South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 571 – January 6th 2023 Editor: Roger Burgess
Main Speaker John Mallett "Why do we think there was a big bang'
Lisa Lacey is standing down as Secretary by the end of August, we need a replacement to take over from her before she stands down

AGM this the one meeting during the year when the Trustees of the South Downs AS run the first half of the meeting. We have to appoint a new committee; anyone wishing to put their name forward can do so at the beginning of the meeting. If you know someone who might be able to serve on the committee, please ask them before nominating them. Being a committee member does not involve too much time or effort, the main thing is to be willing to take on some quite simple tasks, such as meet and greet at the main meetings, attend around six committee meetings each year.

- Alien planet found spiralling to its doom around an aging star

Date: December 19, 2022
Source: Harvard-Smithsonian Centre for Astrophysics


Credit: Gabriel Perez Diaz/Instituto de Astrofisica de Canarias

For the first time, astronomers have spotted an exoplanet whose orbit is decaying around an evolved, or older, host star. The stricken world appears destined to spiral closer and closer to its maturing star until collision and ultimate obliteration.
The discovery offers new insights into the long-winded process of planetary orbital decay by providing the first look at a system at this late stage of evolution.
Death-by-star is a fate thought to await many worlds and could be the Earth's ultimate *adios* billions of years from now as our Sun grows older.
"We've previously detected evidence for exoplanets spiralling in toward their stars, but we have never before seen such a planet around an evolved star," says Shreyas Vissapragada, a 51 Pegasi b Fellow at the Centre for Astrophysics | Harvard & Smithsonian and lead author of a new study describing the results. "Theory predicts that evolved stars are very effective at sapping energy from their planets' orbits, and now we can test those theories with observations."
The findings were published Monday in *The Astrophysical Journal Letters*.
The ill-fated exoplanet is designated Kepler-1658b. As its name indicates, astronomers discovered the exoplanet with the Kepler space telescope, a pioneering planet-hunting mission that launched in 2009. Oddly enough, the world was the very first new exoplanet candidate Kepler ever observed. Yet it took nearly a decade to confirm the planet's existence, at which time the object entered Kepler's catalogue officially as the 1658th entry.
Kepler-1658b is a so-called hot Jupiter, the nickname given to exoplanets on par with Jupiter's mass and size but in scorching ultra-close orbits about their host stars. For Kepler-1658b, that distance is merely an eighth of the space between our Sun and its tightest orbiting planet, Mercury. For hot Jupiter's and other planets like Kepler-1658b that are already very close to their stars, orbital decay looks certain to culminate in destruction.
Measuring the orbital decay of exoplanets has challenged researchers because the process is very slow and gradual. In the case of Kepler-1658b, according to the new study, its orbital period is decreasing at the miniscule rate of about 131 milliseconds (thousandths of a second) per year, with a shorter orbit indicating the planet has moved closer to its star.
Detecting this decline required multiple years of careful observation. The watch started with Kepler and then was picked up by the

Palomar Observatory's Hale Telescope in Southern California and finally the Transiting Exoplanet Survey Telescope, or TESS, which launched in 2018. All three instruments captured transits, the term for when an exoplanet crosses the face of its star and causes a very slight dimming of the star's brightness. Over the past 13 years, the interval between Kepler-1658b's transits has slightly but steadily decreased.

The root cause of the orbital decay experienced by Kepler-1658b is tides -- the same phenomenon responsible for the daily rise and fall in Earth's oceans. Tides are generated by gravitational interactions between two orbiting bodies, such as between our world and the Moon or Kepler-1658b and its star. The bodies' gravities distort each other's shapes, and as the bodies respond to these changes, energy is released. Depending on the distances between, sizes, and rotation rates of the bodies involved, these tidal interactions can result in bodies pushing each other away -- the case for the Earth and the slowly outward-spiralling Moon -- or inward, as with Kepler-1658b toward its star.

There is still a lot researchers do not understand about these dynamics, particularly in star-planet scenarios. Accordingly, further study of the Kepler-1658 system should prove instructive.

The star has evolved to the point in its stellar life cycle where it has started to expand, just as our Sun is expected to, and has entered into what astronomers call a subgiant phase. The internal structure of evolved stars should more readily lead to dissipation of tidal energy taken from hosted planets' orbits compared to unevolved stars like our Sun. This accelerates the orbital decay process, making it easier to study on human timescales.

The results further help in explaining an intrinsic oddity about Kepler-1658b, which appears brighter and hotter than expected. The tidal interactions shrinking the planet's orbit may also be cranking out extra energy within the planet itself, the team says.

Vissapragada points to a similar situation with Jupiter's moon Io, the most volcanic body in the Solar System. The gravitational push-and-pull from Jupiter on Io melts the planet's innards. This molten rock then erupts out onto the moon's famously infernal, pizza-like surface of yellow sulphurous deposits and fresh red lava.

Stacking additional observations of Kepler-1658b should shed more light on celestial body interactions. And, with TESS slated to keep scrutinizing thousands of nearby stars, Vissapragada and colleagues expect the telescope to uncover numerous other instances of exoplanets circling down the drains of their host stars.

"Now that we have evidence of in spiralling of a planet around an evolved star, we can really start to refine our models of tidal physics," Vissapragada says. "The Kepler-1658 system can serve as a celestial laboratory in this way for years to come, and with any luck, there will soon be many more of these labs."

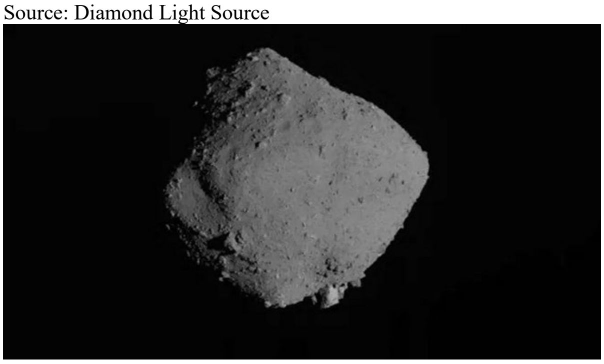
Vissapragada, who recently joined the Centre for Astrophysics a few months ago and is now being mentored by Mercedes López-Morales, looks forward to the science of exoplanets continuing too dramatically advance.

"Shreyas has been a welcome addition to our team working on characterizing the evolution of exoplanets and their atmospheres," says López-Morales, an astronomer at the Centre for Astrophysics.

"I can't wait to see what all of us end up discovering together," adds Vissapragada.

- Ancient asteroid grains provide insight into the evolution of our solar system

Date: December 19, 2022
Source: Diamond Light Source



This file handout photograph released by Japan Aerospace Exploration Agency (JAXA) via Jiji Press on 13 November, 2019 shows the asteroid Ryugu after Hayabusa2 departed its orbit around a distant asteroid and head for Earth. AFP file photo

The UK's national synchrotron facility, Diamond Light Source, was used by a large, international collaboration to study grains collected from a near-Earth asteroid to further our understanding of the evolution of our solar system.

Researchers from the University of Leicester brought a fragment of the Ryugu asteroid to Diamond's Nanoprobe beamline I14 where a special technique called X-ray Absorption Near Edge Spectroscopy (XANES) was used to map out the chemical states of the elements within the asteroid material, to examine its composition in fine detail. The team also studied the asteroid grains using an electron microscope at Diamond's electron Physical Science Imaging Centre (ePSIC).

Julia Parker is the Principal Beamline Scientist for I14 at Diamond. She said: "*The X-ray Nanoprobe allows scientists to examine the chemical structure of their samples at micron to nano length scales, which is complemented by the nano to atomic resolution of the imaging at ePSIC. It's very exciting to be able to contribute to the understanding of these unique samples, and to work with the team at Leicester to demonstrate how the techniques at the beamline, and correlatively at ePSIC, can benefit future sample return missions*."

The data collected at Diamond contributed to a wider study of the space weathering signatures on the asteroid. The pristine asteroid samples enabled the collaborators to explore how space weathering can alter the physical and chemical composition of the surface of carbonaceous asteroids like Ryugu. The researchers discovered that the surface of Ryugu is dehydrated and that it is likely that space weathering is responsible. The findings of the study, published today in *Nature Astronomy*, have led the authors to conclude that asteroids that appear dry on the surface may be water-rich, potentially requiring revision of our understanding of the abundances of asteroid types and the formation history of the asteroid belt.

Ryugu is a near-Earth asteroid, around 900 metres in diameter, first discovered in 1999 within the asteroid belt between Mars and Jupiter. It is named after the undersea palace of the Dragon God in Japanese mythology. In 2014, the Japanese state space agency JAXA launched Hayabusa2, an asteroid sample-return mission, to rendezvous with the Ryugu asteroid and collect material samples from its surface and sub-surface. The spacecraft returned to Earth in 2020, releasing a capsule containing precious fragments of the asteroid. These small samples were distributed to labs around the world for scientific study, including the University of Leicester's School of Physics & Astronomy and Space Park where John Bridges, one of the authors on the paper, is a Professor of Planetary Science.

John said: "*This unique mission to gather samples from the most primitive, carbonaceous, building blocks of the Solar System needs the world's most detailed microscopy, and that's why JAXA and the Fine-Grained Mineralogy team wanted us to analyse samples at Diamond's X-ray nanoprobe beamline. We helped reveal the nature of space weathering on this asteroid with micrometeorite impacts and the solar wind creating dehydrated serpentine minerals, and an associated reduction from oxidised* Fe^{3+} *to more reduced* Fe^{2+}.

It's important to build up experience in studying samples returned from asteroids, as in the Hayabusa2 mission, because soon there will be new samples from other asteroid types, the Moon and within the next 10 years Mars, returned to Earth. The UK community will be able to perform some of the critical analyses due to our facilities at Diamond and the electron microscopes at ePSIC."

The building blocks of Ryugu are remnants of interactions between water, minerals and organics in the early Solar System prior to the formation of Earth. Understanding the composition of asteroids can help explain how the early solar system developed, and subsequently how the Earth formed. They may even help explain how life on Earth came about, with asteroids believed to have delivered much of the planet's water as well as organic compounds such as amino acids, which provide the fundamental building blocks from which all human life is constructed. The information that is being gleaned from these tiny asteroid samples will help us to better understand the origin not only of the planets and stars but also of life itself. Whether it's fragments of asteroids, ancient paintings or unknown virus structures, at the synchrotron, scientists can study their samples using a machine that is 10,000 times more powerful than a traditional microscope.

- Webb Space Telescope reveals previously shrouded new-born stars

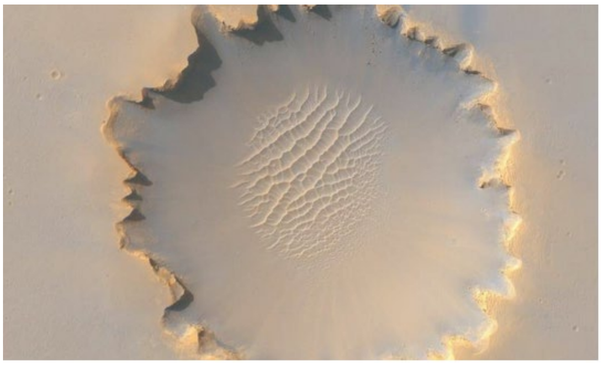
Webb's infrared camera peers through dust clouds, enabling discovery

Date: December 16, 2022
Source: Rice University

Rice University astronomer Megan Reiter and colleagues took a "deep dive" into one of the first images from NASA's James Webb Space Telescope and were rewarded with the discovery of tell-tale signs from two dozen previously unseen young stars about 7,500 light years from Earth.
The published research in the December issue of the Monthly Notices of the Royal Astronomical Society offers a glimpse of what astronomers will find with Webb's near-infrared camera. The instrument is designed to peer through clouds of interstellar dust that have previously blocked astronomers' view of stellar nurseries, especially those that produce stars similar to Earth's sun.
Reiter, an assistant professor of physics and astronomy, and co-authors from the California Institute of Technology, the University of Arizona, Queen Mary University in London and the United Kingdom's Royal Observatory in Edinburgh, Scotland, analysed a portion of Webb's first images of the Cosmic Cliffs, a star-forming region in a cluster of stars known as NGC 3324.
"What Webb gives us is a snapshot in time to see just how much star formation is going on in what may be a more typical corner of the universe that we haven't been able to see before," said Reiter, who led the study.
Located in the southern constellation Carina, NGC 3324 hosts several well-known regions of star formation that astronomers have studied for decades. Many details from the region have been obscured by dust in images from the Hubble Space Telescope and other observatories. Webb's infrared camera was built to see through dust in such regions and to detect jets of gas and dust that spew from the poles of very young stars.
Reiter and colleagues focused their attention on a portion of NGC 3324 where only a few young stars had previously been found. By analysing a specific infrared wavelength, 4.7 microns, they discovered two dozen previously unknown outflows of molecular hydrogen from young stars. The outflows range in size, but many appear to come from protostars that will eventually become low-mass stars like Earth's sun.
"The findings speak both to how good the telescope is and to how much there is going on in even quiet corners of the universe," Reiter said.
Within their first 10,000 years, new-born stars gather material from the gas and dust around them. Most young stars eject a fraction of that material back into space via jets that stream out in opposite directions from their poles. Dust and gas pile up in front of the jets, which clear paths through nebular clouds like snowploughs. One vital ingredient for baby stars, molecular hydrogen, gets swept up by these jets and is visible in Webb's infrared images.
"Jets like these are signposts for the most exciting part of the star formation process," said study co-author Nathan Smith of the University of Arizona. "We only see them during a brief window of time when the protostar is actively accreting."
The accretion period of early star formation has been especially difficult for astronomers to study because it is fleeting -- usually just a few thousand years in the earliest portion of a star's multimillion-year childhood.
Study co-author Jon Morse of the California Institute of Technology said jets like those discovered in the study "are only visible when you embark on that deep dive -- dissecting data from each of the different filters and analysing each area alone.
"It's like finding buried treasure," Morse said.
Reiter said the size of the Webb telescope also played a role in the discovery.
"It's just a huge light bucket," Reiter said. "That lets us see smaller things that we might have missed with a smaller telescope. And it also gives us really good angular resolution. So, we get a level of sharpness that allows us to see relatively small features, even in faraway regions."
The Webb Space Telescope program is led by NASA in partnership with the European Space Agency (ESA) and the Canadian Space Agency (CSA). The telescope's science and mission operations are led by the Space Telescope Science Institute (STScI) in Baltimore.
The research was supported by NASA (NAS 5-0312, NAS 5-26555), STScI and a Dorothy Hodgkin Fellowship from the UK's Royal Society.

- Experimentalists: Sorry, no oxygen required to make these minerals on Mars

Date: December 22, 2022
Source: Washington University in St. Louis



When NASA's Mars rovers found manganese oxides in rocks in the Gale and Endeavor craters on Mars in 2014, the discovery sparked some scientists to suggest that the red planet might have once had more oxygen in its atmosphere billions of years ago.

The minerals probably required abundant water and strongly oxidizing conditions to form, the scientists said. Using lessons learned from Earth's geologic record, scientists concluded that the presence of manganese oxides indicated that Mars had experienced periodic increases in atmospheric oxygen in its past -- before declining to today's low levels.

But a new experimental study from Washington University in St. Louis upends this view.

Scientists discovered that under Mars-like conditions, manganese oxides can be readily formed without atmospheric oxygen. Using kinetic modelling, the scientists also showed that manganese oxidation is not possible in the carbon dioxide-rich atmosphere expected on ancient Mars.

"The link between manganese oxides and oxygen suffers from an array of fundamental geochemical problems," said Jeffrey Catalano, a professor of earth and planetary sciences in Arts & Sciences and corresponding author of the study published Dec. 22 in *Nature Geoscience*. Catalano is a faculty fellow of the McDonnell Centre for the Space Sciences.

The first author of the study is Kaushik Mitra, now a postdoctoral research associate at Stony Brook University, who completed this work as part of his graduate research at Washington University.

Mars is a planet rich in the halogen elements chlorine and bromine compared to Earth.

"Halogens occur on Mars in forms different from on the Earth, and in much larger amounts, and we guessed that they would be important to the fate of manganese," Catalano said.

Catalano and Mitra conducted laboratory experiments using chlorate and bromate -- dominant forms of these elements on Mars -- to oxidize manganese in water samples that they made to replicate fluids on the Mars surface in the ancient past.

"We were inspired by reactions seen during chlorination of drinking water," Catalano said. "Understanding other planets sometimes requires us to apply knowledge gained from seemingly unrelated fields of science and engineering."

The scientists found that halogens converted manganese dissolved in water into manganese oxide minerals thousands to millions of times faster than by oxygen. Further, under the weakly acidic conditions that scientists believe were found on the surface of early Mars, bromate produces manganese oxide minerals more quickly than any other available oxidant. Under many of these conditions, oxygen is altogether incapable of forming manganese oxides.

"Oxidation does not necessitate the involvement of oxygen by definition," Mitra said. "Earlier, we proposed viable oxidants on Mars, other than oxygen or via UV photooxidation, that help explain why the red planet is red. In the case of manganese, we just did not have a viable alternative to oxygen that could explain manganese oxides until now."

The new results alter foundational interpretations of the habitability of early Mars, which is an important driver of ongoing research by NASA and the European Space Agency.

But just because there was likely no atmospheric oxygen in the past, there's no particular reason to believe that there was no life, the scientists said.

"There are several life forms even on Earth that do not require oxygen to survive," Mitra said. "I don't think of it as a 'setback' to habitability -- only that there were probably no oxygen-based lifeforms."

Extremophile organisms that can survive in a halogen-rich environment -- like the salt-loving single-celled organisms and bacteria that thrive in the Great Salt Lake and the Dead Sea on Earth -- might also do well on Mars.

"We need more experiments conducted in diverse geochemical conditions that are more relevant to specific planets like Mars, Venus, and 'ocean worlds' like Europa and Enceladus in order to have the correct and full understanding of the geochemical and geological environments on these planetary bodies," Mitra said. "Every planet is unique in its own right, and we cannot extrapolate the observations made on one planet to exactly understand a different planet."

- Light from outside our galaxy brighter than expected

Study led by RIT scientists uses data taken by LORRI on NASA's New Horizons mission

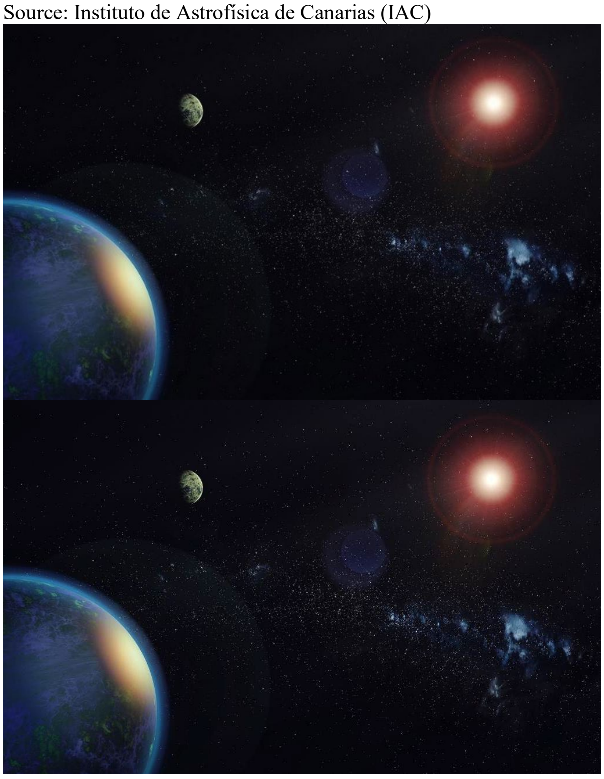
Date: December 16, 2022
Source: Rochester Institute of Technology

Artist's impression of NASA's New Horizons spacecraft. (CREDIT: NASA/APL/SwRI and NASA/JPL-Caltech)

Scientists analysed new measurements showing that the light emitted by stars outside our galaxy is two to three times brighter than the light from known populations of galaxies, challenging assumptions about the number and environment of stars are in the universe.
Results of the study led by researchers at Rochester Institute of Technology have been posted to ArXiv and accepted for publication in *The Astrophysical Journal*.
The research team analysed hundreds of images of background light taken by the Long-Range Reconnaissance Imager (LORRI) on NASA's New Horizons mission to calculate the cosmic optical background (COB) -- the sum of light emitted by stars beyond the Milky Way over the history of the universe. If the COB brightness doesn't equal the light from galaxies we know about, it suggests there might be missing sources of optical light in the universe.
"We see more light than we should see based on the populations of galaxies that we understand to exist and how much light we estimate they should produce," said Teresa Symons '22 Ph.D. (astrophysical sciences and technology), who led the study for her dissertation and is now a postdoctoral researcher at University of California Irvine. "Determining what is producing that light could change our fundamental understanding of how the universe formed over time."
Earlier this year, an independent team of scientists reported the COB was twice as large as originally believed in *Astrophysical Journal Letters*. Those results were no fluke, as corroborated using a much broader set of LORRI observations in the new study by Symons, RIT Associate Professor Michael Zemcov, and researchers at the Jet Propulsion Laboratory at Caltech, UC Irvine, UC Berkeley, and Johns Hopkins University.
While an unobscured measurement of the COB is difficult to achieve from the Earth due to dust between planets, the New Horizons spacecraft is at the edge of our solar system where this foreground is minimal and provides a much clearer view for this type of study. The scientists hope that future missions and instruments can be developed to help explore the discrepancy.
"This has gotten to the point where it's an actual mystery that needs to be solved," said Zemcov, a research professor at RIT's Centre for Detectors and School of Physics and Astronomy. "I hope that some of the experiments we're involved in here at RIT including CIBER-2 and SPHEREx can help us resolve the discrepancy."

- ESPRESSO and CARMENES discover two potentially habitable exo-Earths around a star near the sun

Date: December 15, 2022
Source: Instituto de Astrofísica de Canarias (IAC)



The newly discovered planets orbit the star GJ 1002, which is at a distance of less than 16 light years from the Solar System

An international scientific team led by researchers at the Instituto de Astrofísica de Canarias (IAC) has discovered the presence of two planets with Earth-like masses in orbit around the star GJ 1002, a red dwarf not far from the Solar System. Both planets are in the habitability zone of the star.
"Nature seems bent on showing us that Earth-like planets are very common. With these two we now know 7 in planetary systems quite near to the Sun," explains Alejandro Suárez Mascareño, an IAC researcher, who is the first author of the study accepted for publication in *Astronomy & Astrophysics.*
The newly discovered planets orbit the star GJ 1002, which is at a distance of less than 16 light years from the Solar System. Both of them have masses similar to that of the Earth, and they are in the habitability zone of their star. GJ 1002b, the inner of the two, takes little more than 10 days to complete an orbit around the star, while GJ 1002c needs a little over 21 days. "GJ 1002 is a red dwarf star, with barely one eighth the mass of the Sun. It is quite a cool, faint star. This means that its habitability zone is very close to the star," explains Vera María Passegger, a co-author of the article and an IAC researcher.
The proximity of the star to our Solar System implies that the two planets, especially GJ 1002c, are excellent candidates for the characterization of their atmospheres based either on their reflected light, or on their thermal emission. "The future ANDES spectrograph for the ELT telescope at ESO in which the IAC is participating, could study the presence of oxygen in the atmosphere of GJ 1002c," notes Jonay I. González Hernández, an IAC researcher who is a co-author of the article. In addition, both planets satisfy the characteristics needed for them to be objectives for the future LIFE mission, which is presently in a study phase.
The discovery was made during a collaboration between the consortia of the two instruments ESPRESSO and CARMENES. GJ 1002 was observed by CARMENES between 2017 and 2019, and by ESPRESSO between 2019 and 2021. "Because of its low temperature the visible light from GJ 1002 is too faint to measure its variations in velocity with the majority of spectrographs," says Ignasi Ribas, researcher at the Institute of Space Sciences (ICE-CSIC) and director of the *Institut d'Estudis Espacials de Catalunya* (IEEC). CARMENES has a sensitivity over a wide range of near infrared wavelengths which is superior to those of other spectrographs aimed at detecting variations in the velocities of stars, and this allowed it to study GJ 1002, from the 3.5m telescope at Calar Alto observatory.
The combination of ESPRESSO, and the light gathering power of the VLT 8m telescopes at ESO allowed measurements to be made with an accuracy of only 30 cm/sec, not attainable with any other instrument in the world.
"Either of the two groups would have have had many difficulties if they had tackled this work independently. Jointly we have been able to get much further than we would have done acting independently," states Suárez Mascareño.

- Astronomers find that two exoplanets may be mostly water

Date: December 15, 2022
Source: University of Montreal

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A team led by UdeM astronomers has found evidence that two exoplanets orbiting a red dwarf star are "water worlds," planets where water makes up a large fraction of the volume. These worlds, located in a planetary system 218 light-years away in the constellation Lyra, are unlike any planets found in our solar system.
The team, led by PhD student Caroline Piaulet of the Trottier Institute for Research on Exoplanets (iREx) at the Université de Montréal, published a detailed study of a planetary system known as Kepler-138 in the journal *Nature Astronomy* today.
Piaulet, who is part of Björn Benneke's research team, observed exoplanets Kepler-138c and Kepler-138d with NASA's Hubble and the retired Spitzer space telescopes and discovered that the planets -- which are about one and a half times the size of the Earth -- could be composed largely of water. These planets and a planetary companion closer to the star, Kepler-138b, had been discovered

previously by NASA's Kepler Space Telescope.

Water wasn't directly detected, but by comparing the sizes and masses of the planets to models, they conclude that a significant fraction of their volume -- up to half of it -- should be made of materials that are lighter than rock but heavier than hydrogen or helium (which constitute the bulk of gas giant planets like Jupiter). The most common of these candidate materials is water.

"We previously thought that planets that were a bit larger than Earth were big balls of metal and rock, like scaled-up versions of Earth, and that's why we called them super-Earths," explained Benneke. "However, we have now shown that these two planets, Kepler-138c and d, are quite different in nature: a big fraction of their entire volume is likely composed of water. It is the first time we observe planets that can be confidently identified as water worlds, a type of planet that was theorized by astronomers to exist for a long time."

With volumes more than three times that of Earth and masses twice as big, planets c and d have much lower densities than Earth. This is surprising because most of the planets just slightly bigger than Earth that have been studied in detail so far all seemed to be rocky worlds like ours. The closest comparison to the two planets, say researchers, would be some of the icy moons in the outer solar system that are also largely composed of water surrounding a rocky core.

"Imagine larger versions of Europa or Enceladus, the water-rich moons orbiting Jupiter and Saturn, but brought much closer to their star," explained Piaulet. "Instead of an icy surface, Kepler-138 c and d would harbour large water-vapor envelopes."

Researchers caution the planets may not have oceans like those on Earth directly at the planet's surface. "The temperature in Kepler-138c's and Kepler-138d's atmospheres is likely above the boiling point of water, and we expect a thick, dense atmosphere made of steam on these planets. Only under that steam atmosphere there could potentially be liquid water at high pressure, or even water in another phase that occurs at high pressures, called a supercritical fluid," Piaulet said.

Recently, another team at the University of Montreal found another planet, called TOI-1452 b, that could potentially be covered with a liquid-water ocean, but NASA's James Webb Space Telescope will be needed to study its atmosphere and confirm the presence of the ocean.

A new exoplanet in the system

In 2014, data from NASA's Kepler Space Telescope allowed astronomers to announce the detection of three planets orbiting Kepler-138, a red dwarf star in the constellation Lyra. This was based on a measurable dip in starlight as the planet momentarily passed in from of their star, a transit.

Benneke and his colleague Diana Dragomir, from the University of New Mexico, came up with the idea of re-observing the planetary system with the Hubble and Spitzer space telescopes between 2014 and 2016 to catch more transits of Kepler-138d, the third planet in the system, in order to study its atmosphere.

While earlier NASA Kepler space telescope observations only showed transits of three small planets around Kepler-138, Piaulet and her team were surprised to find that the Hubble and Spitzer observations suggested the presence of a fourth planet in the system, Kepler-138e.

This newly found planet is small and farther from its star than the three others, taking 38 days to complete an orbit. The planet is in the habitable zone of its star, a temperate region where a planet receives just the right amount of heat from its cool star to be neither too hot nor too cold to allow the presence of liquid water.

The nature of this additional, newly found planet, however, remains an open question because it does not seem to transit its host star. Observing the exoplanet's transit would have allowed astronomers to determine its size.

With Kepler-138e now in the picture, the masses of the previously known planets were measured again via the transit timing-variation method, which consists of tracking small variations in the precise moments of the planets' transits in front of their star caused by the gravitational pull of other nearby planets.

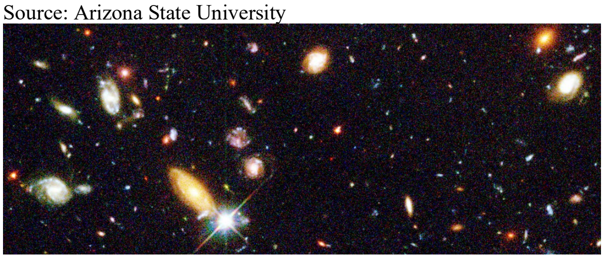
The researchers had another surprise: they found that the two water worlds Kepler-138c and d are "twin" planets, with virtually the same size and mass, while they were previously thought to be drastically different.

The closer-in planet, Kepler-138b, on the other hand, is confirmed to be a small Mars-mass planet, one of the smallest exoplanets known to date.

"As our instruments and techniques become sensitive enough to find and study planets that are farther from their stars, we might start finding a lot more water worlds like Kepler-138 c and d," Benneke concluded.

❖ Exquisite views of distant galaxies

Date: December 15, 2022
Source: Arizona State University

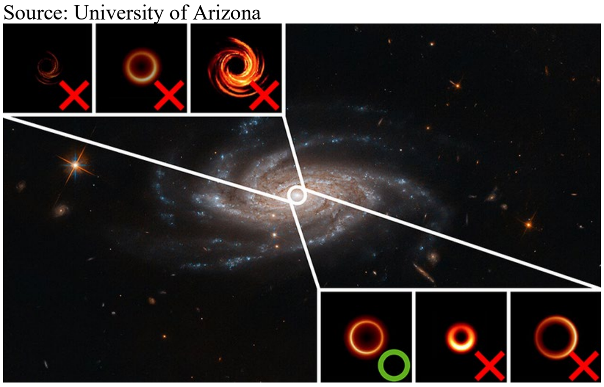


For decades, the Hubble Space Telescope and ground-based telescopes have provided us with spectacular images of galaxies. This all changed when the James Webb Space Telescope (JWST) launched in December 2021 and successfully completed commissioning during the first half of 2022. For astronomers, the universe, as we had seen it, is now revealed in a new way never imagined by the telescope's Near-Infrared Camera (NIRCam) instrument.
The NIRCam is Webb's primary imager that covers the infrared wavelength range from 0.6 to 5 microns. NIRCam detects light from the earliest stars and galaxies in the process of formation, the population of stars in nearby galaxies, as well as young stars in the Milky Way and Kuiper Belt objects.
The Prime Extragalactic Areas for Reionization and Lensing Science, or PEARLS, project is the subject of a recent study published in *Astronomical Journal* by a team of researchers, including Arizona State University School of Earth and Space Exploration Regents Professor Rogier Windhorst, Research Scientist Rolf Jansen, Associate Research Scientist Seth Cohen, Research Assistant Jake Summers and Graduate Associate Rosalia O'Brien, along with the contribution of many other researchers.
For researchers, the PEARLS program's images of the earliest galaxies show the amount of gravitational lensing of objects in the background of massive clusters of galaxies, allowing the team to see some of these very distant objects. In one of these relatively deep fields, the team has worked with stunning multicolour images to identify interacting galaxies with active nuclei. Windhorst and his team's data show evidence for giant black holes in their centre where you can see the accretion disc -- the stuff falling into the black hole, shining very brightly in the galaxy centre. Plus, lots of galactic stars show up like drops on your car's windshields -- like you're driving through intergalactic space. This colourful field is straight up from the ecliptic plane, the plane in which the Earth and the moon, and all the other planets, orbit around the sun.
"For over two decades, I've worked with a large international team of scientists to prepare our Webb science program," Windhorst said. "Webb's images are truly phenomenal, really beyond my wildest dreams. They allow us to measure the number density of galaxies shining to very faint infrared limits and the total amount of light they produce. This light is much dimmer than the very dark infrared sky measured between those galaxies."
The first thing the team can see in these new images is that many galaxies that were next to or truly invisible to Hubble are bright in the images taken by Webb. These galaxies are so far away that the light emitted by stars has been stretched.
The team focused on the North Ecliptic Pole time domain field with the Webb telescope -- easily viewed due to its location in the sky. Windhorst and the team plan to observe it four times.
The first observations, consisting of two overlapping tiles, produced an image that shows objects as faint as the brightness of 10 fireflies at the distance of the moon (with the moon not there). The ultimate limit for Webb is one or two fireflies. The faintest reddest objects visible in the image are distant galaxies that go back to the first few hundred million years after the Big Bang.
For most of Jansen's career, he's worked with cameras on the ground and in space, where you have a single instrument with a single camera that produces one image. Now scientists have an instrument that has not just one detector or one image coming out of it, but 10 simultaneously. For every exposure NIRCam takes, it gives 10 of these images. That's a massive amount of data, and the sheer volume can be overwhelming.
To process that data and channel it through the analysis software of collaborators around the globe, Summers has been instrumental.

"The JWST images far exceed what we expected from my simulations prior to the first science observations," Summers said. "Analysing these JWST images, I was most surprised by their exquisite resolution."
Jansen's primary interest is to figure out how galaxies like our own Milky Way came to be. And the way to do that is by looking far back in time at how galaxies came together, seeing how they evolved, effectively, and so tracing the path from the Big Bang to people like us.
"I was blown away by the first PEARLS images," Jansen said. "Little did I know, when I selected this field near the North Ecliptic Pole, that it would yield such a treasure trove of distant galaxies, and that we would get direct clues about the processes by which galaxies assemble and grow -- I can see streams, tails, shells and halos of stars in their outskirts, the leftovers of their building blocks."
Third-year astrophysics graduate student O'Brien designed algorithms to measure faint light between the galaxies and stars that first catch our eye.
"The diffuse light that I measured in between stars and galaxies has cosmological significance, encoding the history of the universe," O'Brien said. "I feel fortunate to start my career right now -- JWST data is like nothing we have ever seen, and I'm excited about the opportunities and challenges it offers."
"I expect that this field will be monitored throughout the JWST mission, to reveal objects that move, vary in brightness or briefly flare up, like distant exploding supernovae or accreting gas around black holes in active galaxies," Jansen said.

- Machine learning reveals how black holes grow

Date: December 15, 2022
Source: University of Arizona



As different as they may seem, black holes and Las Vegas have one thing in common: What happens there stays there -- much to the frustration of astrophysicists trying to understand how, when and why black holes form and grow. Black holes are surrounded by a mysterious, invisible layer -- the event horizon -- from which nothing can escape, be it matter, light or information. The event horizon swallows every bit of evidence about the black hole's past.
"Because of these physical facts, it had been thought impossible to measure how black holes formed," said Peter Behroozi, an associate professor at the University of Arizona Steward Observatory and a project researcher at the National Astronomical Observatory of Japan.
Together with Haowen Zhang, a doctoral student at Steward, Behroozi led an international team to use machine learning and supercomputers to reconstruct the growth histories of black holes, effectively peeling back their event horizons to reveal what lies beyond.
Simulations of millions of computer-generated "universes" revealed that supermassive black holes grow in lockstep with their host galaxies. This had been suspected for 20 years, but scientists had not been able to confirm this relationship until now. A paper with the team's findings has been published in *Monthly Notices of the Royal Astronomical Society.*
"If you go back to earlier and earlier times in the universe, you find that exactly the same relationship was present," said Behroozi, a co-author on the paper. "So, as the galaxy grows from small to large, its black hole, too, is growing from small to large, in exactly the same way as we see in galaxies today all across the universe."
Most, if not all, galaxies scattered throughout the cosmos are thought to harbour a supermassive black hole at their centre. These black holes pack masses greater than 100,000 times that of the sun, with some boasting millions, even billions of solar masses. One of astrophysics' most vexing questions has been how these behemoths grow as fast they do, and how they form in the first place.
To find answers, Zhang, Behroozi and their colleagues created Trinity, a platform that uses a novel form of machine learning capable of generating millions of different universes on a supercomputer, each of which obeys different physical theories for how galaxies should form. The researchers built a framework in which computers propose new

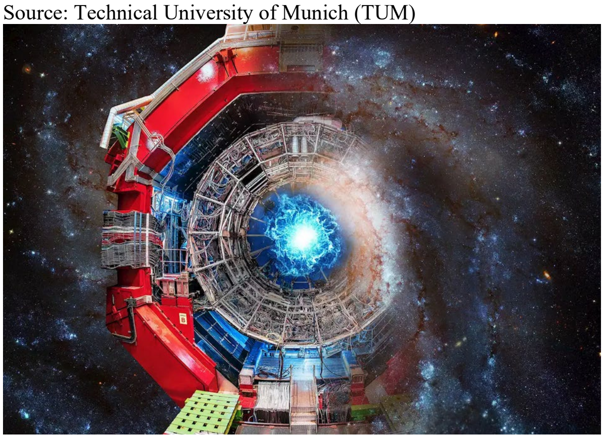
rules for how supermassive black holes grow over time. They then used those rules to simulate the growth of billions of black holes in a virtual universe and "observed" the virtual universe to test whether it agreed with decades of actual observations of black holes across the real universe. After millions of proposed and rejected rule sets, the computers settled on rules that best described existing observations.
"We're trying to understand the rules of how galaxies form," Behroozi said. "In a nutshell, we make Trinity guess what the physical laws may be and let them go in a simulated universe and see how that universe turns out. Does it look anything like the real one or not?"
According to the researchers, this approach works equally well for anything else inside of the universe, not just galaxies.
The project's name, Trinity, is in reference to its three main areas of study: galaxies, their supermassive black holes and their dark matter halos -- vast cocoons of dark matter that are invisible to direct measurements but whose existence is necessary to explain the physical characteristics of galaxies everywhere. In previous studies, the researchers used an earlier version of their framework, called the UniverseMachine, to simulate millions of galaxies and their dark matter halos. The team discovered that galaxies growing in their dark matter halos follow a very specific relationship between the mass of the halo and the mass of the galaxy.
"In our new work, we added black holes to this relationship," Behroozi said, "and then asked how black holes could grow in those galaxies to reproduce all the observations people have made about them."
"We have very good observations of black hole masses," said Zhang, the paper's lead author. "However, those are largely restricted to the local universe. As you look farther away, it becomes increasingly difficult, and eventually impossible, to accurately measure the relationships between the masses of black holes and their host galaxies. Because of that uncertainty, observations can't directly tell us whether that relationship holds up throughout the universe."
Trinity allows astrophysicists to sidestep not only that limitation, but also the event horizon information barrier for individual black holes by stitching together information from millions of observed black holes at different stages of their growth. Even though no individual black hole's history could be reconstructed, the researchers could measure the average growth history of all black holes taken together.
"If you put black holes into the simulated galaxies and enter rules about how they grow, you can compare the resulting universe to all the observations of actual black holes that we have," Zhang said. "We can then reconstruct how any black hole and galaxy in the universe looked from today back to the very beginning of the cosmos."
The simulations shed light on another puzzling phenomenon: Supermassive black holes -- like the one found in the centre of the Milky Way -- grew most vigorously during their infancy, when the universe was only a few billion years old, only to slow down dramatically during the ensuing time, over the last 10 billion years or so.
"We've known for a while that galaxies have this strange behaviour, where they reach a peak in their rate of forming new stars, then it dwindles over time, and then, later on, they stop forming stars altogether," Behroozi said. "Now, we've been able to show that black holes do the same: growing and shutting off at the same times as their host galaxies. This confirms a decades-old hypothesis about black hole growth in galaxies."
However, the result poses more questions, he added. Black holes are much smaller than the galaxies in which they live. If the Milky Way were scaled down to the size of Earth, its supermassive black hole would be the size of the period at the end of this sentence.
For the black hole to double in mass within the same timeframe as the larger galaxy requires synchronization between gas flows at vastly different scales. How black holes conspire with galaxies to achieve this balance is yet to be understood.
"I think the really original thing about Trinity is that it provides us with a way to find out what kind of connections between black holes and galaxies are consistent with a wide variety of different datasets and observational methods," Zhang said. "The algorithm allows us to pick out precisely those relationships between dark matter halos, galaxies and black holes that are able to reproduce all the observations that have been made. It basically tells us, 'OK, given all these data, we know the connection between galaxies and black

holes must look like this, rather than like that.' And that approach is extremely powerful."

- Antihelium nuclei as messengers from the depths of the galaxy

New findings lay the foundation for the search for dark matter

Date: December 12, 2022
Source: Technical University of Munich (TUM)



How are galaxies born, and what holds them together? Astronomers assume that dark matter plays an essential role. However, as yet it has not been possible to prove directly that dark matter exists. A research team including Technical University of Munich (TUM) scientists has now measured for the first time the survival rate of antihelium nuclei from the depths of the galaxy -- a necessary prerequisite for the indirect search for Dark Matter.

Many things point to the existence of dark matter. The way in which galaxies move in galactic clusters, or how fast stars circle the centre of a galaxy results in calculations which indicate that there must be far more mass present than what we can see. Approximately 85 percent of our Milky Way for example consists of a substance which is not visible and which can only be detected based on its gravitational effects. As of today it has still not been possible to directly prove the existence of this material.

Several theoretical models of dark matter predict that it could be composed of particles which interact weakly with one another. This produces antihelium-3 nuclei, which consist of two antiprotons and one antineutron. These nuclei are also generated in high-energy collisions between cosmic radiation and common matter like hydrogen and helium -- however, with energies different from those that would be expected in the interaction of dark matter particles.

In both processes, the antiparticles originate in the depths of the galaxy, several tens of thousands of lightyears away from us. After their creation, a part of them makes its way in our direction. How many of these particles survive this journey unscathed and reach the vicinity of the Earth as messengers of their formation process determines the transparency of the Milky Way for antihelium nuclei. Until now scientists have only been able to roughly estimate this value. However, an improved approximation of transparency, a unit of measure for the number and energies of antinuclei, will be important for interpreting future antihelium measurements.

LHC particle accelerator as antimatter factory

Researchers from the ALICE collaboration have now carried out measurements that have enabled them to determine the transparency more precisely for the first time. ALICE stands for A Large Ion Collider Experiment and is one of the largest experiments in the world to explore physics on the smallest length scales. ALICE is part of the Large Hadron Collider (LHC) at CERN.

The LHC can generate large amounts of light antinuclei such as antihelium. To do so, protons and lead atoms are each put on a collision course. The collisions produce particle showers which are then recorded by the detector of the ALICE experiment. Thanks to several subsystems of the detector, the researchers can then detect the antihelium-3 nuclei that have formed and follow their trails in the detector material. This makes it possible to quantify the probability that an antihelium-3 nucleus will interact with the detector material and disappear. Scientists from TUM and the Excellence Cluster ORIGINS have contributed significantly to the analysis of the experimental data.

Galaxy transparent for antinuclei

Using simulations, the researchers were able to transfer the findings from the ALICE experiment to the entire galaxy. The result: About half of the antihelium-3 nuclei which were expected to be generated in the interaction of dark matter particles would reach the vicinity of the Earth. Our Milky Way is thus 50 percent permeable for these antinuclei. For antinuclei generated in collisions between cosmic radiation and the interstellar medium, the resulting transparency varies from 25 to 90 percent with increasing antihelium-3 momentum. However, these antinuclei can be distinguished from those

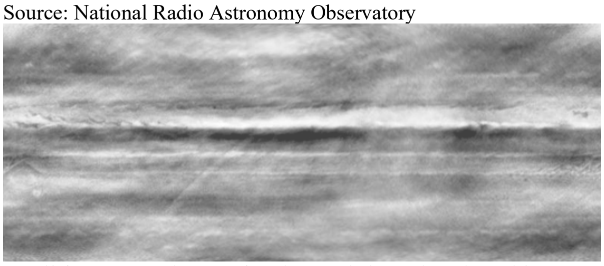
generated from dark matter based on their higher energy.
This means that antihelium nuclei can not only travel long distances in the Milky Way, but also serve as important informants in future experiments: Depending on how many antinuclei arrive at the Earth and with which energies, the origin of these well-travelled messengers can be interpreted as cosmic rays or dark matter thanks to the new calculations.

Reference for future antinuclei measurements in space

"This is an excellent example of an interdisciplinary analysis that illustrates how measurements at particle accelerators can be directly linked with the study of cosmic rays in space," says ORIGINS scientist Prof. Laura Fabbietti of the TUM School of Natural Sciences. The results from the ALICE experiment at the LHC are of great importance for the search for antimatter in space with the AMS-02 module (Alpha Magnetic Spectrometer) on the International Space Station (ISS). Starting in 2025 the GAPS balloon experiment over the Arctic will also examine incoming cosmic rays for antihelium-3.

- VLA and ALMA study Jupiter and Io

Date: December 13, 2022
Source: National Radio Astronomy Observatory



Detail from a VLA image of Jupiter made in conjunction with observations by the Juno spacecraft in orbit around that planet. Credit: Moeckel, et al., Bill Saxton, NRAO/AUI/NSF

While the National Science Foundation's Karl G. Jansky Very Large Array (VLA) and the Atacama Large Millimetre/submillimetre Array (ALMA) frequently reveal important new facts about objects far beyond our own Milky Way Galaxy -- at distances of many millions or billions of light-years -- they also are vital tools for unravelling much closer mysteries, right here in our own Solar System.
A pair of recent scientific papers illustrate how these telescopes are helping planetary scientists understand the workings of the Solar System's largest planet, Jupiter, and its innermost moon Io.
Jupiter's atmosphere is complex and dynamic, and changes rapidly. To study the giant planet's atmosphere at different depths, scientists combined observations made with instruments aboard NASA's Juno spacecraft, in orbit around Jupiter, with observations with the VLA. They collected data about the distribution of the trace gas ammonia at different levels in the atmosphere to help determine the vertical structure of the atmosphere. These observations needed to be sufficiently detailed to combine Juno's long wavelength observations with the VLA's high-frequency resolution to understand vertical transport in the atmosphere. The spatial resolution of the ground-based VLA observations was comparable to that of the instrument aboard the spacecraft orbiting the planet. These observations produced the highest-resolution radio image yet made of Jupiter. This technique is helping the scientists advance their understanding of Jupiter's deep atmosphere.
Io, whose interior constantly is heated by strong gravitational tidal forces, is the most volcanically-active body in our Solar System. The moon has a tenuous atmosphere primarily composed of Sulphur Dioxide (SO_2), which comes from eruptions of its many volcanoes and sublimation of its SO_2 surface frost. Scientists have used ALMA to study the trace gases of Sodium Chloride (NaCl -- table salt) and Potassium Chloride (KCl) in the atmosphere. They found that these compounds are largely confined in extent and are at high temperatures, indicating that they, too, are expelled by volcanoes. They also found that they are in different locations from where the SO_2 is emitted, which suggests that there may be differences in the subsurface magma or in the eruptive processes between the volcanoes that emit SO_2 and those that emit NaCl and KCl.
The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

- Discovering rare red spiral galaxy population from early universe with the James Webb Space Telescope

Date: December 13, 2022
Source: Waseda University


The first publicly released science-quality image from NASA's James Webb Space Telescope, revealed on July 11, 2022, is the deepest infrared view of the universe to date. (Image credit: NASA, ESA, CSA, and STScI)

Spiral galaxies represent one of the most spectacular features in our universe. Among them, spiral galaxies in the distant universe contain significant information about their origin and evolution. However, we have had a limited understanding of these galaxies due to them being too distant to study in detail.

"While these galaxies were already detected among the previous observations using NASA's Hubble Space Telescope and Spitzer Space Telescope, their limited spatial resolution and/or sensitivity did not allow us to study their detailed shapes and properties," explains Junior Researcher Yoshinobu Fudamoto from Waseda University in Japan, who has been researching galaxies' evolution. Now, NASA's James Webb Space Telescope (JWST) has taken things to the next level. In its very first imaging of the galaxy cluster, SMACS J0723.3-7327, JWST has managed to capture infrared images of a population of red spiral galaxies at an unprecedented resolution, revealing their morphology in detail!

Against this backdrop, in a recent article published in *The Astrophysical Journal Letters* on 21 October 2022, a team of researchers comprising Junior Researcher Yoshinobu Fudamoto, Prof. Akio K. Inoue, and Dr. Yuma Sugahara from Waseda University, Japan, has revealed surprising insights into these red spiral galaxies. Among the several red spiral galaxies detected, the researchers focused on the two most extremely red galaxies, RS13 and RS14.

Using spectral energy distribution (SED) analysis, the researchers measured the distribution of energy over wide wavelength range for these galaxies. The SED analysis revealed that these red spiral galaxies belong to the early universe from a period known as the "cosmic noon" (8-10 billion years ago), which followed the Big Bang and the "cosmic dawn." Remarkably, these are among the farthest known spiral galaxies till date.

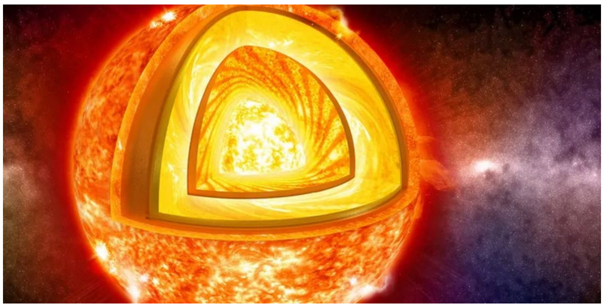
Rare, red spiral galaxies account for only 2% of the galaxies in the local universe. This discovery of red spiral galaxies in the early universe, from the JWST observation covering only an insignificant fraction of space, suggests that such spiral galaxies existed in large numbers in the early universe. The researchers further discovered that one of the red spiral galaxies, RS14, is a "passive" (not forming stars) spiral galaxy, contrary to the intuitive expectation that galaxies in the early universe would be actively forming stars. This detection of a passive spiral galaxy in the JWST's limited field of view is particularly surprising, since it suggests that such passive spiral galaxies could also exist in large numbers in the early universe.

Overall, the findings of this study significantly enhances our knowledge about red spiral galaxies, and the universe as a whole. "Our study showed for the first time that passive spiral galaxies could be abundant in the early universe. While this paper is a pilot study about spiral galaxies in the early universe, confirming and expanding upon this study would largely influence our understanding of the formation and evolution of galactic morphologies," concludes Fudamoto.

- ❖ First ultraviolet imaging of Sun's middle corona

Researchers observed long, web-like structures that discharge particles from the Sun into space

Date: December 12, 2022
Source: Southwest Research Institute


Stock, adventtr

A team of researchers from Southwest Research Institute (SwRI), NASA and the Max Planck Institute for Solar System Research (MPS) have discovered web-like plasma structures in the Sun's middle corona. The researchers describe their innovative new observation method, imaging the middled corona in ultraviolet (UV) wavelength, in a new study published in *Nature Astronomy*. The findings could lead to a better understanding of the solar wind's origins and

its interactions with the rest of the solar system.
Since 1995, the U.S. National Oceanic and Atmospheric Administration has observed the Sun's corona with the Large Angle and Spectrometric Coronagraph (LASCO) stationed aboard the NASA and European Space Agency Solar and Heliospheric Observatory (SOHO) spacecraft to monitor space weather that could affect the Earth. But LASCO has a gap in observations that obscures our view of the middle solar corona, where the solar wind originates.
"We've known since the 1950s about the outflow of the solar wind. As the solar wind evolves, it can drive space weather and affect things like power grids, satellites and astronauts," said SwRI Principal Scientist Dr. Dan Seaton, one of the authors of the study. "The origins of the solar wind itself and its structure remain somewhat mysterious. While we have a basic understanding of processes, we haven't had observations like these before, so we had to work with a gap in information."
To find new ways to observe the Sun's corona, Seaton suggested pointing a different instrument, the Solar Ultraviolet Imager (SUVI) on NOAA's Geostationary Operational Environmental Satellites (GOES), at either side of the Sun instead of directly at it and making UV observations for a month. What Seaton and his colleagues saw were elongated, web-like plasma structures in the Sun's middle corona. Interactions within these structures release stored magnetic energy propelling particles into space.
"No one had monitored what the Sun's corona was doing in UV at this height for that amount of time. We had no idea if it would work or what we would see," he said. "The results were very exciting. For the first time, we have high-quality observations that completely unite our observations of the Sun and the heliosphere as a single system."
Seaton believes these observations could lead to more comprehensive insights and even more exciting discoveries from missions like PUNCH (Polarimeter to Unify the Corona and Heliosphere), an SwRI-led NASA mission that will image how the Sun's outer corona becomes the solar wind.
"Now that we can image the Sun's middle corona, we can connect what PUNCH sees back to its origins and have a more complete view of how the solar wind interacts with the rest of the solar system," Seaton said. "Prior to these observations, very few people believed you could observe the middle corona to these distances in UV. These studies have opened up a whole new approach to observing the corona on a large scale."

- Giant mantle plume reveals Mars is more active than previously thought

Date: December 5, 2022
Source: University of Arizona

Planet Mars illustration (stock image).
Credit: © revers_jr / stock.adobe.com

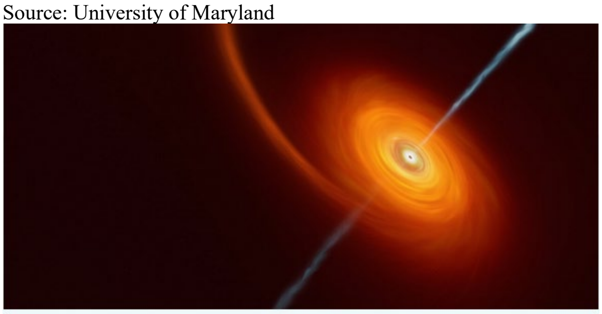
On Earth, shifting tectonic plates reshuffle the planet's surface and make for a dynamic interior, so the absence of such processes on Mars led many to think of it as a dead planet, where not much happened in the past 3 billion years.
In the current issue of *Nature Astronomy*, scientists from the University of Arizona challenge current views of Martian geodynamic evolution with a report on the discovery of an active mantle plume pushing the surface upward and causing earthquakes and volcanic eruptions. The finding suggests that the planet's deceptively quiet surface may hide a more tumultuous interior than previously thought.
"Our study presents multiple lines of evidence that reveal the presence of a giant active mantle plume on present-day Mars," said Adrien Broquet, a postdoctoral research associate in the UArizona Lunar and Planetary Laboratory and co-author of the study with Jeff Andrews-Hanna, an associate professor of planetary science at the LPL.
Mantle plumes are large blobs of warm and buoyant rock that rise from deep inside a planet and push through its intermediate layer -- the mantle -- to reach the base of its crust, causing earthquakes, faulting and volcanic eruptions. The island chain of Hawaii, for example, formed as the Pacific plate slowly drifted over a mantle plume.
"We have strong evidence for mantle plumes being active on Earth and Venus, but this isn't expected on a small and supposedly cold

world like Mars," Andrews-Hanna said.
"Mars was most active 3 to 4 billion years ago, and the prevailing view is that the planet is essentially dead today."
"A tremendous amount of volcanic activity early in the planet's history built the tallest volcanoes in the solar system and blanketed most of the northern hemisphere in volcanic deposits," Broquet said. "What little activity has occurred in recent history is typically attributed to passive processes on a cooling planet."
The researchers were drawn to a surprising amount of activity in an otherwise nondescript region of Mars called Elysium Planitia, a plain within Mars' northern lowlands close to the equator. Unlike other volcanic regions on Mars, which haven't seen major activity for billions of years, Elysium Planitia experienced large eruptions over the past 200 million years.
"Previous work by our group found evidence in Elysium Planitia for the youngest volcanic eruption known on Mars," Andrews-Hanna said. "It created a small explosion of volcanic ash around 53,000 years ago, which in geologic time is essentially yesterday."
Volcanism at Elysium Planitia originates from the Cerberus Fossae, a set of young fissures that stretch for more than 800 miles across the Martian surface. Recently, NASA's InSight team found that nearly all Martian quakes, or mars quakes, emanate from this one region. Although this young volcanic and tectonic activity had been documented, the underlying cause remained unknown.
On Earth, volcanism and earthquakes tend to be associated with either mantle plumes or plate tectonics, the global cycle of drifting continents that continually recycles the crust.
"We know that Mars does not have plate tectonics, so we investigated whether the activity we see in the Cerberus Fossae region could be the result of a mantle plume," Broquet said.
Mantle plumes, which can be viewed as analogous to hot blobs of wax rising in lava lamps. give away their presence on Earth through a classical sequence of events. Warm plume material pushes against the surface, uplifting and stretching the crust. Molten rock from the plume then erupts as flood basalts that create vast volcanic plains.
When the team studied the features of Elysium Planitia, they found evidence of the same sequence of events on Mars. The surface has been uplifted by more than a mile, making it one of the highest regions in Mars' vast northern lowlands. Analyses of subtle variations in the gravity field indicated that this uplift is supported from deep within the planet, consistent with the presence of a mantle plume.
Other measurements showed that the floor of impact craters is tilted in the direction of the plume, further supporting the idea that something pushed the surface up after the craters formed. Finally, when researchers applied a tectonic model to the area, they found that the presence of a giant plume, 2,500 miles wide, was the only way to explain the extension responsible for forming the Cerberus Fossae.
"In terms of what you expect to see with an active mantle plume, Elysium Planitia is checking all the right boxes," Broquet said, adding that the finding poses a challenge for models used by planetary scientists to study the thermal evolution of planets. "This mantle plume has affected an area of Mars roughly equivalent to that of the continental United States. Future studies will have to find a way to account for a very large mantle plume that wasn't expected to be there.
"We used to think that InSight landed in one of the most geologically boring regions on Mars -- a nice flat surface that should be roughly representative of the planet's lowlands," Broquet added. "Instead, our study demonstrates that InSight landed right on top of an active plume head."
The presence of an active plume will affect interpretations of the seismic data recorded by InSight, which must now take into account the fact that this region is far from normal for Mars.
"Having an active mantle plume on Mars today is a paradigm shift for our understanding of the planet's geologic evolution," Broquet said, "similar to when analyses of seismic measurements recorded during the Apollo era demonstrated the moon's core to be molten."
Their findings could also have implications for life on Mars, the authors say. The studied region experienced floods of liquid water in its recent geologic past, though the cause has remained a mystery. The same heat from the plume that is fuelling ongoing volcanic and seismic activity could also melt ice to make the floods -- and drive chemical reactions that could sustain life deep underground.

"Microbes on Earth flourish in environments like this, and that could be true on Mars, as well," Andrews-Hanna said, adding that the discovery goes beyond explaining the enigmatic seismic activity and resurgence in volcanic activity. "Knowing that there is an active giant mantle plume underneath the Martian surface raises important questions regarding how the planet has evolved over time. "We're convinced that the future has more surprises in store."

- ❖ Rare sighting of luminous jet spewed by supermassive black hole

Date: November 30, 2022
Source: University of Maryland



An artistic illustration of how it might look when a star approaches too close to a black hole, where the star is squeezed by the intense gravitational pull of the black hole. Some of the star's material gets pulled in and swirls around the black hole forming a disc. In rare cases, such as this one, jets of matter and radiation are shot out from the poles of the black hole. Credit: ESO/M.Kornmesser

What happens when a dying star flies too close to a supermassive black hole?
According to University of Maryland astronomer Igor Andreoni, several things happen: first, the star is violently ripped apart by the black hole's gravitational tidal forces -- similar to how the Moon pulls tides on Earth but with greater strength. Then, pieces of the star are captured into a swiftly spinning disk orbiting the black hole. Finally, the black hole consumes what remains of the doomed star in the disk. This is what astronomers call a tidal disruption event (TDE).
But in some extremely rare cases, the supermassive black hole launches "relativistic jets" -- beams of matter traveling close to the speed of light -- after destroying a star.
Andreoni, who is a postdoctoral associate in the Department of Astronomy at UMD and NASA Goddard Space Flight Centre, discovered one such case with his team in the Zwicky Transient Facility (ZTF) survey in February 2022. After the group publicly announced the sighting, the event was named "AT2022cmc." The team published its findings in the journal *Nature* on November 30, 2022.
"The last time scientists discovered one of these jets was well over a decade ago," said Michael Coughlin, an assistant professor of astronomy at the University of Minnesota Twin Cities and co-lead on the project. "From the data we have, we can estimate that relativistic jets are launched in only 1% of these destructive events, making AT2022cmc an extremely rare occurrence. In fact, the luminous flash from the event is among the brightest ever observed."
Before AT2022cmc, the only two previously known jetted TDEs were discovered through gamma-ray space missions, which detect the highest-energy forms of radiation produced by these jets. As the last such discovery was made in 2012, new methods were required to find more events of this nature. To help address that need, Andreoni and his team implemented a novel, "big picture" tactic to find AT2022cmc: ground-based optical surveys, or general maps of the sky without specific observational targets. Using ZTF, a wide-field sky survey taken by the Samuel Oschin Telescope in California, the team was able to identify and uniquely study the otherwise dormant-looking black hole.
"We developed an open-source data pipeline to store and mine important information from the ZTF survey and alert us about atypical events in real time," Andreoni explained. "The rapid analysis of ZTF data, the equivalent to a million pages of information every night, allowed us to quickly identify the TDE with relativistic jets and make follow-up observations that revealed an exceptionally high luminosity across the electromagnetic spectrum, from the X-rays to the millimetre and radio."
Follow up observations with many observatories confirmed that AT2022cmc was fading rapidly and the ESO Very Large Telescope revealed that AT2022cmc was at cosmological distance, 8.5 billion light years away.
Hubble Space Telescope optical/infrared images and radio observations from the Very Large Array pinpointed the location of AT2022cmc with extreme precision. The researchers believe that AT2022cmc was at the centre of a galaxy that is not yet visible because the light from AT2022cmc outshone it, but future space observations with Hubble or James Webb Space Telescopes may unveil the galaxy when the transient eventually disappears.
It is still a mystery why some TDEs launch jets while others do not seem to. From their observations, Andreoni and his team

concluded that the black holes in AT2022cmc and other similarly jetted TDEs are likely spinning rapidly so as to power the extremely luminous jets. This suggests that a rapid black hole spin may be one necessary ingredient for jet launching -- an idea that brings researchers closer to understanding the physics of supermassive black holes at the centre of galaxies billions of light years away.
"Astronomy is changing rapidly," Andreoni said. "More optical and infrared all-sky surveys are now active or will soon come online. Scientists can use AT2022cmc as a model for what to look for and find more disruptive events from distant black holes. This means that more than ever, big data mining is an important tool to advance our knowledge of the universe."