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Astronomy & Physics Weekly News

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Top News

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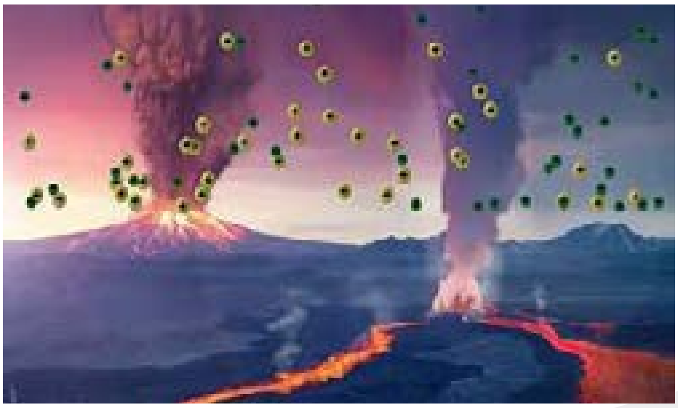
NASA finds planets of red dwarf stars may face oxygen loss in habitable zones



In this artist's concept, X-ray and extreme ultraviolet light from a young red dwarf star cause ions to escape from an exoplanet's atmosphere. Scientists have developed a model that estimates the oxygen ion escape rate on planets around red dwarfs, which plays an important role in determining an exoplanet's habitability. Image courtesy NASA Goddard/Conceptual Image Lab, Michael Lentz, animator/Genna Duberstein, producer.

The search for life beyond Earth starts in habitable zones, the regions around stars where conditions could potentially allow liquid water - which is essential for life as we know it - to pool on a planet's surface. New NASA research suggests some of these zones might not actually be able to support life due to frequent stellar eruptions - which spew huge amounts of stellar material and radiation out into space - from young red dwarf stars.

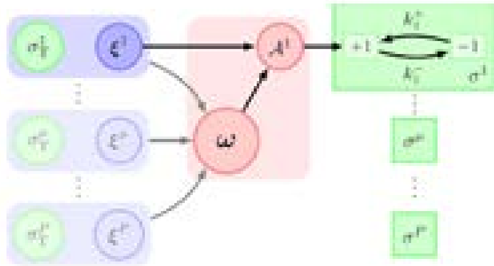
Now, an interdisciplinary team of NASA scientists wants to expand how habitable zones are defined, taking into account the impact of stellar activity, which can threaten an exoplanet's atmosphere with oxygen loss. This research was published in the Astrophysical Journal Letters on Feb. 6, 2017.

"If we want to find an exoplanet that can develop and sustain life, we must figure out which stars make the best parents," said Vladimir Airapetian, lead author of the paper and a solar scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "We're coming closer to understanding what kind of parent stars we need."

To determine a star's habitable zone, scientists have traditionally considered how much heat and light the star emits. Stars more massive than our sun produce more heat and light, so the habitable zone must be farther out. Smaller, cooler stars yield close-in habitable zones.

But along with heat and visible light, stars emit X-ray and ultraviolet radiation, and produce stellar eruptions such as flares and coronal mass ejections - collectively called space weather. One possible effect of this radiation is atmospheric erosion, in which high-energy particles drag atmospheric molecules - such as hydrogen and oxygen, the two ingredients for water - out into space. ...Read More...

The thermodynamics of learning



In this model of a neuron, the neuron learns by adjusting the weights of its connections with other neurons. Credit: Goldt et al. ©2017 American Physical Society

While investigating how efficiently the brain can learn new information, physicists have found that, at the neuronal level, learning efficiency is ultimately limited by the laws of thermodynamics—the same principles that limit the efficiency of many other familiar processes.

"The greatest significance of our work is that we bring the second law of thermodynamics to the analysis of neural networks," Sebastian Goldt at the University of Stuttgart, Germany, told Phys.org. "The second law is a very powerful statement about which transformations are possible—and learning is just a transformation of a neural network at the expense of energy. This makes our results quite general and takes us one step towards understanding the ultimate limits of the efficiency of neural networks."

Goldt and coauthor Udo Seifert have published a paper on their work in a recent issue of Physical Review Letters.

Since all brain activity is tied to the firing of billions of neurons, at the neuronal level, the question of "how efficiently can we learn?" becomes the question of "how efficiently can a neuron adjust its output signal in response to the patterns of input signals it receives from other neurons?" As neurons get better at firing in response to certain patterns, the corresponding thoughts are reinforced in our brains, as implied by the adage "fire together, wire together."

In the new study, the scientists showed that learning efficiency is bounded by the total entropy production of a neural network. They demonstrated that, the slower a neuron learns, the less heat and entropy it produces, increasing its efficiency. In light of this finding, the scientists introduced a new measure of learning efficiency based on energy requirements and thermodynamics.

As the results are very general, they can be applied to any learning algorithm that does not use feedback, such as those used in artificial neural networks.

"Having a thermodynamic perspective on neural networks gives us a new tool to think about their efficiency and gives us a new way to rate their performance," ...Read More....

Pure iron grains are rare in the universe

The researchers simulated supernova conditions by sending a rocket into sub-orbit where it was mostly free from the effect of gravity. The S-520-28 rocket was launched from JAXA's Uchinoura Space Center on Dec. 17, 2012. In the three years to follow, the researchers conducted additional micro-gravity experiments using aircraft to gather and analyze data. Image courtesy Kimura Y., et al., Pure iron grains are rare in the universe. Science Advances, Jan. 18, 2017.

Pure iron grains in interstellar space are far rarer than previously thought, shedding new light on the evolution history of matters in the universe. Scientists are unsure what form iron takes in outer space even though it is one of its most abundant refractory elements.

Extensive analysis of meteorites and other measurements show only low levels of gaseous iron and solid iron compounds, such as iron oxides, sulfides and carbides. That leaves a substantial amount of iron missing, given how much is expected to exist in the universe. Scientists surmise that if iron is not combining with other particles, it might be forming pure metal which is invisible in outer space.

That theory now appears unlikely, according to a paper recently published in the journal Science Advances.

A research team led by Hokkaido University and the Japanese Aerospace Exploration Agency conducted a rocket-based experiment to simulate the formation of pure iron grains in space. Their measurements revealed grain formation is extremely rare, contrary to the previous theory.

In space, tiny solid grains are often formed following the epic explosion of a star, or supernova, which releases extremely hot gases full of different elements. As those gas molecules collide and start to cool, they might stick to each other and begin condensing into solid particles, a process called nucleation.

The researchers simulated supernova conditions by sending a rocket into sub-orbit, 321 kilometers above the ground, where it was mostly free from the effect of gravity, which can throw off experiments. They set up a nucleation chamber with iron gas, a heating element, lasers and an image-recording system in the rocket. The iron was heated to extremely hot temperatures until it evaporated, much like after a supernova. As the gas cooled, the group measured how much iron condensed into ...Read More...

What happened to the sun over 7,000 years ago?

Picture of the bristlecone pine forest in California, the United States where the bristlecone pine sample for this study used to live (taken by Prof. A.J.T. Jull). In this forest, there are many living old trees exceed 1000 years old. Harsh environments make bristlecone pines very dense and long lives. Image courtesy A.J.T.Jull.

An international team led by researchers at Nagoya University, along with US and Swiss colleagues, has identified a new type of solar event and dated it to the year 5480 BC; they did this by measuring carbon-14 levels in tree rings, which reflect the effects of cosmic radiation on the atmosphere at the time. They have also proposed causes of this event, thereby extending knowledge of how the sun behaves.

When the activity of the sun changes, it has direct effects on the earth. For example, when the sun is relatively inactive, the amount of a type of carbon called carbon-14 increases in the earth's atmosphere.

Because carbon in the air is absorbed by trees, carbon-14 levels in tree rings actually reflect solar activity and unusual solar events in the past. The team took advantage of such a phenomenon by analyzing a specimen from a bristlecone pine tree, a species that can live for thousands of years, to look back deep into the history of the sun.

"We measured the 14C levels in the pine sample at three different laboratories in Japan, the US, and Switzerland, to ensure the reliability of our results," A. J. Timothy Jull of the University of Arizona says.

"We found a change in 14C that was more abrupt than any found previously, except for cosmic ray events in AD 775 and AD 994, and our use of annual data rather than data for each decade allowed us to pinpoint exactly when this occurred."

The team attempted to develop an explanation for the anomalous solar activity data by comparing the features of the 14C change with those of other solar events known to have occurred over the last couple of millennia.

"Although this newly discovered event is more dramatic than others found to date, comparisons of the 14C data among them can help us to work out ...Read More...

Physicists address loophole in tests of Bell's inequality using 600-year-old starlight

Physicists from MIT, the University of Vienna, and elsewhere have presented a strong demonstration of quantum entanglement even when vulnerability to the freedom-of-choice loophole is significantly restricted. Credit: Christine Daniloff/MIT

Quantum entanglement may appear to be closer to science fiction than anything in our physical reality. But according to the laws of quantum mechanics—a branch of physics that describes the world at the scale of atoms and subatomic particles—quantum entanglement, which Einstein once skeptically viewed as "spooky action at a distance," is, in fact, real.

Imagine two specks of dust at opposite ends of the universe, separated by several billion light years. Quantum theory predicts that, regardless of the vast distance separating them, these two particles can be entangled. That is, any measurement made on one will instantaneously convey information about the outcome of a future measurement on its partner. In that case, the outcomes of measurements on each member of the pair can become highly correlated.

If, instead, the universe behaves as Einstein imagined it should—with particles having their own, definite properties prior to measurement, and with local causes only capable of yielding local effects—then there should be an upper limit to the degree to which measurements on each member of the pair of particles could be correlated. Physicist John Bell quantified that upper limit, now known as "Bell's inequality," more than 50 years ago.

In numerous previous experiments, physicists have observed correlations between particles in excess of the limit set by Bell's inequality, which suggests that they are indeed entangled, just as predicted by quantum theory. But each such test has been subject to various "loopholes," scenarios that might account for the observed correlations even if the world were not governed by quantum mechanics.

Now, physicists from MIT, the University of Vienna, and elsewhere have addressed a loophole in tests of Bell's inequality, known as the freedom-of-choice loophole, and have presented a strong demonstration of ...Read More...

Measuring time without a clock

Credit: Ecole Polytechnique Federale de Lausanne

EPFL scientists have been able to measure the ultrashort time delay in electron photoemission without using a clock. The discovery has important implications for fundamental research and cutting-edge technology.

When light shines on certain materials, it causes them to emit electrons. This is called "photoemission" and it was discovered by Albert Einstein in 1905, winning him the Nobel Prize. But only in the last few years, with advancements in laser technology, have scientists been able to approach the incredibly short timescales of photoemission. Researchers at EPFL have now determined a delay of one billionth of one billionth of a second in photoemission by measuring the spin of photoemitted electrons without the need of ultrashort laser pulses. The discovery is published in Physical Review Letters.

Photoemission

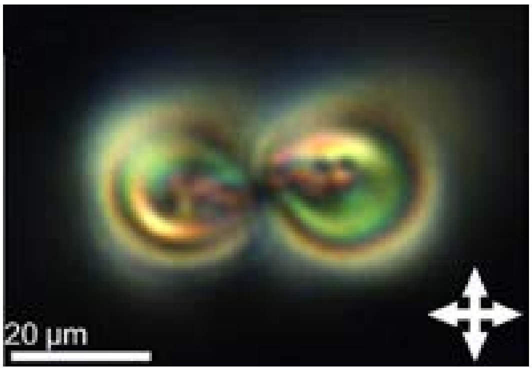
Photoemission has proven to be an important phenomenon, forming a platform for cutting-edge spectroscopy techniques that allow scientists to study the properties of electrons in a solid. One such property is spin, an intrinsic quantum property of particles that makes them look like as if they were rotating around their axis. The degree to which this axis is aligned towards a particular direction is referred to as spin polarization, which is what gives some materials, like iron, magnetic properties.

Although there has been great progress in using photoemission and spin polarization of photo-emitted electrons, the time scale in which this entire process takes places have not been explored in great detail. The common assumption is that, once light reaches the material, electrons are instantaneously excited and emitted. But more recent studies using advanced laser technology have challenged this, showing that there is actually a time delay on the scale of attoseconds.

Time without a clock

The lab of Hugo Dil at EPFL, with colleagues in Germany, showed that during photoemission, the spin polarization of emitted electrons can be related to the ..Read More...

Never-before-seen topological solitons experimentally realized in liquid crystals



A polarizing optical micrograph of the twistion, a type of topological soliton, observed in chiral nematic liquid crystals. Credit: Ackerman and Smalyukh. Published by the American Physical Society

Physicists have discovered that dozens of 3-D knotted structures called "topological solitons," which have remained experimentally elusive for hundreds of years, can be created and frozen for long periods of time in liquid crystals like those used in electronic displays. Until now, topological solitons have been realized only in a few experiments, and for such a short time that it has been impossible to study them in any detail.

The new results may change all that, as they provide a way to produce a wide diversity of long-lasting topological solitons that can be studied with microscopes and, perhaps one day, play a role in novel optical and electrical applications.

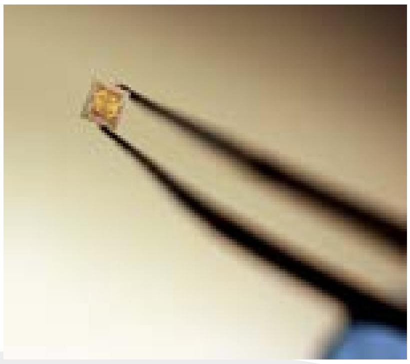
The researchers, Paul J. Ackerman and Ivan I. Smalyukh at the University of Colorado, Boulder, have published a paper on the experimental realization of topological solitons in a recent issue of Physical Review X.

"Our work establishes experimental and numerical approaches for detailed studies of 3-D topological solitons, with the great advantage of enabling a direct comparison between experimental and theoretical results and with a potential impact on many branches of physics and the mathematical field of topology," Smalyukh told Phys.org. "Our work not only experimentally demonstrates 3-D topological solitons that mathematicians and theoretical physicists envisaged previously, but also reveals a series of solitonic structures that have not been anticipated."

Knotted background

Interest in topological solitons dates back to the early 1800s, when the mathematician Carl Friedrich Gauss suggested that the lines of magnetic and electric fields form 3-D knots that might behave like particles. Later, Lord Kelvin and others considered knotted vortices as an early model of the atom, in which the knots' ..Read More...

Wave of the future: Terahertz chips a new way of seeing through matter



Princeton University researchers have drastically shrunk the equipment for producing terahertz -- important electromagnetic pulses lasting one millionth of a millionth of a second -- from a tabletop setup with lasers and mirrors to a pair of microchips small enough to fit on a fingertip (above). The simpler, cheaper generation of terahertz has potential for advances in medical imaging, communications and drug development. Credit: Frank Wojciechowski for the Office of Engineering Communications

Electromagnetic pulses lasting one millionth of a millionth of a second may hold the key to advances in medical imaging, communications and drug development. But the pulses, called terahertz waves, have long required elaborate and expensive equipment to use.

Now, researchers at Princeton University have drastically shrunk much of that equipment: moving from a tabletop setup with lasers and mirrors to a pair of microchips small enough to fit on a fingertip.

In two articles recently published in the IEEE Journal of Solid State Circuits, the researchers describe one microchip that can generate terahertz waves, and a second chip that can capture and read intricate details of these waves.

"The system is realized in the same silicon chip technology that powers all modern electronic devices from smartphones to tablets, and therefore costs only a few dollars to make on a large scale" said lead researcher Kaushik Sengupta, a Princeton assistant professor of electrical engineering.

Terahertz waves are part of the electromagnetic spectrum—the broad class of waves that includes radio, X-rays and visible light—and sit between the microwave and infrared light wavebands. The waves have some unique characteristics that make them interesting to science. For one, they pass through most non-conducting material, so they could be used to peer through clothing or boxes for security purposes, and because they have less energy than X-rays, they don't damage human tissue or DNA.

Terahertz waves also interact in distinct ways with different chemicals, so they can be used to characterize specific substances. Known as spectroscopy, the ...Read More...

New evidence in favor of dark matter

This is barred spiral galaxy NGC 7479 located in the Pegasus constellation about 105 million light years and discovered in 1784 by the German astronomer William Herschel. Its central bar is highlighted and very luminous. Image courtesy Daniel Lopez and IAC.

Why do the majority of astronomers believe in dark matter: matter whose composition is unknown but which seems to make up 80% of the mass of the galaxies? The concept was invented in the 1930's by Fritz Zwicky who used it to explain why the galaxies in the Coma cluster are moving much more quickly than can be explained in terms of their known masses.

The most decisive step was taken in the 1970's by the great Vera Rubin, who showed that the outer parts of galaxies are rotating much more quickly than we can explain using the combined masses of their stars, gas, and dust, and the law of gravity of Newton or Einstein.

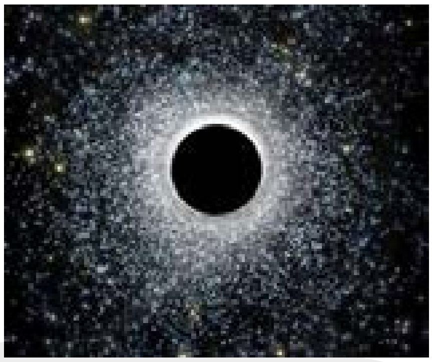
Since then astrophysicists have taken it as their standard scenario that galaxies are surrounded by a halo of this dark matter, which dominates their gravitational fields. But nobody has been able to identify what this dark matter is made of, in spite of the best efforts of the particle physicists. This has stimulated the researchers to think up additional tests.

One of these was proposed 20 years ago. The theorists predicted that the halos ought to brake the rotation of the bars in galaxies. If they spin slowly this would be a strong proof of the reality of the halos, but if they spin quickly this would throw doubt on their existence and thus cast doubt on the standard model of modern cosmology.

In spiral galaxies, the stars of the bar usually rotate faster than their arms due to gravitation. Around the galactic nucleus, there is a so-called "corroding circle", equidistant points from the center of the galaxy where the stars of the bar and those of the rest of the disk rotate at the same speed.

All these points form the circle, and the distance between them and the nucleus is the "corotation ...Read More...

A middleweight black hole is hiding at the center of a giant star cluster



In this artist's illustration, an intermediate-mass black hole in the foreground distorts light from the globular star cluster in the background. New research suggests that a 2,200 solar-mass black hole resides at the center of the globular cluster 47 Tucanae. Image courtesy CfA and M. Weiss.

All known black holes fall into two categories: small, stellar-mass black holes weighing a few Suns, and supermassive black holes weighing millions or billions of Suns. Astronomers expect that intermediate-mass black holes weighing 100 - 10,000 Suns also exist, but so far no conclusive proof of such middleweights has been found. Today, astronomers are announcing new evidence that an intermediate-mass black hole (IMBH) weighing 2,200 Suns is hiding at the center of the globular star cluster 47 Tucanae.

"We want to find intermediate-mass black holes because they are between stellar-mass and supermassive black holes. They may be the primordial seeds that grew into the monsters we see in the centers of galaxies today," says lead author Bulent Kiziltan of the Harvard-Smithsonian Center for Astrophysics (CfA).

This work appears in the Feb. 9, 2017, issue of the prestigious science journal Nature.

47 Tucanae is a 12-billion-year-old star cluster located 13,000 light-years from Earth in the southern constellation of Tucana the Toucan. It contains thousands of stars in a ball only about 120 light-years in diameter. It also holds about two dozen pulsars that were important targets of this investigation.

47 Tucanae has been examined for a central black hole before without success. In most cases, a black hole is found by looking for X-rays coming from a hot disk of material swirling around it. This method only works if the black hole is actively feeding on nearby gas. The center of 47 Tucanae is gas-free, effectively starving any black hole that might lurk there.

The supermassive black hole at the center of the Milky Way also betrays its presence by its influence on nearby stars. Years of infrared observations have ...Read More...

Scientists Estimate Solar Nebula's Lifetime

File Image.

About 4.6 billion years ago, an enormous cloud of hydrogen gas and dust collapsed under its own weight, eventually flattening into a disk called the solar nebula. Most of this interstellar material contracted at the disk's center to form the Sun, and part of the solar nebula's remaining gas and dust condensed to form the planets and the rest of our solar system.

Now scientists from MIT and their colleagues have estimated the lifetime of the solar nebula - a key stage during which much of the solar system took shape.

This new estimate suggests that the gas giants Jupiter and Saturn must have formed within the first 4 million years of the solar system's formation. Furthermore, they must have completed gas-driven migration of their orbital positions by this time.

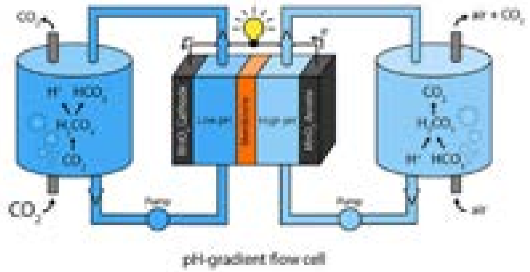
"So much happens right at the beginning of the solar system's history," says Benjamin Weiss, professor of Earth, atmospheric, and planetary sciences at MIT. "Of course the planets evolve after that, but the large-scale structure of the solar system was essentially established in the first 4 million years."

Weiss and MIT postdoc Huapei Wang, the first author of this study, report their results in the journal Science. Their co-authors are Brynna Downey, Clement Suavet, and Roger Fu from MIT; Xue-Ning Bai of the Harvard-Smithsonian Center for Astrophysics; Jun Wang and Jiajun Wang of Brookhaven National Laboratory; and Maria Zucolotto of the National Museum in Rio de Janeiro.

Spectacular Recorders

By studying the magnetic orientations in pristine samples of ancient meteorites that formed 4.653 billion years ago, the team determined that the solar nebula lasted around 3 to 4 million years. This is a more precise figure than previous estimates, which placed the solar nebula's lifetime at somewhere between 1 and 10 million years. ..Read More...

Battery can be recharged with carbon dioxide



The pH-gradient flow cell has two channels: one containing an aqueous solution sparged with carbon dioxide (low pH) and the other containing an aqueous solution sparged with ambient air (high pH). The pH gradient causes ions to flow across the membrane, creating a voltage difference between the two electrodes and causing electrons to flow along a wire connecting the electrodes. Credit: Kim et al. ©2017 American Chemical Society

Researchers have developed a type of rechargeable battery called a flow cell that can be recharged with a water-based solution containing dissolved carbon dioxide (CO2) emitted from fossil fuel power plants. The device works by taking advantage of the CO2 concentration difference between CO2 emissions and ambient air, which can ultimately be used to generate electricity.

The new flow cell produces an average power density of 0.82 W/m2, which is almost 200 times higher than values obtained using previous similar methods. Although it is not yet clear whether the process could be economically viable on a large scale, the early results appear promising and could be further improved with future research.

The scientists, Taeyong Kim, Bruce E. Logan, and Christopher A. Gorski at The Pennsylvania State University, have published a paper on the new method of CO2-to-electricity conversion in a recent issue of Environmental Science & Technology Letters.

"This work offers an alternative, simpler means to capturing energy from CO2 emissions compared to existing technologies that require expensive catalyst materials and very high temperatures to convert CO2 into useful fuels," Gorski told Phys.org.

While the contrast of gray-white smoke against a blue sky illustrates the adverse environmental impact of burning fossil fuels, the large difference in CO2 concentration between the two gases is also what provides an untapped energy source for generating electricity.

In order to harness the potential energy in this concentration difference, the researchers first dissolved CO2 gas and ambient air in separate containers of an aqueous solution, in a process called sparging. ...Read More...

This Week's Sky at a Glance, Feb. 11 - 18

Feb. 11	Full Moon 04:32
Feb. 11	Penumbral Eclipse (Starts 02:34 - Ends 07:00)
Feb. 11	Moon at ascending node 23:49
Feb. 15	Jupiter 2.7° S of Moon 18:55
Feb. 18	Third Quarter Moon 23:33

A bridge of stars connects two dwarf galaxies

The Magellanic Clouds, the two largest satellite galaxies of the Milky Way, appear to be connected by a bridge stretching across 43,000 light years, according to an international team of astronomers led by researchers from the University of Cambridge. The discovery is reported in the journal Monthly Notices of the Royal Astronomical Society (MNRAS) and is based on the Galactic stellar census being conducted by the European Space Observatory, Gaia.

For the past 15 years, scientists have been eagerly anticipating the data from Gaia. The first portion of information from the satellite was released three months ago and is freely accessible to everyone. This dataset of unprecedented quality is a catalogue of the positions and brightness of a billion stars in our Milky Way galaxy and its environs.

What Gaia has sent to Earth is unique. The satellite's angular resolution is similar to that of the Hubble Space Telescope, but given its greater field of view, it can cover the entire sky rather than a small portion of it. In fact, Gaia uses the largest number of pixels to take digital images of the sky for any space-borne instrument. Better still, the Observatory has not just one telescope but two, sharing the one metre wide focal plane.

Unlike typical telescopes, Gaia does not just point and stare: it constantly spins around its axis, sweeping the entire sky in less than a month. Therefore, it not only measures the instantaneous properties of the stars, but also tracks their changes over time. This provides a perfect opportunity for finding a variety of objects, for example stars that pulsate or explode - even if this is not what the satellite was primarily designed for.

The Cambridge team concentrated on the area around the Magellanic Clouds and used the Gaia data to pick out pulsating stars of a particular type: the so-called RR Lyrae, very old and chemically un-evolved. As these stars have been around since the earliest days of the Clouds' existence, they offer an insight into the pair's history. Studying the Large and Small Magellanic Clouds (LMC and SMC respectively) has always been difficult as they sprawl out over a large area. But with Gaia's all-sky view, this has become a much easier task.
.... Read More...

The white line gives the approximate (average) track of the stellar bridge and the blue line shows the track of the gaseous bridge. The stars and the gas do not follow the same path. Credit: V. Belokurov, D. Erkal and A. Mellinger