SF2A 2004
F. Combes, D. Barret, T. Contini, F. Meynadier and L. Pagani (eds)

ASTROMETRY OF ASTEROIDS WITH THE GAIA SPACE MISSION

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Abstract. The ESA cornerstone space mission Gaia (Perryman et al. 2005), to be launched in 2011, will provide a 3D census of the Galaxy by observing a huge number of stars with an unprecedented astrometric accuracy (approx. 20 micro-arcsecond at $V \sim 15$ and down to $V \leq 20$). In addition the satellite will provide astrometric, spectometric and photometric measurements for a large number of solar system objects, mainly asteroids. Focusing on the astrometric measurements, we will present the peculiarities of solar systems observation with the Gaia scanning satellite. Next we discuss how Gaia observations of Trojans, main-belt, and near-Earth asteroids will provide 1) orbit improvement, 2) asteroids mass determination, and 3) direct determination of the solar J2 and relativistic PPN parameters. Interestingly these two latter parameters will be obtained directly and simultaneously, without any assumption on the internal structure of the Sun. In all aspects the scientific results achievable with Gaia appear to be competitive with present and future ground- or space-based experiments.

Gaia is an approved and funded astrometric cornerstone mission from the European Space Agency to be launched in 2011. Its main objective is to obtain a '3D census of our milky way' by accurate measures of positions distances and motions of approximately one billion stars. Beside, the Gaia satellite will – through its systematic survey of the sky with particular scanning law and down to magnitude $V \leq 20$ – observe a large number of solar system objects (about 500,000 mainly main-belt asteroids). Asteroids are thus observed at time-intervals differing from classical ground-based observations and at solar elongations in large zone around quadratures. The particular binning of the CCDs pixels implies that the astrometry is essentially one-dimensional in the along-scan direction. Main-belt asteroids, have an average motion of about 10 mas/s, their magnitude size depends mainly

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on the albedo and heliocentric distance. Astrometric precision is obtained through simulation with GIBIS (Babusiaux et al., 2005) and Pyxis (Arenou et al. 2005) of the focal plane images for resolved and moving objects as a function of magnitude. To reduce data-transmission, a windowing strategy is applied as a function of the object brightness. Solar system objects can be resolved (when larger than approximately 30-40 mas) and have a significant motion wrt the background stars. The astrometric precision varies essentially with the magnitude of the object, with $\sigma_\lambda \sim 0.2-0.3$ for $V < 14$ and growing exponentialy $\sigma_\lambda \sim 10^{0.15\,V-2.7}$. Large-size saturated objects can be cut by the window which reduces the estimation, especially with the barycenter estimator that was used. Changing the TDI strategy instead of the window shape seems more suitable, with the draw-back of reducing the integration-time on a complete CCD row, not exclusively the bright source.

There are several application to solar system science from Gaia observations (e.g. Zapallà & Cellino 2002). Simulations of Gaia observations for a subset of asteroids show that orbits of known objects will be considerably improved with only 5 years observations. This holds for Trojans even if their orbital period is about twice the mission duration. On the other hand the case of near-Earth objects is less advantageous, yielding to a rank-deficient problem and leaving us with undetermined orbital element corrections. Except for the degenerate cases, orbits will be provided with an accuracy about 50 times better than present ground-based ones. Masses of about hundred asteroids shall be determined through their perturbations on numerous smaller target asteroids. In a first step we are constructing the variational equations for the mass determination of a single perturber among N perturbed test-particle asteroids. The undeterminancy seen in the orbit improvement of some NEAs has however no consquence on the determination of global parameters such as the perihelion precession arrising from the Solar non-spherical gravity field (through its J_2) and the general relativity (through the PPN parameter β). Taking into account the orbit perturbation by oblate Sun and the relativistic perihelion precession, one sees that a precise and separate determination of J_2 and $\Gamma = (2\gamma - \beta + 2)/3$ is possible by combining data at large eccentricities and different semi-major axis. A simulation of the Gaia observations based on about 1500 objects gives the formal precisions of $\sigma_{J_2} \sim 10^{-7} - 10^{-8}$ and $\sigma_\beta \sim 10^{-3} - 10^{-4}$. In all aspects the scientific results achievable with Gaia appear to be competitive with present and future ground- or space-based experiments in the Solar system experiments (e.g. Williams et al. 2004; Will 2004).

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