South Downs Mercury

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Main Speaker William Joyce Scientific Exploration of the Moon

- Massive fuel-hungry black holes feed off intergalactic gas

Date: January 19, 2023
Source: University of Southampton

Two interacting galaxies viewed from the Hubble Space Telescope: NASA/ESA/Hubble Heritage Team.

Research led by the University of Southampton has revealed how supermassive black holes (SMBHs) are feeding off gas clouds which reach them by travelling hundreds of thousands of light years from one galaxy to another.

An international team of scientists has shown there is a crucial link between the interaction of neighbouring galaxies and the enormous amount of gas needed to 'fuel' these giant, super-dense, space phenomena. Their findings are due to be published in the journal *Nature Astronomy*.

A black hole can be created when a star collapses, squeezing matter into a relatively tiny space. This increases the force of gravity to a point where nothing can escape, not even light -- hence the name.

Some black holes are gigantic, with masses millions of times greater than our sun, emitting enormous amounts of energy. These are known as 'supermassive black holes' and exactly how they are formed or gain enough fuel to power themselves is still a mystery.

Astrophysicist and lead researcher from the University of Southampton, Dr Sandra Raimundo, comments: "Supermassive black holes fuel their activity by, in part, the gradual accumulation of gas from the environment around them. Supermassive black holes can make the centres of galaxies shine very brightly when they capture gas and it's thought this process can be a major influence on the way that galaxies look today. How SMBHs get enough fuel to sustain their activity and growth still puzzles astronomers, but the work we have carried out provides a step towards understanding this."

The Southampton scientist, working with researchers at the universities of Copenhagen and California, used data from the 4-metre Anglo-Australian telescope in New South Wales, Australia* to study the orbits of gas and stars in a large sample of more than 3000 galaxies. They identified those with the presence of what is known as 'misaligned' gas -- in other words, gas which rotates in a different direction from the stars in the galaxy, signalling a past galaxy interaction. They then found that galaxies with misaligned gas had a higher fraction of active supermassive black holes.

The results showed a clear link between misaligned gas and supermassive black hole activity -- suggesting the gas is transferred where two galaxies meet, meanders vast distances through space and then succumbs to the huge gravitational forces of the supermassive black hole -- pulled in and swallowed up as a vital source of fuel.

Astronomers have long suspected that a merger with another galaxy could provide this source of gas, but direct evidence for this has been elusive.

Dr Raimundo explains: "The work that we carried out shows the presence of gas that is misaligned from stars is associated with an increase in the fraction of active supermassive black holes. Since misaligned gas is a clear sign of a past interaction between two galaxies, our work shows that galaxy interactions provide fuel to power active supermassive black holes.

"This is the first time that a direct connection has been observed between the formation and

presence of misaligned gas and the fuelling of active supermassive black holes."
Dr Marianne Vestergaard, a co-author in the study, highlights: "What is exciting about these observations is that we can now, for the very first time, identify the captured gas and trace it all the way to the centre where the black hole is devouring it."
The scientists now hope to extend their research and use their findings to calculate how much of the total mass of supermassive black holes grew from this mechanism and how important this was in the early Universe.

- Billions of celestial objects revealed in gargantuan survey of the Milky Way

Colossal astronomical data tapestry displaying the majesty of our Milky Way in unprecedented detail
Date: January 18, 2023
Source: Association of Universities for Research in Astronomy (AURA)

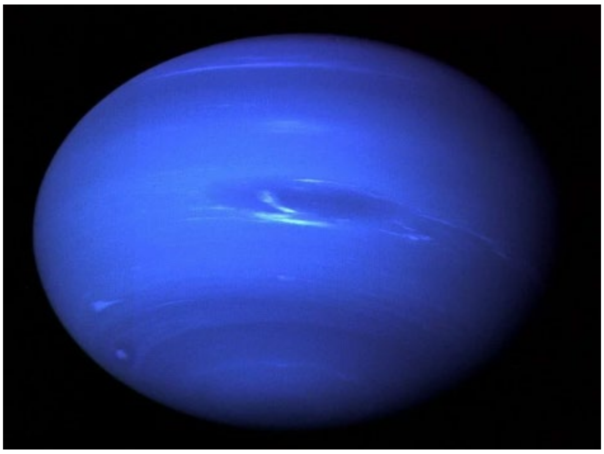
This image shows part of a gargantuan new survey of the Milky Way's galactic plane conducted by the Dark Energy Camera at the U.S. National Science Foundation's Cerro Tololo Inter-American Observatory in Chile. The new dataset contains 3.32 billion celestial objects. (Image credit: DECaPS2/DOE/FNAL/DECam/CTIO/NOIRLab/NSF/AURA; Image processing: M. Zamani & D. de Martin (NSF's NOIRLab))

Astronomers have released a gargantuan survey of the galactic plane of the Milky Way. The new dataset contains a staggering 3.32 billion celestial objects -- arguably the largest such catalogue so far. The data for this unprecedented survey were taken with the Dark Energy Camera, built by the US Department of Energy, at the NSF's Cerro Tololo Inter-American Observatory in Chile, a Program of NOIRLab.
The Milky Way Galaxy contains hundreds of billions of stars, glimmering star-forming regions, and towering dark clouds of dust and gas. Imaging and cataloguing these objects for study is a herculean task, but a newly released astronomical dataset known as the second data release of the Dark Energy Camera Plane Survey (DECaPS2) reveals a staggering number of these objects in unprecedented detail. The DECaPS2 survey, which took two years to complete and produced more than 10 terabytes of data from 21,400 individual exposures, identified approximately 3.32 billion objects -- arguably the largest such catalogue compiled to date. Astronomers and the public can explore the dataset here.
This unprecedented collection was captured by the Dark Energy Camera (DECam) instrument on the Víctor M. Blanco 4-meter Telescope at Cerro Tololo Inter-American Observatory (CTIO), a Program of NSF's NOIRLab. CTIO is a constellation of international astronomical telescopes perched atop Cerro Tololo in Chile at an altitude of 2200 meters (7200 feet). CTIO's lofty vantage point gives astronomers an unrivalled view of the southern celestial hemisphere, which allowed DECam to capture the southern Galactic plane in such detail.
DECaPS2 is a survey of the plane of the Milky Way as seen from the southern sky taken at optical and near-infrared wavelengths. The first trove of data from DECaPS was released in 2017, and with the addition of the new data release, the survey now covers 6.5% of the night sky and spans a staggering 130 degrees in length. While it might sound modest, this equates to 13,000 times the angular area of the full Moon.
The DECaPS2 dataset is available to the entire scientific community and is hosted by NOIRLab's Astro Data Lab, which is part of the Community Science and Data Centre. Interactive access to the imaging with panning/zooming inside of a web-browser is available from the Legacy Survey Viewer, the World-Wide Telescope and Aladin.
Most of the stars and dust in the Milky Way are located in its disk -- the bright band stretching across this image -- in which the spiral arms lie. While this profusion of stars and dust makes for beautiful images, it also makes the Galactic plane challenging to observe. The dark tendrils of dust seen threading through this image absorb starlight and blot out fainter stars entirely, and the light from diffuse nebulae interferes with any attempts to measure the brightness of individual objects. Another challenge arises from the sheer number of stars, which can overlap in the image and make it difficult to disentangle individual stars from their neighbours.
Despite the challenges, astronomers delved into the Galactic plane to gain a better understanding of our Milky Way. By observing at near-infrared wavelengths, they were able to peer past much of the light-absorbing dust. The researchers also used an

innovative data-processing approach, which allowed them to better predict the background behind each star. This helped to mitigate the effects of nebulae and crowded star fields on such large astronomical images, ensuring that the final catalogue of processed data is more accurate.
"One of the main reasons for the success of DECaPS2 is that we simply pointed at a region with an extraordinarily high density of stars and were careful about identifying sources that appear nearly on top of each other," said Andrew Saydjari, a graduate student at Harvard University, researcher at the Centre for Astrophysics | Harvard & Smithsonian and lead author of the paper. "Doing so allowed us to produce the largest such catalogue ever from a single camera, in terms of the number of objects observed."
"When combined with images from Pan-STARRS 1, DECaPS2 completes a 360-degree panoramic view of the Milky Way's disk and additionally reaches much fainter stars," said Edward Schlafly, a researcher at the AURA-managed Space Telescope Science Institute and a co-author of the paper describing DECaPS2 published in the Astrophysical Journal Supplement. "With this new survey, we can map the three-dimensional structure of the Milky Way's stars and dust in unprecedented detail."
"Since my work on the Sloan Digital Sky Survey two decades ago, I have been looking for a way to make better measurements on top of complex backgrounds," said Douglas Finkbeiner, a professor at the Centre for Astrophysics, co-author of the paper, and principal investigator behind the project. "This work has achieved that and more!"
"This is quite a technical feat. Imagine a group photo of over three billion people and every single individual is recognizable!" says Debra Fischer, division director of Astronomical Sciences at NSF. "Astronomers will be poring over this detailed portrait of more than three billion stars in the Milky Way for decades to come. This is a fantastic example of what partnerships across federal agencies can achieve."
DECam was originally built to carry out the Dark Energy Survey, which was conducted by the Department of Energy and the US National Science Foundation between 2013 and 2019.

- ❖ Tumultuous migration on the edge of the Hot Neptune Desert

Date: January 18, 2023
Source: Université de Genève



All kinds of exoplanets orbit very close to their star. Some look like the Earth, others like Jupiter. Very few, however, are similar to Neptune. Why this anomaly in the distribution of exoplanets? Researchers from the University of Geneva (UNIGE) and the National Centre of Competence in Research (NCCR) PlanetS have observed a sample of planets located at the edge of this Hot Neptune Desert to understand its creation. Using a technique combining the two main methods of studying exoplanets (radial velocities and transits), they were able to establish that a part of these exoplanets has migrated in a turbulent way near their star, which pushed them out of the orbital plane where they were formed. These results are published in the specialized journal *Astronomy & Astrophysics*.
Since the discovery of the first exoplanet in 1995, researchers have detected more than 5'000 planets in our galactic neighbourhood, most of them orbiting very close to their star. If the diversity of these new world's ranges from gas giants the size of Jupiter or Saturn to smaller planets the size of Mercury, including rocky planets larger than the Earth, gas planets the size of Neptune seem to be missing. Astronomers call this empty "box" in the distribution of close-in planets the Hot Neptune Desert.
"The distribution of planets close to their star is shaped by a complex interaction between atmospheric and dynamical processes, i.e., the motions of the planets over time," comments Vincent Bourrier, assistant professor in the Department of Astronomy at the UNIGE Faculty of Science. "Today we have several hypotheses to explain this desert but nothing is certain yet and the mystery remains". Did these planets lose their atmosphere entirely,

eroded by the intense radiation of their star? Did they migrate from their birthplace to the outer parts of the system by a different mechanism than other types of planets, preventing them from reaching the same close orbits?

Disrupted migration

In a recent work, a team of scientists from the UNIGE brings some answers by looking at the orbital architecture of the planets located at the edge of this desert. By surveying fourteen planets around this area, ranging from small planets to gas giants, the astronomers were interested in the way their orbits are oriented with respect to the axis of rotation of their star. This information makes it possible to distinguish the processes of soft migration (the planets move in the equatorial plane of their star where they were formed) from the processes of disruptive migration (the planets migrate and are pushed out of the plane where they were formed).

The researchers were able to show that most of the planets in their sample have an orbit misaligned with the stellar equator. "We found that three-quarters of these planets have a polar orbit (they rotate above the poles of their star), which is a larger fraction than for planets further away from the desert. This reflects the role of disruptive migration processes in the formation of the desert," summarizes Vincent Bourrier, first author.

Two methods combined

To achieve these results, the scientists used the radial velocity method and the transit method, which are employed to study exoplanets. "Analysing the radial velocities during the transit of a planet allows us to determine if it orbits around the stellar equator, around the poles, or if the system is in an intermediate configuration, because different architectures will produce different signatures," explains Omar Attia, a doctoral student in the Department of Astronomy at the UNIGE Faculty of Science and second author of the study. These two methods were combined with data obtained with the HARPS and HARPS-North spectrographs, created at UNIGE and located on the 3.6m telescope of ESO (European Southern Observatory) and TNG (Telescopio Nazionale Galileo).

The path to understand all of the mechanisms involved in the formation of the Hot Neptune Desert is still long. It will be necessary in particular to explore with this technique the smallest planets at the edge of the desert, today difficult to access even with instruments of last generation such as the spectrograph ESPRESSO, built by the UNIGE and installed on the largest European telescopes. It will be necessary to wait for the commissioning of the ELT, the 39-meter super telescope of ESO, planned for 2027.

This research was conducted within the framework of the SPICE DUNE project (SpectroPhotometric Inquiry of Close-in Exoplanets around the Desert to Understand their Nature and Evolution), for which Vincent Bourrier was supported by the European Research Council (ERC).

- How did the Butterfly Nebula get its wings? It's complicated

Date: January 12, 2023

Source: University of Washington

Planetary nebulae form when red giant stars expel their outermost layers as they run out of helium fuel -- becoming hot, dense white dwarf stars that are roughly the size of Earth. The material that was shed, enriched in carbon, forms dazzling patterns as it is blown gently into the interstellar medium.

Most planetary nebulae are roughly circular, but a few have an hourglass or wing-like shape, like the aptly named "Butterfly Nebula." These shapes are likely formed by the gravitational tug of a second star orbiting the nebula's "parent" star, causing the material to expand into a pair of nebular lobes, or "wings." Like an expanding balloon, the wings grow over time without changing their original shape.

Yet new research shows that something is amiss in the Butterfly Nebula. When a team led by astronomers at the University of Washington compared two exposures of the Butterfly Nebula taken by the Hubble Space Telescope in 2009 and 2020, they saw dramatic changes in the material within the wings. As they will report on Jan. 12 at the 241st meeting of the American Astronomical Society in Seattle, powerful winds are driving complex alterations of material within the nebula's wings. They want to understand how such activity is possible from what should be a "sputtering, largely moribund star with no remaining fuel."

"The Butterfly Nebula is extreme for the mass, speed and complexity of its ejections from its central star, whose temperature is more than 200 times hotter than the sun yet is just slightly larger than the Earth," said team leader Bruce Balick, a UW professor emeritus of astronomy. "I've been comparing Hubble images for years and I've never seen anything quite like it."

The team compared high-quality Hubble images taken 11 years apart to chart the speeds and growth patterns of features within the nebula's wings. The bulk of the analysis was performed by Lars Borchert, a graduate student at Aarhus University in Denmark who participated in this study as a UW undergraduate student.

Borchert discovered roughly half a dozen "jets" -- beginning about 2,300 years ago and ending 900 years ago -- pushing material out in a series of asymmetrical outflows. Material in the outer portions of the nebula is moving rapidly, at about 500 miles per second, while material closer to the hidden central star is expanding much more slowly, at about a tenth of that speed. Paths of the jets cross one another, forming "messy" structures and growth patterns within the wings.

The nebula's multi-polar and swiftly changing interior structure is not easy to explain using existing models of how planetary nebulae form and evolve, according to Balick. The star at the centre of the nebula, which is hidden by dust and debris, could have merged with a companion star or drew off material from a nearby star, creating complex magnetic fields and generating the jets.

"At this point, these are all just hypotheses," said Balick. "What this shows us is that we don't fully understand the full range of shaping processes at work when planetary nebulae form. The next step is to image the nebular centre using the James Webb Space Telescope, since infrared light from the star can penetrate through the dust."

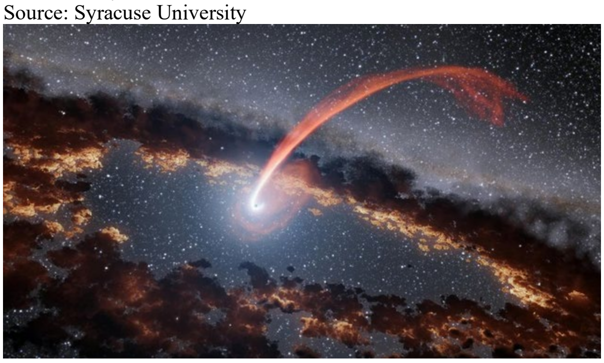
Stars like our sun will swell into a red giant and form planetary nebulae someday, expelling carbon and other relatively heavy elements into the interstellar medium to form star systems and planets in the far future. This new research, and other "time-lapse" analyses of planetary nebulae, can help illustrate not just how the materials for the star systems of tomorrow will take shape, but also how the building blocks of our own oasis were produced and gathered billions of years ago.

"It's a creation story that is happening over and over again in our universe," said Balick. "The shaping processes provide key insight into the history and impacts of the stellar activity."

Other team members are Joel Kastner of the Rochester Institute of Technology and Adam Frank of the University of Rochester.

- A star's unexpected survival

Date: January 13, 2023
Source: Syracuse University



This illustration shows a glowing stream of material from a star as it is being devoured by a supermassive black hole in a tidal disruption flare. When a star passes within a certain distance of a black hole - close enough to be gravitationally disrupted - the stellar material gets stretched and compressed as it falls into the black hole. Credit: NASA/JPL-Caltech

Hundreds of millions of light-years away in a distant galaxy, a star orbiting a supermassive black hole is being violently ripped apart under the black hole's immense gravitational pull. As the star is shredded, its remnants are transformed into a stream of debris that rains back down onto the black hole to form a very hot, very bright disk of material swirling around the black hole, called an accretion disc. This phenomenon -- where a star is destroyed by a supermassive black hole and fuels a luminous accretion flare -- is known as a tidal disruption event (TDE), and it is predicted that TDEs occur roughly once every 10,000 to 100,000 years in a given galaxy.

With luminosities exceeding entire galaxies (i.e., billions of times brighter than our Sun) for brief periods of time (months to years), accretion events enable astrophysicists to study supermassive black holes (SMBHs) from cosmological distances, providing a window into the central regions of otherwise-quiescent -- or dormant -- galaxies. By probing these ``strong-gravity" events, where Einstein's general theory of relativity is critical for determining how matter behaves, TDEs yield information about one of the most extreme environments in the universe: the event horizon -- the point of no return -- of a black hole.

TDEs are usually "once-and-done" because the extreme gravitational field of the SMBH destroys the star, meaning that the SMBH fades back into darkness following the accretion flare. In some instances, however, the high-density core of the star can survive the gravitational interaction with the SMBH,

allowing it to orbit the black hole more than once. Researchers call this a repeating partial TDE.
A team of physicists, including lead author Thomas Wevers, Fellow of the European Southern Observatory, and co-authors Eric Coughlin, assistant professor of physics at Syracuse University, and Dheeraj R. "DJ" Pasham, research scientist at MIT's Kavli Institute for Astrophysics and Space Research, have proposed a model for a repeating partial TDE. Their findings, published in *Astrophysical Journal Letters,* describe the capture of the star by a SMBH, the stripping of the material each time the star comes close to the black hole, and the delay between when the material is stripped and when it feeds the black hole again. The team's work is the first to develop and use a detailed model of a repeating partial TDE to explain the observations, make predictions about the orbital properties of a star in a distant galaxy, and understand the partial tidal disruption process.
The team is studying a TDE known as AT2018fyk (AT stands for ``Astrophysical Transient"). The star was captured by a SMBH through an exchange process known as "Hills capture," where the star was originally part of a binary system (two stars that orbit one another under their mutual gravitational attraction) that was ripped apart by the gravitational field of the black hole. The other (non-captured) star was ejected from the centre of the galaxy at speeds comparable to ~ 1000 km/s, which is known as a hypervelocity star.
Once bound to the SMBH, the star powering the emission from AT2018fyk has been repeatedly stripped of its outer envelope each time it passes through its point of closest approach with the black hole. The stripped outer layers of the star form the bright accretion disk, which researchers can study using X-Ray and Ultraviolet /Optical telescopes that observe light from distant galaxies.
According to Wevers, having the opportunity to study a partial TDE gives unprecedented insight into the existence of supermassive black holes and the orbital dynamics of stars in the centres of galaxies.
"Until now, the assumption has been that when we see the aftermath of a close encounter between a star and a supermassive black hole, the outcome will be fatal for the star, that is, the star is completely destroyed," he says. "But contrary to all other TDEs we know of, when we pointed our telescopes to the same location again several years later, we found that it had re-brightened again. This led us to propose that rather than being fatal, part of the star survived the initial encounter and returned to the same location to be stripped of material once more, explaining the re-brightening phase."
First detected in 2018, AT2018fyk was initially perceived as an ordinary TDE. For approximately 600 days the source stayed bright in the X-ray, but then abruptly went dark and was undetectable -- a result of the stellar remnant core returning to a black hole, explains MIT physicist Dheeraj R. Pasham. "When the core returns to the black hole it essentially steals all the gas away from the black hole via gravity and as a result there is no matter to accrete and hence the system goes dark," Pasham says.
It wasn't immediately clear what caused the precipitous decline in the luminosity of AT2018fyk, because TDEs normally decay smoothly and gradually -- not abruptly -- in their emission. But around 600 days after the drop, the source was again found to be X-ray bright. This led the researchers to propose that the star survived its close encounter with the SMBH the first time and was in orbit about the black hole.
Using detailed modelling, the team's findings suggest that the orbital period of the star about the black hole is roughly 1,200 days, and it takes approximately 600 days for the material that is shed from the star to return to the black hole and start accreting. Their model also constrained the size of the captured star, which they believe was about the size of the sun. As for the original binary, the team believes the two stars were extremely close to one another before being ripped apart by the black hole, likely orbiting each other every few days.
So how could a star survive its brush with death? It all comes down to a matter of proximity and trajectory. If the star collided head-on with the black hole and passed the event horizon -- the threshold where the speed needed to escape the black hole surpasses the speed of light -- the star would be consumed by the black hole. If the star passed very close to the black hole and crossed the so-called "tidal radius" -- where the tidal force of the hole is stronger than the gravitational force

that keeps the star together -- it would be destroyed. In the model they have proposed, the star's orbit reaches a point of closest approach that is just outside of the tidal radius, but doesn't cross it completely: some of the material at the stellar surface is stripped by the black hole, but the material at its centre remains intact.
How, or if, the process of the star orbiting the SMBH can occur over many repeated passages is a theoretical question that the team plans to investigate with future simulations.
Syracuse physicist Eric Coughlin explains that they estimate between 1 to 10% of the mass of the star is lost each time it passes the black hole, with the large range due to uncertainty in modelling the emission from the TDE.
"If the mass loss is only at the 1% level, then we expect the star to survive for many more encounters, whereas if it is closer to 10%, the star may have already been destroyed," notes Coughlin.
The team will keep their eyes to the sky in the coming years to test their predictions. Based on their model, they forecast that the source will abruptly disappear around March 2023 and brighten again when the freshly stripped material accretes onto the black hole in 2025.
The team says their study offers a new way forward for tracking and monitoring follow-up sources that have been detected in the past. The work also suggests a new paradigm for the origin of repeating flares from the centres of external galaxies.
"In the future, it is likely that more systems will be checked for late-time flares, especially now that this project puts forth a theoretical picture of the capture of the star through a dynamical exchange process and the ensuing repeated partial tidal disruption," says Coughlin. "We're hopeful this model can be used to infer the properties of distant supermassive black holes and gain an understanding of their "demographics," being the number of black holes within a given mass range, which is otherwise difficult to achieve directly."
The team says the model also makes several testable predictions about the tidal disruption process, and with more observations of systems like AT2018fyk, it should give insight into the physics of partial tidal disruption events and the extreme environments around supermassive black holes.

"This study outlines methodology to potentially predict the next snack times of supermassive black holes in external galaxies," says Pasham. "If you think about it, it is pretty remarkable that we on Earth can align our telescopes to black holes millions of light years away to understand how they feed and grow."
Additional co-authors include: M. Guolo, Department of Physics and Astronomy, Johns Hopkins University; Y. Sun, University of Arizona; S. Wen, Department of Astrophysics/IMAPP, Radboud University ; P.G. Jonker, Department of Astrophysics/IMAPP, Radboud University and SRON, Netherlands Institute for Space Research ; A. Zabludoff, University of Arizona; A. Malyali, R. Arcodia, Z. Liu, A. Merloni, A. Rau and I. Grotova, Max-Planck-Institut fu ?r extraterrestrische Physik , Germany; P. Short, Institute for Astronomy, University of Edinburgh; and Z. Cao, Department of Astrophysics/IMAPP, Radboud University
Video: https://youtu.be/_TRtPDbaQ2k

- Researchers measure size-luminosity relation of galaxies less than a billion years after Big Bang

Date: January 13, 2023
Source: Kavli Institute for the Physics and Mathematics of the Universe

An international team of researchers including the Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) has studied the relation between galaxy size and luminosity of some of the earliest galaxies in the universe taken by the brand-new James Webb Space Telescope (JWST), less than a billion years after the Big Bang, reports a recent study in *The Astrophysical Journal Letters* [below].

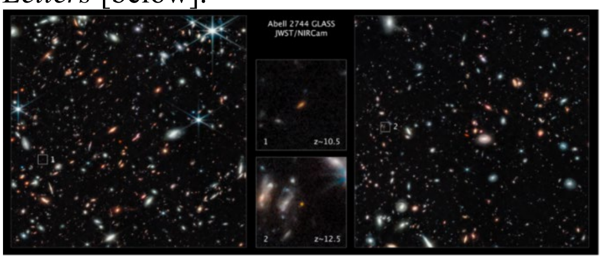
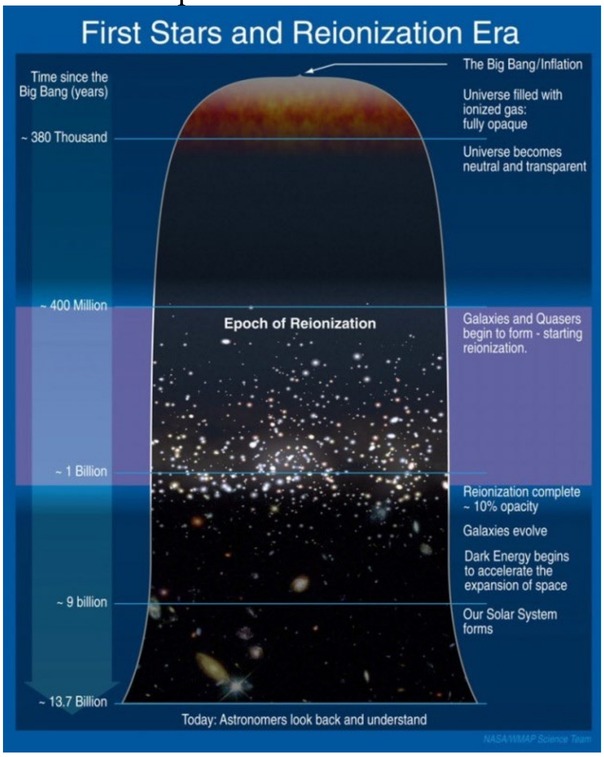


Figure 1. Two exceptionally bright galaxies were captured in GLASS-JWST program. These galaxies existed approximately 450 and 350 million years after the Big Bang (with a redshift of approximately 10.5 and 12.5, respectively), and sizes are roughly 500 parsecs and 170 parsecs, respectively. (Credit: Tommaso Treu (UCLA)/ NASA/ESA/CSA).

The result is part of the Grim Lens-Amplified Survey form Space (GLASS) Early-Release Science Program, led by University of California-Los Angeles Professor Tommaso Treu. It is aimed at studying the early universe when the first stars/galaxies ignited, which ionized the neutral gas in the universe at the time and allowed light to shine through. This is called the epoch of reionization.



[Epoch of Reionization and first stars. Credit: California Institute of Technology.]

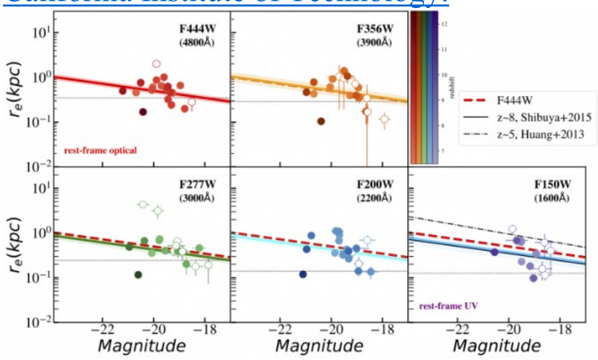


Figure 2: Size–luminosity relationships of galaxies observed in five wavelength bands with fixed slope owing to limited data. The black solid and dashed–dotted lines in the F150W panel show the relation derived from HST data by Shibuya et al. (2015; z ~ 8) and Huang et al. (2013; z ~ 5) at a similar rest-frame wavelength, respectively. (Credit: Yang et al.)

However, details of reionization have remained unknown because telescopes until today have not been capable of observing galaxies in this period of the universe's history in detail. Finding out more about the epoch of reionization would help researchers understand how stars and galaxies have evolved to create today's universe as we see it.

One study, led by Kavli IPMU JSPS Fellow Lilan Yang, and including Project Researcher Xuheng Ding, used multiband NIRCAM imaging data from the GLASS-JWST program to measure galaxy size and luminosity to figure out the morphology and the size-luminosity relation from rest-frame optical to UV.

"It's the first time that we can study the galaxy's properties in rest-frame optical at redshift larger than 7 with JWST, and the size-luminosity is important for determining the shape of luminosity function which indicates the primary sources responsible for the cosmic reionization, i.e., numerous faint galaxies or relatively less bright galaxies.

"The original wavelength of light will shift to longer wavelength when it travels from the early universe to us. Thus, the rest-frame wavelength is used to clarify their intrinsic wavelength, rather than observed wavelength. Previously, with Hubble Space Telescope, we know the properties of galaxies only in rest-frame UV band. Now, with JWST, we can measure longer wavelength than UV," said first author Yang.

The researchers found the first rest-frame optical size-luminosity relation of galaxies at redshift larger than 7, or roughly 800 million years after the Big Bang, allowing them to study the size as function of wavelength. They found the median size at the reference luminosity is roughly 450-600 parsecs and decreased slightly from rest-frame optical to UV. But was this expected?

"The answer is we don't know what's to expect. Previous simulation studies give a range of predictions," said Yang.

The team also found the slope of the size–luminosity relationship was somewhat steeper in the shortest wavelength band when allowing the slope to vary.

"That would suggest higher surface brightness density at shorter wavelength, hence less observational incompleteness correction when estimating luminosity function, but the result is not conclusive. We don't want to over-interpret here," said Yang.

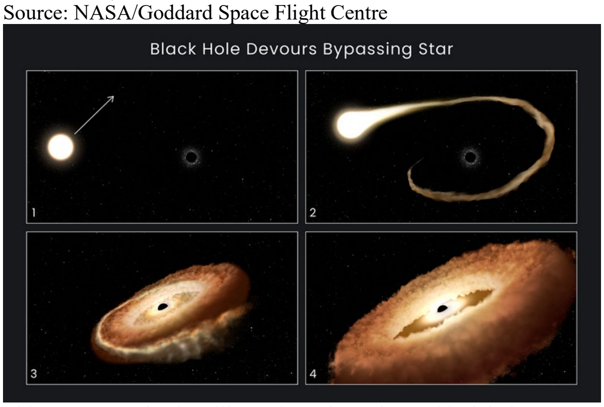
The team's paper was published on October 18, 2022, by *The Astrophysical Journal Letters*.

Science paper:
The Astrophysical Journal Letters

See the science paper for instructive material with images.

❖ Hubble finds hungry black hole twisting captured star into donut shape

Date: January 12, 2023
Source: NASA/Goddard Space Flight Centre



This sequence of artist's illustrations shows how a black hole can devour a bypassing star. 1. A normal star passes near a supermassive black hole in the centre of a galaxy. 2. The star's outer gasses are pulled into the black hole's gravitational field. 3. The star is shredded as tidal forces pull it apart. 4. The stellar remnants are pulled into a donut-shaped ring around the black hole, and will eventually fall into the black hole, unleashing a tremendous amount of light and high-energy radiation.
Credits: NASA, ESA, Leah Hustak (STScI)

Black holes are gatherers, not hunters. They lie in wait until a hapless star wanders by. When the star gets close enough, the black hole's gravitational grasp violently rips it apart and sloppily devours its gasses while belching out intense radiation.

Astronomers using NASA's Hubble Space Telescope have recorded a star's final moments in detail as it gets gobbled up by a black hole.

These are termed "tidal disruption events." But the wording belies the complex, raw violence of a black hole encounter. There is a balance between the black hole's gravity pulling in star stuff, and radiation blowing material out. In other words, black holes are messy eaters. Astronomers are using Hubble to find out the details of what happens when a wayward star plunges into the gravitational abyss.

Hubble can't photograph the AT2022dsb tidal event's mayhem up close, since the munched-up star is nearly 300 million light-years away at the core of the galaxy ESO 583-G004. But astronomers used Hubble's powerful ultraviolet sensitivity to study the light from the shredded star, which include hydrogen, carbon, and more. The spectroscopy provides forensic clues to the black hole homicide.

About 100 tidal disruption events around black holes have been detected by astronomers using various telescopes. NASA recently reported that several of its high-energy space observatories spotted another black hole tidal disruption event on March 1, 2021, and it happened in another galaxy. Unlike Hubble observations, data was collected in X-ray light from an extremely hot corona around the black hole that formed after the star was already torn apart.

"However, there are still very few tidal events that are observed in ultraviolet light given the observing time. This is really unfortunate because there's a lot of information that you can get from the ultraviolet spectra," said Emily Engelthaler of the Centre for Astrophysics | Harvard & Smithsonian (CfA) in Cambridge, Massachusetts. "We're excited because we can get these details about what the debris is doing. The tidal event can tell us a lot about a black hole." Changes in the doomed star's condition are taking place on the order of days or months.

For any given galaxy with a quiescent supermassive black hole at the centre, it's estimated that the stellar shredding happens only a few times in every 100,000 years.

This AT2022dsb stellar snacking event was first caught on March 1, 2022 by the All-Sky Automated Survey for Supernovae (ASAS-SN or "Assassin"), a network of ground-based telescopes that surveys the extragalactic sky roughly once a week for violent, variable, and transient events that are shaping our universe. This energetic collision was close enough to Earth and bright enough for the Hubble astronomers to do ultraviolet spectroscopy over a longer than normal period of time.

"Typically, these events are hard to observe. You get maybe a few observations at the beginning of the disruption when it's really bright. Our program is different in that it is designed to look at a few tidal events over a year to see what happens," said Peter Maksym of the CfA. "We saw this early enough that we could observe it at these very intense black hole accretion stages. We saw the accretion rate drop as it turned to a trickle over time."

The Hubble spectroscopic data are interpreted as coming from a very bright, hot, donut-shaped area of gas that was once the star. This area, known as a torus, is the size of the solar system and is swirling around a black hole in the middle.

"We're looking somewhere on the edge of that donut. We're seeing a stellar wind from the black hole sweeping over the surface that's being projected towards us at speeds of 20 million miles per hour (three percent the

speed of light)," said Maksym. "We really are still getting our heads around the event. You shred the star and then it's got this material that's making its way into the black hole. And so, you've got models where you think you know what is going on, and then you've got what you actually see. This is an exciting place for scientists to be: right at the interface of the known and the unknown."
The results were reported at the 241st meeting of the American Astronomical Society in Seattle, Washington.

- ❖ How do rocky planets really form?

Scientists unveil a unified theory for rocky planet formation
Date: January 12, 2023
Source: California Institute of Technology

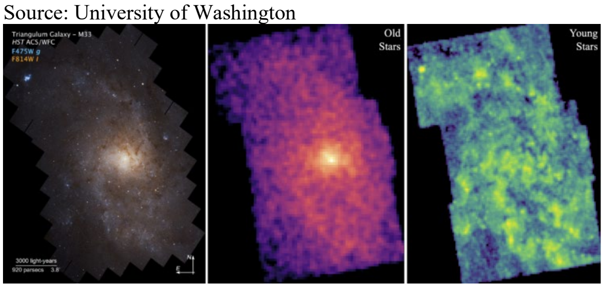
The origins of rocky planets may lie in a single disk at the point where silicates solidify, with one planet produced after another before migrating inwards. Image credit: Caltech

A new theory for how rocky planets form could explain the origin of so-called "super-Earths" -- a class of exoplanets a few times more massive than the Earth that are the most abundant type of planet in the galaxy.
Further, it could explain why super-Earths within a single planetary system often wind up looking strangely similar in size, as though each system were only capable of producing a single kind of planet.
"As our observations of exoplanets have grown over the past decade, it has become clear that the standard theory of planet formation needs to be revised, starting with the fundamentals. We need a theory that can simultaneously explain the formation of the terrestrial planets in our solar system as well as the origins of self-similar systems of super-Earths, many of which appear rocky in composition," says Caltech professor of planetary science Konstantin Batygin (MS '10, PhD '12), who collaborated with Alessandro Morbidelli of the Observatoire de la Côte d'Azur in France on the new theory. A paper explaining their work was published by *Nature Astronomy* on Jan. 12.
Planetary systems begin their lifecycles as large spinning disks of gas and dust that consolidate over the course of a few million years or so. Most of the gas accretes into the star at the centre of the system, while solid material slowly coalesces into asteroids, comets, planets, and moons.
In our solar system, there are two distinct types of planets: the smaller rocky inner planets closest to the sun and the outer larger water- and hydrogen-rich gas giants that are farther from the sun. In an earlier study published in *Nature Astronomy* at the end of 2021, this dichotomy led Morbidelli, Batygin, and colleagues to suggest that planet formation in our solar system occurred in two distinct rings in the protoplanetary disk: an inner one where the small rocky planets formed and an outer one for the more massive icy planets (two of which -- Jupiter and Saturn -- later grew into gas giants).
Super-Earths, as the name suggests, are more massive than the Earth. Some even have hydrogen atmospheres, which makes them appear almost gas giant-like. Moreover, they are often found orbiting close to their stars, suggesting that they migrated to their current location from more distant orbits.
"A few years ago, we built a model where super-Earths formed in the icy part of the protoplanetary disk and migrated all the way to the inner edge of the disk, near the star," says Morbidelli. "The model could explain the masses and orbits of super-Earths but predicted that all are water-rich. Recent observations, however, have demonstrated that most super-Earths are rocky, like the Earth, even if surrounded by a hydrogen atmosphere. That was the death sentence for our old model."
Over the past five years, the story has gotten even weirder as scientists -- including a team led by Andrew Howard, professor of astronomy at Caltech; Lauren Weiss, assistant professor at the University of Notre Dame; and Erik Petigura, formerly a Sagan Postdoctoral Scholar in Astronomy at Caltech and now a professor at UCLA -- have studied these exoplanets and made an unusual discovery: while there exists a wide variety of types of super-Earths, all of the super-Earths within a single planetary system tend to be similar in terms of orbital spacing, size, mass, and other key features.
"Lauren discovered that, within a single planetary system, super-Earths are like 'peas

in a pod,'" says Howard, who was not directly connected with the Batygin-Morbidelli paper but has reviewed it. "You basically have a planet factory that only knows how to make planets of one mass, and it just squirts them out one after the other."
So, what single process could have given rise to the rocky planets in our solar system but also to uniform systems of rocky super-Earths?
"The answer turns out to be related to something we figured out in 2020 but didn't realize applied to planetary formation more broadly," Batygin says.
In 2020, Batygin and Morbidelli proposed a new theory for the formation of Jupiter's four largest moons (Io, Europa, Ganymede, and Callisto). In essence, they demonstrated that, for a specific size range of dust grains, the force dragging the grains toward Jupiter and the force (or entrainment) carrying those grains in an outward flow of gas cancel each other perfectly. That balance in forces created a ring of material that constituted the solid building blocks for the subsequent formation of the moons. Further, the theory suggests that bodies would grow in the ring until they become large enough to exit the ring due to gas-driven migration. After that, they stop growing, which explains why the process produces bodies of similar sizes.
In their new paper, Batygin and Morbidelli suggest that the mechanism for forming planets around stars is largely the same. In the planetary case, the large-scale concentration of solid rocky material occurs at a narrow band in the disk called the silicate sublimation line -- a region where silicate vapours condense to form solid, rocky pebbles. "If you're a dust grain, you feel considerable headwind in the disk because the gas is orbiting a bit more slowly, and you spiral toward the star; but if you're in vapor form, you simply spiral outward, together with the gas in the expanding disk. So that place where you turn from vapor into solids is where material accumulates," Batygin says.
The new theory identifies this band as the likely site for a "planet factory" that, over time, can produce several similarly sized rocky planets. Moreover, as planets grow sufficiently massive, their interactions with the disk will tend to draw these worlds inward, closer to the star.
Batygin and Morbidelli's theory is backed up by extensive computer modelling but began with a simple question. "We looked at the existing model of planet formation, knowing that it does not reproduce what we see, and asked, 'What assertion are we taking for granted?'" Batygin says. "The trick is to look at something that everybody takes to be true but for no good reason."
In this case, the assumption was that solid material is dispersed throughout the protoplanetary disks. By jettisoning that assumption and instead supposing that the first solid bodies form in rings, the new theory can explain different types of planetary systems with a unified framework, Batygin says.
If the rocky ring contains a lot of mass, planets grow until they migrate away from the ring, resulting in a system of similar super-Earths. If the ring contains little mass, it produces a system that looks much more like our solar system's terrestrial planets.
"I'm an observer and an instrument builder, but I pay extremely close attention to the literature," Howard says. "We get a regular dribble of little-but-still-important contributions. But every five years or so, someone comes out with something that creates a seismic shift in the field. This is one of those papers."
Video: https://youtu.be/EaKJWtMQGKY

- Old and new stars paint very different pictures of the Triangulum Galaxy

Date: January 11, 2023
Source: University of Washington



A. Smercina/M.J. Durbin/J. Dalcanton/B.F. Williams/University of Washington/NASA/ESA
The Panchromatic Hubble Andromeda Treasury Triangulum Extended Region — or PHATTER — survey has given astrophysicists an in-depth look at the Triangulum galaxy in different wavelength filters. Dr. Adam Smercina reveals the surprising discovery that the old and young stars trace form structures within the galaxy

Astronomers have been gazing at the Triangulum galaxy for centuries. But they've never seen it quite like this.
On Jan. 11 at the 241st meeting of the American Astronomical Society in Seattle, a team led by scientists at the University of Washington and the Centre for Computational Astrophysics will unveil results using the Panchromatic Hubble Andromeda Treasury

Triangulum Extended Region -- or PHATTER -- survey. The endeavour is giving astrophysicists their first in-depth look at the distinct populations of stars that make up the Triangulum galaxy.
Researchers discovered that this satellite galaxy, a close companion of the much larger Andromeda galaxy, has two drastically different structures depending on the age of the stars.
"The youngest stars and the oldest stars in the Triangulum galaxy -- which we can separate out using multiple wavelength filters on the Hubble Space Telescope -- are organized very differently," said Adam Smercina, a postdoctoral researcher at the UW. "This is surprising. For a lot of galaxies, like the Milky Way and Andromeda, the stars are distributed roughly consistently, regardless of their age. That is not the case with Triangulum."
At about 61,000 light years across, Triangulum is the third-largest galaxy in our local group, after Andromeda and our own Milky Way. In lower-resolution images it has a "flocculent" structure -- with many small spiral arms radiating out from a well-defined centre.
For the PHATTER survey, the Hubble Space Telescope obtained hundreds of high-resolution images of different sections of the Triangulum galaxy in 108 orbits over the course of more than a year. The team tiled these smaller-section images together to create a comprehensive, high-resolution dataset for Triangulum that for the first time showed the galaxy's individual stars over a large region in its centre.
Thanks to Hubble's array of filters, researchers could also separate those stars by age. The distribution of younger, massive stars -- those less than 1 billion years in age -- were roughly in line with the "flocculent" pattern, for which the Triangulum is so renowned. But its older, redder stars are distributed in a very different pattern: two spiral arms radiating out from a rectangular bar at the galaxy's centre.
"This was a largely unknown and hidden feature of the Triangulum galaxy that was very difficult to see without this kind of detailed survey," said Smercina.
Old stars make up the majority of Triangulum's mass, but are dimmer than their younger counterparts, according to Smercina. That could explain why the "flocculent" pattern prevails in low-resolution images of the galaxy.
The survey team also does not know why young and old stars have such divergent distributions in Triangulum. Satellite galaxies in general are an eclectic bunch, and many questions remain about their formation and evolution. Satellite galaxies come in many different shapes and can be moulded by interactions with their parent galaxies. The Milky Way's largest satellite galaxy, the Large Magellanic Cloud, for example, is similar in size and mass to Triangulum, but has an irregular and globular shape due to its proximity to our own galaxy.
The PHATTER survey's on-going analysis should shed light on how these types of galaxies form and interact with their larger neighbours. The team plans to follow up on these initial findings by tracing the history of star formation in Triangulum, comparing different sections of the galaxy.
"A major goal of the PHATTER survey was to generate the kind of detailed, high-resolution data on this prominent satellite galaxy that will allow us to examine its structure in depth, trace its history of star formation and compare what we see to theories of galaxy formation and evolution," said Smercina. "We're already finding surprises."
Other team members include Julianne Dalcanton, director of the Centre for Computational Astrophysics in New York, a UW professor of astronomy and principal investigator of the PHATTER project; UW research associate professor of astronomy Benjamin Williams; UW doctoral student Meredith Durbin; and Margaret Lazzarini, a postdoctoral researcher at Caltech.

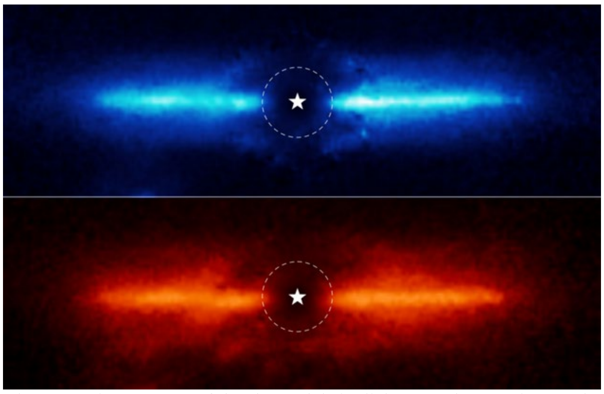
- NASA's Webb uncovers star formation in cluster's dusty ribbons

Date: January 11, 2023
Source: NASA/Goddard Space Flight Centre

NGC 346, one of the most dynamic star-forming regions in nearby galaxies, is full of mystery. Now, it is less mysterious with new findings from NASA's James Webb Space Telescope.
NCG 346 is located in the Small Magellanic Cloud (SMC), a dwarf galaxy close to our Milky Way. The SMC contains lower concentrations of elements heavier than hydrogen or helium, which astronomers call metals, compared to the Milky Way. Since dust grains in space are composed mostly of metals, scientists expected there would be low amounts of dust, and that it would be hard to detect. New data from Webb reveals the opposite.
Astronomers probed this region because the conditions and number of metals within the SMC resemble those seen in galaxies billions of years ago, during an era in the universe known as "cosmic noon," when star formation was at its peak. Some 2 to 3 billion years after the big bang, galaxies were forming stars at a furious rate. The fireworks of star formation happening then still shape the galaxies we see around us today.
"A galaxy during cosmic noon wouldn't have one NGC 346 like the Small Magellanic Cloud does; it would have thousands" of star-forming regions like this one, said Margaret Meixner, an astronomer at the Universities Space Research Association and principal investigator of the research team. "But even if NGC 346 is now the one and only massive cluster furiously forming stars in its galaxy, it offers us a great opportunity to probe conditions that were in place at cosmic noon."
By observing protostars still in the process of forming, researchers can learn if the star formation process in the SMC is different from what we observe in our own Milky Way.
Previous infrared studies of NGC 346 have focused on protostars heavier than about 5 to 8 times the mass of our Sun. "With Webb, we can probe down to lighter-weight protostars, as small as one tenth of our Sun, to see if their formation process is affected by the lower metal content," said Olivia Jones of the United Kingdom Astronomy Technology Centre, Royal Observatory Edinburgh, a co-investigator on the program.
As stars form, they gather gas and dust, which can look like ribbons in Webb imagery, from the surrounding molecular cloud. The material collects into an accretion disk that feeds the central protostar. Astronomers have detected gas around protostars within NGC 346, but Webb's near-infrared observations mark the first time they have also detected dust in these disks.
"We're seeing the building blocks, not only of stars, but also potentially of planets," said Guido De Marchi of the European Space Agency, a co-investigator on the research team. "And since the Small Magellanic Cloud has a similar environment to galaxies during cosmic noon, it's possible that rocky planets could have formed earlier in the universe than we might have thought."
The team also has spectroscopic observations from Webb's NIRSpec instrument that they are continuing to analyze. These data are expected to provide new insights into the material accreting onto individual protostars, as well as the environment immediately surrounding the protostar.
These results are being presented Jan. 11 in a press conference at the 241st meeting of the American Astronomical Society. The observations were obtained as part of program 1227.

- New Webb image reveals dusty disk like never seen before

Date: January 11, 2023
Source: NASA/Goddard Space Flight Centre

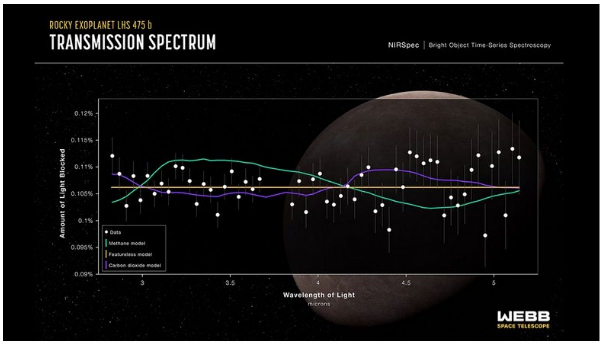


These two images are of the dusty debris disk around AU Mic, a red dwarf star located 32 light-years away in the southern constellation Microscopium. Scientists used Webb’s Near-Infrared Camera (NIRCam) to study AU Mic. NIRCam’s coronagraph, which blocked the intense light of the central star, allowed the team to study the region very close to the star. The location of the star, which is masked out, is marked by a white, graphical representation at the centre of each image. The region blocked by the coronagraph is shown by a dashed circle.
Credits: NASA, ESA, CSA, and K. Lawson (Goddard Space Flight Centre). Image processing: A. Pagan (STScI)
Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

NASA's James Webb Space Telescope has imaged the inner workings of a dusty disk surrounding a nearby red dwarf star. These observations represent the first time the previously known disk has been imaged at these infrared wavelengths of light. They also provide clues to the composition of the disk.
The star system in question, AU Microscopii or AU Mic, is located 32 light-years away in the southern constellation Microscopium. It's approximately 23 million years old, meaning that planet formation has ended since that process typically takes less than 10 million years. The star has two known planets, discovered by other telescopes. The dusty debris disk that remains is the result of collisions between leftover planetesimals -- a more massive equivalent of the dust in our solar system that creates a phenomenon known as zodiacal light.
"A debris disk is continuously replenished by collisions of planetesimals. By studying it, we get a unique window into the recent dynamical history of this system," said Kellen Lawson of NASA's Goddard Space Flight Centre, lead author on the study and a member of the research team that studied AU Mic.
"This system is one of the very few examples of a young star, with known exoplanets, and a debris disk that is near enough and bright enough to study holistically using Webb's uniquely powerful instruments," said Josh Schlieder of NASA's Goddard Space Flight Centre, principal investigator for the observing program and a study co-author.
The team used Webb's Near-Infrared Camera (NIRCam) to study AU Mic. With the help of NIRCam's coronagraph, which blocks the intense light of the central star, they were able to study the region very close to the star. The NIRCam images allowed the researchers to trace the disk as close to the star as 5 astronomical units (460 million miles) -- the equivalent of Jupiter's orbit in our solar system.
"Our first look at the data far exceeded expectations. It was more detailed than we expected. It was brighter than we expected. We detected the disk closer in than we expected. We're hoping that as we dig deeper, there's going to be some more surprises that we hadn't predicted," stated Schlieder.
The observing program obtained images at wavelengths of 3.56 and 4.44 microns. The team found that the disk was brighter at the shorter wavelength, or "bluer," likely meaning that it contains a lot of fine dust that is more efficient at scattering shorter wavelengths of light. This finding is consistent with the results of prior studies, which found that the radiation pressure from AU Mic -- unlike that of more massive stars -- would not be strong enough to eject fine dust from the disk.
While detecting the disk is significant, the team's ultimate goal is to search for giant planets in wide orbits, similar to Jupiter, Saturn, or the ice giants of our solar system. Such worlds are very difficult to detect around distant stars using either the transit or radial velocity methods.
"This is the first time that we really have sensitivity to directly observe planets with wide orbits that are significantly lower in mass than Jupiter and Saturn. This really is new, uncharted territory in terms of direct imaging around low-mass stars," explained Lawson.
These results are being presented today in a press conference at the 241st meeting of the American Astronomical Society. The observations were obtained as part of Webb's Guaranteed Time program 1184.

- NASA's Webb confirms its first exoplanet

Date: January 11, 2023
Source: NASA/Goddard Space Flight Centre



Researchers used NASA’s James Webb Space Telescope’s Near-Infrared Spectrograph (NIRSpec) to observe exoplanet LHS 475 b on August 31, 2022. As this spectrum shows, Webb did not observe a detectable quantity of any element or molecule. The data (white dots) are consistent with a featureless spectrum representative of a planet that has no atmosphere (yellow line). The purple line represents a pure carbon dioxide atmosphere and is indistinguishable from a flat line at the current level of precision. The green line represents a pure methane atmosphere, which is not favoured since if methane were present, it would be expected to block more starlight at 3.3 microns

Researchers confirmed an exoplanet, a planet that orbits another star, using NASA's James Webb Space Telescope for the first time. Formally classified as LHS 475 b, the planet is almost exactly the same size as our own, clocking in at 99% of Earth's diameter. The research team is led by Kevin Stevenson and Jacob Lustig-Yaeger, both of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland.

The team chose to observe this target with Webb after carefully reviewing targets of interest from NASA's Transiting Exoplanet Survey Satellite (TESS), which hinted at the planet's existence. Webb's Near-Infrared Spectrograph (NIRSpec) captured the planet easily and clearly with only two transit observations. "There is no question that the planet is there. Webb's pristine data validate it," said Lustig-Yaeger. "The fact that it is also a small, rocky planet is impressive for the observatory," Stevenson added.

"These first observational results from an Earth-size, rocky planet opens the door to many future possibilities for studying rocky planet atmospheres with Webb," agreed Mark Clampin, Astrophysics Division director at NASA Headquarters in Washington. "Webb is bringing us closer and closer to a new understanding of Earth-like worlds outside our solar system, and the mission is only just getting started."

Among all operating telescopes, only Webb is capable of characterizing the atmospheres of Earth-sized exoplanets. The team attempted to assess what is in the planet's atmosphere by analysing its transmission spectrum. Although the data shows that this is an Earth-sized terrestrial planet, they do not yet know if it has an atmosphere. "The observatory's data are beautiful," said Erin May, also of the Johns Hopkins University Applied Physics Laboratory. "The telescope is so sensitive that it can easily detect a range of molecules, but we can't yet make any definitive conclusions about the planet's atmosphere."

Although the team can't conclude what is present, they can definitely say what is *not* present. "There are some terrestrial-type atmospheres that we can rule out," explained Lustig-Yaeger. "It can't have a thick methane-dominated atmosphere, similar to that of Saturn's moon Titan."

The team also notes that while it's possible the planet has no atmosphere, there are some atmospheric compositions that have not been ruled out, such as a pure carbon dioxide atmosphere. "Counterintuitively, a 100% carbon dioxide atmosphere is so much more compact that it becomes very challenging to detect," said Lustig-Yaeger. Even more precise measurements are required for the team to distinguish a pure carbon dioxide atmosphere from no atmosphere at all. The researchers are scheduled to obtain additional spectra with upcoming observations this summer.

Webb also revealed that the planet is a few hundred degrees warmer than Earth, so if clouds are detected, it may lead the researchers to conclude that the planet is more like Venus, which has a carbon dioxide atmosphere and is perpetually shrouded in thick clouds. "We're at the forefront of studying small, rocky exoplanets," Lustig-Yaeger said. "We have barely begun scratching the surface of what their atmospheres might be like."

The researchers also confirmed that the planet completes an orbit in just two days, information that was almost instantaneously revealed by Webb's precise light curve.

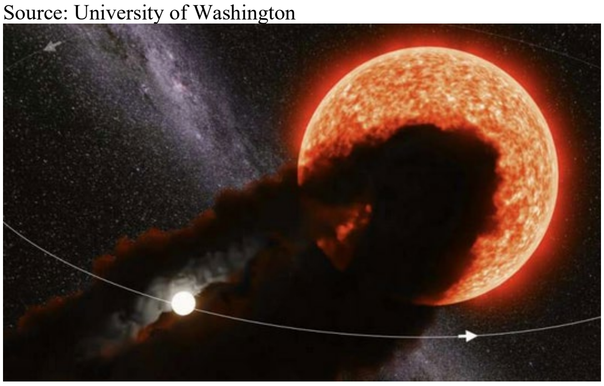
Although LHS 475 b is closer to its star than any planet in our solar system, its red dwarf star is less than half the temperature of the Sun, so the researchers project it still could have an atmosphere.

The researchers' findings have opened the possibilities of pinpointing Earth-sized planets orbiting smaller red dwarf stars. "This rocky planet confirmation highlights the precision of the mission's instruments," Stevenson said. "And it is only the first of many discoveries that it will make." Lustig-Yaeger agreed. "With this telescope, rocky exoplanets are the new frontier."

LHS 475 b is relatively close, at only 41 light-years away, in the constellation Octans.

- The seven-year photobomb: Distant star's dimming was likely a 'dusty' companion getting in the way, astronomers say

Date: January 10, 2023
Source: University of Washington



An artistic rending of the star Gaia17bpp being partially eclipsed by the dust

By their own admission, Anastasios "Andy" Tzanidakis and James Davenport are interested in unusual stars. The University of Washington astronomers were on the lookout for "stars behaving strangely" when an automated alert from the Gaia survey pointed them to Gaia17bpp. Survey data indicated that this star had gradually brightened over a 2 1/2-year period.

As Tzanidakis will report on Jan. 10 at the 241st meeting of the American Astronomical Society in Seattle, follow-up analyses indicated that Gaia17bpp itself wasn't changing. Instead, the star is likely part of a rare type of binary system, and its apparent brightening was the end a years-long eclipse by an unusual stellar companion.

"We believe that this star is part of an exceptionally rare type of binary system, between a large, puffy older star -- Gaia17bpp -- and a small companion star that is surrounded by an expansive disk of dusty material," said Tzanidakis, a UW doctoral student in astronomy. "Based on our analysis, these two stars orbit each other over an exceptionally long period of time -- as much as 1,000 years. So, catching this bright star being eclipsed by its dusty companion is a once-in-a-lifetime opportunity."

Since the Gaia spacecraft's observations about the star only went back to 2014, Tzanidakis and Davenport, a UW research assistant professor of astronomy and associate director of the DiRAC Institute, had to do a little detective work to reach this conclusion. First, they stitched together Gaia's observations of the star with observations by other missions stretching back to 2010 -- including Pan-STARRS1, WISE/NEOWISE and the Zwicky Transient Facility.

Those observations, coupled with the Gaia data, showed that Gaia17bpp dimmed by about 4.5 orders of magnitude -- or roughly 45,000 times. The star remained dim over the course of nearly seven years, from 2012 to 2019. The sudden brightening that the Gaia survey had uncovered was the end of that seven-year dim.

No other stars near Gaia17bpp showed similar dimming behaviour. Through the DASCH program, a digital catalogue of more than a century's worth of Astro-photographic plates at Harvard, Tzanidakis and Davenport analysed observations of the star stretching back to the 1950s.

"Over 66 years of observational history, we found no other signs of significant dimming in this star," said Tzanidakis.

The two believe that Gaia17bpp is part of a rare type of binary star system, with a stellar companion that is -- quite simply -- dusty.

"Based on the data currently available, this star appears to have a slow-moving companion that is surrounded by a large disk of material," said Tzanidakis. "If that material were in the solar system, it would extend from the sun to Earth's orbit, or farther."

A handful of other similar, "dusty" systems have been identified over the years, most notably Epsilon Aurigae, a star in the constellation Auriga that is eclipsed for two out of every 27 years by a relatively large, dim companion. The system that Tzanidakis and Davenport discovered is unique among these few dusty binaries in the length of the eclipse -- at nearly seven years, it is by far the longest. Unlike the Epsilon Aurigae binary, Gaia17bpp and its companion are also so far apart that it would be centuries or more before an astute observer on Earth witnesses another such eclipse.

For Epsilon Aurigae and similar systems, the identity of the dusty companion is a matter of debate. Some preliminary data indicate that Gaia17bpp's companion could be a small, massive white dwarf star. The source of its debris disk is also a mystery.

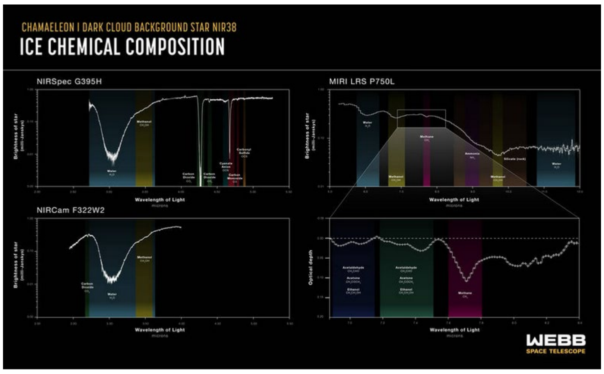
"This was a serendipitous discovery," said Tzanidakis. "If we had been a few years off, we would've missed it. It also indicates that these types of binaries might be much more common. If so, we need to come up with theories about how this type of pairing even

arose. It's definitely an oddity, but it might be much more common than anyone has appreciated."
Additional team members on this study are Eric Bellm, a UW research assistant professor of astronomy, and David Wang, a UW graduate student in astronomy.

- Darkest view ever of interstellar ices

Researchers utilized the James Webb Space Telescope to look at primordial interstellar ices

Date: January 23, 2023
Source: Southwest Research Institute



Astronomers have taken an inventory of the most deeply embedded ices in a cold molecular cloud to date. They used light from a background star, named NIR38, to illuminate the dark cloud called Chamaeleon I. Ices within the cloud absorbed certain wavelengths of infrared light, leaving spectral fingerprints called absorption lines. These lines indicate which substances are present within the molecular cloud. These graphs show spectral data from three of the James Webb Space Telescope's instruments. In addition to simple ices like water, the science team was able to identify frozen forms of a wide range of molecules, from carbon dioxide, ammonia, and methane, to the simplest complex organic molecule, methanol. Credits: NASA, ESA, CSA, and J. Olmsted (STScI)

An international team including Southwest Research Institute, Leiden University and NASA used observations from the James Webb Space Telescope (JWST) to achieve the darkest ever view of a dense interstellar cloud. These observations have revealed the composition of a virtual treasure chest of ices from the early universe, providing new insights into the chemical processes of one of the coldest, darkest places in the universe as well as the origins of the molecules that make up planetary atmospheres.
"The JWST allowed us to study ices that exist on dust grains within the darkest regions of interstellar molecular clouds," said SwRI Research Scientist Dr. Danna Qasim, co-author of the study published in *Nature Astronomy*. "The clouds are so dense that these ices have been mostly protected from the harsh radiation of nearby stars, so they are quite pristine. These are the first ices to be formed and also contain biogenic elements, which are important to life."
NASA's JWST has a 6.5-meter-wide mirror providing remarkable spatial resolution and sensitivity, optimized for infrared light. As a result, the telescope has been able to image the densest, darkest clouds in the universe for the first time.
"These observations provide new insights into the chemical processes in one of the coldest, darkest places in the universe to better understand the molecular origins of protoplanetary disks, planetary atmospheres, and other Solar System objects," Qasim said.
Most interstellar ices contain very small amounts of elements like oxygen and sulphur. Qasim and her co-authors seek to understand the lack of sulphur in interstellar ices.
"The ices we observed only contain 1% of the sulphur we're expecting. 99% of that sulphur is locked-up somewhere else, and we need to figure out where in order to understand how sulphur will eventually be incorporated into the planets that may host life," Qasim explained.
In the study, Qasim and colleagues propose that the sulphur may be locked in reactive minerals like iron sulphide, which may react with ices to form the sulphur-bearing ices observed.
"Iron sulphide is a highly reactive mineral that has been detected in the accretion disks of young stars and in samples returned from comets. It's also the most common sulphide mineral in lunar rocks," Qasim said. "If sulphur is locked-up in these minerals, that could explain the low amount of sulphur in interstellar ices, which has implications for where sulphur is stored in our Solar System. For example, the atmosphere of Venus has sulphur-containing molecules, in which the sulphur could have partially come from interstellar-inherited minerals."