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LISA Pathfinder: A technology demonstrator mission for future in-space gravitational wave detection

ISA Pathfinder is an ESA mission for the in-flight testing of the concept of gravitational wave detection. Two test masses are set inside the spacecraft in an unprecedented level of free-fall purity under the action of the planetary gravitational field, by reducing any force disturbance at the femto-N order of magnitude. The achievement of this level of free-fall purity constitutes the key requirement for the measurement of gravitational waves in the frequency bandwidth (10-4 up to 10-1 Hz) where the most predictable and powerful sources (galactic binaries and massive black holes) predominantly emits their radiation. This bandwidth is not covered by ground-based detectors (e.g. LIGO) due to the terrestrial Newtonian gravitational field noise and can only be explored by space-based instruments, like LISA (Laser Interferometer Space Antenna). The mission was launched on December 3rd 2015 and successfully concluded the science operations on June 30th 2017, after a nominal and an extended mission phase. In general, the mission provided the demonstration that an extended object can be set into a geodesic trajectory with an acceleration noise level of the fms- $2/\sqrt{\text{Hz}}$ (over a bandwidth of 0.1mHz to 0.1Hz), which fulfills the requirements for the full observation program of the LISA observatory for the gravitational waves. The key technologies tested in LISA Pathfinder, ranging from the inertial sensor, the optical metrology, the spacecraft drag free and attitude control system to the micro-propulsion system, combine with several other system challenges: gravitational balancing, thermal stability, control of the magnetic environment. This complex experiment aims at confirming the physical model of the forces acting on the test masses, understanding the dynamics of the spacecraft-test mass system to an exceptional detail. The increase of knowledge about all these topics is the real outcome of the mission. As a technology demonstrator for LISA, it addressed its main criticalities and provided strong support to its formal selection as the 3rd large class mission in the ESA cosmic vision program. In this framework, its heritage becomes part of a long-term planning strategy implemented by ESA to push the frontiers of space exploration to new limits.



Figure 1: LISA Pathfinder

Biography

Daniele Bortoluzzi is an Associate Professor of Mechanics in Department of Industrial Engineering at University of Trento. He collaborates with the European Space Agency and several industrial partners in the design of payloads for scientific missions, with particular emphasis on mechanisms. He is responsible for the qualification of the release mechanism for the LISA Pathfinder mission, where tribological, dynamics and control issues are involved.