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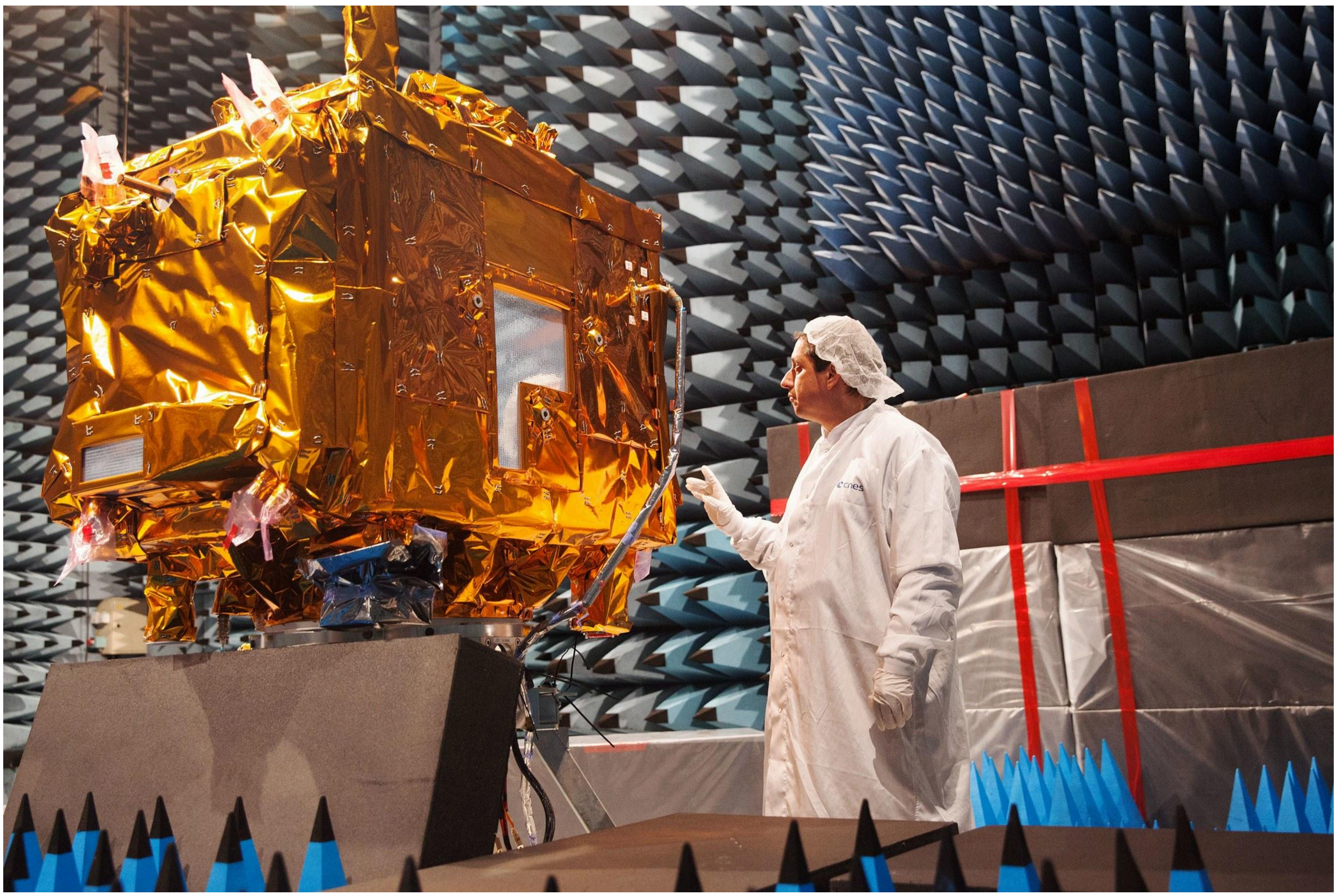
How the Extreme Art of Dropping Stuff Could Upend Physics

Scientists are going to great lengths to try to make gravity fail, so as to link Einstein's theory of general relativity with quantum mechanics.



A satellite called Microscope was used to probe the limits of general relativity.PHOTOGRAPH: MALIGNE FREDERIC/CNES

Babies love it, and Galileo supposedly tried it: Drop some objects from on high, and see how fast they fall. According to Einstein's theory of general relativity, all objects in Earth's gravity, regardless of mass, should descend at the same rate in the absence of air resistance. But there are plenty of reasons to believe this might not be true. Some physicists think that under certain circumstances, objects might fall slightly faster or slower—and they're going to extreme lengths to try to spot such glitches.

In a recent paper in *Physical Review Letters*, physicists in France recount perhaps the most ambitious test of gravity to date: dropping stuff from space. "Once you go to space, you can throw your object, and it will be in free fall for a long time," says physicist Aurélien Hees of the Paris Observatory, a member of the team. The longer you watch two objects fall, the more obvious their discrepancies become.

In the experiment, the researchers buckled two metal cylinders inside a satellite called Microscope, launched them into low-Earth orbit, and measured how the cylinders fell around Earth for two years. Inside the satellite, they used glorified seat belts to secure the cylinders, each made of a different metal alloy. As the satellite hurtled 440 miles overhead, the smart seat belts measured the force required to keep each cylinder in place. Should one cylinder require more force to stay still, that would indicate its free-fall acceleration was faster than its neighbor's. If a deviation in gravity existed, surely this years-long drop would reveal it.

But it didn't. The physicists found that the two cylinders fell at identical rates, within two-trillionths of a percent of each other—confirming Einstein's theory of gravity yet again with almost 100 times more precision than any prior experiment. "There was no deviation from general relativity," says Hees.

That was kind of a bummer. In particular, physicists had hoped the experiment would refute one fundamental assumption of general relativity: that the laws of gravity are the same for all objects, regardless of their location, speed, and orientation. Whether it's the moon orbiting Earth, Earth orbiting the Sun, or two cylinders falling toward the planet, general relativity says that they all obey identical equations. Physicists refer to this assumed consistency of gravity throughout the universe as Lorentz symmetry, and it reflects the “deepest symmetry in the nature of spacetime,” says physicist Alan Kostelecky of Indiana University, who was not involved in the work.

Beautiful as that symmetry may be, physicists like Kostelecky suspect that it doesn’t actually exist. Physicists have long known that general relativity is incomplete, as it contradicts the reigning description of the very small: quantum mechanics. You can think of quantum mechanics and general relativity as two pieces of a larger puzzle whose shapes don’t snap together, says Kostelecky. Many theories attempt to reshape the puzzle pieces by allowing gravity to behave slightly differently under certain conditions.

With the Microscope test a bust, researchers are pinning their hopes on other methods. Physicists at Cern are developing multiple experiments in which they drop antimatter atoms and compare them to regular atoms. No one has ever measured an antimatter particle falling, so the hope is its behavior can reveal something new about gravity. In an experiment called Aegis, for example, the plan is to launch antimatter atoms like cannonballs and measure how far they drop, says physicist Michael Doser, spokesperson for the team. So far, the team has successfully produced antihydrogen, the antimatter version of a hydrogen atom, and they are now building and testing parts of the apparatus to perform the antimatter launch in a few years.

Doser thinks that the anti-atoms will fall at exactly the same rates as regular matter. But if they fall at a different rate, or even fall up, as some more fringe theories predict, physicists might finally have found a crack in general relativity.

As for Microscope, the satellite stopped collecting data in 2018, and its keepers are letting it incinerate in the atmosphere as it parachutes down to Earth over the next 25 years. But physicists are continuing to analyze its data. Hees is also part of a team proposing a new space mission called STE-Quest, in which they plan to measure two different isotopes of rubidium atoms in free-fall. The instruments involved would be about 10 times more precise than Microscope.

Even though Microscope researchers didn’t upend general relativity, the level of precision by which they monitored the cylinders is an achievement, says Kostelecky. As physicists develop even better sensors, he is optimistic they’ll uncover some clue for improving the theory. For now, gravity may be behaving in a stubbornly old-school manner, but at least that means physicists still get to do science by dropping things.