

# New and updated convex shape models of asteroids based on optical data from a large collaboration network

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Received 24 September 2015 / Accepted 22 October 2015

## ABSTRACT

**Context.** Asteroid modeling efforts in the last decade resulted in a comprehensive dataset of almost 400 convex shape models and their rotation states. These efforts already provided deep insight into physical properties of main-belt asteroids or large collisional families. Going into finer detail (e.g., smaller collisional families, asteroids with sizes  $\lesssim 20$  km) requires knowledge of physical parameters of more objects.

**Aims.** We aim to increase the number of asteroid shape models and rotation states. Such results provide important input for further studies, such as analysis of asteroid physical properties in different populations, including smaller collisional families, thermophysical modeling, and scaling shape models by disk-resolved images, or stellar occultation data. This provides bulk density estimates in combination with known masses, but also constrains theoretical collisional and evolutionary models of the solar system.

**Methods.** We use all available disk-integrated optical data (i.e., classical dense-in-time photometry obtained from public databases and through a large collaboration network as well as sparse-in-time individual measurements from a few sky surveys) as input for the convex inversion method, and derive 3D shape models of asteroids together with their rotation periods and orientations of rotation axes. The key ingredient is the support of more than 100 observers who submit their optical data to publicly available databases.

**Results.** We present updated shape models for 36 asteroids, for which mass estimates are currently available in the literature, or for which masses will most likely be determined from their gravitational influence on smaller bodies whose orbital deflections will be observed by the ESA *Gaia* astrometric mission. Moreover, we also present new shape model determinations for 250 asteroids, including 13 Hungarias and three near-Earth asteroids. The shape model revisions and determinations were enabled by using additional optical data from recent apparitions for shape optimization.

**Key words.** minor planets, asteroids: general – techniques: photometric – methods: observational – methods: numerical

† Deceased.

## 1. Introduction

Asteroid modeling efforts in the last decade resulted in an extensive dataset of almost 400 convex shape models and rotation states (see the review by Āurech et al. 2015a). The majority of these models was determined by the lightcurve inversion method (LI) developed by Kaasalainen & Torppa (2001) and Kaasalainen et al. (2001). About 100 models are based on disk-integrated, dense-in-time optical data (e.g., Torppa et al. 2003; Slivan et al. 2003; Michałowski et al. 2005; Marciniak et al. 2009, 2011). Combining dense-in-time data with sparse-in-time measurements from large sky surveys, or using only sparse-in-time data, increased the number of available shape models by a factor of 4 (Āurech et al. 2009; Hanuš et al. 2011, 2013a,c). Future data from *Gaia*, Panoramic Survey Telescope and Rapid Response System (PanSTARRS), and Large Synoptic Survey Telescope (LSST) should result in an increase of shape models by an order of at least one magnitude (Āurech et al. 2005). The methods that will be used for analysis of these future data of unprecedented amount and quality, by the means of complex shape modeling, are similar to those applied here and developed within the scope of our recent studies.

Most asteroid shape models derived by the LI method and their optical data are available in the Database of Asteroid Models from Inversion Techniques (DAMIT<sup>1</sup>; Āurech et al. 2010).

We would like to emphasize and acknowledge that the shape modeling stands on the shoulders of hundreds of observers, often amateurs, who regularly obtain photometric data with their small and mid-sized telescopes. These observations have significantly contributed to the great progress of the shape modeling field in the last decade. Although there is much more sparse than dense data available, the latter will always remain important because their much higher photometric accuracy and rotation coverage leads to higher quality shape models. This is a typical example of the great interaction between the professional and amateur community (Mousis et al. 2014).

Knowing the rotational parameters and shapes of asteroids is very important for numerous applications. The large amount of currently known asteroid models already provided a deep insight into physical properties of main-belt asteroids (MBAs) and large collisional families: (i) an excess of prograde rotators within (MBAs) larger than ~50 km in diameter, predicted by numerical simulations (Johansen & Lacerda 2010), was confirmed by Kryszczyńska et al. (2007), Hanuš et al. (2011); (ii) an excess of retrograde rotators within near-Earth asteroids (NEAs) is consistent with the fact that most of the NEAs come from the  $\nu_6$  resonance (La Spina et al. 2004). To enter the  $\nu_6$  resonance via Yarkovsky effect<sup>2</sup>, the object must be a retrograde rotator; (iii) an anisotropy of spin-axis directions of MBAs asteroids with diameters  $\lesssim 30$  km and NEAs was revealed and explained by the YORP effect<sup>3</sup>, collisions, and mass shedding (Hanus et al. 2011; Pravec et al. 2012); (iv) a bimodality of prograde and retrograde rotators symmetric with respect to the center of the family is caused by the combined Yarkovsky, YORP,

and collisional dynamical evolution (Kryszczyńska 2013; Hanuš et al. 2013a); (v) the larger dispersion of spin-axis directions of smaller ( $D \lesssim 50$  km) prograde than retrograde asteroids suggests that spin states of prograde rotators are affected by resonances (Hanus et al. 2013c); or (vi) the disruption of asteroid pairs<sup>4</sup> was most likely the outcome of the YORP effect that spun up the original asteroid (Polishook 2014).

With the use of convex shape models in combination with asteroidal stellar occultations and disk-resolved images obtained by space telescopes or ground-based telescopes equipped with adaptive optics (AO) systems, the size of the model can be constrained, making it possible to determine the asteroid volume. Even when the object is considerably nonconvex, the scaled convex model from occultations and AO data tends to compensate by average fitting to the disk-resolved data. As a result, the overestimation of the volume is smaller than would correspond to the convex hull. The volume can then provide, in combination with mass estimates, realistic values of bulk densities (Āurech et al. 2011; Hanuš et al. 2013b).

The mass is one of the most challenging parameters to measure for an asteroid. Mass estimates are now available for 280 asteroids, but only 113 of these are more precise than 20% (Carry 2012; Scheeres et al. 2015). However, the situation is expected to improve significantly in the near future. The observations of the ESA *Gaia* astrometric satellite will provide masses accurate to better than 50% for  $\approx 150$  asteroids (and for  $\approx 50$  with an accuracy better than 10%; Mouret et al. 2007, 2008) by the orbit deflection method. The advantage of the masses determined by *Gaia* is in the uniqueness of the mission: we should obtain a comprehensive sample with well-described biases (e.g., the current mass estimates are currently strongly biased toward the inner main belt).

To maximize the possible outcome by means of density determinations, we focus on determination of shape models for asteroids for which accurate mass estimates are available or will most likely be determined by *Gaia*. Moreover, it is also important to update shape models for such asteroids using recently obtained optical data. By doing this, we can provide better constraints on the rotational phase (i.e., on the asteroid orientation, which is important for scaling the size) of these asteroids due to the improvement of the rotation period, and more accurate rotation state and shape parameters.

Convex models, together with thermal infrared observations, have also been used as inputs for thermophysical modeling, enabling the determination of geometric visible albedo, size, and surface properties (e.g., Müller et al. 2011; Hanuš et al. 2015). This application is particularly important because it can make use of the large sample of infrared data for more than 100 000 asteroids acquired by the NASA's Wide-field Infrared Survey Explorer (WISE). The missing input here is shape models of sufficient quality (Delbo et al. 2015).

Moreover, convex models or at least rotational states are usually necessary inputs for more complex shape modeling, which can be performed if additional data, such as stellar occultations, AO images or interferometry containing information about the nonconvexities, (Kaasalainen & Viikinkoski 2012; Carry et al. 2010a,b, 2012; Viikinkoski et al. 2015; Tanga et al. 2015) are available.

Finally, large flat areas/facets on convex shape models, represented by polyhedra, usually indicate possible concavities

<sup>1</sup> <http://astro.troja.mff.cuni.cz/projects/asteroids3D>

<sup>2</sup> A thermal recoil force affecting rotating asteroids (Bottke et al. 2001).

<sup>3</sup> Yarkovsky–O'Keefe–Radzievskii–Paddack effect, a torque caused by the recoil force from anisotropic thermal emission, can alter the rotational periods and orientation of spin axes; see, e.g., Rubincam (2000), Vokrouhlický et al. (2003).

<sup>4</sup> An asteroid pair consists of two unbound objects with almost identical heliocentric orbital elements that were originally part of a bound system.

(Devogèle et al. 2015). Candidates for highly irregular bodies can be identified for further studies.

In Sect. 2, we introduce the dense- and sparse-in-time optical disk-integrated data, which we used for the shape model determinations. We describe the lightcurve (convex) inversion method in Sect. 3, present updated and new shape model determinations in Sects. 4.1 and 4.2, comment on several individual solutions in Sect. 4.3, and conclude our work in Sect. 5.

## 2. Optical disk-integrated photometry

Similar to Hanuš et al. (2011, 2013a,c), we use two different types of optical disk-integrated data: (i) dense-in-time photometry, i.e., classical continuous multihour observations; and (ii) sparse-in-time photometry consisting of a few hundred individual calibrated measurements from several astrometric observatories, typically covering ~15 years.

Dense photometry was acquired from publicly available databases, from those of our collaborators, or directly from several individual observers. The historical data from the second half of the twentieth Century are mainly stored in the Asteroid Photometric Catalogue (APC<sup>5</sup>; Piironen et al. 2001). Currently, the common practice, which is used mostly by observers from the United States, is a regular data submission to the Minor Planet Center in the Asteroid Lightcurve Data Exchange Format (ALCDEF<sup>6</sup>; Warner et al. 2011). These data are publicly available and often also published in the Minor Planet Bulletin<sup>7</sup>, where the synodic rotation period is reported. Many European observers send their data to the Courbes de rotation d’astéroïdes et de comètes database (CdR<sup>8</sup>), maintained by Raoul Behrend at Observatoire de Genève. Composite lightcurves with best-fitting synodic rotation periods are then published on the web page.

We obtained the first type of sparse-in-time photometric data for this study from the AstDyS site (Asteroids – Dynamic Site<sup>9</sup>) and processed the data according to Hanuš et al. (2011). We solely employ sparse data from the USNO-Flagstaff station (IAU code 689) and the Catalina Sky Survey Observatory (IAU code 703, Larson et al. 2003), weighting them with respect to dense data (unity weight) by 0.3 and 0.15, respectively. As an alternative to this type of sparse-in-time data, we use the Lowell Photometric Database (Oszkiewicz et al. 2011; Bowell et al. 2014). The photometry from several astrometric surveys, including both USNO-Flagstaff and Catalina Sky Survey, reported to the Minor Planet Center (MPC), was reprocessed; e.g., systematic effects in the magnitude calibration were removed. This enormous dataset typically consists of several hundreds of individual measurements for each of the ~320 000 asteroids that were processed so far. Although the accuracy of the recalibrated photometry is improved, the dataset for each asteroid is still a mixture of measurements from several observatories with different photometric quality. Compared to the data of USNO-Flagstaff and Catalina observatories downloaded from AstDyS, Lowell data provide an increased quantity of measurements from more observing geometries. These data, however, are, on average, of poor photometric quality, as they also contain measurements from observatories that were originally rejected in Hanuš et al. (2011) owing to low accuracy. We assigned to Lowell data the weight of 0.1. A subset of Lowell

data was already analyzed by Ďurech et al. (2013) and a complex analysis of the reliability of shape models, based solely on these data, is underway (Ďurech et al. 2016). On top of that, the volunteer project Asteroids at home<sup>10</sup>, which makes use of distributed computing and runs in the framework of Berkeley Open Infrastructure for Network Computing (BOINC), currently employs shape model computations based on Lowell data (Ďurech et al. 2015b). Thousands of individual home computational stations of volunteers are currently participating in the project.

Tables 1 and A.1 include the information about the optical data used for the shape model determination, such as the number of dense-in-time lightcurves and apparitions covered by dense-in-time observations and the number of sparse-in-time measurements from corresponding astrometric surveys. Table A.2 provides references to the dense data used for the shape model determinations and Table A.3 links the observers to their observatories.

## 3. Convex inversion and reproducibility

In this work, we use the lightcurve inversion method of Kaasalainen & Torppa (2001) and Kaasalainen et al. (2001), which is already a well-documented, investigated, and employed technique for asteroid shape modeling (for more details, see the review by Ďurech et al. 2015a).

The main advantage of using convex inversion is that convex models are usually the only stable or unambiguous inversion result (Ďurech & Kaasalainen 2003); they best portray the resolution level or information content of disk-integrated photometry. To demonstrate this more intuitively, consider an asteroid with a large planar region (or many regions) on the surface (e.g., an ellipsoid with a sizable chunk or chunks chopped off), and a large crater (say, half the size of the plane) at one end of the plane. Then it is impossible to tell from lightcurve data (no matter how large solar phase angles, i.e., shadows) where the crater is in the plane, or whether it is two craters half the size, or even myriads of small craters on the surface that have the same combined area as the big one (even if the crater filled most of the plane). In other words, one simply cannot say whether the lightcurves are caused just by small-scale surface roughness on a convex shape, or by huge nonconvexities that would be obvious in any disk-resolved data. Hence, any nonconvex model from disk-integrated photometric data is inevitably ambiguous, while the convex model is unambiguous. This also explains why the assumption of the nonconvexity represented by a large plane in the convex model (e.g., Devogèle et al. 2015), while often a good guess because of physical constraints, cannot usually be more than an assumption.

Convex inversion was successfully used for shape model determinations of almost 400 asteroids. On top of that, several convex models were validated by disk-resolved and delay-Doppler images or by direct comparison with images obtained by space probes (e.g., Kaasalainen et al. 2001; Carry et al. 2012). The parameter space of shape, rotation period, spin vector orientation, and scattering properties (simple three-parameter empirical model) is systematically investigated in the means of a  $\chi^2$ -metric

$$\chi^2 = \sum_i \frac{\|L_{\text{OBS}}^{(i)} - L_{\text{MOD}}^{(i)}\|}{\sigma_i^2}, \quad (1)$$

<sup>10</sup> <https://asteroidsathome.net/>

<sup>5</sup> <http://asteroid.astro.helsinki.fi/>

<sup>6</sup> <http://www.minorplanet.info/alcdef.html>

<sup>7</sup> <http://www.minorplanet.info/minorplanetbulletin.html>

<sup>8</sup> [http://obswww.unige.ch/~behrend/page\\_cou.html](http://obswww.unige.ch/~behrend/page_cou.html)

<sup>9</sup> <http://hamilton.dm.unipi.it/>

**Table 1.** Rotational states and summary of used photometry for asteroids for which we updated their shape models based on new disk-integrated optical data.

| Asteroid       | $\lambda_1$<br>[deg] | $\beta_1$<br>[deg] | $\lambda_2$<br>[deg] | $\beta_2$<br>[deg] | $P$<br>[h] | $N_{lc}$ | $N_{app}$ | $N_{LOW}$ | Original model<br>published by                    |
|----------------|----------------------|--------------------|----------------------|--------------------|------------|----------|-----------|-----------|---|
| 3 Juno         | 104                  | 20                 |                      |                    | 7.209532   | 38       | 11        | 332       | Kaasalainen et al. (2002)                         |
| 7 Iris         | 19                   | 19                 | 198                  | 5                  | 7.138843   | 39       | 14        | 372       | Kaasalainen et al. (2002)                         |
| 16 Psyche      | 32                   | -7                 |                      |                    | 4.195948   | 118      | 19        | 567       | Kaasalainen et al. (2002)                         |
| 17 Thetis      | 240                  | 22                 |                      |                    | 12.26603   | 57       | 10        | 690       | Đurech et al. (2009)                              |
| 19 Fortuna     | 96                   | 56                 |                      |                    | 7.44322    | 48       | 11        | 565       | Torppa et al. (2003)                              |
| 20 Massalia    | 304                  | 76                 | 124                  | 81                 | 8.09759    | 36       | 9         | 380       | Kaasalainen et al. (2002)                         |
| 22 Kalliope    | 196                  | 4                  |                      |                    | 4.148201   | 102      | 17        | 343       | Kaasalainen et al. (2002)                         |
| 23 Thalia      | 159                  | -40                |                      |                    | 12.31241   | 50       | 12        | 466       | Torppa et al. (2003)                              |
| 27 Euterpe     | 82                   | 44                 | 265                  | 39                 | 10.40193   | 54       | 6         |           | Stephens et al. (2012)                            |
| 29 Amphitrite  | 136                  | -20                |                      |                    | 5.390119   | 66       | 15        | 323       | Kaasalainen et al. (2002)                         |
| 39 Laetitia    | 322                  | 30                 |                      |                    | 5.138238   | 68       | 26        | 448       | Kaasalainen et al. (2002)                         |
| 40 Harmonia    | 22                   | 34                 |                      |                    | 8.90848    | 23       | 7         | 405       | Hanuš et al. (2011)                               |
| 41 Daphne      | 199                  | -30                |                      |                    | 5.98798    | 33       | 8         | 508       | Kaasalainen et al. (2002)                         |
| 42 Isis        | 113                  | 45                 |                      |                    | 13.58364   | 31       | 8         | 499       | Hanuš et al. (2011)                               |
| 45 Eugenia     | 125                  | -34                |                      |                    | 5.699151   | 101      | 16        | 574       | Hanuš et al. (2013b)                              |
| 54 Alexandra   | 152                  | 19                 |                      |                    | 7.02264    | 38       | 8         | 506       | Warner et al. (2008b)                             |
| 64 Angelina    | 135                  | 6                  | 315                  | 5                  | 8.75171    | 24       | 4         | 450       | Đurech et al. (2011)                              |
| 76 Freia       | 138                  | 12                 | 319                  | 17                 | 9.97306    | 57       | 12        | 463       | Marciniak et al. (2012)                           |
| 87 Sylvia      | 82                   | 64                 |                      |                    | 5.183641   | 55       | 12        | 545       | Kaasalainen et al. (2002), Berthier et al. (2014) |
| 88 Thisbe      | 82                   | 69                 |                      |                    | 6.04132    | 28       | 8         | 554       | Torppa et al. (2003)                              |
| 94 Aurora      | 65                   | 9                  | 242                  | -7                 | 7.22619    | 22       | 8         | 550       | Marciniak et al. (2011)                           |
| 95 Arethusa    | 119                  | 23                 |                      |                    | 8.70221    | 15       | 2         | 417       | Đurech et al. (2011)                              |
| 107 Camilla    | 72                   | 51                 |                      |                    | 4.843928   | 34       | 10        | 543       | Torppa et al. (2003)                              |
| 110 Lydia      | 148                  | -39                | 340                  | -57                | 10.92581   | 53       | 11        | 398       | Đurech et al. (2007)                              |
| 121 Hermione   | 1                    | 16                 |                      |                    | 5.550881   | 48       | 9         | 536       | Descamps et al. (2009)                            |
| 129 Antigone   | 211                  | 55                 |                      |                    | 4.957160   | 52       | 11        | 535       | Torppa et al. (2003)                              |
| 130 Elektra    | 176                  | -89                |                      |                    | 5.224663   | 56       | 13        | 358       | Đurech et al. (2007)                              |
| 354 Eleonora   | 162                  | 43                 |                      |                    | 4.277184   | 64       | 13        | 482       | Hanuš et al. (2011)                               |
| 360 Carlota    | 3                    | 56                 | 143                  | 67                 | 6.18959    | 9        | 4         | 435       | Đurech et al. (2009)                              |
| 372 Palma      | 234                  | -5                 | 51                   | 54                 | 8.57964    | 38       | 8         | 406       | Hanuš et al. (2011)                               |
| 386 Siegena    | 289                  | 25                 |                      |                    | 9.76503    | 83       | 12        | 460       | Marciniak et al. (2012)                           |
| 409 Aspasia    | 2                    | 28                 |                      |                    | 9.02145    | 22       | 8         | 438       | Warner et al. (2008b), Hanuš et al. (2013b)       |
| 423 Diotima    | 351                  | 4                  |                      |                    | 4.775377   | 58       | 12        | 540       | Đurech et al. (2007)                              |
| 511 Davida     | 298                  | 22                 |                      |                    | 5.129365   | 58       | 17        | 588       | Torppa et al. (2003)                              |
| 532 Herculina  | 100                  | 9                  |                      |                    | 9.40494    | 74       | 11        | 410       | Kaasalainen et al. (2002)                         |
| 776 Berbericia | 346                  | 25                 |                      |                    | 7.66701    | 59       | 11        | 402       | Đurech et al. (2007)                              |

**Notes.** We also provide the reference to the original model and in two cases to the plausible non-convex model as well. The table gives ecliptic coordinates  $\lambda_1$  and  $\beta_1$  of the best-fitting pole solution, ecliptic coordinates  $\lambda_2$  and  $\beta_2$  for the possible second (mirror) pole solution, sidereal rotational period  $P$ , the number of dense lightcurves  $N_{lc}$  spanning  $N_{app}$  apparitions, the number of sparse-in-time measurements from Lowell  $N_{LOW}$ , and the reference to the original model.

where the  $i$ th brightness measurement  $L_{OBS}^{(i)}$  (with an uncertainty of  $\sigma_i$ ) is compared to the corresponding modeled brightness  $L_{MOD}^{(i)}$ . The best-fitting parameter set is searched for.

A significant minimum in the parameter space indicates a unique solution. Visual examination of the fit in the period subspace is performed as well as the comparison between observed and modeled lightcurves. Additionally, the pole-ecliptic latitudes should be similar within the two pole solutions, which are typically determined as a result of the ambiguity (symmetry) presented in most lightcurve inversion models (Kaasalainen & Lamberg 2006). On the other hand, the pole-ecliptic longitudes of these so-called mirror solutions should differ by  $\sim 180$  degrees. The pole ambiguity is present in the majority of our shape models.

Moreover, we also compute the principal moments of inertia of each shape model, assuming a homogeneous mass distribution, and compare these moments with the moment of inertia along the rotation axis. A reliable solution should rotate within  $\sim 10$ – $20$  degrees of the axis with the largest moment of inertia.

If available, we use a priori information about the rotation period of the asteroid from the Minor Planet Lightcurve Database<sup>11</sup> (Warner et al. 2009) to significantly reduce, usually by at least two orders of magnitude, computation requirements. Hence, we investigate the parameter space only in the proximity of the expected rotation period.

It should be kept in mind that none of the shape models should be taken as granted, i.e., each asteroid model contains an uncertainty (both in shape and rotation state), which increases with decreasing amount, variety, and quality of the optical data. It was already shown in Hanuš et al. (2015) that by varying a shape model within its uncertainty, one can obtain significantly different fits to the thermal infrared data by the thermophysical modeling. Thus, the shape uncertainty plays an important role for the interpretation of the thermal infrared data. This demonstrates the need of accounting for the shape model uncertainties

<sup>11</sup> <http://cfa-www.harvard.edu/iau/lists/Lightcurve\discretionary-Dat.html>

in all further shape model applications. Also, the overall shape model based mostly on sparse data usually contains many flat facets (areas) with rather sharp edges, thus most of the low-detail topography is hidden (i.e., we have a large uncertainty in the shape). As we use more dense data, the shape becomes smoother and has more details. This limits the application of the lower-resolution shape models based mostly on sparse data.

In the ecliptic coordinate frame, the typical pole direction uncertainties are: (i)  $\lesssim 5^\circ$  in latitude  $\beta$  and  $\lesssim 5^\circ/\cos\beta$  in longitude  $\lambda$  for asteroid models based on large multiapparition dense lightcurve datasets; (ii)  $\sim 5\text{--}10^\circ$  in  $\beta$  and  $\sim 5\text{--}10^\circ/\cos\beta$  in  $\lambda$  for models based on combined multiapparition dense data and sparse-in-time measurements; and finally; (iii)  $\sim 10\text{--}30^\circ$  in  $\beta$  and  $\sim 10\text{--}30^\circ/\cos\beta$  in  $\lambda$  for models based on combined few-apparition dense data with sparse-in-time measurements or only sparse-in-time data.

To sum up, we follow the same procedure for the shape model determinations as in Hanuš et al. (2011, 2013a,c). Finally, we would like to emphasize that our work can be easily reproduced by anyone who is interested. The LI code and the lightcurve data are available in DAMIT, as well as the user manual.

## 4. Results and discussions

### 4.1. Updated shape models

We updated shape models of 36 asteroids with known mass estimates or for which masses will be most likely determined by the orbit deflection method from the *Gaia* astrometric observations (Mouret et al. 2007, 2008, and personal communication with François Mignard). For each one of these asteroids, there were new available optical dense data (see Table A.2). We combined these new data with Lowell data and the already available dense photometry from DAMIT. If applicable, we replaced the original sparse data from AstDyS with the Lowell data.

In most cases, rotational states of updated shape models are similar to those of the original models in the DAMIT database. The only exceptions, which we individually commented on in Sect. 4.3, are asteroids (27) Euterpe, and (532) Herculina. We performed the LI independently from any previous shape modeling results (e.g., we did not use information about the spin axis).

Updated models provide better constraints on the rotational phase, thus these models allow us, for example, to better link recently obtained AO and occultation profiles with the orientation of the shape model at the time of the observation. This is essential for a potential scaling of the sizes of shape models to compute the volume, and consequently bulk densities. Obviously, the uncertainties in rotation period, spin axis direction, and shape model should be improved as there are more data used for the modeling.

Optimized rotation state parameters and information about optical data are listed in Table 1. References to the optical dense-in-time data can be found in Table A.2.

### 4.2. New shape models

The majority of our new shape model determinations is obtained by combining dense-in-time data with sparse-in-time measurements from the Lowell database. However, the fact that Lowell data contain for each asteroid a mixture of measurements from several observatories makes it difficult to find a representative weight with respect to the dense data. Indeed, a specific single

value of the weight can result in an overestimation for some asteroids, while it can underestimate others. Despite these issues, we decided to use a weight of 0.1 for the Lowell data as a whole and to present corresponding shape models. As a consequence, we sometimes obtained a unique shape solution if we combined dense data and the sparse data from AstDyS (i.e., from USNO and Catalina), but not if we used the Lowell data instead. We present these shape models as well.

Moreover, 57 out of 250 shape models are based only on sparse data from USNO-Flagstaff and Catalina Sky Survey observatories. That these models can nevertheless be reliable was already shown in Hanuš & Ďurech (2012) and Hanuš et al. (2013c). As suggested there, we ran the LI search for shape and rotation state parameters with two different shape resolutions: (i) standard one; and (ii) lower one, which serves as a test of the solution stability. For this case, the asteroid's synodic rotation period is also available in the Minor Planet Lightcurve Database (LCDB, Warner et al. 2009), an additional test for the reliability can be performed. A rotation period derived by the LI (a period interval of 2–1000 h is typically scanned), which matches that already reported, points to a secure solution. In practice, all shape solutions based solely on sparse data that fulfilled our stability tests had rotation periods in an agreement with synodic periods from LCDB. This also demonstrates that our other unique solutions, for which a previous period estimate is not available, are reliable. We present nine of these shape and rotation state solutions; these are labeled in Table A.1.

We present shape models of three NEAs, which all have negative values of their pole latitudes  $\beta$ , and obliquities larger than  $90^\circ$ . The fact that they all show retrograde rotation supports the consensus that about half of the NEAs migrated through the  $\nu_6$  secular resonance, which causes an observed excess of retrograde rotators (La Spina et al. 2004).

We further present shape models of 13 asteroids that are classified as Hungarias. The majority of them (10 out of 13) exhibit retrograde rotation, which is in an agreement with the findings of Warner et al. (2014), who reported, in a sample of 53 Hungarias, a 75% representation of retrograde rotators.

Thirty-one of the derived shape models are those asteroids whose density will be measured in future or was already obtained. While for some of them, estimations on their masses are already available, the masses of the others will be determined from *Gaia* astrometric measurements. Constraining the model sizes of these asteroids using disk-resolved images, stellar occultation data, or thermophysical modeling will directly facilitate estimation of bulk densities.

Rotation state parameters and information about used optical data for all new shape model determinations are listed in Table A.1. References to the optical dense-in-time data can be found in Table A.2.

### 4.3. Individual asteroids

(27) *Euterpe*. The lightcurve amplitude of this asteroid is very low ( $\leq 0.1$  mag) and the dense data cover multiple apparitions. Thus, we decided to exclude the Lowell data from the shape modeling because they were dominated by noise. Our derived rotation period (10.40193 h) is slightly different than that derived by Stephens et al. (2012) (10.40825 h), which resulted in a different pole solution of  $(\lambda, \beta) = (82, 44)^\circ$  and  $(\lambda, \beta) = (265, 39)^\circ$  for the mirror solution. The solution in longitude  $\lambda$  is similar to that of Stephens et al. (2012), but their latitude has a different sign ( $-39$  and  $-30$ , respectively).

(532) *Herculina*. Our (single) pole solution only differs by  $\sim 180^\circ$  in longitude  $\lambda$  from that reported by Kaasalainen et al. (2002), thus it corresponds to their mirror solution. In contrast to their solution, our model is based on additional data from 2005 and 2010 apparitions.

(537) *Pauly*. The rotation period of 14.15 h from the LCDB is in contradiction with our shape modeling result: our period of 16.2961 h fits the data significantly better and thus is preferred.

(596) *Scheila*. The observations taken on December 11th, 2010 with the Catalina Schmidt telescope exhibited a comet-like appearance (Larson 2010). This behavior was later confirmed by Jewitt et al. (2011) from the HST observations on December 27th, 2010 and on January 4th, 2011 and interpreted as caused most likely by a collision with a 35m asteroid. All photometric data used for the shape modeling date prior to this event, so the shape model does not reflect any potential changes in the shape, period, or spin orientation induced by the collision (Bodewits et al. 2014).

(8567) 1996 HW<sub>1</sub>. The shape model of this NEAs was already determined by Magri et al. (2011) from a combination of dense lightcurves and radar Doppler images. We derived a consistent shape model and rotational state solution from combined dense and sparse data. The main difference between these two models is the fact that the Doppler images contain nonconvex signatures that were translated into their shape model. Even if our shape model is purely convex, it reliably represents the overall shape of the real asteroid. This case once again demonstrates the reliability of the convex inversion method.

(9563) *Kitty*. We derived the shape model of this asteroid without knowledge of a previous period estimate. However, Chang et al. (2015) recently reported period  $P = 5.35 \pm 0.03$  h based on the optical data from the Intermediate Palomar Transient Factory that is in perfect agreement with our independent determination of  $P = 5.38191 \pm 0.00005$  h.

## 5. Conclusions

In this work, we updated shape models of 36 asteroids with mass estimates by including new optical dense-in-time data in the shape modeling. For 250 asteroids, including 13 Hungarias and three NEAs, we derived their convex shape models and rotation states from combined disk-integrated dense- and sparse-in-time photometric data or from only sparse-in-time data. This effort was achieved with the help of the community of  $\sim 100$  individual observers who shared their lightcurves. All new models are now included in the DAMIT database and are available to anyone for additional studies. For nine asteroids, we provide, together with shape models and pole orientations, their first rotation period estimates.

Our work is a typical example in which a contribution of hundreds of observers, who are regularly obtaining photometric data with their small and mid-sized telescopes, was necessary to achieve presented results. The initial motivation of the observers is to derive the synodic rotation period (sometimes this is an object of a publication in the *Minor Planet Bulletin*), however, the shape modeling provides a welcome additional opportunity for the usage of their optical data. We acknowledge all the observers who submit their observations to the public databases and invite others to do so as well. This practice allows us an easy and straightforward access to the data and largely avoids an overlook of the precious data.

The shape models can be used as inputs for various studies, such as spin-vector analysis, detection of concavities,

thermophysical modeling with the varied-shape approach by Hanuš et al. (2015), nonconvex modeling, size optimization by disk-resolved images or occultation data, or density determinations.

Shape models based only on sparse data (or combined with a few dense lightcurves) are convenient candidates for follow-up observations, both to confirm the rotation periods and to improve the shape models, which is necessary, e.g., for thermophysical modeling. Finally, we maintain a web page with a list of asteroids, for which mass estimates are available and the shape model determination still requires additional photometric data (Hanus 2015). These objects are candidates for accurate density determination and any lightcurve support is welcome.

*Acknowledgements.* J.H. greatly appreciates the CNES post-doctoral fellowship program. J.H. and M.D. were supported by the project under the contract 11-B556-008 (SHOCKS) of the French Agence National de la Recherche (ANR), JD by grant GACR 15-04816S of the Czech Science Foundation, DO by the grant NCN 2012/S/ST9/00022 of Polish National Science Center, and A. Marciniak by grant 2014/13/D/ST9/01818 of Polish National Science Center. We thank the referee, Mikko Kaasalainen, for his thorough review of our manuscript and his constructive comments and suggestions that led to a significant improvement of the text. The computations have been carried out on the “Mesocentre” computers, hosted by the Observatoire de la Côte d’Azur, and on the computational cluster Tiger at the Astronomical Institute of Charles University in Prague (<http://sirrah.troja.mff.cuni.cz/tiger>). Data from Pic du Midi Observatory were partly obtained with the 0.6 m telescope, a facility operated by observatoire Midi-Pyrénées and Association T60, an amateur association. The Joan Oró Telescope (TJO) of the Montsec Astronomical Observatory (OAdM) is owned by the Catalan Government and operated by the Institute for Space Studies of Catalonia (IEEC). We thank Franck Pino (INO-AZ) and Lech Mankiewicz (EU-HOU/Comenius) for the remote access to Ironwood North.

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## Appendix A: Additional tables

Table A.1. New asteroid shape model determinations from disk-integrated optical data.

| Asteroid                       | $\lambda_1$<br>[deg] | $\beta_1$<br>[deg] | $\lambda_2$<br>[deg] | $\beta_2$<br>[deg] | $P$<br>[h] | $N_{lc}$ | $N_{app}$ | $N_{689}$ | $N_{703}$ | $N_{LOW}$ |
|--------------------------------|----------------------|--------------------|----------------------|--------------------|------------|----------|-----------|-----------|-----------|-----------|
| Near-Earth asteroids           |                      |                    |                      |                    |            |          |           |           |           |           |
| 3752 Camillo                   | 256                  | -14                |                      |                    | 37.881     | 9        | 1         |           |           | 77        |
| 5332 1990 DA                   | 266                  | -21                |                      |                    | 5.80285    | 6        | 3         |           |           | 190       |
| 8567 1996 HW1                  | 283                  | -34                |                      |                    | 8.76239    | 45       | 2         |           |           | 333       |
| Hungarias                      |                      |                    |                      |                    |            |          |           |           |           |           |
| 434 Hungaria                   | 109                  | 67                 |                      |                    | 26.4879    | 40       | 5         |           |           | 331       |
| 1103 Sequoia                   | 60                   | -59                |                      |                    | 3.037976   | 13       | 3         |           |           | 320       |
| 2001 Einstein                  | 87                   | -43                |                      |                    | 5.48503    | 13       | 4         |           |           | 382       |
| 2495 Noviomagum                | 12                   | -57                |                      |                    | 6.65168    | 4        | 1         |           |           | 190       |
| 3266 Bernardus                 | 227                  | -32                |                      |                    | 10.75954   | 15       | 4         |           |           | 321       |
| 4490 Bamberg                   | 53                   | 59                 |                      |                    | 5.82345    | 15       | 5         |           |           | 323       |
| 4764 Joneberhart               | 219                  | -36                |                      |                    | 5.48411    | 8        | 3         |           |           | 313       |
| 6087 Lupo                      | 248                  | -16                |                      |                    | 4.71654    | 7        | 2         |           | 78        |           |
| 6517 Buzzi                     | 227                  | -75                |                      |                    | 8.64468    | 17       | 4         |           |           | 337       |
| 7660 1993 VM1                  | 321                  | -44                |                      |                    | 5.91818    | 8        | 2         |           |           | 333       |
| 11058 1991 PN10                | 234                  | -64                |                      |                    | 6.51669    | 7        | 2         |           | 96        |           |
| 67404 2000 PG26                | 149                  | 69                 |                      |                    | 5.39877    | 7        | 2         |           |           | 275       |
| 86257 1999 TK207               | 28                   | -60                |                      |                    | 32.4029    | 13       | 2         |           |           | 201       |
| Main-belt asteroids            |                      |                    |                      |                    |            |          |           |           |           |           |
| 12 Victoria <sup>a</sup>       | 174                  | -17                |                      |                    | 8.66034    | 53       | 8         |           |           | 352       |
| 18 Melpomene <sup>a</sup>      | 11                   | 14                 |                      |                    | 11.57031   | 64       | 8         |           |           | 326       |
| 24 Themis <sup>a</sup>         | 331                  | 52                 | 137                  | 59                 | 8.37419    | 46       | 7         |           |           | 713       |
| 26 Proserpina                  | 88                   | -52                |                      |                    | 13.10977   | 29       | 7         |           |           | 563       |
| 31 Euphrosyne <sup>a</sup>     | 88                   | 66                 | 290                  | 6                  | 5.529597   | 29       | 8         |           |           | 366       |
| 35 Leukothea                   | 15                   | 7                  | 196                  | 0                  | 31.9009    | 52       | 7         |           |           | 417       |
| 36 Atalante                    | 45                   | -49                | 190                  | -55                | 9.92692    | 30       | 6         |           |           | 369       |
| 48 Doris <sup>a</sup>          | 297                  | 61                 | 108                  | 47                 | 11.89010   | 31       | 4         |           |           | 591       |
| 51 Nemausa <sup>a</sup>        | 169                  | -62                | 347                  | -68                | 7.78484    | 60       | 17        |           |           | 446       |
| 56 Melete <sup>a</sup>         | 103                  | -27                | 282                  | -5                 | 18.1482    | 37       | 6         |           |           | 400       |
| 66 Maja                        | 49                   | -70                | 225                  | -68                | 9.73570    | 16       | 5         |           |           | 436       |
| 71 Niobe                       | 88                   | -33                |                      |                    | 35.8521    | 49       | 7         |           |           | 426       |
| 98 Ianthé <sup>a</sup>         | 286                  | 18                 |                      |                    | 16.4801    | 9        | 2         |           |           | 382       |
| 99 Dike                        | 233                  | 50                 |                      |                    | 18.1191    | 29       | 4         |           |           | 410       |
| 103 Hera                       | 85                   | 24                 | 270                  | 40                 | 23.7427    | 29       | 3         |           |           | 516       |
| 104 Klymene <sup>a</sup>       | 112                  | 2                  | 292                  | -4                 | 8.98059    | 12       | 3         |           |           | 519       |
| 112 Iphigenia <sup>a</sup>     | 101                  | -66                | 286                  | -50                | 31.4625    | 7        | 1         |           |           | 416       |
| 117 Lomia <sup>a</sup>         | 312                  | -40                | 117                  | -18                | 9.12417    | 19       | 4         |           |           | 459       |
| 120 Lachesis <sup>a</sup>      | 256                  | 39                 | 82                   | 55                 | 46.5508    | 35       | 4         |           |           | 467       |
| 122 Gerda                      | 201                  | 22                 | 23                   | 20                 | 10.68724   | 17       | 6         |           |           | 553       |
| 136 Austria                    | 117                  | 53                 | 357                  | 81                 | 11.49662   | 4        | 1         |           |           | 401       |
| 144 Vibilia <sup>a</sup>       | 248                  | 56                 | 54                   | 48                 | 13.82516   | 43       | 4         |           |           | 417       |
| 150 Nuwa <sup>a</sup>          | 359                  | 25                 | 177                  | 22                 | 8.13456    | 33       | 5         |           |           | 543       |
| 154 Bertha <sup>a</sup>        | 28                   | 34                 | 234                  | 32                 | 25.2285    | 18       | 3         |           |           | 431       |
| 155 Scylla                     | 201                  | 69                 | 356                  | 53                 | 7.95880    | 7        | 1         | 110       | 108       |           |
| 164 Eva                        | 54                   | -10                |                      |                    | 13.66380   | 18       | 4         |           |           | 390       |
| 171 Ophelia                    | 144                  | 29                 | 329                  | 23                 | 6.66454    | 37       | 4         |           |           | 453       |
| 179 Klytaemnestra <sup>a</sup> | 65                   | -6                 | 248                  | -9                 | 11.17342   | 3        | 1         |           |           | 391       |
| 180 Garumna                    | 41                   | -64                | 196                  | -64                | 23.8592    | 23       | 2         |           |           | 467       |
| 187 Lamberta <sup>a</sup>      | 153                  | -56                | 328                  | -62                | 10.66703   | 20       | 5         |           |           | 482       |
| 189 Phthia <sup>a</sup>        | 26                   | 35                 | 197                  | 45                 | 22.3416    | 15       | 3         | 135       | 60        |           |
| 210 Isabella <sup>a</sup>      | 100                  | -14                | 278                  | -26                | 6.67190    |          |           | 176       | 64        |           |
| 212 Medea <sup>a</sup>         | 40                   | -24                | 220                  | -33                | 10.28414   | 46       | 8         |           |           | 397       |
| 226 Weringia                   | 284                  | -14                |                      |                    | 11.14849   | 24       | 4         |           |           | 485       |
| 233 Asterope                   | 132                  | 36                 | 322                  | 59                 | 19.6981    | 13       | 3         |           |           | 427       |
| 237 Coelestina                 | 42                   | 14                 | 230                  | 30                 | 29.1758    | 10       | 1         |           |           | 366       |
| 245 Vera                       | 265                  | -51                | 96                   | -50                | 14.35651   | 3        | 1         |           |           | 351       |
| 246 Asporina                   | 235                  | -10                | 47                   | -36                | 16.25222   | 6        | 1         |           |           | 438       |
| 247 Eukrate                    | 103                  | -22                |                      |                    | 12.09480   | 41       | 3         |           |           | 315       |
| 249 Ilse                       | 3                    | 85                 | 222                  | 41                 | 84.995     | 29       | 3         |           |           | 461       |

**Notes.** The table provides ecliptic coordinates  $\lambda_1$  and  $\beta_1$  of the best-fitting pole solution, ecliptic coordinates  $\lambda_2$  and  $\beta_2$  for the possible second (mirror) pole solution, sidereal rotational period  $P$ , the number of dense lightcurves  $N_{lc}$  spanning  $N_{app}$  apparitions, and the number of sparse-in-time measurements from three sources:  $N_{689}$  (USNO-Flagstaff),  $N_{703}$  (Catalina Sky Survey) and  $N_{LOW}$  (Lowell). <sup>(a)</sup> Reliable mass estimate exists or the mass will be most likely determined from Gaia astrometric measurements. <sup>(b)</sup> First rotation period estimate.

Table A.1. continued.

| Asteroid                     | $\lambda_1$<br>[deg] | $\beta_1$<br>[deg] | $\lambda_2$<br>[deg] | $\beta_2$<br>[deg] | $P$<br>[h] | $N_{ic}$ | $N_{app}$ | $N_{689}$ | $N_{703}$ | $N_{Low}$ |
|------------------------------|----------------------|--------------------|----------------------|--------------------|------------|----------|-----------|-----------|-----------|-----------|
| 254 Augusta                  | 179                  | -52                | 25                   | -53                | 5.89505    | 6        | 2         |           |           | 371       |
| 263 Dresda                   | 99                   | 54                 | 272                  | 61                 | 16.8139    | 12       | 4         |           |           | 605       |
| 270 Anahita                  | 15                   | -50                | 207                  | -59                | 15.05906   | 12       | 4         |           |           | 492       |
| 271 Penthesilea              | 225                  | 49                 | 42                   | 53                 | 18.7875    | 7        | 1         | 129       | 83        |           |
| 274 Philagoria               | 328                  | -71                | 154                  | -65                | 17.9410    | 12       | 3         |           |           | 460       |
| 287 Nephthys                 | 356                  | 36                 | 158                  | 39                 | 7.60411    | 8        | 3         | 291       | 90        |           |
| 293 Brasilia                 | 103                  | -7                 | 274                  | -34                | 8.17410    | 4        | 1         |           |           | 411       |
| 296 Phaetusa                 | 146                  | 53                 | 330                  | 52                 | 4.53809    | 5        | 1         |           |           | 340       |
| 313 Chaldaea <sup>a</sup>    | 219                  | 34                 | 45                   | 10                 | 8.38993    | 21       | 5         |           |           | 390       |
| 315 Constantia               | 162                  | 56                 | 353                  | 45                 | 5.34750    | 3        | 1         | 49        | 115       |           |
| 317 Roxane                   | 220                  | -62                | 40                   | -70                | 8.16961    | 16       | 2         |           |           | 504       |
| 327 Columbia                 | 52                   | 43                 | 238                  | 26                 | 5.93183    |          |           | 161       | 108       |           |
| 343 Ostara                   | 103                  | 64                 | 294                  | 48                 | 110.028    | 13       | 2         |           |           | 348       |
| 353 Ruperto-Carola           | 183                  | -58                | 43                   | -64                | 2.738963   | 6        | 1         | 106       | 80        |           |
| 361 Bononia                  | 294                  | 13                 | 115                  | 45                 | 13.80634   | 5        | 2         | 183       | 73        |           |
| 365 Corduba <sup>a</sup>     | 255                  | 33                 | 80                   | 4                  | 12.7054    | 49       | 5         |           |           | 446       |
| 381 Myrrha <sup>a</sup>      | 219                  | 72                 | 37                   | 43                 | 6.57196    | 10       | 4         |           |           | 496       |
| 389 Industria                | 98                   | -38                | 291                  | -29                | 8.49520    | 9        | 3         |           |           | 505       |
| 391 Ingeborg                 | 354                  | -65                |                      |                    | 26.4146    | 24       | 2         |           |           | 409       |
| 394 Arduina                  | 195                  | -61                | 56                   | -79                | 16.6217    | 8        | 1         |           |           | 395       |
| 402 Chloe                    | 312                  | -49                | 160                  | -37                | 10.66844   | 13       | 3         |           |           | 375       |
| 407 Arachne                  | 241                  | -63                | 43                   | -58                | 22.6263    | 5        | 1         |           |           | 433       |
| 419 Aurelia <sup>a</sup>     | 0                    | 48                 | 174                  | 42                 | 16.8       | 47       | 9         |           |           |           |
| 455 Bruchsalia <sup>a</sup>  | 242                  | -13                | 73                   | -21                | 11.8401    | 15       | 2         |           |           | 429       |
| 474 Prudentia                | 301                  | -54                | 136                  | -64                | 8.57227    | 5        | 1         |           |           | 374       |
| 480 Hansa                    | 352                  | 18                 | 173                  | -32                | 16.1894    | 8        | 3         | 200       | 64        |           |
| 482 Petrina                  | 281                  | 61                 | 94                   | 24                 | 11.79214   | 42       | 5         |           |           | 337       |
| 489 Comacina                 | 265                  | -16                | 88                   | -43                | 9.02321    | 5        | 3         |           |           | 434       |
| 490 Veritas <sup>a</sup>     | 56                   | 34                 | 231                  | 43                 | 7.92811    | 10       | 1         |           |           | 435       |
| 497 Iva                      | 121                  | -22                | 303                  | -32                | 4.620850   | 8        | 2         |           |           | 359       |
| 502 Sigune                   | 178                  | -36                |                      |                    | 10.92666   | 23       | 3         |           |           | 378       |
| 520 Franziska                | 282                  | -79                | 114                  | -45                | 16.5045    | 9        | 2         |           |           | 384       |
| 526 Jena                     | 5                    | 36                 | 183                  | 48                 | 9.51664    | 3        | 1         | 151       | 44        |           |
| 537 Pauly                    | 31                   | 32                 | 211                  | 51                 | 16.2961    | 7        | 3         |           |           | 472       |
| 562 Salome                   | 78                   | 41                 | 275                  | 28                 | 6.35031    | 9        | 3         |           |           | 425       |
| 564 Dudu                     | 73                   | -51                | 213                  | -36                | 8.88504    | 3        | 1         |           |           | 327       |
| 565 Marbachia                | 334                  | -22                | 163                  | -47                | 4.58782    | 7        | 2         |           |           | 452       |
| 567 Eleutheria               | 317                  | 33                 | 131                  | 53                 | 7.71743    | 19       | 4         |           |           | 395       |
| 586 Thekla                   | 232                  | 36                 | 55                   | 32                 | 13.6816    | 3        | 1         |           |           | 432       |
| 596 Scheila <sup>a</sup>     | 264                  | -18                | 89                   | -9                 | 15.8666    | 7        | 1         | 153       | 76        |           |
| 622 Esther                   | 248                  | -60                |                      |                    | 47.5039    | 5        | 1         |           |           | 431       |
| 625 Xenia                    | 307                  | 9                  | 122                  | 7                  | 21.0122    | 3        | 1         |           |           | 415       |
| 632 Pyrrha                   | 74                   | -72                | 253                  | -74                | 4.11686    | 5        | 1         |           |           | 487       |
| 639 Latona                   | 204                  | 10                 | 25                   | 12                 | 6.19127    | 5        | 2         | 160       | 42        |           |
| 644 Cosima                   | 278                  | -31                | 100                  | -30                | 7.55709    | 16       | 2         |           |           | 461       |
| 660 Crescentia               | 68                   | 11                 | 236                  | 49                 | 7.91036    | 18       | 3         |           |           | 438       |
| 670 Ottegebe                 | 128                  | 75                 |                      |                    | 10.03991   | 4        | 1         |           |           | 540       |
| 681 Gorgo                    | 310                  | -50                | 150                  | -50                | 6.46063    | 4        | 1         |           |           | 319       |
| 682 Hagar                    | 56                   | -78                | 255                  | -57                | 4.85042    | 6        | 1         |           |           | 334       |
| 686 Gersuind                 | 125                  | 53                 | 260                  | 58                 | 6.31240    | 5        | 1         |           |           | 400       |
| 687 Tinette                  | 271                  | 18                 | 100                  | 43                 | 7.39710    | 3        | 1         |           |           | 297       |
| 692 Hippodamia               | 233                  | -53                |                      |                    | 8.99690    | 3        | 1         |           |           | 396       |
| 698 Ernestina                | 213                  | -66                | 76                   | -49                | 5.03660    |          |           | 140       | 76        |           |
| 706 Hirundo                  | 92                   | 66                 | 244                  | 54                 | 22.0160    | 6        | 1         |           |           | 365       |
| 742 Edisona                  | 46                   | -54                | 175                  | -43                | 18.5833    | 15       | 3         | 141       | 115       |           |
| 746 Marlu                    | 202                  | -66                | 64                   | -27                | 7.78887    | 11       | 2         |           |           | 373       |
| 749 Malzovia                 | 55                   | 46                 | 246                  | 55                 | 5.92748    | 5        | 1         |           |           | 423       |
| 756 Lilliana                 | 201                  | 31                 | 53                   | 36                 | 7.83250    | 21       | 4         |           |           | 372       |
| 757 Portlandia               | 263                  | -69                | 90                   | -56                | 6.58112    | 12       | 2         |           |           | 566       |
| 758 Mancunia <sup>a</sup>    | 111                  | 48                 | 306                  | 44                 | 12.72011   | 26       | 3         |           |           | 461       |
| 762 Pulcova <sup>a</sup>     | 194                  | -42                | 17                   | -14                | 5.83977    | 8        | 2         |           |           | 408       |
| 784 Pickeringia <sup>a</sup> | 282                  | 35                 | 103                  | 68                 | 13.16998   | 1        | 1         |           |           | 437       |
| 797 Montana                  | 6                    | 61                 | 179                  | 45                 | 4.54619    |          |           | 145       | 124       |           |
| 798 Ruth                     | 84                   | 27                 |                      |                    | 8.55068    | 18       | 5         |           |           | 426       |
| 802 Epyaxa                   | 347                  | -87                |                      |                    | 4.39012    | 4        | 2         | 92        | 50        |           |
| 830 Petropolitana            | 217                  | 36                 | 34                   | 41                 | 37.347     |          |           | 151       | 51        |           |

Table A.1. continued.

| Asteroid                    | $\lambda_1$<br>[deg] | $\beta_1$<br>[deg] | $\lambda_2$<br>[deg] | $\beta_2$<br>[deg] | $P$<br>[h] | $N_{ic}$ | $N_{app}$ | $N_{689}$ | $N_{703}$ | $N_{Low}$ |
|-----------------------------|----------------------|--------------------|----------------------|--------------------|------------|----------|-----------|-----------|-----------|-----------|
| 856 Backlunda               | 42                   | 44                 | 226                  | 73                 | 12.02894   | 2        | 1         | 155       | 103       |           |
| 870 Manto                   | 96                   | 30                 | 283                  | 35                 | 122.166    | 44       | 2         |           |           | 363       |
| 872 Holda                   | 77                   | 24                 | 253                  | 32                 | 5.94052    | 12       | 2         | 169       | 77        |           |
| 873 Mechthild               | 249                  | -52                | 51                   | -61                | 11.00639   | 9        | 2         |           |           | 391       |
| 877 Walkure                 | 262                  | 71                 | 47                   | 66                 | 17.4217    | 3        | 1         |           |           | 596       |
| 881 Athene                  | 115                  | -77                | 338                  | -43                | 13.8943    |          |           | 92        | 89        |           |
| 908 Buda                    | 40                   | 5                  | 225                  | 16                 | 14.57498   | 6        | 2         |           |           | 303       |
| 928 Hildrun                 | 247                  | -29                | 86                   | -63                | 14.1163    |          |           | 146       | 114       |           |
| 944 Hidalgo                 | 277                  | 16                 | -999                 | -999               | 10.05822   | 15       | 4         | 0         | 0         | 99        |
| 986 Amelia                  | 80                   | 30                 | 282                  | 30                 | 9.51856    | 4        | 1         | 147       | 110       |           |
| 898 Hildegard               | 344                  | 27                 | 164                  | 8                  | 24.8544    | 15       | 2         | 0         | 0         | 242       |
| 1010 Marlene                | 299                  | 42                 | 106                  | 47                 | 31.0651    | 8        | 1         |           |           | 364       |
| 1021 Flammario <sup>a</sup> | 32                   | 22                 | 216                  | 55                 | 12.15186   | 10       | 2         |           |           | 368       |
| 1023 Thomana                | 86                   | -65                | 272                  | -42                | 17.5611    | 8        | 1         |           |           | 486       |
| 1080 Orchis                 | 255                  | 27                 | 71                   | 28                 | 16.0657    | 13       | 1         |           |           | 447       |
| 1110 Jaroslawa              | 236                  | 75                 |                      |                    | 97.278     | 50       | 2         |           |           | 307       |
| 1119 Euboea                 | 79                   | 75                 | 282                  | 55                 | 11.3981    |          |           | 132       | 147       |           |
| 1125 China                  | 132                  | -46                | 305                  | -49                | 5.36863    | 2        | 1         |           |           | 357       |
| 1135 Colchis                | 139                  | -58                | 330                  | -81                | 23.4830    |          |           | 142       | 97        |           |
| 1137 Raissa                 | 220                  | -66                | 40                   | -77                | 143.644    | 33       | 2         |           |           | 408       |
| 1150 Achaia                 | 169                  | -69                | 347                  | -62                | 61.072     |          |           | 67        | 98        |           |
| 1175 Margo                  | 184                  | -43                | 353                  | -17                | 6.01375    | 4        | 1         |           |           | 395       |
| 1192 Prisma                 | 133                  | -78                |                      |                    | 6.55836    | 5        | 1         |           |           | 193       |
| 1204 Renzia                 | 142                  | -50                | 305                  | -45                | 7.88695    | 1        | 1         |           |           | 528       |
| 1244 Deira                  | 314                  | -46                | 107                  | -56                | 216.98     | 21       | 1         |           |           | 331       |
| 1278 Kenya                  | 164                  | -66                | 281                  | -77                | 187.60     | 27       | 1         |           |           | 466       |
| 1310 Villigera              | 3                    | 63                 | 240                  | 26                 | 7.83001    | 4        | 1         |           |           | 319       |
| 1312 Vassar                 | 251                  | -23                |                      |                    | 7.93190    | 4        | 1         |           |           | 317       |
| 1352 Wawel                  | 200                  | 59                 | 32                   | 61                 | 16.9543    | 5        | 1         |           |           | 356       |
| 1360 Tarka                  | 323                  | -55                |                      |                    | 8.86606    | 10       | 2         |           |           | 242       |
| 1366 Piccolo                | 352                  | 49                 | 201                  | 55                 | 16.1834    | 9        | 3         | 136       | 110       |           |
| 1368 Numidia                | 201                  | -62                |                      |                    | 3.640739   | 3        | 1         | 129       | 83        |           |
| 1424 Sundmania              | 51                   | 76                 | 275                  | 58                 | 94.537     | 16       | 1         |           |           | 490       |
| 1430 Somalia                | 297                  | 42                 | 128                  | 47                 | 6.90907    | 6        | 1         |           |           | 409       |
| 1449 Virtanen               | 307                  | 58                 | 99                   | 58                 | 30.5005    | 11       | 1         |           |           | 354       |
| 1459 Magnya                 | 72                   | -59                | 207                  | -51                | 4.67911    |          |           | 137       | 96        |           |
| 1486 Marilyn                | 88                   | -66                | 267                  | -66                | 4.56695    | 5        | 1         |           |           | 492       |
| 1508 Kemi                   | 352                  | 108                | 166                  | 73                 | 9.19182    | 6        | 2         | 0         | 0         | 246       |
| 1534 Nasi                   | 82                   | 23                 | 268                  | 13                 | 7.93161    | 3        | 1         |           |           | 362       |
| 1546 Izsak                  | 124                  | 32                 | 322                  | 60                 | 7.33200    | 3        | 1         | 80        | 80        |           |
| 1621 Druzhba                | 240                  | 71                 |                      |                    | 99.100     | 1        | 1         |           |           | 365       |
| 1648 Shajna                 | 117                  | 54                 | 306                  | 53                 | 6.41369    |          |           | 75        | 136       |           |
| 1665 Gaby                   | 261                  | 41                 | 66                   | 32                 | 67.911     | 1        | 1         |           |           | 296       |
| 1672 Gezelle                | 45                   | 79                 |                      |                    | 40.6824    | 12       | 2         |           |           | 366       |
| 1676 Kariba                 | 74                   | 74                 | 281                  | 60                 | 3.167338   | 3        | 1         |           |           | 342       |
| 1730 Marceline              | 264                  | 68                 | 82                   | 44                 | 3.836544   | 2        | 1         |           |           | 268       |
| 1735 ITA                    | 39                   | -46                | 178                  | -52                | 12.6103    |          |           | 148       | 107       |           |
| 1746 Brouwer                | 21                   | -67                | 158                  | -71                | 19.7255    | 4        | 1         | 88        | 64        |           |
| 1750 Eckert                 | 176                  | 60                 | -999                 | -999               | 377.5      | 23       | 1         | 0         | 0         | 193       |
| 1772 Gagarin                | 183                  | 22                 | 358                  | 5                  | 10.93791   | 3        | 1         | 46        | 110       |           |
| 1789 Dobrovolsky            | 319                  | 30                 | 137                  | 34                 | 4.811096   | 3        | 2         |           |           | 380       |
| 1793 Zoya                   | 238                  | 64                 | 62                   | 64                 | 5.751872   | 5        | 2         |           |           | 398       |
| 1816 Liberia                | 73                   | -68                |                      |                    | 3.086156   |          |           | 86        | 104       |           |
| 1820 Lohmann                | 264                  | 65                 | 69                   | 55                 | 14.0449    | 16       | 1         |           |           | 281       |
| 1825 Klare                  | 2                    | -58                |                      |                    | 4.74288    | 5        | 1         |           |           | 336       |
| 1837 Osita                  | 36                   | -52                | 228                  | -58                | 3.81880    | 4        | 1         |           |           | 337       |
| 1838 Ursa                   | 42                   | 64                 | 284                  | 29                 | 16.1635    |          |           | 102       | 91        |           |
| 1892 Lucienne               | 26                   | -40                | 213                  | -61                | 9.31556    | 1        | 1         |           |           | 286       |
| 1902 Shaposhnikov           | 326                  | 37                 | 144                  | 79                 | 20.9959    | 15       | 4         |           |           | 459       |
| 1925 Franklin-Adams         | 277                  | 57                 | 66                   | 48                 | 2.978301   | 2        | 1         |           |           | 270       |
| 1946 Walraven               | 259                  | -80                | 80                   | -59                | 10.2101    |          |           | 101       | 73        |           |
| 2306 Bauschinger            | 0                    | -64                | 225                  | -65                | 21.6704    | 6        | 1         |           |           | 63        |
| 2313 Aruna                  | 80                   | -75                |                      |                    | 8.88620    |          |           |           |           | 103       |
| 2358 Bahner                 | 360                  | 57                 | 193                  | 52                 | 10.8528    | 13       | 1         |           |           | 69        |
| 2381 Landi                  | 220                  | -36                | 14                   | -66                | 3.986041   | 6        | 1         |           |           | 364       |
| 2382 Nonie                  | 205                  | 52                 |                      |                    | 15.1117    | 7        | 2         |           |           | 354       |

Table A.1. continued.

| Asteroid                        | $\lambda_1$<br>[deg] | $\beta_1$<br>[deg] | $\lambda_2$<br>[deg] | $\beta_2$<br>[deg] | $P$<br>[h] | $N_{lc}$ | $N_{app}$ | $N_{689}$ | $N_{703}$ | $N_{LOW}$ |
|---------------------------------|----------------------|--------------------|----------------------|--------------------|------------|----------|-----------|-----------|-----------|-----------|
| 2393 Suzuki                     | 80                   | 53                 | 222                  | 38                 | 9.2875     |          |           |           | 92        |           |
| 2659 Millis                     | 109                  | -49                | 288                  | -48                | 6.12464    | 2        | 1         |           |           | 566       |
| 2713 Luxembourg                 | 164                  | 4                  | 343                  | 4                  | 3.58132    |          |           |           | 97        |           |
| 2725 David Bender               | 198                  | -37                | 58                   | -57                | 9.95798    | 3        | 1         | 37        | 115       |           |
| 2741 Valdivia                   | 269                  | -31                | 103                  | -59                | 4.09668    | 4        | 1         |           |           | 482       |
| 2785 Sedov                      | 206                  | 48                 | 26                   | 54                 | 5.47761    |          |           |           | 127       |           |
| 2791 Paradise                   | 100                  | -16                |                      |                    | 9.80729    | 3        | 1         |           | 40        |           |
| 2802 Weisell                    | 255                  | -50                | 112                  | -63                | 37.705     |          |           | 27        | 156       |           |
| 2948 Amosov                     | 267                  | -64                | 33                   | -73                | 7.39889    |          |           |           | 120       |           |
| 2962 Otto                       | 230                  | -58                |                      |                    | 2.53632    |          |           |           | 111       |           |
| 3247 Di Martino                 | 53                   | -70                | 231                  | -75                | 5.44517    |          |           |           | 87        |           |
| 3258 Somnium                    | 119                  | -47                | 274                  | -71                | 5.33803    | 7        | 1         |           |           | 567       |
| 3285 Ruth Wolfe                 | 142                  | 33                 |                      |                    | 3.93494    | 3        | 1         |           | 75        |           |
| 3301 Jansje                     | 361                  | 28                 | 173                  | 40                 | 9.42533    | 8        | 1         |           |           | 630       |
| 3428 Roberts                    | 63                   | 49                 | 231                  | 49                 | 3.27835    |          |           | 24        | 129       |           |
| 3455 Kristensen                 | 9                    | 10                 | 186                  | 10                 | 8.09218    |          |           |           | 129       |           |
| 3478 Fanale                     | 95                   | 64                 | 297                  | 62                 | 3.244843   | 5        | 1         |           |           | 627       |
| 3544 Borodino                   | 294                  | -60                | 157                  | -57                | 5.43460    | 7        | 2         |           |           | 515       |
| 3693 Barringer                  | 243                  | -43                |                      |                    | 6.62564    |          |           |           | 81        |           |
| 3725 Valsecchi                  | 77                   | -54                | 242                  | -53                | 3.56973    |          |           |           | 83        |           |
| 3773 Smithsonian                | 257                  | -51                | 81                   | -50                | 6.98132    | 5        | 1         |           |           | 622       |
| 3786 Yamada                     | 84                   | 52                 | 218                  | 48                 | 4.03295    | 3        | 1         |           |           | 463       |
| 3787 Aivazovskij                | 75                   | 59                 | 238                  | 57                 | 2.980807   |          |           |           | 138       |           |
| 3918 Brel                       | 71                   | 58                 | 238                  | 47                 | 3.09679    | 1        | 1         |           | 114       |           |
| 4080 Galinskij                  | 209                  | -74                |                      |                    | 7.35845    |          |           |           | 162       |           |
| 4265 Kani                       | 106                  | 60                 | 310                  | 54                 | 5.72755    | 4        | 1         |           |           | 730       |
| 4284 Kaho                       | 6                    | -21                | 193                  | 0                  | 4.05763    |          |           |           | 79        |           |
| 4554 Fanyinka                   | 220                  | 55                 | 64                   | 63                 | 4.77502    |          |           |           | 84        |           |
| 4570 Runcorn                    | 123                  | 57                 | 287                  | 31                 | 20.1514    | 11       | 1         |           | 87        |           |
| 4917 Yurilvovia <sup>b</sup>    | 224                  | 20                 | 48                   | 1                  | 4.17744    |          |           |           | 90        |           |
| 5008 Miyazawakenji <sup>b</sup> | 144                  | -52                | 322                  | -25                | 49.239     |          |           |           | 101       |           |
| 5111 Jacliff                    | 259                  | -45                |                      |                    | 2.83990    |          |           |           | 107       |           |
| 5208 Royer                      | 258                  | 74                 | 54                   | 37                 | 3.88494    |          |           |           | 138       |           |
| 5231 Verne                      | 175                  | -45                | 359                  | -88                | 4.32058    |          |           | 20        | 76        |           |
| 5317 Verolacqua                 | 224                  | -51                |                      |                    | 3.02181    |          |           |           | 119       |           |
| 5489 Oberkochen                 | 195                  | -41                | 13                   | -66                | 5.62439    | 3        | 1         |           |           | 470       |
| 5596 Morbidelli                 | 173                  | -80                |                      |                    | 5.40043    |          |           |           | 78        |           |
| 5776 1989 UT2 <sup>b</sup>      | 360                  | -72                |                      |                    | 4.34079    |          |           |           | 133       |           |
| 6000 United Nations             | 13                   | -84                |                      |                    | 3.26191    |          |           | 21        | 143       |           |
| 6026 Xenophanes <sup>b</sup>    | 266                  | -54                | 80                   | -56                | 3.78170    |          |           |           | 100       |           |
| 6192 1990 KB1                   | 61                   | 67                 | 239                  | 75                 | 78.631     | 16       | 2         |           | 91        |           |
| 6406 1992 MJ                    | 20                   | -63                | 221                  | -55                | 6.81818    | 3        | 1         |           |           | 508       |
| 6410 Fujiwara                   | 243                  | -85                |                      |                    | 7.00669    | 2        | 1         |           |           | 552       |
| 6755 Solov'yanenko              | 224                  | 54                 | 47                   | 58                 | 8.1680     |          |           |           | 101       |           |
| 6905 Miyazaki                   | 33                   | 7                  | 214                  | -4                 | 2.733348   |          |           |           | 120       |           |
| 7233 Majella                    | 298                  | -87                | 80                   | -71                | 3.81240    |          |           |           | 77        |           |
| 8043 Fukuhara <sup>b</sup>      | 96                   | -41                |                      |                    | 22.7606    |          |           |           | 117       |           |
| 8860 Rohloff <sup>b</sup>       | 37                   | -58                |                      |                    | 18.8411    |          |           |           | 114       |           |
| 9542 Eryan <sup>b</sup>         | 200                  | -5                 | 21                   | -22                | 2.79473    |          |           |           | 120       |           |
| 9563 Kitty                      | 272                  | -28                | 91                   | -34                | 5.38191    |          |           |           | 111       |           |
| 10064 1988 UO <sup>b</sup>      | 78                   | -45                | 240                  | -57                | 12.1277    |          |           |           | 122       |           |
| 14197 1998 XK72                 | 192                  | -74                | 38                   | -62                | 10.6453    | 4        | 1         |           |           | 441       |
| 16173 2000 AC98                 | 37                   | -48                | 209                  | -37                | 6.48550    |          |           |           | 97        |           |
| 16468 1990 HW1 <sup>b</sup>     | 119                  | -84                |                      |                    | 94.13      | 1        | 1         |           | 72        |           |
| 18487 1996 AU3                  | 245                  | -45                | 91                   | -70                | 6.59077    |          |           |           | 120       |           |
| 28736 2000 GE133                | 249                  | -52                | 134                  | -84                | 4.65442    | 3        | 1         |           | 118       |           |
| 28887 2000 KQ58                 | 182                  | -35                | 354                  | -78                | 6.84315    | 6        | 1         |           |           | 368       |
| 31060 1996 TB6                  | 216                  | -66                | 74                   | -39                | 5.10432    |          |           |           | 108       |           |
| 32776 Nriag                     | 239                  | -59                | 102                  | -76                | 3.98679    |          |           |           | 141       |           |
| 33116 1998 BO12                 | 244                  | 69                 | 45                   | 54                 | 6.34669    | 4        | 1         |           | 122       |           |
| 34484 2000 SR124                | 116                  | -59                | 268                  | -80                | 6.17516    |          |           |           | 99        |           |
| 42923 1999 SR18                 | 46                   | 69                 |                      |                    | 8.3889     |          |           |           | 155       |           |

**Table A.2.** New observations used for updating the shape models and observations that are not included in the UAPC used for new shape model determinations.

| Asteroid      | Date              | $N_{LC}$ | Observer  |
|---------------|-------------------|----------|---|
| 3 Juno        | 2013 09 – 2013 09 | 1        | Maurice Audejean  |
| 7 Iris        | 2010 12 – 2010 12 | 2        | Gérald Rousseau   |
| 16 Psyche     | 2013 08 – 2013 08 | 1        | Patrick Sogorb  |
|               | 2003 05 – 2003 05 | 2        | Eric Barbotin   |
| 17 Thetis     | 2003 05 – 2003 05 | 2        | Laurent Bernasconi  |
|               | 2007 04 – 2007 04 | 1        | Arnaud Leroy  |
|               | 2011 02 – 2011 02 | 3        | Ramón Naves   |
| 19 Fortuna    | 2011 03 – 2011 03 | 1        | Quentin Déhais  |
|               | 2011 04 – 2011 04 | 1        | Ramón Naves   |
|               | 2011 04 – 2011 04 | 2        | Gérald Rousseau   |
| 20 Massalia   | 2012 03 – 2012 05 | 13       | David Higgins   |
|               | 2012 06 – 2012 06 | 2        | Frederick Pilcher   |
| 22 Kalliope   | 2004 06 – 2004 06 | 2        | Alain Klotz   |
|               | 2004 06 – 2004 06 | 3        | René Roy, Raoul Behrend   |
|               | 2004 06 – 2012 02 | 10       | René Roy  |
|               | 2006 11 – 2006 11 | 4        | Hiromi Hamanowa, Hiroko Hamanowa  |
|               | 2006 12 – 2006 12 | 1        | Jean-François Coliac  |
|               | 2007 02 – 2007 03 | 5        | Enric Forné   |
|               | 2007 02 – 2007 03 | 9        | <a href="#">Warner (2007a)</a>  |
|               | 2007 03 – 2007 03 | 1        | Arnaud Leroy, Sylvain Bouley  |
|               |                   |          | Guillaume Dubos, Raoul Behrend  |
|               | 2007 03 – 2007 03 | 1        | Ramón Costa   |
|               | 2012 01 – 2012 01 | 4        | Emmanuel Conseil  |
|               | 2012 02 – 2012 02 | 1        | Jacques Montier   |
|               | 2012 02 – 2012 02 | 1        | Jean-François Colliac   |
|               | 2012 02 – 2012 02 | 1        | Maurice Audejean  |
| 23 Thalia     | 2009 08 – 2009 09 | 8        | <a href="#">Pilcher (2010f)</a>   |
|               | 2010 12 – 2011 01 | 3        | Gérald Rousseau   |
|               | 2011 01 – 2011 02 | 4        | Ramón Naves   |
|               | 2015 02 – 2015 02 | 1        | Greg Tumolo, Veronika Afonina   |
|               |                   |          |   |
| 27 Euterpe    | 2000 07 – 2011 08 | 43       | <a href="#">Stephens et al. (2001)</a> , <a href="#">Stephens (2001)</a> , <a href="#">Stephens et al. (2012)</a> |
|               | 2010 06 – 2010 07 | 5        | <a href="#">Pilcher (2011c)</a>   |
| 29 Amphitrite | 2010 07 – 2010 07 | 1        | Jacques Montier, Serge Heterier   |
|               | 2006 10 – 2006 11 | 9        | Hiromi Hamanowa, Hiroko Hamanowa  |
|               | 2007 11 – 2007 11 | 1        | Enric Forné   |
|               | 2008 02 – 2008 02 | 1        | <a href="#">Polishook (2009)</a>  |
|               | 2009 04 – 2009 04 | 2        | Arnaud Stiepen, Olivier Wertz   |
|               |                   |          |   |
|               |                   |          | René Giraud, Raoul Behrend  |
|               | 2009 04 – 2009 04 | 2        | Jean-François Pirenne, Pierre Piron   |
|               |                   |          | Damien Renault, Lucas Salvador  |
|               |                   |          | Benjamin Vanoutryve, Raoul Behrend  |
|               | 2009 04 – 2009 04 | 2        | Mathieu Waucomont, Alice Decock   |
|               |                   |          | Sophie Delmelle, Maïte Dumont   |
|               |                   |          | Thomas Fauchez, Raoul Behrend   |
|               | 2009 04 – 2009 04 | 2        | Olivier Adam, Arnaud Collet   |
|               |                   |          | Benjamin Modave, Niyonzima Innocent   |
|               |                   |          | Raoul Behrend   |
| 39 Laetitia   | 2012 02 – 2012 02 | 3        | François Kugel, Jérôme Caron  |
|               | 1998 03 – 1998 03 | 1        | Yurij Krugly  |
|               | 2003 03 – 2003 03 | 1        | Claudine Rinner   |
|               | 2003 03 – 2003 03 | 1        | Stéphane Charbonnel   |
|               | 2004 05 – 2005 07 | 4        | Josep Coloma  |
|               | 2010 10 – 2010 11 | 3        | Ramón Naves   |
| 40 Harmonia   | 2012 02 – 2012 02 | 2        | Maurice Audejean  |
|               | 2003 01 – 2003 01 | 1        | Alain Klotz   |
|               | 2003 05 – 2003 05 | 3        | Laurent Bernasconi  |
|               | 2008 12 – 2010 06 | 10       | <a href="#">Pilcher (2009a, 2010b)</a>  |
| 41 Daphne     | 2001 11 – 2001 11 | 4        | Laurent Bernasconi  |
| 42 Isis       | 2011 01 – 2011 02 | 5        | René Roy  |
| 45 Eugenia    | 1998 12 – 1999 01 | 2        | Federico Manzini, Raoul Behrend   |
|               | 1998 12 – 2005 06 | 5        | Federico Manzini  |
|               | 2005 06 – 2005 07 | 3        | Matthieu Conjat   |
|               | 2007 11 – 2009 05 | 15       | <a href="#">Marchis et al. (2010)</a>   |
|               | 2010 07 – 2010 07 | 1        | René Roy  |

Table A.2. continued.

| Asteroid     | Date              | $N_{LC}$ | Observer   |
|--------------|-------------------|----------|--|
| 54 Alexandra | 2014 05 – 2014 06 | 3        | Jean-Paul Teng, André Peyrot<br>Alain Klotz, Raoul Behrend |
|              | 2014 06 – 2014 06 | 2        | Ramón Naves  |
|              | 2014 06 – 2014 06 | 2        | Romain Montaignut, Arnaud Leroy<br>Raoul Behrend           |
|              | 2014 06 – 2014 06 | 3        | Nicolas Esseiva, Raoul Behrend                             |
|              | 2005 06 – 2005 06 | 5        | Jean-Paul Teng, Raoul Behrend                              |
|              | 2006 12 – 2007 01 | 5        | Michael Fauerbach  |
|              | 2007 02 – 2007 02 | 2        | Stéphane Fauvaud, Marcel Fauvaud<br>Jean-Marie Vugnon      |
|              | 2008 01 – 2008 01 | 5        | <a href="#">Warner et al. (2008b)</a>                      |
|              | 2009 03 – 2009 05 | 8        | <a href="#">Higgins &amp; Warner (2009)</a>                |
|              | 2005 01 – 2005 01 | 3        | Laurent Bernasconi   |
| 64 Angelina  | 2005 09 – 2005 09 | 1        | Pierre Antonini  |
|              | 2000 09 – 2000 10 | 6        | <a href="#">Shevchenko et al. (2008)</a>                   |
| 76 Freia     | 2007 12 – 2007 12 | 3        | <a href="#">Stephens &amp; Warner (2008)</a>               |
|              | 2009 03 – 2009 03 | 2        | Christophe Demeautis                                       |
|              | 2012 06 – 2012 07 | 6        | Emmanuel Jehin, Jean Manfroid<br>Michael Gillon            |
|              | 2014 12 – 2015 04 | 5        | Nicolas Esseiva, Raoul Behrend                             |
|              | 2015 04 – 2015 04 | 3        | Robin Esseiva, Nicolas Esseiva<br>Raoul Behrend            |
| 88 Thisbe    | 2007 01 – 2007 01 | 1        | René Roy   |
|              | 2012 02 – 2012 02 | 4        | Maurice Audejean   |
| 94 Aurora    | 2010 03 – 2010 03 | 1        | Raymond Poncy  |
| 95 Arethusa  | 2006 07 – 2006 07 | 4        | Laurent Bernasconi   |
|              | 2006 08 – 2006 08 | 1        | Jean-Gabriel Bosch   |
| 107 Camilla  | 2006 08 – 2006 08 | 4        | Raymond Poncy  |
|              | 2004 09 – 2004 11 | 2        | Laurent Bernasconi   |
|              | 2008 05 – 2008 06 | 3        | <a href="#">Polishook (2009)</a>                           |
|              | 2010 07 – 2010 07 | 1        | Fabien Reignier  |
| 110 Lydia    | 2010 07 – 2010 07 | 2        | Jacques Montier, Serge Heterier                            |
|              | 2003 12 – 2003 12 | 11       | <a href="#">Pray (2004a)</a>                               |
|              | 2003 12 – 2012 10 | 5        | <a href="#">Stephens &amp; Warner (2013)</a>               |
|              | 2006 06 – 2006 06 | 2        | Roberto Crippa, Federico Manzini                           |
|              | 2008 12 – 2015 05 | 8        | Maurice Audejean   |
| 121 Hermione | 2012 10 – 2014 01 | 6        | <a href="#">Warner (2014b)</a>                             |
|              | 2003 12 – 2003 12 | 1        | Laurent Brunetto   |
|              | 2003 12 – 2003 12 | 1        | Philippe Baudouin  |
|              | 2003 12 – 2004 02 | 4        | René Roy   |
|              | 2004 01 – 2004 01 | 1        | Stefano Sposetti   |
|              | 2004 01 – 2004 01 | 2        | Jean Lecacheux, François Colas                             |
|              | 2004 02 – 2004 02 | 2        | Federico Manzini   |
|              | 2004 02 – 2005 02 | 4        | Laurent Bernasconi   |
|              | 2007 03 – 2007 09 | 19       | <a href="#">Descamps et al. (2009)</a>                     |
|              | 2009 11 – 2009 11 | 4        | Robert Buchheim  |
| 129 Antigone | 2011 01 – 2011 02 | 3        | Jérôme Caron   |
|              | 2004 02 – 2004 03 | 4        | Josep Coloma, Raoul Behrend                                |
|              | 2005 01 – 2005 01 | 1        | Yassine Damerdji   |
|              | 2005 04 – 2005 04 | 2        | René Roy   |
|              | 2010 05 – 2010 05 | 1        | John Ruthroff  |
|              | 2010 05 – 2010 05 | 5        | Axel Martin  |
|              | 2010 06 – 2010 07 | 3        | Jérôme Caron   |
| 130 Elektra  | 2009 12 – 2009 12 | 1        | Père Antoni Salom, Mateu Esteban<br>Raoul Behrend          |
|              | 2011 03 – 2011 03 | 3        | Jacques Montier, Raoul Behrend                             |
|              | 2011 04 – 2011 04 | 1        | Giovanni Casalnuovo, B. Chinaglia                          |
| 354 Eleonora | 2011 04 – 2011 04 | 1        | Giovanni Casalnuovo  |
|              | 2001 04 – 2001 04 | 1        | Stefano Sposetti   |
|              | 2002 06 – 2002 06 | 2        | Silvano Casulli  |
|              | 2006 06 – 2006 06 | 1        | Hilari Pallares  |
|              | 2006 06 – 2006 06 | 2        | Josep Coloma   |
|              | 2006 07 – 2006 08 | 4        | Enric Forné  |
|              | 2011 05 – 2011 05 | 3        | Etienne Morelle, Raoul Behrend                             |
|              | 2011 05 – 2011 05 | 3        | Maurice Audejean   |
|              | 2011 05 – 2011 05 | 4        | Giovanni Casalnuovo, B. Chinaglia                          |
|              | 2011 05 – 2011 05 | 1        | Giovanni Casalnuovo  |

Table A.2. continued.

|     | Asteroid   | Date              | $N_{LC}$ | Observer  |                                |
|-----|------------|-------------------|----------|---|--------------------------------|
| 360 | Carlova    | 2012 01 – 2012 02 | 3        | Maurice Audejean  |                                |
| 372 | Palma      | 2005 08 – 2005 08 | 2        | Pierre Antonini   |                                |
|     |            | 2005 08 – 2005 09 | 5        | Laurent Bernasconi  |                                |
|     |            | 2011 09 – 2011 10 | 4        | Eric Barbotin   |                                |
| 386 | Siegena    | 2007 02 – 2007 03 | 7        | <a href="#">Stephens (2007c)</a>  |                                |
| 409 | Aspasia    | 2004 02 – 2004 02 | 1        | Laurent Bernasconi  |                                |
|     |            | 2008 01 – 2008 01 | 5        | <a href="#">Warner et al. (2008b)</a>   |                                |
|     |            | 2008 02 – 2008 02 | 1        | Arnaud Leroy  |                                |
|     |            | 2008 02 – 2008 02 | 1        | Christophe Demeautis  |                                |
|     |            | 2008 02 – 2008 02 | 1        | Jean-François Coliac  |                                |
| 423 | Diotima    | 2010 10 – 2010 11 | 3        | Raymond Poncy   |                                |
|     |            | 2005 01 – 2005 01 | 1        | Roger Dymock  |                                |
|     |            | 2009 11 – 2009 11 | 3        | Maurice Audejean  |                                |
| 511 | Davida     | 2009 11 – 2009 11 | 4        | Père Antoni Salom, Mateu Esteban  |                                |
|     |            | 2005 06 – 2005 06 | 2        | Reiner Stoss, Jaime Nomen   |                                |
|     |            | 2005 06 – 2005 06 | 2        | Salvador Sanchez, Raoul Behrend   |                                |
| 532 | Herculina  | 2010 05 – 2010 06 | 6        | Maurice Audejean  |                                |
|     |            | 2010 06 – 2010 06 | 3        | Joe Garlitz   |                                |
|     |            | 2015 04 – 2015 04 | 1        | Christophe Gillier  |                                |
|     |            | 2015 04 – 2015 04 | 1        | Inna Bozhinova, Alexander Scholz  |                                |
|     |            |                   |          |   | Alex Hygate                    |
|     |            | 2015 04 – 2015 05 | 2        | René Roy, Raoul Behrend   |                                |
|     |            | 2015 04 – 2015 05 | 1        | René Roy  |                                |
|     |            | 2015 05 – 2015 05 | 1        | David Romeuf  |                                |
|     |            | 2015 05 – 2015 05 | 1        | Pierre Antonini, Raoul Behrend  |                                |
|     |            | 2015 05 – 2015 05 | 1        | Pierre Antonini   |                                |
|     |            | 2005 01 – 2005 04 | 4        | Josep Coloma  |                                |
|     |            | 2005 02 – 2005 02 | 1        | Hilari Pallares   |                                |
|     |            | 2010 04 – 2010 04 | 1        | Florian, Corentin   |                                |
| 776 | Berbericia | 2010 05 – 2010 05 | 1        | Titouan, Raoul Behrend  |                                |
|     |            | 2010 05 – 2010 05 | 1        | Jacques Montier, Jean-Pierre Previt   |                                |
|     |            | 2010 05 – 2010 05 | 2        | René Roy  |                                |
|     |            | 2010 05 – 2010 06 | 3        | Maurice Audejean  |                                |
|     |            | 2010 06 – 2010 06 | 1        | Jacques Montier, Serge Heterier   |                                |
|     |            |                   |          |   | Jean-Pierre Previt             |
|     |            | 2003 11 – 2003 11 | 2        | <a href="#">Pray (2004a)</a>  |                                |
| 12  | Victoria   | 2005 02 – 2005 02 | 2        | Federico Manzini  |                                |
|     |            | 2005 03 – 2005 03 | 2        | Laurent Bernasconi  |                                |
|     |            | 2006 06 – 2010 03 | 8        | <a href="#">Stephens (2010b)</a>  |                                |
|     |            | 2008 12 – 2008 12 | 2        | Mateu Cerda, Père Antoni Salom  |                                |
|     |            | 2010 02 – 2010 04 | 11       | Axel Martin   |                                |
|     |            | 2015 03 – 2015 03 | 2        | René Roy  |                                |
|     |            | 2015 04 – 2015 04 | 1        | David Romeuf  |                                |
| 18  | Melpomene  |                   |          | New models  |                                |
|     |            | 2000 10 – 2000 10 | 9        | López-González  |                                |
|     |            | 2010 07 – 2010 07 | 1        | René Roy, Raoul Behrend   |                                |
|     |            | 2010 07 – 2010 07 | 3        | Donn Starkey  |                                |
|     |            | 2011 11 – 2011 11 | 1        | André Debackère, Loïc Chalamet  |                                |
|     |            |                   |          |   | Carine Fournel, Raoul Behrend  |
|     |            | 2011 11 – 2011 11 | 2        | Anna Marciniak  |                                |
|     |            | 2012 02 – 2012 02 | 1        | Maurice Audejean, Raoul Behrend   |                                |
|     |            | 2012 02 – 2012 02 | 5        | Maurice Audejean  |                                |
|     |            | 2013 01 – 2013 03 | 7        | <a href="#">Pilcher (2013d)</a>   |                                |
| 24  | Themis     | 2012 08 – 2014 01 | 16       | <a href="#">Pilcher (2013a, 2014a)</a>  |                                |
|     |            | 2012 07 – 2012 08 | 3        | Ewa Kosturkiewicz, Waldemar Ogłóza  |                                |
|     |            |                   |          |   | Marek Drózdź                   |
| 26  | Proserpina | 2012 07 – 2012 07 | 5        | Stefano Mottola   |                                |
|     |            | 2012 10 – 2014 04 | 9        | <a href="#">Pilcher (2013c, 2014c)</a>  |                                |
| 31  | Euphrosyne | 2011 11 – 2011 11 | 1        | Toni Santana-Ros  |                                |
|     |            | 2007 12 – 2009 06 | 11       | <a href="#">Pilcher (2008c, 2013b)</a>  |                                |
|     |            | 2010 07 – 2010 07 | 1        | Axelle Spiridakis, Tanguy Déléage   |                                |
|     |            |                   |          |   | André Debackère, Raoul Behrend |
|     |            | 2010 08 – 2010 08 | 2        | Jacques Montier   |                                |
| 31  | Euphrosyne | 2010 09 – 2010 09 | 2        | Pierre Antonini   |                                |
|     |            | 2012 03 – 2012 03 | 2        | Anna Marciniak, Toni Santana-Ros  |                                |
|     |            | 2008 04 – 2013 04 | 18       | <a href="#">Pilcher &amp; Jardine (2009)</a> , <a href="#">Pilcher (2012a, 2013b)</a> |                                |
|     |            | 2011 09 – 2011 09 | 1        | Pierre Farissier  |                                |



Table A.2. continued.

|     | Asteroid  | Date              | $N_{LC}$ | Observer   |
|-----|-----------|-------------------|----------|--|
|     |           | 2011 10 – 2011 10 | 1        | Arnaud Leroy   |
| 35  | Leukothea | 2004 12 – 2004 12 | 6        | Laurent Bernasconi   |
|     |           | 2007 10 – 2010 02 | 40       | <a href="#">Pilcher (2008a)</a> , <a href="#">Pilcher &amp; Jardine (2009)</a> , <a href="#">Pilcher (2010c)</a>                                     |
|     |           | 2012 09 – 2012 09 | 3        | Maurice Audejean   |
| 36  | Atalante  | 1978 08 – 1978 08 | 1        | David Higgins  |
|     |           | 2007 02 – 2012 04 | 11       | Gérald Rousseau  |
|     |           | 2007 03 – 2007 03 | 2        | <a href="#">Warner (2007a)</a>   |
|     |           | 2007 03 – 2008 06 | 3        | <a href="#">Brinsfield (2007a)</a>   |
|     |           | 2010 10 – 2010 09 | 6        | Pierre Antonini  |
| 48  | Doris     | 2009 05 – 2009 06 | 8        | <a href="#">Higgins &amp; Pilcher (2009)</a>   |
|     |           | 2010 07 – 2010 07 | 1        | Jacques Montier, Serge Heterier<br>Raoul Behrend   |
|     |           | 2010 07 – 2010 08 | 3        | Gérald Rousseau  |
|     |           | 2010 07 – 2010 09 | 3        | Jacques Montier, Serge Heterier  |
|     |           | 2010 08 – 2010 08 | 1        | Arnaud Leroy   |
|     |           | 2010 08 – 2010 08 | 1        | Romain Montaigut, Rémi Anquetin<br>Pierre Barroy, Bruno Mallecot   |
|     |           | 2010 08 – 2010 09 | 6        | Pierre Antonini  |
| 51  | Nemausa   | 2007 03 – 2007 03 | 1        | Josef Hanus, Marek Wolf  |
|     |           | 2008 08 – 2012 09 | 6        | Maurice Audejean   |
|     |           | 2009 10 – 2009 10 | 1        | Pére Antoni Salom, Mateu Esteban   |
|     |           | 2011 05 – 2011 06 | 13       | Axel Martin  |
|     |           | 2014 03 – 2014 03 | 1        | Pierre Aurard, Thomas Dulcamara<br>Lucas Berard, Bryan Baduel<br>Marine Lutz, Gwendoline Séné<br>Emilia Splanska, Olivier Labrevoir<br>Raoul Behrend |
| 56  | Melete    | 2003 05 – 2003 05 | 6        | Laurent Bernasconi   |
|     |           | 2007 04 – 2007 05 | 8        | <a href="#">Warner (2007b)</a>   |
|     |           | 2008 10 – 2008 11 | 8        | <a href="#">Pilcher &amp; Jardine (2009)</a>   |
|     |           | 2012 09 – 2012 11 | 4        | Maurice Audejean   |
| 66  | Maja      | 2007 03 – 2007 03 | 1        | Jean-Gabriel Bosch   |
|     |           | 2009 08 – 2011 04 | 8        | Maurice Audejean   |
|     |           | 2011 01 – 2011 01 | 1        | Jérôme Caron   |
| 71  | Niobe     | 2006 02 – 2006 03 | 14       | <a href="#">Warner et al. (2006)</a>   |
|     |           | 2009 11 – 2010 03 | 13       | <a href="#">Pilcher (2010a)</a>  |
| 98  | Ianthe    | 2007 10 – 2007 11 | 5        | <a href="#">Pilcher (2008b)</a>  |
| 99  | Dike      | 2007 03 – 2007 04 | 6        | Jean-Gabriel Bosch   |
|     |           | 2007 04 – 2007 04 | 1        | Enric Forné  |
|     |           | 2007 04 – 2007 04 | 9        | Axel Martin  |
|     |           | 2011 03 – 2011 04 | 8        | <a href="#">Pilcher (2011a)</a>  |
| 103 | Hera      | 2010 06 – 2010 11 | 19       | <a href="#">Pilcher &amp; Higgins (2011)</a>   |
|     |           | 2010 07 – 2010 07 | 1        | David Higgins  |
| 104 | Klymene   | 2011 04 – 2011 04 | 2        | Gérald Rousseau  |
|     |           | 2011 05 – 2011 05 | 3        | Stefano Mottola  |
| 112 | Iphigenia | 2007 10 – 2007 12 | 7        | <a href="#">Pilcher (2008b)</a>  |
| 117 | Lomia     | 2003 03 – 2003 03 | 1        | Nathanal Berger  |
|     |           | 2003 03 – 2003 03 | 2        | Claudine Rinner  |
|     |           | 2003 03 – 2003 03 | 3        | René Roy   |
|     |           | 2003 03 – 2003 04 | 3        | Stéphane Charbonnel  |
|     |           | 2006 11 – 2006 11 | 3        | Raymond Poncy  |
|     |           | 2013 03 – 2013 03 | 4        | Maurice Audejean   |
| 120 | Lachesis  | 2008 12 – 2012 09 | 30       | <a href="#">Pilcher (2009c)</a>  |
| 122 | Gerda     | 2005 08 – 2005 09 | 3        | <a href="#">Buchheim (2007)</a>  |
|     |           | 2006 12 – 2006 12 | 2        | Raymond Poncy  |
|     |           | 2008 02 – 2008 02 | 2        | Hervé Jacquinet  |
|     |           | 2009 04 – 2009 04 | 3        | <a href="#">Pilcher (2009a)</a>  |
|     |           | 2011 11 – 2011 11 | 2        | René Roy   |
| 144 | Vibilia   | 2006 12 – 2006 12 | 3        | René Roy   |
|     |           | 2011 01 – 2011 01 | 1        | Arnaud Leroy   |
|     |           | 2011 01 – 2011 02 | 6        | Pierre Antonini  |
|     |           | 2011 12 – 2012 04 | 16       | Stephan Hellmich   |
|     |           | 2012 03 – 2012 04 | 4        | Krzysztof Sobkowiak, Roman Hirsch<br>Toni Santana-Ros  |
| 150 | Nuwa      | 2005 01 – 2005 01 | 3        | Laurent Bernasconi   |
|     |           | 2006 02 – 2006 02 | 3        | Raymond Poncy  |
|     |           | 2009 10 – 2009 10 | 1        | Sergison   |

Table A.2. continued.

|     | Asteroid    | Date              | $N_{LC}$ | Observer  |
|-----|-------------|-------------------|----------|---|
|     |             | 2009 10 – 2009 10 | 2        | Mendicini   |
|     |             | 2009 10 – 2009 10 | 2        | Vincent   |
|     |             | 2009 10 – 2009 11 | 4        | Crow  |
|     |             | 2009 10 – 2009 11 | 7        | Miles   |
|     |             | 2009 11 – 2009 11 | 1        | Faillace  |
|     |             | 2010 12 – 2011 01 | 5        | <a href="#">Pilcher (2011d)</a>   |
|     |             | 2011 02 – 2011 02 | 2        | René Roy  |
| 154 | Bertha      | 2006 11 – 2006 11 | 1        | Raymond Poncy   |
|     |             | 2007 01 – 2007 01 | 5        | <a href="#">Warner (2007a)</a>  |
|     |             | 2011 09 – 2011 10 | 10       | <a href="#">Pilcher (2012a)</a>   |
| 155 | Scylla      | 2008 11 – 2008 12 | 7        | <a href="#">Pilcher &amp; Jardine (2009)</a>  |
| 164 | Eva         | 2008 05 – 2008 06 | 6        | <a href="#">Warner (2009b)</a>  |
|     |             | 2012 04 – 2012 05 | 3        | Anna Marciniak, Roman Hirsch<br>Magdalena Polinska  |
| 171 | Ophelia     | 2005 03 – 2005 04 | 5        | Pierre Antonini   |
|     |             | 2005 03 – 2006 07 | 11       | Rui Goncalves   |
|     |             | 2005 04 – 2005 04 | 2        | Yassine Damerdji  |
|     |             | 2005 04 – 2005 04 | 2        | Federico Manzini  |
|     |             | 2005 06 – 2005 06 | 1        | Rui Goncalves, Raoul Behrend  |
|     |             | 2006 03 – 2006 04 | 6        | <a href="#">Oey (2006)</a>  |
|     |             | 2006 04 – 2006 04 | 1        | Arnaud Leroy, Giller Canaud<br>Denis Fradet, Jean-Paul Godard<br>Raoul Behrend                          |
|     |             | 2011 04 – 2011 04 | 1        | Jacques Montier, Denys Robilliard   |
|     |             | 2011 04 – 2011 04 | 1        | Jacques Montier   |
|     |             | 2011 04 – 2011 04 | 5        | Christophe Demeautis  |
| 180 | Garumna     | 2004 02 – 2011 09 | 9        | <a href="#">Clark (2010)</a>  |
|     |             | 2004 03 – 2004 03 | 1        | Donn Starkey  |
|     |             | 2004 03 – 2004 03 | 2        | Stefano Sposetti, Raoul Behrend   |
|     |             | 2004 03 – 2004 03 | 4        | René Roy  |
|     |             | 2007 12 – 2007 12 | 4        | <a href="#">Stephens (2008)</a>   |
|     |             | 2011 10 – 2011 11 | 19       | <a href="#">Pilcher et al. (2012a)</a>  |
| 187 | Lamberta    | 2004 02 – 2004 02 | 1        | Laurent Bernasconi  |
|     |             | 2006 10 – 2007 01 | 3        | Hilari Pallares   |
|     |             | 2006 11 – 2006 11 | 1        | Enric Forné, Luis Miguel  |
|     |             | 2006 11 – 2006 11 | 1        | Enric Forné, Ramón Costa  |
|     |             | 2006 11 – 2007 01 | 3        | Enric Forné   |
|     |             | 2011 11 – 2011 11 | 2        | Stéphane Fauvaud, Marcel Fauvaud<br>Franck Richard  |
| 189 | Phthia      | 2008 07 – 2008 09 | 13       | <a href="#">Pilcher (2009b)</a>   |
| 212 | Medea       | 2004 09 – 2013 06 | 7        | René Roy  |
|     |             | 2004 10 – 2004 11 | 4        | <a href="#">Koff (2005)</a>   |
|     |             | 2004 11 – 2004 11 | 1        | Rui Goncalves   |
|     |             | 2004 11 – 2006 02 | 3        | Raymond Poncy   |
|     |             | 2010 11 – 2011 03 | 8        | Fabien Reignier   |
|     |             | 2010 12 – 2011 02 | 4        | Fabien Reignier, Raoul Behrend  |
|     |             | 2011 01 – 2011 01 | 8        | Hiromi Hamanowa, Hiroko Hamanowa  |
|     |             | 2014 09 – 2014 09 | 1        | Olivier Gerteis, Paul Krafft<br>Michel Polotto, Benoit Lesquerbault<br>Luc Arnold, Matthieu Bachschmidt |
| 226 | Weringia    | 2007 08 – 2008 12 | 15       | <a href="#">Oey (2008, 2009b)</a>   |
|     |             | 2012 09 – 2012 11 | 7        | <a href="#">Pilcher (2013c)</a>   |
| 237 | Coolestina  | 2009 09 – 2009 09 | 10       | <a href="#">Stephens (2010a)</a>  |
| 247 | Eukrate     | 2010 11 – 2012 05 | 26       | Joe Garlitz   |
|     |             | 2012 01 – 2012 05 | 10       | <a href="#">Pilcher et al. (2012b)</a>  |
| 249 | Ilse        | 2014 11 – 2015 02 | 22       | <a href="#">Pilcher (2015a)</a>   |
| 254 | Augusta     | 2014 10 – 2014 11 | 5        | <a href="#">Pilcher (2015c)</a>   |
| 271 | Penthesilea | 2009 01 – 2009 02 | 7        | <a href="#">Pilcher (2009c)</a>   |
| 274 | Philagoria  | 2004 02 – 2004 02 | 2        | René Roy  |
|     |             | 2005 04 – 2005 05 | 4        | Pierre Antonini   |
|     |             | 2010 02 – 2010 04 | 6        | <a href="#">Pilcher (2010d)</a>   |
| 293 | Brasilia    | 2006 04 – 2006 04 | 1        | <a href="#">Stephens (2006)</a>   |
|     |             | 2006 04 – 2006 06 | 3        | <a href="#">Oey (2006)</a>  |
| 296 | Phaetusa    | 2010 09 – 2010 10 | 5        | <a href="#">Pilcher (2011c)</a>   |
| 313 | Chaldaea    | 2003 02 – 2003 03 | 5        | Silvano Casulli   |
|     |             | 2003 03 – 2003 04 | 3        | Antonio Vagnozzi, Marco Cristofanelli<br>Marco Paiella, Vairo Risoldi                                   |

Table A.2. continued.

|     | Asteroid       | Date              | $N_{LC}$ | Observer  |
|-----|----------------|-------------------|----------|---|
|     |                | 2004 07 – 2004 07 | 4        | Laurent Bernasconi  |
| 315 | Constantia     | 2008 07 – 2008 07 | 3        | Oey (2009a)   |
| 317 | Roxane         | 2013 12 – 2013 12 | 2        | Stéphane Fauvaud  |
|     |                | 2014 02 – 2014 02 | 4        | Stephens (2014c)  |
| 343 | Ostara         | 2008 10 – 2008 11 | 11       | Stephens (2009)   |
| 353 | Ruperto-Carola | 2006 02 – 2006 02 | 6        | Warner (2006a)  |
| 365 | Corduba        | 1994 12 – 2012 07 | 25       | Stefano Mottola, Stephan Hellmich   |
|     |                | 2006 04 – 2006 05 | 3        | Raymond Poncy   |
|     |                | 2007 07 – 2007 08 | 8        | Warner (2008a)  |
|     |                | 2012 07 – 2012 07 | 2        | Pierre Antonini   |
|     |                | 2012 07 – 2012 07 | 2        | Maurice Audejean  |
|     |                | 2012 07 – 2012 08 | 8        | Joe Garlitz   |
| 381 | Myrrha         | 2005 08 – 2005 08 | 1        | Reiner Stoss, Petra Korlevic<br>Maja Hren, Aleksandar Cikota<br>Ljuban Jerosimic, Raoul Behrend |
|     |                | 2005 08 – 2005 08 | 3        | Reiner Stoss, Jaime Nomen<br>Salvador Sanchez, Raoul Behrend                                    |
|     |                | 2010 07 – 2010 07 | 2        | Jacques Montier, Serge Heterier   |
|     |                | 2015 03 – 2015 03 | 1        | Alexander Scholz, Kirstin Hay<br>Ben Morton, Gabriella Hodosan                                  |
| 386 | Siegena        | 1998 04 – 2010 04 | 40       | Marciniak et al. (2012)   |
|     |                | 2004 07 – 2007 03 | 16       | Stephens (2005, 2007c)  |
|     |                | 2011 12 – 2011 12 | 3        | Stephan Hellmich  |
|     |                | 2011 02 – 2011 03 | 7        | Emmanuel Jehin, Mikael Gillon   |
|     |                | 2012 02 – 2012 04 | 11       | Stefano Mottola   |
|     |                | 2012 03 – 2012 03 | 1        | Romain Montaignut   |
|     |                | 2012 03 – 2012 03 | 4        | Jacques Montier   |
| 391 | Ingeborg       | 2000 08 – 2000 12 | 20       | Koff et al. (2001)  |
| 402 | Chloe          | 2009 02 – 2009 02 | 4        | Warner (2009a)  |
|     |                | 2014 05 – 2014 05 | 3        | Stephens (2014b)  |
| 419 | Aurelia        | 2006 12 – 2006 12 | 1        | René Roy  |
|     |                | 2007 01 – 2007 01 | 1        | Jean-François Coliac  |
|     |                | 2008 02 – 2011 02 | 31       | Pilcher (2008c, 2010e, 2011d)   |
| 434 | Hungaria       | 2009 07 – 2014 03 | 30       | Warner (2010b, 2011a, 2014b)  |
| 455 | Bruchsalia     | 2005 11 – 2005 12 | 6        | Koff (2006)   |
|     |                | 2008 05 – 2008 06 | 9        | Brinsfield (2008a)  |
| 474 | Prudentia      | 2014 08 – 2014 08 | 5        | Stephens (2015a)  |
| 475 | Occhio         | 2010 11 – 2010 12 | 4        | Pilcher (2011b)   |
|     |                | 2014 11 – 2014 11 | 4        | Stephens (2015b)  |
| 482 | Petrina        | 2007 07 – 2007 08 | 10       | Stephens (2009)   |
|     |                | 2010 02 – 2010 02 | 1        | James Brinsfield  |
|     |                | 2012 05 – 2013 10 | 29       | Pilcher et al. (2012c), Pilcher (2014b)   |
| 489 | Comacina       | 2001 04 – 2001 04 | 1        | William Koff  |
| 490 | Veritas        | 2001 02 – 2001 03 | 10       | Koff & Brincat (2001)   |
| 497 | Iva            | 2009 01 – 2009 01 | 3        | Warner (2009a)  |
| 502 | Sigune         | 2007 06 – 2014 03 | 19       | Stephens (2007b, 2014c)   |
|     |                | 2014 04 – 2014 04 | 3        | Buchheim (2014)   |
| 520 | Franziska      | 2013 12 – 2014 01 | 7        | Pilcher (2014a)   |
| 562 | Salome         | 2006 10 – 2006 10 | 4        | David Higgins   |
|     |                | 2012 11 – 2012 11 | 4        | Alkema (2013b)  |
| 565 | Marbachia      | 2000 03 – 2000 03 | 4        | Koff & Brincat (2000)   |
|     |                | 2013 08 – 2013 09 | 3        | Stéphane Fauvaud  |
| 567 | Eleutheria     | 2006 10 – 2006 10 | 2        | David Higgins   |
|     |                | 2010 04 – 2010 04 | 6        | Ruthroff (2010)   |
|     |                | 2010 04 – 2010 06 | 6        | Pilcher (2010d)   |
|     |                | 2012 11 – 2012 11 | 1        | Maurice Audejean  |
|     |                | 2013 11 – 2013 11 | 2        | Stephens (2014a)  |
|     |                | 2013 12 – 2013 12 | 2        | Stéphane Fauvaud  |
| 586 | Thekla         | 1999 10 – 1999 11 | 3        | Warner (2000, 2010d)  |
| 596 | Scheila        | 2005 12 – 2006 01 | 7        | Warner (2006b)  |
| 625 | Xenia          | 2010 02 – 2010 02 | 3        | PTF, Polishook et al. (2012)  |
| 632 | Pyrrha         | 2011 02 – 2011 03 | 5        | Pilcher (2011d)   |
| 639 | Latona         | 2007 09 – 2007 10 | 3        | Warner (2008a)  |
| 644 | Cosima         | 2012 12 – 2013 02 | 6        | Strabla et al. (2013)   |
|     |                | 2013 02 – 2013 02 | 8        | Alkema (2013a)  |
| 660 | Crescentia     | 2009 03 – 2009 03 | 5        | Warner (2009a)  |
|     |                | 2014 04 – 2014 05 | 6        | Stephens et al. (2014)  |

Table A.2. continued.

|      | Asteroid   | Date              | $N_{LC}$ | Observer  |
|------|------------|-------------------|----------|---|
|      |            | 2014 06 – 2014 06 | 4        | Maurice Audejean                                  |
| 670  | Ottegebe   | 2014 02 – 2014 02 | 4        | Stephens (2014c)                                  |
| 681  | Gorgo      | 2013 04 – 2013 05 | 4        | Pilcher (2013b)                                   |
| 682  | Hagar      | 2013 07 – 2013 08 | 6        | Pilcher & Franco (2014)                           |
| 686  | Gersuind   | 2013 07 – 2013 07 | 5        | Stéphane Fauvaud                                  |
| 687  | Tinette    | 1999 10 – 1999 10 | 3        | Warner (2000, 2010d)                              |
| 706  | Hirundo    | 2000 09 – 2000 09 | 6        | Warner (2001)                                     |
| 742  | Edisona    | 2003 02 – 2003 05 | 7        | Martin Lehký                                      |
|      |            | 2008 04 – 2008 05 | 4        | Brinsfield (2008a)                                |
|      |            | 2012 01 – 2012 02 | 4        | Martin Lehký                                      |
| 746  | Marlu      | 2014 10 – 2014 10 | 8        | Klinglesmith et al. (2015)                        |
| 749  | Malzovia   | 2014 04 – 2014 06 | 5        | Pilcher (2014c)                                   |
| 756  | Lilliana   | 2001 07 – 2007 08 | 9        | Warner (2010d, 2008a)                             |
|      |            | 2006 04 – 2006 04 | 2        | Russell Durkee                                    |
|      |            | 2012 04 – 2012 06 | 10       | Pilcher (2012b)                                   |
| 757  | Portlandia | 2014 11 – 2014 11 | 2        | Stephens (2015b)                                  |
| 758  | Mancunia   | 2006 12 – 2006 12 | 4        | Warner et al. (2008a)                             |
|      |            | 2006 12 – 2007 01 | 3        | Raymond Poncy                                     |
|      |            | 2007 01 – 2007 01 | 1        | Jean-François Coliac, Raoul Behrend               |
|      |            | 2007 01 – 2007 01 | 1        | Rui Goncalves                                     |
|      |            | 2007 01 – 2007 01 | 2        | Jean-François Coliac                              |
|      |            | 2015 06 – 2015 06 | 2        | OAdM  |
|      |            | 2015 06 – 2015 07 | 7        | Waldemar Ogłóza, Maciej Winiarski<br>Marek Drózdź |
| 762  | Pulcova    | 2006 02 – 2006 03 | 5        | Oey (2006)  |
|      |            | 2009 11 – 2009 12 | 3        | Alton (2011)                                      |
| 798  | Ruth       | 2002 08 – 2012 07 | 10       | Stephens (2003), new                              |
|      |            | 2011 05 – 2011 05 | 1        | Martin Lehký                                      |
| 802  | Epyaxa     | 2009 01 – 2011 11 | 4        | Warner (2009a, 2012c)                             |
| 870  | Manto      | 2013 08 – 2013 10 | 37       | Pilcher et al. (2014)                             |
| 872  | Holda      | 2007 05 – 2007 05 | 8        | Brinsfield (2007b)                                |
| 873  | Mechthild  | 2015 04 – 2015 06 | 8        | Pilcher (2015b)                                   |
| 898  | Hildegard  | 1999 06 – 1999 06 | 2        | Warner (1999)                                     |
|      |            | 2008 04 – 2008 05 | 13       | David Higgins                                     |
| 908  | Buda       | 2009 03 – 2009 03 | 5        | Warner (2009a)                                    |
| 944  | Hidalgo    | 2004 10 – 2004 10 | 4        | William Koff                                      |
| 986  | Amelia     | 2000 10 – 2000 10 | 4        | Koff (2001)                                       |
| 1010 | Marlene    | 2005 01 – 2005 03 | 8        | Warner (2005b)                                    |
| 1021 | Flammario  | 2005 01 – 2005 01 | 2        | Buchheim (2005)                                   |
| 1023 | Thomana    | 2009 09 – 2009 10 | 8        | Brinsfield (2010b)                                |
| 1080 | Orchis     | 2010 10 – 2010 10 | 5        | Strabla et al. (2011)                             |
|      |            | 2010 10 – 2010 11 | 8        | Ruthroff (2011)                                   |
| 1103 | Sequoia    | 2011 08 – 2014 11 | 11       | Warner (2011b, 2015a,c)                           |
| 1110 | Jaroslawa  | 2013 02 – 2013 04 | 20       | Julian Oey  |
|      |            | 2014 08 – 2014 11 | 24       | Pilcher et al. (2015)                             |
| 1125 | China      | 2013 10 – 2013 10 | 2        | Stephens (2014a)                                  |
| 1137 | Raissa     | 2012 09 – 2012 12 | 31       | Ferrero et al. (2014)                             |
| 1175 | Margo      | 2009 06 – 2009 07 | 4        | Brinsfield (2010a)                                |
| 1244 | Deira      | 2007 02 – 2007 04 | 21       | Julian Oey  |
| 1278 | Kenya      | 2011 04 – 2011 06 | 27       | Oey et al. (2012)                                 |
| 1310 | Villigera  | 2001 09 – 2001 10 | 4        | Koff (2002)                                       |
| 1312 | Vassar     | 2010 11 – 2010 11 | 1        | Julian Oey  |
|      |            | 2010 11 – 2010 11 | 3        | David Higgins                                     |
| 1352 | Wawel      | 2007 12 – 2007 12 | 5        | Brinsfield (2008b)                                |
| 1360 | Tarka      | 2004 09 – 2014 02 | 10       | Warner (2005a, 2014b)                             |
| 1366 | Piccolo    | 2003 04 – 2005 12 | 7        | René Roy, Raoul Behrend                           |
| 1424 | Sundmania  | 2012 03 – 2012 04 | 14       | Stephens (2012)                                   |
| 1430 | Somalia    | 2011 09 – 2011 09 | 6        | Strabla et al. (2012)                             |
| 1449 | Virtanen   | 2008 05 – 2008 07 | 11       | Oey (2009b)                                       |
| 1486 | Marilyn    | 2013 08 – 2013 08 | 5        | Benishek (2014)                                   |
| 1508 | Kemi       | 2004 02 – 2004 03 | 3        | Koff (2004)                                       |
| 1546 | Izsak      | 2006 04 – 2006 04 | 3        | Warner (2006c)                                    |
| 1672 | Gezelle    | 2008 10 – 2008 11 | 9        | Brinsfield (2009)                                 |
|      |            | 2008 11 – 2008 11 | 2        | Brian Warner                                      |
| 1676 | Kariba     | 2009 03 – 2009 03 | 3        | David Higgins                                     |
| 1730 | Marceline  | 2010 09 – 2010 09 | 2        | Brinsfield (2011)                                 |
| 1750 | Eckert     | 2009 09 – 2009 11 | 23       | Warner (2010c)                                    |

Table A.2. continued.

|       | Asteroid       | Date              | $N_{LC}$ | Observer                                   |
|-------|----------------|-------------------|----------|--|
| 1789  | Dobrovolsky    | 2011 03 – 2011 03 | 2        | Brian Skiff                                |
| 1793  | Zoya           | 2008 05 – 2008 05 | 4        | Brinsfield (2008a)                         |
| 1820  | Lohmann        | 2011 08 – 2011 10 | 8        | David Higgins                              |
|       |                | 2011 09 – 2011 10 | 8        | Martinez (2012)                            |
| 1825  | Klare          | 2003 12 – 2004 01 | 5        | Pray (2004a)                               |
| 1925  | Franklin-Adams | 2013 01 – 2013 01 | 2        | Warner (2013b)                             |
| 2001  | Einstein       | 2004 12 – 2012 12 | 13       | Warner (2005b, 2008b, 2010c, 2013a)        |
| 2306  | Bauschinger    | 2011 08 – 2011 08 | 6        | Warner (2012b)                             |
| 2358  | Bahner         | 2008 09 – 2008 10 | 13       | Owings (2009)                              |
| 2381  | Landi          | 2014 01 – 2014 02 | 4        | Klinglesmith et al. (2014)                 |
|       |                | 2014 02 – 2014 02 | 2        | Stephens (2014c)                           |
| 2382  | Nonie          | 2005 08 – 2005 08 | 6        | Warner (2006d)                             |
| 2495  | Noviomagum     | 2013 07 – 2013 07 | 4        | Warner (2014a)                             |
| 2725  | David          | 2006 02 – 2006 02 | 3        | Warner (2006a)                             |
| 2741  | Valdivia       | 2003 05 – 2003 06 | 4        | Pray (2004b)                               |
| 3258  | Somnium        | 2006 10 – 2006 10 | 7        | Oey et al. (2007)                          |
| 3266  | Bernardus      | 2009 03 – 2014 01 | 15       | Warner (2009c, 2011a, 2012d, 2014b)        |
| 3285  | Ruth Wolfe     | 1999 11 – 1999 11 | 3        | Warner (2011c)                             |
| 3301  | Jansje         | 2012 06 – 2012 07 | 8        | Owings (2013b)                             |
| 3478  | Fanale         | 2012 10 – 2012 10 | 2        | Stephens (2013)                            |
|       |                | 2012 10 – 2012 10 | 3        | Owings (2013a)                             |
| 3544  | Borodino       | 2007 10 – 2007 10 | 2        | David Higgins                              |
|       |                | 2014 06 – 2014 07 | 5        | Cantu et al. (2015)                        |
| 3752  | Camillo        | 1995 08 – 1995 08 | 9        | Pravec et al. (1998)                       |
| 3773  | Smithsonian    | 2006 09 – 2006 09 | 5        | Stephens (2007a)                           |
| 3786  | Yamada         | 2002 07 – 2002 08 | 3        | Stephens (2003)                            |
| 3918  | Brel           | 2005 11 – 2005 11 | 1        | David Higgins                              |
| 4265  | Kani           | 2008 10 – 2008 10 | 4        | Miles & Warner (2009)                      |
| 4490  | Bamberg        | 2006 02 – 2014 01 | 15       | Warner (2006a, 2009c, 2011a, 2012d, 2014b) |
| 4570  | Runcorn        | 2007 03 – 2007 05 | 11       | Julian Oey                                 |
| 4764  | Joneberhart    | 2007 01 – 2010 03 | 5        | Warner (2007a, 2010a)                      |
|       |                | 2013 05 – 2013 05 | 3        | Stephens et al. (2014)                     |
| 5332  | Davidaguilar   | 2006 01 – 2006 01 | 1        | Julian Oey                                 |
|       |                | 2008 09 – 2009 02 | 3        | Skiff et al. (2012)                        |
| 5489  | Oberkochen     | 2013 12 – 2013 12 | 3        | Stephens (2014a)                           |
| 6087  | Lupo           | 2010 07 – 2012 02 | 7        | Warner (2011b, 2012a)                      |
| 6192  | 1990 KB1       | 2010 02 – 2010 02 | 2        | PTF, Polishook et al. (2012)               |
|       |                | 2011 06 – 2011 07 | 14       | Brinsfield (2012)                          |
| 6406  | 1992 MJ        | 2006 06 – 2006 06 | 3        | Higgins & Goncalves (2007)                 |
| 6410  | Fujiwara       | 2005 07 – 2005 08 | 2        | David Higgins                              |
| 6517  | Buzzi          | 2004 07 – 2014 02 | 17       | Warner (2005c, 2009a, 2012d, 2014b)        |
| 7660  | 1993 VM1       | 2011 07 – 2014 08 | 8        | Warner (2012b, 2015a)                      |
| 8567  | 1996 HW1       | 2005 06 – 2005 07 | 6        | Higgins et al. (2006b)                     |
|       |                | 2008 08 – 2009 01 | 39       | Magri et al. (2011)                        |
| 11058 | 1991 PN10      | 2010 07 – 2012 02 | 7        | Warner (2011b, 2012a)                      |
| 14197 | -              | 2010 02 – 2010 02 | 4        | PTF, Polishook et al. (2012)               |
| 16468 | -              | 2010 02 – 2010 02 | 1        | PTF, Polishook et al. (2012)               |
| 28736 | 2000 GE133     | 2007 05 – 2007 05 | 3        | Higgins (2008)                             |
| 28887 | 2000 KQ58      | 2005 11 – 2005 12 | 6        | Higgins et al. (2006c)                     |
| 33116 | 1998 BO12      | 2006 05 – 2006 05 | 4        | Higgins et al. (2006a)                     |
| 67404 | -              | 2011 08 – 2014 10 | 7        | Warner (2012b, 2015a)                      |
| 86257 | 1999 WK13      | 2010 12 – 2012 07 | 13       | Warner (2015b)                             |

**Table A.3.** Observers, observatory code and observatory name.

| Observer name        | Obs code | Observatory name   |
|----------------------|----------|--|
| Olivier Adam         | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Veronika Afonina     | 482      | Observatory of the University of St Andrews, United-Kingdom  |
| Rémi Anquetin        | 586      | Pic du Midi Observatory  |
| Pierre Antonini      | 132      | Observatoire des Hauts Patys, F-84410 Bédoin, France   |
| Luc Arnold           | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Maurice Audejean     | B92      | Observatoire de Chinon, Mairie de Chinon, 37500 Chinon, France   |
| Pierre Aurard        | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Matthieu Bachschmidt | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Bryan Baduel         | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Eric Barbotin        |          | Villefagnan Observatory, France  |
| Pierre Barroy        | 586      | Pic du Midi Observatory  |
| Philippe Baudouin    |          | Harfleur Observatory, France   |
| Lucas Berard         | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Nathanael Berger     |          | 490 chemin du gonnet, F-38440 Saint Jean de Bournay, France  |
| Laurent Bernasconi   | A14      | Observatoire des Engarouines, 1606 chemin de Rigoy, F-84570 Malemort-du-Comtat, France   |
| Jean-Gabriel Bosch   | 178      | Collonges Observatory, 90 allée des résidences, F-74160 Collonges, France  |
| Sylvain Bouley       | 586      | Pic du Midi Observatory  |
| Inna Bozhinova       | 482      | Observatory of the University of St Andrews, United-Kingdom  |
| James Brinsfield     | G69      | Via Capote Observatory, Thousand Oaks, CA 91320, USA   |
| Laurent Brunetto     | 139      | Le Florian, Villa 4, 880 chemin de Ribac-Estagnol, F-06600 Antibes, France   |
| Giller Canaud        | 586      | Pic du Midi Observatory  |
| Jérôme Caron         | A77      | Observatoire de Dauban, F-04150 Banon, France  |
| Jérôme Caron         | C26      | Levendaal Observatory, Uiterstegeacht 48, 2312 TE Leiden, Netherlands  |
| Fabien Carrier       | 809      | European Southern Observatory, La Silla, Coquimbo, Chile   |
| Giovanni Casalnuovo  | C62      | Eurac Observatory, Bolzano, Italy  |
| Silvano Casulli      | A55      | Vallemare di Bordona, Rieti, Italy   |
| Mateu Cerda          | B81      | Observatorio Astronómico Caimari   |
| Loïc Chalamet        | F59      | Ironwood North, Hawaii, USA  |
| Stéphane Charbonnel  | 949      | Observatoire de Durtal, F-49430 Durtal, France   |
| Chinaglia            | C62      | Eurac Observatory, Bolzano, Italy  |
| Aleksandar Cikota    | 620      | OAM - Mallorca   |
| François Colas       | 586      | Pic du Midi Observatory  |
| Jean-François Coliac |          | 20 parc des Pervenches, F-13012 Marseille, France  |
| Arnaud Collet        | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Josep Coloma         | 619      | Agrupación Astronómica de Sabadell, Apartado de Correos 50, PO Box 50, 08200 Sabadell, Barcelona, Spain  |
| Josep Coloma         | B71      | Observatorio El Vendrell   |
| Matthieu Conjat      | 020      | Observatoire de Nice, France   |
| Emmanuel Conseil     |          | AFOEV (Association Française des Observateurs d'Etoiles Variables), Observatoire de Strasbourg 11, rue de l'Université, 67000 Strasbourg, France |
| Corentin             | C62      | Eurac Observatory, Bolzano, Italy  |
| Ramón Costa          | 619      | Agrupación Astronómica de Sabadell, Apartado de Correos 50, PO Box 50, 08200 Sabadell, Barcelona, Spain  |
| Ramón Costa          | B22      | Observatorio d'Ager, Barcelona, Spain  |
| Roberto Crippa       | A12      | Stazione Astronomica di Sozzago, I-28060 Sozzago, Italy  |
| Marco Cristofanelli  | 589      | Santa Lucia Stroncone, Italy   |
| Yassine Damerdj      | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Andre Debackère      | F59      | Ironwood North, Hawaii, USA  |
| Alice Decock         | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Quentin Déhais       |          | Seine-Maritime, Le Havre, Haute-Normandie 76600, France  |
| Tanguy Déléage       | F65      | Haleakala-Faulkes Telescope North, Hawaii, US  |
| Sophie Delmelle      | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Christophe Demeautis | 138      | Village-Neuf Observatory, 9bis rue du Sauvage, F-68300 Saint-Louis, France   |
| Marek Drózdź         |          | Mt. Suhora Observatory, Pedagogical University. Podchorążych 2, 30-084, Cracow, Poland   |
| Guillaume Dubos      | 586      | Pic du Midi Observatory  |
| Thomas Dulcamara     | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Maïte Dumont         | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |
| Russell Durkee       | H39      | Shed of Science Observatory, 5213 Washburn Ave. S, Minneapolis, MN 55410, USA  |
| Roger Dymock         | 940      | Waterlooville  |
| Nicolas Esseiva      | K27      | Observatoire St-Martin, 31 grande rue, F-25330 Amathay Vésigneux, France   |
| Robin Esseiva        | K27      | Observatoire St-Martin, 31 grande rue, F-25330 Amathay Vésigneux, France   |
| Mateu Esteban        | B81      | Observatorio Astronómico Caimari   |
| Mateu Esteban        | C33      | Observatorio CEAM, Caimari, Canary Islands, Spain  |
| Thomas Fauchez       | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France   |

**Notes.** TRAPPIST – TRAnsiting Planets and Planetesimal Small Telescope, [Jehin et al. \(2011\)](#).

Table A.3. continued.

| Observer name        | Obs code | Observatory name  |
|----------------------|----------|---|
| Michael Fauerbach    | H72      | Florida Gulf Coast University, 10501 FGCU Boulevard South, Fort Myers, FL 33965, USA                    |
| Marcel Fauvaud       |          | Observatoire du Bois de Bardon, F-16110 Taponnat, France  |
| Stéphane Fauvaud     |          | Observatoire du Bois de Bardon, F-16110 Taponnat, France  |
| Stéphane Fauvaud     | 586      | Pic du Midi Observatory   |
| Florian              | 517      | Geneva Observatory, 1290 Sauverny, Switzerland  |
| Enric Forné          | 619      | Agrupación Astronómica de Sabadell, Apartado de Correos 50, PO Box 50, 08200 Sabadell, Barcelona, Spain |
| Enric Forné          | B29      | Osservatorio l'Ampolla, Tarragona, Spain  |
| Carine Fournel       | F59      | Ironwood North, Hawaii, USA   |
| Denis Fradet         | 586      | Pic du Midi Observatory   |
| Joe Garlitz          |          | International Occultation Timing Association, Montgomery, AL, USA                                       |
| Olivier Gerteis      | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Christophe Gillier   | 634      | Club d'Astronomie de Lyon Ampere (CALA), Place de la Nation, 69120 Vaulx-en-Velin, France               |
| Mikael Gillon        | 140      | TRAPPIST, ESO la Silla Observatory, Chile   |
| René Giraud          | 140      | TRAPPIST, ESO la Silla Observatory, Chile   |
| Jean-Paul Godard     | 586      | Pic du Midi Observatory   |
| Rui Goncalves        | 938      | Linhaceira Observatory, Portugal  |
| Hiroko Hamanowa      | D19      | Hong Kong Space Museum, Tsimshatsui, Hong Kong, China   |
| Hiroki Hamanowa      | D19      | Hong Kong Space Museum, Tsimshatsui, Hong Kong, China   |
| Josef Hanuš          | 557      | Ondřejov Observatory, Czech Republic  |
| Kirstin Hay          | 482      | Observatory of the University of St Andrews, United-Kingdom   |
| Stephan Hellmich     | 493      | Calar Alto Observatory  |
| Serge Heterier       | 615      | St. Véran   |
| Serge Heterier       | J23      | Centre astronomique de la Couyère, 30 rue de la Boulais, F-35000 Rennes, France                         |
| David Higgins        | E14      | Hunters Hill Observatory, 7 Mawalan Street, Ngunnawal ACT 2913, Australia                               |
| Roman Hirsch         | 187      | Borowiec station of Astronomical Observatory Institute UAM, Poznań, Poland                              |
| Gabriella Hodosan    | 482      | Observatory of the University of St Andrews, United-Kingdom   |
| Maja Hren            | 620      | OAM - Mallorca  |
| Alex Hygate          | 482      | Observatory of the University of St Andrews, United-Kingdom   |
| Niyonzima Innocent   | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Herve Jacquinet      | B26      | Observatoire des Terres Blanches, Reillanne   |
| Sharat Jawahar       | 482      | Observatory of the University of St Andrews, United-Kingdom   |
| Emmanuel Jehin       | 140      | TRAPPIST, ESO la Silla Observatory, Chile   |
| Ljuban Jerosimic     | 620      | OAM - Mallorca  |
| Alain Klotz          | 148      | Guitalens Observatory, 5 chemin d'En Combes, F-81220 Guitalens, France                                  |
| Alain Klotz          | 181      | Observatoire Les Makes, G. Bizet 18, F-97421 La Rivière, France   |
| Alain Klotz          | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| William Koff         | H09      | 980 Antelope Drive West, Bennett, CO 80102, USA   |
| Petra Korlevic       | 620      | OAM - Mallorca  |
| Ewa Kosturkiewicz    |          | Mt. Suhora Observatory, Pedagogical University, Podchorążych 2, 30-084, Cracow, Poland                  |
| Paul Krafft          | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Yurij Krugly         | 121      | Institute of Astronomy of Kharkiv National University, Kharkiv, Ukraine                                 |
| François Kugel       | A77      | Observatoire de Dauban, F-04150 Banon, France   |
| Olivier Labrevoir    | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Jean Lecacheux       | 586      | Pic du Midi Observatory   |
| Martin Lehký         |          | Severní 765, 50003, Hradec Králové, Czech republic  |
| Arnaud Leroy         | 586      | Pic du Midi Observatory   |
| Arnaud Leroy         | A07      | Uranoscope, Avenue Carnot 7, F-77220 Gretz-Armainvilliers, France                                       |
| Arnaud Leroy         | Z97      | Observatoire OPERA, France  |
| Benoit Lesquerbault  | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| M. J. López-González |          | Instituto de Astrofísica de Andalucía, CSIC, Apdo. 9481, 08080 Barcelona, Spain                         |
| Marine Lutz          | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Bruno Mallecot       | 586      | Pic du Midi Observatory   |
| Jean Manfroid        | 140      | TRAPPIST, ESO la Silla Observatory, Chile   |
| Federico Manzini     | A12      | Stazione Astronomica di Sozzago, I-28060 Sozzago, Italy   |
| Anna Marciniak       | 187      | Borowiec station of Astronomical Observatory Institute UAM, Poznań, Poland                              |
| Axel Martin          | 628      | Mulheim-Ruhr, Germany   |
| Axel Martin          | H10      | Tzec Maun Foundation Observatory, Mayhill, New Mexico, US   |
| Benjamin Modave      | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Romain Montaigut     | 586      | Pic du Midi Observatory   |
| Romain Montaigut     | 634      | Club d'Astronomie de Lyon Ampere (CALA), Place de la Nation, 69120 Vaulx-en-Velin, France               |
| Romain Montaigut     | Z97      | Observatoire OPERA, France  |
| Jacques Montier      | 615      | Astroqueyras, Mairie, F-05350 Saint-Véran, France   |
| Jacques Montier      | J23      | 51 Centre astronomique de la Couyère, La Ville d'ABas, F-35320 La Couyère, France                       |
| Etienne Morelle      |          | 20 parc des Pervenches, F-13012 Marseille, France   |
| Ben Morton           | 482      | Observatory of the University of St Andrews, United-Kingdom   |
| Stefano Mottola      |          | Institute of Planetary Research, German Aerospace Center, Rutherfordstrasse 2,                          |

Table A.3. continued.

| Observer name         | Obs code | Observatory name  |
|-----------------------|----------|---|
|                       |          | 12489, Berlin, Germany  |
| Ramon Naves           | 213      | Observatorio Montcabrer, C/Jaume Balmes nb 24, Cabrils 08348, Barcelona, Spain                          |
| Jaime Nomen           | 620      | OAM - Mallorca  |
| Julian Oey            | E19      | Kingsgrove, NSW, Australia  |
| Waldemar Ogłozza      |          | Mt. Suhora Observatory, Pedagogical University. Podchorążych 2, 30-084, Cracow, Poland                  |
| Marco Paiella         | 589      | Santa Lucia Stroncone, Italy  |
| Hilari Pallares       | 619      | Agrupación Astronómica de Sabadell, Apartado de Correos 50, PO Box 50, 08200 Sabadell, Barcelona, Spain |
| Hilari Pallares       | A90      | Sant Gervasi Observatory, Barcelona   |
| Andre Peyrot          | 181      | Observatoire Les Makes, G. Bizet 18, F-97421 La Rivière, France   |
| Frederick Pilcher     | G50      | 4438 Organ Mesa Loop, Las Cruces, NM 88011, USA   |
| Jean-François Pirenne | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Pierre Piron          | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Magdalena Polinska    | 187      | Borowiec station of Astronomical Observatory Institute UAM, Poznań, Poland                              |
| Michel Polotto        | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Raymond Poncy         | 177      | Rue des Ecoles 2, F-34920 Le Crès, France   |
| Jean Pierre Previt    | J23      | Centre astronomique de la Couyère, 30 rue de la Boulais, F-35000 Rennes, France                         |
| Fabien Reigner        |          | 11 rue François-Nouteau, F-49650 Brain-sur-Allonnes, France   |
| Damien Renauld        | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Davide Ricci          | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Franck Richard        | 586      | Pic du Midi Observatory   |
| Claudine Rinner       | 224      | Ottmarsheim Observatory, 5 rue du Lièvre, F-68490 Ottmarsheim, France                                   |
| Vairo Risoldi         | 589      | Santa Lucia Stroncone, Italy  |
| Denys Robilliard      | J23      | Centre astronomique de la Couyère, 30 rue de la Boulais, F-35000 Rennes, France                         |
| David Romeuf          |          | Université Claude BERNARD Lyon 1, Observatoire de Pommier, POMMIER, F-63230 Chapdes-Beaufort, France    |
| Gérald Rousseau       |          | 4 rue de la Bruyère, F-37500 La Roche Clermault, France   |
| René Roy              | 627      | Observatoire de Blauvac, 293 chemin de St Guillaume, F-84570 Blauvac, France                            |
| John Ruthroff         |          | Shadowbox Observatory, 12745 Crescent Drive, Carmel, IN 46032, USA                                      |
| Pére Antoni Salom     | B81      | Observatorio Astronómico Caimari  |
| Pére Antoni Salom     | C33      | Observatorio CEAM, Caimari, Canary Islands, Spain   |
| Toni Santana-Ros      | 187      | Borowiec station of Astronomical Observatory Institute UAM, Poznań, Poland                              |
| Lucas Salvador        | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Salvador Sanchez      | 620      | OAM - Mallorca  |
| Alexander Scholz      | 482      | Observatory of the University of St Andrews, United-Kingdom   |
| Gwendoline Séné       | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Brian Skiff           | 690      | Lowell Observatory, Flagstaff, AZ 86001, USA  |
| Krzysztof Sobkowiak   | 187      | Borowiec station of Astronomical Observatory Institute UAM, Poznań, Poland                              |
| Patrick Sogorb        | B00      | Savigny-le-Temple   |
| Francisco Soldán      | Z74      | Observatorio Amanecer de Arrakis, Alcalá de Guadaíra, Sevilla, Spain                                    |
| Axelle Spiridakis     | F65      | Haleakala-Faulkes Telescope North, Hawaii, US   |
| Emilia Splanska       | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Stefano Sposetti      | 143      | Gnosca Observatory, CH-6525 Gnosca, Switzerland   |
| Donn Starkey          | H63      | DeKalb Observatory, 2507 CR 60, Auburn, IN 46706, USA   |
| Robert Stephens       | 646      | Center for Solar System Studies, 9302 Pittsburgh Ave, Suite 105, Rancho Cucamonga, CA 91730, USA        |
| Arnaud Stiepen        | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Reiner Stoss          | 620      | OAM - Mallorca  |
| Jean Strajnic         | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Jean-Paul Teng        | 181      | Observatoire Les Makes, G. Bizet 18, F-97421 La Rivière, France   |
| Titouan               | C62      | Eurac Observatory, Bolzano, Italy   |
| Greg Tumolo           | 482      | Observatory of the University of St Andrews, United-Kingdom   |
| Antonio Vagnozzi      | 589      | Santa Lucia Stroncone, Italy  |
| Benjamin Vanoutryve   | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Jean Marie Vugnon     |          | Association T60, 14 avenue Edouard Belin, F-31400 Toulouse, France                                      |
| Brian Warner          | 716      | Palmer Divide Observatory, 17995 Bakers Farm Rd., Colorado Springs, CO 80908, USA                       |
| Jean Marie Vugnon     | 586      | Pic du Midi Observatory   |
| Brian Warner          | U82      | Center for Solar System Studies/MoreData!, 446 Sycamore Ave., Eaton, CO 80615, USA                      |
| Mathieu Waucomont     | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Olivier Wertz         | 511      | Haute-Provence Observatory, St-Michel l'Observatoire, France  |
| Maciej Winiarski      |          | Mt. Suhora Observatory, Pedagogical University. Podchorążych 2, 30-084, Cracow, Poland                  |
| Marek Wolf            | 557      | Ondřejov Observatory, Czech Republic  |
| OAdM                  | C65      | Joan Oró Telescope (TJO) of the Montsec Astronomical Observatory (OAdM)                                 |