Abstract

The LISA Pathfinder mission has paved the way to the Gravitational-Wave space astronomy. Not only it tested the technology needed by a space observatory LISA-like, but also studied and analysed the non-gravitational forces that appear between two free-falling test masses. Indeed, after about a year and a half of the mission (including commissioning, science operation, and extension phases), the satellite measured a residual acceleration noise between the masses of $(1.74 \pm 0.05)\,\mathrm{fm\,s^{-2}/\sqrt{Hz}}$ above 2 mHz. It is an improvement roughly of a factor 15 with respect the LISA Pathfinder requirement established before the mission, and a factor 5 with respect the LISA requirement in that moment. This achievement has been possible thanks to the fact that the spacecraft had different subsystems which, besides acting on 15 degrees of freedom of the spacecraft, allowed to perform experiments to estimate and subtract the several disturbances.

Thermal fluctuations were one of the sources of perturbation that modified the relative acceleration between both test masses. Depending on whether they induce real forces on the masses or only changes in the optical path length, we distinguish two kinds of thermal disturbances, namely: those that are around the test masses and which produce real forces on them, and those that appear in locations such as the optical windows or the struts (thermo-optical and thermo-elastic contributions), where these thermal fluctuations can produce distortions that in turn change the optical path length of the laser. Aiming to monitor and analyse the temperature onboard the satellite, it was equipped with 24 thermal sensors and 14 heaters distributed around the more critical parts of the instrument. With the thermal sensors we measured the temperature in those locations and with the heaters we stimulated thermally those components where the two kind of thermal disturbances commented before could acted.

In this thesis, in addition to showing the main results obtained during LISA Pathfinder, I focus on the temperature. I will show how the temperature evolved thorough the mission in its different phases and the thermal stability we achieved, which was, in terms of amplitude spectral noise, $10\,\mu\mathrm{K}/\sqrt{\mathrm{Hz}}$ in the band $1\,\mathrm{mHz} < \mathrm{f} < 30\,\mathrm{mHz}$. Furthermore, I present the different in-flight experiments carried out to analyse and estimate the thermo-optical and thermo-elastic contributions. It allows us to show their impact on the total differential acceleration noise: roughly $10^{-18}\,\mathrm{m\,s^{-2}/\sqrt{Hz}}$ for the thermo-optical effects, and roughly $3 \cdot 10^{-18}\,\mathrm{m\,s^{-2}/\sqrt{Hz}}$ for the thermo-elastic effects at 0.05 mHz. Finally, we discuss the implications of these analyses to the future Gravitational-Wave observatory, LISA.

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