THE SOLAR SYSTEM SEEN BY GAIA

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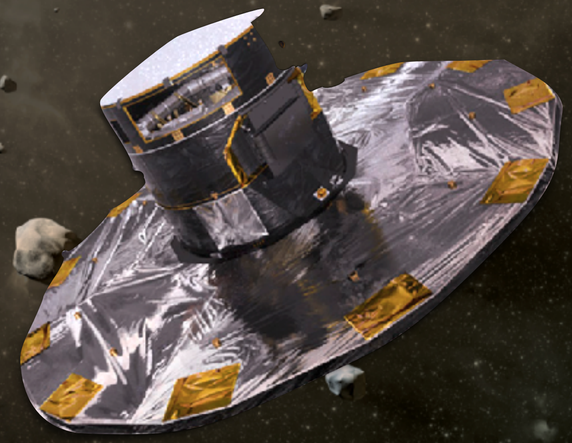
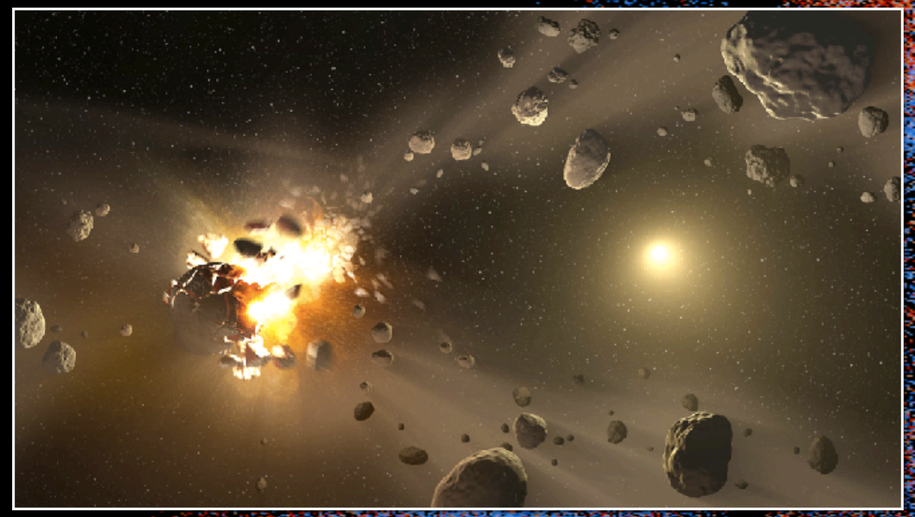
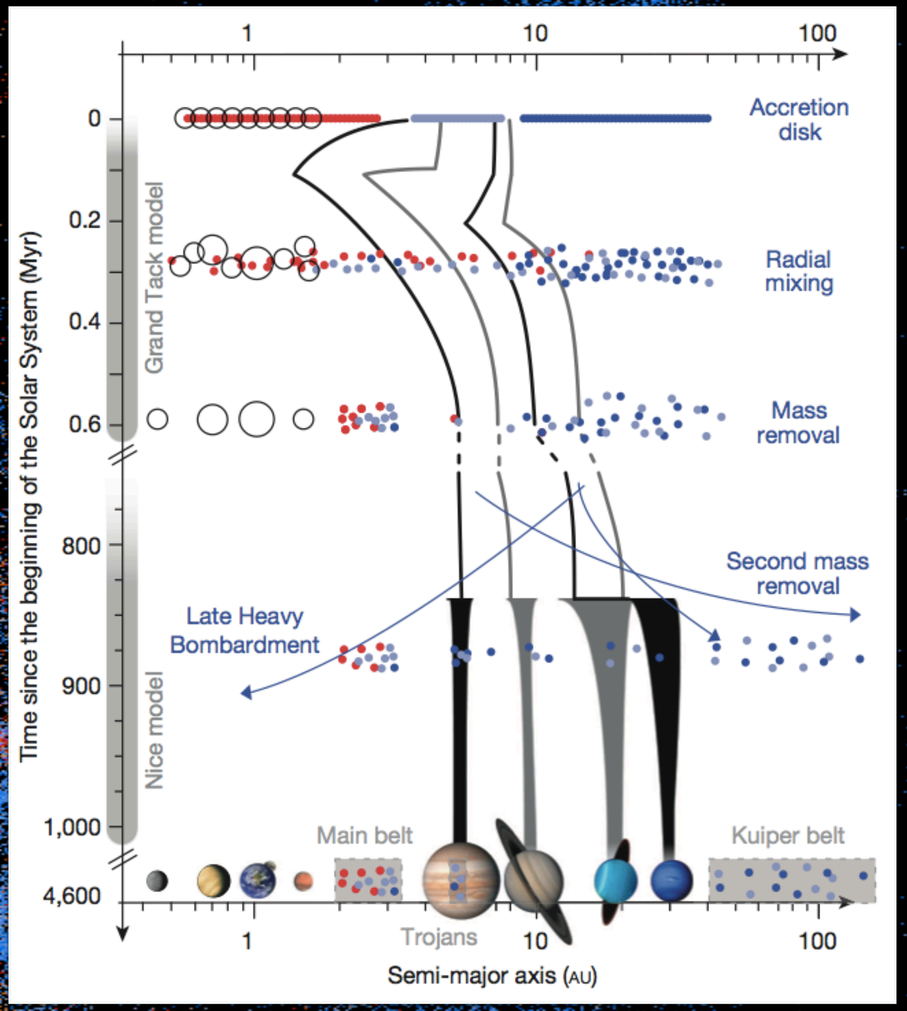


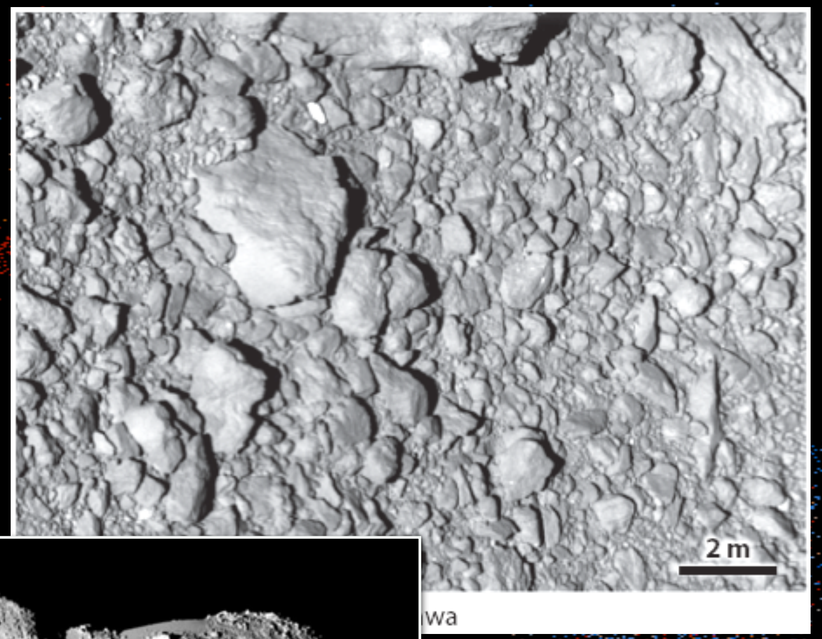
Understanding the Solar System

- Where the Earth water comes from?
- How the asteroid population formed?
- Collisional evolution: how it sculpted small bodies and planets?
- How the first solids grew into planetesimals?

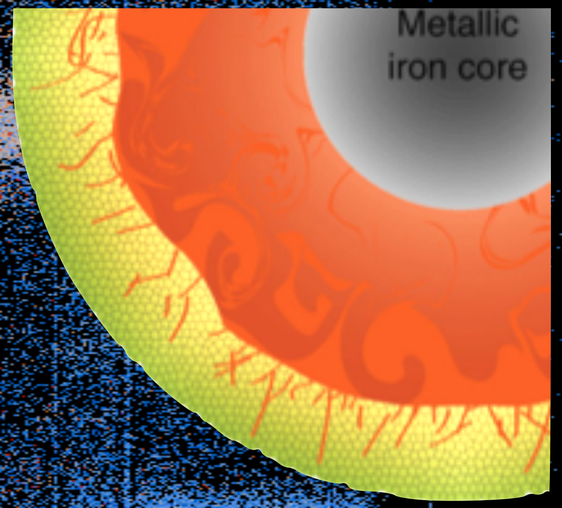




What do we need to know



- composition of small bodies
- mass, size, density
- composition and mixing of the asteroid belt
- meteorite-asteroid compositional link
- dynamical and collisional mechanism
- surface phenomena



The impact of Gaia on asteroid science

- **What Gaia observes**
  - –350.000 asteroids at V=20 (>700.000 known today)
  - –comets, TNOs (10-20)
  - –large planetary satellites

- **Why we are interested**
  - – very poorly known properties:
    - a few 1000s spectra, 10s masses, ~400 shapes…
    - direct determination from Gaia data

The contribution of Gaia astrometry

- Better orbits —> talk by F. Spoto
- Accurate masses of large perturbers in the Main Belt

  ~60 of them (Gaia 5 yr) at 10% level vs. ~10 known today —> talks by A. Ivantsov
- Presence of satellites from the motion of primaries around the center of mass
- Non-gravitational effects

  Yarkovsky thermal recoil effect
- Impact on ground-based observational activities

  stellar occultations —> talks by B. Sicardy / D. Berard / J. Desmars / A. Ramos-Gomez

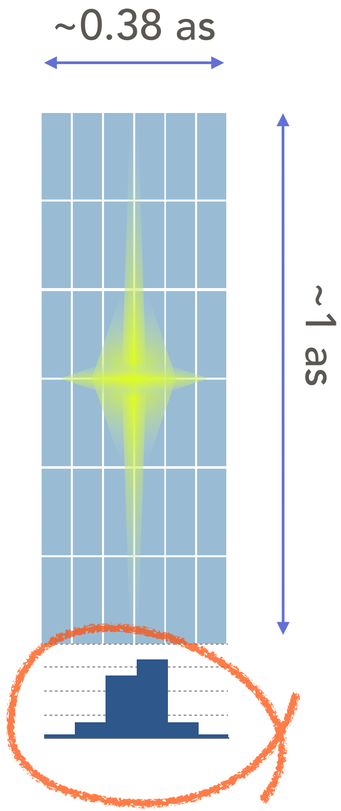
  impact hazard monitoring, archive observations —> talk by F. Spoto
- Contribution to spacecraft navigation in the Solar System

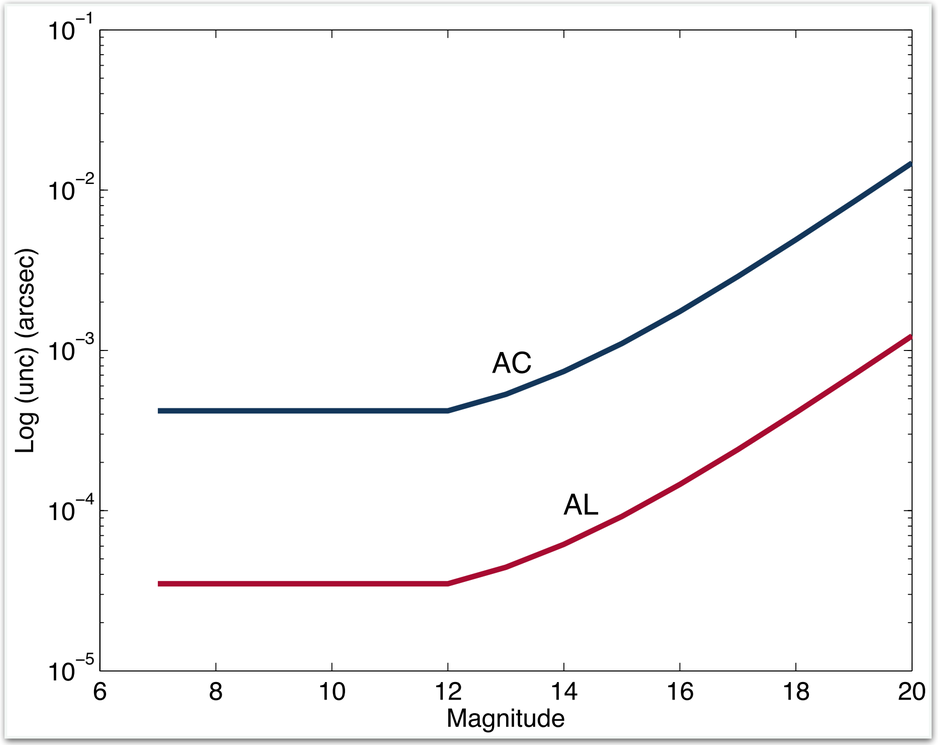
  the example of New Horizons flyby with (486958) *2014 MU69* on Jan. 1, 2019

—> + several posters!!

Simulations of Gaia asteroid astrometry

- activity developed in the frame of CU4 by F. Mignard
- requires to look for detections by crossing Gaia scanning law to asteroid trajectories
- appropriate error model required

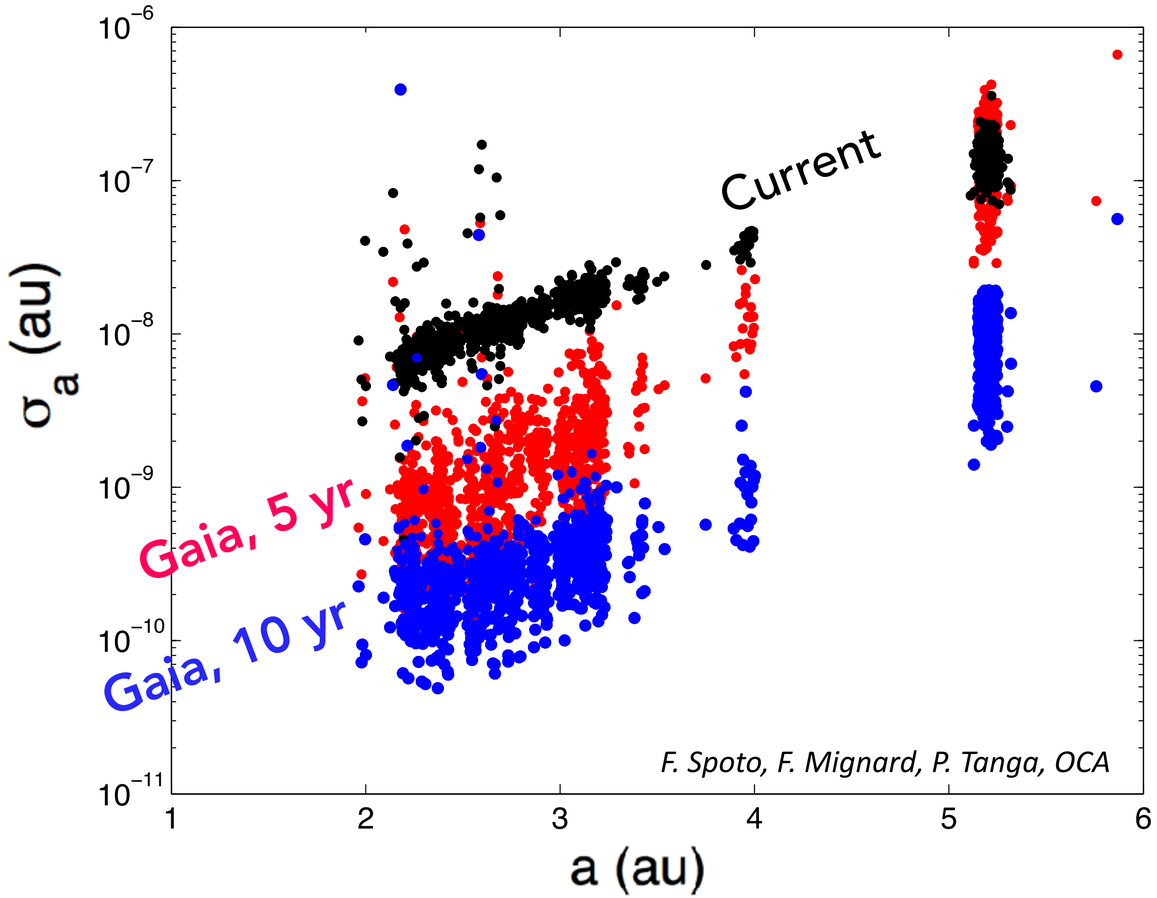




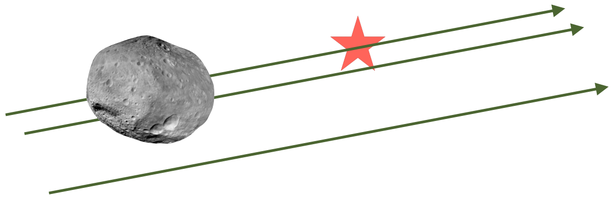
F. Mignard, F. Spoto

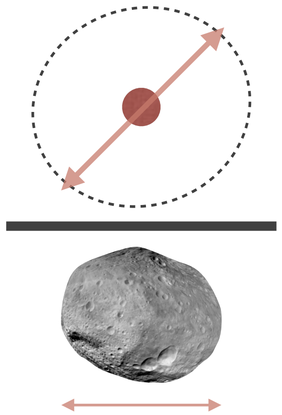
Orbit improvement perspectives

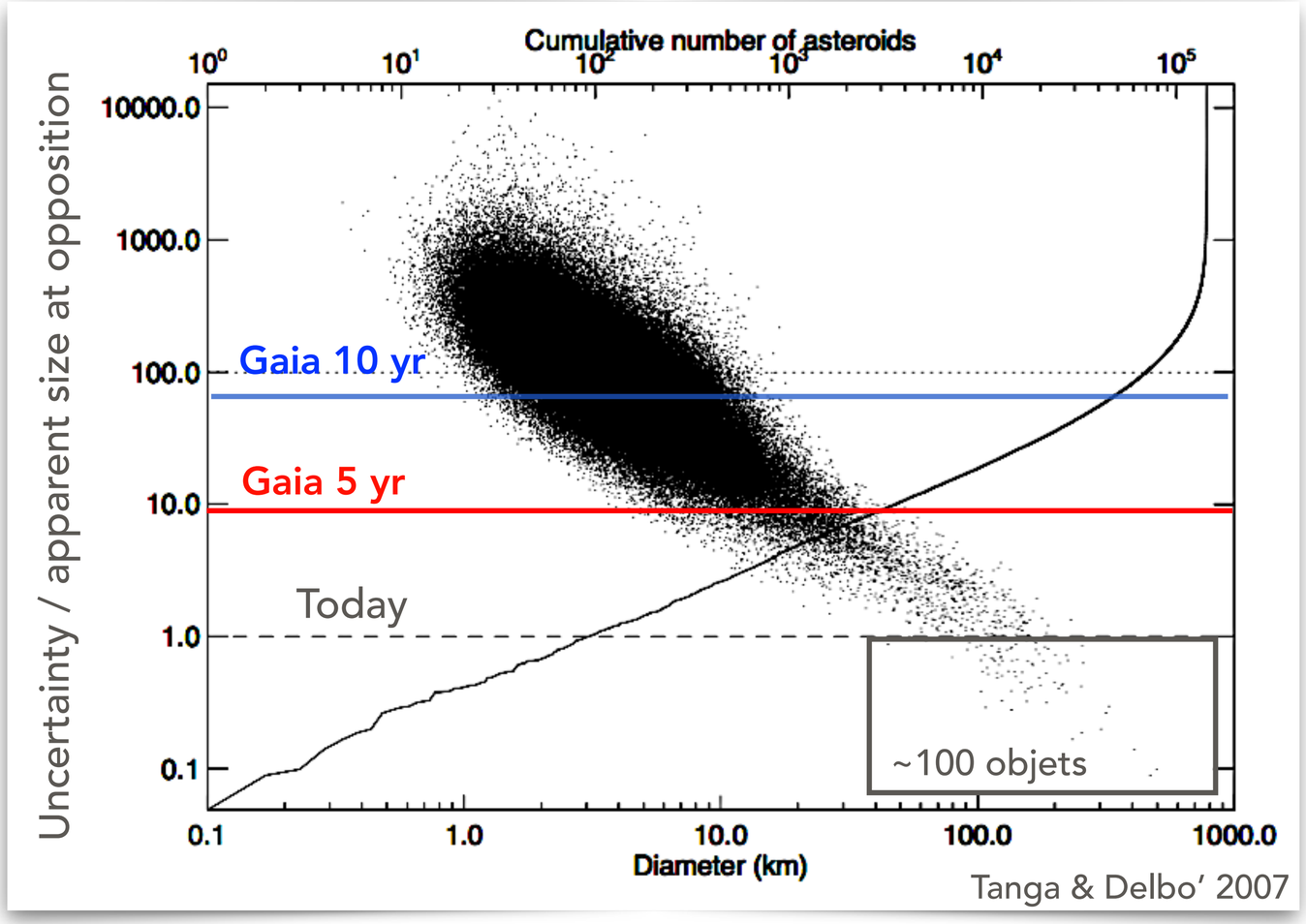
Simulated detections, with realistic error models + orbit determination



Asteroid ephemeris and occultation prediction

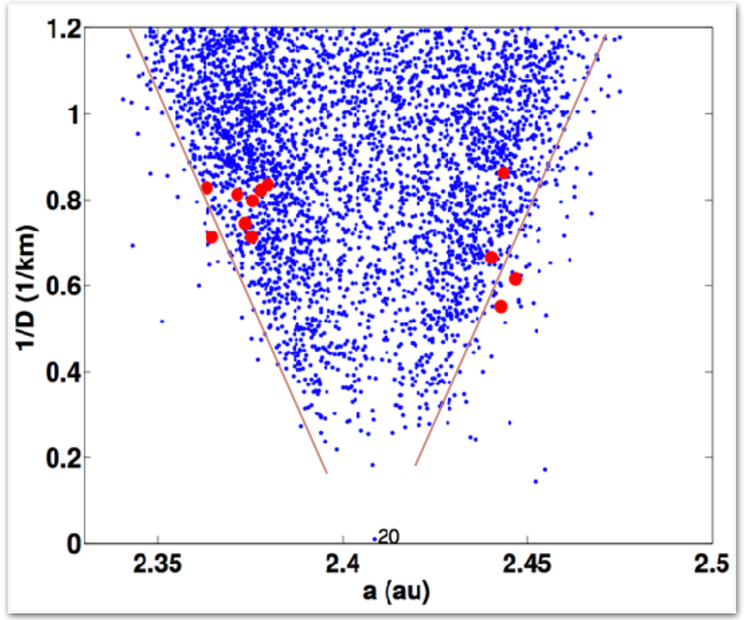


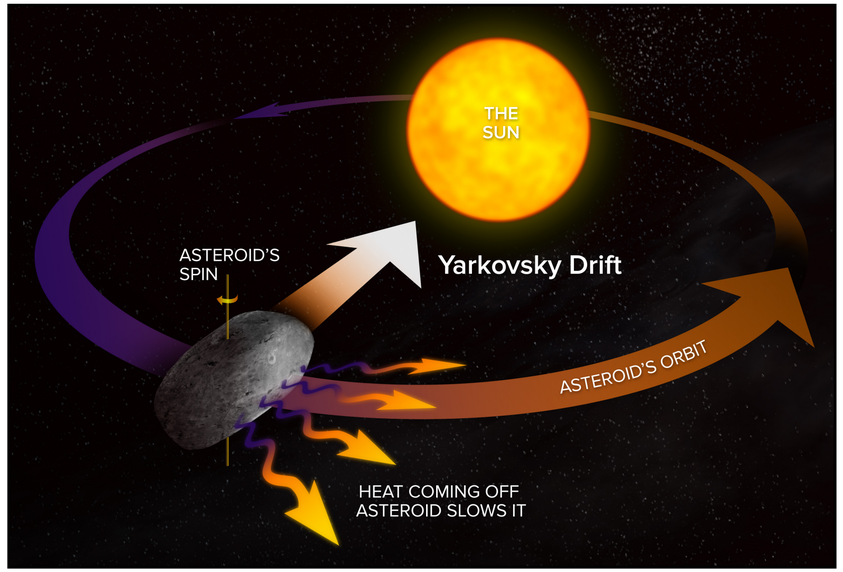




Yarkovsky effect and dynamical family ages

Spoto et al. 2015

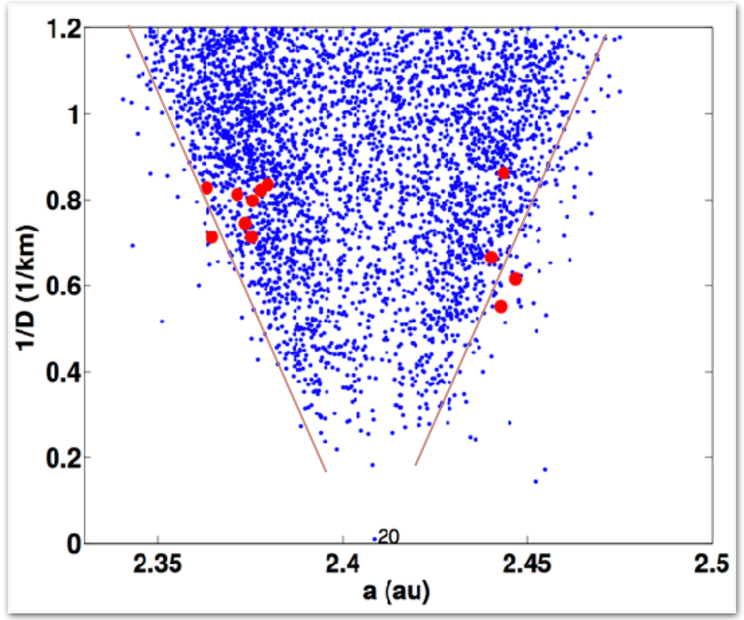


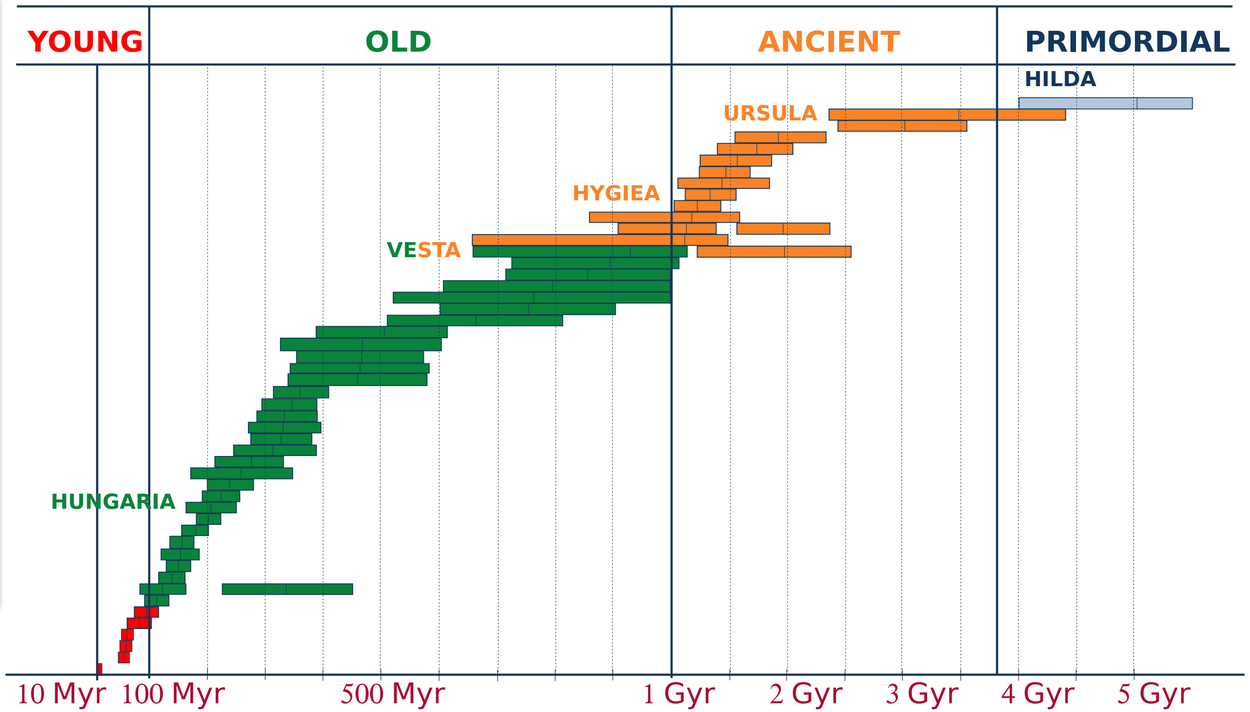


$$\Delta(t) = \Delta(a)/(da/dt)$$

Yarkovsky effect and dynamical family ages

Spoto et al. 2015

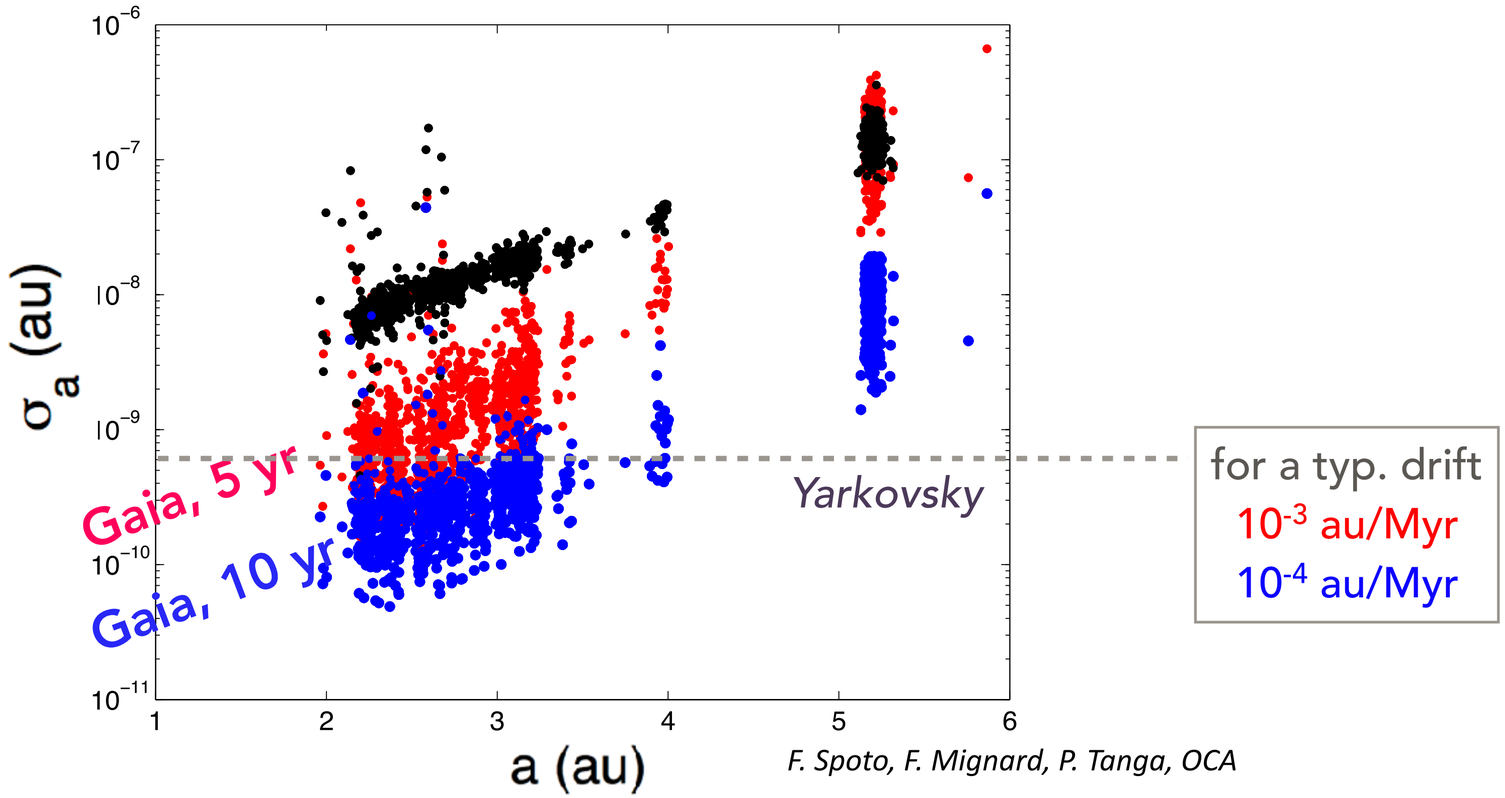




$$\Delta(t) = \Delta(a)/(da/dt)$$

- Strong hypothesis: homogeneity inside the family
- Yarkovsky calibrated on a single asteroid (Bennu)…
- …can be rescaled using the family spectral class

Yarkovsky by Gaia (alone …or not)



F. Spoto, F. Mignard, P. Tanga, OCA

- Enormous potential of re-calibrated, “old" astrometry

  debiasing of MPC astrometry (Farnocchia et al. 2015)

  new measurements of old plates (NAROO project, Arlot et al. 2013)

The contribution of Gaia on physical properties

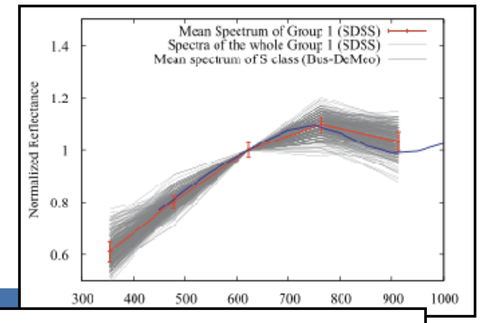
- Asteroid low resolution spectroscopy
  resolution + number of objects: simply the most extensive survey *ever* in the visible
  today: 3000 spectra; 10.000s “colors”

- A new taxonomy
  look for differentiation in asteroid families
  discover old, dispersed families

- Photometry: shapes from photometric inversion
  ellipsoids foreseen in the data reduction
  + ground-based “dense” photometry for complex shapes —> talk by J. Durech

- Photometry: phase - magnitude curves
  allow to determine absolute magnitudes —> albedos
  + ground-based photometry around opposition

—> + several posters!



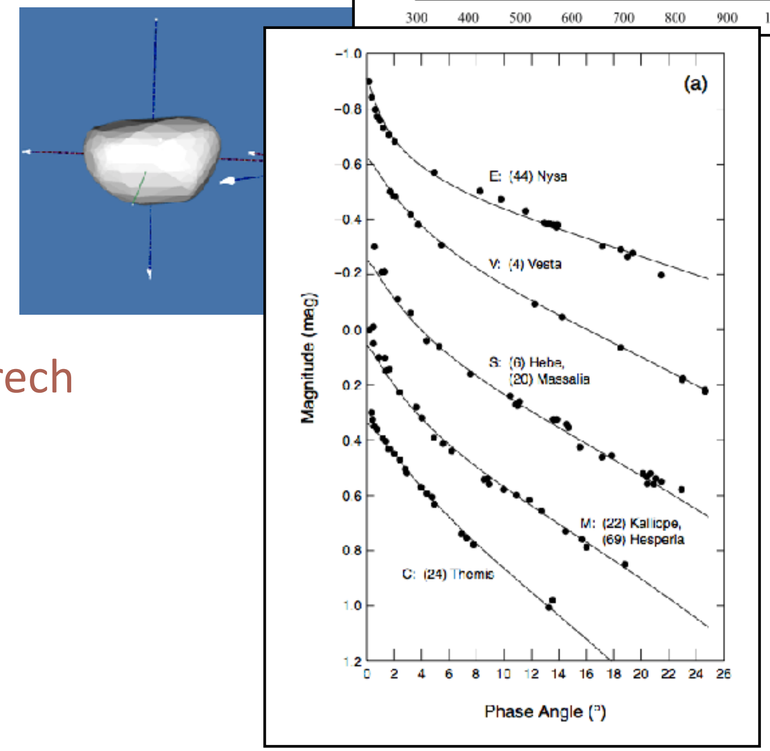
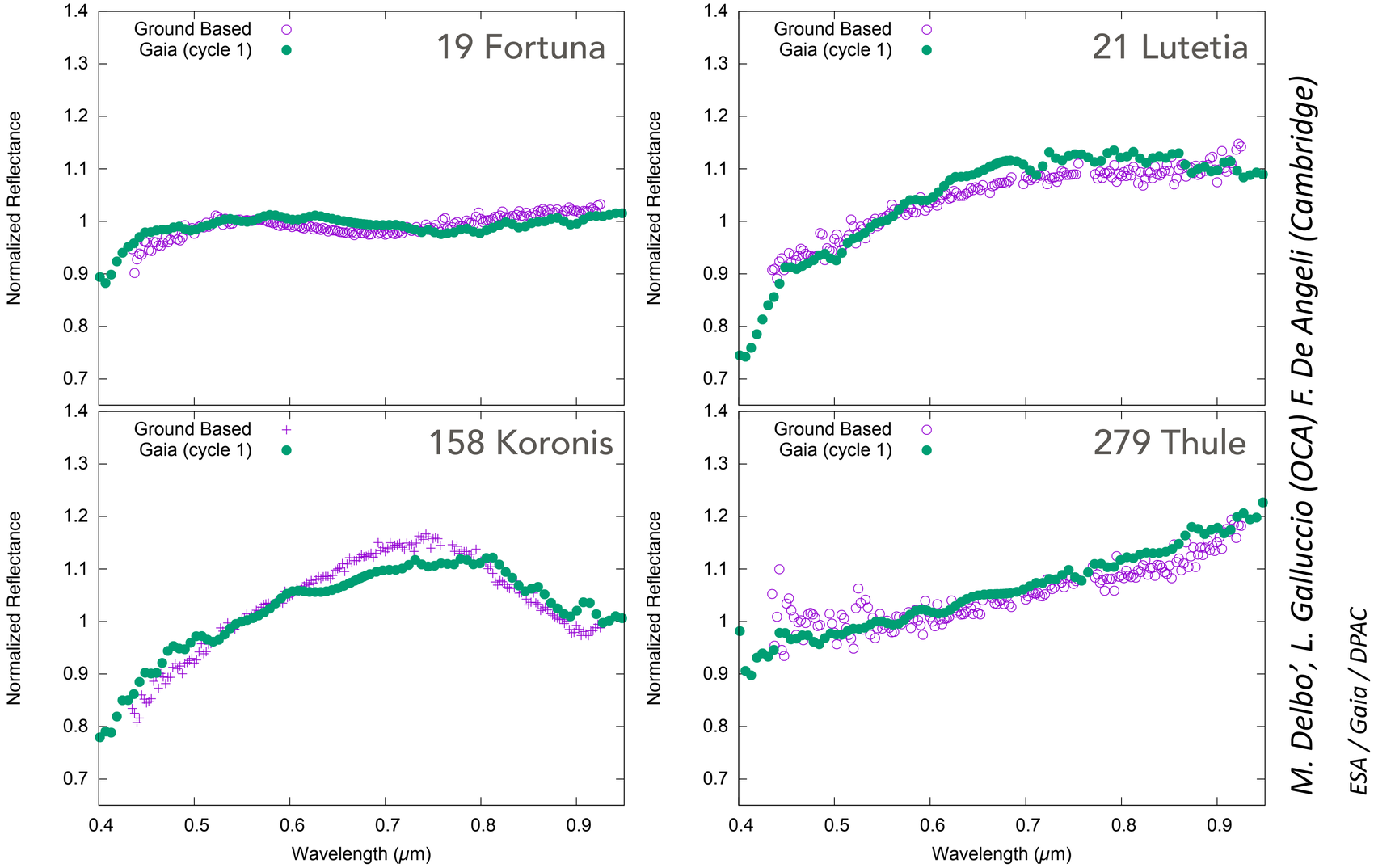


Image of the week! asteroid spectra



M. Delbo', L. Galluccio (OCA) F. De Angeli (Cambridge)

ESA / Gaia / DPAC

Asteroids for the Gaia Data Release 2 (Apr. 2018)

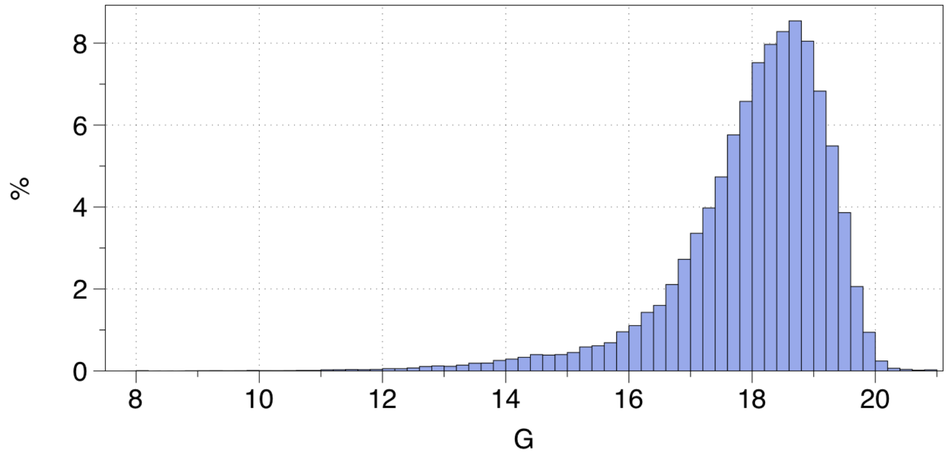
Content:

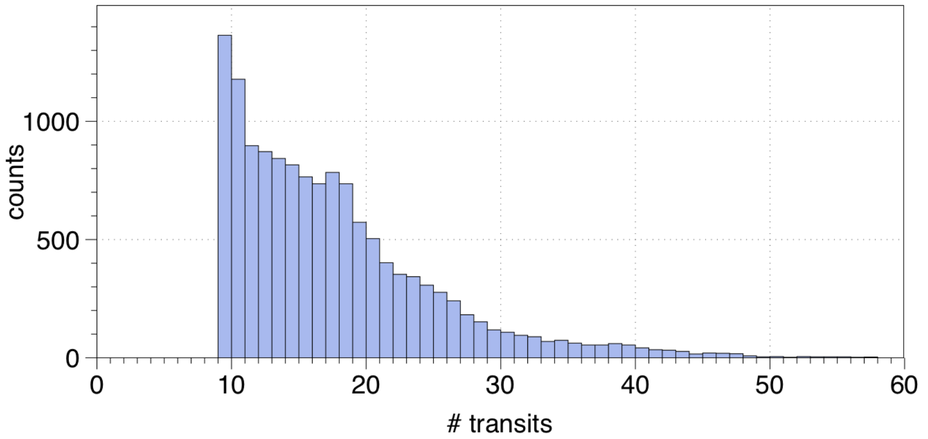
- asteroid ID and positions (Ra, Dec) max. 10 per transit
- positions of Gaia
- TCB gaiacentric epochs associated to the positions
- corrections (relativistic, aberration…)
- uncertainties & correlations
- brightness (1 per transit) and uncertainty

Processing and scientific validation - main contributors:

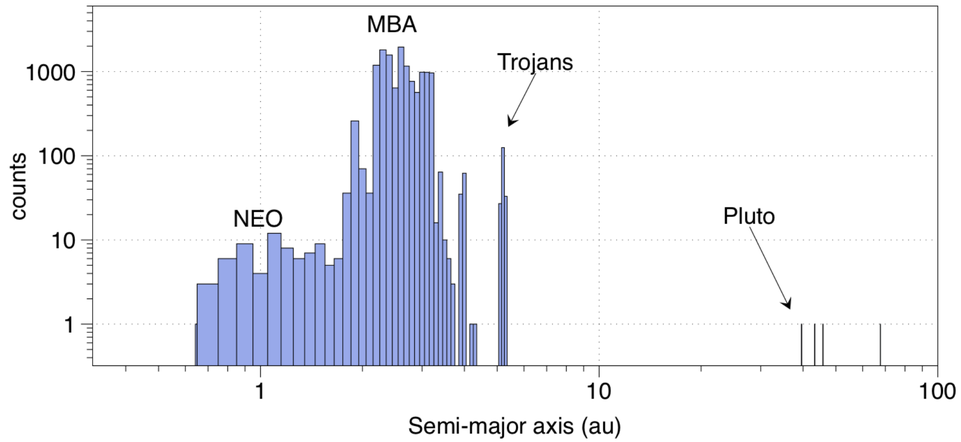
IMCCE, France:	J. Berthier, D. Hestroffer
INAF, Italy:	A. Cellino, A. Dell'Oro
UTINAM, France:	J.M. Petit
OCA, France:	M. Delbo, L. Galluccio, F. Mignard, Ch. Ordenovic, F. Spoto, P. Tanga
ORB, Belgium:	Th. Pauwels
U. Helsinki, Finland:	K. Muinonen, G. Fedorets

Selection for the Gaia Data Release 2 (Apr. 2018)



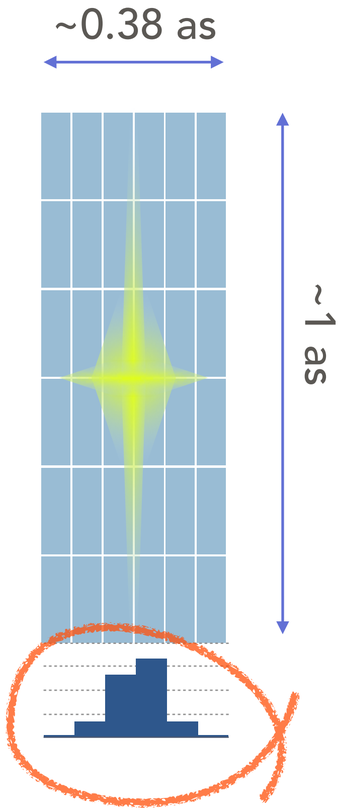


F. Mignard, OCA

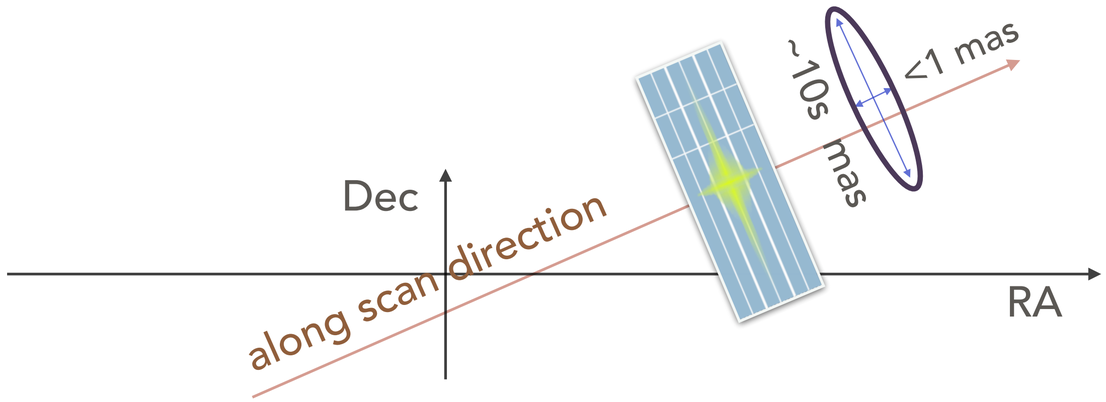


- “bright” asteroids having more than 9 transits
- selected objets have all of their transits included
- 13,400 asteroids (195,000 transits)

Be prepared: some warnings

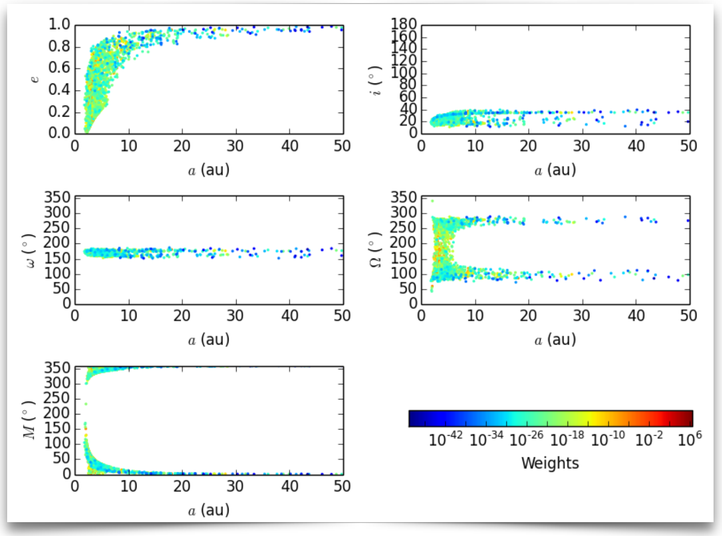


- Tools must be ready to handle accuracy ~100 X better
- difficulties in exploiting existing archive observations (reduced with biased catalogues)
- Highly correlated (RA, Dec) epoch positions
- Fundamental for asteroids!

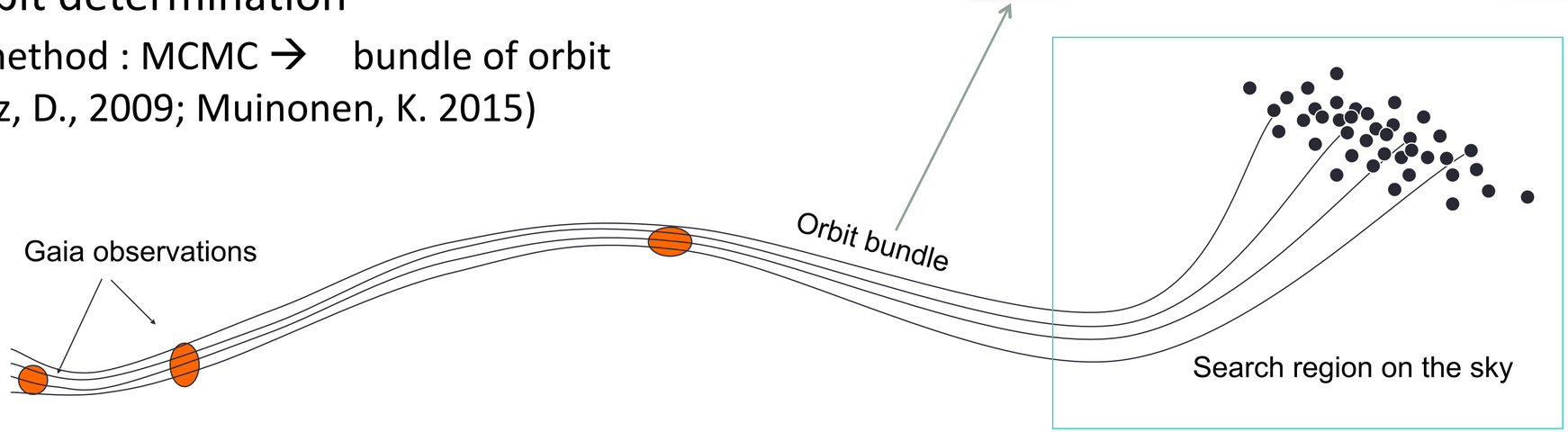


Asteroid alerts

- Goal:
  - identify potentially “new” asteroids
  - diffuse predictions of sky search areas to ground-based observers
- Exploits daily attitude solution
  - 70-100 mas accuracy
- Short arc orbit determination
  - Statistical method : MCMC → bundle of orbit (Oszkiewicz, D., 2009; Muinonen, K. 2015)



K. Muinonen, G. Fedorets, Helsinki Univ.

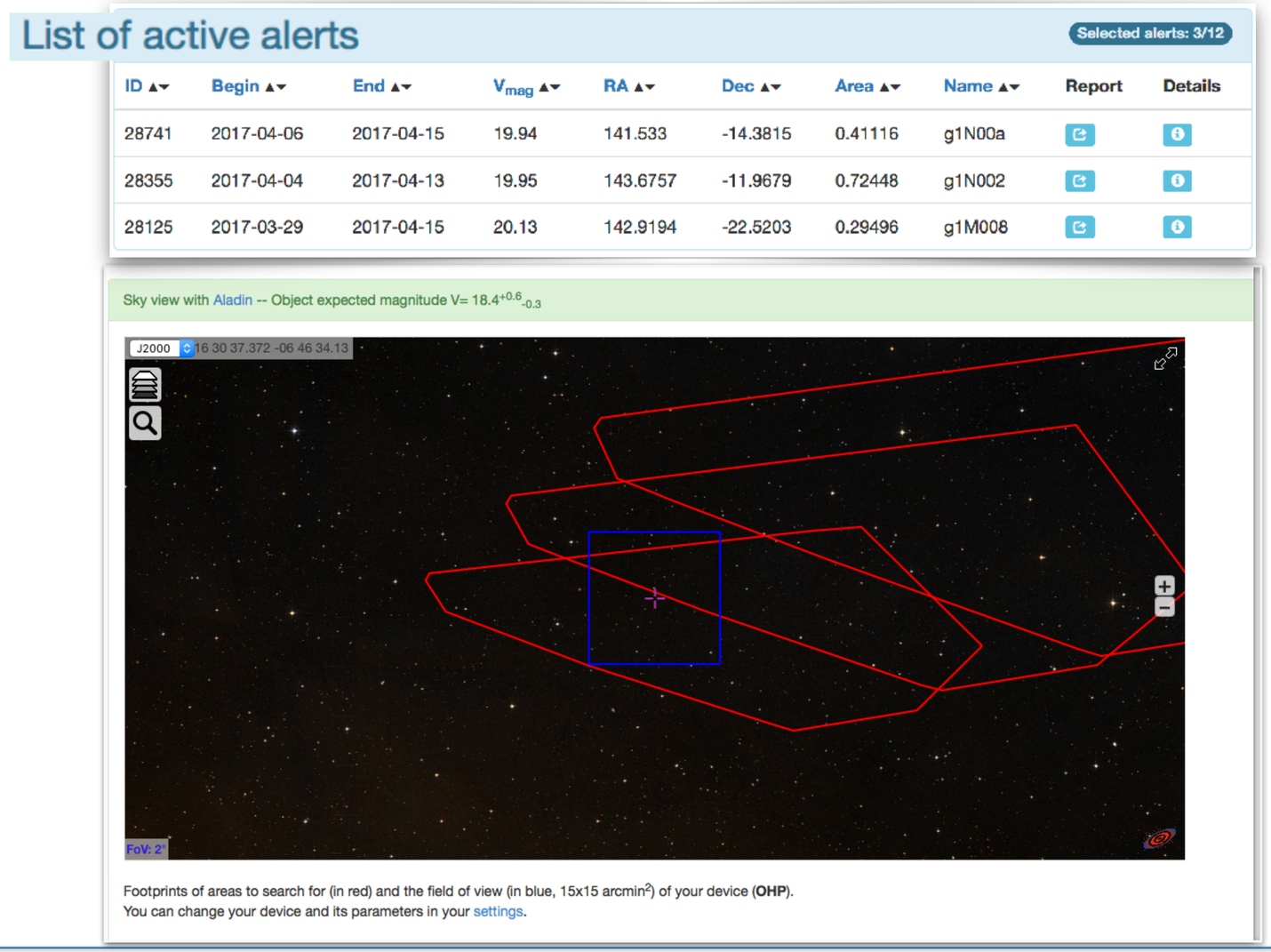


Tanga et al. 2016

Diffusion of asteroid alerts

http://gaiafunsso.imcce.fr

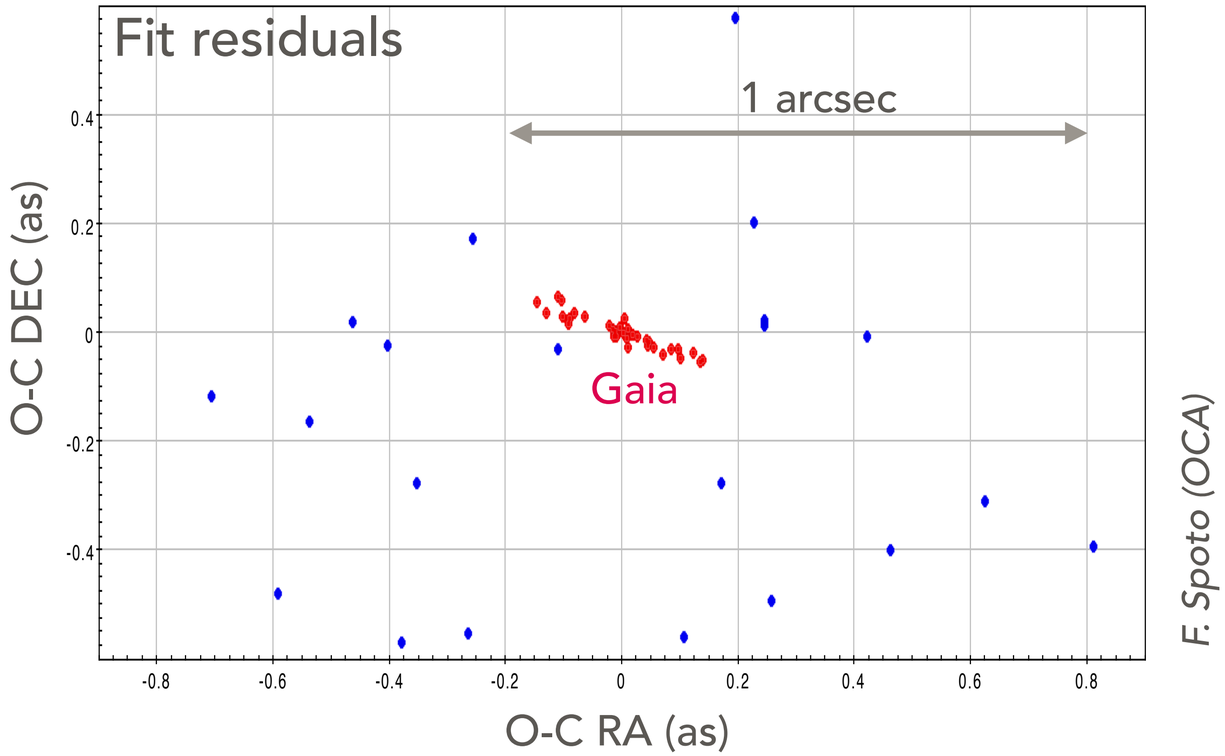
B. Carry (OCA), W. Thuillot (IMCCE)



Register and contribute!

First confirmation of an asteroid alert

- Observations on Dec. 29 (Gaia - 4 transits) and Jan. 3-4 (OHP, 2 nights)
- Orbit computation: Gaia + ground



Conclusions

- Gaia is an extraordinary tool for Solar System studies
- be ready for asteroids in GDR2!
- …and asteroid alerts are already running
- Non-negligible impact on ground-based activities
- Stellar astrometry by Gaia is fundamental for Solar System studies, too