'Galileo Galilei'– GG final statements

Anna M. Nobili[1], Suresh Doravari[2] and Lijing Shao[3]
(on behalf of the GG collaboration)

[1] *Department of Physics Enrico Fermi, University of Pisa, Italy*
[2] *Albert Einstein Institute, Hannover, Germany*
[3] *Max Planck Institute for Radioastronomy, Bonn, Germany*

Interview by SARP-M5 and SSC-M5 panels of ESA
ESTEC 7 November 2017

The basic facts

- For WEP to hold, it must be $\eta_{eötvös} \equiv \Delta a/a = 0$ for different composition test masses falling in the gravitational field of a source body.
- By detecting $\Delta a \simeq 8 \cdot 10^{-17}\,\mathrm{ms}^{-2}$ ($\Delta r \simeq 0.6\,\mathrm{pm}$ displacement) @ 1 Hz, GG can measure $\eta_{eötvös}$ with 17 digits, with well chosen composition dipole(s) in a controllable experiment.
- **If $\eta_{eötvös} \neq 0$, it amounts to the discovery of a new long-range force of nature and will make a revolution in physics.**
- If $\eta_{eötvös} = 0$ to 1 part in 10^{17}, it will be no longer viable for many physical theories to rely on fine-tuning. Substantial re-shaping, and perhaps completely new avenues, will have to be pursued to come to terms with such strong experimental result.

Theories

- The WEP is at the crossroads of the open problems of fundamental physics: the relation of quantum fields and gravitation; the nature of dark matter and dark energy; the absolute character of the fundamental constants of physics.
- Tests of the WEP provide the most severe constraints to theories attempting to go beyond the current unsatisfactory situation −with GR on one side and the Standard Model of particle physics on the other, unreconcilable with each other− or make sense of dark matter and dark energy.
- Lab and LLR tests of the WEP are near their limits, while Microscope and GG gain a factor of 500 just by being in low Earth orbit (not so cold atom drop tests).

  Microscope may have already ruled out a number of phenomenological models . . . and that is just the beginning!
- The results of Microscope will need corroboration. A new test, at higher sensitivity, with partially different systematics, is what is needed. Most importantly, it is feasible.

Experiments

- GG was born within the ESA science team of STEP −twice candidate to an M-size mission for testing the WEP to 10^{-17}− when we realized that there was a better way to reach this ambitious target.

  The simple and effective idea to decrease thermal noise is not to go cryogenic, but to up-convert the signal to higher frequency where thermal noise (and not only thermal noise...) is lower, as Microscope has shown. To do that most effectively you have to rotate about the symmetry axis perpendicular to the detection plane, while conservation of angular momentum ensures that there will be no motor noise because there is no motor. This, in a nutshell, is GG.

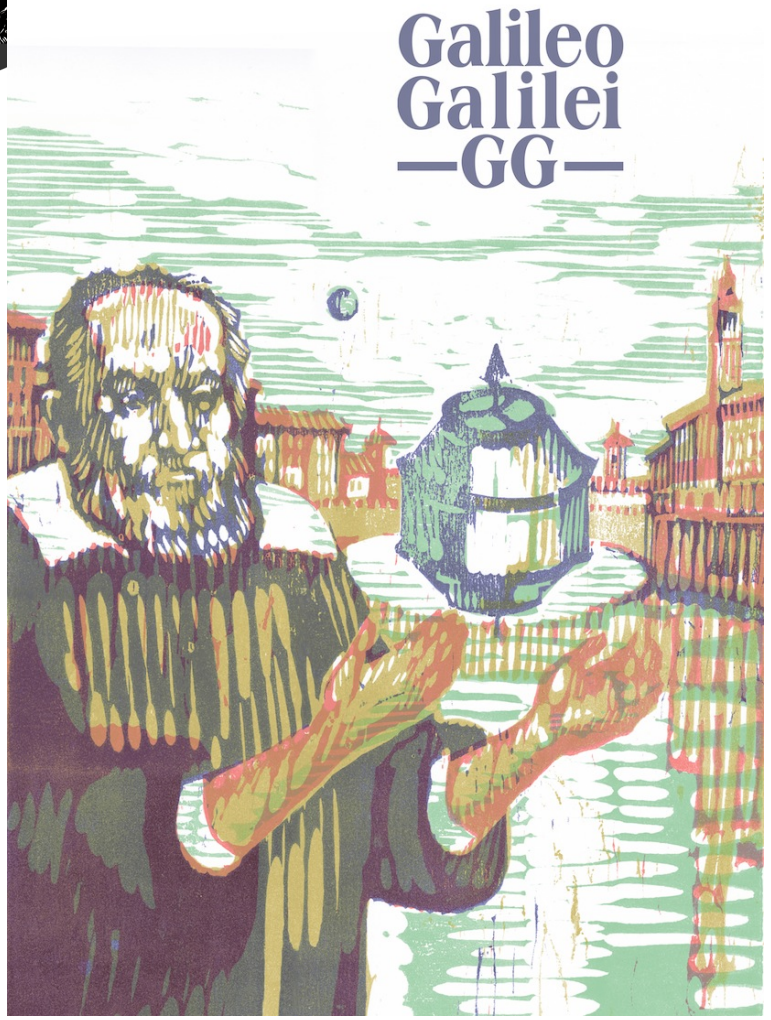
- GG continued to be developed for over 20 years, was tested in the lab as far as it goes, has generated many papers in the best physics journals, in constant conversation with the best experimental physicists in the field.

- The best instrument for testing the WEP on ground is the slowly rotating torsion 'balance'. GG is a rapidly rotating 'balance' for testing the WEP in orbit, where it will gain a factor of 500 by default, and an extra factor of 20 thanks to a design which combines all the advantages of being in orbit with those of a low noise laser interferometry readout.
  ($0.6\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ **@** $1\,\mathrm{Hz}$ ***shown in the lab; more demanding performance demonstrated by LPF in space***)

- The performance expected in space can only be achieved in space, but all the building blocks of GG have been demonstrated, theoretically and/or experimentally, as it will become apparent should GG be given the chance of an Assessment study for M5.

Programmatics

- With LISA solidly relying on the technology demonstration of LPF, Europe is in the forefront of fundamental physics in space, and Microscope will soon make headlines.
- Following up with a mission which can yield another 100-fold improvement in a relatively short time is just what is needed to keep Europe in the lead, while LISA is prepared with due care and time to become a long lasting, successful, gravitational wave observatory in space.
- GG is relatively inexpensive, certainly within the M5 budget, certainly feasible in the allotted time, without technology or programmatic risk.
- We have proposed GG as an ESA-only mission; participation by all member states is open, according to the usual ESA rules, at no extra cost for national space agencies. The Assessment phase that will follow the selection into the final shortlist will be open to contributions, without prejudice, especially from Microscope and LPF.
- Building on the experience of the best ground tests, after Microscope and LPF, ESA can achieve an experimental result which will constrain the quest for new physics for decades to come (confirmation) or revolutionize physics altogether (violation).



- **GG will test the WEP to 10^{-17} in the field of the Earth − 4 orders of magnitude better than now, 2 orders of magnitude better than Microsope**
- **Will test the assumption that dark matter couples to ordinary matter only gravitationally 20 times better than now**
- Will improve current WEP tests in the field of the Sun by 20 times

No matter how small an undertaking,
it cannot start or come to fruition
without knowledge,
without means,
or without loving tenacity.

(anonymous from Florence, 1300)

GG webpage: http://eotvos.dm.unipi.it