LOCAL TESTS OF GR AND REFERENCE FRAMES LINKING WITH GAIA ASTROMETRY OF ASTEROIDS

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ABSTRACT. The Gaia satellite, an ESA cornerstone mission to be launched at the end of the year 2011, will observe a large number of celestial bodies including also small bodies of the solar system (mainly near-Earth objects and main-belt asteroids). The scanning telescope will observe all objects brighter than magnitude $V \leq 20$ providing, over the 5 years mission, high precision photometry and astrometry with an unprecedented accuracy ranging roughly from ≈ 0.3 to 3 milli-arcsecond on the CCD level, and depending on the target's magnitude. In addition, several hundreds of QSOs directly observed by Gaia will provide the kinematically non-rotating reference frame in the visible light, resulting in the construction of a 'Gaia-ICRF'. The positions of the asteroids hence enable to relate the dynamical reference frame as defined by the equations of motions to the kinematic one, and to further check the non-rotating consistency between both frames definition. Here we show the results of a variance analysis obtained from a realistic simulation of observations for such link. The simulation takes into account the time sequences and geometry of the observations that are particular to Gaia observations of solar system objects, as well as the instrument sensitivity and photon noise. Additionally, we show the achievable precision for the determination of a possible time variation of the gravitational constant $\dot{G}/G$. Taking into account the non-completeness of the actually known population of NEOs, we also give updated values for the nominal precision of the joint determination of the solar quadrupole J_2 and PPN parameter β. Comparison to the results obtained from other techniques is also given.

1. AN OVERVIEW

The Gaia mission is a cornerstone mission of the ESA Horizon 2000+ program. This next generation space astrometry mission will overcome the already important results achieved by the Hipparcos satellite's observations, or enabled by the Hipparcos/Tycho astrometric catalogues. Gaia will be launched at the end of 2011 and will have a 5 years lifetime. Although its main objective is to observe stars (3D Census of our Milky-Way), Gaia will also detect and observe a large number of 'secondary' sources: the distant quasars, and the closer solar system objects (SSOs). The bulk of solar systems objects will be made of the asteroids in the main belt (MBAs) and some additional but a good proportion of near-Earth objects (NEOs). Gaia is a survey satellite, not a pointing telescope, and is not specifically designed to observations of solar system objects; but its scanning law and limiting magnitude ($V \leq 20$) will allow good observations over 5 years of $\approx 300,000$ asteroids, a much larger sample than allowed by e.g. Hipparcos. One additional limitation is that the object should not be larger in size than ≈ 250 mas (Ceres and the Galilean satellites for instance will not get through the detection process). Also they will not be optimally observed if they move too fast: The CCD reading —in TDI mode— together with the particular windowing for telemetry-download are not adapted to the apparent motion of fast moving NEOs.

Nevertheless, there are many direct and indirect valuable scientific outputs from Gaia observations of

SSOs (e.g. Mignard et al., 2008): moderate imaging, radial velocity for calibration purpose, to accurate photometry and global astrometry. Here we will focus on what can be derived from the high accuracy astrometry of asteroids (varying between 0.3 and 3 mas, depending on the object magnitude) in terms of orbits improvement and small perturbative effects associated to these orbit 'measures'. These concern the positioning of the equinox and ecliptic in the optical-ICRS, and test of a possible net rotation between the two supposedly non-rotating frames (through a rotation $\mathbf{\Omega}$ and rotation rate $\mathbf{d\Omega/dt}$). It also concerns determination of asteroids mass (Mouret et al. 2007), test of GR from the perihelion precession (PPN β and solar J_2), and variation of the constant of gravity G. The fundamental relation that is fitted here, is a difference between observed and computed location on a great circle $\Delta\lambda = \lambda_o - \lambda_c = A.\mathbf{dC}$ linearized as mean of a small variation $\mathbf{dC}$ (correction to orbital elements, orbit perturbation from the model, different frame for the observed and computed value).

The general results of the variance analysis for the estimation of $\mathbf{dC}$ are given in Table 1. For further details and references the reader is referred to Hestroffer et al. (2008).

β	J_2	$\dot{G}/G$	$\mathbf{\Omega}$	$\mathbf{d\Omega/dt}$
–	–	year^{-1}	μas	μas/year
			$x-y-z$	$x-y-z$
5×10^{-4}	1×10^{-8}	2×10^{-12}	$5-5-14$	$1-1-5$

Table 1: Standard deviation for the various fitted parameters. The correlation between the solar quadrupole J_2 and the PPN parameter β can be as low as 0.11.

2. REFERENCES

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