Asteroid studies supported by Gaia

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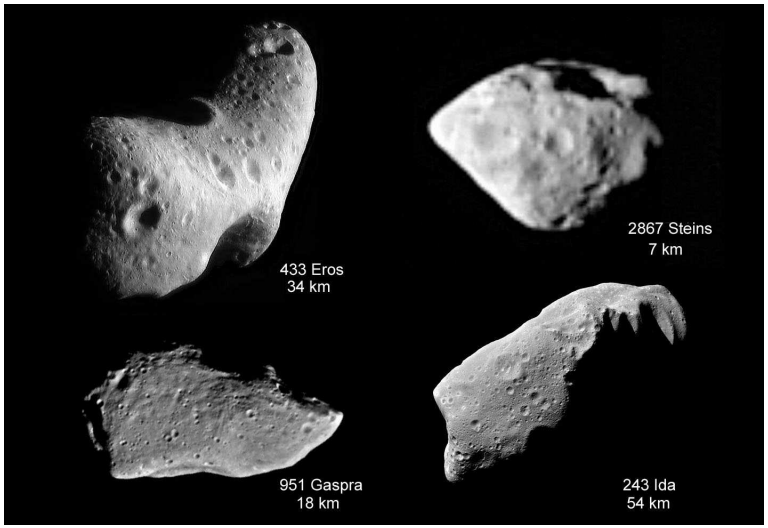
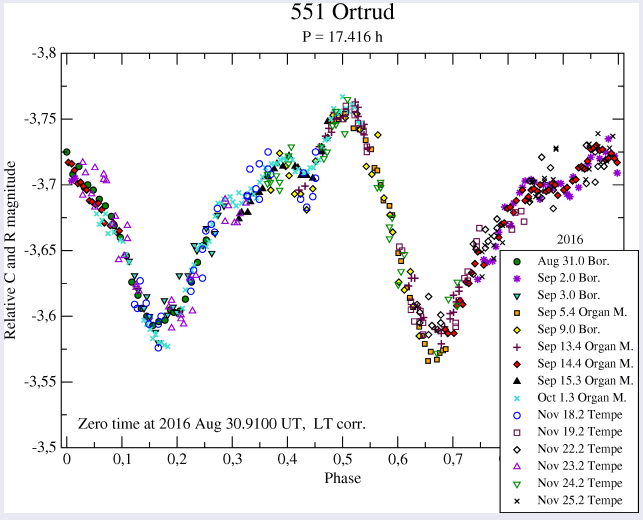
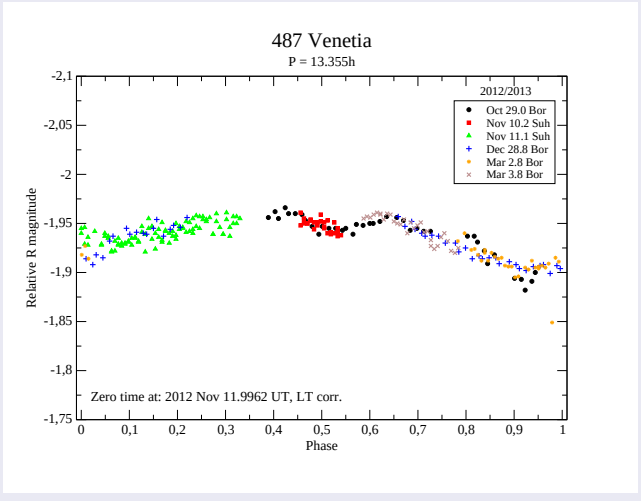
Why study asteroids?

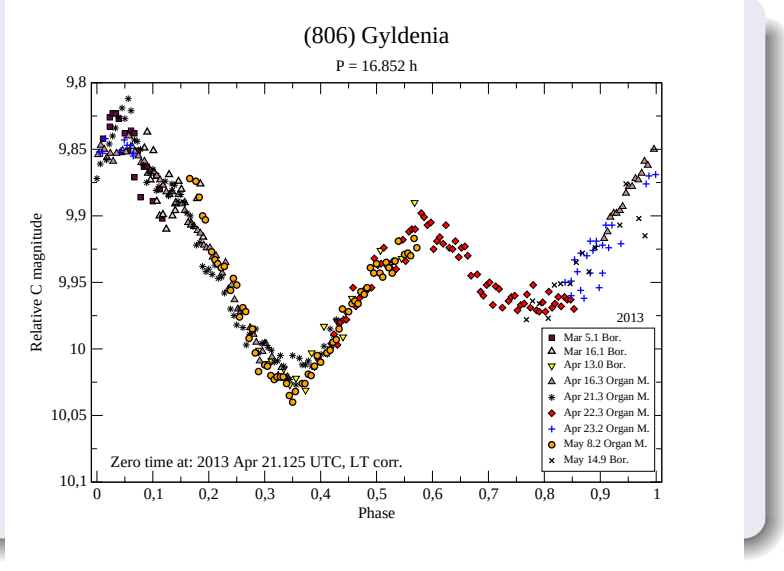
- Leftovers from Solar System formation
- Record of conditions and composition of protoplanetary disc
- Record of intensive migrations and heavy bombardment epochs
- Link between meteorites and their parent bodies
- Differentiated and hydrously altered little worlds
- Grouped in asteroid families and clusters
- Record of thermal recoil forces (Yarkovsky and YORP)
- Varying in thermal properties of regolith and deeper sub-surface layers

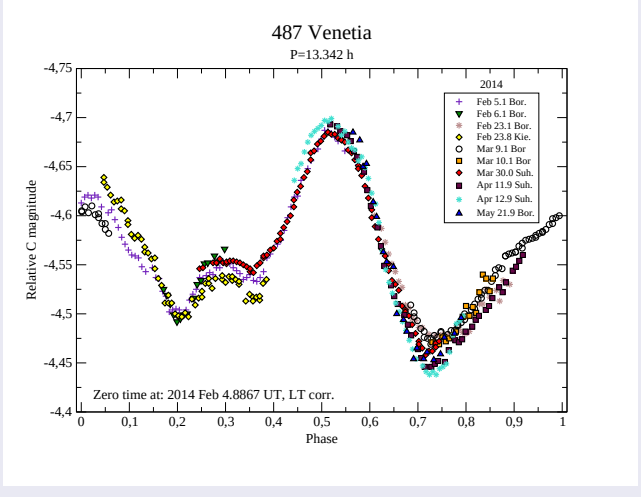


Asteroid lightcurves



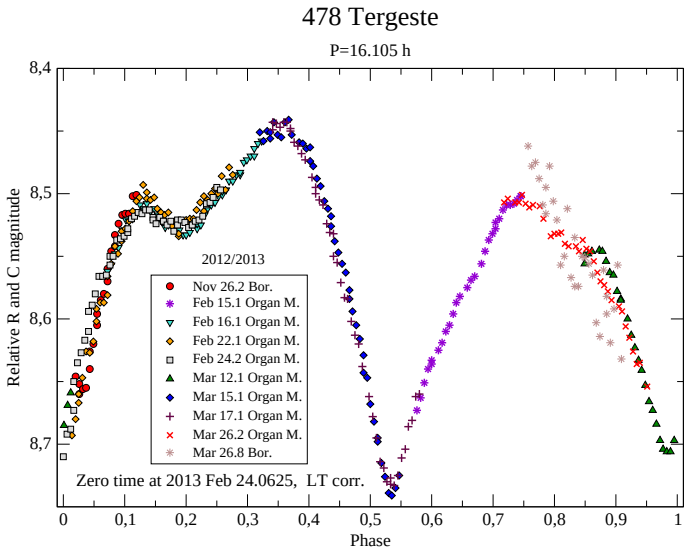


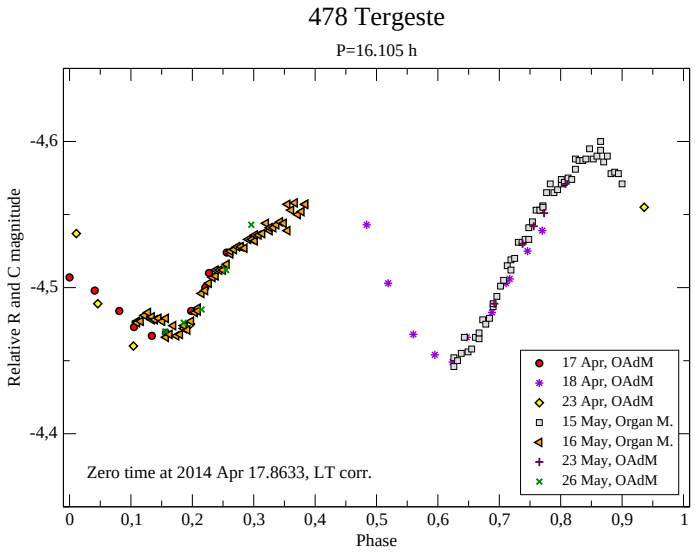


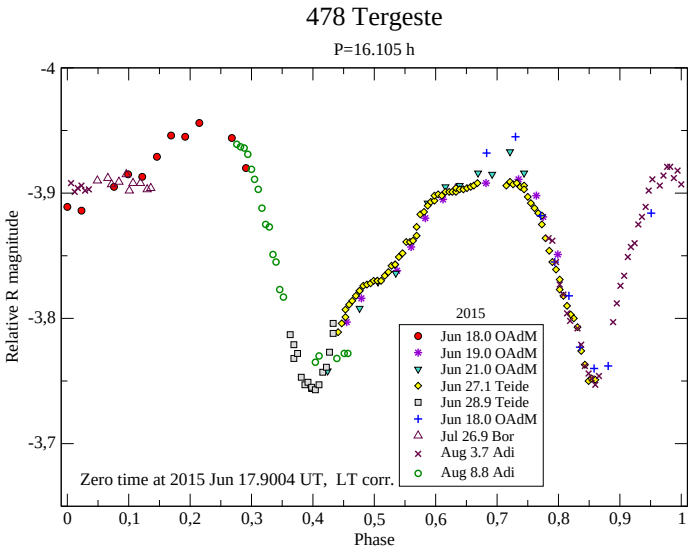


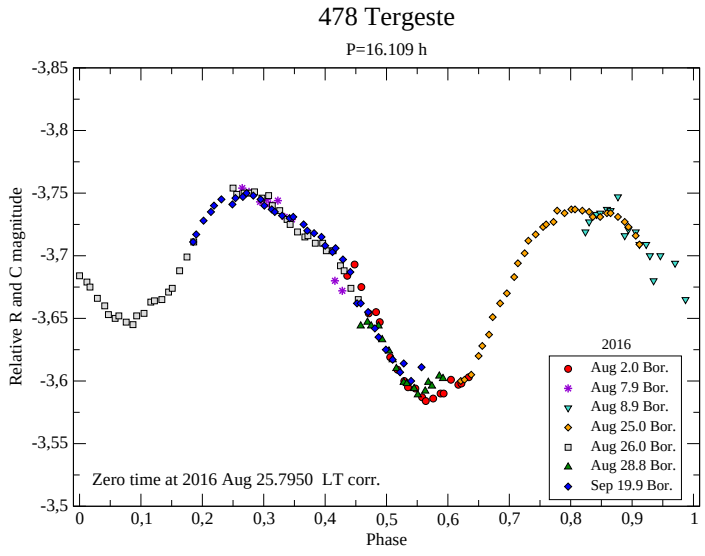
Marciniak et al. 2015, 2018

478 Tergeste - lightcurves



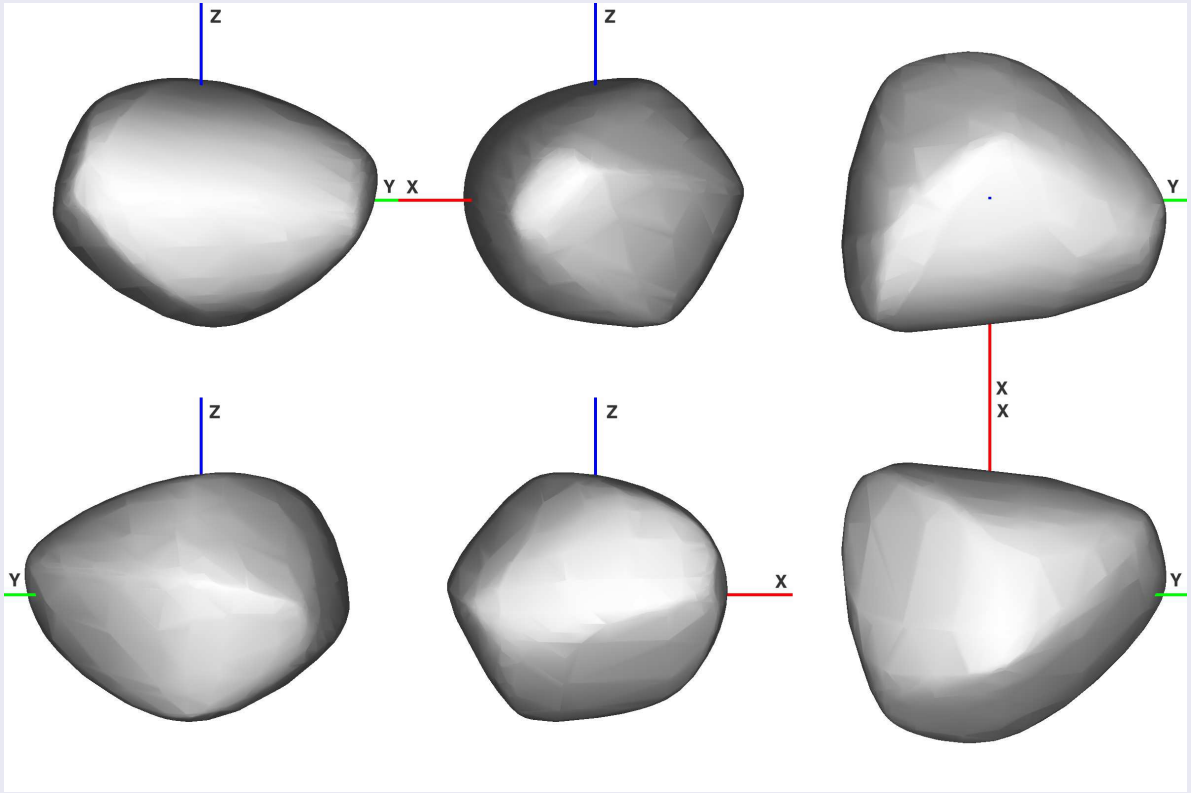






Marciniak et al. 2018

478 Tergeste - lighcurve inversion model



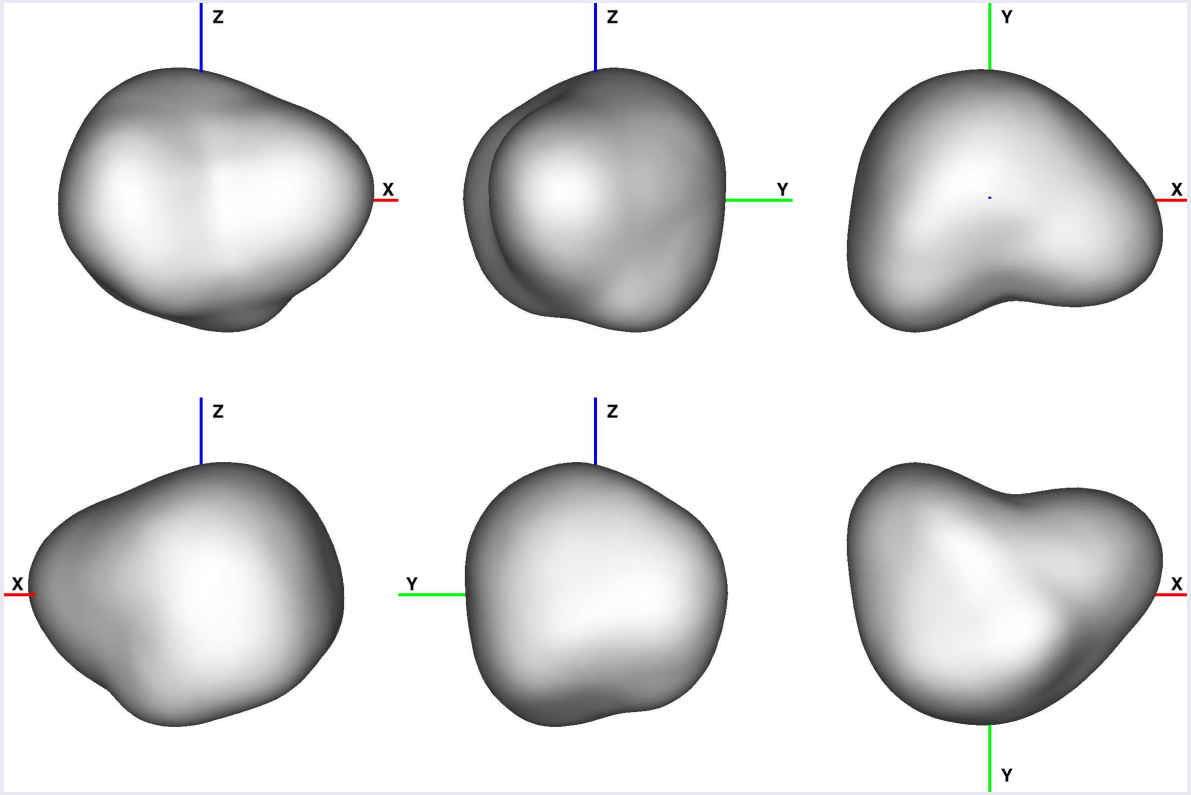
$P = 16.10311 \pm 0.0001$ h; rmsd $= 0.011$ mag

$\lambda_{p1} = 2° \pm 10°$ $\lambda_{p2} = 216° \pm 8°$

$\beta_{p1} = -42° \pm 6°$ $\beta_{p2} = -56° \pm 5°$

Marciniak et al. 2018

478 Tergeste - SAGE model (Shaping asteroids with Genetic Evolution)



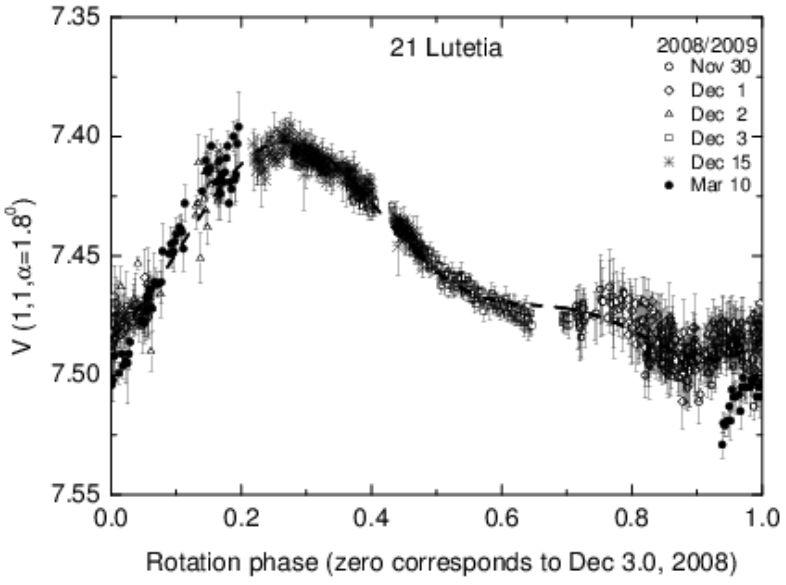
$P = 16.10312 \pm 0.00001$ h; rmsd $= 0.012$ mag

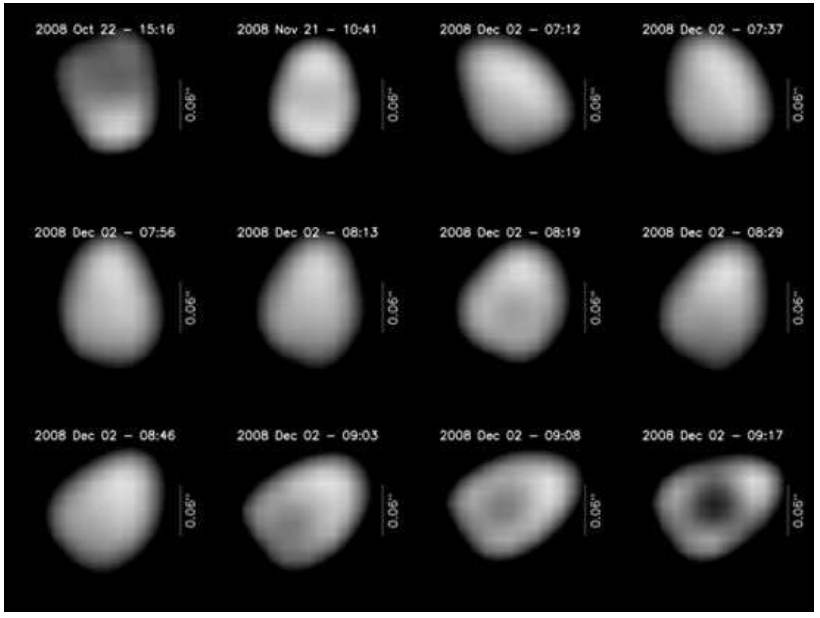
$\lambda_{p1} = 4° \pm 5°$ $\lambda_{p2} = 218° \pm 5°$

$\beta_{p1} = -43° \pm 5°$ $\beta_{p2} = -56° \pm 5°$

Marciniak et al. 2018

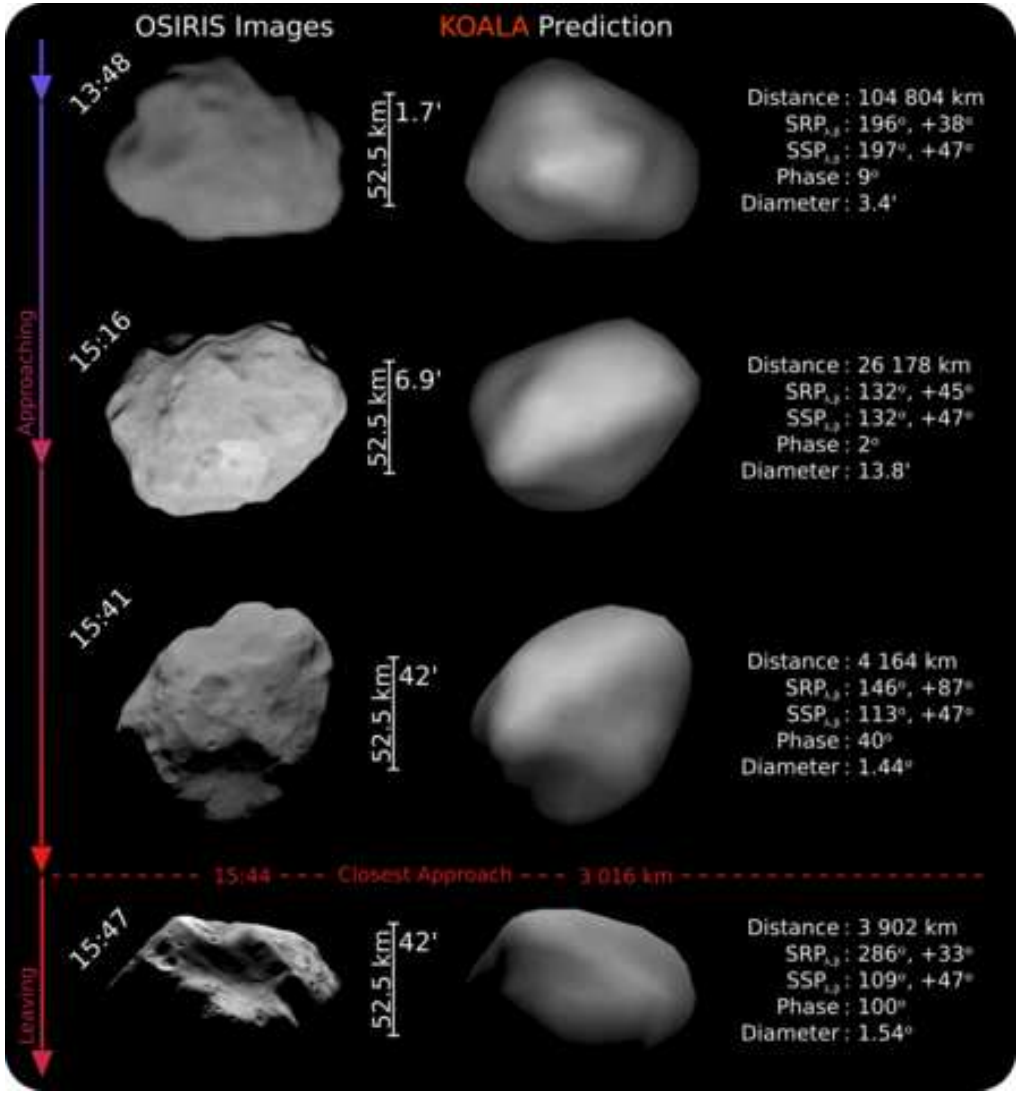
21 Lutetia - lightcurves and Adaptive Optics images





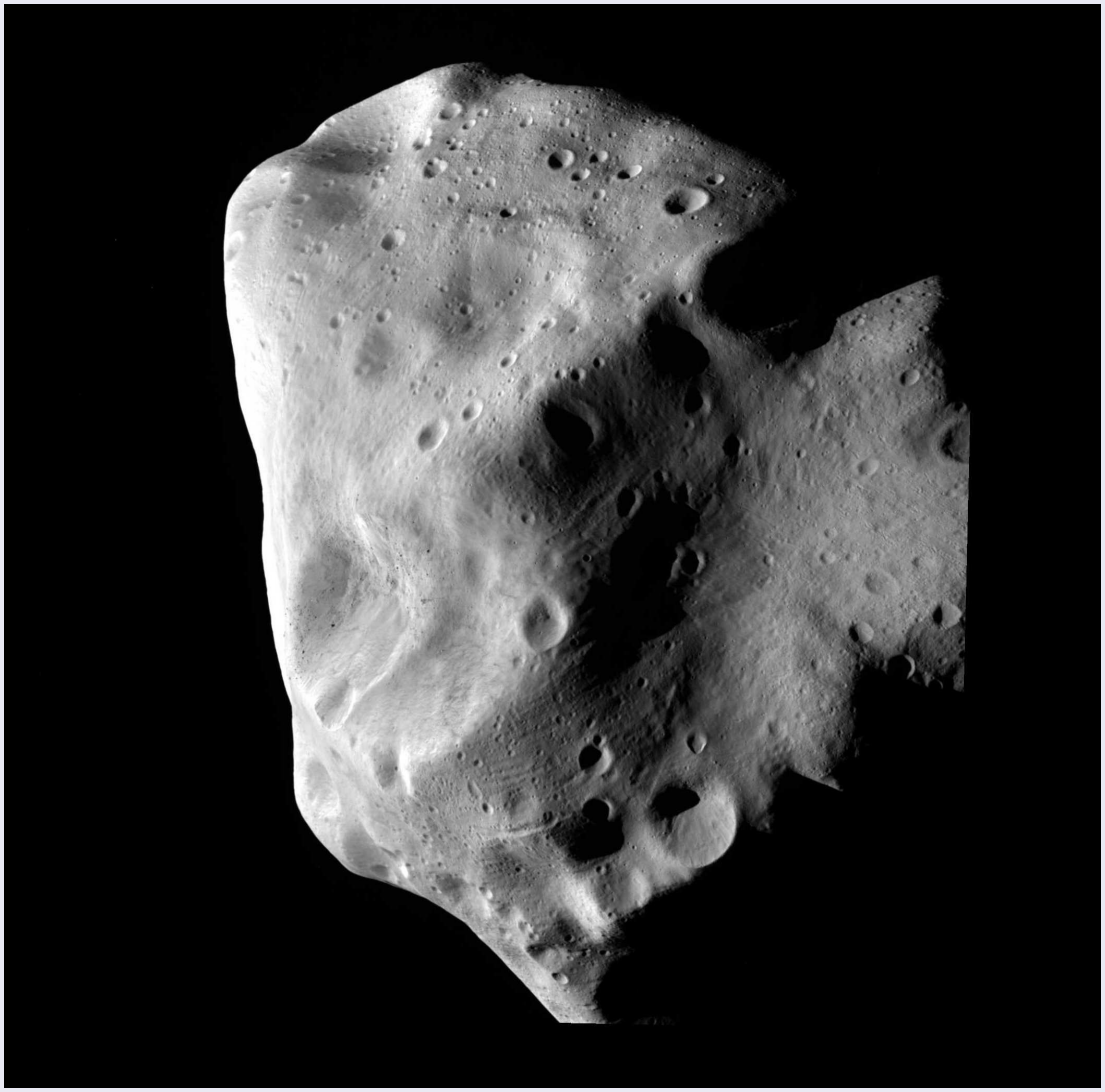
Belskaya et al. 2010, Carry et al. 2010

21 Lutetia - KOALA model (Knitted Occultation, Adaptive-optics, and Lightcurve Analysis)



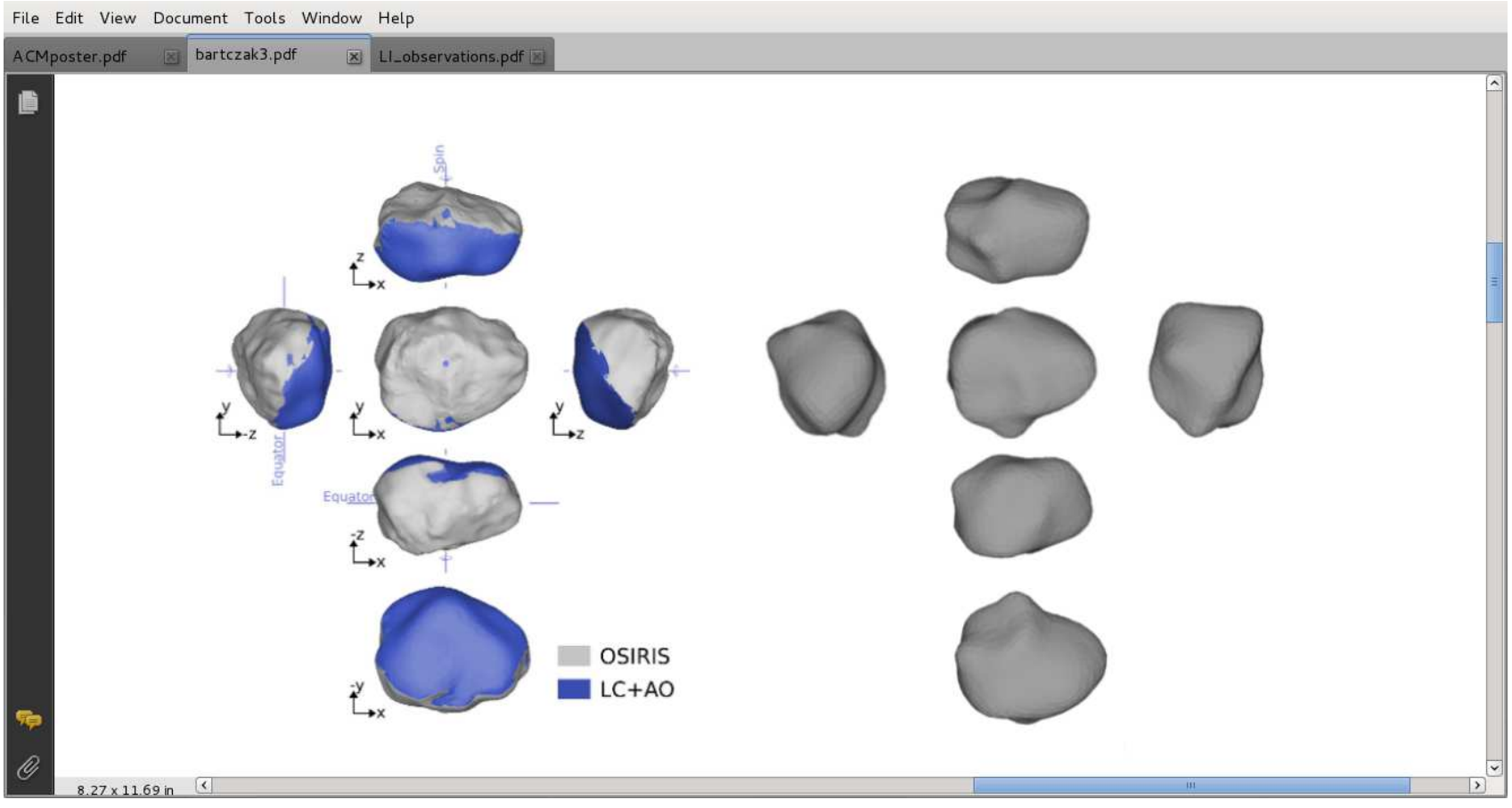
Carry et al. 2010

21 Lutetia as seen by the Rosetta spacecraft



ESA 2010 MPS for OSIRIS Team

21 Lutetia - model comparison



Carry et al. 2010, Bartczak et al. 2014

162 173 Ryugu - the best model prior to Hayabusa mission

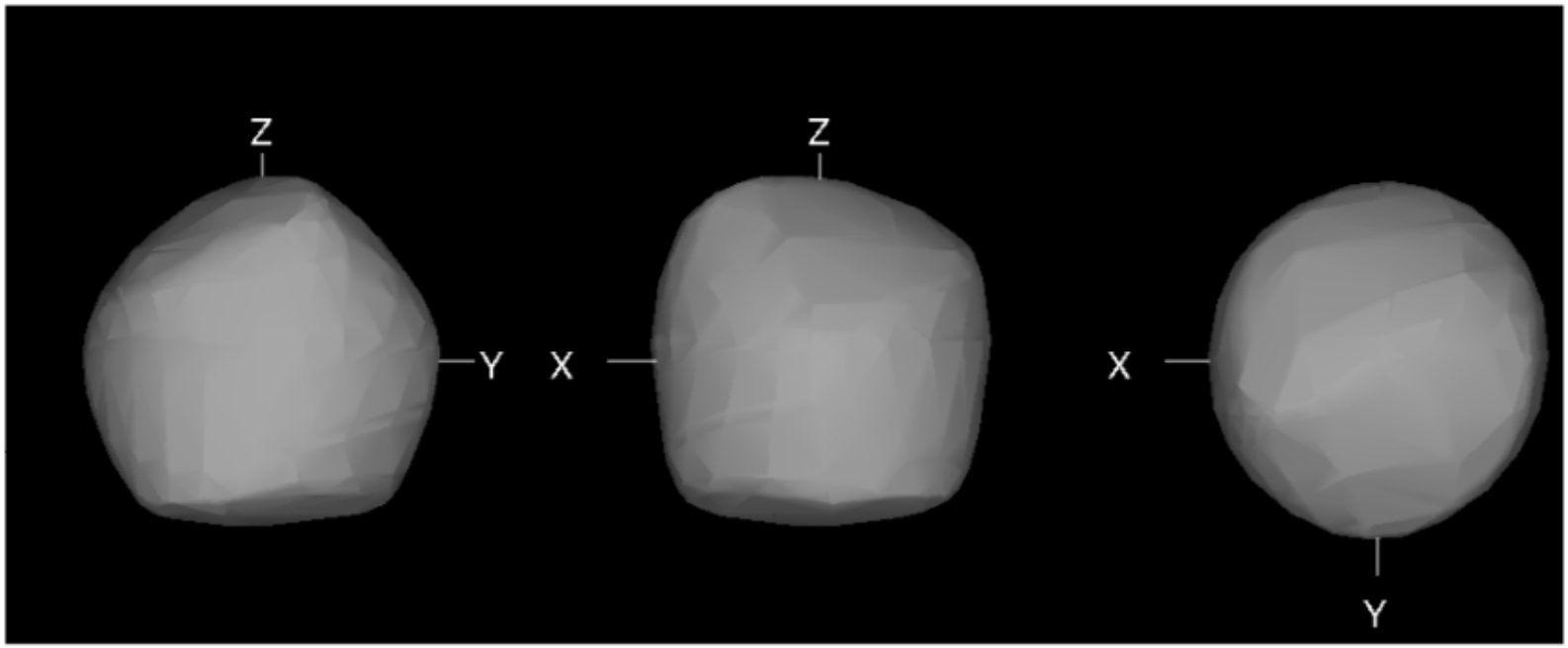
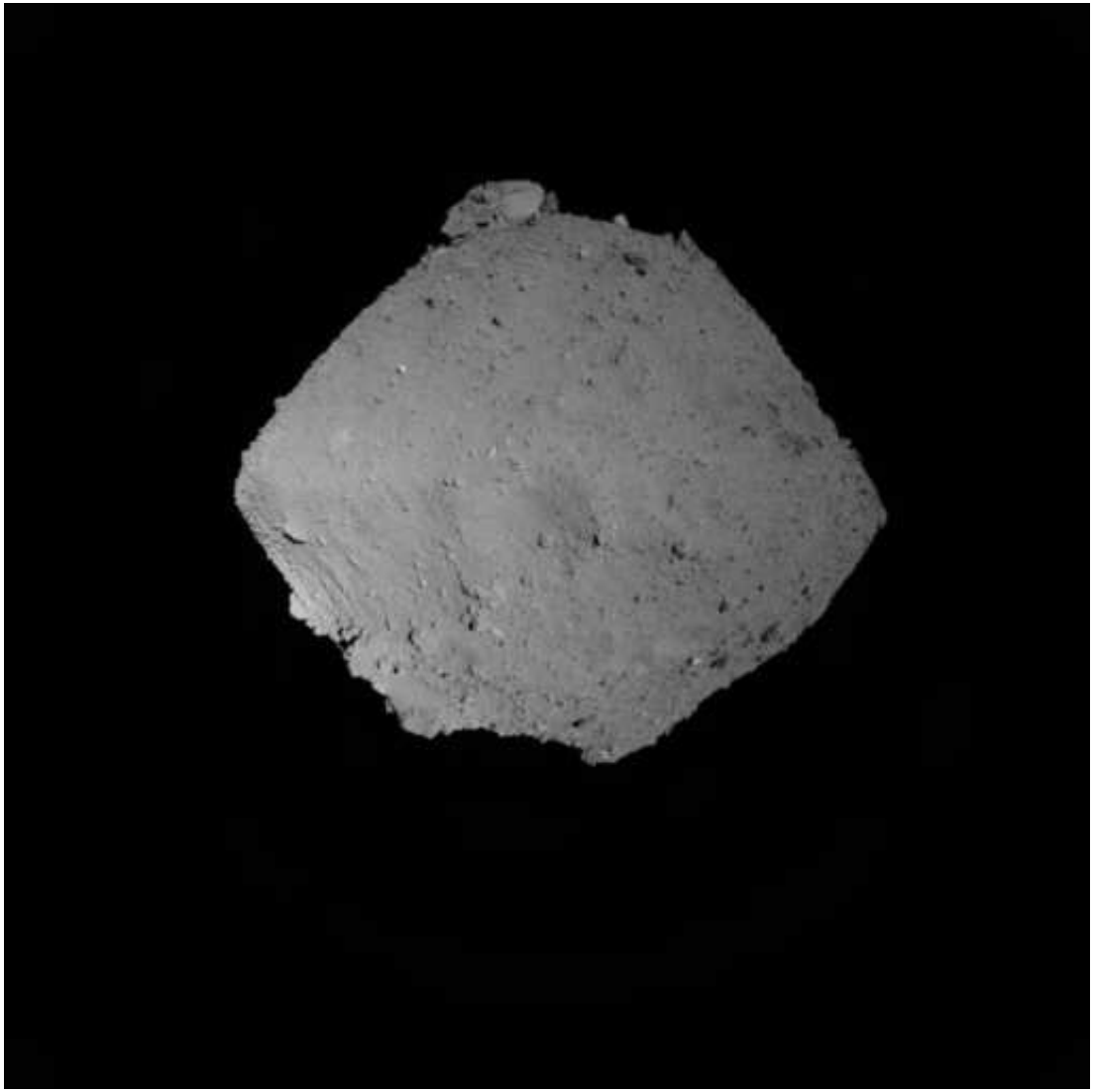


Fig. 8. The formally best-fit shape model of Ryugu for pole direction (340°, −40°).

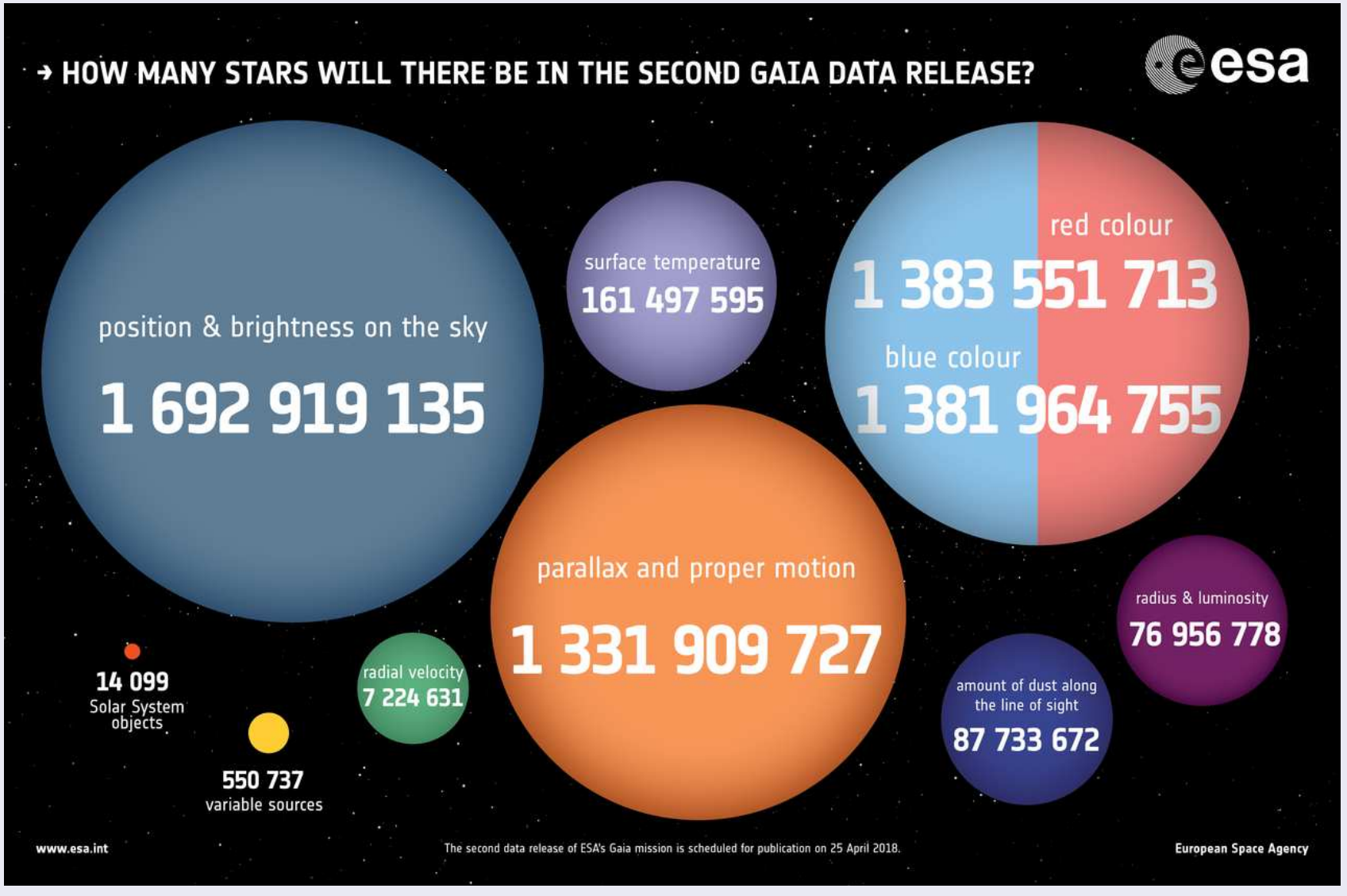
Müller et al. 2017

162 173 Ryugu - in reality

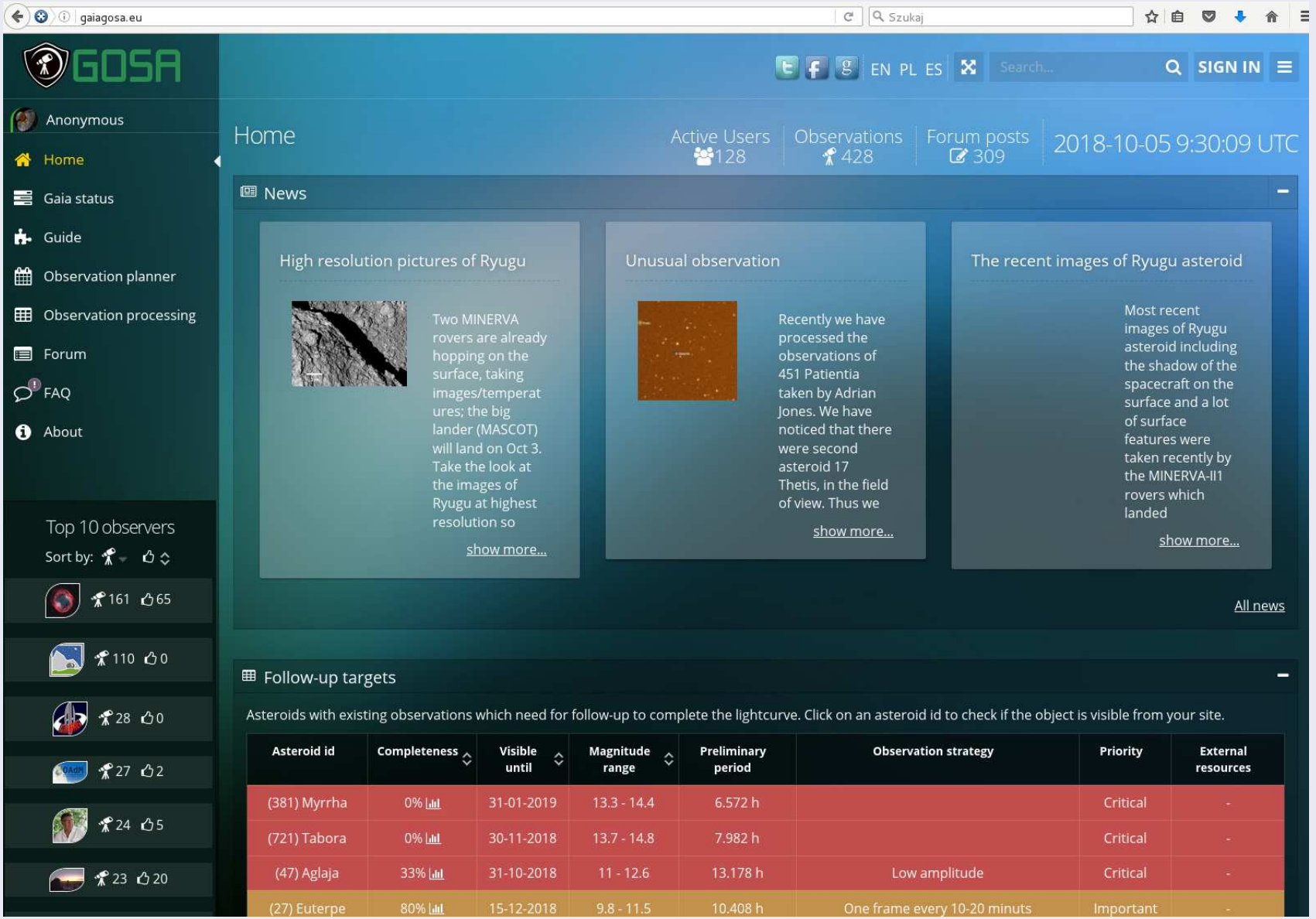


JAXA

Gaia and asteroids

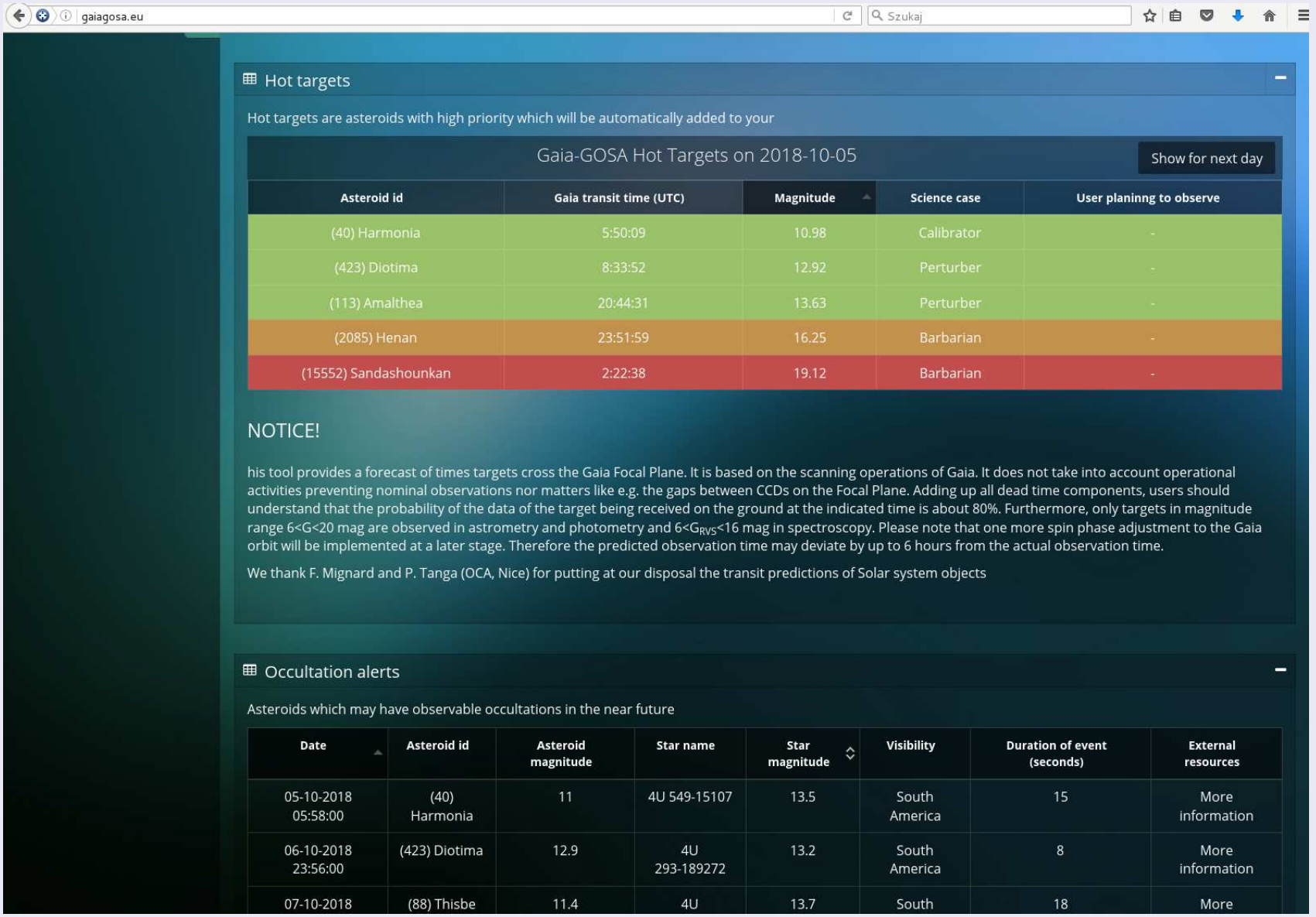


Gaia-GOSA (Gaia-Groundbased Observational Service for Asteroids)



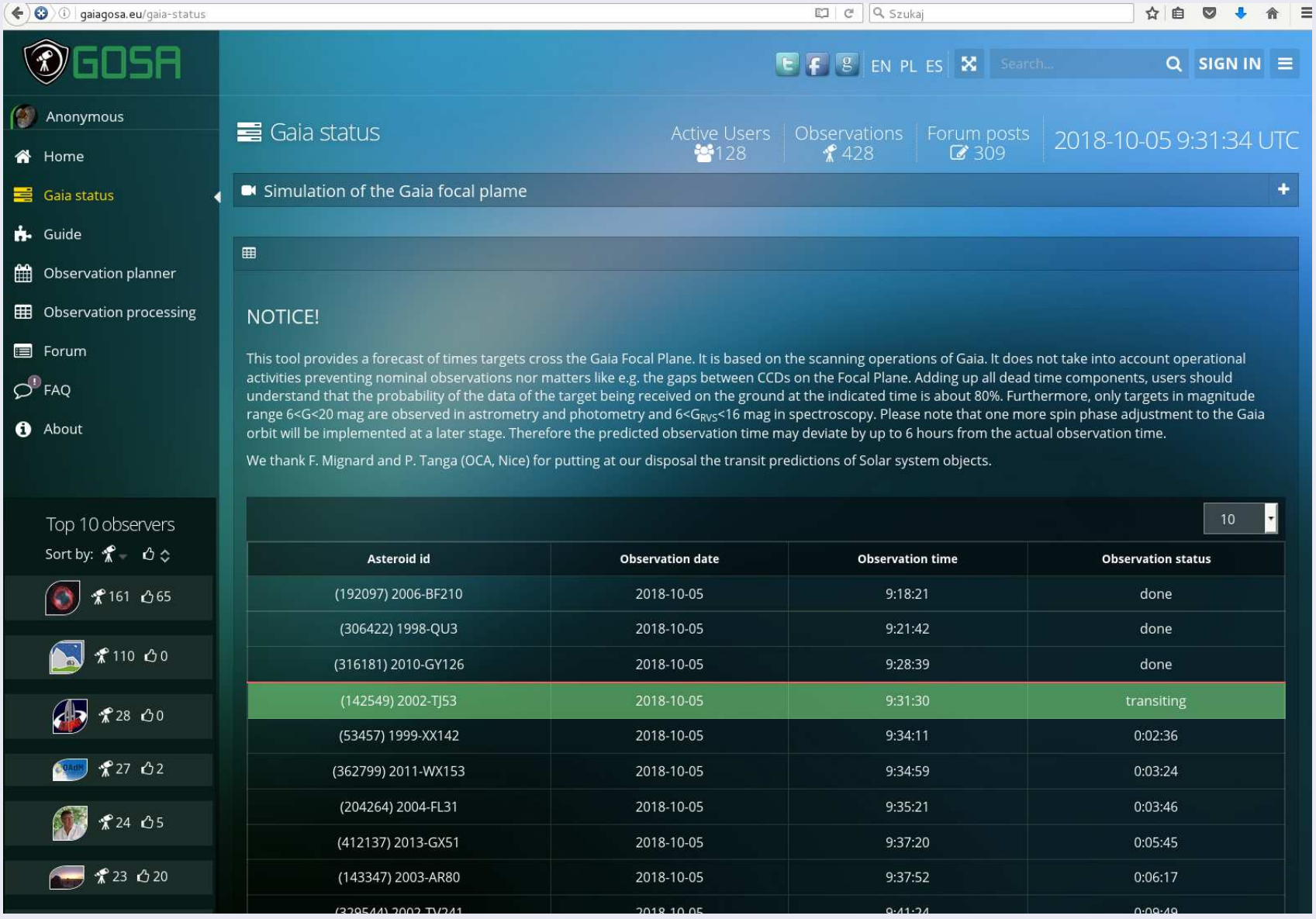
http://www.gaiagosa.eu

Gaia-GOSA hot targets



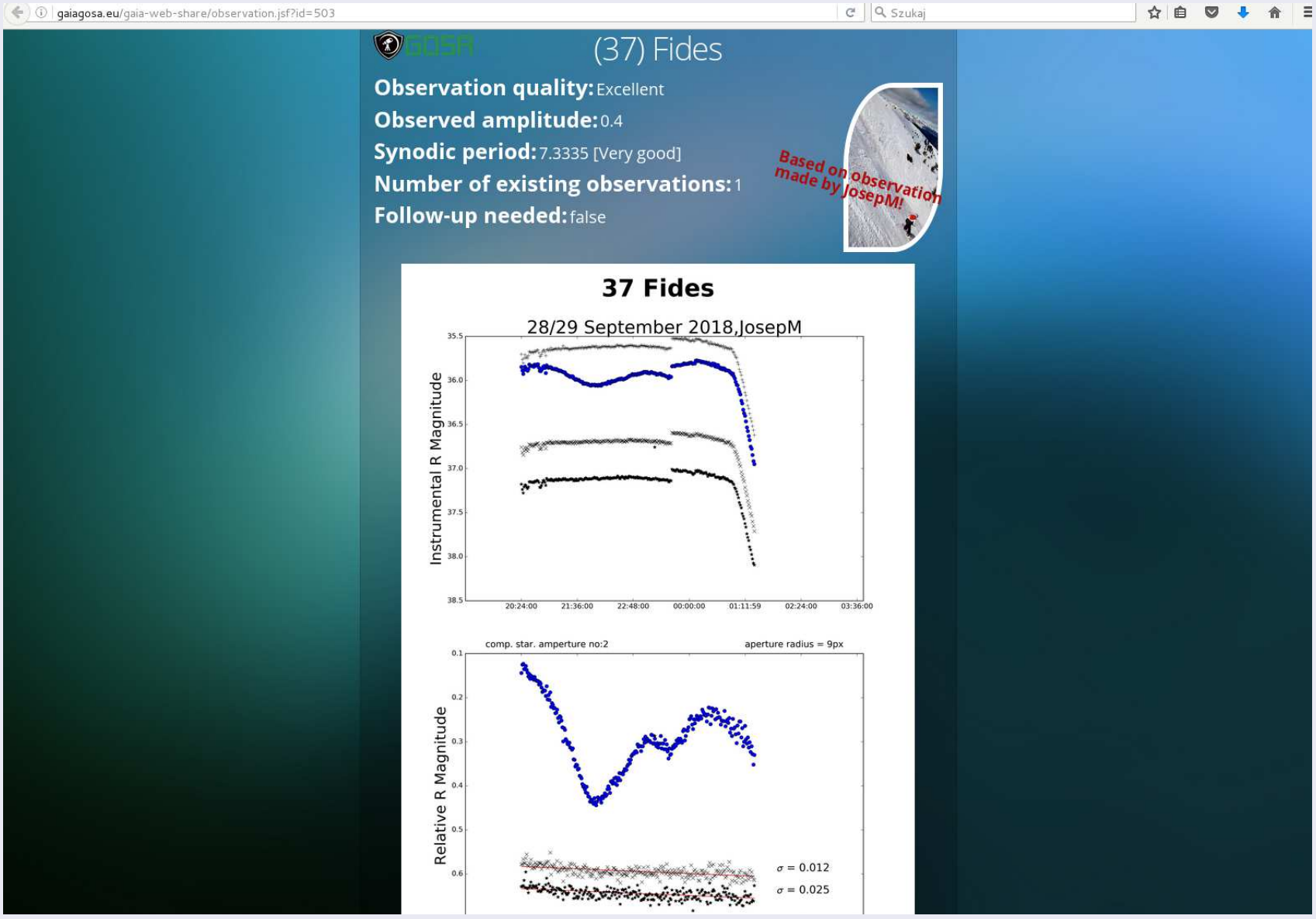
http://www.gaiagosa.eu

Gaia-GOSA, asteroid transiting Gaia focal plane



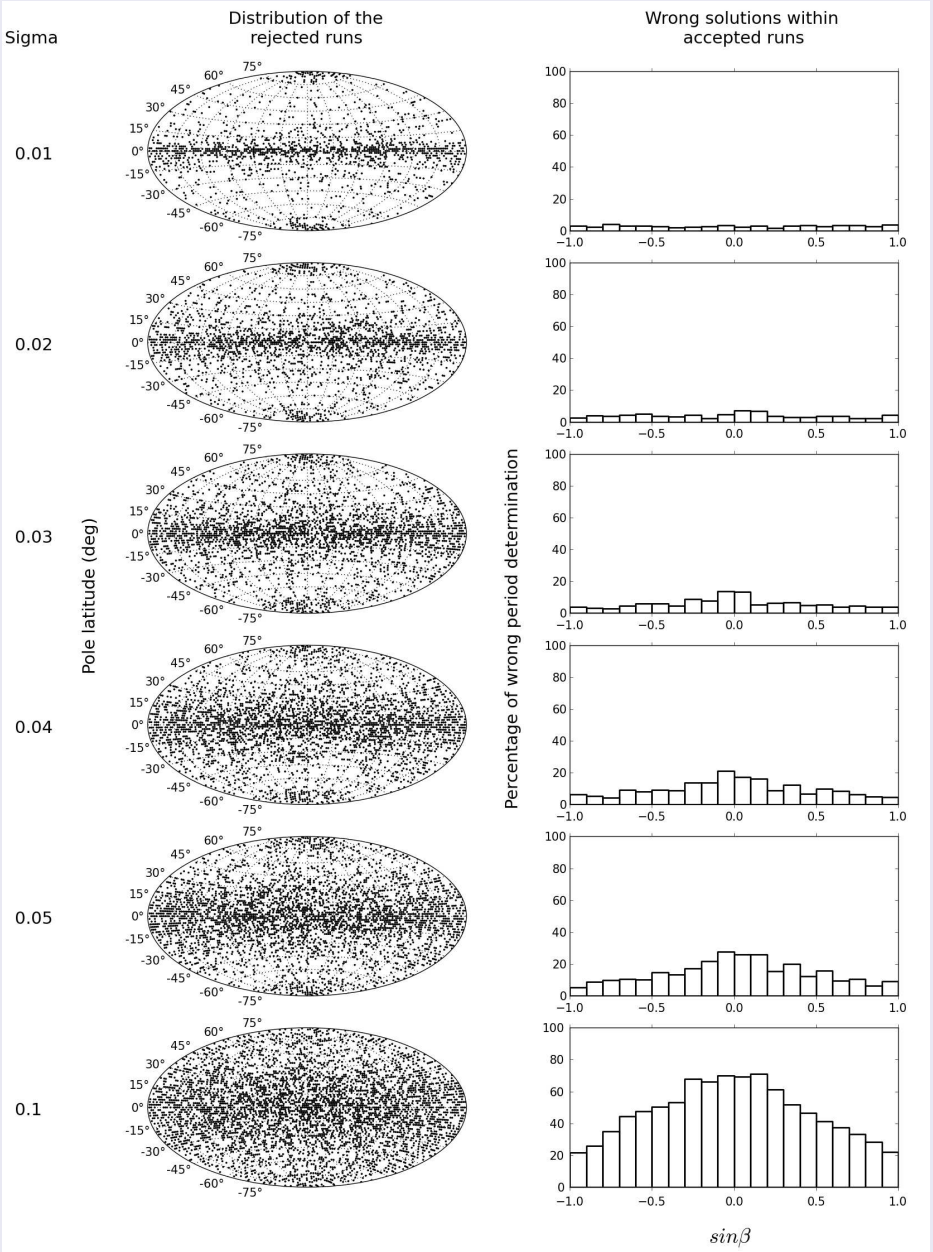
http://www.gaiagosa.eu

Gaia-GOSA sample results



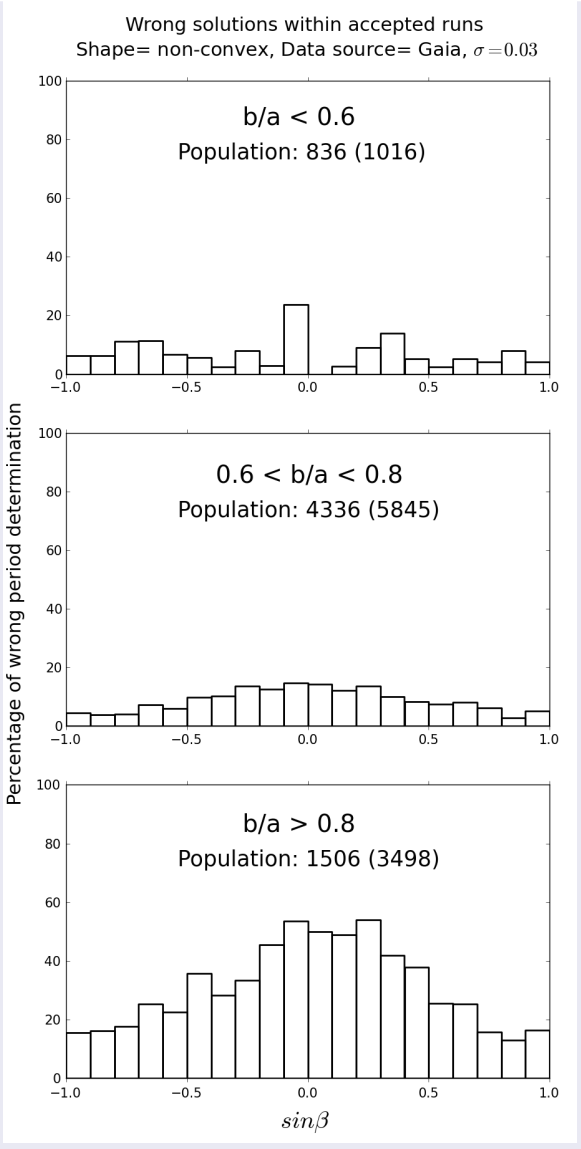
http://www.gaiagosa.eu

Selection effects in asteroid spin axis positions - Gaia simulator



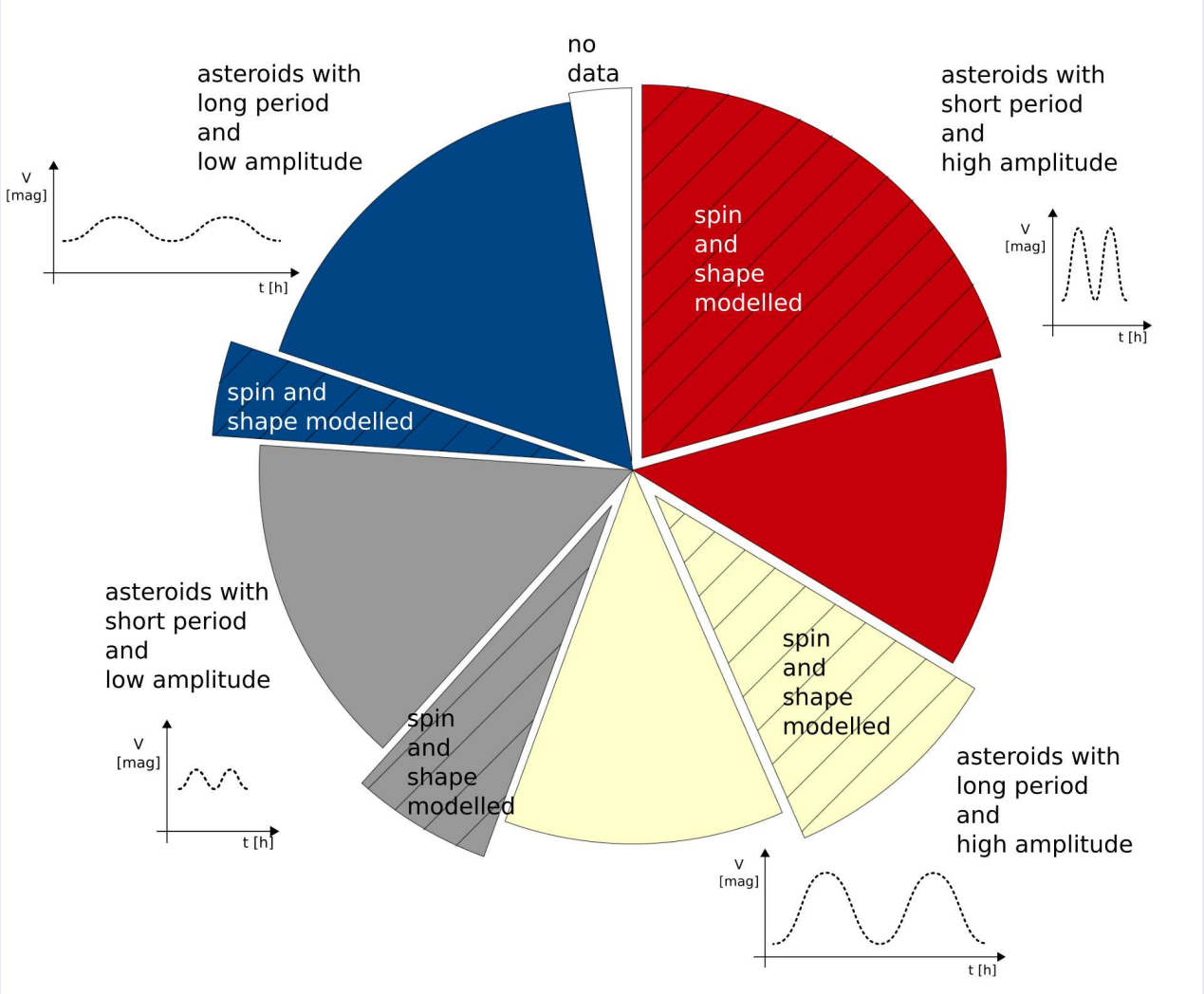
Santana-Ros et al. 2015

Selection effects in asteroid shape - Gaia simulator



Santana-Ros et al. 2015

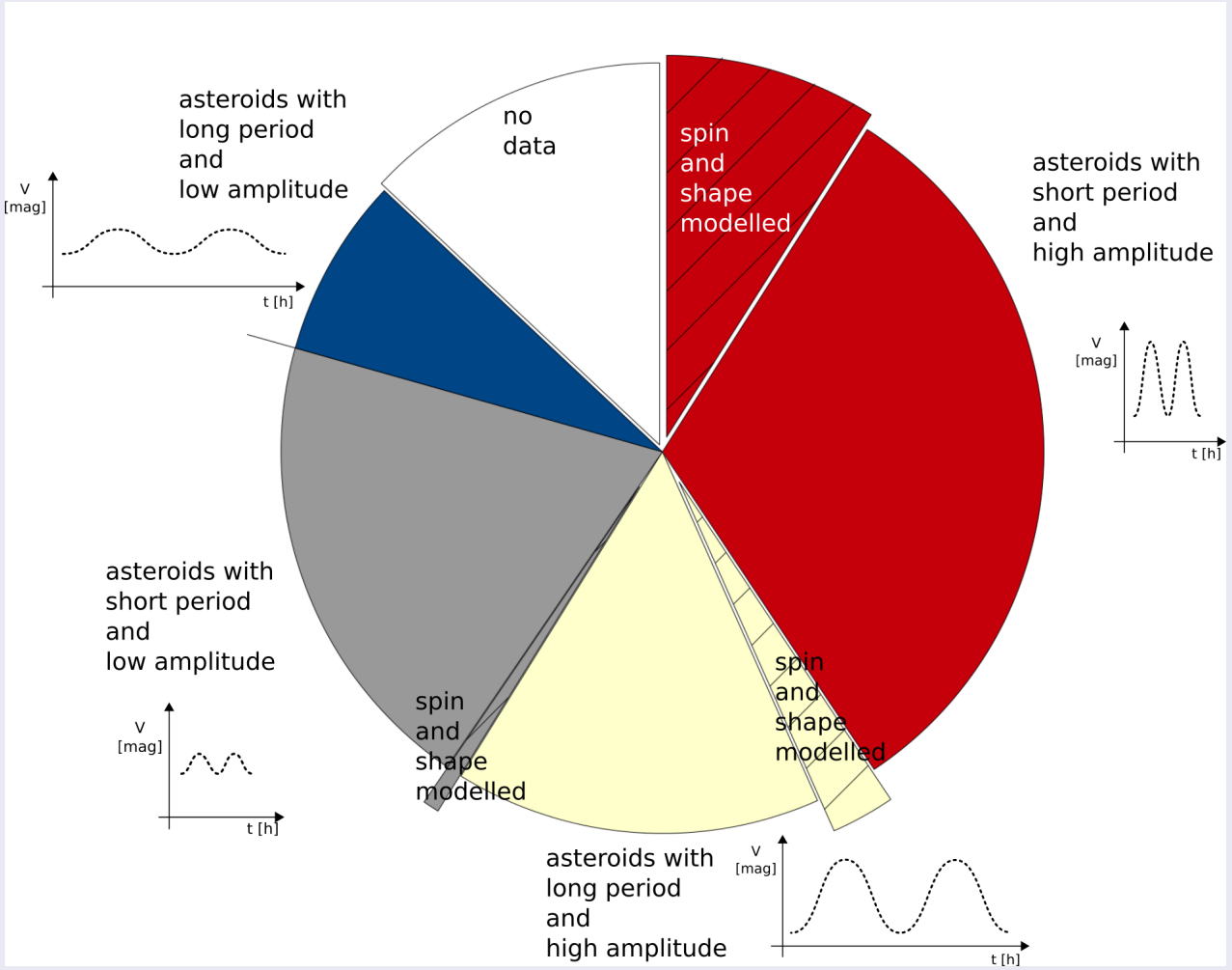
Selection effects in MBA models



All 1230 asteroids with H$\geq$11 mag
Division values: P = 12 h, a_{max} = 0.25 mag.

Marciniak et al. 2018

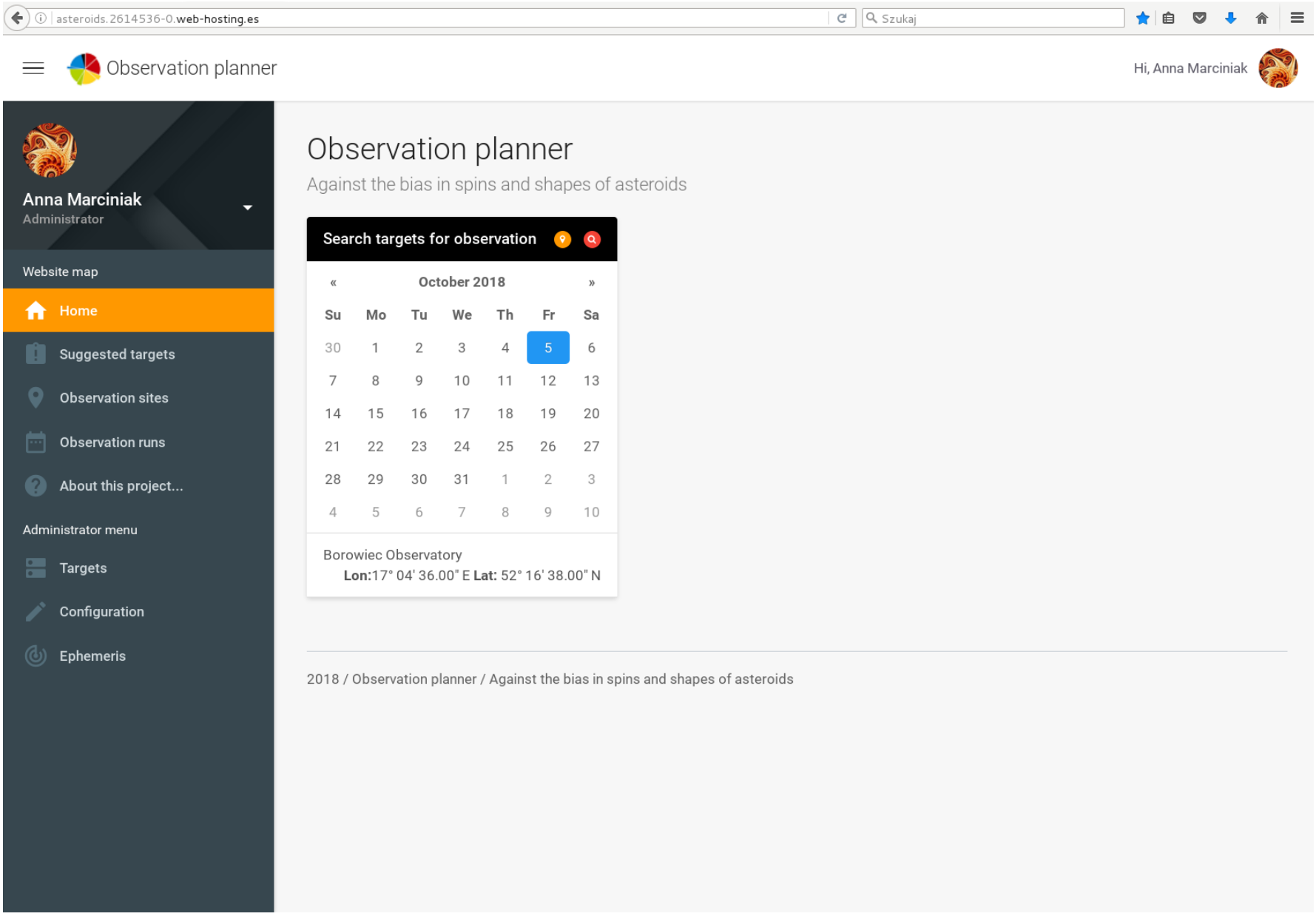
Selection effects in fainter MBA models



All 2274 asteroids with $11 < H \leq 13$ mag
Division values: P = 12 h, a_{max} = 0.25 mag.

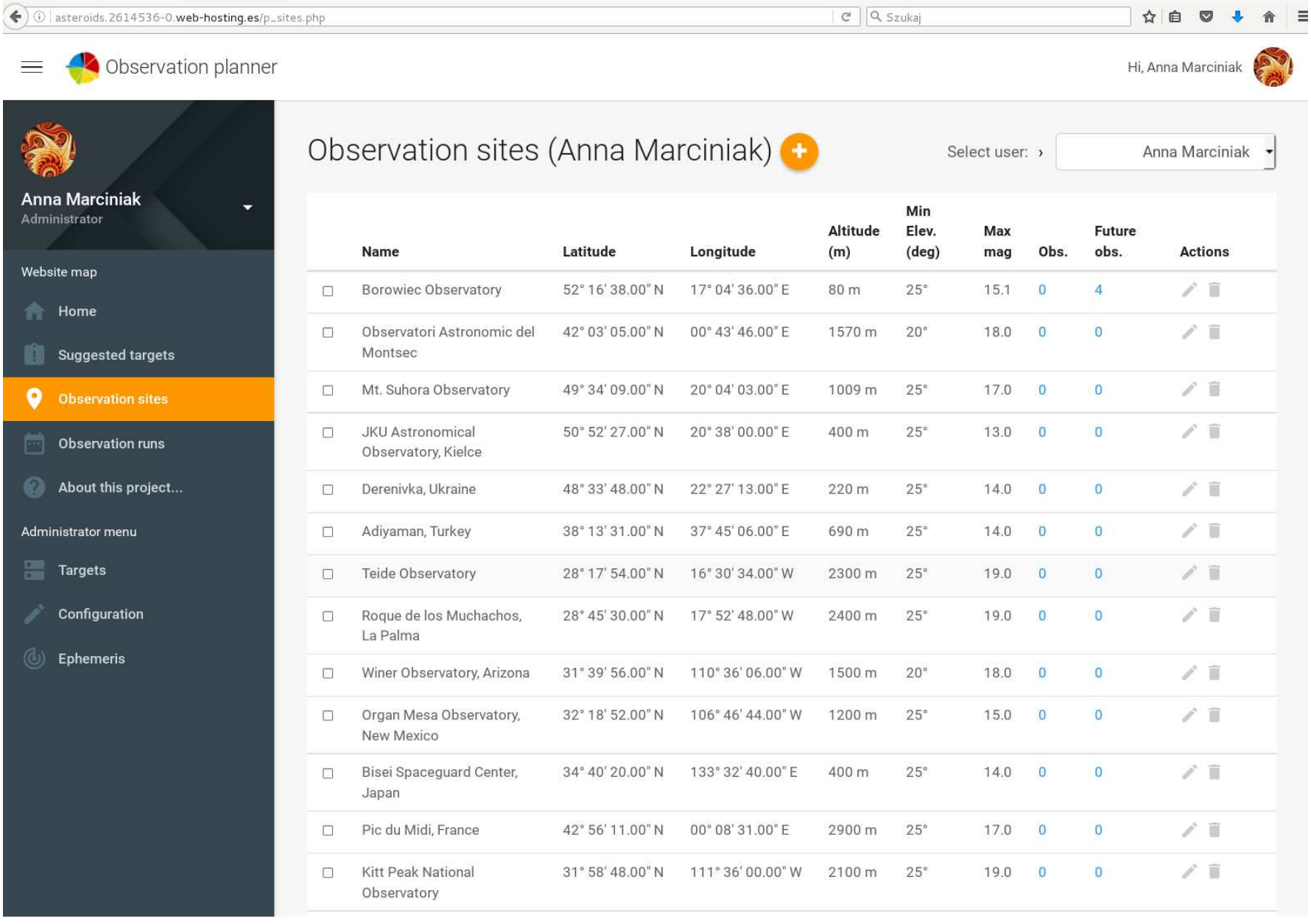
Marciniak et al. 2018

Observation planner for project against biases



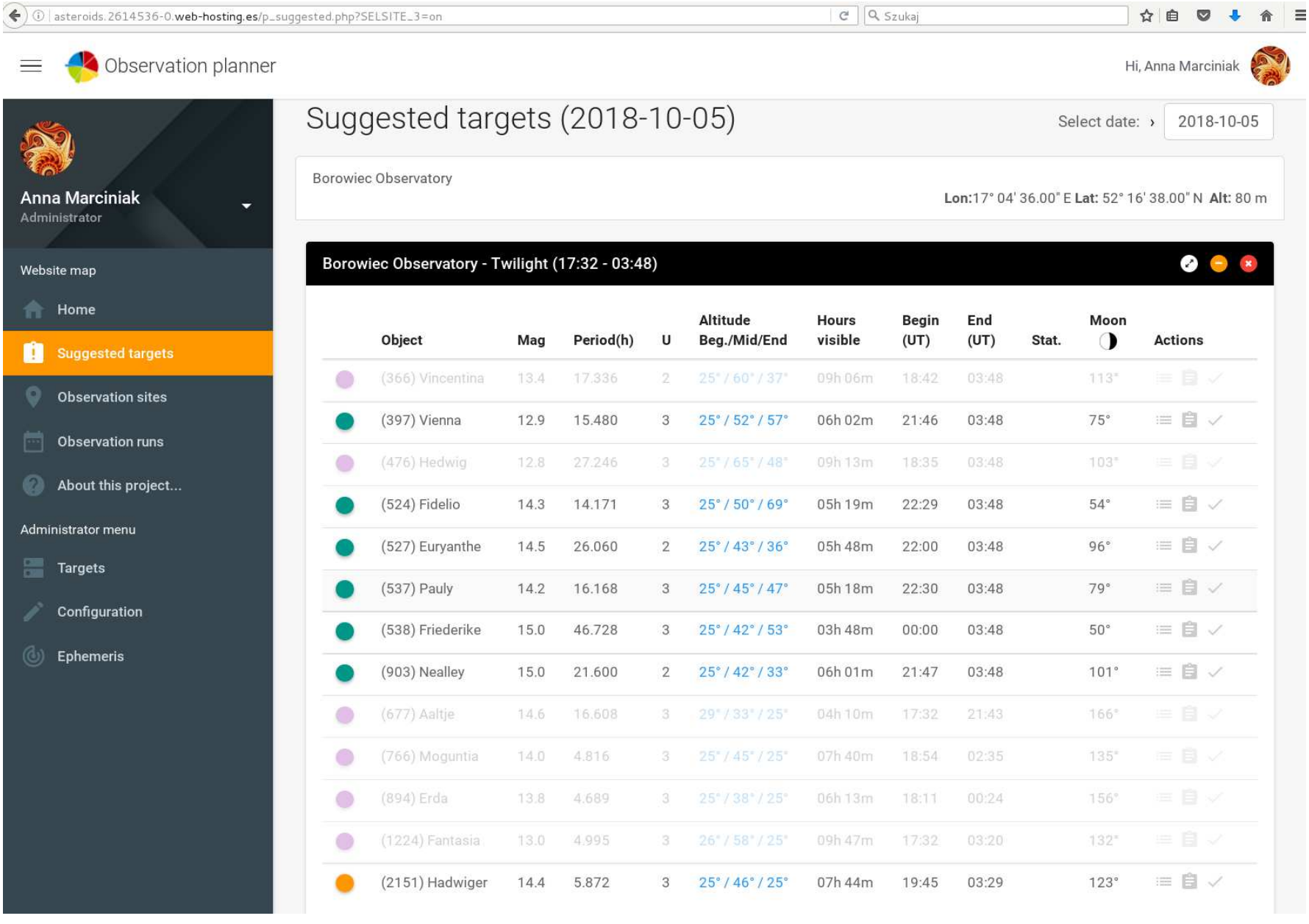
http://asteroids.2614536-0.web-hosting.es

Observation planner, site selection



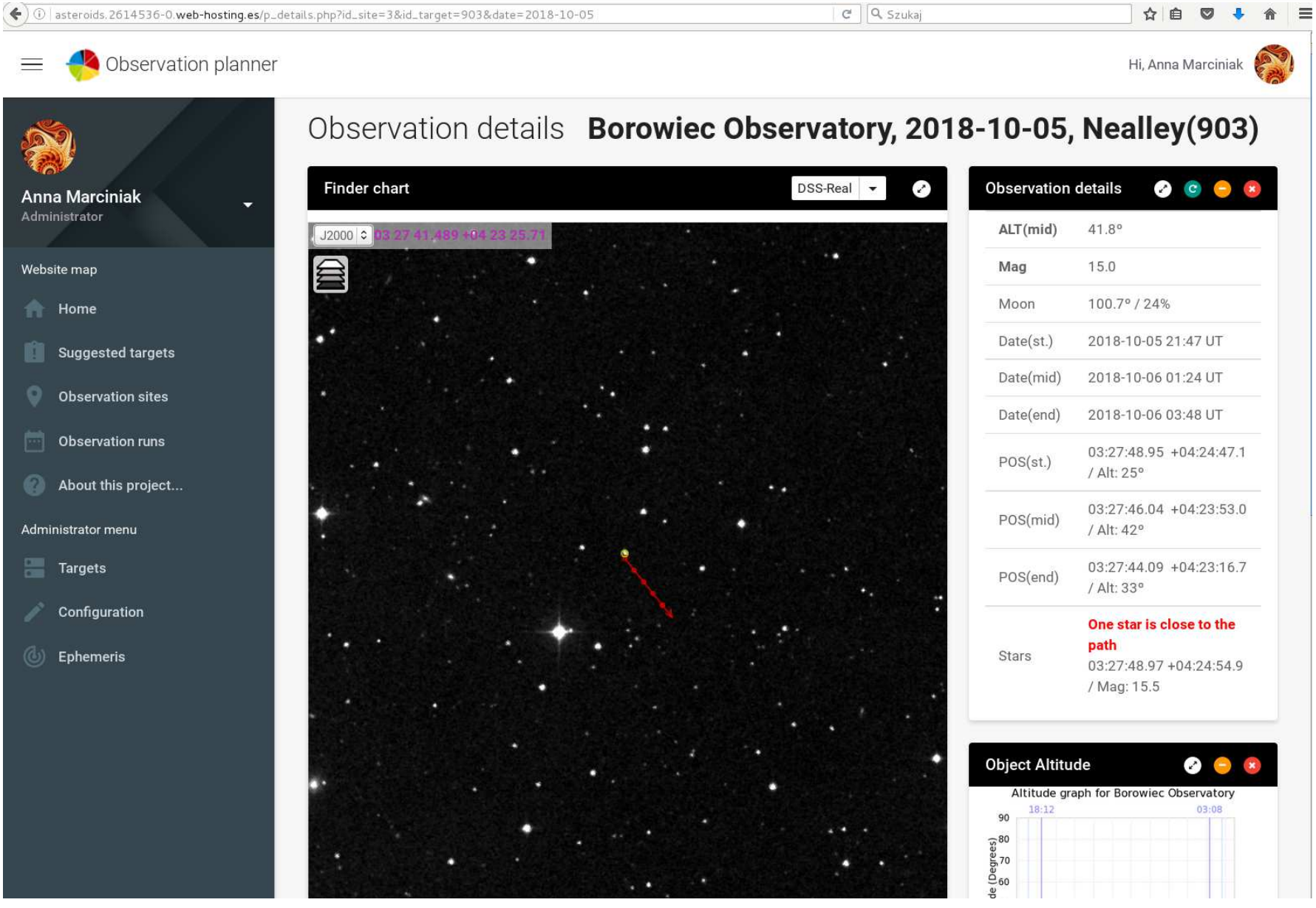
	Name	Latitude	Longitude	Altitude (m)	Min Elev. (deg)	Max mag	Obs.	Future obs.	Actions
☐	Borowiec Observatory	52° 16' 38.00" N	17° 04' 36.00" E	80 m	25°	15.1	0	4	
☐	Observatori Astronomic del Montsec	42° 03' 05.00" N	00° 43' 46.00" E	1570 m	20°	18.0	0	0	
☐	Mt. Suhora Observatory	49° 34' 09.00" N	20° 04' 03.00" E	1009 m	25°	17.0	0	0	
☐	JKU Astronomical Observatory, Kielce	50° 52' 27.00" N	20° 38' 00.00" E	400 m	25°	13.0	0	0	
☐	Derenivka, Ukraine	48° 33' 48.00" N	22° 27' 13.00" E	220 m	25°	14.0	0	0	
☐	Adiyaman, Turkey	38° 13' 31.00" N	37° 45' 06.00" E	690 m	25°	14.0	0	0	
☐	Teide Observatory	28° 17' 54.00" N	16° 30' 34.00" W	2300 m	25°	19.0	0	0	
☐	Roque de los Muchachos, La Palma	28° 45' 30.00" N	17° 52' 48.00" W	2400 m	25°	19.0	0	0	
☐	Winer Observatory, Arizona	31° 39' 56.00" N	110° 36' 06.00" W	1500 m	20°	18.0	0	0	
☐	Organ Mesa Observatory, New Mexico	32° 18' 52.00" N	106° 46' 44.00" W	1200 m	25°	15.0	0	0	
☐	Bisei Spaceguard Center, Japan	34° 40' 20.00" N	133° 32' 40.00" E	400 m	25°	14.0	0	0	
☐	Pic du Midi, France	42° 56' 11.00" N	00° 08' 31.00" E	2900 m	25°	17.0	0	0	
☐	Kitt Peak National Observatory	31° 58' 48.00" N	111° 36' 00.00" W	2100 m	25°	19.0	0	0	

Observation planner, suggested targets

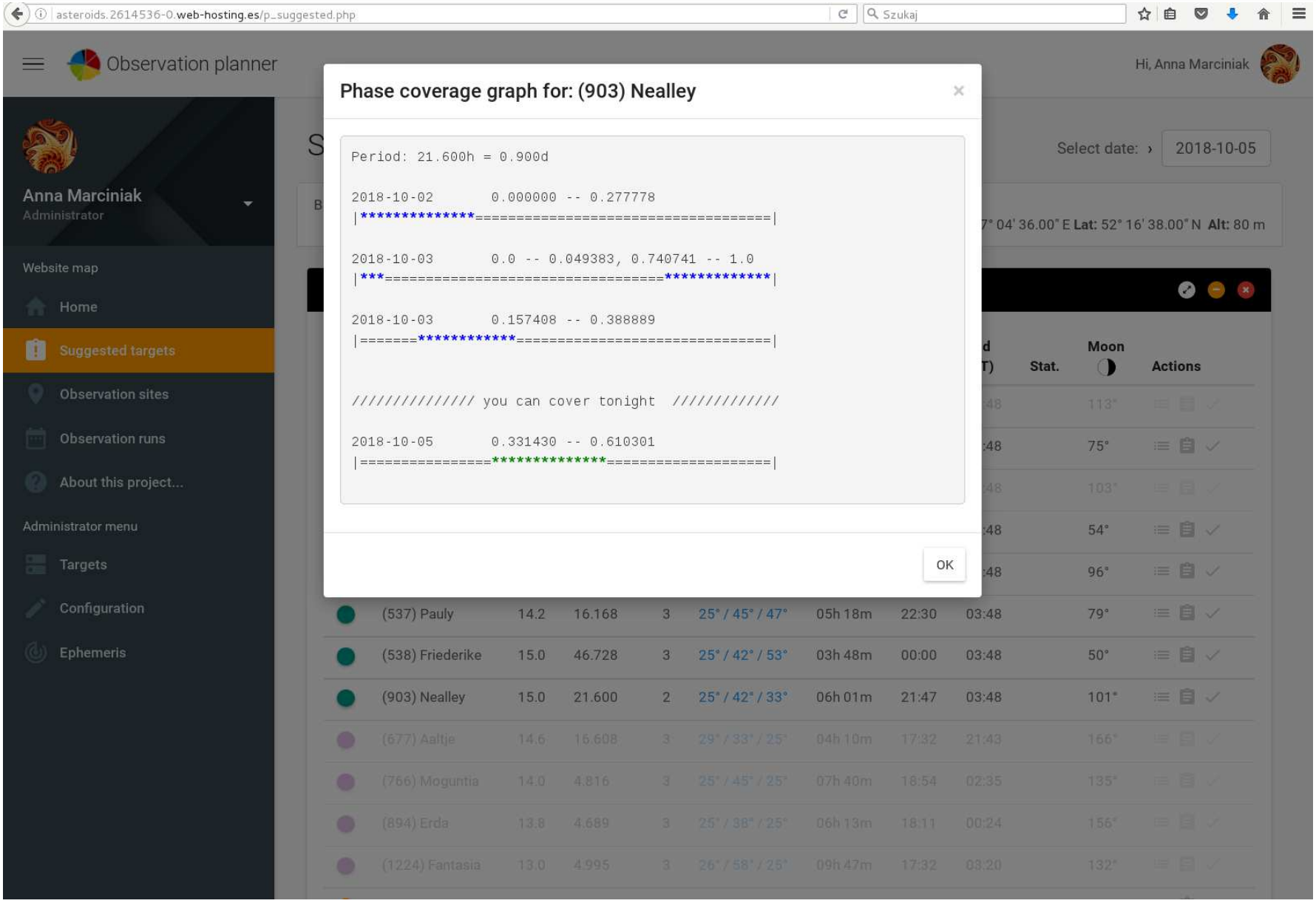


Object	Mag	Period(h)	U	Altitude Beg./Mid/End	Hours visible	Begin (UT)	End (UT)	Stat.	Moon	Actions
(366) Vincentina	13.4	17.336	2	25° / 60° / 37°	09h 06m	18:42	03:48		113°	
(397) Vienna	12.9	15.480	3	25° / 52° / 57°	06h 02m	21:46	03:48		75°	
(476) Hedwig	12.8	27.246	3	25° / 65° / 48°	09h 13m	18:35	03:48		103°	
(524) Fidelio	14.3	14.171	3	25° / 50° / 69°	05h 19m	22:29	03:48		54°	
(527) Euryanthe	14.5	26.060	2	25° / 43° / 36°	05h 48m	22:00	03:48		96°	
(537) Pauly	14.2	16.168	3	25° / 45° / 47°	05h 18m	22:30	03:48		79°	
(538) Friederike	15.0	46.728	3	25° / 42° / 53°	03h 48m	00:00	03:48		50°	
(903) Nealley	15.0	21.600	2	25° / 42° / 33°	06h 01m	21:47	03:48		101°	
(677) Aaltje	14.6	16.608	3	29° / 33° / 25°	04h 10m	17:32	21:43		166°	
(766) Moguntia	14.0	4.816	3	25° / 45° / 25°	07h 40m	18:54	02:35		135°	
(894) Erda	13.8	4.689	3	25° / 38° / 25°	06h 13m	18:11	00:24		156°	
(1224) Fantasia	13.0	4.995	3	26° / 58° / 25°	09h 47m	17:32	03:20		132°	
(2151) Hadwiger	14.4	5.872	3	25° / 46° / 25°	07h 44m	19:45	03:29		123°	

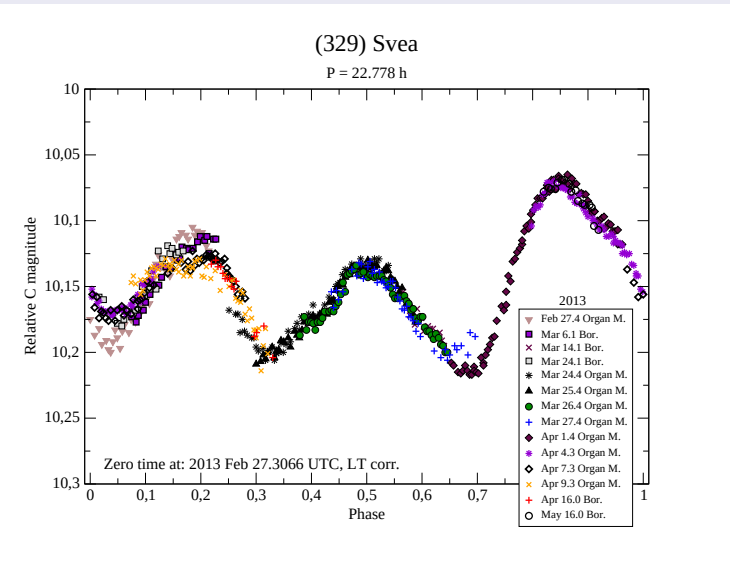
Observation planner, sky charts

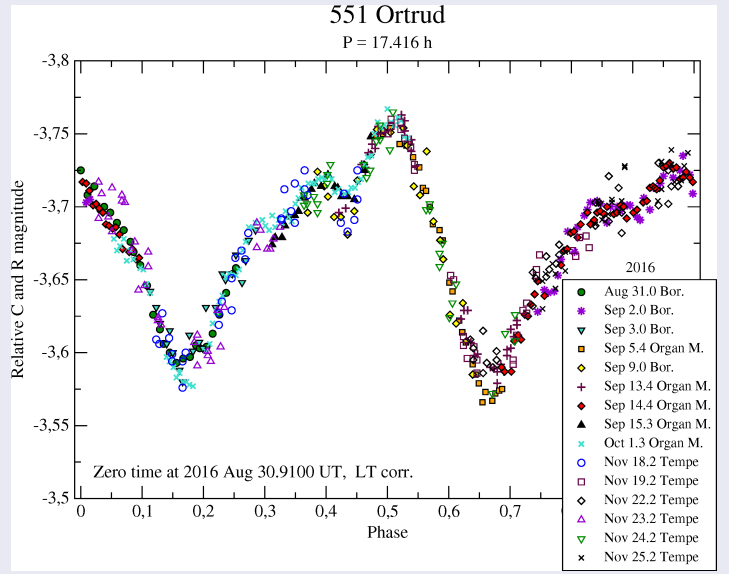


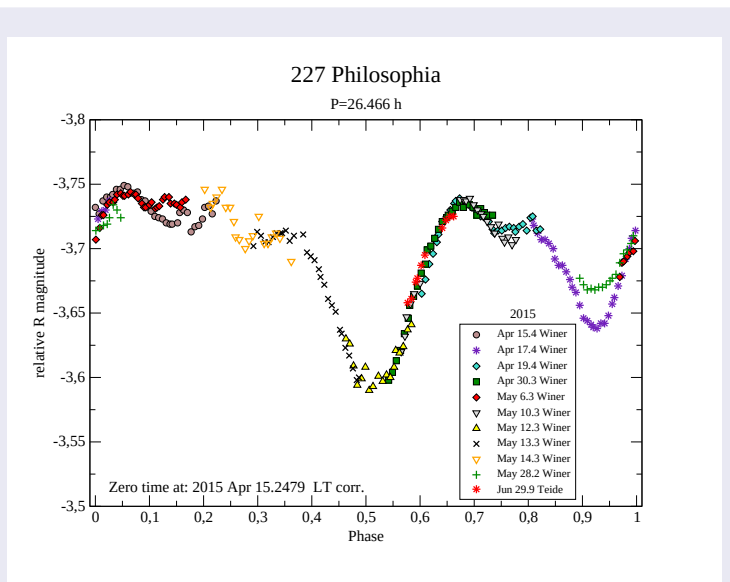
Observation planner, phase coverage

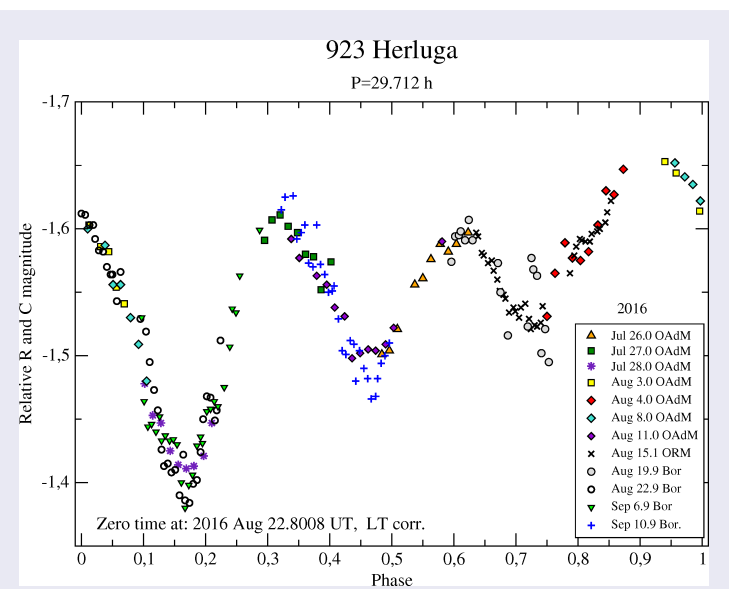


Selected lightcurves



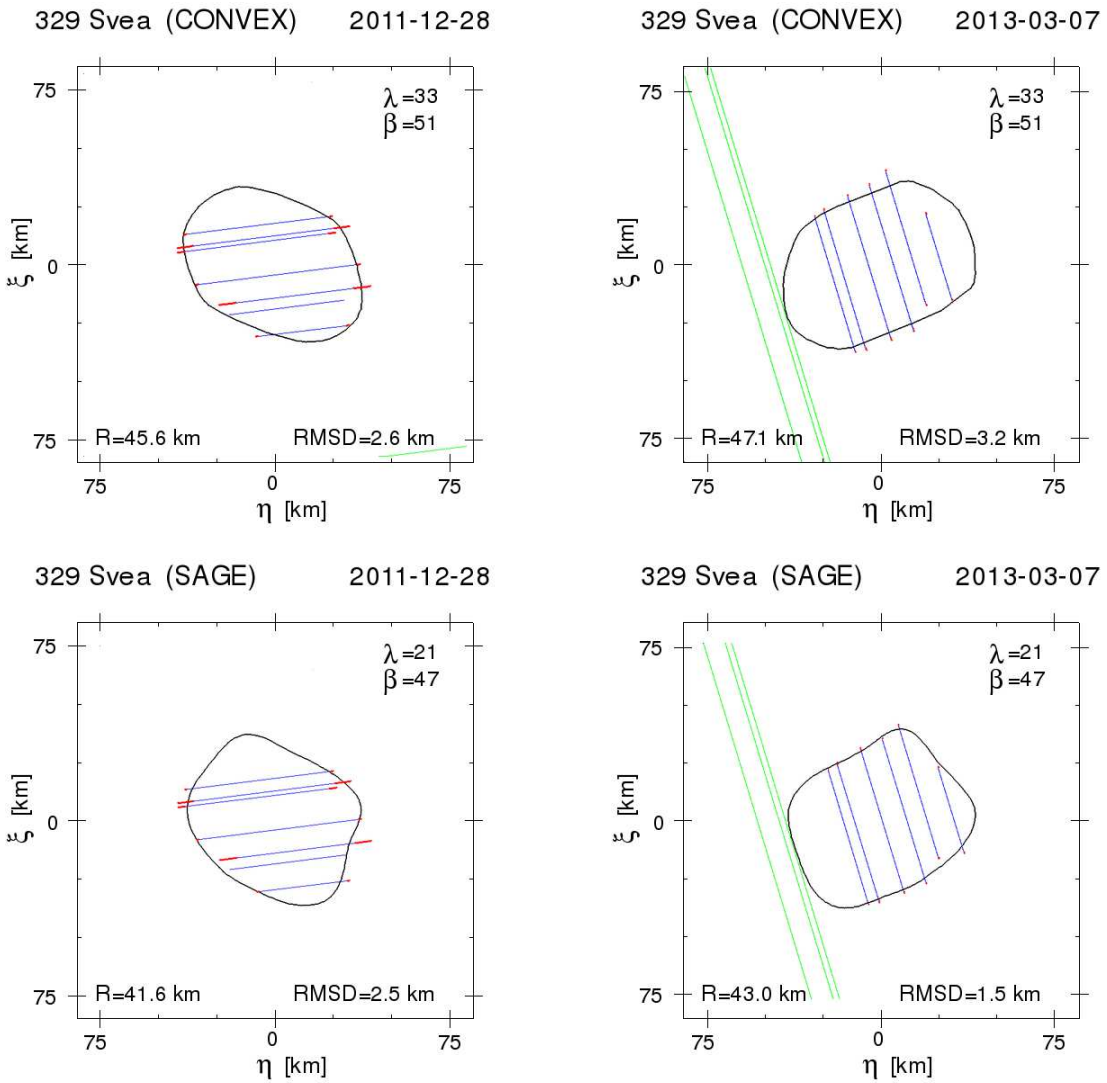






Marciniak et al. 2015, 2018

Fitting the shape models to stellar occultation chords

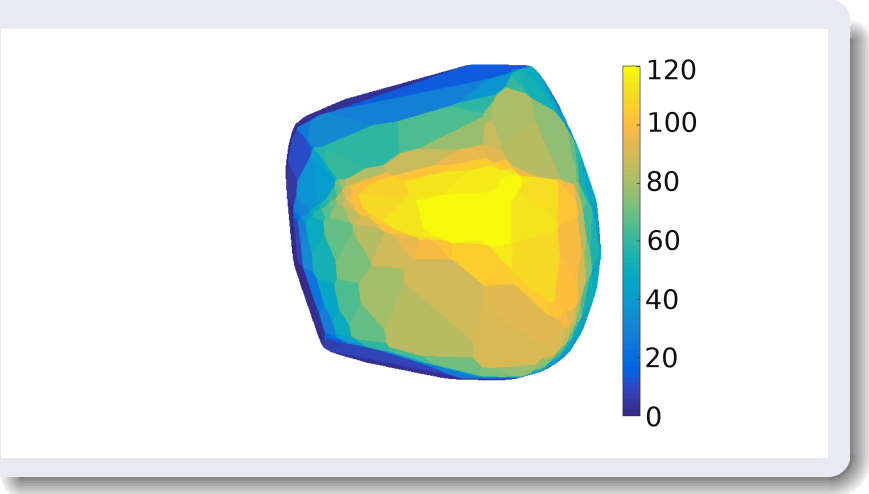


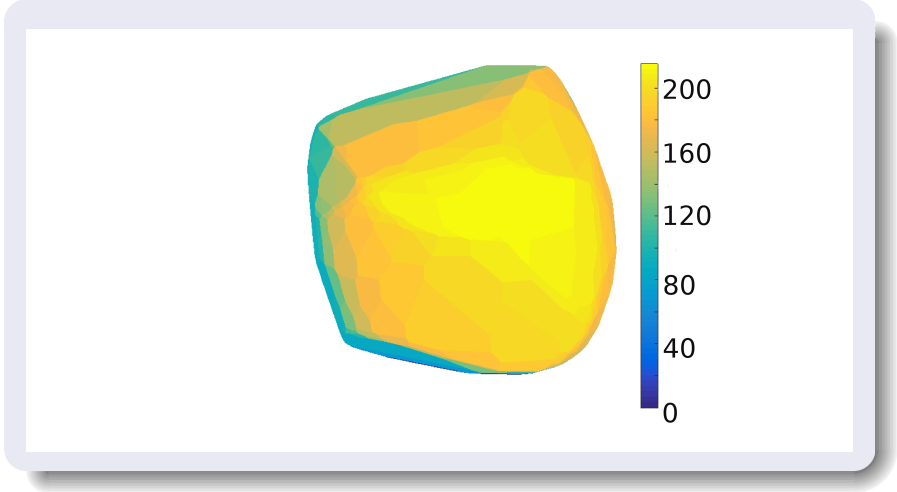
Diameters of equivalent volume sphere:
CONVEX (2011): 72 ± 4 km; CONVEX (2013): 74 ± 5 km
SAGE (2011): 70 ± 4 km; SAGE (2013): 72 ± 3 km

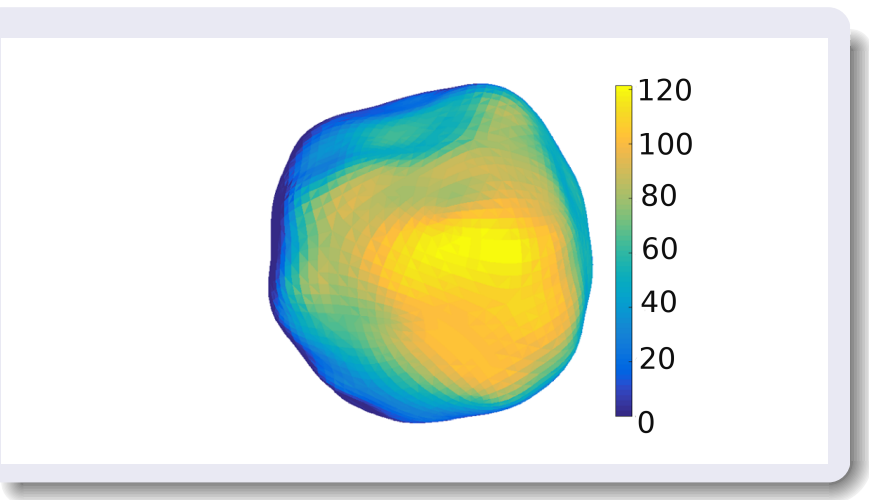
Marciniak et al. 2018

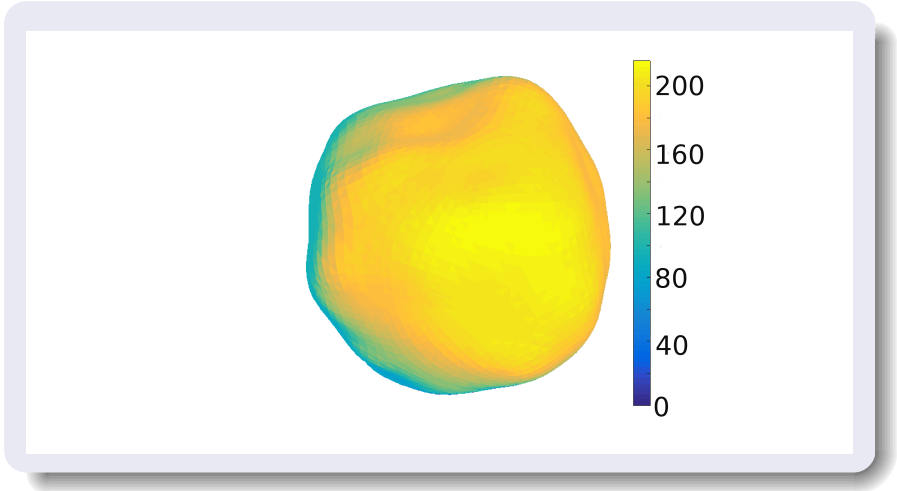
Thermophysical modelling

Insolation and surface temperature distribution: (159) Aemilia

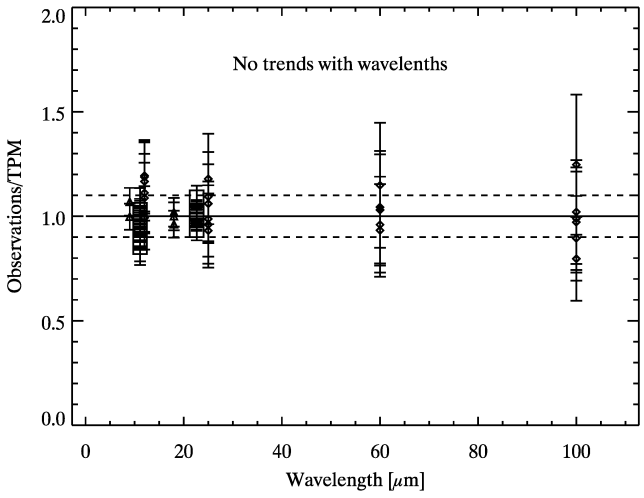


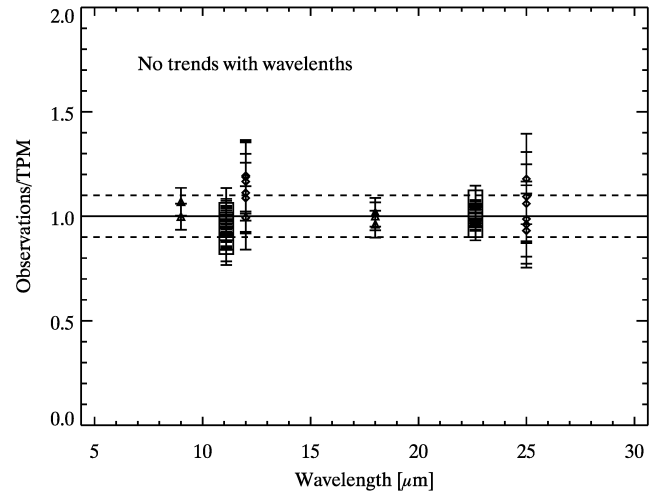


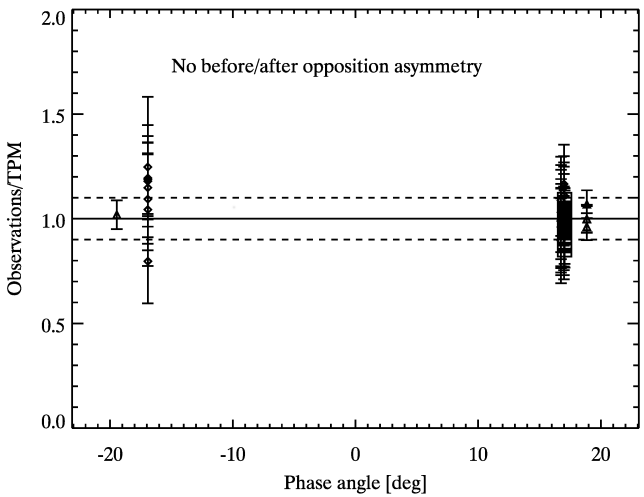


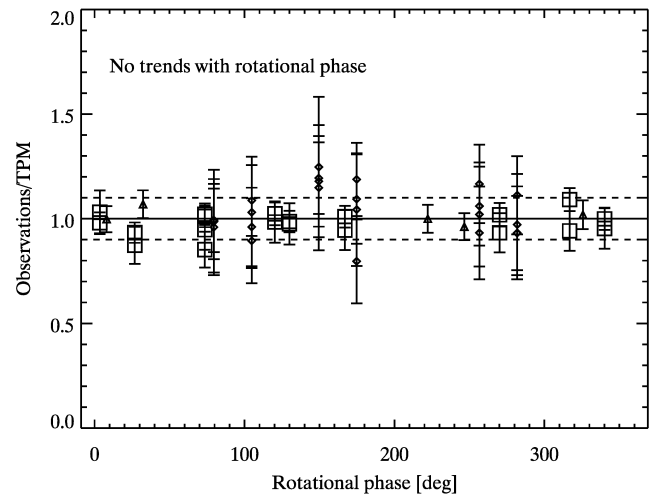


O-C plots for (159) Aemilia model applied in TPM





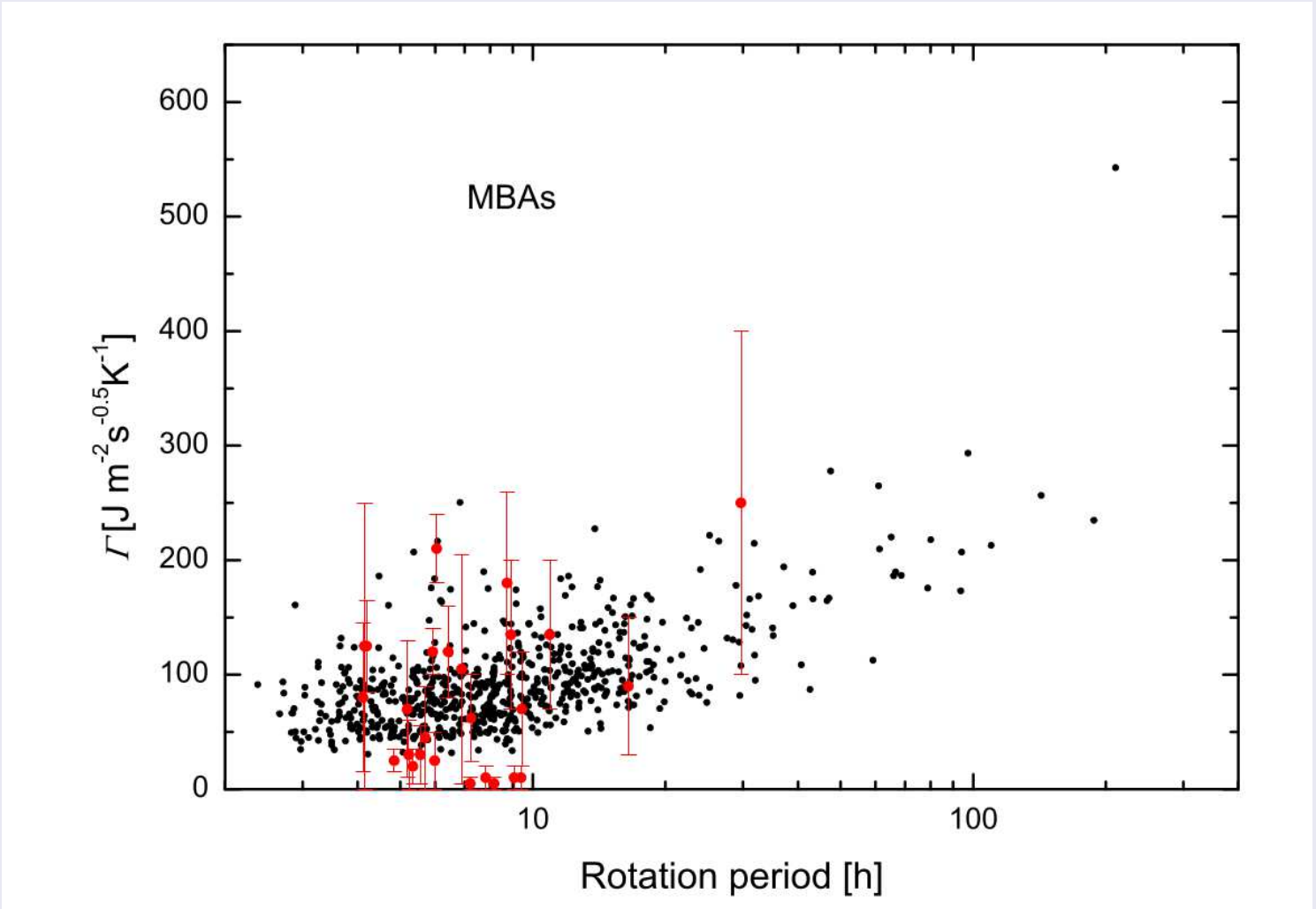




Target	Rotation period [h]	Radiometric solution for combined data. Diameter [km]	Albedo	Thermal inertia [$Jm^{-2}s^{-0.5}K^{-1}$]
159 Aemilia	24.4787	137	0.054	50
	±0.0001	±8	±0.015	±50
227 Philosophia	26.4614	101	0.041	125
	±0.0001	±5	±0.005	±90
329 Svea	22.7670	78	0.055	75
	±0.0001	±4	±0.015	±50
478 Tergeste	16.10312	87	0.15	75
	±0.00003	±6	±0.02	±45
487 Venetia	13.34133	70	0.21	100
	±0.00002	±4	±0.02	±75

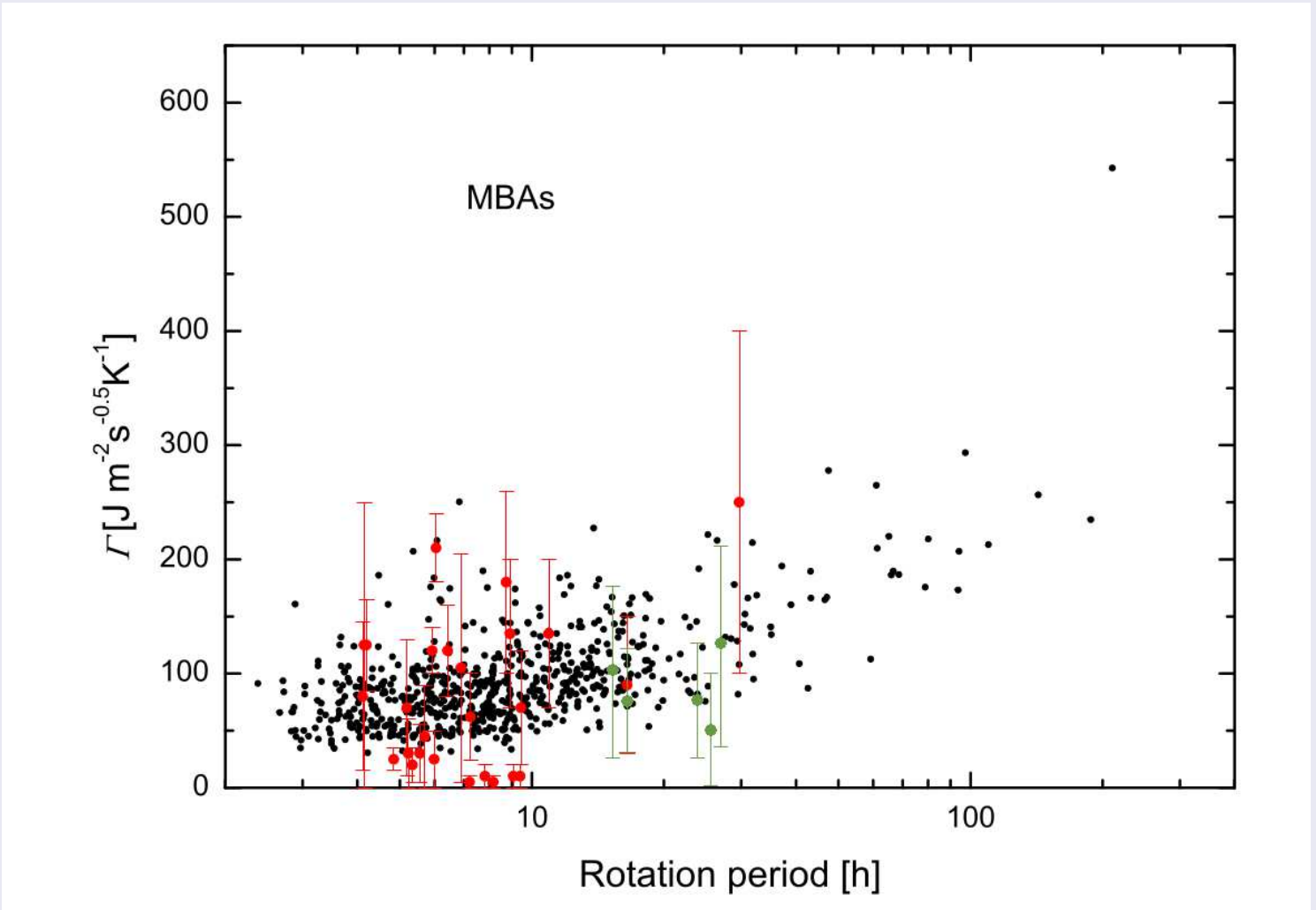
Marciniak et al. 2018

Thermal inertia of Main Belt Asteroids



Harris & Drube 2016

Thermal inertia of slow rotators



after: Harris & Drube 2016

Summary

- Gaia provides valuable data for physical studies of asteroids, but ground-based support neccessary
- Observations of targets transiting Gaia FOV, Gaia mass targets, suspected binaries etc. in Gaia-GOSA service
- Selection effects: spin and shape models mainly available for short-period, elongated asteroids with extreme obliquities (will still be present in models based on Gaia data)
- Biased spatial spin axis and size-frequency distributions, lack of models for slow rotators
- Our targeted survey of 100 long-period, low-amplitude MB asteroids.
  Gathered over 10 000 hours of lightcurve data in 20 stations worldwide.
- Modelled 10 targets from this sample, scaled by TPM using IR data from IRAS, AKARI and WISE
- Found both high and very low thermal inertia values
- Differences due to sub-surface temperatures and different material properties?
- Indication of fresh and old surfaces connected with formation age?

Interested in joining our projects? Please contact:
Edyta Podlewska-Gaca (edypod@amu.edu.pl) for Gaia-GOSA service,
Anna Marciniak (am@amu.edu.pl) for project on selection effects.

This work was supported by grant no. 2014/13/D/ST9/01818 from National Science Centre, Poland.

Small Bodies Near And Far

The research leading to these results has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement no 687378.