

THE SOLAR SYSTEM SEEN BY GAIA

P. Tanga

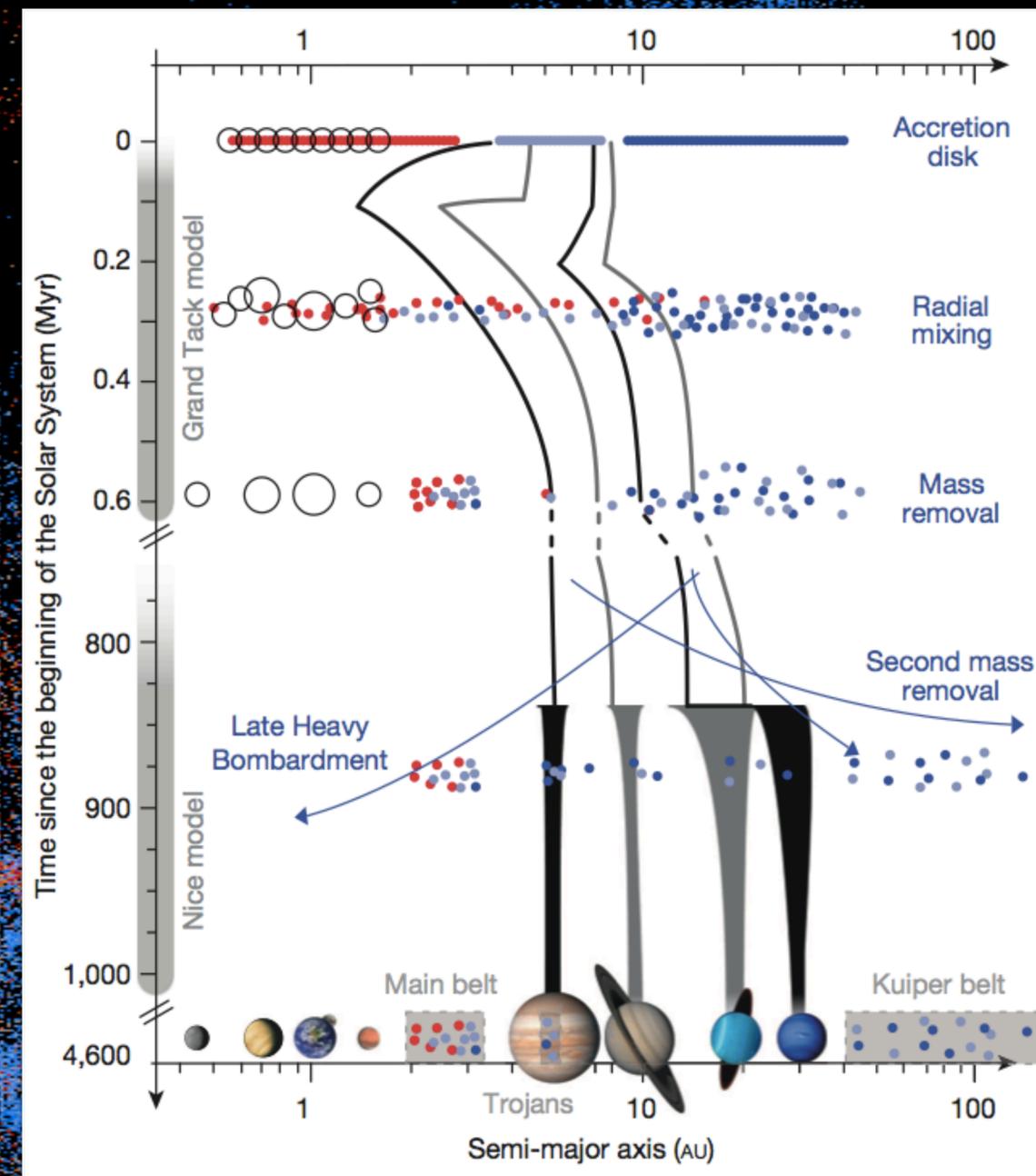
Laboratoire Lagrange,
Observatoire de la Côte d'Azur, France



Observatoire
de la CÔTE d'AZUR

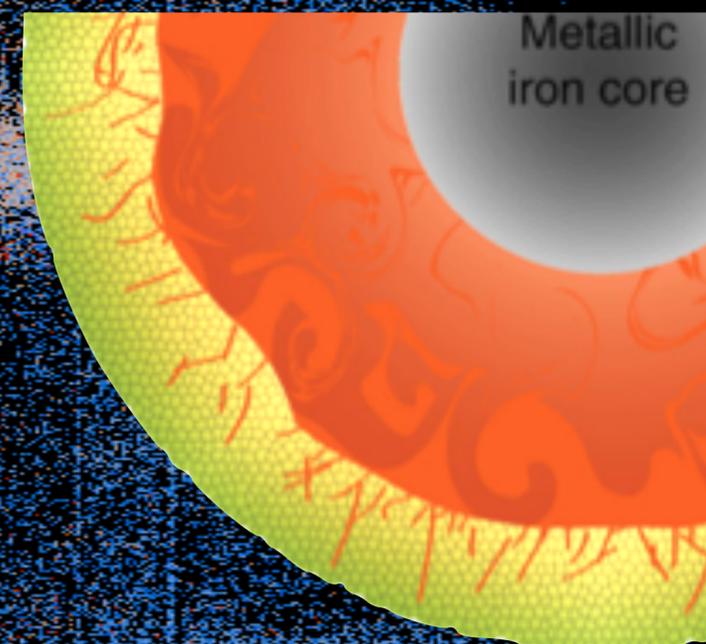
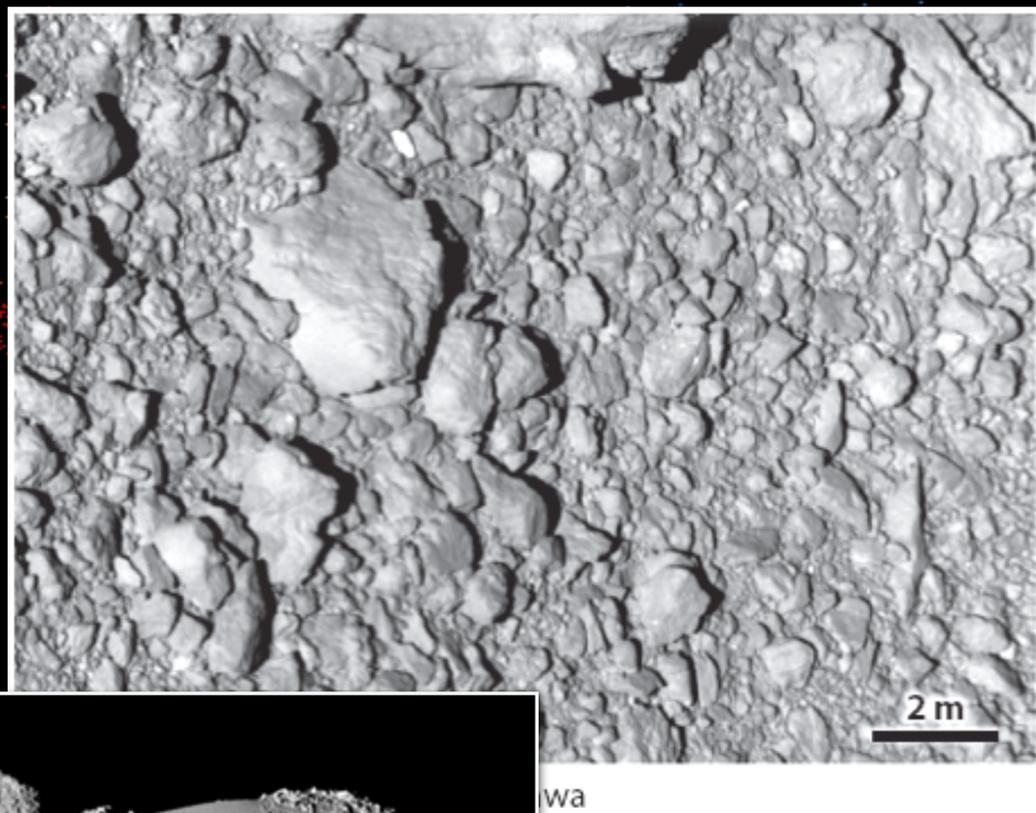
Understanding the Solar System

- 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



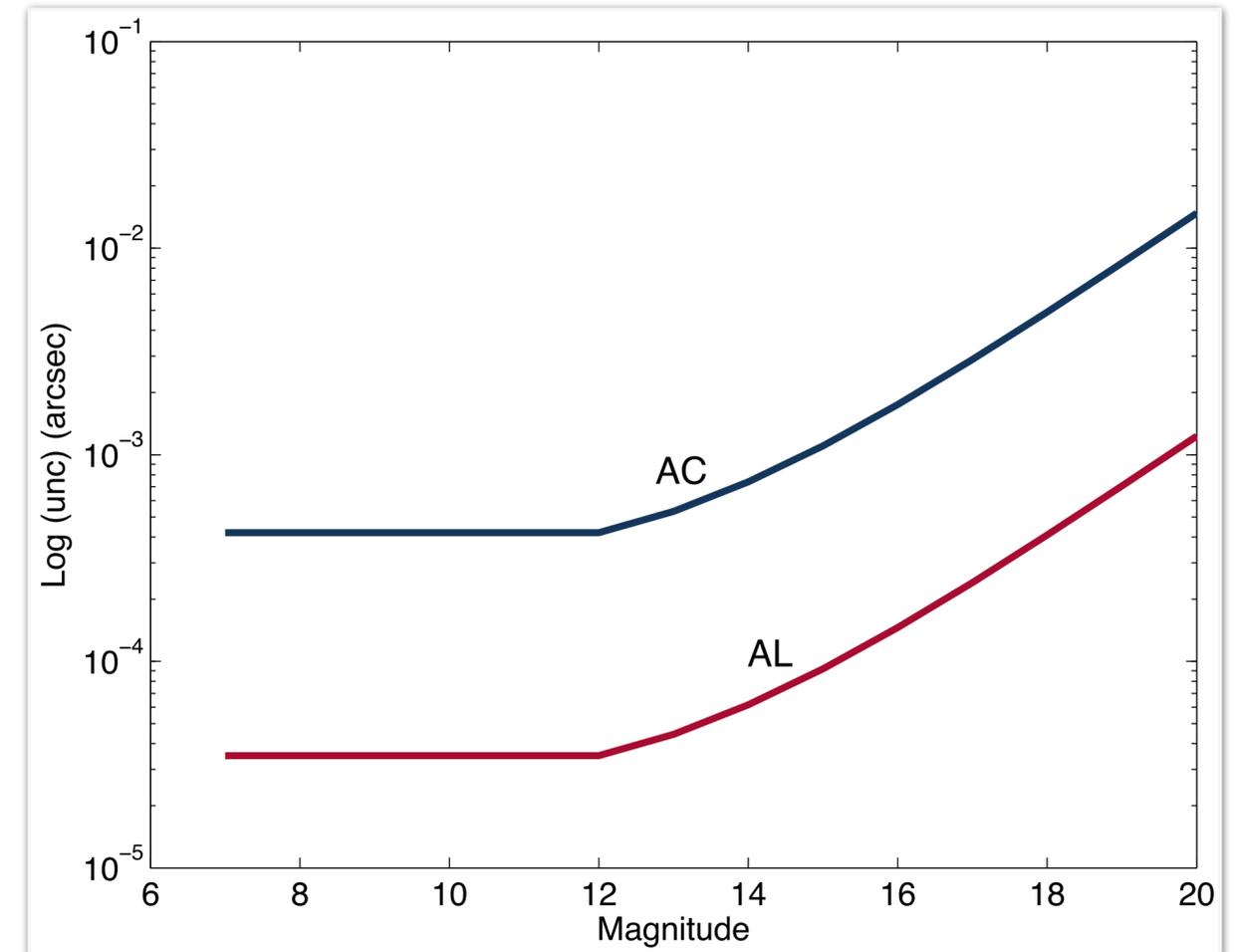
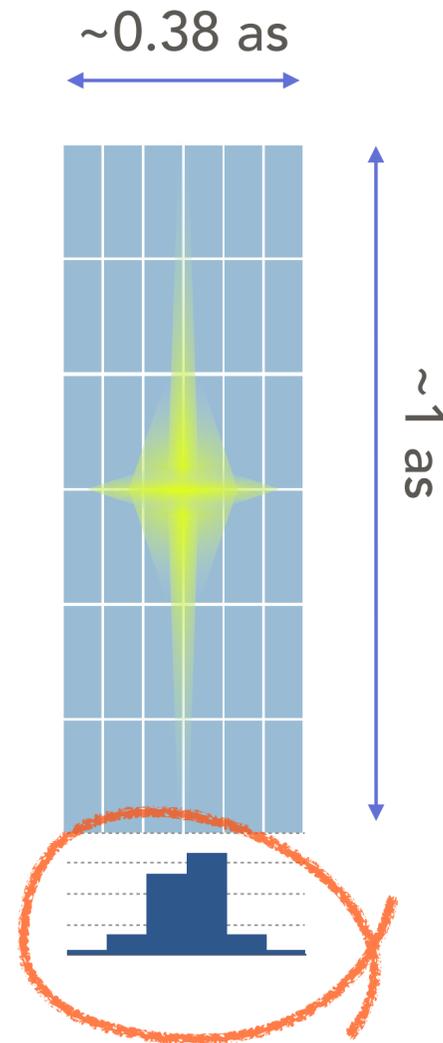
- **What Gaia observes**
 - 350.000 asteroids at $V=20$ (>700.000 known today)
 - comets, TNOs (10-20)
 - large planetary satellites
- **Why we are interested**
 - very poorly known properties:
 - a few 1000s spectra, 10s masses, ~400 shapes...
 - direct determination from Gaia data

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

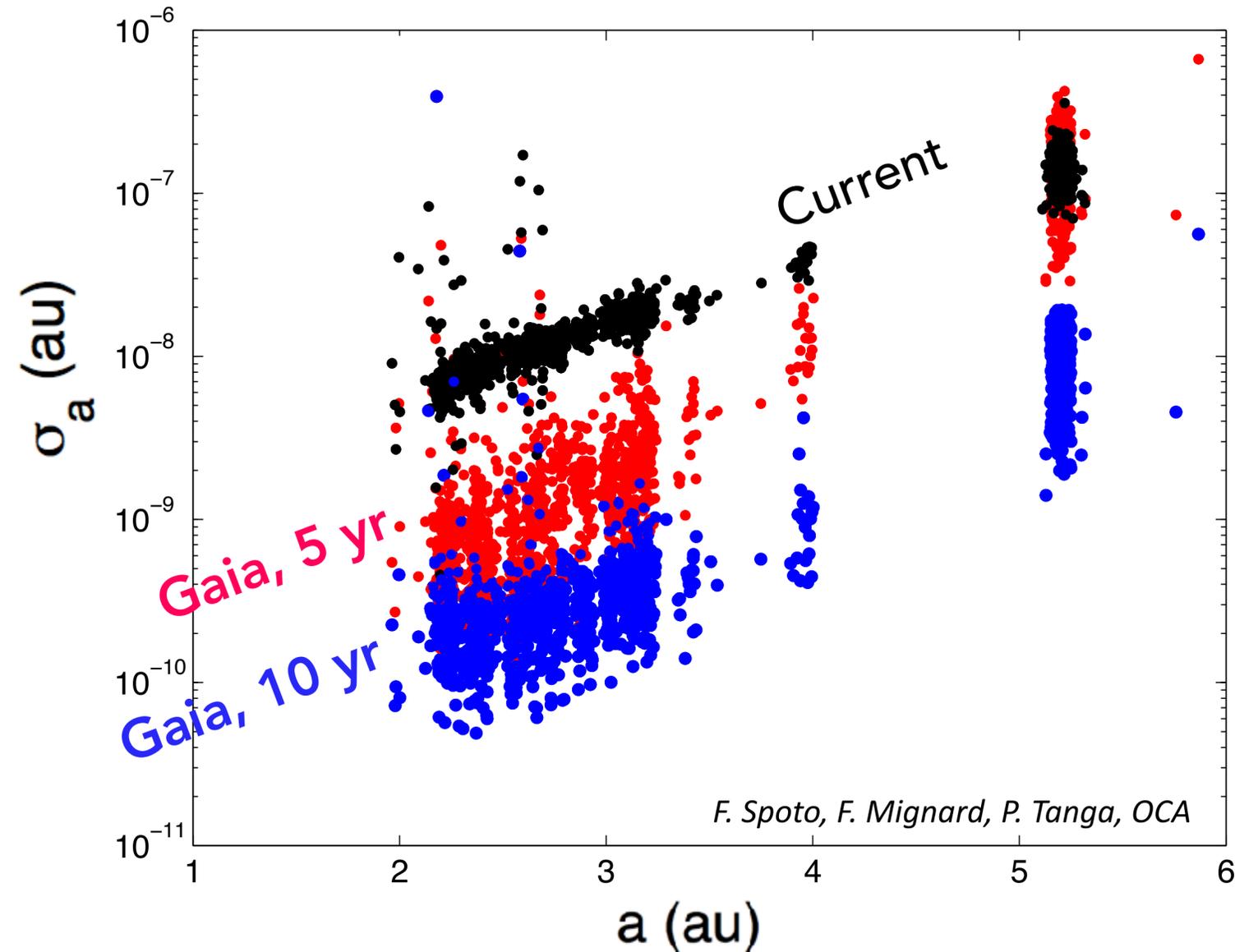
- activity developed in the frame of CU4 by F. Mignard
- requires to look for detections by crossing Gaia scanning law to asteroid trajectories
- appropriate error model required



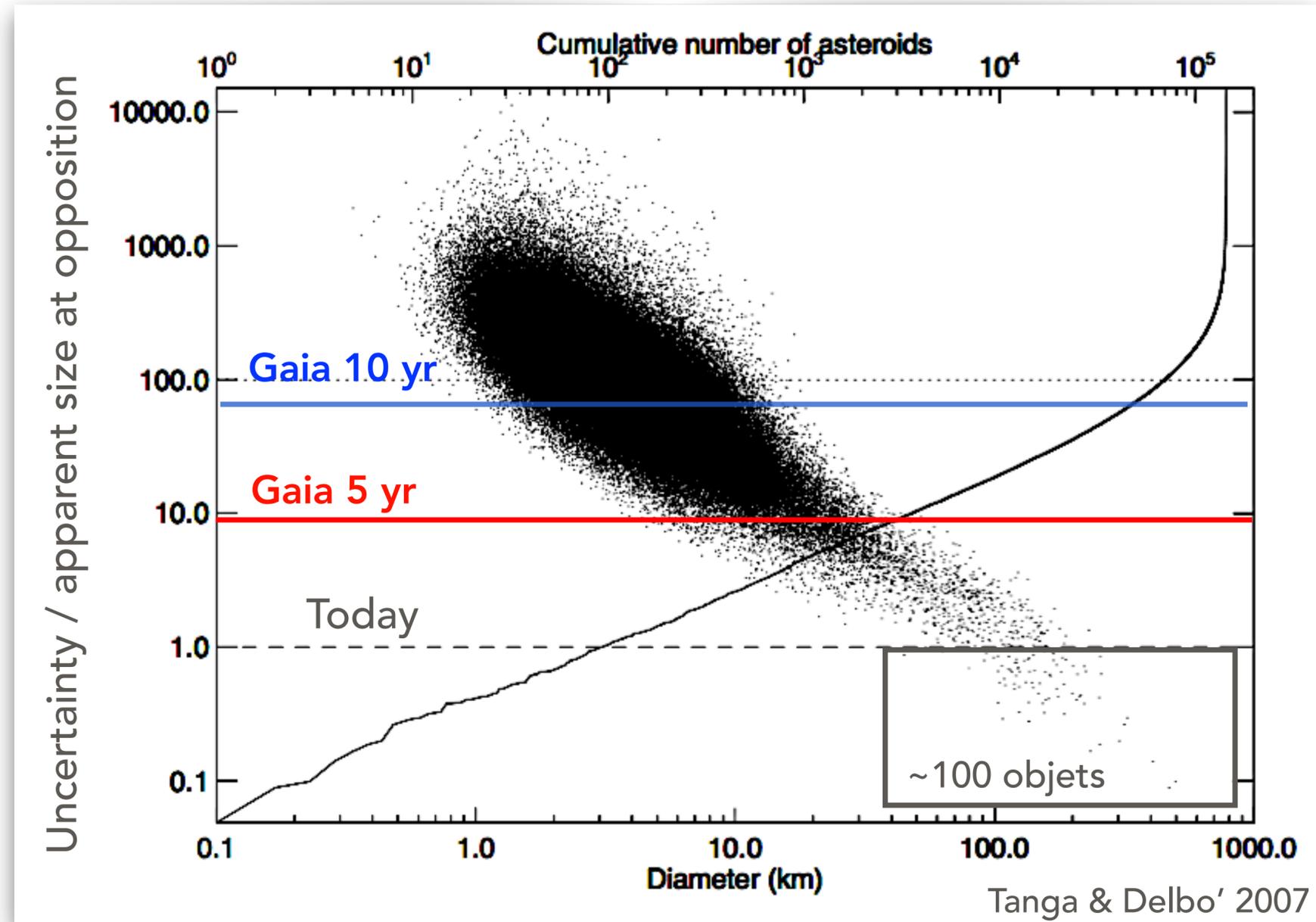
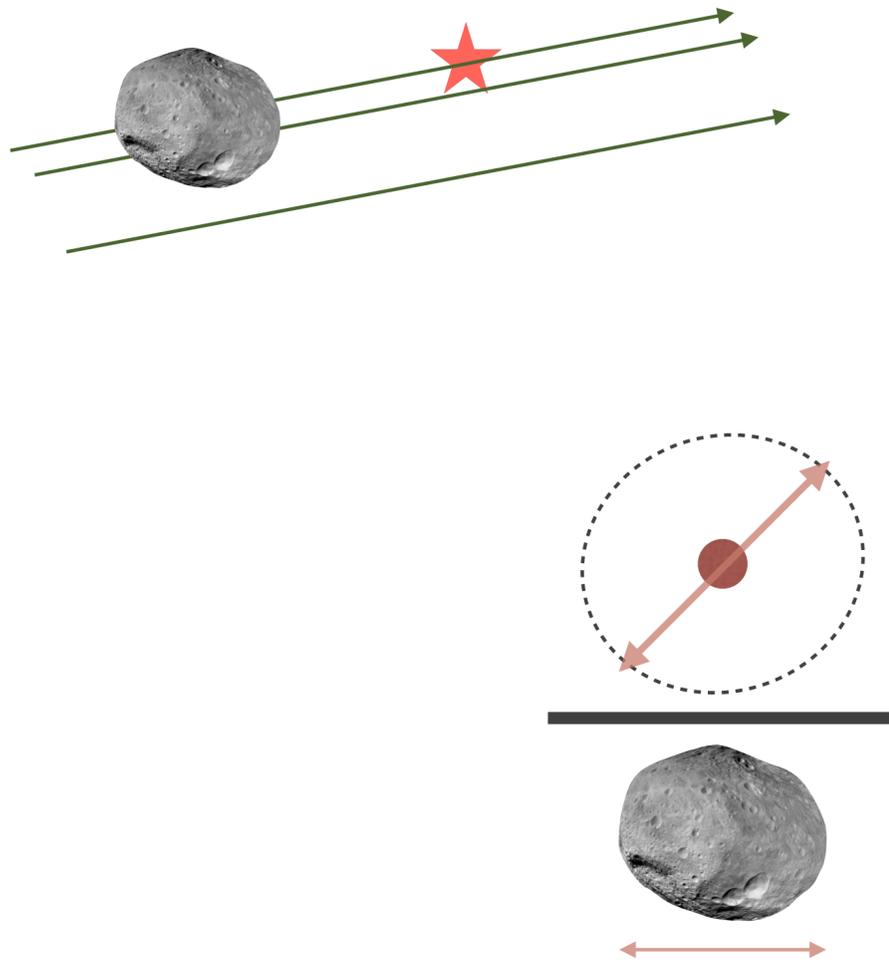
F. Mignard, F. Spoto

Orbit improvement perspectives

Simulated detections, with realistic error models + orbit determination

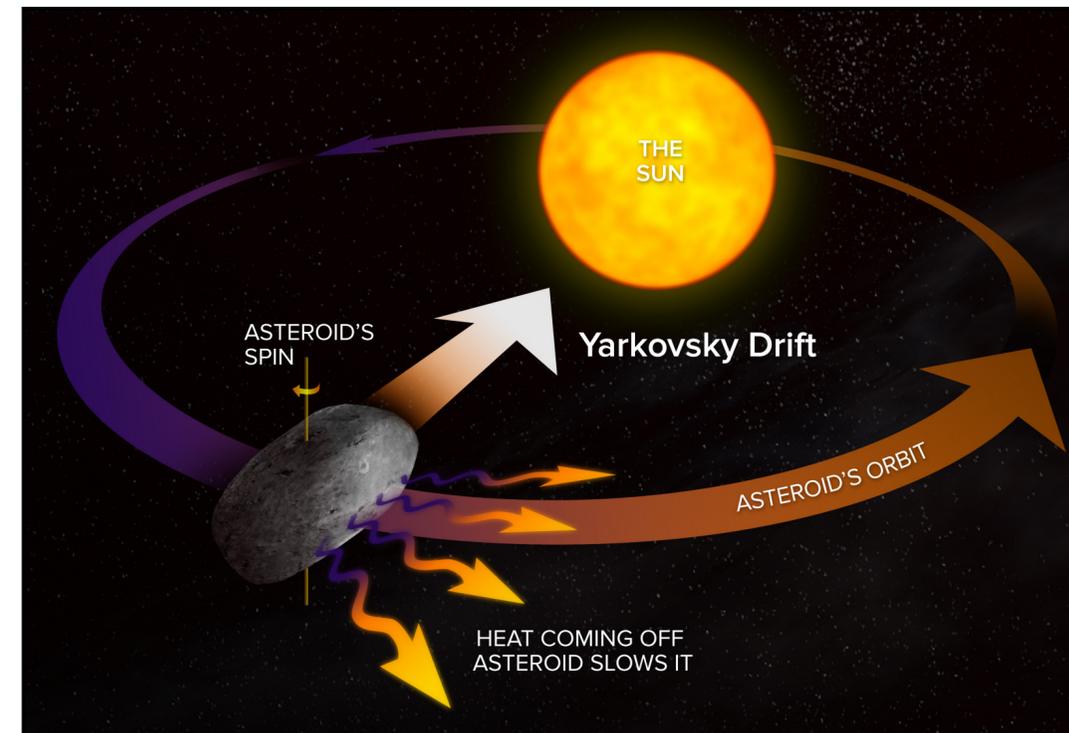
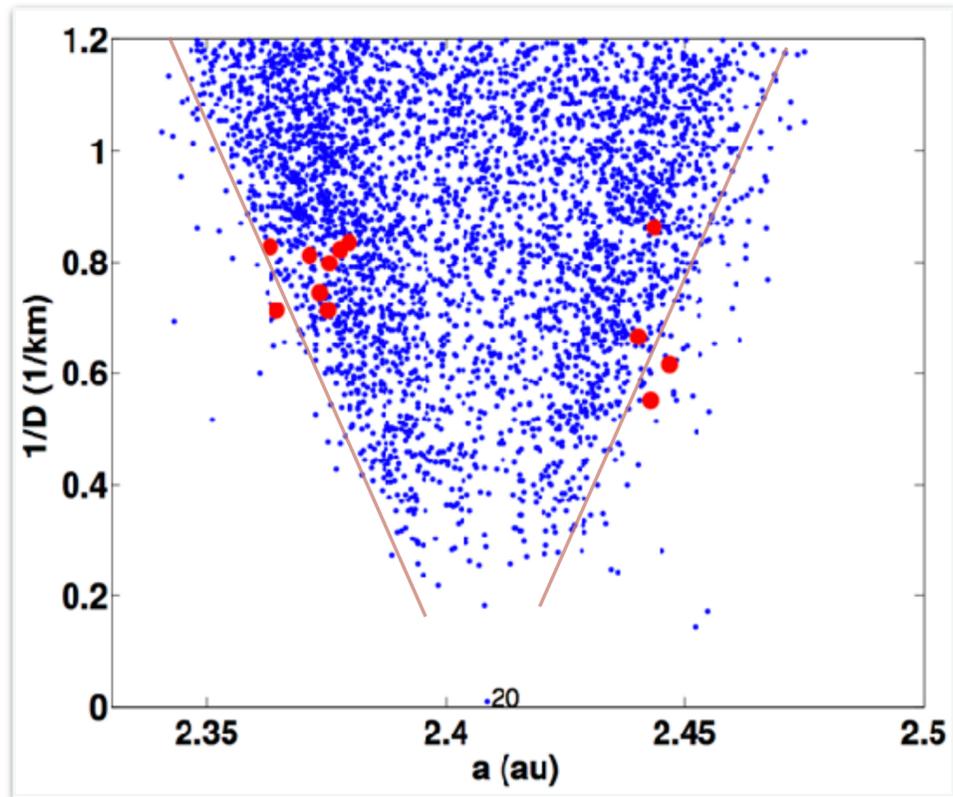


Asteroid ephemeris and occultation prediction



Yarkovsky effect and dynamical family ages

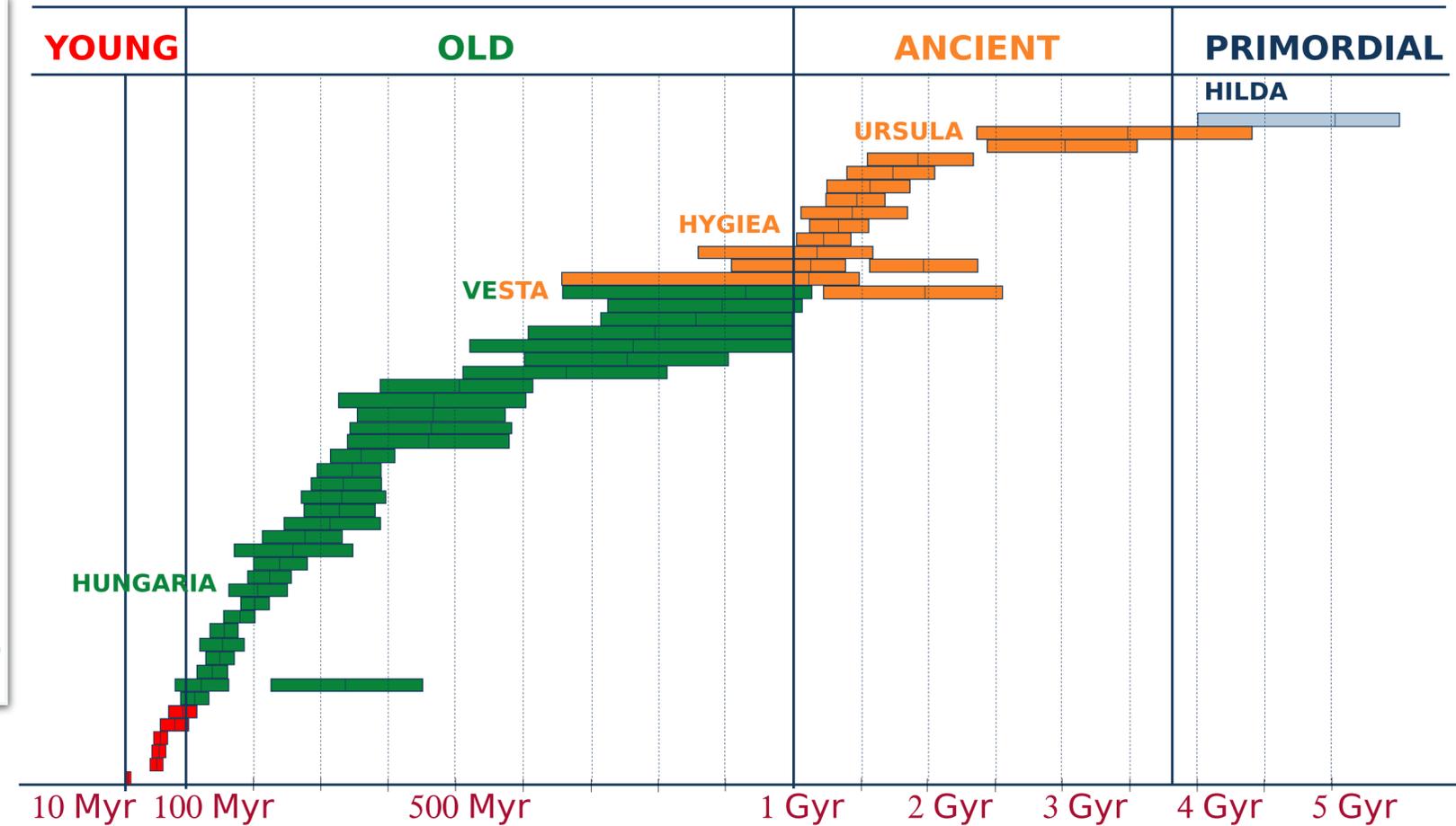
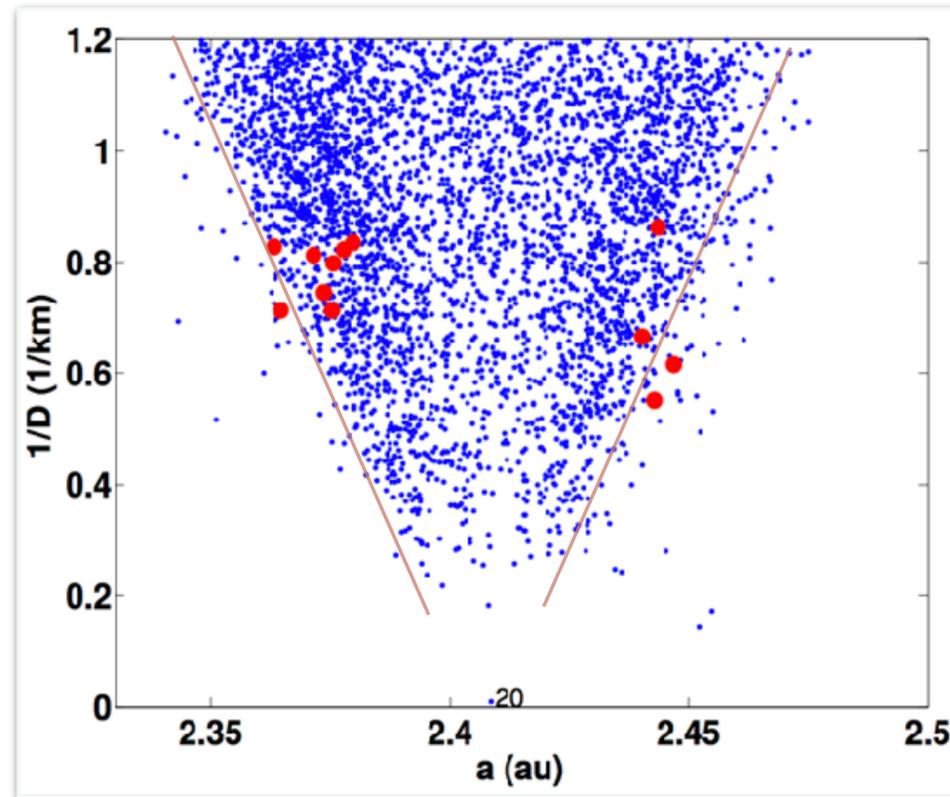
Spoto et al. 2015



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

Yarkovsky effect and dynamical family ages

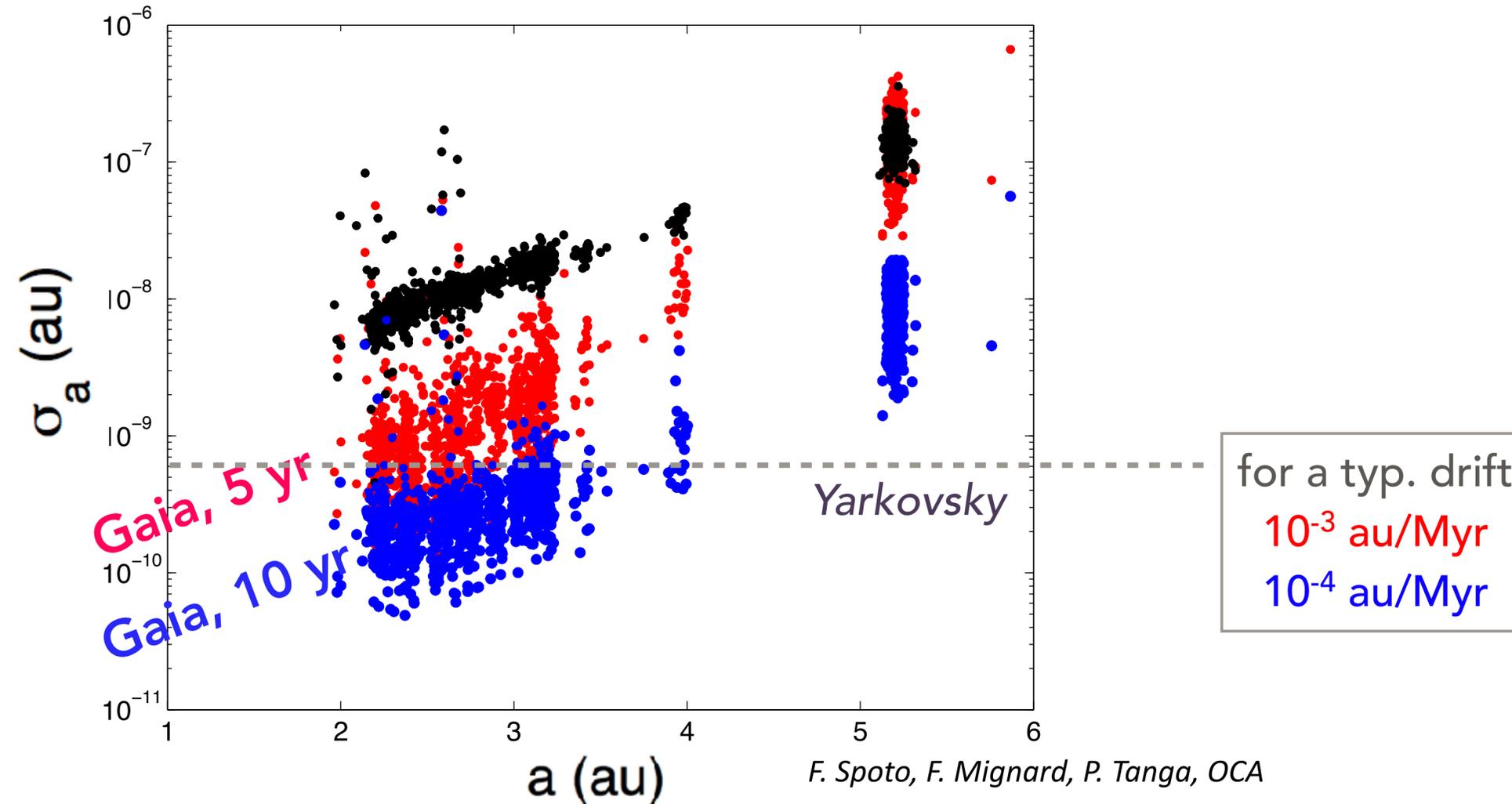
Spoto et al. 2015



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

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

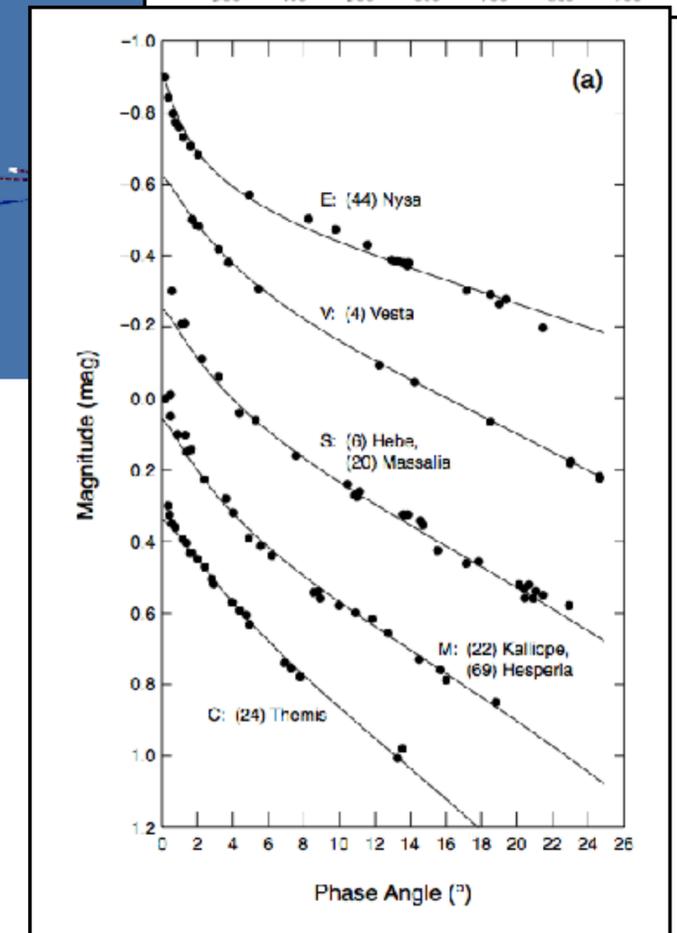
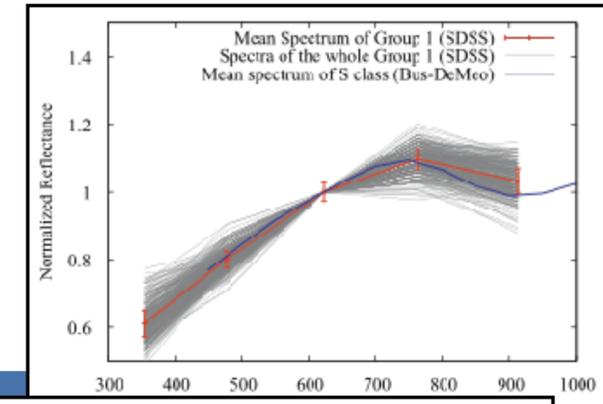
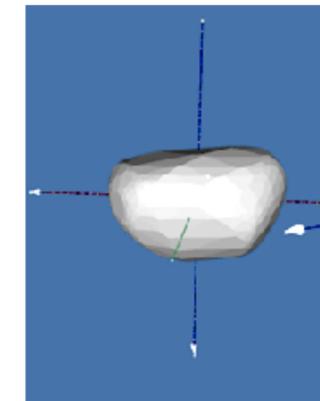
Yarkovsky by Gaia (alone ...or not)



- 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)

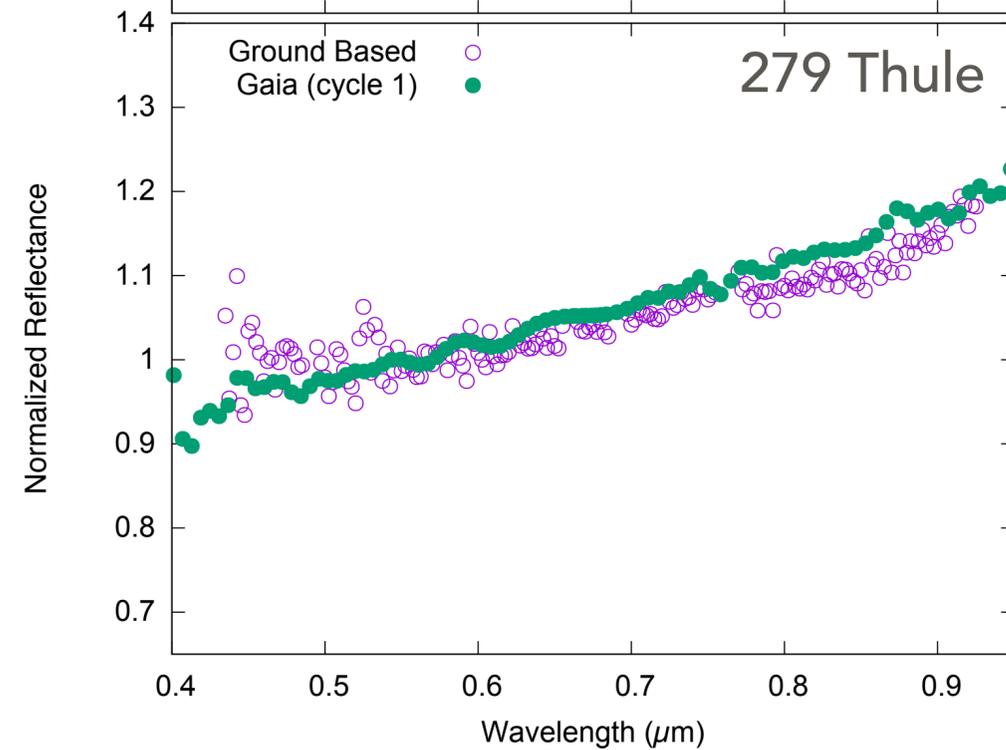
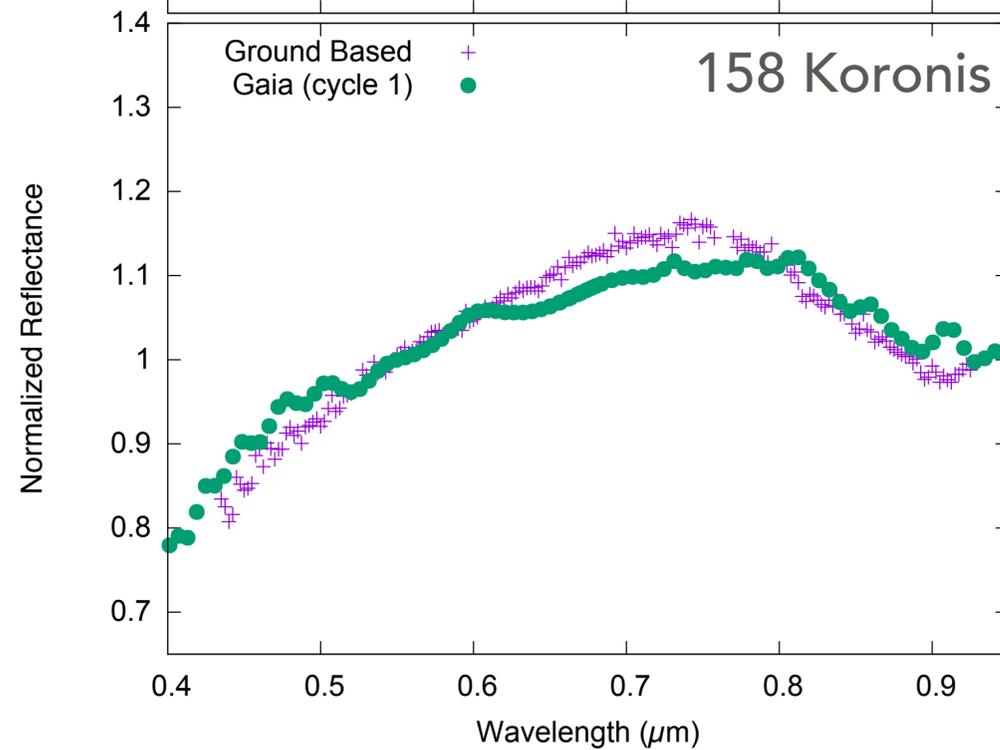
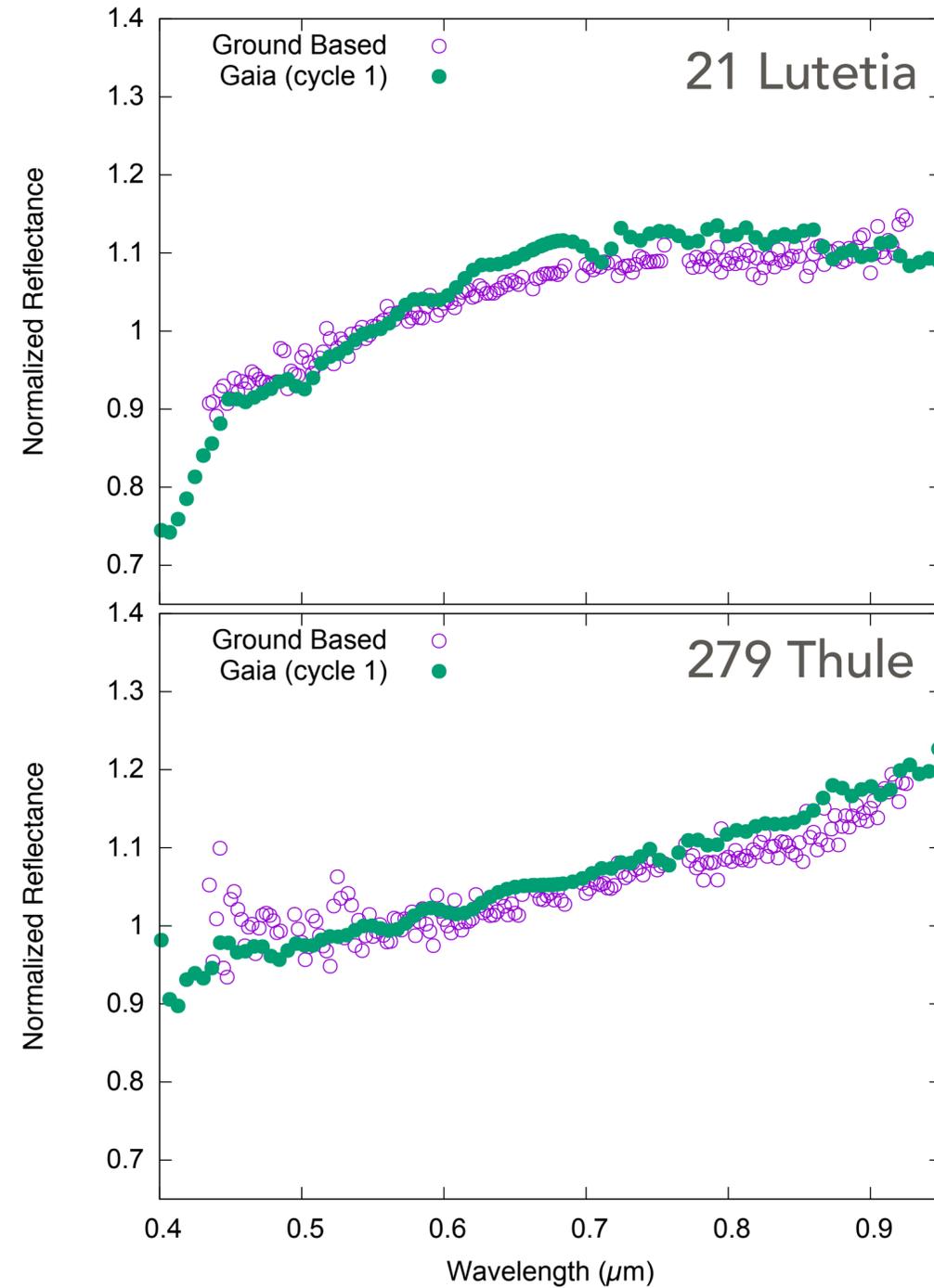
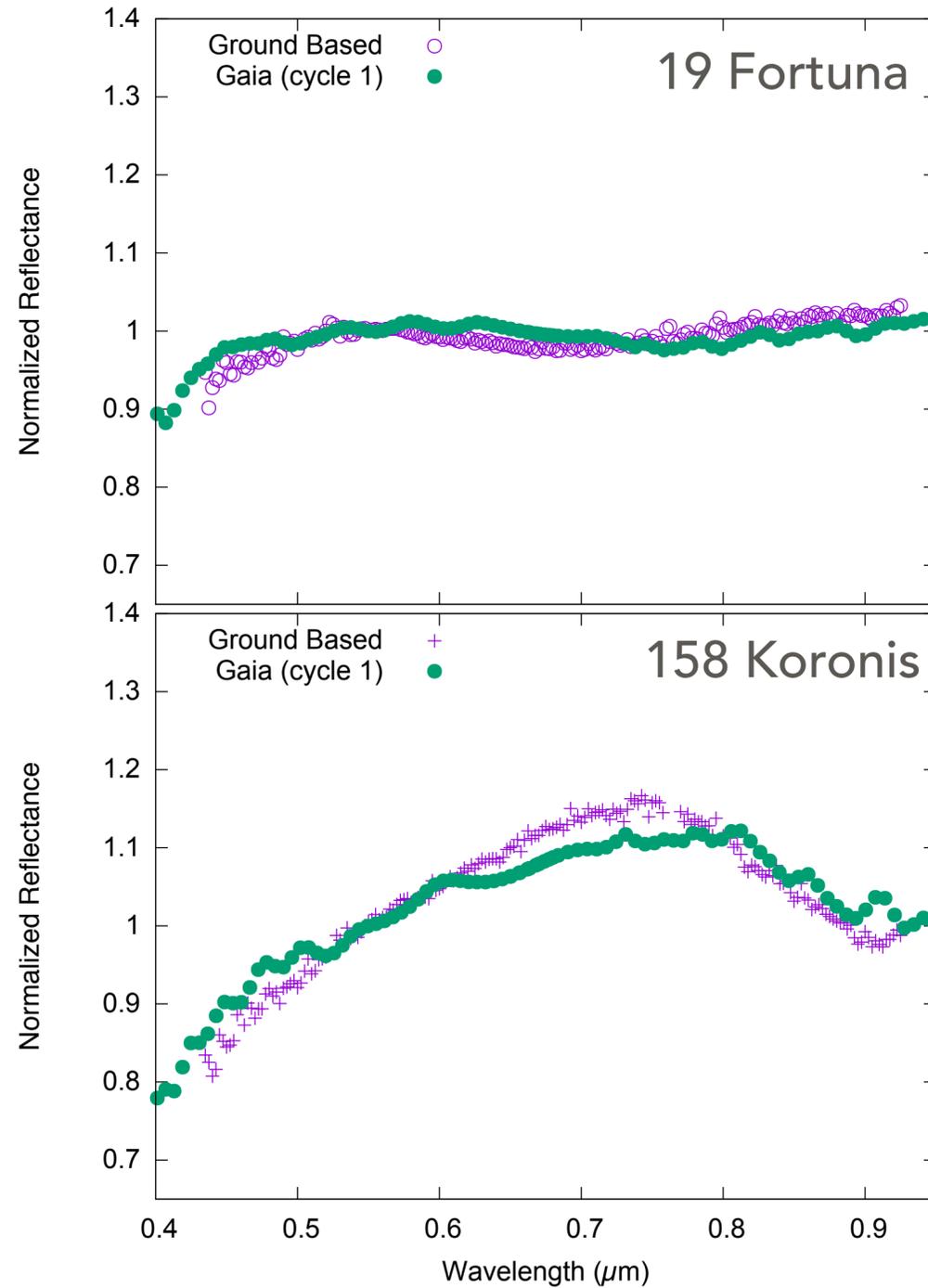
The contribution of Gaia on physical properties

- 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)

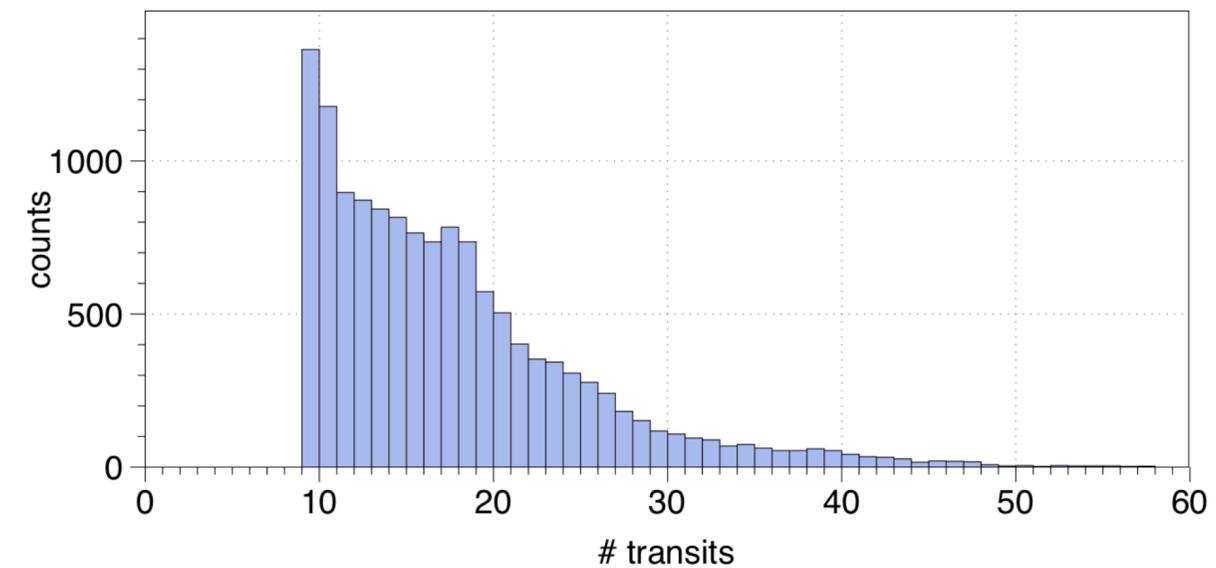
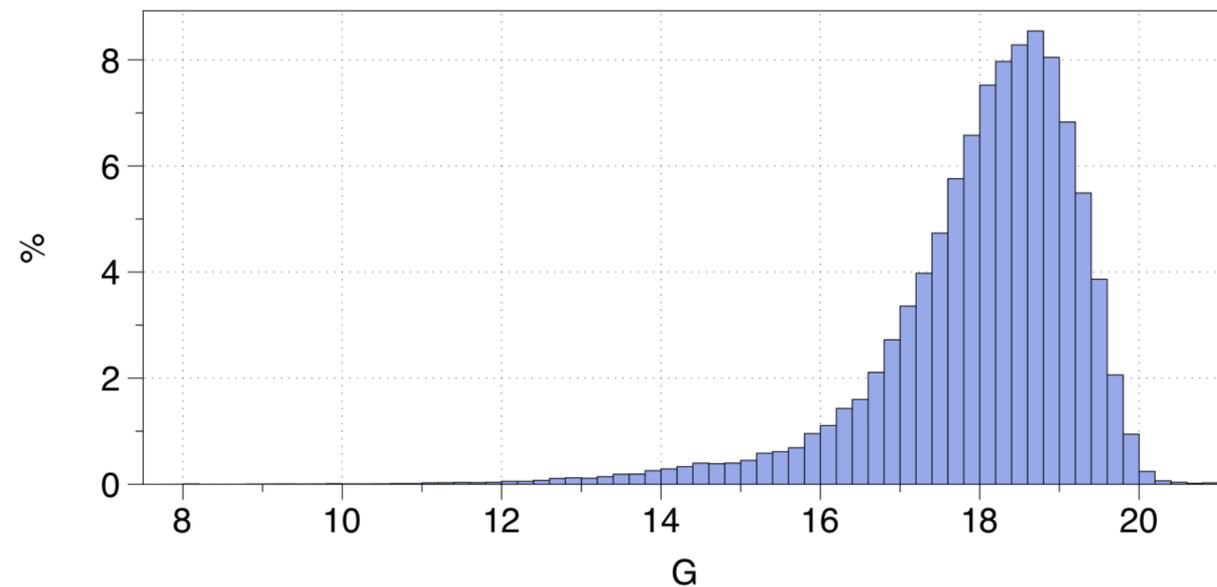
Content:

- 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

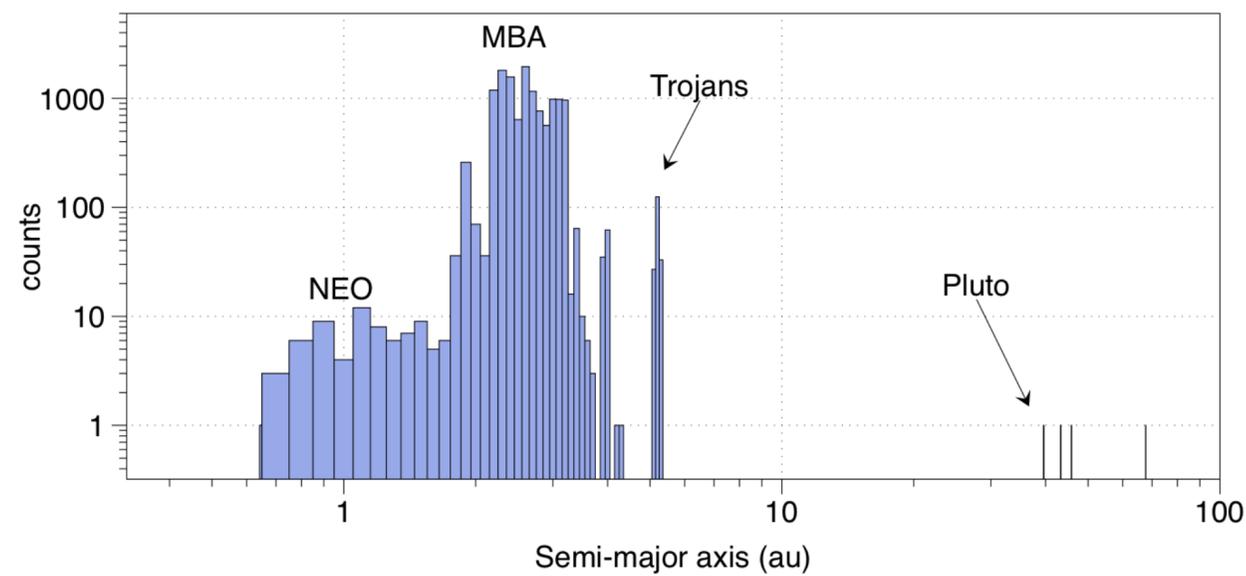
Processing and scientific validation - main contributors:

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)

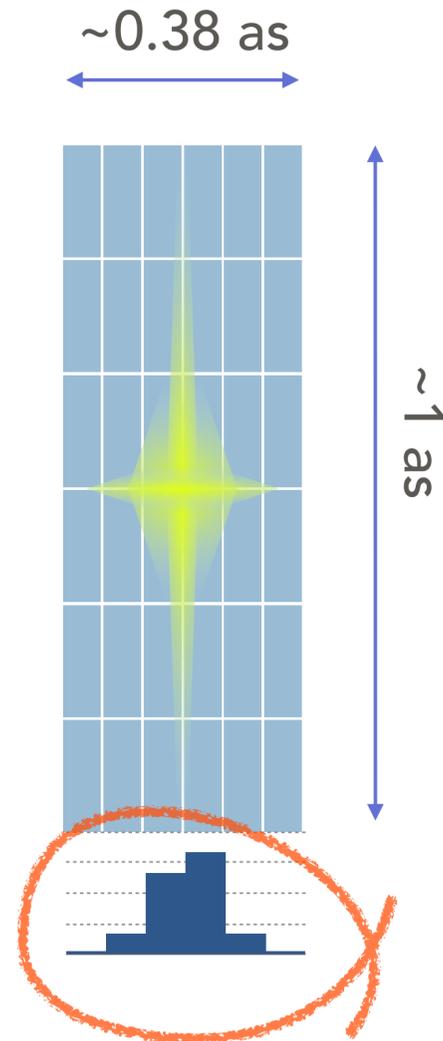


F. Mignard, OCA

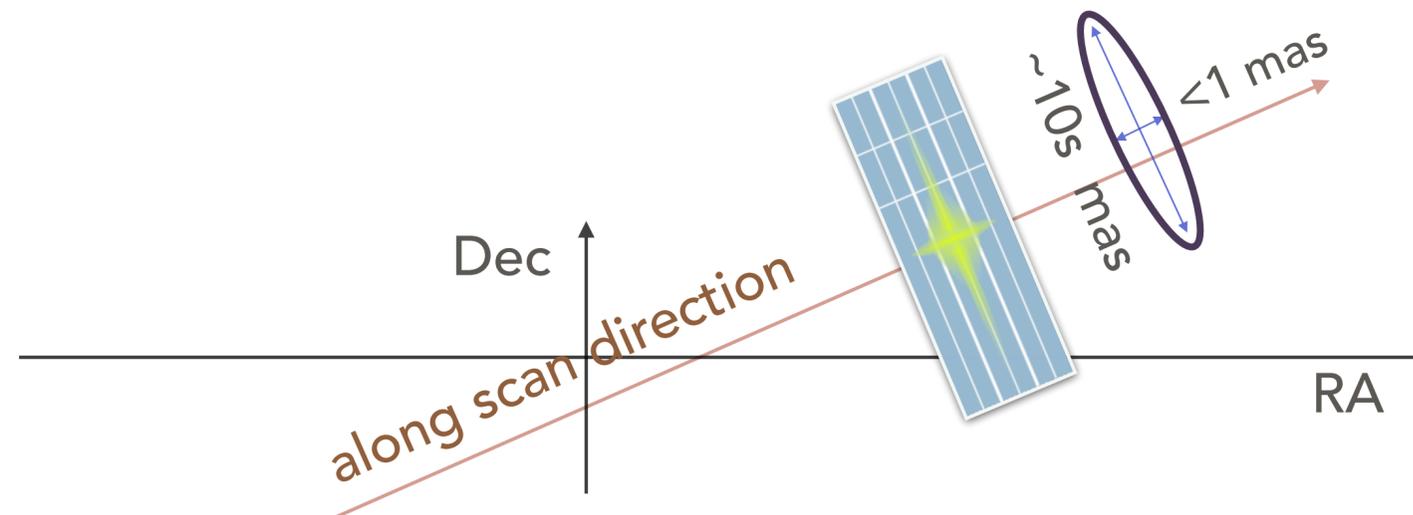


- “bright” asteroids having more than 9 transits
- selected objets have all of their transits included
- 13,400 asteroids (195,000 transits)

Be prepared: some warnings

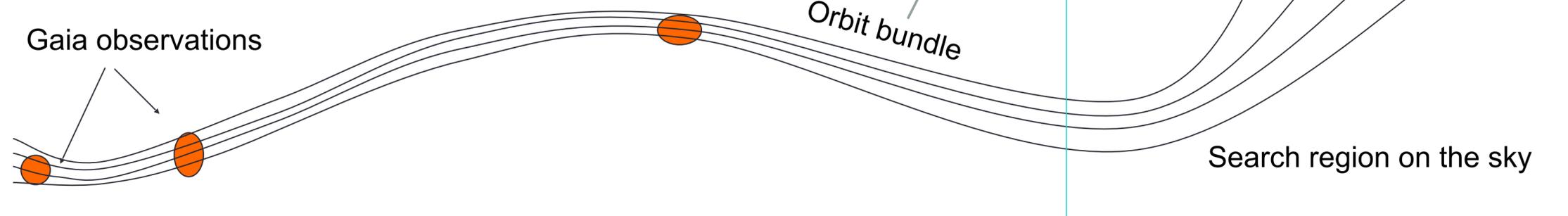


- Tools must be ready to handle accuracy ~ 100 X better
- difficulties in exploiting existing archive observations (reduced with biased catalogues)
- Highly correlated (RA, Dec) epoch positions
- Fundamental for asteroids!

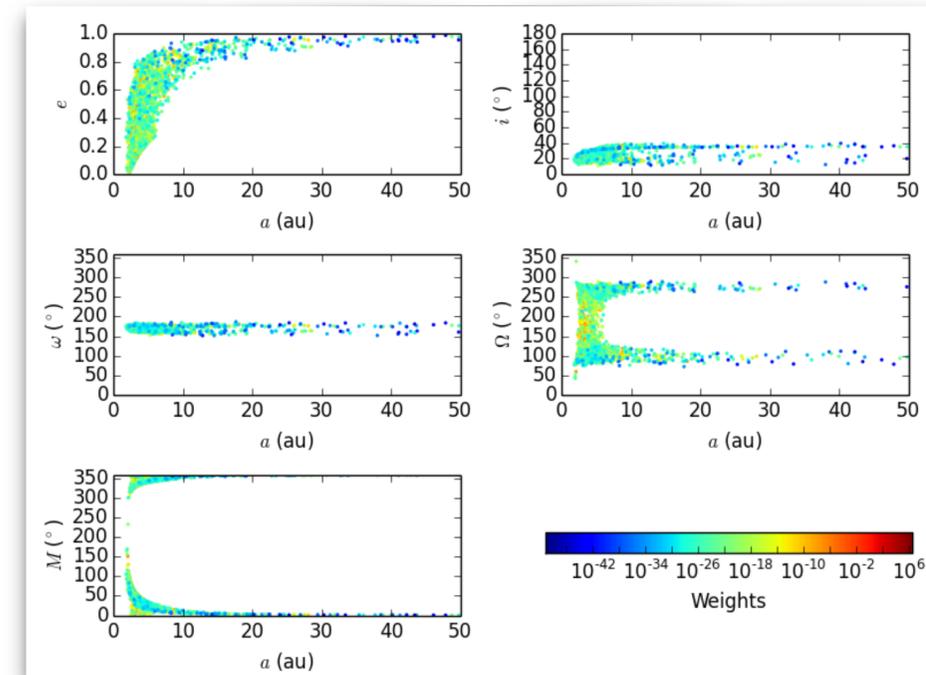


Asteroid alerts

- 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)



Tanga et al. 2016



K. Muinonen, G. Fedorets, Helsinki Univ.

Diffusion of asteroid alerts

Gaia Follow-Up Network for Solar System Objects

Goal
 The Gaia Follow-Up Network for Solar System Objects (Gaia-FUN-SSO) has been set up in the framework of a task (TS 1004) of the Collaboration Unit 4 (Object processing) of the DPAC Gaia consortium. Its goal is to coordinate ground-based observations on alert triggered by the data processing system during the mission for the confirmation of newly detected moving objects or for the improvement of orbits of some critical targets. Gaia will scan the sky following a pre-defined scanning law and such ground-based observations are required to avoid the loss of newly detected Solar System objects and to facilitate their subsequent identification by the probe.

These pages provide an access to the alerts, including the ephemeris to help finding the targets, for the registered members of the Gaia Follow-up network. The network currently (September 2015) consists in 50 observing sites, spread all over the world.



Workshops
 Three Gaia-FUN-SSO workshops dedicated to the astrometric follow-up of the Solar System Objects have already been organized in 2010, 2012 and 2014 in Paris Observatory. Discussion has been held about this network and the tasks to be accomplished, the capabilities of the observing sites and the preliminary actions already performed.

- Proceedings of the 2010 workshop have been published and can be freely downloaded from the workshop web site.
- Proceedings of the 2012 workshop have been published. These proceedings and the talks are accessible on the workshop web site.
- Proceedings of the 2014 workshop have been published. These proceedings and the talks are accessible on the workshop web site.

Registration
 To get a full access to these pages and to share data, you need be registered as active participant of this observing network. For this registration, please use this form. This network needs to have a large geographical coverage: if you are interested, do not hesitate to contact us!
 © Please report bugs here in project "Gaia-FUN-SSO", or contact us at gaia-fun-ss@imcce.fr.

<http://gaiafunssso.imcce.fr>

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

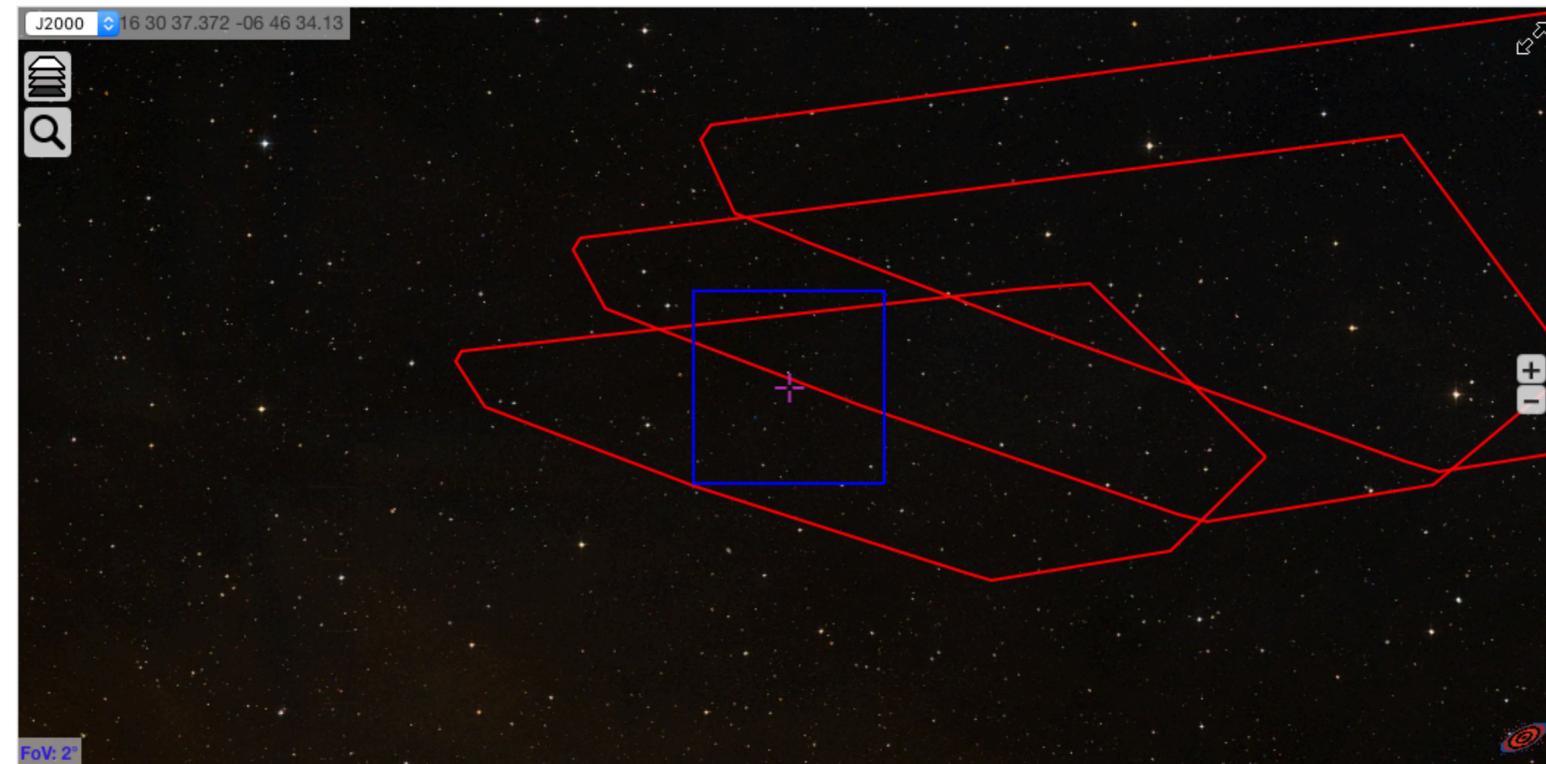
Register and contribute!

List of active alerts

Selected alerts: 3/12

ID ▲▼	Begin ▲▼	End ▲▼	V _{mag} ▲▼	RA ▲▼	Dec ▲▼	Area ▲▼	Name ▲▼	Report	Details
28741	2017-04-06	2017-04-15	19.94	141.533	-14.3815	0.41116	g1N00a		
28355	2017-04-04	2017-04-13	19.95	143.6757	-11.9679	0.72448	g1N002		
28125	2017-03-29	2017-04-15	20.13	142.9194	-22.5203	0.29496	g1M008		

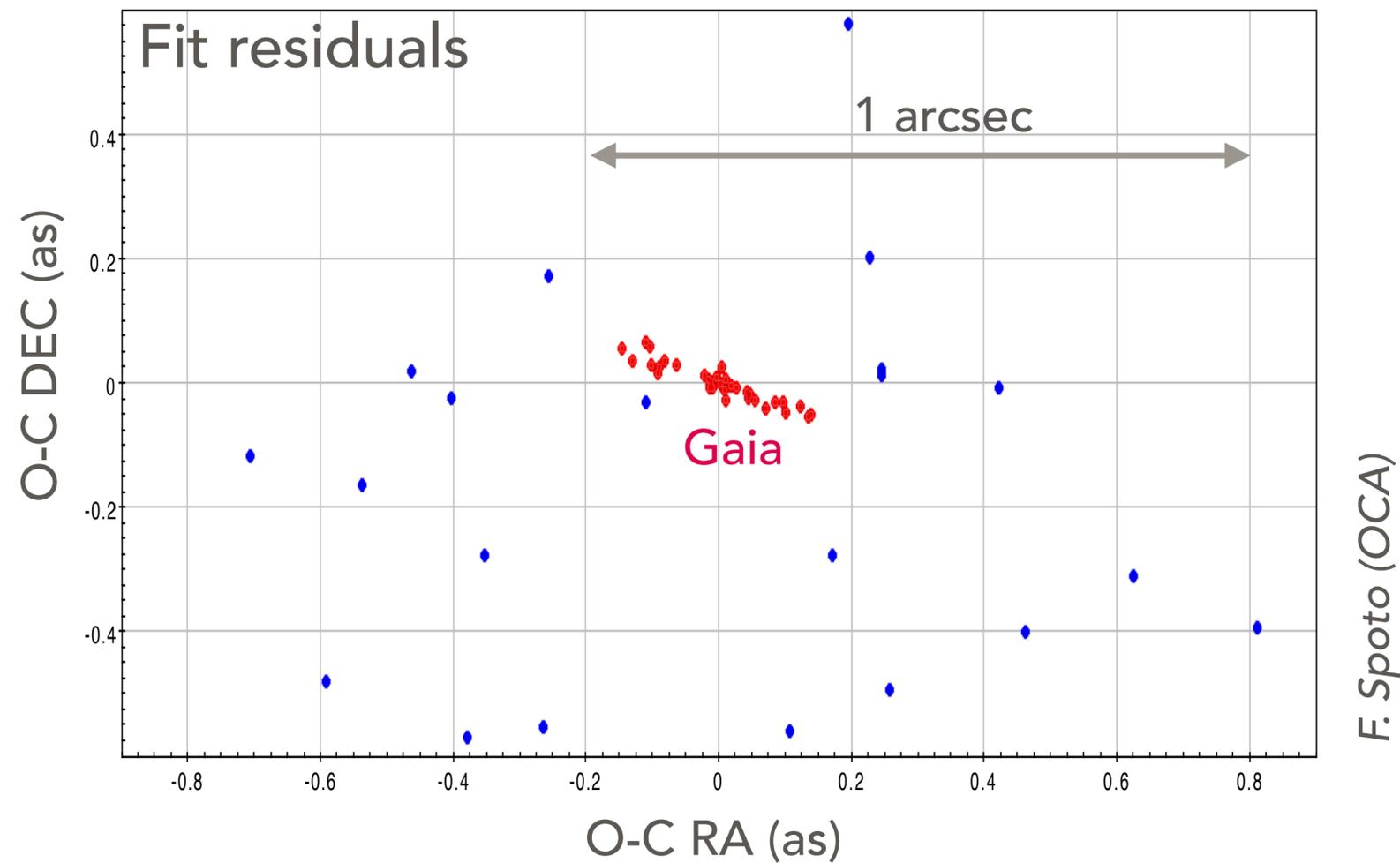
Sky view with Aladin -- Object expected magnitude $V = 18.4^{+0.6}_{-0.3}$



Footprints of areas to search for (in red) and the field of view (in blue, 15x15 arcmin²) of your device (OHP). You can change your device and its parameters in your settings.

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

