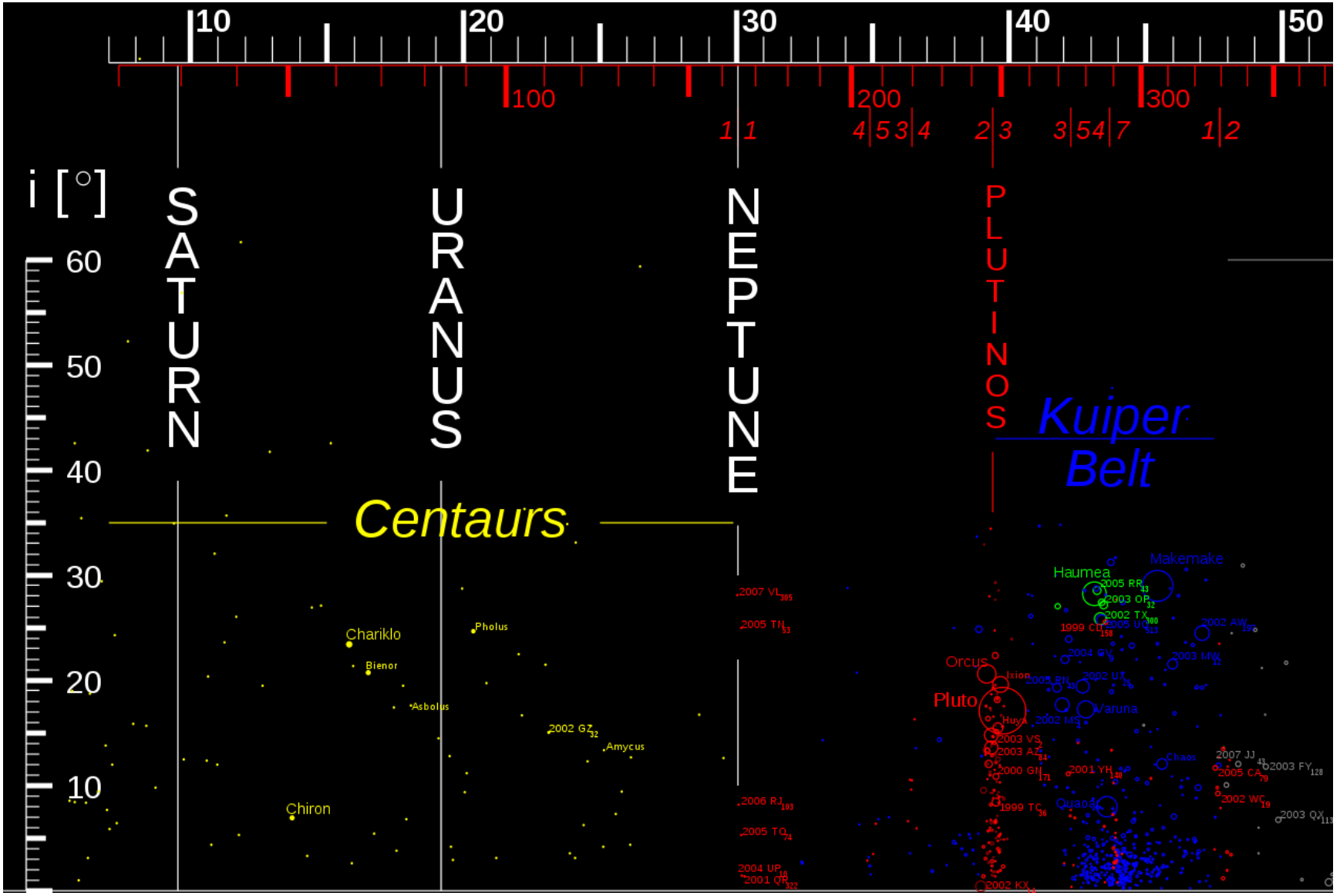
(10199) Chariklo

Mike Kretlow, Germany, IOTA/ES & MPC 244 / C95

Kleinplanetentagung 2017, Leiden, Netherlands
June 9-11, 2017

Beyond Jupiter ...



Centaurs

- MPC definition: q > 5.2 AU and a < 30.1 AU
- Origin was mysterious for long time. Now we think:
  - They come from the Kuiper belt, a reservoir of cometary nuclei beyond Neptune and Pluto.
  - Having been perturbed inward by Uranus and / or Neptune.
  - Currently in dynamically unstable orbits:
    - Will either be ejected from SS or
    - Will impact the Sun or a Planet or
    - Will become short-period comet due to gravitational influence of giant planets
  - => continually replenished from the Kuiper belt

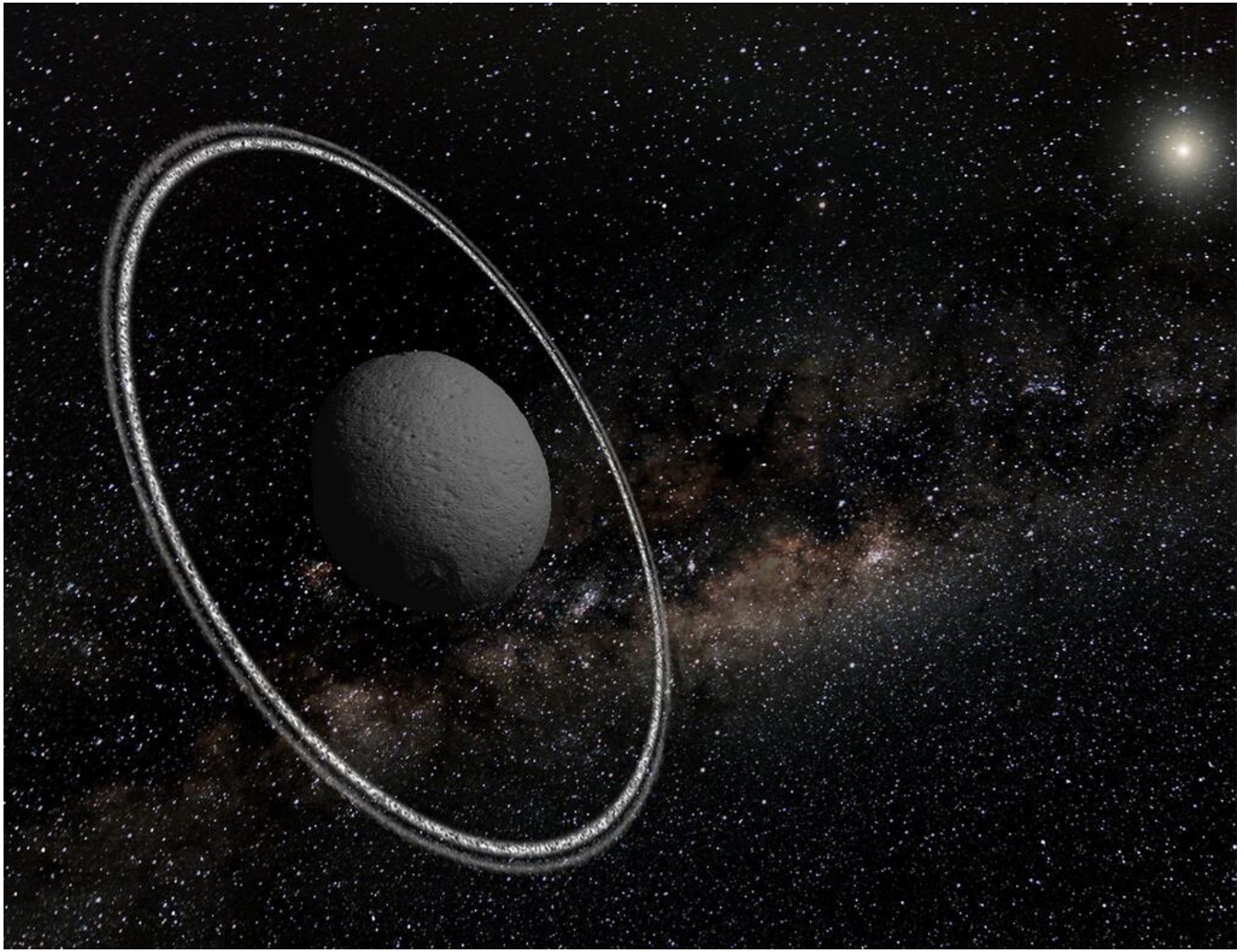
Notable Centaurs

- (2060) Chiron: Coma detected near perihelion (1988 / 1989)
  =>classified as asteroid AND comet.
- Dito for (60558) Echeclus.
- 29P/SW and 38P/Stephan-Oterma referred as Centaurs (typical Centaur orbit).
- Etc.

(10199) Chariklo – some numbers

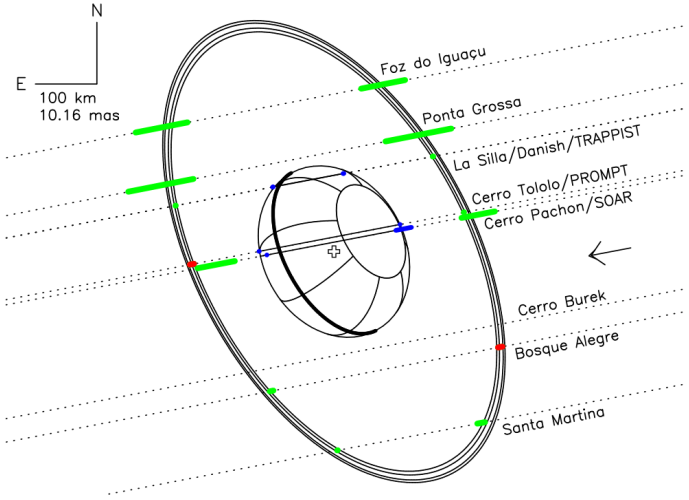
- Discovered Feb. 15, 1997 (Spacewatch, Kitt Peak)
- Chariklo is the largest known Centaur (d ~260 km)
- Orbit: q ~ 13 AU, e = 0.172, i = 23.4°
- Last perihelion in 2004, next in 2066.
- Rotation period P = 7h, geometric albedo only 0.042.
- Amplitude small, only ~0.1 mag (@ V ~ 18-19 mag)
- Variation of H of about 0.8 mag between 1997 and 2008 (Cometary activity? Spin axis effects? NO!).

Chariklo has a ring system !

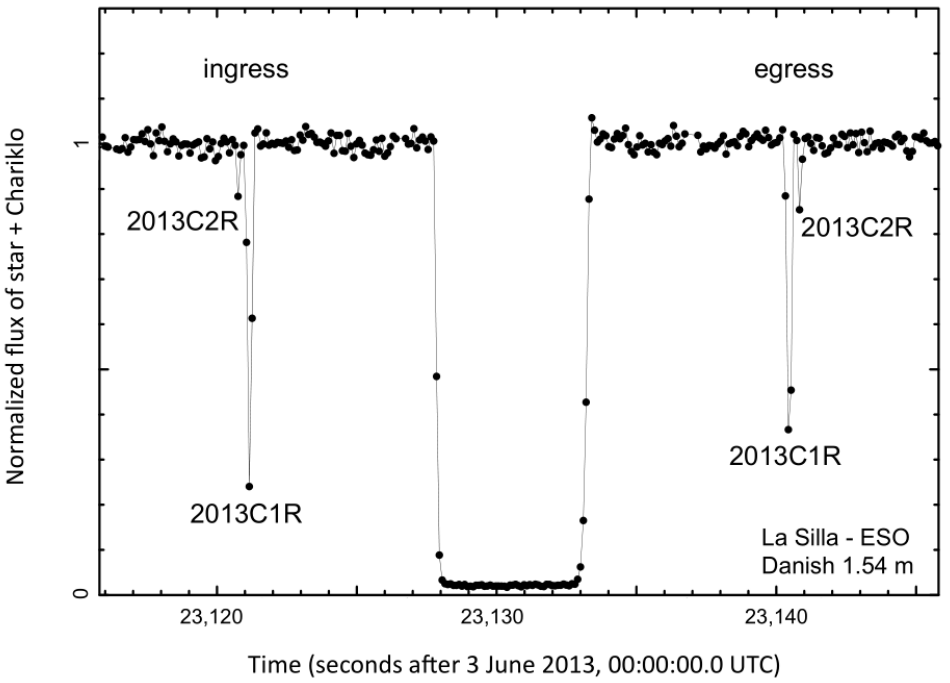


The first known asteroid-like sized object to have rings

Occultation in 2013 revealed rings



- Inner, denser ring at 390 km distance from body center.
- Second ring 15 km outside inner ring.
- 9 km gap between.



The ring system can explain the dimming of the Chariklo system !

Big question is:

Are there more Centaurs having rings !?
Probably: YES

(2060) Chiron is suspected to have rings, based on unexpected occultation events in 1993,1994, 2011 (at that time interpreted as coma jets etc.)

Occultations are a powerful tool !

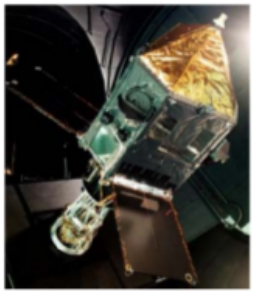
Unfortunately accurate predictions of distant objects were difficult in the past, because of uncerainties in star position and ephemeris

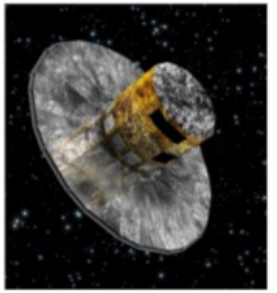
500 mas in 10 AU : ~3600 km

But we profit now from some recent improvements:

From Hipparcos to Gaia

	Hipparcos	GAIA
Magnitude limit	12	20 mag
Completeness	7.3 – 9.0	~20 mag
Bright limit	~0	~3-7 mag
Number of objects	120 000	26 million to V = 15 250 million to V = 18 1000 million to V = 20
Effective distance limit	1 kpc	1 Mpc
Quasars	None	$\sim 5 \times 10^5$
Galaxies	None	10^6 - 10^7
Accuracy	~1 milliarcsec	7 μarcsec at V = 10
	J1991.25	12-25 μarcsec at V = 15 200-300 μarcsec at V = 20
Broad band	2-colour (B and V)	5-colour to V = 20
Medium band	None	11-colour to V = 20
Radial velocity	None	1-10 km/s to V = 16-17
Observing programme	Pre-selected	Complete and unbiased





Problem: Occultation prediction uncertainty for distant objects

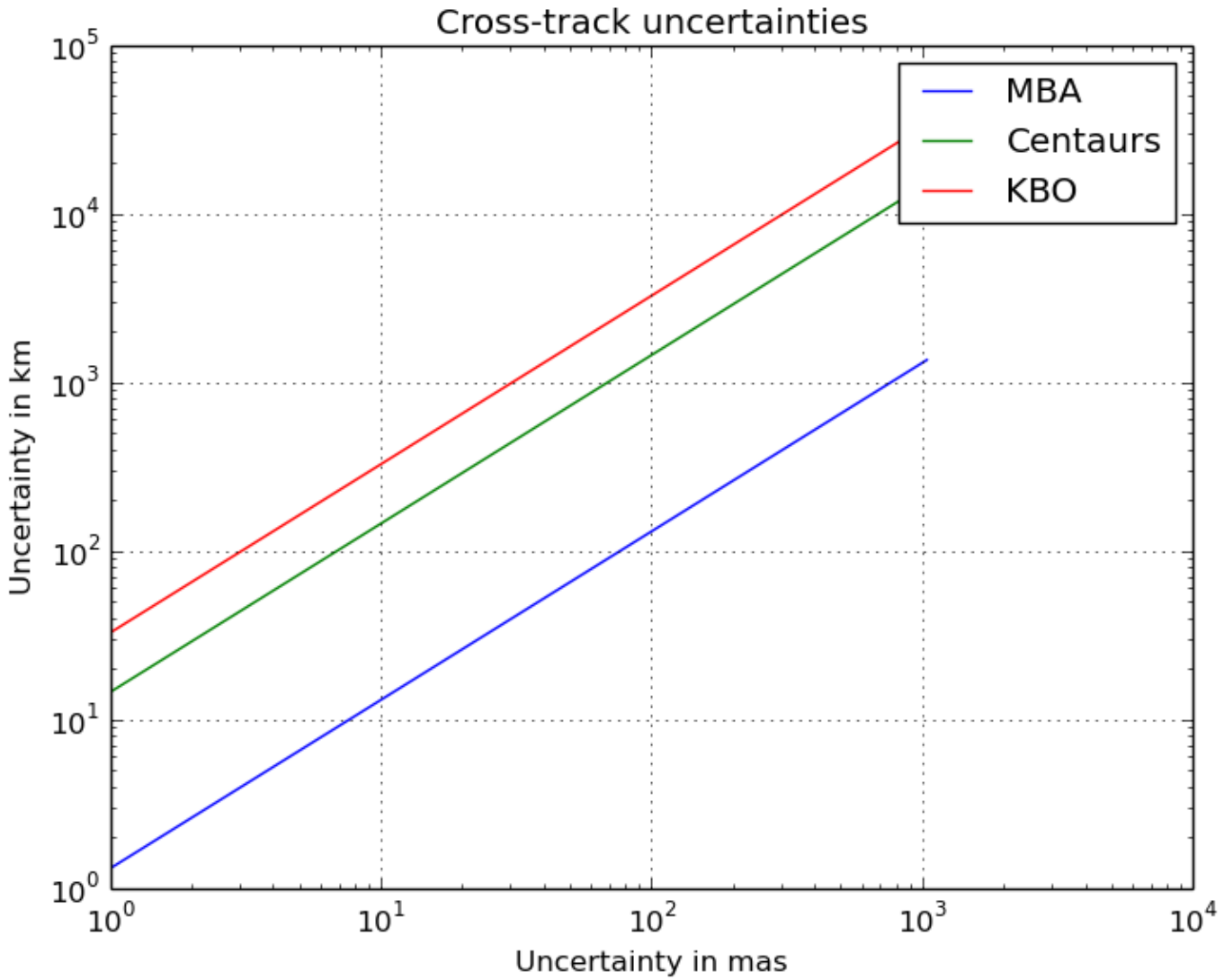
- Typical uncertainty for latest non-Gaia star positions:
  - URAT1: < ~ 50 mas
  - UCAC4: < ~100 mas

- Typical uncertainty for latest Gaia based star positions:
  - HSOY, UCAC5: 1-5 mas
  - GDR1, GDR2 : sub-mas (mas is PM unknown)
  - Gaia final: 5 µas (3-13 mag), 10^2 µas (faintest stars)

- Typical ephemeris uncertainty for MBA's: ~30...500 mas.
  Dedicated updated orbit solutions typically < 50 mas).

- Typical ephemeris uncertainty for distant objects: 10^2 mas
  Dedicated objects (Lucky Star project): 10^0-10^1 mas

Cross-track uncertainties :-(



•ERC Project Lucky Star

- Long-term project led by Brunon Sicardy in collaboration with groups from Paris, Meudon, Granada ,Rio and others.
- Dedicated astrometric observations at ESO, Pic du Midi, Calar Alto, Sierra Nevada, Pico dos Dias etc.
- Specialized software and dedicated manual orbit calculation for selected Centaurs and TNO‘s. Highest precision currently available.
- Providing occultation predictions and planning / supporting observation expeditions in collaboration with amateur astronomers and groups (e.g. IOTA).

(10199) Chariklo

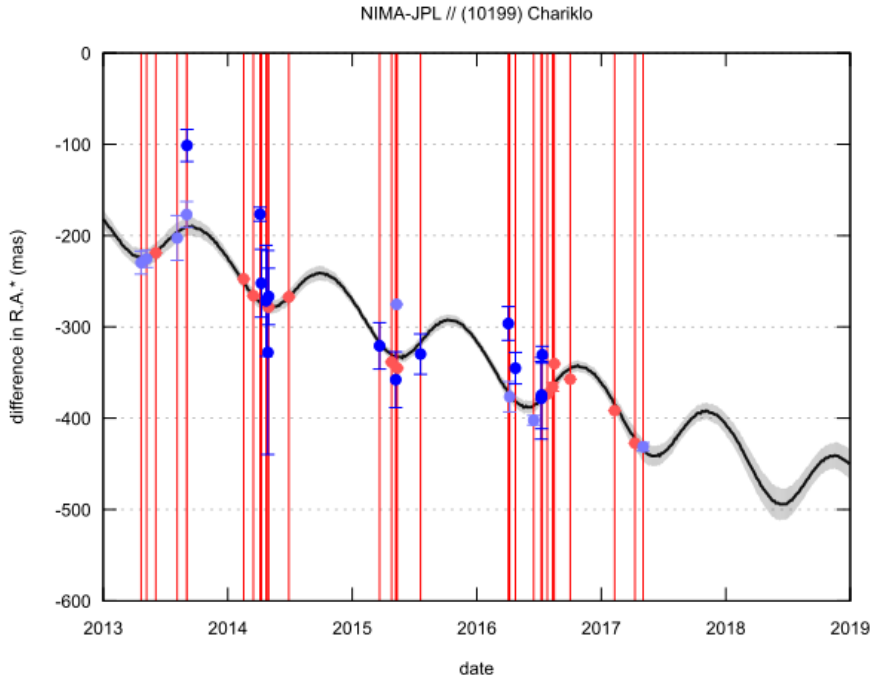
Ephemeris solution

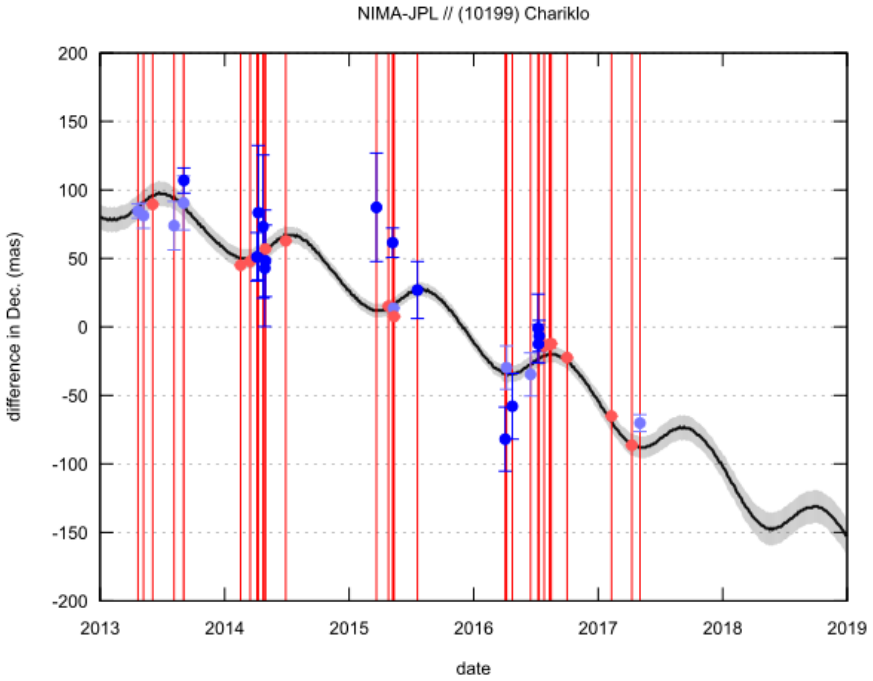
- ***Observations used***: MPC (1988-2011) + OPD (2011,2013,2014) + ESO (2013-2014,GaiaDR1+derivedPM)+ Cerro Tololo (2014) + Occ (2013.06.03,GaiaDR1+derivedPM) + Occ (2014.02.16,GaiaDR1+derivedPM) + Occ (2014.03.16,GaiaDR1+derivedPM) + Occ (2014.04.29,GaiaDR1+derivedPM) + Occ (2014.06.28,GaiaDR1+derivedPM) + THA (2015.03,GaiaDR1+derivedPM) + Occ (2014.04.26,GaiaDR1+derivedPM) + ESO (2015.05) + Occ (2015.05.12,GaiaDR1+derivedPM) + SOAR (2015.07) + ESO (2016.04,GaiaDR1+derivedPM) + SHOC (2016.04.12, offset) + OPD (2016.04) + ESO (2016.06,GaiaDR1+derivedPM) + OPD (2016.07,GaiaDR1+derivedPM) + Occ (2016.07.25,GaiaDR1+derivedPM) + Occ (2016.08.10a,GaiaDR1+derivedPM) + Occ (2016.08.15,GaiaDR1+derivedPM) + Occ (2016.10.01,GaiaDR1+derivedPM) + Occ (2017.02.08, GaiaDR1+derivedPM) + Occ (2017.04.09, GaiaDR1+derivedPM) + + OPD (2017.05, GaiaDR1)
- ***Observations not used***: OPD (2013.08.03) because of bad O-C + Occ (2015.05.12) from MPC (doublon) + Occ (2016.08.08) because bad O-C.
- ***Observations and residuals file***: omc_ast.res
- ***bsp file***: 10199_Chariklo_nima_v12.bsp
- ***Ephemeris file***: ephembsp.res
- ***Ephemeris version***: v12
- ***Comments***: This is an update version of v11 version with additional observations from OPD (2017.05) and position from OCC (2017.04.09)
- ***Date of creation***: 2017-05-31 14:17 (UTC)

Orbit quality

time	+0	+6	+12	+18	+24
σ (α)	0.012	0.009	0.018	0.014	0.025
σ (δ)	0.008	0.009	0.012	0.012	0.017

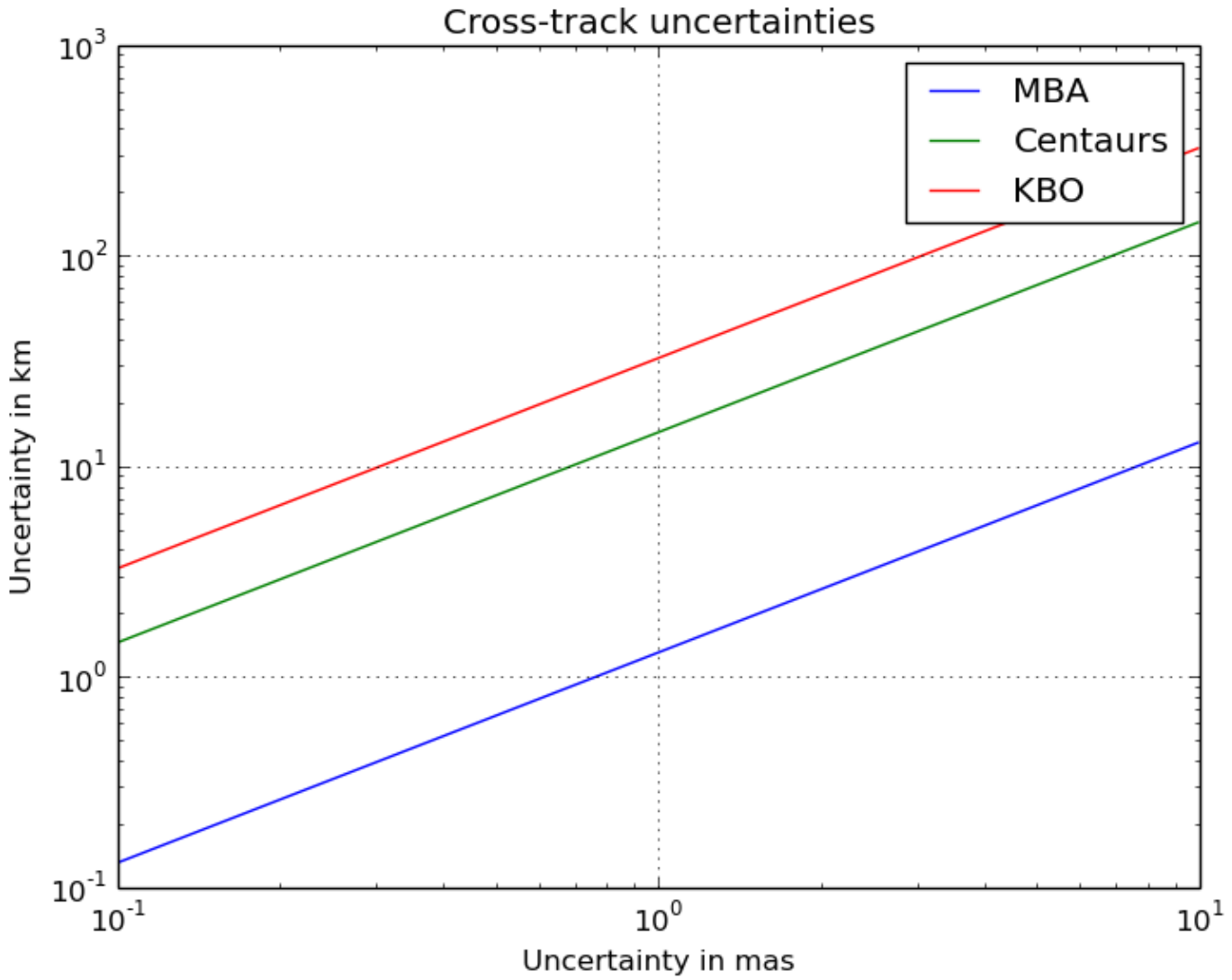
Time is number of months after last observation (2017-05-03) and σ are in arcsec.



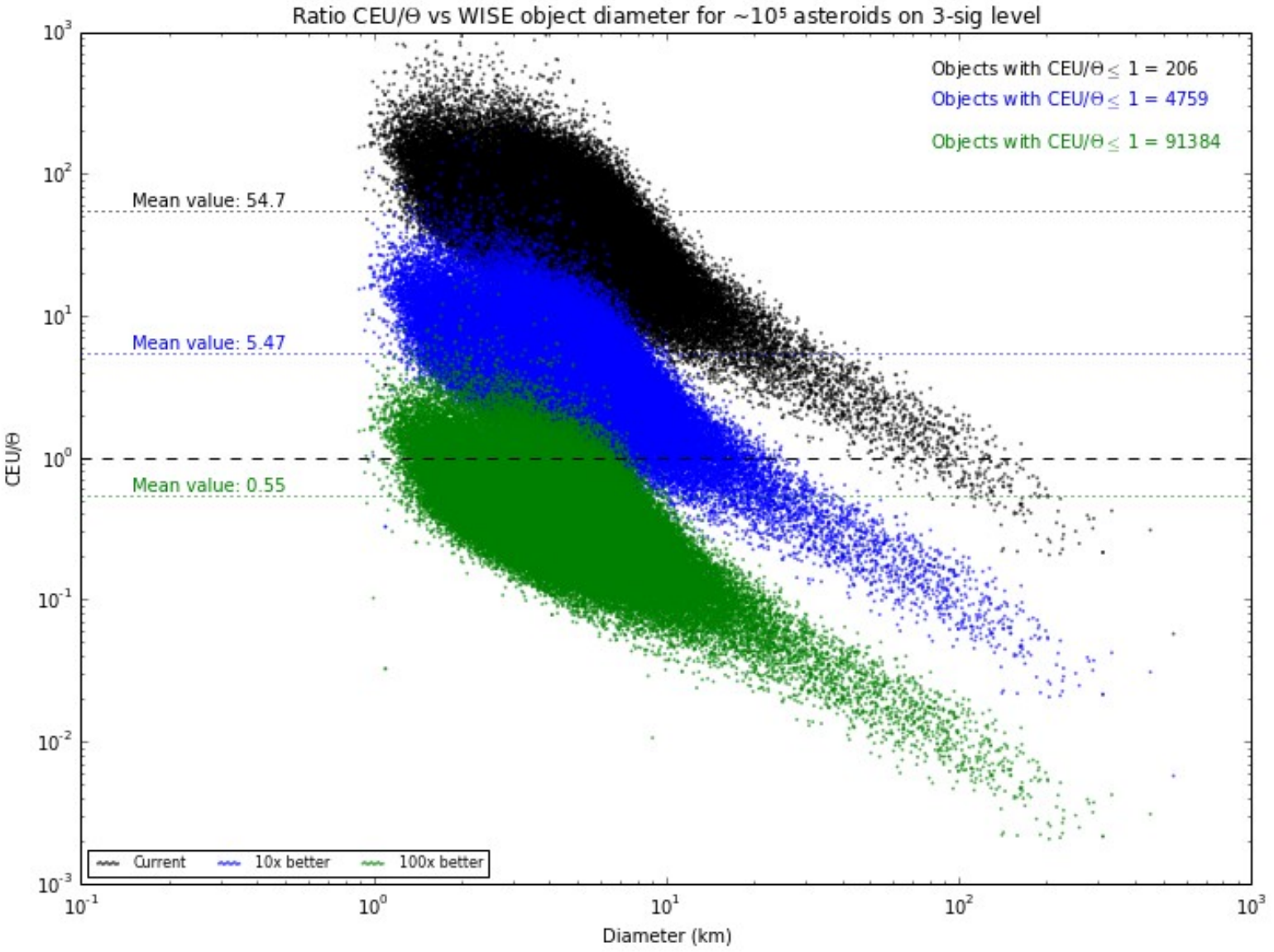


emeris

Cross-track uncertainties :-)



The Gaia Era


Ratio CEU/Θ vs WISE object diameter for ~10⁵ asteroids on 3-sig level
Objects with CEU/Θ ≤ 1 = 206
Objects with CEU/Θ ≤ 1 = 4759
Objects with CEU/Θ ≤ 1 = 91384
Mean value: 54.7
Mean value: 5.47
Mean value: 0.55
CEU/Θ
Diameter (km)
Current
10x better
100x better

Chariklo occultation campaign 2017

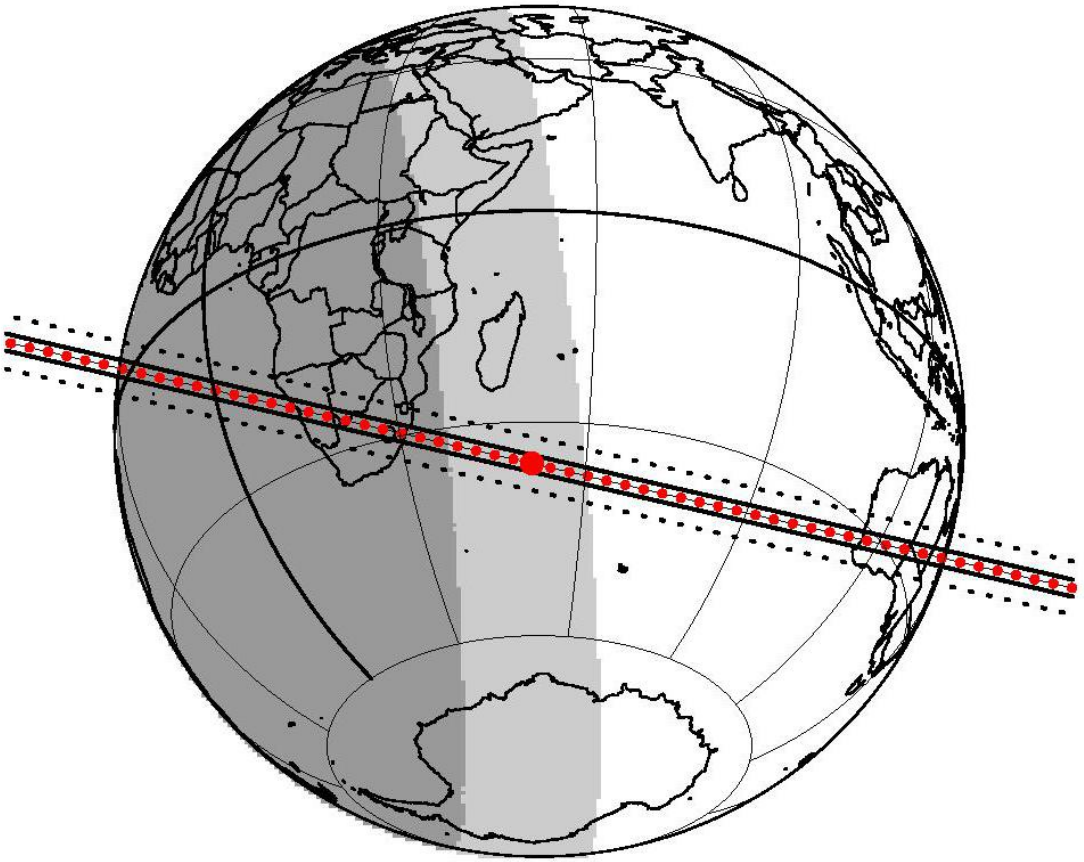
Three remarkable occultations by Chariklo this year:

Apr 09 : Namibia, Botswana and South Africa
June 22 : dito
Jul 23 : South America

By observing these occultations, a better shape of Chariklo and the detailed structure of the rings can be obtained.

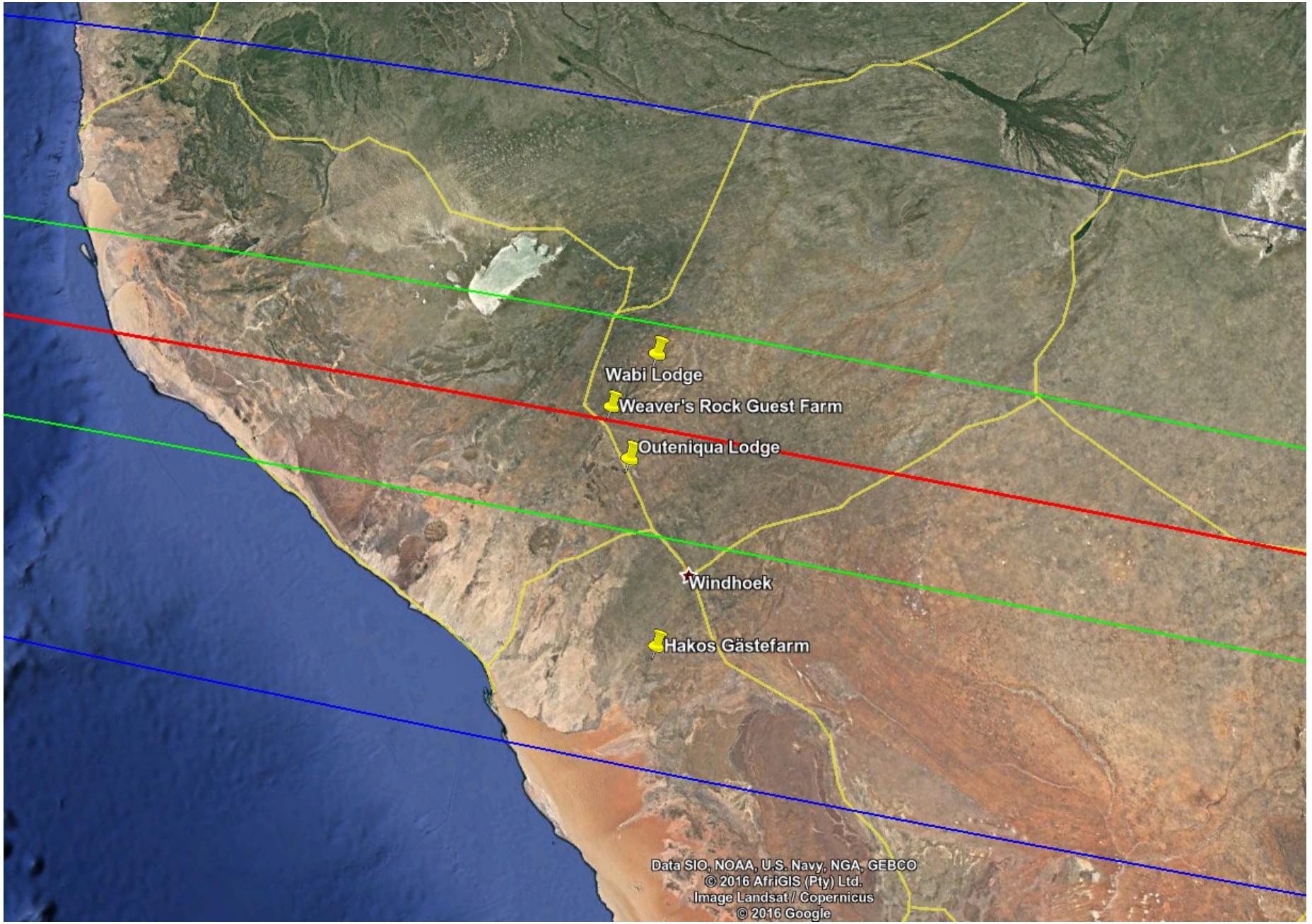
Knowing these characteristics improves our understanding of the ring stability and formation.

Chariklo: GaiaDR1, NIMAv11 ephem. Offset (mas): 0.0 0.0



by: LuckyStar

d	m	year	h:m:s	UT	ra___dec___J2000_candidate	C/A	P/A	vel	Delta	G*	J*	long
09	04	2017	02	24	58. 19 04 03.6287 −31 17 15.224	0.044	192.98	4.78	15.47	12.4	9.6	52.


Wabi Lodge
Weaver's Rock Guest Farm
Outeniqua Lodge
Windhoek
Hakos Gästefarm
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2016 AfriGIS (Pty) Ltd.
Image Landsat / Copernicus
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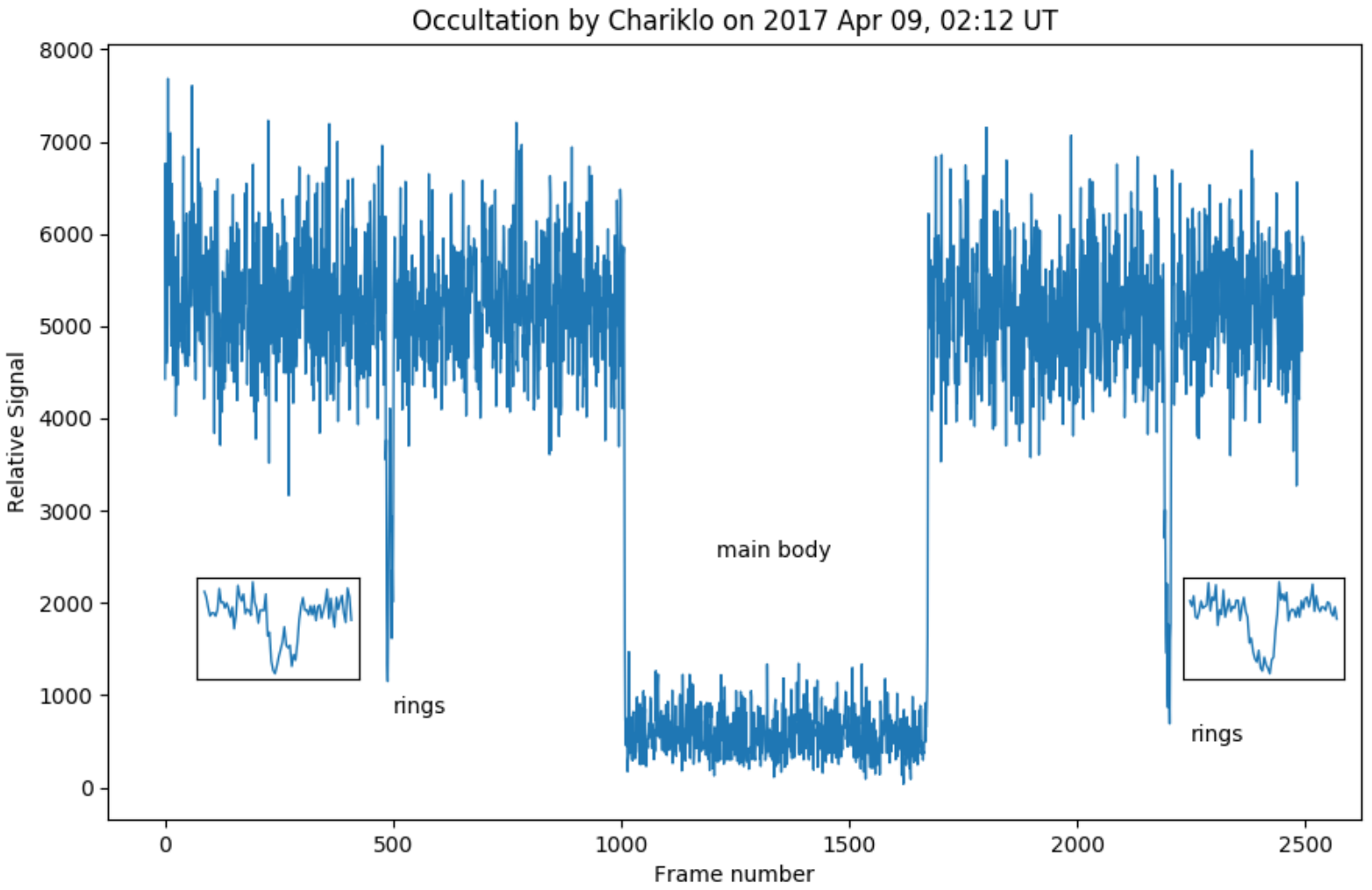
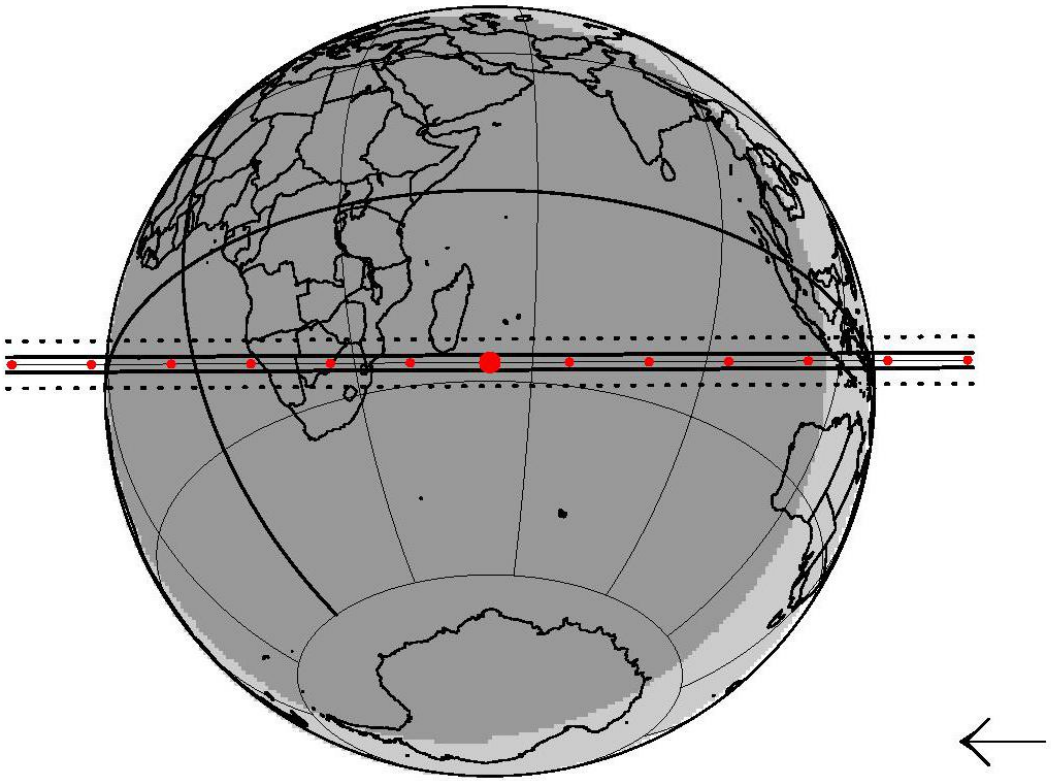
Some impressions

Occultation by Chariklo on 2017 Apr 09.

50 cm f/4 telescope, 12.5 Hz data rate. EM247 CCD camera.
Observer: M.Kretlow @ Weavers Rock Guest Farm, Namibia.

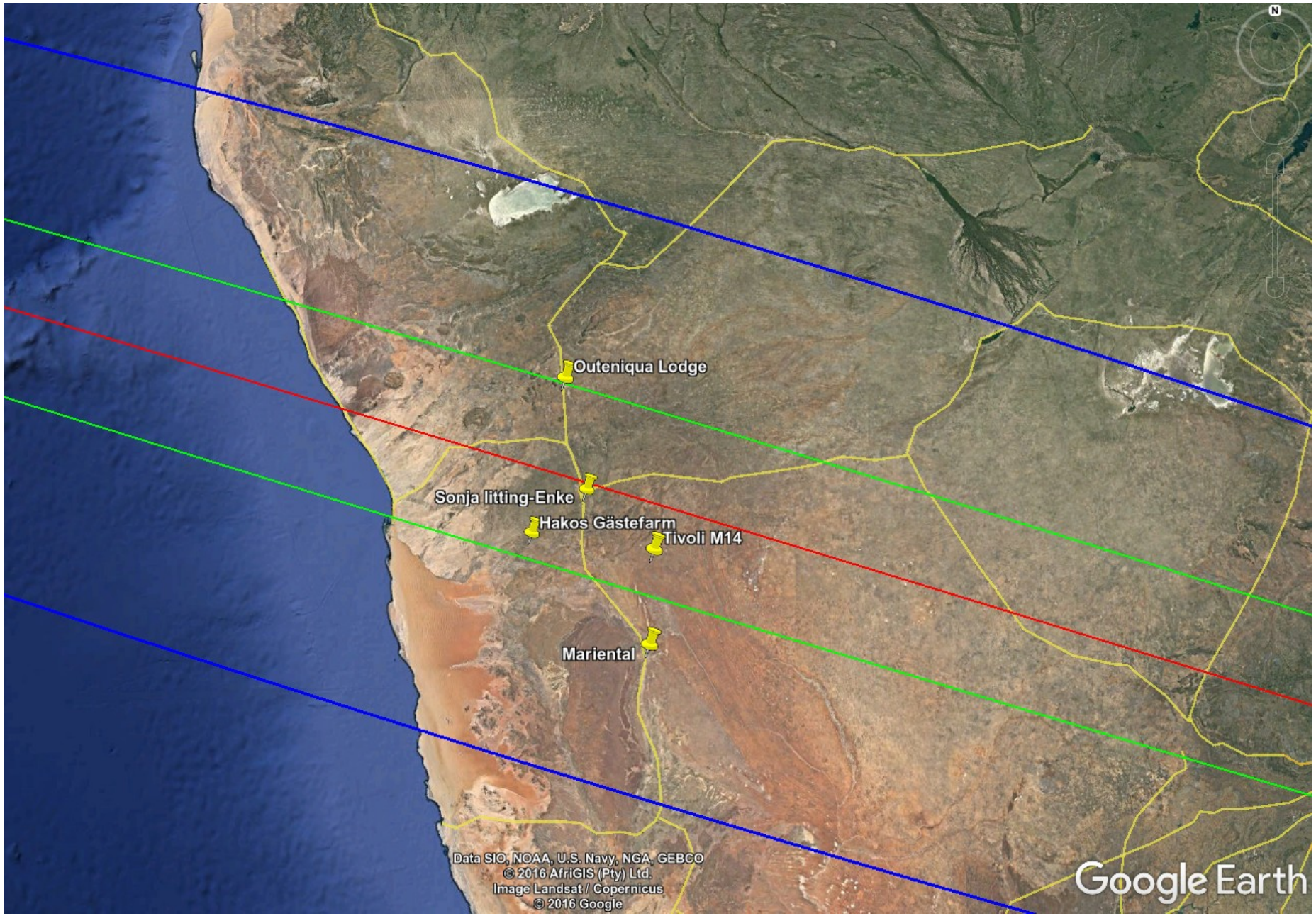


Chariklo: GaiaDR2+pmGDR2, NIMAv11 ephem. Offset (mas): 0.0 0.0



by: LuckyStar

d	m	year	h:m:s UT	ra___dec___J2000_candidate	C/A	P/A	vel	Delta	G*	J*	long
22	06	2017	21 18 51.	18 55 15.6525 −31 31 21.671	0.045	359.71	−22.00	14.66	14.2	12.5	53.



Planned stations for occultation by Chariklo on June 22

More about Chariklo at ESOP in Freiberg, Germany

ESOP XXXVI Programme Information Accommodation Registration Participants Contact

36th European Symposium ESOP XXXVI on Occultation Projects

ESOP XXXVI

INTERNATIONAL OCCULTATION TIMING ASSOCIATION EUROPEAN SECTION

36th European Symposium on Occultation Projects (ESOP)

in Freiberg, Germany, September 15th-19th 2017

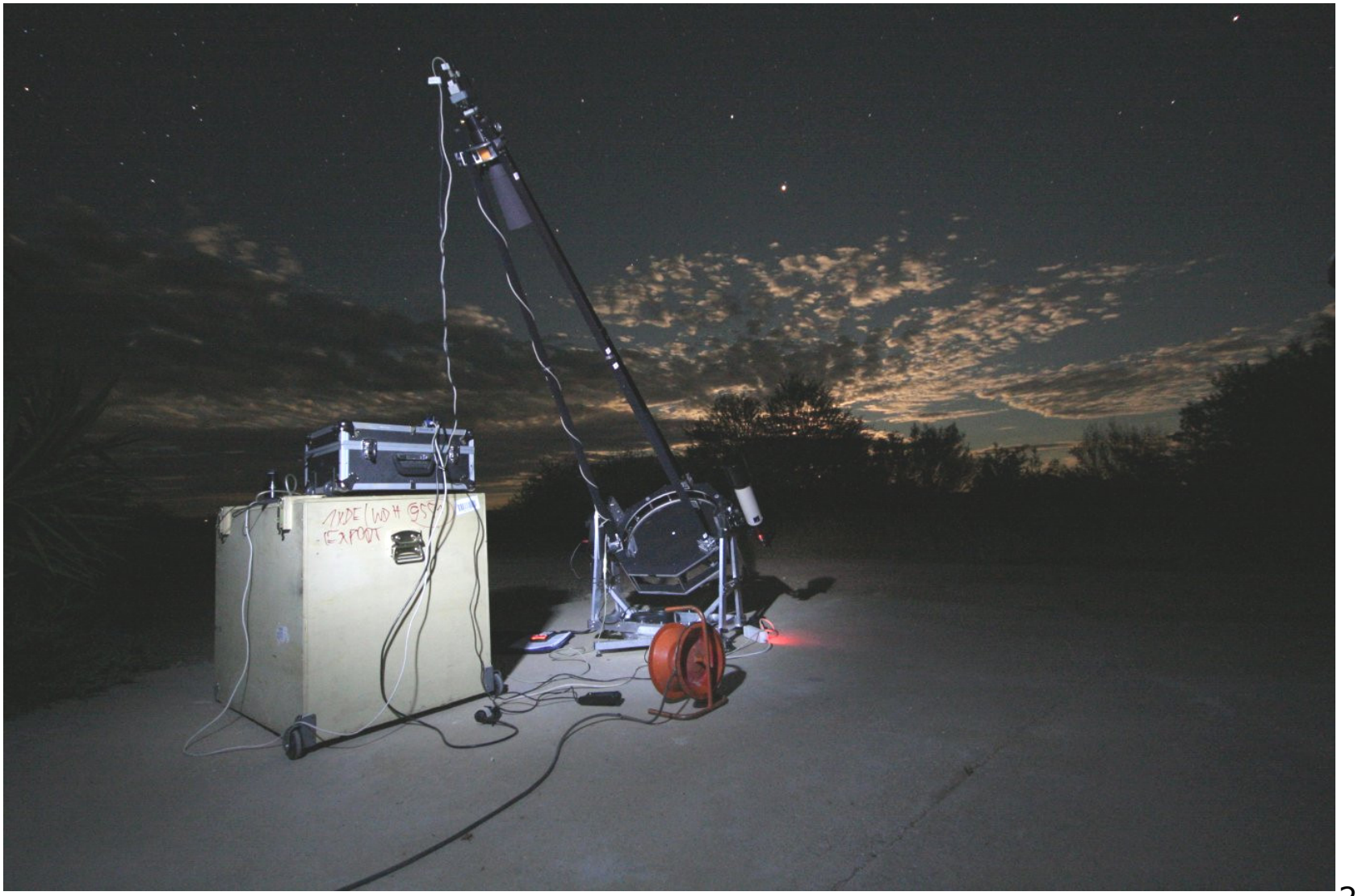
view of the towers of St. Peter's Church ("Petrikirche")

We are pleased to invite all interested parties to Freiberg, Germany for the 36th installment of the European Symposium on Occultation Projects. IOTA-ESs annual conference will, as always, include talks and lectures as well as interesting excursions.

Hosting town this time is Freiberg (German for: *free mountain*), Germany's oldest mining town. Founded in the 12th century in order to exploit silver deposits, the town is closely associated with mining and minerals.
Not only is the largest mineral collection on display at the castle in the heart of the historic old town, Freiberg is also home to the technical university Bergakademie, where two elements of the periodic table were discovered (indium and germanium). The Bergakademie is the oldest university of mining and metallurgy in the world, and educated polymaths such as M. Lomonossow and A. Humboldt.

In keeping with ESOP tradition, post conference excursions will be offered.

Thank You for Your Attention !



One hour after successful recording of the occultation :-)