

Scaling slowly rotating asteroids by stellar occultations

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ABSTRACT

Context. As evidenced by recent survey results, majority of asteroids are slow rotators (have spin periods longer than 12 hours), but lack spin and shape models due to selection bias. This is skewing the big picture of asteroids spins, shapes, sizes and other properties. Also, diameter determinations for large (>60km) and medium-sized asteroids (between 30 and 60 km) often vary by over 30% for multiple reasons.

Aims. Our long-term project targets a few tens of slow rotators with periods up to 60 hours, to obtain their full lightcurves and reconstruct their spins and shapes. We also precisely scale the models, typically with a few percent accuracy.

Methods. Wide sets of dense lightcurves serve for spin and shape reconstructions via lightcurve inversion. Precise scaling them with thermal data was not possible here due to poor infrared datasets: large bodies tend to saturate in WISE mission detectors. So recently we also launched a special campaign among stellar occultation observers, to put these models into scale this way, and also to verify the shape solutions, often allowing to break the mirror-pole ambiguity.

Results. Presented scheme resulted in shape models for 16 slow rotators, most of them for the first time. Fitting them to chords from stellar occultation timings resolved previous inconsistencies in size determinations. For around half of the targets this fitting also allowed **to identify clearly preferred pole solutions out of the pair of two mirror pole solutions**, thus removing the ambiguity inherent to lightcurve inversion. **The influence of uncertainty of the shape models on the derived diameters is also addressed.**

Conclusions. Overall, our project already provided reliable models for around 50 slow rotators. Such well determined and scaled asteroid shapes will e.g. constitute a solid basis for precise density determinations, when coupled with mass information. Spin and shape models in general keep filling the gap caused by various biases.

Key words. minor planets: asteroids – techniques: photometric – occultations

1. Introduction

One of the ultimate aims in asteroid research are density determinations, that would allow to study their internal structure (micro-

and macroporosity), and mineralogical composition to link meteorites with their parent bodies. Asteroids larger than 100 km in diameter are considered primitive, largely intact bodies since their formation (Morbideilli et al. 2009), while smaller ones are seen as remnants of collisional disruptions and reaccumulations, with substantial macroporosity (Carry 2012).

Asteroid sizes, a necessary prerequisite to derive conclusions on internal structure and density where mass is available, are not easy to determine. Possibly best size determinations are of vital importance, as their relative error is tripled in density determinations, while to clearly distinguish various mineralogies of asteroid interiors, the density needs to be known with 20% precision (Carry 2012). In the majority of cases asteroid sizes are calculated from known value of absolute magnitude, and an assumed geometric albedo (Harris & Harris 1997), what leads to large uncertainties in the derived diameter, at the level of 20-30% for main belt asteroids, reaching over 50% in some cases (Tanga et al. 2013)¹. The solution is to use infrared measurements: in the visible light a small target with highly reflective surface is equally bright as a large target with dark surface. However in the infrared light they look substantially different. Visually dark object, due to smaller albedo, absorbs most of the solar radiation, and gets warmer than its visually brighter counterpart (Harris & Lagerros 2002). So thermal data combined with absolute brightness in the visible light enable to put tight constraints on the object size reducing its uncertainty to 5 - 10%, typically (Delbo' et al. 2015), but only if spin and shape model is available. Without a model the accuracy of this method is greatly reduced. Also, this method is only limited to objects with rich thermal datasets from multiple space observatories. For example, large objects, around 100 km in diameter tend to be saturated in W3 and/or W4 bands (11.1 and 22.64 μm respectively) of the WISE mission (Wright et al. 2010), so data from WISE cannot be used in their thermophysical modelling (Delbo' et al. 2015). Diameters of these targets must thus be determined with other methods.

Somehow complementary method that allows to image large asteroid surfaces, and determine their shapes and sizes, is the high resolution imaging with the state of the art adaptive optics systems used with modern deconvolution techniques. Recent large programme at VLT using SPHERE/ZIMPOL instrument provided detailed shapes and accurate sizes for around 40 main-belt asteroids representing all main taxonomic classes (see e.g. Vernazza et al. 2021). This technique, although spectacular, is limited to the relatively nearby and large asteroids though.

Another powerful technique to measure asteroid sizes practically irrelevant of their size or distance are stellar occultation timings (Herald et al. 2020). Asteroids in their on-sky paths sometimes cross background stars, casting a shadow on the Earth surface. Observations of these rare events from a few separate sites within the predicted shadow path, thanks to precise timings, enable almost direct asteroid size measurements in kilometers, additionally outlining the target silhouette at the time of the occultation, verifying the shape models (Durech et al. 2011). Sometimes such events lead to discoveries of asteroid satellites or rings (Gault et al. 2022; Ortiz et al. 2017), enabling the mass to be determined. An important advantage of this technique, is the possibility to break the symmetry between two mirror pole solutions, inherent to photometric lightcurve inversions of asteroids orbiting close to the ecliptic plane (Kaasalainen & Lamberg 2006).

A desired situation would be to have at least three occultation chords for each event (Durech et al. 2011). Thus a necessity for a dense network of ground based observatories, like the network built within the Lucky Star project², RECON network (Buie & Keller 2016), or wide and well organised regional networks of International Occultation Timing Association³. With Gaia catalogues available (Gaia Collaboration et al. 2021), the accuracy of occultation predictions has substantially improved (Tanga et al. 2022), and is expected to improve even more with the release of full Gaia catalogue. So now is the unique time, when both stellar positions and asteroid orbits are known with unprecedented accuracy, for most reliable occultation predictions. **In the perspective of decades** both quantities will start to deteriorate, due to uncertainties in stellar proper motions, and perturbations of asteroid orbits.

Great majority of asteroid shape models being published today are scale-free, approximate shape representations, because the focus is mainly on determining their spin parameters (see e.g. Hanuš et al. 2018; Durech et al. 2020). Such shape models, due to their angular appearance with sharp edges and large planar areas tend to be problematic in further applications like thermophysical modelling, or fitting their silhouettes to stellar occultations (Hanus et al. 2016), main outcome of both being diameter determinations.

In parallel, the targets on which most of such studies have been focused, are highly nonrepresentative for various populations of main belt asteroids (Marciniak et al. 2015). Most of spin and shape asteroid models available today are for relatively quickly rotating targets, while e.g. the TESS mission has revealed that slow rotators (bodies rotating with periods longer than 12 hours), strongly dominate in all asteroid populations at various sizes (**making around 5700 objects out of 9900, in the TESS DR1 sample**⁴, (Pál et al. 2020)).

Motivated by the trends described above, our survey (see e.g. Marciniak et al. 2018) aims at reconstructing precise spin and three dimensional shape models of challenging, slowly rotating asteroids, followed by determining their sizes with the best available methods (thermophysical modelling, and/or stellar occultation fitting). It has resulted in the most accurate shape models and size values of over 30 of these targets to date (Marciniak et al. 2021). In this work we present another set of 16 slow rotators, most of which have been previously lacking shape models or even good lightcurves. Unlike our previous targets (published in Marciniak et al. 2018, 2019, 2021), the current set could not be reliably scaled using thermal data due to poor infrared datasets existing for them, so here we focus on scaling them by stellar occultations.

Section 2 describes our two observing campaigns targeted at these bodies, one to obtain their lightcurves in multiple apparitions, and another to observe them in stellar occultations. Sections 3 and 4 present the methods used for shape reconstruction and to fit the models to stellar occultation chords. Next, section 5 contains asteroid spin and shape models, verified and put to scale by occultation fitting, which in many cases enabled **to identify a preferred pole solution**. The last section summarises the work and presents future plans, with possible applications of our results.

² <http://lesia.obspm.fr/lucky-star/>

³ <https://occultations.org/>

⁴ <https://archive.konkoly.hu/pub/tssys/dr1/>

¹ <https://mp3c.oca.eu/>

2. Observing campaigns

2.1. Photometric campaign for dense lightcurves

Our wide photometric campaign, described in detail in Marciniak et al. (2015), has been triggered by the fact of very bad representation of main belt asteroid population as a whole by their available spin and shape models. Asteroids relatively easy to be modelled had their models constructed, while others have been left behind. Thus we focused on asteroids with long periods and low amplitudes, to counterbalance this unequal distribution. In the meantime slow rotators proved to be important targets also in the light of thermal studies, as it has been speculated they might allow to study deeper surface regolith layers (see Harris & Drube 2016, 2020; Marciniak et al. 2021, for the discussion). Finally, as evident from the results from Kepler (Molnár et al. 2018; Kalup et al. 2021) and confirmed by TESS missions (Pál et al. 2020) the main focus in asteroid physical studies should be on slow rotators.

The lightcurve campaign for slow rotators relies on wide network of small telescopes, up to 1-m in diameter, with good geographic distribution, and an efficient coordination (Table A.1 in the Appendix presents the observing runs, sites, and participating observers). This way even targets with rotation periods reaching 60 hours had their lightcurves fully covered in reasonable time. Data collection took a long time, partly because of long periods of our targets, but also due to paucity of previous data, thus a necessity to observe each target in five or more apparitions, what finally enables obtaining their unique spin and shape models using convex inversion method by Kaasalainen et al. (2001). Where possible, our lightcurves have been supplemented with data from Kepler and TESS missions, and from previous ground-based observations resulting in dense lightcurves (see Table A.1 in the Appendix for references), mostly through ALCDEF database⁵.

2.2. Stellar occultation campaign

In October 2020 we launched an auxiliary campaign for slow rotators. Although some of them have been previously observed in stellar occultations, the results were mostly single positive chord observations, not usable for precise scaling (Herald et al. 2019). Therefore in cooperation with the European Section of International Occultation Timing Association (IOTA/ES) we started an occultation campaign for “Neglected Asteroids”⁶. Later this campaign gained its separate tag in the Occult Watcher Cloud⁷, a tool widely used for occultation planning and coordination. The aim has been to register multichord stellar occultations for slow rotators from our target list. In contrast to the lightcurve campaign, where hundreds of hours on-target are needed, occultation events require only one or two minute observations, as they last only a few seconds. A good coordination and timing are even more important than in the other campaign though. The occultation predictions have been made using JPL Horizons database for asteroid orbits⁸, and Gaia EDR3⁹ for star positions. Although these events are rare, the campaign already resulted in a dozen or so successfully observed occultations, with the number of positive chords per event reaching nine (see e.g. the events from the years 2021 and 2022 in Figures 11 and 19).

Archival occultation data have been downloaded from Planetary Data System (PDS) archive¹⁰ (Herald et al. 2019), and more recent ones were obtained from the archive of the Occult programme¹¹, or directly from the regional IOTA coordinators, who do data evaluation and vetting, ascertaining good quality and consistency of occultation results. Most of the occultation observers are amateur astronomers, what makes the campaign an example of a successful pro-am collaboration. Table A.2 in the Appendix contains observer names and site locations for each occultation event used here.

3. Convex inversion with shape regularization

Majority of asteroid models presented in this work have been constructed using common convex inversion method of Kaasalainen & Torppa (2001); Kaasalainen et al. (2001). When lightcurve data are abundant to uniquely determine the sidereal rotation period and the pole direction, the shape model reconstructed from the Gaussian image is usually such that its rotation axis z is very close to the principal axis of the inertia tensor with the largest moment of inertia. Shapes that fit the data but strongly violate this condition have to be rejected as physically unacceptable solutions of the inverse problem. In some cases, however, the data are so abundant, that it is clear that the solution is correct, but the shape is not physically acceptable. By “squeezing” the shape along the rotation axis, the inertia tensor can be changed in such way that its greatest axis is close to the rotation axis. However, this can be done only after the best-fit model is found and it has to be checked if this shrinking along the rotation axis does not affect the lightcurve fit significantly.

When working with the Gaussian image during the optimization, the shape is not known and we cannot regularize it to have maximum moment of inertia around the rotation axis. However, even without computing the inertia tensor exactly, the shapes that are not rotating along the shortest axis are elongated along the z axis. This elongation means that the cross-section viewed from the pole direction is smaller than that from the equatorial view (xy plane). Although the 3D shape is not available during optimization, the areas of surface facets and their normals are known, so their projections can be computed. So the regularization term R that we introduced was

$$R = \frac{\sum_{i=1}^N \sigma_i (|\hat{n}_i \cdot \hat{x}| + |\hat{n}_i \cdot \hat{y}|)}{2 \sum_{i=1}^N \sigma_i |\hat{n}_i \cdot \hat{z}|}, \quad (1)$$

where $\hat{n}_i$ are unit normals to surface elements of areas σ_i , and $\hat{x}, \hat{y}, \hat{z}$ are unit vectors of along the coordinate axes, the summation is over all N surface elements. The more extended the shape is along the z axis, the higher is R , so the penalty function that was added to the χ^2 was R^2 times some weight w . By increasing w , the shape model is forced to have projected areas along the x and y axes smaller than along the z axis, which makes it more oblate and ensures physically correct rotation. This way, we were able to produce physically realistic shapes for (439) Ohio and (566) Stereoskopia, for which the standard lightcurve inversion without regularization led to unphysical shapes. With regularization, the fit to the data remained **practically** the same (**RMS changed from 0.0073 to 0.0074 for the example shown in Fig. 1**), meaning that the dimension along the rotation axis was not

⁵ <https://alcdef.org>

⁶ https://www.iota-es.de/neglected_asteroids.html

⁷ <https://cloud.occultwatcher.net/>

⁸ <https://ssd.jpl.nasa.gov/horizons/>

⁹ <https://www.cosmos.esa.int/web/gaia/earlydr3>

¹⁰ <http://sbn.psi.edu/pds/resource/occ.html>

¹¹ <http://www.lunar-occultations.com/iota/occult4.htm>

constrained by the data, and the regularization helped to produce realistic shapes without affecting the fit. A “negative regularization” mentioned in the next section means using the regularization term $1/R^2$ which produces more stretched shapes when needed.

4. Occultation fitting

As mentioned in Sect. 1, shape models derived from photometry do not carry information about the size; they are scale-free. We scaled them using the same approach as Ďurech et al. (2011) and recently Marciniak et al. (2021). Positions of observers detecting an occultation were projected on the fundamental plane, which is the plane crossing the geocenter and being perpendicular to the direction from the asteroid to the star. Then we computed the orientation of the shape model for the mean time of occultation and projected it also to the fundamental plane. Because the time span of occultation timings is usually much shorter than the asteroid’s rotation period, the rotation is neglected, and the silhouette is assumed to be constant. The size of the asteroid and the relative position of its projection on the fundamental plane with respect to chords are three parameters optimized to converge to the best agreement between the asteroid’s projection and occultation chords. The goodness of fit is described by standard χ^2 measure with timing uncertainties taken into account.

The uncertainty of the derived size is affected by many aspects: the number of occultation events, the number of chords in individual occultations and their distribution across the silhouette, timing errors of individual chords, and the uncertainty of the asteroid’s projection (thus the uncertainty in asteroid’s shape and spin state). When there are several occultations by one asteroid with many chords covering the whole projected disk, the RMS (root mean square) residual in kilometers is **some** estimation of the size uncertainty (see the last column in Table 1).

However the uncertainty in size of the asteroids determined this way does not take into account the uncertainty of the models themselves. The main problem is that relative lightcurves supporting the models are largely insensitive to a vertical stretch of flattening the models, as the ratio between biggest and smallest projected area in a given aspect remains similar regardless this dimension. To tackle this problem, we used the ability of inertia regularization to influence the vertical stretch of the derived models. We created ten versions of each model, with both positive and negative regularizations, creating flatter and rounder shapes, that would still fit the lightcurves similarly well as the nominal solution, and at the same time remained physical (rotating around the shortest axis), and realistic (e.g. not being extremely thin). Models fitting the lightcurves within 10% RMS of the best fit solution are accepted, following Kaasalainen et al. (2001). With tens of lightcurves and thousands of photometric points, the 10% increase in RMS is really an extreme limit and upper boundary for “acceptable” models, as the example in Fig. 2 shows. The upper model is the nominal one, without inertia regularisation, while the bottom one was created with relatively high regularisation. The other model fitted the lightcurves within 7% of the best solution (RMS of 0.0117 vs. 0.0110 for the best fit) and is already unrealistically flattened. Another approach relates the χ^2 limit to the number of data points (see e.g. Hanuš et al. 2021; Ďurech et al. 2022, Appendix A).

Those variations of each model have been fitted to occultations too, resulting in a pool of plausible sizes. It also revealed the shape versions fitting the occultations with sub-

stantially higher RMS, or not fitting some chords at all. In some cases it strengthened the case for preference between two pole solutions, where all the versions of shape for one pole resulted in a similar value for the size and consistently small RMS of the fit, while for the other pole the sizes varied substantially, and the RMS was high. Such cases are described in more detail in the next section.

The key point here was to check whether the range of sizes derived this way would be higher or smaller than the nominal RMS of the occultation fit, which is ruled mainly by the occultation timing uncertainties. When it was higher, it replaced the nominal RMS value as a measure of diameter uncertainty in Table 1. However when the range of sizes was smaller than the RMS of the fit, it meant that the uncertainty here was dominated by the occultation timing errors or the convex approximation of the shape.

5. Results

Rich datasets of dense lightcurves from our campaign (see Figures B.1-B.77 in the Appendix 1) have been used for spin and shape modelling with the classical lightcurve inversion method or its slight variation with shape regularization, to make problematic models rotate in a physical manner, around the axis of largest inertia (see Section 3). Table 1 summarises spin parameters and diameters determined in this work. The fit of the shape models to occultation chords can be seen in Figures 3 - 22. Good fit has manifold benefits: primarily it serves for scaling the models in kilometers, but it also verifies the shape features, and often clearly points to the solution that must be close to the real one, **making its mirror counterpart less probable**. We should note, that the asteroid sizes determined here are diameters of volume-equivalent spheres, while sizes determined from infrared measurements are for surface-equivalent spheres. However the difference between the two diameters for the same shape model is at the level of 5% or less, which is smaller than the uncertainty of the models themselves, especially with NEATM spherical shape approximation. Thus it is justified to directly compare sizes determined with both methods, without any scaling factors.

In parallel, in a few justified cases (275 Sapiientia, 464 Megaira, 530 Turandot) where the occultation results hinted the presence of nonconvex shape features, we additionally used ADAM method (All-Data Asteroid Modelling, Viikinkoski et al. 2015) for shape reconstruction. This technique uses both lightcurves and occultation timings as input data in a single optimisation process. The results are presented in Figures 5, 6, 13, and 17 and in Table 1. They can be compared with the respective shape models constructed with traditional convex inversion without occultations, but fitted to them later (Figures 4, 12, and 16). Determined sizes and spin parameters are consistent between the two methods, while ADAM shapes slightly better fit the occultations, as expected. **The size uncertainties for ADAM shape models presented in Table 1 come from the scatter of solutions and are clearly underestimated.**

For each model Table 1 presents the spin axis ecliptic coordinates, with the sidereal period of rotation, together with the uncertainties of each parameter. It also contains the details on lightcurve datasets, and the volume-equivalent diameters with uncertainties based on the deviation of the shape models silhouettes from the occultation chord ends, **or on the scatter of sizes for various versions of the same shape, whichever source dominated the error budget**. Pole solutions that are preferred ones after the occultation fitting are marked with boldface. In Figures 3 - 22 the **less preferred** solutions are marked as dashed

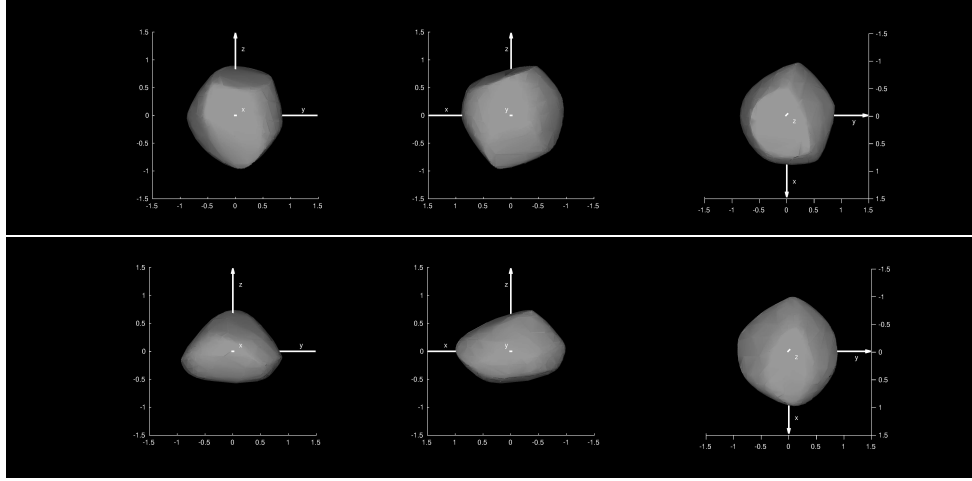


Fig. 1: Two versions of shape model 2 for (566) Stereoskopia: without shape regularization (top) and with regularization applied (bottom), using the same starting parameters otherwise. The three views show, from left to right: two equatorial views 90° apart in phase, and the pole-on view (rightmost one). Note that the pole-on silhouettes generally agree between two versions of the shape model, as it is the equatorial cross-section that effectively influences the lightcurves most.

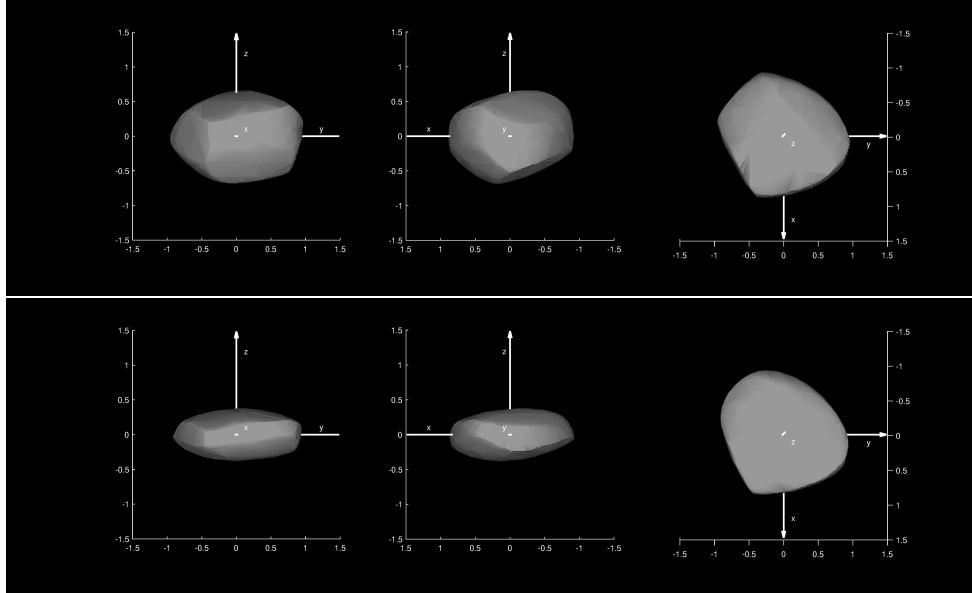


Fig. 2: Two versions of shape model 2 for (412) Elisabetha. High regularisation model (bottom) still fits the lightcurves on formally acceptable level, but is unrealistically flat. See Section 4 for discussion.

magenta contours, as opposed to solid blue contours of the **preferred** solutions. In the case of **only** slightly preferred solutions both contours are solid lines, just the preferred solution is shown in blue. **In some cases the preference seems to be based on single chords, but it is rather the duration, than absolute position that decided. The duration of the occultation events are usually recorded correctly, while the gross timing error might shift the whole chord, but not change its length. There are of course exceptions to this rule, see the discussion on (275) Sapientia in Section 5.** The cases with no preference for the spin solution are also shown with solid contours of two colours, see the text and figure captions for details.

Additionally, Table 2 contains the range of previously determined sizes, with the source references. Please note, how diverse some literature diameters are, differing by **even 50%** for some targets according to various works. Below we describe all targets in more detail.

5.1. (70) Panopaea

Our result for spin and shape of Panopaea (see Table 1) closely agrees with the one recently published by Hanuš et al. (2021). There existed three multichord occultations for Panopaea, one of them with particularly rich set of 13 positive chords (see Figure 3). However, many of them were visual observations, and also the chords had unrealistically small error bars. All errors have been changed here to 0.05 seconds for photoelectric and video observations, and to 0.5 second in case of visual observations. Both shape solutions are consistent with the occultations, resulting in size determination of 128 km with very small uncertainty **of a few percent** (Table 1). Previous literature diameter determinations for Panopaea varied widely from 105 km to 163 km (Table 2), basing mostly on NEATM model (Harris 1998), that approximates the body shape with a sphere.

Table 1: Spin parameters and sizes of asteroid models obtained in this work. The columns contain asteroid name, J2000 ecliptic coordinates λ_p , β_p of the spin axis solution, and the sidereal rotation period P , with mirror pole solution in the second row. Next follow the main characteristics of the lightcurve dataset (same for both pole solutions): observing span in calendar years, number of apparitions (N_{app}) and number of lightcurves (N_{lc}). Last two columns give volume-equivalent **diameter** D and its RMS residual from the stellar occultations fitting. Boldface highlights the solution preferred by means of occultation fits. See Section 4 for the discussion on diameter uncertainties

Asteroid	λ_p [°]	Pole β_p [°]	P [hours]	Observing span (yr)	N_{app}	N_{lc}	D [km]	D RMS [km]
(70) Panopaea	42 ± 5	$+27 \pm 3$	15.80440 ± 0.00002	1980 – 2019	7	122	128 ± 7	7
	240 ± 6	$+26 \pm 4$	15.80439 ± 0.00001				128^{+7}_{-11}	7
(275) Sapiientia	85 ± 11	-10 ± 18	14.93045 ± 0.00005	1998 – 2018	7	38	98^{+6}_{-11}	6
	264 ± 4	-1 ± 20	14.93045 ± 0.00005				103^{+6}_{-7}	6
(275) Sapiientia (ADAM)	82 ± 8	-11 ± 17	14.93044 ± 0.00005	1998 – 2018	7	38	100 ± 1	-
	260 ± 7	-2 ± 20	14.93044 ± 0.00005				100 ± 1	-
(286) Iclea	31 ± 5	$+13 \pm 4$	15.36120 ± 0.00004	2002 – 2019	9	52	86^{+13}_{-7}	2
	196 ± 5	$+44 \pm 7$	15.36114 ± 0.0007				69^{+3}_{-12}	3
(326) Tamara	79 ± 1	-3 ± 3	14.46130 ± 0.0005	1981 – 2019	9	69	77^{+5}_{-10}	5
	242 ± 1	-36 ± 3	14.46136 ± 0.0004				81 ± 9	9
(412) Elisabetha	3 ± 20	$+17 \pm 7$	19.65610 ± 0.00003	1990 – 2021	7	77	119 ± 9	9
	191 ± 23	$+52 \pm 8$	19.65618 ± 0.00004				97^{+7}_{-14}	4
(426) Hippo	62 ± 55	-49 ± 20	67.5038 ± 0.0005	1993 – 2021	7	103	129^{+19}_{-8}	6
	223 ± 80	-89 ± 17	67.5041 ± 0.0005				122 ± 4	4
(439) Ohio	308 ± 50	-61 ± 7	37.46726 ± 0.00005	1984 – 2022	10	66	74^{+3}_{-8}	2
(464) Megaira	47 ± 2	$+16 \pm 5$	12.878572 ± 0.000002	1979 – 2020	9	85	76^{+3}_{-6}	3
	236 ± 5	$+38 \pm 10$	12.878572 ± 0.000002				76^{+2}_{-11}	2
(464) Megaira (ADAM)	45 ± 3	$+13 \pm 5$	12.878573 ± 0.000001	1979 – 2020	9	85	75 ± 1	-
	234 ± 4	$+34 \pm 14$	12.878573 ± 0.000001				79 ± 1	-
(476) Hedwig	49 ± 4	$+60 \pm 7$	27.2403 ± 0.0006	1982 – 2018	6	58	116^{+6}_{-16}	6
	218 ± 4	$+36 \pm 4$	27.2404 ± 0.0005				122 ± 10	10
(524) Fidelio	52 ± 50	$+76 \pm 6$	14.171031 ± 0.000005	2005 – 2019	6	31	66 ± 5	5
	186 ± 25	$+54 \pm 10$	14.171042 ± 0.000005				67 ± 3	3
(530) Turandot	42 ± 3	$+28 \pm 5$	19.95240 ± 0.00009	1986 – 2019	8	62	89 ± 11	11
	226 ± 9	$+54 \pm 10$	19.95231 ± 0.000009				89 ± 6	6
(530) Turandot (ADAM)	39 ± 6	$+31 \pm 11$	19.95239 ± 0.00009	1986 – 2019	8	62	89 ± 2	-
	223 ± 9	$+60 \pm 9$	19.95232 ± 0.000009				89 ± 2	-
(551) Ortrud	149 ± 35	-63 ± 9	17.41924 ± 0.00003	2006–2021	7	88	85 ± 11	11
	305 ± 30	-66 ± 8	17.41921 ± 0.00002				86 ± 10	10
(566) Stereoscopia	164 ± 15	-2 ± 2	12.08466 ± 0.00006	1990 – 2022	6	35	148 ± 8	8
	338 ± 9	-13 ± 2	12.08463 ± 0.00003				148 ± 11	11
(657) Gunlod	127 ± 25	$+61 \pm 6$	15.92872 ± 0.00003	1984 – 2022	6	47	37 ± 3	3
	252 ± 50	$+51 \pm 20$	15.92870 ± 0.00004	1984 – 2022	6	47	39^{+2}_{-1}	1
(738) Alagasta	67 ± 7	-47 ± 5	17.8888 ± 0.0005	2015 – 2020	5	41	56 ± 6	6
	246 ± 10	-41 ± 8	17.8889 ± 0.0006				54 ± 4	4
(806) Gyldenien	34 ± 12	$+39 \pm 2$	16.85695 ± 0.00003	2010 – 2021	8	63	57 ± 8	8
	235 ± 15	$+42 \pm 5$	16.85699 ± 0.00007				55 ± 4	4

Table 2: Previously published diameters for asteroids studied here. Minimum and maximum diameters are given, with their uncertainties and references. For the full list see the MP3C database.

Asteroid	D_{min} [km]	D_{min} reference	D_{max} [km]	D_{max} reference
(70) Panopaea	105.17 ± 2.797	Ryan & Woodward (2010)	162.63 ± 1.280	Masiero et al. (2012)
(275) Sapiientia	89.05 ± 25.310	Masiero et al. (2020)	124.59 ± 35.830	Masiero et al. (2021)
(286) Iclea	81.31 ± 2.762	Ryan & Woodward (2010)	125.20 ± 40.850	Masiero et al. (2021)
(326) Tamara	63.30 ± 14.530	Masiero et al. (2021)	116.98 ± 36.530	Masiero et al. (2021)
(412) Elisabetha	76.38 ± 2.114	Ryan & Woodward (2010)	111.12 ± 22.220	Alí-Lagoa et al. (2018)
(426) Hippo	107.33 ± 4.405	Ryan & Woodward (2010)	137.56 ± 1.080	Masiero et al. (2012)
(439) Ohio	69.53 ± 2.060	Ryan & Woodward (2010)	86.86 ± 0.750	Masiero et al. (2012)
(464) Megaira	56.93 ± 15.508	Masiero et al. (2017)	91.81 ± 31.750	Masiero et al. (2021)
(476) Hedwig	106.15 ± 27.050	Nugent et al. (2016)	138.49 ± 0.970	Masiero et al. (2012)
(524) Fidelio	61.71 ± 26.030	Nugent et al. (2016)	83.26 ± 4.093	Ryan & Woodward (2010)
(530) Turandot	75.88 ± 19.520	Masiero et al. (2021)	89.50 ± 17.900	Alí-Lagoa et al. (2018)
(551) Ortrud	65.91 ± 14.860	Nugent et al. (2016)	86.04 ± 4.731	Ryan & Woodward (2010)
(566) Stereoscopia	134.00 ± 6.627	Masiero et al. (2011)	190.08 ± 7.909	Ryan & Woodward (2010)
(657) Gunlod	31.44 ± 8.570	Masiero et al. (2020)	46.59 ± 3.149	Ryan & Woodward (2010)
(738) Alagasta	55.36 ± 1.867	Ryan & Woodward (2010)	77.94 ± 24.740	Nugent et al. (2016)
(806) Gyldenien	56.43 ± 3.098	Ryan & Woodward (2010)	83.10 ± 0.740	Masiero et al. (2012)

5.2. (275) Sapiientia

This target had 7 pre-existing occultation observations (one with 16 chords!), and another two events have been added within our campaign for “Neglected asteroids”. From that set four chords had to be removed due to their clear inconsistency with the remaining ones: either the duration or the absolute timing must have been burdened with a gross error. The fitting to occultations clearly pointed at pole 2 as the **preferred** solution (Table 1), which is especially evident from the fit to occultations from years 2015, 2020, and 2021 (see Fig. 4). The size is determined with high accuracy (7%).

With such a rich set of occultations, and some of them hinting nonconvex shape features, also ADAM method was applied. The resulting shape for pole 2 slightly better fits to all occultations simultaneously (see Figs. 5 and 6), however the fit is still not perfect. In particular, the 4-chord event from the year 2018 cannot be fitted by any of the models, even though here we allow the occultations influence the shape. Probably the northernmost chord has an underestimated duration (this event is actually annotated as: “short low drop event in noisy recording”) or it points to some small shape feature below the resolution of the ADAM shape reconstruction procedure. The size of Sapiientia from ADAM method (100 km) is consistent with the one described above, and the **scatter of possible sizes** shrank to mere 1%. Previous size determinations for Sapiientia were somewhat less discrepant than for Panopaea, ranging from 89 to 124 km (Table 2).

5.3. (286) Iclea

Although the fit to the only available 3-chord occultation for Iclea only slightly favours pole 1 solution (see Fig. 7), the sizes from the fitting for both solutions are clearly discrepant: the size for pole 2 solution is much smaller than size for the pole 1 (69 vs. 86 km), and is also inconsistent with all the previous sizes determined using infrared data (81–125 km, see Table 2). Also, pole 1 spin parameters are confirmed by Ďurech et al. (2020) results, where it is the only solution for the pole of Iclea. Considering all the above, we think that our solution for pole 2 (Table 1) can be safely rejected.

5.4. (326) Tamara

Especially worth noting fact in case of Tamara is its extremely wide range of literature diameters (see Table 2): from 63 km to as much as 117 km, almost twice as large. It might be due to quite unusual orbit of Tamara as for a main-belt asteroid: eccentricity of 0.19, and inclination of 23°. As a consequence, thermal measurements of Tamara must have been taken at substantially varied heliocentric distances, complicating thermal analysis. Our result, being independent of thermal aspect resolves these inconsistencies, pinpointing the diameter of this body at 77^{+5}_{-10} km. The **first pole solution is preferred** based on the quality of occultation fit (Fig 8), **with RMS almost twice as good as any version of model 2**. Also, the spin solution found here well agrees with the one from Hanuš et al. (2021).

5.5. (412) Elisabetha

Model 2 solution for Elisabetha gives much better fit to occultations than **any version of** model 1 (compare the events from years 2011 and 2016 between the two poles in Fig. 9), thus **model 2 is the preferred** solution (Table 1). Our size determi-

nation (97^{+7}_{-14} km) confirms those of previous determinations (76–112 km) that tended towards larger values (see Table 2, and MP3C database).

5.6. (426) Hippo

For Hippo we obtained two pole solutions from lightcurve inversion, however the second pole (see Table 1) was at the verge of rejection on the basis of RMS fit to lightcurves, that was almost 10% **higher** than for the first pole. **See Section 4 for the discussion of this threshold.**

Our spin solutions roughly agree with the previously published ones by Hanuš et al. (2021) and Ďurech et al. (2019), but disagree in longitude of the second spin solution.

We decided to fit both shape solutions to the rich set of occultations, see Fig. 10. Surprisingly, it is the shape connected to pole solution 2 that fits better to most of the occultations (blue contour in Fig. 10), especially to the richest one from 2021/12/27. Thus we **consider pole 1 solution less probable** (magenta dashed contour), even though it provided formally better fit to lightcurves. Size determined here (122 ± 4 km) is close to the middle of the size range from previous works (Table 2).

5.7. (439) Ohio

Our research on asteroid Ohio is a success story in multiple ways. First, we proved previously accepted rotation wrong, identifying period around 37.46 hours as the correct one (Marciniak et al. 2015), instead of 19.2 hours persistent for decades in the Asteroid Lightcurve Database (Warner et al. 2009). Later, after gathering enough lightcurve data over multiple apparitions, we managed to obtain its physically rotating model, which was possible thanks to regularization added to lightcurve inversion routines. There was only a single pole solution (Table 1) already on the level of lightcurve inversion, as the mirror pole solution gave much worse fit to lightcurves. This is facilitated by relatively high orbital inclination of 19° for Ohio. Our spin solution compared to pole 2 solution from Ďurech et al. (2018), is $\sim 30^\circ$ and $\sim 50^\circ$ away in spin axis latitude and longitude respectively.

Later, in March 2022, we coordinated observers around two stellar occultation events (resulting in 6 and 9 positive chords, including one grazing event observed by the first author), where there were no multichord events (i.e. containing more than 3 positive chords) recorded previously. In the end, our shape model was fitted to these occultations, presenting a very good quality of the fit (see Figure 11). Thanks to quality of both the model, and the occultation timings, the shape was precisely scaled with **small** residual RMS. The only small discrepancies between the model and the chords from the last occultation probably reveal the shape resolution limits of a classical lightcurve inversion.

5.8. (464) Megaira

The fit to occultations for Megaira is puzzling: model 2 gives somewhat better fit than model 1 (Fig. 12), but it **always** leaves the southernmost chord outside the profile. **Some** variations of shape for model 1 can fit that chord, but then, they give clearly worse fit to the remaining chords. The situation is similar when modelling this target with ADAM algorithm (Fig. 13). Summing up, model 2 is slightly preferred, but cannot fit all the chords. Previously published sizes ranged here from 57 km up to 92 km. Our determination resulted in sizes of 75–79 km.

5.9. (476) Hedwig

Both pole solutions for Hedwig agree with those found by Hanuš et al. (2021), but pole 1 solution is **clearly preferred** one by the fit to practically all of six occultations, especially to the event from the year 2000 (see Fig. 14). Determined diameter (116^{+6}_{-16} km) is around the mean of the range of previous determinations (106–138 km, Table 2.)

5.10. (524) Fidelio

Pole 2 (see Table 1) is preferred by occultations here (Fig. 15). This solution is also confirmed by the value for β_p found by Ďurech et al. (2020) and full spin solution by Hanuš et al. (2021). The size determined here (67 ± 3 km) is closer to the lower end of the range of literature sizes (62–83 km).

5.11. (530) Turandot

The occultation set for Turandot contained a few discrepant chords, so we had to remove four chords from the first event in the year 2006, and completely leave out the second, 3-chord event from that year, due to strong mutual inconsistencies among the chords. The remaining set allowed us to clearly **point the preferred** one of two pole solutions (see Fig. 16), especially in the ADAM version of the model. With ADAM model for pole 2 the southernmost chord of 2006 event is finally fitted, revealing a nonconvex feature on the shape (Fig. 17). Both methods gave the same size for both models 89 km, while previous determinations were in the narrow range from 76 to 89 km. Our spin latitude found with ADAM method is almost 30° off the value found by Hanuš et al. (2021) using convex inversion.

5.12. (551) Ortrud

Occultation event for Ortrud from July 2021 contains problematic, mutually inconsistent chords (Fig. 18). Because it is hard to tell which chords are wrong, we keep them all for the scaling. This results in larger RMS residual for the diameter (12%). Previous determinations ranged from 66 to 86 km (see Table 2), while ours are **around** 85 km, confirming the upper values.

5.13. (566) Stereoskopia

One of the best covered occultations for Stereoskopia was observed within our campaign (see the event from 2021 in Fig. 19). Since the shape solutions tended to be non-physical and unstable here, we used the regularization, and tried a few versions of the shape model for each of two pole solutions. We adopted the one that gave the best fit to occultations. All the shape fits for pole 1 were clearly superior to any shape fits for pole 2. Still, no shape could fit all the chords from the event in 2021. It might be due to insufficient information on the shape contained in lightcurves of this low-pole asteroid (see very low $|\beta_p|$ values in Table 1). Some lightcurves were obtained in pole-on geometries, thus showed hardly any brightness variations.

There were large discrepancies in literature diameter determinations for Stereoskopia: from 134 up to even 190 km. The value found here (148 km) is consistent with lower of the values, and in spite of imperfect fit, has only 5–7% RMS.

5.14. (657) Gunlod

The values for both pole coordinates for Gunlod are roughly consistent with the ones determined previously by Ďurech et al. (2019), just poles found here have notably higher ($\sim 20^\circ$) values of β_p , being closer to the values found by Hanuš et al. (2021). The fit to the only multichord occultation by Gunlod **prefers** pole 2 solution (see Fig. 20), however that preference is based on only one chord, and smaller RMS value for the diameter (Table 1). Literature size determinations for Gunlod ranged from 31 to 46 km, while this work places its diameter in the middle of this range (37–39 km).

5.15. (738) Alagasta

The fit to occultations shows that solution for pole 2 of Alagasta is slightly better, still imperfect (Fig. 21). Sizes from the literature were from 55 km to 78 km, while the size determined here is at the level of 55 ± 5 km, confirming the values at the lower end of this range.

5.16. (806) Gyldenja

The spin solution for asteroid Gyldenja is within a few degrees from the one found by Ďurech et al. (2019). Pole 2 solution seems to better fit the only available occultation (Fig. 22), as also evidenced by smaller RMS residual for the volume-equivalent size determined this way (Table 1). Still, it also fails to fit the longest occultation chord. **On the other hand, pole 1 has difficulties fitting the short chord at the edge of the shape, that are in general problematic to fit.** Previous diameter determinations ranged from 56 km to 83 km (Table 2), presented here values (55–57 km) being consistent with the lowest of the published values.

6. Conclusions and future prospects

Our project, by the comprehensive approach, have provided almost 50 high quality, scaled models (Marciniak et al. 2018, 2019, 2021) for poorly studied, but large and ubiquitous asteroids, including 16 presented here. Two observing campaigns – for lightcurves and occultations, were done in wide collaboration networks, engaging many amateur astronomers, but also bringing new people to the field. We are going to continue the occultation campaign, and to a lesser extent, also the one for time-series photometry, as the latter is gradually being replaced by wide ground-based and space-based sky surveys. Since so many asteroids have poorly determined sizes, stellar occultations are the best technique to reliably determine sizes of a large number of targets from all groups, especially in the era of Gaia mission.

Our precise determinations of spins, shapes and sizes for many, previously largely omitted targets, have enriched and complemented available sample of modelled asteroids¹² (Ďurech et al. 2010). Our set includes asteroids belonging to a few asteroid families, believed to form in catastrophic disruptions of larger parent bodies. Current theories of collisional evolution of the Solar System predict a steady number of existing asteroid families throughout the history, but observational evidence deny this prediction (Brož et al. 2013). The key to solve this inconsistency is to determine family ages by determining the drift rate of family members from the center, by studying the V-shaped dependence of the inverse size $1/D$ on the proper semimajor axis

¹² <https://astro.troja.mff.cuni.cz/projects/damit/>

a_p (Vokrouhlický et al. 2006). Our improved size determinations and spin properties, **among many applications** facilitate making better predictions of the thermally driven drift of the asteroids within their families.

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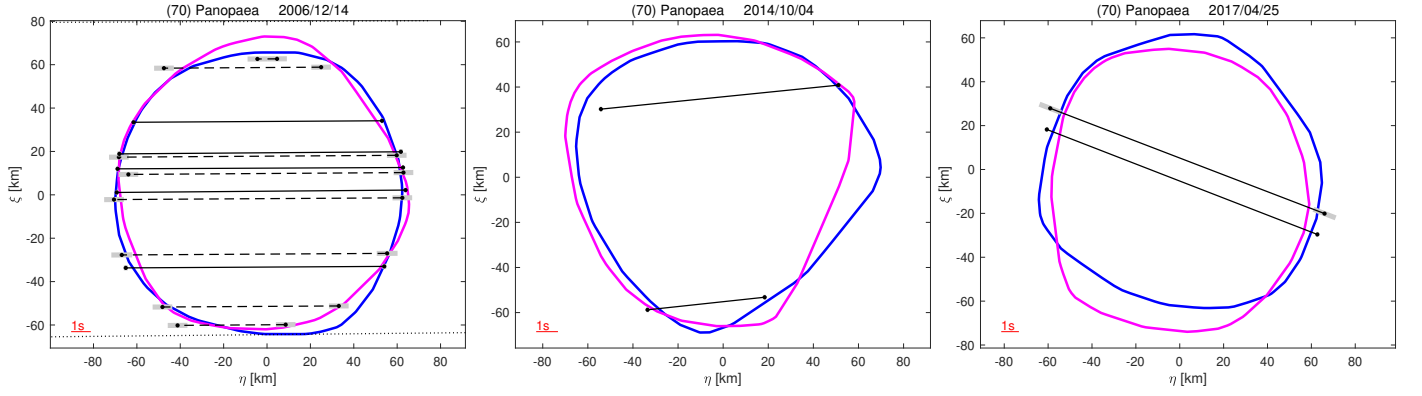


Fig. 3: (70) Panopaea, model fit to occultation chords shown in the fundamental plane. North is up and west is right. Dashed lines mark visual observations, as opposed to video or photoelectric ones, marked with solid lines. Grey segments correspond to timing uncertainties. Blue contour: instantaneous silhouette of shape model 1 (see Table 1), magenta: same for model 2. In this case occultations show no preference for any of the models.

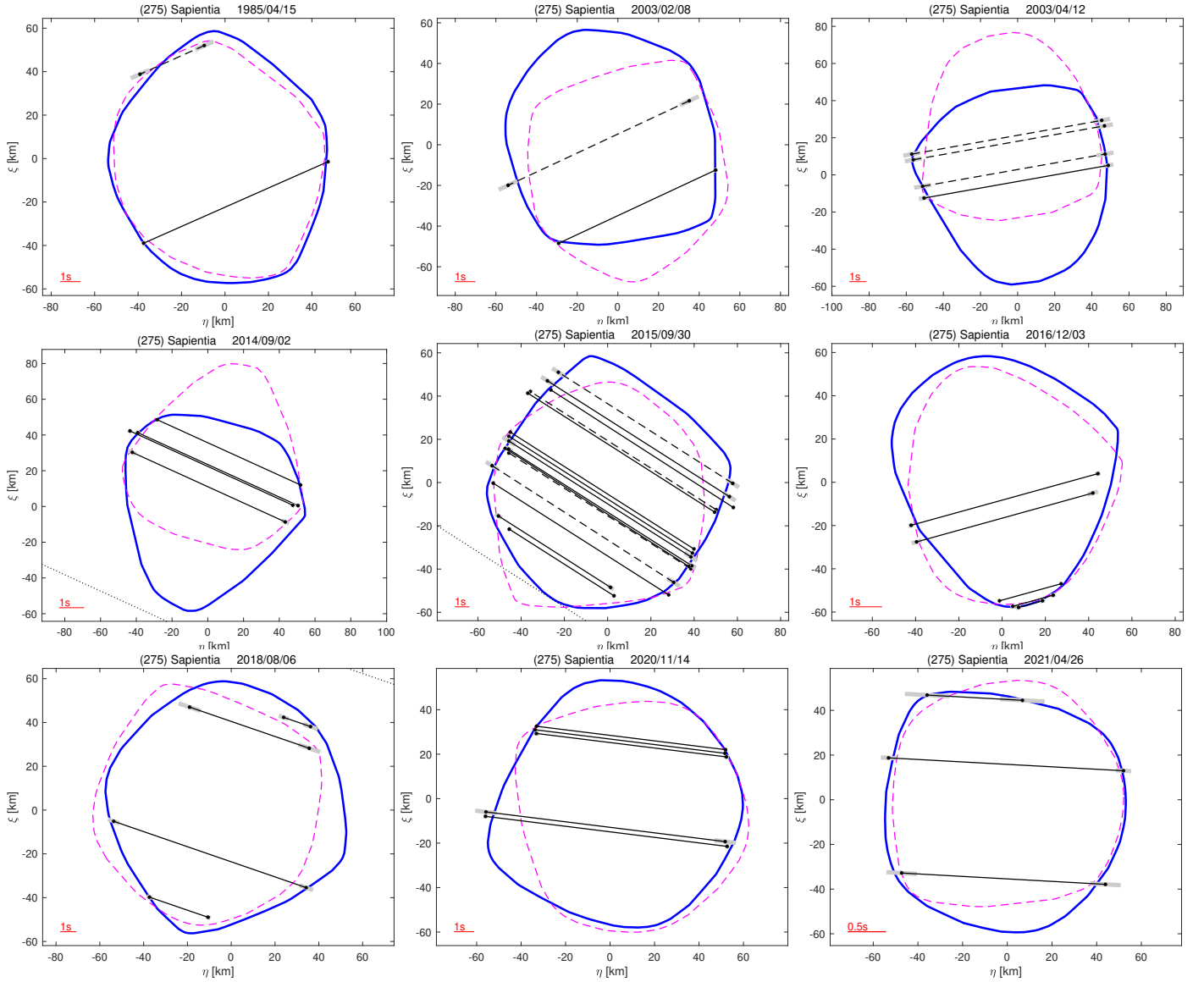


Fig. 4: (275) Sappientia, model fit to occultation chords. Here, model 2 is preferred (blue solid contour).

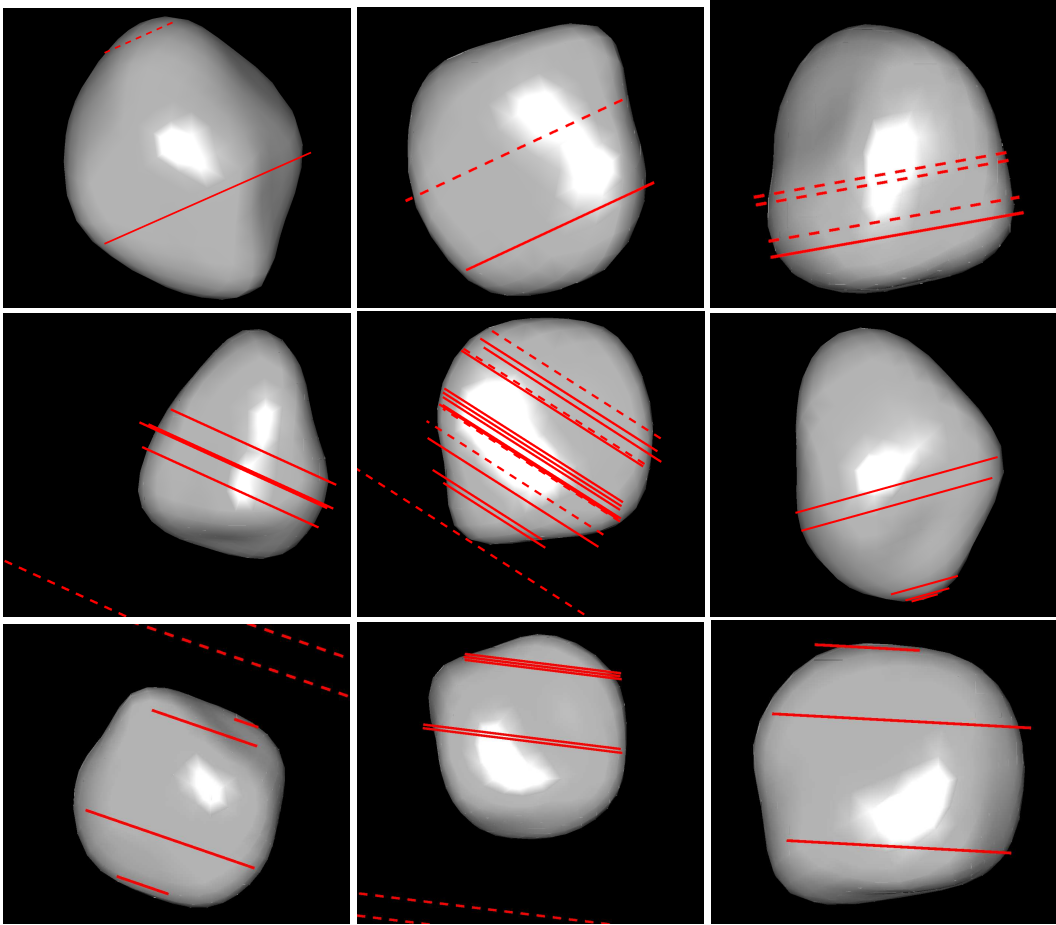


Fig. 5: (275) Sapienia, ADAM solution pole 1, shown with occultation chords used to construct the model. Occultation events same as in Fig. 4.

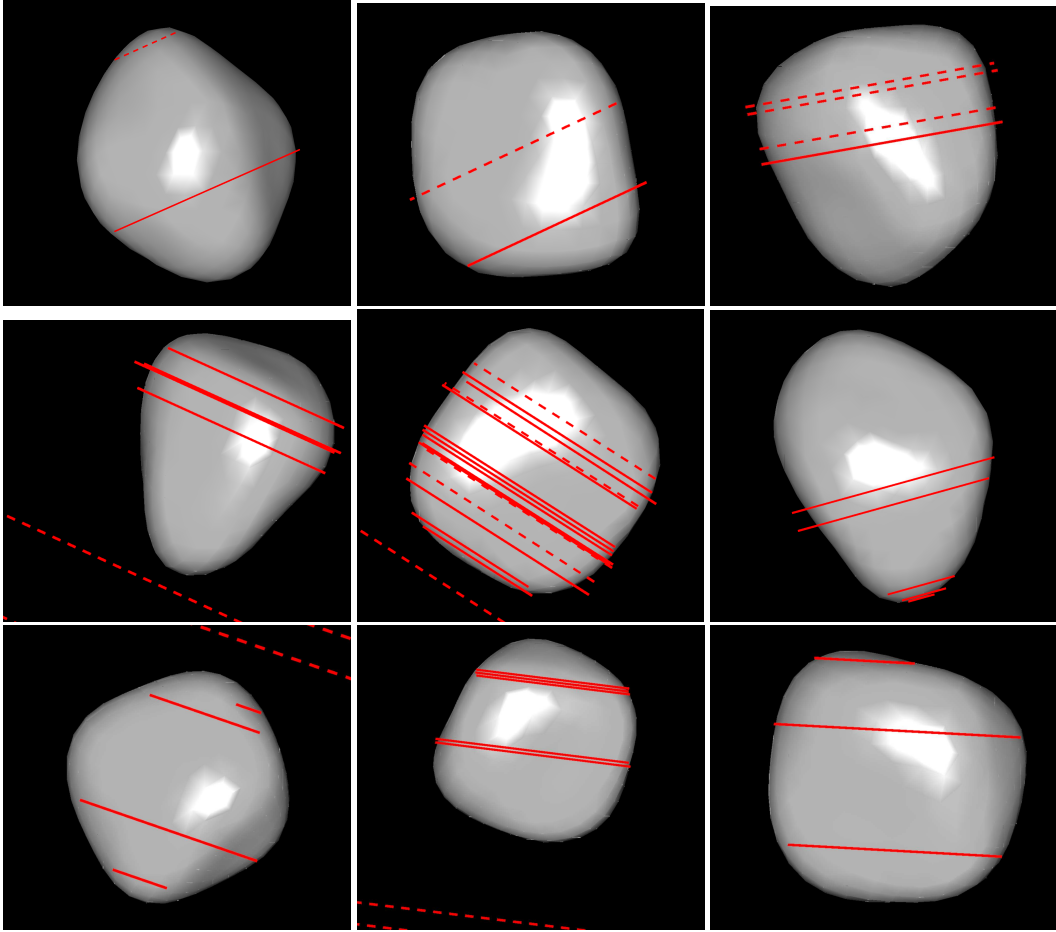


Fig. 6: (275) Sapiientia, ADAM solution pole 2, shown with occultation chords used to construct the model. Occultation events same as in Fig. 4.

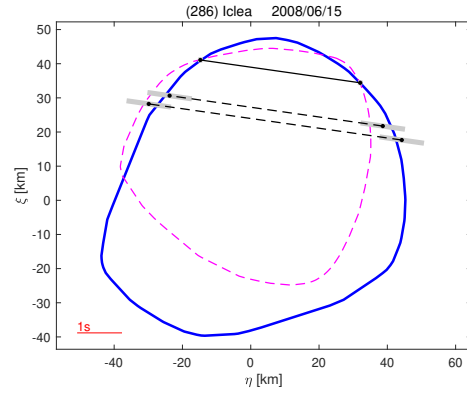
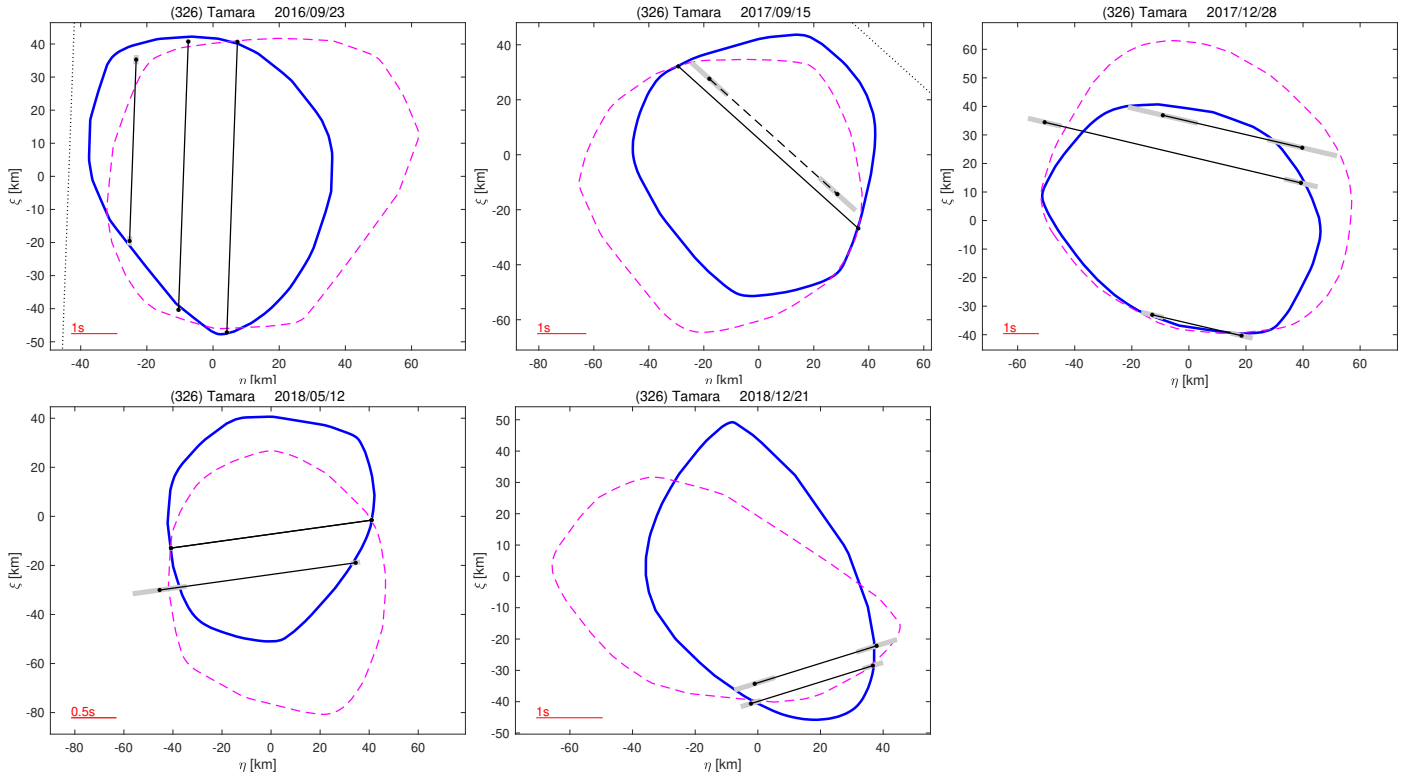
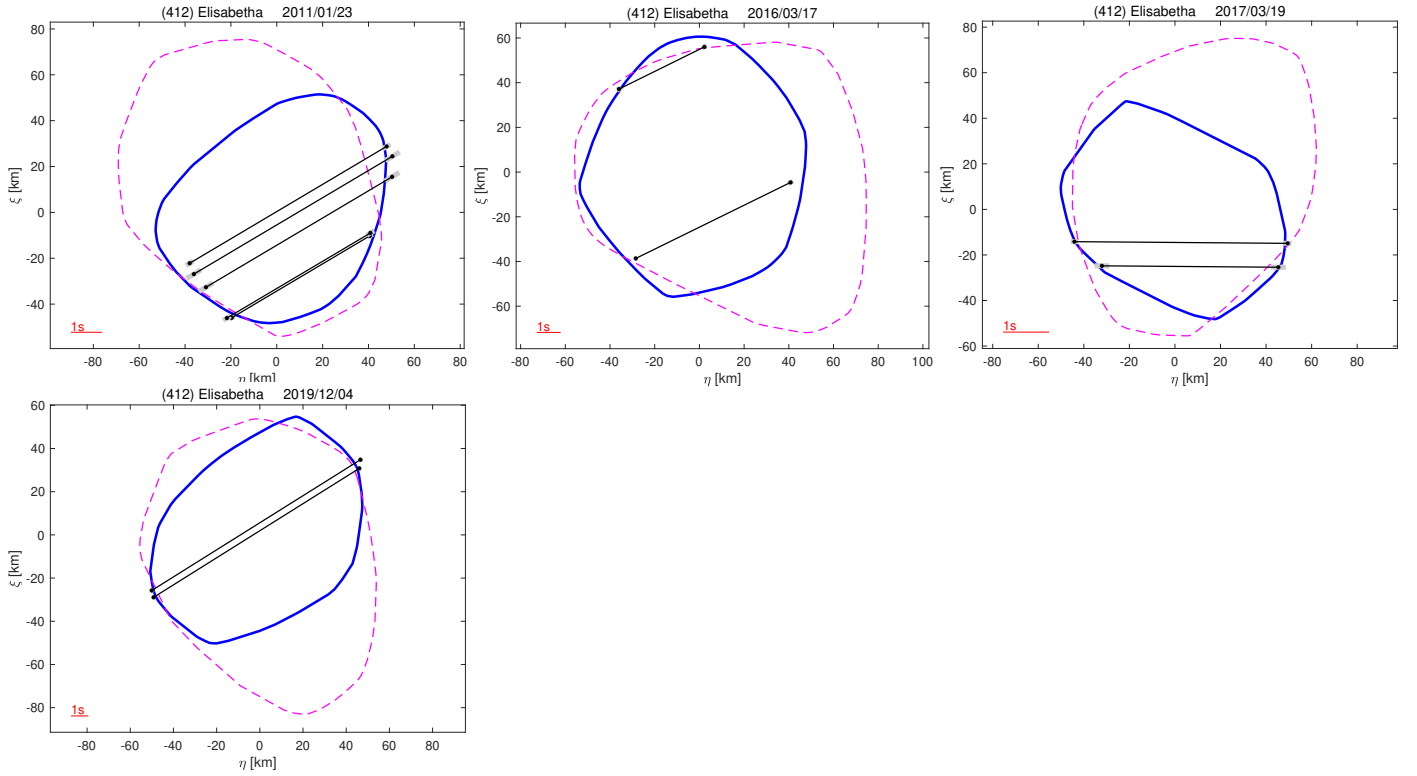


Fig. 7: (286) Iclea, model fit to occultation chords. Pole 2 (dashed contour) is rejected as inconicent with all previous size determinations.


 Fig. 8: (326) Tamara, model fit to occultation chords. **Pole 1 is preferred (solid contour).**

 Fig. 9: (412) Elisabetha, model fit to occultation chords. **Pole 2 is preferred (solid contour).**

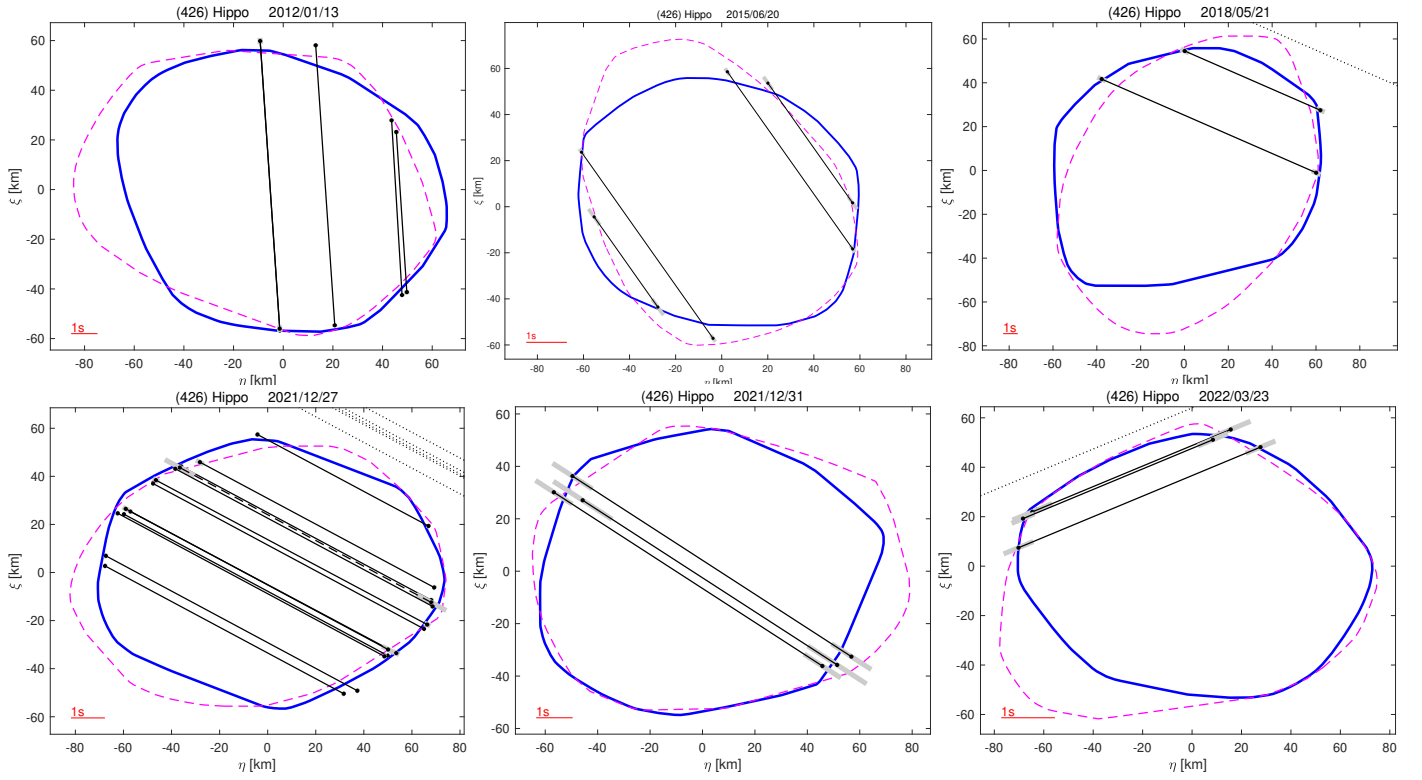
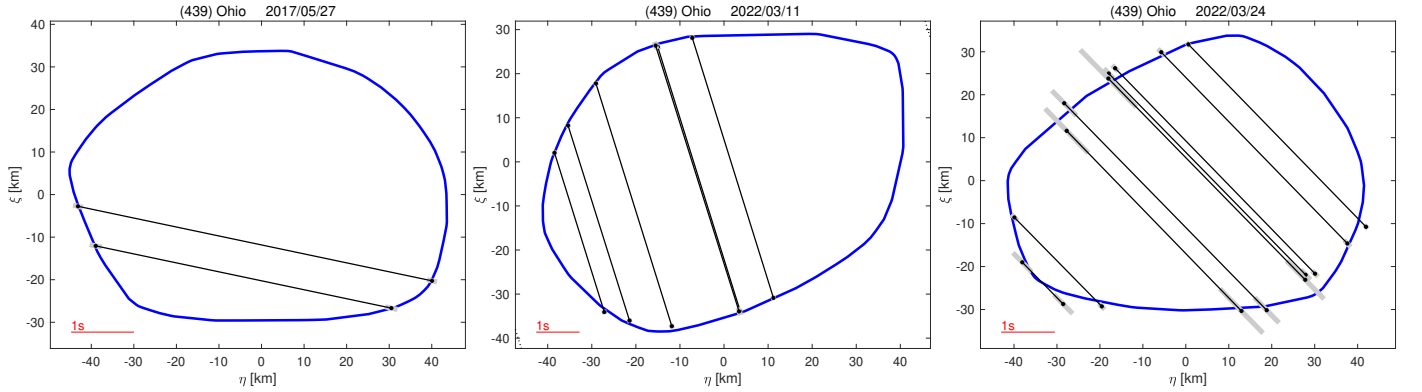
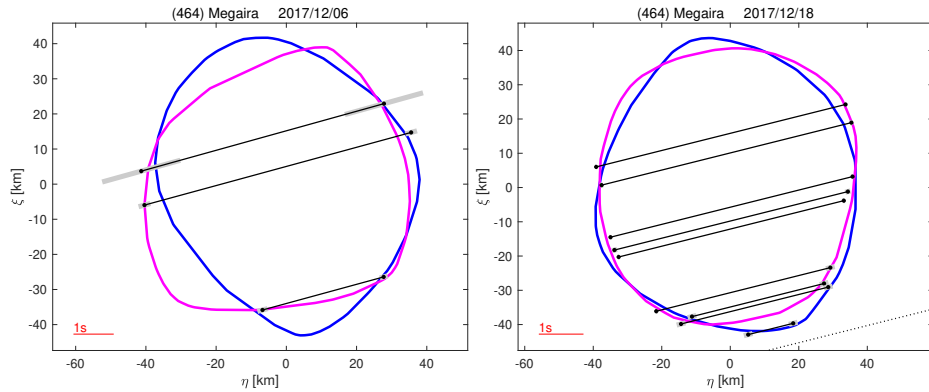

 Fig. 10: (426) Hippo, model fit to occultation chords. **Pole 2 is preferred (solid contour).**


Fig. 11: (439) Ohio, model fit to occultation chords.


 Fig. 12: (464) Megaira, model fit to occultation chords: **pole 1 (blue), and pole 2 (magenta).**

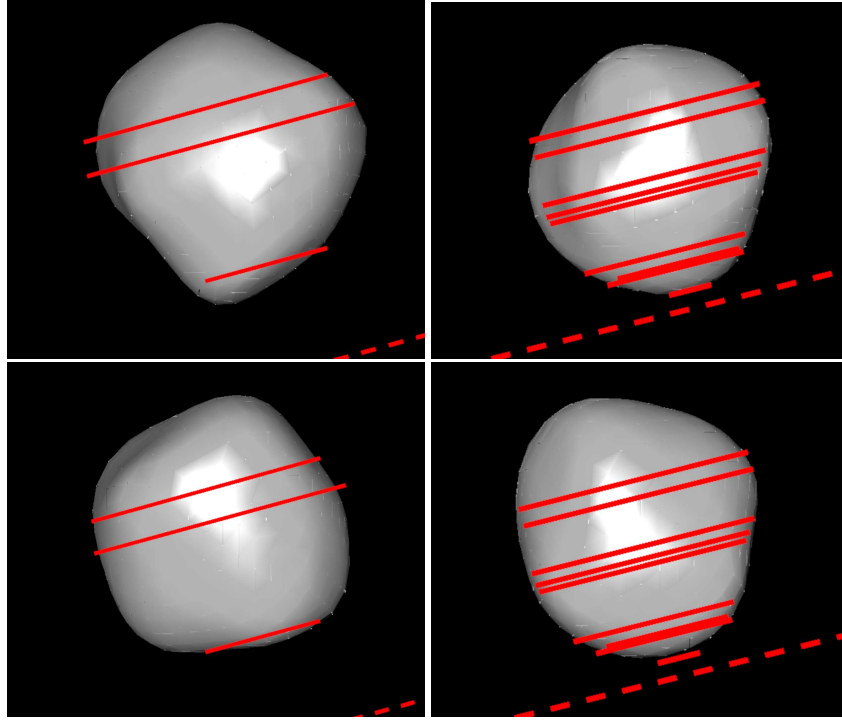


Fig. 13: (464) Megaira, ADAM solution pole 1 (top row), pole 2 (bottom row), shown with occultation chords used to construct the models. Occultation events same as in Fig. 12.

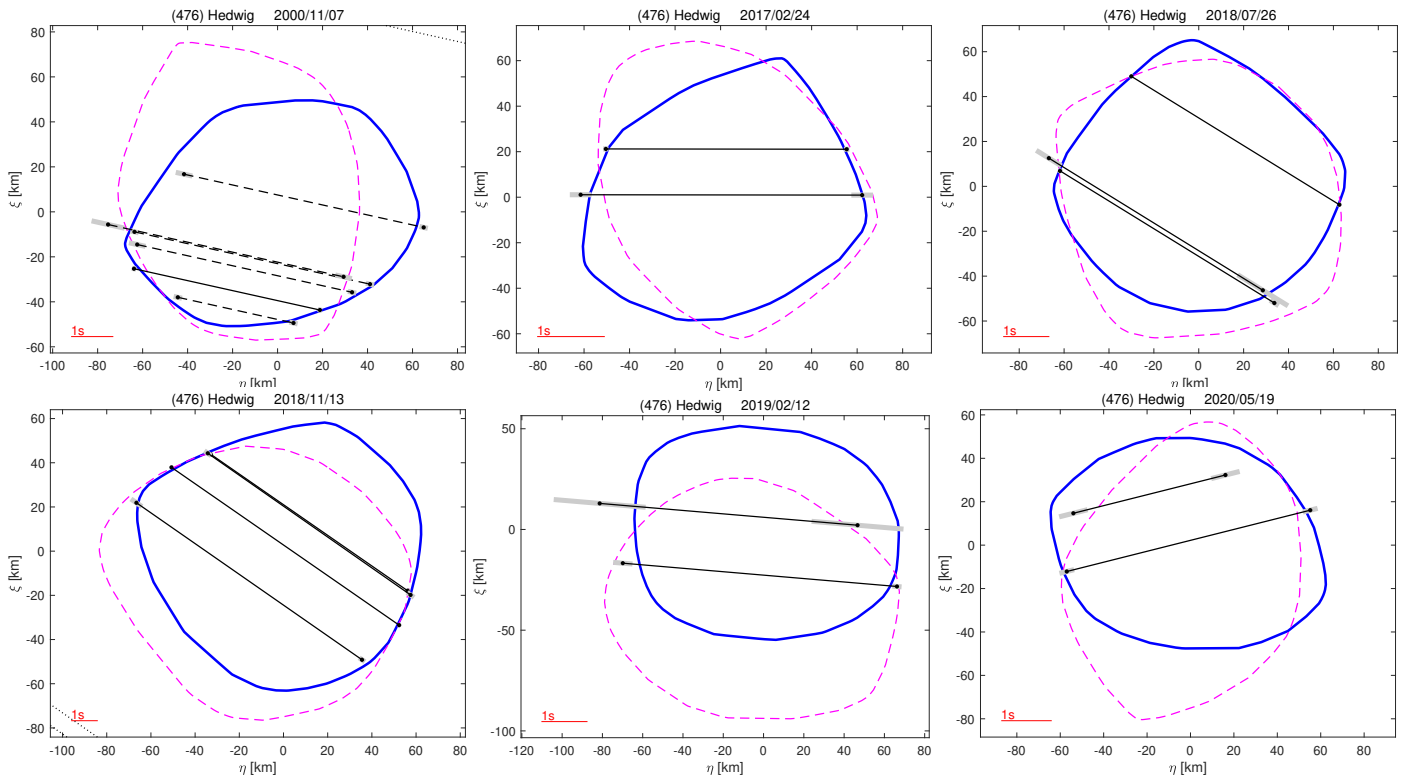


Fig. 14: (476) Hedwig, model fit to occultation chords. **Pole 1 is preferred (solid contour).**

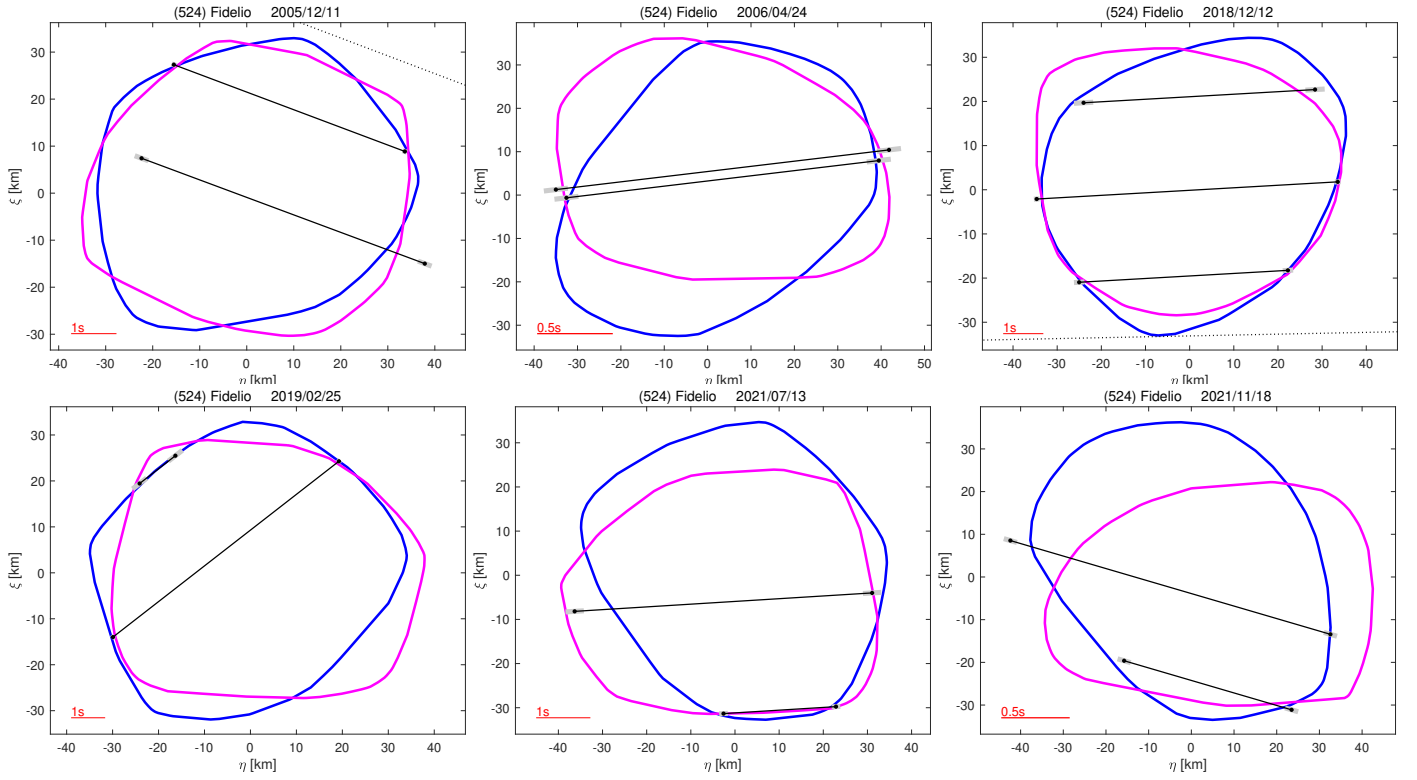


Fig. 15: (524) Fidelio, model fit to occultation chords. Pole 2 is preferred (blue contour).

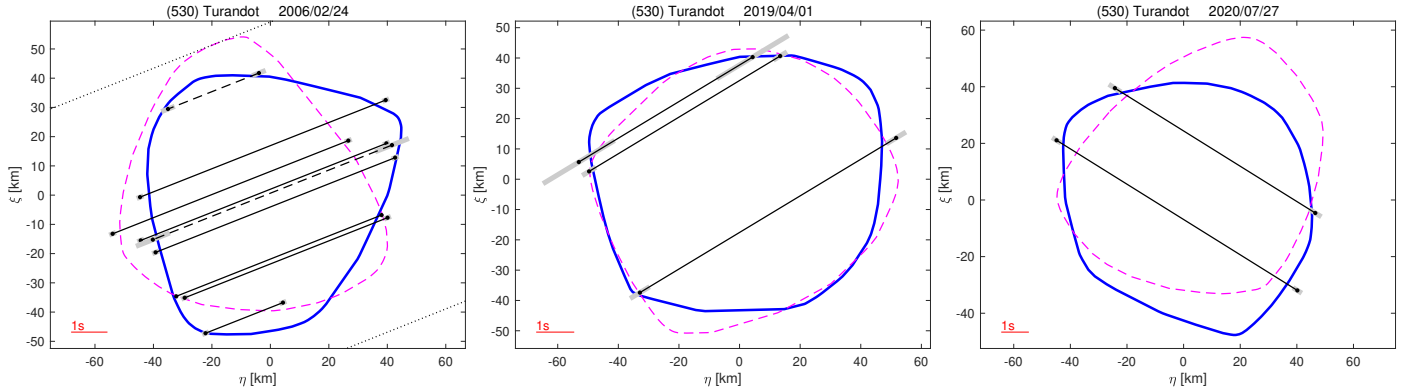


Fig. 16: (530) Turandot, model fit to occultation chords. Pole 2 is preferred (solid contour).

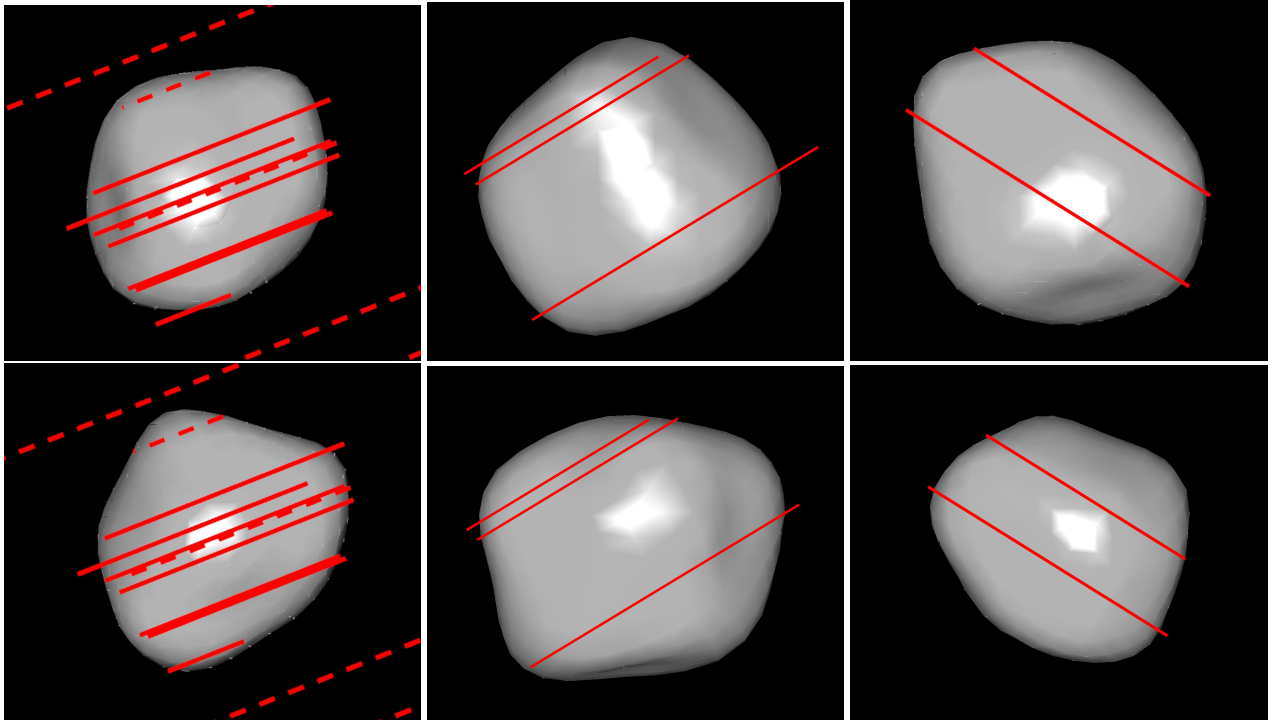


Fig. 17: (530) Turandot, ADAM solution pole 1 (top row), pole 2 (bottom row), shown with occultation chords used to construct the models. Occultation events same as in Fig. 16.

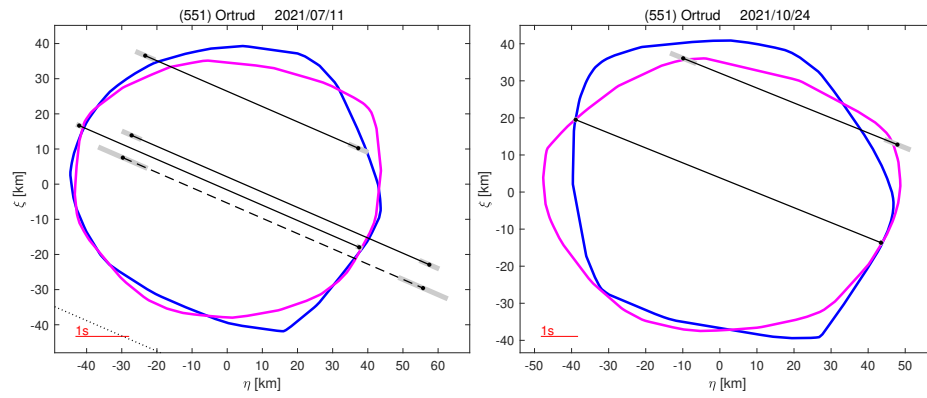


Fig. 18: (551) Ortrud, model fit to occultation chords: **pole 1 (blue), and pole 2 (magenta)**.

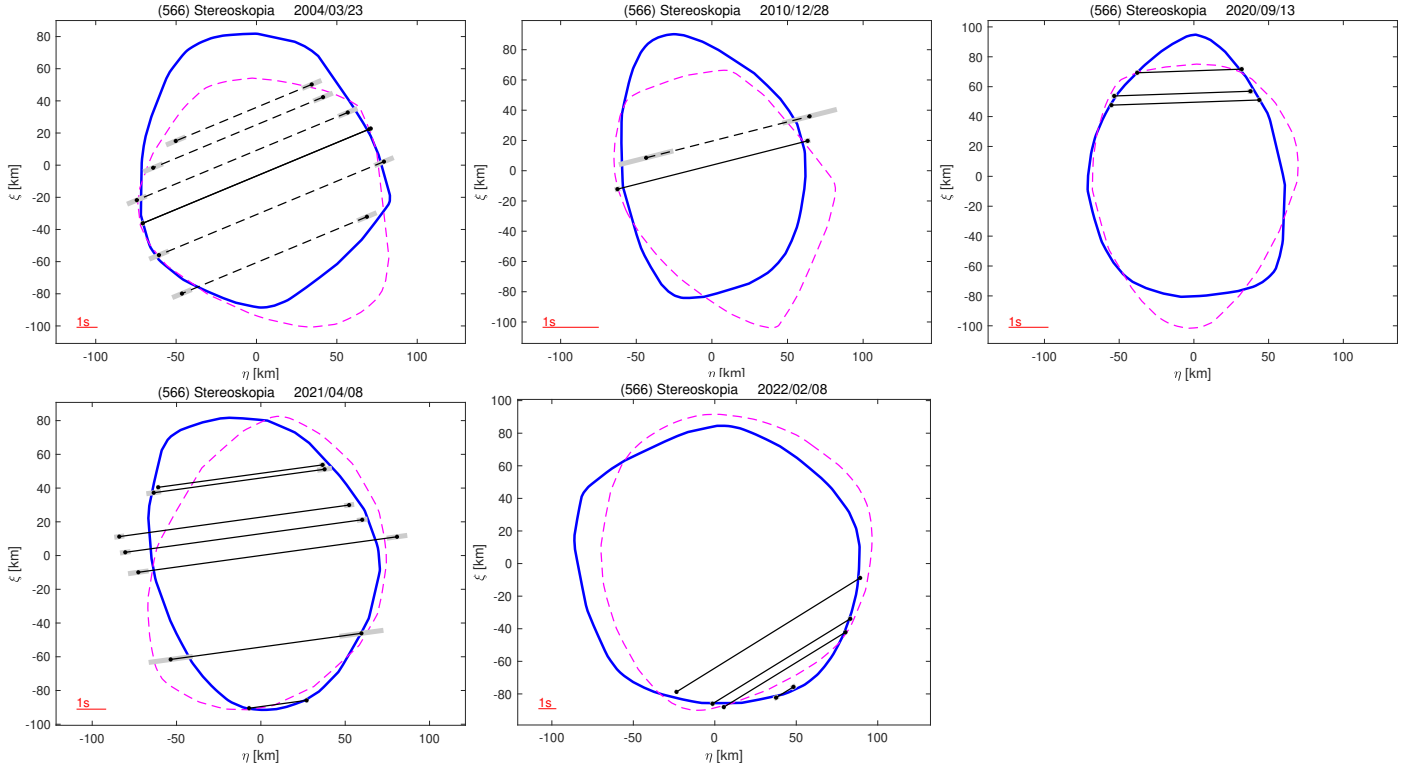


Fig. 19: (566) Stereoskopia, model fit to occultation chords. **Pole 1 is preferred (solid contour).**

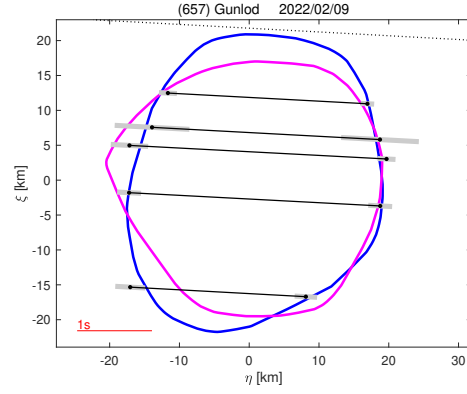


Fig. 20: (657) Gunlod, model fit to occultation chords. **Pole 2 is preferred (blue contour).**

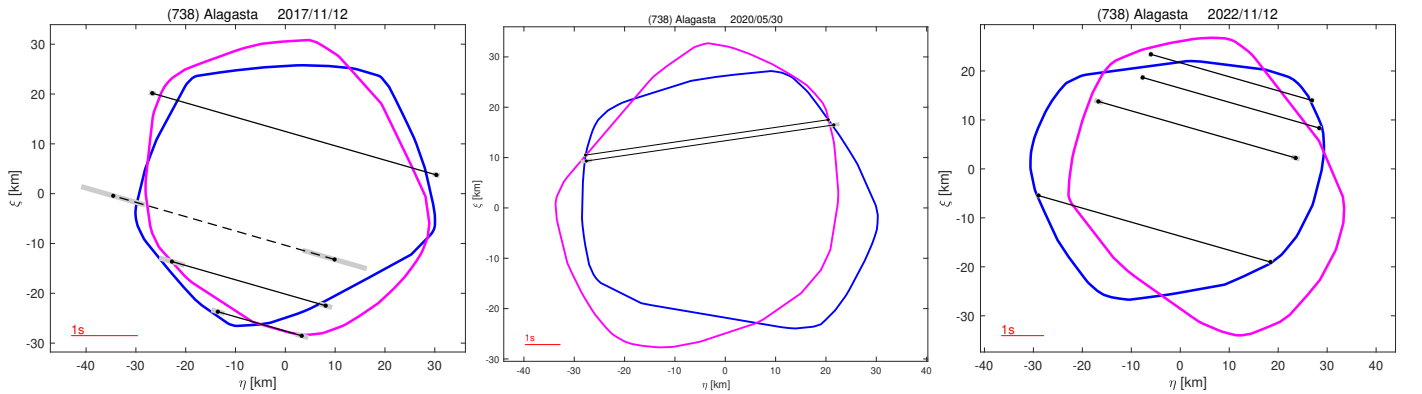


Fig. 21: (738) Alagasta, model fit to occultation chords: **pole 2 (blue), and pole 1 (magenta).**

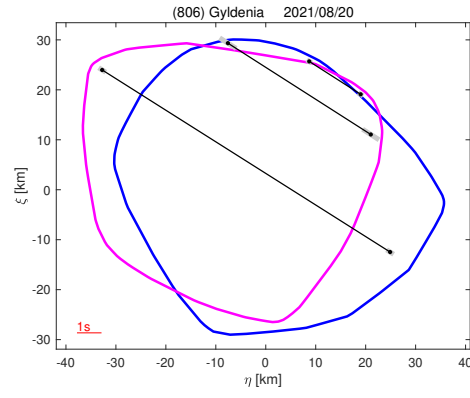


Fig. 22: (806) Gyldenlia, model fit to occultation chords: **pole 1 (blue), and pole 2 (magenta)**.

Appendix A: Observing campaigns details

This section contains summarised details of all time-series observations used for the modelling (Table A.1), and the list of stellar occultation events observers and sites (TableA.2).

Table A.1: Details of all photometric observations for lightcurves: observing dates, number of lightcurves, range of ecliptic longitudes of the target, and sun-target-observer phase angles, observer's name (or paper citation in case of published data), and the observing site. Some data come from robotic telescopes, so there is no observer specified. For data from the TESS spacecraft, N_{lc} denotes the number of days of continuous observations. CSSS stands for Center for Solar System Studies, CTIO - Cerro Tololo Interamerican Observatory, e-EyE - Entre Encinas y Estrellas, ESO - European Southern Observatory, OASI - Observatório Astronômico do Sertão de Itaparica, ORM - Roque de los Muchachos Observatory, OT - Observatorio del Teide, and SOAO - Sobaeksan Optical Astronomy Observatory.

Date	N_{lc}	λ [deg]	Phase angle [deg]	Observer	Site
70 Panopaea					
1980 08 20 - 1980 08 21	2	329 - 330	10	Harris & Young (1989)	Mountain Observatory, CA, USA
1980 09 05	1	326	12	Schroll & Schober (1983)	Table Mountain Observatory, CA, USA
2006 09 23 - 2006 12 24	22	48 - 63	3 - 20	-	Super WASP
2014 09 11 - 2014 12 30	15	353 - 3	8 - 24	Marciniak et al. (2015)	Montsec, Catalonia, Spain; Bisei Spaceguard Center, Japan
2015 10 27 - 2015 12 18	16	103 - 108	7 - 19	Marciniak et al. (2016)	Borowiec, Poland; Organ Mesa Observatory, NM, USA; Montsec, Catalonia, Spain
2016 01 04	1	99	4	F. Pilcher	Organ Mesa Observatory, NM, USA
2016 12 26 - 2017 01 30	10	181 - 184	16 - 19	T. Polakis, B. Skiff	Tempe, AZ, USA
2017 01 27 - 2017 03 28	2	174 - 184	7 - 17	V. Kudak, V. Perig	Derenivka, Ukraine
2017 03 26	1	175	6	A. Marciniak	Borowiec, Poland
2018 06 26 - 2018 10 16	20	313 - 324	14 - 25	B. Skiff	Lowell Observatory, AZ, USA
2018 07 26 - 2018 08 17	24	317 - 321	10 - 13	Pál et al. (2020)	TESS spacecraft
2019 09 05 - 2019 10 16	3	84 - 90	19 - 21	M. Drózd	Suhora, Poland
2019 09 17	1	87	21	E. Pakštienė	Molėtai Astronomical Observatory, Lithuania
2019 09 26 - 2019 10 25	3	88 - 90	17 - 21	W. Ogłóza	Adiyaman, Turkey
2019 12 16	1	82	3	R. Szakáts	Piszkéstető, Hungary
275 Sapientia					
1998 01 01 - 1998 01 03	2	82	7 - 8	Denchev (2000)	Rozhen National Observatory, Bulgaria
2007 01 01 - 2007 01 10	5	56	14 - 17	Warner (2007)	CSSS - Palmer Divide Station, CO USA
2013 04 23	1	249	14	F. Pilcher	Organ Mesa Observatory, NM, USA
2014 07 25 - 2014 09 10	8	329 - 338	2 - 11	Pilcher (2015)	Organ Mesa Observatory, NM, USA
2015 09 28 - 2015 11 20	5	40 - 49	3 - 13	Pilcher (2016)	Organ Mesa Observatory, NM, USA
2016 12 4 - 2017 01 09	4	154 - 159	18 - 24	R. Hirsch, A. Marciniak, Butkiewicz - Bąk	Borowiec, Poland
2017 01 18	1	159	16	A. Marciniak	CTIO, Chile
2017 01 25 - 2017 01 30	6	158	11 - 13	T. Polakis, B. Skiff	Tempe, AZ, USA
2017 01 29	1	158	11	V. Kudak, V. Perig	Derenivka, Ukraine
2018 05 15	1	289	9	M.-J. Kim, D.-H. Kim	SOAO, South Korea
2018 05 17 - 2018 05 18	2	292	17	K. Kamiński	Winer, AZ, USA
2018 05 26	1	287	4	S. Geier	Kitt Peak Observatory, AZ, USA
2018 06 08	1	290	11	S. Geier	ORM, La Palma, Spain
286 Iclea					
2002 05 30	1	230	9	J. G. Bosch	Collonges Observatory, France
2003 08 02	1	311	3	L. Bernasconi	Observatoire des Engarouines, France
2007 04 13 - 2007 04 24	6	176 - 177	9 - 12	R. Hirsch, M. K. Kamińska, K. Kamiński, A. Marciniak, M. Polińska	Borowiec, Poland
2007 04 17	1	177	10	P. Kankiewicz	Kielce, Poland
2013 04 08 - 2013 05 19	6	201	6 - 13	M. Bronikowska, K. Sobkowiak, M. Murawiecka, R. Hirsch	Borowiec, Poland
2014 05 20 - 2014 08 12	7	272 - 285	13 - 14	A. Marciniak, P. Trela, I. Konstanciak, R. Hirsch	Borowiec, Poland
2014 05 24	1	285	13	K. Kamiński	Winer, AZ, USA
2014 08 10 - 2014 08 17	4	272 - 273	14 - 15	-	Montsec, Catalonia, Spain
2015 09 06 - 2015 10 03	8	353 - 359	4 - 7	-	Montsec, Catalonia, Spain
2016 11 13 - 2017 02 27	5	72 - 82	8 - 18	J. Horbowicz, M. Butkiewicz - Bąk, A. Marciniak, R. Hirsch	Borowiec, Poland
2017 01 07	1	74	11	S. Geier	Kitt-Peak, AZ, USA
2017 01 22	1	73	14	R. Hirsch	CTIO, Chile
2017 12 30 - 2018 04 19	3	145 - 159	13 - 16	A. Marciniak, K. Żukowski, J. Horbowicz	Borowiec, Poland
2018 02 15	1	151	2	V. Kudak, V. Perig	Derenivka, Ukraine
2019 04 18 - 2019 04 25	2	225 - 226	8 - 9	M. K. Kamińska, M. Pawłowski	Borowiec, Poland
2019 05 07	1	222	8	D.-H. Kim, M.-Y. Kim	SOAO, South Korea
2019 05 24	1	219	10	K. Kamiński	Winer, AZ, USA
2019 06 01 - 2019 06 02	2	218	11	S. Fauvaud	Le Bois de Bardon Observatory, France
326 Tamara					
1981 09 20 - 1981 09 27	3	7 - 9	9 - 10	Harris et al. (1992)	Table Mountain Observatory, CA, USA
1991 04 27	1	233	10	Hainaut-Rouelle et al. (1995)	ESO, La Silla, Chile
2006 11 17 - 2006 12 22	10	32 - 37	7 - 19	-	Super WASP
2009 05 07 - 2009 05 29	5	317 - 326	32	Higgins (2011)	Hunters Hill Observatory, Australia
2012 04 19 - 2012 06 09	24	189 - 194	9 - 28	F. Kugel, J. Caron	Observatoire de Dauban, France
2015 04 05 - 2015 04 09	2	121 - 122	23	V. Kudak, V. Perig	Derenivka, Ukraine
2015 04 13 - 2015 05 16	3	122 - 131	23 - 24	W. Ogłóza	Suhora, Poland
2015 04 29 - 2015 05 2	3	126	24	P. Kulczak	Borowiec, Poland
2016 05 25 - 2016 10 30	6	287 - 315	22 - 31	S. Geier, A. Marciniak	CTIO, Chile
2017 09 25 - 2017 12 18	8	76 - 87	10 - 22	-	Montsec, Catalonia, Spain
2019 02 17 - 2019 05 02	2	197 - 198	17 - 20	V. Kudak, V. Perig	Derenivka, Ukraine
2019 02 19	1	198	20	M. K. Kamińska	Borowiec, Poland
2019 02 19	1	198	20	S. Fauvaud, J. J. Rives, G. Biguet	Pic du Midi Observatory, France

Date	N_{Ic}	λ [deg]	Phase angle [deg]	Observer	Site
412 Elisabetha					
1990 08 22 - 1990 08 29	6	328-329	5-6	Lagerkvist et al. (1992)	ESO, La Silla, Chile
2012 05 10 - 2012 05 18	7	231-233	7	Stephens (2012)	Rancho Cucamonga, CA USA
2016 02 25 - 2016 03 10	2	163-166	7	K. Kamiński	Winer, AZ, USA
2016 03 4 - 2016 04 3	4	158-164	7-14	V. Kudak, V. Perig	Derenivka, Ukraine
2017 06 19 - 2017 07 17	7	271-277	2-8	F. Pilcher	Organ Mesa Observatory, NM, USA
2018 09 4 - 2018 10 5	11	10-17	7-13	-	Montsec, Catalonia, Spain
2018 10 4 - 2018 10 17	15	8-11	7-9	Pál et al. (2020)	TESS spacecraft
2019 11 21 - 2020 04 17	3	105 - 111	13 - 21	W. Ogłóza	Adiyaman, Turkey
2020 02 8	1	97	14	A. Marciniak	Borowiec, Poland
2020 03 27	1	100	21	R. Szakáts	Piszkéstető, Hungary
2021 02 18 - 2021 02 20	3	217	20	D.-H. Kim, M.-J. Kim	Mt. Lemmon, USA
2021 02 18	1	217	20	D.-H. Kim, M.-J. Kim	SOAO, South Korea
2021 02 21 - 2021 04 23	5	210 - 217	8 - 20	W. Ogłóza	Adiyaman, Turkey
2021 02 23	1	217	20	W. Ogłóza	Suhora, Poland
2021 02 25	1	218	19	V. Kudak, V. Perig	Derenivka, Ukraine
2021 02 26 - 2021 04 24	5	210-218	8-19	A. Jones	Maidenhead, UK
2021 03 10	1	218	17	S. Fauvaud, A. Bruno	Pic du Midi, France
2021 04 19 - 2021 04 21	3	211-212	8	Polakis (2021a)	Tempe, AZ USA
426 Hippi					
1993 02 15	1	126	8	Mohamed et al. (1995)	Astronomical Observatory, Kharkiv, Ukraine
2008 03 01 - 2008 04 11	7	155 - 163	6 - 17	J. Oey, D. Higgins	Leura, Australia
2015 08 05 - 2015 10 27	7	349 - 3	7 - 14	P. Kulczak, A. Marciniak, R. Hirsch, M. Butkiewicz - Bąk	Borowiec, Poland
2015 09 08 - 2015 09 24	10	354 - 358	6 - 7	-	Montsec, Catalonia, Spain
2016 09 27 - 2016 11 29	4	80 - 83	9 - 19	R. Hirsch, J. Horbowicz	Borowiec, Poland
2016 10 26 - 2016 12 28	11	73 - 85	8 - 16	-	Montsec, Catalonia, Spain
2016 12 26 - 2017 01 18	9	71 - 74	10 - 15	T. Polakis, B. Skiff	Tempe, AZ, USA
2017 01 07	1	72	13	W. Ogłóza	Suhora, Poland
2019 06 27 - 2019 07 17	15	289 - 293	4 - 7	Pál et al. (2020)	TESS spacecraft
2020 07 23 - 2020 07 24	2	9	17	S. Fauvaud, F. Livet, J. J. Rives	Pic de Château-Renard, France
2020 08 10	1	9	15	M. Żejmo	Suhora, Poland
2020 08 20 - 2020 08 21	2	8 - 9	12 - 13	V. Kudak, V. Perig	Derenivka, Ukraine
2020 08 28 - 2020 09 16	9	4 - 8	7 - 11	Pilcher et al. (2021)	Organ Mesa Observatory, NM, USA
2020 09 20 - 2020 09 30	9	1 - 3	7	Polakis (2021b)	Tempe, AZ, USA
2020 11 29	1	355	17	W. Ogłóza	Adiyaman, Turkey
2021 09 07	1	86	20	A. Pál	Piszkéstető, Hungary
2021 09 12 - 2021 10 31	7	87 - 93	17 - 20	E. Pakštienė, R. Urbonavičiūtė	Molėtai Astronomical Observatory, Lithuania
2021 10 01 - 2021 12 04	9	89 - 93	9 - 20	A. Popowicz	Otívar, Spain
2021 10 30 - 2021 11 12	2	93	14 - 17	V. Kudak, V. Perig	Derenivka, Ukraine
2021 12 03 - 2021 12 05	3	89	9	M. Żejmo	e-Eye, Spain
439 Ohio					
1984 03 02 - 1984 03 05	4	192 - 193	9 - 10	Lagerkvist et al. (1987)	ESO, Chile
2014 08 21 - 2014 11 20	12	344 - 356	5 - 18	Marciniak et al. (2015)	Borowiec, Poland; Montsec, Spain; Winer, AZ, USA
2015 11 30 - 2015 12 09	6	74 - 76	8	F. Pilcher	Organ Mesa Observatory, NM, USA
2016 01 26 - 2016 01 27	2	67	17	K. Kamiński	Winer, AZ, USA
2017 03 09	1	166	5	A. Marciniak	CTIO, Chile
2017 03 14 - 2017 03 20	3	164 - 165	6 - 7	-	Montsec, Catalonia, Spain
2017 04 04	1	161	11	R. Hirsch	Borowiec, Poland
2018 04 22 - 2018 05 24	10	236 - 242	5 - 16	K. Żukowski, R. Hirsch, J. Skrzypek, J. Horbowicz	Borowiec, Poland
2018 05 31 - 2018 06 20	3	231 - 234	7 - 12	R. Szakáts, R. Könyves - Tóth	Piszkéstető, Hungary
2019 07 30 - 2019 10 15	7	303 - 310	7 - 18	R. Szakáts, B. Ignác,	Piszkéstető, Hungary
2019 08 08 - 2019 09 06	2	303 - 308	8 - 13	-	OAdM, Montsec, Catalonia, Spain
2019 09 14	1	302	14	J. Skrzypek	Borowiec, Poland
2020 08 15 - 2020 09 12	4	32	13 - 18	R. Szakáts	Piszkéstető, Hungary
2020 09 18 - 2020 09 19	2	31	11	W. Ogłóza	Suhora, Poland
2020 09 21	1	31	10	A. Marciniak	Borowiec, Poland
2020 09 24 - 2020 10 23	3	25 - 31	2 - 9	W. Ogłóza	Adiyaman, Turkey
2020 10 10	1	28	4	A. Jones	Maidenhead, UK
2021 12 01	1	125	17	M. Żejmo	e-Eye, Spain
2022 01 10	1	119	9	M. Komraus, L. Rogiński, K. Szyszka, S. Żywica	Piwnice, Poland
2022 03 27	1	112	19	K. Kamiński	Winer, AZ, USA

Date	N_{lc}	λ [deg]	Phase angle [deg]	Observer	Site
464 Megaira					
1979 10 28	1	29	8	Harris & Young (1989)	Table Mountain Observatory, USA
2007 09 11 - 2007 09 23	8	1 - 3	8 - 10	J. Oey	Australia
2010 04 02 - 2010 07 01	24	182 - 189	4 - 18	Waszczak et al. (2015)	Mt. Palomar, CA, USA
2014 02 18	1	145	3	J. Horbowicz	Borowiec, Poland
2015 04 22 - 2015 05 24	3	203 - 208	4 - 11	P. Kulczak, A. Marciniak	Borowiec, Poland
2015 05 20	1	204	10	M. Żejmo	Adiyaman, Turkey
2015 06 02 - 2015 06 16	5	201-202	14 - 17	K. Kamiński	Winer, AZ, USA
2015 06 17	1	201	17	-	Montsec, Catalonia, Spain
2016 04 27	1	299	22	S. Geier	ORM, La Palma, Spain
2016 05 24 - 2016 07 27	2	296 - 303	4 - 20	A. Marciniak	OT, Tenerife, Spain
2016 06 14	1	304	15	K. Kamiński	Winer, AZ, USA
2016 07 01 - 2016 07 16	5	299 - 302	3 - 9	-	Montsec, Catalonia, Spain
2016 08 26	1	291	16	A. Marciniak	CTIO, Chile
2017 09 17 - 2017 09 23	7	91 - 93	24	T. Polakis, B. Skiff	Tempe, AZ, USA
2017 10 18	1	97	22	J. Skrzypek	Borowiec, Poland
2017 10 28 - 2017 11 15	6	97 - 98	15 - 20	-	Montsec, Catalonia, Spain
2018 12 09 - 2019 01 11	2	171 - 173	15 - 17	R. Szakáts	Piszkéstető, Hungary
2019 01 05	1	173	16	R. Duffard, N. Morales	La Sagra, Spain
2019 02 17 - 2019 04 18	2	159 - 170	7 - 13	J. Skrzypek, M. Pawłowski	Borowiec, Poland
2019 02 28 - 2019 03 25	7	162 - 167	4 - 7	Pilcher (2019)	Organ Mesa Observatory, NM, USA
2019 03 12	1	165	4	E. Pakštienė	Molėtai Astronomical Observatory, Lithuania
2020 03 22	1	238	15	M.-Y. Kim, D.-H. Kim	SOAO, South Korea
2020 04 02 - 2020 04 29	2	233 - 237	6 - 13	R. Szakáts	Piszkéstető, Hungary
2020 04 17 - 2020 05 14	2	230 - 235	4 - 9	W. Ogłóża	Adiyaman, Turkey
476 Hedwig					
1982 03 27 - 1982 04 01	6	223	13 - 14	Schober & Schroll (1985)	-
2013 08 07 - 2013 12 27	12	321 - 336	5 - 22	K. Sobkowiak, A. Marciniak, R. Hirsch, D. Oszkiewicz	Borowiec, Poland
2014 09 17	1	77	21	P. Kankiewicz	Kielce, Poland
2014 10 05 - 2015 02 19	7	65 - 79	4 - 20	R. Hirsch, J. Horbowicz, M. Polińska, A. Marciniak	Borowiec, Poland
2014 10 18 - 2014 10 19	2	79	17	K. Kamiński	Winer, AZ, USA
2016 01 13 - 2016 03 27	7	157 - 169	10 - 17	-	Montsec, Catalonia, Spain
2016 01 20 - 2016 01 25	4	169	14 - 16	K. Kamiński	Winer, AZ, USA
2017 05 25 - 2017 06 03	2	285 - 286	13 - 16	K. Kamiński	Winer, AZ, USA
2017 06 19 - 2017 07 12	4	278 - 283	1 - 6	E. Jehin	TRAPPIST-S
2017 07 24	1	275	11	-	Montsec, Catalonia, Spain
2017 08 06	1	274	16	S. Geier	OT, Tenerife, Spain
2017 10 02	1	280	24	S. Geier	Kitt Peak, AZ, USA
2018 09 11	2	48	18 - 19	S. Fauvaud	Le Bois de Bardon Observatory, France
2018 09 09 - 2018 10 31	6	42 - 48	6 - 20	J. Skrzypek, R. Hirsch, A. Marciniak, M. K. Kamińska	Borowiec Observatory, Poland
2018 10 04 - 2018 10 04	2	47	13 - 14	S. Fauvaud, J. Michelet, F. Richard	Pic du Midi Observatory, France
524 Fidelio					
2005 10 25 - 2005 11 02	5	78 - 79	16 - 19	Koff (2006)	Antelope Hills Observatory, CO, USA
2013 09 30 - 2013 10 30	5	348 - 351	10 - 20	D. Oszkiewicz, R. Hirsch, A. Marciniak	Borowiec, Poland
2014 11 24 - 2015 04 21	4	126 - 137	7 - 23	A. Marciniak, K. Sobkowiak, J. Horbowicz	Borowiec, Poland
2015 02 17	1	127	8	V. Kudak, V. Perig	Derenivka, Ukraine
2015 02 18 - 2015 02 20	2	127	9	S. Fauvaud, C. Durandet, F. Livet, J. J. Rives	Pic du Midi Observatory, France
2016 04 26 - 2016 04 30	2	224	4 - 5	S. Geier	ORM, La Palma, Spain
2016 05 10 - 2016 05 23	2	218 - 221	5 - 9	S. Geier, A. Marciniak	OT, Tenerife, Spain
2017 08 03	1	314	2	S. Geier	OT, Tenerife, Spain
2017 10 06	1	307	21	S. Geier	ORM, La Palma, Spain
2017 10 31	1	311	23	A. Marciniak	CTIO, Chile
2018 09 28	1	96	26	M. Drózd	Suhora, Poland
2018 10 06	1	98	25	S. Fauvaud, J. Michelet, F. Richard	Pic du Midi Observatory, France
2018 10 17 - 2019 02 17	4	90 - 103	20 - 25	M. K. Kamińska, R. Hirsch, M. Pawłowski, J. Krajewski	Borowiec, Poland
2019 04 15	1	102	23	R. Szakáts	Piszkéstető, Hungary
530 Turandot					
1986 07 12 - 1986 07 27	3	318 - 320	5 - 12	di Martino et al. (1995)	ESO, La Silla, Chile
2002 04 19 - 2002 05 13	3	209 - 214	4 - 7	C. Demeautis	Village-Neuf Observatory, France
2005 01 04 - 2005 02 03	6	62	12 - 17	P. Antonini	Observatoire des Hauts Patys, France
2014 05 31 - 2014 06 30	16	265 - 271	3 - 8	Pilcher (2014)	Organ Mesa Observatory, NM, USA
2014 06 10 - 2014 06 22	4	267 - 269	3 - 5	-	Montsec, Catalonia, Spain
2015 09 20 - 2016 01 03	8	29 - 41	5 - 15	M. Butkiewicz - Bąk, P. Kulczak, A. Marciniak, R. Hirsch, K. Żukowski	Borowiec, Poland
2016 01 22 - 2016 02 03	4	33 - 36	19	K. Kamiński	Winer, AZ, USA
2016 12 07 - 2016 12 11	4	114	9 - 10	S. Fauvaud, M. Fauvaud, F. Richard	Pic du Midi Observatory, France
2016 12 09	1	114	9	S. Geier	ORM, La Palma, Spain
2018 01 26 - 2018 03 018	3	153 - 162	6 - 9	K. Kamiński	Winer, AZ, USA
2018 03 15	1	154	6	M. Drózd	Suhora, Poland
2019 06 02	1	217	14	V. Kudak, V. Perig	Derenivka, Ukraine
2019 04 01 - 2019 04 14	4	211 - 214	4 - 7	A. Marciniak, M. Pawłowski, K. Żukowski	Borowiec, Poland
2019 04 02	1	214	7	E. Pakštienė	Molėtai Astronomical Observatory, Lithuania
2019 04 02 - 2019 04 04	2	213 - 214	6 - 7	W. Ogłóża	Suhora, Poland
2019 05 09	1	206	7	M.-Y. Kim, D.-H. Kim	SOAO, South Korea

Date	N_{Ic}	λ [deg]	Phase angle [deg]	Observer	Site
551 Ortrud					
2006 11 10 - 2006 12 08	8	46 - 51	1 - 11	-	Super WASP
2015 06 30	1	302	7	A. Marciniak	OT, Tenerife, Spain
2015 07 07 - 2015 09 13	8	291 - 301	1 - 16	-	Montsec, Catalonia, Spain
2016 08 31 - 2016 11 25	15	21 - 33	8 - 18	Marciniak et al. (2018)	Borowiec, Poland; Organ Mesa, NM, USA; Tempe, AZ, USA
2018 01 08 - 2018 04 17	4	136 - 147	5 - 19	R. Hirsch, J. Skrzypek, A. Marciniak	Borowiec, Poland
2019 03 28 - 2019 04 29	10	224 - 229	2 - 12	-	OAdM, Montsec, Catalonia, Spain
2019 04 10	1	227	8	D.-H. Kim, M.-Y. Kim	SOAO, South Korea
2020 05 23 - 2020 05 25	2	297	14 - 15	K. Kamiński	Winer, AZ, USA
2019 05 24	1	219	7	K. Kamiński	Winer, AZ, USA
2020 07 17 - 2020 08 13	4	285 - 289	2 - 11	W. Ogłóza	Adiyaman, Turkey
2021 08 21 - 2021 10 11	33	13 - 20	0 - 16	-	TESS spacecraft
2021 12 06	1	8	19	M. Żejmo	e-Eye, Spain
566 Stereoscopia					
1990 02 24 - 1990 02 25	2	108	12	Binzel & Sauter (1992)	McDonald Observatory, TX, USA
2006 10 24 - 2006 11 16	6	328 - 331	17 - 19	D. J. Higgins	Australia
2017 09 12 - 2017 09 19	8	235 - 236	14 - 15	-	Kepler Spacecraft
2019 09 04 - 2019 10 01	3	25 - 28	6 - 14	M. Drózd	Suhora, Poland
2019 09 23 - 2019 11 04	3	19 - 27	5 - 9	W. Ogłóza	Adiyaman, Turkey
2020 01 23 - 2020 01 23	1	24	19	V. Kudak, V. Perig	Derenivka, Ukraine
2020 10 16 - 2021 01 10	4	106 - 113	1 - 18	W. Ogłóza	Adiyaman, Turkey
2020 11 04	1	113	17	A. Jones	Maidenhead, UK
2022 02 27 - 2022 03 20	3	166 - 170	2 - 4	E. Pakštienė, R. Urbonavičiūtė	Molėtai Astronomical Observatory, Lithuania
2022 03 01 - 2022 03 12	2	168 - 170	2 - 3	J. Golonka, M. Motyliński, K. Szyszka, B. Joachimczyk, A. Demirkol	Piwnice, Poland
2022 03 26	1	165	6	A. Jones	Maidenhead, UK
2022 04 22	1	162	12	W. Ogłóza	Adiyaman, Turkey
657 Gunlod					
1984 02 09	1	121	8	Binzel (1987)	McDonald Observatory, TX, USA
2015 07 03	1	323	14	A. Marciniak	OT, Tenerife, Spain
2015 08 04	1	317	3	M. Żejmo	Adiyaman, Turkey
2015 09 05 - 2015 09 13	4	310 - 311	11 - 14	-	Montsec, Catalonia, Spain
2016 10 05	1	51	13	A. Marciniak	ORM, La Palma, Spain
2016 10 07 - 2016 10 09	2	50	12	R. Szakáts	Piszkéstető, Hungary
2016 10 08 - 2016 10 10	2	50	12	R. Duffard, N. Morales	La Sagra, Spain
2016 12 27	1	37	18	M.-J. Kim, D.-H. Kim	SOAO, South Korea
2018 02 26 - 2018 04 21	5	153 - 160	5 - 22	K. Żukowski, J. Skrzypek	Borowiec, Poland
2020 10 09 - 2021 02 04	2	26 - 27	6 - 19	R. Szakáts	Piszkéstető, Hungary
2020 10 21	1	23	6	K. Kamiński	Winer, AZ, USA
2020 10 22 - 2020 10 27	3	22 - 23	6 - 7	W. Ogłóza	Suhora, Poland
2020 10 24	1	23	6	W. Ogłóza	Adiyaman, Turkey
2021 10 21 - 2021 11 28	16	126 - 135	22 - 23	-	TESS spacecraft
2021 11 13	1	132	23	M. Drózd	Suhora, Poland
2021 12 13 - 2022 01 11	2	133 - 136	9 - 19	M. Żejmo	e-EYE, Spain
2021 12 29	1	135	14	E. Pakštienė, R. Urbonavičiūtė	Molėtai Astronomical Observatory, Lithuania
2022 01 06 - 2022 01 07	2	134	10 - 11	D.-H. Kim, M.-J. Kim	SOAO, South Korea
738 Alagasta					
2015 06 05 - 2015 06 09	2	244 - 245	3 - 5	-	Montsec, Catalonia, Spain
2015 06 11 - 2015 07 04	7	241 - 244	6 - 13	W. Ogłóza, M. Winiarski	Suhora, Poland
2015 07 20	1	240	17	M. Żejmo	Adiyaman, Turkey
2016 09 06 - 2016 09 11	2	323 - 324	6 - 8	-	Montsec, Catalonia, Spain
2016 09 20 - 2016 10 06	4	321 - 322	11 - 14	J. Licandro, A. Marciniak	ORM, La Palma, Spain
2016 10 29	1	322	17	A. Marciniak	CTIO, Chile
2017 10 15 - 2017 12 09	9	36 - 47	3 - 12	-	Montsec, Catalonia, Spain
2018 12 05 - 2019 02 24	2	120 - 132	12 - 17	K. Żukowski, M. Pawłowski	Borowiec, Poland
2019 01 05 - 2019 02 11	4	122 - 129	6 - 8	M.-Y. Kim, D.-H. Kim	SOAO, South Korea
2019 01 10	1	128	6	V. Kudak, V. Perig	Derenivka, Ukraine
2020 03 16 - 2020 04 23	4	221 - 226	3 - 15	R. Szakáts	Piszkéstető, Hungary
2020 04 18 - 2020 06 13	4	214 - 222	3 - 15	W. Ogłóza	Adiyaman, Turkey

Date	N_{lc}	λ [deg]	Phase angle [deg]	Observer	Site
806 Gyldenja					
2010 07 25 - 2010 12 08	9	38 - 47	4 - 18	Waszczak et al. (2015)	Mt. Palomar, CA, USA
2013 03 05 - 2013 05 08	9	210 - 211	2 - 15	Marciniak et al. (2015)	Borowiec, Poland; Organ Mesa Observatory, NM, USA
2013 04 07 - 2013 04 18	9	212 - 214	2 - 6	Alkema (2013)	-
2015 06 28	1	0	17	A. Marciniak	OT, Tenerife, Spain
2015 09 11 - 2015 11 01	5	348 - 356	5 - 13	-	Montsec, Catalonia, Spain
2015 11 12	1	348	15	R. Duffard, N. Morales	La Sagra, Spain
2016 10 04	1	67	15	A. Marciniak	ORM, La Palma, Spain
2016 10 07 - 2016 10 09	3	67	14	R. Szakáts	Piszkéstető, Hungary
2016 10 11 - 2016 10 30	3	65 - 67	8 - 13	R. Duffard, N. Morales	LaSagra, Spain
2016 10 29	1	65	8	A. Marciniak	CTIO, Chile
2018 02 13	1	143	7	M.-Y. Kim, D.-H. Kim	SOAO, South Korea
2018 02 13 - 2018 03 19	4	138 - 143	7 - 14	J. Skrzypek, R. Hirsch	Borowiec, Poland
2018 03 17	1	138	13	K. Kamiński	Winer, AZ, USA
2019 04 30 - 2019 05 21	4	230 - 234	3 - 5	K. Kamiński	Winer, AZ, USA
2019 05 06 - 2019 05 07	2	233	2	D.-H. Kim, M. -Y. Kim	SOAO, South Korea
2020 09 17 - 2020 09 20	5	299	14 - 15	F. Monteiro, W. Mesquita, W. Pereira, M. Evangelista, E. Rondón, J. Michimani, D. Lazzaro, T. Rodrigues	OASI, Itacuruba, Brasil
2021 09 08 - 2021 11 25	4	4 - 15	8 - 15	M. Drózd	Suhora, Poland

(70) Panopaea, 2006-12-14		(275) Sapientia, 2015-09-30	
S. Herchak	Mesa, AZ	C. Hills	GB
B. Roberts	Shady Grove, MS	S. Clarke	GB
B. Richardson	Hewitt, TX	J. Warell	SE
J. Barton	Robinson, TX	C. Hooker	GB
R. Nugent	Centerville, TX	S. Kidd	GB
D. Craig Smith	Ozona, TX	T. Haymes	GB
M. McCants	Oakalla, TX	A. Jones	GB
D. Dunham	McComb, MS	M. Charron	GB
W. Aulenbacher	L. Bunshannon, TX	D. Arditti	GB
D. Nye	Marfa, TX	H. Paulus	DE
P. Maley	Madisonville, TX	T. Law	GB
D. Rask	Huntsville, TX	H. Denzau	DE
D. Clark	Providence, TX	P. Denyer	GB
K. Drake	Willis, TX	P. Carson	GB
P. Nolan	Mountain Home, TX	M. Jennings	GB
A. Sanchez-Ibarra	Sonora, MX	E. Edens	NL
B. Cudnik	Houston, TX		
R. Frankenberger	San Antonio, TX		
(70) Panopaea, 2014-10-04		(275) Sapientia, 2016-12-03	
J. Broughton	Eagleby, AU	O. Klös	DE
G. Bolt	Perth, AUS	V. Přibáň	CZ
		K. Halíř	CZ
		M. Rottenborn	CZ
		J. Polák	Cz
(70) Panopaea, 2014-04-25		(275) Sapientia, 2018-08-06	
A. Olsen	Urbana, IL	G. Vaudescal, A. Cazaux	FR
P. Maley	Marana, AZ	P. Lindner	DE
J. Moore	Blackwell, OK	C. Schnabel	ES
		B. Kattentidt	DE
		G. Dangel	AT
		J. Polák	CZ
(275) Sapientia, 1985-04-15		(275) Sapientia, 2020-11-14	
A. Olsen	Urbana, IL	G. Vaudescal	FR
P. Maley	Marana, AZ	E. Frappa, A. Klotz	FR
J. Moore	Blackwell, OK	M. Conjat	FR
		A. Manna	CH
		S. Sposetti	CH
		G. Casalnuovo	IT
		A. Kreutzer, R. Schäfer	AT
		M. Billiani	FR
(275) Sapientia, 2003-02-08		(275) Sapientia, 2021-04-26	
R. Venable	Pelham, USA	T. George	Scottsdale, AZ
D. Rowley	North Henderson, NC	P. Stuart	Clear Lake Shores, TX
		S. Brazill	Georgetown, TX
(275) Sapientia, 2003-04-12		(286) Iclea, 2008-06-15	
J. Nosaka	Masuda: Shimane, JP	D. Lowe	Mt. Mee, AU
M. Uchiyama	Owase: Mie, JP	J. Bradshaw, A. Beck	Samford, AU
I. Yamanihi, Naoko Kaifu et al	JP	P. Anderson	The Gap, Qld, AU
M. Yamanishi	Yuasa: Wakayama, JP	D. Breadsell	Toowoomba, AU
(275) Sapientia, 2014-09-02		(326) Tamara, 2016-09-23	
J. Rovira	ES	J. Broughton	Reedy Creek, AU
J. Juan	ES	J. Broughton	Brunswick Heads, AU
E. Frappa, A. Klotz	FR	J. Broughton	Ballina, AU
C. Perelló, A. Selva	ES	J. Broughton	Broadwater, AU
P. Baruffetti	IT		
M. Bachini	IT		

Table A.2: List of stellar occultation observers and locations of their observing sites. Source: Occult programme.

(326) Tamara, 2017-09-15		(426) Hippo, 2018-05-21	
D. Breit	Morgan Hill, CA	J. Broughton	Tumbulgum, AU
R. Nolthenius	Paicine, CA	J. Broughton	Brunswick Heads, AU
J. Bardecker	Gardnerville, NV	J. Broughton	Ballina, AU
(326) Tamara, 2017-12-28		(426) Hippo, 2021-12-27	
H. De Groot	NL	H. Yoshihara	Soja, Okayama, JP
E. Conseil	FR	M. Yamashita	Ikedo, Osaka, JP
T. Janík	CZ	T. Goto	Yamada Higashi, JP
R. Boninsegna	BE	M. Higuchi	Shigokamachi, JP
(326) Tamara, 2018-05-12		M. Nishimura	Kitakuzuhacho, JP
B. Leonard	Sherman, TX	H. Kasebe	Osaka, JP
M. Smith	Sherman, TX	A. Asai	Kuwana, Mie, JP
K. Cobble	Princeton, TX	A. Hashimoto	Chichibu, Saitama, JP
(326) Tamara, 2018-12-21		H. Watanabe, H. Watanabe	Tsu, Mie, JP
A. Manna	CH	M. Ishida	Tsu, Mie, JP
S. Sposetti	CH	R. Aikawa	Sakado, Saitama, JP
(412) Elisabetha, 2011-01-23		M. Ida	Tsu, Mie, JP
M. Ida	Higashiomi, Shiga, JP	R. Kukita	Nabekura, JP
M. Ishida	Koka, Shiga, JP	T. Horaguchi	Tsukuba, JP
A. Asai	Inabe, Mie, JP	K. Fukui	Nagakunidai, JP
H. Watanabe et al	Inabe, mie, JP	K. Kouno	Miyazaki, JP
M. Owada	Hamamatsu, Shizuoka, JP	K. Terakubo	Kokubunji, Tokyo, JP
(412) Elisabetha, 2016-03-17		K. Kitazaki	Musashino, Tokyo, JP
P. Delincak	SK	S. Uchiyama	Kashiwa, Chiba, JP
B. Gährken	DE	T. Hirose	Ohtaku, Tokyo, JP
M. Korec	SK	M. Owada	Hamamatsu, Shizuoka, JP
(412) Elisabetha, 2017-03-19		(426) Hippo, 2021-12-31	
A. Ossola	CH	A. Selva	ES
A. Manna	CH	J. Juan	ES
(412) Elisabetha, 2019-12-04		C. Schnabel	ES
P. Baruffetti	IT	(426) Hippo, 2022-03-23	
S. Donati	IT	J. Mánek	CZ
(426) Hippo, 2012-01-13		J. Kubánek	CZ
D. Ewald	DE	K. Halří	CZ
G. Wortmann, K. Walzel	DE	M. Rottenborn	CZ
W. Rothe	DE	J. Polák	CZ
O. Canales, F. Campos	ES	E. Kowald	AT
E. Frappa, M. Lavayssière	FR	B. Kattentidt	DE
P. Lindner	DE	(439) Ohio, 2017-05-27	
C. Schnabel, J. Juan	ES	D. Gault	Hawkesbury Heights, AU
J. Rovira	ES	T. Barry	Penrith, AU
A. Selva	ES	D. Herald	Murrumbateman:nsw, AU
(426) Hippo, 2015-06-20		J. Newman	Flynn:act, AU
R. Baldridge	Los Altos Hills, CA	(439) Ohio, 2022-03-11	
T. Swift	Davis, CA	P. Zelený	CZ
J. Bardecker	Gardnerville, NV	P. Delincak	SK
C. McPartlin	Santa Barbara, CA	M. Urbanik	SK
		M. Zawilski	PL
		L. Benedyktowicz	PL
		M. Borkowski	PL
		M. Filipek	PL
		M. Harman	SK
		D. Błażewicz	PL

(439) Ohio, 2022-03-24	
O. Schreurs	BE
B. Goffin	BE
R. Boninsegna, P. Assoignon	BE
K. Guhl	DE
O. Hofschulz	DE
S. Andersson	DE
J. Delpau	FR
M. Borkowski	PL
A. Marciniak	PL

(464) Megaira, 2017-12-06	
G. Lyzenga	Altadena, CA
J. Moore	Tulsa, OK
C. Ellington	Edmond, OK
P. Maley	Congress, AZ

(464) Megaira, 2017-12-18	
H. Tomioka	Hitachi, Ibaraki, JP
H. Watanabe	Tarui, Gifu, JP
S. Uchiyama	Hamamatsu, Shizuoka, JP
A. Asai	Inabe, Mie, JP
H. Watanabe	Inabe, Mie, JP
M. Owada	Hamamatsu, Shizuoka, JP
M. Ishida	Moriyama, Shiga, JP
Y. Ikari	Moriyama, Shiga, JP
T. Ito	Suzuka, Mie, JP
H. Yamamura	Tsu, Mie, JP
M. Ida	Tsu, Mie, JP

(476) Hedwig, 2000-11-07	
N. Quinn	GB
J. Moellmann	DE
D. Ewald	DE
N. Wünsche	DE
M. Dentel	DE
S. Andersson, M. Haupt	DE
P. Enskonatus	DE
J. A. Berdejo	ES
J. Grados	ES

(476) Hedwig, 2017-02-24	
B. Loader	Nelson, NZL
G. McKay	Blenheim

(476) Hedwig, 2018-07-26	
P. Delincak	SK
J. Kubánek	HU
M. Jarmoc	PL

(476) Hedwig, 2018-11-13	
C. Perelló, A. Selva	ES
C. Perelló, A. Selva	ES
J. Rovira	ES
J. Rovira	ES
S. Meister	CH
A. Ossola	CH
S. Sposetti	CH
J. Polák	CZ
M. Rottenborn	CZ
C. Weber	DE
C. Weber	DE

(476) Hedwig, 2019-02-12	
E. Frappa	FR
M. Conjat	FR

(476) Hedwig, 2020-05-19	
P. Le Cam	FR
E. Frappa	FR
E. Frappa, A. Klotz	FR

(524) Fidelio, 2005-12-11	
R. Gonçalves	PT
O. Canales, J. L. Marco	ES
R. Poncy	FR
P. Bernascolle	FR

(524) Fidelio, 2006-04-24	
H. Denzau	DE
W. Rothe	DE
T. Janík	CZ
V. Přibán	CZ
J. Vilagi, L. Kornos	SK
G. Dengl	AT
E. Frappa, A. Klotz	Tarot, Calern, FR
J. Lecacheux	FR

(524) Fidelio, 2018-12-12	
E. Frappa, A. Klotz	Grasse, FR
R. Venable	Lovejoy, GA
R. Venable	Griffin, GA
R. Venable	Barnesville, GA
V. Tsamis, A. Tserionis et al.	Ellinogermaniki, GR

(524) Fidelio, 2019-02-25	
R. Reeves	Parker, AZ
P. Maley	Dateland, AZ

(524) Fidelio, 2021-07-13	
J. Newman	Flynn, Act, AU
W. Hanna	Yass, Nsw AU

(524) Fidelio, 2021-11-18	
R. Venable	Chester, GA
R. Venable	Tarversville, GA

(530) Turandot, 2006-02-24	
S. Jamieson	Eagle, WI
S. Ballaron	Lake Villa, IL
C. Bueter	Gas City, IN
D. Drake	Indian Head Park, IL
D. Dunham	Gaston, IN
G. Samolyk	Shirland, IL
B. Oldham	Pelham, NC
D. Oesper	Dodgeville, WI
S. Messner	Harvest Moon Obs, MN
R. Huziak	Saskatoon:sk, CAN
P. Maley et al	Cincinnati, OH
D. Dunham	Fisher, IN
J. Armor	Villa Hilles, KY
M. Hoskinson	Vilna Alberta, CAN
G. Stone	Lorborn:sk, CAN
D. Carton	Dark Sky Obs, CAN
O. Piechowski	Versailles, KY
D. Breit	Martinez, CA

(530) Turandot, 2019-04-01	
P. Maley	Carefree, AZ
T. George	Scottsdale, AZ
W. Thomas	Florence, AZ
(530) Turandot, 2020-07-27	
S. Preston	Medina, WA
D. Gamble	Summerland, BC
(551) Ortrud, 2021-07-11	
A. Asai	Inabe, Mie, JP
H. Yamamura	Suzuka, Mie, JP
K. Isobe	Uda, Mie, JP
A. Hashimoto	Chichibu, Saitama, JP
M. Owada	Hammatsu, Shizuoka, JP
(551) Ortrud, 2021-10-24	
J. Barton	Robinson, TX
D. Eisfeldt	Waco, TX
(566) Stereoscopia, 2004-03-23	
T. Janík	CZ
D. Naillon	FR
H. McGee	GB
A. Christou, D. Asher	GB
J. Lecacheux	FR
T. Midavaine, O. Dechambre et al	FR
B. Christophe, J. M. Vugnon	FR
L. Parmeggiani	FR
G. Kirby	GB
(566) Stereoscopia, 2010-12-28	
H. Tomioka	Hitachi, Ibaraki, JP
R. Aikawa	Sakado, Saitama, JP
K. Kitazaki	Musashino, Tokyo, JP
M. Owada	Hamamatsu, Shizuoka, JP
H. Watanabe	Inabe, Mie, JP
(566) Stereoscopia, 2020-09-13	
H. Watanabe	Tarui: Gifu, JP
H. Yamamura	Wanouchi: Gifu, JP
A. Asai	Inabe: Mie, JP
(566) Stereoscopia, 2021-04-08	
R. Boninsegna	BE
K. L. Bath	DE
S. Meister	CH
M. Simon	DE
W. Hasubick	DE
G. Krannich	DE
B. Gährken	DE
B. Kattentidt	DE

(566) Stereoscopia, 2022-02-08	
P. Ceravolo	Osoyoos, CAN
V. Nikitin	Boulder, CO
S. Messner	Jefferson, TX
M. Skrutskie	Nederland, CO
(657) Gunlod, 2022-02-09	
J. J. Castellani	FR
P. Baruffetti	IT
M. Conjat	FR
M. Conjat	FR
G. Vaudescal	FR
Y. Argentin	FR
P. Fini	IT
(738) Alagasta, 2017-11-12	
M. Kashiwagura	Ōe, Yamagata, JP
H. Togashi	Ōe, Yamagata, JP
I. Otsuki	Date, Fukushima, JP
K. Hosoi	Miharu, Fukushima, JP
A. Hashimoto	Ono, Fukushima, JP
H. Yamamura	Hodatsushimizu, Ishikawa, JP
M. Ida	Kahoku, Ishikawa, JP
M. Ishida	Kanazawa, Ishikawa, JP
H. Tomioka	Hitachi, Ibaraki, JP
A. Yaeza	Hitachi, Ibaraki, JP
A. Asai	Inabe, Mie, JP
H. Watanabe	Inabe, Mie, JP
Y. Ikari	Moriyama, Shiga, JP
(738) Alagasta, 2020-05-30	
J. Bourgeois	BE
F. Van Den Abbeel	BE
O. Schreurs, E. Fernandez	BE
J. M. Winkel	NL
J. Polák	CZ
M. Rottenborn	CZ
J. Kubánek	CZ
(738) Alagasta, 2022-11-12	
K. Kitazaki	Musashino, Tokyo, JP
Ha. Watanabe, Hi. Watanabe	Tamaki, JP
M. Owada	Hamamatsu, Shizuoka, JP
H. Matsushita	Shima, Mie, JP
N. Manago	Kamitonda, Wakayama, JP
(806) Gyldenla, 2021-08-20	
W. Thomas	Florence, AZ
P. Maley	Toltec, AZ
S. Messner	Hudson, WI

Appendix B: Lightcurves

Composite lightcurves presenting new data for target asteroids. (Figures B.1 - B.77).

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- ⁵ CSFK, MTA Centre of Excellence, Budapest, Konkoly Thege Miklós út 15-17, H-1121, Hungary
- ⁶ MTA CSFK Lendület Near-Field Cosmology Research Group
- ⁷ ELTE Eötvös Loránd University, Institute of Physics, 1117, Pázmány Péter sétány 1/A, Budapest, Hungary
- ⁸ Astronomy Department, Eötvös Loránd University, Pázmány P. s. 1/A, H-1171 Budapest, Hungary
- ⁹ Observatório Nacional, R. Gen. José Cristino, 77 - São Cristóvão, 20921-400, Rio de Janeiro - RJ, Brazil
- ¹⁰ EURASTER, 8 rue du Tonnelier, 46100 Faycelles, France
- ¹¹ International Occultation Timing Association/European Section, Am Brombeerhag 13, 30459, Hannover, Germany
- ¹² International Occultation Timing Association (IOTA), PO Box 7152, WA, 98042, USA
- ¹³ Institute of Theoretical Physics and Astronomy, Vilnius University, Saulėtekio al. 3, 10257 Vilnius, Lithuania
- ¹⁴ Japanese Occultation Information Network
- ¹⁵ Geneva Observatory, CH-1290 Sauverny, Switzerland
- ¹⁶ Les Engarouines Observatory, F-84570 Mallemort-du-Comtat, France
- ¹⁷ Association T60, Observatoire Midi-Pyrénées, 14, avenue Edouard Belin, 31400 Toulouse, France
- ¹⁸ Collonges Observatory, F-74160 Collonges, France
- ¹⁹ Institute of Astronomy, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University in Toruń, ul. Grudziądzka 5, 87-100 Toruń, Poland
- ²⁰ Departamento de Sistema Solar, Instituto de Astrofísica de Andalucía (CSIC), Glorieta de la Astronomía s/n, 18008 Granada, Spain
- ²¹ Observatoire du Bois de Bardou, 16110 Taponnat, France
- ²² Arecibo Observatory, University of Central Florida, HC-3 Box 53995, Arecibo, PR 00612, USA
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- ²⁴ Gran Telescopio Canarias (GRANTECAN), Cuesta de San José s/n, E-38712, Breña Baja, La Palma, Spain
- ²⁵ Open University, School of Physical Sciences, The Open University, MK7 6AA, UK
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- ²⁹ British Astronomical Association, Burlington House, Piccadilly, Mayfair, W1J 0DU, London, UK
- ³⁰ Institute of Physics, Jan Kochanowski University, ul. Uniwersytecka 7, 25-406 Kielce
- ³¹ Chungbuk National University, 1, Chungdae-ro, Seowon-gu, Cheongju-si, Chungcheongbuk-do, Republic of Korea
- ³² Korea Astronomy and Space Science Institute, 776 Daedeok-daero, Yuseong-gu, Daejeon 34055, Korea
- ³³ Laboratory of Space Researches, Uzhhorod National University, Daleka st. 2a, 88000, Uzhhorod, Ukraine
- ³⁴ Departamento de Astrofísica, Universidad de La Laguna - ULL, Tenerife, Spain
- ³⁵ NASA Johnson Space Center Astronomical Society, Houston, TX USA
- ³⁶ Blue Mountains Observatory, Leura, Australia
- ³⁷ Organ Mesa Observatory, 4438 Organ Mesa Loop, Las Cruces, New Mexico 88011 USA
- ³⁸ Command Module Observatory, 121 W. Alameda Dr., Tempe, AZ 85282 USA
- ³⁹ Silesian University of Technology, Department of Electronics, Electrical Engineering and Microelectronics, Akademicka 16, 44-100 Gliwice, Poland
- ⁴⁰ Lowell Observatory, 1400 West Mars Hill Road, Flagstaff, Arizona, 86001 USA
- ⁴¹ Department of Astronomy, University of Virginia, Charlottesville, VA, 22904 USA
- ⁴² Department of Physics, Adiyaman University, 02040 Adiyaman, Turkey
- ⁴³ Observatory, Vsetínská 78, Valašské Meziříčí, Czechia
- ⁴⁴ Kepler Institute of Astronomy, University of Zielona Góra, Lubuska 2, 65-265 Zielona Góra, Poland

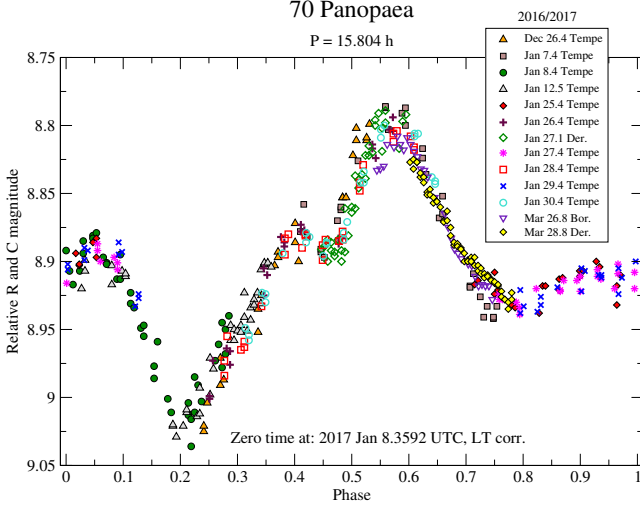


Fig. B.1: Composite lightcurve of (70) Panopaea from the years 2016-2017.

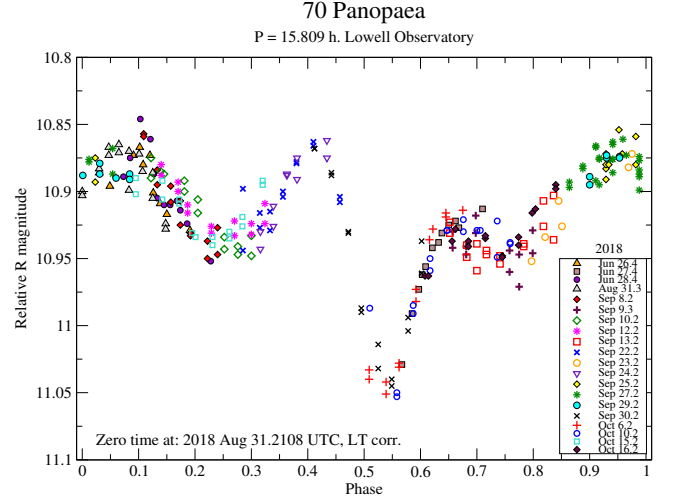


Fig. B.2: Composite lightcurve of (70) Panopaea from the year 2018.

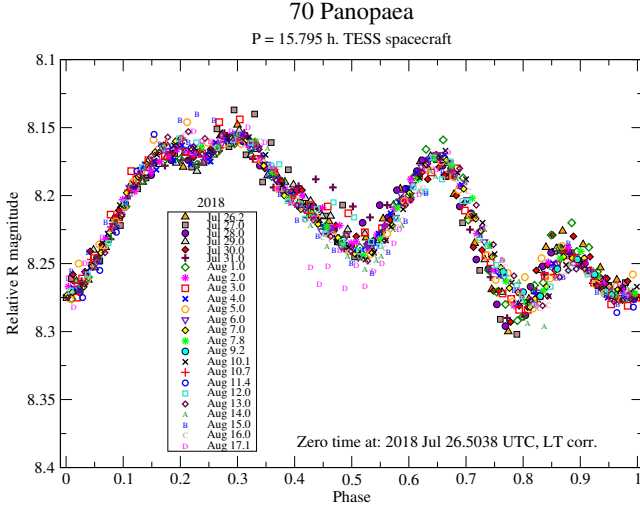


Fig. B.3: Composite lightcurve of (70) Panopaea from the year 2018 observed by TESS spacecraft.

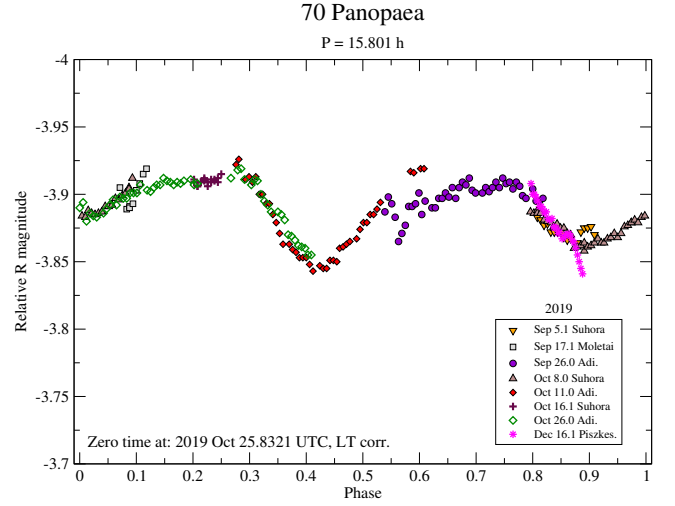


Fig. B.4: Composite lightcurve of (70) Panopaea from the year 2019.

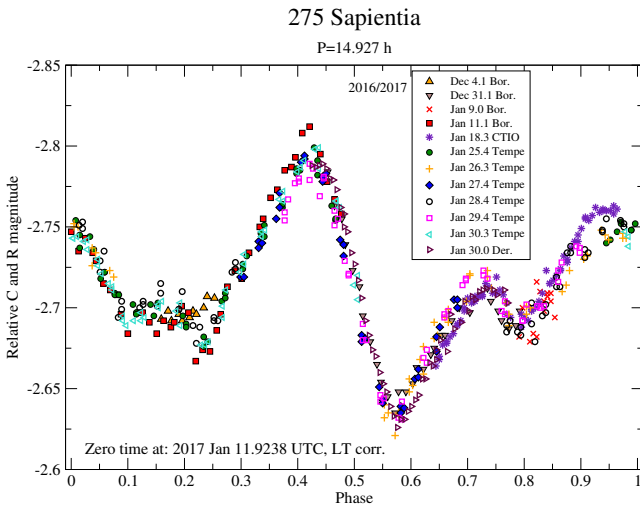


Fig. B.5: Composite lightcurve of (275) Sapiientia from the years 2016-2017.

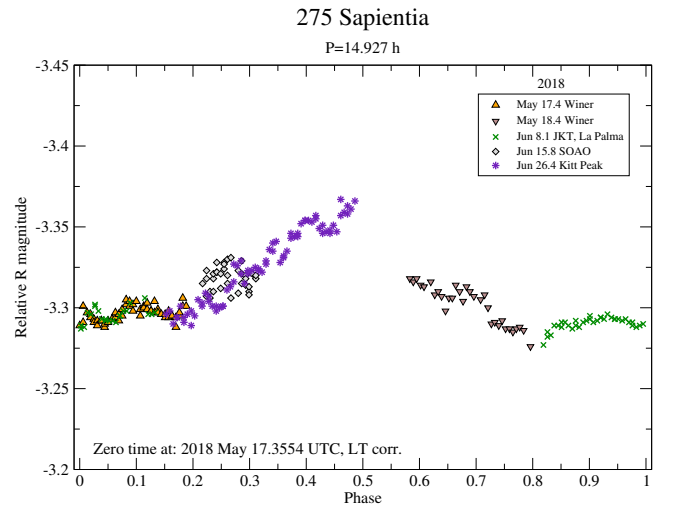


Fig. B.6: Composite lightcurve of (275) Sapiientia from the year 2018.

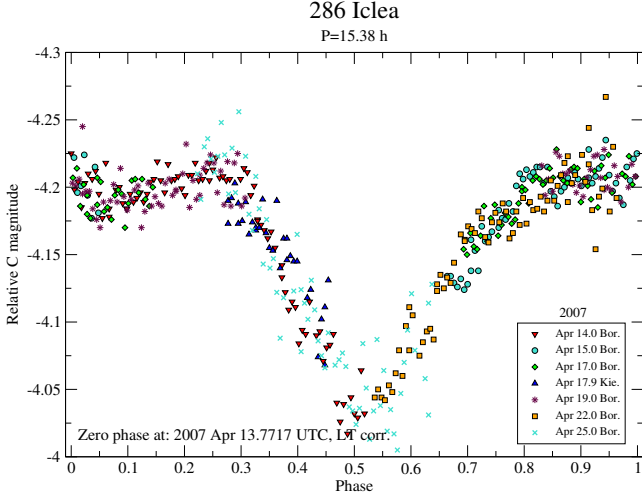


Fig. B.7: Composite lightcurve of (286) Iclea from the year 2007.

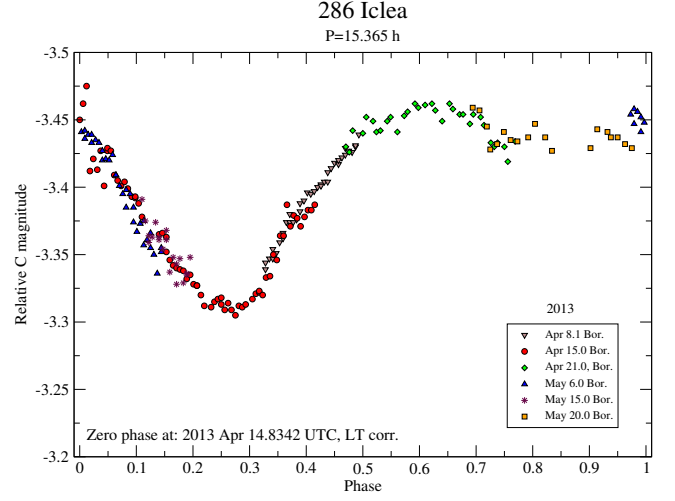


Fig. B.8: Composite lightcurve of (286) Iclea from the year 2013.

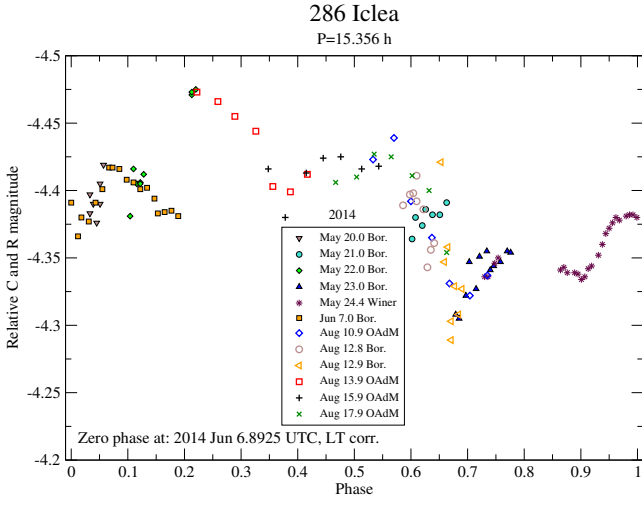


Fig. B.9: Composite lightcurve of (286) Iclea from the year 2014.

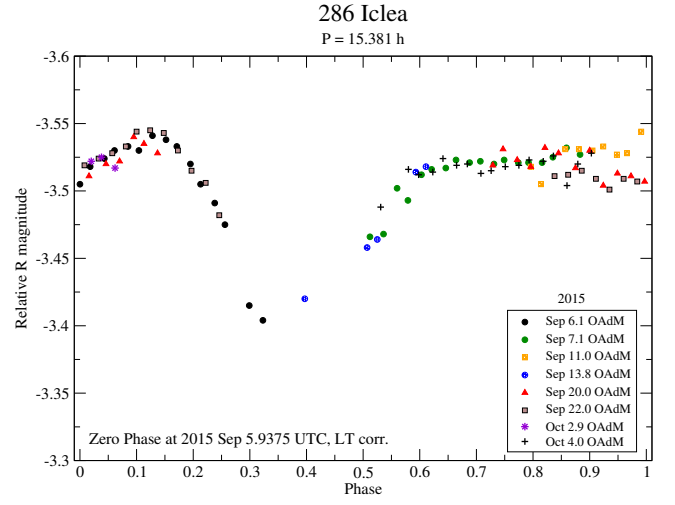


Fig. B.10: Composite lightcurve of (286) Iclea from the year 2015.

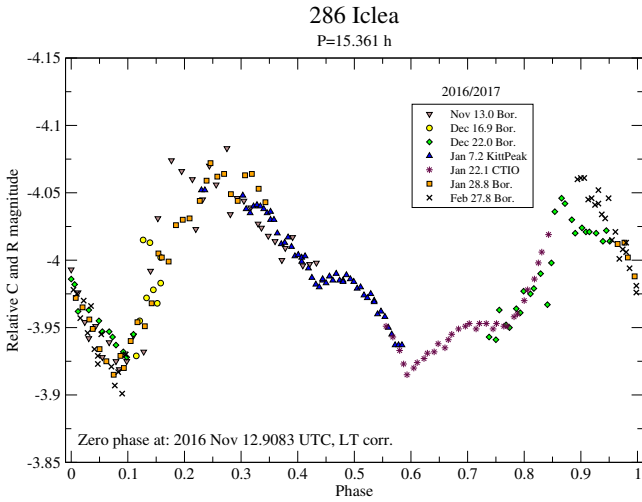


Fig. B.11: Composite lightcurve of (286) Iclea from the years 2016-2017.

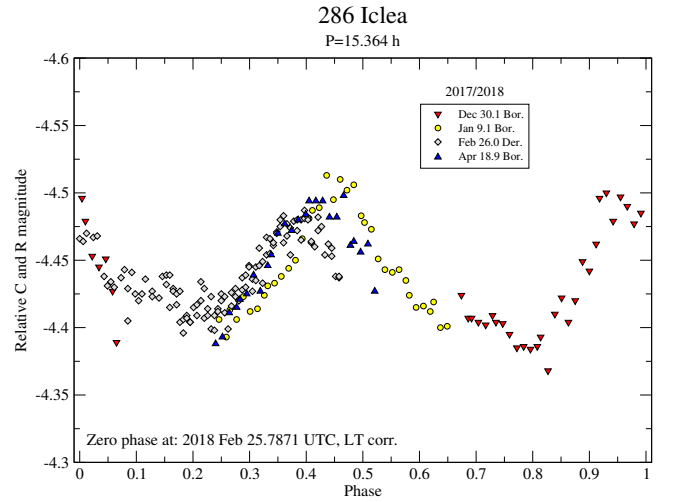


Fig. B.12: Composite lightcurve of (286) Iclea from the years 2017-2018.

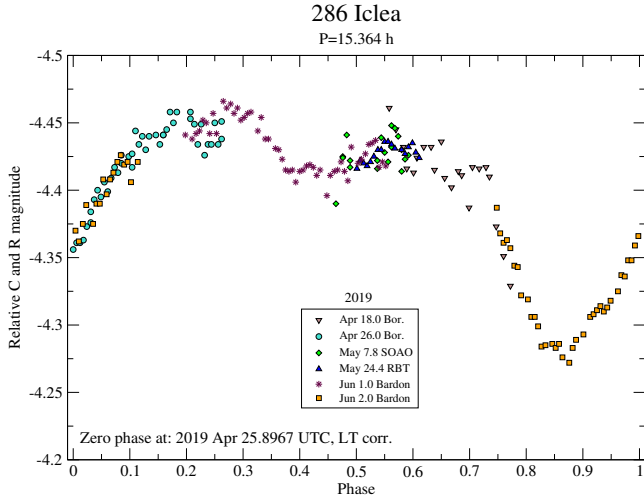


Fig. B.13: Composite lightcurve of (286) Iclea from the year 2019.

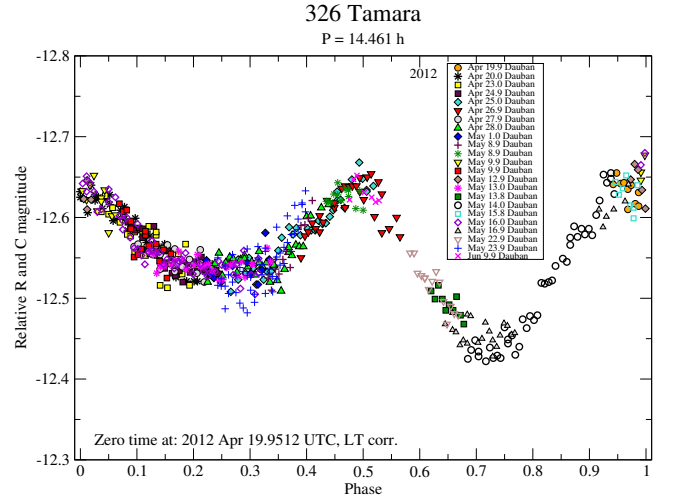


Fig. B.14: Composite lightcurve of (326) Tamara from the year 2012.

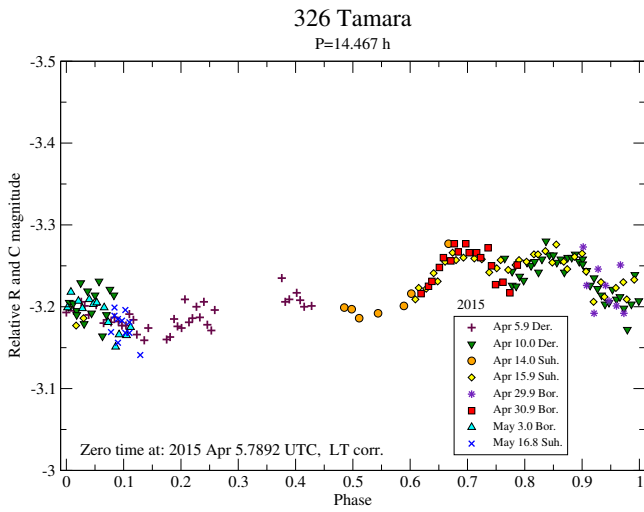


Fig. B.15: Composite lightcurve of (326) Tamara from the year 2015.

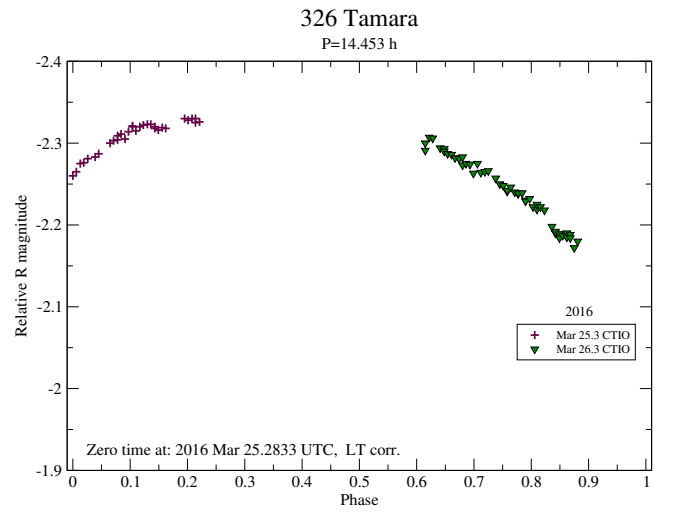


Fig. B.16: Composite lightcurve of (326) Tamara from March 2016.

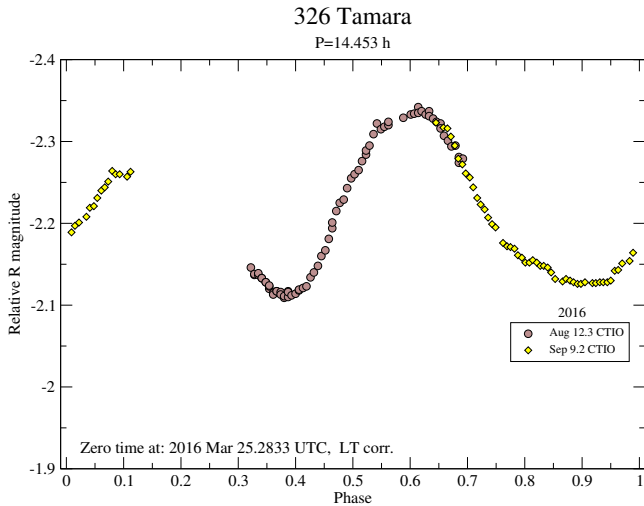


Fig. B.17: Composite lightcurve of (326) Tamara August-September 2016.

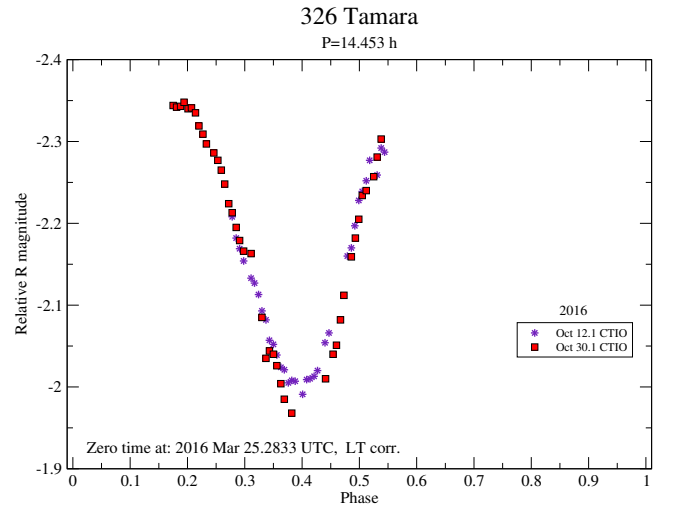


Fig. B.18: Composite lightcurve of (326) Tamara from October 2016. Data in 2016 were gathered in greatly varied phase angles and ecliptic longitudes, disabling creation of one composite lightcurve (see Fig. B.16, and B.17).

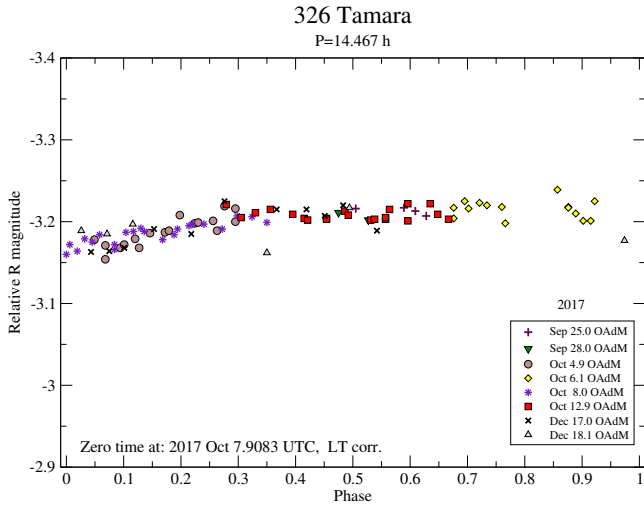


Fig. B.19: Composite lightcurve of (326) Tamara from the year 2017.

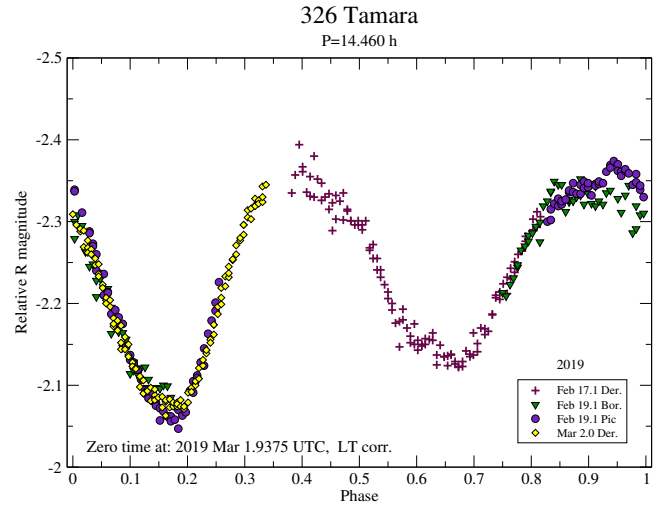


Fig. B.20: Composite lightcurve of (326) Tamara from the year 2019.

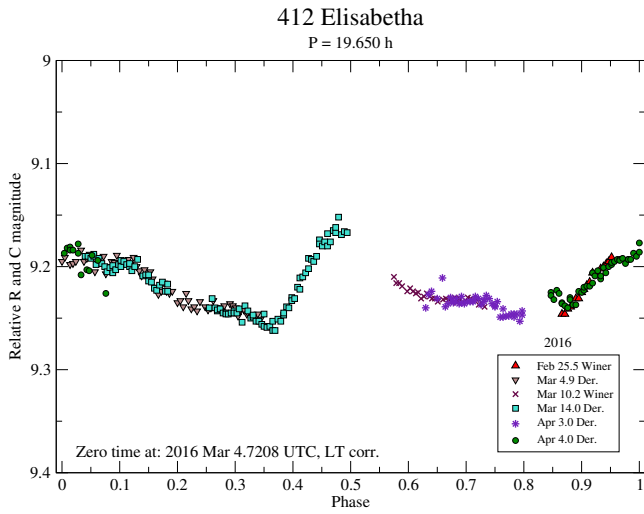


Fig. B.21: Composite lightcurve of (412) Elisabetha from the year 2016.

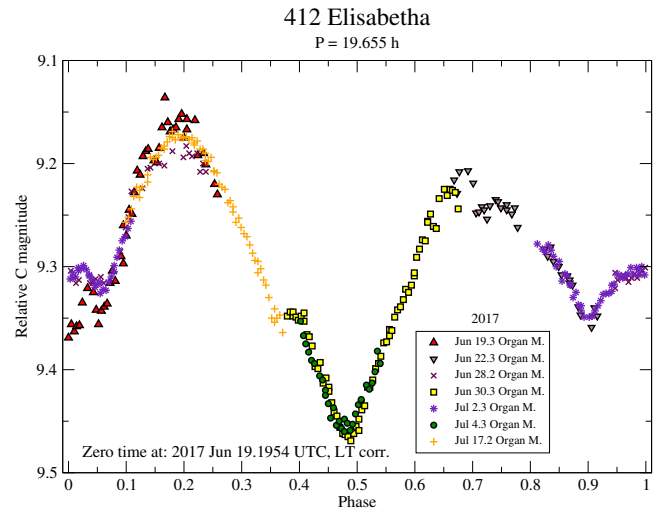


Fig. B.22: Composite lightcurve of (412) Elisabetha from the year 2017.

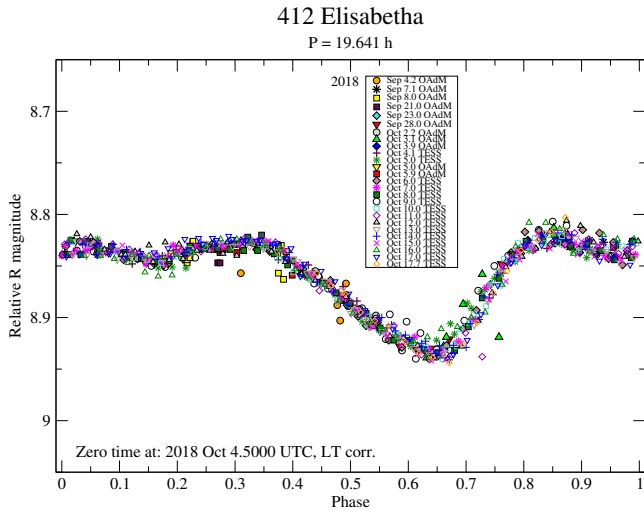


Fig. B.23: Composite lightcurve of (412) Elisabetha from the year 2018.

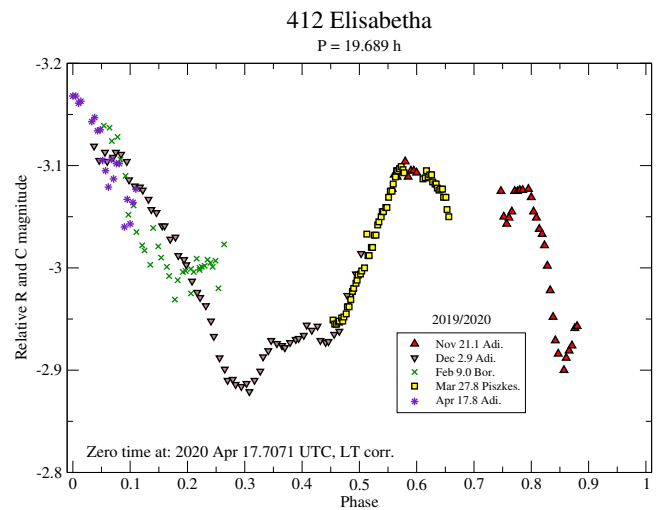


Fig. B.24: Composite lightcurve of (412) Elisabetha from the years 2019-2020.

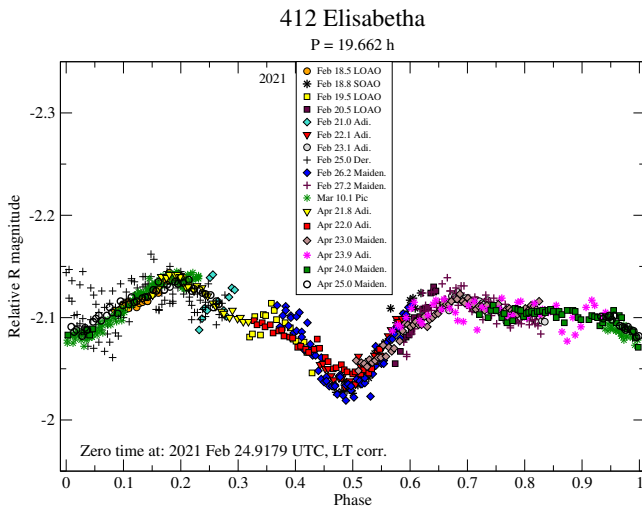


Fig.B.25: Composite lightcurve of (412) Elisabetha from the year 2021.

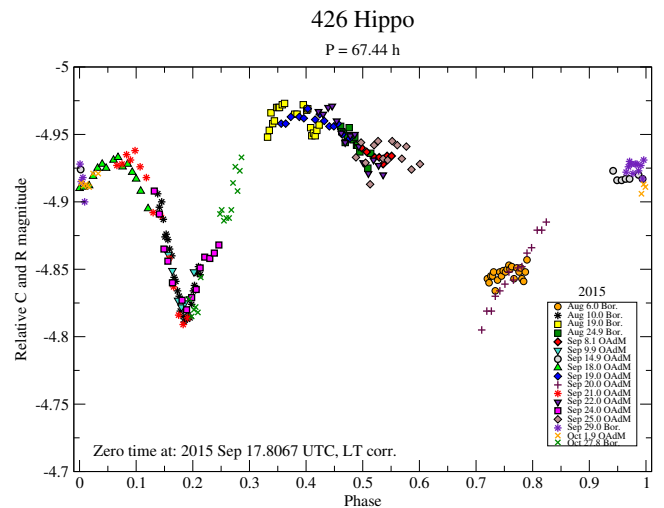


Fig. B.26: Composite lightcurve of (426) Hippo from the year 2015.

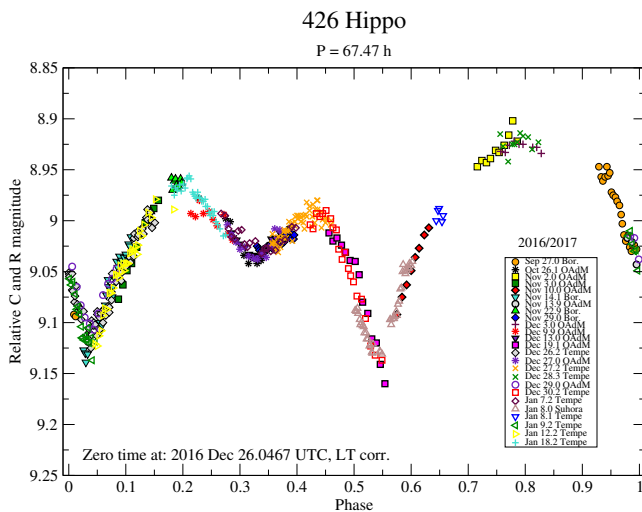


Fig. B.27: Composite lightcurve of (426) Hippo from the years 2016-2017.

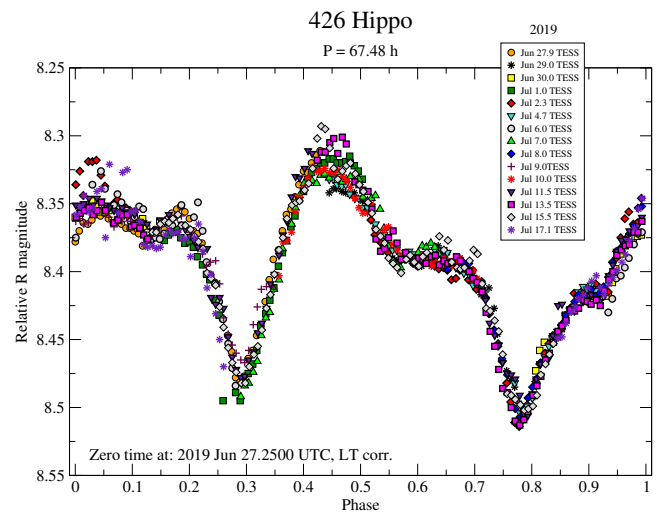


Fig. B.28: Composite lightcurve of (426) Hippo from the year 2019 observed by TESS spacecraft.

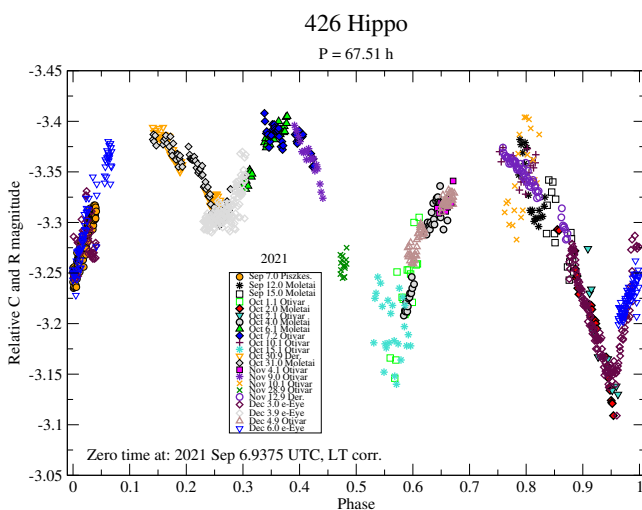


Fig. B.29: Composite lightcurve of (426) Hippo from the year 2021.

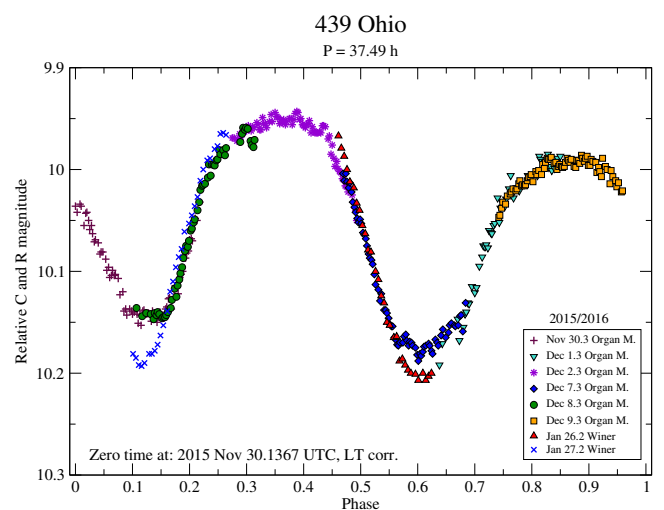


Fig. B.30: Composite lightcurve of (439) Ohio from the years 2015-2016.

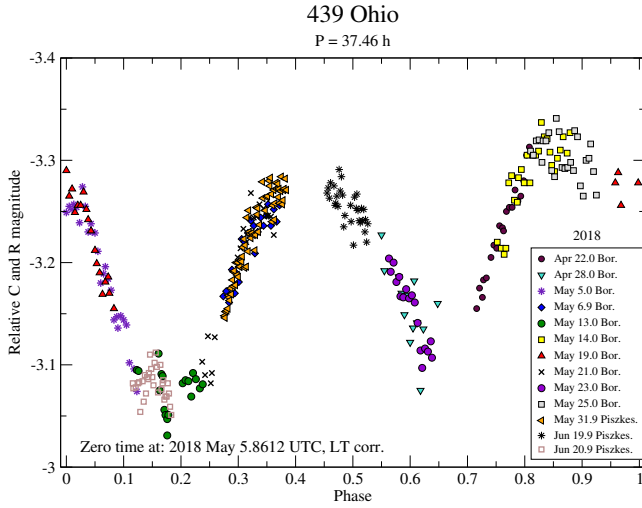


Fig. B.31: Composite lightcurve of (439) Ohio from the year 2018.

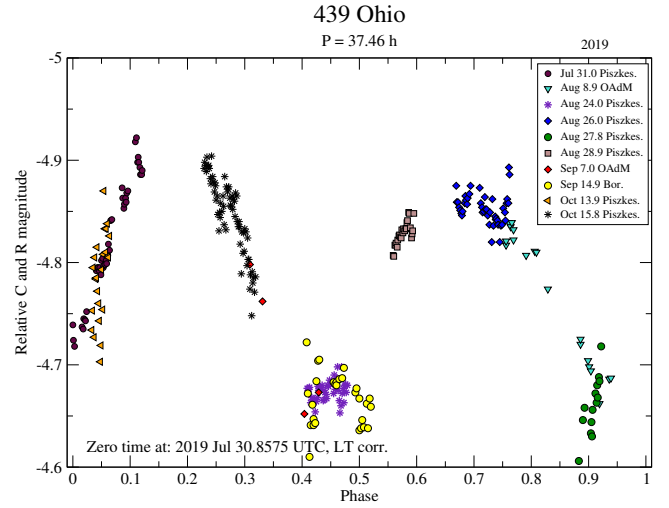


Fig. B.32: Composite lightcurve of (439) Ohio from the year 2019.

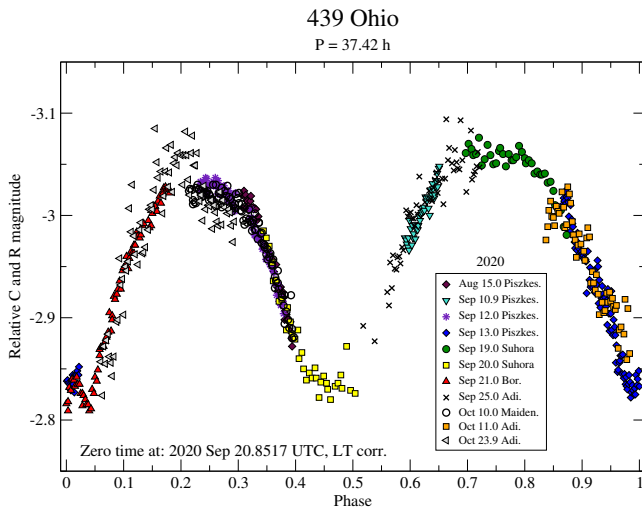


Fig. B.33: Composite lightcurve of (439) Ohio from the year 2020.

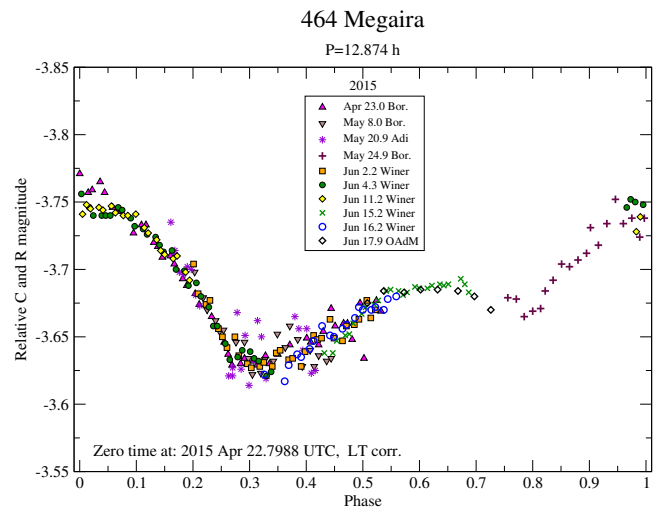


Fig. B.34: Composite lightcurve of (464) Megaira from the year 2015.

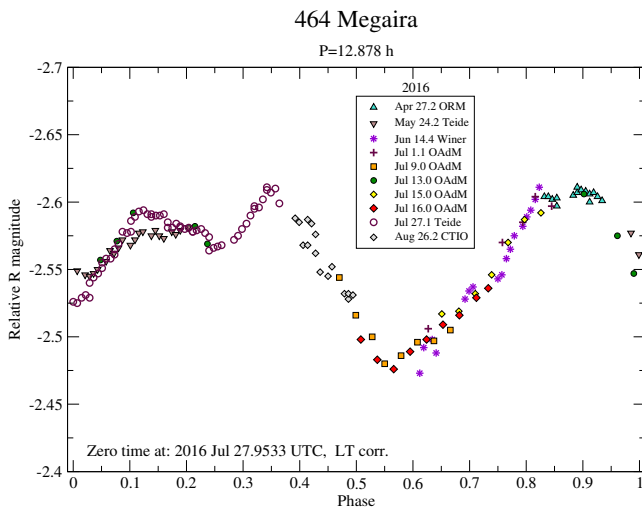


Fig. B.35: Composite lightcurve of (464) Megaira from the year 2016.

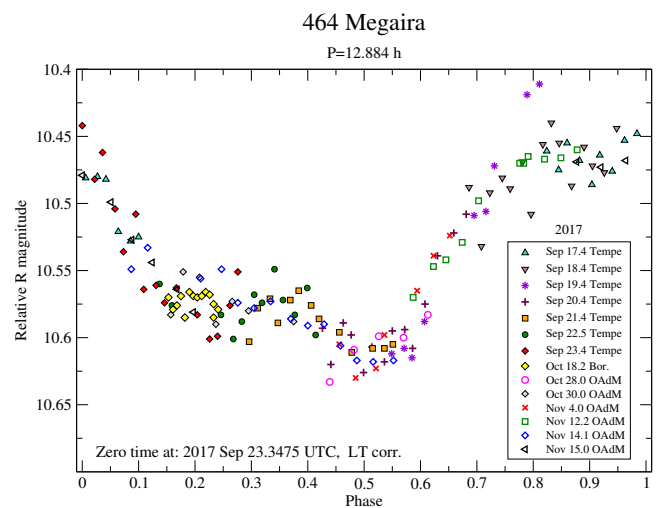


Fig. B.36: Composite lightcurve of (464) Megaira from the year 2017.

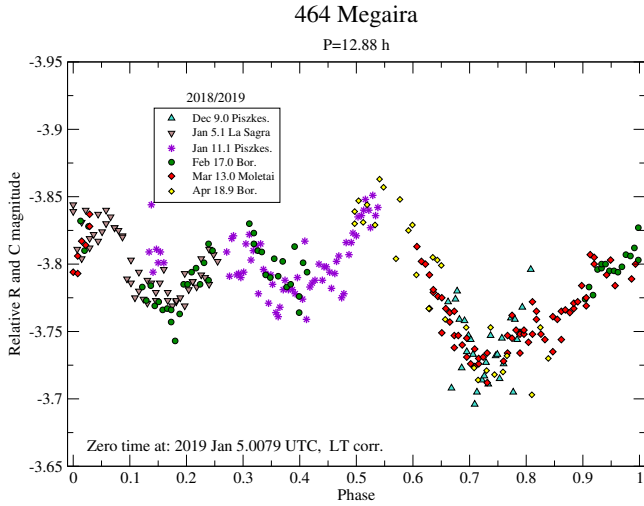


Fig. B.37: Composite lightcurve of (464) Megaira from the years 2018-2019.

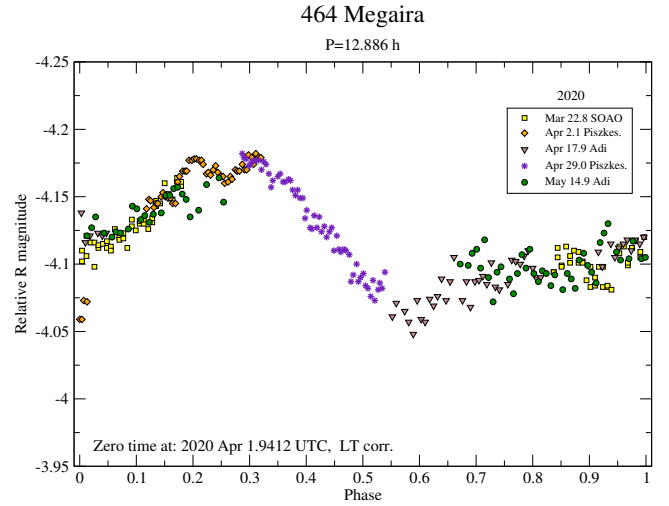


Fig. B.38: Composite lightcurve of (464) Megaira from the year 2020.

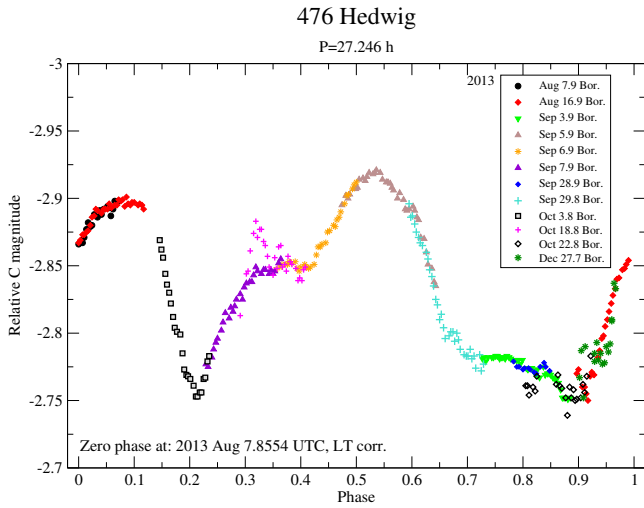


Fig. B.39: Composite lightcurve of (476) Hedwig from the year 2013.

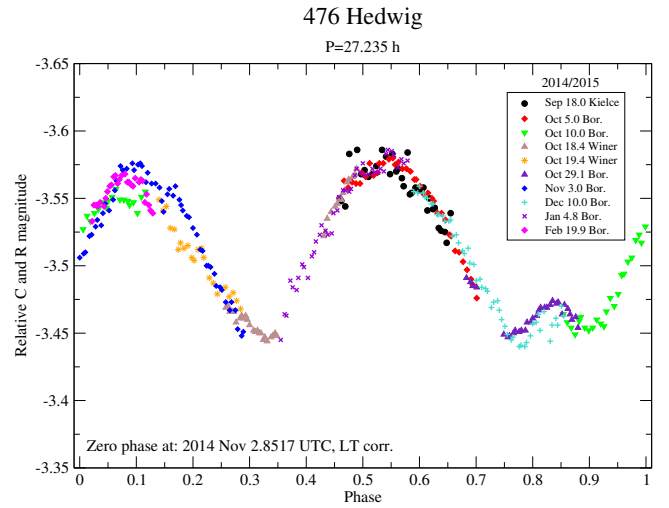


Fig. B.40: Composite lightcurve of (476) Hedwig from the years 2014-2015.

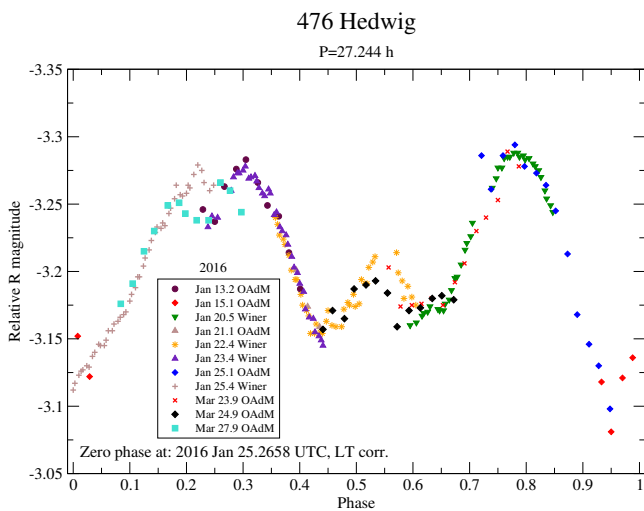


Fig. B.41: Composite lightcurve of (476) Hedwig from the year 2016.

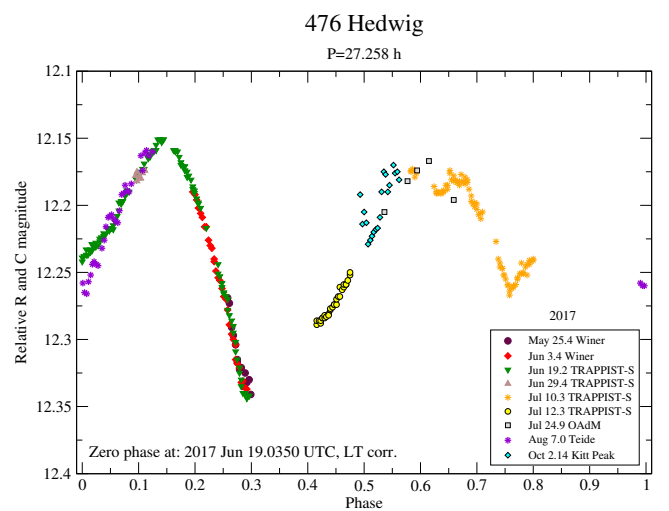


Fig. B.42: Composite lightcurve of (476) Hedwig from the year 2017.

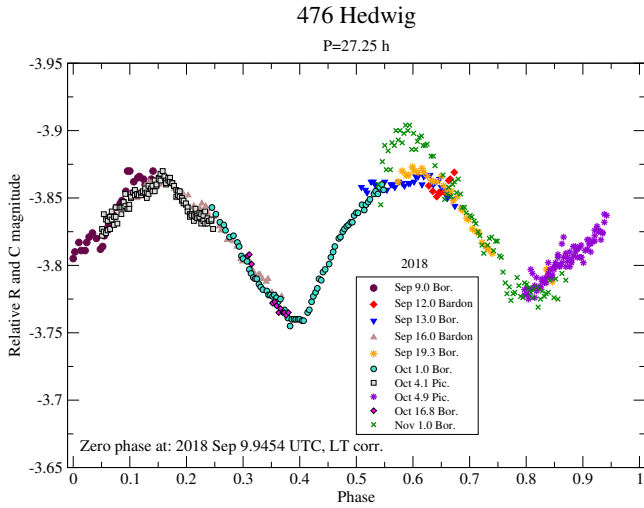


Fig. B.43: Composite lightcurve of (476) Hedwig from the year 2018.

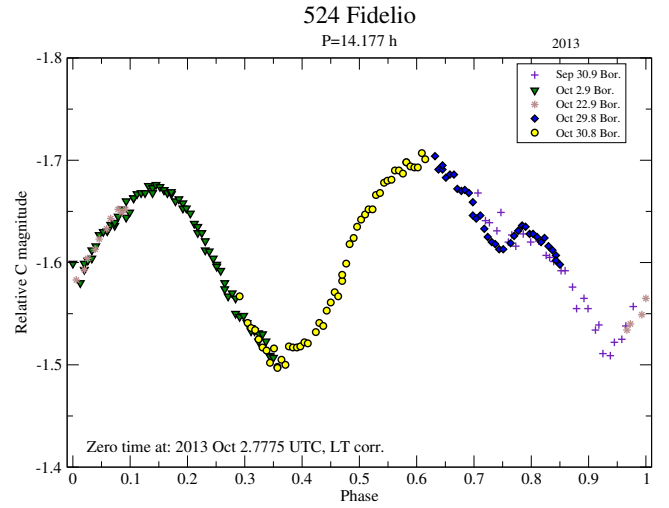


Fig. B.44: Composite lightcurve of (524) Fidelio from the year 2013.

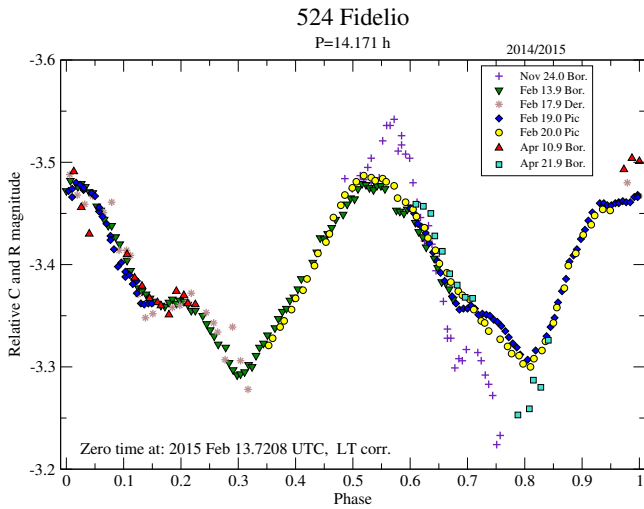


Fig. B.45: Composite lightcurve of (524) Fidelio from the years 2014-2015.

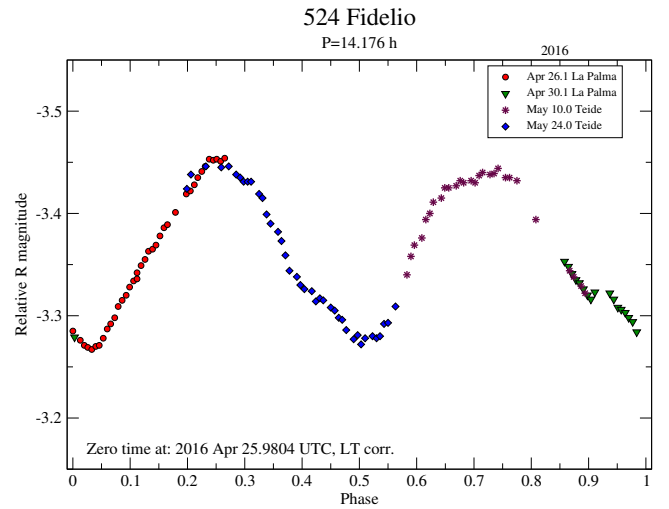


Fig. B.46: Composite lightcurve of (524) Fidelio from the year 2016.

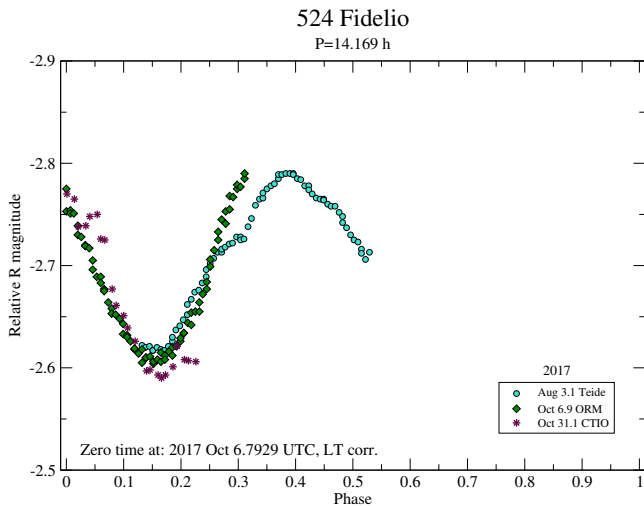


Fig. B.47: Composite lightcurve of (524) Fidelio from the year 2017.

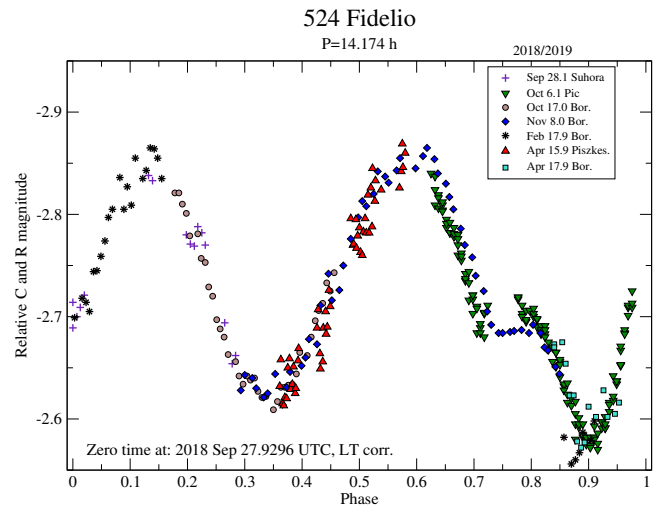


Fig. B.48: Composite lightcurve of (524) Fidelio from the years 2018-2019.

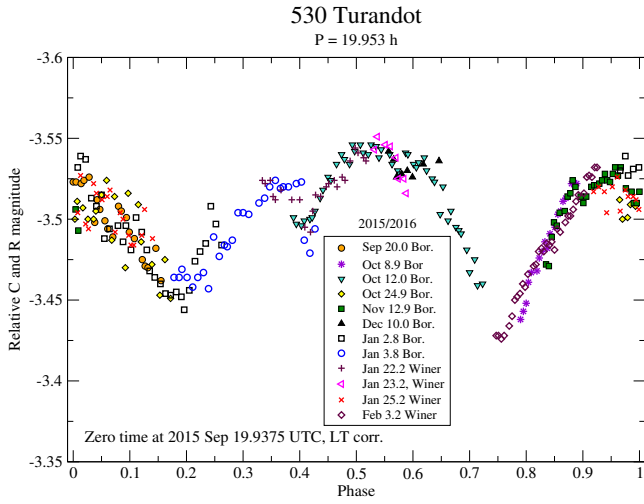


Fig.B.49: Composite lightcurve of (530) Turandot from the years 2015-2016.

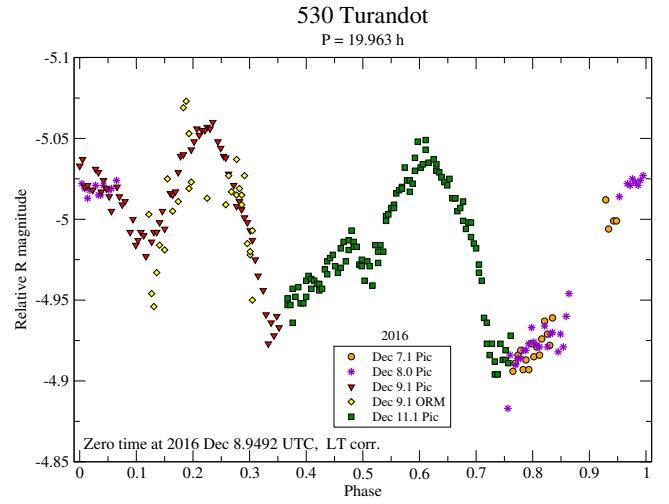


Fig.B.50: Composite lightcurve of (530) Turandot from the year 2016.

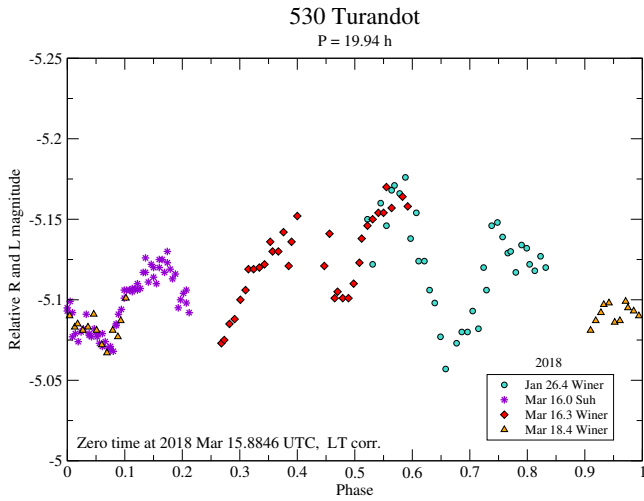


Fig.B.51: Composite lightcurve of (530) Turandot from the year 2018.

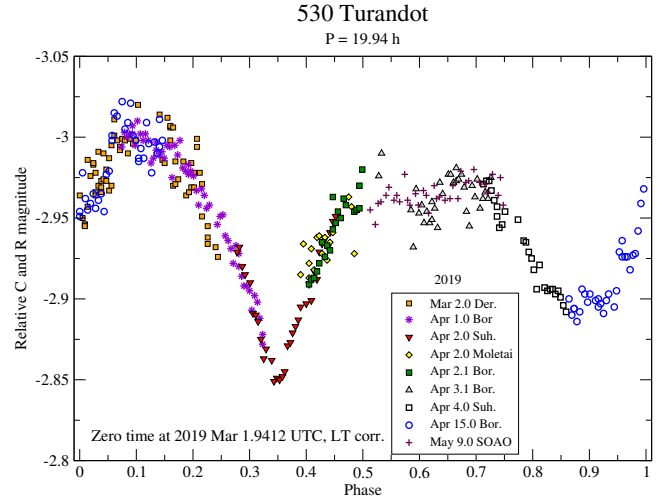


Fig.B.52: Composite lightcurve of (530) Turandot from the year 2019.

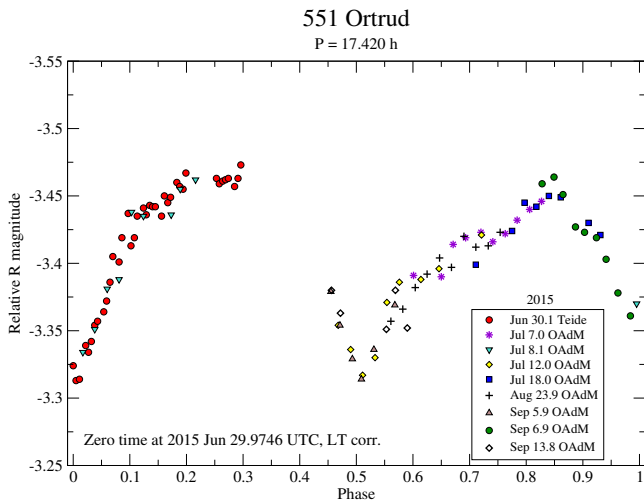


Fig. B.53: Composite lightcurve of (551) Ortrud from the year 2015.

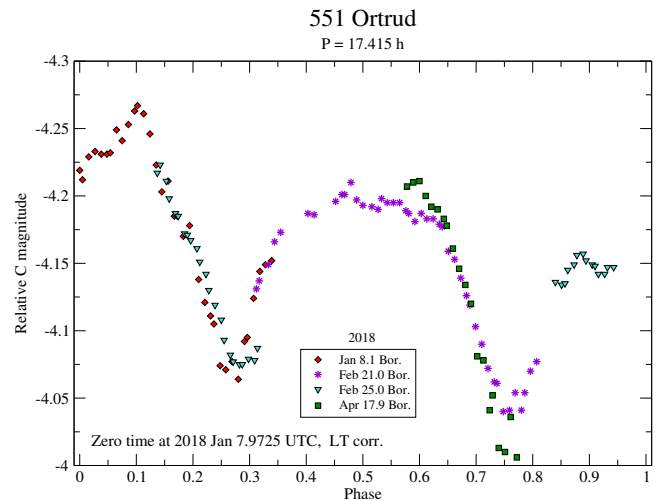


Fig. B.54: Composite lightcurve of (551) Ortrud from the year 2018.

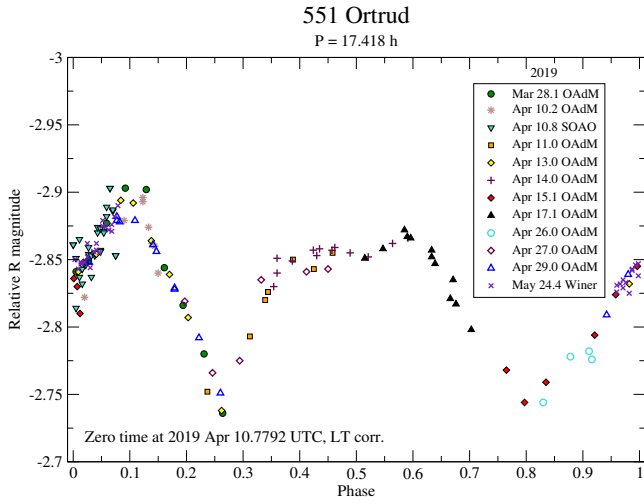


Fig. B.55: Composite lightcurve of (551) Ortrud from the year 2019.

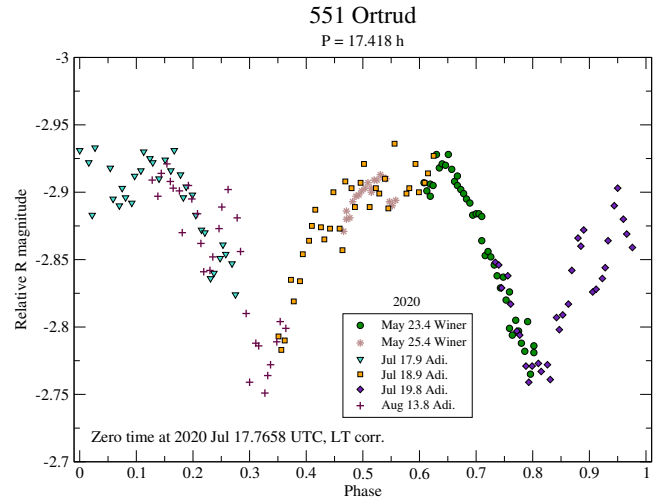


Fig. B.56: Composite lightcurve of (551) Ortrud from the year 2020.

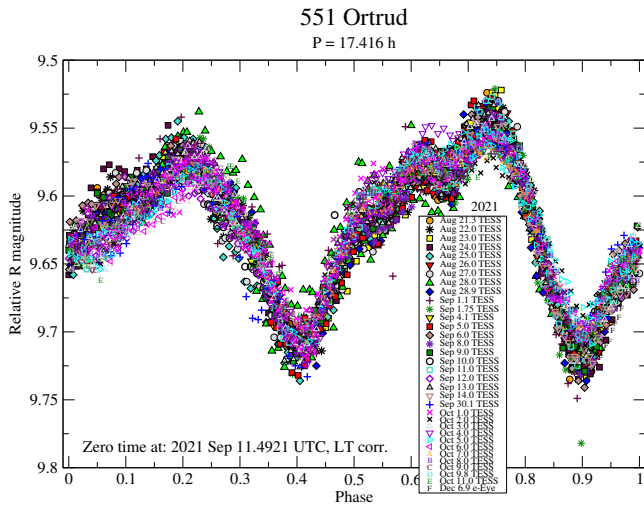


Fig. B.57: Composite lightcurve of (551) Ortrud from the year 2021, observed mainly from TESS spacecraft.

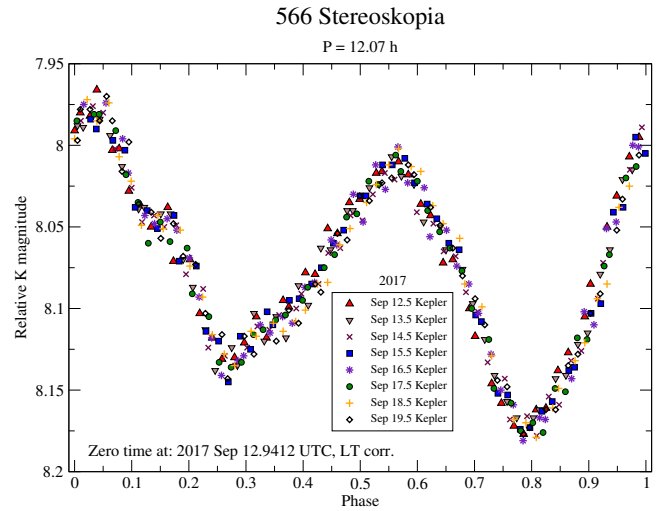


Fig. B.58: Composite lightcurve of (566) Stereoskopia from the year 2017, observed by Kepler mission.

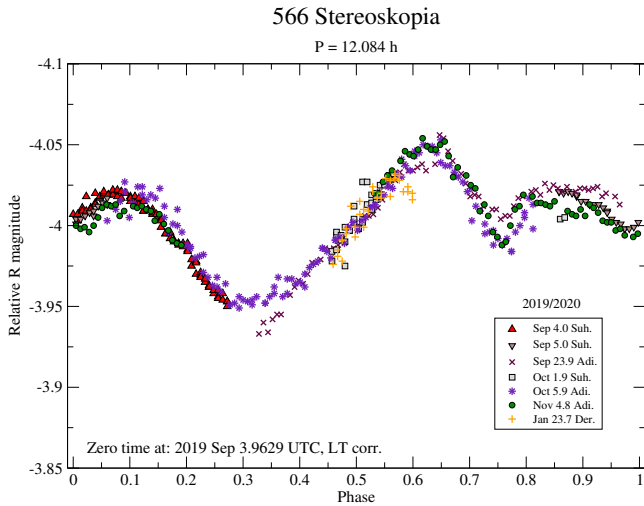


Fig. B.59: Composite lightcurve of (566) Stereoskopia from the years 2019-2020.

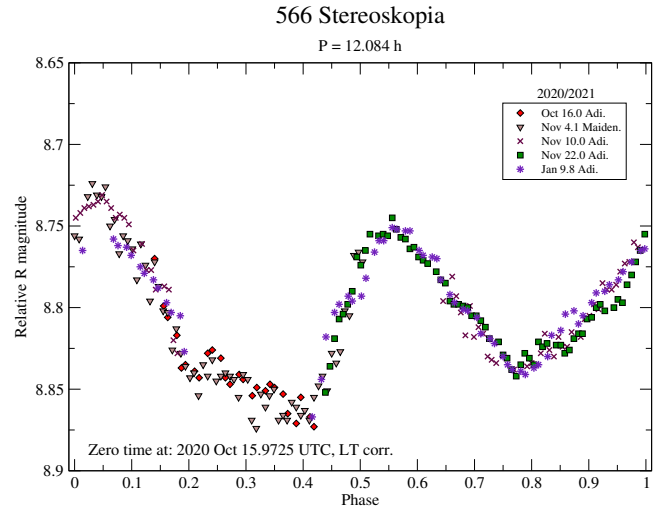


Fig. B.60: Composite lightcurve of (566) Stereoskopia from the years 2020-2021.

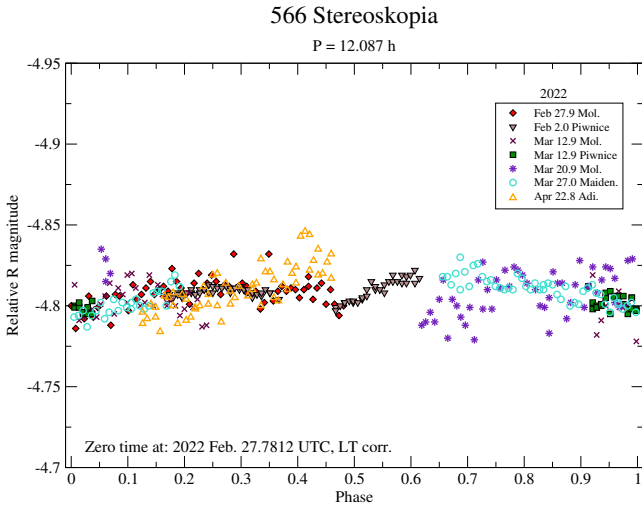


Fig. B.61: Composite lightcurve of (566) Stereoskopia from the year 2022.

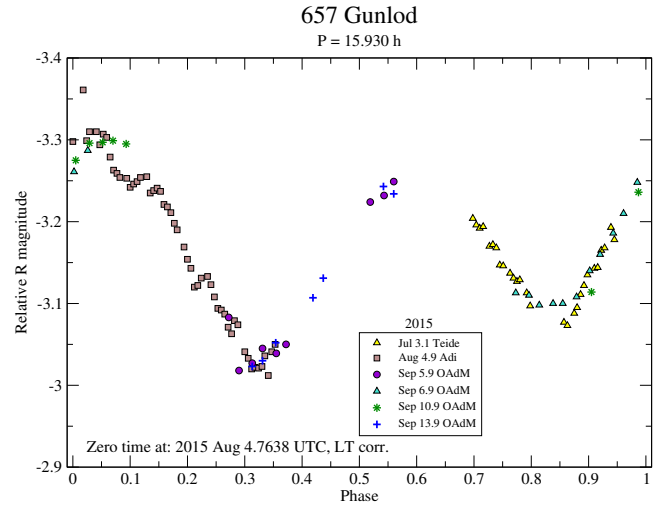


Fig. B.62: Composite lightcurve of (657) Gunlod from the year 2015.

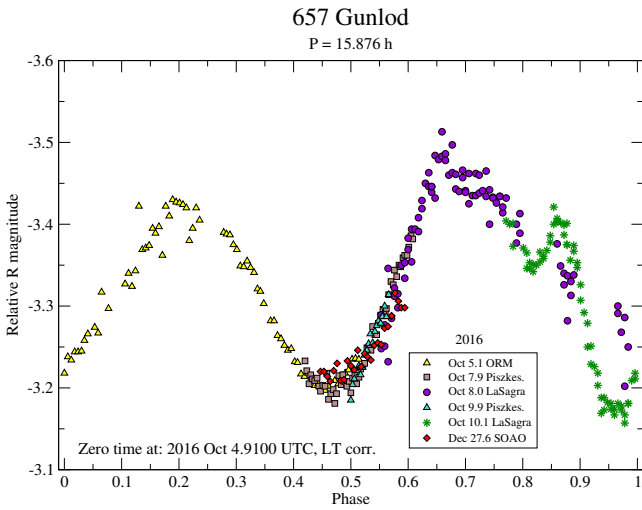


Fig. B.63: Composite lightcurve of (657) Gunlod from the year 2016, observed mainly from TESS spacecraft.

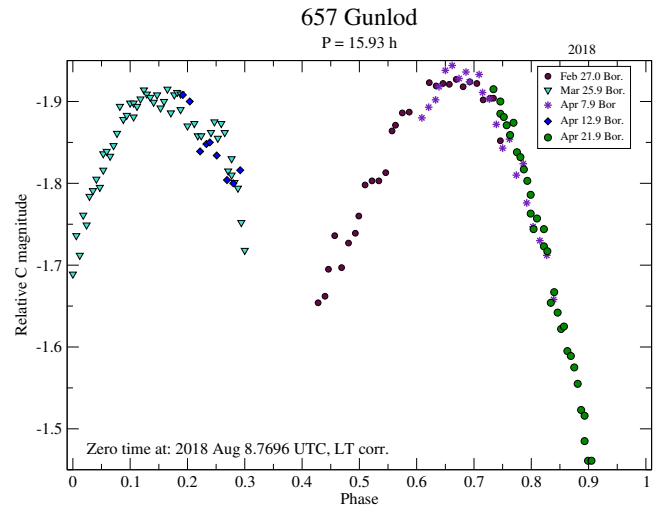


Fig. B.64: Composite lightcurve of (657) Gunlod from the year 2018, observed by Kepler mission.

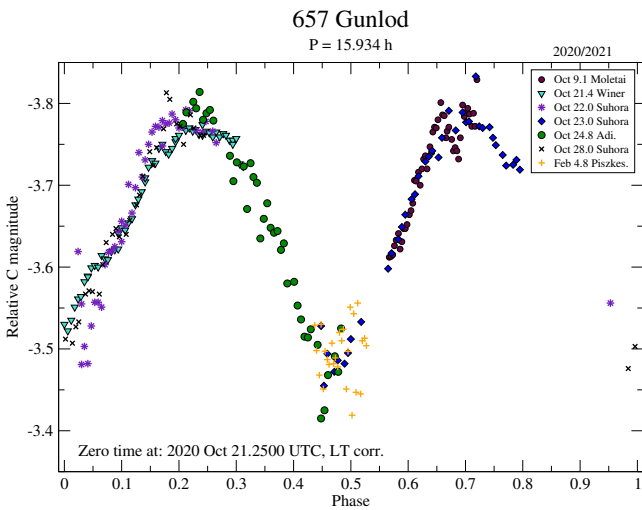


Fig. B.65: Composite lightcurve of (657) Gunlod from the year 2020.

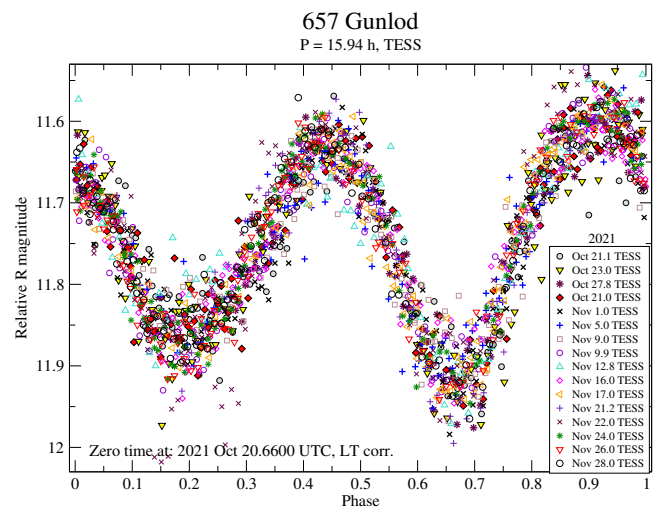


Fig. B.66: Composite lightcurve of (657) Gunlod from the year 2021 from TESS spacecraft.

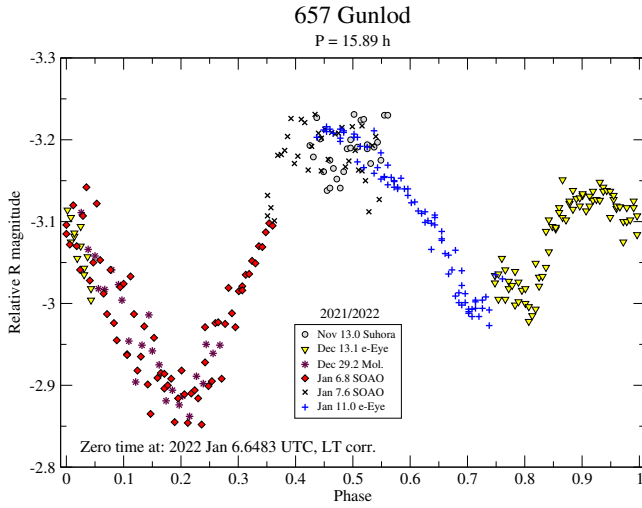


Fig. B.67: Composite lightcurve of (657) Gunlod from the years 2021-2022. Due to different character of the lightcurve caused by slightly different viewing geometry, it could not be folded with lightcurve from Fig. B.66.

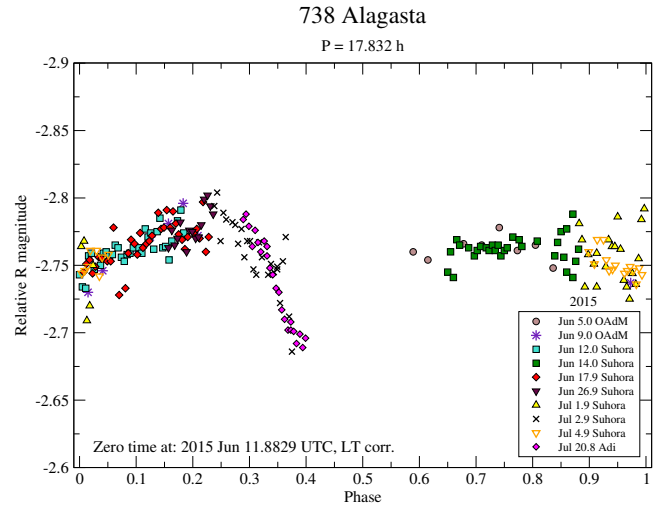


Fig. B.68: Composite lightcurve of (738) Alagasta from the year 2015.

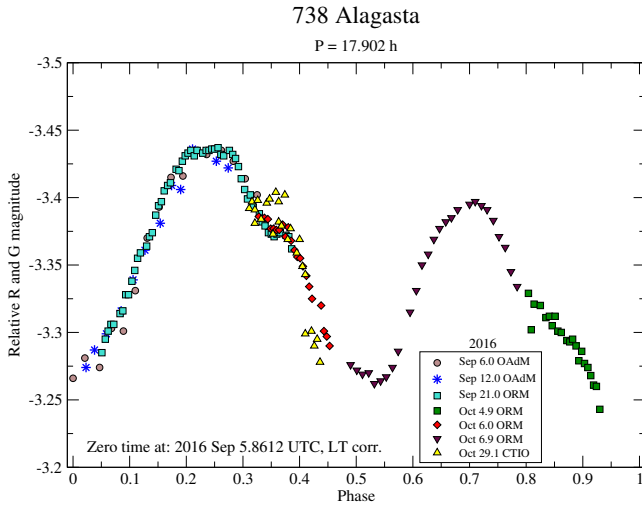


Fig. B.69: Composite lightcurve of (738) Alagasta from the year 2016.

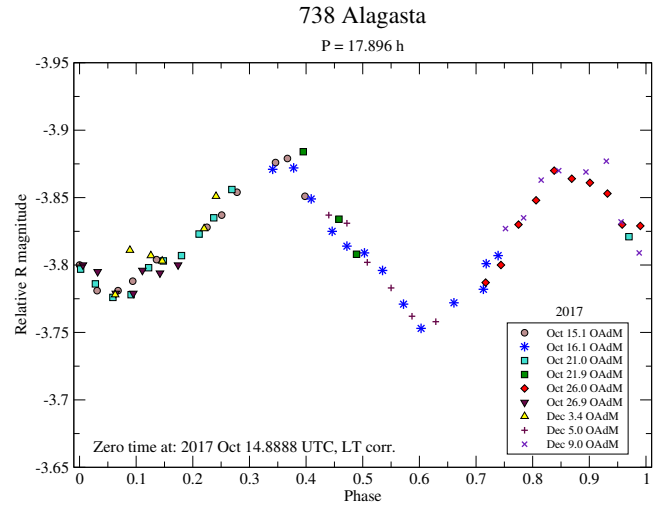


Fig. B.70: Composite lightcurve of (738) Alagasta from the year 2017.

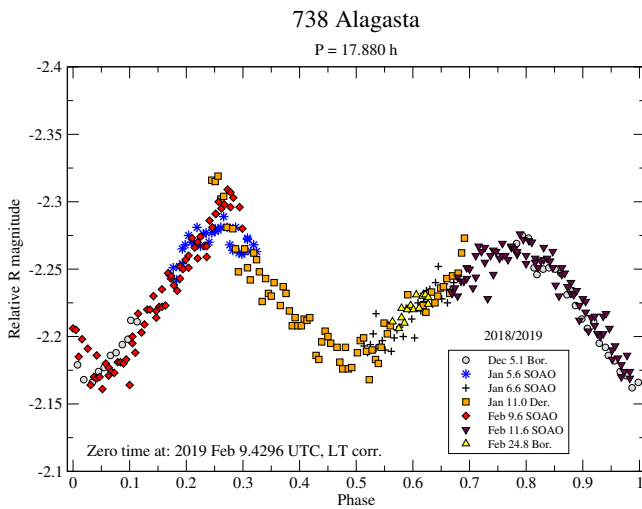


Fig. B.71: Composite lightcurve of (738) Alagasta from the years 2018-2019.

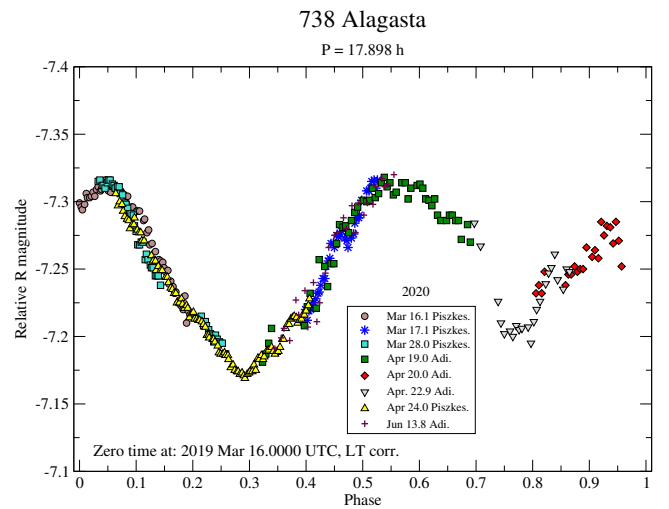


Fig. B.72: Composite lightcurve of (738) Alagasta from the year 2020.

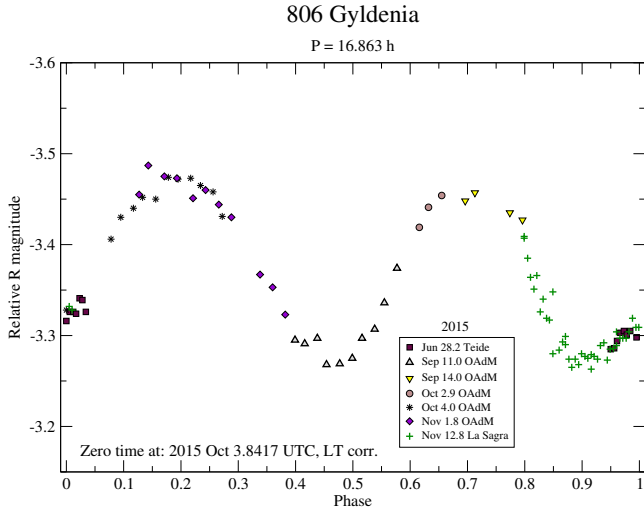


Fig.B.73: Composite lightcurve of (806) Gyldenja from the year 2015.

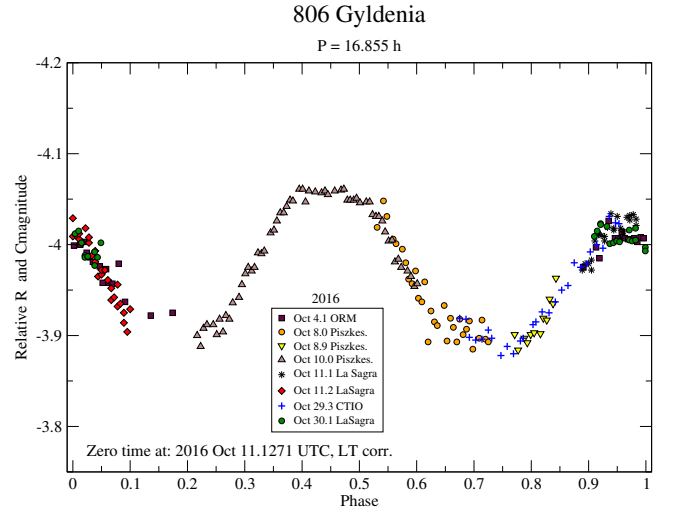


Fig.B.74: Composite lightcurve of (806) Gyldenja from the year 2016.

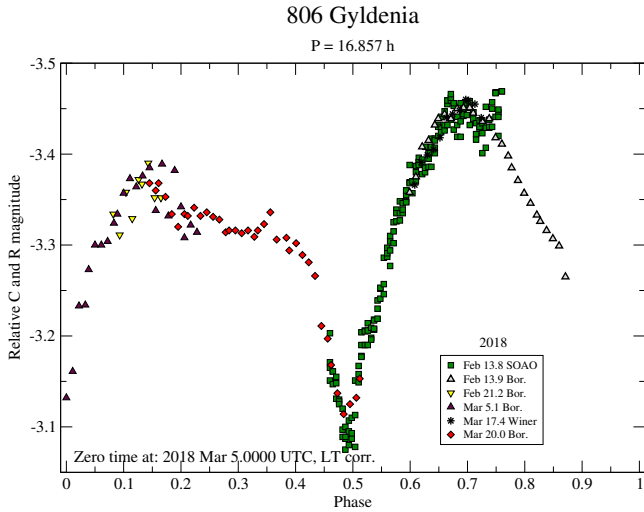


Fig.B.75: Composite lightcurve of (806) Gyldenja from the year 2018.

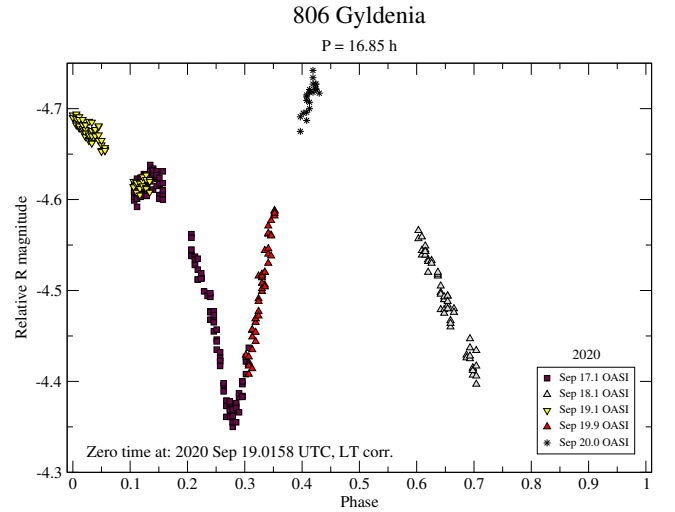


Fig.B.76: Composite lightcurve of (806) Gyldenja from the year 2020.

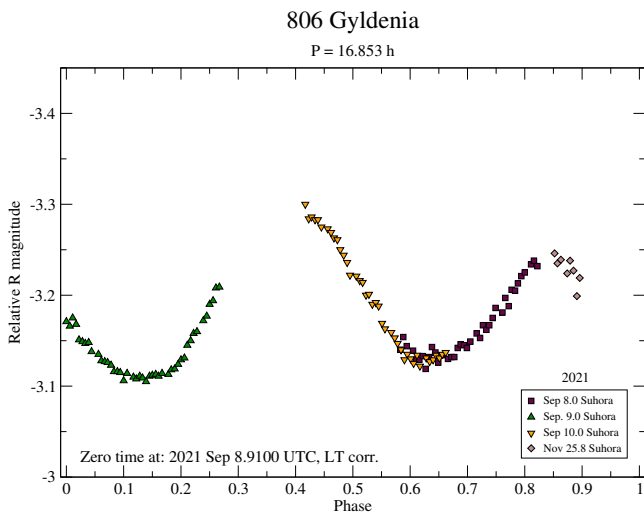


Fig.B.77: Composite lightcurve of (806) Gyldenja from the year 2021.