New dynamical relativistic modeling of the Moon orbital and rotational motion developed by POLAC (Paris Observatory Lunar Analysis Center) .

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Introduction: We present here work in progress, carried out at SYRTE in Paris Observatory by POLAC (Paris Observatory Lunar Analysis Center). We currently develop a numerical solution of the differential equations, which govern the Moon's orbital and rotational motion. This numerical solution will be useful for two main purposes. The first one is to enable tests of General Relativity with Lunar Laser ranging data (LLR). The second one is to improve the ELP ephemeris (Ephéméride Lunaire Parisienne).

Tests of General Relativity: For this purpose we focus on a new generation of software that simulate the observables from a given spacetime generic metric [1]. This flexible approach allows to perform simulations in any alternative metric theories of gravity. The output of this software will provide templates of anomalous residuals that should show up in real data if the underlying theory of gravity is not General Relativity. Those templates can be used to give a rough estimation of the constraints on additional parameters involved in alternatives theory of gravity. They also provide signatures that can be searched for LLR's data aiming at testing gravitational laws.

Improvement of ELP ephemeris: The ELP ephemeris (Ephéméride Lunaire Parisienne) are semi-analytical solution of the dynamical equations governing the motion of Moon gravity center. This ephemeris was developed in the 70's by Michelle Chapront-Touzé, Jean Chapront and Gérard Francou [2] and are still of a great interest (as for the study of underlying resonances or to separate the different contributions). However, in its purely semi-analytical form this solution reaches a mean difference of 70cm after fitting with more recent numerical ephemeris (e.g. INPOPxx e.g. [3], Dexxx e.g. [4]). This difference, mainly explained by the slow convergence of Poisson series (e.g. planetary effects), the truncation of series and the implicit physical parameters impossible to fit, is not adapted to the current sub-centimetric LLR observations. The comparison of our numerical modeling with the different parts of the ELP solution, will show up the real precision of each series and this will allow us to clearly identify which contributions should be improved. Furthermore, numerical integration could let the possibility of changing the too slowly converging series by their numerical counterpart.

References: [1] A. Hees, PhD thesis, ORB, 2012. [2] M. Chapront-Touze and J. Chapront. Lunar solution elp 2000-82b. VizieR Online Data Catalog, 1995. [3] A. Fienga, J. Laskar, P. Kuchynka, H. Manche, G. Desvignes, M. Gastineau, I. Cognard, and G. Theureau. The inpop10a planetary ephemeris and its applications in fundamental physics. Celestial Mechanics and Dynamical Astronomy, 111 :363–385, Nov. 2011. [4] E. M. Standish, 1998, JPL planetary and Lunar Ephemerides DE405/LE405, Tech. Rep., Jet Propulsion Laboratory.