Stellar occultation by asteroids and Trans-Neptunian bodies: **A powerful technique**

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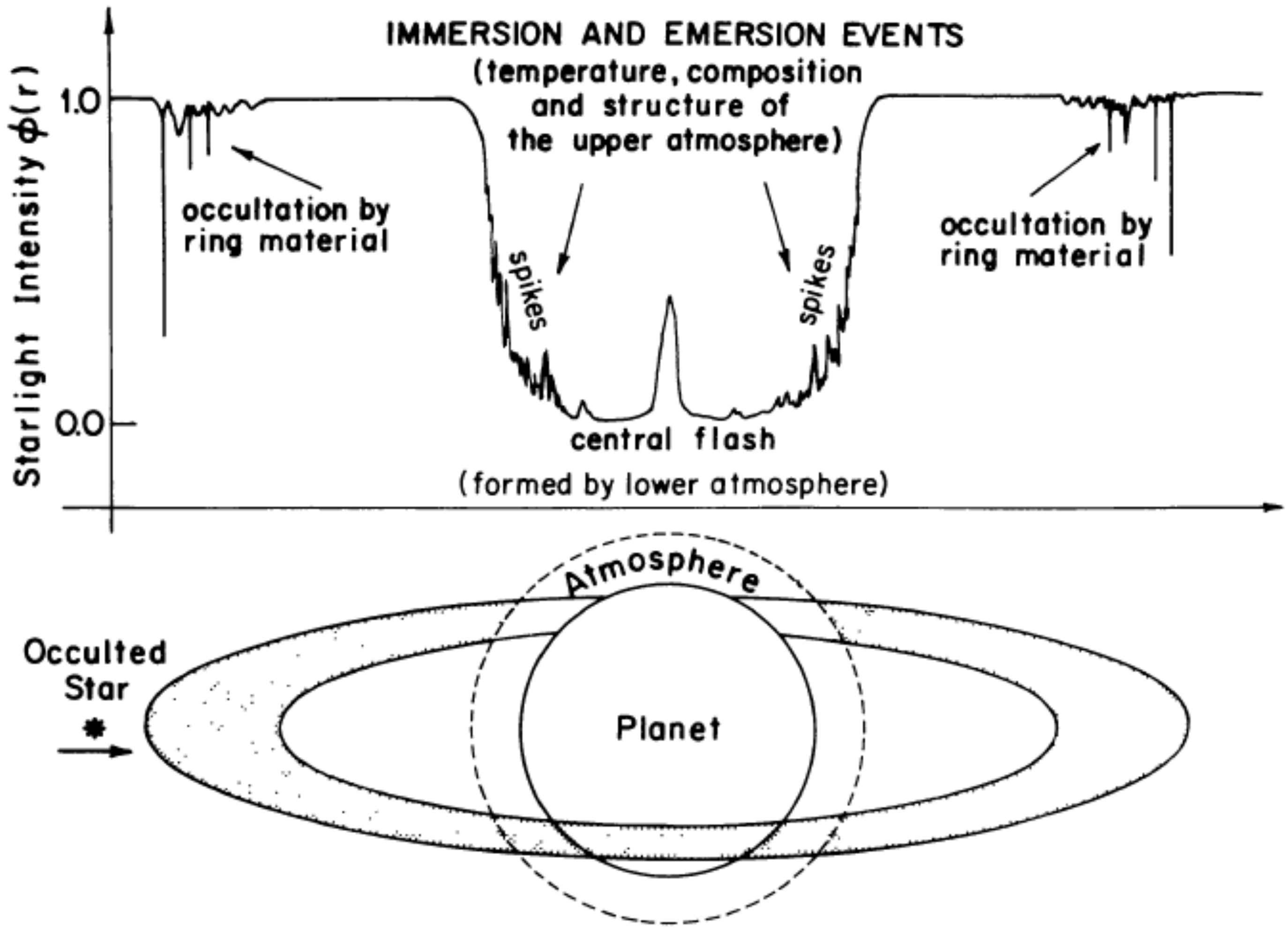
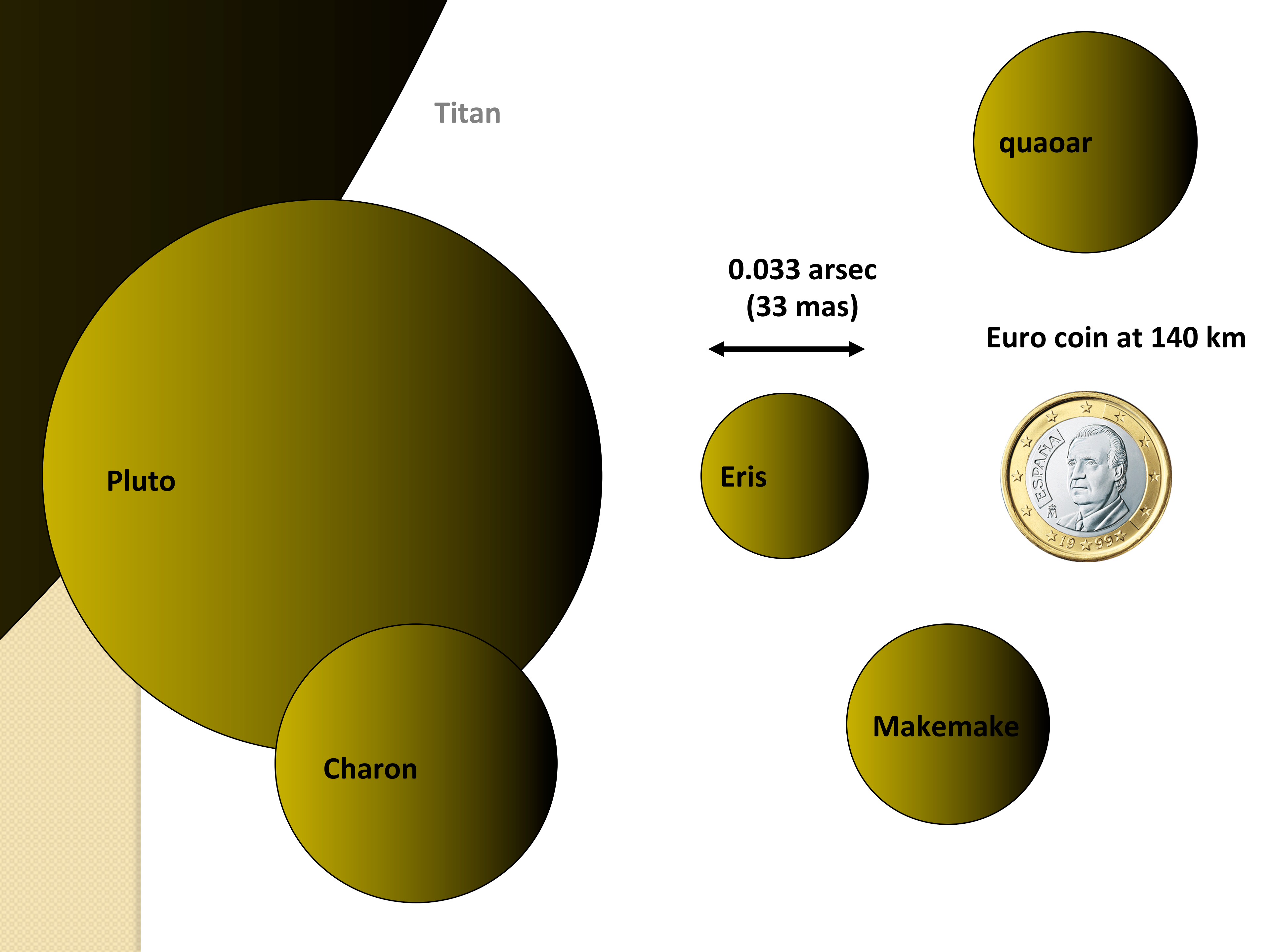
Stellar Occultations

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

- Difficult to predict (small angular diameters, uncertainties in TNO orbits, less uncertainties in stellar position after GAIA)
- Event lasting few second, fast CCD cameras needed

Stellar Occultations




Titan
quaoar
0.033 arsec
(33 mas)
Euro coin at 140 km
Pluto
Eris
ESPAÑA
19 99
Charon
Makemake

Successful occultation by TNOs

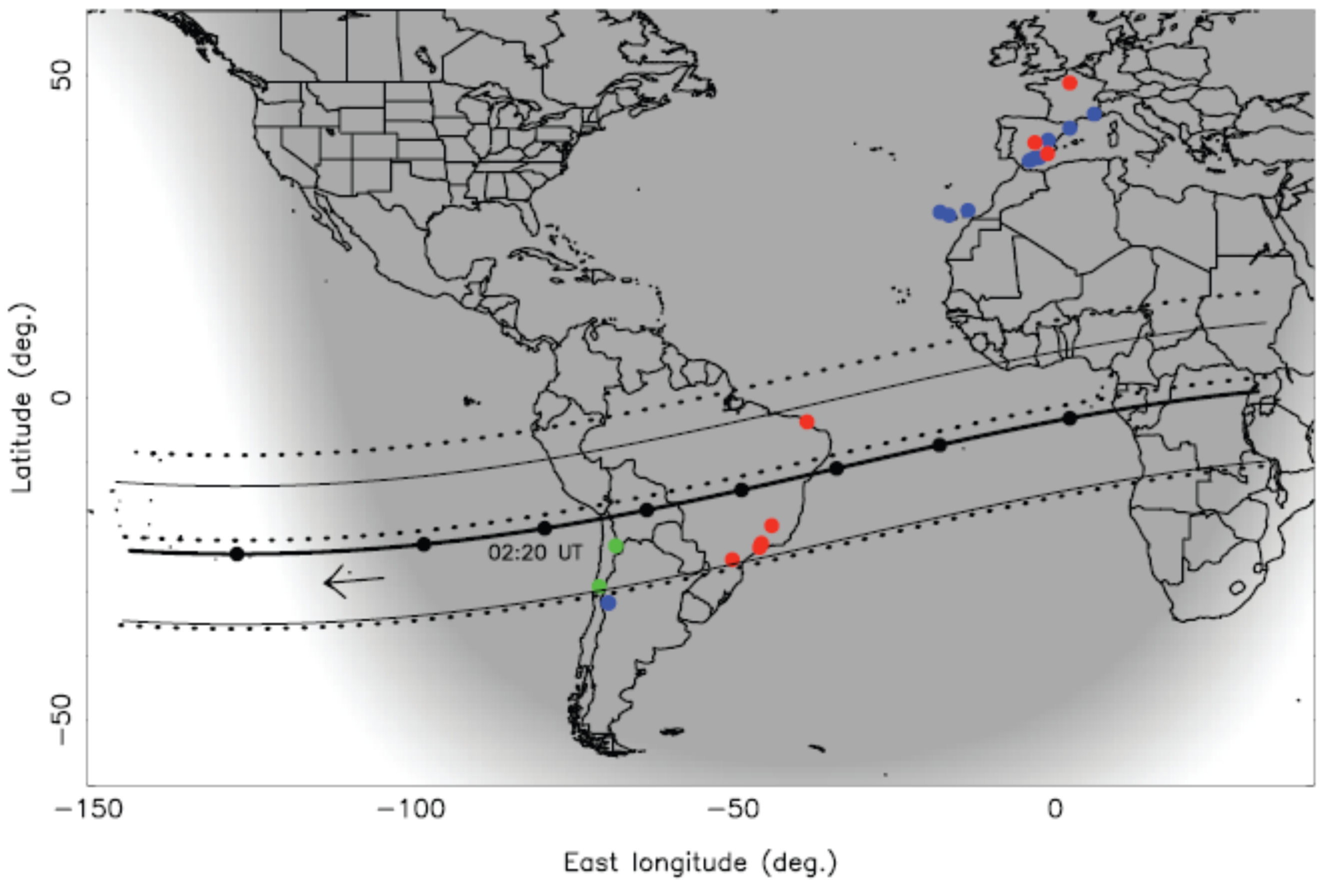
TNO	Date	Location
2002TX300	9 Oct, 2009	Hawaii, multi
Varuna	19 Feb, 2010	Brazil, single
Eris	6 Nov, 2010	Chile, multi
2003AZ84	8 Jan, 2011	Chile, single
Quaoar	11 Feb, 2011	USA, single
Makemake	23 Apr, 2011	Chile, Brazil
Quaoar	4 May, 2011	Chile, Brazil
2003AZ84	3 Feb, 2012	Israel, India
Quaoar	17 Feb, 2012	France, Switzerland
2002KX14	26 Apr, 2012	Spain, single
Quaoar	15 Oct, 2012	Chile, single
Varuna	8 Jan, 2013	Japan, multi
Sedna	13 Jan, 2013	Australia, single
Quaoar	8 Jul, 2013	Venezuela,single
2003VS2	12 Dec, 2013	Reunion Island, single
Varuna	11 Feb, 2014	Chile, multi
2003VS2	4 Mar, 2014	Israel, single
Orcus’ satellite	1 Mar, 2014	Japan, single
Ixion	24 Jun, 2014	Australia, single
2003VS2	7 Nov, 2014	Argentina, Uruguay
2007UK126	15 Nov, 2014	USA, multi
2003AZ84	15 Nov, 2014	Japan,China,Thailand

Some examples

- Eris
- Makemake
- Quaoar
- Haumea
- Chariklo

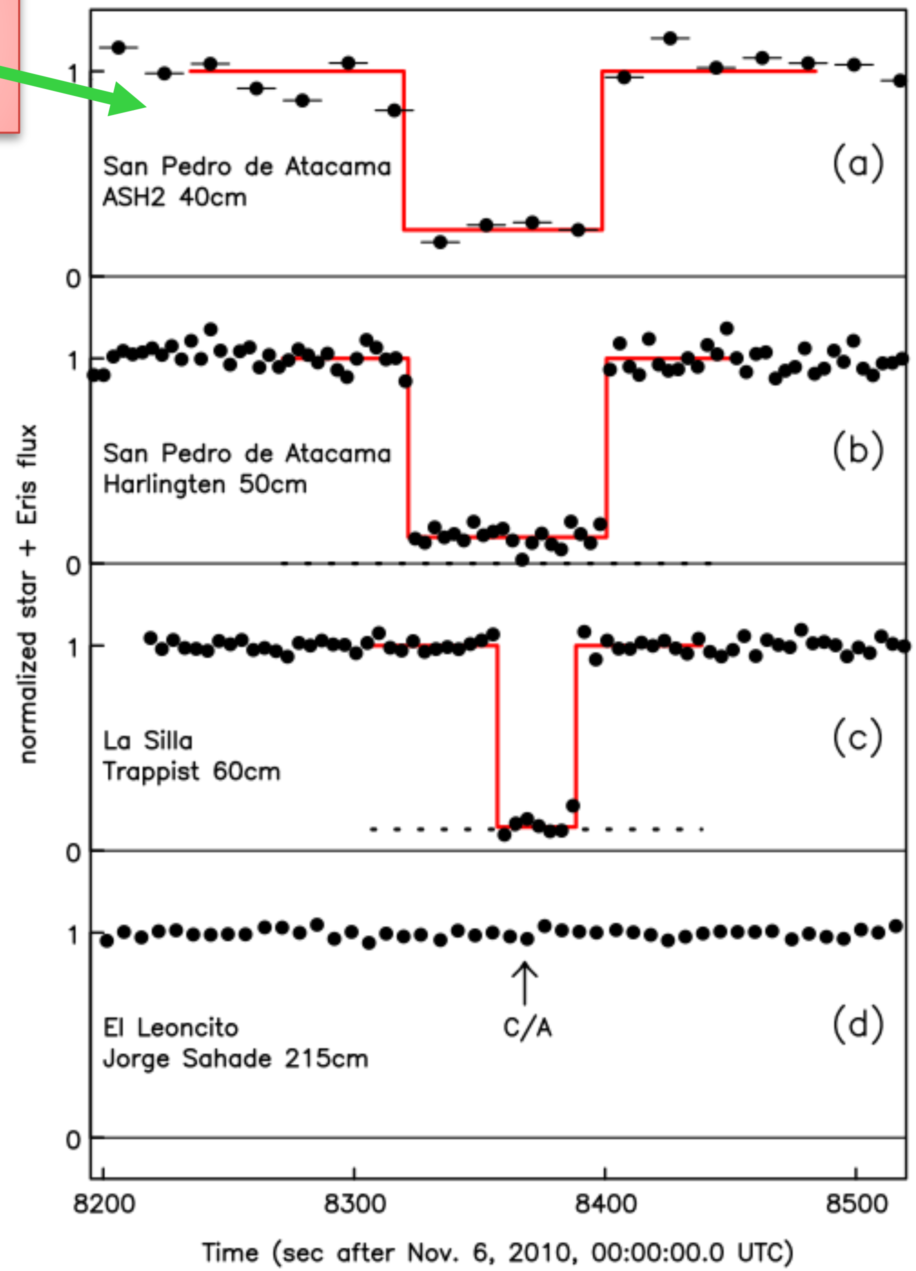
The three teams (Granada, Paris, Rio) arranged observations with many different telescopes around the globe

ERIS



26 telescopes were involved !!!
Only 3 were successful, relatively faint star: 17.2 mag in V

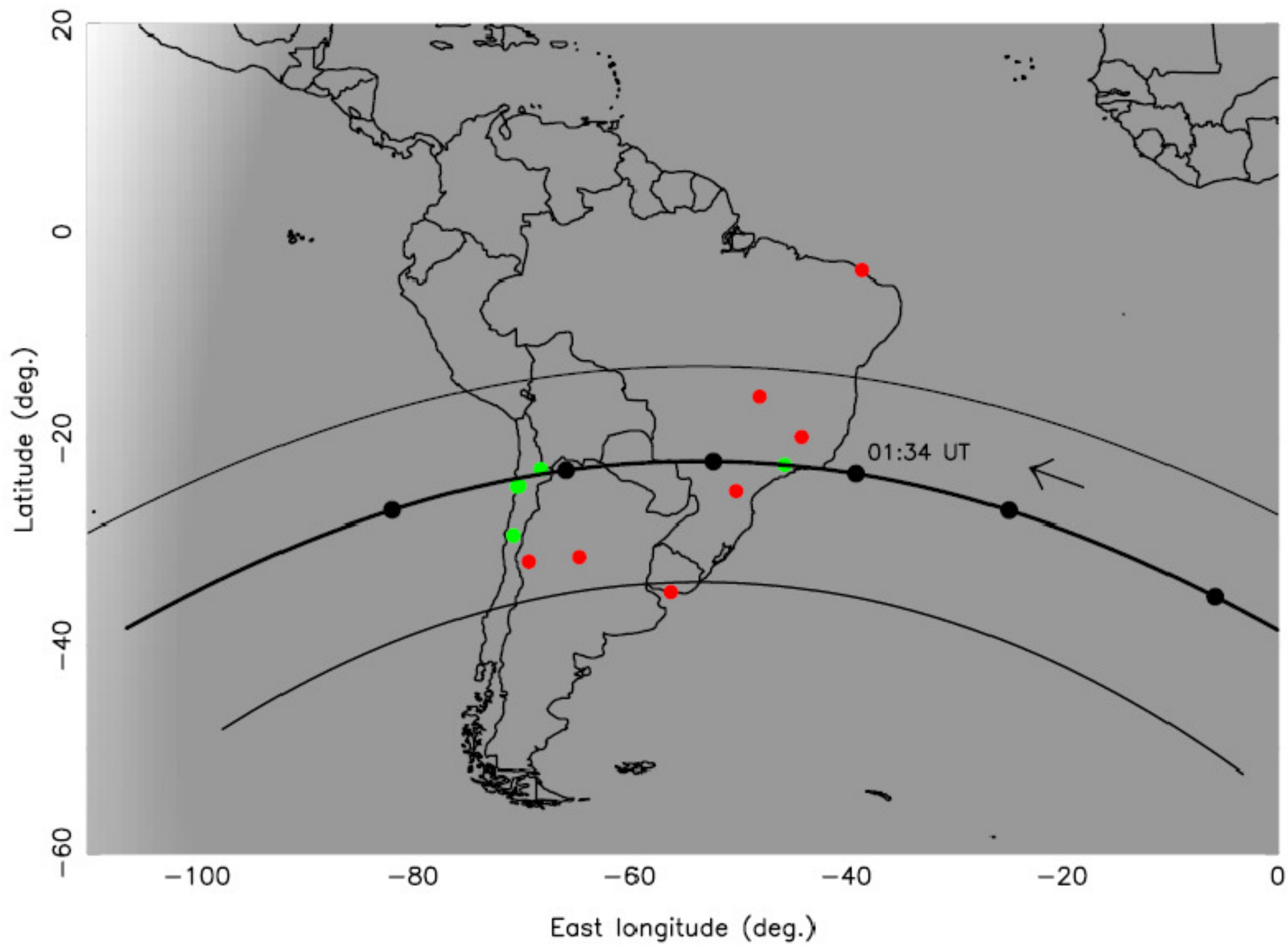
“Our own” telescope in Chile



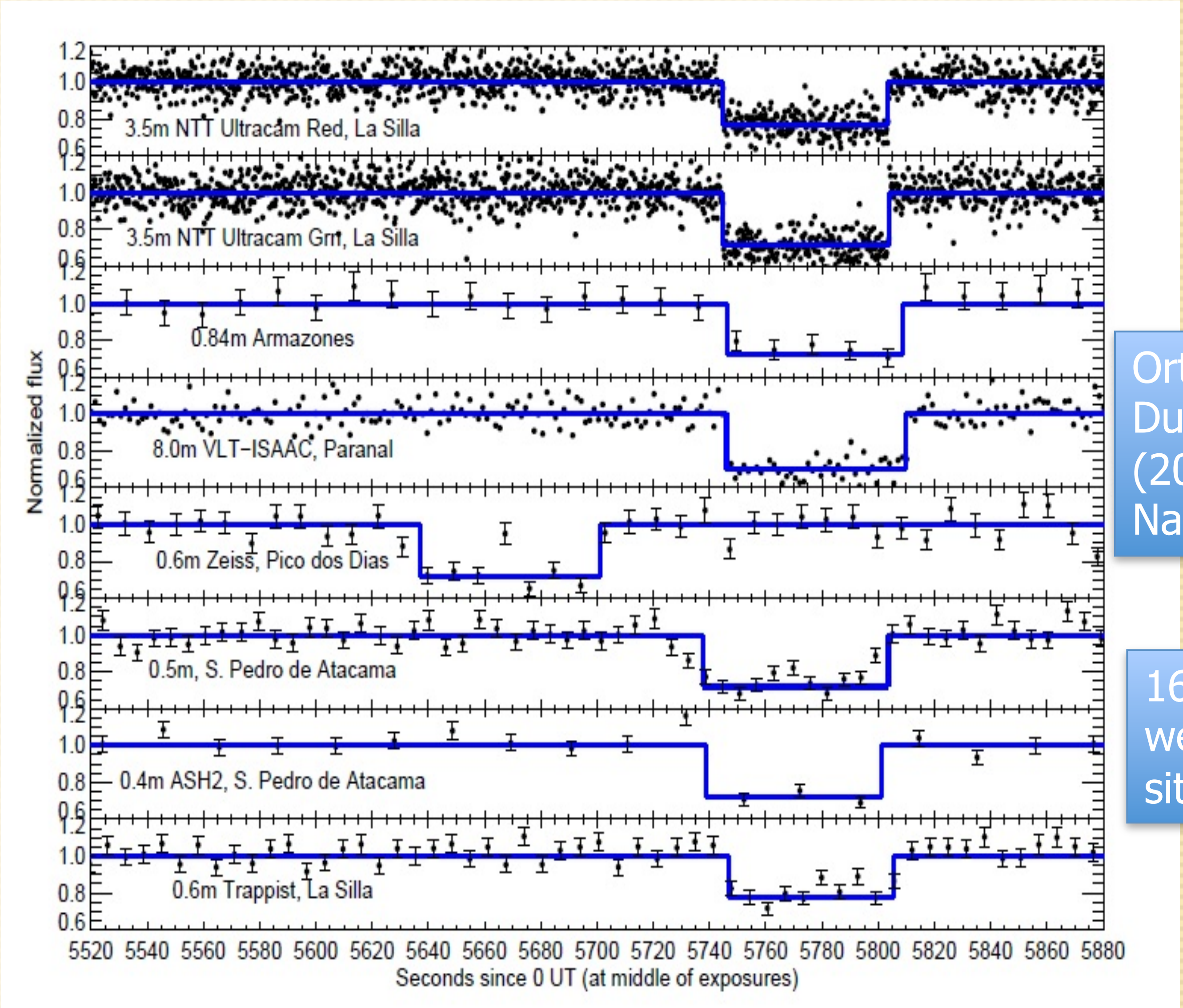
Sicardy, Ortiz et al. (2011). Nature 478, 493

The star was relatively faint: 17.2 mag in V band

Occultation by Makemake: Observing sites



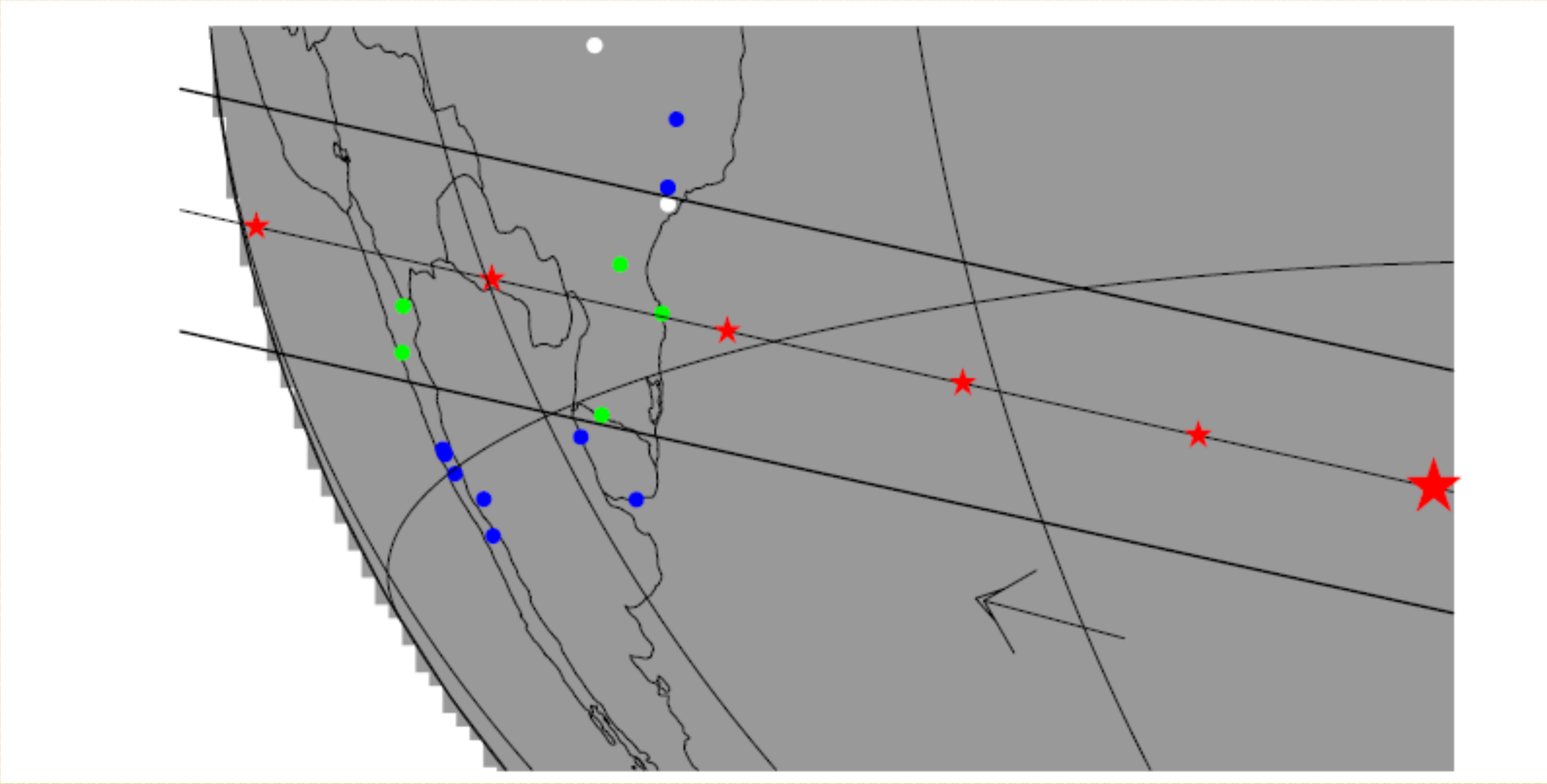
Occultation by Makemake: Data



Ortiz, Sicardy, Braga-Ribas, Duffard, Santos-Sanz, et al. (2012)
Nature, 491,566

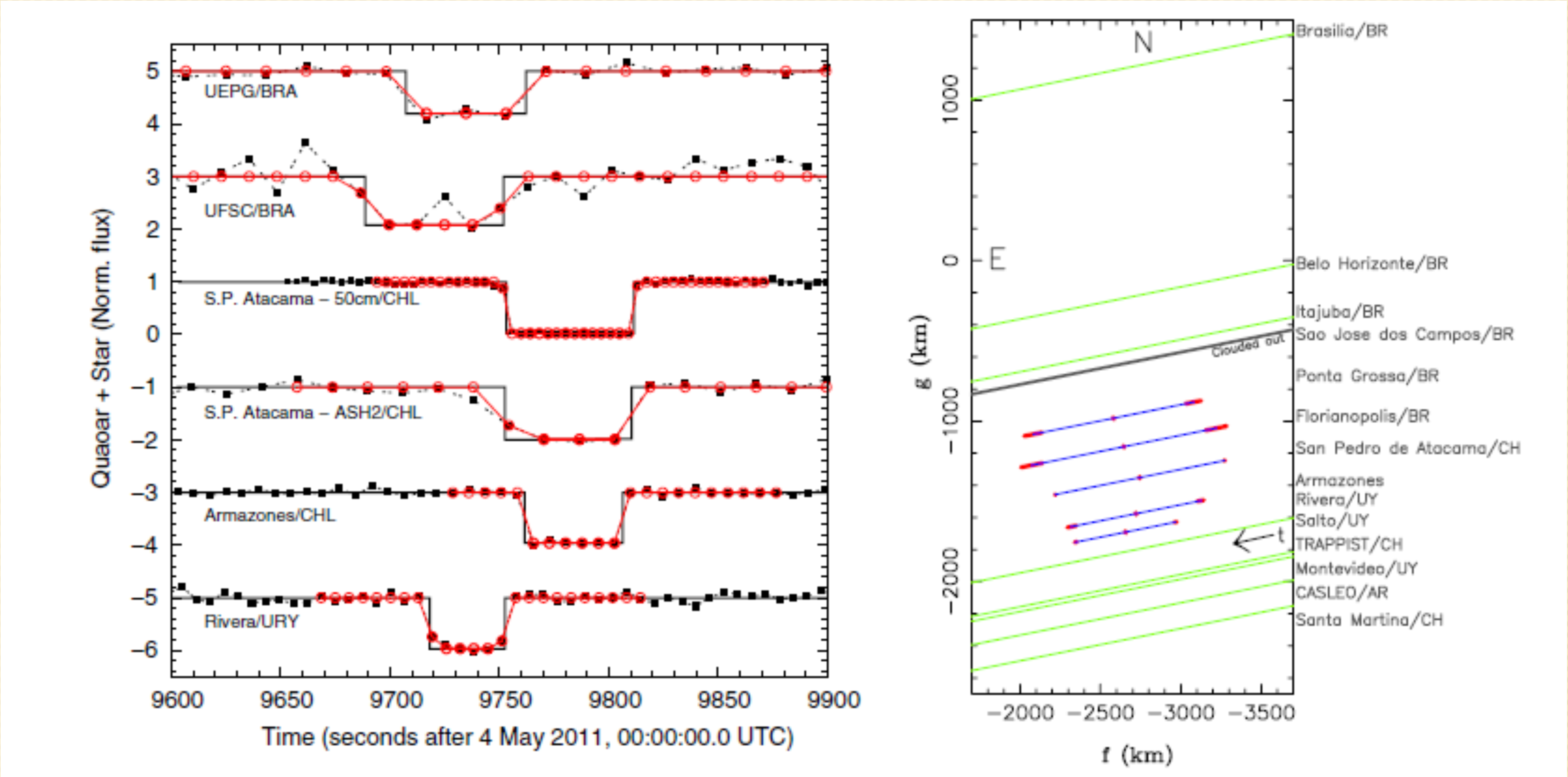
16 telescopes involved, 7 were successful from 5 sites

Occultation by Quaoar May 4th, 2011:



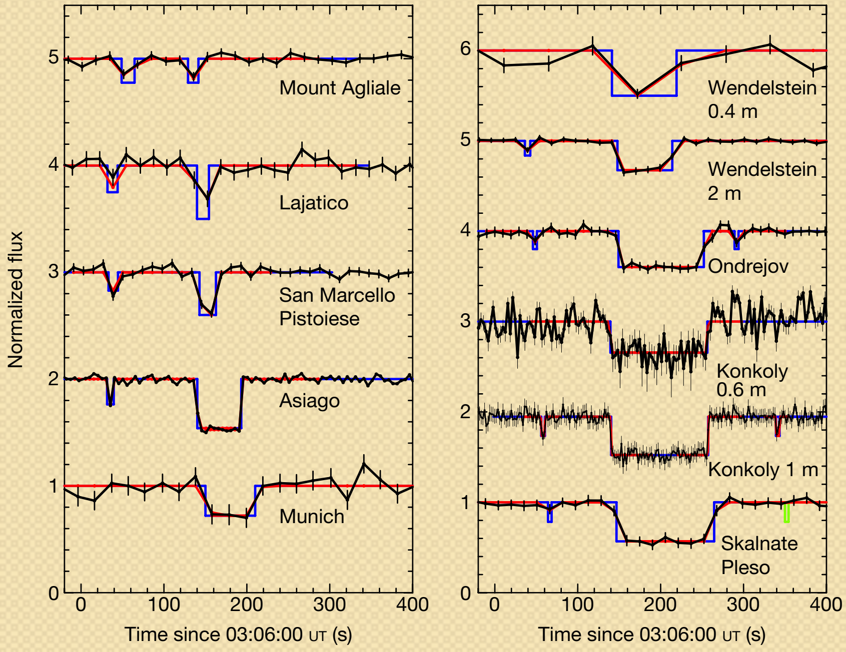
Braga-Ribas, Sicardy, Ortiz, Sicady et al. (2013). Astrophysical Journal

Occultation by Quaoar May 4th, 2011

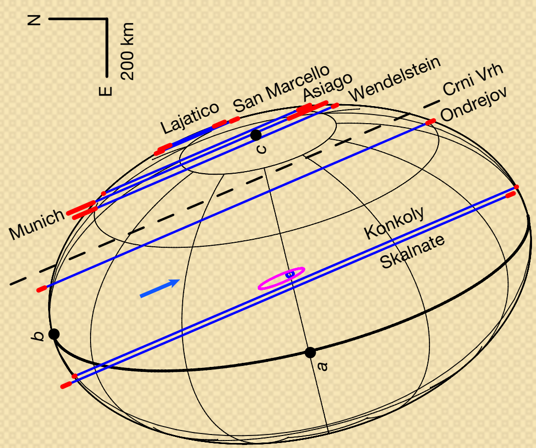


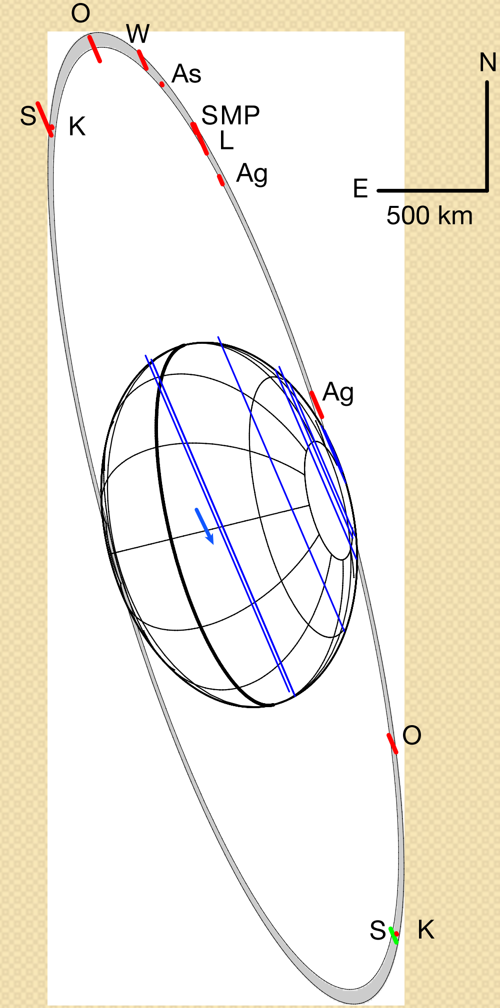
Braga-Ribas, Sicardy, Ortiz, Duffard, Santos-Sanz, et al. (2013). Astrophysical Journal 773, 26

HAUMEA AND RINGS



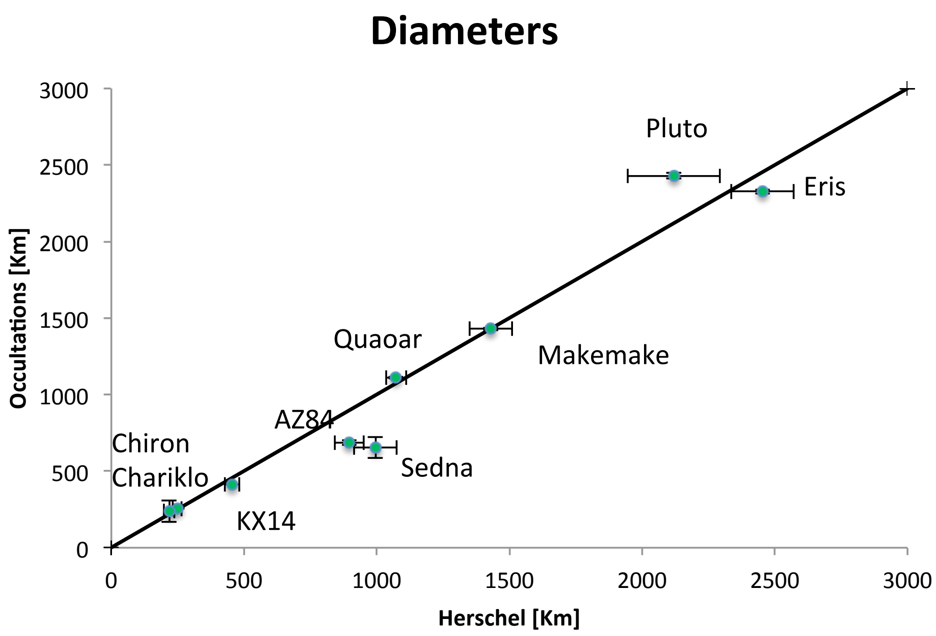
Fast CCD

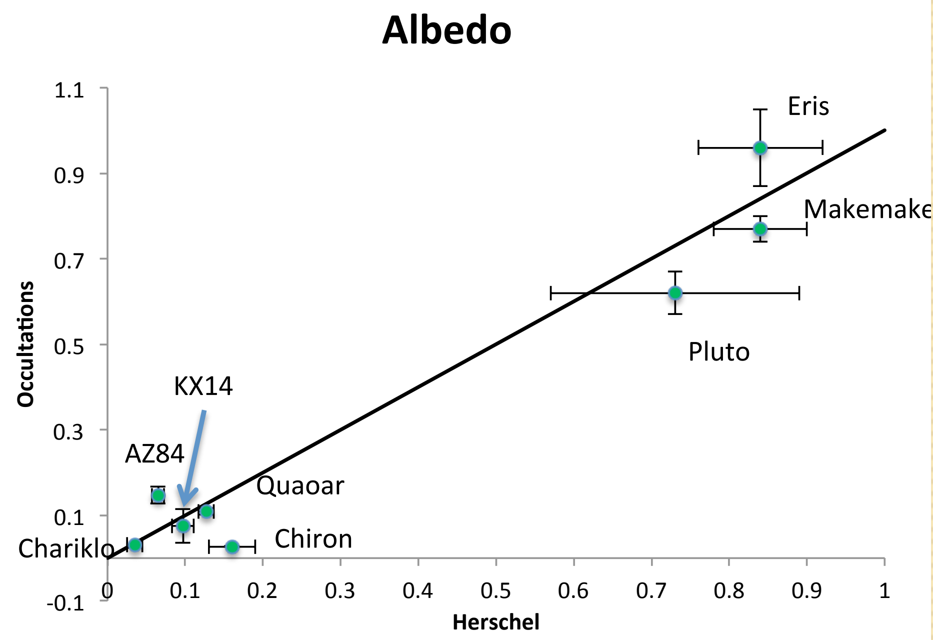




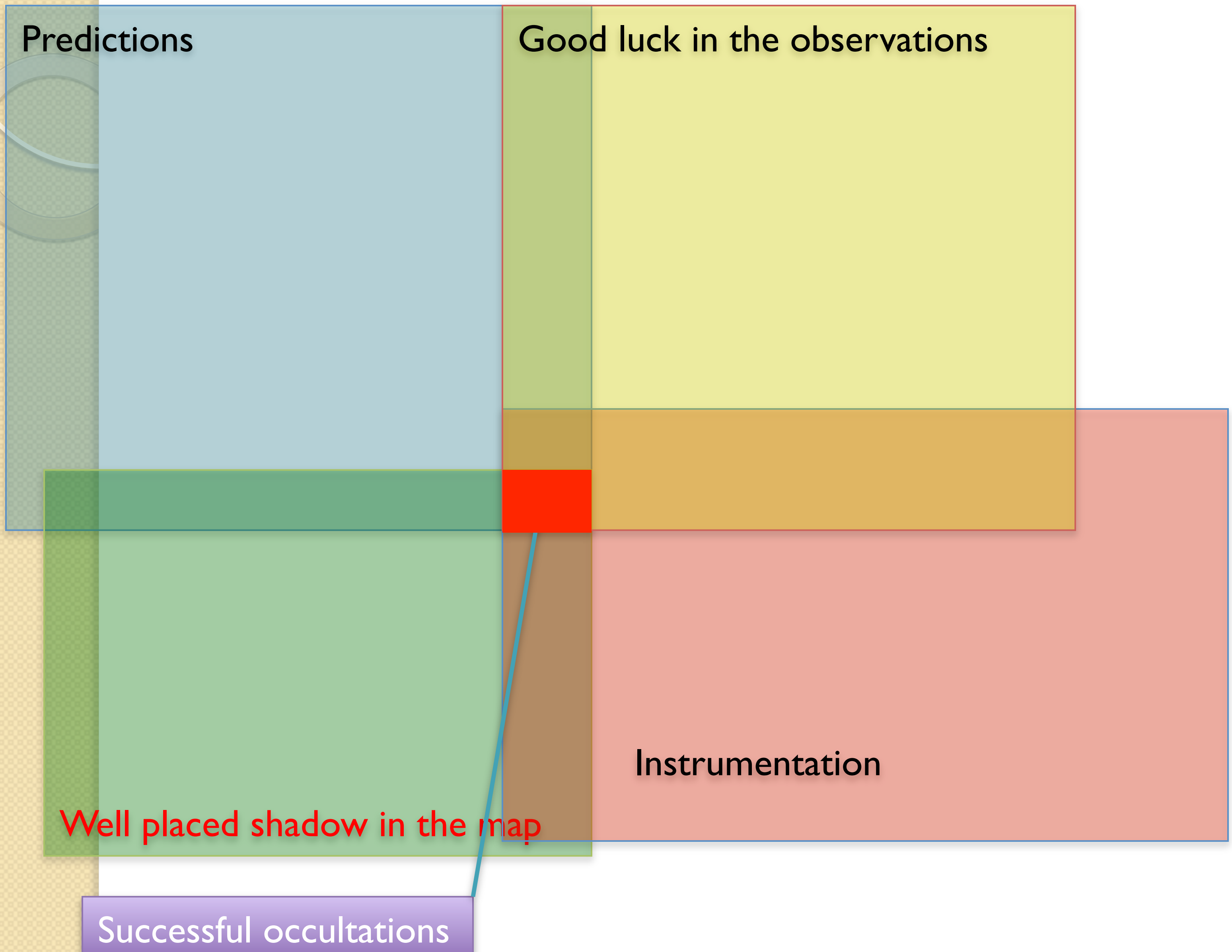
Ortiz et al, Nature 2017

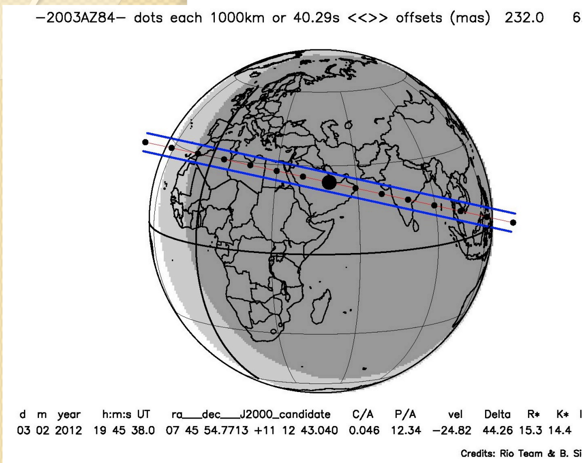
Occultation vs.
Herschel Space Telescope (TNO's are Coll! Key project)

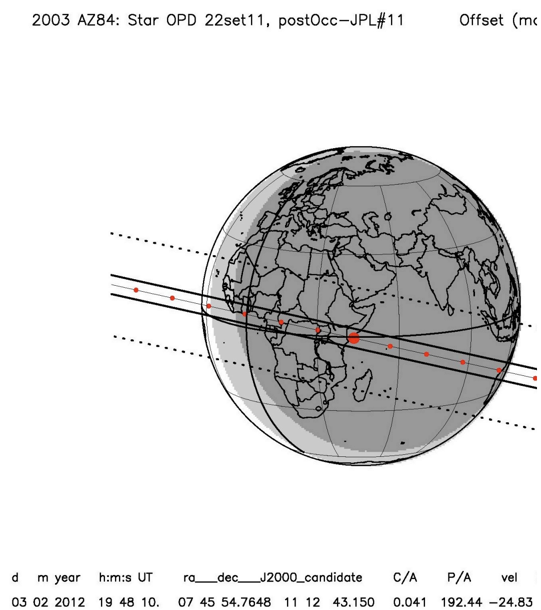


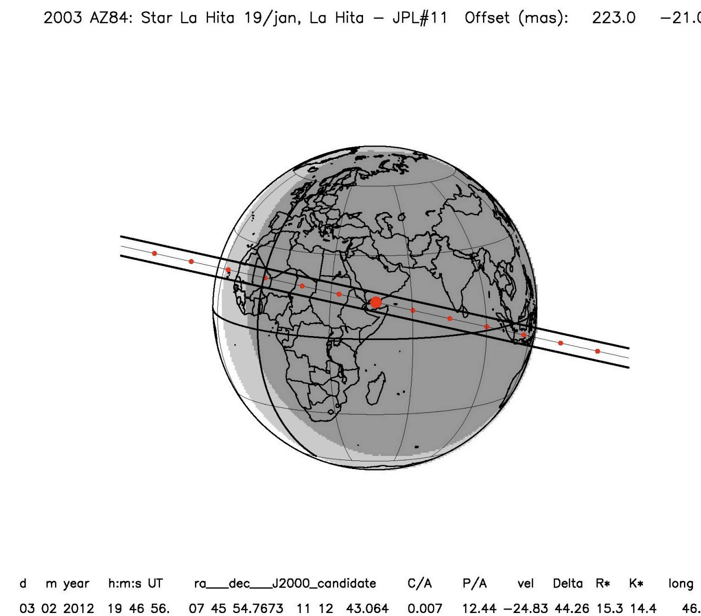


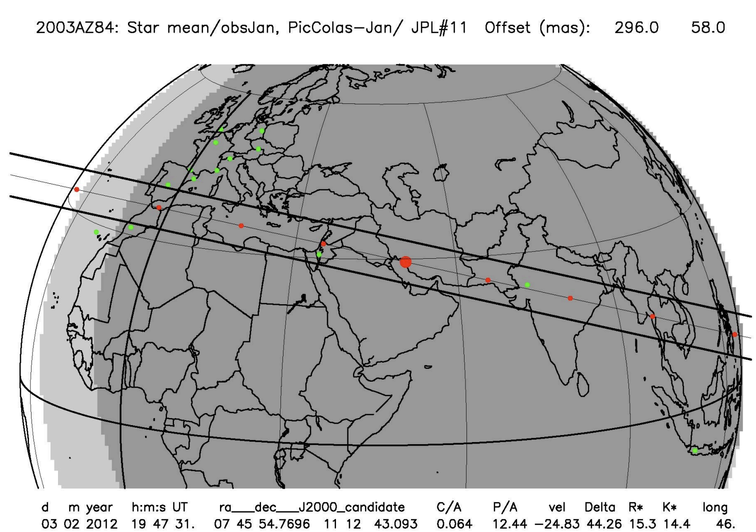
Observations: looking for collaborations





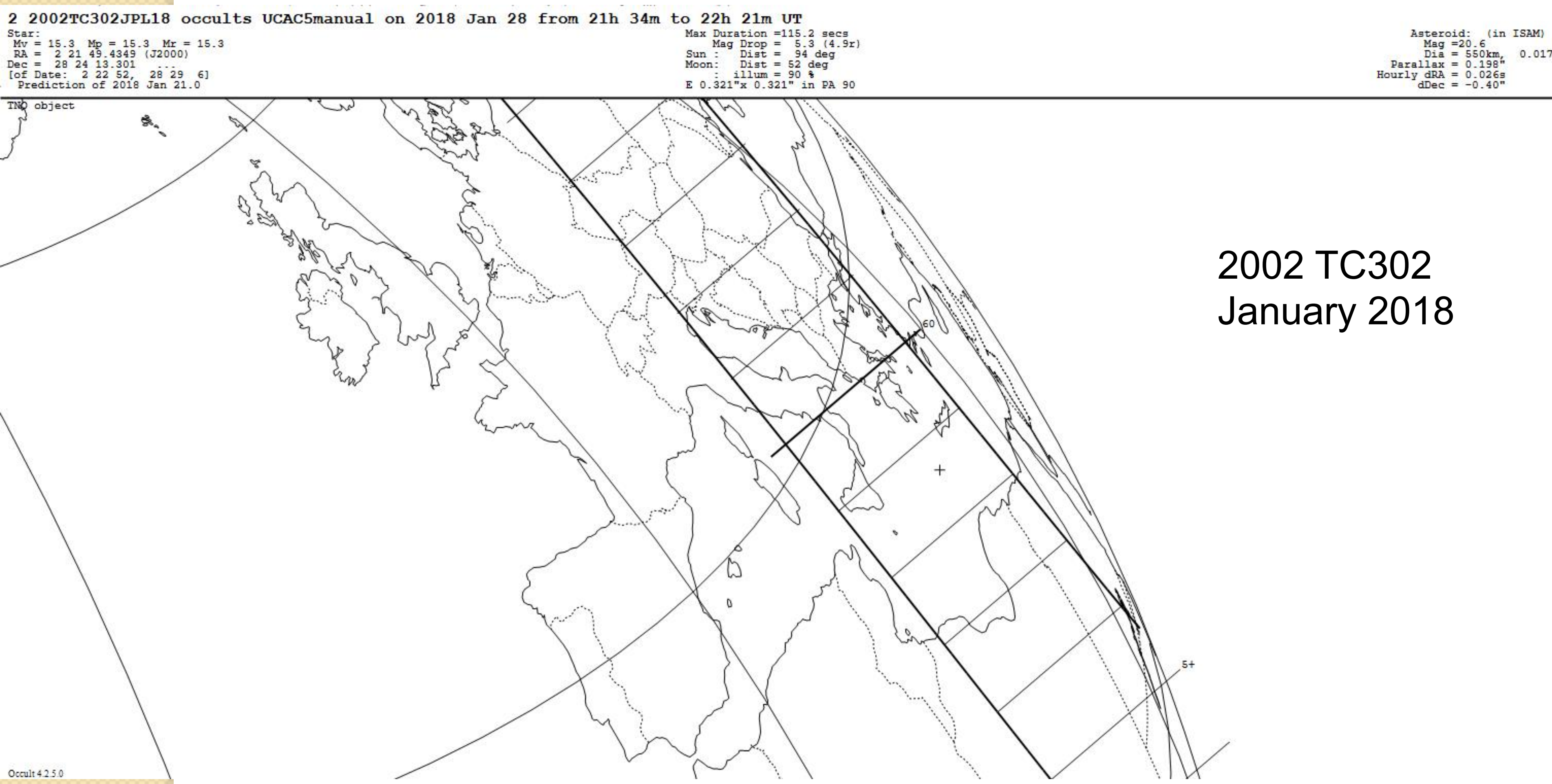






Improvements with GAIA

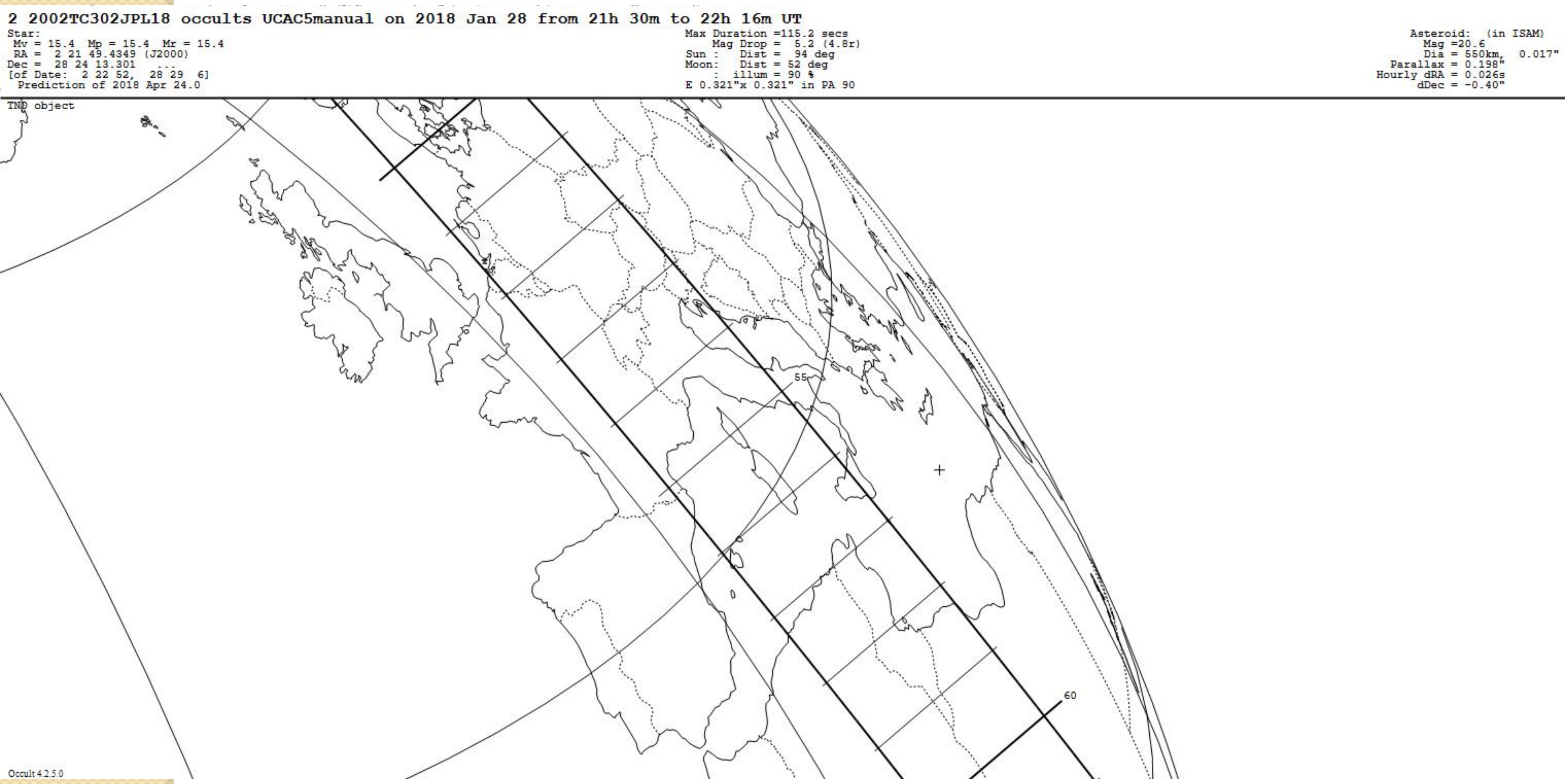
Last minute prediction of the occultation



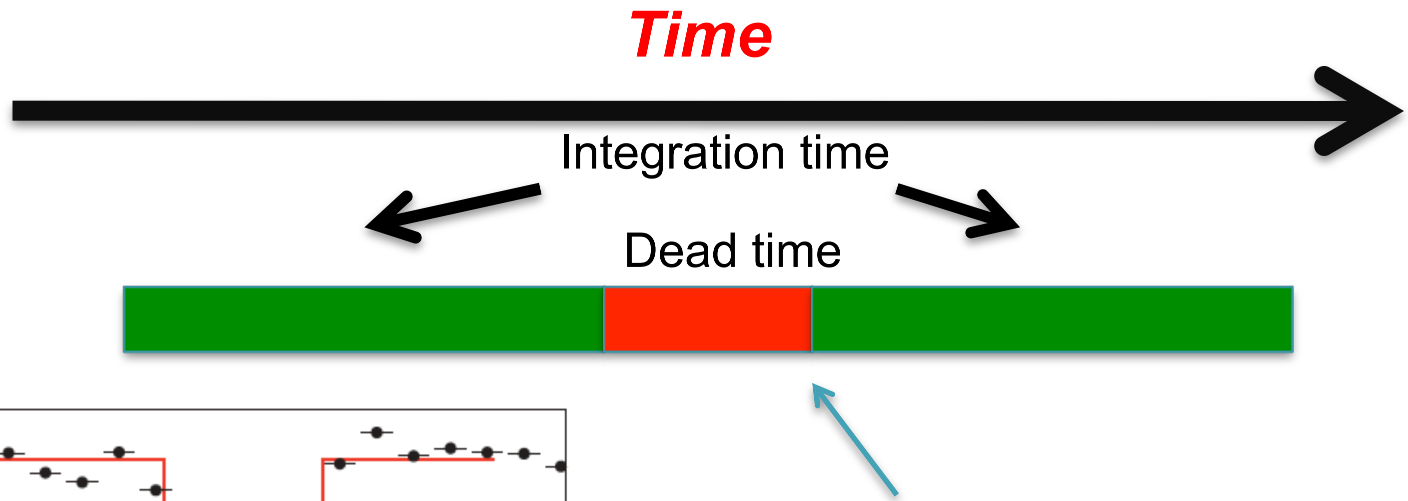
2002 TC302
January 2018

Using observations from the Sierra Nevada Observatory 1.5m telescope on January 19th, 2018, just a week before the occultation. ANALYZED WITH GAIA DR1

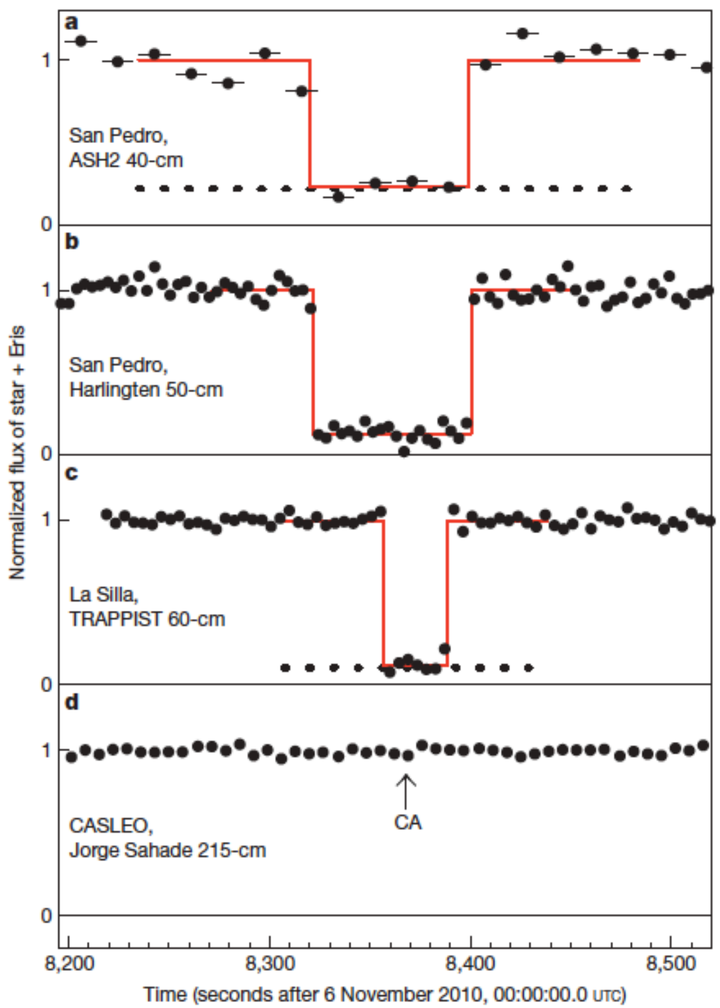
The reality. The final observed path



In Right Ascension the final prediction was off by only around 15 mas with respect to the last minute update, but in declination the offset was around 35 mas.



CCD shutter delay (0.2 – 0.3 seg)



-Each CCD has its own dead time
-EMCCD = zero deadtime

-Integration times depends on the relation StarMagnitude/Telescope/instrument

Some lessons learnt on strategies

Binary TNOs, difficulty in getting the astrometry: photocenter is not in the center of the body.

Binary stars: we do not know most of the time whether the star to be occulted is binary so the photocenter does not fall in te center of the star.

Proper motions of the stars: important for the initial predictions, but the problem is solved with astrometric updates.

Summary

In the last 3 years we have been successful in 18 TNOs occultations, 12 within our international collaboration. We can now predict and observe occultations of very faint stars.

Currently, a key issue is the high accuracy updates to refine predictions. We have developed the tools and the methods. But this requires a lot of observing time.

Sizes, shapes, diameters, albedos and densities have been determined for 10 TNOs and very accurate values were derived for 7 of them.

Future

-We expect to be able to observe around 3-5 new occultations per year, for the 10 to 15 largest TNOs using our current techniques.

-We expect to be able to extend the success to the 100 largest TNOs.

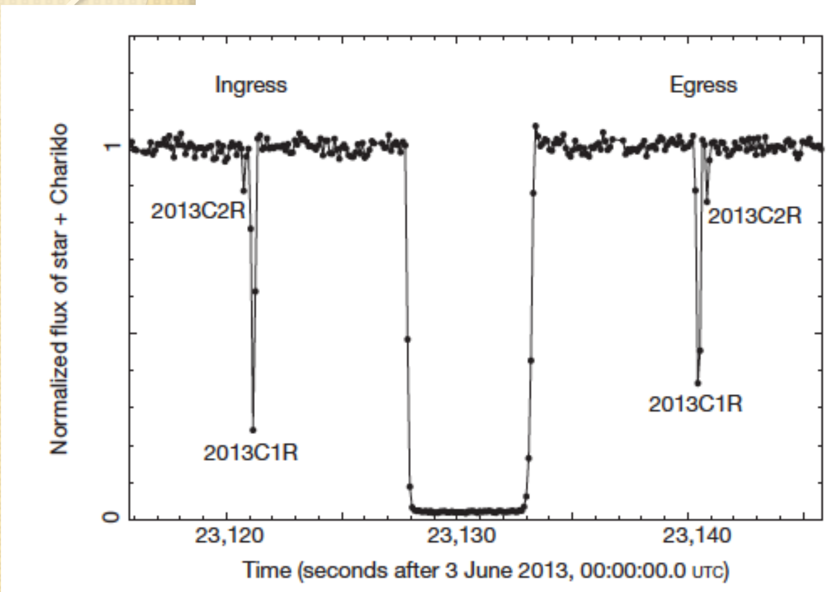
- Moving to smaller TNOs is difficult (orbits, access to telescopes to make prediction, etc), but we can do it.

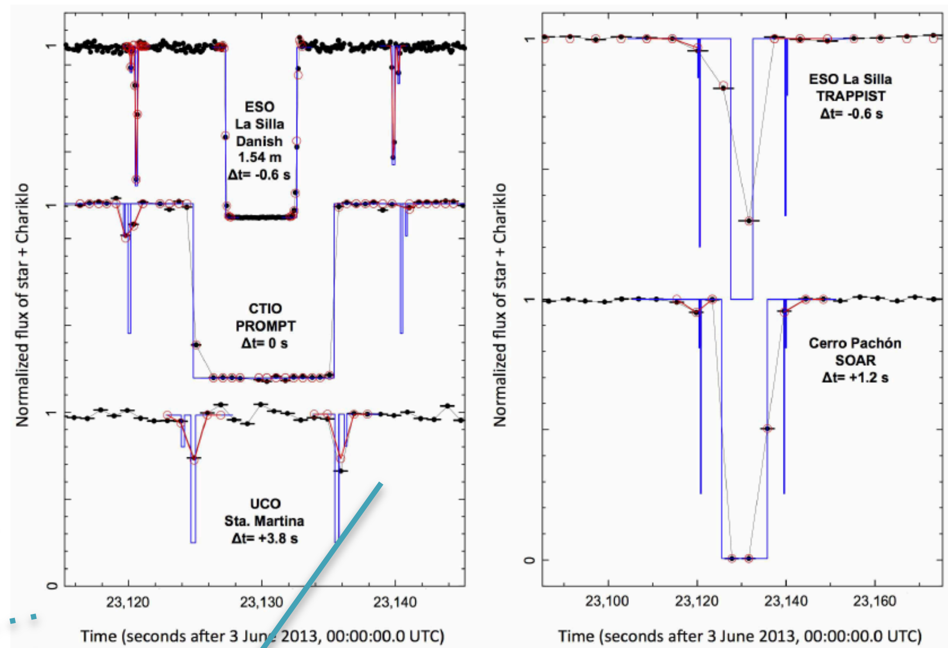
-To observe future occultations, amateur and small observatories will play an important role.

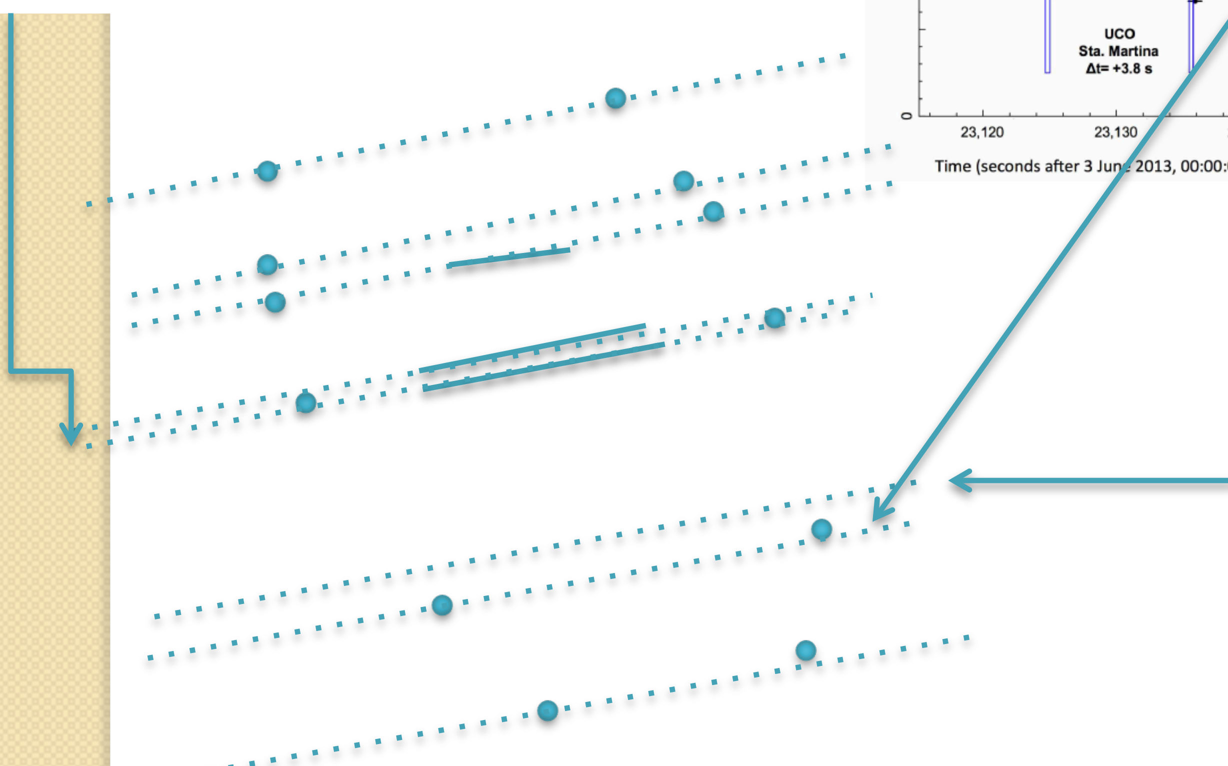
WE WANT ,WE NEED……….. YOUR COLLABORATION

- Small telescopes
- Normal CCD or EMCCD (better)
- No filter
- Time stamp
- FOV of several arcmin
- Good S/N in the occulted star flux

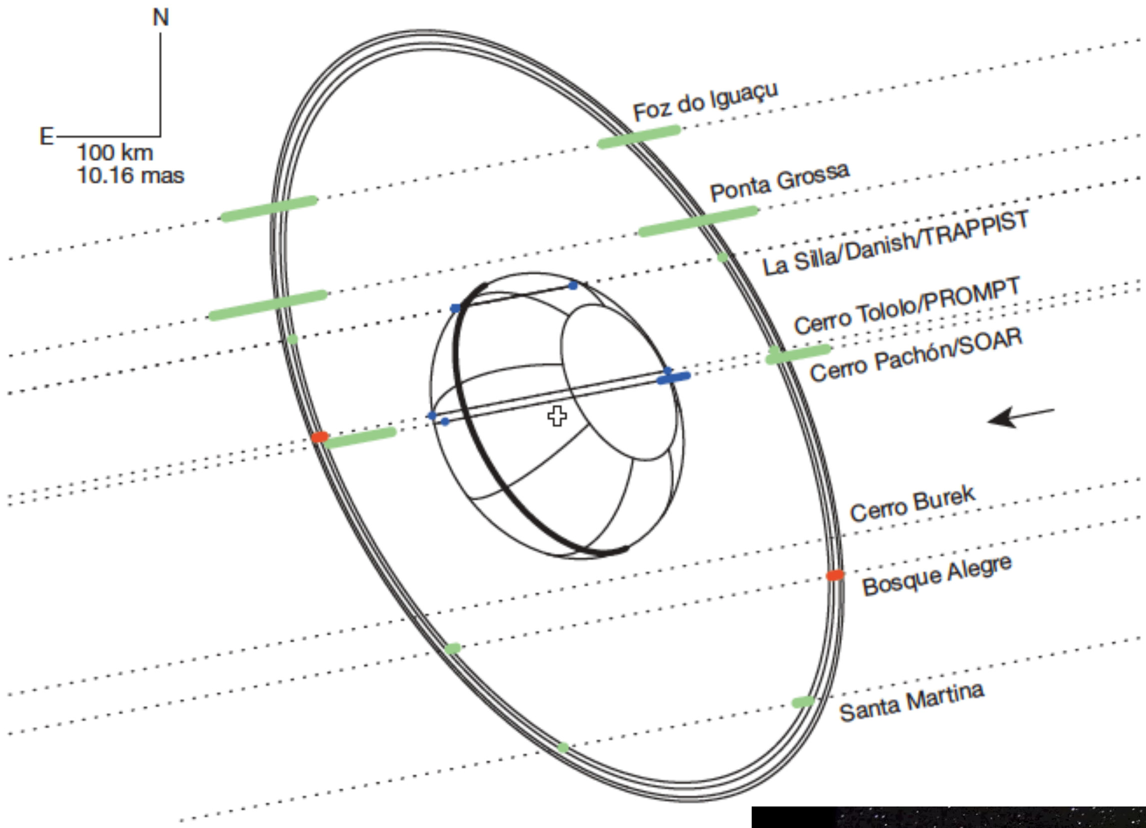
June 2013 / stellar occultation





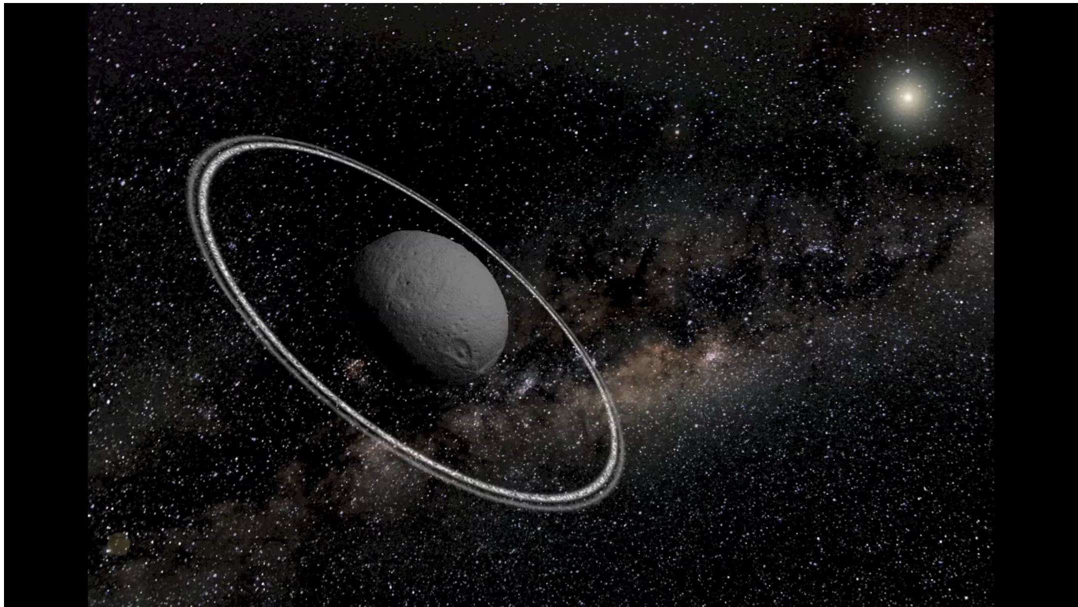


Nothing !!??



Pole solution: λ = 138° β=28°

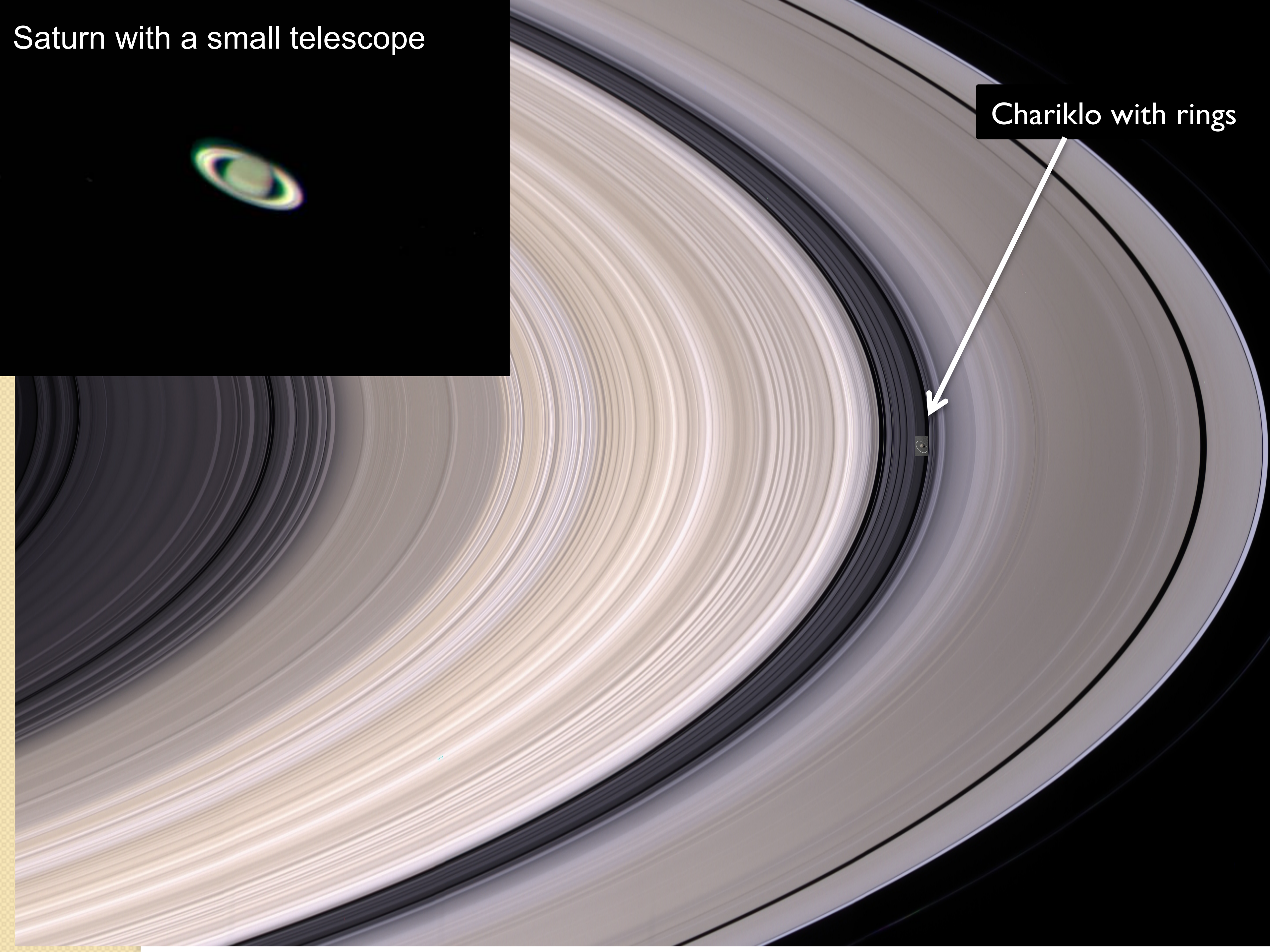
4 more occultations by Chariklo during 2014.
Few more ring occultations



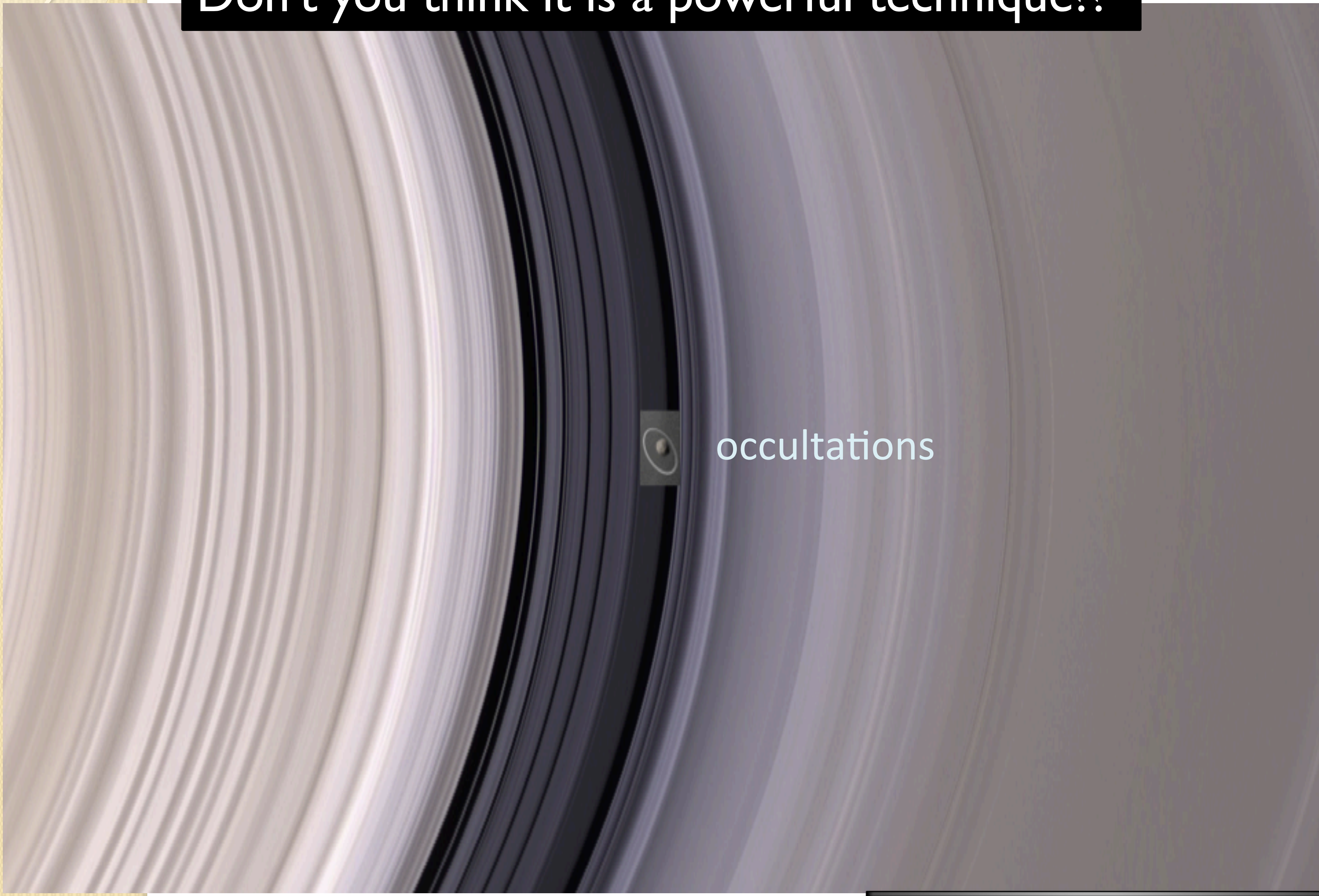
Chariklo
200 km diameter

Rings 400 Km (4 km width)

At 15 AU !!!!


Saturn with a small telescope
Chariklo with rings

Don't you think it is a powerful technique??



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