"Confirmed": spinning Earth drags space along

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Courtesy of Stanford University
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Researchers say they have confirmed two predictions of Albert Einstein's general theory of relativity, concluding a project that has spanned more than half a century.

The first prediction is the geodetic effect, or the warping of space and time around a body that exerts gravitational force. The second is frame-dragging, which is the amount a spinning object pulls space and time with it as it rotates.

"Imagine the Earth as if it were immersed in honey. As the planet rotated its axis and orbited the Sun, the honey around it would warp and swirl, and it's the same with space and time," said Francis Everitt, a physicist at Stanford University in California and principal investigator for the project, dubbed Gravity Probe B.

Previous studies had also backed up the predictions, but less directly, the researchers said. They used four ultra-precise gyroscopes housed in a satellite to measure the effects. A gyroscope is a spinning wheel mounted in a frame that lets the wheel keep its orientation independently of the movement of the frame.

After 52 years of conceiving, building, testing and waiting, the test measured both effects with unprecedented precision by pointing at a star, IM Pegasi, while in a polar orbit around Earth, the scientists explained. A polar orbit is one in which a satellite circles Earth while going over the North and South poles on each orbit.

If gravity didn't affect space and time, the gyroscopes would point in the same direction forever while in orbit, researchers said—but following Einstein's general theory of relativity, they underwent measurable, tiny changes in the direction of their spin. The findings appear online in the research journal *Physical Review Letters*.

The test "confirmed two of the most profound predictions of Einstein's universe, having far-reaching implications across astrophysics research," Everitt said.

"The decades of technological innovation behind the mission will have a lasting legacy," he added. Much of the technology needed to test Einstein's theory hadn't yet been invented in 1959 when Leonard Schiff, head of Stanford's physics department, and George E. Pugh of the U.S. Defense Department independently proposed to observe the behavior of a gyroscope in an Earth-orbiting satellite with respect to a distant star. Toward that end, Schiff teamed up with Stanford colleagues and subsequently, in 1962, recruited Everitt.

NASA joined the project in 1963 with the initial funding to develop the requisite equipment. Forty-one years later, the satellite was launched into orbit. The project was soon beset by problems and disappointment when an unexpected wobble in the gyroscopes changed their orientation and interfered with the data. It took years for a team of scientists to sift through the muddy data and sal-

vage the information they needed.

Despite the setback, Gravity Probe B's decades of development led to groundbreaking technologies to control environmental disturbances on spacecraft, such as aerodynamic drag, magnetic fields and thermal variations, physicists said.

Innovations enabled by the project have also been used in the Global Positioning System, such as carrier-phase differential GPS, with its precision positioning that can allow an airplane to land unaided. Additional technologies were applied to NASA's Cosmic Background Explorer mission, which determined the universe's background radiation. That measurement is the underpinning of the "big bang theory" and led to a Nobel Prize for NASA's John Mather.

"The mission results will have a long term impact on the work of theoretical physicists for years to come," said Bill Danchi, senior astrophysicist and program scientist at NASA Headquarters in Washington.