South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 537 – February 2020 Editor: Roger Burgess
Main Talk James Fradgley "Five short talks: Przybylski's Star The Earliest Stars Blue Stragglers The Big Bang Lagrange Points

Next meeting Friday 7th February Lecture room of the South Downs Planetarium, Chichester, at 7:30
Please support a raffle we are organizing this month.
We have a new Chairwoman Lisa Lacey is taking over from Mark Ford
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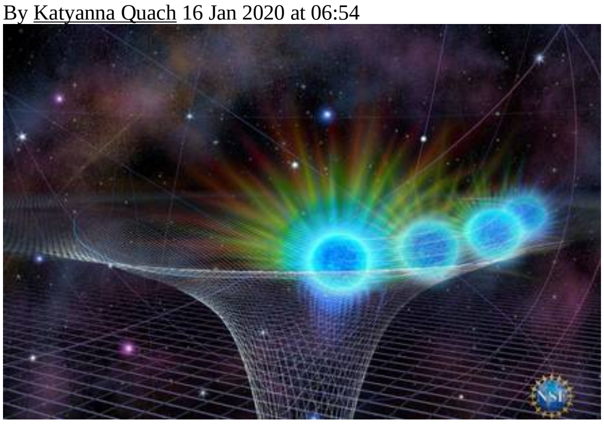
- The mysterious giant blobs of gas around our galaxy's black hole are actually massive merger stars being shredded

Yum, long noodle-like stars
By Katyanna Quach 16 Jan 2020 at 06:54



Astronomers have finally figured out what the peculiar object known as "G2" orbiting the supermassive black hole at the centre of the Milky Way is: a behemoth star created from the merger of two binary stars being stretched by the extreme tidal forces around the black hole.
The peculiar object has baffled scientists for years. The mystery deepened after a team of researchers led by the University of California, Los Angeles (UCLA) uncovered other bodies behaving in a similar way to G2 elsewhere. They had stumbled across a new class of objects, but weren't quite sure what those things were exactly.
"They are strange because they appear as gas and dust blobs, but then they behave like stars, making us believe that there is actually a star hidden inside," Anna Ciurlo, lead author of the study published in Nature on Wednesday and a postdoctoral scholar at UCLA, told *The Register*.
"The question is: how do you get all this material around a star? That's what led us to put them all in a new class."
If G2 was just a giant cloud of gas and dust, it would have been ripped apart by the black hole, which would release copious amounts of electromagnetic radiation. But the object continues to persist despite living in such a harsh environment.
"G2 survived and continued happily on its orbit; a simple gas cloud would not have done that," said Andrea Ghez, co-author of the paper and a professor of physics and astronomy at UCLA. "G2 was basically unaffected by the black hole. There were no fireworks."
Instead, G2 is actually the result of two massive binary stars merging together to produce one giant star shrouded by gas and dust. The researchers believe that the strong gravitational effects of the supermassive black hole forces stars to smash into one another to create objects like G2. The new star then expands for more than a million years before being swallowed.
"This may be happening more than we thought. The stars at the centre of the galaxy are massive and mostly binaries. It's possible that many of the stars we've been watching and not understanding may be the end product of mergers that are calm now," said Ghez.
G2 currently appears to be stretching from "spaghettification," a process describing the stretching and compression of objects into long thin spaghetti-like shape. It occurs when things get too close to a black hole and come under the effects of extreme tidal forces.
"We believe these [objects like G2] are merged binary systems. This process creates a lot of gas and dust around the newly formed star. This material makes these objects large. Therefore, when they pass close enough to the black hole this material can interact with the gravity of the black hole and become stretched, and in some cases pulled away," Ciurlo explained to *El Reg*.
The team carried out their research at the W.M. Keck Observatory in Hawaii, home to the world's two largest optical and infrared telescopes.
"We are starting to understand the physics of black holes in a way that has never been possible before," Ghez concluded.

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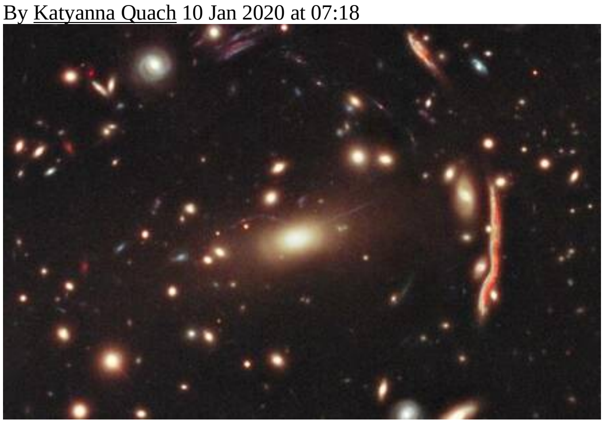
H0LiCOW: Cosmologist still have no idea why universe seems to be expanding more rapidly than expected

New estimation of Hubble Constant emerges

By Katyanna Quach 10 Jan 2020 at 07:18



A picture of galaxy cluster MACS 1206 taken with NASA's Hubble Space Telescope. Image credit: NASA, ESA, M. Postman (STScI), and the CLASH Team

Cosmologists are scratching their heads after the latest measurements of just how fast the universe is expanding raises more questions than answers.

Scientists have been trying to pin down the exact value of the Hubble Constant, a number that describes how far galaxies are receding over a specific time and distance as the universe expands, for nearly a century. Georges Lemaître, a Catholic priest and physicist who also first proposed the Big Bang theory (no, not the TV show), attempted to calculate that number in 1927.

Now, thanks to better technology, scientists can actually rely on real data rather than just mathematical wizardry. The latest measurement made by a large team of cosmologists known as the H0LiCOW collaboration, which stands for H0 (an abbreviation for the Hubble Constant) and Lenses in COSMOGRAIL's Wellspring confirms that the universe appears to be expanding faster than expected – and can't be explained by the current standard model.

"There has been an intriguing pattern of differences in the Hubble Constant that appear to depend on which end of cosmic history its value is measured," Adam Reiss, a professor of physics and astronomy at John Hopkins University, who isn't part of the H0LiCOW team explained to *The Register*. Reiss was part of the trio of physicists who won the Nobel Prize in Physics in 2011 for discovering that the universe is expanding at an accelerated rate.

"This has been widely known as 'The Hubble Tension'. Measurements in the 'Late Universe' - or the present time - cluster around 73 kilometres per second per megaparsec. Measurements from the 'Early Universe' - or shortly after the Big Bang - get a value of about 67 kilometres per second per megaparsec."

"Of course, we should get the same answer at either end assuming we understand the physics of the universe. There is a lot of well-motivated speculation that the source of the discrepancy involves our understanding of the Universe and the new H0LiCOW results reinforce this tension," he said.

The Early Universe vs the Late Universe

The Late Universe measurements are made using what's called the standard candle method, a technique that allows scientists to measure long distances by studying the brightness of Type Ia supernovae. The Early Universe measurements, however, looks at cosmic microwave background (CMB) radiation leftover from the Big Bang.

"People believed that the differences between both measurements could be down to some internal systematic error," Geoff Chih-Fan Chen, a PhD student at the University of California, Davis and a member of the H0LiCOW team, told *El Reg*.

"So, we used an independent method that involves looking at the gravitational lensing effects of quasars to measure distance and calculate the Hubble Constant using the Hubble Space Telescope."

The team estimated a value of 73.3 kilometres per second per megaparsec, a number that supports the standard candle method. "So, the initial idea that it could be down to a systematic error is not true, and, therefore, the contention is real," Chen added.

The CMB method relies on strong assumptions from the standard model of cosmology, where the universe is considered flat, or that the density of dark energy - an unknown source of energy that could be driving the expansion of the universe - permeating space does not change over time.

If these assumptions are wrong then it'll mean the standard model of cosmology is wrong too. "It's a problem for theoretical physicists, they need to figure out how to resolve this tension," he said. In the meantime, however, the H0LiCOW collaboration hopes to contribute to this issue by taking more precise measurements of the gravitational lensing effect of quasars.

In their first experiment they studied three quasars, in their latest attempt they studied six quasars. Next, they hope to expand their sample size to 40 quasars.

Chen presented the team's research at the 235th meeting of the American Astronomical Society in Hawaii, this week.

- Astronomers discover Sun is surfing on 9,000-light-year gas wave that acts as Milky Way's stellar nursery

The Radcliffe is totally radical

By Katyanna Quach 9 Jan 2020 at 06:51

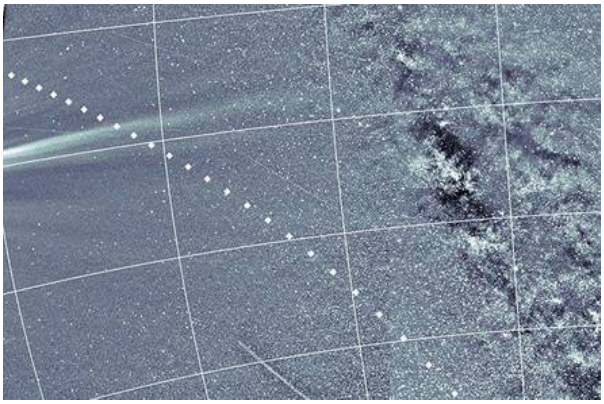
The Milky Way's spiral arm that's home to our Solar System has been found to cradle the largest gaseous structure in the galaxy – a long, thin strip of jumbled star-forming matter measuring 9,000 light-years long and 400 light-years wide.

A team of researchers published details of their discovery in Nature this week. Named the Radcliffe Wave, after the Radcliffe Institute for

Advanced Study at Harvard University, where the study was led, the structure had never been observed before and overturns 150 years of cosmological theory.
“No astronomer expected that we live next to a giant, wave-like collection of gas - or that it forms the local arm of the Milky Way,” said Alyssa Goodman, co-author of the paper and professor of applied astronomy at America's Harvard University.
Although the structure is giant - taking up nearly all of the space in what is known as the Orion Arm, or Local Arm, of the Milky Way - it was difficult to find. Scientists only spotted the giant thread of gas after mapping the smattering of young stars being born within that area when they analysed the data recorded by the European Space Agency’s Gaia spacecraft, which launched in 2013.
“Only within the last year or two have we obtained super accurate distance to these stellar nurseries, enabled by novel statistical analyses of Gaia data. It is not possible to see this structure on the sky,” Catherine Zucker, co-author of the paper and a graduate student at the Harvard Smithsonian Centre for Astrophysics, told *The Register*.
Instead, the researchers combined 2D snapshots of different patches of the sky in order to piece together a 3D map of the interstellar matter in the Milky Way. Only then did the structure emerge, she explained.
“It has transformed our understanding of the Local Arm of our galaxy, which is the arm closest to our Sun. Previous models of the arm model it as a spiral shape which lies in the disk of the galaxy,” Zucker added. The new study shows that the Local Arm is actually the Radcliffe Wave itself.
As the Sun travels along its galactic orbit around the Milky Way, it crosses in and out of the Radcliffe Wave, a motion the researchers have described as “surfing”.
“It appears that the Sun, on its galactic orbit, crossed the Radcliffe Wave 13 million years ago, and may cross it again in the future. So, in a way we are 'surfing' the wave,” said Zucker.
She estimates that about one per cent of the total gas mass, about three million solar masses, has been used to form the tens of thousands of new stars across the Radcliffe Wave. The researchers are unsure how the structure formed itself, whether the Milky Way contains more of these colossal gas structures, and how it might impact star formation over time, but research is ongoing.

- It's a billion-ton, 14-million-mile long mysterious alien formation – and Earth is heading right into it

Yes, it's the debris tail of asteroid 3200 Phaethon, the source of the annual Geminids meteor shower
By Katyanna Quach 12 Dec 2019 at 12:04


An image of the asteroid tail captured in the top left. Image credit: Brendan Gallagher and Guillermo Stenborg

Asteroid 3200 Phaethon's thick trail of debris, which is the source of the annual Geminids meteor shower here on Earth, has a mass of about a billion tons, is 60,000 miles wide, and is more than 14 million miles long.
Scientists at America's Naval Research Laboratory (NRL) built a specialized camera known as the Wide-Field Imager for Solar Probe (WISPR) to study the solar wind and how space weather can disrupt GPS satellites and energy grids. The instrument, attached on top of NASA’s Parker Solar Probe, has revealed the elusive trail of dust left over from the space rock in unprecedented detail.
3200 Phaethon has a wildly eccentric orbit that brings it closer to the Sun than Mercury, and flings it back out further than Mars. Astronomers have detected the spray of debris emitted from the asteroid before. As the asteroid whips around, the dirt is compressed into a tail. Although the streak stretches long and wide, and collectively contains more than a billion tons of dirt, it’s difficult for telescopes to find – though when our home world passes through the debris, the material shows up as the Geminids meteor shower to us Earthlings.
The trail as a whole is best observed near the Sun; it’s believed that solar radiation pressure causes bits to break away from the asteroid, so when it's close to our star, more stuff is possibly knocked off the cosmic rock. But our star’s glare drowns out its presence making it hard for telescopes to see it.
“This is why NRL’s heliospheric imagers are so ground-breaking,” Karl Battams, a computational scientist at the NRL’s space science division, said on Wednesday. “They allow you to see near-Sun outflows massively fainter than the Sun itself, which would otherwise blind our cameras. And in this case, you can also see solar system objects extremely close to the Sun, which most telescopes cannot do.”
WISPR captured enough detailed data to allow researchers to estimate the size and mass of 3200 Phaethon’s dust trail. The sheer amount has led them to question the nature of the asteroid itself.
“There’s no way the asteroid is anywhere near active enough when it is near the Sun to produce the mass of dust we are seeing,” Battams said.

There must be something else other than solar radiation pressure that is making the space rock emit so much debris seen in the Geminids meteor shower, though the eggheads aren't quite sure what exactly.
"Something catastrophic [must have] happened to Phaethon a couple of thousand years ago and created the Geminid Meteor shower," he added.
WISPR takes snapshots in the visible light spectrum of the solar corona and solar outflow using two overlapping cameras. NASA's Parker Solar Probe was launched in 2018 and is expected to continue orbiting our star, approaching as close as 4.3 million miles from its centre, for another five years or so.

- Geologists find the oldest matter on Earth: Ancient stardust created before the Solar System formed

By Katyanna Quach 14 Jan 2020 at 05:16

Geologists think they have found the oldest known substance on Earth, dust grains that were formed around five to seven billion years ago - before the Solar System had even formed.
"This is one of the most exciting studies I've worked on," said Philipp Heck, lead author of the paper published in the Proceedings of the National Academy of Sciences on Monday and an associate professor of geophysical sciences at the University of Chicago. "These are the oldest solid materials ever found, and they tell us about how stars formed in our galaxy."
The tiny dust grains were found in the Murchison meteorite, which landed in Australia over 50 years ago. The research team analysed samples of the meteorite by grinding it up into a fine powder to create a chemical paste that can be dissolved with acid to leave "presolar" grains behind.
"It starts with crushing fragments of the meteorite down into a powder," said Jennika Greer, a graduate student at the University of Chicago and a co-author of the study. "Once all the pieces are segregated, it's a kind of paste, and it has a pungent characteristic—it smells like rotten peanut butter."
These presolar particles were forged before the Sun was formed in environments with completely different chemical compositions. After inserting the samples into a mass spectrometer, the researchers could study the concentrations of different isotopes.
Isotopes like neon-21 are created when the meteorite was bombarded with galactic cosmic rays. The concentration of certain isotopes provides an estimation of how long ago the rock was zapped by the rays.
"Some of these cosmic rays interact with the matter and form new elements. And the longer they get exposed, the more those elements form," Heck explained. "By measuring how many of these new cosmic ray-produced elements are present in a presolar grain, we can tell how long it was exposed to cosmic rays, which tells us how old it is."
Enough neon-21 had accumulated in the Murchison meteorite that the oldest parts of it were found to be older than 5.5 billion years old. Most of the grains, however, were around 4.6 to 4.9 billion years old, a time that predates the formation of the Sun 4.6 billion years ago.
Presolar grains are formed when material made in stars is shed and thrown off from dying stars, where they go on to mix and mingle with interstellar material. The oldest grains in the Murchison meteorite, therefore, were created in an ancient star that predates 5.5 billion years ago.
The researchers reckon parts of the grains started off in a star that formed seven billion years ago, during a time when part of the Milky Way was experiencing higher levels of star formation than today.
"Some people think that the star formation rate of the galaxy is constant," Heck said. "But thanks to these grains, we now have direct evidence for a period of enhanced star formation in our galaxy seven billion years ago with samples from meteorites. This is one of the key findings of our study."

- Mars' water was mineral-rich and salty

New study finds surface waters on early Mars may have been habitable for microbial life

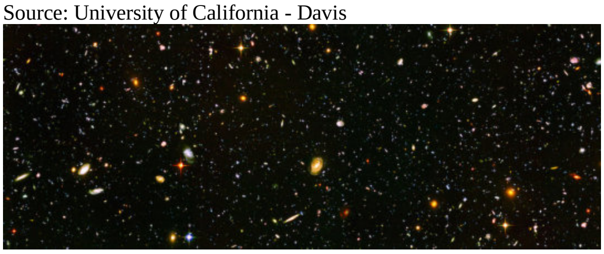
Date: January 21, 2020
Source: Tokyo Institute of Technology

Presently, Earth is the only known location where life exists in the Universe. This year the Nobel Prize in physics was awarded to three astronomers who proved, almost 20 years ago, that planets are common around stars beyond the solar system. Life comes in various forms, from cell-phone-toting organisms like humans to the ubiquitous micro-organisms that inhabit almost every square inch of the planet Earth, affecting almost everything that happens on it. It will likely be some time before it is possible to measure or detect life beyond the solar system, but the solar system offers a host of sites that might get a handle on how hard it is for life to start.
Mars is at the top of this list for two reasons. First, it is relatively close to Earth compared to the moons of Saturn and Jupiter (which are also considered good candidates for discovering life beyond Earth in the solar system, and are targeted for exploration in the coming decade). Second, Mars is extremely observable because it lacks a thick atmosphere like Venus, and so far, there are pretty good evidence that Mars' surface temperature and pressure hovers around the

point liquid water -- considered essential for life -- can exist. Further, there is good evidence in the form of observable river deltas, and more recent measurements made on Mars' surface, that liquid water did in fact flow on Mars billions of years ago.
Scientists are becoming increasingly convinced that billions of years Mars was habitable. Whether it was in fact inhabited, or is still inhabited, remains hotly debated. To better constrain these questions, scientists are trying to understand the kinds of water chemistry that could have generated the minerals observed on Mars today, which were produced billions of years ago.
Salinity (how much salt was present), pH (a measure of how acidic the water was), and redox state (roughly a measure of the abundance of gases such as hydrogen [H_2, which are termed reducing environments] or oxygen [O_2, which are termed oxidising environments; the two types are generally mutually incompatible]) are fundamental properties of natural waters. As an example, Earth's modern atmosphere is highly oxygenated (containing large amounts of O_2), but one need only dig a few inches into the bottom of a beach or lake today on Earth to find environments which are highly reduced.
Recent remote measurements on Mars suggest its ancient environments may provide clues about Mars' early habitability. Specifically, the properties of pore water within sediments apparently deposited in lakes in Gale Crater on Mars suggest these sediments formed in the presence of liquid water which was of a pH close to that of Earth's modern oceans.
Earth's oceans are of course host to myriad forms of life; thus, it seems compelling that Mars' early surface environment was a place contemporary Earth life could have lived, but it remains a mystery as to why evidence of life on Mars is so hard to find.

- Taking the temperature of dark matter

Date: January 15, 2020
Source: University of California - Davis



Distant galaxies (stock image; elements furnished by NASA).

Credit: © allexxandarx / Adobe Stock

Warm, cold, just right? Physicists at the University of California, Davis are taking the temperature of dark matter, the mysterious substance that makes up about a quarter of our universe.

We have very little idea of what dark matter is and physicists have yet to detect a dark matter particle. But we do know that the gravity of clumps of dark matter can distort light from distant objects. Chris Fassnacht, a physics professor at UC Davis and colleagues are using this distortion, called gravitational lensing, to learn more about the properties of dark matter.

The standard model for dark matter is that it is 'cold,' meaning that the particles move slowly compared to the speed of light, Fassnacht said. This is also tied to the mass of dark matter particles. The lower the mass of the particle, the 'warmer' it is and the faster it will move.

The model of cold (more massive) dark matter holds at very large scales, Fassnacht said, but doesn't work so well on the scale of individual galaxies. That's led to other models including 'warm' dark matter with lighter, faster-moving particles. 'Hot' dark matter with particles moving close to the speed of light has been ruled out by observations.

Former UC Davis graduate student Jen-Wei Hsueh, Fassnacht and colleagues used gravitational lensing to put a limit on the warmth and therefore the mass of dark matter. They measured the brightness of seven distant gravitationally lensed quasars to look for changes caused by additional intervening blobs of dark matter and used these results to measure the size of these dark matter lenses.

If dark matter particles are lighter, warmer and more rapidly-moving, then they will not form structures below a certain size, Fassnacht said.

"Below a certain size, they would just get smeared out," he said.

The results put a lower limit on the mass of a potential dark matter particle while not ruling out cold dark matter, he said. The team's results represent a major improvement over a previous analysis, from 2002, and are comparable to recent results from a team at UCLA.

Fassnacht hopes to continue adding lensed objects to the survey to improve the statistical accuracy.

"We need to look at about 50 objects to get a good constraint on how warm dark matter can be," he said.

A paper describing the work is published in the *Monthly Notices of the Royal Astronomical Society*. Additional co-authors are: W. Enzi, S. Vegetti and G. Despali, Max Planck Institute for Astrophysics, Garching, Germany; M. W. Auger, Institute of Astronomy, University of Cambridge, U.K.; L. V. E. Koopmans, Kapteyn Astronomical Institute, University of Groningen, The Netherlands and J. P. McKean, Netherlands Institute for Radio Astronomy. The work was supported by the National Science Foundation, the Netherlands Organization for Scientific Research and the Chinese Academy of Sciences.

- Astronomers detect large amounts of oxygen in ancient star's atmosphere

Date: January 23, 2020
Source: W. M. Keck Observatory

An international team of astronomers from the University of California San Diego, the Instituto de Astrofísica de Canarias (IAC), and the University of Cambridge have detected large amounts of oxygen in the atmosphere of one of the oldest and most elementally depleted stars known -- a "primitive star" scientists call J0815+4729.

This new finding, which was made using W. M. Keck Observatory on Maunakea in Hawaii to analyse the chemical makeup of the ancient star, provides an important clue on how oxygen and other important elements were produced in the first generations of stars in the universe.

The results are published in the January 21, 2020 edition of The *Astrophysical Journal Letters*.

"This result is very exciting. It tells us about some of the earliest times in the universe by using stars in our cosmic back yard," said Keck Observatory Chief Scientist John O'Meara. "I look forward to seeing more measurements like this one so we can better understand the earliest seeding of oxygen and other elements throughout the young universe."

Oxygen is the third most abundant element in the universe after hydrogen and helium, and is essential for all forms of life on Earth, as the chemical basis of respiration and a building block of carbohydrates. It is also the main elemental component of the Earth's crust. However, oxygen didn't exist in the early universe; it is created through nuclear fusion reactions that occur deep inside the most massive stars, those with masses roughly 10 times the mass of the Sun or greater.

Tracing the early production of oxygen and other elements requires studying the oldest stars still in existence. J0815+4729 is one such star; it resides over 5,000 light years away toward the constellation Lynx.

"Stars like J0815+4729 are referred to as halo stars," explained UC San Diego astrophysicist Adam Burgasser, a co-author of the study. "This is due to their roughly spherical distribution around the Milky Way, as opposed to the more familiar flat disk of younger stars that include the Sun."

Halo stars like J0815+4729 are truly ancient stars, allowing astronomers a peek into element production early in the history of the universe.

The research team observed J0815+4729 using Keck Observatory's High-Resolution Echelle Spectrometer (HIRES) on the 10m Keck I telescope. The data, which required more than five hours of staring at the star over a single night, were used to measure the abundances of 16 chemical species in the star's atmosphere, including oxygen.

"The primitive composition of the star indicates that it was formed during the first hundred of millions of years after the Big Bang, possibly from the material expelled from the first supernovae of the Milky Way," said Jonay González Hernández, Ramón y Cajal postdoctoral researcher and lead author of the study.

Keck Observatory's HIRES data of the star revealed a very unusual chemical composition. While it has relatively large amounts of carbon, nitrogen, and oxygen -- approximately 10, 8, and 3 percent of the abundances measured in the Sun -- other elements like calcium and iron have abundances around one millionth that of the Sun.

"Only a few such stars are known in the halo of our galaxy, but none have such an enormous amount of carbon, nitrogen, and oxygen compared to their iron content," said David Aguado, a postdoctoral researcher at the University of Cambridge and co-author of the study.

The search for stars of this type involves dedicated projects that sift through hundreds of thousands of stellar spectra to uncover a few rare sources like J0815+4729, then follow-up observations to measure their chemical composition. This star was first identified in data obtained with the Sloan Digital Sky Survey (SDSS), then characterized by the IAC team in 2017 using the Grand Canary Telescope in La Palma, Spain.

"Thirty years ago, we started at the IAC to study the presence of oxygen in the oldest stars of the Galaxy; those results had already indicated that this element was produced enormously in the first generations of supernovae. However, we could not imagine that we would find a case of enrichment as spectacular as that of this star," noted Rafael Rebolo, IAC director and co-author of the study.

- Inner complexity of Saturn moon, Enceladus, revealed

Enceladus' subsurface ocean composition hints at habitable conditions

Date: January 22, 2020

Source: Southwest Research Institute

A Southwest Research Institute team developed a new geochemical model that reveals that carbon dioxide (CO_2) from within Enceladus, an ocean-harbouring moon of Saturn, may be controlled by chemical reactions at its seafloor. Studying the plume of gases and frozen sea spray released through cracks in the moon's icy surface suggests an interior more complex than previously thought.

"By understanding the composition of the plume, we can learn about what the ocean is like, how it got to be this way and whether it provides environments where life as we know it could survive," said SwRI's Dr. Christopher Glein, lead author of a paper in *Geophysical Research Letters* outlining the research. "We came up with a new technique for analysing the plume composition to estimate the concentration of dissolved CO_2 in the ocean. This enabled modelling to probe deeper interior processes."

Analysis of mass spectrometry data from NASA's Cassini spacecraft indicates that the abundance of CO_2 is best explained by geochemical reactions between the moon's rocky core and liquid water from its subsurface ocean. Integrating this information with previous discoveries of silica and molecular hydrogen (H_2) points to a more complex, geochemically diverse core.

"Based on our findings, Enceladus appears to demonstrate a massive carbon sequestration experiment," Glein said. "On Earth, climate scientists are exploring whether a similar process can be utilized to mitigate industrial emissions of CO_2. Using two different data sets, we derived CO_2 concentration ranges that are intriguingly similar to what would be expected from the dissolution and formation of certain mixtures of silicon- and carbon-bearing minerals at the seafloor."

Another phenomenon that contributes to this complexity is the likely presence of hydrothermal vents inside Enceladus. At Earth's ocean floor, hydrothermal vents emit hot, energy-rich, mineral-laden fluids that allow unique ecosystems teeming with unusual creatures to thrive.

"The dynamic interface of a complex core and seawater could potentially create energy sources that might support life," said SwRI's Dr. Hunter Waite, principal investigator of Cassini's Ion Neutral Mass Spectrometer (INMS). "While we have not found evidence of the presence of microbial life in the ocean of Enceladus, the growing evidence for chemical disequilibrium offers a tantalizing hint that habitable conditions could exist beneath the moon's icy crust."

The scientific community continues reaping the benefits of Cassini's close flyby of Enceladus on Oct. 28, 2015, prior to the end of the mission. INMS detected H_2 as the spacecraft flew through the plume, and a different instrument had earlier detected tiny particles of silica, two chemicals that are considered to be markers for hydrothermal processes.

"Distinct sources of observed CO_2, silica and H_2 imply mineralogically and thermally diverse environments in a heterogeneous rocky core," Glein said. "We suggest that the core is composed of a carbonated upper layer and a serpentinized interior." Carbonates commonly occur as sedimentary rocks such as limestone on Earth, while serpentine minerals are formed from igneous seafloor rocks that are rich in magnesium and iron.

It is proposed that hydrothermal oxidation of reduced iron deep in the core creates H_2, while hydrothermal activity intersecting quartz-bearing carbonated rocks produces silica-rich fluids. Such rocks also have potential to influence the CO_2 chemistry of the ocean via low-temperature reactions involving silicates and carbonates at the seafloor.

"The implications for possible life enabled by a heterogeneous core structure are intriguing," said Glein. "This model could explain how planetary differentiation and alteration processes create chemical (energy) gradients needed by subsurface life."

- The salt of the comet

Date: January 21, 2020
Source: University of Bern

More than 30 years ago, the European comet mission Giotto flew past Halley's comet. The Bernese ion mass spectrometer IMS, led by Prof. em. Hans Balsiger, was on board. A key finding from the measurements taken by this instrument was that there appeared to be a lack of nitrogen in Halley's coma -- the nebulous covering of comets which forms when a comet passes close to the sun. Although nitrogen (N) was discovered in the form of ammonia (NH3) and hydrocyanic acid (HCN), the incidence was far removed from the expected cosmic incidence. More than 30 years later, researchers have solved this mystery thanks to a happy accident. This is a result of the analysis of data from the Bernese mass spectrometer ROSINA, which collected data on the comet 67P/Churyumov-Gerasimenko, called Chury for short, on board the ESA space probe Rosetta.

Risky flight through the comet Chury's dust cloud

Less than a month before the end of the Rosetta mission, the space probe was just 1.9 km above the surface of Chury as it flew through a dust cloud from the comet. This resulted in a direct impact of dust in the ion source of the mass spectrometer ROSINA-DFMS (Rosetta Orbiter Sensor for Ion and Neutral Analysis-Double Focusing Mass Spectrometer), led by the University of Bern. Kathrin Altwegg, lead researcher on ROSINA and co-author of the new study published today in the journal *Nature Astronomy*, says: "This dust almost destroyed our instrument and confused Rosetta's position control."

Thanks to the flight through the dust cloud, it was possible to detect substances which normally remain in the cold environment of the comet on the dust particles and therefore cannot be measured. The amount of particles, some of which had never before been measured on a comet, was astonishing. In particular, the incidence of ammonia, the chemical compound of nitrogen and hydrogen with the formula NH3, was suddenly many times greater. "We came up with the idea that the incidence of ammonia in the ROSINA data could potentially be traced back to the occurrence of ammonium salts," explains Altwegg. "As a salt, ammonia has a much higher evaporation temperature than ice and is therefore mostly present in the form of a solid in the cold environment of a comet. It has not been possible to measure these solids either through remote sensing with telescopes or on the spot until now."

Ammonium salt and its role in the emergence of life

Extensive laboratory work was needed in order to prove the presence of these salts in cometary ice. "The ROSINA team has found traces of five different ammonium salts: ammonium chloride, ammonium cyanide, ammonium cyanate, ammonium formate and ammonium acetate," says the chemist on the ROSINA team and co-author of the current study, Dr. Nora Hänni. "Until now, the apparent absence of nitrogen on comets was a mystery. Our study now shows that it is very probable that nitrogen is present on comets, namely in the form of ammonium salts," Hänni continues.

The ammonium salts discovered include several astrobiologically relevant molecules which may result in the development of urea, amino acids, adenine and nucleotides. Kathrin Altwegg says: "This is definitely a further indication that comet impacts may be linked with the emergence of life on Earth."

- Scientists measure the evolving energy of a solar flare's explosive first minutes

Date: January 17, 2020
Source: New Jersey Institute of Technology

Toward the end of 2017, a massive new region of magnetic field erupted on the Sun's surface next to an existing sunspot. The powerful collision of magnetic energy produced a series of potent solar flares, causing turbulent space weather conditions at Earth. These were the first flares to be captured, in their moment-by-moment progression, by NJIT's then recently opened Expanded Owens Valley Solar Array (EOVSA) radio telescope.

In research published in the journal *Science*, the solar scientists who recorded those images have pinpointed for the first time ever exactly when and where the explosion released the energy that heated spewing plasma to energies equivalent to 1 billion degrees in temperature. With data collected in the microwave spectrum, they have been able to provide quantitative measurements of the evolving magnetic field strength directly following the flare's ignition and have tracked its conversion into other energy forms -- kinetic, thermal and super thermal -- that power the flare's explosive 5-minute trip through the corona.

To date, these changes in the corona's magnetic field during a flare or other large-scale eruption have been quantified only indirectly, from extrapolations, for example, of the magnetic field measured at the photosphere -- the surface layer of the Sun seen in white light. These extrapolations do not permit precise measurements of the dynamic local changes of the magnetic field in the locations and at time scales short enough to characterize the flare's energy release.

"We have been able to pinpoint the most critical location of the magnetic energy release in the corona," said Gregory Fleishman, a distinguished research professor of physics in NJIT's Centre for Solar-Terrestrial Research and author of the paper. "These are the first images that capture the microphysics of a flare -- the detailed chain of processes that occur on small spatial and time scales that enable the energy conversion."

By measuring the decline in magnetic energy, and the simultaneous strength of the electric field in the region, they are able to show that the two concord with the law of energy conservation are thus able to quantify the particle acceleration that powers the solar flare, including the associated eruption and plasma heating.

These fundamental processes are the same as those occurring in the most powerful astrophysical sources, including gamma ray bursts, as well as in laboratory experiments of interest to both basic research and the generation of practical fusion energy.

With 13 antennas working together, EOVSA takes pictures at hundreds of frequencies in the 1-18 GHz range, including optical, ultraviolet, X-rays and radio wavelengths, within a second. This enhanced ability to peer into the mechanics of flares opens new pathways to investigate the most powerful eruptions in our solar system, which are ignited by the reconnection of magnetic field lines on the Sun's surface and powered by stored energy in its corona.

"Microwave emission is the only mechanism that is sensitive to the coronal magnetic field environment, so the unique, high-cadence EOVSA microwave spectral observations are the key to enabling this discovery of rapid changes in the magnetic field," noted Dale Gary, a distinguished professor of physics at NJIT, EOVSA's director and a co-author of the paper. "The measurement is possible because the high-energy electrons traveling in the coronal magnetic field dominantly emit their magnetic-sensitive radiation in the microwave range."

Before EOVSA's observations, there was no way to see the vast region of space over which high-energy particles are accelerated and then become available for further acceleration by the powerful shock waves driven by the flare eruption, which, if directed at Earth, can destroy spacecraft and endanger astronauts.

"The connection of the flare-accelerated particles to those accelerated by shocks is an important piece in our understanding of which events are benign and which pose a serious threat," Gary said.

Just over two years after the expanded array began operating, it is automatically generating microwave images of the Sun and making them available to the scientific community on a day-to-day basis. As solar activity increases over the course of the 11-year solar cycle, they will be used to provide the first daily coronal magnetograms, maps of magnetic field strength 1,500 miles above the Sun's surface.

- The core of massive dying galaxies already formed 1.5 billion years after the Big Bang

Date: January 17, 2020
Source: University of Copenhagen

The most distant dying galaxy discovered so far, more massive than our Milky Way -- with more than a trillion stars -- has revealed that the 'cores' of these systems had formed already 1.5 billion years after the Big Bang, about 1 billion years earlier than previous measurements revealed. The discovery will add to our knowledge on the formation of the Universe more generally, and may cause the computer models astronomers use, one of the most fundamental tools, to be revised. The result was obtained in close collaboration with Masayuki Tanaka and his colleagues at the National Observatory of Japan is now published in two works in the *Astrophysical Journal Letters* and the *Astrophysical Journal*.

What is a "dead" galaxy?

Galaxies are broadly categorized as dead or alive: dead galaxies are no longer forming stars, while alive galaxies are still bright with star formation activity. A 'quenching' galaxy is a galaxy in the process of dying -- meaning its star formation is significantly suppressed. Quenching galaxies are not as bright as fully alive galaxies, but they are not as dark as dead galaxies. Researchers use this spectrum of brightness as the first line of identification when observing galaxies in the Universe.

The farthest dying galaxy discovered so far reveals remarkable maturity

A team of researchers of the Cosmic Dawn Centre at the Niels Bohr Institute and the National Observatory of Japan recently discovered a massive galaxy dying already 1.5 billion years after the Big Bang, the most distant of its kind. "Moreover, we found that its core seems already fully formed at that time," says Masayuki Tanaka, the author of the letter. "This result pairs up with the fact that, when these dying gigantic systems were still alive and forming stars, they might have not been that extreme compared with the average population of galaxies," adds Francesco Valentino, assistant professor at the Cosmic Dawn Centre at the Niels Bohr Institute and author of an article on the past history of dead galaxies appeared in the *Astrophysical Journal*.

Why do galaxies die? -- One of the biggest and still unanswered questions in astrophysics

"The suppressed star formation tells us that a galaxy is dying, sadly, but that is exactly the kind of galaxy we want to study in detail to understand why it dies," continues Valentino. One of the biggest questions that astrophysics still has not answered is how a galaxy goes from being star-forming to being dead. For instance, the Milky Way is still alive and slowly forming new stars, but not too far away (in astronomical terms), the central galaxy of the Virgo cluster -- M87 -- is dead and completely different. Why is that? "It might have to do with the presence of gigantic and active black hole at the centre of galaxies like M87" Valentino says.

Earth based telescopes find extremes -- but astronomers look for normality

One of the problems in observing galaxies in this much detail is that the telescopes available now on Earth are generally able to find only the most extreme systems. However, the key to describe the history of the Universe is held by the vastly more numerous populations of normal objects. "Since we are trying hard to discover this normality, the current observational limitations are an obstacle that has to be overcome."

The James Webb Telescope (JWST) represents hope for better data material in the near future

The new James Webb Space Telescope, scheduled for launch in 2021, will be able to provide the astronomers with data in a level of detail that should be able to map exactly this "normality." The methods developed in close collaboration between the Japanese team and the team at the Niels Bohr Institute have already proven to be successful, given the recent result. "This is significant, because it will enable us to look for the most promising galaxies from the start, when JWST gives us access to much higher quality data" Francesco Valentino explains.

Combining observations with the tool -- the computer models of the Universe

What has been found observationally is not too far away from what the most recent models predict. "Until very recently, we did not have many observations to compare with the models. However, the situation is in rapid evolution, and with JWST we will have valuable larger samples of ``normal" galaxies in a few years. The more galaxies we can study, the better we are able to understand the properties or situations leading to a certain state -- if the galaxy is alive, quenching or dead. It is basically a question of writing the history of the Universe correctly, and in greater and greater detail. At the same time, we are tuning the computer models to take our observations into account, which will be a huge improvement, not just for our branch of work, but for astronomy in general" Francesco Valentino explains.

The Cosmic Dawn Centre is supported by the Danish National Research Foundation and Francesco Valentino's research by a grant from the Carlsberg Foundation: "Galaxies: Rise and Death."

- Here and gone: Outbound comets are likely of alien origin

Date: January 17, 2020
Source: National Institutes of Natural Sciences

Astronomers at the National Astronomical Observatory of Japan (NAOJ) have analysed the paths of two objects heading out of the Solar System forever and determined that they also most likely originated from outside of the Solar System. These results improve our understanding of the outer Solar System and beyond.

Not all comets follow closed orbits around the Sun. Some fly through the Solar System at

high speed before heading out to interstellar space, never to return. Although it is simple to calculate where these comets are going, determining where they came from is more difficult.
There are two possible scenarios. In the first scenario, a comet is originally in a stable orbit far from the Sun, but gravitational interactions with a passing object pull the comet out of its orbit. The comet then falls into the inner Solar System where it can be observed before being flung out into interstellar space. In the second scenario, a comet originates someplace very far away, perhaps a different planetary system, and as it flies through interstellar space, by random chance it passes through the Solar System once before continuing on its way.
Arika Higuchi and Eiichiro Kokubo at NAOJ calculated the types of trajectories which would typically be expected in each scenario. The team then compared their calculations to observations of two unusual outbound objects, 1I/'Oumuamua discovered in 2017 and 2I/Borisov discovered in 2019. They found that the interstellar origin scenario provides the better match for the paths of both objects. The team also showed that it is possible for gas-giant-sized bodies passing close to the Solar System to destabilize long-orbit comets and set them on paths similar to the paths of these two objects. Survey observations have not uncovered any gas-giant-sized bodies which can be linked to these two outbound objects, but further study, both theoretical and observational, of small interstellar objects is needed to better determine the origins of these objects.

- When the Milky Way collided with dwarf galaxy Gaia-Enceladus

Date: January 15, 2020
Source: Max-Planck-Gesellschaft

The dwarf galaxy Gaia-Enceladus collided with the Milky Way probably approximately 11.5 billion years ago. A team of researchers including scientists from the Max Planck Institute for Solar System Research in Germany for the first time used a single star affected by the collision as a clue for dating. Using observational data from ground-based observatories and space telescopes, the scientists led by the University of Birmingham were able to determine the age of the star and the role it played in the collision. The research group describes its results in today's issue of *Nature Astronomy*.
On cosmic time scales, the colliding and merging of galaxies is not uncommon. Even if both galaxies involved are of very different sizes, such a collision leaves clear traces in the larger one. For example, the smaller galaxy introduces stars with a different chemical composition, the motion of many stars is altered, and myriads of new stars are formed.
The Milky Way has encountered several other galaxies in its 13.5 billion-year history. One of them is the dwarf galaxy Gaia-Enceladus. To understand how this event affected our galaxy and changed it permanently, it is important to reliably date the collision. To this end, the researchers led by Prof. Dr. Bill Chaplin of the University of Birmingham turned their attention to a single star: Indi is found in the constellation Indus; with an apparent brightness comparable to that of Uranus, it is visible even to the naked eye and can be easily studied in detail.
"The space telescope TESS collected data from Indi already in its first month of scientific operation," says Dr. Saskia Hekker, head of the research group "Stellar Ages and Galactic Evolution (SAGE)" at MPS and co-author of the new study. The space telescope was launched in 2018 to perform a full-sky survey and characterize as many stars as possible. "The data from TESS allow us to determine the age of the star very accurately," Hekker adds.
Moreover, Indi provided clues on the history of the collision with the dwarf galaxy Gaia-Enceladus. To reconstruct its role in the collision, the research group evaluated numerous data sets on Indi obtained with the help of the spectrographs HARPS (High Accuracy Radial velocity Planet Searcher) and FEROS (Fiber-fed Extended Range Optical Spectrograph) of the European Southern Observatory, the Galaxy Evolution Experiment of the Apache Point Observatory in New Mexico, and ESA's Gaia Space Telescope. This allowed them to specify both the chemical composition of the star and its movement within the galaxy with great precision.
The cosmic detective work produced a clear picture: v Indi has been part of the halo, the outer region of the Milky Way, and the collision changed its trajectory. "Since the motion of v Indi was affected by the collision, it must have taken place when the star was already formed," Chaplin explains the line of

argument. The age of the star therefore puts a constraint on the time of the collision.
To determine the age of a star, researchers use its natural oscillations, which can be observed as brightness fluctuations. "Similar to the way seismic waves on Earth allow conclusions about the interior of our planet, stellar oscillations help us to reveal the internal structure and composition of the star and thus its age," explains co-author Dr. Nathalie Themessl.
The calculations carried out by MPS researchers and other research groups showed that with a probability of 95 percent the galaxy merger must have occurred 13.2 billion years ago. With a probability of 68 percent, the collision took place approximately 11.5 billion years ago. "This chronological classification not only helps us to understand how the collision changed our galaxy," says Hekker. "It also gives us a sense, of how collisions and mergers impacted other galaxies and influenced their evolution."

- Astronomers reveal interstellar thread of one of life's building blocks

ALMA and Rosetta map the journey of phosphorus
Date: January 15, 2020
Source: ESO

Phosphorus, present in our DNA and cell membranes, is an essential element for life as we know it. But how it arrived on the early Earth is something of a mystery. Astronomers have now traced the journey of phosphorus from star-forming regions to comets using the combined powers of ALMA and the European Space Agency's probe Rosetta. Their research shows, for the first time, where molecules containing phosphorus form, how this element is carried in comets, and how a particular molecule may have played a crucial role in starting life on our planet.
"Life appeared on Earth about 4 billion years ago, but we still do not know the processes that made it possible," says Víctor Rivilla, the lead author of a new study published today in the journal *Monthly Notices of the Royal Astronomical Society*. The new results from the Atacama Large Millimetre/Submillimetre Array (ALMA), in which the European Southern Observatory (ESO) is a partner, and from the ROSINA instrument on board Rosetta, show that phosphorus monoxide is a key piece in the origin-of-life puzzle.
With the power of ALMA, which allowed a detailed look into the star-forming region AFGL 5142, astronomers could pinpoint where phosphorus-bearing molecules, like phosphorus monoxide, form. New stars and planetary systems arise in cloud-like regions of gas and dust in between stars, making these interstellar clouds the ideal places to start the search for life's building blocks.
The ALMA observations showed that phosphorus-bearing molecules are created as massive stars are formed. Flows of gas from young massive stars open up cavities in interstellar clouds. Molecules containing phosphorus form on the cavity walls, through the combined action of shocks and radiation from the infant star. The astronomers have also shown that phosphorus monoxide is the most abundant phosphorus-bearing molecule in the cavity walls.
After searching for this molecule in star-forming regions with ALMA, the European team moved on to a Solar System object: the now-famous comet 67P/Churyumov-Gerasimenko. The idea was to follow the trail of these phosphorus-bearing compounds. If the cavity walls collapse to form a star, particularly a less-massive one like the Sun, phosphorus monoxide can freeze out and get trapped in the icy dust grains that remain around the new star. Even before the star is fully formed, those dust grains come together to form pebbles, rocks and ultimately comets, which become transporters of phosphorus monoxide.
ROSINA, which stands for Rosetta Orbiter Spectrometer for Ion and Neutral Analysis, collected data from 67P for two years as Rosetta orbited the comet. Astronomers had found hints of phosphorus in the ROSINA data before, but they did not know what molecule had carried it there. Kathrin Altwegg, the Principal Investigator for Rosina and an author in the new study, got a clue about what this molecule could be after being approached at a conference by an astronomer studying star-forming regions with ALMA: "She said that phosphorus monoxide would be a very likely candidate, so I went back to our data and there it was!"
This first sighting of phosphorus monoxide on a comet helps astronomers draw a connection between star-forming regions, where the molecule is created, all the way to Earth.
"The combination of the ALMA and ROSINA data has revealed a sort of chemical thread during the whole process of star formation, in which phosphorus monoxide plays the

dominant role," says Rivilla, who is a researcher at the Arcetri Astrophysical Observatory of INAF, Italy's National Institute for Astrophysics.

"Phosphorus is essential for life as we know it," adds Altwegg. "As comets most probably delivered large amounts of organic compounds to the Earth, the phosphorus monoxide found in comet 67P may strengthen the link between comets and life on Earth."

This intriguing journey could be documented because of the collaborative efforts between astronomers. "The detection of phosphorus monoxide was clearly thanks to an interdisciplinary exchange between telescopes on Earth and instruments in space," says Altwegg.

Leonardo Testi, ESO astronomer and ALMA European Operations Manager, concludes: "Understanding our cosmic origins, including how common the chemical conditions favourable for the emergence of life are, is a major topic of modern astrophysics. While ESO and ALMA focus on the observations of molecules in distant young planetary systems, the direct exploration of the chemical inventory within our Solar System is made possible by ESA missions, like Rosetta. The synergy between world leading ground-based and space facilities, through the collaboration between ESO and ESA, is a powerful asset for European researchers and enables transformational discoveries like the one reported in this paper."

This research was presented in a paper to appear in *Monthly Notices of the Royal Astronomical Society*.

- ❖ X-rays and gravitational waves will combine to illuminate massive black hole collisions

Date: January 14, 2020
Source: University of Birmingham

A new study by a group of researchers at the University of Birmingham has found that collisions of supermassive black holes may be simultaneously observable in both gravitational waves and X-rays at the beginning of the next decade.

The European Space Agency (ESA) has recently announced that its two major space observatories of the 2030s will have their launches timed for simultaneous use. These missions, Athena, the next generation X-ray space telescope and LISA, the first space-based gravitational wave observatory, will be coordinated to begin observing within a year of each other and are likely to have at least four years of overlapping science operations.

According to the new study, published this week in *Nature Astronomy*, ESA's decision will give astronomers an unprecedented opportunity to produce multi-messenger maps of some of the most violent cosmic events in the Universe, which have not been observed so far and which lie at the heart of long-standing mysteries surrounding the evolution of the Universe.

They include the collision of supermassive black holes in the core of galaxies in the distant universe and the "swallowing up" of stellar compact objects such as neutron stars and black holes by massive black holes harboured in the centres of most galaxies.

The gravitational waves measured by LISA will pinpoint the ripples of space time that the mergers cause while the X-rays observed with Athena reveal the hot and highly energetic physical processes in that environment.

Combining these two messengers to observe the same phenomenon in these systems would bring a huge leap in our understanding of how massive black holes and galaxies co-evolve, how massive black holes grow their mass and accrete, and the role of gas around these black holes.

These are some of the big unanswered questions in astrophysics that have puzzled scientists for decades.

Dr Sean McGee, Lecturer in Astrophysics at the University of Birmingham and a member of both the Athena and LISA consortiums, led the study. He said, "The prospect of simultaneous observations of these events is uncharted territory, and could lead to huge advances. This promises to be a revolution in our understanding of supermassive black holes and how they growth within galaxies."

Professor Alberto Vecchio, Director of the Institute for Gravitational Wave Astronomy, University of Birmingham, and a co-author on the study, said: "I have worked on LISA for twenty years and the prospect of combining forces with the most powerful X-ray eyes ever designed to look right at the centre of galaxies promises to make this long haul even more rewarding. It is difficult to predict exactly what we're going to discover: we should just buckle up, because it is going to be quite a ride."

During the life of the missions, there may be as many as 10 mergers of black holes with masses of 100,000 to 10,000,000 times the

mass of the sun that have signals strong enough to be observed by both observatories. Although due to our current lack of understanding of the physics occurring during these mergers and how frequently they occur, the observatories could observe many more or many fewer of these events. Indeed, these are questions which will be answered by the observations.
In addition, LISA will detect the early stages of stellar mass black holes mergers which will conclude with the detection in ground based gravitational wave observatories. This early detection will allow Athena to be observing the binary location at the precise moment the merger will occur.

- Connecting the dots in the sky could shed new light on dark matter

Date: January 13, 2020
Source: DOE/SLAC National Accelerator Laboratory

Astrophysicists have come a step closer to understanding the origin of a faint glow of gamma rays covering the night sky. They found that this light is brighter in regions that contain a lot of matter and dimmer where matter is sparser -- a correlation that could help them narrow down the properties of exotic astrophysical objects and invisible dark matter.
The glow, known as unresolved gamma-ray background, stems from sources that are so faint and far away that researchers can't identify them individually. Yet, the fact that the locations where these gamma rays originate match up with where mass is found in the distant universe could be a key puzzle piece in identifying those sources.
"The background is the sum of a lot of things 'out there' that produce gamma rays. Having been able to measure for the first time its correlation with gravitational lensing -- tiny distortions of images of far galaxies produced by the distribution of matter -- helps us disentangle them," said Simone Ammazzalorso from the University of Turin and the National Institute for Nuclear Physics (INFN) in Italy, who co-led the analysis.
The study used one year of data from the Dark Energy Survey (DES), which takes optical images of the sky, and nine years of data from the Fermi Gamma-ray Space Telescope, which observes cosmic gamma rays while it orbits the Earth.
"What's really intriguing is that the correlation we measured doesn't completely match our expectations," said Panofsky fellow Daniel Gruen from the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) at the Department of Energy's SLAC National Accelerator Laboratory and Stanford University, who led the analysis for the DES collaboration. "This could mean that we either need to adjust our existing models for objects that emit gamma rays, or it could hint at other sources, such as dark matter."
The study was accepted today for publication in *Physical Review Letters*.

Two sensitive 'eyes' on the sky

Gamma radiation, the most energetic form of light, is produced in a wide range of cosmic phenomena -- often extremely violent ones, such as exploding stars, dense neutron stars rotating at high speeds and powerful beams of particles shooting out of active galaxies whose central supermassive black holes gobble up matter.
Another potential source is invisible dark matter, which is believed to make up 85 percent of all matter in the universe. It could produce gamma rays when dark matter particles meet and destroy each other in space.
The Large Area Telescope (LAT) onboard the Fermi spacecraft is a highly sensitive "eye" for gamma radiation, and its data provide a detailed map of gamma-ray sources in the sky.
But when scientists subtract all the sources they already know, their map is far from empty; it still contains a gamma-ray background whose brightness varies from region to region.
"Unfortunately, gamma rays don't have a label that would tell us where they came from," Gruen said. "That's why we need additional information to unravel their origin."
That's where DES comes in. With its 570-megapixel Dark Energy Camera, mounted on the Victor M. Blanco 4-meter Telescope at the Cerro Tololo Inter-American Observatory in Chile, it snaps images of hundreds of millions of galaxies. Their exact shapes tell researchers how the gravitational pull of matter bends light in the universe -- an effect that shows itself as tiny distortions in galaxy images, known as weak gravitational lensing. Based on these data, the DES researchers create the most detailed maps yet of matter in the cosmos.
In the new study, the scientists superimposed the Fermi and DES maps, which revealed that the two aren't independent. The unresolved gamma-ray background is more intense in

regions with more matter and less intense in regions with less matter.
"The result itself is not surprising. We expect that there are more gamma ray producing processes in regions that contain more matter, and we've been predicting this correlation for a while," said Nicolao Fornengo, one of Ammazzalorso's supervisors in Turin. "But now we've succeeded in actually detecting this correlation for the first time, and we can use it to understand what causes the gamma ray background."

Potential hint at dark matter

One of the most likely sources for the gamma-ray glow is very distant blazars -- active galaxies with supermassive black holes at their centres. As the black holes swallow surrounding matter, they spew high-speed jets of plasma and gamma rays that, if the jets point at us, are detected by the Fermi spacecraft.
Blazars would be the simplest assumption, but the new data suggest that a simple population of blazars might not be enough to explain the observed correlation between gamma rays and mass distribution, the researchers said.
"In fact, our models for emissions from blazars can fairly well explain the low-energy part of the correlation, but we see deviations for high-energy gamma rays," Gruen said. "This can mean several things: It could indicate that we need to improve our models for blazars or that the gamma rays could come from other sources."
One of these other sources could be dark matter. A leading theory predicts the mysterious stuff is made of weakly interacting massive particles, or WIMPs, which could annihilate each other in a flash of gamma rays when they collide. Gamma rays from certain matter-rich cosmic regions could therefore stem from these particle interactions.
The idea to look for gamma-ray signatures of annihilating WIMPs is not a new one. Over the past years, scientists have searched for them in various locations believed to contain a lot of dark matter, including the centre of the Milky Way and the Milky Way's companion galaxies. However, these searches haven't produced identifiable dark matter signals yet. The new results could be used for additional searches that test the WIMP hypothesis.

Planning next steps

Although the probability that the measured correlation is just a random effect is only about one in a thousand, the researchers need more data for a conclusive analysis.
"These results, connecting for the first time our maps of gamma rays and matter, are very interesting and have a lot of potential, but at the moment the connection is still relatively weak, and one has to interpret the data carefully," said KIPAC Director Risa Wechsler, who was not involved in the study.
One of the main limitations of the current analysis is the amount of available lensing data, Gruen said. "With data from 40 million galaxies, DES has already pushed this to a new level, and that's why we were able to do the analysis in the first place. But we need even better measurements," he said.
With its next data release, DES will provide lensing data for 100 million galaxies, and the future Large Synoptic Survey Telescope (LSST) will look at billions of galaxies in a much larger region of the sky.
"Our study demonstrates with actual data that we can use the correlation between the distributions of matter and gamma rays to learn more about what causes the gamma-ray background," Fornengo said. "With more DES data, LSST coming online and other projects like the Euclid space telescope on the horizon, we'll be able to go much deeper in our understanding of the potential sources."
Then, the scientists might be able to tell if some of that gamma-ray glow stems from dark matter's self-destruction.
DES is an international project with over 400 scientists from 25 institutions in 7 countries, who have come together to carry out the survey. Parts of the project were funded by DOE's Office of Science and the National Science Foundation. NASA's Fermi Gamma-ray Space Telescope is an international and multi-agency space observatory. The analysis used Fermi-LAT data that were publicly released by the international LAT collaboration.

- 'Cold Neptune' and two temperate super-Earths found orbiting nearby stars

Date: January 14, 2020
Source: Carnegie Institution for Science

A "cold Neptune" and two potentially habitable worlds are part of a cache of five newly discovered exoplanets and eight exoplanet candidates found orbiting nearby red dwarf stars, which are reported in *The Astrophysical Journal Supplement Series* by a team led by Carnegie's Fabo Feng and Paul Butler.

The two potentially habitable planets are orbiting GJ180 and GJ229A, which are among the nearest stars to our own Sun, making them prime targets for observations by next-generation space- and land-based telescopes. They are both super-Earths with at least 7.5 and 7.9 times our planet's mass and orbital periods of 106 and 122 days respectively.

The Neptune-mass planet -- found orbiting GJ433 at a distance at which surface water is likely to be frozen -- is probably the first of its kind that is a realistic candidate for future direct imaging.

"GJ 433 d is the nearest, widest, and coldest Neptune-like planet ever detected," Feng added.

The newfound worlds were discovered using the radial velocity method for finding planets, which takes advantage of the fact that not only does a star's gravity influence the planet orbiting it, but the planet's gravity also affects the star in turn. This creates tiny wobbles in the star's orbit that can be detected using advanced instruments. Due to their lower mass, red dwarfs are the primary class of stars around which terrestrial mass planets can be found using this technique.

Cooler and smaller than our Sun, red dwarfs -- also called M dwarfs -- are the most common stars in the galaxy and the primary class of stars known to host terrestrial planets. What's more, compared to other types of stars, red dwarfs can host planets at the right temperature to have liquid water on their surfaces on much closer orbits than those found in this so-called "habitable zone" around other types of stars.

"Many planets that orbit red dwarfs in the habitable zone are tidally locked, meaning that the period at which they spin around their axes is the same as the period at which they orbit their host star. This is similar to how our Moon is tidally locked to Earth, meaning that we only ever see one side of it from here. As a result, these exoplanets are a very cold permanent night on one side and very hot permanent day on the other -- not good for habitability," explained lead author Feng.

"GJ180d is the nearest temperate super-Earth to us that is not tidally locked to its star, which probably boosts its likelihood of being able to host and sustain life."

The other potentially habitable planet, GJ229Ac is the nearest temperate super-Earth to us located in a system in which the host star has a brown dwarf companion. Sometimes called failed stars, brown dwarfs are not able to sustain hydrogen fusion. The brown dwarf in this system, GJ229B, was one of the first brown dwarfs to be imaged. It is not known if they can host exoplanets on their own, but this planetary system is a perfect case study for how exoplanets form and evolve in a star-brown dwarf binary system.

"Our discovery adds to the list of planets that can potentially be directly imaged by the next generation of telescopes," Feng said.

"Ultimately, we are working toward the goal of being able to determine if planets orbiting nearby stars host life."

"We eventually want to build a map of all of the planets orbiting the nearest stars to our own Solar System, especially those that are potentially habitable," added Carnegie co-author Jeff Crane.

This research effort -- which also included Carnegie's Steve Shectman, John Chambers, Sharon Wang, Johanna Teske, Matías Díaz, and Ian Thompson, as well as Steve Vogt of U.C. Santa Cruz, Hugh Jones of University of Hertfordshire and Jennifer Burt of NASA's Jet Propulsion Laboratory -- culled and reanalysed data from the European Southern Observatory's Ultraviolet and Visual Echelle Spectrograph survey of 33 nearby red dwarf stars, which operated from 2000 to 2007 and was released in 2009.

"We have been led to this result by antique data," joked Butler.

Once targets were discovered in the UVES archives, the researchers used observations from three planet-hunting instruments to increase the precision of the data. The Carnegie Planet Finder Spectrograph (PFS) at our Las Campanas Observatory in Chile, ESO's High Accuracy Radial Velocity Planet Searcher (HARPS) at La Silla Observatory, and the High-Resolution Echelle Spectrometer (HIRES) at the Keck Observatory were all crucial to this effort.

"Combining the data from multiple telescopes increases the number of observations and the time baseline, and minimizes instrumental biases," Butler explained.

- How the solar system got its 'Great Divide,' and why it matters for life on Earth

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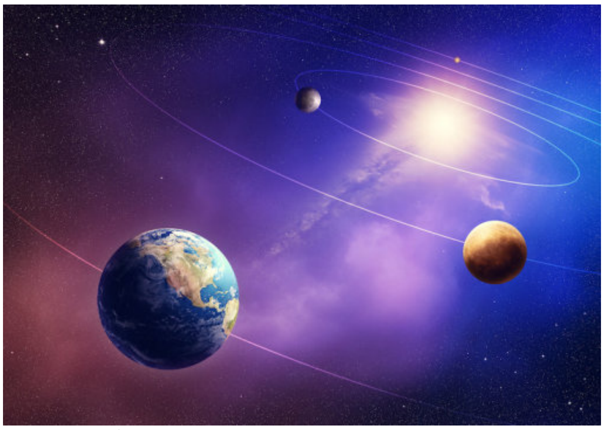

Illustration of inner solar system (stock image).
Credit: © JohanSwanepoel / Adobe Stock

Scientists, including those from the University of Colorado Boulder, have finally scaled the solar system's equivalent of the Rocky Mountain range.

In a study published today in *Nature Astronomy*, researchers from the United States and Japan unveil the possible origins of our cosmic neighbourhood's "Great Divide." This well-known schism may have separated the solar system just after the sun first formed.

The phenomenon is a bit like how the Rocky Mountains divide North America into east and west. On the one side are "terrestrial" planet, such as Earth and Mars. They are made up of fundamentally different types of materials than the more distant "jovians," such as Jupiter and Saturn.

"The question is: How do you create this compositional dichotomy?" said lead author Ramon Brasser, a researcher at the Earth-Life Science Institute (ELSI) at the Tokyo Institute of Technology in Japan. "How do you ensure that material from the inner and outer solar system didn't mix from very early on in its history?"

Brasser and co-author Stephen Mojzsis, a professor in CU Boulder's Department of Geological Sciences, think they have the answer, and it may just shed new light on how life originated on Earth.

A sun disk holds vital clues

The duo suggests that the early solar system was partitioned into at least two regions by a ring-like structure that formed a disk around the young sun. This disk might have held major implications for the evolution of planets and asteroids, and even the history of life on Earth.

"The most likely explanation for that compositional difference is that it emerged from an intrinsic structure of this disk of gas and dust," Mojzsis said.

Mojzsis noted that the Great Divide, a term that he and Brasser coined, does not look like much today. It is a relatively empty stretch of space that sits near Jupiter, just beyond what astronomers call the asteroid belt.

But you can still detect its presence throughout the solar system. Move sunward from that line, and most planets and asteroids tend to carry relatively low abundances of organic molecules. Go the other direction toward Jupiter and beyond, however, and a different picture emerges: Almost everything in this distant part of the solar system is made up of materials that are rich in carbon.

This dichotomy "was really a surprise when it was first found," Mojzsis said.

Many scientists assumed that Jupiter was the agent responsible for that surprise. The thinking went that the planet is so massive that it may have acted as a gravitational barrier, preventing pebbles and dust from the outer solar system from spiralling toward the sun.

But Mojzsis and Brasser were not convinced. The scientists used a series of computer simulations to explore Jupiter's role in the evolving solar system. They found that while Jupiter is big, it was probably never big enough early in its formation to entirely block the flow of rocky material from moving sunward.

"We banged our head against the wall," Brasser said. "If Jupiter wasn't the agent responsible for creating and maintaining that compositional dichotomy, what else could be?"

A solution in plain sight

For years, scientists operating an observatory in Chile called the Atacama Large Millimetre/submillimetre Array (ALMA) had noticed something unusual around distant stars: Young stellar systems were often surrounded by disks of gas and dust that, in infrared light, looked a bit like a tiger's eye.

If a similar ring existed in our own solar system billions of years ago, Brasser and Mojzsis reasoned, it could theoretically be responsible for the Great Divide.

That's because such a ring would create alternating bands of high- and low-pressure gas and dust. Those bands, in turn, might pull the solar system's earliest building blocks into several distinct sinks -- one that would have given rise to Jupiter and Saturn, and another Earth and Mars.

In the mountains, "the Great Divide causes water to drain one way or another," Mojzsis said. "It's similar to how this pressure bump would have divided material" in the solar system.

But, he added, there's a caveat: That barrier in space likely was not perfect. Some outer solar system material may still have climbed across the divide. And those fugitives could have been important for the evolution of our own world.

"Those materials that might go to the Earth would be those volatile, carbon-rich materials," Mojzsis said. "And that gives you water. It gives you organics."

The rest is Earth history.