# PROPOSALS FOR AN EXPERIMENT TO DETECT THE EARTH'S GRAVITOMAGNETIC FIELD

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ABSTRACT. Some experiments are discussed for measuring the earth's gravitomagnetic field, using a pendulum or an oscillator rather than a gyroscope.

## 1. INTRODUCTION

General Relativity predicts that a rotating massive body, along with Newtonian-like gravity, generates curl-like gravitational field, which is similar to the magnetic field in electrodynamics, i.e. "gravitomagnetic" field, "GMF" |1|

Up to now the GMF has never been detected. The only experiment which is at the stage of preparation now is the experiment with Relativistic Gyroscope aboard the earth satellite, the so called gravity probe B, "GPB", which supposed to fly in 1990 |2|. Since GMF-measurements are important for astrophysics and gravitational physics it is rather interesting to consider some other possible experiments.

## 2. SPIN-QUADRUPOLE EFFECT

The first problem to be solved is whether it is possible to detect the GMF in a "local" experiment, i.e. without locking to distant stars with the help of a telescope. The answer is yes, however, the value to be measured in such experiment is not the GMF itself (here referred to as $\vec{H}_G$) but its gradient $(\vec{x}\vec{\nabla})\vec{H}_G$, in accordance with the principle of equivalence. This principle applied to the GMF says: it is impossible to distinguish GMF accelerations from Coriolis ones which arise in non-inertial rotating frames. It means that the only effect which can be detected without a telescope is spin-quadrupole one.



J. Kovalevsky and V. A. Brumberg (eds.), Relativity in Celestial Mechanics and Astrometry, 401–405.

A space version of the spin-quadrupole effect has been discussed by V. Braginsky and the author |3| (see Figure 1). In this scheme an oscillator consisting of two probe masses connected by a spring is excited as it moves through the nonuniform field $\vec{H}_G$.

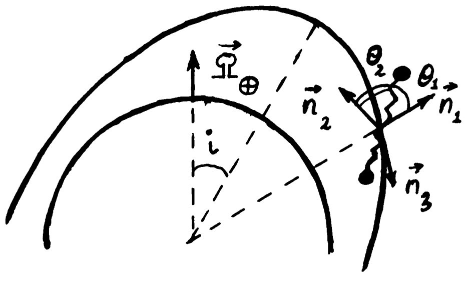


Figure 1. The principal scheme of the space experiment to detect spin quadrupole effect. $\vec{n}_1$, $\vec{n}_2$, $\vec{n}_3$ are unit vectors; $\vec{n}_1$ lies within the plane of the orbit and is directed normally to the satellite velocity; $\vec{n}_2$ is normal to the plane of the orbit; and $\vec{n}_3$ is tangential to the orbit, $\underline{i}$ is the slope angle of the orbit plane relative to the vector of the Earth's angular velocity, $\Theta_1$ and $\Theta_2$ determine the oscillator orientation relative to the satellite.

As was shown in |3| even in nonresonance regime the amplitude of oscillations can be as large as $\Delta l/l \simeq 10^{-10}$, and can be easily measured with a capacity sensor. The most dangerous spurious effects considered in |3| (Newtonian tidal accelerations; oblateness of the Earth; ellipticity of the orbit and so on) can be "subtracted", since the dependences of different spurious effects and the spin-quadrupole effect on $\Theta_1, \Theta_2$ and $\underline{i}$ are different. So in contrast to gyroscope whose orientation is fixed it is possible to change the orientation of oscillator in the experiment. In this case there is no need to know parameters of spurious effects in advance because they can be measured and subtracted during the experiment |3|.

## 3. FOUCAULT PENDULUM AT THE SOUTH POLE

The second problem to be solved, is whether it is possible to detect the GMF in the ground-based experiments. The paper by V. Braginsky, K. Thorne and the author |4| proposed the

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following version of the experiment. The experimental apparatus would consist of a Foucault pendulum and an astrometric telescope with its optical axis locked to the azimuth of a reference star (e.g. Canopus). As explained in |4|, to exclude the well-known Foucault effect due to the earth's angular velocity it is necessary to operate within a few kilometers of the North or South pole. The South Pole is preferable, since there is a scientific station there. The GMF causes a precession of the pendulum's swing plane with respect to the reference star's azimuth (see Figure 2).

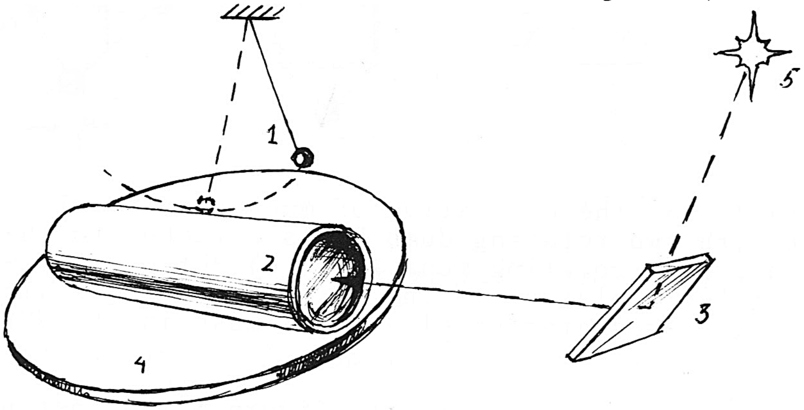


Figure 2. Foucault pendulum at the South pole.
1 - Foucault pendulum, 2 - a telescope, 3 - a mirror,
4 - a rotating platform, 5 - a reference star

The angle between the swing plane and the axis of the telescope must increase with the duration of the experiment, $\tau$, as

$$\Delta\Psi_{GMF} = \Omega_{GMF}\tau = 0.036'' \ (\tau/60d) \qquad (1)$$

The paper |4| described the most dangerous sources of experimental error: magnetic forces, frictional damping, Pippard precession, frequency anisotropy, seismic noise, atmospheric refraction, distortion of the telescope, tilt of the telescope. The conclusion has been done: while the proposed experiment is very difficult it might be feasible.

## 4. LOCAL EARTH-BASED EXPERIMENT

The last problem to be solved is whether it is possible to detect the GMF with neither satellite nor telescope. The

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paper by V. Braginsky and the author |5| discussed some variants of an earth-based spin-quadrupole experiment (see Figure 3)

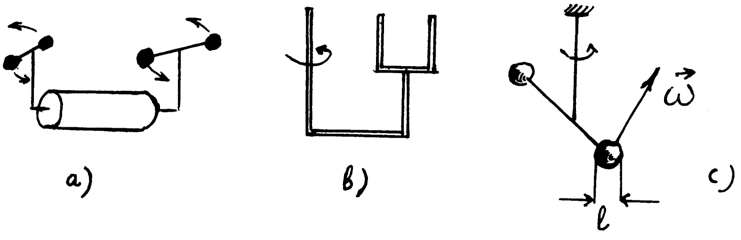


Figure 3. a) The excitation of mechanical oscilations in a bar with two rotating dumb bells attached to the ends of the bar, b) A rotating tune fork; c) Eötvös-type experiment. The seeming violation of the principle of equivalence is due to the acceleration of a point mass in the GMF.

Among the three schemes in the Figure 3 the most promising is the Eötvös-type experiment. The acceleration due to the spin-quadropole effect is estimated as |5|

$$a_{SQ} \approx 10^{-18}\ \mathrm{cm/s^2}\ (\omega/1\ \mathrm{kHz})\ (\mathbf{l}/10\ \mathrm{cm})^2 \qquad (2)$$

$\omega$ and $\mathbf{l}$ are defined in Figure 3c. The effect is so weak that the thermal noise is the most serious obstacle. To overcome this obstacle the sensitivity must be five orders better than in the last check of the principle of equivalence |6|. The paper |5| analyzed the role of Newtonian accelerations due to nonuniformity of the rotating mass.

## 5. CONCLUSION

The Foucault pendulum experiment is extremely difficult but seems to be feasible. The local space experiment to detect spin-quadrupole effect needs further analysis. The Eötvös-type experiment seems too difficult to realize in the reasonable future.

ACKNOWLEDGEMENT

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DISCUSSION

Kreinovich : is it technically possible to obtain satellite parameters with such an accuracy ? Even if you manage to launch such a satellite it will soon change its orbit. Or do you suppose that there are some micro-thrusters on the satellite ?

Polnarev : it is not necessary to know the parameters of the orbit with great precision ; our algorithm allows to obtain both parameters of the orbit and relativistic parameters.

Reasenberg : how much will your south pole experiment cost ?

Polnarev : approximately ten million dollars i.e. much less then cosmic experiments ($10^9$ dollars).

Reasenberg : when will they start ?

Polnarev : these are joint Soviet-American experiments, they must be started by Thorne's group. I do not know whether they have already started their preparation or not.

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