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NOBEL PRIZE IN PHYSICS

FERENC KRAUSZ

Ferenc Krausz received the Nobel medal from King Carl Gustaf in Stockholm on December 10, 2023.

A Nobel Prize is not a walk in the park. You could clearly see how intensely Ferenc Krausz was concentrating at the award ceremony on December 10. The Director at the Max Planck Institute of Quantum Optics and Professor at the Ludwig Maximilian University of Munich (LMU) was awarded the Nobel Prize in Physics together with Pierre Agostini from Ohio State University (USA) and Anne L'Huillier from the University of Lund (Sweden), for the establishment of attosecond physics. During the introduction to the subject, before Swedish King Carl Gustaf presented the medals, there was a deep wrinkle on Krausz's forehead. The tension may not only have been due to the magnitude of the moment. Ferenc Krausz and the other prize winners had already had to complete a rigorous program during Nobel Week: press appointments, rehearsals, receptions, public presentations – all within a tight schedule followed by a banquet in the evening.

What's more, before the Nobel Committee even becomes aware of them, laureates have already come a long way and mastered many challenges. Nevertheless, for Ferenc Krausz, all the effort was worth it. "It is a very nice feeling to see that it pays off not to be discouraged by setbacks, but to continue on the path undeterred," said Ferenc Krausz, shortly after the Nobel Committee had notified him. "And that's what I want to pass on to future generations."

The physicist, who comes from Hungary, began his path into attosecond physics in the 1990s. At the beginning of the 2000s, his team succeeded for the first time in generating light pulses in the attosecond range – an attosecond is one billionth of a billionth of a second. For comparison, as many attoseconds fit into one second as seconds fit into the amount of time that has passed since the Big Bang. Ferenc Krausz and his compatriot Robert Szipöcs laid the foundation for this achievement by developing mirrors that can be used to generate extremely intense laser pulses, in which a light wave oscillates just a few times. In 2002, Krausz and Theodor Hänsch, who is also Director at the Max Planck Institute of Quantum Optics and a Professor at LMU, succeeded in controlling the exact shape of a light wave with Hänsch's likewise Nobel Prize-winning frequency comb technique. Krausz's team fired these flashes of light, which lasted a few femtoseconds, at noble gas atoms. The strong electromagnetic fields of the pulses pulled electrons out of the atoms. When they captured the electrons again, they emitted flashes lasting a few hundred attoseconds. The shortest light pulses last significantly less than 100 attoseconds.

With the extremely short laser flashes, Ferenc Krausz's team of researchers can film electrons, for example in the quantum mechanical process of tunneling. Here, the charge carriers penetrate an energy barrier that they should not be able to break through according to the laws of classical physics. The team also photographed the pulsating positively charged hole that an electron leaves in a noble gas atom after being knocked out by a flash of light. The researchers are now also tracking electrons in solids. For example, they have observed how quickly electrons pass through individual atomic layers of a metal. Attosecond physics makes it possible to control the electrons. This could also help in the development of faster electronic components.

←

GERMAN-UKRAINIAN CORE OF EXCELLENCE LAUNCHED IN HALLE

To strengthen Ukrainian science, the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF) will support four centers of excellence with 2.5 million euros each over the next four years. These centers will also make an important contribution to rebuilding the country. One of these centers of excellence – called Plasma-Spin Energy – will be established in cooperation between the Max Planck Institute of Microstructure Physics in Halle and the W.N. Karazin Kharkiv National University. The center of excellence will probably be located in Kharkiv. The researchers aim to produce components for spintronics using plasma techniques. Unlike conventional electronics, spintronics uses the spin of electrons rather than their charge to create more efficient electronic devices. ***www.mpg.de/21108595***

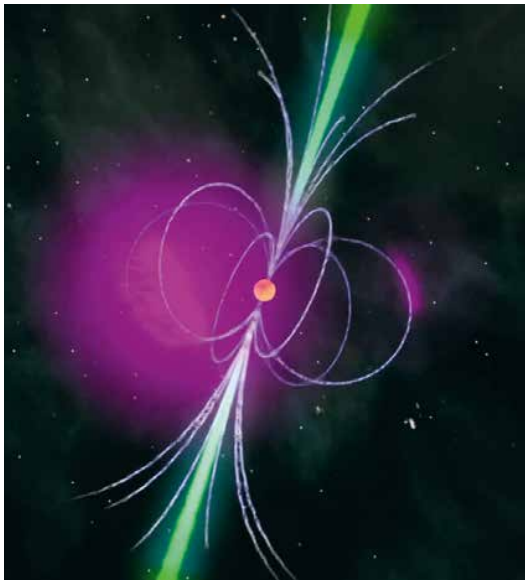

PHOTO: NASA/FERMI/CRUZ DEWILDE

Cosmic lighthouse: The illustration shows a neutron star emitting radio waves (green) from its magnetic poles. As a radio pulsar like this one rotates, it appears to glow periodically when viewed from Earth.

STARGAZING FROM THE COMFORT OF YOUR COUCH

Einstein@Home harnesses the otherwise wasted computing power of the PCs of over 15,000 volunteers, making it one of the largest citizen science projects of its kind in the world. Since 2009, Einstein@Home has analyzed over 150,000 observations from the Arecibo Radio Telescope, identifying a staggering 60 billion pulsar candidates hidden in the data. Using a new algorithm, researchers at the Max Planck Institute for Gravitational Physics have reduced this number and created a database of 50,000 particularly promising candidates for rapidly rotating neutron stars. For each of these potential new pulsars, the research team has produced a series of graphs of the measurement data. As part of the new "Pulsar Seekers" citizen science project, hosted on the Zooniverse platform, volunteers can now classify the graphical representations of the Einstein@Home results to discover the actual pulsars in them. ***www.mpg.de/21023035***

OUTSTANDING!

PHOTO: CHRIS KETTNER

TOBIAS ERB

The Director at the Max Planck Institute for Terrestrial Microbiology in Marburg has been awarded the EUR 2.5 million Gottfried Wilhelm Leibniz Prize. He is being honored for his research into the metabolic pathways of microorganisms, particularly those involved in photosynthesis. Erb studies microbial enzymes, modifies their properties, and uses synthetic biology to construct metabolic pathways that convert CO_2 more efficiently than their natural counterparts. His work is opening up new ways of producing sustainable raw materials from CO_2 by using light.

PHOTO: MPI FOR BRAIN RESEARCH

MORITZ HELMSTAEDTER

Moritz Helmstaedter, Director at the Max Planck Institute for Brain Research in Frankfurt, will also receive a Leibniz Prize. He is being honored for his pioneering work in neuroscience. Helmstaedter has developed tools and techniques that provide insights into the densely packed neuronal networks of the brain. He is one of the founders of connectomics, which reconstructs thousands of neurons and their synaptic connections. Research in this field fundamentally improves our understanding of how circuits in the mammalian brain are organized and how they function.

IN BRIEF

PHOTO: YONI KELBERMAN / MPG

Patrick Cramer at the Yad Vashem Holocaust Memorial in Jerusalem, with other members of the Max Planck delegation in the background.

MAX PLANCK DELEGATION IN ISRAEL

It was a visit during difficult times. There should have been reason to celebrate this year. The Minerva scholarship program, which promotes Israeli-German scientific exchange, is celebrating its 50th anniversary. But because of the barbaric terrorist attack by Hamas and the terrible war in Gaza, the planned event was canceled. Nevertheless, a small delegation from the Max Planck Society and the Minerva Foundation, led by President Patrick Cramer, traveled to Israel at the end of November to express solidarity with long-standing colleagues at Israeli universities and the Weizmann Institute of Science. It was the first and so far only visit by an international research organization to Israel since October 7. At the Van Leer Jerusalem Institute, the delegation met with the presidents and vice-presidents of Israeli universities and research facilities, as well as the directors of the Minerva Centers. They brought with them offers of scientific support, as research is hardly possible in Israel at the moment. The Max Planck Society and the Minerva Foundation are therefore helping Israeli researchers to continue their projects at Max Planck Institutes in Germany or to hold conferences that are no longer possible in Tel Aviv, Haifa, or Jerusalem. The delegation also visited the Yad Vashem Holocaust memorial and laid a wreath in memory of the persecuted scientists of the Kaiser Wilhelm Society.

SUCCESSFUL IN EUROPE

They want to develop a new mathematical language, explore the regenerative abilities of the axolotl brain, search for habitable worlds beyond our solar system, and work on transmitting odors over the internet. In the call for tenders in the ERC Synergy Grants 2023, 37 projects were selected for funding out of a total of 396 applications from across Europe. Four grants totaling around EUR 40 million were awarded to research teams from the Max Planck Society. In addition, four Max Planck projects were awarded Consolidator Grants, each worth around EUR 2 million. These grants are awarded to researchers who recently completed their doctorates and have promising scientific careers ahead of them. The diverse range of research topics have included giant viruses, origami DNA for optimizing essential enzyme functions, microorganisms as biofuel sources, and reconstructing prehistoric neighborhood structures using ancient DNA.

www.mpg.de/21011308
www.mpg.de/21142051

A HEART CAN BE REPAIRED

Mouse heart about one month after a heart attack: In mice with a functioning Cpt1b gene, the ventricle is enlarged and the muscle tissue is damaged (left). In contrast, the hearts of animals without a functional Cpt1b gene have fully regenerated after the heart attack (right).

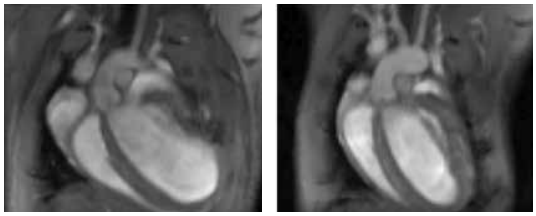

PHOTO: MPI FOR HEART AND LUNG RESEARCH

Because heart muscle cells cannot divide after birth, the human heart loses almost all of its ability to repair damage. This is why a heart attack in adults usually causes permanent damage to the heart muscle. When cells lose their ability to divide, their energy metabolism also changes. Instead of getting energy from sugar, they rely mainly on fats. Researchers at the Max Planck Institute for Heart and Lung Research have now successfully restored the hearts of adult mice after a heart attack. They focused on a gene called Cpt1b that is essential for the burning of fatty acids. Mice in which Cpt1b was deactivated in heart muscle cells showed almost no scarring in the heart muscle a few weeks after a heart attack. The hearts of these animals were able to beat almost as strongly as before the heart attack. Deactivating the gene causes heart muscle cells to revert to an immature state, allowing them to regenerate. Inhibitors that block the action of Cpt1b may be an option for new therapies. ***www.mpg.de/20981292***

HUMANS AND BATS

Bats are commonly thought to carry viruses that can be transmitted to humans. A team of researchers at the Max Planck Institute of Animal Behavior has analyzed studies of viruses from more than 160 African bat species. Apart from the Egyptian fruit bat, which can carry Marburg and Sosuga viruses, they found no evidence that African bats carry viruses that are dangerous to humans. Transmission of viruses from bats to humans in Africa has only been confirmed in two cases. Despite research to the contrary, bats are still considered to be disease carriers. This can be fatal for these animals, as it increases their already growing persecution by humans. The decline of bats in Africa is also having a dramatic impact on nature, as bats carry tree seeds and help reforest previously deforested areas.

www.mpg.de/21135641

EXOMOONS PLAYING HIDE-AND-SEEK

Just as planets are thought to orbit most of the stars in our Milky Way, moons around these exoplanets should be no rarity. Finding them, however, is even more challenging than finding exoplanets and resembles a game of hide-and-seek. Both planets and their moons can be detected using the transit method. When such a celestial body passes in front of its star or planet, as seen from Earth, it slightly dims its light. However, when an exomoon accompanies the planet, the effect is easily lost in the noise within the data. Various analyses have confirmed the existence of moons to varying degrees. So far, only two of the more than 5,300 known exoplanets, namely Kepler-1625b and Kepler-1708b, have shown potential evidence of moons. However, a team from the Max Planck Institute for Solar System Research and the Sonneberg Observatory has re-analyzed the data using an algorithm specifically designed for exomoons. They haven't found any evidence yet, but the game of hide-and-seek continues. ***www.mpg.de/21217437***

Illustration of an exoplanet orbiting a sun-like star.

PHOTO: NASA/JPL-CALTECH

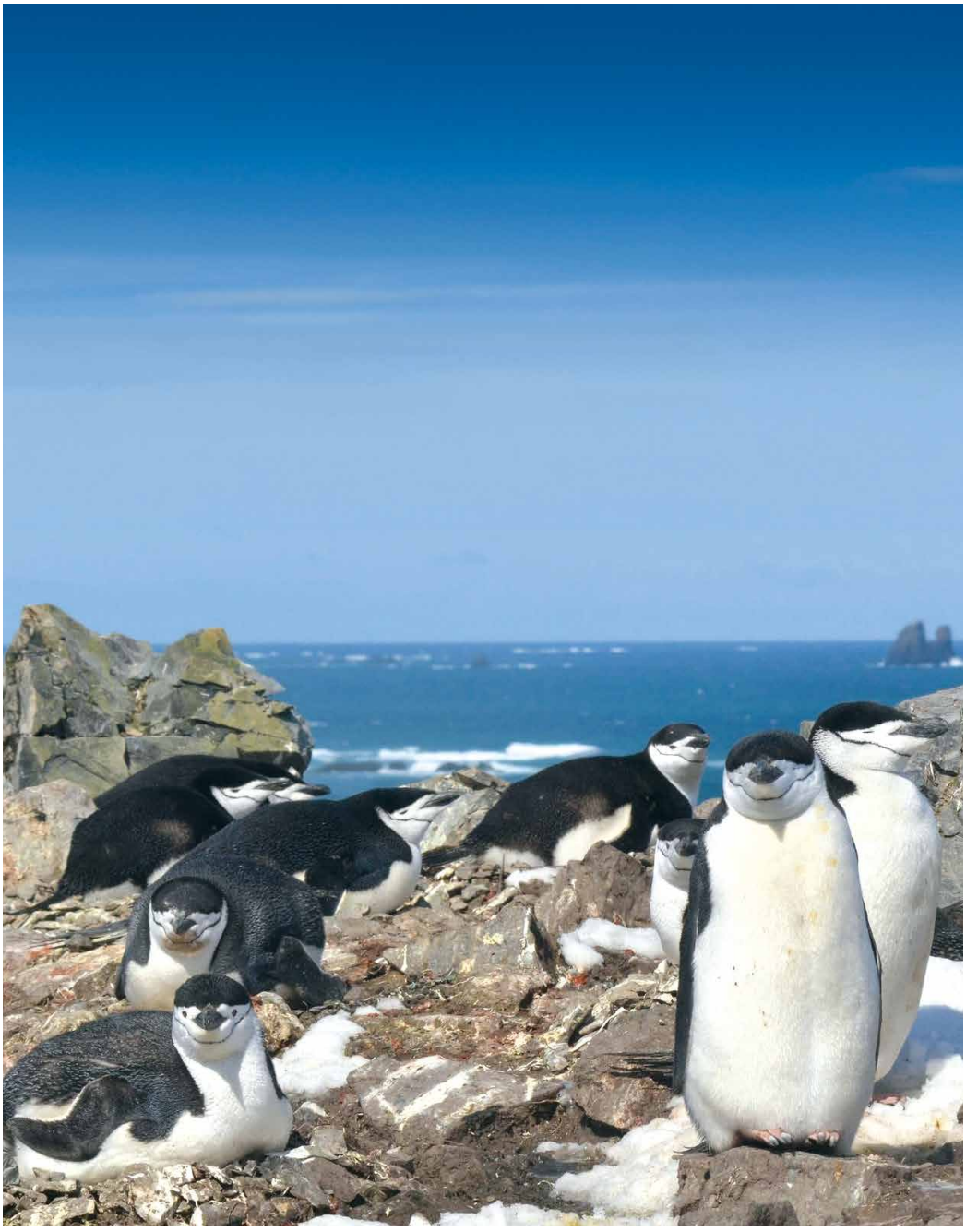

PHOTO: PAUL-ANTOINE LIBOUREL, LYON NEUROSCIENCE RESEARCH CENTRE, FRANCE

Breeding Adélie penguins on King George Island, Antarctica.

MICROSLEEP

Penguins have perfected what some people wish for in their hectic daily lives: the ability to doze off for a moment and regenerate in the process. An international team, including the Max Planck Institute for Biological Intelligence, recorded the brain activity of Adélie penguins during the breeding season and discovered that these birds sleep for an average of only four seconds at a time, but can enter such a microsleep up to around 600 times per hour during the breeding season. Over the course of the day, they accumulate up to twelve hours of slow-wave sleep, the typical bird sleep pattern. During this sleep, they may alternately doze off in one hemisphere of the brain or the other, or both hemispheres may sleep together. They can also sleep while floating in the sea, but then almost exclusively with both hemispheres. Especially at the edge of a colony, there is a risk that nest robbers stealing eggs will take advantage of penguins sleeping with both hemispheres. However, the measurements show that penguins at the edge of a colony do not sleep longer or more often with only one hemisphere than those in the center of the colony. The unusual sleeping behavior of the penguins appears to be a result of disturbance and aggression from conspecifics rather than fear of predators.

www.mpg.de/21169426

STAR NURSERY WITHOUT UV DISASTER

Although the sun's UV radiation can cause sunburn and, in the worst cases, skin cancer, it hasn't prevented life on Earth. But the situation is different on many planets in the universe. In the vicinity of more than half of all star systems and their planets, possibly including our own solar system, there were or are particularly massive stars. During their short lives, these stars bombard many planets with intense UV radiation. Complex molecules, and therefore life, were thought to be unlikely to form there. A team led by María C. Ramírez-Tannus from the Max Planck Institute for Astronomy set out to test this assumption by studying the birthplace of planets in a truly inhospitable environment – the star-forming region NGC 6357, a region 5500 light-years away. To their surprise, the researchers discovered water, carbon monoxide, carbon dioxide, acetylene, and silicate dust in the material reservoir of the gas and dust disk known as XUE-1. These are all key molecules for the formation of Earth-like planets and, in part, for the origin of life – despite the enormous radiation from neighboring giant stars. Earth-like planets could therefore form under much harsher conditions than researchers previously thought.

www.mpg.de/21124740

PHOTO: MARIA CRISTINA FORTUNA (WWW.MARIACRISTINAFORTUNA.COM)

Illustration of a star-forming region with a planet-forming disk in the foreground and a massive star in the upper left.

FASTING IN OLD AGE

Diets that alternate between fasting and eating keep the metabolism flexible. In this way, intermittent fasting promotes health and increases life expectancy. However, studies in different animal species have shown that the effect of such diets declines with age. Researchers at the Max Planck Institute for Biology of Ageing have now found out why. They prescribed fasting periods for killifish of different ages and studied the response of the fish's fat tissue to the end of the fast. In contrast to young fish, fasting puts the fat tissue of older animals into a permanent dormant state. This leads to a shutdown of energy metabolism, a reduction in protein production and tissue non-renewal. This negatively affects the energy balance of the whole body. A subunit of a cellular energy sensor called AMP kinase plays a central role in this process. It is less active in older fish than in younger ones. This molecule may also influence the ageing process in humans, as people with higher levels of the AMP kinase subunit tend to be healthier in old age. The researchers are therefore looking for molecules that activate the subunit and promote health in old age.

www.mpg.de/21105996

A CYCLE IN THE BRAIN

Fluctuations in female hormone levels affect the brain. A team of researchers at the Max Planck Institute for Human Cognitive and Brain Sciences has found that some brain regions grow and shrink during the menstrual cycle. The team took blood samples and performed magnetic resonance imaging of the brains of 27 participants at six different times. The researchers found that during periods of high estradiol and low progesterone, which are typical around ovulation, some regions of the medial temporal lobe of the cerebral cortex expand. These areas of the brain are important for aspects of long-term memory and spatial perception. The exact neurological changes responsible for the growth of these regions are still unclear. However, part of the increase in volume could be explained by an increase in the number of synaptic connections between nerve cells.

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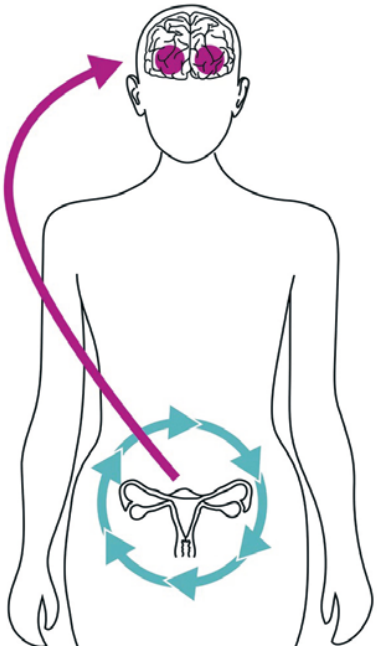

During the menstrual cycle, brain regions in the cerebral cortex of women grow and shrink.

GRAPHIC: MPI FOR HUMAN COGNITIVE AND BRAIN SCIENCES

COLLECTIVE APPROACH FOR BETTER DIAGNOSES

Medical diagnoses become much more accurate when the expertise of several doctors is combined. A diagnosis is correct 76 percent of the time when the judgments of ten medical experts are combined. When one person makes a diagnosis alone, it is correct only 46 percent of the time. This has been shown by an international team, including scientists from the Max Planck Institute for Human Development, using more than 1,300 medical cases from a global database. In medicine, pooled assessments can save lives – in the United States alone, around 250,000 people die each year as a result of medical errors, many of which occur during diagnosis. Until now, multiple expert opinions could only be evaluated efficiently if they were standardized. However, this is rarely the case with medical diagnoses. The team is using artificial intelligence, among other methods, to combine the opinions of different experts. The researchers are currently working on implementing their development in medical practice.

www.mpg.de/20991718

5,000,000

deaths per year could be avoided by transitioning away from fossil fuels.

ENERGY TRANSITION SAVES MILLIONS OF LIVES

A rapid phase-out of fossil fuels wouldn't just slow climate change. It could also prevent 5 million deaths worldwide each year from air pollution. This is the conclusion of an international team including researchers from the Max Planck Institute for Chemistry. The researchers assessed the impact of air pollution, particularly fine particulate matter and ozone, and its effects on health. They attributed both total mortality and disease-specific deaths to specific emission sources. They found that about half of fossil fuel deaths were from cardiovascular disease, which is primarily caused or aggravated by particulate matter.

www.mpg.de/13275159

PHOTO: MPI FOR MULTIDISCIPLINARY SCIENCES/ MIQUEL VILA-FARRÉ

Flatworms can regenerate body parts to varying degrees. This may be related to the way the species reproduce.

HEADLESS, BUT SEXY

In Greek mythology, if you cut off the head of the monster known as the Hydra, two new ones grow in its place. Some species of flatworms are also masters at regenerating body parts. In general, very few animals have the ability to regenerate body parts, even though it would be a survival advantage. Researchers at the Max Planck Institute for Multidisciplinary Sciences have found an explanation for why some species have developed the ability to regenerate while others have not. A key factor is a cell signaling pathway called Wnt. When the pathway is "on", an animal forms a new tail; when it is "off", it forms a head. Wnt signals also control the formation of testes and egg yolk. In sexually reproducing flatworms, the Wnt signaling pathway must be active in order to produce eggs and sperm. However, this comes at the cost of their ability to regenerate, as the worms cannot survive without a head. By contrast, asexually reproducing flatworms must be able to regenerate body parts because they split into two parts, each of which grows into a complete new organism. Thus, flatworms may have evolved the ability to regenerate for the purpose of asexual reproduction by division rather than for wound repair.

www.mpg.de/20977630

EUROPE UNDER HEAT STRESS

Extreme heat waves and droughts that were virtually impossible less than 20 years ago were expected to become more common by the end of the century due to human-induced climate change. However, new calculations by a team including researchers from the Max Planck Institute for Meteorology suggest that these extremes could occur earlier than expected. According to their findings, a natural climate variability, in which the surface temperature of the North Atlantic Ocean fluctuates over several decades, amplifies the effects of global warming. As a result, the likelihood of extreme heat waves and droughts in the next two decades has increased to ten percent. By 2050, there is also a ten percent chance of extreme heat waves occurring in two consecutive years.

www.mpg.de/mpr-2023-042

PHOTO: DEBBIE FROM PIXABAY

Monk parakeets originate from South America. In recent decades, birds that escaped from the zoo trade have established new populations in European cities.

PARROT TALK

"We can do everything except speak standard German," the Swabians say of themselves. At least when it comes to dialect, some parrots may feel the same way. Researchers from the Max Planck Institute of Animal Behavior in Konstanz and the Max Planck Institute for Evolutionary Anthropology in Leipzig have studied monk parakeets, which have spread across Europe over the last 50 years. They recorded the birds' vocalizations in eight cities in Spain, Belgium, Italy, and Greece and analyzed them using a novel statistical method. Their analyses showed that the parakeets modulate the pitch of their calls differently in each city. However, within each city, the calls did not differ. This suggests that the dialects of monk parakeets in Europe may have evolved as individuals imitating their conspecifics made small errors that accumulated over time and differed from city to city. The researchers had previously discovered that each parakeet may have a unique voice. It might be the case that monk parakeets, like humans, recognize each other by voice.

www.mpg.de/21165360

My neighborhood, the prime numbers

At the Max Planck Institute for Mathematics, Peter Scholze uses geometric methods to study the properties of integers.

With the “perfectoid spaces”, he discovered a new class of geometric structures and problems in number theory could be solved. We support his research because the intellectual adventures and accomplishments of pure mathematics are an indispensable base for our life in the 21st century.

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RISKY PAYDAY

An international study, involving Peter Eibich, a scientist at the Max Planck Institute for Demographic Research, has found that individuals receiving state social benefits or low pensions tend to take higher risks shortly before their income is paid out. This behavior was observed among socially disadvantaged pensioners in both the USA and Japan. Risk-taking behaviors include taking out loans, engaging in gambling activities like the lottery, or smoking. To gauge risk tolerance, the research team analyzed survey responses regarding preferences between a job offer with a steady, guaranteed income versus one with varying probabilities of higher or lower salaries. By correlating this data with the timing of the surveys, the researchers were able to observe changes in risk-taking behavior around payday. The results indicate that, in both the USA and Japan, where individuals generally exhibit lower risk-taking tendencies, those with very low incomes display an increased willingness to take risks as their funds run short before payday and they become stressed as a result. Shortening the intervals between payment dates could potentially assist payment recipients in better managing their finances, thereby reducing stress levels and the associated propensity for higher risk-taking behaviors.

www.mpg.de/20938976

ENERGY RECORD IN NUCLEAR FUSION

At the Joint European Torus (Jet) in the UK, a European team, including scientists from the Max Planck Institute for Plasma Physics in Garching, has released the largest amount of energy ever produced by a fusion experiment. During a 5.2 second plasma discharge, they generated 69 megajoules of energy from 0.2 milligrams of fuel. This surpasses their previous record from 2021, where they attained 59 megajoules in 5 seconds. However, the energy required to ignite the plasma still exceeded the energy produced by the fusion process itself. Achieving a positive energy balance will only be possible with significantly larger fusion facilities, such as Iter. The record-breaking discharge was one of the last experiments at Jet, as the facility ceased operations at the end of 2023 after four decades.

www.mpg.de/21522737

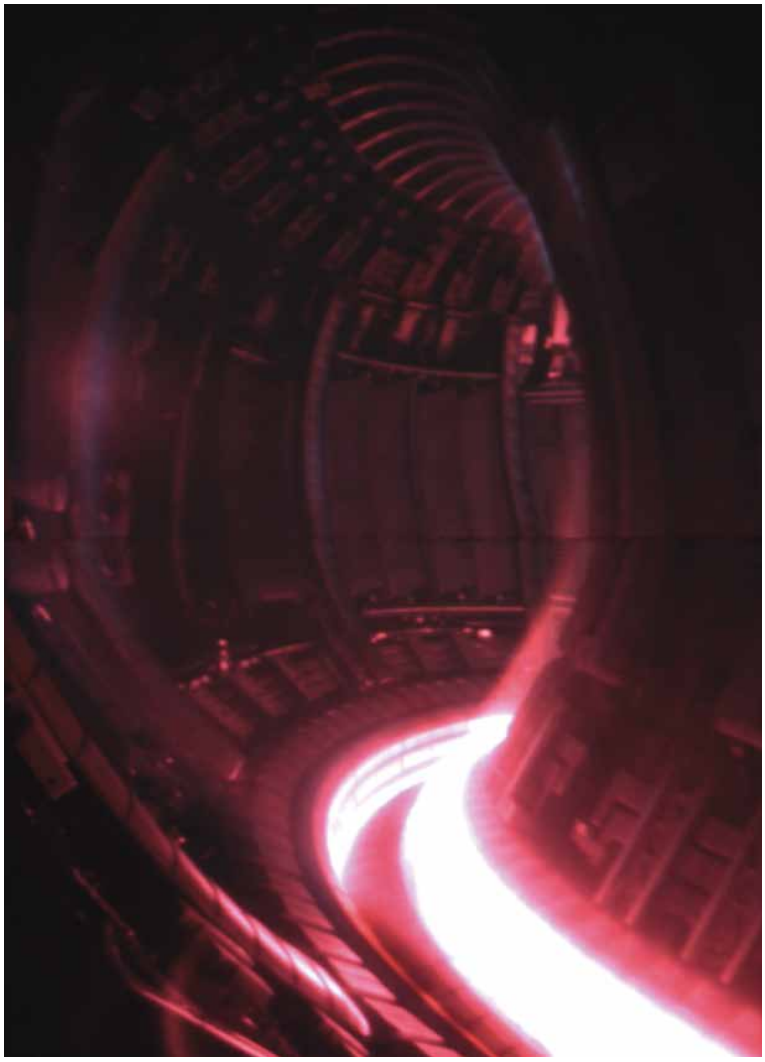

PHOTO: UNITED KINGDOM ATOMIC ENERGY AUTHORITY

Plasma discharge #104,522: The energy record was achieved in this Jet experiment.

ELECTRONIC MUSIC WITH A HUMAN RHYTHM

Electronically generated rhythms are often perceived as sounding too artificial. New software is changing that perception by allowing producers to create rhythms that sound more natural in computer-produced music. Research conducted at the Max Planck Institute for Dynamics and Self-Organization and at Harvard University forms the basis for new and patented methods of electronically generated rhythms imitating deviations of musicians, which follow fractal patterns. The process, which produces natural-sounding rhythms, has been licensed to Mixed In Key LLC, whose music software is used worldwide by music producers and DJs. A product called Human Plugins, which uses this technology, has now been launched.

www.mpg.de/21479985

A software called human plugins generates rhythms with deviations of human musicians.

IMAGE: MIXED IN KEY

Two grams of paclitaxel are needed to treat one cancer patient. To obtain this amount, ten tonnes of yew needles must be processed. Laboratory synthesis of paclitaxel involves numerous complex steps and is therefore still more costly than extraction from trees.

PHOTO: ALPSDAKE / CC BY-SA 3.0

SYNTHESIS OF ANTI-CANCER AGENT ELUCIDATED

Paclitaxel, a commonly used chemotherapeutic agent in the treatment of cancer, is synthesized by yew trees with the help of various enzymes. However, until recently, many of the molecules and the genes involved in the biosynthetic pathway remained unknown. Researchers at the Max Planck Institute of Molecular Plant Physiology in Potsdam have now successfully identified all the missing enzymes required by yew trees to produce paclitaxel. By equipping tobacco plants with both the previously known and newly discovered genes, similar amounts of paclitaxel can be produced as in yew tree. This breakthrough suggests the potential for genetically modified plants or microorganisms to be utilized in the production of this chemotherapeutic agent. However, some of the enzymes currently do not function effectively in bacteria. This may be due to the fact that many of these enzymes are bound to membranes, but bacteria possess different membranes compared to plants. As a result, the enzymes in the single-celled organisms may not find each other. Nevertheless, it may be possible to adapt the synthetic pathway so that it also functions effectively in bacteria. The discovery holds promise to help produce the anti-cancer drug more efficiently in future.

www.mpg.de/21255442