Gaia as a Solar System observatory: Perspectives for binary asteroids

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Introduction

The Gaia satellite of the European Space Agency is expected to be launched in mid-2013. The scientific aim of Gaia is to obtain a new global picture of the Galaxy, by exploiting unprecedented astrometric accuracy and multi-wavelength data [1]. During its continuous scanning of the sky, it will observe all sources brighter than V~20, thus also collecting valuable observations of Solar System objects. A wide and significant impact on Solar System science is foreseen [2].
Among the main expectations concerning the Solar System, asteroid astrometry will result in orbit uncertainties not less than ~2 orders of magnitude smaller than the current ones. To reach this accuracy, the dynamical model has to take into account accurate masses of the ~100 most massive perturbers [3] and relativistic parameters [4] that will be determined altogether during the data processing. Physical data will include low-resolution spectra for most of the sample and a new taxonomic classification. Bulk shapes, modelled as 3-axial ellipsoids, will be derived by the inversion of sparse photometry, as well as the direction of the spin axis and period [5]. For a smaller number of asteroids, the disk-resolved signal will provide direct measurements of size.
The total number of asteroids that Gaia will observe will be close to ~400,000. The bulk of the sample, consisting of Main Belt asteroids, will be observed between 40 and 100 times, with exceptions related to peculiar geometries, which can result either in an increase above 150 detections or in a decrease down to a few observations.
Most of those asteroids will be know when Gaia flies. The small fraction that will be discovered by Gaia will undergo a specific treatment for recovering them from the ground.
A description of the observing strategy of Gaia and the expected performances was already provided in other papers ([2] and references therein) and would be redundant in this context. In the following, we would rather focus briefly on the role that Gaia will play in the study of satellites of Solar System objects in general, and in particular of multiple asteroid systems.

1. Satellites and binaries in the Solar System

1.1 Planetary satellites

All the satellites of major planets will be observed, provided that they are brighter than V~20 and their apparent size smaller than ~600-700 mas. These criteria include several objects of the family of Jupiter and Saturn, in particular, but exclude the large satellites (such as the Galilean ones, or Titan). For the same reasons, the main bodies of these systems (the planets) won't be selected for detection by the on-board system. The precise astrometry of planetary satellites, however, at better than ~1 mas per observation, has a great potential for refining their dynamical models.

1.2 Main Belt binaries with large primary bodies (~100 km)

These objects are fairly bright, but their satellites – discovered by ground-based imaging with Adaptive Optics - are small and faint. A fraction of them will be detected by Gaia. Given their apparent separation (0.1-1 as maximum) these systems can be detected as two separate bodies when geometric conditions are favourable (see Fig. 1). This way, they will benefit of accurate astrometry, separately for each component.

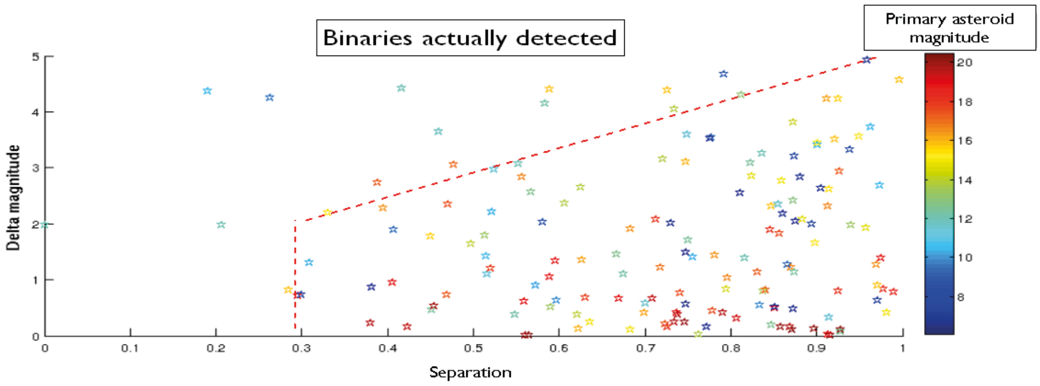

Figure 1: Detection performance of a binary asteroid as a function of the components' separation and magnitude difference. The graph is given for the sky mapper (SM) with 2x2 pixel binning, colour code corresponds to the apparent brightest of the primary. For separation larger than 0.3arcsec, most of the systems will have both components identified individually; for smaller separations the systems will be processed in a single windowing patch on the highest resolution astrometric field (AF) CCDs.

1.3 *Small Main Belt binaries (primary ~10 km and smaller)*

Having a small apparent separation, they have been discovered by photometry given the signature of mutual eclipses and occultations on the lightcurves (Pravec and Harris 2007). In this size range, binaries seem to be abundant (15% of the total).

2. Conclusions

The current situation concerning asteroid binaries is sketched in Fig. 2. As the plot shows, two groups of objects are present. The first one, with the largest primary bodies, collects asteroids mainly discovered by imaging (ground-based AO or Hubble Space Telescope). The smaller binaries discovered by photometry of radar (NEOs) cluster below ~20 mas of apparent separation. It appears that a no-man's-land exist in between, in a range of separation accessible, in principle, to Gaia observations at highest resolution. For pairs that are not resolved due to the rather modest imaging capabilities of the telescope, detection from the astrometric signal in favourable conditions will still be possible. Gaia has thus a good potential for discovering binary asteroids, and also for the dynamical characterization of a relevant fraction of them. Moreover, for those resolved binaries, Gaia will provide the relative astrometry of the component together with the motion of the system's centre of mass and hence the mass of each component individually.

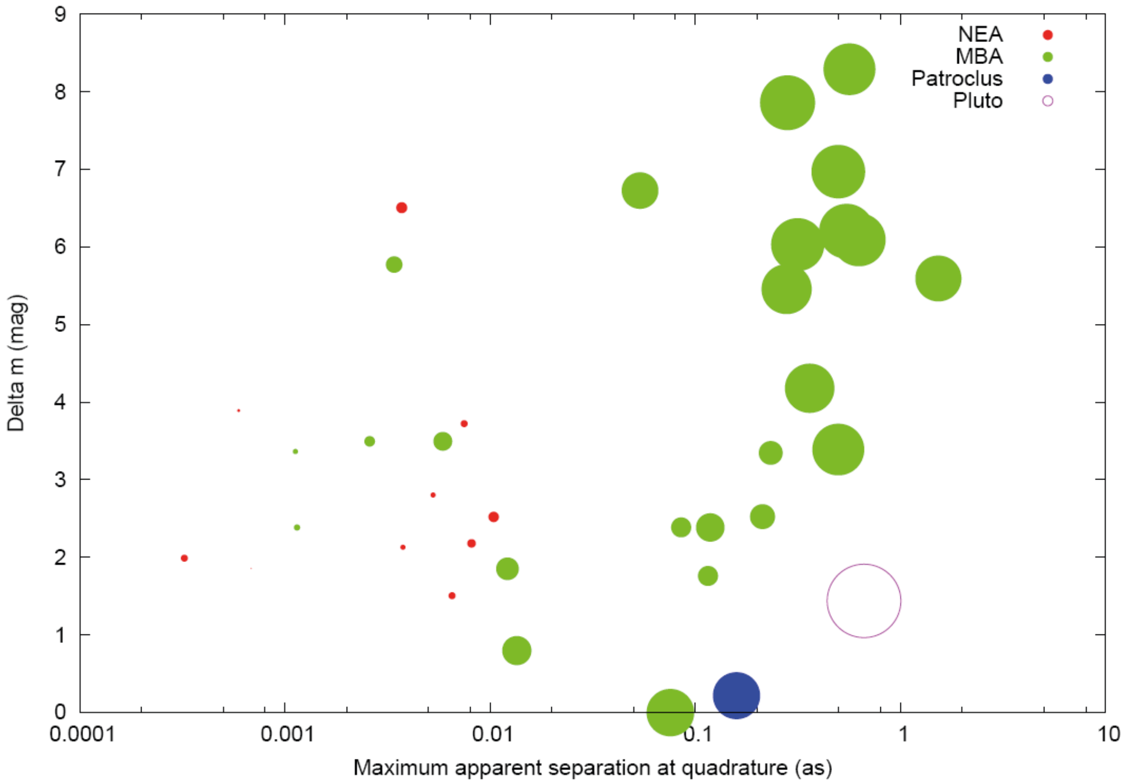

Figure 2: The main sample of confirmed asteroid couples. Each couple is represented by a circle whose size is proportional to the Log_{10} of the size of the primary body. The position is defined by the magnitude difference of the components (vertical axis) and the maximum apparent separation at quadrature (horizontal axis), the median geometry for Gaia observations. Pluto and Patroclus are added for comparison. See text for additional comments.

References

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[5] Cellino *et al.* 2007, *Adv. Space Res.*, **40**, 202.