DF/IST-3.2002
February 2002

Gravity Control and Spacecraft Propulsion

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Abstract

A scientific analysis of the conditions under which gravity can be controlled has been the scope of a ESA study carried by the author in collaboration with Martin Tajmar. It has been shown that no workable scheme is available and that none of the suggested proposals are compatible with prevailing physical theories. Moreover, it has been demonstrated that even if gravity could be modified it would bring somewhat modest gains in terms of launching of spacecraft and no breakthrough for space propulsion.

The subject of gravity control has been the subject of quite diverse interest ranging from scientific publications to experiments and even patents. Aiming to critically assess the existing literature and to reach a set of recommendations for future strategy ESA has ordered a scientific study under the ESTEC Contract 15464/01/NL/SFe. This study [1] is being carried out by the author in collaboration with Martin Tajmar from the ARC Seibersdorf research GmbH, Space Propulsion of Austria and with Clovis Jacinto de Matos as the agency technical officer.

Our starting point has been a definition of *gravity control*. On quite general grounds, we call *gravity control* any proposal to alter the strength of the gravitational coupling to matter or that can lead, through the intervention of other forces, to a change of the local gravity force. For achieving this control, at least one of the following conditions must be fulfilled:

1) Existence of a new fundamental interaction of Nature to alter the strength of the gravitational coupling to matter. This implies in violations of the Weak Equivalence Principle.

2) Existence of net forces due to the interplay between gravity and electrostatic forces in shielded experimental configurations, as found in the well-known Schiff-Barnhill effect.

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3) Analogous effect for magnetic fields in quantum materials involving the gravitomagnetic field.

4) Physically altering the vacuum properties so to change the relative strength of known fundamental interactions of Nature.

In order to critically examine the existing proposals and to consider lines of research that could lead to new unknown phenomena, a survey of the following topics has been carried out:

- General Relativity
- Einstein Equivalence Principle: Weak Equivalence Principle, Local Lorentz Invariance, Local Position Invariance
- New Interactions of Nature
- String/M-Theory
- Gravitoelectromagnetism and Quantum Materials
- "Vacuum Engineering"
- Gravity Controlled Propulsion

The conclusions of our survey can be summarized as follows:

- Schemes involving heterodox concepts such as *negative masses*, *negative energy densities*, *Mach's principle, warp drive*, etc, defy well tested conventional physical theories and cannot be seriously considered.
- Gravitational anomalies related to shielding effects (claimed to be observed during total eclipses), reduction of weight due to rotation of quantum materials and amplification of gravitomagnetic fields are almost entirely ruled out. Experimental examination of claims that have not yet been ruled out is recommended through specifically dedicated experiments to measure the gravitomagnetic properties of rotating quantum materials.
- The Weak Equivalence Principle holds with great accuracy and expected violations, such as the one emerging from string theory, are far too small to lead to any workable scheme to control gravity. The same can be stated about Lorentz and CPT symmetries.
- Local Position Invariance is rather poorly established in comparison to the Weak Equivalence Principle and Local Lorentz Invariance. Clock experiments at the International Space Station are recommended as they represent the most promising way to further improve the level of accuracy of this symmetry.

- Schemes to alter vacuum properties and the relative strength of the known fundamental interactions of Nature are beyond current theoretical knowledge and out of reach of forseable technological developments.

In what concerns propulsion we have shown that even if gravity could be modified, independently from the underlying of its *modus operandi*, the following conclusions can be reached:

- If modification of gravity were through any scheme that would diminish the inertial mass of a spacecraft then thrust would be lost as the propellant mass would be diminished as well.
- If modification of gravity were through a scheme that would affect the gravitational mass then some gain would be achieved even though it would be rather modest as gravity is just one of the components of the so-called Δv requirement to achieve a Low Earth Orbit. In this case, however, one can envisage a change in the philosophy of reaching space, but only for certain orbits, a vanishing gravitational mass could drastically reduce launcher requirements.
- Dipolar gravitoelectric field or wire-like gravitomagnetic field assisted propulsion schemes lead to irrelevant thrust as compared to conventional devices such as deployable booms or electrodynamical tethers.
- Control of gravity would bring a somewhat modest gain in terms of launching of spacecraft and no breakthrough for propulsion in general.

In view of these conclusions we have suggested a set of recommendations to reflect our view that amphasis in what respect the subject of gravity control should remain focused on the existing fundamental reasearch programme of ESA. Furthermore, we strongly recommend that this programme should be extended in order to emcompass the search for violations of the Weak Equivalence Principle for antiparticles and charged particles and that the analysis of tracking data of existing and forthcoming missions is performed so to examine possible existence of a new long range fundamental interaction of Nature.

Reference

[1] O. Bertolami, M. Tajmar, "Gravity Control and Possible Influence on Space Propulsion: A Scientific Study", ESA Report (2002).