South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 564 – May 6th 2022 Editor: Roger Burgess
Main Speaker 19:30 19:30 Stephen Tonkin The Right Light at Night
The meeting will be accessible via Zoom

Covid-19 rules 1 encouraging the wearing of face coverings, 2 use of hand sanitiser, 3 cleaning surfaces down with sanitiser, 4 insisting on unwell members staying away, 5 if possible, members undertaking a lateral flow test before attending a SDAS meeting

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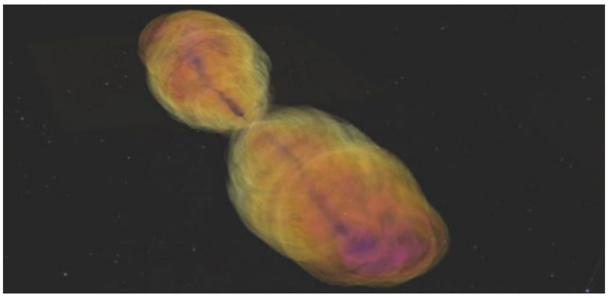
- Dying stars' cocoons might explain fast blue optical transients

First model that is fully consistent with all FBOT observations

Date: April 20, 2022
Source: Northwestern University



Ever since they were discovered in 2018, fast blue optical transients (FBOTs) have utterly surprised and completely confounded both observational and theoretical astrophysicists. So hot that they glow blue, these mysterious objects are the brightest known optical phenomenon in the universe. But with only a few discovered so far, FBOTs' origins have remained elusive.

Now a Northwestern University astrophysics team presents a bold new explanation for the origin of these curious anomalies. Using a new model, the astrophysicists believe FBOTs could result from the actively cooling cocoons that surround jets launched by dying stars. It marks the first astrophysics model that is fully consistent with all observations related to FBOTs.

The research was published April 11 in the *Monthly Notices of the Royal Astronomical Society*.

As a massive star collapses, it can launch outflows of debris at rates near the speed of light. These outflows, or jets, collide into collapsing layers of the dying star to form a "cocoon" around the jet. The new model shows that as the jet pushes the cocoon outward -- away from the core of the collapsing star -- it cools, releasing heat as an observed FBOT emission.

"A jet starts deep inside of a star and then drills its way out to escape," said Northwestern's Ore Gottlieb, who led the study. "As the jet moves through the star, it forms an extended structure, known as the cocoon. The cocoon envelopes the jet, and it continues to do so even after the jet escapes the star, this cocoon escapes with the jet. When we calculated how much energy the cocoon has, it turned out to be as powerful as an FBOT."

Gottlieb is a Rothschild Fellow in Northwestern's Centre for Interdisciplinary Exploration and Research in Astrophysics (CIERA). He co-authored the paper with CIERA member Sasha Tchekovskoy, an assistant professor of physics and astronomy in Northwestern's Weinberg College of Arts and Sciences.

The hydrogen problem

FBOTs (pronounced F-bot) are a type of cosmic explosion initially detected in the optical wavelength. As their name implies, transients fade almost as quickly as they appear. FBOTs reach peak brightness within a matter of days and then quickly fade -- much faster than standard supernovae rise and decay.

After discovering FBOTs just eight years ago, astrophysicists wondered if the mysterious events were related to another transient class: gamma ray bursts (GRBs). The strongest and brightest explosions across all wavelengths, GRBs also are associated with dying stars. When a massive star exhausts its fuel and

collapses into a black hole, it launches jets to produce a powerful gamma ray emission.
"The reason why we think GRBs and FBOTs might be related is because both are very fast -- moving at close to the speed of light -- and both are asymmetrically shaped, breaking the spherical shape of the star," Gottlieb said. "But there was a problem. Stars that produce GRBs lack hydrogen. We don't see any signs of hydrogen in GRBs, whereas in FBOTs, we see hydrogen everywhere. So, it could not be the same phenomenon."
Using their new model, Gottlieb and his co-authors think they might have found an answer to this problem. Hydrogen-rich stars tend to house hydrogen in their outermost layer -- a layer too thick for a jet to penetrate.
"Basically, the star would be too massive for the jet to pierce through," Gottlieb said. "So the jet will never make it out of the star, and that's why it fails to produce a GRB. However, in these stars, the dying jet transfers all its energy to the cocoon, which is the only component to escape the star. The cocoon will emit FBOT emissions, which will include hydrogen. This is another area where our model is fully consistent with all FBOT observations."

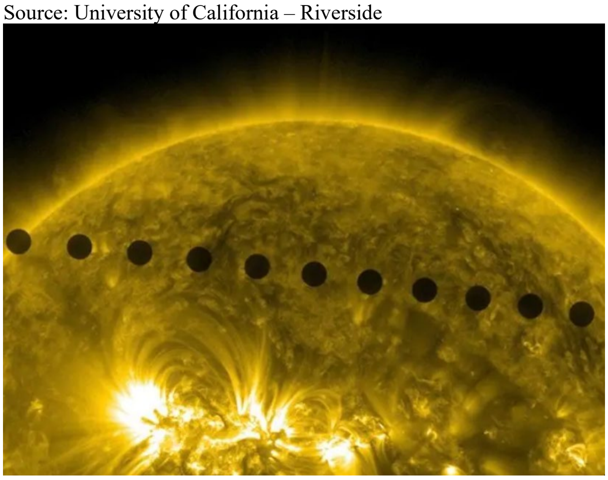
Putting the picture together

Although FBOTs glow bright in optical wavelengths, they also emit radio waves and X-rays. Gottlieb's model explains these too. When the cocoon interacts with the dense gas surrounding the star, this interaction heats up stellar material to release a radio emission. And when the cocoon expands far enough away from the black hole (formed from the collapsed star), X-rays can leak out from the black hole. The X-rays join radio and optical light to form a full picture of the FBOT event.
While Gottlieb is encouraged by his team's findings, he says more observations and models are needed before we can definitively understand FBOTs' mysterious origins.
"This is a new class of transients, and we know so little about them," Gottlieb said. "We need to detect more of them earlier in their evolution before we can fully understand these explosions. But our model is able to draw a line among supernovae, GRBs and FBOTs, which I think is very elegant."
"This study paves the way for more advanced simulations of FBOTs," Tchekovskoy said. "This next-generation model will allow us to directly connect the physics of the central black hole to the observables, enabling us to reveal otherwise hidden physics of the FBOT central engine."
The study, "Shocked jets in CCSNe can power the zoo of fast blue optical transients," was supported by the National Science Foundation (award numbers AST-1815304 and AST-2107839). The authors developed the simulation using supercomputers at the Texas Advanced Computing Centre at the University of Texas at Austin.
Video: https://youtu.be/MquOKdZEaDw

- Why Venus rotates, slowly, despite sun's powerful grip

Planet's atmosphere explains the gravity of the situation

Date: April 20, 2022
Source: University of California – Riverside



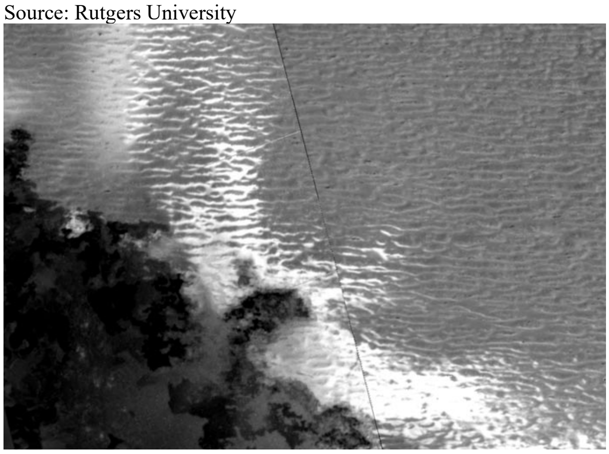
A sequence of images composited together to show path of Venus across the Sun. | Source: NASA

If not for the soupy, fast-moving atmosphere on Venus, Earth's sister planet would likely not rotate. Instead, Venus would be locked in place, always facing the sun the way the same side of the moon always faces Earth.
The gravity of a large object in space can keep a smaller object from spinning, a phenomenon called tidal locking. Because it prevents this locking, a UC Riverside scientist argues the atmosphere needs to be a more prominent factor in studies of Venus as well as other planets.
These arguments, as well as descriptions of Venus as a partially tidally locked planet, were published today in a *Nature Astronomy* article.
"We think of the atmosphere as a thin, almost separate layer on top of a planet that has minimal interaction with the solid planet," said Stephen Kane, UCR astrophysicist and lead paper author. "Venus' powerful atmosphere teaches us that it's a much more integrated part of the planet that affects absolutely everything, even how fast the planet rotates."
Venus takes 243 Earth days to rotate one time, but its atmosphere circulates the planet every

four days. Extremely fast winds cause the atmosphere to drag along the surface of the planet as it circulates, slowing its rotation while also loosening the grip of the sun's gravity.
Slow rotation in turn has dramatic consequences for the sweltering Venusian climate, with average temperatures of up to 900 degrees Fahrenheit -- hot enough to melt lead.
"It's incredibly alien, a wildly different experience than being on Earth," Kane said. "Standing on the surface of Venus would be like standing at the bottom of a very hot ocean. You couldn't breathe on it."
One reason for the heat is that nearly all of the sun's energy absorbed by the planet is soaked up by Venus' atmosphere, never reaching the surface. This means that a rover with solar panels like the one NASA sent to Mars wouldn't work.
The Venusian atmosphere also blocks the sun's energy from leaving the planet, preventing cooling or liquid water on its surface, a state known as a runaway greenhouse effect.
It is unclear whether being partially tidally locked contributes to this runaway greenhouse state, a condition which ultimately renders a planet uninhabitable by life as we know it.
Not only is it important to gain clarity on this question to understand Venus, it is important for studying the exoplanets likely to be targeted for future NASA missions.
Most of the planets likely to be observed with the recently launched James Webb Space Telescope are very close to their stars, even closer than Venus is to the sun. Therefore, they're also likely to be tidally locked.
Since humans may never be able to visit exoplanets in person, making sure computer models account for the effects of tidal locking is critical. "Venus is our opportunity to get these models correct, so we can properly understand the surface environments of planets around other stars," Kane said.
"We aren't doing a good job of considering this right now. We're mostly using Earth-type models to interpret the properties of exoplanets. Venus is waving both arms around saying, 'look over here!'"
Gaining clarity about the factors that contributed to a runaway greenhouse state on Venus, Earth's closest planetary neighbour, can also help improve models of what could one day happen to Earth's climate.
"Ultimately, my motivation in studying Venus is to better understand the Earth," Kane said.

- Jupiter's moon has splendid dunes

New way dunes can form on varied celestial surfaces
Date: April 19, 2022
Source: Rutgers University



Potential dunes on Jupiter's moon Io. An analysis indicates that the dark material (lower left) is recently emplaced lava flows, while the repeated, line-like features dominating the image are potential dunes. The bright, white areas may be newly emplaced grains as the lava flows vaporize adjacent frost.
Credit: NASA/JPL-Caltech/Rutgers

Scientists have long wondered how Jupiter's innermost moon, Io, has meandering ridges as grand as any that can be seen in movies like "Dune." Now, a Rutgers research study has provided a new explanation of how dunes can form even on a surface as icy and roiling as Io's.
The study, published in the journal *Nature Communications*, is based on a study of the physical processes controlling grain motion coupled with an analysis of images from the 14-year mission of NASA's Galileo spacecraft, which allowed the creation of the first detailed maps of Jupiter's moons. The new study is expected to expand our scientific understanding of the geological features on these planet-like worlds. "Our studies point to the possibility of Io as a new 'dune world,'" said first author George McDonald, a postdoctoral researcher in Rutgers' Earth and Planetary Sciences Department. "We have proposed, and quantitatively tested, a mechanism by which sand grains can move, and in turn dunes could be forming there."
Current scientific understanding dictates that dunes, by their nature, are hills or ridges of sand piled up by the wind. And scientists in previous studies of Io, while describing its surface as containing some dune-like features, concluded the ridges could not be dunes since the forces from winds on Io are weak due to the moon's low-density atmosphere. "This work tells us that the environments in which

dunes are found are considerably more varied than the classical, endless desert landscapes on parts of Earth or on the fictional planet Arrakis in 'Dune,'" McDonald said.
The Galileo mission, which lasted from 1989 -- 2003, logged so many scientific firsts that researchers to this day are still studying the data it collected. One of the major insights gleaned from the data was the high extent of volcanic activity on Io -- so much so that its volcanoes repeatedly and rapidly resurface the little world. Io's surface is a mix of black solidified lava flows and sand, flowing "effusive" lava streams, and "snows" of sulphur dioxide. The scientists used mathematical equations to simulate the forces on a single grain of basalt or frost and calculate its path. When lava flows into sulphur dioxide beneath the moon's surface, its venting is "dense and fast moving enough to move grains on Io and possibly enable the formation of large-scale features like dunes," McDonald said. Once the researchers devised a mechanism by which the dunes could form, they looked to photos of Io's surface taken by the Galileo spacecraft for more proof. The spacing of the crests and the height-to-width ratios they observed were consistent with trends for dunes seen on Earth and other planets. "Work like this really allows us to understand how the cosmos works," said Lujendra Ojha, a co-author and an assistant professor in the Department of Earth and Planetary Sciences. "In the end, in planetary science, that is what we are trying to do." The paper also included authors from the University of Oregon, the Massachusetts Institute of Technology, Texas A&M University and the Jet Propulsion Laboratory at the California Institute of Technology.

- Astronomers identify likely location of medium-sized black holes

Date: April 20, 2022
Source: Washington State University

Galaxy NGC 1385 is one of the 29 galaxies in the sample that showed evidence for growing black holes near their centres (photo by NASA/ESA/STScI).

Intermediate-mass black holes are notoriously hard to find but a new study indicates there may be some at the centre of dense star clusters located throughout the universe.
The study, published today in the *Astrophysical Journal*, sheds new light on when and where black holes of about 100-100,000 solar masses could form and how they came into being.
"One of the biggest open questions in black hole astrophysics right now is how do black holes form that are between the size of a stellar mass black hole and a supermassive black hole," said Vivienne Baldassare, lead author of the study and an assistant professor of physics and astronomy at Washington State University. "Most of the theories for their formation rely on conditions that are found only in the very early universe. We wanted to test another theory that says they can form throughout cosmic time in these really dense star clusters."
For decades, astronomers have detected smaller black holes equal in mass either to a few suns or giant black holes with mass similar to millions of suns but the missing-link of black holes in between those sizes have eluded discovery.
The existence of these intermediate-sized or massive black holes has long been theorized but finding them has proven difficult as the light emitted by objects falling into them is not easy to detect.
To address this challenge, the research team used the Chandra X-Ray Observatory, the world's most powerful X-ray telescope, to look for X-ray signatures of black holes in nuclear star clusters in 108 different galaxies.
"Chandra is basically the only instrument in the world that is able to do this kind of work," Baldassare said. "It is able to pinpoint the locations of x-ray sources very precisely, which is important when you are looking for black hole signatures in these very compact nuclear star clusters."
Nuclear star clusters are found at the centre of most small or low-mass galaxies and are the densest known stellar environments. Previous research has identified the presence of black holes in nuclear star clusters but little is known about the specific properties that make these regions conducive for the formation of black holes.
Baldassare and colleagues' analysis showed that nuclear star clusters that were above a certain mass and density threshold emitted the

X-ray signatures indicative of a black hole at twice the rate of those below the threshold. Their work provides the first observational evidence supporting the theory that intermediate-sized black holes can form in nuclear star clusters.
"Basically, it means that star clusters that are sufficiently massive and compact should be able to form a blackhole," Baldassare said. "It is exciting because we expect many of these black holes to be in the intermediate mass regime between supermassive black holes and stellar mass black holes where there is very little evidence for their existence."
The research team's work not only suggests that intermediate-sized black holes can form in nuclear star clusters but also provides a mechanism by which they could potentially form throughout cosmic time rather than just during the first few billion years of the universe.
"One of the prevailing theories out there is that massive black holes could only have formed during the early universe when things were denser," Baldassare said. "Our research is more consistent with the picture where massive blackholes don't need to form in the very early universe but could rather continue to form throughout cosmic time in these particular environments."
Moving forward, the researchers plan to continue using Chandra to collect x-ray measurements of nuclear star clusters with the ultimate goal of learning more about the specific conditions where massive black holes can form.

- Neptune is cooler than we thought: Study reveals unexpected changes in atmospheric temperatures

Date: April 11, 2022
Source: University of Leicester

Neptune illustration (stock image).
Credit: © Media Whalestock / stock.adobe.com

New research led by space scientists at the University of Leicester has revealed how temperatures in Neptune's atmosphere have unexpectedly fluctuated over the past two decades.
The study, published today (Monday) in *Planetary Science Journal*, used observations in thermal-infrared wavelengths beyond the visible light spectrum, effectively sensing heat emitted from the planet's atmosphere.
An international team of researchers, including scientists from Leicester and NASA's Jet Propulsion Laboratory (JPL), combined all existing thermal infrared images of Neptune gathered from multiple observatories over almost two decades. These include the European Southern Observatory's Very Large Telescope and Gemini South telescope in Chile, together with the Subaru Telescope, Keck Telescope, and the Gemini North telescope, all in Hawai'i, and spectra from NASA's Spitzer Space Telescope.
By analysing the data, the researchers were able to reveal a more complete picture of trends in Neptune's temperatures than ever before.
But to the researchers' surprise, these collective datasets show a decline in Neptune's thermal brightness since reliable thermal imaging began in 2003, indicating that globally-averaged temperatures in Neptune's stratosphere -- the layer of the atmosphere just above its active weather layer -- have dropped by roughly 8 degrees Celsius (14 degrees Fahrenheit) between 2003 and 2018.
Dr Michael Roman, Postdoctoral Research Associate at the University of Leicester and lead author on the paper, said:
"This change was unexpected. Since we have been observing Neptune during its early southern summer, we would expect temperatures to be slowly growing warmer, not colder."
Neptune has an axial tilt, and so it experiences seasons, just like Earth. However, given its great distance from the Sun, Neptune takes over 165 years to complete an orbit around its host star, and so its seasons change slowly, lasting over 40 Earth-years each.
Dr Glenn Orton, Senior Research Scientist at JPL and co-author on the study, noted:
"Our data cover less than half of a Neptune season, so no one was expecting to see large and rapid changes."
Yet, at Neptune's south pole, the data reveal a different and surprisingly dramatic change. A combination of observations from Gemini North in 2019 and Subaru in 2020 reveal that Neptune's polar stratosphere warmed by

roughly 11?C (~20?F) between 2018 and 2020, reversing the previous globally-averaged cooling trend. Such polar warming has never been observed on Neptune before. The cause of these unexpected stratospheric temperature changes is currently unknown, and the results challenge scientists' understanding of Neptune's atmospheric variability.

Dr Roman continued:

"Temperature variations may be related to seasonal changes in Neptune's atmospheric chemistry, which can alter how effectively the atmosphere cools.

"But random variability in weather patterns or even a response to the 11-year solar activity cycle may also have an effect."

The 11-year solar cycle (marked by periodic variation in the Sun's activity and sunspots) has been previously suggested to affect Neptune's visible brightness, and the new study reveals a possible, but tentative, correlation between the solar activity, stratospheric temperatures, and the number of bright clouds seen on Neptune.

Follow-up observations of the temperature and cloud patterns are needed to further assess any possible connection in the years ahead.

Answers to these mysteries and more will come from the James Webb Space Telescope (JWST), which is set to observe both ice giants, Uranus and Neptune, later this year.

Leigh Fletcher, Professor of Planetary Science at the University of Leicester, will lead such observations with allocated time of JWST's suite of instruments. Professor Fletcher, also a co-author on this study, said:

"The exquisite sensitivity of the space telescope's mid-infrared instrument, MIRI, will provide unprecedented new maps of the chemistry and temperatures in Neptune's atmosphere, helping to better identify the nature of these recent changes."

This study was funded by a European Research Council grant to the University of Leicester, known as GIANTCLIMES. This project has previously discovered long-term changes in atmospheric temperatures and clouds on the gas giants, Jupiter and Saturn, and it provided the first maps of the stratospheric temperatures of Uranus. GIANTCLIMES has paved the way for new discoveries on all four giant planets from JWST in the years to come.

Additional co-authors on this work include Thomas Greathouse (Southwest Research Institute), Julianne Moses (Space Science Institute), Naomi Rowe-Gurney (Howard University / NASA Goddard Space Flight Centre), Patrick Irwin (Oxford), Arrate Antuñano (UPV/EHU), James Sinclair (JPL), Yasumasa Kasaba (Tohoku University), Takuya Fujiyoshi (Subaru Telescope), Imke de Pater (UC Berkeley), and Heidi Hammel (Association of Universities for Research in Astronomy).

'Sub-Seasonal Variation in Neptune's Mid-Infrared Emission' is published in *Planetary Science Journal*.

- Perseverance records the first ever sounds from Mars

Date: April 1, 2022
Source: CNRS

Illustration of Mars rover (stock image; elements furnished by NASA).
Credit: © Tryfonov / stock.adobe.com

NASA's Perseverance rover, which has been surveying the surface of Mars since February 2021, has for the first time recorded the acoustic environment of the Red Planet. An international team1 led by an academic at the University of Toulouse III -- Paul Sabatier and including scientists from the CNRS and ISAE-SUPAERO, carried out an analysis of these sounds, which were obtained using the SuperCam instrument built in France under the authority of the French space agency CNES. Their findings are published on 1st April 2022 in *Nature*.

For 50 years, interplanetary probes have returned thousands of striking images of the surface of Mars, but never a single sound. Now, NASA's Perseverance mission has put an end to this deafening silence by recording the first ever Martian sounds. The scientific team[1] for the French-US SuperCam[2] instrument installed on Perseverance was convinced that the study of the soundscape of Mars could advance our understanding of the planet. This scientific challenge led them to design a microphone dedicated to the

exploration of Mars, at ISAE-SUPAERO in Toulouse, France.
Perseverance first recorded sounds from the Red Planet on February 19, 2021, the day after its arrival. These sounds fall within the human audible spectrum, between 20 Hz and 20 kHz. First of all, they reveal that Mars is quiet, in fact so quiet that on several occasions the scientists thought the microphone was no longer working. It is obvious that, apart from the wind, natural sound sources are rare.
In addition to this investigation, the scientists focused on the sounds generated by the rover itself[3], including the shock waves produced by the impact of the SuperCam laser on rocks, and flights by the Ingenuity helicopter. By studying the propagation on Mars of these sounds, whose behaviour is very well understood on Earth, they were able to accurately characterise the acoustic properties of the Martian atmosphere.
The researchers show that the speed of sound is lower on Mars than on Earth: 240 m/s, as compared to 340 m/s on our planet. However, the most surprising thing is that it turns out that there are actually two speeds of sound on Mars, one for high-pitched sounds and one for low frequencies[4]. Sound attenuation is greater on Mars than on Earth, especially for high frequencies, which, unlike low frequencies, are attenuated very quickly, even at short distances. All these various factors would make it difficult for two people standing only five metres apart to have a conversation. They are due to the composition of the Martian atmosphere (96% CO_2, compared to 0.04% on Earth) and the very low atmospheric surface pressure (170 times lower than on Earth).
After one year of the mission, a total of five hours of recordings of the acoustic environment have been obtained. In-depth analysis of these sounds has made the sound generated by the turbulence of the Martian atmosphere perceptible. The study of this turbulence, at scales 1000 times smaller than anything previously known, should enhance our knowledge of the interaction of the atmosphere with the surface of Mars. In the future, the use of other robots equipped with microphones could help us to better understand planetary atmospheres.

Footnotes

[1] Scientists from the following laboratories also took part: Institut de Recherche en Astrophysique et Planétologie (Université Toulouse III -- Paul Sabatier/CNRS/CNES), Institut de Mécanique des Fluides de Toulouse (Université Toulouse III -- Paul Sabatier/CNRS/INP), Laboratoire d'Etudes Spatiales et d'Instrumentation en Astrophysique (Observatoire de Paris-PSL/CNRS/Sorbonne Université/Université Paris Cité), Laboratoire Atmosphères, Milieux, Observations Spatiales (CNRS/Sorbonne Université/Université de Versailles St Quentin-en-Yvelines), Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie (CNRS/MNHN/Sorbonne Université), Laboratoire Planétologie et Géosciences (CNRS/Université Nantes/Université Angers), Institut de Planétologie et Astrophysique de Grenoble (CNRS/Université Grenoble Alpes), Centre Lasers Intenses et Applications (CNRS/CEA/Université de Bordeaux), Laboratoire d'Astrophysique de Bordeaux (CNRS /Université de Bordeaux), Institut d'Astrophysique Spatiale (CNRS/Université Paris Saclay), Laboratoire de Géologie de Lyon : Terre, Planètes, Environnement (CNRS/ENS Lyon/Université Claude Bernard), and Laboratoire GeoRessources (CNRS/Université de Lorraine).

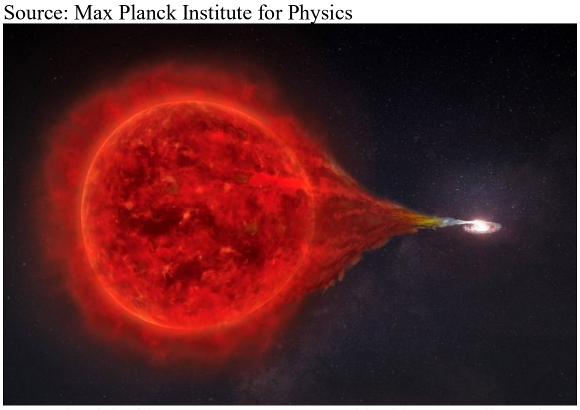
[2] SuperCam was jointly developed by LANL (Los Alamos National Laboratory, USA) and a consortium of laboratories affiliated to the CNRS and French universities and research institutions. The CNES is responsible to NASA for the French contribution to SuperCam.

[3] The microphone also acts as a stethoscope for the rover since it provides an acoustic diagnosis of its health.

[4] Approximately 240 m/s for frequencies below 240 Hz, and 250 m/s above

- Nova outbursts are apparently a source for cosmic rays

Date: April 14, 2022
Source: Max Planck Institute for Physics



Artwork of the binary star system RS Ophiuchi: Matter flows from the red giant onto the white dwarf. The newly added stellar envelopes explode in a bright nova about every 15 years. Credit: superbossa.com/MPP

Light on, light off -- this is how one could describe the behaviour of the nova, which goes by the name RS Ophiuchi (RS Oph). Every 15 years or so, a dramatic explosion occurs in the constellation of the Serpent Bearer. Birthplaces of a nova are systems in which two very different stars live in a parasitic relationship: A white dwarf, a small, burned-out and tremendously dense star -- a teaspoon of its matter weighs about 1 ton -- orbits a red giant, an old star that will soon burn up.
The dying giant star feeds the white dwarf with matter shedding its outer hydrogen layer as the gas flows onto the nearby white dwarf. This flow of matter continues, until the white dwarf over(h)eats itself. The temperature and pressure in the newly gained stellar shells become too large and are flung away in a gigantic thermonuclear explosion. The dwarf star remains intact and the cycle begins again -- until the spectacle repeats itself.

Explosion in the high-energy range

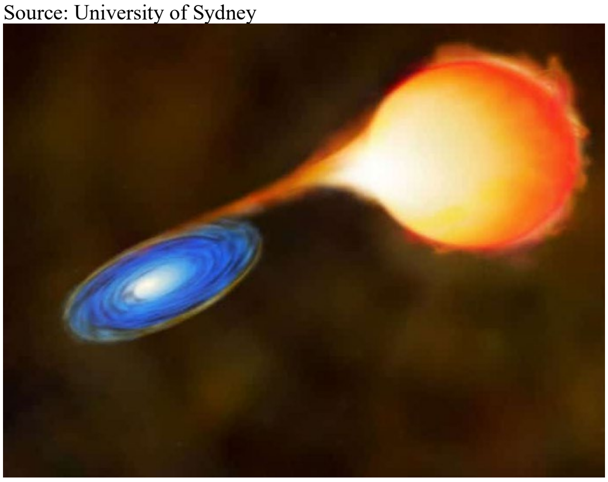
It had been speculated that such explosions involve high energies. The two MAGIC telescopes recorded gamma rays with the value of 250 gigaelectronvolts (GeV), among the highest energies ever measured in a nova. By comparison, the radiation is a hundred billion times more energetic than visible light. MAGIC was able to make its observations following initial alerts from other instruments measuring at different wavelengths. "The spectacular eruption of the RS Ophiuchi shows that the MAGIC telescopes' fast response really pays off: It takes them no more than 30 seconds to move to a new target," said David Green, a scientist at the Max Planck Institute for Physics and one of the authors of the paper.

Accelerated protons as a part of cosmic rays

After the explosion, several shock fronts propagated through the stellar wind from the Red Giant and the interstellar medium surrounding the binary system. These shock waves work like a giant power plant in which particles are accelerated to near the speed of light. The combined measurements suggest that the gamma rays emanate from energetic protons, nuclei of hydrogen atoms.
"This also makes nova outbursts a source of cosmic rays," explains David Green. "However, they tend to play the role of local heroes -- meaning to only contribute to the cosmic rays in the close neighbourhood. The big players for cosmic rays are supernova remnants. The shock fronts created from stellar explosions are far more violent compared to novae.
To fully understand the complicated interplay of violent events with the interstellar medium in the Milky Way, more observations like those reported now will be necessary. The MAGIC collaboration will therefore continue to look for "restless" objects in our Galaxy and beyond.

- Giant stars undergo dramatic weight loss program

Date: April 14, 2022
Source: University of Sydney



In the binary named Mira, a red giant star transfers mass to a white dwarf. © NASA/CXC/M.Weiss.

Astronomers at the University of Sydney have found a slimmer type of red giant star for the first time. These stars have undergone dramatic weight loss, possibly due to the presence a greedy neighbour. Published in *Nature Astronomy*, the discovery is an important step forward to understanding the life of stars in the Milky Way -- our closest stellar neighbours.
There are millions of 'red giant' stars found in our galaxy. These cool and luminous objects are what our Sun will become in four billion years. For some time, astronomers have predicted the existence of slimmer red giants. After finding a smattering of them, the University of Sydney team can finally confirm their existence.
"It's like finding Waldo," said lead author, PhD candidate Mr Yaguang Li from the University of Sydney. "We were extremely lucky to find about 40 slimmer red giants, hidden in a sea of normal ones. The slimmer red giants are either smaller in size or less massive than normal red giants."
How and why did they slim down? Most stars in the sky are in binary systems -- two stars

that are gravitationally bound to each other. When the stars in close binaries expand, as stars do as they age, some material can reach the gravitational sphere of their companion and be sucked away. "In the case of relatively tiny red giants, we think a companion could possibly be present," Mr Li said.

An intragalactic treasure hunt

The team analysed archival data from NASA's Kepler space telescope. From 2009 to 2013, the telescope continuously recorded brightness variations on tens of thousands of red giants. Using this incredibly accurate and large dataset, the team conducted a thorough census of this stellar population, providing the groundwork for spotting any outliers.

Two types of unusual stars were revealed: very low-mass red giants, and under luminous (dimmer) red giants.

The very low-mass stars weigh only 0.5 to 0.7 solar mass -- around half the weight of our Sun. If the very low-mass stars had not suddenly lost weight, their masses would indicate they were older than the age of the Universe -- an impossibility.

"So, when we first obtained the masses of these stars, we thought there was something wrong with the measurement," Mr Li said. "But it turns out there wasn't."

The under luminous stars, on the other hand, have normal masses, ranging from 0.8 to 2.0 solar mass. "However, they are much less 'giant' than we expect," said study co-author, Dr Simon Murphy from the University of Southern Queensland. "They've slimmed down somewhat and because they're smaller, they're also fainter, hence 'under luminous' compared to normal red giants."

Only seven such under luminous stars were found, and the authors suspect many more are hiding in the sample. "The problem is that most of them are very good at blending in. It was a real treasure hunt to find them," Dr Murphy said.

These unusual data points could not be explained by simple expectations from stellar evolution. This led the researchers to conclude that another mechanism must be at work, forcing these stars to undergo dramatic weight loss: theft of mass by nearby stars.

Stellar population census

The researchers relied on asteroseismology -- the study of stellar vibrations -- to determine the properties of the red giants.

Traditional methods to study a star are limited to their surface properties, for example, surface temperature and luminosity. By contrast, asteroseismology, which uses sound waves, probes beneath this. "The waves penetrate the stellar interior, giving us rich information on another dimension," Mr Li said.

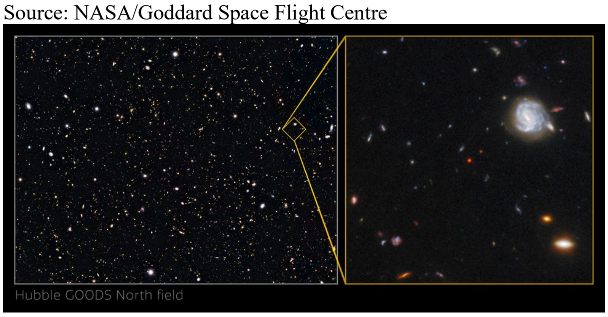
The researchers could precisely determine stars' evolutionary stages, masses, and sizes with this method. And when they looked at the distributions of these properties, something unusual was immediately noticed: some stars have tiny masses or sizes.

"It is highly unusual for a PhD student to make such an important discovery," said Professor Tim Bedding, Mr Li's academic supervisor. "By sifting carefully through data from NASA's Kepler space telescope, Yaguang spotted something that everyone else had missed."

- ❖ Hubble sheds light on origins of supermassive black holes

Astronomers have identified a rapidly growing black hole in the early universe that is considered a crucial

Date: April 13, 2022
Source: NASA/Goddard Space Flight Centre



Astronomers have identified a rapidly growing black hole in the early universe that is considered a crucial "missing link" between young star-forming galaxies and the first supermassive black holes. They used data from NASA's Hubble Space Telescope to make this discovery.

Until now, the monster, nicknamed GNz7q, had been lurking unnoticed in one of the best-studied areas of the night sky, the Great Observatories Origins Deep Survey-North (GOODS-North) field.

Archival Hubble data from Hubble's Advanced Camera for Surveys helped the team determine that GNz7q existed just 750 million years after the big bang. The team obtained evidence that GNz7q is a newly formed black hole. Hubble found a compact source of ultraviolet (UV) and infrared light. This couldn't be caused by emission from galaxies, but is consistent with the radiation

expected from materials that are falling onto a black hole.
Rapidly growing black holes in dusty, early star-forming galaxies are predicted by theories and computer simulations, but had not been observed until now.
"Our analysis suggests that GNz7q is the first example of a rapidly growing black hole in the dusty core of a starburst galaxy at an epoch close to the earliest supermassive black hole known in the universe," explained Seiji Fujimoto, an astronomer at the Niels Bohr Institute of the University of Copenhagen and lead author of the Nature paper describing this discovery. "The object's properties across the electromagnetic spectrum are in excellent agreement with predictions from theoretical simulations."
One of the outstanding mysteries in astronomy today is: How did supermassive black holes, weighing millions to billions of times the mass of the Sun, get to be so huge so fast?
Current theories predict that supermassive black holes begin their lives in the dust-shrouded cores of vigorously star-forming "starburst" galaxies before expelling the surrounding gas and dust and emerging as extremely luminous quasars. While extremely rare, both these dusty starburst galaxies and luminous quasars have been detected in the early universe.
The team believes that GNz7q could be a missing link between these two classes of objects. GNz7q has exactly both aspects of the dusty starburst galaxy and the quasar, where the quasar light shows the dust reddened colour. Also, GNz7q lacks various features that are usually observed in typical, very luminous quasars (corresponding to the emission from the accretion disk of the supermassive black hole), which is most likely explained that the central black hole in GN7q is still in a young and less massive phase. These properties perfectly match with the young, transition phase quasar that has been predicted in simulations, but never identified at similarly high-redshift universe as the very luminous quasars so far identified up to a redshift of 7.6.
"GNz7q provides a direct connection between these two rare populations and provides a new avenue toward understanding the rapid growth of supermassive black holes in the early days of the universe," continued Fujimoto. "Our discovery provides an example of precursors to the supermassive black holes we observe at later epochs."
While other interpretations of the team's data cannot be completely ruled out, the observed properties of GNz7q are in strong agreement with theoretical predictions. GNz7q's host galaxy is forming stars at the rate of 1,600 solar masses per year, and GNz7q itself appears bright at UV wavelengths but very faint at X-ray wavelengths.
Generally, the accretion disk of a massive black hole should be very bright in both UV and X-ray light. But this time, although the team detected UV light with Hubble, X-ray light was invisible even with one of the deepest X-ray datasets. These results suggest that the core of the accretion disk, where X-rays originate, is still obscured; while the outer part of the accretion disk, where UV light originates, is becoming unobscured. This interpretation is that GNz7q is a rapidly growing black hole still obscured by the dusty core of its star-forming host galaxy.
"GNz7q is a unique discovery that was found just at the centre of a famous, well-studied sky field -- it shows that big discoveries can often be hidden just in front of you," commented Gabriel Brammer, another astronomer from the Niels Bohr Institute of the University of Copenhagen and a member of the team behind this result. "It's unlikely that discovering GNz7q within the relatively small GOODS-North survey area was just 'dumb luck,' but rather that the prevalence of such sources may in fact be significantly higher than previously thought."
Finding GNz7q hiding in plain sight was only possible thanks to the uniquely detailed, multiwavelength datasets available for GOODS-North. Without this richness of data GNz7q would have been easy to overlook, as it lacks the distinguishing features usually used to identify quasars in the early universe.
The team now hopes to systematically search for similar objects using dedicated high-resolution surveys and to take advantage of the NASA James Webb Space Telescope's spectroscopic instruments to study objects such as GNz7q in unprecedented detail.
"Fully characterizing these objects and probing their evolution and underlying physics in much greater detail will become possible with the James Webb Space Telescope," concluded Fujimoto. "Once in regular operation, Webb will have the power to

decisively determine how common these rapidly growing black holes truly are."
The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Centre in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

- Simulating supernova remnants, star formation in earthbound lab

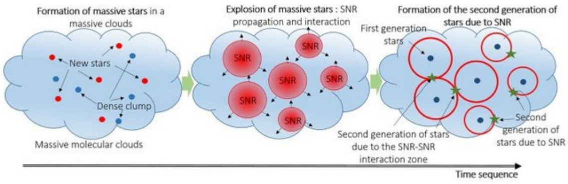


Illustration of the evolution of a massive cloud which indicates the importance of SNR propagation in forming new stars. CREDIT: Albertazzi et al.

High-power laser, foam ball show how blast waves from supernova remnant might trigger star formation in a molecular cloud

Date: April 12, 2022
Source: American Institute of Physics

Molecular clouds are collections of gas and dust in space. When left alone, the clouds remain in their state of peaceful equilibrium. But when triggered by some external agent, like supernova remnants, shockwaves can propagate through the gas and dust to create pockets of dense material. At a certain limit, that dense gas and dust collapses and begins to form new stars.
Astronomical observations do not have high enough spatial resolution to observe these processes, and numerical simulations cannot handle the complexity of the interaction between clouds and supernova remnants. Therefore, the triggering and formation of new stars in this way remains mostly shrouded in mystery.
In Matter and Radiation at Extremes, by AIP Publishing in partnership with China Academy of Engineering Physics, researchers from the Polytechnic Institute of Paris, the Free University of Berlin, the Joint Institute for High Temperatures of the Russian Academy of Sciences, the Moscow Engineering Physics Institute, the French Alternative Energies and Atomic Energy Commission, the University of Oxford, and Osaka University modelled the interaction between supernova remnants and molecular clouds using a high-power laser and a foam ball.
The foam ball represents a dense area within a molecular cloud. The high-power laser creates a blast wave that propagates through a surrounding chamber of gas and into the ball, where the team observed the compression using X-ray images.
"We are really looking at the beginning of the interaction," said author Bruno Albertazzi. "In this way, you can see if the average density of the foam increases and if you will begin to form stars more easily."
The mechanisms for triggering star formation are interesting on a number of scales. They can impact the star formation rate and evolution of a galaxy, help explain the formation of the most massive stars, and have consequences in our own solar system.
"Our primitive molecular cloud, where the sun was formed, was probably triggered by supernova remnants," said author Albertazzi. "This experiment opens a new and promising path for laboratory astrophysics to understand all these major points."
While some of the foam compressed, some of it also stretched out. This changed the average density of the material, so in the future, the authors will need to account for the stretched mass to truly measure the compressed material and the shockwave's impact on star formation. They plan to explore the influence of radiation, magnetic field, and turbulence.
"This first paper was really to demonstrate the possibilities of this new platform opening a new topic that could be investigated using high-power lasers," said Albertazzi.

- Modelling Earth's magnetosphere in the laboratory

Date: April 12, 2022
Source: American Institute of Physics

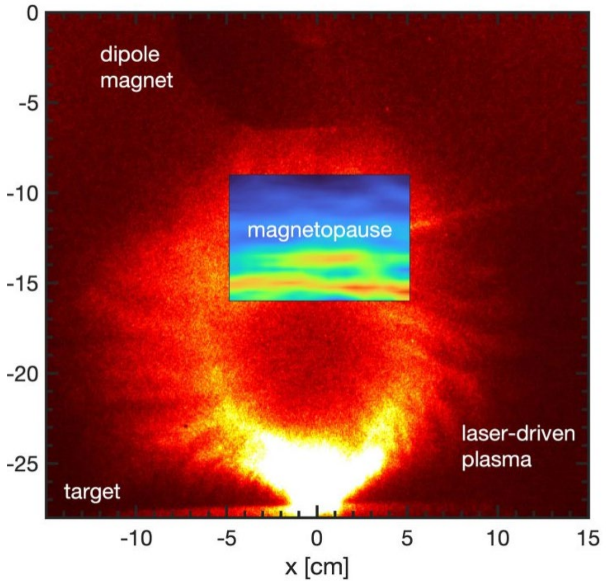


Image of the laser-driven plasma expanding into the dipole magnetic field. Magnetic field measurements showing the location of the magnetopause are overlaid. Credit: Derek Schaeffer

A magnetosphere forms around any magnetized object, such as a planet, that is immersed within a stream of ionized gas, called plasma. Because Earth possesses an intrinsic magnetic field, the planet is surrounded by a large magnetosphere that extends out into space, blocks lethal cosmic rays and particles from the sun and stars, and allows life itself to exist.

In *Physics of Plasmas*, by AIP Publishing, scientists from Princeton, UCLA, and the Instituto Superior Técnico, Portugal, report a method to study smaller magnetospheres, sometimes just millimetres thick, in the laboratory.

These mini-magnetospheres have been observed around comets and near certain regions of the moon and have been suggested to propel spacecraft. They are good testbeds for studying larger planet-sized magnetospheres.

Previous laboratory experiments have been carried out utilizing plasma wind tunnels or high-energy lasers to create mini-magnetospheres. However, these earlier experiments were limited to 1D measurements of magnetic fields that do not capture the full 3D behaviour scientists need to understand.

"To overcome these limitations, we have developed a new experimental platform to study mini-magnetospheres on the Large Plasma Device (LAPD) at UCLA," said author Derek Schaeffer.

This platform combines the magnetic field of the LAPD with a fast laser-driven plasma and a current-driven dipole magnet.

The LAPD magnetic field provides a model of the solar system's interplanetary magnetic field, while the laser-driven plasma models the solar wind and the dipole magnet provides a model for the Earth's inherent magnetic field. Motorized probes allow system scans in three dimensions by combining data from tens of thousands of laser shots.

One advantage to using this setup is that the magnetic field and other parameters can be carefully varied and controlled.

If the dipole magnet is switched off, all signs of a magnetosphere disappear. When the magnetic field of the dipole is switched on, a magnetopause can be detected, which is key evidence of the formation of a magnetosphere.

A magnetopause is the place in the magnetosphere where pressure from the planetary magnetic field is exactly balanced by the solar wind. The experiments revealed that as the dipole magnetic field is increased, the magnetopause gets larger and stronger.

The effect on the magnetopause was predicted by computer simulations, which were carried out by the investigators to understand and validate their experimental results more fully.

These simulations will also guide future experiments, including studies utilizing a cathode recently installed on the LAPD.

"The new cathode will enable faster plasma flows, which in turn will allow us to study the bow shocks observed around many planets," Schaeffer said.

Other experiments will study magnetic reconnection, an important process in Earth's magnetosphere in which magnetic fields annihilate to release tremendous energy.

- 4 billion-year-old relic from early solar system heading our way

But we're in no danger, professor assures

Date: April 12, 2022
Source: University of California - Los Angeles

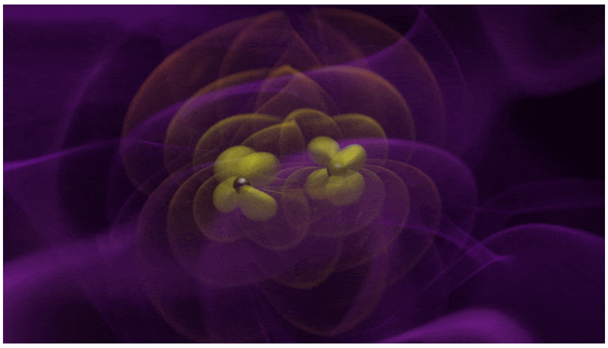

Comet C/2014 UN271 could be as large as 85 miles across. Credit: NASA, ESA, Zena Levy (STScI)

An enormous comet -- approximately 80 miles across, more than twice the width of Rhode Island -- is heading our way at 22,000 miles

per hour from the edge of the solar system. Fortunately, it will never get closer than 1 billion miles from the sun, which is slightly farther from Earth than Saturn; that will be in 2031.
Comets, among the oldest objects in the solar system, are icy bodies that were unceremoniously tossed out of the solar system in a gravitational pinball game among the massive outer planets, said David Jewitt. The UCLA professor of planetary science and astronomy co-authored a new study of the comet in the *Astrophysical Journal Letters*.
The evicted comets took up residence in the Oort cloud, a vast reservoir of far-flung comets encircling the solar system out too many billions of miles into deep space, he said.
A typical comet's spectacular multimillion-mile-long tail, which makes it look like a skyrocket, belies the fact that the source at the heart of the fireworks is a solid nucleus of ice mixed with dust -- essentially a dirty snowball. This huge one, called Comet C/2014 UN271 and discovered by astronomers Pedro Bernardinelli and Gary Bernstein, could be as large as 85 miles across.
"This comet is literally the tip of the iceberg for many thousands of comets that are too faint to see in the more distant parts of the solar system," Jewitt said. "We've always suspected this comet had to be big because it is so bright at such a large distance. Now we confirm it is."
This comet has the largest nucleus ever seen in a comet by astronomers. Jewitt and his colleagues determined the size of its nucleus using NASA's Hubble Space Telescope. Its nucleus is about 50 times larger than those of most known comets. Its mass is estimated to be 500 trillion tons, a hundred thousand times greater than the mass of a typical comet found much closer to the sun.
"This is an amazing object, given how active it is when it's still so far from the sun," said lead author Man-To Hui, who earned his doctorate from UCLA in 2019 and is now with the Macau University of Science and Technology in Taipa, Macau. "We guessed the comet might be pretty big, but we needed the best data to confirm this."
So the researchers used Hubble to take five photos of the comet on Jan. 8, 2022, and incorporated radio observations of the comet into their analysis.
The comet is now less than 2 billion miles from the sun and in a few million years will loop back to its nesting ground in the Oort cloud, Jewitt said.
Comet C/2014 UN271 was first serendipitously observed in 2010, when it was 3 billion miles from the sun. Since then, it has been intensively studied by ground and space-based telescopes.
The challenge in measuring this comet was how to determine the solid nucleus from the huge dusty coma -- the cloud of dust and gas -- enveloping it. The comet is currently too far away for its nucleus to be visually resolved by Hubble. Instead, the Hubble data show a bright spike of light at the nucleus' location. Hui and his colleagues next made a computer model of the surrounding coma and adjusted it to fit the Hubble images. Then, they subtracted the glow of the coma, leaving behind the nucleus.
Hui and his team compared the brightness of the nucleus to earlier radio observations from the Atacama Large Millimetre/submillimetre Array, or ALMA, in Chile. The new Hubble measurements are close to the earlier size estimates from ALMA, but convincingly suggest a darker nucleus surface than previously thought.
"It's big and it's blacker than coal," Jewitt said.
The comet has been falling toward the sun for well over 1 million years. The Oort cloud is thought to be the nesting ground for trillions of comets. Jewitt thinks the Oort cloud extends from a few hundred times the distance between the sun and the Earth to at least a quarter of the way out to the distance of the nearest stars to our sun, in the Alpha Centauri system.
The Oort cloud's comets were tossed out of the solar system billions of years ago by the gravitation of the massive outer planets, according to Jewitt. The far-flung comets travel back toward the sun and planets only if their orbits are disturbed by the gravitational tug of a passing star, the professor said.
First hypothesized in 1950 by Dutch astronomer Jan Oort, the Oort cloud still remains a theory because the comets that make it up are too faint and distant to be directly observed. This means the solar system's largest structure is all but invisible, Jewitt said.

- ❖ Hunting for gravitational waves from monster black holes

Date: April 7, 2022
Source: NASA/Goddard Space Flight Centre


This visualization shows gravitational waves emitted by two black holes of nearly equal mass as they spiral around each other. Orange ripples represent distortions of space-time caused by the rapidly orbiting masses. These distortions spread out and weaken, ultimately becoming gravitational waves (purple). This simulation was performed on the Pleiades supercomputer at NASA's Ames Research Centre. Credit: NASA/Bernard J. Kelly (Goddard and Univ. of Maryland Baltimore County), Chris Henze (Ames) and Tim Sandstrom (CSC Government Solutions LLC)

Our universe is a chaotic sea of ripples in space-time called gravitational waves. Astronomers think waves from orbiting pairs of supermassive black holes in distant galaxies are light-years long and have been trying to observe them for decades, and now they're one step closer thanks to NASA's Fermi Gamma-ray Space Telescope.

Fermi detects gamma rays, the highest-energy form of light. An international team of scientists examined over a decade of Fermi data collected from pulsars, rapidly rotating cores of stars that exploded as supernovae. They looked for slight variations in the arrival time of gamma rays from these pulsars, changes which could have been caused by the light passing through gravitational waves on the way to Earth. But they didn't find any. While no waves were detected, the analysis shows that, with more observations, these waves may be within Fermi's reach.

"We kind of surprised ourselves when we discovered Fermi could help us hunt for long gravitational waves," said Matthew Kerr, a research physicist at the U.S. Naval Research Laboratory in Washington. "It's new to the fray -- radio studies have been doing similar searches for years. But Fermi and gamma rays have some special characteristics that together make them a very powerful tool in this investigation."

The results of the study, co-led by Kerr and Aditya Parthasarathy, a researcher at the Max Planck Institute for Radio Astronomy in Bonn, Germany, were published online by the journal *Science* on April 7.

When massive objects accelerate, they produce gravitational waves traveling at light speed. The ground-based Laser Interferometer Gravitational Wave Observatory -- which first detected gravitational waves in 2015 -- can sense ripples tens to hundreds of miles long from crest to crest, which roll past Earth in just fractions of a second. The upcoming space-based Laser Interferometer Space Antenna will pick up waves millions to billions of miles long.

Kerr and his team are searching for waves that are light-years, or trillions of miles, long and take years to pass Earth. These long ripples are part of the gravitational wave background, a random sea of waves generated in part by pairs of supermassive black holes in the centres of merged galaxies across the universe.

To find them, scientists need galaxy-sized detectors called pulsar timing arrays. These arrays use specific sets of millisecond pulsars, which rotate as fast as blender blades. Millisecond pulsars sweep beams of radiation, from radio to gamma rays, past our line of sight, appearing to pulse with incredible regularity -- like cosmic clocks.

As long gravitational waves pass between one of these pulsars and Earth, they delay or advance the light arrival time by billionths of a second. By looking for a specific pattern of pulse variations among pulsars of an array, scientists expect they can reveal gravitational waves rolling past them.

Radio astronomers have been using pulsar timing arrays for decades, and their observations are the most sensitive to these gravitational waves. But interstellar effects complicate the analysis of radio data. Space is speckled with stray electrons. Across light-years, their effects combine to bend the trajectory of radio waves. This alters the arrival times of pulses at different frequencies. Gamma rays don't suffer from these complications, providing both a complementary probe and an independent confirmation of the radio results.

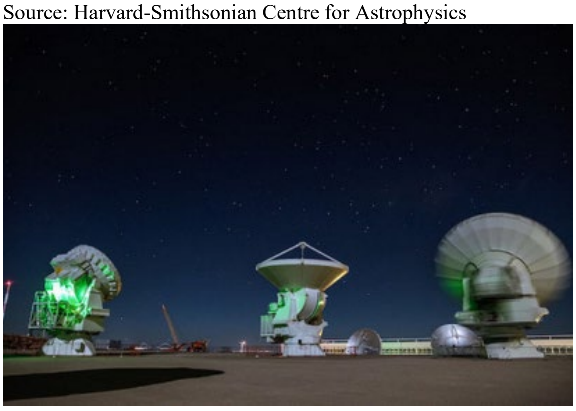
"The Fermi results are already 30% as good as the radio pulsar timing arrays when it comes to potentially detecting the gravitational wave background," Parthasarathy said. "With another five years of pulsar data collection and analysis, it'll be equally capable with the added bonus of not having to worry about all those stray electrons."

Within the next decade, both radio and gamma-ray astronomers expect to reach sensitivities that will allow them to pick up gravitational waves from orbiting pairs of monster black holes.

"Fermi's unprecedented ability to precisely time the arrival of gamma rays and its wide field of view make this measurement possible," said Judith Racusin, Fermi deputy project scientist at NASA's Goddard Space Flight Centre in Greenbelt, Maryland. "Since it launched, the mission has consistently surprised us with new information about the gamma-ray sky. We're all looking forward to the next amazing discovery."

- Astronomers have spotted the farthest galaxy ever

Date: April 7, 2022
Source: Harvard-Smithsonian Centre for Astrophysics



Atacama Large Millimetre/submillimetre Array (ALMA) (stock image).
Credit: © Chr. Offenberg / stock.adobe.com

An international team of astronomers, including researchers at the Centre for Astrophysics | Harvard & Smithsonian, has spotted the most distant astronomical object ever: a galaxy.
Named HD1, the galaxy candidate is some 13.5 billion light-years away and is described Thursday in the *Astrophysical Journal*. In an accompanying paper published in the *Monthly Notices of the Royal Astronomical Society Letters*, scientists have begun to speculate exactly what the galaxy is.
The team proposes two ideas: HD1 may be forming stars at an astounding rate and is possibly even home to Population III stars, the universe's very first stars -- which, until now, have never been observed. Alternatively, HD1 may contain a supermassive black hole about 100 million times the mass of our Sun.
"Answering questions about the nature of a source so far away can be challenging," says Fabio Pacucci, lead author of the *MNRAS* study, co-author in the discovery paper on *ApJ*, and an astronomer at the Centre for Astrophysics. "It's like guessing the nationality of a ship from the flag it flies, while being faraway ashore, with the vessel in the middle of a gale and dense fog. One can maybe see some colours and shapes of the flag, but not in their entirety. It's ultimately a long game of analysis and exclusion of implausible scenarios."
HD1 is extremely bright in ultraviolet light. To explain this, "some energetic processes are occurring there or, better yet, did occur some billions of years ago," Pacucci says.
At first, the researchers assumed HD1 was a standard starburst galaxy, a galaxy that is creating stars at a high rate. But after calculating how many stars HD1 was producing, they obtained "an incredible rate -- HD1 would be forming more than 100 stars every single year. This is at least 10 times higher than what we expect for these galaxies."
That's when the team began suspecting that HD1 might not be forming normal, everyday stars.
"The very first population of stars that formed in the universe were more massive, more luminous and hotter than modern stars," Pacucci says. "If we assume the stars produced in HD1 are these first, or Population III, stars, then its properties could be explained more easily. In fact, Population III stars are capable of producing more UV light than normal stars, which could clarify the extreme ultraviolet luminosity of HD1."
A supermassive black hole, however, could also explain the extreme luminosity of HD1. As it gobbles down enormous amounts of gas, high energy photons may be emitted by the region around the black hole.
If that's the case, it would be by far the earliest supermassive black hole known to humankind, observed much closer in time to the Big Bang compared to the current record-holder.
"HD1 would represent a giant baby in the delivery room of the early universe," says Avi Loeb an astronomer at the Centre for Astrophysics and co-author on the *MNRAS* study. "It breaks the highest quasar redshift on record by almost a factor of two, a remarkable feat."
HD1 was discovered after more than 1,200 hours of observing time with the Subaru Telescope, VISTA Telescope, UK Infrared Telescope and Spitzer Space Telescope.
"It was very hard work to find HD1 out of more than 700,000 objects," says Yuichi Harikane, an astronomer at the University of Tokyo who discovered the galaxy. "HD1's red colour matched the expected characteristics of a galaxy 13.5 billion light-years away surprisingly well, giving me a little bit of goosebumps when I found it."

The team then conducted follow-up observations using the Atacama Large Millimetre/submillimetre Array (ALMA) to confirm the distance, which is 100 million light years further than GN-z11, the current record-holder for the furthest galaxy.
Using the James Webb Space Telescope, the research team will soon once again observe HD1 to verify its distance from Earth. If current calculations prove correct, HD1 will be the most distant -- and oldest -- galaxy ever recorded.
The same observations will allow the team to dig deeper into HD1's identity and confirm if one of their theories is correct.
"Forming a few hundred million years after the Big Bang, a black hole in HD1 must have grown out of a massive seed at an unprecedented rate," Loeb says. "Once again, nature appears to be more imaginative than we are."

- Hubble probes extreme weather on ultra-hot Jupiter's

Date: April 6, 2022
Source: NASA/Goddard Space Flight Centre

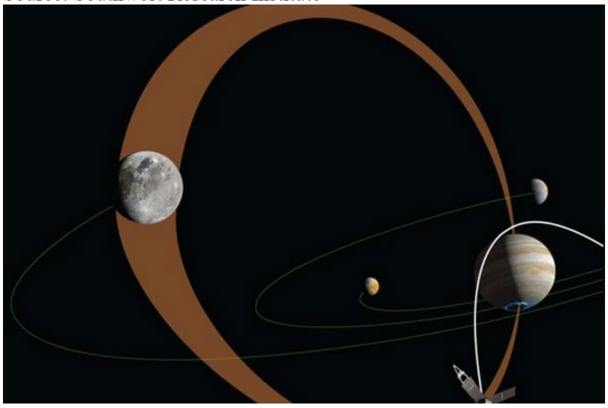
In studying a unique class of ultra-hot exoplanets, NASA Hubble Space Telescope astronomers may be in the mood for dancing to the Calypso party song "Hot, Hot, Hot." That's because these bloated Jupiter-sized worlds are so precariously close to their parent star they are being roasted at seething temperatures above 3,000 degrees Fahrenheit. That's hot enough to vaporize most metals, including titanium. They have the hottest planetary atmospheres ever seen.
In two new papers, teams of Hubble astronomers are reporting on bizarre weather conditions on these sizzling worlds. It's raining vaporized rock on one planet, and another one has its upper atmosphere getting hotter rather than cooler because it is being "sunburned" by intense ultraviolet (UV) radiation from its star.
This research goes beyond simply finding weird and quirky planet atmospheres. Studying extreme weather gives astronomers better insights into the diversity, complexity, and exotic chemistry taking place in far-flung worlds across our galaxy.
"We still don't have a good understanding of weather in different planetary environments," said David Sing of the Johns Hopkins University in Baltimore, Maryland, co-author on two studies being reported. "When you look at Earth, all our weather predictions are still finely tuned to what we can measure. But when you go to a distant exoplanet, you have limited predictive powers because you haven't built a general theory about how everything in an atmosphere goes together and responds to extreme conditions. Even though you know the basic chemistry and physics, you don't know how it's going to manifest in complex ways."
In a paper in the April 7 journal *Nature*, astronomers describe Hubble observations of WASP-178b, located about 1,300 light-years away. On the daytime side the atmosphere is cloudless, and is enriched in silicon monoxide gas. Because one side of the planet permanently faces its star, the torrid atmosphere whips around to the night time side at super-hurricane speeds exceeding 2,000 miles per hour. On the dark side, the silicon monoxide may cool enough to condense into rock that rains out of clouds, but even at dawn and dusk, the planet is hot enough to vaporize rock. "We knew we had seen something really interesting with this silicon monoxide feature," said Josh Lothringer of the Utah Valley University in Orem, Utah.
In a paper published in the January 24 issue of *Astrophysical Journal Letters*, Guangwei Fu of the University of Maryland, College Park, reported on a super-hot Jupiter, KELT-20b, located about 400 light-years away. On this planet a blast of ultraviolet light from its parent star is creating a thermal layer in the atmosphere, much like Earth's stratosphere. "Until now we never knew how the host star affected a planet's atmosphere directly. There have been lots of theories, but now we have the first observational data," Fu said.
By comparison, on Earth, ozone in the atmosphere absorbs UV light and raises temperatures in a layer between 7 to 31 miles above Earth's surface. On KELT-20b the UV radiation from the star is heating metals in the atmosphere which makes for a very strong thermal inversion layer.

Evidence came from Hubble's detection of water in near-infrared observations, and from NASA's Spitzer Space Telescope's detection of carbon monoxide. They radiate through the hot, transparent upper atmosphere that is produced by the inversion layer. This signature is unique from what astronomers see in the atmospheres of hot-Jupiter's orbiting cooler stars, like our Sun. "The emission spectrum for KELT-20b is quite different from other hot-Jupiter's," said Fu. "This is compelling evidence that planets don't live in isolation but are affected by their host star."
Though super-hot Jupiter's are uninhabitable, this kind of research helps pave the way to better understanding the atmospheres of potentially inhabitable terrestrial planets. "If we can't figure out what's happening on super-hot Jupiter's where we have reliable solid observational data, we're not going to have a chance to figure out what's happening in weaker spectra from observing terrestrial exoplanets," said Lothringer. "This is a test of our techniques that allows us to build a general understanding of physical properties such as cloud formation and atmospheric structure."
The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Centre in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

- Scientists connect the dots between Galilean moon, auroral emissions on Jupiter

Juno spacecraft discovered clues about mysterious processes creating the dance of the auroral footprints

Date: April 5, 2022
Source: Southwest Research Institute



NASA's Juno spacecraft flew through the intense beam of electrons traveling

On November 8, 2020, NASA's Juno spacecraft flew through an intense beam of electrons traveling from Ganymede, Jupiter's largest moon, to its auroral footprint on the gas giant. Southwest Research Institute scientists used data from Juno's payload to study the particle population traveling along the magnetic field line connecting Ganymede to Jupiter while, at the same time, remotely sensing the associated auroral emissions to unveil the mysterious processes creating the shimmering lights.
"Jupiter's most massive moons each create their own auroras on Jupiter's north and south poles," said Dr. Vincent Hue, lead author of a paper outlining the results of this research. "Each auroral footprint, as we call them, is magnetically connected to their respective moon, kind of like a magnetic leash connected to the moon glowing on Jupiter itself."
Like the Earth, Jupiter experiences auroral light around the polar regions as particles from its massive magnetosphere interact with molecules in the Jovian atmosphere. However, Jupiter's auroras are significantly more intense than Earth's, and unlike Earth, Jupiter's largest moons also create auroral spots. The Juno mission, led by SwRI's Dr. Scott Bolton, is circling Jupiter in a polar orbit and flew through the electron "thread" connecting Ganymede with its associated auroral footprint.
"Prior to Juno, we knew that these emissions can be quite complex, ranging from a single auroral spot to multiple spots, which sometimes trail an auroral curtain that we called the footprint tail," said Dr. Jamey Szalay, a co-author from Princeton University. "Juno, flying extremely close to Jupiter, revealed these auroral spots to be even more complex than previously thought."
Ganymede is the only moon in our solar system that has its own magnetic field. Its mini-magnetosphere interacts with Jupiter's massive magnetosphere, creating waves that accelerate electrons along the gas giant's magnetic field lines, which can be directly measured by Juno.
Two SwRI-led instruments on Juno, the Jovian Auroral Distributions Experiment (JADE) and the Ultraviolet Spectrometer (UVS) provided key data for this study, which was also supported by Juno's magnetic field sensor built at NASA's Goddard Space Flight Centre.

"JADE measured the electrons traveling along the magnetic field lines, while UVS imaged the related auroral footprint spot," said SwRI's Dr. Thomas Greathouse, a co-author on this study.
In this way, Juno is both able to measure the electron "rain" and immediately observe the UV light it creates when it crashes into Jupiter. Previous Juno measurements showed that large magnetic perturbations accompanied the electron beams causing the auroral footprint. However, this time, Juno did not observe similar perturbations with the electron beam.
"If our interpretation is correct, this a confirmation of a decade-old theory that we put together to explain the morphology of the auroral footprints," said Dr. Bertrand Bonfond, a co-author of the study from the Liège University in Belgium. The theory suggests that electrons accelerated in both directions create the multi-spot dance of auroral footprints.
"The Jupiter-Ganymede relationship will be further explored by Juno's extended mission, as well as the forthcoming JUICE mission from the European Space Agency," Hue said. "SwRI is building the next generation of UVS instrumentation for the mission."
Video: https://youtu.be/xGUtx0IvYZI

- 'Prenatal' protoplanet upends planet formation models

Date: April 4, 2022
Source: National Institutes of Natural Sciences

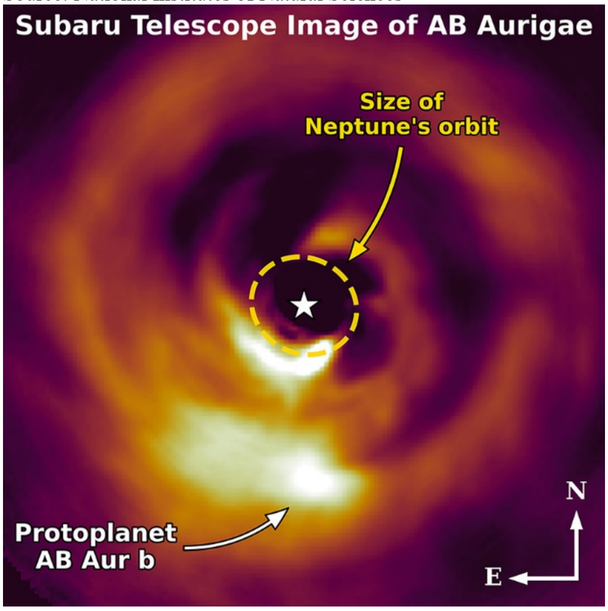
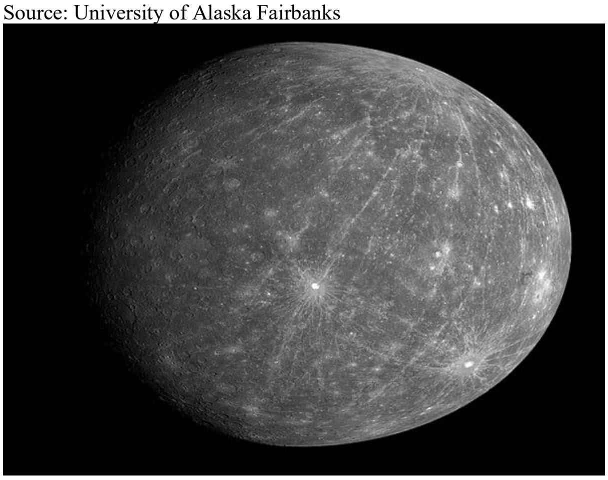


Image of the star AB Aurigae taken by the Subaru Telescope showing the spiral arms in the disk and the newly-discovered protoplanet AB Aur b. The bright central star has been masked, and its location is indicated by the star mark (☆). The size of Neptune's orbit in the Solar System is shown to provide scale. (Credit: T. Currie/Subaru Telescope) Original size (5.7MB) Without text (5.0MB)

An international research team has discovered a new planet so young that it has yet to emerge from the womb of matter where it is forming. This is the youngest protoplanet discovered to date. It's location and the surrounding patterns of matter suggest that an alternative method of planet formation may be at work. This discovery could help to explain the histories and features of extrasolar planets seen around other stars.
In the standard model of planet formation, a large Jupiter-like gas planet starts as a rocky core in a protoplanetary disk around a young star. This core then accretes gas from the disk, growing into a giant planet. While this model works well for the planets in the Solar System, it has trouble explaining exoplanets which have been discovered around other stars at distances much larger than the orbit of Neptune, the outermost Solar System planet. Rocky cores aren't expected to form far away from the central star, so core accretion can't drive distant planet formation. One theory holds that outlying planets form close to the central star and move outwards. But new observations using an extreme adaptive optics system which allows the Subaru Telescope to directly image faint objects close to brighter stars show what appears to be a protoplanet in the process of forming directly at a distance of 93 au: over three times the distance between the Sun and Neptune.
Analysis of this object, named AB Aur b, shows that a simple model of starlight reflected from an anomaly in the disk can't reproduce the observations; but neither can a model of a naked planet. The best fit models indicate that AB Aur b is a protoplanet so young that it is still forming in a womb of matter in the protoplanetary disk. Nearby spiral structures in the disk match models where a planet forms directly from the gravitational collapse of the surrounding matter. This discovery has profound implications for explaining the many observed outlying exoplanets and the overall theoretical model of planet formation.
``This study sheds new light on our understanding of the different ways that planets form," says Thayne Currie, lead author of the discovery paper.
The 8.2-meter Subaru Telescope is located near the summit of Maunakea in Hawai`i, an inactive volcano known for its unsurpassed qualities as an astronomy site and its deep personal and cultural significance to many Native Hawaiians.

❖ Mercury has magnetic storms

Date: March 31, 2022
Source: University of Alaska Fairbanks



An international team of scientists has proved that Mercury, our solar system's smallest planet, has geomagnetic storms similar to those on Earth.

The research by scientists in the United States, Canada and China includes work by Hui Zhang, a space physics professor at the University of Alaska Fairbanks Geophysical Institute.

Their finding, a first, answers the question of whether other planets, including those outside our solar system, can have geomagnetic storms regardless of the size of their magnetosphere or whether they have an Earth-like ionosphere.

The research was published in two papers in February. Zhang is among the co-authors of each paper.

The first of those papers proves the planet has a ring current, a doughnut-shaped field of charged particles flowing laterally around the planet and excluding the poles. The second proves the existence of geomagnetic storms triggered by the ring current.

A geomagnetic storm is a major disturbance in a planet's magnetosphere caused by the transfer of energy from the solar wind. Such storms in Earth's magnetosphere produce the aurora and can disrupt radio communications.

The geomagnetic storms finding was published Feb. 18 in the journal *Science China Technological Sciences*. QiuGang Zong of the Institute of Space Physics and Applied Technology at Peking University and the Polar Research Institute of China is the author.

That paper built on a finding published one day earlier that verified through data observation earlier suggestions that Mercury has a ring current. Earth also has a ring current.

The ring current paper, published in Nature Communications, is authored by Jiutong Zhao, also of the Institute of Space Physics and Applied Technology at Peking University. Seven of the 14 scientists involved worked on both papers.

"The processes are quite similar to here on Earth,' Zhang said of Mercury's magnetic storms. "The main differences are the size of the planet and Mercury has a weak magnetic field and virtually no atmosphere."

Confirmation about geomagnetic storms on Mercury results from research made possible by a fortuitous coincidence: a series of coronal mass ejections from the sun on April 8-18, 2015, and the end of NASA's Messenger space probe, which launched in 2004 and crashed into the planet's surface on April 30, 2015, at the expected end of its mission.

A coronal mass ejection, or CME, is an ejected cloud of the sun's plasma -- a gas made of charged particles. That cloud includes the plasma's embedded magnetic field.

The coronal mass ejection of April 14 proved to be the key for scientists. It compressed Mercury's ring current on the sun-facing side and increased the current's energy.

New analysis of data from Messenger, which had dropped closer to the planet, shows "the presence of a ring current intensification that is essential for triggering magnetic storms," the second of the two papers reads.

"The sudden intensification of a ring current causes the main phase of a magnetic storm," Zhang said.

But this doesn't mean Mercury has auroral displays like those on Earth.

On Earth, the storms produce aurora displays when solar wind particles interact with the particles of the atmosphere. On Mercury, however, solar wind particles don't encounter an atmosphere. Instead, they reach the surface unimpeded and may therefore be visible only through X-ray and gamma ray examination.

The results of the two papers show that magnetic storms are "potentially a common feature of magnetized planets," the second of the papers reads.

"The results obtained from Messenger provide a further fascinating insight into Mercury's place in the evolution of the solar system following the discovery of its intrinsic planetary magnetic field," it concludes.

Other institutions involved in the research include the University of Alberta, Edmonton; University of Michigan and the Heliophysics

Science Division at NASA's Goddard Space Flight Centre.

- ❖ Scientists observe mysterious death of a star emitting six rings

Date: March 28, 2022
Source: University of California - Los Angeles

Astrophysicists studying in unprecedented detail a red giant star named V Hydrae -- abbreviated as V Hya -- have witnessed the star's mysterious death throes.
Researchers from UCLA and NASA's Jet Propulsion Laboratory discovered that the carbon-rich star has expelled six slowly expanding molecular rings and an hourglass-shaped structure ejecting matter out into space at high speeds, signalling that the star is undergoing rapid evolution as it ends its life in a blaze of glory before shutting down its energy production.
"This is the first and only time that a series of expanding rings has been seen around a star that is in its death throes -- a series of expanding 'smoke rings' that we have calculated are being blown every few hundred years," said Mark Morris, a UCLA professor of physics and astronomy and a co-author of the study.
The results of the study, which was conducted using the Atacama Large Millimetre/submillimetre Array, known as ALMA, and data from the Hubble Space Telescope, are published March 28 in the *Astrophysical Journal.*
More than 90% of stars with a mass equal to or greater than the sun's mass evolve into what scientists call asymptotic giant branch stars, or AGB stars, of which V Hya is an example. The star is located approximately 1,300 light-years from Earth in the constellation Hydra. Among these millions of stars, V Hya has been of particular interest to astronomers due to its unique behaviours and features, including extremely large eruptions of plasma that occur approximately every eight years and the presence of a nearly invisible companion star that contributes to V Hya's explosive behaviour.
"We have caught this dying star in the process of shedding its atmosphere -- ultimately most of its mass -- which is something that most late-stage red giant stars do," Morris said. "But much to our surprise, we have found that the matter in this case is being expelled as a series of rings."
Morris said the team also observed high-speed blasts of gas, perpendicular to those rings, that were expelled into two opposite directions. He added that the mechanism that produces the rings is unknown and will require further investigation.
"We suspect that it might be related to the presence of orbiting companion stars, but it is difficult to explain that given the few-hundred-year interval between ring ejections," Morris said. "This star is providing a new and fascinating wrinkle to our understanding of how stars end their lives."
Raghvendra Sahai, an astronomer at JPL and the study's lead author, said the research indicates that previous assumptions about star deaths may be wrong.
"Our study dramatically reveals that the traditional model of how AGB stars die -- through the mass ejection of fuel via a slow, relatively steady, spherical wind over 100,000 years or more -- is at best, incomplete, or at worst, incorrect," he said.
The six rings that have expanded outward from V Hya over the course of roughly 2,100 years have formed a warped, disk-like structure, creating a dust-rich region around the star, the researchers report. The team dubbed the structure the DUDE, for Disk Undergoing Dynamical Expansion.
"V Hya is in the brief but critical transition phase that dying stars go through at the end of their lives," Sahai said. "It's the phase when they lose most of their mass. It's likely that this phase does not last very long, so it is difficult to catch them in the act. We got lucky with V Hya, and were able to image all of the different activities going on in and around this star to better understand how dying stars lose mass at the end of their lives."
V Hya's final act also has produced an hourglass-shaped structure cantered on the star and oriented perpendicularly to the disk. The two lobes of the hourglass have been shaped by a directed, fast wind that is blowing in two opposite directions at speeds up to 500,000 miles per hour.

Due to the large quantities of dust surrounding the star, studying V Hya required a unique instrument with the power to clearly see cold matter that is impossible to detect with optical telescopes. ALMA's receivers are exceptionally sensitive to very short radio wavelengths of approximately 1 millimetre, which revealed the star's multiple rings and outflows of molecular gas in stark clarity.
The researchers used additional infrared, optical and ultraviolet data to produce a remarkable picture of a spectacular show in our galaxy, much of which was unexpected, Morris said.
"Each time we observe V Hya, it becomes more and more like a circus, with each new evolutionary stage characterized by an even bigger variety of impressive feats," Sahai said. "V Hydrae has impressed us with its multiple rings and acts, and because our own sun may one day experience a similar fate, it has us at rapt attention."
The research was funded in part by the National Science Foundation and NASA.

- Record broken: Hubble spots farthest star ever seen

Date: March 30, 2022
Source: NASA/Goddard Space Flight Centre

Hubble Space Telescope illustration (stock image; elements furnished by NASA).
Credit: © dimazel / stock.adobe.com

NASA's Hubble Space Telescope has established an extraordinary new benchmark: detecting the light of a star that existed within the first billion years after the universe's birth in the big bang -- the farthest individual star ever seen to date.
The find is a huge leap further back in time from the previous single-star record holder; detected by Hubble in 2018. That star existed when the universe was about 4 billion years old, or 30 percent of its current age, at a time that astronomers refer to as "redshift 1.5." Scientists use the word "redshift" because as the universe expands, light from distant objects is stretched or "shifted" to longer, redder wavelengths as it travels toward us.
The newly detected star is so far away that its light has taken 12.9 billion years to reach Earth, appearing to us as it did when the universe was only 7 percent of its current age, at redshift 6.2. The smallest objects previously seen at such a great distance are clusters of stars, embedded inside early galaxies.
"We almost didn't believe it at first, it was so much farther than the previous most-distant, highest redshift star," said astronomer Brian Welch of the Johns Hopkins University in Baltimore, lead author of the paper describing the discovery, which is published in the March 30 journal *Nature*. The discovery was made from data collected during Hubble's RELICS (Reionization Lensing Cluster Survey) program, led by co-author Dan Coe at the Space Telescope Science Institute (STScI), also in Baltimore.
"Normally at these distances, entire galaxies look like small smudges, with the light from millions of stars blending together," said Welch. "The galaxy hosting this star has been magnified and distorted by gravitational lensing into a long crescent that we named the Sunrise Arc."
After studying the galaxy in detail, Welch determined that one feature is an extremely magnified star that he called Earendel, which means "morning star" in Old English. The discovery holds promise for opening up an uncharted era of very early star formation.
"Earendel existed so long ago that it may not have had all the same raw materials as the stars around us today," Welch explained. "Studying Earendel will be a window into an era of the universe that we are unfamiliar with, but that led to everything we do know. It's like we've been reading a really interesting book, but we started with the second chapter, and now we will have a chance to see how it all got started," Welch said.

When Stars Align

The research team estimates that Earendel is at least 50 times the mass of our Sun and millions of times as bright, rivalling the most massive stars known. But even such a brilliant, very high-mass star would be impossible to see at such a great distance without the aid of natural magnification by a huge galaxy cluster, WHL0137-08, sitting between us and Earendel. The mass of the galaxy cluster warps the fabric of space, creating a powerful natural magnifying glass that distorts and greatly amplifies the light from distant objects behind it.

Thanks to the rare alignment with the magnifying galaxy cluster, the star Earendel appears directly on, or extremely close to, a ripple in the fabric of space. This ripple, which is defined in optics as a "caustic," provides maximum magnification and brightening. The effect is analogous to the rippled surface of a swimming pool creating patterns of bright light on the bottom of the pool on a sunny day. The ripples on the surface act as lenses and focus sunlight to maximum brightness on the pool floor.

This caustic causes the star Earendel to pop out from the general glow of its home galaxy. Its brightness is magnified a thousandfold or more. At this point, astronomers are not able to determine if Earendel is a binary star, though most massive stars have at least one smaller companion star.

Confirmation with Webb

Astronomers expect that Earendel will remain highly magnified for years to come. It will be observed by NASA's James Webb Space Telescope. Webb's high sensitivity to infrared light is needed to learn more about Earendel, because its light is stretched (redshifted) to longer infrared wavelengths due to the universe's expansion.

"With Webb we expect to confirm Earendel is indeed a star, as well as measure its brightness and temperature," Coe said. These details will narrow down its type and stage in the stellar lifecycle. "We also expect to find the Sunrise Arc galaxy is lacking in heavy elements that form in subsequent generations of stars. This would suggest Earendel is a rare, massive metal-poor star," Coe said.

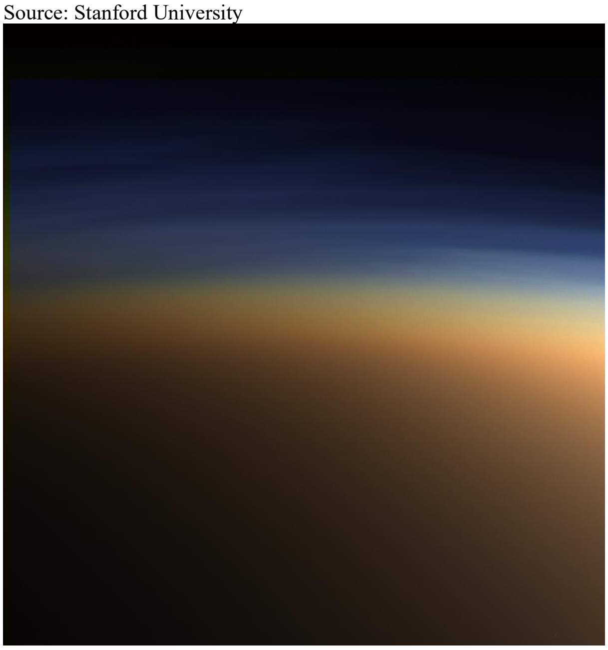
Earendel's composition will be of great interest for astronomers, because it formed before the universe was filled with the heavy elements produced by successive generations of massive stars. If follow-up studies find that Earendel is only made up of primordial hydrogen and helium, it would be the first evidence for the legendary Population III stars, which are hypothesized to be the very first stars born after the big bang. While the probability is small, Welch admits it is enticing all the same.

"With Webb, we may see stars even farther than Earendel, which would be incredibly exciting," Welch said. "We'll go as far back as we can. I would love to see Webb break Earendel's distance record."

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Centre in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

- Scientists model landscape formation on Titan, revealing an Earth-like alien world

Date: April 25, 2022
Source: Stanford University



Saturn's moon Titan looks very much like Earth from space, with rivers, lakes, and seas filled by rain tumbling through a thick atmosphere. While these landscapes may look familiar, they are composed of materials that are undoubtedly different -- liquid methane streams streak Titan's icy surface and nitrogen winds build hydrocarbon sand dunes.

The presence of these materials -- whose mechanical properties are vastly different from those of silicate-based substances that make up other known sedimentary bodies in our solar system -- makes Titan's landscape formation enigmatic. By identifying a process that would allow for hydrocarbon-based substances to form sand grains or bedrock depending on how often winds blow and streams flow, Stanford University geologist Mathieu Lapôtre and his colleagues have shown how Titan's distinct dunes, plains, and labyrinth terrains could be formed.

Titan, which is a target for space exploration because of its potential habitability, is the only other body in our solar system known to have an Earth-like, seasonal liquid transport cycle today. The new model, published in

Geophysical Research Letters April 25, shows how that seasonal cycle drives the movement of grains over the moon's surface.

"Our model adds a unifying framework that allows us to understand how all of these sedimentary environments work together," said Lapôtre, an assistant professor of geological sciences at Stanford's School of Earth, Energy & Environmental Sciences (Stanford Earth). "If we understand how the different pieces of the puzzle fit together and their mechanics, then we can start using the landforms left behind by those sedimentary processes to say something about the climate or the geological history of Titan -- and how they could impact the prospect for life on Titan."

A missing mechanism

In order to build a model that could simulate the formation of Titan's distinct landscapes, Lapôtre and his colleagues first had to solve one of the biggest mysteries about sediment on the planetary body: How can its basic organic compounds -- which are thought to be much more fragile than inorganic silicate grains on Earth -- transform into grains that form distinct structures rather than just wearing down and blowing away as dust?

On Earth, silicate rocks and minerals on the surface erode into sediment grains over time, moving through winds and streams to be deposited in layers of sediments that eventually -- with the help of pressure, groundwater, and sometimes heat -- turn back into rocks. Those rocks then continue through the erosion process and the materials are recycled through Earth's layers over geologic time.

On Titan, researchers think similar processes formed the dunes, plains, and labyrinth terrains seen from space. But unlike on Earth, Mars, and Venus, where silicate-derived rocks are the dominant geological material from which sediments are derived, Titan's sediments are thought to be composed of solid organic compounds. Scientists haven't been able to demonstrate how these organic compounds may grow into sediment grains that can be transported across the moon's landscapes and over geologic time.

"As winds transport grains, the grains collide with each other and with the surface. These collisions tend to decrease grain size through time. What we were missing was the growth mechanism that could counterbalance that and enable sand grains to maintain a stable size through time," Lapôtre said.

An alien analogue

The research team found an answer by looking at sediments on Earth called ooids, which are small, spherical grains most often found in shallow tropical seas, such as around the Bahamas. Ooids form when calcium carbonate is pulled from the water column and attaches in layers around a grain, such as quartz.

What makes ooids unique is their formation through chemical precipitation, which allows ooids to grow, while the simultaneous process of erosion slows the growth as the grains are smashed into each other by waves and storms. These two competing mechanisms balance each other out through time to form a constant grain size -- a process the researchers suggest could also be happening on Titan.

"We were able to resolve the paradox of why there could have been sand dunes on Titan for so long even though the materials are very weak, Lapôtre said. "We hypothesized that sintering -- which involves neighbouring grains fusing together into one piece -- could counterbalance abrasion when winds transport the grains."

Global landscapes

Armed with a hypothesis for sediment formation, Lapôtre and the study co-authors used existing data about Titan's climate and the direction of wind-driven sediment transport to explain its distinct parallel bands of geological formations: dunes near the equator, plains at the mid-latitudes, and labyrinth terrains near the poles.

Atmospheric modelling and data from the Cassini mission reveal that winds are common near the equator, supporting the idea that less sintering and therefore fine sand grains could be created there -- a critical component of dunes. The study authors predict a lull in sediment transport at mid-latitudes on either side of the equator, where sintering could dominate and create coarser and coarser grains, eventually turning into bedrock that makes up Titan's plains.

Sand grains are also necessary for the formation of the moon's labyrinth terrains near the poles. Researchers think these distinct crags could be like karsts in limestone on Earth -- but on Titan, they would be collapsed features made of dissolved organic sandstones. River flow and rainstorms occur much more frequently near the poles, making sediments more likely to be transported by rivers than winds. A similar process of sintering and abrasion during river transport could provide a local supply of coarse sand grains -- the source for the sandstones thought to make up labyrinth terrains.

"We're showing that on Titan -- just like on Earth and what used to be the case on Mars -- we have an active sedimentary cycle that can explain the latitudinal distribution of landscapes through episodic abrasion and sintering driven by Titan's seasons," Lapôtre said. "It's pretty fascinating to think about how there's this alternative world so far out there, where things are so different, yet so similar."

Lapôtre is also an assistant professor, by courtesy, of geophysics. Study co-authors are from NASA's Jet Propulsion Laboratory (JPL).

This research was supported by a NASA Solar System Workings grant.