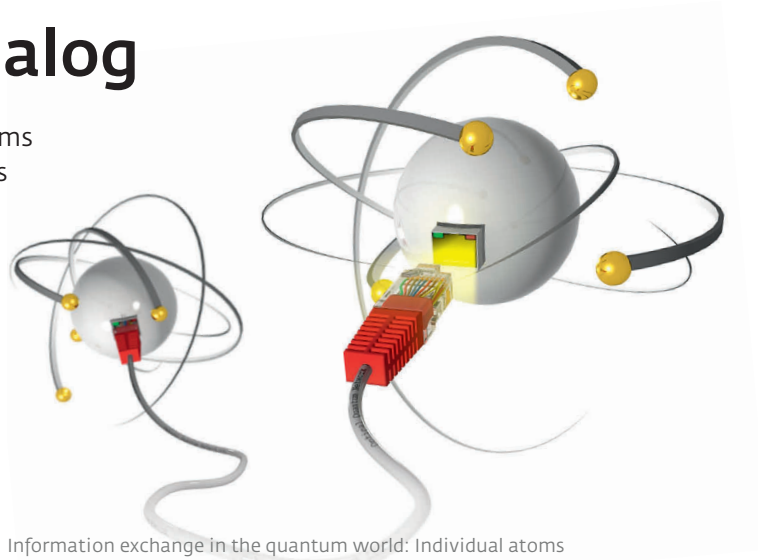
Atoms in Quantum Dialog

Quantum bits can now be transmitted between two atoms in a controlled manner and reversibly stored in the atoms



Information exchange in the quantum world: Individual atoms form the nodes of a symbolic quantum network. Quantum information is transmitted between the atoms in the form of individual photons.

The door to a completely new way of transmitting information is now open. Physicists working with Stephan Ritter and Gerhard Rempe at the Max Planck Institute of Quantum Optics in Garching created an elementary quantum network in which they transmitted quantum information between two atoms trapped in resonators. Quantum information is stored in particular energy states of atoms, for example, and transmitted using special states of photons. Quantum information possesses fundamentally different characteristics than the conventional information with which, for instance, most computers today operate, and that is transmitted over telephone cables or fiber optics. This raises hope that information will be able to be processed more efficiently in some applications. However, the information must be handled with extreme care so that it doesn't lose its quantum character. The physicists in Garching have now, for the first time, transmitted quantum bits in the form of individual photons from one atom to another over a 60-meter-long fiber optic cable and reliably stored them in the receptor atom. This configuration is suitable for more than just exchanging information between computers, when they one day calculate using quantum bits. (Nature, April 12, 2012)

Step by Step to the Right Diagnosis

Various combinations of biomarkers are required to clearly distinguish between tuberculosis and sarcoidosis

Biomarkers or combinations of several biomarkers – known as biosignatures – are markers with which physicians are able to identify a disease. Such biosignatures are apparently not always unambiguous. Researchers at the Max Planck Institute for Infection Biology discovered that the biosignatures of tuberculosis and sarcoidosis closely resemble one another. To this end, the Berlin-based researchers created complete profiles of genes and micro-RNAs, as well as important blood-borne inflammatory mediators for tuberculosis and sarcoidosis. Although unhealthy and healthy individuals can, of course, be distinguished through a series of changes, the differentiation of tuberculosis from sarcoidosis is almost impossible with the same combination of biomarkers. Thus, a single signature is insufficient to unambiguously identify some illnesses. Multiple biosignatures are better suited for this: one for differentiating between diseased and healthy individuals, and additional ones for differentiating between the individual diseases. In African countries, for example, tuberculosis, AIDS and malaria could be quickly and unambiguously diagnosed in this way. (PNAS, May 2, 2012)

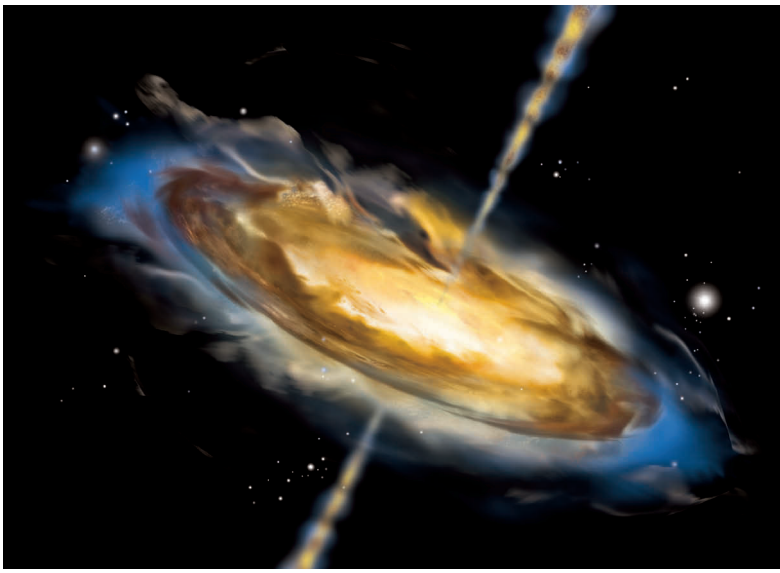
Thanks to a particularly resilient envelope, tuberculosis bacteria can survive for years in the cytophages, or white blood cells, of the immune system and be released again when the immune system weakens. Here, the bacteria (yellow) are surrounded by the cell membrane of a cytophage, or white blood cell (red).

Photo: MPI for Infection Biology – Volker Brinkmann (bottom); graphic: MPI of Quantum Optics – Andreas Neuzner

Fuel for the Black Hole

New observations show the dust torus surrounding the supermassive black hole in the center of a galaxy

Black holes devour everything that comes too close to them. Gas and dust from the vicinity serve as fuel. An international team headed by Gerd Weigelt from the Max Planck Institute for Radio Astronomy in Bonn has now taken a closer look at this storeroom. Using near-infrared interferometry, the researchers observed the inner region of Galaxy NGC 3783, where a black hole is located, surrounded by a torus of dust. This forms a reservoir of material from which the hot gaseous disk and the supermassive black hole feed. The torus measures half a light-year across. To measure it within the galaxy that is located approximately 150 million light years away, the astronomers required very high resolution. They achieved this by superposing the infrared light from several individual telescopes of the Very Large Telescope Interferometer of the European Southern Observatory.
(Astronomy & Astrophysics, May 16, 2012)



Cosmic storeroom: An artist's depiction of a dust torus in the vicinity of the accretion disk of a black hole.

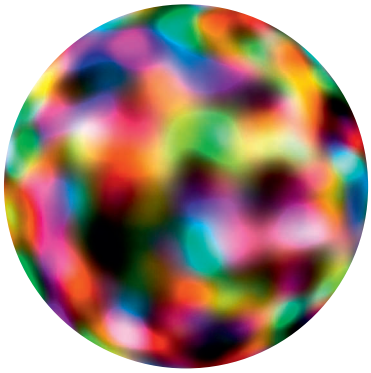
Optics with Gamma Vision

In optics, not much happens without kinks – that is, without bending. Light rays allow detailed analysis of a material or a biological process only because they can be deflected and focused with lenses. Scientists at Ludwig Maximilian University in Munich and the Max Planck Institute of Quantum Optics in Garching have now focused gamma rays for the first time. In doing so, they toppled the decades-old fundamental assumption in physics that this extremely energetic radiation can't be deflected. Using gamma-ray optics and isotopes that respond to gamma rays quite sensitively, tumors could be simultaneously combated and the success of the treatment monitored, for instance. In addition, gamma rays could help to more precisely investigate the aging process inside lithium batteries in order to ultimately suppress it. Current analytical methods can only reveal these processes on the batteries' surface.
(Physical Review Letters, May 3, 2012)

Organization is Half the Battle

Cell membrane forms a molecular patchwork quilt

The cell membrane consists of a double layer of fat molecules that contain proteins. However, according to the latest findings of scientists at the Max Planck Institute of Biochemistry in Martinsried, these membrane proteins are not distributed randomly over the surface of a cell. Instead, they are organized in bounded areas of the membrane. Accordingly, the cell membrane of yeast cells consists completely of these domains, which contain one or more types of proteins. These zones are essential for membrane proteins because the proteins function efficiently only in their own domains. The patchwork quilt of protein domains presumably arises because fat molecules also form these areas in the cell membrane. As fats within one domain having identical or similar anchor molecules fix proteins, they direct the proteins into bounded areas.
(Nature Cell Biology, April 29, 2012)



Color-labeled membrane protein domains in a yeast cell.

Photo: NASA E/PO, Sonoma State University, Aurore Simonnet (top), MPI of Biochemistry – Wedlich-Söldner (bottom)

Wallflowers of the Earth System

Algae, lichens and mosses have been unfairly ignored in the global carbon dioxide and nitrogen balance up to now

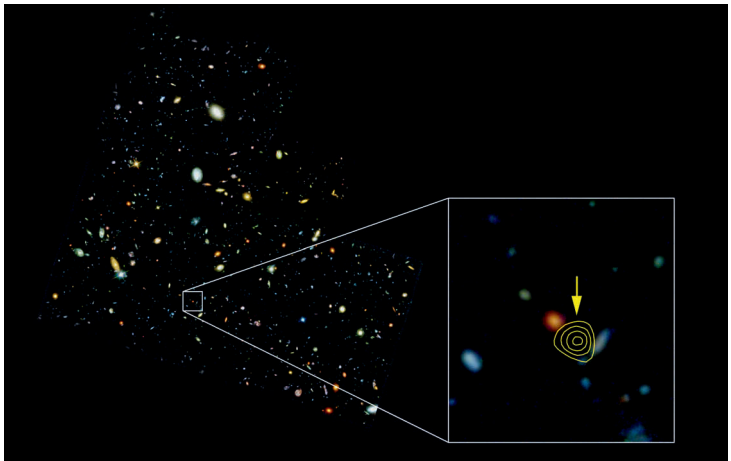
Algae, lichens and mosses on walls and roofs are usually considered to be ugly or annoying, and the scientific community had long disregarded them as well – completely unjustly. The cryptogamic cover, as the flat growths are referred to scientifically, plays a more important role in the global nitrogen budget, and thus also for climate, than previously assumed. They cover an estimated 30 percent of the land mass surface worldwide, which also includes surfaces of plants. And, as scientists led by Ulrich Pöschl at the Max Planck Institute for Chemistry in Mainz discovered, they fix about half of the nitrogen that becomes bound naturally on land, and absorb as much carbon dioxide annually as is formed by forest fires and biomass combustion. These findings help improve models of global material cycles and the climate that have thus far neglected the carbon and nitrogen equilibrium of the cryptogamic cover. (Nature Geoscience, June 3, 2012)

Underestimated players in the global mass balance: The yellow-scale lichen (*Xanthoria parietina*) populates a limb here with other lichens. Lichens belong to the cryptogams and are a biocenosis of one fungus and one blue or green alga each. Cryptogamic cover can bind carbon and nitrogen from the air, depending on the species.

At the Edge of Space and Time

Galaxy HDF850.1 appears just as it did 12.5 billion years ago

HDF850.1 is invisible in the sky survey of the Hubble space telescope. However, astronomers knew from other observations that the object concealed one of the most productive galaxies in the universe – a Milky Way system with an extremely high birth rate of 1,000 suns per year. Now, a team headed by Fabian Walter from the Max Planck Institute for Astronomy in Heidelberg has established the distance to HDF850.1 for the first time: the light that reaches us from there today left on its trip when the cosmos was just 10 percent as old as it is now, or in other words about 12.5 billion years ago. The researchers used six radio antennas of the IRAM Observatory for their millimeter-wavelength observations. They derived the vast distance from the spectral lines they measured. In addition, they found that HDF850.1 is not alone, but rather belongs to a cluster of proto-galaxies – systems that formed a few hundred million years after the birth of the universe. (Nature, June 14, 2012)



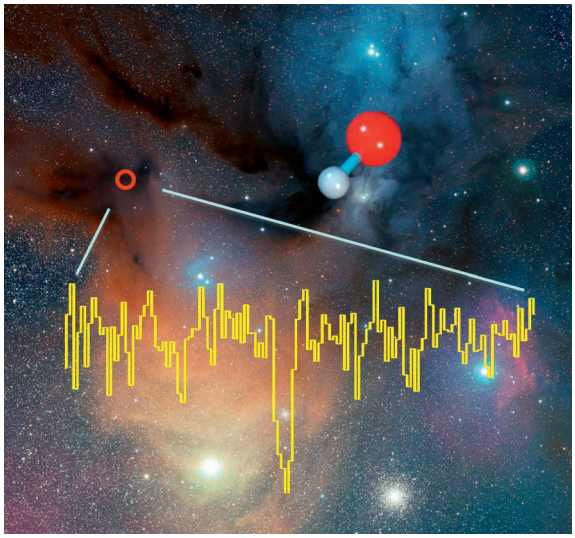
Gazing into the depths of the universe: The light that we receive from Galaxy HDF850.1 (concentric yellow lines on the right part of the image) traveled for 12.5 billion years to reach us.

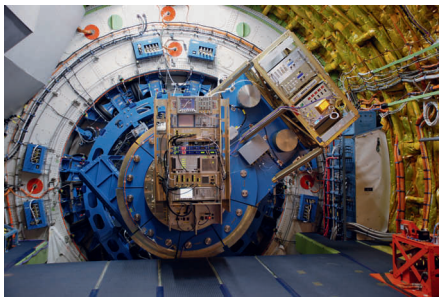
Photos: W. Elbert/MPI for Chemistry (top); STScI and NASA (bottom)

Two Molecules in Space

Spectrometers on an airborne observatory detect OD and HS•

The airborne observatory *SOFIA* has delivered a wealth of results. Shortly after the first series of scientific flights with the *GREAT* instrument, researchers detected two molecules in outer space and investigated various stages of stellar birth in detail. A German consortium headed by Rolf Güsten from the Max Planck Institute for Radio Astronomy in Bonn developed the spectrometer. Among other things, *GREAT* obtained direct proof of protostellar envelope collapse from three infant stars that allows conclusions to be drawn about the dynamic processes of stellar birth. Another important discovery was the first evidence of two new molecules in the universe: OD, an isotopic variant of hydroxyl (OH) in which the hydrogen atom has been replaced by its heavier isotope deuterium, as well as sulfanyl (HS•), or hydrosulfide. (Astronomy & Astrophysics, May 10, 2012)



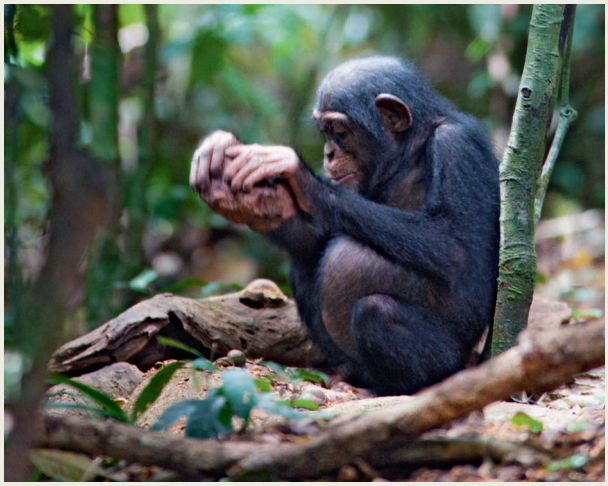


Colorful birth: The photo shows the area of stellar birth around Rho Ophiuchi, at a distance of about 400 light-years. *GREAT* first detected the molecule OD in the universe there. The instrument also found sulfanyl (HS•), or hydrosulfide. Developed by a German consortium, the spectrometer (above) is one of the instruments on board the airborne observatory *SOFIA* (top).

Chimpanzees Cultivate Food Culture

Neighboring groups use different tools despite similar ecological conditions in their habitats

An essential precondition for the formation of cultures is the transfer of information or capabilities to the next generation, independent of genes. A research team from the Max Planck Institute for Evolutionary Anthropology in Leipzig observed that adjacent groups of chimpanzees living under similar ecological conditions and hardly distinguishable from one another genetically are able to develop distinct cultures. Chimpanzee groups in the West African country of Ivory Coast crack nuts with help of stone and wooden hammers, using tree roots as anvils. According to the findings, the hammers used differed significantly in material and size from group to group. The animals in two groups, for example, replaced stone hammers with wooden ones over the course of a season, while the members of another group consistently preferred stone hammers – and that even though there was always sufficient wood and stones available throughout all regions. The selection of a specific tool is therefore not only an adaptation to changing environmental conditions themselves, but rather a cultural behavior that is learned and handed down within the group. (Current Biology, May 10, 2012)



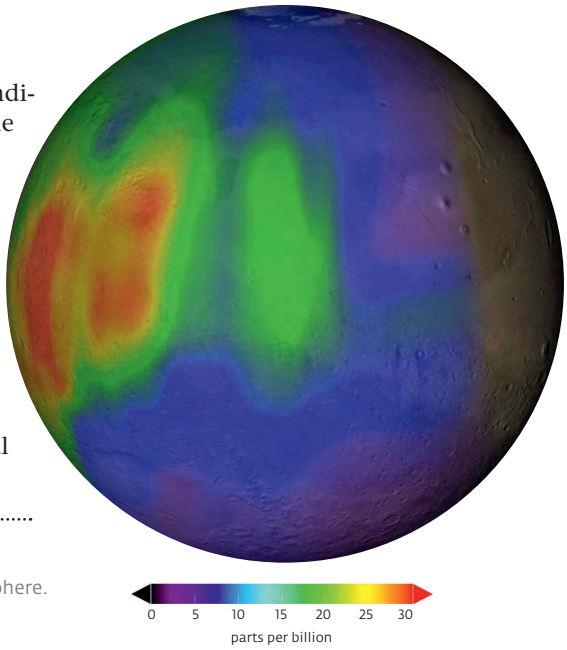
Chimpanzee cracking nuts with a stone hammer.

Photo: MPIfR/B. Parise (spectrum), ESO/S. Guisard (background) (top left), NASA, R. Güsten (top right); Mark Linfield (bottom)

Still No Life on Mars

Intense UV radiation on the red planet releases methane from organic material transported to the surface by meteorites

Some astronomers eagerly pursue every clue about life on Mars – but one of them might just have gotten away from them. The methane that was discovered in the Martian atmosphere nine years ago and that was considered as a possible sign of living organisms very probably originates from a geochemical process. An international research team led by Frank Keppler of the Max Planck Institute for Chemistry in Mainz has established that a meteorite found on Earth releases methane when the scientists irradiate it with intense ultraviolet light under Martian conditions. The constituents of the heavenly body resemble those of meteorites and stellar dust particles from space that bring carbon-containing molecules with them and continually collide with the Martian surface. Some researchers considered the methane on Mars to be evidence of extraterrestrial life because, on Earth, it originates primarily in biological processes. (Nature, May 31, 2012)

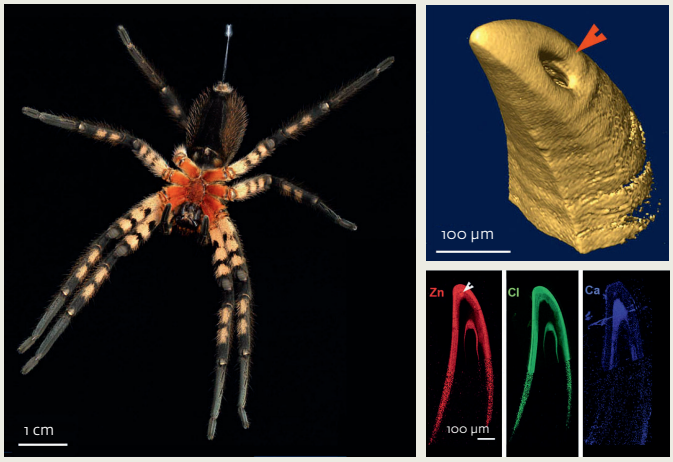


Methane concentration on Mars: The graphic shows the calculated atmospheric methane concentration in parts per billion (ppb) on Mars during the summer in the northern hemisphere. Violet and blue areas indicate little methane, while red areas signal large quantities.

The Incisive Design of the Spider Claw

The animals owe their predatory success to, among other things, the ingenious composition and structure of the material that makes up their venomous fangs

Flies and other insect prey can do little to counter the bite of a spider – even though their armor consists mainly of chitin and proteins, just like the venomous fangs of the predator. However, the exact chemical make-up and microstructure of the venomous fangs have been optimized to be able to penetrate the armor of the prey. A research team headed by Yael Politi and Peter Fratzl from the Max Planck Institute of Colloids and Interfaces in Potsdam discovered this while researching the wandering spider *Cupiennius salei*. Accordingly, the chitin fiber in the venomous fangs runs parallel to the trajectory of the spider bite; they are more rigid in this direction than perpendicular to it. Moreover, the proteins that form the tip and shell of the fang are strongly cross-linked with metal ions, so that they transfer pressure especially well to the cuticular armor. These findings can provide inspiration as to how similar materials can be optimized for various applications. (Advanced Functional Materials, March 22, 2012)



left image: The tropical wandering spider *Cupiennius salei*

left top: Computer tomography image of the tip of a venomous fang. The orange arrow indicates the opening of the venom canal.

left bottom: Distribution of the zinc ions (red), calcium (blue), and chlorine (green) is analyzed with energy-dispersive X-ray spectroscopy and made visible using false colors. Zinc and chlorine occur in the external layer, while calcium is located in the inner layer. In addition, an increased concentration of zinc was observed in the fang tip interior.

Photos: NASA (top), R. Barth (bottom left), MPI of Colloids and Interfaces (bottom right)

Buried under Sediment

Erosion in tropical coastal regions triggers a deadly chain reaction in corals

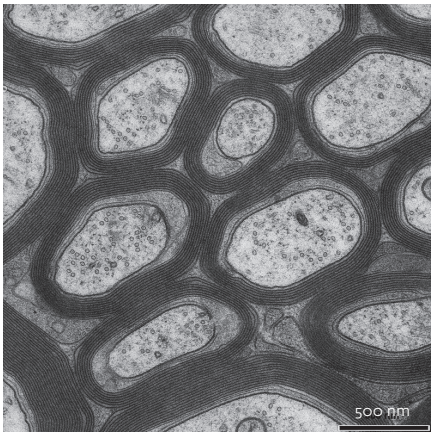
Soil erosion due to advanced industrialization, deforestation and intensive agriculture in coastal areas flushes nutrient-rich soil into the sea and leads to the dying off of coral reefs. Researchers from the Bremen-based Max Planck Institute for Marine Microbiology have now explained the causes of the death of the corals. According to their findings, the digestion of nutrients in the sedimentary deposits by naturally occurring bacteria causes oxygen depletion and, together with an acidification of the environment, triggers a chain reaction. At the end of this phase, the microorganisms release hydrogen sulfide from the damaged coral tissue. This cellular toxin kills the surrounding polyps within a very short time. Even the smallest amount of organic material is sufficient to produce the fatal effect for the coral. Sediments with little organic content that are stirred up by wind and wave action, in contrast, have almost no effect on the reefs. (PNAS, May 21, 2012)

Reef-building corals along the Great Barrier Reef off the east coast of Australia. They are covered by a two-millimeter layer of sediment that is carried into the sea by rivers.

Lactic Acid for Nerve Cells

Glial cells transfer metabolic products to nerve cells

A group of highly specialized cells known as oligodendrocytes surround the nerve filaments of the brain and spinal cord. This insulating layer, also known as the myelitic sheath, not only increases the transmission speed of the nerve filaments and reduces their energy consumption, it additionally provides the nerve cells with energy-rich metabolic products. A study by researchers at the Max Planck Institute for Experimental Medicine in Göttingen has shown that the oligodendrocytes obtain energy primarily from the cleavage of sugar into lactic acid in their mitochondria. The oligodendrocytes can use metabolic products themselves that result from the cleavage of the glucose as components for the construction of the myelins in their cellular walls. In addition, they transfer the lactic acid to the axons of the nerve cells, which create energy out of it in their own mitochondria. Among other things, a lack of energy could thus be the reason why nerve cells are often irreversibly damaged in multiple sclerosis when the myelin sheath is destroyed. (Nature, April 29, 2012)



Electron micrographic cross-section of optic nerve axons. The axons are surrounded by oligodendrocytes that wind around them in several layers. Between them are the astrocytes, another type of glial cell.

Photos: M. Weber/Hydra, MPI for Marine Microbiology (top), MPI for Experimental Medicine, K.-A. Nave (bottom)