that magnetite plays no part in pigeon magnetoreception.

Xie says that he has found a protein in fruit flies that both binds to iron and interacts with Cry. Known as CG8198, it binds iron and sulfur atoms and is involved in fruit-fly circadian rhythms. Together with Cry, it forms a nanoscale 'needle': a rod-like core of CG8198 polymers with an outer layer of Cry proteins that twists around the core.

Using an electron microscope, Xie's team saw assemblies of these rods orienting themselves in a weak magnetic field in the same way as compass needles. Xie gave CG8198 the new name of MagR, for magnetic receptor.

The discovery offers scientists the prospect of using magnetic fields to control cells. Over the past decade, scientists have commandeered the light-sensing capacity of some proteins to manipulate neurons, usually by inserting a fibre-optic cable directly into the brain — a tool called optogenetics. But magnetosensing proteins have the advantage that they could be manipulated by magnetic fields outside the brain.

Zhang Sheng-jia, a neuroscientist at Tsinghua University in Beijing, claims to have already demonstrated this 'magnetogenetic' capability. In September, he provided a surprise preview of Xie's work when he published a paper reporting use of the biocompass to manipulate neurons in worms (X. Long *et al. Sci. Bull.* http://doi.org/883; 2015). Xie and others complained that Zhang's early publication violated a collaboration agreement between the two researchers — the details of which are disputed — and asked for it to be retracted. In October, Zhang was fired from his university, a decision that he is contesting (see *Nature* http://doi.org/882; 2015).

"If MagR is the real magnetoreceptor, I'll eat my hat."

Xie says that in April, he submitted a Chinese patent application that includes the use of magnetogenetics and the protein's magnetic capacity to manipulate large molecules. He is also starting to look at the structure of MagR proteins in other animals, including humans. Variants in the human version of MagR might even relate to differences in people's sense of direction, he suggests.

SCEPTICAL VOICES

Other scientists are not convinced that the biological needles function like compasses in living organisms. Xie's team has shown that MagR and Cry are produced in the same cells in pigeon retinas — the birds' proposed magnetoreception centre — but MagR and Cry are found in many cells, says Keays. "With such a small amount of iron, one has to ask whether *in vivo*, at physiological temperatures, MagR is capable of possessing magnetic properties at all," he says. "If MagR is the real magnetoreceptor, I'll eat my hat."

Xie hopes that others will strengthen his case with further experiments, such as inactivating the gene for MagR in certain fruit-fly tissues to see whether it affects the animals' sense of direction. He published without doing this work, he says, because he just wanted to report the findings, which he has been working on for six years.

The lack of an exact mechanism for how the protein complex senses magnetism, or how any signal it sends might be processed by the brain, gives some researchers pause. MagR's biocompass activity might simply be the result of experimental contamination, says Michael Winklhofer, a magnetism specialist and Earth scientist at Ludwig Maximilian University of Munich in Germany. He is planning experiments to follow up on Xie's team's findings. If it holds up, says Winklhofer, then the discovery of MagR "appears to be a major step forward towards unravelling the molecular basis of magnetoreception". ■

PHYSICS

Space test for long-awaited gravitational-wave detector

Europe's LISA Pathfinder spacecraft has two metal cubes at its heart, which it will attempt to isolate from every force except for gravity.

BY ELIZABETH GIBNEY

There is a lot riding on the LISA Pathfinder mission, an ambitious effort to test whether intricate technology designed to detect ripples in space-time can be deployed in space.

Scheduled to launch on 2 December, the spacecraft is a long-awaited test-drive for a future €1-billion (US$1.1-billion) space observatory planned by the European Space Agency (ESA). The follow-up mission would track the largest objects in the Universe, including mergers between supermassive black holes and collisions between galaxies, by the space-time ripples that they create.

First predicted by Albert Einstein almost exactly 100 years ago as part of his general theory of relativity (see nature.com/relativity100), such gravitational waves have never been observed directly — let alone used to study the cosmos. There are already Earth-based observatories hunting these waves, but a space-based one would search for waves at the opposite end of the spectrum (see *Nature* **525,** 301–302; 2015). "It's like having a radio telescope as well as an optical one," says Karsten Danzmann, director of the Max Planck Institute for Gravitational Physics in Hanover, Germany, and co-principal investigator for the Pathfinder mission. "The part of the Universe you see is completely different."

The final space-based observatory will try to spot the stretching and compressing of space by bouncing laser beams between three masses floating in freefall, each separated from the others by some 5 million kilometres. Because the masses would be protected from all other external forces, only a gravitational wave should disrupt the synchrony of their falling motion — a disturbance that would affect laser frequency.

The LISA Pathfinder (named after the Laser Interferometer Space Antenna, the concept behind the gravitational-wave observatory) is a smaller-scale test of this ultimate plan. With a pricetag of €400 million, it uses just two masses — each a 2-kilogram cube of gold and platinum — separated by a mere 38 centimetres, which allows them to fit inside the same spacecraft.

Unlike that of the observatory that it is designed to test-drive, this set-up is not sensitive enough to detect gravitational waves — instead, its purpose is to show that the masses can be completely isolated, and that any deviations in their relative motion can be measured with picometre accuracy. "We're missing out the 5 million kilometres, but so what?" says Paul McNamara, the mission's project scientist. "Pretty much everything that could affect our ability to measure gravitational waves is here."

From the time of Pathfinder's launch from ESA's spaceport in Kourou, French Guiana, to the end of its subsequent eight-week journey, the masses will stay pinned to their housing deep inside the craft. But on arrival in orbit around a stable point between the Sun and Earth called Lagrange point 1, or L-1, about 1.5 million kilometres away, the cubes will be gently released to float within the spacecraft (see 'Precision lab in space').

Once in freefall, "the challenge is to isolate this little cube from everything around it, so the only thing it sees is space-time", says McNamara. Expected disturbances are pressure from solar radiation and stray magnetic fields; the equipment is so precise that it should detect even a force equal to the weight of a small bacterium on Earth.

As a high-precision laboratory in space, the LISA Pathfinder is unlike anything that ESA has done before, says Tim Sumner, an astrophysicist at Imperial College London who led the team that constructed one of the craft's protection mechanisms.

Another unusual element is that the major cargo — the cubes — will define the craft's trajectory, rather than vice versa. As they orbit around L-1 and fall in microgravity, Pathfinder will deploy microthrusters that are so gentle, it would take around 1,000 to lift a piece of paper on Earth. The thrusters will monitor the cubes' positions, ensuring that the craft hovers around the cubes without letting them touch its sides. Such a set-up required the teams who built the instruments and the engineers who made the craft to work together to an unprecedented degree, says Sumner.

These complexities go a long way towards explaining why the launch has taken so long to orchestrate, says Stefano Vitale, a physicist at the University of Trento in Italy, and a principal investigator for the Pathfinder mission; Pathfinder was approved by ESA in 2000 and originally intended for launch in 2006 (see *Nature* **469,** 280; 2011). "Coarsely speaking, I think people underestimated the difficulty," says Vitale. "But that's why you have a Pathfinder."

The final step in the planned mission will test Pathfinder's limits by instructing onboard instruments to tweak the internal temperature

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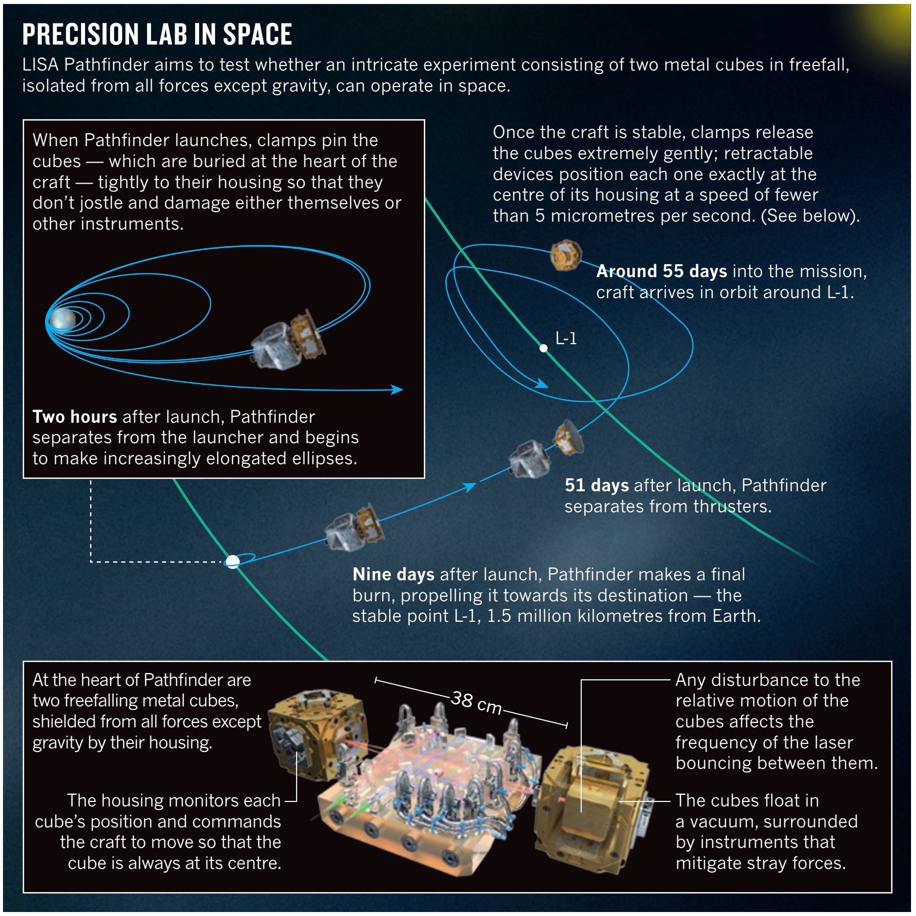

and magnetic and electrostatic fields to see how such changes affect the cubes. "We want to learn everything we can about the physics of a free-floating body, and everything we learn will feed back into design of the future mission," says McNamara.

"The challenge is to isolate this little cube from everything around it, so the only thing it sees is space-time."

However, some opportunistic ESA scientists are already thinking about how Pathfinder's instruments could be used to inform other problems once its main mission, which could take up to a year, is complete. Measurement of the gravitational constant, known as Big *G*, for example, should fall naturally out of Pathfinder's data, Sumner says. Because the true value of Big *G* is disputed, a fresh measurement from space would provide useful perspective.

To get a higher precision measurement, ESA may also consider extending the mission — although Sumner says that scientists would only request this after Pathfinder has proved itself, a few months in. He and his colleagues have also discussed using the craft's thrusters to send it to a spot known as a saddle point, where the gravitational pulls of Earth and the Sun cancel each other out. This could reveal how gravity behaves at its lowest level possible in the Solar System, with little extra cost. Few scientists doubt that Einstein's theories hold, says Sumner, but it would be interesting to do the test nonetheless.

Vitale, however, points out that it is important for researchers to stay focused on the mission's immediate goal. "Our main objective is to demonstrate freefall," he says, "and we don't want to be distracted from that." ■

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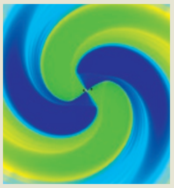

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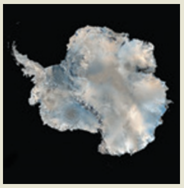

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