Gaia: les observations du Système Solaire

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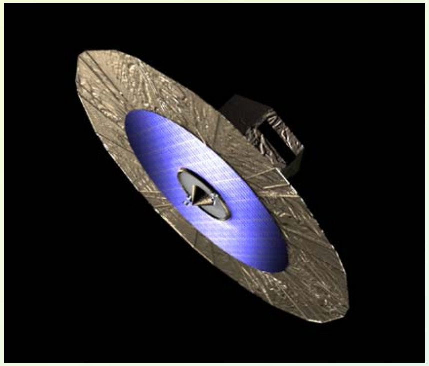
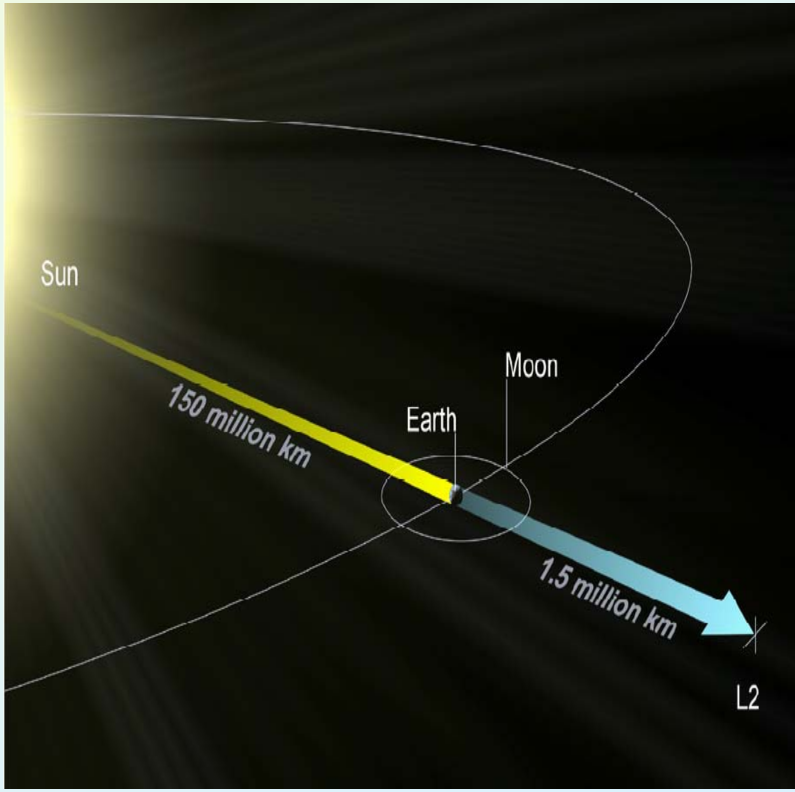
Résume

- Gaia
- L’intérêt des observations du Système Solaire par Gaia
- Relation avec les observations au sol

Gaia – fact sheet

- **ESA cornerstone mission**
- Launch end-2011 from Kourou
  Soyuz–Fregat
- **5 years** of observations
- **Astrometry**: **10^9 stars**, **V<20** (automatic selection) **25 μas** at V~15
- **Orbit around L2**
- **Physical observations**:
  - Radial velocities
  - Spectro-photometry
- It is a **scientific mission**:
  - ESA: building, operation
  - Scientific community: data reduction





Gaia - strenghts

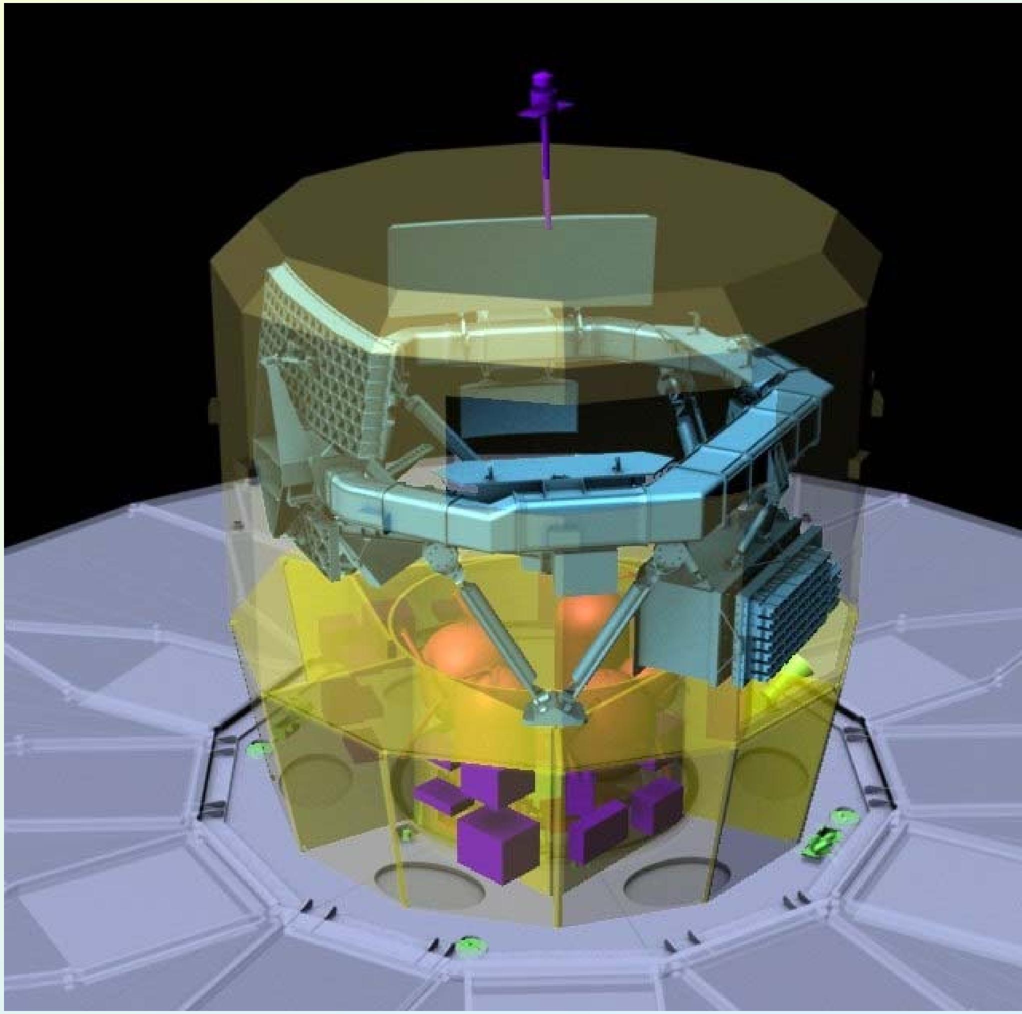
- **Three instruments** covering several needs:
  - astrometry
  - photometry
  - spectroscopy

- Uniform sky coverage, 60-100 obs/object

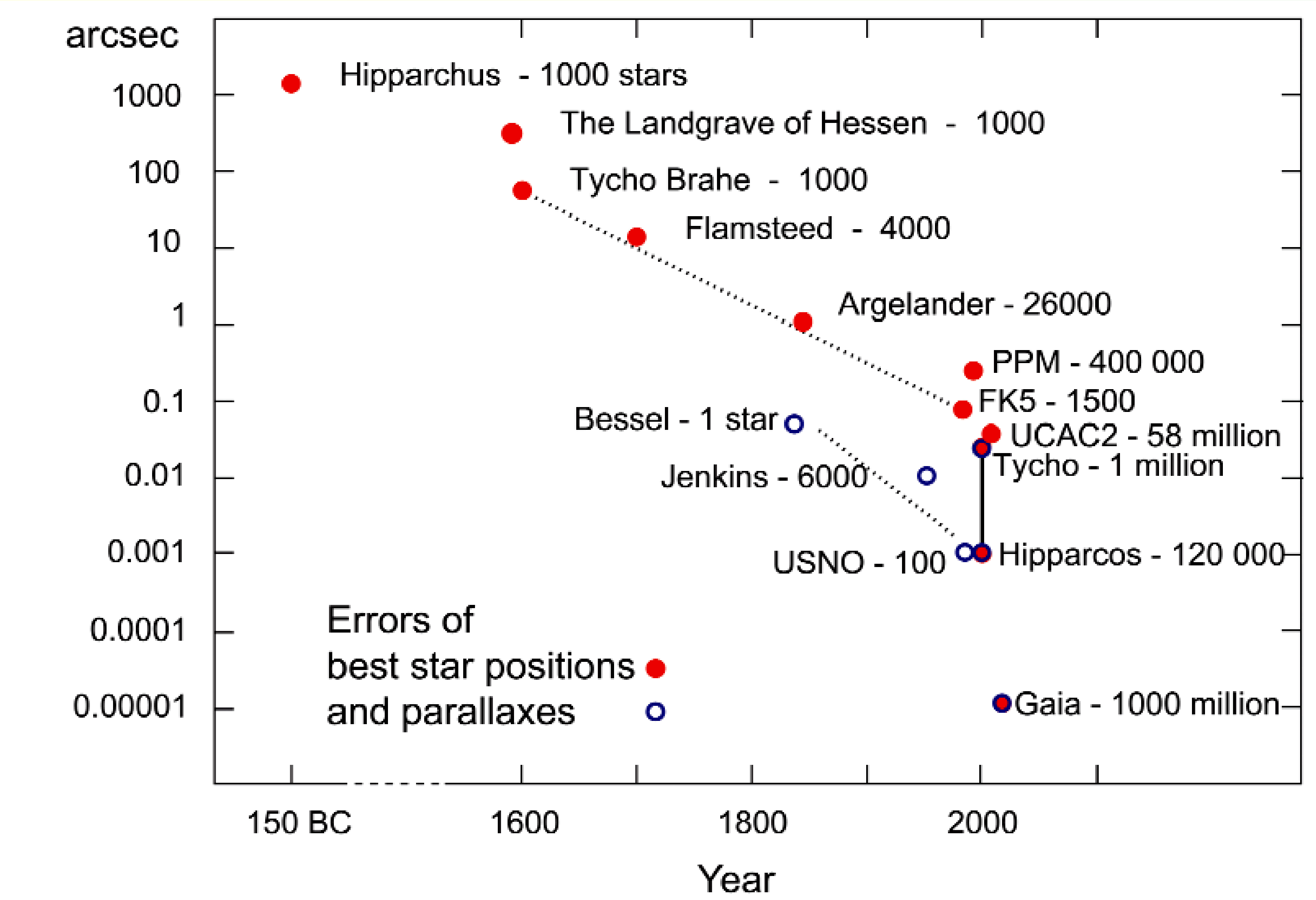
- **No input catalogue, all sources V<20**

- Self-calibration, thermal monitoring

- **Strongly motivated community**, experience of Hipparcos



Gaia in the history of astrometry



Optics

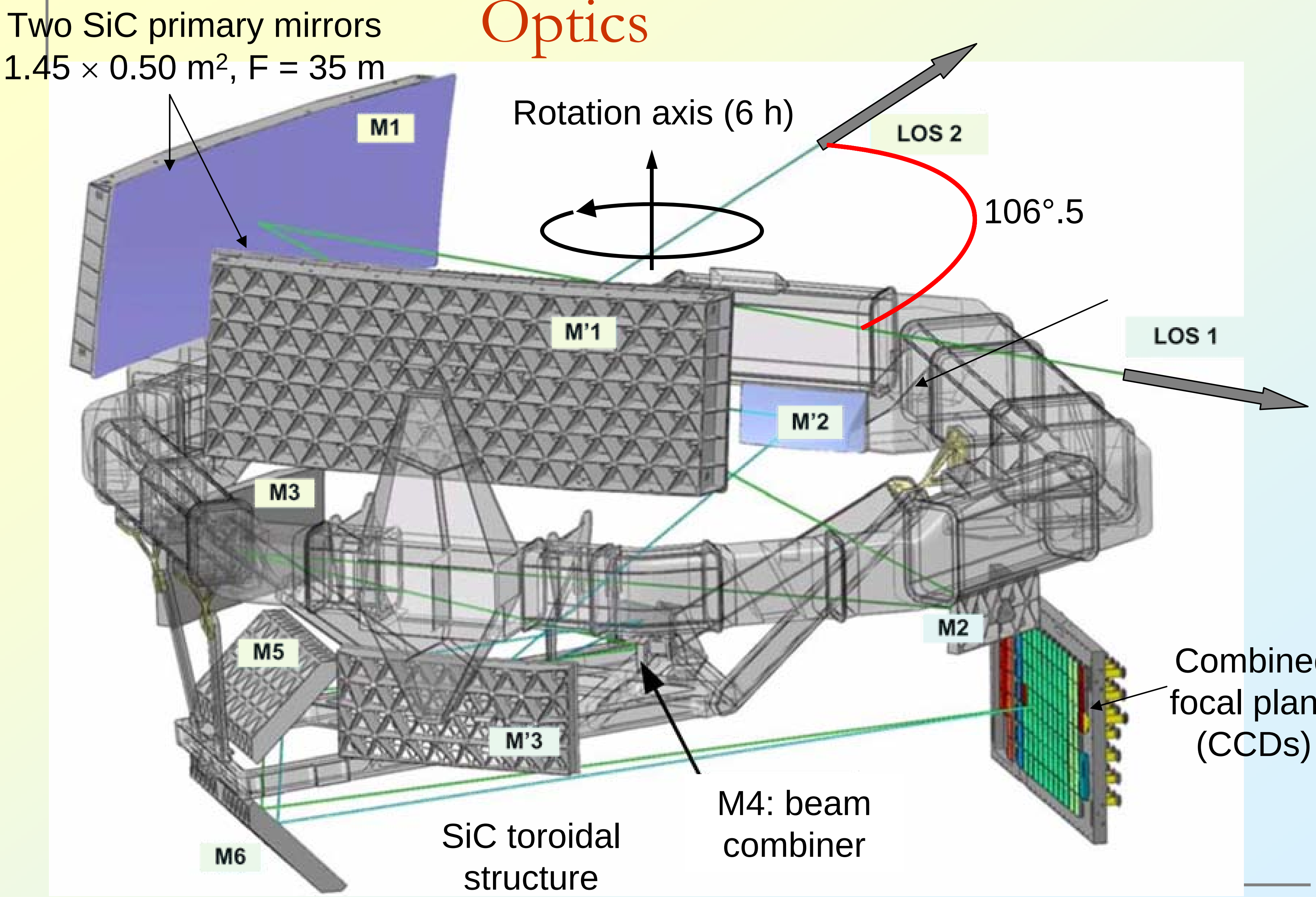
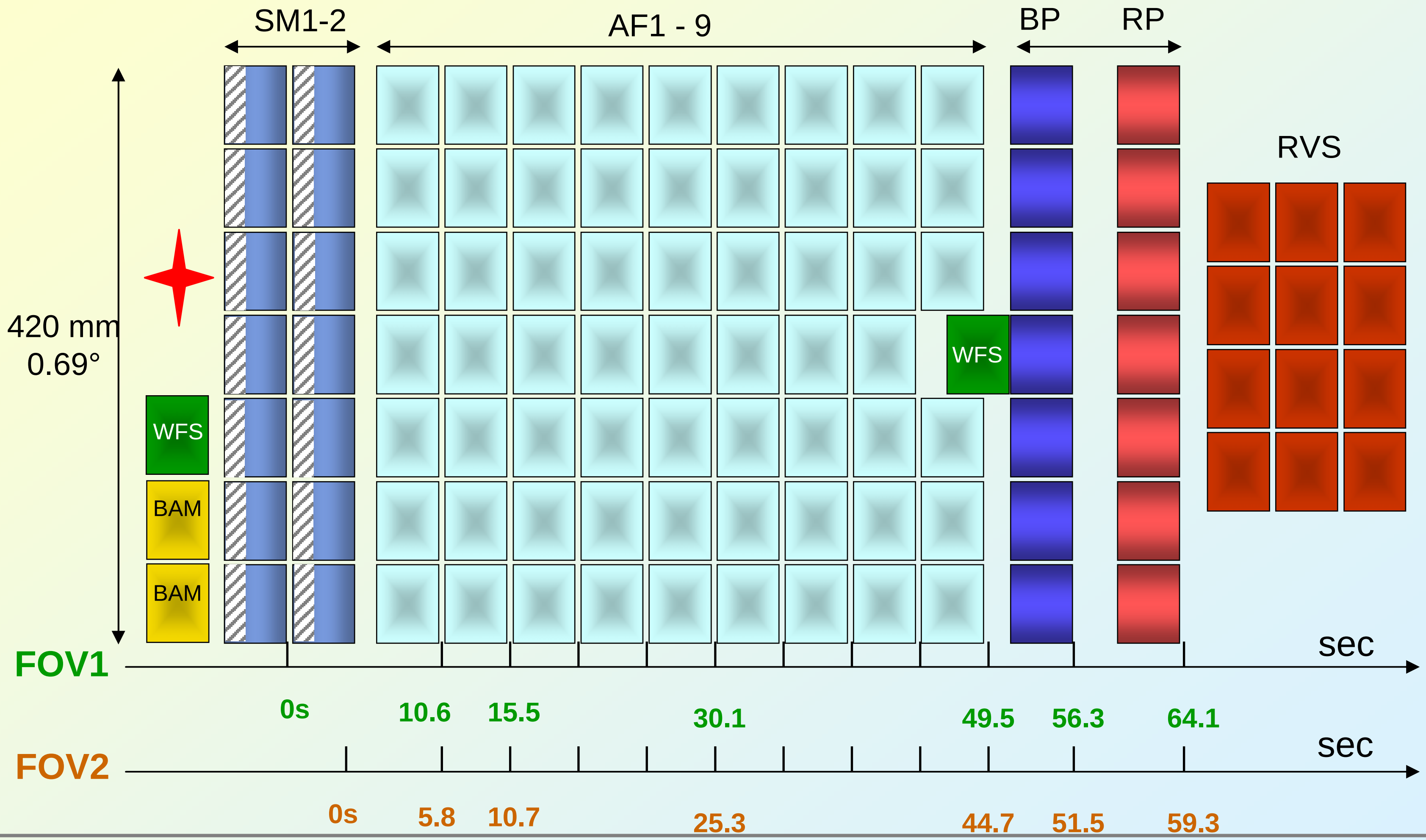


Figure courtesy EADS-Astrium

Focal plane

1 pixel 60 x 180 mas

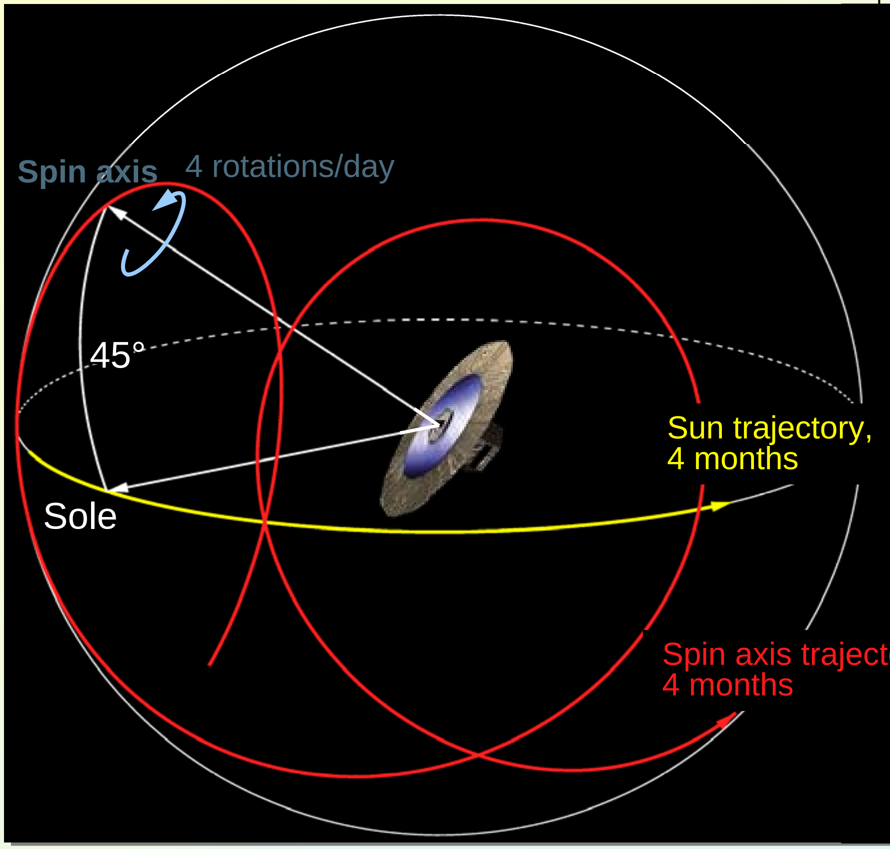
106 CCDs (4.5 x 2 kpix) = 1 Gpixel

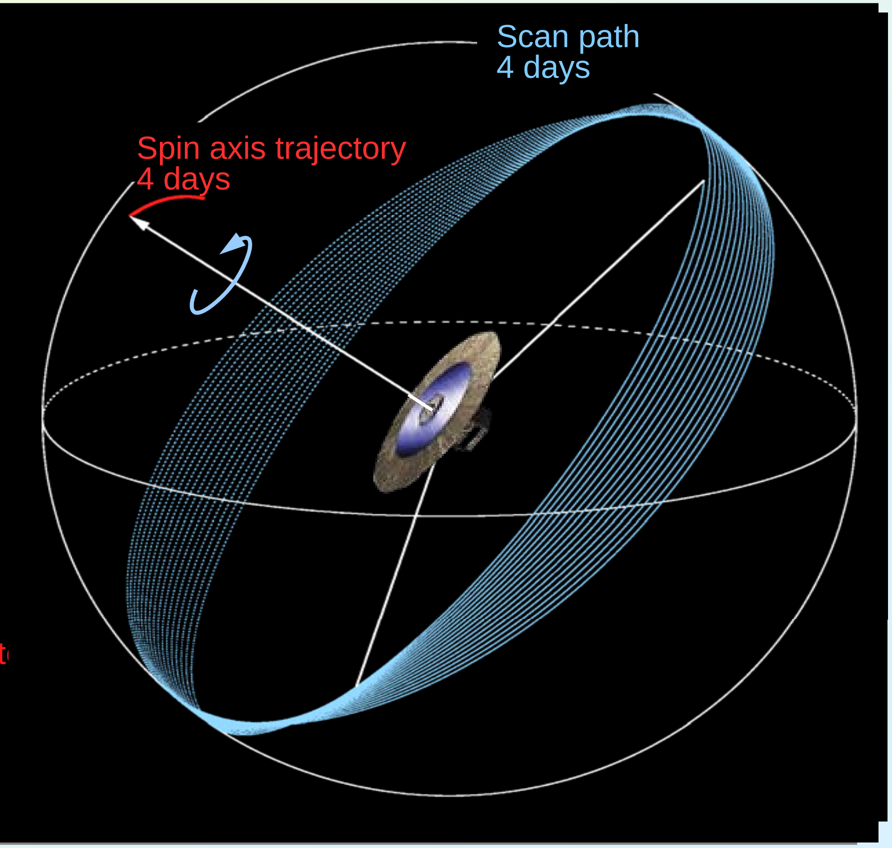


The scanning law

Rotation axis movement

Scan path in 4 days





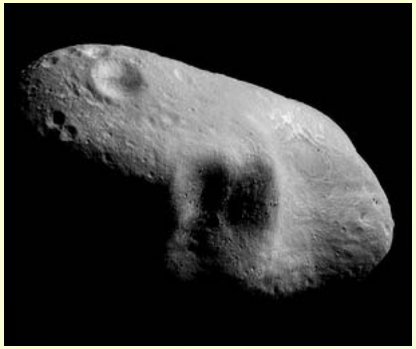
Gaia will also observe…

- Asteroids (~250.000 – most known)
  - Mainly Main Belt Asteroids (MBA)
  - Several NEOs
  - Other populations (trojans, Centaurs,..)

- Comets
  - Primitive material from the outer Solar System
- « Small » planetary satellites
  - « regular »
  - « irregular » (retrograde orbits)
- Gaia will probably NOT collect observations of « large » bodies (~200 mas?)
  - Main Planets, large satellites (Galilean, Titan..)
  - A few largest asteroids

The importance of asteroids…

The great issues:



→ Origin: collisional life, related physics

→ Dynamical processes: transport, mixing in the primitive nebula, origin of meteorites

→ Impact risks and mitigation strategy

The problem…

Very limited knowledge of basic properties:

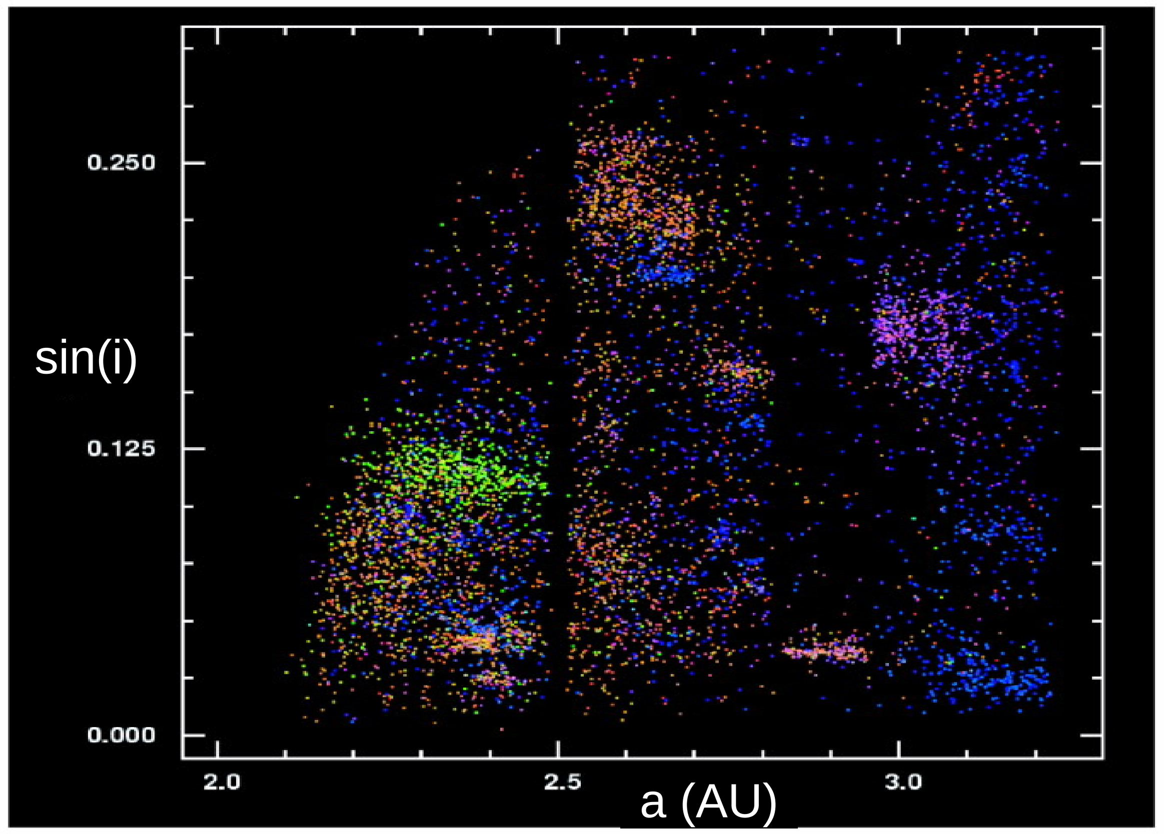
- density, porosity…
- Spectral types and connection to composition
- Shapes, satellites
- Size distribution

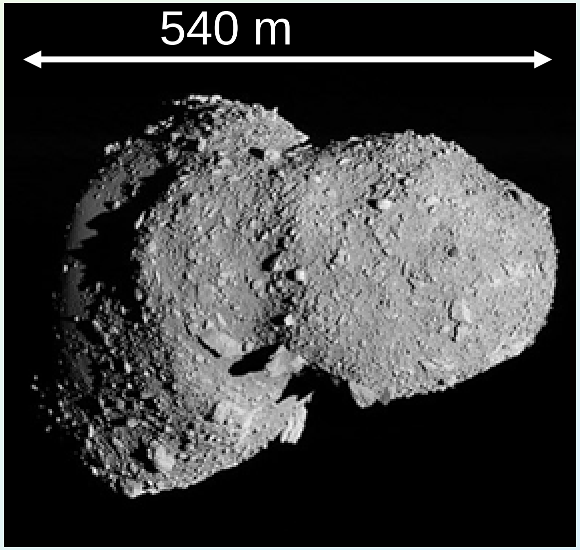
Open questions, from dynamical families to NEOs…

Small members of dynamical families: quantity? Sub-families?

How many asteroids have satellites?

How many asteroids are cohesionless rubble-piles? Size range ?





Itokawa as seen by the Hayabusa mission

Present situation

	N
Photometry → shapes, poles	~100
rotation periods	~1000
Satellites	~20 (MBA)
Low-res spectroscopy: surface composition	~1500
Astrometry, orbit determination → masses, σ<60%	~40
Size / albedos	~2000 (indirect method)

Asteroid dynamics and physics by Gaia

Gaia and asteroid dynamics

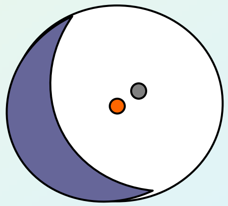
- Astrometry

ground-based	Gaia single measurement
0.1 - 1 arcsec	*0.1 – 1 mas*

Orbit improvement (> 100)

Uncertainty < d for d > 20 km

- Larger sensitivity to « small » effects:
  - Mutual perturbations (<100 mas) …among several bodies!
    - Masses of ~100 objects
  - Shape effects (<0.1 x diameter)
    - Photocenter-barycenter difference



  - Non-gravitational accelerations
    - Thermal emission (Yarkovsky, ~0.1 mas)
    - Comet jets
  - Relativity effects

Asteroid masses: today

- limited astrometric precision, long periods of observation → perturbations by other unknown masses
- uncertainty > 10^{-11} $M_\odot$ (10-30% Ceres, Pallas, Vesta)
- ~40 asteroids at better than 60% (Mouret *et al.* 2007)

Asteroid	**Mass ($M_\odot$)**	**Reference**
10 Hygiea	$(4.7 \pm 2.3) \times 10^{-11}$	Scholl et al. 1987
	$(5.6 \pm 0.7) \times 10^{-11}$	Michalak 2001
11 Parthenope	$(2.6 \pm 0.10) \times 10^{-12}$	Viateau Rapaport 1997
15 Eunomia	$(4.2 \pm 1.1) \times 10^{-12}$	Hilton 1997
	$(1.2 \pm 0.4) \times 10^{-11}$	Michalak 2001

Final statistics for mass determination

- N-body system of « unknown » masses
- The *global* solution (orbits + masses) must take into account the *complete* system.

~100 Larger perturbers better than 15% !!
→ General improvement of SS dyn. model

Number of perturbers	
Total	602
$\sigma(m)/m < 0.1\%$	2
$\sigma(m)/m < 1\%$	3
$\sigma(m)/m < 10\%$	36
$\sigma(m)/m < 15\%$	59
$\sigma(m)/m < 20\%$	75
$\sigma(m)/m < 30\%$	106
$\sigma(m)/m < 40\%$	135
$\sigma(m)/m < 50\%$	149

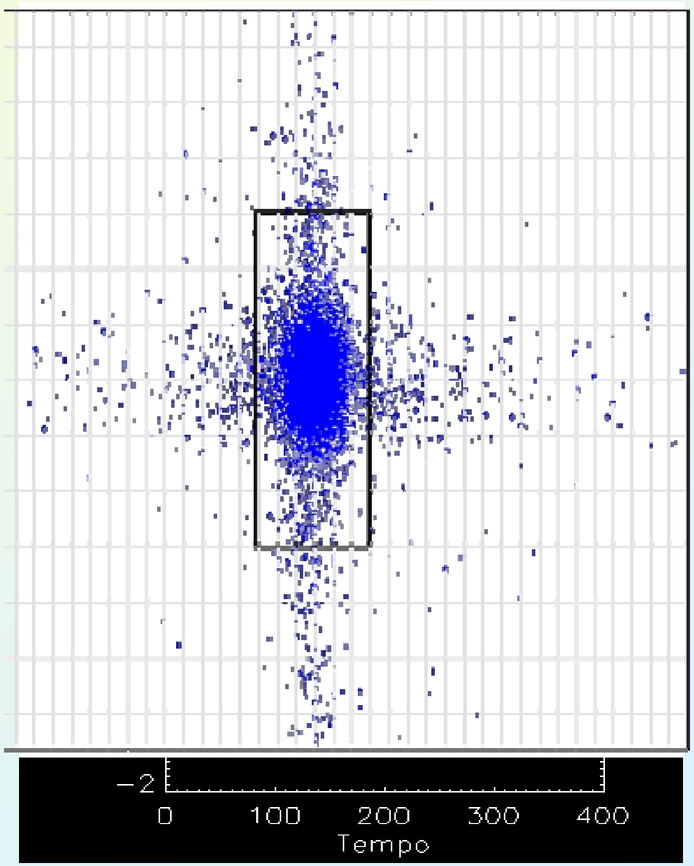
Mouret 2007

<u>But:</u>

- Reality will be better : ~10 times more objects observed
- Problem (opportunity): several encounters occouring « before » and « after » Gaia

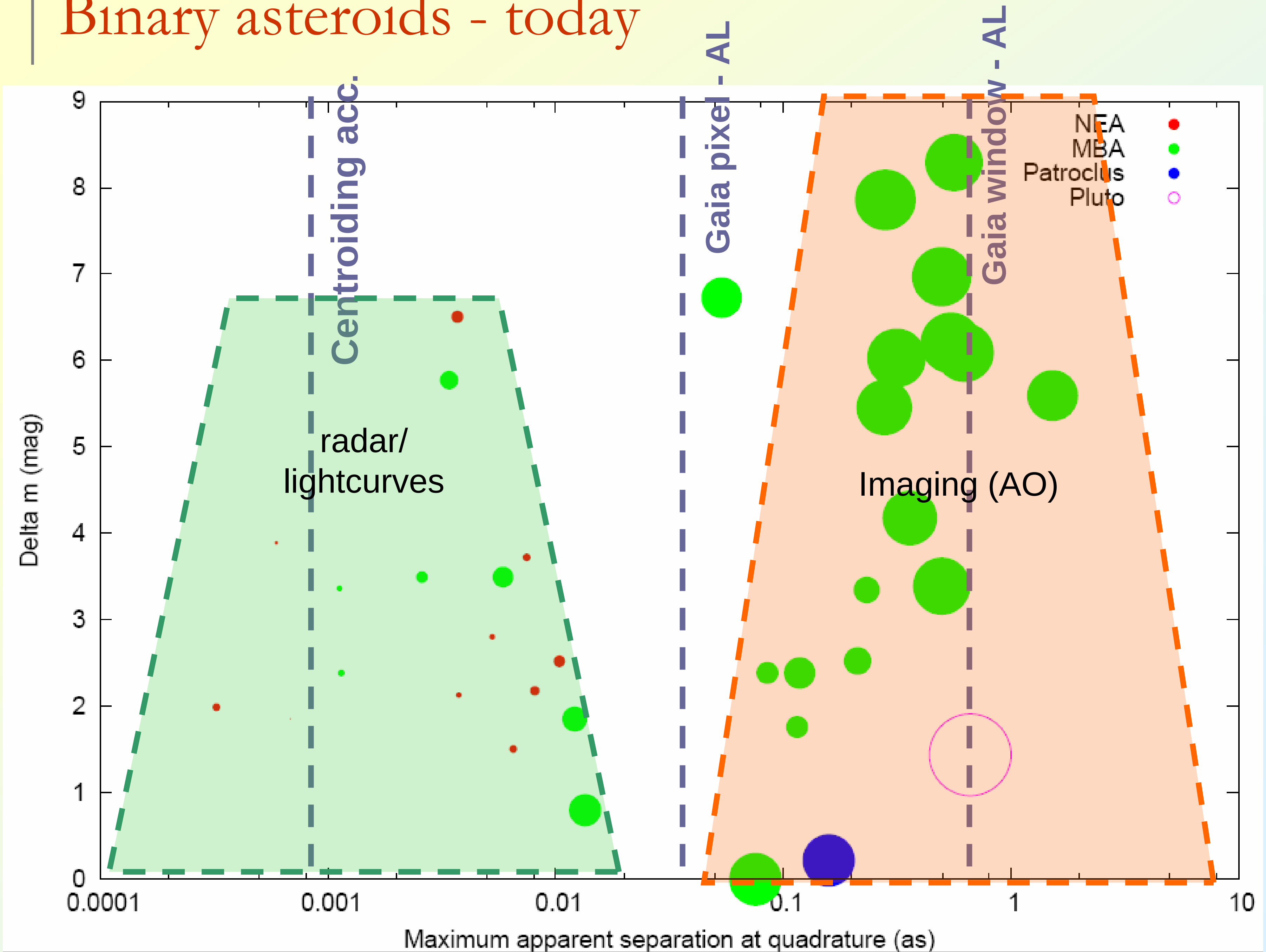
Gaia and asteroid physical properties

- AF instrument:
  - Photometry
    - accuracy ~10^{-3}
    - Lightcurve inversion → shape, rotation poles, period
  - Size / satellites
- RP and BP (330-1000 nm)
  - spectro-photometry
    - Equivalent to ~ 20 bands
  - → New taxonomy system

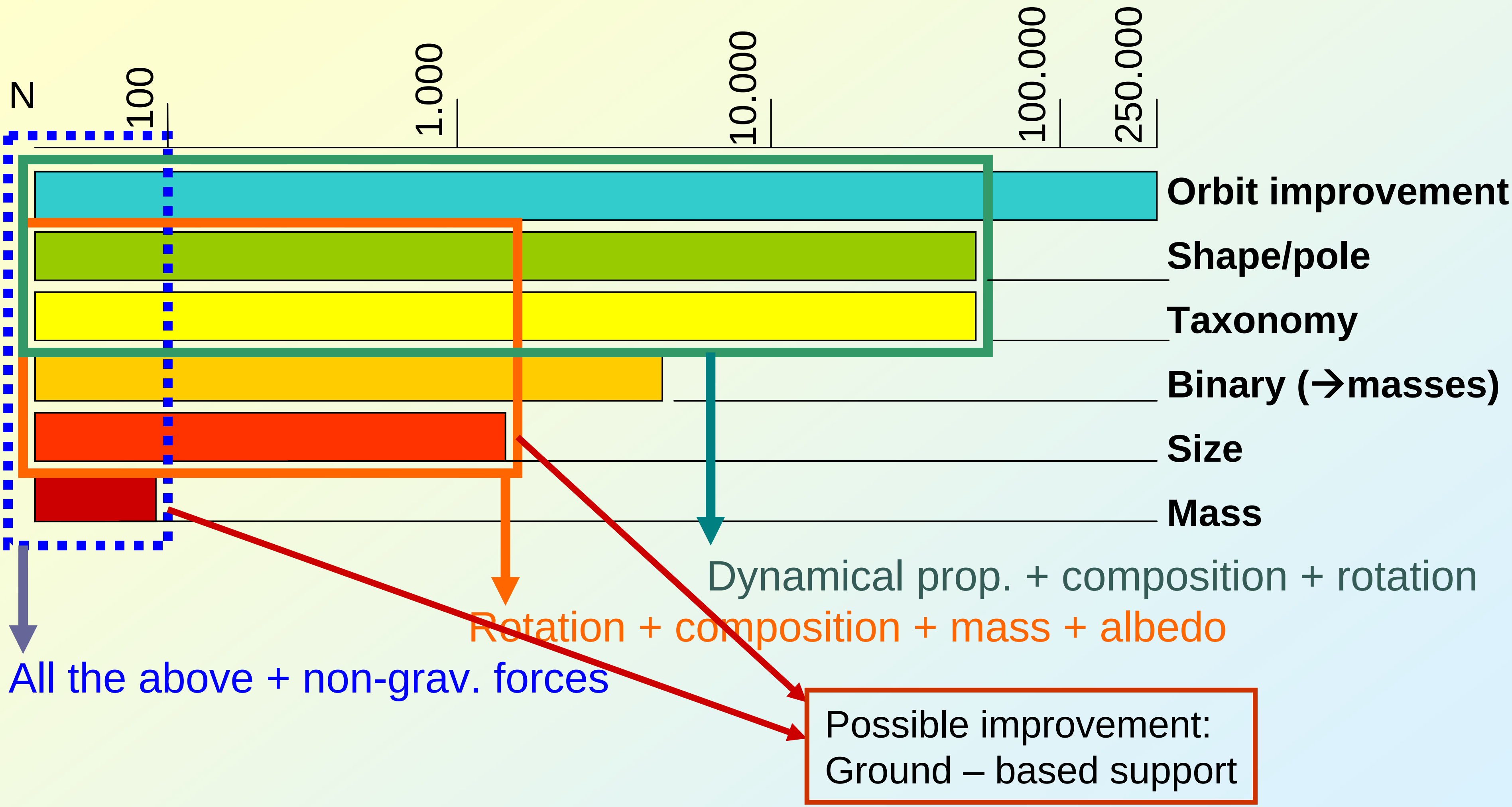


Courtesy of M. Delbò
A. Dell'Oro

Binary asteroids - today



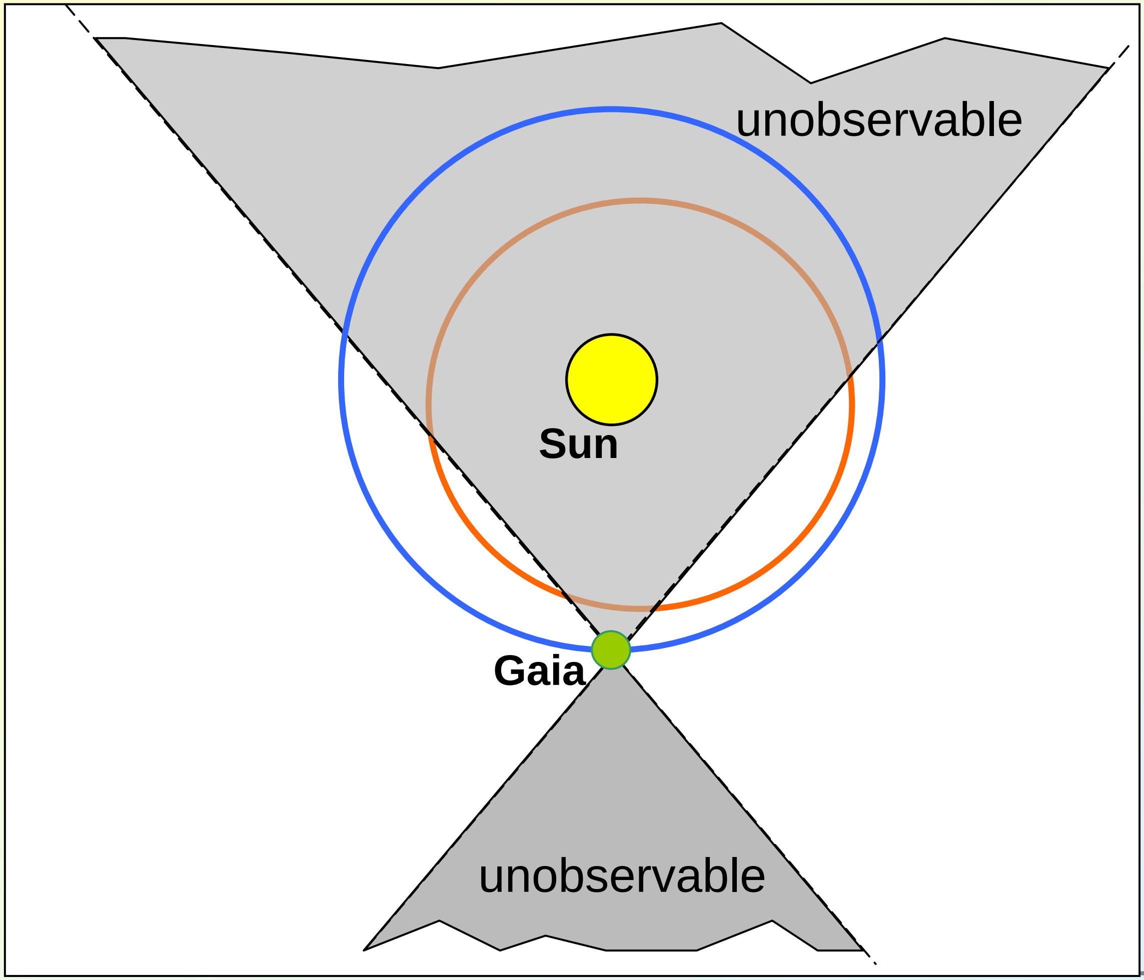
Gaia and the asteroids: a new global picture



Data complement by ground-based observations

Discovery potential and follow-up

Observable region on the ecliptic plane



- Discovery space:
  - Low elongations (~45-60°)
  - Inner Earth Objects (unknown population)
  - Other NEOs
- Need of ground-based follow-up (resp. W. Thuillot)

Improving the scientific return

- Masses
  - astrometric measurements before and after Gaia, on specific objects
  - about 25 added
  - + interferometry / AO → size → bulk density
- Non-gravitational effects (Yarkovsky thermal acceleration)
  - astrometric measurements before and after Gaia, on specific objects
  - ~50 expected

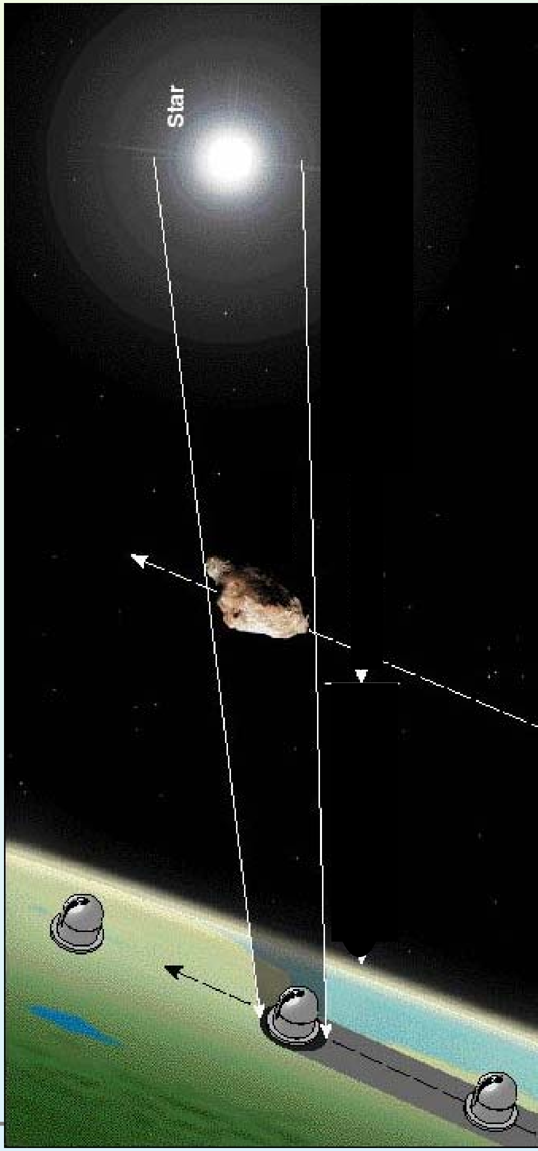
After Gaia : the occultation revival

Today

- poor predictability for objects <50 km
- bright Hipparcos/Tycho stars favoured
- ~0.1 events/objects/year
- Current practical limit: 100 km at 10% accuracy

After Gaia (100 X orbit improvement):

- Uncertainty smaller than the asteroid at >20 km
- 1-m automated telescope(s):
  - Single site: 20-40 events/yr for an object of ~20 km
  - Network: completeness of diameters > 20 km in a few yr
- Projected shape known

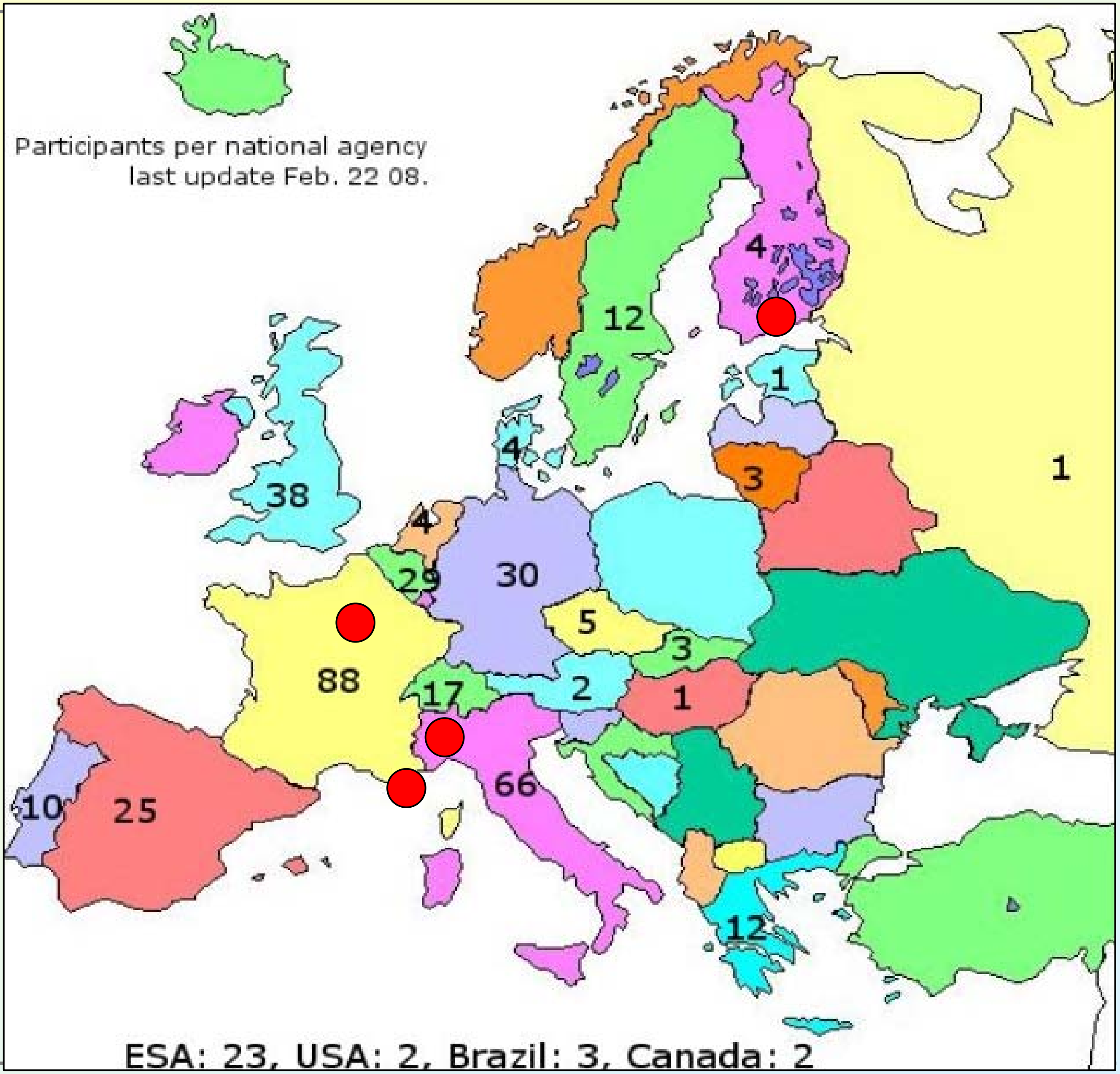


Tanga, Delbo A&A 2007

Problems to be solved

- Object motion
  - Loss of observations during the transit on the focal plane
  - Smearing of the signal
- Finite size
  - Smearing
- CTI – radiation damage
  - Alteration of the instrument response – memory effect
- Identification (threading, parasites…)
  - Sparse observations to be linked toghether
- accuracy of Gaia position
  - Need to be of the same level as the expected astrometric accuracy (~10-15 km)

The DPAC


Participants per national agency
last update Feb. 22 08.
12
4
1
3
1
4
38
4
29
30
5
3
88
17
2
1
66
10
25
12
ESA: 23, USA: 2, Brazil: 3, Canada: 2

CU4/Solar System Objects en France

- **Besançon**
  - **J.-M. Petit** ● ● ●
  - **A. Fienga** ●
- **Nice**
  - O. Michel ●
  - **F. Mignard** ● ● ●
  - Ph. Bendjoya ●
  - A. Minussi ●
  - Ch. Ordenovich ●
  - **P. Tanga** ● ● ●
  - M. Delbò ● ● ●
- **Lilles** (IMCCE)
  - M. Fouchard ● ●
  - V. Lainey ● ●
- **Paris** (IMMCE)
  - **J.-E. Arlot** ● ●
  - **J. Berthier** ●
  - F. Colas ●
  - **D. Hestroffer** ● ● ●
  - S. Mouret ● ●

    → post-doc Obs. de Helsinki (K. Muinonen)
  - **W. Thuillot** ● ●
  - F. Vachier ●
  - J. Vaubaillon ●
  - N. Rambaux ●

- ● **coordination**
- ● **analyse du signal, prétraitement**
- ● **bases de données, identification**
- ● **propriétés dynamique**
- ● **propriétés physiques**
- ● **classification, simulation**

The End