Solar System science by Gaia observations

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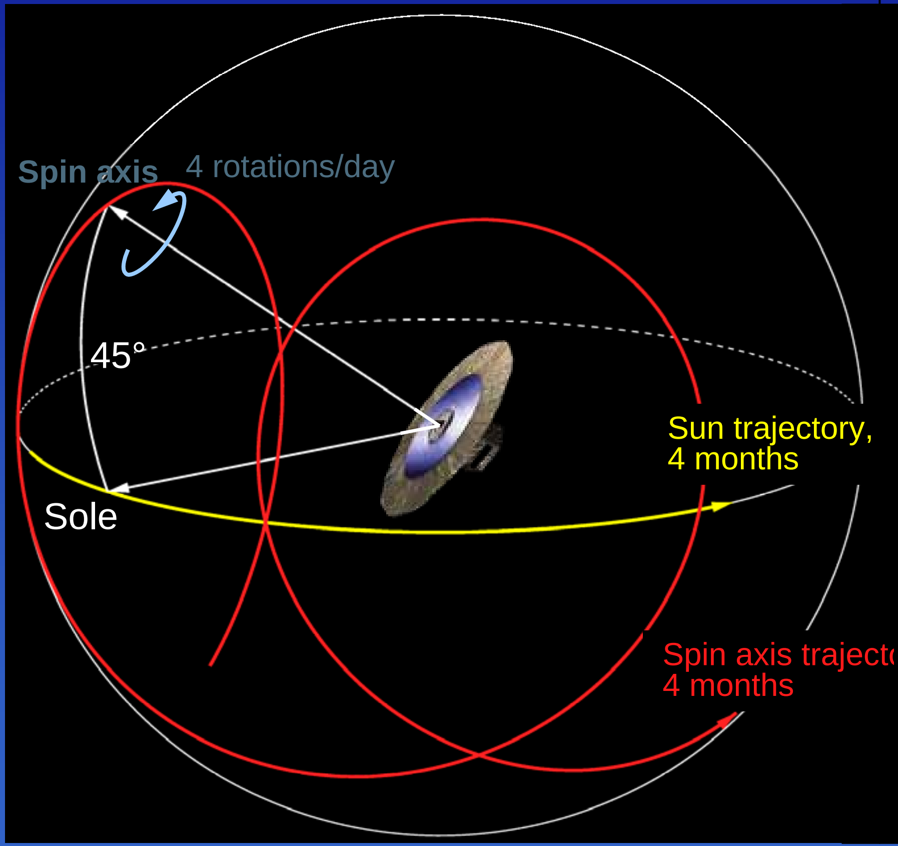
Gaia and the Solar System…

- Asteroids (~400.000 – most known)
  - Mainly Main Belt Asteroids (MBA)
  - Several NEOs
  - Other populations (trojans, Centaurs,..)

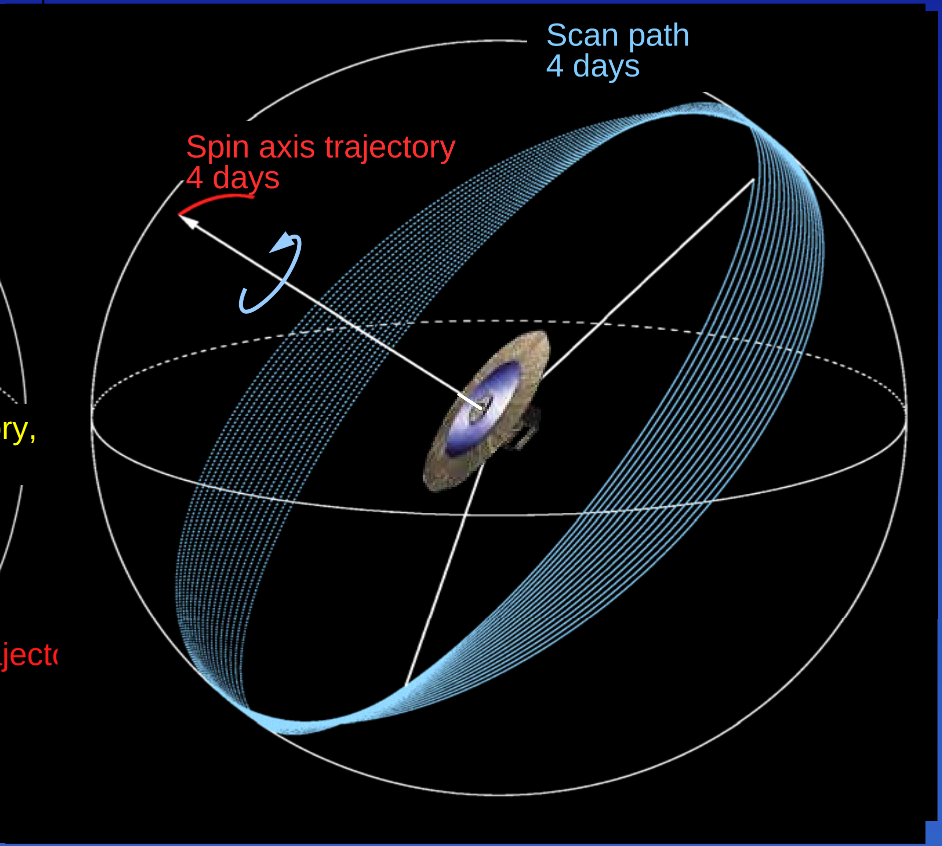
- Comets
  - Primitive material from the outer Solar System
- « Small » planetary satellites
  - « regular »
  - « irregular » (retrograde orbits)
- Gaia will probably NOT collect observations of « large » bodies (>600 mas?)
  - Main Planets, large satellites
  - A few largest asteroids

The scanning law

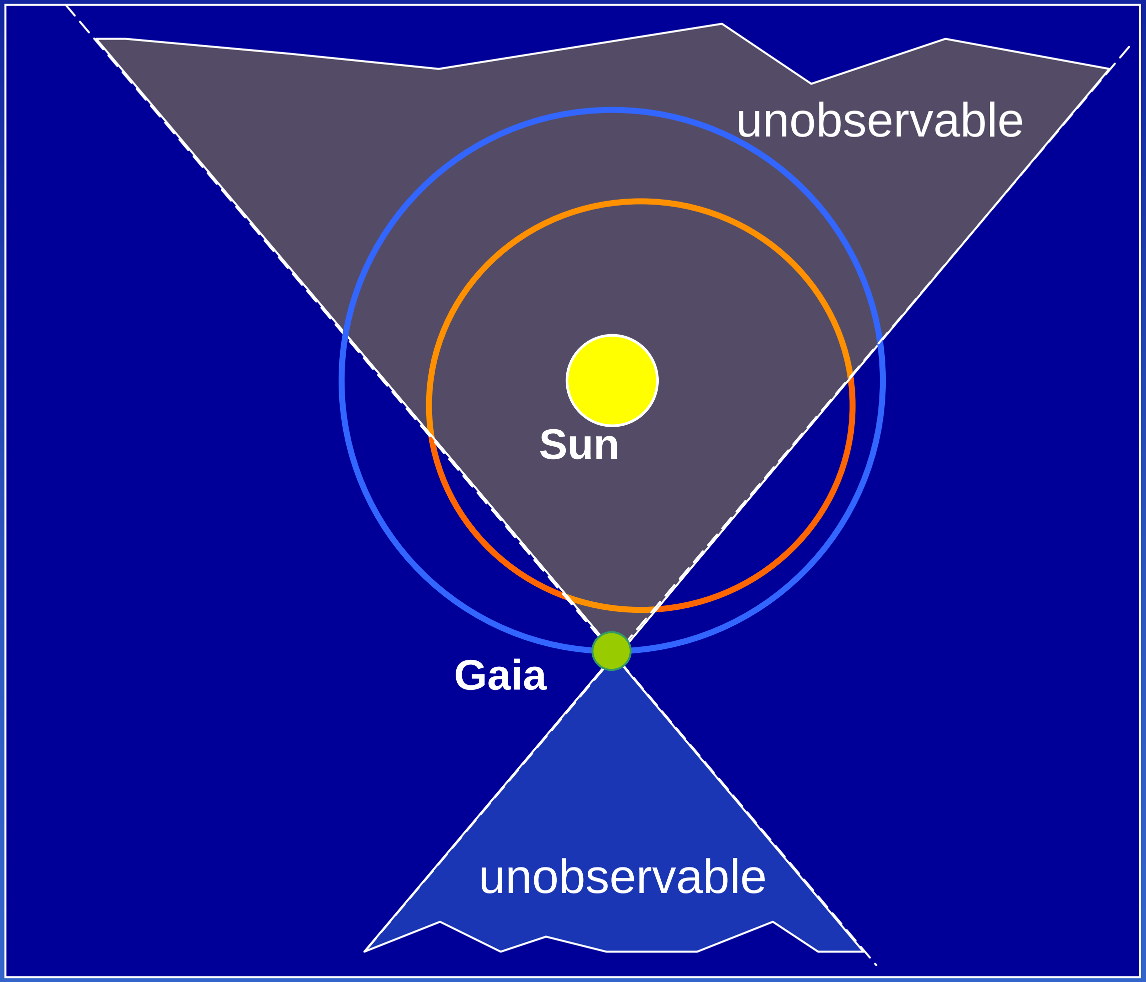
Rotation axis movement



Scan path in 4 days



Observable region on the ecliptic

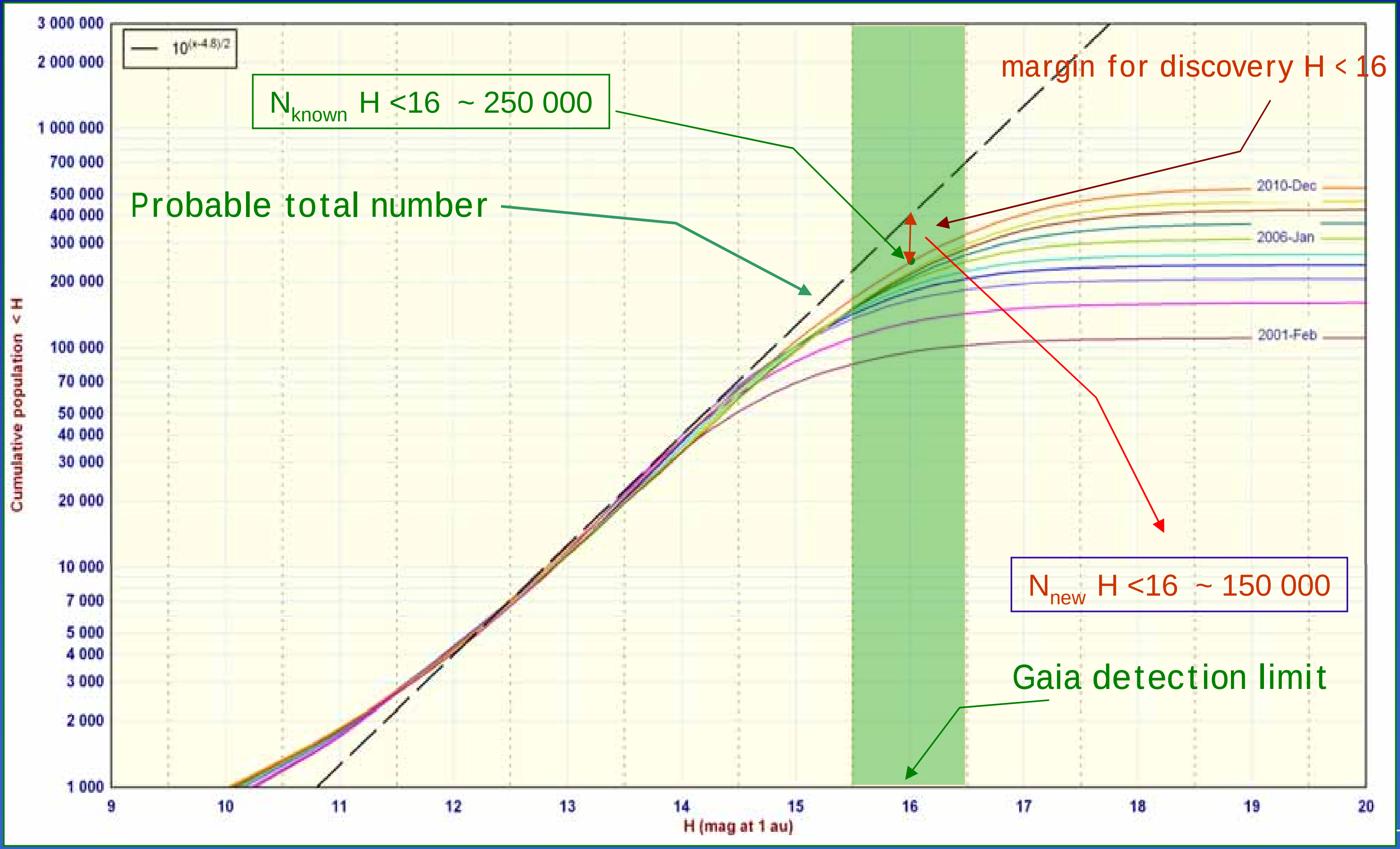


- ~ 60 detections/ 5 years for Main Belt asteroids
- ~ 1 SSO object in the FOV every second around the ecliptic

- Discovery space:
  - Low elongations (~45-60°)
  - Inner Earth Objects (~unknown)
  - Other NEOs

How many asteroids with Gaia?

- Evolution of the number of entries $H < H_{lim}$

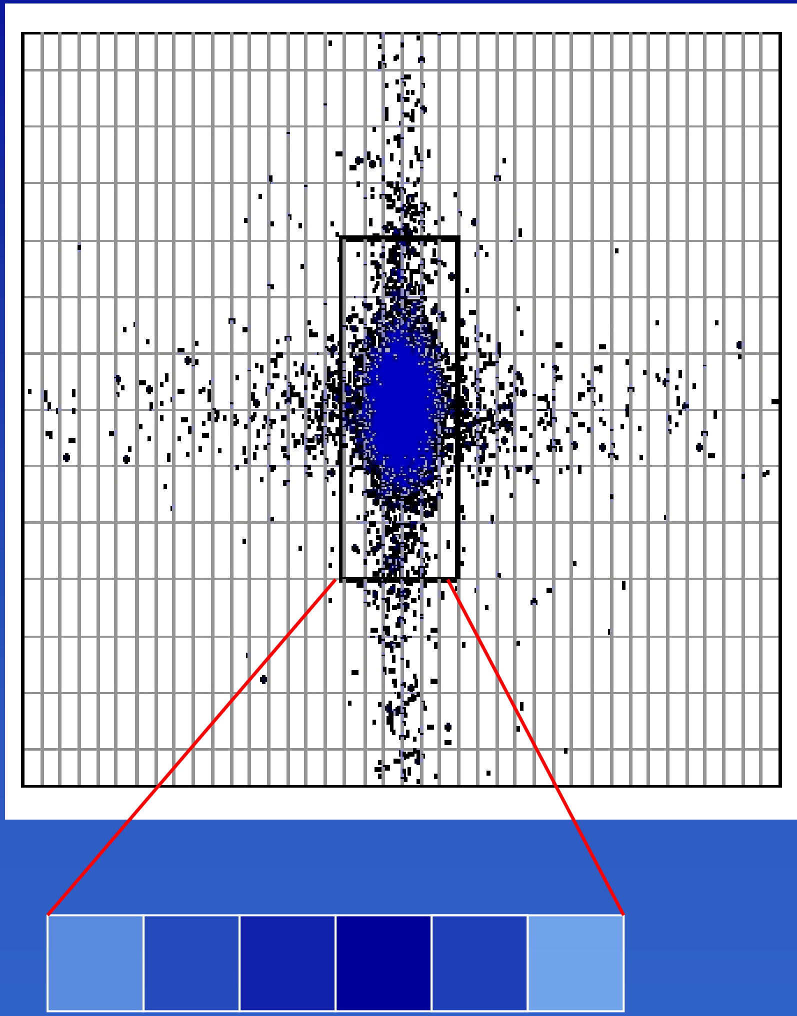


Gaia data for asteroids

- Astrometric Field
  - Main source of photometric and astrometric data
  - Read-on window assigned on board around each source
  - Window is tracked during the transit
  - For most sources the signal is binned across scan

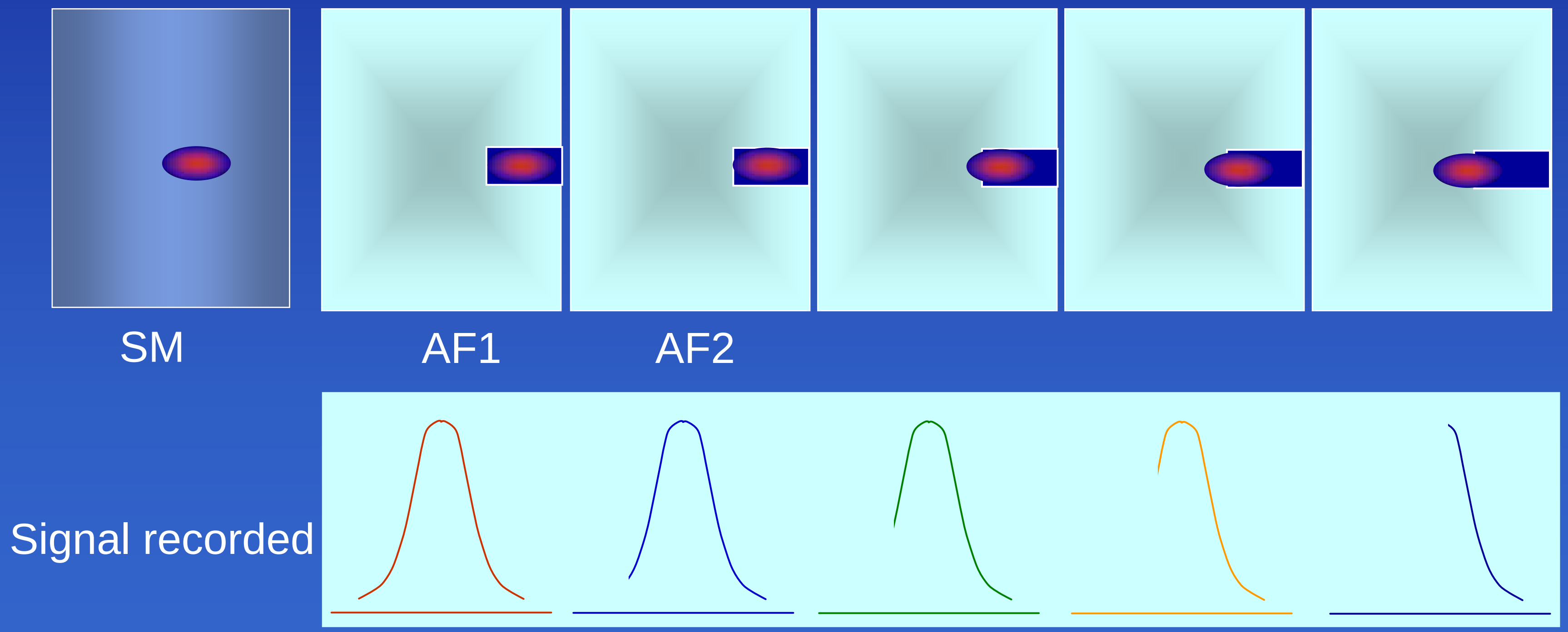
→ Best accuracy in the « along scan » direction

→ Across Scan uncertainty ~ window size

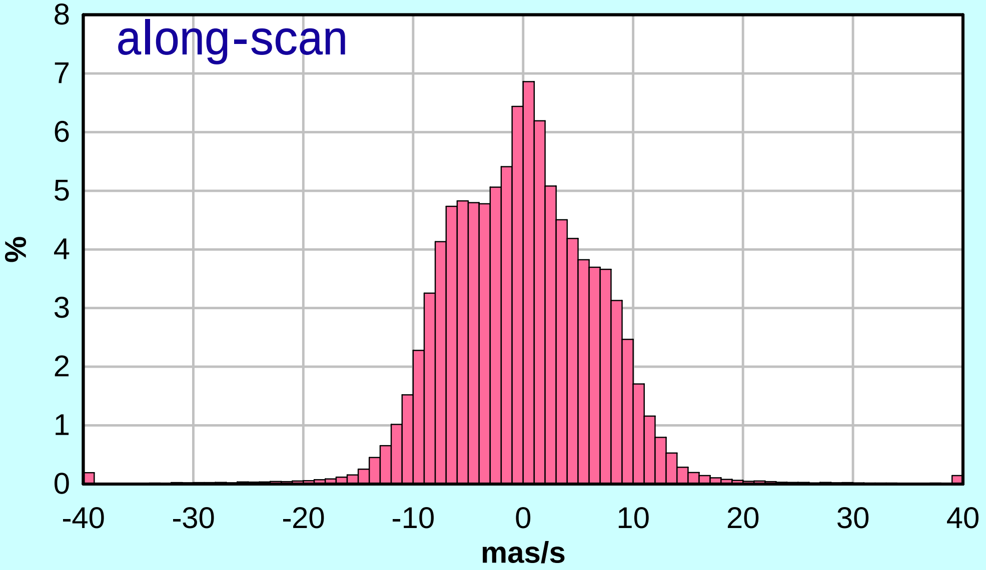


Windows on moving sources

- Windows are allocated from ASM centroiding
  - centroiding errors lead to offset in the window
  - transit velocity errors lead to a drift in the window
- A moving object will also drift relative to the window
  - the total effect depends on the window size and V_{al}



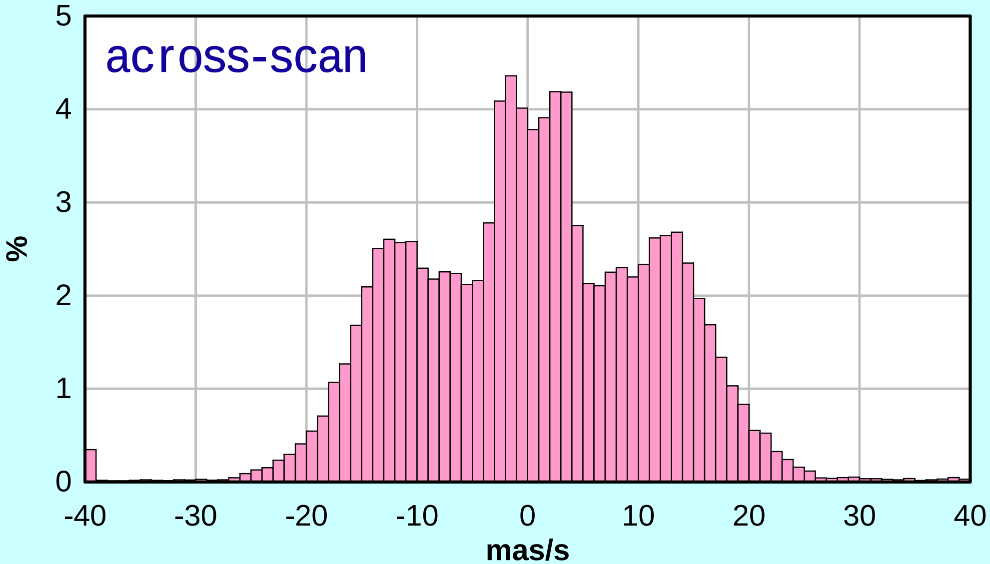
Velocity distribution



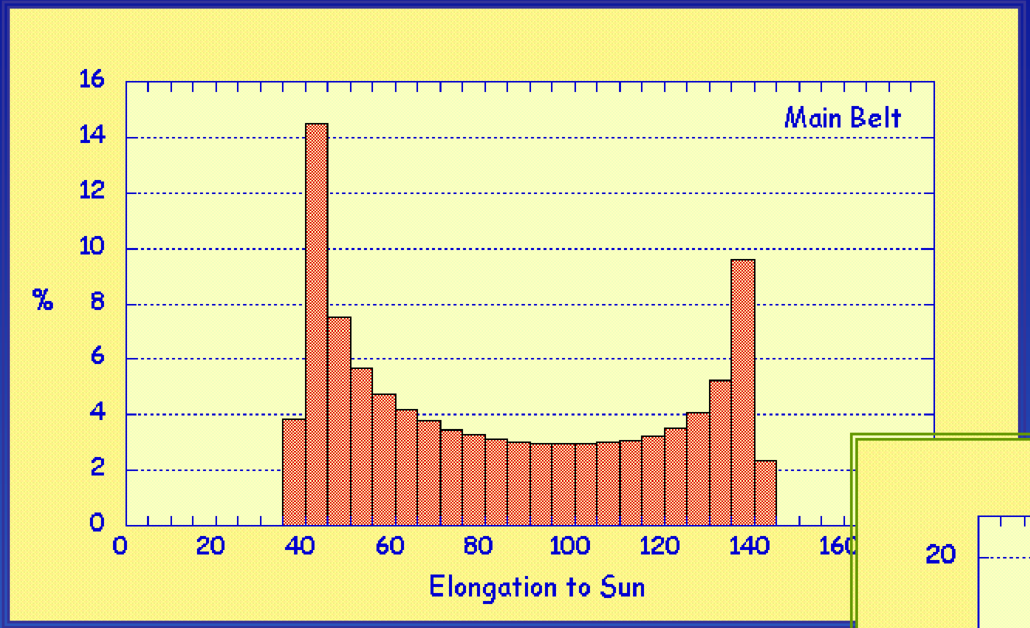
- simulation on 5,000 objects
  - main-belt, NEOs
- motion detectable over 1 transit

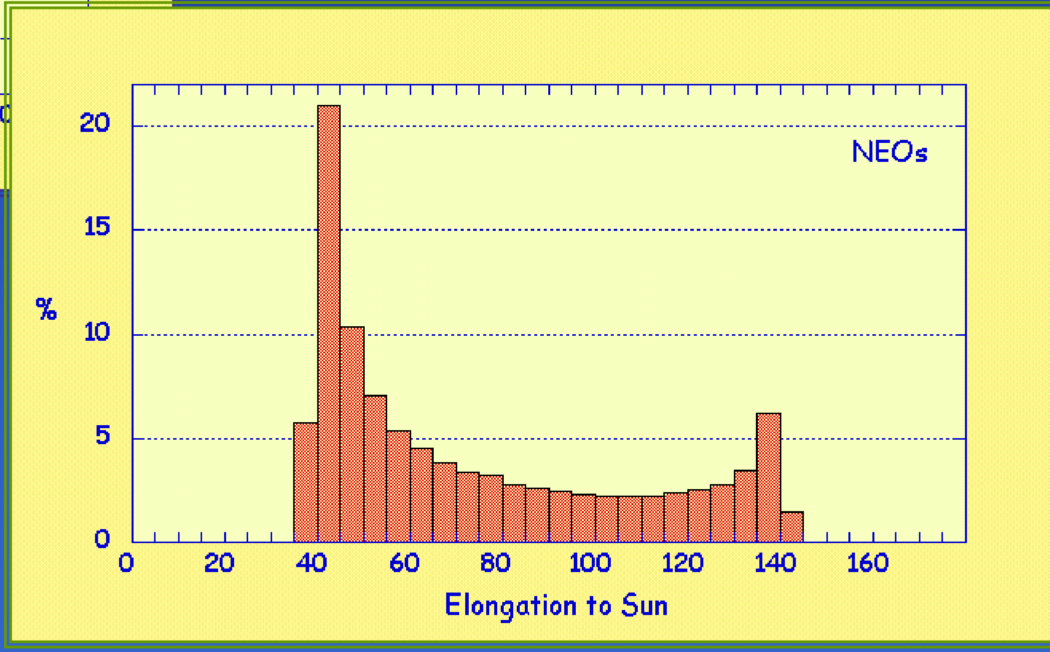
σ ~ 7 mas/s

σ ~ 12 mas/s

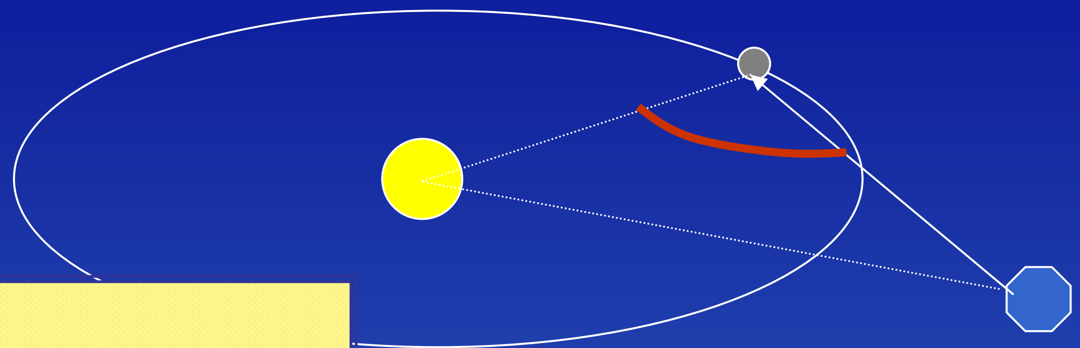


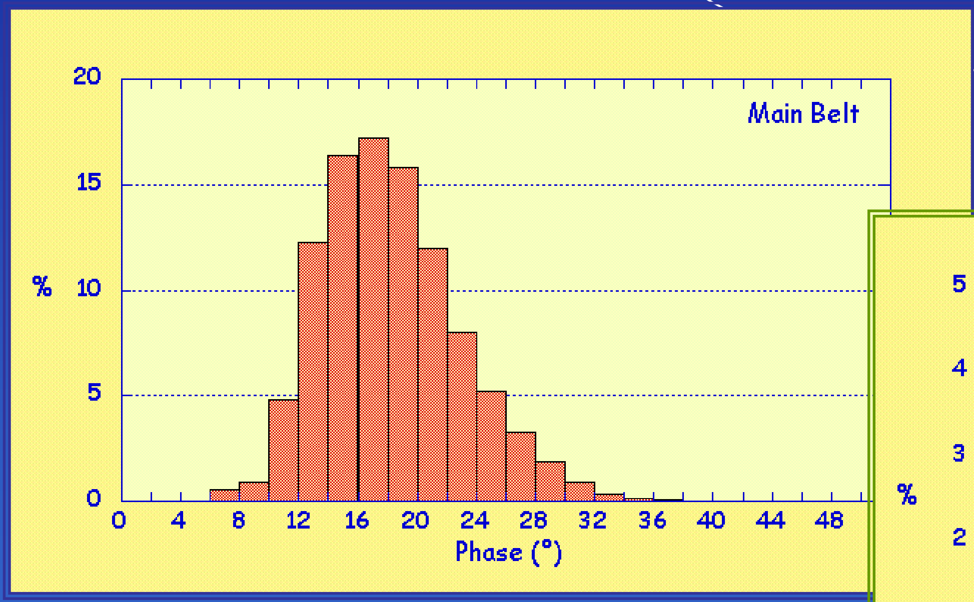
Solar elongations

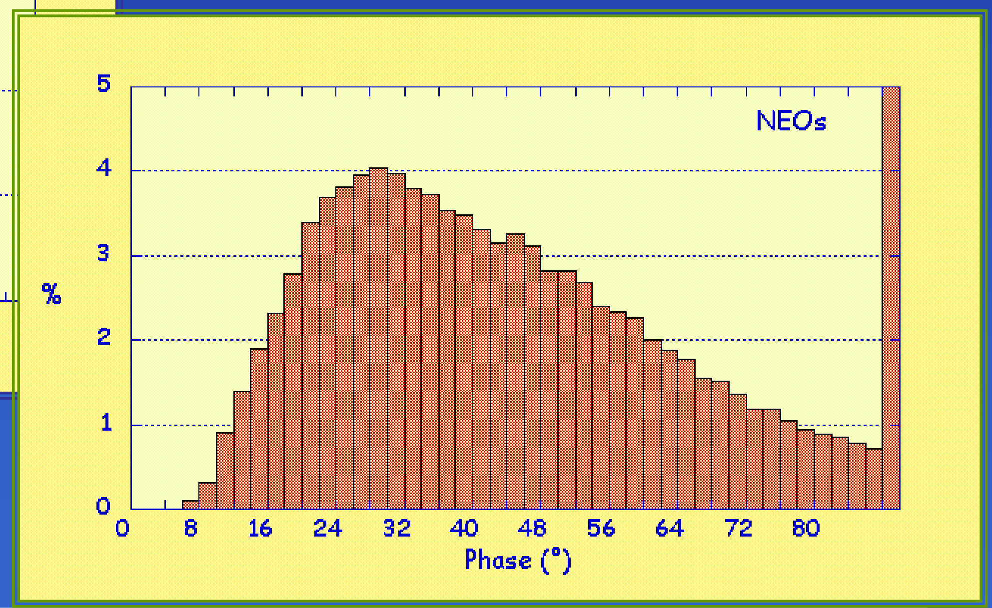




Phase angles







Statistics on 20000 brightest objects

Expected properties of Gaia data: summary

- 1 linear signal per CCD column
  - 2D data available in some cases
  - Loss of data due to motion
- High accuracy in the along scan (AL) direction, poor accuracy across-scan (AC)
  - Resulting in strongly correlated ucertainties on single-epoch equatorial positions
- 50-70 observations of a given Main Belt Asteroid over 5 years
- Low elongations (~45°) accessible
- Frequent subsequent observations in the two FOVs
- parallax effect relative to Earth (observations from L2)

Science goals

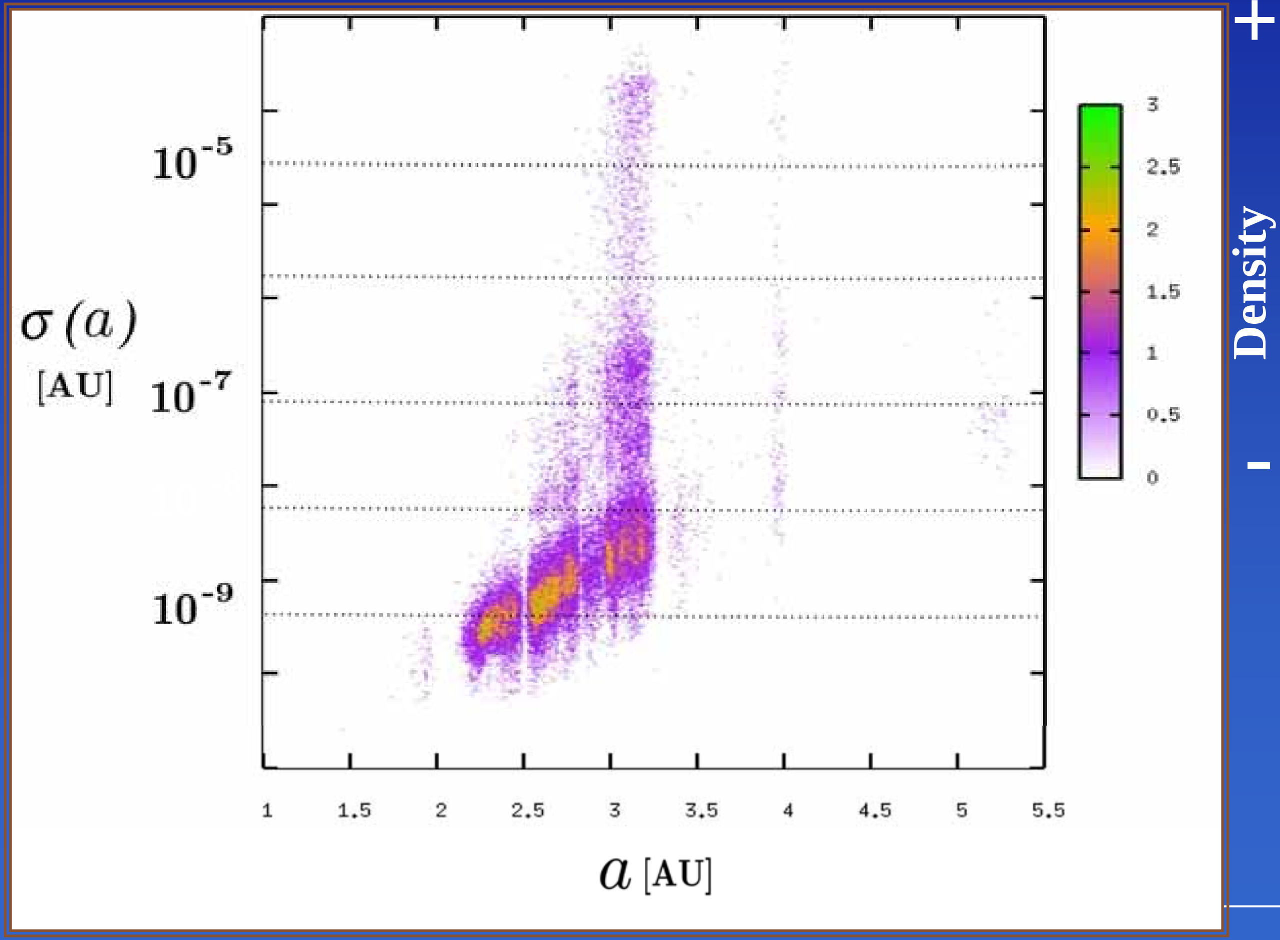
- Systematic survey down to 20 mag ~ $3x10^5$ objects
    - Main belt
    - NEOs
- Orbits : virtually all object observed - x30 better than now

  higher resolution of dynamical families
- Masses from close encounters ~ 100 masses expected

- Diameter for over 1000 asteroids : shape, density
- Binary asteroids
- Photometric data in several bands : albedo, taxonomic classification
- Light curves over 5 years : rotation, pole, shape
- Space distribution vs. physical properties
- Perihelion precession for 300 planets : GR tests

Astrometry → orbit refinement

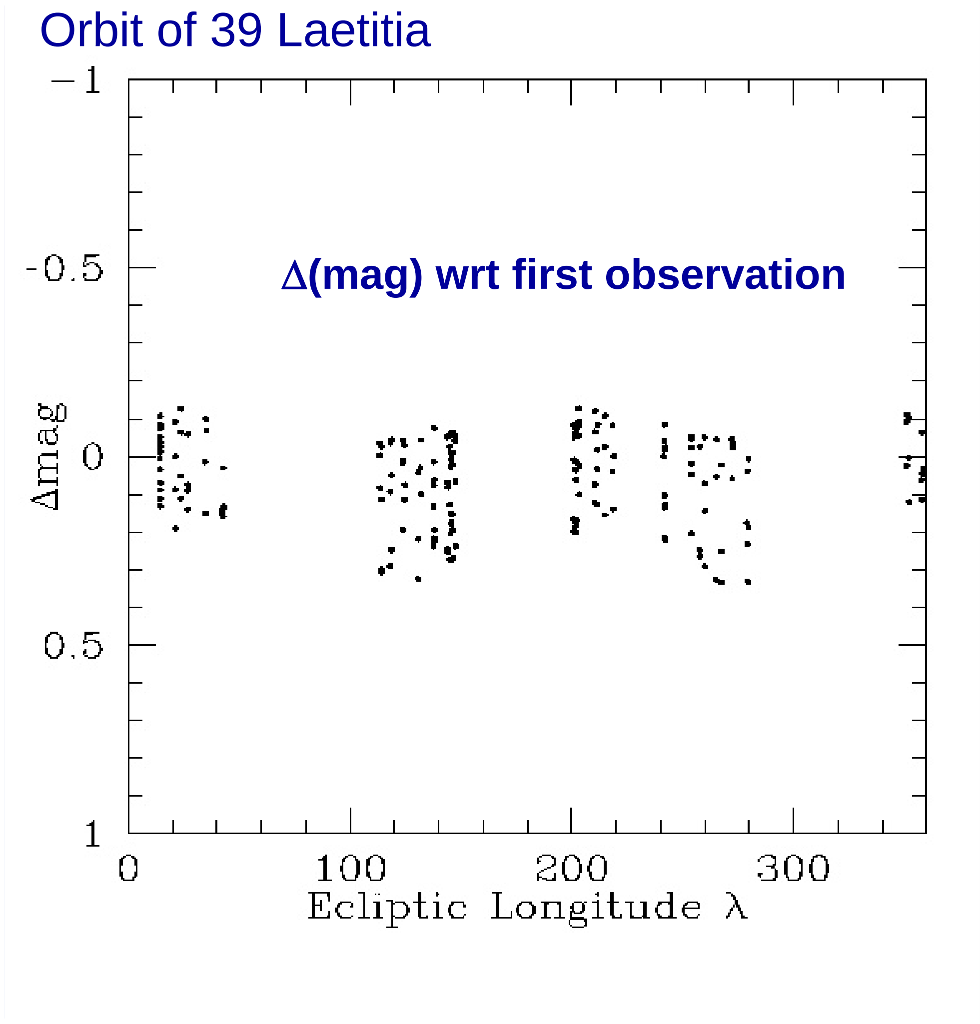
- Orbit reconstruction from simulated data
  - point sources & gravitational interaction
  - solar system perturbations



> 10^2 better than current accuracy

Mouret et al. 2007

Simulated Gaia photometry



λ_p = 30

β_p = 60

b/a = 0.7

c/a = 0.5

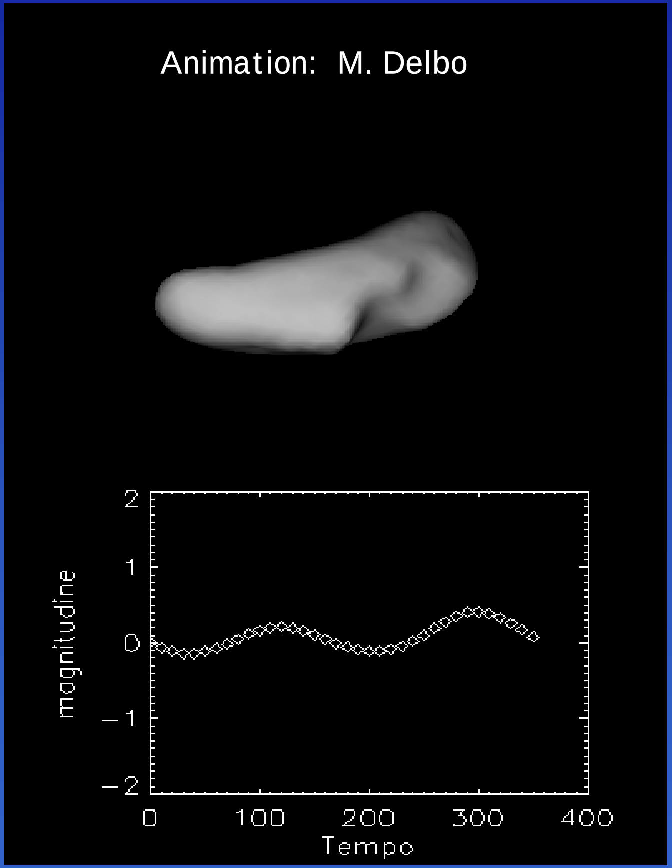
P = $7^h.527$

ϕ_0 = 0.4

A. Cellino, P. Tanga, M. Delbo

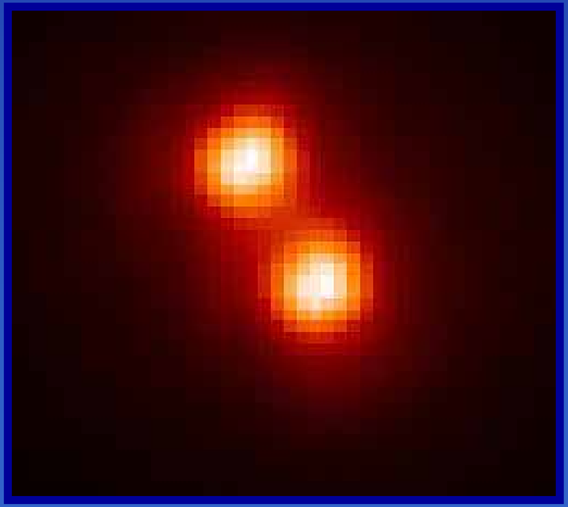
Photometry → Shapes

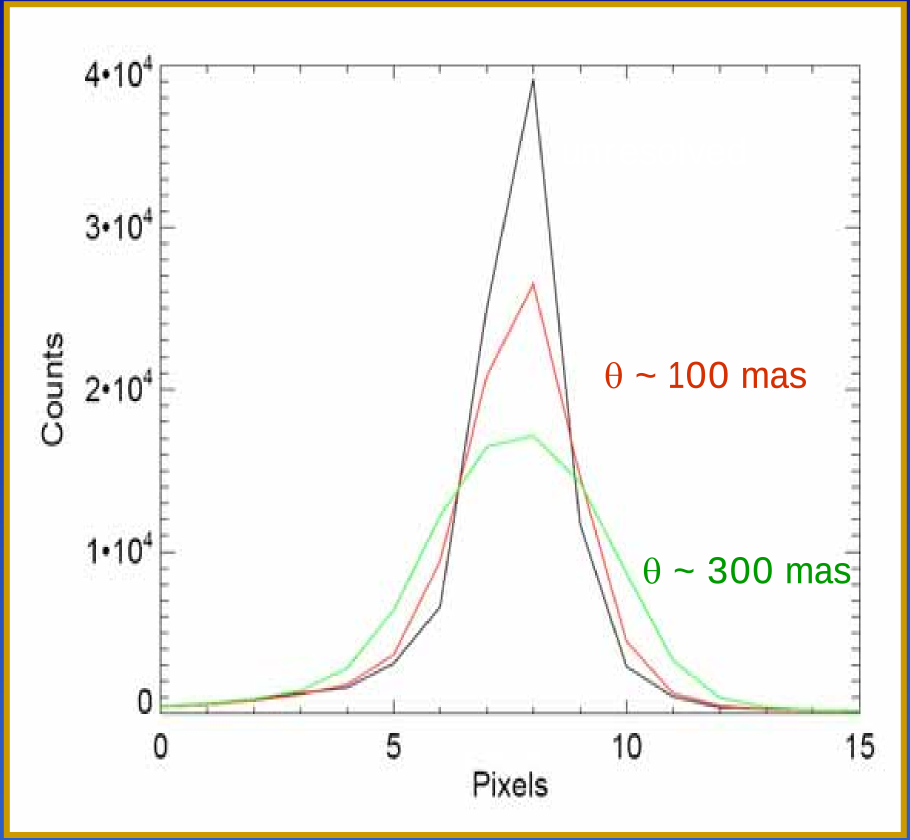
- Asteroid's magnitude function of:
  - shape, rotation period, direction of spin axis
- Direct problem:
  - model of light curves for different shapes and rotation
- Inverse problem:
  - find the rotation parameters from photometric data
  - strongly non linear
- Choice for Gaia:
  - Three-axial ellipsoids



Size of the asteroids

- Direct size determination for over 1000 asteroids
- Good quality sizes for D>40km
- Object's size at different epochs
  → overall shape
- Binarity

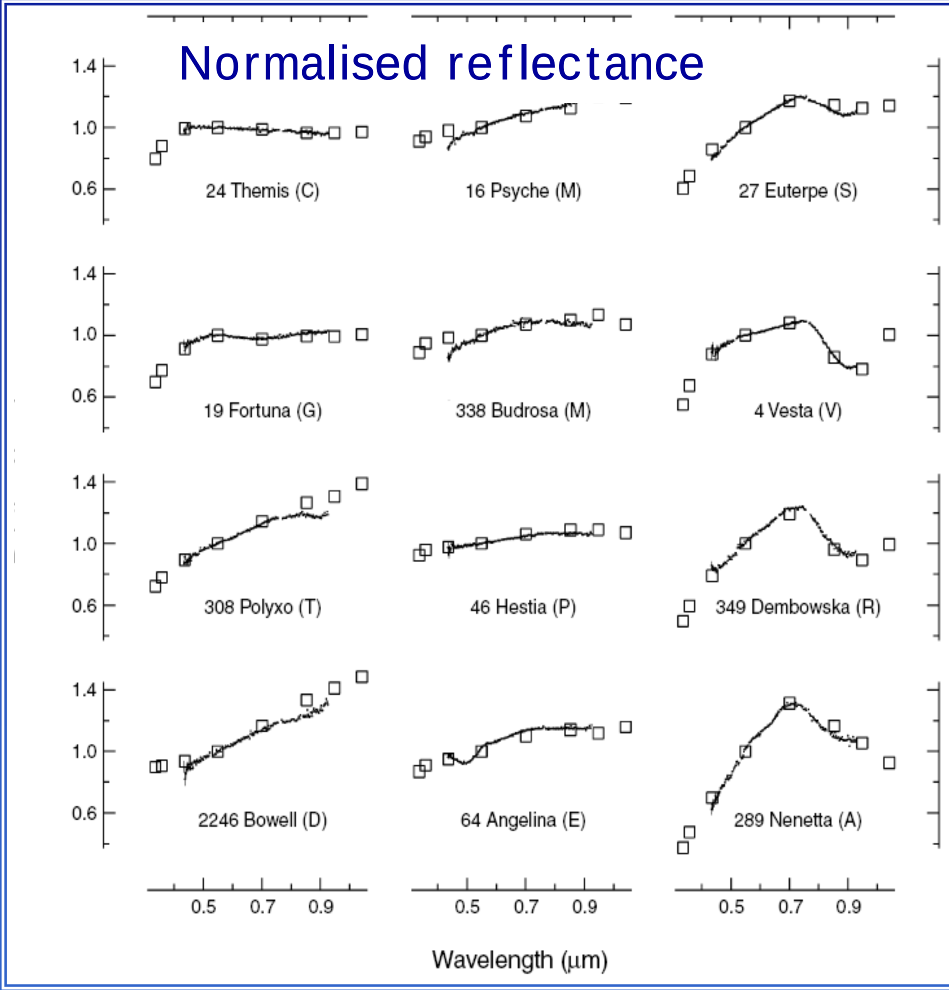




Signals for different source diameter

RP/BP → Taxonomic classification

- Taxonomy classifies asteroids on the basis of visible *and* near-IR reflectance spectroscopy
  - Based on ~1000 objects today
- Gaia special features:
  - High solar elongation
  - Blue spectrum coverage
  - Several "bands"
  - → Preliminary investigation on earth-based observations
- Limitations
  - …no albedo → ambiguity E,M,P…
- automatic classifier developed for Gaia
  → Gaia taxonomy



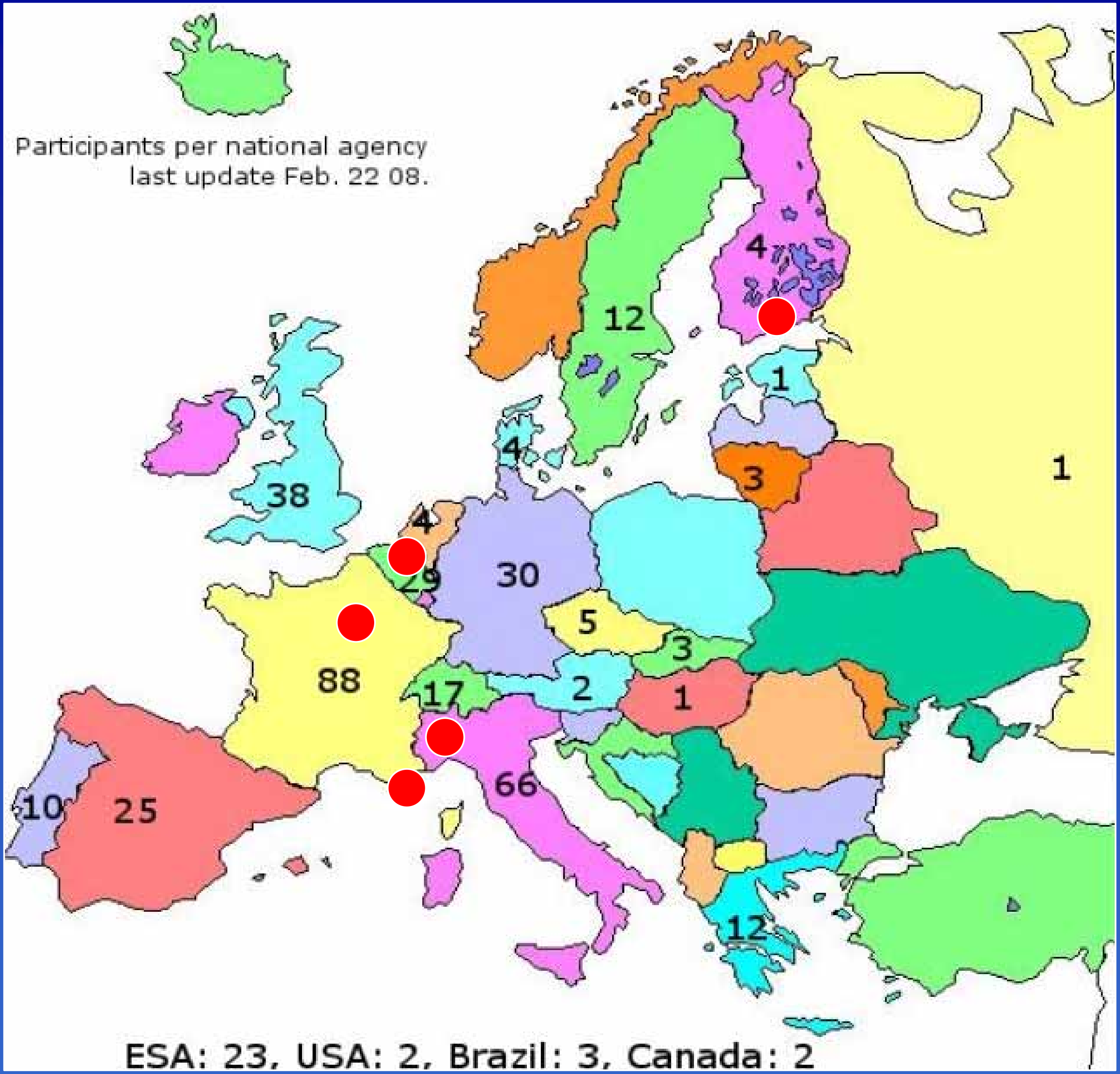
How much is / will be known

Property	today	Gaia
astrometry	~ 0"5	0"005
rotation periods	3000	~100,000
shapes, poles	~200	~100,000
spectral type	~ 1800	~200,000
masses, σ < 60%	~ 40	150
size , σ < 10%	~ 500	1000
satellites	~ 20 (MBA)	?

Processing of SSO data

The DPAC

- SSO



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

SSOs in the Gaia DPAC

- Coordination Unit 4
  - manager : D. Pourbaix; deputy: P. Tanga
  - Implementation of software in the Data Processing Center
  - ~ 20 european astronomers working on SSOs

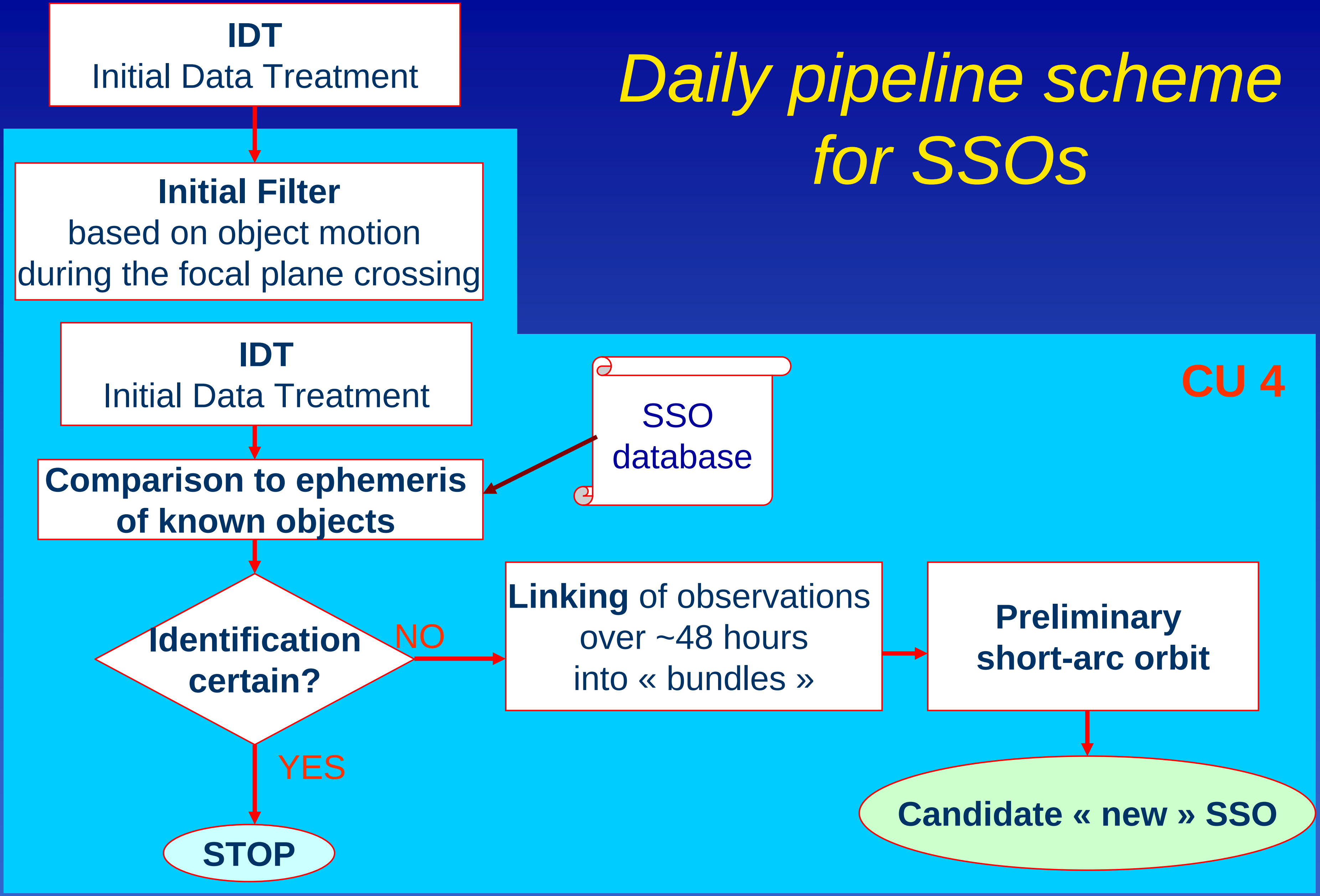
Two pipelines for SSO:

- Short-term (daily) processing
  - Working on 24h of data
  - Fast processing for identifying anomalous/unknown asteroids

  → Triggering of alerts

- Long term processing
  - Best accuracy
  - Complex object model (shapes, motion,…), best astrometric solution, all effects taken into account
  - Aims: intermediate → final data releases

Daily pipeline scheme for SSOs



Gaia Follow-Up-Network for SSO

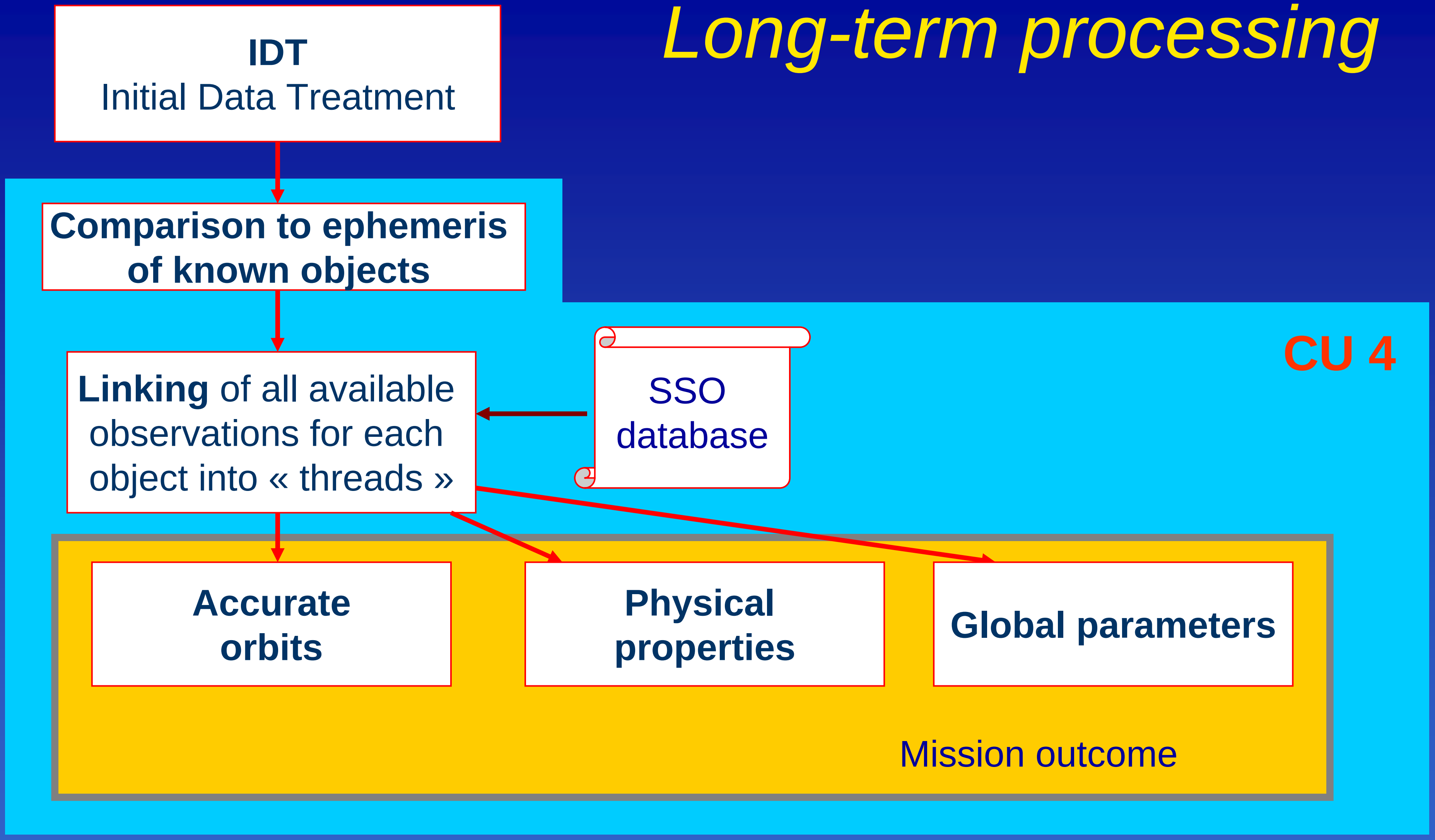
- Validation of SSO nature of the «new» objects
  - Ground based recovery can discriminate « false » and « true » SSO
  - Reliability verification of the daily processing chain

- Recovery of the highest possible number of
  - New objects, discovered by Gaia
  - Objects with « poor » orbits (→ ambiguous identification)

- Improve orbit accuracy
  - a single ground-based detection can “collapse” the uncertainty of an orbit

- Advantages
  - contamination of data sent to Minor Planet Center during the early mission operations is avoided
  - the science impact of the mission is maximized

Long-term processing



- No external data sources used for DPAC processing
  - probably for validation purposes only

Possible actions triggered by the Gaia output

- Further data exploitation
  - Computation of proper elements, new dynamical family classifications
  - Deeper analysis of anomalous sources (suspect binaries, comets…)
- Obtention of new data
  - TNO/asteroid occultations
  - Complementary observations:
    - Spectra
    - Photometry
    - Astrometry (candidates for mass / Yarkovsky determination)
- Exploitation by associating data of other surveys:
  - Pan-STARRS, LSST, Spitzer & WISE …

This is the reason why we are in Pisa now!

The End…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