

Near-Earth Orbit Propagation with Gaia Observations

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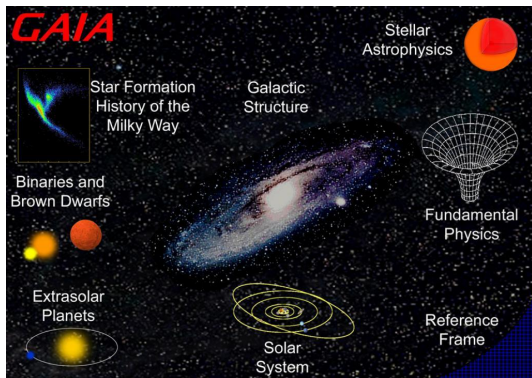
Outline

- 1 **The Gaia Mission**
- 2 **Astrometry for known NEAs**
 - Observations of Apophis
 - Orbital improvement
- 3 **Astrometry for newly discovered asteroids**
 - Follow-up network
 - NEA alerts expected
 - Strategy of recovery
- 4 **Conclusion**

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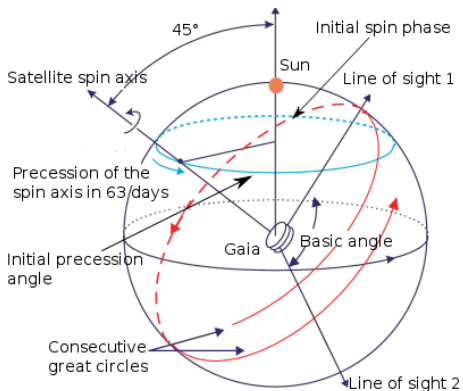
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The mission



- 5-years mission from 2013, L2 position
- 3D map of our Galaxy
- $V < 20$ & parallax $7\mu\text{s}$
- Solar System Science:
 - Astrometry: Orbital determination
 - Dynamic: Mass determination
 - Photometry: surf. properties, spin, shape
 - Imaging: diameter

Nominal scanning law



Fixed parameters

- Basic angle = 106.5°
- Spin rotation = $1^\circ/\text{min}$
- Spin orientation = 45°
- Spin precession = 63 days

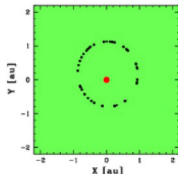
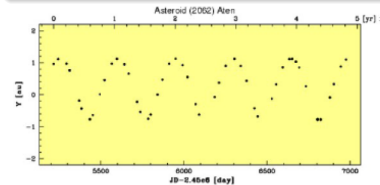
Free parameters

- Initial spin phase \Rightarrow date of observation
- Initial precession angle \Rightarrow number of observations



Nominal scanning law

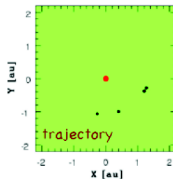
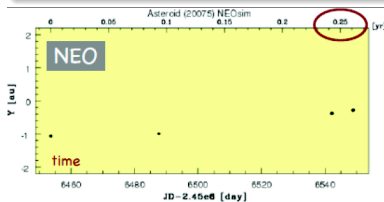
Well-observed NEA



Aten
distribution of
96 obs. over 5yrs

orbit in EC-J2000
96 obs.

Poorly-observed NEA



NEO sim.
distribution of
11 obs. over 3 months

orbit in EC-J2000
11 obs

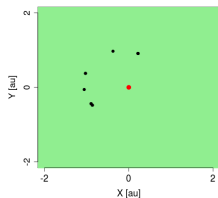
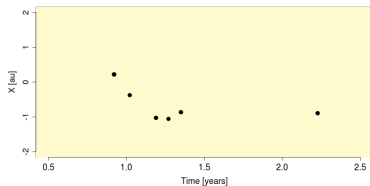
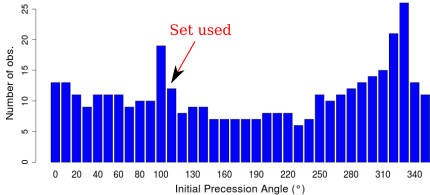
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Observations of Apophis

Precession angle influence

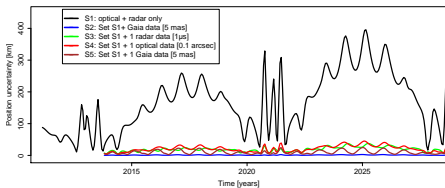
Set used for simulation



Orbital elements

	σ (G.B. only)	σ (G.B. + Gaia)
a [AU]	1.3×10^{-08}	6.8×10^{-11}
e	5.7×10^{-08}	3.9×10^{-09}
i [°]	1.8×10^{-06}	1.2×10^{-07}
Ω [°]	8.0×10^{-05}	2.2×10^{-06}
ω [°]	8.0×10^{-05}	2.3×10^{-06}
M [°]	5.5×10^{-05}	6.5×10^{-07}

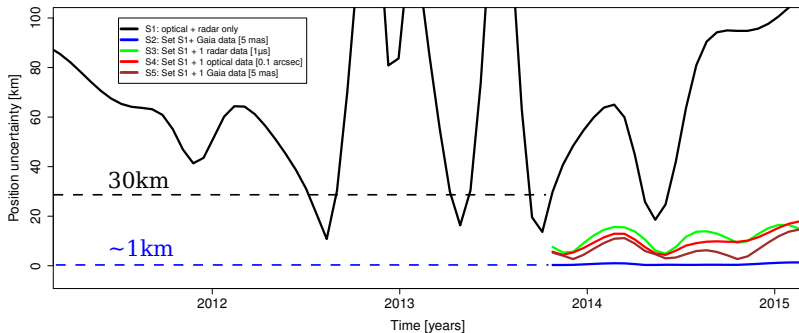
Position uncertainty



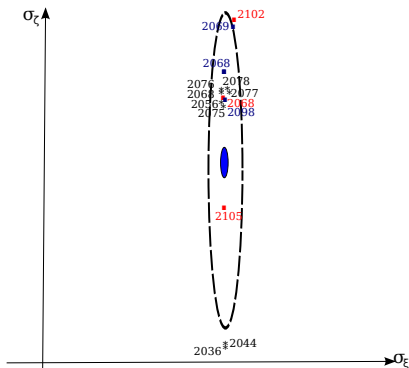


Orbital improvement

Position uncertainty improvement



2029-b-plane uncertainty improvement



- S_1 : optical + radar only
- S_2 : Set S_1 + Gaia data [5 mas]
- S_3 : Set S_1 + 1 radar data [1 μ s]
- S_4 : Set S_1 + 1 optical data [0.1 arcsec]
- S_5 : Set S_1 + 1 Gaia data [5 mas]

2029-b-plane uncertainty

	S_1	S_2	S_3	S_4	S_5
σ_ξ (km)	10	0.3	7	8	6
σ_ζ (km)	240	1.6	10.5	24	11.5

Future stellar catalogue (~ 2020)

Orbital elements

2029-b-plane

	Without reduction	With reduction
a [AU]	1.3×10^{-08}	1.3×10^{-09}
e	5.7×10^{-08}	4.9×10^{-09}
i [°]	1.8×10^{-06}	9.9×10^{-09}
Ω [°]	8.0×10^{-05}	3.9×10^{-06}
ω [°]	8.0×10^{-05}	3.9×10^{-06}
M [°]	5.5×10^{-05}	5.6×10^{-06}

	Without reduction	With reduction
σ_ξ (km)	10	1.5
σ_ζ (km)	240	23.5

Outline

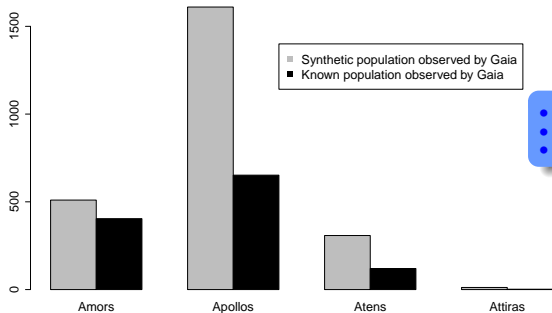
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Gaia FUN-SSO

- Discoveries are expected
- Gaia is not a follow-up mission
- Track potential alert
- Optimisation of the alert-mode

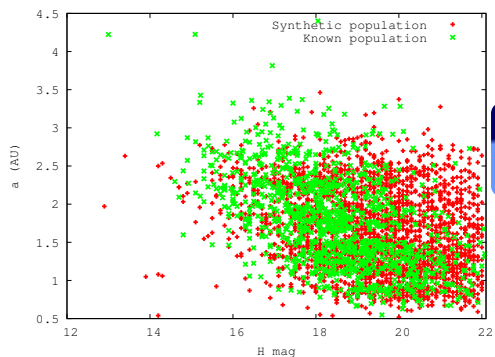


NEA alerts expected



- Synthetic population from Greensheet et al. 2012
- $N = 30000$
- $H \leq 22.0$

NEA alerts expected

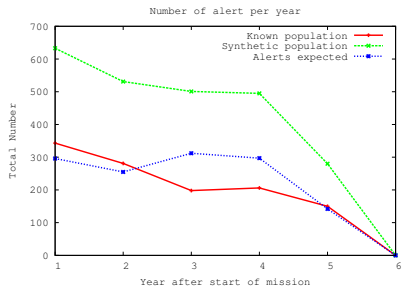
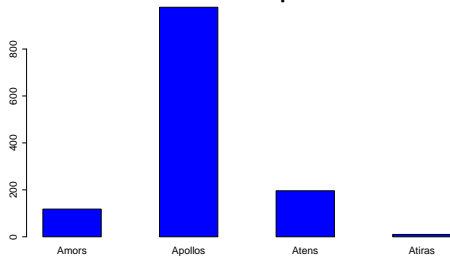


Alerts identification

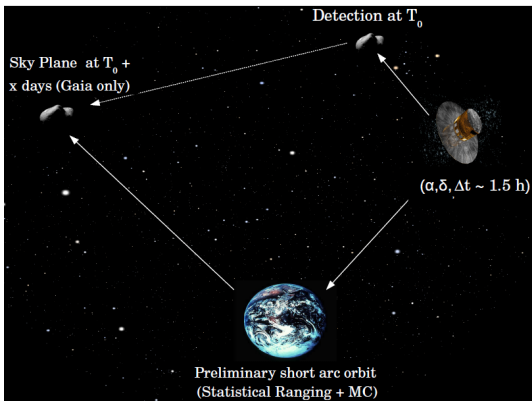
- $H_{min} < H < H_{max}$
- $a_{min} < a < a_{max}$

NEA alerts expected

NEA alerts expected



Strategy of recovery



Method

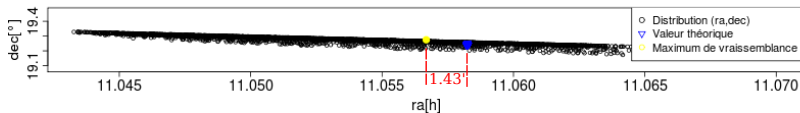
- Statistical Ranging for orbit determination
- Extract Maximum Likelihood (ML) of the (α, δ) distribution
- Center a given window ($\text{FOV}_\alpha, \text{FOV}_\delta$) on the ML



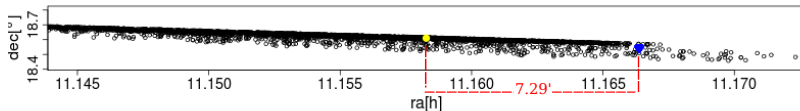
Application for (1620) Geographos

Prediction 4 jours après la découverte de l'hypothétique Géographos

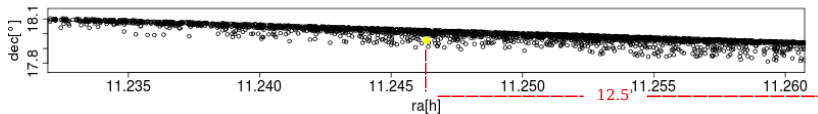
FOV: 24'x24'



Prediction 7 jours après la découverte de l'hypothétique Géographos

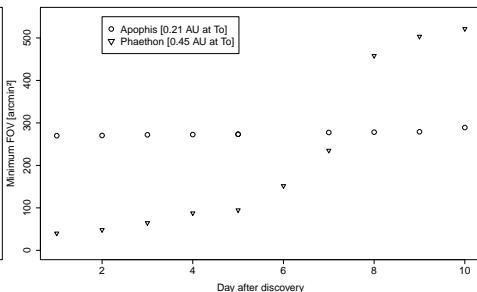
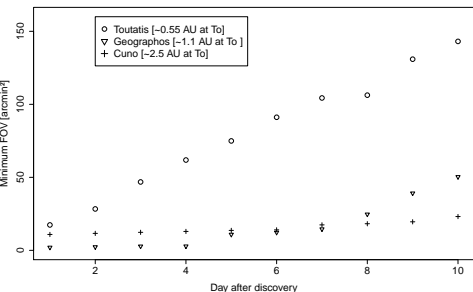


Prediction 10 jours après la découverte de l'hypothétique Géographos



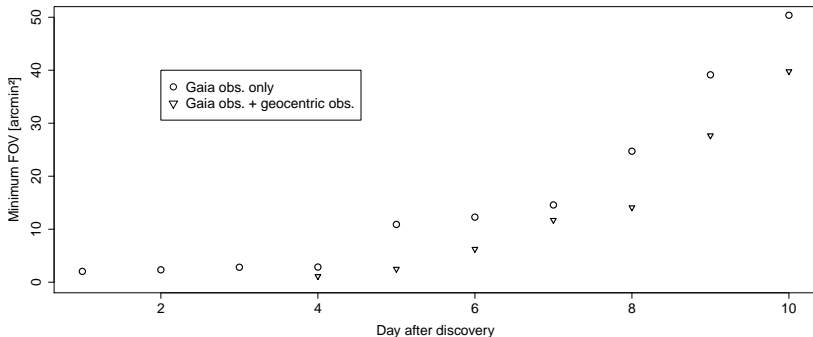
Strategy of recovery

Application for other PHAs



Synergy ground/space-based data

- Geographos recovered on 3rd day
- One night follow-up (8 obs. ~ 500 mas)
- ⇒ ↘ FOV required
- ⇒ ⇒ optimisation of the data processing



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Conclusion

- Orbital improvement for known objects
 - using Gaia data
 - using future stellar catalog
- ⇒ Significant improvement of the b-plane uncertainties

- Few Gaia data for newly discovered asteroids
- Few alerts expected $< 3 \sim 4/\text{week}$
 - Needs of a follow-up strategy
 - Needs of a follow-up network
- ⇒ data processing optimisation