDING? GALAXIES PROVIDE ONE ANSWER.

By Robert Sanders, March 2021

Determining how rapidly the universe is expanding is key to understanding our cosmic fate, but with more precise data has come a conundrum: Estimates based on measurements within our local universe don't agree with extrapolations from the era shortly after the Big Bang 13.8 billion years ago.

A new estimate of the local expansion rate, the Hubble constant, or H0 (H-naught), reinforces that discrepancy.

Using a relatively new and potentially more precise technique for measuring cosmic distances, which employs the average stellar brightness within giant elliptical galaxies as a rung on the distance ladder, astronomers calculate a rate — 73.3 kilometers per second per megaparsec, give or take 2.5 km/sec/Mpc — that lies in the middle of three other good estimates, including the gold standard estimate from Type Ia supernovae. This means that for every megaparsec — 3.3 million light years, or 3 billion trillion kilometers — from Earth, the universe is expanding an extra 73.3 ±2.5 kilometers per second. The average from the three other techniques is 73.5 ±1.4 km/sec/Mpc.

Perplexingly, estimates of the local expansion rate based on measured fluctuations in the cosmic microwave background and, independently,

News and Noteworthy

The American Astronomical Society has announced that their 2021 Newton Lacy Pierce Prize in Astronomy goes to Assistant Professor **Courtney Dressing** "for her leading contributions that have dramatically advanced our understanding of the formation rate, composition, and evolution of planets around low-mass M dwarf stars." The Pierce Prize is awarded annually for outstanding achievement, over the preceding five years, in observational astronomical research. It is given to an astronomer who has not attained 36 years of age in the year designated for the award.

Raffaella Margutti, Associate Professor of Astronomy, received the 2021 New Horizons in Physics Prize from the Breakthrough Prizes Foundation for her work on the sources of gravitational waves. Margutti, the Marc and Cristina Bensadoun Associate Professor, will share the prize with three colleagues for "laying the foundations for electromagnetic observations of sources of gravitational waves, and leadership in extracting rich information from the first observed collision of two neutron stars."

Dan Werthimer, a co-founder of SETI@home and a UC Berkeley astronomer who developed ever-more-sensitive radio receivers to aid the search for extraterrestrial intelligence on other planets, will share the 2021 Drake Award, an accolade that honors scientists and engineers who have made substantial contributions to the search for and understanding of life beyond Earth. Werthimer co-founded and served as principal investigator for the enormously popular screensaver SETI@home, which more than 8 million members of the public have used to process data collected by radio telescopes searching for emissions from other intelligence. SETI@home brought SETI literally into people's homes and helped establish it as a mainstream science in the public's mind.

fluctuations in the density of normal matter in the early universe (baryon acoustic oscillations), give a very different answer: 67.4 ±0.5 km/sec/Mpc.

Astronomers are understandably concerned about this mismatch, because the expansion rate is a critical parameter in understanding the physics and evolution of the universe and is key to understanding dark energy, which accelerates the rate of expansion of the universe and thus causes the Hubble constant to change more rapidly than expected with increasing distance from Earth. Dark energy comprises about two-thirds of the mass and energy in the universe, but is still a mystery.

For the new estimate, astronomers measured fluctuations in the surface brightness of 63 giant elliptical galaxies to determine the distance and plotted distance against velocity for each to obtain H0. The surface brightness fluctuation (SBF) technique is independent of other techniques and has the potential to provide more precise distance estimates than other methods within about 100 Mpc of Earth, or 330 million light years. The 63 galaxies in the sample are at distances ranging from 15 to 99 Mpc, looking back in time a mere fraction of the age of the universe.

"For measuring distances to galaxies out to 100 megaparsecs, this is a fantastic method," said cosmologist Chung-Pei Ma, the Judy Chandler Webb Professor in the Physical Sciences at the University of California, Berkeley, and professor of astronomy and physics. "This is the first paper that assembles a large, homogeneous set of data, on 63 galaxies, for the goal of studying H-naught using the SBF method."

Ma leads the MASSIVE survey of local galaxies, which provided data for 43 of the galaxies, two-thirds of those employed in the new analysis.

The data on these 63 galaxies was assembled and analyzed by John Blakeslee, an astronomer with the National Science Foundation's NOIRLab. He is first author of a paper now accepted for publication in *The Astrophysical Journal* that he co-authored with colleague Joseph Jensen of Utah Valley University in Orem. Blakeslee, who heads the science staff that support NSF's optical and infrared observatories, is a pioneer in using SBF to measure distances to galaxies, and Jensen was one of the first to apply the method at infrared wavelengths. The two worked closely with Ma on the analysis.

This illustration shows how estimates of the local expansion rate from observations of the universe today — 13.8 billion years after the Big Bang (top, Late Route) — do not match estimates from observations of the early universe (Early Route). Estimates from surface brightness fluctuations are second from the top of the upper bridge segment.. (Graphic by Andi James/STScI and Chung-Pei Ma/UC Berkeley)

NGC 1453, a giant elliptical galaxy situated in the constellation Eridanus, was one of 63 galaxies used to calculate the expansion rate of the local universe. Last year, the MASSIVE survey team determined that the galaxy is located 166 million light years from Earth and has a black hole at its center with a mass nearly 3 billion times that of the sun. (Photo courtesy of the Carnegie-Irvine Galaxy Survey)

"The whole story of astronomy is, in a sense, the effort to understand the absolute scale of the universe, which then tells us about the physics," Blakeslee said, harkening back to James Cook's voyage to Tahiti in 1769 to measure a transit of Venus so that scientists could calculate the true size of the solar system. "The SBF method is more broadly applicable to the general population of evolved galaxies in the local universe, and certainly if we get enough galaxies with the James Webb Space Telescope, this method has the potential to give the best local measurement of the Hubble constant."

The James Webb Space Telescope, 100 times more powerful than the Hubble Space Telescope, is scheduled for launch in October.

GIANT ELLIPTICAL GALAXIES

The Hubble constant has been a bone of contention for decades, ever since Edwin Hubble first measured the local expansion rate and came up with an answer seven times too big, implying that the universe was actually younger than its oldest stars. The problem, then and now, lies in pinning down the location of objects in space that give few clues about how far away they are.

Astronomers over the years have laddered up to greater distances, starting with calculating the distance to objects close enough that they seem to move slightly, because of parallax, as the Earth orbits the sun. Variable stars called Cepheids get you farther, because their brightness is linked to their period of variability, and Type Ia supernovae get you even farther, because they are extremely powerful explosions that, at their peak, shine as bright as a whole galaxy. For both Cepheids and Type Ia supernovae, it is possible to figure out the absolute brightness from the way they change over time, and then the distance can be calculated from their apparent brightness as seen from Earth.

The best current estimate of H0 comes from distances determined by Type Ia supernova explosions in distant galaxies, though newer methods — time delays caused by gravitational lensing of distant quasars and the brightness of water masers orbiting black holes — all give around the same number.

The technique using surface brightness fluctuations is one of the newest and relies on the fact that giant elliptical galaxies are old and have a consistent population of old stars, mostly red giant stars, that can be modeled to give an average infrared brightness across their surface. The researchers obtained high-resolution infrared images of each galaxy with the Wide Field Camera 3 on the Hubble Space Telescope and determined how much each pixel in the image differed from the "average", the smoother the fluctuations over the entire image, the farther the galaxy, once corrections are made for blemishes like bright star-forming regions, which the authors exclude from the analysis.

Neither Blakeslee nor Ma was surprised that the expansion rate came out close to that of the other local measurements. But they are equally confounded by the glaring conflict with estimates from the early universe—a conflict that many astronomers say means that our current cosmological theories are wrong, or at least incomplete.

The extrapolations from the early universe are based on the simplest cosmological theory, called lambda cold dark matter, or CDM, which employs just a few parameters to describe the evolution of the universe. Does the new estimate drive a stake into the heart of CDM?

"I think it pushes that stake in a bit more," Blakeslee said. "But it (CDM) is still alive. Some people think, regarding all these local measurements, (that) the observers are wrong. But it is getting harder and harder to make that claim — it would require there to be systematic errors in the same direction for several different methods: supernovae, SBF, gravitational lensing, water masers. So, as we get more independent measurements, that stake goes a little deeper."

Ma wonders whether the uncertainties astronomers ascribe to their measurements, which reflect both systematic errors and statistical errors, are too optimistic, and that perhaps the two ranges of estimates can still be reconciled.

"The jury is out," she said. "I think it really is in the error bars. But assuming everyone's error bars are not underestimated, the tension is getting uncomfortable."

In fact, one of the giants of the field, astronomer Wendy Freedman, recently published a study pegging the Hubble constant at 69.8 ±1.9 km/sec/Mpc, roiling the waters even further. The latest result from Adam Riess, an astronomer who shared the 2011 Nobel Prize in Physics for discovering dark energy, reports 73.2 ±1.3 km/sec/Mpc. Riess was a Miller Postdoctoral Fellow at UC Berkeley when he performed this research, and he shared the prize with UC Berkeley and Berkeley Lab physicist Saul Perlmutter.

MASSIVE GALAXIES

The new value of H0 is a byproduct of two other surveys of nearby galaxies, in particular, Ma's MASSIVE survey, which uses space and ground-based telescopes to exhaustively study the 100 most massive galaxies within about 100 Mpc of Earth. A major goal is to weigh the supermassive black holes at the centers of each one.To do that, precise distances are needed, and the SBF method is the best to date, she said. The MASSIVE survey team used this method last year to determine the distance to a giant elliptical galaxy, NGC 1453, in the southern sky constellation of Eridanus. Combining that distance, 166 million light years, with extensive spectroscopic data from the Gemini and McDonald telescopes, which allowed Ma's graduate students Chris Liepold and Matthew Quenneville to measure the velocities of the stars near the center of the galaxy. They concluded that NGC 1453 has a central black hole with a mass nearly 3 billion times that of the sun.

To determine H0, Blakeslee calculated SBF distances to 43 of the galaxies in the MASSIVE survey, based on 45 to 90 minutes of HST observing time for each galaxy. The other 20 came from another survey that employed HST to image large galaxies, specifically ones in which Type Ia supernovae have been detected.

Most of the 63 galaxies are between 8 and 12 billion years old, which means that they contain a large population of old red stars, which are key to the SBF method and can also be used to improve the precision of distance calculations. In the paper, Blakeslee employed both Cepheid variable stars and a technique that uses the brightest red giant stars in a galaxy, referred to as the tip of the red giant branch, or TRGB technique, to ladder up to galaxies at large distances. They produced consistent results. The TRGB technique takes account of the fact that the brightest red giants in galaxies have about the same absolute brightness.

"The goal is to make this SBF method completely independent of the Cepheid-calibrated Type Ia supernova method by using the James Webb Space Telescope to get a red giant branch calibration for SBFs," he said.

"The James Webb telescope has the potential to really decrease the error bars for SBF," Ma added. But for now, the two discordant measures of the Hubble constant will have to learn to live with one another.

"I was not setting out to measure H0; it was a great product of our survey," she said. "But I am a cosmologist and am watching this with great interest."

Co-authors of the paper with Blakeslee, Ma and Jensen are Jenny Greene of Princeton University, who is a leader of the MASSIVE team, and Peter Milne of the University of Arizona in Tucson, who leads the team studying Type Ia supernovae. The work was supported by the National Aeronautics and Space Administration (HST-GO-14219, HST-GO-14654, HST GO-15265) and the National Science Foundation (AST-1815417, AST-1817100).

Read the full article here: https://news.berkeley.edu/2021/03/08/how-fast-is-the-universe-expanding-galaxies-provide-one-answer/

Research Fellows and Postdocs

Dr. Marta Bryan is a NHFP Sagan Fellow. Since coming to UC Berkeley in 2018, Marta has led a NIR high-resolution spectroscopy survey to directly detect thermal emission of gas giant planets in their infancy. With these spectra she measures how fast planets spin, providing the first look at their angular momentum evolution. Marta has also led a collaboration to measure the first and only two exoplanetary obliquities (i.e. why the Earth has seasons), a new observable that is a unique window into planet formation histories.

Dr. John Hoang describes how moving to UC Berkeley amid the pandemic in Oct 2020 has been a surreal experience. Prior to joining Cal, John received a PhD in Madrid where he studied the time-domain and transient aspects of compact objects using gamma-ray Cherenkov telescopes. John is currently in his second year of postdoc with the Breakthrough Listen group, searching for, among other anomalous optical signals, the so-called technosignatures that could have implications on the existence of extraterrestrial intelligence. In addition, John is also experimenting with new ML techniques to synthesize and classify signals at a rate that is at least one order of magnitude faster than the current methods in the field.

Dr. Antonell Palmese is a NASA Einstein Fellow working on observational cosmology and multi-messenger astronomy. Most of her research is focused on studies related to cataclysmic events such as mergers of two neutrons stars or black holes that emit gravitational waves. She is particularly interested in searching for the optical emission coming from those events and in studying their host galaxies and environment. Antonella's research goal is ultimately to use those observations to measure the expansion of the Universe and to understand the origin of gravitational wave sources. She is more broadly involved in transient astronomy, cosmology, and galaxy evolution with the Dark Energy Spectroscopic Instrument, the Dark Energy Survey, and Dark Energy Camera observations.

Dr. Alessandro Savino's major research area is galactic archaeology. Alessandro work's on resolved galaxies in the Local Volume, using the fossil record encoded in their stellar populations to gain insights into galaxy evolution, star formation, stellar physics, and astrophysical processes of the early Universe. Alessandro joined U.C. Berkeley in 2020 to work on a large Hubble Space Telescope survey of the satellite-galaxy system around the Andromeda galaxy. He is using deep photometric observations to measure the star formation history of these galaxies, study their variable-star population and reconstruct the 3D configuration of the Andromeda galactic ecosystem. Combined, these results will provide us with a new observational window on galaxy evolution at the small scales, the imprint of cosmic reionization in our local neighbourhood, and on the assembly history of our close galactic companion.

Undergrad Research Opportunities

Cal-Undergraduate Research Scholarships in Astronomy (Cal-URSA) was born out of the recognition that financial need is one of the reasons that students holding traditionally underrepresented identities in STEM are unable to pursue unpaid research experiences. Secondly, it provides opportunities for astronomy research staff and postdocs to act as research advisors without the burden of soliciting external funding.

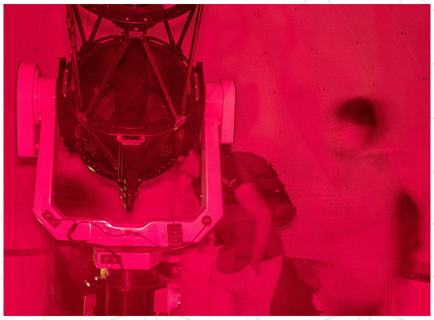
Cal-URSA offers semester-long paid research opportunities at UC Berkeley Astronomy Department for students majoring in physics or astronomy at any institution in the nine Bay Area area counties. The program is open to all students, regardless of residency or immigration status, and encourages students identifying with historically marginalized identities and non-traditional backgrounds to apply. In our initial cohort for Fall 2021, we received over 40 applications from students at nearly a dozen institutions and three local community college students were selected to participate thanks to funding donated in honor of Don Backer. This year's cohort includes the following students who presented their research findings on December 2, 2021.

Bradley Arias, Victor Valley College
Kirsten Fraser, Chabot College
Tonya Peshel, San Francisco State University

Lead Coordinator & Developer: Ekta Patel

Co-Developers: Ken Shen, Gaspard Duchene, Anna Ho, Marta Bryan, Steve Croft, Yong Zheng, Ben Margalit

Mentors: Ken Shen, Gaspard Duchene, Sofia Sheikh



Campbell Hall Undergraduate Astronomy Society Star Party images by Neil Freese

Message from the Chair

This past year was time for perseverance, hope, and renewal. In the Spring, during the early phases of the vaccine roll out, the ongoing pandemic dictated our conduct for research and teaching, keeping us largely remote. In the summer, we saw the glimmers of a post-pandemic world and, within a science-driven framework for safety, began to plan for an in-person Fall semester. And indeed this semester we got "Back to Campbell Hall" with a sense of fervor and renewed purpose. We are still getting accustomed to wearing masks indoors, daily health checks, and hybrid meetings but it's safe to say that Campbell, with a new sense of togetherness in the face of a whole lot of uncertainty, has become once again our research home.

In this newsletter, we see evidence of the amazing perseverance and research success of our members. Highlighted here, from the work of Prof. **Alex Fillippenko** and Prof. **Chung-Pei Ma,** are just two of the countless exciting results that continue to propel Berkeley Astronomy to the scientific fore. What's often less heralded is the work that our members do in support of each other, in teaching, and in mentorship. This summer Prof. **Jessica Lu** created and ran AstroTech, a weeklong astronomical instrumentation school designed to help reverse the underrepresentation of traditionally marginalized groups. Prof. **Eugene Chiang** spearheaded the award of the Berkeley Discovery program designed to revitalize our undergraduate major with curriculum reform, laboratory upgrades, and a new scholars program. Postdoctoral scholars **Ekta Patel** and **Ken Shen** created Cal-URSA, a program providing access to paid undergraduate research opportunities with postdocs and staff scientists. With a robust teaching and mentorship focus, it should come as no surprise to learn that we graduated more astronomy bachelors (51) last year than any other department in the country. Our major has more than doubled in the past decade.

Apart from the new students and postdocs you're reading about in this newsletter, the department continued to be transformed by arrivals and departures. Following successful searches run by manager **Maria Kies, Brandye Johnson** (coordinator) and **Brianna Franklin** (student services) assumed two critical staff roles. Our department welcomed Associate Prof. **Raffaella Margutti** (Marc and Cristina Bensadoun Chair in Physics) and Adjunct Prof. **Ryan Chornock** this summer. They so quickly ramped up their teaching, service, and mentorship that it's now hard to remember a time when they weren't part of our faculty! At the same time, Prof. **Mariska Kriek** returned to the Netherlands to take up a faculty position in Leiden—she is sorely missed but we all continue to support her decision. We were also saddened to learn of the passing of former faculty members **Stu Bowyer** and **Ivan King**.

The accolades for our members continue to pour in. Prof. **Courtney Dressing** was awarded the prestigious Newton Lacy Pierce Prize from the American Astronomical Society *"for her leading contributions that have dramatically advanced our understanding of the formation rate, composition, and evolution of planets around low-mass M-dwarf stars."* **Dan Wertheimer** won the Drake Award for *"contributions to SETI research and associated technology developments have transformed the field."* And Prof. Margutti was honored with the Breakthrough Foundation New Horizons in Physics Prize for *"laying the foundations for electromagnetic observations of sources of gravitational waves, and leadership in extracting rich information from the first observed collision of two neutron stars."* Prof. **Uroš Seljak** won the 2021 Gruber Cosmology Prize, recognizing *"contributions to methods essential for studying the early universe."* Graduate student **Sarafina Nance** was recently named to Forbes' 30 under 30 in Science.

The end of the year is also a great moment to look ahead. We indeed look forward to the arrival of **Wenbin Lu** as a new professor in our department and Prof. **Steven Kahn** who will become our new Dean of Math and Physical Sciences soon. On the research front, The Astro2020 Decadal survey (with committee membership from Dressing, Margutti, **Richard Plambeck**) lays out an ambitious two decades of scientific effort that will directly impact our research, from gravitational wave astronomy to planet imaging. As a community we will continue to focus our efforts to forge and foster a sense of belonging and create opportunities to thrive in research for BIPOC and URM students in Astrophysics.

It continues to be an honor and a privilege to work in the best public educational institution in the world. Thank you to all of our department members and those that support us. Wishing you a safe, happy, and productive 2022. Go Bears!

-Josh Bloom, Chair

Chair's welcoming party for the 1st, 2nd and transfer grad students (Aug 26, 2021).

Black hole expert Chung-Pei Ma, center, painting the supermassive black hole at the center of Amanda Phingbodhipakkiya's new women-in-science mural, Horizon Light, on June 23, 2021 in San Carlos, California. (Photo courtesy of Ethan Michon)

Read the full article here: https://news.berkeley.edu/2021/06/30/black-hole-at-center-of-swirling-new-women-in-science-mural/

Astrophysics Roundtable

The Astronomy Department hosted our annual Astrophysics Roundtable on November 4th. This was the first year we had a hybrid event, with 24 people attending in person and 25 virtually. The theme was Black Holes: Origins, Evolution, and the Technology Needed to Find Them. Prof. Jessica Lu emceed the event and showcased results from her team's hunt for free-floating stellar mass black holes in the Milky Way. Prof. Reinhard Genzel regaled the audience with stories of the discovery of the supermassive black hole at the Galactic Center and the continuation of experiments to test theories of gravity around the black hole. Prof. Geoffrey Penington, from the physics department, dove into the intersection of quantum mechanics and gravity and other theoretical advances. Prof. Raffaella Margutti, the newest faculty member of the Astronomy department, highlighted the time when humans first detected gravitational waves from two neutron stars merging to form a black hole and how her team found the electromagnetic counterpart! Finally, two outstanding graduate students presented their work: Chris Liepold and Prof. Chung-Pei Ma covered the connection between a galaxy and its supermassive black hole and Hannah Gulick introduced a new concept, developed with Prof. Jessica Lu, Prof. Steve Beckwith, and Prof. Josh Bloom, for a constellation of satellites called CuRIOS, that could survey all-sky, all-the-time to find black hole-related transient phenomena. The roundtable was an exciting event with many interesting questions posed by attendees on the theoretical, observational, and experimental advances needed to better understand some of the most exotic objects in the Universe.

Berkeley Discover: Physics & Astronomy

Professor Eugene Chiang is spearheading a new joint program in Astronomy and Physics that aims to develop new opportunities for creative and collaborative discovery for undergraduate students in both departments. The project was awarded a multi-year Berkeley Discover Departmental Innovation Award and it provides resources to embed discovery into various aspects of Physics and Astronomy majors' learning environments. The program aims to achieve this through a new Scholars mentoring community, open to all and especially the under-represented; curriculum reforms that bring physics to life through order-of-magnitude thinking and under-the-hood hardware and coding skills; and expanding capstone experiences with partners including CalTeach, Space Sciences Lab, and Lawrence Berkeley Lab.

The desired outcome is every Astrophysics major graduating knowing the full utility of their degrees and joining the ranks of educated citizenry. They should be able to explain quantitatively and from first principles how, e.g., global warming works; they should know how to code and manipulate electro-mechanical devices; but most importantly, they should know how to ask questions and break problems down to make the ill-posed well-posed.

What we hope and expect to see rise include the number of majors from under-represented minorities, the number of majors entering teaching (i.e. number of CalTeach minors and accreditations), the number of honors theses, and a sense of belonging.


Campbell Hall | UAS Star Party

2020–2021 Commencement Information

The future of Astronomy at Berkeley is held by the next generation of students who will come from around the world in pursuit of academic excellence. Their capacity to explore, innovate, and discover will continue to be limitless!

ASTROPHYSICS, PH.D. DEGREES

SPRING & SUMMER 2021

Fatima Abdurrahman
Dissertation Committee Members: Kris Gutierrez, Gibor Basri, Dan Weisz
"Black Holes: Finding Them, Building Instruments that Help You Look, and how Systemic Racism can Prevent You From Doing Any of That"

Kareem El-Badry
Dissertation Committee Members: Eliot Quataert, Dan Weisz, Martin White
Advisor(s): Eliot Quataert & Dan Weisz
"Binary Stars Across the Milky Way: Probes of Star Formation and Evolution"

Michael Medford
Dissertation Committee Members: Jessica Lu, Joshua Bloom, Daniel Weisz, Daniel McKinsey
Advisor(s): Jessica Lu, Peter Nugent
"Bump in the Night: Scalable Methods for Modeling and Detecting Rare Photometric Signals in Large Scale Time Domain Surveys"

Deepthi Gorthi
Dissertation Committee Members: Aaron Parsons, Jessica Lu, Uros Seljak
Advisor(s): Aaron Parsons
"Instrumentation for Radio Interferometers Built on a Regular Grid"

Wren Suess
Dissertation Committee Members: Mariska Kriek, Eliot Quataert, Martin White
Advisor(s): Mariska Kriek
"The Growth & Transformation of Galaxies Over Cosmic Time"

ASTROPHYSICS, M.A. DEGREES

SUMMER 2020
Aliza Beverage
Brian Lorenz
Kishore Patra

FALL 2020
Bryan Brzycki
Maude Gull
Massimo Pascale
Keming Zhang

SPRING 2021
Ellianna Abrahams
Sal Wanying Fu
Emily Ramey
Sergiy Vasylyev

SUMMER 2021
Emma Turtleboom

ASTROPHYSICS, B.A. DEGREES

FALL 2020
Vaibhav Bhat
Hunter Hall
Andrew Hoffman
Max Lee
Yukei Murakami
Patricia Natividad
John Ortiz
Giovanni Pecorino
Daniel Sallurday
Audrey Salo
Ryan Tom
Delphine Veronese-Milin

SPRING 2021
Erandi Chavez
Erica Clay
Julia Davila
Jay Garg
Rebecca Gore
Robert Jennings
Daniel Klyde
Kyubin Kwon
Minjoo Lee
Rebecca Lehman
Carissa Lewis
Jamie Lin
Sandra Lucero-Ramirez
James Mang
Nishant Mishra
Morgan Nanez
Ruhee Nirodi
Alejandro Olvera
William Ortiz
Derek Perera
Savannah Perez-Piel
Fatima Rodriguez
Olivia Salaben
Madeline Sandfrey
Kian Shahin
Parker Trautwein
Ethan Ward
Glenn Wysen
Benjamin Zhang
Robert Zhu

SUMMER 2021
Jacob Brumm
Lukas Finkbeiner
Rahul Rajeev
Ellen Thompson

ASTROPHYSICS, MINORS

SPRING 2021
Carrie Zuckerman

PRIZES & AWARDS

Department Citation
Erandi Chavez

Dorothea Klumpke Roberts Prize
Michael Jennings

Mary Elizabeth Uhl Prize
Wren Suess
Kareem El-Badry

Daniel Edward Wark Award
Sam Rose

Robert J. Trumpler Award
Casey Lam

Outstanding Graduate Student Instructor Awards
Aliza Beverage
Tyler Cox
Kareem El-Badry
Hannah Gulick
Jacob Pilawa
James Sunseri
Sergiy Vasylyev

Welcome to our Newest Group of Graduate Students!

Natasha Abrams

Bachelor's Degree: Astrophysics and Physics, Harvard University

Natasha is interested in finding black holes dynamically in time domain surveys such as Rubin. She studies using microlensing to search for black holes with Prof. Jessica Lu, and has used the Light Travel Time Effect to look for black holes in binaries with RR Lyrae stars. She participated in the Harvard Observing Project, where she taught the broader community about observational astronomy, and revived the Harvard Astronomy Society. Natasha is a Berkeley Fellow.

Daniel Brethauer

Bachelor's Degree: Physics in the Integrated Science Program at Northwestern University

Daniel worked on studying mass loss in massive stars shortly before they explode as a supernova, with a focus on SN 2014C through X-ray emission. Daniel is now working with Prof. Raffaella Margutti on studying radiation from compact object mergers like binary neutron stars. Outside of research, Daniel also volunteer with organizations like Letters to a Pre-scientist, UPchieve, and Popping the Science Bubble to make STEM more accessible to underprivileged communities.

Christian Hellum Bye

Bachelor's degree: Mathematics and Physics, McGill University

Christian is trying to measure the sky-averaged 21-cm line of neutral hydrogen to study the early universe. Having worked on the MIST-experiment as an undergrad, Christian is now part of a new experiment lead by Prof. Aaron Parsons called EIGSEP. Christian has most experience with computer simulations but also enjoys doing hands-on work in the radio astronomy lab.

Wynn Jacobson-Galán

Bachelor's Degree: Physics & Astrophysics, UC Santa Cruz

Wynn is an NSF Graduate Research Fellow who works on supernova progenitor systems and transient astronomy. Fascinated by the final moments of a star's life before death, his research focuses on winding back the cosmic clock to understand how certain stars produce the various supernovae observed today. He is currently working with Prof. Raffaella Margutti on combining multi-wavelength observations (radio to X-ray) of a variety of supernova types to create a complete picture of the final stages of stellar instability and mass-loss before explosion.

David Matthews

Master's degree: Astronomy, Northwestern University

David works on multi-wavelength observations of explosive transients. He focuses on radio and X-ray observations of superluminous supernovae to better understand the nature of their underlying energy sources. David is also passionate about teaching, and hopes to make science more accessible for everyone.

Getting to Know Astronomy!

Q&A with Raffaella Margutti

What drew you towards studying transient astrophysical events like supernova explosions and gamma-ray bursts? Why are these events important?

Astrophysics aside, I deeply enjoy the burst of adrenaline associated with the discovery of new explosions, and I like competing (in a healthy way, I mean the good competition). This field of time domain astrophysics is highly competitive and it is a natural environment for me. These events probe Physics at the very extreme, under conditions that we cannot achieve here on this planet Earth. It is just like having the most powerful laboratory up high in the sky where to perform the most extreme experiments that you can think of (the problem is that you do not know when and where the lab is open for business—i.e. when and where some star explodes—which for me is part of the fun). Also, for reasons that I can't explain in any logical way I have always been attracted to Gravity and these violent explosions are the places in our Universe where Gravity happens at the very extreme. These events are manifestations of how Gravity always wins.

How did you become an expert at investigating astronomical explosions across a wide range of the electromagnetic spectrum including X-ray, UV, optical, and radio?

For my thesis for the second level degree in Astrophysics (i.e. equivalent to your Master) I studied optical spectroscopy of galaxies that host Gamma-Ray Burst explosions. Then just by chance, my PhD aligned with the beginning of the Swift mission and the Swift team happened to be from US+UK+Italy, and I started working with X-ray data from Swift-XRT. From there I expanded to the gamma-rays and, for my postdoc at Harvard, I decided to embark on UV as well. There, I understood the value of radio for stellar explosions. And here is how it all happened. Multi-wavelength is the only way to constrain the Physics of these phenomena and make progress.

During your outreach activities, what are some comments made or questions asked by kids that have tickled you?

Some of the most amusing questions were about acquiring super powers by absorbing the energy of stellar explosions, to which I reply by saying that we already have super powers, which are those that allow us to use simple equations to understand something deep about the Universe.

At what point in your life did you decide to become an astronomer? What inspired that decision?

I have always been deeply fascinated by the fact that we can use Math as a language to interpret the most distant phenomena that we know of. I could just not resist the attraction of using a language invented here on Earth (Math) to learn about the past and future of our Universe. There was never a moment in my life where I felt that I took that decision. I have always felt that the only thing I could do is Astrophysics. I do not necessarily like traditional Astronomy, I like Physics and I want to apply the Physics to the Cosmos. I do not have any inspirational astronomer figure that played a role when I was young, and I fundamentally have never looked up to others.

What do you like doing when not studying violent astrophysical events?

Singing. I was trained as a soprano while I was growing up in Italy. Singing brings me peace of mind and allows me to focus and concentrate, and relax, in ways that I cannot do otherwise.

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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.

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: https://astro.berkeley.edu/astronomy-fans/make-a-gift/

Thank you for your supporting the future of Berkeley Astronomy!

GO BEARS!

New Giving Opportunity

The Astronomy Equity and Inclusion Programs and Initiatives Fund

Give to Berkeley: https://give.berkeley.edu/funddrive/235

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.

Your gift supports our department's diversity, equity, inclusion, and belonging efforts. You can read about some of these efforts in this newsletter, such as the new undergraduate research program launched by the Astronomy postdocs and researchers on pg 4, and more on the department website at https://astro.berkeley.edu/about/diversity-and-climate/

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)