Gravity Probe B mission, testing Einstein's theory of gravity, completes first year in space

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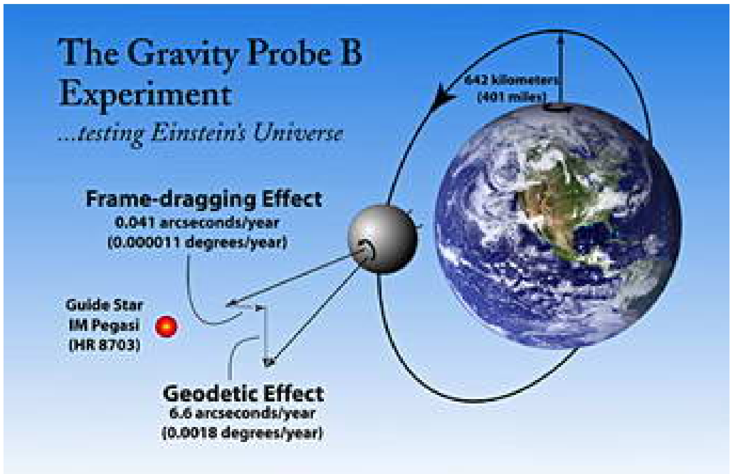

According to Einstein's 1916 general theory of relativity—our present theory of gravitation—space and time are inextricably woven into a four-dimensional fabric called spacetime, and gravity is nothing but the warping and twisting of spacetime by massive celestial bodies. Is this theory correct? The Gravity Probe B (GP-B) satellite recently completed its first year in orbit around the Earth and is continuing to collect data in the first controlled experiment specifically designed to answer this question.

Image: In polar orbit 400 miles above the Earth's surface, Gravity Probe B locks on a guide star. IM Pegasi provides both the initial alignment direction of the spin axes of the four gyros onboard and a fixed reference for measuring any changes in spin axis orientation over the course of the experiment. These changes will ultimately confirm or disprove the geodetic and frame-dragging predictions of general relativity. GRAPHICS COURTESY OF GRAVITY PROBE B IMAGE ARCHIVES

The GP-B experiment is a collaboration between Stanford University, NASA and Lockheed Martin Corp. Launched just over a year ago, it uses four spherical gyroscopes—listed in the Guinness Database of World Records as the roundest objects ever made—to test, with unprecedented precision, two extraordinary effects predicted by Einstein's theory of gravitation. One is the geodetic effect—the amount by which the Earth warps the local spacetime in which it resides. The other is the frame-dragging effect—the amount by which the rotating Earth drags its local spacetime around with it.

The four gyroscopes are housed inside a pristine cryogenic space-borne laboratory, specifically designed to eliminate or at least minimize all possible sources of external disturbance and noise. Within this chamber, which is maintained at a vacuum 100 times greater than that of space 400 miles above the Earth and at a temperature just 1.8 degrees above absolute zero, the four GP-B science gyroscopes spin in complete isolation—their spin axes are affected only by the relativistic warping and twisting of Earth's local spacetime.

While these warping and twisting effects of gravity are calculated to be enormous in the neighborhood of ultra-massive celestial bodies such as black holes, they are minuscule and extremely difficult to measure in the vicinity of a tiny celestial object such as our Earth. Since 1916, various tests of general relativity—including two suggested by Einstein himself, and made within his lifetime—suggest that he was on the right track. In most previous tests, however, the relativity signals had to be extracted from a significant level of background noise, whereas in the GP-B experiment, the background noise has been systematically eliminated or reduced to insignificant levels so the relativity signals can be clearly detected. Thus, GP-B promises to yield results several orders of magnitude more accurate than those of previous observational tests.

Gravity is a fundamental force in nature. It affects all of us all the time, but it is still somewhat an enigma. With his general theory of relativity, Einstein forever changed our notions of space, time and gravity. And although it has become one of the cornerstones of modern physics, general relativity remains the least tested of Einstein's theories.

When GP-B finishes the data-collection phase of the mission this summer, project scientists will have collected more than 10 months of relativity data, which when analyzed over the coming year will tell us—to a very high level of accuracy—whether or not these measurements of the geodetic and frame-dragging effects match the predictions of Einstein's theory. Such rigorous experimental verification is essential to furthering our understanding of the nature of our universe, particularly our knowledge of massive objects in space, such as black holes and quasars.

As GP-B physicist John Mester puts it, "General relativity is our current theory of gravitation, and it has wide ranging implications for our understanding of the structure of the cosmos. At present, Einstein's theory of gravitation lies outside the other three forces of nature [the strong force, the weak force and the electromagnetic force], which are explained within a unified framework called the Standard Model. Attempts to unify all four forces of nature have eluded physicists from Einstein to the current day. Testing theories to high precision will help define their range of validity or reveal where these theories break down."

GP-B program manager Gaylord Green adds: "Physics is an experimental science. If a theory is not tested, it becomes a philosophy, not physics."

Just over one year ago, on April 20, 2004, GP-B was launched into a nearly perfect polar orbit from Vandenberg Air Force Base, Calif., atop a Boeing Delta II launch vehicle. During a four-month initialization phase, the spacecraft underwent a complete checkout and optimization of all systems. On-board computers successfully executed more than 10,000 commands. The four gyroscopes were spun up to their final speeds, averaging 4,300 rpm, and their spin axes were aligned with the GP-B guide star (IM Pegasi/HR 8703). The guide star provides both the initial alignment direction of the spin axes of the four gyros, and it provides a fixed reference for measuring any changes in the spin axis orientation of the gyros over the course of the experiment. On August 28, 2004, the GP-B team began at least 10 months of collecting data on the changing spin axis orientation of the four gyros that will ultimately confirm or disprove the geodetic and frame-dragging predictions of general relativity.

Data collection and final instrument calibrations will continue through the end of August 2005, when up to a year of data analysis will begin. It is fitting that the data-collection phase of the GP-B experiment, the most rigorous test to date of general relativity, will be completed this year—the 100th anniversary of Einstein's "miracle" year, in which he published four seminal papers detailing the special theory of relativity and the production and transformation of light; the latter was the topic for which he was awarded the Nobel Prize in 1921.

"The GP-B team has shown that through hard work and sustained effort, great things can be accomplished," said Tony Lyons, NASA's GP-B program manager at the Marshall Spaceflight Center in Huntsville, Ala. "The spacecraft keeps getting better as we get farther into the mission, and that's a tribute to the hard work of our excellent team."

Just past the one-year mark, the spacecraft continues to perform exceptionally well. The four on-board gyroscopes have now experienced and measured relativistic effects for eight months. The GP-B team is currently in the process of updating their measurement of the amount of liquid helium remaining in the spacecraft's dewar, a cement-mixer-sized thermos vessel that maintains the cryogenic environment for the probe. Shortly before the helium runs out sometime toward the end of August or beginning of September, the team plans to perform an important series of instrument calibrations. "The purpose of the calibration phase is to ensure data accuracy and analysis integrity prior to releasing results," says Stanford physicist Mac Keiser, chief scientist for data analysis.

So, was Einstein correct? Keiser is not saying. Project policy maintains that the program will not release any scientific results obtained during the mission until after all the data analysis has been completed—sometime in the summer of 2006.

Source: Stanford University

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