After-dinner speech: the path of LISA to become ‘L3’

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After-dinner speech: the path of LISA to become 'L3'

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Abstract. We describe the state of fundamental-physics experiments in space in the mid 1980s on both sides of the Atlantic, and then follow the development of this field within ESA's Scientific Programme. The special case of LISA — a fundamental physics experiment in space also supported by astronomers, and now, following the ground-based detection of gravitational waves, the means to extend the observable spectrum of such waves towards lower frequencies and long-lasting signals — is then followed in its rise to become the 'Large Project L3' of ESA.

LISA is a well-deserved piece of luck! It has its roots in the quest for fundamental physics in space, has met the interest of astronomers and is now the preferred model for ESA's so-called L3 mission. Its current, high profile is based on two recent, impressive experimental achievements:

- the direct detection of gravitational waves by the advanced LIGO interferometers and
- the LISA-Pathfinder mission, whose performance moreover exceeded the specifications.

In his address yesterday, Alvaro Gimenez emphasised that ESA-missions, such as PLANCK, GAIA and EUCLID, make contributions to fundamental physics and pointed out that ESA supports space missions, which specifically address fundamental physics — among those MICROSCOPE and ACES (the Atomic Clock Ensemble in Space), both tests of the equivalence principle, under French leadership.

When I joined ESA in the mid-eighties, a mission's contribution to testing the foundations of physics was not yet considered an asset worth mentioning. At that time ESA's Science Directorate and its advisory structure were strictly focused on addressing two areas of space science, namely 'Solar System Science' and 'Astronomy'.

The astrometry mission HIPPARCOS, for example — a mission close to launch in the mid-eighties —, had to account for the deflection of light by the Sun's gravitation, and thus was promising to deliver another, competitive test of General Relativity. Pointing this out was deemed expedient only after the idea of 'Fundamental Physics in Space' had been introduced into ESA's Science Programme.

Things had been different on the other side of the Atlantic; there fundamental physics was actively pursued by experiments on rocket flights and orbiting satellites.

A test of the gravitational red shift provided by NASA's Gravity Probe A had been published in 1980 already. Bob Vessot and his colleagues at the Smithsonian Astrophysical Observatory in Cambridge, Mass., had confirmed the gravitational redshift predicted by General Relativity to 60 ppm by launching a rocket with a hydrogen maser on board to an altitude of 10'000 km.

A second, more complex Gravity Probe, GP-B, had in the mid-eighties been under development for 20 years. The aim of GP-B was to establish the existence of the Lense-Thirring effect — also referred to as 'gravito-magnetic' effect, or simply called 'frame-dragging'. GP-B was going to measure this 'drag' by observing the deflection of the axes of rotation of cryogenic gyroscopes orbiting in a polar orbit at 642 km altitude, as a consequence of the Earth's rotation underneath. The deflection predicted by General Relativity, is a minute 39.2 milli-arc-second per year!

I had the opportunity to visit the W. W. Hansen Experimental Physics Laboratory at Stanford, where Francis Everitt and his team worked on the many technical challenges that they had to overcome in order to achieve GP-B's goal. There I encountered a wonder-world of high technology dealing with cryogenics, drag-free operation, magnetics, SQUIDs and gyroscopes. The latter, for example, were the most round objects on Earth at the time — five times rounder than the best industrial spheres. GP-B, launched in 2004, did indeed confirm the existence of the Lense-Thirring effect and directly measured its minuscule size, with an accuracy of 19 %.

Alvaro's mentioning yesterday that ESA's Science Programme Committee had nearly cancelled LISA in 2011, reminded me of a nice story about Francis Everitt. While ESA generally shies away from cancelling missions, rescissions are more frequent in NASA. Indeed, over the course of its development, Gravity Probe B has been cancelled several times. But Francis regularly managed to reinstate it. While overcoming these recurring hurdles, he seems to have developed a particular sense of humour. So, when he had been invited to lecture on the development of Gravity Probe B in front of a prominent audience, he took the opportunity to welcome a person in the audience, whom he praised as a real pioneer — this was the person, who had cancelled GP-B for the first time.

Now back to ESA in the mid-80s: in contrast to NASA, we were nowhere with 'Fundamental Physics in Space'. Notably though, Fundamental Physics had been included as a discipline in 'Space Science – Horizon 2000' (H2000), the long-term programme championed by the then new ESA-Director of Science, Roger Bonnet. (I should perhaps underline here the importance of 'Horizon 2000' for Science in ESA: in the ten years following the approval of H2000 in 1984, the funding of ESA's Science Directorate grew by about a factor of two.)

Studying and, later, implementing fundamental-physics experiments, it turned out, led to a paradigm shift in mission-design within ESA's Science Directorate. The reason was that most such experiments require a pico-gravity environment, and thus drag-free technology.

Traditionally designing, building and testing a spacecraft and its scientific experiments could be neatly separated. The spacecraft, which provided the pointing, was built by Industry under the surveillance of the Project Manager and his engineers in the Project Department. The Project Scientist from the Science Department, on the other hand, closely monitored the development of the observing instruments, which were being built in Research Institutes and Universities across Europe, to assure that they accomplished the mission goals.

The instruments were eventually inserted into the spacecraft according to the interface documentation. In other words: the development of the satellite and its instruments could proceed in parallel, with conflict resolution, where needed, between Project Manager and Project Scientist, i.e. within ESA internally.

With missions in 'Fundamental Physics in Space' there was a game-change. As performance in the pico-gravity range required drag-free conditions, it was now an experiment rather than the spacecraft that contained the sensor that delivered the error signal to point and steer the spacecraft. Some people now suggested replacing the word spacecraft by 'sciencecraft'. In any case, the staff of the Project and Science Departments had to collaborate much more closely, sometimes involving the Principal Investigators and parts of their Science Team in the discussions with the Project Team.

One of the best things I did in my life — even before this paradigm shift became obvious — was to ask Rüdeger Reinhard to promote the topic of 'Fundamental Physics in Space' within ESA's Science Directorate. Rüdeger was an experienced Project Scientist. He had been Project Scientist of Giotto, the mission that had a close encounter (596 km) with comet Halley in 1986. This mission attracted worldwide attention to ESA. In a way, Giotto put ESA on the map.

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In no time Rüdeger had assembled a Fundamental Physics Advisory Committee (FPAC) consisting of the best people in the field — many of them here with us tonight. There was a sequence of excellent chairs: Jean-Pierre Blaser of ETHZ, Maurice Jacob of CERN, Stefano Vitale of Trento and Bernard Schutz of the Albert Einstein Institute in Potsdam. And within a short time we could hire an additional staff member, Yusuf Jafry, to give support to Rüdeger. Yusuf came from Stanford, his thesis adviser, Dan de Bra, had flown the first drag-free spacecraft in 1973.

Rüdeger then encouraged people to submit mission proposals with topics in Fundamental Physics that were to be evaluated by FPAC. As a consequence, the response to a call for mission proposals consisted from now on of about a third of the proposals dealing with Fundamental Physics, while the remaining proposals were distributed more or less evenly between 'Solar System Science' and 'Astronomy'. As a result of such a call, the fundamental-physics proposal 'LISA' was selected for further study. While it dealt with the direct detection of low-frequency gravitational waves — an outstanding problem in Fundamental Physics — it eventually met the interest of astronomers, too.

Rüdeger knew that building a community was absolutely crucial in the European context. ESA is built on a grass-roots system — we have no 'National Academy of Sciences' (yet) in Europe, and there is no country in Europe, where the Academy has a say beyond the borders. The first grass roots efforts were followed by the backing through important institutions, such as Max Planck Institutes and Universities in France, Great Britain and Italy, and so we are on track today! As mentioned by Karsten Danzmann, it was Rüdeger who insisted on organising LISA Symposia to maintain the community's interest in the mission. In this 11th LISA Symposium, we celebrate this week an important milestone in LISA's way to become the 3rd Large Mission of ESA's long-term programme!

Rüdeger died in January 2015. It is a pity that he cannot see how his ideas came to fruition.

To conclude let me make a plea regarding the LISA launch date, which is currently planned for the year 2034. When I was working at ESA in the Netherlands, my neighbour in Leiden happened to be the LISA Project Manager. So, I asked him to invite me to the launch. Although I doubt that this rendezvous remains valid, I still want to attend the launch of LISA. The problem is that I will be 98 years old in 2034. Although I seem to be in good shape today, I reckon that another 18 years is stretching it a bit. So, please work hard to bring the launch forward by half a decade for example!