A Quantum Tug-of-War

In a molecule made up of two rubidium atoms, a charge imbalance is created when one atom is excited to a Rydberg state

A tug-of-war between two rubidium atoms recently ended in a result that would be almost unimaginable in recreational sports: Normally, two similar atoms are equally matched in the fight for the binding electrons with which they are welded into a single molecule. Nevertheless, one atom succeeded in pulling the electrons closer, so that a negative and a positive pole formed, creating a molecule with a permanent electric dipole moment. This contradicts the scientific consensus on the force ratio between two identical atoms in one molecule.

Nevertheless, an international team working with Jan-Michael Rost at the Max Planck Institute for the Physics of Complex Systems in Dresden helped a rubidium atom to win this electronic tug-of-war. At temperatures close to absolute zero, the researchers used laser light to excite its opponent to a Rydberg state, which caused its electron shell to inflate enormously. With the distribution of electrons distorted in a molecule with a non-excited atom, the non-excited atom became the negative pole of a weak permanent dipole moment. (Science, November 25, 2011)

A trilobite molecule: When a strongly excited Rydberg atom binds with an unexcited atom, the resulting molecule looks like a prehistoric animal. The Rydberg atom sits in the center of the circle, the unexcited atom on the upper edge. The difference in size between the two atoms distorts the distribution of the charge and a dipole is created from two identical atoms in the molecule.

"Just look at that!"

Ravens gesticulate with their beaks to draw the attention of other ravens to objects

Ravens are more intelligent and are able to cooperate more than most other bird species. In fact, they score as well as great apes in intelligence tests.

Human language probably evolved from deictic or pointing gestures. Even before children start to talk, between the ages of nine months and a year, they use their fingers to point at objects or they hold them up. Up to now, these gestures have been observed only in humans and great apes. However, behavioral biologists at the Max Planck Institute for Ornithology in Seewiesen and at the University of Vienna have shown that ravens *(Corvus corax)* also make use of such gestures. The birds use their beaks like hands and hold up objects such as moss, small stones and twigs. In this way, they test the interest of a potential partner or reinforce an existing relationship. The researchers assume that other animal species that have a strong capacity to cooperate also communicate using gestures. (Nature Communications, November 29, 2011)

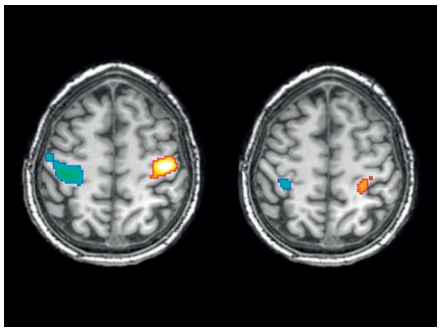
Photos: MPI for the Physics of Complex Systems - University of Stuttgart (top), Accipiter - R. Altenkamp, Berlin (bottom)

Am I Awake – or Dreaming?

Dreams activate the brain in a similar way to real action

In our dreams, we experience vivid images and intense feelings. But exactly what happens in the brain during this process is still largely a mystery. Researchers at the Max Planck Institute of Psychiatry in Munich and the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig have been helped by a "lucid dreamer," a person who is aware of dreaming and who can influence the content of their dreams. As the test person slept in an MRI scanner, he was asked to deliberately dream that he was clenching first his left hand and then his right, and to signal this to the researchers with eye movements.

The dreamed movement activated the sensorimotor cortex, which is an area of the brain that is active during actual activity. In addition, a brain region that plays an important part in planning movement was also active. Therefore, it is not the case that we only observe events passively while we dream. In fact, brain regions that play a role in our waking actions are also involved. (Current Biology, October 2011)



Activity in the motor cortex during actual hand movements while awake (left) and during a dreamed movement (right). Blue regions reflect activity through movement of the right hand, red the activity through movement of the left hand.

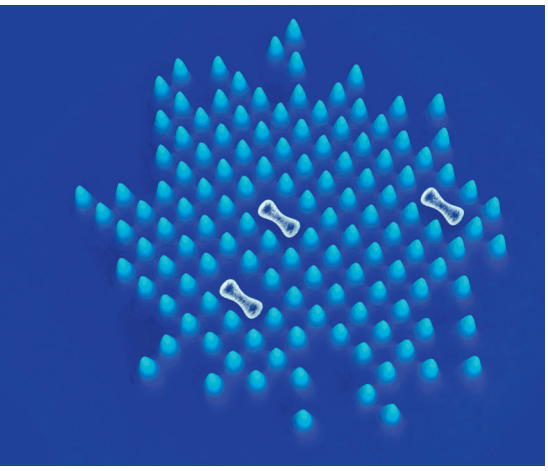
Fading Environmental Traces in DNA

Jean-Baptiste de Lamarck would have been pleased: His conviction that living beings can pass on acquired characteristics to their offspring, which had been forgotten in the triumphant wake of Darwin's theory of evolution, has been rehabilitated over the last few years. Environmental influences do indeed leave traces in DNA – in the form of small molecular attachments on the genetic substance, called epigenetic changes. Scientists at the Max Planck Institute for Developmental Biology in Tübingen have, however, used mouse-ear cress *(Arabidopsis thaliana)* to determine that epigenetic changes occur much more frequently than classic mutations, but are often short-lived: many epigenetic changes are reversed after a few generations. They contribute to the short-term inheritance of characteristics by children from parents or by grandchildren from grandparents. (Nature, September 20, 2011)

Photos: MPI of Psychiatry (top), MPI of Quantum Optics – Immanuel Bloch (bottom)

Quantum Leaps from a Standing Start

A particularly high-resolution microscope has shed light on quantum fluctuations at a temperature of absolute zero



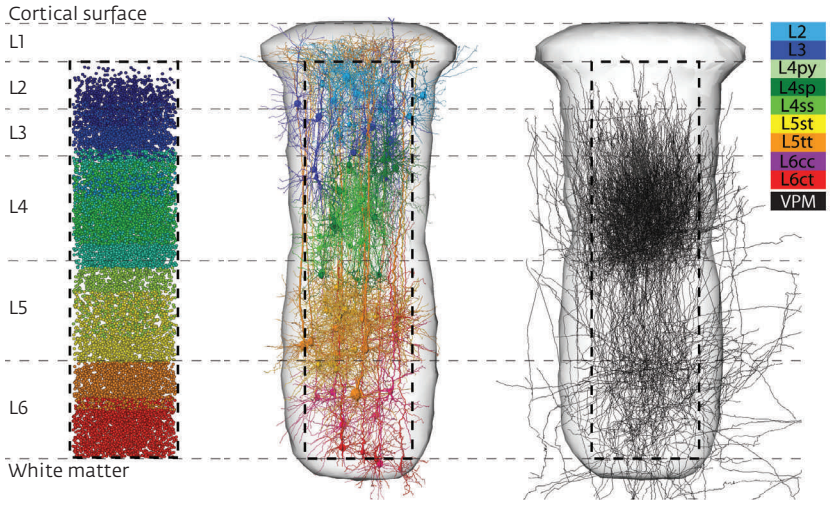
Traces of quantum fluctuation: A lattice of laser light forces atoms (light blue) into a regular structure. In this arrangement, particles tunnel from one position to the next and form atomic pairs, even at a temperature of absolute zero. These quantum fluctuations can be recognized as adjacent holes, as the detection laser catapults the atomic pairs out of the lattice.

There is no such thing as a total standstill – not even at a temperature of absolute zero, which is minus 273.16 degrees Celsius. The laws of quantum mechanics demand that the smallest particles, such as atoms and molecules, still remain in motion long after our familiar world has frozen. A team working with Stefan Kuhr and Immanuel Bloch at the Max Planck Institute of Quantum Optics in Garching has now used a particularly high-resolution microscope for direct observation of quantum fluctuations, which is the name physicists give to atomic movements when the temperature is approaching absolute zero. The researchers trapped rubidium atoms in a laser lattice and cooled it to below minus 273 degrees Celsius. The atoms jumped from one lattice position to the next even though their remaining thermal energy wouldn't be sufficient to allow them to do this. (Science, October 14, 2011)

The Cerebrum in 3-D

Researchers simulate electrical signals in a cortical column on a computer

In the cerebral cortex, vertical rows of linked nerve cells form the basis of a brain circuit. Researchers at the Max Planck Florida Institute have now, for the first time, reconstructed these cortical columns three-dimensionally in rats in a waking state. They have thus succeeded in completing the first stage of a complete computer model of the brain. The neuroscientists examined around 15,000 nerve cells of nine different types and reconstructed their axons and dendrites. The researchers are now able to measure the connections between nerve cells in these networks and their responses to stimuli in both anesthetized and conscious animals. (Cerebral Cortex, published in advance online, November 16, 2011)



Cortical column nerve cells in the sensory cortex of a rat (left), dendrites of these nerve cells (center) and axons (right). The colors indicate the different types of cells.

An Opportunity for Successful Climate Conferences

The prospect of medium-term damage from global warming could persuade poor and rich countries to effectively reduce carbon dioxide emissions

Climate change could cause storm damage, such as here in the US, more frequently and more severely over the next 10 to 20 years. If this medium-term threat could be credibly proven through scientific means, the rich industrial nations might be prepared to invest more in climate protection.

The climate conference in Durban might have ended with binding agreements on climate protection – if findings by Max Planck researchers had been introduced into the negotiations. These findings revealed that the UN conferences were more likely to succeed if they focused more closely on the economic damage caused by global warming in 20 years, and on countermeasures to protect the climate. This could induce rich industrial countries to reduce their greenhouse gas emissions to the extent that they would compensate for the lack of contributions from developing and emerging nations. Scientists working with Manfred Milinski at the Max Planck Institute for Evolutionary Biology and Jochem Marotzke at the Max Planck Institute for Meteorology came to this conclusion during an experimental game. The investigation represented their response to the failure of the most recent climate conferences due to the inability of rich and poor nations to agree on how much they should each contribute. (Climate Change Letters, October 15, 2011)

Graphic: MPI Florida – Marcel Oberländer; photo: iStockphoto

Fast Winds with Little Energy

The upper atmosphere delivers less renewable energy than previously assumed

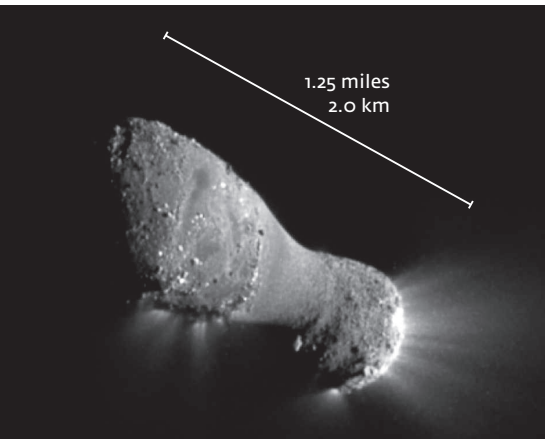
The energy mix in the future will probably have to be composed differently from the way some visionaries currently see it. This is because only half a percent of the energy previously assumed can be generated from the jet streams that rush at great wind speeds through the upper atmosphere. This calculation was made by Axel Kleidon and his colleagues at the Max Planck Institute for Biogeochemistry in Jena. Up to now, the fast winds have been considered a very productive source of renewable energy, and engineers are already working on ways to harness it. However, the high speeds of the winds are due to very low friction and not to strong propulsion, which is required for high-output wind power systems. With the aid of simulators, the scientists have also determined that the climate is likely to undergo massive changes if large amounts of energy were to be extracted from the jet stream winds. (Earth System Dynamics, November 29, 2011)

Like kites with rotors, wind turbines would be suspended in the upper atmosphere where the jet streams blow. This composite photo shows what they might look like.

Photo: Lee Miller (top), NASA/JPL-Caltech/UMD (bottom)

Comets That Carry Water

Scientists have found the first comet – Hartley 2 – whose water is similar to that on Earth

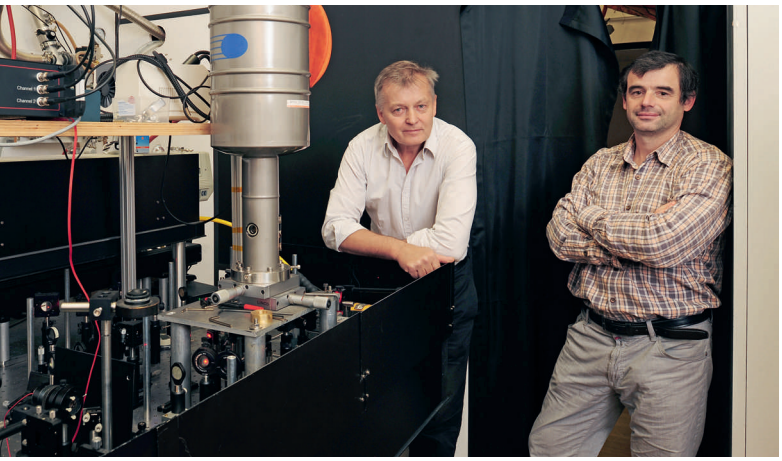


Water fell from the skies. Scientists believe that crashing cosmic bodies brought the Earth's water with them – or at least a large proportion of this valuable commodity. New measurements taken by the Herschel Space Observatory indicate that comets were apparently also involved. In 103P/Hartley 2, a team under the leadership of the Max Planck Institute for Solar System Research, has identified for the first time a comet with water in which the ratio of heavy water to normal water is the same as that on Earth. Heavy hydrogen, or deuterium, has one neutron more in its nucleus than normal hydrogen. In the water on Earth, the proportion of deuterium to hydrogen is approximately 1:6,400. The bodies that brought water to the Earth would be expected to have the two isotopes in a similar ratio. And indeed, the measurements showed that, in the Hartley 2 water, there are approximately 6,200 normal hydrogen atoms to each deuterium atom – much like the values on Earth. (Nature, published online, October 5, 2011)

The heart of the comet: The water on 103P/Hartley 2 revealed a deuterium-hydrogen ratio similar to that on Earth.

Pressure Makes Hydrogen Metallic

At 2.7 megabars, the lightest element conducts current and possibly becomes a quantum liquid that flows without friction



Creating extreme pressure: In this apparatus at 2.7 million times the Earth's atmospheric pressure, Mikhail Eremets (left) and Ivan Troyan forced hydrogen to assume a form in which it conducted current.

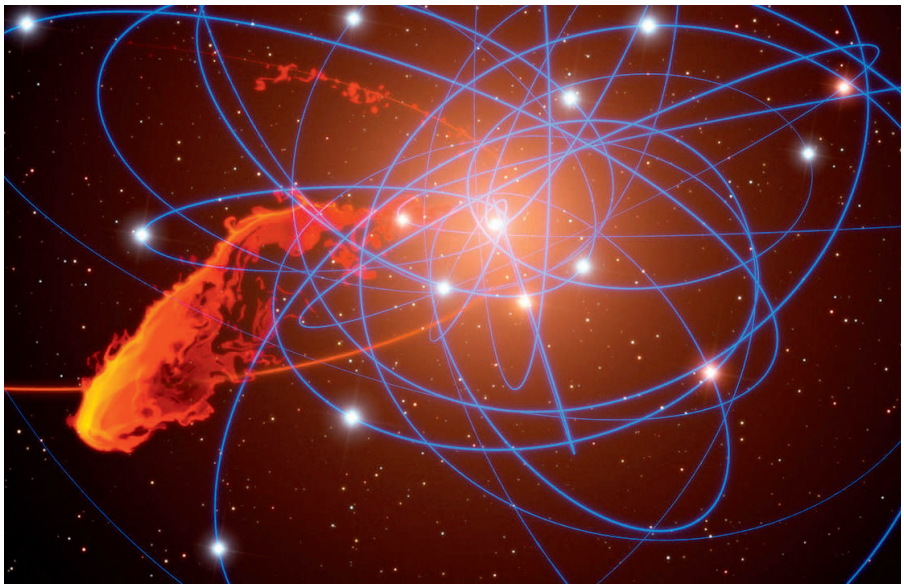
Usually, hydrogen has as much in common with a metal as a handful of confetti has with a book. And turning it into a metal conductor is as difficult as putting little scraps of paper together to form a printed page. But that is exactly what Mikhail Eremets and Ivan Troyan at the Max Planck Institute for Chemistry in Mainz have done. They gradually increased the pressure on a hydrogen sample at 25 degrees Celsius to more than 3 megabars – three million times higher than the atmospheric pressure on Earth. Pressure of this magnitude is found on stars, for example, or deep in the interior of large planets. At pressures exceeding 2.2 megabars, hydrogen behaves like a semi-conductor – a characteristic of the element that was previously unknown. At around 2.7 megabars, it assumed metallic properties, and at a much lower pressure than predicted. Under this pressure, it is possible that the hydrogen will become a superconductor, which loses its electrical resistance even at room temperature. The researchers want to investigate this in more experiments. (Nature Materials, published online, November 13, 2011)

Rich Pickings for a Galactic Black Hole

Astronomers discover a gas cloud that will soon fall into Sagittarius A*

The black hole at the heart of the Milky Way is still hungry – but the end of the diet is in sight. A gas cloud has ventured too near to the massive monster and, over the next few years, will disappear into its maw. Scientists will be able to observe feeding time for this gravitational trap (which goes by the name of Sagittarius A*) from 26,000 light years away. At the Max Planck Institute for Extraterrestrial Physics, they are already observing how the extremely powerful pull of the black hole is elongating the gas cloud.

The closer the cloud gets to the black hole (it is currently moving toward it at around 2,350 kilometers per second), the more it will interact with the hot gas in its vicinity and then be destroyed by turbulence. In 2013, at 40 billion kilometers, it should be close enough to the black hole for the feast to begin. (Nature online, December 15, 2011)



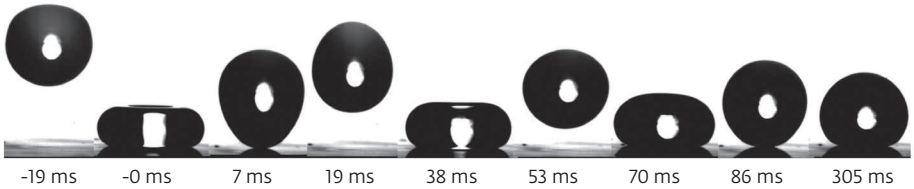
Toward the gravitational maw: The image shows the gas cloud (red) and the orbits of the stars (blue) around the black hole at the heart of the Milky Way.

Photos: MPI for Chemistry (top), ESO/MPE/Marc Schartmann (bottom)

Self-Cleaning Glass

A silicon dioxide sponge made of nanospheres and coated with fluorine atoms proves extremely water and oil-repellent

No need to polish your eye glasses ever again, and no more dirty windshields! This is the aim of Doris Vollmer and her colleagues at the Max Planck Institute for Polymer Research in Mainz and at the Technical University in Darmstadt, who have now taken a big step closer to achieving this. The researchers used candle soot to create a transparent, superamphiphobic coating of quartz glass. Both water and oil run off the coating completely. This remained the case even when the researchers blasted the surface with sand to damage it. The spongy layer has these characteristics thanks to a coating of fluorine atoms on the one hand and, on the other, its very uneven surface consisting entirely of nanospheres. The spherical soot particles supply the model for this structure. Surfaces sealed in this way could be used wherever contamination or a film of water could be harmful or simply irritating.
(Science Express, December 1, 2011)



A drip falling from a short distance onto the extremely water- and oil-repellent layer first rebounds and then lies in an almost completely spherical shape, even when it is a strongly wetting liquid.

Population Explosion in Dwarf Galaxies

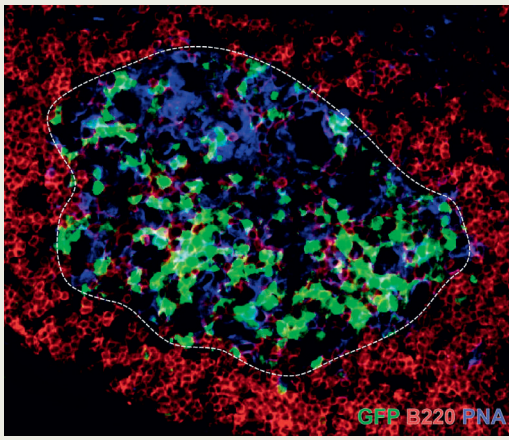
Unusually productive dwarf galaxies are a mystery, but simultaneously appear to solve the riddle of the unusual distribution of dark matter

In the early universe, there were small, young galaxies that produced new stars at absolutely breathtaking speed. Current models offer no explanation for such a high birth rate. Nevertheless, these active dwarf galaxies are a reality: astronomers working with Arjen van der Wel from the Max Planck Institute for Astronomy in Heidelberg have observed them with the Hubble space telescope. The researchers found 69 dwarf galaxies almost ten billion light years away and concluded, from the unusual color of these systems, that the rate of star birth was a thousand times higher than in our Milky Way. The high birth rate of new suns could explain why the ominous dark matter is distributed throughout these galaxies and not just in their centers, as calculated in simulations. This is because the creation of new stars forces the gas in the galaxies outward. It pulls the dark matter with it and distributes it around the galaxy. (Astrophysical Journal, November 10, 2011)

Multiple Sclerosis Develops in the Intestinal Flora

Useful bacteria in the intestine can activate immune cells and trigger an overreaction in the immune system

Multiple sclerosis is caused by a combination of genetic predisposition and environmental factors, such as microbes. However, according to researchers at the Max Planck Institute for Neurobiology in Martinsried, it is not pathogens, but useful bacteria – the healthy intestinal flora that everyone needs for their digestion – that trigger multiple sclerosis. The scientists discovered that genetically modified mice develop an inflammation of the brain similar to the human disease when their intestinal flora is normal. Conversely, animals that are raised in a germ-free atmosphere and do not develop any intestinal flora remain healthy. The results indicate that the starting point for multiple sclerosis in humans with a predisposition is bacteria in the intestine. (Nature, published online in advance, October 26, 2011)



Lymph node with auto-aggressive B-cells (green). These are activated in the lymph node's germinal centers. The activated cells produce antibodies that attack the myelin sheath in the brain and play a part in inflammatory responses.

Photos: Science - Xu Deng – MPI for Polymer Research (top), MPI for Neurobiology (bottom right)