UNIVERSITA` DI PISA

DIPARTIMENTO DI MATEMATICA , GRUPPO DI MECCANICA SPAZIALE

Via Filippo Buonarroti 2, I-56127 Pisa, Italia
Tel 39 050 844252; fax 39 050 844224; mobile 39 347 2522634; e-mail nobili@dm.unipi.it
Website http://eötvös.dm.unipi.it/nobili/homenobili.html

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Prof STEFANO VITALE, Chairman of FPAG
Department of Physics
University of Trento
38050, Povo, TRENTO

cc : Dr Sergio Volontè, ESA Science Directorate
Prof David Southwood, Director of ESA Science Programme

Dear Stefano:

I was pleased to learn at the recent Stockholm Workshop on small missions in Europe that ESA is maintaining a strong interest for an Equivalence Principle test in space, in particular by contributing to the French µSCOPE mission which aims at testing the Equivalence Principle to 1 part in 10^{15}. The target is 2 orders of magnitude short of the STEP target (as established at Phase A level during the M2 and M3 competitions of ESA) and of the GG target (assessed at Phase A level during the small mission competition of ASI in 1998). But it is 2 orders of magnitude better than the best results obtained so far with torsion balance experiments on the ground (Phys. Rev. Lett. **83** 3585**,** 1999) and as such it would be a remarkable achievement. In addition, µSCOPE is the first mission in Fundamental Physics ever attempted in Europe.

For these reasons it is extremely important for it to be successful. Failing to reach the target would not only appear as a waste of public money (by the inevitable comparison with much cheaper ground experiments); it would also negatively affect the future of Fundamental Physics in space in Europe and elsewhere. After the long and troubled history of GPB (Nature **402** 7,1999), which I hope will be launched soon to fully achieve its goal, with AMS coming in the near future on the ISS and LISA still far ahead, µSCOPE is the first Fundamental Physics mission on a dedicated spacecraft at a reasonable cost and on a reasonable timescale. Its success will show funding agencies, scientists and the general public that very delicate physics experiments –which need to detect extremely small effects– <u>can</u> indeed be carried out in space, and that present day space technology is ready for these experiments to exploit the advantages of space.

This is why I wish to draw the attention of yourself and the FPAG on two issues of the µSCOPE experiment.

One issue is the radiometer effect. According to a recent analysis of this effect (Phys. Rev. D Rapid Comm. **63** 101101(R), 2001) it appears that it should be carefully taken care of, for the mission to achieve its goal. Experimental evidence is necessary to make sure that spatial temperature gradients across the test masses will be small enough for the radiometer effect to be below the signal.

The second issue is the nature of the µSCOPE accelerometer. Since a violation of the Equivalence Principle would give rise to a differential effect, scientists have always tried to design sensing instruments which are inherently differential. This is the case with the torsion balance, which has provided (in its old and recent variants) the most sensitive tests ever; this is also the case with the proposed STEP and GG accelerometers. Within the GG science team we have built and operated in the laboratory an accelerometer which is differential in two ways: because its test masses are coupled by the suspension, and because the (capacitance) read-out is itself also differential (preprint online at http://eotvos.dm.unipi.it/nobili/ggg). On the basis of this experience It seems to me that there is much more to a differential accelerometer than just making the difference of the individual measurements of the test masses as it is planned for μSCOPE (Touboul et al., Acta Astron., in press). Indeed, I would find it appropriate if scientists with first hand experience in ground tests of the Equivalence Principle were asked to analyze the main features of the μSCOPE accelerometer. Among the numerous groups active in this field all around the world, the most successful one is the "Eöt-Wash" group at the University of Washington in Seattle, led by Professor Eric Adelberger. In a remarkable series of experiments carried out in the last 10 years with rotating torsion balances of various carefully conceived designs, they have achieved unchallenged results not only in testing the Equivalence Principle but also in the measurement of the universal constant big G and in testing the inverse square law of gravity at sub-mm distances, at ranges where no measurements of gravity at all existed before. Their results have been highlighted on Nature several times.

The reputation of the ONERA group which is in charge of the μSCOPE accelerometer is beyond question. Since the old days of CACTUS on CASTOR satellite, to the ASTRE tests on the space shuttle, to STAR on CHAMP, this group has put together a highly valuable expertise in the field of space accelerometers based on capacitance sensing. However, these accelerometers (and those in preparation by the same group for GRACE, GOCE and LISA) are general purpose instruments, while Equivalence Principle tests require ad hoc sensors, designed from the very beginning for best sensitivity to an extremely weak signal with a specific and well known signature (for instance by being also naturally suitable to rotation, for the signal to be modulated). Space experiments are always risky, so even the malfunction of the STAR accelerometer on CHAMP, as reported on the Web in the June 2001 Newsletter of this mission, should be taken positively, as a useful experience for the future. What should be avoided is flying an instrument if its very design is not appropriate to the task. Whether it is so or not for the μSCOPE accelerometer can (and should) be assessed before flying the mission.

I hope this information will be useful to you and to the FPAG. Yours,

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