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Astronomy & Physics Weekly News

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Top News

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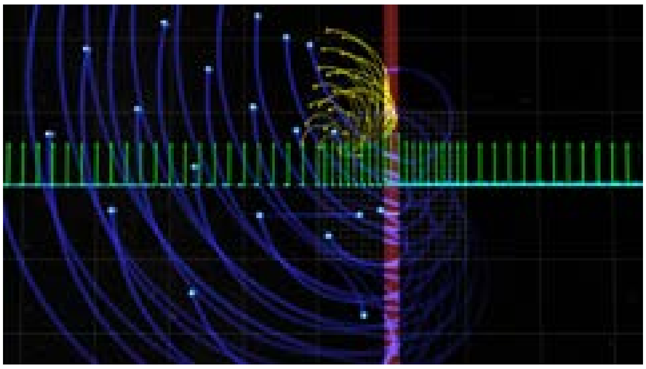
NASA finds unusual origins of high-energy electrons



This image represents one of the traditional proposed mechanisms for accelerating particles across a shock, called a shock drift acceleration. The electrons (yellow) and protons (blue) can be seen moving in the collision area where two hot plasma bubbles collide (red vertical line). The cyan arrows represent the magnetic field and the light green arrows, the electric field. Credit: NASA Goddard's Scientific Visualization Studio/Tom Bridgman, data visualizer

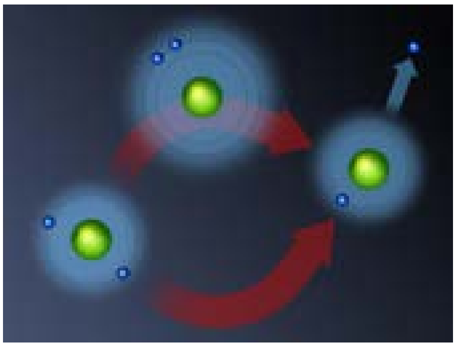
High above the surface, Earth's magnetic field constantly deflects incoming supersonic particles from the sun. These particles are disturbed in regions just outside of Earth's magnetic field - and some are reflected into a turbulent region called the foreshock. New observations from NASA's THEMIS mission show that this turbulent region can accelerate electrons up to speeds approaching the speed of light. Such extremely fast particles have been observed in near-Earth space and many other places in the universe, but the mechanisms that accelerate them have not yet been concretely understood.

The new results provide the first steps towards an answer, while opening up more questions. The research finds electrons can be accelerated to extremely high speeds in a region farther from Earth than previously thought possible - leading to new inquiries about what causes the acceleration. These findings may change the accepted theories on how electrons can be accelerated not only in shocks near Earth, but also throughout the universe. Having a better understanding of how particles are energized will help scientists and engineers better equip spacecraft and astronauts to deal with these particles, which can cause equipment to malfunction and affect space travelers.

"This affects pretty much every field that deals with high-energy particles, from studies of cosmic rays to solar flares and coronal mass ejections, which have the potential to damage satellites and affect astronauts on expeditions to Mars," said Lynn Wilson, lead author of the paper on these results at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

The results, published in Physical Review Letters on Nov. 14, 2016, describe how such particles may get accelerated in specific regions just beyond Earth's magnetic field. Typically, a particle streaming toward Earth first encounters a boundary region known as the bow shock ...Read More...

Watching the buildup of quantum superpositions



There are two different ways the helium atom can be ionized. Image courtesy TU Wien.

It is definitely the most famous experiment in quantum physics: in the double slit experiment, a particle is fired onto a plate with two parallel slits, so there are two different paths on which the particle can reach the detector on the other side. Due to its quantum properties, the particle does not have to choose between these two possibilities, it can pass through both slits at the same time. Something quite similar can be observed when a helium atom is ionized with a laser beam.

Just like the two paths through the plate, the ionization of helium can happen via two different processes at the same time, and this leads to characteristic interference effects. In the case of the helium atom, they are called "Fano resonances". A team of scientists from TU Wien (Vienna, Austria), the Max-Planck Institute for Nuclear Physics in Heidelberg (Germany) and Kansas State University (USA) has now managed to observe the buildup up of these Fano resonances - even though this effect takes place on a time scale of femtoseconds.

The experiment was performed in Heidelberg, the original proposal for such an experiment and computer simulations were developed by the team from Vienna, additional theoretical calculations came from Kansas State University.

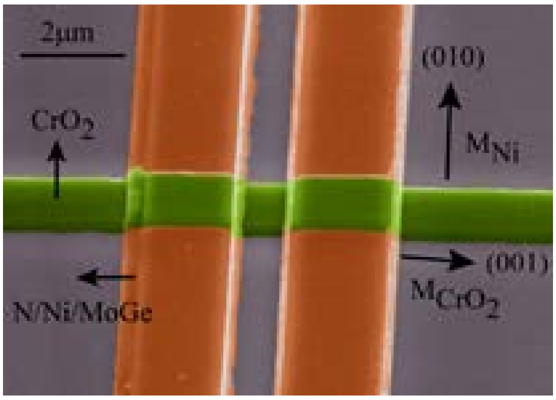
Direct and Indirect Path

When a laser pulse transfers enough energy to one of the electrons in the helium atom, the electron is ripped out of the atom right away.

There is, however, another way to ionize the helium atom, which is a little bit more complex, as Professor Joachim Burgdorfer (TU Wien) explains: "If at first the laser lifts both electrons to a state of higher energy, one of the electrons may return into the state of lower energy. Part of this electron's energy is transferred to the second electron, which can then leave the helium atom."

The outcome of these two processes is exactly the same - both turn the neutral helium atom into an ion with one remaining electron. From this perspective, they are fundamentally indistinguishable. ...Read More...

Record distance for alternative super-current



Electron microscope image of a chromium dioxide devices based on wires. The green wire is the chromium dioxide ferromagnet. The orange wires are superconductors and are necessary to produce a superconducting current through the green wire. Credit: Leiden Institute of Physics

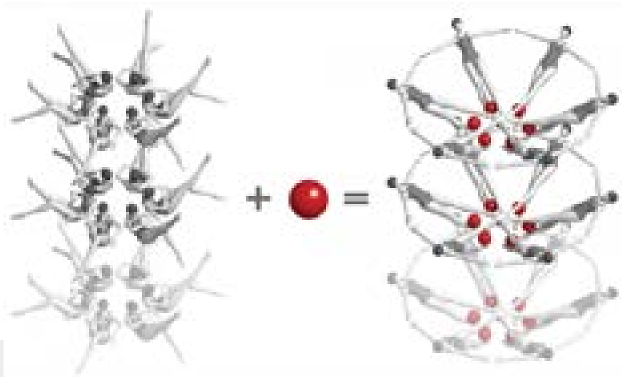
Researchers have discovered that electrons that spin synchronously around their axes remain superconductive across large distances within magnetic chrome dioxide. Electric current from these electrons can flip small magnets, and its superconductive version could form the basis of a hard drive without energy loss. The study has been published in Physical Review X.

In Leiden in 1911, Nobel Prize-winner Heike Kamerlingh Onnes discovered the principle of superconduction; electric current flowing through ice-cold metal without any resistance. This super-current can transport electricity or power an electromagnet without energy loss, an essential property for MRI scanners, maglev trains and nuclear fusion reactors.

Half a century later, scientists discovered that electrons appear to form pairs, enabling the super-current to escape the classical rules of electricity. Physicists assumed that both electrons spin around their axes in opposite directions, so that the pairs have a net 'spin' of zero. Around the turn of the century, that assumption proved to be premature. Super-currents can, indeed, have a net 'spin,' and even possibly manipulate small magnets.

Leiden physicist Prof. Jan Aarts and his group have now created a wire made of chrome dioxide, which only carries currents with 'spin.' They cooled it to a superconducting state and measured a particularly strong current of a billion A/m2. That's powerful enough to flip magnets, potentially facilitating future hard drives without energy loss. Moreover, the super-current covered a record distance of 600 nanometer. This seems like a small stretch—bacteria are bigger—but it lets electron pairs survive long enough for practical use. ...Read More...

X-ray laser gets first real-time snapshots of a chemical flipping a biological switch



In a landmark experiment at SLAC National Accelerator Laboratory, scientists used an X-ray laser to capture the first snapshots of a chemical interaction between two biomolecules in real time and at an atomic level. It involves 'riboswitches' from bacterial RNA -- shown here as synchronized swimmers -- and a small molecule called adenine (red balls). When the two interact, riboswitches flip into a dramatically different shape, and this in turn changes the shape of the crystals they're embedded in. Studies like these, which can only be done at X-ray free-electron lasers, open a path to understanding how RNA and other complex biomolecules function, and ultimately to developing treatments for disease. Credit: Joseph Meyer/Frederick National Laboratory for Cancer Research

Scientists have used the powerful X-ray laser at the Department of Energy's SLAC National Accelerator Laboratory to make the first snapshots of a chemical interaction between two biomolecules - one that flips an RNA "switch" that regulates production of proteins, the workhorse molecules of life.

The results, published today in Nature, show the game-changing potential of X-ray free-electron lasers, or XFELs, for studying RNA, which guides protein manufacturing in the cell, serves as the primary genetic material in retroviruses such as HIV and also plays a role in most forms of cancer.

And because this particular type of RNA switch, known as a riboswitch, is found only in bacteria, a deeper understanding of its function may offer a way to turn off protein production and kill harmful germs without causing side effects in the humans they infect.

"Previous experiments at SLAC's X-ray laser have studied biological reactions like photosynthesis that are triggered by light. But this is the first to observe one that is triggered by the chemical interaction of two biomolecules in real time and at the atomic scale," said Yun-Xing Wang, a structural biologist at the National Cancer Institute's Center for Cancer Research who led the international research team. "This really demonstrates the unique capability that X-ray free-electron lasers offer that no current technology, or any other technology on the horizon, can do. It's like you have a camera with a very fast shutter ...Read More...

Distant star is roundest object ever observed in nature

The star Kepler 11145123 is the roundest natural object ever measured in the universe. Stellar oscillations imply a difference in radius between the equator and the poles of only 3 km. This star is significantly more round than the Sun. Image courtesy Laurent Gizon et al. and the Max Planck Institute for Solar System Research, Germany. Illustration by Mark A. Garlick.

Stars are not perfect spheres; several mechanisms can change their shape. One mechanism is rotation: the more quickly a star rotates, the more flat it becomes due to the centrifugal force.

Since distant stars appear as points in the sky, measuring their shape is a challenging task. A team of researchers led by Prof. Laurent Gizon from the Max Planck Institute for Solar System Research (MPS) and the University of Gottingen succeeded in measuring the oblateness of a slowly rotating star.

In their study, which is published on 16 November 2016 in the journal Science Advances, they determine for the first time stellar oblateness with unprecedented precision using asteroseismology - the study of the oscillations of stars.

The technique is applied to a star 5,000 light-years (47,000,000 billion kilometers) away from Earth and reveals that the difference between the equatorial and polar radii of the star is only 3 kilometers - a number that is astonishing small compared to the star's mean radius of 1.5 million kilometers.

All stars rotate and are therefore flattened by the centrifugal force. The faster the rotation, the more oblate the star becomes. Our Sun rotates with a period of 27 days and has a radius at the equator that is 10 km larger than at the poles; for the Earth this difference is 21 km.

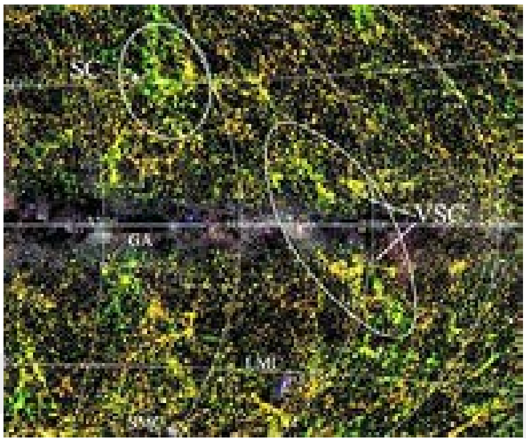
Gizon and his colleagues selected a slowly rotating star named Kepler 11145123. This hot and luminous star is more than twice the size of the Sun and rotates three times more slowly than the Sun.

Gizon and his colleagues selected this star to study because it supports purely sinusoidal oscillations. The periodic expansions and contractions of the star can be detected in the fluctuations in brightness of the star.

NASA's Kepler mission observed the star's oscillations continuously for more than four years. Different modes of oscillation are sensitive to different stellar latitudes.

For their study, the authors compare the frequencies of the modes of oscillation that are more sensitive to the low-latitude regions and the frequencies ...Read More...

Supercluster of galaxies found hidden by the Milky Way



The Vela supercluster in its wider surroundings: The image displays the smoothed redshift distribution of galaxies in and around the Vela supercluster (larger ellipse; VSC). The centre of the image, so-called the Zone of Avoidance, is covered by the Milky Way (with its stellar fields and dust layers shown in grey scale), which obscures all structures behind it

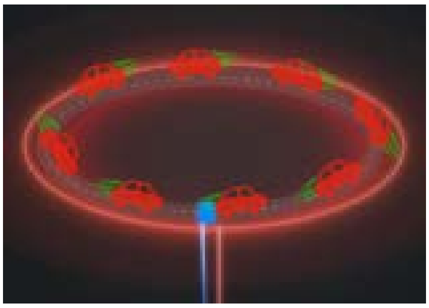
An international team of astronomers has discovered a previously unknown major concentration of galaxies in the constellation Vela, which they have dubbed the Vela supercluster. The gravitational attraction from this large mass concentration in our cosmic neighbourhood may have an important effect on the motion of our Local Group of Galaxies including the Milky Way. It may also help to explain the direction and amplitude of the Local Group's peculiar velocity with respect to the cosmic microwave background.

Superclusters are the largest and most massive known structures in the universe. They consist of clusters of galaxies and walls that span up to 200 million light-years across the sky. The most famous supercluster is the Shapley supercluster, some 650 million light-years away containing two dozens of massive X-ray clusters for which thousands of galaxy velocities have been measured. It is believed to be the largest of its kind in our cosmic neighbourhood.

Now a team from South Africa, the Netherlands, Germany, and Australia including two scientists at the Max-Planck-Institut fur Extraterrestrische Physik in Garching, has discovered another major supercluster, slightly further away (800 million light-years distant), which covers an even larger sky area than Shapley.

The Vela supercluster had gone unnoticed due to its location behind the plane of the Milky Way, where dust and stars obscure background galaxies, resulting in a broad band void of extragalactic sources. The team's results suggest the Vela supercluster might be as massive as Shapley, which indicates that its influence on local bulk flows is comparable to that of Shapley. ...Read More...

Atomic beltway could solve problems of cosmic gravity



This artist's conception imagines the proposed ring of atoms as cars on a beltway. Captured and then stirred into motion by lasers, the atoms would form a "superposition", a quantum state in which they would be simultaneously circulating around the ring and stationary. This state could allow scientists to measure motion precisely, and also potentially the effects of gravity at micrometer length scales. Credit: Hanacek / NIST

When is a traffic jam not a traffic jam? When it's a quantum traffic jam, of course. Only in quantum physics can traffic be standing still and moving at the same time.

A new theoretical paper from scientists at the National Institute of Standards and Technology (NIST) and the University of Maryland suggests that intentionally creating just such a traffic jam out of a ring of several thousand ultracold atoms could enable precise measurements of motion. If implemented with the right experimental setup, the atoms could provide a measurement of gravity, possibly even at distances as short as 10 micrometers - about a tenth of a human hair's width.

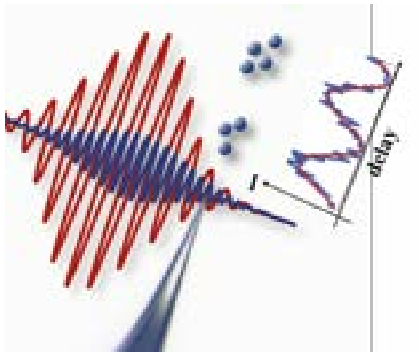
While the authors stress that a great deal of work remains to show that such a measurement would be attainable, the potential payoff would be a clarification of gravity's pull at very short length scales. Anomalies could provide major clues on gravity's behavior, including why our universe appears to be expanding at an accelerating rate.

In addition to potentially answering deep fundamental questions, these atom rings may have practical applications, too. They could lead to motion sensors far more precise than previously possible, or serve as switches for quantum computers, with 0 represented by atomic gridlock and 1 by moving atom traffic.

The authors of the paper are affiliated with the Joint Quantum Institute and the Joint Center for Quantum Information and Computer Science, both of which are partnerships between NIST and the University of Maryland.

Over the past two decades, physicists have explored an exotic state of matter called a Bose-Einstein condensate (BEC), which exists when atoms overlap one another at frigid temperatures a smidgen of a degree away from absolute zero. Under these conditions, a tiny cloud of atoms can essentially become one large ...Read More...

Controlling electrons in time and space



Credit: FAU Erlangen-Nürnberg

In an electron microscope, electrons are emitted by pointy metal tips, so they can be steered and controlled with high precision. Recently, such metal tips have also been used as high precision electron sources for generating X-rays. A team of researchers at TU Wien (Vienna), together with colleagues from the FAU Erlangen-Nürnberg (Germany), have developed a method of controlling electron emissions with higher precision than ever before. With the help of two laser pulses, it is now possible to switch the flow of electrons on and off on extremely short time scales.

It's Just the Tip of the Needle

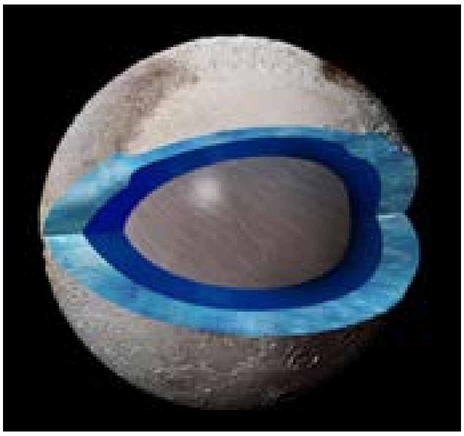
"The basic idea resembles a lightning rod," says Christoph Lemell (TU Wien). "The electrical field around a needle is always strongest right at the tip. That's why the lightning always strikes the tip of a rod, and for the same reason, electrons leave a needle right at the tip."

Extremely pointy needles can be fabricated with the methods of modern nanotechnology. Their tip is just a few nanometres wide, so the point at which the electrons are emitted is known with very high accuracy. In addition to that, it is also important to control at which point in time the electrons are emitted.

This kind of temporal control has now become possible using a new approach: "Two different laser pulses are fired at the metal tip," explains Florian Libisch (TU Wien). The colours of these two lasers are chosen such that the photons of one laser have exactly twice the energy of the other laser's photons. Also, it is important to ensure that both light waves oscillate in perfect synchronicity.

With the help of computer simulations, the team from TU Wien was able to predict that a small time delay between the two laser pulses can serve as a "switch" for electron emission. This prediction has now been confirmed by experiments performed by Professor Peter Hommelhoff's research group at FAU Erlangen-Nürnberg. Based on these experiments, it is now possible to understand the process in detail. ...Read More...

New analysis adds to support for a subsurface ocean on Pluto



This cutaway image of Pluto shows a section through the area of Sputnik Planitia, with dark blue representing a subsurface ocean and light blue for the frozen crust. Image courtesy Pam Engebretson.

A liquid ocean lying deep beneath Pluto's frozen surface is the best explanation for features revealed by NASA's New Horizons spacecraft, according to a new analysis. The idea that Pluto has a subsurface ocean is not new, but the study provides the most detailed investigation yet of its likely role in the evolution of key features such as the vast, low-lying plain known as Sputnik Planitia (formerly Sputnik Planum).

Sputnik Planitia, which forms one side of the famous heart-shaped feature seen in the first New Horizons images, is suspiciously well aligned with Pluto's tidal axis. The likelihood that this is just a coincidence is only 5 percent, so the alignment suggests that extra mass in that location interacted with tidal forces between Pluto and its moon Charon to reorient Pluto, putting Sputnik Planitia directly opposite the side facing Charon. But a deep basin seems unlikely to provide the extra mass needed to cause that kind of reorientation.

"It's a big, elliptical hole in the ground, so the extra weight must be hiding somewhere beneath the surface. And an ocean is a natural way to get that," said Francis Nimmo, professor of Earth and planetary sciences at UC Santa Cruz and first author of a paper on the new findings published November 16 in Nature. Another paper in the same issue, led by James Keane at the University of Arizona, also argues for reorientation and points to fractures on Pluto as evide nce that this happened.

Like other large basins in the solar system, Sputnik Planitia was most likely created by the impact of a giant meteorite, which would have blasted away a huge amount of Pluto's icy crust. With a subsurface ocean, the response to this would be an upwelling of water pushing up against the thinned and weakened crust of ice. At equilibrium, because water is denser than ice, that would still leave a fairly deep basin with a thin crust of ice over the upwelled mass of water. ..Read More...

Can we grow potatoes on Mars?

File Image.

In the Hollywood science fiction movie "The Martian," the astronaut stranded on the Red Planet lives on potatoes he grows there for more than 500 days while awaiting rescue. But will potatoes really grow on Mars one day? Although humans haven't set foot on Mars, astronauts have tasted lettuce grown on the International Space Station.

On Tiangong-2, China's first space lab which was launched in September, an experiment is underway to grow rice and thale cress (Arabidopsis thaliana), a kind of vegetable. Chinese scientists hope the plants will go through the whole cycle, from seed to seed.

Scientists are eager to know whether plants in space - where there is no distinction between up and down, day and night and different seasons - still blossom according to an Earth-based cycle, and yield the same seeds.

"We want to study the growth rhythm and the flowering of plants in micro-gravity conditions," says Zheng Huiqiong, chief scientist in charge of plant research on Tiangong-2, and a researcher with the Institute of Plant Physiology and Ecology of the Shanghai Institutes for Biological Sciences under the Chinese Academy of Sciences (CAS).

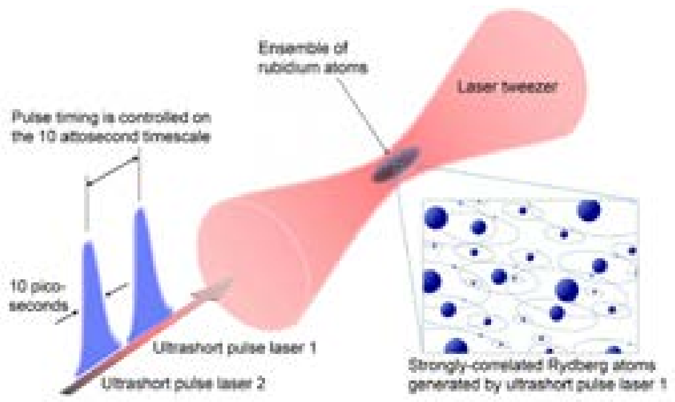
"So far, the plants on Tiangong-2 have been growing well. Some Arabidopsis thaliana are blooming, and the rice is about 10 centimeters tall," Zheng says.

When the two Chinese astronauts who flew the Shenzhou-11 spacecraft to the space lab on Oct. 17 return to Earth later in November, they will bring back samples of the Arabidopsis thaliana, which is expected to yield seeds in space, says Zheng.

The rice experiment will continue on Tiangong-2 for about half a year. "This is China's longest plant-growing experiment in space," says Zhang Tao, a researcher with the Shanghai Institute of Technical Physics of CAS, who is in charge of developing the plant incubator on Tiangong-2.

"Unlike similar experiments on the International Space Station usually conducted by astronauts ...Read More...

World's fastest quantum simulator operating at the atomic level



Schematic explanation of the world's fastest quantum simulator. Credit: NINS/IMS

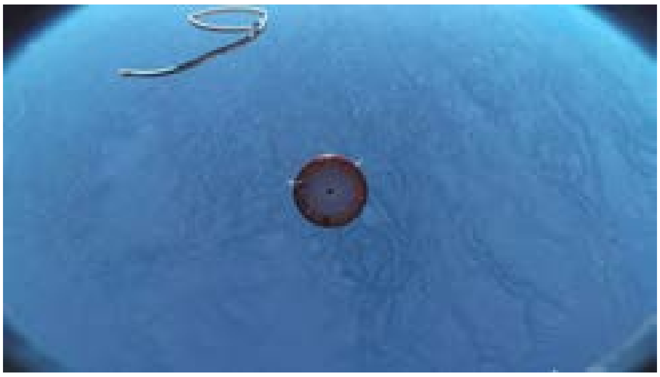
Kenji Ohmori (Institute for Molecular Science, National Institutes of Natural Sciences, Japan) and a group of collaborators have developed the world's fastest simulator for the quantum mechanical dynamics of a large number of particles interacting with each other within one billionths of a second.

The dynamics of interactions between large numbers of electrons govern a variety of important physical and chemical phenomena, including superconductivity, magnetism and chemical reactions. An ensemble of many particles thus interacting with each other is referred to as a "strongly correlated system." Understanding the properties of strongly correlated systems is thus one of the central goals of modern sciences. It is extremely difficult, however, to predict theoretically the properties of a strongly correlated system even using the Japanese post-K supercomputer, which is planned for completion by the year 2020.

For example, the post-K cannot even calculate the precise energy, the most basic property of matter, when the number of particles in the system is more than 30. Instead of calculating with a classical computer such as the post-K, an alternative concept, a "quantum simulator," has been proposed, in which quantum mechanical particles such as atoms are assembled into an artificial strongly correlated system whose properties are known and controllable. The latter is then used to simulate and understand the properties of a different strongly correlated system whose properties are not known.

The team has now developed a completely new quantum simulator for the dynamics of a strongly correlated system of more than 40 atoms within one billionths of a second. This has been realized by introducing a novel approach in which an ultrashort laser pulse at a pulse-width of only 100 billionths of a second is employed to control a high-density ensemble of atoms cooled to temperatures close to absolute zero. Furthermore, they have succeeded ...Read More...

Optical clock technology tested in space for first time



This view of Earth from the research rocket shows the detachment of the last booster -- the moment when the optical clock began operating under microgravity. Credit: Airbus Defense & Space GmbH

For the first time, an optical clock has traveled to space, surviving harsh rocket launch conditions and successfully operating under the microgravity that would be experienced on a satellite. This demonstration brings optical clock technology much closer to implementation in space, where it could eventually allow GPS-based navigation with centimeter-level location precision.

In The Optical Society's journal for high impact research, Optica, researchers report on a new compact, robust and automated frequency comb laser system that was key to the operation of the space-borne optical clock. Frequency combs are the "gears" necessary to run clocks ticking at optical frequencies.

"Our device represents a cornerstone in the development of future space-based precision clocks and metrology," said Matthias Lezius of Menlo Systems GmbH, first author of the paper. "The optical clock performed the same in space as it had on the ground, showing that our system engineering worked very well."

Using time for location

Phones and other GPS-enabled devices pinpoint your location on Earth by contacting at least four satellites bearing atomic clocks. Each of these satellites provides a time stamp, and the system calculates your location based on the relative differences among those times. The atomic clocks used on today's satellites are based on natural oscillation of the cesium atom—a frequency in the microwave region of the electromagnetic spectrum.

Optical clocks use atoms or ions that oscillate about 100,000 times higher than microwave frequencies, in the optical, or visible, part of the electromagnetic spectrum. The higher frequencies mean that optical clocks "tick" faster than microwave atomic clocks and could thus provide time-stamps that are 100 to 1,000 times more accurate, greatly improving the ...Read More...

This Week's Sky at a Glance - Nov. 19 - 25

Nov 19	Beehive 4.3°N of Moon (21:51)
Nov 21	Last Quarter Moon (12:33)
Nov 22	Moon at ascending node (06:48)
Nov 25	Jupiter 1.9°S of Moon (05:47)

SCASS ACTIVITIES

Friday - Nov. 25, 2016

Event: SCASS Observatory Open House
Time: 18:00 - 20:00
Location: SCASS Observatory

Why a halo around the Sun or Moon?

What makes a halo around the sun or moon? There's an old weather saying: ring around the moon means rain soon. There's truth to this saying, because high cirrus clouds often come before a storm. Notice in these photos that the sky looks fairly clear. After all, you can see the sun or moon. And yet halos are a sign of high thin cirrus clouds drifting 20,000 feet or more above our heads.

These clouds contain millions of tiny ice crystals. The halos you see are caused by both refraction, or splitting of light, and also by reflection, or glints of light from these ice crystals. The crystals have to be oriented and positioned just so with respect to your eye, in order for the halo to appear.

That's why, like rainbows, halos around the sun – or moon – are personal. Everyone sees their own particular halo, made by their own particular ice crystals, which are different from the ice crystals making the halo of the person standing next to you.

Why is it called a 22-degree halo? Because the ring has a radius of approximately 22° around the sun or moon.

Moon halo captured by Aaron Robinson in Idaho Falls, Idaho on January 30, 2015. ...Read More...

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