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The expected Gaia revolution in asteroid science.

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Abstract

Apart from producing a huge improvement in the determination of asteroid orbits, Gaia is also expected to trigger a revolution in the field of the determination of asteroid physical properties. This includes the determination of accurate values of the mass and bulk density for about 100 of the largest objects in the main belt; the determination of the spin properties (rotation period, pole orientation) and approximate shapes for tens of thousands of objects; the measurement of reflectance spectra for an even larger number of asteroids, for all of whom also the blue part of the spectrum will be measured; the development of a new taxonomic classification. All this will open new perspectives in many fields of investigation, including the physical properties and age determination of many asteroid families, and the study of the relation between surface properties and bulk density, just to mention a couple of examples.

1. Gaia as an asteroid observatory

While scanning the sky, Gaia will detect large numbers of Solar System objects (mostly asteroids, but also comets, planetary satellites). The main difference with respect to stars will come from their much faster apparent motion. This will have two main consequences: (1) solar system objects will never be re-observed in the same position in the sky, and in the same observing circumstances (apparent magnitude, orientation of the body with respect to the observer, etc.); (2) their motion will not be negligible even during a single transit.

Based on mission specifications, all sources that will appear larger than ∼200 mas will be discarded. This selection automatically excludes from observations the major planets and some large satellites (such as the Galilean satellites of Jupiter, or Titan). The upper magnitude limit for detection will be close to $V = 20$.

The vast majority of the observed objects will consist therefore of asteroids of every category: mostly from the Main Belt, but also many belonging to the Near Earth Object population, plus some additional tens among Jupiter Trojans, Centaurs, and Trans-neptunians. A population of more than $200,000$ asteroids should be observable by Gaia.

Each asteroid will be observed (by the astrometric CCD detectors) a number between ∼60-80 times during the nominal mission operational lifetime of five years, although the number of detections will be generally lower for Near Earth Objects. On average, we can estimate that no less than 1 asteroid/sec will enter the Gaia astrometric instrument when the viewing direction is close to the ecliptic.

Gaia will never observe either at the opposition or toward conjunction, but mostly around quadrature. Most asteroids will be known when Gaia will detect them, so the discovery potential of Gaia is fairly low due to its upper magnitude limit. A major exception is expected to be represented by objects whose detection by most ground-based surveys is particularly difficult, in particular low solar elongation objects having orbits interior to that of the Earth. The region at ∼45 degrees elongation from the Sun will be explored and could represent the most fruitful area for discovery purposes.

The physical and dynamical characterization of known objects is the much more ambitious and rewarding goal that is expected from the Gaia mission. In fact, the expected accuracy of Gaia observations (for photometry, spectroscopy and astrometry) will be such as to improve by more than 2 orders of magnitude the quality of asteroids orbits [1], and to obtain a wealth of information for the physical characterization of the objects, to derive a mass from mutual perturbations, to derive for most of them a shape and the rotational properties by photometry inversion, to directly measure asteroid sizes. The determination of asteroid physical properties will be one of the fundamental contributions of Gaia to Planetary Science. A list of expected results includes:

- The measurement of about 100 asteroid masses [2].
- The direct measurement of about $1,000$ asteroid sizes [3].
- The determination of the rotational properties (spin period and polar axis orientation) and overall shapes for a number of the order of $100,000$ objects [4].
- Based on the measured masses and volumes, the determination of the average densities for about 100 objects belonging to practically all the known taxonomic classes.
- The measurement of spectral reflectance in a wavelength interval between 330 and 1050 nm for a number of objects of the order of $100,000$.
- A new taxonomic classification based on reflectance spectra (including wavelengths in the blue region of the spectrum) obtained for several tens of thousands of objects.

To the items of the above list, we have to add, of course, the derivation of much improved orbits for a data-set of about $200,000$ objects, taking profit of the unprecedented astrometric accuracy of the Gaia mission.

As a result, we can expect that Gaia will open a new era in the field of asteroid science, (the "Gaia revolution" in asteroid science).

Most results for asteroid physical characterization will be obtained and published at the end of the mission, when all the data collected for each object in different observing circumstances will be finally processed and interpreted. In the case of the inversion of Gaia photometric data, which will consist of sparse measurements, and not of full lightcurves, a genetic algorithm has been designed and implemented. The objects are supposed to have triaxial ellipsoid shapes, and the goal is to find for each of them the best set of spin (rotation period and pole orientation) and shape (axial ratios) properties which best represent the obtained measurements, taking also into account a relation between magnitude and phase angle, which can also be used to assess qualitatively the geometric albedo. An optimization of the inversion algorithm is currently in development, in order to find an optimal compromise between the need of minimizing wrong inversion solutions (which are always possible) and the need of keeping the required CPU time within reasonable limits. The role played by light scattering effects by the surfaces of the objects is also being taken into account and explored by means of dedicated simulations.

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