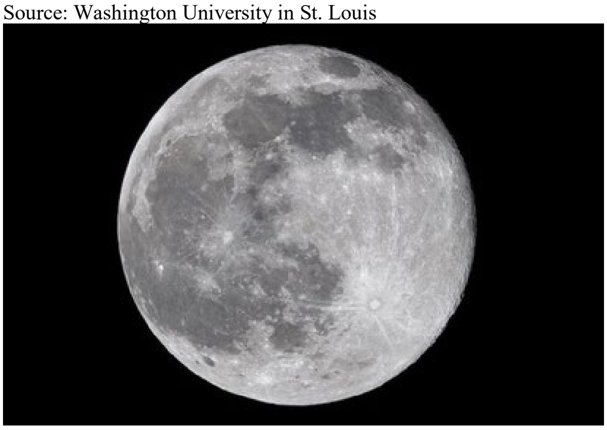
South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 558 – November 5th 2021 Editor: Roger Burgess
Main Speaker 19:30 Dr Steve Barrett Department of Physics University of Liverpool Weird World of the Very Very Small

The main talk will also be available to participate in via Zoom
Last month's Covid-19 rules still apply at the planetarium

- Chang'e-5 samples reveal key age of moon rocks

Scientists share analysis of first fresh samples from the moon in more than 40 years
Date: October 7, 2021
Source: Washington University in St. Louis



Moon (stock image).
Credit: © Simon van Hemert / stock.adobe.com

A lunar probe launched by the Chinese space agency recently brought back the first fresh samples of rock and debris from the moon in more than 40 years. Now an international team of scientists -- including an expert from Washington University in St. Louis -- has determined the age of these moon rocks at close to 1.97 billion years old.

"It is the perfect sample to close a 2-billion-year gap," said Brad Jolliff, the Scott Rudolph Professor of Earth and Planetary Sciences in Arts & Sciences and director of the university's McDonnell Centre for the Space Sciences. Jolliff is a U.S.-based co-author of an analysis of the new moon rocks led by the Chinese Academy of Geological Sciences, published Oct. 7 in the journal *Science*.

The age determination is among the first scientific results reported from the successful Chang'e-5 mission, which was designed to collect and return to Earth rocks from some of the youngest volcanic surfaces on the moon.

"Of course, 'young' is relative," Jolliff said. "All of the volcanic rocks collected by Apollo were older than 3 billion years. And all of the young impact craters whose ages have been determined from the analysis of samples are younger than 1 billion years. So the Chang'e-5 samples fill a critical gap."

The gap that Jolliff references is important not only for studying the moon, but also for studying other rocky planets in the solar system.

As a planetary body, the moon itself is about 4.5 billion years old, almost as old as the Earth. But unlike the Earth, the moon doesn't have the erosive or mountain-building processes that tend to erase craters over the years. Scientists have taken advantage of the moon's enduring craters to develop methods of estimating the ages of different regions on its surface, based in part on how pocked by craters the area appears to be.

This study shows that the moon rocks returned by Chang'e-5 are only about 2 billion years old. Knowing the age of these rocks with certainty, scientists are now able to more accurately calibrate their important chronology tools, Jolliff said.

"Planetary scientists know that the more craters on a surface, the older it is; the fewer craters, the younger the surface. That's a nice relative determination," Jolliff said. "But to

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put absolute age dates on that, one has to have samples from those surfaces."

"The Apollo samples gave us a number of surfaces that we were able to date and correlate with crater densities," Jolliff explained. "This cratering chronology has been extended to other planets -- for example, for Mercury and Mars -- to say that surfaces with a certain density of craters have a certain age."

"In this study, we got a very precise age right around 2 billion years, plus or minus 50 million years," Jolliff said. "It's a phenomenal result. In terms of planetary time, that's a very precise determination. And that's good enough to distinguish between the different formulations of the chronology."

Other interesting findings from the study relate to the composition of basalts in the returned samples and what that means for the moon's volcanic history, Jolliff noted.

The results presented in the Science paper are just the tip of the iceberg, so to speak. Jolliff and colleagues are now sifting through the regolith samples for keys to other significant lunar science issues, such as finding bits and pieces tossed into the Chang'e 5 collection site from distant, young impact craters such as Aristarchus, to possibly determining the ages of these small rocks and the nature of the materials at those other impact sites.

Jolliff has worked with the scientists at the Sensitive High Resolution Ion MicroProbe (SHRIMP) Centre in Beijing that led this study, including study co-author Dunyi Liu, for over 15 years. This long-term relationship is possible through a special collaboration agreement that includes Washington University and its Department of Earth and Planetary Sciences, and Shandong University in Weihai, China, with support from Washington University's McDonnell Centre for the Space Sciences.

"The lab in Beijing where the new analyses were done is among the best in the world, and they did a phenomenal job in characterizing and analysing the volcanic rock samples," Jolliff said.

"The consortium includes members from China, Australia, the U.S., the U.K. and Sweden," Jolliff continued. "This is science done in the ideal way: an international collaboration, with free sharing of data and knowledge -- and all done in the most collegial way possible. This is diplomacy by science."

Jolliff is a specialist in mineralogy and provided his expertise for this study of the Chang'e-5 samples. His personal research background is focused on the moon and Mars, the materials that make up their surfaces and what they tell about the planets' history.

As a member of the Lunar Reconnaissance Orbiter Camera science team and leader of the Washington University team in support of NASA's Apollo Next Generation Sample Analysis (ANGSA) program, Jolliff investigates the surface of the moon, relating what can be seen from orbit to what is known about the moon through the study of lunar meteorites and Apollo samples -- and now, from Chang'e-5 samples.

- Dwarf planet Vesta a window to the early solar system

Date: October 6, 2021
Source: University of California - Davis

Dwarf planet Vesta illustration (stock image). *Credit: © mode_list / stock.adobe.com*

The dwarf planet Vesta is helping scientists better understand the earliest era in the formation of our solar system. Two recent papers involving scientists from the University of California, Davis, use data from meteorites derived from Vesta to resolve the "missing mantle problem" and push back our knowledge of the solar system to just a couple of million years after it began to form. The papers were published in *Nature Communications* Sept. 14 and *Nature Astronomy* Sept. 30.

Vesta is the second-largest body in the asteroid belt at 500 kilometres across. It's big enough to have evolved in the same way as rocky, terrestrial bodies like the Earth, moon and Mars. Early on, these were balls of molten rock heated by collisions. Iron and the siderophiles, or 'iron-loving' elements such as rhenium, osmium, iridium, platinum and palladium sank to the centre to form a metallic core, leaving the mantle poor in these elements. As the planet cooled, a thin solid crust formed over the mantle. Later, meteorites brought iron and other elements to the crust.

Most of the bulk of a planet like Earth is mantle. But mantle-type rocks are rare among asteroids and meteorites.

"If we look at meteorites, we have core material, we have crust, but we don't see mantle," said Qing-Zhu Yin, professor of earth and planetary sciences in the UC Davis College of Letters and Science. Planetary scientists have called this the "missing mantle problem."

In the recent Nature Communications paper, Yin and UC Davis graduate students Supratim Dey and Audrey Miller worked with first author Zoltan Vaci at the University of New Mexico to describe three recently discovered meteorites that do include mantle rock, called ultramafic that include mineral olivine as a major component. The UC Davis team contributed precise analysis of isotopes, creating a fingerprint that allowed them to identify the meteorites as coming from Vesta or a very similar body.

"This is the first time we've been able to sample the mantle of Vesta," Yin said.

NASA's Dawn mission remotely observed rocks from the largest south pole impact crater on Vesta in 2011 but did not find mantle rock.

Probing the early solar system

Because it is so small, Vesta formed a solid crust long before larger bodies like the Earth, moon and Mars. So the siderophile elements that accumulated in its crust and mantle form a record of the very early solar system after core formation. Over time, collisions have broken pieces off Vesta that sometimes fall to Earth as meteorites.

Yin's lab at UC Davis had previously collaborated with an international team looking at elements in lunar crust to probe the early solar system. In the second paper, published in Nature Astronomy, Meng-Hua Zhu at the Macau University of Science and Technology, Yin and colleagues extended this work using Vesta.

"Because Vesta formed very early, it's a good template to look at the entire history of the Solar System," Yin said. "This pushes us back to two million years after the beginning of solar system formation."

It had been thought that Vesta and the larger inner planets could have got much of their material from the asteroid belt. But a key finding from the study was that the inner planets (Mercury, Venus, Earth and moon, Mars and inner dwarf planets) got most of their mass from colliding and merging with other large, molten bodies early in the solar system. The asteroid belt itself represents the leftover material of planet formation, but did not contribute much to the larger worlds.

Additional co-authors on the *Nature Communications* paper are: James Day and Marine Paquet, Scripps Institute of Oceanography, UC San Diego; Karen Ziegler and Carl Agee, University of New Mexico; Rainer Bartoschewitz, Bartoschewitz Meteorite Laboratory, Gifhorn, Germany; and Andreas Pack, Georg-August-Universität, Göttingen, Germany. Yin's other co-authors on the Nature Astronomy paper are: Alessandro Morbidelli, University of Nice-Sophia Antipolis, France; Wladimir Neumann, Universität Heidelberg, Germany; James Day, Scripps Institute of Oceanography, UCSD; David Rubie, University of Bayreuth, Germany; Gregory Archer, University of Münster, Germany; Natalia Artemieva, Planetary Science Institute, Tucson; Harry Becker and Kai Wünnemann, Freie Universität Berlin.

The work was partly supported by the Science and Technology Development Fund, Macau, the Deutsche Forschungsgemeinschaft and NASA.

- ❖ Did Venus ever have oceans?

Date: October 13, 2021
Source: Université de Genève

Planet Venus illustration (stock image).
Credit: © Igor_Filonenko / stock.adobe.com

The planet Venus can be seen as the Earth's evil twin. At first sight, it is of comparable mass and size as our home planet, similarly consists mostly of rocky material, holds some water and has an atmosphere. Yet, a closer look reveals striking differences between them: Venus' thick CO_2 atmosphere, extreme surface temperature and pressure, and sulphuric acid clouds are indeed a stark contrast to the conditions needed for life on Earth. This may, however, have not always been the case. Previous studies have suggested that Venus may have been a much more hospitable place in the past, with its own liquid water oceans. A team of astrophysicists led by the University of Geneva (UNIGE) and the National Centre of Competence in Research (NCCR) PlanetS, Switzerland, investigated whether our planet's twin did indeed have milder periods. The results, published in the journal *Nature*, suggest that this is not the case.

Venus has recently become an important research topic for astrophysicists. ESA and NASA have decided this year to send no less than three space exploration missions over the next decade to the second closest planet to the Sun. One of the key questions these missions aim to answer is whether or not Venus ever hosted early oceans. Astrophysicists led by Martin Turbet, researcher at the Department of Astronomy of the Faculty of Science of the UNIGE and member of the NCCR PlanetS, have tried to answer this question with the tools available on Earth. "We simulated the climate of the Earth and Venus at the very beginning of their evolution, more than four billion years ago, when the surface of the planets was still molten," explains Martin Turbet. "The associated high temperatures meant that any water would have been present in the form of steam, as in a gigantic pressure cooker." Using sophisticated three-dimensional models of the atmosphere, similar to those scientists use to simulate the Earth's current climate and future evolution, the team studied how the atmospheres of the two planets would evolve over time and whether oceans could form in the process.

"Thanks to our simulations, we were able to show that the climatic conditions did not allow water vapour to condense in the atmosphere of Venus," says Martin Turbet. This means that the temperatures never got low enough for the water in its atmosphere to form raindrops that could fall on its surface. Instead, water remained as a gas in the atmosphere and oceans never formed. "One of the main reasons for this is the clouds that form preferentially on the night side of the planet. These clouds cause a very powerful greenhouse effect that prevented Venus from cooling as quickly as previously thought," continues the Geneva researcher.

Small differences with serious consequences

Surprisingly, the astrophysicists' simulations also reveal that the Earth could easily have suffered the same fate as Venus. If the Earth had been just a little closer to the Sun, or if the Sun had shone as brightly in its 'youth' as it does nowadays, our home planet would look very different today. It is likely the relatively weak radiation of the young Sun that allowed the Earth to cool down enough to condense the water that forms our oceans. For Emeline Bolmont, professor at UNIGE, member of PlaneS and co-author of the study, "this is a complete reversal in the way we look at what has long been called the 'Faint Young Sun paradox'. It has always been considered as a major obstacle to the appearance of life on Earth!" The argument was that if the Sun's radiation was much weaker than today, it would have turned the Earth into a ball of ice hostile to life. "But it turns out that for the young, very hot Earth, this weak Sun may have in fact been an unhoped-for opportunity," continues the researcher.

"Our results are based on theoretical models and are an important building-block in answering the question of the history of Venus," says study co-author David Ehrenreich, professor in the Department of Astronomy at UNIGE and member of the NCCR PlanetS. "But we will not be able to rule on the matter definitively on our computers. The observations of the three future Venusian space missions will be essential to confirm -- or refute -- our work." These prospects delight Emeline Bolmont, for whom "these fascinating questions can be addressed by the new Centre for Life in the Universe, which has just been set up within the UNIGE's Faculty of Science."

- Extreme exoplanet even more exotic than originally thought

Date: October 5, 2021
Source: Cornell University

Considered an ultra-hot Jupiter -- a place where iron gets vaporized, condenses on the night side and then falls from the sky like rain -- the fiery, inferno-like WASP-76b exoplanet

may be even more sizzling than scientists had realized.
An international team, led by scientists at Cornell University, University of Toronto and Queen's University Belfast, reports the discovery of ionized calcium on the planet -- suggesting an atmospheric temperature higher than previously thought, or strong upper atmosphere winds.
The discovery was made in high-resolution spectra obtained with Gemini North near the summit of Mauna Kea in Hawaii.
Hot Jupiters are named for their high temperatures, due to proximity to their stars. WASP-76b, discovered in 2016, is about 640 light-years from Earth, but so close to its F-type star, which is slightly hotter than the sun, that the giant planet completes one orbit every 1.8 Earth days.
The research results are the first of a multiyear, Cornell-led project, Exoplanets with Gemini Spectroscopy survey, or ExoGemS, that explores the diversity of planetary atmospheres.
"As we do remote sensing of dozens of exoplanets, spanning a range of masses and temperatures, we will develop a more complete picture of the true diversity of alien worlds -- from those hot enough to harbour iron rain to others with more moderate climates, from those heftier than Jupiter to others not much bigger than the Earth," said co-author Ray Jayawardhana, Harold Tanner Dean of the College of Arts and Sciences at Cornell University and a professor of astronomy.
"It's remarkable that with today's telescopes and instruments, we can already learn so much about the atmospheres -- their constituents, physical properties, presence of clouds and even large-scale wind patterns -- of planets that are orbiting stars hundreds of light-years away," Jayawardhana said.
The group spotted a rare trio of spectral lines in highly sensitive observations of the exoplanet WASP-76b's atmosphere, published in the *Astrophysical Journal Letters* on Sept. 28 and presented on Oct. 5 at the annual meeting of the Division for Planetary Sciences of the American Astronomical Society.
"We're seeing so much calcium; it's a really strong feature," said first author Emily Deibert, a University of Toronto doctoral student, whose adviser is Jayawardhana.
"This spectral signature of ionized calcium could indicate that the exoplanet has very strong upper atmosphere winds," Deibert said. "Or the atmospheric temperature on the exoplanet is much higher than we thought."
Gemini North is part of the international Gemini Observatory, a program of National Science Foundation's NOIRLab.

- ❖ Strange radio waves emerge from the direction of the galactic centre

A variable signal aligned to the heart of the Milky Way is tantalising scientists
Date: October 12, 2021
Source: University of Sydney

Milky Way (stock image).
Credit: © VincentBesse / stock.adobe.com

Astronomers have discovered unusual signals coming from the direction of the Milky Way's centre. The radio waves fit no currently understood pattern of variable radio source and could suggest a new class of stellar object.
"The strangest property of this new signal is that it is has a very high polarisation. This means its light oscillates in only one direction, but that direction rotates with time," said Ziteng Wang, lead author of the new study and a PhD student in the School of Physics at the University of Sydney.
"The brightness of the object also varies dramatically, by a factor of 100, and the signal switches on and off apparently at random. We've never seen anything like it."
Many types of star emit variable light across the electromagnetic spectrum. With tremendous advances in radio astronomy, the study of variable or transient objects in radio waves is a huge field of study helping us to reveal the secrets of the Universe. Pulsars, supernovae, flaring stars and fast radio bursts are all types of astronomical objects whose brightness varies.
"At first we thought it could be a pulsar -- a very dense type of spinning dead star -- or else a type of star that emits huge solar flares. But the signals from this new source don't match what we expect from these types of celestial objects," Mr Wang said.

The discovery of the object has been published today in the *Astrophysical Journal*.
Mr Wang and an international team, including scientists from Australia's national science agency CSIRO, Germany, the United States, Canada, South Africa, Spain and France discovered the object using the CSIRO's ASKAP radio telescope in Western Australia. Follow-up observations were with the South African Radio Astronomy Observatory's MeerKAT telescope.
Mr Wang's PhD supervisor is Professor Tara Murphy also from the Sydney Institute for Astronomy and the School of Physics.
Professor Murphy said: "We have been surveying the sky with ASKAP to find unusual new objects with a project known as Variables and Slow Transients (VAST), throughout 2020 and 2021.
"Looking towards the centre of the Galaxy, we found ASKAP J173608.2-321635, named after its coordinates. This object was unique in that it started out invisible, became bright, faded away and then reappeared. This behaviour was extraordinary."
After detecting six radio signals from the source over nine months in 2020, the astronomers tried to find the object in visual light. They found nothing.
They turned to the Parkes radio telescope and again failed to detect the source.
Professor Murphy said: "We then tried the more sensitive MeerKAT radio telescope in South Africa. Because the signal was intermittent, we observed it for 15 minutes every few weeks, hoping that we would see it again.
"Luckily, the signal returned, but we found that the behaviour of the source was dramatically different -- the source disappeared in a single day, even though it had lasted for weeks in our previous ASKAP observations."
However, this further discovery did not reveal much more about the secrets of this transient radio source.
Mr Wang's co-supervisor, Professor David Kaplan from the University of Wisconsin-Milwaukee, said: "The information we do have has some parallels with another emerging class of mysterious objects known as Galactic Centre Radio Transients, including one dubbed the 'cosmic burper'.
"While our new object, ASKAP J173608.2-321635, does share some properties with GCRTs there are also differences. And we don't really understand those sources, anyway, so this adds to the mystery."
The scientists plan to keep a close eye on the object to look for more clues as to what it might be.
"Within the next decade, the transcontinental Square Kilometre Array (SKA) radio telescope will come online. It will be able to make sensitive maps of the sky every day," Professor Murphy said. "We expect the power of this telescope will help us solve mysteries such as this latest discovery, but it will also open vast new swathes of the cosmos to exploration in the radio spectrum."
Video showing an artist's impression of signals from space:
https://www.youtube.com/watch?v=J_eGd9Ps9fE&t=5s

- Astronomers may have discovered first planet to orbit 3 stars

Potential discovery of a circumtriple planet has implications for bolstering our understanding of planet formation
Date: October 2, 2021
Source: University of Nevada, Las Vegas
In a distant star system -- a mere 1,300 light years away from Earth -- UNLV researchers and colleagues may have identified the first known planet to orbit three stars.
Unlike our solar system, which consists of a solitary star, it is believed that half of all star systems, like GW Ori where astronomers observed the novel phenomenon, consist of two or more stars that are gravitationally bound to each other.
But no planet orbiting three stars -- a circumptriple orbit -- has ever been discovered. Perhaps until now.
Takeaways
Using observations from the powerful Atacama Large Millimetre/submillimetre Array (ALMA) telescope, UNLV astronomers analysed the three observed dust rings around the three stars, which are critical to forming planets.
But they found a substantial, yet puzzling, gap in the circumtriple disc.
The research team investigated different origins, including the possibility that the gap was created by gravitational torque from the three stars. But after constructing a comprehensive model of GW Ori, they found that the more likely, and fascinating, explanation for the space in the disc is the presence of one or more massive planets, Jupiter-like in nature. Gas giants, according to

Jeremy Smallwood, lead author and a recent Ph.D. graduate in astronomy from UNLV, are usually the first planets to form within a star system. Terrestrial planets like Earth and Mars follow.
The planet itself cannot be seen, but the finding -- highlighted in a September study in the *Monthly Notices of the Royal Astronomical Society* -- suggests that this is the first circumtriple planet ever discovered. Further observations from the ALMA telescope are expected in the coming months, which could provide direct evidence of the phenomenon.
"It's really exciting because it makes the theory of planet formation really robust," Smallwood said. "It could mean that planet formation is much more active than we thought, which is pretty cool."

- Extreme exoplanet even more exotic than originally thought

Date: October 5, 2021
Source: Cornell University
Considered an ultra-hot Jupiter -- a place where iron gets vaporized, condenses on the night side and then falls from the sky like rain -- the fiery, inferno-like WASP-76b exoplanet may be even more sizzling than scientists had realized.
An international team, led by scientists at Cornell University, University of Toronto and Queen's University Belfast, reports the discovery of ionized calcium on the planet -- suggesting an atmospheric temperature higher than previously thought, or strong upper atmosphere winds.
The discovery was made in high-resolution spectra obtained with Gemini North near the summit of Mauna Kea in Hawaii.
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The research results are the first of a multiyear, Cornell-led project, Exoplanets with Gemini Spectroscopy survey, or ExoGemS, that explores the diversity of planetary atmospheres.
"As we do remote sensing of dozens of exoplanets, spanning a range of masses and temperatures, we will develop a more complete picture of the true diversity of alien worlds -- from those hot enough to harbour iron rain to others with more moderate climates, from those heftier than Jupiter to others not much bigger than the Earth," said co-author Ray Jayawardhana, Harold Tanner Dean of the College of Arts and Sciences at Cornell University and a professor of astronomy.
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Gemini North is part of the international Gemini Observatory, a program of National Science Foundation's NOIRLab.

- 'Mini psyches' give insights into mysterious metal-rich near-earth asteroids

New research into metal-rich asteroids reveals information about the origins and compositions of these rare bodies that could one day be mined.
Date: October 1, 2021
Source: University of Arizona
Metal-rich near-Earth asteroids, or NEAs, are rare, but their presence provides the intriguing possibility that iron, nickel and cobalt could someday be mined for use on Earth or in Space.
New research, published in the Planetary Science Journal, investigated two metal-rich asteroids in our own cosmic backyard to learn more about their origins, compositions and relationships with meteorites found on Earth.
These metal-rich NEAs were thought to be created when the cores of developing planets were catastrophically destroyed early in the solar system's history, but little more is known about them. A team of students co-led by

University of Arizona planetary science associate professor Vishnu Reddy studied asteroids 1986 DA and 2016 ED85 and discovered that their spectral signatures are quite similar to asteroid 16 Psyche, the largest metal-rich body in the solar system. Psyche, located in the main asteroid belt between the orbits of Mars and Jupiter rather than near Earth, is the target of NASA's Psyche mission.
"Our analysis shows that both NEAs have surfaces with 85% metal such as iron and nickel and 15% silicate material, which is basically rock," said lead author Juan Sanchez, who is based at the Planetary Science Institute. "These asteroids are similar to some stony-iron meteorites such as mesosiderites found on Earth."
Astronomers have been speculating as to what the surface of Psyche is made of for decades. By studying metal-rich NEAs that come close to the Earth, they hope to identify specific meteorites that resemble Psyche's surface.
"We started a compositional survey of the NEA population in 2005, when I was a graduate student, with the goal of identifying and characterizing rare NEAs such as these metal-rich asteroids," said Reddy, principal investigator of the NASA grant that funded the work. "It is rewarding that we have discovered these 'mini Psyches' so close to the Earth."
"For perspective, a 50-meter (164-foot) metallic object similar to the two asteroids we studied created the Meteor Crater in Arizona," said Adam Battle, who is a co-author of the paper along with fellow Lunar and Planetary Laboratory graduate students Benjamin Sharkey and Theodore Kareta, and David Cantillo, an undergraduate student in the Department of Geosciences.
The paper also explored the mining potential of 1986 DA and found that the amount of iron, nickel and cobalt that could be present on the asteroid would exceed the global reserves of these metals.
Additionally, when an asteroid is catastrophically destroyed, it produces what is called an asteroid family -- a bunch of small asteroids that share similar compositions and orbital paths.
The team used the compositions and orbits of asteroids 1986 DA and 2016 ED85 to identify four possible asteroid families in the outer region of the main asteroid belt, which is home to the largest reservoir of small bodies in the inner part of the solar system. This also happens to be the region where most of the largest known metallic asteroids including 16 Psyche reside.
"We believe that these two 'mini Psyches' are probably fragments from a large metallic asteroid in the main belt, but not 16 Psyche itself," Cantillo said. "It's possible that some of the iron and stony-iron meteorites found on Earth could have also come from that region in the solar system too."
The paper's findings are based on observations from the NASA Infrared Telescope Facility on the island of Hawaii. The work was funded by the NASA Near-Earth Object Observations Program, which also funds the NASA Infrared Telescope Facility.

- Using dunes to interpret wind on Mars

Date: October 1, 2021
Source: Geological Society of America

Dunes develop when wind-blown sand organizes into patterns, most often in deserts and arid or semi-arid parts of the world. Every continent on Earth has dune fields, but dunes and dune-like sand patterns are also found across the solar system: on Mars, Venus, Titan, Comet 67P, and Pluto. On Earth, weather stations measure the wind speed and direction, allowing us to predict and understand airflow in the atmosphere.
On other planets and planetary bodies, we do not yet have weather stations measuring the winds (with a few recent exceptions on Mars only). Without a way to directly measure wind on the surface of another planet, we can use the patterns in dunes to interpret what the wind must be doing, based on our knowledge of dunes on Earth. Furthermore, by studying dunes across planets, we can get a better understanding of how wind and sand behave in general.
In this *Geology* paper, published today, Mackenzie Day of the University of California Los Angeles focuses on what happens when two dunes collide.
"On Earth, we know that dunes collide, combine, link, and merge all the time," says Day. This is what drives changes in dune-field patterns over time. When this happens, the dune-dune interaction leaves behind a particular pattern in the sand, but that pattern is usually covered by actively moving sand and difficult to see without special tools."
On Mars, many dunes look and behave similar to dunes on Earth, but in addition Mars hosts patterns of organized sand that are dune-like but have some differences that have yet to be explained by the scientific community.

Whether or not these unusual features, sometimes called "transverse aeolian ridges" or "megaripples," are formed like dunes has been long debated.

"In this work, says Day, I show that these unusual wind-blown sand ridges sometimes show on their surfaces the pattern that forms when two dunes combine."

In the Iapygia region of Mars, transverse aeolian ridges incorporated both light and dark sands, leading to light-dark banding in the upwind side of the ridges. Banding occurring only on one side of the ridges suggests that the banding formed as the ridges migrated. Furthermore, the dune-interaction pattern known from Earth can be seen in some ridges where the banding is truncated and then reconnects, just like two dunes touching and then combining downwind.

The pattern associated with dune-interactions only forms when two dunes combine, therefore seeing it in these Martian sand ridges demonstrates that these enigmatic features (like those shown in the image attached) behave like dunes on Earth. "Just like dunes on Earth, transvers aeolian ridges on Mars migrate, combine, and develop complex patterns in response to the wind."

Transverse aeolian ridges are incredibly common on Mars, and the results of this work allow us to better interpret the wind at the surface of Mars using these dune-like features.

"Overall," Day says, "this work leverages both knowledge of Mars and knowledge of Earth to understand the other planet and opens the door to improving how we interpret wind across planetary bodies further into the solar system."

- ‘Planet confusion’ could slow Earth-like exoplanet exploration

Date: September 30, 2021
Source: Cornell University

When it comes to directly imaging Earth-like exoplanets orbiting faraway stars, seeing isn't always believing. A new Cornell University study finds that next-generation telescopes used to see exoplanets could confuse Earth-like planets with other types of planets in the same solar system.

With today's telescopes, dim distant planets are hard to see against the glare of their host stars, but next-generation tools such as the Nancy Grace Roman Space Telescope, currently under development by NASA, will be better at imaging Earth-like planets, which orbit stars at just the right distance to offer prime conditions for life.

"Once we have the capability of imaging Earth-like planets, we're actually going to have to worry about confusing them with completely different types of planets," said Dmitry Savransky, associate professor of mechanical and aerospace engineering and of astronomy.

"The future telescopes that will enable these observations will be so huge, expensive, and difficult to build and launch that we can't afford to waste a single second of time on them," Savransky said, "which is why it is so important to think through all of these potential issues ahead of time."

By using Earth's own solar system as a model of an unexplored star system, Savransky and doctoral student Dean Keithly, calculated that even with direct-imaging techniques and the increased capabilities of future, high-powered telescopes, exoplanets as different as Uranus and Earth could be mistaken for one another.

The research details how measurements estimating planet-star separation and brightness can cause "planet confusion." The modelling finds that when two planets share the same separation and magnitude along their orbits, one planet can be confused for the other.

Keithly and Savransky identified 21 cases within their solar system model in which an individual planet had the same apparent planet-star separation and brightness as another planet. Using this data, it was calculated that an Earth-like planet could be misidentified with a Mercury-like planet in 36% of randomly generated solar systems; with a Mars-like planet in about 43% of randomly generated solar systems; and with a Venus-like planet in more than 72% of randomly generated solar systems.

In contrast, confusion between Earth-like planets and larger gas-giant planets similar to Neptune, Saturn and Uranus was less likely, and could occur in 1-4% of randomly generated solar systems.

Confusing planets for one another can be an expensive and time-consuming problem for scientists. Extensive planning and funds go into each use of a high-powered telescope, so the false identification of a habitable exoplanet wastes valuable telescope time. With this problem identified, researchers can design more efficient exoplanet direct-imaging mission surveys.

The researchers warn that further improvements to instrument contrast and inner-working angles could exacerbate the problem and advise that future exoplanet direct-imaging missions make multiple observations to more accurately differentiate between planets.

- Investigating the potential for life around the galaxy's smallest stars

New telescope will see planetary neighbours' atmospheres

Date: September 29, 2021
Source: University of California - Riverside

When the world's most powerful telescope launches into space this year, scientists will learn whether Earth-sized planets in our 'solar neighbourhood' have a key prerequisite for life -- an atmosphere.

These planets orbit an M-dwarf, the smallest and most common type of star in the galaxy. Scientists do not currently know how common it is for Earth-like planets around this type of star to have characteristics that would make them habitable.

"As a starting place, it is important to know whether small, rocky planets orbiting M-dwarfs have atmospheres," said Daria Pidhorodetska, a doctoral student in UC Riverside's Department of Earth and Planetary Sciences. "If so, it opens up our search for life outside our solar system."

To help fill this gap in understanding, Pidhorodetska and her team studied whether the soon-to-launch James Webb Space Telescope, or the currently-in-orbit Hubble Space Telescope, are capable of detecting atmospheres on these planets. They also modelled the types of atmospheres likely to be found, if they exist, and how they could be distinguished from each other. The study has now been published in the *Astronomical Journal*.

Study co-authors include astrobiologists Edward Schwieterman and Stephen Kane from UCR, as well as scientists from Johns Hopkins University, NASA's Goddard Space Flight Centre, Cornell University and the University of Chicago.

The star at the centre of the study is an M-dwarf called L 98-59, which measures only 8% of our sun's mass. Though small, it is only 35 light years from Earth. It's brightness and relative closeness make it an ideal target for observation.

Shortly after they form, M-dwarfs go through a phase in which they can shine two orders of magnitude brighter than normal. Strong ultraviolet radiation during this phase has the potential to dry out their orbiting planets, evaporating any water from the surface and destroying many gases in the atmosphere.

"We wanted to know if the ablation was complete in the case of the two rocky planets, or if those terrestrial worlds were able to replenish their atmospheres," Pidhorodetska said.

The researchers modelled four different atmospheric scenarios: one in which the L 98-59 worlds are dominated by water, one in which the atmosphere is mainly composed of hydrogen, a Venus-like carbon dioxide atmosphere, and one in which the hydrogen in the atmosphere escaped into space, leaving behind only oxygen and ozone.

They found that the two telescopes could offer complementary information using transit observations, which measure a dip in light that occurs as a planet passes in front of its star.

The L 98-59 planets are much closer to their star than Earth is to the sun. They complete their orbits in less than a week, making transit observations by telescope faster and more cost effective than observing other systems in which the planets are farther from their stars.

"It would only take a few transits with Hubble to detect or rule out a hydrogen- or steam-dominated atmosphere without clouds," Schwieterman said. "With as few as 20 transits, Webb would allow us to characterize gases in heavy carbon dioxide or oxygen-dominated atmospheres."

Of the four atmospheric scenarios the researchers considered, Pidhorodetska said the dried-out oxygen-dominated atmosphere is the most likely.

"The amount of radiation these planets are getting at that distance from the star is intense," she said.

Though they may not have atmospheres that lend themselves to life today, these planets can offer an important glimpse into what might happen to Earth under different conditions, and what might be possible on Earth-like worlds elsewhere in the galaxy.

The L 98-59 system was only discovered in 2019, and Pidhorodetska said she is excited to get more information about it when Webb is launched later this year.

"We're on the precipice of revealing the secrets of a star system that was hidden until very recently," Pidhorodetska said.

- This is what it looks like when a black hole snacks on a star

Astronomers documented a fatal encounter between an unlucky star and an intermediate-mass black hole

Date: September 27, 2021
Source: University of Arizona

While black holes and toddlers don't seem to have much in common, they are remarkably similar in one aspect: Both are messy eaters, generating ample evidence that a meal has taken place.

But whereas one might leave behind droppings of pasta or splatters of yogurt, the other creates an aftermath of mind-boggling proportions. When a black hole gobbles up a star, it produces what astronomers call a "tidal disruption event." The shredding of the hapless star is accompanied by an outburst of radiation that can outshine the combined light of every star in the black hole's host galaxy for months, even years.

In a paper published in *The Astrophysical Journal*, a team of astronomers led by Sixiang Wen, a postdoctoral research associate at the University of Arizona Steward Observatory, use the X-rays emitted by a tidal disruption event known as J2150 to make the first measurements of both the black hole's mass and spin. This black hole is of a particular type -- an intermediate-mass black hole -- which has long eluded observation.

"The fact that we were able to catch this black hole while it was devouring a star offers a remarkable opportunity to observe what otherwise would be invisible," said Ann Zabludoff, UArizona professor of astronomy and co-author on the paper. "Not only that, by analysing the flare we were able to better understand this elusive category of black holes, which may well account for the majority of black holes in the centres of galaxies."

By re-analysing the X-ray data used to observe the J2150 flare, and comparing it with sophisticated theoretical models, the authors showed that this flare did indeed originate from an encounter between an unlucky star and an intermediate-mass black hole. The intermediate black hole in question is of particularly low mass -- for a black hole, that is -- weighing in at roughly 10,000 times the mass of the sun.

"The X-ray emissions from the inner disk formed by the debris of the dead star made it possible for us to infer the mass and spin of this black hole and classify it as an intermediate black hole," Wen said.

Dozens of tidal disruption events have been seen in the centres of large galaxies hosting supermassive black holes, and a handful have also been observed in the centres of small galaxies that might contain intermediate black holes. However, past data has never been detailed enough to prove that an individual tidal disruption flare was powered by an intermediate black hole.

"Thanks to modern astronomical observations, we know that the centres of almost all galaxies that are similar to or larger in size than our Milky Way host central supermassive black holes," said study co-author Nicholas Stone, a senior lecturer at Hebrew University in Jerusalem. "These behemoths range in size from 1 million to 10 billion times the mass of our sun, and they become powerful sources of electromagnetic radiation when too much interstellar gas falls into their vicinity."

The mass of these black hole’s correlates closely with the total mass of their host galaxies; the largest galaxies host the largest supermassive black holes.

"We still know very little about the existence of black holes in the centres of galaxies smaller than the Milky Way," said co-author Peter Jonker of Radboud University and SRON Netherlands Institute for Space Research, both in the Netherlands. "Due to observational limitations, it is challenging to discover central black holes much smaller than 1 million solar masses."

Despite their presumed abundance, the origins of supermassive black holes remain unknown, and many different theories currently vie to explain them, according to Jonker. Intermediate-mass black holes could be the seeds from which supermassive black holes grow.

"Therefore, if we get a better handle of how many bona fide intermediate black holes are out there, it can help determine which theories of supermassive black hole formation are correct," he said.

Even more exciting, according to Zabludoff, is the measurement of J2150's spin that the group was able to obtain. The spin measurement holds clues as to how black holes grow, and possibly to particle physics. This black hole has a fast spin, but not the fastest possible spin, Zabludoff explained, begging the question of how the black hole ends up with a spin in this range.

"It's possible that the black hole formed that way and hasn't changed much since, or that two intermediate-mass black holes merged recently to form this one," she said. "We do know that the spin we measured excludes scenarios where the black hole grows over a long time from steadily eating gas or from many quick gas snacks that arrive from random directions."

In addition, the spin measurement allows astrophysicists to test hypotheses about the nature of dark matter, which is thought to make up most of the matter in the universe. Dark matter may consist of unknown elementary particles not yet seen in laboratory experiments. Among the candidates are hypothetical particles known as ultralight bosons, Stone explained.

"If those particles exist and have masses in a certain range, they will prevent an intermediate-mass black hole from having a fast spin," he said. "Yet J2150's black hole is spinning fast. So, our spin measurement rules out a broad class of ultralight boson theories, showcasing the value of black holes as extra-terrestrial laboratories for particle physics."

In the future, new observations of tidal disruption flares might let astronomers fill in the gaps in the black hole mass distribution, the authors hope.

"If it turns out that most dwarf galaxies contain intermediate-mass black holes, then they will dominate the rate of stellar tidal disruption," Stone said. "By fitting the X-ray emission from these flares to theoretical models, we can conduct a census of the intermediate-mass black hole population in the universe," Wen added.

To do that, however, more tidal disruption events have to be observed. That's why astronomers hold high hopes for new telescopes coming online soon, both on Earth and in space, including the Vera C. Rubin Observatory, also known as the Legacy Survey of Space and Time, or LSST, which is expected to discover thousands of tidal disruption events per year.

This research was supported by grants from NASA and the U.S.-Israel Binational Science Foundation.

- Earth and Venus grew up as rambunctious planets

Date: September 27, 2021
Source: University of Arizona

Planet formation -- the process by which neat, round, distinct planets form from a roiling, swirling cloud of rugged asteroids and mini planets -- was likely even messier and more complicated than most scientists would care to admit, according to new research led by researchers at the University of Arizona Lunar and Planetary Laboratory.

The findings challenge the conventional view, in which collisions between smaller building blocks cause them to stick together and, over time, repeated collisions accrete new material to the growing baby planet.

Instead, the authors propose and demonstrate evidence for a novel "hit-and-run-return" scenario, in which pre-planetary bodies spent a good part of their journey through the inner solar system crashing into and ricocheting off of each other, before running into each other again at a later time. Having been slowed down by their first collision, they would be more likely to stick together the next time. Picture a game of billiards, with the balls coming to rest, as opposed to pelting a snowman with snowballs, and you get the idea.

The research is published in two reports appearing in the Sept. 23 issue of The Planetary Science Journal, with one focusing on Venus and Earth, and the other on Earth's moon. Central to both publications, according to the author team, which was led by planetary sciences and LPL professor Erik Asphaug, is the largely unrecognized point that giant impacts are not the efficient mergers scientists believed them to be.

"We find that most giant impacts, even relatively 'slow' ones, are hit-and-runs. This means that for two planets to merge, you usually first have to slow them down in a hit-and-run collision," Asphaug said. "To think of giant impacts, for instance the formation of the moon, as a singular event is probably wrong. More likely it took two collisions in a row."

One implication is that Venus and Earth would have had very different experiences in their growth as planets, despite being immediate neighbours in the inner solar system. In the first paper, led by Alexandre Emsenhuber, who did this work during a postdoctoral fellowship in Asphaug's lab and is now at Ludwig Maximilian University in Munich, the young Earth would have served to slow down interloping planetary bodies, making them ultimately more likely to collide with and stick to Venus.

"We think that during solar system formation, the early Earth acted like a vanguard for Venus," Emsenhuber said.
The solar system is what scientists call a gravity well, the concept behind a popular attraction at science exhibits. Visitors toss a coin into a funnel-shaped gravity well, and then watch their cash complete several orbits before it drops into the centre hole. The closer a planet is to the sun, the stronger the gravitation experienced by planets. That's why the inner planets of the solar system on which these studies were focused -- Mercury, Venus, Earth and Mars -- orbit the sun faster than, say, Jupiter, Saturn and Neptune. As a result, the closer an object ventures to the sun, the more likely it is to stay there.
So when an interloping planet hit the Earth, it was less likely to stick to Earth, and instead more likely to end up at Venus, Asphaug explained.
"The Earth acts as a shield, providing a first stop against these impacting planets," he said. "More likely than not, a planet that bounces off of Earth is going to hit Venus and merge with it."
Emsenhuber uses the analogy of a ball bouncing down a staircase to illustrate the idea of what drives the vanguard effect: A body coming in from the outer solar system is like a ball bouncing down a set of stairs, with each bounce representing a collision with another body.
"Along the way, the ball loses energy, and you'll find it will always bounce downstairs, never upstairs," he said. "Because of that, the body cannot leave the inner solar system anymore. You generally only go downstairs, toward Venus, and an impactor that collides with Venus is pretty happy staying in the inner solar system, so at some point it is going to hit Venus again."
Earth has no such vanguard to slow down its interloping planets. This leads to a difference between the two similar-sized planets that conventional theories cannot explain, the authors argue.
"The prevailing idea has been that it doesn't really matter if planets collide and don't merge right away, because they are going to run into each other again at some point and merge then," Emsenhuber said. "But that is not what we find. We find they end up more frequently becoming part of Venus, instead of returning back to Earth. It's easier to go from Earth to Venus than the other way around."
To track all these planetary orbits and collisions, and ultimately their mergers, the team used machine learning to obtain predictive models from 3D simulations of giant impacts. The team then used these data to rapidly compute the orbital evolution, including hit-and-run and merging collisions, to simulate terrestrial planet formation over the course of 100 million years. In the second paper, the authors propose and demonstrate their hit-and-run-return scenario for the moon's formation, recognizing the primary problems with the standard giant impact model.
"The standard model for the moon requires a very slow collision, relatively speaking," Asphaug said, "and it creates a moon that is composed mostly of the impacting planet, not the proto-Earth, which is a major problem since the moon has an isotopic chemistry almost identical to Earth."
In the team's new scenario, a roughly Mars-sized protoplanet hits the Earth, as in the standard model, but is a bit faster so it keeps going. It returns in about 1 million years for a giant impact that looks a lot like the standard model.
"The double impact mixes things up much more than a single event," Asphaug said, "which could explain the isotopic similarity of Earth and moon, and also how the second, slow, merging collision would have happened in the first place."
The researchers think the resulting asymmetry in how the planets were put together points the way to future studies addressing the diversity of terrestrial planets. For example, we don't understand how Earth ended up with a magnetic field that is much stronger than that of Venus, or why Venus has no moon.
Their research indicates systematic differences in dynamics and composition, according to Asphaug.
"In our view, Earth would have accreted most of its material from collisions that were head-on hits, or else slower than those experienced by Venus," he said. "Collisions into the Earth that were more oblique and higher velocity would have preferentially ended up on Venus."
This would create a bias in which, for example, protoplanets from the outer solar system, at higher velocity, would have preferentially accreted to Venus instead of Earth. In short, Venus could be composed of

material that was harder for the Earth to get a hold of.
"You would think that Earth is made up more of material from the outer system because it is closer to the outer solar system than Venus. But actually, with Earth in this vanguard role, it makes it actually more likely for Venus to accrete outer solar system material," Asphaug said.
The co-authors on the two papers are Saverio Cambioni and Stephen R. Schwartz at the Lunar and Planetary Laboratory and Travis S. J. Gabriel at Arizona State University in Tempe, Arizona.

- ❖ Gamma rays and neutrinos from mellow supermassive black holes

Date: September 24, 2021
Source: Tohoku University

The Universe is filled with energetic particles, such as X rays, gamma rays, and neutrinos. However, most of the high-energy cosmic particles' origins remain unexplained.
Now, an international research team has proposed a scenario that explains these; black holes with low activity act as major factories of high-energy cosmic particles.
Details of their research were published in the journal *Nature Communications*.
Gamma rays are high-energy photons that are many orders of magnitude more energetic than visible light. Space satellites have detected cosmic gamma rays with energies of megaelectron to gigaelectron volts.
Neutrinos are subatomic particles whose mass is nearly zero. They rarely interact with ordinary matter. Researchers at the IceCube Neutrino Observatory have also measured high-energy cosmic neutrinos.
Both gamma rays and neutrinos should be created by powerful cosmic-ray accelerators or surrounding environments in the Universe. However, their origins are still unknown. It is widely believed that active supermassive black holes (so-called active galactic nuclei), especially those with powerful jets, are the most promising emitters of high-energy gamma rays and neutrinos. However, recent studies have revealed that they do not explain the observed gamma rays and neutrinos, suggesting that other source classes are necessary.
The new model shows that not only active black holes but also non-active, "mellow" ones are important, acting as gamma-ray and neutrino factories.
All galaxies are expected to contain supermassive black holes at their centres. When matter falls into a black hole, a huge amount of gravitational energy is released. This process heats the gas, forming high-temperature plasma. The temperature can reach as high as tens of billions of Celsius degrees for low-accreting black holes because of inefficient cooling, and the plasma can generate gamma rays in the megaelectron volt range.
Such mellow black holes are dim as individual objects, but they are numerous in the Universe. The research team found that the resulting gamma rays from low-accreting supermassive black holes may contribute significantly to the observed gamma rays in the megaelectron volt range.
In the plasma, protons can be accelerated to energies roughly 10,000 times higher than those achieved by the Large Hadron Collider -- the largest human-made particle accelerator. The sped-up protons produce high-energy neutrinos through interactions with matter and radiation, which can account for the higher-energy part of the cosmic neutrino data. This picture can be applied to active black holes as demonstrated by previous research. The supermassive black holes including both active and non-active galactic nuclei can explain a large fraction of the observed IceCube neutrinos in a wide energy range.
Future multi-messenger observational programs are crucial to identify the origin of cosmic high-energy particles. The proposed scenario predicts gamma-ray counterparts in the megaelectron volt range to the neutrino sources. Most of the existing gamma-ray detectors are not tuned to detect them; but future gamma-ray experiments, together with next-generation neutrino experiments, will be able to detect the multi-messenger signals.

- ❖ Peering into the Moon's shadows with AI

Date: September 23, 2021
Source: Max Planck Institute for Solar System Research

The Moon's polar regions are home to craters and other depressions that never receive sunlight. Today, a group of researchers led by the Max Planck Institute for Solar System Research (MPS) in Germany presents the highest-resolution images to date covering 17 such craters in the journal *Nature Communications*.
Craters of this type could contain frozen water, making them attractive targets for

future lunar missions, and the researchers focused further on relatively small and accessible craters surrounded by gentle slopes. In fact, three of the craters have turned out to lie within the just-announced mission area of NASA's Volatiles Investigating Polar Exploration Rover (VIPER), which is scheduled to touch down on the Moon in 2023. Imaging the interior of permanently shadowed craters is difficult, and efforts so far have relied on long exposure times resulting in smearing and lower resolution. By taking advantage of reflected sunlight from nearby hills and a novel image processing method, the researchers have now produced images at 1-2 meters per pixel, which is at or very close to the best capability of the cameras.

The Moon is a cold, dry desert. Unlike the Earth, it is not surrounded by a protective atmosphere and water which existed during the Moon's formation has long since evaporated under the influence of solar radiation and escaped into space. Nevertheless, craters and depressions in the polar regions give some reason to hope for limited water resources. Scientists from MPS, the University of Oxford and the NASA Ames Research Centre have now taken a closer look at some of these regions.

"Near the lunar north and south poles, the incident sunlight enters the craters and depressions at a very shallow angle and never reaches some of their floors," MPS-scientist Dr. Valentin Bickel, first author of the new paper, explains. In this "eternal night," temperatures in some places are so cold that frozen water is expected to have lasted for millions of years. Impacts from comets or asteroids could have delivered it, or it could have been outgassed by volcanic eruptions, or formed by the interaction of the surface with the solar wind. Measurements of neutron flux and infrared radiation obtained by space probes in recent years indicate the presence of water in these regions. Eventually, NASA's Lunar Crater Observation and Sensing Satellite (LCROSS) provided direct proof: twelve years ago, the probe fired a projectile into the shadowed south pole crater Cabeus. As later analysis showed, the dust cloud emitted into space contained a considerable amount of water.

However, permanently shadowed regions are not only of scientific interest. If humans are to ever spend extended periods of time on the Moon, naturally occurring water will be a valuable resource -- and shadowed craters and depressions will be an important destination. NASA's uncrewed VIPER rover, for example, will explore the South Pole region in 2023 and enter such craters. In order to get a precise picture of their topography and geology in advance -- for mission planning purposes, for example -- images from space probes are indispensable. NASA's Lunar Reconnaissance Orbiter (LRO) has been providing such images since 2009.

However, capturing images within the deep darkness of permanently shadowed regions is exceptionally difficult; after all, the only sources of light are scattered light, such as that reflecting off the Earth and the surrounding topography, and faint starlight. "Because the spacecraft is in motion, the LRO images are completely blurred at long exposure times," explains Ben Moseley of the University of Oxford, a co-author of the study. At short exposure times, the spatial resolution is much better. However, due to the small amounts of light available, these images are dominated by noise, making it hard to distinguish real geological features.

To address this problem, the researchers have developed a machine learning algorithm called HORUS (Hyper-effective nOise Removal U-net Software) that "cleans up" such noisy images. It uses more than 70,000 LRO calibration images taken on the dark side of the Moon as well as information about camera temperature and the spacecraft's trajectory to distinguish which structures in the image are artefacts and which are real. This way, the researchers can achieve a resolution of about 1-2 meters per pixel, which is five to ten times higher than the resolution of all previously available images.

Using this method, the researchers have now re-evaluated images of 17 shadowed regions from the lunar south pole region which measure between 0.18 and 54 square kilometres in size. In the resulting images, small geological structures only a few meters across can be discerned much more clearly than before. These structures include boulders or very small craters, which can be found everywhere on the lunar surface. Since the Moon has no atmosphere, very small meteorites repeatedly fall onto its surface and create such mini-craters.

"With the help of the new HORUS images, it is now possible to understand the geology of lunar shadowed regions much better than

before," explains Moseley. For example, the number and shape of the small craters provide information about the age and composition of the surface. It also makes it easier to identify potential obstacles and hazards for rovers or astronauts. In one of the studied craters, located on the Leibnitz Plateau, the researchers discovered a strikingly bright mini-crater. "Its comparatively bright colour may indicate that this crater is relatively young," says Bickel. Because such a fresh scar provides fairly unhindered insight into deeper layers, this site could be an interesting target for future missions, the researchers suggest.
The new images do not provide evidence of frozen water on the surface, such as bright patches. "Some of the regions we've targeted might be slightly too warm," Bickel speculates. It is likely that lunar water does not exist as a clearly visible deposit on the surface at all -- instead, it could be intermixed with the regolith and dust, or may be hidden underground.
To address this and other questions, the researchers' next step is to use HORUS to study as many shadowed regions as possible. "In the current publication, we wanted to show what our algorithm can do. Now we want to apply it as comprehensively as possible," says Bickel.
This work has been enabled by the Frontier Development Lab (FDL.ai). FDL is a co-operative agreement between NASA, the SETI Institute and Trillium Technologies Inc, in partnership with the Luxembourg Space Agency and Google Cloud.

- Hubble finds early, massive galaxies running on empty

Date: September 22, 2021
Source: NASA/Goddard Space Flight Centre

When the universe was about 3 billion years old, just 20% of its current age, it experienced the most prolific period of star birth in its history. But when NASA's Hubble Space Telescope and the Atacama Large Millimetre/submillimetre Array (ALMA) in northern Chile gazed toward cosmic objects in this period, they found something odd: six early, massive, "dead" galaxies that had run out of the cold hydrogen gas needed to make stars.
Without more fuel for star formation, these galaxies were literally running on empty. The findings are published in the journal *Nature.*
"At this point in our universe, all galaxies should be forming lots of stars. It's the peak epoch of star formation," explained lead author Kate Whitaker, assistant professor of astronomy at the University of Massachusetts, Amherst. Whitaker is also associate faculty at the Cosmic Dawn Centre in Copenhagen, Denmark. "So what happened to all the cold gas in these galaxies so early on?"
This study is a classic example of the harmony between Hubble and ALMA observations. Hubble pinpointed where in the galaxies the stars exist, showing where they formed in the past. By detecting the cold dust that serves as a proxy for the cold hydrogen gas, ALMA showed astronomers where stars could form in the future if enough fuel were present.
Using Nature's Own Telescopes
The study of these early, distant, dead galaxies was part of the appropriately named REQUIEM program, which stands for Resolving QUIEscent Magnified Galaxies At High Redshift. (Redshift happens when light is stretched by the expansion of space and appears shifted toward the red part of the spectrum. The farther away a galaxy is with respect to the observer, the redder it appears.)
The REQUIEM team uses extremely massive foreground galaxy clusters as natural telescopes. The immense gravity of a galaxy cluster warps space, bending and magnifying light from background objects. When an early, massive, and very distant galaxy is positioned behind such a cluster, it appears greatly stretched and magnified, allowing astronomers to study details that would otherwise be impossible to see. This is called "strong gravitational lensing."
Only by combining the exquisite resolution of Hubble and ALMA with this strong lensing was the REQUIEM team able to able to understand the formation of these six galaxies, which appear as they did only a few billion years after the big bang.
"By using strong gravitational lensing as a natural telescope, we can find the distant, most massive, and first galaxies to shut down their star formation," said Whitaker. "I like to think about it like doing science of the 2030s or 40s -- with powerful next-generation space telescopes -- but today instead by combining the capabilities of Hubble and ALMA, which are boosted by strong lensing."
"REQUIEM pulled together the largest sample to date of these rare, strong-lensed, dead galaxies in the early universe, and strong lensing is the key here," said Mohammad Akhshik, principal investigator of the Hubble

observing program. "It amplifies the light across all wavelengths so that it's easier to detect, and you also get higher spatial resolution when you have these galaxies stretched across the sky. You can essentially see inside of them at much finer physical scales to figure out what's happening."

Live Fast, Die Young

These sorts of dead galaxies don't appear to rejuvenate, even though later minor mergers and accretions of nearby, small galaxies and gas. Gobbling up things around them mostly just "puffs up" the galaxies. If star formation does turn back on, Whitaker described it as "a kind of a frosting." About 11 billion years later in the present-day universe, these formerly compact galaxies are thought to have evolved to be larger but are still dead in terms of any new star formation.

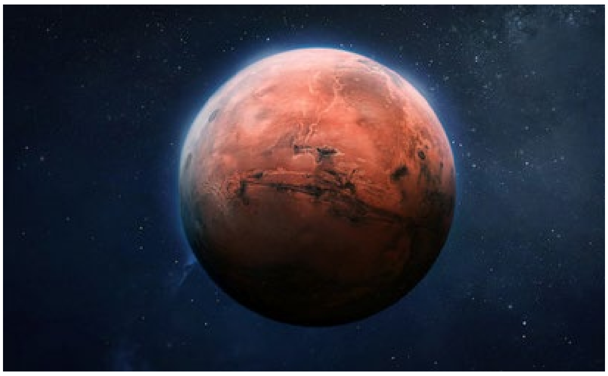
These six galaxies lived fast and furious lives, creating their stars in a remarkably short time. Why they shut down star formation so early is still a puzzle.

Whitaker proposes several possible explanations: "Did a supermassive black hole in the galaxy's centre turn on and heat up all the gas? If so, the gas could still be there, but now it's hot. Or it could have been expelled and now it's being prevented from accreting back onto the galaxy. Or did the galaxy just use it all up, and the supply is cut off? These are some of the open questions that we'll continue to explore with new observations down the road."

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Centre in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

- ❖ Mars habitability limited by its small size, isotope study suggests

Date: September 20, 2021
Source: Washington University in St. Louis



Mars illustration (stock image; elements furnished by NASA).
Credit: © dimazel / stock.adobe.com

Water is essential for life on Earth and other planets, and scientists have found ample evidence of water in Mars' early history. But Mars has no liquid water on its surface today. New research from Washington University in St. Louis suggests a fundamental reason: Mars may be just too small to hold onto large amounts of water.

Remote sensing studies and analyses of Martian meteorites dating back to the 1980s posit that Mars was once water-rich, compared with Earth. NASA's Viking orbiter spacecraft -- and, more recently, the Curiosity and Perseverance rovers on the ground -- returned dramatic images of Martian landscapes marked by river valleys and flood channels. Despite this evidence, no liquid water remains on the surface. Researchers proposed many possible explanations, including a weakening of Mars' magnetic field that could have resulted in the loss of a thick atmosphere.

But a study published the week of Sept. 20 in the *Proceedings of the National Academy of Sciences* suggests a more fundamental reason why today's Mars looks so drastically different from the "blue marble" of Earth.

"Mars' fate was decided from the beginning," said Kun Wang, assistant professor of earth and planetary sciences in Arts & Sciences at Washington University, senior author of the study. "There is likely a threshold on the size requirements of rocky planets to retain enough water to enable habitability and plate tectonics, with mass exceeding that of Mars."

For the new study, Wang and his collaborators used stable isotopes of the element potassium (K) to estimate the presence, distribution and abundance of volatile elements on different planetary bodies.

Potassium is a moderately volatile element, but the scientists decided to use it as a kind of tracer for more volatile elements and compounds, such as water. This is a relatively new method that diverges from previous attempts to use potassium-to-thorium (Th) ratios gathered by remote sensing and chemical analysis to determine the amount of volatiles Mars once had. In previous research, members of the research group used a potassium tracer method to study the formation of the moon.

Wang and his team measured the potassium isotope compositions of 20 previously confirmed Martian meteorites, selected to be representative of the bulk silicate composition of the red planet.

Using this approach, the researchers determined that Mars lost more potassium and other volatiles than Earth during its formation, but retained more of these volatiles than the moon and asteroid 4-Vesta, two much smaller and drier bodies than Earth and Mars.

The researchers found a well-defined correlation between body size and potassium isotopic composition.

"The reason for far lower abundances of volatile elements and their compounds in differentiated planets than in primitive undifferentiated meteorites has been a longstanding question," said Katharina Lodders, research professor of earth and planetary sciences at Washington University, a co-author of the study. "The finding of the correlation of K isotopic compositions with planet gravity is a novel discovery with important quantitative implications for when and how the differentiated planets received and lost their volatiles."

"Martian meteorites are the only samples available to us to study the chemical makeup of the bulk Mars," Wang said. "Those Martian meteorites have ages varying from several hundred millions to 4 billion years and recorded Mars' volatile evolution history. Through measuring the isotopes of moderately volatile elements, such as potassium, we can infer the degree of volatile depletion of bulk planets and make comparisons between different solar system bodies.

"It's indisputable that there used to be liquid water on the surface of Mars, but how much water in total Mars once had is hard to quantify through remote sensing and rover studies alone," Wang said. "There are many models out there for the bulk water content of Mars. In some of them, early Mars was even wetter than the Earth. We don't believe that was the case."

Zhen Tian, a graduate student in Wang's laboratory and a McDonnell International Academy Scholar, is first author of the paper. Postdoctoral research associate Piers Koefoed is a co-author, as is Hannah Bloom, who graduated from Washington University in 2020. Wang and Lodders are faculty fellows of the university's McDonnell Centre for the Space Sciences.

The findings have implications for the search for life on other planets besides Mars, the researchers noted.

Being too close to the sun (or, for exoplanets, being too close to their star) can affect the amount of volatiles that a planetary body can retain. This distance-from-star measurement is often factored into indexes of "habitable zones" around stars.

"This study emphasizes that there is a very limited size range for planets to have just enough but not too much water to develop a habitable surface environment," said Klaus Mezger of the Centre for Space and Habitability at the University of Bern, Switzerland, a co-author of the study. "These results will guide astronomers in their search for habitable exoplanets in other solar systems."

Wang now thinks that, for planets that are within habitable zones, planetary size probably should be more emphasized and routinely considered when thinking about whether an exoplanet could support life.

"The size of an exoplanet is one of the parameters that is easiest to determine," Wang said. "Based on size and mass, we now know whether an exoplanet is a candidate for life, because a first-order determining factor for volatile retention is size."

- Unveiling galaxies at cosmic dawn that were hiding behind the dust

Scientists serendipitously discover two heavily dust-enshrouded galaxies that formed when the Universe was only 5% of its present age

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Source: Waseda University

When astronomers peer deep into the night sky, they observe what the Universe looked like a long time ago. Because the speed of light is finite, studying the most distant observable galaxies allows us to glimpse billions of years into the past when the Universe was very young and galaxies had just started to form stars. Studying this "early Universe" is one of the last frontiers in astronomy and is essential for constructing accurate and consistent astrophysics models. A key goal of scientists is to identify all the galaxies in the first billion years of cosmic history and to measure the rate at which galaxies were growing by forming new stars. Various efforts have been made over the past decades to observe distant galaxies, which are characterized by electromagnetic emissions that become strongly redshifted (shifted towards longer wavelengths) before reaching the Earth. So far, our knowledge of early galaxies has mostly relied on observations with the Hubble Space Telescope (HST) and large ground-based telescopes, which probe their ultra-violet (UV) emission. However, recently, astronomers have started to use the unique capability of the Atacama Large Millimetre/submillimetre Array (ALMA) telescope to study distant galaxies at submillimetre wavelengths. This could be particularly useful for studying dusty galaxies missed in the HST surveys due to the dust absorbing UV emission. Since ALMA observes in submillimetre wavelengths, it can detect these galaxies by observing the dust emissions instead.

In an ongoing large program called REBELS (Reionization-Era Bright Emission Line Survey), astronomers are using ALMA to observe the emissions of 40 target galaxies at cosmic dawn. Using this dataset, they have recently discovered that the regions around some of these galaxies contain more than meets the eye.

While analysing the observed data for two REBELS galaxies, Dr. Yoshinobu Fudamoto of the Research Institute for Science and Engineering at Waseda University, Japan, and the National Astronomical Observatory of Japan (NAOJ), noticed strong emission by dust and singly ionized carbon in positions substantially offset from the initial targets. To his surprise, even highly sensitive equipment like the HST couldn't detect any UV emission from these locations. To understand these mysterious signals, Fudamoto and his colleagues investigated matters further.

In their latest paper published in Nature, they presented a thorough analysis, revealing that these unexpected emissions came from two previously unknown galaxies located near the two original REBELS targets. These galaxies are not visible in the UV or visible wavelengths as they are almost completely obscured by cosmic dust. One of them represents the most distant dust-obscured galaxy discovered so far.

What is most surprising about this serendipitous finding is that the newly discovered galaxies, which formed more than 13 billion years ago, are not strange at all when compared with typical galaxies at the same epoch. "These new galaxies were missed not because they are extremely rare, but only because they are completely dust-obscured," explains Fudamoto. However, it is uncommon to find such "dusty" galaxies in the early period of the Universe (less than 1 billion years after the Big Bang), suggesting that the current census of early galaxy formation is most likely incomplete, and would call for deeper, blind surveys. "It is possible that we have been missing up to one out of every five galaxies in the early Universe so far," Fudamoto adds.

The researchers expect that the unprecedented capability of the James Webb Space Telescope (JWST) and its strong synergy with ALMA would lead to significant advances in this field in the coming years. "Completing our census of early galaxies with the currently missing dust-obscured galaxies, like the ones we found this time, will be one of the main objectives of JWST and ALMA surveys in the near future," states Pascal Oesch from University of Geneva.

Overall, this study constitutes an important step in uncovering when the very first galaxies started to form in the early Universe, which in turn shall help us understand where we are standing today.