Asteroid astrometry in the Gaia era

How Gaia observations are changing our view of asteroid astrometry

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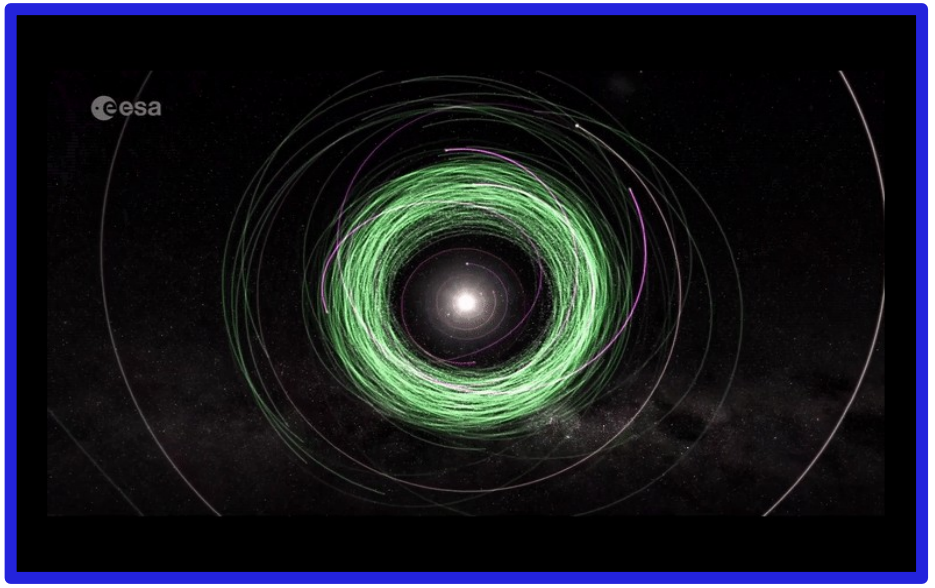
ESA/ESTEC[3]

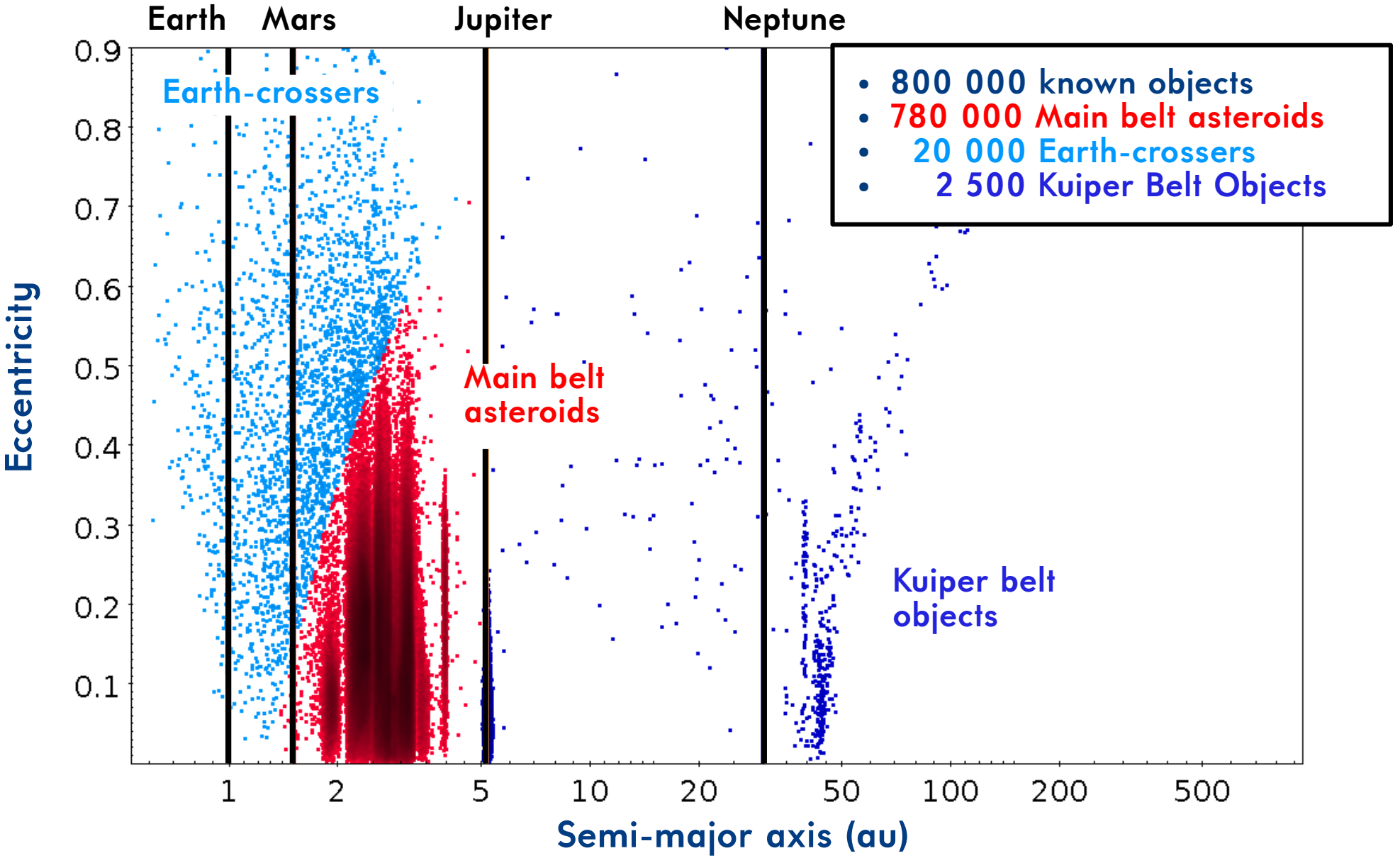


Asteroid in our Solar System observed by Gaia

Visualization: Gaia Sky

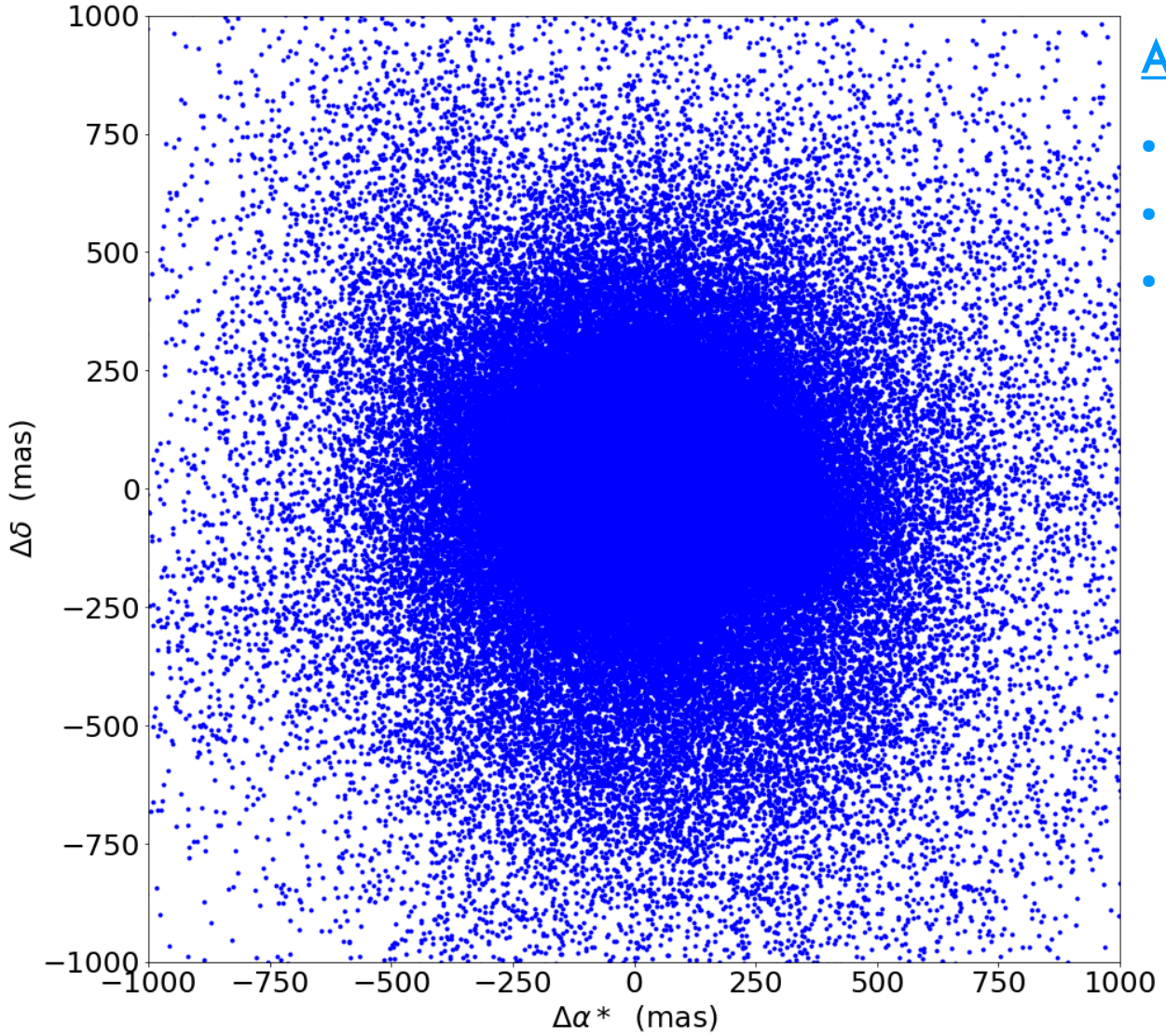
"Journées 2019:
Astrometry, Earth Rotation and Reference Systems in the Gaia era"
Paris, 7/10/2019

Our knowledge of the asteroid population



Typical asteroid observation residuals

Post -fit residuals on the sky : Observed - Computed



Available ground-based astrometry

- **200 millions** of observations
- Typical accuracy: **400 / 500 mas**
- **2 000** accurate observations (mostly radar)

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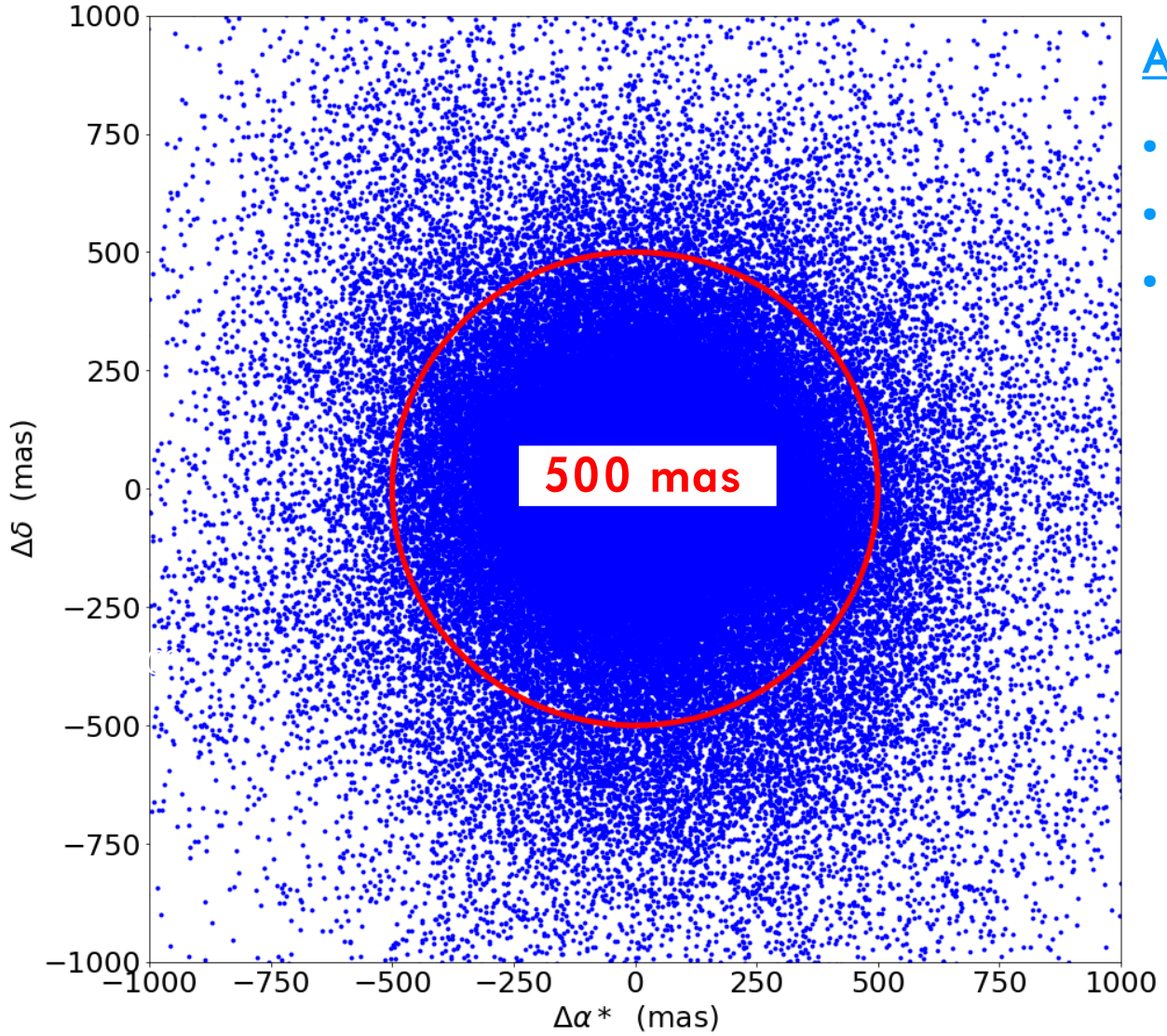

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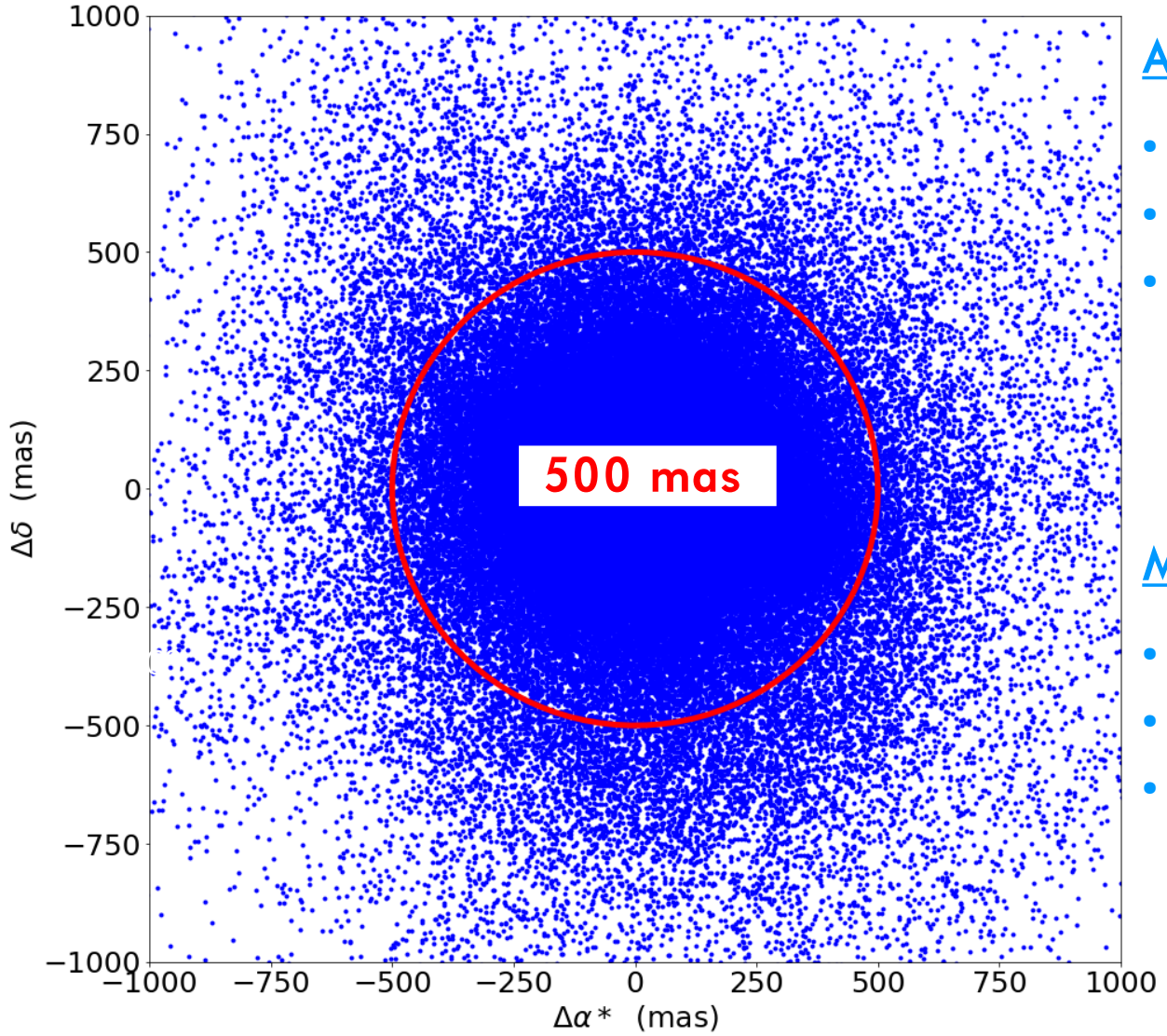

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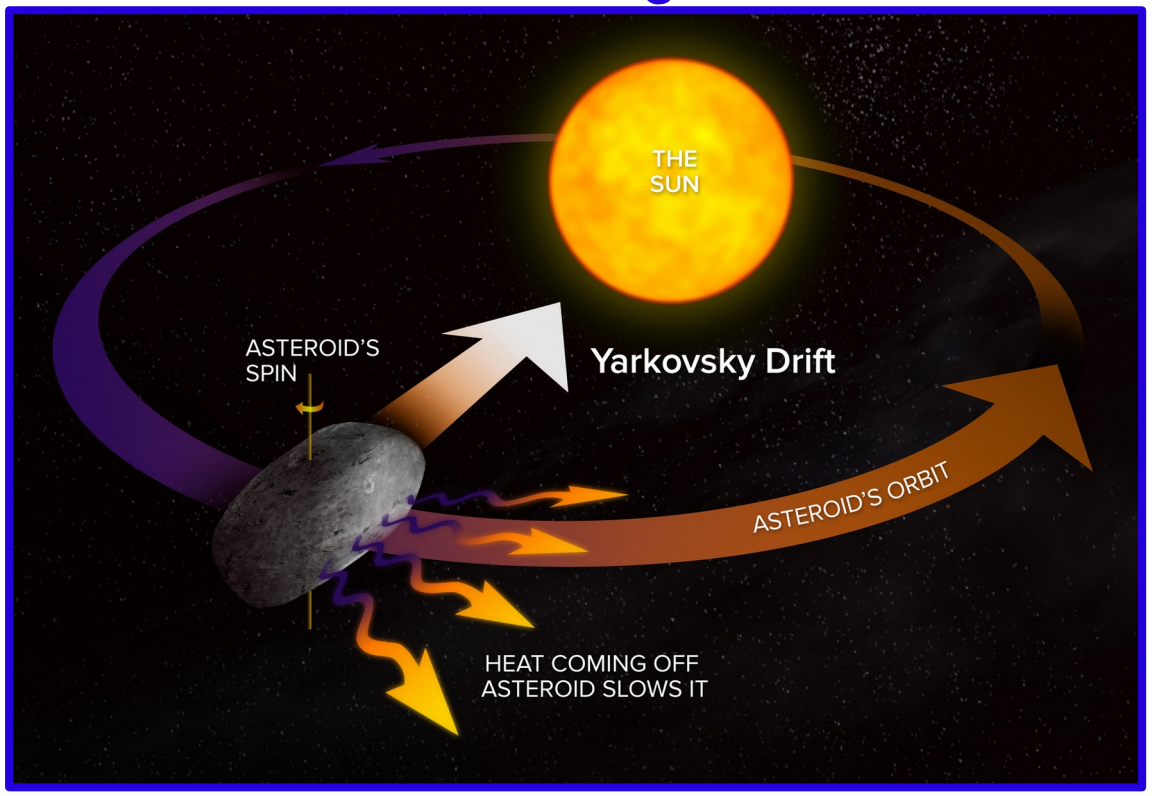
Main consequences

- **Orbital elements : large uncertainties**
- **Poorly known orbits**
- Observations focused **on NEAs**

Why do we need good astrometry ?

The Yarkovsky effect



Description

- Subtle **non-gravitational** perturbation
- Resulting from the **anisotropic thermal emission** of the solar radiation
- Dependence on **physical parameter** usually unknown

Consequences

- **Secular semi-major axis drift**
- Necessary to **understand** the **evolution of our Solar System**
  - **Collisional history**
  - **Delivery of NEAs from the Main Belt**

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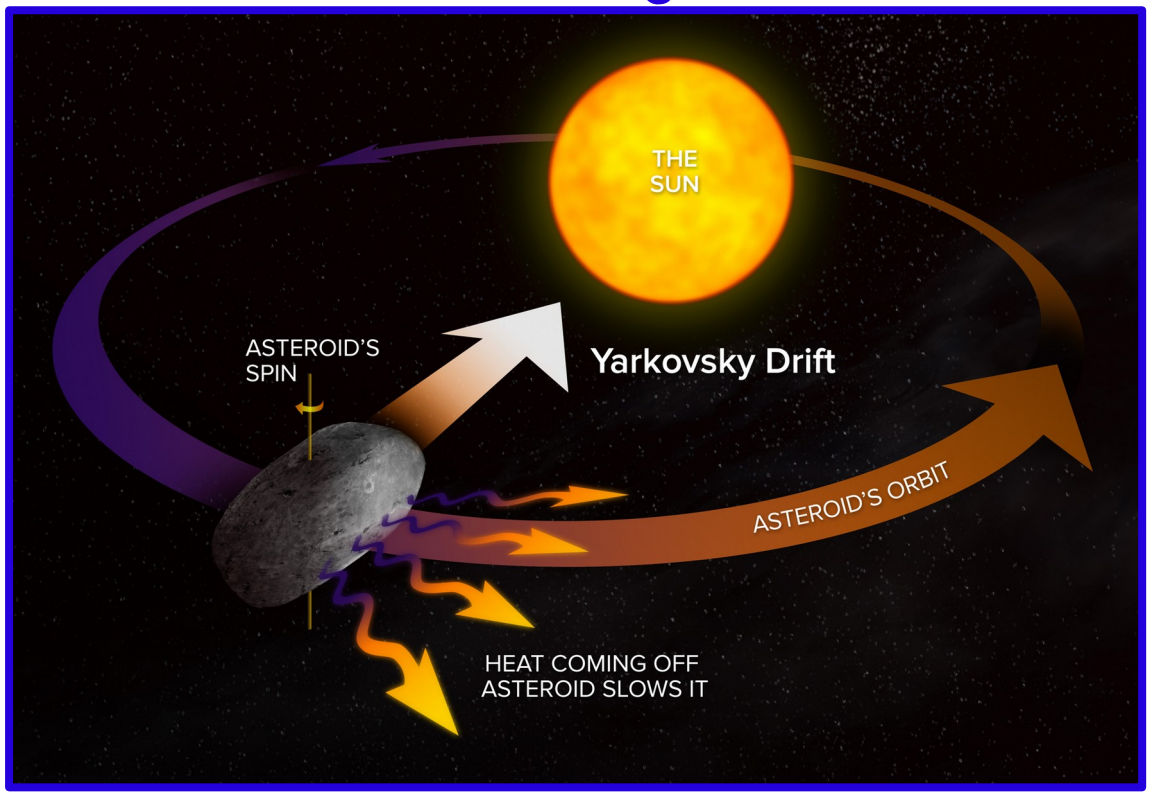

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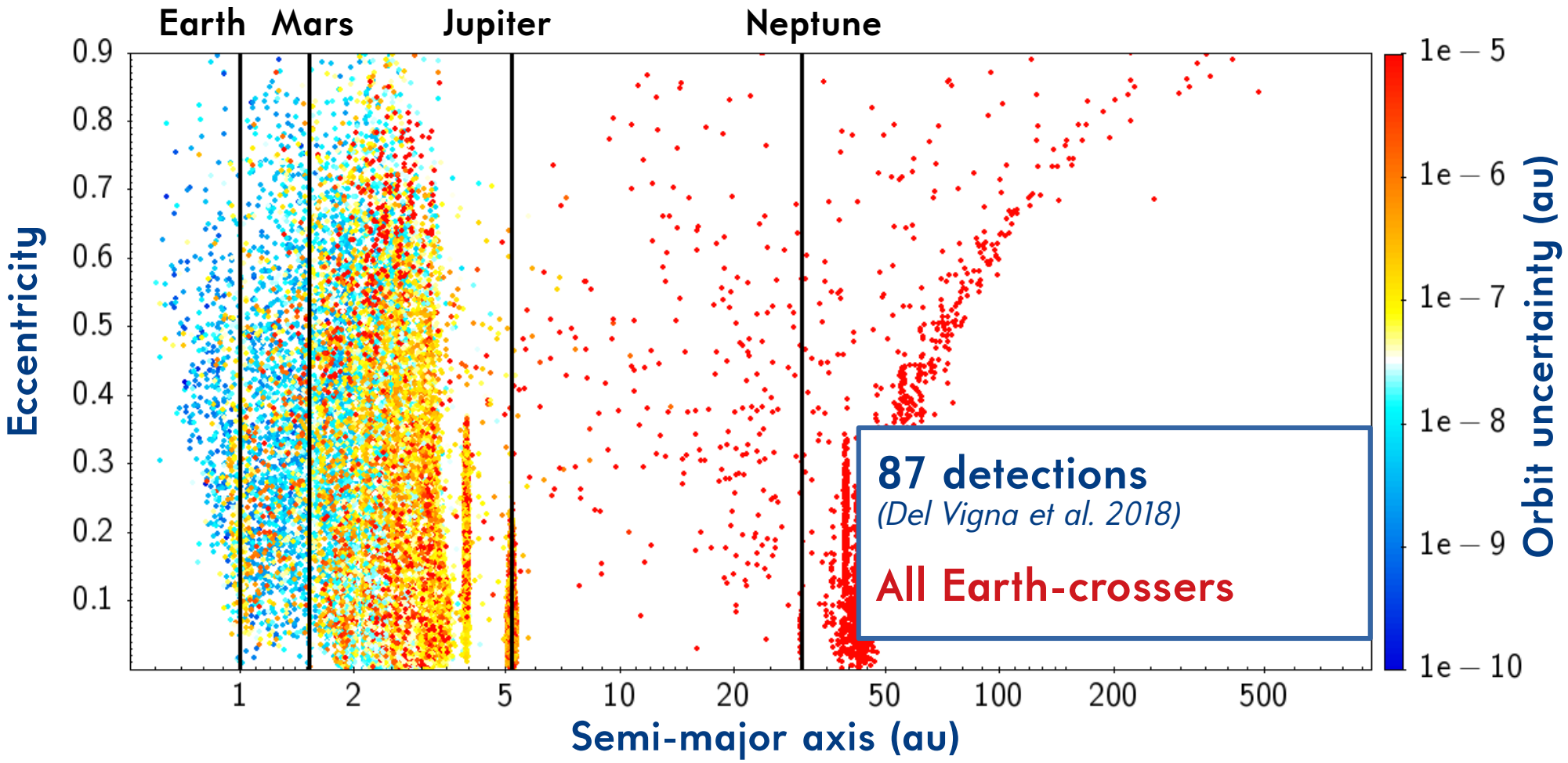
Detections

- **Detected from the astrometry:** least-square orbit determination (6 orbital elements + Yarkovsky parameter)
- **Very accurate orbits & long time span**
- **Small objects** (proportional to 1/D)

Yarkovsky detections (before Gaia)

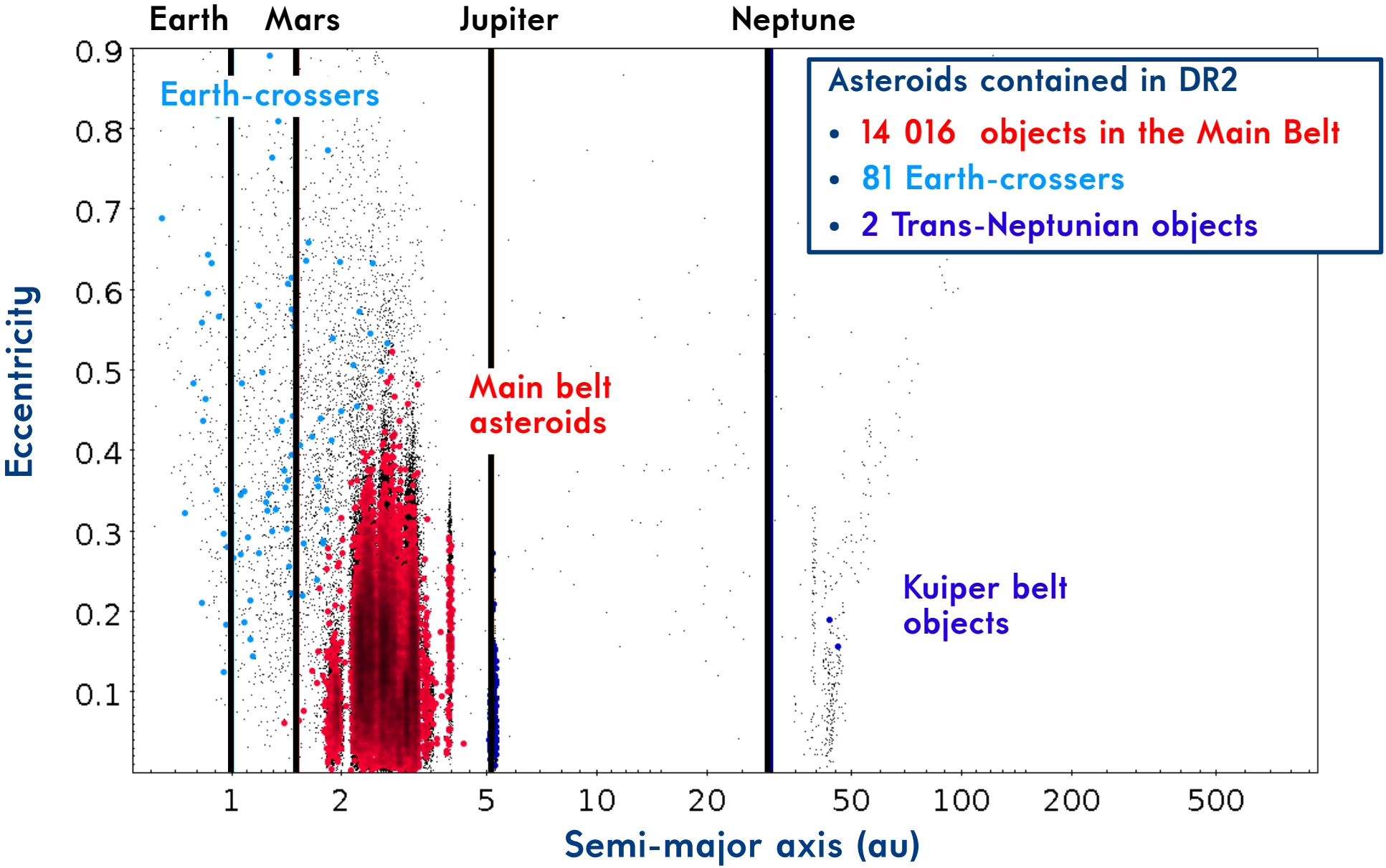


800 000 asteroids

900 small with « good » orbits
uncertaintity < 3e-9 au (~ 450 m)

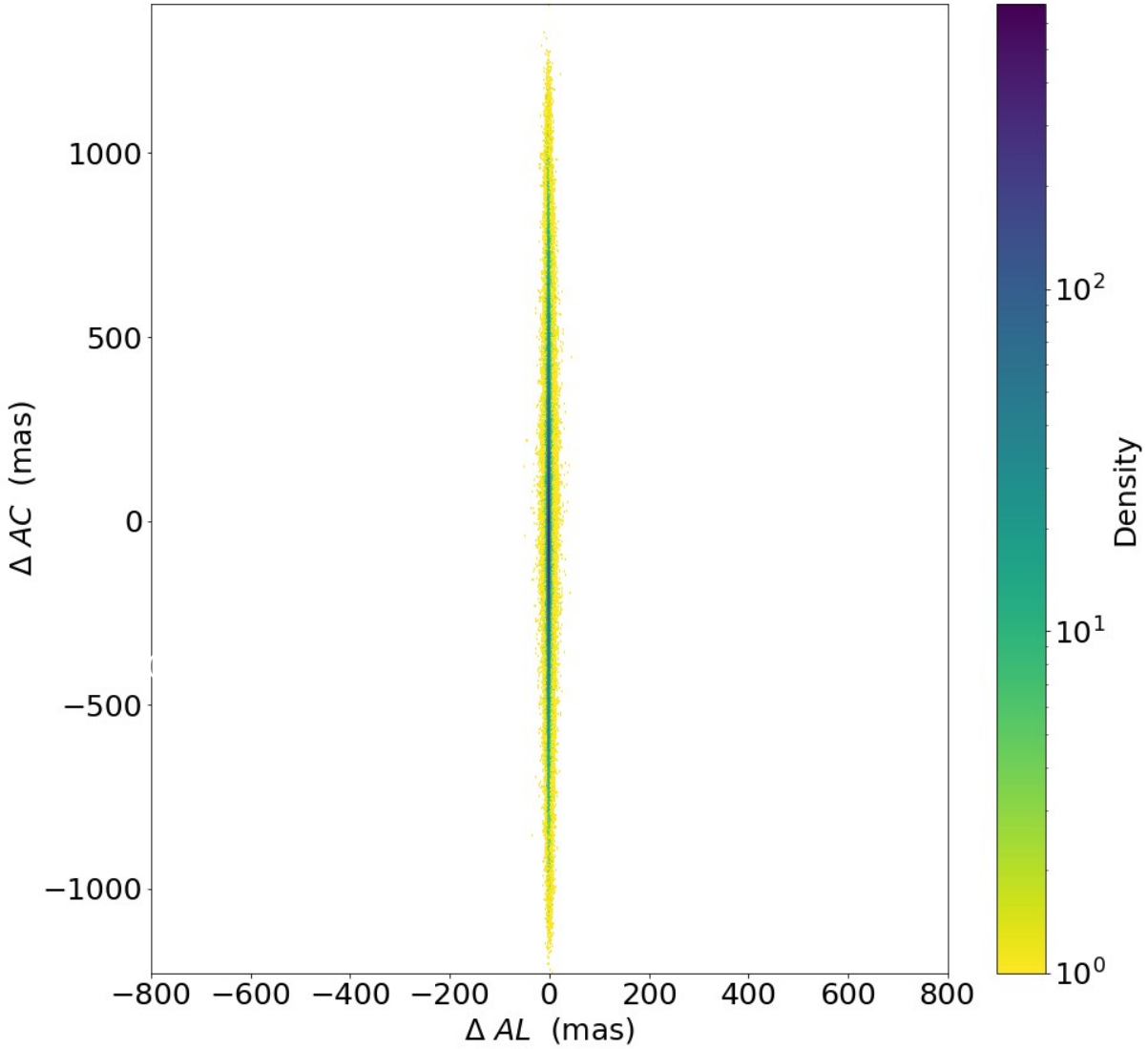
No Main Belt asteroids

Gaia Data Release 2



Gaia DR2 asteroid observation residuals

Post -fit residuals in the **ALong** scan – **ACross** scan **plane**



Gaia asteroid astrometry

- ~ **2 millions** of observations
- 22 months
- Accuracy is in the **ALong** scan direction

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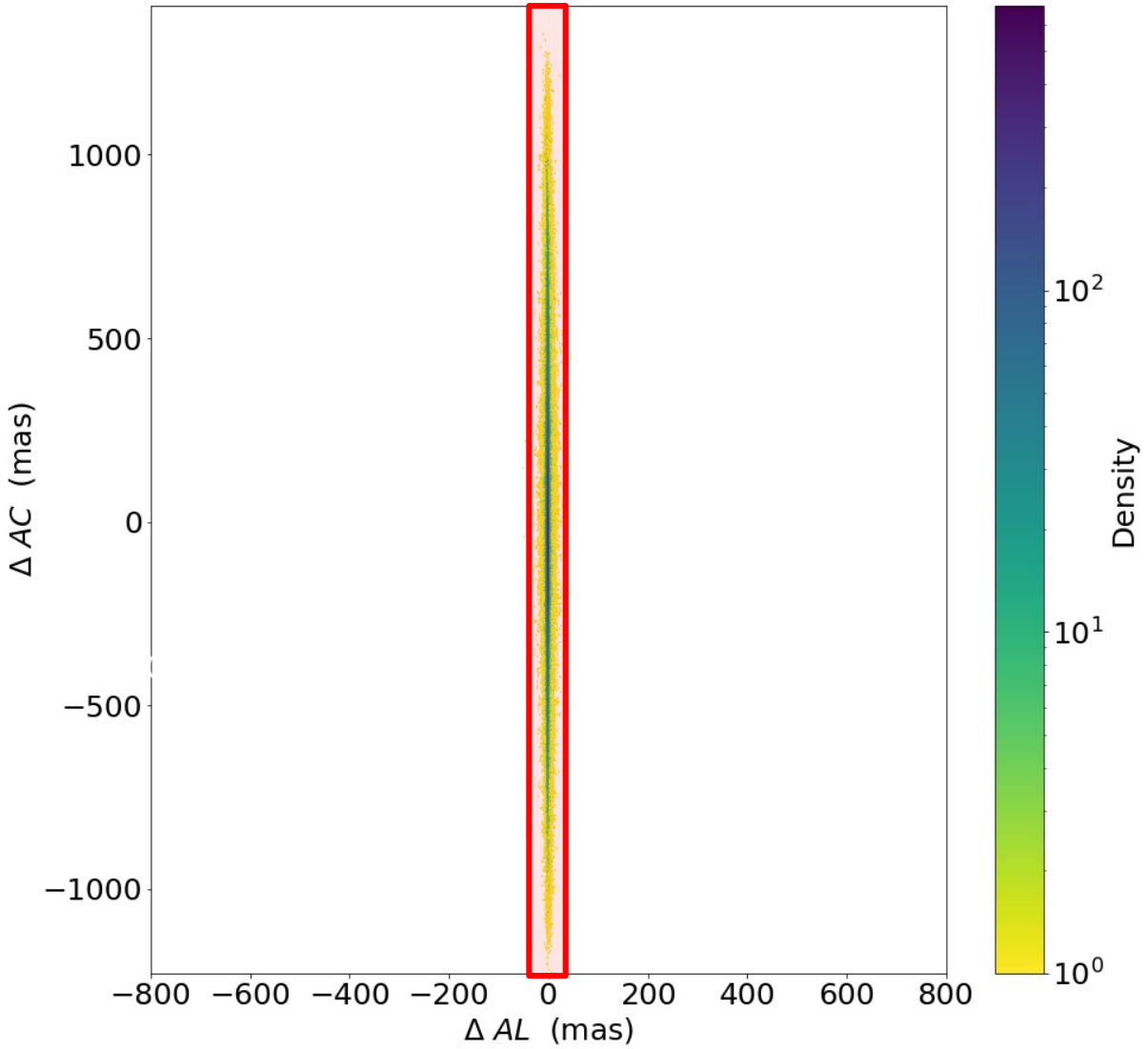

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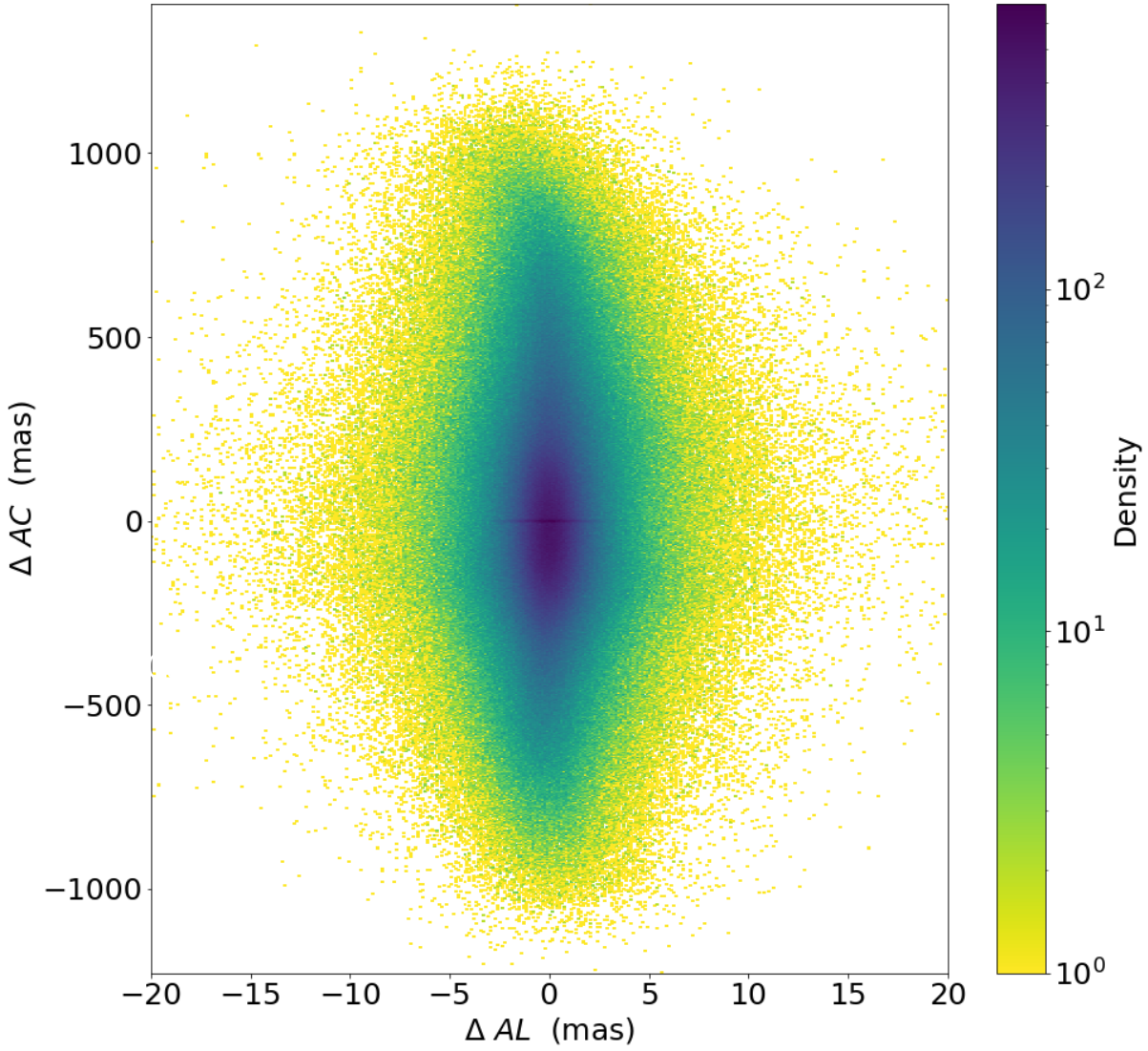

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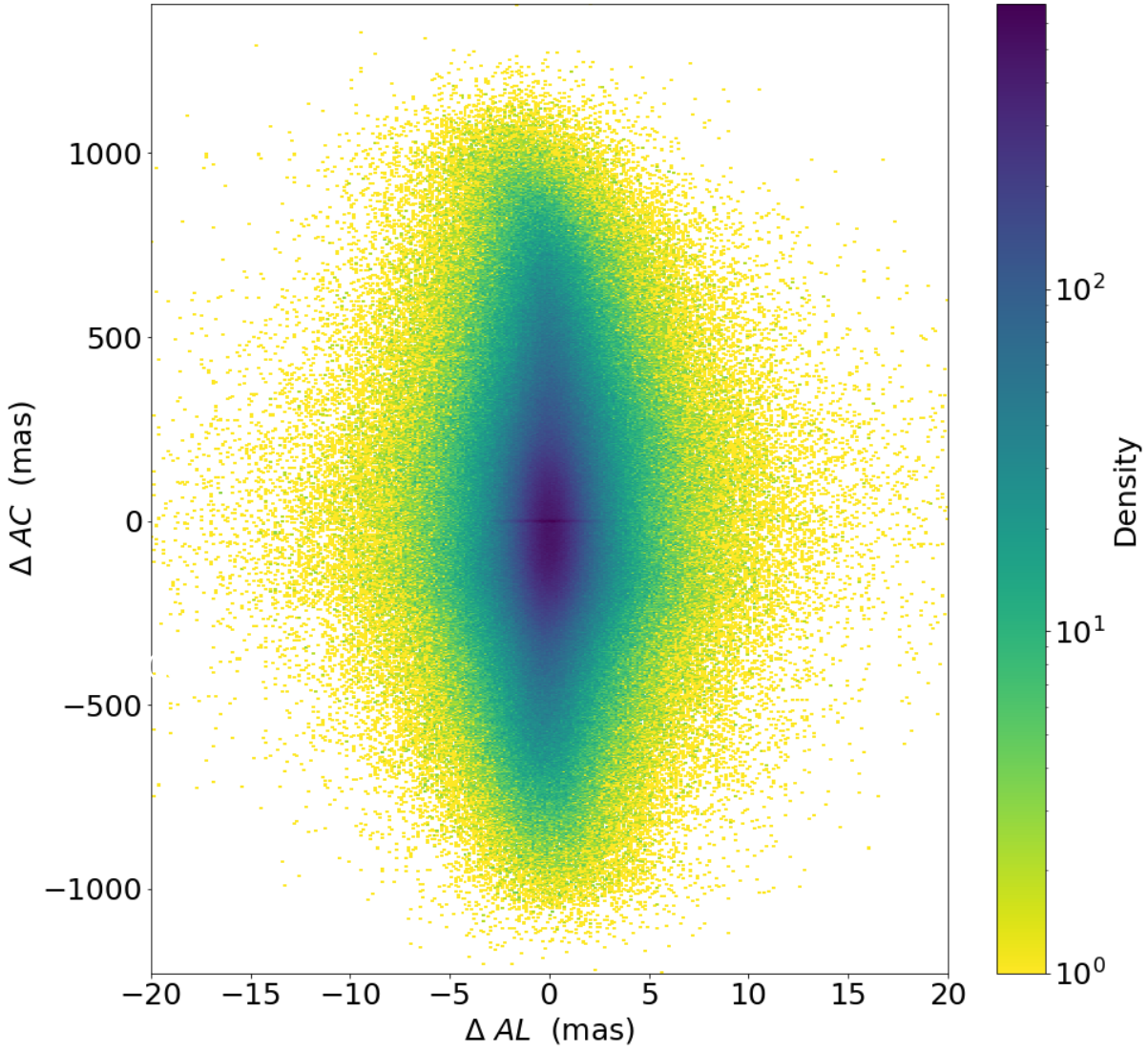

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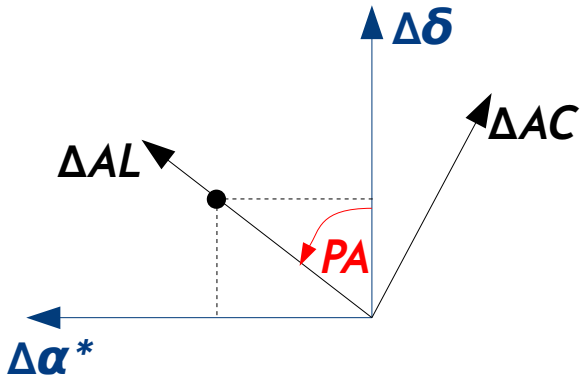
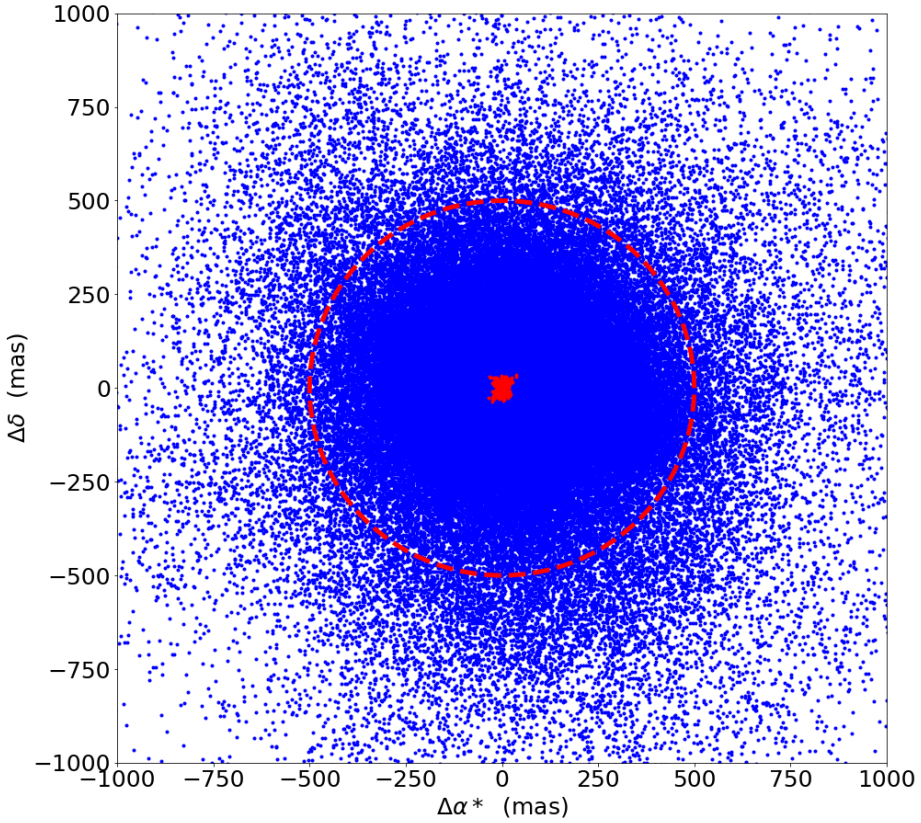
How can we make a comparison between Gaia and ground-based astrometry ?



Gaia DR2 vs ground-based asteroid astrometry

Post – fit residuals on the sky



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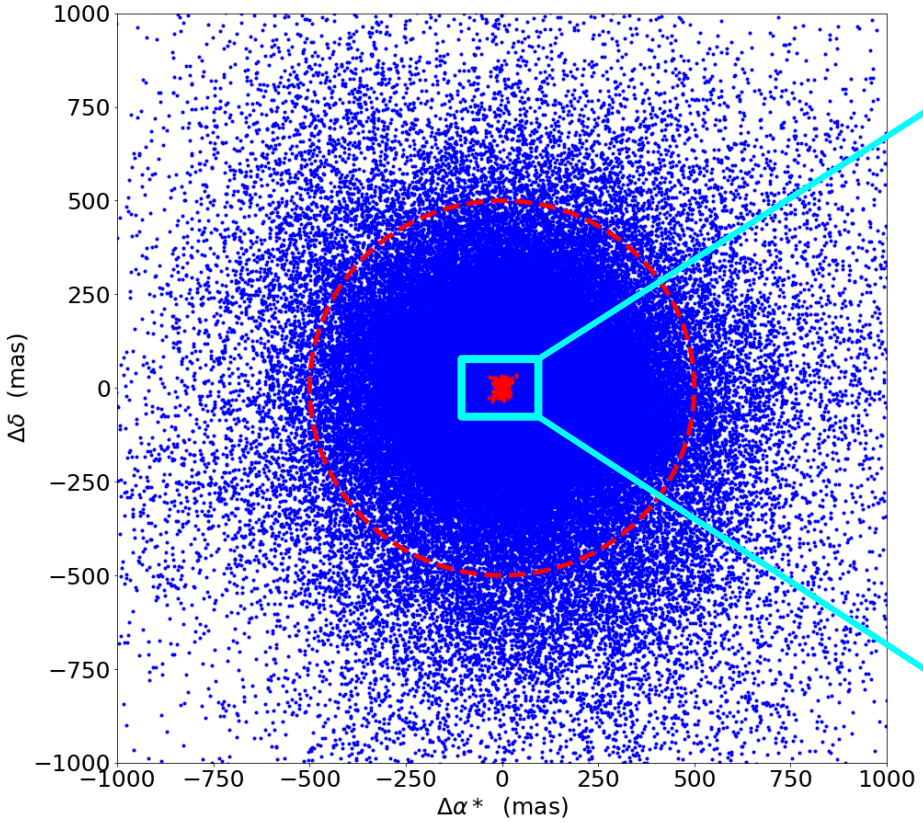
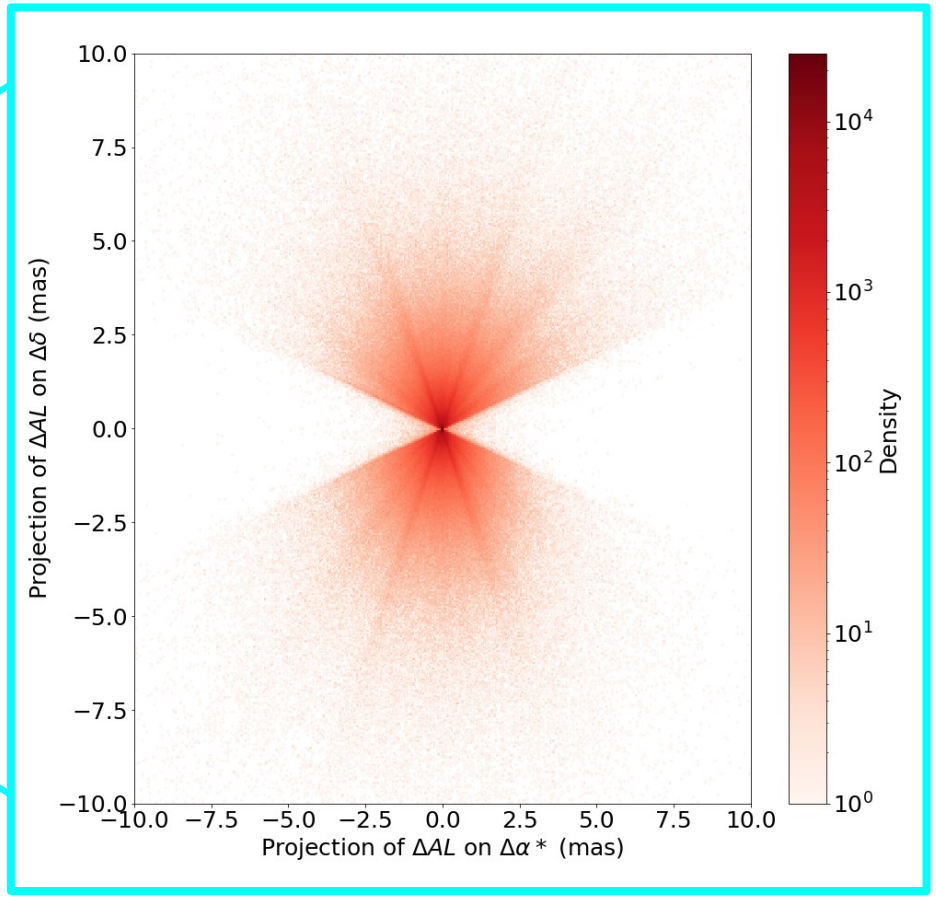
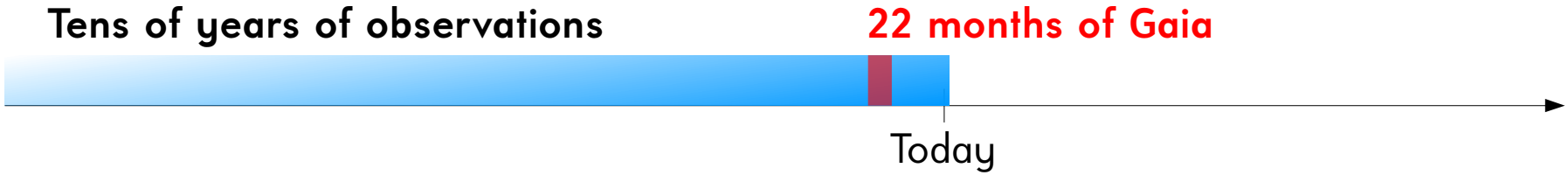




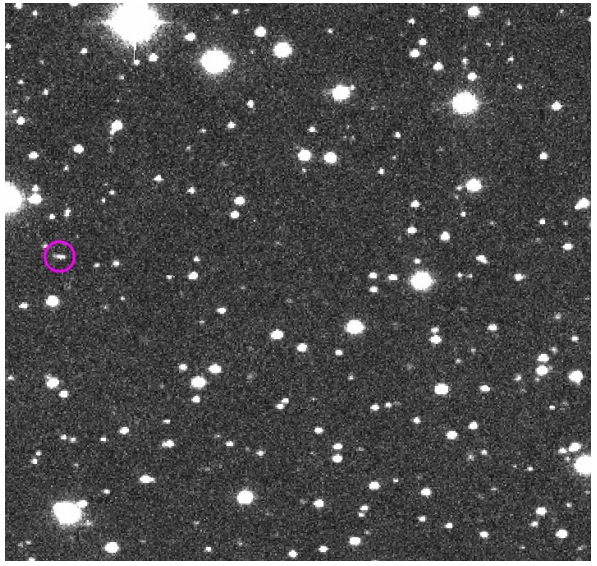
Main « issues » :

- 2 millions of very accurate observations
- New vision of asteroid astrometry
- Short observational arc

How to combine Gaia and ground-based observations?



1. Debiasing of old stellar catalogs



Discovery observations of the asteroid 2014 AA

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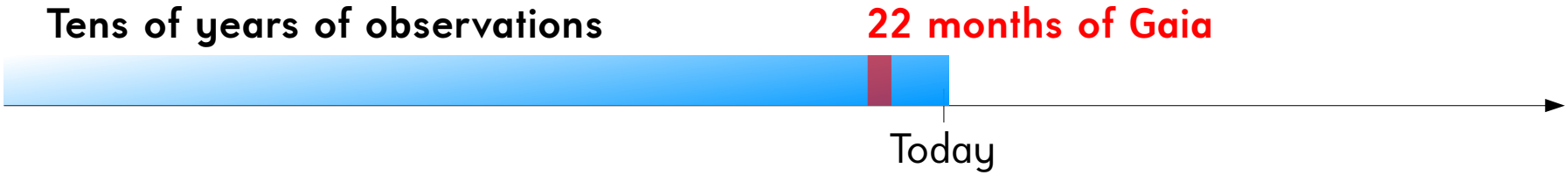

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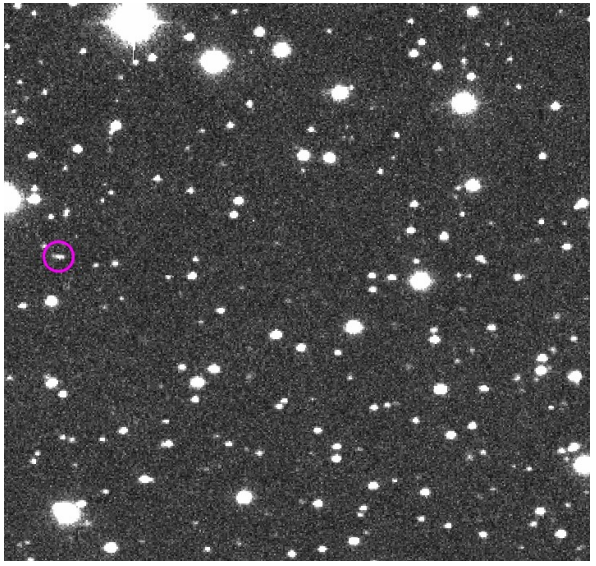


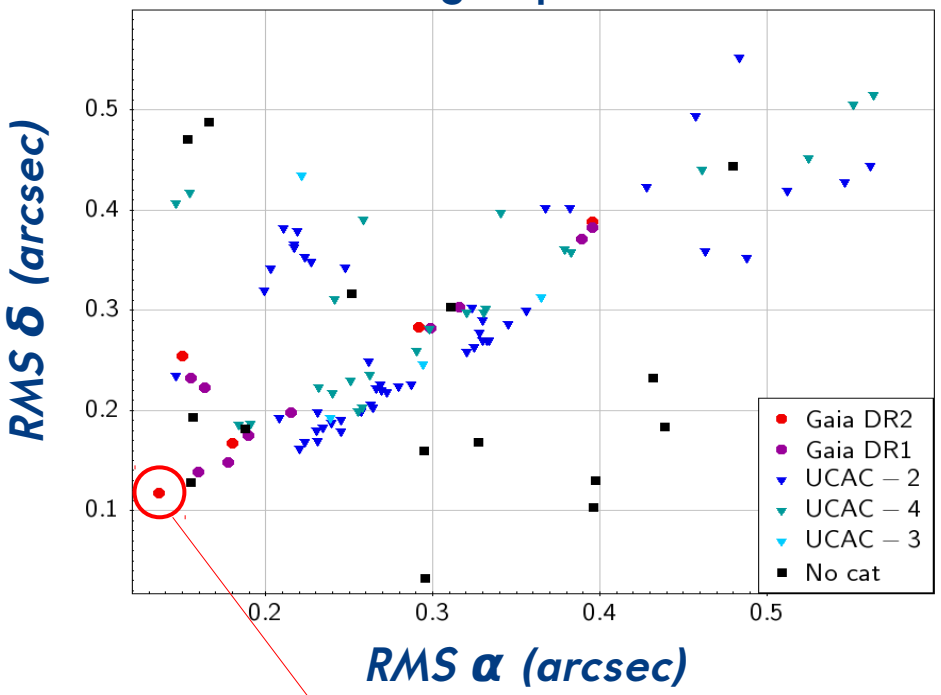
Discovery observations of the asteroid 2014 AA

Next talk : Paolo Tanga

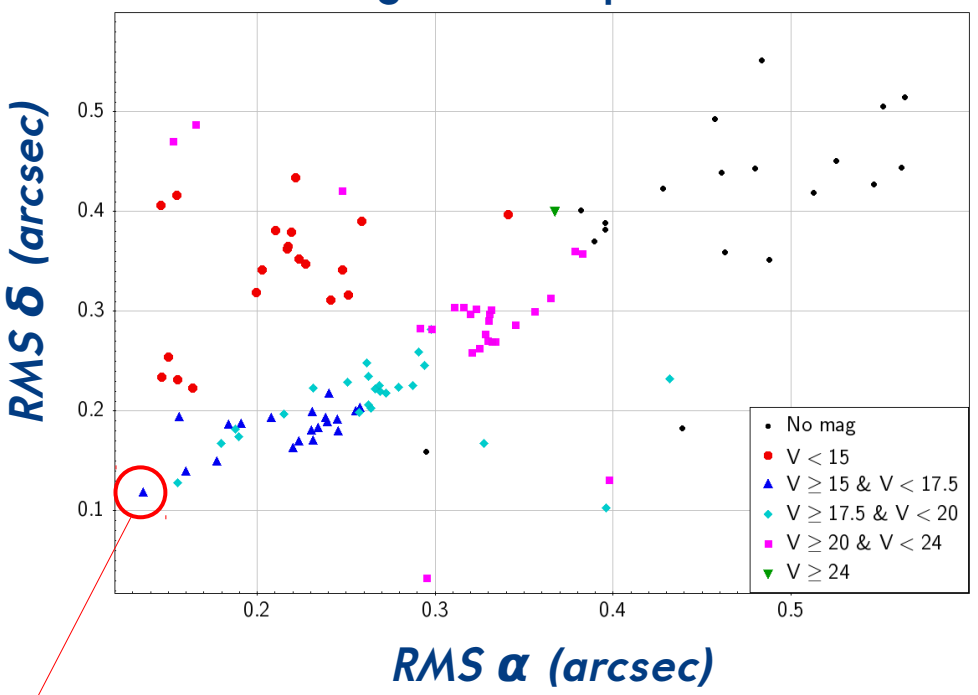
How to combine Gaia and ground-based observations?

2. Error model : weights to give to each observatory

Catalog dependence



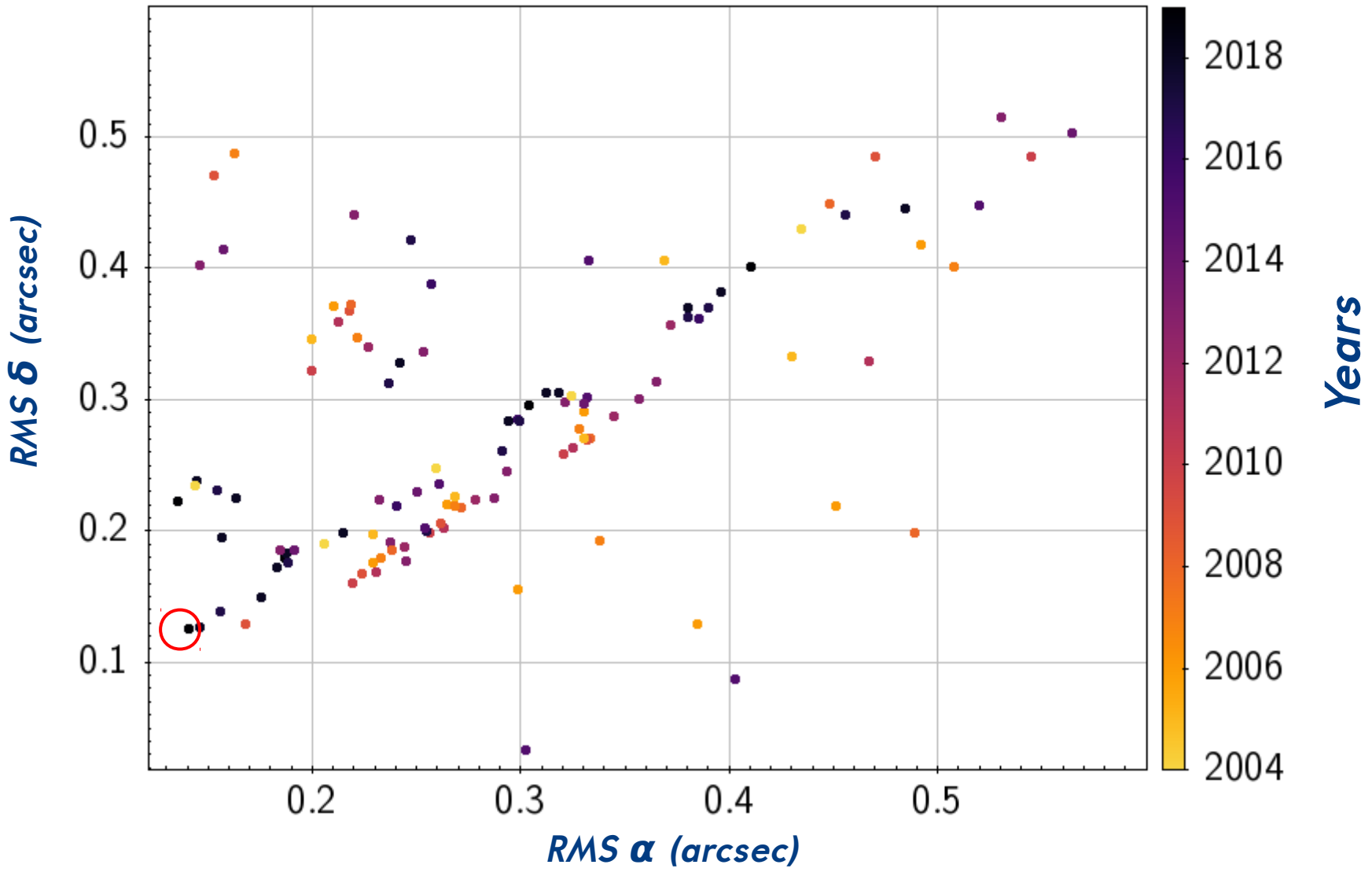
Magnitude dependence



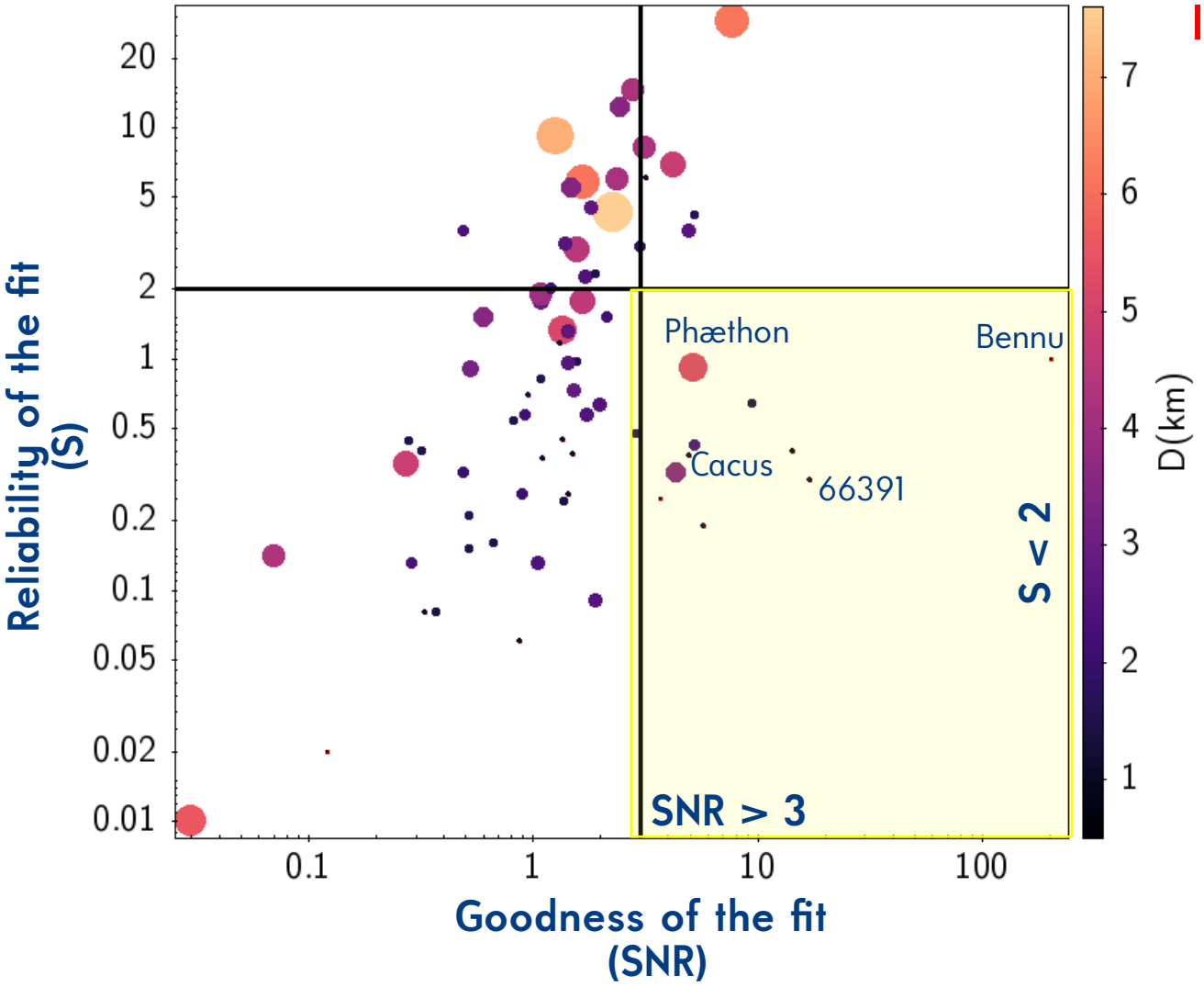
(Observatory, year, catalog, magnitude class)
(G96, 2019, V, 2)

How to combine Gaia and ground-based observations?

2. Error model : weights to give to each observatory



Results : new Yarkovsky detections



Initial sample from Gaia DR2

- ~ 60 objects
- Diameter < 10 km
- Orbit uncertainty < 1 km

Detections

- 10 new + densities
- Cases not possible before Gaia

Conclusions

- Gaia has already changed our view of the asteroid astrometry
- Our knowledge of the Main Belt is still very limited:
  we are missing quantity and quality
- We are on the verge of a revolution : Gaia is producing ultra-accurate astrometry for millions of observations
- We need to combined Gaia and tens of ground-based observations to detect subtle non-gravitational perturbations like the Yarkovsky effect
- We have analyzed and corrected all the available astrometry
- The combination has already produced amazing results, but moreover it shows that now we are ready for the next Gaia releases
- To the Main Belt and beyond.