Complementary ground-based observations for Solar System applications

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Need of ground-based observations ?

- Solar System Objects : important part of the Gaia mission

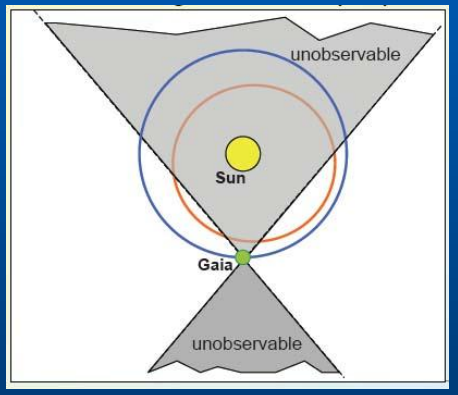
- High astrometric accuracy cannot completely rule out the use of ground-based data for increasing the extent of the final mission products

- Workshop in Beaulieu/mer (near Nice, France) in October 2008

- Different aspects of the ground-based observations can be considered, in these domains:
  - ✓Improvement of the orbital modeling
  - ✓Search for a better physical characterization

Gaia Solar System Observations

- Gaia obs. for asteroids : prec. singl meas.: 0.3-3 mas
- 250 000 asteroids (most known)
- including several NEAs, Trojans, Centaurs
- Other SSO: comets, natural satellites



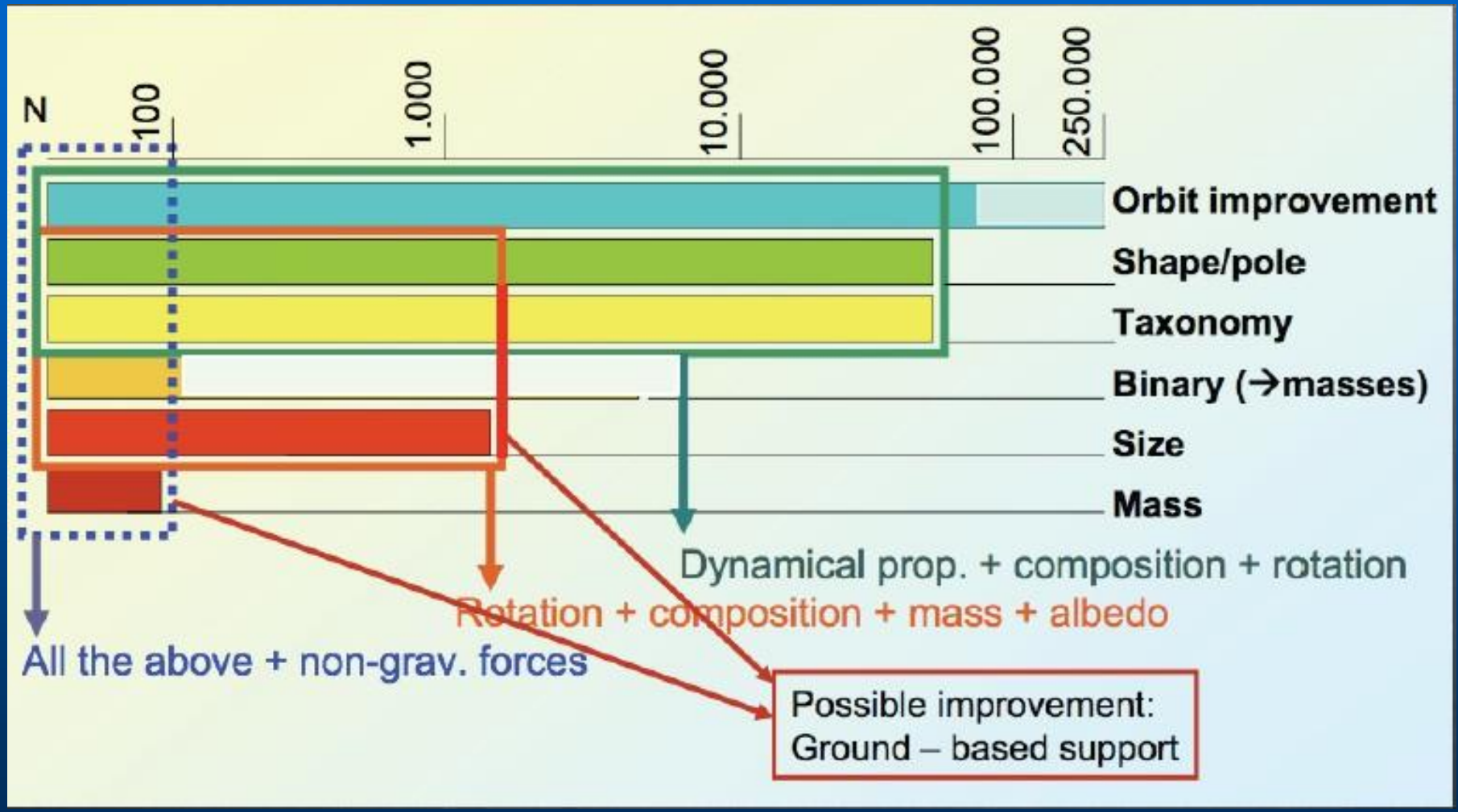
- Low Solar elongations 45 deg.
- High astrometric accuracy

- Sampling
- Magnitude
- Duration
- Imaging

Limiting factors for SSO

Complementary GB observations

Gaia and the asteroids : a new global picture



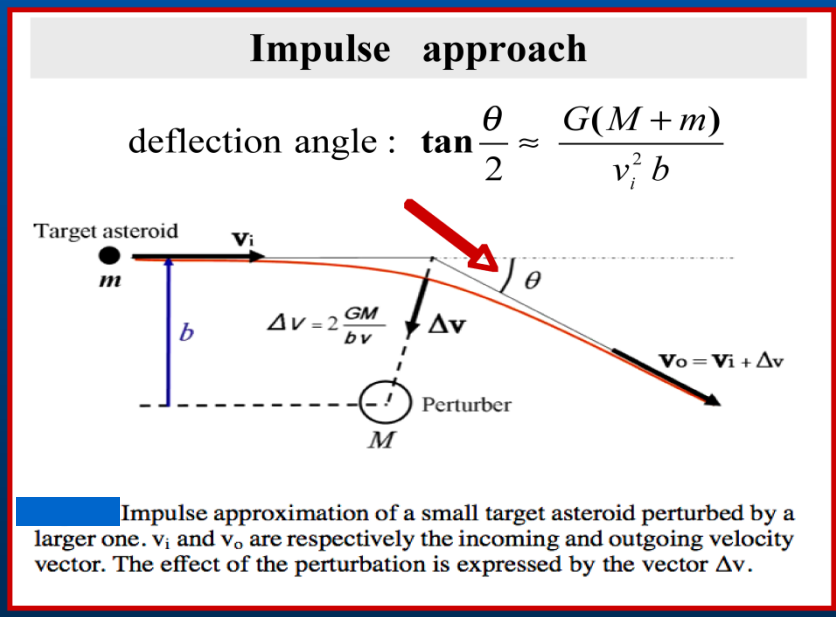
Asteroid mass determination

Mouret et al. 2007, 2009

GB observations before, during, after the mission

- astrometry during close encounters
- now: 40 masses with σ<60%
- Gaia → 150 with σ<50%

- modest sampling
- edges of mission
- GB obs. → +25

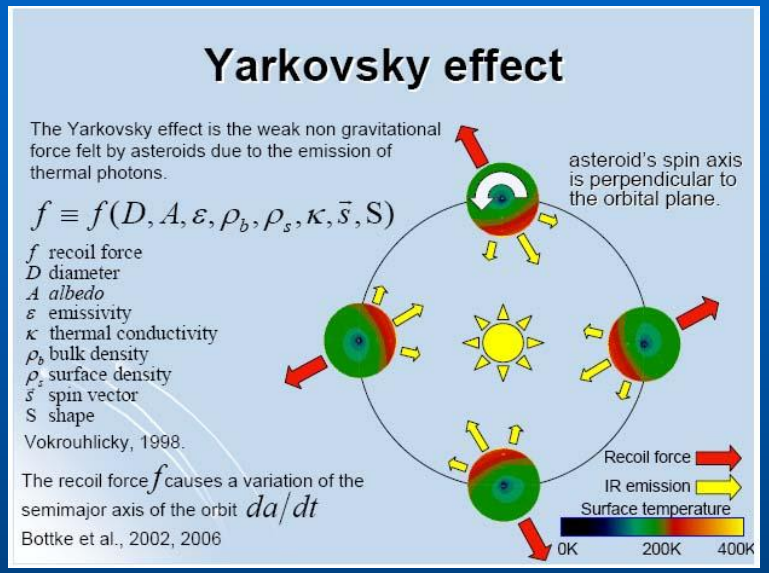


Impulse approximation of a small target asteroid perturbed by a larger one. v_i and v_o are respectively the incoming and outgoing velocity vector. The effect of the perturbation is expressed by the vector Δv.

The Yarkovsky effect on Near-Earth asteroids with Gaia

M. Delbo et al.

- Yarkovsky effect depends on the size, spin vector, thermal properties,…very faint orbital drift



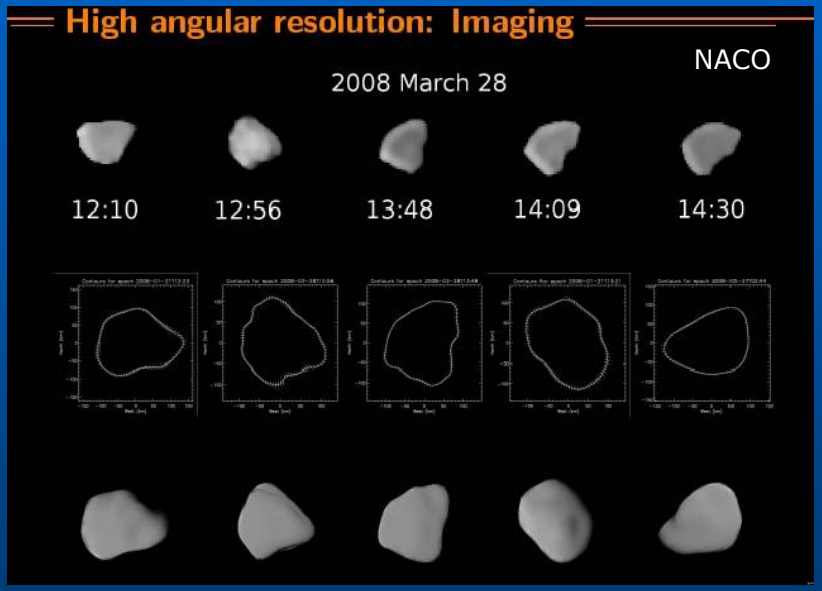
- Direct detection:
  - (6489) Golevka
  - 1992 BF
  - …Apophis in 2013?

- Gaia astrom. will allow the
  - detection of the YE for ~ 30-50 NEAs
  - improved dyn. model : test of GR effect
- Gaia+ Radar astrometry: + 60 NEAs
- Size measurements (HRA observations,…) give access to bulk density and internal structure

High Angular Resolution observations support to Gaia mission

B. Carry et al.

- HAR Imaging (ESO-VLT, 50 mas)
- 57 targets
- involved in the mass determination
- Photocenter offset / Barycenter
- size
- density measurement
- taxonomy/density
- albedo distribution
- duplicity
- Rotation parameters
- Can be combined to classical rotation lightcurves

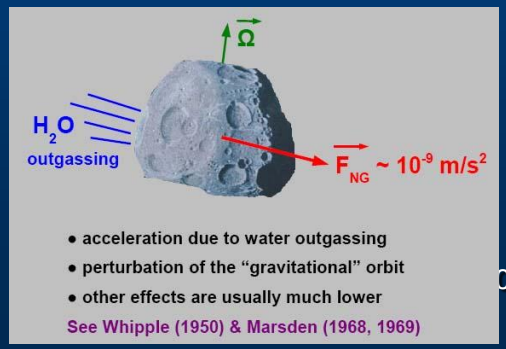


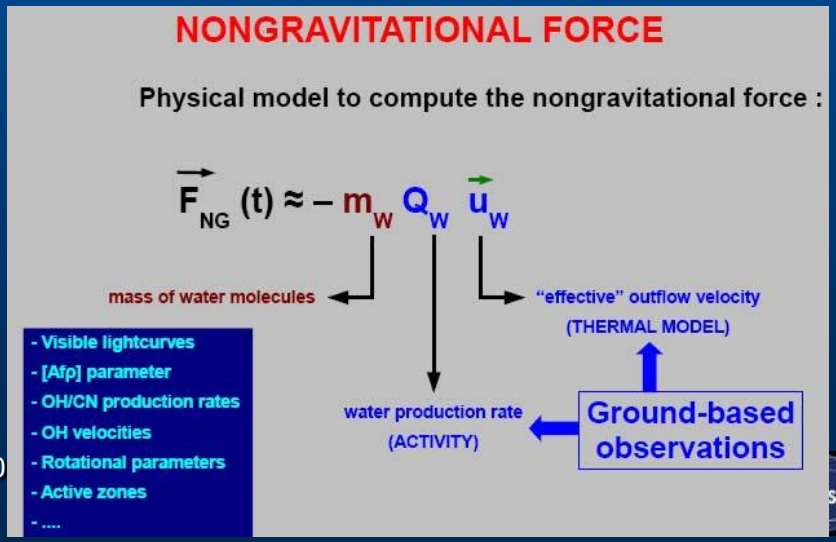
Non gravitational forces in comets

- Gaia is not well suited for comets imaging

- If Gaia can give accurate astrometry, ground-based obs. are necessary to compute the NG forces

- Mass can be deduced from the measurement of NG forces



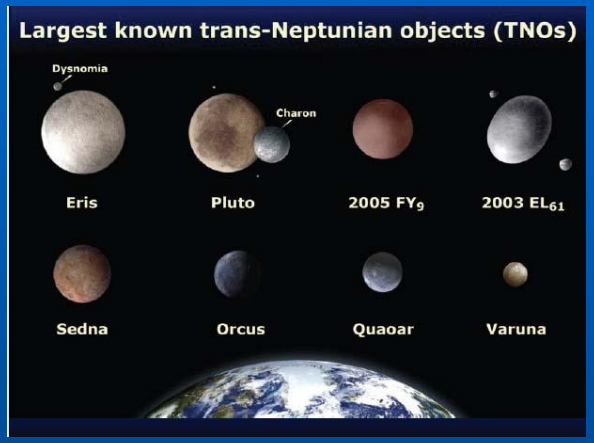


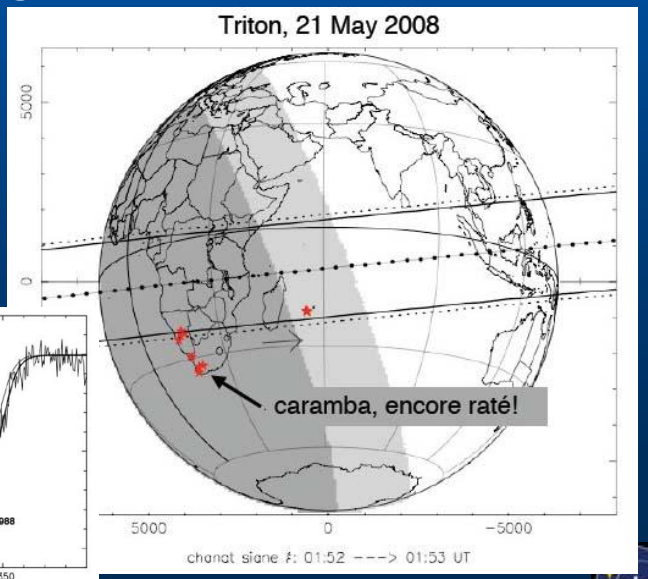
Probing remote Solar System bodies with stellar occultations

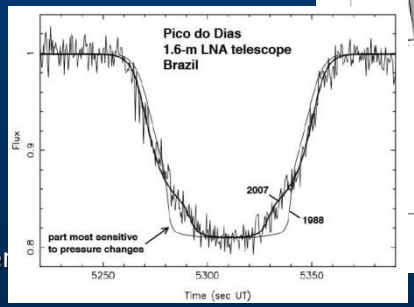
B. Sicardy et al.

- Occultation : powerful method
- Planetary atmospheres
- Size, shape
- Natural satellites, Pluto, TNOs (100mas diam.)

- Gaia stellar catalogue will drastically improve the predictions:
  - ✓At 90% level for large TNOs
  - ✓Deployment of stations (edge, shadow)
  - ✓TAC: access faint stars
  - ✓Increase number of events



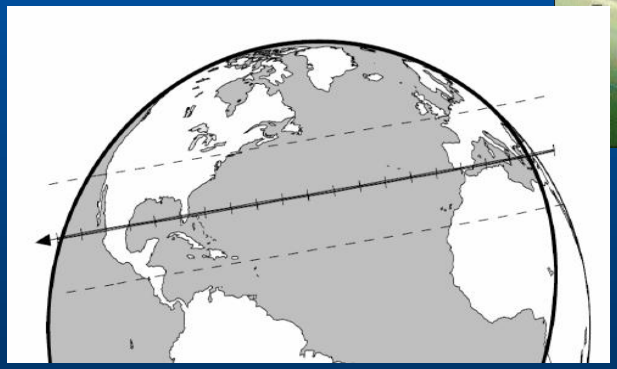




Stellar occultations after Gaia

Tanga & Delbo
- Stellar occultations by asteroids
- Shape, diameter, duplicity
- Today poor predictability for objects < 50km

Predictions using the Gaia stellar catalogue



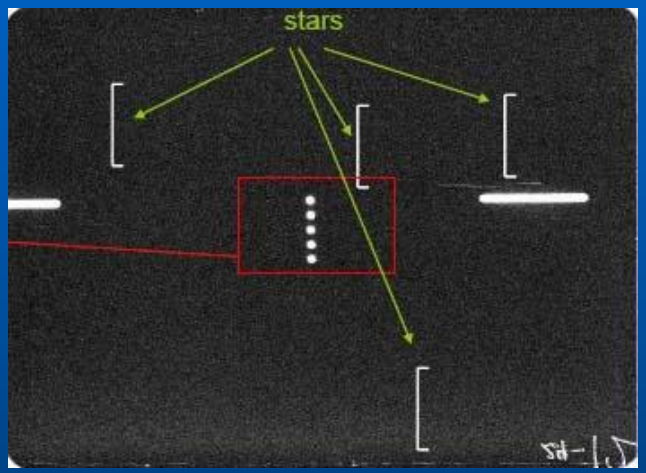
- 1m telescope: ensure 20-40 events/year for 20km diam.

- Network: completness of diameters>20km in a few year

Natural satellites dynamics: what Gaia will bring

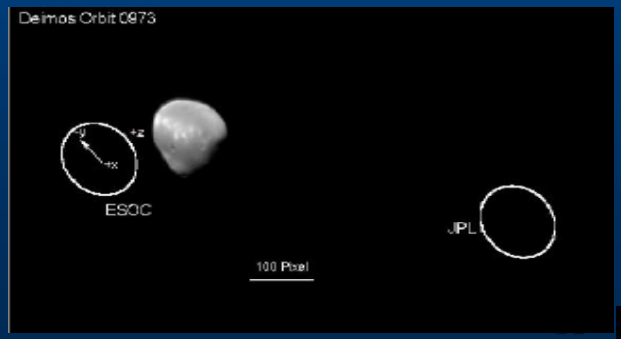
- V. Lainey et al.

- Gaia stellar catalogue / Gaia satellites observations



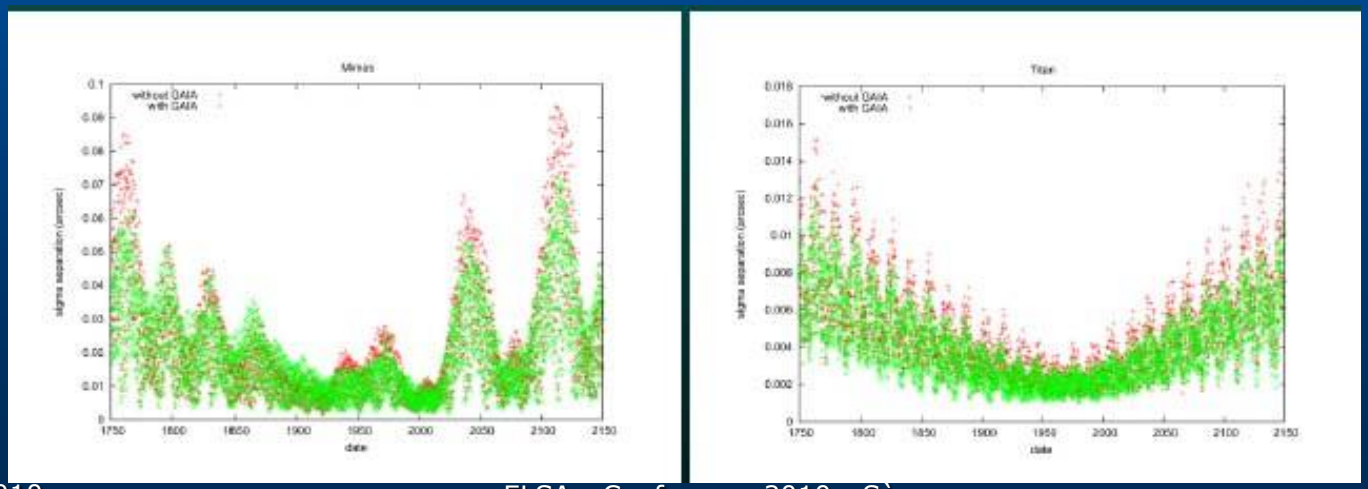
- Extended period of accurate re-reduced positions: better determination of tidal effects, planetary precession,…(Jupiter, Saturn)

- Gaia astrometry of Martian, Uranian moons combined with other space data (MXpress, Cassini, Voyager):
  improvement of the dynamical parameters
  pseudo positions of planets

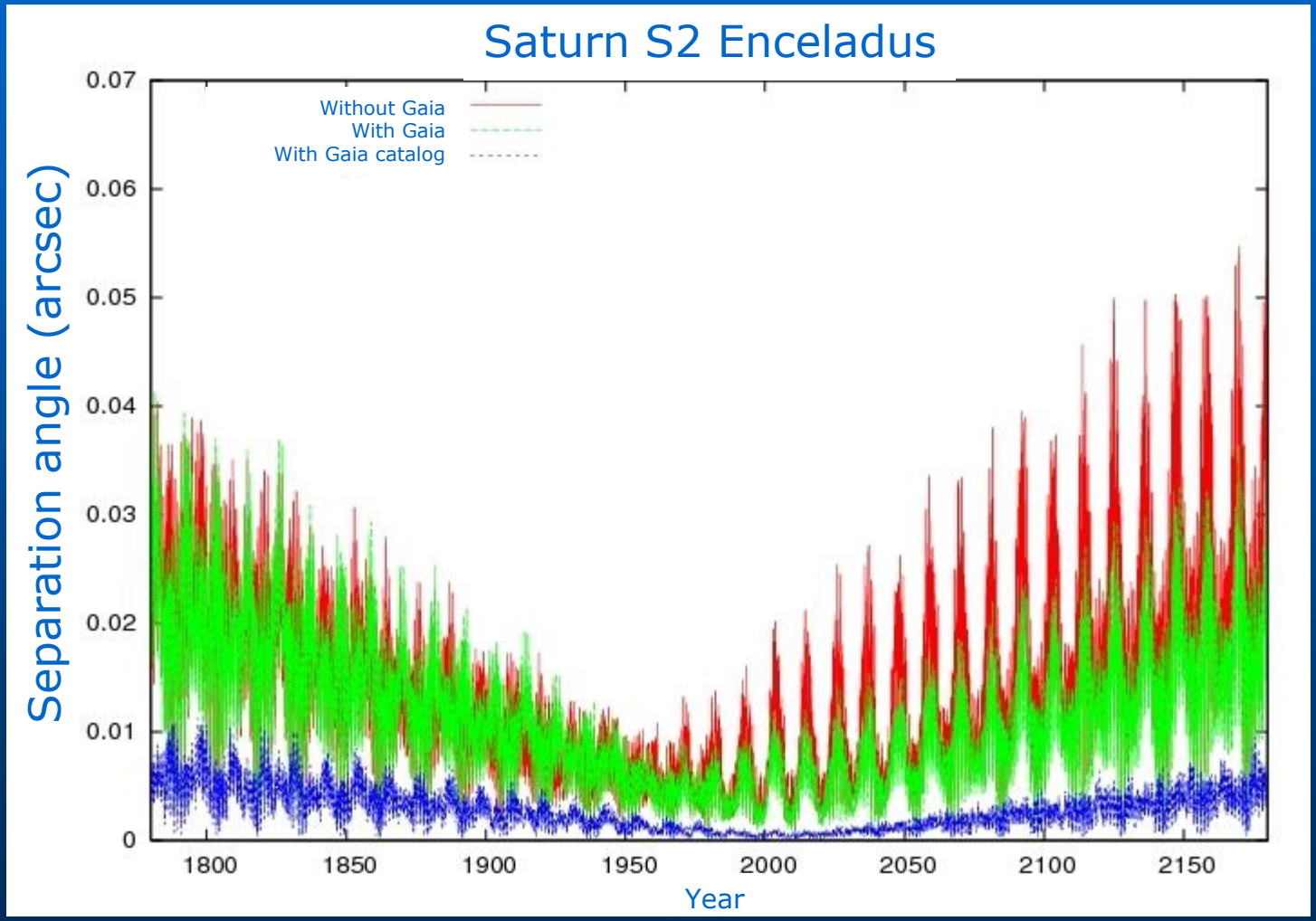


Natural satellites dynamics: what Gaia will bring

- J. Desmars 2009
- Saturnian satellites : Mimas-Titan (130 000 GB obs >1874@600mas)
- Study of the propagation of error *out of the observing period*
- *« Bootstrap method »*
- Simulation of Gaia obs. on the 2012-2017 period (50@1mas)
- Accurate absolute coordinates…but:
- Modest improvement of precision of the model
- Too short interval of time vs. Inequalities to modelise (LP terms)

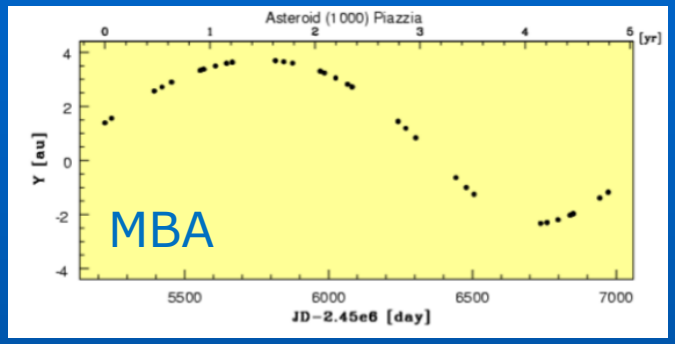


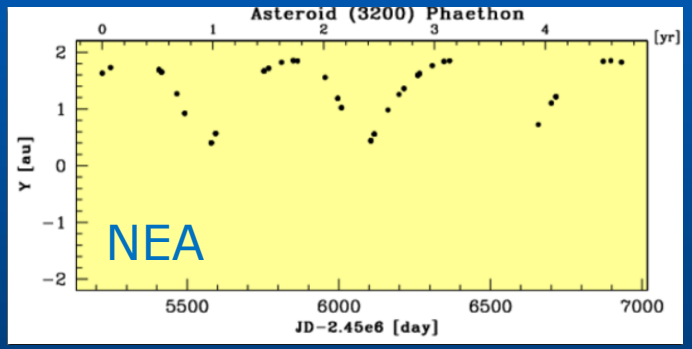
Natural satellites dynamics: what Gaia will bring



J. Desmars 2009

Observations of Asteroids Orbital modeling / detection



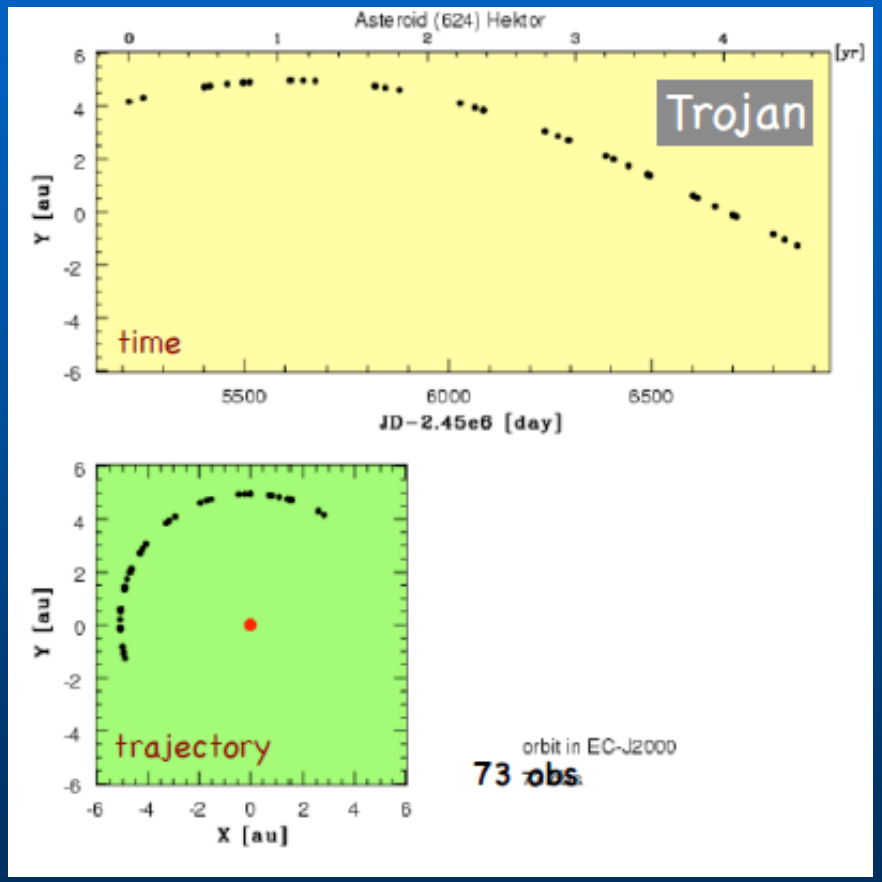


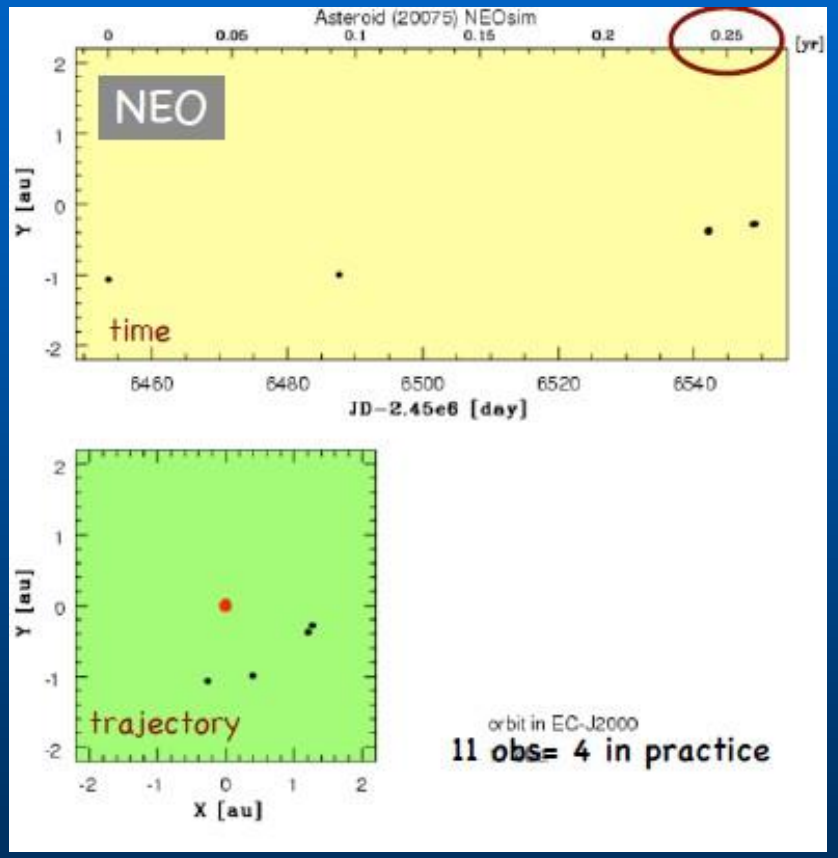
- Limiting mag. 20
- Objects with high excentricity
- Mean interval between two Gaia obs : 30 days,…

GB obs. useful/necessary for:

✓ improvement of orbital modeling
✓ Long term secular effect
✓ avoid to loose a newly detected object

Observations of Asteroids
Orbital modeling / detection





Observations of NEOs : 99 942 Apophis

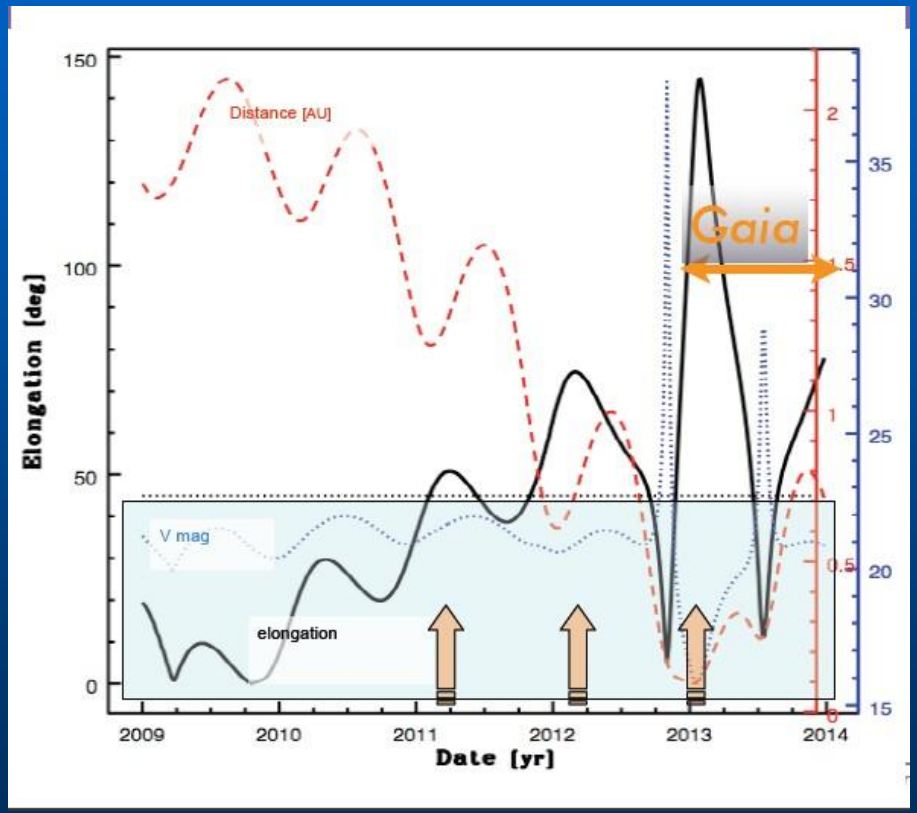
- Aten family
- Potentially Hazardous Object
- Discovery : 2004
- Close Earth encounters
- 2026 - 2039

- Low Solar elongation
- Observable 2011-2012-2013

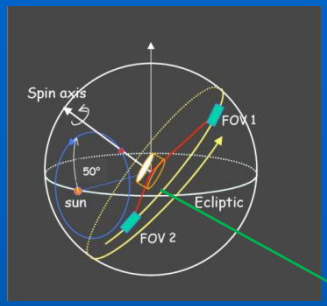
- GB observating campaigns for orbital improvement

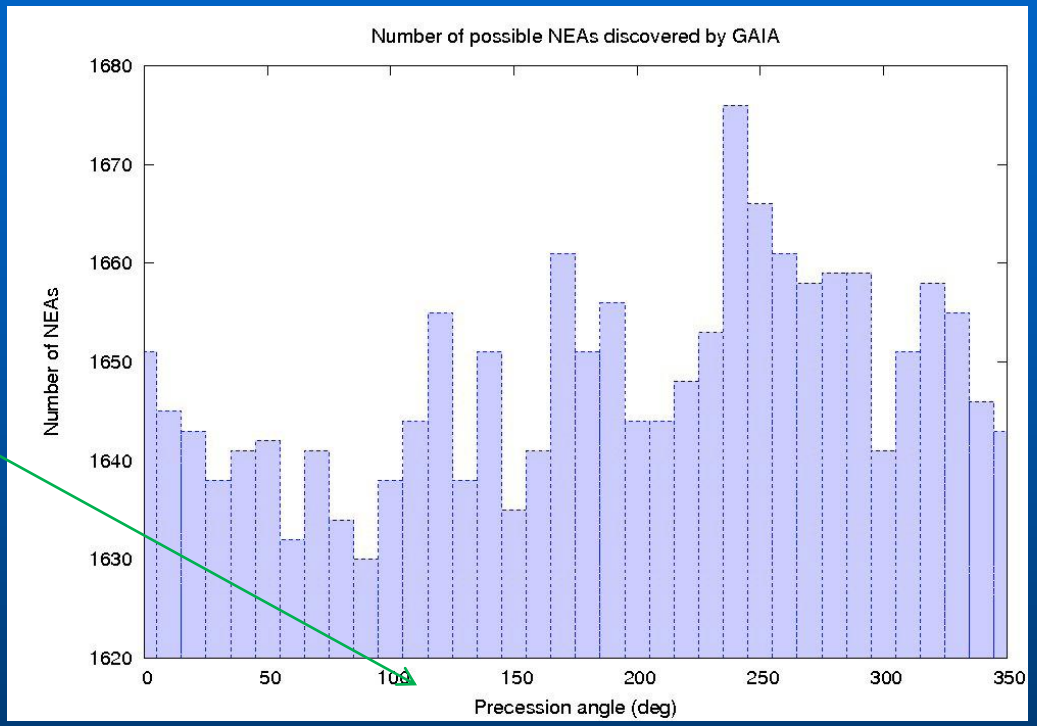
- Preparation of expected space missions for 2029

- Gaia will provide important astrometric observations



Observations of NEOs: detection of new objects ?





- Synthetic population (Botke et al. 2002)
- D. Bancelin: Estimate up to 1675 NEA possibly detected (including up to 28 IEAs)

- Contribution to the SSA (Space Situational Awareness)

Program of ESA : European survey of the space environment

An alert network for supporting Gaia asteroid observations

CU4-DU 459 GB follow-up network

1. to avoid to loose an object
2. to follow up an object with critical behaviour

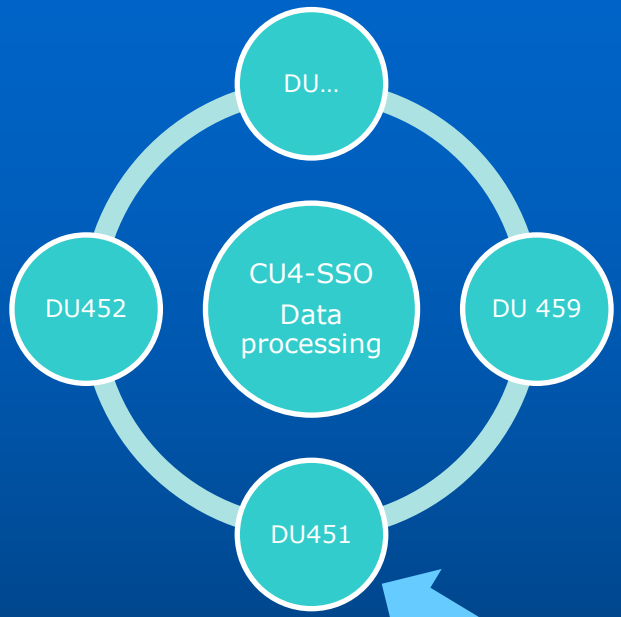
Dedicated network:

- to ensure observations on alert
- to ensure astrometric precision
- to apply a GB strategy after detection from space
- to ensure a coordination

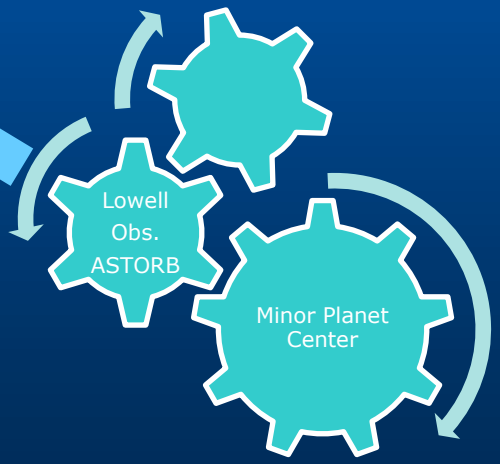
To be done
done

- 25 candidate sites
- 37 telescopes (0.25 to 2.4 m)

CU4/DU459: FOLLOW-UP NETWORK

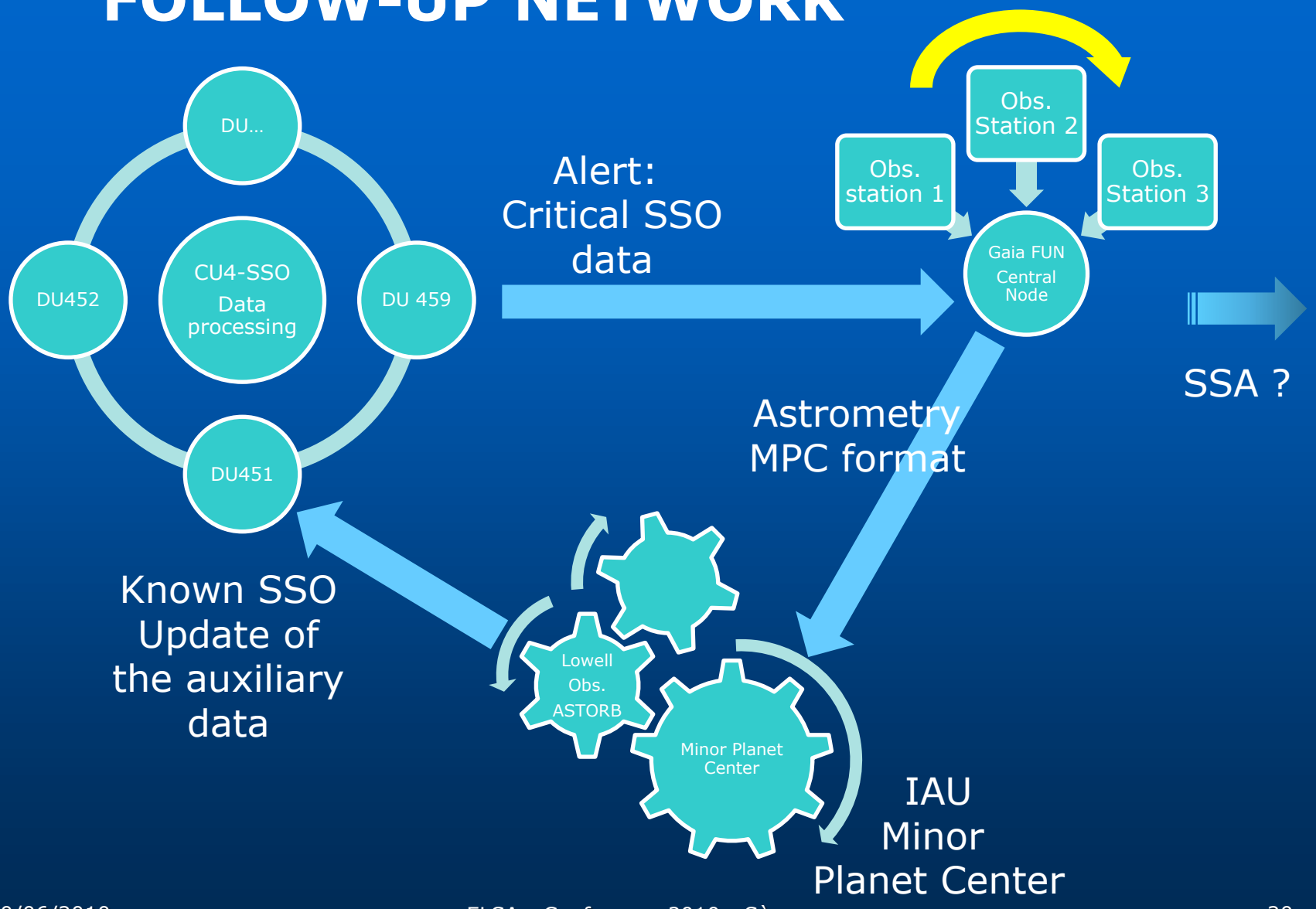


Known SSO Update of the auxiliary data



IAU Minor Planet Center

CU4/DU459: FOLLOW-UP NETWORK



http://gaia-fun.imcce.fr

2010 Nov. 29 - Dec. 1, Paris observatory

SOC: W.Thuillot (France), P.Tanga (France), J.-E.Arlot (France), J. Berthier, (France),A. Cellino (Italy), D. Hestroffer (France), F. Mignard (France), R. Teixeira (Brazil), Zheng Hong Tang (China)

- Focus: CU4-DU459 objectives
- Make the network active
- Be informed about the instrumentation
- Discuss the goals, the methods, the needs
- Discuss the data policy

Conclusion

- Gaia observations can be completed with GB observations: the estimate of physical and dynamical parameters of Minor Bodies can be improved

- Asteroid astrometry : mass, dynamical effects, follow-up of Gaia discov.

- High Angular Resolution (AO) and Photometry (Stellar occ.): sizes and shapes for bodies with mass determined by Gaia. Access to the bulk density and estimate of Yarkovsky effect.

- The Gaia stellar catalogue will have an important impact on: astrometric meas. (natural satellites, stellar occultation predictions) : strong interest to access intermediate releases