contents

Contents

Jantar Mantar ● Children's Science Observatory ● May - June 2016 ● Year - 16 No - 3 Issue - 93 website : http://hsb.iitm.ac.in/~jm

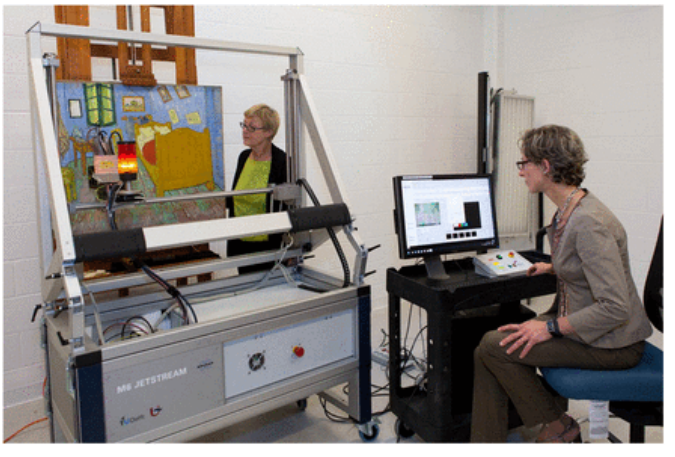
Puzzling Scales

This puzzle is an early example of balancing scales using abstract quantities, a visual representation of simple algebra.

Given that the top two scales are in perfect balance, how many marbles are required to balance the bottom scales?

Science and Culture: High-tech tries to reveal artistic motivations

Amber Dance, Science Writer



One day in 1896, while working on his painting Why Are You Angry?, artist Paul Gauguin changed his mind. He painted over the doorway in a bamboo hut behind the irate-looking Tahitian woman and her companions, leaving it opaque black.

Figure

In a new window

Conservation scientist Francesca Casadio (Right) and Inge Fiedler (Left) at the Art Institute of Chicago use a macro-XRF scanner to examine the pigment composition of Vincent Van Gogh's The Bedroom (1889, Helen Birch Bartlett Memorial Collection). Image courtesy of © The Art Institute of Chicago.

About 118 years later, analytical chemist and senior conservation scientist Francesca Casadio, of the Art Institute of Chicago, sat in front of an X-ray fluorescence (XRF) scanner waiting for it to reveal the original image behind the doorway.

Casadio compares the process to peeking through a time machine. With an array of tools—such as microscopy, spectrometry, infrared, and UV imaging—she and her art-detective colleagues can see where the artist painted over something, or identify the vibrant colors, now faded, that characterized a fresh painting. In so doing, they can uncover the choices the artists made and even speculate about what they were thinking, says Kristin Lister, a conservator of paintings at the institute. Although science cannot confirm an artist's intentions or creative actions, it can give art aficionados and historians plenty of novel insights to ponder and consider.

Next Section

Big Reveal

Scientists have facilitated all manner of art history revelations in recent years. In 2011, for example, a team of physics and art history experts came up with equations to describe the flow of liquid paint as Jackson Pollock poured it onto his canvases (1). In 2006, researchers used infrared imaging to determine that Leonardo da Vinci originally painted the Mona Lisa with clenched hands (2).

And the technological tools available to scientists probing artwork keep improving. The XRF scanner Casadio used on Why Are You Angry? is one of the field's newer devices. The scanner emits an X-ray that displaces electrons in the atoms of the

target material. As new electrons move to replace the missing ones, each element emits a unique fluorescence signature. NASA's Mars rovers use similar technology to identify the components of rock and soil. In the art world, the signatures indicate the elements that are common in specific pigments: copper for green or blue, mercury for red, chromium for yellow or green, and so forth.

The previous handheld point-and-shoot XRF technology, in use for more than a decade, could determine the pigment composition for a specific place on the canvas. But for Casadio to analyze that blackened doorway, she needed more than a single point. Fortunately, in 2013 scientists and conservators working with the Bruker Corporation of Berlin developed a commercial XRF scanner that traverses a painting 100 microns at a time (3). "If you're patient enough and you scan for two days you're going to have an image of the entire painting," Casadio says. "It's like having an X-ray in color."

Casadio used the newly developed scanner in 2014 when a prototype toured United States museums. In Gauguin's mysterious doorway, she discovered that the figure in the doorway was once larger, and accompanied by mercury and chromium: red and yellow. Perhaps, the investigators hypothesize, the doorway originally contained firelight. Lister speculates that the original bright colors overpowered the women in front. "He didn't want a background element to be too strong," she suggests.

Figure

Conservation scientists discovered that Van Gogh, in The Bedroom, had actually intended the walls to be purple (as in the digital recolorized visualization, Right) rather than blue (as in the existing painting, Left, 1889, Helen Birch Bartlett Memorial Collection). Images courtesy of © The Art Institute of Chicago.

Bedroom Mysteries

Sometimes multiple technologies can shore up the evidence provided by just one. Casadio and colleagues combined scanning

XRF with microscopy and spectroscopy to analyze the light blue walls of Van Gogh's Bedroom. In letters at the time, Van Gogh described the walls as purple. As Casadio announced at the February American Association for the Advancement of Science meeting in Washington, DC, the researchers found evidence of pink pigment, most of which had long since faded. Pink pigment, plus the blue in the painting (still present today), would together have created purple when Van Gogh originally daubed the canvas. And that original purple would have nicely complimented the yellow of the bed and chairs, Casadio observed.

But conservators don't always require the latest technology to answer their questions. Van Gogh painted three versions of Bedroom: one in 1888 before he was hospitalized after drinking paint and cutting off his earlobe, and two in 1889 when he was in an asylum, the year before he committed suicide. In addition to the version owned by the Art Institute of Chicago, the Van Gogh Museum in Amsterdam and Paris' Musée d'Orsay each possess a Bedroom. Scholars knew the Paris version was from 1889, but disagreed on which of the other two came first. In 2014, Casadio used standard X-ray imaging to compare them. The X-rays told her how thick the paint was, and which areas used lighter or denser elements. She saw evidence that Van Gogh was still thinking through the Amsterdam composition as he painted the Chicago version.

For example, in the Amsterdam Bedroom, he painted the purple walls completely and then added the portraits hanging on them on top. In the Chicago version, he did not paint the walls completely; he left an unpainted space where he knew those portraits would go. It would have been easier to achieve the colors he wanted for those portraits when painting them over a white background, as opposed to a purple one, Casadio explains. Thus, although it's not proof, the researchers suspect Amsterdam's Bedroom likely came first. All three versions are on display at the Art Institute of Chicago until May 10, 2016.

Street Credibility

Sometimes even primitive technologies—and some old-fashioned sleuthing—can help tell the story behind the painting. While studying Gustave Caillebotte's Paris Street; Rainy Day, Kelly Keegan, assistant conservator of paintings at the Art Institute of Chicago, noticed that the painting, Caillebotte's preparatory sketch, and the real-life Rue de Turin site have remarkably similar proportions. It would be difficult for an artist to capture the scene so perfectly merely by viewing it with the naked eye, Keegan says. How did Caillebotte transfer those proportions from the street to his sketch to the canvas?

Keegan suspected Caillebotte might have used some sort of optical device to capture the scene. Across the street at the School of the Art Institute of Chicago, she found an expert in historical imaging technology, assistant professor Pablo Garcia. He and Keegan thought Caillebotte might have used a camera lucida, basically a prism on a stick. By setting a camera lucida up in the Rue de Turin and looking down through the prism, the artist could have seen an optical illusion of the scene on his sketch paper, and traced it. The institute sent Garcia to Paris to try it out. He found the

spot where Caillebotte probably set up and was able to line up the ghostly image produced by the camera lucida with a copy of the artist's original sketch.

As for the transition from sketch to canvas, Art Institute of Chicago senior conservator of prints and drawings, Antoinette Owen, found a clue when she examined the sketch under a high-powered microscope. She noticed tiny divots, as if Caillebotte had measured the proportions with calipers. Garcia used the same method to blow up the sketch onto a canvas.

Neither experiment provides proof of Caillebotte's techniques, Garcia notes. But like so many of these studies, they do offer up potentially illuminating hints at how and why the artist approached aspects of his work. Says Garcia: "We're piling up a lot of really good clues."

Michelangelo Hid Anatomy Lesson In The Sistine Chapel

Robert George

Detailed analysis of Michelangelo's Sistine Chapel frescoes reveals a secret that's been hidden for 500 years: an image of the human brainstem in a panel showing God at the beginning of Creation, according to an article in the May issue of Neurosurgery, official journal of the Congress of Neurological Surgeons. The journal is published by Lippincott Williams & Wilkins, a part of Wolters Kluwer Health, a leading provider of information and business intelligence for students, professionals, and institutions in medicine, nursing, allied health, and pharmacy.

"We propose that Michelangelo, a deeply religious man and an accomplished anatomist, intended to enhance the meaning of this iconographically critical panel and possibly document his anatomic accomplishments by concealing this sophisticated neuroanatomic rendering within the image of God," write medical illustrator Ian Suk, BSc, BMC, and neurosurgeon Rafael Tamargo, MD, of The Johns Hopkins School of Medicine, Baltimore.

Image of Brainstem Concealed in Panel Showing Separation of Light from Darkness

The "concealed neuroanatomy" is found in Michelangelo's painting of the Separation of Light from Darkness, one of a series of nine Sistine Chapel panels showing scenes from the Book of Genesis. According to Suk and Tamargo, "anatomically correct ventral [front] depiction" of the brainstem can be seen in God's neck.

The authors present several lines of evidence to support their contention. History shows that Michelangelo was an avid student of anatomy, who performed

cadaver dissections throughout his life. "We speculate that during his numerous dissections, Michelangelo possibly dissected the brain and spinal cord and that over the years he probably acquired a sophisticated understanding of gross neuroanatomy," Suk and Tamargo write.

They buttress their argument by showing that the anatomy of God's neck is inaccurate. That discrepancy has been noticed before, with one previous critic suggesting that Michelangelo had painted God with a goiter (enlarged thyroid). Suk and Tamargo also show that the light source illuminating God's neck differs from that of the rest of the painting. For an artist of Michelangelo's anatomical and technical prowess, it's unlikely that these discrepancies were simple mistakes, Suk and Tamargo believe. They also note that God's beard appears "rolled up," as if to draw attention to the neck, whereas other panels show God with a long, flowing beard.

Suk and Tamargo aren't the first to suggest that Michelangelo included images of the brain in his Sistine Chapel frescoes. A previous researcher found an outline of the brain embedded in the famous panel depicting the Creation of Adam.

"We speculate that having used the brain motif successfully in the Creation of Adam almost a year earlier, Michelangelo wanted to once again associate the figure of God with a brain in the iconographically critical Separation of Light From Darkness," Suk and Tamargo write. They note the powerful symbolism of incorporating the human brain into a depiction of "the first act performed by God in the creation of the universe... situated immediately above the altar in the chapel." The authors acknowledge "the perils of overinterpreting a masterpiece"- and that not all art historians and other viewers will agree with their conclusions. However, they believe that a close analysis of the image, supported by the historical record, backs their interpretation: that Michelangelo "cleverly enhanced his depiction of God...with concealed images of the brain, and in this way celebrated not only the glory of God but also that of His most magnificent creation."

About Neurosurgery

Neurosurgery, the Official Journal of the Congress of Neurological Surgeons, is your most complete window on the contemporary field of neurosurgery. Members of the Congress and non-member subscribers receive 3000 pages per year packed with the very latest science, technology, and medicine, not to mention full-text online access to the world's most complete, up-to-the-minute neurosurgery resource. For professionals aware of the rapid pace of developments in the field, Neurosurgery is nothing short of indispensable.

Source: Wolters Kluwer Health: Lippincott Williams & Wilkins

News Feature: The perfect planet

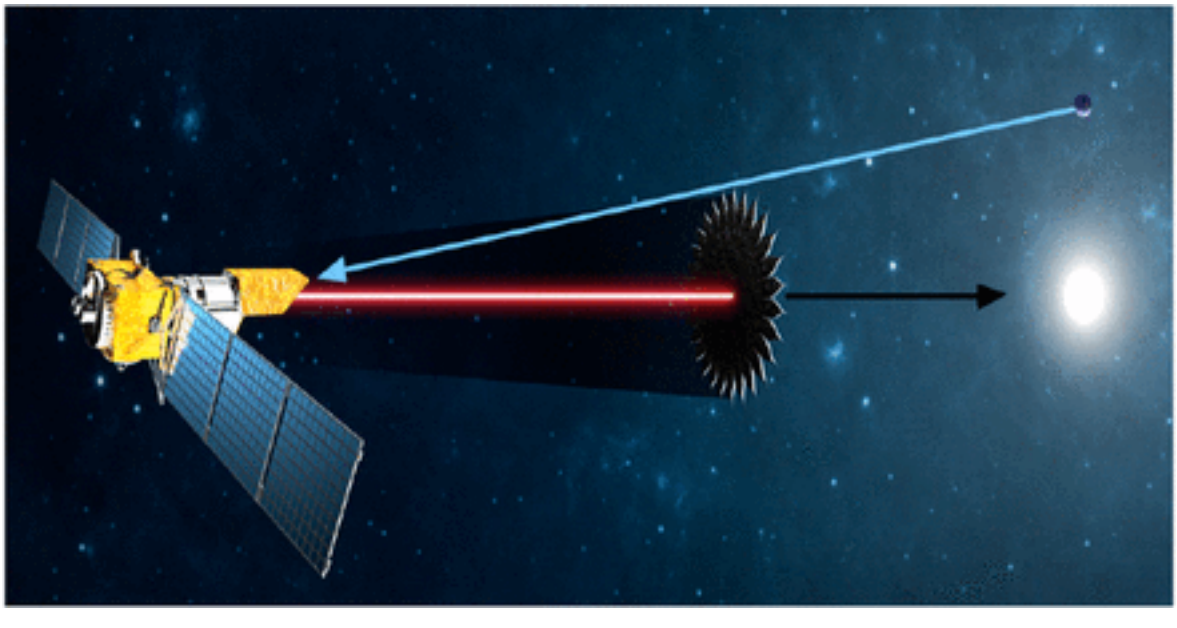
Adam Mann,
Science Writer

Astronomers are at odds over what makes exoplanets "habitable."

These days, astronomers barely bat an eyelid when they find a new exoplanet: there have been nearly 2,000 discovered in the last 10 years, up from roughly 100 in the previous 10 years. Nonetheless, astronomers were intrigued by a distant world discovered in July of 2015 (1). The planet, named Kepler-452b, is among the most Earth-like exoplanets ever discovered. It is only about 60% larger than Earth and takes 385 days to orbit a star slightly older and larger than our Sun. The question on everyone's mind: could Kepler-452b harbor life?

Figure

To directly detect exoplanets, a starshade, such as in this concept drawing, would fly in formation tens of thousands of kilometers in front of a telescope. At ~30 meters in diameter, the starshade would



block starlight, creating a shadow and allowing only planet light to enter the telescope. Image courtesy of NASA/JPL-Caltech.

The answer depends on whether a planet is in the habitable zone, often described as the narrow range of distances that a planet can be from its parent star, which would allow liquid water to exist on the planet's surface. Kepler-452b's host star shines a bit brighter than our Sun, so the standard account would place the exoplanet just on the edge of what's considered a likely place to find lakes and oceans. But prospects for life on Kepler-452b improved when the researchers adopted a more expansive version of the habitable zone, acknowledging that it is an "evolving concept." Their conceptual flexibility belies an ongoing debate among astronomers and astrophysicists about which planets could potentially harbor life.

Traditional models of what's inhabitable assume a planet not too different from our own: small, rocky, full of water, and with a thin atmosphere similar to ours. But are we being too narrow-minded, colored by ideas about life on Earth? Possibly, and so some astronomers are now broadening their horizons. "The whole concept of the habitable zone, it's not really that helpful anymore," argues planetary scientist Sara Seager of the Massachusetts Institute of Technology.

In recent years, researchers have contemplated superdry desert worlds, or giant Earths with atmospheres full of hydrogen, or even lonely planets wandering in deep space, untethered from their host stars, as examples of exotic exoplanets that could conceivably exist and harbor life, extending the habitable zone to more places, potentially making it easier to find signs of life elsewhere in the universe.

War of Worlds

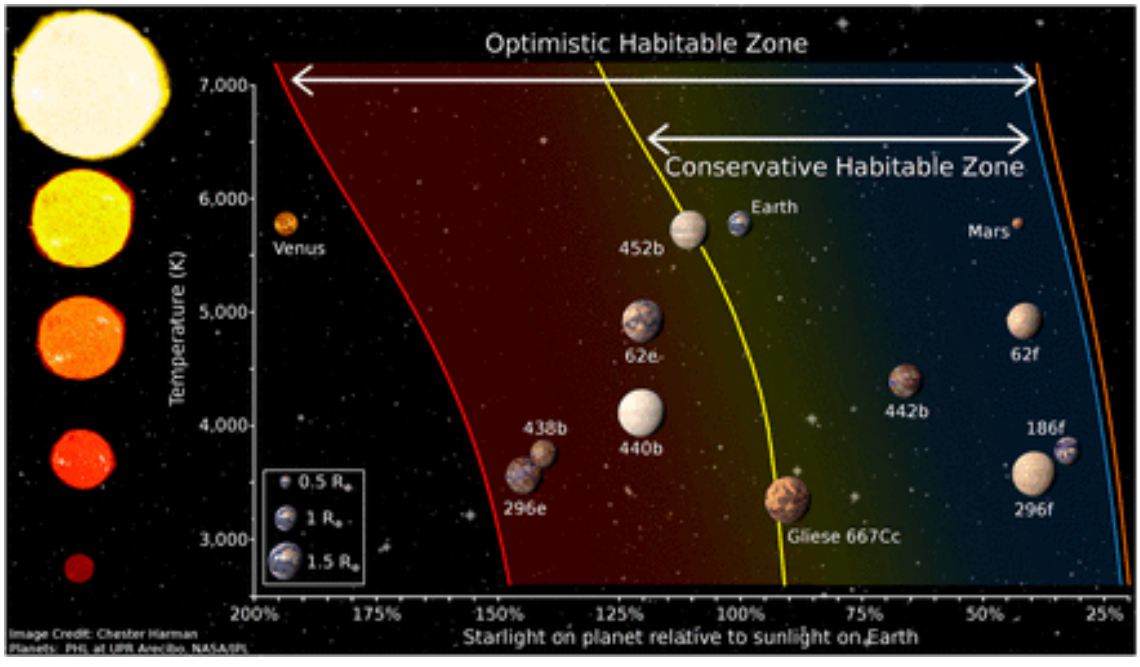
In 2013, Seager summarized such new ideas about the habitable zone in an invited review for the journal Science (2). "They wanted it to be provocative," she says, "and it did unleash a storm."

What followed was a spirited back-and-forth in the scientific literature, with many rejecting a wide expansion of the habitable zone's definition. Scientists argued that although weird worlds might be interesting, so far they remain purely speculative. Such speculation could have consequences.

The astronomy community is currently dreaming up next-generation space telescopes to launch in upcoming decades, which will be able to gather starlight reflected off of planets and identify potential biosignatures in their atmospheres. It might be a risky strategy to plan these observatories around hypothetical life-bearing exoplanets because the more places they need to look, the larger and more expensive the telescopes will have to be.

"I think everyone in the community understands that the work we've done on the habitable zone doesn't necessarily reflect perfect knowledge of the universe we live in, and needs to be revisited and revised," says planetary scientist Shawn Domagal-Goldman of NASA's Goddard Spaceflight Center in Greenbelt, Maryland. "There's an incentive to think outside the box. But the question is: how aggressively?"

Figure



One recent depiction of known planets in the habitable zone, based on climate model results reported in 2014 (10). More advanced models are in the works that could change the parameters. Image courtesy of Sonny Harman and exoplanets courtesy of The Planetary Habitability Laboratory at the University of Puerto Rico at Arecibo.

Homeward Bound

The inquiry begins with Earth: the only planet we know of that supports life. If it weren't for the chemical composition of its atmosphere, Earth would be uninhabitable. The Earth, on average, orbits the Sun at a distance of about 150 million kilometers. The amount of solar radiation Earth receives should give it a surface temperature below the freezing point of water. Life on Earth is only possible because our atmosphere traps infrared light radiated by the ground—the well-known greenhouse effect—heating the planet by around 33 °C. But even so, our planet's orbital distance from the Sun had to be just right, or else even this protective atmospheric blanket couldn't maintain a comfortable temperature.

With Earth as a guide, astronomers began wondering about the habitable zone around Sun-like stars. In 1979, astronomer Michael Hart calculated the extent of such a habitable zone, creating a simple model to test the zone's inner and outer edges (3). His work showed that even a nudge of about 7.5 million kilometers (a small fraction of the Earth–Sun distance) toward the Sun would heat the Earth and cause excess evaporation from the oceans. Because water is a potent greenhouse gas, the planet would warm further and vaporize more water, leading to a runaway greenhouse effect that would turn Earth into a hellish Venusian world.

On the other hand, moving Earth a

fraction farther away from the Sun would lower global temperatures, covering the ground in ice and snow, both of which reflect sunlight and cool the globe. This would create more ice and lock the planet in a frozen feedback loop from which it would never escape. Hart's calculations suggested that the habitable zone spanned only about 9 million kilometers, a precarious knife edge on cosmic scales.

Later, researchers revised Hart's narrow estimate, which had left out the effects of important processes. In 1993, geoscientist James Kasting of Pennsylvania State University took into account the carbonate–silicate cycle, which stabilizes the Earth's long-term climate by releasing carbon dioxide whenever global temperatures drop (4). Several times in Earth's geologic history, the entire planet has been covered in ice—creating the so-called "snowball Earth"—but managed to return to a temperate climate thanks to the carbonate–silicate cycle. Kasting showed that the cycle could disrupt Hart's frozen feedback loop, expanding the habitable zone out an extra 80 million kilometers to roughly the orbit of Mars.

Both Hart and Kasting presented their work before the discovery of a single exoplanet around a Sun-like star. Since then, astronomers have cataloged hundreds of other extrasolar systems, many containing planets unlike anything they'd ever imagined. Jupiter-scale behemoths orbiting closer to their parent star than Mercury does to the Sun and supersized rocky Earths are both common, even though our solar system contains no such worlds. Knowing that nature often proves to be more complex than our initial assumptions, some scientists have begun to think of the traditional habitable zone as too restricted. For ""“It should be called the conventional, Earth-like, life-as-we-know-it, if-there's liquid-water, potentially-habitable zone.”"""—Raymond Pierrehumbert"example, Kasting and colleagues pointed out that relaxing the definition even slightly creates what they call the "optimistic habitable zone," within which Kepler-452b falls (5).

Deep-Space Denizens

No wonder, then, that the traditional habitable zone has become contentious. "It should be called the conventional, Earth-like, life-as-we-know-it, if-there's-liquid-water, potentially-habitable zone," says physicist Raymond Pierrehumbert of the University of Oxford.

In 2011, Pierrehumbert and his collaborator, Eric Gaidos, suggested a way to greatly expand the habitable zone by bringing molecular hydrogen into the picture (6). Earth lost most of this light gas to space early in its history, but a slightly more massive planet would have enough gravity to retain vast amounts of it. Some microbes on our planet can use hydrogen as a food source, suggesting such hydrogen-rich worlds might be suitable for life. Hydrogen is a powerful greenhouse gas that—unlike water or carbon dioxide—doesn't condense into clouds, which reflect starlight and cool a planet down. Having a thick hydrogen atmosphere could allow an exoplanet to sustain the temperatures needed for liquid water out as far as the orbit of Saturn.

An atmosphere of hydrogen also bestows an unusual life-affirming advantage. On occasion, gravitational perturbations can eject planets from their

home system. With sufficient hydrogen, one of these rogue worlds could conceivably retain enough warmth to nurture life despite roaming starless through cold depths of deep space (7).

"It's creative talk to think about those planets, but whether we can observe them or not is the question," says geoscientist Ravi kumar Kopparapu, also of Pennsylvania State University.

To see an exoplanet, a direct-imaging telescope would need to block out the light of its parent star, which can be 10 billion times brighter than a planet orbiting at the same distance as Earth. A hydrogen-laden world orbiting out beyond Jupiter would be 25 times fainter, making such observations even more challenging.

Finding wandering planets is a still more demanding task. Should one of these orphan worlds pass between the Earth and a distant star, the exoplanet's gravity would bend and focus the starlight like a lens, briefly making the star flicker more brightly. Some astronomers think they've spotted space-farers using this technique, known as microlensing, but there's no consensus that these "sightings" are of true rogue planets.

Even if hydrogen-filled worlds fail to impress, perhaps a special sort of arid planet, with scant water, could harbor life. In 2011, a team led by planetary scientist Yutaka Abe, of the University of Tokyo in Japan, proposed expanding the habitable zone by modeling a hypothetical exoplanet that formed with little water (8). Similar to the fictional planet Arrakis in Frank Herbert's Dune series, such a world would be mostly desert with a few habitable lakes or ponds near the poles.

Although that doesn't seem like a promising prospect for life, including the possibility of dry exoplanets would make a star's habitable zone roughly three times wider than in traditional models. That's because a desert world can't create excessive amounts of ice and snow, so transferring it farther from its parent star doesn't lead to the snowball-Earth scenario. And it could exist much closer to its parent star than Earth is to the Sun and still be potentially habitable. Without vast oceans, water vapor wouldn't be able to accumulate in the atmosphere and trigger a runaway greenhouse effect.

Despite these advantages, some researchers dismiss such Dune-worlds. "I actually don't think they exist," says Kasting, explaining that atmospheric circulation is likely to carry rain clouds on a one-way journey from the poles down toward the drier equators. Once that water gets locked up in the crust in the form of hydrated silicates, it can't re-enter the atmosphere and be available for life. Kasting suggests that looking too close to a star is more likely to yield Venus-like planets than Earth-like ones.

But Seager points to the extreme diversity already seen in exoplanets, which suggests that even configurations that we think unlikely are possible. Findings published on May 2, for example, revealed the first case of Earth-like exoplanets orbiting an ultracool dwarf star, a star much cooler than our sun. Though two of these planets are perilously close to their star, with orbital periods of just 1.5 and 2.4 days, the lack of stellar heat puts the planets in the star's habitable zone (9). "Nature is smarter than us," she says. "And we'll observe what's out there."

Stepping-Up the Search

The search for habitable worlds will soon kick into high gear. Next year, NASA will launch the Transiting Exoplanet Survey Satellite (TESS), a sort of successor to the planet-hunting Kepler telescope. Whereas Kepler mostly observed worlds that are orbiting faint, faraway stars (making it difficult to do follow-up studies), TESS is designed to look specifically for exoplanets orbiting stars that are much closer to home and about 30 to 100 times brighter than those targeted by Kepler. TESS's catalog will provide targets for the James Webb Space Telescope (JWST), set to launch in 2018, which might be able to observe light from these worlds.

With its large 6.5-meter mirror, JWST will be the most powerful space-based telescope. Although astronomers are hopeful that it'll spot a small handful of worlds, gathering the few photons reflected off an exoplanet's atmosphere will be a tremendous challenge. Seager estimates that JWST will need to observe a small rocky planet for tens or even hundreds of hours to collect enough data to say something about its atmospheric composition. Because other astronomers will be using the telescope to conduct important observations of stars, galaxies, and large-scale structures in the universe, its time will be a limited resource.

"JWST was not designed to look for signs of life on planets around other stars," says Domagal-Goldman. "This is a difficult enough problem that you really want to design a mission from the ground up specifically for that."

That is exactly what astronomers are contemplating. At this year's American Astronomical Society conference, NASA astrophysics division director Paul Hertz announced the formation of four groups to study the feasibility of different flagship missions that could fly sometime in the 2030s. Two of the proposed telescopes—currently known as the Habitable Exoplanet Imager (HabEx) and the Large UV Optical and Infrared (LUVOIR) telescope—would be direct-imaging exoplanet observatories. Both could use either a starshade (a roughly 30-meter petal-like screen that would unfold and float tens of thousands kilometers in front of the telescope) or a coronagraph (a light-blocking instrument that sits within the telescope itself). Such implements would effectively block starlight and let in light from exoplanets, allowing astronomers to obtain spectra of planetary atmospheres and look for potential biomarkers, like oxygen.

HabEx would be a smaller mission focused on characterizing different exoplanets' properties and compositions to tell scientists about the variety of worlds in our galaxy. The more ambitious LUVOIR would surpass JWST, using an 8- to 12-meter mirror to study the formation of galaxies, stars, and planets in addition to detecting the biosignatures of life. Because both HabEx and LUVOIR share many objectives, the study teams aim to collaborate as much as possible on their scientific and technical investigations.

"How big the habitable zone is matters a lot," says Hertz. "It will have an impact on how big and powerful the telescope needs to be in order to collect enough of the kinds of planets you want to study."

Under a broadened definition, for example, researchers looking out to around 100 light-years away from Earth might think

they're going to find a total of 100 rocky planets in their stars' habitable zones. But if the habitable zone actually ends up being narrower than expected, then astronomers will have to either double the distance they look out toward or settle for finding only half the habitable planets they'd hoped for.

Those advocating for a traditional definition of the habitable zone argue that it makes a good guide as to where to start the search. "It's really the 'where-we-would-look-first' zone, more than anything else," says Domagal-Goldman. Adopting this conservative tactic, he says, wouldn't preclude using a direct-imaging telescope to study a promising candidate slightly outside the habitable zone. "Once you get it designed and up, then you can broaden your horizons," says Kasting.

But others think this approach carries its own risks. "I don't think we want to exclude anything," says Seager. "We have a very small chance of finding a true habitable planet, and we don't want to miss it because we were too dumb or too argumentative about which planet we should be looking at."

The good news is that researchers will have more information long before HabEx or LUVOIR fly. Both TESS and JWST will provide important information, as will the 2.4-meter Wide-Field Infrared Survey Telescope, an observatory about the same size as Hubble, which will launch in the mid-2020s and also carry a coronagraph to attempt direct exoplanet imaging. As the spectra come in, they will no doubt provide astronomers with a great deal of new data to mull over. "People love to argue," says Seager, "but it's nice when you can settle an argument with something real."

Excavation

Harappa of the South: Ten fascinating images of 2500-yr-old Sangam-era settlements

The News Minute takes you to the ancient site in 10 fascinating images

Keezhadi Pallai Sandhaipudur, a small village in Sivaganga has found a page in the history books. The Archaeological Survey of India believes that the village, now an excavation site, was once a settlement dating back to 2500 years ago, to the Pandya era. Around 3000 ancient artefacts have been found during the excavation. The News Minute takes you to the ancient site in 10 fascinating images.

1: A team of ASI experts has been carrying out the excavation in phases since February 2015. The second phase of the project started this January.

2: The most exciting discovery till date is that the village may have once been a settlement like Harappa and Mohenjo Daro.

3: ASI experts say Keezhadi village bears signs of being an ancient urban civilisation on the banks of Vaigai.

4: ASI has also unearthed a drainage system, similar to the Harappan civilisation site.

5: ASI also believes that the ancient settlement had trade links with countries like Rome after unearthing beads of agate, carnelian and quartz, reports The Hindu.

6: Tamil-Brahmi inscribed pots with

"typical Sangam Age Tamil names" such as Thisan, Aadhan and Udhiran have been found.

7: The treasure trove includes semi-precious stones such as chalcedony, agate, milky quartz, crystal ear lobe and pearl beads, reports The New Indian Express

8: The antiquities include iron implements, ivory dice, signets and pottery.

9: Archaeologists told TOI that there are 53 excavation trenches spread across 3.5km circumference in 80 acres of private agricultural land.

10: The excavation at Keezhadi continues until September this year. The site is open to the public.

Science & Environment

Fish eat plastic like teens eat fast food, researchers say

Matt McGrath

Environment correspondent

Image copyright Oona Lonnstedt

Image caption A Damselfish larva that has ingested tiny plastic particles

Young fish become hooked on eating plastic in the seas in the same way that teenagers prefer unhealthy fast food, Swedish researchers have said.

Their study, reported in Science, found exposure to high concentrations of polystyrene makes perch larvae favour the particles over more natural foods.

As a result of exposure to plastic, the young perch are smaller, slower and more susceptible to predators.

The researchers called for plastic micro-beads to be banned in cosmetics.

Chemical degradation

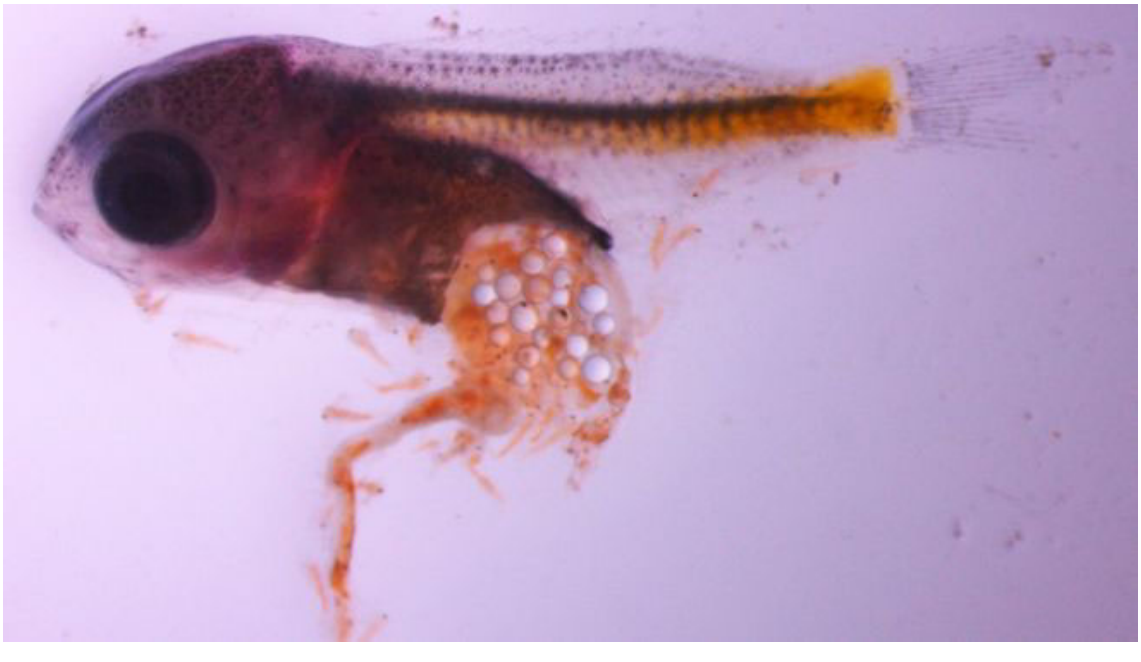
Concerns have been growing about the amount of plastic in the seas in recent years.

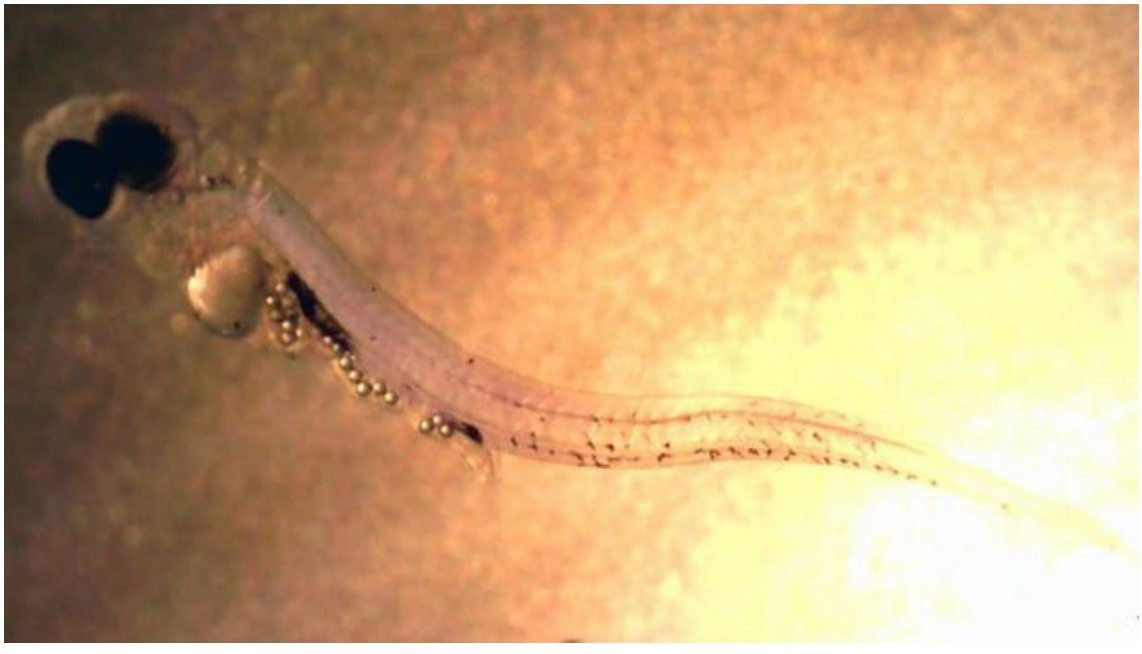
A study that came out last year estimated that about 8 million tonnes of plastic waste enters the oceans annually.

I think of it as unhealthy fast food for teenagers, and they are just stuffing themselves

Dr Oona Lonnstedt, Uppsala University

When exposed to UV radiation, chemical degradation and the movement of the waves, this plastic breaks down into tiny pieces. Those smaller than 5mm are referred to as micro-plastics. The term also covers plastic micro-beads from personal





care products.

Scientists have been worried that these tiny fragments can build up in the guts of marine creatures and can also leach toxic chemicals.

Image copyright Oona Lonnstedt

Image caption Young perch preferred plastic particles over natural foods in this study

To look at the impact of micro-plastics on the early life stages of fish, Swedish researchers exposed perch larvae to different concentrations of polystyrene in water tanks.

In the absence of micro-plastics, about 96% of the eggs successfully hatched. This dropped to 81% for those exposed to large quantities.

'Stuffing themselves'

The fish that did hatch in these waters with high quantities of micro-plastics were "smaller, slower, and more stupid" than those that hatched in clean waters, lead author Dr Oona Lonnstedt, from Uppsala University, said.

When exposed to predators, about half the young perch from clean waters survived for 24 hours. Those that had been raised with the strongest plastic concentrations were all consumed by pike over the same period.

Most surprising for the research team was the way that plastic changed food preferences.

"They all had access to zooplankton and yet they decided to just eat plastic in that treatment. It seems to be a chemical or physical cue that the plastic has, that triggers a feeding response in fish," Dr Lonnstedt told BBC News.

Image copyright Getty Images

Image caption Global plastic production is estimated to be 300 million tonnes annually with a significant amount ending up in the world's oceans

"They are basically fooled into thinking it's a high-energy resource that they need to eat a lot of. I think of it as unhealthy fast food for teenagers, and they are just stuffing themselves."

In the study, the researchers link the

decline of species such as perch and pike, observed in the Baltic Sea over the past two decades, to increased deaths at the juvenile stage. They argue that if plastics are impacting young fish across species, it could have "profound effects" on ecosystems.

'Silent threat'

Other researchers said the new study was an important step forward in understanding the mechanisms of impact on marine species.

"The observations we have so far are about the amount of plastic we find in the seas, and the amount we find within animals," commented Dr Erik Van Sebille from Imperial College London.

"Your intuition would say it is not good for a fish to eat plastic, but scientifically you want to prove it, you want to be able to show what the impacts plastic are having, and that has been very hard to determine until now, and that's why this is such a big paper."

The US has banned the use of plastic micro-beads in cosmetic and personal care products and there is growing pressure in the UK and Europe to do the same.

"It's body care products, it's not just toothpaste and scrubbers; some mascara and some lipsticks have plastic in them too," said Dr Lonnstedt.

"It's a silent threat that we haven't really thought about before. We need to ban the products that have micro-beads in them."

Ministers in the UK have already said that if the EU cannot adopt a common position on the issue then Britain is prepared to ban them unilaterally.

The House of Commons Environmental Audit Committee will be questioning witnesses about micro-plastics next week.

Follow Matt on Twitter @mattmcgrathbbc and on Facebook.

Science & Environment

Flat lens promises possible revolution in optics

By Roland Pease BBC Radio Science Unit

From the section Science & Environment

Image copyright Federico Capasso

Image caption This electron microscope image shows the structure of the lens (white line is 0.002mm long)

A flat lens made of paint whitener on a sliver of glass could revolutionise optics, according to its US inventors.

Just 2mm across and finer than a human hair, the tiny device can magnify nanoscale objects and gives a sharper focus than top-end microscope lenses.

It is the latest example of the power of metamaterials, whose novel properties emerge from their structure.

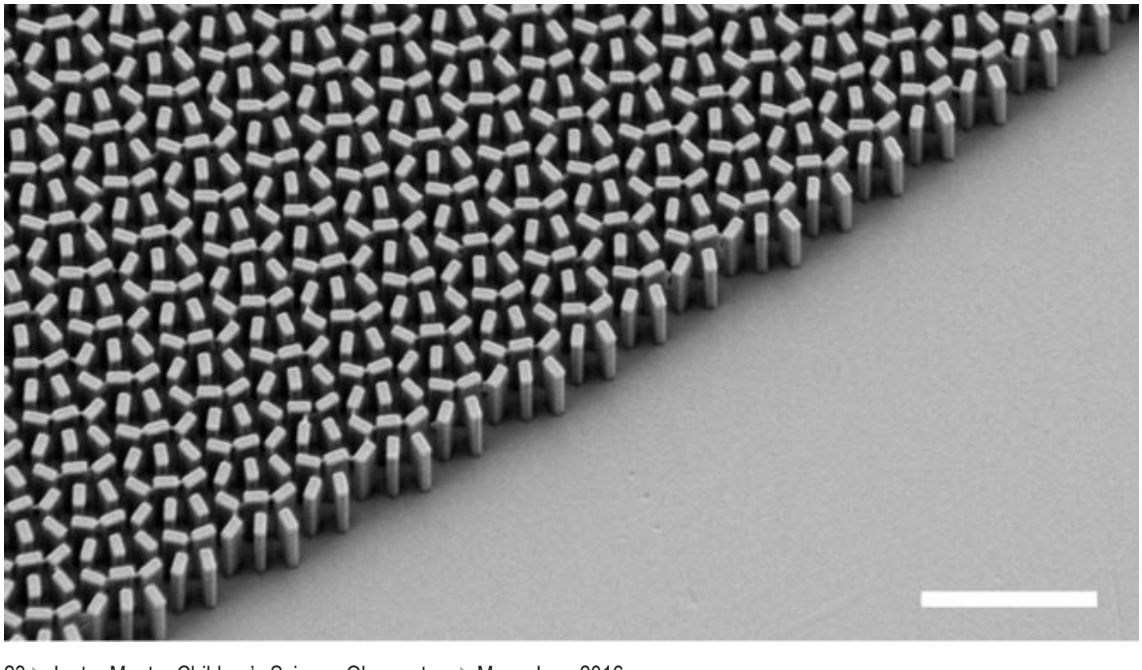
Shapes on the surface of this lens are smaller than the wavelength of light involved: a thousandth of a millimetre.

"In my opinion, this technology will be game-changing," said Federico Capasso of Harvard University, the senior author of a report on the new lens which appears in the journal Science.

The lens is quite unlike the curved disks of glass familiar from cameras and binoculars. Instead, it is made of a thin layer of transparent quartz coated in millions of tiny pillars, each just tens of nanometres across and hundreds high.

Singly, each pillar interacts strongly with light. Their combined effect is to slice up a light beam and remould it as the rays pass through the array (see video below).

Jump media player



Media player help

Out of media player. Press enter to return or tab to continue.

Media captionLight passing through the "metalens" is focussed by the array of nanostructures on its surface (video: Capasso Lab/Harvard)

Computer calculations are needed to find the exact pattern which will replicate the focussing effect of a conventional lens.

The advantage, Prof Capasso said, is that these "metalenses" avoid shortfalls - called aberrations - that are inherent in traditional glass optics.

"The quality of our images is actually better than with a state-of-the-art objective lens. I think it is no exaggeration to say that this is potentially revolutionary."

Those comparisons were made against top-end lenses used in research microscopes, designed to achieve absolute maximum magnification. The focal spot of the flat lens was typically 30% sharper than its competition, meaning that in a lab setting, finer details can be revealed.

But the technology could be revolutionary for another reason, Prof Capasso maintains.

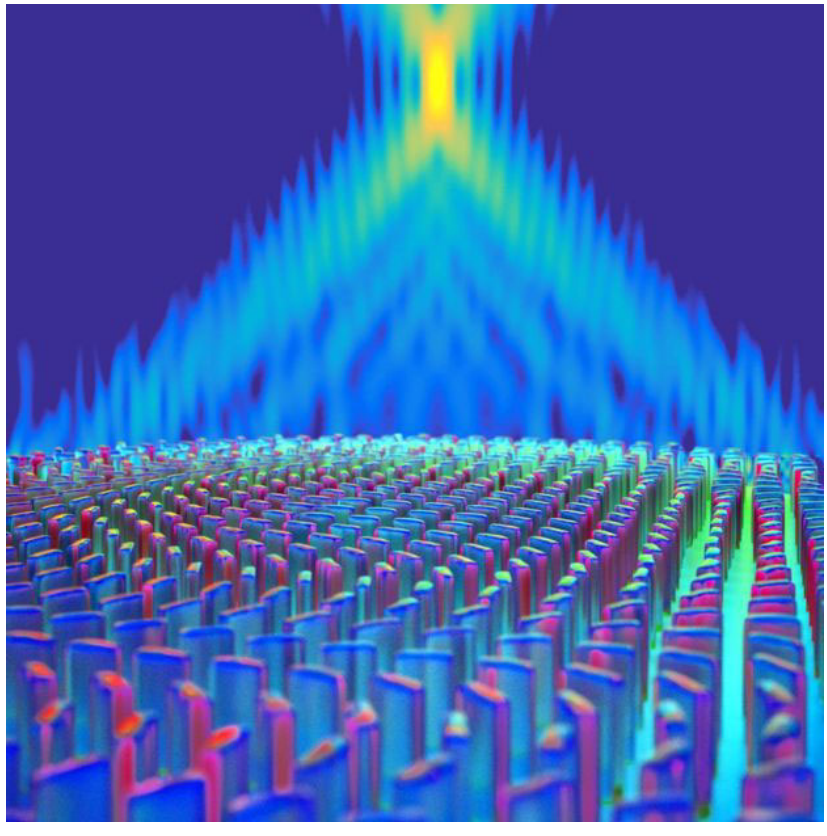
"The conventional fabrication of shaped lenses depends on moulding and essentially goes back to 19th Century technology.

"But our lenses, being planar, can be fabricated in the same foundries that make computer chips. So all of a sudden the factories that make integrated circuits can make our lenses."

And with ease. Electronics manufacturers making microprocessors and memory chips routinely craft components far smaller than the pillars in the flat lenses. Yet a memory chip containing billions of components may cost just a few pounds.

Image copyright Federico Capasso

Image caption The lens is much more compact than a traditional microscope objective



Mass production is the key to managing costs, which is why Prof Capasso sees cell-phone cameras as an obvious target. Most of their other components, including the camera's detector, are already made with chip technology. Extending that to include the lens would be natural, he argues.

There are many other potential uses: mass-produced cameras for quality control in factories, light-weight optics for virtual-reality headsets, even contact lenses. "We can make these on soft materials," Prof Capasso assured the BBC.

The prototypes lenses are 2mm across, but only because of the limitations of the Harvard manufacturing equipment. In principle, the method could scale to any size, Prof Capasso said.

"Once you have the foundry - you want a 12-inch lens? Feel free, you can make a 12-inch lens. There's no limit."

The precise character of the lens depends on the layout and composition of the pillars. Paint-whitener - titanium dioxide - is used to make the pillars, because it is transparent and interacts strongly with visible light. It is also cheap.

Image copyright Peter Allen/Harvard

Image caption The minuscule pillars have a powerful effect on light passing through

The team has previously worked with silicon, which functions well in the infrared. Other materials could be used to make ultraviolet lenses.

Or to get a different focus, engineers could change the size, spacing and orientation of the pillars. It simply means doing the computer calculations and dialling the results into the new design.

The team is already working on beating the performance of its first prototypes. Watch this space, they say - if possible, with a pair of metalenses.

Snails use 'two brain cells' to make decisions, Sussex University discovers

Image caption It is hoped the research may help engineers design more efficient "robot brains"

Snails use two brain cells to make "complex decisions", a team of scientists has found.

Researchers at the University of Sussex said one cell told the snail if it was hungry while the other cell told it if food was present.

The experiments used electrodes to measure brain activity of the molluscs when searching for lettuce.

Lead researcher Prof George Kemenes said the discovery would help engineers design "robot brains".

He said these would be based on the principle of using the fewest possible components necessary to perform complex tasks.

"Our study reveals for the first time how just two neurons can create a mechanism in an animal's brain which drives and optimises complex decision-making tasks," he said.

"It also shows how this system helps to manage how much energy they use once they have made a decision.

"Our findings can help scientists to identify other core neuronal systems which underlie similar decision-making processes."

The study was published in the journal Nature Communications

World Environment Day

THE THEME

Each WED is organized around a theme that focuses attention on a particularly pressing environmental concern. WED 2016 is themed on the illegal trade in wildlife under the slogan'Go Wild for Life'.

THE HOST

Every WED has a different global host country, where the official celebrations take place. WED highlights the environmental challenges facing that country, and supports the effort to address them. This year's host is Angola.

EVERY ACTION COUNTS

Through decades of WED celebrations, millions of people from all over the world and from all sectors of society have taken part in environmental action. By bundling their energy, WED has the power to generate hugely positive impacts on the planet.

GO WILD FOR LIFE

The booming illegal trade in wildlife products is eroding Earth's precious biodiversity, robbing us of our natural heritage and driving whole species to the brink of extinction. The killing and smuggling is also undermining economies and ecosystems, fuelling organized crime, and feeding corruption and insecurity across the globe.

Wildlife crime endangers iconic elephants, rhinos, tigers, gorillas and sea turtles. In 2011, a subspecies of Javan rhino went extinct in Vietnam, while the last western black rhinos vanished from Cameroon the same year. Great apes have disappeared from Gambia, Burkina Faso, Benin and Togo, and other countries could quickly follow. Lesser-known victims include helmeted hornbills and pangolins as well as wild orchids and timbers like Rosewood – flowers and timber are also considered wildlife!

Huge efforts to counter the illicit trade - including stronger policies, awareness campaigns and investments in community

conservation and law enforcement - have scored some great successes. However, many species remain at risk and it will take a dedicated and sustained effort by each and every one of us to turn the tide.

How can we do it? More people need to understand the damage this illicit business is doing to our environment, livelihoods, communities and security. We must change our habits and behaviour so that demand for illegal wildlife products falls. More awareness and action pushes governments and international bodies to introduce and enforce tougher laws and combat those still willing to break them.

This year's theme for WED – Go Wild for Life – encourages you to celebrate all those species under threat and take action of your own to help safeguard them for future generations. This can be about animals or plants that are threatened within your local area as well as at the national or global level - many local extinctions will eventually add up to a global extinction! Whoever you are, and wherever you live, show zero-tolerance for the illegal trade in wildlife in word and deed, and make a difference.

A HOST WITH A MISSION

This year's World Environment Day celebrations are hosted by Angola, a country seeking to restore its elephant herds, conserve Africa's biodiversity-rich wildlife, and safeguard the environment as it continues to rebuild after more than a quarter-century of civil war.

Every World Environment Day (WED) is organized around a theme that reflects a pressing environmental concern. The theme for WED 2016 is the illegal trade in wildlife, which threatens species such as rhinos and tigers with extinction. Wildlife crime also

undermines economies and security, especially in developing countries.

"Angola is delighted to host World Environment Day, which will focus on an issue close to our hearts," *said Angolan Environment Minister Maria de Fatima Jardim.****"The illegal wildlife trade, particularly the trade in ivory and rhino horn, is a major problem across our continent. By hosting this day of celebration and awareness-raising, we aim to send a clear message that such practices will soon be eradicated."***

Angola boasts environmental assets including pristine coastline as well as forests and grasslands comparable to those that draw many tourists to neighbours Namibia and Zambia.

The country's wildlife includes lions, great

apes and giant sable antelope, a critically endangered species found only in Angola and listed as critically endangered by the International Union of Conservation of Nature. The Great Elephant Census is expected to release the results of its Angola survey in the coming months. Bird life includes African Grey Parrots, whose decline across the continent is widely blamed on their illegal harvesting for the pet trade.

The government recently launched a string of initiatives to enhance conservation and stiffen law enforcement. To demonstrate its commitment to curb elephant poaching, Angola last year submitted a National Ivory Action Plan as part of its membership of CITES, the UNEP-hosted international convention designed to prevent trade in wild animals and plants from threatening their survival.

The plan includes stiff penalties for poaching and ivory trafficking and stronger policing, including more training for wildlife rangers and the posting of a wildlife crime unit to the international airport in the capital, Luanda. In March, officials presented a draft law banning the sale of ivory, a move that would end the open sale of ivory artefacts at Luanda's bustling Benfica market. Angola also is discussing the establishment of several vast trans-frontier conservation areas, including one that would include the wildlife-rich Okavango delta in Botswana, and another that incorporates Namibia's wild Skeleton Coast.

Angola is embracing this ambitious agenda – and the high-profile role as host of WED – even as it continues to rebuild after a long and damaging civil war that only ended in 2002. The country can look to other African countries, especially safari destinations, and the growing revenues they earn from ecotourism to appreciate the value of safeguarding the environment and protecting iconic species from illegal poaching and trafficking.

With organized crime increasingly involved in the trade, experts also warn that trafficking also threatens to heighten corruption and insecurity in source countries as well as destroying their national heritage.

COMMITTED TO CURBING WILDLIFE CRIME

Angola, the global host of World Environment Day 2016, has announced a drive against wildlife crime in order to safeguard its natural heritage and help protect Southern Africa's rich biodiversity. Its commitments have been welcomed by international organisations and conservation groups. Ahead of WED, Angola has:

· Vowed to end the trade in illegal wildlife products in the country, including at Benfica Market in the capital, Luanda, one of the largest ivory markets in Africa.

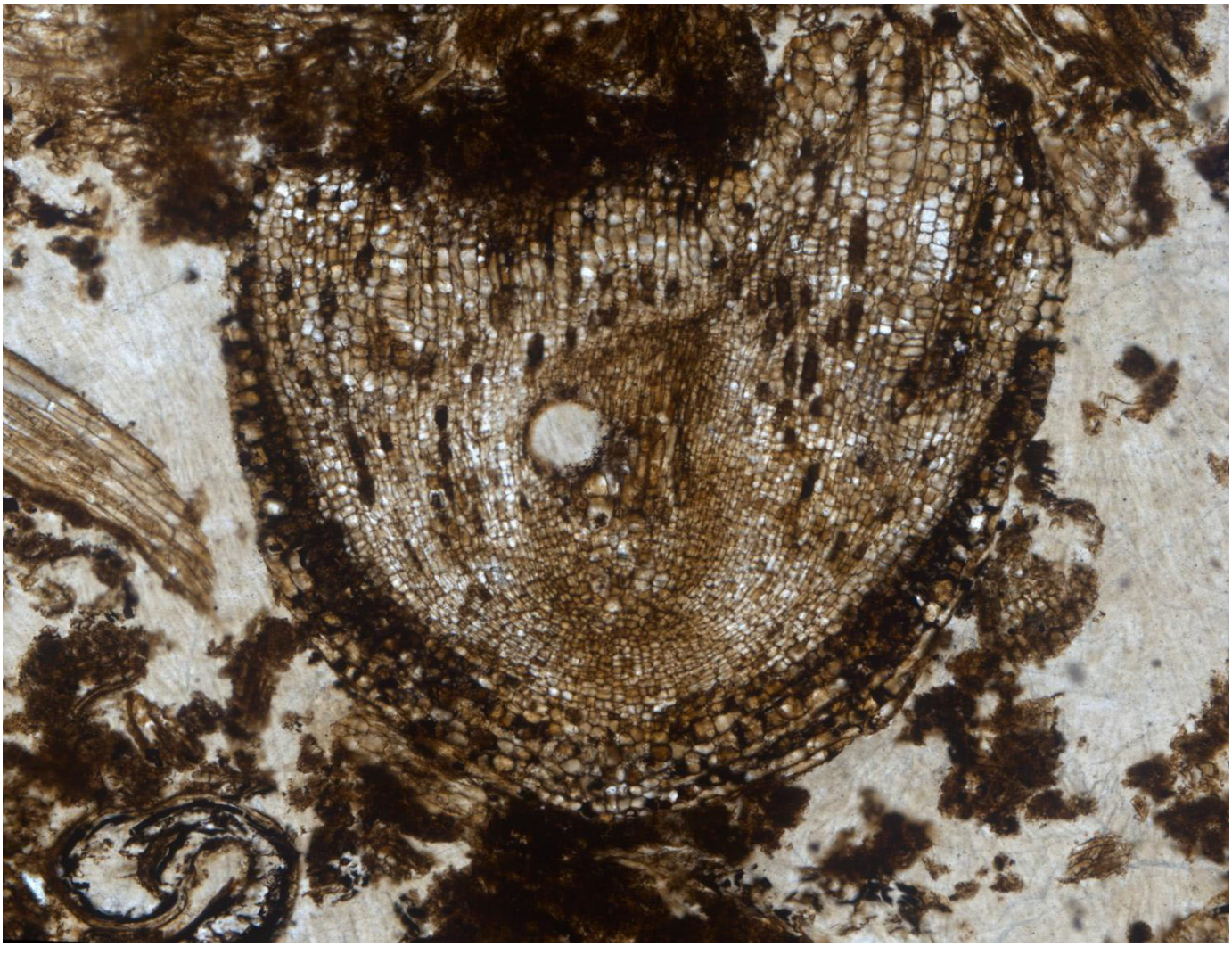
· Announced tougher border and airport screening controls to counter the smuggling of illegal wildlife products.

· Joined 12 other African nations in signing the Elephant Protection Initiative, which focuses on safeguarding elephants through measures such as closing down domestic markets.

· Pledged to undertake a robust inventory of its ivory stockpile.

· Promised to fulfill its commitments under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), including stepping up implementation of its National Ivory Action Plan.

· Hosted the International Conference of the Africa Prosecutors' Association, which resulted in a declaration calling for strengthened cooperation within the CITES framework.



Scientists discover oldest plant root stem cells

Scientists at Oxford University have discovered the oldest known population of plant root stem cells in a 320-million-year-old fossil.

The cells, which gave rise to the roots of an ancient plant, were found in a fossilized root tip held in the Oxford University Herbaria.

As well as revealing the oldest plant root stem cells identified to date, the research also marks the first time an actively growing fossilised root has been discovered — in effect, an ancient plant frozen in time.

The study is published in the journal *Current Biology*.

Oxford Plant Sciences PhD student Alexander (Sandy) Hetherington, who made the discovery during the course of his research, said: 'I was examining one of the fossilised soil slides held at the University Herbaria as part of my research into the rooting systems of ancient trees when I noticed a structure that looked like the living root tips we see in plants today.

'I began to realise that I was looking at a population of 320 million-year-old plant stem cells preserved as they were growing — and that it was the first time anything like this had ever been found.

'It gives us a unique window into how roots developed hundreds of millions of years ago.'

Stem cells — self-renewing cells responsible for the formation of multicellular organisms — are located in plants at the tips of shoots and roots in groups called meristems. The 320 million-year-old stem cells discovered in Oxford are different to all those living today, with a unique pattern of cell division that remained unknown until now. That tells us that some of the mechanisms controlling root formation in plants and trees have now become extinct and may have been more diverse than thought.

These roots were important because they comprised the rooting structures of the plants growing in Earth's first global tropical wetland forests with tall trees over 50m in height and were in part responsible for one of the most dramatic climate change events in history. The evolution of deep rooting systems increased the rate of chemical weathering of silicate minerals in rocks — a chemical reaction that pulled CO_2 out of the atmosphere, leading to the cooling of Earth and thus one of the planet's great ice ages.

The fossils studied during this research are the remains of the soil from the first giant tropical rainforests on Earth. The rock in which the soil is preserved formed in the Carboniferous swamps that gave rise to the coal sources spanning what is now Appalachia to central Europe, including the coal fields in Wales, northern England and Scotland.

Sandy has named the stem-cell fossil *Radix carbonica* (Latin for 'coal root').

Professor Liam Dolan, Head of the Department of Plant Sciences at Oxford University and senior author of the paper, said: 'These fossils demonstrate how the roots of these ancient plants grew for the first time. It is startling that something so small could have had such a dramatic effect on Earth's climate.

'This discovery also shows the importance of collections such as the Oxford University Herbaria — they are so valuable, and we need to maintain them for future generations.'

How the brain makes, and breaks, a habit

Not all habits are bad. Some are even necessary. It's a good thing, for example, that we can find our way home on "autopilot" or wash our hands without having to ponder every step. But inability to switch from acting habitually to acting in a deliberate way can underlie addiction and obsessive compulsive disorders.

Working with a mouse model, an international team of researchers demonstrates what happens in the brain for habits to control behavior.

The study is published in *Neuron* and was led by Christina Gremel, assistant professor of psychology at the University of California San Diego, who began the work as a postdoctoral researcher at the National Institute on Alcohol Abuse and Alcoholism of the National Institutes of Health. Senior authors on the study are Rui Costa, of the Champalimaud Centre for the Unknown in Lisbon, and David Lovinger of the NIAAA/NIH.

The study provides the strongest evidence to date, Gremel said, that the brain's circuits for habitual and goal-directed action compete for control — in the orbitofrontal cortex, a decision-making area of the brain — and that neurochemicals called endocannabinoids allow for habit to take over, by acting as a sort of brake on the goal-directed circuit.

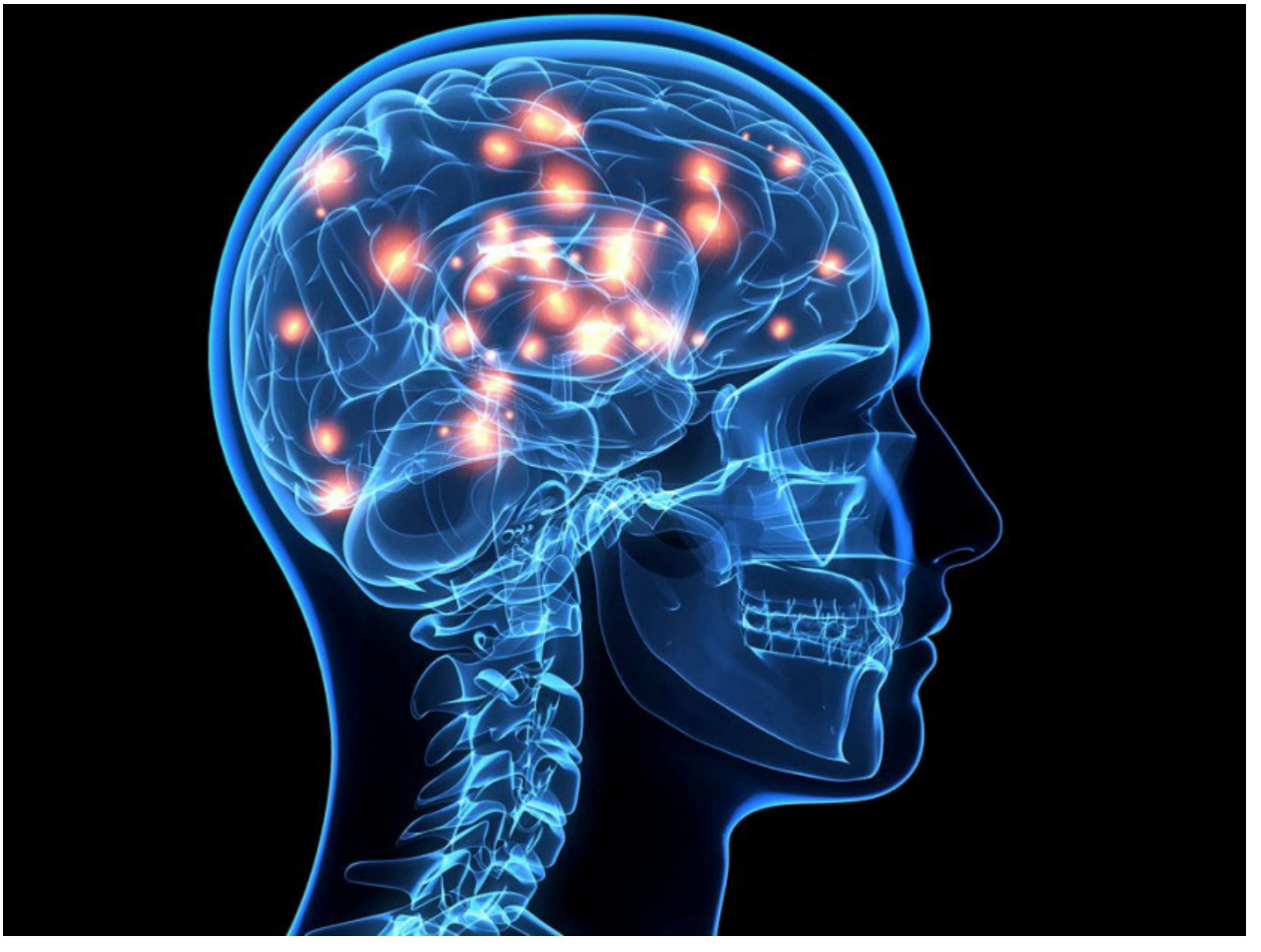
Endocannabinoids are a class of chemicals produced naturally by humans and other animals. Receptors for endocannabinoids are found throughout the body and brain, and the endocannabinoid system is implicated in a variety of physiological processes — including appetite, pain sensation, mood and memory. It is also the system that mediates the psychoactive effects of cannabis.

Earlier work by Gremel and Costa had shown that the orbitofrontal cortex, or OFC, is an important brain area for relaying information on goal-directed action. They found that by increasing the output of neurons in the OFC with a technique called optogenetics — precisely turning neurons on and off with flashes of light — they increased goal-directed actions. In contrast, when they decreased activity in the same area with a chemical approach, they disrupted goal-directed actions and the mice relied on habit instead.

"Habit takes over when the OFC is quieted," Gremel said.

In the current study, since endocannabinoids are known to reduce the activity of neurons in general, the researchers hypothesized that endocannabinoids may be quieting or reducing activity in the OFC and, with it, the ability to shift to goal-directed action. They focused particularly on neurons projecting from the OFC into the dorsomedial striatum.

They trained mice to perform the same lever-pressing action for the same food reward but in two different environments that differentially bias the development of goal-directed versus habitual actions. Like humans who don't suffer from neuropsychiatric disorders, healthy mice will readily shift between performing the same action using a goal-directed versus habitual action strategy. To stick with the earlier example of getting home, we can switch the homing autopilot off and shift to goal-directed behavior when



we need to get to a new or different location.

To test their hypothesis on the role played by endocannabinoids, the researchers then deleted a particular endocannabinoid receptor, called cannabinoid type 1, or CB1, in the OFC-to-striatum pathway. Mice missing these receptors did not form habits — showing the critical role played by the neurochemicals as well as that particular pathway.

"We need a balance between habitual and goal-directed actions. For everyday function, we need to be able to make routine actions quickly and efficiently, and habits serve this purpose," Gremel said. "However, we also encounter changing circumstances, and need the capacity to 'break habits' and perform a goal-directed action based on updated information. When we can't, there can be devastating consequences."

The findings may suggest, the authors say, a new therapeutic target for people suffering from OCD or addictions: To stop overreliance on habit and restore the ability to shift from habit to goal-directed action, it may be helpful to treat the brain's endocannabinoid system and so reduce habitual control over behavior. Treatment could be pharmaceutical or might involve behavioral therapy. Further research is needed.

Was Planet 9 once an exoplanet, stolen by our sun?

Through a computer-simulated study, astronomers at Lund University in Sweden show that it is highly likely that the so-called Planet 9 is an exoplanet. This would make it the first exoplanet to be discovered inside our own solar system. The theory is that our sun, in its youth some 4.5 billion years ago, stole Planet 9 from its original star.

An extrasolar planet, or exoplanet, is by definition a planet located outside our solar system. Now it appears that this definition is no longer viable. According to astronomers in Lund, there is a lot to indicate that Planet 9 was captured by the young sun and has been a part of our solar system completely undetected ever since.

"It is almost ironic that while astronomers often find exoplanets hundreds of light years away in other solar systems, there's probably one hiding in our own backyard," says Alexander Mustill, astronomer at Lund University.

Stars are born in clusters and often pass by one another. It is during these encounters that a star can "steal" one or more planets in orbit around another star. This is probably what happened when our own sun captured Planet 9.

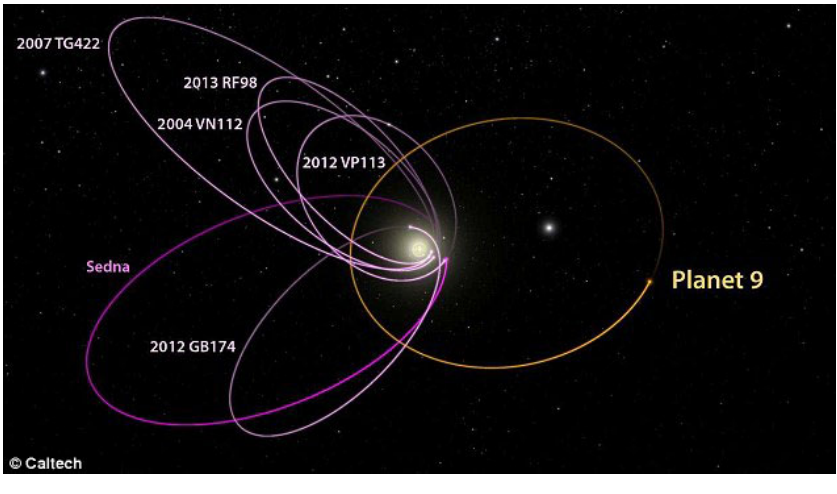
In a computer-simulated model, Alexander together with astronomers in Lund and Bordeaux has shown that Planet 9 was probably captured by the sun when coming in close contact while orbiting another star.

"Planet 9 may very well have been 'shoved' by other planets, and when it ended up in an orbit that was too wide around its own star, our sun may have taken the opportunity to steal and capture Planet 9 from its original star. When the sun later departed from the stellar cluster in which it was born, Planet 9 was stuck in an orbit around the sun," says Alexander Mustill.

"There is still no image of Planet 9, not even a point of light. We don't know if it is made up of rock, ice, or gas. All we know is that its mass is probably around ten times the mass of earth."

It requires a lot more research before it can be ascertained that Planet 9 is the first exoplanet in our solar system. If the theory is correct, Alexander Mustill believes that the study of space and the understanding of the sun and the Earth will take a giant leap forward.

"This is the only exoplanet that we, realistically, would be able to reach using a space probe," he says.



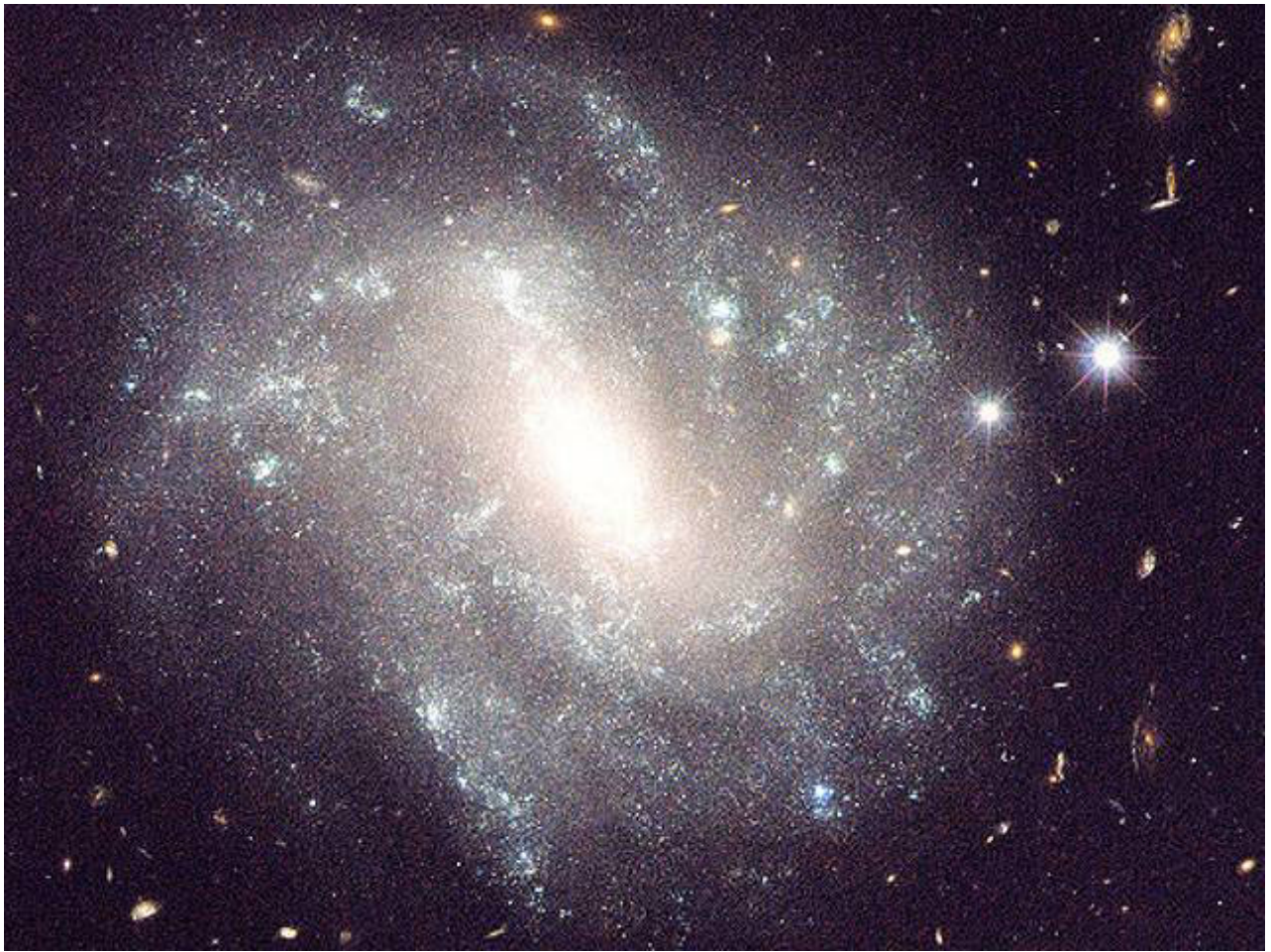
The universe is expanding even faster than expected

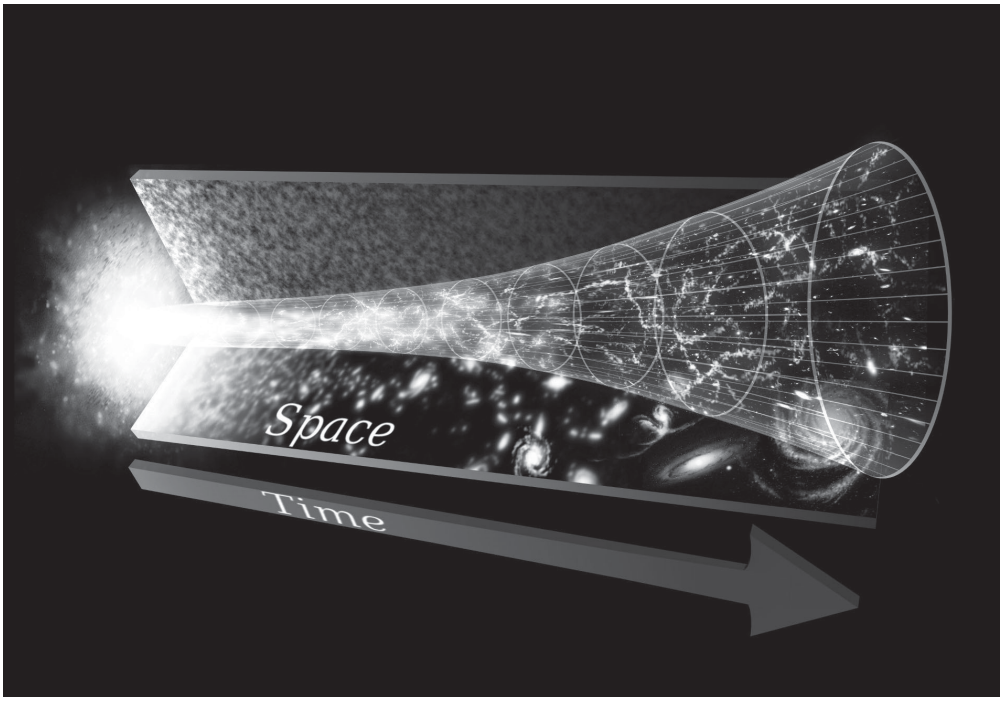
Astronomers using NASA's Hubble Space Telescope have discovered that the universe is expanding 5 percent to 9 percent faster than expected.

"This surprising finding may be an important clue to understanding those mysterious parts of the universe that make up 95 percent of everything and don't emit light, such as dark energy, dark matter, and dark radiation," said study leader and Nobel Laureate Adam Riess of the Space Telescope Science Institute and The Johns Hopkins University, both in Baltimore, Maryland.

The results will appear in an upcoming issue of *The Astrophysical Journal.*

Riess' team made the discovery by refining the universe's current expansion rate to unprecedented accuracy, reducing





and calculated distances to roughly 300 Type Ia supernovae in far-flung galaxies.

The team compared those distances with the expansion of space as measured by the stretching of light from receding galaxies. The team used these two values to calculate how fast the universe expands with time, or the Hubble constant.

The improved Hubble constant value is 73.2 kilometers per second per megaparsec. (A megaparsec equals 3.26 million light-years.) The new value means the distance between cosmic objects will double in another 9.8 billion years.

This refined calibration presents a puzzle, however, because it does not quite match the expansion rate predicted for the universe from its trajectory seen shortly after the Big Bang. Measurements of the afterglow from the Big Bang by NASA's Wilkinson Microwave Anisotropy Probe (WMAP) and the European Space Agency's Planck satellite mission yield predictions for the Hubble constant that are 5 percent and 9 percent smaller, respectively.

"If we know the initial amounts of stuff in the universe, such as dark energy and dark matter, and we have the physics correct, then you can go from a measurement at the

the uncertainty to only 2.4 percent. The team made the refinements by developing innovative techniques that improved the precision of distance measurements to faraway galaxies.

The team looked for galaxies containing both Cepheid stars and Type Ia supernovae. Cepheid stars pulsate at rates that correspond to their true brightness, which can be compared with their apparent brightness as seen from Earth to accurately determine their distance. Type Ia supernovae, another commonly used cosmic yardstick, are exploding stars that flare with the same brightness and are brilliant enough to be seen from relatively longer distances.

By measuring about 2,400 Cepheid stars in 19 galaxies and comparing the observed brightness of both types of stars, they accurately measured their true brightness

time shortly after the big bang and use that understanding to predict how fast the universe should be expanding today," said Riess. "However, if this discrepancy holds up, it appears we may not have the right understanding, and it changes how big the Hubble constant should be today."

Comparing the universe's expansion rate with WMAP, Planck, and Hubble is like building a bridge, Riess explained. On the distant shore are the cosmic microwave background observations of the early universe. On the nearby shore are the measurements made by Riess' team using Hubble. "You start at two ends, and you expect to meet in the middle if all of your drawings are right and your measurements are right," Riess said. "But now the ends are not quite meeting in the middle and we want to know why."

There are a few possible explanations for the universe's excessive speed. One possibility is that dark energy, already known to be accelerating the universe, may be shoving galaxies away from each other with even greater — or growing — strength.

Another idea is that the cosmos contained a new subatomic particle in its early history that traveled close to the speed of light. Such speedy particles are collectively referred to as "dark radiation" and include previously known particles like neutrinos. More energy from additional dark radiation could be throwing off the best efforts to predict today's expansion rate from its post-big bang trajectory.

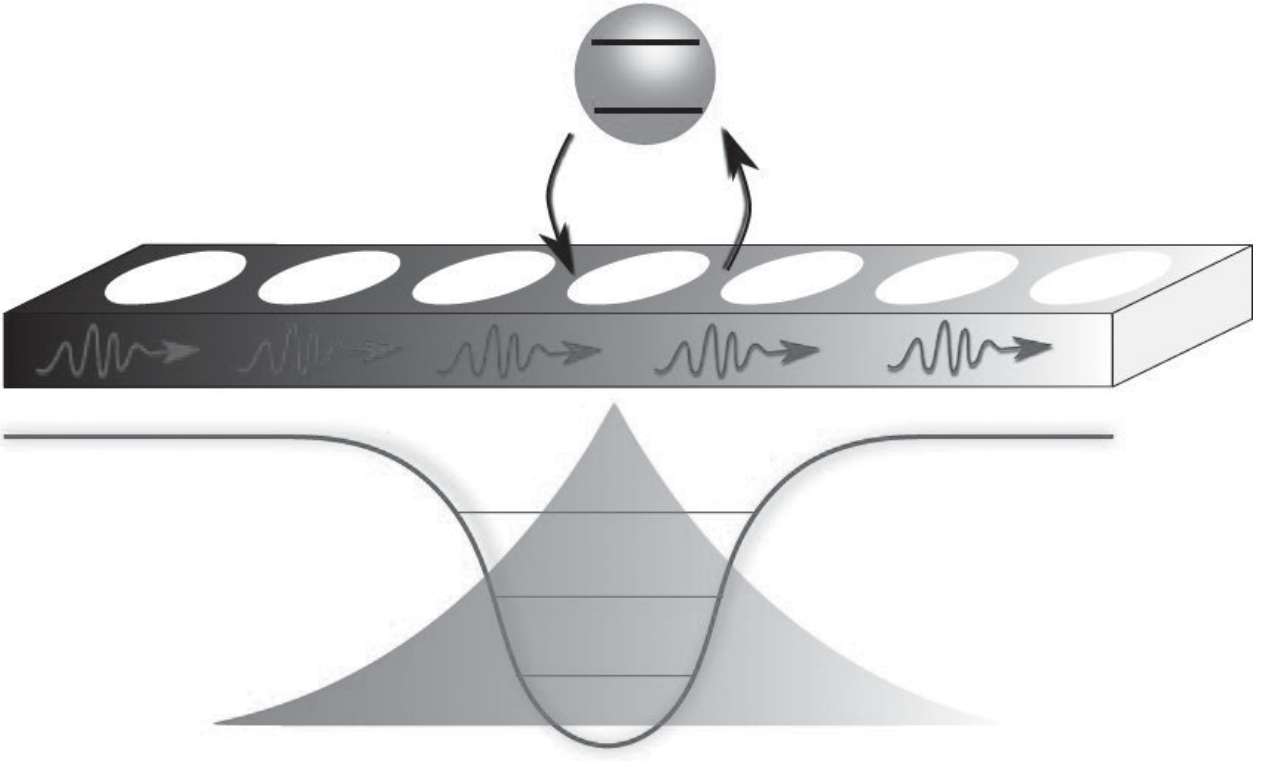
The boost in acceleration could also mean that dark matter possesses some weird, unexpected characteristics. Dark matter is the backbone of the universe upon which galaxies built themselves up into the large-scale structures seen today.

And finally, the speedier universe may be telling astronomers that Einstein's theory of gravity is incomplete. "We know so little about the dark parts of the universe, it's important to measure how they push and pull on space over cosmic history," said Lucas Macri of Texas A&M University in College Station, a key collaborator on the study.

The Hubble observations were made with Hubble's sharp-eyed Wide Field Camera 3 (WFC3), and were conducted by the Supernova H0 for the Equation of State (SH0ES) team, which works to refine the accuracy of the Hubble constant to a precision that allows for a better understanding of the universe's behavior.

The SH0ES Team is still using Hubble to reduce the uncertainty in the Hubble constant even more, with a goal to reach an accuracy of 1 percent. Current telescopes such as the European Space Agency's Gaia satellite, and future telescopes such as the James Webb Space Telescope (JWST), an infrared observatory, and the Wide Field Infrared Space Telescope (WFIRST), also could help astronomers make better measurements of the expansion rate.

Before Hubble was launched in 1990, the estimates of the Hubble constant varied by a factor of two. In the late 1990s the Hubble Space Telescope Key Project on the Extragalactic Distance Scale refined the value of the Hubble constant to within an error of only 10 percent, accomplishing one of the telescope's key goals. The SH0ES team has reduced the uncertainty in the Hubble constant value by 76 percent since beginning its quest in 2005.



One impurity to bind them all

Nobody is perfect, but sometimes it is the defect that makes the difference. For example, the electric properties of semiconductors undergo significant changes by the slightest variation in the dopant concentration, and though a perfect diamond is without any colour, atomic impurities make them shine in pale blue, violet or pink which even enhances their value. All these effects go back to processes that are triggered by the interaction of the impurity with the quantum many-body system it is embedded in. A team of physicists in the Theory Division of Prof. Ignacio Cirac at the Max Planck Institute of Quantum Optics (MPQ) has now investigated the more general case where an impurity atom is coupled to a structured bath of bosons (for example, photons in a periodically engineered dielectric) showing how a single atom can bind many bosons around it. Bound states of bosons are of particular interest because they give rise to long and strong interactions enabling new regimes for quantum simulations.

The interaction of spin impurities with bosonic reservoirs lies at the heart of very paradigmatic models in Quantum Optics and Condensed Matter and gives rise to very rich phenomena. For example, in the context of atoms coupled to engineered dielectrics, i.e., photonic crystals, it was predicted that a single atom can localize a single-photon cloud around it if the atomic frequency lies in the photonic bandgap of

the material. With the recent advances in interfacing atomic systems with photonic crystal structures, these atom-photon bound states have experienced a renewed interest in the context of quantum simulation as they have been proposed to mediate strong and long-range interactions between atoms.

In their newly published work, Tao Shi, Ying-Hai Wu and Alejandro González-Tudela from the Theory Division of Prof. Ignacio Cirac study the general problem of a single spin impurity coupled to a generic bosonic bath and show that a single atom can indeed trap not a single, but infinitely many bosons around it. Loosely speaking, the coupling of the impurity to the bath generates an effective potential to the bosons that is able to localize the bosons around it. In particular, a single atom can localize a multi-photon cloud around it within a photonic crystal. Moreover, the authors also provide a variational description that allows them to describe their behaviour in all parameter space, unveiling the existence of many different regimes with different scaling of physical properties like the energy or the size of the bound states.

Due to the generality of the model, these bound states can potentially be prepared and observed in many different platforms, ranging from atoms coupled to photonic crystals to circuit QED or even cold atoms in state dependent optical lattices. The existence of these boson bound states spans the possibilities of these platforms to simulate new exotic many-body phenomena.