LAGEOS-type satellites pericenter as a tool to search for Yukawa-like interactions

D.M. Lucchesi (1,2), R. Peron (1)

(1) Istituto di Fisica dello Spazio Interplanetario (IFSI/INAF), 00133 Roma, Italy; (2) Istituto di Scienza e Tecnologie della Informazione (ISTI/CNR), 56124 Pisa;

Twenty years ago, the hypothesis of a fifth-force of nature has thrust scientists to a strong experimental investigation of possible deviations from the gravitational inverse-square-law. In fact, the deviations from the usual 1/r law for the gravitational potential would lead to new weak interactions between macroscopic objects. The interesting point is that these supplementary interactions may be either consistent with Einstein Equivalence Principle (EEP) or not. In this second case, non-metric phenomena will be produced with tiny, but significant, consequences in the gravitational experiments. The characteristic of such very weak interactions, which are predicted by several theories, is to produce deviations for masses separations ranging through several orders of magnitude, starting from the sub-millimeter level up to the astronomical scale. Among the several techniques useful for the search of this additional physics at the various scales, the accurate measurements of the pericenter shift \(\Delta\omega\) of a binary system may be used to test for a New-Long-Range-Interaction (NLRI) with a characteristic range comparable with the system semimajor axis. These very weak NLRIs are usually described by means of a Yukawa-like potential with strength \alpha and range \lambda. The LAGEOS satellites, thanks to the very accurate determination of their orbit by the Satellite Laser Ranging (SLR) technique, could be considered the best candidates for the study of a possible NLRI with a characteristic range close to the radius of the Earth. Indeed, the SLR technique tracks the orbit of the two LAGEOS satellites with an accuracy approaching the cm value in range and with a precision of a few mm in the so-called normal points. We are then able to determine their orbital elements with about the same accuracy. In particular, LAGEOS II pericenter, thanks to its higher orbital eccentricity \(e\) (about 0.014) with respect to that of LAGEOS (about 0.004), could be considered the best probe. Indeed, the measurement quantity is \(ea\Delta\omega\), with \(a\) the satellite semimajor axis (about 12,163 km). For instance, assuming that we are able to fit LAGEOS II orbit to a few cm level over 15 days arcs, over 1 year we obtain an estimate for the constraint of the strength \alpha of a few 10ˆ-11 at a range \lambda of about 1 Earth radii. Of course, this estimate does not include the contributions from the systematic errors due to the various gravitational and non-gravitational perturbations, which must be considered in order to estimate a reliable error budget. However, thanks to the most recent gravity field models from CHAMP and GRACE space missions, the systematic errors from the Earth gravitational field uncertainties have been strongly reduced with respect to the previous multi-satellite models (as the EGM96) or the first preliminary models from the CHAMP and GRACE missions, as EIGEN2S and GGM01S. Therefore, only the subtle effects of the non-gravitational perturbations, as those produced by the solar radiation pressure, will be effective in biasing the measurement of the strength \alpha of a possible Yukawa-like interaction with respect to the 10ˆ-11 value. We focus on the constraints in \(\alpha\) that can be obtained with the actual gravity field models and on the systematic errors produced on such a measurement by the most important non-gravitational perturbations. The accurate measurement of LAGEOS II pericenter over a time span of several years, should result in an improvement of about three orders-of-magnitude with respect to the best constraints obtained in the past with LAGEOS (abs(\alpha) < 10ˆ-5–10ˆ-8).