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EINSTEIN WAS RIGHT, AGAIN

After the withdrawal of a report on neutrinos travelling faster than light, a paper redeems Einstein's physics by revealing the reason for the slowdown of the Pioneer space probes

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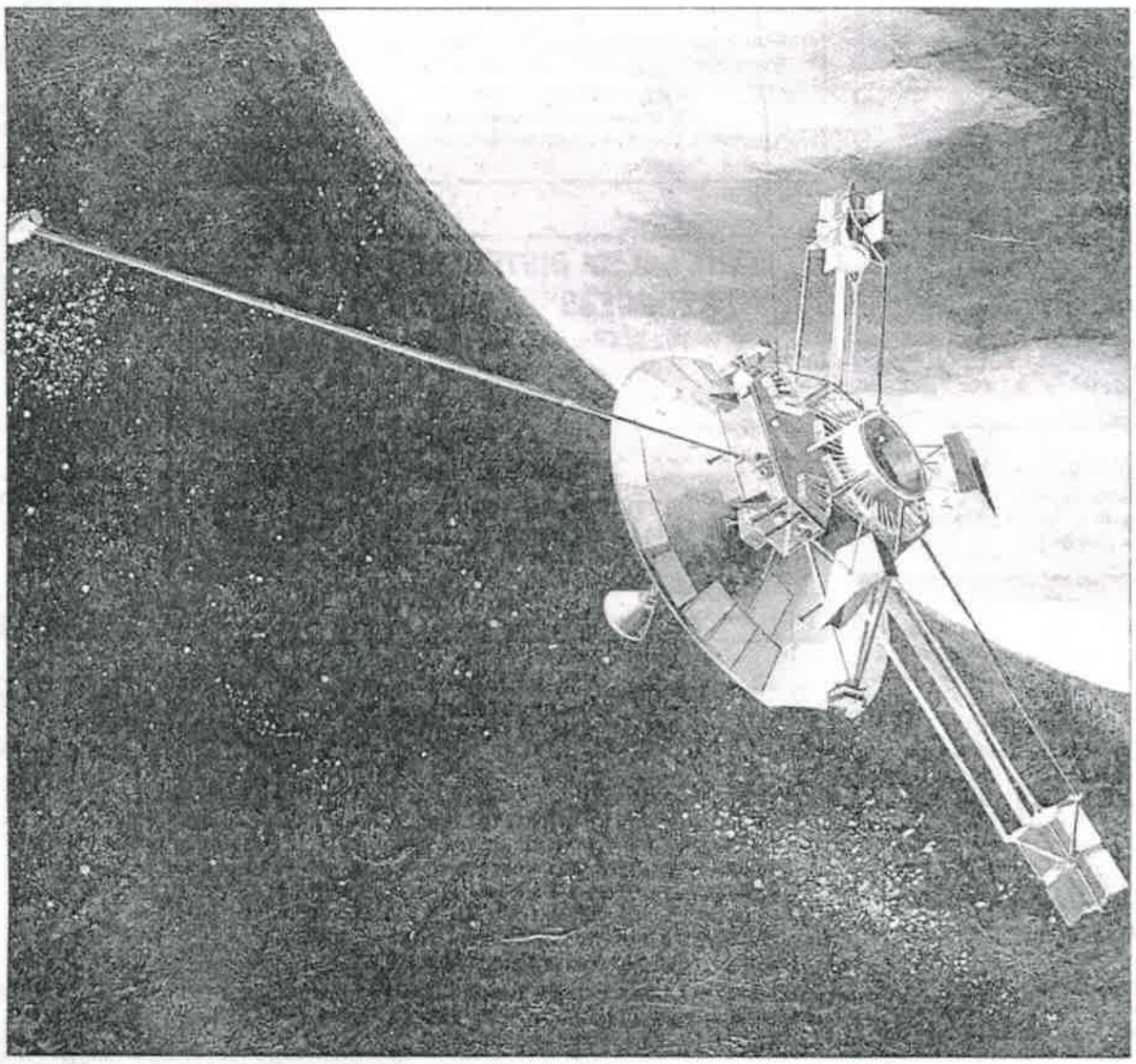

IT'S been a bad year to bet against Albert Einstein. In the spring, physicists had to withdraw a sensational report that the subatomic particles known as neutrinos were going faster than light, Einstein's cosmic speed limit; they discovered they had plugged in a cable wrong. Now scientists from NASA's Jet Propulsion Laboratory have reported that they have explained one of the great mysteries of the space age, one that loomed for 30 years as a threat to the credibility of Einsteinian gravity.

The story starts with the Pioneer 10 and 11 space probes, which went past Jupiter and Saturn in the late 1970s and now are on their way out of the solar system. In the 1980s it became apparent that a mysterious force was slowing them down a little more than should have been expected from gravity of the sun and planets. Was there an unknown planet or asteroid out there tugging on the spacecraft? Was it drag from interplanetary gas or dust? Something weird about the spacecraft? Or was something wrong in our calculation of gravity out there in the dark?

That last explanation would have been big news indeed. Much of what we know about the universe—for example, the existence of dark matter, which seems to swaddle and shape the galaxies, and of dark energy, which seems to be speeding up the expansion of the universe—comes from presuming that Einstein's General Theory of Relativity, which describes gravity as the warping of space-time geometry, is correct over cosmic distances. General relativity has passed every test on Earth. Without it GPS systems would not work. But some theorists have suggested that if gravity behaved differently over large distances from what Einstein thought, it would relieve astronomers of the embarrassing need to posit that 96 per cent of the universe consists of various kinds of unknown dark stuff. A similar, but larger, kind of deviation from Einsteinian theory could explain the Pioneer anomaly, as it is called. Pioneers 10 and 11 were launched in 1972 and 1973, respectively, and are now both about 10 billion miles out. They were last heard from in 2003, when the radio signal from Pioneer 10 got too weak to be detected. In 1998, when John D. Anderson of the Jet Propulsion Laboratory and his colleagues discovered that the spacecrafts were running a little late on their timetable to eternity, it seemed as if general relativity might be up for grabs—allowing the news media to ask their favourite science question: Was Einstein wrong? There was talk of a special deep space probe whose only mission would be to track its own movements.

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The effect was slight—slowing the spacecraft by about 250 miles a year. Slava G. Turyshev, a Russian physicist and gravitational expert working at the JPL, heard the challenge and took it on, feeling "a sense of responsibility to get to the bottom of it." And so he set out to reconstruct the history of the Pioneer voyages. The Pioneers spanned the history of the space age and also of the computer age, occasioning a major effort in what Turyshev calls "space archaeology". He and his colleagues had to scour NASA labs for old punch cards and magnetic tapes and for vintage devices that could read the data stored on them, then reformat all that data to a single modern standard. Among other things, that meant ascertaining the positions of every antenna in NASA's Deep Space Network to an accuracy of one cm over all that time.

Soon, it became apparent that the fault with the Pioneers' travels turned out to lie not in the stars or the shape of space-time but in the spacecraft themselves. As designed, they radiated more heat in one direction from the circuits and generators that produced their electricity. And that imbalance, Turyshev and his colleagues concluded in a recent paper in *Physical Review Letters*, was all that was needed to explain the Pioneers' behaviour.

Gravity did not need to be fixed. Einstein was right again. In fact he was doubly right, as it turns out. The idea that light, of which heat radiation is one form, can carry momentum and thus a propulsive force is implicit in the basic equations of electromagnetism. A comet's tail, blown by sunlight, is one example. But it acquired new visceral meaning when Einstein, beginning in 1905, showed that light can be thought of as little particles that carry energy and momentum. As with bullets, if you shoot them in one direction, there will be a recoil in the other. If you drive at night, Turyshev explained, "your high beams would emit photons and it would push you back." So the Pioneers' problem is that they have been driving the solar system with their high beams on. The findings should help in designing new spacecraft for sensitive missions like measuring gravitational waves. *NYT*