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ENVIRONMENTAL DISTURBANCES ON MISSIONS FOR PRECISE TESTS OF RELATIVISTIC GRAVITY AND SOLAR SYSTEM DYNAMICS: THE BEPICOLOMBO CASE

Abstract

MORE (Mercury Orbiter Radioscience Experiment) is one of the investigations carried out by the BepiColombo ESA/JAXA mission to Mercury. This experiment exploits a state-of-the-art radio-tracking system which aims to study the interior structure of Mercury and to carry out fundamental physics tests. A Ka-band Translator together with a Deep Space Transponder, provide a multifrequency radio-link in X and Ka bands (8 and 34 GHz respectively): the three links (X/X, X/Ka, Ka/Ka) allow the complete cancellation of the plasma noise enabling very accurate radio-metric observables. The accuracy on Doppler and range measurements is expected to be, respectively, 3×10^{-3} mm/s at an integration time of 1000 s, and 20 cm after just a few second integration. A general relativity test will be carried out both during the cruise phase, through a Solar Conjunction Experiment (SCE), and during the orbital phase. The objective of the SCE is the estimation of the Eddington parameter γ, which controls the deflection of a radio-wave travelling from the spacecraft to the Earth. According to general relativity γ=1, thus a precise determination of this parameter represents a test of validity of this theory. The best constraint on γ has been obtained with the SCE of NASA's Cassini mission in 2002, which estimated $\gamma - 1 = 2.1 \pm 2.3 \times 10^{-5}$. Previous analyses of the MORE SCE (Imperi&Iess, 2018) found a limit accuracy on the determination of γ of 2.5×10^{-6}. This work assesses the SCE performances taking into account the dynamic noise caused by temporal variations of the solar irradiance. Random solar irradiance fluctuations range from 0.01 to 0.1% over timescales from a few days to a few hours (Kopp, 2006). The corresponding non-gravitational accelerations cannot be reliably measured by the onboard high accuracy accelerometer, as the time scales are outside the bandwidth of the instrument. This effect can't be neglected, considering that BepiColombo cruise phase is in the innermost region of the solar system. We verified through numerical simulations that a dynamical model which neglects these fluctuations is not able to obtain reliable results. Previous estimates of the attainable accuracy were therefore optimistic, because of the strong correlation of the effect of solar irradiance variations with the spacecraft state and γ. We investigate several strategies to absorb the effect of this disturbance, invariably ending up in an increase of the formal uncertainty on γ. Our analysis shows the need for precise accelerometers with larger bandwidths, extended toward the extremely low frequencies ($<10^{-6}$Hz).