South Downs Mercury

The monthly circular of South Downs Astronomical Society
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Main Talk **Andrew Ritchie Green BSc (Hons) FRAS via Zoom at the planetarium. "One Small Step" The Apollo missions to the moon are considered to be human kinds greatest achievement and landing people on the moon the culmination of the Space Race between the USA and Soviet Union. The story of how they got there, and the sacrifices made after Kennedy set the goal of landing in the moon in 1962 is interesting as well. How a NAZI became the doyen of the USA, Astronauts lost, musical interludes and ultimate success We then go to the conspiracy theorist who say**

Please support a raffle we are organizing this month

- New type of star gives clues to mysterious origin of magnetars

Date: August 17, 2023
Source: ESO

Magnetars are the strongest magnets in the Universe. These super-dense dead stars with ultra-strong magnetic fields can be found all over our galaxy but astronomers don't know exactly how they form. Now, using multiple telescopes around the world, including European Southern Observatory (ESO) facilities, researchers have uncovered a living star that is likely to become a magnetar. This finding marks the discovery of a new type of astronomical object — massive magnetic helium stars — and sheds light on the origin of magnetars

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Despite having been observed for over 100 years, the enigmatic nature of the star HD 45166 could not be easily explained by conventional models, and little was known about it beyond the fact that it is one of a pair of stars [1], is rich in helium and is a few times more massive than our Sun.

"This star became a bit of an obsession of mine," says Tomer Shenar, the lead author of a study on this object published today in Science and an astronomer at the University of Amsterdam, the Netherlands. "Tomer and I refer to HD 45166 as the 'zombie star'," says co-author and ESO astronomer Julia Bodensteiner, based in Germany. "This is not only because this star is so unique, but also because I jokingly said that it turns Tomer into a zombie."

Having studied similar helium-rich stars before, Shenar thought magnetic fields could crack the case. Indeed, magnetic fields are known to influence the behaviour of stars and could explain why traditional models failed to describe HD 45166, which is located about 3000 light-years away in the constellation Monoceros. "I remember having a Eureka moment while reading the literature: 'What if the star is magnetic?'," says Shenar, who is currently based at the Centre for Astrobiology in Madrid, Spain.

Shenar and his team set out to study the star using multiple facilities around the globe. The main observations were conducted in February 2022 using an instrument on the Canada-France-Hawaii Telescope that can detect and measure magnetic fields. The team also relied on key archive data taken with the Fiber-fed Extended Range Optical Spectrograph (FEROS) at ESO's La Silla Observatory in Chile.

Once the observations were in, Shenar asked co-author Gregg Wade, an expert on magnetic fields in stars at the Royal Military College of Canada, to examine the data. Wade's response confirmed Shenar's hunch: "Well my friend, whatever this thing is -- it is definitely magnetic."

Shenar's team had found that the star has an incredibly strong magnetic field, of 43,000 gauss, making HD 45166 the most magnetic massive star found to date [2]. "The entire surface of the helium star has a magnetic field almost 100,000 times stronger than Earth's," explains co-author Pablo Marchant, an astronomer at KU Leuven's Institute of Astronomy in BelgiumThis observation marks the discovery of the very first massive magnetic helium star. "It is exciting to uncover a new type of astronomical object," says Shenar, "especially when it's been hiding in plain sight all along."

Moreover, it provides clues to the origin of magnetars, compact dead stars laced with magnetic fields at least a billion times stronger than the one in HD 45166. The team's calculations suggest that this star will end its life as a magnetar. As it collapses under its own gravity, its magnetic field will strengthen, and the star will eventually become a very compact core with a magnetic field of around 100 trillion gauss [3] -- the most powerful type of magnet in the Universe.

Shenar and his team also found that HD 45166 has a mass smaller than previously reported, around twice the mass of the Sun, and that its stellar pair orbits at a far larger distance than believed before. Furthermore, their research indicates that HD 45166 formed through the merger of two smaller helium-rich stars. "Our findings completely reshape our understanding of HD 45166," concludes Bodensteiner.

Notes

[1] While HD 45166 is a binary system, in this text HD 45166 refers to the helium-rich star, not to both stars.

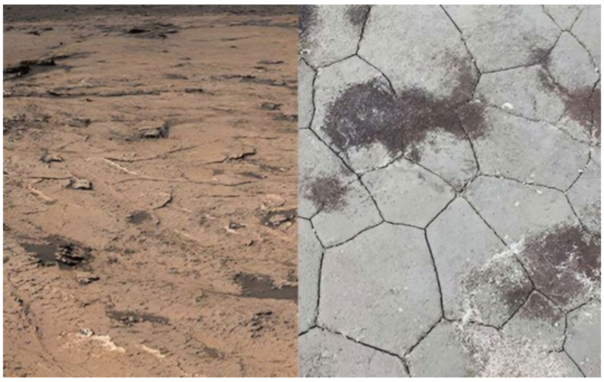
[2] The magnetic field of 43,000 gauss is the strongest magnetic field ever detected in a star that exceeds the Chandrasekhar mass limit, which is the critical limit above which stars may collapse into neutron stars (magnetars are a type of neutron star).

[3] In this text, a billion refers to one followed by nine zeros and a trillion refers to one followed by 12 zeros.

- Possible seasonal climate patterns on early Mars

The Curiosity Rover finds evidence of high frequency wet-dry cycling in the Gale Crater

Date: August 9, 2023
Source: DOE/Los Alamos National Laboratory



Patterns in mud cracks show that Mars may have had cyclical moisture patterns. Left: the terrain in the Gale Crater where Curiosity is currently exploring. Right: mud cracks on Earth, where wet-dry cycling has occurred, creating Y-shaped patterns. Credit: *Nature* (2023). DOI: 10.1038/s41586-023-06220-3

New observations of mud cracks made by the Curiosity rover show that high-frequency, wet-dry cycling occurred in early Martian surface environments, indicating that the red planet may have once seen seasonal weather patterns or even flash floods. The research was published today in Nature.

"These exciting observations of mature mud cracks are allowing us to fill in some of the missing history of water on Mars. How did Mars go from a warm, wet planet to the cold, dry place we know today? These mud cracks show us that transitional time, when liquid water was less abundant but still active on the Martian surface," said Nina Lanza, principal investigator of the ChemCam instrument onboard the Curiosity rover. "These features also point to the existence of wet-dry environments that on Earth are extremely conducive to the development of organic molecules and potentially life. Taken as a whole, these results a giving us a clearer picture of Mars as a habitable world."

The presence of long-term wet environments, such as evidence of ancient lakes on Mars, is well-documented, but far less is known about short-term climate fluctuations.

After years of exploring terrain largely composed of silicates, the rover entered a new area filled with sulphates, marking a major environment transition. In this new environment, the research team found a change in mud crack patterns, signifying a change in the way the surface would have dried. This indicates that water was still present on the surface of Mars episodically, meaning water could have been present for a time, evaporated, and repeated until polygons, or mud cracks, formed.

"A major focus of the Curiosity mission, and one of the main reasons for selecting Gale Crater, is to understand the transition of a 'warm and wet' ancient Mars to a 'cold and

dry' Mars we see today," said Patrick Gasda of the Laboratory's Space Remote Sensing and Data Science group and coauthor of the paper. "The rover's drive from clay lakebed sediments to drier non-lakebed and sulphate-rich sediments is part of this transition."
On Earth, initial mud cracks in mud form a T-shaped pattern, but subsequent wetting and drying cycles cause the cracks to form more of a Y-shaped pattern, which is what Curiosity observed. Additionally, the rover found evidence that the mud cracks were only a few centimetres deep, which could mean that wet-dry cycles were seasonal, or may have even occurred more quickly, such as in a flash flood.
These findings could mean that Mars once had an Earth-like wet climate, with seasonal or short-term flooding, and that Mars may have been able to support life at some point.
"What's important about this phenomenon is that it's the perfect place for the formation of polymeric molecules required for life, including proteins and RNA, if the right organic molecules were present at this location," Gasda said "Wet periods bring molecules together while dry periods drive reactions to form polymers. When these processes occur repeatedly at the same location, the chance increases that more complex molecules formed there."

- Using supernovae to study neutrinos' strange properties

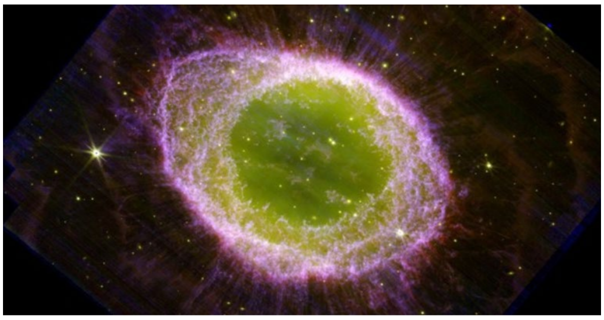
New study offers hope to long-standing scientific problem
Date: August 15, 2023
Source: Ohio State University

In a new study, researchers have taken an important step toward understanding how exploding stars can help reveal how neutrinos, mysterious subatomic particles, secretly interact with themselves.
One of the less well-understood elementary particles, neutrinos rarely interact with normal matter, and instead travel invisibly through it at almost the speed of light. These ghostly particles outnumber all the atoms in the universe and are always passing harmlessly through our bodies, but due to their low mass and lack of an electric charge they can be incredibly difficult to find and study.
But in a study published today in the journal *Physical Review Letters*, researchers at The Ohio State University have established a new framework detailing how supernovae -- massive explosions that herald the death of collapsing stars -- could be used as powerful tools to study how neutrino self-interactions can cause vast cosmological changes in the universe.
"Neutrinos only have very small rates of interaction with typical matter, so it's difficult to detect them and test any of their properties," said Po-Wen Chang, lead author of the study and a graduate student in physics at Ohio State. "That's why we have to use astrophysics and cosmology to discover interesting phenomena about them."
Thought to have been important to the formation of the early universe, neutrinos are still puzzling to scientists, despite having learned that they originate from a number of sources, such as in nuclear reactors or the insides of dying stars. But by calculating how self-interactions would affect the neutrino signal from Supernova 1987A, the nearest supernova observed in modern times, researchers found that when neutrinos do interact with themselves, they form a tightly coupled fluid that expands under relativistic hydrodynamics -- a branch of physics that deals with how flows impact solid objects in one of two different ways.
In the case of what's called a "burst outflow," the team theorizes that much like popping a highly pressurized balloon in the vacuum of space would push energy outward, a burst produces a neutrino fluid that moves in all directions. The second case, described as a "wind outflow," imagines a highly pressurized balloon with many nozzles, wherein neutrinos escape at a more constant flow rate, similar to a jet of steady wind.
While the wind-outflow theory is more likely to take place in nature, said Chang, if the burst case is realized, scientists could see new observable neutrino signatures emitted from supernovae, allowing unprecedented sensitivity to neutrino self-interactions.
One of the reasons it's so vital to understand these mechanisms is that if neutrinos are acting as a fluid, that means they are acting together, as a collective. And if the properties

of neutrinos are different as a collective than individually, then the physics of supernovae could experience changes too. But whether these changes are due solely to the burst case or the outflow case remains to be seen.
"The dynamics of supernovae are complicated, but this result is promising because with relativistic hydrodynamics we know there's a fork in the road in understanding how they work now," said Chang.
Still, further research needs to be done before scientists can cross off the possibility of the burst case happening inside supernovae as well.
Despite these uncertainties, the study is a huge milestone in answering the decades-old astrophysical issue of how neutrinos actually scatter when ejected from supernovae, said John Beacom, co-author of the study and a professor of physics and astronomy at Ohio State. This study found that in the burst case, unprecedented sensitivity to neutrino self-interactions is possible even with sparse neutrino data from SN 1987A and conservative analysis assumptions.
"This problem has lain basically untouched for 35 years," said Beacom. "So even though we were not able to completely solve how neutrinos affect supernovae, what we're excited about is that we were able to make a substantial step forward."
Down the road, the team hopes their work will be used as a stepping stone to further investigate neutrino self-interactions. Yet because only about two or three supernovae happen per century in the Milky Way, it's likely researchers will have to wait decades more to collect enough new neutrino data to prove their ideas.
"We're always praying for another galactic supernova to happen somewhere and soon, but the best we can do is try to build on what we know as much as possible before it happens," said Chang.
Other co-authors were Ivan Esteban, Todd Thompson and Christopher M. Hirata, all of Ohio State. This work was supported by the National Science Foundation, NASA, and the David & Lucile Packard Foundation.

- James Webb Space Telescope captures stunning images of the Ring Nebula

Date: August 3, 2023
Source: University of Manchester



NASA's James Webb Space Telescope (JWST) has recorded breath-taking new images of the iconic Ring Nebula, also known as Messier 57.
The images, released today by an international team of astronomers led by Professor Mike Barlow (UCL, UK) and Dr Nick Cox (ACRI-ST, France), with Professor Albert Zijlstra of The University of Manchester, showcase the nebula's intricate and ethereal beauty in unprecedented detail, providing scientists and the public with a mesmerizing view of this celestial wonder.
For many sky enthusiasts, the Ring Nebula is a well-known object that is visible all summer long and is located in the constellation Lyra. A small telescope will already reveal the characteristic donut-like structure of glowing gas that gave the Ring Nebula its name.
The Ring Nebula is a planetary nebula -- objects that are the colourful remnants of dying stars that have thrown out much of their mass at the end of their lives.
Its distinct structure and its vibrant colours have long captivated the human imagination and the stunning new images captured by the JWST offer an unparalleled opportunity to study and understand the complex processes that shaped this cosmic masterpiece.
Albert Zijlstra, Professor in Astrophysics at the University of Manchester, said: "We are amazed by the details in the images, better than we have ever seen before. We always knew planetary nebulae were pretty. What we see now is spectacular."
Dr Mike Barlow, the lead scientist of the JWST Ring Nebula Project, added: "The James Webb Space Telescope has provided us with an extraordinary view of the Ring Nebula that we've never seen before. The high-resolution images not only showcase the intricate details of the nebula's expanding shell but also reveal the inner region around the central white dwarf in exquisite clarity. We are witnessing the final chapters of a star's life, a preview of the Sun's distant future so to speak, and JWST's observations have opened

a new window into understanding these awe-inspiring cosmic events. We can use the Ring Nebula as our laboratory to study how planetary nebulae form and evolve." The Ring Nebula's mesmerizing features are a testament to the stellar life cycle.
Approximately 2,600 lightyears away from Earth, the nebula was born from a dying star that expelled its outer layers into space. What makes these nebulae truly breath-taking is their variety of shapes and patterns, that often include delicate, glowing rings, expanding bubbles or intricate, wispy clouds.
These patterns are the consequence of the complex interplay of different physical processes that are not well understood yet. Light from the hot central star now illuminates these layers.
Just like fireworks, different chemical elements in the nebula emit light of specific colours. This then results in exquisite and colourful objects, and furthermore allows astronomers to study the chemical evolution of these objects in detail.
Dr Cox, the co-lead scientist, said: "These images hold more than just aesthetic appeal; they provide a wealth of scientific insights into the processes of stellar evolution. By studying the Ring Nebula with JWST, we hope to gain a deeper understanding of the life cycles of stars and the elements they release into the cosmos."
The international research team analysing these images is composed of researchers from the UK, France, Canada, USA, Sweden, Spain, Brazil, Ireland and Belgium.
They say that JWST/MIRI images of the Ring Nebula are coming soon.
Video: https://youtu.be/78sjkGypk20

- Hundred-year storms? That's how long they last on Saturn

Mega storms leave marks on Saturn's atmosphere for centuries
Date: August 11, 2023
Source: University of California – Berkeley

The largest storm in the solar system, a 10,000-mile-wide anticyclone called the Great Red Spot, has decorated Jupiter's surface for hundreds of years.
A new study now shows that Saturn -- though much blander and less colourful than Jupiter -- also has long-lasting mega storms with impacts deep in the atmosphere that persist for centuries.
The study was conducted by astronomers from the University of California, Berkeley, and the University of Michigan, Ann Arbor, who looked at radio emissions from the planet, which come from below the surface, and found long-term disruptions in the distribution of ammonia gas.
The study was published today (Aug. 11) in the journal *Science Advances.*
Mega storms occur approximately every 20 to 30 years on Saturn and are similar to hurricanes on Earth, although significantly larger. But unlike Earth's hurricanes, no one knows what causes mega storms in Saturn's atmosphere, which is composed mainly of hydrogen and helium with traces of methane, water and ammonia.
"Understanding the mechanisms of the largest storms in the solar system puts the theory of hurricanes into a broader cosmic context, challenging our current knowledge and pushing the boundaries of terrestrial meteorology," said lead author Cheng Li, a former 51 Peg b Fellow at UC Berkeley who is now an assistant professor at the University of Michigan.
Imke de Pater, a UC Berkeley professor emerita of astronomy and of earth and planetary sciences, has been studying gas giants for over four decades to better understand their composition and what makes them unique, employing the Karl G. Jansky Very Large Array in New Mexico to probe the radio emissions from deep inside the planet.
"At radio wavelengths, we probe below the visible cloud layers on giant planets. Since chemical reactions and dynamics will alter the composition of a planet's atmosphere, observations below these cloud layers are required to constrain the planet's true atmospheric composition, a key parameter for planet formation models," she said. "Radio observations help characterize dynamical, physical and chemical processes including heat transport, cloud formation and convection in the atmospheres of giant planets on both global and local scales."
As reported in the new study, de Pater, Li and UC Berkeley graduate student Chris Moeckel

found something surprising in the radio emissions from the planet: anomalies in the concentration of ammonia gas in the atmosphere, which they connected to the past occurrences of mega storms in the planet's northern hemisphere.
According to the team, the concentration of ammonia is lower at midlatitudes, just below the uppermost ammonia-ice cloud layer, but has become enriched at lower altitudes, 100 to 200 kilometres deeper in the atmosphere. They believe that the ammonia is being transported from the upper to the lower atmosphere via the processes of precipitation and reevaporation. What's more, that effect can last for hundreds of years.
The study further revealed that although both Saturn and Jupiter are made of hydrogen gas, the two gas giants are remarkably dissimilar. While Jupiter does have tropospheric anomalies, they have been tied to its zones (whitish bands) and belts (darkish bands) and are not caused by storms like they are on Saturn. The considerable difference between these neighbouring gas giants is challenging what scientists know about the formation of mega storms on gas giants and other planets and may inform how they're found and studied on exoplanets in the future.
The National Radio Astronomy Observatory (NRAO) is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities Inc.

- Could artificially dimming the sun prevent ice melt?

Date: August 11, 2023
Source: University of Bern

With methods of so-called geoengineering, the climate could theoretically be artificially influenced and cooled. Bernese researchers have now investigated whether it would be possible to prevent the melting of the West Antarctic ice sheet by artificially "dimming the sun." The results show that artificial influence does not work without decarbonization and entails high risks.

Is there an emergency solution that could stop climate change? Technical methods that artificially influence the climate have been discussed for some time under the term geoengineering. However, the majority of climate researchers have been critical of them: high risks, incalculable consequences for future generations.
In a study just published in the journal *Nature Climate Change*, researchers led by Johannes Sutter of the Climate and Environmental Physics Division (KUP) at the Institute of Physics and the Oeschger Centre for Climate Research at the University of Bern investigate the question of whether the melting of ice in West Antarctica could be prevented by artificially influencing solar radiation. The researchers also warn of unforeseeable side effects of geoengineering.

Avoiding a key climate tipping point

"The window of opportunity to limit the global temperature increase to below 2 degrees is closing fast," says ice modelling specialist Johannes Sutter, "so it is possible that technical measures to influence the climate will be seriously considered in the future." That is why, he says, it is necessary to use theoretical models to study the effects and risks of "solar radiation management." Solar Radiation Management (SRM) is a term used to describe various methods of blocking solar radiation in order to make the Earth cooler.
A key reason for the increased interest in geoengineering is the avoidance of tipping points at which the climate could change abruptly and irreversibly. These include the melting of the West Antarctic and Greenland ice sheets and the associated meter-high sea level rise. "Observations of ice flows in West Antarctica indicate that we are very close to a so-called tipping point or have already passed it," explains Johannes Sutter, "with our study, we therefore wanted to find out whether a collapse of the ice sheet could theoretically be prevented with solar radiation management."

Artificially dimming the sun

Specifically, Sutter and his colleagues have investigated what would happen if so-called aerosols -- suspended particles in a gas -- introduced into the stratosphere succeeded in blocking solar radiation from the earth -- a dimming of the sun, so to speak. So far, research has focused on the global effects of solar radiation management (SRM). The Bern study is the first to use ice model simulations to show what effect such a measure would have on the Antarctic ice sheet. The study examines the possible development of the ice sheet under different future greenhouse gas scenarios and yields differentiated results: If emissions continue unabated and the SRM occurs in the middle of this century, the collapse of the West Antarctic Ice Sheet could be delayed somewhat, but not prevented. In a medium emissions scenario, SRM deployed by mid-century could prove to be an "effective tool" to slow or even prevent ice sheet collapse.

According to the model calculations, SRM works best when it occurs as early as possible and is combined with ambitious climate mitigation measures. But, the study authors emphasize, "our simulations show that the most effective way to prevent long-term collapse of the West Antarctic Ice Sheet is rapid decarbonization." The chances of a longer-term stable ice sheet are greatest if greenhouse gas emissions were reduced to net zero "without delay."

Possible side effects still hardly studied

But how should one imagine a dimming of the sun in practical terms? According to Johannes Sutter, a whole fleet of extremely high-flying airplanes would have to spread millions of tons of aerosols in the stratosphere. However, this technical intervention in the climate would have to be maintained without interruption and for centuries. If the intervention were stopped as long as the greenhouse concentration in the atmosphere remained high, the temperature on earth would quickly rise by several degrees.

The consequences of such a termination shock, Johannes Sutter points out, are only one of the possible dangers posed by SRM. The potential side effects are still insufficiently researched and range from a shift in the monsoon regime to changes in ocean and atmospheric circulation. Ocean acidification would also continue. Critical voices also caution political and social effects: The use of techniques such as solar dimming could lead to climate protection measures being slowed down or even prevented.

Thomas Stocker, professor of climate and environmental physics at the University of Bern and co-author of the study, says: "Geoengineering would be another global experiment and a potentially dangerous human intervention in the climate system, which should in any case be prevented according to Article 2 of the UN Framework Convention on Climate Change."

- After seventeen years, a spacecraft makes its first visit home

Date: August 10, 2023
Source: NASA/Goddard Space Flight Centre

Artist's illustration of STEREO-A: credit NASA-JPL via SWNS

On Aug. 12, 2023, NASA's STEREO-A spacecraft will pass between the Sun and Earth, marking the first Earth flyby of the nearly 17-year-old mission. The visit home brings a special chance for the spacecraft to collaborate with NASA missions near Earth and reveal new insights into our closest star.

The twin STEREO (Solar TErrestrial RElations Observatory) spacecraft launched on Oct. 25, 2006, from the Cape Canaveral Air Force Station in Florida. STEREO-A (for "Ahead") advanced its lead on Earth as STEREO-B (for "Behind") lagged behind, both charting Earth-like orbits around the Sun. During the first years after launch, the dual-spacecraft mission achieved its landmark goal: providing the first stereoscopic, or multiple-perspective, view of our closest star. On Feb. 6, 2011, the mission achieved another landmark: STEREO-A and -B reached a 180-degree separation in their orbits. For the first time, humanity saw our Sun as a complete sphere.

"Prior to that we were 'tethered' to the Sun-Earth line -- we only saw one side of the Sun at a time," said Lika Guhathakurta, STEREO program scientist at NASA Headquarters in Washington, D.C. "STEREO broke that tether and gave us a view of the Sun as a three-dimensional object."

The mission accomplished many other scientific feats over the years, and researchers studied both spacecraft views until 2014, when mission control lost contact with STEREO-B after a planned reset. However, STEREO-A continues its journey, capturing solar views unavailable from Earth.

On Aug. 12, 2023, STEREO-A's lead on Earth has grown to one full revolution as the spacecraft "laps" us in our orbit around the

Sun. In the few weeks before and after STEREO-A's flyby, scientists are seizing the opportunity to ask questions normally beyond the mission's reach.

A 3D View of the Sun

During the Earth flyby, STEREO-A will once again do something it used to do with its twin in the early years: combine views to achieve stereoscopic vision.

Stereoscopic vision allows us to extract 3D information from two-dimensional, or flat, images. It's how two eyeballs, looking out at the world from offset locations, create depth perception. Your brain compares the images from each eye, and the slight differences between those images reveal which objects are closer or farther away.

STEREO-A will enable such 3D viewing by synthesizing its views with NASA's and the European Space Agency's Solar and Heliospheric Observatory (SOHO) and NASA's Solar Dynamics Observatory (SDO). Better yet, STEREO-A's distance from Earth changes throughout the flyby, optimizing its stereo vision for different sized solar features at different times. It's as if scientists were adjusting the focus on a several million-mile-wide telescope.

STEREO scientists are using the opportunity to make much-needed measurements. They are identifying active regions, the magnetically complex regions underlying sunspots, hoping to uncover 3D information about their structure usually lost in 2D images. They'll also test a new theory that coronal loops -- giant arches often seen in close-up images of the Sun -- aren't what they appear to be.

"There is a recent idea that coronal loops might just be optical illusions," said Terry Kucera, STEREO project scientist at NASA's Goddard Space Flight Centre in Greenbelt, Maryland. Some scientists have suggested that our limited viewing angles make them appear to have shapes they may not truly have. "If you look at them from multiple points of view, that should become more apparent," Kucera added.

Inside a Solar Eruption

It's not just what STEREO-A will see as it flies by Earth, but also what it will "feel," that could lead to major discoveries.

When a plume of solar material known as a coronal mass ejection, or CME, arrives at Earth, it can disrupt satellite and radio signals, or even cause surges in our power grids. Or, it may have hardly any effect at all. It all depends on the magnetic field embedded within it, which can change dramatically in the 93 million miles between the Sun and Earth.

To understand how a CME's magnetic field evolves on the way to Earth, scientists build computer models of these solar eruptions, updating them with each new spacecraft observation. But a single spacecraft's data can only tell us so much.

"It's like the parable about the blind men and the elephant -- the one who feels the legs says 'it's like a tree trunk,' and the one who feels the tail says 'it's like a snake,'" said Toni Galvin, a professor at the University of New Hampshire and principal investigator for one of STEREO-A's instruments. "That's what we're stuck with right now with CMEs, because we typically only have one or two spacecraft right next to each other measuring it."

During the months before and after STEREO-A's Earth flyby, any Earth-directed CMEs will pass over STEREO-A and other near-Earth spacecraft, giving scientists much-needed multipoint measurements from inside a CME.

A Fundamentally Different Sun

STEREO-A was also close to Earth in 2006, shortly after launch. That was during "solar minimum," the low-point in the Sun's roughly 11-year cycle of high and low activity.

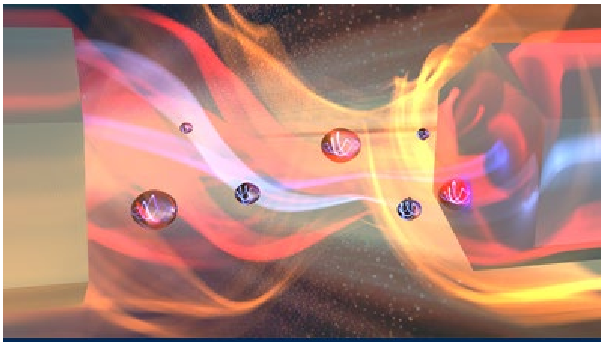
"The Sun was so quiet at that point! I was looking back at the data and I said 'Oh yeah, I recognize that active region' -- there was one, and we studied it," Kucera said, laughing. "OK, it wasn't quite that bad -- but it was close."

Now, as we approach solar maximum predicted for 2025, the Sun isn't quite so sleepy.

"In this phase of the solar cycle, STEREO-A is going to experience a fundamentally different Sun," Guhathakurta said. "There is so much knowledge to be gained from that."

- Physicists demonstrate how sound can be transmitted through vacuum

Date: August 9, 2023
Source: University of Jyväskylä - Jyväskylän yliopisto



Sound waves tunneling across a vacuum gap.

A classic movie was once promoted with the punchline: "In space, no one can hear you scream." Physicists Zhuoran Geng and Ilari Maasilta from the Nanoscience Centre at the University of Jyväskylä, Finland, have demonstrated, on the contrary, that in certain situations sound can be transmitted strongly across a vacuum region!

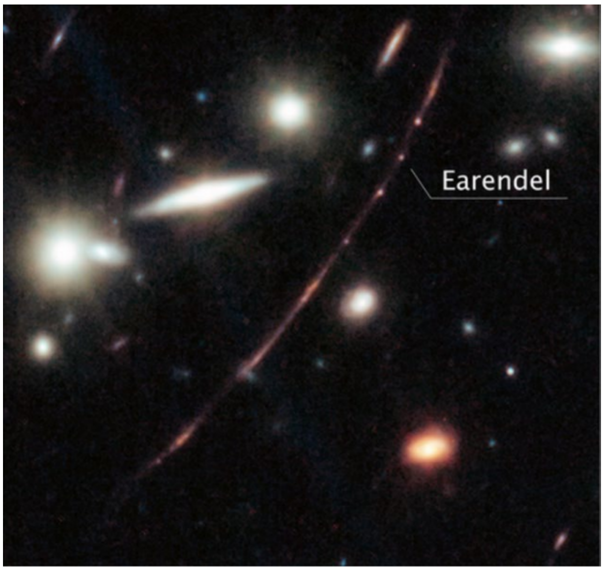
In a recent publication they show that in some cases a sound wave can jump or "tunnel" fully across a vacuum gap between two solids if the materials in question are piezoelectric. In such materials, vibrations (sound waves) produce an electrical response, as well, and since an electric field can exist in vacuum, it can transmit the sound waves across. The requirement is that the size of the gap is smaller than the wavelength of the sound wave. This effect works not only in audio range of frequencies (Hz-kHz), but also in ultrasound (MHz) and hyper sound (GHz) frequencies, as long as the vacuum gap is made smaller as the frequencies increase.

- In most cases the effect is small, but we also found situations, where the full energy of the wave jumps across the vacuum with 100 % efficiency, without any reflections. As such, the phenomenon could find applications in microelectromechanical components (MEMS, smartphone technology) and in the control of heat, says professor Ilari Maasilta from the Nanoscience Centre at the University of Jyväskylä.

The study was funded by the Academy of Finland and European Union's Horizon 2020 program, and was published in the journal Communications Physics, on 15th July 2023.

- Webb reveals colours of Earendel, most distant star ever detected

Date: August 9, 2023
Source: NASA/Goddard Space Flight Centre



The Webb space telescope has revealed the colours of Earendel. Earendel is the most distant star we've ever seen. Image via NASA/ ESA/ CSA/ D. Coe (STScI/ AURA for ESA; Johns Hopkins University)/ B. Welch (NASA's Goddard Space Flight Centre; University of Maryland, College Park). Image processing: Z. Levay

NASA's James Webb Space Telescope has followed up on observations by the Hubble Space Telescope of the farthest star ever detected in the very distant universe, within the first billion years after the big bang. Webb's NIRCam (Near-Infrared Camera) instrument reveals the star to be a massive B-type star more than twice as hot as our Sun, and about a million times more luminous.

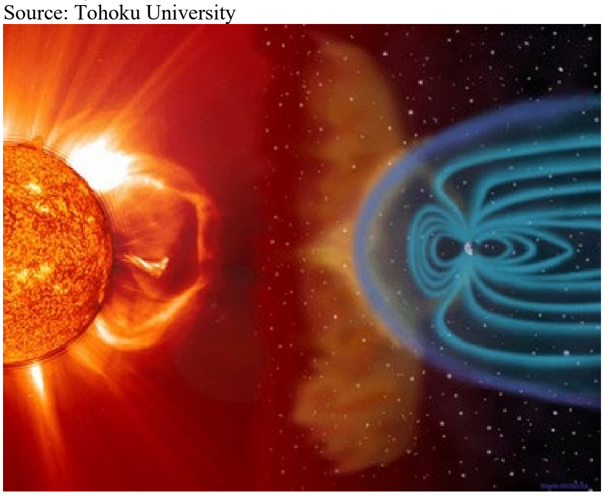
The star, which the research team has dubbed Earendel, is located in the Sunrise Arc galaxy and is detectable only due to the combined power of human technology and nature via an effect called gravitational lensing. Both Hubble and Webb were able to detect Earendel due to its lucky alignment behind a wrinkle in space-time created by the massive galaxy cluster WHL0137-08. The galaxy cluster, located between us and Earendel, is so massive that it warps the fabric of space itself, which produces a magnifying effect, allowing astronomers to look through the cluster like a magnifying glass.

While other features in the galaxy appear multiple times due to the gravitational lensing, Earendel only appears as a single point of light even in Webb's high-resolution infrared imaging. Based on this, astronomers determine the object is magnified by a factor of at least 4,000, and thus is extremely small -- the most distant star ever detected, observed 1 billion years after the big bang. The previous record-holder for the most distant star was detected by Hubble and observed around 4 billion years after the big bang. Another research team using Webb recently identified a gravitationally lensed star they

nicknamed Quyllur, a red giant star observed 3 billion years after the big bang.
Stars as massive as Earendel often have companions. Astronomers did not expect Webb to reveal any companions of Earendel since they would be so close together and indistinguishable on the sky. However, based solely on the colours of Earendel, astronomers think they see hints of a cooler, redder companion star. This light has been stretched by the expansion of the universe to wavelengths longer than Hubble's instruments can detect, and so was only detectable with Webb.
Webb's NIRCam also shows other notable details in the Sunrise Arc, which is the most highly magnified galaxy yet detected in the universe's first billion years. Features include both young star-forming regions and older established star clusters as small as 10 light-years across. On either side of the wrinkle of maximum magnification, which runs right through Earendel, these features are mirrored by the distortion of the gravitational lens. The region forming stars appears elongated, and is estimated to be less than 5 million years old. Smaller dots on either side of Earendel are two images of one older, more established star cluster, estimated to be at least 10 million years old. Astronomers determined this star cluster is gravitationally bound and likely to persist until the present day. This shows us how the globular clusters in our own Milky Way might have looked when they formed 13 billion years ago.
Astronomers are currently analysing data from Webb's NIRSpec (Near-Infrared Spectrograph) instrument observations of the Sunrise Arc galaxy and Earendel, which will provide precise composition and distance measurements for the galaxy.
Since Hubble's discovery of Earendel, Webb has detected other very distant stars using this technique, though none quite as far as Earendel. The discoveries have opened a new realm of the universe to stellar physics, and new subject matter to scientists studying the early universe, where once galaxies were the smallest detectable cosmic objects. The research team has cautious hope that this could be a step toward the eventual detection of one of the very first generation of stars, composed only of the raw ingredients of the universe created in the big bang -- hydrogen and helium.

- Geomagnetic field protects Earth from electron showers

Date: August 4, 2023
Source: Tohoku University

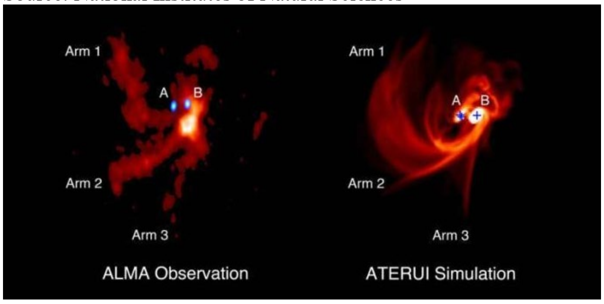


Tohoku University geophysicist Yuto Katoh led a study into the activity of high energy electrons and clarified the unexpected role of the geomagnetic field surrounding the Earth in protecting.
Understanding the ionosphere high in the Earth's atmosphere is important due to its effects on communications systems, satellites and crucial chemical features including the ozone layer. New insights into the activity of high energy electrons have come from a simulation study led by geophysicist Yuto Katoh at Tohoku University, reported in the journal *Earth, Planets and Space*.
"Our results clarify the unexpected role of the geomagnetic field surrounding the Earth in protecting the atmosphere from high energy electrons," says Katoh.
The ionosphere is a wide region between roughly 60 and more than 600 kilometres above the Earth's surface. It contains electrically charged particles that are a mixture of ions and free electrons generated by the interaction of the atmosphere with radiation from the sun.
Polar regions of the ionosphere are subjected to a particularly steady and energetic stream of incoming electrons in a process called electron precipitation. These 'relativistic' electrons move at close to the speed of light, where the effects of Einstein's relativity theory become ever more significant. They collide with gas molecules and contribute to many phenomena in the ionosphere, including colourful auroral displays. The processes are heavily influenced by the effects of the geomagnetic field on the charged particles involved.
The Tohoku team, with colleagues in Germany and other institutions in Japan,

developed a sophisticated software code that focused particular attention on simulating the effects of a relatively unstudied 'mirror force' on the electron precipitation. This is caused by the magnetic force acting on charged particles under the influence of the geomagnetic field.
The simulations demonstrated how the mirror force causes relativistic electrons to bounce back upwards, to an extent dependent on the angles at which the electrons arrive. The predicted effects mean that electrons collide with other charged particles higher in the ionosphere than previously suspected.
Illustrating one example of the significance of this work, Katoh comments: "Precipitating electrons that manage to pass through the mirror force can reach the middle and lower atmosphere, contributing to chemical reactions related to variations in ozone levels." Decreased ozone levels at the poles caused by atmospheric pollution reduce the protection ozone offers living organisms from ultraviolet radiation.
Katoh emphasizes the key theoretical advance of the research is in revealing the surprising significance of the geomagnetic field and the mirror force in protecting the lower atmosphere from the effects of electron precipitation activities by keeping them further away.
"We have now started a project to combine the simulation studies used in this work with real observations of the polar ionosphere to build even deeper understanding of these crucial geophysical processes," says Katoh.

- Gas streamers feed triple baby stars

Date: August 4, 2023
Source: National Institutes of Natural Sciences

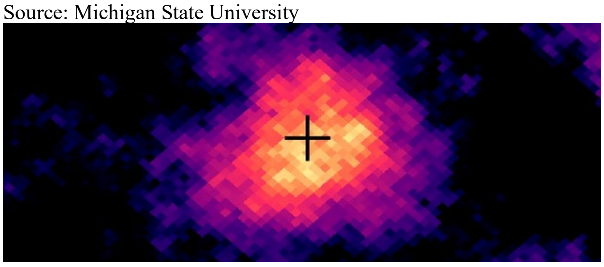


Credit: ALMA (ESO/NAOJ/NRAO), J.-E. Lee et al.

New observations and simulations of three spiral arms of gas feeding material to three protostars forming in a trinary system have clarified the formation of multi-star systems.
Most stars with a mass similar to the Sun form in multi-star systems together with other stars. So, an understanding of multi-star system formation is important to an overall theory of star formation. However, the complexity and lack of high-resolution, high-sensitivity data left astronomers uncertain about the formation scenario. In particular, recent observations of protostars often reported structures called "streamers" of gas flows toward the protostars, but it has been unclear how these streamers form.
An international team led by Jeong-Eun Lee, a professor at Seoul National University, used the Atacama Large Millimetre/submillimetre Array (ALMA) to observe the trinary protostar system IRAS 04239+2436 located 460 light-years away in the constellation Taurus.
The team found that emissions from sulphur monoxide (SO) molecules trace three spiral arms around the three protostars forming in the system.
Comparison with simulations led by Tomoaki Matsumoto, a professor at Hosei University using the supercomputers "ATERUI" and "ATERUI II" in the Centre for Computational Astrophysics at the National Astronomical Observatory of Japan (NAOJ) indicate that the three spiral arms are streamers feeding material to the three protostars. The combination of observations and simulations revealed, for the first time, how the streamers are created and contribute to the growth of the protostars at the centre.
Video: https://youtu.be/_2d8p-NRuBc

- Scientists discover the highest-energy light coming from the sun

Date: August 3, 2023
Source: Michigan State University



Excess solar gamma rays, per the High-Altitude Water Cherenkov Observatory Collaboration. (HAWC Collaboration)

Sometimes, the best place to hide a secret is in broad daylight. Just ask the sun.
"The sun is more surprising than we knew," said Mehr Un Nisa, a postdoctoral research associate at Michigan State University. "We thought we had this star figured out, but that's not the case."
Nisa, who will soon be joining MSU's faculty, is the corresponding author of a new paper in the journal *Physical Review Letters* that details the discovery of the highest-energy light ever observed from the sun.

The international team behind the discovery also found that this type of light, known as gamma rays, is surprisingly bright. That is, there's more of it than scientists had previously anticipated.

Watching like a HAWC

Although the high-energy light doesn't reach the Earth's surface, these gamma rays create telltale signatures that were detected by Nisa and her colleagues working with the High-Altitude Water Cherenkov Observatory, or HAWC.

Funded by the National Science Foundation and the National Council of Humanities Science and Technology, HAWC is an important part of the story. Unlike other observatories, it works around the clock.

"We now have observational techniques that weren't possible a few years ago," said Nisa, who works in the Department of Physics and Astronomy in the College of Natural Science. "In this particular energy regime, other ground-based telescopes couldn't look at the sun because they only work at night," she said. "Ours operates 24/7."

In addition to working differently from conventional telescopes, HAWC looks a lot different from the typical telescope.

Rather than a tube outfitted with glass lenses, HAWC uses a network of 300 large water tanks, each filled with about 200 metric tons of water. The network is nestled between two dormant volcano peaks in Mexico, more than 13,000 feet above sea level.

From this vantage point, it can observe the aftermath of gamma rays striking air in the atmosphere. Such collisions create what are called air showers, which are a bit like particle explosions that are imperceptible to the naked eye.

The energy of the original gamma ray is liberated and redistributed amongst new fragments consisting of lower energy particles and light. It's these particles -- and the new particles they create on their way down -- that HAWC can "see."

When the shower particles interact with water in HAWC's tanks, they create what's known as Cherenkov radiation that can be detected with the observatory's instruments.

Nisa and her colleagues began collecting data in 2015. In 2021, the team had accrued enough data to start examining the sun's gamma rays with sufficient scrutiny.

"After looking at six years' worth of data, out popped this excess of gamma rays," Nisa said. "When we first saw it, we were like, 'We definitely messed this up. The sun cannot be this bright at these energies.'"

Making history

The sun gives off a lot of light spanning a range of energies, but some energies are more abundant than others.

For example, through its nuclear reactions, the sun provides a ton of visible light -- that is, the light we see. This form of light carries an energy of about 1 electron volt, which is a handy unit of measure in physics.

The gamma rays that Nisa and her colleagues observed had about 1 trillion electron volts, or 1 tera electron volt, abbreviated 1 TeV. Not only was this energy level surprising, but so was the fact that they were seeing so much of it.

In the 1990s, scientists predicted that the sun could produce gamma rays when high-energy cosmic rays -- particles accelerated by a cosmic powerhouse like a black hole or supernova -- smash into protons in the sun. But, based on what was known about cosmic rays and the sun, the researchers also hypothesized it would be rare to see these gamma rays reach Earth.

At the time, though, there wasn't an instrument capable of detecting such high-energy gamma rays and there wouldn't be for a while. The first observation of gamma rays with energies of more than a billion electron volts came from NASA's Fermi Gamma-ray Space Telescope in 2011.

Over the next several years, the Fermi mission showed that not only could these rays be very energetic, but also that there were about seven times more of them than scientists had originally expected. And it looked like there were gamma rays left to discover at even higher energies.

When a telescope launches into space, there's a limit to how big and powerful its detectors can be. The Fermi telescope's measurements of the sun's gamma rays maxed out around 200 billion electron volts.

Theorists led by John Beacom and Annika Peter, both professors at Ohio State University, encouraged the HAWC Collaboration to take a look.

"They nudged us and said, 'We're not seeing a cutoff. You might be able to see something,'' Nisa said.

The HAWC Collaboration includes more than 30 institutions across North America, Europe and Asia, and a sizable portion of that is represented in the nearly 100 authors on the new paper. That includes three additional Spartans: graduate student Daniel Salazar-Gallegos, Professor Emeritus James Linnemann and Kirsten Tollefson, a professor of physics and astronomy and associate dean in the Graduate School at MSU.

Now, for the first time, the team has shown that the energies of the sun's rays extend into the TeV range, up to nearly 10 TeV, which does appear to be the maximum, Nisa said.

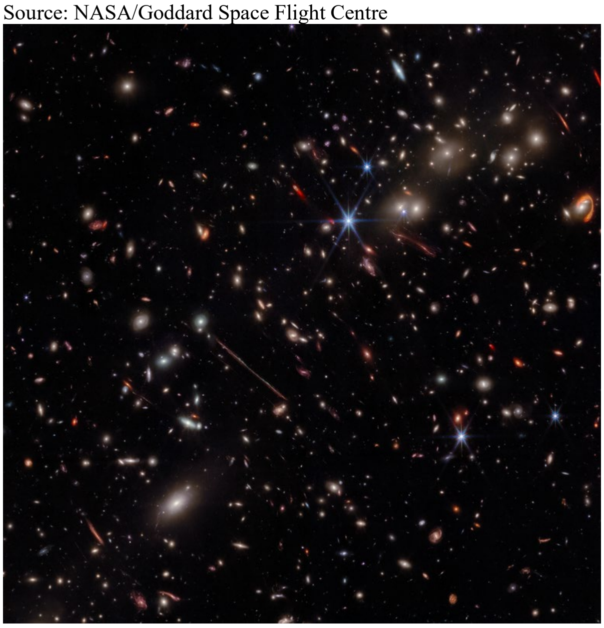
Currently, the discovery creates more questions than answers. Solar scientists will now scratch their heads over how exactly these gamma rays achieve such high energies and what role the sun's magnetic fields play in this phenomenon, Nisa said.

When it comes to the cosmos, though, that's part of the excitement. It tells us that there was something wrong, missing or perhaps both when it comes to how we understand our nearest and dearest star.

"This shows that HAWC is adding to our knowledge of our galaxy at the highest energies, and it's opening up questions about our very own sun," Nisa said. "It's making us see things in a different light. Literally."

- Gravitational arcs in 'El Gordo' galaxy cluster

Date: August 2, 2023
Source: NASA/Goddard Space Flight Centre



Webb's infrared image of the galaxy cluster El Gordo ("the Fat One") reveals hundreds of galaxies, some never before seen at this level of detail. El Gordo acts as a gravitational lens, distorting and magnifying the light from distant background galaxies. Image: NASA, ESA, CSA. Science: Jose Diego (Instituto de Física de Cantabria), Brenda Frye (University of Arizona), Patrick Kamieneski (Arizona State University), Tim Carleton (Arizona State University), and Rogier Windhorst (Arizona State University). Image processing: Alyssa Pagan (STScI), Jake Summers (Arizona State University), Jordan D'Silva (University of Western Australia), Anton Koekemoer (STScI), Aaron Robotham (University of Western Australia), and Rogier Windhorst (Arizona State University).
Download the full-resolution version from the Space Telescope Science Institute.

A new image of the galaxy cluster known as "El Gordo" is revealing distant and dusty objects never seen before, and providing a bounty of fresh science. The infrared image, taken by NASA's James Webb Space Telescope, displays a variety of unusual, distorted background galaxies that were only hinted at in previous Hubble Space Telescope images.

El Gordo is a cluster of hundreds of galaxies that existed when the universe was 6.2 billion years old, making it a "cosmic teenager." It's the most massive cluster known to exist at that time. ("El Gordo" is Spanish for the "Fat One.")

The team targeted El Gordo because it acts as a natural, cosmic magnifying glass through a phenomenon known as gravitational lensing. Its powerful gravity bends and distorts the light of objects lying behind it, much like an eyeglass lens.

"Lensing by El Gordo boosts the brightness and magnifies the sizes of distant galaxies. This lensing effect provides a unique window into the distant universe," said Brenda Frye of the University of Arizona. Frye is co-lead of the PEARLS-Clusters branch of the Prime Extragalactic Areas for Reionization and Lensing Science (PEARLS) team and lead author of one of four papers analysing the El Gordo observations.

The Fishhook

Within the image of El Gordo, one of the most striking features is a bright arc represented in red at upper right. Nicknamed "El Anzuelo" (The Fishhook) by one of Frye's students, the light from this galaxy took 10.6 billion years to reach Earth. Its distinctive red colour is due to a combination of reddening from dust within the galaxy itself and cosmological redshift due to its extreme distance.

By correcting for the distortions created by lensing, the team was able to determine that the background galaxy is disk-shaped but only 26,000 light-years in diameter -- about one-fourth the size of the Milky Way. They also were able to study the galaxy's star formation history, finding that star formation was already rapidly declining in the galaxy's centre, a process known as quenching.

"We were able to carefully dissect the shroud of dust that envelops the galaxy centre where stars are actively forming," said Patrick Kamieneski of Arizona State University, lead author on a second paper. "Now, with Webb, we can peer through this thick curtain of dust with ease, allowing us to see firsthand the assembly of galaxies from the inside out."

The Thin One

Another prominent feature in the Webb image is a long, pencil-thin line at left of centre. Known as "La Flaca" (the Thin One), it is another lensed background galaxy whose light also took nearly 11 billion years to reach Earth.

Not far from La Flaca is another lensed galaxy. When the researchers examined that galaxy closely, they found a single red giant star that they nicknamed Quyllur, which is the Quechua term for star.

Previously, Hubble has found other lensed stars (such as Earendel), but they were all blue supergiants. Quyllur is the first individual red giant star observed beyond 1 billion light-years from Earth. Such stars at high redshift are only detectable using the infrared filters and sensitivity of Webb.

"It's almost impossible to see lensed red giant stars unless you go into the infrared. This is the first one we've found with Webb, but we expect there will be many more to come," said Jose Diego of the Instituto de Física de Cantabria in Spain, lead author of a third paper on El Gordo.

Galaxy Group and Smudges

Other objects within the Webb image, while less prominent, are equally interesting scientifically. For example, Frye and her team (which includes nine students from high school to graduate students) identified five multiply lensed galaxies which appear to be a baby galaxy cluster forming about 12.1 billion years ago. There are another dozen candidate galaxies which may also be part of this distant cluster.

"While additional data are required to confirm that there are 17 members of this cluster, we may be witnessing a new galaxy cluster forming right before our eyes, just over a billion years after the big bang," said Frye.

A final paper examines very faint, smudge-like galaxies known as ultra-diffuse galaxies. As their name suggests, these objects, which are scattered throughout the El Gordo cluster, have their stars widely spread out across space. The team identified some of the most distant ultra-diffuse galaxies ever observed, whose light travelled 7.2 billion years to reach us.

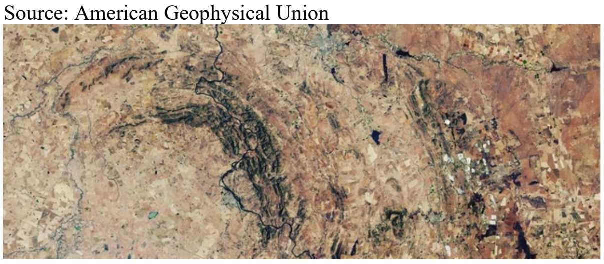
"We examined whether the properties of these galaxies are any different than the ultra-diffuse galaxies we see in the local universe, and we do actually see some differences. In particular, they are bluer, younger, more extended, and more evenly distributed throughout the cluster. This suggests that living in the cluster environment for the past 6 billion years has had a significant effect on these galaxies," explained Timothy Carleton of Arizona State University, lead author on the fourth paper.

"Gravitational lensing was predicted by Albert Einstein more than 100 years ago. In the El Gordo cluster, we see the power of gravitational lensing in action," concluded Rogier Windhorst of Arizona State University, principal investigator of the PEARLS program. "The PEARLS images of El Gordo are out-of-this-world beautiful. And, they have shown us how Webb can unlock Einstein's treasure chest."

The paper by Frye et al. has been published in the *Astrophysical Journal.* The paper by Kamieneski et al. has been accepted for publication in the *Astrophysical Journal*. The paper by Diego et al. has been published in *Astronomy & Astrophysics*. The paper by Carleton et al. has been accepted for publication in the *Astrophysical Journal.*

- Earth's most ancient impact craters are disappearing

Date: August 1, 2023
Source: American Geophysical Union



All that remains of the Vredefort impact. (NASA Earth Observatory image by Lauren Dauphin, using Landsat data from the U.S. Geological Survey)

Earth's oldest craters could give scientists critical information about the structure of the early Earth and the composition of bodies in the solar system as well as help to interpret crater records on other planets. But geologists can't find them, and they might never be able to, according to a new study. The study was published in the *Journal of Geophysical Research Planets*, AGU's journal for research on the formation and evolution of the planets, moons and objects of our Solar System and beyond.

Geologists have found evidence of impacts, such as ejecta (material flung far away from the impact), melted rocks, and high-pressure minerals from more than 3.5 billion years ago. But the actual craters from so long ago have remained elusive. The planet's oldest known impact structures, which is what scientists call these massive craters, are only about 2 billion years old. We're missing two and a half billion years of mega-craters.

The steady tick of time and the relentless process of erosion are responsible for the gap, according to Matthew S. Huber, a planetary scientist at the University of the Western Cape in South Africa who studies impact structures and led the new study.

"It's almost a fluke that the old structures we do have are preserved at all," Huber said. "There are a lot of questions we'd be able to answer if we had those older craters. But that's the normal story in geology. We have to make a story out of what's available."

Geologists can sometimes spot hidden, buried craters using geophysical tools, such as seismic imaging or gravity mapping. Once they've identified potential impact structures, they can search for physical remnants of the impact process to confirm its existence, such as ejecta and impact minerals.

The big question for Huber and his team was how much of a crater can be swept away by erosion before the last lingering geophysical traces disappear. Geophysicists have suggested that 10 kilometres (6.2 miles) of vertical erosion would erase even the biggest impact structures, but that threshold had never been tested in the field.

To find out, the researchers dug into one of the planet's oldest known impact structures: the Vredefort crater in South Africa. The structure is about 300 kilometres (186 miles) across and was formed about 2 billion years ago when an impactor about 20 kilometres (12.4 miles) across slammed into the planet. The impactor hit with such energy that the crust and mantle rose up where the impact occurred, leaving a long-term dome. Farther from the centre, ridges of rock jutted up, minerals transformed and rock melted. And then time took its course, eroding about 10 kilometres (6.2 miles) down from the surface in two billion years.

Today, all that remains at the surface is a semicircle of low hills southwest of Johannesburg, which marks the centre of the structure, and some smaller, telltale signs of impact. The bullseye, caused by the uplift of the mantle, appears in gravity maps, but beyond the centre, geophysical evidence of the impact is lacking.

"That pattern is one of the last geophysical signatures that is still detectable, and that only happens for the largest-scale impact structures," Huber said. Because only the deepest layers of the structure remain, the other geophysical traces have disappeared. But that's okay, because Huber wanted to know just how reliable those deep layers are for recording ancient impacts from both a mineralogical and geophysical perspective.

"Erosion makes these structures disappear from the top down," Huber said. "So, we went from the bottom up."

The researchers sampled rock cores across a 22-kilometer (13.7-mile) transect and analysed their physical properties, searching for differences in density, porosity and mineralogy between impacted and non-impacted rocks. They also modelled the impact event and what its effects on rock and mineral physics would be and compared that to what they saw in their samples.

What they found was not encouraging for the search for Earth's oldest craters. While some impact melt and minerals remained, the rocks in the outer ridges of the Vredefort structure were essentially indistinguishable from the non-impact rocks around them when viewed through a geophysical lens.

"That was not exactly the result we were expecting," Huber said. "The difference, where there was any, was incredibly muted. It took us a while to really make sense of the data. Ten kilometres of erosion and all the geophysical evidence of the impact just disappears, even with the largest craters," confirming what geophysicists had estimated previously.

The researchers caught Vredefort just in time; if much more erosion occurs, the impact structure will be gone. The odds of finding buried impact structures from more than 2 billion years ago are low, Huber said.

"In order to have an Archean impact crater preserved until today, it would have to have experienced really unusual conditions of preservation," Huber said. "But then, Earth is full of unusual conditions. So maybe there's something unexpected somewhere, and so we keep looking."

❖ New clues on the source of the universe's magnetic fields

The source of magnetic fields has long been debated: New research offers clues on their origins

Date: July 31, 2023
Source: Columbia University

The magnetic field in the Whirlpool Galaxy (M51), captured by NASA's flying Stratospheric Observatory for Infrared Astronomy (SOFIA) observatory superimposed on a Hubble telescope picture of the galaxy. The image shows infrared images of grains of dust in the M51 galaxy. Their magnetic orientation largely follows the spiral shape of the galaxy, but it is also being pulled in the direction of the neighbouring galaxy at the right of the frame. (Credit: NASA, SOFIA, HAWC+, Alejandro S. Borlaff; JPL-Caltech, ESA, Hubble)

It isn't just your refrigerator that has magnets on it. The earth, the stars, galaxies, and the space between galaxies are all magnetized, too. The more places' scientists have looked for magnetic fields across the universe, the more they've found them. But the question of why that is the case and where those magnetic fields originate from has remained a mystery and a subject of ongoing scientific inquiry.

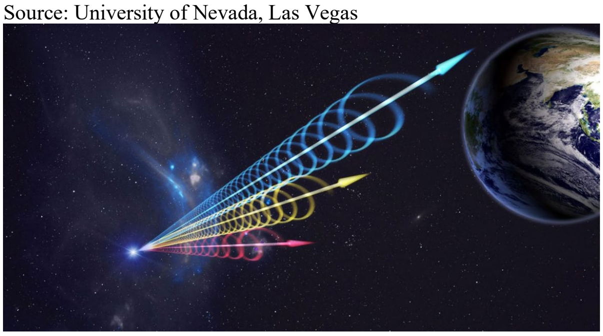
A new paper by Columbia researchers offers insight into the source of these fields. The team used models to show that magnetic fields may spontaneously arise in turbulent plasma. Plasma is a kind of matter often found in ultra-hot environments like that near the surface of the sun, but plasma is also scattered across the universe in low-density environments, like the expansive space between galaxies; the team's research focused on those low-density environments. Their simulations showed that, in addition to generating new magnetic fields, the turbulence of those plasmas can also amplify magnetic fields once they've been generated, which helps explain how magnetic fields that originate on small scales can sometimes eventually reach to stretch across vast distances.

The paper was written by astronomy professor Lorenzo Sironi, astronomy research scientist Luca Comisso, and astronomy doctoral candidate Ryan Golant.

"This new research allows us to imagine the kinds of spaces where magnetic fields are born: even in the most pristine, vast, and remote spaces of our universe, roiling plasma particles in turbulent motion can spontaneously give birth to new magnetic fields," Sironi said. "The search for the 'seed' that can sow a new magnetic field has been long, and we're excited to bring new evidence of that original source, as well as data on how a magnetic field, once born, can grow."

❖ Astronomers shed new light on formation of mysterious fast radio bursts

Date: July 28, 2023
Source: University of Nevada, Las Vegas



Credit: Jingchuan Yu, Beijing Planetarium

More than 15 years after the discovery of fast radio bursts (FRBs) -- millisecond-long, deep-space cosmic explosions of electromagnetic radiation -- astronomers worldwide have been combing the universe to uncover clues about how and why they form.

Nearly all FRBs identified have originated in deep space outside our Milky Way galaxy. That is until April 2020, when the first Galactic FRB, named FRB 20200428, was detected. This FRB was produced by a magnetar (SGR J1935+2154), a dense, city-sized neutron star with an incredibly powerful magnetic field.

This groundbreaking discovery led some to believe that FRBs identified at cosmological distances outside our galaxy may also be produced by magnetars. However, the smoking gun for such a scenario, a rotation period due to the spin of the magnetar, has so far escaped detection. New research into SGR J1935+2154 sheds light on this curious discrepancy.

In the July 28 issue of the journal *Science Advances*, an international team of scientists, including UNLV astrophysicist Bing Zhang, report on continued monitoring of SGR J1935+2154 following the April 2020 FRB, and the discovery of another cosmological phenomenon known as a radio pulsar phase five months later.

Unravelling a Cosmological Conundrum

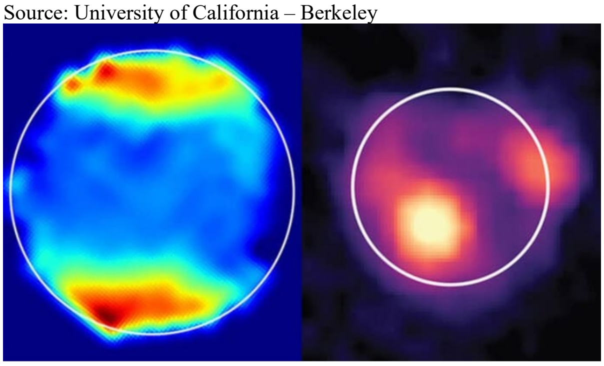
To aid them in their quest for answers, astronomers rely in part on powerful radio telescopes like the massive Five-hundred-meter Aperture Spherical radio Telescope (FAST) in China to track FRBs and other deep-space activity. Using FAST, astronomers observed that FRB 20200428 and the later pulsar phase originated from different regions within the scope of the magnetar, which hints towards different origins.
"FAST detected 795 pulses in 16.5 hours over 13 days from the source," said Weiwei Zhu, lead author of the paper from National Astronomical Observatory of China (NAOC). "These pulses show different observational properties from the bursts observed from the source."
This dichotomy in emission modes from the region of a magnetosphere helps astronomers understand how -- and where -- FRBs and related phenomena occur within our galaxy and perhaps also those at further cosmological distances.
Radio pulses are cosmic electromagnetic explosions, similar to FRBs, but typically emit a brightness roughly 10 orders of magnitude less than an FRB. Pulses are typically observed not in magnetars but in other rotating neutron stars known as pulsars.
According to Zhang, a corresponding author on the paper and director of the Nevada Centre for Astrophysics, most magnetars do not emit radio pulses most of the time, probably due to their extremely strong magnetic fields. But, as was the case with SGR J1935+2154, some of them become temporary radio pulsars after some bursting activities.
Another trait that makes bursts and pulses different are their emission "phases," i.e., the time window where radio emission is emitted in each period of emission.
"Like pulses in radio pulsars, the magnetar pulses are emitted within a narrow phase window within the period," said Zhang. "This is the well-known `lighthouse' effect, namely, the emission beam sweeps the line of sight once a period and only during a short interval in time in each period. One can then observe the pulsed radio emission."
Zhang said the April 2020 FRB, and several later, less energetic bursts were emitted in random phases not within the pulse window identified in the pulsar phase.
"This strongly suggests that pulses and bursts originate from different locations within the magnetar magnetosphere, suggesting possibly different emission mechanisms between pulses and bursts," he said.

Implications for Cosmological FRBs

Such a detailed observation of a Galactic FRB source sheds light on the mysterious FRBs prevailing at cosmological distances.
Many sources of cosmological FRBs -- those occurring outside our galaxy -- have been observed to repeat. In some instances, FAST has detected thousands of repeated bursts from a few sources. Deep searches for seconds-level periodicity have been carried out using these bursts in the past and so far, no period was discovered.
According to Zhang, this casts doubt on the popular idea that repeating FRBs are powered by magnetars in the past.
"Our discovery that bursts tend to be generated in random phases provides a natural interpretation to the non-detection of periodicity from repeating FRBs," he said. "For unknown reasons, bursts tend to be emitted in all directions from a magnetar, making it impossible to identify periods from FRB sources."

- James Webb Space Telescope sees Jupiter moons in a new light

Hydrogen peroxide detected at Ganymede's poles; sulphur monoxide from Io's volcanos
Date: July 27, 2023
Source: University of California – Berkeley



A spectroscopic map of Ganymede (left) derived from JWST measurements shows light absorption around the pole’s characteristic of the molecule hydrogen peroxide. A JWST infrared image of Io (right) shows hot volcanic eruptions at Kanehekili Fluctus (centre) and Loki Patera (right). The circles outline the surfaces of the two moons. (Image credit: Ganymede: Samantha Trumbo, Cornell; Io: Imke de Pater, UC Berkeley)

With its sensitive infrared cameras and high-resolution spectrometer, the James Webb Space Telescope (JWST) is revealing new secrets of Jupiter's Galilean satellites, in particular Ganymede, the largest moon, and Io, the most volcanically active.
In two separate publications, astronomers who are part of JWST's Early Release Science program report the first detection of hydrogen peroxide on Ganymede and sulphurous fumes

on Io, both the result of Jupiter's domineering influence.

"This shows that we can do incredible science with the James Webb Space Telescope on solar system objects, even if the object is really very bright, like Jupiter, but also when you look at very faint things next to Jupiter," said Imke de Pater, professor emerita of astronomy and earth and planetary science at the University of California, Berkeley. De Pater and Thierry Fouchet from the Paris Observatory are co-principal investigators for the Early Release Science solar system observation team, one of 13 teams given early access to the telescope.

Samantha Trumbo, a 51 Pegasi b postdoctoral fellow at Cornell University, led the study of Ganymede, which was published July 21 in the journal *Science Advances.* Using measurements captured by the near infrared spectrometer (NIRSpec) on JWST, the team detected the absorption of light by hydrogen peroxide -- H_2O_2 -- around the north and south poles of the moon, a result of charged particles around Jupiter and Ganymede impacting the ice that blankets the moon.

"JWST revealing the presence of hydrogen peroxide at Ganymede's poles shows for the first time that charged particles funnelled along Ganymede's magnetic field are preferentially altering the surface chemistry of its polar caps," Trumbo said.

The astronomers argue that the peroxide is produced by charged particles hitting the frozen water ice around the poles and breaking the water molecules into fragments -- a process called radiolysis -- which then recombine to form H_2O_2. They suspected that radiolysis would occur primarily around the poles on Ganymede because, unlike all other moons in our solar system, it has a magnetic field that directs charged particles toward the poles.

"Just like how Earth's magnetic field directs charged particles from the sun to the highest latitudes, causing the aurora, Ganymede's magnetic field does the same thing to charged particles from Jupiter's magnetosphere," she added. "Not only do these particles result in aurorae at Ganymede, as well, but they also impact the icy surface."

Trumbo and Michael Brown, professor of planetary astronomy at Caltech, where Trumbo recently received her Ph.D., had earlier studied hydrogen peroxide on Europa, another of Jupiter's four Galilean satellites. On Europa, however, the peroxide was detectable over much of the surface, perhaps, in part, because it has no magnetic field to protect the surface from the fast-moving particles zipping around Jupiter.

"This is likely a really important and widespread process," Trumbo said. "These observations of Ganymede provide a key window to understand how such water radiolysis might drive chemistry on icy bodies throughout the outer solar system, including on neighbouring Europa and Callisto (the fourth Galilean moon)."

"It helps to actually understand how this so-called radiolysis works and that, indeed, it works as people expected, based on lab experiments on Earth," de Pater said.

Io's sulphurous environment

In a second paper, accepted for publication in the journal *JGR: Planets*, a publication of the American Geophysical Union, de Pater and her colleagues report new Webb observations of Io that show several ongoing eruptions, including a brightening at a volcanic complex called Loki Patera and an exceptionally bright eruption at Kanehekili Fluctus. Because Io is the only volcanically active moon in the solar system -- Jupiter's gravitational push and pull heats it up -- studies like this give planetary scientists a different perspective than can be obtained by studying volcanos on Earth.

For the first time, the researchers were able to link a volcanic eruption -- at Kanehekili Fluctus -- to a specific emission line, a so-called "forbidden" line, of the gas sulphur monoxide (SO).

Sulphur dioxide (SO_2) is the main component of Io's atmosphere, coming from sublimation of SO_2 ice, as well as ongoing volcanic eruptions, similar to the production of SO_2 by volcanos on Earth. The volcanos also produce SO, which is much harder to detect than SO_2. In particular, the forbidden SO emission line is very weak because SO is in such low concentrations and produced for only a short time after being excited. Moreover, the observations can only be made when Io is in Jupiter's shadow, when it is easier to see the glowing SO gases. When Io is in Jupiter's shadow, the SO_2 gas in Io's atmosphere freezes out onto its surface, leaving only SO and newly emitted volcanic SO_2 gas in the atmosphere.

"These observations with Webb show for the first time that the SO actually did come from a volcano," de Pater said.

De Pater had made previous observations of Io with the Keck Telescope in Hawaii and found low levels of the forbidden SO emission over much of the moon, but she was unable to tie SO hotspots specifically to an active volcano. She suspects that much of this SO, as well as the SO_2 seen during an eclipse, is coming from so-called stealth volcanoes, which erupt gas but not dust, which would make them visible.

Twenty years ago, de Pater and her team proposed that this excited state of SO could only be produced in hot volcanic vents, and that the tenuous atmosphere allowed this state to stick around long enough -- a few seconds -- to emit the forbidden line. Normally, excited states that produce this emission are quickly damped out by collisions with other molecules in the atmosphere and never seen. Only in parts of the atmosphere where the gas is sparse do such excited states last long enough to emit forbidden lines. The greens and reds of Earth's auroras are produced by forbidden transitions of oxygen in the tenuous upper atmosphere.

"The link between SO and volcanoes ties in with a hypothesis we had in 2002 to explain how we could see SO emission at all," she said. "The only way we could explain this emission is if the SO is excited in the volcanic vent at a temperature of 1500 Kelvin or so, and that it comes out in this excited state, loses its photon within a few seconds, and that is the emission we see. So, these observations are the first that actually show that this is the most likely mechanism of why we see that SO."

Webb will observe Io again in August with NIRSpec. The upcoming observation and the earlier one, which took place on Nov. 15, 2022, were taken when Io was in the shadow of Jupiter so that light reflected from the planet did not overwhelm the light coming from Io.

De Pater noted, too, that the brightening of Loki Patera was consistent with the observed period of eruptions at the volcano, which brighten, on average, about every 500 Earth days, with the brightening lasting for a couple of months. She determined this because it was not bright when she observed the moon with Keck in August and September 2022, nor was it bright when another astronomer observed it from April through July 2022. Only the JWST captured the event.

"The Webb observations showed that actually eruptions had started, and that it was much brighter than what we had seen in September," she said.

While De Pater is primarily focused on the Jovian system -- its rings, small moons and the larger moons Ganymede and Io -- she and other members of the early science team of some 80 astronomers are also using JWST to study the planetary systems of Saturn, Uranus and Neptune.