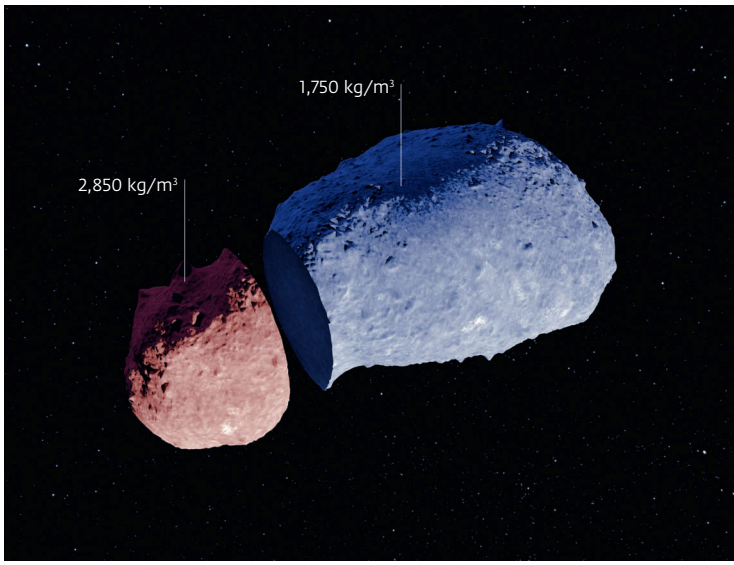
An Asteroid with Two Faces

Researchers have discovered that the minor planet Itokawa suffered a collision in its early days

Few minor planets in our solar system have been studied in as much detail as Itokawa. And this not just because the barely 600-meter-long object ranks as one of the group of near-Earth asteroids entering Earth's orbit roughly every 556 days. Itokawa was also the target of the Japanese probe *Hayabusa*, which actually brought material back to Earth from Itokawa's surface. However, what lies under the skin of the asteroid remained virtually unknown. Now we are a little wiser: from the object's rotation, a team including scientists from the Max Planck Institute for Solar System Research drew some conclusions about the internal structure of the elongated asteroid. They found it to be non-uniform: one part of the peanut-shaped object exhibits a density similar to that of granite, while the other is much looser, like tightly packed sand. Evidently Itokawa was formed when two boulders collided. (Astronomy & Astrophysics, February 5, 2014)



Cosmic peanut: The density of the smaller end (red) of the asteroid Itokawa is around 2,850 kilograms per cubic meter, and that of the larger part (blue), around 1,750 kilograms per cubic meter.

Colors – not Barriers

Instead of lignifying, maize plants affected by smut fungus exhibit bright hues

Maize affected by the corn smut *Ustilago maydis* looks scary: in place of the usual yellow kernels, the cobs display a mass of shapeless black galls inside which the fungus replicates itself. When the fungus infects a plant, it first has to find its way into the plant's vascular tissue, where it can divert the nutrients transported via this tissue for its own use. To prevent this and stop the fungus from spreading, the plant reinforces its cell walls with lignin. However, scientists at the Max Planck Institute for Terrestrial Microbiology in Marburg have discovered that the fungus manipulates the plant's metabolism: The protein Tin2 ensures that the components required to manufacture lignin are used instead in greater quantities to synthesize pigments. The effect is to weaken the plant's protective wall, while the infected areas turn red in color. Maize varieties that are low in lignin, such as those grown for the production of biofuels, are thus particularly susceptible to infection with *U. maydis*. The researchers suspect that other pathogens also prevent plants from strengthening their tissue with lignin. (eLife, January 28, 2014)

Maize leaves infected with corn smut.
Top: Infection with the wild type of the fungus.
Bottom: Infection with a mutant strain that lacks the protein Tin2. With the mutant infection, the galls are smaller and the red pigment is absent.

Clean Power from the Nano-Net

Researchers discover a potential replacement for platinum in fuel cells

Fuel cells generate electricity that is clean but expensive. Now a team at the Max Planck Institute for Solid State Research in Stuttgart has pointed out a way to build them more cheaply. The researchers have created a highly regular network of manganese or iron atoms and organic molecules on a metallic substrate that, following the principle of corresponding enzymes, acts as a catalyst in the reduction of oxygen. The metal-organic nano-net supports an important subreaction in the conversion of hydrogen and oxygen into water – the process that takes place at the two electrodes of a fuel cell. Currently, the most efficient materials to support this reaction are platinum and other rare and

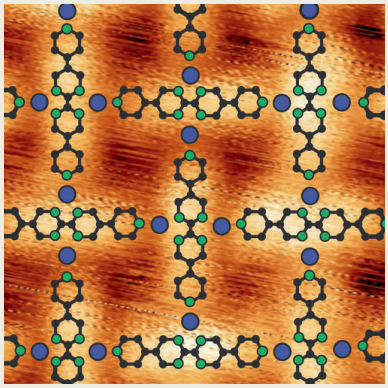
Photos: ESO/JAXA (top), MPI for Terrestrial Microbiology (bottom)

Say Cheese

Max Planck scientists reconstruct a recipe from the early Bronze Age

Normally, the protein specialists at the Max Planck Institute of Molecular Cell Biology and Genetics in Dresden spend their time analyzing proteins and fats in the cells of fruit flies and roundworms. In this case, however, their mass spectrometer had some highly unusual objects under its gaze: grave goods found with a roughly 4,000-year-old mummified body in the Xiaohe burial ground in Xinjiang in western China. In order to analyze the shapeless lumps on the neck and chest of the mummy, the scientists first had to find ways to identify proteins in organisms that hadn't previously been genetically sequenced. The lumps finally proved to be the remains of some early Bronze Age cheese. The oldest cheese known to date, it was made, like kefir, of milk mixed with a blend of bacteria and yeast and left to ferment. This type of cheese contains virtually no lactose – ideal for population groups in Asia, where lactose intolerance is common. (Journal of Archaeological Science, December 4, 2013)

The "Beauty of Xiaohe": When she died in western China around 4,000 years ago, this woman was laid to rest with small pieces of cheese as grave goods.



Self-organization: Under the right conditions, molecules of nitrogenous bispyridyl bipyrimidine (PBP) link iron atoms (blue dots) on a metallic surface to form a self-organized regular network, as shown in this image taken with a scanning tunneling microscope with superimposed graphics.

expensive precious metals. If a metal-organic network of atoms of cheaper metals and simple organic substances could be employed as a catalyst even for this part of the reaction, the cost of producing electricity from fuel cells could be reduced. (Nature Communications, December 5, 2013)

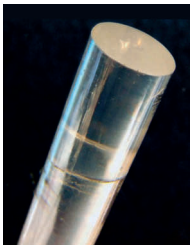
Photos: Y. Liu, Y. Yang (top), Nature communications 2013 (center left), Igor Zlotnikov/MPI for Colloids and Interfaces (bottom right)

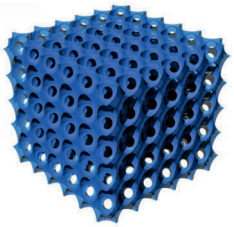
Nanotechnology in a Glass Sponge

Monorhaphis chuni produces a spicule with a perfect periodic arrangement of nanopores

Materials scientists resolve many problems by following the example of nature – and sometimes they don't realize this until after the fact. Take, for example, the synthetic nanoporous materials with potential applications in biomedicine, sensors and chemical catalysis. Their structure is similar to that of the glass rod or spicule, around a centimeter thick and up to three meters in length, that supports the sea sponge *Monorhaphis chuni*. And they are produced in a similar way. These similarities in structure and production have been identified by a team at the Max Planck Institutes of Colloids and Interfaces and Microstructure Physics. *M. chuni* wraps silicate – that is, glass – around regularly arranged silicatein proteins. These proteins then fill the pores, which are around 5 nanometers in size. This creates a structure that resembles a stack of cartons containing eggs. The eggs represent the protein molecules, while the cartons represent the glass. For certain technical applications, silicate structures are already being assembled around droplets of fat. However, the resultant materials exhibit a pore size that isn't as uniform as the protein-filled cavities in the spicule of *M. chuni*. (Advanced Materials, December 12, 2013)

Glass spicule measures up: *M. chuni* grows on a silicate spicule, the pores of which are uniform in size and even more regular in their arrangement than the cavities in technical mesoporous materials. This optical microscope image shows a glass spicule that has been ground into an exact cylinder in order to investigate its structure.





Greenhouse Sensitivity

The carbon balance of tropical rainforests is reacting more and more strongly to short-term temperature changes

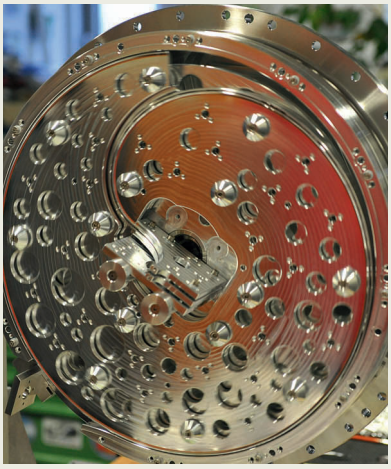
Climate researchers have had their suspicions for a while. Now it has been confirmed that climate change can intensify feedback between the Earth's carbon cycle, and thus also the carbon dioxide content in the air, as well as changes in temperature. Proof comes from an international team that included Martin Heimann, Director at the Max Planck Institute for Biogeochemistry in Jena. The scientists analyzed the natural fluctuations in the volume of carbon dioxide absorbed by tropical rainforests in cooler and in warmer years. Their findings show that, as average temperatures rise, the tropical carbon balance is becoming more and more sensitive to temperature changes. Given that both upward and downward fluctuations in the carbon balance are increasing to an equal extent, the mean carbon dioxide content in the atmosphere isn't rising. However, other feedback loops between the release of greenhouse gases and climate change may very well have such an effect, which would lead to a further increase in temperature. (Nature, published online January 26, 2014)

Tropical rainforests such as those in the Amazon basin are becoming increasingly sensitive to temperature changes. As a result of global warming, the carbon balance in the tropics now fluctuates more widely within a matter of a few years than it did in the 1960s or 1970s.

Disk Brakes for Molecules

Using centrifugal force to slow particles down creates new opportunities for chemistry and quantum information processing

The particles in the air we breathe travel as fast as a jet plane. Nitrogen molecules, for example, can manage a speed of more than 1,700 kilometers per hour at room temperature, one and a half times the speed of sound. These particles are simply too fast for many experiments, and some conceivable applications. Physicists at the Max Planck Institute of Quantum Optics in Garching, near Munich, have now found a very simple way to slow down molecules with a negative and a positive pole to around 70 kilometers per hour. They used electrodes to introduce various substances, such as fluoromethane, onto the center of a rotating disk against centrifugal force. The speed of the molecules after braking in this way corresponds to a temperature of minus 272 degrees Celsius. The new method allows researchers to produce relatively large quantities of cold molecules in a continuous flow, which could be useful, for example, in studying specific chemical reactions between particles, or in processing quantum information. (Physical Review Letters, January 6, 2014)

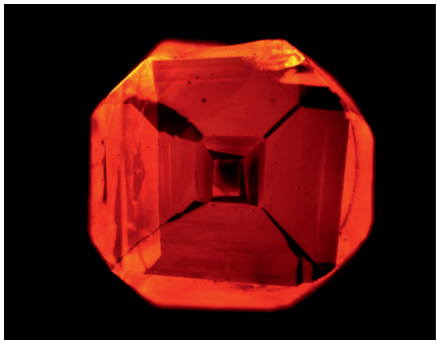


Centrifugal slowdown: Molecules drastically lose speed when directed by electrodes against centrifugal force into the center of a rotating disk. The inward-facing electrodes that rotate with the disk are themselves designed as disks in order to increase their stability. The holes compensate for any lack of symmetry in the plates.

Photos: fotolia (top), MPI of Quantum Optics (bottom)

Brilliant Quantum Computing

A logical operation and error correction have successfully been performed in a diamond nuclear spin quantum register



Glowing testimony: Nitrogen contaminants in a diamond can be excited with green light, causing the stone to glow red. The diamond that the scientists in Stuttgart use as the basis for their experiments contains remarkably few nitrogen defects.

Computers need not calculate with perfect accuracy in order to deliver accurate results – they simply need to be able to reliably correct their own errors. In the future, this will become even more important if quantum computers employing highly efficient but also sensitive computing processes are to perform tasks at many times the speed of conventional PCs. An international team headed by physicists at the University of Stuttgart and the Stuttgart-based Max Planck Institute for Solid State Research has now found a possible answer. The researchers created a simple quantum register comprising three atoms and one electron in a diamond containing minimal nitrogen impurities. Information is stored and processed in the direction of the atoms' nuclear spin. The electron spin acts as a control element. A quantum register of this kind with hundreds or even thousands of nuclear spins could perform a similar function in a quantum computer to that of a conventional computer processor. Using their simple quantum register, the physicists performed a logical operation involving a CNOT gate, which switches a qubit from "0" to "1" or vice versa, depending on the condition of other qubits. This logic gate lends itself to the detection and correction of errors in quantum computing calculations. (Nature, published online January 29, 2014)

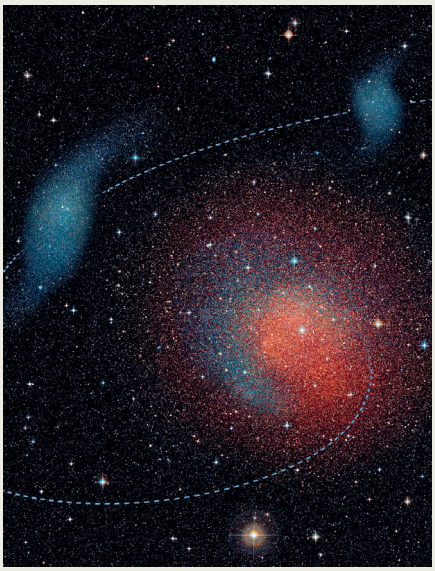
Genes with History

Who wouldn't like to trace their ancestry back to Alexander the Great? According to their traditions, the Kalash, a people living in isolation in the Hindu Kush in Pakistan, are indeed descended from the legendary Macedonian ruler. DNA analyses carried out by a team of researchers including scientists from the Max Planck Institute for Evolutionary Anthropology in Leipzig now appear to confirm the myths of these mountain people. Apparently there are some parts of the genetic makeup of the Kalash that originate from Western Europeans and that were introduced into the genome between 1000 and 200 BCE. So Alexander (356 to 323 BCE) could indeed have brought these genes with him on his Asian campaign. For the purpose of their analysis, the researchers studied the DNA of 1,500 people from around the globe and drew up a world map that enables them to reconstruct the history of almost a hundred populations. The map also provides indications of previously unknown cases of genetic crossovers. For example, the DNA of the Tu people currently living in China shows that, around the year 1200, the then-population intermingled with Europeans of Greek origin. The European DNA probably originates from traders journeying along the Silk Road. The study also shows that genetic intermingling is the rule rather than the exception in recent human history: almost all of the populations studied had mingled with others in the course of their history. (Science, February 14, 2014)

When Dwarves Collide

The Andromeda II system shows where small galaxies come from

Galaxies grow either by incorporating smaller galaxies or merging with others. Now researchers, including scientists at the Max Planck Institute for Astronomy, have identified the dwarf galaxy Andromeda II as the smallest example yet known of the residue of such a galactic merger. Based on the movements of the suns in this Milky Way system, the researchers discovered two distinct groups: stars that had belonged to the original AndII dwarf galaxy, and others from another dwarf system that evidently collided with AndII more than three billion years ago. According to the generally accepted model of galaxy formation, the growth chain is believed to start with small dwarf galaxies swallowing even smaller dwarves. The astronomers have evidently now found proof of this theory. (Nature, February 24, 2014)



When worlds collide: This artistic impression depicts the merger of two predecessor galaxies to form the Andromeda II system.

Photos: University of Stuttgart (top), N. C. Amorisco & M. Høst (Niels Bohr Institute) and ESO/Digitized Sky Survey 2 (bottom)

Aping Success!

Researchers in the Congo discover a previously unknown population of several thousand chimpanzees

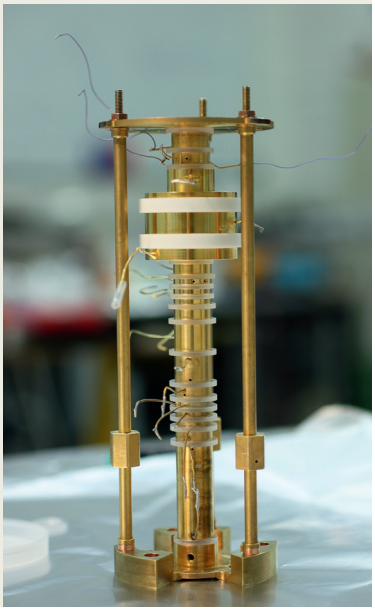
Over the past twenty years, the number of primates in some regions of Africa has declined by up to 90 percent. The reasons range from rainforest clearances to poaching and diseases spread by humans. Now, however, a discovery by scientists from the Max Planck Institute for Evolutionary Anthropology and the University of Amsterdam has raised hopes for the survival of chimpanzees in the wild. In the inaccessible forests of the Bili Gangu region in the north of the Democratic Republic of Congo, there lives a previously unknown population of eastern chimpanzees. Comprising several thousand individuals, it may even be the largest population of this sub-species in Central Africa. Although their numbers appear to have remained stable over the past ten years, the apes are evidently now at increasing risk from the bush meat trade. The researchers hope that Congo will launch a new conservation initiative to protect the chimpanzees, elephants, leopards and other large mammals that live here but are already extinct elsewhere. (Biological Conservation, February 5, 2014)

Living in a patchwork of dense forest, wooded savannas and open grassland in the north of Congo is a previously unknown population of chimpanzees. Like all primates living in the wild, these animals are at risk from poaching and loss of habitat.

Electron on the Scale

A measurement of the particle's mass that is 13 times more precise could have an impact on the fundamental laws of physics

Continuous improvements in the accuracy with which natural constants are measured are a driving force in physics. Greater accuracy helps scientists test fundamental theories and refine or even radically alter our view of the world. Now a team headed by Klaus Blaum and Christoph Keitel of the Max Planck Institute for Nuclear Physics has succeeded in ascertaining the mass of an electron 13 times more accurately than ever before. To calculate this extremely precise result, the physicists measured the frequency with which a carbon nucleus with a single electron traverses a circular path. The carbon atom with its charge of five is compelled to follow this path by a very strong magnetic field exerted by an ion trap. The scientists also determined the frequency of the electron's spin within the magnetic field. The mass of the electron can then be ascertained on the basis of these two frequencies. This greater accuracy could, for example, provide a starting point in improving the standard model of particle physics, which describes three of the four fundamental forces. (Nature, February 20, 2014)



Absolute lightweights on the scale: Physicists used this Penning trap to determine the mass of an electron by compelling it to follow a circular path together with a single carbon-12 nucleus.

Photos: Arco Images (top), MPI for Nuclear Physics (bottom)

Self-Organization in Stone

The rare Kinneyia formations are evidence of patterning in prehistoric biofilms

Some rock formations might have been created by the hand of man: in the case of Kinneyia formations, which are found in places like Namibia and occasionally even in Germany, outcroppings of sandstone or siltstone are covered with a sweeping pattern of parallel ripples. Researchers at the Max Planck Institute for Dynamics and Self-Organization and Georg August University in Göttingen have now discovered that the Kinneyia originated more than 2.5 billion years ago when water flowed over organic biofilms. The experiments reveal that whether or not the rippled structures are formed depends solely on the thickness of the layers. Provided that the films of microorganisms are between 0.5 and 4 millimeters thick, the structure becomes petrified under the right conditions. Kinneyia formations are generally well over half a billion years old, since the biofilms were later consumed by higher organisms. (Philosophical Transactions of the Royal Society A, November 4, 2013)

Patterns of nature: This Kinneyia formation was found on Neuras Farm, 200 kilometers southwest of the Namibian capital Windhoek.

The wolf spider *Camptocosa parallela* is repelled by nicotine in the breath of tobacco hornworm larvae.

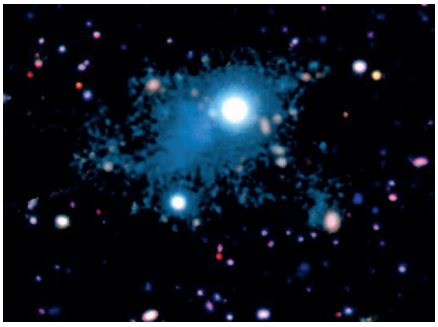
Toxic Breath

A smoker's breath doesn't smell good – a view the wolf spider *Camptocosa parallela* evidently shares. It shows an interest in the larvae of the tobacco hornworm only when their breath is free of nicotine. Scientists at the Max Planck Institute for Chemical Ecology in Jena have discovered that the larvae divert a tiny amount of the highly toxic nicotine consumed with their food into their bodily fluids, and from there to their respiratory system. The nicotine is then expelled with their breath, protecting them from the spider. In contrast, larvae that have been eating nicotine-free leaves or are unable to process the nicotine are easy prey. Other species that prey on the larvae are entirely unaffected by this defense mechanism. (PNAS, published online December 30, 2013)

Black Hole Illuminates Cosmic Web

Astronomers obtain the first direct images of large-scale filamentary structures in space

Computer simulations indicate that the universe is permeated by hydrogen gas. However, it wasn't previously possible to directly test this concept, since even at the densest nodes, the gas is so rarefied that it emits virtually no light. Now an international team including scientists at the Max Planck Institute for Astronomy has obtained direct images of a part of the cosmic web. It was nature that came to their aid: located at one of the nodes is a quasar called UM 287, which acts as a floodlight, illuminating the surrounding gas filaments. Hidden behind a quasar is a distant galaxy, in the center of which there is a supermassive black hole; matter falling into this massive monster releases huge amounts of energy. This energy, in turn, causes the gas in the surrounding area to emit light – on exactly the same principle as a fluorescent lamp. In other words, the filaments glow in the fluorescent light and become visible through a telescope. (Nature, January 19, 2014)



In the spotlight: This image shows a section of the cosmic web (turquoise) with a spread of around two million light years that astronomers have observed in the direct vicinity of the quasar UM 287 (center).

Photos: MPI for Chemical Ecology/P. Kumar (top right), MPI for Dynamics and Self-Organization (center left), S. Cantalupo (UCSC) (bottom right)