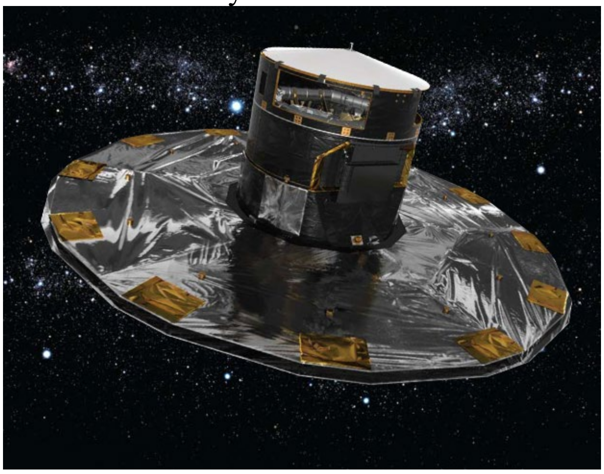
South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 566 – July 1st 2022 Editor: Roger Burgess
Main Speaker 19:30 19:30 Rob Peeling, William Henry Smyth and the Bedford Catalogue
The meeting will be Zoom only

Lisa Lacey is standing down as Secretary by the end of August, we need a replacement to take over from her before she stands down

- Gaia space telescope rocks the science of asteroids

Date: June 17, 2022
Source: University of Helsinki



The European Gaia space mission has produced an unprecedented amount of new, improved, and detailed data for almost two billion objects in the Milky Way galaxy and the surrounding cosmos. The Gaia Data Release 3 on Monday revolutionizes our knowledge of the Solar System and the Milky Way and its satellite galaxies.
The Gaia space mission of the European Space Agency ESA is constructing an ultraprecise three-dimensional map of our Milky Way galaxy, observing almost two billion stars or roughly one percent of all the stars in our galaxy. Gaia was launched in December 2013 and has collected science data from July 2014. On Monday, June 13, ESA released Gaia data in Data Release 3 (DR3). Finnish researchers were strongly involved in the release.
Gaia data allows, for example, for the derivation of asteroid and exoplanet orbits and physical properties. The data helps unveil the origin and future evolution of the Solar System and the Milky Way and helps understand stellar and planetary-system evolution and our place in the cosmos.
Gaia revolves about its axis slowly in about six hours and is composed of two optical space telescopes. Three science instruments allow for accurate determination of stellar positions and velocities as well as the spectral properties. Gaia resides at about 1,5 million kilometres from the Earth in the anti-Sun direction, where it orbits the Sun together with the Earth in the proximity of the so-called Sun-Earth Lagrange L2-point.
Gaia DR3 on June 13, 2022 was significant across astronomy. Some 50 scientific articles are being published with DR3, of which nine articles have been devoted to underscoring the exceptionally significant potential of DR3 for future research.
The new DR3 data comprises, for example, the chemical compositions, temperatures, colours, masses, brightness's, ages, and radial velocities of stars. DR3 includes the largest ever binary star catalogue for the Milky Way, more than 150 000 Solar System objects, largely asteroids but also planetary satellites, as well as millions of galaxies and quasars beyond the Milky Way.
"There are so many revolutionary advances that it is difficult to pinpoint a single most significant advance. Based on Gaia DR3, Finnish researchers will change the conception of asteroids in our Solar System, exoplanets and stars in our Milky Way galaxy, as well as galaxies themselves, including the Milky Way and its surrounding satellite galaxies. Returning to our home planet, Gaia will produce an ultraprecise reference frame for navigation and positioning," says Academy Professor Karri Muinonen from the University of Helsinki.

Gaia and asteroids

The ten-fold increase in the number of asteroids reported in Gaia DR3 as compared to DR2 means that there is a significant increase in the number of close encounters between Gaia-detected asteroids. These close

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encounters can be utilized for asteroid mass estimation and we expect a significant increase in the number of asteroid masses to be derived by using Gaia DR3 astrometry, in particular, when combined with astrometry obtained by other telescopes.

In the conventional computation of an asteroid's orbit, the asteroid is assumed to be a point-like object and its size, shape, rotation and surface light scattering properties are not taken into account. The Gaia DR3 astrometry is, however, so accurate that the angular offset between the asteroid's centre of mass and the centre of the area illuminated by the Sun and visible to Gaia must be accounted for. Based on Gaia DR3, the offset has been certified for asteroid (21) Lutetia (Figure 2). The ESA Rosetta space mission imaged Lutetia during the flyby on July 10, 2010. With the help of the Rosetta Lutetia imagery and ground-based astronomical observations, a rotation period, rotational pole orientation, and detailed shape model were derived. When the physical modelling is incorporated into orbit computation, the systematic errors are removed and, contrary to conventional computation, all observations can be incorporated into the orbit solution. Consequently, the Gaia astrometry provides information about the physical properties of asteroids. These properties need to be taken into account using physical models or empirical error models for the astrometry.

The Gaia DR3 includes, for the first time, spectral observations. The spectrum measures the colour of the target, meaning the brightness at different wavelengths. One especially interesting feature is that the new release contains about 60 000 spectra of asteroids in our Solar System (Figure 3). The asteroid spectrum contains information on their composition and, thus, about their origin and the evolution of the whole Solar System. Before the Gaia DR3, there has been only few thousand asteroid spectra available, so Gaia will multiply the amount of data by more than an order of magnitude.

Gaia and exoplanets

Gaia is expected to produce detections of up to 20 000 giant exoplanets by measuring their gravitational effect on the movement of their host stars. This will enable finding virtually all Jupiter-like exoplanets in the Solar neighbourhood over the coming years and determining how common are Solar System - like architectures. The first such astrometric Gaia detection was a giant exoplanet around epsilon Indi A, that corresponds to the nearest Jupiter-like exoplanet only 12 light years away. The first such detections are possible because acceleration observed in radial velocity surveys can be combined with movement data from Gaia to determine the orbits and planetary masses.

Gaia and galaxies

The microarc second resolution of Gaia DR3 provides precise measurements of the motions of stars, not only within our own Milky Way galaxy, but also for the many satellite galaxies that surround it. From the motion of stars within the Milky Way itself, we can accurately measure its mass, and together with the proper motion of satellites, we can now accurately determine their orbits. This lets us look both into the past and into the future of the Milky Way galaxy system. For example, we can find out which of the galaxies that surround the Milky Way are true satellites, and which are just passing by. We can also investigate if the evolution of the Milky Way conforms to cosmological models, and in particular, whether the satellite orbits fit the standard dark matter model.

Gaia and reference frames

The International Celestial Reference Frame, ICRF3, is based on the position of a few thousand quasars determined by Very Long Baseline Interferometry (VLBI) at radio wavelengths. ICRF3 is used to obtain the coordinates of celestial objects and to determine the orbits of satellites. Quasars of ICRF3 are also fixed points on the sky that can be used to determine the precise orientation of the Earth in space at any time. Without this information, for example, satellite positioning would not work.

Gaia's data contain about 1,6 million quasars, which can be used to create a more accurate Celestial Reference Frame in visible light replacing the current one. In the future, this will have an impact on the accuracy of both satellite positioning and measurements of Earth-exploring satellites.

- ❖ Mysterious 'blue blobs' reveal a new kind of star system

Date: June 16, 2022

Source: University of Arizona

University of Arizona astronomers have identified five examples of a new class of stellar system. They're not quite galaxies and only exist in isolation.
The new stellar systems contain only young, blue stars, which are distributed in an irregular pattern and seem to exist in surprising isolation from any potential parent galaxy.
The stellar systems -- which astronomers say appear through a telescope as "blue blobs" and are about the size of tiny dwarf galaxies -- are located within the relatively nearby Virgo galaxy cluster. The five systems are separated from any potential parent galaxies by over 300,000 light years in some cases, making it challenging to identify their origins.
The astronomers found the new systems after another research group, led by the Netherlands Institute for Radio Astronomy's Elizabeth Adams, compiled a catalogue of nearby gas clouds, providing a list of potential sites of new galaxies. Once that catalogue was published, several research groups, including one led by UArizona associate astronomy professor David Sand, started looking for stars that could be associated with those gas clouds.
The gas clouds were thought to be associated with our own galaxy, and most of them probably are, but when the first collection of stars, called SECCO1, was discovered, astronomers realized that it was not near the Milky Way at all, but rather in the Virgo cluster, which is much farther away but still very nearby in the scale of the universe.
SECCO1 was one of the very unusual "blue blobs," said Michael Jones, a postdoctoral fellow in the UArizona Steward Observatory and lead author of a study that describes the new stellar systems. Jones presented the findings, which Sand co-authored, during the 240th American Astronomical Society meeting in Pasadena, California, Wednesday.
"It's a lesson in the unexpected," Jones said. "When you're looking for things, you're not necessarily going to find the thing you're looking for, but you might find something else very interesting."
The team obtained their observations from the Hubble Space Telescope, the Very Large Array telescope in New Mexico and the Very Large Telescope in Chile. Study co-author Michele Bellazzini, with the Istituto Nazionale di Astrofisica in Italy, led the analysis of the data from Very Large Telescope and has submitted a companion paper focusing on that data.
Together, the team learned that most of the stars in each system are very blue and very young and that they contain very little atomic hydrogen gas. This is significant because star formation begins with atomic hydrogen gas, which eventually evolves into dense clouds of molecular hydrogen gas before forming into stars.
"We observed that most of the systems lack atomic gas, but that doesn't mean there isn't molecular gas," Jones said. "In fact, there must be some molecular gas because they are still forming stars. The existence of mostly young stars and little gas signals that these systems must have lost their gas recently."
The combination of blue stars and lack of gas was unexpected, as was a lack of older stars in the systems. Most galaxies have older stars, which astronomers refer to as being "red and dead."
"Stars that are born red are lower mass and therefore live longer than blue stars, which burn fast and die young, so old red stars are usually the last ones left living," Jones said. "And they're dead because they don't have any more gas with which to form new stars. These blue stars are like an oasis in the desert, basically."
The fact that the new stellar systems are abundant in metals hints at how they might have formed.
"To astronomers, metals are any element heavier than helium," Jones said. "This tells us that these stellar systems formed from gas that was stripped from a big galaxy, because how metals are built up is by many repeated episodes of star formation, and you only really get that in a big galaxy."
There are two main ways gas can be stripped from a galaxy. The first is tidal stripping, which occurs when two big galaxies pass by each other and gravitationally tear away gas and stars.

The other is what's known as ram pressure stripping.
"This is like if you belly flop into a swimming pool," Jones said. "When a galaxy belly flops into a cluster that is full of hot gas, then its gas gets forced out behind it. That's the mechanism that we think we're seeing here to create these objects."
The team prefers the ram pressure stripping explanation because in order for the blue blobs to have become as isolated as they are, they must have been moving very quickly, and the speed of tidal stripping is low compared to ram pressure stripping.
Astronomers expect that one day these systems will eventually split off into individual clusters of stars and spread out across the larger galaxy cluster.
What researchers have learned feeds into the larger "story of recycling of gas and stars in the universe," Sand said. "We think that this belly flopping process changes a lot of spiral galaxies into elliptical galaxies on some level, so learning more about the general process teaches us more about galaxy formation."

- ❖ Martian meteorite upsets planet formation theory

Date: June 16, 2022
Source: University of California – Davis

A new study of an old meteorite contradicts current thinking about how rocky planets like the Earth and Mars acquire volatile elements such as hydrogen, carbon, oxygen, nitrogen and noble gases as they form. The work is published June 16 in *Science*.
A basic assumption about planet formation is that planets first collect these volatiles from the nebula around a young star, said Sandrine Péron, a postdoctoral scholar working with Professor Sujoy Mukhopadhyay in the Department of Earth and Planetary Sciences, University of California, Davis.
Because the planet is a ball of molten rock at this point, these elements initially dissolve into the magma ocean and then degass back into the atmosphere. Later on, chondritic meteorites crashing into the young planet deliver more volatile materials.
So scientists expect that the volatile elements in the interior of the planet should reflect the composition of the solar nebula, or a mixture of solar and meteoritic volatiles, while the volatiles in the atmosphere would come mostly from meteorites. These two sources -- solar vs. chondritic -- can be distinguished by the ratios of isotopes of noble gases, in particular krypton.
Mars is of special interest because it formed relatively quickly -- solidifying in about 4 million years after the birth of the Solar System, while the Earth took 50 to 100 million years to form.
"We can reconstruct the history of volatile delivery in the first few million years of the Solar System," Péron said.

Meteorite from Mars' interior

Some meteorites that fall to Earth come from Mars. Most come from surface rocks that have been exposed to Mars' atmosphere. The Chassigny meteorite, which fell to Earth in north-eastern France in 1815, is rare and unusual because it is thought to represent the interior of the planet.
By making extremely careful measurements of minute quantities of krypton isotopes in samples of the meteorite using a new method set up at the UC Davis Noble Gas Laboratory, the researchers could deduce the origin of elements in the rock.
"Because of their low abundance, krypton isotopes are challenging to measure," Péron said.
Surprisingly, the krypton isotopes in the meteorite correspond to those from chondritic meteorites, not the solar nebula. That means that meteorites were delivering volatile elements to the forming planet much earlier than previously thought, and in the presence of the nebula, reversing conventional thinking.
"The Martian interior composition for krypton is nearly purely chondritic, but the atmosphere is solar," Péron said. "It's very distinct."
The results show that Mars' atmosphere cannot have formed purely by outgassing from the mantle, as that would have given it a chondritic composition. The planet must have acquired atmosphere from the solar nebula, after the magma ocean cooled, to prevent substantial mixing between interior chondritic gases and atmospheric solar gases.

The new results suggest that Mars' growth was completed before the solar nebula was dissipated by radiation from the Sun. But the irradiation should also have blown off the nebular atmosphere on Mars, suggesting that atmospheric krypton must have somehow been preserved, possibly trapped underground or in polar ice caps.

"However, that would require Mars to have been cold in the immediate aftermath of its accretion," Mukhopadhyay said. "While our study clearly points to the chondritic gases in the Martian interior, it also raises some interesting questions about the origin and composition of Mars' early atmosphere."

Péron and Mukhopadhyay hope their study will stimulate further work on the topic.

Péron is now a postdoctoral fellow at ETH Zürich, Switzerland.

- Watching the death of a rare giant star

Date: June 16, 2022

Source: University of Arizona

A University of Arizona-led team of astronomers has created a detailed, three-dimensional image of a dying hypergiant star. The team, led by UArizona researchers Ambesh Singh and Lucy Ziurys, traced the distribution, directions and velocities of a variety of molecules surrounding a red hypergiant star known as VY Canis Majoris. Their findings, which they presented on June 13 at the 240th Meeting of the American Astronomical Society in Pasadena, California, offer insights, at an unprecedented scale, into the processes that accompany the death of giant stars. The work was done with collaborators Robert Humphreys from the University of Minnesota and Anita Richards from the University of Manchester in the United Kingdom.

Extreme supergiant stars known as hypergiants are very rare, with only a few known to exist in the Milky Way. Examples include Betelgeuse, the second brightest star in the constellation Orion, and NML Cygni, also known as V1489 Cygni, in the constellation Cygnus. Unlike stars with lower masses -- which are more likely to puff up once they enter the red giant phase but generally retain a spherical shape -- hypergiants tend to experience substantial, sporadic mass loss events that form complex, highly irregular structures composed of arcs, clumps and knots.

Located about 3,009 light-years from Earth, VY Canis Majoris -- or VY CMa, for short -- is a pulsating variable star in the slightly southern constellation of Canis Major. Spanning anywhere from 10,000 to 15,000 astronomical units (with 1 AU being the average distance between Earth and the sun) VY CMa is possibly the most massive star in the Milky Way, according to Ziurys.

"Think of it as Betelgeuse on steroids," said Ziurys, a Regents Professor with joint appointments in UArizona Department of Chemistry and Biochemistry and Steward Observatory, both part of the College of Science. "It is much larger, much more massive and undergoes violent mass eruptions every 200 years or so."

The team chose to study VY CMa because it is one of the best examples of these types of stars.

"We are particularly interested in what hypergiant stars do at end of their lives," said Singh, a fourth-year doctoral student in Ziurys' lab. "People used to think these massive stars simply evolve into supernovae explosions, but we are no longer sure about that."

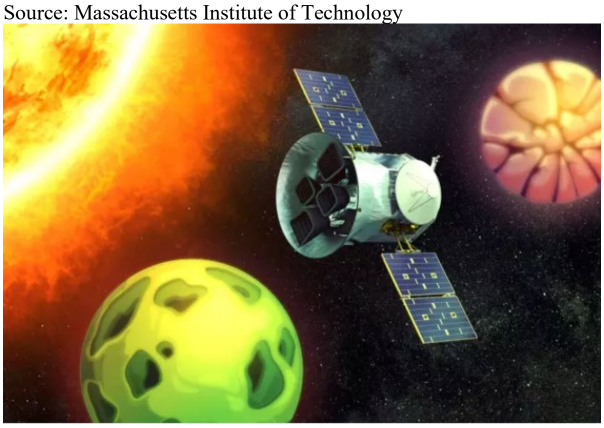
"If that were the case, we should see many more supernovae explosions across the sky," Ziurys added. "We now think they might quietly collapse into black holes, but we don't know which ones end their lives like that, or why that happens and how."

Previous imaging of VY CMa with NASA's Hubble Space Telescope and spectroscopy showed the presence of distinct arcs and other clumps and knots, many extending thousands of AU from the central star. To uncover more details of the processes by which hypergiant stars end their lives, the team set out to trace

certain molecules around the hypergiant and map them to pre-existing images of the dust, taken by the Hubble Space Telescope.
"Nobody has been able to make a complete image of this star," Ziurys said, explaining that her team set out to understand the mechanisms by which the star sheds mass, which appear to be different from those of smaller stars entering their red giant phase at the end of their lives.
"You don't see this nice, symmetrical mass loss, but rather convection cells that blow through the star's photosphere like giant bullets and eject mass in different directions," Ziurys said. "These are analogous to the coronal arcs seen in the sun, but a billion times larger."
The team used the Atacama Large Millimetre Array, or ALMA, in Chile to trace a variety of molecules in material ejected from the stellar surface. While some observations are still in progress, preliminary maps of sulphur oxide, sulphur dioxide, silicon oxide, phosphorus oxide and sodium chloride were obtained.
From these data, the group constructed an image of the global molecular outflow structure of VY CMa on scales that encompassed all ejected material from the star.
"The molecules trace the arcs in the envelope, which tells us molecules and dust are well-mixed," Singh said. "The nice thing about emissions of molecules at radio wavelengths is that they provide us with velocity information, as opposed to the dust emission, which is static."
By moving ALMA's 48 radio dishes into different configurations, the researchers were able to obtain information about the directions and velocities of the molecules and map them across the different regions of the hypergiant's envelope in considerable detail, even correlating them to different mass ejection events over time.
Processing the data required some heavy lifting in terms of computing power, Singh said.
"So far, we have processed almost a terabyte from ALMA, and we still receive data that we have to go through to get the best resolution possible," he said. "Just calibrating and cleaning the data requires up to 20,000 iterations, which takes a day or two for each molecule."
"With these observations, we can now put these on maps on the sky," Ziurys said. "Until now, only small portions of this enormous structure had been studied, but you can't understand the mass loss and how these big stars die unless you look at the entire region. That's why we wanted to create a complete image."
With funding from the National Science Foundation, the team plans to publish its findings in a series of papers.

- ❖ Astronomers discover a multiplanet system nearby

Just 33 light years from Earth, the system appears to host two rocky, Earth-sized planets
Date: June 15, 2022
Source: Massachusetts Institute of Technology


Artist's fictional illustration of the discovered system and TESS, the satellite that made the initial discovery. (Image credit: MIT, NASA)

Astronomers at MIT and elsewhere have discovered a new multiplanet system within our galactic neighbourhood that lies just 10 parsecs, or about 33 light-years, from Earth, making it one of the closest known multiplanet systems to our own.
At the heart of the system lies a small and cool M-dwarf star, named HD 260655, and astronomers have found that it hosts at least two terrestrial, Earth-sized planets. The rocky worlds are likely not habitable, as their orbits are relatively tight, exposing the planets to temperatures that are too high to sustain liquid surface water.
Nevertheless, scientists are excited about this system because the proximity and brightness of its star will give them a closer look at the properties of the planets and signs of any atmosphere they might hold.
"Both planets in this system are each considered among the best targets for atmospheric study because of the brightness of their star," says Michelle Kunimoto, a postdoc in MIT's Kavli Institute for Astrophysics and Space Research and one of the discovery's lead scientists. "Is there a volatile-rich atmosphere around these planets? And are there signs of water or carbon-based

species? These planets are fantastic test beds for those explorations."
The team will present its discovery today at the meeting of the American Astronomical Society in Pasadena, California. Team members at MIT include Katharine Hesse, George Ricker, Sara Seager, Avi Shporer, Roland Vanderspek, and Joel Villasen?or, along with collaborators from institutions around the world.

Data power

The new planetary system was initially identified by NASA's Transiting Exoplanet Survey Satellite (TESS), an MIT-led mission that is designed to observe the nearest and brightest stars, and detect periodic dips in light that could signal a passing planet.
In October 2021, Kunimoto, a member of MIT's TESS science team, was monitoring the satellite's incoming data when she noticed a pair of periodic dips in starlight, or transits, from the star HD 260655.
She ran the detections through the mission's science inspection pipeline, and the signals were soon classified as two TESS Objects of Interest, or TOIs -- objects that are flagged as potential planets. The same signals were also found independently by the Science Processing Operations Centre (SPOC), the official TESS planet search pipeline based at NASA Ames. Scientists typically plan to follow up with other telescopes to confirm that the objects are indeed planets.
The process of classifying and subsequently confirming new planets can often take several years. For HD 260655, that process was shortened significantly with the help of archival data.
Soon after Kunimoto identified the two potential planets around HD 260655, Shporer looked to see whether the star was observed previously by other telescopes. As luck would have it, HD 260655 was listed in a survey of stars taken by the High Resolution Echelle Spectrometer (HIRES), an instrument that operates as part of the Keck Observatory in Hawaii. HIRES had been monitoring the star, along with a host of other stars, since 1998, and the researchers were able to access the survey's publicly available data.
HD 260655 was also listed as part of another independent survey by CARMENES, an instrument that operates as part of the Calar Alto Observatory in Spain. As these data were private, the team reached out to members of both HIRES and CARMENES with the goal of combining their data power.
"These negotiations are sometimes quite delicate," Shporer notes. "Luckily, the teams agreed to work together. This human interaction is almost as important in getting the data [as the actual observations]."

Planetary pull

In the end, this collaborative effort quickly confirmed the presence of two planets around HD 260655 in about six months.
To confirm that the signals from TESS were indeed from two orbiting planets, the researchers looked through both HIRES and CARMENES data of the star. Both surveys measure a star's gravitational wobble, also known as its radial velocity.
"Every planet orbiting a star is going to have a little gravitational pull on its star," Kunimoto explains. "What we're looking for is any slight movement of that star that could indicate a planetary-mass object is tugging on it."
From both sets of archival data, the researchers found statistically significant signs that the signals detected by TESS were indeed two orbiting planets.
"Then we knew we had something very exciting," Shporer says.
The team then looked more closely at TESS data to pin down properties of both planets, including their orbital period and size. They determined that the inner planet, dubbed HD 260655b, orbits the star every 2.8 days and is about 1.2 times as big as the Earth. The second outer planet, HD 260655c, orbits every 5.7 days and is 1.5 times as big as the Earth.
From the radial-velocity data from HIRES and CARMENES, the researchers were able to calculate the planets' mass, which is directly related to the amplitude by which each planet tugs on its star. They found the inner planet is about twice as massive as the Earth, while the outer planet is about three Earth masses. From their size and mass, the team estimated each planet's density. The inner, smaller planet is slightly denser than the Earth, while the outer, larger planet is a bit less dense. Both planets, based on their density, are likely terrestrial, or rocky in composition.
The researchers also estimate, based on their short orbits, that the surface of the inner planet is a roasting 710 kelvins (818 degrees Fahrenheit), while the outer planet is around 560 K (548 F).

"We consider that range outside the habitable zone, too hot for liquid water to exist on the surface," Kunimoto says.
"But there might be more planets in the system," Shporer adds. "There are many multiplanet systems hosting five or six planets, especially around small stars like this one. Hopefully we will find more, and one might be in the habitable zone. That's optimistic thinking."
This research was supported, in part, by NASA, the Max-Planck-Gesellschaft, the Consejo Superior de Investigaciones Científicas, the Ministerio de Economía y Competitividad, and the European Regional Development Fund.

- ❖ Astronomers may have detected a 'dark' free-floating black hole

Gravitational microlensing turns up black hole candidate, one of 200 million in the galaxy

Date: June 10, 2022
Source: University of California - Berkeley

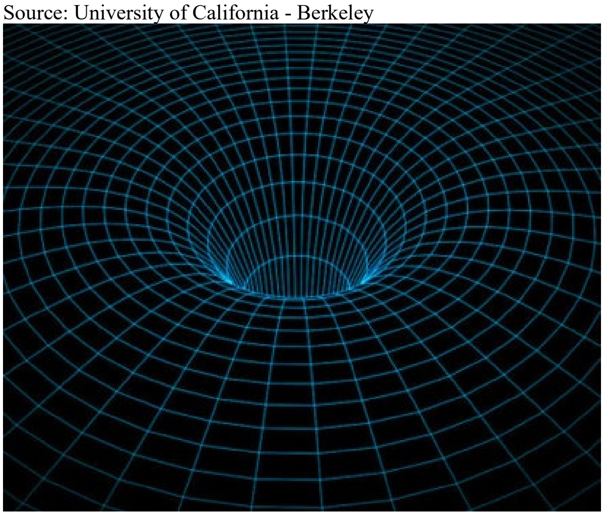


Illustration of black hole warping spacetime (stock image).
Credit: © trahko / stock.adobe.com

Black holes, by their nature, are invisible unless part of a stellar binary or surrounded by an accretion disk. Most stellar-sized black holes aren't, but astronomers have been searching for them through gravitational microlensing events, where the black hole brightens and distorts light from stars toward the galactic centre. A UC Berkeley-led team may have found the first free-floating black hole, though more data is needed to rule out a neutron star.
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 Telescope Science Institute (STScI) in Baltimore analysed 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*.

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 centre 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."

When Lam analysed 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 micro lenses 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."

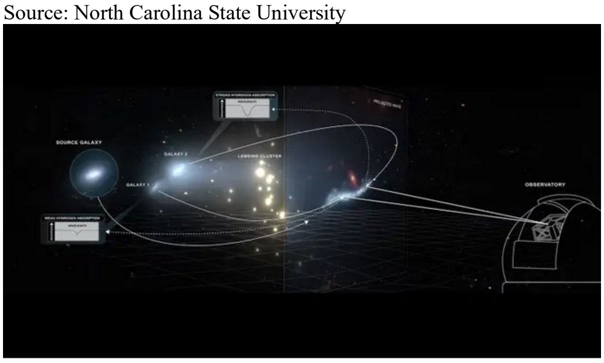
According to Lu, the gravitational influence of OB110462 on the light of the background star was amazingly long. It took about one year for the star to brighten to its peak in 2011, then about a year to dim back to normal.

More data will distinguish black hole from neutron star

To confirm that OB110462 was caused by a super-compact object, Lu and Lam asked for more astrometric data from Hubble, some of which arrived last October. That new data showed that the change in position of the star as a result of the gravitational field of the lens is still observable 10 years after the event. Further Hubble observations of the micro lens are tentatively scheduled for fall 2022.
Analysis of the new data confirmed that OB110462 was likely a black hole or neutron star.
Lu and Lam suspect that the differing conclusions of the two teams are due to the fact that the astrometric and photometric data give different measures of the relative motions of the foreground and background objects. The astrometric analysis also differs between the two teams. The UC Berkeley-led team argues that it is not yet possible to distinguish whether the object is a black hole or a neutron star, but they hope to resolve the discrepancy with more Hubble data and improved analysis in the future.
"As much as we would like to say it is definitively a black hole, we must report all allowed solutions. This includes both lower mass black holes and possibly even a neutron star," Lu said.
"If you can't believe the light curve, the brightness, then that says something important. If you don't believe the position versus time, that tells you something important," Lam said. "So, if one of them is wrong, we have to understand why. Or the other possibility is that what we measure in both data sets is correct, but our model is incorrect. The photometry and astrometry data arise from the same physical process, which means the brightness and position must be consistent with each other. So, there's something missing there. "
Both teams also estimated the velocity of the super-compact lensing object. The Lu/Lam team found a relatively sedate speed, less than 30 kilometres per second. The STScI team found an unusually large velocity, 45 km/s, which it interpreted as the result of an extra kick that the purported black hole got from the supernova that generated it.
Lu interprets her team's low velocity estimate as potentially supporting a new theory that black holes are not the result of supernovas -- the reigning assumption today -- but instead come from failed supernovas that don't make a bright splash in the universe or give the resulting black hole a kick.
The work of Lu and Lam is supported by the National Science Foundation (1909641) and the National Aeronautics and Space Administration (NNG16PJ26C, NASA FINESST 80NSSC21K2043)

- Researchers use galaxy as a 'cosmic telescope' to study heart of the young universe

Date: May 18, 2022
Source: North Carolina State University

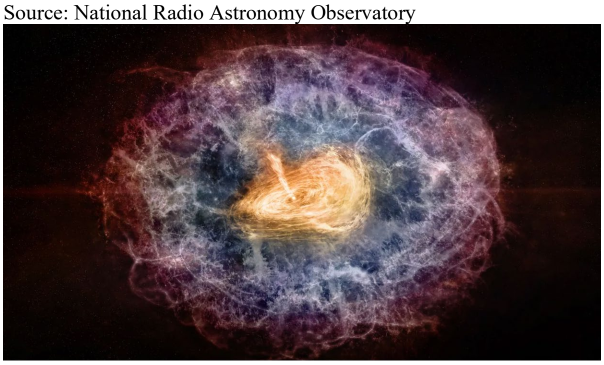


A unique new instrument, coupled with a powerful telescope and a little help from nature, has given researchers the ability to peer into galactic nurseries at the heart of the young universe.
After the big bang some 13.8 billion years ago, the early universe was filled with enormous clouds of neutral diffuse gas, known as Damped Lyman-α systems, or DLAs. These DLAs served as galactic nurseries, as the gasses within slowly condensed to fuel the formation of stars and galaxies. They can still be observed today, but it isn't easy.
"DLAs are a key to understanding how galaxies form in the universe, but they are typically difficult to observe since the clouds are too diffuse and don't emit any light themselves," says Rongmon Bordoloi, assistant professor of physics at North Carolina State University and corresponding author of the research.
Currently, astrophysicists use quasars -- supermassive black holes that emit light -- as "backlight" to detect the DLA clouds. And while this method does allow researchers to pinpoint DLA locations, the light from the quasars only acts as small skewers through a massive cloud, hampering efforts to measure their total size and mass.
But Bordoloi and John O'Meara, chief scientist at the W.M. Keck Observatory in Kamuela, Hawaii, found a way around the problem by using a gravitationally lensed galaxy and integral field spectroscopy to

observe two DLAs -- and the host galaxies within -- that formed around 11 billion years ago, not long after the big bang.
"Gravitationally lensed galaxies refers to galaxies that appear stretched and brightened," Bordoloi says. "This is because there is a gravitationally massive structure in front of the galaxy that bends the light coming from it as it travels toward us. So we end up looking at an extended version of the object -- it's like using a cosmic telescope that increases magnification and gives us better visualization.
"The advantage to this is twofold: One, the background object is extended across the sky and bright, so it is easy to take spectrum readings on different parts of the object. Two, because lensing extends the object, you can probe very small scales. For example, if the object is one light year across, we can study small bits in very high fidelity."
Spectrum readings allow astrophysicists to "see" elements in deep space that are not visible to the naked eye, such as diffuse gaseous DLAs and the potential galaxies within them. Normally, gathering the readings is a long and painstaking process. But the team solved that issue by performing integral field spectroscopy with the Keck Cosmic Web Imager.
Integral field spectroscopy allowed the researchers to obtain a spectrum at every single pixel on the part of the sky it targeted, making spectroscopy of an extended object on the sky very efficient. This innovation combined with the stretched and brightened gravitationally lensed galaxy allowed the team to map out the diffuse DLA gas in the sky at high fidelity. Through this method the researchers were able to determine not only the size of the two DLAs, but also that they both contained host galaxies.
"I've waited most of my career for this combination: a telescope and instrument powerful enough, and nature giving us a bit of lucky alignments to study not one but two DLAs in a rich new way," O'Meara says. "It's great to see the science come to fruition."
The DLAs are huge, by the way. With diameters greater than 17.4 kiloparsecs, they're more than two thirds the size of the Milky Way galaxy today. For comparison, 13 billion years ago, a typical galaxy would have a diameter of less than 5 kiloparsecs. A parsec is 3.26 light years, and a kiloparsec is 1,000 parsecs, so it would take light about 56,723 years to travel across each DLA.
"But to me, the most amazing thing about the DLAs we observed is that they aren't unique -- they seem to have similarities in structure, host galaxies were detected in both, and their masses indicate that they contain enough fuel for the next generation of star formation," Bordoloi says. "With this new technology at our disposal, we are going to be able to dig deeper into how stars formed in the early universe."
The work appears in *Nature* and was supported by the National Aeronautics and Space Administration, the W.M. Keck Foundation and the National Science Foundation. The Australian Research Council Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D) also contributed to the work.

- Astronomers find evidence for most powerful pulsar in distant galaxy

Date: June 15, 2022
Source: National Radio Astronomy Observatory

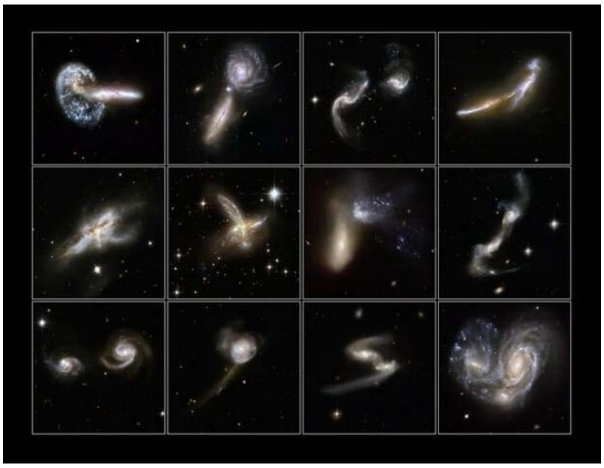


Astronomers analysing data from the VLA Sky Survey (VLASS) have discovered one of the youngest known neutron stars -- the superdense remnant of a massive star that exploded as a supernova. Images from the National Science Foundation's Karl G. Jansky Very Large Array (VLA) indicate that bright radio emission powered by the spinning pulsar's magnetic field has only recently emerged from behind a dense shell of debris from the supernova explosion.
The object, called VT 1137-0337, is in a dwarf galaxy 395 million light-years from Earth. It first appeared in a VLASS image made in January of 2018. It did not appear in an image of the same region made by the VLA's FIRST Survey in 1998. It continued to appear in later VLASS observations in 2018, 2019, 2020, and 2022.
"What we're most likely seeing is a pulsar wind nebula," said Dillon Dong, a Caltech graduate who will begin a Jansky Postdoctoral Fellowship at the National Radio Astronomy

Observatory (NRAO) later this year. A pulsar wind nebula is created when the powerful magnetic field of a rapidly spinning neutron star accelerates surrounding charged particles to nearly the speed of light.
"Based on its characteristics, this is a very young pulsar -- possibly as young as only 14 years, but no older than 60 to 80 years," said Gregg Hallinan, Dong's Ph.D advisor at Caltech.
The scientists reported their findings at the American Astronomical Society's meeting in Pasadena, California.
Dong and Hallinan discovered the object in data from VLASS, an NRAO project that began in 2017 to survey the entire sky visible from the VLA -- about 80 percent of the sky. Over a period of seven years, VLASS is conducting a complete scan of the sky three times, with one of the objectives to find transient objects. The astronomers found VT 1137-0337 in the first VLASS scan from 2018.
Comparing that VLASS scan to data from an earlier VLA sky survey called FIRST revealed 20 particularly luminous transient objects that could be associated with known galaxies.
"This one stood out because its galaxy is experiencing a burst of star formation, and also because of the characteristics of its radio emission," Dong said. The galaxy, called SDSS J113706.18-033737.1, is a dwarf galaxy containing about 100 million times the mass of the Sun.
In studying the characteristics of VT 1137-0337, the astronomers considered several possible explanations, including a supernova, gamma ray burst, or tidal disruption event in which a star is shredded by a supermassive black hole. They concluded that the best explanation is a pulsar wind nebula.
In this scenario, a star much more massive than the Sun exploded as a supernova, leaving behind a neutron star. Most of the original star's mass was blown outward as a shell of debris. The neutron star spins rapidly, and as its powerful magnetic field sweeps through the surrounding space it accelerates charged particles, causing strong radio emission. Initially, the radio emission was blocked from view by the shell of explosion debris. As that shell expanded, it became progressively less dense until eventually the radio waves from the pulsar wind nebula could pass through.
"This happened between the FIRST observation in 1998 and the VLASS observation in 2018," Hallinan said.
Probably the most famous example of a pulsar wind nebula is the Crab Nebula in the constellation Taurus, the result of a supernova that shone brightly in the year 1054. The Crab is readily visible today in small telescopes.
"The object we have found appears to be approximately 10,000 times more energetic than the Crab, with a stronger magnetic field," Dong said. "It likely is an emerging 'super Crab'," he added.
While Dong and Hallinan consider VT 1137-0337 to most likely be a pulsar wind nebula, it also is possible that its magnetic field may be strong enough for the neutron star to qualify as a magnetar -- a class of super-magnetic objects. Magnetars are a leading candidate for the origin of the mysterious Fast Radio Bursts (FRBs) now under intense study.
"In that case, this would be the first magnetar caught in the act of appearing, and that, too, is extremely exciting," Dong said.
Indeed some Fast Radio Bursts have been found to be associated with persistent radio sources, the nature of which also is a mystery. They bear a strong resemblance in their properties to VT 1137-0337, but have shown no evidence of strong variability.
"Our discovery of a very similar source switching on suggests that the radio sources associated with FRBs also may be luminous pulsar wind nebulae," Dong said.
The astronomers plan to conduct further observations to learn more about the object and to monitor its behaviour over time.
The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

- Tracing the remnants of Andromeda's violent history

A detailed analysis of the composition and motion of more than 500 stars revealed conclusive evidence of ancient a collision between Andromeda and a neighbouring galaxy
Date: June 15, 2022
Source: Carnegie Institution for Science



A detailed analysis of the composition and motion of more than 500 stars revealed conclusive evidence of ancient a collision between Andromeda and a neighbouring galaxy. The findings, which improve our understanding of the events that shape galaxy evolution, were presented by Carnegie's Ivanna Escala Monday at the meeting of the American Astronomical Society.

Galaxies grow by accreting material from nearby objects -- other galaxies and dense clumps of stars called globular clusters -- often in the aftermath of a catastrophic crash. And these events leave behind relics in the form of stellar associations that astronomers call tidal features. This can include elongated streams or arcing shells moving around the surviving galaxy. Studying these phenomena can help us understand a galaxy's history and the forces that shaped its appearance and makeup.

"The remnants of each crash can be identified by studying the movement of the stars and their chemical compositions. Together this information serves as a kind of fingerprint that identifies stars that joined a galaxy in a collision," Escala explained.

She and her collaborators -- Karoline Gilbert and Mark Fardal of the Space Telescope Science Institute, Puragra Guhathakurta of UC Santa Cruz, Robyn Sanderson of the University of Pennsylvania, Jason Kalirai of Johns Hopkins Applied Physics Laboratory, and Bahram Mobasher of UC Riverside -- studied 556 red giant branch stars in a physical feature of Andromeda called the Northeast shelf, which forms a sharp ledge in the density of the galaxy's material.

"We performed the first detailed characterization of the chemical composition and geometric motion of the stars in this region of our neighbouring galaxy, demonstrating conclusively that the NE shelf is a tidal shell predominately composed of debris from the aftermath of a collision," Escala explained.

Their work also demonstrates that the NE shelf is part of a multi-shell system with the galaxy's West and Southeast shelves and that the material in these regions is consistent with that of Andromeda's Giant Stellar Stream, linking all of these tidal features as potentially originating from the same source.

"Our results are in line with modelling that predicted the Giant Stellar Stream is the first loop of material from a collision and the NE shelf is the second layer wrap-around," Escala concluded.

This level of analysis confirms predictions about Andromeda's violent past and informs astronomer's understanding of how material accreted by collisions shapes a galaxy's surrounding features and evolutionary history.

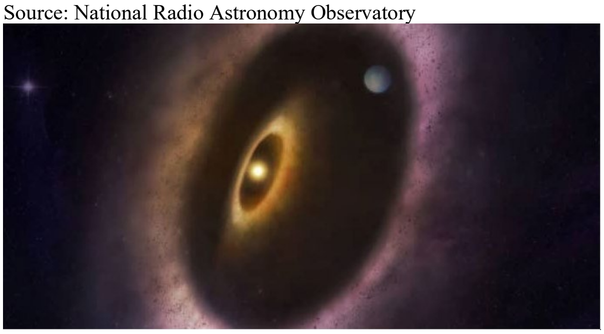
This work was supported by a Carnegie Princeton Fellowship, the U.S. National Science Foundation, NASA, the Research Corporation for Scientific Advancement's Scialog fellows' program on Time Domain Astronomy, and from the Space Telescope Science Institute.

- Scientists on the hunt for planetary formation fossils reveal unexpected eccentricities in nearby debris disk

First radio images of HD 53143 shed new light on the early development of Sun-like systems

Date: June 15, 2022

Source: National Radio Astronomy Observatory



Artist's impression of the billion-year-old Sun-like star, HD 53143, and its highly eccentric debris disk. The star and a second inner disk are shown near the southern foci of the elliptical debris disk. A planet, which scientists assume is shaping the disk through gravitational force, is shown to the north. Debris disks are the fossils of planetary formation and since we can't directly study our own disk— also known as the Kuiper Belt— scientists glean information about the formation of our Solar System by studying those we can see from a distance. Credit: ALMA (ESO/NAOJ/NRAO); M. Weiss (NRAO/AUI/NSF)

Using the Atacama Large Millimetre/submillimetre Array (ALMA), astronomers have imaged the debris disk of the nearby star HD 53143 at millimetre wavelengths for the first time, and it looks *nothing* like they expected. Based on early coronagraphic data, scientists expected ALMA to confirm the debris disk as a face-on ring peppered with clumps of dust. Instead, the observations took a surprise turn, revealing the most complicated and eccentric debris disk observed to date. The observations were presented today in a press conference at the 240th meeting of the American Astronomical Society (AAS) in Pasadena, California, and will be published in an upcoming edition of *The Astrophysical Journal Letters (ApJL).*

HD 53143 -- a roughly billion-year-old Sun-like star located 59.8 light-years from Earth in the Carina constellation -- was first observed with the coronagraphic Advanced Camera for Surveys on the Hubble Space Telescope (HST) in 2006. It also is surrounded by a debris disk -- a belt of comets orbiting a star that are constantly colliding and grinding down into smaller dust and debris -- that scientist previously believed to be a face-on ring similar to the debris disk surrounding our Sun, more commonly known as the Kuiper Belt.

The new observations were made of HD 53143 using the highly-sensitive Band 6 receivers on ALMA, an observatory co-operated by the U.S. National Science Foundation's National Radio Astronomy Observatory (NRAO), and have revealed that the star system's debris disk is actually highly eccentric. In ring-shaped debris disks, the star is typically located at or near the centre of the disk. But in elliptically-shaped eccentric disks, the star resides at one focus of the ellipse, far away from the disk's centre. Such is the case with HD 53143, which wasn't seen in previous coronagraphic studies because coronagraphs purposely block the light of a star in order to more clearly see nearby objects. The star system may also be harbouring a second disk and at least one planet.

"Until now, scientists had never seen a debris disk with such a complicated structure. In addition to being an ellipse with a star at one focus, it also likely has a second inner disk that is misaligned or tilted relative to the outer disk," said Meredith MacGregor, an assistant professor at the Centre for Astrophysics and Space Astronomy (CASA) and Department of Astrophysical and Planetary Sciences (APS) at CU Boulder, and the lead author on the study. "In order to produce this structure, there must be a planet or planets in the system that are gravitationally perturbing the material in the disk."

This level of eccentricity, MacGregor said, makes HD 53143 the most eccentric debris disk observed to date, being twice as eccentric as the Fomalhaut debris disk, which MacGregor fully imaged at millimetre wavelengths using ALMA in 2017. "So far, we have not found many disks with a significant eccentricity. In general, we don't expect disks to be very eccentric unless something, like a planet, is sculpting them and forcing them to be eccentric. Without that force, orbits tend to circularize, like what we see in our own Solar System."

Importantly, MacGregor notes that debris disks aren't just collections of dust and rocks in space. They are a historical record of planetary formation and how planetary systems evolve over time. and provide a peek into their futures. "We can't study the formation of Earth and the Solar System directly, but we can study other systems that appear similar to but younger than our own. It's a bit like looking back in time," she said. "Debris disks are the fossil record of planet formation, and this new result is confirmation that there is much more to be learned from these systems and that knowledge may provide a glimpse into the complicated dynamics of young star systems similar to our own Solar System."

Dr. Joe Pesce, NSF program officer for ALMA, added, "We are finding planets everywhere we look, and these fabulous results by ALMA are showing us how planets form -- both those around other stars and in our own Solar System. This research demonstrates how astronomy works and how progress is made, informing not only what we know about the field but also about ourselves."

- Dead star's cannibalism of its planetary system is most far-reaching ever witnessed

White dwarf sheds light on the systemic chaos that occurs when a star dies

Date: June 15, 2022
Source: University of California - Los Angeles

This illustration shows a white dwarf star siphoning off debris from shattered objects in a planetary system. The Hubble Space Telescope detects the spectral signature of the vaporized debris that revealed a combination of rocky-metallic and icy material, the ingredients of planets. The findings help describe the violent nature of evolved planetary systems and the composition of their disintegrating bodies. Credit: NASA, ESA, Joseph Olmsted (STScI)

The violent death throes of a nearby star so thoroughly disrupted its planetary system that the dead star left behind -- known as a white dwarf -- is sucking in debris from both the system's inner and outer reaches, UCLA astronomers and colleagues report today.

This is the first case of cosmic cannibalism in which astronomers have observed a white dwarf consuming both rocky-metallic material, likely from a nearby asteroid, and icy material, presumed to be from a body similar to those found in the Kuiper belt at the fringe of our own solar system.

"We have never seen both of these kinds of objects accreting onto a white dwarf at the same time," said lead researcher Ted Johnson, a physics and astronomy major at UCLA who graduated last week. "By studying these white dwarfs, we hope to gain a better understanding of planetary systems that are still intact."

The findings are based on an analysis of materials captured by the atmosphere of G238-44, a white dwarf some 86 light-years from Earth, using archival data from the Hubble Space Telescope and additional NASA satellites and observatories. A white dwarf is the burned-out core that remains after a star like our sun sheds its outer layers and stops burning fuel through nuclear fusion.

As surprising as the white dwarf's wide-ranging diet is, the findings are also intriguing because astronomers believe icy objects crashed into and irrigated dry, rocky planets in our solar system -- including Earth. Billions of years ago, comets and asteroids are thought to have delivered water to our planet, sparking the conditions necessary for life. The makeup of the material detected raining onto G238-44 implies that icy reservoirs might be common among planetary systems, said research co-author Benjamin Zuckerman, a UCLA professor of physics and astronomy.

"Life as we know it requires a rocky planet covered with a variety of volatile elements like carbon, nitrogen and oxygen," Zuckerman said. "The abundances of the elements we see on this white dwarf appear to have come from both a rocky parent body and a volatile-rich parent body -- the first example we've found among studies of hundreds of white dwarfs."

Chaos and destruction: From living star to red giant to white dwarf

Theories of planetary-system evolution describe the demise of a star as a turbulent, chaotic event, one that begins when it first balloons exponentially into what is known as a red giant and then quickly loses its outer layers, collapsing into a white dwarf -- a super-dense star about the size of Earth, with a mass of our sun. The process dramatically disrupts the remaining planets' orbits, and smaller objects -- asteroids, comets, moons -- that venture too close to them can be scattered like pinballs and sent hurtling toward the white dwarf.

This study confirms the true scale of the chaos, showing that within 100 million years after the beginning of its white dwarf phase, the star is able to simultaneously capture and consume material from its nearby asteroid belt and its far-flung Kuiper belt-like regions.

Though astronomers have catalogued more than 5,000 planets outside our solar system, the only planet whose interior makeup we have some direct knowledge of is Earth. Because the materials accreting onto G238-44 are representative of the building blocks of major planets, this white dwarf cannibalism provides a unique opportunity to take planets apart and see what they were made of when they first formed around the star, said UCLA astronomy researcher Beth Klein, a member of the team.

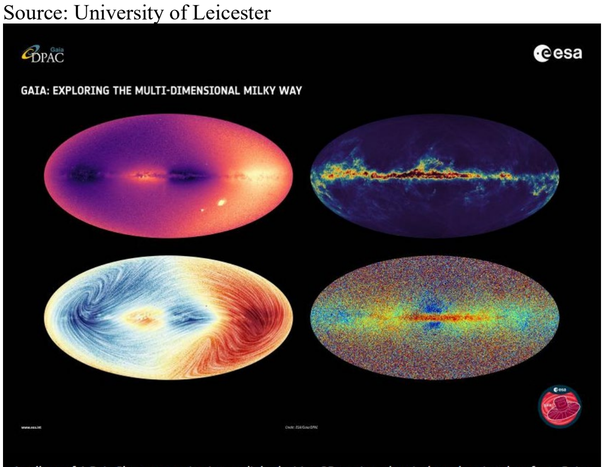
The team measured the presence of nitrogen, oxygen, magnesium, silicon and iron, among other elements, in the white dwarf's atmosphere. Their detection of iron in very high abundance is evidence for metallic cores of terrestrial planets, like Earth, Venus, Mars and Mercury, Johnson said. Unexpectedly high nitrogen abundances led them to conclude that icy bodies were also present.

"The best fit for our data was a nearly two-to-one mix of Mercury-like material and comet-like material, which is made up of ice and dust," Johnson said. "Iron metal and nitrogen

ice each suggest wildly different conditions of planetary formation. There is no known solar system object with so much of both."
The researchers say the ultimate scenario for our own sun some 5 billion years from now will likely be quite similar to what has been seen with G238-44. During the sun's red giant phase, the Earth might be completely vaporized along with the inner planets, they predict.
The orbits of many of the asteroids in our solar system's main asteroid belt will be gravitationally perturbed by Jupiter and will also fall onto the white dwarf remnant that the sun will become, he said.
For more than two years, the research group at UCLA, along with colleagues at UC San Diego and the University of Kiel in Germany, has worked to unravel the mystery of G238-44 by analysing the elements detected on the white dwarf star.
Their analysis included data from NASA's retired Far Ultraviolet Spectroscopic Explorer, the Keck Observatory's High Resolution Echelle Spectrometer in Hawaii and the Hubble Space Telescope's Cosmic Origins Spectrograph and Space Telescope Imaging Spectrograph. The Hubble Space Telescope is a project of international cooperation between NASA and the European Space Agency.
The team's results were presented at an American Astronomical Society press conference on June 15.

- Gaia Data Release 3: 'Complete step change' in understanding of our Universe

Date: June 15, 2022
Source: University of Leicester



A collage of 4 Gaia Sky maps: extinction, radial velocities, 3D motion, chemical, made using data from Gaia.
Credit: *ESA/Gaia/DPAC*
Licence type: *Attribution (CC BY 4.0)*

Space scientists have recently announced the discovery of a 'super Jupiter' orbiting a white dwarf, the first detected using direct observations with the European Space Agency (ESA)'s Gaia mission.
The discovery forms part of a treasure trove of data made available in Gaia's Data Release 3, which provides the most detailed survey of our galactic neighbourhood to date.
Observations made by the Gaia observatory, which orbits a point in space about 1.5 million km from Earth, will allow astronomers to create the most accurate and complete multi-dimensional map of the Milky Way and better understand our place in the Universe.
Martin Barstow, Professor of Astrophysics and Space Science at the University of Leicester and Director of Strategic Partnerships for Space Park Leicester, is part of the Gaia collaboration to have co-authored multiple papers using the new data.
Other highlights of Data Release 3 include description of 'starquakes', stellar DNA and a new binary star catalogue of more than 800,000 binary systems. Before Gaia launched in 2013, only around 30,000 binaries were known in our galaxy.
Professor Barstow said:
"Gaia data has been moving through astronomy like a tidal wave. It's the most productive observatory we have available to use right now, and it's transforming both astronomy and our understanding of the Universe.
"This Data Release 3 is a complete step change. All the data we have catalogued using spectra -- stellar distances, ages, composition, and more -- adds an extra dimension to what we know about the stars in our galaxy, and represents a huge leap forward."

Data reveals a 'super Jupiter' companion

Observations of exoplanets orbiting white dwarfs is notoriously difficult. White dwarfs are the core remnant of stars not massive enough to become a black hole or neutron star.
However, by analysing the motion of the metal-rich white dwarf WD 0141-675 and noting a 'wobble' in its orbit, researchers inferred the existence of a companion object with a mass around nine times that of Jupiter. Too small to be a star, this must be an exoplanet.
This 'super Jupiter' is only the third known exoplanet to orbit a white dwarf, and makes WD 0141-675 the closest white dwarf to Earth to host a planet.

Stars in their eyes: Gaia more than doubles number of known binaries

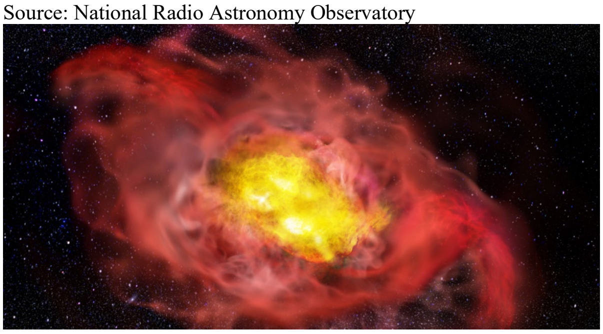
Gaia's Data Release 3 also expands astronomers' understanding of binary systems, where two stars are gravitationally bound to one another. Sirius, the brightest star visible from Earth (after our Sun), is a binary system comprising a main sequence star, Sirius A, and a faint white dwarf companion, Sirius B. These new datasets both refine the stellar catalogue of known binaries and add many newer such systems, bringing the total of known binary systems from around 300,000 before Data Release 3 to more than 800,000.
Researchers detect binaries using Gaia's radial velocity spectrometer and a variety of techniques;

- astrometry: by detecting the motion of source objects which are not uniform and are observed to 'wobble' or otherwise change direction from what would otherwise be expected;
- photometry: when aligned with Gaia's line of sight, where one star is observed to pass in front of another and periodically 'eclipse' its companion;
- and spectroscopy: these binaries have a radial velocity that varies periodically, depending on whether a star approaches or recedes from our viewpoint at Earth.

Professor Barstow continued:
"We have so much more data on binaries with this release and, crucially, that data is so much more precise than what has gone before.
"Once you have more precise data about a binary system you can work out all sorts of things such as ages and composition: all aspects we haven't had information on before.
"And by answering those questions, we can start to understand more of the fundamentals about how our Universe works, including how stars live and die."

- Young galaxy's coming of age: Early galaxies may be surprisingly big and complex

Date: June 15, 2022
Source: National Radio Astronomy Observatory



Scientists using the Atacama Large Millimetre/submillimetre Array (ALMA) -- an international observatory co-operated by the US National Science Foundation's National Radio Astronomy Observatory (NRAO) -- have observed a significant amount of cold, neutral gas in the outer regions of the young galaxy A1689-zD1, as well as outflows of hot gas coming from the galaxy's centre. These results may shed light on a critical stage of galactic evolution for early galaxies, where young galaxies begin the transformation to be increasingly like their later, more structured cousins. The observations were presented today in a press conference at the 240th meeting of the American Astronomical Society (AAS) in Pasadena, California, and will be published in an upcoming edition of *The Astrophysical Journal (ApJ).*
A1689-zD1 -- a young, active, star-forming galaxy that is slightly less luminous and less massive than the Milky Way -- is located roughly 13 billion light-years away from Earth in the Virgo constellation cluster. It was discovered hiding out behind the Abell 1689 galaxy cluster in 2007 and confirmed in 2015 thanks to gravitational lensing, which amplified the brightness of the young galaxy by more than 9x. Since then, scientists have continued to study the galaxy as a possible analogue for the evolution of other "normal" galaxies. That label -- normal -- is an important distinction that has helped researchers divide A1689-zD1's behaviours and characteristics into two buckets: typical and uncommon, with the uncommon characteristics mimicking those of later and more massive galaxies.
"A1689-zD1 is located in the very early Universe -- only 700 million years after the Big Bang. This is the era where galaxies were just beginning to form," said Hollis Akins, an undergraduate student in astronomy at Grinnell College and the lead author of the research. "What we're seeing in these new observations is evidence of processes that may contribute to the evolution of what we call normal galaxies as opposed to massive galaxies. More importantly, these processes are ones we did not previously believe applied to these normal galaxies."
One of these uncommon processes is the galaxy's production and distribution of star-forming fuel, and potentially a lot of it. The team used ALMA's highly-sensitive Band 6

receiver to home in on a halo of carbon gas that extends far beyond the centre of the young galaxy. This could be evidence of ongoing star formation in the same region or the result of structural disruptions, such as mergers or outflows, in the earliest stages of the galaxy's formation.

According to Akins, this is unusual for early galaxies. "The carbon gas we observed in this galaxy is typically found in the same regions as neutral hydrogen gas, which is also where new stars tend to form. If that is the case with A1689-zD1, the galaxy is likely much larger than previously thought. It's also possible that this halo is a remnant of previous galactic activity, like mergers that exerted complex gravitational forces on the galaxy leading to the ejection of a lot of neutral gas out to these large distances. In either case, the early evolution of this galaxy was likely active and dynamic, and we're learning that this may be a common, although previously unobserved, theme in early galaxy formation."

More than just uncommon, the discovery could have significant implications for the study of galactic evolution, particularly as radio observations uncover details unseen at optical wavelengths. Seiji Fujimoto, a postdoctoral researcher at the Niels Bohr Institute's Cosmic Dawn Centre, and a co-author of the research said, "The emission from the carbon gas in A1689-zD1 is much more extended than what was observed with Hubble Space Telescope, and this could mean that early galaxies are not as small as they appear. If, in fact, early galaxies are larger than we previously believed this would have a major impact on the theory of galaxy formation and evolution in the early Universe."

Led by Akins, the team also observed outflows of hot, ionized gas -- commonly caused by violent galactic activity like supernovae -- pushing outward from the centre of the galaxy. It's possible, given their potentially explosive nature, that the outflows have something to do with the carbon halo. "Outflows occur as a result of violent activity, such as the explosion of supernovae -- which blast nearby gaseous material out of the galaxy -- or black holes in the centres of galaxies -- which have strong magnetic effects that can eject material in powerful jets. Because of this, there's a strong possibility that the hot outflows have something to do with the presence of the cold carbon halo," said Akins. "And that further highlights the importance of the multiphase, or hot to cold, nature of the outflowing gas."

Darach Watson, an associate professor at the Niels Bohr Institute's Cosmic Dawn Centre, and co-author of the new research confirmed A1689-zD1 as a high-redshift galaxy in 2015, making it the most distant dusty galaxy known. "We have seen this type of extended gas halo emission from galaxies that formed later in the Universe, but seeing it in such an early galaxy means that this type of behaviour is universal even in the more modest galaxies that formed most of the stars in the early Universe. Understanding how these processes occurred in such a young galaxy is critical to understanding how star-formation happens in the early Universe."

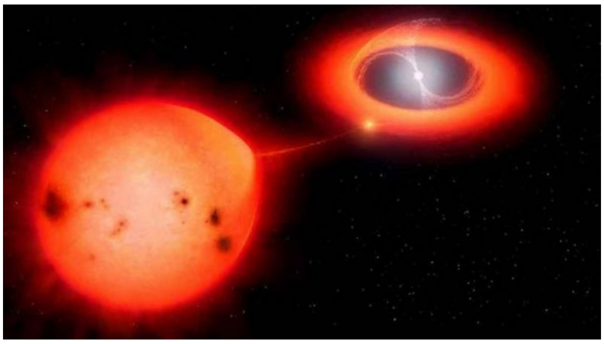
Kirsten Knudsen, a professor of astrophysics in the Department of Space, Earth, and Environment at Chalmers University of Technology, and co-author of the research found evidence of A1689-zD1's dust continuum in 2017. Knudsen pointed out the serendipitous role of extreme gravitational lensing in making each new discovery in the research possible. "Because A1689-zD1 is magnified more than nine times, we can see critical details that are otherwise difficult to observe in ordinary observations of such distant galaxies. Ultimately, what we're seeing here is that early Universe galaxies are very complex, and this galaxy will continue to present new research challenges and results for some time."

Dr. Joe Pesce, NSF program officer for ALMA, added, "This fascinating ALMA research adds to a growing body of results indicating that things aren't quite as we expected in the early Universe, but they are really interesting and exciting nonetheless!"

Spectroscopy and infrared observations of A1689-zD1 are planned for January 2023, using the NIRSpec Integral Field Unit (IFU) and NIRCam on the James Webb Space Telescope. The new observations will complement previous HST and ALMA data, offering a deeper and more complete multi-wavelength look at the young galaxy.

- A weird star produced the fastest nova on record

Date: June 15, 2022
Source: Arizona State University



This illustration shows an intermediate polar system, a type of two-star system that the research team thinks V1674 Hercules belongs to. A flow of gas from the large companion star impacts an accretion disk before flowing along magnetic field lines onto the white dwarf. Credit: Mark Garlick

Astronomers are buzzing after observing the fastest nova ever recorded. The unusual event drew scientists' attention to an even more unusual star. As they study it, they may find answers to not only the nova's many baffling traits, but to larger questions about the chemistry of our solar system, the death of stars and the evolution of the universe.

The research team, led by Arizona State University Regents Professor Sumner Starrfield, Professor Charles Woodward from University of Minnesota and Research Scientist Mark Wagner from The Ohio State University, co-authored a report published today in the *Research Notes of the American Astronomical Society*.

A nova is a sudden explosion of bright light from a two-star system. Every nova is created by a white dwarf -- the very dense leftover core of a star -- and a nearby companion star. Over time, the white dwarf draws matter from its companion, which falls onto the white dwarf. The white dwarf heats this material, causing an uncontrolled reaction that releases a burst of energy. The explosion shoots the matter away at high speeds, which we observe as visible light.

The bright nova usually fades over a couple of weeks or longer. On June 12, 2021, the nova V1674 Hercules burst so bright that it was visible to the naked eye -- but in just over one day, it was faint once more. It was like someone flicked a flashlight on and off.

Nova events at this level of speed are rare, making this nova a precious study subject.

"It was only about one day, and the previous fastest nova was one we studied back in 1991, V838 Herculis, which declined in about two or three days," says Starrfield, an astrophysicist in ASU's School of Earth and Space Exploration.

As the astronomy world watched V1674 Hercules, other researchers found that its speed wasn't its only unusual trait. The light and energy it sends out is also pulsing like the sound of a reverberating bell.

Every 501 seconds, there's a wobble that observers can see in both visible light waves and X-rays. A year after its explosion, the nova is still showing this wobble, and it seems it's been going on for even longer. Starrfield and his colleagues have continued to study this quirk.

"The most unusual thing is that this oscillation was seen before the outburst, but it was also evident when the nova was some 10 magnitudes brighter," says Wagner, who is also the head of science at the Large Binocular Telescope Observatory being used to observe the nova. "A mystery that people are trying to wrestle with is what's driving this periodicity that you would see it over that range of brightness in the system."

The team also noticed something strange as they monitored the matter ejected by the nova explosion -- some kind of wind, which may be dependent on the positions of the white dwarf and its companion star, is shaping the flow of material into space surrounding the system.

Though the fastest nova is (literally) flashy, the reason its worth further study is that novae can tell us important information about our solar system and even the universe as a whole.

A white dwarf collects and alters matter, then seasons the surrounding space with new material during a nova explosion. It's an important part of the cycle of matter in space. The materials ejected by novae will eventually form new stellar systems. Such events helped form our solar system as well, ensuring that Earth is more than a lump of carbon.

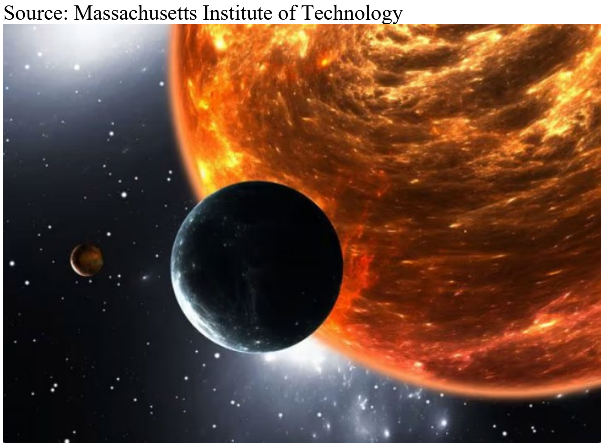
"We're always trying to figure out how the solar system formed, where the chemical elements in the solar system came from," Starrfield says. "One of the things that we're going to learn from this nova is, for example, how much lithium was produced by this explosion. We're fairly sure now that a significant fraction of the lithium that we have on the Earth was produced by these kinds of explosions."

Sometimes a white dwarf star doesn't lose all of its collected matter during a nova explosion, so with each cycle, it gains mass. This would eventually make it unstable, and the white dwarf could generate a type 1a supernova, which is one of the brightest events in the universe. Each type 1a

supernova reaches the same level of brightness, so they are known as standard candles.
"Standard candles are so bright that we can see them at great distances across the universe. By looking at how the brightness of light changes, we can ask questions about how the universe is accelerating or about the overall three-dimensional structure of the universe," Woodward says. "This is one of the interesting reasons that we study some of these systems."
Additionally, novae can tell us more about how stars in binary systems evolve to their death, a process that is not well understood. They also act as living laboratories where scientists can see nuclear physics in action and test theoretical concepts.
The nova took the astronomy world by surprise. It wasn't on scientists' radar until an amateur astronomer from Japan, Seidji Ueda, discovered and reported it.
Citizen scientists play an increasingly important role in the field of astronomy, as does modern technology. Even though it is now too faint for other types of telescopes to see, the team is still able to monitor the nova thanks to the Large Binocular Telescope's wide aperture and its observatory's other equipment, including its pair of multi-object double spectrographs and exceptional PEPSI high resolution spectrograph.
They plan to investigate the cause of the outburst and the processes that led to it, the reason for its record-breaking decline, the forces behind the observed wind, and the cause of its pulsing brightness.

- Astronomers discover a multiplanet system nearby

Just 33 light years from Earth, the system appears to host two rocky, Earth-sized planets
Date: June 15, 2022
Source: Massachusetts Institute of Technology



Astronomers at MIT and elsewhere have discovered a new multiplanet system within our galactic neighbourhood that lies just 10 parsecs, or about 33 light-years, from Earth, making it one of the closest known multiplanet systems to our own.
At the heart of the system lies a small and cool M-dwarf star, named HD 260655, and astronomers have found that it hosts at least two terrestrial, Earth-sized planets. The rocky worlds are likely not habitable, as their orbits are relatively tight, exposing the planets to temperatures that are too high to sustain liquid surface water.
Nevertheless, scientists are excited about this system because the proximity and brightness of its star will give them a closer look at the properties of the planets and signs of any atmosphere they might hold.
"Both planets in this system are each considered among the best targets for atmospheric study because of the brightness of their star," says Michelle Kunimoto, a postdoc in MIT's Kavli Institute for Astrophysics and Space Research and one of the discovery's lead scientists. "Is there a volatile-rich atmosphere around these planets? And are there signs of water or carbon-based species? These planets are fantastic test beds for those explorations."
The team will present its discovery today at the meeting of the American Astronomical Society in Pasadena, California. Team members at MIT include Katharine Hesse, George Ricker, Sara Seager, Avi Shporer, Roland Vanderspek, and Joel Villasen?or, along with collaborators from institutions around the world.
Data power
The new planetary system was initially identified by NASA's Transiting Exoplanet Survey Satellite (TESS), an MIT-led mission that is designed to observe the nearest and brightest stars, and detect periodic dips in light that could signal a passing planet.
In October 2021, Kunimoto, a member of MIT's TESS science team, was monitoring the satellite's incoming data when she noticed a pair of periodic dips in starlight, or transits, from the star HD 260655.
She ran the detections through the mission's science inspection pipeline, and the signals were soon classified as two TESS Objects of Interest, or TOIs -- objects that are flagged as potential planets. The same signals were also found independently by the Science

Processing Operations Centre (SPOC), the official TESS planet search pipeline based at NASA Ames. Scientists typically plan to follow up with other telescopes to confirm that the objects are indeed planets.
The process of classifying and subsequently confirming new planets can often take several years. For HD 260655, that process was shortened significantly with the help of archival data.
Soon after Kunimoto identified the two potential planets around HD 260655, Shporer looked to see whether the star was observed previously by other telescopes. As luck would have it, HD 260655 was listed in a survey of stars taken by the High Resolution Echelle Spectrometer (HIRES), an instrument that operates as part of the Keck Observatory in Hawaii. HIRES had been monitoring the star, along with a host of other stars, since 1998, and the researchers were able to access the survey's publicly available data.
HD 260655 was also listed as part of another independent survey by CARMENES, an instrument that operates as part of the Calar Alto Observatory in Spain. As these data were private, the team reached out to members of both HIRES and CARMENES with the goal of combining their data power.
"These negotiations are sometimes quite delicate," Shporer notes. "Luckily, the teams agreed to work together. This human interaction is almost as important in getting the data [as the actual observations]."

Planetary pull

In the end, this collaborative effort quickly confirmed the presence of two planets around HD 260655 in about six months.
To confirm that the signals from TESS were indeed from two orbiting planets, the researchers looked through both HIRES and CARMENES data of the star. Both surveys measure a star's gravitational wobble, also known as its radial velocity.
"Every planet orbiting a star is going to have a little gravitational pull on its star," Kunimoto explains. "What we're looking for is any slight movement of that star that could indicate a planetary-mass object is tugging on it."
From both sets of archival data, the researchers found statistically significant signs that the signals detected by TESS were indeed two orbiting planets.
"Then we knew we had something very exciting," Shporer says.
The team then looked more closely at TESS data to pin down properties of both planets, including their orbital period and size. They determined that the inner planet, dubbed HD 260655b, orbits the star every 2.8 days and is about 1.2 times as big as the Earth. The second outer planet, HD 260655c, orbits every 5.7 days and is 1.5 times as big as the Earth.
From the radial-velocity data from HIRES and CARMENES, the researchers were able to calculate the planets' mass, which is directly related to the amplitude by which each planet tugs on its star. They found the inner planet is about twice as massive as the Earth, while the outer planet is about three Earth masses. From their size and mass, the team estimated each planet's density. The inner, smaller planet is slightly denser than the Earth, while the outer, larger planet is a bit less dense. Both planets, based on their density, are likely terrestrial, or rocky in composition.
The researchers also estimate, based on their short orbits, that the surface of the inner planet is a roasting 710 kelvins (818 degrees Fahrenheit), while the outer planet is around 560 K (548 F).
"We consider that range outside the habitable zone, too hot for liquid water to exist on the surface," Kunimoto says.
"But there might be more planets in the system," Shporer adds. "There are many multiplanet systems hosting five or six planets, especially around small stars like this one. Hopefully we will find more, and one might be in the habitable zone. That's optimistic thinking."
This research was supported, in part, by NASA, the Max-Planck-Gesellschaft, the Consejo Superior de Investigaciones Científicas, the Ministerio de Economía y Competitividad, and the European Regional Development Fund.