Asteroid astrometry in the Gaia era

How Gaia observations are changing our view of asteroid astrometry

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Our knowledge of the asteroid population

- 800,000 known objects
- 780,000 Main belt asteroids
- 20,000 Earth-crossers
- 2,500 Kuiper Belt Objects
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)
Typical asteroid observation residuals

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- 2000 accurate observations (mostly radar)

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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**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 uncertainty < 3e-9 au (~ 450 m)
No Main Belt asteroids

87 detections
(Del Vigna et al. 2018)

All Earth-crossers
Gaia Data Release 2

Semi-major axis (au)

Earth-crossers

Main belt asteroids

Kuiper belt objects

Asteroids contained in DR2
- 14,016 objects in the Main Belt
- 81 Earth-crossers
- 2 Trans-Neptunian objects
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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  - < 5 mas faint objects
  - < 1 mas bright objects
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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
Gaia DR2 vs ground-based asteroid astrometry

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
How to combine Gaia and ground-based observations?

Tens of years of observations  |  22 months of Gaia

Today

1. Debiasing of old stellar catalogs

Discovery observations of the asteroid 2014 AA

BIG NEWS AHEAD
STAY TUNED

Next talk: Paolo Tanga
2. Error model: weights to give to each observatory

Catalog dependence

Magnitude dependence

(Observatory, year, catalog, magnitude class) (G96, 2019, V, 2)
2. Error model: weights to give to each observatory

How to combine Gaia and ground-based observations?
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.