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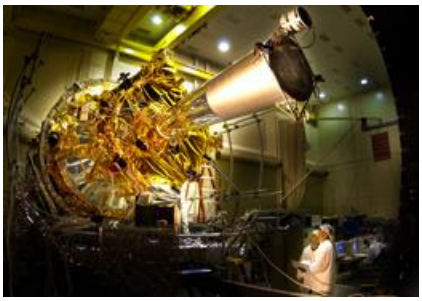
News

Troubled probe upholds Einstein

General relativity vindicated, but was the mission worth it?

Eugenie Samuel Reich



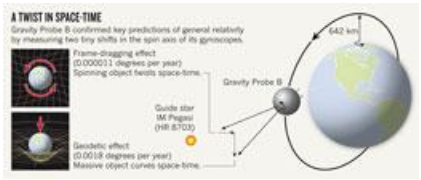
By the time Gravity Probe B launched, its goals had largely been met by other projects. *Stanford Univ.*

An epic victory over daunting challenges, or a costly project that should never have flown? After nearly half a century of work and US$750 million spent, Gravity Probe B, one of NASA's longest-running mission programmes, has finally achieved some scientific closure. But it has yet to quiet its critics.

On 4 May, researchers released the results of a tortuous five-year data analysis that relied on the largesse of a Saudi funding agency to complete. The verdict, to be published in *Physical Review Letters*: Einstein was right. "I am both glad and relieved that we pulled this off," says physicist Francis Everitt of Stanford University in California, who has led the effort since the beginning.

To some physicists, however, the real impact of Gravity Probe B is to illustrate why future missions should be ranked against competing proposals to improve the scientific return on investment. "I think there are a lot of lessons in this," says Neil Cornish, a physicist at Montana State University in Bozeman, who has long been sceptical that the mission offered value for money.

First funded in 1963, Gravity Probe B relied on technology that was out of reach for decades. Finally launched in 2004, it carried four gyroscopes — made up of fused quartz balls coated with superconducting niobium that rotated up to 5,000 times per minute. Each ball produced a magnetic field, so that changes in their orientations relative to a guide star, IM Pegasi, could be measured. The point of the measurement was to confirm two predictions of general relativity. One is geodetic precession, in which the curvature of space-time around a massive object, such as Earth, induces a slight wobble in an orbiting gyroscope. Another, much smaller effect is gravitomagnetism, or frame-dragging, in which the spin of a massive object tugs space-time in the direction of its rotation, like a spoon twisted in honey (see **'A twist in space-time'**). Gravity Probe B has confirmed the first effect to within 0.3% and the second to within 19%, Everitt says.



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But geodetic precession had already been confirmed to nearly this level of accuracy in measurements of laser light bouncing off mirrors on the Moon, and the frame-dragging result is no more accurate than an estimate extracted from measurements of the precession of the orbits of the Laser Geodynamics Satellites (LAGEOS) launched in 1976 and 1992. Furthermore, Gravity Probe B's stated goal was to measure the effects to a precision of 0.01% and 1%, respectively.

Both of Gravity Probe B's results had to be carefully teased out of the data because of unexpected electrostatic effects discovered during the probe's 17-month mission that particularly swamped the frame-dragging signal. "It's a heroic rescue," says Clifford Will of Washington University in St Louis, Missouri, the chair of Gravity Probe B's advisory board.

Others see the complexity of the calculations as a reason to doubt the probe's frame-dragging measurement. "It may be that people repeating this analysis with another working hypothesis on the nature of the systematic errors would get another result," says Ignazio Ciufolini of the University of Salento in Lecce, Italy, who published the results from LAGEOS (**I. Ciufolini and E. C. Pavlis *Nature* 431, 958–960; 2004**).

Conscious of previous confirmations of general relativity's effects, NASA convened an external panel in 1995 to assess whether Gravity Probe B was still worthwhile. The panel gave the probe a green light, but it did not rank it against other possible missions. That was a mistake, says Cornish, because most well-conceived missions look useful when considered in isolation. "It is a waste of time to do reviews of a single mission," he says. Everitt responds that Gravity Probe B was competitively reviewed numerous times during its development, but he acknowledges that, as a fundamental physics mission, it did not go through the

same review process used to select astronomy missions.

In 2008, when researchers were analysing data from the flight, Cornish served on a review panel that ranked Gravity Probe B as the lowest of eight then-active missions in terms of science per dollar. In response, NASA took the remarkable step of cutting off funding for the probe before its results were in. But Stanford University, the prime contractor on the mission, succeeded in keeping the data analysis alive. Everitt and his team raised an additional $3.73 million from private sources, most of it from the Saudi science-funding agency King Abdulaziz City for Science and Technology (KACST), arranged through Turki Al Saud, a Saudi Arabian prince with a PhD from Stanford who is vice-president for research at the KACST.

Gravitation expert Bernard Schutz of the Max Planck Institute for Gravitational Physics in Potsdam, Germany, says he thinks that the mission was worthwhile because general relativity should be checked in a variety of ways. "The fact that they're getting the same thing is what we want in physics. I think it's fantastic," he says. But he laments the delays to launching a dedicated satellite that would amount to a more precise version of LAGEOS, as proposed by Ciufolini in the 1980s."This could have been done a decade ago," Schutz says.

The Laser Relativity Satellite (LARES), on which Ciufolini is principal investigator, will finally be launched this year by the Italian Space Agency. The team intends to measure frame-dragging with 1% precision by monitoring the precession of LARES's orbit. Its cost of about €4 million (US$5.7 million), not including launch, pales by comparison with that of Gravity Probe B.

*UPDATE: The paper is now available on **ArXiv**.*

Comments

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About the LAGEOS tests, I would say that they should be repeated by varying in a substantial way the approach followed so far, which basically remained unchanged during all these years. Indeed, frame-dragging should be explicitly solved-for in a least-square way, as usual in all such kind of analyses. Instead, it was never included in LAGEOS' force models. It was never estimated in the usual way. I would also add that, so far, all the institutions worldwide producing global Earth gravity field models from GOCE, GRACE, CHAMP data never explicitly solved for general relativity. Moreover, there is also an issue concerning the actual removal of the first multipole C20 of the Earth's gravity field from the combination used so far, which was assumed to be exact. About LARES, the one which will actually fly will have a quite different orbit (much lower) with respect to that originally proposed in 1986. The expected 1% is likely unrealistic because of too much multipoles whose action is difficult to be reliably evaluated. Finally, the C20 issue will hold also for it. Some refs. supporting these views are Astrophysics and Space Science, vol. 331, no. 2, pp. 351-395, 2011. General Relativity and Gravitation, vol. 43, no. 6, pp.1697-1706, 2011. Journal of Modern Physics, vol. 2, no. 4, pp. 210-218, 2011 **#21135**

Report this comment Posted by: **John Fuller** | 2011-05-11 03:10:08 PM

I would add that another issue is the correct treatment of the Newton's multipoles. Indeed, GR was not independently estimated in any of the several global gravity field solutions produced so far worldwide. Thus, it may a-priori "imprint" the data of all satellites which can conceivably be used to test frame-dragging, LAGEOS included. One may read Communications and Network, Volume 2, Number 1 (Feb. 2010), pp. 26-30. Moreover, many of such models used previous solutions for the Earth's gravity field as background reference models. But they were obtained just from LAGEOS observations themselves. Another concern is that, after 15 years, no other really independent tests yet exist in peer-reviewed literature, apart from 2-3 talks and conference presentations, based all on the same approach. In other words, in such talks frame-dragging was not explicitly modeled and solved-for. **#21166**

Report this comment Posted by: **John Fuller** | 2011-05-12 06:09:46 AM

Now, a step further is required to try to put frame-dragging-both Schiff gyro precession and Lense-Thirring orbital precessions-on the test in

different scenarios. **#21178**
I see that in literature first, preliminary steps towards the implementation of this goal have been taken.
For example,
New Astronomy, vol. 15, no. 6, pp. 554-560, 2010 (spinning Jupiter and Juno spacecraft)
General Relativity and Gravitation, vol. 41, no. 6, pp. 1273-1284, 2009 (spinning Mars and orbiting probes)
International Journal of Modern Physics D, vol. 20, no. 2, pp. 181-232, 2011 (spinning Sun and orbiting planets)

About the ongoing LARES, there are issues also for the atmospheric drag. One may look at
Acta Physica Polonica B, vol. 41, no. 4, pp. 753-765, 2010. Other critical aspects of LARES are here
Advances in Space Research, vol. 43, no. 7, pp. 1148-1157, 2009.
General Relativity and Gravitation, vol. 43, no. 6, pp.1697-1706, 2011.

Report this comment Posted by: **John Fuller** | 2011-05-12 11:26:01 AM

First, there were errors due to the niobium spheres being a few atoms short of perfectly round. Then came patches of surface charge **#21181**
that skewed the data. Ground testing simulated the true environment, compromising the scientific method.
And GPS technology was dependent on GP-B ..... (because they both start with GP?)

At all times there was a sense that the destination was known, and only the path to it was an issue.... a journey that took over 4 decades and approached 1 gigabuck.

No empirics can 'confirm' a theory... only support it with a greater CL. A dynamic aether theory where c depends on aether motion and density is also 'confirmed' by the GP-B results.
Confirmation of GR requires it be both necessary and sufficient to explain the results .... logically equivalent.

Report this comment Posted by: **Robert Bennett** | 2011-05-12 11:49:35 AM

I wonder, and not only I, how can one scientist seriously believe a five years data analysis with a measurement coming out from huge**#21216**
systematic errors, orders of magnitude larger than the original planned GP-B accuracy? To me it looks like a rabbit coming out from a black hat!

The GP-B data analysis was very much dependent on the models that the GP-B team made. Just one example: the GP-B team is somehow modelling the electrostatic charges on and around the gyroscopes but what about the modelling of the unknown quadrupole moment induced by the gyroscopes rotation: its magnitude and its relative direction with respect to the quadrupole moment due to fabrication and finally, last but not least, its unknown rate of change because of variations of the gyroscopes rotation rate. As soon as the Phys. Rev. Lett. paper will be available, I believe that a number of papers will point out these and other relevant problems of the ossGP-B analysis .

Report this comment Posted by: **francis drake** | 2011-05-13 05:25:01 AM

There are a number of replies to the Iorio papers about the error budget of the LAGEOS and LARES experiments mentioned **#21219**
by â€œ â€œJohn Fullerâ€□ â€œ, see for example:

New Astronomy, 10, 636-651, 2005, New Astronomy, 11, 527-550, 2006, Space Science Reviews, 148, 71-104 (2009), â€œGeneral Relativity and John Archibald Wheelerâ€□, Springer 2010, with two papers, one on LAGEOS p. 371-434 and one on LARES p. 467-492, etc. Other papers are soon to appear. The results of the LAGEOS+GRACE measurements have been published in Nature (Letters), 431, 958-960 (2004), Nature (Review), 449, 41-47 (2007) and also in the above papers.

The independent results by the University of Texas at Austin, JPL Caltech have been presented at invited talks at: 16th International Workshop on Laser Ranging, Poznan, Poland, 13â€“17 October 2008 (John C. Ries, Richard J. Eanes, Michael M. Watkins â€œConfirming the frame-dragging effect with satellite laser rangingâ€□), and at: International Astronomical Union Symposium 261, Relativity in Fundamental Astronomy, Virginia Beach, VA, USA, 27 April-1 May 2009. These presentations are available, e.g., on the internet at:

http://cddis.gsfc.nasa.gov/lw16/docs/presentations/sci_3_Ries.pdf

and (abstract) at:
http://cddis.gsfc.nasa.gov/lw16/docs/papers/sci_3_Ries_p.pdf

The readers of this blog should carefully read these papers, presentations and replies and form their own idea.

Report this comment Posted by: **Cecilia Sagui** | 2011-05-13 06:56:24 AM

For example, regarding the atmospheric drag, the variations of the orbital elements of the LAGEOS satellites, e.g., inclination and semimajor axis, are very accurately determined by laser ranging and the variation of the nodal longitude of a satellite, due to atmospheric drag, is substantially null (a classical result of celestial mechanics that can be found in books of celestial mechanics). This and other potential issues raised by Iorio are, for example, treated in: Ã¢â‚¬Å“General Relativity and John Archibald WheelerÃ¢â‚¬Â□, Springer 2010 (see. e-g., p.420 for the variations of the inclination due to atmospheric drag). **#21220**

Report this comment Posted by: **Cecilia Sagui** | 2011-05-13 06:59:00 AM

I disagree with Cecilia Sagui about the truly and affordable independence of the tests suggested by him. Indeed, just two conference presentations in 15 years is really not enough. Moreover, he quotes two chapters appeared in an edited book by Ciufolini himself. More importantly, the approach followed by these other authors is the same of the one used by Ciufolini himself, not representing anyhing really new: they simply used a different orbit processor. By carefully reading such drafts it is possible to note that they share some of the shortcomings of the analyses by Ciufolini. For example, they use some Earth gravity models which include data from LAGEOS themselves and/or which were built by using as reference background models previous solutions obtained from SLR data. See Central European Journal of Physics, Volume 8, Number 1, 25-32, 2009. These other authors should, instead, attempt to publish their own papers, without Ciufolini, and, especially, trying to implement the points previously listed, or explaining why they were not successful in doing that. About the comment by Cecilia Guidi on the atmospheric drag, it seems he did not read Acta Physica Polonica B, vol. 41, no. 4, pp. 753-765, 2010. Indeed, the problem is not the direct impact of the atmospheric drag on the node, but its indirect, mixed effect through the inclination variation entering the classical node precession of the node due to the first multipole.
Cecilia Guidi is, actually, Nightmare-Robin who posted his comments in the blogs of Science (Nightmare) and Nature News (Robin). **#21227**

Report this comment Posted by: **John Fuller** | 2011-05-13 08:52:57 AM

"John Fuller" should please read p.75 of Space Science Reviews, 148, 71-104 (2009) or p.420 of "General Relativity and John Archibald Wheeler". Then, he should directly ask to any researcher that knows the technique of orbital estimation and knows how to run an orbital estimator, what is the difference between **determining** (for example with Satellite Laser Ranging) an orbital element, e.g., the inclination, and **modelling** that same element, i.e., predicting its behaviour on the basis of the known physical models. Similarly, for the other questions that he would like to clarify, he should read the two papers on LAGEOS and LARES in "General Relativity and John Archibald Wheeler" pp.371-434 and pp.467-492 or ask to any researcher working in space geodesy. **#21259**

Report this comment Posted by: **Cecilia Sagui** | 2011-05-15 04:41:06 PM

Concerning the remark by Robin Cecilia Nightmare (RCN), it seems to me that Acta Physica Polonica B, vol. 41, no. 4, pp. 753-765, 2010, which is neither a review paper nor a book chapter inserted in a book edited by RCN himself, explains the point. Anyway, RCN should be less confident in the consensus by the rest of space geodesy community in view of the fact that a large number of peer-reviewed research papers disagreeing with him were published so far. This means that the consensus hoped by RCN in the community is, actually, non-existent. Anyway, in General Relativity and Gravitation, vol. 43, no. 6, pp.1697-1706, 2011 it is shown that other critical issues are, in fact, present even in the case in which the inclinations can be determined with the optimistic accuracy claimed by RCN himself. **#21260**

Report this comment Posted by: **John Fuller** | 2011-05-15 05:13:43 PM

Gravity probe-B is an expensive misleader! The findings of this project clearly confirm the existence of a real physical medium in space to propagate light and gravitational field but the uncanny haste with which *Phys Rev Lett* accepted the concerned paper within 4 days of submission is fraught with the danger that these results will be misinterpreted to support the *non-existent* 4-dimensional spacetime continuum basic to the Einstein's General Relativity. **#21367**
In fact space and time are not substantive entities but mere abstract concepts evolving from our life-long perceptions of successive motions and changes in the surroundings. The concept of space evolves from the successive perceptions of 'there, here, there' and that of time from those of 'then, now, then'. The concepts of space & time are too intangible and abstract to fuse into any tangible spacetime continuum. A multidimensional continuum would retard motions of mass bodies, even of the photon to propagate light across it. A non-composite static spacetime cannot undulate to transmit transverse light wave. Therefore all the four- and higher- dimensional spacetime continua are mere mathematical constructs bereft of real physical existence.
But the existence of the all-composing and all-pervading light-propagating real physical **sharmon medium** as the **basic substance** is supported by innumerable experiments including those on the interference and diffraction of light proving wave nature of light. The new particle **sharmon** is composed by an electrically positive *positrino* and a negative *negatrino*. The non-composite and indivisible elementary positrino and negatrino compose all forms of mass and energy of all the particles like quarks & leptons and energy quanta like photon in the **Cosmos**, hence are named as **cosmino** .
Actual computations show that a cosmino has the diameter of Planck length lp = 1.6156x10^-33^ cm, mass = 2.596x 10^-48^ gm, electric charge = Â± 1.3729x10^-30^ esu, and spin = Â±Â½.

Of further great interest and relevance is the following excerpt from section 2.4.11 of the 2010-book:**THE UNIFIED THEORY** : *A complete paradigm shift in Physics & Cosmology* URL: http://www.lulu.com/content/paperback-book/the-unified-theory-a-complete-paradigm-shift-in-physics-cosmology/8347654 .
On 21st April 2004 the US$700m (now US$750m) Gravity Probe-B (Gp-B) was launched. Its primary task was to use four ultra-precise gyroscopes to measure directly two effects predicted by general relativity. One is the *geodetic effect*â€"the amount by which the mass of the Earth warps the local 4-dimensional spacetime continuum in which it resides. The second effect, called *frame-dragging* , is the amount by which the rotating earth drags local spacetime around with it. Because the spacecraft is in a polar orbit, the two effects occur at right angles to each other, giving a clean separation between them. Furthermore, the gyros are arranged such that each measures both effects. It is a tribute to the preparation, knowledge and skill of the Stanford-NASA-Lockheed Martin development team. The website http://einstein.stanford.edu/ presents the details and updates.
However, a sharmon 1.616x10^-33^ cm across and 3.23x10^-33^ cm long can pass through inter-atomic spaces and between the orbital electrons in the densest solid. Therefore the sharmon medium is irremovably present in the high vacuum of Gp-B, vide Chapter-8 of this 2010-book The sharmon medium is viscous, with a viscosity constant 0.57x10^-22^ dyne.sec/cm2. In Unified Theory the sharmons mediate gravitational and electromagnetic fields, forces and phenomena including light, vide Chapters 7, 8 & 10 of this 2010-book. **Therefore sharmon medium can account for all the effects that General Relativity ascribes to the 4-D spacetime continuum, which propagates electromagnetic light and gravitation**. The *geodetic effect* is the gravitation related curvature of the sharmon medium and the *frame drag* is the â€˜*sharmon medium drag*â€™ due to viscosity combined with gravitation. It, for example, is a common experience that a body rotating and/or moving in a viscous medium distorts the medium and carries it along. The earth spins on its axis as it revolves around the sun. The Gp-B cannot differentiate 'frame-drag' from the 'sharmon medium drag' of Unified Theory. The two are the same. However, the 4-D spacetime continuum is non-existent (sec. 2.4.1 in the above book), and so is the 'frame-drag'. But 'sharmon medium' and hence the 'sharmon medium drag' is real (sec. 2.4.2 in the above book). So, what the Gp-B proposes to measure in the name of 'frame drag' is only the 'sharmon medium drag'. It is also the *aether drag* measured by Dayton Miller

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link to Natural Philosophy Alliance-profile: http://www.worldsci.org/people/Rati_Ram_Sharma

Report this comment Posted by: **Rati Ram Sharma** | 2011-05-17 03:26:07 AM

I went to the webpage of the GRACE mission at GFZ http://op.gfz-potsdam.de/grace/ By clicking on the link "Publications" on the left column I retrieved a list of publications related to the GRACE products listed per alphabetical order. I found some papers by Ciufolini, many papers by Iorio, and, above all, none of the allegedly existing papers claimed by Cecilia-Robin-Nightmare by GFZ people making independent tests with the LAGEOS satellites. It looks quite strange. If the reiterated bombastic and pompous claims by Cecilia-Robin-Nightmare on the existence of such independent tests really existed, it is clear that they should be well emphasized by GFZ itself. **#21918**

Report this comment Posted by: **John Fuller** | 2011-05-22 05:50:02 AM

I did the same with the GRACE-dedicated webpage http://www.csr.utexas.edu/grace/ by the CSR and with the webpage of the Center for Space Research itself of the University of Texas http://www.csr.utexas.edu/ **#21929**
The result is the same: no mention at all for frame-dragging, Lense-Thirring and any independent tests of them performed by CSR members themselves.

Report this comment Posted by: **John Fuller** | 2011-05-22 10:42:40 AM

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