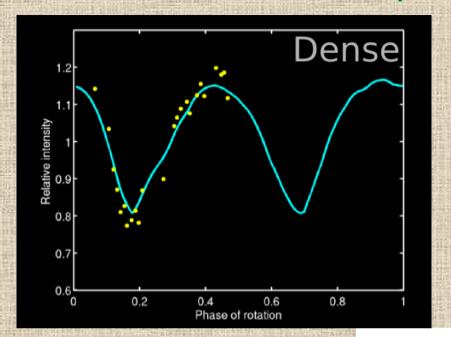
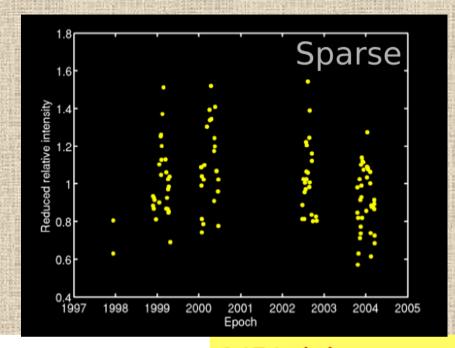
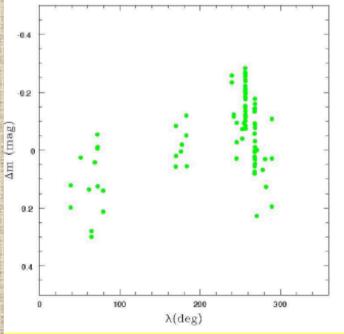
#### **Asteroids Photometry**





Need GB observations to relate

Dense → Sparse



## GAIA disk-integrated photometry

Sparse photometric measurements (no light-curves)

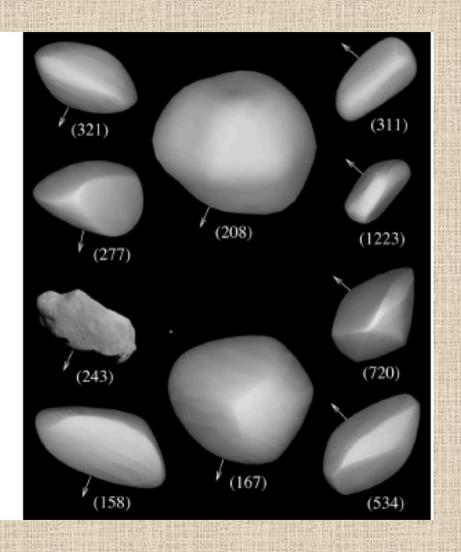
Good coverage of aspect angle variation over five years (65 observations per object, on the average).

Simulations of Gaia observations of (15) Eunomia

We expect to find solutions (poles, periods and axial ratios) for no less than 10,000 asteroids (maybe many more).

General application: Spin properties as a new, important constraint to modern models of the collisional evolution of Main Belt asteroids.

Specific applications: (1) test of the existence of possible preferential alignments of the spin axes of family members, possibly due to YORP effect.



# GAIA used for predictions in stellar occultations

Rene Duffard

IAA-CSIC

Granada

#### Data release scenario (II)

	Dara relea	se scend	110 (11)	
First release: launch + 22	<ul> <li>Positions (α,δ) and G-mag for single-like stars (90% of the sky)</li> <li>the Hundred Thousand Proper Motions (HTPM) catalogue based on the Hipparcos</li> </ul>			
Months				
Aug-2013	stars			
→June-2015	_			
Second	Updates of above +			
release:	Mean radial velocities for stars with non-variable radial velocity (90% of the sky)			
launch + 28 Months				
Dec-2015				
Third release: launch + 40	(1), (1), (1), (1), (1), (1), (1), (1),			
Months	Orbital solution for period between 2 months and 75% of the observation duration			
	Integrated photometry RP/BP			
	Spectrophotometry fro			
	simulaneously release Data release s			
	classification data	Fourth release:	Updates of all above +	
Dec-2016	• M Spectra fo	launch + 65 Months	Source classification plus multiple BP/RP_RVS and astrometry for the	

Madrid, March 2012

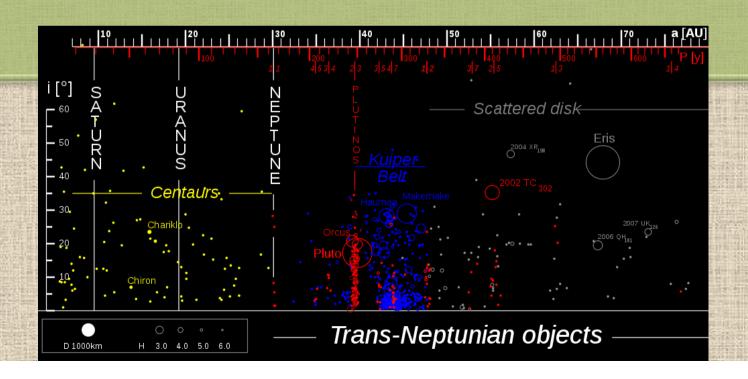
#### Data release scenario (III)

Fourth release:	Updates of all above +			
launch + 65	Source classification plus multiple stellar astrophysical parameters derived from			
Months	BP/RP, RVS and astrometry for the majority of stars			
	Variable star classifications and parameters as available, and the epoch			
	photometry			
Jan-2019	Solar system results with preliminary orbital solutions and individual epoch observations			
	Non-single star catalogue			
Final release:	Full astrometric, photometric, radial velocity catalogue			
End Mission + 3 years (36 months)	All available variables and non-single stars solutions			
	<ul> <li>Source classifications (probabilities) plus multiple astrophysical parameters derived from BP/RP, RVS and astrometry for stars, unresolved binaries, galaxies and quasars.</li> </ul>			
	Precision improved with respect to 4th release. Some parameters may not be available for fainter stars.			
	Non Single Stars solutions and exo-planet list			
	All epoch and transit data for all sources			
Aug-2021/2022	All Ground Based Observations made for data processing purposes (or links to it)			

#### **TNOs**

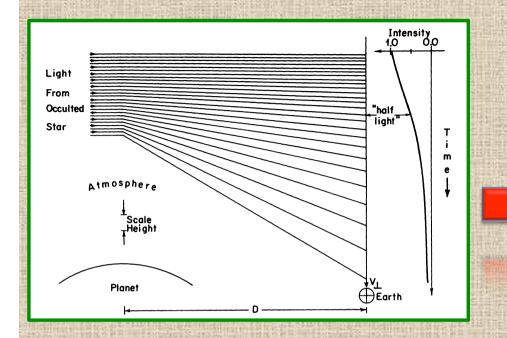
Only around 1200 TNOs are currently known. Most of them are fainter than mag\_R=22. They move slowly with respect to the background stars. Very difficult to study with current telescopes.

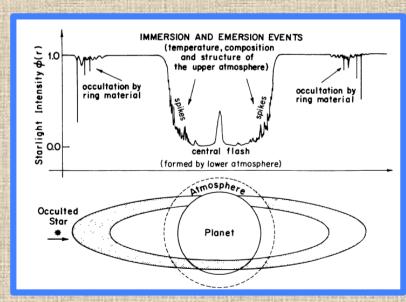
There are a few bodies such as Pluto, Eris, Makemake, Haumea which are large bodies and are somewhat brighter, so they are the ones that can be studied best.



#### Stellar Occultations

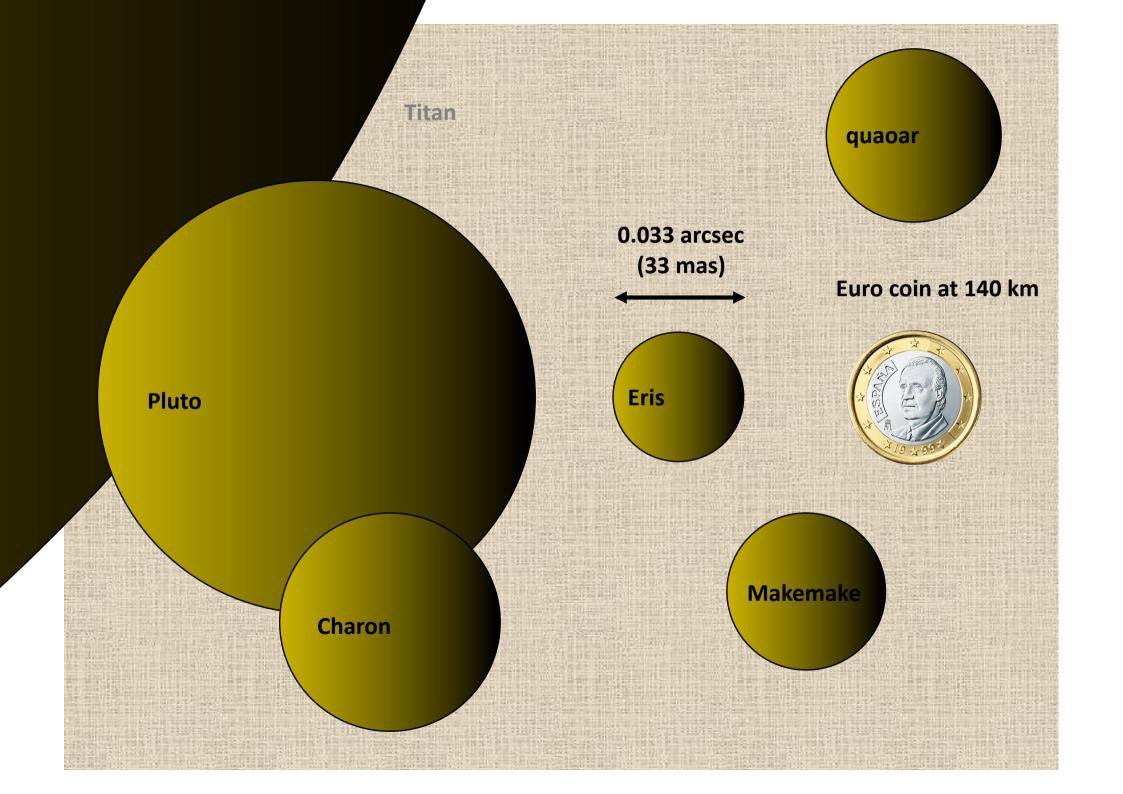
- Promising technique for TNOs
- Accurate TNO position relative to the star
- Radius and/or apparent elliptical figure
- Atmospheres (T, P, composition)
- Albedos using the optical constraint.





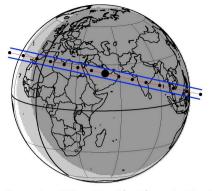
d m year h:m:s UT ra\_dec\_\_J2000\_candidate C/A P/A vel Delta R\* K\* long

d m year h:m:s UT ra\_\_dec\_\_J2000\_candidate C/A P/A vel Delta R\* K\* long 03 02 2012 19 45 38.0 07 45 54.7713 +11 12 43.040 0.046 12.34 -24.82 44.26 15.3 14.4 47

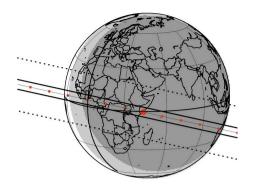


#### **Predictions**

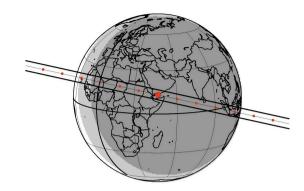
- Initial prediction using the NOMAD catalog (limiting mag = 20), or other catalogs.
- First list of possible occultations selected by regions in the World.
- For the promising events (bright star, dense telescope cover) we observe for 1-2 weeks
   BEFORE the occultation



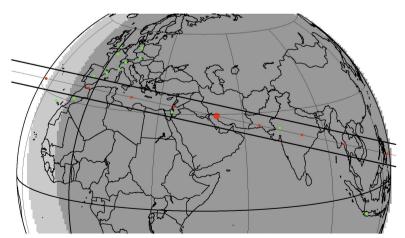
d m year h:m:s UT ra\_\_dec\_\_J2000\_candidate C/A P/A vel Delta R\* K\* I 03 02 2012 19 45 38.0 07 45 54.7713 +11 12 43.040 0.046 12.34 -24.82 44.26 15.3 14.4



Offset (mo



\_J2000\_candidate C/A P/A vel Delta R\* K\* long 03 02 2012 19 46 56. 07 45 54.7673 11 12 43.064 0.007 12.44 -24.83 44.26 15.3 14.4 46.

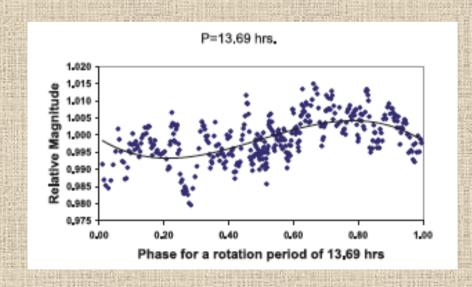


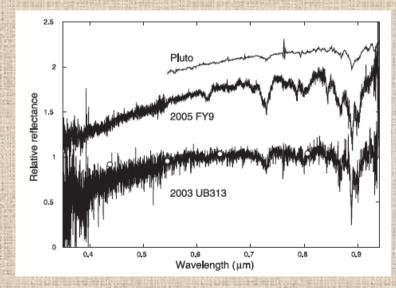
d m year h:m:s UT ra\_\_dec\_\_J2000\_candidate C/A P/A vel Delta R\* K\* long 03 02 2012 19 47 31. 07 45 54.7696 11 12 43.093 0.064 12.44 -24.83 44.26 15.3 14.4 46.



#### Eris

- Distance to the SUN  $\rightarrow$  a = 67 AU
- Rotational Period  $\rightarrow$  13.7 hrs  $\Delta m = 0.01$  (Duffard et al. 2008)
- Presence of CH<sub>4</sub> in the surface (Licandro et al 2006)

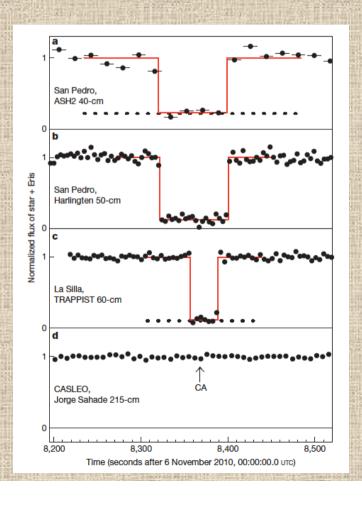


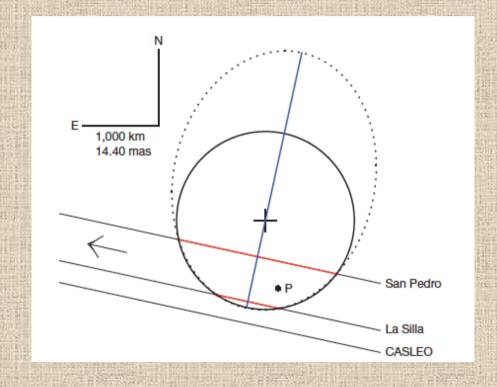


#### Eris

• D= 2326 ± 12 Km, Albedo=0.96

(Sicardy et al 2011, Nature 478, 493)





Eris by Herschel/Spitzer: 2454 ± 117 Km (Santos-Sanz et al. 2012)

#### Occultation by Eris

The star is ~17 mag

Instituto de Astrofisica de Andalucia - CSIC Eris occults this star 2010-11-08

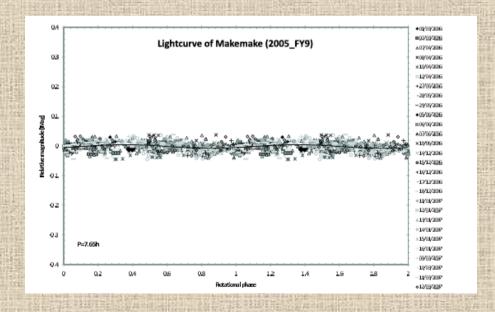
Time steps of ~13s

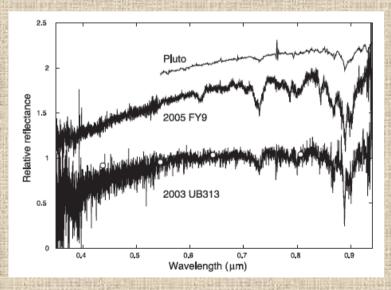
W

N

#### Makemake

- a = 45 AU (between Pluto and Eris)
- Rot Period = 7.7 hrs  $\Delta m = 0.014$  (Thirouin et al 2010)

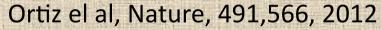


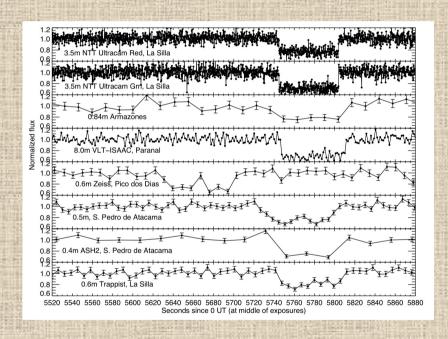


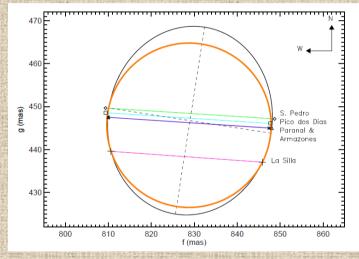
#### Makemake

Makemake 

 1430 ± 10 Km, Albedo 0.78



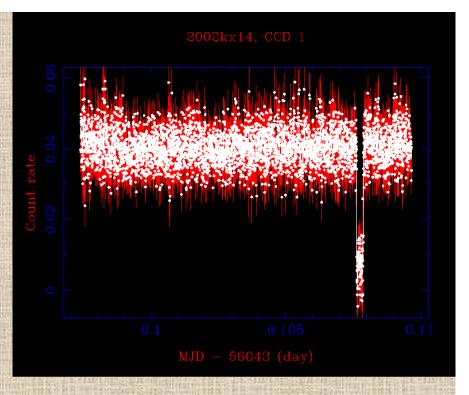




Herschel/Spitzer: 1 Terrain----- 1350 < D < 1510 Km 2 Terrain----- 1320 < D < 1430 Km and 310 < D < 380 Km (bright) (dark)

## 2002 KX<sub>14</sub>

Alvarez-Candal et al. In preparation



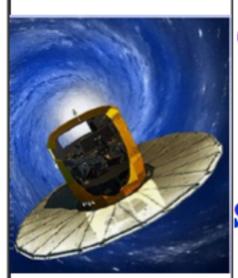
- Ultracam@WHT (La Palma, Spain)
- Exp-time: 0.2407 sec (no dead-time)
- Duration: 20.87 ± 0.05 sec
- Size (1 chord): 415 ± 1 Km
- Herschel Diameter -> PACS => 485 (+83 -93) Km
   Herschel/Spitzer=> 455 (±27) Km

UCAC2  $\rightarrow$  50 mas precision TNOs orbits  $\rightarrow$  100 – 300 mas TNO size  $\rightarrow$  30 mas or less (diameter)

#### TNOs occultation in the Gaia era

- -Solve ONE of the biggest problem in occultation predictions
- Need more TNOs astrometry from ground telescopes
- -Huge relieve in occultation planning (now 99% time spent in astrometric prediction & updates
- Good prediction → good distribution of efforts (telescopes, persons, etc.)

-Get satellites: Shape & orbital elements



#### WORKSHOP Gaia-FUN-SSO

follow-up network for the Solar System Objects

from November 29 to December 1, 2010





"Solar System science before and after Gaia" Pisa, Italy, May 4-6



#### **Asteroid Spectroscopy in Support of Gaia**

Nice, France June 6 - June 7, 2013













### Need of ground-based observations

- Identification of detections
- Classification of moving objects
- Identification of specific objects or events
- Tuning the detection algorithms

## Need of ground-based SSO observations

- 300 000 asteroids (most known)
- Including several NEAs, Trojans, Centaurs
- Other SSO: comets, natural satellites
- High astrometric accuracy

Identification of families, orbit determination, occultations.

## New taxonomy

- Gaia will obtain R ~20-90 visible spectra of asteroids
- Average spectra will be published
- Gaia + Wise(albedos): spectral class degeneracy to be remove.
- HOMOGENEUS Mineralogical map of the Main Belt
- GB spectral observations to test algorithms: Spectra of asteroids belonging to all spectral classes were obtained at TNG under Gaia-like observing geometry.