South Downs Mercury

The monthly circular of South Downs Astronomical Society
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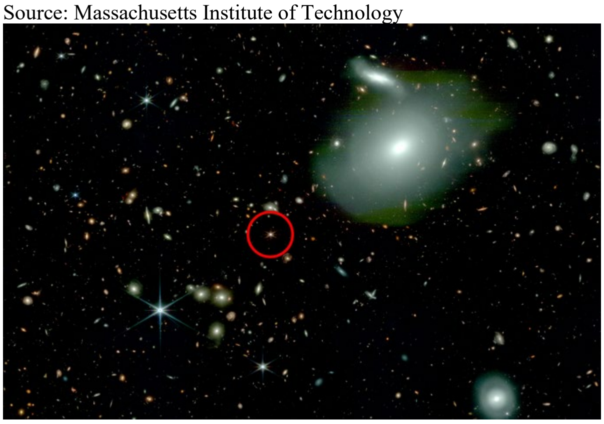
Main Talk Ian Sharp FRAS "How to get started with Photometry".
Ian has a background in physics, electronics and programming. He is a very enthusiastic, active member of the Altair Group which is currently carrying out research into the detection of exoplanets in PCEB binary systems using Eclipse Time Variations (ETVs). The most recent published paper by the Group is:
Eclipse timing variations in post-common envelope binaries: Are they a reliable indicator of circumbinary companions?

Please support a raffle we are organizing this month.

- Astronomers detect ancient lonely quasars with murky origins

The quasars appear to have few cosmic neighbours, raising questions about how they first emerged more than 13 billion years ago

Date: October 17, 2024
Source: Massachusetts Institute of Technology



This image, taken by NASA's James Webb Space Telescope, shows an ancient quasar (circled in red) with fewer than expected neighbouring galaxies (bright spheres), challenging physicists' understanding of how the first quasars and supermassive black holes formed.
Credits:
Credit: Christina Eilers/EIGER team

A quasar is the extremely bright core of a galaxy that hosts an active supermassive black hole at its centre. As the black hole draws in surrounding gas and dust, it blasts out an enormous amount of energy, making quasars some of the brightest objects in the universe. Quasars have been observed as early as a few hundred million years after the Big Bang, and it's been a mystery as to how these objects could have grown so bright and massive in such a short amount of cosmic time.
Scientists have proposed that the earliest quasars sprang from overly dense regions of primordial matter, which would also have produced many smaller galaxies in the quasars' environment. But in a new MIT-led study, astronomers observed some ancient quasars that appear to be surprisingly alone in the early universe.
The astronomers used NASA's James Webb Space Telescope (JWST) to peer back in time, more than 13 billion years, to study the cosmic surroundings of five known ancient quasars. They found a surprising variety in their neighbourhoods, or "quasar fields." While some quasars reside in very crowded fields with more than 50 neighbouring galaxies, as all models predict, the remaining quasars appear to drift in voids, with only a few stray galaxies in their vicinity.
These lonely quasars are challenging physicists' understanding of how such luminous objects could have formed so early on in the universe, without a significant source of surrounding matter to fuel their black hole growth.
"Contrary to previous belief, we find on average, these quasars are not necessarily in those highest-density regions of the early universe. Some of them seem to be sitting in the middle of nowhere," says Anna-Christina Eilers, assistant professor of physics at MIT. "It's difficult to explain how these quasars could have grown so big if they appear to have nothing to feed from."
There is a possibility that these quasars may not be as solitary as they appear, but are instead surrounded by galaxies that are heavily shrouded in dust and therefore hidden from view. Eilers and her colleagues hope to

tune their observations to try and see through any such cosmic dust, in order to understand how quasars grew so big, so fast, in the early universe.
Eilers and her colleagues report their findings in a paper appearing today in the *Astrophysical Journal.* The MIT co-authors include postdocs Rohan Naidu and Minghao Yue; Robert Simcoe, the Francis Friedman Professor of Physics and director of MIT's Kavli Institute for Astrophysics and Space Research; and collaborators from institutions including Leiden University, the University of California at Santa Barbara, ETH Zurich, and elsewhere.

Galactic neighbours

The five newly observed quasars are among the oldest quasars observed to date. More than 13 billion years old, the objects are thought to have formed between 600 to 700 million years after the Big Bang. The supermassive black holes powering the quasars are a billion times more massive than the sun, and more than a trillion times brighter. Due to their extreme luminosity, the light from each quasar is able to travel over the age of the universe, far enough to reach JWST's highly sensitive detectors today.
"It's just phenomenal that we now have a telescope that can capture light from 13 billion years ago in so much detail," Eilers says. "For the first time, JWST enabled us to look at the environment of these quasars, where they grew up, and what their neighbourhood was like."
The team analysed images of the five ancient quasars taken by JWST between August 2022 and June 2023. The observations of each quasar comprised multiple "mosaic" images, or partial views of the quasar's field, which the team effectively stitched together to produce a complete picture of each quasar's surrounding neighbourhood.
The telescope also took measurements of light in multiple wavelengths across each quasar's field, which the team then processed to determine whether a given object in the field was light from a neighbouring galaxy, and how far a galaxy is from the much more luminous central quasar.
"We found that the only difference between these five quasars is that their environments look so different," Eilers says. "For instance, one quasar has almost 50 galaxies around it, while another has just two. And both quasars are within the same size, volume, brightness, and time of the universe. That was really surprising to see."

Growth spurts

The disparity in quasar fields introduces a kink in the standard picture of black hole growth and galaxy formation. According to physicists' best understanding of how the first objects in the universe emerged, a cosmic web of dark matter should have set the course. Dark matter is an as-yet unknown form of matter that has no other interactions with its surroundings other than through gravity. Shortly after the Big Bang, the early universe is thought to have formed filaments of dark matter that acted as a sort of gravitational road, attracting gas and dust along its tendrils. In overly dense regions of this web, matter would have accumulated to form more massive objects. And the brightest, most massive early objects, such as quasars, would have formed in the web's highest-density regions, which would have also churned out many more, smaller galaxies.
"The cosmic web of dark matter is a solid prediction of our cosmological model of the Universe, and it can be described in detail using numerical simulations," says co-author says Elia Pizzati, a graduate student at Leiden University. "By comparing our observations to these simulations, we can determine where in the cosmic web quasars are located."
Scientists estimate that quasars would have had to grow continuously with very high accretion rates in order to reach the extreme mass and luminosities at the times that astronomers have observed them, fewer than 1 billion years after the Big Bang.
"The main question we're trying to answer is, how do these billion-solar-mass black holes form at a time when the universe is still really, really young? It's still in its infancy," Eilers says.
The team's findings may raise more questions than answers. The "lonely" quasars appear to live in relatively empty regions of space. If physicists' cosmological models are correct, these barren regions signify very little dark matter, or starting material for brewing up stars and galaxies. How, then, did extremely bright and massive quasars come to be?
"Our results show that there's still a significant piece of the puzzle missing of how these supermassive black holes grow," Eilers says. "If there's not enough material around for some quasars to be able to grow continuously, that means there must be some

other way that they can grow, that we have yet to figure out."

This research was supported, in part, by the European Research Council.

- Liftoff! NASA's Europa Clipper sails toward ocean moon of Jupiter

The massive spacecraft heads for Europa to search for signs of whether the ocean thought to exist beneath the moon's icy shell could support life.

Date: October 14, 2024
Source: NASA/Jet Propulsion Laboratory

A SpaceX Falcon Heavy rocket carrying NASA's Europa Clipper spacecraft lifts off from Launch Complex 39A at NASA's Kennedy Space Centre in Florida at 12:06 p.m. EDT on Monday, Oct. 14, 2024. After launch, the spacecraft plans to fly by Mars in February 2025, then back by Earth in December 2026, using the gravity of each planet to increase its momentum. With help of these "gravity assists," Europa Clipper will achieve the velocity needed to reach Jupiter in April 2030.
Credit: NASA/Kim Shiflett

NASA's Europa Clipper has embarked on its long voyage to Jupiter, where it will investigate Europa, a moon with an enormous subsurface ocean that may have conditions to support life. The spacecraft launched at 12:06 p.m. EDT Monday aboard a SpaceX Falcon Heavy rocket from Launch Pad 39A at NASA's Kennedy Space Centre in Florida.

The largest spacecraft NASA ever built for a mission headed to another planet, Europa Clipper also is the first NASA mission dedicated to studying an ocean world beyond Earth. The spacecraft will travel 1.8 billion miles (2.9 billion kilometres) on a trajectory that will leverage the power of gravity assists, first to Mars in four months and then back to Earth for another gravity assist flyby in 2026. After it begins orbiting Jupiter in April 2030, the spacecraft will fly past Europa 49 times.

"Congratulations to our Europa Clipper team for beginning the first journey to an ocean world beyond Earth," said NASA Administrator Bill Nelson. "NASA leads the world in exploration and discovery, and the Europa Clipper mission is no different. By exploring the unknown, Europa Clipper will help us better understand whether there is the potential for life not just within our solar system, but among the billions of moons and planets beyond our Sun."

Approximately five minutes after liftoff, the rocket's second stage fired up and the payload fairing, or the rocket's nose cone, opened to reveal Europa Clipper. About an hour after launch, the spacecraft separated from the rocket. Ground controllers received a signal soon after, and two-way communication was established at 1:13 p.m. with NASA's Deep Space Network facility in Canberra, Australia. Mission teams celebrated as initial telemetry reports showed Europa Clipper is in good health and operating as expected.

"We could not be more excited for the incredible and unprecedented science NASA's Europa Clipper mission will deliver in the generations to come," said Nicky Fox, associate administrator, Science Mission Directorate at NASA Headquarters in Washington. "Everything in NASA science is interconnected, and Europa Clipper's scientific discoveries will build upon the legacy that our other missions exploring Jupiter -- including Juno, Galileo, and Voyager -- created in our search for habitable worlds beyond our home planet."

The main goal of the mission is to determine whether Europa has conditions that could support life. Europa is about the size of our own Moon, but its interior is different. Information from NASA's Galileo mission in the 1990s showed strong evidence that under Europa's ice lies an enormous, salty ocean with more water than all of Earth's oceans combined. Scientists also have found evidence that Europa may host organic compounds and energy sources under its surface.

If the mission determines Europa is habitable, it may mean there are more habitable worlds in our solar system and beyond than imagined.

"We're ecstatic to send Europa Clipper on its way to explore a potentially habitable ocean world, thanks to our colleagues and partners who've worked so hard to get us to this day," said Laurie Leshin, director, NASA's Jet Propulsion Laboratory in Southern California. "Europa Clipper will undoubtedly deliver mind-blowing science. While always bittersweet to send something we've laboured over for years off on its long journey, we know this remarkable team and spacecraft will expand our knowledge of our solar system and inspire future exploration."

In 2031, the spacecraft will begin conducting its science-dedicated flybys of Europa. Coming as close as 16 miles (25 kilometres) to the surface, Europa Clipper is equipped with nine science instruments and a gravity experiment, including an ice-penetrating radar, cameras, and a thermal instrument to look for areas of warmer ice and any recent eruptions of water. As the most sophisticated suite of science instruments NASA has ever sent to Jupiter, they will work in concert to learn more about the moon's icy shell, thin atmosphere, and deep interior.

To power those instruments in the faint sunlight that reaches Jupiter, Europa Clipper also carries the largest solar arrays NASA has ever used for an interplanetary mission. With arrays extended, the spacecraft spans 100 feet (30.5 meters) from end to end. With propellant loaded, it weighs about 13,000 pounds (5,900 kilograms).

In all, more than 4,000 people have contributed to Europa Clipper mission since it was formally approved in 2015.

"As Europa Clipper embarks on its journey, I'll be thinking about the countless hours of dedication, innovation, and teamwork that made this moment possible," said Jordan Evans, project manager, NASA JPL. "This launch isn't just the next chapter in our exploration of the solar system; it's a leap toward uncovering the mysteries of another ocean world, driven by our shared curiosity and continued search to answer the question, 'are we alone?'"

More About Europa Clipper

Europa Clipper's three main science objectives are to determine the thickness of the moon's icy shell and its interactions with the ocean below, to investigate its composition, and to characterize its geology. The mission's detailed exploration of Europa will help scientists better understand the Astro biological potential for habitable worlds beyond our planet.

Managed by Caltech in Pasadena, California, NASA JPL leads the development of the Europa Clipper mission in partnership with the Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland, for NASA's Science Mission Directorate in Washington. The main spacecraft body was designed by APL in collaboration with NASA JPL and NASA's Goddard Space Flight Centre in Greenbelt, Maryland, NASA's Marshall Space Flight Centre in Huntsville, Alabama, and NASA's Langley Research Centre in Hampton, Virginia. The Planetary Missions Program Office at Marshall executes program management of the Europa Clipper mission.

NASA's Launch Services Program, based at NASA Kennedy, managed the launch service for the Europa Clipper spacecraft.

Find more information about NASA's Europa Clipper mission here: https://science.nasa.gov/mission/europa-clipper/

- The origin of most meteorites finally revealed

Date: October 16, 2024
Source: CNRS

El Médano 128 meteorite, an ordinary chondrite (group L), found in the Atacama desert in 2011 by a team of researchers from the Centre de recherche et d'enseignement des géosciences de l'environnement (CEREGE – Aix-Marseille Université/CNRS/INRAE/IRD). CREDIT © Jérôme Gattacceca, CNRS, CEREGE

An international team led by three researchers from the CNRS[1], the European Southern Observatory (ESO, Europe), and Charles University (Czech Republic) has successfully demonstrated that 70% of all known meteorite falls originate from just three young asteroid families. These families were produced by three recent collisions that occurred in the main asteroid belt 5.8, 7.5, and about 40 million years ago. The team also revealed the sources of other types of meteorites; with this research, the origin of more than 90% of meteorites has now been identified. This discovery is detailed in three papers, a first published on 13 September 2024 in the journal *Astronomy and Astrophysics*, and two new papers to be published on 16 October 2024 in *Nature*.

An international team of researchers has shown that 70% of all known meteorite falls originate from three young asteroid families (Karin, Koronis and Massalia) formed by collisions in the main asteroid belt 5.8, 7.5 and about 40 million years ago. In particular, the Massalia family has been identified as the source of 37% of known meteorites.

While more than 70,000 meteorites are known, only 6% had been clearly identified by their composition (achondrites) as coming from the Moon, Mars, or Vesta, one of the largest asteroids in the main belt. The source of the other 94% of meteorites, the majority of which are ordinary chondrites[2], had remained unidentified.

Why are these three young families the source of so many meteorites?

This can be explained by the life cycle of asteroid families. Young families are characterised by an abundance of small fragments left over from collisions. This abundance increases the risk of collisions between fragments and, coupled with their high mobility, their escape from the belt, possibly in the direction of Earth. The asteroid families produced by older collisions, on the other hand, are "depleted" sources of meteorites. The abundance of small fragments that once made them up has naturally eroded and finally disappeared after tens of millions of years of successive collisions and their dynamic evolution. Thus, Karin, Koronis and Massalia will inevitably coexist with new sources of meteorites from more recent collisions and eventually give way to them.

A method for tracing the family tree of meteorites and asteroids

This historic discovery was made possible by a telescopic survey of the composition of all the major asteroid families in the main belt, combined with state-of-the-art computer simulations of the collisional and dynamical evolution of these major families. This approach has been extended to all meteorite families, revealing the primary sources of the carbonaceous chondrites and achondrites, which come in addition to those from the Moon, Mars, and Vesta.

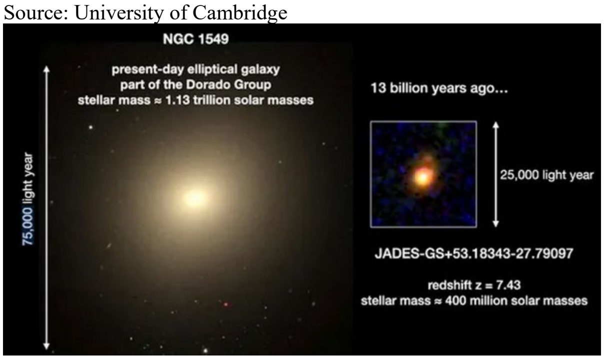
Thanks to this research, the origin of more than 90% of meteorites has now been identified. It has also enabled scientists to trace the origin of kilometre-sized asteroids (a size that threatens life on Earth). These objects are the focus of many space missions (NEAR Shoemaker, Hayabusa1, Chang'E 2, Hayabusa2, OSIRIS-Rex, DART, Hera, etc.). In particular, it appears that the asteroids Ryugu and Bennu, recently sampled by the Hayabusa2 (Japanese Aerospace Exploration Agency JAXA) and OSIRIS-REx (NASA) missions and studied in laboratories around the world, particularly in France, are derived from the same parent asteroid as the Polana family.

The origin of the remaining 10 per cent of known meteorites is still unknown. To remedy this, the team plans to continue their research, this time focusing on characterising all young families that were formed less than 50 million years ago.

1. From the Laboratory of Astrophysics of Marseille (Aix-Marseille Université/CNRS/CNES).
2. Meteorites consisting of silicates, representing approximately 80% of all known meteorites.

- 'Inside-out' galaxy growth observed in the early universe

Date: October 11, 2024
Source: University of Cambridge



Astronomers have used the James Webb Space Telescope (JWST) to observe the ‘inside-out’ growth of a galaxy in the early universe, only 700 million years after the Big Bang. (Image credit: JADES Collaboration)

Astronomers have used the NASA/ESA James Webb Space Telescope (JWST) to observe the 'inside-out' growth of a galaxy in the early universe, only 700 million years after the Big Bang.

This galaxy is one hundred times smaller than the Milky Way, but is surprisingly mature for so early in the universe. Like a large city, this galaxy has a dense collection of stars at its core but becomes less dense in the galactic 'suburbs'. And like a large city, this galaxy is starting to sprawl, with star formation accelerating in the outskirts.

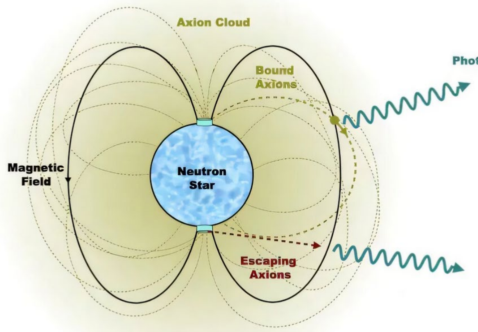
This is the earliest-ever detection of inside-out galactic growth. Until Webb, it had not been possible to study galaxy growth so early in the universe's history. Although the images obtained with Webb represent a snapshot in time, the researchers, led by the University of Cambridge, say that studying similar galaxies could help us understand how they transform from clouds of gas into the complex structures we observe today. The results are reported in the journal *Nature Astronomy*.

"The question of how galaxies evolve over cosmic time is an important one in

astrophysics," said co-lead author Dr Sandro Tacchella from Cambridge's Cavendish Laboratory. "We've had lots of excellent data for the last ten million years and for galaxies in our corner of the universe, but now with Webb, we can get observational data from billions of years back in time, probing the first billion years of cosmic history, which opens up all kinds of new questions."
The galaxies we observe today grow via two main mechanisms: either they pull in, or accrete, gas to form new stars, or they grow by merging with smaller galaxies. Whether different mechanisms were at work in the early universe is an open question which astronomers are hoping to address with Webb.
"You expect galaxies to start small as gas clouds collapse under their own gravity, forming very dense cores of stars and possibly black holes," said Tacchella. "As the galaxy grows and star formation increases, it's sort of like a spinning figure skater: as the skater pulls in their arms, they gather momentum, and they spin faster and faster. Galaxies are somewhat similar, with gas accreting later from larger and larger distances spinning the galaxy up, which is why they often form spiral or disc shapes."
This galaxy, observed as part of the JADES (JWST Advanced Extragalactic Survey) collaboration, is actively forming stars in the early universe. It has a highly dense core, which despite its relatively young age, is of a similar density to present-day massive elliptical galaxies, which have 1000 times more stars. Most of the star formation is happening further away from the core, with a star-forming 'clump' even further out.
The star formation activity is strongly rising toward the outskirts, as the star formation spreads out and the galaxy grows in size. This type of growth had been predicted with theoretical models, but with Webb, it is now possible to observe it.
"One of the many reasons that Webb is so transformational to us as astronomers is that we're now able to observe what had previously been predicted through modelling," said co-author William Baker, a PhD student at the Cavendish. "It's like being able to check your homework."
Using Webb, the researchers extracted information from the light emitted by the galaxy at different wavelengths, which they then used to estimate the number of younger stars versus older stars, which is converted into an estimate of the stellar mass and star formation rate.
Because the galaxy is so compact, the individual images of the galaxy were 'forward modelled' to take into account instrumental effects. By using stellar population modelling that includes prescriptions for gas emission and dust absorption, the researchers found older stars in the core, while the surrounding disc component is undergoing very active star formation. This galaxy doubles its stellar mass in the outskirts roughly every 10 million years, which is very rapid: the Milky Way galaxy doubles its mass only every 10 billion years.
The density of the galactic core, as well as the high star formation rate, suggest that this young galaxy is rich with the gas it needs to form new stars, which may reflect different conditions in the early universe.
"Of course, this is only one galaxy, so we need to know what other galaxies at the time were doing," said Tacchella. "Were all galaxies like this one? We're now analysing similar data from other galaxies. By looking at different galaxies across cosmic time, we may be able to reconstruct the growth cycle and demonstrate how galaxies grow to their eventual size today."

- Neutron stars may be shrouded in axions

Physicists show that neutron stars may be shrouded in clouds of 'axions' -- and that these clouds can teach us a lot
Date: October 18, 2024
Source: Universiteit van Amsterdam



An axion cloud around a neutron star. While some axions escape the star’s gravitational pull, many remain bound to the star and over a long period of time form a cloud surrounding it. The interaction with the neutron star’s strong magnetic field causes some axions to convert into photons – light that we can eventually detect with our telescopes on Earth. Credit: University of Amsterdam
A team of physicists from the universities of Amsterdam, Princeton and Oxford have shown that extremely light particles known as axions may occur in large clouds around neutron stars. These axions could form an explanation for the elusive dark matter that

cosmologists search for -- and moreover, they might not be too difficult to observe.

Earlier this week, the new research was published in the journal *Physical Review X*. The paper is a follow-up to previous work, in which the authors also studied axions and neutron stars, but from a completely different point of view. While in their previous work they investigated the axions that *escape* the neutron star, now the researchers focus on the ones that are left behind -- the axions that get captured by the star's gravity. As time goes by, these particles should gradually form a hazy cloud around the neutron star, and it turns out that such axion clouds may well be observable in our telescopes. But why would astronomers and physicists be so interested in hazy clouds around far away stars?

Axions: from soap to dark matter

Protons, neutrons, electrons, photons -- most of us are familiar with the names of at least some of these tiny particles. The axion is lesser known, and for a good reason: at the moment it is only a *hypothetical* type of particle -- one that nobody has yet detected. Named after a brand of soap, its existence was first postulated in the 1970s, to clean up a problem -- hence the soap reference -- in our understanding of one of the particles we could observe very well: the neutron. However, while theoretically very nice, if these axions existed they would be extremely light, making them very hard to detect in experiments or observations.

Today, axions are also known as a frontrunning candidate to explain dark matter, one of the biggest mysteries in contemporary physics. Many different pieces of evidence suggest that approximately 85% of the matter content in our Universe is 'dark', which simply means that it is not made up of any type of matter that we know and can currently observe. Instead, the existence of dark matter is only inferred indirectly through the gravitational influence it exerts on visible matter. Fortunately, this does not automatically mean that dark matter has no other interactions with visible matter at all, but if such interactions exist their strength is necessarily tiny. As the name suggests, any viable dark matter candidate is thus incredibly difficult to directly observe.

Putting one and one together, physicists have realized that the axion may be exactly what they are looking for to solve the dark matter problem. A particle that has not yet been observed, which would be extremely light, and have very weak interactions with other particles… could axions be at least part of the explanation for dark matter?

Neutron stars as magnifying glasses

The idea of the axion as a dark matter particle is nice, but in physics an idea is only truly nice if it has observable consequences. Would there be a way to observe axions after all, fifty years after their possible existence was first proposed?

When exposed to electric and magnetic fields, axions are expected to be able to convert into photons -- particles of light -- and vice versa. Light is something we know how to observe, but as mentioned, the corresponding interaction strength should be very small, and therefore so is the amount of light that axions generally produce. That is, unless one considers an environment containing a truly massive amount of axions, ideally in very strong electromagnetic fields.

This led the researchers to consider neutron stars, the densest known stars in our Universe. These objects have masses similar to that of our Sun but compressed into stars of 12 to 15 kilometres in size. Such extreme densities create an equally extreme environment that, notably, also contains enormous magnetic fields, billions of times stronger than any we find on Earth. Recent research has shown that if axions exist, these magnetic fields allow for neutron stars to mass-produce these particles near their surface.

The ones that stay behind

In their previous work, the authors focused on the axions that after production escaped the star -- they computed the amounts in which these axions would be produced, which trajectories they would follow, and how their conversion into light could lead to a weak but potentially observable signal. This time, they consider the axions that do not manage to escape -- the ones that, despite their tiny mass, get caught by the neutron star's immense gravity.

Due to the axion's very feeble interactions, these particles will stay around, and on timescales up to millions of years they will accumulate around the neutron star. This can result in the formation of very dense clouds of axions around neutron stars, which provide some incredible new opportunities for axion research. In their paper, the researchers study the formation, as well as the properties and further evolution, of these axion clouds, pointing out that they should, and in many cases must, exist. In fact, the authors argue that if axions exist, axion clouds should be *generic* (for a wide range of axion properties they should form around most, perhaps even all, neutron stars), they should in general be *very dense* (forming a density possibly twenty orders of magnitude larger than local dark matter densities), and because of this they should lead to *powerful observational signatures*. The latter potentially come in many types, of which the authors discuss two: a continuous signal emitted during large parts of a neutron star's lifetime, but also a one-time burst of light at the end of a neutron star's life, when it stops producing its electromagnetic radiation. Both of these signatures could be observed and used to probe the interaction between axions and photons beyond current limits, even using existing radio telescopes.

What's next?

While so far, no axion clouds have been observed, with the new results we know very precisely what to look for, making a thorough search for axions much more feasible. While the main point on the to do-list is therefore 'search for axion clouds', the work also opens up several new theoretical avenues to explore. For one thing, one of the authors is already involved in follow-up work that studies how the axion clouds can change the dynamics of neutron stars themselves. Another important future research direction is the numerical modelling of axion clouds: the present paper shows great discovery potential, but there is more numerical modelling needed to know even more precisely what to look for and where. Finally, the present results are all for single neutron stars, but many of these stars appear as components of binaries -- sometimes together with another neutron star, sometimes together with a black hole. Understanding the physics of axion clouds in such systems, and potentially understanding their observational signals, would be very valuable.

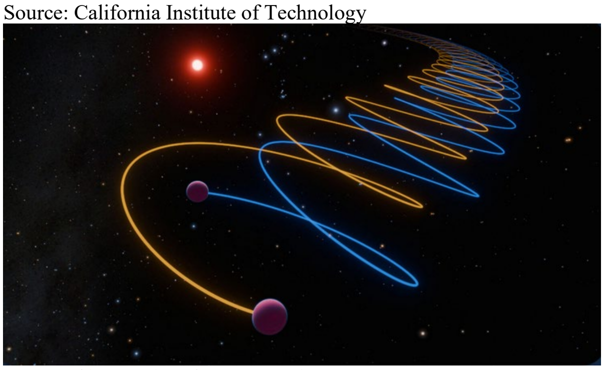
Thus, the present work is an important step in a new and exciting research direction. A full understanding of axion clouds will require complementary efforts from multiple branches of science, including particle (astro)physics, plasma physics, and observational radio astronomy. This work opens up this new, cross-disciplinary field with lots of opportunities for future research.

- It's twins! Mystery of famed brown dwarf solved

Astronomers have discovered that a well-studied brown dwarf is in fact two that are orbiting closely around each other

Date: October 16, 2024

Source: California Institute of Technology



A pair of brown dwarfs. Source: phys.org

Hundreds of papers have been written about the first known brown dwarf, Gliese 229B, since its discovery by Caltech researchers at the Institute's Palomar Observatory in 1995. But a pressing mystery has persisted about this orb: It is too dim for its mass. Brown dwarfs are lighter than stars, and heavier than gas giants like Jupiter. And while astronomers had measured the mass of Gliese 229B to be about 70 times that of Jupiter, an object of that heft should shine more brightly than what the telescopes had observed.

Now, a Caltech-led international team of astronomers has at last solved that mystery: The brown dwarf is actually a pair of tight-knit brown dwarfs, weighing about 38 and 34 times the mass of Jupiter, that whip around each other every 12 days. The observed brightness levels of the pair match what is expected for two small, dim brown dwarfs in this mass range.

"Gliese 229B was considered the poster-child brown dwarf," says Jerry W. Xuan, a graduate student working with Dimitri Mawet, the David Morrisroe Professor of Astronomy. "And now we know we were wrong all along about the nature of the object. It's not one but two. We just weren't able to probe separations this close until now." Xuan is lead author of a new study reporting the findings in the journal *Nature*. A separate independent study in *The Astrophysical Journal Letters*, led by Sam Whitebook, a Caltech graduate student, and Tim Brandt, an associate astronomer at the Space Telescope Science Institute in Baltimore, also concluded that Gliese 229B is a pair of brown dwarfs.

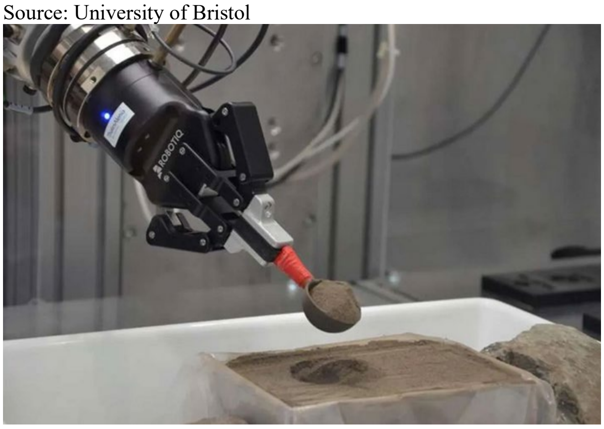
The discovery leads to new questions about how tight-knit brown dwarf duos like this one form and suggests that similar brown dwarf

binaries -- or even exoplanet binaries -- may be waiting to be found. (An exoplanet is a planet that orbits a star other than our Sun.)
"This discovery that Gliese 229B is binary not only resolves the recent tension observed between its mass and luminosity but also significantly deepens our understanding of brown dwarfs, which straddle the line between stars and giant planets," says Mawet, who is also a senior research scientist at JPL, which is managed by Caltech for NASA.
Gliese 229B was discovered in 1995 by a Caltech team that included Rebecca Oppenheimer, then a Caltech graduate student; Shri Kulkarni, the George Ellery Hale Professor of Astronomy and Planetary Science; Keith Matthews, an instrument specialist at Caltech; and other colleagues. The astronomers used Palomar Observatory to discover that Gliese 229B possessed methane in its atmosphere -- a phenomenon typical of gas giants like Jupiter but not of stars. The finding marked the first confirmed detection of a class of cool star-like objects called brown dwarfs -- the missing link between planets and stars -- that had been theorized about 30 years prior.
"Seeing the first object smaller than a star orbiting another sun was exhilarating," says Oppenheimer, who is a co-author of the new study and an astrophysicist at the American Museum of Natural History. "It started a cottage industry of people seeking oddballs like it back then, but it remained an enigma for decades."
Indeed, nearly 30 years after its discovery and hundreds of observations later, Gliese 229B still puzzled astronomers with its unexpected dimness. The scientists suspected Gliese 229B might be twins, but "to evade notice by astronomers for 30 years, the two brown dwarfs would have to be very close to each other," says Xuan.
To resolve Gliese 229B into two objects, the team used two different instruments, both based at the European Southern Observatory's Very Large Telescope in Chile. They used the GRAVITY instrument, an interferometer that combines light from four different telescopes, to spatially resolve the body into two, and they used the CRIRES+ (CRyogenic high-resolution InfraRed Echelle Spectrograph) instrument to detect distinct spectral signatures from the two objects. The latter method involved measuring the motion (or doppler shift) of molecules in the atmosphere of the brown dwarfs, which indicated that one body was headed toward us on Earth and the other away -- and vice versa as the pair orbited each other.
"It is so nice to see that almost 30 years later, there has been a new development," says Kulkarni, who is not an author on the current paper. "Now this binary system stuns again."
These observations, taken over five months, showed that the brown dwarf duo, now called Gliese 229Ba and Gliese 229Bb, orbit each other every 12 days with a separation only 16 times larger than the distance between Earth and the Moon. Together, the pair orbit an M-dwarf star (a smaller, redder star than our Sun) every 250 years.
"These two worlds whipping around each other are actually smaller in radius than Jupiter. They'd look quite strange in our night sky if we had something like them in our own solar system," says Oppenheimer. "This is the most exciting and fascinating discovery in substellar astrophysics in decades."
How this whirling pair of cosmic orbs came to be is still a mystery. Some theories say brown dwarf pairs could form within the swirling disks of material that encircle a forming star. The disk would fragment into two seeds of brown dwarfs, which would then become gravitationally bound after a close encounter. Whether these same formation mechanisms are at work to form pairs of planets around other stars remains to be seen.
In the future, the team would like to search for even more closely orbiting brown dwarf binaries with instruments such as the Keck Planet Imager and Characterizer (KPIC), which was developed by a team led by Mawet at the W. M. Keck Observatory in Hawai'i, as well as the Keck Observatory's upcoming High-resolution Infrared SPectrograph for Exoplanet Characterization (HISPEC), which is under construction at Caltech and other laboratories by a team led by Mawet.
"The fact that the first known brown dwarf companion is a binary bodes well for ongoing efforts to find more," says Xuan.
The work described in the paper, titled "The cool brown dwarf Gliese 229B is a close binary," was funded by NASA and the Heising-Simons Foundation. Other Caltech authors include Yapeng Zhang, a 51 Pegasi b Postdoctoral Scholar Research Associate in Astronomy; Aniket Sanghi, a graduate student; Konstantin Batygin, professor of

planetary science; and Heather Knutson, professor of planetary science.

- Out-of-this-world simulation key to collecting moon dust

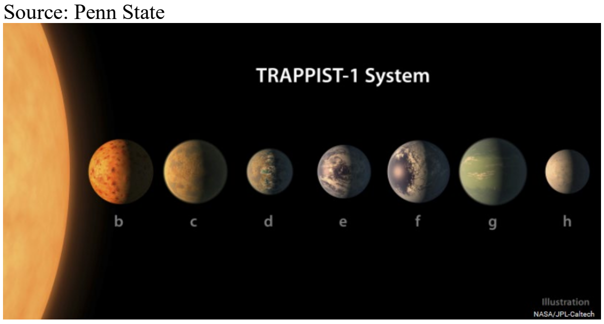
Date: October 16, 2024
Source: University of Bristol



Teleoperated robots for gathering moon dust are a step closer, according to new research by scientists at the University of Bristol.
The team were able to complete a sample collection task by controlling a virtual simulation, which then sent commands to a physical robot to mirror the simulation's actions. They were able to do so while only monitoring the simulation -- without needing physical camera streams -- meaning this tool could be particularly useful for delayed teleoperation on the Moon.
Alongside a boom in lunar lander missions this decade, several public and private organisations are now researching how best to extract valuable resources, such as oxygen and water, from readily available materials such as lunar regolith (moon dust). Remote handling of regolith will be an essential step in these activities, as it would first need to be collected from the Moon's surface. Beyond this, moon dust is not easy to work with. It's sticky and abrasive, and will be handled under reduced gravity.
Lead author Joe Louca from the Bristol's School of Engineering Mathematics and Technology, and the Bristol Robotics Laboratory, explained: "One option could be to have astronauts use this simulation to prepare for upcoming lunar exploration missions.
"We can adjust how strong gravity is in this model, and provide haptic feedback, so we could give astronauts a sense of how Moon dust would feel and behave in lunar conditions -- which has a sixth of the gravitational pull of the Earth's.
"This simulation could also help us to operate lunar robots remotely from Earth, avoiding the problem of signal delays."
Using a virtual model of regolith can also reduce the barriers to entry for people looking to develop lunar robots. Instead of needing to invest in expensive simulants (artificial dust with the same properties as regolith), or have access to facilities, people developing lunar robots could use this simulation to carry out initial tests on their systems.
Now, the team will investigate how people actually respond to this system when controlling a robot with several seconds of delay. Systems with human operators that are technically effective may still have to overcome non-technical barriers, like whether a person trusts that the system will work.
Joe added: "The model predicted the outcome of a regolith simulant scooping task with sufficient accuracy to be considered effective and trustworthy 100% and 92.5% of the time.
"In the next decade we're going to see several crewed and uncrewed missions to the Moon, such as NASA's Artemis program and China's Chang'e program.
"This simulation could be a valuable tool to support preparation or operation for these missions."
The testing was carried out at the European Space Agency's European Centre for Space Applications and Telecommunications site in Harwell.
Paper: 'Demonstrating Trustworthiness in Open-Loop Model Mediated Teleoperation for Collecting Lunar Regolith Simulant' by Joe Louca, Aliz Zemeny, Antonia Tzemanaki and Romain Charles presented at the IROS 2024 (IEEE/RSJ International Conference on Intelligent Robots and Systems)

- Are nearby planets sending radio signals to each other?

Scientists use Allen Telescope Array to search for interplanetary communications in the TRAPPIST-1 star system
Date: October 16, 2024
Source: Penn State



A new technique allows astronomers to home in on planets beyond our solar system that are in line with each other and with Earth to search for radio signals similar, for example, to ones used to communicate with the rovers on Mars. Penn State astronomers and scientists at the SETI Institute spent 28 hours scanning the TRAPPIST-1 star system for these signs of alien technology with the Allen Telescope Array (ATA).

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A paper describing the research was accepted for publication in the *Astronomical Journal* and is available online as a preprint.

"This research shows that we are getting closer to technology and methods that could detect radio signals similar to the ones we send into space," said Nick Tusay, a graduate student research fellow at Penn State and first author of the paper. "Most searches assume a powerful signal, like a beacon intended to reach distant planets, because our receivers have a sensitivity limit to a minimum transmitter power beyond anything we unintentionally send out. But, with better equipment, like the upcoming Square Kilometre Array, we might soon be able to detect signals from an alien civilization communicating with its spacecraft."

The project focused on a phenomenon called planet-planet occultations (PPOs). PPOs happen when one planet moves in front of another from Earth's perspective. If intelligent life exists in that star system, radio signals sent between planets could leak and be detected from Earth.

Using the upgraded ATA -- a series of radio antennae dedicated to the search for extraterrestrial technology located at the Hat Creek Observatory in the Cascade Mountains about 300 miles north of San Francisco -- the team scanned a wide range of frequencies, looking for narrowband signals, which are considered possible signs of alien technology. The team filtered millions of potential signals, narrowing down to about 11,000 candidates for detailed analysis. The team detected 2,264 of these signals during predicted PPO windows. However, none of the signals were of non-human origin.

The ATA's new capabilities, which include advanced software to filter signals, helped the team separate possible alien signals from Earth-based ones. The researchers said they believe that refining these methods and focusing on events like PPOs could help increase the chances of detecting alien signals in the future.

"This project included work by undergraduate students in the 2023 SETI Institute Research Experience for Undergraduates program," said Sofia Sheikh, a SETI researcher at the SETI Institute who earned her doctoral degree at Penn State. "The students looked for signals from human-made orbiters around Mars to check if the system could detect signals correctly. It was an exciting way to involve students in cutting-edge SETI research."

The TRAPPIST-1 system is a small, cool star about 41 light years from Earth. It has seven rocky planets, some of which are in the habitable zone, where conditions might allow liquid water to exist -- an essential ingredient for life as we know it. This makes TRAPPIST-1 a prime target searching for life beyond Earth.

"The TRAPPIST-1 system is relatively close to Earth, and we have detailed information about the orbit of its planets, making it an excellent natural laboratory to test these techniques," Tusay said. "The methods and algorithms that we developed for this project can eventually be applied to other star systems and increase our chances of finding regular communications among planets beyond our solar system, if they exist."

The team did not find any alien signals this time, but they will continue improving their search techniques and exploring other star systems. Future searches with bigger and more powerful telescopes could help scientists detect even fainter signals and expand our understanding of the universe, the team said.

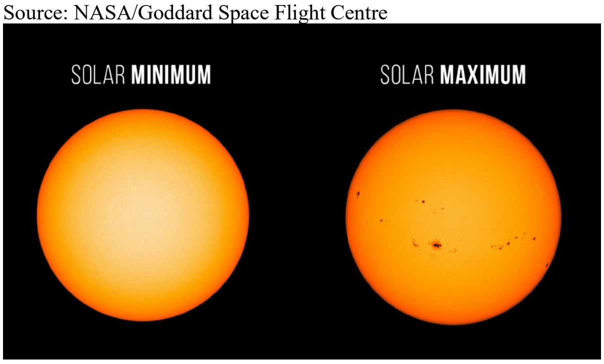
In addition to Tusay and Sheikh, the research team includes Jason T. Wright at Penn State; Evan L. Sneed at the University of California, Riverside; Wael Farah, Andrew Siemion and David R. DeBoer at the University of California, Berkeley; and Alexander W. Pollak and Luigi F. Cruz at the SETI Institute.

This research was primarily funded through grants from the U.S. National Science Foundation with additional support from the Penn State Extraterrestrial Intelligence Centre

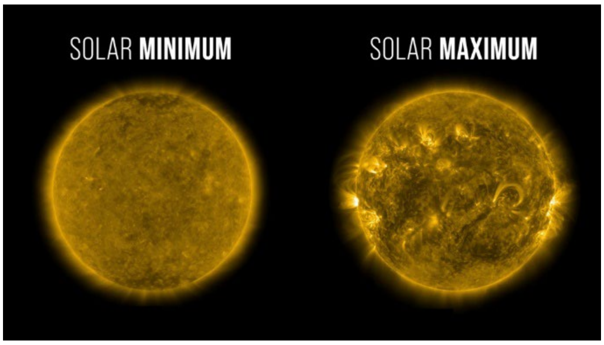
and the Penn State Centre for Exoplanets and Habitable Worlds, which are supported by the Penn State and the Penn State Eberly College of Science.

- NASA, NOAA: Sun reaches maximum phase in 11-year solar cycle

Date: October 15, 2024
Source: NASA/Goddard Space Flight Centre



Visible light images from NASA's Solar Dynamics Observatory highlight the appearance of the Sun at solar minimum (left, Dec. 2019) versus solar maximum (right, May 2024). During solar minimum, the Sun is often spotless. Sunspots are associated with solar activity and are used to track solar cycle progress.



Images from NASA's Solar Dynamics Observatory highlight the appearance of the Sun at solar minimum (left, December 2019) versus solar maximum (right, May 2024). These images are in the 171-angstrom wavelength of extreme ultraviolet light, which reveals the active regions on the Sun that are more common during solar maximum.

For these images and more relating to solar maximum, visit https://svs.gsfc.nasa.gov/14683.
NASA/SDO

In a teleconference with reporters on Tuesday, representatives from NASA, the National Oceanic and Atmospheric Administration (NOAA), and the international Solar Cycle Prediction Panel announced that the Sun has reached its solar maximum period, which could continue for the next year.
The solar cycle is a natural cycle the Sun goes through as it transitions between low and high magnetic activity. Roughly every 11 years, at the height of the solar cycle, the Sun's magnetic poles flip -- on Earth, that'd be like the North and South poles swapping places every decade -- and the Sun transitions from being calm to an active and stormy state.
NASA and NOAA track sunspots to determine and predict the progress of the solar cycle -- and ultimately, solar activity.
Sunspots are cooler regions on the Sun caused by a concentration of magnetic field lines. Sunspots are the visible component of active regions, areas of intense and complex magnetic fields on the Sun that are the source of solar eruptions.
"During solar maximum, the number of sunspots, and therefore, the amount of solar activity, increases," said Jamie Favors, director, Space Weather Program at NASA Headquarters in Washington. "This increase in activity provides an exciting opportunity to learn about our closest star -- but also causes real effects at Earth and throughout our solar system."
Solar activity strongly influences conditions in space known as space weather. This can affect satellites and astronauts in space, as well as communications and navigation systems -- such as radio and GPS -- and power grids on Earth. When the Sun is most active, space weather events become more frequent. Solar activity has led to increased aurora visibility and impacts on satellites and infrastructure in recent months.
During May 2024, a barrage of large solar flares and coronal mass ejections (CMEs) launched clouds of charged particles and magnetic fields toward Earth, creating the strongest geomagnetic storm at Earth in two decades -- and possibly among the strongest displays of auroras on record in the past 500 years.
"This announcement doesn't mean that this is the peak of solar activity we'll see this solar cycle," said Elsayed Talaat, director of space weather operations at NOAA. "While the Sun has reached the solar maximum period, the month that solar activity peaks on the Sun will not be identified for months or years."
Scientists will not be able to determine the exact peak of this solar maximum period for many months because it's only identifiable after they've tracked a consistent decline in solar activity after that peak. However, scientists have identified that the last two years on the Sun have been part of this active phase of the solar cycle, due to the consistently high number of sunspots during this period. Scientists anticipate that the maximum phase will last another year or so before the Sun enters the declining phase, which leads back to solar minimum. Since 1989, the Solar Cycle Prediction Panel -- an international panel of experts sponsored by

NASA and NOAA -- has worked together to make their prediction for the next solar cycle. Solar cycles have been tracked by astronomers since Galileo first observed sunspots in the 1600s. Each solar cycle is different -- some cycles peak for larger and shorter amounts of time, and others have smaller peaks that last longer.
"Solar Cycle 25 sunspot activity has slightly exceeded expectations," said Lisa Upton, co-chair of the Solar Cycle Prediction Panel and lead scientist at Southwest Research Institute in San Antonio, Texas. "However, despite seeing a few large storms, they aren't larger than what we might expect during the maximum phase of the cycle."
The most powerful flare of the solar cycle so far was an X9.0 on Oct. 3 (X-class denotes the most intense flares, while the number provides more information about its strength).
NOAA anticipates additional solar and geomagnetic storms during the current solar maximum period, leading to opportunities to spot auroras over the next several months, as well as potential technology impacts. Additionally, though less frequent, scientists often see fairly significant storms during the declining phase of the solar cycle.
NASA and NOAA are preparing for the future of space weather research and prediction. In December 2024, NASA's Parker Solar Probe mission will make its closest-ever approach to the Sun, beating its own record of closest human-made object to the Sun. This will be the first of three planned approaches for Parker at this distance, helping researchers to understand space weather right at the source. NASA is launching several missions over the next year that will help us better understand space weather and its impacts across the solar system.
Space weather predictions are critical for supporting the spacecraft and astronauts of NASA's Artemis campaign. Surveying this space environment is a vital part of understanding and mitigating astronaut exposure to space radiation.
NASA works as a research arm of the nation's space weather effort. To see how space weather can affect Earth, please visit NOAA's Space Weather Prediction Centre, the U.S. government's official source for space weather forecasts, watches, warnings, and alerts: https://www.spaceweather.gov/

- Simulated mission to Mars: Survey of lichen species

Date: October 15, 2024
Source: Pensoft Publishers

Crew biologist Anushree Srivastava collecting lichens near the Mars Desert Research Station while wearing a simulated spacesuit, an important part of analogue space missions at this research site

Once you know where to look for them, lichens are everywhere! These composite organisms -- fungal and photosynthetic partners joined into a greater whole, can survive on a vast array of surfaces, from rocks and trees to bare ground and buildings. They are known from every continent, and almost certainly every land mass on planet Earth; some species have even survived exposure to the exterior of the International Space Station. This hardy nature has long interested researchers studying what life could survive on Mars, and the astrobiologists studying life on Earth as an analogue of our planetary neighbour. In the deserts surrounding two Mars analogue stations in North America, lichens comprise such an important part of the local ecosystems that they inspired a biodiversity assessment with a unique twist: this collections-based inventory took place during a simulated mission to Mars!

The Mars Desert Research Station in Utah, USA (on Ute and Paiute Territory), and the Flashline Mars Arctic Research Station in Nunavut, Canada (in Inuit Nunangat, the Inuit Homeland) are simulated Martian habitats operated by The Mars Society, where crews participate in dress rehearsals for crewed Martian exploration. While learning what it would take to live and work on our planetary neighbour, these "Martians" frequently study the deserts at both sites, often exploring techniques for documenting microbial life and their biosignatures as a prelude to deploying these tools and methods off world. These studies are enhanced by a comprehensive understanding of the ecosystems being studied, even if they are full of Earthbound life. During the Mars 160 -- a set of twin missions to both Utah and Nunavut in 2016 and 2017 -- our team undertook a floristic survey of the lichen biodiversity present at each site.

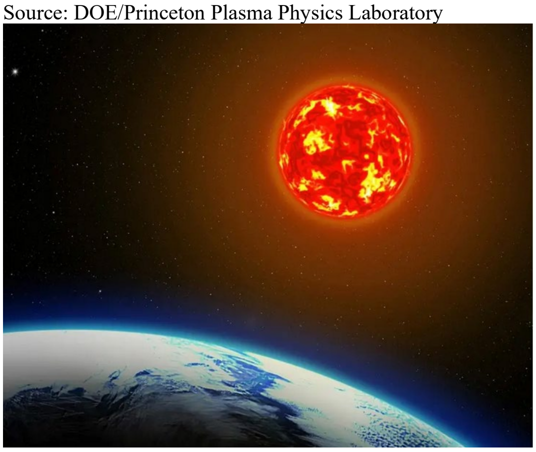
During simulated extra-vehicular activities, Mars 160 mission specialists wearing simulated spacesuits scouted out various habitats at both stations, seeking out lichen species growing in various microhabitats. Collecting over 150 specimens, these samples were "returned to Earth," and identified at the National Herbarium of Canada at the Canadian Museum of Nature. Through morphological examination, investigations of internal anatomy and chemistry, and DNA barcoding, "Mission Support" identified 35 lichen species from the Mars Desert Research Station, and 13 species from the Flashline Mars Arctic Research Station.

These species, along with photographs and a synopsis of their identifying characteristics, are summarized in a new paper out now in the open-access journal *Check List*. This new annotated checklist should prove useful to future crews working at both analogue research stations, while also helping Earthly lichenologists better understand the distribution of these fascinating organisms, including new records of rarely reported or newly described species from some of Earth's most interesting, and otherworldly habitats.

- Researchers find clues to the mysterious heating of the sun's atmosphere

Experimental findings about plasma wave reflection could answer questions about high temperatures

Date: October 11, 2024
Source: DOE/Princeton Plasma Physics Laboratory



There is a profound mystery in our sun. While the sun's surface temperature measures around 10,000 degrees Fahrenheit, its outer atmosphere, known as the solar corona, measures more like 2 million degrees Fahrenheit, about 200 times hotter. This increase in temperature away from the sun is perplexing and has been an unsolved mystery since 1939, when the high temperature of the corona was first identified. In the ensuing decades, scientists have tried to determine the mechanism that could cause this unexpected heating, but so far, they have not succeeded. Now, a team led by Sayak Bose, a researcher at the U.S.Department of Energy's (DOE)Princeton Plasma Physics Laboratory (PPPL), has made a significant advancement in understanding the underlying heating mechanism. Their recent findings show that reflected plasma waves could drive the heating of coronal holes, which are low-density regions of the solar corona with open magnetic field lines extending into interplanetary space. These findings represent major progress toward solving one of the most mysterious quandaries about our closest star. "Scientists knew that coronal holes have high temperatures, but the underlying mechanism responsible for the heating is not well understood," said Bose, the lead author of the paper reporting the results in *The Astrophysical Journal*. "Our findings reveal that plasma wave reflection can do the job. This is the first laboratory experiment demonstrating that Alfvén waves reflect under conditions relevant to coronal holes."

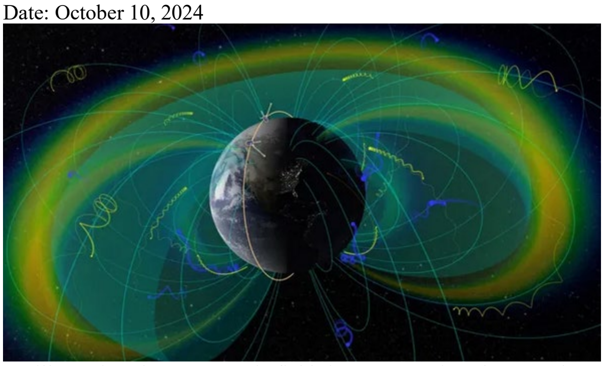
First predicted by Swedish physicist and Nobel Prize winner Hannes Alfvén, the waves that bear his name resemble the vibrations of plucked guitar strings, except that in this case, the plasma waves are caused by wiggling magnetic fields.

Bose and other members of the team used the 20-meter-long plasma column of the Large Plasma Device (LAPD) at the University of California-Los Angeles (UCLA) to excite Alfvén waves under conditions that mimic those occurring around coronal holes. The experiment demonstrated that when Alfvén waves encounter regions of varying plasma density and magnetic field intensity, as they do in the solar atmosphere around coronal holes, they can be reflected and travel backward toward their source. The collision

of the outward-moving and reflected waves causes turbulence that, in turn, causes heating. "Physicists have long hypothesized that Alfvén wave reflection could help explain the heating of coronal holes, but it has been impossible to either verify in the laboratory or directly measure," said Jason TenBarge, a visiting research scholar at PPPL, who also contributed to the research. "This work provides the first experimental verification that Alfvén wave reflection is not only possible, but also that the amount of reflected energy is sufficient to heat coronal holes."
Along with conducting the laboratory experiments, the team performed computer simulations of the experiments, which corroborated the reflection of Alfvén waves under conditions similar to coronal holes. "We routinely conduct multiple verifications to ensure the accuracy of our observed results," said Bose, "and conducting simulations was one of those steps. The physics of Alfvén wave reflection is very fascinating and complicated! It is amazing how profoundly basic physics laboratory experiments and simulations can significantly improve our understanding of natural systems like our sun."
Collaborators included scientists from Princeton University; the University of California-Los Angeles; and Columbia University. The research was funded by the DOE under contracts DE-AC0209CH11466, and DE-SC0021261, as well as the National Science Foundation (NSF) under grant number 2209471. The experiment was performed at the Basic Plasma Science Facility, which is a collaborative user facility that is part of the DOE Office of Science Fusion Energy Sciences program and is funded by DOE contract DE-FC02-07ER54918 and the NSF under contract NSF-PHY 1036140.

- Lightning strikes kick off a game of electron pinball in space

Date: October 10, 2024



An illustration shows magnetic fields in cyan trapping electrons that can be freed by lightning. (Image credit: UCLA EPSS/NASA SVS)
Source: University of Colorado at Boulder

When lightning strikes, the electrons come pouring down.
In a new study, researchers at the University of Colorado Boulder led by an undergraduate student have discovered a new link between weather on Earth and weather in space. The group used satellite data to show that lightning storms on our planet can knock especially high-energy, or "extra-hot," electrons out of the inner radiation belt -- a region of space filled with charged particles that surrounds Earth like an inner tube.
The team's results could help satellites and even astronauts avoid dangerous radiation in space. This is one kind of downpour you don't want to get caught in, said lead author and undergraduate Max Feinland.
"These particles are the scary ones or what some people call 'killer electrons,'" said Feinland, who received his bachelor's degree in aerospace engineering sciences at CU Boulder in spring 2024. "They can penetrate metal on satellites, hit circuit boards and can be carcinogenic if they hit a person in space."
The study appeared Oct.8 in the journal *Nature Communications.*
The findings cast an eye toward the radiation belts, which are generated by Earth's magnetic field. Lauren Blum, a co-author of the paper and assistant professor in the Laboratory for Atmospheric and Space Physics (LASP) at CU Boulder, explained that two of these regions encircle our planet: While they move a lot over time, the inner belt tends to begin more than 600 miles above the surface. The outer belt starts roughly around 12,000 miles from Earth. These pool floaties in space trap charged particles streaming toward our planet from the sun, forming a sort of barrier between Earth's atmosphere and the rest of the solar system.
But they're not exactly airtight. Scientists, for example, have long known that high-energy electrons can fall toward Earth from the outer radiation belt. Blum and her colleagues, however, are the first to spot a similar rain coming from the inner belt.
Earth and space, in other words, may not be as separate as they look.
"Space weather is really driven both from above and below," Blum said.

Bolt from the blue

It's a testament to the power of lightning. When a lightning bolt flashes in the sky on Earth, that burst of energy may also send

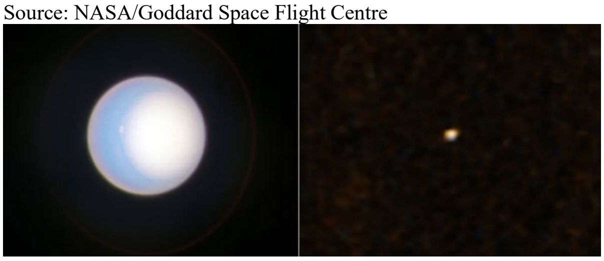
radio waves spiralling deep into space. If those waves smack into electrons in the radiation belts, they can jostle them free -- a bit like shaking your umbrella to knock the water off. In some cases, such "lightning-induced electron precipitation" can even influence the chemistry of Earth's atmosphere.
To date, researchers had only collected direct measurements of lower energy, or "colder," electrons falling from the inner radiation belt.
"Typically, the inner belt is thought to be kind of boring," Blum said. "It's stable. It's always there."
Her team's new discovery came about almost by accident. Feinland was analysing data from NASA's now-decommissioned Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) satellite when he saw something odd: clumps of what seemed to be high-energy electrons moving through the inner belt.
"I showed Lauren some of my events, and she said, 'That's not where these are supposed to be,'" Feinland said. "Some literature suggests that there aren't any high-energy electrons in the inner belt at all."
The team decided to dig deeper.
In all, Feinland counted 45 surges of high-energy electrons in the inner belt from 1996 to 2006. He compared those events to records of lightning strikes in North America. Sure enough, some of the spikes in electrons seemed to happen less than a second after lightning strikes on the ground.

Electron pinball

Here's what the team thinks is happening: Following a lightning strike, radio waves from Earth kick off a kind of manic pinball game in space. They knock into electrons in the inner belt, which then begin to bounce between Earth's northern and southern hemispheres -- going back and forth in just 0.2 seconds.
And each time the electrons bounce, some of them fall out of the belt and into our atmosphere.
"You have a big blob of electrons that bounces, and then returns and bounces again," Blum said. "You'll see this initial signal, and it will decay away."
Blum isn't sure how often such events happen. They may occur mostly during periods of high solar activity when the sun spits out a lot of high-energy electrons, stocking the inner belt with these particles.
The researchers want to understand these events better so that they can predict when they may be likely to occur, potentially helping to keep people and electronics in orbit safe.
Feinland, for his part, is grateful for the chance to study these magnificent storms.
"I didn't even realize how much I liked research until I got to do this project," he said.

❖ NASA's Hubble, New Horizons team up for a simultaneous look at Uranus

Date: October 11, 2024
Source: NASA/Goddard Space Flight Centre



NASA's Hubble Space Telescope (left) and NASA's New Horizon's spacecraft (right) image the planet Uranus.
NASA, ESA, STScI, Samantha Hasler (MIT), Amy Simon (NASA-GSFC), New Horizons Planetary Science Theme Team; Image Processing: Joseph DePasquale (STScI), Joseph Olmsted (STScI)

NASA's Hubble Space Telescope and New Horizons spacecraft simultaneously set their sights on Uranus recently, allowing scientists to make a direct comparison of the planet from two very different viewpoints. The results inform future plans to study like types of planets around other stars.
Astronomers used Uranus as a proxy for similar planets beyond our solar system, known as exoplanets, comparing high-resolution images from Hubble to the more-distant view from New Horizons. This combined perspective will help scientists learn more about what to expect while imaging planets around other stars with future telescopes.
"While we expected Uranus to appear differently in each filter of the observations, we found that Uranus was actually dimmer than predicted in the New Horizons data taken from a different viewpoint," said lead author Samantha Hasler of the Massachusetts Institute of Technology in Cambridge and New Horizons science team collaborator.
Direct imaging of exoplanets is a key technique for learning about their potential habitability, and offers new clues to the origin and formation of our own solar system. Astronomers use both direct imaging and spectroscopy to collect light from the observed planet and compare its brightness at different wavelengths. However, imaging exoplanets is a notoriously difficult process because they're so far away. Their images are

mere pinpoints and so are not as detailed as the close-up views that we have of worlds orbiting our Sun. Researchers can also only directly image exoplanets at "partial phases," when only a portion of the planet is illuminated by their star as seen from Earth.
Uranus was an ideal target as a test for understanding future distant observations of exoplanets by other telescopes for a few reasons. First, many known exoplanets are also gas giants similar in nature. Also, at the time of the observations, New Horizons was on the far side of Uranus, 6.5 billion miles away, allowing its twilight crescent to be studied -- something that cannot be done from Earth. At that distance, the New Horizons view of the planet was just several pixels in its colour camera, called the Multispectral Visible Imaging Camera.
On the other hand, Hubble, with its high resolution, and in its low-Earth orbit 1.7 billion miles away from Uranus, was able to see atmospheric features such as clouds and storms on the day side of the gaseous world.
"Uranus appears as just a small dot on the New Horizons observations, similar to the dots seen of directly-imaged exoplanets from observatories like Webb or ground-based observatories," added Hasler. "Hubble provides context for what the atmosphere is doing when it was observed with New Horizons."
The gas giant planets in our solar system have dynamic and variable atmospheres with changing cloud cover. How common is this among exoplanets? By knowing the details of what the clouds on Uranus looked like from Hubble, researchers are able to verify what is interpreted from the New Horizons data. In the case of Uranus, both Hubble and New Horizons saw that the brightness did not vary as the planet rotated, which indicates that the cloud features were not changing with the planet's rotation.
However, the importance of the detection by New Horizons has to do with how the planet reflects light at a different phase than what Hubble, or other observatories on or near Earth, can see. New Horizons showed that exoplanets may be dimmer than predicted at partial and high phase angles, and that the atmosphere reflects light differently at partial phase.
NASA has two major upcoming observatories in the works to advance studies of exoplanet atmospheres and potential habitability.
"These landmark New Horizons studies of Uranus from a vantage point unobservable by any other means add to the mission's treasure trove of new scientific knowledge, and have, like many other datasets obtained in the mission, yielded surprising new insights into the worlds of our solar system," added New Horizons principal investigator Alan Stern of the Southwest Research Institute.
NASA's upcoming Nancy Grace Roman Space Telescope, set to launch by 2027, will use a coronagraph to block out a star's light to directly see gas giant exoplanets. NASA's Habitable Worlds Observatory, in an early planning phase, will be the first telescope designed specifically to search for atmospheric biosignatures on Earth-sized, rocky planets orbiting other stars.
"Studying how known benchmarks like Uranus appear in distant imaging can help us have more robust expectations when preparing for these future missions," concluded Hasler. "And that will be critical to our success."
Launched in January 2006, New Horizons made the historic flyby of Pluto and its moons in July 2015, before giving humankind its first close-up look at one of these planetary building block and Kuiper Belt object, Arrokoth, in January 2019. New Horizons is now in its second extended mission, studying distant Kuiper Belt objects, characterizing the outer heliosphere of the Sun, and making important astrophysical observations from its unmatched vantage point in distant regions of the solar system.
The Uranus results are being presented this week at the 56th annual meeting of the American Astronomical Society Division for Planetary Sciences, in Boise, Idaho.
The Hubble Space Telescope has been operating for over three decades and continues to make ground-breaking discoveries that shape our fundamental understanding of the universe. Hubble is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Centre in Greenbelt, Maryland, manages the telescope and mission operations. Lockheed Martin Space, based in Denver, Colorado, also supports mission operations at Goddard. The Space Telescope Science Institute in Baltimore, Maryland, which is operated by the Association of Universities for Research in Astronomy, conducts Hubble science operations for NASA.

The Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland, built and operates the New Horizons spacecraft and manages the mission for NASA's Science Mission Directorate. Southwest Research Institute, based in San Antonio and Boulder, Colorado, directs the mission via Principal Investigator Alan Stern and leads the science team, payload operations and encounter science planning. New Horizons is part of NASA's New Frontiers program, managed by NASA's Marshall Space Flight Centre in Huntsville, Alabama.

- How did the building blocks of life arrive on Earth?

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Source: University of Cambridge

Researchers have used the chemical fingerprints of zinc contained in meteorites to determine the origin of volatile elements on Earth. The results suggest that without 'unmelted' asteroids, there may not have been enough of these compounds on Earth for life to emerge.

Volatiles are elements or compounds that change into vapour at relatively low temperatures. They include the six most common elements found in living organisms, as well as water. The zinc found in meteorites has a unique composition, which can be used to identify the sources of Earth's volatiles.

The researchers, from the University of Cambridge and Imperial College London, have previously found that Earth's zinc came from different parts of our Solar System: about half came from beyond Jupiter and half originated closer to Earth.

"One of the most fundamental questions on the origin of life is where the materials we need for life to evolve came from," said Dr Rayssa Martins from Cambridge's Department of Earth Sciences. "If we can understand how these materials came to be on Earth, it might give us clues to how life originated here, and how it might emerge elsewhere."

Planetesimals are the main building blocks of rocky planets, such as Earth. These small bodies are formed through a process called accretion, where particles around a young star start to stick together, and form progressively larger bodies.

But not all planetesimals are made equal. The earliest planetesimals that formed in the Solar System were exposed to high levels of radioactivity, which caused them to melt and lose their volatiles. But some planetesimals formed after these sources of radioactivity were mostly extinct, which helped them survive the melting process and preserved more of their volatiles.

In a study published in the journal *Science Advances*, Martins and her colleagues looked at the different forms of zinc that arrived on Earth from these planetesimals. The researchers measured the zinc from a large sample of meteorites originating from different planetesimals and used this data to model how Earth got its zinc, by tracing the entire period of the Earth's accretion, which took tens of millions of years.

Their results show that while these 'melted' planetesimals contributed about 70% of Earth's overall mass, they only provided around 10% of its zinc.

According to the model, the rest of Earth's zinc came from materials that didn't melt and lose their volatile elements. Their findings suggest that unmelted, or 'primitive' materials were an essential source of volatiles for Earth.

"We know that the distance between a planet and its star is a determining a factor in establishing the necessary conditions for that planet to sustain liquid water on its surface," said Martins, the study's lead author. "But our results show that there's no guarantee that planets incorporate the right materials to have enough water and other volatiles in the first place -- regardless of their physical state."

The ability to trace elements through millions or even billions of years of evolution could be a vital tool in the search for life elsewhere, such as on Mars, or on planets outside our Solar System.

"Similar conditions and processes are also likely in other young planetary systems," said Martins. "The roles these different materials play in supplying volatiles is something we should keep in mind when looking for habitable planets elsewhere."

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