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THE FIRST STEP TOWARDS OBSERVING GRAVITATIONAL WAVES FROM SPACE

At 5 am Central European Time on 3 December, LISA Pathfinder (*Laser Interferometer Space Antenna Pathfinder*) took off from the European spaceport in French Guiana. LISA Pathfinder is the technological forerunner of eLISA (evolved LISA), the spatial interferometer for detecting gravitational waves and the third of the ESA's large missions in its Cosmic Vision scientific programme. A few weeks ago LISA Pathfinder was placed in an elliptical orbit at a distance of between 200 and 1540 kilometres from Earth. Over the next few weeks the probe will move from this transitional "parking" orbit to reach its final position where it will orbit about the L1 Lagrangian point, at about 1.5 million kilometres from Earth, locked in a gravitational equilibrium between the Sun and the Earth.
Built by the ESA with the fundamental contribution of the ASI and in collaboration with the INFN and the University of Trento, LISA Pathfinder has the ambitious task of opening the way for observing gravitational waves from space, a mission that will start by 2034 with the launching of eLISA. Once complete, eLISA will be a highly valuable observatory for astrophysics, cosmology and general relativity and will enlarge our understanding of the evolution of the universe, when galaxies, stars and planets started to take shape. Gravitational waves are emitted by all bodies, whether visible or not. They record the motion of objects in the most remote depths of the universe and carry the information to us, like the sounds of the night, capable of passing undisturbed through any kind of matter or energy. LISA Pathfinder will thus pave the way for this new mission that will bring about a profound revolution in the fields of astrophysics, astronomy and cosmology.
The probe will serve as a testbed for the technology needed to observe gravitational waves from space. Its main aim is to test the possibility of monitoring and measuring the movement of two test masses (gold-platinum cubes) placed in a near-perfect free-fall, with extremely high precision. LISA Pathfinder's high-precision instruments will be able to detect the ripples in the fabric of space-time caused by collisions between massive celestial bodies. Scientists have calculated that such events

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should produce a relative motion between the LISA Pathfinder cubes of the average size of an atom.
But the astonishing precision of this probe and the distance of its orbit are only a fraction of those that will characterise the full-fledged eLISA observatory. Conceptually identical to the large terrestrial interferometers like Virgo - the interferometer operated by the European Gravitational Observatory (EGO) based in Càscina - eLISA will consist of three satellites placed at the vertices of an equilateral triangle, one million kilometres apart. Each satellite will contain the same masses of gold and platinum that are currently less than one metre apart in LISA Pathfinder. The three satellites will follow the Earth in its orbit, sending laser beams from one to the other so that the distance between each pair of satellites is constantly measured. By measuring these distances, and any differences caused by the arrival of a gravitational wave, it will be possible to detect the presence of such waves and measure their intensity.
The high-precision instruments that will encase the test masses in LISA Pathfinder, inertial sensors, were built by CGS (Compagnia Generale per lo Spazio), as industrial prime contractor for the Italian Space Agency. They were designed by researchers at the University of Trento and the INFN. The INFN is currently contributing to the project through the TIFPA (*Trento Institute for Fundamental Physics and Applications*), the new centre of excellence established in 2013 in Trento. ■