

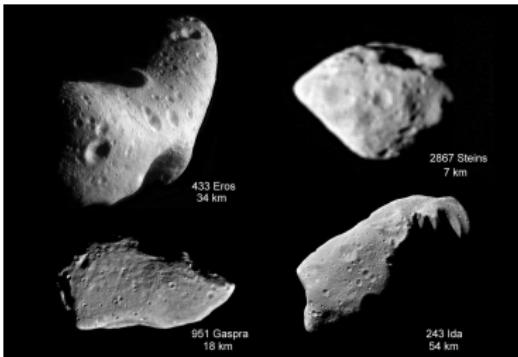
## Asteroid studies supported by Gaia

**A. Marciniak<sup>1</sup>**, T. Müller, V. Alí-Lagoa, P. Bartczak, R. Behrend,  
M. Butkiewicz-Bąk, G. Dudziński, R. Duffard, K. Dziadura, S. Fauvaud, S. Geier,  
R. Hirsch, J. Horbowicz, K. Kamiński, P. Kankiewicz, M.-J. Kim, I. Konstanciak,  
V. Kudak, W. Ogłoza, D. Oszkiewicz, F. Pilcher, T. Polakis, J. J. Sanabria,  
T. Santana-Ros, B. Skiff, K. Sobkowiak, R. Szakats, S. Urakawa, M. Żejmo,  
K. Żukowski

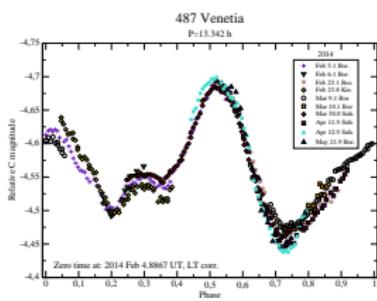
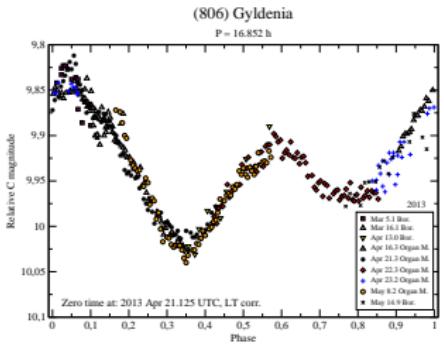
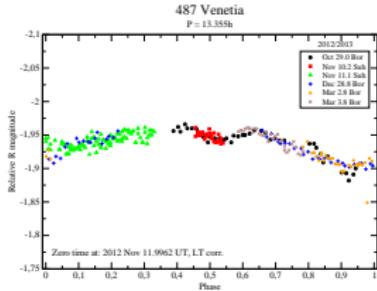
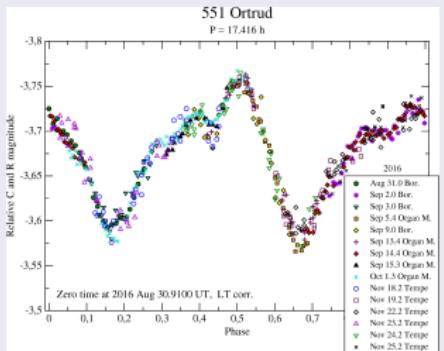
1. Astronomical Observatory Institute, Faculty of Physics, A. Mickiewicz University,  
Poznań, Poland.

# Why study asteroids?

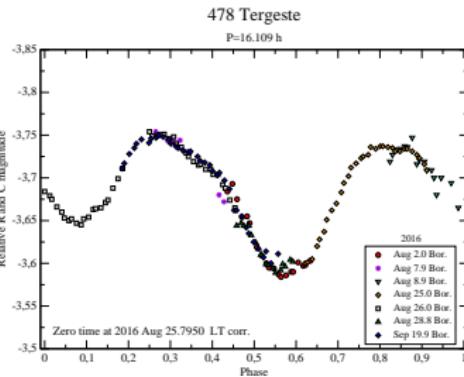
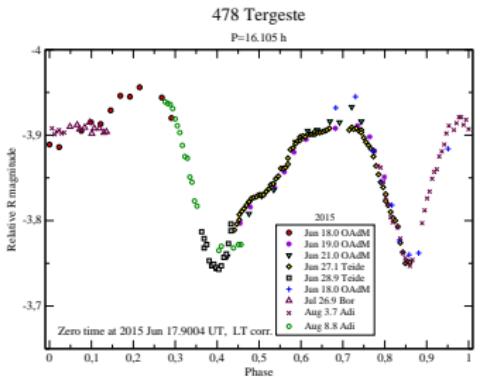
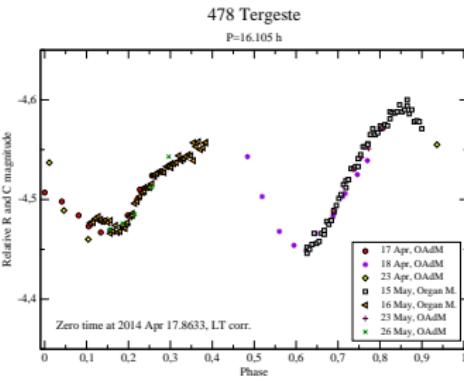
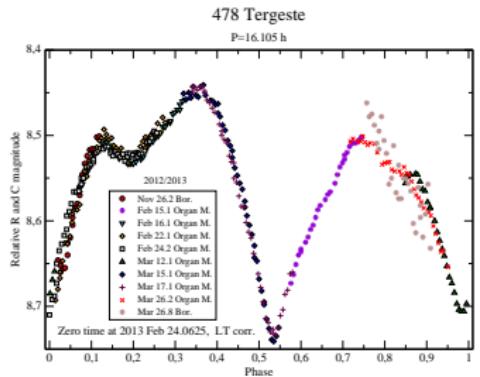
- Leftovers from Solar System formation
- Record of conditions and composition of protoplanetary disc
- Record of intensive migrations and heavy bombardment epochs
- Link between meteorites and their parent bodies
- Differentiated and hydrously altered little worlds
- Grouped in asteroid families and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



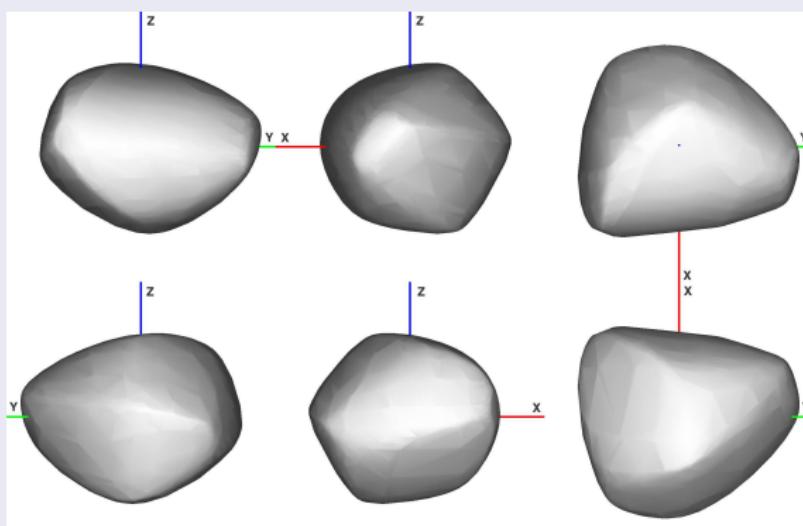
# Asteroid lightcurves



## 478 Tergeste - lightcurves



478 Tergeste - lighcurve inversion model



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

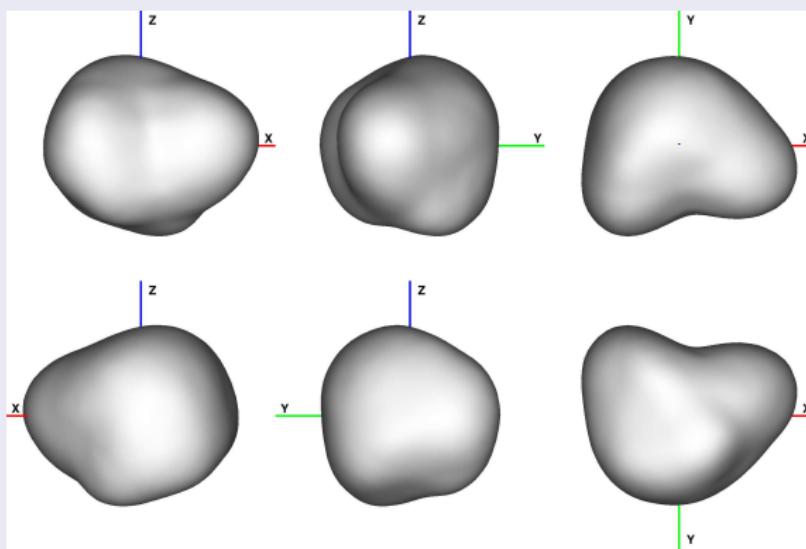
$$\lambda_{p1} = 2^\circ \pm 10^\circ$$

$$\beta_{p1} = -42^\circ \pm 6^\circ$$

$$\lambda_{p2} = 216^\circ \pm 8^\circ$$

$$\beta_{p2} = -56^\circ \pm 5^\circ$$

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



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

$$\lambda_{p1} = 4^\circ \pm 5^\circ$$

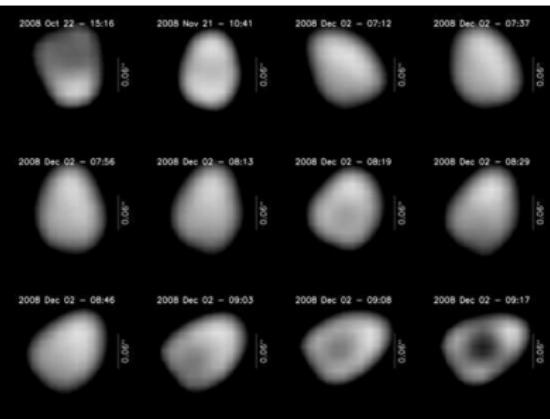
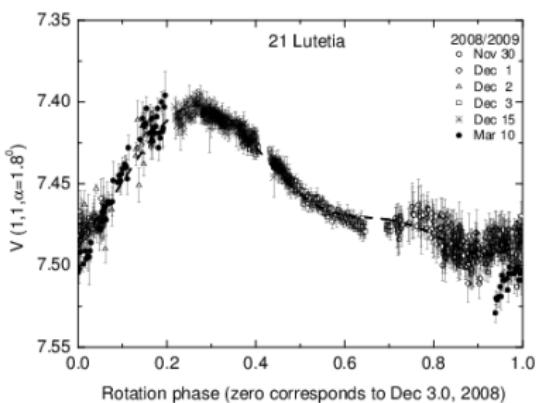
$$\lambda_{p2} = 218^\circ \pm 5^\circ$$

$$\beta_{p1} = -43^\circ \pm 5^\circ$$

$$\beta_{p2} = -56^\circ \pm 5^\circ$$

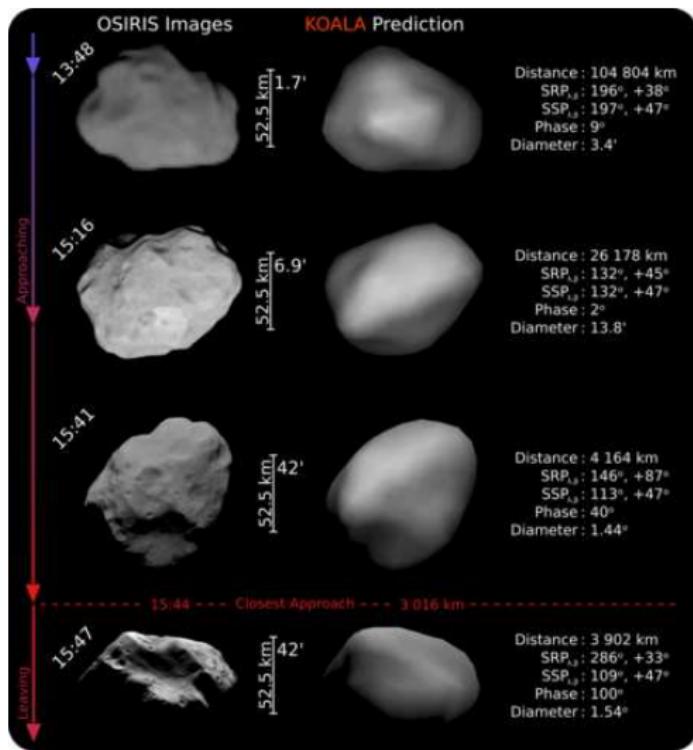


# 21 Lutetia - lightcurves and Adaptive Optics images



Belskaya et al. 2010, Carry et al. 2010

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



Asteroid studies  
○○

Models  
○○○○●○○○

Gaia and asteroids  
○○○○○○○○○○

Selection effects  
○○○○○○○○

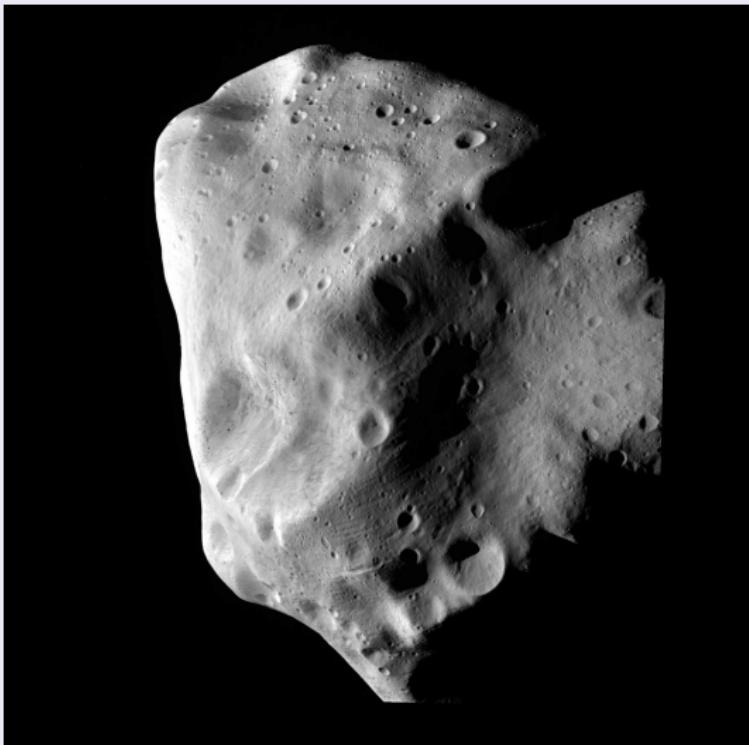
Models  
○

TPM  
○

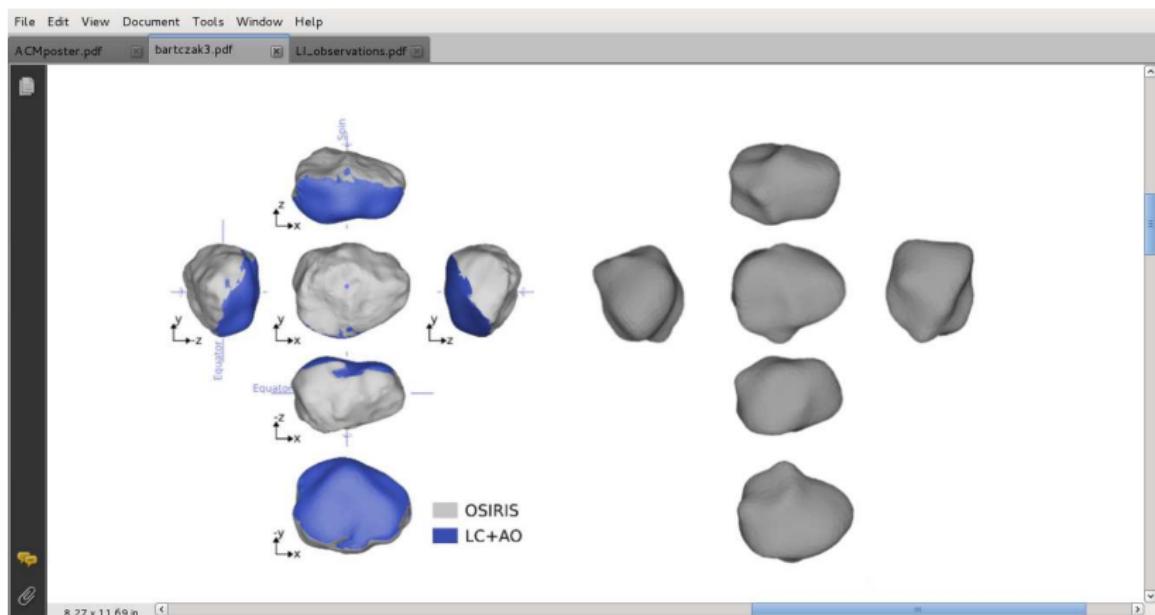
Results  
○○○

Summary  
○

# 21 Lutetia as seen by the Rosetta spacecraft

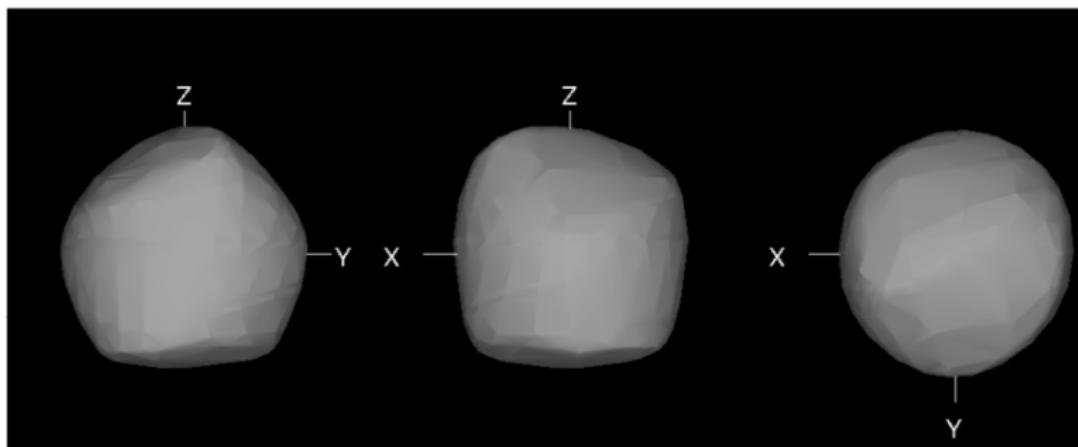


# 21 Lutetia - model comparison



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  $(340^\circ, -40^\circ)$ .

Müller et al. 2017

Asteroid studies  
○○

Models  
○○○○○○○●○○○○○○

Gaia and asteroids

Selection effects  
○○○○○○○

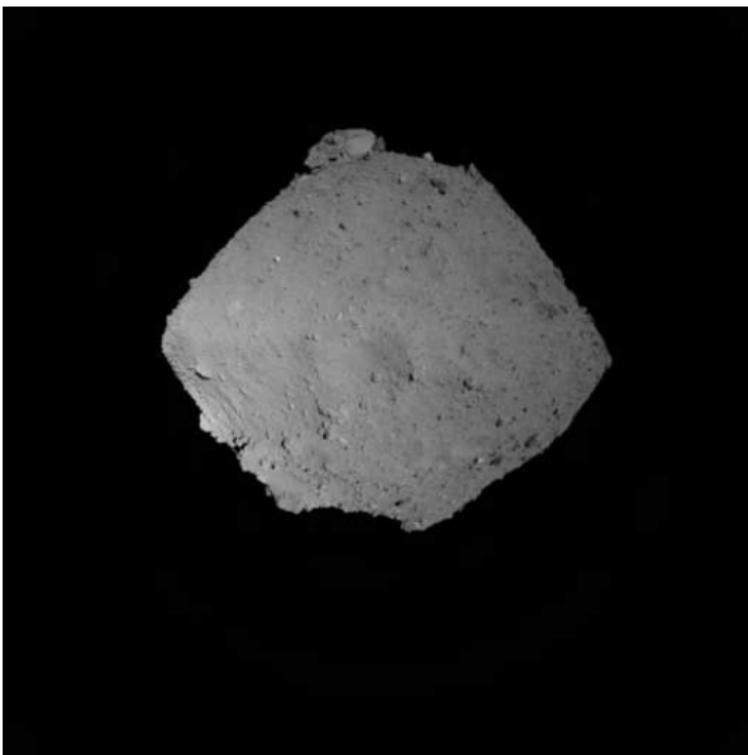
Models  
○

TPM  
○

Results  
○○○

Summary  
○

# 162 173 Ryugu - in reality



JAXA

# Gaia and asteroids



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

gaigosa.eu

 **GOSA**

Anonymous

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- [Observation planner](#)
- [Observation processing](#)
- [Forum](#)
- [FAQ](#)
- [About](#)

Top 10 observers

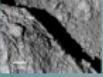
	Sort by:	⬆	⬇
	161	65	
	110	0	
	28	0	
	27	2	
	24	5	
	23	20	

Home

Active Users 128 | Observations 428 | Forum posts 309 | 2018-10-05 9:30:09 UTC

**News**

High resolution pictures of Ryugu



Two MINERVA rovers are already hopping on the surface, taking images/temperatures; the big lander (MASCOT) will land on Oct 3. Take the look at the images of Ryugu at highest resolution so

[show more...](#)

Unusual observation



Recently we have processed the observations of 451 Patientia taken by Adrian Jones. We have noticed that there were second asteroid 17 Thetis, in the field of view. Thus we

[show more...](#)

The recent images of Ryugu asteroid



Most recent images of Ryugu asteroid including the shadow of the spacecraft on the surface and a lot of surface features were taken recently by the MINERVA-III rovers which landed

[show more...](#)

All news

**Follow-up targets**

Asteroids with existing observations which need for follow-up to complete the lightcurve. Click on an asteroid id to check if the object is visible from your site.

Asteroid id	Completeness	Visible until	Magnitude range	Preliminary period	Observation strategy	Priority	External resources
(381) Myrrha	0% 	31-01-2019	13.3 - 14.4	6.572 h		Critical	-
(721) Tabora	0% 	30-11-2018	13.7 - 14.8	7.982 h		Critical	-
(47) Aglaia	33% 	31-10-2018	11 - 12.6	13.178 h	Low amplitude	Critical	-
(27) Euterpe	80% 	15-12-2018	9.8 - 11.5	10.408 h	One frame every 10-20 minutes	Important	-



# Gaia-GOSA hot targets

gaigosa.eu

Szuka

**Hot targets**

Hot targets are asteroids with high priority which will be automatically added to your

Gaia-GOSA Hot Targets on 2018-10-05

Show for next day

Asteroid id	Gaia transit time (UTC)	Magnitude	Science case	User planning to observe
(40) Harmonia	5:50:09	10.98	Calibrator	-
(423) Diotima	8:33:52	12.92	Perturber	-
(113) Amalthea	20:44:31	13.63	Perturber	-
(2085) Henan	23:51:59	16.25	Barbarian	-
(15552) Sandashounkan	2:22:38	19.12	Barbarian	-

**NOTICE!**

This tool provides a forecast of times targets cross the Gaia Focal Plane. It is based on the scanning operations of Gaia. It does not take into account operational activities preventing nominal observations nor matters like e.g. the gaps between CCDs on the Focal Plane. Adding up all dead time components, users should understand that the probability of the data of the target being received on the ground at the indicated time is about 80%. Furthermore, only targets in magnitude range 6<G<20 mag are observed in astrometry and photometry and 6<G<sub>spec</sub><16 mag in spectroscopy. Please note that one more spin phase adjustment to the Gaia orbit will be implemented at a later stage. Therefore the predicted observation time may deviate by up to 6 hours from the actual observation time.

We thank F. Mignard and P. Tanga (OCA, Nice) for putting at our disposal the transit predictions of Solar system objects

**Occultation alerts**

Asteroids which may have observable occultations in the near future

Date	Asteroid id	Asteroid magnitude	Star name	Star magnitude	Visibility	Duration of event (seconds)	External resources
05-10-2018 05:58:00	(40) Harmonia	11	4U 549-15107	13.5	South America	15	More information
06-10-2018 23:56:00	(423) Diotima	12.9	4U 293-189272	13.2	South America	8	More information
07-10-2018	(88) Thisbe	11.4	4U	13.7	South	18	More



# Gaia-GOSA, asteroid transiting Gaia focal plane

gaigosa.eu/gosa-status

 [GOSA](#)

Anonymous

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**Gaia status**

Active Users 128 | Observations 428 | Forum posts 309 | 2018-10-05 9:31:34 UTC

**Simulation of the Gaia focal plane**

**NOTICE!**

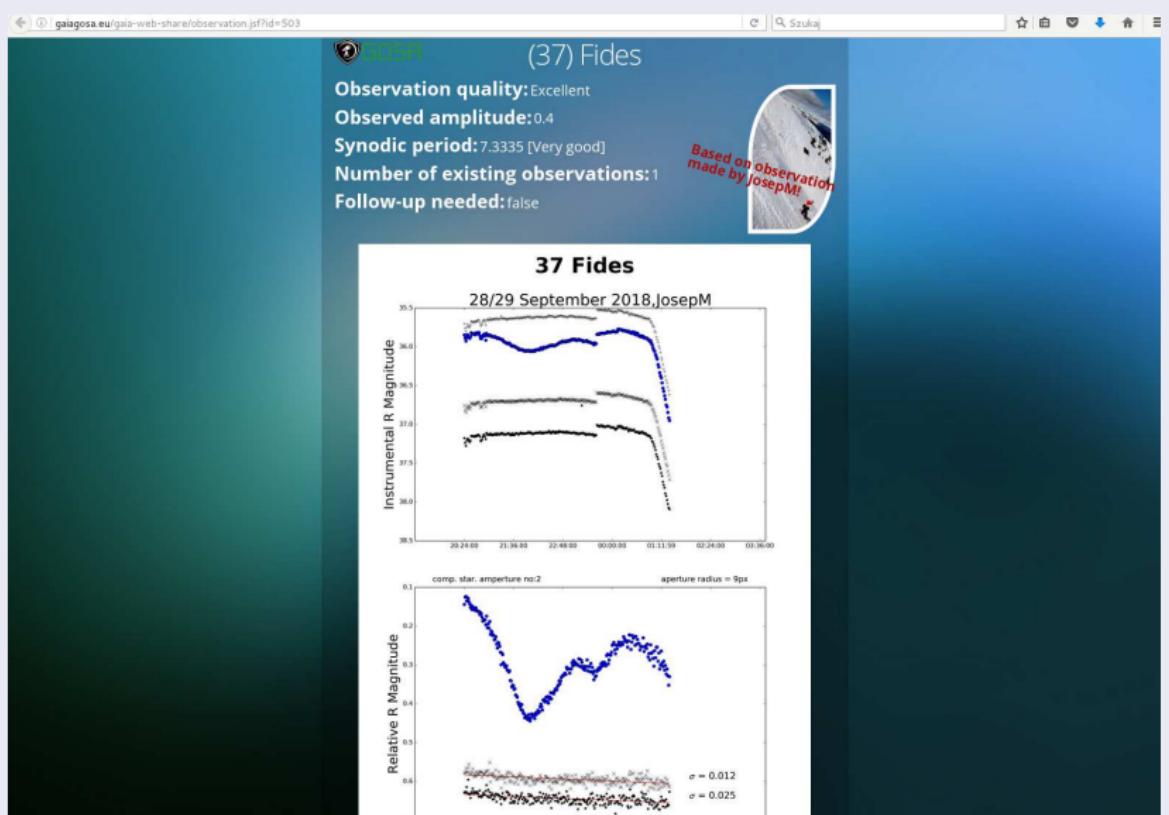
This tool provides a forecast of times targets cross the Gaia Focal Plane. It is based on the scanning operations of Gaia. It does not take into account operational activities preventing nominal observations nor matters like e.g. the gaps between CCDs on the Focal Plane. Adding up all dead time components, users should understand that the probability of the data of the target being received on the ground at the indicated time is about 80%. Furthermore, only targets in magnitude range 6<G<20 mag are observed in astrometry and photometry and 6<G<sub>Gaos</sub><16 mag in spectroscopy. Please note that one more spin phase adjustment to the Gaia orbit will be implemented at a later stage. Therefore the predicted observation time may deviate by up to 6 hours from the actual observation time.

We thank F. Mignard and P. Tanga (OCA, Nice) for putting at our disposal the transit predictions of Solar system objects.

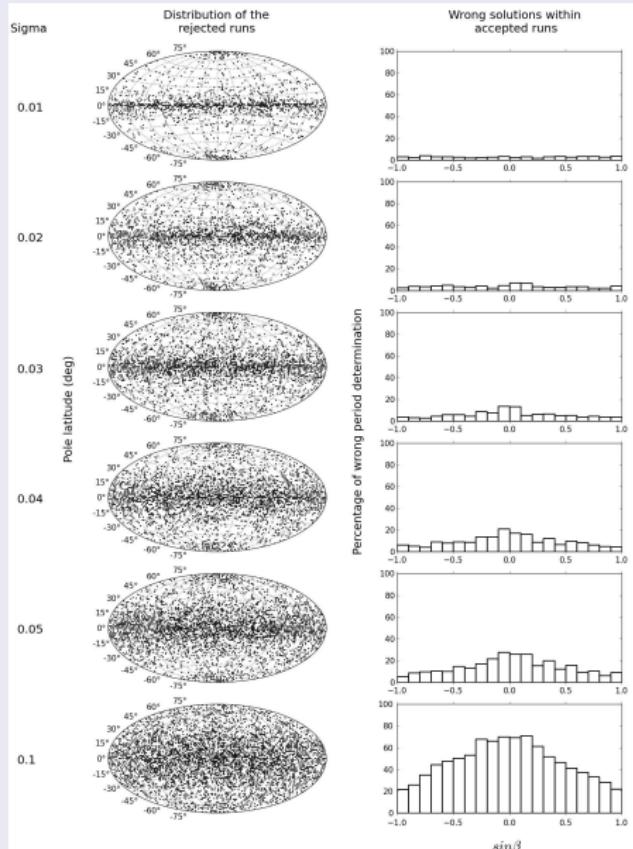
Asteroid id	Observation date	Observation time	Observation status
(192097) 2006-BF210	2018-10-05	9:18:21	done
(306422) 1998-QU3	2018-10-05	9:21:42	done
(316181) 2010-GY126	2018-10-05	9:28:39	done
(142549) 2002-TJ53	2018-10-05	9:31:30	transiting
(53457) 1999-XX142	2018-10-05	9:34:11	0:02:36
(362799) 2011-WX153	2018-10-05	9:34:59	0:03:24
(204264) 2004-FL31	2018-10-05	9:35:21	0:03:46
(412137) 2013-GX51	2018-10-05	9:37:20	0:05:45
(143347) 2003-AR80	2018-10-05	9:37:52	0:06:17
(239544) 2003-TV241	2018-10-05	9:41:24	0:09:49



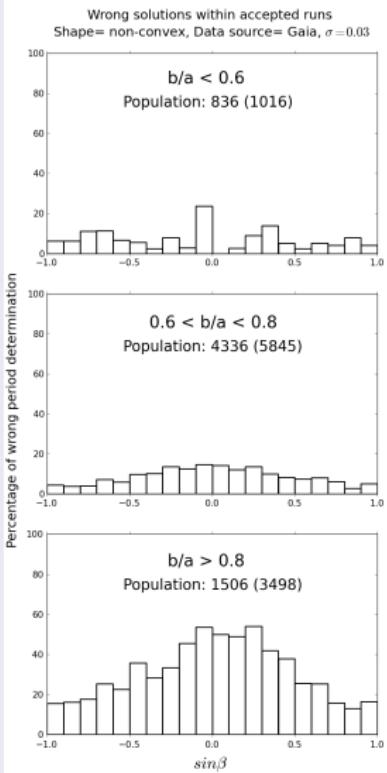
# Gaia-GOSA sample results



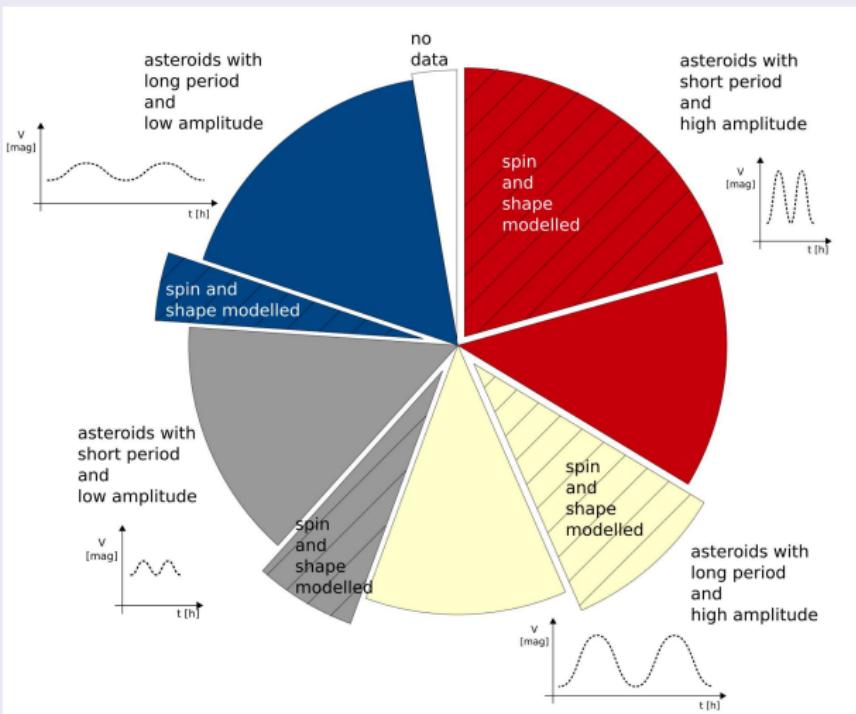
# Selection effects in asteroid spin axis positions - Gaia simulator



# Selection effects in asteroid shape - Gaia simulator



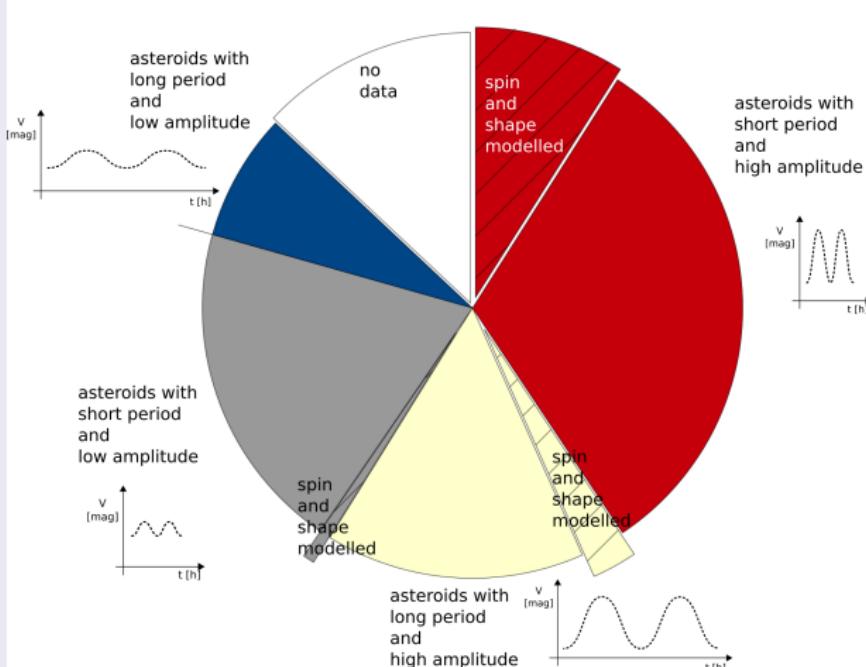
# Selection effects in MBA models



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



# 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.





# Observation planner for project against biases

[asteroids.2614536-0.web-hosting.es](http://asteroids.2614536-0.web-hosting.es)



Szukaj



Hi, Anna Marciniak



Observation planner



Anna Marciniak  
Administrator

Website map



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Ephemeris

## Observation planner

Against the bias in spins and shapes of asteroids

Search targets for observation

« October 2018 »

Su	Mo	Tu	We	Th	Fr	Sa
30	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3
4	5	6	7	8	9	10

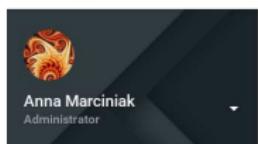
Borowiec Observatory

Lon: 17° 04' 36.00" E Lat: 52° 16' 38.00" N

2018 / Observation planner / Against the bias in spins and shapes of asteroids



# Observation planner, site selection



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Ephemeris

## Observation sites (Anna Marciniak)

Select user:

Anna Marciniak

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

asteroids.2614536-0.web-hosting.es/p\_suggested.php?SEL SITE\_3=on

Szukaj



Hi, Anna Marciniak



Observation planner



Anna Marciniak  
Administrator

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**Suggested targets**

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## Suggested targets (2018-10-05)

Select date: → 2018-10-05

Borowiec Observatory

Lon: 17° 04' 36.00" E Lat: 52° 16' 38.00" N Alt: 80 m

Borowiec Observatory - Twilight (17:32 - 03:48)

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

[asteroids.2614536-0.web-hosting.es/p\\_details.php?id\\_site=3&id\\_target=903&date=2018-10-05](http://asteroids.2614536-0.web-hosting.es/p_details.php?id_site=3&id_target=903&date=2018-10-05)

Szukaj



Hi, Anna Marciniaik



≡ Observation planner



Anna Marciniaik  
Administrator

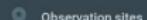
Website map



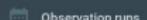
Home



Suggested targets



Observation sites



Observation runs

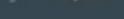


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Targets



Configuration



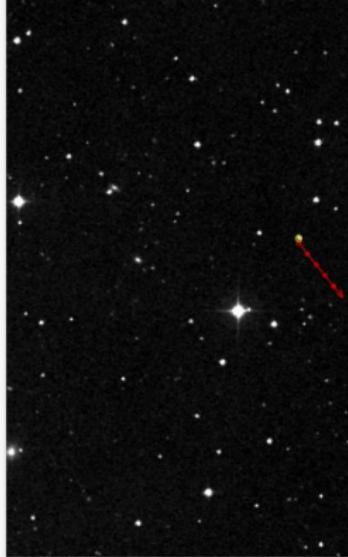
Ephemeris

## Observation details Borowiec Observatory, 2018-10-05, Nealley(903)

Finder chart

DSS-Real

J2000 03:27:51.489 +04:23:25.71



Observation details

ALT(mid) 41.8°

Mag 15.0

Moon 100.7° / 24%

Date(st.) 2018-10-05 21:47 UT

Date(mid) 2018-10-06 01:24 UT

Date(end) 2018-10-06 03:48 UT

POS(st.) 03:27:48.95 +04:24:47.1  
/ Alt: 25°

POS(mid) 03:27:46.04 +04:23:53.0  
/ Alt: 42°

POS(end) 03:27:44.09 +04:23:16.7  
/ Alt: 33°

**One star is close to the path**

Stars 03:27:48.97 +04:24:54.9  
/ Mag: 15.5

Object Altitude

Altitude graph for Borowiec Observatory





# Observation planner, phase coverage

( [asteroids.2614536-0.web-hosting.es/p\\_suggested.php](#)) Szukaj

Hi, Anna Marciniak

**Observation planner**

Anna Marciniak  
Administrator

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Targets Configuration Ephemeris

Period: 21.600h = 0.900d

2018-10-02 0.000000 -- 0.277778  
|\*\*\*\*\*-----|

2018-10-03 0.0 -- 0.049383, 0.740741 -- 1.0  
|\*\*\*\*\*-----|

2018-10-03 0.157408 -- 0.388889  
|=====\*\*\*\*\*-----|

/////////// you can cover tonight ///////////

2018-10-05 0.331430 -- 0.610301  
|\*\*\*\*\*-----|

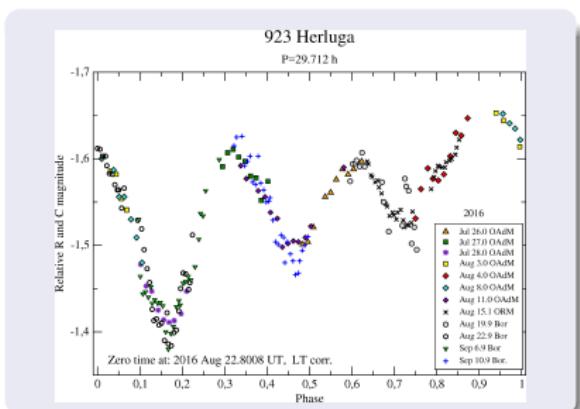
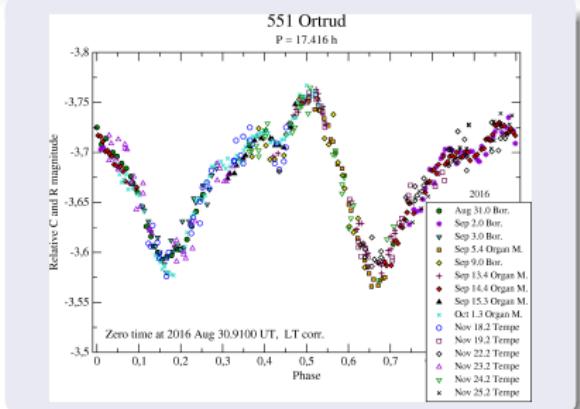
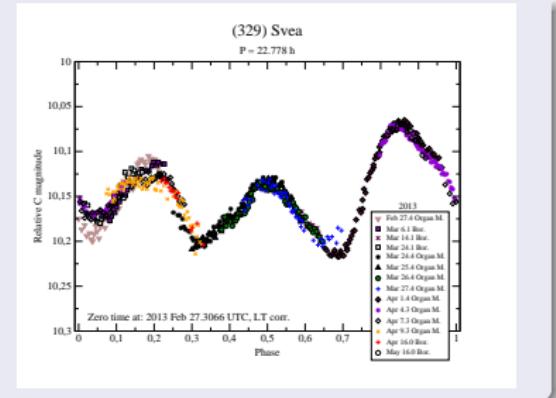
Select date:  T° 04° 36.00' E Lat: 52° 16' 38.00" N Alt: 80 m

Target	Stat.	Moon	Actions
48	113°		
48	75°		
48	103°		
48	54°		
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°
(786) 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 28° / 58° / 25° 09h 47m 17:32 03:20 132°

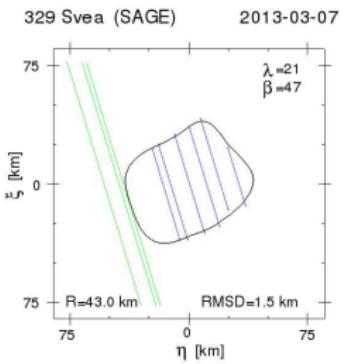
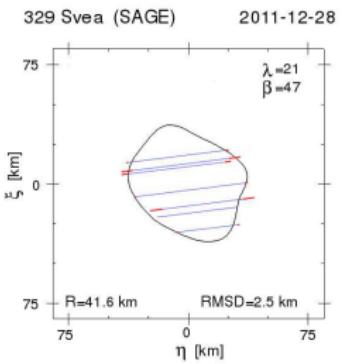
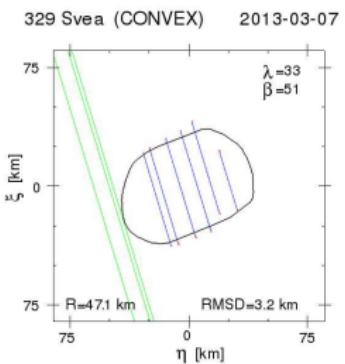
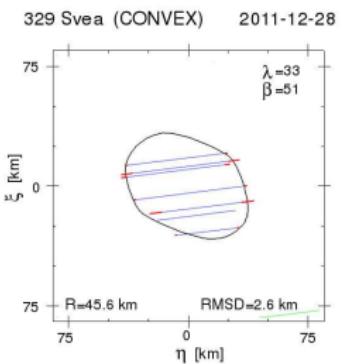
**Phase coverage graph for: (903) Nealley**

OK

# Selected lightcurves



# Fitting the shape models to stellar occultation chords

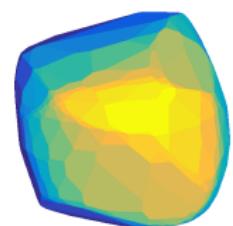


Diameters of equivalent volume sphere:

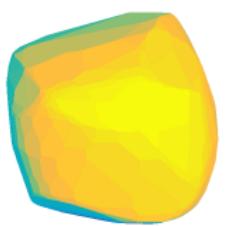
CONVEX (2011):  $72 \pm 4 \text{ km}$ ; CONVEX (2013):  $74 \pm 5 \text{ km}$   
SAGE (2011):  $70 \pm 4 \text{ km}$ ;      SAGE (2013):  $72 \pm 3 \text{ km}$

# Thermophysical modelling

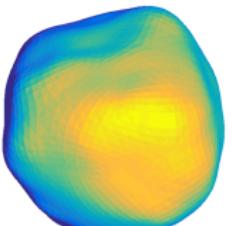
Insolation and surface temperature distribution: (159) Aemilia



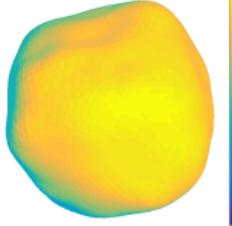
120  
100  
80  
60  
40  
20  
0



200  
160  
120  
80  
40  
0

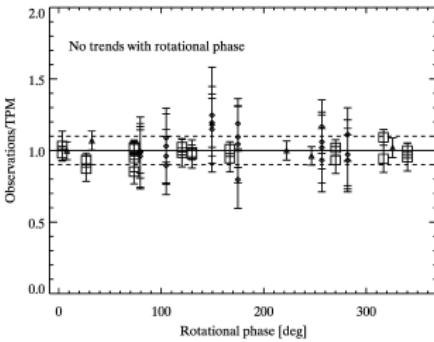
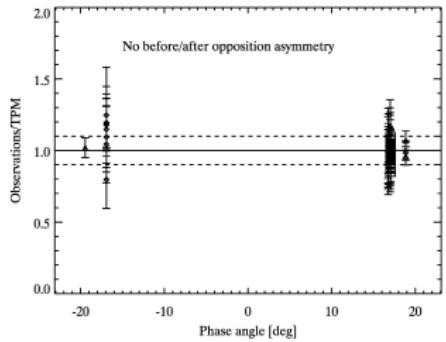
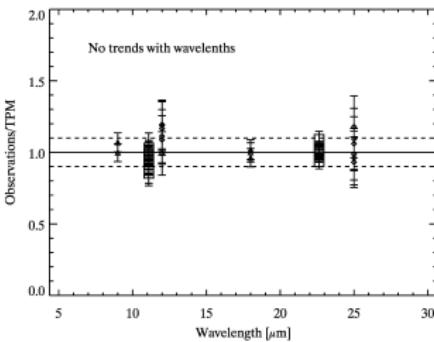
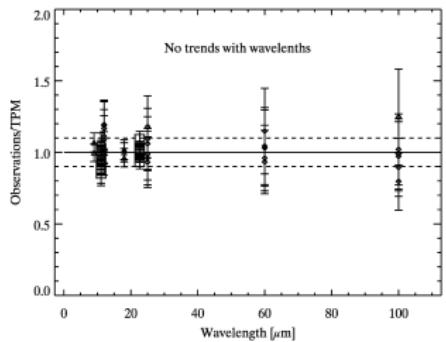


120  
100  
80  
60  
40  
20  
0



200  
160  
120  
80  
40  
0

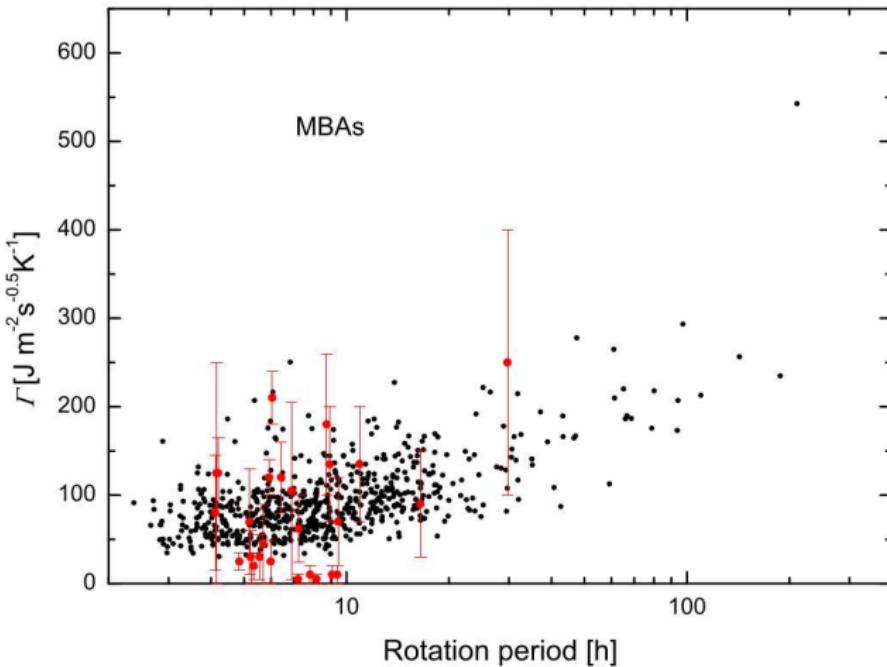
# O-C plots for (159) Aemilia model applied in TPM



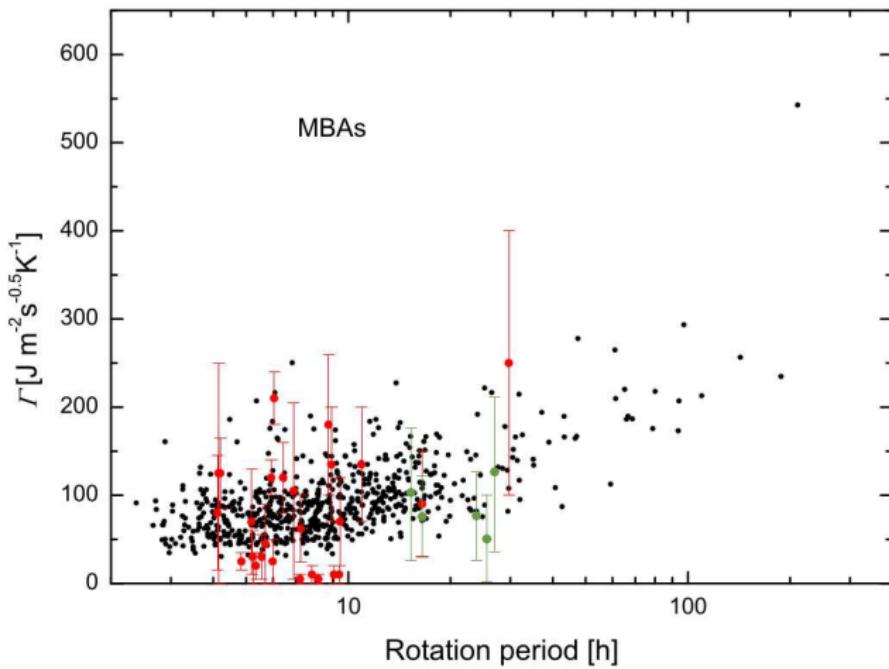
Target	Rotation period [h]	Radiometric solution for combined data.		
		Diameter [km]	Albedo	Thermal inertia $[Jm^{-2}s^{-0.5}K^{-1}]$
159 Aemilia	24.4787	137	0.054	50
	±0.0001	±8	±0.015	±50
227 Philosophia	26.4614	101	0.041	125
	±0.0001	±5	±0.005	±90
329 Svea	22.7670	78	0.055	75
	±0.0001	±4	±0.015	±50
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

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## Thermal inertia of Main Belt Asteroids



# Thermal inertia of slow rotators



after: Harris &amp; Drube 2016

# Summary

- Gaia provides valuable data for physical studies of asteroids, but ground-based support necessary
- 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](mailto:edypod@amu.edu.pl)) for Gaia-GOSA service,  
Anna Marciniak ([am@amu.edu.pl](mailto:am@amu.edu.pl)) for project on selection effects.

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