

Astrowatch

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Gravity Probe B confirms Einstein's general relativity

The final results of the Gravity Probe B (GP-B) satellite confirm two key predictions of Albert Einstein's general theory of relativity: the geodetic and frame-dragging effects. The precise determination of these two effects, first proposed 50 years ago, seals the success of this extremely challenging mission.

The history of Gravity Probe B started in 1961 with a proposal to NASA to develop a relativity gyroscope experiment. A refined "Proposal to develop a zero-G, drag-free satellite and to perform a gyro test of general relativity in a satellite" was submitted in November 1962 and funded one year later. Defining the mission was relatively simple but solving all of the technological challenges to obtain the desired precision became an odyssey.

The basic idea is to place gyroscopes and a telescope in a polar-orbiting satellite; to align both the telescope and the spin axis of each gyroscope with a distant reference point, a guide star; and to keep pointing at this star for a year while measuring the drift in the spin-axis alignment of each gyroscope. The problem is that this has to be achieved with an accuracy of 1 milliarcsecond (mas). In practice, the gyroscopes are four perfect spheres the size of a ping-pong ball with a spin rate of around 70 Hz, which are made of quartz coated with niobium. They have to be kept without any contact inside a quartz housing with an inner radius only 32 μm larger than the balls. One of the gyroscopes is even left free-floating and the entire spacecraft is moved round to keep the



One of the four gyroscopes – a perfect niobium-coated quartz ball – and its housing equipped with six electrodes to suspend the ball electrically, and a channel to spin it up with a stream of helium. (Image credit: Gravity Probe B.)

device in its housing. Everything has to be completely isolated magnetically and cooled to 1.8 K to achieve superconductivity in the niobium coating that is used to measure the spin axis of the gyroscopes.

On 4 May, the GP-B team proudly announced: "After 31 years of research and development, 10 years of flight preparation, a 1.5-year flight mission and 5 years of data analysis, our GP-B team has arrived at the final experimental results for this landmark test of Einstein's 1916 general theory of relativity." The results are values for two measurements: a geodetic drift rate of -6601.8 ± 18.3 mas/yr and a frame-dragging drift rate of -37.2 ± 7.2 mas/yr. Both effects are clearly detected and the

values are consistent with the predictions of general relativity of -6606.1 mas/yr and -39.2 mas/yr, respectively. The final results are an error-weighted average of the drifts of the spin axes measured on the four individual gyroscopes. The geodetic effect – the deformation of space-time around the Earth – leads to a drift in the north-south direction, while the frame-dragging or Lense-Thirring effect – the entrainment of space-time by the daily rotation of the Earth – results in a west-east drift.

The eventual publication of the results from data acquired between 28 August 2004 and 14 August 2005 must be a relief for Francis Everitt, the principal investigator of GP-B and his team at Stanford University. Extracting the signal from the noise and accounting for all of the systematic effects was a difficult process. The final uncertainty on the frame-dragging effect remains relatively high (19%) and far from the prelaunch goal of achieving an accuracy of 1% (*CERN Courier* June 2004 p13). It does not supersede the accuracy obtained with the Laser GEOdynamics Satellites (LAGEOS) published shortly after the launch of GP-B, although the uncertainty on these measurements remains controversial (*CERN Courier* December 2004 p15). Perhaps the success of the GP-B mission resides more in the extraordinary technological achievements than in the actual results.

● Further reading

CWF Everitt *et al.* 2011, *Phys. Rev. Lett.*, in press.

Picture of the month

This stunning, colourful image depicts a small region of the Lagoon Nebula. Also known as Messier 8 (M8) it is located some 5000 light-years away in the direction of the Galactic centre and the constellation Sagittarius. Seen through small telescopes and binoculars as a fuzzy glow, M8 is a region of intense star formation with a characteristic pink hue from ionized hydrogen (Balmer H- α recombination line). While red is indeed the hydrogen emission in this image by the 8-m Gemini South telescope on Cerro Pachón in the Chilean Andes, the other colours are false. Ionized sulphur emission is coded in green and infrared starlight in blue. (Image credit: Julia I Arias and Rodolfo H Barbá Departamento de Física, Universidad de La Serena, Chile; and ICATE-CONICET, Argentina.)

