South Downs Mercury

The monthly circular of South Downs Astronomical Society
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Main Talk Dr Colin McGill Galaxies - Colin will show a series of pictures of galaxies, then ask people what questions do they have (e.g. why are disks formed, why is there spiral structure, what do the colours mean) and try and answer them.

BIOGRAPHY

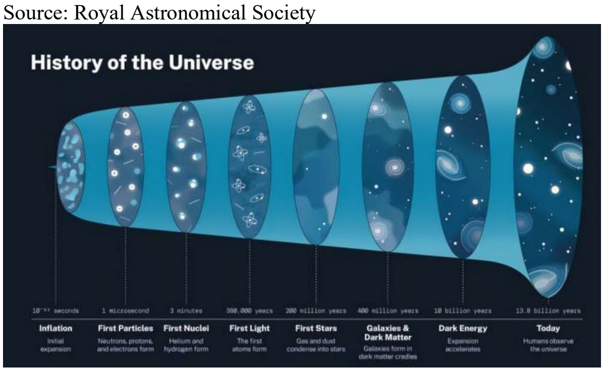
Colin had a 3” refractor at school, but found it difficult to see anything except the moon. At University, he studied physics as a degree, and theoretical astrophysics for his Doctorate, followed by two post-docs in cosmology and galactic dynamics.

At that point, family life got in the way - it was not until Colin was 40 that he bought himself his next telescope - an original Nexstar 8. The frustration of not being able to see more than a smudge for even the brightest galaxies led him to imaging and a remote telescope in Spain. After retirement, Colin became the president of the Guildford Astronomical Society

Please support a raffle we are organizing this month. AGM this the one meeting during the year when the Trustees of the South Downs AS run the first half of the meeting. We have to appoint a new committee; anyone wishing to put their name forward can do so at the beginning of the meeting. If you know someone who might be able to serve on the committee, please ask them before nominating them. Being a committee member does not involve too much time or effort, the main thing is to be willing to take on some quite simple tasks, such as meet and greet at the main meetings, attend around six committee meetings each year.

- Dark energy 'doesn't exist' so can't be pushing 'lumpy' Universe apart

Date: December 20, 2024
Source: Royal Astronomical Society



One of the biggest mysteries in science -- dark energy -- doesn't actually exist, according to researchers looking to solve the riddle of how the Universe is expanding.

For the past 100 years, physicists have generally assumed that the cosmos is growing equally in all directions. They employed the concept of dark energy as a placeholder to explain unknown physics they couldn't understand, but the contentious theory has always had its problems.

Now a team of physicists and astronomers at the University of Canterbury in Christchurch, New Zealand are challenging the status quo, using improved analysis of supernovae light curves to show that the Universe is expanding in a more varied, "lumpier" way.

The new evidence supports the "timescape" model of cosmic expansion, which doesn't have a need for dark energy because the differences in stretching light aren't the result of an accelerating Universe but instead a consequence of how we calibrate time and distance.

It takes into account that gravity slows time, so an ideal clock in empty space ticks faster than inside a galaxy.

The model suggests that a clock in the Milky Way would be about 35 per cent slower than the same one at an average position in large cosmic voids, meaning billions more years would have passed in voids. This would in turn allow more expansion of space, making it seem like the expansion is getting faster when such vast empty voids grow to dominate the Universe.

Professor David Wiltshire, who led the study, said: "Our findings show that we do not need dark energy to explain why the Universe appears to expand at an accelerating rate.

"Dark energy is a misidentification of variations in the kinetic energy of expansion, which is not uniform in a Universe as lumpy as the one we actually live in."

He added: "The research provides compelling evidence that may resolve some of the key questions around the quirks of our expanding cosmos.

"With new data, the Universe's biggest mystery could be settled by the end of the decade."

The new analysis has been published in the journal *Monthly Notices of the Royal Astronomical Society Letters*.

Dark energy is commonly thought to be a weak anti-gravity force which acts independently of matter and makes up around two thirds of the mass-energy density of the Universe.

The standard Lambda Cold Dark Matter (ΛCDM) model of the Universe requires dark energy to explain the observed acceleration in the rate at which the cosmos is expanding.

Scientists base this conclusion on measurements of the distances to supernova explosions in distant galaxies, which appear to be farther away than they should be if the Universe's expansion were not accelerating.

However, the present expansion rate of the Universe is increasingly being challenged by new observations.

Firstly, evidence from the afterglow of the Big Bang -- known as the Cosmic Microwave Background (CMB) -- shows the expansion of the early Universe is at odds with current expansion, an anomaly known as the "Hubble tension."

In addition, recent analysis of new high precision data by the Dark Energy Spectroscopic Instrument (DESI) has found that the ΛCDM model does not fit as well as models in which dark energy is "evolving" over time, rather than remaining constant.

Both the Hubble tension and the surprises revealed by DESI are difficult to resolve in models which use a simplified 100-year-old cosmic expansion law -- Friedmann's equation.

This assumes that, on average, the Universe expands uniformly -- as if all cosmic structures could be put through a blender to make a featureless soup, with no complicating structure. However, the present Universe actually contains a complex cosmic web of galaxy clusters in sheets and filaments that surround and thread vast empty voids.

Professor Wiltshire added: "We now have so much data that in the 21st century we can finally answer the question -- how and why does a simple average expansion law emerge from complexity?

"A simple expansion law consistent with Einstein's general relativity does not have to obey Friedmann's equation."

The researchers say that the European Space Agency's Euclid satellite, which was launched in July 2023, has the power to test and distinguish the Friedmann equation from the timescape alternative. However, this will require at least 1,000 independent high quality supernovae observations.

When the proposed timescape model was last tested in 2017 the analysis suggested it was only a slightly better fit than the ΛCDM as an explanation for cosmic expansion, so the Christchurch team worked closely with the Pantheon+ collaboration team who had painstakingly produced a catalogue of 1,535 distinct supernovae.

They say the new data now provides "very strong evidence" for timescape. It may also point to a compelling resolution of the Hubble tension and other anomalies related to the expansion of the Universe.

Further observations from Euclid and the Nancy Grace Roman Space Telescope are needed to bolster support for the timescape model, the researchers say, with the race now on to use this wealth of new data to reveal the true nature of cosmic expansion and dark energy.

- New evidence exists for hidden water reservoirs and rare magmas on ancient Mars

Rice University research findings have 'significant implications for habitability'

Date: December 19, 2024
Source: Rice University

A new study explores how variations in Mars' crustal thickness during its ancient history may have influenced the planet's magmatic

evolution and hydrological systems. The research, published in *Earth and Planetary Science Letters,* suggests that the thick crust of Mars' southern highlands formed billions of years ago generated granitic magmas and sustained vast underground aquifers, challenging long-held assumptions about the red planet's geological and hydrological past.
The study, led by Rice University's Cin-Ty Lee, demonstrates that the southern highlands' thick crust -- up to 80 kilometres in some areas -- was hot enough during the Noachian and early Hesperian periods (3-4 billion years ago) to undergo partial melting in the lower crust. This process, driven by radioactive heating, could have produced significant amounts of silicic magmas such as granites and supported subsurface aquifers beneath a frozen surface layer.
"Our findings indicate that Mars' crustal processes were far more dynamic than previously thought," said Lee, the Harry Carothers Wiess Professor of Geology and professor of Earth, environmental and planetary sciences. "Not only could thick crust in the southern highlands have generated granitic magmas without plate tectonics, but it also created the thermal conditions for stable groundwater aquifers -- reservoirs of liquid water -- on a planet we've often considered dry and frozen."
The research team -- including Rice professors Rajdeep Dasgupta and Kirsten Siebach, postdoctoral research associate Duncan Keller, graduate students Jackson Borchardt and Julin Zhang and Patrick McGovern of the Lunar and Planetary Institute -- employed advanced thermal modelling to reconstruct the thermal state of Mars' crust during the Noachian and early Hesperian periods. By considering factors such as crustal thickness, radioactive heat generation and mantle heat flow, the researchers simulated how heat affected the potential for crustal melting and groundwater stability.
Their models revealed that regions with crustal thicknesses exceeding 50 kilometres would have experienced widespread partial melting, producing felsic magmas either directly through dehydration melting or indirectly via fractional crystallization of intermediate magmas. Moreover, due to the elevated heat flow, the southern highlands' thick crust would have sustained significant groundwater aquifers extending several kilometres below the surface.
The study challenges the notion that granites are unique to Earth, demonstrating that Mars could also produce granitic magmas through radiogenic heating even without plate tectonics. These granites likely remain hidden beneath basaltic flows in the southern highlands, offering new insights into Martian geology. Additionally, the research highlights the possible formation of ancient groundwater systems in Mars' southern highlands, where high surface heat flux reduced the extent of permafrost and created stable subsurface aquifers. These reservoirs of water might have been periodically accessed by volcanic activity or impacts, resulting in episodic flooding events on the planet's surface.
The findings have significant implications for habitability as the presence of liquid water and the ability to generate granitic magmas, which often contain elements critical for life, suggest that Mars' southern highlands may have been more hospitable for life in the past than previously thought.
"Granites aren't just rocks; they're geological archives that tell us about a planet's thermal and chemical evolution," said Dasgupta, the Maurice Ewing Professor of Earth, Environmental and Planetary Sciences. "On Earth, granites are tied to tectonics and water recycling. The fact that we see evidence for similar magmas on Mars through deep crustal remelting underscores the planet's complexity and its potential for hosting life in the past."
The study highlights regions on Mars where future missions could focus on detecting granitic rocks or exploring ancient water reservoirs. Large craters and fractures in the southern highlands, for example, may provide glimpses into the planet's deep crust.
"Every insight into Mars' crustal processes brings us closer to answering some of the most profound questions in planetary science, including how Mars evolved and how it may have supported life," Siebach said. "Our research provides a roadmap for where to look and what to look for as we search for these answers."
This research was made possible by NASA grant 80NSSC18K0828 .

- ❖ Astrophysicists capture astonishing images of gamma-ray flare from supermassive black hole M87

The jet is tens of millions of times larger than the black hole's event horizon

Date: December 13, 2024

Source: University of California - Los Angeles

The supermassive black hole (centre) shown by the Event Horizon Telescope is located in the centre of galaxy M87. The short linear feature near the centre is a jet produced by the black hole

The first-ever photo of a black hole rocked the world in 2019, when the Event Horizon Telescope, or EHT, published an image of the supermassive black hole at the centre of the galaxy M87, also known as Virgo A or NGC 4486, located in the constellation of Virgo. This black hole is surprising scientists again with a teraelectronvolt gamma-ray flare -- emitting photons billions of times more energetic than visible light. Such an intense flare has not been observed in over a decade, offering crucial insights into how particles, such as electrons and positrons, are accelerated in the extreme environments near black holes.

The jet coming out of the centre of M87 is seven orders of magnitude -- tens of millions of times -- larger than the event horizon, or surface of the black hole itself. The bright burst of high-energy emission was well above the energies typically detected by radio telescopes from the black hole region. The flare lasted about three days and probably emerged from a region less than three light-days in size, or a little under 15 billion miles.

A gamma ray is a packet of electromagnetic energy, also known as a photon. Gamma rays have the most energy of any wavelength in the electromagnetic spectrum and are produced by the hottest and most energetic environments in the universe, such as regions around black holes. The photons in M87's gamma ray flare have energy levels up to a few teraelectronvolts. Teraelectronvolts are used to measure the energy in subatomic particles and are equivalent to the energy of a mosquito in motion. This is a huge amount of energy for particles that are many trillion times smaller than a mosquito. Photons with several teraelectronvolts of energy are vastly more energetic than the photons that make up visible light.

As matter falls toward a black hole, it forms an accretion disk where particles are accelerated due to the loss of gravitational potential energy. Some are even redirected away from the black hole's poles as a powerful outflow, called "jets," driven by intense magnetic fields. This process is irregular, which often causes a rapid energy outburst called a "flare." However, gamma rays cannot penetrate Earth's atmosphere. Nearly 70 years ago, physicists discovered that gamma rays can be detected from the ground by observing the secondary radiation generated when they strike the atmosphere.

"We still don't fully understand how particles are accelerated near the black hole or within the jet," said Weidong Jin, a postdoctoral researcher at UCLA and a corresponding author of a paper describing the findings published by an international team of authors in Astronomy & Astrophysics. "These particles are so energetic, they're traveling near the speed of light, and we want to understand where and how they gain such energy. Our study presents the most comprehensive spectral data ever collected for this galaxy, along with modelling to shed light on these processes."

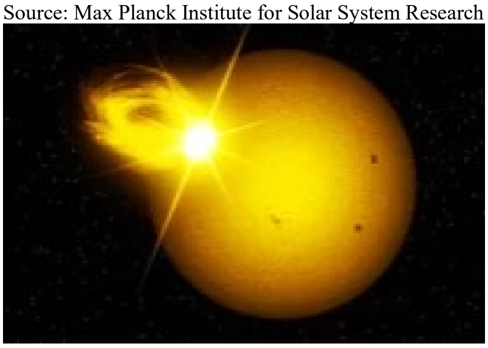
Jin contributed to analysis of the highest energy part of the dataset, called the very-high-energy gamma rays, which was collected by VERITAS -- a ground-based gamma-ray instrument operating at the Fred Lawrence Whipple Observatory in southern Arizona. UCLA played a major role in the construction of VERITAS -- short for Very Energetic Radiation Imaging Telescope Array System -- participating in the development of the electronics to read out the telescope sensors and in the development of computer software to analyse the telescope data and to simulate the telescope performance. This analysis helped detect the flare, as indicated by large luminosity changes that are a significant departure from the baseline variability.

More than two dozen high-profile ground- and space-based observational facilities, including NASA's Fermi-LAT, Hubble Space Telescope, NuSTAR, Chandra and Swift telescopes, together with the world's three largest imaging atmospheric Cherenkov telescope arrays (VERITAS, H.E.S.S. and MAGIC) joined this second EHT and multi-

wavelength campaign in 2018. These observatories are sensitive to X-ray photons as well as high-energy and very-high-energy gamma-rays, respectively.
One of the key datasets used in this study is called spectral energy distribution.
"The spectrum describes how energy from astronomical sources, like M87, is distributed across different wavelengths of light," Jin said. "It's like breaking the light into a rainbow and measuring how much energy is present in each colour. This analysis helps us uncover the different processes that drive the acceleration of high-energy particles in the jet of the supermassive black hole."
Further analysis by the paper's authors found a significant variation in the position and angle of the ring, also called the event horizon, and the jet position. This suggests a physical relationship between the particles and the event horizon, at different size scales, influences the jet's position.
"One of the most striking features of M87's black hole is a bipolar jet extending thousands of light years from the core," Jin said. "This study provided a unique opportunity to investigate the origin of the very-high-energy gamma-ray emission during the flare, and to identify the location where the particles causing the flare are being accelerated. Our findings could help resolve a long-standing debate about the origins of cosmic rays detected on Earth."

- Super flares once per century

More often than previously thought, sun-like stars hurl huge amounts of radiation into space: The Sun, too, is capable of such outbursts
Date: December 12, 2024
Source: Max Planck Institute for Solar System Research



More often than previously thought, sun-like stars hurl huge amounts of radiation into space. The Sun, too, is capable of such outbursts

Stars similar to the Sun produce a gigantic outburst of radiation on average about once every hundred years per star. Such super flares release more energy than a trillion hydrogen bombs and make all previously recorded solar flares pale in comparison. This estimate is based on an inventory of 56450 sun-like stars, which an international team of researchers led by the Max Planck Institute for Solar System Research (MPS) in Germany presents on Friday, December 13th, 2024, in the journal *Science*. It shows that previous studies have significantly underestimated the eruptive potential of these stars. In data from NASA's space telescope Kepler, super flaring, sun-like stars can be found ten to a hundred times more frequently than previously assumed. The Sun, too, is likely capable of similarly violent eruptions.
There is no question that the Sun is a temperamental star, as alone this year's unusually strong solar storms prove. Some of them led to remarkable auroras even at low latitudes. But can our star become even more furious? Evidence of the most violent solar "tantrums" can be found in prehistoric tree trunks and in samples of millennia-old glacial ice. However, from these indirect sources, the frequency of super flares cannot be determined. And direct measurements of the amount of radiation reaching the Earth from the Sun have only been available since the beginning of the space age.
Another way to learn about our Sun's long-term behaviour is to turn to the stars, as is the approach of the new study. Modern space telescopes observe thousands and thousands of stars and record their brightness fluctuations in visible light. Super flares, which release amounts of energy of more than one octillion joules within a short period of time, show themselves in the observational data as short, pronounced peaks in brightness.
"We cannot observe the Sun over thousands of years," Prof. Dr. Sami Solanki, Director at the MPS and coauthor, explained the basic idea behind the investigation. "Instead, however, we can monitor the behaviour of thousands of stars very similar to the Sun over short periods of time. This helps us to estimate how frequently super flares occur," he adds.

Looking for close relatives of the Sun

In the current study, the team including researchers from the University of Graz (Austria), the University of Oulu (Finland), the National Astronomical Observatory of Japan, the University of Colorado Boulder (USA) and the Commissariat of Atomic and Alternative Energies of Paris-Saclay and the University of Paris-Cité, analysed the data from 56450 sun-like stars as seen by NASA's

space telescope Kepler between 2009 and 2013. "In their entirety, the Kepler data provide us with evidence of 220000 years of stellar activity," said Prof. Dr. Alexander Shapiro from the University of Graz.
Crucial for the study was the careful selection of the stars to be taken into account. After all, the chosen stars should be particularly close "relatives" of the Sun. The scientists therefore only admitted stars whose surface temperature and brightness were similar to the Sun's. The researchers also ruled out numerous sources of error, such as cosmic radiation, passing asteroids or comets, as well as non-sun-like stars that in Kepler images may by chance flare up in the vicinity of a sun-like star. To do this, the team carefully analysed the images of each potential super flare -- only a few pixels in size -- and only counted those events that could reliably be assigned to one of the selected stars.
In this way, the researchers identified 2889 super flares on 2527 of the 56450 observed stars. This means that on average, one sun-like star produces a super flare approximately once per century.
"High performance dynamo computations of these solar-type stars easily explain the magnetic origins of the intense release of energy during such super flares," said coauthor Dr. Allan Sacha Brun of the Commissariat of Atomic and Alternative Energies of Paris-Saclay and the University of Paris-Cité.

Surprisingly frequent

"We were very surprised that sun-like stars are prone to such frequent super flares," said first author Dr. Valeriy Vasilyev from the MPS. Earlier surveys by other research groups had found average intervals of a thousand or even ten thousand years. However, earlier studies were unable to determine the exact source of the observed flare and therefore had to limit themselves to stars that did not have any too close neighbours in the telescope images. The current study is the most precise and sensitive to date.
Longer average time intervals between extreme solar events have also been suggested by studies looking for evidence of violent solar storms impacting Earth. When a particularly high flux of energetic particles from the Sun reaches the Earth's atmosphere, they produce a detectable number of radioactive atoms such as the radioactive carbon isotope ^{14}C. These atoms are then deposited in natural archives such as tree rings and glacial ice. Even thousands of years later, the sudden influx of high-energy solar particles can thus be deduced by measuring the amount of 14C using modern technologies.
In this way, researchers were able to identify five extreme solar particle events and three candidates within the past twelve thousand years of the Holocene, leading to an average occurrence rate of once per 1500 years. The most violent is believed to have occurred in the year 775 AD. However, it is quite possible that more such violent particle events and also more super flares occurred on the Sun in the past. "It is unclear whether gigantic flares are always accompanied by coronal mass ejections and what is the relationship between super flares and extreme solar particle events. This requires further investigation," co-author Prof. Dr. Ilya Usoskin from the University of Oulu in Finland pointed out. Looking at the terrestrial evidence of past extreme solar events could therefore underestimate the frequency of super flares.

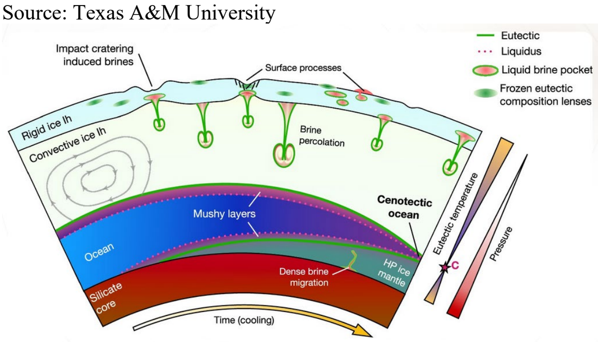
Forecasting dangerous space weather

The new study does not reveal when the Sun will throw its next fit. However, the results urge caution. "The new data are a stark reminder that even the most extreme solar events are part of the Sun's natural repertoire," said coauthor Dr. Natalie Krivova from the MPS. During the Carrington event of 1859, one of the most violent solar storms of the past 200 years, the telegraph network collapsed in large parts of northern Europe and North America. According to estimates, the associated flare released only a hundredth of the energy of a super flare. Today, in addition to the infrastructure on the Earth's surface, especially satellites would be at risk. The most important preparation for strong solar storms is therefore reliable and timely forecasting. As a precaution, satellites, for example, could be switched off. From 2031, ESA's space probe Vigil will help in the endeavour of forecasting. From its observation position in space, it will look at the Sun from the side and notice sooner than Earth-bound probes when processes that might drive dangerous space weather are brewing up on our star. The MPS is currently developing the Polarimetric and Magnetic Imager for this mission.

- ❖ Mysteries of icy ocean worlds

New research advances understanding of the habitability of icy moons

Date: December 20, 2024
Source: Texas A&M University



As NASA's Europa Clipper embarks on its historic journey to Jupiter's icy moon, Europa, Dr. Matt Powell-Palm, a faculty member at Texas A&M University's J. Mike Walker '66 Department of Mechanical Engineering, has unveiled groundbreaking research that could transform our understanding of icy ocean worlds across the solar system. The study published in *Nature Communications*, co-authored with planetary scientist Dr. Baptiste Journaux of the University of Washington, introduces a novel thermodynamic concept called the "centotectic" and investigates the stability of liquids in extreme conditions -- critical information for determining the habitability of icy moons like Europa.

Revolutionizing the Search for Habitability

The exploration of icy ocean worlds represents a new frontier in planetary science, focusing on understanding the potential for these environments to support life. Powell-Palm's research addresses a fundamental question in this field: under what conditions can liquid water remain stable on these distant, frozen bodies? By defining and measuring the cenotectic, the absolute lowest temperature at which a liquid remains stable under varying pressures and concentrations, the team provides a critical framework for interpreting data from planetary exploration efforts.

This study combines Powell-Palm's expertise in cryobiology -- specifically the low-temperature thermodynamics of water -- initially focused on medical applications like organ preservation for transplantation, with Journaux's expertise in planetary science and high-pressure water-ice systems. Together, they developed a framework that bridges disciplines to tackle one of the most fascinating challenges in planetary science.

"With the launch of NASA Europa Clipper, the largest planetary exploration mission ever launched, we are entering a multi-decade era of exploration of cold and icy ocean worlds. Measurements from this and other missions will tell us how deep the ocean is and its composition," said Journaux. "Laboratory measurements of liquid stability, and notably the lowest temperature possible (the newly-defined cenotectic), combined with mission results, will allow us to fully constrain how habitable the cold and deep oceans of our solar system are, and also what their final fate will be when the moons or planets have cooled down entirely."

A Texas A&M Legacy of Innovation in Space Research

The research was conducted at Texas A&M and led by mechanical engineering graduate student Arian Zarriz. The work reflects Texas A&M's deep expertise in water-ice systems and tradition of excellence in space research, which spans multiple disciplines. With the recent groundbreaking of the Texas A&M Space Institute, the university is poised to play an even larger role in space exploration, providing intellectual leadership for missions pushing the boundaries of human knowledge.

"The study of icy worlds is a particular priority for both NASA and the European Space Agency, as evidenced by the flurry of recent and upcoming spacecraft launches," said Powell-Palm. "We hope that Texas A&M will help to provide intellectual leadership in this space."

Looking Ahead

As planetary exploration missions, such as those targeting icy moons, continue to expand our understanding of the solar system, researchers at Texas A&M and beyond prepare to analyse the wealth of data they will provide. By combining experimental studies like those conducted by Powell-Palm and Journaux with the findings from these missions, scientists aim to unlock the secrets of cold, ocean-bearing worlds and evaluate their potential to harbour life.

- ❖ First results from 2021 rocket launch shed light on aurora's birth

Date: December 19, 2024
Source: University of Alaska Fairbanks

UAF photo by Eric Engman
The northern lights adorn the sky over the UAF Agricultural and Forestry Experiment Station early Sunday morning, April 21, 2024.

Newly published results from a 2021 experiment led by a University of Alaska Fairbanks scientist have begun to reveal the particle-level processes that create the type of auroras that dance rapidly across the sky.

The Kinetic-scale Energy and momentum Transport experiment -- KiNET-X -- lifted off from NASA's Wallops Flight Facility in Virginia on May 16, 2021, in the final minutes of the final night of the nine-day launch window.

UAF professor Peter Delamere's analysis of the experiment's results was published Nov. 19 in *Physics of Plasmas*.

"The dazzling lights are extremely complicated," Delamere said. "There's a lot happening in there, and there's a lot happening in the Earth's space environment that gives rise to what we observe.

"Understanding causality in the system is extremely difficult, because we don't know exactly what's happening in space that's giving rise to the light that we observe in the aurora," he said. "KiNET-X was a highly successful experiment that will reveal more of the aurora's secrets."

One of NASA's largest sounding rockets soared over the Atlantic Ocean into the ionosphere and released two canisters of barium thermite. The canisters were then detonated, one at about 249 miles high and one 90 seconds later on the downward trajectory at about 186 miles, near Bermuda. The resulting clouds were monitored on the ground at Bermuda and by a NASA research aircraft.

The experiment aimed to replicate, on a minute scale, an environment in which the low energy of the solar wind becomes the high energy that creates the rapidly moving and shimmering curtains known as the discrete aurora. Through KiNET-X, Delamere and colleagues on the experiment are closer to understanding how electrons are accelerated.

"We generated energized electrons," Delamere said. "We just didn't generate enough of them to make an aurora, but the fundamental physics associated with electron energization was present in the experiment."

The experiment aimed to create an Alfvén wave, a type of wave that exists in magnetized plasmas such as those found in the sun's outer atmosphere, Earth's magnetosphere and elsewhere in the solar system. Plasmas -- a form of matter composed largely of charged particles -- also can be created in laboratories and experiments such as KiNET-X.

Alfvén waves originate when disturbances in plasma affect the magnetic field. Plasma disturbances can be caused in a variety of ways, such as through the sudden injection of particles from solar flares or the interaction of two plasmas with different densities.

KiNET-X created an Alfvén wave by disturbing the ambient plasma with the injection of barium into the far upper atmosphere.

Sunlight converted the barium into an ionized plasma. The two plasma clouds interacted, creating the Alfvén wave.

That Alfvén wave instantly created electric field lines parallel to the planet's magnetic field lines. And, as theorized, that electric field significantly accelerated the electrons on the magnetic field lines.

"It showed that the barium plasma cloud coupled with, and transferred energy and momentum to, the ambient plasma for a brief moment," Delamere said.

The transfer manifested as a small beam of accelerated barium electrons heading toward Earth along the magnetic field line. The beam is visible only in the experiment's magnetic field line data.

"That's analogous to an auroral beam of electrons," Delamere said.

He calls it the experiment's "golden data point."

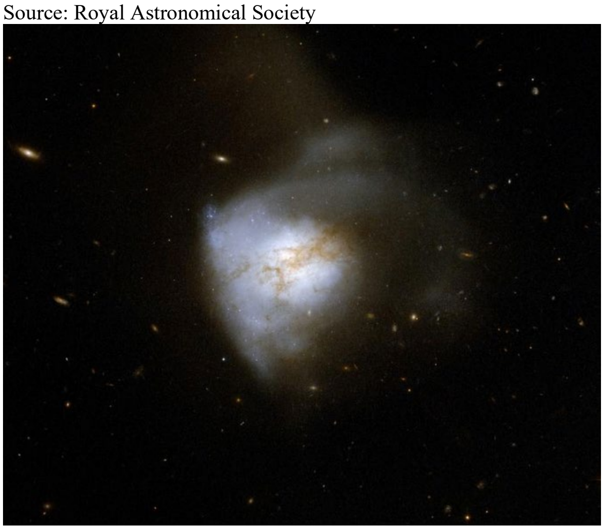
Analysis of the beam, visible only as a varying shade of green, blue and yellow pixels in Delamere's data imagery, can help scientists learn what is happening to the particles to create the dancing northern lights.

The results so far show a successful project, one that can even allow more information to be gleaned from its predecessor experiments.

"It's a question of trying to piece together the whole picture using all of the data products and numerical simulations," Delamere said. Three UAF students doing their doctoral research at the UAF Geophysical Institute also participated. Matthew Blandin supported optical operations at Wallops Flight Facility, Kylee Branning operated cameras on a NASA Gulfstream III aircraft out of Langley Research Centre, also in Virginia, and Nathan Barnes assisted with computer modelling in Fairbanks..
The experiment also included researchers and equipment from Dartmouth College, the University of New Hampshire and Clemson University.

- Clever trick to cook stars like Christmas pudding detected for first time

Date: December 20, 2024
Source: Royal Astronomical Society



Astronomers have found evidence of magnetic fields associated with a disc of gas and dust a few hundred light-years across deep inside a system of two merging galaxies known as Arp220 (pictured).
Credit
NASA, ESA, the Hubble Heritage (STScl/AURA), ESA, Hubble Collaboration, and A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University)
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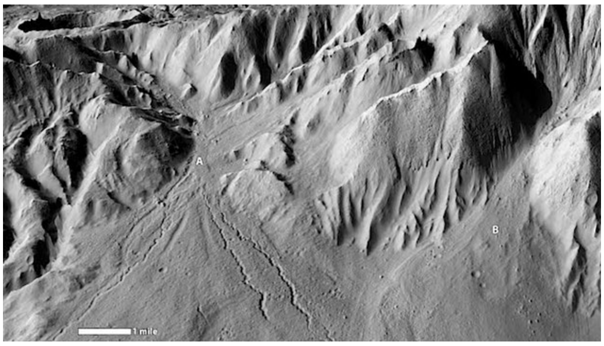
The missing ingredient for cooking up stars in the same way you might steam your Christmas pudding has been spotted for the first time by astronomers.
Much like a pressure cooker has a weight on top of its lid to keep the pressure in and get your festive dessert dense, moist and ready to eat, merging galaxies may need magnetic fields to create the ideal conditions for star formation.
Until now, however, the existence of such a force had only been theorised rather than observed.
An international team of researchers led by Imperial College astrophysicist Dr David Clements found evidence of magnetic fields associated with a disc of gas and dust a few hundred light-years across deep inside a system of two merging galaxies known as Arp220.
They say these regions could be the key to making the centres of interacting galaxies just right for cooking lots of hydrogen gas into young stars. This is because magnetic fields may be able to stop intense bursts of star formation in the cores of merging galaxies from effectively 'boiling over' when the heat is turned up too high.
A new paper revealing the discovery has been published today in *Monthly Notices of the Royal Astronomical Society*.
"This is the first time we've found evidence of magnetic fields in the core of a merger," said Dr Clements, "but this discovery is just a starting point. We now need better models, and to see what's happening in other galaxy mergers."
He gave a cooking analogy when explaining the role of magnetic fields in star formation. "If you want to cook up a lot of stars (Christmas puddings) in a short period of time you need to squeeze lots of gas (or ingredients) together. This is what we see in the cores of mergers. But then, as the heat from young stars (or your cooker) builds, things can boil over, and the gas (or pudding mixture) gets dispersed," Dr Clements said. "To stop this happening, you need to add something to hold it all together -- a magnetic field in a galaxy, or the lid and weight of a pressure cooker."
Astronomers have long been looking for the magic ingredient that makes some galaxies form stars more efficiently than is normal. One of the issues about galaxy mergers is that they can form stars very quickly, in what is known as a starburst. This means they're behaving differently to other star-forming galaxies in terms of the relationship between star formation rate and the mass of stars in the galaxy -- they seem to be turning gas into stars more efficiently than non-starburst galaxies. Astronomers are baffled as to why this happens.
One possibility is that magnetic fields could act as an extra 'binding force' that holds the star-forming gas together for longer, resisting the tendency for the gas to expand and

dissipate as it is heated by young, hot stars, or by supernovae as massive stars die.
Theoretical models have previously suggested this, but the new observations are the first to show that magnetic fields are present in the case of at least one galaxy.
Researchers used the Submillimetre Array (SMA) on Maunakea in Hawaii to probe deep inside the ultra-luminous infrared galaxy Arp220.
The SMA is designed to take images of light in wavelengths of about a millimetre -- which lies at the boundary between infrared and radio wavelengths. This opens up a window to a wide range of astronomical phenomena including supermassive black holes and the birth of stars and planets.
Arp220 is one of the brightest objects in the extragalactic far-infrared sky and is the result of a merger between two gas-rich spiral galaxies, which has triggered star bursting activity in the merger's nuclear regions.
The extragalactic far-infrared sky is a cosmic background radiation made up of the integrated light from distant galaxies' dust emissions. About half of all starlight emerges at far-infrared wavelengths.
The next step for the research team will be to use the Atacama Large Millimetre/submillimetre Array (ALMA) -- the most powerful telescope for observing molecular gas and dust in the cool universe -- to search for magnetic fields in other ultra luminous infrared galaxies.
That is because the next brightest local ultra luminous infrared galaxy to Arp220 is a factor of four or more fainter.
With their result, and further observations, the researchers hope the role of magnetic fields in some of the most luminous galaxies in the local universe will become much clearer.

- ❖ Scientists solving meteorological mysteries on Mars

Groundbreaking new paper answers key climate questions

Date: December 19, 2024
Source: University of Houston



A perspective view of two valley glaciers (labelled A and B) in Batson crater on Mars. The sinuous valleys radiating from glacier A were eroded by meltwater from the glacier. These glaciers likely filled the valleys more deeply in the past. Image credit: Murray Lab at Caltech and Alan Howard/PSI

A groundbreaking achievement by scientists at the University of Houston is changing our understanding of climate and weather on Mars and providing critical insights into Earth's atmospheric processes as well.
The study, led by Larry Guan, a graduate student in the Department of Physics at UH's College of Natural Sciences and Mathematics, under the guidance of his advisors, Professor Liming Li from the Department of Physics and Professor Xun Jiang from the Department of Earth and Atmospheric Sciences and several planetary scientists, generated the first-ever meridional profile of Mars' radiant energy budget, or REB, which represents the balance or imbalance between absorbed solar energy and emitted thermal energy across the latitudes. On a global scale, an energy surplus leads to global warming, while a deficit results in global cooling. Furthermore, the meridional profile of Mars' REB fundamentally influences weather and climate patterns on the red planet.
The findings are in a new paper just published in *AGU Advances* and will be featured in AGU's science magazine EOS.
"The work in establishing Mars' first meridional radiant energy budget profile is noteworthy," Guan said. "Understanding Earth's large-scale climate and atmospheric circulation relies heavily on REB profiles, so having one for Mars allows critical climatological comparisons and lays the groundwork for Martian meteorology."
The profile, based on long-term observations from orbiting spacecraft, offers a detailed comparison of Mars' REB to that of Earth, uncovering striking differences in the way each planet receives and radiates energy.
While Earth exhibits an energy surplus in the tropics and a deficit in the polar regions, Mars displays the opposite configuration.

"On Earth, the tropical energy surplus drives warming and upward atmospheric motion, while the polar energy deficit causes cooling and downward atmospheric motion," Jiang explained. "These atmospheric motions significantly influence weather and climate on our home planet. However, on Mars, we observe a polar energy surplus and a tropical energy deficit."

That surplus, Guan says, is especially pronounced in Mars' southern hemisphere during spring, playing a critical role in driving the planet's atmospheric circulation and triggering global dust storms, the most prominent feature of Martian weather. These massive storms, which can envelop the entire planet, significantly alter the distribution of energy, providing a dynamic element that affects Mars' weather patterns and climate.

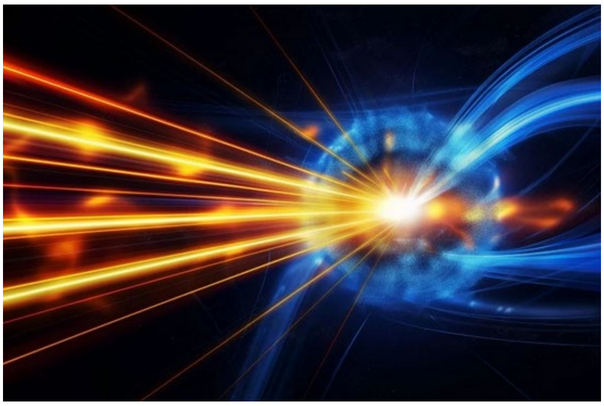
"The interaction between dust storms and the REB, as well as with polar ice dynamics, brings to light the complex feedback processes that likely shape Martian weather patterns and long-term climate stability," Guan said.

Earth's global-scale energy imbalance has been recently discovered, which significantly contributes to global warming at a magnitude comparable to that caused by increasing greenhouse gases. Mars presents a distinct environment due to its thinner atmosphere and lack of anthropogenic effects. The research team is now examining potential long-term energy imbalances on Mars and their implications for the planet's climate evolution.

"The REB difference between the two planets is truly fascinating, so continued monitoring will deepen our understanding of Mars' climate dynamics," Li said. "This research not only deepens our knowledge of the red planet but also provides critical insights into planetary atmospheric processes."

- Large Hadron Collider regularly makes magic

Date: December 19, 2024
Source: University of Adelaide



A surprising connection between LHC top quarks and quantum computing's "magic" property may unlock revolutionary computing possibilities. Credit: SciTechDaily.com

A brotherly research duo has discovered that when the Large Hadron Collider (LHC) produces top quarks -- the heaviest known fundamental particles -- it regularly creates a property known as magic.

This finding, published in *Physical Review D*, has implications for the progression of quantum computing, with magic being a measure that describes how difficult a quantum system is for a non-quantum computer to calculate.

"The higher the magic, the more we need quantum computers to describe the behaviour," explains Professor Martin White, from the University of Adelaide's School of Physics, Chemistry and Earth Sciences, who co-led the study with his twin brother, Professor Chris White, a physicist from Queen Mary University of London.

"Studying the magic properties of quantum systems generates significant insights into the development and potential uses of quantum computers."

The LHC is the world's largest and most powerful particle accelerator, consisting of a 27-kilometre ring of superconducting magnets with a number of accelerating structures through which two high-energy particle beams travel at close to the speed of light before they are made to collide.

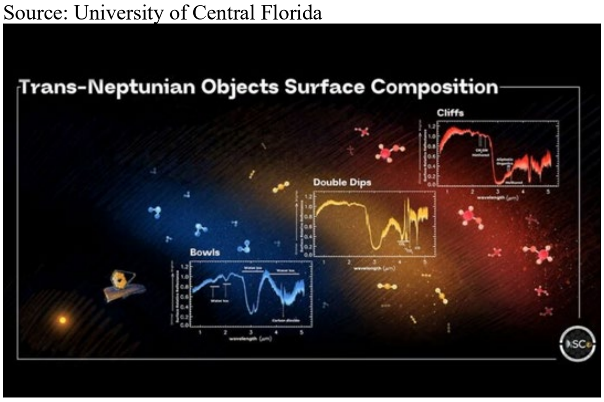
The amount of magic exhibited by top quarks depends on how fast they are moving and their direction of travel, all of which can be measured by the ATLAS and CMS detectors that observe the results of the LHC proton collisions.

"Quantum research has long focused on entanglement, which is where particles become linked; however, our work on magic explores how well-suited particles are for building powerful quantum computers," says Professor White.

"The ATLAS experiment has already observed evidence of quantum entanglement. We have shown that the LHC can also observe more complex patterns of quantum behaviour at the highest energies yet attempted for these kinds of experiments."
For decades, scientists have strived to build quantum computers that leverage the laws of quantum mechanics to achieve far greater processing power than traditional computers. The potential benefits of quantum computers are vast, impacting fields like drug discovery and materials science. Harnessing this power requires robust and controllable quantum states, and magic plays a critical role in achieving that control.
"Our research paves the way for a deeper understanding of the connection between quantum information theory and high-energy physics," says Professor White.
"This discovery is not just about the heaviest particles in the universe, it's about unlocking the potential of a revolutionary new computing paradigm."

- Best glimpse ever into icy planetesimals of the early solar system

Date: December 19, 2024
Source: University of Central Florida



Artistic representation of the distribution of trans-Neptunian objects in the planetesimal disk, with overlaid representative spectra of each compositional group highlighting the dominant molecules on their surfaces. Credit: Graphic art by William D. González Sierra for the Florida Space Institute, University of Central Florida

New studies led by researchers at the University of Central Florida offer for the first time a clearer picture of how the outer solar system formed and evolved based on analyses of trans-Neptunian objects (TNOs) and centaurs.
The findings, published today in *Nature Astronomy,* reveal the distribution of ices in the early solar system and how TNOs evolve when they travel inward into the region of the giant planets between Jupiter and Saturn, becoming centaurs.
TNOs are small bodies, or 'planetesimals,' orbiting the sun beyond Pluto. They never accreted into planets, and serve as pristine time capsules, preserving crucial evidence of the molecular processes and planetary migrations that shaped the solar system billions of years ago. These solar system objects are like icy asteroids and have orbits comparable to or larger than Neptune's orbit.
Prior to the new UCF-led study, TNOs were known to be a diverse population based on their orbital properties and surface colours, but the molecular composition of these objects remained poorly understood. For decades, this lack of detailed knowledge hindered interpretation of their colour and dynamical diversity. Now, the new results unlock the long-standing question of the interpretation of colour diversity by providing compositional information.
"With this new research, a more-complete picture of the diversity is presented and the pieces of the puzzle are starting to come together," says Noemí Pinilla-Alonso, the study's lead author.
"For the very first time, we have identified the specific molecules responsible for the remarkable diversity of spectra, colours and albedo observed in trans-Neptunian objects," Pinilla-Alonso says. "These molecules -- like water ice, carbon dioxide, methanol and complex organics -- give us a direct connection between the spectral features of TNOs and their chemical compositions."
Using the James Webb Space Telescope (JWST), the researchers found that TNOs can be categorized into three distinct compositional groups, shaped by ice retention lines that existed in the era when the solar system formed billions of years ago.
These lines are identified as regions where temperatures were cold enough for specific ices to form and survive within the protoplanetary disk. These regions, defined by their distance from the sun, mark key points in the early solar system's temperature gradient and offer a direct link between the formation conditions of planetesimals and their present-day compositions.
Rosario Brunetto, the paper's second author and a Centre National de la Recherche Scientifique researcher at the Institute d'Astrophysique Spatiale (Université Paris-Saclay), says the results are the first clear connection between formation of planetesimals in the protoplanetary disk and their later evolution. The work sheds light on how today's observed spectral and dynamical

distributions emerged in a planetary system that's shaped by complex dynamical evolution, he says.
"The compositional groups of TNOs are not evenly distributed among objects with similar orbits," Brunetto says. "For instance, cold classicals, which formed in the outermost regions of the protoplanetary disk, belong exclusively to a class dominated by methanol and complex organics. In contrast, TNOs on orbits linked to the Oort cloud, which originated closer to the giant planets, are all part of the spectral group characterized by water ice and silicates."
Brittany Harvison, a UCF physics doctoral student who worked on the project while studying under Pinilla-Alonso, says the three groups defined by their surface compositions exhibit qualities hinting at the protoplanetary disk's compositional structure.
"This supports our understanding of the available material that helped form outer solar system bodies such as the gas giants and their moons or Pluto and the other inhabitants of the trans-Neptunian region," she says.
In a complementary study of centaurs published in the same volume of *Nature Astronomy*, the researchers found unique spectral signatures, different from TNOs, that reveal the presence of dusty regolith mantles on their surfaces.
This finding about centaurs, which are TNOs that have shifted their orbits into the region of the giant planets after a close gravitational encounter with Neptune, helps illuminate how TNOs become centaurs as they warm up when getting closer to the sun and sometimes develop comet-like tails.
Their work revealed that all observed centaur surfaces showed special characteristics when compared with the surfaces of TNOs, suggesting modifications occurred as a consequence of their journey into the inner solar system.
Among the three classes of TNO surface types, two -- Bowl and Cliff -- were observed in the centaur population, both of which are poor in volatile ices, Pinilla-Alonso says. However, in centaurs, these surfaces show a distinguishing feature: they are covered by a layer of dusty regolith intermixed with the ice, she says.
"Intriguingly, we identify a new surface class, non-existent among TNOs, resembling ice poor surfaces in the inner solar system, cometary nuclei and active asteroids," she says.
Javier Licandro, senior researcher at the Instituto de Astrofisica de Canarias (IAC, Tenerife, Spain) and lead author of the centaur's work says the spectral diversity observed in centaurs is broader than expected, suggesting that existing models of their thermal and chemical evolution may need refinement.
For instance, the variety of organic signatures and the degree of irradiation effects observed were not fully anticipated, Licandro says.
"The diversity detected in the centaurs' populations in terms of water, dust, and complex organics suggests varied origins in the TNO population and different evolutionary stages, highlighting that centaurs are not a homogenous group but rather dynamic and transitional objects" Licandro says. "The effects of thermal evolution observed in the surface composition of centaurs are key to establishing the relationship between TNOs and other small bodies populations, such as the irregular satellites of the giant planets and their Trojan asteroids."
Study co-author Charles Schambeau, a planetary scientist with UCF's Florida Space Institute (FSI) who specializes in studying centaurs and comets, emphasized the importance of the observations and that some centaurs can be classified into the same categories as the DiSCo-observed TNOs.
"This is pretty profound because when a TNO transitions into a centaur, it experiences a warmer environment where surface ices and materials are changed," Schambeau says. "Apparently, though, in some cases the surface changes are minimal, allowing individual centaurs to be linked to their parent TNO population. The TNO versus centaur spectral types are different, but similar enough to be linked."
How the Research Was Performed
The studies are part of the Discovering the Surface Composition of the trans-Neptunian Objects, (DiSCo) project, led by Pinilla-Alonso, to uncover the molecular composition of TNOs. Pinilla-Alonso is now a distinguished professor with the Institute of Space Science and Technology in Asturias at the Universidad de Oviedo and performed the work as a planetary scientist with FSI.
For the studies, the researchers used the JWST, launched almost three years ago, that

provided unprecedented views of the molecular diversity of the surfaces of the TNOs and centaurs through near-infrared observations, overcoming the limitations of terrestrial observations and other available instruments.
For the TNOs study, the researchers measured the spectra of 54 TNOs using the JWST, capturing detailed light patterns of these objects. By analysing these high-sensitivity spectra, the researchers could identify specific molecules on their surface. Using clustering techniques, the TNOs were categorized into three distinct groups based on their surface compositions. The groups were nicknamed "Bowl," "Double-dip" and "Cliff" due to the shapes of their light absorption patterns.
They found that:

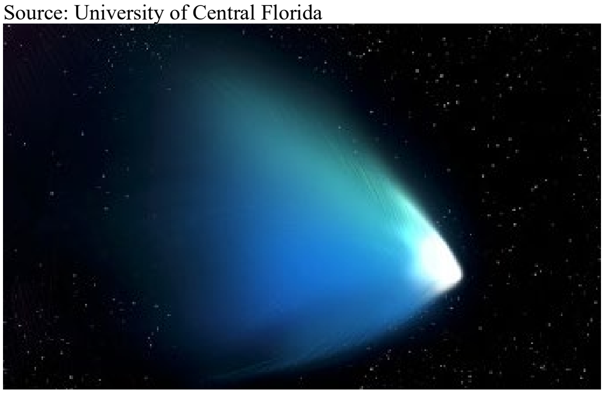
- **Bowl-type TNOs** made up 25% of the sample and were characterized by strong water ice absorptions and a dusty surface. They showed clear signs of crystalline water ice and had low reflectivity, indicating the presence of dark, refractory materials.
- **Double-dip TNOs** accounted for 43% of the sample and showed strong carbon dioxide (CO2) bands and some signs of complex organics.
- **Cliff-type TNOs** made up 32% of the sample and had strong signs of complex organics, methanol, and nitrogen-bearing molecules, and were the reddest in colour.

For the centaurs' study, the researchers observed and analysed the reflectance spectra of five centaurs (52872 Okyrhoe, 3253226 Thereus, 136204, 250112 and 310071). This allowed them to identify the surface compositions of the centaurs, revealing considerable diversity among the observed sample.
They found that Thereus and 2003 WL7 belong to the Bowl-type, while 2002 KY14 belongs to the Cliff-type. The remaining two centaurs, Okyrhoe and 2010 KR59, did not fit into any existing spectral classes and were categorized as "Shallow-type" due to their unique spectra. This newly defined group is characterized by a high concentration of primitive, comet-like dust and little to no volatile ices.

Previous Research and Next Steps

Pinilla-Alonso says that previous DiSCo research revealed the presence of carbon oxides widespread on the surfaces of TNOs, which was a significant discovery.
"Now, we build on that finding by offering a more comprehensive understanding of TNO surfaces" she says. "One of the big realizations is that water ice, previously thought to be the most abundant surface ice, is not as prevalent as we once assumed. Instead, carbon dioxide (CO_2) -- a gas at Earth's temperature -- and other carbon oxides, such as the super volatile carbon monoxide (CO), are found in a larger number of bodies."
The new study's findings are only the beginning, Harvison says.
"Now that we have general information about the identified compositional groups, we have much more to explore and discover," she says. "As a community, we can start exploring the specifics of what produced the groups as we see them today."
The research was supported by NASA through a grant from the Space Telescope Science Institute.

- Uncovering a centaur's tracks: Scientists examine unique asteroid-comet hybrid

Date: December 18, 2024
Source: University of Central Florida

Credit: William Gonzalez Sierra
Although our Solar System is billions of years old, we've only recently become better acquainted with one of its more dynamic and captivating inhabitants known as (2060) Chiron.
Chiron belongs to the class of objects that astronomers call "Centaurs." Centaurs are space objects that orbit the Sun between Jupiter and Neptune. They are akin to the mythological creature they borrow their name from in that they are hybrid, possessing characteristics of both asteroids and comets.
Using the James Webb Space Telescope, UCF Florida Space Institute (FSI) scientists recently led a team that found, for the first time, that Chiron has surface chemistry unlike another centaur. Its surface it has both carbon

dioxide and carbon monoxide ice along with carbon dioxide and methane gases in its coma, the cloud-like envelope of dust and gas surrounding it.

The researchers' results were recently published in the journal *Astronomy & Astrophysics.*

UCF FSI Associate Scientist Noemí Pinilla-Alonso, who now works at the University of Oviedo in Spain, and Assistant Scientist Charles Schambeau led the research. The new findings build upon prior discoveries from Pinilla-Alonso and colleagues that detected carbon monoxide and carbon dioxide ice on trans-Neptunian objects (TNOs) for the first time earlier this year.

Those observations, paired with ones of Chiron, are creating foundational knowledge for understanding the creation of our Solar System, as these objects have largely remained unchanged since the Solar System was formed, Pinilla-Alonso says.

"All the small bodies in the Solar System talk to us about how it was back in time, which is a period of time we can't really observe anymore," she says. "But active centaurs tell us much more. They are undergoing transformation driven by solar heating and they provide a unique opportunity to learn about the surface and subsurface layers."

Since Chiron possesses characteristics of both an asteroid and a comet, it makes it rich for studying many processes that could assist in understanding them, she says.

"What is unique about Chiron is that we can observe both the surface, where most of the ices can be found, and the coma, where we see gases that are originating from the surface or just below it," Pinilla-Alonso says. "TNOs don't have this kind of activity because they're too far and too cold. Asteroids don't have this kind of activity because they don't have ice on them. Comets, on the other hand, show activity like centaurs, but they are typically observed closer to the Sun, and their comas are so thick that they complicate the interpretations of observations of the ices on the surface. Discovering which gases are part of the coma and their different relationships with the ices on the surface help us learn the physical and chemical properties, such as the thickness and the porosity of the ice layer, its composition, and how irradiation is affecting it."

The discovery of these ices and gases on an object as distant as Chiron -- observed near its farthest point from the Sun -- is exciting because it could help contextualize other centaurs and provide insight into the earliest era of our Solar System, Schambeau says.

"These results are like nothing we've seen before," he says. "Detecting gas comae around objects as far away from the Sun as Chiron is very challenging, but JWST has made it accessible. These detections enhance our understanding of Chiron's interior composition and how that material produces the unique behaviours as we observe Chiron."

Schambeau specializes in studying centaurs, comets and other space objects. He analysed the methane gas coma and determined that the outflowing gas detected was consistent with it being sourced from a surface area that was exposed to the most heating from the Sun.

Chiron, first discovered in 1977, is characterized much better than most centaurs and comparatively is unique, Schambeau says.

The newly analysed information helps scientists better understand the thermophysical process going on in Chiron that produces methane gas, he says.

"It's an oddball when compared to the majority of other Centaurs," Schambeau says. "It has periods where it behaves like a comet, it has rings of material around it, and potentially a debris field of small dust or rocky material orbiting around it. So, many questions arise about Chiron's properties that allow these unique behaviours."

The researchers concluded that the coexistence of the molecules in various states adds another layer of intrigue for studying comets and centaurs. The study also highlighted the presence of irradiated byproducts of methane, carbon monoxide and carbon dioxide that will require further research and could help scientists further reveal the unique processes producing Chiron's surface composition.

Chiron originated from the TNO region and has travelled around our Solar System since its creation, says Pinilla-Alonso. The orbits of Chiron and many other large non-planetary objects occasionally experience close encounters with one of the giant planets where the gravitational pull from the planet changes the smaller object's orbit, taking them all over our Solar System and exposing them to many different environments, she says.

"We know it has been ejected from the TNO population and is only now transiting through the region of the giant planets, where it will not stay for too long," Pinilla-Alonso says. "After about 1 million years, centaurs like Chiron typically are ejected from the giant planets region, where they may end their lives as Jupiter Family comets or they may return to the TNOs region."

Pinilla-Alonso notes that the JWST's spectra showed for the first time Chiron's plethora of ices with different volatilities and their formation processes, she says.

Some of these ices, such as methane, carbon dioxide, and water ice, may be primordial components of Chiron inherited from the pre-solar nebula. Others, such as acetylene, propane, ethane, and carbon oxide, could have formed on the surface because of reduction and oxidation processes, she says.

"Based on our new JWST data, I'm not so sure we have a standard centaur," Pinilla-Alonso says. "Every active centaur that we are observing with JWST shows some peculiarity. But they cannot be all outliers. There must be something that explains why they appear to all behave differently or something that is common between them all that we cannot yet see."

The analysis of Chiron's gases and ices opens new frontiers and opportunities for exciting research, she says.

"We're going to follow up with Chiron," Pinilla-Alonso says. "It will come closer to us, and if we can study it at nearer distances and get better reads on the quantities and nature of the ices, silicates, and organics, we will be able to better understand how seasonal insolation variations and different illumination patterns can affect its behaviour and its ice reservoir."

The JWST is the world's premier space science observatory, and it 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. The JWST is an international collaboration led by NASA with its partners the European Space Agency and the Canadian Space Agency.

Researchers' Credentials

Pinilla-Alonso was a professor at FSI who joined UCF in 2015. Most of her work on this project was conducted while she was at UCF. Pinilla-Alonso also holds a joint appointment as a research professor in UCF's Department of Physics and has led numerous international observational campaigns in support of NASA missions, such as New Horizons, OSIRIS-REx and Lucy. Pinilla-Alonso is a distinguished professor at the Institute for Space Sciences and Technologies in Asturias, within the Universidad de Oviedo. She received her doctoral degree in astrophysics and planetary sciences from the Universidad de La Laguna in Spain.

Schambeau is an assistant scientist who received his doctoral degree in physics with a concentration in planetary sciences in 2018 from UCF. He subsequently joined FSI where he expanded upon his work examining comets and centaurs as part of UCF's Preeminent Postdoctoral Program.

- Origins of lunar water and its connection to Earth's early history

Date: December 19, 2024
Source: Vrije Universiteit Brussel

A study shares new insights into the origins of water on the moon. (Credit: zulfachri zulkifli/Shutterstock)

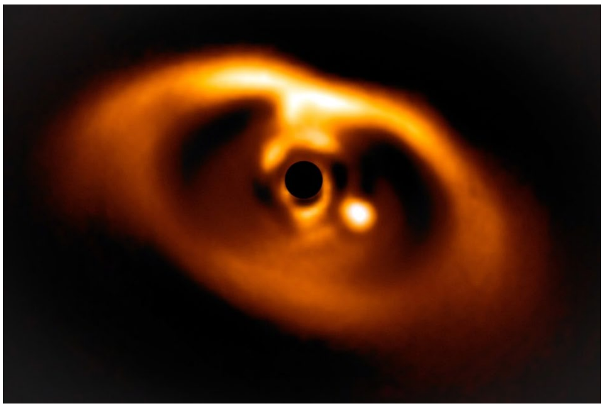
A team of international scientists has unveiled groundbreaking research on the origins of lunar water, offering insights that could reshape our understanding of the Earth-Moon system and the broader solar system. The pioneering study explores the isotopic signatures of lunar water, revealing a mix of indigenous and cometary sources.

The team analysed water in nine samples from the Apollo lunar mission, using a high-precision triple oxygen isotope technique. This method, developed by Dr. Morgan Nunn Martinez of the University of California, San Diego, separates water into its various binding phases -- loosely bound, tightly bound, and trapped within minerals -- via stepwise heating at 50°C, 150°C, and 1,000°C. Their findings provide crucial evidence that lunar water has a dual heritage: one part originating from early Earth-like material and another delivered through cometary impacts.

"This is a major step forward in unravelling where lunar water comes from," Dr. Maxwell Thiemens of the AMGC research group of the VUB explained. "Our data suggest that the Moon inherited water tracing back to Earth's formation, followed by later contributions from comets, delivering the water reservoirs we see today."
Three key results are central to the report: An early Earth signature: The oxygen isotopic composition closely matches enstatite chondrites, a meteorite type believed to be the building blocks of the Earth. There are also clear signs of cometary contribution: A significant portion of lunar water shows isotopic similarities to comets. A reduced importance of solar wind: the study challenges the prevalent theory that the majority of lunar water was produced in situ via solar interactions with lunar silicates, presenting instead a complex mixing of sources.
This discovery is timely as nations and private enterprises intensify their efforts to establish permanent lunar bases. Understanding the water's origins and distribution could have significant implications for sustaining human presence on the Moon.
"The data not only enhance our understanding of the Moon's past but also pave the way for future space exploration and resource utilization. These findings should redefine how we think about water as a resource for long-term lunar habitation." Thiemens concludes.
This research has the potential to shape lunar and planetary science for decades to come, offering a deeper connection between Earth's water-rich environment and the Moon's arid surface. With Artemis missions on the horizon, this pioneering study provides a crucial foundation for future exploration and resource planning.

- Young exoplanet's atmosphere unexpectedly differs from its birthplace

New study shows planet formation might be more complicated than previously thought
Date: December 18, 2024
Source: Northwestern University


The natal disk of PDS 70 with new planet PDS 70b (bright spot on the right). By studying this system, researchers uncovered a mismatched composition of gases in the planet’s atmosphere compared to gases within the disk. Image by ESO/A. Müller et al.

Just as some children physically resemble their parents, many scientists have long thought that developing planets should resemble the swirling disk of gas and dust that births them.
But, in a new study, a Northwestern University-led team of astrophysicists discovered the resemblance might be looser than previously thought. By studying a still-forming exoplanet and its surrounding natal disk, the researchers uncovered a mismatched composition of gases in the planet's atmosphere compared to gases within the disk.
The surprising finding potentially confirms long-held scepticism that scientists' current model of planet formation is too simplified.
The study will be published on Wednesday (Dec. 18) in the *Astrophysical Journal Letters*. It marks the first time physicists have compared information from an exoplanet, its natal disk and host star.
"For observational astrophysicists, one widely accepted picture of planet formation was likely too simplified," said Northwestern's Chih-Chun "Dino" Hsu, who led the study. "According to that simplified picture, the ratio of carbon and oxygen gases in a planet's atmosphere should match the ratio of carbon and oxygen gases in its natal disk -- assuming the planet accretes materials through gases in its disk. Instead, we found a planet with a carbon and oxygen ratio that is much lower compared to its disk. Now, we can confirm suspicions that the picture of planet formation was too simplified."
Hsu is a postdoctoral associate at the Centre for Interdisciplinary Exploration and Research in Astrophysics(CIERA). He is advised by Jason Wang, an assistant professor of physics and astronomy at Northwestern's Weinberg

College of Arts and Sciences and member of CIERA.

Searching for visible birth material

All planets are born from a natal disk, a rotating disk of gas and dust that surrounds a new star. Over millions of years, gravity pulls gas and dust together to form clumps, which eventually grow into planets. Until recently, it was impossible to obtain a direct view of a natal disk in order to track a planet's birth. Most observable exoplanets are too old, so their natal disks have already disappeared.

The exception, however, is PDS 70, a natal disk that envelopes two fledgling gas-giant exoplanets -- similar to Jupiter -- called PDS 70b and PDS 70c. Located just 366 million lightyears from Earth within the constellation Centaurus, the planets are, at most, a youthful 5 million years old.

"This is a system where we see both planets still forming as well as the materials from which they formed," Wang said. "Previous studies have analysed this disk of gas to understand its composition. For the first time, we were able to measure the composition of the still-forming planet itself and see how similar the materials are in the planet compared to the materials in the disk."

Examining planetary fingerprints

To measure the materials, Hsu, Wang and their team examined the light emitted from PDS 70b. This light, or spectra, is like a fingerprint, revealing an object's composition, motion, temperature and other characteristics. Each molecule or element produces its own spectrum. So, by studying these spectra, researchers can pinpoint the specific molecules or elements within an object.

In previous work, Wang co-developed new photonics technologies that enable astronomers to capture the spectrum of targeted faint objects near much brighter stars. The researchers used this technique to zero in on the faint features of the young planetary system.

"These new tools make it possible to take a really detailed spectra of faint objects next to really bright objects," Wang said. "Because the challenge here is there's a really faint planet next to a really bright star. It's hard to isolate the light of the planet in order to analyse its atmosphere."

With the spectra, the researchers obtained information about carbon monoxide and water from PDS 70b. From that, they calculated the inferred ratio of carbon and oxygen within the planet's atmosphere. Then, they compared that ratio to previously reported measurements of gases in the disk.

"We initially expected the carbon-to-oxygen ratio in the planet might be similar to the disk," Hsu said. "But, instead, we found the carbon, relative to oxygen, in the planet was much lower than the ratio in the disk. That was a bit surprising, and it shows that our widely accepted picture of planet formation was too simplified."

Solid components might make the difference

To explain this mismatch, Hsu and Wang think two different scenarios might be at play. One explanation is the planet might have formed before its disk became enriched in carbon. Another explanation is the planet might have grown mostly by absorbing large amounts of solid materials in addition to gases. While the spectra show only gases, some of the carbon and oxygen initially could be accreted from solid -- trapped in ice and dust.

"If the planet preferentially absorbed ice and dust, then that ice and dust would have evaporated before going into the planet," Wang said. "So, it might be telling us that we can't just compare gas versus gas. The solid components might be making a big difference in the carbon to oxygen ratio."

For this study, the team only studied PDS 70b. Next, they plan to observe the spectra from the other planet in the PDS 70 system.

"By studying these two planets together, we can understand the system's formation history even better," Hsu said. "But, also, this is just one system. Ideally, we need to identify more of them to better understand how planets form."

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