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Author: Ms. Anja Schuster
TU Darmstadt, Germany, akschuster@gmx.net

Dr. Rüdiger Jehn
ESA, Germany, ruediger.jehn@esa.int

ACCURACY OF BEPICOLOMBO'S DETERMINATION OF THE POST-NEWTONIAN PARAMETERS

Abstract

ESA's mission BepiColombo is designed to bring new insights into the nature of Mercury, the innermost planet with a peculiarly high density and a difficult to explain chemical composition. The recent technology development surpasses the previous order of accuracy in terms of tracking techniques. In particular, the dual ranging method in X band and Ka band can compensate the error induced by the solar plasma. The unprecedented precision that can be achieved makes this mission ideally suited for a modern version of relativity test of the theory of general relativity (GR) named Mercury Orbiter Radio science Experiment (MORE).
Using the framework of the post-Newtonian formalism, all metric theories of gravity, GR among them, can be compared by estimating the post-Newtonian parameters (PNP) from the radiometric data. In this work the software tool GRETCHEN from DeimosSpace exploiting the Square Root Information Filter (SRIF) is used for the simulation of MPO's orbit around Mercury and the estimation of the PNP. Especially, the Eddington parameters γ, a measure for the curvature of space-time, and β, describing the non-linearity of gravity, along with the Nordtvedt parameter η, denoting the potential violation of the Strong Equivalence Principle (SEP), are of high interest. So far, their values were constrained by the measurements of the delay of Cassini's radio signal, lunar laser ranging and the orbital parameters of a pulsar in the PSR J0337+1715 system to $\gamma - 1 = (2,1 \pm 2,3) \cdot 10^{-5}$ [1], 4β-$\gamma - 3 = (0,6 \pm 5,2) \cdot 10^{-4}$ [1] and $\eta < 1.0 \cdot 10^{-4}$ [2] respectively. In comparison, previous studies predicted BepiColombo to perform better, namely γ and $\beta \sim 10^{-6}$ and $\eta \sim 10^{-5}$ [3]. However, some experimental restrictions having a negative impact on the high precision of PNP estimation have not been explicitly taken into account. The essential outcome of this analysis is to obtain a sense for the achievable accuracy of the PNP estimations depending on specific experimental constraints. On a larger scale, this valuable scientific goal of a tighter observational verification of GR will either place more confidence in the models based on the theory or it will require a revision of our current understanding of physics.

[1] Hohmann, M., Järv, L., Kuusk, P., & Randla, E. (2013).
[2] Han, W. B., & Liao, S. L. (2014).
[3] Milani, A., Vokrouhlický, D., Villani, D., Bonanno, C., & Rossi, A. (2002).