

Gravity-Like Fields for Space Propulsion

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Spaceflight, as we know it, is based on the century old rocket equation that is an embodiment of the conservation of linear momentum. Moreover, in our spacetime, special relativity puts an upper limit on the speed of any space-vehicle in the form of the velocity of light in vacuum. Thus, current physics puts severe limits on space propulsion technology. These limitations can only be overcome if novel physical laws can be found. Therefore, during the last two decades, numerous experiments related to gravity shielding or gravitomagnetic interaction (coupling between electromagnetism and gravitation) were carried out, but eventually all proved to be incorrect.

However, on 23 March 2006, the European Space Agency (ESA), on their webpage, announced credible experimental results, reporting **on the generation of a gravity-like field (or artificial gravitational field, details below) in the laboratory**. M. Tajmar et al. at the ARC Seibersdorf, Austria (a certified ESA test center) had carried out these experiments over a period of about three years. The authors report that a rotating niobium (Nb) superconductor ring of some 15 cm diameter generated the AGF. Every time the superconducting Nb ring was subjected to *angular acceleration*, an AGF was measured in the plane of the ring in circumferential direction. The induced acceleration field was *opposite* to the angular acceleration, following some kind of gravitational Lenz rule. In addition, an acceleration field was also observed when the Nb ring was rotating with constant angular velocity, but undergoing a phase change that is, from the normal to the superconducting state. This was achieved by reducing the temperature below 9.2 K, the critical temperature for Nb. Moreover, no acceleration was measured when the Nb ring was in normal conducting state.

General relativity (GR) predicts that any rotating massive body (Earth) drags its local spacetime around, called the *frame-dragging effect, generating the so-called gravitomagnetic field*. This effect, predicted by Lense-Thirring 1918, however, is *far too small to be seen in a laboratory on Earth*. For this reason the **Gravity-Probe B (GP-B)** experiment was launched in 2004 (see below). On the other hand, the values measured by Tajmar et al. were about **30 orders of magnitude higher than predicted by GR**, and therefore are outside GR. *They cannot be explained by the classical frame-dragging effect of GR and represent a new kind of physical phenomenon.*

In October 2006, Tajmar et al. repeated their experiments employing both accelerometers for the AGF as well as laser ring-gyros that very accurately measured the gravitomagnetic field. The gravitomagnetic field, despite its name is a purely gravitational field, is observed when the Nb ring is rotating at constant speed. To generate an AGF, the Nb ring needs to be accelerated (changing its rpm). Again, the AGF was clearly observed, and its rotational nature was then determined by a set of four staggered accelerometers. However, as recent experiments showed, the *experimental situation is more complex*, since the gravitomagnetic effect occurs already at temperatures higher than the critical temperature for superconducting. Provided the experiments are correct, for the **first time**, a gravitational field would have been generated without the presence of a large mass. Moreover, the experiment would demonstrate that gravity might be controllable, enabling, in principle, a **new type of transportation technology**.

There is one caveat, however, when space propulsion is considered. First, the AGF as measured by Tajmar et al. is produced during *angular acceleration or deceleration* of the ring that is, its angular frequency (rpm) *has to change*. Second, the AGF produced lies in the *plane of the rotating superconducting ring that is, in circumferential direction*. These restrictions make it difficult to construct an *effective advanced propulsion system*, though Tajmar (2005) already presented the physical principle for such a device. There exist *theoretical considerations*, however, indicating that an experiment generating an AGF along the axis of rotation might also be possible.

Two questions naturally arise, namely *how to explain these experimental findings* and what about their *independent experimental confirmation*?

Let us discuss the first topic. The title on the ESA webpage was: *On a New Test of General Relativity (GR)?* Immediately similarities with Stanford University's Gravity Probe B experiment come to mind. This flight experiment was first conceived in 1959 and eventually launched from Vandenberg AFB in 2004. Data collection of this experiment was finished in September 2005. The goal of the experiment is twofold. The presence of the earth causes spacetime to be curved (warped). Second, the rotation of the earth should drag spacetime with it and also twist it (frame-dragging). The data analysis for GP-B is not finished yet, the warping effect was found, but the inertial frame dragging effect has not yet been demonstrated (foreseen for the end of 2007), despite the fact that GP-B is a marvel of measurement technology. This clearly shows the substantial difficulties in determining this effect. On the other hand, the acceleration measured by Tajmar is about *30 orders of magnitude larger* than the frame-dragging phenomenon predicted by GR. The frame dragging effect of the superconducting Nb ring clearly **cannot be observed in the laboratory** given the small mass of the superconducting ring as compared to the Earth. *Non-Newtonian gravity in the form of frame-dragging cannot be used to explain the existence of the AGF as measured by Tajmar.* Furthermore, the small mass of the ring rules out Newtonian gravity. Since the experiment is electromagnetically well shielded, *electromagnetic interaction cannot take place.* The *weak force cannot play a role* either, since there is no particle decay, while the *range of the strong force is limited to distances within a nucleus.* Other physical interactions are not known. Therefore, these independent experiments provide substantial evidence for the existence of a **novel physical interaction**.

To answer the second question, namely independent experimental confirmation, recently, a *second experiment* to measuring the gravitomagnetic field was performed by Graham et al., Univ. of Canterbury, New Zealand (July 2007), using the world's most accurate laser-gyro. Both experiments measured a signal much larger than predicted by GR. In his recent paper, 25 August 2007, Tajmar compares his gravitomagnetic field results with those of the Canterbury group and *finds good agreement.* The measurement techniques of the two experiments are *completely different.* Tajmar's measurements were done in the near field of the Nb ring, while Graham measured the far field. Therefore, Graham's results needed to be extrapolated to the near field, assuming a dipolar gravitomagnetic field. In addition, there is a *third source* of independent data, namely from the GP-B experiment itself that uses *most sophisticated measurement techniques.* The GP-B experiment uses two pairs of coated, superconducting Nb spheres (gyros) that were spun up from 0 to 4,000 rpm. Now, if the effect, as measured by Tajmar, is real, these rotating gyros must have produced a gravitomagnetic field, too. This field should have caused a spin-spin interaction between the two laser-gyros forming a pair (i.e. affecting the orientation of each other's spin axis). Indeed, substantial gyro precession anomaly was observed in the GP-B experiment. When Tajmar (2007) applied his *measured gravitomagnetic field data to calculating the respective precession values of the GP-B gyros,* he was able to explain, at least, a large part of this anomaly. Theoretical predictions do also exist. Naturally, this needs to be more closely investigated.

Extreme caution is needed when *announcing novel physical interactions.* Several years ago, a novel physical interaction (fifth force) was announced by a group of physicists of Purdue University and Brookhaven National Laboratory (Fischbach, 1986) who claimed to have experimental evidence for a distinct deviation from Newton's law at intermediate distances between 1m and 1 km. After four years of elaboration and 12 more experiments, agreement was reached that there was no fifth or sixth force. This time **the situation is different** in that no geological structure or chemical composition of the environment is of importance. The physical effects measured by Tajmar and Graham are large, and clearly reproducible independent on location and geological formation.

What does *theoretical physics* have to say about these experiments? The answer is very short, namely *there is no place for these experimental results.* According to current theory nothing should have been measured. What about alternative theories? At present, there are no theories capable of completely explaining these experiments. There exist, however, several preliminary theoretical models. Among

them, there are physical considerations postulating two additional fundamental gravitational like interactions, which were used to analyze both Tajmar's and Graham's experiments as well as the GP-B gyro data. However, experiments are producing many new results, and no firm conclusions from these physical models are available at present.

Regarding the **construction of an advanced propulsion device**, an additional base experiment might be feasible, in *which the AGF is directed along the axis of rotation*, and thus could provide a more direct mechanism for a field propulsion principle working without propellant. To this end, existing preliminary theoretical ideas need to be extended into a more comprehensive physical model to providing proper guidelines for the experimenters. Naturally, such a propellantless propulsion system would be far superior to any existing propulsion technology, while its technology might be substantially simpler than the chemical, fission and fusion rockets. There is, of course, insufficient knowledge at present whether such a device is technically feasible. On the other hand, benefits would be enormous, justifying more extensive research in this field.

The **current situation** (August 2007) can be summarized as follows. There is experimental data from three completely unrelated sources, employing *completely different measuring techniques* that have seen physical effects that are approximately **30 orders of magnitude larger** than predicted by GR. In all experiments a *phase transition occurred at low temperatures* (not necessarily at T_c , the critical temperature for superconducting, but possibly two-electron interaction took place?). GR cannot explain these phenomena, even if the full nonlinear Einstein field equations were used. The GP-B experiment has clearly demonstrated that the inertial frame dragging effect, even from celestial bodies, is extremely small and within GR. These facts provide certain evidence **for novel physics** in the form of **additional fundamental forces**.

How to proceed? It seems that there is sufficient data to start a comprehensive theoretical and experimental research program. There exist physical models that can partly reproduce experimental facts, and also provide guidelines for an experiment generating an AGF along the axis of rotation, while the ring or disk is rotating at *constant speed*. If such an experiment were successful, the goal of **gravity-controlled propulsion** without propellant would be much closer.