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LISA Pathfinder: mission accomplished

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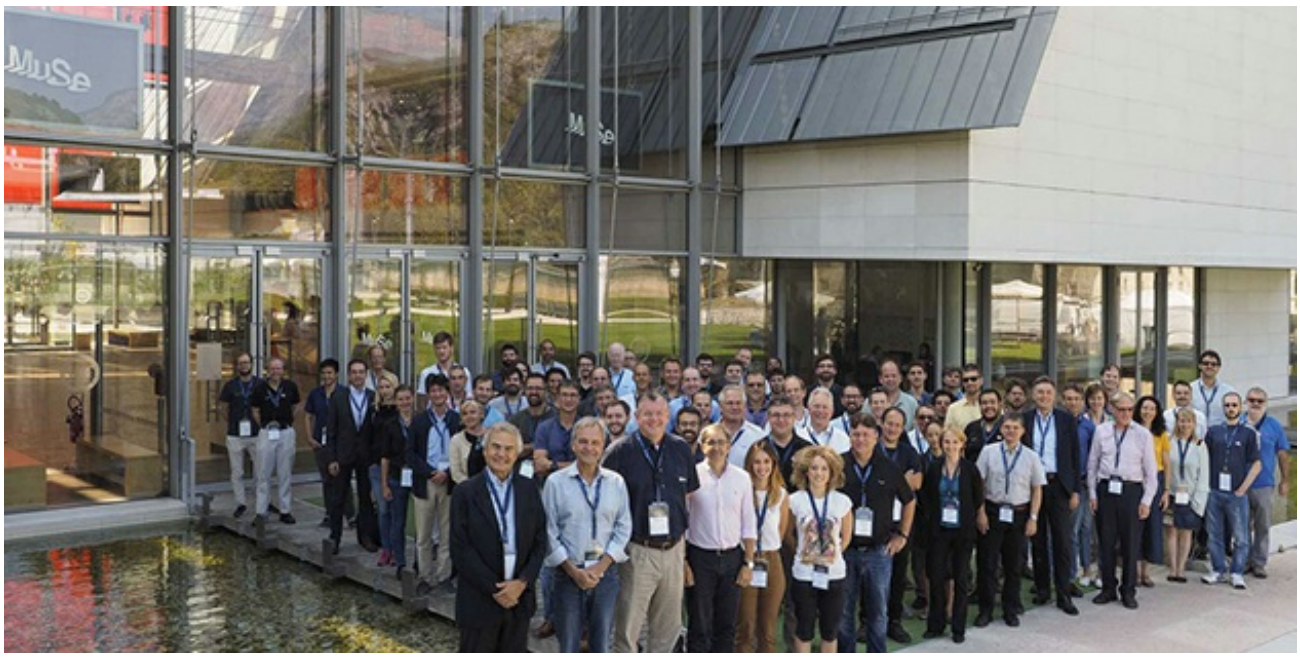

The LISA Pathfinder collaboration meeting at the Trento Museum of Science. Credits: ©RomanoMagrone per UniTrento.

Just one month ago, the LISA Pathfinder collaboration met in Trento to discuss (and celebrate!) the outstanding scientific achievements of the mission. LISA Pathfinder is the precursor mission to the planned LISA space borne gravitational wave observatory, which the European Space Agency (ESA) has flown and operated in 2016-2017. Its goal was to demonstrate that the minute tide-like acceleration that gravitational waves produce on a constellation of free-falling test-masses are indeed measurable against the background of all other forces that accelerate the same test-masses.

By minute I mean here less than 0.3 femto-g, that is 3×10^{-16} times the acceleration of gravity on the Earth surface. This is the figure that would make LISA the outstanding cosmological gravitational observatory that all astronomers are longing for.

Getting such a small figure in the harsher environment of LISA Pathfinder was deemed challenging and expensive. To cut cost, scientists were only requested to get to within a factor 10 of the ultimate LISA performance requirements, a mere 3 femto-g. In addition, while LISA will search for waves with periods of oscillation as long as a fraction of a day, something as slow as the ocean

tides, we were only requested to demonstrate performance for a period shorter than just half an hour.

But the team of industries, scientific institutes and space agencies that have been working for over a decade to implement the mission took the task with an almost religious dedication. The end result has been amazing: test-particles can be put in free fall with residual accelerations *better than LISA requirements* and down to the lowest frequency.

Almost all space missions that study gravity, like those that map the gravitational field of the Earth, use free-falling test-masses and measure their relative accelerations. Compared to any of such missions, LISA Pathfinder pushed the purity of free-fall by at least three orders of magnitude. To capture the essence of such an achievement some people refer to LISA Pathfinder test-masses as the stillest bodies in the Universe!

Instrumental to achieving these results was the concept of LISA Pathfinder: an orbiting physics laboratory. A wealth of experiments has been run while in operation, in addition to the measurement of the relative acceleration of our gold platinum test-masses. Interactions with cosmic rays, impact of gas molecules, radiation pressure noise, surface electrical properties, Brownian motion, gravitational fluctuations, just to mention some, have been thoroughly investigated to build up a physical model of the environment of a nominally free body in space. These studies have produced and are producing a series of scientific papers which are an essential part of the mission legacy.

The most outstanding element of LISA Pathfinder legacy though, is the decision of the European Space Agency, together with a large group of its member states and NASA, to proceed full speed with the implementation of LISA. LISA is now undergoing a final phase-A study, and all elements of its instrumentation that have not been tested on LISA Pathfinder are subject to an intense (and so far successful) development.

Space-borne gravitational wave astronomy, a probe of the entire physically accessible space-time, is on the move. Stay tuned.

In homepage: Rendering of LISA Pathfinder test-masses following their purely gravitational trajectory, while their relative acceleration is measured by a laser interferometer. Credits: ESA/ATG medialab.