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# Astronomy & Physics Weekly News

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مركز الشارقة لعلوم الفضاء والفلك
Sharjah Center for Astronomy & Space Sciences

## Top News



## Special Read:



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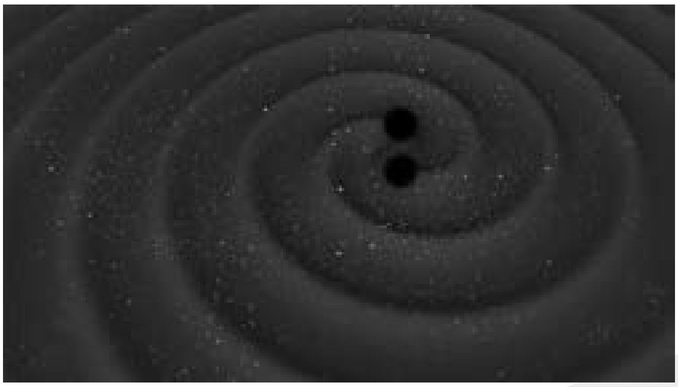
# Next step toward a gravitational-wave observatory in space



Artist's impression of two black holes as they spiral towards each other before merging, releasing gravitational waves - fluctuations in the fabric of spacetime. Image courtesy ESA-C. Carreau.

ESA has invited European scientists to propose concepts for the third large mission in its science programme, to study the gravitational universe.

A spaceborne observatory of gravitational waves - ripples in the fabric of spacetime created by accelerating massive objects - was identified in 2013 as the goal for the third large mission (L3) in ESA's Cosmic Vision plan.

A Gravitational Observatory Advisory Team was appointed in 2014, composed of independent experts. The team completed its final report earlier this year, further recommending ESA to pursue the mission having verified the feasibility of a multisatellite design with free-falling test masses linked over millions of kilometres by lasers.

"Gravitational waves promise to open a new window for astronomy, revealing powerful phenomena across the universe that are not accessible via observations of cosmic light," says Alvaro Gimenez, ESA's Director of Science.

Predicted a century ago by Albert Einstein's general theory of relativity, gravitational waves remained elusive until the first direct detection by the ground-based Laser Interferometer Gravitational-Wave Observatory and Virgo collaborations, made in September 2015 and announced earlier this year.

The signal originated from the coalescence of two black holes, each with some 30 times the mass of the Sun and about 1.3 billion light-years away. A second detection was made in December 2015 and announced in June, and revealed gravitational waves from another black hole merger, this time involving smaller objects with masses around 7 and 14 solar masses. Meanwhile, the LISA Pathfinder mission was launched in December 2015 and started its scientific operations in March this year ...Read More...

# Proxima "b" could be an ocean planet

This artist's impression shows a view of the surface of the planet Proxima b orbiting the red dwarf star Proxima Centauri, the closest star to the solar system. The double star Alpha Centauri AB also appears in the image. Proxima b is a little more massive than the Earth and orbits in the habitable zone around Proxima Centauri, where the temperature is suitable for liquid water to exist on its surface. Image courtesy ESO/M. Kornmesser.

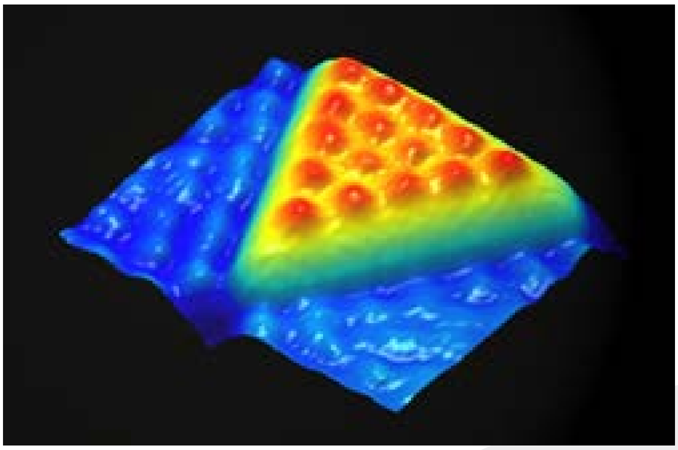
A rocky extrasolar planet with a mass similar to Earth's was recently detected around Proxima Centauri, the nearest star to our sun. This planet, called Proxima b, is in an orbit that would allow it to have liquid water on its surface, thus raising the question of its habitability. In a study to be published in The Astrophysical Journal Letters, an international team led by researchers at the Marseille Astrophysics Laboratory (CNRS/Aix-Marseille Universite) has determined the planet's dimensions and properties of its surface, which actually favor its habitability.

The team says Proxima b could be an "ocean planet," with an ocean covering its entire surface, the water perhaps similar to that of subsurface oceans detected inside icy moons around Jupiter and Saturn. The researchers also show that Proxima b's composition might resemble Mercury's, with a metal core making up two-thirds of the mass of the planet. These results provide the basis for future studies to determine the habitability of Proxima b.

Proxima Centauri, the star nearest the sun, has a planetary system consisting of at least one planet. The new study analyzes and supplements earlier observations. These new measurements show that this planet, named Proxima Centauri b or simply Proxima b, has a mass close to that of Earth (1.3 times Earth's mass) and orbits its star at a distance of 0.05 astronomical units (one tenth of the sun-Mercury distance).

Contrary to what one might think, such a small distance does not imply a high temperature on the surface of Proxima b because the host star, Proxima Centauri, is a red dwarf with a mass and radius that are only one-tenth that of the Sun, and a brightness a thousand times smaller than the sun's. Hence Proxima b is in the habitable zone of its star and may harbor liquid water at its surface. ...Read More...

# How nanoscience will improve our health and lives in the coming years



Nanoscience will make major contributions in health care, energy and many other areas, researchers say. Credit: University of California, Los Angeles

Nanoscience research involves molecules that are only 1/100th the size of cancer cells and that have the potential to profoundly improve the quality of our health and our lives. Now nine prominent nanoscientists look ahead to what we can expect in the coming decade, and conclude that nanoscience is poised to make important contributions in many areas, including health care, electronics, energy, food and water.

Significant progress has already been made in nanomaterials, report authors Paul Weiss, who holds a UC presidential chair and is a distinguished professor of chemistry and biochemistry at UCLA, and Dr. Andre Nel, chief of nanomedicine at the David Geffen School of Medicine at UCLA. In the journal ACS Nano, Weiss, Nel and their colleagues say the following:

Nanoparticles can be designed to target infectious disease. Nanomaterials may target the lungs to deliver potent antibiotics and anti-inflammatory drugs could fight bacterial and viral infection.

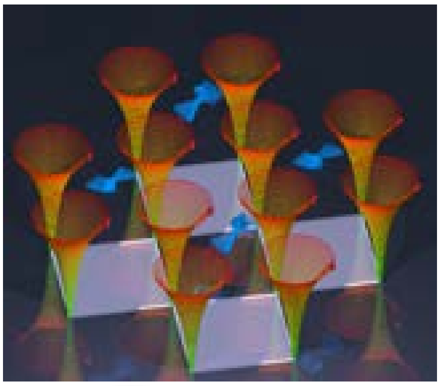
Nanoparticles may lead to more effective treatments of neurological disorders such as Parkinson's disease and Alzheimer's disease, as well as arthritis.

The emerging field of immuno-oncology is likely to produce advances that will activate the body's immune system to attack tumor cells. Important advantages of nanoparticles are that they can bind selectively to receptors over-expressed on tumors and may be delivered to the same cell at a predetermined dose and timing, although significant scientific challenges remain.

The microelectronics industry has been manufacturing products with nanoscale structures for decades—a market currently valued at approximately $500 billion annually. The researchers say there is still plenty of room for major improvements, including many opportunities in creative design of devices for data processing and information storage.

Nanotechnology is likely to capture ...Read More...

# Light-driven atomic rotations excite magnetic waves



Light-driven atomic rotations (spirals) induce coherent motion of the electronic spins (blue arrows). Credit: © Jörg M. Harms/MPSD

Controlling functional properties by light is one of the grand goals in modern condensed matter physics and materials science. A new study now demonstrates how the ultrafast light-induced modulation of the atomic positions in a material can control its magnetization. An international research team led by Andrea Cavalleri from the Max Planck Institute for the Structure and Dynamics of Matter at CFEL in Hamburg used terahertz light pulses to excite pairs of lattice vibrations in a magnetic crystal. These short bursts of light caused the lattice ions to rotate around their equilibrium positions, acting as an ultrafast effective magnetic field on the electronic spins to coherently drive a magnetic wave. These findings represent an important hallmark on how light interacts with matter and establish a novel approach in the control of magnetization at terahertz speed, making the research potentially relevant for magnetic storage technologies.

### Ultrafast vibrational control of materials

Understanding microscopic interactions and engineering collective responses to tailor material functionalities has been a driving force for the fields of condensed matter physics and materials science, both from a fundamental and technological point of view. Conventional static approaches to modify and control material properties include chemical substitution, i.e. the replacement of particular atoms in the crystal lattice by atoms of another chemical element, or the application of external perturbations like pressure and magnetic fields.

A conceptually different path consists in the ultrafast dynamical modulation of material parameters. In particular, the direct excitation of lattice vibrations in solid-state systems (collective excitations of the ions called phonons) by ultra-short and ultra-intense terahertz light pulses has proven to be an extremely efficient route to material control. The Hamburg group has been playing a pioneering role in this technique, called nonlinear phononics. Recent successful examples include the control of insulator-metal transitions, melting of magnetic order and enhancement of superconductivity. ...Read More...

## Gaining a revolutionary view of the Sun in STEREO

This animation shows the orbits of the two STEREO spacecraft from October 2006 to October 2016. Because of the twin probes' unique positions in space, the STEREO mission has given scientists an unprecedented look at the sun, helping us to understand our home star. Image courtesy NASA Goddard's Scientific Visualization Studio. Watch a video on the technology here.

Launched 10 years ago, on Oct. 25, 2006, the twin spacecraft of NASA's STEREO mission - short for Solar and Terrestrial Relations Observatory - have given us unprecedented views of the sun, including the first-ever simultaneous view of the entire star at once.

This kind of comprehensive data is key to understanding how the sun erupts with things like coronal mass ejections and energetic particles, as well as how those events move through space, sometimes impacting Earth and other worlds. Ten years ago, the twin STEREO spacecraft joined a fleet of NASA spacecraft monitoring the sun and its influence on Earth and space - and they provided a new and unique perspective.

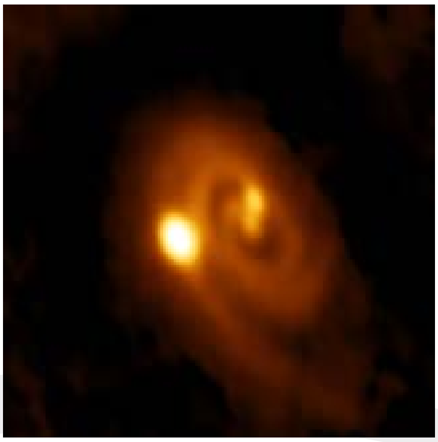
The two STEREO observatories, called STEREO-A and STEREO-B - for Ahead and Behind, respectively - were sent out from Earth in opposite directions. Using gravitational assists from both the moon and Earth, the STEREO spacecraft were accelerated to Earth-escape velocities. STEREO-A was inserted into an orbit slightly smaller, and therefore faster, than Earth's.

For STEREO-B, the reverse happened: It was nudged into an orbit slightly larger than Earth's so that it traveled around the sun more slowly, falling increasingly behind the Earth. As the spacecraft slowly fanned out away from the centerline between Earth and the sun - where every other sun-watching spacecraft is located - they revealed more and more new information about our closest star.

"STEREO gives us a much more thorough view of the sun, solar wind and solar activity," said Terry Kucera, deputy project scientist for STEREO at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "The view from the far side of the sun lets us record more events and get more complete pictures of each event."

When observed through a solar telescope, the surface of the sun can be seen to be churning with near-constant activity, sometimes including the larger solar ...Read More...

## Young stellar system caught in act of forming close multiples



ALMA image of the L1448 IRS3B system, with two young stars at the center and a third distant from them. Spiral structure in the dusty disk surrounding them indicates instability in the disk, astronomers said. Credit: Bill Saxton, ALMA (ESO/NAOJ/NRAO), NRAO/AUI/NSF.

For the first time, astronomers have seen a dusty disk of material around a young star fragmenting into a multiple-star system. Scientists had suspected such a process, caused by gravitational instability, was at work, but new observations with the Atacama Large Millimeter/submillimeter Array (ALMA) and the Karl G. Jansky Very Large Array (VLA) revealed the process in action.

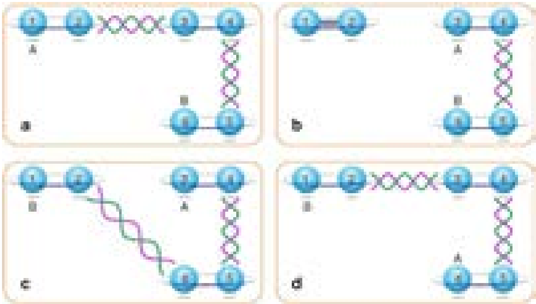
"This new work directly supports the conclusion that there are two mechanisms that produce multiple star systems—fragmentation of circumstellar disks, such as we see here, and fragmentation of the larger cloud of gas and dust from which young stars are formed," said John Tobin, of the University of Oklahoma and Leiden Observatory in the Netherlands.

Stars form in giant clouds of gas and dust, when the tenuous material in the clouds collapses gravitationally into denser cores that begin to draw additional material inward. The infalling material forms a rotating disk around the young star. Eventually, the young star gathers enough mass to create the temperatures and pressures at its center that will trigger thermonuclear reactions.

Previous studies had indicated that multiple star systems tend to have companion stars either relatively close, within about 500 times the Earth-Sun distance, or significantly farther apart, more than 1,000 times that distance. Astronomers concluded that the differences in distance result from different formation mechanisms. The more widely-separated systems, they said, are formed when the larger cloud fragments through turbulence, and recent observations have supported that idea.

The closer systems were thought to result from fragmentation of the smaller disk surrounding a young protostar, but that conclusion was based principally on the relative proximity of the companion stars. ...Read More...

# Scientists discover particles similar to Majorana fermions



The braiding of Majorana zero modes is shown. Credit: LI et. al

Majorana fermions were first proposed by the physicist Ettore Majorana in 1937. They are fermion particles that are also their own antiparticles. These fermions are vital to the research of superconducting materials and topological quantum computation. However, 80 years later, scientists have not found a Majorana elementary particle. Though it is hypothesized that neutrinos are Majorana fermions, there is still no evidence to support this conjecture.

In condensed matter physics, scientists found that a particlular kind of quasiparticle—Majorana zero modes (MZMs)—have characteristics similar to Majorana fermions. Recently, a research team from the Key Laboratory of Quantum Information of the Chinese Academy of Sciences achieved the fabrication and manipulation of MZMs in an optical simulator.

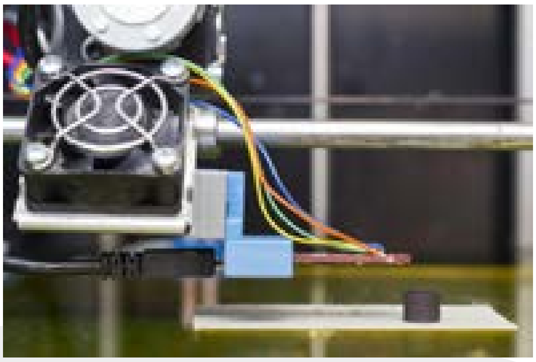
The team led by Professors LI Chuangfeng, XU Jinshi, and HAN Yongjian implemented the exchange of two MZMs such that the non-Abelian statistics of MZMs are supported. This work is published in Nature Communications on October 25th.

Generally, the statistics of the identical particles can be determined by their exchange characteristics. For example, the internal quantum states remain the same when two bosons are exchanged, and are imposed by a pi phase when two fermions are exchanged. The bosons and fermions belong to particles with more general statistics, called Abelian anyons. A global phase (not necessarily 0 or pi) is gained after the exchange of two identical Abelian anyons.

Moreover, there may exist some exotic particles, called non-Abelian anyons, which undertake a unitary transformation (not just a global phase) after exchange. The Majorana fermions with their own antiparticles are widely believed to be non-Abelian particles.

The research team took advantage of the quantum simulation approach: While the simulated system is not experimentally accessible with current technology, the quantum simulator and its measurement results provide information about the simulated system. ...Read More...

# For the first time, magnets are be made with a 3-D printer



A magentic cup-like shape, created in the 3-D printer. Credit: TU Wien

Today, manufacturing strong magnets is no problem from a technical perspective. It is, however, difficult to produce a permanent magnet with a magnetic field of a specific pre-determined shape. That is, until now, thanks to the new solution devised at TU Wien: for the first time ever, permanent magnets can be produced using a 3D printer. This allows magnets to be produced in complex forms and precisely customised magnetic fields, required, for example, in magnetic sensors.

## Designed on a computer

"The strength of a magnetic field is not the only factor," says Dieter Süss, Head of the Christian-Doppler Advanced Magnetic Sensing and Materials laboratory at TU Wien. "We often require special magnetic fields, with field lines arranged in a very specific way - such as a magnetic field that is relatively constant in one direction, but which varies in strength in another direction."

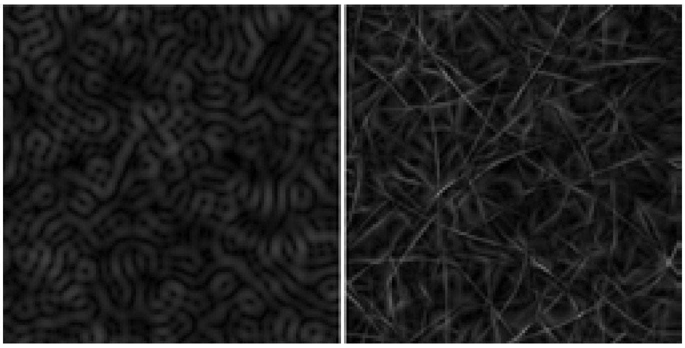
In order to achieve such requirements, magnets must be produced with a sophisticated geometric form. "A magnet can be designed on a computer, adjusting its shape until all requirements for its magnetic field are met," explains Christian Huber, a doctoral student in Dieter Süss' team.

But once you have the desired geometric shape, how do you go about implementing the design? The injection moulding process is one solution, but this requires the creation of a mould, which is time-consuming and expensive, rendering this method barely worthwhile for producing small quantities.

## Tiny magnetic particles in the polymer matrix

Now, there is a much simpler method: the first-ever 3D printer which can be used to produce magnetic materials, created at TU Wien. 3D printers which generate plastic structures have existed for some time, and the magnet printer functions in much the same way. The difference is that the magnet printer uses specially ...Read More...

# Shocks in the early universe could be detectable today



Simulation showing cosmological initial conditions (left) evolving into shocks (right). Credit: Pen and Turok. ©2016 American Physical Society

Physicists have discovered a surprising consequence of a widely supported model of the early universe: according to the model, tiny cosmological perturbations produced shocks in the radiation fluid just a fraction of a second after the big bang. These shocks would have collided with each other to generate gravitational waves that are large enough to be detected by today's gravitational wave detectors.

The physicists, Ue-Li Pen at the Canadian Institute for Theoretical Astrophysics in Toronto, and Neil Turok at the Perimeter Institute for Theoretical Physics in Waterloo, have published a paper on the shocks in the early universe and their aftermath in a recent issue of Physical Review Letters.

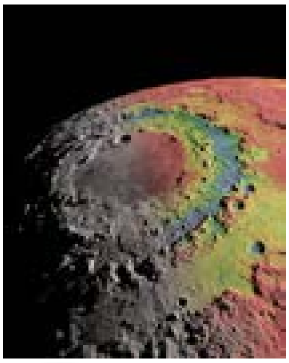
As the scientists explain, the most widely supported model of the early universe is one with a radiation-dominated background that is almost perfectly homogeneous, except for some tiny waves, or perturbations, in the radiation.

In the new study, Pen and Turok have theoretically shown that some of these early, tiny perturbations, which are small-amplitude waves, would have spiked to form large-amplitude waves, or shocks. These shocks would have formed only at very high temperatures, like those that occur immediately after the big bang.

The physicists also showed that, when two or more shocks collide with each other, they generate gravitational waves.

The results suggest that both colliding shocks and merging black holes—like those detected earlier this year by the Laser Interferometer Gravitational-Wave Observatory (LIGO) experiment—contribute to the gravitational wave background. Some researchers have previously speculated that the mergining black holes may have formed from the same perturbations that created the shocks and, further, that black holes of this size may make up the dark matter in our galaxy. ...Read More...

# Research helps explain formation of ringed crater on the moon



T Free-air gravitational anomalies and shaded topographic relief of the moon's 930-km-diameterOrientale impact basin. Red corresponds to mass excesses and blue to mass deficits relative to areference value. This gravitational field model, based on measurements acquired from the NASAGRAIL mission, shows the detailed structure of the central basin depression that is filled with densemare basalts, as well as the rings that formed due to gravitational collapse of the initial crater cavityshortly after the impact. The shaded relief map, from a digital elevation model from the laser altimeteron the NASA Lunar Reconnaissance Orbiter and the SELENE Terrain Camera, is rendered with thevirtual sun just after sunrise at Orientale, a day after the full moon. Credit: Ernest Wright, NASA/GSFC Scientific Visualization Studio

Using data from NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission, scientists have shed new light on the formation of a huge bull's-eye-shaped impact feature on the Moon. The findings, described in two papers published in the journal Science, could help scientists better understand how these kinds of giant impacts influenced the early evolution of the Moon, Mars and Earth

Formed about 3.8 billion years ago, the Orientale basin is located on the southwestern edge of the Moon's nearside, just barely visible from Earth. The basin's most prominent features are three concentric rings of rock, the outermost of which has a diameter of nearly 580 miles.

Scientists have debated for years about how those rings formed. Thanks to targeted close passes over Orientale by the twin GRAIL spacecraft in 2012, mission scientists think they've finally figured it out. The GRAIL data revealed new details about the interior structure of Orientale. Scientists used that information to calibrate a computer model that, for the first time, was able to recreate the rings' formation.

"Big impacts like the one that formed Orientale were the most important drivers of change on planetary crusts in the early solar system," said Brandon Johnson, a geologist at Brown University, lead author of one of the papers and a co-author of the other. "Thanks to the tremendous data supplied by GRAIL, we have a much better idea of how these basins form, and we can apply that knowledge to big basins on other planets and moons." In one of the Science papers, a research team led by MIT's Maria Zuber, a Brown Ph.D. graduate, performed a detailed examination of the data returned by GRAIL. ...Read More...

# Physicists make it possible to 3-D print your own baby universe

Researchers have created a 3D printed cosmic microwave background - a map of the oldest light in the universe - and provided the files for download.

The cosmic microwave background (CMB) is a glow that the universe has in the microwave range that maps the oldest light in the universe. It was imprinted when the universe first became transparent, instead of an opaque fog of plasma and radiation.

The CMB formed when the universe was only 380,000 years old - very early on in its now 13.8 billion-year history.

The Planck satellite is making ever-more detailed maps of the CMB, which tells astronomers more about the early universe and the formation of structures within it, such as galaxies. However, more detailed maps are increasingly difficult to view and explore.

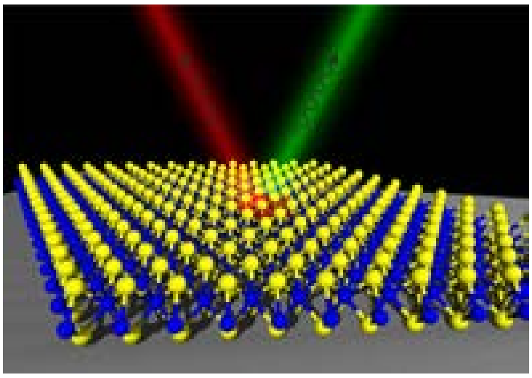
To address this issue, Dr Dave Clements from the Department of Physics at Imperial, and two final-year undergraduate students in Physics, have created the plans for 3D printing the CMB. A paper describing the process is published today in the European Journal of Physics.

Dr Clements said: "Presenting the CMB in a truly 3D form, that can be held in the hand and felt rather than viewed, has many potential benefits for teaching and outreach work, and is especially relevant for those with a visual disability.

"Differences in the temperature of the CMB relate to different densities, and it is these that spawned the formation of structure in the universe - including galaxies, galaxy clusters and superclusters.

"Representing these differences as bumps and dips on a spherical surface allows anyone to appreciate the structure of the early universe. For example, the famous 'CMB cold spot', an unusually low temperature region in the CMB, can be felt as a small but isolated depression." The CMB can be printed from a range of 3D printers, and two files types have been created by the team: one for simple single-colour structures and one that includes ...Read More...

# Novel light sources made of 2-D materials



Artistic representation of a two-photon source: The monolayer (below) emits exactly two photons of different frequencies under suitable conditions. They are depicted in red and green in the picture. Credit: Karol Winkler

Physicists from the University of Würzburg have designed a light source that emits photon pairs, which are particularly well suited for tap-proof data encryption. The experiment's key ingredients: a semiconductor crystal and some sticky tape.

So-called monolayers are at the heart of the research activities. These so-called "super materials" have been surrounded by hype over the past decade. This is because they show great promise to revolutionise many areas of physics.

In physics, the term "monolayer" refers to solid materials of minimum thickness. Occasionally, it is only a single layer of atoms thick; in crystals, monolayers can be three or more layers. Experts also speak of two-dimensional materials. In this form, monolayers can exhibit unexpected properties that make them interesting for research. The so-called transition metal dichalcogenides (TMDC) are particularly promising. They behave like semiconductors and can be used to manufacture ultra-small and energy-efficient chips, for example.

Moreover, TMDCs are capable of generating light when supplied with energy. Dr. Christian Schneider, Professor Sven Höfling and their research team from the Chair of Technical Physics of the Julius-Maximilians-Universität Würzburg (JMU) in Bavaria, Germany, have harnessed exactly this effect for their experiments.

**Experiments started with sticky tape**

First, a monolayer was produced using a simple method. The researchers used a piece of sticky tape to peel a multi-layer film from a TMDC crystal. Using the same procedure, they stripped increasingly thin layers from the film, repeating the process until the material on the tape was only one layer thick.

The researchers then cooled this monolayer to a temperature of just above absolute zero and excited it with a laser. This caused the monolayer to emit ...Read More...

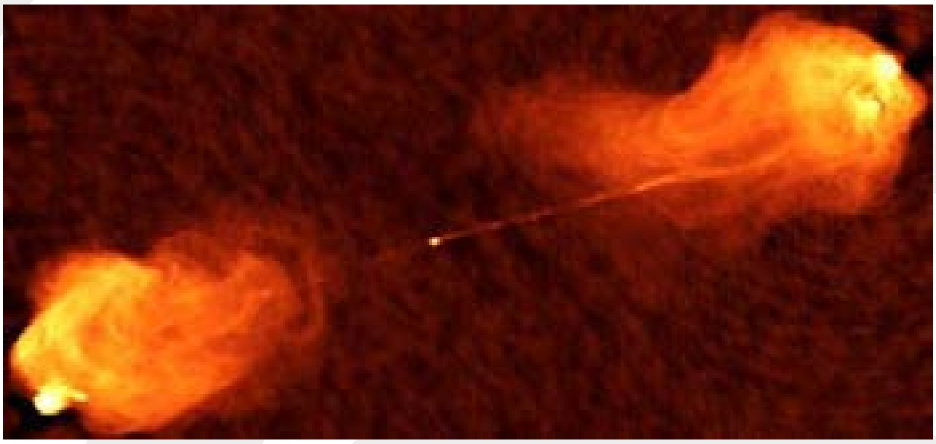
# This Week's Sky at a Glance
# Oct. 29 - Nov. 04

| | |
|---|---|
| **Oct. 30** | New Moon (21:37) - Meridian passage (11:53) – Altitude: 56° |
| **Oct. 31** | Moon at apogee: 406660 km (Local Time: 23:29) |
| **Nov. 03** | Meteor shower Taurids - Parent body: Comet Encke - Active dates: 20 Oct. - 30 Nov. |

## Hotspots in an active galactic nucleus

The nucleus of a so-called "active" galaxy contains a massive black hole that is vigorously accreting material. As a result, the nucleus often ejects bipolar jets of rapidly moving charged particles that radiate brightly at many wavelengths, in particular radio wavelengths. Active galaxies display a range of dramatically different properties, and the ones that are bright in the radio can beam as much as one trillion solar luminosities of radiation into space at those wavelengths.

The intense emission arises from the hot environment of the black hole because electrons, moving at close to the speed of light in an environment of strong magnetic fields, radiate in the radio. The directed particle jets eventually collide with the ambient medium and convert much of their bulk energy of motion into shocks. The points of termination in the jet flow are seen as very hot spots, bright and compact structures. The hotspots can reverse the flow the jets back towards the black hole, and thereby generate additional turbulence and random motions. The characteristic temperature of a hot spot (or more accurately, the spectral dependence of the brightness versus wavelength) reveals the nature of the physical processes at work. Most known active radio galaxies have hotspots whose spectral dependence conforms well with the idea of termination shocks and reverse flows, but some very luminous radio galaxies do not conform. ...Read More...



An image taken at radio wavelengths of the dramatic jets of charged particles being ejected from the nucleus of the galaxy Cygnus-A. Newly obtained radio images were able to resolve hotspots in the jets at the places where they impact the surrounding medium. The conventional thinking is that the bulk of the radiation in such hotspots is produced by shocks, but the new results found that some other processes, perhaps absorption, must be involved. Credit: NRAO/AU

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