

Science of the Solar System with GAIA

**D. Hestroffer^{1,2}, V. Zappalà², D. Carollo²,
M. Gai², F. Mignard³, P. Tanga²**



1/ IMCCE, Paris Observatory, France

2/ OATo, Turin, Italy

3/ CERGA/OCA, Grasse, France

Abstract

Gaia is a proposed mission for ESA's next cornerstone mission dedicated to high accuracy astrometry of our Galaxy.

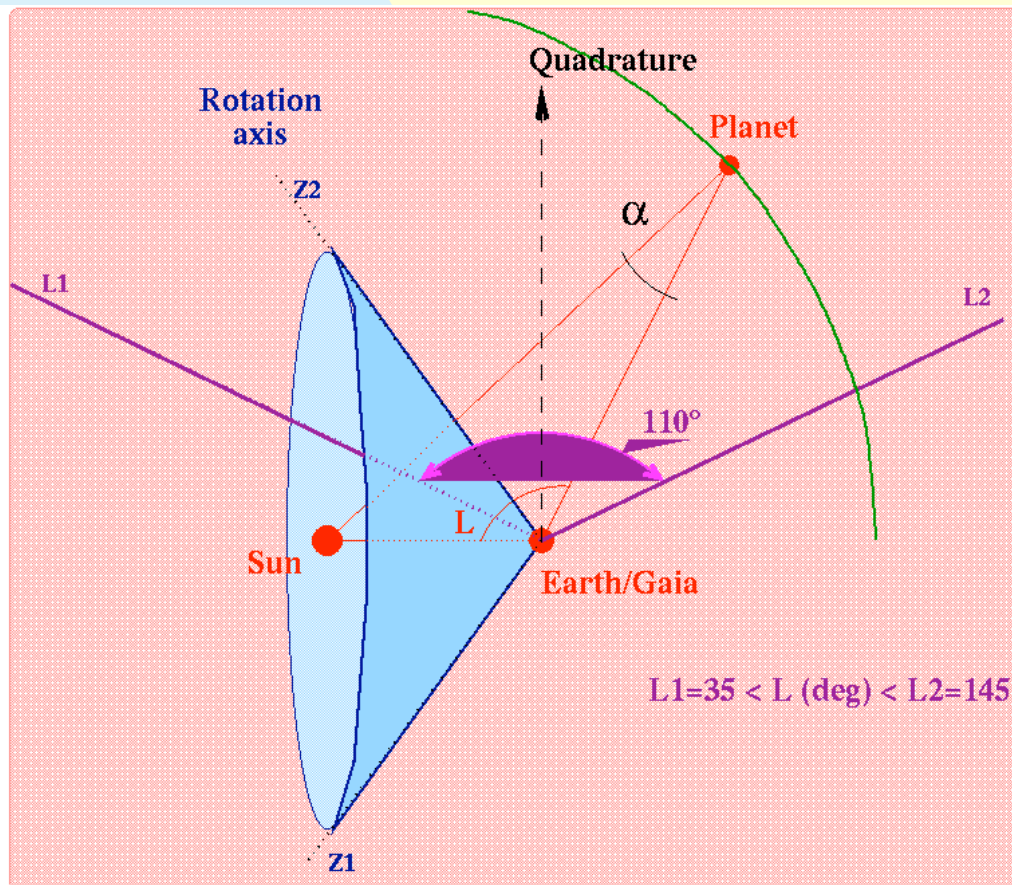
With its complete sky coverage down to $V \leq 20$, the Gaia telescope will observe a huge number of solar system objects, mainly main-belt asteroids, and possibly detect new ones in particular at small solar elongations or larger distances from the ecliptic where usual surveys are lacking observations.

Gaia will provide high precision astrometry ($\sigma \sim 1$ mas) and photometry ($\sigma \sim 0.001$ mag). This will yield taxonomy and orbits determination for about 10^6 objects. Gaia will also enable tests of general relativity, mass and direct size determination for about thousand asteroids. From these better constrained physical and dynamical parameters, the Gaia mission will improve in many aspects our knowledge of the formation and evolution of our Solar System.

Basic parameters

| | |
|---|----------------------------------|
| Launch: | expected for 2009 |
| Duration: | 5 years |
| Orbit: | L2 point Earth-Sun |
| Telescope: | 1.7 x 0.7 m ² |
| Receptors: | big CCD array, high QE, TDI mode |
| Wavelength: | 0.3-1.1 μm |
| Observations: | scans the whole sky |
| Other: | well defined instrument |
| Detection by ASM: | rate of motion < 40 mas/s |
| Observation by AF: | V < 20 |
| Multi-wavth photometry: | V < 18 (no strict definition) |

Scanning law - Solar system



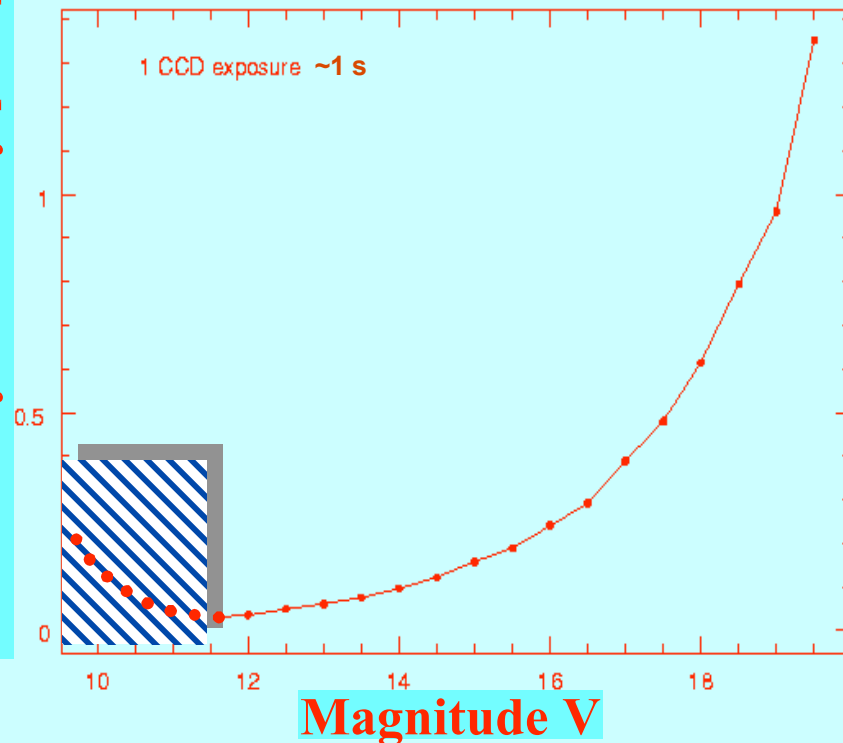
The spin axis of the satellite is precessing around the direction of the sun. The FOVs are in directions perpendicular to the spin axis and scan a great circle of the sky during a rotation period.

Thus solar system objects are observed in a **large band around the quadratures** with:

$$35 \leq L \text{ (elongation)} < 145 \text{ deg}$$

Measurements precision

Astrometry: Accuracy [mas]



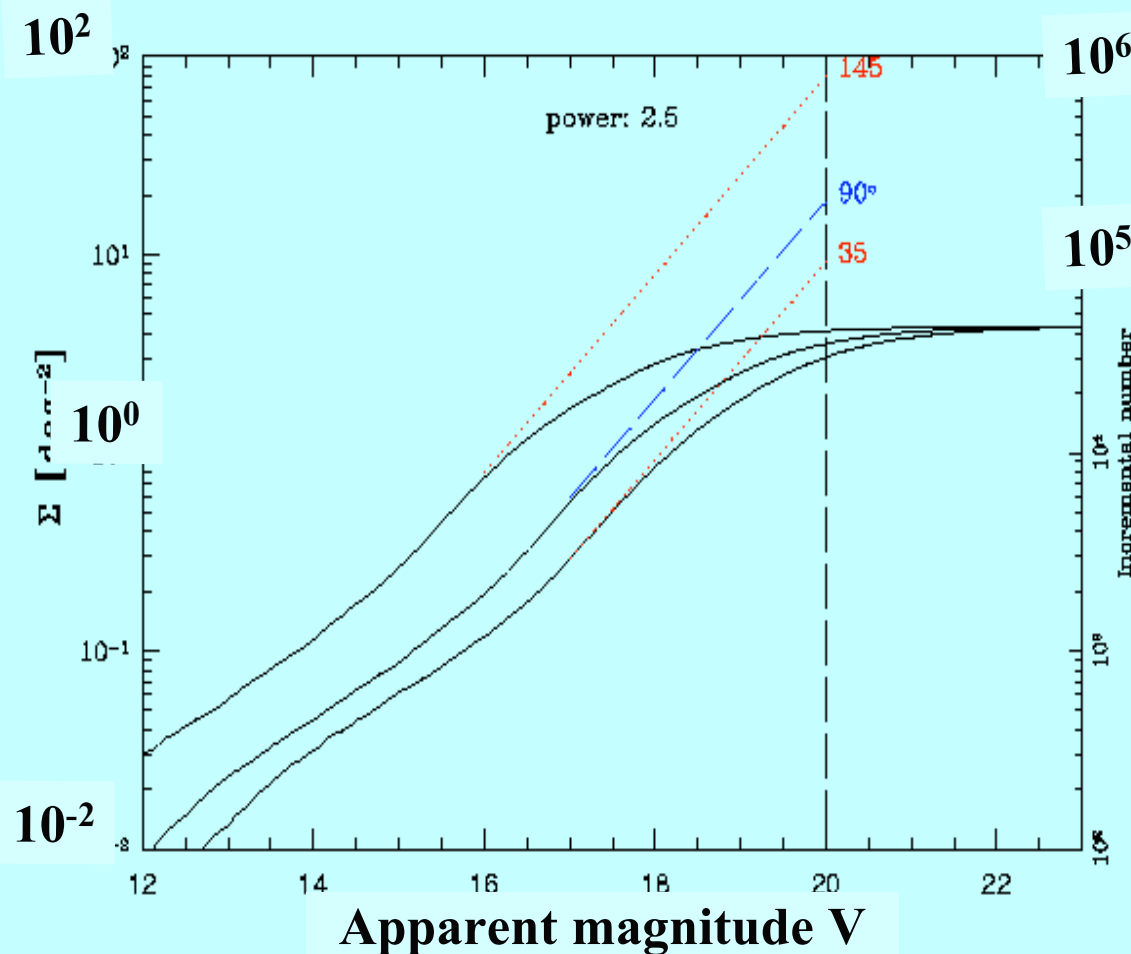
Astrometry: $\sigma \sim 0.1-1$ mas

- Depends on object's motion, apparent size, etc..., but essentially on its magnitude.
- Improved by taking a normal point over a FOV transit.

Photometry: $\sigma \sim 0.001$ mag

- large band (G) : same well calibrated system over 5 years;
- N colours: => taxonomy.

Observed objects

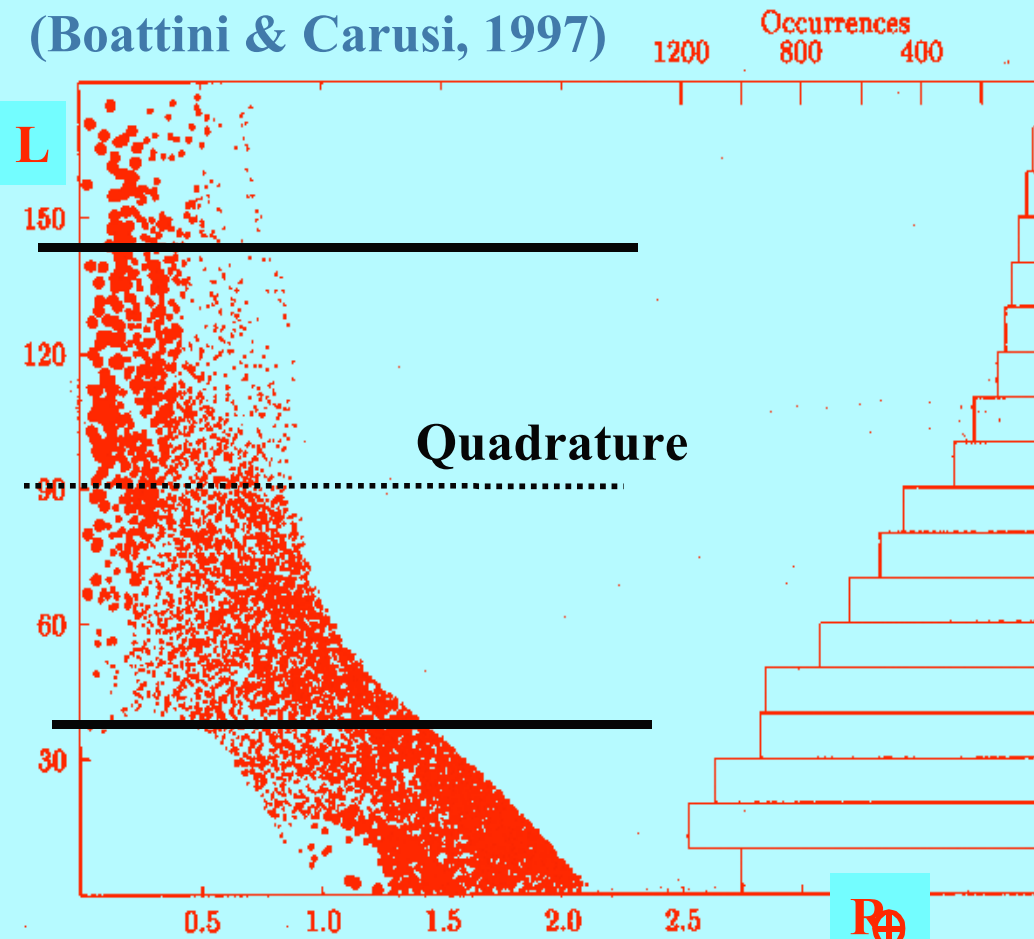


There is no input catalogue and all objects crossing the FOV that are brighter than $V < 20$ will be observed: planetary satellites, comets, major planets, and mainly main-belt asteroids.

About 10^6 known and unknown asteroids will be observed.

NEOs

(Boattini & Carusi, 1997)

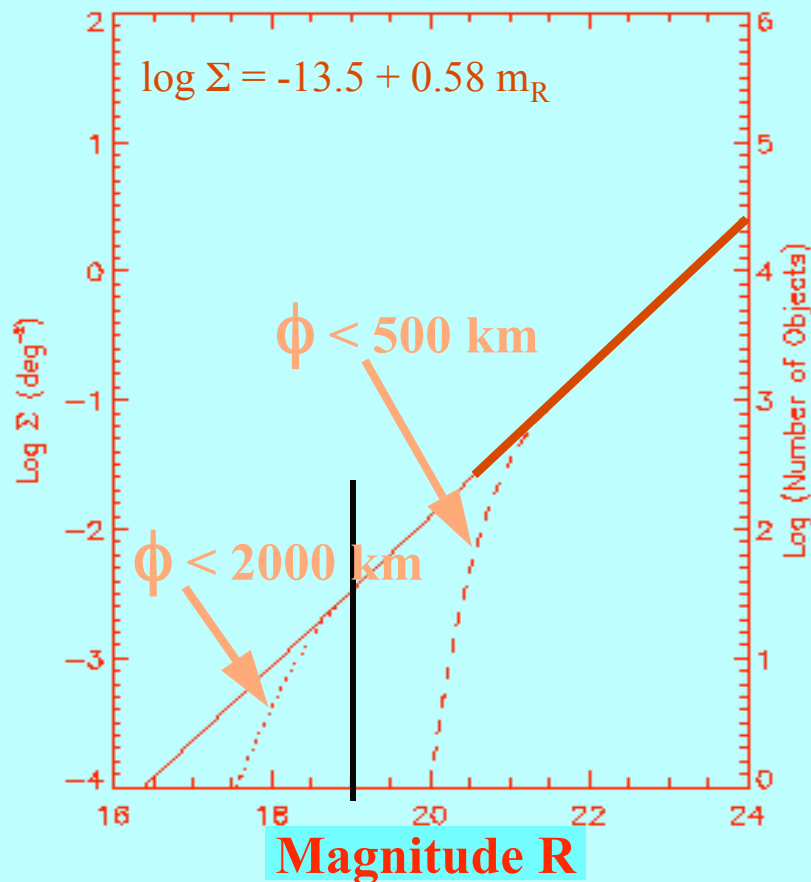


NEOs which rate of motion is not too high will be detected. Since Gaia will perform observations to relatively small elongations, it will detect **Atens and IEAs** which are:

- significant members of this population (Michel et al., subm.)
- not easily observed from ground.

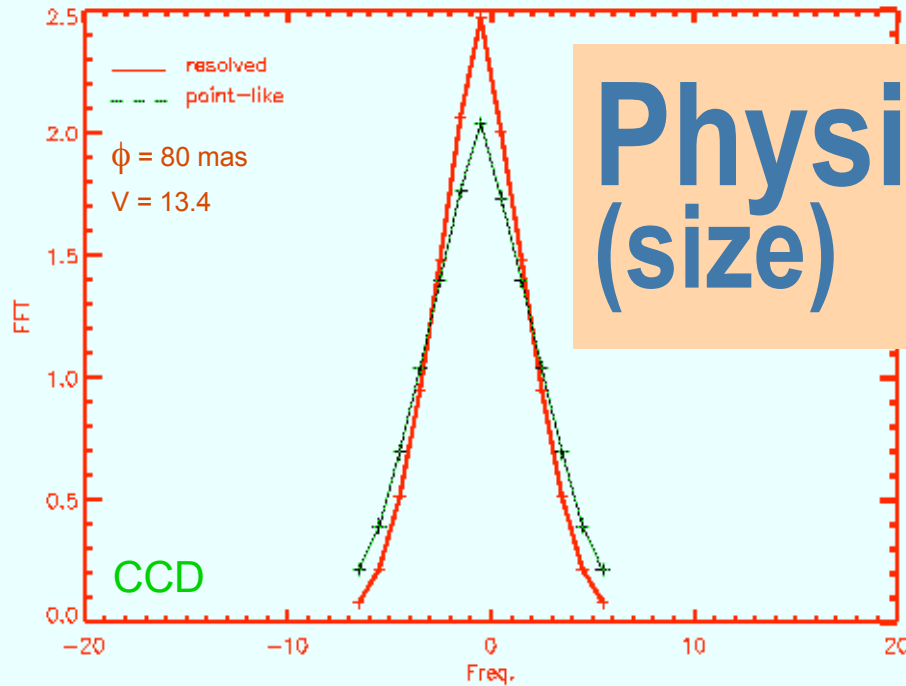
The detection efficiency should be analysed in more details.

Centaur - KBOs



The limiting magnitude is of $V \leq 20$ only, but on the other hand the **sky coverage will be complete**. Thus Gaia will detect all close, large or high albedos KBOs and Centaurs. Gaia may also detect **other hypothetical Plutos**. One should stress that even a **non detection** of some system (bright KBO, binary asteroids,...) yields valuable constrains for formation and evolution models.

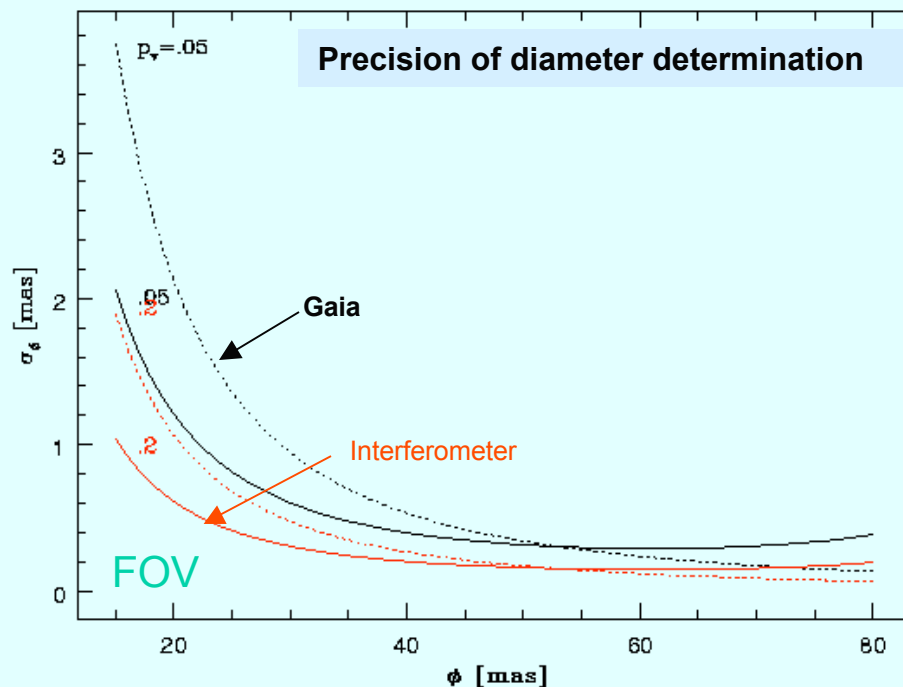
Physical parameters (size)



Gaia will provide images of solar system bodies. The image of an **asteroid $\phi > 30$ mas** will depart significantly (on a 3σ basis) from the PSF.

Gaia will provide:

- **size estimates** during a single **FOV transit** for ~ 1000 asteroids;
- **mean diameters** for ~ 2000 more objects over the **whole mission**.
- detection of eventual contact **binaries or moons**
- **mean diameters** of a few **stars**.



Physical parameters (cont.)

- Ephemerides have shown that ~100 large ($D > 120$ km) asteroids are involved in close encounters with large or high impact parameter (Bange, Viateau, private comm.). Gaia observations (+complementary ground-based CCD, radar,...) combined with size estimates will provide the **mass and density** for these objects.
- The wide G-band photometry and N-colours photometry will provide , from a single instrument, '**light-curves**' and a basic **taxonomy** for all observed objects.
- Size estimates combined with the well calibrated photometry will provide **albedos** for a large class of objects **through the main belt** and also **trojans**.

General relativity

- About 400 asteroids have a perihelion shift > 10 mas/year. It will be possible to separate the contribution of the solar quadrupole J_2 from the **parameters of the PPN formalism** (Will 1993).
- Data for the planetary satellites will also provide information on the **Nordtvedt parameter** through the Lense-Thirring effect.
- High precision astrometry of trojans of Jupiter or in 2:1 resonance provides a test of the **equivalence principle** (Orellana & Vucetich 1988, Plastino & Vucetich 1992).
- Gaia provides direct observations of stellar-like asteroids and QSOs. It will be possible to link the dynamical and kinematical reference frames, and test the existence of a **vortex of the Universe** of the order of $\approx 5-10 \cdot 10^{-12}$ rad/year.
- Need of **further simulations** for the affordable precision and value of complementing with other high-precision observations.

Conclusion & future work

The GAIA mission will collect a huge quantity of valuable astro-metric and photometric measurements of solar system objects. From the many better constrained physical parameters, dynam-ics, size distributions, etc..., it will led to a better knowledge of the formation and evolution of our Solar System.

Some aspects however need future studies e.g.:

- (re)-identification of asteroids;
- reduction to astrometric locations;
- post-Gaia reduction of CCD images;
- detection/observation of NEOs, comets & binary systems;
- precision of the determination of asteroids' mass, of PPN parameters, of reference frames linking,...;
- catalogue completion to magnitude $V=20$;
- ...