RESEARCH *in Brief*

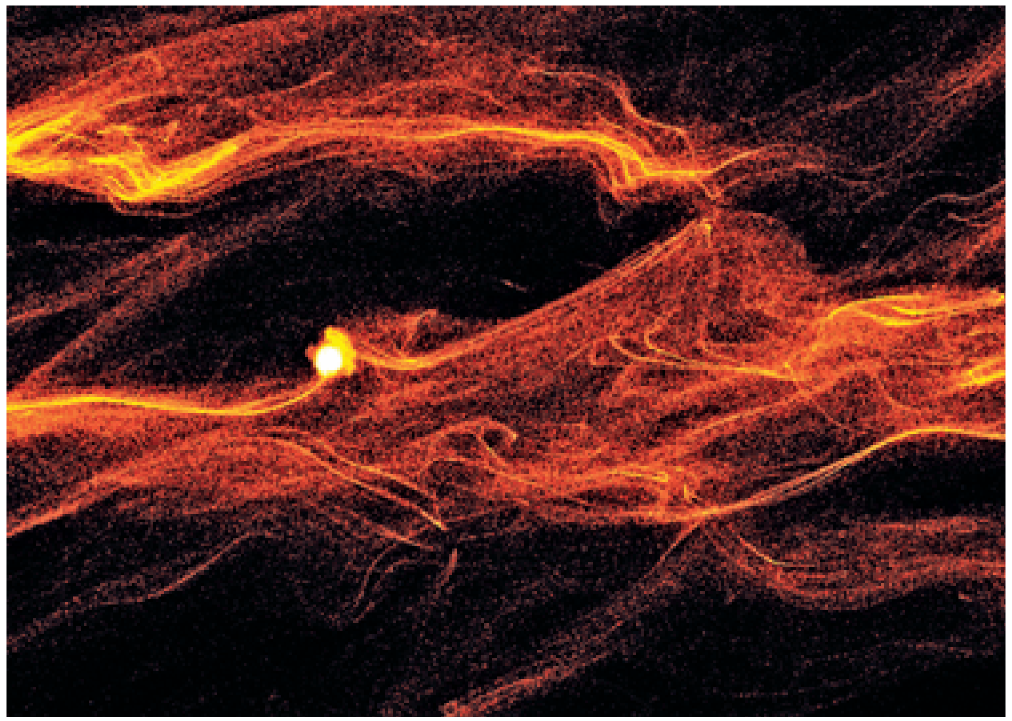

Photo: MPI for Astronomy

Born in a primeval cloud: A lot of matter agglomerates at the bright point in the cutout of the circumstellar disk. This consolidation remains stable and captures more and more matter – until a baby planet is formed, which then slowly grows into a large planet.

Astronomy

Born out of Turbulence

A nursery made of gas and dust? Hardly a very cozy place and certainly not a safe one: A planet forms in a disk of dust and gas surrounding a young star. However, as long as the emerging body measures barely more than a meter across, it faces the very real threat of either plummeting into its central star or exploding in a violent collision with another rock of similar size. An international team including researchers from the Max Planck Institute for Astronomy in Heidelberg has now simulated how it is possible for planets to form despite these difficult conditions. (*Nature*, August 30, 2007)

Even our solar system originally started out small. During its birth, the Sun formed in the center of a cloud of gas and dust. In the process, it absorbed most of the matter in the cloud. The remaining gas and dust particles were then compressed into a flattened layer, the so-called circumstellar disk, which rotated around the Sun.

Current theory describes the mechanism by which planets form in this disk as follows: the dust particles clash with each other in the gas disk and clump together into rocks and boulders that measure about one meter in diameter. However, this theory has one problem. When the meter-sized boulders collide with each other, they don't adhere to each other. Instead, they bounce off each other and sometimes even destroy each other in particularly violent collisions. Moreover, the gas of the circumstellar disk acts as a headwind and slows down the embryonic planets, causing the boulders to spiral into their central star after a few centuries. Thus far, this scenario describes a miscarriage.

However, Max Planck researchers and astronomers from the US and Canada have now come up with a simulation that describes how the boulders overcome this critical situation and grow into planets. It shows that the central role is played by the turbulence in the circumstellar dust disk, which is created by magnetic fields. This turbulence creates high-pressure zones in the gas, and these, in turn, slow down the boulders as they drift through the gas. "The effect is similar to a lane narrowing on the highway causing traffic to back up," says Anders Johansen from the Heidelberg-based Max Planck Institute, who developed and carried out the simulation.

"We are helping the theory of planetary formation out of a scientific dead-end," says Thomas Henning, head of the department in which Johansen and his colleagues work. Under the turbulent conditions, the meter-sized boulders can then also find their way to each other and gradually gather into planetary precursors, the planetesimals, solid bodies of several kilometers in size. "The old theory works fine again for planetesimals," says Henning. Thanks to their own gravity, they now have enough mass to attract each other, allowing them to gradually form planets.

The risk of plunging into the central star also no longer exists for the planetesimals, as the headwind of the more slowly rotating gas no longer affects them. This wind is felt by boulders because they rotate faster around the star than the gas in the circumstellar disk; the gas is hotter closer to the star than it is at the disk's edge. This results in a force that opposes the gravitational pull of the star. However, it is gravitation that drives the rotation of the gas. If this is weakened due to the pressure, then the gas rotates more slowly, as well.

Planetesimals, asteroids or even baby planets can no longer be slowed down by the headwind. At the end of the planetesimal formation epoch, several million planetesimals orbit unhindered in the disk. Some of them become larger and turn into baby planets that exert such a high gravitational force that the gas, dust and smaller boulders around them begin to crash into them faster and faster. In this way, they gradually grow into a real planet. The planets eventually swallow up the remaining boulders bit by bit until the disk is cleared and almost completely empty. Only a few solitary individuals survive this cannibalism in the circumstellar disk and orbit through the solar system as comets and asteroids.

"This growth process is surprisingly effective," explains Hubert Klahr, another of the Heidelberg scientists. "It takes no more than about one hundred years." If it happens according to the theory. Ultimately, the only way to find out is to take a closer look at a stellar delivery room, where astronomers can observe the birth of a remote solar system.

However, there is still plenty of work for Anders Johansen, his colleagues and their computers. "We have not yet taken into account that the meter-sized boulders are capable of destroying each other," says the scientist. "In particular, we have used only a fairly crude simulation of the turbulence so far." It is actually possible that this turbulence causes a stir only near the surface of the circumstellar disk, and not throughout, as the magnetic field that causes the turbulence acts only on gas that was previously ionized by cosmic radiation, and this radiation does not penetrate deep into the disk. "This is something we are now going to simulate in more detail," explains Johansen.

This may help the scientists get a more accurate picture of what happens when a planet is born. Even then, however, there is still one uncertainty that will not have been cleared up: they do not yet know exactly where the magnetic field comes from that they believe is responsible for the turbulence. It could come from the central star – in which case it would probably be very weak – or from the stellar cloud in which the solar system is created. "This is a question our simulations will not be able to answer," says Johansen. "Observations are the only way to find out."

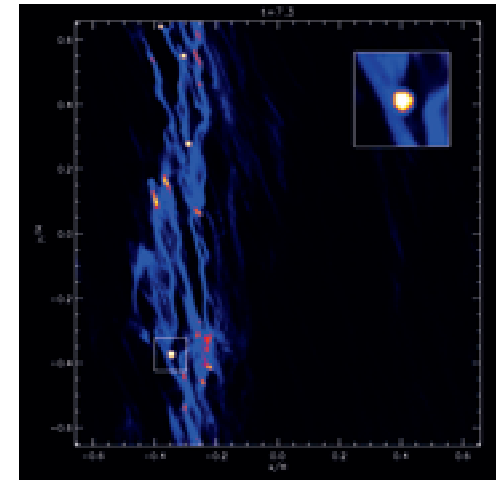

Image: MPI for Astronomy - Anders Johansen

Even heavenly bodies start out small: At the bright point, bottom left, rocks and boulders have amassed to become a planet embryo, shown enlarged at the top right.

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ANTHROPOLOGY

Puzzle Solver versus Copycat Genius

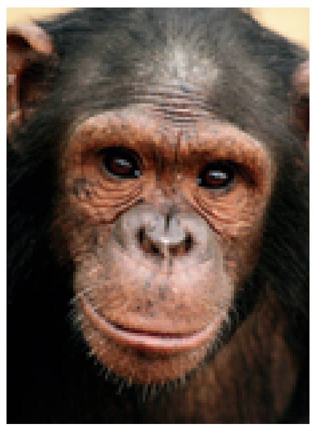
Most people would say that humans are more intelligent than apes, but that is not necessarily true. Biologists at the Max Planck Institute for Evolutionary Anthropology in Leipzig have discovered that, while our social-cognitive skills are superior to those of apes, when it comes to what behavioral researchers refer to as physical tasks – solving problems by understanding causality or adding small quantities together – apes can sometimes outperform us. (*Science*, August 7, 2007)

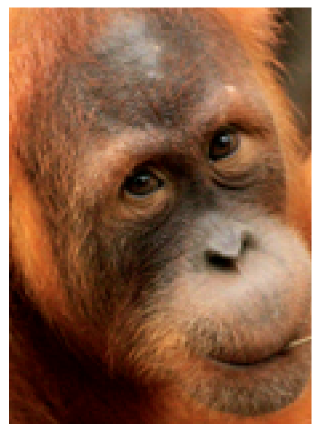
One problem, two solutions: A scientist uses a stick to open a tube containing a toy or some food. Small children copy each move exactly and have no problem accessing its contents. Apes, on the other hand, bite the tube, bang it around and try to open it using their own methods.

"Children that young are at the same level as apes," explains Michael Tomasello.

For the study, the scientists conducted a kind of shell game, setting up a row of upside-down cups, hiding food under one of them and moving them around. The children and apes then had to guess which cup the treat was hidden under. "The chimps were better at this task," says Esther Herrmann, who helped design and conduct the tests.

The same thing happened in another test: the researchers gave the children and the apes a stick and placed a reward out of their reach. While the apes immediately used the stick to reach the food, the children simply played with the tool, many of them having no idea what to do with it. "Since the children did not perform nearly as well as the apes on such seemingly simple tasks, they cannot be generally more intelligent," notes Michael Tomasello.





Competition: Young children, chimpanzees and orangutans were given various tasks to solve. While the apes were better at spatial tasks, the children were better at imitating another's solution to a problem.

PHOTOS: ARGO IMAGES GMBH (LEFT) / MPI FOR EVOLUTIONARY ANTHROPOLOGY

This is not all that unexpected: after all, humans have larger brains, so they must be smarter, according to the theory of general intelligence. However, evolutionary biologists in Leipzig have disproved this theory. They have shown that humans do not have more general intelligence than apes, but that it is our social-cognitive skills that account for our greater intellect.

"Because even young children learn from others and imitate their behavior, they quickly become more clever than apes," says Michael Tomasello, Director of the Max Planck Institute for Evolutionary Anthropology and head of the project. Children also rely on the help of others to later acquire linguistic and mathematical skills.

Together with his colleagues, Michael Tomasello conducted the first study to compare the physical and social-cognitive skills of humans and apes. They selected 105 two-year-old children as their human subjects, and compared their abilities to 106 chimpanzees and 32 orangutans in Uganda, the Republic of the Congo and Borneo.

Only when tasks were introduced that involved understanding communicative cues and communicating non-verbally with the tester did the specialized intelligence of humans become apparent. When the researchers used gestures to show where treats could be found, the children interpreted these cues much better than the chimpanzees and orangutans did. They were also better at imitating the researchers' actions. The apes, however, always tried to do things their own way.

Just how successful social learning is is clearly evidenced by, for example, intellectual progress, which is always a group achievement. "The computer was not invented by a single person," Herrmann points out. "Someone had the initial idea and others then refined it." Michael Tomasello takes that even one step further. He believes that a human being on a deserted island with no other people or culture would remain at the level of an ape, since he would have no one to learn from.

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RESEARCH IN BRIEF

SOLID STATE PHYSICS

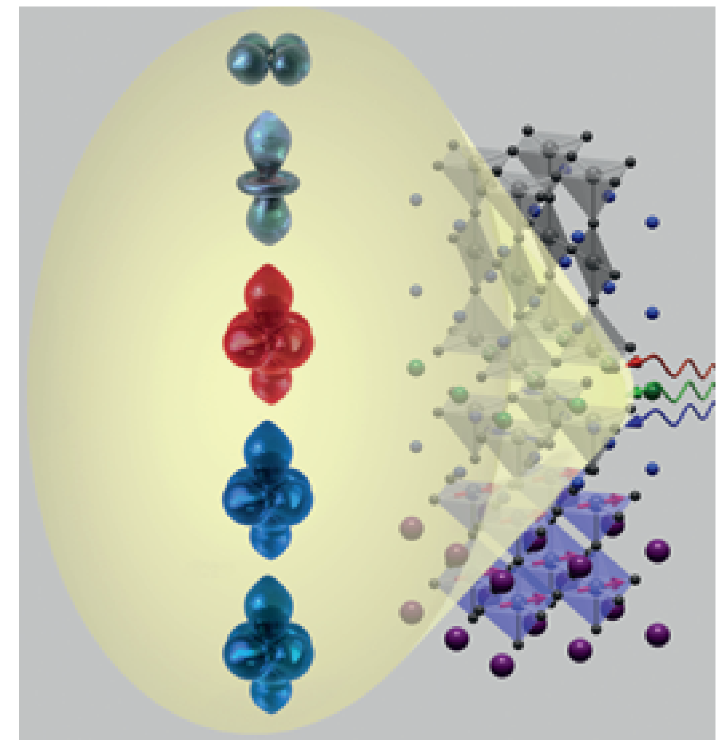
On the Verge of Superconductivity

The semiconductor industry may have to change its name in a few years: superconductors may be able to perform much more quickly and efficiently what semiconductors such as silicon manage in chips today. Superconductors conduct electricity without resistance, but to date this has been possible only at temperatures well below freezing. Scientists at the Max Planck Institute for Solid State Research in Stuttgart have now found a previously unknown possibility to influence superconductivity – possibly in a way that will make the material interesting for chips. (*Science*, November 16, 2007)

Microelectronics is based on the penetration of interfaces by electrons – in a transistor, they travel between the layers of different semiconductors when a tiny charge gives them a little push. In this case, physicists say that an external charge increases conductivity. If it were possible to completely eliminate electrical resistance at material interfaces in a similar way and at room temperature, electronics could work more quickly and efficiently. However, for this to happen, physicists must first better understand the electronic processes at the interfaces. Scientists at the Max Planck Institute for Solid State Research in Stuttgart have made a contribution to this understanding: they have investigated a sandwich in which layers of the high-temperature superconductor yttrium barium copper oxide, or YBCO for short, alternate with layers of ferromagnetic manganese oxide, which has magnetic properties similar to those of iron – and that with very sharp interfaces between the two materials. At these interfaces, however, chemical crossovers occur. As the Max Planck physicists have now established, the atoms of the two layers form covalent bonds with one another. Electron pairs in these bonds act much like chemical putty.

The electrons then take on a new configuration at the interfaces. Through the chemical bonds, the manganese oxide influences the electronic properties of the superconductor. "In our case, superconductivity is weakened," says Bernhard Keimer, Director at the institute in Stuttgart. Described in simplified terms, the bonds transfer the ferromagnetism of the manganese oxide across the interface. This weakens superconductivity, as ferromagnetism and superconductivity are antagonistic phenomena; they are based on different electron arrangements.

"Since we now understand the mechanism, we may also be able to combine a high-temperature superconductor with a material that allows resistance-free conductivity at a higher temperature than has previously been possible," says Keimer. "It will take some time, however, before we can build transistors out of superconductors." This is because the term "high-temperature superconductor" can be a bit misleading when used by physicists: materials such as YCBO may lose resistance at higher temperatures than the materials that first became known as superconductors, but even YBCO only begins conducting electricity without losses at minus 180 degrees Celsius.



View across the border: X-rays reveal something about electron density where a superconducting copper oxide (top) and a ferromagnetic manganese oxide (bottom) come into contact. Possible spatial distributions of the electrons are seen at left.

IMAGE: SCIENCE

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Astrophysics

A Heavyweight Duo

Astronomers have discovered the most massive stellar black hole to date in a neighboring galaxy of the Milky Way. The object, designated M 33 X-7, has nearly 16 times the Sun's mass and is part of a binary star system. Researchers at the Max Planck Institute for Extraterrestrial Physics played a significant role in "weighing" the black hole. (Nature, October 18, 2007)

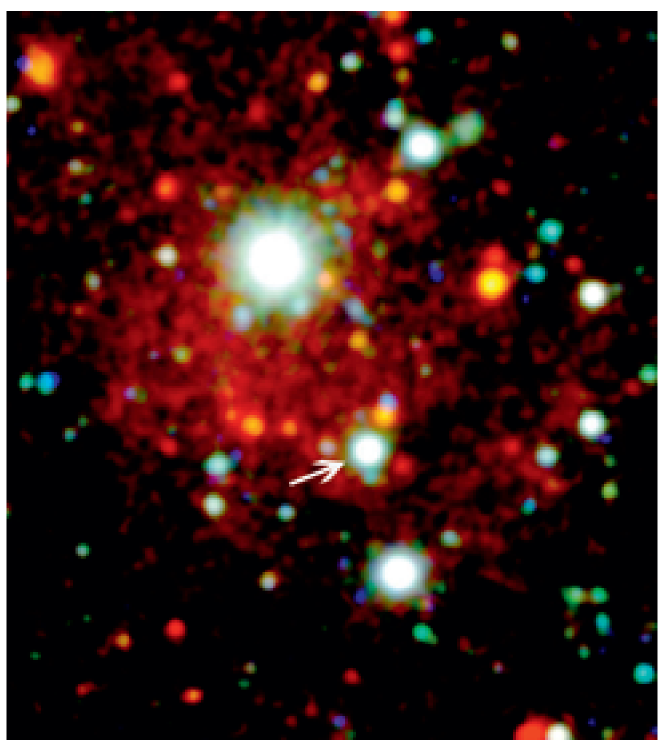
Black holes herald the death of a massive star. When such a gas ball has exhausted its fuel supply at the end of its life, it can no longer produce any energy. Within seconds, the core of the star collapses under its own weight, while its temperature rises. While the interior continues to cave in upon itself, a shock wave is generated that travels outward from the center, sweeping away the stellar gas layer. The star flares up as a supernova. What is left is an extremely dense and massive stellar corpse whose gravitational pull is so strong that even light cannot escape it: a black hole.

Such black holes are frequently part of a binary star system, which means that they orbit together with another star around a common center of gravity. The object M 33 X-7 in the galaxy M 33, about 3 million light-years from Earth, in the constellation Triangulum, also has such a companion star. During its orbit, it passes the black hole every three and a half days, regularly "eclipsing" the X-ray emission that surrounds the monster mass in the process. This is because the black hole is located in the center of a so-called accretion disk, in which gas matter swirls around like water running down the drain of a bathtub, heats up significantly on the inside and, as a result, emits X-rays.

"Based on the length of the eclipse of the X-ray source and the speed of the companion star in relation to the observer, and based on its spectrum, we were able to make very precise calculations of the masses of the binary star system's two components," says Wolfgang Pietsch from the Max Planck Institute for Extraterrestrial Physics in Garching, near Munich. In the process, the scientists used data obtained from NASA's Chandra X-ray satellite. Further information about the system was gleaned from observations made with the Gemini telescope on Mauna Kea in Hawaii. The astronomers were quite amazed at the masses of both cosmic partners: the black hole has 15.7 times the mass of our Sun, and its companion star is even 70 times heavier than the Sun. This is the heaviest pairing of a black hole and a star that researchers have yet come across – and leaves quite a lot to be explained.

This is because conventional models of the evolution of stars cannot readily explain the mighty duo. For example, the progenitor of the black hole must have had an even greater mass than its companion, as well as an enormous radius. Due to their relative proximity, the stars should have originally even touched each other: the outer layers of their atmospheres would have merged with each other. Although astronomers do know systems in which both partners have such close contact, this scenario usually entails an enormous loss of mass for the stars.

Why should one of the cosmic gas balls have contained so much substance that it could leave behind a black hole with nearly 16 times the mass of our Sun? Researchers suspect that the progenitor star has lost considerably less mass than theory predicts. Nevertheless, the system remains puzzling: for example, how did the binary star system survive the enormous supernova explosion? The object M 33 X-7 is sure to keep astronomers occupied for some time: "Because of its peculiarities, the black hole is a wonderful touchstone for astrophysics," says Wolfgang Pietsch.



A "monster mass" weighs in: A stellar black hole (arrow) is lurking in galaxy M 33. It is part of a binary star system and, at 16 times the mass of our Sun, is a genuine "heavyweight champion."

Photo: Wolfgang Pietsch - MPE Garching/ESA

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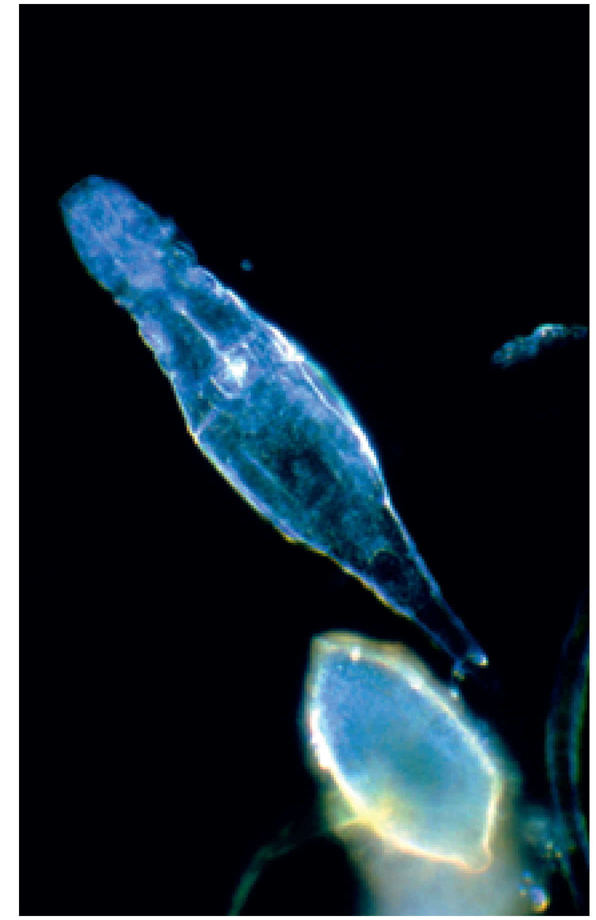
Evolutionary Biology

Diversity without Sex

Asexual reproduction has one significant disadvantage: it usually results in a lack of genetic diversity. However, this is not the case for the rotifer *Adineta ricciae*. Although it reproduces asexually, variants of its genes are able to evolve differently, ultimately giving rise to proteins with different functions. Scientists at the Max Planck Institute of Molecular Plant Physiology in Potsdam and the Universities of Cambridge and Angers have now succeeded in demonstrating this phenomenon with genes that protect the rotifer from damage during desiccation. (Science, October 12, 2007)



Life without males: Some rotifers can become mothers without procreation.

Photo: SPL - Agentur Focus

If sheer numbers were the recipe for success, sex would not have withstood the process of evolution: organisms that reproduce asexually produce far more progeny than those that produce their offspring via sexual reproduction. This is because sexual reproduction requires males that cannot reproduce themselves. Most multi-cellular organisms accept this because sexual reproduction leads to greater genetic diversity, allowing the organisms to adapt better to changes in their environment.

However, the rotifer *Adineta ricciae*, which has reproduced via unfertilized eggs for millions of years, has achieved this without sex. The organism lives in puddles that dry up soon after it has rained – and may not see water again for several days. Most organisms cannot survive such extended dry periods because, without water, their proteins clump together and the membranes of their cells tear. *Adineta ricciae*, however, has armed itself with proteins that protect it from the effects of dehydration. The international research team has now discovered that *Adineta ricciae* acquired this ability to adapt through the Meselson effect. This results from alleles – variants of one and the same gene – developing independently in asexual reproduction. In organisms that reproduce sexually, a control mechanism checks whether the alleles for sex cells have been copied identically. Rotifers, though, do not have this control mechanism, so their allele pairs can change.

Consequently, two copies of the gene that protects the rotifer from dehydration have evolved into Ar-lea-1a and Ar-lea-1b, where 13.5 percent of their genetic sequences are no longer identical. "Such a sequence difference between two alleles cannot be achieved by sexually reproducing organisms," says Dirk Hincha, head of the research group at the Max Planck Institute in Potsdam. These alleles code for proteins that affect different areas of the cell and therefore assume different functions: Ar-lea-1a protects the cell membrane from tearing during dehydration, while Ar-lea-1b stops the proteins from clumping together.

"Consequently, we have proven that there is a viable alternative to sexual reproduction," explains Dirk Hincha. However, the biologists are interested less in rotifers' reproductive practices than in the proteins encoded by the alleles Ar-lea-1a and Ar-lea-1b, as related proteins can also be found in plants. If biologists succeed in fully understanding how these proteins function, they may be able to breed agricultural crops that are more tolerant to drought. This would make farming possible in areas of the world where rain is scarce due to climate change. The proteins could also be used in the pharmaceutical industry, making it possible to preserve, for instance, therapeutic antibodies – which quickly become ineffective outside of an organism – in the form of powder that could be kept in a tin.

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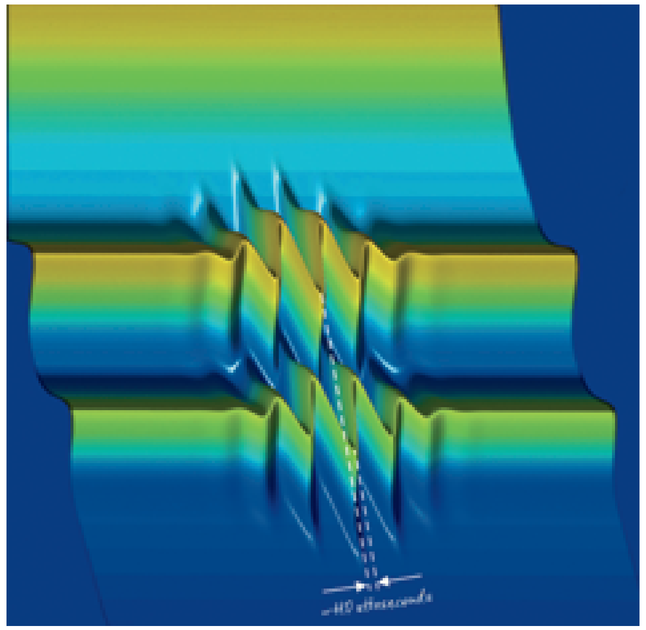
QUANTUM OPTICS

Electrons Caught in the Act

The performance of any computer chip is ultimately limited by the speed at which electrons move. However, present electronics are still a long way from this ultimate limit. In solids, electrons travel between neighboring atoms in less than 100 attoseconds, that is, in less than one ten-millionth of a billionth of a second. An international team at the Max Planck Institute of Quantum Optics in Garching has now successfully taken one of the first steps on the road to one day enabling chips to process bits at such speeds. For the first time, the researchers succeeded in performing a real-time measurement of the electron movement in a solid object. This is one of the requirements for actually being able to technically control the process. (*Nature*, October 25, 2007)



Racing through the crystal: The loosely bound conduction electrons reach the surface 110 attoseconds before the core electrons.

Image: Barbara Ferus - MPI for Quantum Optics

The physicists determined the speed of the electrons with attosecond pulses and precisely synchronized infrared laser pulses. Previously, such experiments were only possible in gases. "The intensity of the laser pulses must be high enough to measure the effect being investigated, but it must not be large enough for the laser pulse to knock all of the charge carriers out of the solid," explains Reinhard Kienberger, one of the scientists involved. This new technology could help in the development of electronic components which perform significantly faster calculations than the current state-of-the-art.

However, with this experiment, the scientists have not only successfully used attosecond spectroscopy to examine solids for the first time. They were also able to resolve the movement of the electrons with greater accuracy than ever before, namely to within a few tens of attoseconds. "The relationship between ten attoseconds and one second is the equivalent of the relationship between one second and around three billion years," explains Ferenc Krausz, who is the Director of the Max Planck Institute in Garching and in charge of the experiments.

The scientists achieved this resolution by shining a 300-attosecond pulse of extreme ultraviolet light on the surface of a tungsten crystal. In addition, they shone an infrared laser pulse comprising less than two oscillation cycles of its electric field on the specimen.

The ultraviolet attosecond pulse penetrates the crystal and frees electrons – both loosely bound electrons responsible for conduction and electrons bound tightly to the cores of the atoms forming the crystal lattice. The conduction electrons then travel faster to the surface than the tightly bound core electrons. Once at the surface, both types of electrons experience the field of the infrared pulse. Depending on when they reach the surface, they will feel either a peak or a trough of the infrared pulse's field. In the case of the former, they will be accelerated, while in the case of the latter they will be slowed down. This change in velocity can also be detected by a time-of-flight detector.

The researchers then continuously shift the timing at which they fire off the attosecond pulse. "You can imagine the peaks of the electric field in the infrared pulse like the fingers of one hand, with the attosecond pulse like a single, particularly slim finger," says Reinhard Kienberger. "We then position the attosecond finger at different points in the infrared laser hand."

These different measurements work like an attosecond stopwatch. This showed the scientists that the conduction electrons reach the finishing line at the surface of the crystal around 110 attoseconds earlier than the core electrons. From this, the researchers were, in turn, able to calculate that the conduction electrons within the crystal move twice as fast as the core electrons.

"The experiment demonstrates the technical ability to observe the transportation of charge in a solid in real time," says Krausz. "This paves the way for the development of ultra-fast circuits."

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Panorama

Big-headed bird: The dominant white-browed sparrow weaver male has a visibly larger brain than the subdominant male.

Photo: MPI for Ornithology

HIGH STATUS MEANS more brains – at least in the case of the white-browed sparrow-weaver, a songbird native to southern Africa. Scientists at the Max Planck Institute for Ornithology in Seewiesen uncovered this fact while studying the song behavior of this bird. White-browed sparrow-weavers live in groups of up to 10 individuals that occupy a circumscribed territory together. In each group, a dominant breeding pair reigns and all other group members help it raise its young. Each white-browed sparrow-weaver has a group-specific song repertoire that is sung in a duet or in many-voiced choirs by the group to defend its common territory. However, the male of the dominant breeding pair also performs a solo song – generally at sunrise during the breeding period – that is significantly different from the group song. It has been shown that this "bilingualism" in the dominant male is accompanied by a significant increase in the number of nerve cells in the regions of the brain that are involved in the production and motor control of song. In terms of purely outward physical characteristics, however, the dominant soloists look just like other subdominant males with a normal brain.

AN EXTREMELY SHARP RADIO IMAGE of the galaxy M87 in the constellation Virgo was achieved by researchers at the Max Planck Institute for Radio Astronomy. To do this, they used a network of radio telescopes in North America, Hawaii and on the Virgin Islands, thus creating an image of the central region of M87 at a resolution that is 50 times higher than that taken by the Hubble Space Telescope in the optical range. In this way, an image was made for the first time of the counterpart to the jet that was detected some time ago – a stream of material emitted from the core of M87 out toward Earth. The counter-jet, as it is known, is emitted in the opposite direction out of the black hole in the central region of M87. In other words, it points away from the Earth. The counter-jet was hidden until now due to its low luminosity.

DIRECT DAMAGE TO NERVE CELLS, caused by auto-aggressive antibodies, seems, in some cases, to contribute to the clinical picture of multiple sclerosis (MS). An international team including researchers from the Max Planck Institute of Neurobiology in Martinsried detected antibodies against a protein called neurofascin in the blood of MS patients. One form of this protein is a component of the protective myelin sheath, the insulating layer around nerve fibers that is attacked and destroyed as multiple sclerosis progresses. However, a second form of neurofascin is also found at what is known as the nodes of Ranvier, gaps in the myelin sheath at which the surface of the nerve fibers is exposed. These nodes create a more rapid and efficient signal transmission along the nerve fibers. As has now been discovered, the auto-aggressive antibodies in the blood of MS patients react against both forms of neurofascin – and do not restrict themselves to the myelin sheath, but attack and damage the nerve fibers directly, as well. Now the question must be answered whether antibodies against neurofascin are accompanied by especially serious MS processes. And if so, it might be possible to alleviate and delay the disease's progression in such cases by filtering antibodies out of the blood.

A SPECIAL SWIMSUIT for nanoparticles has been developed by scientists at the Max Planck Institute of Colloids and Interfaces in Potsdam. It consists of polymer chains of methacrylate units that have each been supplied with polyethylene glycol chains. The structures created in this way resemble cleaning brushes – and exhibit remarkable characteristics: they are initially strongly water soluble, but heating or the addition of salts makes them fat soluble. It also works the other way around, too: the fat-soluble brushes become water soluble once again if citric acid is added to them. Nanoparticles of gold coated with these brush structures become "crossover artists": when the exterior conditions were changed accordingly, they traveled between watery and oily mediums. The researchers believe that this principle has potential applications in medicine and catalyst technology.

www Further information is available at www.maxplanck.de