South Downs Mercury

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Main Talk Peter Goodhew

Peter will describe how amateur astronomers go about making such discoveries, and some of the challenges involved. He will take the audience through a typical case study. He will share some of the most remarkable, and beautiful discoveries made by the team, including some strange and unexpected objects.

Peter is part of an international team of amateur astronomers collaborating in searching the Cosmos for undiscovered objects. The team have already made over 200 discoveries. He coordinates the operation of a network of 6 high-performance robotic telescopes located in dark sites in Spain. Peter is a Fellow of The Royal Astronomical Society and a frequent contributor to Astronomy Now magazine.

Please support a raffle we are organizing this month.

- Star clusters observed within a galaxy in the early Universe

Date: June 24, 2024
Source: Stockholm University

The Cosmic Gems is one of the most highly magnified objects in space, thanks to a phenomenon called gravitational lensing. (Image credit: ESA/Webb, NASA & CSA, L. Bradley (STScI), A. Adamo (Stockholm University) and the Cosmic Spring collaboration)

The history of how stars and galaxies came to be and evolved into the present day remains among the most challenging astrophysical questions to solve yet, but new research brings us closer to understanding it.

In a new study by an international team led by Dr. Angela Adamo at Stockholm University, new insights about young galaxies during the Epoch of Reionization have been revealed. Observations with the James Webb Space Telescope (JWST) of the galaxy Cosmic Gems arc (SPT0615-JD) have confirmed that the light of the galaxy was emitted 460 million years after the big bang. What makes this galaxy unique is that it is magnified through an effect called gravitational lensing, which has not been observed in other galaxies formed during that age. The magnification of the Cosmic Gems arc has allowed the team to study the smaller structures inside an infant galaxy for the first time. The authors found that the Cosmic Gems arc harbours five young massive star clusters in which stars are formed. "The surprise and astonishment were incredible when we opened the JWST images for the first time" says Adamo.

The mystery of the early Universe

The Epoch of Reionization (EoR) is a crucial time during the evolution of the Universe, which occurred within the first billion years after the Big Bang. During this period, the Universe went through an important transition. In its early days it was filled with neutral Hydrogen gas, but this changed during the EoR. The matter of the Universe went from its neutral form to being fully ionized; the atoms were stripped from their electrons. The earliest galaxies of the Universe are believed to have driven this transformation.

In order to study the earliest galaxies, one has to look far away in space. Light travels at a finite speed. By observing objects at far distances, we can "look back in time" as we see the state of the object at the time when the light was emitted from it. However, it is difficult to observe small details of an object at large enough distances to study the early Universe. One method to observe finer details in a galaxy at a great distance is through the use of gravitational lensing. Gravitational lensing occurs when a celestial body of high mass curves the path of light around it due to its strong gravity. When the light emitted from a source passes through the gravitational

lens it is distorted similar to the effect of a magnifying glass. In this way, astronomers can observe small details in objects far away. Galaxies slowly build their stellar population through a process referred to as star formation. In local galaxies we see that a large fraction of stars form in star clusters. Star clusters are groups of stars held together by gravitational forces. Star clusters can have varying sizes, where some only contain a small number of stars to others that can contain millions. Globular clusters are very old star clusters where stars have previously been formed, but not anymore. How and where the globular clusters were formed has been a long-standing mystery.

New insights into the formation of the first stars and galaxies

In a new study published in the scientific journal *Nature*, the team of astronomers present the discovery of star clusters in a galaxy whose light has passed through a gravitational lens on its way towards the Earth. "This achievement could only be possible thanks to JWST unmatched capabilities," says Dr. Adélaïde Claeyssens of Stockholm University and co-author of the publication. The galaxy SPT0615-JD, also known as the Cosmic Gems Arc, is located in the distant Universe. The light that has reached the Earth in the present day was emitted from this galaxy only 460 million years after the Big Bang. By studying this object, the astronomers look back 97% of the cosmic time.

"Due to the gravitational lensing, the Cosmic Gems Arc could be resolved down to small enough scales to study the objects within it," adds Claeyssens. The team used the instrument Near Infrared Camera (NIRCam) onboard the JWST for their observations. The NIRCam is an instrument built to take high-resolution images in the near-infrared part of the light spectrum, in which the earliest stars and galaxies can be detected. Using the high resolution of the JWST NIRCam, the resulting observations showed a chain of bright dots mirrored from one side to the other. It was discovered that these dots were five young massive star clusters.

Through analysis of the light spectra emitted by the galaxy, it could be determined that the stellar clusters are gravitationally bound and have a three-times larger stellar density than typical young star clusters in the local Universe. It was also found that the clusters were formed recently, within 50 million years. They are very massive, although much smaller than globular clusters. "It was incredible to see the JWST images of the Cosmic Gems arc and realize that we were looking at star clusters in such a young galaxy. We observe globular clusters around local galaxies, but we don't know when and where they formed. The Cosmic Gems arc observations have opened a unique window for us into the works of infant galaxies as well as showing us where globular clusters formed" says Adamo. "These clusters will have enough time to relax and become globular clusters, due to them being formed at such a young age of the Universe," she adds.

Understanding the early Universe

Through studies of star clusters in young galaxies born shortly after the Big Bang, further understanding of how and where globular clusters are formed can be achieved. Since young galaxies are believed to drive the reionization during the EoR, it is crucial to study them in depth in order to gain knowledge about the early Universe. Using the discoveries made by the authors of this study, more information is added to our understanding about how the stars in the earliest galaxies were born, and where and how globular clusters are formed.

Looking onwards

In the future, the group is planning to build a larger sample of similar galaxies. "We have one galaxy so far, but we need many more if we want to create demographics of the cluster populations forming in the earliest galaxies." says Adamo. The team also has an approved program for the next cycle of JWST observations, where they will study the Cosmic Gems Arc galaxy and the recently discovered star clusters in further detail. "Spectroscopic observations will allow us to spatially map the star formation rate and ionizing photon production efficiency along the galaxy" adds Dr. Larry Bradley, principal investigator of the JWST program and the second author of this article.

- Pair of merging quasars at cosmic dawn

Observations with the Gemini North telescope aid in the discovery of the most distant pair of merging quasars, seen only 900 million years after the Big Bang

Date: June 17, 2024

Source: Association of Universities for Research in Astronomy (AURA)

Artist's concept of a pair of quasars – bright, active galaxies – merging. Scientists saw these quasars merging only 900 million years after the Big Bang, in a time period known as the Cosmic Dawn. This makes the merging quasars the most distant merging pair known and the first pair astronomers have seen at the Cosmic Dawn. Image via International Gemini Observatory/ NOIRLab/ NSF/ AURA/ M. Garlick.

Since the very first instant after the Big Bang the Universe has been expanding. This means that the early Universe was considerably smaller and early-formed galaxies were more likely to interact and merge. Galaxy mergers fuel the formation of quasars -- extremely luminous galactic cores where gas and dust falling into a central supermassive black hole emit enormous amounts of light. So, when looking back at the early Universe astronomers would expect to find numerous pairs of quasars in close proximity to each other as their host galaxies undergo mergers. However, they have been surprised to find exactly none -- until now.

With the aid of the Gemini North telescope, one half of the International Gemini Observatory, which is supported in part by the U.S. National Science Foundation and operated by NSF NOIRLab, a team of astronomers have discovered a pair of merging quasars seen only 900 million years after the Big Bang. Not only is this the most distant pair of merging quasars ever found, but also the first confirmed pair in the period of the Universe's history known as Cosmic Dawn.

Cosmic Dawn spanned from about 50 million years to one billion years after the Big Bang. During this period the first stars and galaxies began appearing, filling the dark Universe with light for the first time. The arrival of the first stars and galaxies kicked off a new era in the formation of the cosmos known as the Epoch of Reionization.

The Epoch of Reionization, which took place within Cosmic Dawn, was a period of cosmological transition. Beginning roughly 400 million years after the Big Bang, ultraviolet light from the first stars, galaxies and quasars spread throughout the cosmos, interacting with the intergalactic medium and stripping the Universe's primordial hydrogen atoms of their electrons in a process known as ionization. The Epoch of Reionization was a critical epoch in the history of the Universe that marked the end of the cosmic dark ages and seeded the large structures we observe in our local Universe today.

To understand the exact role that quasars played during the Epoch of Reionization, astronomers are interested in finding and studying quasars populating this early and distant era. "The statistical properties of quasars in the Epoch of Reionization tell us many things, such as the progress and origin of the reionization, the formation of supermassive black holes during Cosmic Dawn, and the earliest evolution of the quasar host galaxies," said Yoshiki Matsuoka, an astronomer at Ehime University in Japan and lead author of the paper describing these results, published in the Astrophysical Journal Letters.

About 300 quasars have been discovered in the Epoch of Reionization, but none of them have been found in a pair. That is until Matsuoka and their team were reviewing images taken with the Hyper Suprime-Cam on the Subaru Telescope and a faint patch of red caught their eye. "While screening images of quasar candidates I noticed two similarly and extremely red sources next to each other," said Matsuoka. "The discovery was purely serendipitous."

The team was not sure that they were a quasar pair since distant quasar candidates are contaminated by numerous other sources, such as foreground stars and galaxies and the effects of gravitational lensing. To confirm the nature of these objects the team conducted follow-up spectroscopy using the Faint Object Camera and Spectrograph (FOCAS) on the Subaru Telescope and the Gemini Near-Infrared Spectrograph (GNIRS) on Gemini North. The spectra, which break down the emitted light from a source into its component wavelengths, obtained with GNIRS were crucial to characterizing the nature of the quasar pair and their host galaxies.

"What we learned from the GNIRS observations was that the quasars are too faint to detect in near-infrared, even with one of the largest telescopes on the ground," said Matsuoka. This allowed the team to estimate that a portion of the light detected in the optical wavelength range is not coming from the quasars themselves, but from ongoing star

formation taking place in their host galaxies. The team also found that the two black holes are whoppers, each being 100 million times the mass of the Sun. This, coupled with the presence of a bridge of gas stretching between the two quasars, suggests that they and their host galaxies are undergoing a major-scale merger [1].

"The existence of merging quasars in the Epoch of Reionization has been anticipated for a long time. It has now been confirmed for the first time," said Matsuoka [2].

The Epoch of Reionization connects the earliest formation of cosmic structure to the complex Universe that we observe billions of years later. By studying distant objects from this period astronomers gain valuable insight into the process of reionization and the formation of the first objects in the Universe. More discoveries like this may be on the horizon with NSF-DOE Vera C. Rubin Observatory's decade-long Legacy Survey of Space and Time (LSST), beginning in 2025, which is poised to detect millions of quasars using its deep imaging capabilities.

Notes

[1] A companion paper accepted for publication in AAS Journals presents further analysis of the quasar pair, the gas bridge between them and their host galaxies using observations taken with the Atacama Large Millimetre/submillimetre Array (ALMA).

[2] There have been candidates, but it is difficult to separate them from possibly gravitationally-lensed images of a single quasar. There are also some candidates for being dual active galactic nuclei embedded in individual Epoch of Reionization galaxies, but these have much lower luminosity (black hole activity) than quasars and are two components within a single galaxy, which are qualitatively different from what is described here.

- Scientists spot more Milky Way-like galaxies in early universe

The study advances our understanding of how galaxies were formed.

Date: June 11, 2024

Source: University of Missouri-Columbia

University of Missouri scientists are peering into the past and uncovering new clues about the early universe. Since light takes a long time to travel through space, they are now able to see how galaxies looked billions of years ago.

In a new study, the Mizzou researchers have discovered that spiral galaxies were more common in the early universe than previously thought.

"Scientists formerly believed most spiral galaxies developed around 6 to 7 billion years after the universe formed," said Yicheng Guo, an associate professor in Mizzou's Department of Physics and Astronomy and co-author on the study. "However, our study shows spiral galaxies were already prevalent as early as 2 billion years afterward. This means galaxy formation happened more rapidly than we previously thought."

This insight could help scientists develop a better understanding of how spiral galaxies such as the Milky Way, Earth's home galaxy, formed over time.

"Knowing when spiral galaxies formed in the universe has been a popular question in astronomy because it helps us understand the evolution and history of the cosmos," said Vicki Kuhn, a graduate student in Mizzou's Department of Physics and Astronomy who led the study. "Many theoretical ideas exist about how spiral arms are formed, but the formation mechanisms can vary amongst different types of spiral galaxies. This new information helps us better match the physical properties of galaxies with theories -- creating a more comprehensive cosmic timeline."

Using recent images from NASA's James Webb Space Telescope (JWST), the scientists found that nearly 30% of galaxies have a spiral structure about 2 billion years after the universe formed. The discovery provides a significant update to the universe's origin story as previously told using data from NASA's Hubble Space Telescope. Studying distant galaxies with JWST gives Guo, Kuhn and other scientists an opportunity to solve a cosmic puzzle by determining the meaning of each clue.

"Using advanced instruments such as JWST allows us to study more distant galaxies with greater detail than ever before," Guo said. "A galaxy's spiral arms are a fundamental feature used by astronomers to categorize galaxies and understand how they form over time. Even though we still have many questions about the universe's past, analysing this data helps us uncover additional clues and deepens our understanding of the physics that shaped the nature of our universe."

"JWST Reveals a Surprisingly High Fraction of Galaxies Being Spiral-like at $0.5 \leq z \leq 4$," was published in *The Astrophysical Journal Letters.* Additional co-authors are Alec Martin, Julianna Bayless, Ellie Gates and AJ Puleo. This project was supported by University of Missouri Research

Council grants and the Missouri Space Grant Consortium.
This study was presented by Kuhn at the 244th meeting of the American Astronomical Society in Madison, Wisconsin.

- New class of Mars quakes reveals daily meteorite strikes

Date: June 28, 2024
Source: ETH Zurich

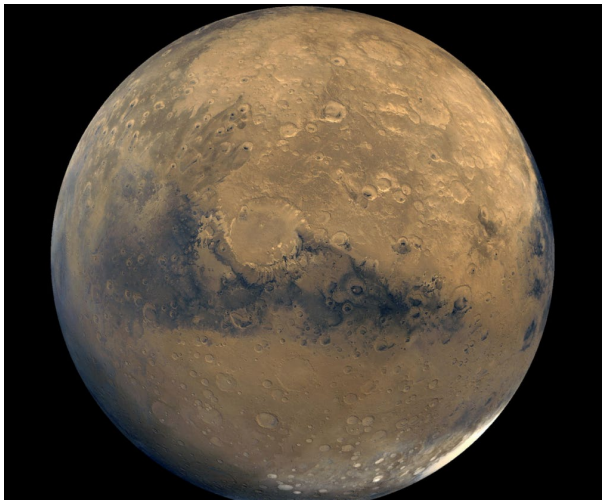


Photo: NASA/JPL-Caltech/USGS

An international team of researchers, co-lead by ETH Zurich and Imperial College London, have derived the first estimate of global meteorite impacts on Mars using seismic data. Their findings indicate between 280 to 360 meteorites strike the planet each year forming impact craters greater than 8 metres (about 26 feet) across. Geraldine Zenhaeusern who co-led the study commented, "This rate was about five times higher than the number estimated from orbital imagery alone. Aligned with orbital imagery, our findings demonstrate that seismology is an excellent tool for measuring impact rates."

Seismic "chirp" signals new class of quakes

Using data from the seismometer deployed during the NASA InSight Mission to Mars, researchers found that 6 seismic events recorded in the near proximity of the station had been previously identified as meteoric impacts (Garcia et al., 2023) -- a process enabled by the recording of a specific acoustic atmospheric signal generated when meteorites enter the Martian atmosphere. Now, Zenhäusern, ETH Zurich, co-lead, Natalia Wójcicka, Imperial College London, and the research team have found that these 6 seismic events belong to a much larger group of mars quakes, so called *very high frequency (VF)* events. The source process of these quakes occurs much faster than for a tectonic mars quake of similar size. Where a normal magnitude 3-quake on Mars takes several seconds, an impact-generated event of the same size takes only 0.2 seconds or less, due to the hypervelocity of the collision. By analysing mars quake spectra, a further 80 mars quakes were identified that are now thought to be caused by meteoroid strikes. Their research quest began in December 2021, a year before accumulated dust on the solar panels put an end to the InSight mission, when a large distant quake recorded by the seismometer reverberated a broadband seismic signal throughout the planet. Remote sensing associated the quake with a 150-metre-wide crater. To confirm, the InSight team partnered with Mars Reconnaissance Orbiter (MRO) Context Camera (CTX) to search for other fresh craters that would match the timing and location of the seismic events detected by InSight. The teams' detective work paid off and they were lucky to find a second fresh crater over a 100-metres (320 feet) in diameter. Smaller craters, however, formed when basketball-sized meteoroids strike the planet and which should be far more common, remained elusive. Now, the number of meteorite strikes is newly estimated by the occurrence of these special high-frequency quakes.

First meteorite impact rate from seismic data

Approximately 17,000 meteorites fall to Earth each year, but unless they streak across the night's sky, they are rarely noticed. Most meteors disintegrate as they enter Earth's atmosphere, but on Mars the atmosphere is 100 times thinner leaving its surface exposed to larger and more frequent meteorite strikes. Until now, planetary scientists have relied on orbital images and models inferred from well-preserved meteorite impacts on the Moon but extrapolating these estimates to Mars proved challenging. Scientists had to account for the stronger gravitational pull of Mars and its proximity to the asteroid belt, which both mean that more meteorites hit the red planet. On the other hand, regular sandstorms result in craters that are much less well-preserved than those on the Moon, and, therefore, not as easily detected with orbital imagery. When a meteorite strikes the planet, the seismic waves of the impact travel through the crust and mantle and can be picked up by seismometers. Wójcicka explains, "We estimated crater diameters from the magnitude of all the VF-mars quakes and their distances, then used it to calculate how many craters formed around

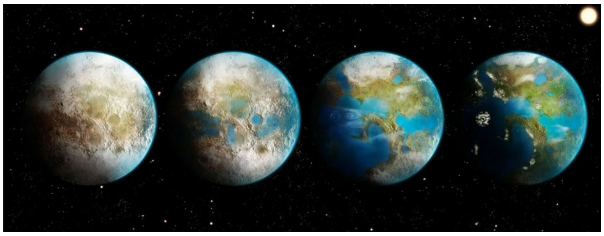
the InSight lander over the course of a year. We then extrapolated this data to estimate the number of impacts that happen annually on the whole surface of Mars."
Zenhäusern adds, "While new craters can best be seen on flat and dusty terrain where they really stand out, this type of terrain covers less than half of the surface of Mars. The sensitive InSight seismometer, however, could hear every single impact within the landers' range."

Insight into Mars age and future missions

Much like the lines and wrinkles on our face, the size and density of craters from meteorite strikes reveal clues about the age of different regions of a planetary body. The less craters, the younger the region of the planet. Venus, for example, has almost no visible craters because its surface is continually reworked by volcanism, while Mercury and the Moon with their ancient surfaces are heavily cratered. Mars falls in between these examples, with some old and some young regions that can be distinguished by the number of craters.
New data shows, an 8-metre (26-feet) crater happens somewhere on the surface of Mars nearly every day and a 30-metre (98-feet) crater occurs about once a month. Since hypervelocity impacts cause blast zones that are easily 100 times larger in diameter than the crater, knowing the exact number of impacts is important for the safety of robotic, but also future human missions to the red planet.
"This is the first paper of its kind to determine how often meteorites impact the surface of Mars from seismological data -- which was a level one mission goal of the Mars InSight Mission," says Domenico Giardini, Professor of Seismology and Geodynamics at ETH Zurich and co-Principal Investigator for the NASA Mars InSight Mission. "Such data factors into the planning for future missions to Mars."
According to Zenhäusern and Wójcicka, the next steps in advancing this research involve the use of machine learning technologies to aid researchers in identifying further craters in satellite images and identifying seismic events in the data.

- Telltale greenhouse gases could signal alien activity

Date: June 25, 2024
Source: University of California – Riverside



If aliens modified a planet in their solar system to make it warmer, we'd be able to tell. A new UC Riverside study identifies the artificial greenhouse gases that would be giveaways of a terraformed planet.
A terraformed planet has been artificially made hospitable for life. The gases described in the study would be detectable even at relatively low concentrations in the atmospheres of planets outside our solar system using existing technology. This could include the James Webb Space Telescope, or a future European-led space telescope concept.
And while such pollutant gases must be controlled on Earth to prevent harmful climate effects, there are reasons they might be used intentionally on an exoplanet.
"For us, these gases are bad because we don't want to increase warming. But they'd be good for a civilization that perhaps wanted to forestall an impending ice age or terraform an otherwise-uninhabitable planet in their system, as humans have proposed for Mars," said UCR astrobiologist and lead study author Edward Schwieterman.
Since these gases are not known to occur in significant quantities in nature, they must be manufactured. Finding them, therefore, would be a sign of intelligent, technology-using life forms. Such signs are called techno signatures.
The five gases proposed by the researchers are used on Earth in industrial applications such as making computer chips. They include fluorinated versions of methane, ethane, and propane, along with gases made of nitrogen and fluorine or sulphur and fluorine. A new *Astrophysical Journal* paper details their merits as terraforming gases.
One advantage is that they are incredibly effective greenhouse gases. Sulphur hexafluoride, for example, has 23,500 times the warming power of carbon dioxide. A relatively small amount could heat a freezing planet to the point where liquid water could persist on its surface.
Another advantage of the proposed gases -- at least from an alien point of view -- is that they are exceptionally long-lived and would persist

in an Earth-like atmosphere for up to 50,000 years. "They wouldn't need to be replenished too often for a hospitable climate to be maintained," Schwieterman said.
Others have proposed refrigerant chemicals, like CFCs, as techno signature gases because they are almost exclusively artificial and visible in Earth's atmosphere. However, CFCs may not be advantageous because they destroy the ozone layer, unlike the fully fluorinated gases discussed in the new paper, which are chemically inert.
"If another civilization had an oxygen-rich atmosphere, they'd also have an ozone layer they'd want to protect," Schwieterman said. "CFCs would be broken apart in the ozone layer even as they catalysed its destruction."
As they're more easily broken apart, CFCs are also short-lived, making them harder to detect.
Finally, the fluorinated gases have to absorb infrared radiation to have an impact on the climate. That absorption produces a corresponding infrared signature that could be detectable with space-based telescopes. With current or planned technology, scientists could detect these chemicals in certain nearby exoplanetary systems.
"With an atmosphere like Earth's, only one out of every million molecules could be one of these gases, and it would be potentially detectable," Schwieterman said. "That gas concentration would also be sufficient to modify the climate."
To arrive at this calculation, the researchers simulated a planet in the TRAPPIST-1 system, about 40 light-years away from Earth. They chose this system, which contains seven known rocky planets, because it is one of the most studied planetary systems aside from our own. It is also a realistic target for existing space-based telescopes to examine.
The group also considered the European LIFE mission's ability to detect the fluorinated gases. The LIFE mission would be able to directly image planets using infrared light, allowing it to target more exoplanets than the Webb telescope, which looks at planets as they pass in front of their stars.
This work was done in collaboration with Daniel Angerhausen at Swiss Federal Institute of Technology/PlanetS, and with researchers at NASA's Goddard Space Flight Centre, the Blue Marble Space Institute of Science, and Paris University.
While the researchers cannot quantify the likelihood of finding these gases in the near future, they are confident that -- if they are present -- it is entirely possible to detect them during currently planned missions to characterize planetary atmospheres.
"You wouldn't need extra effort to look for these techno signatures, if your telescope is already characterizing the planet for other reasons," said Schwieterman. "And it would be jaw-droppingly amazing to find them."
Other members of the research team echo not only enthusiasm for the potential of finding signs of intelligent life, but also for how much closer current technology has brought us to that goal.
"Our thought experiment shows how powerful our next-generation telescopes will be. We are the first generation in history that has the technology to systematically look for life and intelligence in our galactic neighbourhood," added Angerhausen.

- Too many missing satellite galaxies found

Date: June 28, 2024
Source: Tohoku University

Two dwarf galaxies (top and bottom) orbit the much larger Andromeda galaxy. David Dayag/Wikimedia Commons

For years, astronomers have worried about how to explain why the Milky Way has fewer satellite galaxies than the standard dark matter model predicts. This is called the "missing satellites problem." In order to bring us closer to solving this problem, an international team of researchers used data from the Hyper Suprime-Cam (HSC) Subaru Strategic Program (SSP) to discover two completely new satellite galaxies.
These results were published in the *Publications of the Astronomical Society of Japan* on June 8, 2024 by a team of researchers from Japan, Taiwan, and America.
We live in a galaxy called The Milky Way, which has other, smaller galaxies orbiting it called satellite galaxies. Studying these satellite galaxies can help researchers unravel mysteries surrounding dark matter, and better understand how galaxies evolve over time.

"How many satellite galaxies does the Milky Way have? This has been an important question for astronomers for decades," remarks Masahi Chiba, a professor at Tohoku University.

The research team recognized the possibility that there are likely many undiscovered, small satellite galaxies (dwarf galaxies) which are far away and difficult to detect. The powerful ability of the Subaru telescope -- which sits atop an isolated mountain above the clouds in Hawaii -- is well-suited to find these galaxies. In fact, this research team previously found three new dwarf galaxies using the Subaru telescope.

Now, the team has discovered an additional two new dwarf galaxies (Virgo III and Sextans II). With this discovery, a total of nine satellite galaxies have been found overall by different research teams. This is still much fewer than the 220 satellite galaxies predicted by the standard theory of dark matter. However, the footprint of the HSC-SSP does not cover the entire Milky Way. If the distribution of those nine satellite galaxies across the entire Mily Way is similar to what was found in the footprint captured by the HSC-SSP, the research team calculates that there actually may be closer to 500 satellite galaxies. Now, we are faced with a "too many satellites problem," rather than a "missing satellites problem."

To better characterize the actual amount of satellite galaxies, more high-resolution imaging and analysis is required. "The next step is to use a more powerful telescope that captures a wider view of the sky," explains Chiba, "Next year, the Vera C. Rubin Observatory in Chile will be used to fulfil that purpose. I hope that many new satellite galaxies will be discovered.

- The density difference of sub-Neptune's finally deciphered

An international team has shown the existence of two distinct populations of sub-Neptune's, resolving a debate in the scientific community

Date: June 27, 2024
Source: Université de Genève

This artist's impression shows the view from the planet in the TOI-178 system found orbiting furthest from the star. New research by Adrien Leleu and his colleagues with several telescopes, including ESO's Very Large Telescope, has revealed that the resonant system boasts six exoplanets and that all but the one closest to the star are locked in a rare rhythm as they move in their orbits. Credit: ESO/L.

The majority of stars in our galaxy are home to planets. The most abundant are the sub-Neptune's, planets between the size of Earth and Neptune. Calculating their density poses a problem for scientists: depending on the method used to measure their mass, two populations are highlighted, the dense and the less dense. Is this due to an observational bias or the physical existence of two distinct populations of sub-Neptune's? Recent work by the NCCR PlanetS, the University of Geneva (UNIGE) and the University of Bern (UNIBE) argues for the latter. Find out more in the journal *Astronomy & Astrophysics*.

Exoplanets are abundant in our galaxy. The most common are those between the radius of the Earth (around 6,400 km) and Neptune (around 25,000 km), known as "sub-Neptune's". It is estimated that 30% to 50% of sun-like stars contain at least one of these. Calculating the density of these planets is a scientific challenge. To estimate their density, we must first measure their mass and radius. Problem: planets whose mass is measured by the TTV (Transit-Timing Variation) method are less dense than planets whose mass has been measured by the radial velocity method, the other possible measurement method.

"The TTV method involves measuring variations in transit timing. Gravitational interactions between planets in the same system will slightly modify the moment at which the planets pass in front of their star," explains Jean-Baptiste Delisle, scientific collaborator in the Astronomy Department of the UNIGE Faculty of Science and co-author of the study. "The radial velocity method, on the other hand, involves measuring the variations in the star's velocity induced by the presence of the planet around it".

Eliminating any bias

An international team led by scientists from NCCR PlanetS, UNIGE and UNIBE has published a study explaining this phenomenon. It is due not to selection or observational biases, but to physical reasons. "The majority of systems measured by the TTV method are in resonance," explains Adrien Leleu, assistant professor in the Astronomy Department of the UNIGE Faculty of Science and principal author of the study. Two planets are in resonance when the ratio between their orbital periods is a rational

number. For example, when a planet makes two orbits around its star, another planet makes exactly one. If several planets are in resonance, it forms a chain of Laplace resonances. "We therefore wondered whether there was an intrinsic connection between density and the resonant orbital configuration of a planetary system," continues the researcher.

To establish the link between density and resonance, astronomers first had to rule out any bias in the data by rigorously selecting planetary systems for statistical analysis. For example, a large, low-mass planet detected in transit requires more time to be detected in radial velocities. This increases the risk of observations being interrupted before the planet is visible in the radial velocity data, and therefore before its mass is estimated.

"This selection process would lead to a bias in the literature in Favor of higher masses and densities for planets characterized with the radial velocity method. As we have no measurement of their masses, the less dense planets would be excluded from our analyses," explains Adrien Leleu.

Once this data cleaning had been carried out, the astronomers were able to determine, using statistical tests, that the density of sub-Neptune's is lower in resonant systems than their counterparts in non-resonant systems, regardless of the method used to determine their mass.

A question of resonance

The scientists suggest several possible explanations for this link, including the processes involved in the formation of planetary systems. The study's main hypothesis is that all planetary systems converge towards a resonance chain state in the first few moments of their existence, but only 5% remain stable. The other 95% become unstable. The resonance chain then breaks down, generating a series of "catastrophes", such as collisions between planets. The planets fuse together, increasing their density and then stabilizing in non-resonant orbits.

This process generates two very distinct populations of Sub-Neptune's: dense and less dense. "The numerical models of planetary system formation and evolution that we have developed at Bern over the last two decades reproduce exactly this trend: planets in resonance are less dense. This study, moreover, confirms that most planetary systems have been the site of giant collisions, similar or even more violent than the one that gave rise to our Moon," concludes Yann Alibert, professor at UNIBE's Space Research and Planetary Sciences Division (WP) and co-director of the Centre for Space and Habitability and co-author of the study.

- Precision instrument bolsters efforts to find elusive dark energy

Experiment captures atoms in free fall to look for gravitational anomalies caused by universe's missing energy

Date: June 26, 2024

Source: University of California – Berkeley

Dark energy -- a mysterious force pushing the universe apart at an ever-increasing rate -- was discovered 26 years ago, and ever since, scientists have been searching for a new and exotic particle causing the expansion.

Pushing the boundaries of this search, University of California, Berkeley physicists have now built the most precise experiment yet to look for minor deviations from the accepted theory of gravity that could be evidence for such a particle, which theorists have dubbed a chameleon or symmetron.

The experiment, which combines an atom interferometer for precise gravity measurements with an optical lattice to hold the atoms in place, allowed the researchers to immobilize free-falling atoms for seconds instead of milliseconds to look for gravitational effects, besting the current most precise measurement by a factor of five.

Though the researchers found no deviation from what is predicted by the theory spelled out by Isaac Newton 400 years ago, expected improvements in the precision of the experiment could eventually turn up evidence that supports or disproves theories of a hypothetical fifth force mediated by chameleons or symmetrons.

The ability of the lattice atom interferometer to hold atoms for up to 70 seconds -- and potentially 10 times longer -- also opens up the possibility of probing gravity at the quantum level, said Holger Müller, UC Berkeley professor of physics. While physicists have well-tested theories describing the quantum nature of three of the four forces of nature -- electromagnetism and the strong and weak forces -- the quantum nature of gravity has never been demonstrated.

"Most theorists probably agree that gravity is quantum. But nobody has ever seen an

experimental signature of that," Müller said. "It's very hard to even know whether gravity is quantum, but if we could hold our atoms 20 or 30 times longer than anyone else, because our sensitivity increases with the second or fourth power of the hold time, we could have a 400 to 800,000 times better chance of finding experimental proof that gravity is indeed quantum mechanical."

Aside from precision measurements of gravity, other applications of the lattice atom interferometer include quantum sensing. "Atom interferometry is particularly sensitive to gravity or inertial effects. You can build gyroscopes and accelerometers," said UC Berkeley postdoctoral fellow Cristian Panda, who is first author of a paper about the gravity measurements set to be published this week in the journal *Nature* and is co-authored by Müller. "But this gives a new direction in atom interferometry, where quantum sensing of gravity, acceleration and rotation could be done with atoms held in optical lattices in a compact package that is resilient to environmental imperfections or noise."

Because the optical lattice holds atoms rigidly in place, the lattice atom interferometer could even operate at sea, where sensitive gravity measurements are employed to map the geology of the ocean floor.

Screened forces can hide in plain sight

Dark energy was discovered in 1998 by two teams of scientists: a group of physicists based at Lawrence Berkeley National Laboratory, led by Saul Perlmutter, now a UC Berkeley professor of physics, and a group of astronomers that included UC Berkeley postdoctoral fellow Adam Riess. The two shared the 2011 Nobel Prize in Physics for the discovery.

The realization that the universe was expanding more rapidly than it should came from tracking distant supernovas and using them to measure cosmic distances. Despite much speculation by theorists about what's actually pushing space apart, dark energy remains an enigma -- a large enigma, since about 70% of the entire matter and energy of the universe is in the form of dark energy.

One theory is that dark energy is merely the vacuum energy of space. Another is that it is an energy field called quintessence, which varies over time and space.

Another proposal is that dark energy is a fifth force much weaker than gravity and mediated by a particle that exerts a repulsive force that varies with the density of surrounding matter. In the emptiness of space, it would exert a repulsive force over long distances, able to push space apart. In a laboratory on Earth, with matter all around to shield it, the particle would have an extremely small reach.

This particle has been dubbed a chameleon, as if it's hiding in plain sight.

In 2015, Müller adapted an atom interferometer to search for evidence of chameleons using cesium atoms launched into a vacuum chamber, which mimics the emptiness of space. During the 10 to 20 milliseconds, it took the atoms to rise and fall above a heavy aluminium sphere, he and his team detected no deviation from what would be expected from the normal gravitational attraction of the sphere and Earth.

The key to using free-falling atoms to test gravity is the ability to excite each atom into a quantum superposition of two states, each with a slightly different momentum that carries them different distances from a heavy tungsten weight hanging overhead. The higher momentum, higher elevation state experiences more gravitational attraction to the tungsten, changing its phase. When the atom's wave function collapses, the phase difference between the two parts of the matter wave reveals the difference in gravitational attraction between them.

"Atom interferometry is the art and science of using the quantum properties of a particle, that is, the fact that it's both a particle and a wave. We split the wave up so that the particle is taking two paths at the same time and then interfere them at the end," Müller said. "The waves can either be in phase and add up, or the waves can be out of phase and cancel each other out. The trick is that whether they are in phase or out of phase depends very sensitively on some quantities that you might want to measure, such as acceleration, gravity, rotation or fundamental constants."

In 2019, Müller and his colleagues added an optical lattice to keep the atoms close to the tungsten weight for a much longer time -- an astounding 20 seconds -- to increase the effect of gravity on the phase. The optical lattice employs two crossed laser beams that create a lattice-like array of stable places for atoms to congregate, levitating in the vacuum. But was 20 seconds the limit, he wondered?

During the height of the COVID-19 pandemic, Panda worked tirelessly to extend the hold time, systematically fixing a list of 40

possible roadblocks until establishing that the wiggling tilt of the laser beam, caused by vibrations, was a major limitation. By stabilizing the beam within a resonant chamber and tweaking the temperature to be a bit colder -- in this case less than a millionth of a Kelvin above absolute zero, or a billion times colder than room temperature -- he was able to extend the hold time to 70 seconds.
He and Müller published those results in the June 11, 2024, issue of *Nature Physics*.

Gravitational entanglement

In the newly reported gravity experiment, Panda and Müller traded a shorter time, 2 seconds, for a greater separation of the wave packets to several microns, or several thousandths of a millimetre. There are about 10,000 cesium atoms in the vacuum chamber for each experiment -- too sparsely distributed to interact with one another -- dispersed by the optical lattice into clouds of about 10 atoms each.
"Gravity is trying to push them down with a force a billion times stronger than their attraction to the tungsten mass, but you have the restoring force from the optical lattice that's holding them, kind of like a shelf," Panda said. "We then take each atom and split it into two wave packets, so now it's in a superposition of two heights. And then we take each one of those two wave packets and load them in a separate lattice site, a separate shelf, so it looks like a cupboard. When we turn off the lattice, the wave packets recombine, and all the quantum information that was acquired during the hold can be read out."
Panda plans to build his own lattice atom interferometer at the University of Arizona, where he was just appointed an assistant professor of physics. He hopes to use it to, among other things, more precisely measure the gravitational constant that links the force of gravity with mass.
Meanwhile, Müller and his team are building from scratch a new lattice atom interferometer with better vibration control and a lower temperature. The new device could produce results that are 100 times better than the current experiment, sensitive enough to detect the quantum properties of gravity. The planned experiment to detect gravitational entanglement, if successful, would be akin to the first demonstration of quantum entanglement of photons performed at UC Berkeley in 1972 by the late Stuart Freedman and former postdoctoral fellow John Clauser. Clauser shared the 2022 Nobel Prize in Physics for that work.
Other co-authors of the gravity paper are graduate student Matthew Tao and former undergraduate student Miguel Ceja of UC Berkeley, Justin Khoury of the University of Pennsylvania in Philadelphia and Guglielmo Tino of the University of Florence in Italy.
The work is supported by the National Science Foundation (1708160, 2208029), Office of Naval Research (N00014-20-1-2656) and Jet Propulsion Laboratory (1659506, 1669913).

Pillars of creation star in new visualization from NASA's Hubble and Webb telescopes

Date: June 26, 2024
Source: NASA/Goddard Space Flight Centre

The Webb version showcases orange and orange-brown dust that is semi-transparent, with light blue ionized gas against a dark blue background.

Made famous in 1995 by NASA's Hubble Space Telescope, the Pillars of Creation in the heart of the Eagle Nebula have captured imaginations worldwide with their arresting, ethereal beauty.
Now, NASA has released a new 3D visualization of these towering celestial structures using data from NASA's Hubble and James Webb space telescopes. This is the most comprehensive and detailed multiwavelength movie yet of these star-birthing clouds.
"By flying past and amongst the pillars, viewers experience their three-dimensional structure and see how they look different in the Hubble visible-light view versus the Webb infrared-light view," explained principal visualization scientist Frank Summers of the Space Telescope Science Institute (STScI) in Baltimore, who led the movie development team for NASA's Universe of Learning.

"The contrast helps them understand why we have more than one space telescope to observe different aspects of the same object."
The four Pillars of Creation, made primarily of cool molecular hydrogen and dust, are being eroded by the fierce winds and punishing ultraviolet light of nearby hot, young stars. Finger-like structures larger than the solar system protrude from the tops of the pillars. Within these fingers can be embedded, embryonic stars. The tallest pillar stretches across three light-years, three-quarters of the distance between our Sun and the next nearest star.
The movie takes visitors into the three-dimensional structures of the pillars. Rather than an artistic interpretation, the video is based on observational data from a science paper led by Anna McLeod, an associate professor at the University of Durham in the United Kingdom. McLeod also served as a scientific advisor on the movie project.
"The Pillars of Creation were always on our minds to create in 3D. Webb data in combination with Hubble data allowed us to see the Pillars in more complete detail," said production lead Greg Bacon of STScI. "Understanding the science and how to best represent it allowed our small, talented team to meet the challenge of visualizing this iconic structure."
The new visualization helps viewers experience how two of the world's most powerful space telescopes work together to provide a more complex and holistic portrait of the pillars. Hubble sees objects that glow in visible light, at thousands of degrees. Webb's infrared vision, which is sensitive to cooler objects with temperatures of just hundreds of degrees, pierces through obscuring dust to see stars embedded in the pillars.
"When we combine observations from NASA's space telescopes across different wavelengths of light, we broaden our understanding of the universe," said Mark Clampin, Astrophysics Division director at NASA Headquarters in Washington. "The Pillars of Creation region continues to offer us new insights that hone our understanding of how stars form. Now, with this new visualization, everyone can experience this rich, captivating landscape in a new way."
Produced for NASA by STScI with partners at Caltech/IPAC, and developed by the AstroViz Project of NASA's Universe of Learning, the 3D visualization is part of a longer, narrated video that combines a direct connection to the science and scientists of NASA's Astrophysics missions with attention to the needs of an audience of youth, families, and lifelong learners. It enables viewers to explore fundamental questions in science, experience how science is done, and discover the universe for themselves.
Several stages of star formation are highlighted in the visualization. As viewers approach the central pillar, they see at its top an embedded, infant protostar glimmering bright red in infrared light. Near the top of the left pillar is a diagonal jet of material ejected from a newborn star. Though the jet is evidence of star birth, viewers can't see the star itself. Finally, at the end of one of the left pillar's protruding "fingers" is a blazing, brand-new star.
A bonus product from this visualization is a new 3D printable model of the Pillars of Creation.
The base model of the four pillars used in the visualization has been adapted to the STL file format, so that viewers can download the model file and print it out on 3D printers. Examining the structure of the pillars in this tactile and interactive way adds new perspectives and insights to the overall experience.

- Shocked quartz reveals evidence of historical cosmic airburst

Date: June 26, 2024
Source: University of California - Santa Barbara

Researchers continue to expand the case for the Younger Dryas Impact hypothesis. The idea proposes that a fragmented comet smashed into the Earth's atmosphere 12,800 years ago, causing a widespread climatic shift that, among other things, led to the abrupt reversal of the Earth's warming trend and into an anomalous near-glacial period called the Younger Dryas.
Now, UC Santa Barbara emeritus professor James Kennett and colleagues report the presence of proxies associated with the cosmic airburst distributed over several

separate sites in the eastern United States (New Jersey, Maryland and South Carolina), materials indicative of the force and temperature involved in such an event, including platinum, micro spherules, melt glass and shock-fractured quartz. The study appears in ScienceOpen's journal *Airbursts and Cratering*.

"What we've found is that the pressures and temperatures were not characteristic of major crater-forming impacts but were consistent with so-called 'touchdown' airbursts that don't form much in the way of craters," Kennett said.

The Earth is bombarded every day by tons of celestial debris, in the form of tiny dust particles. On the other end of the scale are the extremely rare and cataclysmic impacts like the Chicxulub event that 65 million years ago caused the extinction of dinosaurs and other species. Its 150-kilometer-wide (93 miles) impact crater can be found in the Yucatán Peninsula in Mexico.

Somewhere in between are the impacts that don't leave craters on the Earth's surface but are nevertheless destructive. The shockwave from the 1908 Tunguska event knocked down 2,150 square kilometres (830 square miles) of forest, as the roughly 40-meter (130 ft) diameter asteroid collided with the atmosphere almost 10 kilometres (6 miles) above the Siberian taiga.

The comet thought to be responsible for the Younger Dryas cooling episode is estimated to have been 100 kilometres wide (62 miles) -- much larger than the Tunguska object, and fragmented into thousands of pieces. The sediment layer associated with the airburst stretches across much of the northern hemisphere, but can also be found in locations south of the equator. This layer contains unusually high levels of rare materials associated with cosmic impacts, such as iridium and platinum, and materials formed under high pressures and temperatures, such as magnetic micro spherules (cooled-down metallic droplets), melt glass and nanodiamonds.

Shocked quartz and amorphous silica

The researchers are particularly interested in the presence of shocked quartz, indicated by a pattern of lines, called lamellae, that shows stress great enough to deform the crystal structure of quartz, a very hard material. This "crème de la crème" of cosmic impact evidence is present in impact craters, however linking shocked quartz to cosmic airbursts has proven to be more of a challenge.

"In the extreme form, such as when an asteroid hammers into the Earth's surface, all the fractures are very parallel," Kennett explained. In the realm of cosmic airbursts, different variables are present in the realm of cosmic airbursts. "When you think about it, the pressures and temperatures that produce these fractures will vary depending on the density, entry angle, altitude of the impact and the impactor's size.

"What we found -- and this is what is characteristic of the impact layer, called the Younger Dryas Boundary -- is that although we do occasionally see in the quartz grains examples of the 'traditional' shocked quartz with parallel fractures, we mostly see grains that are not parallel," he said. These fractures are seen in an irregular, web-like pattern of intersecting, meandering lines and surface and subsurface fissures, in contrast to the parallel and planar deformations of impact-associated shocked quartz found at craters. These subparallel and sub planar deformations are due in large part to the relatively lower pressures caused by explosions that occur above the ground, the researchers assert, as opposed to impacts that make contact with the Earth.

What these sediments do share with the shocked quartz at crater sites is the presence of amorphous silica -- melted glass -- in these fractures. And that, the researchers say, is evidence of the combination of pressure and high temperatures (greater than 2000 degrees Celsius) that could have come from a low-altitude bolide airburst. Similarly fractured quartz grains and melt glass have been found in more present-day samples of above ground explosions, such as at the Trinity atomic bomb test site in New Mexico. The roughly 20-kiloton bomb was detonated atop a 30.5-meter (100 foot) tower.

These lower-pressure shocked quartz grains join a growing suite of impact proxies that together make a case for a fragmented comet that not only caused widespread burning, but also abrupt climatic change that resulted in the extinctions of 35 genera of megafauna in North America, such as the mammoths and giant ground sloths, and led to the collapse of a flourishing human culture called Clovis, according to the researchers.

"There's a whole range of different shocked quartz, so we have to make a well-

documented case that they are indeed significant for interpreting cosmic impact, even though they're not reflecting a traditional major crater-forming event," Kennett said. "These are from very-low-altitude 'touchdown' airbursts almost certainly associated with cometary impact."

- Mars quakes may help reveal whether liquid water exists underground on red planet

Date: June 25, 2024
Source: Penn State

One of the last images ever taken by NASA's InSight Mars lander shows its seismometer on the red planet's surface in 2022. A team of scientists suggest that using data from the seismometer and a magnetometer on the lander could help reveal whether liquid water is present deep under the Martian surface. (Image credit: NASA/JPL-Caltech)

If liquid water exists today on Mars, it may be too deep underground to detect with traditional methods used on Earth. But listening to earthquakes that occur on Mars -- or mars quakes -- could offer a new tool in the search, according to a team led by Penn State scientists.

When quakes rumble and move through aquifers deep underground, they produce electromagnetic signals. The researchers reported in the journal *JGR Planets* how those signals, if also produced on Mars, could identify water miles under the surface. The study may lay the groundwork for future analyses of data from Mars missions, according to Nolan Roth, a doctoral candidate in the Department of Geosciences at Penn State and lead author.

"The scientific community has theories that Mars used to have oceans and that, over the course of its history, all that water went away," Roth said. "But there is evidence that some water is trapped somewhere in the subsurface. We just haven't been able to find it. The idea is, if we can find these electromagnetic signals, then we find water on Mars."

If scientists want to find water on Earth, they can use tools like ground-penetrating radar to map the subsurface. But this technology is not effective miles under the surface, depths where water may be on Mars, the scientists said.

Instead, the researchers recommend a novel application of the seismoelectric method, a newer technique developed to non-invasively characterize Earth's subsurface. When seismic waves from an earthquake move through an aquifer underground, differences in how rocks and water move produce electromagnetic fields. These signals, which can be heard by sensors on the surface, can reveal information about aquifer depth, volume, location and chemical compositions, according to the researchers.

"If we listen to the mars quakes that are moving through the subsurface, if they pass through water, they'll create these wonderful, unique signals of electromagnetic fields," Roth said. "These signals would be diagnostic of current, modern-day water on Mars."

On water-rich Earth, using this method to identify active aquifers is challenging because water exists in the subsurface even outside of aquifers, creating other electric signals as seismic waves move through the ground. This background noise must be separated from the aquifers' signals, the scientists said, for accurate identification and characterization.

"On Mars, where the near-surface is certainly desiccated, no such separation is needed," said Tieyuan Zhu, associate professor of geosciences at Penn State and Roth's adviser and co-author. "In contrast to how seismoelectric signals often appear on Earth, Mars' surface naturally removes the noise and exposes useful data that allows us to characterize several aquifer properties."

The researchers created a model of the Martian subsurface and added aquifers to simulate how the seismoelectric method would perform. They found they could successfully use the technique to analyse details about the aquifers, including how thick or thin they are and their physical and chemical properties, like salinity.

"If we can understand the signals, we can go back and characterize the aquifers themselves," Roth said. "And that would give us more constraints than we've ever had before for understanding water on Mars today and how it has changed over the last 4 billion years. And that would be a big step ahead."

Roth said future work will -- surprisingly -- involve analysing data already collected on Mars.

NASA's Insight lander, launched in 2018, delivered a seismometer to Mars that has been listening to mars quakes and mapping the subsurface. But seismometers have difficulty distinguishing water from gas or less dense rock.
However, the mission also included a magnetometer as a diagnostic tool to help the seismometer. Combing data from the magnetometer and the seismometer could reveal seismoelectric signals, the scientists said.
Sending a dedicated magnetometer meant to conduct scientific experiments on future NASA missions could potentially produce even better results, the researchers said.
"This shouldn't be limited to Mars -- the technique has potential, for example, to measure the thickness of icy oceans on a moon of Jupiter," Zhu said. "The message we want to give the community is there is this promising physical phenomenon -- which received less attention in the past -- that may have great potential for planetary geophysics."
Yongxin Gao, professor at Hefei University of Technology in China, also contributed.
The Penn State E. Willard and Ruby S. Miller Fellowship and the National Natural Science Foundation of China supported researchers involved on this work.

- First of its kind detection made in striking new Webb image

Date: June 24, 2024
Source: NASA/Goddard Space Flight Centre

In this image of the Serpens Nebula from NASA's James Webb Space Telescope, astronomers found a grouping of aligned protostellar outflows within one small region (the top left corner). Serpens is a reflection nebula, which means it's a cloud of gas and dust that does not create its own light, but instead shines by reflecting the light from stars close to or within the nebula.
NASA, ESA, CSA, K. Pontoppidan (NASA's Jet Propulsion Laboratory) and J. Green (Space Telescope Science Institute).

For the first time, a phenomenon astronomer has long hoped to directly image has been captured by NASA's James Webb Space Telescope's Near-Infrared Camera (NIRCam). In this stunning image of the Serpens Nebula, the discovery lies in the northern area (seen at the upper left) of this young, nearby star-forming region.
Astronomers found an intriguing group of protostellar outflows, formed when jets of gas spewing from newborn stars collide with nearby gas and dust at high speeds. Typically, these objects have varied orientations within one region. Here, however, they are slanted in the same direction, to the same degree, like sleet pouring down during a storm.
The discovery of these aligned objects, made possible due to Webb's exquisite spatial resolution and sensitivity in near-infrared wavelengths, is providing information into the fundamentals of how stars are born.
"Astronomers have long assumed that as clouds collapse to form stars, the stars will tend to spin in the same direction," said principal investigator Klaus Pontoppidan, of NASA's Jet Propulsion Laboratory in Pasadena, California. "However, this has not been seen so directly before. These aligned, elongated structures are a historical record of the fundamental way that stars are born."
So just how does the alignment of the stellar jets relate to the rotation of the star? As an interstellar gas cloud crashes in on itself to form a star, it spins more rapidly. The only way for the gas to continue moving inward is for some of the spin (known as angular momentum) to be removed. A disk of material forms around the young star to transport material down, like a whirlpool around a drain. The swirling magnetic fields in the inner disk launch some of the material into twin jets that shoot outward in opposite directions, perpendicular to the disk of material.
In the Webb image, these jets are signified by bright clumpy streaks that appear red, which are shockwaves from the jet hitting surrounding gas and dust. Here, the red colour represents the presence of molecular hydrogen and carbon monoxide.
"This area of the Serpens Nebula -- Serpens North -- only comes into clear view with Webb," said lead author Joel Green of the Space Telescope Science Institute in Baltimore. "We're now able to catch these extremely young stars and their outflows, some of which previously appeared as just blobs or were completely invisible in optical wavelengths because of the thick dust surrounding them."
Astronomers say there are a few forces that potentially can shift the direction of the

outflows during this period of a young star's life. One way is when binary stars spin around each other and wobble in orientation, twisting the direction of the outflows over time.

Stars of the Serpens

The Serpens Nebula, located 1,300 light-years from Earth, is only one or two million years old, which is very young in cosmic terms. It's also home to a particularly dense cluster of newly forming stars (~100,000 years old), seen at the centre of this image. Some of these stars will eventually grow to the mass of our Sun.

"Webb is a young stellar object-finding machine," Green said. "In this field, we pick up sign posts of every single young star, down to the lowest mass stars."

"It's a very complete picture we're seeing now," added Pontoppidan.

So, throughout the region in this image, filaments and wisps of different hues represent reflected starlight from still-forming protostars within the cloud. In some areas, there is dust in front of that reflection, which appears here with an orange, diffuse shade. This region has been home to other coincidental discoveries, including the flapping "Bat Shadow," which earned its name when 2020 data from NASA's Hubble Space Telescope revealed a star's planet-forming disk to flap, or shift. This feature is visible at the centre of the Webb image.

Future Studies

The new image, and serendipitous discovery of the aligned objects, is actually just the first step in this scientific program. The team will now use Webb's NIRSpec (Near-Infrared Spectrograph) to investigate the chemical make-up of the cloud.

The astronomers are interested in determining how volatile chemicals survive star and planet formation. Volatiles are compounds that sublimate, or transition from a solid directly to a gas, at a relatively low temperature -- including water and carbon monoxide. They'll then compare their findings to amounts found in protoplanetary disks of similar-type stars.

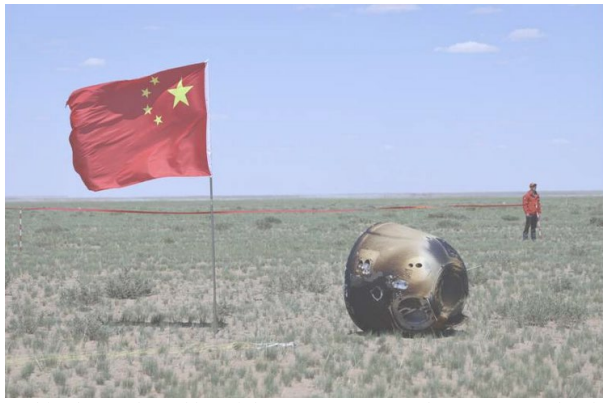
"At the most basic form, we are all made of matter that came from these volatiles. The majority of water here on Earth originated when the Sun was an infant protostar billions of years ago," Pontoppidan said. "Looking at the abundance of these critical compounds in protostars just before their protoplanetary disks have formed could help us understand how unique the circumstances were when our own solar system formed."

These observations were taken as part of General Observer program 1611. The team's initial results have been accepted in the Astrophysical Journal.

The James Webb Space Telescope is the world's premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and CSA (Canadian Space Agency).

- Geologists expect Chang'e-6 lunar surface samples to contain volcanic rock and impact ejecta

Date: June 24, 2024
Source: Cell Press



In this photo released by Xinhua News Agency, the return capsule of the Chang'e 6 probe is seen in Siziwang Banner, northern China's Inner Mongolia Autonomous Region on Tuesday, June 25, 2024. China's Chang'e 6 probe has returned on Earth with rock and soil samples from the little-explored far side of the moon in a global first. Credit: Bei He/Xinhua via AP

On June 25, China's Chang'e-6 (CE-6) lunar probe is set to return to Earth, carrying the first surface samples collected from the far side of the Moon. In anticipation of this historic event, scientists from the Institute of Geology and Geophysics at the Chinese Academy of Sciences are publishing their predictions for the unique materials that may be found in the CE-6 samples in the journal *The Innovation*.

Based on the geological characteristics of the probe's landing site, the researchers anticipate that the returned surface samples will consist of 2.5-million-year-old volcanic rock combined with small amounts of material generated by nearby meteorite strikes. There is also the possibility that evidence of distant impacts will be found in the samples.

"There are significant differences between the far side and the nearside of the Moon in terms of lunar crustal thickness, volcanic activity,

composition, etc., especially considering that CE-6 landed on the South Polar-Aitkin (SPA) basin, the special terrane of the Moon," says first author Zongyu Yue, a geologist at the Chinese Academy of Sciences. "The CE-6 samples, being the first obtained from the far side of the Moon, are expected to answer one of the most fundamental scientific questions in lunar science research: what geologic activity is responsible for the differences between the two sides?"

Nearly 3 weeks ago, on June 2, CE-6 landed in the Apollo Crater, located at the edge of the largest depression on the Moon known as the SPA basin. The probe used core drilling and surface scooping to collect rocks and minerals that are likely to contain traces of early meteorite impacts. The data will reveal how far ejecta from early collisions spread across the Moon and whether there are any differences compared to what's been recorded on the asymmetrical nearside.

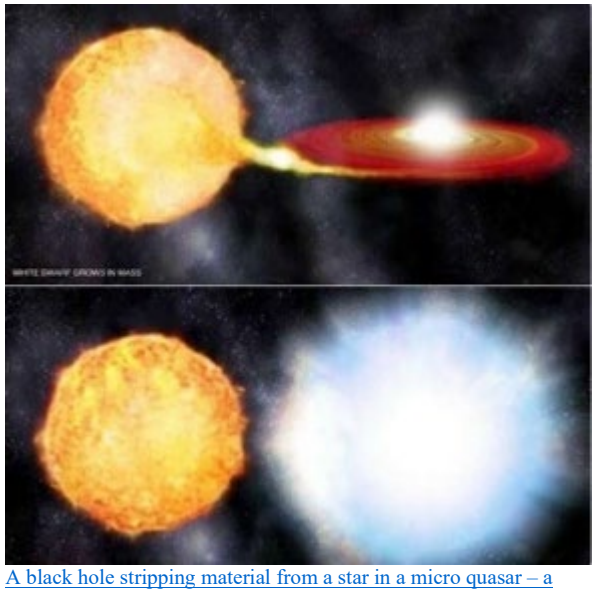
"My greatest hope is that the CE-6 samples contain some impact melts (fragments generated when smaller bodies crashing into the Moon) from the Apollo Crater and the SPA basin, which can provide crucial constraints on the early impact flux of the Moon," says Yue. "Once this information is obtained, it will not only help clarify the role of early lunar meteorite impacts on the Moon's evolution, but also be of great significance in analysing the early impact history of the inner solar system."

With 10 successful lunar sample return missions conducted on the nearside of the Moon, the CE-6 lunar probe samples represent the first collected from the far side of the Moon. Researchers expect their analysis in the coming months and years to contribute to a more comprehensive understanding of lunar evolution.

The study was supported by the National Key Research and Development Program of China, the Chinese Academy of Sciences, and Key Research Programs of IGGCAS.

- A hidden treasure in the Milky Way -- Astronomers uncover ultrabright x-ray source

Date: June 24, 2024
Source: University of Turku



A black hole stripping material from a star in a micro quasar – a cosmic particle accelerator that could be the source of high-energy cosmic rays. A white dwarf fed by a normal star reaches the critical mass and explodes as a Type Ia supernova. Credit: M Weiss/NASA/CXC.

X-ray binaries are intriguing systems consisting of two celestial bodies: a normal star and a compact, dead object such as a black hole or a neutron star that sucks material from its stellar companion. A few hundred such sources have been identified thus far in our Galaxy. When it comes to the most powerful phenomena in the Universe, the release of gravitational energy in X-ray binary systems stands out as a highly efficient process.

Among the first X-ray binary systems discovered in the cosmos is the system Cygnus X-3. Since the early 1970s, this binary system was noted for its ability to briefly emerge as one of the most intense radio sources, yet in a few days it dims or vanishes altogether. These peculiar characteristic spurred early efforts, coordinated by telephone calls, to unite astronomical observations across the globe. The unique behaviour of the system during these short-lived, highly energetic events, contrasting its otherwise "normal" nature, led to it being dubbed the "astronomical puzzle Cygnus X-3" by R.M. Hjellming in 1973. Numerous efforts have been aimed at understanding its nature ever since.

The breakthrough in unravelling this puzzle has been achieved thanks to the study of this system with the satellite Imaging X-ray Polarimetry Explorer (IXPE) that was launched by NASA in December 2021. According to Alexandra Veledina, an Academy Research Fellow at the University of Turku in Finland and the lead author of the study, the use of X-ray polarized vision has

provided insights into the configuration of matter surrounding the compact object in the nearest proximity to the black hole.
"We have discovered that the compact object is surrounded by an envelope of a dense, opaque matter. The light that we observe is a reflection off the inner funnel walls formed by the surrounding gas, resembling a cup with a mirror interior," Veledina explains.
This revelation has led to the identification of Cygnus X-3 as a member of the class of ultra-luminous X-ray sources (ULXs), which consume matter at such a gargantuan rate that a considerable fraction of the infalling material does not fit inside the event horizon, but rather is being spat away from the system.
"ULXs are typically observed as luminous spots in the images of distant galaxies, with their emissions amplified by the focusing effects of the compact object's surrounding funnel, acting akin to a megaphone," elaborates Juri Poutanen, Professor at the Department of Physics and Astronomy of the University of Turku and a co-author of the research.
"However, due to the vast distances to these sources, thousands of times beyond the span of the Milky Way, they appear relatively faint to X-ray telescopes. Our discovery has now unveiled a bright counterpart of these distant ULXs residing within our own Galaxy."
This significant finding marks a new chapter in the investigation of this extraordinary cosmic source, offering an opportunity for in-depth exploration of extreme matter consumption.

- Star clusters observed within a galaxy in the early Universe

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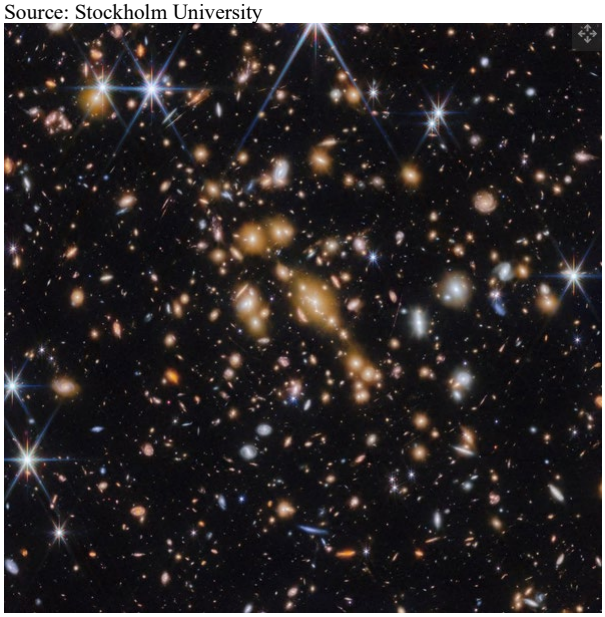

The Galaxy cluster SPT-CL J0615−5746 as seen by the JWST as an arc of cosmic Gems (Image credit: ESA/Webb, NASA & CSA, L. Bradley (STScI), A. Adamo (Stockholm University) and the Cosmic Spring collaboration)

The history of how stars and galaxies came to be and evolved into the present day remains among the most challenging astrophysical questions to solve yet, but new research brings us closer to understanding it.
In a new study by an international team led by Dr. Angela Adamo at Stockholm University, new insights about young galaxies during the Epoch of Reionization have been revealed. Observations with the James Webb Space Telescope (JWST) of the galaxy Cosmic Gems arc (SPT0615-JD) have confirmed that the light of the galaxy was emitted 460 million years after the big bang. What makes this galaxy unique is that it is magnified through an effect called gravitational lensing, which has not been observed in other galaxies formed during that age. The magnification of the Cosmic Gems arc has allowed the team to study the smaller structures inside an infant galaxy for the first time. The authors found that the Cosmic Gems arc harbours five young massive star clusters in which stars are formed. "The surprise and astonishment were incredible when we opened the JWST images for the first time" says Adamo.

The mystery of the early Universe

The Epoch of Reionization (EoR) is a crucial time during the evolution of the Universe, which occurred within the first billion years after the Big Bang. During this period, the Universe went through an important transition. In its early days it was filled with neutral Hydrogen gas, but this changed during the EoR. The matter of the Universe went from its neutral form to being fully ionized; the atoms were stripped from their electrons. The earliest galaxies of the Universe are believed to have driven this transformation.
In order to study the earliest galaxies, one has to look far away in space. Light travels at a finite speed. By observing objects at far distances, we can "look back in time" as we see the state of the object at the time when the light was emitted from it. However, it is difficult to observe small details of an object at large enough distances to study the early Universe. One method to observe finer details in a galaxy at a great distance is through the use of gravitational lensing. Gravitational lensing occurs when a celestial body of high mass curves the path of light around it due to its strong gravity. When the light emitted

from a source passes through the gravitational lens it is distorted similar to the effect of a magnifying glass. In this way, astronomers can observe small details in objects far away. Galaxies slowly build their stellar population through a process referred to as star formation. In local galaxies we see that a large fraction of stars form in star clusters. Star clusters are groups of stars held together by gravitational forces. Star clusters can have varying sizes, where some only contain a small number of stars to others that can contain millions. Globular clusters are very old star clusters where stars have previously been formed, but not anymore. How and where the globular clusters were formed has been a long-standing mystery.

New insights into the formation of the first stars and galaxies

In a new study published in the scientific journal *Nature*, the team of astronomers present the discovery of star clusters in a galaxy whose light has passed through a gravitational lens on its way towards the Earth. "This achievement could only be possible thanks to JWST unmatched capabilities," says Dr. Adélaïde Claeyssens of Stockholm University and co-author of the publication. The galaxy SPT0615-JD, also known as the Cosmic Gems Arc, is located in the distant Universe. The light that has reached the Earth in the present day was emitted from this galaxy only 460 million years after the Big Bang. By studying this object, the astronomers look back 97% of the cosmic time.

"Due to the gravitational lensing, the Cosmic Gems Arc could be resolved down to small enough scales to study the objects within it," adds Claeyssens. The team used the instrument Near Infrared Camera (NIRCam) onboard the JWST for their observations. The NIRCam is an instrument built to take high-resolution images in the near-infrared part of the light spectrum, in which the earliest stars and galaxies can be detected. Using the high resolution of the JWST NIRCam, the resulting observations showed a chain of bright dots mirrored from one side to the other. It was discovered that these dots were five young massive star clusters.

Through analysis of the light spectra emitted by the galaxy, it could be determined that the stellar clusters are gravitationally bound and have a three-times larger stellar density than typical young star clusters in the local Universe. It was also found that the clusters were formed recently, within 50 million years. They are very massive, although much smaller than globular clusters. "It was incredible to see the JWST images of the Cosmic Gems arc and realize that we were looking at star clusters in such a young galaxy. We observe globular clusters around local galaxies, but we don't know when and where they formed. The Cosmic Gems arc observations have opened a unique window for us into the works of infant galaxies as well as showing us where globular clusters formed" says Adamo. "These clusters will have enough time to relax and become globular clusters, due to them being formed at such a young age of the Universe," she adds.

Understanding the early Universe

Through studies of star clusters in young galaxies born shortly after the Big Bang, further understanding of how and where globular clusters are formed can be achieved. Since young galaxies are believed to drive the reionization during the EoR, it is crucial to study them in depth in order to gain knowledge about the early Universe. Using the discoveries made by the authors of this study, more information is added to our understanding about how the stars in the earliest galaxies were born, and where and how globular clusters are formed.

Looking onwards

In the future, the group is planning to build a larger sample of similar galaxies. "We have one galaxy so far, but we need many more if we want to create demographics of the cluster populations forming in the earliest galaxies." says Adamo. The team also has an approved program for the next cycle of JWST observations, where they will study the Cosmic Gems Arc galaxy and the recently discovered star clusters in further detail. "Spectroscopic observations will allow us to spatially map the star formation rate and ionizing photon production efficiency along the galaxy" adds Dr. Larry Bradley, principal investigator of the JWST program and the second author of this article.