Paper ID: 31159

MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM (A2)
Gravity and Fundamental Physics (1)

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MINI-LABORATORIES ON-BOARD DEEP SPACE PROBES FOR TESTING THE LOCAL SPACE-TIME STABILITY OF FUNDAMENTAL PHYSICAL CONSTANTS: THE CASE OF G

Abstract

Deep space missions are characterized by long cruise phases in which the probes are in hibernation mode and their instruments are used mostly to analyze the interplanetary medium. Despite that, the natuaral isolation given by the distance from planetary bodies and their perturbing fields, as well as the extremely low vibration levels, make deep space probes in inertial coasting, especially those using tri-axial stabilization, unique and extremely useful locations for local fundamental physics measurements, like the measurement of the space-time stability of the locally measured value of some fundamental physical constants. In particular, due to the discordance of the last two decades of high precision laboratory measurements, the Universal Gravitational Constant could be the first candidate for such a study. A robotic mini-laboratory on the probe could hold two mutually attracting test masses, like two 1Kg cylinders made of gold, which could be released at 1000 micron of separation and their free motion of gravitational attraction could be tracked with ultra-compact laser interferometric displacement sensors. After the measurement the test masses would be repositioned to the starting positions and released again. The obtained data could be automatically reduced and evaluated by the probe to verify any variation of G over the mission duration. For the purpose of testing the feasibilty and performance of such an automatic test platform, a first laboratory model of the space apparatus has been designed and built by the author with support from attocube systems AG, which rented the main instruments, and invaluable technical assistance from jeweler Siro Lombardini. Two 1Kg tungsten cylinders provided with thin gold mirrors have been suspended with 0.1mm micro-Dyneema strings inside an AVE vacuum bell on top of a custom 0.4Hz Minus-K tabletop vibration isolator. Using ECS3030 piezoelectric nanopositioners with 2 nanometers of feedback resolution moving on an Ergal frame, the cylinders have been placed at separation distances between 10 micron and 5000 micron. Their axial motions have been measured with 1 picometer of resolution using a FPS3010 compact laser interferometric displacement sensor and mutual forces have been calculated. Measurements of up to 1550s of duration with sampling frequencies between 1.5KHz and 97KHz have been performed. While the scientific results are still being evaluated, the instrument has demonstrated a good capacity of automatic fine alignement which could be useful in fully automatic tests. An adaptation of the setup is currently being designed for repeating the measurement in microgravity with parabolic flights.