

VAMORCAD - VALIDATION OF ASTEROID MODELLS BY OCCULTATION RESULTS

Results from Observation of Asteroids:

Till appr. 1900 – Position and brightness

1901: v. Oppolzer showed that (433) Eros performed brightness fluctuations of "almost one magnitude"

1906: H.N. Russell: "ON THE LIGHT-VARIATIONS OF ASTEROIDS AND SATELLITES", conclusion: not possible to get the shape

Since 1970: Taxonomie based on spectroscopy, photometry and polarimetrie, IR-flux → Albedo and calculated diameter

Since 1983(?) 2D simulation of chords → observations fitting an ellipse

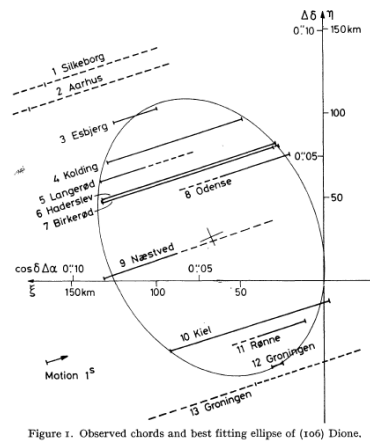
Since 1991: visits by spacecrafts → till today 17 objects

2001: M. Kaasalainen&Torppa: Optimization Methods for Asteroid Lightcurve Inversion. → Shape Determination

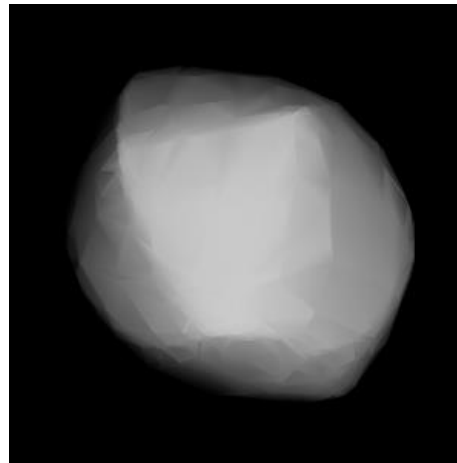
2009: J. Durech, V. Sidorin, M. Kaasalainen: DAMIT = a database of asteroid models

Since 2009: 2D simulation of chords → observations fitting a view to the model in DAMIT and similar sources

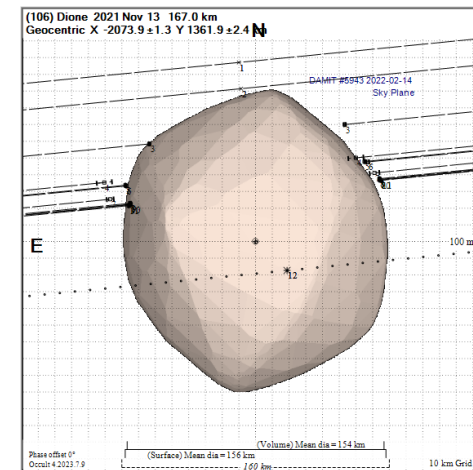
2023: spatial representation possible with VAMORCAD



AN 1983



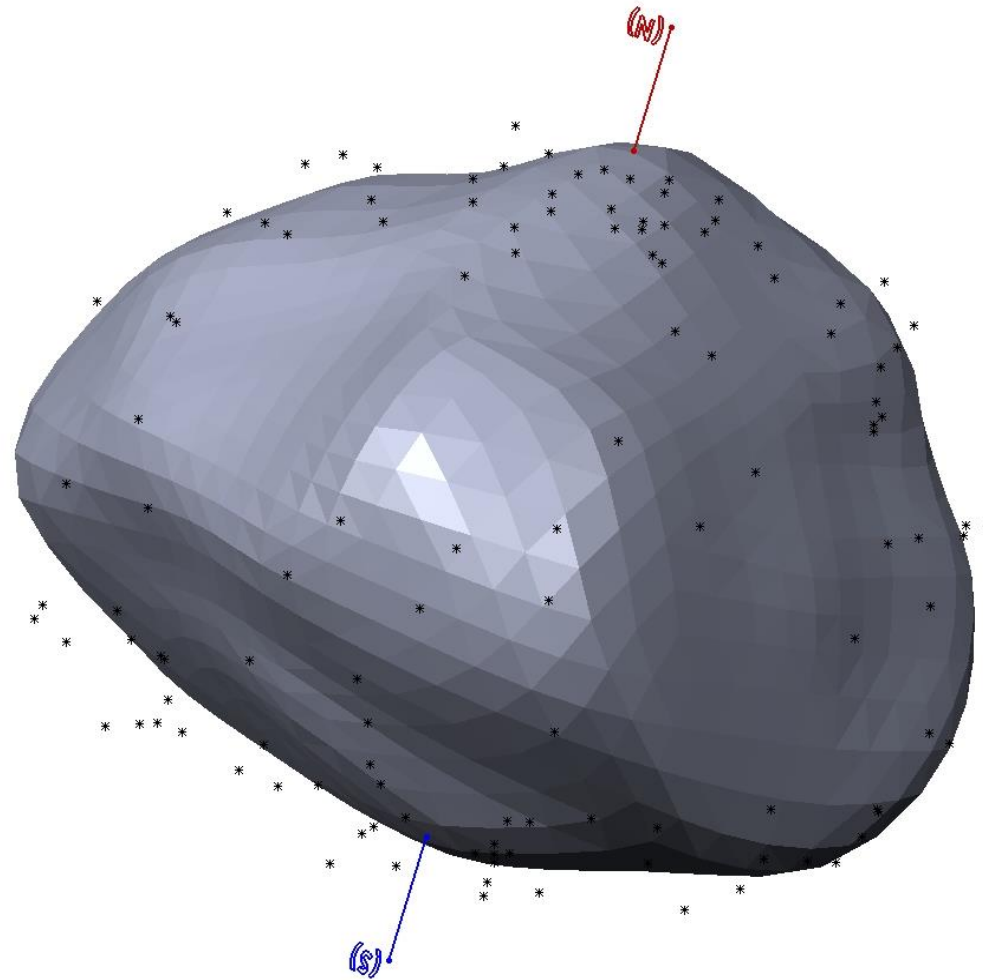
DAMIT



DAMIT + OCCULT

Spatial representation of occultation events by using 3D-models of asteroids

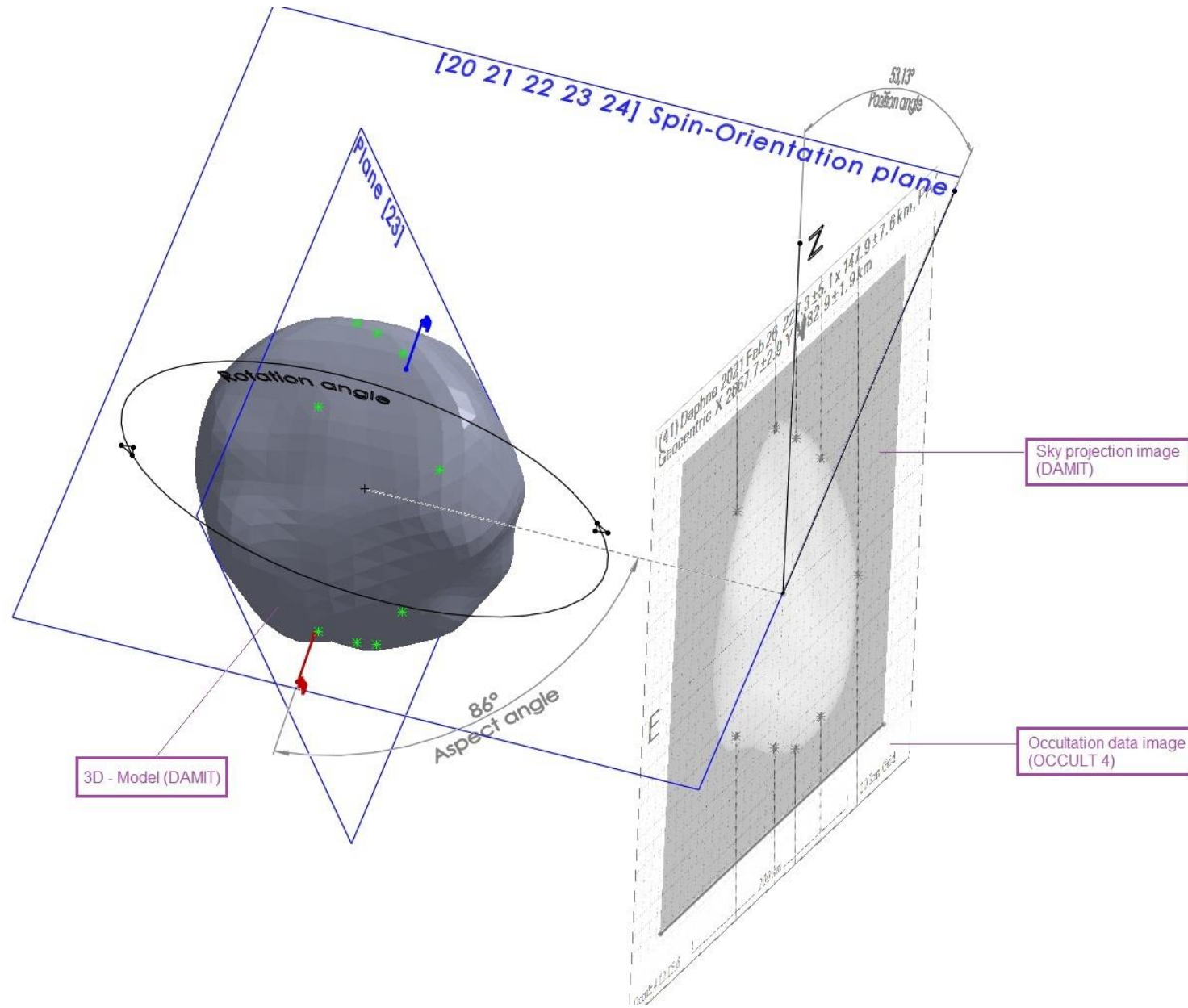
- derived from light curves measurements



(41) Daphne

Occultation events from OCCULT4-Database combined with DAMIT 3D-model 1793

(All events [24] are shown)



General view of the process structure

1. Download of occultation data images (OCCULT 4)

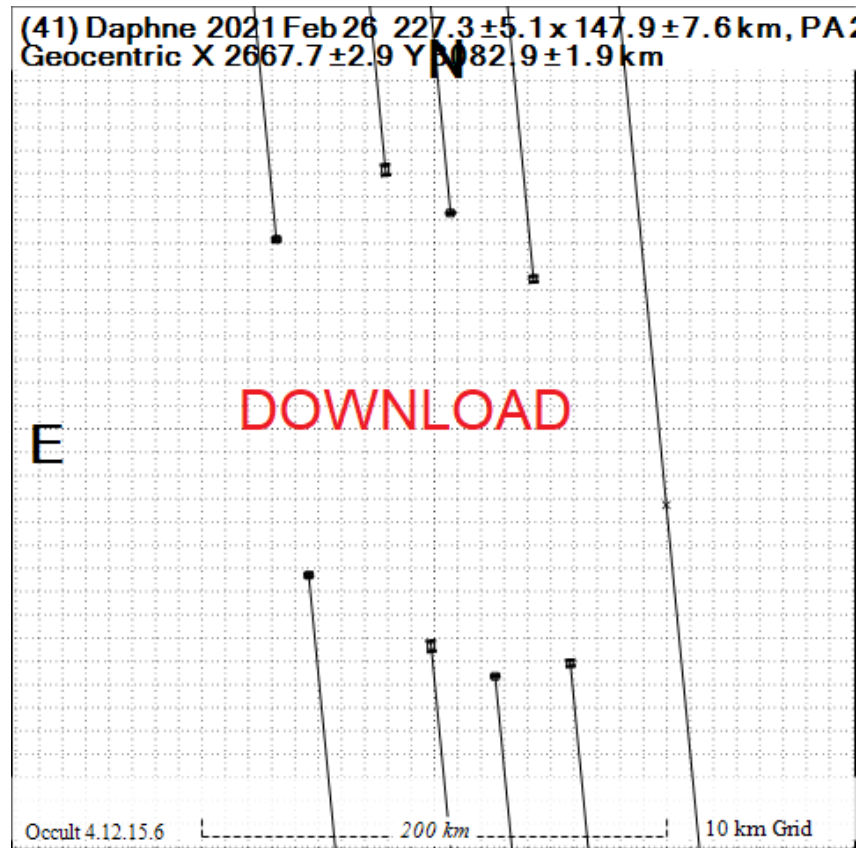
The screenshot shows two windows from the OCCULT 4 software. The left window, titled 'Minor Planet occultation observations', contains several sections: 'Add / Edit / Plot observed asteroidal occultations', 'Analysis tools' (including AOTA Asteroidal Occn Time Analyser and Star diameter analyser), 'Light curves' (Report a light curve, View light curves, Light curve simulator), 'Summary lists' (Astrometric results, Observed diameters, Shape model fits, Observed chords, Double stars, (b) Binary asteroids, (r) Ringed asteroids, (b) or (r), no main body, Events by class, Unfitted events, Large uncerts, Kepler2 stars, Observations by an observer, Statistics + Find occulted stars, Generate Graphics files for Many events, Events marked 'For review'), and 'Maintenance [for administrator use]' (List events on same-day, by same asteroid, List poor star positions, Add Kepler2 references, Process reports for: * Minor Planet Center * NASA PDS, Run data validity check on Historical file, Check specified MidT values, Observations file: Merge main file with edited, Close all Asteroid observation forms).

The right window, titled 'Reduction plots : Occult v.4.2023.5.9', shows the 'Select events for output' section with filters: by Date (2023), by Name (All), by Number (1 - 99), by Class (Amor), and options for 'Limit to Shape Models', '#Records', and 'Planets only'. Below the filters is a table of events:

Year	Month	Day	Time	Planet	Records	Planets
2008	9	27#	40	Harmonia	1	1
2009	3	22#	40	Harmonia	3	1
2011	11	21#	40	Harmonia	2	1
2017	3	9#	40	Harmonia	2	2
2017	6	1#	40	Harmonia	3	2
2018	11	17#	40	Harmonia	10	8
2021	9	27#	40	Harmonia	10	8
1997	10	31#	41	Daphne	1	1
1999	5	31#	41	Daphne	2	1
1999	7	2#	41	Daphne	39	20
2004	7	18#	41	Daphne	1	1
2004	9	4#	41	Daphne	1	1
2007	5	9#	41	Daphne	1	1
2008	4	1#	41	Daphne	3	2
2008	8	6#	41	Daphne	1	1
2012	1	9#	41	Daphne	4	1
2012	2	23#	41	Daphne	4	3
2012	3	2#	41	Daphne	5	1
2013	3	30#	41	Daphne	2	2
2013	9	5#	41	Daphne	6	4
2013	11	29#	41	Daphne	2	2
2016	1	17#	41	Daphne	19	13
2017	3	2#	41	Daphne	1	1
2020	9	25#	41	Daphne	1	1
2020	9	29#	41	Daphne	1	1
2020	12	22#	41	Daphne	5	4
2020	12	31#	41	Daphne	6	5
2021	1	1#	41	Daphne	7	5
2021	1	16#	41	Daphne	5	1
2021	2	26#	41	Daphne	5	4
2021	3	16#	41	Daphne	1	1
2022	7	20#	41	Daphne	1	1
2022	11	13#	41	Daphne	5	4
1985	3	28#	42	Isis	1	1

The right window also features a 'Generate graphic files' section with the following steps:

1. Set quality criterion
 - Include
 - Astrometry only. No reliable size
 - Limits on size, but no shape
 - Reliable size. Can fit to shape models
 - Resolution better than shape models
2. also save Astrometric solution
3. Set output directory
 - C:\Ocult4\Asteroid\Results\PDS
 - Files\2023\Graphics
4. Set file format: PNG
 - NASA PDS requires .png
5. Set image size (pixels): 480 x 480
 - 640x640 avoids text overlaying plot
6. Plot on Black background
7. Plot paths when visible
8. Plot paths in color
9. Include predicted path
10. Create PDS files + Web page
 - Uses plot settings from the plot form
 - Make sure they are set for your needs
11. Create plots



Downloaded occultation data image for event [23] (png-file 480x480), optical appearance depending on the set parameters

2. Download of sky projection images and 3D - models (DAMIT)

(<https://astro.troja.mff.cuni.cz/projects/damit/>)

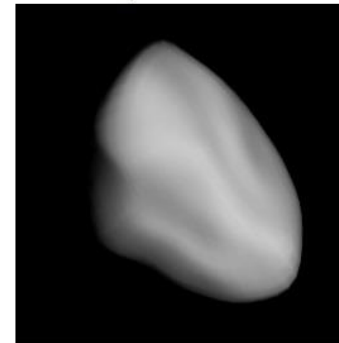
(41) Daphne – Model 1793

Details

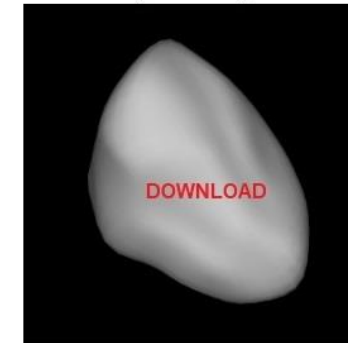
ID	1793
Asteroid	(41) Daphne
λ	200
β	-32
P	5.987981
YORP	
t_0	2444771.8
φ_0	0
Light Scattering Model	LSL
p_1	0.1
p_2	
p_3	
p_4	
p_5	
Calibrated Size	1 (Yes)
D	187
σ_D	7
Γ	
Γ_{\min}	
Γ_{\max}	
p_V	
σ_{p_V}	
γ_c	
b_c	
Quality Flag	4
Nonconvex	1 (Yes)
Version	2018-08-24
Comment	
Created	2017-05-30 08:36:22
Modified	2019-01-11 14:23:38

Sky projection

Illuminated by the Sun



Illuminated by artificial light



Projection details

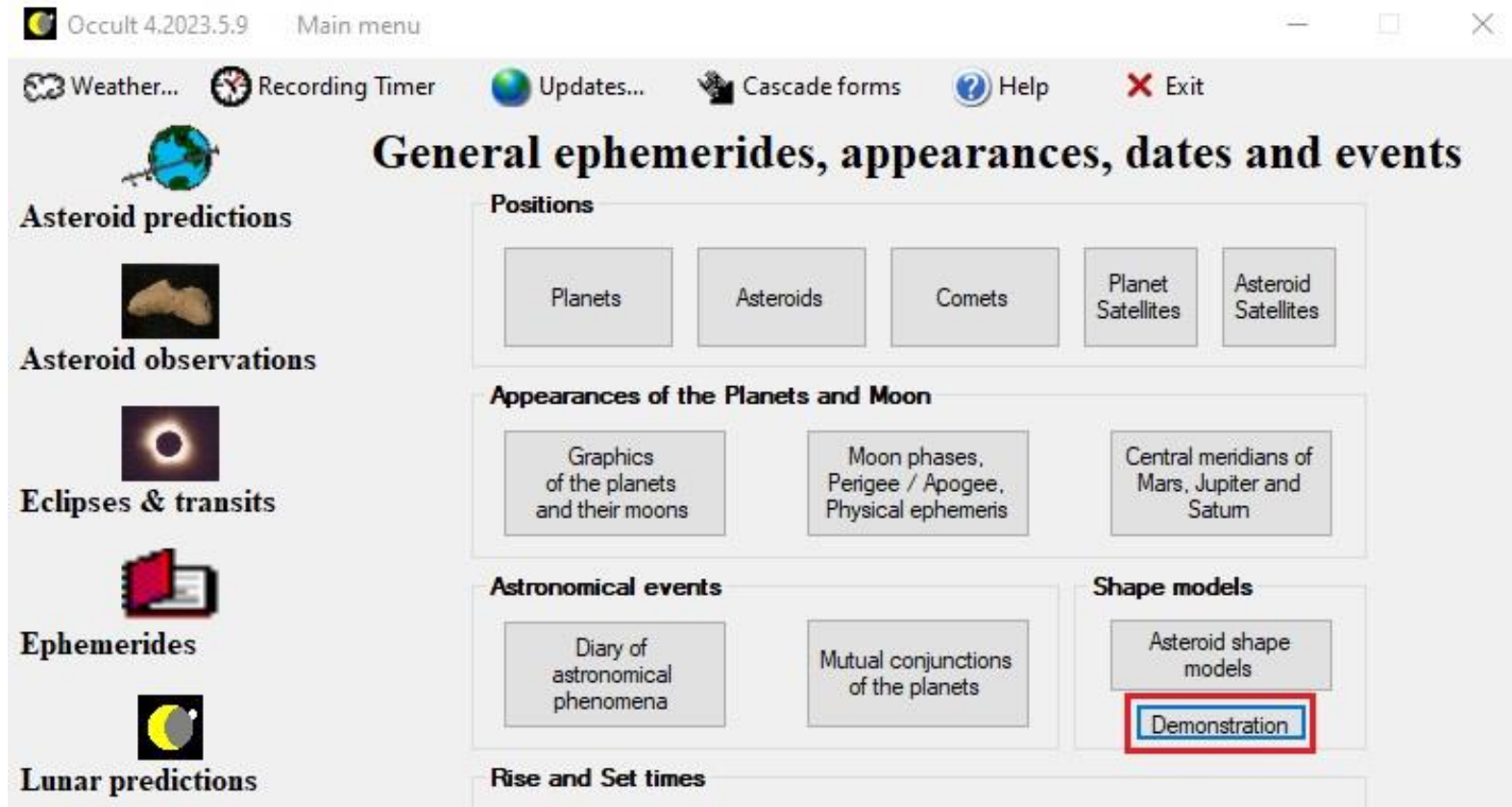
Julian Date	2459271.7229
Image size (side) (px)	300
Image size (side) (km)	286.20 (\pm 3.7%)
Image size (side) (milliarcsecond)	171.52 (\pm 3.7%)
Pixel size (km)	0.95400 (\pm 3.7%)
Pixel size (milliarcsecond)	0.57173 (\pm 3.7%)
Volume-equivalent diameter (px)	196.33
Surface-equivalent diameter (px)	202.61
Subsolar-point longitude (°)	72.7
Subsolar-point latitude (°)	-9.4
Subearth-point longitude (°)	85.6
Subearth-point latitude (°)	3.9
Phase-angle-bisector longitude (°)	79.2
Phase-angle-bisector latitude (°)	-2.8
Solar phase angle (°)	18.4

Files

AO_1.png AO_2.png AO_3.png AO_4.png AO_5.png IAUsin.txt shape.png shape.txt

Generated files: spin.txt [shape.obj](#) [DOWNLOAD \(3D - Model\)](#)

3. Determination of the angle parameters adapted to work with a 3D-Design program (CAD)



Position angle (PA) = - (180° - PA) West / (PA - 180°) East

Aspect angle (Aspect) = 90° - Alt

FUNDAMENTEL WORKFLOW - VAMORCAD

Test for for for plotting shape models obtained from the DAMIT v3 system

Form Opacity

Select asteroid

- 40
- 41
- 42
- 43
- 44
- 45
- 46
- 47
- 48
- 51
- 52
- 53
- 54
- 55
- 56
- 59
- 60
- 62
- 63
- 64
- 65
- 66
- 67
- 68
- 69
- 70
- 71

Year: 2021, Month: 2, Day: 26
JD at 12hrs = 2459272
Hour: 5, Minute: 21

Display 1-degree animation for one rotation
 Save as animated GIF

Background
 Black White LightBlue

Projection
 Sky plane Earth Plane

Include axes of rotation PA 126.8°, Alt 3.9°

Plot

Plot width (pixels) 405
... of plot width pixels

Volume-equivalent diameter 0.720 = 265.0
Surface-equivalent diameter 0.743 = 273.5

Select model
 131 -
 1793 -
 A41-1 -
 A41-2 -
 A41-3 -
 - -

Quality = 4
Version: 2018-08-24
Comment:

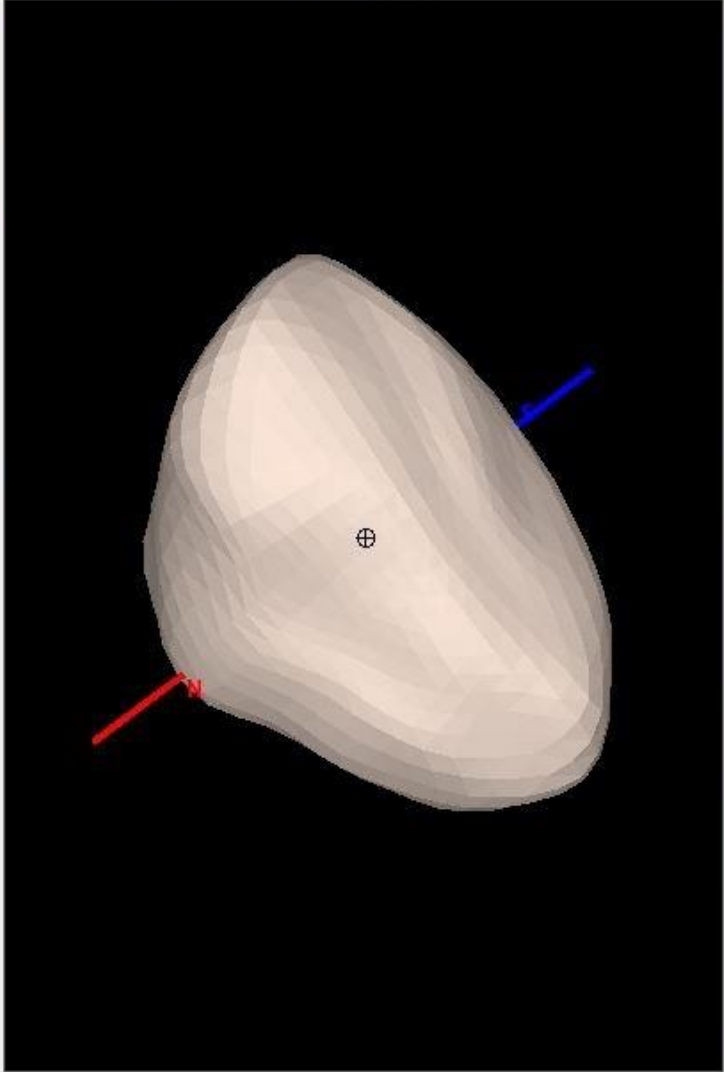
Created: 2017-05-30
Modified: 2019-01-11

300 pixels 600 pixels

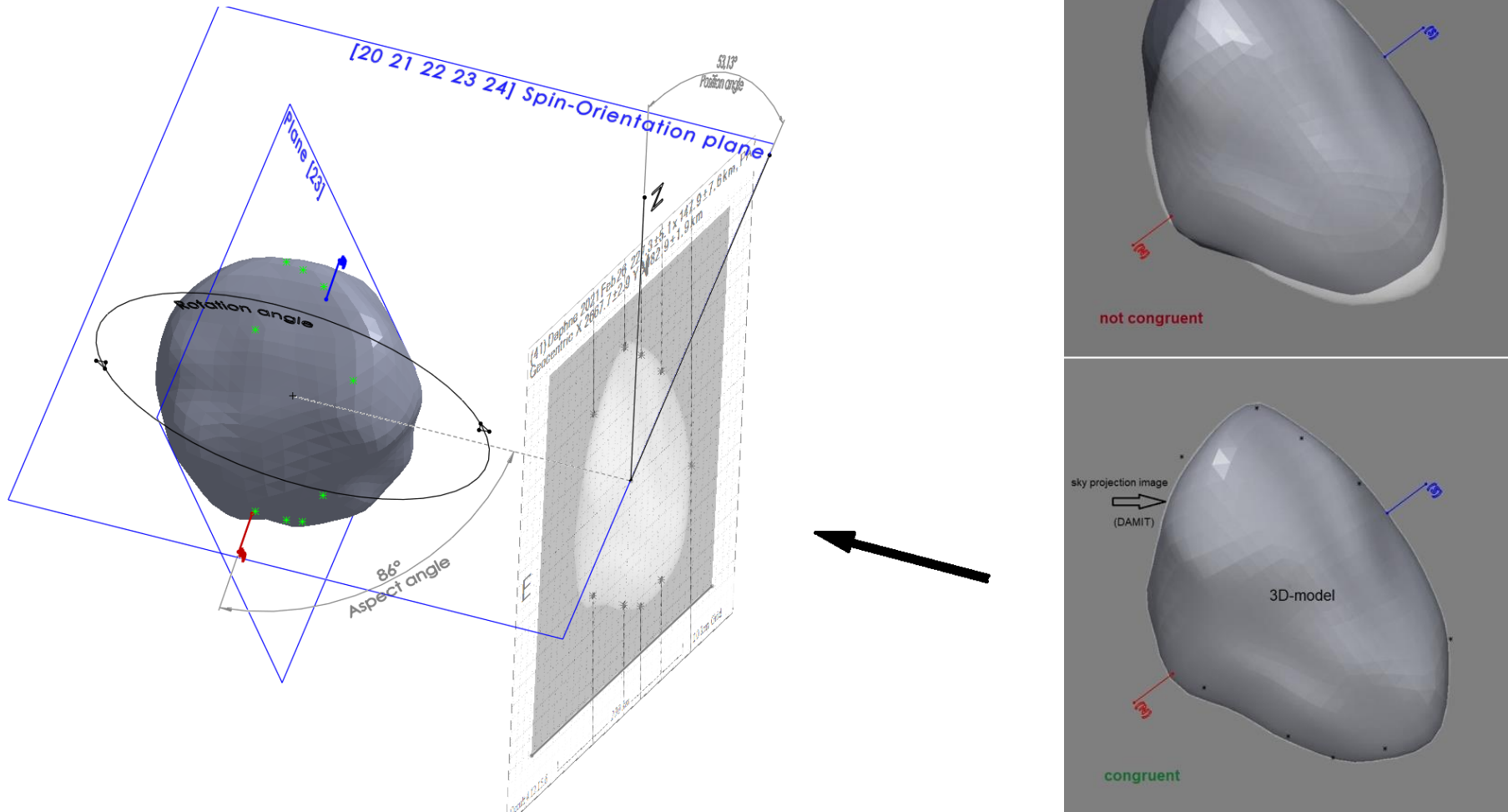
DAMIT
 V2 V3

Update list of models Download all models

Generate file of Surface/Volume ratios



4. Correct positioning and checking the 3D-model in space and transfer the occultation data into the 3D-design program (black points)

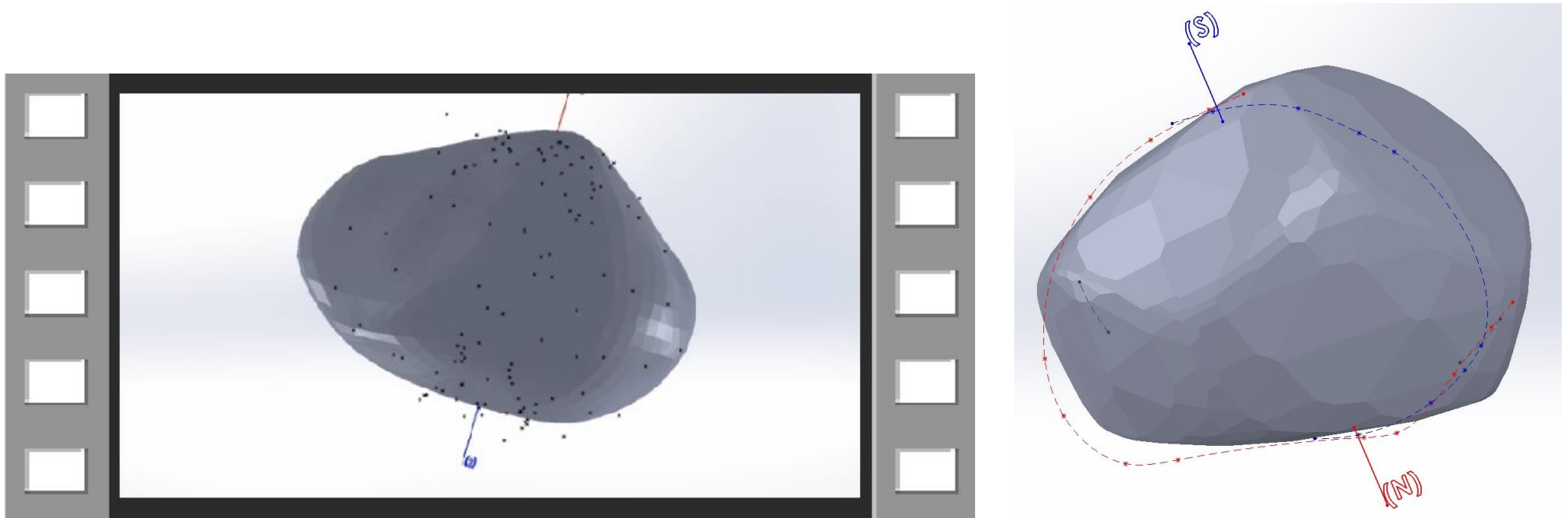


5. Projection of occultation points (green points) parallel on a central plane across the center point of the model

A. Graphical output data

After steps 1 to 5 have been done for each event, based on the functionality of the given 3D- design program, a **mp4-file** (model rotates) and **images** from any perspective can be created, for giving a complete / special overview.

[https://www.iota-es.de/vamor/\(41\) Simulation.mp4](https://www.iota-es.de/vamor/(41) Simulation.mp4)



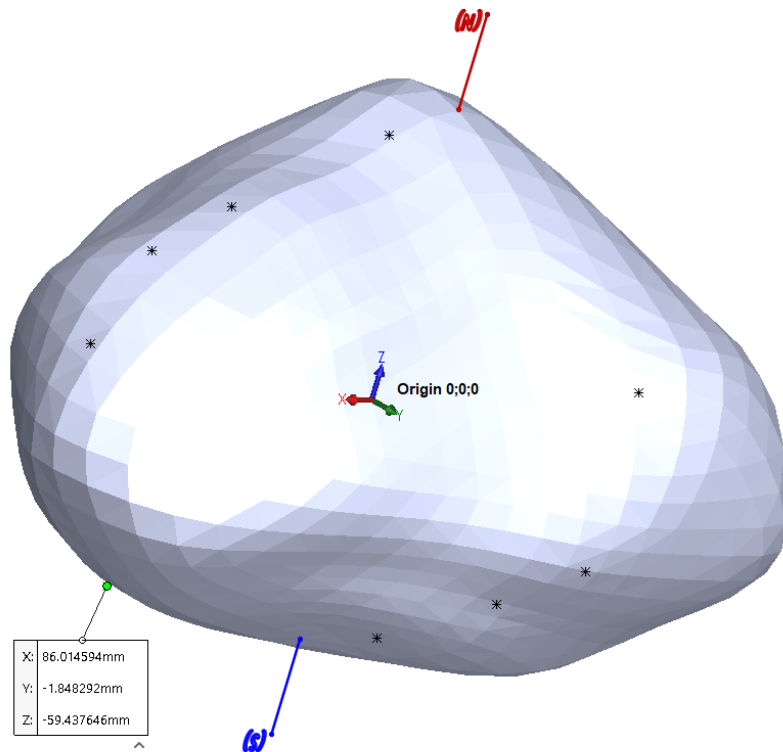
Features are:

- 3 - Dimensional representation of all / selected occultation events
- Highlighting of specific occultation events by color or/and lines (splines)

B. Numerical output data

A professional 3D-design program allows the calculation of various parameters via an embedded programming language.

X-, Y-, Z- coordinates (numerical basis)

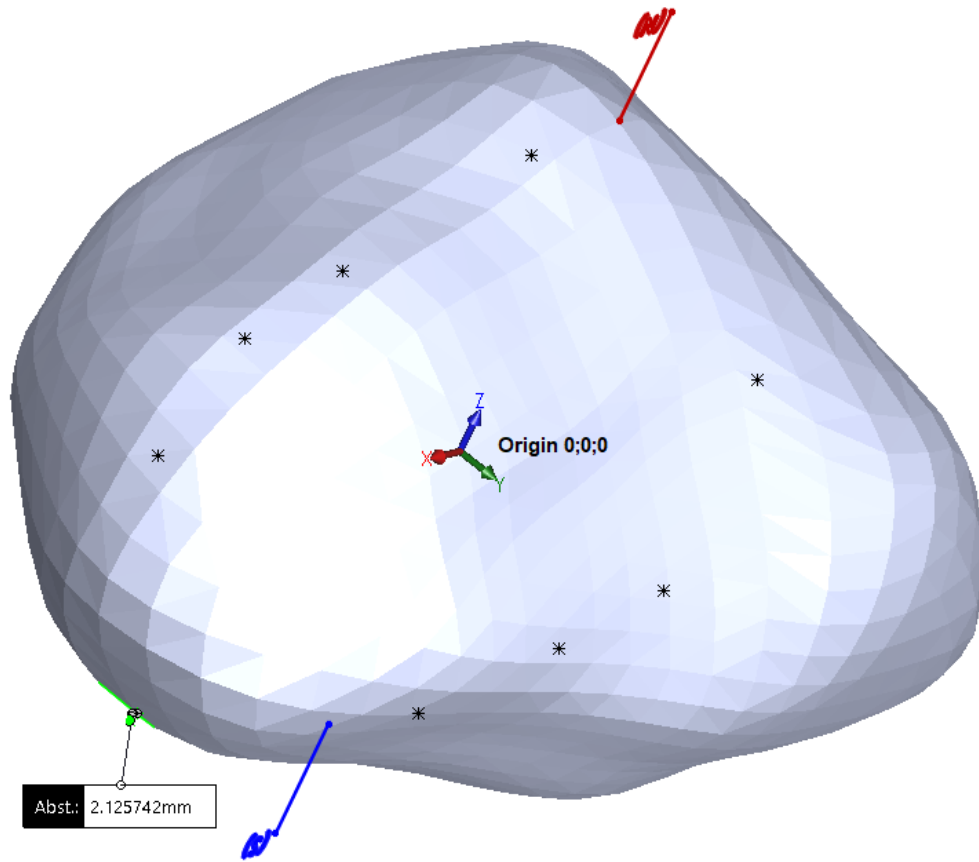


	-80.171767	-51.95379	-39.166028
	-79.425206	-50.658477	-46.39952
	-71.496528	-44.173534	-55.137239
	-61.780727	-38.343839	-46.023505
	-0.641995	8.37518	-82.625319
[22]	25.096243	-13.671377	-79.571131
	-23.783906	13.118514	79.681621
[23]	115.429171	-9.017937	13.500377
	100.399287	-9.999298	42.493565
	73.248925	-9.093863	56.661013
	18.014199	-6.873734	80.089207
	-103.854871	6.883995	5.395978
	-100.001539	10.458471	-49.440834
	-68.406833	9.022418	-60.472092
	-24.656796	6.77154	-72.004911
	86.014594	-1.848292	-59.437646
[24]	51.155329	67.845459	-16.675148
	-50.466704	-66.953868	16.603428

Coordinates for events [22], [23] and [24] (in chronological order)

Coordinates X,Y,Z of occultation points at the specified positions

Closest distances to the surface of the model and their statistical distribution



#[22] *2*	5,781255 1,959543	3,870399	4,316406
#[23] *9*	5,613474 0,204266 2,533058 5,444009 8,588125 1,463298 1,691404 1,306431 2,125742	3,218868	4,117577
#[24] *2*	1,065445 9,303801	5,184623	6,621778
#	<hr/>		
# Total:	8,798387	12,579059	
	mean values	RMS	

Calculation of the arithmetic and quadratic mean values (RMS - root mean square)

Analysis of the 3D-model

```
# (41) Daphne (1793)

# Number of vertices: 902
# Number of faces: 1800
# Number of edges: 2700
# Calculation of Euler's polyhedron theorem = 2 (when 2 then in accordance with the theorem)

# Diameter (volume-based): 187,295 km
# Diameter (surface-based): 193,289 km

-0,000073          10,775237          86,923035
10,752237          0,012047          88,737221
-0,000073          0,012047          90,591125
-0,000073          -10,927783         92,601799
-10,980663         0,012047          89,148842
14,960337          -14,230153         89,421906
```

Coordinates X,Y,Z of vertices of the 3D-model

Calculation further, possible parameters:

- Volume related diameter
- Surface related diameter

END OF THE WORKFLOW

Data maintenance:

- Creation of the first data set relatively time-consuming, but user-friendly
- Easy addition of further single and/or multiple events possible
- Adjustment of statistical calculations at any time, also possible for selected events only

Valuations for further discussions:

- Valuation of the quality of single (multiple) occultation events in terms of entire statistical distribution
- Estimation of possible and realistic changes in size and / or shape of the model under consideration of the DAMIT-quality flag and its processing status, described on <https://astro.troja.mff.cuni.cz/projects/damit/>.

Next steps:

- Collection of spatial representation for specific, selected asteroids on <https://www.iota-es.de> (updateable)
- Identification of special asteroids and definition of possible further parameters for their description in collaboration with other colleagues