New Scientist

WEEKLY 12 September 2026

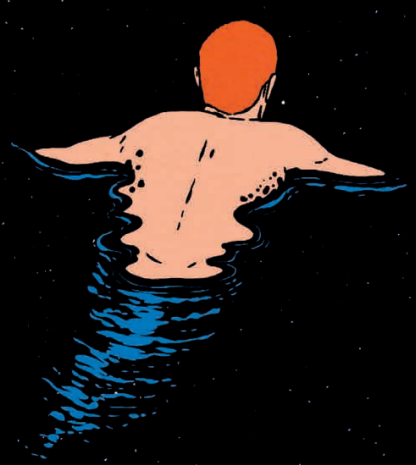
WE MAY FINALLY HAVE FOUND DARK MATTER – WHAT NOW?

SHOCK AI SUCCESS WITH FERMAT'S LAST THEOREM

DELICIOUS MUSHROOM THREATENS ANCIENT WOODLANDS

WHAT IS NOTHING?

We're about to see inside empty space – and reveal the quantum foundations of the universe



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Christopher Ward

christopherward.com

This week's issue

On the cover

32 What is nothing?
We're about to see inside empty space – and reveal the quantum foundations of the universe

Vol 271 No 3612
Cover image: Simon Bailly/Sepia

A note from the editor

Dear reader,

The end of the summer in the UK tends to mean one thing for all of us at *New Scientist* HQ: it's nearly time for our biggest event of the year, New Scientist Live. This annual extravaganza takes place over two days, with an additional day for school students.

If you haven't been before, you can expect four stages packed with mind-changing talks. This year, they feature speakers on everything from the secrets of human evolution and building lifelong brain health to how children can flourish in the age of AI and whether the universe is just a simulation.

New to the show, we have a dedicated family stage with talks for all ages, as well as bite-sized sessions over lunch that blend science with art, music and comedy. As always, the show floor will be packed with interactive experiences, including a walk through a giant gut, virtual-reality adventures and a chance to meet the robots of the future.

The show takes place on 10 and 11 October in London, but if you can't make it in person, all the talks will also be streamed live online. Find out more and book tickets at newscientistlive.com.

I hope to see you there!

Catherine de Lange
New Scientist editor

News

Views

PAVLO BAHMUT/UKRINFORM/NURPHOTO VIA GETTY IMAGES

Features

The back pages

Alive and kicking

Unexpected hints of dark matter show particle physics is far from dead

THE past decade has been tough for particle physics. In 2012, the long-expected discovery of the Higgs boson confirmed that the standard model of particle physics, our best theory of the fundamental ingredients of reality, was correct. Still, it was obvious that this beautiful picture of reality was incomplete. It touches only vaguely on gravity and is silent on dark matter, the unidentified stuff that we believe makes up most of the universe.

In other words, there must be something beyond the standard model, and we have looked exceedingly hard for it. The fact that we have found zilch has prompted mutterings about whether particle physics has hit a dead end.

Some physicists reckon we simply need to look harder. One proposal is to replace the Large Hadron Collider, the machine that discovered the Higgs boson, with a more powerful successor called the Future Circular Collider. Maybe searching the debris from more energetic collisions will reveal the missing pieces of reality?

Now, however, an exciting result

"Building ever-larger particle smashers may not be the best way to make progress"

suggests this strategy is too simplistic. Researchers at the LUX-ZEPLIN detector in South Dakota have picked up a signal that might prove to have come from dark matter. Crucially, the signal seems to have derived from a much more complex interaction between the dark matter particle and the detector than had previously been envisaged (see page 4).

All this suggests that building ever-larger particle smashers may not be the best way to make progress in physics. Instead, we might be able to make fresh discoveries by thinking more creatively about how nature could work and looking for the resulting signals using existing experiments. Physicists are already exploring these avenues. One idea is to harness quantum computers to scan the fallout from particle collisions (see page 40). Another involves scrutinising our assumptions about the nature of empty space itself (see page 32).

So particle physics isn't dead. It might just be that the make-up of reality is a tad more sophisticated than we thought. ▮

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ISSN 0262 4079. New Scientist (Online) ISSN 2059 5387. Registered at the Post Office as a newspaper and printed in England by Warners Midlands Plc

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Physics

Has a dark matter particle been found?

Directly observing dark matter could reveal some of the universe's biggest secrets. The first particle may have been spotted, but it's not an overriding victory just yet, finds **Leah Crane**

THE first signs of a dark matter particle may have been spotted. If the result is confirmed, it could be one of the most monumental discoveries in the history of physics.

Dark matter makes up about 85 per cent of matter in the universe, but for decades physicists have been unable to determine what it itself is made of. Hypotheses have ranged from different sorts of particles and forces to strangely behaving gravity and everything in between – but the leading idea has always been that of the weakly interacting massive particle, or WIMP. As we have built more and more powerful detectors to search for WIMPs, though, their failure to show up has led many to doubt their existence and move on to more exotic ideas.

That doubt may soon come to an end. A new analysis of data from the LUX-ZEPLIN (LZ) experiment in South Dakota has revealed a single particle that may be the first WIMP ever detected. "This result is certainly an exciting one, because it provides some potential positive hint for what dark matter could be, not just what dark matter could not be," says JiJi Fan at Brown University in Rhode Island, who wasn't part of the analysis.

LZ looks for dark matter using a 7-tonne tank of liquid xenon, surrounded by several layers of shielding and buried more than a kilometre down to keep out other types of particles. When an outside particle hits a xenon atom, it creates a tiny burst of light that is measured by sensitive detectors surrounding the tank. Researchers can then use that light to reconstruct the path of the incoming particle and the energy level of the interaction.

In the search for WIMPs, we generally look for events with energies below about 30 kiloelectronvolts (keV), says LZ spokesperson Richard Gaitskell, also at Brown University. That assumes the simplest sort of interaction, in which the WIMP is essentially bouncing off an individual nucleon in the xenon nucleus. Having not found any hints of WIMPs in that energy range, the LZ researchers decided to reanalyse the first 220 days of data from the detector, searching for events with higher energies.

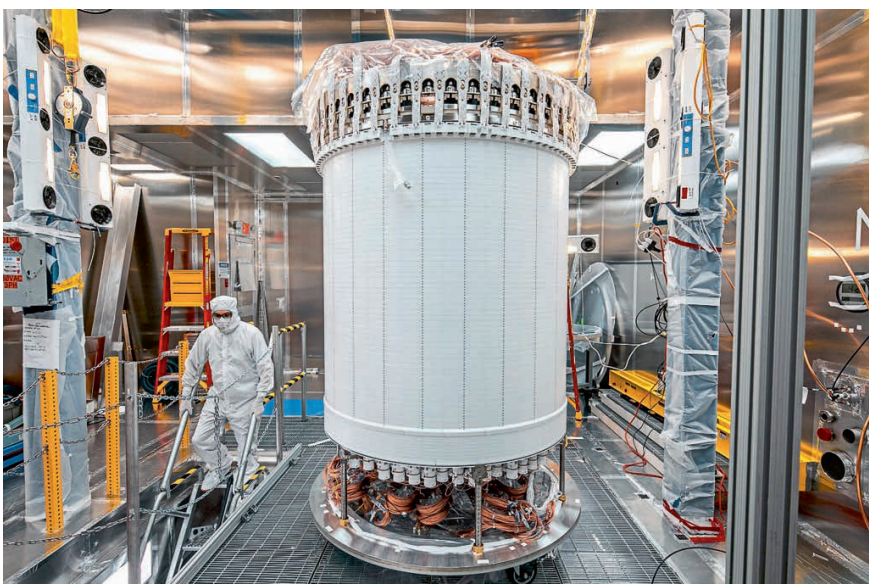
That is where they found their dark matter particle candidate, at about 248 keV. "You must never make an assumption that nature is going to do something the easy way," says Gaitskell. "Nobody can accuse our universe of making the simplest and most natural-seeming choices."

Such a high-energy event can't have come from the most simple type of interaction between a WIMP and a nucleon – instead, it must have happened through a more complicated coupling between the WIMP and the entire xenon nucleus. If that is the case, the WIMP must have a mass more than 200 times the mass of a proton.

"It's not just that they're seeing something, but that there's a hint at what the underlying mechanism might be," says Wick Haxton at the University of California, Berkeley, who wasn't involved in the analysis. "If this all stands up, our learning curve is going to be pretty steep from now on."

Actually detecting a dark matter particle could reveal some of the universe's most closely held secrets, including information about the early universe that is otherwise nearly impossible to determine, and drastically shake up our standard model of particle physics. But as Haxton says, this detection isn't yet certain.

In particle physics, the statistical threshold for a finding to go from an exciting hint to a solid discovery is a number called 5 sigma, which means there is about a 1-in-3.5 million chance that a signal like



MATTHEW KAPUST/SANFORD UNDERGROUND RESEARCH LABORATORY

The single potential dark matter particle was seen using the LUX-ZEPLIN detector (above), which uses a tank of liquid xenon surrounded by layers of shielding (above right)

85%
The percentage of matter in the universe that is dark matter

248 keV
The dark matter particle candidate was detected in an event with this much energy

1-in-200
The chance that the detection of the dark matter particle candidate is a fluke

this would show up as a fluke rather than a true sign of dark matter. Right now, this detection from LZ sits at 2.6 sigma, which means that there is about a 1-in-200 chance it could appear as a fluke.

That might still seem fairly secure, but in the search for dark matter it is far from enough. "In science, we sit down and we do so many damned experiments, I'm afraid you come across a 1-in-100 event fairly often," says Gaitskell.

"Before one can declare victory, you need a few more data points, but now they have something to aim for, they know where to look," says Haxton. The good news is that this analysis only covered about one-third of the data that LZ has already taken, and other dark matter detectors around the world have their own data, as well. A few more events in the same energy range could bump the discovery of WIMPs up to 5 sigma – and change our understanding of physics and the universe forever. ▮

For more on dark matter, turn to pages 32 and 40

Health

Pig kidney kept a man off dialysis for a record time

Chris Simms

A GENETICALLY modified pig's kidney kept a man with organ failure off dialysis for nine months while he waited for a suitable human donor's kidney. This suggests pig kidneys could act as a temporary measure amid lengthy organ waiting lists, but they may also work as a permanent replacement one day.

"I think it's incredible in terms of the science behind it and what they've achieved," says Michelle Willicombe at Imperial College London, who wasn't involved in the work.

For people with severe kidney disease, where these organs are failing and dialysis is needed, a kidney transplant provides the best chance of survival and better quality of life. However, demand for donor organs exceeds supply. One possible solution is xenotransplantation, the transfer of organs from other animals into humans.

A pig's kidney was transplanted into a living person for the first time in 2024. The recipient, Richard Slayman, aged 62, died 52 days later from cardiac-related causes. In the latest development, Tim Andrews, a 66-year-old man with end-stage kidney failure, opted to receive a kidney from a pig to avoid dialysis while he waited for a suitable human organ.

"This marks the first time a pig kidney has been used as a bridge to a human transplant"

Leonardo Riella at Mass General Brigham hospital in Boston and his colleagues transplanted the kidney, which came from a Yucatan miniature pig, into Andrews in January 2025. The organ had been genetically modified to improve compatibility with the human immune system, such as by removing some sugars that we produce antibodies against and adding seven human genes.

The transplant was initially a success, and Andrews – who also received immunosuppression drugs to stop his body rejecting the organ – came off dialysis and resumed normal life. However, after about six months, he was admitted to hospital with a methicillin-resistant *Staphylococcus aureus* (MRSA) infection, which most antibiotics can't kill.

Riella and his team reduced the immunosuppression drugs Andrews was on, but then damage started to develop in the kidney's blood vessels. This progressed to organ failure, and the kidney was removed a record 271 days after transplantation. "He had a kidney that lasted nine months, which is mind-blowing," says Riella.

Andrews went back onto dialysis for about three months, before finally receiving a suitable human kidney in January 2026. This marks the first time a pig kidney has been used as a temporary bridge to a human transplant (*The Lancet*, doi.org/rm9g).

"Such transplants may allow patients to avoid going through dialysis, which is so important because it causes so much wear and tear to the body," says Riella. "Hopefully, maybe 15 years from now, pig kidneys will compete with a human kidney transplant, but you're not there yet."

It is an experimental procedure, and Riella couldn't give an estimate of how much it might cost. But in the US, there are about 600,000 people on dialysis, which can cost about $100,000 a year per individual, he says.

Riella says the team has now done five such transplants and two more case reports will be published this year, including one of a person who has already beaten Andrews's record of nine months with a functioning pig kidney.

"I think these will be carried out more widely in the future, but it'll be a little while," says Willicombe, largely due to their probable high cost. Scientists should also continue researching artificial kidneys, as well as ways to regenerate damaged organs and optimise donated ones, she says. ▮

KERRY CRISALLI

Transplant recipient Tim Andrews (left) with clinician Leonardo Riella

K. FLOCK/MGH PHOTOGRAPHY/MGH

The pig kidney was modified to improve compatibility with human immune systems

Climate change

Europe's expanding wildfire threat

Conditions this year have sparked wildfires in countries that are normally considered to be damp and cool. What can we do to mitigate the risk in the future, asks **Madeleine Cuff**

SUMMER in Europe is no longer just a season of heatwaves and holidays. It is also, increasingly, a season of fire.

Following the pattern of recent years, 2026 saw huge fires break out across the continent, fuelled by weeks of hot, dry weather. Fires in France and Spain hit the headlines, but the UK, Belgium, Germany, Portugal and Italy have also seen fierce blazes sweep through forests, grasslands and nature reserves.

Since the start of the year, almost 650,000 hectares of land have burned across the European Union, according to the European Commission, the result of over 1913 separate large wildfires.

"Europe's wildfires this summer have been extremely severe and destructive, and reached new corners of our continent," Wopke Hoekstra, European commissioner for climate, net zero and clean growth, wrote on LinkedIn at the end of August.

On both sides of the Atlantic, the fire season has been far more severe than normal. In Europe, the area of land burned so far this year is almost double the long-term average. In the US, the area of land burned so far this year is 163 per cent of the 10-year average.

"What has been notable about this year's blazes is where they have appeared"

But although this year has been bad by past standards, it still doesn't come close to surpassing the devastation wildfires wreaked in 2025, still by far the most severe year on record for Europe, with more than 1 million hectares burned.

Instead, what has been notable about this year's blazes is where they have appeared. Fires have burned across the European continent, but in southern Europe, traditionally the most fire-prone region, it has been relatively quiet. Northern and western European countries, however, like France, Belgium, the Netherlands and the UK – which aren't used to dealing with severe wildfires – have suffered intense burns. For some, these have been larger and more widespread than ever seen before.

THIBAUD MORITZ/AFP VIA GETTY IMAGES

Almost 650,000 hectares of land have burned across the EU since the start of the year

In England and Wales, for example, fire and rescue services have responded to 1132 wildfires so far this year, outstripping the total for the whole of 2025, which was itself a record year.

"I think what is particularly interesting for this season, in 2026, is not the total area burned... but how quickly conditions developed, and how geographically widespread the fire danger became," says Francesca Di Giuseppe at the European Centre for Medium-Range Weather Forecasts.

The conditions in Europe this year have been perfect for wildfires. An unusually wet winter encouraged rampant growth of grasslands, shrublands and forest understories. In May, the weather then shifted abruptly, bringing heatwaves in rapid succession and very little rainfall across swathes of the continent. The ground dried out, vegetation withered and a flash drought emerged on a grand scale. That left a hot, dry landscape littered with fuel. Add in high winds and it was only a matter of time before fires broke out.

"If you have 30 per cent of Europe fire-prone, somewhere it is going to happen," says Di Giuseppe. "And if those conditions are sufficiently extreme, it will be very difficult to suppress the fire."

This summer's weather may have been unusually intense, but it will become the new normal as global temperatures rise. Europe is one of the fastest-warming regions of the world. Across southern Europe, the number of summer days with fire-prone conditions has more than doubled since 1981, and the threat of catastrophic fires will only increase on the continent as the climate continues to warm, scientists predict.

Shifting mindsets

And, as we have seen this summer, the risk in northern Europe is rising rapidly from what was a low baseline. Managing the growing threat will require a significant shift in mindset, warns Alexander Held at the European Forest Institute. "When people outside of the UK think about the UK, they think of rain," he says. "If you look

at Ireland or Wales, where, in a good year, you have 2000 millimetres of rain, it is difficult for people to grasp that these landscapes are now burning."

Much comes down to adopting common-sense behaviour in a fire-prone landscape – behaviour that is probably second nature to most citizens of southern Europe. In May, a major fire broke out at a Dutch military training ground, after the army trained with explosives during dry weather, prompting calls for training exercises to be halted at times of high fire risk.

In the UK, disposable barbecues were banned in August after they were found to have started fires in London, Staffordshire and Cheshire this summer. Simultaneously, the UK government sent out a nationwide alert to citizen smartphones, warning of a "very high risk of wildfires nationally" in the hope of curbing risky behaviours such as lighting barbecues or letting off fireworks.

Managing migration from the countryside into cities is also a factor. In the US, urban sprawl has been blamed for bringing residents of cities such as Los Angeles into closer contact with the wildfire-prone countryside. But across Europe, rural abandonment is having the opposite effect; experts have warned that abandoned farmland provided plentiful fuel for the 2025 wildfires that swept through Greece, Turkey and Cyprus. The pruning, bush clearing and grazing that comes with managing a working farm is essential for fire suppression.

Fire prevention can sometimes take the form of more unusual action – such as deer culling, says

ARIS OIKONOMOU/AFP VIA GETTY IMAGES

"The threat of catastrophic fires will only increase in Europe as the climate continues to warm"

Held. In countries like the UK and Germany, earthworms are vital for clearing up leaf litter in forests before it becomes fire fuel in dry weather. But offering them the right species of leaf litter is important. In Germany's Black Forest, for instance, earthworms love maple, cherry, lime and oak litter, but dislike conifer needles and beech litter. Unfortunately, the wild deer that roam the region's woodlands have the same preference. As they graze and kill saplings, they are leaving the forests full of beech and conifers.

Technology can also help. In May, a SpaceX rocket carried four new satellites into space, designed to help Greece better detect and track wildfires across its territories. FireSat is the same idea on a grander scale. Run by the non-profit Earth Fire Alliance with the help of Google, by 2030 it aims to have 50 satellites scanning the most fire-prone spots on Earth, able to identify a fire as small as a beach bonfire. Three satellites entered orbit in July, joining the pilot satellite launched last year.

Meanwhile, at ground level, feeds from camera networks can be monitored by AI software to spot the first signs of smoke. In California, a network of more than 1300 cameras covers fire-prone areas across the state. AI technology is used to scan the feeds and alert emergency services if fire is detected, with the aim of stopping fires before they have a chance to gather strength.

The system has helped firefighters react quickly to smother blazes that would have burned thousands of acres, according to Neal Driscoll at University of California San Diego. The same technology is now arriving in Europe: in the Gironde, a region of France hit hardest by wildfires this summer, firefighters are now employing AI-assisted cameras to raise the alarm on emerging blazes.

FBM MEDIA/GETTY IMAGES

Blazes have torn through southern (top) and western (bottom) Europe this summer

Managing the future

Yet fire management can take us only so far. Research published in August warns that, by the end of this century, the area burned by wildfires in Europe will increase by 39 per cent even under a low-emissions scenario, and could almost triple under high emissions. Improvements in fire management could reduce these increases by more than 70 per cent, but not eliminate them entirely, the study found.

Some researchers think the fire risk is already beyond our control, particularly in southern Europe, which normally bears the brunt of "fire weather". Raul Cordero Carrasco at the University of Groningen in the Netherlands points out that the burned area in southern Europe has been rising since 2018. He thinks this is a sign that investment in suppression and management is hitting its limit. In southern Europe, "climate change is making fires unstoppable", he says. "When the temperature is very high and the winds are very strong, there is nothing you can do to stop the fire."

But for northern Europe at least, where large fires are still a mercifully rare event, there is plenty of work that can and must be done to mitigate further risk. Not every summer will be like 2026. But the threat is advancing, and this summer has been our amber warning to prepare.

Analysis Artificial intelligence

The scramble for Ukraine war data to feed AI

Foreign states and technology firms want access to drone data so they can train AI models that might be used for national security, reports **Matthew Sparkes**

GLOBAL superpowers and giant technology firms are vying for real-world data from the war in Ukraine to build next-generation AI models that will empower militaries in future conflicts. Videos of drone strikes and other sensor data are like "gold dust" for training AI, experts say.

Last month, Ukraine signed a deal with the UK to share a vast treasure trove of data collected from drones, cameras and sensors since Russia staged its full-scale invasion in 2022. It is claimed the deal will make the UK the first foreign state to have access to Ukraine's so-called Avengers AI model, which is already being used to identify adversaries and their equipment in real time and slash the time taken to stage attacks.

"Access to actual, real, credible battlefield data from Ukraine is a big commercial advantage"

The UK claims that the first fruits of this deal are about to be tested through a project that is turning buried fibre-optic cables into sensors to detect hostile intrusions at an unnamed UK defence site.

Peter Lee at the University of Portsmouth, UK, says the varied data will be invaluable in creating a wide range of defence and military tools, which will make both the UK and Ukraine more secure.

"This is the gold dust that allows the UK to enter the autonomous age of drones," he says. "You can't really put a price on the data they're going to get access to. Add up everything that the UK has given to Ukraine over the last several years – this data is worth all of that and more."

Ukraine flies thousands of drones a day, both in the war zone and penetrating deep into Russia, and has a vast array of sensors on the front line. This data has long been fed into a government department known as Brave1, which analyses it with AI to find strategic weaknesses and opportunities. It feeds that information back to troops on the front line and defence contractors.

AI models can be used to autonomously steer drones to their targets, monitor thousands of video feeds and other sensors for tell-tale signs of adversaries' movements, or analyse footage of attacks to spot design flaws in military hardware. The models can even plan strikes and pick targets.

Numerous efforts are under way in Ukraine to use AI to eke out an advantage, including at the defence ministry's "A1" organisation – which the Ukrainian government launched with UK government support in March, long before this latest announcement.

Lee says the possibilities are so compelling that it is almost certain that China is doing the same with Russian data, taken from the opposite side of the front line – and it probably had a head start. He thinks that, in the earliest stage of negotiations between Russia and China about military and intelligence support for the invasion, China will have raised the issue of data sharing.

War machines

"China understands that data is king when it comes to AI, and that the more data you have, the more powerful your systems are likely to be," says Lee. "It would be a strategic oversight of grotesque proportions [if China hadn't sought data]."

Joe Burton at Lancaster University in the UK says that despite the UK's support of Ukraine with weapons, training and intelligence, it is unlikely that raw data has been shared on a wide scale until recently. But a deterioration in relations with the US may be an incentive for Ukraine to create stronger ties with other allies.

"The Trump presidency has been very volatile in its approach to Ukraine and, if you're in [Kyiv], it makes sense to have a broader set of partnerships around AI data, which can help support you in what will probably still be a long-term war," says Burton. "I would not be surprised if Ukraine are hedging their bets."

Big technology firms are also getting involved. Ukraine has long worked with AI company Palantir, and signed a data-sharing deal with the firm months before the agreement with the UK was announced. US company Clearview AI's facial-recognition technology has been used to find Russian spies operating in Ukraine, while another US firm, Scale AI, has used satellite data to identify Russian troop movements and detect building damage across Ukraine.

"All these companies are competing for data. If you have access to actual, real, credible battlefield data from Ukraine instead of simulated data that you're generating in a lab, that's a big commercial advantage," says Burton.

In short, if you are pitching your product to states looking for AI tools to protect national security or support their militaries, then having a battle-tested product is a strong selling point.

But despite the vast expansion of data collection, AI analysis and high-tech weapons systems, the day-to-day reality for troops in Ukraine remains a muddy trench, not dissimilar to those dug in the first world war. "This idea that you can deploy a load of robots to the battlefield and you don't need to send soldiers into harm's way, it's not [happening] in Ukraine," says Burton.

FRANCISCO RICHART BARBEIRA/NURPHOTO VIA GETTY IMAGES

Ukraine flies thousands of drones a day that capture all sorts of useful data

Mathematics

AI beats mathematicians – again

Formalising Fermat's last theorem was expected to take years, but AI has done it in 11 days

AI COMPANY Anthropic has created a formalised proof of Fermat's last theorem. It took just 11 days for a group of AI agents to complete the task, confirming that the human-found proof proposed in the 1990s is correct.

Mathematician Pierre de Fermat posed the puzzle in the 17th century. It states that there are no whole numbers a, b and c that satisfy the equation $a^n + b^n = c^n$, where n is a whole number greater than 2. Mathematicians were puzzled for centuries until it was proved in 1995 by Andrew Wiles with help from Richard Taylor.

Proofs often involve lengthy logical arguments that build on each other. If a single step contains an error, then the whole thing can collapse. Formalising theorems is a solution to this problem. It puts them into computer code that allows machines to methodically work through the logic and expose any flaws.

Earlier this year, a conference of AI experts, computer scientists and mathematicians was held in London by Kevin Buzzard at

SCIENCE HISTORY IMAGES/ALAMY

Mathematician Pierre de Fermat penned his last theorem in around 1637

Imperial College London, who was, until Anthropic's announcement, working on a five-year project to formalise Wiles and Taylor's 100-page proof in a programming language called Lean, so that it could be formally checked and used as a basis for further research.

Buzzard said at the time that, when his project began, he was confident of success, but that recent advances in AI had convinced him that the project would be completed much faster than he had thought possible. Anthropic's announcement has now overtaken that effort.

Buzzard said in a statement published by Anthropic that the company's proof leaves "no assumptions other than the axioms of mathematics". In short, the problem is solved.

"Along the way we see autoformalisation of algebra, harmonic analysis, geometry and number theory, and we learn that AI autoformalisation artefacts are now robust enough to be built upon; the proof is multi-layered," said Buzzard. "If the automatic formalisation of FLT is possible now, then we have taken a big step towards automatic formalisation of the modern mathematical literature."

In its blog post announcing the result, Anthropic wrote that its Claude model worked non-stop and autonomously for 11 days to write the proof. Multiple AI agents were involved, with different tasks, like tackling smaller chunks of the theorem, being assigned to each.

Human experts occasionally issued "high-level instructions" to keep the work on track, the company said. Several times, the agents "lost track of the project's state and stopped collaborating effectively". Interestingly, the company said that success came after it began using a tool designed for human mathematical collaboration called Prove2Me, which helped different agents track their work and decide on next tasks.

Anthropic's formalisation runs to 13 million lines of Lean and covers roughly 29,500 intermediate theorems that were necessary stepping stones towards completing the overall work. ▮ MS

Cosmology

Novel black hole formation may explain baffling find

THERE may have been black holes in the early universe before the first stars, and they could have formed using the heat of the cosmic microwave background (CMB). The idea may be the best explanation for the "little red dots" identified by the James Webb Space Telescope (JWST) – distant galaxies that seem to host surprisingly large numbers of astonishingly ancient black holes.

An existing idea is that primordial black holes formed in violent space-time spasms in the early universe before any stars appeared. But these violent spasms are hard to reconcile with the milder ripples that astronomers see in the CMB, faint light left over from the primordial universe. Theorists have had to propose complicated new physical laws to make the explanation fit.

Instead, Wenzer Qin and Neal Weiner at New York University and Soubhik Kumar at Tufts University in Massachusetts have now assumed milder ripples of dark matter moved through the early universe, and argued that large black holes would be able to form inside clumps of this dark matter, with the hot CMB keeping gas and dust from collapsing into smaller ones instead.

They call these black holes "not-quite-primordial" and argue they provide an explanation for the black holes spotted via the JWST that doesn't require drastic changes to cosmologists' picture of the early universe (*Physical Review Letters*, doi.org/rnkz).

The researchers reached out to Priyamvada Natarajan at Yale University to help confirm their logic.

"This is a case where you could actually have a black hole forming before the stars"

"This is a case where you could actually have a black hole forming before the stars," says Natarajan.

"What's nice about the model is that it invokes less speculative physics than traditional primordial black hole physics," says John Regan at Maynooth University, Ireland, who wasn't involved in the paper. He says concrete observations are needed. "We'll need to see some ultra-early-universe signatures of black holes, be that from gravitational waves or from some future CMB observations, to see if black holes truly existed at the very earliest times." ▮

Matt von Hippel

Cancer

Psilocybin may stop nerve damage

The psychedelic compound could prevent a common side effect of chemotherapy that can disrupt treatment, potentially improving cancer outcomes, finds **Carissa Wong**

PSILOCYBIN may prevent a debilitating side effect of chemotherapy: nerve damage that can cause lasting numbness, tingling or pain in the hands and feet. In tests in nerve samples from mice and humans, the psychedelic seemed to maintain the energy supply in nerve endings that is commonly disrupted by chemotherapy, resulting in less damage and fewer complications.

This is the first time a therapy has been shown to prevent this common side effect, which lacks effective treatments and can limit access to cancer drugs.

"If these findings can be replicated in clinical trials, the implications could be substantial," says Maria Maiaru at the University of Reading in the UK, who wasn't involved in the research. "Patients could avoid long-lasting sensory problems and chronic pain that often remain after cancer has been successfully treated."

"Patients could avoid chronic pain that often remains after cancer has been successfully treated"

What's more, "if nerve damage can be prevented, fewer patients may need dose reductions or interruptions of chemotherapy, potentially improving cancer outcomes", she says.

But people with cancer shouldn't take psilocybin, the psychedelic compound in magic mushrooms, without medical supervision. "Please don't take psilocybin at home for chemotherapy-related pain," says team member Moran Amit at the University of Texas MD Anderson Cancer Center in Houston. "It hasn't been shown to be safe or effective in patients undergoing chemotherapy. It can interact dangerously with cancer medications."

Chemotherapy-induced peripheral neuropathy (CIPN) affects around 75 per cent of cancer patients who undergo the treatment to some extent, said Patrick Dougherty, also at the University of Texas MD Anderson Cancer Center, in a press briefing. It is usually treated with duloxetine, an antidepressant that provides moderate pain relief. But no drug had been shown to prevent CIPN, said Amit at the briefing.

CIPN occurs when chemotherapy drugs enter nerve cells and disrupt machinery around microtubules. These are structures that usually transport mitochondria from the main body of neurons, near the spinal cord, to nerve endings in the skin. The mitochondria supply energy to maintain nerve endings, but the disruption means they wear out and retract, causing issues like tingling.

The researchers tested whether psilocybin, which has been shown to alter nerve metabolism and growth, could preserve these nerve endings. They studied a group of mice with abdominal tumours, half of which were given two doses of psilocybin – each equivalent to a 25-milligram dose in people – via injections into the abdomen, one week apart. The remaining mice had saline injections. All of them then received daily injections of cisplatin, a type of chemotherapy that commonly causes CIPN, for one week.

TED KINSMAN/SCIENCE PHOTO LIBRARY

Psilocybin is the psychedelic compound in magic mushrooms

After receiving cisplatin, the mice were touched with a thin plastic filament to test their pain sensitivity. Those that received psilocybin before cisplatin responded similarly to a third group of mice with cancer that didn't receive cisplatin or psilocybin. The mice that received cisplatin without psilocybin seemed to be much more sensitive to the filament's touch.

To explore how psilocybin may have this effect, the team analysed nerve samples from the mice. This showed that, after the psychedelic is processed to its active ingredient, psilocin, it activates a receptor called 5HT2A, confirming findings from prior studies. But it also revealed that this receptor sends molecular signals that prevent chemotherapy-related disruption of mitochondrial transport.

The researchers then confirmed the results in human neurons treated with either psilocybin or a saline solution before receiving cisplatin (*Science*, doi.org/rm96). "Psilocybin seemed to help nerves withstand the toxic effects of chemotherapy and maintain normal function," says Maiaru.

They now plan to begin a randomised controlled trial in November. This will comprise about 80 people with breast, colorectal or head and neck cancer, testing two doses of psilocybin before chemotherapy. Results are expected in about five years.

Psilocybin has already been shown to relieve symptoms of depression and anxiety in people with cancer. Although not a psychedelic, cannabis is also approved to treat cancer-related chronic pain in the UK. The US Food and Drug Administration has also approved two drugs that are made up of chemicals similar to those in cannabis to relieve chemotherapy-related nausea and vomiting.

FATCAMERA/GETTY IMAGES

Around 75 per cent of people undergoing chemotherapy experience nerve damage

Can we really reverse global warming after passing 1.5°C? A UN report says we could cool the planet back down to current temperatures in the future, but many researchers regard this as highly unlikely, reports **Michael Le Page**

THE world is likely to overshoot 1.5°C of warming within the next few years, a report by the UN Environment Programme (UNEP) acknowledges. However, it says it is still possible to cool the planet back down to this level by the end of the century. Can it really be done? It isn't impossible, but it isn't the most likely outcome.

The goal of limiting the increase in the average global surface temperature to 1.5°C above pre-industrial levels looked implausible even back in 2015, when it was adopted as part of the Paris Agreement. The UNEP report can be seen as "official" recognition of what many have been saying for years: that it is now certain that we are going to blast right past this limit.

But some aren't giving up on the target. There are no good outcomes if we remain above 1.5°C, says Inger Andersen at UNEP. "Even if we exceed 1.5, let's be very clear: that 1.5 target is still the goal. But now we need to approach it differently, from above."

Much of the report looks at the consequences of overshooting 1.5°C and the need for adaptation to cope with the impacts this will bring. "We will see increased food insecurity, increased water insecurity, impacts on human health – physical and mental – danger to our homes and our infrastructure," says Debra Roberts at the University of KwaZulu-Natal in South Africa, one of the report's authors. "This will lead to the loss of livelihoods and certainly lives."

The world isn't prepared for this, she says. "Therefore we have to advance our adaptation and development strategies to deal with those higher levels of warming... Adaptation needs to be transformational to allow us to plan for a changing world."

There will be no going back to how things were, says Roberts. "Some losses will be irreversible, which means returning to 1.5 doesn't mean we return back to the same world we left."

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Fossil fuel emissions are likely to push the world past 1.5°C of warming

Cascading effects

What, exactly, should we be preparing for? The report focuses on a scenario in which rapid emissions cuts and massive-scale removal of carbon dioxide from the atmosphere result in a return to 1.5°C of warming by the end of the century. But achieving this would require limiting temperature rises to no more than 1.8°C, says Roberts. Beyond this, there will be cascading effects from all the irreversible changes that make it much harder.

However, restricting warming to this level requires a halving of global emissions by 2035, says report author Joeri Rogelj at Imperial College London. That seems highly unlikely given that emissions are still rising globally.

In addition to emissions cuts, the scenario envisaged in the report also requires carbon removal on a truly gigantic scale – enough to not just balance out hard-to-tackle emission sources, such as farming, and achieve net zero, but to go well beyond that to remove around 10 gigatonnes of CO_2 each year. That compares with current emissions of around 40 gigatonnes.

This means scaling up carbon removal by a factor of around 100,000, says Reto Knutti at ETH Zurich in Switzerland, who wasn't involved in the report. Cheap forms of carbon removal, such as planting forests, can't be scaled up this much because there isn't enough land. Direct air capture could be scaled up, but it is really expensive, he says.

> **"The overshoot concept may turn out to be no more than a way to mask ongoing failure"**

Knutti thinks achieving this is technically and financially possible, but not politically plausible. "We should be honest when we talk to policy-makers and the public that this is not the thing to plan for," he says. "I think the plan should be to adapt for at least 2 degrees, if not more."

James Dyke at the University of Exeter in the UK is even less optimistic. "There are still no credible plans for large-scale carbon dioxide removal," he says. "Human societies must adapt and prepare for a warmer and more dangerous world that will persist potentially for centuries."

Konstantin Weber, also at ETH Zurich, points out that among the latest emissions scenarios that will be used by climate modellers, only two imply a return to 1.5°C before 2150. The scenario based on current policies suggests warming of around 3°C by 2100.

Until recently, overshooting and returning to 1.5°C was no more than a scientific thought experiment, says Oliver Geden at the German Institute for International and Security Affairs. Now it could become the "official" plan B for 1.5°C. "The overshoot concept may turn out to be no more than a way to mask ongoing failure," he says.

But even if getting the temperature back down to 1.5°C isn't likely, we have to try, says Weber. "We have to give it a shot. There's no real alternative."

"Now is the time to double down on climate action, not to give up on it," says Andersen. "Every fraction of a degree avoided, every year by which overshoot is shortened and every adaptation action taken will save lives, protect ecosystems and reduce economic losses." ▮

Health

Laughter therapy may help people with a common form of lung disease

Christa Lesté-Lasserre

PEOPLE with chronic lung disease breathe better after two months of laughter therapy, results from a small trial show. The promising findings may prompt further research into the low-cost treatment option.

In chronic obstructive pulmonary disease (COPD), air isn't fully expelled when exhaling, meaning stale air remains trapped inside the lungs. Doctors treat COPD with medications, and may also recommend specialised breathing exercises like pursed-lip breathing, in which people with COPD breathe in through the nose and out slowly through the lips. But many people with COPD continue to become more dependent on others for care over time.

Goncagul Aldan, formerly at Hacettepe University Faculty of Nursing in Ankara, Turkey, wanted to see if laughter therapy, which shows promise in people with other conditions like diabetes, might also help those with COPD.

She and her colleagues recruited 63 people who were already being treated for COPD and divided them into three groups of 21. In their randomised controlled trial, all participants continued their medications, but those in one group also performed pursed-lip breathing exercises and those in another group received laughter therapy. Participants in the third, control, group did neither.

"Laughter therapy includes exercises like mimicking a motorcycle starting and relaxation with smiling"

Laughter therapy is an established programme that differs from simple responses to humour. It includes playful exercises like mimicking a motorcycle starting and relaxation with calm breathing and smiling. The participants were coached by laughter therapists in face-to-face sessions and then instructed to perform the techniques on their own for 30 minutes, three times per week.

After eight weeks, participants in the laughter therapy and the pursed-lip breathing groups had less difficulty breathing and better overall health than those in the control group. Those benefits were still ongoing even a month after the trial ended, says Aldan. Even so, the therapies didn't change how much daily assistance participants needed from caregivers. The researchers didn't directly compare the effects of pursed-lip breathing and laughter therapy. They reported the results on 7 August at the European Respiratory Society Congress in Barcelona, Spain.

While more work could clarify exactly how laughter therapy helps, Aldan says "this structured approach may help facilitate gentle air expulsion and reduce air trapping without overwhelming the respiratory system".

Importantly, laughter therapy is distinct from intense or unguided laughter, which can actually trigger adverse effects like acute airway collapse or exertion, says Aldan.

"These results – showing that patients can breathe more easily and feel better in general – are promising. Laughter therapy is simple and low-cost, meaning it could be used by anyone, anywhere," says Marc Miravitlles at Vall d'Hebron University Hospital in Barcelona. ▮

Solar system

Venus could have gobbled up a long-standing moon

VENUS may have had a moon for nearly 2 billion years, and then ate it.

Many large objects probably hit Venus in the early solar system, which could have formed a moon, similar to the giant impact that is thought to have formed Earth's moon. "There's a very good chance that Venus did have a moon-forming impact," says Stephen Kane at the University of California, Riverside.

The lack of a moon today is therefore quite unusual, but Kane and his colleagues might have an answer. They modelled what would have happened if Venus did have a moon, and found that in almost all scenarios, it would have been consumed by the planet, long erased from existence by the present day.

Venus rotates quite strangely with respect to the sun, completing a rotation once every 243 days, compared with its orbit of 225 days. This is possibly a result of its thick atmosphere slowing its spin.

In contrast, Earth's much faster spin transfers angular momentum to our moon, meaning it is moving away a few centimetres each year. For Venus, the opposite would have been true. "The moon is transferring angular momentum inward instead of outward," says Kane. "It causes the moon's orbit to catastrophically collapse."

The researchers found that at the upper limit of their models, amoon about half the mass of our own could have survived around Venus for 1.7 billion years. At twice the mass of our moon, it would have survived just 30 million years, because of the stronger tidal effect.

NASA

A moon about half the mass of our own could have orbited Venus for 1.7 billion years

Once the moon reached a distance of about 15,000 kilometres, it would have encountered a boundary where Venus's gravity ripped the moon apart and consumed it, says Kane. The moon's debris would have temporarily formed a ring around Venus until it fell into the atmosphere (arXiv, doi.org/hchmbk).

Paul Byrne at Washington University in St Louis, Missouri, says the model is interesting, but hard to prove, as "there is basically nothing left behind". This is because Venus's surface has been repeatedly resurfaced by volcanism, he says.

Kane, however, says a future mission to the surface of Venus could include a seismometer, a device that measures seismic waves, to study the planet's interior. This could look for evidence of a consumed moon buried underground. ▮

Jonathan O'Callaghan

Climate change

Warning over mountain warming

There will be more disasters like the Nepal flood as mountainous regions around the globe warm rapidly, melting the ice that glues rocky slopes together, discovers **Michael Le Page**

THE terrible disaster in Nepal isn't a one-off event, but a harbinger of things to come. There will be more catastrophes of this kind as mountain ranges around the world continue to warm fast, researchers warn.

"In coming years, we can expect more of these events happening," says Gunjan Silwal at Newcastle University in the UK. "Maybe this is just a trailer."

Initial analyses suggested the cause of the flash flood in Tibet and Nepal on 26 August was the collapse of a glacier. Better satellite images now show that an entire slope collapsed, with huge amounts of rock below and around the glacier also falling.

The rock and ice plummeted into the valley below, leading to a catastrophic wave of water and debris that swept down the river. It is still not entirely clear where such a huge volume of flood water came from, says Daniel Shugar at the University of Calgary in Canada. But it appears the falling rock and ice landed on other ice left by retreating glaciers. "So the ice in the valley bottom, as well as the ice on the glacier, is probably a lot of the water that we're seeing in those videos," says Shugar.

Researchers are now discussing to what extent global heating contributed to this disaster in informal online forums. Bethan Davies, also at Newcastle University, who has been studying glaciers in the area with Silwal and others, thinks climate change could have played a substantial part. "We do know the area is warming very rapidly," she says. "Pictures from the 1970s show a much more substantial glacier."

That glacier would have helped support the rock slope down which it was flowing, so its thinning and retreat may have destabilised the slope to the extent it gave way.

SAMEER SHRESTHA/ANADOLU VIA GETTY IMAGES

The aftermath of severe flooding along the Trishuli river valley in Nepal

Another factor could be the degrading of permafrost. Ice in cracks helps hold rocky slopes together, and helps glaciers stick to the surfaces they flow over. "The permafrost acts like a glue that holds everything together," says Davies.

The glacier involved in this disaster is just one of many retreating glaciers in the region. What's more, the rate of retreat is increasing – it was 1.5 times higher from 2000 to 2023 than from 1964 to 2000.

The large glaciers on valley floors are relatively stable because of their size, but the smaller ones that flow down steep slopes and feed the valley glaciers are more vulnerable. In many cases, their lower parts are vanishing, disconnecting them from the valley glaciers. "We're seeing this really significant fragmentation, and that's leaving lots of glaciers perched high up in the same way as this one that collapsed was," says Davies.

The fundamental problem is that the region is warming fast, at around 0.3°C per decade compared with a global average of under 0.1°C per decade, says Silwal. The same is happening in other

"We will continue to see bigger and more events in mountain ranges around the world"

mountainous regions around the world, a phenomenon called elevation-dependent warming.

There are three reasons for this, says Mike Byrne at the University of St Andrews in the UK. Firstly, land areas in general warm faster than the seas.

The second reason is the loss of snow and ice cover. High-elevation areas are usually covered in snow, even in the tropics, which reflects the most sunlight. When warming melts snow, the darker surfaces absorb most of the sunlight, leading to yet more warming.

The third reason is more complex. As atmospheric carbon dioxide levels increase, more long-wave radiation – heat – is being bounced back to Earth's surface instead of escaping to space.

Heat balance

Hot regions that are already radiating lots of heat have to warm only a little before the extra heat they radiate balances out the extra heat coming back down. This Planck feedback, as it is known, is why Earth would stop warming if CO_2 levels stopped rising.

But cold regions aren't close to radiating enough heat to balance out the extra heat arriving, so they warm more. "Elevated regions, because they're colder, somewhat counterintuitively warm up more rapidly," says Byrne.

The bottom line is that mountainous regions will keep warming fast for the foreseeable future, leading to many more disasters. "We will continue to see bigger and more events in mountain ranges around the world," says Shugar. "Will they be bigger than this one? I don't know."

So what can be done to prevent them? "Stopping emitting carbon dioxide would be the single most effective measure that we can deploy," says Davies.

In the absence of stopping CO_2 emissions, an effective early warning system is needed so people can move to higher ground in time. That is going to be expensive, and the high-income countries that are mostly responsible for climate change should pay, says Davies. "Nepal has contributed very little to the climate crisis, yet is suffering a lot of consequences." ▮

Solar system

Bizarre weather pattern seen on Saturn

Jonathan O'Callaghan

SATURN has a new, odd weather pattern resembling a decagon near its south pole. This may have formed due to a large storm nearby, but researchers aren't totally sure.

The pattern has clearly defined sides shaped by powerful winds, and looks like a decagon – a geometric polygon with 10 sides and 10 angles – from above. It is similar to a hexagonal weather pattern first seen at the planet's north pole more than 40 years ago.

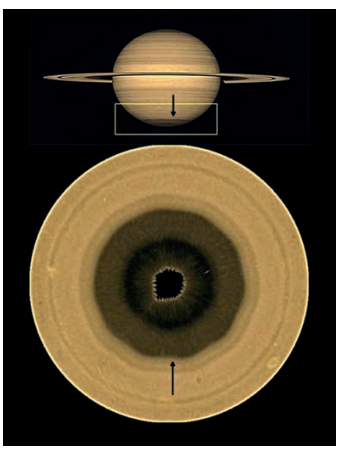
"[But] the one at the north is a bit smaller," says Amy Simon at NASA's Goddard Space Flight Center in Maryland. The south pole pattern also seems to be moving a bit more with the rotation of the planet.

The feature was first spotted by amateur astronomers in 2024. Simon and her colleagues then examined images taken by the Hubble Space Telescope from 2023 to 2025. "We confirmed the existence of the decagon with absolute clarity," says team member Agustín Sánchez-Lavega at the University of the Basque Country in Spain.

It is unclear exactly when the pattern formed, with no spacecraft having orbited Saturn since 2017. "It most certainly wasn't expected," says Simon. "The hexagon has been there for decades, but this is something new."

The decagon measures about 13,000 kilometres across, slightly wider than Earth. It is thought to result from a large atmospheric wave shaped by wind from a powerful jet stream that meanders near the planet's south pole.

Its formation may be linked to a large nearby storm, although the exact cause is a bit of a mystery



NASA, ESA, A. SÁNCHEZ-LAVEGA (BASQUE COUNTRY UNIVERSITY, EHU)

An unusual decagon (indicated by the arrow) is on the planet's south pole

(*Science Advances*, doi.org/hchhtm). "It's a very complicated fluid dynamics sort of thing," says Simon. "It's telling us something about what's going on deeper below the clouds."

Andrew Ingersoll at the California Institute of Technology says the discovery highlights that Saturn is a dynamic, changing world. "It's very interesting to see these features," he says.

No similar pattern has been observed on any other planets, although Jupiter does have an arrangement of cyclones at its poles. "People didn't really predict that such an organised, polygonal pattern would exist on another planet," says Ingersoll.

We don't know how long the pattern will last. Other telescopes, including the James Webb Space Telescope, are poised to study it in more detail, but many scientists are vying for access to those. "We'll look as frequently as anyone will let us," says Simon. ▮

Sleep

You can learn to control your dreams

Emma Young

LUCID dreams, when a person is aware they are dreaming and can often influence what happens, can be induced in some people via cognitive and multisensory stimulation.

Fascinated by the concept of lucid dreams, Tobi Matzek at the University of Montreal in Canada and their colleagues recruited 60 adults with no known health conditions who had experienced at least one lucid dream before. The frequency of these dreams varied, with 15 of the individuals experiencing them less than once a year and others having lucid dreams several times a week.

The participants came into one of three labs – in Italy, Canada or the Netherlands – on two mornings to nap for up to 2.5 hours. Immediately before each nap, they were given half an hour of lucidity training.

This involved lying in bed with their eyes closed while a ZMax EEG headband, a sleep-tracking device, delivered red-light flashes, played a short melody and administered a few soft vibrations on their forehead.

At the same time, a soundtrack guided them to focus their attention on these sensations and asked them to be aware of any differences between the sensations they were feeling during this experience and what they felt during normal wakefulness.

"This may train people to pay closer attention to changes in their sensory experience and make them more likely to recognise the odd or inconsistent experiences that occur in dreams and realise 'I must be dreaming'," says team member Claudia Picard-Deland, also at the University of Montreal.

During one of the two naps, these sensory stimulations were repeated when the participant entered the rapid eye movement (REM) stage of sleep, when we have our most powerful dreams.

Earlier, the researchers taught the participants to move their eyes from left to right to signal that a lucid dream had started and was ongoing. Overall, just over half of the participants gave this signal while the headset readings confirmed they were asleep, usually in the REM stage. After waking, these participants also reported that they'd had a lucid dream (bioRxiv, doi.org/rm9t).

"The training led to a relatively high rate of lucid dreaming, even in people who rarely had lucid dreams before," says Matzek.

Kristoffer Appel at the Institute of Sleep and Dream Technologies in Hamburg, Germany, calls the results "remarkable". "They suggest that lucidity is far more trainable on short notice than the spontaneous and rare reputation that it usually has," he says.

> "Lucidity is far more trainable than the rare reputation that it usually has"

The lucid dreams were no more likely to occur during the nap in which the sensory stimulations were re-applied during the REM stage. However, the gap between the participants' first and last eye signals indicated that they lasted around twice as long in this condition.

Only about 55 per cent of people have experienced lucid dreams, and it is unclear if this approach can induce them in individuals who have never had one. ▮

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Energy

Deepest-ever nuclear reactor

A nuclear reactor will be installed further underground than ever before, setting the stage for a radically different way to build small nuclear plants, finds **Vanessa Bates Ramirez**

NUCLEAR power start-up Deep Fission wants to put a reactor where no reactor has gone before: a mile underground. The California-based company received safety approval for its reactor design from the US Department of Energy early last month, and is preparing the site for its commercial pilot outside Parsons, a small city in south-east Kansas.

The firm hopes that placing a reactor deep underground will cut installation and operational costs, particularly since the bedrock can provide natural containment and pressure for the reactor. This eliminates the need for a heavy-duty concrete containment dome like those that enclose conventional nuclear reactors, which account for a significant portion of their cost and the time it takes to build them. But independent engineers say it is unclear how successful the approach will be.

Deep Fission has already drilled a 1830-metre data-collection well, and will soon begin drilling a 762-metre proof-of-concept borehole. Its next phase will involve installing the reactor canister, heat exchanger and other components into the borehole. A spokesperson for the company says the plan is to then install a working reactor a full mile (approximately 1600 metres) below ground next year, if final permission to do so is granted by the Department of Energy.

The company's Gravity reactor uses one of the most common nuclear technologies: a pressurised water reactor, which runs on standard low-enriched uranium fuel and is water-cooled. It is 9 metres tall, but less than a metre in diameter, and is designed to produce 15 megawatts of electricity.

Drilling deep boreholes is routine in the oil and gas industry, and the heat exchanger technology that will create electricity is standard in geothermal energy production: the heat created by the reactor converts water to steam, which turns a turbine.

While the components of Deep Fission's model aren't novel, combining them is. "The biggest technical challenge is proving that all of these individually familiar technologies will work together in this unfamiliar configuration," says Leslie Dewan, a nuclear engineer at independent consulting firm Neutronic Designs.

"Deep Fission is using the environment itself to perform functions that we normally have to engineer"

The company says its design will not only work, but improve safety and reduce costs compared with conventional nuclear power projects. Putting the reactor 1600 metres underground means the surrounding rock will serve as a built-in containment structure, and the weight of the water column above will create a pressure of 160 atmospheres – high enough to keep water in liquid form at ultra-high temperatures and eliminating the need for a pressuriser that is a necessary component of ground surface reactors.

Michael Brasel, Deep Fission's chief operating officer, says the reactor design also cuts the need for "engineered active emergency core cooling systems with pumps and backup power".

"We anticipate that could translate into real capital and operating savings," he says.

"They're using the environment itself to perform functions that we normally have to engineer into a nuclear power plant," says Dewan. However, the trade-off is a lack of easy access to the reactor, she says, which will make inspection and maintenance "both more difficult and more important".

Todd Allen, a nuclear engineer at the University of Michigan, says that even if Deep Fission designs the Gravity reactor for minimal maintenance, it is impossible to prepare for all eventualities. "I'd be more concerned about something happening that you didn't anticipate."

Brasel says the company isn't planning to raise the reactor to the surface for routine maintenance, but will be able to do so if needed.

DEEP FISSION

Deep Fission has already begun drilling at the site outside Parsons, Kansas

Fresh ground

No reactor has ever operated any deeper than 100 metres below ground. It is uncertain how Deep Fission's borehole, casing, reactor vessel and surrounding geology will hold up over potentially decades of operation. "Just due to the fact that you're putting a reactor underground, there will be a learning curve," says Allen.

It is a curve the company hopes to overcome quickly. Its modular approach would ultimately group several Gravity reactors at one site, scaling the 15-MW capacity to 150 MW or even over a gigawatt.

Deep Fission isn't alone in trying to make nuclear power smaller, cheaper and easier to build. Small modular reactors are intended to replace conventional nuclear power with smaller standardised units that can be manufactured and deployed in series.

This technology could challenge long-standing assumptions within the nuclear industry. For instance, for many companies working on small modular reactors, "their business bet is that the changes in technology and improvements in safety will mean you won't need containment", says Allen. "The question with the Deep Fission idea, where you're going to the work of drilling a very deep borehole, is: is it necessary?"

For now, Deep Fission is betting that it is, and will continue to work towards showing that a reactor can work at the bottom of a hole. If it succeeds, it could offer a radically different way to build small nuclear plants. ▮

Physics

Groundbreaking neutrino laser may be impossible to build

Karmela Padavic-Callaghan

NEUTRINOS pose some of the biggest mysteries of modern physics, but researchers thought they could get a handle on them by corralling them into a laser beam. Now, two new analyses show that neutrinos are more slippery than that, making the proposed neutrino laser design impossible.

Neutrinos are among the most abundant particles in the universe, but much about them remains unknown. Notably, they are extremely light, yet their exact mass is unclear.

In 2025, Ben Jones at the University of Manchester in the UK and Joseph Formaggio at the Massachusetts Institute of Technology (MIT) suggested a novel and surprising way to gain clarity – they proposed using thousands of extremely cold radioactive atoms to create a laser beam of neutrinos.

Wolfgang Ketterle, also at MIT, heard a lecture about the idea and immediately worried about it being too good to be true. He and his colleagues have now confirmed that hunch with two rigorous mathematical investigations.

Neutrinos are produced when radioactive atoms undergo nuclear decay. Jones and Formaggio theorised that if many such decaying atoms were pushed into a quantum phase of matter called a Bose-Einstein condensate (BEC), where they all share a quantum state, then their respective neutrino emissions would be amplified, forming a laser-like beam. Creating such a BEC would require making thousands of radioactive atoms extremely cold so they could behave quantumly, which is a big technical challenge.

"The proposal was to use thousands of very cold radioactive atoms to create a neutrino laser beam"

But Ketterle, who received the Nobel prize for creating some of the first-ever BECs in the 1990s, and his team uncovered a more fundamental obstacle.

The key to the neutrino laser proposal was a memory effect: when an atom in the BEC emitted a neutrino, it would be more likely to continue emitting more neutrinos in the same direction, thus pushing them into a beam, because the quantum state that all the ultracold atoms share would retain a trace of that first emission. Ketterle and his colleagues showed that this memory, although present, would be about 10,000 billion times too brief to affect the neutrinos as intended (*Physical Review Letters*, doi.org/rm44).

Even more troublingly, the team uncovered that the memory would actually have the opposite effect from that intended, which Ketterle calls an anti-memory (*Physical Review Letters*, doi.org/hchhps).

"If I am an atom and I have emitted a neutrino, I am not allowed to [immediately] emit a neutrino again," he says. This effect's origin is subtle, stemming from neutrinos being a type of particle called fermions, which fundamentally behave differently than particles of light that our ideas about lasers tend to be built upon.

"I think these papers sharpen where the real difficulty lies," says Kyle Leach at Queen's University in Canada. "For nuclear-scale energies [pertaining to atoms' decay], these requirements become extraordinarily demanding."

He says the new analyses don't categorically rule out every possible way to build a neutrino laser, but show that the most conventional scenario, where each atom emits one neutrino, cannot work. If each atom emitted two neutrinos at a time, the analysis may be different, he says.

Formaggio and Jones didn't respond to *New Scientist*'s request for comment before going to press. ▮

Animal behaviour

Pygmy raccoons teach each other to make toys

YOUNG pygmy raccoons on a Mexican island have been seen teaching each other to make balls out of rubbish, in a rare example of animals crafting objects purely to play with.

"My first reaction was, oh my gosh, that's absolutely adorable!" says Nessie O'Neil at Miami University in Ohio, who is researching the impact of tourism on the critically endangered pygmy raccoons (*Procyon pygmaeus*) of Cozumel Island.

O'Neil filmed as one of the younger raccoons fished paper out of a rubbish bin, dipped it in a bowl of water and rolled it in sand, making a ball (*Wild*, doi.org/rm5p).

Over days of observation, she recorded the animals as they made more balls and used them to play "football" with other raccoons and dwarf coatis (*Nasua narica nelsoni*), a raccoon-like animal. Siblings taught each other the ball-making procedure, and even tried to get their mother involved, though she couldn't quite figure it out.

O'Neil's colleague at Miami University, Michelle Szydlowski, was impressed by the footage. While others have watched animals like chimps or tigers at play, researchers have seldom seen animals custom-making toys for later use. "It shouldn't be surprising that raccoons are where we're seeing this, just because they're so tactile, they see with their hands," says Szydlowski.

NESSIE O'NEIL

Ready to play ball: A young pygmy raccoon holds a homemade toy

"The observations show how complex animal play behaviour can be," says Marek Špinka at the Institute of Animal Science in the Czech Republic. "It will be intriguing to see whether the behaviour will get a hold in the population as a new cultural trait or will disappear."

The observations may also help with conservation efforts. There are fewer than 200 pygmy raccoons in the wild. Understanding how they learn from each other might help conservationists discourage unhealthy behaviours like begging for snacks. ▮

Matt von Hippel

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Lithium's new frontier

Should we all be taking low doses of lithium to prevent Alzheimer's? As a human trial is about to start, **Alice Klein** looks into the benefits and downsides of the metal

Alice Klein is a reporter at *New Scientist* based in New South Wales, Australia, who mainly writes about health, biology and the environment

Alice's week

What I'm reading
Painted People: Humanity in 21 tattoos *by Matt Lodder*

What I'm watching
"Colour drenching" interior design videos for inspiration

What I'm working on
A piece on the role of the immune system in childbirth

IN THE 1880s, a newly dug well in Texas became known as the "Crazy Well" after a woman who drank from it daily allegedly overcame dementia. Her legendary recovery has since been suggested to be due to the naturally occurring lithium in the area's groundwater. This lithium-containing "Crazy Water" is still available to buy in the local town of Mineral Wells.

The idea that lithium, a simple metal, might have a role in treating and/or preventing dementia is starting to gain traction. Beginning next month, lithium orotate, a type of lithium salt, will be tested for the first time in people with early Alzheimer's disease in a clinical trial at Johns Hopkins University in Maryland. This comes on the back of research published last year by Bruce Yankner at Harvard University and his colleagues showing that lithium orotate reversed memory loss in mouse models of Alzheimer's disease, the most common cause of dementia.

Yankner's team also found that the brains of people who died of Alzheimer's disease had lower levels of lithium than those who didn't have any cognitive impairment when they died. And earlier this year, a study of more than 2000 US counties led by

> **"US counties with low levels of naturally occurring lithium in their water had higher rates of dementia"**

Hyeong-Moo Shin at Baylor University in Texas revealed that counties with low levels of naturally occurring lithium in their public water supplies had higher rates of dementia than those with high lithium levels in the water.

These findings don't prove a causal link between lithium deficiency and dementia; however,

THOMAS DEERINCK, NCMIR/SCIENCE PHOTO LIBRARY

Alzheimer's is marked by tangles of tau proteins (red) and the build-up of amyloid plaques in the brain

they are certainly intriguing, and they have inspired many people to rush out and buy lithium supplements. Is it too early to jump on this bandwagon? And are there any risks of boosting your lithium levels with supplements?

Lithium is best known for its use in rechargeable batteries, but also has a long history of use in psychiatry. Since it is highly reactive, it is usually paired with other substances like orotate or carbonate to form lithium salts. Lithium carbonate is the type typically prescribed for bipolar disorder.

However, Yankner's team found that lithium orotate was far better for treating Alzheimer's-like disease in mice. This was thought to be because lithium orotate is less likely to be taken up by amyloid plaques, the abnormal clumps of protein in Alzheimer's-affected brains, leaving more lithium available in the healthy parts of the brain.

We still don't know exactly how lithium protects against neurodegeneration, but one mechanism seems to involve the fact that it inhibits an enzyme called glycogen synthase kinase-3 beta. Animal studies have found that blocking this enzyme reduces the build-up of amyloid plaques and helps to regulate inflammation.

So far, only lithium carbonate has been investigated for slowing cognitive decline in humans. The latest trial, conducted by researchers at the University of Pittsburgh, Pennsylvania, disappointingly found no benefit of taking a daily lithium carbonate pill for two years in adults aged 60 and over with early signs of memory loss. I hope, and I'm sure many others do too, that the upcoming trial of lithium orotate will be more successful, but we won't know the results for years because the trial is scheduled to run until 2029.

In the meantime, lithium orotate supplements are already available to buy, leading some people to try to get ahead of the curve and start taking them now just in case they are eventually proven to work.

Caution is warranted, however, because taking too much lithium can cause side effects like tremors, thirst, nausea and headache, as well as thyroid and kidney toxicity. In Yankner's study, the dose of lithium that was given to mice was much lower than the dose typically prescribed in bipolar treatment, so it is hoped that similar "microdoses" might ward off neurodegeneration in people too. However, no studies have examined the long-term safety of lithium orotate supplementation, even in low doses. There is also no agreed definition of lithium deficiency or standard test for it, so there is no way to know if your levels are too low.

Personally, I'll wait for the results of the clinical trial of lithium orotate to come out before I consider taking supplements. But if I ever find myself in Texas, I will definitely stop in at Mineral Wells for a big glass of Crazy Water. ▮

Don't make changes to your diet, exercise or medication regimes without first speaking to a doctor

Against the clock Is time dilation real? Einstein thought so, but he also thought it is an apparent phenomenon related to our perception. **Karmela Padavic-Callaghan** looks at why he was right both times

Karmela Padavic-Callaghan is a reporter at *New Scientist*, specialising in physics, materials science and quantum technology. Karmela earned a PhD in theoretical condensed matter physics and atomic, molecular and optical physics from the University of Illinois Urbana-Champaign. Their physics memoir *Entangled States* is out now

Karmela's week

What I'm reading
Spawning Season: An experiment in queer parenthood *by Joseph Osmundson*

What I'm watching
The time-bending sci-fi thriller Chronovisor

What I'm working on
Getting over my fear of headstands in yoga class

THE passage of time often seems like the most malleable thing in the world. A minute may feel much longer when you're asked to hold a plank position in a workout class, and an hour may fly by when you're chatting with a friend. In these cases, your perception of time is altered. But real, physical time dilation also happens. According to Albert Einstein's special theory of relativity, clocks that are closer to Earth's centre of gravity, say at sea level, tick more slowly than those at the top of a mountain. A similar slowing happens when a clock is physically travelling extremely fast.

Undeniably, this sounds bizarre, but decades' worth of experiments haven't managed to disprove it. Yet in what exact sense time dilation is real, and what it means for a physical effect to be real at all, has inspired philosophical debates ever since Einstein first formulated his theory in 1905.

In fact, in June, at the Foundations of Physics conference in Irvine, California, I heard Marco Giovanelli discuss how time dilation is both real and apparent at once. It sounds paradoxical, but when I called Giovanelli, who

"In what exact sense time dilation is real has inspired debates since Einstein formulated his theory in 1905"

is a historian of philosophy and science at the University of Turin in Italy, to talk through it, I started to understand that it reflects the facets of our physical world that Einstein's work first uncovered.

For Einstein, it was all about rods and clocks, explains Giovanelli. Suppose that you and a friend each had an identical clock and a metre-long rod. You stand still, while your friend gets into an incredibly fast

TETRA IMAGES/GETTY IMAGES

The passage of time can feel very different depending on what you are doing

spaceship and sets off on a journey. Compared with yours, their clock will tick less quickly and their rod will contract in size. If you want to know by how much, Einstein's got your back: he worked out those calculations more than a century ago. Finally, if you also acquire a spaceship and catch up with your friend, your clocks will start to tick at the same rate again, and your metre-long rods will again look the same length.

To discuss these effects, physicists use the language of "inertial frames", similar to comparing a room at rest, or a rest frame, with a spaceship travelling at a constant speed, or a moving frame. In your individual frames, you and your friend can each establish a coordinate system, the familiar grid of width, depth and height. Your coordinate systems will match when you are both at rest or when your spaceships move side by side at the same speed.

When one of you moves more quickly, though, special relativity shows that their grid will deform, contracting in the direction of motion. It is this detail that bothered Einstein's contemporaries. It seemed that the change in the rod length was uncomfortably intertwined with changes in the coordinate system used to situate it. But an effect that is a function of a coordinate system cannot possibly be real, critics argued. Ultimately, coordinate systems themselves are of dubious reality. They seem to simply be tools that we humans made up to help us organise our theories and observations of the physical world.

Time for a rethink

In 1911, physicist Vladimir Varićak argued that the rod's length contraction "is only a psychological and not a physical fact, i.e., the body has not really undergone any change". Giovanelli recounts another anecdote where, in the 1970s, physicist John Stewart Bell surveyed his colleagues at the CERN particle physics laboratory about whether length contraction could break a thread suspended between two spaceships accelerating at exactly the same rate. Most physicists said the thread wouldn't break, endorsing the idea that nothing physically

changes about the atoms in the thread. Could they have possibly been wrong? This made my head spin.

I will admit to having always been a rather terrible student of relativity, learning it only just well enough to pass my preliminary exams in graduate school. However, I'm certain I was previously taught that relativistic time dilation and length contraction are unquestionably real. We know they are, from experience in everyday life. The precise clocks on GPS satellites tick at different rates than those on Earth. This is partly because they move quickly and partly because of the gravitational effects explained by Einstein in his general theory of relativity.

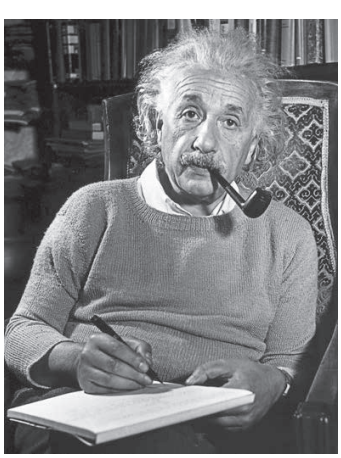
For GPS to be accurate, the difference in ticks must be corrected for. Failing to do so would have very real consequences, like ending up in someone's backyard when I try to use my phone to visit a new café. But here's the crucial thing: the clocks on GPS satellites derive their precision from leveraging quantum control over atoms rather than some macroscopic clock gears, so it feels especially egregious to suggest that time dilation does nothing to an atom.

Einstein himself was thinking about this, too, Giovanelli tells me. In fact, an atomic effect was at the centre of a 1906 debate he had with Johannes Stark, a physicist who was awarded the Nobel prize for discovering how electromagnetic fields can affect the energy states of atoms. Stark was studying fast-moving charged atoms and Einstein recognised that these experiments may display the transverse Doppler effect – in the same way that a siren changes pitch as it approaches you due to a shift in the frequency of its sound waves, a similar effect can happen due to time dilation. It is a distinct prediction of special relativity, an effect that doesn't exist in other theories, says Giovanelli.

For the standard Doppler effect, you know that you could cancel it out by driving after the police car and that what is happening isn't due to something changing inside the car's speaker. The same question reared its head for the transverse Doppler effect. "Stark really thought, kind of naively but naturally, that something is going on in the atom," says Giovanelli – in our analogy, the speaker in the car would be physically changing. Einstein rejected this. He posited that all the atoms remain the same and that their inner workings are unaffected by motion. Time dilation was the only explanation. Seemingly apparent, here it was confronted with a real, empirical test.

Ironically, when the transverse Doppler effect was experimentally verified in 1938, one of the two physicists involved was Herbert Ives, who never accepted special relativity. Ives thought that he had found signatures of the "luminiferous aether",

Albert Einstein questioned how certain he could be that two clocks were reliably identical



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a hypothetical substance that some researchers thought permeated the universe and provided one preferred, true reference frame. A preponderance of other experimental evidence, much of it obtained even prior to Ives's work, completely ruled out this option, and special relativity became the only game in town.

"Special relativity has passed every test we've put it to. What more could you ask from a theory?"

For all the clamouring about the oddity of an effect related to an observer's perspective, one that many physicists wanted to dismiss, time dilation withstood the test of time. Over the ensuing decades, ever-increasingly precise atomic clocks have never uncovered any evidence that something more "real" could be happening.

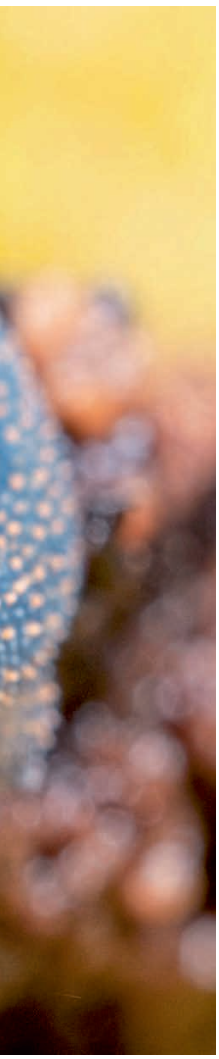
As far as Giovanelli is concerned, what happened was not so much a dispute over physics, but rather a run-in between physics and philosophy. Underneath the sticky question of whether time dilation is real hides another, even stickier philosophical one: what does it mean to be real?

"At a certain point, you cannot avoid it," says Giovanelli. "And so, Einstein was forced to address the question philosophically. OK, really, let's define: 'apparent' means disappears for the co-moving observer, 'real' means empirically testable." In some sense, the situation ought to never have become that complicated, he says. Scientific theories provide testable hypotheses – it is what they are designed for – and special relativity has passed every test we've put it to. What more could you ask from a theory?

Well, it's hard to understand from an intuitive point of view, says Giovanelli. Einstein even had his own questions, primarily about how certain he could really be that two clocks, or two atoms being used as clocks, could be reliably identical. The advent of quantum physics offered some assurances, but Einstein had his qualms with quantum theory and worried about it way beyond how it applies to rods and clocks. But he never questioned the empirical reality of time dilation and length contraction, says Giovanelli.

As we talked, I wondered whether for me, like Einstein's critics, it was my notable lack of relativistic intuition that made time dilation so hard to grasp. It may have been easier to accept that when atoms within a clock or a rod move at a certain speed, some as-yet-unknown mechanism physically changes them, leading to time dilation and length contraction. Instead, I have to grapple with there really being no such thing as absolute time.

Being a student of modern physics, however, I am not necessarily surprised by this somewhat frustrating duel between the words "apparent" and "real". I gained my intuition about the behaviour of physical objects by interacting with mundane things like pens and oranges, never anything extremely small or cold, nor anything incredibly fast. Quantum theory, which governs all things tiny and chilled, taught me that I can't always expect just one thing about an object to be unambiguously true at once. In fact, quantum objects can exist in states akin to clouds of probability that contain completely contradictory options. Absolute precision and absolute certainty are simply off the table. Special relativity may be teaching me a similar lesson about time. ▮



A micro-safari

Frank Ashwood
Hodder Press

WE CANNOT live without soil. It provides us with building materials, most of our antibiotics and 95 per cent of our food.

In *The World Beneath Our Feet: The hidden life of soil and why it matters to us all,* photographer and soil ecologist Frank Ashwood urges us to better appreciate and protect the soil we rely on. He does so with stunning images of the creatures that call soil home.

The velvet worm in the main photo was found under a log in a misty beech forest on the South Island of New Zealand. "They look like little worms rolled in sequins," says Ashwood. But looks can be deceiving: "They crawl around and shoot glue out of special organs on their heads to immobilise their prey, which they'll then go and eat while alive."

To its right, a droplet of sperm deposited by a male springtail, a tiny insect-like creature, sits atop a delicate stem made of protein-rich secretions. "It's like a lollipop, basically, with a bit of sperm-rich fluid on the top, which the males leave for the females to come and find," says Ashwood, who is based at Lincoln University in New Zealand.

Below it is a giant springtail that was found in a forest in New Zealand. Its orange spines help camouflage it against logs. "Because they're rare, when you do see one, it's a moment of pure exhilaration," says Ashwood. "They're an indicator of the forest being in really good condition."

Moving clockwise, the next image shows a bright yellow slime mould on a decaying log. Finally, a woodlouse spider stares down the lens of Ashwood's camera. Its large fangs have evolved to better hunt woodlice.

Carissa Wong

Hunting the real Vikings

The stories we tell about the Vikings often say more about us than them. A fascinating book tries to show the Norse as they were, says **Michael Marshall**

Book
The Sea-King and the Sorceress
Neil Price
Allen Lane (UK)
Basic Books (US), out 13 October

THE first thing to understand about the Vikings is that the people we label Vikings never called themselves by that name; it wasn't their ethnic identity in the way "Roman" or "Puerto Rican" has been. The Old Norse word *víkingr* probably meant something like "pirate", explains Neil Price on page 2 of his richly informative new book, *The Sea-King and the Sorceress: Life and death in the Viking Age*. It described a job or activity "that could be taken up or left off at different times in a life".

During the Viking Age, roughly AD 750-1050, most Scandinavians were farmers: they "never went anywhere or did much harm to anyone". The word "Viking" is a label that was applied to the Norse peoples of Scandinavia by others – specifically, by western European writers in the 1800s, centuries after the phenomenon had ended.

From the start, these reports of Viking activity were tinged with political agendas. Early accounts were viewed through a "distorting lens of racialized imperialism", Price writes. These Vikings were seen as the ancestors of modern Europeans, whose thrusting and conquering ways helped to build modern civilisation.

Many writers have had "an ideological crush on the Vikings", writes Price: you can see it in the ideology and imagery of the Nazis and in the modern white supremacy movement.

"To understand the Norse, we must begin by rejecting any notion of a monolithic Norse culture"

Price is an archaeologist at Uppsala University in Sweden, where he studies the Viking Age. His debut book *The Children of Ash and Elm: A history of the Vikings* was published to general acclaim in 2020. He subsequently worked as a historical consultant for the 2022 film *The Northman*, which inspired him to write about "a past that did not care in the slightest what we think of it".

In *The Sea-King and the Sorceress*, his second book, Price tries to help us see the Norse people, and their practice of going a-viking, through new eyes. He does so by describing 21 burials, spanning four centuries and a wide geographical area. Each is given a title, like "the sea-king", "the shapeshifter" and "the matriarch".

The aim is to show the variety of lives that were being lived, and how they changed over the centuries. If we want to understand the Norse, Price writes, "we must begin by rejecting any notion of a monolithic Norse culture". He certainly succeeds at showcasing the rich diversity of the Norse world: we meet not just warriors but also traders, farmers, nomads and slaves.

However, your mileage may vary on the book's episodic structure. There is no overall narrative – the burials are arranged roughly chronologically,

but that is all. As a result, I found the book a bit of a struggle to read all the way through. Readers may get a better experience by dipping in and out, a chapter or two at a time.

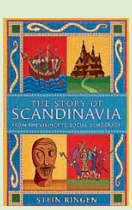
Price begins with the Salme ship burials on Saaremaa Island in present-day Estonia. Discovered by accident in 2008, two boats had been buried about 100 metres from the sea, one of them containing eight men and the other 34. Alongside their bodies were joints of meat, tools and playing pieces from strategy games. Four brothers, identified as such using preserved DNA, were laid side by side. Price argues that the dead men were probably "the remains of a raid or a war party... these men were casualties buried by their friends". Molecular evidence suggests most of them were from the Mälaren valley in what is now Sweden.

This, then, is the earliest archaeological evidence we have of a Viking raiding party. Dated to around AD 750, it is nearly half a

Three more books that cast a new light on historical societies

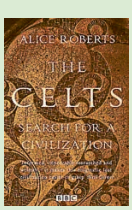
American Vikings: How the Norse sailed into the lands and imaginations of America by Martyn Whittock

Filling in one of the few gaps in Neil Price's burials, historian Martyn Whittock explores the many claims of Norse visitors to the Americas, some backed by unimpeachable archaeology, others wildly fanciful.



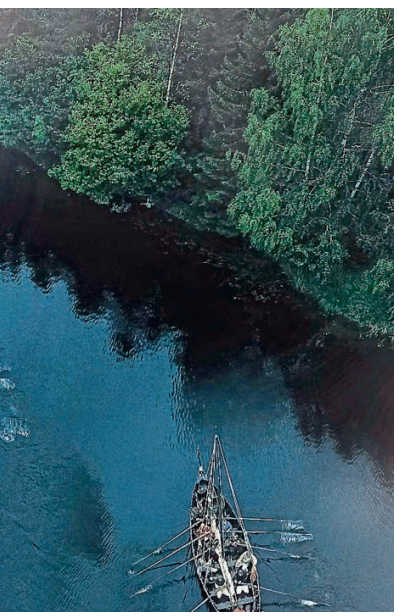
The Story of Scandinavia: From the Vikings to social democracy by Stein Ringen

How did Norse societies, famed for violent raids and reliance on slave labour, develop into today's peaceful, democratic societies? Stein Ringen traces them through a seemingly endless sequence of brutal wars.



The Celts: Search for a civilization by Alice Roberts

"Celt" is another ethnic label that was applied to one group of peoples by another – in this case, the Romans. Alice Roberts tries to figure out who they really were and if there were people who can usefully be labelled "Celtic".



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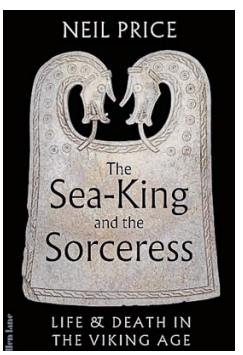
Left: A real outing for reconstructed longships. Below: A Viking burial ground in Denmark



century before the AD 793 attack on Lindisfarne Abbey in England, which early accounts pinpointed as the start of the Viking Age. Right from the start, Price is tweaking our narratives about the Norse.

Further revisions come in chapter 4. "The 'shield-maiden'" describes a burial from around AD 950. A tall person was buried, "armed to the teeth" as Price puts it, with a sword, knife, war-axe, bow, two lances and shield. When first excavated in 1878, this person was identified as a male warrior. Analyses in the 1970s strongly suggested that they were female, but this went unremarked. It took until the 2010s, and specifically a study of preserved DNA published in 2017 (on which Price worked), to establish that this person was, in fact, female.

This finding prompted a storm of comment, which Price addresses with admirable nuance. Archaeologists pointed out that one can't assume a person's profession based on how they were buried. This is true, but, as Price remarks, "none of these 'problems' were ever raised in connection with this grave for the century and more that it was assumed to be the burial of a man".

However, Price is also not keen on the idea of this woman as a "kickass feminist role model". As he points out, if she was a Viking, she presumably kidnapped people into slavery, as was common practice. Despite the expanding evidence, we still struggle to see this person for who she really was. It doesn't help that the stories we have about shield-maidens and Valkyries are often fetishised and reveal more about the men who wrote them than about the real lives of fighting women.

The other 19 burials are explored with a similar detail and care. Price's achievement is to show us people who are both exactly like us and wildly different. "The people of this Viking Age have moral codes that are emphatically not ours," he writes. They took and used slaves, routinely and seemingly without a second thought. Their raids were often shockingly ruthless, with no regard for life.

Yet they built extensive trading networks, something that requires a high degree of trust and reliability. Norse trade crossed the Atlantic and extended deep into Eurasia via the Silk Roads. The Norse were also pioneers of deliberative, loosely democratic decision-making in the forums known as "things".

In short, they were a mess of contradictions – like every other society. ▮

SUGARO607/GETTY IMAGES

Michael Marshall is a science writer based in Devon, UK

New Scientist *recommends*

Karmela Padavic-Callaghan
Reporter
New York

"This all sounds very abstract, and also, this is us," writes Chanda Prescod-Weinstein in **The Edge of Space-Time**, a book that ranges from Isaac Newton's laws to the edge of the universe. At its core, it recognises that humanity doesn't just inhabit the cosmos but instantiates its magnificence and its oddness.

We are invited by the author, who works at the intersection of particle physics, astrophysics and cosmology, to build a model of the physical world, starting with its fabric (space-time), moving to the quantum

fields that permeate it.

This may challenge, but Prescod-Weinstein, a *New Scientist* columnist, is direct about the value of thinking through hard things. The more we expand our imagination with physics, she notes, the better we dream.

And this is a dreamer's book: the spectrum from human to cosmic, imaginative to analytical, is continuous. It is a political statement on the value of imagination and a timely read.

How to boldly go...

As *Star Trek* celebrates its 60th birthday, how can newcomers bond with its sprawling universe? **Bethan Ackerley** seeks help from three of *New Scientist*'s crew

DESPITE loving both science fiction and TV, I have never really got far with *Star Trek*, arguably the quintessential marriage of the two. I've seen and enjoyed the odd episode, and even flirted with the first season of *The Next Generation*, yet nothing has really stuck.

In August, knowing that the 60th anniversary of *Star Trek: The Original Series* was approaching in September, I decided to give it a proper go. But which, if any, show would pull me into this vast sci-fi universe? And what would I learn about the heart of *Star Trek*?

I set out to watch at least three episodes from as many *Star Trek* shows as possible, then continue with whichever piqued my interest the most. Due to time limitations, I would stick to TV, *Star Trek*'s first and truest home. I would steer clear of *The Animated Series* (1973-74) and *Picard* (2020-23) – continuations of *The Original Series* and *The Next Generation*, respectively – until I knew I enjoyed their predecessors. And I omitted the much-loved animated comedy *Lower Decks* (2020-24), only because its charms rely on an investment in the franchise I didn't yet have.

My rapid-fire approach came with a risk: how could I be sure I had picked episodes representative of the tone and quality of a given series? I decided to consult a wise council – a Federation, if you will – of *New Scientist* superfans: physics reporter Karmela Padavic-Callaghan, senior editor Jacob Aron and technology reporter Matthew Sparkes. I came to think of them as my Kirk, Spock and Bones (I'll let you decide who is whom), each offering a distinctive perspective on the franchise.

Where to start? Instantly, my advisers began to clash. Jacob suggested I begin with the second season of *The Next Generation* and specifically "The Measure of a Man". "I've never disagreed with Jacob more," replied Matt. "*TNG* is very good, but how could you skip the original? Sacrilege."

CBS VIA GETTY IMAGES

The original *Star Trek* crew on the deck of the Enterprise

Having fatally undermined the collegial relationship between Jacob and Matt, I decided it was only right to begin with the original (1966-69). Like most people, I knew a fair bit about it: the phasers, the red shirts, the boldly going. I was keen to get to grips with its near-future setting, in which members of the space force Starfleet aboard the starship Enterprise set out on a five-year mission of discovery.

Karmela lovingly called it "campy and low budget", and I enjoyed watching pop-culture stalwarts like "Amok Time", the famed episode in which Spock goes into heat. I also loved the way the show was shot: its universe is awash with colour, so unlike too much modern sci-fi. I could see how the world fell in love with it.

There was surprising substance amid the goofiness, too. "The Man Trap" is both a soapy love triangle about an alien disguised as Bones's old flame and a poignant story about the extinction of a once-great species. "The Ultimate Computer", flagged by Matt as "a nice comparison with current events", is a remarkably prescient look at the dangers of AI.

"I loved the way the show was shot: its universe is awash with colour, so unlike too much modern sci-fi"

Off to a great start, I tried *TNG* (1987-94) – the series with "the most genuinely good episodes", according to Karmela, and "where things get both more utopian and more philosophical". This was the only *Star Trek* show of which I had seen more than a handful of episodes, so I knew some parts I'd enjoy – like Patrick Stewart's delivery as Jean-Luc Picard, captain of the Enterprise years after James T. Kirk.

By watching later instalments recommended by the *New Scientist* superfans, I realised how much *TNG* gathers steam as it goes along. "The Measure of a Man" is as great an entry point as Jacob described: full of heart, the thorny, well-written episode sees android officer Data's self-determination rights come under fire by a Starfleet scientist who wants to create copies of him.

Next up was *Deep Space Nine* (1993-1999), of which I had almost no knowledge. It is "the true answer for the best *Star Trek* series", according to Jacob, "but also the least *Star Trek*". The latter was immediately clear: set on a space station rather than a spacecraft, it is a markedly political drama that felt far away from what

I'd come to know as *Star Trek*.

It took me a while to warm to Benjamin Sisko, the Starfleet captain running the station in conjunction with the Bajorans, a society that had just liberated itself from occupation by the fascist Cardassians. But once I'd watched later episodes ("Duet", about Bajoran Kira's conviction that a Cardassian war criminal is on the station, and "In the Pale Moonlight", Karmela's pick , which sees Sisko betray his ideals), I was pretty invested in him.

Voyager (1995-2001) was another divisive one. It was "full of great characters", according to Karmela, but "it squandered its premise" in Jacob's eyes. What a great premise: when the crews of Voyager and a rebel ship are both stranded 70,000 light years from Earth, Starfleet's Kathryn Janeway must unite former enemies and lead them through uncharted space. Janeway – a Katharine Hepburn-lookalike on whom I instantly imprinted like a duckling – became my favourite Starfleet captain.

But I struggled to connect with the other characters in *Voyager*. Except during the stand-out two-parter "Scorpion", another of Karmela's picks that sees Janeway negotiate passage through territory controlled by the cyborg hivemind the Borg, I found myself missing Data and the rest of Picard's crew.

At this point, recommendations from Matt, Karmela and Jacob were starting to dry up. From then on, I simply watched the first three episodes from my remaining shortlist – while reminding myself that sometimes series can take a while to find their feet.

But perhaps not coincidentally, *Enterprise* (2001-05) – described by Jacob as "the forgotten child" of the franchise – was the first *Star Trek* series I really didn't enjoy. Set 100 years before the original series, it follows the first crew of Enterprise as humanity is just beginning to explore space. While it's an interesting concept, elements of it felt regressive and completely unlike *Star Trek*. If watching *Enterprise* had any value, it was in making me realise I had developed opinions about what *Star Trek* ought to be.

There was a long gap between *Enterprise* and *Discovery* (2017-24), the first show of what might be termed the modern *Star Trek* era. Setting out on my *Star Trek* journey, I had asked my Federation for any thoughts on the newer series. "None that can be printed," Matt replied. Ouch.

As a result, I wasn't optimistic about *Discovery*, but it became one of my favourites thanks to its propulsive early episodes. "The Vulcan Hello", the show's first, is an incredible shot across the bow. First Officer Michael Burnham, a human raised by Vulcans, is both a natural leader and a rebel willing to break rules to save the day. She is a natural counterpart to Kirk, and this, with the heightened, slightly soapy nature *Discovery* shares with the original, felt like a welcome return to classic *Trek*.

"If *Enterprise* had value, it was in making me realise I had developed opinions about what *Star Trek* ought to be"

Finally, I took on two more shows that defied expectations. *Strange New Worlds* (2020 to present) was the series I'd expected to enjoy the most. Jacob had described it as "genuinely good and innovative". I knew it made experimental choices: following Kirk's predecessor Christopher Pike, its episodes see the crew swapping bodies one week and transforming into puppets the next, with more serious fare in between. Unfortunately, the three episodes I watched were all in the latter group. As such, I reserve judgement, but I was a little let down by my limited viewing.

I found *Starfleet Academy* (2026), which aired earlier this year and was unceremoniously cancelled soon after, to be far better than its reputation suggested. This young-adult series, in which the training school is being rebuilt after a galaxy-wide disaster in the far future, has a very fun premise and some incredible guest stars like Holly Hunter and Paul Giamatti. It can struggle to replicate the Gen Z voice, but it is perfectly good fare for its intended audience, and it deserved better than it got.

By the end of my experiment, I had thought a lot about what makes a good *Star Trek* episode. Is it philosophy? Predictive power? Or entertainment value? I didn't have a good answer. Perhaps *Star Trek*'s enduring power comes from its flexibility. It offers a galaxy's worth of tones, tastes and tribulations, all of them valued. Personally, I knew I intended to continue watching *TNG* and *Discovery* – a little of *Star Trek*, both old and new. I can't wait to get properly stuck in.

Our picks for what to watch after *Star Trek: The Original Series*

1987-94: *The Next Generation*

1993-99: *Deep Space Nine*

1995-2001: *Voyager*

2017-24: *Discovery*

2020 to present: *Strange New Worlds*

2026: *Starfleet Academy*

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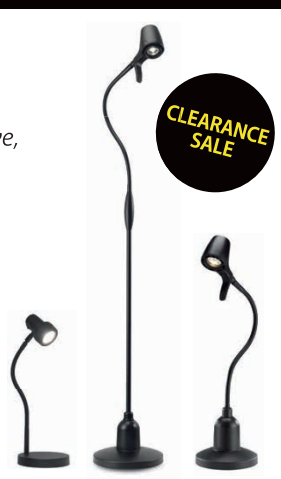
Mr Reeves



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Editor's pick

We shouldn't want AIs to have a human-like reality

8 August, p 30

From Will Mayall, Santa Cruz, California, US

Your article on "world models", which would let AIs understand cause and effect in the real world, largely assumes that the goal is to give them something resembling the human experience of reality: objects, motion, cause and effect, and physical interaction at the scale of everyday life.

But humans have only the faintest sensory access to reality. We perceive a narrow band of electromagnetic radiation, a limited range of sound and a small set of chemical and mechanical signals. We don't directly experience the molecular world, radio waves, magnetic fields, geological time, atomic processes or the scale of galaxies. Even our familiar senses fail to present reality itself – they provide highly filtered biological signals from which our brains construct useful models.

Why assume AIs should be limited in the same way? They could instead receive information from all spectra of light, molecular sensors, astronomical instruments, seismic networks and countless other sources. With that flood of information, an AI's "world model" might be nothing like ours.

World models may indeed be important to advanced AI. But defining the "world" by what humans happen to sense is an unnecessarily narrow place to start.

An alternative to topical flea treatments for pets

15 August, p 14

From Jens Christian Jensenius, Odense, Denmark

There are interesting and worrisome elements in your report about the environmental safety of flea treatments for pets. However, it focuses entirely on treatments applied to animals' skin. Chewable tablets are given orally, so they seem unlikely to be detrimental to the environment. I guess that, to be sure, you should collect your pet's faeces for a couple of days after treatment to be disposed of as burnable rubbish.

Quantum maths solution isn't in the spirit of things

22 August, p 6

From Dyane Silvester, Arnside, Cumbria, UK

I am unconvinced that adding a quantum element (which I presume Catherine the Great didn't mention in her original challenge) counts as "solving" the puzzle she set mathematician Leonhard Euler. Surely this actually amounts to changing the rules, so that it becomes a different puzzle, which has a solution?

More work needed to refute Boltzmann brains

22 August, p 38

From Toby Pereira, Rayne, Essex, UK

In his interview with Jacklin Kwan, Sean Carroll doesn't fully address the problem of Boltzmann brains. He has designed a universe where the issue is mitigated, but has offered no explanation as to how or why this universe might have become *the* universe.

If other universes exist that do have a proliferation of Boltzmann brains, we can still wonder why we exist as a mind from a brain in this universe, rather than some other. For Carroll's theory to work, the proportion of minds that come from Boltzmann brains needs to be sufficiently small across all of existence, meaning his universe must be the only one, or at least statistically typical. It is hard to reconcile his universe with being statistically typical, as it relies on setting things up perfectly in order for entropy to spontaneously start decreasing until it reaches the same starting point.

Heatwaves reveal a flaw in push for nuclear power

15 August, p 9

From Sam Edge, Ringwood, Hampshire, UK

The shutdown of nuclear power plants across Europe due to low water levels from recent heatwaves is alarming. It demonstrates that building large nuclear fission plants, small modular reactors or even the mythical sustainable fusion reactor is never going to be a viable part of the fossil fuel transition.

Wind, solar and tidal power with electrochemical battery or thermal back-ups are clearly the only solution. Fortunately, those technologies already exist and are constantly becoming cheaper and more efficient.

Could we recover a literary great's microbial traces?

8 August, p 36

From Stephen Durnford, Saltdean, East Sussex, UK

Matthew Ponsford writes about microbiome forensics in police investigations and testing for our microbial "fingerprints". I have been wondering about the persistence of fingerprints on paper myself. During the 1870s, one of my great-grandfathers was a clerical colleague of Charles Dodgson, who wrote as Lewis Carroll and took a photograph of my great-uncle Cecil Crofts and two of his sisters. My great-aunts also received some of Dodgson's letters and, in 1943, Cecil gave his print of the photograph to my mother, who later gave it to me.

Few other people are likely to have handled it, and Dodgson's fingerprints may be among those present. Perhaps forensic analysis could even recover his DNA?

Anglo-Saxons may have seen a huge solar storm

15 August, p 34

From Mark Spinney, Haslemere, Surrey, UK

I was very interested in your recent article on solar storms. It struck me that an incident 10 times stronger than the 1859 Carrington event, estimated to have occurred around AD 774, might have been noticed and recorded at the time. Looking in the *Anglo-Saxon Chronicle*, a set of annals in Old English that was first compiled around AD 890, I see that the entry for AD 776 says: "Men saw Christ's red cross in the heavens after sunset". Could these observations have been a result of a solar event?

Unexpected implications of red-light research

15 August, p 30

From Richard Brown, Huntly, Aberdeenshire, UK

I note from Graham Lawton's article "Red-light starvation" that many of us are deficient in exposure to infrared light. Bill Gifford's earlier piece "Heat therapy" (18 July, p 26) highlighted the possible benefits of saunas. Does this not suggest that a prime area of immediate research should be the indoor personal saunas that use infrared to heat the body?

From Bob Foster, Leek, Staffordshire, UK

I have often wondered why dogs love to lie out in the sun. After reading your article, I perhaps have the answer: they are soaking up red and infrared light. ▮

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SIMON BAILLY/SEPIA

Inside the vacuum

Quantum theory says a vacuum isn't truly empty. Probing it with powerful lasers could finally expose its hidden structure, discovers **Jon Cartwright**

ON THE outskirts of Hamburg, Germany, pulses from one of the world's biggest X-ray lasers race underground towards a stainless-steel chamber. Directly above, another huge laser waits. Soon, its beam will be sent down to meet the X-rays head on, bringing the two extraordinarily powerful beams of light together in an almighty burst of energy.

All very exciting, to be sure. But there is a serious side to these theatrics: the scientists behind them are hoping to see the vacuum. Not stray material in the chamber, or leftover gas, or particles of any kind, but the vacuum itself – what most people regard as pure emptiness, but modern physics says is brimming with quantum fields. Usually, these fields are perfectly undetectable, and the vacuum looks like nothing. But with enough light, even nothing can start to look like something.

"The hope is that, if it exists according to theory, we'll be able to see it," says Tom Cowan, an experimentalist at the Helmholtz-Zentrum Dresden-Rossendorf laboratory in Germany. "If it's not there, there's a problem."

Seeing the vacuum doesn't merely require massive lasers, but also extremely sensitive detection equipment. But the payoff could be great. The results will put our best theories of the vacuum to the test, and potentially give us a better handle on the dark matter that seems to occupy most of the universe. There is also a chance they could reveal that empty space is even stranger than quantum theory predicts.

The modern concept of the vacuum can be traced to the work of theorist Paul Dirac in the late 1920s. At that time, physicists already believed that the electromagnetic field filled all of space, but they still thought of matter as discrete particles, such as electrons and protons. Dirac saw that electrons could also be understood as energetic blips in an underlying field. Over a decade or so, his idea blossomed into quantum electrodynamics, or QED for short – the first successful quantum field theory.

By the 1970s, a more elaborate quantum field theory, the "standard model" of particle physics, had grown to encompass QED and account for all known matter and fundamental forces, besides gravity. When space is empty, these fields remain, but they aren't placid. The uncertainty built into quantum theory predicts that a field can never be guaranteed to have any particular strength, even zero: there must always be the possibility of something a little more, the chance of a fluctuation.

Quantum fluctuations

This isn't just abstract physics. As theorist Hendrik Casimir predicted in the late 1940s, quantum fluctuations can exert a measurable force. Put two metal plates extremely close together in a vacuum and the gap restricts the wavelengths of the fluctuating electromagnetic field that can fit between them. Outside the plates, the quantum fluctuations pile up, and the resulting imbalance draws the plates together. Today, engineers battle with this effect when building nano-devices for smartphones, game controllers and other technology.

Still, no one has actually seen the quantum vacuum itself. Normally, seeing something – even something transparent – involves it changing the light in some way. Take water in a cup: light passes through it, reflecting and refracting off the electrons surrounding the water's atoms. The distinctive optical pattern reaching our eyes is what tells us the cup contains water, rather than nothing.

But when light passes through a vacuum, we don't see a response from its fields at all, even if they are rife with fluctuations. The fields are invisible – they might as well not be there.

Except, maybe we haven't been looking hard enough. In the mid-1930s, when QED was still in its infancy, the theorists Werner Heisenberg and Hans Euler showed that if light is strong enough, it should begin to strain the vacuum fields, such that they affect the passage of any more light passing through – an effect known as vacuum birefringence.

"One must attribute certain properties to empty space itself," remarked theorist Victor Weisskopf, who furthered the analysis a year later. If they were right, the vacuum fields ought to be visible, after all.

Trouble is, no one had light bright enough to explore this uncharted realm of QED. In those days, the brightest light sources were arc lamps, commonly found in black-and-white cinema projectors, operating at a few kilowatts. But technology moved on. Once lasers arrived in the 1960s, maximum intensities ramped up to megawatts, then gigawatts and beyond.

More recently, "chirped pulse amplification" has opened the gateway to petawatt lasers, powerful enough to vaporise anything placed in their focus. Meanwhile, advances in particle accelerators have led to huge lasers that emit X-rays, rather than visible or infrared light.

None of these instruments was invented to probe the quantum vacuum. High-power optical lasers were developed mainly to study how light interacts with matter, and ›

to develop new methods of nuclear fusion. The scientists behind X-ray lasers mostly wanted to obtain the molecular structures of proteins, and to watch chemical reactions in real time. Still, "you get a new hammer, and you look for a new nail to hit with it", says Tom Heinzl, a theorist at the University of Plymouth, UK.

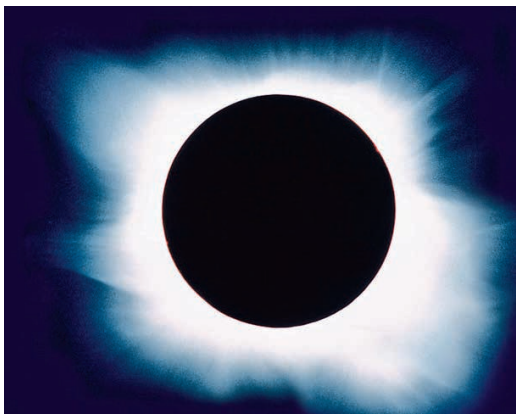
Two years ago, Heinzl was one of more than 50 authors who published a proposal to use one of the world's most powerful X-ray lasers, the European X-Ray Free-Electron Laser (XFEL) in Germany, to test Heisenberg and Euler's predictions of vacuum birefringence. The idea, which had been brewing for nearly two decades, involved crossing the XFEL's pulsed X-ray beam with that from a separate, 300-terawatt optical laser. The optical laser would strain the electron field, such that when the X-rays passed through, their orientation, or polarisation, would be very slightly rotated: the signature of the vacuum itself. "This is QED in an uncharted regime," says Heinzl. "No one has tested it before."

This could sound like juvenile antics – firing two powerful lasers at each other to see what happens. But the predicted effect is anything but dramatic. A single pulse of the XFEL, which lasts around a hundred-trillionth of a second, contains 100 billion X-ray photons. Out of those, just one would have its polarisation flipped by the vacuum, according to Felix Karbstein at the Helmholtz Institute Jena in Germany. No detector on Earth could hope to pan for that kind of signal. A trick was needed.

The potential answer came from several members of the experiment's research team, including Cowan. Known as a dark-field technique, it involves placing a small, circular object in the middle of the X-ray beam, just after it passes the light-strained region. Most of the X-rays are blanked out, but not those that have been affected by the vacuum: in the process of having their polarisations flipped, they are simultaneously diverted into a dark halo surrounding the beam, where a detector can spot them more easily. "It's like looking at the sun during an eclipse," says Cowan. "Thanks to the moon's shadow, you can see the sun's corona because it's no longer overwhelmed."

Last year, the team conducted a proof-of-principle experiment at the XFEL's Helmholtz International Beamline for Extreme Fields (HIBEF) research facility to test the dark-field concept, and found that it did indeed block out the background signal. "Our goal wasn't to do the measurement in that run," says Ulf Zastrau, who leads research on matter under extreme conditions at XFEL. "Really we just learned what we have to do." The researchers hope to attempt the first proper observation next year.

"The hope is that, if the vacuum exists according to theory, we'll be able to see it. If it's not there, there's a problem"



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EUROPEAN XFEL/JAN HOSAN

The vacuum volcano

With sufficiently powerful lasers, the vacuum should become visible, twisting the paths of passing photons (see main story). But push the vacuum even harder and it should produce particles of its own – an eruption of electrons and their antimatter partners, positrons. The phenomenon was first predicted by theorist Julian Schwinger in 1951, and requires immensely powerful laser fields – above 1 quintillion (10^{18}) volts per metre.

Researchers at facilities such as the Extreme Light Infrastructure in the Czech Republic, Hungary and Romania are hoping they might still break the Schwinger limit by crossing several beams at one spot, or reflecting a laser from a plasma "mirror" travelling at near the speed of light. So far, though, these all remain blueprints.

If they are successful, they won't be the first to claim to have detected vacuum birefringence. Ten years ago, astrophysicists using the European Southern Observatory's Very Large Telescope (VLT) in Chile detected polarisation in the faint light coming from a neutron star 400 light years away. Neutron stars are the dense remnants of massive stars with extreme magnetic fields. The researchers argued that if the star's light had started off polarised, the magnetic fields ought to have scrambled it – so the fact that there was polarisation meant it could only have been generated by the surrounding vacuum. "The [results] that we measured with the VLT can't be easily explained by our models unless the vacuum birefringence effects predicted by QED are included," said Roberto Mignani at the National Institute

VIKTORIYA SKORIKOVA/GETTY IMAGES

Light passing through water is reflected and refracted by its atoms (above), helping us see the clear liquid. To find an analogous response for the vacuum, a team at HIBEF in Germany (left) will use a method similar to how an eclipse lets us see the sun's corona (above left)

for Astrophysics in Milan, Italy, at the time.

But almost immediately after the team's claim was published, independent theorists began to dispute it, saying that the models depended too heavily on assumptions about the neutron star and its magnetic field. Earlier this year, results from NASA's Imaging X-ray Polarimetry Explorer strengthened the case for vacuum birefringence, but the analysis still depends on various model assumptions about neutron star behaviour.

By contrast, the polarisations of the X-ray photons at the HIBEF experiment will be clearly known, before and after. If any are detected in a different polarisation, there will be little debate that it was the vacuum that flipped them.

Of course, this depends on the QED predictions being correct – which they always have been. No theory has proved as successful as QED in the history of science. Famously, one particle property, the magnetic strength of the electron, can be predicted by QED to a relative accuracy of around 1 part in 1 trillion. "If you talk to a particle physicist and say you want to test QED, they'll start yawning," says Heinzl. "They'll say that's already been done decades ago." In this view, an observation of vacuum birefringence would just be the icing on the cake.

But, as Heinzl points out, past predictions of QED have all involved relatively weak light fields, and the addition of numerous corrections or "perturbations" to get the right answer, while avoiding any infinities cropping up in the calculations. For strong light fields, this type of maths almost always doesn't work – the calculations sum to infinity, whatever you do. The Heisenberg-Euler prediction of vacuum birefringence is a rare, lucky case in which a strong-field QED effect can be calculated without resorting to perturbations, and without any infinities. It is quite possible that this strong-field regime of QED fails to live up to the success of what has been tested before, and that some other, yet-unknown theory governs strong-field behaviour. "That's why we get excited," says Heinzl.

In such unexplored terrain, one new thing that could show up is the signature of a new particle related to dark matter. In the universe as a whole, dark matter is believed to account for 85 per cent of all matter, yet no one knows what it is. One of the leading candidates is a hypothetical, electrically neutral particle known as an axion, which barely interacts with ordinary matter. Current experiments involve looking for photons that might have been generated by axions in the presence of strong magnetic fields. But so far, no luck.

As these searches continue, theorists have begun to consider broader possibilities of axion-like particles – even a rich "dark sector" of various new particles and fields interacting with one another. In this case, an axion-like particle could be too short-lived to be detected by existing experiments, but could make its fleeting appearance known in a stronger-than-expected birefringence effect at HIBEF.

It's a long shot, says theorist Andreas Ringwald at the DESY particle accelerator lab in Germany, but a unique window nevertheless. "I think the experiment should be done," he says. "It's very well motivated. QED in this regime has never been tested in the laboratory before."

There is even the question of whether QED itself is the whole story of how strong light affects the vacuum. Since the 1930s, physicists have explored other theories of electromagnetism, in which empty space responds differently. Some predict vacuum birefringence much like QED does, but not all, at least not to the same extent. HIBEF itself won't be able to distinguish between these theories, but it will crack open the window to a new experimental testing ground that could potentially be explored in future experiments.

Not so empty space

As laser powers increase, physicists are looking not only to see the vacuum, but to force its quantum fields to erupt into real particles and antiparticles – the Schwinger effect, named after QED theorist Julian Schwinger, who described it (see "The vacuum volcano", left). "The wonderful thing about physics is that, as you probe new experimental regimes, there's always the possibility of surprises," says David Tong at the University of Cambridge.

In truth, though, any deviation from strict QED predictions wouldn't immediately be cause to throw away the theory. For over 30 years, the PVLAS ("polarisation of the vacuum with a laser") experiment at the National Institute of Nuclear Physics in Ferrara, Italy, has been trying – and failing – to pick out vacuum birefringence from background noise by reflecting a dim laser beam back and forth though a magnetic field hundreds of thousands of times. In 2006, its team reported a deviation from QED predictions, which some theorists took as evidence for axions. However, two years later, the team rebuilt the experiment, including replacing the laser, and found nothing. Likewise, any signal measured by HIBEF will need to be scrutinised for experimental artefacts.

Even with the dark-field technique and massive lasers, seeing the vacuum will be difficult. According to calculations by Karbstein, they can expect the vacuum to flip just two photons per hour. They can't simply let the experiment run forever, as XFEL beamtime is sparingly distributed. In a limited time window, success isn't guaranteed.

"It's all about controlling background noise," says Heinzl. "We might get lucky, we might not." Yet, if just a handful of photons emerge from the blinding laser collision with their polarisation altered, then, for the first time, physicists will have seen empty space itself. ∎

Jon Cartwright is a science journalist who specialises in cosmology, materials science and the quantum world

The great escape

As golden oyster mushrooms are declared a high-risk invasive species in the UK, mycologist **Joni Wildman** looks at whether hobbyist home-grow kits are seeding a biodiversity crisis

IN SPRING 2024, fungi enthusiast Heather Clarke was foraging near an ancient woodland in northern England when she spotted hundreds of bright yellow mushrooms carpeting the length of a fallen log. "My immediate thought was that they were oyster mushrooms," she recalls. "Except the oysters I'd found before weren't that colour." Although they look innocuous – and happen to be delicious, too – the discovery of this crop sent alarm bells ringing among the UK's fungi experts.

This is one of two confirmed sightings of golden oyster mushrooms in the UK, which have spread explosively throughout 25 states in the US in recent years, introduced there through small-scale growers and hobbyists. "This mushroom is like the Midas touch for ecosystems," says mycologist Aishwarya Veerabahu at the University of Wisconsin-Madison. "Wherever it spreads, it outcompetes native fungi, turning everything into golden oyster mushrooms."

Following these sightings in the UK, the fungus was last month declared a high-risk invasive species by the UK government, joining Japanese knotweed, grey squirrels and other notorious interlopers.

If the golden oyster mushroom takes hold in the UK, mycologists fear that it would outcompete native fungi, disrupting ecosystems and harming biodiversity. Climate models are now being used to find out how quickly it could spread throughout the UK, Europe and beyond.

What's more, there are signs that hobbyist breeding programmes may have supercharged the fungus's ability to multiply, leading mycologists to call for a rapid response to the incursion. "If we are going to have our mushroom and eat it, then we need to think about containment procedures," says Veerabahu.

The golden oyster mushroom (*Pleurotus citrinopileatus*) is a prized edible mushroom, foraged from the wild in its native range of East Asia and eastern Russia. It is also cultivated across this region, where it is enjoyed in soups and stir-fries and has been recognised in modern research as having potential health benefits, including antioxidant properties.

"Wherever the golden oyster mushroom spreads, it outcompetes native fungi"

Golden oyster mushrooms are native to East Asia and eastern Russia

FOR SUBMIT/ALAMY

But in recent decades, golden oysters have also been widely cultivated in the US and elsewhere. In the early 2010s, the species escaped into the wild in the US, quickly expanding from these niche cultivations to a continent-scale invasion now spanning some 2 million square kilometres. The events that followed in North America suggest what might be in store for the UK, too. "We already have the evidence of what this species can do," says Veerabahu. "If it has escaped and taken hold in the UK, I have no doubt that the same thing will follow."

For instance, mycologists in the US found that golden oyster mushrooms don't just spread quickly; they also reshape the ecosystems they invade. A study published in August by Veerabahu and her colleagues found that its aggressive colonisation excludes dozens of different native species from wood in typical habitats – with the share of wood colonised by some species reduced by as much as 55 per cent.

Shifts on this scale disrupt processes such as nutrient cycling and the symbiotic relationships fungi have with other organisms, such as trees that collaborate with particular fungi species to access nutrients, and insects that rely on native fungi as a food source or breeding habitat. "Fungi are deeply integrated into a complex web of interactions in the ecosystem," says mycologist Daniel Henk at the University of Bath in the UK.

Golden oyster mushrooms are also known for having a particularly ravenous appetite for deadwood. This allows them to fruit rapidly (mushrooms are the temporary fruiting bodies of a fungus) and produce many spores that reach newly available wood before their competitors. Once established, their fast growth also allows them to fully colonise the woody substrate quickly, giving them an advantage over slower-growing native fungi. The speed with which they decompose wood destroys deadwood habitats relied upon by already threatened insects such as the European stag beetle, whose larvae rely on slowly decaying hardwood as they develop over several years, as well as other animals and tree seedlings.

What's more, the rapid decay of deadwood ›

releases carbon dioxide into the atmosphere quickly, reducing how much carbon is stored in the forest long-term – and further harming Earth's already faltering carbon sinks.

This declining biodiversity could damage the resilience of forest ecosystems, as they depend on a wide variety of species to adapt to changing environments. An assessment published by the UK body for invasive species on 26 August says that there is a very high likelihood that the risks posed by the fungi will increase as the climate changes further. Forests already stressed by drought, floods and other extreme weather may become unable to tolerate further disruption to the balance of the ecosystem.

"Golden oyster mushrooms put irreplaceable ecosystems including ancient woodlands and primeval forests in even greater jeopardy than they already are," says Matt Wainhouse, a fungi and lichen specialist at Natural England.

Built to thrive

Our heating planet is also expected to favour the golden oyster mushroom invasion. Rising temperatures in the UK create conditions similar to the temperate and subtropical regions of East Asia, where golden oysters naturally thrive. "Climate change will increase the spread of this species," says Wainhouse.

Indeed, climate modelling of the mushroom's spread in the US, together with climate data on Europe, has led the assessment to conclude that countries across the continent are now at risk. These models use geolocations of the mushroom's sightings, combined with local environmental data, to identify the conditions in which it thrives. This information is then projected onto current and future climate scenarios worldwide to highlight areas that are at greatest risk, with large parts of Europe matching those favourable conditions.

The prospect of Europe-wide invasion is backed up by sightings of fruiting populations. Aside from those spotted in the UK, near the northern English cities of Liverpool and Barnsley, the species has been found in the wild across Europe, including in Denmark, Hungary, Italy, France, Germany, Spain, Switzerland, Austria and Belgium. These sightings may be "the tip of the iceberg", says Wainhouse, who suggests a spread on the same scale as that in the US may already be under way.

"This is not a local issue but a concern for the European continent," says Wainhouse, adding that he and his colleagues across the region are calling for a coordinated response. They recommend adding the golden oyster to the European Union's list of restricted non-native species and urge European regulators to work together to detect potentially invasive fungi earlier. To date, no fungi have made it onto the EU's Invasive Alien Species Regulation list of 114 restricted plants and animals.

So, how do mushroom farms and home-grow kits feature in all this? In controlled conditions, growers replicate the golden oyster's reproductive cycle. Grow boxes contain organic material already colonised by fungal mycelium, the main body of the fungus, which can produce a flush of mushrooms that spore as they mature and continue to do so until they decay or are destroyed. Each day billions of spores can be released, which travel tens to hundreds of kilometres. That creates multiple opportunities for escape – and genetic evidence leaves little doubt about where the golden oyster invasion is coming from.

Recent DNA-sequencing studies found that cultivation is the main route by which the species escaped into the wild in the US. The genetic data revealed that these wild samples didn't cluster into genetically distinct populations in each location, which you would expect if the mushrooms had spread naturally after the initial colonisation. Rather, samples from distant areas were genetically similar, a pattern consistent with repeated introductions of the same strain and human-mediated spread.

Crucially, the traits that make a mushroom suitable for commercial cultivation are the same ones that increase its invasive potential. "Commercial strains of fungi have been

MIRIAM-DOERR/GETTY IMAGES

DOUG WECHSLER/NATUREPL.COM

"If we are going to have our mushroom and eat it, then we need containment procedures"

ANDY SANDS/NATURE PICTURE LIBRARY/ALAMY

Spores released by hobbyist growing kits (left) have helped golden oyster mushrooms escape into the wild in the US (below left). Their spread in Europe threatens creatures that rely on deadwood, like stag beetles (bottom left)

selectively bred for specific qualities such as rapid growth, large fruitbodies that reproduce many times, mould resistance and temperature tolerance," says Wainhouse. As a result, these strains are very efficient at colonising new material. Indeed, all wild colonies that have been tested in the US are derived from two highly invasive strains, says Wainhouse.

Weighing the risk

According to the assessment, the escape of cultivated strains is a likely route for the establishment of future invasive populations, such as those already found in Liverpool and Barnsley. The UK also has an increasing appreciation, and appetite, for the fungal kingdom, says Chris Dowdeswell, the owner of the UK mushroom-growing business MycoPunks. Alongside the rise in foraging and broader interest in fungi, "we've seen an explosive growth in mushroom growing over recent years", he says.

Now that the golden oyster mushroom has been assessed as a high-risk invasive species, mycologists such as Wainhouse are urging UK government regulators, including the biosecurity minister and the Non-Native Species Secretariat, to ask mushroom cultivators and suppliers to voluntarily halt their trade. If this doesn't happen, golden oyster mushrooms could be added to the UK's alien species lists, which gives the government further power to ban the sale and distribution of the species in all of its forms.

Some parts of the fungi-enthusiast community didn't wait for the official risk assessment to act, with responsible growers and hobbyists already changing their practices. Last year the golden oyster mushroom was notably absent from the All Things Fungi Festival, a weekend event in West Sussex that attracts thousands of visitors. Despite mushroom-growing companies trading at the festival, the species was explicitly banned by the organisers. "Our role is to protect the land we celebrate while promoting responsible fungal engagement," says festival organiser Max Mudie. Several commercial growers have also already withdrawn the species from sale, including MycoPunks, citing concerns about its potential environmental impact.

The risk assessment echoes this view, encouraging people to grow native species instead. Dowdeswell says the company's decision has also prompted wider conversations with customers. "It is a great way that we, as mushroom growers, can talk to customers about the wider roles of fungi," he says.

The golden oyster mushroom isn't the only non-native fungus already being sold in mushroom-growing kits. For example, the pink oyster mushroom, *Pleurotus djamor*, is another fast-growing, selectively bred, non-native fungus that has been recorded in the wild in the UK on the citizen-science website iNaturalist. What sets the golden oyster apart is that its spread in the US has generated a body of research substantial enough to inform a formal risk assessment.

"DNA sequencing found that cultivation is the main route by which the species escaped into the wild in the US"

Even if the golden oyster mushroom's spread is curbed, this isn't the first, nor will it be the last, invasive fungus to cause harm. One notorious example is the death cap mushroom (*Amanita phalloides*), a highly toxic species that has spread into new regions around the world in recent decades. In places where it is non-native but now widespread, such as parts of California, poisonings have risen well above historical levels. "The invasive species story is a completely repeated pattern," says Veerabahu. "We see it over and over again."

At least the golden oyster mushroom is unlikely to poison anyone, and the assessment acknowledges a silver lining in the form of "economic benefit through wild harvesting and mushroom selling". Picking the fruiting bodies is unlikely, in itself, to drive its spread, provided they are placed in a sealed container straight away. Taking them home to the kitchen may even reduce the chance of further spore dispersal.

Foragers, at least, can still take some pleasure in the discovery, even if the wider ecosystem may be paying the price. When golden oyster mushrooms returned to the same log in Barnsley last year, Clarke was expecting them, placing them by the handful into sealed bags.

Did she try them? "It would be criminal not to!" she says. ▮

STOCKINASIA/ALAMY

Golden oyster mushrooms are a mainstay of East Asian cooking

Joni Wildman is a mycologist at the University of Bath, UK

PARTICLE physics is entering a new age of exploration. For decades, theory provided a map that pointed physicists towards new particles and told them roughly what to look for. Now, as the Large Hadron Collider (LHC) prepares for its most powerful incarnation yet, we have reached the limits of the map.

In late June, the LHC shut down high-energy operations ahead of a major overhaul. When it switches back on in 2030 as the High-Luminosity LHC, it will produce around 10 times as many collisions as before. Somewhere in that sea of data, physicists hope, may be signs of particles and forces we have never seen.

This situation leaves particle physicists with an unusual problem. The upgraded LHC will give them more territory to explore than ever before, but fewer clues about where the treasure is buried. Worse, its torrent of collisions will create an extraordinary computational challenge: any glimpse of new physics may be buried under billions of perfectly ordinary events.

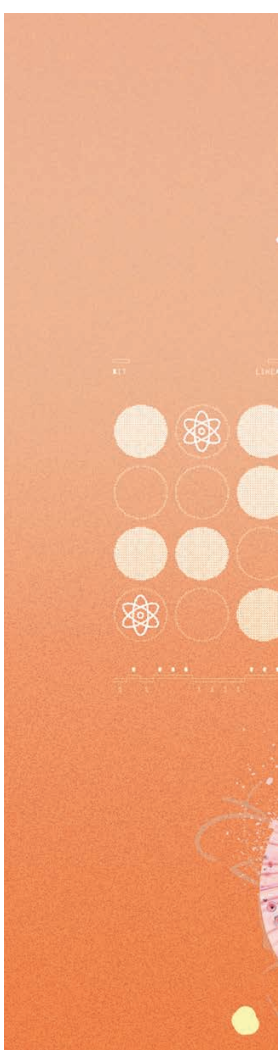
Sarah Alam Malik, a particle physicist at University College London, thinks quantum technologies could help. After more than a decade searching for dark matter at the LHC, she is developing quantum algorithms to spot unusual patterns in collision data. The hope is that, if physicists can record more of the strange quantum features inherent in particle collisions, her algorithms could probe those to search for new physics beyond the standard model – our best theory of the universe so far.

New Scientist spoke with Malik about how quantum computers could help us parse this coming deluge of data for new particles and even reveal clues in the elusive search for dark matter.

Thomas Lewton: Why are we sure that there are new particles out there to find?
Sarah Alam Malik: Partly, because we can't explain everything we've seen in the universe with just the standard model, the best theory of reality that we have so far. For example, we know there's something that we've dubbed dark matter, which accounts for a quarter of the universe. It is some invisible scaffolding

"We're trying to leverage quantum computers to accelerate the process of looking for new particles"

Particle collisions are inherently quantum, but much of that character is lost when we turn them into classical data. Particle physicist **Sarah Alam Malik** tells Thomas Lewton how preserving more of it could help us uncover new physics



PABLO PASADAS

that holds together the universe at large, and we have evidence of it from the scales of individual galaxies – from the rotational velocities of stars within those galaxies – all the way through to the large-scale structure formation of the universe. So, there's overwhelming evidence that there is something out there, some kind of unseen mass.

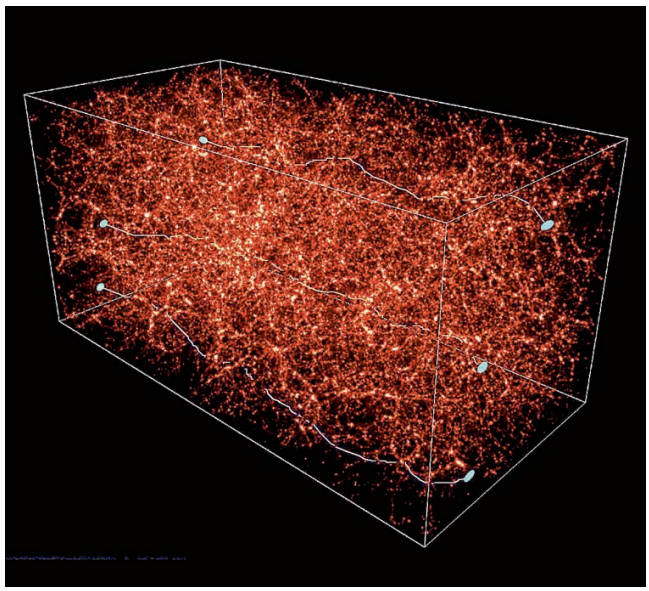
One of the most compelling proposals for what it might be lies within the domain of particle physics, and is something we call weakly interacting massive particles (WIMPs). We think it might be some new kind of particle or an entire sector of particles that we haven't observed so far, which may not interact with light, but have mass and interact gravitationally.

A few theories have predicted the existence of WIMPs for different reasons. For example, a theory called supersymmetry predicted a whole host of new particles that helped explain why a particle we discovered in 2012, known as the Higgs Boson, is much lighter than what the standard model suggests.

Among these new particles is the WIMP, which has all the right attributes to account for dark matter. The possibility that we could explain both dark matter and the Higgs's light mass with WIMPs was called the "WIMP miracle". Since 2010, we've been hunting for WIMPs at the LHC by smashing protons together and accounting for the energy carried away by the resulting particles. If some energy appears to be missing, it ›

"We can't explain everything we've seen in the universe with just the standard model"

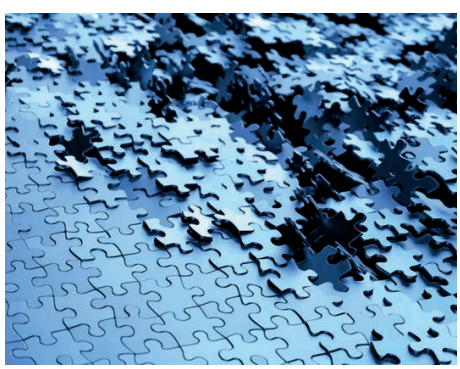
"Quantum computers may pick up anomalies that diverge from the standard model with greater sensitivity and accuracy"



YANNICK MELLIER/IAP/SCIENCE PHOTO LIBRARY

Left: Dark matter forms an invisible scaffolding that shapes galaxies and the large-scale structure of the universe

Below left: Scientific discovery has been likened to piecing together a jigsaw puzzle



KTSDESIGN/SCIENCE PHOTO LIBRARY/ALAMY

could mean an invisible particle – perhaps dark matter – escaped the detector.

The LHC hasn't found dark matter particles so far. But how are scientists planning to use quantum computers and AI to improve their chances?
There's now a huge desire to look for dark matter via a more bottom-up approach. Nature has just seemed far too clever for us so far. So, being more model-agnostic in our searches is, I think, the way to go.

Instead of looking for particles predicted by our current theories, like the WIMPs of supersymmetry, you write down the simplest interaction that could take place between, say, the core constituents of protons and dark matter particles. Then you work your way up from there. Or you dispense with theory and let the data be your guide.

There's a lot of excitement about quantum computers in this regard. They might be one of the most disruptive technologies of the century, and we're trying to leverage them to see if we can accelerate the process of looking for new particles in a model-agnostic way.

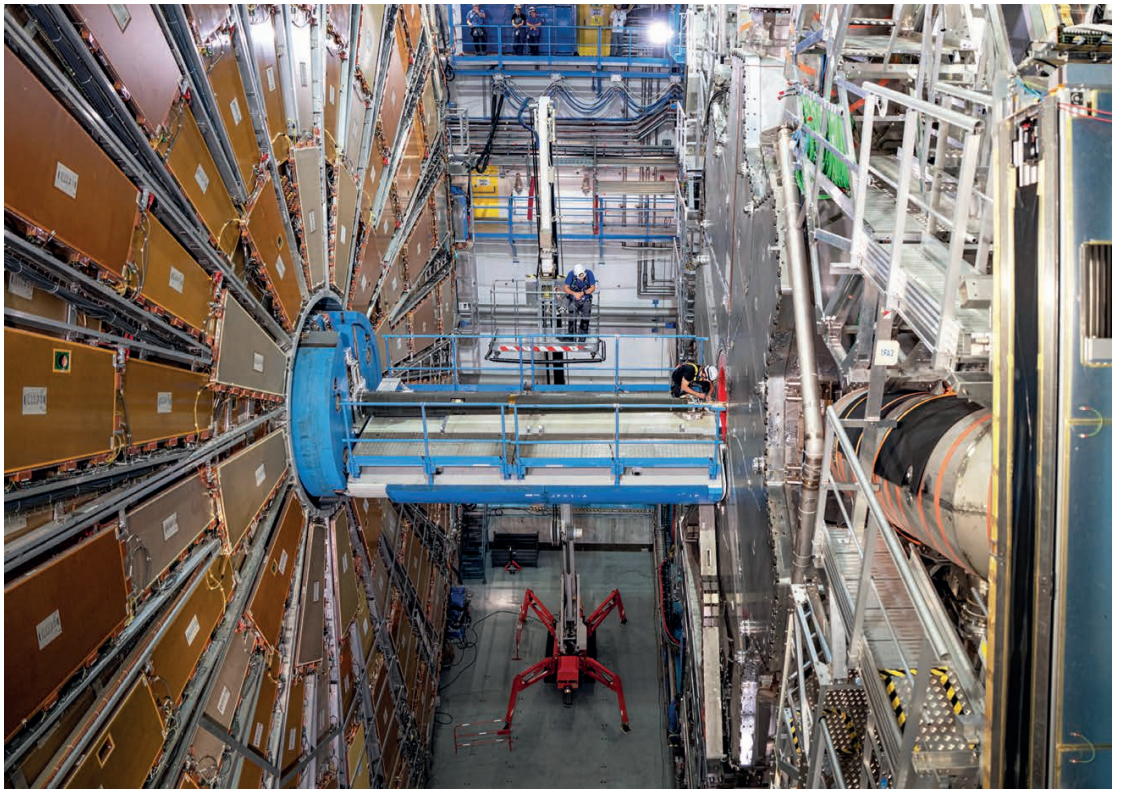
One of the examples of such a technique is called anomaly detection, which finds patterns in information using machine-learning techniques. Your bank might use techniques like these to detect whether your bank card has been used fraudulently based on deviations from past behaviour, which they know very well. In my research, we are training algorithms on standard-model processes. The idea is that quantum computers may pick up anomalies that diverge from the standard model with greater sensitivity and accuracy.

That sounds like a challenge. Tell me more about how it would work.
We're ultimately trying to draw some kind of "decision boundary" between two classes of data. This boundary helps us divide events at the LHC into two groups: those that are expected from the standard model, and potential anomalies or deviations from that.

We're developing quantum approaches that we think can yield an advantage. The key point is that the particle collisions at the LHC are inherently quantum processes – but when quantum particles pass through our classical detectors, they pretty much become classical data. A quantum system, unlike a classical one, can contain information about a range of possible outcomes and about correlations between particles. Once we measure it, however, we only record a particular outcome, and some of that underlying quantum information is lost.

The hope is that by applying as little classical processing as possible to the detector data, we can retain more of the information preserved in the original measurements. In doing so, quantum computers and algorithms might be able to identify subtle patterns in this less-processed data and separate different kinds of events in ways that are difficult for classical methods.

Exploratory studies in this direction look



TRACZYK, PIOTR/CERN

When the LHC switches back on in 2030 after an upgrade, it will produce 10 times more collisions than it did before

promising, but it is too early to gauge the extent to which quantum computing methods will be advantageous.

People are also looking at quantum sensors and whether we can extract information from the system without fully destroying the delicate quantum processes. This is very much in its infancy, but it is an exciting possibility.

Will these quantum algorithms be ready for when the LHC turns back on in 2030?
Quantum computing is expected to really come of age in the next, say, 10 years or so. So, you would hope that there is going to be some confluence of those timelines where we are able to really leverage it to its full potential, once we have this enormous dataset to play with.

Might we have got the wrong end of the stick entirely? What if dark matter isn't a new particle at all?
Maybe. One of the attractions of looking at dark matter is that it bridges the gap between cosmology and particle physics. Ultimately, that largest of scales is composed of these tiny particles that you're studying at these particle colliders.

If we discover something at a collider, and it seems to have the right attributes to explain dark matter, we still couldn't immediately conclude that it is the substance responsible for the dark matter we infer from the cosmos. Collider experiments probe processes that unfold over very short timescales – around 10^{-23} seconds – whereas dark matter has shaped the universe over billions of years. So, a particle that looks promising in the lab would still have to be shown to behave in the right way over cosmological timescales. And it remains possible that dark matter isn't a single new particle at all, but something more unexpected.

Currently, there's been this tension between two hypotheses: one is particle-based dark matter, and the other is modified gravity scenarios. These scenarios propose that the laws of gravity are actually different over large scales. Particle-based dark matter has been the leading contender so far, mainly because it can explain much more of the breadth of observation that we have, from individual galaxies and galaxy clusters to the cosmic microwave background radiation.

You have recently written a book that takes a much longer-term view of physics. Has that changed your perspective on all this?
My book *A Brief History of the Universe (and our place in it)* is about cosmic upheaval and our relationship with the universe: these big breakthroughs that overturned our worldview and also our perception of our place in it. So, it takes us from the ancient Babylonians, who looked at the stars and thought that they were gods or the messengers of great deities, through the ancient Greeks and the Islamic Golden Age and the Copernican revolution to the modern era.

It's made me realise that our frameworks have only ever been provisional, and [that we need to] treat our current framework as the same: that we shouldn't get too wedded to our ideas; that we know they are liable to be swept away in the next scientific revolution; that they will be upended by future generations in favour of something that may be quite radically different from anything we can imagine right now, because they will have much greater knowledge and access to technologies that might light up the universe in ways that we cannot foresee.

I really like a quote by astrophysicist Arthur Eddington, where he likens scientific discovery to putting together a great jigsaw puzzle. He said that one day you may ask a scientist how they're getting along, and the scientist says, "Very well. I've nearly finished this piece of blue sky." And the next day, you ask how the sky is progressing, and he says, "Oh, I've added a lot more, but it was sea, not sky. There's a boat floating on top of it." And next time, the boat might turn out to be a parasol upside down.

A new discovery may not mean that the already arranged pieces have to be taken apart, but that the whole picture has to be reinterpreted. It's just very exciting to speculate about how things might look thousands of years from now. ▮

Thomas Lewton is a features editor at *New Scientist*

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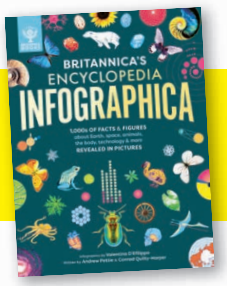

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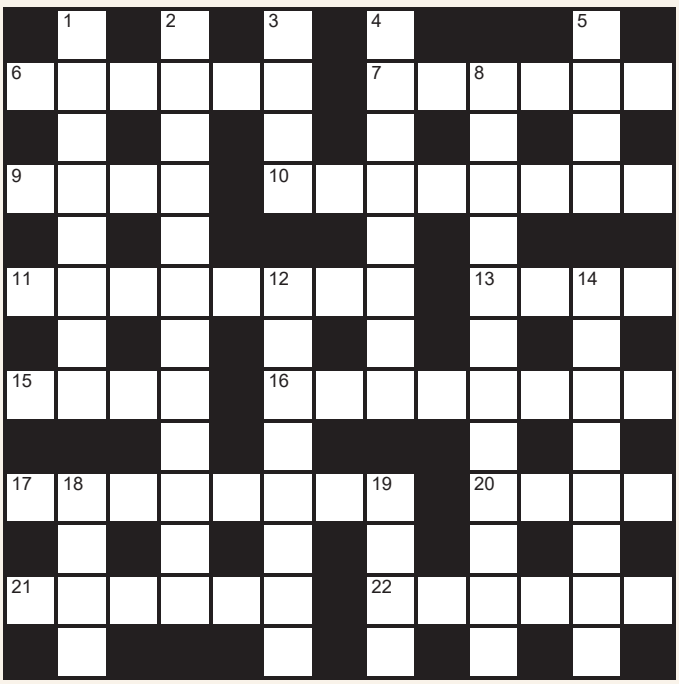
Cryptic crossword #196 *Set by Rasa*



Scribble zone

Quick crossword next week

ACROSS

6 Inform harbour dweller about heat and potential energy (6)
7 I don't care which solvent contains iodine (6)
9 Briefly, other audio device picks up soprano (4)
10 Head of geology spoke and threatened to go out (8)
11 Particular genre describes gym culture, primarily (8)
13 Increased bit of money with mining find (4)
15 Send back manufactured cheese (4)
16 Email me pitches involving new durable plastic (8)
17 Rodent fluff absent inside power unit (5,3)
20 One must leave to win settlement (4)
21 Scimitars alongside exhibits of ankle bones (6)
22 Graphs copper resistance versus binding energy (6)

DOWN

1 Having all the gear, expedition's leader made a joke (8)
2 Accuses jockeys eating reddish-brown marine delicacies (3,9)
3 Place to post mail ultimately engulfed by wetland (4)
4 Retail CV improved standing (8)
5 Surrender plant to an auditor (4)
8 Curious setter acquiring her parent's diagnostic tools (12)
12 Vent loudly over actress Thurman as the Bride, say? (8)
14 Famous knight is after present hidden in grass (8)
18 A cloth for cleaning up lab gel (4)
19 Check little arachnid (4)

Quick quiz #369
set by Chelsea Whyte

1 What animals have been released into the Mediterranean and Adriatic seas to fight an invasion of Atlantic blue crabs?

2 El Niño events have been gathering strength over the past 40 years, as shown by records from what animals in the Galapagos Islands?

3 A newly found star is the fastest ever detected, hurtling through its orbit at more than 8 per cent the speed of light. In which galaxy was it found?

4 What activity causes a type of brain cell called astrocytes to contract, leading to the formation of new neurons?

5 A baby echidna has been born and reared at a university for the first time. What is the name for the young of these egg-laying monotremes?

Plus Side
created by Puzzlr

Circle numbers in the grid below to use them, or cross them out to get rid of them. Circled numbers must add up to both the target at the end of each row and the target below each column.

9	7	5	9	7	7
2	7	5	1	2	17
9	6	7	6	8	15
9	1	4	8	5	10
4	6	1	9	7	7
20	21	5	1	9	

Answers to this week's puzzles on page 47

Our games are now playable online
newscientist.com/games

Feeling negative

Would it be possible to have anti-black holes, and how could we tell if we were looking at one?

Alex McDowell
London, UK
A black hole formed by the death of a star composed of antimatter would behave the same way as if its parent star had been matter. The antimatter would have as much gravity as the equivalent amount of matter. Hence, we would see no difference and it is possible that anti-black holes exist.

Experiments at the CERN particle physics laboratory show that antimatter falls down, not up. Therefore, an antimatter black hole would still attract matter and not repel it. The anti-black hole would still get heavier with anything that falls into it, whether it be matter or antimatter.

When matter comes into contact with antimatter, the two annihilate, converting mass into energy, given by Albert Einstein's famous equation: $E = mc^2$. Energy, mass and information can never get out of a black hole, and so, black holes – both regular and the anti variety – get heavier by absorbing energy.

"Relativity predicts white holes, but there is no experimental or observational evidence for their existence"

A neutron star is formed by the death of a star that is too small to form a black hole. It could become a black hole if more matter fell onto it. However, the opposite would happen with an anti-neutron star: it would get lighter as matter fell onto it because the matter and antimatter would annihilate each other, producing energy in the form of gamma rays and pions that would be able to escape. We would then be able to detect these gamma rays.

Relativity predicts white holes, but there is no experimental or observational evidence for their existence. White holes are the opposite of black holes: they spit out matter and energy and have an event horizon through which nothing can enter. Since they are predicted to spew out matter and energy, they should be easy to detect.

SHUTTERSTOCK/MAX4E PHOTO

Why do people look better in a mirror than they do in a photograph?

This week's new questions

Mirror mirror **Why do people appear younger and better-looking in a mirror than in a photograph?**
John Healey*, Semaphore, South Australia*

Don't cry **Are humans the only animals that cry? If so, why?**
Ray Smith*, Guyra, New South Wales, Australia*

Beautiful things

Why do humans have a common sense of beauty for things like sunsets and do other animals share this appreciation?

Ros Groves
Watford, Hertfordshire, UK
Human feelings of beauty often share similar characteristics, despite the object of beauty varying considerably among individuals.

What is common is a noticeable amplification of what an individual ordinarily finds merely pleasant and, crucially, non-threatening. A faint red glow of sunset or a hazy rainbow will turn into objects of intense beauty if they are particularly striking or vivid, spreading across the whole sky. A lush forest will always aesthetically trump a scattering of trees in the local park. Symmetry is also perceived as beautiful in facial and anatomical features.

Significantly, ancient civilisations saw both the rainbow and a vivid red and orange evening sunset as reassuring signs that a storm and its associated dangers had passed. Deep forests and abundant tree growth were viewed as providing wood for fires and offering shelter along with food. Within their community, physical signs of health and wellbeing would come to be perceived as attractive.

Today in industrialised societies, modern technology has mitigated the need for many of these survival-based observations, leaving an evolved sense of aesthetics so that we can be free to admire beauty per se. We even subconsciously transpose appealing aspects of natural phenomena to inanimate objects, in that bright rainbow-type colours tend to cheer us up, while the beauty of symmetry in the human form is also reflected in that seen in plants, ornaments and buildings.

It is virtually impossible to assess whether or not animals have a sense of beauty without falling into the trap of anthropomorphism. My own view is that, without the level of higher human understanding, animals will react solely with the business of survival in mind should they experience an unfamiliar version of something that is normally commonplace. In short, they may be curious and stare in assessing whether it poses a threat or not. They may then investigate further or retreat.

Bless you

Why don't we sneeze when we are asleep (continued)?

Lyndal Thorburn
Via email
Well, I know people aren't meant to sneeze in their sleep, but there is at least one factor that does enable people to start to sneeze and then wake in the middle of it.

I speak from experience. I have vasomotor rhinitis, a condition that is non-allergic inflammation of the nasal tissue, leading to sneezing and a blocked nose.

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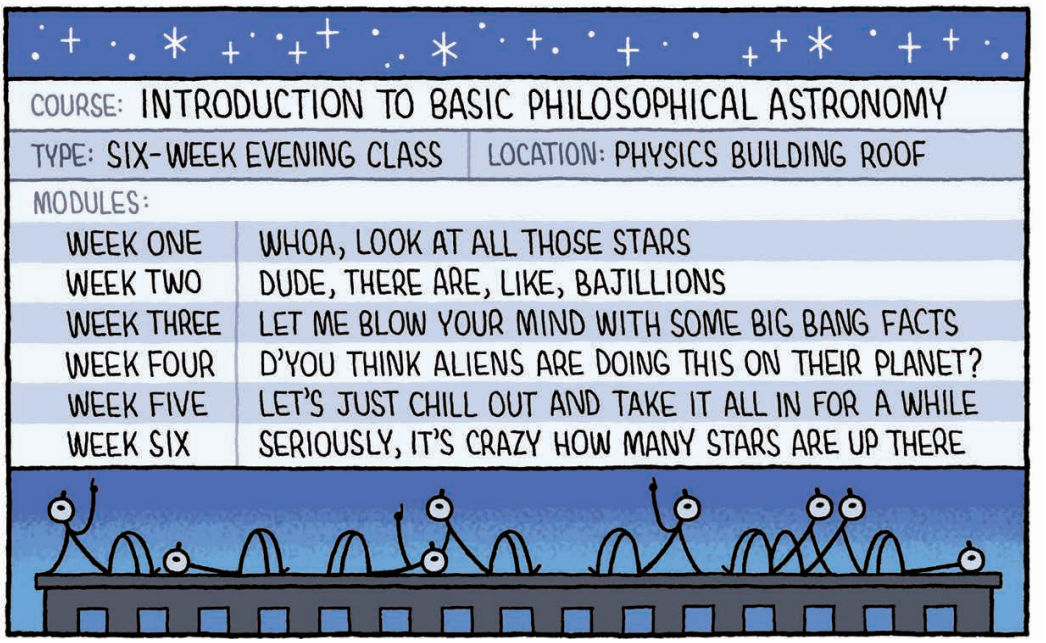
Tom Gauld
for New Scientist



Mine is initiated by strong perfumes, cigarette smoke or a drop in air temperature, particularly if the latter leads to feeling a chill around my torso.

It can strike while I am asleep on a hot night, particularly if I have fallen asleep with few bedclothes on and then my skin chills as the temperature falls. It can even occur if I just have a foot out from under a sheet, and it means I must have at least a sheet on when going to sleep on even the hottest nights. While I mostly wake and snuffle for several hours as a result of this, I recall two occasions when I actually woke up from a deep sleep in the middle of a big sneeze (the "choo" part of "ah-choo"). It was surprising to say the least.

Moon move

What changes will occur on Earth as the moon moves further away from us (continued)?

James Fradgley
Wimborne Minster, Dorset, UK
I have a few thoughts on this. In 200 million years, the day length will have increased about 5 per cent, so not hugely significant. The sun is getting brighter, by about 1 per cent in 200 million years, and so in a few hundred million years we will need no greenhouse effects at all, after which it will just get hotter and hotter. After something over 1 billion years, all the oceans will have boiled away, and Earth will be rather like Venus is today.

"I recall two occasions when I actually woke up from a deep sleep in the middle of a big sneeze (the "choo" part of "ah-choo")"

As for Earth's axial tilt, or obliquity, as the moon recedes, some gravitational interactions will arise that will throw it all over the place. But not for a billion years or so, so not our problem! But let's put on our thinking caps anyway and do something about it. Maybe move Earth away from the sun, terraform Mars, etc!

Hear that?

Why don't dogs look up when a low-flying plane or helicopter passes overhead? I've never seen one do this. (continued)

Ian Tindal
Via email
Most dogs I have owned looked up when there was a treat in my hand. Some dogs learn that food lives on tables and kitchen work surfaces very quickly. Dogs look up to follow the trajectory of a stick or ball – a rescue dog we had used to chase flocks of seagulls on the beach, leaping to try to catch one.

They will climb up or down very steep inclines on walks and seem to enjoy wide views from mountain tops. When I climbed trees in my youth, several dogs we had used to stand on their rear legs with front their feet on the trunk, looking up. My Keeshond was fascinated by the yellow Wessex helicopter that used to patrol the coast of Northumberland in the 1970s, often looking up before we could hear or see it. ▮

Answers

Quick quiz #369

1 Octopuses

2 Corals

3 The Milky Way galaxy

4 Exercise

5 Puggles

Cryptic crossword #196

ACROSS 6 Squeal, **7** Either, **9** Misc, **10** Guttered, **11** Specific, **13** More, **15** Edam, **16** Melamine, **17** Water rat, **20** Town, **21** Tarsal, **22** Curves

DOWN 1 Equipped, **2** Sea cucumbers, **3** Blog, **4** Vertical, **5** Cede, **8** Thermometers, **12** Fumarole, **14** Renowned, **18** Agar, **19** Tick

Plus Side *Solution*

9	7	5	9	7
2	7	5	1	17
9	6	7	8	15
9	1	4	8	10
4	6	1	9	7
20	21	5	1	9

PlantGPT

There are some things Feedback just isn't good at, and one of them is plant care. Whatever's the opposite of a green thumb (a red toe?), that is what we have. Plants wither and die under our ministrations, and we aren't alone in this: Mrs Feedback is, if anything, even worse, to the point where she once managed to kill a house cactus.

Hence, there was great rejoicing in the Feedback household when executive editor Timothy Revell sent us a press release about PlantSenso, "a gamified plant companion that transforms indoor greenery into an intelligent, interactive journey by giving nature a personality and voice through generative AI".

O frabjous day, we thought. A solution is at hand: finally our plants will live. And so we read on.

PlantSenso is a plastic gizmo with a little screen on the front. You insert it into the soil of a plant pot, whereupon it monitors light, moisture and temperature. This raw data is then displayed on the screen through the medium of an animated critter that looks like a reject from *Animal Crossing* or *Pokémon*. Readers old enough to remember the original *Tamagotchi*, or retro enough to still own one, may also experience a spark of recognition. If the plant is struggling, the PlantSenso animal will alert its owner, who can then intervene.

For instance, if the plant has been overwatered, the onscreen critter will be seen bobbing around in floodwater. If it isn't getting enough light, its environment becomes glumly crepuscular.

The press release explains the overall vision: "Designed specifically for plant beginners, Gen Z, and millennial families, PlantSenso replaces complex charts, technical parameters, and soil percentages with an intuitive, low-learning-curve visual experience. Instead of managing plants like a care chore, PlantSenso turns standard potted plants into emotionally connected digital pets, making plant care completely stress-free, fun, and highly giftable."

Twisteddoodles *for New Scientist*

Got a story for Feedback?
Send it to feedback@newscientist.com
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Consideration of items sent in the post will be delayed

We discussed PlantSenso with Mrs Feedback and she made the distressingly valid point that, over the years, we have supported our plant-care efforts by purchasing expert books, reading online guides, setting routines, trying to rope in Feedback Jr (prompting much eye-rolling) and even creating online reminders. None of these got through to us for more than a few weeks, and she suspected PlantSenso would be the same. We might get her one for Christmas.

Ottawasn't

Reader Kim Brooks was seeking information about Ottawa Comiccon, a gathering of fans of comic books, science fiction and other fun things, which is being held in Canada's capital city from 11 to 13 September. She proceeded to the search engine DuckDuckGo, only to be met with a strange assertion. Ottawa Comiccon, according to the AI summary at the top of the page, was a "Multi-genre fan convention in the United States".

Feedback would never just believe a story like this, even with the screenshot that Kim helpfully supplied, so we plugged "Ottawa Comiccon" into DuckDuckGo and got exactly the same thing.

To be fair to DuckDuckGo, there are places in Illinois, Kansas and other US states called Ottawa. But the AI summary included a link to the actual convention website, which is explicitly Canadian, with an Ontario address at the bottom. This is exactly the sort of thing one might want an intelligent system to be able to figure out.

However, Kim offers an alternative explanation, beyond mere AI tomfoolery: "Perhaps I have simply missed an annexation decree."

Abbrev

Lately, we have been collecting examples of names that have been unfortunately truncated by social media and other modern afflictions, such as the Stroke Association being deprived of its -ociation (15 August) and a quality assurance manager being similarly offensively abbreviated (29 August).

On this note, we have a story sent in by Steve Powell. Steve wasn't able to confirm it and our attempt also failed, as we will explain, but we like it, so what the heck.

Decades ago, Steve was told a story about "the late great Christopher Strachey", a computer scientist who, among many other things, created one of the first video games. "Apparently some periodical (it could have been *Computer Weekly*), in the 1970s, received a complaining letter about computer-typed correspondence always truncating their name," says Steve. "This complainant firmly blamed the computer. In response to this Christopher wrote a letter (which was, I believe, printed, though I cannot find a reference to it online)."

At this point, Feedback will cut in with a reminder that we, too, could not confirm this. *Computer Weekly*'s online archive extends only as far back as 2000, and while Strachey's papers are preserved by the Bodleian Library in Oxford, UK, Feedback was unable to find the letter Steve refers to in its online database. So take the following with a pinch of salt.

Strachey's letter apparently argued that the computer shouldn't be blamed for truncating the name. "The fault lies entirely with the programmer that did not allow for names longer than a fixed amount. I myself suffer from this affliction receiving letters addressed to STRACHEY, CHRIST: a title to which, I need hardly add, I do not aspire."

Feedback really wants this to be true. Can anyone, perhaps a hoarder of old computing magazines, shed some light on it?

New Scientist Discovery Tours

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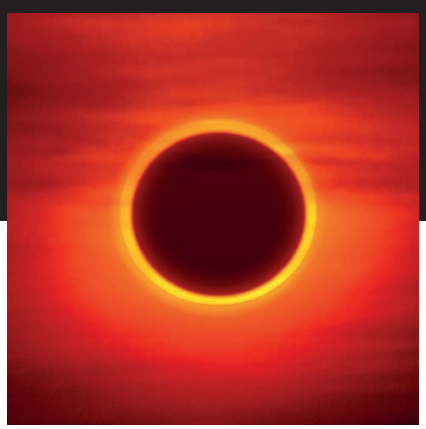
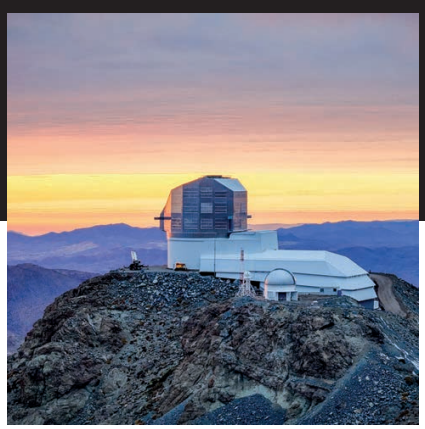


Annular solar eclipse 2027: Patagonia, Argentina

3 February 2027 | 8 days

Bronze Age, Phoenician and Roman Sardinia: Italy

11 April 2027 | 8 days



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