South Downs Mercury

The monthly circular of South Downs Astronomical Society
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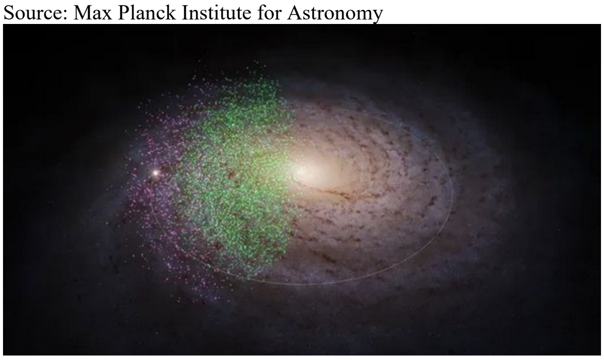
Main Ian Smith **"Imaging Planetary Nebulae" during which I'll describe my take on narrow band imaging of Planetary Nebula, what they are and why they are interesting to astronomers both pro and amateur. That will lead us into the kind of equipment and techniques best suited to this kind of imaging followed by some pictures.**
I've been an amateur astronomer for several decades and used to be chairman of the Abingdon Astronomical Society for many years. My own astronomical interests started with planetary observing and then imaging. Then when the planets effectively disappeared from UK skies, I turned to imaging PNe, which I've now been doing now for the last 6 years or so

Please support a raffle we are organizing this month.

- Two of the Milky Way's earliest building blocks identified

Date: March 21, 2024
Source: Max Planck Institute for Astronomy



Two gargantuan streams of stars named Shiva (shown in green) and Shakti (purple) may be some of the oldest building blocks of the Milky Way galaxy. (Image credit: © S. Payne-Wardenaar / K. Malhan / MPIA)

Astronomers have identified what could be two of the Milky Way's earliest building blocks: Named "Shakti" and "Shiva," these appear to be the remnants of two galaxies that merged between 12 and 13 billion years ago with an early version of the Milky Way, contributing to our home galaxy's initial growth. The new find is the astronomical equivalent of archaeologists identifying traces of an initial settlement that grew into a large present-day city. It required combining data for nearly 6 million stars from ESA's Gaia mission with measurements from the SDSS survey. The results have been published in the *Astrophysical Journal*.

The early history of our home galaxy, the Milky Way, is one of joining smaller galaxies, which makes for fairly large building blocks. Now, Khyati Malhan and Hans-Walter Rix of the Max Planck Institute for Astronomy have succeeded in identifying what could be two of the earliest building blocks that can still be recognized as such today: proto-galactic fragments that merged with an early version of our Milky Way between 12 and 13 billion years ago, at the very beginning of the era of galaxy formation in the Universe. The components, which the astronomers have named Shakti and Shiva, were identified by combining data from ESA's astrometry satellite Gaia with data from the SDSS survey. For astronomers, the result is the equivalent of finding traces of an initial settlement that grew into a large present-day city.

Tracing the origins of stars that came from other galaxies

When galaxies collide and merge, several processes happen in parallel. Each galaxy carries along its own reservoir of hydrogen gas. Upon collision, those hydrogen gas clouds are destabilized, and numerous new stars are formed inside. Of course, the incoming galaxies also already have their own stars, and in a merger, stars from the galaxies will mingle. In the long run, such "accreted stars" will also account for some of the stellar population of the newly-formed combined galaxy. Once the merger is completed, it might seem hopeless to identify which stars came from which predecessor galaxy. But in fact, at least some ways of tracing back stellar ancestry exist.

Help comes from basic physics. When galaxies collide and their stellar populations mingle, most of the stars retain very basic properties, which are directly linked to the speed and direction of the galaxy in which they originated. Stars from the same pre-merger galaxy share similar values for both their energy and what physicists call angular momentum -- the momentum associated with orbital motion or rotation. For stars moving in a galaxy's gravitational field, both energy and angular momentum are conserved: they remain the same over time. Look for large groups of stars with similar, unusual values for energy and angular momentum -- and chances are, you might find a merger remnant. Additional pointers can assist identification. Stars that formed more recently contain more heavier elements, what astronomers call "metals," than stars that formed a long time ago. The lower the metal content ("metallicity"), the earlier the star presumably formed. When trying to identify stars that already existed 13 billion years ago, one should look for stars with very low metal content ("metal-poor").

Virtual excavations in a large data set

Identifying the stars that joined our Milky Way as parts of another galaxy has only become possible comparatively recently. It requires large, high-quality data sets, and the analysis involves sifting the data in clever ways so as to identify the searched-for class of objects. This kind of data set has only been available for a few years. The ESA astrometry satellite Gaia provides an ideal data set for this kind of big-data galactic archaeology. Launched in 2013, it has produced an increasingly accurate data set over the past decade, which by now includes positions, changes in position and distances for almost 1.5 billion stars within our galaxy.

Gaia data revolutionized studies of the dynamics of stars in our home galaxy, and has already led to the discovery of previously unknown substructures. This includes the so-called Gaia Enceladus/Sausage stream, a remnant of the most recent larger merger our home galaxy has undergone, between 8 and 11 billion years ago. It also includes two structures identified in 2022: the Pontus stream identified by Malhan and colleagues and the "poor old heart" of the Milky Way identified by Rix and colleagues. The latter is a population of stars that newly formed during the initial mergers that created the proto-Milky Way, and continue to reside in our galaxy's central region.

Traces of Shakti and Shiva

For their present search, Malhan and Rix used Gaia data combined with detailed stellar spectra from the Sloan Digital Sky Survey (DR17). The latter provide detailed information about the stars' chemical composition. Malhan says: "We observed that, for a certain range of metal-poor stars, stars were crowded around two specific combinations of energy and angular momentum."

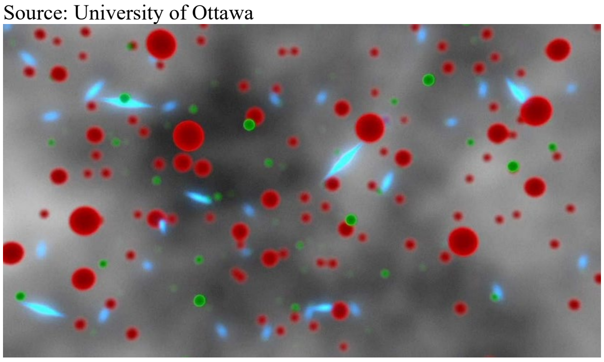
In contrast with the "poor old heart," which was also visible in those plots, the two groups of like-minded stars had comparatively large angular momentum, consistent with groups of stars that had been part of separate galaxies which had merged with the Milky Way. Malhan has named these two structures Shakti and Shiva, the latter one of the principal deities of Hinduism and the former a female cosmic force often portrayed as Shiva's consort.

Their energy and angular momentum values, plus their overall low metallicity on par with that of the "poor old heart," makes Shakti and Shiva good candidates for some of the earliest ancestors of our Milky Way. Rix says: "Shakti and Shiva might be the first two additions to the 'poor old heart' of our Milky Way, initiating its growth towards a large galaxy."

Several surveys that are either already ongoing or bound to start over the next couple of years promise relevant additional data, both spectra (SDSS-V, 4MOST) and precise distances (LSST/Rubin Observatory), should enable astronomers to make a firm decision on whether or not Shakti and Shiva are indeed a glimpse of our home galaxy's earliest prehistory.

- New research suggests that our universe has no dark matter

Date: March 15, 2024
Source: University of Ottawa



Frame from an animation depicting a photon as it travels across space and time. Credit: NASA/JPL-Caltech.

The current theoretical model for the composition of the universe is that it's made of 'normal matter,' 'dark energy' and 'dark matter.' A new uOttawa study challenges this.

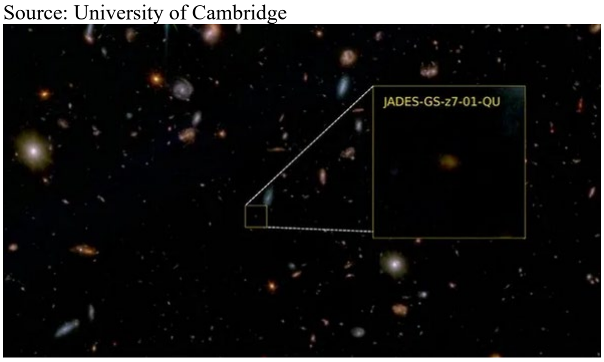
A University of Ottawa study published today challenges the current model of the universe by showing that, in fact, it has no room for dark matter.
In cosmology, the term "dark matter" describes all that appears not to interact with light or the electromagnetic field, or that can only be explained through gravitational force. We can't see it, nor do we know what it's made of, but it helps us understand how galaxies, planets and stars behave.
Rajendra Gupta, a physics professor at the Faculty of Science, used a combination of the covarying coupling constants (CCC) and "tired light" (TL) theories (the CCC+TL model) to reach this conclusion. This model combines two ideas -- about how the forces of nature decrease over cosmic time and about light losing energy when it travels a long distance. It's been tested and has been shown to match up with several observations, such as about how galaxies are spread out and how light from the early universe has evolved.
This discovery challenges the prevailing understanding of the universe, which suggests that roughly 27% of it is composed of dark matter and less than 5% of ordinary matter, remaining being the dark energy.

Challenging the need for dark matter in the universe

"The study's findings confirm that our previous work ("JWST early Universe observations and ΛCDM cosmology") about the age of the universe being 26.7billionyears has allowed us to discover that the universe does not require dark matter to exist," explains Gupta. "In standard cosmology, the accelerated expansion of the universe is said to be caused by dark energy but is in fact due to the weakening forces of nature as it expands, not due to dark energy."
"Redshifts" refer to when light is shifted toward the red part of the spectrum. The researcher analysed data from recent papers on the distribution of galaxies at low redshifts and the angular size of the sound horizon in the literature at high redshift.
"There are several papers that question the existence of dark matter, but mine is the first one, to my knowledge, that eliminates its cosmological existence while being consistent with key cosmological observations that we have had time to confirm," says Gupta.
By challenging the need for dark matter in the universe and providing evidence for a new cosmological model, this study opens up new avenues for exploring the fundamental properties of the universe.

- Astronomers spot oldest 'dead' galaxy yet observed

Date: March 6, 2024
Source: University of Cambridge



False-colour JWST image of a small fraction of the GOODS South field, with JADES-GS-z7-01-QU highlighted. (Image credit: JADES Collaboration)

A galaxy that suddenly stopped forming new stars more than 13 billion years ago has been observed by astronomers.
Using the James Webb Space Telescope, an international team of astronomers led by the University of Cambridge have spotted a 'dead' galaxy when the universe was just 700 million years old, the oldest such galaxy ever observed.
This galaxy appears to have lived fast and died young: star formation happened quickly and stopped almost as quickly, which is unexpected for so early in the universe's evolution. However, it is unclear whether this galaxy's 'quenched' state is temporary or permanent, and what caused it to stop forming new stars.
The results, reported in the journal *Nature*, could be important to help astronomers understand how and why galaxies stop forming new stars, and whether the factors affecting star formation have changed over billions of years.
"The first few hundred million years of the universe was a very active phase, with lots of gas clouds collapsing to form new stars," said Tobias Looser from the Kavli Institute for Cosmology, the paper's first author. "Galaxies need a rich supply of gas to form new stars, and the early universe was like an all-you-can-eat buffet."
"It's only later in the universe that we start to see galaxies stop forming stars, whether that's due to a black hole or something else," said co-author Dr Francesco D'Eugenio, also from the Kavli Institute for Cosmology.
Astronomers believe that star formation can be slowed or stopped by different factors, all of which will starve a galaxy of the gas it

needs to form new stars. Internal factors, such as a supermassive black hole or feedback from star formation, can push gas out of the galaxy, causing star formation to stop rapidly. Alternatively, gas can be consumed very quickly by star formation, without being promptly replenished by fresh gas from the surroundings of the galaxy, resulting in galaxy starvation.

"We're not sure if any of those scenarios can explain what we've now seen with Webb," said co-author Professor Roberto Maiolino. "Until now, to understand the early universe, we've used models based on the modern universe. But now that we can see so much further back in time, and observe that the star formation was quenched so rapidly in this galaxy, models based on the modern universe may need to be revisited."

Using data from JADES (JWST Advanced Deep Extragalactic Survey), the astronomers determined that this galaxy experienced a short and intense period of star formation over a period between 30 and 90 million years. But between 10 and 20 million years before the point in time where it was observed with Webb, star formation suddenly stopped.

"Everything seems to happen faster and more dramatically in the early universe, and that might include galaxies moving from a star-forming phase to dormant or quenched," said Looser.

Astronomers have previously observed dead galaxies in the early universe, but this galaxy is the oldest yet -- just 700 million years after the big bang, more than 13 billion years ago. This observation is one of the deepest yet made with Webb.

In addition to the oldest, this galaxy is also relatively low mass -- about the same as the Small Magellanic Cloud (SMC), a dwarf galaxy near the Milky Way, although the SMC is still forming new stars. Other quenched galaxies in the early universe have been far more massive, but Webb's improved sensitivity allows smaller and fainter galaxies to be observed and analysed.

The astronomers say that although it appears dead at the time of observation, it's possible that in the roughly 13 billion years since, this galaxy may have come back to life and started forming new stars again.

"We're looking for other galaxies like this one in the early universe, which will help us place some constraints on how and why galaxies stop forming new stars," said D'Eugenio. "It could be the case that galaxies in the early universe 'die' and then burst back to life -- we'll need more observations to help us figure that out."

The research was supported in part by the European Research Council, the Royal Society, and the Science and Technology Facilities Council (STFC), part of UK Research and Innovation (UKRI)

- ❖ Secrets of the Van Allen belt revealed in new study

Date: March 21, 2024
Source: University of Birmingham

A challenge to space scientists to better understand our hazardous near-Earth space environment has been set in a new study led by the University of Birmingham.

The research represents the first step towards new theories and methods that will help scientists predict and analyse the behaviour of particles in space. It has implications for theoretical research, as well as for practical applications such as space weather forecasting.

The research focused on two bands of energetic particles in near earth space, referred to as the Radiation Belts, or the Van Allen Belts. These particles are trapped within the Earth's magnetosphere and can damage electronics on satellites and spacecraft passing through, as well as posing risks to astronauts. Understanding how these particles behave has been a goal for physicists and engineers for decades. Since the 1960s, researchers have used principles contained within 'quasilinear models' to explain how the charged particles move through space.

In the new study, however, researchers have found evidence that the standard theory might not apply as often as previously assumed. The team of 16 scientists, from institutions in the UK, USA and Finland, explored the limits of standard theories. The application of the quasilinear theory can seem straightforward, but in fact integrating it into space physics models in accordance with scientific measurements made in space is a delicate procedure. This paper breaks down the challenges behind this process.

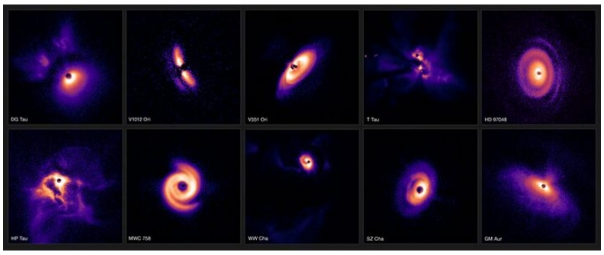
The findings are published in a special edition of *Frontiers in Astronomy and Space Sciences*: "Editor's Challenge in Space Physics: Solved and Unsolved Problems in Space Physics."

Lead author, Dr Oliver Allanson, from the Space Environment and Radio Engineering

(SERENE) Group at the University of Birmingham, said: "Gaining a better understanding of the behaviour of these particles is crucial for interpreting satellite data and for understanding the underlying physics of space environments."
Researchers involved in the study are based in the UK at the Universities of Birmingham, Exeter, Northumbria, Warwick, St Andrews, and at the British Antarctic Survey; in the USA at the University of California at Los Angeles, University of Iowa and the US Air Force Research Lab, New Mexico; and in Finland at the University of Helsinki.
Next steps for the research will include an enhanced theoretical description based on the findings in this work, that can then be used in space weather models to forecast the behaviour of these hazardous particles in near-Earth space.

- Groundbreaking survey reveals secrets of planet birth around dozens of stars

Date: March 5, 2024
Source: ESO



In a series of studies, a team of astronomers has shed new light on the fascinating and complex process of planet formation. The stunning images, captured using the European Southern Observatory's Very Large Telescope (ESO’s VLT) in Chile, represent one of the largest ever surveys of planet-forming discs. The research brings together observations of more than 80 young stars that might have planets forming around them, providing astronomers with a wealth of data and unique insights into how planets arise in different regions of our galaxy.

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"This is really a shift in our field of study," says Christian Ginski, a lecturer at the University of Galway, Ireland, and lead author of one of three new papers published today in Astronomy & Astrophysics. "We've gone from the intense study of individual star systems to this huge overview of entire star-forming regions."
To date more than 5000 planets have been discovered orbiting stars other than the Sun, often within systems markedly different from our own Solar System. To understand where and how this diversity arises, astronomers must observe the dust- and gas-rich discs that envelop young stars -- the very cradles of planet formation. These are best found in huge gas clouds where the stars themselves are forming.
Much like mature planetary systems, the new images showcase the extraordinary diversity of planet-forming discs. "Some of these discs show huge spiral arms, presumably driven by the intricate ballet of orbiting planets," says Ginski. "Others show rings and large cavities carved out by forming planets, while yet others seem smooth and almost dormant among all this bustle of activity," adds Antonio Garufi, an astronomer at the Arcetri Astrophysical Observatory, Italian National Institute for Astrophysics (INAF), and lead author of one of the papers.
The team studied a total of 86 stars across three different star-forming regions of our galaxy: Taurus and Chamaeleon I, both around 600 light-years from Earth, and Orion, a gas-rich cloud about 1600 light-years from us that is known to be the birthplace of several stars more massive than the Sun. The observations were gathered by a large international team, comprising scientists from more than 10 countries.
The team was able to glean several key insights from the dataset. For example, in Orion they found that stars in groups of two or more were less likely to have large planet-forming discs. This is a significant result given that, unlike our Sun, most stars in our galaxy have companions. As well as this, the uneven appearance of the discs in this region suggests the possibility of massive planets embedded within them, which could be causing the discs to warp and become misaligned.
While planet-forming discs can extend for distances hundreds of times greater than the distance between Earth and the Sun, their location several hundreds of light-years from us makes them appear as tiny pinpricks in the night sky. To observe the discs, the team employed the sophisticated Spectro-Polarimetric High-contrast Exoplanet REsearch instrument (SPHERE) mounted on

ESO's VLT. SPHERE's state-of-the-art extreme adaptive optics system corrects for the turbulent effects of Earth's atmosphere, yielding crisp images of the discs. This meant the team were able to image discs around stars with masses as low as half the mass of the Sun, which are typically too faint for most other instruments available today. Additional data for the survey were obtained using the VLT's X-shooter instrument, which allowed astronomers to determine how young and how massive the stars are. The Atacama Large Millimetre/submillimetre Array (ALMA), in which ESO is a partner, on the other hand, helped the team understand more about the amount of dust surrounding some of the stars.
As technology advances, the team hopes to delve even deeper into the heart of planet-forming systems. The large 39-metre mirror of ESO's forthcoming Extremely Large Telescope (ELT), for example, will enable the team to study the innermost regions around young stars, where rocky planets like our own might be forming.
For now, these spectacular images provide researchers with a treasure trove of data to help unpick the mysteries of planet formation. "It is almost poetic that the processes that mark the start of the journey towards forming planets and ultimately life in our own Solar System should be so beautiful," concludes Per-Gunnar Valegård, a doctoral student at the University of Amsterdam, the Netherlands, who led the Orion study. Valegård, who is also a part-time teacher at the International School Hilversum in the Netherlands, hopes the images will inspire his pupils to become scientists in the future.

- James Webb Space Telescope captures the end of planet formation

Date: March 22, 2024
Source: University of Arizona

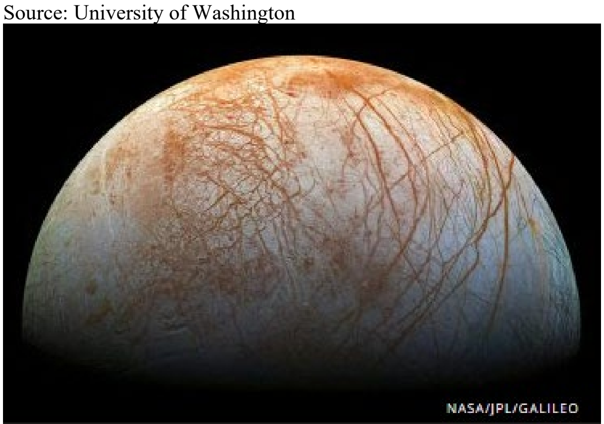
An artistic impression adapted to highlight gas dispersing from a planet-forming disk. Credit: ESO/M. Kornmesser

Scientists believe that planetary systems like our solar system contain more rocky objects than gas-rich ones. Around our sun, these include the inner planets -- Mercury, Venus, Earth and Mars -- the asteroid belt and the Kuiper belt objects such as Pluto.
Jupiter, Saturn, Uranus and Neptune, on the other hand, contain mostly gas. But scientists also have known for a long time that planet-forming disks start out with 100 times more mass in gas than solids, which leads to a pressing question: When and how does most of the gas leave a nascent planetary system?
A new study led by Naman Bajaj at the University of Arizona Lunar and Planetary Laboratory, published in the *Astronomical Journal*, provides answers. Using the James Webb Space Telescope, or JWST, the team obtained images from such a nascent planetary system -- also known as a circumstellar disk -- in the process of actively dispersing its gas into surrounding space.
"Knowing when the gas disperses is important as it gives us a better idea of how much time gaseous planets have to consume the gas from their surroundings," said Bajaj, a second-year doctoral student at UArizona's Lunar and Planetary Laboratory. "With unprecedented glimpses into these disks surrounding young stars, the birthplaces of planets, JWST helps us uncover how planets form."
During the very early stages of planetary system formation, planets coalesce in a spinning disk of gas and tiny dust around the young star, according to Bajaj. These particles clump together, building up into bigger and bigger chunks called planetesimals. Over time, these planetesimals collide and stick together, eventually forming planets. The type, size and location of planets that form depend on the amount of material available and how long it remains in the disk.
"So, in short, the outcome of planet formation depends on the evolution and dispersal of the disk," Bajaj said.
At the heart of this discovery is the observation of T Cha, a young star -- relative to the sun, which is about 4.6 billion years old -- enveloped by an eroding circumstellar disk notable for a vast dust gap, spanning approximately 30 astronomical units, or au, with one au being the average distance between the Earth and the sun.
Bajaj and his team were able, for the first time, to image the disk wind, as the gas is referred to when it slowly leaves the planet-forming disk. The astronomers took advantage of the telescope's sensitivity to light emitted

by an atom when high-energy radiation -- for example, in starlight -- strips one or more electrons from its nucleus. This is known as ionization, and the light emitted in the process can be used as a sort of chemical "fingerprint" -- in the case of the T Cha system, tracing two noble gases, neon and argon. The observations also mark the first time a double ionization of argon has been detected in a planet-forming disk; the team writes in the paper.
"The neon signature in our images tells us that the disk wind is coming from an extended region away from the disk," Bajaj said. "These winds could be driven either by high-energy photons -- essentially the light streaming from the star -- or by the magnetic field that weaves through the planet-forming disk."
In an effort to differentiate between the two, the same group, this time led by Andrew Sellek, a postdoctoral researcher at Leiden University in the Netherlands, performed simulations of the dispersal driven by stellar photons, the intense light streaming from the young star. They compared these simulations to the actual observations and found dispersal by high-energy stellar photons can explain the observations, and hence cannot be excluded as a possibility. That study concluded that the amount of gas dispersing from the T Cha disk every year is equivalent to that of Earth's moon. These results will be published in a companion paper, currently under review with the *Astronomical Journal*.
While neon signatures had been detected in many other astronomical objects, they weren't known to originate in low-mass planet-forming disks until first discovered in 2007 with JWST's predecessor, NASA's Spitzer Space Telescope, by Ilaria Pascucci, a professor at LPL who soon identified them as a tracer of disk winds. Those early findings transformed research efforts focused on understanding gas dispersal from circumstellar disks. Pascucci is the principal investigator on the most recent observing project and a co-author on the publications reported here.
"Our discovery of spatially resolved neon emission -- and the first detection of double ionized argon -- using the James Webb Space Telescope could become the next step towards transforming our understanding of how gas clears out of a planet-forming disk," Pascucci said. "These insights will help us get a better idea of the history and impact on our own solar system."
In addition, the group has also discovered that the inner disk of T Cha is evolving on very short timescales of decades; they found that the spectrum observed by JWST differs from the earlier spectrum detected by Spitzer. According to Chengyan Xie, a second-year doctoral student at LPL who leads this in-progress work, this mismatch could be explained by a small, asymmetric disk inside of T Cha that has lost some of its mass in the short 17 years that have elapsed between the two observations.
"Along with the other studies, this also hints that the disk of T Cha is at the end of its evolution," Xie said. "We might be able to witness the dispersal of all the dust mass in T Cha's inner disk within our lifetime."
Co-authors on the publications include Uma Gorti with the SETI Institute, Richard Alexander with the University of Leicester, Jane Morrison and Andras Gaspar with the UArizona's Steward Observatory, Cathie Clarke with the University of Cambridge, Giulia Ballabio with Imperial College London, and Dingshan Deng with the Lunar and Planetary Laboratory.

- ❖ Signs of life would be detectable in single ice grain emitted from extraterrestrial moons

Date: March 22, 2024
Source: University of Washington



This image shows red streaks across the surface of Europa, the smallest of Jupiter's four large moons. The upcoming Europa Clipper mission will send instruments to investigate this moon.

The ice-encrusted oceans of some of the moons orbiting Saturn and Jupiter are leading candidates in the search for extraterrestrial life. A new lab-based study led by the University of Washington in Seattle and the Freie Universität Berlin shows that individual ice grains ejected from these planetary bodies may contain enough material for instruments

headed there in the fall to detect signs of life, if such life exists.
"For the first time we have shown that even a tiny fraction of cellular material could be identified by a mass spectrometer onboard a spacecraft," said lead author Fabian Klenner, a UW postdoctoral researcher in Earth and space sciences. "Our results give us more confidence that using upcoming instruments, we will be able to detect lifeforms similar to those on Earth, which we increasingly believe could be present on ocean-bearing moons."
The open-access study was published March 22 in *Science Advances*. Other authors in the international team are from The Open University in the U.K.; NASA's Jet Propulsion Laboratory; the University of Colorado, Boulder; and the University of Leipzig.
The Cassini mission that ended in 2017 discovered parallel cracks near the south pole of Saturn's moon Enceladus. Emanating from these cracks are plumes containing gas and ice grains. NASA's Europa Clipper mission, scheduled to launch in October, will carry more instruments to explore in even more detail an icy moon of Jupiter, Europa.
To prepare for that mission, researchers are studying what this new generation of instruments might find. It is technically prohibitive to directly simulate grains of ice flying through space at 4 to 6 kilometres per second to hit an observational instrument, as the actual collision speed will be. Instead, the authors used an experimental setup that sends a thin beam of liquid water into a vacuum, where it disintegrates into droplets. They then used a laser beam to excite the droplets and mass spectral analysis to mimic what instruments on the space probe will detect.
Newly published results show that instruments slated to go on future missions, like the SUrface Dust Analyzer onboard Europa Clipper, can detect cellular material in one out of hundreds of thousands of ice grains.
The study focused on *Sphingopyxis alaskensis*, a common bacterium in waters off Alaska. While many studies use the bacterium *Escherichia coli* as a model organism, this single-celled organism is much smaller, lives in cold environments, and can survive with few nutrients. All these things make it a better candidate for potential life on the icy moons of Saturn or Jupiter.
"They are extremely small, so they are in theory capable of fitting into ice grains that are emitted from an ocean world like Enceladus or Europa," Klenner said.
Results show that the instruments can detect this bacterium, or portions of it, in a single ice grain. Different molecules end up in different ice grains. The new research shows that analysing single ice grains, where biomaterial may be concentrated, is more successful than averaging across a larger sample containing billions of individual grains.
A recent study led by the same researchers showed evidence of phosphate on Enceladus. This planetary body now appears to contain energy, water, phosphate, other salts and carbon-based organic material, making it increasingly likely to support lifeforms similar to those found on Earth.
The authors hypothesize that if bacterial cells are encased in a lipid membrane, like those on Earth, then they would also form a skin on the ocean's surface. On Earth, ocean scum is a key part of sea spray that contributes to the smell of the ocean. On an icy moon where the ocean is connected to the surface (e.g., through cracks in the ice shell), the vacuum of outer space would cause this subsurface ocean to boil. Gas bubbles rise through the ocean and burst at the surface, where cellular material gets incorporated into ice grains within the plume.
"We here describe a plausible scenario for how bacterial cells can, in theory, be incorporated into icy material that is formed from liquid water on Enceladus or Europa and then gets emitted into space," Klenner said.
The SUrface Dust Analyzer onboard Europa Clipper will be higher-powered than instruments on past missions. This and future instruments also will for the first time be able to detect ions with negative charges, making them better suited to detecting fatty acids and lipids.
"For me, it is even more exciting to look for lipids, or for fatty acids, than to look for building blocks of DNA, and the reason is because fatty acids appear to be more stable," Klenner said.
"With suitable instrumentation, such as the SUrface Dust Analyzer on NASA's Europa Clipper space probe, it might be easier than we thought to find life, or traces of it, on icy moons," said senior author Frank Postberg, a professor of planetary sciences at the Freie Universität Berlin. "If life is present there, of

course, and cares to be enclosed in ice grains originating from an environment such as a subsurface water reservoir."

The study was funded by the European Research Council, NASA and the German Research Foundation (DFG). Other co-authors are Janine Bönigk, Maryse Napoleoni, Jon Hillier and Nozair Khawaja at the Freie Universität Berlin; Karen Olsson-Francis at The Open University in the U.K.; Morgan Cable and Michael Malaska at the NASA Jet Propulsion Laboratory; Sascha Kempf at the University of Colorado, Boulder; and Bernd Abel at the University of Leipzig.

- Astrophysicist's research could provide a hint in the search for dark matter

Study provides some of the most stringent constraints on the nature of black matter yet

Date: March 20, 2024
Source: Clemson University

Credit: NASA, ESA, and D. Coe (NASA JPL/Caltech and STScI)

Dark matter is one of science's greatest mysteries. Although it is believed to make up about 85 percent of the cosmos, scientists know very little about its fundamental nature. Research by Clemson University postdoctoral fellow Alex McDaniel provides some of the most stringent constraints on the nature of dark matter yet. It also revealed a small hint of a signal that, if real, could be confirmed in the next decade or so.

Dark matter is one of science's greatest mysteries.

It doesn't absorb, reflect or emit light, so we can't see it. But its presence is implied by the gravitational effects it appears to have on galaxies.

Although dark matter makes up about 85 percent of the cosmos, scientists know very little about its fundamental nature.

Theories abound, and research by Clemson University postdoctoral fellow Alex McDaniel provides some of the most stringent constraints on the nature of dark matter yet.

His research also reveals a small hint of a signal that, if real, could be confirmed sometime in the next decade or so.

"With data collection and new discoveries in the future, this small hint could potentially turn into a very concrete detection of a dark matter model," McDaniel said.

Detecting dark matter would be groundbreaking.

"Dark matter is one of the most important things in astrophysics, and we know next to nothing about it. Discovering it will be a tremendous breakthrough," said Marco Ajello, an associate professor in the Clemson Department of Physics and Astronomy and McDaniel's adviser. "Whoever discovers may win a Nobel Prize. It's that big."

In this work, McDaniel and collaborators were searching dwarf galaxies for dark matter that self-annihilates into ordinary matter and gamma rays, a form of light at the highest energy levels. Dwarf galaxies are ideal for study because they are small, rich in dark matter and mostly lack other astrophysics phenomena such as gas, dust and supernova that could contaminate the findings.

"We look for these because, ideally, they give us a clean signal or allow us to rule out certain particle theories," McDaniel said.

Some models predict that dark matter has a certain mass or cross section, which is the probability of a specific event occurring due to the interaction of particles. That would determine what researchers would expect to see in gamma rays. If they don't see that, they can rule out those masses and cross sections, he said.

"In this paper, we do more ruling out, saying that dark matter can't have those masses or cross section," said Chris Karwin, a former postdoc at Clemson and a co-author of the study. Karwin is now a postdoctoral fellow at the NASA Goddard Space Flight Centre. "But compared to previous studies, we do start to see a hint of something that might be a signal from these systems."

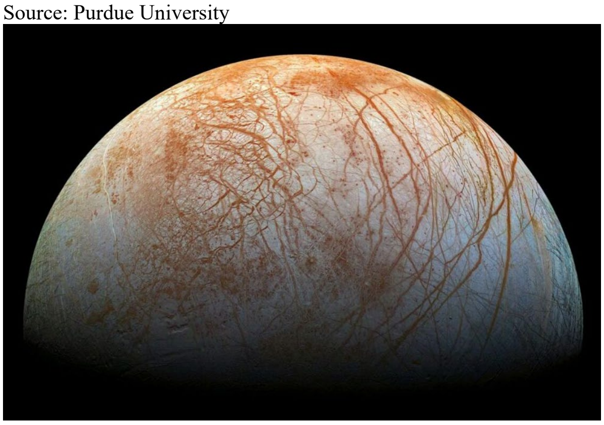
McDaniel's study uses the larger samples that include additional discovered dwarf galaxies and larger amounts of data than previous studies. He included about 50 dwarf galaxies in his study but said that with new, more powerful telescopes coming online in the near future, he expects that number to increase to 150-200.

"The new telescopes are basically dwarf galaxy detectors," he said. "We're projecting

with those improvements it's possible that instead of having just a little hint of a signal, we can have something that's a bona fide detection."
Ajello added, "If it (the signal) is real, eventually it will be confirmed."

- Icy impacts: Planetary scientists use physics and images of impact craters to gauge the thickness of ice on Europa

Jupiter's icy moon may be the next place humans find life, but first, they need to understand the structure of the moon
Date: March 20, 2024
Source: Purdue University


Jupiter's second Galilean moon, Europa. Its smooth surface has fewer craters than other moons, but they help us understand its icy shell. (Credit: NASA/JPL/Galileo spacecraft)

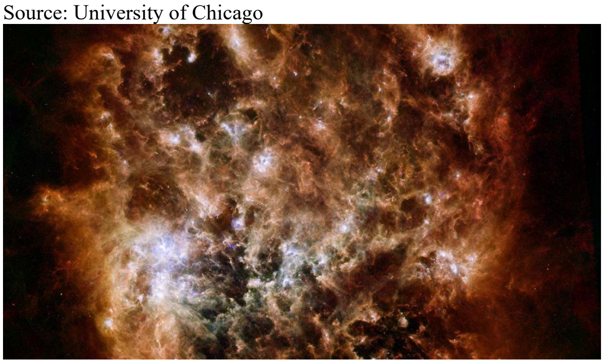
Sometimes planetary physics is like being in a snowball fight. Most people, if handed an already-formed snowball, can use their experience and the feel of the ball to guess what kind of snow it is comprised of: packable and fluffy, or wet and icy.
Using nearly the same principles, planetary scientists have been able to study the structure of Europa, Jupiter's icy moon.
Europa is a rocky moon, home to saltwater oceans twice the volume of Earth's, encased in a shell of ice. Scientists have long thought that Europa may be one of the best places in our solar system to look for no terrestrial life. The likelihood and nature of that life, though, heavily depend on the thickness of its icy shell, something astronomers have not yet been able to ascertain.
A team of planetary science experts including Brandon Johnson, an associate professor, and Shigeru Wakita, a research scientist, in the Department of Earth, Atmospheric, and Planetary Sciences in Purdue University's College of Science, announced in a new paper published in Science Advances [ES1] that Europa's ice shell is at least 20 kilometres thick.
To reach their conclusion, the scientists studied large craters on Europa, running a variety of models to determine what combination of physical characteristics could have created such a surface structure.
"This is the first work that has been done on this large crater on Europa," Wakita said. "Previous estimates showed a very thin ice layer over a thick ocean. But our research showed that there needs to be a thick layer -- so thick that convection in the ice, which has previously been debated, is likely."
Using data and images from the spacecraft Galileo, which studied Europa in 1998, Johnson analysed the impact craters to decode truths about Europa's structure. An expert in planetary physics and colossal collisions, Johnson has studied almost every major planetary body in the solar system. Scientists have long debated the thickness of Europa's ice shell; no one has visited to measure it directly, so scientists are creatively using the evidence at hand: the craters on Europa's icy surface.
"Impact cratering is the most ubiquitous surface process shaping planetary bodies," Johnson said. "Craters are found on almost every solid body we've ever seen. They are a major driver of change in planetary bodies. When an impact crater forms, it is essentially probing the subsurface structure of a planetary body. By understanding the sizes and shapes of craters on Europa and reproducing their formation with numerical simulations, we're able to infer information about how thick its ice shell is."
Europa is a frozen world, but the ice shelters a rocky core. The icy surface, though, is not stagnant. Plate tectonics and convection currents in the oceans and the ice itself refresh the surface fairly frequently. This means the surface itself is only 50 million to 100 million years old -- which sounds old to short-lived organisms like humans, but is young as far as geological periods go.
That smooth, young surface means that craters are clearly defined, easier to analyse and not very deep. Their impacts tell scientists more about the icy shell of the moon and the water ocean below, rather than conveying much information about its rocky heart.
"Understanding the thickness of the ice is vital to theorizing about possible life on Europa," Johnson said. "How thick the ice shell is controls what kind of processes are happening within it, and that is really important for

understanding the exchange of material between the surface and the ocean. That is what will help us understand how all kinds of processes happen on Europa -- and help us understand the possibility of life."

- Scientists find one of the most ancient stars that formed in another galaxy

Stars from the Large Magellanic Cloud reveal new hints about how the universe got its elements

Date: March 20, 2024
Source: University of Chicago



The Large Magellanic Cloud, a galaxy that fell into our billions of years ago, could help reveal how the universe evolved in other regions. Above, images of the Cloud taken in infrared light.

The first generation of stars transformed the universe. Inside their cores, simple hydrogen and helium fused into a rainbow of elements. When these stars died, they exploded and sent these new elements across the universe. The iron running in your veins and the calcium in your teeth and the sodium powering your thoughts were all born in the heart of a long-dead star.

No one has been able to find one of those first generation of stars, but scientists have announced a unique finding: a star from the second generation that originally formed in a different galaxy from ours.

"This star provides a unique window into the very early element-forming process in galaxies other than our own," said Anirudh Chiti, a University of Chicago postdoctoral fellow and first author on a paper announcing the findings. "We have built up an idea of the how these stars that were chemically enriched by the first stars look like in the Milky Way, but we don't yet know if some of these signatures are unique, or if things happened similarly across other galaxies."

The paper was published March 20 in *Nature Astronomy*.

'Fishing needles out of haystacks'

Chiti specializes in what is called stellar archaeology: Reconstructing how the earliest generations of stars changed the universe.

"We want to understand what the properties of those first stars were and what were the elements they produced," said Chiti.

But no one has yet managed to directly see these first-generation stars, if any remain in the universe. Instead, Chiti and his colleagues look for stars that formed from the ashes of that first generation.

It's hard work, because even the second generation of stars is now incredibly ancient and rare. Most stars in the universe, including our own sun, are the result of tens to thousands of generations, building up more and more heavy elements each time. "Maybe fewer than 1 in 100,000 stars in the Milky Way is one of these second-gen stars," he said. "You really are fishing needles out of haystacks."

But it's worth it to get snapshots of what the universe looked like back in time. "In their outer layers, these stars preserve the elements near where they formed," he explained. "If you can find a very old star and get its chemical composition, you can understand what the chemical composition of the universe was like where that star formed, billions of years ago."

An intriguing oddity

For this study, Chiti and his colleagues aimed their telescopes at an unusual target: the stars that make up the Large Magellanic Cloud.

The Large Magellanic Cloud is a bright swath of stars visible to the naked eye in the Southern Hemisphere. We now think it was once a separate galaxy that was captured by the Milky Way's gravity just a few billion years ago. This makes it particularly interesting because its oldest stars were formed outside the Milky Way -- giving astronomers a chance to learn about whether conditions in the early universe all looked the same, or were different in other places.

The scientists searched for evidence of these particularly ancient stars in the Large Magellanic Cloud and catalogued ten of them, first with the European Space Agency's *Gaia* satellite and then with the Magellan Telescope in Chile.

One of these stars immediately jumped out as an oddity. It had much, much less of the heavier elements in it than any other star yet seen in the Large Magellanic Cloud. This means it was probably formed in the wake of the first generation of stars -- so it had not yet built-up heavier elements over the course of repeated star births and deaths.

Mapping out its elements, the scientists were surprised to see that it had a lot less carbon than iron compared to what we see in Milky Way stars.

"That was very intriguing, and it suggests that perhaps carbon enhancement of the earliest generation, as we see in the Milky Way, was not universal," Chiti said. "We'll have to do further studies, but it suggests there are differences from place to place.

"I think we're filling out the picture of what the early element enrichment process looked like in different environments," he said.

Their findings also corroborated other studies that have suggested that the Large Magellanic Cloud made much fewer stars early on compared to the Milky Way.

Chiti is currently leading an imaging program to map out a large portion of the southern sky to find the earliest stars possible. "This discovery suggests there should be many of these stars in the Large Magellanic Cloud if we look closely," he said. "It's really exciting to be opening up stellar archaeology of the Large Magellanic Cloud, and to be able to map out in such detail how the first stars chemically enriched the universe in different regions."

- ❖ Quantum tornado provides gateway to understanding black holes

Date: March 20, 2024
Source: University of Nottingham

Scientists have for the first time created a giant quantum vortex to mimic a black hole in superfluid helium that has allowed them to see in greater detail how analogue black holes behave and interact with their surroundings.

Research led by the University of Nottingham, in collaboration with King's College London and Newcastle University, have created a novel experimental platform: a quantum tornado. They have created a giant swirling vortex within superfluid helium that is chilled to the lowest possible temperatures. Through the observation of minute wave dynamics on the superfluid's surface, the research team has shown that these quantum tornados mimic gravitational conditions near rotating black holes. The research has been published today in *Nature*.

Lead author of the paper, Dr Patrik Svancara from the School of Mathematical Sciences at the University of Nottingham explains:

"Using superfluid helium has allowed us to study tiny surface waves in greater detail and accuracy than with our previous experiments in water. As the viscosity of superfluid helium is extremely small, we were able to meticulously investigate their interaction with the superfluid tornado and compare the findings with our own theoretical projections."

The team constructed a bespoke cryogenic system capable of containing several litres of superfluid helium at temperatures lower than -271 °C. At this temperature liquid helium acquires unusual quantum properties. These properties typically hinder the formation of giant vortices in other quantum fluids like ultracold atomic gases or quantum fluids of light, this system demonstrates how the interface of superfluid helium acts as a stabilizing force for these objects.

Dr Svancara continues: "Superfluid helium contains tiny objects called quantum vortices, which tend to spread apart from each other. In our set-up, we've managed to confine tens of thousands of these quanta in a compact object resembling a small tornado, achieving a vortex flow with record-breaking strength in the realm of quantum fluids."

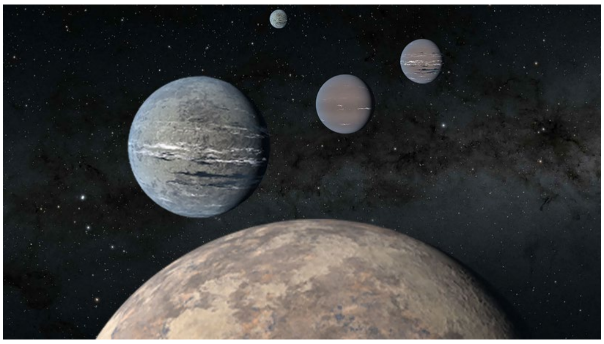
Researchers uncovered intriguing parallels between the vortex flow and the gravitational influence of black holes on the surrounding spacetime. This achievement opens new avenues for simulations of finite-temperature quantum field theories within the complex realm of curved spacetimes.

Professor Silke Weinfurtner, leading the work in the Black Hole Laboratory where this experiment was developed, highlights the significance of this work: "When we first observed clear signatures of black hole physics in our initial analogue experiment back in 2017, it was a breakthrough moment for understanding some of the bizarre phenomena that are often challenging, if not impossible, to study otherwise. Now, with our more sophisticated experiment, we have taken this research to the next level, which could eventually lead us to predict how quantum

fields behave in curved spacetimes around astrophysical black holes."
This groundbreaking research is funded by a £5 million grant from the Science Technology Facilities Council, distributed among teams at seven leading UK institutions, including the University of Nottingham, Newcastle University and King's College London. The project has also been supported by both the UKRI Network grant on Quantum Simulators for Fundamental Physics and the Leverhulme Research Leaders Fellowship held by Professor Silke Weinfurtner.
The culmination of this research will be celebrated and creatively explored in an ambi exhibitiontitled *Cosmic Titans* at the Djanogly Gallery, Lakeside Arts, The University of Nottingham, from 25 January to 27 April 2025 (and touring to venues in the UK and overseas). The exhibition will comprise newly commissioned sculptures, installations, and immersive art works by leading artists including Conrad Shawcross RA that result from a series of innovative collaborations between artists and scientists facilitated by the ARTlab Nottingham. The exhibition will marry creative and theoretical inquiries into black holes and the birth of our Universe.

- High school students contribute to exoplanet discovery

The high school students' involvement in this research underscores the potential of hands-on science education to motivate and engage young minds
Date: March 20, 2024
Source: SETI Institute



An artist rendering of the five-planet system around TOI-1233 includes a super-Earth (foreground) that could help solve mysteries of planet formation.
Credit: NASA/JPL-Caltech

In a project aimed at democratizing science and fostering educational enrichment, a group of high school students from the Galaxy Explorer program at the Chabot Space & Science Centre in Oakland, California, made contributions to the field of exoplanet research. Researchers from the SETI Institute worked with the students to use backpack-sized digital smart telescopes provided by Unistellar; these young citizen scientists played a role in observing and confirming the nature of a warm and dense sub-Saturn planet, known as TIC 139270665 b, orbiting a metal-rich G2 star.
"By using new technology available with digital smart telescopes, we can take large steps towards the democratization of modern astronomy and education since the outcomes of initiatives like this can contribute to both astronomical research and education with easy-to-use and increasingly accessible technology," said Dr. Dan Peluso, SETI Institute Affiliate. "In such endeavours, participants are 'learning by doing' and the doing is not some meaningless tasks. Instead, the 'doing' is the astronomical data collection, which in the past has been mostly left to professional astronomers and their observatories, or with highly skilled citizen astronomers with technical telescope setups. With TIC 139270665 b, our high school students had a challenging but meaningful task -- capture the second transit of an exoplanet with a poorly understood orbital period. These students were engaged, inspired, and were easily able to setup and control the Unistellar telescopes with very little training. Citizen science opportunities like this and new technology with digital smart telescopes represent a fundamental shift and revolution for how we can approach and perform astronomical research moving forward."
The discovery of TIC 139270665 b, the densest known warm sub-Saturn within the TESS (Transiting Exoplanet Survey Satellite) family, marks a milestone in exploring exoplanets. The initial clues of TIC 139270665 b's existence were initially discovered by a citizen science group inspecting TESS photometric data, highlighting the role of public engagement in advancing scientific knowledge. Through further study by analysing radial velocity data from the Lick Observatory, Peluso and Dr. Paul Dalba and their team were able to confirm that TIC 139270665 b is indeed a planet and even has a sibling planet, TIC 139270665 c. The photometric data from the global Unistellar Citizen Science Network, including the Galaxy Explorers, was not able to definitively confirm a second transit with 100% confidence, however, their data was

useful for the exoplanet study since it helped to rule out times when a transit was not happening and because it helped the scientists to learn valuable lessons about how to approach citizen scientist campaigns such as this in the future.

The SETI Institute is the scientific partner of the Unistellar network, known for its global distribution of citizen astronomers. Citizen astronomers with Unistellar telescopes collected data that furthered the understanding of this exoplanet's orbital period and characteristics as part of the *Unistellar Network Investigating TESS Exoplanets* (UNITE) program, a NASA citizen science project that is part of the Unistellar Transiting Exoplanets campaign. This effort, funded by the Gordon and Betty Moore Foundation and NASA, contributes to the scientific community's knowledge of planetary formation and evolution and is an educational initiative integrating young students into astrophysics data collection.

The high school students' involvement in this research underscores the potential of hands-on science education to motivate and engage young minds. Through their participation, students gained real-life skills and insights into the scientific process, from planning and conducting observations to analysing data and contributing to a scientific publication, on which they are all co-authors. This experience demonstrates the power of blending educational empowerment with research, allowing students to contribute to our understanding of the universe.

"This experience further propelled my fascination with the subject of astronomy, specifically in regard to exoplanetary science," said Serina Jain, student at San Francisco University High School. "Working on this observation fuelled my joy of engaging in astrophysics research and my plans to pursue this as a major in college, as well as my love of sharing astronomy with others. Since helping Dr. Peluso with this observation, I have been able to bring even more passion and knowledge to my role as co-founder and leader of the San Francisco University High School Astronomy Club. This past summer, I went on to partake in a 7-week lab internship with the California Institute of Technology (Caltech) Mawet Astrophysics Lab, researching in exoplanet detection by way of direct imaging, using coronagraphy and spectroscopy. My inspiration to seek this involvement largely stemmed from my overwhelmingly positive experience working on this observation with Dr. Peluso."

This initiative is a testament to the collaborative spirit of the scientific and educational communities. It showcases how integrating citizen science and education can lead to discoveries and inspire the next generation of scientists and explorers. The high school students' enthusiasm for this project is a beacon of hope for the future of scientific inquiry and education, proving that young minds can contribute to our understanding of the cosmos when given the opportunity.

As we continue to explore the vast expanse of space, the contributions of these young citizen scientists remind us of the pivotal role of education and public engagement in the pursuit of knowledge and discovery. The future of astronomy and space exploration is bright, with students like those in the Galaxy Explorer program leading the way toward new horizons and uncovering the mysteries of the universe.

This research was funded by the Gordon and Betty Moore Foundation (#10561) and NASA Citizen Science Seed Funding Program grant (Goddard-80NSSC22K113), with additional funding from the NSF Astronomy and Astrophysics Postdoctoral Fellowship (AST-1903811) and the 51 Pegasi b Postdoctoral Fellowship, courtesy of the Heising-Simons Foundation.

- ❖ Pioneering muscle monitoring in space to help astronauts stay strong in low-gravity

Handheld device could also bring about a step-change in muscle monitoring back on Earth

Date: March 20, 2024
Source: University of Southampton

NASA astronaut using the Advanced Resistive Exercise Device (ARED) onboard the ISS. Credit NASA

Astronauts have been able to track their muscle health in spaceflight for the first time using a handheld device, revealing which muscles are most at risk of weakening in low gravity conditions.

An international research team, including the University of Southampton and led by Charité University in Berlin, monitored the muscle health of twelve astronauts before, during and after a stay on the International Space Station (ISS).

Findings published in *Nature Scientific Reports*indicate that the astronauts' daily exercise regime was effective in preserving most muscle groups, but crucial lower leg muscles showed signs of deterioration.

The technology and assessment protocol used in space could also bring about a step-change in healthcare back on Earth, allowing healthcare professionals to better monitor muscle health in neuro-musculoskeletal conditions, such as Parkinson's Disease and stroke, and in patients in critical care.

"Being able to perform inflight muscle health checks will allow the astronauts to see which muscles are losing strength and adjust their exercise programme accordingly," says Professor Maria Stokes OBE, UK lead of the project, from the School of Health Sciences at the University of Southampton. "Being able to personalise exercises like this will be crucial on future long-duration missions to the Moon and Mars."

Muscle loss in space

Microgravity conditions during spaceflight mean astronauts' bodies aren't subjected to the workload they are used to on Earth, meaning muscles don't have to work very hard to perform functional tasks onboard the spacecraft. This puts astronauts at risk of muscle weakness and bone loss, with up to a 20 per cent decrease in skeletal muscle mass over a month.

To counteract this, astronauts onboard the ISS perform an exercise programme for around two hours a day, six or seven days a week. Until now, monitoring the effectiveness of this programme has only been possible with pre- and post-flight checks due to a lack of appropriate equipment.

Handheld device

The MyotonPRO is a smartphone-sized device which measures the properties of superficial skeletal muscles, tendons, ligaments, adipose tissue (fat), and skin. It's non-invasive and uses a 'tap and listen' method, sending a precision impulse causing the tissues to oscillate and recording the way the tissue responds to compute various characteristics, such as stiffness, tone and elasticity.

The device was used to measure specific points on the astronauts' bodies throughout their mission, before the flight, during a 4 to 11-month stay onboard the ISS, and up to three months post-flight. Researchers were particularly interested in measuring passive muscle stiffness, as it reflects muscle strength, which is not possible to measure in multiple muscles in space.

"People tend to associate stiffness with poor flexibility and mobility, but an adequate degree of passive stiffness is needed to maintain joint stability and posture," says co-lead author Paul Muckelt, a research fellow at the University of Southampton. "Stiffness provides support during movement, preventing excessive stretching of muscles and reducing the risk of injury. It also contributes to the efficiency of movement by storing and releasing elastic energy during activities, such as walking or running."

Passive muscle stiffness can shift throughout the day, so recording conditions needed to be standardised to ensure accuracy.

Weakening of crucial leg muscles

The team found that the astronauts' exercise programme was effective in preserving muscle stiffness in most sites measured, including the shoulders, neck, back and thigh. But crucially, the tibialis anterior showed signs of waning in all 12 astronauts. The tibialis anterior, located in the front of the lower leg, lifts the foot upwards towards the shin. This movement is essential for walking and running.

The soleus and gastrocnemius muscles in the calf act in opposition to the tibialis anterior, pointing the foot downward. The soleus also showed a decrease in stiffness compared to preflight, but it did increase gradually over time on the ISS. The gastrocnemius increased in stiffness, indicating it might take over most of the function of the calf.

The Achilles tendon (attached to both muscles) also decreased in stiffness compared to preflight measurements. Monitoring the Achilles is important as sudden reloading, such as that induced by a change in gravitation force, could result in injury or even rupture.

Professor Dieter Blottner at the Charité - Universitätsmedizin Berlin, Germany, who led the Myotones Project said: "These lower leg muscles have a vital role in gait and ankle joint stabilisation. Impaired function could hinder performance on missions during planetary excursions and risk injury on return to Earth's gravity, so exercises which target these muscles should be included in the astronauts' exercise regimes going forward."

Use on Earth

Measuring muscle health in this relatively simple way in space could translate to everyday life back on Earth -- in healthcare settings, sports, remote communities and even people's homes.

Assessing stiffness and other muscle characteristics helps in managing neurological disorders, like Parkinson's disease and stroke. Currently, clinical assessments involve subjective methods, rating stiffness as mild, moderate or severe.

MyotonPRO offers objective measurements for a more accurate and sensitive assessment of the effects of different treatments. In the future, devices like this could be used by patients to monitor drug effects at home, akin to self-testing blood in diabetes.

Dr Martin Warner, co-senior author of the research paper from the University of Southampton said: "This technology and the use of passive muscle stiffness as a muscle health indicator could be used by many health professionals during clinical assessments. Widespread uptake could revolutionise healthcare in neuro-musculoskeletal, critical care and geriatric medicine, rehabilitation and precision medicine."

Libby Moxon, Exploration Science Officer for Lunar and Microgravity at the UK Space Agency (UKSA), said: "As we approach increasingly ambitious missions that will see us travel deeper into space for longer, it's imperative we fully understand how space travel impacts human muscle properties, so we can protect astronauts' muscle health on long-duration missions.

"The University of Southampton's fascinating research, supported by the UK Space Agency, demonstrates how innovative technology can support this goal, taking advantage of the microgravity environment to provide insights that will also help improve healthcare in space and back on Earth."

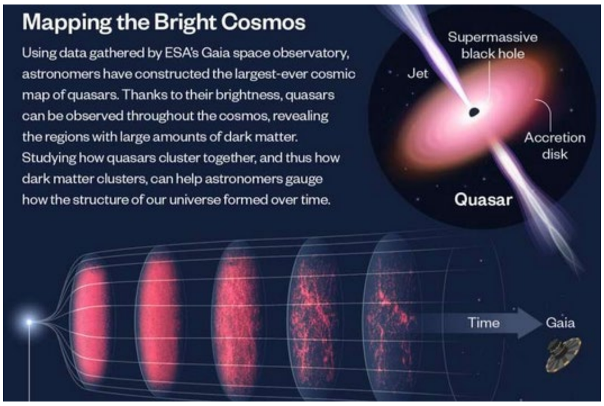
Muscle stiffness indicating mission crew health in space is published in the *Nature* journal *Scientific Reports* and is available online.

The study was funded through the UK Space Agency (UKSA), the German Aerospace Agency (DLR), the European Space Agency (ESA) and the Science Technology Facilities Council (STFC).

- Largest-ever map of universe's active supermassive black holes released

The new map includes around 1.3 million quasars from across the visible universe and could help scientists better understand the properties of dark matter

Date: March 18, 2024
Source: Simons Foundation



Astronomers have charted the largest-ever volume of the universe with a new map of active supermassive black holes living at the centres of galaxies. Called quasars, the gas-gobbling black holes are, ironically, some of the universe's brightest objects.

The new map logs the location of about 1.3 million quasars in space and time, the furthest of which shone bright when the universe was only 1.5 billion years old. (For comparison, the universe is now 13.7 billion years old.)

"This quasar catalogue is different from all previous catalogues in that it gives us a three-dimensional map of the largest-ever volume of the universe," says map co-creator David Hogg, a senior research scientist at the Flatiron Institute's Centre for Computational Astrophysics in New York City and a professor of physics and data science at New York University. "It isn't the catalogue with the most quasars, and it isn't the catalogue with the best-quality measurements of quasars, but it is the catalogue with the largest total volume of the universe mapped."

Hogg and his colleagues present the map in a paper published March 18 in *The Astrophysical Journal*. The paper's lead author, Kate Storey-Fisher, is a postdoctoral researcher at the Donostia International Physics Centre in Spain.

The scientists built the new map using data from the European Space Agency's Gaia space telescope. While Gaia's main objective is to map the stars in our galaxy, it also inadvertently spots objects outside the Milky Way, such as quasars and other galaxies, as it scans the sky.

"We were able to make measurements of how matter clusters together in the early universe that are as precise as some of those from major international survey projects -- which is quite remarkable given that we got our data as a 'bonus' from the Milky Way-focused Gaia project," Storey-Fisher says.

Quasars are powered by supermassive black holes at the centres of galaxies and can be hundreds of times as bright as an entire galaxy. As the black hole's gravitational pull spins up nearby gas, the process generates an extremely bright disk and sometimes jets of light that telescopes can observe.

The galaxies that quasars inhabit are surrounded by massive halos of invisible material called dark matter. By studying quasars, astronomers can learn more about dark matter, such as how much it clumps together.

Astronomers can also use the locations of distant quasars and their host galaxies to better understand how the cosmos expanded over time. For example, scientists have already compared the new quasar map with the oldest light in our cosmos, the cosmic microwave background. As this light travels to us, it is bent by the intervening web of dark matter -- the same web mapped out by the quasars. By comparing the two, scientists can measure how strongly matter clumps together.

"It has been very exciting to see this catalogue spurring so much new science," Storey-Fisher says. "Researchers around the world are using the quasar map to measure everything from the initial density fluctuations that seeded the cosmic web to the distribution of cosmic voids to the motion of our solar system through the universe."

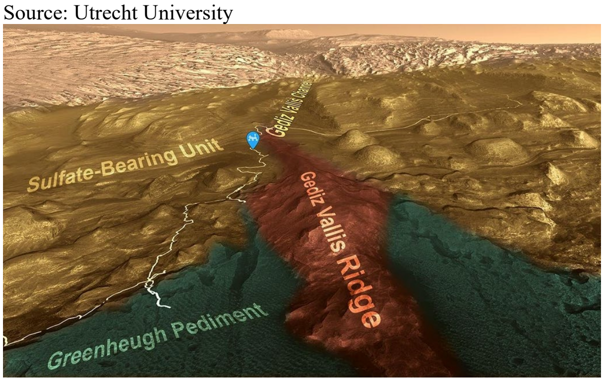
The team used data from Gaia's third data release, which contained 6.6 million quasar candidates, and data from NASA's Wide-Field Infrared Survey Explorer and the Sloan Digital Sky Survey. By combining the datasets, the team removed contaminants such as stars and galaxies from Gaia's original dataset and more precisely pinpointed the distances to the quasars. The team also created a map showing where dust, stars and other nuisances are expected to block our view of certain quasars, which is critical for interpreting the quasar map.

"This quasar catalogue is a great example of how productive astronomical projects are," says Hogg. "Gaia was designed to measure stars in our own galaxy, but it also found millions of quasars at the same time, which give us a map of the entire universe."

- ❖ Surprising insights about debris flows on Mars

Research pushes the presence of water on Mars further into the past

Date: March 14, 2024
Source: Utrecht University



The route NASA's Curiosity Mars rover has taken while driving through the lower part of Mount Sharp is shown as a pale line here. Different parts of the mountain are labelled by colour; Curiosity is currently near the top end of Gediz Vallis Ridge, which appears in red. Credit: NASA/JPL-Caltech/ESA/University of Arizona/JHUAPL/MSSS/USGS Astrogeology Science Centre

The period that liquid water was present on the surface of Mars may have been shorter than previously thought. Channel landforms called gullies, previously thought to be formed exclusively by liquid water, can also be formed by the action of evaporating CO_2 ice. That is the conclusion of a new study by Lonneke Roelofs, a planetary researcher at Utrecht University. "This influences our ideas about water on Mars in general, and therefore our search for life on the planet." The results of the study are published this week in the journal *Communications Earth and Environment*.

"The Martian atmosphere is 95% CO_2," Lonneke Roelofs explains. "In winter, air temperatures drop below -120 degrees Celsius, which is cold enough for CO_2 in the atmosphere to freeze." In the process of freezing, CO_2 gas can change directly to CO_2 ice, skipping the liquid phase. The process is similar to frost on Earth, where water vapour forms ice crystals and blankets the landscape in a white film. Warmer spring temperatures, combined with the thin Martian atmosphere,

causes CO_2 ice to evaporate directly back to gas, again skipping the liquid phase. "We call that 'sublimation'. The process is extremely explosive due to Mars' low air pressure. The created gas pressure pushes sediment grains apart causing the material to flow, similar to debris flows in mountainous areas on Earth. These flows can reshape the Martian landscape -- even in the absence of water."
Scientists have long hypothesised that CO_2 ice could be a driving force behind these Martian landscape structures. "But those hypotheses were mainly based on models or satellite studies," Roelofs explains. "With our experiments in a so-called 'Mars chamber', we were able to simulate this process under Martian conditions. Using this specialised lab equipment, we could directly study this process with our own eyes. We even observed that debris flows driven by CO_2 ice under Martian conditions flow just as efficiently as the debris flows driven by water on Earth."

Extraterrestrial life

"We know for sure that there was once water on the surface of Mars. This study does not prove the contrary," Roelofs says. "But the emergence of life likely needs a long period where liquid water was present. Previously, we thought that these landscape structures were formed by debris flows driven by water, because of their similarity to debris flow systems on Earth. My research now shows that, in addition to debris flows powered by water, the sublimation of frozen CO_2 can also serve as a driving force behind the formation of these Martian gully landscapes. That pushes the presence of water on Mars further into the past, making the chance of life on Mars smaller." And that makes us even more unique than we thought.

Why Mars?

But what makes someone interested in landscapes 330 million km away? "Mars is our closest neighbour. It's the only other rocky planet close to our solar system's 'green zone'. The zone is precisely far enough from the sun to allow for liquid water to exist, a prerequisite for life. So, Mars is a place where we possibly can find answers to questions about how life developed, including potential extraterrestrial life," answers Roelofs. "Plus, studying the formation of landscape structures on other planets is a way for us to step outside our Earthly context. You ask different questions, which leads to new insights on processes here on Earth. For example, we can also observe the process of gas-driven debris flows in pyroclastic flows around volcanoes, here on Earth. So, this research could contribute to a better understanding of terrestrial volcanic hazards."