Gravity Probe-B:
The Relativity Mission

EXAMINING THE VERY FOUNDATIONS OF SPACE AND TIME

Gravity Probe B is a relativity gyroscope experiment being developed by NASA, Stanford University, and Lockheed Martin to test two extraordinary, unverified predictions of Albert Einstein's general theory of relativity.

The experiment will check very tiny changes in the direction of the spin axis of four gyroscopes in a satellite orbiting at a 400-mile altitude directly over the Earth's poles. The gyroscopes will measure the amount that the presence of Earth has warped space and time, and, more profoundly, how the Earth's rotation drags spacetime around with it. These effects, though small for the Earth, have far-reaching implications for the nature of matter and the structure of the Universe.

Gravity Probe B is attempting to measure two infinitesimal angles -- a predicted 6.6 arcsecs of spacetime curvature, and a predicted 42 milliarc-secs of twist, or "frame-dragging." Several cutting-edge technologies have been developed to distinguish these miniscule angles and "see" our invisible intangible spacetime.

- The gyroscopes are the most spherical objects ever made; they are within three ten-millionths of an inch of perfect sphericity.
- A superconducting niobium coating creates a magnetic field around the spinning gyroscopes at super-low temperatures (<9K), allowing us to detect each gyroscope's axis direction.
- An nine-foot-tall dewar (or thermos) keeps the probe near absolute zero for longer than any other satellite using "porous plugs".
- The telescope, made of solid quartz, uses "dithering" to focus on the center of the star (IM Pegasus) The telescope locates the center of the star to within 0.1 milliarc-seconds.

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Education & Public Outreach

Gravity Probe B has several educational products, and has given numerous classroom presentations and a few conference workshops.

Currently available:
- A lesson plan guiding teachers and students from Newton's gravity through Einstein's relativity to Gravity Probe B
- A poster giving an overview and information on the entire mission

In production:
- A General Guide to Relativity and GP-B
- Textbook supplements connecting the GP-B science and technology to core physics curriculum.
- A short animated video on GP-B
- A Gravity Probe B CD-ROM

Two Observations, One Revolution

Newton's theory of gravity is as familiar to us as the experience of walking down the street. As we put one foot in front of the other, the invisible force of gravity pulls that foot down to the ground and we continue strolling on our merry way. The same invisible force that keeps us Earth-bound keeps the planets in orbit around the Sun. The Sun's gravity constantly pulls the planets toward it, preventing them from zinging off into space in straight lines.

This theory remained strong until the early 1900's when Einstein made two observations that questioned this theory of gravity. The exercises below highlight these contradictory observations, and suggest a new way of understanding the structure of our universe.

Observation #1

1. According to Newton, how long does it take for planets to "feel" the force of gravity coming from the Sun? What is the value for t in Newton's gravitational equation? ($F = G\, m_1\, m_2 / r^2$).

2. How long does it take light to travel from the Sun to the Earth? To Jupiter? To Pluto?

	Earth distance = 149,600,000 km	*Time =*
Speed of light = 300,000 km/sec	*Jupiter distance = 778,300,000 km*	*Time =*
	Pluto distance = 5,913,000,000 km	*Time =*

3. According to Einstein's theory of special relativity (1905), the speed of light is the speed limit of all matter and energy in the universe. **How could the force of gravity transmit instantly from the Sun to the planets if it takes light several minutes and hours to cross our solar system?**

Observation #2

Imagine you and a friend are each pushing a large wagon across the roof of a tall building. Your wagon is filled with rocks; your friend's wagon is empty. It takes a lot more force to push your wagon across the roof at the same acceleration as your friend's wagon.

You push the wagons off the roof simultaneously. You watch them fall to the ground. You notice that the wagons hit the ground at the same time. The force of gravity, which was pulling the wagons down, must have been pulling on the more massive wagon with more force, since it takes more force to accelerate a heavier wagon at the same rate as a lighter wagon. **How do you think gravity "knows" to pull harder on the more massive wagon?**

A New Understanding

According to Einstein, the answer to these questions was that the "force of gravity" was actually the **"structure of spacetime."** Planets orbit the Sun because the Sun creates a depression in the structure of spacetime. The planets follow the curves of the depression and revolve around the Sun like a marble in a bowl. Gravity Probe B is examining the amount of "depression" or curvature that Earth is creating in spacetime, as well as the amount of "twisting" or frame-dragging the Earth is causing by its rotation.

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