Gravity & lesser beings

Is gravity related to other forces in nature?

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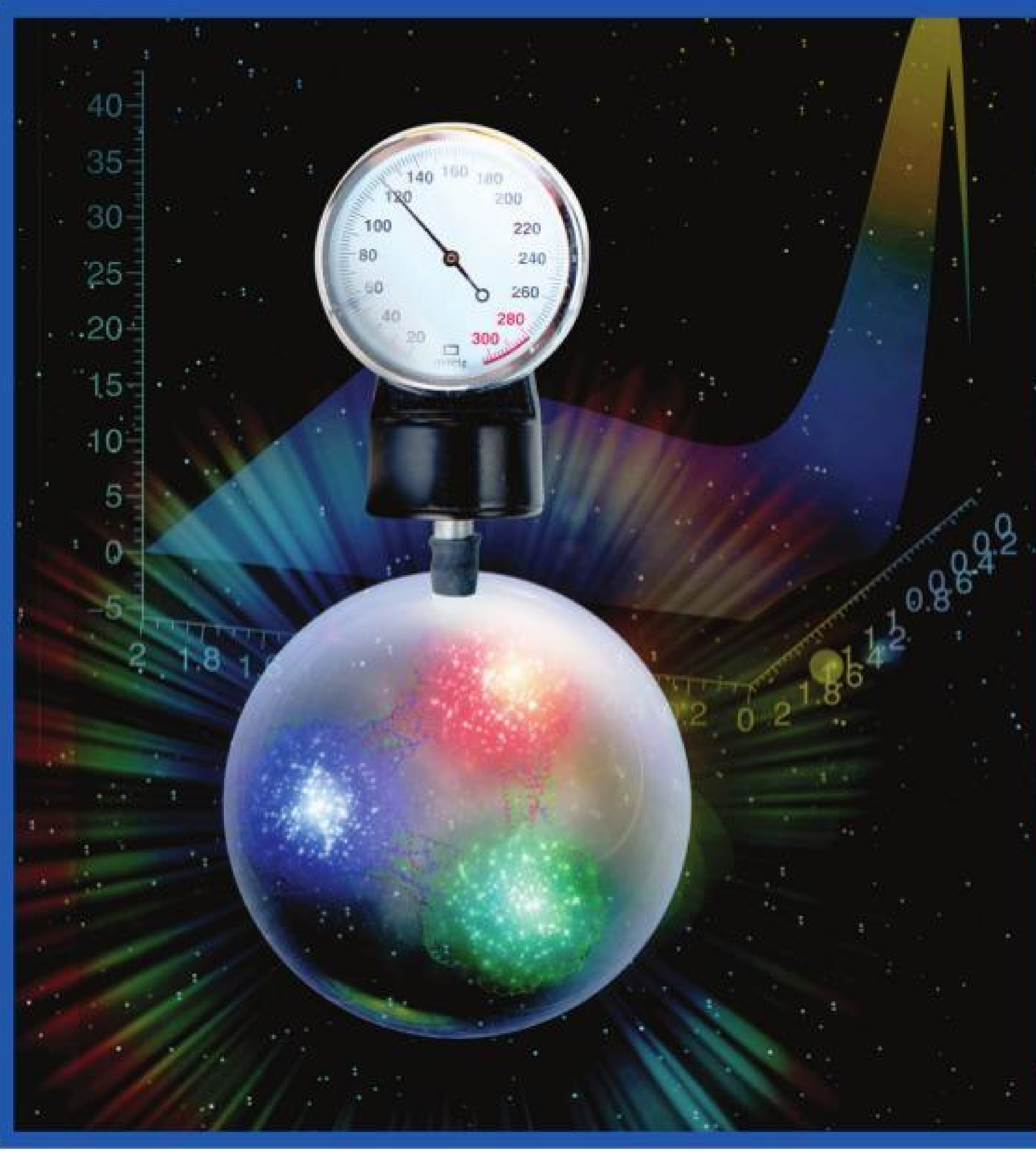

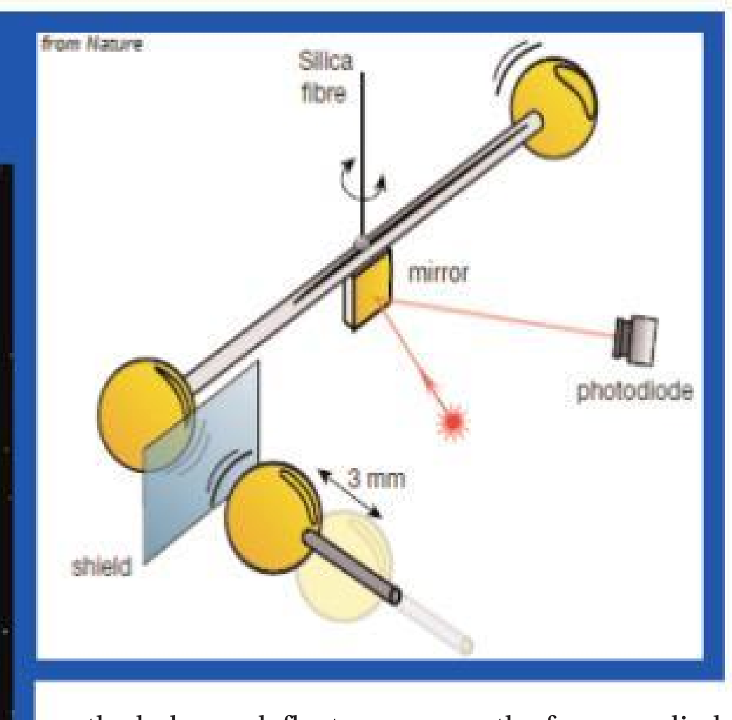

The force of gravity, which we feel and take for granted from the moment we are born, is apparent to us thanks to large masses, like the Earth, Sun and heavenly bodies. Between ordinary objects, however, gravity is imperceptible. Ordinary things, even atoms, are held together by electrical forces. While there is another set of forces within the atomic nucleus, the masses at that scale are so small that the effects of gravity would vanish.

Tobias Westphal, Hans Hepach, Jeremias Pfaff and Markus Aspelmeyer, from the Austrian Academy of Sciences, Vienna and the University of Vienna, describe in the journal, *Nature*, their sally into measuring the faintest effects of gravity between objects down to milligrams. Measuring gravitational forces between smaller masses could elucidate the role of gravity at the subnuclear distance scale, the authors say.

Our understanding of gravity, thanks to Albert Einstein's General Theory of Relativity, is sophisticated, and seemingly exact. At the subatomic scale too, we have unparalleled precision. A bridge between the theory behind gravity and the understanding of other forces, however, has been elusive.

We are aware of the force of gravity because of our weight, which keeps us rooted to the ground, and because we see that things tend to fall earthward. It took the genius of Isaac Newton to connect gravity as the force, which kept heavenly bodies in their courses and to formalise a mathematical framework. The other force that the ancients knew, and we now understand, is the electrical force. The huge difference in the magnitude of the two forces, however, keeps them separate – gravity acts at the scale of the cosmos and it is irrelevant in the domains where electrical forces dominate.

When the structure of the atom was discovered, a question to answer was how positively charged protons could be packed within the atomic nucleus, as electrical forces should drive them apart. It led to the discovery of a new kind of a very strong, attractive force, that acted only when distances were very small, which is the case within the atomic nucleus. Once outside the nucleus, those forces fall to zero, and only electrical forces stay relevant.

Electrical and gravitational forces do not abruptly disappear, in this way. When the distance increases, they get weaker, but do not fall to zero. The electrical force is pretty strong too, but electric charges, the source of the electrical force, cannot accumulate. That is because electrical charges mutually repel. And then, they get neutralised by equal positive charges, which cannot be kept away for long.

Electrical effects are hence strong, but measurable only over distances of millimetres.

The case of gravitational forces is the opposite. The force is feeble and can hardly be made out between ordinary objects. But the cosmos does consist of very huge objects, like planets, suns and galaxies, and, despite the long distances, gravitational forces are powerful.

The comparison of how the mass of objects and the force of gravity varies over dimensions is instructive. As we know, the volume, and hence mass, of an object, say a sphere, increases according to the cube of its dimensions. This is to say that a sphere that is twice the size of another would weigh eight times as much. And one that is twice the size of the second sphere would weigh 64 times as much as the first sphere. The force of gravity, however, falls only according to the square of the distance. Thus, the force between objects would fall just to a fourth, if they are drawn twice as far apart, and by a factor of only 16 if the distance is doubled.

Over larger differences of size, say a million, the mass changes by a factor of 10^{18}. But going the same million times further apart reduces the force of gravity only by a factor of 10^{12}. The force of gravity is still a million times stronger! The same thing applies the other way around. If the distance was reduced by a factor of a million, the force of gravity would get 10^{12} times stronger. But if the dimensions of the object were a million times less, the mass falls by a factor of 10^{18}. The net force is hence a million times weaker!

The force of gravity has hence been challenging to measure while using objects that it would be practical to handle. Following suggestions by scientists who had developed a sensitive method to measure weak electrical forces, Henry Cavendish, in 1798, set up an arrangement to detect the weak gravitational force that acts between objects at the everyday scale of masses.

Cavendish

The arrangement was of a pair of heavy balls of lead at the ends of a long baton, which was suspended from its middle by a thin fibre, like a silk thread. Next to the two balls, at the ends of the baton, were placed a pair of much larger lead balls, to attract the smaller balls by gravity. The force is feeble indeed, but the arrangement is so sensitive that the force causes a deflection – just a tiny deflection, balanced by the torsion of the silk thread.

The torsion balance can be calibrated using known forces, so that the angle through which the balance deflects measures the force applied, and hence gravitational attraction that causes the deflection. Cavendish compared the force by which the balls were attracted with their weight, which is the force of attraction by the Earth. As the mass of the larger balls was known, Cavendish could get the mass of the Earth, and a mean density, or the mass per cm3, of 5.48 gm, which is close to the modern figure – 5.5153 gm.

Coming back to how gravity and the other forces known to us could be explained by a unified theory, the authors of the paper in *Nature* say that measuring how gravity behaves when dimensions get really small could help find answers. As a first step towards lesser dimensions, the group has adapted the Cavendish method with gold particles just one millimetre across, in place of the lead balls.

The particles are at the ends of a thin, 40 mm-long, glass capillary, suspended at its middle by a 35 mm-long, four micron-diameter silica thread. A similar particle of gold is placed next to one of the particles, and is moved back and forth, to provide a rhythmic acceleration to the test ball. That affects the pattern of oscillation of the arrangement, from which the feeble gravitational effect can be worked out.

An important requirement of the method, as of the Cavendish method, is to eliminate external disturbances. The arrangement was hence elaborately insulated from vibrations, seismic and acoustic, and conducted inside a vacuum chamber, to eliminate effects of molecules of air. The result of the trials was a value of the gravitational constant, the factor that connects the masses and the gravitational force, which was nine per cent off the best-known value. Given the uncertainties that are intrinsic, the paper says, this is a demonstration that we can measure gravitational effects of small objects to within 10 per cent.

As the sources of error are known, improvements could make it possible to study gravity at the sub-atomic scale, the paper says. If we understand how gravity behaves at this scale, it would set the course for explaining puzzling aspects of the cosmos, and gravity, the nature of dark matter, being one.

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BEFORE THEY TAKE FLIGHT

Here's an account of how the epic journeys of migratory birds are being tracked by a scientist in North-west Mexico

The antenna being set up

Tiny transmitters are attached to the birds

JULIAN GARCIA WALTHER

One morning in January, I found myself 30 feet up a tall metal pole, carrying 35 kilograms of aluminium antennas and thick weatherproofed cabling. From that vantage point, I could clearly see the entire Punta Banda Estuary in North-western Mexico. As I looked through my binoculars, I observed the estuary's sandy bar and extensive mudflats packed with thousands of migratory shorebirds frenetically pecking the mud for food.

In winter, more than one million shorebirds that breed in the Arctic will visit and move throughout the coastline of North-west Mexico. It's possible they are tracking rare superabundant seasonal resources like fish spawning events. Or maybe they are scouting for sites with better habitat to spend their non-breeding season. The truth is, researchers don't actually know. It has been incredibly hard to elucidate how birds use the region and what drives their movements in this vast network of coastal wetlands spanning 5,000 kilometres of coastline.

Tracking birds has always been a challenge. To make it easier, scientists have built a massive network of radio antenna devices called Motus stations across the US and Canada that can automatically track the movements of tagged birds. However, Motus stations – Motus means movement in Latin – are still missing in much of Latin America. It has resulted in large gaps in biologists' understanding of where migratory shorebirds go during their non-breeding season.

A biology doctoral student studying bird migration, I am collaborating with the non-profit Pronatura Noroeste. We have one goal – to expand the Motus network in North-west Mexico and unravel the mystery of where shorebirds are going during the winter.

How to track a bird

Much of my work is focused on red knots – stubby sandpipers that feed on muddy flats that are uncovered during low tide in many estuaries.

In the past, to learn how red knots move among wetlands meant walking through knee-deep mud with a scope, trying to find birds with colour-coded flags on their legs. I would then have to get close enough to read the writing on the flags to determine who had attached the flag and where in the continent the bird had been seen before. That is not easy work. It requires large numbers of flagged birds and many skilled ecologists trying to find them, so you get very limited data in return for a lot of time and effort.

Motus stations make this job much easier, and with a Motus network in Mexico, ecologists like me will get much more data on the movements of these animals. The project involves two parts – attaching tiny radio transmitters to birds and building a network of stations to track them.

Motus stations work similarly to a cell phone tower. Researchers attach tiny transmitters weighing just 0.45 grams to animals and these transmitters emit a radio pulse every five seconds. Each station has multiple antennas pointing toward a site used by birds -- like the mudflats at Punta Banda -- and is always listening for these radio signals.

Motus stations can pick up signals from tagged birds in a 20-km radius, 24/7. A small computer built into the Motus station can then record and send information to researchers about when animals arrive to the site, how long they stay and in which direction they are headed when they leave.

Building a network

The station at Punta Banda is the first and, so far, the only tower my team and I have erected. But the ultimate goal of our project is to deploy two dozen Motus stations in 15 coastal wetlands spanning the whole North-west coast of Mexico. When we are done, we will use these stations to track the movements of birds among these sites, as well as the more than 1,000 other sites with active stations across the world.

The Punta Banda Estuary is one of the key stopovers for red knots. To maximise our chances of detecting birds, we chose to build the station on top of an old 30-foot metal pole overlooking the whole estuary. After getting approval from the pole owner, my colleagues and I assembled the station components. Then I climbed the pole, hoisting multiple antennas with me, and pointed them in all directions over the estuary.

By the time red knots start arriving in the fall, after breeding in the Arctic, our team hopes to have built many more stations like this one across North-west Mexico, ready to detect passing birds.

Tagging birds

The stations alone can't detect these animals. The final step, which will happen in the coming months, is to catch birds and tag them. To do this, our team will set up a soft, spring-loaded net, called a whoosh net, in sandy areas where the red knots rest above the high-tide line. When birds walk past the net, the crew leader will release the trigger, safely trapping the birds with the net.

Once we've successfully caught a bird, we will attach a transmitter to its back. Transmitters are solar-powered and very light -- less than one per cent of the bird's weight -- and they can thus provide many years of data without harming the birds. Because younger birds may move differently than adults across the region, our team hopes to tag 130 red knots of different ages at other estuaries in North-west Mexico. The larger Motus project has already tagged more than 25,000 animals, so any other birds that come to northwest Mexico will also get picked up by our stations.

Filling important gaps in knowledge

Migratory shorebirds are among the most threatened bird groups. Their populations have plummeted by 37 per cent since 1970 owing to habitat loss, human disturbance and climate change. Without robust information on how birds use important sites like the ones we are working on in Mexico, it is hard to focus conservation actions when and where they are most needed. As our network of stations grows, the data they collect will help fill critical knowledge gaps.

For researchers like me, this data will allow us to understand how the movement of shorebirds might be disrupted as global threats such as sea level rise continue to affect the coastal wetlands they depend on. In turn, conservationists will be able to implement better and more effective on-the-ground actions to conserve species like red knots.

The writer is a PhD student in ornithology, University of South Carolina, US. This article first appeared on www.theconversation.com

PLUS POINTS

Think before discarding

The huge demand for face masks in the year since the coronavirus pandemic has swept the globe has resulted in enormous production of disposable masks, but it is now feared that not disposed properly, they pose a major threat to the natural world.

Recent studies estimate around the world, humans are now using a mind-boggling 129 billion face masks every month. Taking 31 days in a month that is an average usage of 2.8 million masks a minute being used across the planet.

Researchers now warn the huge volume of masks, with their plastic composition, pose a growing environmental threat and are urging action to prevent it from becoming the next plastic problem.

Environmental toxicologist Elvis Genbo Xu from the University of Southern Denmark and professor Zhiyong Jason Ren, an expert in civil and environmental engineering at Princeton University, said, "Disposable masks are plastic products, that cannot be readily biodegraded but may fragment into smaller plastic particles, namely micro- and nanoplastics that spread widely in ecosystems.

"The enormous production of disposable masks is on a similar scale as plastic bottles, which is estimated to be 43 billion per month."

But they said unlike plastic bottles, of which approximately 25 per cent are recycled, there is no official guidance on mask recycling, making them more likely to be disposed of in inappropriate ways, the researchers said.

If not disposed of for recycling, like other plastic waste, disposable masks can end up in the environment, freshwater systems, and oceans, where weathering can generate a large number of micro-sized particles (smaller than five mm) in a matter of weeks and

further fragment into nanoplastics (smaller than one micrometre).

Last summer marine biologists warned that improper disposal of pandemic-related waste meant there could soon be "more masks than jellyfish" in the Mediterranean Sea.

French politician Eric Pauget, who represents the department of *Alpes-Maritimes*, said, "The friable polypropylene nanoparticles making up these masks which protect humans, risk lastingly affecting our ecosystems and their biodiversity."

The scientists now warn that the composition of the masks means they breakdown into dangerous micro-sized particles very quickly.

"When breaking down in the environment, the mask may release more micro-sized plastics, easier and faster than bulk plastics like plastic bags," they said.

The researchers stressed they do not know exactly how masks contribute to the large number of plastic particles detected in the environment – simply because no data on mask degradation in nature exists.

"But we know that, like other plastic debris, disposable masks may also accumulate and release harmful chemical and biological substances, such as bisphenol A, heavy metals, as well as pathogenic micro-organisms," said Genbo Xu, "These may pose indirect adverse impacts on plants, animals and humans."

The researchers have urged authorities to set up "mask-only" trash cans for collection and disposal, and said other means of reducing the impact of the masks could be for more people to use reusable cotton masks, developing biodegradable disposable masks, and implementing standardised waste management for disposing of masks.

The research is published in *Frontiers of Environmental Science & Engineering*.

– THE INDEPENDENT