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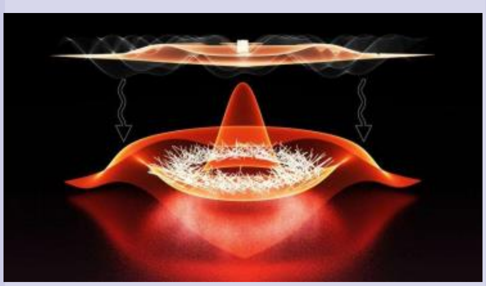
Inside this issue:

Shaking bosons into fermions

Particles can be classified as bosons or fermions. A defining characteristic of a boson is its ability to pile into a single quantum state with other bosons. Fermions are not allowed to do this. One broad impact of fermionic anti-social behavior is that it allows for carbon-based life forms, like us, to exist. If the universe were solely made from bosons, life would certainly not look like it does. Recently, JQI theorists have proposed an elegant method for achieving transmutation—that is, making bosons act like fermions. This work was published in the journal Physical Review Letters.

This transmutation is an example of emergent behavior, specifically what's known as quasiparticle excitations—one of the concepts that make condensed matter systems so interesting. Particles by themselves have mostly well-defined characteristics, but en masse, can work together such that completely distinctive, even exotic phenomena appear. Typically collective behaviors are difficult to study because the large numbers of real particles and all of their interactions are computationally challenging and in many ...Read More...

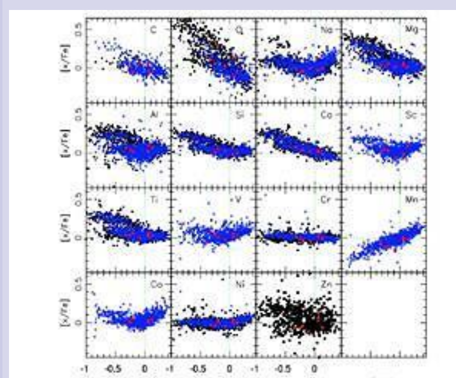


Graphic depiction of the changing band structure and its effect on the bosons. The upper part of the graphic depicts the lowest energy band in the presence of an optical lattice. The linearly aligned clump of white lines in the middle of this band represent bosons condensing prior to shaking. When the lattice shakes (represented here by a grey oscillatory overlay), a moat appears in the band structure, as shown in the lower part of the graphic. Now the lines--bosons-- are fermionic, and are clearly not aligned, indicating a lack of condensation and long-range order. Credit: E. Edwards/JQI

What kinds of stars form rocky planets

As astronomers continue to find more and more planets around stars beyond our own Sun, they are trying to discover patterns and features that indicate what types of planets are likely to form around different kinds of stars. This will hopefully inform and make more efficient the ongoing planet hunting process, and also help us better understand our own Solar System's formation.

When a star is young, it is surrounded by a rotating disk of gas and dust, from which its planets form. As such, it's expected that chemical composition of the star should in some way affect the compositions of the planets orbiting it. Indeed, previous research has demonstrated that gas giant planets preferentially form around iron-rich stars. But more recent results have started to suggest that smaller planets do not require such high iron content in their stars to form. ...Read More...



This figure from the paper shows the abundance of different elements in stars versus their abundances of iron. In each square, you can see a plot of the abundance of one element (represented by [x/Fe]) against the abundance of iron (represented by [Fe/H]). Each red dot, black square, or blue X represents a star. The red dots are the small planet-hosting stars studied in this new work. You can see how they do not stand out from the rest of the stars, which were studied in other publications, some of which host planets and some of which have no known planets. The green dashed lines show these values for our Sun.

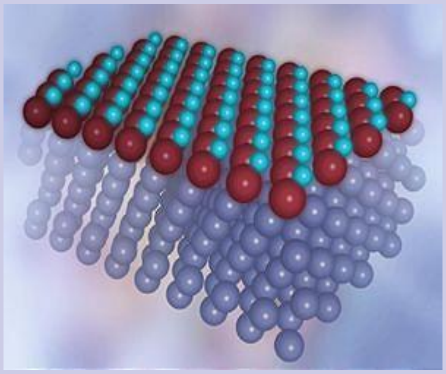
Dimensionality transition in a newly created material

Iron oxides occur in nature in many forms, often significantly different from each other in terms of structure and physical properties. However, a new variety of iron oxide, recently created and tested by scientists in Cracow, surprised both physicists and engineers, as it revealed features previously unobserved in any other material.

The new form of iron oxide (FeO) is a metallic crystal with virtually no defects, a unique conglomerate of electrical and magnetic characteristics, and atoms that vibrate as if the number of dimensions has been reduced. This remarkable material has been prepared, modelled and tested by physicists at the Leading National Research Centre (KNOW) in Cracow, Poland.

"We've been working with modelling materials, including varieties of iron oxide, for years. Our models, constructed on the basis of the fundamental principles of quantum mechanics and statistical physics, have allowed us to determine the positions of atoms in the crystal lattice and to predict the electric, magnetic and thermodynamic properties of materials," explains Dr. Przemyslaw Piekarz, head of Computational Materials Science at IFJ PAN.

The theorists in Cracow specialize in studying lattice dynamics, allowing them to determine how atoms in a crystal of a material vibrate. One of the basic tools they use is the PHONON program, created and developed by Prof. Krzysztof Parlinski (IFJ PAN). The VASP (Vienna Ab-initio Simulation Package) software ...Read More..



This is a computer visualization of a single layer of a new form of iron oxide on a platinum substrate. Iron atoms in brown, oxygen atoms in light blue. Image courtesy IFJ PAN.

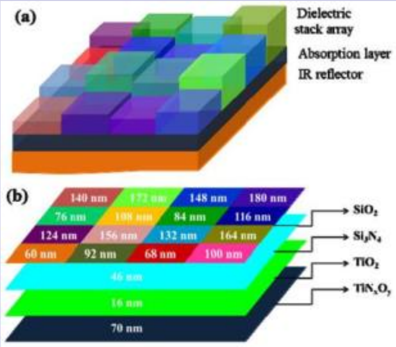
Making colorful buildings that convert solar light into energy

By converting sunlight into usable energy, solar thermal devices could become an important part of a sustainable future. To that end, researchers have developed a new solar-light-absorbing surface that can have almost any design, pattern, and color – useful for turning building facades and roofs into energy-capturing exteriors without sacrificing aesthetics.

Since they also use similar materials as existing solar absorbers, this new kind of solar absorber could lead to wider use of solar thermal technology and more energy efficiency, said Shao-Wei Wang, Shanghai Institute of Technical Physics, China. Wang and his colleagues describe their design in Optics Express, a journal of The Optical Society (OSA). "A significant amount of energy might come from our building facades and roofs," he said.

One of the most common uses of solar thermal technology is to heat water, allowing for an enjoyable hot shower or a dip in a warm swimming pool. Hot water could also heat buildings during winter. Additionally, solar thermal technology can generate electricity. While solar panels convert sunlight directly into electricity, solar thermal devices use sunlight to first boil a liquid like water, producing gas or steam that drives power generators.

At the heart of this technology are layered surfaces called solar selective absorbers, which, as their name implies, are made from ...Read More...



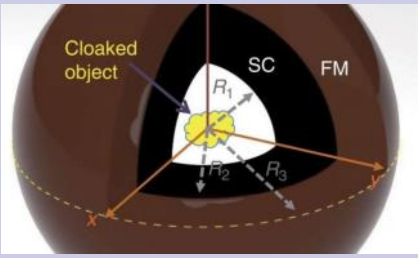
(a) Schematic diagram of monolithic integrated colored solar selective absorber array with structure of IR reflector/absorption layer /dielectric stack. (b) Schematic diagram of monolithic integrated colored solar selective absorber array with different thickness of SiO2. Credit: Optics Express

Magnetic invisibility cloak shields magnets from magnetic fields

Typically when two magnets are brought close together, they either attract or repel each other due to interactions between their magnetic fields. In a new study, researchers have designed a 3D magnetic invisibility cloak, inside of which they placed a magnetic object, and showed that the cloaked magnet is no longer affected by nearby magnetic fields. It appears as if the cloaked magnet has become demagnetized, but in reality the magnet is simply hidden.

The researchers, led by Yungui Ma at Zhejiang University in Hangzhou, China, have published a paper titled "Three-dimensional magnetic cloak working from d.c. to 250 kHz" in a recent issue of Nature Communications. Like other invisibility cloaks, the new cloak is made of metamaterials (man-made materials with repeating patterns) and works by manipulating electromagnetic waves in unusual ways.

To achieve the cloaking effect, the researchers used a new type of invisibility cloak called a bilayer cloak, first demonstrated in 2012 by Alvaro Sanchez and colleagues at the Autonomous University of Barcelona. The cloak has a spherical structure consisting of two shells: a superconducting inner shell (made of single-crystal YBCO) and a ferromagnetic outer shell (made of a nickel zinc composite). These two materials have opposite magnetic behaviors, which causes them to have opposite effects on an external ...Read More….



The bilayer cloak consists of an inner superconducting shell and an outer ferromagnetic shell, whose opposite effects on an external magnetic field completely cancel each other out to shield a cloaked magnetic object (yellow) from the external magnetic field. Credit: Zhu, et al. ©2015 Nature Communications

Event Horizon Telescope reveals magnetic fields in central black hole

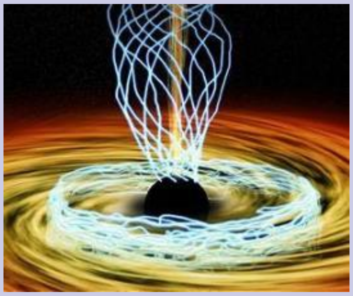
Most people think of black holes as giant vacuum cleaners sucking in everything that gets too close. But the supermassive black holes at the centers of galaxies are more like cosmic engines, converting energy from infalling matter into intense radiation that can outshine the combined light from all surrounding stars.

If the black hole is spinning, it can generate strong jets that blast across thousands of light-years and shape entire galaxies. These black hole engines are thought to be powered by magnetic fields. For the first time, astronomers have detected magnetic fields just outside the event horizon of the black hole at the center of our Milky Way galaxy.

"Understanding these magnetic fields is critical. Nobody has been able to resolve magnetic fields near the event horizon until now," says lead author Michael Johnson of the Harvard-Smithsonian Center for Astrophysics (CfA). The results appear in the Dec. 4th issue of the journal Science.

"These magnetic fields have been predicted to exist, but no one has seen them before. Our data puts decades of theoretical work on solid observational ground," adds principal investigator Shep Doeleman (CfA/MIT), who is assistant director of MIT's Haystack Observatory.

This feat was achieved using the Event Horizon Telescope (EHT) - a global network of radio telescopes that link together to function as one giant telescope the size ...Read More...



In this artist's conception, the black hole at the center of our galaxy is surrounded by a hot disk of accreting material. Blue lines trace magnetic fields. The Event Horizon Telescope has measured those magnetic fields for the first time with a resolution six times the size of the event horizon (6 Schwarzschild radii). It found the fields in the disk to be disorderly, with jumbled loops and whorls resembling intertwined spaghetti. In contrast, other regions showed a much more organized pattern, possibly in the region where jets (shown by the narrow yellow streamer) would be generated. Image courtesy M. Weiss/CfA.

Magnified image of faintest galaxy from early universe

Astronomers harnessing the combined power of NASA's Hubble and Spitzer space telescopes have found the faintest object ever seen in the early universe. It existed about 400 million years after the big bang, 13.8 billion years ago. The team has nicknamed the object Tayna, which means "first-born" in Aymara, a language spoken in the Andes and Altiplano regions of South America.

Though Hubble and Spitzer have detected other galaxies that are record-breakers for distance, this object represents a smaller, fainter class of newly forming galaxies that until now had largely evaded detection. These very dim objects may be more representative of the early universe, and offer new insight on the formation and evolution of the first galaxies.

"Thanks to this detection, the team has been able to study for the first time the properties of extremely faint objects formed not long after the big bang," said lead author Leopoldo Infante, an astronomer at the Pontifical Catholic University of Chile. The remote object is part of a discovery of 22 young galaxies at ancient times located nearly at the ...Read More...

This is a Hubble Space Telescope view of a very massive cluster of galaxies, MACS J0416.1-2403, located roughly 4 billion light-years away and weighing as much as a million billion suns. Image courtesy NASA, ESA, and Pontificia

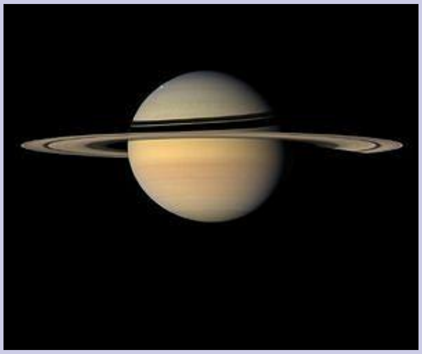
NASA team discover how water escapes from Saturn

A University of Montana professor who studies astrophysics has discovered how water ions escape from Saturn's environment. His findings recently were published in the journal Nature Physics. UM Professor Daniel Reisenfeld is a member of the Cassini research team. Cassini is a NASA-managed probe that studies Saturn. It has been in orbit continuously collecting data since 2004.

One of the instruments on Cassini measures the planet's magnetosphere - the charged particles, known as plasma, that are trapped in the space surrounding Saturn by its magnetic field. One of Cassini's past discoveries is that Saturn's plasma comprises water ions, which are derived from Saturn's moon Enceladus, which spews water vapors from its Yellowstone-like geysers. Knowing that the water ions would not be able to accumulate indefinitely, the team of researchers set out to explain how the water ions escape from Saturn's magnetosphere.

The answers to this phenomenon were published by Nature Physics in an article titled "Cassini in situ observations of long-duration magnetic reconnection in Saturn's magnetotail."

In the paper, the authors explain that the plasma found a place to exhaust out of the magnetosphere at a reconnection point - basically where magnetic fields from one environment disconnect and reconnect with magnetic fields from another environment. In the case of Saturn, researchers discovered the reconnection point was located at the back of the planet, where the magnetotail was connecting with the solar winds' magnetic field. ...Read More...



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Spacecraft Launches to Test the Hunt for Ripples in the Fabric of Spacetime

The European Space Agency successfully launched the LISA Pathfinder, a spacecraft designed to demonstrate technology for observing gravitational waves in space. The launch took place at Europe's spaceport in Kourou, French Guiana on a Vega rocket, at 4:04 GMT on December 3, (10:04 pm EST Dec 2), 2015.

Gravitational waves are ripples in the fabric of spacetime, which were predicted by Albert Einstein in his General Theory of Relativity. So far, because they are extremely tiny and incredibly faint, gravitational waves have proved to be elusive. The technology needed to detect them is highly sensitive and therefore has been difficult to conceive, plan and build.

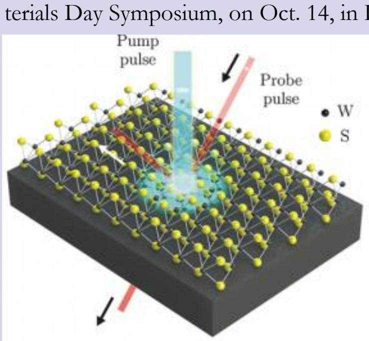
The LISA Pathfinder mission is only testing the technology to see if it will be possible to detect the waves caused by a gravitational event such as the collision of two black holes, a supernova or a star with a wobbly spin. Such an event should cause a minute distortion in the fabric of space, and it is predicted that these tiny changes should be detectable. However, the accuracy needed to detect any gravitational waves is extraordinary. An example of how tiny gravitational waves are: the ripples emitted by a pair of orbiting black holes would stretch a million kilometer-long ruler by less than the size of an atom.

LISA Pathfinder will use a specialized laser and interferometer to measure the distance between two free-floating gold–platinum cubes that will be released into two separate vacuum chambers that are 38 cm apart. Between these chambers is the interferometer detectors. The cubes will be in the equivalent of freefall, and therefore be free from all external and internal forces acting on them, except for gravity. The detectors will monitor the cubes' relative ...Read More...

Grad student discovers unique valleytronics properties of tungsten disulfide monolayer film

Monolayer films of tungsten disulfide, just three atoms thick, have unique electronic valleys which can be manipulated with laser light. This finding, by MIT physics graduate student Edbert Jarvis Sie, Associate Professor Nuh Gedik, and colleagues, was significant enough to warrant placement on the cover of Nature Materials earlier this year.

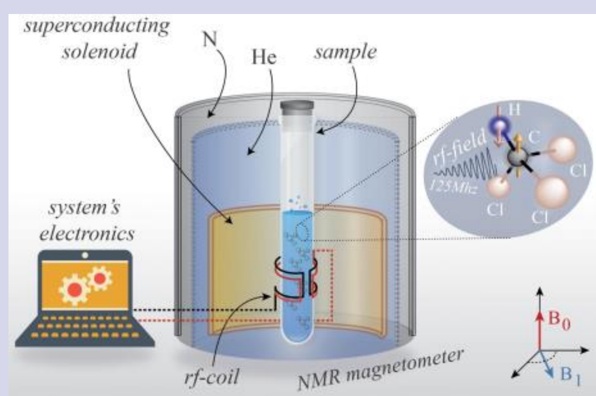
The cover illustrates a tornado-like whorl of light, lifting an electronic band in the material to a higher energy state, which widens the band gap in the material. This widening is known as the optical Stark effect. The researchers, under senior author Nuh Gedik, the Lawrence C. (1944) and Sarah W. Biedenharn Career Development Associate Professor of Physics at MIT, found that applying circularly polarized laser light lifted the energy in one valley while leaving the energy in the other valley unaffected. "There are two valleys. If we switch the laser polarization, the effect switches to the other valley," Sie says. Gedik spoke about his group's research on topological insulators at the Materials Day Symposium, on Oct. 14, in Kresge ...Read More….



Researchers at the Gedik Lab at MIT use strong ultrafast laser pulses to stimulate changes in material, followed by a weaker probe laser pulse after some time delay to monitor the changes with femtosecond time resolution. Tungsten (W) atoms are black, and sulfur (S) atoms are yellow. Credit: Edbert Jarvis Sie

Physicists confirm thermodynamic irreversibility in a quantum system

For the first time, physicists have performed an experiment confirming that thermodynamic processes are irreversible in a quantum system—meaning that, even on the quantum level, you can't put a broken egg back into its shell. The results have implications for understanding thermodynamics in quantum systems and, in turn, designing quantum computers and other quantum information technologies. ..Read More...



In the experiment, a sample of liquid chloroform (CHCl3) is placed at the center of a superconducting magnet inside a nuclear magnetic resonance (NMR) magnetometer. Forward and reverse magnetic pulses are applied to the sample, which drives the carbon nuclear spins out of equilibrium and produces irreversible entropy. Credit: Batalhão, et al. ©2015 American Physical Society