

# Analysis of stellar occultations by asteroids observed from station in Borowiec

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# Analiza obserwacji zakryć gwiazd przez planetoidy w stacji w Borowcu

## Bachelor thesis

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### Thesis information

Language of the thesis:	Polish [PL]
Title:	 Analiza obserwacji zakryć gwiazd przez planetoidy w stacji w Borowcu  Analysis of stellar occultations by asteroids observed from station in Borowiec
Dissertation advisor:	prof. UAM dr hab. Anna Marciniak
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Organizational unit:	Faculty of Physics





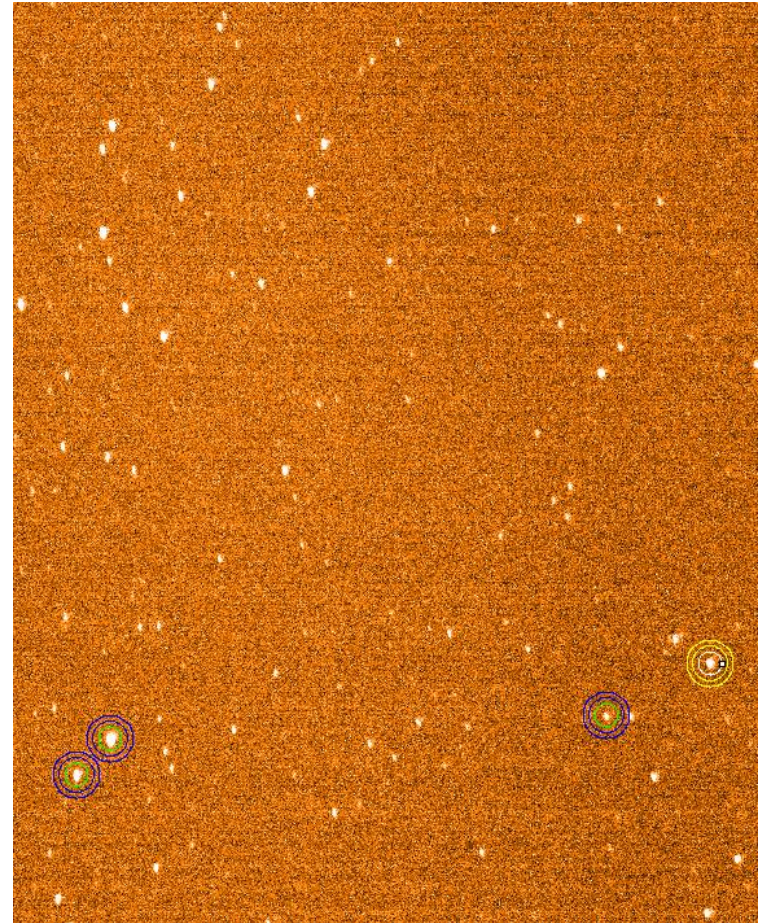
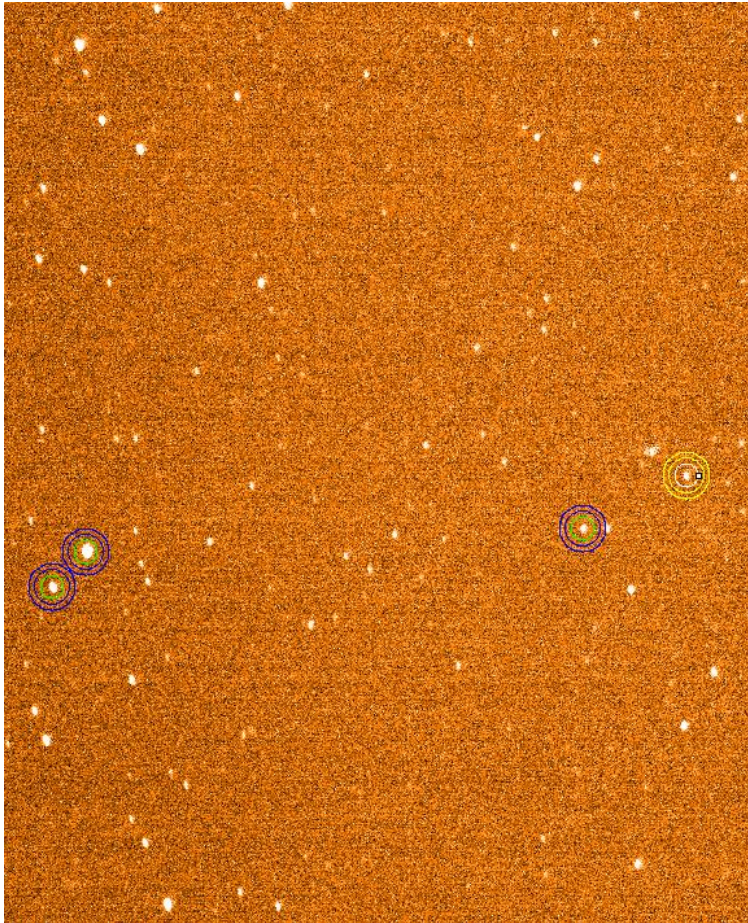
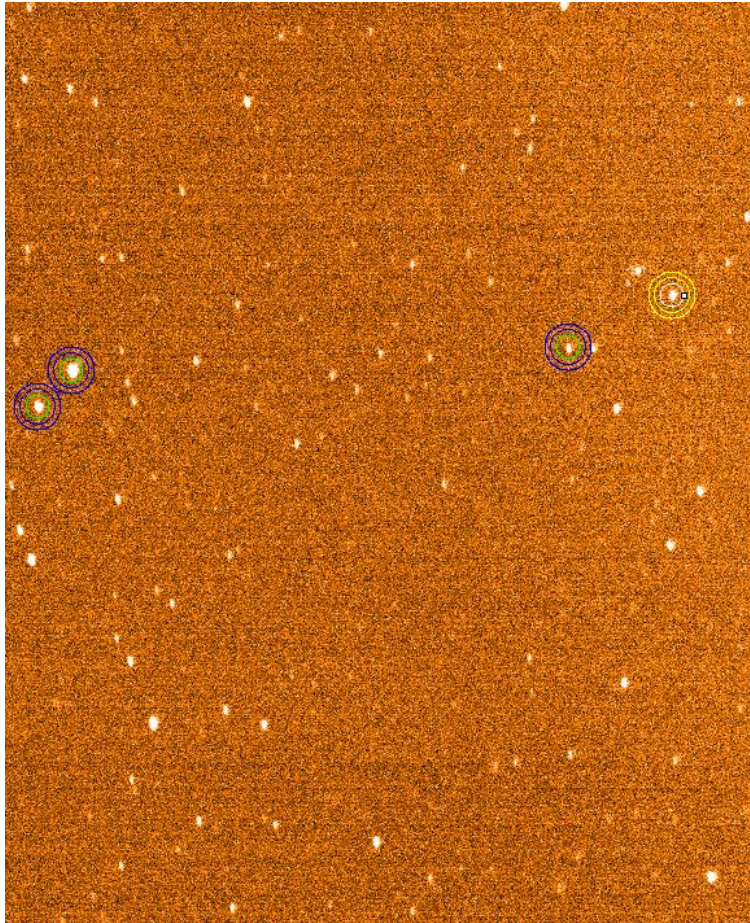
# Borowiec Station

- Photometric telescope
- Mirror diameter 40 cm
- Focal length 1.8 m
- Newtonian
- Parallactic mount
- Andor Zyla 5.5 camera with sCMOS sensor
- Readout 0.01 s
- Time source GPS

# The possibilities of the telescope

- The field of view of the telescope less than 2 minutes in the hour angle and in declination
- Broken: telescope guidance, camera focusing (currently operational since summer holidays)
- Trees on the eastern horizon - see above  $25^{\circ}$
- Brightness range of the observed stars - 12/13 magnitude (depending on the focusing)
- The appropriate number of frames during occultation (duration, frame exposure time)







# Data reduction

- Reduction: C and Python programs
- Photometry: GAIA - Graphical Astronomy and Image Analysis Tool (the advantage is good tracking of apertures behind objects on frames from a fixed telescope)



<http://star-www.dur.ac.uk/~pdraper/gaia/gaia.html>

# Statistics of results from the station in Borowiec

Positive	Negative
(790) Pretoria	(6419) Susono
(7680) Cari	(629) Bernardina
(268) Adorea	(45403) 2000 AL141
(387) Aquitania	
(165) Loreley	
(5889) Mickiewicz	
(98) lanthe	

# Results statistics continued

Determination of sizes in two axes	Determination of diameter	Only the minimum size is calculated
(790) Pretoria	(268 Adorea)	(7680) Cari
	(387) Aquitania	(5889) Mickiewicz
	(165) Loreley	
	(98) Ianthe	

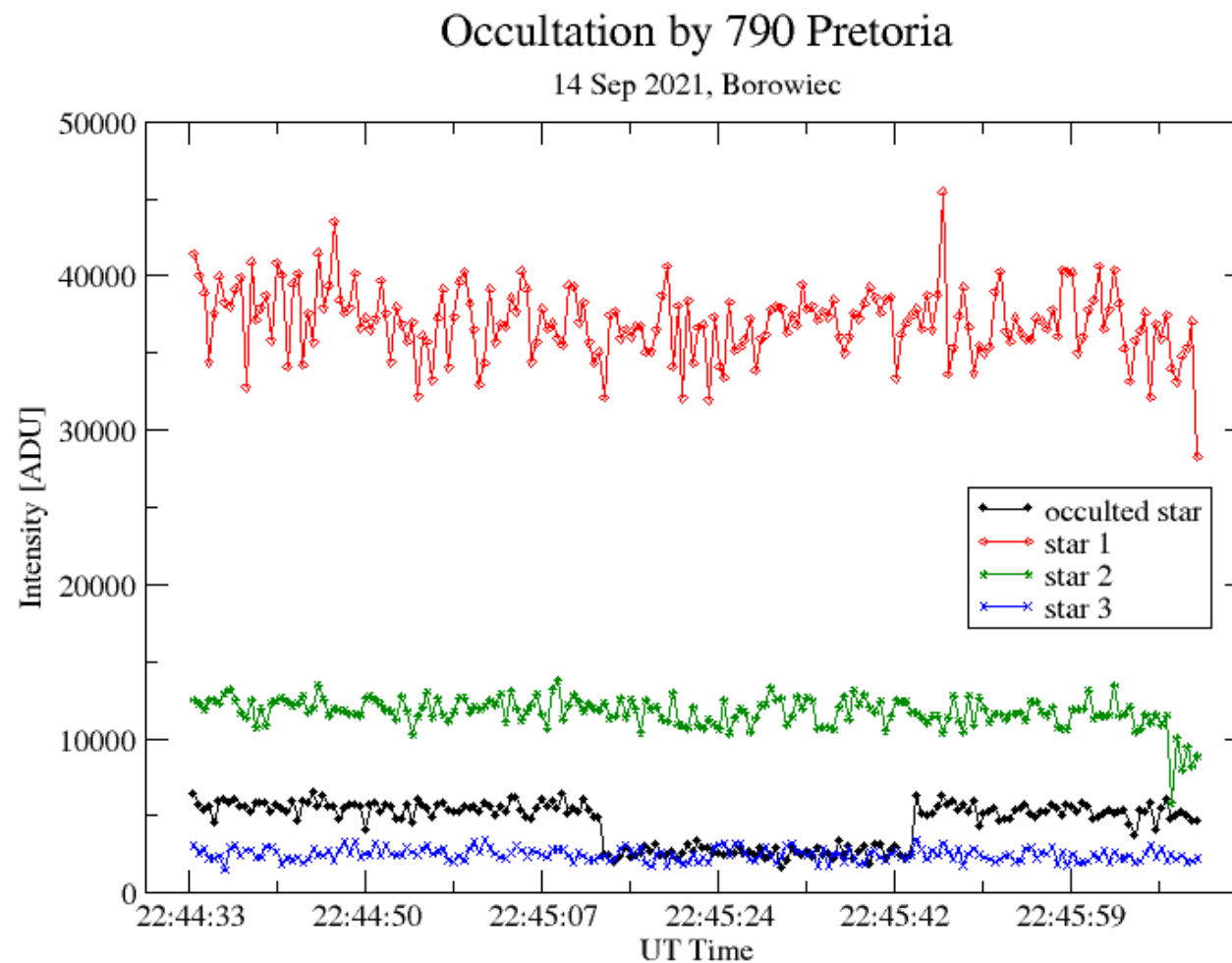
The asteroids for which the results from the occultation phenomena may indicate the incorrectness of one of the diameter values proposed in the literature are marked in red.

Additionally, future predictions for asteroids (7680) Cari and (5889) Mickiewicz (phenomena captured on the border of the shadow belt or the 1-sigma belt with low probability) were refined.

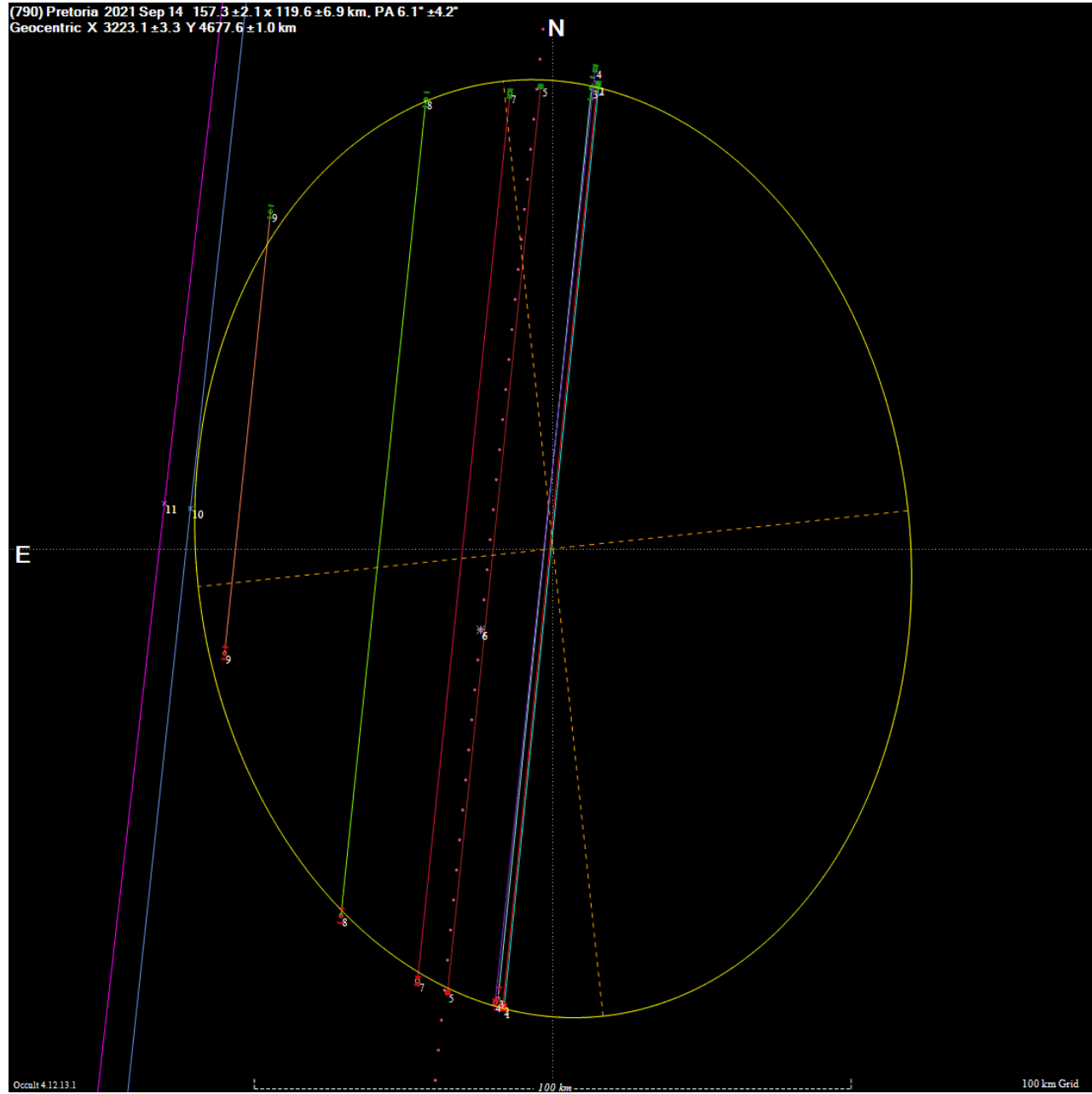


# (790) Pretoria

- DATE: 14 September 2021      STAR: UCAC4 471-110652
  - ASTEROID: Pretoria            No: 790
  - Star magnitude: 12.8
  - Minor planet magnitude: 13.1
  - Distance (km): 9.5 km
  - Exposure time: 0.5 s
  - Predicted max. duration (secs) : 32.0
  - Predicted max. drop (mag) : 0.9
  - Predicted mid-event (UT): 22:45:25
  - Predicted error in time (secs) : 12
  - Probability: 83.5 %
  - POSITIVE
- S - 22:44:32.80 - - 0.01  
D - 22:45:13.09 - - 0.1  
R - 22:45:44.20 - - 0.1  
E - 22:46:11.23 - - 0.01
- Duration : 31.11 +/- 0.14
  - Mid-event : 22:45:28.64 +/- 0.1



(790) Pretoria 2021 Sep 14 157.3 ±2.1 x 119.6 ±6.9 km. PA 6.1° ±4.2°  
Geocentric X 3223.1 ±3.3 Y 4677.6 ±1.0 km



Occult 4.12.13.1

100 km

100 km Grid

Find best fit

Center X	23.7	<input checked="" type="checkbox"/>	0.0	Mass X	0.0
Center Y	-1.8	<input checked="" type="checkbox"/>	0.0	Mass Y	0.0
Major axis (km)	157.3	<input checked="" type="checkbox"/>	0.0	Shape model	<input type="checkbox"/>
Minor axis (km)	119.6	<input checked="" type="checkbox"/>	0.0	a/b=1.32 $\Delta$ ag=-0.30	
Orientation	6.1	<input checked="" type="checkbox"/>	0.0	Motion	5.02km/s.

Circular  Use assumed diameter  Include Miss events

Double stars - show  Both  Primary  Secondary

Quality of the fit Reliable size. Can fit to shape models  
 Flag for future review

Scale

Size  normal  x 2  x 5 Form opacity

Scroll range x1.25

RMS fit 0.0 ±1.4 km

1	Michal Rottenborn
2	Jiri Polak
3	Josef Hanus
4	Julia Perla
5	Karel Halir
6 (P)	Predicted
7	Jiri Kubanek
8	Jiri Kubanek
9	Jan Manek
10 (M)	Marek Zawilski
11 (M)	Donatas Tamonis

# Occultation analysis - size determination

Positive observations : 8

Negative observations : 2

Size	Method	Reference
(157.3 ± 2.1) km x (119.6 ± 6.9) km	Stellar occultation	Euraster <a href="https://euraster.net/">https://euraster.net/</a>
Diameter 144 km	AKARI Satellite	(Usui i inni, 2011) <a href="https://doi.org/10.1093/pasj/63.5.1117">https://doi.org/10.1093/pasj/63.5.1117</a>
Diameter 170 km	IRAS Satellite	(Tedesco i inni, 2002) <a href="https://iopscience.iop.org/article/10.1086/338320">https://iopscience.iop.org/article/10.1086/338320</a>

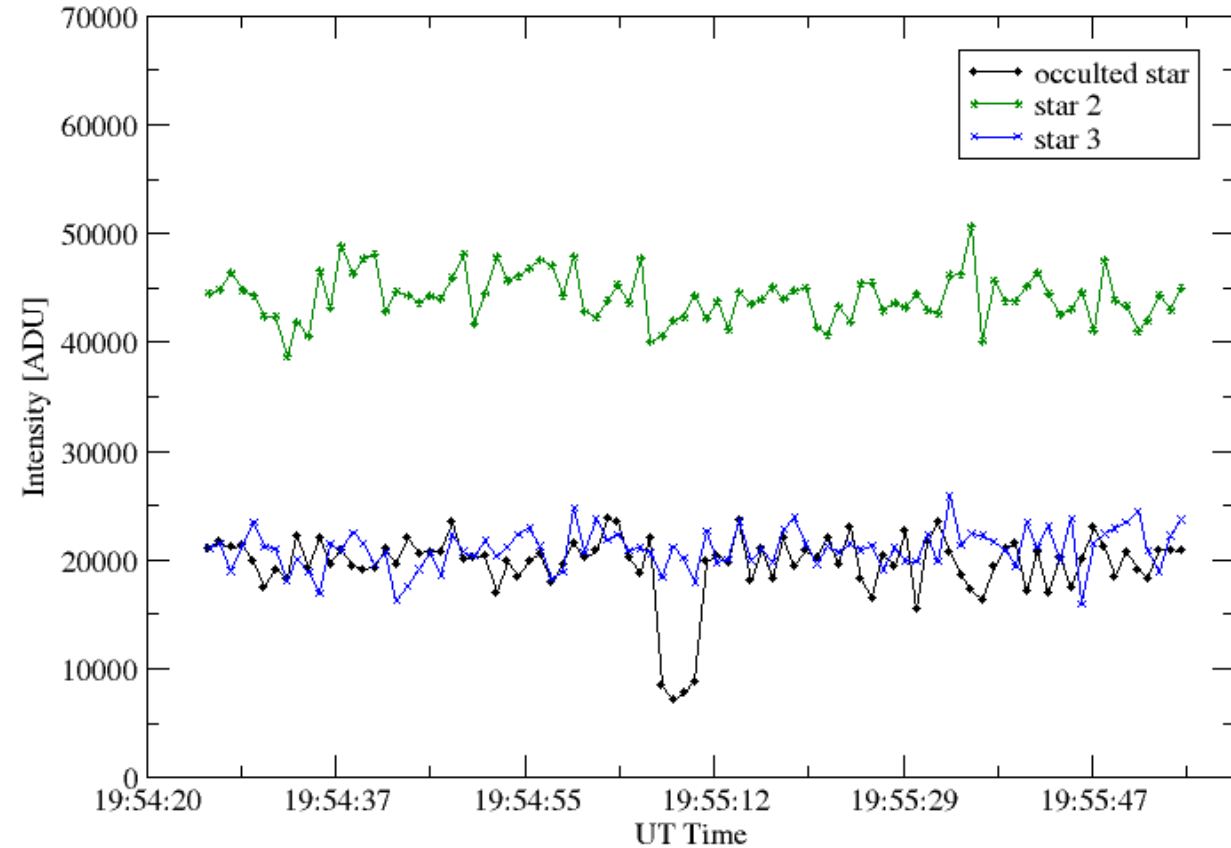


# (165) Loreley

- DATE: 21 March 2022
- STAR: UCAC4 584-008178
- ASTEROID: Loreley
- No: 165
- Star magnitude : 13.3 ,
- Minor planet magnitude : 14.2
- Distance (km) : 76.7
- Exposure time : 1.0 s
- Predicted max. duration (secs) : 5.51
- Predicted max. drop (mag) : 1.3
- Predicted mid-event (UT) : 19:55:08
- Predicted error in time (secs) : 0.6
- Probability : 99.9 %
- POSITIVE
- S - 19:54:25.34 -- 0.01
- D - 19:55:06.75 -- 0.50
- R - 19:55:10.79 -- 0.50
- E - 19:55:54.22 -- 0.01
- Duration : 4.04s +/- 0.70s
- Mid-event : 19:55:08.77 UT +/- 0.5s

## Occultation by 165 Loreley

21 March 2022, Borowiec

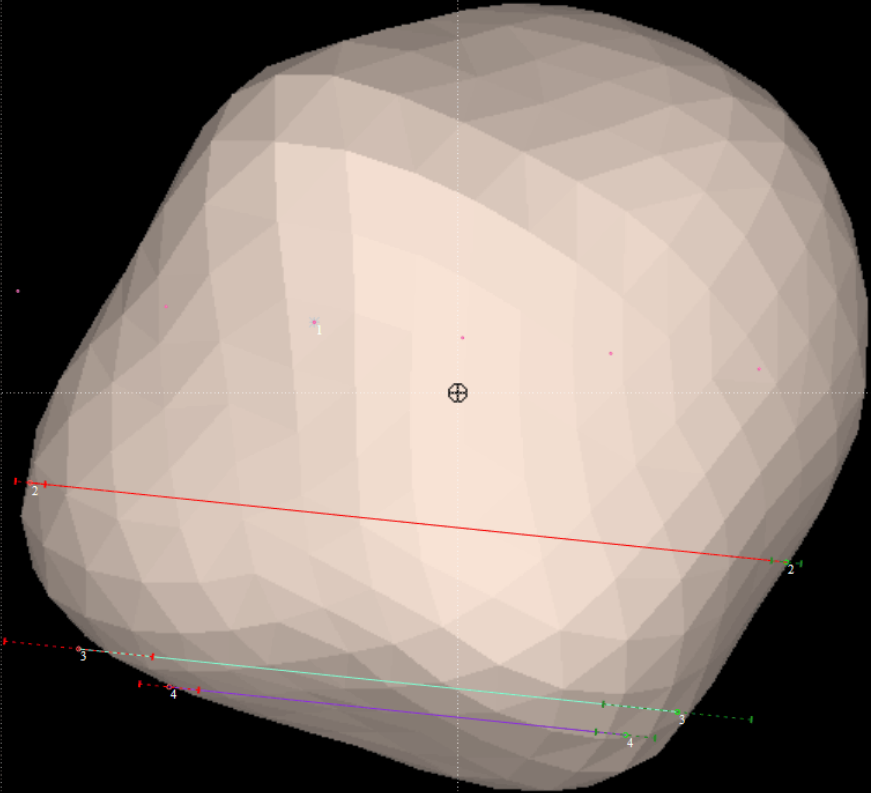


(165) Loreley 2022 Mar 21 175.0 km  
Geocentric X 3888.9 ± 1.4 Y 4348.8 ± 1.7 km

N

DAMIT #1809 2017-06-16  
Sky Plane

E



Phase offset 0°  
Occult 4.2022 4.11

100 km

100 km Grid

Find best fit

Center X	2.3	<input checked="" type="checkbox"/>	0.0	Mass X	0.0
Center Y	45.9	<input checked="" type="checkbox"/>	0.0	Mass Y	0.0
Major axis (km)	175.0	<input type="checkbox"/>	0.0	Shape model	<input type="checkbox"/>
Minor axis (km)	175.0	<input type="checkbox"/>	0.0	a/b: 1.00, dMag: 0.00	
Orientation	0.0	<input type="checkbox"/>	0.0	Motion: 32.62 km/s	

Circular  Use assumed diameter  Include Miss events

Double stars - show  Both  Primary  Secondary

Quality of the fit   Flag for future review

p Scale

L O Size  normal  x 2  x 5

T Scroll range x1.25

RMS fit 0.2 ± 2.7 km

1 (P)	Predicted
2	Marek Zawilski
3	Julia Perla
4	Anna Marciniak

# Occultation analysis - size determination

Positive observations : 3

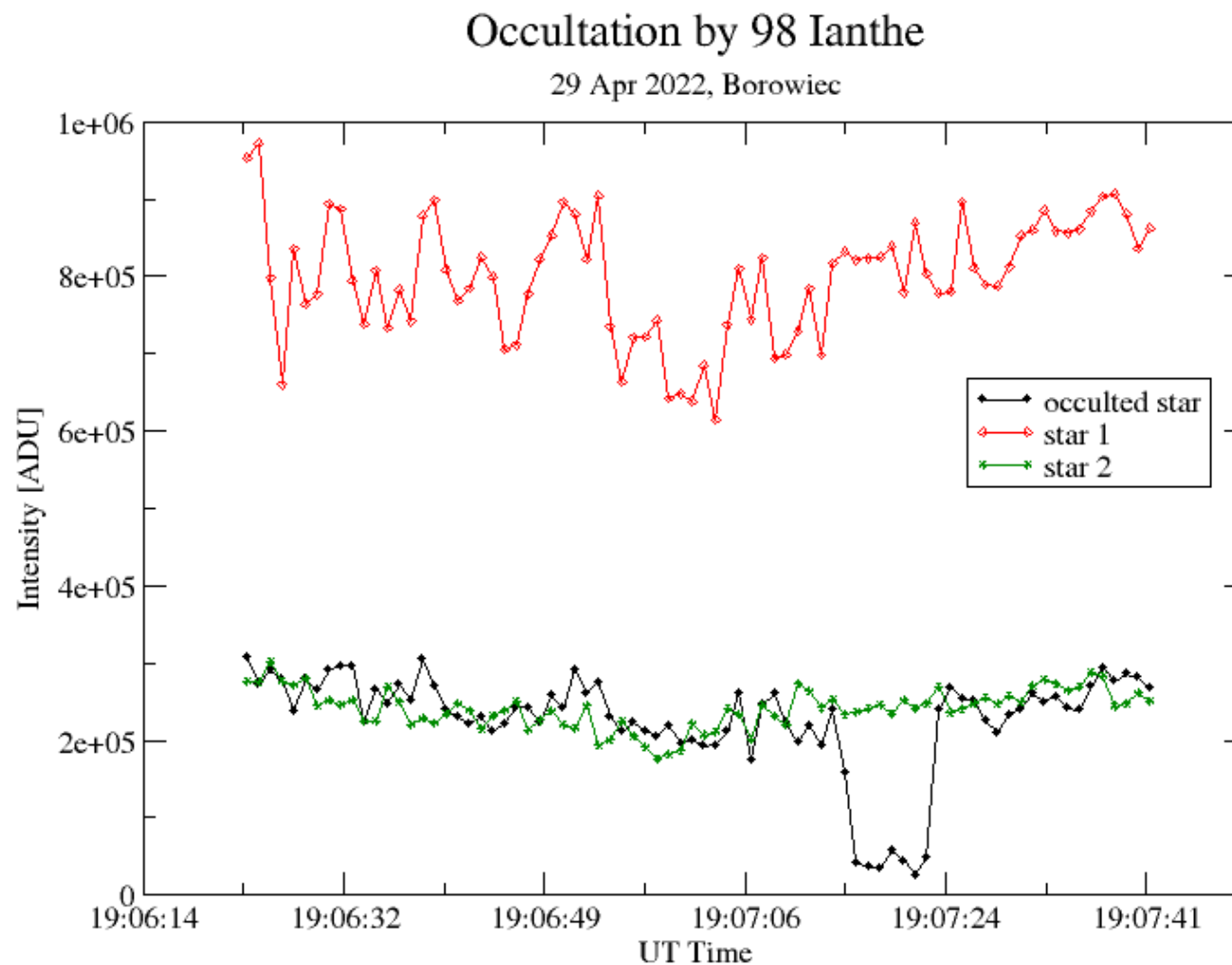
Negative observations : 0

Size	Method	Reference
175 ± 2.7 km (based on the shape model)	Stellar occultation	Euraster <a href="https://euraster.net/">https://euraster.net/</a>
173 km	AKARI Satellite	(Usui i inni, 2011) <a href="https://doi.org/10.1093/pasj/63.5.1117">https://doi.org/10.1093/pasj/63.5.1117</a>
154 km	IRAS Satellite	(Tedesco i inni, 2002) <a href="https://iopscience.iop.org/article/10.1086/338320">https://iopscience.iop.org/article/10.1086/338320</a>

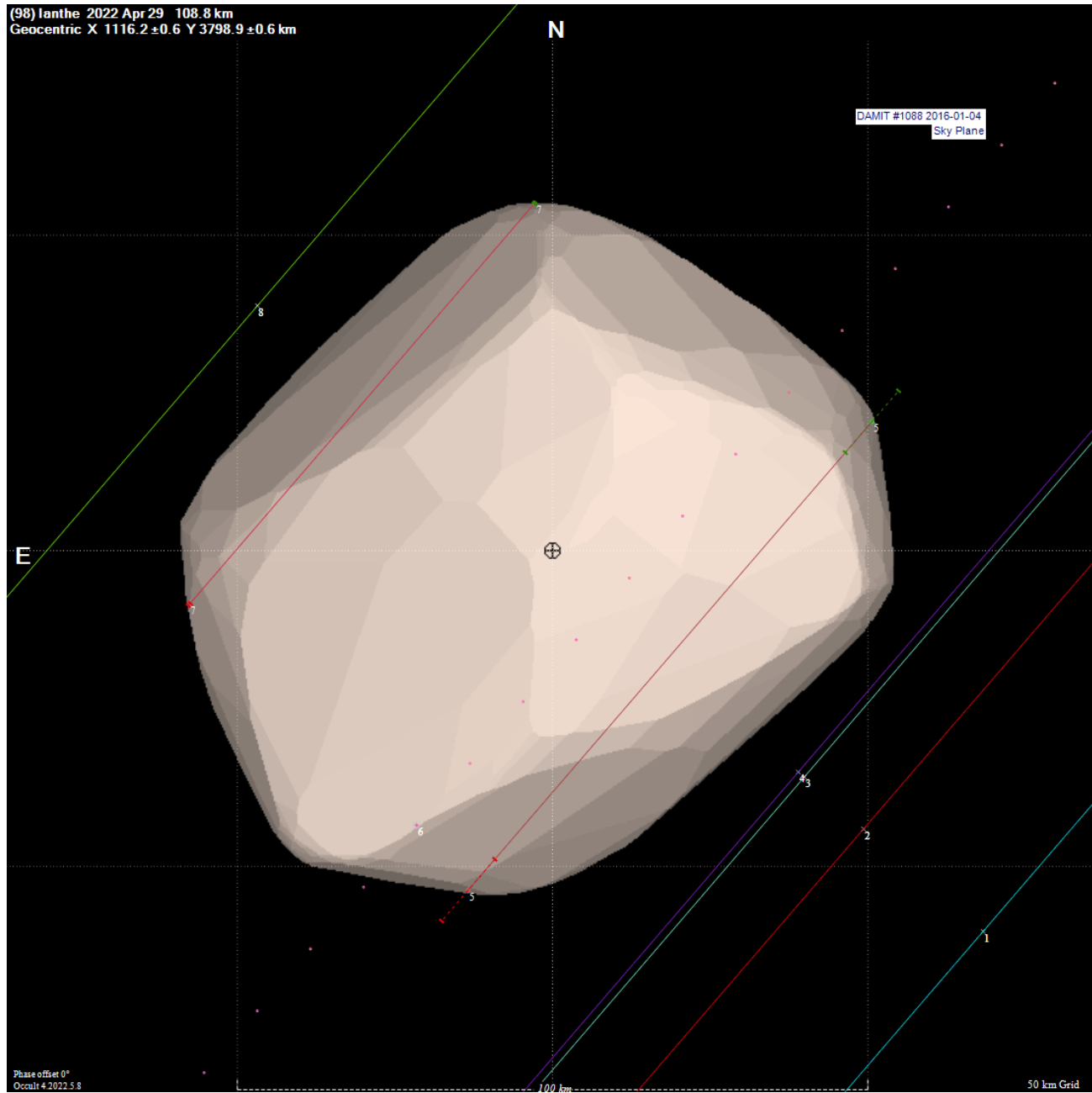


# (98) IANthe

- DATE: 29 April 2022 STAR: TYC 834-01376-1  
ASTEROID: IANthe No: 98
- Star magnitude : 9.9
- Minor planet magnitude : 13.0
- Distance (km) : 13.0 km
- Exposure time : 1.0 s
- Predicted max. duration (secs) : 8.3
- Predicted max. drop (mag) : 3.2
- Predicted mid-event (UT) : 19:06:21
- Predicted error in time (secs) : 3
- Probability : 97.3 %
- POSITIVE
- S - 19:06:22.83 -- 0.01
- D - 19:07:15.34 -- 0.5
- R - 19:07:21.91 -- 0.5
- E - 19:07:40.60 -- 0.01
- Duration : 6.57s +/- 0.70s
- Mid-event : 19:07:18.63 UT +/- 0.5s



(98) Ianthe 2022 Apr 29 108.8 km  
Geocentric X 1116.2 ± 0.6 Y 3798.9 ± 0.6 km



DAMIT #1088 2016-01-04  
Sky Plane

Hind best fit

Center X 1.1  0.3 Mass X 0.0  
Center Y -0.1  -0.3 Mass Y 0.0

Major axis (km) 108.8  0.0 Shape model   
Minor axis (km) 108.8  0.0 a/b: 1.00, dMag: 0.00  
Orientation 0.0  0.0 Motion: 12.92 km/s

Circular  Use assumed diameter  Include Miss events

Double stars - show  Both  Primary  Secondary

Quality of the fit Limits on size, but no shape  
 Flag for future review

P Scale

L Size  normal  x 2  x 5 Form opacity

O

T Scroll range x1.25

RMS fit 1.2 ± 0.8 km

1 (M)	Petr Zeleny
2 (M)	Anna Marciniak
3 (M)	Peter Nosal
4 (M)	Peter Delincak
5	Julia Perla
6 (P)	Predicted
7	Marcin Filipek
8 (M)	Daniel Blazewicz

Phase offset 0°  
Occult 4 2022.5.8

# Occultation analysis - size determination

Positive observations : 2

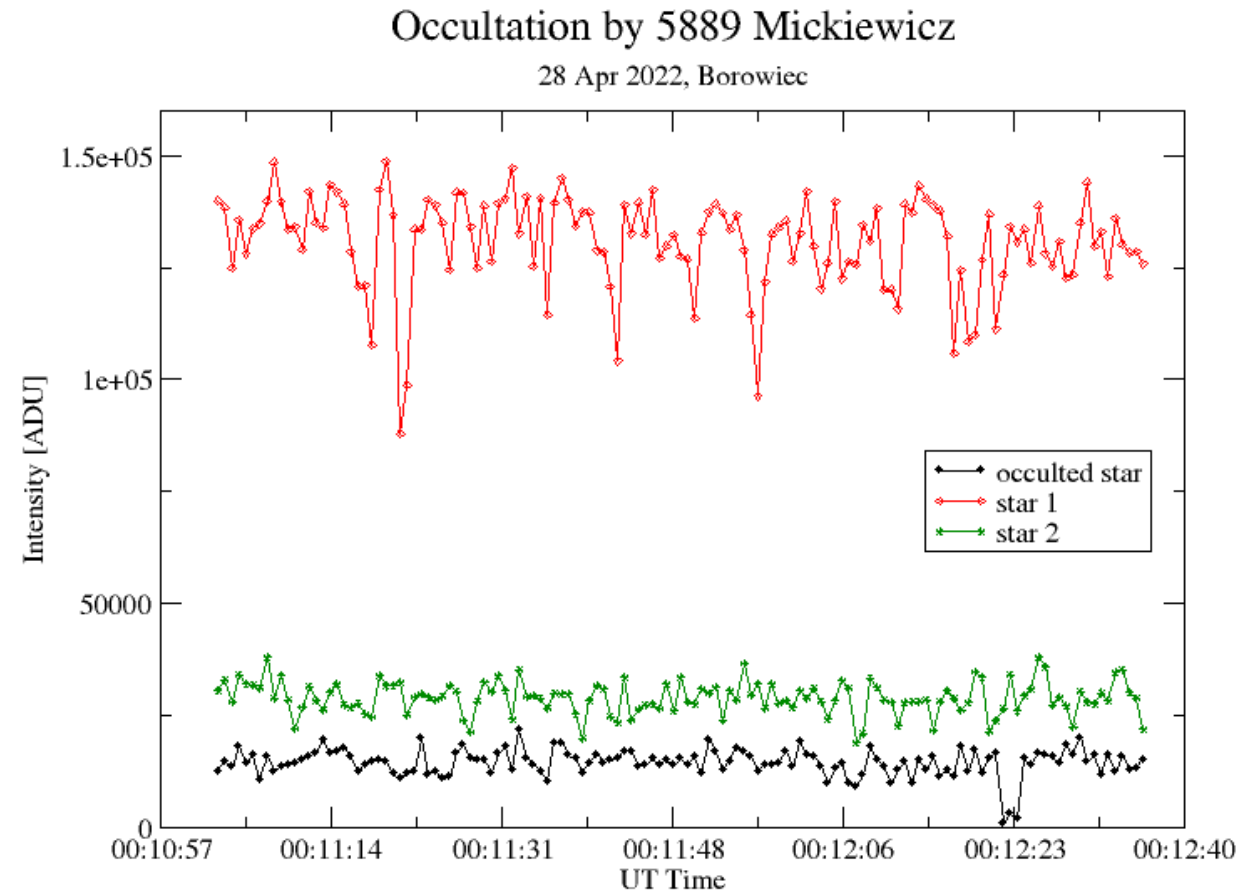
Negative observations : 5

Size	Method	Reference
108.8 ± 0.8 km (based on the shape model)	Stellar occultation	Euraster <a href="https://euraster.net/">https://euraster.net/</a>
104 km	AKARI Satellite	(Usui i inni, 2011) <a href="https://doi.org/10.1093/pasj/63.5.1117">https://doi.org/10.1093/pasj/63.5.1117</a>
110 km	WISE Satellite	(Wright i inni, 2010) <a href="https://doi.org/10.48550/arXiv.1008.0031">https://doi.org/10.48550/arXiv.1008.0031</a>



# (5889) Mickiewicz

- DATE: 28 April 2022  
ASTEROID: Mickiewicz
  - STAR: UCAC4 462-057484  
No: 5889
  - Star magnitude : 12.7
  - Minor planet magnitude : 16.4
  - Distance (km) : 24.1 km
  - Exposure time : 0.7 s
  - Predicted max. duration (secs) : 2.5
  - Predicted max. drop (mag) : 3.6
  - Predicted mid-event (UT) : 00:12:21
  - Predicted error in time (secs) : 5
  - Probability : 20.7 %
  - POSITIVE
- S - 00:11:02.12 -- 0.01  
D - 00:12:21.29 -- 0.35  
R - 00:12:23.41 -- 0.35  
E - 00:12:35.84 -- 0.01
- Duration : 2.12s +/- 0.50s
  - Mid-event : 00:12:22.35 UT +/- 0.35s



# Occultation analysis - size determination

Positive observations : 1

Negative observations : 1

Size	Method	Reference
at least 23 km	Stellar occultation	Euraster <a href="https://euraster.net/">https://euraster.net/</a>
23 km	AKARI Satellite	(Usui i inni, 2011) <a href="https://doi.org/10.1093/pasj/63.5.1117">https://doi.org/10.1093/pasj/63.5.1117</a>
26 km	WISE Satellite	(Wright i inni, 2010) <a href="https://doi.org/10.48550/arXiv.1008.0031">https://doi.org/10.48550/arXiv.1008.0031</a>

# Summary

- The presentation included the results of my own observations of several occultation phenomena. Despite the poor condition of the research equipment (faulty focusing and no tracking of the sky movement), there were seven positive and three negative results.
- Eight observations were included in the Euraster database.
- The data collected in the thesis helped to verify and scale two asteroid models ((98) lanthe, (165) Loreley), and to determine the size in two axes for the asteroid (790) Pretoria.
- Future predictions for stellar occultations by asteroids (7680) Cari and (5889) Mickiewicz were refined.
- For each of the asteroids its minimum diameter was determined. Size analysis helped to verify possible incorrectly determined diameters for the two asteroids.
- The results contained in the thesis in the future will be used for further research and publication.
- Focusing has been fixed in recent months.