Class. Quantum Grav. **22** (2005) 3815–3816 doi:10.1088/0264-9381/22/17/N01

COMMENTS, REPLIES AND NOTES

A note on frame dragging

R F O'Connell

Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70804-4001, USA

Received 9 May 2005
Published 22 August 2005
Online at stacks.iop.org/CQG/22/3815

Abstract
The measurement of spin effects in general relativity has recently taken centre stage with the successfully launched Gravity Probe B experiment coming towards an end, coupled with recently reported measurements using laser ranging. Many accounts of these experiments have been in terms of frame dragging. We point out that this terminology has given rise to much confusion and that a better description is in terms of spin–orbit and spin–spin effects. In particular, we point out that the de Sitter precession (which has been measured to a high accuracy) is also a frame-dragging effect and provides an accurate benchmark measurement of spin–orbit effects which GPB needs to emulate.

A measurement of the Lense–Thirring frame-dragging general relativistic effect of the earth's rotation, by use of laser ranging to two earth satellites [1], has recently been carried out to within 10% accuracy. The original article, as well as comments on the same [2, 3], assumes that this is so far the most accurate measurement of 'frame dragging'. These articles also discuss the de Sitter (geodesic) precession but refer to it as being 'one aspect of the class of relativistic phenomena loosely known as gravitomagnetism' [2], different from that of frame dragging. These are common beliefs, but they are not correct, as we now point out.

First, we point out that de Sitter precession is also a frame-dragging effect. In particular, because of its distance from the sun, the earth–moon system can be regarded as a single body which is rotating in the gravitational field of the sun. In other words, the earth–moon system is essentially a gyroscope in the field of the sun (no different in principle than the earth acting as a gyroscope or a quartz ball in the Gravity Probe B (GPB) experiment acting as a gyroscope) and its frame-dragging effect due to interaction with the sun has been measured, using lunar laser ranging, to an accuracy of 0.35% [4, 5]. This is the accuracy which the GPB experiment or precession observations of the recently discovered double pulsar system [6] needs to exceed! We note that the high accuracy achieved for the de Sitter geodetic effect required analysis of gravitational three-body (earth, moon and sun) theory but, to quote the authors of this work, 'geodetic precession is implicit in the relativistic equations of motion' [5]. Ultimately, we expect that the most accurate results will emerge from analysis of the double pulsar system (because the gravitational forces are significantly stronger and there are no observational time limits, in contrast to the GPB experiment), which has the added bonus of testing two-body effects.

Second, whereas 'frame dragging' is a very catchy appellation, gravitational effects due to rotation (spin) are best described, using the language of QED, as spin–orbit and spin–spin effects since they also denote the interactions by which such effects are measured; in fact these are the only such spin contributions to the basic Hamiltonian describing the gravitational two-body system with arbitrary masses, spins and quadruple moments [7]. They manifest themselves in just two ways, spin and orbital precessions, and whereas these can be measured in a variety of ways (for example, as discussed in [8] orbital precession can be subdivided into periastron, nodal and inclination precessions [9]), such different measurements are simply 'variations on the theme'.

Third, all measurements reported up to now as well as observations on binary pulsar systems have been confined solely to spin–orbit effects. It appears that the only immediate prospect of measuring the spin–spin effect is the GPB experiment. However, the significance of such a measurement will be tempered by the fact that, given the verification of the spin–orbit prediction, the predicted spin–spin result is necessary to ensure conservation of total angular momentum [7].

Note added in proof. More recent analysis of lunar laser ranging 'increases the uncertainty of the geodetic precession' [10]. Also, spin–orbit coupling has been measured in the binary-pulsar system PSRB1534+12 [11].

References

[1] Ciufolini I and Pavlis E C 2004 *Nature* **431** 958
[2] Ashby N 2004 *Nature* **431** 918
[3] Seife C 2004 *Science* **306** 502
[4] Williams J G, Boggs D H, Dickey J O and Folkner W M 2002 *Proc. 9th Marcel Grossmann Meeting* (Singapore: World Scientific)
[5] Williams J G, Newhall X X and Dickey J O 1996 *Phys. Rev.* D **53** 6730
[6] Lyne A G *et al* 2004 *Science* **303** 1153
[7] Barker B M and O'Connell R F 1975 *Phys. Rev.* D **12** 329
[8] Barker B M and O'Connell R F 1970 *Phys. Rev.* D **2** 1428
[9] O'Connell R F 2004 *Phys. Rev. Lett.* **93** 081103, 1
[10] Williams J G *et al* 2004 *Phys. Rev. Lett.* **93** 261101
[11] Stairs I H *et al* 2004 *Phys. Rev. Lett.* **93** 141101