South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 594 – February 7th 2025 Editor: Roger Burgess

Main Talk **Claire Bradshaw FRAS** "From Sky to Screen"
I have been interested in space and astronomy most of my life, gaining my first set of binoculars as a child followed by a Tasco reflector telescope. From these early days, interruptions came with University, marriage etc and it wasn't until 2012 that I obtained my first real telescope - an eq3 Skywatcher 150p gifted from a friend's lottery winnings! After that things took off, using webcams to image planets and a DSLR to shoot deep space. I then leapt into dedicated astro-camera imaging and things moved on from there. I love doing talks, having my work on display in galleries and trying to get the next best shot, learning more as I go. I am also part of a five-woman strong team creating a forthcoming book on Women

Please support a raffle we are organizing this month.

- Japan's wooden satellite exits International Space Station

Carefully crafted wooden box, LignoSat, is on its own

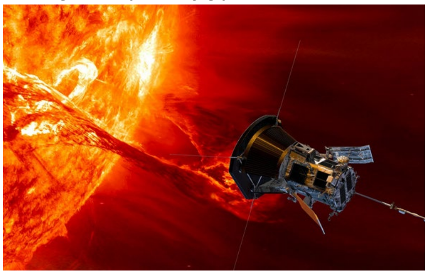
Richard Speed
Wed 8 Jan 2025 // 14:45 UTC

LignoSat was sent to the ISS in November 2024 on a mission to demonstrate that wood could be a viable material from which to build spacecraft. The goal of the satellite includes studying how the selected wood reacts when exposed to the environment of space and its resistance to cosmic radiation.
Researchers will also monitor geomagnetic levels to determine whether the geomagnetic field can penetrate the satellite and interfere with the electronics.
According to NASA, three wood species had previously been exposed to space before honoki magnolia was selected to construct the cubesat. The 10cm long wood panels used in the constructions were assembled using a Japanese wood joinery method called "Blind Miter Dovetail Joint." This method means that glue and nails are not required.
Researchers are considering wood for spacecraft construction as a sustainable alternative to conventional materials. While America's finest news source, satirical website The Onion, humorously noted "delays" encountered by Russia in "carving" its contribution to the ISS in 1998, JAXA's project is a serious demonstration of how wood could be an alternative to aluminium and other metals that generally go into satellite construction.
LignoSat was part of the Japanese Experiment Module (JEM) Small Satellite Orbital Deployer-30 (J-SSOD-30) CubeSat deployment mission, handled by the JEM Remote Manipulator System (JEMRMS). It is expected to spend a few months in low Earth orbit before eventually re-entering the Earth's atmosphere and burning up.

- Parker Solar Probe set for blisteringly hot date with the Sun on Christmas Eve

Ho-ho-holy heatshield!

Richard Speed
Mon 23 Dec 2024 // 15:30 UTC



NASA's Parker Solar Probe is scheduled to make its closest approach yet to the Sun, approximately 3.8 million miles from the star's surface, on Christmas Eve.

"No human-made object has ever passed this close to a star, so Parker will truly be returning data from uncharted territory," said Nick Pinkine, Parker Solar Probe mission operations manager at the Johns Hopkins Applied Physics Laboratory (APL).

In addition to traveling far closer to the Sun than any previous mission, the spacecraft will also be barrelling along at approximately 430,000 miles per hour.

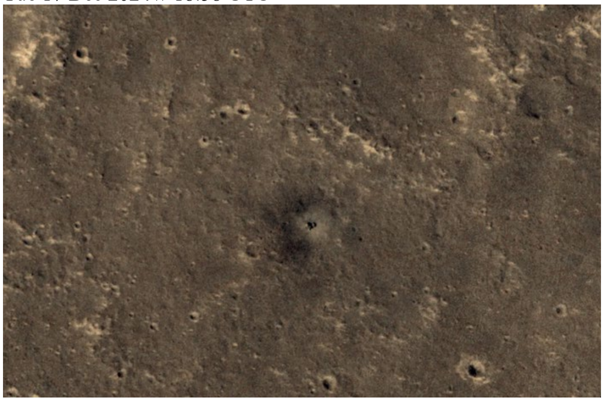
The spacecraft was launched on August 12, 2018, and is designed to study the workings of the Sun, specifically how solar corona and wind function. To do this, it must come closer to the star than any other mission, make its observations, and transmit them back to Earth over subsequent weeks. Scientists expect to receive a beacon tone on December 27 to confirm that it survived the flyby.

The spacecraft has a 73 kg heat shield, measuring 11.4 centimetres thick with a diameter of 2.5 meters. Scientists reckon that the Sun-facing side of the carbon-composite shield will experience temperatures of about 1,000°C (1,832°F) during its flyby, but the instruments in the shield's shadow should remain at a more comfortable 29°C (84°F). The heat shield is designed to withstand temperatures as high as 1,377°C (2,511°F).

- ❖ Silent NASA lander gives astronomers insight into Martian dust

NASA to bid a final farewell to InSight

Richard Speed
Tue 17 Dec 2024 // 18:58 UTC



Two years after NASA retired the InSight lander, scientists are continuing to use the vehicle to learn more about Mars.

InSight was retired in 2022 after it stopped communicating with Earth. The silence started during the lander's extended mission and was expected. Dust had been building up on the lander's solar arrays, preventing its batteries from recharging and eventually leading to its demise. Hopeful that a passing dust devil might clean the arrays, NASA has been listening for a signal from the lander, but with not a peep from InSight over the last two years, that effort will end at the close of 2024. However, scientists have kept an eye on the lander thanks to images taken by the High-Resolution Imaging Science Experiment (HiRISE) camera aboard NASA's Mars Reconnaissance Orbiter (MRO). Those images have helped scientists better understand how dust works on the Martian surface.

Science team member Ingrid Daubar of Brown University in Providence, Rhode Island said, "Even though we're no longer hearing from InSight, it's still teaching us about Mars.

"By monitoring how much dust collects on the surface — and how much gets vacuumed away by wind and dust devils — we learn more about the wind, dust cycle, and other processes that shape the planet."

Dust plays a critical role in both the atmosphere and landscape of Mars. It can block out light from the Sun and shape the surface. And it has implications for future missions; as well as coating solar panels, the dust can wreak havoc when it gets into mechanical parts.

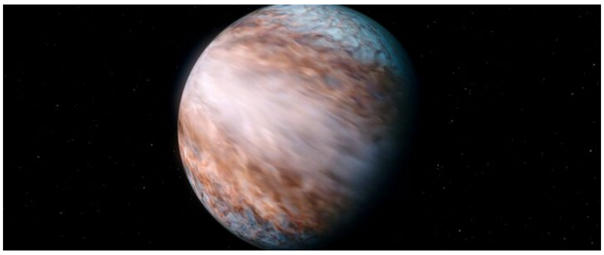
The imagery has helped scientists understand how quickly marks around craters can fade over time as dust covers them, giving an idea of their age. InSight used rockets to land in 2018, leaving marks visible from orbit. Those marks are fading while InSight's solar panels gradually acquire the same reddish-brown hue as the rest of the Martian surface. InSight touched down in November 2018. While it was the first to detect mars quakes, according to NASA, its mission did not go entirely to plan. It was also supposed to send a "mole" five meters into the Martian surface to measure the planet's internal temperature, but the soil's unexpected habit of clumping around the device put paid to the experiment, and NASA announced it was giving up trying to coax the mole into Mars at the beginning of 2021

The lander is no longer active yet it continues to prove helpful to scientists studying the movement of dust on Mars.

Daubar said, "It feels a little bittersweet to look at InSight now. It was a successful mission that produced lots of great science. Of course, it would have been nice if it kept going forever, but we knew that wouldn't happen."

- Extreme supersonic winds measured on planet outside our Solar System

Date: January 21, 2025
Source: ESO



Astronomers have discovered extremely powerful winds pummelling the equator of WASP-127b, a giant exoplanet. Reaching speeds up to 33,000 km/h, the winds make up the fastest Jetstream of its kind ever measured on a planet. The discovery was made using the European Southern Observatory's Very Large Telescope (ESO's VLT) in Chile and provides unique insights into the weather patterns of a distant world.
Tornados, cyclones and hurricanes wreak havoc on Earth, but scientists have now detected planetary winds on an entirely different scale, far outside the Solar System. Ever since its discovery in 2016, astronomers have been investigating the weather on WASP-127b, a giant gas planet located over 500 light-years from Earth. The planet is slightly larger than Jupiter, but has only a fraction of its mass, making it 'puffy'. An international team of astronomers have now made an unexpected discovery: supersonic winds are raging on the planet.
"Part of the atmosphere of this planet is moving towards us at a high velocity while another part is moving away from us at the same speed," says Lisa Nortmann, a scientist at the University of Göttingen, Germany, and lead author of the study. "This signal shows us that there is a very fast, supersonic, jet wind around the planet's equator."
At 9 km per second (which is close to a whopping 33,000 km/h), the jet winds move at nearly six times the speed at which the planet rotates.* "This is something we haven't seen before," says Nortmann. It is the fastest wind ever measured in a Jetstream that goes around a planet. In comparison, the fastest wind ever measured in the Solar System was found on Neptune, moving at 'only' 0.5 km per second (1800 km/h).
The team, whose research was published today in *Astronomy & Astrophysics*, mapped the weather and make-up of WASP-127b using the CRIRES+ instrument on ESO's VLT. By measuring how the light of the host star travels through the planet's upper atmosphere, they managed to trace its composition. Their results confirm the presence of water vapour and carbon monoxide molecules in the planet's atmosphere. But when the team tracked the speed of this material in the atmosphere, they observed -- much to their surprise -- a double peak, indicating that one side of the atmosphere is moving towards us and the other away from us at high speed. The researchers conclude that powerful Jetstream winds around the equator would explain this unexpected result.
Further building up their weather map, the team also found that the poles are cooler than the rest of the planet. There is also a slight temperature difference between the morning and evening sides of WASP-127b. "This shows that the planet has complex weather patterns just like Earth and other planets of our own System," adds Fei Yan, a co-author of the study and a professor at the University of Science and Technology of China.
The field of exoplanet research is rapidly advancing. Up until a few years ago, astronomers could measure only the mass and the radius of planets outside the Solar System. Today, telescopes like ESO's VLT already allow scientists to map the weather on these distant worlds and analyse their atmospheres. "Understanding the dynamics of these exoplanets helps us explore mechanisms such as heat redistribution and chemical processes, improving our understanding of planet formation and potentially shedding light on the origins of our own Solar System," says David Cont from the Ludwig Maximilian University of Munich, Germany, and a co-author of the paper.
Interestingly, at present, studies like this can only be done by ground-based observatories, as the instruments currently on space telescopes do not have the necessary velocity precision. ESO's Extremely Large Telescope -- which is under construction close to the VLT in Chile -- and its ANDES instrument will allow researchers to delve even deeper into the weather patterns on far-away planets. "This means that we can likely resolve even finer details of the wind patterns and expand

this research to smaller, rocky planets," Nortmann concludes.

Note

* While the team hasn't measured the rotation speed of the planet directly, they expect WASP-127b to be tidally locked, meaning the planet takes as long to rotate around its own axis as it does to orbit the star. Knowing how big the planet is and how long it takes to orbit its star, they can infer how fast it's rotating.

- NASA's Hubble traces hidden history of Andromeda galaxy

Date: January 17, 2025
Source: NASA/Goddard Space Flight Center

In the years following the launch of NASA's Hubble Space Telescope, astronomers have tallied over 1 trillion galaxies in the universe. But only one galaxy stands out as the most important nearby stellar island to our Milky Way -- the magnificent Andromeda galaxy (Messier 31). It can be seen with the naked eye on a very clear autumn night as a faint cigar-shaped object roughly the apparent angular diameter of our Moon.

A century ago, Edwin Hubble first established that this so-called "spiral nebula" was actually very far outside our own Milky Way galaxy -- at a distance of approximately 2.5 million light-years or roughly 25 Milky Way diameters. Prior to that, astronomers had long thought that the Milky way encompassed the entire universe. Overnight, Hubble's discovery turned cosmology upside down by unveiling an infinitely grander universe.

Now, a century later, the space telescope named for Hubble has accomplished the most comprehensive survey of this enticing empire of stars. The Hubble telescope is yielding new clues to the evolutionary history of Andromeda, and it looks markedly different from the Milky Way's history.

Without Andromeda as a proxy for spiral galaxies in the universe at large, astronomers would know much less about the structure and evolution of our own Milky Way. That's because we are embedded inside the Milky Way. This is like trying to understand the layout of New York City by standing in the middle of Central Park.

"With Hubble we can get into enormous detail about what's happening on a holistic scale across the entire disk of the galaxy. You can't do that with any other large galaxy," said principal investigator Ben Williams of the University of Washington. Hubble's sharp imaging capabilities can resolve more than 200 million stars in the Andromeda galaxy, detecting only stars brighter than our Sun. They look like grains of sand across the beach. But that's just the tip of the iceberg. Andromeda's total population is estimated to be 1 trillion stars, with many less massive stars falling below Hubble's sensitivity limit.

Photographing Andromeda was a herculean task because the galaxy is a much bigger target on the sky than the galaxies Hubble routinely observes, which are often billions of light-years away. The full mosaic was carried out under two Hubble programs. In total, it required over 1,000 Hubble orbits, spanning more than a decade.

This panorama started with the Panchromatic Hubble Andromeda Treasury (PHAT) program about a decade ago. Images were obtained at near-ultraviolet, visible, and near-infrared wavelengths using the Advanced Camera for Surveys and the Wide Field Camera 3 aboard Hubble to photograph the northern half of Andromeda.

This program was followed up by the Panchromatic Hubble Andromeda Southern Treasury (PHAST), recently published in The Astrophysical Journal and led by Zhuo Chen at the University of Washington, which added images of approximately 100 million stars in the southern half of Andromeda. This region is structurally unique and more sensitive to the galaxy's merger history than the northern disk mapped by the PHAT survey.

The combined programs collectively cover the entire disk of Andromeda, which is seen almost edge-on -- tilted by 77 degrees relative to Earth's view. The galaxy is so large that the mosaic is assembled from approximately 600 separate fields of view. The mosaic image is made up of at least 2.5 billion pixels.

The complementary Hubble survey programs provide information about the age, heavy-element abundance, and stellar masses inside Andromeda. This will allow astronomers to distinguish between competing scenarios where Andromeda merged with one or more galaxies. Hubble's detailed measurements constrain models of Andromeda's merger history and disk evolution.

A Galactic 'Train Wreck'

Though the Milky Way and Andromeda formed presumably around the same time many billions of years ago, observational evidence shows that they have very different evolutionary histories, despite growing up in the same cosmological neighbourhood. Andromeda seems to be more highly populated with younger stars and unusual features like coherent streams of stars, say researchers. This implies it has a more active recent star-formation and interaction history than the Milky Way.

"Andromeda's a train wreck. It looks like it has been through some kind of event that caused it to form a lot of stars and then just shut down," said Daniel Weisz at the University of California, Berkeley. "This was probably due to a collision with another galaxy in the neighbourhood."

A possible culprit is the compact satellite galaxy Messier 32, which resembles the stripped-down core of a once-spiral galaxy that may have interacted with Andromeda in the past. Computer simulations suggest that when a close encounter with another galaxy uses up all the available interstellar gas, star formation subsides.

"Andromeda looks like a transitional type of galaxy that's between a star-forming spiral and a sort of elliptical galaxy dominated by aging red stars," said Weisz. "We can tell it's got this big central bulge of older stars and a star-forming disk that's not as active as you might expect given the galaxy's mass."

"This detailed look at the resolved stars will help us to piece together the galaxy's past merger and interaction history," added Williams.

Hubble's new findings will support future observations by NASA's James Webb Space Telescope and the upcoming Nancy Grace Roman Space Telescope. Essentially a wide-angle version of Hubble (with the same sized mirror), Roman will capture the equivalent of at least 100 high-resolution Hubble images in a single exposure. These observations will complement and extend Hubble's huge dataset.

- The universe is expanding too fast to fit theories: Hubble tension in crisis

New measurements support faster-than-expected Universe expansion

Date: January 17, 2025
Source: Duke University

A field of distant galaxies captured by the James Webb Space Telescope. (Image credit: NASA, ESA, CSA, and STScI)

The Universe really seems to be expanding fast. Too fast, even.

A new measurement confirms what previous -- and highly debated -- results had shown: The Universe is expanding faster than predicted by theoretical models, and faster than can be explained by our current understanding of physics.

This discrepancy between model and data became known as the Hubble tension. Now, results published in the *Astrophysical Journal Letters* provide even stronger support to the faster rate of expansion.

"The tension now turns into a crisis," said Dan Scolnic, who led the research team.

Determining the expansion rate of the Universe -- known as the Hubble constant -- has been a major scientific pursuit ever since 1929, when Edwin Hubble first discovered that the Universe was expanding.

Scolnic, an associate professor of physics at Duke University, explains it as trying to build the Universe's growth chart: we know what size it had at the Big Bang, but how did it get to the size it is now? In his analogy, the Universe's baby picture represents the distant Universe, the primordial seeds of galaxies. The Universe's current headshot represents the local Universe, which contains the Milky Way and its neighbours. The standard model of cosmology is the growth curve connecting the two. The problem is: things don't connect.

"This is saying, to some respect, that our model of cosmology might be broken," said Scolnic.

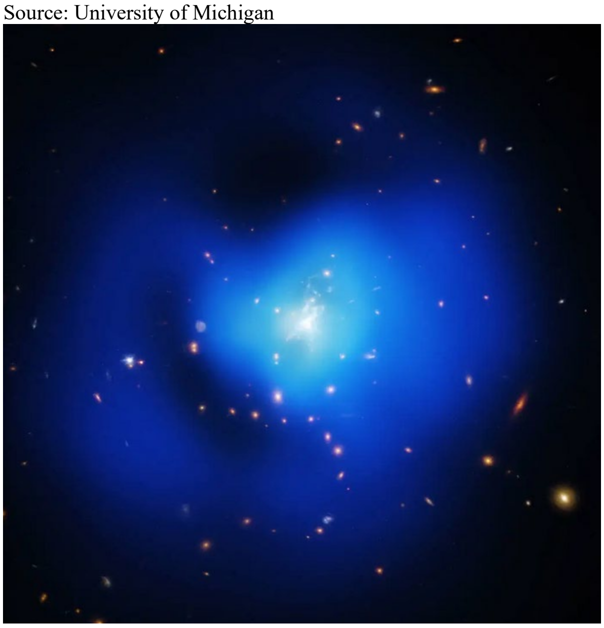
Measuring the Universe requires a cosmic ladder, which is a succession of methods used to measure the distances to celestial objects, with each method, or "rung," relying on the previous for calibration.

The ladder used by Scolnic was created by a separate team using data from the Dark Energy Spectroscopic Instrument (DESI), which is observing more than 100,000 galaxies every night from its vantage point at the Kitt Peak National Observatory.

Scolnic recognized that this ladder could be anchored closer to Earth with a more precise distance to the Coma Cluster, one of the galaxy clusters nearest to us.
"The DESI collaboration did the really hard part, their ladder was missing the first rung," said Scolnic. "I knew how to get it, and I knew that that would give us one of the most precise measurements of the Hubble constant we could get, so when their paper came out, I dropped absolutely everything and worked on this non-stop."
To get a precise distance to the Coma cluster, Scolnic and his collaborators, with funding from the Templeton foundation, used the light curves from 12 Type Ia supernovae within the cluster. Just like candles lighting a dark path, Type Ia supernovae have a predictable luminosity that correlates to their distance, making them reliable objects for distance calculations.
The team arrived at a distance of about 320 million light-years, nearly in the centre of the range of distances reported across 40 years of previous studies -- a reassuring sign of its accuracy.
"This measurement isn't biased by how we think the Hubble tension story will end," said Scolnic. "This cluster is in our backyard; it has been measured long before anyone knew how important it was going to be."
Using this high-precision measurement as a first rung, the team calibrated the rest of the cosmic distance ladder. They arrived at a value for the Hubble constant of 76.5 kilometres per second per megaparsec, which essentially means that the local Universe is expanding 76.5 kilometres per second faster every 3.26 million light-years.
This value matches existing measurements of the expansion rate of the local Universe. However, like all of those measurements, it conflicts with measurements of the Hubble constant using predictions from the distant Universe. In other words: it matches the Universe's expansion rate as other teams have recently measured it, but not as our current understanding of physics predicts it. The longstanding question is: is the flaw in the measurements or in the models?
Scolnic's team's new results adds tremendous support to the emerging picture that the root of the Hubble tension lies in the models.
"Over the last decade or so, there's been a lot of re-analysis from the community to see if my team's original results were correct," said Scolnic, whose research has consistently challenged the Hubble constant predicted using the standard model of physics. "Ultimately, even though we're swapping out so many of the pieces, we all still get a very similar number. So, for me, this is as good of a confirmation as it's ever gotten."
"We're at a point where we're pressing really hard against the models we've been using for two and a half decades, and we're seeing that things aren't matching up," said Scolnic. "This may be reshaping how we think about the Universe, and it's exciting! There are still surprises left in cosmology, and who knows what discoveries will come next?"
This work was conducted with funding from the Templeton Foundation, the Department of Energy, the David and Lucile Packard Foundation, the Sloan Foundation, the National Science Foundation and NASA.

- ❖ How galaxies are clustered and threaded throughout the universe

Date: January 21, 2025
Source: University of Michigan



Galaxy clusters are often described by superlatives. After all, they are huge conglomerations of galaxies, hot gas, and dark matter and represent the largest structures in the Universe held together by gravity.

Research led by the University of Michigan could help put cosmology on the inside track to reaching the full potential of telescopes and other instruments studying some of the universe's largest looming questions.
The project showcased how a new computational method gleans more information than its predecessors from maps showing how galaxies are clustered and threaded throughout the universe.
Scientists are currently using tools like DESI, the Dark Energy Spectroscopic Instrument, to generate these maps and dig deeper into the

nature of dark energy, dark matter and other cosmic mysteries.

The dark side of cosmology

Even as DESI makes headlines now, scientists know they will need more advanced tools to find the answers they seek. Some are developing the next generation of instruments like DESI. Minh Nguyen and his colleagues, however, are focusing on optimizing our understanding of the data we're getting now -- and in the future.

"As we move to bigger and better telescopes, we might also be throwing away more information," said Nguyen, who helped lead the work as a Leinweber Research Fellow in the U-M Department of Physics. "While we're collecting more data, we can also try to get more out of the data."

Teaming up with colleagues at the Max Planck Institute for Astrophysics, or MPA, Nguyen worked with a computational framework dubbed LEFTfield to upgrade how scientists analyse the large-scale structure of the cosmos.

"In the early universe, the structure was Gaussian -- like the static you would see on old TV sets," Nguyen said. "But because of the interplay between dark energy and dark matter, the large-scale structure of the universe today isn't Gaussian anymore. It's more like a spider web."

Dark energy drives the expansion of the universe, but researchers can't directly observe it, hence the "dark" part of its name. The universe's matter works against that expansion with its attractive force of gravity. That matter comes in two distinct varieties: the regular matter that we can observe and interact with, and the dark matter that we can't -- again, hence the "dark" part.

Adding to the intrigue is the fact that the overwhelming majority of the universe's mass and energy balance is tied up in these mysterious dark entities. Studying maps of the universe can thus open new windows to probe the dark energy and dark matter largely responsible for its weblike structure.

With LEFTfield, Nguyen and his colleagues showed they can extract even more information from existing cosmic maps. They published their study in the journal Physical Review Letters, which also earned a 2024 Buchalter Cosmology Prize.

To get that extra information, the team didn't bolster the existing standard methods, which have been very valuable. Rather, they took a fundamentally different approach.

Out of LEFTfield

The key difference is in how LEFTfield sees data compared with standard approaches.

"With a standard analysis, you basically cannot work with the data as is. People have to compress it," Nguyen said. "That reduces the complexity of the analysis and makes it easier to make theoretical predictions, but the trade-off is you lose some information."

For the standard analysis, researchers use computational models that move through the galaxies, grouping them into pairs or triplets, to make statistical measurements and calculations more efficient.

This works very well for the more Gaussian features of the universe, Nguyen said. But he and his colleagues saw an opportunity to push the understanding of our non-Gaussian universe further by keeping information the standard methods omit through compression.

The new approach, which is also called field-level inference, treats cosmic maps as 3D grids. Then each constituent cube or voxel -- the 3D counterpart of a pixel -- becomes a working element of data, containing uncompressed information about the distribution and density of galaxies inside. This preserves the fidelity of the data in a way that's inaccessible to the standard methods, Nguyen said.

"I love the idea of field-level inference because it is, in principle, the actual thing we want to do," said Shaun Hotchkiss, host of the online seminar series, Cosmology Talks. The series recently featured Nguyen and his co-author Beatriz Tucci, a doctoral student at MPA.

"If we've measured the density field, why compress the information inside of it?" Hotchkiss said. "Of course, field-level inference is therefore more difficult to do, but this hasn't stopped Bea and Minh, and shouldn't stop the community."

To benchmark the performance of LEFTfield, the team calculated a cosmological parameter called sigma-8, which essentially measures the clumpiness of the universe, Nguyen explained.

Compared with standard approaches, the team's LEFTfield method could improve the sigma-8 determination by a factor of 3.5 to 5.2.

"That's like going from DESI to the successor of DESI," Nguyen said. "Typically, moving between two generations of surveys would take 10 to 20 years."

Before making that leap forward, though, there is still work to do. A vital hurdle to clear will be integrating LEFTfield with specific instruments and making sure it understands how noise and idiosyncrasies of the tools impact data as it comes in, Nguyen said.

Still, he believes the approach will prove to be a powerful asset.

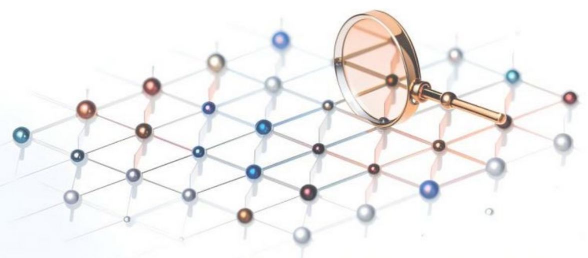
"It really opens the fast track to get insights into dark energy, dark matter and general relativity -- the theory that this is all based on," Nguyen said.

The research team also included Fabian Schmidt, a cosmologist and group leader at MPA, along with staff scientist Martin Reinecke and Andrija Kosti?, who worked on the project as a Ph.D. student then postdoctoral researcher.

Nguyen recently completed his fellowship at U-M and is now a research fellow at the Kavli Institute for the Physics and Mathematics of the Universe in Tokyo.

- Physicists pioneer entanglement microscopy algorithm to explore how matter entangles in quantum many-body systems

Date: January 23, 2025
Source: The University of Hong Kong



Conceptual picture of ‘entanglement microscopy’. Credit: The University of Hong Kong

Quantum entanglement -- a phenomenon where particles are mysteriously linked no matter how far apart, they are -- presents a long-standing challenge in the physical world, particularly in understanding its behaviour within complex quantum systems.

A research team from the Department of Physics at The University of Hong Kong (HKU) and their collaborators have recently developed a novel algorithm in quantum physics known as 'entanglement microscopy' that enables visualisation and mapping of this extraordinary phenomenon at a microscopic scale. By zooming in on the intricate interactions of entangled particles, one can uncover the hidden structures of quantum matter, revealing insights that could transform technology and deepen the understanding of the universe.

This study, led by Professor Zi Yang MENG and co-authored by his PhD students Ting-Tung WANG and Menghan SONG of HKU Department of Physics, in collaboration with Professor William WITCZAK-KREMPA and PhD student Liuke LYU from the University of Montreal, unveils the hidden structures of quantum entanglement in many-body systems, offering a fresh perspective on the behaviour of quantum matter. Their findings were recently published in the journal *Nature Communications.*

A Breakthrough in Mapping Quantum Entanglement

Quantum entanglement describes a deep connection between particles, where the state of one particle is instantly linked to another, even across vast distances. Imagine rolling two dice in different locations -- quantum entanglement is like finding that the outcome of one die always determines the outcome of the other, no matter how far apart they are. This phenomenon, famously called 'spooky action at a distance' by Albert Einstein, is not just a theoretical curiosity but underpins technologies like quantum computing, cryptography, and the study of exotic materials and black holes. However, it is intrinsically difficult to obtain the entanglement information in quantum many-body systems both analytically and numerically due to the exponentially large degree of freedoms.

Researchers have addressed this challenge by developing 'entanglement microscopy', an innovative protocol based on large-scale quantum Monte Carlo simulation that can successfully extract the quantum entanglement information in small regions of quantum systems. By focusing on these microscopic areas, this method reveals how particles interact and organise themselves in intricate ways, especially near critical points in quantum phase transitions -- special states where quantum systems undergo profound changes in behaviour.

Their exploration focused on two prominent models at two-dimension: the transverse field Ising model and fermionic t-V model that realises the Gross-Neveu-Yukawa transition of Dirac fermions, each revealing fascinating insights into the nature of quantum entanglement. They discovered that at the Ising quantum critical point, entanglement is short-range, meaning particles are connected only over small distances. This connection can abruptly vanish due to changes in distance or temperature -- a phenomenon known as 'sudden death'. In contrast, their investigation of the fermionic transition revealed a more gradual decline in entanglement even at larger separations, indicating that particles can maintain connections despite being far apart. Intriguingly, the team discovered that in two-dimensional Ising transitions, three-party entanglement was absent, yet present in one-dimensional systems. This implies that system dimensionality significantly affects entanglement behaviour. To simplify, low-dimensional systems are akin to a small group of friends where deep connections (complex multi-particle entanglement) are more probable. Conversely, high-dimensional systems, comparable to larger, more complex social networks, often suppress such connections. These findings provide important understanding of how entanglement structure alters with increasing system complexity.

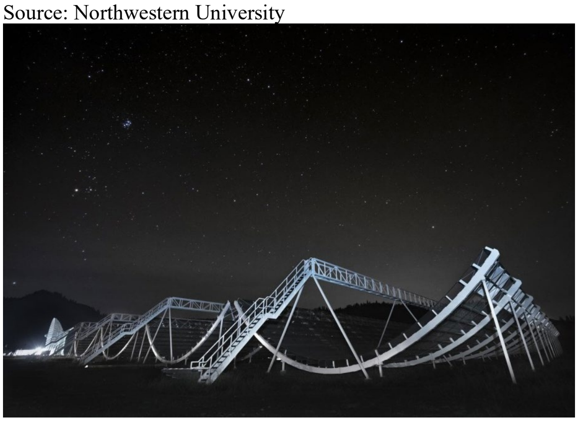
Applications and Impact

This breakthrough has significant implications for advancing quantum technologies. By providing a clearer understanding of entanglement, it could help optimise quantum computing hardware and algorithms, enabling faster problem-solving in fields like cryptography and artificial intelligence. It also opens the door to designing next-generation quantum materials with applications in energy, electronics, and superconductivity. Furthermore, this tool could deepen our understanding of fundamental physics and improve quantum simulations in chemistry and biology.

- First fast radio burst traced to old, dead, elliptical galaxy

'A picture is emerging that shows maybe not all FRBs come from young stars'

Date: January 21, 2025
Source: Northwestern University



CHIME telescopes (shown here) detected the unusual fast radio burst in February 2024. Image by CHIME, Andre Renard, Dunlap Institute for Astronomy & Astrophysics, University of Toronto

For the first time, astronomers have traced a fast radio burst (FRB) to the outskirts of an ancient, dead, elliptical galaxy -- an unprecedented home for a phenomenon previously associated with much younger galaxies.

Detailed in two complementary studies led by Northwestern University and McGill University, the discovery shatters assumptions that FRBs solely emanate from regions of active star formation. The new observational evidence, instead, hints that the origins of these mysterious cosmic events might be more diverse than previously thought.

Both studies will publish on Tuesday (Jan. 21) in the *Astrophysical Journal Letters*.

"The prevailing theory is that FRBs come from magnetars formed through core-collapse supernovae," said Northwestern's Tarraneh Eftekhari, who led one of the studies and coauthored the other. "That doesn't appear to be the case here. While young, massive stars end their lives as core-collapse supernovae, we don't see any evidence of young stars in this galaxy. Thanks to this new discovery, a picture is emerging that shows not all FRBs come from young stars. Maybe there is a subpopulation of FRBs that are associated with older systems."

"This new FRB shows us that just when you think you understand an astrophysical phenomenon, the universe turns around and surprises us," said Northwestern's Wen-fai Fong, a senior author on both studies. "This 'dialogue' with the universe is what makes our field of time-domain astronomy so incredibly thrilling."

Eftekhari is a NASA Einstein Fellow at Northwestern's Center for Interdisciplinary Exploration and Research in Astrophysics (CIERA). Fong is an associate professor of physics and astronomy at Northwestern's Weinberg College of Arts and Sciences and a member of CIERA.

A first for the CHIME outrigger telescopes

Astronomers first detected the new FRB, dubbed FRB 20240209A, in February 2024 with the Canadian Hydrogen Intensity Mapping Experiment (CHIME). Flaring up and disappearing within milliseconds, FRBs are brief, powerful radio blasts that generate more energy in one quick burst than our sun emits in an entire year.

But this event flared up more than once. Between the initial burst in February through July 2024, the same source produced another 21 pulses -- six of which were also detected by an outrigger telescope located 60 kilometres away from CHIME's main station. Smaller versions of CHIME, the outriggers enable astronomers to precisely confine the specific locations of FRBs on the sky.

Most massive FRB host galaxy to date

After the team pinpointed the FRB's position, Eftekhari and her collaborators hurried to use telescopes at the W.M. Keck and Gemini observatories to explore the event's surrounding environment. In a specialized room on the Evanston campus, Northwestern astronomers have remote access to Keck, which enables them to quickly observe phenomena of high interest.

Instead of finding a young galaxy, these observations surprisingly revealed that the FRB originated at the edge of an 11.3-billion-year-old neighbouring galaxy, located just 2 billion lightyears from Earth.

To learn more about this unusual host galaxy, the team used high-performance computers to run simulations. They found that the galaxy is extremely luminous and incredibly massive -- 100 billion times the mass of our sun.

"It seems to be the most massive FRB host galaxy to date," Eftekhari said. "It's among some of the most massive galaxies out there."

A far-flung home

But, while most FRBs originate well within their galaxies, the team traced FRB 20240209A to the outskirts of its home -- 130,000 lightyears from the galaxy's centre where few other stars exist.

"Among the FRB population, this FRB is located the furthest from the centre of its host galaxy," said Vishwangi Shah, a graduate student at McGill, who led the effort to pinpoint the FRB's origins. "This is both surprising and exciting, as FRBs are expected to originate inside galaxies, often in star-forming regions. The location of this FRB so far outside its host galaxy raises questions as to how such energetic events can occur in regions where no new stars are forming."

'Twinning' FRBs

Before this discovery, astronomers had traced only one other FRB to the outer fringes of a galaxy. In 2022, an international team of astronomers detected an FRB, which emanated from a tight cluster of stars on the edge of Messier 81 (M81), a grand design spiral galaxy located about 12 million light years from Earth. Although FRB 20240209A occurred in an elliptical galaxy, the two events share several other similarities.

"A few years ago, the M81 FRB was surprisingly discovered within a dense cluster of stars called a globular cluster," Fong said. "That event single-handedly halted the conventional train of thought and made us explore other progenitor scenarios for FRBs. Since then, no FRB had been seen like it, leading us to believe it was a one-off discovery -- until now.

"In fact, this CHIME FRB could be a twin of the M81 event. It is far from its home galaxy (far away from where any stars are being born), and the population of stars in its home galaxy is extremely old. It's had its hey-day and is now coasting into retirement. At the same time, this type of old environment is making us rethink our standard FRB progenitor models and turning to more exotic formation channels, which is exciting."

Out of the nearly 100 FRBs that have been pinpointed to a galaxy so far, most have likely originated from magnetars, which are formed through core-collapse supernovae. Astrophysicists posit FRB 20240209A's origin, however, might be similar to the FRB found in M81.

Possible explanations

The McGill-led study discusses the likelihood that the new FRB originated within a dense globular cluster. Such clusters are promising sites for magnetars possibly formed through other mechanisms and associated with older stars, including through the merger of two neutron stars or from a white dwarf collapsing under its own gravity.

"A globular cluster origin for this repeating FRB is the most likely scenario to explain why this FRB is located outside its host galaxy," Shah said. "We do not know for a fact if there is a globular cluster present at the FRB position and have submitted a proposal to use the James Webb Space Telescope for follow-up observations of the FRB location. If yes, it would make this FRB only the second FRB known to reside in a globular cluster. If not, we would have to consider alternative exotic scenarios for the FRB's origin."

"It's clear that there's still a lot of exciting discovery space when it comes to FRBs," Eftekhari said, "and that their environments could hold the key to unlocking their secrets."

The studies, "A repeating fast radio burst source in the outskirts of a quiescent galaxy" and "The massive and quiescent elliptical host galaxy of the repeating fast radio burst FRB 20240209A," were supported by Gordon & Betty Moore Foundation, NASA, the Space Telescope Science Institute, the National Science Foundation, the David and Lucile Packard Foundation, the Alfred P. Sloan Foundation, the Research Corporation for Science Advancement, the Canadian Institute for Advanced Research, The Canadian Natural Sciences and Engineering Council of Canada, the Canada Foundation for Innovation and the Trottier Space Institute at McGill.

- Large and small galaxies may grow in ways more similar than expected

New observations suggest that contrary to conventional wisdom, dwarf galaxies can accrete mass from other small galaxies

Date: January 16, 2025
Source: University of Arizona

Arp 273 is a pair of spiral galaxies, which may have collided in the past. Their gravitational interaction pulled the galaxies into the sweeping shapes we see; it also produced a burst of star formation, which is visible as blue splotches in the spiral arms of both galaxies.

A team of astronomers led by University of Arizona researcher Catherine Fielder has obtained the most detailed images of a small galaxy and its surroundings, revealing features typically associated with much larger galaxies. The observations provide a rare, elusive glimpse into how small galaxies form and evolve, suggesting that the mechanisms fuelling galaxy growth may be more universal than previously thought.

Fielder presented the findings at the 245th meeting of the American Astronomical Society in National Harbor, Maryland, during a press briefing on Jan. 16.

Galaxies, including the Milky Way, grow and evolve by merging with smaller galaxies over billions of years in a process called hierarchical assembly. This cosmic "building block" approach has been well observed in large galaxies, where streams of ancient stars -- remnants of swallowed-up galaxies -- trace their turbulent history. These streams, along with other faint features such as old, scattered stars, form a so-called stellar halo: a sprawling, low-density cloud of stars that surrounds the bright central disk of a galaxy and traces its evolutionary history.

According to traditional wisdom, smaller galaxies such as the nearby Large Magellanic Cloud may have fewer opportunities to attract mass and merge with smaller systems, including other dwarf galaxies, because of their weaker gravitational pull. Understanding how such galaxies acquire mass and grow in the context of hierarchical assembly remains an open question.

The researchers used the Dark Energy Camera, or DECam, on the 4-meter Blanco Telescope in Chile's Cerro Tololo Inter-American Observatory to conduct a deep imaging survey of 11 dwarf galaxies, including the spiral galaxy NGC 300, which is similar in mass to the Large Magellanic Cloud. The observations were made as part of the DECam Local Volume Survey, or DELVE, and revealed unprecedented details of NGC 300's features. Spanning about 94,000 light-years, NGC 300's galactic disk is a little smaller than the Milky Way and packs only about 2% of its stellar mass.

"NGC 300 is an ideal candidate for such a study because of its isolated location," said Fielder, a research associate at the U of A Steward Observatory. "This keeps it free from the influential effects of a massive companion like the Milky Way, which affects nearby small galaxies like the Large Magellanic Cloud. It's almost a bit like looking at a cosmic 'fossil record.'"

Fielder and her collaborators created stellar maps around the small galaxy and discovered a vast stellar stream extending more than 100,000 light-years from the galaxy's centre.

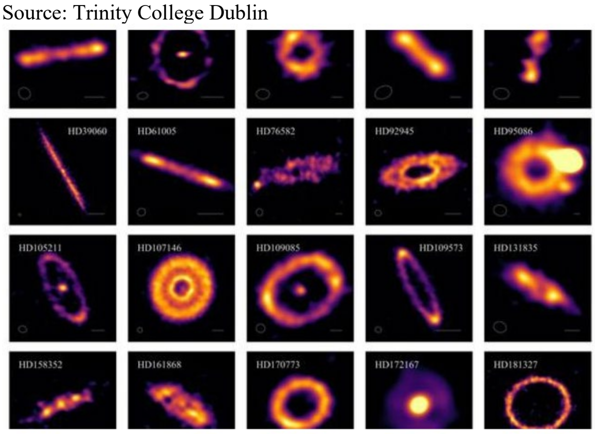
"We consider a stellar stream a telltale sign that a galaxy has accreted mass from its surroundings, because these structures don't form as easily by internal processes," said Fielder, whose findings will be published in *The Astrophysical Journal*.

In addition, the researchers found traces of stars arranged in shell-like patterns reminiscent of concentric waves emanating from the centre of the galaxy, as well as hints

of a stream wrap -- evidence that whatever caused the stream may have changed direction in its orbit around NGC 300.
"We weren't sure we were going to find anything in any of these small galaxies," she said. "These features around NGC 300 provide us with 'smoking gun' evidence that it did accrete something."
The team also identified a previously unknown, metal-poor globular star cluster in the galaxy's halo, another "smoking gun" of past accretion events.
When gauging the age of stellar populations, astronomers frequently turn to a feature known as "metallicity" -- a term referring to the chemical elements present inside stars. Because heavier elements are forged mostly in more massive stars at or near the end of their lifespans, it takes several generations of star formation to enrich those elements. Therefore, stellar populations lacking heavier elements -- or having low metallicity -- are presumed to be older, Fielder explained.
"The stars in the features we observed around NGC 300 are ancient and metal-poor, telling a clear story," Fielder said. "These structures likely originated from a tiny galaxy that was pulled apart and absorbed into NGC 300."
Together, these findings clearly reveal that even dwarf galaxies can build stellar halos through the accretion of smaller galaxies, echoing the growth patterns seen in larger galaxies, Fielder said.
"NGC 300 now stands as one of the most striking examples of accretion-driven stellar halo assembly in a dwarf galaxy of its kind, shedding light on how galaxies grow and evolve across the universe."

❖ Astrophysicists reveal structure of 74 exocomet belts orbiting nearby stars in landmark survey

Date: January 17, 2025
Source: Trinity College Dublin



30 of the exocomet belts, as imaged in this study, showing the extreme variation in such belts. (Credit: Prof Luca Matra, Trinity College Dublin.)

Astrophysicists led by a team from Trinity College Dublin have -- for the first time -- imaged a large number of exocomet belts around nearby stars, and the tiny pebbles within them. The crystal-clear images show light being emitted from these millimetre-sized pebbles within the belts that orbit 74 nearby stars of a wide variety of ages -- from those that are just emerging from birth to those in more mature systems like our own Solar System.
The REASONS (REsolved ALMA and SMA Observations of Nearby Stars) study marks such a significant milestone in the study of exocometary belts because its images and analyses reveal where the pebbles, and hence the exocomets, are located. They are typically tens to hundreds of au (the distance from Earth to the Sun) from their central star.
In these regions, it is so cold (-250 to -150 degrees Celsius) that most compounds including water are frozen as ice on these exocomets. What the astrophysicists are therefore observing is where the ice reservoirs of planetary systems are located. REASONS is the first program to unveil the structure of these belts for a large sample of 74 exoplanetary systems.
The Atacama Large Millimetre/submillimetre Array (ALMA) is an array of 66 radio telescopes in the Atacama Desert of northern Chile, while the Submillimetre Array (SMA) is a similar eight-element array in Hawaii. Both observe electromagnetic radiation at millimetre and submillimetre wavelengths. This study used both to produce the images that have provided more information on populations of exocomets than ever before.
"Exocomets are boulders of rock and ice, at least 1 km in size, which smash together within these belts to produce the pebbles that we observe here with the ALMA and SMA arrays of telescopes. Exocometary belts are found in at least 20% of planetary systems, including our own Solar System," said Luca Matrà, Associate Professor in Trinity's School of Physics, and senior author of the research article that has just been published in the journal *Astronomy and Astrophysics.*
Dr Sebastián Marino, Royal Society University Research Fellow at the University of Exeter, and coauthor in this study, added: "The images reveal a remarkable diversity in the structure of belts. Some are narrow rings, as in the canonical picture of a 'belt' like our Solar System's Edgeworth-Kuiper belt. But a

larger number of them are wide, and probably better described as 'disks' rather than rings." Some systems have multiple rings/disks, some of which are eccentric, which provides evidence that yet undetectable planets are present and their gravity affects the distribution of pebbles in these systems.
"The power of a large study like REASONS is in revealing population-wide properties and trends," explained Prof. Matrà.
"For example, it confirmed that the number of pebbles decreases for older planetary systems as belts run out of larger exocomets smashing together, but showed for the first time that this decrease in pebbles is faster if the belt is closer to the central star. It also indirectly showed -- through the belts' vertical thickness -- that unobservable objects as large as 140 km to Moon-size are likely present in these belts.
Dr David Wilner, Senior Astrophysicist at the Center for Astrophysics | Harvard & Smithsonian, underlined: “Arrays like the ALMA and SMA used in this work are extraordinary tools that are continuing to give us incredible new insights into the universe and its workings. The REASONS survey required a large community effort and has an incredible legacy value, with multiple potential pathways for future investigation.
"For example, the REASONS dataset of belt and planetary system properties will enable studies of the birth and evolution of these belts, as well as follow-up observations across the wavelength range, from JWST to the next generation of Extremely Large Telescopes and ALMA's upcoming ARKS Large Program to zoom even further onto the details of these belts."
This tiny galaxy is answering some big questions
Patterns of star formation in Leo P
Date: January 16, 2025
Source: Rutgers University
Leo P, a small galaxy and a distant neighbour of the Milky Way, is lighting the way for astronomers to better understand star formation and how a galaxy grows.

In a study published in the *Astrophysical Journal*, a team of researchers led by Kristen McQuinn, a scientist at the Space Telescope Science Institute and an associate professor in the Department of Physics and Astronomy at the Rutgers University-New Brunswick School of Arts and Sciences, has reported finding that Leo P "reignited," reactivating during a significant period on the timeline of the universe, producing stars when many other small galaxies didn't.

By studying galaxies early in their formation and in different environments, astronomers said they may gain a deeper understanding of the universe's origins and the fundamental processes that shape it.

McQuinn and other members of the research team studied Leo P through NASA's James Webb Space Telescope, a space-based apparatus that features a large, segmented mirror and an expansive sunshield, both of which enable it to capture detailed images of distant celestial objects.

Leo P, a dwarf galaxy some 5.3 million light years from Earth, was discovered by McQuinn and other scientists in 2013. The celestial structure is far enough away from the Local Group, a clump of galaxies straddling the Milky Way, to be its neighbour without being affected by the gravitational fields of larger star systems.

The galaxy, located in the constellation Leo, is about the same size as a star cluster within the Milky Way and is about the same age as the Milky Way. The "P" in Leo P refers to "pristine," because the galaxy has so few chemical elements beside hydrogen and helium.

"Leo P provides a unique laboratory to explore the early evolution of a low-mass galaxy in detail," said McQuinn, who also is the mission head for the Science Operations Center for the Nancy Grace Roman Space Telescope at the Space Telescope Science Institute in Baltimore.

The team started by looking deeply into the past. Since the stars detected by the team with the telescope are about 13 billion years old, they can serve as "fossil records" of star formation that occurred at earlier times.
"Essentially, instead of studying the stars in-situ [in their original positions] as they are forming in the early universe, we study the stars that have survived over cosmic history and use their present-day properties to infer what was occurring at earlier times," McQuinn said.

The team found that Leo P formed stars early on but then stopped making them for a few billion years. This stoppage happened during a period known as the Epoch of Reionization. It took a few billion years after the epoch for the galaxy to reignite and start forming new stars.

"We have a measurement like this for only three other galaxies -- all isolated from the Milky Way -- and they all show a similar pattern," McQuinn said.

Observations of the dwarf galaxies within the Local Group, however, show that, in contrast, star production disappeared during this period.

The Epoch, regarded by astronomers as a significant period in the history of the universe, occurred between about 150 million and one billion years after the Big Bang. It was during this period that the first stars and galaxies formed.

The contrast between the star production of the dwarf galaxies provides compelling evidence that it isn't just the mass of a galaxy at the time of reionization that determines whether it will be quenched, McQuinn said. Its environment -- meaning whether it is isolated or functioning as a satellite of a larger system -- is an important factor.

McQuinn said the observations will help pin down not only when little galaxies formed their stars, but how the reionization of the universe may have impacted how small structures form.

"If the trend holds, it provides insights on the growth of low-mass structures that is not only a fundamental constraint for structure formation but a benchmark for cosmological simulations," she said.

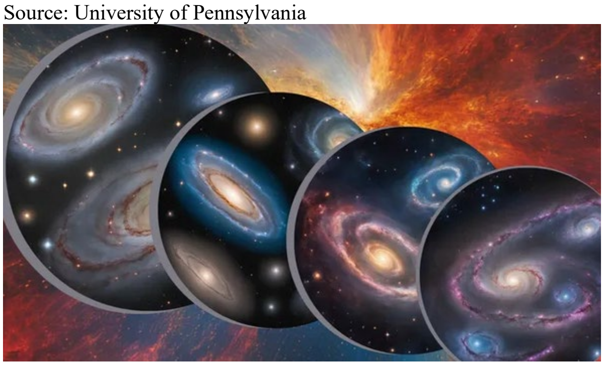
The researchers also found that Leo P is metal-poor, possessing 3% of the sun's metallicity. This means that the stars of the dwarf galaxy contain 30 times fewer heavy elements than the sun, which makes Leo P similar to the primordial galaxies of the early universe.

Knowledge gleaned from these observations will help astronomers piece together the timeline of cosmic events, understand how small structures evolved over billions of years and learn about the processes that led to the creation of stars, McQuinn said.

Other scientists from Rutgers on the study included Alyson Brooks, an associate professor; Roger Cohen, a postdoctoral associate; and Max Newman, a doctoral student, all with the Department of Physics and Astronomy.

- A less 'clumpy,' more complex universe?

Date: January 29, 2025
Source: University of Pennsylvania



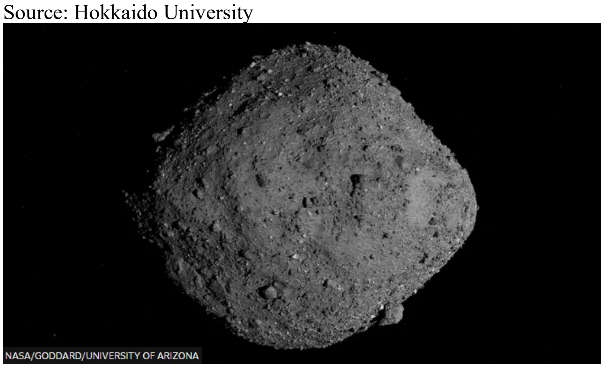
An illustration shows a CT scan of the universe with "slices" of the cosmos as it evolves (Image credit: Robert Lea (created with Canva))

Across cosmic history, powerful forces have acted on matter, reshaping the universe into an increasingly complex web of structures.
Now, new research led by Joshua Kim and Mathew Madhavacheril at the University of Pennsylvania and their collaborators at Lawrence Berkeley National Laboratory suggests our universe has become "messier and more complicated" over the roughly 13.8 billion years it's been around, or rather, the distribution of matter over the years is less "clumpy" than expected.
"Our work cross-correlated two types of datasets from complementary, but very distinct, surveys," says Madhavacheril, "and what we found was that for the most part, the story of structure formation is remarkably consistent with the predictions from Einstein's gravity. We did see a hint for a small discrepancy in the amount of expected clumpiness in recent epochs, around four billion years ago, which could be interesting to pursue."
The data, published in the *Journal of Cosmology and Astroparticle Physics* and the preprint server arXiv, comes from the Atacama Cosmology Telescope's (ACT) final data release (DR6) and the Dark Energy Spectroscopic Instrument's (DESI) Year 1. Madhavacheril says that pairing this data allowed the team to layer cosmic time in a

way that resembles stacking transparencies of ancient cosmic photographs over recent ones, giving a multidimensional perspective of the cosmos.
"ACT, covering approximately 23% of the sky, paints a picture of the universe's infancy by using a distant, faint light that's been travelling since the Big Bang," says first author of the paper Joshua Kim, a graduate researcher in the Madhavacheril Group. "Formally, this light is called the Cosmic Microwave Background (CMB), but we sometimes just call it the universe's baby picture because it's a snapshot of when it was around 380,000 years old."
The path of this ancient light throughout evolutionary time, or as the universe has aged, has not been a straight one, Kim explains. Gravitational forces from large, dense, heavy structures like galaxy clusters in the cosmos have been warping the CMB, sort of like how an image is distorted as it travels through a pair of spectacles. This "gravitational lensing effect," which was first predicted by Einstein more than 100 years ago, is how cosmologists make inferences about its properties like matter distribution and age.
DESI's data, on the other hand, provides a more recent record of the cosmos. Based in the Kitt Peak National Observatory in Arizona and operated by the Lawrence Berkeley National Laboratory, DESI is mapping the universe's three-dimensional structure by studying the distribution of millions of galaxies, particularly luminous red galaxies (LRGs). These galaxies act as cosmic landmarks, making it possible for scientists to trace how matter has spread out over billions of years.
"The LRGs from DESI are like a more recent picture of the universe, showing us how galaxies are distributed at varying distances," Kim says, likening the data to the universe's high school yearbook photo. "It's a powerful way to see how structures have evolved from the CMB map to where galaxies stand today.
By combining the lensing maps from ACT's CMB data with DESI's LRGs, the team created an unprecedented overlap between ancient and recent cosmic history, enabling them to compare early- and late-universe measurements directly. "This process is like a cosmic CT scan," says Madhavacheril, "where we can look through different slices of cosmic history and track how matter clumped together at different epochs. It gives us a direct look into how the gravitational influence of matter changed over billions of years."
In doing so they noticed a small discrepancy: the clumpiness, or density fluctuations, expected at later epochs didn't quite match predictions. Sigma 8 ($\sigma 8$), a metric that measures the amplitude of matter density fluctuations, is a key factor, Kim says, and lower values of $\sigma 8$ indicate less clumping than expected, which could mean that cosmic structures haven't evolved according to the predictions from early-universe models and suggest that the universe's structural growth may have slowed in ways current models don't fully explain.
This slight disagreement with expectations, he explains, "isn't strong enough to suggest new physics conclusively -- it's still possible that this deviation is purely by chance."
If indeed the deviation is not by chance, some unaccounted-for physics could be at play, moderating how structures form and evolve over cosmic time. One hypothesis is that dark energy -- the mysterious force thought to drive the universe's accelerating expansion -- could be influencing cosmic structure formation more than previously understood.
Moving forward, the team will work with more powerful telescopes, like the upcoming Simons Observatory, which will refine these measurements with higher precision, enabling a clearer view of cosmic structures.

- ❖ Life's building blocks in Asteroid Bennu samples

Date: January 29, 2025
Source: Hokkaido University



Asteroid Bennu is a 500m-wide pile of boulders, rocks and rubble

Japanese collaborators detected all five nucleobases -- building blocks of DNA and RNA -- in samples returned from asteroid Bennu by NASA's OSIRIS-REx mission. Asteroids, small airless bodies within the inner Solar System, are theorized to have contributed water and chemical building blocks of life to Earth billions of years ago. Although meteorites on Earth come from asteroids, the combination of exposure to moisture in the atmosphere and to an uncontrolled biosphere means that interpreting the data from them is challenging. Pristine samples collected from asteroids in space would be the ideal candidates, and successful sample collection missions have only been achieved by two countries: Japan (*Hayabusa* and *Hayabusa2*) and the United States (OSIRIS-REx).

NASA's OSIRIS-REx mission returned 121.6 grams of sample from asteroid (101955) Bennu in September 2023 -- the largest sample ever returned to Earth. Now, an international team of OSIRIS-REx sample analysis team scientists, led by Dr. Daniel Glavin and Dr. Jason Dworkin at the NASA Goddard Space Flight Centre, has reported the discovery of ammonia and nitrogen-rich soluble organic matter in these samples. The findings were published in the journal *Nature Astronomy*. Among the findings, the Japanese contributors detected all five nitrogenous bases, molecules required for building DNA and RNA, supporting the theory that asteroids could have brought the building blocks of life to Earth.

The Bennu samples from NASA were handled under nitrogen to prevent contamination by Earth's atmosphere. A 17.75 mg sample was processed and analysed for N-heterocycles -- organic molecules with a ring structure containing carbon and nitrogen -- using high-resolution mass spectrometry at Kyushu University.

The analysis was carried out by a research team, whose members are part of the OSIRIS-REx sample analysis team, consisting of Associate Professor Yasuhiro Oba of Hokkaido University, Principal Researcher Yoshinori Takano of JAMSTEC and Keio University, Dr. Toshiki Koga of JAMSTEC, Professor Hiroshi Naraoka of Kyushu University, and Associate Professor Yoshihiro Furukawa of Tohoku University.

The analysis revealed that the concentration of N-heterocycles is approximately 5 nmol/g, 5-10 times higher than that reported from Ryugu. In addition to the five nitrogenous bases -- adenine, guanine, cytosine, thymine and uracil -- required for building DNA and RNA, the researchers also found xanthine, hypoxanthine, and nicotinic acid (vitamin B_3).

"In previous research, uracil and nicotinic acid were detected in the samples from asteroid Ryugu, but the other four nucleobases were absent. The difference in abundance and complexity of N-heterocycles between Bennu and Ryugu could reflect the differences in the environment to which these asteroids have been exposed in space," Koga explains.

Samples from the meteorites Murchison and Orgueil were also processed and analysed previously under identical conditions for comparison. The research team observed that the ratio of purines (adenine and guanine) to pyrimidines (cytosine, thymine and uracil) was much lower in the Bennu samples compared to both Murchison and Orgueil.

"There are multiple possible reasons for this observed difference," Oba says. "They may be due to differences in parent bodies or formation pathways, or the Bennu asteroid was exposed to a cold molecular cloud environment where pyrimidine formation is more likely to occur."

"Our findings, which contribute to the larger picture painted by all the authors of the paper, indicate that nucleobase chemistry in the Bennu samples must be further studied," concluded Naraoka. Another important result of this study is that, by comparing meteorites with Bennu samples, a reference for the reanalysis of other meteorites in collections across the globe has been created.

- Moon is not as 'geologically dead' as previously thought

Date: January 28, 2025
Source: University of Maryland

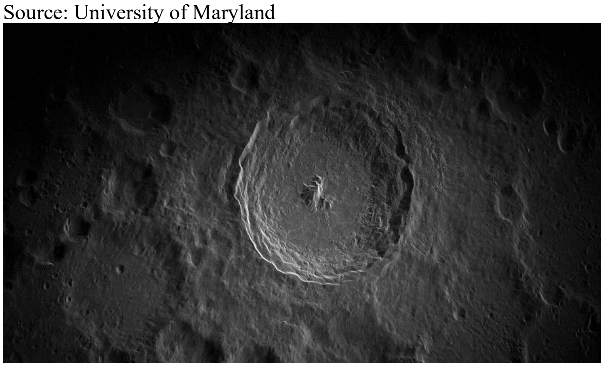


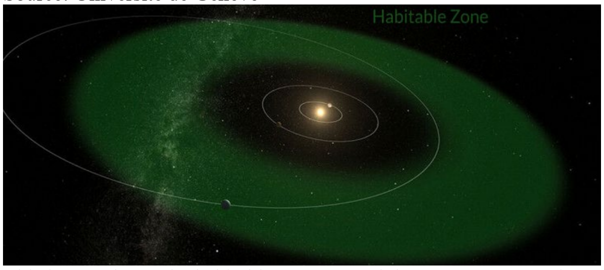
Image: NRAO/GBO/Raytheon/NSF/AUI

Scientists have studied the moon's surface for decades to help piece together its complex geological and evolutionary history. Evidence from the lunar maria (dark, flat areas on the moon filled with solidified lava) suggested that the moon experienced significant compression in its distant past. Researchers suspected that large, arching ridges on the moon's near side were formed by contractions that occurred billions of years ago -- concluding that the moon's maria has remained dormant ever since.

However, a new study reveals that what lies beneath the lunar surface may be more dynamic than previously believed. Two Smithsonian Institution scientists and a University of Maryland geologist discovered that small ridges located on the moon's far side were notably younger than previously studied ridges on the near side. Their findings were published in The Planetary Science Journal on January 21, 2025.
"Many scientists believe that most of the moon's geological movements happened two and a half, maybe three billion years ago," said Jaclyn Clark, an assistant research scientist in UMD's Department of Geology. "But we're seeing that these tectonic landforms have been recently active in the last billion years and may still be active today. These small mare ridges seem to have formed within the last 200 million years or so, which is relatively recent considering the moon's timescale."
Using advanced mapping and modelling techniques, the team found 266 previously unknown small ridges on the moon's far side. The ridges typically appeared in groups of 10 to 40 in volcanic regions that likely formed 3.2 to 3.6 billion years ago in narrow areas where there may be underlying weaknesses in the moon's surface, according to the researchers. To estimate the age of these small ridges, the researchers used a technique called crater counting. They found that the ridges were notably younger than other features in their surroundings.
"Essentially, the more craters a surface has, the older it is; the surface has more time to accumulate more craters," Clark explained. "After counting the craters around these small ridges and seeing that some of the ridges cut through existing impact craters, we believe these landforms were tectonically active in the last 160 million years."
Interestingly, Clark noted that the far-side ridges were similar in structure to ones found on the moon's near side, which suggests that both were created by the same forces, likely a combination of the moon's gradual shrinking and shifts in the lunar orbit. The Apollo missions detected shallow moonquakes decades ago; the new findings suggest that these small ridges might be related to similar seismic activity. Learning more about the evolution of the lunar surface could have important implications for the logistics of future moon missions.
"We hope that future missions to the moon will include tools like ground penetrating radar so researchers can better understand the structures beneath the lunar surface," Clark said. "Knowing that the moon is still geologically dynamic has very real implications for where we're planning to put our astronauts, equipment and infrastructure on the moon."

- A super-Earth laboratory for searching life elsewhere in the Universe

Date: January 28, 2025
Source: Université de Genève



This image shows the habitable zone around the star HD 20794 (in green) and the trajectory of the three planets in the system. © Gabriel Pérez Díaz, SMM (IAC)

Thirty years after the discovery of the first exoplanet, we detected more than 7000 of them in our Galaxy. But there are still billions more to be discovered! At the same time, exoplanetologists have begun to take an interest in their characteristics, with the aim of finding life elsewhere in the Universe. This is the background to the discovery of super-Earth HD 20794 d by an international team including the University of Geneva (UNIGE) and the NCCR PlanetS. The new planet lies in an eccentric orbit, so that it oscillates in and out of its star's habitable zone. This discovery is the fruit of 20 years of observations using the best telescopes in the world. The results are published today in the journal *Astronomy & Astrophysics*.
"Are we alone in the Universe?" For thousands of years, this question was confined to philosophy, and it is only very recently that modern science has begun to provide solid hypotheses and evidence to answer it. However, astronomers are making slow progress. Each new discovery, whether theoretical or observational, adds to the edifice by pushing back the limits of knowledge. This was the case with the discovery in 1995 of the first planet orbiting a star other than the Sun, which earned two UNIGE researchers, Michel Mayor and Didier Queloz, the 2019 Physics Nobel Prize.
Nearly thirty years later, astronomers have taken many small steps towards detecting more than 7,000 of these exoplanets. The

current scientific consensus points to the existence of a planetary system for every star in our galaxy. Astronomers are now looking for exoplanets that are easier to characterise or have interesting features to test their hypotheses and consolidate their knowledge. This is the case of planet HD 20794 d, which has just been detected by a team that includes members of the UNIGE Astronomy Department.

In the habitable zone of its star

This promising planet is a super-Earth, a telluric planet larger than the Earth. It is part of a planetary system containing two other planets. It orbits a G-type star, like the Sun, at a distance of just 19.7 light-years, which is, on the scale of the Universe, in the very close neighbourhood of the Earth. This "closeness" makes it easier to study, as its light signals are more visible and stronger. "HD 20794, around which HD 20794 d orbits, is not an ordinary star," explains Xavier Dumusque, Senior Lecturer and researcher in the Department of Astronomy at the UNIGE and co-author of the study. "Its luminosity and proximity make it an ideal candidate for future telescopes whose mission will be to observe the atmospheres of exoplanets directly."

The interest in planet HD 20794 d lies in its position in the habitable zone of its star, the zone that delimits the place where liquid water can exist, one of the conditions necessary for the development of life as we know it. This zone depends on several factors, mainly the stellar properties. For stars such as the Sun or HD 20794, it can extend from 0.7 to 1.5 astronomical units (AU), encompassing not only the orbit of the Earth but also that of Mars in the case of the Sun. The exoplanet HD 20794 d takes 647 days to orbit its star, around forty days less than Mars.

Instead of following a relatively circular orbit, like the Earth or Mars, HD 20794 d follows an elliptical trajectory with large changes in the distance to its star during its revolution. The planet thus oscillates between the inner edge of its star HZ (0.75 AU) and outside of it (2 AU) along its orbit. This configuration is of particular interest to astronomers because it allows them to adjust theoretical models and test their understanding of the notion of a planet's habitability. If there is water on HD 20794 d, it would pass from the state of ice to the liquid state, conducive to the appearance of life, during the planet's revolution around the star.

Many years of observations

Detecting this super-Earth was not easy and the process was iterative. The team analysed more than twenty years of data from state-of-the-art instruments such as ESPRESSO and HARPS. For the latter, the scientists were able to rely on YARARA, a data reduction algorithm recently developed at the UNIGE. For years, planetary signals had been obscured by noise, making it difficult to discern whether planets actually existed. "We analysed the data for years, carefully eliminating sources of contamination," explains Michael Cretignier, a post-doctoral researcher at Oxford University, co-author of the study and developer of YARARA during his PhD at UNIGE.

The discovery of HD 20794 d provides scientists with an interesting laboratory for modelling and testing new hypotheses in their search for life in the Universe. The proximity of this planetary system to its bright star also makes it a prime target for next-generation instruments such as the ANDES spectrograph for ESO's Extremely Large Telescope (ELT). Knowing whether this planet harbours life will still require a number of scientific milestones and a transdisciplinary approach. The conditions for its habitability are already being studied by the new Centre for Life in the Universe (CVU) at the UNIGE's Faculty of Science.