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Photometry and models of selected main belt asteroids

VII. 350 Ornamenta, 771 Libera, and 984 Gretia[⋆,⋆⋆]

A. Marciniak[1], T. Michałowski[1], R. Hirsch[1], R. Behrend[2], L. Bernasconi[3], P. Descamps[4], F. Colas[4], K. Sobkowiak[1], K. Kamiński[1], A. Kryszczyńska[1], T. Kwiatkowski[1], M. Polińska[1], R. Rudawska[1], S. Fauvaud[5,6], G. Santacana[6], A. Bruno[7], M. Fauvaud[5], J.-P. Teng-Chuen-Yu[8], and A. Peyrot[8]

[1] Astronomical Observatory, Adam Mickiewicz University, Słoneczna 36, 60-286 Poznań, Poland
e-mail: `aniab@lab.astro.amu.edu.pl`
[2] Geneva Observatory, 1290 Sauverny, Switzerland
[3] Les Engarouines Observatory, 84570 Mallemort-du-Comtat, France
[4] IMCCE – Paris Observatory – UMR 8028 CNRS, 77 av. Denfert-Rochereau, 75014 Paris, France
[5] Observatoire du Bois de Bardon, 16110 Taponnat, France
[6] Association T60, 14 avenue Edouard Belin, 31400 Toulouse, France
[7] Université de Rennes 1, Campus de Beaulieu, 35042 Rennes Cedex, France
[8] Makes Observatory, 18 rue G. Bizet – Les Makes, 97421 La Rivière, France

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ABSTRACT

We analyze photometric observations of the three main-belt asteroids 350 Ornamenta, 771 Libera, and 984 Gretia, conducted over a twelve-year interval. Our data and those of other authors allow us to determine pole and shape models using the lightcurve inversion technique. In all three cases, a single pole solution was obtained without any significant mirror solution:
Ornamenta – $P = 9.180\,414$ h, $\lambda_{\rm p} = 184°, \beta_{\rm p} = -29°$
Libera – $P = 5.890\,423$ h, $\lambda_{\rm p} = 64°, \beta_{\rm p} = -78°$
Gretia – $P = 5.778\,025$ h, $\lambda_{\rm p} = 245°, \beta_{\rm p} = +52°$.
This analysis and the development of asteroid models increase the set of asteroids with known spin and shape parameters, which consists of only around 100 objects.

Key words. techniques: photometric – minor planets, asteroids

1. Introduction

There is a constant need for new physical models of asteroids as strong advances continue to search for a statistically significant conclusions about the Solar System's history. Reliable information about these objects' spin axis orientations and shapes can be useful to investigations such as those of YORP effect detection and modelling (Kaasalainen et al. 2007; Lowry et al. 2007; Ďurech et al. 2008).

Lightcurves of more than 3800 asteroids have already been published (as April 2009 release of the Asteroid Lightcurve Database[1] lists). It is important to collect all the available data of one object to construct a model on possibly biggest dataset. Lightcurves collected at a wide range of phase angles are an invaluable source of information about object's shape. A unique model can usually only be obtained when data for at least five apparitions of one main-belt asteroid are available. Here, amateur astronomers provide substantial help, by observing many objects during subsequent apparitions.

This is the seventh paper in the series in which we combine data from either the Asteroid Photometric Catalogue (Lagerkvist et al. 2001) or directly from the authors themselves, including our own photometric observations conducted since 1997 at the Borowiec Observatory. The aim is to create asteroid models using the *lightcurve inversion* method.

The three models presented in this work will be added to two databases[2,3].

2. Photometry of three main-belt asteroids

Asteroid 350 Ornamenta, 771 Libera, and 984 Gretia were observed photometrically during 67 nights spanning twelve years. The majority of observations were made at the Borowiec Station of the Poznań Astronomical Observatory in Poland equipped with the 40-cm Newtonian telescope. A description of both the

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[⋆] Composite lightcurves (Figs. 1–16), and aspect data (Table 1) are only available in electronic form at `http://www.aanda.org`

[⋆⋆] Photometric data are only available in electronic form at the CDS via anonymous ftp to `cdsarc.u-strasbg.fr (130.79.128.5)` or via
`http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/508/1503`

[1] `http://www.minorplanetobserver.com/astlc/LightcurveParameters.htm`

[2] A regularly updated database of all published asteroids′ spin parameters obtained with various techiques is available at our website:
`http://www.astro.amu.edu.pl/Science/Asteroids/`
(Kryszczyńska et al. 2007).

[3] Models from lightcurve inversion are collected at: `http://astro.troja.mff.cuni.cz/projects/asteroids3D`

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Table 2. Asteroid parameters.

Asteroid	D(km)	Albedo	Type	a(AU)	e	i (°)
350 Ornamenta	99.5	0.0679	C	3.1130	0.157	24.90
771 Libera	29	0.13	X	2.6518	0.248	14.94
984 Gretia	32	0.42	S	2.8052	0.196	9.08

equipment and the reduction procedure can be found in the first paper of the present series (Michałowski et al. 2004).

Table 1 (online only) provides aspect data for all of the observing runs. After the date of observation, given as the mid-time of the lightcurve, the distances from the object to either the Sun or the Earth in AU are given. In the fourth column, we indicate the Sun-asteroid-Earth phase angle, and the other two columns show the $J2000$ ecliptic coordinates of a given object at a specific time. The next two columns show the number of points in a single lightcurve and, where available, the standard deviation in the relative brightnesses of one comparison star relative to another star, usually the brightest ones in the image. This provides information about the quality of the given lightcurve. The last column indicates the observatory code.

Table 2 contains the physical and orbital parameters of all three asteroids. There are objects′ *IRAS* diameters, albedos, and taxonomic types, as well as the semi-major axes, eccentricities, and their orbit inclinations[4],[5].

Our original observations are presented in the form of composite lightcurves, one for each of the apparitions (Figs. 1–16, online only). The composites were created from the single relative lightcurves by means of a vertical shift with a fixed synodic period, to obtain the smallest possible scatter. Different symbols denote different observing runs. The vertical scale, which is the same for all the lightcurves of a given object, is the relative magnitude, while the horizontal scale represents the phase of rotation. This composition is being made to obtain a first approximation of the rotation period, that is needed by the inversion procedure. Since we apply no corrections, the lightcurve's changes in shape and amplitude within one apparition are clearly visible in the composites.

2.1. 350 Ornamenta

The first lightcurve of Ornamenta was presented in Schober et al. (1993). The lightcurve was compiled from data of five observing runs in December 1991 using a period 9.17 ± 0.01 h. The lightcurve amplitude was 0.20 mag and the colour indices were determined to be $B - V = 0.71 \pm 0.01$ mag and $U - B = 0.41 \pm 0.02$ mag. Shevchenko & Tedesco (2006) improved this asteroid's albedo and diameter determinations using data from stellar occultations, to 0.0679 and 99.5 km from the values 0.057 and 118 km known previously from IRAS.

Our observations of Ornamenta spanned five appatitions: 1999, 2004, 2005, 2007, and 2008/2009. It was a difficult, long-period object for the short observing runs possible in April or May, so it was not until the last apparition that, mainly because of an almost 8-h lightcurve, we were able to identify synodic period of rotation of 9.178 ± 0.001 h. It confirmed the first determination by Schober et al. (1993). The composite lightcurves shown in Figs. 1 to 5 (online only) were created using that period. Ornamenta exhibited very unusual, asymmetric lightcurves, with three maxima in some apparitions and a long, flat minimum in another. The amplitudes ranged from 0.13 mag to 0.25 mag.

2.2. 771 Libera

In 1984, Binzel (1987) obtained three poorly sampled lightcurves of the asteroid 771 Libera, which had an amplitude of 0.53 mag, and combined them to form a single curve with a period of 5.92 ± 0.01 h. Next, Libera was observed by Warner (2000) during two nearby nights in September 1999, which resulted in a dense composite with 5.892 ± 0.002 h period and a 0.57 mag amplitude. One minimum was about 0.1 mag brighter than another.

We observed this minor planet during four apparitions in the years: 1999, 2005, 2006, and 2008/2009. The lightcurves within each of the apparitions were combined with a period 5.890 ± 0.001 h (Figs. 6 to 9, online only), similar to the value given by Warner (2000). The lightcurves were always of rather high amplitude, from 0.39 mag to 0.48 mag, and changed little between apparitions.

2.3. 984 Gretia

Van Houten (1962) analyzed old photographic plates from the thirties, on which asteroids were recorded, that had exposure times of half an hour each. In the case of Gretia, this resulted in 3 sparse lightcurves, from three nights in August 1931. The derived period was 5.76 h and the amplitude was about 0.4 mag. However, the brightness measurements, as the author remarked, might have been affected by errors.

Other researchers to observe Gretia included, over 50 years later, Di Martino et al. (1984). Observed on three nearby nights in September 1983, Gretia exhibited a 0.63 mag variations and its lightcurves were combined to produce one with a 5.781 ± 0.002 h period.

Piironen et al. (1994) observed this object during two nights in January 1985, at a small phase angle. They confirmed the previous period determinations ($P = 5.781 \pm 0.005$ h) and in addition found a small (0.03 mag) colour variation during its rotation. The lightcurve appeared to be regular, and to have a 0.6 mag variation. An average colour index of $B-V = 0.89$ mag, and data about albedo (Table 2) suggested that this object was S-type of a very high albedo.

In July and August 1997, Riccioli et al. (2001) obtained four very sparsely sampled data points and combined them to produce a curve with a 5.560 ± 0.018 h period. The resulting lightcurve had an amplitude of about 0.8 mag and looked asymmetric. The $B - V$ colour index was 0.95 ± 0.03 mag.

Blanco et al. (2000), using data from three apparitions and the AM-method, obtained the first pole determinations of this object to be: $\lambda_p = 46° \pm 2°$, $\beta_p = 47° \pm 1°$, and $\lambda_p = 228° \pm 9°$, $\beta_p = -12° \pm 9°$. The axes ratios were $a/b = 2.25$, and $b/c = 1.00$.

Finally, during four nights in February 2003, Gandolfi et al. (2009) observed Gretia obtaining very high quality lightcurves with each of the extrema having a different level and an amplitude 0.66 ± 0.02 mag, from which the period was found to be 5.780 ± 0.001 h. All of the published lightcurve data, apart from the last set, was used in our modelling of this object.

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[4] Data for this physical properties (except for 350 Ornamenta) come from *The Small Bodies Node of the NASA Planetary Data System* `http://pdssbn.astro.umd.edu/`), where the diameters and albedos are from the IRAS Minor Planet Survey (Tedesco et al. 2004), and the taxonomic classifications are given after Tholen (1989).

[5] The data on orbital parameters come from the Minor Planet Center database available at: `ftp://cfa-ftp.harvard.edu/pub/MPCORB/MPCORB.DAT`

Table 3. Spin models.

Sidereal period (h)	Pole 1 λ_p	Pole 1 β_p	Pole 2 λ_p	Pole 2 β_p	Observing span (years)	N_{app}	N_{lc}	Method	Reference
350 Ornamenta									
9.180414 ±0.000005	–		184° ±2°	−29° ±2°	1991–2009	6	37	L	Present work
771 Libera									
5.890423 ±0.000 003	64° ±20°	−78° ±5°	–		1984–2009	5	20	L	Present work
984 Gretia									
–	46°	47°	228°	−12°	1931–1985	3	8	AM	Blanco et al. (2000)
5.778025 ±0.000001	–		245° ±2°	+52° ±5°	1931–2009	10	28	L	Present work

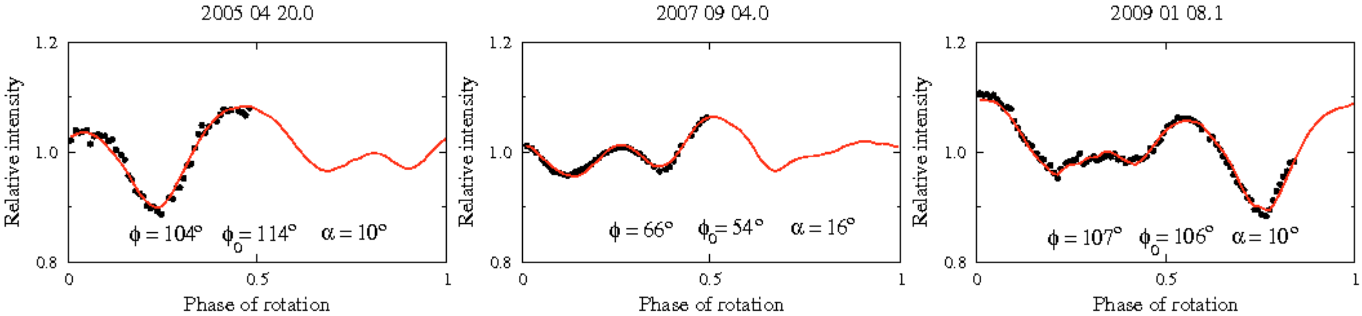

Fig. 17. Observed lightcurves (points) superimposed on the lightcurves created by a model (curves) at the same epochs for 350 Ornamenta.

We added seven apparitions (1997, 1999, 2002, 2005, 2006, 2007/2008, and 2009) to the existing set of observations. The composite lightcurves are shown in Figs. 10 to 16 (online only) and were created using the period 5.778±0.001 h and are regular with large amplitudes, ranging from 0.50 mag to 0.78 mag.

3. Pole and shape results

For the asteroid modelling, we use the *lightcurve inversion* method described in Kaasalainen & Torppa (2001) and Kaasalainen et al. (2001). The method allows us to determine both the pole and period solutions and recover a detailed convex shape model. As a result, the model can reproduce almost all the lightcurve details down to the noise level. Good longitude and phase angle coverage are an advantage in the datasets.

In Table 3, the parameters of the three models are presented. The first column contains the sidereal period with its uncertainty. The next four columns present the pole solution (J2000 ecliptic longitude λ_p and latitude β_p), which has no significant mirror solution. For each of the pole coordinates, a separate error analysis was performed, because errors in this method can only be estimated from the resulting parameter space (see Torppa et al. 2003; Kaasalainen & Ďurech 2007 for more details). As a rule, the pole longitudes are badly constrained for “high” pole latitudes (far from the ecliptic plane), while for other latitudes they can be quite precise, even down to ±1 degree. The next three columns of Table 3 contain the observing span in years, and the number of all apparitions and lightcurves used in the modelling. In the two last columns, the method used (“L” for lightcurve inversion) is indicated and its reference. Only for 984 Gretia has the pole solution been previously reported, but proved to be wrong (predicting too low amplitudes), as new data was gathered.

To show how the model lightcurves reproduce the observed ones, in Figs. 17, 19 and 21 we present three example observing runs for each asteroid (dots) compared to the fits produced by the model (lines). Data on the aspect angles of the Earth and the Sun (ϕ and ϕ_0), and phase angle α are also given.

3.1. 350 Ornamenta

We constructed the model of 350 Ornamenta using 37 lightcurves from 6 apparitions (in the years 1991, 1999, 2004, 2005, 2007, and 2008/2009). The number of lightcurves is high, but individual observing runs were usually short compared to Ornamenta’s over a 9-h period of rotation. The apparitions were well spread along the asteroid’s orbit. The irregular shape model is shown in Fig. 18, and the lightcurves generated by this model, compared to observations, are in Fig. 17.

Apart from the highly accurate pole solution presented in Table 3, we obtained a second solution, at $\lambda_p = 40° \pm 30°$ and $\beta_p = -81 \pm 5°$, with larger errors. This is a mirror solution, but because of Ornamenta’s high orbital inclination, in ecliptic coordinates, it differs profoundly from the first one. However, this solution, although having marginally acceptable deviations, provided far poorer fits in two last apparitions than the first solution. Therefore, it can almost certainly be rejected.

3.2. 771 Libera

Libera was an object that allowed us to obtain a unique model from only a small number of lightcurves. We constructed a final model basing on 20 lightcurves from 5 apparitions (1984, 1999, 2005, 2006, and 2008/2009), but the model solution was clearly distinctive among other solutions even when created from a

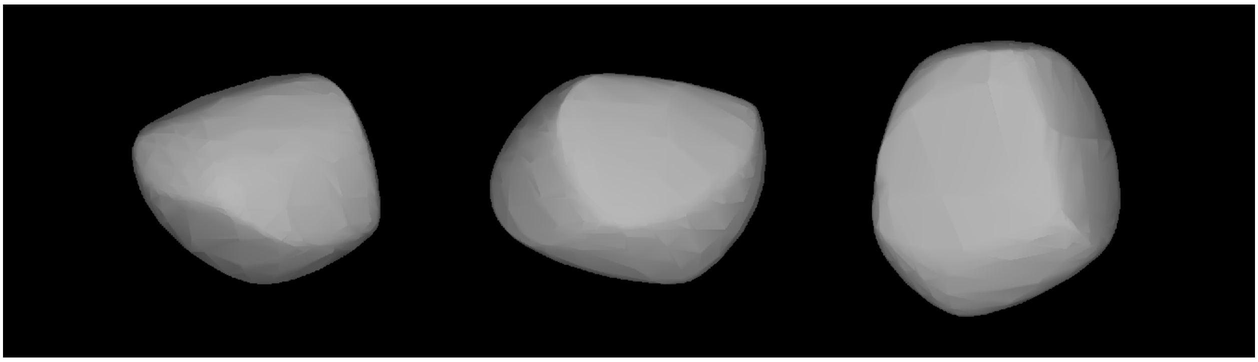

Fig. 18. Shape model of 350 Ornamenta, shown at equatorial viewing and illumination geometry, with rotational phases 90° apart (two pictures on the *left*), and the pole-on view on the *right*.

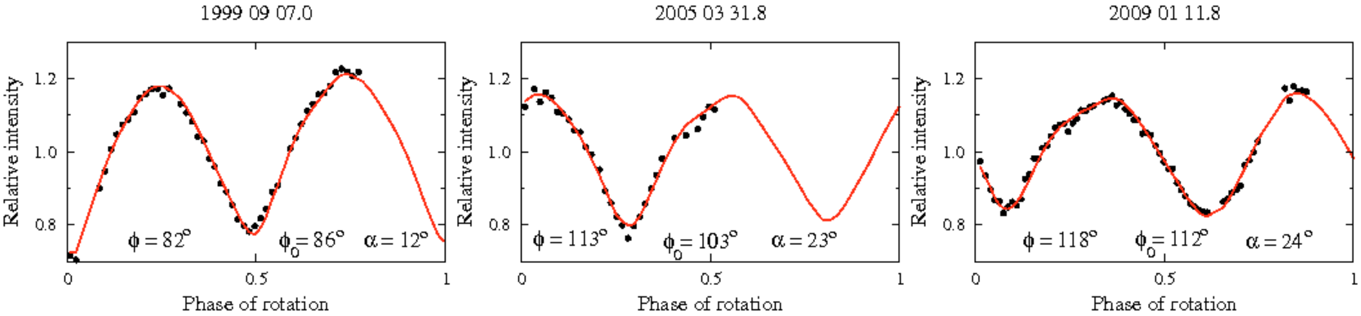

Fig. 19. Observed versus modelled lightcurves for 771 Libera.

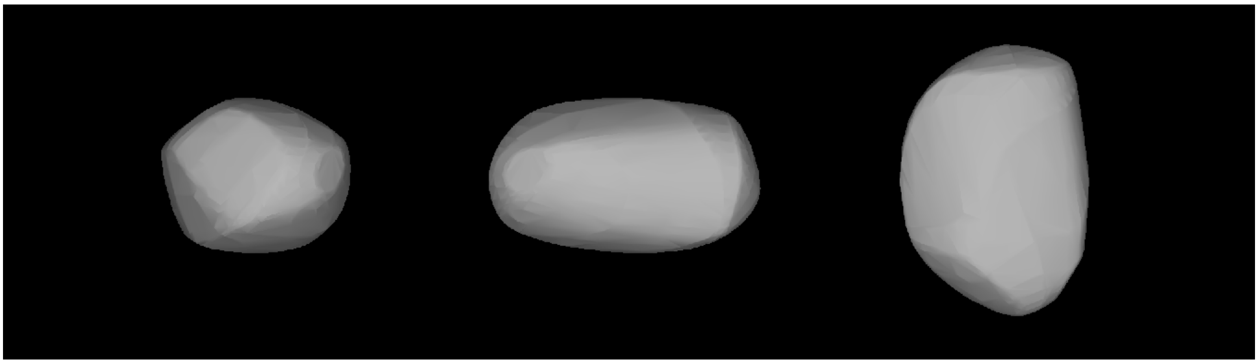

Fig. 20. Shape model of 771 Libera.

smaller dataset. What is more, there is only one, unambiguous pole solution, probably because of a large $|\beta_p|$ value (Table 3).

As expected, the object has an elongated shape (Fig. 20), producing large amplitude lightcurves, shown in Fig. 19. Although the spin axis is almost perpendicular to the ecliptic plane, the amplitudes vary visibly, probably because of Libera's high orbital inclination, as for the main-belt object. The small, round feature in the shape model is probably real, maybe a crater, because it is present in all the shape solutions, regardless of the input parameters or the dataset size.

3.3. 984 Gretia

Gretia is an unusual asteroid, whose photometric observations span almost 80 years. This caused the step in the period scan to be very small, and one single period (5.778025 h) was identified with unprecedented clarity in the periodogram.

The model was obtained using 28 lightcurves from 10 apparitions (1931, 1983, 1985, 1997, 1999, 2002, 2005, 2006, 2007/2008, and 2009). The pole solution in Table 3 was the only one that provided satisfactory fits and realistic shape models, although a second solution at $\lambda_p = 110° \pm 20°$ and $\beta_p = +79 \pm 5°$ was also found.

Before we acquired data for the last apparition, the resulting shape models tended to be non-physical (too large along the axis of rotation), and varied a lot in otherwise similar solutions. However, with these data, the shape model stabilized itself. The colour variation observed by Piironen et al. (1994) was not confirmed, because the sole combination of the pole and shape model reproduces the observed lightcurve features well, even though the observations were made in various filters. The model fit is shown in Fig. 21, and the shape model for the best pole solution is given in Fig. 22.

4. Conclusions and future plans

Including also this paper, we have published models of 21 main-belt asteroids (Michałowski et al. 2004, 2005, 2006; Marciniak et al. 2007, 2008, 2009). Many of these objects were found to

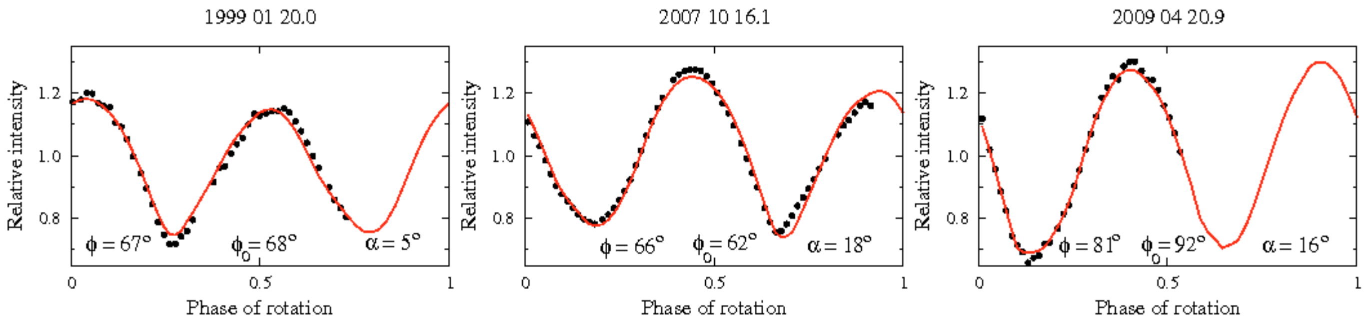

Fig. 21. Observed versus modelled lightcurves for 984 Gretia.

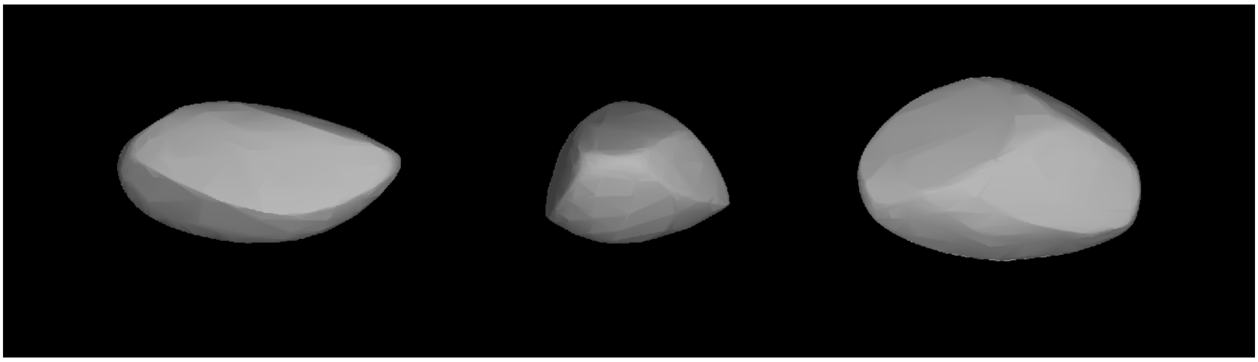

Fig. 22. Shape model of 984 Gretia.

be irregularly shaped bodies that would be impossible to model properly with classical EAM methods, which assume that the asteroids have smooth, ellipsoidal shapes. We are preparing a paper that will combine the results from the lightcurve inversion asteroid modelling. In the meantime, the continual gathering of new data to increase the database of asteroids with known spin and shape parameters is our long-term aim. This database will be especially valuable when the first asteroids models based on Gaia mission data become available. There will then be a need for a large sample of common objects modelled in both ways, to check the accuracy of models obtained basing on sparsely sampled photometric measurements performed by Gaia, compared to traditional, dense photometry.

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References

Binzel, R. P. 1987, Icarus, 72, 135
Blanco, C., Cigna, M., & Riccioli, D. 2000, Planet. Space Sci., 48, 973
Di Martino, M. 1984, Icarus, 60, 541
Gandolfi, D., Cigna, M., Fulvio, D., et al. 2009, Planet. Space Sci., 57, 1
Ďurech, J., Vokrouhlicky, D., Kaasalainen, M., et al. 2008, A&A, 489, L25
Kaasalainen, M., & Ďurech, J. 2007, in Near Earth Objects, our Celestial Neighbors: Opportunity and Risk, ed. A. Milani, G. B. Valsecchi, & D. Vokrouhlicky (Cambridge: Cambridge University Press), 151
Kaasalainen, M., & Torppa, J. 2001, Icarus, 153, 24
Kaasalainen, M., Torrpa, J., & Muinonen, K. 2001, Icarus, 153, 37
Kaasalainen, M., Ďurech, J., Warner, B. D., et al. 2007, Nature, 446, 420
Kryszczyńska, A., La Spina, A., Paolicchi, P., et al. 2007, Icarus, 192, 223
Lowry, S. C., Fitzsimmons, A., Pravec, P., et al. 2007, Science, 316, 272
Lagerkvist, C.-I., Magnusson, P., & Erikson, E. 2001, Asteroid Photometric Catalogue, fifth update, Uppsala Astronomical Observatory
Marciniak, A., Michałowski, T., Kaasalainen, M., et al. 2007, A&A, 473, 633
Marciniak, A., Michałowski, T., Kaasalainen, M., et al. 2008, A&A, 478, 559
Marciniak, A., Michałowski, T., Hirsch, R., et al. 2009, A&A, 498, 313
Michałowski, T., Kwiatkowski, T., Kaasalainen, M., et al. 2004, A&A, 416, 353
Michałowski, T., Kaasalainen, M., Marciniak, A., et al. 2005, A&A, 443, 329
Michałowski, T., Kaasalainen, M., Polińska, M., et al. 2006, A&A, 459, 663
Piironen, J., Bowell, E., Erikson, A., et al. 1994, A&AS, 106, 587
Riccioli, D., Blanco, C., & Cigna, M. 2001, Planetary and Space Sci., 49, 657
Schober, H. J., Erikson, A., Hahn, G., et al. 1993, A&AS, 101, 499
Shevchenko, V. G., & Tedesco, E. F. 2006 Icarus, 184, 211
Tedesco, E. F., Noah, P. V., Noah, M., et al. 2004, IRAS Minor Planet Survey, IRAS-A-FPA-3-RDR-IMPS-V6.0. NASA Planetary Data System
Tholen, D. J. 1989, In Asteroids II, ed. R. P. Binzel, T. Gehrels, & M. S. Matthews (Univ. Arizona Press), 1139
Torppa, J., Kaasalainen, M., Michalowski, T., et al. 2003, Icarus, 164, 346
Van Houten, C. J. 1962, Bul. Astron. Inst. Netherlands 16, 160
Warner, B. D. 2000, Minor Planet Bul. 27, 4

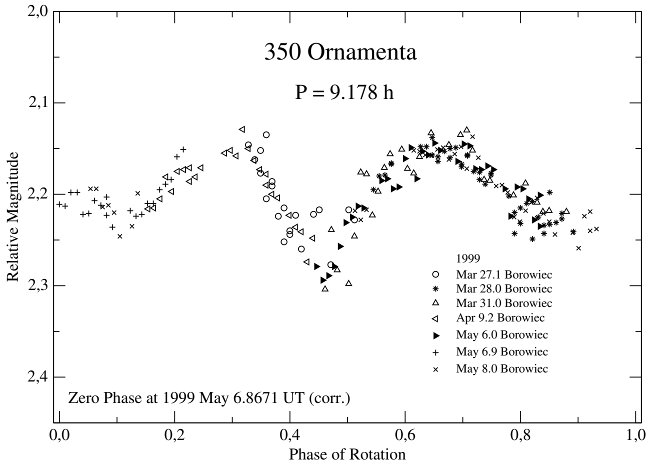

Fig. 1. Composite lightcurve of 350 Ornamenta in 1999.

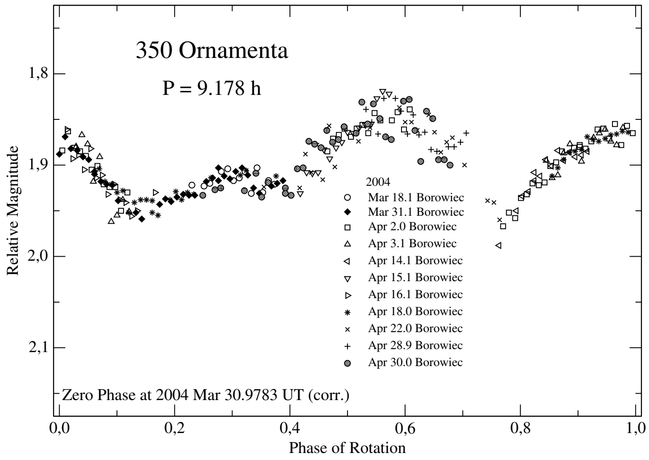

Fig. 2. Composite lightcurve of 350 Ornamenta in 2004.

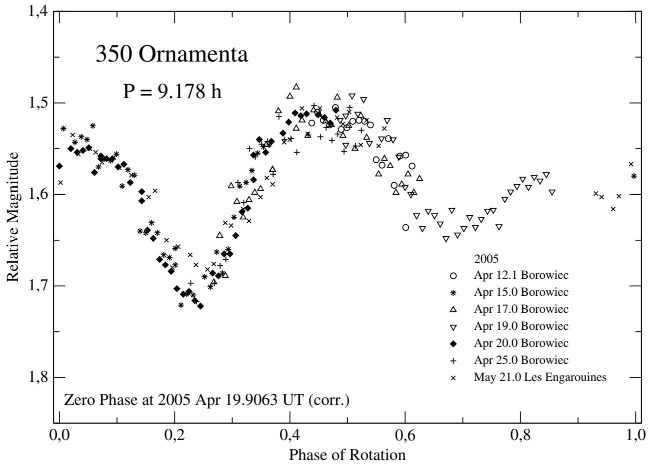

Fig. 3. Composite lightcurve of 350 Ornamenta in 2005.

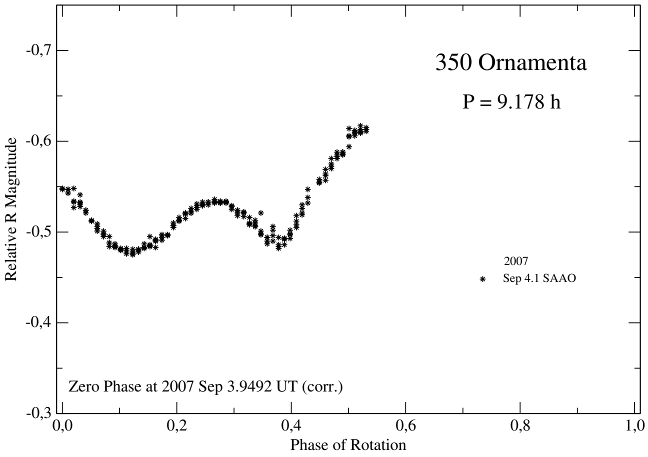

Fig. 4. Lightcurve of 350 Ornamenta in 2007.

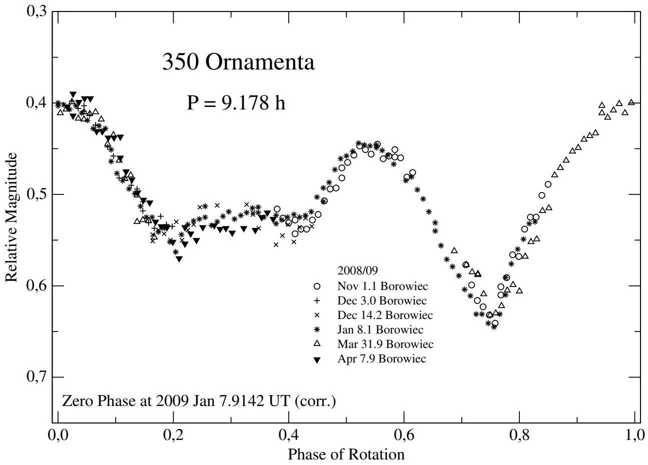

Fig. 5. Composite lightcurve of 350 Ornamenta in 2008/2009.

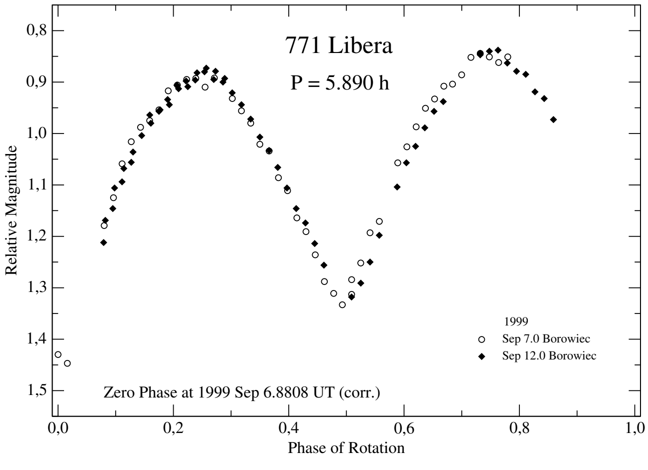

Fig. 6. Composite lightcurve of 771 Libera in 1999.

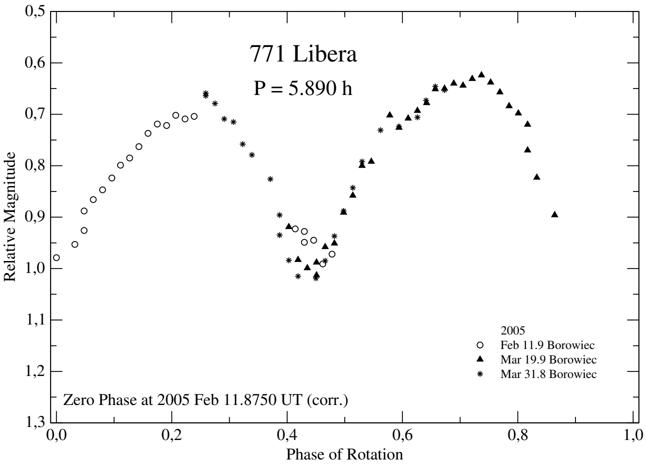

Fig. 7. Composite lightcurve of 771 Libera in 2005.

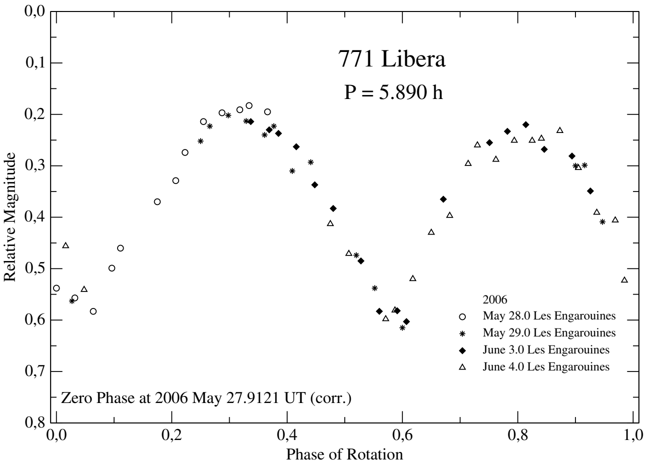

Fig. 8. Composite lightcurve of 771 Libera in 2006.

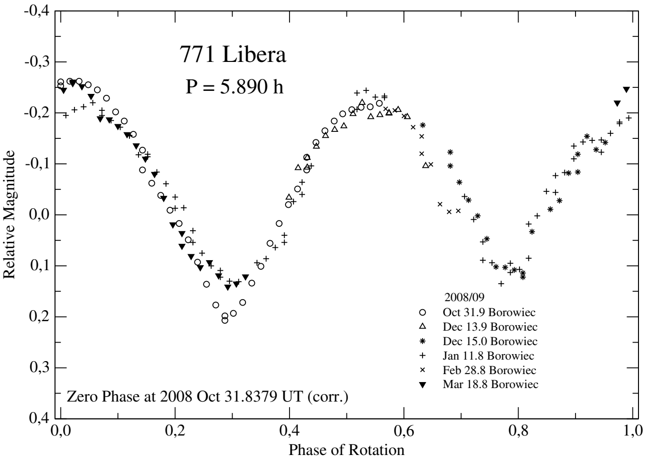

Fig. 9. Composite lightcurve of 771 Libera in 2008/2009.

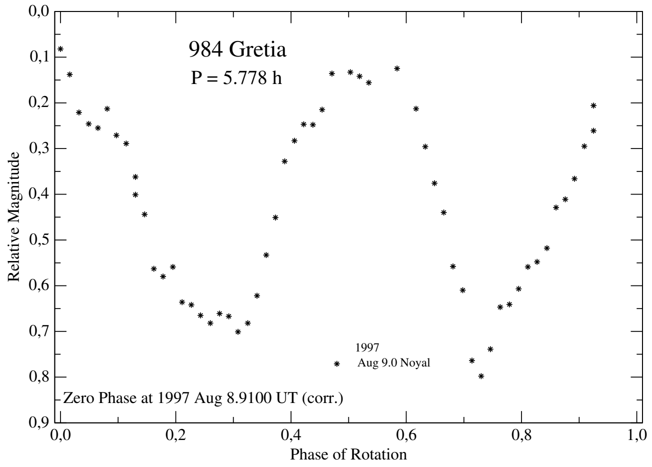

Fig. 10. Lightcurve of 984 Gretia in 1997.

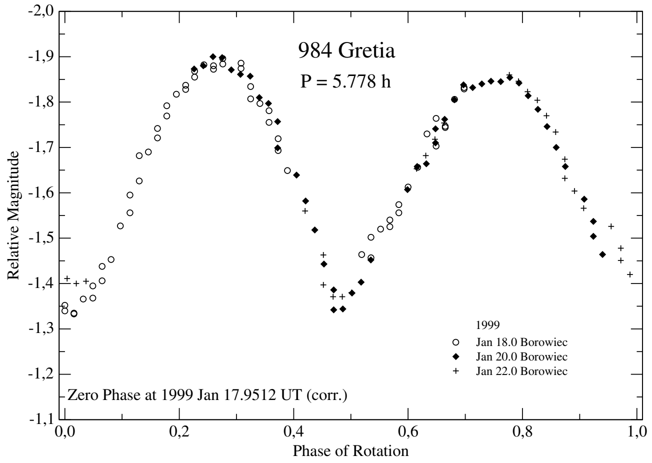

Fig. 11. Composite lightcurve of 984 Gretia in 1999.

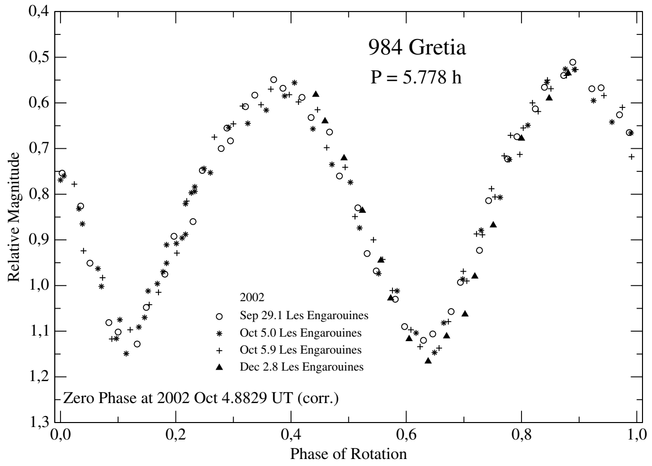

Fig. 12. Composite lightcurve of 984 Gretia in 2002.

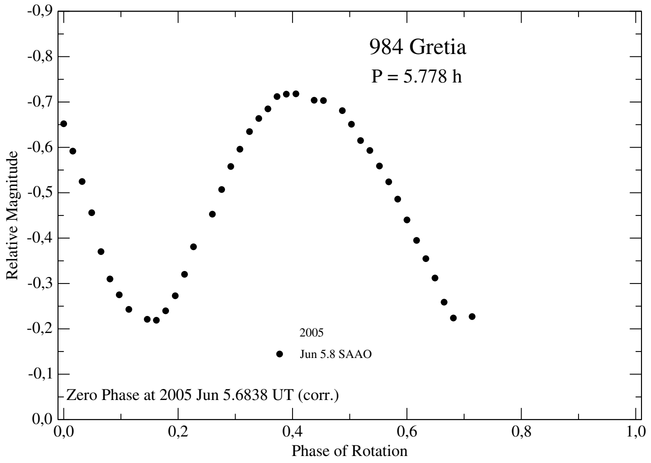

Fig. 13. Lightcurve of 984 Gretia in 2005.

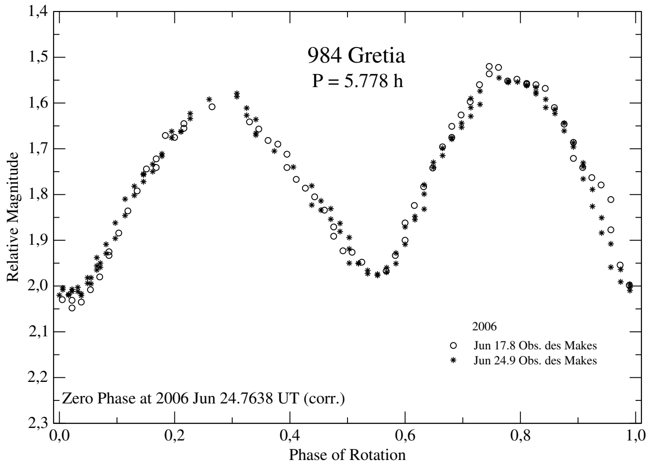

Fig. 14. Composite lightcurve of 984 Gretia in 2006.

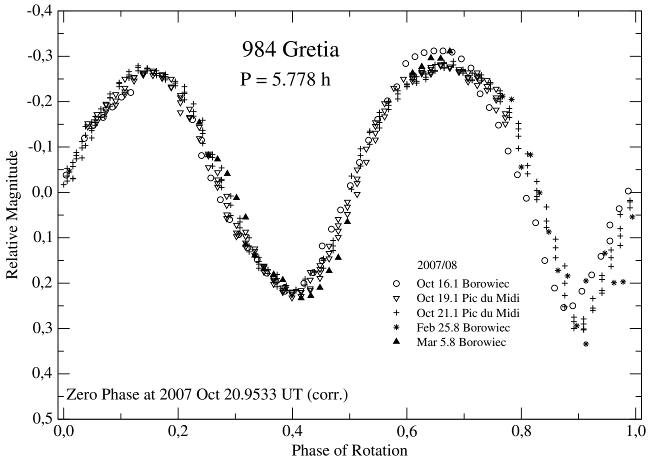

Fig. 15. Composite lightcurve of 984 Gretia in 2007/2008.

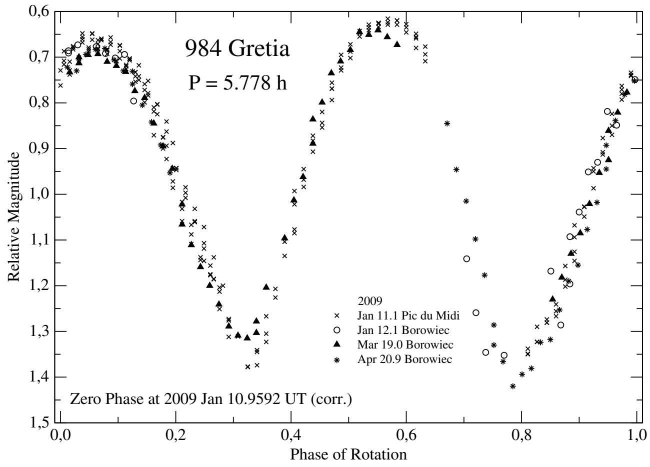

Fig. 16. Composite lightcurve of 984 Gretia in 2009.

Table 1. Aspect data.

Date (UT)	r	Δ	Phase angle	λ (J2000)	β	N_{p}	σ	Obs.
	(AU)	(AU)	(°)	(°)	(°)		**(mag)**	
350 Ornamenta								
1999 03 27.1	3.3996	2.5733	10.85	212.40	31.05	28	0.009	Bor
1999 03 28.0	3.4006	2.5689	10.71	212.23	31.09	46	0.013	Bor
1999 03 31.0	3.4039	2.5560	10.27	211.66	31.18	39	0.036	Bor
1999 04 09.2	3.4137	2.5297	9.18	209.76	31.30	27	0.007	Bor
1999 05 06.0	3.4413	2.5737	9.91	203.95	29.86	36	0.016	Bor
1999 05 06.9	3.4422	2.5785	10.04	203.77	29.77	21	0.004	Bor
1999 05 08.0	3.4432	2.5840	10.18	203.58	29.66	44	0.012	Bor
2004 03 18.1	3.1463	2.2876	10.76	167.69	34.92	13	0.009	Bor
2004 03 31.1	3.1656	2.3507	12.16	165.00	34.28	39	0.013	Bor
2004 04 02.0	3.1684	2.3630	12.42	164.66	34.14	51	0.008	Bor
2004 04 03.1	3.1700	2.3705	12.57	164.48	34.05	34	0.016	Bor
2004 04 14.1	3.1861	2.4584	14.16	163.01	32.96	15	0.004	Bor
2004 04 15.1	3.1876	2.4677	14.31	162.92	32.85	16	0.012	Bor
2004 04 16.1	3.1890	2.4768	14.45	162.82	32.73	16	0.013	Bor
2004 04 18.0	3.1918	2.4950	14.72	162.67	32.51	44	0.013	Bor
2004 04 22.0	3.1976	2.5348	15.25	162.42	32.00	30	0.011	Bor
2004 04 28.9	3.2076	2.6089	16.09	162.22	31.14	18	0.025	Bor
2004 04 30.0	3.2091	2.6211	16.21	162.22	31.00	44	0.010	Bor
2005 04 12.1	3.5623	2.7936	11.71	244.77	20.00	19	0.015	Bor
2005 04 15.0	3.5637	2.7669	11.15	244.43	20.04	36	0.004	Bor
2005 04 17.0	3.5647	2.7497	10.74	244.18	20.05	36	0.007	Bor
2005 04 19.0	3.5656	2.7334	10.34	243.91	20.06	40	0.003	Bor
2005 04 20.0	3.5661	2.7257	10.13	243.76	20.06	47	0.006	Bor
2005 04 25.0	3.5684	2.6897	9.07	242.98	20.04	31	0.016	Bor
2005 05 21.0	3.5788	2.6073	5.32	237.83	19.03	44	0.019	EnO
2007 09 04.0	2.8335	2.0919	16.15	21.85	–34.54	166	0.003	SAAO
2008 11 01.1	2.7058	2.4997	21.52	128.00	7.89	44	0.008	Bor
2008 12 03.0	2.7391	2.1266	18.42	131.74	13.21	20	0.008	Bor
2008 12 14.2	2.7518	2.0212	16.08	131.54	15.33	29	0.009	Bor
2009 01 08.1	2.7819	1.8752	9.57	128.07	19.92	89	0.008	Bor
2009 03 31.9	2.8957	2.4680	19.44	117.81	22.49	51	0.011	Bor
2009 04 07.9	2.9060	2.5641	19.85	118.70	22.14	40	0.019	Bor
771 Libera								
1999 09 07.0	2.4664	1.5371	11.51	8.97	15.56	49	0.006	Bor
1999 09 12.0	2.4531	1.5012	9.80	8.04	15.42	58	0.010	Bor
2005 02 11.9	2.1709	1.2481	12.22	133.91	–26.24	23	0.014	Bor
2005 03 19.9	2.2522	1.5052	20.60	129.83	–21.10	30	0.006	Bor
2005 03 31.8	2.2812	1.6375	22.80	130.73	–19.04	30	0.003	Bor
2006 05 28.0	3.2023	2.2077	4.17	235.78	7.87	13	0.012	EnO
2006 05 29.0	3.2035	2.2116	4.47	235.56	7.91	15	0.019	EnO
2006 06 03.0	3.2092	2.2352	6.05	234.50	8.10	17	0.017	EnO
2006 06 04.0	3.2104	2.2409	6.37	234.29	8.14	21	0.030	EnO
2008 10 31.9	2.0512	1.1361	14.48	69.02	–7.86	40	0.003	Bor
2008 12 13.9	2.0071	1.0789	12.76	60.02	–15.29	18	0.017	Bor
2008 12 15.0	2.0064	1.0829	13.25	59.84	–15.40	21	0.010	Bor
2009 01 11.8	1.9955	1.2636	23.87	58.24	–16.61	67	0.026	Bor
2009 02 28.8	2.0099	1.7471	29.53	70.39	–15.36	10	0.011	Bor
2009 03 18.8	2.0259	1.9456	28.94	77.99	–14.62	25	0.006	Bor
984 Gretia								
1997 08 09.0	2.3761	1.3703	4.06	325.84	4.99	121	–	Noy
1999 01 18.0	2.8027	1.8339	4.33	106.46	5.80	58	0.007	Bor
1999 01 20.0	2.8067	1.8435	5.07	106.02	5.69	44	0.009	Bor
1999 01 22.0	2.8106	1.8541	5.81	105.61	5.57	27	0.012	Bor
2002 09 29.1	2.2578	1.2801	7.38	15.81	13.55	43	0.018	EnO
2002 10 05.0	2.2585	1.2755	6.23	14.54	13.89	50	0.021	EnO
2002 10 05.9	2.2587	1.2756	6.17	14.34	13.93	46	0.016	EnO
2002 12 02.8	2.2871	1.6490	22.31	9.43	12.38	15	0.008	EnO
2005 06 05.8	3.3145	2.7395	15.95	191.85	–10.56	40	0.006	SAAO
2006 06 17.8	2.7684	1.7720	5.14	276.98	–9.44	71	–	Mak
2006 06 24.9	2.7540	1.7463	3.49	275.43	–9.24	123	–	Mak
2007 10 16.1	2.3446	1.5484	18.13	67.74	13.77	60	0.002	Bor
2007 10 19.1	2.3486	1.5281	17.16	67.56	13.96	153	–	Pic
2007 10 21.1	2.3512	1.5158	16.51	67.41	14.07	218	–	Pic
2008 02 25.8	2.5712	2.4301	22.60	63.26	7.22	20	0.007	Bor
2008 03 05.8	2.5892	2.5640	22.19	65.89	6.65	22	0.012	Bor
2009 01 11.1	3.1605	2.4558	14.15	162.71	–2.87	214	–	Pic
2009 01 12.2	3.1619	2.4453	13.92	162.65	–2.92	25	0.024	Bor
2009 03 19.0	3.2414	2.3294	8.32	150.80	–5.29	49	0.005	Bor
2009 04 20.9	3.2737	2.6917	15.86	148.11	–5.49	36	0.006	Bor

Observatory Code: Bor – Borowiec; EnO – Les Engarouines Observatory; SAAO – South African Astronomical Observatory; Noy – Noyal Observatory; Mak – Observatoire des Makes; Pic – Pic du Midi.