South Downs Mercury

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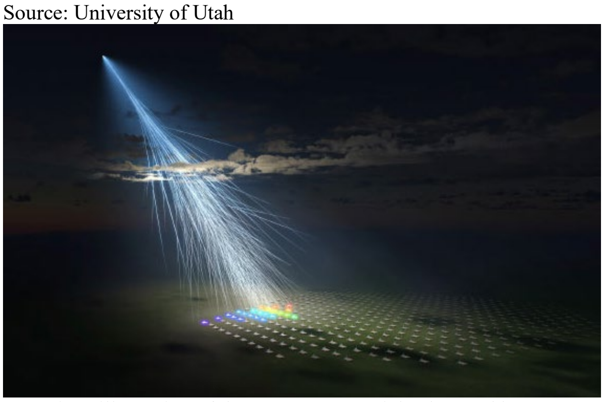
Main Talk Professor Mike Hardcastle Director, Centre for Astrophysics Research, University of Hertfordshire. “Active Galaxies” Radio galaxies and radio-loud quasars are active galaxies characterized by radio emission driven by jets on scales from pc to Mpc. The characteristic radio emission is synchrotron emission: that is, it indicates the presence of magnetic fields and highly relativistic electrons and/or positrons. Synchrotron emission may be seen in other wavebands, and this enabled the detection of the first radio galaxy jet before the advent of radio astronomy (Curtis) but it was only with the capabilities of radio interferometry (Ryle) that it became possible to detect and image these objects in detail and in large numbers. As Mike will discuss in more detail, radio observations remain key to an understanding of active galaxies’ origins, dynamics and energetics.

Please support a raffle we are organizing this month

- Telescope Array detects second highest-energy cosmic ray ever

Date: November 23, 2023
Source: University of Utah



An artist’s illustration of the Amaterasu particle observed by a surface detector array of the Telescope Array experiment. Image credit: Osaka Metropolitan University / L-INSIGHT, Kyoto University / Ryuunosuke Takeshige

In 1991, the University of Utah Fly's Eye experiment detected the highest-energy cosmic ray ever observed. Later dubbed the Oh-My-God particle, the cosmic ray's energy shocked astrophysicists. Nothing in our galaxy had the power to produce it, and the particle had more energy than was theoretically possible for cosmic rays traveling to Earth from other galaxies. Simply put, the particle should not exist.
The Telescope Array has since observed more than 30 ultra-high-energy cosmic rays, though none approaching the Oh-My-God-level energy. No observations have yet revealed their origin or how they are able to travel to the Earth.
On May 27, 2021, the Telescope Array experiment detected the second-highest extreme-energy cosmic ray. At 2.4 x 10^{20}eV, the energy of this single subatomic particle is equivalent to dropping a brick on your toe from waist height. Led by the University of Utah (the U) and the University of Tokyo, the Telescope Array consists of 507 surface detector stations arranged in a square grid that covers 700 km^2 (~270 $miles^2$) outside of Delta, Utah in the state's West Desert. The event triggered 23 detectors at the north-west region of the Telescope Array, splashing across 48 km^2 (18.5 mi^2). Its arrival direction appeared to be from the Local Void, an empty area of space bordering the Milky Way galaxy.
"The particles are so high energy; they shouldn't be affected by galactic and extra-galactic magnetic fields. You should be able to point to where they come from in the sky," said John Matthews, Telescope Array co-spokesperson at the U and co-author of the study. "But in the case of the Oh-My-God particle and this new particle, you trace its trajectory to its source and there's nothing high energy enough to have produced it. That's the mystery of this -- what the heck is going on?"
In their observation that published on Nov. 24, 2023, in the journal *Science*, an international collaboration of researchers describes the ultra-high-energy cosmic ray, evaluate its characteristics, and conclude that the rare phenomena might follow particle physics unknown to science. The researchers named it the Amaterasu particle after the sun goddess in Japanese mythology. The Oh-My-God and the Amaterasu particles were

detected using different observation techniques, confirming that while rare, these ultra-high energy events are real.

"These events seem like they're coming from completely different places in the sky. It's not like there's one mysterious source," said John Belz, professor at the U and co-author of the study. "It could be defects in the structure of spacetime, colliding cosmic strings. I mean, I'm just spit-balling crazy ideas that people are coming up with because there's not a conventional explanation."

Natural particle accelerators

Cosmic rays are echoes of violent celestial events that have stripped matter to its subatomic structures and hurled it through universe at nearly the speed of light. Essentially cosmic rays are charged particles with a wide range of energies consisting of positive protons, negative electrons, or entire atomic nuclei that travel through space and rain down onto Earth nearly constantly.

Cosmic rays hit Earth's upper atmosphere and blasts apart the nucleus of oxygen and nitrogen gas, generating many secondary particles. These travel a short distance in the atmosphere and repeat the process, building a shower of billions of secondary particles that scatter to the surface. The footprint of this secondary shower is massive and requires that detectors cover an area as large as the Telescope Array. The surface detectors utilize a suite of instrumentation that gives researchers information about each cosmic ray; the timing of the signal shows its trajectory and the amount of charged particles hitting each detector reveals the primary particle's energy.

Because particles have a charge, their flight path resembles a ball in a pinball machine as they zigzag against the electromagnetic fields through the cosmic microwave background. It's nearly impossible to trace the trajectory of most cosmic rays, which lie on the low- to middle-end of the energy spectrum. Even high-energy cosmic rays are distorted by the microwave background. Particles with Oh-My-God and Amaterasuenergy blast through intergalactic space relatively unbent. Only the most powerful of celestial events can produce them.

"Things that people think of as energetic, like supernova, are nowhere near energetic enough for this. You need huge amounts of energy, really high magnetic fields to confine the particle while it gets accelerated," said Matthews.

Ultra-high-energy cosmic rays must exceed 5 x 10^{19} eV. This means that a single subatomic particle carries the same kinetic energy as a major league pitcher's fast ball and has tens of millions of times more energy than any human-made particle accelerator can achieve. Astrophysicists calculated this theoretical limit, known as the Greisen-Zatsepin-Kuzmin (GZK) cutoff, as the maximum energy a proton can hold traveling over long distances before the effect of interactions of the microwave background radiation take their energy. Known source candidates, such as active galactic nuclei or black holes with accretion disks emitting particle jets, tend to be more than 160 million light years away from Earth. The new particle's 2.4 x 10^{20} eV and the Oh-My-God particle's 3.2 x 10^{20} eV easily surpass the cutoff.

Researchers also analyse cosmic ray composition for clues of its origins. A heavier particle, like iron nuclei, are heavier, have more charge and are more susceptible to bending in a magnetic field than a lighter particle made of protons from a hydrogen atom. The new particle is likely a proton. Particle physics dictates that a cosmic ray with energy beyond the GZK cutoff is too powerful for the microwave background to distort its path, but back tracing its trajectory points towards empty space.

"Maybe magnetic fields are stronger than we thought, but that disagrees with other observations that show they're not strong enough to produce significant curvature at these ten-to-the-twentieth electron volt energies," said Belz. "It's a real mystery."

Expanding the footprint

The Telescope Array is uniquely positioned to detect ultra-high-energy cosmic rays. It sits at about 1,200 m (4,000 ft), the elevation sweet-spot that allows secondary particles maximum development, but before they start to decay. Its location in Utah's West Desert provides ideal atmospheric conditions in two ways: the dry air is crucial because humidity will absorb the ultraviolet light necessary for detection; and the region's dark skies are essential, as light pollution will create too much noise and obscure the cosmic rays.

Astrophysicists are still baffled by the mysterious phenomena. The Telescope Array is in the middle of an expansion that that they hope will help crack the case. Once completed, 500 new scintillator detectors will expand the Telescope Array will sample cosmic ray-induced particle showers across 2,900 km^2 (1,100 mi^2), an area nearly the size of Rhode Island. The larger footprint will hopefully capture more events that will shed light on what's going on.

- Dwarf galaxies use 10-million-year quiet period to churn out stars

Date: November 21, 2023
Source: University of Michigan

If you look at massive galaxies teeming with stars, you might be forgiven in thinking they are star factories, churning out brilliant balls of gas. But actually, less evolved dwarf galaxies have bigger regions of star factories, with higher rates of star formation.
Now, University of Michigan researchers have discovered the reason underlying this: These galaxies enjoy a 10-million-year delay in blowing out the gas cluttering up their environments. Star-forming regions are able to hang on to their gas and dust, allowing more stars to coalesce and evolve.
In these relatively pristine dwarf galaxies, massive stars -- stars about 20 to 200 times the mass of our sun -- collapse into black holes instead of exploding as supernovae. But in more evolved, polluted galaxies, like our Milky Way, they are more likely to explode, thereby generating a collective superwind. Gas and dust get blasted out of the galaxy, and star formation quickly stops.
Their findings are published in the *Astrophysical Journal*.
"As stars go supernova, they pollute their environment by producing and releasing metals," said Michelle Jecmen, study first author and an undergraduate researcher. "We argue that at low metallicity -- galaxy environments that are relatively unpolluted -- there is a 10-million-year delay in the start of strong superwinds, which, in turn, results in higher star formation."
The U-M researchers point to what's called the Hubble tuning fork, a diagram that depicts the way astronomer Edwin Hubble classified galaxies. In the handle of the tuning fork are the largest galaxies. Huge, round and brimming with stars, these galaxies have already turned all of their gas into stars. Along the tines of the tuning fork are spiral galaxies that do have gas and star-forming regions along their compact arms. At the end of the tuning fork's tines are the least evolved, smallest galaxies.
"But these dwarf galaxies have just these really mondo star-forming regions," said U-M astronomer Sally Oey, senior author of the study. "There have been some ideas around why that is, but Michelle's finding offers a very nice explanation: These galaxies have trouble stopping their star formation because they don't blow away their gas."
Additionally, this 10-million-year period of quiet offers astronomers the opportunity to peer at scenarios similar to the cosmic dawn, a period of time just after the Big Bang, Jecmen said. In pristine dwarf galaxies, gas clumps together and forms gaps through which radiation can escape. This previously known phenomenon is called the "picket fence" model, with UV radiation escaping between slats in the fence. The delay explains why gas would have had time to clump together.
Ultraviolet radiation is important because it ionizes hydrogen -- a process that also occurred right after the Big Bang, causing the universe to go from opaque to transparent.
"And so, looking at low-metallicity dwarf galaxies with lots of UV radiation is somewhat similar to looking all the way back to the cosmic dawn," Jecmen said. "Understanding the time near the Big Bang is so interesting. It's foundational to our knowledge. It's something that happened so long ago -- it's so fascinating that we can see sort of similar situations in galaxies that exist today."
A second study, published in the *Astrophysical Journal Letters* and led by Oey, used the Hubble Space Telescope to look at Mrk 71, a region in a nearby dwarf galaxy about 10 million light years away. In Mrk 71, the team found observational evidence of Jecmen's scenario. Using a new technique with the Hubble Space Telescope, the team employed a filter set that looks at the light of triply ionized carbon.
In more evolved galaxies with lots of supernova explosions, those explosions heat gas in a star cluster to very high temperatures -- to millions of degrees Kelvin, Oey said. As this hot superwind expands, it blasts the rest

of the gas out of the star clusters. But in low metallicity environments such as Mrk 71, where stars aren't blowing up, energy within the region is radiated away. It doesn't have the chance to form a superwind.
The team's filters picked up a diffuse glow of the ionized carbon throughout Mrk 71, demonstrating that the energy is radiating away. Therefore, there is no hot superwind, instead allowing dense gas to remain throughout the environment.
Oey and Jecmen say there are many implications for their work.
"Our findings may also be important in explaining the properties of galaxies that are being seen at cosmic dawn by the James Webb Space Telescope right now," Oey said. "I think we're still in the process of understanding the consequences."

- ❖ NASA's Webb reveals new features in heart of Milky Way

Date: November 21, 2023
Source: NASA/Goddard Space Flight Centre

The latest image from NASA's James Webb Space Telescope shows a portion of the dense centre of our galaxy in unprecedented detail, including never-before-seen features astronomers have yet to explain. The star-forming region, named Sagittarius C (Sgr C), is about 300 light-years from the Milky Way's central supermassive black hole, Sagittarius A*.
"There's never been any infrared data on this region with the level of resolution and sensitivity we get with Webb, so we are seeing lots of features here for the first time," said the observation team's principal investigator Samuel Crowe, an undergraduate student at the University of Virginia in Charlottesville. "Webb reveals an incredible amount of detail, allowing us to study star formation in this sort of environment in a way that wasn't possible previously."
"The galactic centre is the most extreme environment in our Milky Way galaxy, where current theories of star formation can be put to their most rigorous test," added professor Jonathan Tan, one of Crowe's advisors at the University of Virginia.

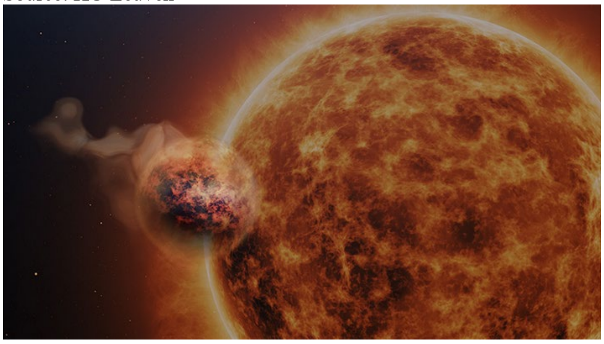
Protostars

Amid the estimated 500,000 stars in the image is a cluster of protostars -- stars that are still forming and gaining mass -- producing outflows that glow like a bonfire in the midst of an infrared-dark cloud. At the heart of this young cluster is a previously known, massive protostar over 30 times the mass of our Sun. The cloud the protostars are emerging from is so dense that the light from stars behind it cannot reach Webb, making it appear less crowded when in fact it is one of the most densely packed areas of the image. Smaller infrared-dark clouds dot the image, looking like holes in the starfield. That's where future stars are forming.
Webb's NIRCam (Near-Infrared Camera) instrument also captured large-scale emission from ionized hydrogen surrounding the lower side of the dark cloud, shown cyan-coloured in the image. Typically, Crowe says, this is the result of energetic photons being emitted by young massive stars, but the vast extent of the region shown by Webb is something of a surprise that bears further investigation. Another feature of the region that Crowe plans to examine further is the needle-like structures in the ionized hydrogen, which appear oriented chaotically in many directions.
"The galactic centre is a crowded, tumultuous place. There are turbulent, magnetized gas clouds that are forming stars, which then impact the surrounding gas with their outflowing winds, jets, and radiation," said Rubén Fedriani, a co-investigator of the project at the Instituto Astrofísica de Andalucía in Spain. "Webb has provided us with a ton of data on this extreme environment, and we are just starting to dig into it."
Around 25,000 light-years from Earth, the galactic centre is close enough to study individual stars with the Webb telescope, allowing astronomers to gather unprecedented information on how stars form, and how this process may depend on the cosmic environment, especially compared to other regions of the galaxy. For example, are more massive stars formed in the centre of the Milky Way, as opposed to the edges of its spiral arms?
"The image from Webb is stunning, and the science we will get from it is even better,"

Crowe said. "Massive stars are factories that produce heavy elements in their nuclear cores, so understanding them better is like learning the origin story of much of the universe."

- James Webb Space Telescope detects water vapor, Sulphur dioxide and sand clouds in the atmosphere of a nearby exoplanet

Date: November 15, 2023
Source: KU Leuven



Artist impression of WASP-107b and its parent star. Illustration credit: LUCA School of Arts, Belgium/ Klaas Verpoest (visuals), Johan Van Looveren (typography)

A team of European astronomers, co-led by researchers from the Institute of Astronomy, KU Leuven, used recent observations made with the James Webb Space Telescope to study the atmosphere of the nearby exoplanet WASP-107b. Peering deep into the fluffy atmosphere of WASP-107b they discovered not only water vapour and Sulphur dioxide, but even silicate sand clouds. These particles reside within a dynamic atmosphere that exhibits vigorous transport of material.

Astronomers worldwide are harnessing the advanced capabilities of the Mid-Infrared Instrument (MIRI) aboard the James Webb Space Telescope (JWST) to conduct groundbreaking observations of exoplanets -- planets orbiting stars other than our own Sun. One of these fascinating worlds is WASP-107b, a unique gaseous exoplanet that orbits a star slightly cooler and less massive than our Sun. The mass of the planet is similar to that of Neptune but its size is much larger than that of Neptune, almost approaching the size of Jupiter. This characteristic renders WASP-107b rather 'fluffy' when compared to the gas giant planets within our solar system. The fluffiness of this exoplanet enables astronomers to look roughly 50 times deeper into its atmosphere compared to the depth of exploration achieved for a solar-system giant like Jupiter.

The team of European astronomers took full advantage of the remarkable fluffiness of this exoplanet, enabling them to look deep into its atmosphere. This opportunity opened a window into unravelling the complex chemical composition of its atmosphere. The reason behind this is quite straightforward: the signals, or spectral features, are far more prominent in a less dense atmosphere compared to a more compact one. Their recent study, now published in *Nature*, reveals the presence of water vapour, Sulphur dioxide (SO_2), and silicate clouds, but notably, there is no trace of the greenhouse gas methane (CH_4).

A dynamic atmosphere

These detections provide crucial insights into the dynamics and chemistry of this captivating exoplanet. First, the absence of methane hints at a potentially warm interior, offering a tantalising glimpse into the movement of heat energy in the planet's atmosphere. Secondly, the discovery of Sulphur dioxide (known for the odour of burnt matches), was a major surprise. Previous models had predicted its absence, but novel climate models of WASP-107b's atmosphere now show that the very fluffiness of WASP-107b accommodates the formation of Sulphur dioxide in its atmosphere. Even though its host star emits a relatively small fraction of high-energy photons due to its cooler nature, these photons can reach deep into the planet's atmosphere thanks to its fluffy nature. This enables the chemical reactions required to produce Sulphur dioxide to occur.

But that's not all they've observed. Both the spectral features of Sulphur dioxide and water vapour are significantly diminished compared to what they would be in a cloudless scenario. High-altitude clouds partially obscure the water vapour and Sulphur dioxide in the atmosphere. While clouds have been inferred on other exoplanets, this marks the first instance where astronomers can definitively identify the chemical composition of these clouds. In this case, the clouds consist of small silicate particles, a familiar substance for humans found in many parts of the world as the primary constituent of sand.

"JWST is revolutionising exoplanet characterisation, providing unprecedented insights at remarkable speed," says lead author Prof. Leen Decin of KU Leuven. "The discovery of clouds of sand, water, and Sulphur dioxide on this fluffy exoplanet by JWST's MIRI instrument is a pivotal milestone. It reshapes our understanding of planetary formation and evolution, shedding new light on our own Solar System."

In contrast to Earth's atmosphere, where water freezes at low temperatures, in gaseous planets reaching temperatures around 1000 degrees Celsius, silicate particles can freeze out to form clouds. However, in the case of WASP-107b, with a temperature of around 500 degrees Celsius in the outer atmosphere, traditional models predicted that these silicate clouds should be forming deeper within the atmosphere, where temperatures are substantially higher. In addition, sand clouds high up in the atmosphere rain out. How is it then possible that these sand clouds exist at high altitudes and continue to endure?

According to lead author Dr. Michiel Min: "The fact that we see these sand clouds high up in the atmosphere must mean that the sand rain droplets evaporate in deeper, very hot layers and the resulting silicate vapour is efficiently moved back up, where they recondense to form silicate clouds once more. This is very similar to the water vapour and cloud cycle on our own Earth but with droplets made of sand." This continuous cycle of sublimation and condensation through vertical transport is responsible for the enduring presence of sand clouds in WASP-107b's atmosphere.

This pioneering research not only sheds light on the exotic world of WASP-107b but also pushes the boundaries of our understanding of exoplanetary atmospheres. It marks a significant milestone in exoplanetary exploration, revealing the intricate interplay of chemicals and climatic conditions on these distant worlds.

"JWST enables a deep atmospheric characterisation of an exoplanet that does not have any counterpart in our Solar System, we are unravelling new worlds!" says lead author Dr. Achrène Dyrek at CEA Paris.

Design and development of the MIRI instrument

Thanks to funding by the Belgian federal science policy office BELSPO via the ESA PRODEX programme, Belgian engineers and scientists played a key role in the design and development of the MIRI instrument, including the Centre Spatial de Liege (CSL), Thales Alenia Space (Charleroi) and OIP Sensor Systems (Oudenaarde). At the Institute of Astronomy at KU Leuven, instrument scientists tested the MIRI instrument extensively in special test chambers simulating the space environment in laboratories in the UK, at NASA Goddard and NASA Johnson Space centres.

"With colleagues across Europe and the United States we have been building and testing the MIRI instrument for almost 20 years. It is rewarding to see our instrument unravel the atmosphere of this intriguing exoplanet," says instrument specialist Dr. Bart Vandenbussche of KU Leuven.

This study combines the results of several independent analyses of the JWST observations, and represents the years of work invested not only in building the MIRI instrument but also in the calibration and analysis tools for the observational data acquired with MIRI," says Dr. Jeroen Bouwman of the Max-Planck-Institut fu?r Astronomie, Germany.

More information

- These observations were taken as part of the Guaranteed Time Observation program 1280.
- The James Webb Space Telescope is the world's premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.
- The European consortium team consists of 46 astronomers from 29 research institutions across 12 countries. From the KU Leuven, the team includes Leen Decin, Thomas Konings, Bart Vandenbussche, Ioannis Argyriou and Linus Heinke.

❖ 'Triple star' discovery could revolutionize understanding of stellar evolution

Date: November 21, 2023
Source: University of Leeds

A ground-breaking new discovery by University of Leeds scientists could transform

the way astronomers understand some of the biggest and most common stars in the Universe.
Research by PhD student Jonathan Dodd and Professor René Oudmaijer, from the University's School of Physics and Astronomy, points to intriguing new evidence that massive Be stars -- until now mainly thought to exist in double stars -- could in fact be "triples."
The remarkable discovery could revolutionise our understanding of the objects -- a subset of B stars -- which are considered an important "test bed" for developing theories on how stars evolve more generally.
These Be stars are surrounded by a characteristic disc made of gas -- similar to the rings of Saturn in our own Solar System.
And although Be stars have been known for about 150 years -- having first been identified by renowned Italian astronomer Angelo Secchi in 1866 -- until now, no one has known how they were formed.
Consensus among astronomers so far has said the discs are formed by the rapid rotation of the Be stars, and that itself can be caused by the stars interacting with another star in a binary system.

Triple systems

Mr Dodd, corresponding author of the research, said: "The best point of reference for that is if you've watched Star Wars, there are planets where they have two Suns."
But now, by analysing data from the European Space Agency's Gaia satellite, the scientists say they have found evidence these stars actually exist in triple systems -- with three bodies interacting instead of just two.
Mr Dodd added: "We observed the way the stars move across the night sky, over longer periods like 10 years, and shorter periods of around six months. If a star moves in a straight line, we know there's just one star, but if there is more than one, we will see a slight wobble or, in the best case, a spiral.
"We applied this across the two groups of stars that we are looking at -- the B stars and the Be stars -- and what we found, confusingly, is that at first it looks like the Be stars have a lower rate of companions than the B stars. This is interesting because we'd expect them to have a higher rate."
However, Principal Investigator Prof Oudmaijer said: "The fact that we do not see them might be because they are now too faint to be detected."

Mass transfer

The researchers then looked at a different set of data, looking for companion stars that are further away, and found that at these larger separations the rate of companion stars is very similar between the B and Be stars.
From this, they were able to infer that in many cases a third star is coming into play, forcing the companion closer to the Be star -- close enough that mass can be transferred from one to the other and form the characteristic Be star disc. This could also explain why we do not see these companions anymore; they have become too small and faint to be detected after the "vampire" Be star has sucked in so much of their mass.
The discovery could have huge impacts on other areas of astronomy -- including our understanding of black holes, neutron stars and gravitational wave sources.
Prof Oudmaijer said: "There's a revolution going on in physics at the moment around gravitational waves. We have only been observing these gravitational waves for a few years now, and these have been found to be due to merging black holes.
"We know that these enigmatic objects -- black holes and neutron stars -- exist, but we don't know much about the stars that would become them. Our findings provide a clue to understanding these gravitational wave sources."
He added: "Over the last decade or so, astronomers have found that binarity is an incredibly important element in stellar evolution. We are now moving more towards the idea it is even more complex than that and that triple stars need to be considered."
"Indeed," Oudmaijer said, "triples have become the new binaries."
The team behind the discovery includes PhD student Mr Dodd and Prof Oudmaijer from Leeds, along with University of Leeds PhD student Isaac Radley and two former Leeds academics Dr Miguel Vioque of the ALMA Observatory in Chile and Dr Abigail Frost at the European Southern Observatory in Chile.
The team received funding from the Science and Technology Facilities Council (STFC).

- Why the vast super galactic plane is teeming with only one type of galaxy

Date: November 20, 2023
Source: University of Helsink

Our own Milky Way galaxy is part of a much larger formation, the local Supercluster structure, which contains several massive galaxy clusters and thousands of individual galaxies. Due to its pancake-like shape, which measures almost a billion light years across, it is also referred to as the Super galactic Plane.
Most galaxies in the universe fall into one of two categories: firstly, elliptical galaxies, made mostly of old stars and containing typically extremely massive central black holes, and secondly actively star-forming disk galaxies, with a spiral-like structure similar to the Milky Way's. Both types of galaxies are also found in the Local Supercluster, but while the Super galactic Plane is teeming with bright ellipticals, bright disk galaxies are conspicuously absent.

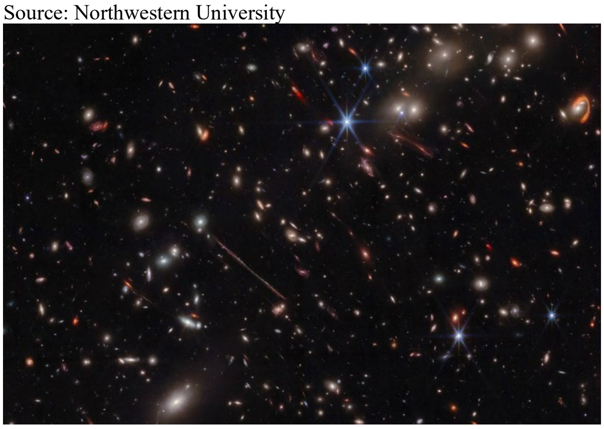
A cosmic anomaly challenges the standard model of cosmology

This peculiar segregation of galaxies in the Local Universe, which has been known since the 1960s, features prominently in a recent list of "cosmic anomalies" compiled by renowned cosmologist and 2019 Nobel laureate Jim Peebles.
Now an international team led by University of Helsinki astrophysicists Till Sawala and Peter Johansson appear to have found an explanation. In an article published in *Nature Astronomy*, they show how the different distributions of elliptical and disk galaxies arise naturally due to the different environments found inside and outside of the Super galactic Plane.
"In the dense galaxy clusters that are found on the Super galactic Plane, galaxies experience frequent interactions and mergers, which leads to the formation of ellipticals and the growth of supermassive black holes. By contrast, away from the plane, galaxies can evolve in relative isolation, which helps them preserve their spiral structure," says Till Sawala.
In their work, the team made use of the SIBELIUS (Simulations Beyond the Local Universe) simulation, that follows the evolution of the universe over 13.8 billion years, from the early universe to the present. It was run on supercomputers in England and on CSC's Mahti supercomputer in Finland.
While most similar simulations consider random patches of the universe which cannot be directly compared to observations, the SIBELIUS simulation aims to precisely reproduce the observed structures, including the Local Supercluster. The final simulation result is remarkably consistent with the observations.
"By chance, I was invited to a symposium in honour of Jim Peebles last December, where he presented the problem in his lecture. And I realised that we had already completed a simulation that might contain the answer," comments Till Sawala. "Our research shows that the known mechanisms of galaxy evolution also work in this unique cosmic environment."
Next to the physics department, the University of Helsinki's Kumpula campus hosts a large statue showing the distribution of galaxies in the Local Supercluster. It was inaugurated 20 years ago by the British cosmologist Carlos Frenk, who is one of the co-authors of this new study. "The distribution of galaxies in the Local Supercluster is indeed remarkable," says Frenk of the new results. "But it is not an anomaly: our result shows that our standard model of dark matter can produce the most remarkable structures in the universe."

- 'Teenage galaxies' are unusually hot, glowing with unexpected elements

Astronomers unexpectedly discovered nickel and oxygen

Date: November 20, 2023
Source: Northwestern University



A Webb telescope image of a galaxy cluster known as "El Gordo," which is an example of a "cosmic teenager." Credit: NASA, ESA, CSA

Similar to human teenagers, teenage galaxies are awkward, experience growth spurts and enjoy heavy metal -- nickel, that is.
A Northwestern University-led team of astrophysicists has just analysed the first results from the CECILIA (Chemical

Evolution Constrained using Ionized Lines in Interstellar Aurorae) Survey, a program that uses NASA's James Webb Space Telescope (JWST) to study the chemistry of distant galaxies.
According to the early results, so-called "teenage galaxies" -- which formed two-to-three billion years after the Big Bang -- are unusually hot and contain unexpected elements, like nickel, which are notoriously difficult to observe.
The research will be published on Monday (Nov. 20) in *The Astrophysical Journal Letters*. It marks the first in a series of forthcoming studies from the CECILIA Survey.
"We're trying to understand how galaxies grew and changed over the 14 billion years of cosmic history," said Northwestern's Allison Strom, who led the study. "Using the JWST, our program targets teenage galaxies when they were going through a messy time of growth spurts and change. Teenagers often have experiences that determine their trajectories into adulthood. For galaxies, it's the same."
One of the principal investigators of the CECILIA Survey, Strom is an assistant professor of physics and astronomy at Northwestern's Weinberg College of Arts and Sciences and a member of Northwestern's Canter for Interdisciplinary Exploration and Research in Astrophysics (CIERA). Strom co-leads the CECILIA Survey with Gwen Rudie, a staff scientist at Carnegie Observatories.
'Chemical DNA' gives insight into galaxy formation
Named after Cecilia Payne-Gaposchkin, one of the first women to earn a Ph.D. in astronomy, the CECILIA Survey observes spectra (or the amount of light across different wavelengths) from distant galaxies. Strom likens a galaxy's spectra to its "chemical DNA." By examining this DNA during a galaxy's "teenage" years, researchers can better understand how it grew and how it will evolve into a more mature galaxy.
For example, astrophysicists still don't understand why some galaxies appear "red and dead" while others, like our Milky Way, are still forming stars. A galaxy's spectrum can reveal its key elements, such as oxygen and Sulphur, which provide a window into what a galaxy was previously doing and what it might do in the future.
"These teenage years are really important because that's when the most growth happens," Strom said. "By studying this, we can begin exploring the physics that caused the Milky Way to look like the Milky Way -- and why it might look different from its neighbouring galaxies."
In the new study, Strom and her collaborators used the JWST to observe 33 distant teenaged galaxies for a continuous 30 hours this past summer. Then, they combined spectra from 23 of those galaxies to construct a composite picture.
"This washes out the details of individual galaxies but gives us a better sense of an average galaxy. It also allows us to see fainter features," Strom said. "It's significantly deeper and more detailed than any spectrum we could collect with ground-based telescopes of galaxies from this time period in the universe's history."
Spectra surprises
The ultra-deep spectrum revealed eight distinct elements: Hydrogen, helium, nitrogen, oxygen, silicon, Sulphur, argon and nickel. All elements that are heavier than hydrogen and helium form inside stars. So, the presence of certain elements provides information about star formation throughout a galaxy's evolution.
While Strom expected to see lighter elements, she was particularly surprised by the presence of nickel. Heavier than iron, nickel is rare and incredibly difficult to observe.
"Never in my wildest dreams did I imagine we would see nickel," Strom said. "Even in nearby galaxies, people don't observe this. There has to be enough of an element present in a galaxy and the right conditions to observe it. No one ever talks about observing nickel. Elements have to be glowing in gas in order for us to see them. So, in order for us to see nickel, there may be something unique about the stars within the galaxies."
Another surprise: The teenage galaxies were extremely hot. By examining the spectra, physicists can calculate a galaxy's temperature. While the hottest pockets with galaxies can reach over 9,700 degrees Celsius (17,492 degrees Fahrenheit), the teenage galaxies clock in at higher than 13,350 degrees Celsius (24,062 degrees Fahrenheit).
"This is just additional evidence of how different galaxies likely were when they were younger," Strom said. "Ultimately, the fact that we see a higher characteristic temperature

is just another manifestation of their different chemical DNA because the temperature and chemistry of gas in galaxies are intrinsically linked."

The study, "CECILIA: Faint emission line spectrum of z~2-3 star-forming galaxies," was supported by NASA, the Pittsburgh Foundation and the Research Corporation for Scientific Advancement. The data were obtained from the Mikulski Archive for Space Telescopes at the Space Telescope Science Institute and from the W.M. Keck Observatory.

- Investigating the contribution of gamma-ray blazar flares to neutrino flux

Date: November 20, 2023
Source: Shibaura Institute of Technology

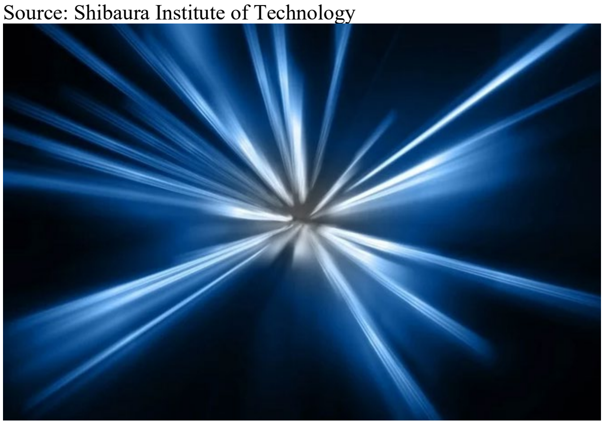


Image Credit: Barbol/Shutterstock.com

Gamma-ray flares from blazars can be accompanied by high-energy neutrino emission. To better understand this phenomenon, an international research team has statistically analysed 145 bright blazars. They constructed weekly binned light curves and utilized a Bayesian algorithm, finding that their sample was dominated by blazars with low flare duty cycles and energy fractions. The study suggests that high-energy neutrinos of blazars might be produced mainly during the flare phase.

Blazars belong to the family of active galactic nuclei called quasars. What differentiates them from quasars is that the flares ejected out of these active galactic nuclei are pointed toward the Earth. These flares contain high-energy cosmic rays which are released from the core of these galaxies as jets spanning many light years. Such cosmic rays can interact with photons to produce subatomic particles called neutrinos.

Gamma-ray flares from blazars are thought to be the primary events behind neutrino detection in the sky. In 2017, the South Pole neutrino detector "IceCube" detected a high-energy neutrino event whose timings and positioning in the night sky coincided with the flare of a blazar called TXS 0506+056. Some scientists suggest that there could be a population of blazars whose flares are accompanied by high-energy neutrino emission. However, the relationship between blazar flaring activity and neutrino flux is yet to be properly understood.

In this regard, an international research team, led by Professor Kenji Yoshida from the Department of Electronic Information Systems at Shibaura Institute of Technology, Japan, has recently performed a comprehensive statistical analysis to understand the contribution of gamma-ray flares to neutrino emission. The team included Maria Petropoulou from the National and Kapodistrian University of Athens, Kohta Murase from The Pennsylvania State University, and Foteini Oikonomou from the Norwegian University of Science and Technology. Their paper was published in Volume 954, Number 2 of *The Astrophysical Journal* on September 6, 2023.

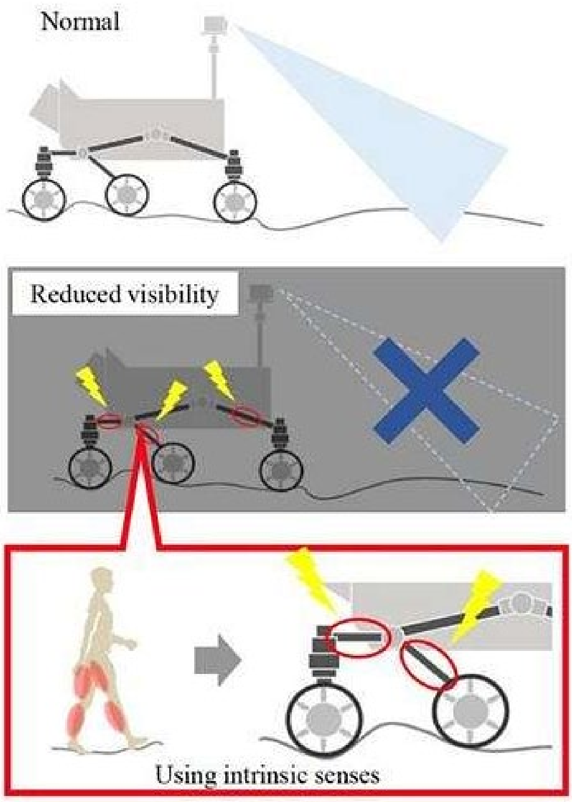
The researchers analysed 145 blazars, 144 of them taken from the Fermi Large Area Telescope Monitored Source List and including TXS 0506+056, in this study. They first calculated a weekly average of the gamma-ray flux of the blazars and plotted their light curves. The team then derived the flare duty cycle (fraction of time spent in flaring state) and the corresponding energy fraction from these curves using a Bayesian blocks algorithm, a statistical method used to identify changes in a time series.

"We find that blazars with lower flare duty cycles and energy fractions are more numerous among our sample. Their flare duty cycles and energy fractions represent power law-like distributions, correlating strongly with each other. We found a significant difference between blazar subclasses for the flare duty cycles at the 5% significant level," says Prof. Yoshida, highlighting the major results of their analysis.

The researchers evaluated the neutrino energy flux of each gamma-ray flare, using a general scaling relation for the neutrino and gamma-ray luminosities with a power law's weighting exponent of 1.0-2.0, normalized to the quiescent gamma-ray or X-ray flux of each blazar. They also found that the gamma-ray flare distribution indicates that blazar neutrino emission may be dominated by flares for the

weighting exponent >1.5. Furthermore, by comparing their neutrino predictions for each blazar for one-week and 10-year periods to the time-integrated IceCube sensitivity, the team placed upper limits on the contributions of the flares to the isotropic diffuse neutrino flux.
Prof. Yoshida remarks: "We hope that this study helps improve our understanding of the contribution of blazars to astrophysical neutrinos. Application of the present method to further observations might have the potential to contribute to the advancement of scientific knowledge of the origin of astrophysical neutrinos."

- ❖ A novel system for slip prevention of unmanned rovers



Similar to how human muscles detect the traveling state of the body, the slip condition of rovers can be determined by detecting the deformation of their chassis. This technology can be used to prevent the slipping of rovers.

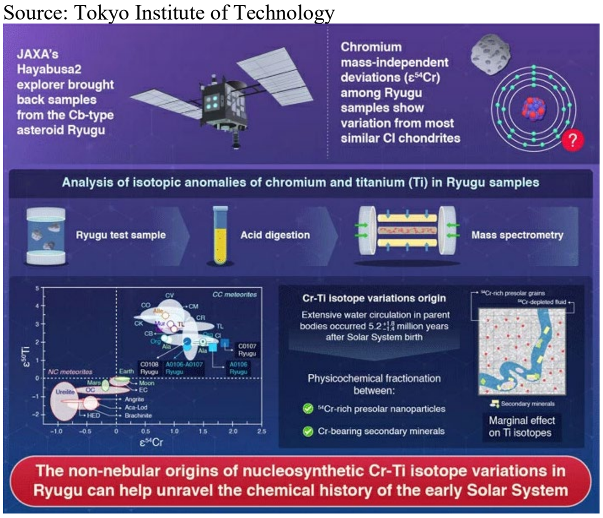
Researchers take inspiration from muscles in the human body to develop a system that helps unmanned rovers detect slip condition
Date: November 15, 2023
Source: Shibaura Institute of Technology

Given the hostile conditions of extraterrestrial environments, unmanned rovers play a critical role in the exploration of planets and moons. NASA's Mars and lunar exploration rovers have significantly contributed to our understanding of these extraterrestrial bodies. Planetary surfaces often present challenging landscapes with slopes, craters, and dunes. More importantly, the presence of regolith, fine particles that cover these surfaces, poses a significant challenge for rover mobility. The slipping of rovers on these loose surfaces can hinder their progress and even jeopardize their missions.
Various methods, primarily relying on visual data from cameras, have been explored to detect the traveling state or slip condition of rovers. However, these methods have limitations as they may struggle to differentiate between various terrain features such as distinguishing rocks from loose sand. A solution to this problem is for the rovers to obtain information about the traction on each wheel. This way, the rover could detect its traveling state faster and correct its posture to avoid slipping.
To realize this, Professor Kojiro Iizuka from the Department of Machinery and Control Systems of the College of Systems Engineering and Science at Shibaura Institute of Technology (SIT), Japan, and Dr. Kohei Inaba, also from SIT, have recently developed a novel system that allows a rover to detect its traveling state by the change in shape of its chassis. "*Our inspiration came from how humans detect their own traveling state based on muscle tension while walking. We aimed to develop a similar system that recognizes the traveling state based on the chassis shape deformation,"* explains Prof. Iizuka. Their study was published in Volume 15, Issue 17 of the journal *Remote Sensing* on August 30, 2023.
The muscles in the human body have special muscle fibres called nuclear chain fibres and nuclear bag fibres which help in detecting the traveling state of the body. The nuclear chain fibres detect the displacement of the tension in the muscles and help in determining the static posture of the body. On the other hand, nuclear bag fibres detect how fast muscle fibres stretch and help in detecting the dynamic state of the body.
Drawing parallels with human muscles, the researchers classified the change in the shape of the chassis of the rover, which manifests as strain, into two categories: displacement of strain and vibrational change in strain. They studied the strain displacement data using nuclear chain fibres analysis and strain velocity as nuclear bag fibres analysis.
The nuclear chain fibre analysis revealed that the forces acting vertically and in the direction of the rover's motion changed with strain.

Therefore, monitoring strain changes can enable the detection of force alterations, ultimately indicating the rover's traveling state. In addition, through nuclear bag analysis, the researchers found that the rate of strain change could effectively gauge the level of slippage and subsequent alterations in the rover's travel state. Using this data, the system can determine the rover's condition in real time, thus enabling the rover to make essential manoeuvres to avert potential slipping incidents.
The study also emphasizes the system's capabilities to detect environmental obstacles, such as rocks and stones, highlighting its potential to enhance the safety and efficiency of rover operations.
Highlighting the importance of this study, Prof. Iizuka remarks: "*During rover route planning, the experiences from this study should be considered to ensure that the rovers can travel safely. These findings represent the first step towards incorporating elements of biological functionality in sensing moving objects. We believe that our approach will also be effective for unmanned aerial vehicles and automatic driving in the future*."
In conclusion, this innovative study marks a significant step towards improving the safety and effectiveness of rover missions, promising advancements in our exploration of other planets and celestial bodies.

- Exploring the origin of nucleosynthetic isotope variations in Ryugu samples

Date: November 9, 2023
Source: Tokyo Institute of Technology



The observed variations in chromium (Cr) isotope ratios in the Ryugu asteroid samples collected by Hayabusa2 likely resulted from elemental redistribution of slightly soluble Cr by water within the parent body, reveals a multinational study led by researchers from Tokyo Tech. The results provide useful insights for expanding our understanding of the origin and evolution of materials in our solar system.
Hayabusa2 space mission by the Japan Aerospace Exploration Agency (JAXA) returned home with samples of the asteroid Ryugu that orbits the Sun between Earth and Mars. Preliminary chemical analysis of Ryugu samples revealed that the asteroid is rich in volatile and organic-rich materials, which shows similarities to the class of meteorites known as Ivuna-type carbonaceous chondrites (CIs). Such asteroids have gained the attention of scientists due to their close chemical resemblance with elemental environments during the birth of the solar system.
Studies have shown that isotopic anomalies in chromium ($^{54}Cr/^{52}Cr$) and titanium ratios ($^{50}Ti/^{47}Ti$), often expressed as $\varepsilon^{54}Cr$ and $\varepsilon^{50}Ti$, respectively, can help decipher the nucleosynthetic origins of chemical components in extraterrestrial materials. While the isotopic variability of other elements in bulk Ryugu samples is similar to that in CIs, anomalies in Cr isotopes are slightly different from those recorded in the literature. To unravel the origin of these deviations, an international team of scientists led by Professor Tetsuya Yokoyama from Tokyo Institute of Technology has recently investigated $\varepsilon^{54}Cr$ and $\varepsilon^{50}Ti$ in five different Ryugu samples. Their results have been published in *Scientific Advances*.
"Prior studies on the asteroid samples established that Ryugu and Ivuna-type carbonaceous chondrites were born in a common place; more distant part of the solar system than other meteorite parent bodies. However, the slight discrepancy in isotopic anomalies of Cr between Ryugu and CIs gave rise to the question whether the heterogeneity is due to the difference in the birth place, or did it arise from secondary processes that occurred after the accretion of their parent bodies," explains Prof. Yokoyama.
For precise analysis of the Cr and Ti anomalies, the team selected two Ryugu samples from the first touchdown and three from the second touchdown site. The samples were first digested in acids and subjected to inductively coupled plasma mass spectrometry (ICP-MS) and thermal ionization mass spectrometry (TIMS). The test results in samples weighing less than 24

milligrams indicated that the variation in $\varepsilon^{50}Ti$ is marginal and agrees with the data available on CIs. The same was not true for $\varepsilon^{54}Cr$ values, where the dispersions exceeded formerly reported values for CIs. However, when the sample was greater than 90 milligrams, isotopic similarity was found. This observation suggested that Cr isotopes are not uniformly distributed in the Ryugu parent body at the microscopic level, while Ryugu has a Cr isotopic composition similar to CIs at the macroscopic level, thus corroborating the idea that Ryugu and CIs share a common genetic heritage.

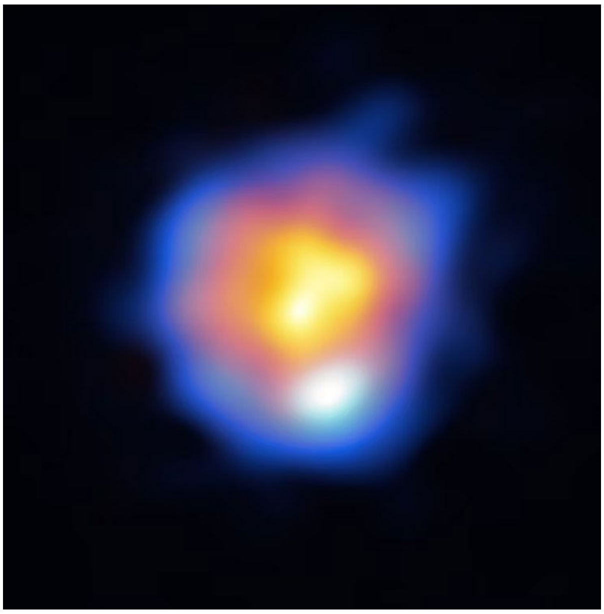
Further analysis of the samples indicated that the microscopic heterogeneity in Cr isotope distribution arose from the physicochemical fractionation of ^{54}Cr-rich presolar nanoparticles and Cr-bearing secondary minerals. This phenomenon was attributed to the aqueous alteration within the asteroid. The water in the asteroid dissolved the mildly soluble Cr while ^{54}Cr-rich presolar nanoparticles undissolved, circulated the ^{54}Cr-depleted fluid within the body, resulting in the precipitation of secondary minerals depleted in ^{54}Cr. This scenario was supported by the analysis of radiogenic isotope ^{53}Cr carried out by the team, which revealed that the precipitation of secondary minerals occurred around 5.2 million years after the birth of the solar system.

Nucleosynthetic ^{54}Cr anomalies in extraterrestrial materials are often connected to their nebular origins, but this study reveals that apparent ^{54}Cr variabilities in asteroidal materials could also rise from parent body processes such as elemental redistribution by water.

"Unlike meteorites that plummet to earth from space, Ryugu samples are unaffected by terrestrial contamination, and they are particularly valuable for unravelling the earliest history of the solar system as they retain primitive chemical characteristics. Therefore, this study is a step closer to fully understanding our chemical past," concludes Prof. Yokoyama.

- An old star with ring-like structure: ALMA demonstrates highest resolution yet

Date: November 15, 2023
Source: National Institutes of Natural Sciences



This is what nearby supergiant star R Leporis, and its halo of gas, would look like if our eyes could see in microwave radiation.

ESO

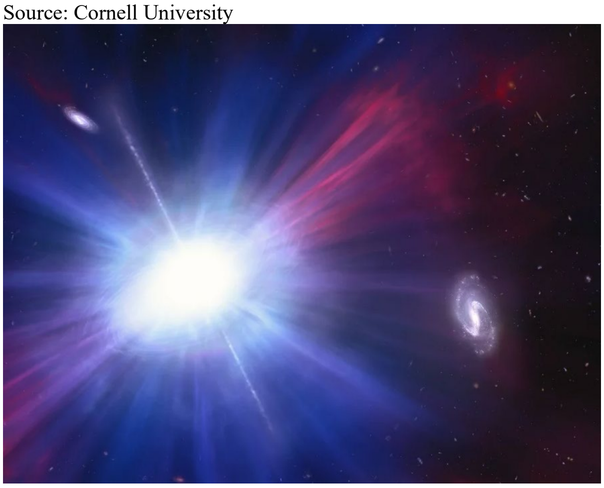
ALMA (Atacama Large Millimetre/submillimetre Array) has demonstrated the highest resolution yet with observations of an old star. The observations show that the star is surrounded by a ring-like structure of gas and that gas from the star is escaping to the surrounding space. Future observations with the newly demonstrated high resolution are expected to elucidate, not only the end of a star's life, but also the beginning, when planets are still forming.

ALMA is a radio interferometric array telescope, in which individual antennas work together to observe a celestial object. ALMA's resolution, the ability to see small details, is determined by the maximum separation between the antennas and the frequency of the observed radio waves. In this research, an international team comprised mainly of astronomers from the Joint ALMA Observatory, National Astronomical Observatory of Japan (NAOJ), National Radio Astronomy Observatory, and European Southern Observatory used ALMA's maximum antenna separation of 16 km and highest frequency receivers (known as Band 10, up to 950 GHz) to achieve the best resolution possible. Pushing ALMA's resolution to new limits also required a new calibration technique to correct for fluctuations in Earth's atmosphere above the antennas. The calibration technique the team used, known as "band-to-band (B2B)," was originally tested in the 1990s at Nobeyama Radio Observatory of NAOJ for future millimetre/submillimetre interferometers.

For their demonstration observations, the team chose R Leporis, a star in the final stage of stellar evolution, located approximately 1,535 light-years away from Earth. The team succeeded in observing R Leporis with the best resolution ever, 5 milli-arcsec, which is the equivalent of being able to see a single human hair two and a half miles away. The observations show the surface of the star and a ring of gas around the star. The team also confirmed that gas from the star is escaping to the surrounding space.
This newly demonstrated high resolution capability can now be applied to young stars with protoplanetary disks where planets are forming. Future high-resolution observations will provide new insights into how planets, particularly Earth-like planets, form.

- With unprecedented flares, stellar corpse shows signs of life

Date: November 15, 2023
Source: Cornell University



Artist's concept of one of the brightest explosions ever seen in space: a Luminous Fast Blue Optical Transient (LFBOT). Credits: NASA, ESA, NSF's NOIRLab, Mark Garlick, Mahdi Zamani

After a distant star's explosive death, an active stellar corpse was the likely source of repeated energetic flares observed over several months -- a phenomenon astronomers had never seen before, a Cornell-led team reports in new research published Nov. 15 in *Nature.*
The bright, brief flashes -- as short as a few minutes in duration, and as powerful as the original explosion 100 days later -- appeared in the aftermath of a rare type of stellar cataclysm that the researchers had set out to find, known as a luminous fast blue optical transient, or LFBOT.
Since their discovery in 2018, astronomers have speculated about what might drive such extreme explosions, which are far brighter than the violent ends massive stars typically experience, but fade in days instead of weeks.
The research team believes the previously unknown flare activity, which was studied by 15 telescopes around the world, confirms the engine must be a stellar corpse: a black hole or neutron star.
"We don't think anything else can make these kinds of flares," said Anna Y. Q. Ho, assistant professor of astronomy in the College of Arts and Sciences. "This settles years of debate about what powers this type of explosion, and reveals an unusually direct method of studying the activity of stellar corpses."
Ho is the first author of "Minutes-duration Optical Flares with Supernova Luminosities," published with more than 70 co-authors who helped characterize the LFBOT officially labelled AT2022tsd and nicknamed "the Tasmanian devil," and the ensuing pulses of light seen roughly a billion light years from Earth.
Ho wrote the software that flagged the event in September 2022, while sifting through a half-million changes, or transients, detected daily in an all-sky survey conducted by the California-based Zwicky Transient Facility. Then in December 2022, while routinely monitoring the fading explosion, Ho and collaborators Daniel Perley of Liverpool John Moores University in England, and Ping Chen of the Weizmann Institute of Science in Israel, met to review new observations conducted and analysed by Ping -- a set of five images, each spanning several minutes. The first showed nothing, as expected, but the second picked up light, followed by an intensely bright spike in the middle frame that quickly vanished.
"No one really knew what to say," Ho recalled. "We had never seen anything like that before -- something so fast, and the brightness as strong as the original explosion months later -- in any supernova or FBOT. We'd never seen that, period, in astronomy."
To further investigate the abrupt rebrightening, the researchers engaged partners who contributed observations from more than a dozen other telescopes, including one equipped with a high-speed camera. The team combed through earlier data and worked to rule out other possible light sources. Their analysis ultimately confirmed at least 14 irregular light pulses over a 120-day period, likely only a fraction of the total number, Ho said.
"Amazingly, instead of fading steadily as one would expect, the source briefly brightened

again -- and again, and again," she said. "LFBOTs are already a kind of weird, exotic event, so this was even weirder."
Exactly what processes were at work -- perhaps a black hole funnelling jets of stellar material outward at close to the speed of light -- continues to be studied. Ho hopes the research advances longstanding goals to map how stars' properties in life may predict the way they'll die, and the type of corpse they produce.
In the case of LFBOTs, rapid rotation or a strong magnetic field likely are key components of their launching mechanisms, Ho said. It's also possible that they aren't conventional supernovas at all, instead triggered by a star's merger with a black hole. "We might be seeing a completely different channel for cosmic cataclysms," she said.
The unusual explosions promise to provide new insight into stellar lifecycles typically only seen in snapshots of different stages -- star, explosion, remnants -- and not as part of a single system, Ho said. LFBOTs may present an opportunity to observe a star in the act of transitioning to its afterlife.
"Because the corpse is not just sitting there, it's active and doing things that we can detect," Ho said. "We think these flares could be coming from one of these newly formed corpses, which gives us a way to study their properties when they've just been formed."

- ❖ Using eclipses to calculate the transparency of Saturn's rings

Date: November 14, 2023
Source: Lancaster University

A Lancaster University PhD student has measured the optical depth of Saturn's rings using a new method based on how much sunlight reached the Cassini spacecraft while it was in the shadow of the rings.
The optical depth is connected to the transparency of an object, and it shows how far light can travel through that object before it gets absorbed or scattered.
The research, led by Lancaster University in collaboration with the Swedish Institute of Space Physics, is published in the Monthly Notices of the Royal Astronomical Society.
The NASA-ESA Cassini spacecraft was launched in 1997 and reached Saturn in 2004, carrying out the most extensive survey of the planet and its moons to date. The mission ended in 2017 when Cassini plunged into the Saturnian atmosphere, after diving 22 times between the planet and its rings.
Lancaster University PhD student George Xystouris, under the supervision of Dr Chris Arridge, analysed historic data from the Langmuir Probe on board Cassini, an instrument that was measuring the cold plasma, i.e., low energy ions and electrons, in the magnetosphere of Saturn.
For their study they focused on solar eclipses of the spacecraft: periods where Cassini was in the shadow of Saturn or the main rings. During each eclipse, the Langmuir Probe recorded dramatic changes in the data.
George said: "As the probe is metallic, whenever it is sunlit, the sunlight can give enough energy to the probe to release electrons. This is the photoelectric effect, and the electrons that are released are so-called 'photoelectrons. They can create problems though, as they have the same properties as the electrons in the cold plasma around Saturn and there is not an easy way to separate the two."
"Focusing on the data variations we realised that they were connected with how much sunlight each ring would allow to pass. Eventually, using the properties of the material that the Langmuir Probe was made of, and how bright the Sun was in Saturn's neighbourhood, we managed to calculate the change in the photoelectrons number for each ring, and calculate Saturn's rings optical depth.
"This was a novel and exciting result! We used an instrument that is mainly used for plasma measurements to measure a planetary feature, which is a unique use of the Langmuir Probe, and our results agreed with studies that used high-resolution imagers to measure the transparency of the rings."
The main rings, which extend up to 140,000 km from the planet, but have a maximum thickness of only 1km, are to disappear from view from Earth by 2025. In that year the rings will be tilted edge-on to Earth, making it almost impossible to view them. They will tilt back towards Earth during the next phase of

Saturn's 29-year orbit and will continue to become more visible and brighter until 2032. Professor Mike Edmunds, the President of the Royal Astronomical Society, added: "It is always good to see a postgraduate student involved in using space probe instrumentation in an unusual and inventive way. Innovation of this kind is just what is needed in astronomical research -- and an approach which many former students who are in a variety of careers are applying to help address the world's problems."