SCIENCE NEWS

Massive Space Explosion Observed Creating Elements Needed for Life

Date: October 25, 2023

Source: University of Birmingham

Scientists have observed the creation of rare chemical elements in the second brightest gamma-ray burst ever seen casting new light on how heavy elements are made.

Researchers examined the exceptionally bright gamma-ray burst GRB 230307A, which was caused by a neutron star merger. The explosion was observed using an array of ground and space-based telescopes, including NASA's James Webb Space Telescope, Fermi Gamma-ray Space Telescope and Neil Gehrels Swift Observatory.

Publishing their findings today in nature (25 Oct), the international research team which included experts from the University of Birmingham, reveal that they found a heavy chemical element tellurium, in the aftermath of the explosion.

Other elements such as iodine and thorium, which are needed to sustain life on earth, are also likely to be amongst the material ejected by the explosion, also known as a kilonova.

Dr. Ben Gompertz, Assistant Professor of Astronomy at the University of Birmingham, and co-author of the study explains: Gamma-ray bursts come from powerful jets travelling at almost the speed of light, in this case driven by a collision between two neutron stars. These stars spent several billion years spiralling towards one another before colliding to produce the gamma-ray burst we observed in March this year. The merger site is the approximate length of the Milky Way (about 120,000 light-years) outside of their home galaxy, meaning they must have been launched out together.

"Colliding neutron stars provide the conditions needed to synthesise very heavy elements, and the radioactive glow of these new elements powered the kilonova was detected as the blast faded. Kilonovae are extremely rare and very difficult to observe and study, which is why this discovery is so exciting."

GRB 230307A was one of the brightest gamma-ray bursts ever observed over a million times brighter than the entire Milky Way Galaxy combined. This is the second time individual heavy elements have been detected using spectroscopic observations after a neutron star merger, providing invaluable insight into how these vital building blocks needed for life are formed.

Lead author of the study Andrew Levan, Professor of Astrophysics at Radboud University in the Netherlands, said: "Just over 150 years since Dmitri Mendeleev wrote down the periodic table of elements, we are now finally in the position to start filling in those last blanks of understanding where everything was made, thanks to the James Webb Telescope."

GRB 230307A lasted for 200 seconds, meaning it is categorised as a long-duration gamma-ray burst. This is unusual as short gamma-ray bursts, which last less than two seconds, are more commonly caused by neutron star mergers. Long gamma-ray bursts like this one are usually caused by the explosive death of a massive star.

The researchers are now seeking to learn more about how these neutron star mergers work and how they power these huge element-generating explosions.

Dr. Samantha Oates, a co-author of the study while a postdoctoral research fellow at the University of Birmingham (now a lecturer at Lancaster University) said: "Just a few short years ago discoveries like this one would not have been possible, but thanks to the James Webb Space Telescope we can observe these mergers in exquisite detail."

Dr. Gompertz concludes: "Until recently, we didn't think mergers could power gamma-ray bursts for more than two seconds. Our next job is to find more of these long-lived mergers and develop a better understanding of what drives them and whether even heavier elements are being created. This discovery has opened the door to a transformative understanding of our universe and how it works."

Scientists Unveil Detailed Cell Maps of the Human Brain and the Non-human Primate Brain

Date: October 12, 2023

Source: NIH/National Institute of Mental Health

A group of international scientists have mapped the genetic, cellular and structural makeup of the human brain and the non-human primate brain. This understanding of brain structure, achieved by funding through the National Institutes of Health's Brain Research Through Advancing Innovative Neurotechnologies (Brain) Initiative, or the BRAIN Initiative®, allows for a deeper knowledge of the cellular basis of brain function and dysfunction, helping pave the way for a new generation of precision therapeutics for people with mental disorders and other disorders of the brain. The findings appear in a compendium of 24 papers across Science, Science Advances, and Science Translational Medicine.

"Mapping the brain's cellular landscape is a critical step toward understanding how this vital organ works in health and disease", said Joshua A. Gordon, M.D., Ph.D., director of the National Institute of Mental Health. "These new detailed cell atlases of the human brain and the non-human primate brain offer a

foundation for designing new therapies that can target the specific brain cells and circuits involved in brain disorders."

The 24 papers in this latest BRAIN Initiative Cell Census Network (BICCN) collection detail the exceptionally complex diversity of cells in the human brain and the non-human primate brain. The studies identify similarities and differences in how cells are organised and how genes are regulated in the human brain and the non-human primate brain. For example:

- Three papers in the collection present the first atlas of cells in the adult human brain, mapping the transcriptional and epigenomic landscape of the brain. The transcriptome is the complete set of gene readouts in a cell, which contains instructions for making proteins and other cellular products. The epigenome refers to chemical modifications to a cell's DNA and chromosomes that alter the way the cell's genetic information is expressed.
- In another paper, a comparison of the cellular and molecular properties of the human brain and several non-human primate brains (chimpanzee, gorilla, macaque and marmoset brains) revealed clear similarities in the types, proportions and spatial organisation of cells in the cerebral cortex of humans and non-human primates. Examination of the genetic expression of cortical cells across species suggests that relatively small changes in gene expression in the human lineage led to changes in neuronal wiring and synaptic function that likely allowed for greater brain plasticity in humans, supporting the human brain's ability to adapt, learn and change.
- A study exploring how cells vary in different brain regions in marmosets found a link between the properties of cells in the adult brain and the properties of those cells during development. The link suggests that developmental programming is embedded in cells, when they are formed and maintained into adulthood and that some observable cellular properties in an adult may have their origins very early in life. This finding could lead to new insights into brain development and function across the lifespan.
- An exploration of the anatomy and physiology of neurons in the outermost layer of the neocortex part of the brain involved in higher-order functions such as cognition, motor commands and language revealed differences in the human brain and the mouse brain that suggest this region may be an evolutionary hotspot, with changes in humans reflecting the higher demands of regulating humans' more complex brain circuits.

The core aim of the BICCN, a groundbreaking effort to understand the brain's cellular makeup, to develop a comprehensive inventory of the cells in the brain where they are, how they develop, how they work together, and how they regulate their activity to better understand how brain disorders develop, progress and are best treated.

"This suite of studies represents a landmark achievement in illuminating the complexity of the human brain at the cellular level",

said John Ngai, Ph.D., Director of the NIH BRAIN Initiative. "The scientific collaborations forged through BICCN are propelling the field forward at an exponential pace; the progress and possibilities have been simply breathtaking."

The census of brain cell types in the human brain and the non-human primate brain presented in this paper collection serves as a key step towards developing the brain treatments of the future. The findings also set the stage for the BRAIN Initiative Cell Atlas Network, a transformative project that, together with two other large-scale projects—the BRAIN Initiative Connectivity Across Scales and the Armamentarium for Precision Brain Cell Access aim to revolutionise neuroscience research by illuminating foundational principles governing the circuit basis of behaviour and informing new approaches to treating human brain disorders.

Scientists Discover the Highest Energy Gamma Rays Ever from a Pulsar

Date: October 5, 2023

Source: Deutsches Elektronen-Synchrotron DESY

Scientists using the H.E.S.S. observatory in Namibia have detected the highest energy gamma rays ever from a dead star called a Pulsar. The energy of these gamma rays clocked in at 20 tera-electronvolts, or about ten trillion times the energy of visible light. This observation is hard to reconcile with the theory of the production of such pulsed gamma rays, as the international team reports in the journal Nature Astronomy.

Pulsars are the left-over corpses of stars that spectacularly exploded in a supernova. The explosions leave behind a tiny, dead star with a diameter of just some 20 kilometres, rotating extremely fast and endowed with an enormous magnetic field. "These dead stars are almost entirely made up of neutrons and are incredibly dense: a teaspoon of their material has a mass of more than five billion tonnes, or about 900 times the mass of the Great Pyramid of Giza", explains H.E.S.S. scientist Emma de Oña Wilhelmi, a co-author of the publication working at DESY.

Pulsars emit rotating beams of electromagnetic radiation, somewhat like cosmic lighthouses. If their beam sweeps across our solar system, we see flashes of radiation at regular time intervals. These flashes, also called pulses of radiation, can be searched for in different energy bands of the electromagnetic spectrum. Scientists think that the source of this radiation is fast electrons produced and accelerated in the pulsar's magnetosphere, while travelling towards its periphery. The magnetosphere is made up of plasma and electromagnetic fields that surround and co-rotate with the star. "On their outward journey, the electrons acquire energy and release it in the form of the observed radiation beams", says Bronek Rudak from the Nicolaus Copernicus Astronomical Center (CAMK PAN) in Poland, also a co-author.

The Vela Pulsar, located in the Southern sky in the constellation Vela (sail of the ship), is the brightest pulsar in the radio band of the electromagnetic spectrum and the brightest persistent source of cosmic gamma rays in the giga-electronvolts (GeV) range. It rotates about eleven times per second. However, above a few GeV, its radiation ends abruptly,

presumably because the electrons reach the end of the Pulsars magnetosphere and escape from it.

But this is not the end of the story: using deep observations with H.E.S.S, a new radiation component at even higher energies has now been discovered, with energies of up to tens of tera-electronvolts (TeV). "That is about 200 times more energetic than all radiation ever detected before from this object", says co-author Christo Venter from the North-West University in South Africa. This very high-energy component appears at the same phase intervals as the one observed in the GeV range. However, to attain these energies, the electrons might have to travel even farther than the magnetosphere, yet the rotational emission pattern needs to remain intact.

"This result challenges our previous knowledge of Pulsars and requires a rethinking of how these natural accelerators work", says Arache Djannati-Atai from the Astroparticle & Cosmology (APC) laboratory in France, who led the research. "The traditional scheme according to which particles are accelerated along magnetic field lines within or slightly outside the magnetosphere cannot sufficiently explain our observations. Perhaps we are witnessing the acceleration of particles through the so-called magnetic reconnection process beyond the light cylinder, which still somehow preserves the rotational pattern? But even this scenario faces difficulties to explain how such extreme radiation is produced."

Whatever the explanation, next to its other superlatives, the Vela Pulsar now officially holds the record as the pulsar with the highest-energy gamma rays discovered to date. "This discovery opens a new observation window for detection of other Pulsars in the tens of teraelectronvolt range with current and upcoming more sensitive gamma-ray telescopes, hence paving the way for a better understanding of the extreme acceleration processes in highly magnetised astrophysical objects", says Djannati-Atai.

Plants Transformed into Detectors of Dangerous Chemicals

Date: October 23, 2023

Source: University of California – Riverside

What if your house plant could tell you your water isn't safe? Scientists are closer to realising this vision, having successfully engineered a plant to turn beet red in the presence of a banned, toxic pesticide.

To achieve this, UC Riverside researchers had to solve an engineering puzzle: how to enable a plant to sense and react to a chemical in the environment without damaging its ability to function normally in all other respects.

"The biggest piece here is we've created an environmental sensor without modifying the plant's native metabolism," said Ian Wheeldon, Associate Professor of chemical and environmental engineering at UCR. "Previously, the biosensor component would have messed up the plant's ability to grow towards light or stop using water when stressed. This won't."

A new paper detailing the chemistry behind the achievement has been published in the journal Nature Chemical Biology. The engineering process begins with a protein called abscisic acid, or ABA, that helps plants acclimate to stressful changes in the environment.

During a drought, soil dries and plants produce ABA. Additional proteins, called receptors, help the plant recognise and respond to ABA. This in turn tells the plant to close pores in its leaves and stems so less water evaporates and the plant is less likely to wilt.

Last year, the research team demonstrated that ABA receptor proteins can be trained to bind to chemicals other than ABA. Now the team has shown that once the receptors bind to this other chemical, the plant will turn beet red.

For this demonstration the team used azinphos-ethyl, a pesticide banned in many places because it is toxic to humans. "People we work with are trying to sense information about chemicals in the environment from a distance", said Sean Cutler, UCR professor of plant cell biology. "If you had a field of these and they turned red, that would be pretty obvious, visually."

As part of the same experiment, the research team also demonstrated the ability to turn another living organism into a sensor: yeast. The team was able to show a response in yeast to two different chemicals at the same time. However, this is not yet possible in plants.

"It would be great if we could eventually design one plant to sense 100 banned pesticides, a one-stop shop", said Cutler. "The more you can stack, the better, especially for applications involving environmental health or defense. But there are limits to what we can engineer for these new sensing capacities at this time."

To be clear, these plants are not being grown commercially. That would require regulatory approvals that would take many years. It is also a new technology, with a suite of issues that would need to be addressed before it could be used in farmers' fields, or elsewhere in the real world. However, the discovery opens up possibilities.

Adults with ADHD are at Increased Risk for Developing Dementia

Date: October 17, 2023

Source: Rutgers University

Adults with attention-deficit or hyperactivity disorder (ADHD) are nearly three times more likely to develop dementia than adults without ADHD, according to a Rutgers study.

The study, coauthored by Michal Schnaider Beeri, director of the Herbert and Jacqueline Krieger Klein Alzheimer's Research Center at Rutgers Brain Health Institute (BHI) was published in JAMA Network Open. It followed more than 1,00,000 older adults in Israel over 17 years to examine, if adults with ADHD are at increased risk for dementia, including Alzheimer's disease.

Although more than 3 per cent of the adult population in the United States has ADHD, there is limited research on this group.

"By determining if adults with ADHD are at higher risk for dementia and if medications and/or lifestyle changes can affect risks, the outcomes of this research can be used to better inform caregivers and clinicians", said Beeri, the Krieger Klein Endowed Chair in Neurodegeneration Research at BHI and a faculty member of the Rutgers Institute for Health, Health Care Policy and Aging Research.

Using data from a national cohort study of more than 1,00,000 people who were followed from 2003 to 2020, researchers analysed those with and without ADHD and the occurrence of dementia among the groups as they aged. Researchers found the presence of adult ADHD was associated with a significantly higher risk of dementia even when other risk factors for dementia were taken into account, such as cardiovascular conditions.

ADHD in adults may materialise as a neurological process that reduces the ability for them to compensate for the effects of cognitive decline later in life, the researchers said.

"Physicians, clinicians and caregivers who work with older adults should monitor ADHD symptoms and associated medications", said Abraham Reichenberg, a professor at the Department of Psychiatry at the Icahn School of Medicine at Mount Sinai and senior author of the study.

"Symptoms of attention deficit and hyperactivity in old age shouldn't be ignored and should be discussed with physicians", said Stephen Levine, a Professor at the School of Public Health at the University of Haifa.

Additionally, the research suggests ADHD treatment incorporating psychostimulants may help reduce the risk of dementia in adults with ADHD as psychostimulants are known to modify the trajectory of cognitive impairment. But researchers said future studies should examine in more detail the impact of medications in patients with ADHD and how they could affect risk.

Early-life Stress Changes More Genes in Brain than a Head Injury

Date: November 13, 2023

Source: Ohio State University

A surprising thing happened when researchers began exploring whether early-life stress compounds the effects of a childhood head injury on health and behaviour later in life—In an animal study, stress changed the activation level of many more genes in the brain than were changed by a bump to the head.

It's already known that head injuries are common in young kids, especially from falling and can be linked to mood disorders and social difficulties that emerge later in life. Adverse childhood experiences are also very common and can raise risk for disease, mental illness and substance misuse in adulthood.

"But we don't know how those two things can interact", said senior study author Kathryn Lenz, associate professor of psychology at The Ohio State University. "We wanted to understand whether experiencing a traumatic brain injury in the context of early life stress circumstances could modulate the response to the brain injury. And using an animal model allows us to really get into the mechanisms through which these two things might be impacting brain development as it's occurring."

This first set of experiments in rats suggests early life stress's potential to lead to a lifetime of health consequences may not be fully appreciated, said Lenz.

"We found many more genes were differentially expressed as a result of our early life stress manipulation than our traumatic brain injury manipulation", said Lenz. "Stress is really powerful, and we shouldn't understate the impact of early life stress on the developing brain. I think it tends to get dismissed but it's an incredibly important public health topic."

The research poster was presented today (Nov. 12, 2023) at Neuroscience 2023, the annual meeting of the Society for Neuroscience.

Researchers temporarily separated newborn rats from their mothers daily for 14 days to induce stress mimicking the effects of adverse childhood experiences, which include a variety of potentially traumatic events. On day 15, a time when Rats are developmentally equivalent to a toddler, stressed and non-stressed rats were given either a concussion-like head injury under anesthesia or no head injury. Three conditions stress alone, head injury alone and stress combined with head injury were compared to uninjured, non-stressed rats.

First author Michaela Breach, a graduate student in Lenz's lab, examined the gene expression changes in the hippocampal region of the animals' brains later in the juvenile period using single-nuclei RNA sequencing.

Stress alone and stress combined with traumatic brain injury (TBI) produced a few noteworthy results. Both conditions activated pathways in excitatory and inhibitory neurons associated with plasticity, which is the brain's ability to adapt to all kinds of changes, mostly to promote flexibility but sometimes, when the changes are maladaptive, resulting in negative outcomes.

"This may suggest that the brain is being opened up to a new period of vulnerability, or is actively changing during this period of time when it could program later life deficits", said Breach.

Both conditions also had an effect on signaling related to oxytocin, a hormone linked to maternal behaviour and social bonding. Stress alone and combined with TBI activated this oxytocin pathway, but brain injury alone inhibited it.

"Both stress and TBI are linked to abnormal social behaviour, but we're finding these differing effects with the oxytocin signaling", said Breach. "That demonstrates that the effect of stress might modulate how TBI is changing the brain since the combination treatment was different from TBI on its own. Oxytocin is involved in the response to stress and repair, so that may mean it could be an interesting modulator for us to pursue in the future."

In behaviour tests in rats that had aged into adulthood, only animals that experienced early-life stress were prone to more frequently entering a wide-open space, a location that typically makes rodents feel vulnerable to predators.

"Overall, that suggests they might be taking more risks later in life, which is consistent with human data showing that early life stress can increase the risk for certain conditions like ADHD, which can be characterised by risk-taking behaviour or substance use disorders", said Breach.

"The behaviour data pointing to detrimental effects of early-life stress provides further evidence of the need to address adverse childhood experiences", said Lenz.

"Things like social support and enrichment can buffer the effects of early-life stress that has been shown in animal models and in people", she said. "I don't think it can be over-emphasised how damaging early-life stressors can be if they're not dealt with."

This work was supported by Ohio State's Chronic Brain Injury Institute, the Brain Injury Association of America and a National Science Foundation Graduate Research Fellowship.

Chlorine Disinfectant is no More Effective than Water at Killing off Hospital Superbug

Date: November 21, 2023

Source: University of Plymouth

According to a new study, one of the primary chlorine disinfectants currently being used to clean hospital scrubs and surfaces does not kill off the most common cause of antibiotic associated sickness in healthcare settings globally.

Research by the University of Plymouth has showed spores of Clostridioides difficile, commonly known as C. diff, are completely unaffected despite being treated with high concentrations of bleach used in many hospitals.

In fact, the chlorine chemicals are no more effective at damaging the spores when used as a surface disinfectant than using water with no additives.

Writing in the journal Microbiology, the study's authors say susceptible people working and being treated in clinical settings might be unknowingly placed at risk of contracting the superbug.

As a result, and with incidence of biocide overuse only serving to fuel rises in antimicrobial resistance (AMR) worldwide, they have called for urgent research to find alternative strategies to disinfect C. diff spores in order to break the chain of transmission in clinical environments.

Dr. Tina Joshi, Associate Professor in Molecular Microbiology at the University of Plymouth, carried out the study with Humaira Ahmed, a fourth year Medicine student from the University's Peninsula Medical School.

Dr. Joshi, said: "With incidence of anti-microbial resistance on the rise, the threat posed by superbugs to human health is increasing. But far from demonstrating that our clinical environments are clean and safe for staff and patients, this study highlights the ability of C. diff spores to tolerate disinfection at in-use and recommended active chlorine concentrations. It shows we need disinfectants and guidelines, that are fit for purpose and work in line with bacterial evolution, and the research should have significant impact on current disinfection protocols in the medical field globally."

C. diff is a microbe that causes diarrhea, colitis and other bowel complications and is known to infect millions of people all over the world each year.

It causes around 29,000 deaths per year in the USA, and almost 8,500 in Europe, with the most recent data showing that incidence of C. diff infection was increasing prior to the start of the COVID-19 pandemic in the UK.

Previously, Dr. Joshi and colleagues had demonstrated the ability of C. diff spores to survive exposure to recommended concentrations of sodium

dichloroisocyanurate in liquid form and within personal protective fabrics, such as surgical gowns.

The new study examined spore response of three different strains of C. diff to three clinical in-use concentrations of sodium hypochlorite. The spores were then spiked onto surgical scrubs and patient gowns, examined using scanning electron microscopes to establish if there were any morphological changes to the outer spore coat.

Head Lice Evolution Mirrors Human Migration and Colonisation in the Americas

Date: November 8, 2023

Source: PLOS

A new analysis of lice genetic diversity suggests that lice came to the Americas twice, once during the first wave of human migration across the Bering Strait and again during European colonisation. Marina Ascunce, currently at the USDA-ARS and colleagues, report these findings in a new study published November 8 in the open-access journal PLOS ONE.

The human louse is a wingless, blood-sucking parasite that lives its entire life on its host. It is one of the oldest known parasites to live on humans and the two species have co-evolved for millennia. Due to this intimate relationship, studying lice can offer clues to how humans evolved as well. In the new study, researchers analysed the genetic variation in 274 human lice from 25 geographic sites around the world.

A genetic analysis based on louse DNA revealed the existence of two distinct clusters of lice that rarely interbred. Cluster I had a worldwide distribution, while cluster II was found in Europe and the Americas. The only lice with ancestry from both clusters are found in the Americas. This distinct group appears to be the result of a mixture between lice descended from populations that arrived with the first people and those descended from European lice, which were brought over during the colonisation of the Americas.

The researchers also identified a genetic relationship between lice in Asia and Central America. This supports the idea that people from East Asia migrated to North America and became the first Native Americans. These people then spread south into Central America, where modern louse populations today still retain a genetic signature from their distant Asian ancestors.

The patterns observed in the new study support existing ideas about human migration and provide additional knowledge about how lice have evolved. The researchers point out that they selected genetic markers that evolve quickly and are best suited to recent events. Thus, future studies that use markers that have changed more slowly could shed light on more ancient events. Additionally, the methods developed for this work could guide the development of new analyses to study other host-parasite systems.

Climate Change Effects Hit Marine Ecosystems in Multiple Waves, According to Marine Ecologists

Date: November 16, 2023

Source: Brown University

A new approach to examining the effects of climate change on marine ecosystems may

provide a more accurate understanding of climate change responses and predictions for future consequences, according to a new paper co-authored by a Brown University biologist.

The paper, published in the Annual Review of Ecology, Evolution and Systematics, highlights the interplay between the trend of climate warming and the fluctuations in local temperature. These two properties cause atypically warm events, such as marine heatwaves to occur with increasing frequency and magnitude.

However, the interaction between the steadily warming climate and the spikes in local temperatures tends to be underappreciated, according to study co-author Jon Witman, a professor of biology at Brown University.

"Climate change studies often focus on the trend of global warming", said Witman. "But organisms in the ocean are also experiencing temperature fluctuations, and that's less studied and therefore less understood. What we're trying to do is to add more reality into ocean climate change studies by considering both the smooth, upward trend of climate warming as well as the variability on top of that trend."

The paper proposes a new approach for understanding and modeling the effects of marine climate change, with suggestions for future research.

Witman offered coral as an example that illustrates the need for a new approach. While an organism like coral is already trying to adapt to the trend of rising temperatures, he noted, it then endures a heat wave, which causes a large and sudden spike in temperature.

Temperature spikes tend to lead to coral bleaching, which is when metabolically stressed corals expel the beneficial microscopic algae living within them and turn white. If the temperature stays high and algae are unable to return to their host coral, the bleached coral will die.

Witman pointed to heat waves in the Mediterranean that have led to an increase in coral bleaching and death of corals and sea fans.

Extreme events such as heat waves may alter or damage marine ecosystems in ways that leave them more vulnerable to both progressive climate change as well as the next temperature fluctuation, Witman added. A more realistic model may help scientists better identify areas where coral is more likely to die off in an extreme event leaving coral-dependent organisms at risk over time, he said.

In other cases, temperature variability can lead to an opposite response in the affected organism: an ability to acclimatise or adapt to temperature extremes, depending on their frequency and intensity.

"These responses to variable events like heat waves compound and are compounded by the effects caused by rapidly and steadily increasing ocean temperatures", said Witman.

Witman collaborated with Andrew Pershing of the non-profit Climate Central, who studied biology as an undergraduate at Brown, and John Bruno, a professor of biology in the University of North Carolina at Chapel Hill, who earned a Ph.D. in ecology and evolutionary biology from Brown.

In their paper, Bruno, Pershing and Witman considered how organisms and communities

adapt or adjust to both smooth trends and variable changes, and then reviewed processes that influence the rate at which marine communities adjust to changes in their physical environment as well as those processes that might hamper adaption or acclimatisation. The researchers stressed that all of these factors illustrate why it's key to consider both types of change when studying marine climates.

"If we just study how organisms respond to the smooth trend, we miss all the variability, which is driving ecological change", Witman said. "It's not just a matter of worsening physiological stress over time; there are also variable events that have their own ripple effects."

In the paper, the researchers created a global model that shows the variability in temperature relative to trend, highlighting regions where extreme temperatures are likely to have particularly deleterious effects. In the areas of the Gulf of Maine, the Caribbean Sea and the Mediterranean Sea, they write, there are high probabilities of exceptional warming events and 'ecological surprises.' Research shows that key foundation species in these regions, such kelp and corals, have already experienced substantial climate-related changes.

Seeing the Unseen: How Butterflies Can Help Scientists Detect Cancer

Date: November 3, 2023

Source: University of Illinois Grainger College of Engineering

There are many creatures on our planet with more advanced senses than humans. Turtles can sense Earths magnetic field. Mantis shrimp can detect polarised light. Elephants can hear much lower frequencies than humans can. Butterflies can perceive a broader range of colours, including ultraviolet (UV) light.

Inspired by the enhanced visual system of the Papilio xuthus butterfly, a team of researchers have developed an imaging sensor capable of 'seeing' into the UV range inaccessible to human eyes. The design of the sensor uses stacked photodiodes and perovskite nanocrystals (PNCs) capable of imaging different wavelengths in the UV range. Using the spectral signatures of biomedical markers, such as amino acids, this new imaging technology is even capable of differentiating between cancer cells and normal cells with 99 per cent confidence.

This new research, led by University of Illinois Urbana-Champaign electrical and computer engineering professor Viktor Gruev and bioengineering professor Shuming Nie, was recently published in the journal Science Advances.

Small Variations

"We've taken inspiration from the visual system of butterflies, who are able to perceive multiple regions in the UV spectrum and designed a camera that replicates that functionality", Gruev says. "We did this by using novel perovskite nanocrystals, combined with silicon imaging technology, and this new camera technology can detect multiple UV regions."

UV light is electromagnetic radiation with wavelengths shorter than that of visible light (but longer than x-rays). We are most familiar with UV radiation from the sun and the

dangers it poses to human health. UV light is categorized into three different regions UVA, UVB and UVC based on different wavelength ranges. Because humans cannot see UV light, it is challenging to capture UV information, especially discerning the small differences between each region.

Butterflies, however, can see these small variations in the UV spectrum, like humans can see shades of blue and green. Gruev notes, "It is intriguing to me how they are able to see those small variations. UV light is incredibly difficult to capture, it just gets absorbed by everything and butterflies have managed to do it extremely well."

The Imitation Game

Humans have trichromatic vision with three photoreceptors, where every colour perceived can be made from a combination of red, green and blue. Butterflies, however, have compound eyes, with six (or more) photoreceptor classes with distinct spectral sensitivities. In particular, the Papilio xuthus, a yellow, Asian swallowtail butterfly, has not only blue, green and red, but also violet, ultraviolet and broadband receptors. Further, butterflies have fluorescent pigments that allow them to convert UV light into visible light, which can then be easily sensed by their photoreceptors. This allows them to perceive a broader range of colours and details in their environment.

Beyond the increased number of photoreceptors, butterflies also exhibit a unique tiered structure in their photoreceptors. To replicate the UV sensing mechanism of the Papilio xuthus butterfly, the UIUC team has emulated the process by combining a thin layer of PNCs with a tiered array of silicon photodiodes.

PNCs are a class of semiconductor nanocrystals that display unique properties similar to that of quantum dots—changing the size and composition of the particle changes the absorption and emission properties of the material. In the last few years, PNCs have emerged as an interesting material for different sensing applications, such as solar cells and LEDs. PNCs are extremely good at detecting UV (and even lower) wavelengths that traditional silicon detectors are not. In the new imaging sensor, the PNC layer is able to absorb UV photons and re-emit light in the visible (green) spectrum, which is then detected by the tiered silicon photodiodes. Processing of these signals allows for mapping and identification of UV signatures.

Healthcare and Beyond

There are various biomedical markers present in cancerous tissues at higher concentrations than in healthy tissues—amino acids (building blocks of proteins), proteins and enzymes. When excited with UV light, these markers light up and fluoresce in the UV and part of the visible spectrum, in a process called autofluorescence. "Imaging in the UV region has been limited and I would say that has been the biggest roadblock for making scientific progress", explains Nie. "Now we have come up with this technology where we can image UV light with high sensitivity and can also distinguish small wavelength differences."

Because cancer and healthy cells have different concentrations of markers and therefore different spectral signatures, the two classes of cells can be differentiated based on their fluorescence in the UV spectrum. The team evaluated their imaging

device on its ability to discriminate cancer-related markers and found that is capable of differentiating between cancer and healthy cells with 99 per cent confidence.

Gruev, Nie and their collaborative research team envision being able to use this sensor during surgery. One of the biggest challenges is knowing how much tissue to remove to ensure clear margins and such a sensor can help facilitate the decision-making process when a surgeon is removing a cancerous tumor.

"This new imaging technology is enabling us to differentiate cancerous versus healthy cells and is opening up new and exciting applications beyond just health", says Nie. There are many other species besides butterflies capable of seeing in the UV and having a way to detect that light will provide interesting opportunities for biologists to learn more about these species, such as their hunting and mating habits. Bringing the sensor underwater can help bring a greater understanding of that environment as well. While a lot of UV is absorbed by water, there is still enough that makes it through to have an impact and there are many animals underwater that also see and use UV light.

Atomic Dance Gives Rise to a Magnet

Date: November 9, 2023

Source: Rice University

Quantum materials hold the key to a future of lightning-speed, energy-efficient information systems. The problem with tapping their transformative potential is that, in solids, the vast number of atoms often drowns out the exotic quantum properties electrons carry.

Rice University researchers in the lab of quantum materials scientist Hanyu Zhu found that when they move in circles, atoms can also work wonders: When the atomic lattice in a rare-earth crystal becomes animated with a corkscrew-shaped vibration known as a chiral phonon, the crystal is transformed into a magnet.

According to a study published in Science, exposing cerium fluoride to ultrafast pulses of light sends its atoms into a dance that momentarily enlists the spins of electrons, causing them to align with the atomic rotation. This alignment would otherwise require a powerful magnetic field to activate, since cerium fluoride is naturally paramagnetic with randomly oriented spins even at zero temperature.

"Each electron possesses a magnetic spin that acts like a tiny compass needle embedded in the material, reacting to the local magnetic field", said Rice materials scientist and co-author Boris Yakobson. "Chirality—also called handedness because of the way in which left and right hands mirror each other without being superimposable—should not affect the energies of the electrons' spin. But in this instance, the chiral movement of the atomic lattice polarises the spins inside the material as if a large magnetic field were applied."

Though short-lived, the force that aligns the spins outlasts the duration of the light pulse by a significant margin. Since atoms only rotate in particular frequencies and move for a longer time at lower temperatures, additional frequency and temperature-dependent measurements further confirm that magnetisation occurs as a result of the atoms' collective chiral dance.

"The effect of atomic motion on electrons is surprising because electrons are so much lighter and faster than atoms", said Zhu, Rice's William Marsh Rice Chair and an assistant professor of materials science and nanoengineering. "Electrons can usually adapt to a new atomic position immediately, forgetting their prior trajectory. Material properties would remain unchanged if atoms went clockwise or counterclockwise, i.e., traveled forward or backward in time—a phenomenon that physicists refer to as time-reversal symmetry."

The idea that the collective motion of atoms breaks time-reversal symmetry is relatively recent. Chiral phonons have now been experimentally demonstrated in a few different materials, but exactly how they impact material properties is not well understood.

"We wanted to quantitatively measure the effect of chiral phonons on a material's electrical, optical and magnetic properties", Zhu said. "Because spin refers to electrons' rotation while phonons describe atomic rotation, there is a naive expectation that the two might talk with each other. So we decided to focus on a fascinating phenomenon called spin-phonon coupling."

Spin-phonon coupling plays an important part in real-world applications like writing data on a hard disk. Earlier this year, Zhu's group demonstrated a new instance of spin-phonon coupling in single molecular layers with atoms moving linearly and shaking spins.

In their new experiments, Zhu and the team members had to find a way to drive a lattice of atoms to move in a chiral fashion. This required both that they pick the right material and that they create light at the right frequency to send its atomic lattice aswirl with the help of theoretical computation from the collaborators.

"There is no off-the-shelf light source for our phonon frequencies at about 10 terahertz", explained Jiaming Luo, an applied physics graduate student and the lead author of the study. "We created our light pulses by mixing intense infrared lights and twisting the electric field to 'talk' to the chiral phonons. Furthermore, we took another two infrared light pulses to monitor the spin and atomic motion, respectively."

In addition to the insights into spin-phonon coupling derived from the research findings, the experimental design and setup will help inform future research on magnetic and quantum materials.

"We hope that quantitatively measuring the magnetic field from chiral phonons can help us develop experiment protocols to study novel physics in dynamic materials", Zhu said. "Our goal is to engineer materials that do not exist in nature through external fields, such as light or quantum fluctuations."

Solar-powered Device Produces Clean Water and Clean Fuel at the Same Time

Date: November 13, 2023

Source: University of Cambridge

A floating, solar-powered device that can turn contaminated water or seawater into clean hydrogen fuel and purified water, anywhere in the world, has been developed by researchers.

The device, developed by researchers at the University of Cambridge, could be useful in resource-limited or off-grid environments, since it works with any open water source and does not require any outside power.

It takes its inspiration from photosynthesis, the process by which plants convert sunlight into food. However, unlike earlier versions of the 'artificial leaf', which could produce green hydrogen fuel from clean water sources, this new device operates from polluted or seawater sources and can produce clean drinking water at the same time.

Tests of the device showed it was able to produce clean water from highly polluted water, seawater and even from the River Cam in central Cambridge. The results are reported in the journal Nature Water.

"Bringing together solar fuels production and water purification in a single device is tricky", said Dr Chanon Pornrungroj from Cambridge's Yusuf Hamied Department of Chemistry, the paper's co-lead author. "Solar-driven water splitting, where water molecules are broken down into hydrogen and oxygen, need to start with totally pure water because any contaminants can poison the catalyst or cause unwanted chemical side-reactions."

"In remote or developing regions, where clean water is relatively scarce and the infrastructure necessary for water purification is not readily available, water splitting is extremely difficult", said co-lead author Ariffin Mohamad Annuar. "A device that could work using contaminated water could solve two problems at once: it could split water to make clean fuel and it could make clean drinking water."

Pornrungroj and Mohamad Annuar, who are both members of Professor Erwin Reisner's research group, came up with a design that did just that. They deposited a photocatalyst on a nanostructured carbon mesh that is a good absorber of both light and heat, generating the water vapour used by the photocatalyst to create hydrogen. The porous carbon mesh, treated to repel water, served both to help the photocatalyst float and to keep it away from the water below, so that contaminants do not interfere with its functionality.

In addition, the new device uses more of the Sun's energy. "The light-driven process for making solar fuels only uses a small portion of the solar spectrum—there's a whole lot of the spectrum that goes unused", said Mohamad Annuar.

The team used a white, UV-absorbing layer on top of the floating device for hydrogen production via water splitting. The rest of the light in the solar spectrum is transmitted to the bottom of the device, which vaporises the water.

"This way, we're making better use of the light—we get the vapour for hydrogen production, and the rest is water vapour", said Pornrungroj. "This way, we're truly mimicking a real leaf, since we've now been able to incorporate the process of transpiration."

A device that can make clean fuel and clean water at once using solar power alone could help address the energy and the water crises facing so many parts of the world. For example, the indoor air pollution caused by cooking with 'dirty' fuels, such as kerosene, is responsible for more than three million deaths annually, according to the World Health Organisation. Cooking with green hydrogen instead could help reduce that number significantly. And 1.8 billion people worldwide still lack safe drinking water at home.

"It's such a simple design as well: in just a few steps, we can build a device that works well on water from a wide variety of sources", said Mohamad Annuar.

"It's so tolerant of pollutants, and the floating design allows the substrate to work in very cloudy or muddy water", said Pornrungroj. "It's a highly versatile system."

"Our device is still a proof of principle, but these are the sorts of solutions we will need if we're going to develop a truly circular economy and sustainable future", said Reisner, who led the research. "The climate crisis and issues around pollution and health are closely related, and developing an approach that could help address both would be a game-changer for so many people."

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