South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 579 – October 7th 2023 Editor: Roger Burgess

Main Talk Dr Mike Leggett FRAS FBIS via Zoom at the planetarium. "Astronomy in the ancient world". Beginning with a brief summary of archaeoastronomy, this talk is an overview of the astronomers and astronomical knowledge in Ancient Egypt, Mesopotamia, Classical Greece and the Hellenistic World (including the Great Library at Alexandria). There are some great names along the way, including Ptolemy, Aristotle, Hipparchus, Eratosthenes, Pythagoras and Aristarchus.

Please support a raffle we are organizing this month

- Astronomers find abundance of Milky Way-like Galaxies in early Universe, rewriting cosmic evolution theories

Date: September 22, 2023
Source: University of Manchester

Galaxies from the early Universe are more like our own Milky Way than previously thought, flipping the entire narrative of how scientists think about structure formation in the Universe, according to new research published today.
Using the James Webb Space Telescope (JWST), an international team of researchers including those at The University of Manchester and University of Victoria in Canada discovered that galaxies like our own Milky Way dominate throughout the universe and are surprisingly common.
These galaxies go far back in the Universe's history with many of these galaxies forming 10 billion years ago or longer.
The Milky Way is a typical 'disk' galaxy, which a shape similar to a pancake or compact disk, rotating about its centre and often containing spiral arms. These galaxies are thought to be the most common in the nearby Universe and might be the types of galaxies where life can develop given the nature of their formation history.
However, astronomers previously considered that these types of galaxies were too fragile to exist in the early Universe when galaxy mergers were more common, destroying what we thought was their delicate shapes.
The new discovery, published today in the *Astrophysical Journal*, finds that these 'disk' galaxies are ten times more common than what astronomers believed based on previous observations with the Hubble Space Telescope.
Christopher Conselice, *Professor* of Extragalactic Astronomy at The University of Manchester, said: "Using the Hubble Space Telescope we thought that disk galaxies were almost non-existent until the Universe was about six billion years old, these new JWST results push the time these Milky Way-like galaxies form to almost the beginning of the Universe."
The research completely overturns the existing understanding of how scientists think our Universe evolves, and the scientists say new ideas need to be considered.
Lead author, Leonardo Ferreira from the University of Victoria, said: "For over 30 years it was thought that these disk galaxies were rare in the early Universe due to the common violent encounters that galaxies undergo. The fact that JWST finds so many is another sign of the power of this instrument and that the structures of galaxies form earlier in the Universe, much earlier in fact, than anyone had anticipated. "
It was once thought that disk galaxies such as the Milky Way were relatively rare through cosmic history, and that they only formed after the Universe was already middle aged.
Previously, astronomers using the Hubble Space Telescope believed that galaxies had mostly irregular and peculiar structures that resemble mergers. However, the superior

abilities of JWST now allows us to see the true structure of these galaxies for the first time.
The researchers say that this is yet another sign that 'structure' in the Universe forms much quicker than anyone had anticipated.
Professor Conselice continues: "These JWST results show that disk galaxies like our own Milky Way, are the most common type of galaxy in the Universe. This implies that most stars exist and form within these galaxies which is changing our complete understanding of how galaxy formation occurs. These results also suggest important questions about dark matter in the early Universe which we know very little about."
"Based on our results astronomers must rethink our understanding of the formation of the first galaxies and how galaxy evolution occurred over the past 10 billion years."

- Water world? Methane, carbon dioxide in atmosphere of massive exoplanet

Date: September 11, 2023
Source: NASA/Goddard Space Flight Centre

An artist's rendition of exoplanet K2-18 b and the dwarf star it orbits. New observations from the James Webb Space Telescope support the idea that the world, discovered in 2015, has a hydrogen-rich atmosphere and water ocean. NASA, ESA, CSA, Joseph Olmsted (STScI)

A new investigation with NASA's James Webb Space Telescope into K2-18 b, an exoplanet 8.6 times as massive as Earth, has revealed the presence of carbon-bearing molecules including methane and carbon dioxide. Webb's discovery adds to recent studies suggesting that K2-18 b could be a Hycean exoplanet, one which has the potential to possess a hydrogen-rich atmosphere and a water ocean-covered surface.
The first insight into the atmospheric properties of this habitable-zone exoplanet came from observations with NASA's Hubble Space Telescope, which prompted further studies that have since changed our understanding of the system.
K2-18 b orbits the cool dwarf star K2-18 in the habitable zone and lies 120 light-years from Earth in the constellation Leo. Exoplanets such as K2-18 b, which have sizes between those of Earth and Neptune, are unlike anything in our solar system. This lack of equivalent nearby planets means that these 'sub-Neptunes' are poorly understood, and the nature of their atmospheres is a matter of active debate among astronomers.
The suggestion that the sub-Neptune K2-18 b could be a Hycean exoplanet is intriguing, as some astronomers believe that these worlds are promising environments to search for evidence for life on exoplanets.
"Our findings underscore the importance of considering diverse habitable environments in the search for life elsewhere," explained Nikku Madhusudhan, an astronomer at the University of Cambridge and lead author of the paper announcing these results. "Traditionally, the search for life on exoplanets has focused primarily on smaller rocky planets, but the larger Hycean worlds are significantly more conducive to atmospheric observations."
The abundance of methane and carbon dioxide, and shortage of ammonia, support the hypothesis that there may be a water ocean underneath a hydrogen-rich atmosphere in K2-18 b. These initial Webb observations also provided a possible detection of a molecule called dimethyl sulphide (DMS). On Earth, this is only produced by life. The bulk of the DMS in Earth's atmosphere is emitted from phytoplankton in marine environments.
The inference of DMS is less robust and requires further validation. "Upcoming Webb observations should be able to confirm if DMS is indeed present in the atmosphere of K2-18 b at significant levels," explained Madhusudhan.
While K2-18 b lies in the habitable zone, and is now known to harbour carbon-bearing molecules, this does not necessarily mean that the planet can support life. The planet's large size -- with a radius 2.6 times the radius of Earth -- means that the planet's interior likely contains a large mantle of high-pressure ice, like Neptune, but with a thinner hydrogen-rich atmosphere and an ocean surface. Hycean worlds are predicted to have oceans of water. However, it is also possible that the ocean is too hot to be habitable or be liquid.

"Although this kind of planet does not exist in our solar system, sub-Neptunes are the most common type of planet known so far in the galaxy," explained team member Subhajit Sarkar of Cardiff University. "We have obtained the most detailed spectrum of a habitable-zone sub-Neptune to date, and this allowed us to work out the molecules that exist in its atmosphere."

Characterizing the atmospheres of exoplanets like K2-18 b -- meaning identifying their gases and physical conditions -- is a very active area in astronomy. However, these planets are outshone -- literally -- by the glare of their much larger parent stars, which makes exploring exoplanet atmospheres particularly challenging.

The team sidestepped this challenge by analysing light from K2-18 b's parent star as it passed through the exoplanet's atmosphere. K2-18 b is a transiting exoplanet, meaning that we can detect a drop in brightness as it passes across the face of its host star. This is how the exoplanet was first discovered in 2015 with NASA's K2 mission. This means that during transits a tiny fraction of starlight will pass through the exoplanet's atmosphere before reaching telescopes like Webb. The starlight's passage through the exoplanet atmosphere leaves traces that astronomers can piece together to determine the gases of the exoplanet's atmosphere.

"This result was only possible because of the extended wavelength range and unprecedented sensitivity of Webb, which enabled robust detection of spectral features with just two transits," said Madhusudhan. "For comparison, one transit observation with Webb provided comparable precision to eight observations with Hubble conducted over a few years and in a relatively narrow wavelength range."

"These results are the product of just two observations of K2-18 b, with many more on the way," explained team member Savvas Constantinou of the University of Cambridge. "This means our work here is but an early demonstration of what Webb can observe in habitable-zone exoplanets."

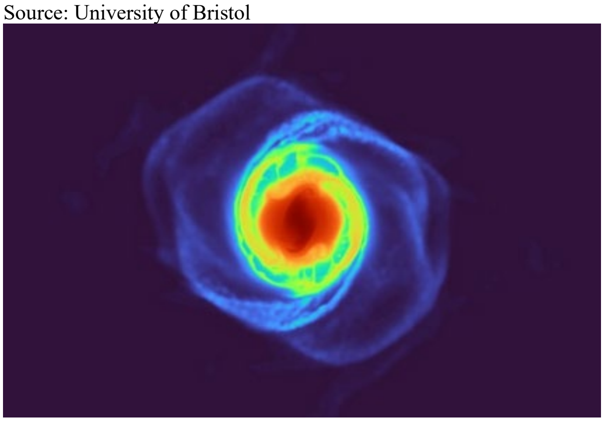
The team's results were accepted for publication in *The Astrophysical Journal Letters.*

The team now intends to conduct follow-up research with the telescope's MIRI (Mid-Infrared Instrument) spectrograph that they hope will further validate their findings and provide new insights into the environmental conditions on K2-18 b.

"Our ultimate goal is the identification of life on a habitable exoplanet, which would transform our understanding of our place in the universe," concluded Madhusudhan. "Our findings are a promising step towards a deeper understanding of Hycean worlds in this quest."

- New giant planet evidence of possible planetary collisions

Date: August 31, 2023
Source: University of Bristol



Impact simulation

A Neptune-sized planet denser than steel has been discovered by an international team of astronomers, who believe its composition could be the result of a giant planetary clash.

TOI-1853b's mass is almost twice that of any other similar-sized planet known and its density is incredibly high, meaning that it is made up of a larger fraction of rock than would typically be expected at that scale.

In the study, published today in *Nature*, scientists led by Luca Naponiello of University of Rome Tor Vergata and the University of Bristol suggest that this is the result of planetary collisions. These huge impacts would have removed some of the lighter atmosphere and water leaving a multitude of rock behind.

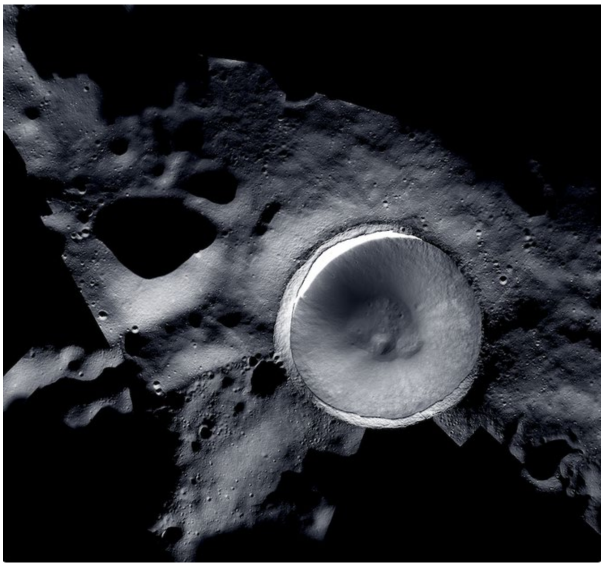
Senior Research Associate and co-author Dr Phil Carter from Bristol's School of Physics, explained: "We have strong evidence for highly energetic collisions between planetary bodies in our solar system, such as the existence of Earth's Moon, and good evidence from a small number of exoplanets.

"We know that there is a huge diversity of planets in exoplanetary systems; many have no analogue in our solar system but often have masses and compositions between that of the rocky planets and Neptune/Uranus (the ice giants).

"Our contribution to the study was to model extreme giant impacts that could potentially remove the lighter atmosphere and water/ice from the original larger planet in order to produce the extreme density measured.
"We found that the initial planetary body would likely have needed to be water-rich and suffer an extreme giant impact at a speed of greater than 75 km/s in order to produce TOI-1853b as it is observed."
This planet provides new evidence for the prevalence of giant impacts in the formation of planets throughout the galaxy. This discovery helps to connect theories for planet formation based on the solar system to the formation of exoplanets. The discovery of this extreme planet provides new insights into the formation and evolution of planetary systems.
Postgraduate student and co-author Jingyao Dou said: "This planet is very surprising! Normally we expect planets forming with this much rock to become gas giants like Jupiter which have densities similar to water.
"TOI-1853b is the size of Neptune but has a density higher than steel. Our work shows that this can happen if the planet experienced extremely energetic planet-planet collisions during its formation.
"These collisions stripped away some of the lighter atmosphere and water leaving a substantially rock-enriched, high-density planet."
Now the team plan detailed follow-up observations of TOI-1853b to attempt to detect any residual atmosphere and examine its composition.
Associate Professor and co-author Dr Zoë Leinhardt concluded: "We had not previously investigated such extreme giant impacts as they are not something we had expected.
There is much work to be done to improve the material models that underlie our simulations, and to extend the range of extreme giant impacts modelled."
The simulations were performed using the computational facilities of the Advanced Computing Research Centre, University of Bristol. Funders include Science and Technology Facilities Council (STFC) and China Scholarship Council.

- New findings suggest Moon may have less water than previously thought

Moon's permanently shadowed regions are younger than previously estimated
Date: September 18, 2023
Source: Southwest Research Institute



View larger. | This is a new composite image of the Shackleton crater at the moon's South Pole. It combines imagery from the Lunar Reconnaissance Orbiter Camera (LROC) and ShadowCam, a NASA instrument onboard the Korea Aerospace Research Institute (KARI) spacecraft called Danuri. The interior of the crater is a permanently shadowed region containing ice deposits. A new study, however, says there is less water ice on the moon in these regions than scientists previously thought. Image via NASA/ KARI/ ASU.

A team including Southwest Research Institute's Dr. Raluca Rufu recently calculated that most of the Moon's permanently shadowed regions (PSRs) are at most around 3.4 billion years old and can contain relatively young deposits of water ice. Water resources are considered key for sustainable exploration of the Moon and beyond, but these findings suggest that current estimates for cold-trapped ices are too high.
The current tilt of the Moon's spin axis combined with its orbital inclination -- the angle to Earth's orbital plane -- and the Sun's low angle creates permanent shadows at its poles. PSRs are some of the coldest spots in the solar system, allowing them to trap volatile chemicals, including water ice, that would immediately transform directly from a solid to a gas in the harsh, airless sunshine that falls in most other places on the Moon.
"We think the Earth-Moon system formed following a giant impact between early Earth and another protoplanet," said Rufu, a Sagan Fellow who is the second author of a Science Advances paper. "The Moon formed from the impact-generated debris disk, migrating away from Earth over time. Around 4.1 billion years ago the Moon experienced a major spin axis reorientation when its tilt reached high angles before it damped down to the configuration we see today. As the axial tilt decreased, PSRs appeared at the poles and grew over time."
The team used AstroGeo22, a new Earth-Moon evolution simulation tool, to calculate

the Moon's axial tilt over time. Together with surface height measurements from the Lunar Orbital Altimeter Laser data (LOLA), the team estimated the evolution of the shadowed areas over time.
"The time evolution of the Moon-Earth distance remained an unsolved problem for half a century," Rufu said. "However, these new geological proxies for the history of the Earth-Moon system allow us to calculate the Moon's axial tilt and the extent of PSRs over time."
In 2009, NASA crashed the two-ton Atlas Centaur rocket body, part of the Lunar Crater Observation and Sensing Satellite (LCROSS), near the south pole of the Moon. It struck the floor of Cabeus crater, creating a plume of debris examined for the presence of water and other chemicals in the lunar regolith. A shepherding satellite travelling four minutes behind the Centaur and several Earth-orbiting satellites, including the Hubble Space Telescope, monitored the impact.
"Our work suggests that Cabeus crater became a PSR less than a billion years ago. The various volatiles detected in the plume created by LCROSS indicate that ice-trapping continued into relatively recent times," said Norbert Schörghofer, the lead author of this paper from the Planetary Science Institute. "Impacts and outgassing are potential sources of water but peaked early in lunar history, when the present-day PSRs did not yet exist. The age of PSRs largely determines the amount of water ice that could be trapped in the lunar polar regions. Information about the abundance of water ice in PSRs is particularly important in planning for upcoming crewed and uncrewed missions to the Moon searching for water."
This key resource can be used to create air and rocket fuel and sustain human habitation. NASA and other entities plan to send rovers and humans to characterize the water ice within PSRs.

- Astronomers discover newborn galaxies with the James Webb Space Telescope

Date: September 22, 2023
Source: University of Copenhagen - Faculty of Science


A look through time with the James Webb Space Telescope. The big galaxy in

With the launch of the James Webb Space Telescope, astronomers are now able to peer so far back in time that we are approaching the epoch where we think that the first galaxies were created. Throughout most of the history of the Universe, galaxies seemingly tend to follow a tight relation between how many stars they have formed, and how many heavy elements they have formed. But for the first time we now see signs that this relation between the number of stars and elements does not hold for the earliest galaxies. The reason is likely that these galaxies simply are in the process of being created, and have not yet had the time to create the heavy elements.
The Universe is teeming with galaxies -- immense collections of stars and gas -- and as we peer deep into the cosmos, we see them near and far. Because the light has spent more time reaching us, the farther away a galaxy is, we are essentially looking back through time, allowing us to construct a visual narrative of their evolution throughout the history of the Universe.
Observations have shown us that galaxies through the last 12 billion years -- that is, 5/6 of the age of the Universe -- have been living their life in a form of equilibrium: There appears to be a fundamental, tight relation between on one hand how many stars they have formed, and on the other hand how many heavy elements they have formed. In this context, "heavy elements," means everything heavier than hydrogen and helium.
This relation makes sense, because the Universe consisted originally only of these two lightest elements. All heavier elements, such as carbon, oxygen, and iron, was created later by the stars.

James Webb peers deeper

The very first galaxies should therefore be "unpolluted" by heavy elements. But until recently we haven't been able to look so far back in time. In addition to being far away, the reason is that the longer light travels through space, the redder it becomes. For the

most distant galaxies you have to look all the way into the infrared part of the spectrum, and only with the launch of James Webb did we have a telescope big and sensitive enough to see so far.
And the space telescope did not disappoint: Several has James Webb broken its own record for the most distant galaxy, and now it finally seems that we are reaching the epoch where some of the very first galaxies were created.
In a new study, published today in the scientific journal Nature Astronomy, a team of astronomers from the Danish research centre Cosmic Dawn Centre at the Niels Bohr Institute and DTU Space in Copenhagen, has discovered what seems indeed to be some of the very first galaxies which are still in the process of being formed.
"Until recently it has been near-impossible to study how the first galaxies are formed in the early Universe, since we simply haven't had the adequate instrumentation. This has now changed completely with the launch of James Webb," says Kasper Elm Heintz, leader of the study and assistant professor at the Cosmic Dawn Centre.

Fundamental relation breaks down

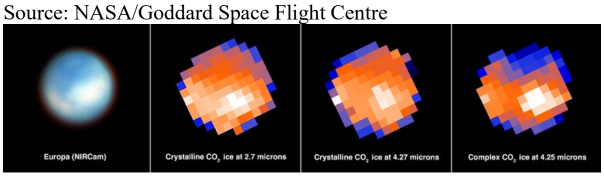
The relationship between the total stellar mass of the galaxy and the number of heavy elements is a bit more complex than that. How fast the galaxy produces new stars also has something to say. But if you correct for that, you get a beautiful, linear relationship: The more massive the galaxy, the more heavy elements.
But this relation is now being challenged by the latest observations.
"When we analysed the light from 16 of these first galaxies, we saw that they had significantly fewer heavy elements, compared to what you'd expect from their stellar masses and the number of new stars they produced," says Kasper Elm Heintz.
In fact, the galaxies turned out to have, on average, four times less amounts of heavy elements that in the later Universe. These results are in stark contrast to the current model where galaxies evolve in a form of equilibrium throughout most of the history of the Universe.

Predicted by theories

The result is not entirely surprising though. Theoretical models of galaxy formation, based on detailed computer programs, do predict something similar. But now we've seen it!
The explanation, as proposed by the authors in the article, is simply that we are witnessing galaxies in the process of being created. Gravity has gathered the first clumps of gas, which have begun to form stars.
If the galaxies then lived their lives undisturbed, the stars would quickly enrich them with heavy elements. But in between the galaxies at that time were large amounts of fresh, unpolluted gas, streaming down to the galaxies faster than the stars can keep up.
"The result gives us the first insight into the earliest stages of galaxy formation which appear to be more intimately connected with the gas in between the galaxies than we thought.
This is one of the first James Webb observations on this topic, so we're still waiting to see what the larger, more comprehensive observations that are currently being carried out can tell us.
There is no doubt that we will shortly have a much clearer understanding of how galaxies and the first structures began their formation during the first billion years after the Big Bang," Kasper Elm Heintz concludes.
The study is published in *Nature Astronomy*.

- ❖ Carbon source found on surface of Jupiter's moon Europa

Date: September 22, 2023
Source: NASA/Goddard Space Flight Centre



This graphic shows a map of Europa's surface with NIRCam (Near Infrared Camera) on NASA's James Webb Space Telescope in the first panel and compositional maps derived from Webb's NIRSpec/IFU (Near Infrared Spectrograph's Integral Field Unit) data in the following three panels. In the compositional maps, the white pixels correspond to carbon dioxide in the large-scale region of disrupted chaos terrain known as Tara Regio (centre and right), with additional concentrations within portions of the chaos region Powys Regio (left). The second and third panels show evidence of crystalline carbon dioxide, while the fourth panel indicates a complexed and amorphous form of carbon dioxide.
Credits: Science Credit: Geronimo Villanueva (NASA/GSFC), Samantha Trumbo (Cornell Univ.), NASA, ESA, CSA. Image Processing Credit: Geronimo Villanueva (NASA/GSFC), Alyssa Pagan (STScI)
Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

Jupiter's moon Europa is one of a handful of worlds in our solar system that could potentially harbour conditions suitable for life. Previous research has shown that beneath its water-ice crust lies a salty ocean of liquid water with a rocky seafloor. However, planetary scientists had not confirmed if that ocean contained the chemicals needed for life, particularly carbon.

Astronomers using data from NASA's James Webb Space Telescope have identified carbon dioxide in a specific region on the icy surface of Europa. Analysis indicates that this carbon likely originated in the subsurface ocean and was not delivered by meteorites or other external sources. Moreover, it was deposited on a geologically recent timescale. This discovery has important implications for the potential habitability of Europa's ocean.

"On Earth, life likes chemical diversity -- the more diversity, the better. We're carbon-based life. Understanding the chemistry of Europa's ocean will help us determine whether it's hostile to life as we know it, or if it might be a good place for life," said Geronimo Villanueva of NASA's Goddard Space Flight Centre in Greenbelt, Maryland, lead author of one of two independent papers describing the findings.

"We now think that we have observational evidence that the carbon we see on Europa's surface came from the ocean. That's not a trivial thing. Carbon is a biologically essential element," added Samantha Trumbo of Cornell University in Ithaca, New York, lead author of the second paper analysing these data.

NASA plans to launch its Europa Clipper spacecraft, which will perform dozens of close flybys of Europa to further investigate whether it could have conditions suitable for life, in October 2024.

A Surface-Ocean Connection

Webb finds that on Europa's surface, carbon dioxide is most abundant in a region called Tara Regio -- a geologically young area of generally resurfaced terrain known as "chaos terrain." The surface ice has been disrupted, and there likely has been an exchange of material between the subsurface ocean and the icy surface.

"Previous observations from the Hubble Space Telescope show evidence for ocean-derived salt in Tara Regio," explained Trumbo. "Now we're seeing that carbon dioxide is heavily concentrated there as well. We think this implies that the carbon probably has its ultimate origin in the internal ocean."

"Scientists are debating how much Europa's ocean connects to its surface. I think that question has been a big driver of Europa exploration," said Villanueva. "This suggests that we may be able to learn some basic things about the ocean's composition even before we drill through the ice to get the full picture."

Both teams identified the carbon dioxide using data from the integral field unit of Webb's Near-Infrared Spectrograph (NIRSpec). This instrument mode provides spectra with a resolution of 200 x 200 miles (320 x 320 kilometres) on the surface of Europa, which has a diameter of 1,944 miles, allowing astronomers to determine where specific chemicals are located.

Carbon dioxide isn't stable on Europa's surface. Therefore, the scientists say it's likely that it was supplied on a geologically recent timescale -- a conclusion bolstered by its concentration in a region of young terrain.

"These observations only took a few minutes of the observatory's time," said Heidi Hammel of the Association of Universities for Research in Astronomy, a Webb interdisciplinary scientist leading Webb's Cycle 1 Guaranteed Time Observations of the solar system. "Even with this short period of time, we were able to do really big science. This work gives a first hint of all the amazing solar system science we'll be able to do with Webb."

Searching for a Plume

Villanueva's team also looked for evidence of a plume of water vapor erupting from Europa's surface. Researchers using NASA's Hubble Space Telescope reported tentative detections of plumes in 2013, 2016, and 2017. However, finding definitive proof has been difficult.

The new Webb data shows no evidence of plume activity, which allowed Villanueva's team to set a strict upper limit on the rate of material potentially being ejected. The team stressed, however, that their non-detection does not rule out a plume.

"There is always a possibility that these plumes are variable and that you can only see them at certain times. All we can say with 100% confidence is that we did not detect a plume at Europa when we made these observations with Webb," said Hammel.

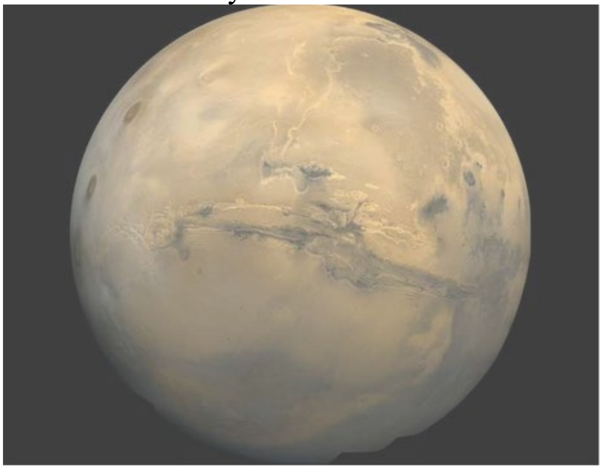
These findings may help inform NASA's Europa Clipper mission, as well as ESA's (European Space Agency's) upcoming Jupiter Icy Moons Explorer (JUICE).

The two papers will be published in *Science* on Sept. 21.

- ❖ New Mars gravity analysis improves understanding of possible ancient ocean

Date: September 20, 2023

Source: University of Alaska Fairbanks



This image is a mosaic of the Valles Marineris hemisphere of Mars in a view similar to that which a person would see from a spacecraft. Credit: NASA, image processing by Jody Swann/Tammy Becker/Alfred McEwen

The first use of a novel method of analysing Mars' gravitational force supports the idea that the planet once had an extensive northern ocean.

In doing so, the method defines the scope of what scientists refer to as the northern Martian paleo-ocean in more detail.

The work was published in July in the journal *Icarus*, which is affiliated with the American Astronomical Society's Division for Planetary Sciences.

The research was led by Jaroslav Klokočník, professor emeritus at the Astronomical Institute of the Czech Academy of Sciences. Gunther Kletetschka, associate research professor at the University of Alaska Fairbanks Geophysical Institute, is among the three co-authors. Kletetschka is also affiliated with Charles University in the Czech Republic.

"A lot of people are excited about water on Mars because there may be life forms that once existed on Mars or maybe exist today in some bacterial form," Kletetschka said. "We can use this gravity approach to look for water on Mars, because we have done it already on Earth.

"In an area of northern Africa, for example, this gravity approach found a shoreline of a long-ago lake, and its finding was consistent with the archaeological evidence indicating a shoreline of that lake," he said.

The authors write that analysing the gravity aspects of Mars to better understand the planet improves upon prior approaches. They note that it can "provide complete information with a better insight of the celestial body, applicable in geology, geophysics, hydrology, glaciology and other disciplines."

The work by Kletetschka and colleagues differs from the traditional approach of mapping a surface based on gravity anomalies alone.

Gravity anomalies are areas of greater or weaker gravitational force exerted by a planetary body's surface features. A mountain would exert a greater gravitational force because it has a higher concentration of mass than would be expected on a planet without surface features. Ocean basins and trenches would have less gravitational force.

In their Mars research, the authors used a process developed by Klokočník that analyses gravity aspects calculated from gravity anomaly measurements. Gravity aspects are mathematical products that characterize the gravity anomalies.

They also used topographic data from the Mars Orbital Laser Altimeter instrument aboard NASA's Mars Global Surveyor, which launched in November 1996 and mapped the planet for 4 ½ years.

Klokočník used that approach to confirm earlier research about the existence of extensive paleolakes or paleoriver systems under the Saharan sands on Earth. His 2017 research paper also suggested a part of the Grand Egyptian Sand Sea as another candidate for a paleolake.

The gravity aspects method has also been used in a comparison of Earth's geographic features to those of the cloud-shrouded Venus. That research is described in a July 2023 paper in the journal *Scientific Reports* in which Kletetschka is a co-author.

- New recipes for origin of life may point way to distant, inhabited planets

Date: September 19, 2023
Source: University of Wisconsin-Madison

Life on a faraway planet -- if it's out there -- might not look anything like life on Earth. But there are only so many chemical ingredients in the universe's pantry, and only so many ways to mix them. A team led by scientists at the University of Wisconsin-Madison has exploited those limitations to write a

cookbook of hundreds of chemical recipes with the potential to give rise to life.
Their ingredient list could focus the search for life elsewhere in the universe by pointing out the most likely conditions -- planetary versions of mixing techniques, oven temperatures and baking times -- for the recipes to come together.
The process of progressing from basic chemical ingredients to the complex cycles of cell metabolism and reproduction that define life, the researchers say, requires not only a simple beginning but also repetition.
"The origin of life really is a something-from-nothing process," says Betül Kaçar, a NASA-supported astrobiologist and UW-Madison professor of bacteriology. "But that something can't happen just once. Life comes down to chemistry and conditions that can generate a self-reproducing pattern of reactions."
Chemical reactions that produce molecules that encourage the same reaction to happen again and again are called autocatalytic reactions. In a new study published Sept. 18 in the *Journal of the American Chemical Society*, Zhen Peng, a postdoctoral researcher in the Kaçar laboratory, and collaborators compiled 270 combinations of molecules -- involving atoms from all groups and series across the periodic table -- with the potential for sustained autocatalysis.
"It was thought that these sorts of reactions are very rare," says Kaçar. "We are showing that it's actually far from rare. You just need to look in the right place."
The researchers focused their search on what are called comproportionation reactions. In these reactions, two compounds that include the same element with different numbers of electrons, or reactive states, combine to create a new compound in which the element is in the middle of the starting reactive states.
To be autocatalytic, the outcome of the reaction also needs to provide starting materials for the reaction to occur again, so the output becomes a new input says Zach Adam, a co-author of the study and a UW-Madison geoscientist studying the origins of life on Earth. Comproportionation reactions result in multiple copies of some of the molecules involved, providing materials for the next steps in autocatalysis.
"If those conditions are right, you can start with relatively few of those outputs," Adam says. "Every time you take a turn of the cycle you spit out at least one extra output which speeds up the reaction and makes it happen even faster."
Autocatalysis is like a growing population of rabbits. Pairs of rabbits come together, produce litters of new rabbits, and then the new rabbits grow up to pair off themselves and make even more rabbits. It doesn't take many rabbits to soon have many more rabbits.
Looking for floppy ears and fuzzy tails out in the universe, however, probably isn't a winning strategy. Instead, Kaçar hopes chemists will pull ideas from the new study's recipe list and test them out in pots and pans simulating extraterrestrial kitchens.
"We will never definitively know what exactly happened on this planet to generate life. We don't have a time machine," Kaçar says. "But, in a test tube, we can create multiple planetary conditions to understand how the dynamics to sustain life can evolve in the first place."
Kaçar leads a NASA-supported consortium called MUSE, for Metal Utilization & Selection Across Eons. Her lab will focus on reactions including the elements molybdenum and iron, and she is excited to see what others cook up from the most exotic and unusual parts of the new recipe book.
"Carl Sagan said if you want to bake a pie from scratch, first you must create the universe," Kaçar says. "I think if we want to understand the universe, first we must bake a few pies."
This research was funded in part by grants from NASA Astrobiology Program (80NSSC22K0546), the John Templeton Foundation (62578 and 61926), the Research Corporation for Science Advancement (28788) and the Australian Research Council (DP210102133 and FT220100757).

- Tag team of the James Webb Space Telescope and ALMA captures the core of the most distant galaxy protocluster

Date: September 20, 2023
Source: University of Tsukuba

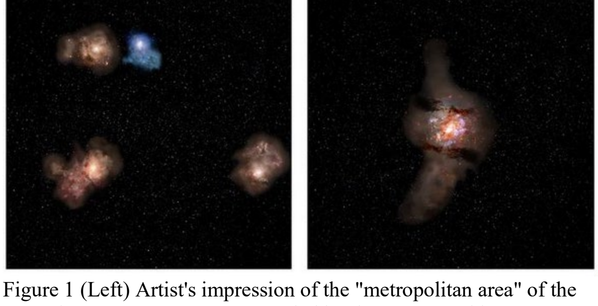


Figure 1 (Left) Artist's impression of the "metropolitan area" of the protocluster A2744ODz7p9 revealed by the James Webb Space

Telescope and ALMA. (Right) Artist's impression of what the "metropolitan area" will become tens of millions of years after the observed time. Credit: NAOJ

An international research team led by Assistant Professor Takuya Hashimoto (University of Tsukuba, Japan) and Researcher Javier Álvarez-Márquez (El Centro de Astrobiología (CAB, CSIC-INTA), Spain) has used the James Webb Space Telescope and the Atacama Large Millimetre/submillimetre Array to observe the most distant galaxy protocluster to date, 13.14 billion light-years away. The team has successfully captured the "core region" of the galaxy protocluster, which corresponds to a metropolitan area with a particularly high number density of galaxies.

The team has revealed that many galaxies are concentrated in a small area and that the growth of galaxies is accelerated. Furthermore, the team used simulations to predict the future of the metropolitan area and found that the region will merge into one larger galaxy within tens of millions of years. These results are expected to provide important clues regarding the birth and growth of galaxies.

The study of how individual stars are born and die in galaxies, how new stars are born from remnants of old stars, and how galaxies themselves grow are important themes in astronomy, as they provide insight into our roots in the Universe. Galaxy clusters, one of the largest structures in the Universe, are the assembly of more than 100 galaxies which are bound together through mutual gravitational force. Observations of nearby galaxies have shown that the growth of a galaxy depends on its environment in the sense that mature stellar populations are commonly seen in regions where galaxies are densely collected. This is referred to as the "environment effect." Although the environment effect has been considered an important piece to understand galaxy formation and evolution, it is not well known when the effect initiated in the history of the Universe. One of the keys to understanding this is to observe the ancestors of galaxy clusters shortly after the birth of the Universe; known as galaxy protoclusters (hereafter protoclusters), these are assemblies of about 10 distant galaxies. Fortunately, astronomy allows us to observe the distant Universe as it was in the past. For example, light from a galaxy 13 billion light-years away takes 13 billion years to reach Earth, so what we observe now is what that galaxy looked like 13 billion years ago. However, light that travels 13 billion light-years becomes fainter, so the telescopes that observe it must have high sensitivity and spatial resolution.

An international research team led by Assistant Professor Takuya Hashimoto (University of Tsukuba, Japan) and researcher Javier Álvarez-Márquez (Spanish Centre for Astrobiology) has used the James Webb Space Telescope (JWST, observing visible and infrared light) and the Atacama Large Millimetre/submillimetre Array (ALMA, observing radio waves) to study the "core region" of the protocluster A2744z7p9OD.

The protocluster A2744z7p9OD had been announced as the most distant proto-cluster at 13.14 billion light-years[1] away based on observations with JWST by another research group[2]. "However, we have not been able to observe the entire core region, the metropolitan area, with the largest number of galaxy candidates in this protocluster. It was unclear whether the environmental effects of galaxies had begun in this protocluster. So, we decided to focus our research on the core region," says Hashimoto.

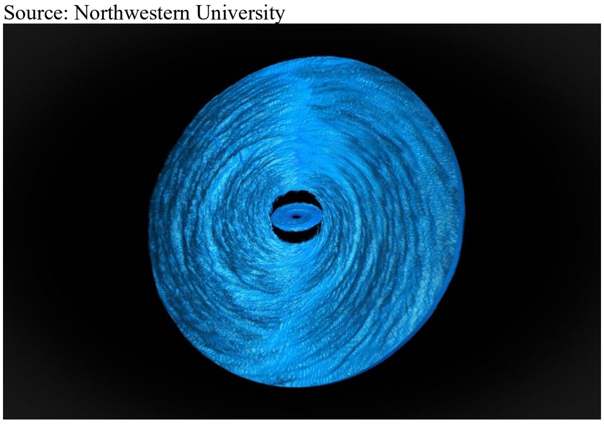
The research team first observed the core region of this protocluster using JWST. Using NIRSpec, an instrument that observes spectra at wavelengths ranging from visible to near-infrared, the team made integral field spectroscopy observations that can simultaneously acquire spectra from all locations within the field of view. The team has successfully detected ionized oxygen-ion light ([OIII] 5008 Å) from four galaxies in a quadrangle region measuring 36,000 light-years along a side, which is equivalent to half the radius of the Milky Way galaxy (. Based on the redshift of this light (the elongation of the wavelength due to the cosmic expansion), the distance of the four galaxies from the Earth was identified as 13.14 billion light years. "I was surprised when we identified four galaxies by detecting oxygen-ion emission at almost the same distance. The 'candidate galaxies' in the core region were indeed members of the most distant protocluster," says Yuma Sugahara (Waseda/NAOJ), who led the JWST data analysis.

In addition, the research team paid attention to the archival ALMA data, which had already been acquired for this region. The data captures radio emission from cosmic dust in these distant galaxies. As a result of analyses,

they detected dust emissions from three of the four galaxies. This is the first detection of dust emission in member galaxies of a protocluster this far back in time. Cosmic dust in galaxies is thought to be supplied by supernova explosions at the end of the evolution of massive stars in the galaxies, which provide the material for new stars. Therefore, the presence of large amounts of dust in a galaxy indicates that many of the first-generation stars in the galaxy have already completed their lives and that the galaxy is growing.
Professor Luis Colina (El Centro de Astrobiología (CAB, CSIC-INTA)) describes the significance of the results: "Emission from cosmic dust was not detected in member galaxies of the protocluster outside the core region. The results indicate that many galaxies are clustered in a small region and that galaxy growth is accelerated, suggesting that environmental effects existed only ~700 million years after the Big Bang."
Furthermore, the research team conducted a galaxy formation simulation to theoretically test how the four galaxies in the core region formed and evolved. The results showed that a region of dense gas particles existed around 680 million years after the Big Bang, and shows that four galaxies are formed, similar to the observed core region. To follow the evolution of these four galaxies, the simulation calculated physical processes such as the kinematics of stars and gas, chemical reactions, star formation, and supernovae. The simulations showed that the four galaxies merge and evolve into a single larger galaxy within a few tens of millions of years, which is a short time scale in the evolution of the Universe. "We successfully reproduced the properties of the galaxies in the core region owing to the high spatial resolution of our simulations and the large number of galaxy samples we have. In the future, we would like to explore the formation mechanism of the core region and its dynamical properties in more detail," says Yurina Nakazato, a graduate student at the University of Tokyo, who analysed the simulation data.
Javier Álvarez-Márquez (Spanish Centre for Astrobiology) says, "We will conduct more sensitive observations of the proto-cluster A2744z7p9OD with ALMA to see if there are any galaxies that were not visible with the previous sensitivity. We will also apply the JWST and ALMA observations, which have proven to be very powerful, to more protoclusters to elucidate the growth mechanism of galaxies, and to explore our roots in the Universe."
This research was supported by JSPS KAKENHI (grant numbers 20K14516, 22H01257, 22H04939, 23H00131), Leading initiative for Excellent Young Researchers, MEXT, Japan (HJH02007), NAOJ ALMA Scientific Research Grant (2020-16B), the Spanish Ministry of Science and Innovation/State Agency of Research (PIB2021-127718NB-100), Program "Garantía Juveníl" from the "Comunidad de Madrid" 2021 (CM21 CAB M2 01), Co-munidad de Madrid under Atracción de Talento (2018-T2/TIC-11612), the Ramón y Cajal program of the Spanish Ministerio de Ciencia e Innovación (RYC2021-033094-I).
[1] The redshift of this object was z = 7.88. Based on this, calculating the distance using the latest cosmological parameters (H0 = 67.7 km/s/Mpc, Ωm = 0.3111, ΩΛ = 0.6899) yields 13.14 billion light years.
[2] The distance for A2744z7p9OD was first determined by the team of Takahiro Morishita (California Institute of Technology).

- Black holes eat faster than previously expected

Date: September 20, 2023
Source: Northwestern University



New high-resolution simulations show that the violent whirlpool of gas that encircles a supermassive black hole breaks apart into inner and outer rings. Image by A. Tchekhovskoy and Nick Kaaz

A new Northwestern University-led study is changing the way astrophysicists understand the eating habits of supermassive black holes. While previous researchers have hypothesized that black holes eat slowly, new simulations indicate that black hole’s scarf food much faster than conventional understanding suggests.
The study will be published on Wednesday (Sept. 20) in *The Astrophysical Journal*.
According to new high-resolution 3D simulations, spinning black holes twist up the surrounding space-time, ultimately ripping

apart the violent whirlpool of gas (or accretion disk) that encircles and feeds them. This results in the disk tearing into inner and outer sub disks. Black holes first devour the inner ring. Then, debris from the outer sub disk spills inward to refill the gap left behind by the wholly consumed inner ring, and the eating process repeats.

One cycle of the endlessly repeating eat-refill-eat process takes mere months -- a shockingly fast timescale compared to the hundreds of years that researchers previously proposed.

This new finding could help explain the dramatic behaviour of some of the brightest objects in the night sky, including quasars, which abruptly flare up and then vanish without explanation.

"Classical accretion disk theory predicts that the disk evolves slowly," said Northwestern's Nick Kaaz, who led the study. "But some quasars -- which result from black holes eating gas from their accretion disks -- appear to drastically change over time scales of months to years. This variation is so drastic. It looks like the inner part of the disk -- where most of the light comes from -- gets destroyed and then replenished. Classical accretion disk theory cannot explain this drastic variation. But the phenomena we see in our simulations potentially could explain this. The quick brightening and dimming are consistent with the inner regions of the disk being destroyed."

Kaaz is a graduate student in astronomy at Northwestern's Weinberg College of Arts and Sciences and member of the Centre for Interdisciplinary Exploration and Research in Astrophysics (CIERA). Kaaz is advised by paper co-author Alexander Tchekhovskoy, an associate professor of physics and astronomy at Weinberg and a CIERA member.

Mistaken assumptions

Accretion disks surrounding black holes are physically complicated objects, making them incredibly difficult to model. Conventional theory has struggled to explain why these disks shine so brightly and then abruptly dim -- sometimes to the point of disappearing completely.

Previous researchers have mistakenly assumed that accretion disks are relatively orderly. In these models, gas and particles swirl around the black hole -- in the same plane as the black hole and in the same direction of the black hole's spin. Then, over a time scale of hundreds to hundreds of thousands of years, gas particles gradually spiral into the black hole to feed it.

"For decades, people made a very big assumption that accretion disks were aligned with the black hole's rotation," Kaaz said. "But the gas that feeds these black holes doesn't necessarily know which way the black hole is rotating, so why would they automatically be aligned? Changing the alignment drastically changes the picture."

The researchers' simulation, which is one of the highest-resolution simulations of accretion disks to date, indicates that the regions surrounding the black hole are much messier and more turbulent places than previously thought.

More like a gyroscope, less like a plate

Using Summit, one of the world's largest supercomputers located at Oak Ridge National Laboratory, the researchers carried out a 3D general relativistic magnetohydrodynamics (GRMHD) simulation of a thin, tilted accretion disk. While previous simulations were not powerful enough to include all the necessary physics needed to construct a realistic black hole, the Northwestern-led model includes gas dynamics, magnetic fields and general relativity to assemble a more complete picture.

"Black holes are extreme general relativistic objects that affect space-time around them," Kaaz said. "So, when they rotate, they drag the space around them like a giant carousel and force it to rotate as well -- a phenomenon called 'frame-dragging.' This creates a really strong effect close to the black hole that becomes increasingly weaker farther away."

Frame-dragging makes the entire disk wobble in circles, similar to how a gyroscope processes. But the inner disk wants to wobble much more rapidly than the outer parts. This mismatch of forces causes the entire disk to warp, causing gas from different parts of the disk to collide. The collisions create bright shocks that violently drive material closer and closer to the black hole.

As the warping becomes more severe, the innermost region of the accretion disk continues to wobble faster and faster until it breaks apart from the rest of the disk. Then, according to the new simulations, the sub disks start evolving independently from one another. Instead of smoothly moving together like a flat plate surrounding the black hole, the sub disks independently wobble at different speeds and angles like the wheels in a gyroscope.

"When the inner disk tears off, it will process independently," Kaaz said. "It processes faster because it's closer to the black hole and because it's small, so it's easier to move."

'Where the black hole wins'

According to the new simulation, the tearing region -- where the inner and outer sub disks disconnect -- is where the feeding frenzy truly begins. While friction tries to keep the disk together, the twisting of space-time by the spinning black hole wants to rip it apart.

"There is competition between the rotation of the black hole and the friction and pressure inside the disk," Kaaz said. "The tearing region is where the black hole wins. The inner and outer disks collide into each other. The outer disk shaves off layers of the inner disk, pushing it inwards."

Now the sub disks intersect at different angles. The outer disk pours material on top of the inner disk. This extra mass also pushes the inner disk toward the black hole, where it is devoured. Then, the black hole's own gravity pulls gas from the outer region toward the now-empty inner region to refill it.

The quasar connection

Kaaz said these fast cycles of eat-refill-eat potentially explain so-called "changing-look" quasars. Quasars are extremely luminous objects that emit 1,000 times more energy than the entire Milky Way's 200 billion to 400 billion stars. Changing-look quasars are even more extreme. They appear to turn on and off over the duration of months -- a tiny amount of time for a typical quasar.

Although classical theory has posed assumptions for how quickly accretion disks evolve and change brightness, observations of changing-look quasars indicate that they actually evolve much, much faster.

"The inner region of an accretion disk, where most of the brightness comes from, can totally disappear -- really quickly over months," Kaaz said. "We basically see it go away entirely. The system stops being bright. Then, it brightens again and the process repeats. Conventional theory doesn't have any way to explain why it disappears in the first place, and it doesn't explain how it refills so quickly."

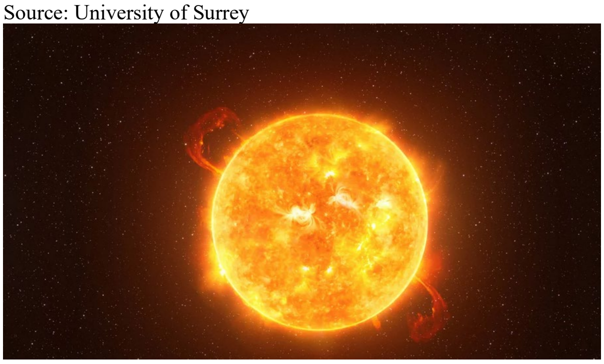
Not only do the new simulations potentially explain quasars, they also could answer ongoing questions about the mysterious nature of black holes.

"How gas gets to a black hole to feed it is the central question in accretion-disk physics," Kaaz said. "If you know how that happens, it will tell you how long the disk lasts, how bright it is and what the light should look like when we observe it with telescopes."

The study, "Nozzle shocks, disk tearing and streamers drive rapid accretion in 3D GRMHD simulations of warped thin disks," was supported by the U.S. Department of Energy and the National Science Foundation.

- Groundbreaking research shows that the limits of nuclear stability change in stellar environments where temperatures reach billions of degrees Celsius

Date: September 18, 2023
Source: University of Surrey



New research is challenging the scientific status quo on the limits of the nuclear chart in hot stellar environments where temperatures reach billions of degrees Celsius.

The nuclear chart is a way to map out different kinds of atomic nuclei based on their number of protons and neutrons, and the "drip lines" can be viewed as the boundaries or edges of this map. Researchers from the University of Surrey and the University of Zagreb have found that these drip lines, which define the maximum number of protons and neutrons within a nucleus, change dynamically with temperature.

The findings challenge the view that drip lines and the number of bound nuclei are not sensitive to the temperature.

Dr Esra Yuksel, co-author of the study from the University of Surrey, argues that the physics community must understand the limits of the nuclear chart. She said:

"Considering that nuclei participating in most of the processes in the universe are hot, understanding how many protons and neutrons bind together in extreme environments is critical. We aim to determine which nuclei can contribute to nuclear reactions and processes, especially in extremely hot stellar environments such as supernovae and neutron star mergers. These extremely hot environments are where most of the chemical elements heavier than iron are produced. Until our study, we didn't know much about these 'drip lines' (limits) at temperatures measured in billions of degrees Celsius."

The study, published in *Nature Communications*, found that increasing temperatures significantly alter the limits of the nuclear chart. The discovery shows that more nuclei exist within the drip lines for hot nuclei than for cold nuclei.

The researchers from Surrey and Zagreb used theoretical calculations to predict nuclear properties and drip lines at temperatures up to 20 billion degrees Celsius. They found that at temperatures up to 10 billion Celsius, the drip lines and the number of bound nuclei has already started to change. At higher temperatures, shell effects disappear, and these changes become more visible.

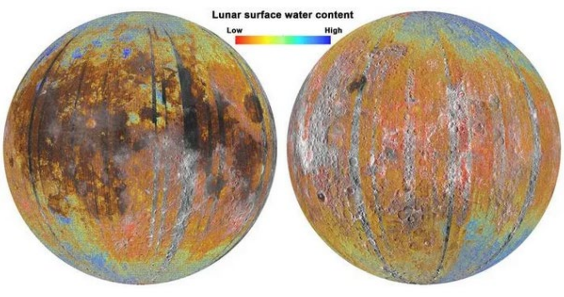
Dr Yuksel concludes:

"Our work demonstrates that the nuclear drip lines should be viewed as evolving limits that dynamically change with temperature. Before this research, nuclear drip lines at finite temperatures were unknown, and knowledge about nuclei in hot stellar environments was limited since most theoretical and experimental studies are restricted to zero temperatures only.

"These new insights help us to understand how temperature changes the stability and structure of atomic nuclei. This knowledge is important not only for nuclear physics but also for understanding the modelling of extreme astrophysical events, such as neutron star mergers and core-collapse supernovae."

- Electrons from Earth may be forming water on the Moon

Date: September 14, 2023
Source: University of Hawaii at Manoa



A water content map of this valuable life-sustaining commodity across the moon. (Image credit: Li, et al., 2023)

A team of researchers, led by a University of Hawai'i (UH) at Manoa planetary scientist, discovered that high energy electrons in Earth's plasma sheet are contributing to weathering processes on the Moon's surface and, importantly, the electrons may have aided the formation of water on the lunar surface. The study was published today in *Nature Astronomy*.

Understanding the concentrations and distributions of water on the Moon is critical to understanding its formation and evolution, and to providing water resources for future human exploration. The new discovery may also help explain the origin of the water ice previously discovered in the lunar permanently shaded regions.

Due to Earth's magnetism, there is a force field surrounding the planet, referred to as the magnetosphere, that protects Earth from space weathering and damaging radiation from the Sun. Solar wind pushes the magnetosphere and reshapes it, making a long tail on the night side. The plasma sheet within this magnetotail is a region consisting of high energy electrons and ions that may be sourced from Earth and the solar wind.

Previously, scientists mostly focused on the role of high energy ions on the space weathering of the Moon and other airless bodies. Solar wind, which is composed of high energy particles such as protons, bombards the lunar surface and is thought to be one of the primary ways in which water has been formed on the Moon.

Building on his previous work that showed oxygen in Earth's magnetotail is rusting iron in the Moon's polar regions, Shuai Li, assistant researcher in the UH Manoa School of Ocean and Earth Science and Technology (SOEST), was interested in investigating the changes in surface weathering as the Moon passes through Earth's magnetotail, an area that almost completely shields the Moon from solar wind but not the Sun's light photons.

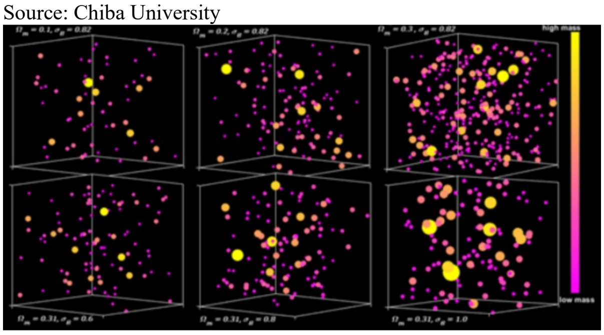
"This provides a natural laboratory for studying the formation processes of lunar surface water," said Li. "When the Moon is outside of the magnetotail, the lunar surface is bombarded with solar wind. Inside the magnetotail, there are almost no solar wind protons and water formation was expected to drop to nearly zero."

Li and co-authors analysed the remote sensing data that were collected by the Moon Mineralogy Mapper instrument onboard India's Chandrayaan 1 mission between 2008 and 2009. Specifically, they assessed the

changes in water formation as the Moon traversed through Earth's magnetotail, which includes the plasma sheet.
"To my surprise, the remote sensing observations showed that the water formation in Earth's magnetotail is almost identical to the time when the Moon was outside of the Earth's magnetotail," said Li. "This indicates that, in the magnetotail, there may be additional formation processes or new sources of water not directly associated with the implantation of solar wind protons. In particular, radiation by high energy electrons exhibits similar effects as the solar wind protons."
"Altogether, this finding and my previous findings of rusty lunar poles indicate that the mother Earth is strongly tied with its Moon in many unrecognized aspects," said Li.
In future research, Li aims to work on a lunar mission through NASA's Artemis programs to monitor the plasma environment and water content on the lunar polar surface when the Moon is at different phases during the traverse of the Earth's magnetotail.

- ❖ Matter comprises of 31% of the total amount of matter and energy in the universe

A research team relies on measuring the number of galaxy members to determine the mass of galaxy clusters
Date: September 13, 2023
Source: Chiba University



Like Goldilocks, the team compared the number of galaxy clusters measured with predictions from numerical simulations to determine which answer was “just right.” Image credit: Mohamed Abdullah (The National Research Institute of Astronomy and Geophysics, Egypt/Chiba University, Japan)

One of the most interesting and important questions in cosmology is, "How much matter exists in the universe?" An international team, including scientists at Chiba University, has now succeeded in measuring the total amount of matter for the second time. Reporting in *The Astrophysical Journal*, the team determined that matter makes up 31% of the total amount of matter and energy in the universe, with the remainder consisting of dark energy.
"Cosmologists believe that only about 20% of the total matter is made of regular or 'baryonic' matter, which includes stars, galaxies, atoms, and life," explains first author Dr. Mohamed Abdullah, a researcher at the National Research Institute of Astronomy and Geophysics-Egypt, Chiba University, Japan. "About 80% is made of dark matter, whose mysterious nature is not yet known but may consist of some as-yet-undiscovered subatomic particles."
"The team used a well-proven technique to determine the total amount of matter in the universe, which is to compare the observed number and mass of galaxy clusters per unit volume with predictions from numerical simulations," says co-author Gillian Wilson, Abdullah's former graduate advisor and Professor of Physics and Vice Chancellor for research, innovation, and economic development at UC Merced. "The number of clusters observed at the present time, the so-called 'cluster abundance,' is very sensitive to cosmological conditions and, in particular, the total amount of matter."
"A higher percentage of the total matter in the universe would result in more clusters being formed," says Anatoly Klypin from University of Virginia. "But it is difficult to measure the mass of any galaxy cluster accurately as most of the matter is dark, and we cannot see it directly with telescopes."
To overcome this difficulty, the team was forced to use an indirect tracer of cluster mass. They relied upon the fact that more massive clusters contain more galaxies than less massive clusters (mass richness relation: MRR). Because galaxies consist of luminous stars, the number of galaxies in each cluster can be utilized as a way of indirectly determining its total mass. By measuring the number of galaxies in each cluster in their sample from the Sloan Digital Sky Survey, the team was able to estimate the total mass of each of the clusters. They were then able to compare the observed number and mass of galaxy clusters per unit volume against predictions from numerical simulations. The best-fit match between observations and simulations was with a universe consisting of 31% of the total matter, a value that was in excellent agreement with that obtained using cosmic microwave background (CMB) observations from the Planck satellite. Notably, CMB is a completely independent technique.

"We have succeeded in making the first measurement of matter density using the MRR, which is in excellent agreement with that obtained by the Planck team using the CMB method," says Tomoaki Ishiyama from Chiba University. "This work further demonstrates that cluster abundance is a competitive technique for constraining cosmological parameters and complementary to non-cluster techniques such as CMB anisotropies, baryon acoustic oscillations, Type Ia supernovae, or gravitational lensing."
The team credits their achievement as being the first to successfully utilize spectroscopy, the technique that separates radiation into a spectrum of individual bands or colours, to precisely determine the distance to each cluster and the true member galaxies that are gravitationally bound to the cluster rather than background or foreground interlopers along the line of sight. Previous studies that attempted to use the MRR technique relied on much cruder and less accurate imaging techniques, such as using pictures of the sky taken at some wavelengths, to determine the distance to each cluster and the nearby galaxies that were true members.

- ❖ Discovery of two potential Polar Ring galaxies suggests these stunning rare clusters might be more common than previously believed

Date: September 13, 2023
Source: Queen's University

A potential polar ring galaxy called NGC 4632. The composite image combines a capture of the galaxy's main disk, taken with the Subaru Telescope, with radio wave data of the hydrogen ring, which has been digitally colorized as white. Jayanne English (U. Manitoba), Nathan Deg (Queen's University) & WALLABY Survey, CSIRO / ASKAP, NAOJ / Subaru Telescope

A group of international astronomers, including researchers from Queen's University, has identified two potential polar ring galaxies, according to results published today in the Monthly Notices of the Royal Astronomical Society.
Queen's researchers Nathan Deg and Kristine Spekkens (Physics, Engineering Physics & Astronomy) led the analysis of data obtained using a telescope owned and operated by CSIRO, Australia's national science agency. Looking at sky maps of hydrogen gas in over 600 galaxies as part of CSIRO's ASKAP radio telescope's WALLABY survey, they identified two potential polar ring galaxies, a type of galaxy that exhibits a ring of stars and gas perpendicular to its main spiral disk.
Although this is not the first time that astronomers have observed polar ring galaxies, they are the first observed using the ASKAP telescope located at Inyarrimanha Ilgari Bundara, CSIRO's Murchison radio astronomy observatory on Wajarri Yamaji Country in Western Australia.
These new detections in gas alone suggest polar ring galaxies might be more common than previously believed.

Understanding how galaxies evolve

Further investigation of polar ring structures can help us better understand how galaxies evolve. For example, one of the main hypotheses to explain the origin of polar rings is a merger where a larger galaxy 'swallows' a smaller one. If polar ring galaxies are more common than previously thought, this could mean that these mergers are more frequent.
In the future, polar ring galaxies can also be used to deepen our understanding of the universe, with potential applications in dark matter research. It is possible to use polar rings to probe the shape of dark matter of the host galaxy, which could lead to new clues about the mysterious properties of the elusive substance.

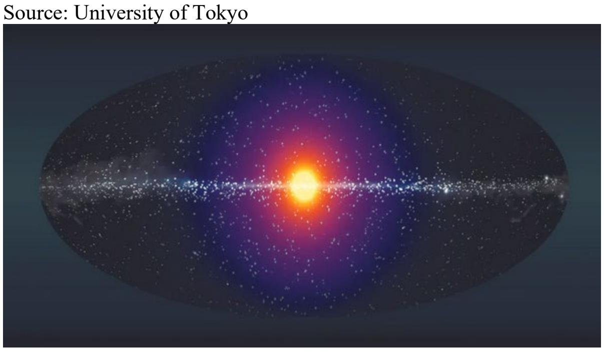
Visualizing polar ring galaxies

Jayanne English, a member of the WALLABY research team and also an expert in astronomy image-making at the University of Manitoba, developed the first images of these gaseous polar ring galaxies using a combination of optical and radio data from the different telescopes. First, optical and infrared data from the Subaru telescope in Hawaii provided the image for the spiral disk of the galaxy. Then, the gaseous ring was added based on data obtained from the WALLABY survey, an international project using CSIRO's ASKAP radio telescope to detect atomic hydrogen emission from about half a million galaxies.

The creation of this and other astronomical images are all composite because they include information that our eyes can't capture. In this particular case, the cold hydrogen gas component, invisible to the human eye, is seen in radio "light" using CSIRO's ASKAP. The subtle colour gradient of this ring represents the orbital motions of the gas, with purple-ish tints at the bottom tracing gas that moves towards the viewer while the top portion moves away. The emission from the ring was separated from the radio emission emanating from the disk of the galaxy using virtual reality tools, in collaboration with Professor Tom Jarrett (University of Cape Town, South Africa).
Over 25 global collaborators from Canada, Australia, South Africa, Ecuador, Burkina Faso, Germany, China, and beyond worked together to analyse the data from the first public data release of the WALLABY survey, resulting in the newly published paper.
The next step for the team is to confirm the polar ring galaxies finding through additional observations using different telescopes, including the MeerKAT radio telescope in South Africa.
"Polar ring galaxies are some of the most spectacular looking galaxies in the Universe. These findings suggest that one to three per cent of nearby galaxies may have gaseous polar rings, which is much higher than suggested by optical telescopes." Dr. Nathan Deg, researcher, Department of Physics, Engineering Physics & and Astronomy, Queen's University, Canada, and lead author on the study.

- ❖ Dark matter halos measured around ancient quasars

Date: September 12, 2023
Source: University of Tokyo



Artist illustration of a dark matter halo. (Image credit: Artistic rendering by Christopher Dessert, Nicholas L. Rodd, Benjamin R. Safdi, Zosia Rostomian (Berkeley Lab), based on data from the Fermi Large Area Telescope.)

At the centre of every galaxy is a supermassive black hole. Beyond a certain size, these become active, emitting huge amounts of radiation, and are then called quasars. It is thought these are activated by the presence of massive dark matter halos (DMH) surrounding the galaxy, directing matter towards the centre, feeding the black hole. A team including researchers from the University of Tokyo have, for the first time, surveyed hundreds of ancient quasars and found this behaviour is very consistent throughout history. This is surprising, as many large-scale processes show variation throughout the life of the universe, so the mechanism of quasar activation could have implications for the evolution of the entire universe.
Measuring the mass of DMHs is not easy; it's famously a very elusive substance, if substance is even the right word to use, given the actual nature of dark matter is unknown. We only know it exists at all due to its gravitational impact on large structures such as galaxies. Thus, dark matter can only be measured by making observations about its gravitational effects on things. This includes the way it might pull on something or affect its movement, or through the lensing (bending of light) of objects behind a suspected area of dark matter.
The challenge becomes greater at large distances, given how weak the light from more distant, and therefore ancient, phenomena can be. But this did not stop Professor Nobunari Kashikawa from the Department of Astronomy, and his team, from trying to answer a long-standing question in astronomy: How are black holes born, and how do they grow? The researchers are especially keen to explore this in relation to supermassive black holes, the largest kind, which exist in the heart of every galaxy. These would be very difficult to study were it not for the fact that some grow so massive they begin to output incredibly powerful jets of matter or spheres of radiation that in either case become what we call quasars. These are so powerful that even at large distances, we can now observe them using modern techniques.
"We measured for the first time the typical mass for dark matter halos surrounding an active black hole in the universe about 13 billion years ago," said Kashikawa. "We find the DMH mass of quasars is pretty constant at about 10 trillion times the mass of our sun. Such measurements have been made for more recent DMH around quasars, and those

measurements are strikingly similar to what we see for more ancient quasars. This is interesting because it suggests there is a characteristic DMH mass which seems to activate a quasar, regardless of whether it happened billions of years ago or right now."

Quasars at great distances appear faint, as the light which left them long ago has spread out, was absorbed by intervening matter, and has been stretched into nearly invisible infrared wavelengths due to the universe expanding over time. So Kashikawa and his team, whose project began in 2016, used multiple surveys of the sky which incorporated a range of different instruments, the main one being Japan's Subaru Telescope, located in U.S. state of Hawaii.

"Upgrades allowed Subaru to see farther than ever, but we can learn more by expanding observation projects internationally," said Kashikawa. "The U.S.-based Vera C. Rubin Observatory and even the space-based Euclid satellite, launched by the EU this year, will scan a larger area of the sky and find more DMH around quasars. We can build a more complete picture of the relationship between galaxies and supermassive black holes. That might help inform our theories about how black holes form and grow."