Was Einstein right? Scientists provide first public peek at Gravity Probe B results (Forwarded)

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Was Einstein right? Scientists provide first public peek at Gravity Probe B results
BY Bob Kahn

For the past three years a satellite has circled the Earth, collecting data to determine whether two predictions of Albert Einstein's general theory of relativity are correct. Today, at the American Physical Society (APS) meeting in Jacksonville, Fla., Professor Francis Everitt, a Stanford University physicist and principal investigator of the Gravity Probe B (GP−B) Relativity Mission, a collaboration of Stanford, NASA and Lockheed Martin, will provide the first public peek at data that will reveal whether Einstein's theory has been confirmed by the most sophisticated orbiting laboratory ever created.

"Gravity Probe B has been a great scientific adventure for all of us, and we are grateful to NASA for its long history of support," Everitt said. "My colleagues and I will be presenting the first results today and tomorrow. It's fascinating to be able to watch the Einstein warping of space−time directly in the tilting of these GP−B gyroscopes −− more than a million times better than the best inertial navigation gyroscopes."

The GP−B satellite was launched in April 2004. It collected more than a year's worth of data that the Stanford GP−B science team has been poring over for the past 18 months. The satellite was designed as a pristine, space−borne laboratory, whose sole task was to use four ultra−precise gyroscopes to measure directly two effects predicted by general relativity. One is the geodetic effect −− the amount by which the mass of the Earth warps the local space−time in which it resides. The other effect, called frame−dragging, is the amount by which the rotating Earth drags local space−time around with it. According to Einstein's theory, over the course of a year, the geodetic warping of Earth's local space−time causes the spin axes of each gyroscope to shift from its initial alignment by a minuscule angle of 6.606 arc−seconds (0.0018 degrees) in the plane of the spacecraft's orbit. Likewise, the twisting of Earth's local space−time causes the spin axis to shift by an even smaller angle of 0.039 arc−seconds (0.000011 degrees) −− about the width of a human hair viewed from a quarter mile away −− in the plane of the Earth's equator.

GP−B scientists expect to announce the final results of the experiment in December 2007, following eight months of further data analysis and refinement. Today, Everitt and his team are poised to share what they have found so far −− namely that the data from the GP−B gyroscopes clearly confirm Einstein's predicted geodetic effect to a precision of better than 1 percent. However, the frame−dragging effect is 170 times smaller than the geodetic effect, and Stanford scientists are still extracting its signature from the spacecraft data. The GP−B instrument has ample resolution to measure the frame−dragging effect precisely, but the team has discovered small torque and sensor effects that must be accurately modeled and removed from the result.

"We anticipate that it will take about eight more months of detailed data analysis to realize the full accuracy of the instrument and to reduce the measurement uncertainty from the 0.1 to 0.05 arc−seconds per year that we've achieved to date down to the expected final accuracy of better than 0.005 arc−seconds per year," said William Bencze, GP−B program manager. "Understanding the details of this science data is a bit like an archeological dig. A scientist starts with a bulldozer, follows with a shovel, and then finally uses dental picks and toothbrushes to clear the dust away from the treasure. We are passing out the toothbrushes now."

The two discoveries

Two important discoveries were made while analyzing the gyroscope data from the spacecraft: one, the "polhode" motion of the gyroscopes dampens over time; two, the spin axes of the gyroscopes were affected by small classical torques. Both of these discoveries are symptoms of a single underlying cause: electrostatic patches on the surface of the rotor and housing. Patch effects in metal surfaces are well known in physics and were carefully studied by the GP−B team during the design of the experiment to limit their effects. Though previously understood to be microscopic surface phenomena that would average to zero, the GP−B rotors show patches of sufficient size to measurably affect the gyroscopes' spins.

The gyroscope's polhode motion is akin to the common "wobble" seen on a poorly thrown American football, though it shows up in a much different form for the ultra−spherical GP−B gyroscopes. While it was expected that this wobble would exhibit a constant pattern over the mission, it was found to slowly change due to minute energy dissipation from interactions of the rotor and housing electrostatic patches. The polhode wobble complicates the measurement of the relativity effects by putting a time−varying wobble signal into the data.

The electrostatic patches also cause small torques on the gyroscopes, particularly when the space vehicle axis of symmetry is not aligned with the gyroscope spin axes. Torques cause the spin axes of the gyroscopes to change orientation, and in certain circumstances, this effect can look like the relativity signal GP−B measures. Fortunately, the drifts due to these torques have a precise geometrical relationship to the misalignment of the gyro spin/vehicle symmetry axis and can be removed from the data without directly affecting the relativity measurement.

Both of these discoveries first had to be investigated, precisely modeled and carefully checked against the experimental data before they could be removed as sources of error. These additional investigations have added more than a year to the data analysis, and this work is still in process. To date, the team has made very good progress in this regard, according to its independent Science Advisory Committee, chaired by relativistic physicist Clifford Will of Washington University in St. Louis, Mo., that has been monitoring every aspect of GP−B for the past decade.

In addition to providing a first peek at the experimental results at the APS meeting, the GP−B team has released an archive of the raw experimental data. The data will be available through the National Space Sciences Data Center at the NASA Goddard Space Flight Center beginning in June.

Conceived by Stanford Professors Leonard Schiff, William Fairbank and Robert Cannon in 1959 and funded by NASA in 1964, GP−B is the longest running, continuous physics research program at both Stanford and NASA. While the experiment is simple in concept −− it utilizes a star, a telescope and a spinning sphere −− it took more than four decades and $760 million to design and produce all the cutting−edge technologies necessary to bring the GP−B satellite to the launch pad, carry out this "simple" experiment and analyze the data. On April 20, 2004, GP−B made history with a perfect launch from Vandenberg Air Force Base in California. After a four−month initialization and on−orbit check−out period, during which the four gyroscopes were spun up to an average of 4,000 rpm and the spacecraft and gyro spin axes were aligned with the guide star, IM Pegasi, the experiment commenced. For 50 weeks, from August 2004 to August 2005, the spacecraft transmitted more than a terabyte of experimental data to the GP−B Mission Operations Center at Stanford. One of the most sophisticated satellites ever launched, the GP−B spacecraft performed magnificently throughout this period, as did the GP−B Mission Operations team, comprised of scientists and engineers from Stanford, NASA and Lockheed Martin, said Stanford Professor Emeritus Bradford Parkinson, a co−principal investigator with John Turneaure and Daniel DeBra, also emeritus professors at Stanford. The data collection ended on Sept. 29, 2005, when the helium in spacecraft's dewar was finally exhausted. At that time, the GP−B team transitioned from mission operations to data analysis.

Over its 47−year lifetime, GP−B has advanced the frontiers of knowledge, provided a training ground for 79 doctoral students at Stanford (and 13 at other universities), 15 master's−degree students, hundreds of undergraduates and dozens of high school students who worked on the project. In addition, GP−B spawned more than a dozen new technologies, including the record−setting gyroscopes and gyro suspension system, the SQUID (for Superconducting QUantum Interference Device) gyro readout system, the ultra−precise star−pointing telescope, the cryogenic dewar and porous plug, the micro−thrusters and drag−free technology, and the Global Positioning System−based orbit determination system. All of these technologies were essential for carrying out the experiment, but none existed in 1959 when the experiment was conceived. Furthermore, some technologies that were designed at Stanford for use in GP−B, such as the porous plug that controlled the escape of helium gas from the dewar, enabled and were used in other NASA experiments such as COBE (the COsmic Background Explorer, which won this year's Nobel prize), WMAP (for Wilkinson Microwave Anisotropy Probe) and the Spitzer Space Telescope.

The experiment's final result is expected upon completion of the data analysis this December. Asked for his final comment, Everitt said: "Always be suspicious of the news you want to hear."

NASA's Marshall Space Flight Center manages the GP−B program and contributed significantly to its technical development. NASA's prime contractor for the mission, Stanford University, conceived the experiment and is responsible for the design and integration of the science instrument, as well as for mission operations and data analysis. Lockheed Martin, Stanford's major subcontractor, designed, integrated and tested the spacecraft and built some of its major payload components, including the dewar and probe that housed the science instrument. NASA's Kennedy Space Center in Florida and Boeing Expendable Launch Systems of Huntington Beach, Calif., were responsible for the launch of the experiment aboard the Delta II rocket.

[Bob Kahn is the public affairs coordinator for Gravity Probe B at Stanford.]

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Editor Note:

Everitt will present the experiment's preliminary results at the American Physical Society meeting in Jacksonville, Fla. His plenary is scheduled for 8:30 a.m. Eastern Time on Saturday, April 14, at the Hyatt Regency Jacksonville Riverfront, 225 East Coast Line Dr., Jacksonville, Fla. 32202. In addition, beginning at 8:30 a.m. Eastern Time on Sunday, April 15, Gravity Probe B co−principal investigators John Turneaure and Bradford Parkinson and GP−B Chief Scientist Mac Keiser will present back−to−back invited talks. Also on Sunday, in a poster session from 2 p.m. to 5 p.m. Eastern Time, members of the GP−B team will make 22 poster presentations covering all aspects of the experiment and technologies.

Photos and graphics are available from GP−B's Image Gallery at
http://einstein.stanford.edu/content/pict_gal/main_index.html
Select high−resolution images are located at
http://einstein.stanford.edu/pix/hires_graphics

Relevant Web URLs:

* Stanford's Gravity Probe B page
http://einstein.stanford.edu/
* NASA's Gravity Probe B page
http://www.nasa.gov/mission_pages/gpb/index.html
* Putting relativity to the test, NASA's Gravity Probe B experiment is one step away from revealing if Einstein was right [Stanford Press Release, Oct. 3, 2005]
http://news−service.stanford.edu/pr/2005/pr−gpbempty−100505.html
* T−minus 45 years: Gravity Probe B finally launches [Stanford Report, April 21, 2004]
http://news−service.stanford.edu/news/2004/april21/gpbshort−421.html

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[http://news−service.stanford.edu/pr/2007/pr−aps_side−041807.html]

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Beyond theory, space mission pushes frontiers of human possibility, engineering

BY Annie Jia

When Gravity Probe B (GP−B) was conceived in 1959, much of the technology needed to conduct the experiment did not exist. An unprecedented level of technological precision was needed to measure the curvature of space, and it took more than three decades for scientists and engineers to create more than a dozen technologies needed to make their vision a reality.

"The number of new technologies that has spawned spinoffs on this experiment is astounding, but probably the most important spinoff is the over 90 PhD theses that have been sponsored by this experiment, because that represents education," said Brad Parkinson, the mission's co−principal investigator and co−inventor of the Global Positioning System (GPS).

Following are just a few examples of the technologies GP−B research has spawned.

Gyroscopes steadier than an owl's eyes

To create wobble−free gyroscopes, scientists produced the world's most perfect spheres. Enlarged to the size of the Earth, the spheres would have mountains no more than 8 feet high. The gyroscopes are now recorded in the Guinness Database of World Records as the roundest manmade objects. They are surpassed in roundness by only one type of object in the entire universe: dense neutron stars.

World's best protractor

The width of a human hair viewed from a quarter of a mile away −− that is the tiny angle by which space−time around Earth was predicted to tilt GP−B's gyroscopes. To measure these minuscule angles, engineers had to develop sensors of astounding precision. The Superconducting QUantum Interference Device (SQUID) magnetometers use a superconducting niobium loop to measure tiny changes in magnetic field that result from the gyroscopes' shift. The devices are so sensitive that they can detect a magnetic field 10 trillion times smaller than Earth's.

Giant thermos

A minivan−sized dewar, or thermos, filled with liquid helium surrounds the gyroscope assembly and keeps it at a cryogenic temperature near absolute zero. To maintain the experimental apparatus at a temperature of 1.8 Kelvin for 16 months in space, the dewar employed advanced technology to insulate, block space radiation and cool by evaporation.

Porous plug

Despite the dewar's incredible insulating abilities, a small amount of heat seeps in and turns some liquid helium into gas. A porous plug allows this "warm" gas to escape while keeping the liquid helium inside to cool the assembly through evaporation, just as sweating cools a person's skin. What's more, the porous plug helps fine−tune the position of the spacecraft. Escaping helium gas is directed through micro−thrusters that puff out amounts one−fiftieth the size of a person's breath to minutely shift and turn the spacecraft to achieve perfect alignment with its guide star. The porous plug has since been used in other NASA flights, including this year's Nobel Prize−winning COBE (for COsmic Background Explorer) mission.

World's best star tracker

Scientists chose a distant star as the fixed reference point for measuring the small angles of deflection of GP−B's gyroscopes. Because of the minuteness of the angles, the telescope's focus on the guide star had to be precise to one 10−millionth of an inch. A telescope lens alone would provide an image 10,000 times too rough, so GP−B engineers created a device to split the incoming telescope image of the star into two separate images, one for the horizontal alignment and one for the vertical. Each image was again divided in two. Then delicate sensors measured the amount of light in each half image, and the spacecraft's orientation was adjusted until the two halves were perfectly balanced, indicating that the star's perfect center had been found.

Gyro suspension system

With the gyroscopes spinning at 4,000 rpm, their suspension system used electrostatic fields to hold each rotor in a vacuum a mere paper's width from the walls of its housing. Any contact of the rotors with the walls would destroy the equipment. The gyro suspension system adjusts the rotors' positions 220 times a second to continually ensure perfect suspension.

Drag−free orbit

It is customary to track the path of an orbiting spacecraft, not the path of the equipment inside it. GP−B's drag−free technology flips that paradigm and instead tracks the path of the equipment inside the spacecraft. Like gnats swarming around a person, the GP−B spacecraft "chases" one of four gyroscopes, which serves as the experiment's central mass. The spacecraft's body shields the gyroscope from outside disturbances, such as friction and magnetic fields, so that the gyroscope is affected only by gravity and orbits the Earth in perfect free−fall. The spacecraft itself, constantly disturbed by the harsh forces of space, adjusts its own position 10 times a second, based on information from the gyro suspension system, to remain perfectly centered around the drag−free gyroscope. Stanford's Aeronautics and Astronautics Department pioneered drag−free satellite technology in the early 1960s.

Precision GPS

Scientists needed an accurate method to map GP−B's orbit because the distortion of space−time varies with location. Hence they adapted conventional GPS technology for GP−B's high speeds and rotating motion. In the process they discovered a way to enhance the standard GPS receiver to measure position down to the centimeter level. Precision GPS has since been adopted in automated tractors, aircraft landing systems and vehicles used in mining and building roads. "[Robotic farm tractors have] launched a market now valued at well over $100 million and growing," Parkinson said. "The productivity enhancements are startling, and clearly benefit many with less expensive food."

[Annie Jia is a science−writing intern at the Stanford News Service.]

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Editor Note:

This is a sidebar to a story about the presentation of Gravity Probe B's first results. Science−writing intern Annie Jia wrote this release. High−resolution images are posted at http://einstein.stanford.edu/pix/hires_graphics/

Relevant Web URLs:

* Gravity Probe B
http://einstein.stanford.edu/

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