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# Homogeneous internal structure of CM-like asteroid (41) Daphne<sup>★,★★</sup>

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## ABSTRACT

**Context.** CM-like asteroids (Ch and Cgh classes) are a major population within the broader C-complex, encompassing about 10% of the mass of the main asteroid belt. Their internal structure has been predicted to be homogeneous, based on their compositional similarity as inferred from spectroscopy and numerical modeling of their early thermal evolution.

**Aims.** Here we aim to test this hypothesis by deriving the density of the CM-like asteroid (41) Daphne from detailed modeling of its shape and the orbit of its small satellite.

**Methods.** We observed Daphne and its satellite within our imaging survey with the Very Large Telescope extreme adaptive-optics SPHERE/ZIMPOL camera and complemented this data set with earlier Keck/NIRC2 and VLT/NACO observations. We analyzed the dynamics of the satellite with our Genoid meta-heuristic algorithm. Combining our high-angular resolution images with optical lightcurves and stellar occultations, we determine the spin period, orientation, and 3D shape, using our ADAM shape modeling algorithm.

**Results.** The satellite orbits Daphne on an equatorial, quasi-circular, prograde orbit, like the satellites of many other large main-belt asteroids. The shape model of Daphne reveals several large flat areas that could be large impact craters. The mass determined from this orbit combined with the volume computed from the shape model implies a density for Daphne of  $1.77 \pm 0.26 \text{ g cm}^{-3}$  ( $3\sigma$ ). This density is consistent with a primordial CM-like homogeneous internal structure with some level of macroporosity ( $\approx 17\%$ ).

**Conclusions.** Based on our analysis of the density of Daphne and 75 other Ch/Cgh-type asteroids gathered from the literature, we conclude that the primordial internal structure of the CM parent bodies was homogeneous.

**Key words.** minor planets, asteroids: general – minor planets, asteroids: individual: Daphne – methods: observational – techniques: high angular resolution

## 1. Introduction

The C-complex encompasses 50% of the mass of the asteroid belt (or 14% if the four largest bodies, Ceres, Vesta, Pallas and Hygeia, are disregarded, DeMeo & Carry 2013, 2014). Within this complex, the Ch- and Cgh-types are defined by the presence of an absorption band around  $0.7 \mu\text{m}$ , and a UV-dropoff (sharper

for the Cgh). These have been estimated to represent between 30 and 65% by number (Rivkin 2012; Fornasier et al. 2014), and are associated with CM chondrites (namely the Ch- and Cgh-types, see Vilas et al. 1993; Burbine 1998; Bus & Binzel 2002; DeMeo et al. 2009; Lantz et al. 2013; Fornasier et al. 2014; Vernazza et al. 2016; Takir et al. 2013). In other words, CM-like bodies represent a significant fraction of the C-complex population and encompass about 10% of the mass of all main-belt asteroids. They are spread over the entire Main Belt, and are found at all diameters (e.g., Rivkin 2012; Fornasier et al. 2014).

Their absorption band at  $0.7 \mu\text{m}$  has been associated with phyllosilicates (Vilas & Sykes 1996). This is supported by the presence of a phyllosilicate band near  $2.8 \mu\text{m}$  (commonly called the  $3 \mu\text{m}$  absorption, Rivkin et al. 2015), as well as a shallow band at  $2.33 \mu\text{m}$ . The  $2.8 \mu\text{m}$  band is very similar to that seen in the B-type asteroid (2) Pallas (Takir & Emery 2012; Rivkin et al. 2015) and interpreted as being due to serpentine (e.g., Takir et al. 2013). The  $2.33 \mu\text{m}$  band is also associated with the serpentine group (i.e., hydrous magnesium-iron phyllosilicates, Beck et al. 2018).

\* Based on observations made with (1) ESO Telescopes at the La Silla Paranal Observatory under programs 281.C-5011 (PI Dumas), 099.D-0098 (SPHERE GTO), and 199.C-0074(A) (PI Vernazza); and (2) the W. M. Keck Observatory, which is operated as a scientific partnership among the California Institute of Technology, the University of California and the National Aeronautics and Space Administration. The Observatory was made possible by the generous financial support of the W. M. Keck Foundation.

\*\* The reduced and deconvolved AO images and the 3D shape model are publicly available at <http://observations.lam.fr/astero/> and at the CDS via anonymous ftp to [cdsarc.u-strasbg.fr](http://cdsarc.u-strasbg.fr) (130.79.128.5) or via <http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/623/A132>

The meteorites originating from these bodies, the CM chondrites, represent 1.6% of all falls (Scott 2007). Together with CI carbonaceous chondrites, they represent the most chemically primitive meteorites (i.e., closest to the solar composition, Scott 2007) while paradoxically having suffered extensive hydration (e.g., Alexander et al. 2013). This aqueous alteration took place at low temperature, and thermal alteration of CM parent bodies peaked around 120 °C (e.g., Dufresne & Anders 1962; Zolensky et al. 1989, 1997; Guo & Eiler 2007), and went up to 150 °C as revealed by the formation of dolomite carbonates (Lee et al. 2014). As such, they are thought to have formed from a mixture of ice and dust where water ice was subsequently brought to a liquid state via the radioactive decay of  $^{26}\text{Al}$  contained in dust particles, leading to the aqueous alteration of a significant fraction of the dust (see, e.g., Krot et al. 2006).

Recently, Vernazza et al. (2016) made a spectral survey of 70 Ch/Cgh asteroids, which included large 200+ km deemed-primordial bodies, but also objects as small as 15 km diameter, presumed to be the collisional fragments of dynamical families created from large bodies. This allowed a probe of the internal composition of prior, larger parent bodies. These authors interpreted the spectral diversity, already reported elsewhere (e.g., Vilas 1994; Fornasier et al. 1999, 2014), as resulting mainly from a variation of the average regolith grain size rather than to different thermal histories (Fornasier et al. 2014; Rivkin et al. 2015), although differences in band depths and centers also argue for some heterogeneity in mineral abundances (Burbine 1998; Cloutis et al. 2011; Fornasier et al. 2014). This evidence points toward an overall homogeneous internal structure for the parent bodies of CM chondrites.

The thermal modeling of the early internal structure of CM parent bodies by Bland & Travis (2017) supports this conclusion. They showed that convection may have prevented strong thermal gradients and differentiation of material. Starting from the accretion of dust and ices beyond the snow line (Scott et al. 2018), the original non-lithified structure of CM parent bodies has allowed large-scale circulation of material. This model explains both the limited temperature experienced by CM parent bodies, and the small-scale heterogeneity (such as temperature and redox state observed at the hundred of micrometer level, see Fujiya et al. 2015) observed in CM chondrites (Guo & Eiler 2007; Bland & Travis 2017).

To test this model, we sought to gather evidence for or against an originally differentiated internal structure within large Ch/Cgh asteroids. Our goal was to measure their bulk density, which, when compared with the density of CM chondrites, can reveal the presence, or absence, of denser material in their interior. Determination of a density requires both a mass and a volume. Masses for larger objects can be determined by their gravitational effects on other bodies, but the precision is often low, and is particularly problematic for objects of low mass (see Carry 2012, for a discussion on the precision and biases in mass determination). If any object is binary, however, the orbit of the satellite yields the primary mass directly. Therefore, binary asteroids are crucial to establish solid and accurate references on which a larger population can be analyzed.

The present article focuses on asteroid (41) Daphne as representative of the Ch spectral class, around which a satellite was discovered in 2008 (S/2008 (41) 1, which we call Peneius<sup>1</sup>, Conrad et al. 2008). Daphne was observed within a survey we are currently conducting (ID 199.C-0074, PI P. Vernazza) to image a substantial fraction of main-belt asteroids

larger than 100 km in diameter, sampling the main compositional classes (see Vernazza et al. 2018, for a description of the survey). We image these asteroids throughout their rotation at high angular-resolution with the SPHERE/ZIMPOL extreme adaptive-optics (AO) camera (Beuzit et al. 2008; Thalmann et al. 2008) mounted on the European Southern Observatory (ESO) Very Large Telescope (VLT). The high-quality correction delivered by the AO system of SPHERE (Fusco et al. 2006, 2014) compared to previous generations of AO cameras, and the use of shorter wavelength (visible *R* band compared to the near-infrared *J/H/K* bands typically used with previous cameras), provides a twofold to threefold improvement in angular resolution. This sharper resolution allows the detailed modeling of asteroid shapes and enhanced satellite detection capability, as recently illustrated on the main-belt asteroids (3) Juno, (6) Hebe, (16) Psyche, (89) Julia, (107) Camilla, and (130) Elektra (Viikinkoski et al. 2015, 2018; Marsset et al. 2016, 2017a,b; Yang et al. 2016; Hanuš et al. 2017a; Pajuelo et al. 2018; Vernazza et al. 2018).

The article is organized as follows: we first describe our observations in Sect. 2, followed by the determination of the 3D shape model (Sect. 3.1), the mutual orbit of Daphne and its satellite (Sect. 3.2), and the diameter and spectrum of the satellite itself (Sect. 3.3). Based on the density of (41) Daphne and a compilation of mass and diameter estimates from the literature, we then discuss the internal structure of CM parent bodies in Sect. 4.

## 2. Observations

Daphne was imaged with ZIMPOL once in May 2017 and three times in August 2018. We also compile 24 epochs of high-angular resolution and high-contrast images (Table B.1) from large ground-based telescopes equipped with adaptive-optics (AO) cameras: NIRC2 at Keck (van Dam et al. 2004) and NACO at ESO VLT (Rousset et al. 2003).

We process the ZIMPOL data with the ESO pipeline (see details in Vernazza et al. 2018). We then reduce all other imaging epochs with the same suite of IDL routines for consistency. The basic data reduction encompasses bad pixel mapping and removal by median interpolation, sky subtraction, and flat-field correction, following the steps described in Carry et al. (2008). We then use *Mistral*, a myopic deconvolution algorithm optimized for celestial targets with sharp boundaries (Fusco et al. 2002; Mugnier et al. 2004), to deconvolve the images and enhance their angular resolution for shape modeling purposes. The results of this approach have already been demonstrated elsewhere (e.g., Witasse et al. 2006; Drummond et al. 2014). In parallel, the diffused halo of light surrounding Daphne was removed by subtracting concentric annuli (as described thoroughly in Pajuelo et al. 2018) for satellite detection.

We complement this data set with an additional epoch of Daphne in May 2017 with the SPHERE integral-field spectrograph (IFS, Claudi et al. 2008) to acquire the near-infrared spectrum of its satellite Peneius. This epoch was obtained within the “Other Science” program (ID: 099.D-0098, PI J.-L. Beuzit) of the guaranteed-time observations (GTO) of the SPHERE consortium. The aim of this program is to illustrate SPHERE’s capabilities in science topics other than its primary goal: direct imaging of planets and disks. The IFS data were reduced using the SPHERE consortium pipeline, which includes bad pixel removal, sky subtraction, flat-field correction, and wavelength calibration.

<sup>1</sup> Pronounced “peh-NEH-oss.”

Together with these images, we retrieve nine stellar occultations by Daphne compiled on the PDS by Dunham et al. (2017). We convert the locations of observers and disappearance timings into chords on the plane of the sky using the recipes by Berthier (1999). We detail the circumstances of observation of these occultations in Table B.2.

We also compile 29 optical lightcurves, from the historical works of Scaltriti & Zappala (1977), Barucci (1983), Barucci et al. (1985), and Weidenschilling et al. (1987, 1990), used by Kaasalainen et al. (2002) and Hanuš et al. (2017b) to reconstruct the 3D shape of Daphne. We complement this data set with twelve lightcurves obtained by amateur astronomers, two lightcurves obtained with the 60 cm *André Peyrot* telescope mounted at Les Makes observatory on Réunion Island (operated as a partnership among Les Makes Observatory and the IMCCE, Paris Observatory), one lightcurve obtained with the Antarctic Search for Transiting ExoPlanet (ASTEP) telescope (Daban et al. 2010) during its commissioning at the Observatoire de la Côte d’Azur in Nice (Matter et al. 2011), and extract three serendipitously observed lightcurves from the SuperWASP image archive (Grice et al. 2017). The details of these lightcurves are provided in Table B.3.

### 3. Properties of Daphne and its satellite

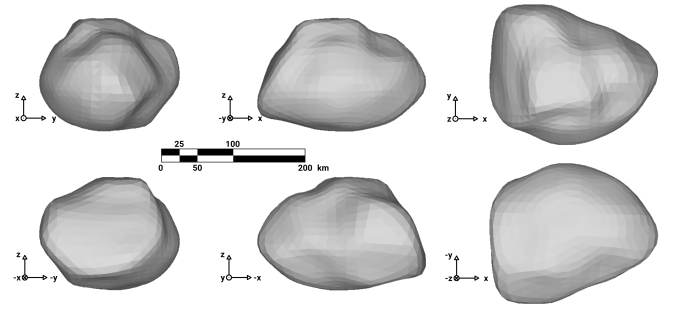
#### 3.1. Spin and 3D shape

We determine the spin properties (rotation period and spin-vector coordinates) and reconstruct the 3D shape of Daphne with the open-source<sup>2</sup> ADAM algorithm (Viikinkoski et al. 2015). ADAM uses the Levenberg-Marquardt optimization algorithm to find the spin and 3D shape that best reproduce the lightcurves, stellar occultation chords, and disk-resolved images simultaneously by comparing the observations with synthetic data generated by the model at each step.

The best-fit solution displayed in Fig. 1, the details of which are listed in Table 1, has a sidereal rotation period  $P_s$  of 5.98798 h and spin-vector ecliptic coordinates of  $(199^\circ, -33^\circ)$ , very similar to the results from convex shape modeling from lightcurves only by Kaasalainen et al. (2002) and multi-data shape reconstruction from a slightly different data set with ADAM by Hanuš et al. (2017b). The shape model is of an irregular body with several large flat areas, putative impact basins, and has a spherical-volume-equivalent diameter  $\mathcal{D}$  of  $187 \pm 21.5$  km ( $3\sigma$  uncertainty). We present all the data compared with the predictions from the shape model in Appendix B.

An almost similar shape model and spin solution had been previously reported by Carry (2009) with the multi-data KOALA shape reconstruction algorithm (based on the same algorithm as ADAM but with different implementation, Carry et al. 2010a; Kaasalainen 2011). Because KOALA has been validated by comparing the shape model of (21) Lutetia (Carry et al. 2010b; Drummond et al. 2010) with the images returned by the ESA Rosetta mission during its flyby of the asteroid (Sierks et al. 2011; Carry et al. 2012), the agreement between the two models provides solid evidence for the reliability of both ADAM and of the shape model of Daphne.

While there is a significant spread of diameter estimates in the literature (average diameter of  $192 \pm 38$  km), all the estimates based on direct measurements, i.e. stellar occultations, disk-resolved imaging, mid-infrared interferometry, are narrowly clustered around our value:  $188 \pm 14$  km ( $3\sigma$  deviation, see



**Fig. 1.** Views of the shape model of Daphne. The  $X$ ,  $Y$  and  $Z$  axes are aligned along the principal axes of inertia.

**Table 1.** Spin solution (coordinates in ecliptic and equatorial J2000 reference frames) and shape model parameters (the overall shape is reported as the  $a > b > c$  diameters of a triaxial ellipsoid fit to the shape model).

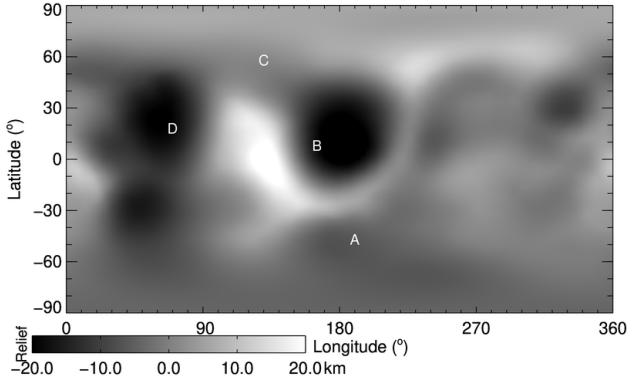
| Parameter       | Symbol        | Value              | Unc.               | Unit               |
|-----------------|---------------|--------------------|--------------------|--------------------|
| Sidereal period | $P_s$         | 5.987981           | $6 \times 10^{-5}$ | (h)                |
| Longitude       | $\lambda$     | 199.4              | 5.                 | ( $^\circ$ )       |
| Latitude        | $\beta$       | -31.9              | 5.                 | ( $^\circ$ )       |
| Right ascension | $\alpha$      | 183.5              | 5.                 | ( $^\circ$ )       |
| Declination     | $\delta$      | -36.6              | 5.                 | ( $^\circ$ )       |
| Ref. epoch      | $T_0$         | 2444771.750        |                    |                    |
| Diameter        | $\mathcal{D}$ | 187                | 21.5               | (km)               |
| Volume          | $V$           | $3.39 \times 10^6$ | $7.1 \times 10^5$  | (km <sup>3</sup> ) |
| Diam. $a$       | $a$           | 237.9              | 21.5               | (km)               |
| Diam. $b$       | $b$           | 184.8              | 21.5               | (km)               |
| Diam. $c$       | $c$           | 156.0              | 21.5               | (km)               |
| Axes ratio      | $a/b$         | 1.29               | 0.19               |                    |
| Axes ratio      | $b/c$         | 1.18               | 0.21               |                    |
| Axes ratio      | $a/c$         | 1.52               | 0.25               |                    |

**Notes.** All uncertainties are reported at  $3\sigma$ .

Table A.1). In particular, the mid-infrared interferometric observations by Matter et al. (2011) provide an independent confirmation, being based on a totally different data set. These authors analyzed their interferometric visibilities using the convex shape model of Kaasalainen et al. (2002) and the non-convex shape model of Carry (2009), almost identical to the model presented here. The associated diameters differ by 15 km, showing how the determination of diameter is sensitive to the shape of the object. Their best-fit diameter associated with the non-convex model was  $185.5 \pm 10.5$  km ( $3\sigma$ ), supporting the present value.

We define the prime meridian of Daphne to be along its longest axis, on which a hill, which we call the nose, is present at the equator (elevation of 11 km above the reference ellipsoid, see the map in Fig. 2). Several flat regions (hereafter A, B, C) can be identified in the images and on the shape model, as well as a clear depression (D). The three flat areas are located near both poles, and on the opposite side of the nose. These flat areas and the depression are large compared with the diameter of Daphne and may be indicative of large impact basins not modeled because concavities could not be detected with the available data (Durech & Kaasalainen 2003; Devogèle et al. 2015). The central location and overall dimensions of these features, including the ratio of their surface-equivalent diameter to the diameter of Daphne, are listed in Table 2.

<sup>2</sup> <https://github.com/matvii/adam>



**Fig. 2.** Topography of Daphne, measured in kilometers with respect to its reference ellipsoid (Table 1). The putative depression is marked by the letter D, while the three flat areas are labeled A, B, and C. They may appear as circular depressions here (in particular B) because the topography is measured with respect to an ellipsoid.

**Table 2.** Dimensions (semi-axes  $\mathcal{L}_a$  and  $\mathcal{L}_b$ , surface area  $\mathcal{A}$ , and fraction  $f$  of Daphne’s diameter) and planetocentric coordinates ( $\lambda_c, \beta_c$ ) of the four notable topographic features of Daphne.

|                 | A             | B             | C             | D             | Unit                    |
|-----------------|---------------|---------------|---------------|---------------|-------------------------|
| $\lambda_c$     | $190 \pm 5$   | $165 \pm 5$   | $130 \pm 5$   | $60 \pm 5$    | (°)                     |
| $\beta_c$       | $-50 \pm 5$   | $+5 \pm 5$    | $+55 \pm 5$   | $+19 \pm 5$   | (°)                     |
| $\mathcal{L}_a$ | $60 \pm 5$    | $68 \pm 5$    | $45 \pm 5$    | $42 \pm 3$    | (km)                    |
| $\mathcal{L}_b$ | $48 \pm 5$    | $42 \pm 5$    | $45 \pm 5$    | $42 \pm 3$    | (km)                    |
| $\mathcal{A}$   | $8.7 \pm 3.3$ | $9.0 \pm 3.3$ | $6.3 \pm 2.8$ | $5.5 \pm 0.8$ | ( $10^3 \text{ km}^2$ ) |
| $f$             | $56 \pm 10$   | $57 \pm 10$   | $47 \pm 10$   | $44 \pm 3$    | (%)                     |

### 3.2. Dynamics of the system

On each image, we measure the relative position of the satellite with respect to center of light of the primary by adjusting a 2D gaussian on the primary using the unmodified images and another on the satellite using the halo-removed images (Fig. 3). We use the meta-heuristic algorithm Genoid (Vachier et al. 2012) to find the set of orbital parameters that best fit the observations. The orbital parameter space is usually 6D for a simple Keplerian motion: orbital period, eccentricity, inclination, longitude of the ascending node, argument of periastris, and time of passage to the periastris. More dimensions are required if the gravitational potential is not central, such as in accounting for a gravitational quadrupole  $J_2$ . Genoid explores this parameter space in successive generations of orbital solutions, randomly merging the parameters of the best solutions to create newer generations. In combination with this broad exploration of the parameter space, Genoid uses gradient descent at each generation to find the minimum closest to each best-trial solution.

The reliability of this approach has been assessed during a stellar occultation by (87) Sylvia in 2013. We had used Genoid to predict the position of its largest satellite Romulus before the event, placing observers on the occultation path of the satellite. Four different observers detected an occultation by Romulus at only 13.5 km off the predicted position (Berthier et al. 2014).

The best-fit orbit adjusts the 30 positions with a root-mean square (rms) residual of 8.3 mas only, i.e., smaller than the pixel size of most observations (21 out of 30 taken with NACO/VLT

**Table 3.** Orbital elements of Peneius, the satellite of Daphne, expressed in EQJ2000, obtained with Genoid.

| Observing data set         |                |                      |
|----------------------------|----------------|----------------------|
| Number of observations     | 30             |                      |
| Time span (days)           | 3783           |                      |
| rms (mas)                  | 8.3            |                      |
| Orbital elements EQJ2000   |                |                      |
| $P$ (day)                  | 1.137 446      | $\pm 0.000\ 009$     |
| $a$ (km)                   | 463.5          | $\pm 22.8$           |
| $e$                        | 0.009          | $+0.021$<br>$-0.009$ |
| $i$ (°)                    | 128.1          | $\pm 6.2$            |
| $\Omega$ (°)               | 272.7          | $\pm 5.7$            |
| $\omega$ (°)               | 171.9          | $\pm 37.6$           |
| $t_p$ (JD)                 | 2454550.586985 | $\pm 0.117331$       |
| Derived parameters         |                |                      |
| $M$ ( $\times 10^{18}$ kg) | 6.10           | $\pm 0.89$           |
| $\lambda_p, \beta_p$ (°)   | 197, -33       | $\pm 6, 7$           |
| $\alpha_p, \delta_p$ (°)   | 182, -38       | $\pm 5, 7$           |
| $\Lambda$ (°)              | 2              | $\pm 4$              |

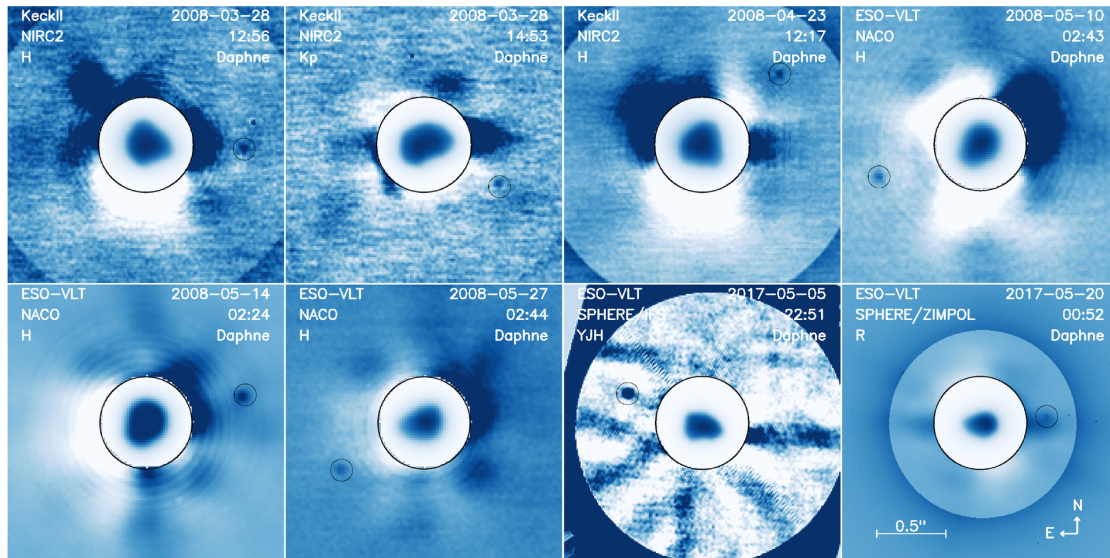
**Notes.** The table lists: orbital period  $P$ , semi-major axis  $a$ , eccentricity  $e$ , inclination  $i$ , longitude of the ascending node  $\Omega$ , argument of pericenter  $\omega$ , time of pericenter  $t_p$ . The number of observations and rms between predicted and observed positions are also provided. Finally, we report the derived primary mass  $M$ , the ecliptic J2000 coordinates of the orbital pole ( $\lambda_p, \beta_p$ ), the equatorial J2000 coordinates of the orbital pole ( $\alpha_p, \delta_p$ ), and the orbital inclination ( $\Lambda$ ) with respect to the equator of Daphne. Uncertainties are given at  $3\sigma$ .

and NIRC2/Keck, see Table C.1). The observations, covering 3783 days or 3326 revolutions, provide solid constraints on the orbital period ( $1.137\ 446 \pm 0.000\ 009$  day). The satellite orbits Daphne on a Keplerian, equatorial, and prograde orbit, slightly eccentric (Table 3), at a distance of only 7.4 primary radii. We searched for a signature of the gravitational quadrupole  $J_2$  but the poor time coverage of the astrometry with a gap of nine years between the positions in 2008 and those in 2017 and 2018 precluded any firm conclusion. A regular follow-up of the position of Peneius is required to conclude on the  $J_2$  of Daphne. These orbital characteristics argue in favor of a formation of the satellite by impact excavation, and re-accumulation of material in orbit, followed by tidal circularization (Weidenschilling et al. 1989; Merline et al. 2002; Durda et al. 2004; Margot et al. 2015).

### 3.3. Spectrum and diameter of the satellite

We recorded the near-infrared spectra of Daphne and its satellite with SPHERE/IFS. Telluric features were removed by observing the nearby star HD 102085 (G3V). Similarly to previous sections, the bright halo of Daphne that contaminated the spectrum of the moon was removed. This was achieved by measuring the background at the location of the moon for each pixel as the median value of the area defined as a  $40 \times 1$ -pixel arc centered on Daphne. To estimate the uncertainty and potential bias on photometry (at each wavelength) introduced by this method, we performed a number of simulations (similarly to our study of the satellite of Camilla, see Pajuelo et al. 2018).

We added synthetic companions on the 39 spectral images of the spectro-imaging cube, at a similar separation to the satellite ( $\approx 300$  mas) and random position angles from the primary. The simulated sources were modeled as the point-spread function



**Fig. 3.** Example images of Daphne and its satellite. Each panel represents a different epoch. The image is displayed in the inner circle, showing the irregular shape of Daphne. The outer region shows the images after halo removal, showing the satellite (highlighted by a small circle). On each panel the telescope, instrument, filter, and UTC date are reported.

from the calibration star images scaled in brightness. The halo from Daphne was then removed from these simulated images using the method described above, and the flux of the simulated companion measured by adjusting a 2D-Gaussian profile (see Sect. 3.2). Based on a total statistics of 100 simulated companions, we find that the median loss of flux at each wavelength is  $13 \pm 9\%$  and that the spectral slope is affected ( $-0.50\%/100$  nm on average).

The measured slope for each individual simulation, however, is not reliable, the standard deviation of all simulations being of  $2.73\%/100$  nm. The value for each depends on the location (position angle) of the simulated satellite. Furthermore, the signal-to-noise ratio (S/N) of the simulations range from virtually zero to four, with an average of 1.8 only. The spectrum of the satellite, therefore, is not reliable, being noisy and likely affected by strong slope effects.

From the integrated fluxes measured with the 2D gaussian functions on Daphne and its satellite at each epoch (Fig. C.2 and Table C.1), we derived their magnitude difference to be  $9.49 \pm 0.32$ . Combined with our determination of a diameter of  $187 \pm 21.5$  km, we derive a diameter of  $2.4^{+1.8}_{-1.1}$  km for the satellite, under the assumption of a similar albedo for both. This assumption is supported by the multiple reports of spectral similarities between the components of multiple asteroid systems: (22) Kalliope (Laver et al. 2009), (90) Antiope (Polishook et al. 2009), (107) Camilla (Pajuelo et al. 2018), (130) Elektra (Yang et al. 2016), and (379) Huenna (DeMeo et al. 2011).

#### 4. Implications on the internal structure

Using the volume determined from ADAM (Sect. 3.1) and the mass from Genoid (Sect. 3.2), we derive a bulk density of  $1.77 \pm 0.26$  ( $\text{g cm}^{-3}$ ,  $3\sigma$  uncertainty). This value is smaller but marginally consistent with the typical density of the CM carbonaceous chondrites, at  $2.13 \pm 0.57$   $\text{g cm}^{-3}$  ( $3\sigma$ , Consolmagno et al. 2008). Comparing these two density values implies a macroporosity of  $17 \pm 3\%$ .

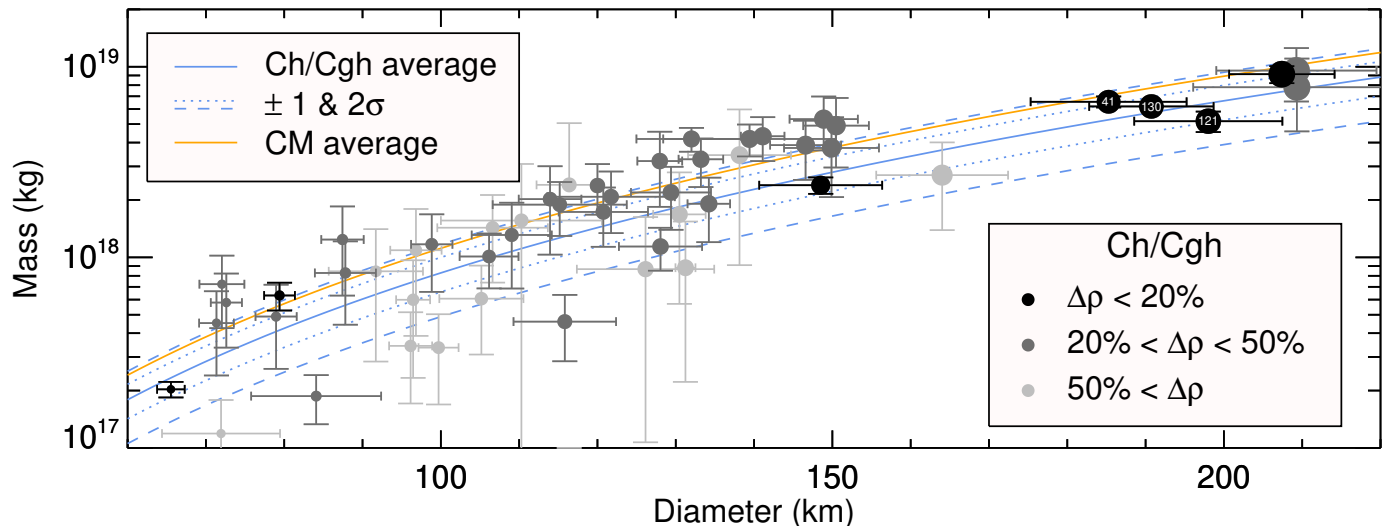
As visible in Fig. 4, Ch and Cgh asteroids over two orders of magnitude in mass follow the same trend and have a density

smaller than that of CM meteorites, although there is definitively some scatter due to large uncertainties and biases in the determination of their density (see Appendix D for the complete list of estimates, and Carry 2012, for a discussion on the reliability of mass, diameter, and density estimates). The distribution of all density estimates weighted by their respective uncertainty is Gaussian with an average value of  $1.40^{+1.92}_{-1.40}$   $\text{g cm}^{-3}$ . This value changes to  $1.58 \pm 0.97$   $\text{g cm}^{-3}$  ( $3\sigma$ ) by considering only the estimates with less than 20% relative uncertainty (represented by the blue curves in Fig. 4). This highlights the importance of the study of binary systems that can be angularly resolved to accurately determine both the volume and the mass, hence the density.

There are three large (150+ km) binary Ch-type asteroids: (41) Daphne, (121) Hermione, and (130) Elektra. The density of Hermione was estimated to  $1.4^{+1.5}_{-0.6}$   $\text{g cm}^{-3}$  by Descamps et al. (2009) and  $1.26 \pm 0.90$   $\text{g cm}^{-3}$  by Viikinkoski et al. (2017). The density of Elektra was reported as  $1.60 \pm 0.39$   $\text{g cm}^{-3}$  by Hanuš et al. (2017a), based on the mass estimate by Marchis et al. (2008a) while the mass recently derived by Yang et al. (2016) leads to  $1.50 \pm 0.36$   $\text{g cm}^{-3}$ . These values are somewhat smaller than the density of the three other large Ch-types: (13) Egeria at  $1.99 \pm 0.69$   $\text{g cm}^{-3}$ , (19) Fortuna at  $1.96 \pm 0.28$   $\text{g cm}^{-3}$ , and (48) Doris at  $1.63 \pm 0.74$   $\text{g cm}^{-3}$  (see Appendix D). The density of these six targets is systematically smaller than CM meteorites.

Over the wide range of mass spanned by the Ch/Cgh asteroids studied here (Fig. 4), the density appears roughly constant although there is a larger spread toward smaller diameters. This larger spread is likely due to larger uncertainties on the density estimates (the gravitational signature of asteroids become harder to detect toward smaller sizes, see Carry 2012). Indeed, the report by Carry (2012) of a correlation between density and mass (or diameter) due to an increasing macroporosity toward smaller diameters mainly happens for objects smaller than 100 km. This density of Ch/Cgh asteroids systematically lower than that of CM meteorites has two implications.

First, the density of the largest Ch/Cgh asteroids argues against the presence of material denser than CM-like material in their interior, i.e., differentiation. If denser material was present, their macroporosity would have to be large to maintain their bulk



**Fig. 4.** Mass vs. diameter distribution for 76 Ch/Cgh asteroids (grey circles). Those more precise than 50 and 20% are plotted as dark grey and black circles, respectively. Unreliable density estimates (below  $0.5 \text{ g cm}^{-3}$ ) are not displayed. The three binary asteroids, (41) Daphne, (121) Hermione, (130) Elektra, are labeled. The solid and dashed blue curves represent the average density ( $1.58 \text{ g cm}^{-3}$ ) and  $1\sigma$ – $2\sigma$  ( $\pm 0.33 \text{ g cm}^{-3}$ ) dispersion of the sample. The solid orange curve stands for the average density of CM chondrites at  $2.13 \pm 0.57 \text{ g cm}^{-3}$  ( $3\sigma$ ).

density, contrarily to what is observed for 100–200+ km bodies (Carry 2012). Together with the observed compositional homogeneity of Ch/Cgh asteroids (Vernazza et al. 2016), it supports the idea of an originally undifferentiated internal structure of CM parent bodies. Because collisional fragments sample the interior of their parent bodies, this spectral homogeneity only modulated by grain sizes together with the density smaller than the surface analog material can be interpreted as evidence for a homogeneous internal structure, without differentiation, of the CM parent bodies. The thermal modeling in “giant mud balls” (non-lithified structure) proposed by Bland & Travis (2017) then provides an explanation for the observed peak temperature of  $120^\circ\text{C}$  (e.g., Guo & Eiler 2007).

Second, the density of Ch/Cgh asteroids being systematically smaller than CM chondrite indicates the presence of large voids, or less dense material, in their interior. Given the extensive hydration suffered by CM chondrites (e.g., Alexander et al. 2013) and the detection of water ice on/near the surface of asteroids well-within the snowline (e.g., Campins et al. 2010; Küppers et al. 2014), one cannot reject the hypothesis of the presence of water ice in Ch/Cgh asteroids. However, considering that all these objects have experienced numerous collisions over the history of the solar system, some macroporosity, i.e. voids, can be expected.

## 5. Conclusion

We have acquired high-angular resolution images and spectro-images of the binary Ch-type asteroid (41) Daphne from large ground-based telescopes, including the new generation extreme adaptive-optics SPHERE camera mounted on the ESO VLT. We determined the orbit of its small satellite Peneius from 30 observations of its position around Daphne, with an rms of 8.3 mas only. Combining our disk-resolved images with optical lightcurves and stellar occultations, we determined the 3D shape of (41) Daphne.

The derived density of  $1.77 \pm 0.26 \text{ g cm}^{-3}$  provides a solid reference to interpret the density of Ch/Cgh asteroids. The density is available for 76 of them and is found systematically

smaller than that of the associated CM carbonaceous chondrites ( $2.13 \pm 0.57 \text{ g cm}^{-3}$ ,  $3\sigma$ ), including for the largest asteroids. This provides robust evidence for a primordial homogeneous internal structure of these asteroids, in agreement with the observation of compositional homogeneity among Ch/Cgh asteroids of very different diameters by Vernazza et al. (2016) and the modeling of their early thermal history by Bland & Travis (2017).

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<sup>3</sup> Miriade: <http://vo.imcce.fr/webservices/miriade/>

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## Appendix A: Compilation of diameter and mass estimates

**Table A.1.** The diameter estimates ( $\mathcal{D}$ ) of (41) Daphne collected in the literature.

| #  | $\mathcal{D}$<br>(km) | $\delta\mathcal{D}$<br>(km) | Method | Reference                                     |
|----|-----------------------|-----------------------------|--------|---|
| 1  | 203.00                | 60.90                       | STM    | <a href="#">Morrison &amp; Zellner (2007)</a> |
| 2  | 174.00                | 35.10                       | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 3  | 172.43                | 12.24                       | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 4  | 207.87                | 31.56                       | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 5  | 187.00                | 60.00                       | LCOCC  | <a href="#">Ďurech et al. (2011)</a>          |
| 6  | 201.50                | 22.50                       | TPM    | <a href="#">Matter et al. (2011)</a>          |
| 7  | 185.50                | 10.50                       | TPM    | <a href="#">Matter et al. (2011)</a>          |
| 8  | 179.61                | 7.74                        | STM    | <a href="#">Usui et al. (2011)</a>            |
| 9  | 205.50                | 5.64                        | NEATM  | <a href="#">Masiero et al. (2012)</a>         |
| 10 | 186.00                | 81.00                       | LCIMG  | <a href="#">Hanuš et al. (2013b)</a>          |
| 11 | 198.74                | 185.13                      | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 12 | 188.00                | 15.00                       | ADAM   | <a href="#">Hanuš et al. (2017b)</a>          |
| 13 | 187.00                | 21.50                       | ADAM   | This work                                     |

**Notes.** For each, the  $3\sigma$  uncertainty, method, and bibliographic reference are reported. The methods are ADAM: Multidata 3D Modeling, LCIMG: 3D Model scaled with Imaging, LCOCC: 3D Model scaled with Occultation, NEATM: Near-Earth Asteroid Thermal Model, STM: Standard Thermal Model, TPM: Thermophysical Model.

**Table A.2.** The mass estimates ( $\mathcal{M}$ ) of (41) Daphne collected in the literature.

| #  | Mass ( $\mathcal{M}$ )<br>( $\times 10^{18}$ kg) | Method | Reference  |
|----|--|--------|--|
| 1  | $10.50 \pm 2.99$                                 | EPHEM  | <a href="#">Fienga et al. (2009)</a>               |
| 2  | $7.90 \pm 2.37$                                  | EPHEM  | <a href="#">Folkner et al. (2009)</a>              |
| 3  | $8.43^{+10.56}_{-8.43}$                          | EPHEM  | <a href="#">Konopliv et al. (2011)</a>             |
| 4  | $18.20^{+21.60}_{-18.20}$                        | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 5  | $0.30^{+17.01}_{-0.30}$                          | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 6  | $4.76^{+16.50}_{-4.76}$                          | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 7  | $12.10^{+31.50}_{-12.10}$                        | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 8  | $10.20 \pm 3.57$                                 | EPHEM  | <a href="#">Fienga et al. (2011)</a>               |
| 9  | $7.79 \pm 5.40$                                  | EPHEM  | <a href="#">Kuchynka &amp; Folkner (2013)</a>      |
| 10 | $8.29 \pm 2.62$                                  | EPHEM  | <a href="#">Pitjeva (2013)</a>                     |
| 11 | $7.13 \pm 2.01$                                  | EPHEM  | <a href="#">Fienga et al. (2014)</a>               |
| 12 | $9.35 \pm 4.17$                                  | DEFL   | <a href="#">Goffin (2014)</a>                      |
| 13 | $9.78^{+13.77}_{-9.78}$                          | DEFL   | <a href="#">Kochetova &amp; Chernetenko (2014)</a> |
| 14 | $4.44 \pm 2.52$                                  | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a>         |
| 15 | $6.10 \pm 0.89$                                  | BGENO  | This work  |

**Notes.** For each, the  $3\sigma$  uncertainty, method, and bibliographic reference are reported. The methods are BGENO: Binary: Genoid, DEFL: Deflection, EPHEM: Ephemeris.

**Appendix B: Shape modeling: data and model predictions****Table B.1.** Date, telescope, camera, number of epochs ( $N_S$ ), heliocentric distance ( $\Delta$ ), range to observer ( $r$ ), phase angle ( $\alpha$ ), angular diameter ( $\Theta$ ), and program ID and Principal Investigator (PI) for each night of AO imaging observations.

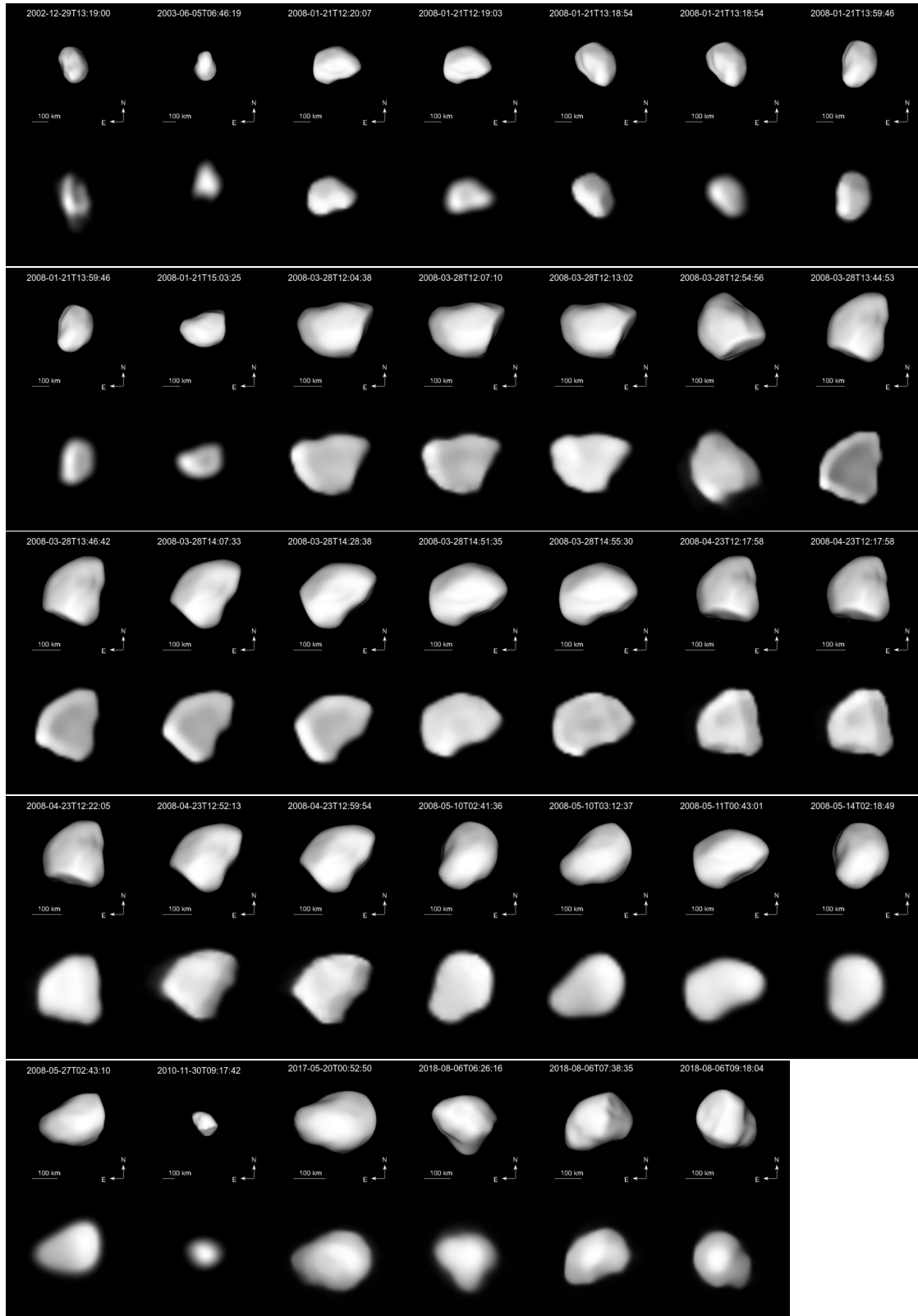
|    | Date       | Telescope | Instrument    | $N_S$ | $\Delta$<br>(au) | $r$<br>(au) | $\alpha$<br>( $^\circ$ ) | $\Theta$<br>(mas) | Prog. ID   | PI            |
|----|------------|-----------|---------------|-------|------------------|-------------|--------------------------|-------------------|------------|---------------|
| 1  | 2002-12-29 | Keck      | NIRC2         | 1     | 2.65             | 1.91        | 16.4                     | 135               | C74N2      | J.-L. Margot  |
| 2  | 2003-05-06 | Keck      | NIRC2         | 1     | 2.28             | 2.06        | 26.2                     | 125               | N17N2      | W. J. Merline |
| 3  | 2008-01-21 | Keck      | NIRC2         | 7     | 2.19             | 1.78        | 26.3                     | 144               | DDT        | A. Conrad     |
| 4  | 2008-03-28 | Keck      | NIRC2         | 10    | 2.06             | 1.09        | 9.1                      | 235               | DDT        | A. Conrad     |
| 5  | 2008-04-23 | Keck      | NIRC2         | 5     | 2.03             | 1.06        | 9.9                      | 243               | DDT        | A. Conrad     |
| 6  | 2008-05-10 | VLT       | NACO          | 4     | 2.02             | 1.12        | 17.5                     | 229               | 281.C-5011 | C. Dumas      |
| 7  | 2008-05-14 | VLT       | NACO          | 2     | 2.02             | 1.14        | 19.1                     | 225               | 281.C-5011 | C. Dumas      |
| 8  | 2008-05-27 | VLT       | NACO          | 2     | 2.01             | 1.23        | 23.6                     | 209               | 281.C-5011 | C. Dumas      |
| 9  | 2010-11-30 | Keck      | NIRC2         | 1     | 3.50             | 2.60        | 7.6                      | 99                | U028N2     | F. Marchis    |
| 10 | 2017-05-05 | VLT       | SPHERE/IFS    | 1     | 2.09             | 1.44        | 25.6                     | 179               | 099.D-0098 | J.-L. Beuzit  |
| 11 | 2017-05-20 | VLT       | SPHERE/ZIMPOL | 1     | 2.06             | 1.56        | 28.3                     | 164               | 199.C-0074 | P. Vernazza   |
| 12 | 2018-08-05 | VLT       | SPHERE/ZIMPOL | 3     | 2.80             | 1.90        | 11.7                     | 136               | 199.C-0074 | P. Vernazza   |

**Table B.2.** Date, number of positive and negative chords ( $\#_p$  and  $\#_n$ ), and average uncertainty in seconds ( $\sigma_s$ ) and kilometers ( $\sigma_{km}$ ) for each stellar occultation.

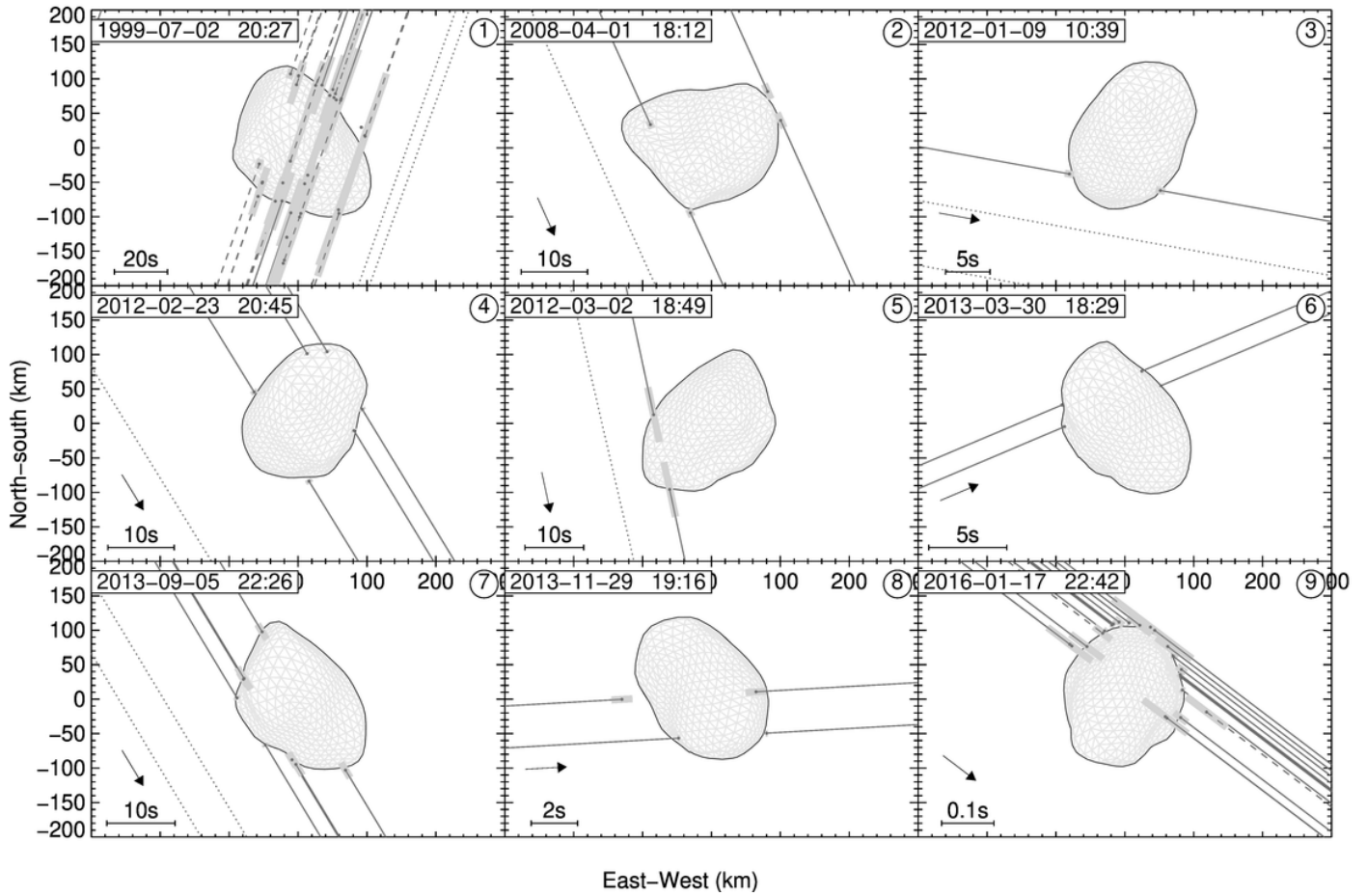
|   | Date       | UT<br>(h) | $\#_p$ | $\#_n$ | $\sigma_s$<br>(s) | $\sigma_{km}$<br>(km) |
|---|------------|-----------|--------|--------|-------------------|-----------------------|
| 1 | 1999-07-02 | 20:27     | 21     | 3      | 1.21              | 46.150                |
| 2 | 2008-04-01 | 18:12     | 2      | 1      | 0.50              | 4.814                 |
| 3 | 2012-01-09 | 10:39     | 1      | 3      | 1.00              | 3.224                 |
| 4 | 2012-02-23 | 20:45     | 3      | 1      | 0.10              | 1.492                 |
| 5 | 2012-03-02 | 18:49     | 1      | 4      | 2.00              | 3.411                 |
| 6 | 2013-03-30 | 18:29     | 2      | 0      | 0.01              | 0.340                 |
| 7 | 2013-09-05 | 22:26     | 4      | 2      | 0.44              | 7.655                 |
| 8 | 2013-11-29 | 19:16     | 2      | 0      | 0.26              | 16.458                |
| 9 | 2016-01-17 | 22:42     | 19     | 0      | 0.41              | 1104.226              |

**Table B.3.** Date, duration ( $\mathcal{L}$ , in hours), number of points ( $\mathcal{N}_p$ ), phase angle ( $\alpha$ ), filter, residual (against the shape model), and observers, for each lightcurve.

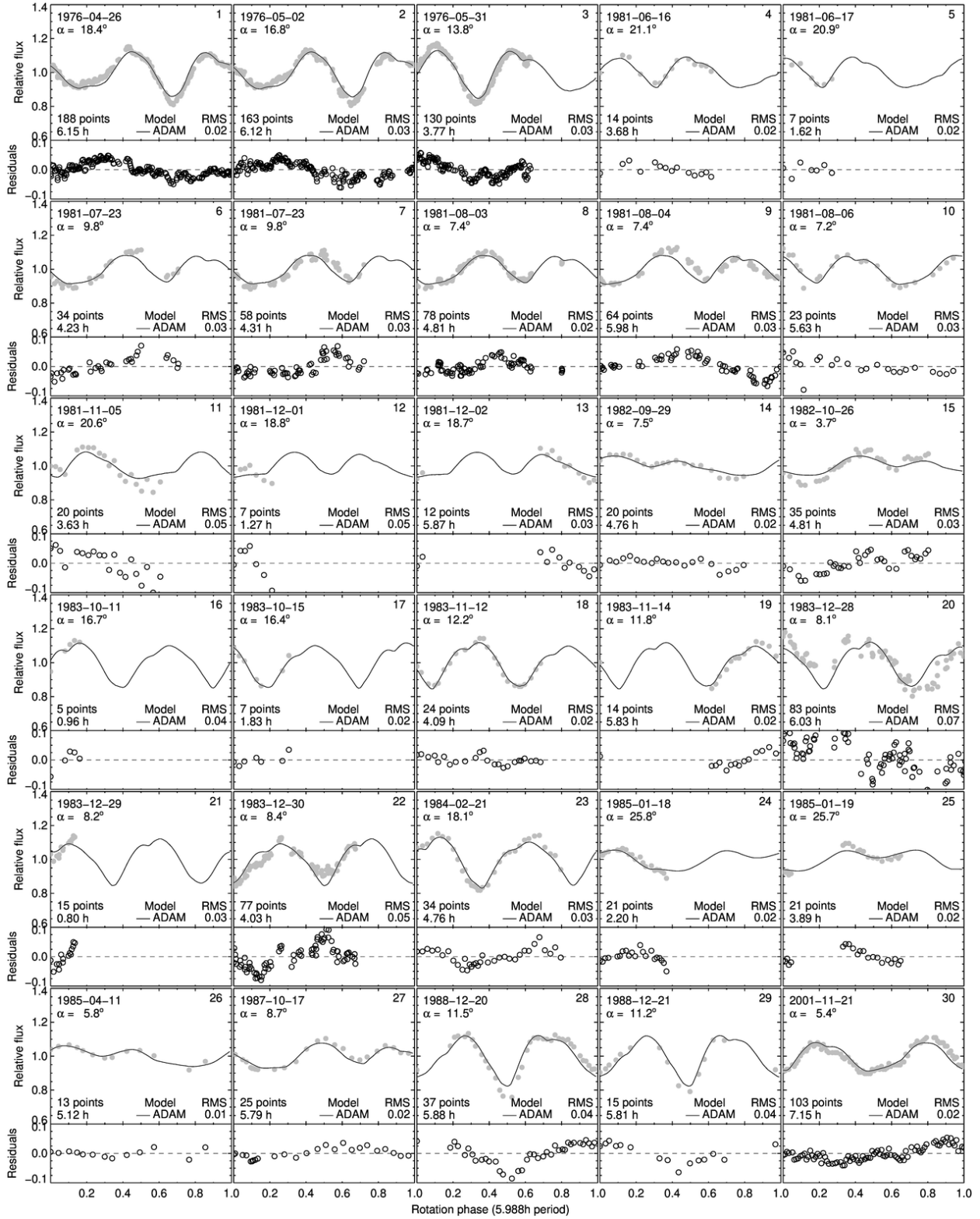
|    | Date       | $\mathcal{L}$<br>(h) | $\mathcal{N}_p$ | $\alpha$<br>( $^\circ$ ) | Filter | rms<br>(mag) | Observers                                       |
|----|------------|----------------------|-----------------|--------------------------|--------|--------------|---|
| 1  | 1976-04-26 | 6.2                  | 188             | 18.4                     | V      | 0.024        | Scaltriti & Zappala (1977)                      |
| 2  | 1976-05-02 | 6.1                  | 163             | 16.8                     | V      | 0.028        | Scaltriti & Zappala (1977)                      |
| 3  | 1976-05-31 | 3.8                  | 130             | 13.8                     | V      | 0.029        | Scaltriti & Zappala (1977)                      |
| 4  | 1981-06-16 | 3.7                  | 14              | 21.1                     | V      | 0.018        | Weidenschilling et al. (1987)                   |
| 5  | 1981-06-17 | 1.6                  | 7               | 20.9                     | V      | 0.018        | Weidenschilling et al. (1987)                   |
| 6  | 1981-07-25 | 4.2                  | 34              | 9.8                      | V      | 0.029        | Barucci (1983)                                  |
| 7  | 1981-07-23 | 4.3                  | 58              | 9.8                      | V      | 0.031        | Barucci (1983)                                  |
| 8  | 1981-08-03 | 4.8                  | 78              | 7.4                      | V      | 0.022        | Barucci (1983)                                  |
| 9  | 1981-08-04 | 6.0                  | 64              | 7.4                      | V      | 0.033        | Barucci (1983)                                  |
| 10 | 1981-08-06 | 5.6                  | 23              | 7.2                      | V      | 0.030        | Weidenschilling et al. (1987)                   |
| 11 | 1981-11-05 | 3.6                  | 20              | 20.6                     | V      | 0.050        | Weidenschilling et al. (1987)                   |
| 12 | 1981-12-01 | 1.3                  | 7               | 18.8                     | V      | 0.054        | Weidenschilling et al. (1987)                   |
| 13 | 1981-12-02 | 5.9                  | 12              | 18.7                     | V      | 0.028        | Weidenschilling et al. (1987)                   |
| 14 | 1982-09-29 | 4.8                  | 20              | 7.5                      | V      | 0.017        | Weidenschilling et al. (1987)                   |
| 15 | 1982-10-26 | 4.8                  | 35              | 3.7                      | V      | 0.033        | Barucci (1983)                                  |
| 16 | 1983-10-11 | 1.0                  | 5               | 16.7                     | V      | 0.035        | Weidenschilling et al. (1987)                   |
| 17 | 1983-10-15 | 1.8                  | 7               | 16.4                     | V      | 0.017        | Weidenschilling et al. (1987)                   |
| 18 | 1983-11-12 | 4.1                  | 24              | 12.2                     | V      | 0.015        | Weidenschilling et al. (1987)                   |
| 19 | 1983-11-14 | 5.8                  | 14              | 11.8                     | V      | 0.024        | Weidenschilling et al. (1987)                   |
| 20 | 1983-12-28 | 6.0                  | 83              | 8.1                      | V      | 0.068        | Barucci (1983)                                  |
| 21 | 1983-12-29 | 0.8                  | 15              | 8.2                      | V      | 0.032        | Barucci (1983)                                  |
| 22 | 1983-12-30 | 4.0                  | 77              | 8.4                      | V      | 0.047        | Barucci (1983)                                  |
| 23 | 1984-02-21 | 4.8                  | 34              | 18.1                     | V      | 0.028        | Weidenschilling et al. (1987)                   |
| 24 | 1985-01-18 | 2.2                  | 21              | 25.8                     | V      | 0.020        | Weidenschilling et al. (1987)                   |
| 25 | 1985-01-19 | 3.9                  | 21              | 25.7                     | V      | 0.023        | Weidenschilling et al. (1987)                   |
| 26 | 1985-04-11 | 5.1                  | 13              | 5.8                      | V      | 0.014        | Weidenschilling et al. (1987)                   |
| 27 | 1987-10-17 | 5.8                  | 25              | 8.7                      | V      | 0.019        | Weidenschilling et al. (1987)                   |
| 28 | 1988-12-20 | 5.9                  | 37              | 11.5                     | V      | 0.042        | Weidenschilling et al. (1987)                   |
| 29 | 1988-12-21 | 5.8                  | 15              | 11.2                     | V      | 0.035        | Weidenschilling et al. (1987)                   |
| 30 | 2001-11-21 | 7.2                  | 103             | 5.4                      | V      | 0.023        | L. Bernasconi                                   |
| 31 | 2001-11-22 | 8.4                  | 107             | 5.4                      | V      | 0.023        | L. Bernasconi                                   |
| 32 | 2001-11-23 | 7.0                  | 102             | 5.5                      | V      | 0.027        | L. Bernasconi                                   |
| 33 | 2001-11-24 | 8.8                  | 87              | 5.5                      | V      | 0.022        | L. Bernasconi                                   |
| 34 | 2008-06-25 | 2.3                  | 49              | 12.9                     | Clear  | 0.018        | SuperWASP - J. Grice                            |
| 35 | 2009-10-16 | 3.0                  | 45              | 4.3                      | Clear  | 0.021        | SuperWASP - J. Grice                            |
| 36 | 2009-09-25 | 2.7                  | 117             | 8.2                      | V      | 0.019        | ASTEP   |
| 37 | 2009-10-16 | 2.8                  | 34              | 11.2                     | Clear  | 0.015        | SuperWASP - J. Grice                            |
| 38 | 2017-01-08 | 2.3                  | 31              | 22.0                     | R      | 0.024        | Vachier, Klotz, Teng, Peyrot, Thierry, Berthier |
| 39 | 2018-07-09 | 10.6                 | 651             | 19.1                     | R      | 0.023        | E. Jehin  |
| 40 | 2018-07-10 | 6.0                  | 507             | 18.9                     | R      | 0.024        | E. Jehin  |
| 41 | 2018-08-03 | 3.6                  | 200             | 12.4                     | R      | 0.023        | S. Fauvaud                                      |
| 42 | 2018-08-04 | 6.2                  | 200             | 12.1                     | R      | 0.020        | S. Fauvaud                                      |
| 43 | 2018-08-05 | 2.1                  | 200             | 11.7                     | R      | 0.019        | S. Fauvaud                                      |
| 44 | 2018-08-05 | 1.9                  | 137             | 11.4                     | R      | 0.013        | S. Fauvaud                                      |
| 45 | 2018-08-06 | 1.8                  | 136             | 11.1                     | R      | 0.012        | S. Fauvaud                                      |
| 46 | 2018-08-11 | 1.6                  | 139             | 9.3                      | R      | 0.009        | S. Fauvaud                                      |
| 47 | 2018-08-14 | 1.8                  | 139             | 8.2                      | R      | 0.008        | S. Fauvaud                                      |
| 48 | 2018-08-15 | 1.4                  | 105             | 7.8                      | R      | 0.007        | S. Fauvaud                                      |
| 49 | 2018-11-19 | 3.1                  | 52              | 18.6                     | R      | 0.016        | Vachier, Klotz, Teng, Peyrot, Thierry, Berthier |



**Fig. B.1.** Comparison of the shape model (top image of each row), oriented and projected on the plane of the sky at the epoch of each disk-resolved observation (bottom image of each row). The brighter ring present in some images (e.g., *second row, last column*) is an artifact from deconvolution.



**Fig. B.2.** The eight stellar occultations by Daphne, compared with the shape model (profile in black and facets in light gray) projected on the plane of the sky at the time of the occultation. Negative chords are represented by dotted lines, visual timings by dashed lines, and electronic timings by solid lines. Disappearance and reappearance timings are marked by filled circles, and their uncertainty by gray rectangles.



**Fig. B.3.** The optical lightcurves of Daphne (grey spheres), compared with the synthetic lightcurves generated with the shape model (black lines). On each panel, the observing date, number of points, duration of the lightcurve (in hours), and rms residuals between the observations and the synthetic lightcurves are displayed. Measurement uncertainties are seldom provided by the observers but can be estimated from the spread of measurements.

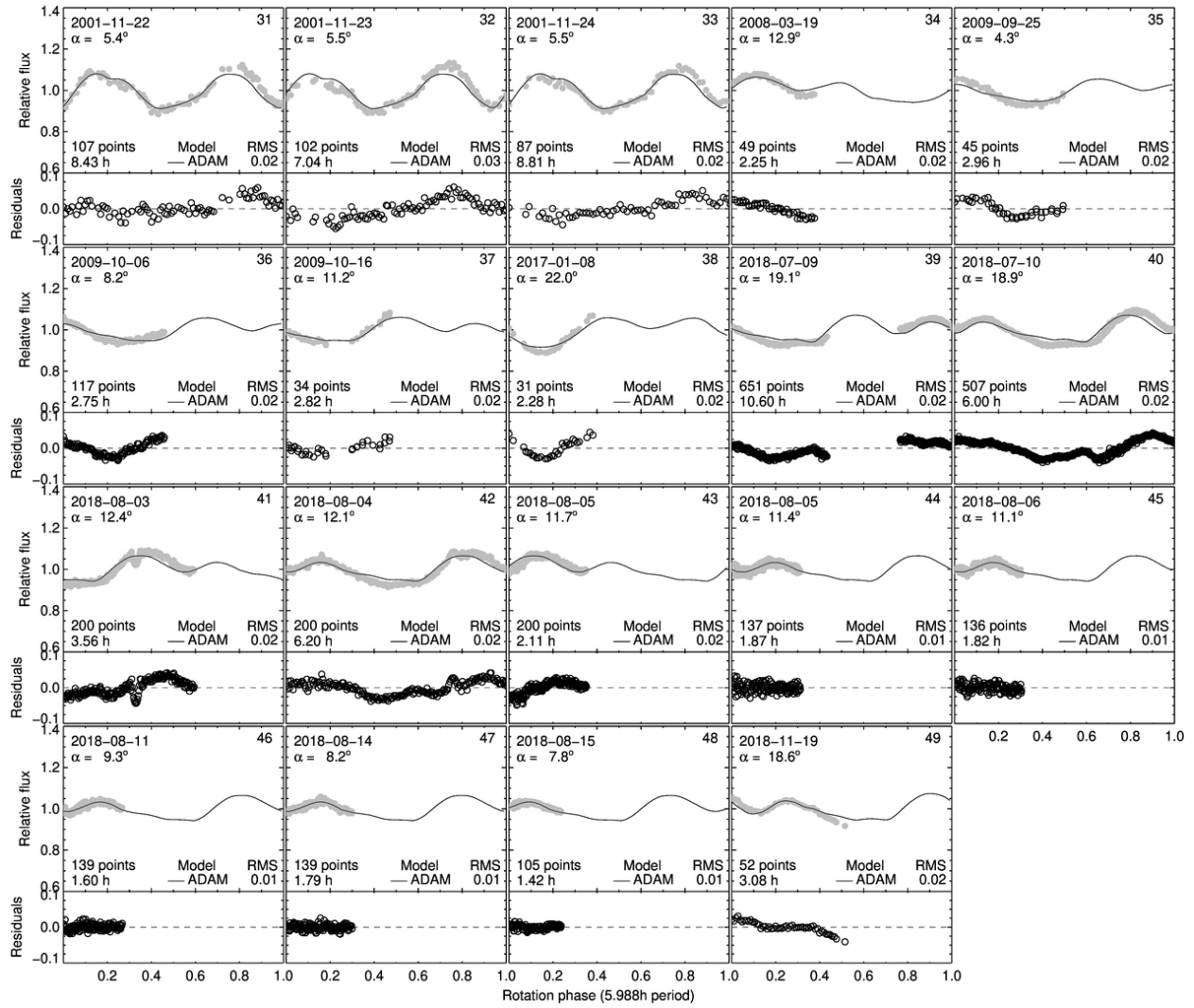
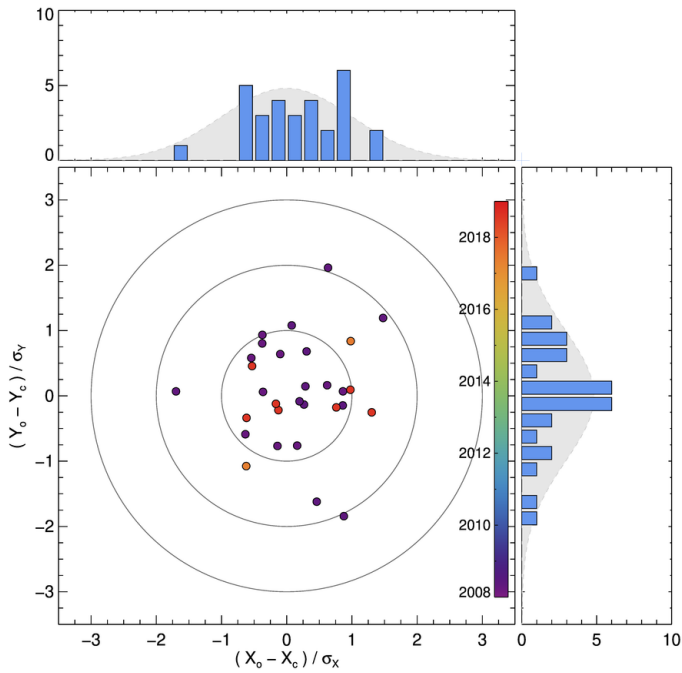


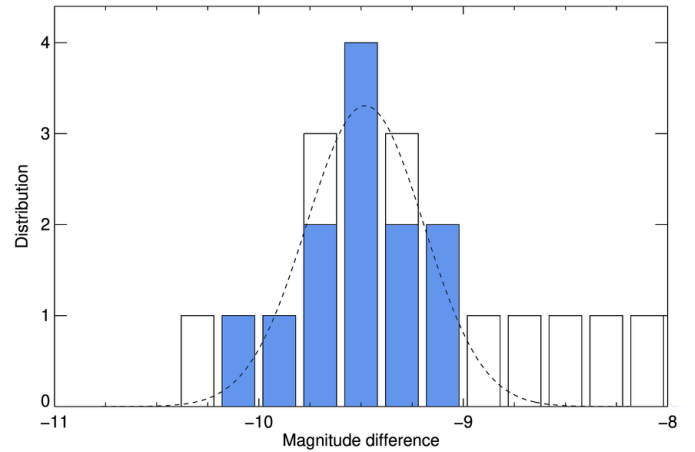
Fig. B.3. continued.



### Appendix C: Magnitude and position of the satellite



**Fig. C.1.** Distribution of residuals for the satellite between the observed (index o) and predicted (index c) positions, normalized by the uncertainty on the measured positions ( $\sigma$ ), and color-coded by observing epoch. X stands for right ascension and Y for declination. The three large gray circles represent the 1, 2, and 3  $\sigma$  limits (typically 10 mas at 1  $\sigma$ ). *Top panel:* histogram of residuals along X. *Right panel:* residuals along Y. The light gray Gaussian in the background has a standard deviation of one.



**Fig. C.2.** Distribution of the magnitude differences between Daphne and its satellite. The open bars represent all measurements, and the blue bars those more precise than 0.75 magnitude. The dashed black line represents the normal distribution fit to our results, with a mean and standard deviation of  $9.49 \pm 0.32$ .

**Table C.1.** Astrometry of the satellite of Daphne.

| Date               | UTC        | Tel. | Cam.   | Filter | $X_o$<br>(mas) | $Y_o$<br>(mas) | $X_{o-c}$<br>(mas) | $Y_{o-c}$<br>(mas) | $\sigma$<br>(mas) | $\Delta M$<br>(mag) | $\delta M$<br>(mag) |
|--------------------|------------|------|--------|--------|----------------|----------------|--------------------|--------------------|-------------------|---------------------|---------------------|
| 2008-03-28         | 12:05:30.1 | Keck | NIRC2  | J      | -554           | 60             | -6                 | -5                 | 9.94              | -9.59               | 0.85                |
| 2008-03-28         | 12:07:59.5 | Keck | NIRC2  | J      | -549           | 53             | -1                 | -7                 | 9.94              | -10.06              | 0.64                |
| 2008-03-28         | 12:56:28.9 | Keck | NIRC2  | H      | -531           | -19            | -5                 | 5                  | 9.94              | -                   | -                   |
| 2008-03-28         | 13:45:16.2 | Keck | NIRC2  | H      | -476           | -110           | 8                  | 0                  | 9.94              | -                   | -                   |
| 2008-03-28         | 13:48:16.8 | Keck | NIRC2  | H      | -475           | -115           | 6                  | 1                  | 9.94              | -9.70               | 0.14                |
| 2008-03-28         | 14:09:03.8 | Keck | NIRC2  | H      | -457           | -160           | 1                  | -7                 | 9.94              | -9.10               | 2.19                |
| 2008-03-28         | 14:30:11.3 | Keck | NIRC2  | H      | -435           | -187           | -3                 | 0                  | 9.94              | -                   | -                   |
| 2008-03-28         | 14:53:08.0 | Keck | NIRC2  | Kp     | -403           | -215           | -3                 | 9                  | 9.94              | -9.84               | 0.73                |
| 2008-03-28         | 14:57:06.5 | Keck | NIRC2  | Kp     | -397           | -222           | -3                 | 7                  | 9.94              | -                   | -                   |
| 2008-03-28         | 15:00:34.9 | Keck | NIRC2  | H      | -389           | -229           | 0                  | 6                  | 9.94              | -                   | -                   |
| 2008-04-23         | 12:17:26.4 | Keck | NIRC2  | H      | -424           | 376            | -16                | 0                  | 9.94              | -                   | -                   |
| 2008-04-23         | 12:53:37.9 | Keck | NIRC2  | H      | -453           | 361            | 6                  | 19                 | 9.94              | -                   | -                   |
| 2008-04-23         | 12:58:51.4 | Keck | NIRC2  | H      | -452           | 347            | 14                 | 11                 | 9.94              | -                   | -                   |
| 2008-05-10         | 02:43:04.5 | VLT  | NACO   | H      | 550            | -177           | 3                  | -1                 | 13.24             | -9.56               | 0.78                |
| 2008-05-10         | 02:47:42.2 | VLT  | NACO   | H      | 552            | -167           | 3                  | 1                  | 13.24             | -9.53               | 1.49                |
| 2008-05-10         | 03:14:05.9 | VLT  | NACO   | H      | 559            | -124           | 4                  | 9                  | 13.24             | -9.52               | 0.84                |
| 2008-05-10         | 03:18:44.1 | VLT  | NACO   | H      | 556            | -112           | 1                  | 14                 | 13.24             | -9.29               | 1.13                |
| 2008-05-14         | 02:20:19.1 | VLT  | NACO   | H      | -516           | 142            | 11                 | -24                | 13.24             | -9.28               | 0.37                |
| 2008-05-14         | 02:24:59.4 | VLT  | NACO   | H      | -523           | 139            | 6                  | -21                | 13.24             | -9.02               | 0.19                |
| 2008-05-27         | 02:44:38.8 | VLT  | NACO   | H      | 449            | -256           | 11                 | -1                 | 13.24             | -                   | -                   |
| 2008-05-27         | 02:49:12.7 | VLT  | NACO   | H      | 445            | -251           | 2                  | -1                 | 13.24             | -9.68               | 0.65                |
| 2017-05-05         | 22:51:25.1 | VLT  | IFS    | YJH    | 404            | 158            | -6                 | -10                | 10.00             | -                   | -                   |
| 2017-05-20         | 01:01:27.4 | VLT  | ZIMPOL | R      | -360           | 35             | 9                  | 8                  | 10.00             | -                   | -                   |
| 2018-08-06         | 06:28:30.9 | VLT  | ZIMPOL | R      | -268           | 208            | -5                 | 4                  | 10.00             | -                   | -                   |
| 2018-08-06         | 06:33:09.9 | VLT  | ZIMPOL | R      | -266           | 203            | -6                 | -3                 | 10.00             | -                   | -                   |
| 2018-08-06         | 07:40:49.4 | VLT  | ZIMPOL | R      | -193           | 244            | 7                  | -1                 | 10.00             | -                   | -                   |
| 2018-08-06         | 07:45:25.2 | VLT  | ZIMPOL | R      | -186           | 249            | 9                  | 0                  | 10.00             | -                   | -                   |
| 2018-08-06         | 07:59:15.8 | VLT  | ZIMPOL | R      | -169           | 251            | 13                 | -2                 | 10.00             | -9.97               | 0.63                |
| 2018-08-06         | 09:20:18.1 | VLT  | ZIMPOL | R      | -92            | 271            | -1                 | -2                 | 10.00             | -                   | -                   |
| 2018-08-06         | 09:24:57.2 | VLT  | ZIMPOL | R      | -87            | 272            | -1                 | -1                 | 10.00             | -10.02              | 1.34                |
| Average            |            |      |        |        |                |                | 2                  | 0                  | 15                | -9.49               | 0.28                |
| Standard deviation |            |      |        |        |                |                | 7                  | 9                  | 2                 | 0.32                | 0.18                |

**Notes.** Date, mid-observing time (UTC), telescope, camera, filter, astrometry ( $X$  is aligned with right ascension, and  $Y$  with declination, and  $o$  and  $c$  indices stand for observed and computed positions), and photometry (magnitude difference  $\Delta M$  with uncertainty  $\delta M$ ).

**Appendix D: Mass and diameter of Ch and Cgh asteroids****Table D.1.** Dynamical class (IMB, MMB, and OMB stand for inner, middle, and outer belt respectively), taxonomic class, mass ( $\mathcal{M}$ ), diameter ( $\mathcal{D}$ ), and density ( $\rho$ ) of Ch/Cgh asteroids used in this work, compiled following the recipes described in Carry (2012).

| #   | Name       | Dyn.   | Taxo. | $\mathcal{M}$<br>(kg) | $\sigma_{\mathcal{M}}$<br>(kg) | $\mathcal{D}$<br>(km) | $\sigma_{\mathcal{D}}$<br>(km) | $\rho$<br>(g cm <sup>-3</sup> ) | $\sigma_{\rho}$<br>(g cm <sup>-3</sup> ) |
|-----|------------|--------|-------|-----------------------|--------------------------------|-----------------------|--------------------------------|---------------------------------|--|
| 13  | Egeria     | MMB    | Ch    | $8.42 \times 10^{18}$ | $2.28 \times 10^{18}$          | 206.56                | 8.22                           | 1.82                            | 0.54                                     |
| 19  | Fortuna    | IMB    | Ch    | $9.03 \times 10^{18}$ | $7.13 \times 10^{17}$          | 207.54                | 5.30                           | 1.93                            | 0.21                                     |
| 34  | Circe      | MMB    | Ch    | $4.16 \times 10^{18}$ | $6.27 \times 10^{17}$          | 114.34                | 3.23                           | 5.31                            | 0.92                                     |
| 38  | Leda       | MMB    | Cgh   | $3.18 \times 10^{18}$ | $5.97 \times 10^{17}$          | 118.62                | 4.22                           | 3.64                            | 0.79                                     |
| 41  | Daphne     | MMB    | Ch    | $6.10 \times 10^{18}$ | $7.50 \times 10^{17}$          | 187.00                | 7.50                           | 1.77                            | 0.22                                     |
| 48  | Doris      | OMB    | Ch    | $7.71 \times 10^{18}$ | $1.57 \times 10^{18}$          | 208.37                | 12.02                          | 1.63                            | 0.44                                     |
| 49  | Pales      | OMB    | Ch    | $4.10 \times 10^{18}$ | $1.77 \times 10^{18}$          | 149.97                | 3.78                           | 2.32                            | 1.02                                     |
| 50  | Virginia   | MMB    | Ch    | $6.26 \times 10^{17}$ | $2.06 \times 10^{17}$          | 88.51                 | 4.65                           | 1.72                            | 0.63                                     |
| 51  | Nemausa    | IMB    | Cgh   | $2.62 \times 10^{18}$ | $8.19 \times 10^{17}$          | 146.80                | 1.56                           | 1.58                            | 0.50                                     |
| 54  | Alexandra  | MMB    | Cgh   | $1.72 \times 10^{18}$ | $5.89 \times 10^{17}$          | 150.12                | 8.14                           | 0.97                            | 0.37                                     |
| 58  | Concordia  | MMB    | Ch    | $1.28 \times 10^{17}$ | $6.41 \times 10^{16}$          | 94.84                 | 1.57                           | 0.29                            | 0.14                                     |
| 62  | Erato      | OMB    | Ch    | $1.38 \times 10^{17}$ | $6.91 \times 10^{16}$          | 96.06                 | 14.26                          | 0.30                            | 0.20                                     |
| 70  | Panopaea   | MMB    | Cgh   | $3.64 \times 10^{18}$ | $5.94 \times 10^{17}$          | 135.34                | 5.47                           | 2.81                            | 0.57                                     |
| 78  | Diana      | MMB    | Ch    | $8.99 \times 10^{17}$ | $5.31 \times 10^{17}$          | 125.33                | 4.77                           | 0.87                            | 0.53                                     |
| 84  | Klio       | IMB    | Ch    | $6.63 \times 10^{17}$ | $1.51 \times 10^{17}$          | 78.76                 | 1.12                           | 2.59                            | 0.60                                     |
| 91  | Aegina     | MMB    | Ch    | $6.07 \times 10^{17}$ | $2.98 \times 10^{17}$          | 103.67                | 4.86                           | 1.04                            | 0.53                                     |
| 95  | Arethusa   | OMB    | Ch    | $4.18 \times 10^{18}$ | $7.95 \times 10^{17}$          | 138.07                | 10.19                          | 3.03                            | 0.89                                     |
| 98  | Ianthe     | MMB    | Ch    | $8.53 \times 10^{17}$ | $1.65 \times 10^{17}$          | 105.48                | 3.29                           | 1.39                            | 0.30                                     |
| 104 | Klymene    | OMB    | Ch    | $1.91 \times 10^{18}$ | $6.59 \times 10^{17}$          | 130.48                | 5.85                           | 1.64                            | 0.61                                     |
| 105 | Artemis    | IMB    | Ch    | $1.43 \times 10^{18}$ | $4.14 \times 10^{17}$          | 122.44                | 2.70                           | 1.49                            | 0.44                                     |
| 106 | Dione      | OMB    | Cgh   | $4.86 \times 10^{18}$ | $2.18 \times 10^{18}$          | 146.60                | 3.41                           | 2.95                            | 1.34                                     |
| 109 | Felicitas  | MMB    | Ch    | $1.69 \times 10^{17}$ | $3.50 \times 10^{16}$          | 82.38                 | 5.09                           | 0.58                            | 0.16                                     |
| 111 | Ate        | MMB    | Ch    | $1.87 \times 10^{18}$ | $3.48 \times 10^{17}$          | 134.28                | 2.08                           | 1.48                            | 0.28                                     |
| 112 | Iphigenia  | IMB    | Ch    | $4.52 \times 10^{17}$ | $2.12 \times 10^{17}$          | 71.06                 | 0.67                           | 2.41                            | 1.13                                     |
| 121 | Hermione   | Cybele | Ch    | $4.94 \times 10^{18}$ | $4.21 \times 10^{17}$          | 196.69                | 8.36                           | 1.24                            | 0.19                                     |
| 127 | Johanna    | MMB    | Ch    | $2.39 \times 10^{18}$ | $9.97 \times 10^{17}$          | 120.04                | 0.05                           | 2.64                            | 1.10                                     |
| 130 | Elektra    | OMB    | Ch    | $6.20 \times 10^{18}$ | $4.45 \times 10^{16}$          | 189.56                | 6.24                           | 1.74                            | 0.17                                     |
| 134 | Sophrosyne | MMB    | Ch    | $9.52 \times 10^{17}$ | $1.24 \times 10^{18}$          | 107.02                | 9.63                           | 1.48                            | 1.97                                     |
| 141 | Lumen      | MMB    | Ch    | $3.27 \times 10^{18}$ | $9.33 \times 10^{17}$          | 132.24                | 1.73                           | 2.70                            | 0.78                                     |
| 144 | Vibilia    | MMB    | Ch    | $3.75 \times 10^{18}$ | $6.95 \times 10^{17}$          | 141.86                | 1.42                           | 2.51                            | 0.47                                     |
| 145 | Adeona     | MMB    | Ch    | $2.32 \times 10^{18}$ | $2.11 \times 10^{17}$          | 149.48                | 5.72                           | 1.33                            | 0.19                                     |
| 146 | Lucina     | MMB    | Ch    | $1.18 \times 10^{17}$ | $5.91 \times 10^{16}$          | 129.10                | 3.94                           | 0.10                            | 0.05                                     |
| 156 | Xanthippe  | MMB    | Ch    | $1.28 \times 10^{18}$ | $2.52 \times 10^{18}$          | 115.93                | 4.26                           | 1.57                            | 3.10                                     |
| 159 | Aemilia    | OMB    | Ch    | $4.18 \times 10^{18}$ | $5.97 \times 10^{17}$          | 133.93                | 7.59                           | 3.32                            | 0.74                                     |
| 162 | Laurentia  | OMB    | Ch    | $3.36 \times 10^{17}$ | $1.67 \times 10^{17}$          | 98.65                 | 1.95                           | 0.67                            | 0.33                                     |
| 163 | Erigone    | IMB    | Ch    | $5.79 \times 10^{17}$ | $2.43 \times 10^{17}$          | 72.29                 | 1.22                           | 2.93                            | 1.24                                     |
| 168 | Sibylla    | Cybele | Ch    | $5.75 \times 10^{18}$ | $1.68 \times 10^{18}$          | 148.97                | 4.51                           | 3.32                            | 1.01                                     |
| 176 | Iduna      | OMB    | Ch    | $3.36 \times 10^{17}$ | $1.68 \times 10^{17}$          | 119.40                | 3.57                           | 0.38                            | 0.19                                     |
| 187 | Lamberta   | MMB    | Ch    | $8.05 \times 10^{17}$ | $7.07 \times 10^{17}$          | 131.18                | 1.21                           | 0.68                            | 0.60                                     |
| 195 | Eurykleia  | OMB    | Ch    | $1.44 \times 10^{17}$ | $7.19 \times 10^{16}$          | 90.22                 | 4.21                           | 0.37                            | 0.19                                     |
| 200 | Dynamene   | MMB    | Ch    | $1.29 \times 10^{18}$ | $8.87 \times 10^{17}$          | 131.11                | 2.95                           | 1.09                            | 0.76                                     |
| 205 | Martha     | MMB    | Ch    | $1.19 \times 10^{17}$ | $5.94 \times 10^{16}$          | 69.44                 | 7.11                           | 0.68                            | 0.40                                     |
| 211 | Isolda     | OMB    | Ch    | $3.31 \times 10^{18}$ | $1.27 \times 10^{18}$          | 151.33                | 4.77                           | 1.83                            | 0.72                                     |
| 238 | Hypatia    | OMB    | Ch    | $3.31 \times 10^{18}$ | $9.25 \times 10^{17}$          | 144.90                | 2.21                           | 2.08                            | 0.59                                     |
| 266 | Aline      | MMB    | Ch    | $1.43 \times 10^{18}$ | $6.93 \times 10^{17}$          | 104.96                | 4.95                           | 2.36                            | 1.19                                     |
| 303 | Josephina  | OMB    | Ch    | $1.31 \times 10^{17}$ | $6.57 \times 10^{16}$          | 100.64                | 7.25                           | 0.25                            | 0.13                                     |
| 345 | Tercidina  | IMB    | Ch    | $1.17 \times 10^{18}$ | $5.11 \times 10^{17}$          | 99.09                 | 1.40                           | 2.30                            | 1.01                                     |
| 350 | Ornamenta  | OMB    | Ch    | $2.59 \times 10^{17}$ | $1.29 \times 10^{17}$          | 111.97                | 8.43                           | 0.35                            | 0.19                                     |
| 356 | Liguria    | MMB    | Ch    | $2.62 \times 10^{18}$ | $2.16 \times 10^{18}$          | 139.97                | 6.22                           | 1.82                            | 1.52                                     |
| 358 | Apollonia  | OMB    | Ch    | $1.60 \times 10^{17}$ | $7.99 \times 10^{16}$          | 89.11                 | 1.78                           | 0.43                            | 0.22                                     |

**Notes.** Individual diameter and mass estimates are listed in Tables D.2 and D.3.

Table D.1. continued.

| #    | Name        | Dyn.   | Taxo. | $M$<br>(kg)           | $\sigma_M$<br>(kg)    | $D$<br>(km) | $\sigma_D$<br>(km) | $\rho$<br>(g cm <sup>-3</sup> ) | $\sigma_\rho$<br>(g cm <sup>-3</sup> ) |
|------|-------------|--------|-------|-----------------------|-----------------------|-------------|--------------------|---------------------------------|--|
| 362  | Havnia      | MMB    | Ch    | $1.67 \times 10^{17}$ | $8.36 \times 10^{16}$ | 89.09       | 3.97               | 0.45                            | 0.23                                   |
| 366  | Vincentina  | OMB    | Ch    | $1.00 \times 10^{17}$ | $5.00 \times 10^{16}$ | 87.73       | 3.54               | 0.28                            | 0.15                                   |
| 373  | Melusina    | OMB    | Ch    | $3.43 \times 10^{17}$ | $1.72 \times 10^{17}$ | 96.76       | 2.85               | 0.72                            | 0.37                                   |
| 377  | Campania    | MMB    | Ch    | $1.52 \times 10^{17}$ | $7.61 \times 10^{16}$ | 92.40       | 1.08               | 0.37                            | 0.18                                   |
| 404  | Arsinoe     | MMB    | Ch    | $8.21 \times 10^{17}$ | $1.70 \times 10^{17}$ | 95.78       | 3.10               | 1.78                            | 0.41                                   |
| 405  | Thia        | MMB    | Ch    | $1.68 \times 10^{18}$ | $6.79 \times 10^{17}$ | 119.36      | 7.70               | 1.89                            | 0.85                                   |
| 407  | Arachne     | MMB    | Ch    | $1.26 \times 10^{17}$ | $6.28 \times 10^{16}$ | 97.33       | 1.16               | 0.26                            | 0.13                                   |
| 410  | Chloris     | MMB    | Ch    | $1.89 \times 10^{18}$ | $5.95 \times 10^{17}$ | 111.18      | 7.35               | 2.63                            | 0.98                                   |
| 442  | Eichsfeldia | IMB    | Ch    | $2.50 \times 10^{17}$ | $1.23 \times 10^{17}$ | 65.30       | 1.65               | 1.71                            | 0.85                                   |
| 445  | Edna        | OMB    | Ch    | $1.24 \times 10^{18}$ | $6.10 \times 10^{17}$ | 88.11       | 2.18               | 3.46                            | 1.72                                   |
| 481  | Emita       | MMB    | Ch    | $1.31 \times 10^{18}$ | $6.24 \times 10^{17}$ | 107.74      | 5.40               | 2.00                            | 1.00                                   |
| 488  | Kreusa      | OMB    | Ch    | $2.47 \times 10^{18}$ | $4.25 \times 10^{17}$ | 167.51      | 6.56               | 1.00                            | 0.21                                   |
| 490  | Veritas     | OMB    | Ch    | $2.02 \times 10^{18}$ | $9.87 \times 10^{17}$ | 114.87      | 3.64               | 2.55                            | 1.27                                   |
| 503  | Evelyn      | MMB    | Ch    | $8.28 \times 10^{17}$ | $3.85 \times 10^{17}$ | 89.48       | 2.49               | 2.21                            | 1.04                                   |
| 521  | Brixia      | MMB    | Ch    | $4.10 \times 10^{17}$ | $2.09 \times 10^{17}$ | 118.11      | 6.86               | 0.47                            | 0.26                                   |
| 554  | Peraga      | IMB    | Ch    | $5.86 \times 10^{17}$ | $2.18 \times 10^{17}$ | 96.65       | 1.19               | 1.24                            | 0.46                                   |
| 602  | Marianna    | OMB    | Ch    | $3.20 \times 10^{18}$ | $1.36 \times 10^{18}$ | 127.54      | 2.55               | 2.95                            | 1.26                                   |
| 654  | Zelinda     | IMB    | Ch    | $1.22 \times 10^{18}$ | $3.51 \times 10^{17}$ | 125.90      | 4.49               | 1.17                            | 0.36                                   |
| 694  | Ekard       | MMB    | Ch    | $1.20 \times 10^{17}$ | $5.94 \times 10^{16}$ | 93.95       | 4.82               | 0.28                            | 0.14                                   |
| 735  | Marghanna   | MMB    | Ch    | $7.23 \times 10^{17}$ | $2.98 \times 10^{17}$ | 71.75       | 2.11               | 3.74                            | 1.58                                   |
| 751  | Faina       | MMB    | Ch    | $3.67 \times 10^{18}$ | $6.38 \times 10^{17}$ | 106.86      | 1.15               | 5.74                            | 1.02                                   |
| 776  | Berbericia  | OMB    | Cgh   | $4.46 \times 10^{18}$ | $4.16 \times 10^{18}$ | 150.92      | 3.20               | 2.48                            | 2.31                                   |
| 788  | Hohensteina | OMB    | Ch    | $1.85 \times 10^{17}$ | $9.22 \times 10^{16}$ | 114.68      | 6.38               | 0.23                            | 0.12                                   |
| 791  | Ani         | OMB    | Ch    | $1.47 \times 10^{17}$ | $7.37 \times 10^{16}$ | 99.20       | 4.96               | 0.29                            | 0.15                                   |
| 914  | Palisana    | IMB    | Ch    | $4.89 \times 10^{17}$ | $2.29 \times 10^{17}$ | 78.71       | 2.64               | 1.92                            | 0.92                                   |
| 1467 | Mashona     | Cybele | Ch    | $2.04 \times 10^{17}$ | $1.02 \times 10^{17}$ | 95.08       | 1.30               | 0.45                            | 0.23                                   |

**Table D.2.** The diameter estimates ( $\mathcal{D}$ ) for all the Ch/Cgh asteroids available in the literature.

| #  | Name    | $\mathcal{D}$<br>(km) | $\delta\mathcal{D}$<br>(km) | Method | Reference                 |
|----|---------|-----------------------|-----------------------------|--------|---------------------------|
| 13 | Egeria  | 244.0                 | 73.2                        | STM    | Morrison & Zellner (2007) |
| 13 | Egeria  | 207.6                 | 24.9                        | STM    | Tedesco et al. (2004b)    |
| 13 | Egeria  | 203.1                 | 5.9                         | OCC    | Dunham et al. (2017)      |
| 13 | Egeria  | 223.1                 | 10.4                        | STM    | Ryan & Woodward (2010)    |
| 13 | Egeria  | 226.1                 | 28.5                        | NEATM  | Ryan & Woodward (2010)    |
| 13 | Egeria  | 203.4                 | 7.7                         | STM    | Usui et al. (2011)        |
| 13 | Egeria  | 227.0                 | 77.9                        | NEATM  | Masiero et al. (2011)     |
| 13 | Egeria  | 202.6                 | 150.2                       | NEATM  | Nugent et al. (2015)      |
| 13 | Egeria  | 209.0                 | 24.0                        | ADAM   | Hanuš et al. (2017b)      |
| 13 | Egeria  | 201.0                 | 12.0                        | ADAM   | Hanuš et al. (2017b)      |
| 19 | Fortuna | 221.0                 | 66.3                        | STM    | Morrison & Zellner (2007) |
| 19 | Fortuna | 210.1                 | 11.3                        | OCC    | Dunham et al. (2017)      |
| 19 | Fortuna | 209.6                 | 14.9                        | IM-TE  | Drummond et al. (2011)    |
| 19 | Fortuna | 199.7                 | 9.1                         | TPM    | Usui et al. (2011)        |
| 19 | Fortuna | 223.0                 | 130.8                       | NEATM  | Masiero et al. (2011)     |
| 19 | Fortuna | 209.8                 | 6.6                         | NEATM  | Masiero et al. (2012)     |
| 19 | Fortuna | 187.0                 | 39.0                        | LCIMG  | Hanuš et al. (2013b)      |
| 19 | Fortuna | 211.0                 | 12.0                        | ADAM   | Hanuš et al. (2017b)      |
| 34 | Circe   | 111.0                 | 33.3                        | STM    | Morrison & Zellner (2007) |
| 34 | Circe   | 113.5                 | 9.9                         | STM    | Tedesco et al. (2004b)    |
| 34 | Circe   | 109.5                 | 5.4                         | OCC    | Dunham et al. (2017)      |
| 34 | Circe   | 97.4                  | 8.5                         | STM    | Ryan & Woodward (2010)    |
| 34 | Circe   | 121.5                 | 21.3                        | NEATM  | Ryan & Woodward (2010)    |
| 34 | Circe   | 96.0                  | 30.0                        | LCOCC  | Đurech et al. (2011)      |
| 34 | Circe   | 107.0                 | 30.0                        | LCOCC  | Đurech et al. (2011)      |
| 34 | Circe   | 116.5                 | 3.4                         | STM    | Usui et al. (2011)        |
| 34 | Circe   | 113.2                 | 8.7                         | NEATM  | Masiero et al. (2011)     |
| 34 | Circe   | 133.0                 | 3.1                         | NEATM  | Masiero et al. (2012)     |
| 34 | Circe   | 117.0                 | 42.0                        | LCIMG  | Hanuš et al. (2013b)      |
| 34 | Circe   | 116.0                 | 33.0                        | LCIMG  | Hanuš et al. (2013b)      |
| 34 | Circe   | 114.1                 | 131.3                       | NEATM  | Nugent et al. (2015)      |
| 38 | Leda    | 115.9                 | 6.3                         | STM    | Tedesco et al. (2004b)    |
| 38 | Leda    | 97.3                  | 8.1                         | STM    | Ryan & Woodward (2010)    |
| 38 | Leda    | 118.1                 | 16.0                        | NEATM  | Ryan & Woodward (2010)    |
| 38 | Leda    | 114.2                 | 4.6                         | STM    | Usui et al. (2011)        |
| 38 | Leda    | 116.0                 | 46.5                        | NEATM  | Masiero et al. (2011)     |
| 38 | Leda    | 122.5                 | 3.7                         | NEATM  | Masiero et al. (2012)     |
| 38 | Leda    | 114.2                 | 84.6                        | NEATM  | Nugent et al. (2015)      |
| 41 | Daphne  | 203.0                 | 60.9                        | STM    | Morrison & Zellner (2007) |
| 41 | Daphne  | 174.0                 | 35.1                        | STM    | Tedesco et al. (2004b)    |
| 41 | Daphne  | 172.4                 | 12.2                        | STM    | Ryan & Woodward (2010)    |
| 41 | Daphne  | 207.9                 | 31.6                        | NEATM  | Ryan & Woodward (2010)    |
| 41 | Daphne  | 187.0                 | 60.0                        | LCOCC  | Đurech et al. (2011)      |
| 41 | Daphne  | 201.5                 | 22.5                        | TPM    | Matter et al. (2011)      |
| 41 | Daphne  | 185.5                 | 10.5                        | TPM    | Matter et al. (2011)      |
| 41 | Daphne  | 179.6                 | 7.7                         | STM    | Usui et al. (2011)        |
| 41 | Daphne  | 205.5                 | 5.6                         | NEATM  | Masiero et al. (2012)     |
| 41 | Daphne  | 186.0                 | 81.0                        | LCIMG  | Hanuš et al. (2013b)      |
| 41 | Daphne  | 198.7                 | 185.1                       | NEATM  | Nugent et al. (2015)      |
| 41 | Daphne  | 188.0                 | 15.0                        | ADAM   | Hanuš et al. (2017b)      |
| 41 | Daphne  | 187.0                 | 27.9                        | KOALA  | This work                 |
| 48 | Doris   | 221.8                 | 22.5                        | STM    | Tedesco et al. (2004b)    |
| 48 | Doris   | 196.3                 | 47.3                        | OCC    | Dunham et al. (2017)      |
| 48 | Doris   | 211.3                 | 48.0                        | STM    | Ryan & Woodward (2010)    |
| 48 | Doris   | 238.8                 | 27.6                        | NEATM  | Ryan & Woodward (2010)    |

**Notes.** For each, the  $3\sigma$  uncertainty, method, and bibliographic reference are reported. The methods are IM-TE: Ellipsoid from Imaging, LCIMG: 3D Model scaled with Imaging, ADAM & KOALA: Multidata 3D Modeling, OCC: Stellar Occultations, STM: Standard Thermal Model, NEATM: Near-Earth Asteroid Thermal Model, and TPM: Thermophysical Model.

Table D.2. continued.

| #  | Name      | $\mathcal{D}$<br>(km) | $\delta\mathcal{D}$<br>(km) | Method | Reference                 |
|----|-----------|-----------------------|-----------------------------|--------|---------------------------|
| 48 | Doris     | 200.3                 | 8.2                         | STM    | Usui et al. (2011)        |
| 48 | Doris     | 223.4                 | 12.5                        | NEATM  | Masiero et al. (2011)     |
| 48 | Doris     | 165.4                 | 125.4                       | NEATM  | Nugent et al. (2015)      |
| 49 | Pales     | 149.8                 | 11.4                        | STM    | Tedesco et al. (2004b)    |
| 49 | Pales     | 157.5                 | 14.7                        | STM    | Ryan & Woodward (2010)    |
| 49 | Pales     | 169.7                 | 27.9                        | NEATM  | Ryan & Woodward (2010)    |
| 49 | Pales     | 148.0                 | 7.7                         | STM    | Usui et al. (2011)        |
| 49 | Pales     | 166.2                 | 6.5                         | NEATM  | Masiero et al. (2012)     |
| 49 | Pales     | 149.3                 | 142.6                       | NEATM  | Nugent et al. (2015)      |
| 49 | Pales     | 138.8                 | 124.6                       | NEATM  | Nugent et al. (2015)      |
| 50 | Virginia  | 99.8                  | 15.6                        | STM    | Tedesco et al. (2004b)    |
| 50 | Virginia  | 99.0                  | 9.1                         | NEATM  | Ryan & Woodward (2010)    |
| 50 | Virginia  | 84.4                  | 2.5                         | STM    | Usui et al. (2011)        |
| 50 | Virginia  | 100.0                 | 22.8                        | NEATM  | Masiero et al. (2011)     |
| 50 | Virginia  | 87.0                  | 2.8                         | NEATM  | Masiero et al. (2012)     |
| 51 | Nemausa   | 151.0                 | 45.3                        | STM    | Morrison & Zellner (2007) |
| 51 | Nemausa   | 147.9                 | 7.2                         | STM    | Tedesco et al. (2004b)    |
| 51 | Nemausa   | 155.9                 | 11.9                        | STM    | Ryan & Woodward (2010)    |
| 51 | Nemausa   | 147.2                 | 5.1                         | STM    | Usui et al. (2011)        |
| 51 | Nemausa   | 142.6                 | 37.5                        | NEATM  | Masiero et al. (2011)     |
| 51 | Nemausa   | 146.1                 | 248.9                       | NEATM  | Masiero et al. (2012)     |
| 51 | Nemausa   | 144.0                 | 9.0                         | ADAM   | Hanuš et al. (2017b)      |
| 54 | Alexandra | 175.0                 | 52.5                        | STM    | Morrison & Zellner (2007) |
| 54 | Alexandra | 165.8                 | 10.2                        | STM    | Tedesco et al. (2004b)    |
| 54 | Alexandra | 147.0                 | 7.0                         | OCC    | Dunham et al. (2017)      |
| 54 | Alexandra | 177.4                 | 13.7                        | STM    | Ryan & Woodward (2010)    |
| 54 | Alexandra | 177.7                 | 22.7                        | NEATM  | Ryan & Woodward (2010)    |
| 54 | Alexandra | 135.0                 | 60.0                        | LCOCC  | Đurech et al. (2011)      |
| 54 | Alexandra | 142.0                 | 27.0                        | LCOCC  | Đurech et al. (2011)      |
| 54 | Alexandra | 144.5                 | 5.4                         | STM    | Usui et al. (2011)        |
| 54 | Alexandra | 142.0                 | 44.3                        | NEATM  | Masiero et al. (2011)     |
| 54 | Alexandra | 160.1                 | 5.6                         | NEATM  | Masiero et al. (2012)     |
| 54 | Alexandra | 128.0                 | 33.0                        | LCIMG  | Hanuš et al. (2013b)      |
| 54 | Alexandra | 143.0                 | 15.0                        | ADAM   | Hanuš et al. (2017b)      |
| 58 | Concordia | 93.4                  | 9.0                         | STM    | Tedesco et al. (2004b)    |
| 58 | Concordia | 93.6                  | 3.2                         | NEATM  | Usui et al. (2011)        |
| 58 | Concordia | 94.6                  | 9.3                         | STM    | Ryan & Woodward (2010)    |
| 58 | Concordia | 102.7                 | 23.3                        | NEATM  | Ryan & Woodward (2010)    |
| 58 | Concordia | 92.3                  | 4.6                         | NEATM  | Masiero et al. (2011)     |
| 58 | Concordia | 106.5                 | 2.2                         | NEATM  | Masiero et al. (2012)     |
| 58 | Concordia | 88.4                  | 72.8                        | NEATM  | Nugent et al. (2015)      |
| 58 | Concordia | 95.8                  | 3.9                         | OCC    | Dunham et al. (2017)      |
| 58 | Concordia | 96.0                  | 2.5                         | OCC    | Dunham et al. (2017)      |
| 62 | Erato     | 95.4                  | 6.0                         | STM    | Tedesco et al. (2004b)    |
| 62 | Erato     | 78.6                  | 2.7                         | NEATM  | Usui et al. (2011)        |
| 62 | Erato     | 80.7                  | 6.3                         | STM    | Ryan & Woodward (2010)    |
| 62 | Erato     | 105.6                 | 16.1                        | NEATM  | Ryan & Woodward (2010)    |
| 62 | Erato     | 106.9                 | 2.0                         | NEATM  | Masiero et al. (2012)     |
| 62 | Erato     | 82.3                  | 71.1                        | NEATM  | Nugent et al. (2015)      |
| 62 | Erato     | 59.4                  | 77.1                        | NEATM  | Nugent et al. (2015)      |
| 70 | Panopaea  | 151.0                 | 45.3                        | STM    | Morrison & Zellner (2007) |
| 70 | Panopaea  | 122.2                 | 6.9                         | STM    | Tedesco et al. (2004b)    |
| 70 | Panopaea  | 105.2                 | 8.4                         | STM    | Ryan & Woodward (2010)    |
| 70 | Panopaea  | 130.9                 | 19.6                        | NEATM  | Ryan & Woodward (2010)    |
| 70 | Panopaea  | 131.2                 | 4.5                         | OCC    | Dunham et al. (2017)      |
| 70 | Panopaea  | 141.4                 | 5.7                         | STM    | Usui et al. (2011)        |
| 70 | Panopaea  | 139.0                 | 11.5                        | NEATM  | Masiero et al. (2011)     |
| 70 | Panopaea  | 162.6                 | 3.8                         | NEATM  | Masiero et al. (2012)     |

Table D.2. continued.

| #   | Name     | $\mathcal{D}$<br>(km) | $\delta\mathcal{D}$<br>(km) | Method | Reference                 |
|-----|----------|-----------------------|-----------------------------|--------|---------------------------|
| 70  | Panopaea | 115.3                 | 127.5                       | NEATM  | Nugent et al. (2015)      |
| 78  | Diana    | 120.6                 | 8.1                         | STM    | Tedesco et al. (2004b)    |
| 78  | Diana    | 131.2                 | 10.5                        | OCC    | Dunham et al. (2017)      |
| 78  | Diana    | 116.0                 | 14.5                        | STM    | Ryan & Woodward (2010)    |
| 78  | Diana    | 130.8                 | 22.0                        | NEATM  | Ryan & Woodward (2010)    |
| 78  | Diana    | 126.5                 | 5.0                         | STM    | Usui et al. (2011)        |
| 78  | Diana    | 179.3                 | 146.2                       | NEATM  | Masiero et al. (2012)     |
| 78  | Diana    | 160.1                 | 137.1                       | NEATM  | Nugent et al. (2015)      |
| 84  | Klio     | 87.0                  | 26.1                        | STM    | Morrison & Zellner (2007) |
| 84  | Klio     | 79.2                  | 4.8                         | STM    | Tedesco et al. (2004b)    |
| 84  | Klio     | 68.1                  | 6.5                         | STM    | Ryan & Woodward (2010)    |
| 84  | Klio     | 81.1                  | 10.3                        | NEATM  | Ryan & Woodward (2010)    |
| 84  | Klio     | 78.3                  | 2.9                         | STM    | Usui et al. (2011)        |
| 84  | Klio     | 79.0                  | 14.6                        | NEATM  | Masiero et al. (2011)     |
| 91  | Aegina   | 104.0                 | 31.2                        | STM    | Morrison & Zellner (2007) |
| 91  | Aegina   | 109.8                 | 9.9                         | STM    | Tedesco et al. (2004b)    |
| 91  | Aegina   | 111.6                 | 6.3                         | OCC    | Dunham et al. (2017)      |
| 91  | Aegina   | 100.2                 | 3.7                         | NEATM  | Usui et al. (2011)        |
| 91  | Aegina   | 123.1                 | 38.7                        | NEATM  | Ryan & Woodward (2010)    |
| 91  | Aegina   | 104.7                 | 9.3                         | NEATM  | Masiero et al. (2011)     |
| 91  | Aegina   | 102.7                 | 5.7                         | NEATM  | Masiero et al. (2011)     |
| 91  | Aegina   | 98.4                  | 111.5                       | NEATM  | Nugent et al. (2015)      |
| 95  | Arethusa | 229.0                 | 68.7                        | STM    | Morrison & Zellner (2007) |
| 95  | Arethusa | 136.0                 | 30.3                        | STM    | Tedesco et al. (2004b)    |
| 95  | Arethusa | 131.1                 | 8.7                         | OCC    | Dunham et al. (2017)      |
| 95  | Arethusa | 157.9                 | 10.2                        | OCC    | Dunham et al. (2017)      |
| 95  | Arethusa | 135.1                 | 4.8                         | OCC    | Dunham et al. (2017)      |
| 95  | Arethusa | 118.3                 | 14.1                        | STM    | Ryan & Woodward (2010)    |
| 95  | Arethusa | 139.5                 | 21.3                        | NEATM  | Ryan & Woodward (2010)    |
| 95  | Arethusa | 143.8                 | 14.7                        | STM    | Usui et al. (2011)        |
| 95  | Arethusa | 152.4                 | 15.3                        | STM    | Masiero et al. (2011)     |
| 95  | Arethusa | 147.9                 | 14.7                        | STM    | Masiero et al. (2011)     |
| 95  | Arethusa | 133.4                 | 118.4                       | NEATM  | Nugent et al. (2015)      |
| 98  | Ianthe   | 104.4                 | 5.4                         | STM    | Tedesco et al. (2004b)    |
| 98  | Ianthe   | 102.0                 | 11.0                        | STM    | Ryan & Woodward (2010)    |
| 98  | Ianthe   | 114.3                 | 15.7                        | NEATM  | Ryan & Woodward (2010)    |
| 98  | Ianthe   | 104.2                 | 3.9                         | STM    | Usui et al. (2011)        |
| 98  | Ianthe   | 110.9                 | 7.0                         | NEATM  | Masiero et al. (2011)     |
| 98  | Ianthe   | 132.8                 | 3.4                         | NEATM  | Masiero et al. (2012)     |
| 104 | Klymene  | 123.7                 | 9.3                         | STM    | Tedesco et al. (2004b)    |
| 104 | Klymene  | 109.9                 | 11.5                        | STM    | Ryan & Woodward (2010)    |
| 104 | Klymene  | 131.2                 | 19.9                        | NEATM  | Ryan & Woodward (2010)    |
| 104 | Klymene  | 126.5                 | 5.6                         | STM    | Usui et al. (2011)        |
| 104 | Klymene  | 125.8                 | 7.9                         | STM    | Masiero et al. (2011)     |
| 104 | Klymene  | 136.6                 | 4.6                         | STM    | Masiero et al. (2012)     |
| 104 | Klymene  | 124.6                 | 110.9                       | NEATM  | Nugent et al. (2015)      |
| 105 | Artemis  | 126.0                 | 37.8                        | STM    | Morrison & Zellner (2007) |
| 105 | Artemis  | 103.7                 | 15.8                        | STM    | Tedesco et al. (2004b)    |
| 105 | Artemis  | 119.1                 | 8.4                         | STM    | Ryan & Woodward (2010)    |
| 105 | Artemis  | 101.1                 | 8.4                         | NEATM  | Ryan & Woodward (2010)    |
| 105 | Artemis  | 123.5                 | 4.5                         | STM    | Usui et al. (2011)        |
| 105 | Artemis  | 119.0                 | 52.0                        | NEATM  | Masiero et al. (2011)     |
| 105 | Artemis  | 112.8                 | 102.1                       | NEATM  | Masiero et al. (2012)     |
| 105 | Artemis  | 112.8                 | 105.7                       | NEATM  | Nugent et al. (2015)      |
| 105 | Artemis  | 94.9                  | 69.7                        | NEATM  | Nugent et al. (2015)      |
| 106 | Dione    | 140.0                 | 42.0                        | STM    | Morrison & Zellner (2007) |
| 106 | Dione    | 145.6                 | 2.5                         | OCC    | Dunham et al. (2017)      |

Table D.2. continued.

| #   | Name      | $\mathcal{D}$<br>(km) | $\delta\mathcal{D}$<br>(km) | Method | Reference                 |
|-----|-----------|-----------------------|-----------------------------|--------|---------------------------|
| 106 | Dione     | 146.6                 | 8.4                         | STM    | Tedesco et al. (2004b)    |
| 106 | Dione     | 127.3                 | 10.1                        | STM    | Ryan & Woodward (2010)    |
| 106 | Dione     | 162.9                 | 23.6                        | NEATM  | Ryan & Woodward (2010)    |
| 106 | Dione     | 153.4                 | 7.1                         | STM    | Usui et al. (2011)        |
| 106 | Dione     | 207.9                 | 6.5                         | NEATM  | Masiero et al. (2012)     |
| 106 | Dione     | 83.4                  | 2.5                         | NEATM  | Grav et al. (2012)        |
| 106 | Dione     | 89.2                  | 101.9                       | NEATM  | Nugent et al. (2015)      |
| 106 | Dione     | 138.8                 | 137.5                       | NEATM  | Nugent et al. (2015)      |
| 106 | Dione     | 151.7                 | 77.7                        | NEATM  | Ryan et al. (2015)        |
| 106 | Dione     | 168.9                 | 86.4                        | NEATM  | Ryan et al. (2015)        |
| 106 | Dione     | 182.9                 | 93.5                        | NEATM  | Ryan et al. (2015)        |
| 109 | Felicitas | 75.0                  | 22.5                        | STM    | Morrison & Zellner (2007) |
| 109 | Felicitas | 89.4                  | 7.5                         | STM    | Tedesco et al. (2004b)    |
| 109 | Felicitas | 88.2                  | 2.4                         | OCC    | Dunham et al. (2017)      |
| 109 | Felicitas | 79.5                  | 7.3                         | STM    | Ryan & Woodward (2010)    |
| 109 | Felicitas | 111.4                 | 27.4                        | NEATM  | Ryan & Woodward (2010)    |
| 109 | Felicitas | 80.8                  | 3.7                         | STM    | Usui et al. (2011)        |
| 109 | Felicitas | 89.0                  | 18.5                        | STM    | Masiero et al. (2011)     |
| 109 | Felicitas | 99.9                  | 3.0                         | STM    | Masiero et al. (2012)     |
| 109 | Felicitas | 67.5                  | 2.0                         | NEATM  | Grav et al. (2012)        |
| 109 | Felicitas | 92.4                  | 94.6                        | NEATM  | Nugent et al. (2015)      |
| 109 | Felicitas | 64.7                  | 71.5                        | NEATM  | Nugent et al. (2015)      |
| 109 | Felicitas | 94.6                  | 85.2                        | NEATM  | Nugent et al. (2015)      |
| 111 | Ate       | 134.6                 | 13.8                        | STM    | Tedesco et al. (2004b)    |
| 111 | Ate       | 119.0                 | 19.2                        | OCC    | Dunham et al. (2017)      |
| 111 | Ate       | 130.4                 | 2.7                         | OCC    | Dunham et al. (2017)      |
| 111 | Ate       | 134.9                 | 1.2                         | OCC    | Dunham et al. (2017)      |
| 111 | Ate       | 140.2                 | 7.2                         | STM    | Ryan & Woodward (2010)    |
| 111 | Ate       | 153.2                 | 17.4                        | NEATM  | Ryan & Woodward (2010)    |
| 111 | Ate       | 146.6                 | 7.0                         | STM    | Usui et al. (2011)        |
| 111 | Ate       | 135.0                 | 55.7                        | NEATM  | Masiero et al. (2011)     |
| 112 | Iphigenia | 72.2                  | 13.2                        | STM    | Tedesco et al. (2004b)    |
| 112 | Iphigenia | 59.8                  | 6.2                         | STM    | Ryan & Woodward (2010)    |
| 112 | Iphigenia | 80.6                  | 12.7                        | NEATM  | Ryan & Woodward (2010)    |
| 112 | Iphigenia | 71.1                  | 2.8                         | STM    | Usui et al. (2011)        |
| 112 | Iphigenia | 70.4                  | 8.7                         | NEATM  | Masiero et al. (2011)     |
| 112 | Iphigenia | 84.9                  | 68.6                        | NEATM  | Masiero et al. (2012)     |
| 112 | Iphigenia | 69.6                  | 64.6                        | NEATM  | Nugent et al. (2015)      |
| 112 | Iphigenia | 70.3                  | 52.9                        | NEATM  | Nugent et al. (2015)      |
| 121 | Hermione  | 209.0                 | 14.1                        | STM    | Tedesco et al. (2004b)    |
| 121 | Hermione  | 178.9                 | 21.6                        | IM     | Marchis et al. (2005)     |
| 121 | Hermione  | 138.8                 | 35.7                        | IM     | Marchis et al. (2005)     |
| 121 | Hermione  | 189.0                 | 21.0                        | IM     | Marchis et al. (2006)     |
| 121 | Hermione  | 187.0                 | 18.0                        | KOALA  | Descamps et al. (2009)    |
| 121 | Hermione  | 221.6                 | 17.9                        | STM    | Ryan & Woodward (2010)    |
| 121 | Hermione  | 212.0                 | 23.1                        | NEATM  | Ryan & Woodward (2010)    |
| 121 | Hermione  | 194.1                 | 8.1                         | STM    | Usui et al. (2011)        |
| 121 | Hermione  | 165.0                 | 13.5                        | NEATM  | Masiero et al. (2011)     |
| 121 | Hermione  | 192.4                 | 22.1                        | NEATM  | Marchis et al. (2012)     |
| 121 | Hermione  | 220.0                 | 66.0                        | TPM    | Marchis et al. (2012)     |
| 121 | Hermione  | 201.1                 | 190.3                       | NEATM  | Nugent et al. (2015)      |
| 121 | Hermione  | 155.3                 | 158.8                       | NEATM  | Nugent et al. (2015)      |
| 127 | Johanna   | 123.3                 | 13.1                        | STM    | Tedesco et al. (2004a)    |
| 127 | Johanna   | 113.0                 | 26.4                        | OCC    | Dunham et al. (2017)      |
| 127 | Johanna   | 109.6                 | 0.0                         | STM    | Ryan & Woodward (2010)    |
| 127 | Johanna   | 120.0                 | 0.0                         | NEATM  | Ryan & Woodward (2010)    |
| 127 | Johanna   | 114.2                 | 4.6                         | TPM    | Usui et al. (2011)        |
| 127 | Johanna   | 129.1                 | 3.0                         | NEATM  | Masiero et al. (2012)     |



Table D.2. continued.

| #   | Name       | $\mathcal{D}$<br>(km) | $\delta\mathcal{D}$<br>(km) | Method | Reference                                     |
|-----|------------|-----------------------|-----------------------------|--------|---|
| 127 | Johanna    | 108.0                 | 30.0                        | LCOCC  | <a href="#">Marciniak et al. (2012)</a>       |
| 127 | Johanna    | 116.0                 | 30.0                        | LCOCC  | <a href="#">Marciniak et al. (2012)</a>       |
| 127 | Johanna    | 106.4                 | 127.9                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 130 | Elektra    | 174.0                 | 52.2                        | STM    | <a href="#">Morrison &amp; Zellner (2007)</a> |
| 130 | Elektra    | 182.2                 | 35.4                        | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 130 | Elektra    | 191.0                 | 6.0                         | IM     | <a href="#">Marchis et al. (2006)</a>         |
| 130 | Elektra    | 196.0                 | 33.0                        | NEATM  | <a href="#">Marchis et al. (2008b)</a>        |
| 130 | Elektra    | 215.0                 | 45.0                        | IM     | <a href="#">Marchis et al. (2008b)</a>        |
| 130 | Elektra    | 158.8                 | 18.3                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 130 | Elektra    | 200.5                 | 40.0                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 130 | Elektra    | 191.0                 | 42.0                        | LCOCC  | <a href="#">Durech et al. (2011)</a>          |
| 130 | Elektra    | 183.0                 | 6.8                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 130 | Elektra    | 198.9                 | 12.3                        | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 130 | Elektra    | 161.9                 | 11.5                        | NEATM  | <a href="#">Masiero et al. (2012)</a>         |
| 130 | Elektra    | 201.2                 | 25.5                        | NEATM  | <a href="#">Marchis et al. (2012)</a>         |
| 130 | Elektra    | 197.0                 | 60.0                        | TPM    | <a href="#">Marchis et al. (2012)</a>         |
| 130 | Elektra    | 185.0                 | 60.0                        | LCIMG  | <a href="#">Hanuš et al. (2013b)</a>          |
| 130 | Elektra    | 158.9                 | 138.0                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 130 | Elektra    | 199.0                 | 21.0                        | ADAM   | <a href="#">Hanuš et al. (2017a)</a>          |
| 134 | Sophrosyne | 123.3                 | 6.0                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 134 | Sophrosyne | 186.1                 | 57.0                        | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 134 | Sophrosyne | 122.9                 | 14.7                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 134 | Sophrosyne | 127.2                 | 18.7                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 134 | Sophrosyne | 100.4                 | 4.0                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 134 | Sophrosyne | 112.2                 | 32.4                        | STM    | <a href="#">Masiero et al. (2011)</a>         |
| 134 | Sophrosyne | 104.5                 | 3.8                         | STM    | <a href="#">Masiero et al. (2012)</a>         |
| 141 | Lumen      | 120.4                 | 13.7                        | STM    | <a href="#">Tedesco et al. (2004a)</a>        |
| 141 | Lumen      | 131.0                 | 8.7                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 141 | Lumen      | 137.4                 | 36.2                        | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 141 | Lumen      | 110.9                 | 9.8                         | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 141 | Lumen      | 139.8                 | 23.7                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 141 | Lumen      | 132.2                 | 4.5                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 141 | Lumen      | 137.1                 | 43.7                        | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 144 | Vibilia    | 131.0                 | 39.3                        | STM    | <a href="#">Morrison &amp; Zellner (2007)</a> |
| 144 | Vibilia    | 142.4                 | 7.8                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 144 | Vibilia    | 142.5                 | 15.0                        | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 144 | Vibilia    | 138.4                 | 27.4                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 144 | Vibilia    | 161.2                 | 27.1                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 144 | Vibilia    | 142.2                 | 5.3                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 144 | Vibilia    | 141.0                 | 9.0                         | ADAM   | <a href="#">Hanuš et al. (2017b)</a>          |
| 144 | Vibilia    | 131.4                 | 99.9                        | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 145 | Adeona     | 151.1                 | 9.6                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 145 | Adeona     | 141.0                 | 71.2                        | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 145 | Adeona     | 126.0                 | 10.8                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 145 | Adeona     | 157.9                 | 22.7                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 145 | Adeona     | 141.4                 | 15.5                        | STM    | <a href="#">Usui et al. (2011)</a>            |
| 145 | Adeona     | 151.0                 | 33.8                        | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 145 | Adeona     | 151.0                 | 25.7                        | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 145 | Adeona     | 115.5                 | 112.9                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 146 | Lucina     | 132.2                 | 7.2                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 146 | Lucina     | 141.0                 | 42.3                        | STM    | <a href="#">Morrison &amp; Zellner (2007)</a> |
| 146 | Lucina     | 107.5                 | 5.0                         | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 146 | Lucina     | 134.0                 | 48.0                        | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 146 | Lucina     | 126.9                 | 4.9                         | NEATM  | <a href="#">Usui et al. (2011)</a>            |
| 146 | Lucina     | 128.0                 | 14.0                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 146 | Lucina     | 144.7                 | 24.8                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 146 | Lucina     | 131.8                 | 14.4                        | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 146 | Lucina     | 160.3                 | 3.6                         | NEATM  | <a href="#">Masiero et al. (2012)</a>         |

Table D.2. continued.

| #   | Name      | $\mathcal{D}$<br>(km) | $\delta\mathcal{D}$<br>(km) | Method | Reference                                     |
|-----|-----------|-----------------------|-----------------------------|--------|---|
| 146 | Lucina    | 113.1                 | 88.9                        | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 146 | Lucina    | 119.0                 | 33.0                        | LCIMG  | <a href="#">Hanuš et al. (2013b)</a>          |
| 156 | Xanthippe | 121.0                 | 7.5                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 156 | Xanthippe | 122.0                 | 10.5                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 156 | Xanthippe | 114.6                 | 12.7                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 156 | Xanthippe | 115.5                 | 5.2                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 156 | Xanthippe | 110.7                 | 6.6                         | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 156 | Xanthippe | 143.4                 | 2.7                         | NEATM  | <a href="#">Masiero et al. (2012)</a>         |
| 156 | Xanthippe | 122.0                 | 95.0                        | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 156 | Xanthippe | 112.4                 | 116.6                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 159 | Aemilia   | 140.0                 | 42.0                        | STM    | <a href="#">Morrison &amp; Zellner (2007)</a> |
| 159 | Aemilia   | 125.0                 | 7.2                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 159 | Aemilia   | 141.7                 | 4.5                         | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 159 | Aemilia   | 123.3                 | 15.3                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 159 | Aemilia   | 132.6                 | 24.8                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 159 | Aemilia   | 130.0                 | 6.9                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 159 | Aemilia   | 127.4                 | 8.1                         | STM    | <a href="#">Masiero et al. (2011)</a>         |
| 159 | Aemilia   | 130.0                 | 21.0                        | LCOCC  | <a href="#">Marciniak et al. (2018)</a>       |
| 159 | Aemilia   | 138.0                 | 21.0                        | LCOCC  | <a href="#">Marciniak et al. (2018)</a>       |
| 159 | Aemilia   | 137.0                 | 24.0                        | LCTPM  | <a href="#">Marciniak et al. (2018)</a>       |
| 162 | Laurentia | 99.1                  | 7.8                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 162 | Laurentia | 85.3                  | 8.6                         | NEATM  | <a href="#">Usui et al. (2011)</a>            |
| 162 | Laurentia | 102.4                 | 12.2                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 162 | Laurentia | 106.4                 | 18.0                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 162 | Laurentia | 104.0                 | 9.8                         | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 162 | Laurentia | 101.3                 | 3.2                         | NEATM  | <a href="#">Masiero et al. (2012)</a>         |
| 162 | Laurentia | 97.7                  | 1.7                         | NEATM  | <a href="#">Masiero et al. (2012)</a>         |
| 162 | Laurentia | 97.2                  | 11.1                        | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 163 | Erigone   | 72.6                  | 17.1                        | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 163 | Erigone   | 70.7                  | 13.6                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 163 | Erigone   | 77.6                  | 14.0                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 163 | Erigone   | 72.1                  | 2.8                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 163 | Erigone   | 81.6                  | 9.2                         | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 163 | Erigone   | 69.7                  | 59.8                        | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 168 | Sibylla   | 148.4                 | 12.0                        | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 168 | Sibylla   | 154.6                 | 6.0                         | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 168 | Sibylla   | 155.8                 | 31.8                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 168 | Sibylla   | 146.5                 | 5.2                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 168 | Sibylla   | 144.0                 | 8.6                         | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 168 | Sibylla   | 145.1                 | 154.1                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 168 | Sibylla   | 141.8                 | 92.5                        | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 176 | Iduna     | 121.0                 | 6.6                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 176 | Iduna     | 119.5                 | 3.9                         | NEATM  | <a href="#">Usui et al. (2011)</a>            |
| 176 | Iduna     | 112.6                 | 13.2                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 176 | Iduna     | 131.1                 | 18.4                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 176 | Iduna     | 122.2                 | 8.1                         | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 176 | Iduna     | 115.1                 | 127.8                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 176 | Iduna     | 115.6                 | 5.5                         | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 176 | Iduna     | 126.9                 | 12.6                        | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 187 | Lamberta  | 130.4                 | 8.1                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 187 | Lamberta  | 131.4                 | 14.0                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 187 | Lamberta  | 132.1                 | 23.2                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 187 | Lamberta  | 130.4                 | 5.7                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 187 | Lamberta  | 133.0                 | 7.5                         | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 187 | Lamberta  | 147.3                 | 4.2                         | NEATM  | <a href="#">Masiero et al. (2012)</a>         |
| 187 | Lamberta  | 132.1                 | 123.0                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 187 | Lamberta  | 125.2                 | 137.1                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 195 | Eurykleia | 85.7                  | 5.1                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |

Table D.2. continued.

| #   | Name      | $\mathcal{D}$<br>(km) | $\delta\mathcal{D}$<br>(km) | Method | Reference                 |
|-----|-----------|-----------------------|-----------------------------|--------|---------------------------|
| 195 | Eurykleia | 89.4                  | 3.3                         | NEATM  | Usui et al. (2011)        |
| 195 | Eurykleia | 82.9                  | 10.0                        | STM    | Ryan & Woodward (2010)    |
| 195 | Eurykleia | 88.3                  | 12.2                        | NEATM  | Ryan & Woodward (2010)    |
| 195 | Eurykleia | 80.3                  | 6.0                         | NEATM  | Masiero et al. (2011)     |
| 195 | Eurykleia | 93.1                  | 2.2                         | NEATM  | Masiero et al. (2012)     |
| 195 | Eurykleia | 75.0                  | 56.8                        | NEATM  | Nugent et al. (2015)      |
| 195 | Eurykleia | 80.0                  | 78.4                        | NEATM  | Nugent et al. (2015)      |
| 200 | Dynamene  | 128.4                 | 6.3                         | STM    | Tedesco et al. (2004b)    |
| 200 | Dynamene  | 125.1                 | 17.7                        | STM    | Ryan & Woodward (2010)    |
| 200 | Dynamene  | 135.9                 | 20.7                        | NEATM  | Ryan & Woodward (2010)    |
| 200 | Dynamene  | 129.2                 | 10.9                        | OCC    | Dunham et al. (2017)      |
| 200 | Dynamene  | 133.8                 | 5.2                         | STM    | Usui et al. (2011)        |
| 200 | Dynamene  | 130.5                 | 8.6                         | NEATM  | Masiero et al. (2011)     |
| 200 | Dynamene  | 121.5                 | 111.6                       | NEATM  | Nugent et al. (2015)      |
| 200 | Dynamene  | 120.1                 | 123.3                       | NEATM  | Nugent et al. (2015)      |
| 205 | Martha    | 80.6                  | 4.2                         | STM    | Tedesco et al. (2004b)    |
| 205 | Martha    | 78.0                  | 15.0                        | STM    | Tedesco et al. (2004a)    |
| 205 | Martha    | 82.2                  | 3.2                         | NEATM  | Usui et al. (2011)        |
| 205 | Martha    | 68.5                  | 5.6                         | STM    | Ryan & Woodward (2010)    |
| 205 | Martha    | 79.8                  | 10.8                        | NEATM  | Ryan & Woodward (2010)    |
| 205 | Martha    | 65.5                  | 1.6                         | STM    | Ryan & Woodward (2010)    |
| 205 | Martha    | 96.3                  | 26.1                        | NEATM  | Ryan & Woodward (2010)    |
| 205 | Martha    | 81.5                  | 2.3                         | NEATM  | Masiero et al. (2011)     |
| 205 | Martha    | 93.2                  | 2.2                         | NEATM  | Masiero et al. (2012)     |
| 205 | Martha    | 71.4                  | 59.3                        | NEATM  | Nugent et al. (2015)      |
| 205 | Martha    | 64.4                  | 11.7                        | OCC    | Dunham et al. (2017)      |
| 205 | Martha    | 65.7                  | 1.2                         | OCC    | Dunham et al. (2017)      |
| 211 | Isolda    | 166.0                 | 49.8                        | STM    | Morrison & Zellner (2007) |
| 211 | Isolda    | 143.2                 | 15.3                        | STM    | Tedesco et al. (2004b)    |
| 211 | Isolda    | 142.6                 | 13.1                        | STM    | Ryan & Woodward (2010)    |
| 211 | Isolda    | 150.9                 | 22.5                        | NEATM  | Ryan & Woodward (2010)    |
| 211 | Isolda    | 153.5                 | 5.1                         | STM    | Usui et al. (2011)        |
| 211 | Isolda    | 143.0                 | 64.9                        | NEATM  | Masiero et al. (2011)     |
| 211 | Isolda    | 154.2                 | 51.3                        | NEATM  | Masiero et al. (2012)     |
| 211 | Isolda    | 142.5                 | 144.2                       | NEATM  | Nugent et al. (2015)      |
| 238 | Hypatia   | 154.0                 | 46.2                        | STM    | Morrison & Zellner (2007) |
| 238 | Hypatia   | 145.9                 | 23.0                        | OCC    | Dunham et al. (2017)      |
| 238 | Hypatia   | 148.5                 | 10.8                        | STM    | Tedesco et al. (2004b)    |
| 238 | Hypatia   | 149.2                 | 42.5                        | STM    | Ryan & Woodward (2010)    |
| 238 | Hypatia   | 163.6                 | 21.5                        | NEATM  | Ryan & Woodward (2010)    |
| 238 | Hypatia   | 144.0                 | 4.6                         | STM    | Usui et al. (2011)        |
| 238 | Hypatia   | 146.5                 | 26.0                        | NEATM  | Masiero et al. (2011)     |
| 238 | Hypatia   | 135.6                 | 4.5                         | NEATM  | Masiero et al. (2012)     |
| 238 | Hypatia   | 176.7                 | 154.5                       | NEATM  | Nugent et al. (2015)      |
| 266 | Aline     | 125.8                 | 19.5                        | STM    | Tedesco et al. (2004a)    |
| 266 | Aline     | 109.1                 | 8.7                         | STM    | Tedesco et al. (2004b)    |
| 266 | Aline     | 112.9                 | 8.3                         | STM    | Ryan & Woodward (2010)    |
| 266 | Aline     | 125.2                 | 25.2                        | NEATM  | Ryan & Woodward (2010)    |
| 266 | Aline     | 102.0                 | 4.2                         | STM    | Usui et al. (2011)        |
| 266 | Aline     | 109.0                 | 55.0                        | NEATM  | Masiero et al. (2011)     |
| 266 | Aline     | 152.5                 | 190.2                       | NEATM  | Masiero et al. (2012)     |
| 266 | Aline     | 89.4                  | 79.0                        | NEATM  | Nugent et al. (2015)      |
| 303 | Josephina | 99.3                  | 5.7                         | STM    | Tedesco et al. (2004b)    |
| 303 | Josephina | 98.7                  | 5.2                         | NEATM  | Usui et al. (2011)        |
| 303 | Josephina | 105.4                 | 1.6                         | NEATM  | Hasegawa et al. (2013)    |
| 303 | Josephina | 100.5                 | 8.9                         | STM    | Ryan & Woodward (2010)    |
| 303 | Josephina | 105.6                 | 20.3                        | NEATM  | Ryan & Woodward (2010)    |
| 303 | Josephina | 105.9                 | 9.3                         | NEATM  | Masiero et al. (2011)     |

Table D.2. continued.

| #   | Name       | $\mathcal{D}$<br>(km) | $\delta\mathcal{D}$<br>(km) | Method | Reference                 |
|-----|------------|-----------------------|-----------------------------|--------|---------------------------|
| 303 | Josephina  | 124.9                 | 2.8                         | NEATM  | Masiero et al. (2012)     |
| 303 | Josephina  | 97.6                  | 0.8                         | OCC    | Dunham et al. (2017)      |
| 345 | Tercidina  | 94.1                  | 14.7                        | STM    | Tedesco et al. (2004b)    |
| 345 | Tercidina  | 99.3                  | 4.2                         | OCC    | Dunham et al. (2017)      |
| 345 | Tercidina  | 93.8                  | 17.7                        | STM    | Ryan & Woodward (2010)    |
| 345 | Tercidina  | 106.2                 | 23.4                        | NEATM  | Ryan & Woodward (2010)    |
| 345 | Tercidina  | 99.2                  | 3.0                         | STM    | Usui et al. (2011)        |
| 345 | Tercidina  | 99.0                  | 34.4                        | NEATM  | Masiero et al. (2011)     |
| 345 | Tercidina  | 101.8                 | 79.3                        | NEATM  | Masiero et al. (2012)     |
| 345 | Tercidina  | 96.0                  | 30.0                        | LCOCC  | Hanuš et al. (2013a)      |
| 350 | Ornamenta  | 118.3                 | 13.5                        | STM    | Tedesco et al. (2004b)    |
| 350 | Ornamenta  | 117.2                 | 4.5                         | NEATM  | Usui et al. (2011)        |
| 350 | Ornamenta  | 109.8                 | 12.3                        | STM    | Ryan & Woodward (2010)    |
| 350 | Ornamenta  | 126.3                 | 18.4                        | NEATM  | Ryan & Woodward (2010)    |
| 350 | Ornamenta  | 99.5                  | 19.1                        | NEATM  | Masiero et al. (2011)     |
| 350 | Ornamenta  | 99.5                  | 32.0                        | NEATM  | Masiero et al. (2011)     |
| 350 | Ornamenta  | 101.6                 | 108.0                       | NEATM  | Nugent et al. (2015)      |
| 350 | Ornamenta  | 99.4                  | 7.3                         | OCC    | Dunham et al. (2017)      |
| 356 | Liguria    | 155.0                 | 46.5                        | STM    | Morrison & Zellner (2007) |
| 356 | Liguria    | 126.6                 | 31.8                        | OCC    | Dunham et al. (2017)      |
| 356 | Liguria    | 131.3                 | 7.8                         | STM    | Tedesco et al. (2004b)    |
| 356 | Liguria    | 135.7                 | 15.2                        | STM    | Ryan & Woodward (2010)    |
| 356 | Liguria    | 135.1                 | 21.2                        | NEATM  | Ryan & Woodward (2010)    |
| 356 | Liguria    | 136.6                 | 5.6                         | STM    | Usui et al. (2011)        |
| 356 | Liguria    | 131.0                 | 29.1                        | NEATM  | Masiero et al. (2011)     |
| 356 | Liguria    | 145.5                 | 4.3                         | NEATM  | Masiero et al. (2012)     |
| 358 | Apollonia  | 89.4                  | 8.1                         | STM    | Tedesco et al. (2004b)    |
| 358 | Apollonia  | 89.4                  | 3.7                         | NEATM  | Usui et al. (2011)        |
| 358 | Apollonia  | 83.7                  | 10.1                        | STM    | Ryan & Woodward (2010)    |
| 358 | Apollonia  | 88.1                  | 12.0                        | NEATM  | Ryan & Woodward (2010)    |
| 358 | Apollonia  | 90.5                  | 6.4                         | NEATM  | Masiero et al. (2011)     |
| 358 | Apollonia  | 93.4                  | 77.8                        | NEATM  | Nugent et al. (2015)      |
| 358 | Apollonia  | 87.8                  | 81.8                        | NEATM  | Nugent et al. (2015)      |
| 362 | Havnia     | 85.1                  | 3.1                         | NEATM  | Usui et al. (2011)        |
| 362 | Havnia     | 89.2                  | 6.4                         | NEATM  | Masiero et al. (2011)     |
| 362 | Havnia     | 92.0                  | 2.6                         | NEATM  | Masiero et al. (2012)     |
| 366 | Vincentina | 93.8                  | 9.6                         | STM    | Tedesco et al. (2004b)    |
| 366 | Vincentina | 86.2                  | 2.2                         | NEATM  | Usui et al. (2011)        |
| 366 | Vincentina | 93.6                  | 15.2                        | STM    | Ryan & Woodward (2010)    |
| 366 | Vincentina | 98.2                  | 13.9                        | NEATM  | Ryan & Woodward (2010)    |
| 366 | Vincentina | 94.4                  | 6.2                         | NEATM  | Masiero et al. (2011)     |
| 366 | Vincentina | 89.5                  | 88.4                        | NEATM  | Nugent et al. (2015)      |
| 366 | Vincentina | 85.0                  | 39.6                        | OCC    | Dunham et al. (2017)      |
| 366 | Vincentina | 82.0                  | 89.7                        | OCC    | Dunham et al. (2017)      |
| 373 | Melusina   | 95.8                  | 11.1                        | STM    | Tedesco et al. (2004b)    |
| 373 | Melusina   | 96.7                  | 3.7                         | NEATM  | Usui et al. (2011)        |
| 373 | Melusina   | 84.9                  | 9.4                         | STM    | Ryan & Woodward (2010)    |
| 373 | Melusina   | 107.7                 | 17.4                        | NEATM  | Ryan & Woodward (2010)    |
| 373 | Melusina   | 91.6                  | 4.8                         | NEATM  | Masiero et al. (2011)     |
| 373 | Melusina   | 98.7                  | 2.8                         | NEATM  | Masiero et al. (2012)     |
| 373 | Melusina   | 90.4                  | 88.8                        | NEATM  | Nugent et al. (2015)      |
| 377 | Campania   | 91.1                  | 6.0                         | STM    | Tedesco et al. (2004b)    |
| 377 | Campania   | 92.6                  | 3.3                         | NEATM  | Usui et al. (2011)        |
| 377 | Campania   | 75.3                  | 7.0                         | STM    | Ryan & Woodward (2010)    |
| 377 | Campania   | 96.4                  | 16.9                        | NEATM  | Ryan & Woodward (2010)    |
| 377 | Campania   | 94.0                  | 20.1                        | NEATM  | Masiero et al. (2011)     |
| 377 | Campania   | 91.0                  | 224.7                       | OCC    | Dunham et al. (2017)      |
| 404 | Arsinoe    | 101.0                 | 30.3                        | STM    | Morrison & Zellner (2007) |

Table D.2. continued.

| #   | Name        | $\mathcal{D}$<br>(km) | $\delta\mathcal{D}$<br>(km) | Method | Reference                 |
|-----|-------------|-----------------------|-----------------------------|--------|---------------------------|
| 404 | Arsinoe     | 97.7                  | 4.5                         | STM    | Tedesco et al. (2004b)    |
| 404 | Arsinoe     | 98.8                  | 9.6                         | OCC    | Dunham et al. (2017)      |
| 404 | Arsinoe     | 98.4                  | 12.5                        | STM    | Ryan & Woodward (2010)    |
| 404 | Arsinoe     | 102.3                 | 13.6                        | NEATM  | Ryan & Woodward (2010)    |
| 404 | Arsinoe     | 93.0                  | 3.4                         | STM    | Usui et al. (2011)        |
| 404 | Arsinoe     | 98.7                  | 10.4                        | NEATM  | Masiero et al. (2011)     |
| 404 | Arsinoe     | 108.6                 | 3.3                         | NEATM  | Masiero et al. (2012)     |
| 404 | Arsinoe     | 101.0                 | 15.0                        | LCOCC  | Hanuš et al. (2013a)      |
| 404 | Arsinoe     | 85.1                  | 84.8                        | NEATM  | Nugent et al. (2015)      |
| 405 | Thia        | 124.9                 | 6.9                         | STM    | Tedesco et al. (2004b)    |
| 405 | Thia        | 129.6                 | 11.9                        | STM    | Ryan & Woodward (2010)    |
| 405 | Thia        | 134.9                 | 20.2                        | NEATM  | Ryan & Woodward (2010)    |
| 405 | Thia        | 113.3                 | 5.2                         | STM    | Usui et al. (2011)        |
| 405 | Thia        | 125.0                 | 52.3                        | NEATM  | Masiero et al. (2011)     |
| 405 | Thia        | 101.5                 | 100.6                       | NEATM  | Nugent et al. (2015)      |
| 407 | Arachne     | 95.1                  | 16.2                        | STM    | Tedesco et al. (2004b)    |
| 407 | Arachne     | 97.5                  | 4.8                         | NEATM  | Usui et al. (2011)        |
| 407 | Arachne     | 82.2                  | 8.9                         | STM    | Ryan & Woodward (2010)    |
| 407 | Arachne     | 97.8                  | 14.8                        | NEATM  | Ryan & Woodward (2010)    |
| 407 | Arachne     | 86.3                  | 62.7                        | NEATM  | Nugent et al. (2015)      |
| 410 | Chloris     | 135.0                 | 40.5                        | STM    | Morrison & Zellner (2007) |
| 410 | Chloris     | 123.6                 | 16.2                        | STM    | Tedesco et al. (2004b)    |
| 410 | Chloris     | 118.0                 | 15.7                        | STM    | Ryan & Woodward (2010)    |
| 410 | Chloris     | 124.2                 | 16.5                        | NEATM  | Ryan & Woodward (2010)    |
| 410 | Chloris     | 106.7                 | 4.3                         | STM    | Usui et al. (2011)        |
| 410 | Chloris     | 118.9                 | 8.6                         | NEATM  | Masiero et al. (2011)     |
| 410 | Chloris     | 96.8                  | 87.5                        | NEATM  | Nugent et al. (2015)      |
| 442 | Eichsfeldia | 66.7                  | 4.2                         | STM    | Tedesco et al. (2004b)    |
| 442 | Eichsfeldia | 68.7                  | 5.9                         | STM    | Ryan & Woodward (2010)    |
| 442 | Eichsfeldia | 65.9                  | 7.7                         | NEATM  | Ryan & Woodward (2010)    |
| 442 | Eichsfeldia | 65.1                  | 2.5                         | STM    | Usui et al. (2011)        |
| 442 | Eichsfeldia | 63.2                  | 3.7                         | NEATM  | Masiero et al. (2011)     |
| 442 | Eichsfeldia | 61.6                  | 60.5                        | NEATM  | Nugent et al. (2015)      |
| 445 | Edna        | 89.3                  | 13.6                        | STM    | Tedesco et al. (2004a)    |
| 445 | Edna        | 87.2                  | 6.3                         | STM    | Tedesco et al. (2004b)    |
| 445 | Edna        | 81.4                  | 13.0                        | STM    | Ryan & Woodward (2010)    |
| 445 | Edna        | 98.2                  | 15.9                        | NEATM  | Ryan & Woodward (2010)    |
| 445 | Edna        | 89.2                  | 4.3                         | STM    | Usui et al. (2011)        |
| 445 | Edna        | 105.5                 | 4.5                         | NEATM  | Masiero et al. (2011)     |
| 445 | Edna        | 90.2                  | 92.6                        | NEATM  | Nugent et al. (2015)      |
| 445 | Edna        | 82.5                  | 79.1                        | NEATM  | Nugent et al. (2015)      |
| 481 | Emita       | 113.2                 | 9.2                         | STM    | Tedesco et al. (2004b)    |
| 481 | Emita       | 113.2                 | 9.2                         | STM    | Tedesco et al. (2004a)    |
| 481 | Emita       | 102.0                 | 0.0                         | STM    | Ryan & Woodward (2010)    |
| 481 | Emita       | 108.4                 | 0.0                         | NEATM  | Ryan & Woodward (2010)    |
| 481 | Emita       | 103.5                 | 5.7                         | STM    | Usui et al. (2011)        |
| 481 | Emita       | 121.6                 | 117.9                       | NEATM  | Masiero et al. (2012)     |
| 481 | Emita       | 104.1                 | 119.1                       | NEATM  | Nugent et al. (2015)      |
| 488 | Kreusa      | 150.1                 | 19.2                        | STM    | Tedesco et al. (2004b)    |
| 488 | Kreusa      | 156.0                 | 20.8                        | STM    | Ryan & Woodward (2010)    |
| 488 | Kreusa      | 161.6                 | 22.2                        | NEATM  | Ryan & Woodward (2010)    |
| 488 | Kreusa      | 172.6                 | 7.6                         | STM    | Usui et al. (2011)        |
| 488 | Kreusa      | 150.0                 | 34.0                        | NEATM  | Masiero et al. (2011)     |
| 488 | Kreusa      | 168.1                 | 6.2                         | NEATM  | Masiero et al. (2012)     |
| 488 | Kreusa      | 143.9                 | 156.2                       | NEATM  | Nugent et al. (2015)      |
| 488 | Kreusa      | 161.5                 | 145.5                       | NEATM  | Nugent et al. (2015)      |
| 490 | Veritas     | 108.1                 | 13.8                        | OCC    | Dunham et al. (2017)      |
| 490 | Veritas     | 115.6                 | 16.5                        | STM    | Tedesco et al. (2004b)    |

Table D.2. continued.

| #   | Name      | $\mathcal{D}$<br>(km) | $\delta\mathcal{D}$<br>(km) | Method | Reference                                     |
|-----|-----------|-----------------------|-----------------------------|--------|---|
| 490 | Veritas   | 131.5                 | 12.0                        | IM     | <a href="#">Marchis et al. (2006)</a>         |
| 490 | Veritas   | 102.9                 | 15.8                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 490 | Veritas   | 112.0                 | 15.2                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 490 | Veritas   | 112.8                 | 5.0                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 490 | Veritas   | 118.8                 | 5.5                         | NEATM  | <a href="#">Masiero et al. (2012)</a>         |
| 490 | Veritas   | 100.8                 | 88.9                        | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 490 | Veritas   | 108.4                 | 108.0                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 503 | Evelyn    | 81.7                  | 14.7                        | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 503 | Evelyn    | 83.4                  | 14.7                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 503 | Evelyn    | 83.6                  | 29.7                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 503 | Evelyn    | 90.2                  | 3.1                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 503 | Evelyn    | 99.2                  | 102.8                       | NEATM  | <a href="#">Masiero et al. (2012)</a>         |
| 521 | Brixia    | 115.7                 | 6.0                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 521 | Brixia    | 109.3                 | 15.6                        | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 521 | Brixia    | 125.4                 | 4.9                         | NEATM  | <a href="#">Usui et al. (2011)</a>            |
| 521 | Brixia    | 108.2                 | 12.6                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 521 | Brixia    | 120.0                 | 15.9                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 521 | Brixia    | 111.9                 | 12.2                        | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 521 | Brixia    | 110.6                 | 8.9                         | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 521 | Brixia    | 104.6                 | 91.8                        | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 521 | Brixia    | 104.0                 | 110.9                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 554 | Peraga    | 101.0                 | 30.3                        | STM    | <a href="#">Morrison &amp; Zellner (2007)</a> |
| 554 | Peraga    | 95.9                  | 12.3                        | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 554 | Peraga    | 93.9                  | 10.2                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 554 | Peraga    | 109.1                 | 17.0                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 554 | Peraga    | 97.0                  | 3.5                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 554 | Peraga    | 102.8                 | 81.8                        | NEATM  | <a href="#">Masiero et al. (2012)</a>         |
| 554 | Peraga    | 89.4                  | 91.0                        | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 602 | Marianna  | 137.0                 | 41.1                        | STM    | <a href="#">Morrison &amp; Zellner (2007)</a> |
| 602 | Marianna  | 124.7                 | 6.6                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 602 | Marianna  | 111.1                 | 10.5                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 602 | Marianna  | 130.1                 | 16.6                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 602 | Marianna  | 129.9                 | 5.8                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 602 | Marianna  | 126.8                 | 6.2                         | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 654 | Zelinda   | 127.4                 | 11.7                        | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 654 | Zelinda   | 129.1                 | 11.4                        | STM    | <a href="#">Tedesco et al. (2004a)</a>        |
| 654 | Zelinda   | 119.3                 | 52.6                        | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 654 | Zelinda   | 112.5                 | 12.0                        | IM     | <a href="#">Marchis et al. (2006)</a>         |
| 654 | Zelinda   | 138.0                 | 13.9                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 654 | Zelinda   | 134.3                 | 18.8                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 654 | Zelinda   | 123.6                 | 4.4                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 654 | Zelinda   | 127.0                 | 61.4                        | NEATM  | <a href="#">Masiero et al. (2011)</a>         |
| 654 | Zelinda   | 160.7                 | 4.0                         | NEATM  | <a href="#">Masiero et al. (2012)</a>         |
| 654 | Zelinda   | 135.9                 | 119.1                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 654 | Zelinda   | 134.8                 | 116.8                       | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 694 | Ekard     | 101.0                 | 30.3                        | STM    | <a href="#">Morrison &amp; Zellner (2007)</a> |
| 694 | Ekard     | 90.8                  | 12.0                        | STM    | <a href="#">Tedesco et al. (2004b)</a>        |
| 694 | Ekard     | 99.2                  | 21.8                        | STM    | <a href="#">Tedesco et al. (2004a)</a>        |
| 694 | Ekard     | 104.8                 | 8.5                         | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 694 | Ekard     | 95.9                  | 110.5                       | OCC    | <a href="#">Dunham et al. (2017)</a>          |
| 694 | Ekard     | 90.5                  | 13.0                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 694 | Ekard     | 101.9                 | 51.4                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 694 | Ekard     | 63.9                  | 10.9                        | STM    | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 694 | Ekard     | 92.8                  | 17.0                        | NEATM  | <a href="#">Ryan &amp; Woodward (2010)</a>    |
| 694 | Ekard     | 92.1                  | 3.8                         | STM    | <a href="#">Usui et al. (2011)</a>            |
| 694 | Ekard     | 121.9                 | 2.2                         | STM    | <a href="#">Masiero et al. (2012)</a>         |
| 694 | Ekard     | 98.9                  | 76.2                        | NEATM  | <a href="#">Nugent et al. (2015)</a>          |
| 735 | Marghanna | 74.3                  | 4.8                         | STM    | <a href="#">Tedesco et al. (2004b)</a>        |

Table D.2. continued.

| #    | Name        | $D$<br>(km) | $\delta D$<br>(km) | Method | Reference              |
|------|-------------|-------------|--------------------|--------|------------------------|
| 735  | Marghanna   | 65.1        | 5.9                | STM    | Ryan & Woodward (2010) |
| 735  | Marghanna   | 76.9        | 11.2               | NEATM  | Ryan & Woodward (2010) |
| 735  | Marghanna   | 78.7        | 4.9                | STM    | Usui et al. (2011)     |
| 735  | Marghanna   | 70.6        | 3.7                | NEATM  | Masiero et al. (2011)  |
| 735  | Marghanna   | 70.8        | 3.8                | NEATM  | Masiero et al. (2011)  |
| 735  | Marghanna   | 57.2        | 78.2               | NEATM  | Nugent et al. (2015)   |
| 751  | Faina       | 110.5       | 12.9               | STM    | Tedesco et al. (2004b) |
| 751  | Faina       | 109.6       | 23.7               | STM    | Ryan & Woodward (2010) |
| 751  | Faina       | 122.5       | 18.7               | NEATM  | Ryan & Woodward (2010) |
| 751  | Faina       | 106.8       | 3.8                | STM    | Usui et al. (2011)     |
| 751  | Faina       | 106.3       | 4.9                | NEATM  | Masiero et al. (2011)  |
| 751  | Faina       | 123.7       | 130.4              | NEATM  | Nugent et al. (2015)   |
| 776  | Berbericia  | 151.2       | 12.0               | STM    | Tedesco et al. (2004b) |
| 776  | Berbericia  | 172.4       | 80.4               | OCC    | Dunham et al. (2017)   |
| 776  | Berbericia  | 155.8       | 15.4               | STM    | Ryan & Woodward (2010) |
| 776  | Berbericia  | 165.9       | 31.1               | NEATM  | Ryan & Woodward (2010) |
| 776  | Berbericia  | 149.8       | 5.3                | STM    | Usui et al. (2011)     |
| 776  | Berbericia  | 151.1       | 12.3               | NEATM  | Masiero et al. (2011)  |
| 776  | Berbericia  | 135.1       | 102.9              | NEATM  | Nugent et al. (2015)   |
| 788  | Hohensteina | 103.7       | 10.2               | STM    | Tedesco et al. (2004b) |
| 788  | Hohensteina | 105.5       | 13.5               | OCC    | Dunham et al. (2017)   |
| 788  | Hohensteina | 100.6       | 7.5                | OCC    | Dunham et al. (2017)   |
| 788  | Hohensteina | 118.3       | 5.0                | NEATM  | Usui et al. (2011)     |
| 788  | Hohensteina | 108.1       | 11.2               | STM    | Ryan & Woodward (2010) |
| 788  | Hohensteina | 121.0       | 23.3               | NEATM  | Ryan & Woodward (2010) |
| 788  | Hohensteina | 118.3       | 8.2                | NEATM  | Masiero et al. (2011)  |
| 788  | Hohensteina | 125.8       | 4.5                | NEATM  | Masiero et al. (2012)  |
| 788  | Hohensteina | 101.2       | 97.4               | NEATM  | Nugent et al. (2015)   |
| 791  | Ani         | 103.5       | 5.7                | STM    | Tedesco et al. (2004b) |
| 791  | Ani         | 82.5        | 9.6                | OCC    | Dunham et al. (2017)   |
| 791  | Ani         | 85.9        | 26.9               | OCC    | Dunham et al. (2017)   |
| 791  | Ani         | 97.9        | 3.4                | NEATM  | Usui et al. (2011)     |
| 791  | Ani         | 93.4        | 8.5                | STM    | Ryan & Woodward (2010) |
| 791  | Ani         | 115.0       | 14.0               | NEATM  | Ryan & Woodward (2010) |
| 791  | Ani         | 82.5        | 17.9               | NEATM  | Masiero et al. (2011)  |
| 791  | Ani         | 116.9       | 3.1                | NEATM  | Masiero et al. (2012)  |
| 791  | Ani         | 83.3        | 63.9               | NEATM  | Nugent et al. (2015)   |
| 914  | Palisana    | 80.5        | 5.8                | STM    | Tedesco et al. (2004a) |
| 914  | Palisana    | 76.6        | 5.1                | STM    | Tedesco et al. (2004b) |
| 914  | Palisana    | 91.2        | 7.8                | OCC    | Dunham et al. (2017)   |
| 914  | Palisana    | 76.5        | 15.0               | IM     | Marchis et al. (2006)  |
| 914  | Palisana    | 67.0        | 6.3                | STM    | Ryan & Woodward (2010) |
| 914  | Palisana    | 83.6        | 11.3               | NEATM  | Ryan & Woodward (2010) |
| 914  | Palisana    | 97.3        | 4.5                | STM    | Usui et al. (2011)     |
| 914  | Palisana    | 77.0        | 39.4               | NEATM  | Masiero et al. (2011)  |
| 914  | Palisana    | 78.9        | 61.3               | NEATM  | Nugent et al. (2015)   |
| 1467 | Mashona     | 95.1        | 3.9                | NEATM  | Usui et al. (2011)     |

**Table D.3.** The mass ( $\mathcal{M}$ ) for all the Ch/Cgh asteroids available in the literature.

| #  | Name    | $\mathcal{M}$<br>(kg) | $\delta\mathcal{M}$<br>(kg) | Method | Reference                      |
|----|---------|-----------------------|-----------------------------|--------|--------------------------------|
| 13 | Egeria  | $1.63 \times 10^{19}$ | $9.54 \times 10^{18}$       | DEFL   | Baer et al. (2008)             |
| 13 | Egeria  | $6.17 \times 10^{18}$ | $1.85 \times 10^{18}$       | EPHEM  | Folkner et al. (2009)          |
| 13 | Egeria  | $1.59 \times 10^{19}$ | $1.31 \times 10^{19}$       | DEFL   | Baer et al. (2011)             |
| 13 | Egeria  | $1.29 \times 10^{19}$ | $1.41 \times 10^{19}$       | DEFL   | Zielenbach (2011)              |
| 13 | Egeria  | $7.39 \times 10^{18}$ | $9.72 \times 10^{18}$       | DEFL   | Zielenbach (2011)              |
| 13 | Egeria  | $6.07 \times 10^{18}$ | $9.60 \times 10^{18}$       | DEFL   | Zielenbach (2011)              |
| 13 | Egeria  | $8.26 \times 10^{18}$ | $1.83 \times 10^{19}$       | DEFL   | Zielenbach (2011)              |
| 13 | Egeria  | $9.37 \times 10^{18}$ | $4.65 \times 10^{18}$       | EPHEM  | Fienga et al. (2013)           |
| 13 | Egeria  | $1.23 \times 10^{19}$ | $9.90 \times 10^{18}$       | EPHEM  | Kuchynka & Folkner (2013)      |
| 13 | Egeria  | $9.37 \times 10^{18}$ | $7.08 \times 10^{18}$       | EPHEM  | Fienga et al. (2014)           |
| 13 | Egeria  | $9.35 \times 10^{18}$ | $2.39 \times 10^{18}$       | DEFL   | Goffin (2014)                  |
| 13 | Egeria  | $9.62 \times 10^{18}$ | $4.47 \times 10^{18}$       | DEFL   | Kochetova & Chernetenko (2014) |
| 13 | Egeria  | $1.04 \times 10^{19}$ | $4.65 \times 10^{18}$       | EPHEM  | Viswanathan et al. (2017)      |
| 13 | Egeria  | $2.25 \times 10^{19}$ | $7.83 \times 10^{19}$       | DEFL   | Siltala & Granvik (2017)       |
| 13 | Egeria  | $1.08 \times 10^{19}$ | $4.38 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.)     |
| 19 | Fortuna | $1.27 \times 10^{19}$ | $1.49 \times 10^{18}$       | DEFL   | Baer et al. (2008)             |
| 19 | Fortuna | $4.02 \times 10^{18}$ | $1.19 \times 10^{18}$       | EPHEM  | Fienga et al. (2009)           |
| 19 | Fortuna | $6.94 \times 10^{18}$ | $2.08 \times 10^{18}$       | EPHEM  | Folkner et al. (2009)          |
| 19 | Fortuna | $6.37 \times 10^{18}$ | $8.70 \times 10^{18}$       | DEFL   | Somenzi et al. (2010)          |
| 19 | Fortuna | $8.31 \times 10^{18}$ | $2.15 \times 10^{18}$       | DEFL   | Baer et al. (2011)             |
| 19 | Fortuna | $6.37 \times 10^{18}$ | $3.15 \times 10^{18}$       | EPHEM  | Konopliv et al. (2011)         |
| 19 | Fortuna | $1.00 \times 10^{19}$ | $3.24 \times 10^{18}$       | DEFL   | Zielenbach (2011)              |
| 19 | Fortuna | $1.02 \times 10^{19}$ | $2.84 \times 10^{18}$       | DEFL   | Zielenbach (2011)              |
| 19 | Fortuna | $1.01 \times 10^{19}$ | $2.81 \times 10^{18}$       | DEFL   | Zielenbach (2011)              |
| 19 | Fortuna | $1.05 \times 10^{19}$ | $3.69 \times 10^{18}$       | DEFL   | Zielenbach (2011)              |
| 19 | Fortuna | $8.35 \times 10^{18}$ | $1.79 \times 10^{18}$       | EPHEM  | Fienga et al. (2011)           |
| 19 | Fortuna | $9.73 \times 10^{18}$ | $3.03 \times 10^{18}$       | EPHEM  | Fienga et al. (2013)           |
| 19 | Fortuna | $7.79 \times 10^{18}$ | $2.70 \times 10^{18}$       | EPHEM  | Kuchynka & Folkner (2013)      |
| 19 | Fortuna | $8.67 \times 10^{18}$ | $7.77 \times 10^{17}$       | EPHEM  | Pitjeva (2013)                 |
| 19 | Fortuna | $8.00 \times 10^{18}$ | $2.81 \times 10^{18}$       | EPHEM  | Fienga et al. (2014)           |
| 19 | Fortuna | $8.95 \times 10^{18}$ | $5.97 \times 10^{17}$       | DEFL   | Goffin (2014)                  |
| 19 | Fortuna | $8.83 \times 10^{18}$ | $1.25 \times 10^{18}$       | DEFL   | Kochetova & Chernetenko (2014) |
| 19 | Fortuna | $1.03 \times 10^{19}$ | $1.68 \times 10^{18}$       | EPHEM  | Viswanathan et al. (2017)      |
| 19 | Fortuna | $2.80 \times 10^{18}$ | $9.33 \times 10^{18}$       | DEFL   | Siltala & Granvik (2017)       |
| 19 | Fortuna | $2.21 \times 10^{19}$ | $3.03 \times 10^{19}$       | DEFL   | Siltala & Granvik (2017)       |
| 19 | Fortuna | $1.10 \times 10^{19}$ | $1.90 \times 10^{18}$       | EPHEM  | Baer & Chesley (2017)          |
| 19 | Fortuna | $1.17 \times 10^{19}$ | $1.42 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.)     |
| 34 | Circe   | $3.68 \times 10^{18}$ | $4.53 \times 10^{18}$       | EPHEM  | Fienga et al. (2011)           |
| 34 | Circe   | $2.89 \times 10^{18}$ | $3.63 \times 10^{18}$       | EPHEM  | Fienga et al. (2013)           |
| 34 | Circe   | $4.18 \times 10^{18}$ | $1.19 \times 10^{18}$       | DEFL   | Goffin (2014)                  |
| 34 | Circe   | $5.01 \times 10^{18}$ | $4.86 \times 10^{18}$       | EPHEM  | Viswanathan et al. (2017)      |
| 34 | Circe   | $5.96 \times 10^{18}$ | $5.19 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.)     |
| 38 | Leda    | $3.18 \times 10^{18}$ | $1.79 \times 10^{18}$       | DEFL   | Goffin (2014)                  |
| 38 | Leda    | $6.03 \times 10^{18}$ | $4.38 \times 10^{18}$       | EPHEM  | Viswanathan et al. (2017)      |
| 38 | Leda    | $7.07 \times 10^{18}$ | $4.44 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.)     |
| 41 | Daphne  | $1.05 \times 10^{19}$ | $2.99 \times 10^{18}$       | EPHEM  | Fienga et al. (2009)           |
| 41 | Daphne  | $7.90 \times 10^{18}$ | $2.37 \times 10^{18}$       | EPHEM  | Folkner et al. (2009)          |
| 41 | Daphne  | $8.43 \times 10^{18}$ | $1.06 \times 10^{19}$       | EPHEM  | Konopliv et al. (2011)         |
| 41 | Daphne  | $1.82 \times 10^{19}$ | $2.16 \times 10^{19}$       | DEFL   | Zielenbach (2011)              |
| 41 | Daphne  | $3.02 \times 10^{17}$ | $1.70 \times 10^{19}$       | DEFL   | Zielenbach (2011)              |
| 41 | Daphne  | $4.76 \times 10^{18}$ | $1.65 \times 10^{19}$       | DEFL   | Zielenbach (2011)              |
| 41 | Daphne  | $1.21 \times 10^{19}$ | $3.15 \times 10^{19}$       | DEFL   | Zielenbach (2011)              |
| 41 | Daphne  | $1.02 \times 10^{19}$ | $3.57 \times 10^{18}$       | EPHEM  | Fienga et al. (2011)           |

**Notes.** For each, the  $3\sigma$  uncertainty, method, and bibliographic reference are reported. The methods are DEFL: Deflection, EPHEM: Ephemeris, BIMG: Binary: Imaging, and BGENO: Binary: Genoid.



Table D.3. continued.

| #  | Name      | $M$<br>(kg)           | $\delta M$<br>(kg)    | Method | Reference  |
|----|-----------|-----------------------|-----------------------|--------|--|
| 41 | Daphne    | $7.79 \times 10^{18}$ | $5.40 \times 10^{18}$ | EPHEM  | <a href="#">Kuchynka &amp; Folkner (2013)</a>      |
| 41 | Daphne    | $8.29 \times 10^{18}$ | $2.62 \times 10^{18}$ | EPHEM  | <a href="#">Pitjeva (2013)</a>                     |
| 41 | Daphne    | $7.13 \times 10^{18}$ | $2.01 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2014)</a>               |
| 41 | Daphne    | $9.35 \times 10^{18}$ | $4.17 \times 10^{18}$ | DEFL   | <a href="#">Goffin (2014)</a>                      |
| 41 | Daphne    | $9.78 \times 10^{18}$ | $1.38 \times 10^{19}$ | DEFL   | <a href="#">Kochetova &amp; Chernetenko (2014)</a> |
| 41 | Daphne    | $4.44 \times 10^{18}$ | $2.52 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.)                         |
| 41 | Daphne    | $5.95 \times 10^{18}$ | $1.70 \times 10^{18}$ | BGENO  | This work  |
| 48 | Doris     | $1.21 \times 10^{19}$ | $1.79 \times 10^{19}$ | DEFL   | <a href="#">Kochetova (2004)</a>                   |
| 48 | Doris     | $5.89 \times 10^{18}$ | $1.45 \times 10^{19}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 48 | Doris     | $3.78 \times 10^{18}$ | $1.12 \times 10^{19}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 48 | Doris     | $3.84 \times 10^{18}$ | $1.11 \times 10^{19}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 48 | Doris     | $7.94 \times 10^{18}$ | $1.92 \times 10^{19}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 48 | Doris     | $2.40 \times 10^{19}$ | $2.05 \times 10^{19}$ | EPHEM  | <a href="#">Fienga et al. (2011)</a>               |
| 48 | Doris     | $5.99 \times 10^{15}$ | $1.13 \times 10^{17}$ | EPHEM  | <a href="#">Fienga et al. (2014)</a>               |
| 48 | Doris     | $7.76 \times 10^{18}$ | $1.79 \times 10^{18}$ | DEFL   | <a href="#">Goffin (2014)</a>                      |
| 48 | Doris     | $1.75 \times 10^{19}$ | $1.54 \times 10^{19}$ | EPHEM  | Fienga (2018, priv. comm.)                         |
| 49 | Pales     | $2.69 \times 10^{18}$ | $1.49 \times 10^{18}$ | DEFL   | <a href="#">Baer et al. (2008)</a>                 |
| 49 | Pales     | $5.07 \times 10^{18}$ | $1.16 \times 10^{19}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 49 | Pales     | $8.11 \times 10^{18}$ | $8.04 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 49 | Pales     | $7.61 \times 10^{18}$ | $8.01 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 49 | Pales     | $4.93 \times 10^{18}$ | $1.47 \times 10^{19}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 49 | Pales     | $5.37 \times 10^{18}$ | $1.79 \times 10^{18}$ | DEFL   | <a href="#">Goffin (2014)</a>                      |
| 49 | Pales     | $7.59 \times 10^{18}$ | $5.52 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.)                         |
| 50 | Virginia  | $1.95 \times 10^{18}$ | $2.18 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2011)</a>               |
| 50 | Virginia  | $5.97 \times 10^{17}$ | $1.79 \times 10^{17}$ | DEFL   | <a href="#">Goffin (2014)</a>                      |
| 50 | Virginia  | $1.46 \times 10^{18}$ | $1.16 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.)                         |
| 51 | Nemausa   | $2.16 \times 10^{18}$ | $6.48 \times 10^{17}$ | EPHEM  | <a href="#">Folkner et al. (2009)</a>              |
| 51 | Nemausa   | $4.55 \times 10^{18}$ | $8.16 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 51 | Nemausa   | $3.39 \times 10^{18}$ | $4.86 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 51 | Nemausa   | $3.36 \times 10^{18}$ | $4.86 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 51 | Nemausa   | $4.25 \times 10^{18}$ | $6.24 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 51 | Nemausa   | $5.63 \times 10^{18}$ | $3.90 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2011)</a>               |
| 51 | Nemausa   | $1.79 \times 10^{16}$ | $2.69 \times 10^{16}$ | EPHEM  | <a href="#">Fienga et al. (2013)</a>               |
| 51 | Nemausa   | $4.76 \times 10^{15}$ | $1.65 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2014)</a>               |
| 51 | Nemausa   | $2.78 \times 10^{18}$ | $1.19 \times 10^{18}$ | DEFL   | <a href="#">Goffin (2014)</a>                      |
| 51 | Nemausa   | $4.79 \times 10^{18}$ | $2.53 \times 10^{18}$ | EPHEM  | <a href="#">Baer &amp; Chesley (2017)</a>          |
| 51 | Nemausa   | $4.22 \times 10^{18}$ | $2.26 \times 10^{18}$ | EPHEM  | <a href="#">Baer &amp; Chesley (2017)</a>          |
| 51 | Nemausa   | $3.98 \times 10^{18}$ | $2.54 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.)                         |
| 54 | Alexandra | $1.08 \times 10^{19}$ | $1.83 \times 10^{19}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 54 | Alexandra | $1.74 \times 10^{18}$ | $9.57 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 54 | Alexandra | $2.94 \times 10^{18}$ | $9.45 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 54 | Alexandra | $6.44 \times 10^{18}$ | $2.08 \times 10^{19}$ | DEFL   | <a href="#">Zielenbach (2011)</a>                  |
| 54 | Alexandra | $1.03 \times 10^{19}$ | $5.22 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2011)</a>               |
| 54 | Alexandra | $1.67 \times 10^{19}$ | $6.45 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2013)</a>               |
| 54 | Alexandra | $1.21 \times 10^{19}$ | $3.42 \times 10^{18}$ | EPHEM  | <a href="#">Viswanathan et al. (2017)</a>          |
| 54 | Alexandra | $1.62 \times 10^{18}$ | $2.02 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.)                         |
| 58 | Concordia | $1.28 \times 10^{17}$ | $1.92 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.)                         |
| 62 | Erato     | $1.38 \times 10^{17}$ | $2.07 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.)                         |
| 70 | Panopaea  | $4.33 \times 10^{18}$ | $3.27 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2011)</a>               |
| 70 | Panopaea  | $3.38 \times 10^{18}$ | $1.19 \times 10^{18}$ | DEFL   | <a href="#">Goffin (2014)</a>                      |
| 70 | Panopaea  | $4.67 \times 10^{18}$ | $2.95 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.)                         |
| 78 | Diana     | $1.27 \times 10^{18}$ | $3.81 \times 10^{17}$ | EPHEM  | <a href="#">Folkner et al. (2009)</a>              |
| 78 | Diana     | $5.09 \times 10^{18}$ | $3.39 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2013)</a>               |
| 78 | Diana     | $4.29 \times 10^{17}$ | $8.07 \times 10^{17}$ | EPHEM  | <a href="#">Viswanathan et al. (2017)</a>          |
| 78 | Diana     | $3.76 \times 10^{17}$ | $5.34 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.)                         |

Table D.3. continued.

| #   | Name      | $M$<br>(kg)           | $\delta M$<br>(kg)    | Method | Reference                                  |
|-----|-----------|-----------------------|-----------------------|--------|--|
| 84  | Klio      | $5.45 \times 10^{17}$ | $8.04 \times 10^{17}$ | EPHEM  | <a href="#">Viswanathan et al. (2017)</a>  |
| 84  | Klio      | $7.60 \times 10^{17}$ | $7.32 \times 10^{17}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 91  | Aegina    | $6.07 \times 10^{17}$ | $8.94 \times 10^{17}$ | EPHEM  | <a href="#">Viswanathan et al. (2017)</a>  |
| 91  | Aegina    | $2.00 \times 10^{17}$ | $2.99 \times 10^{17}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 95  | Arethusa  | $4.18 \times 10^{18}$ | $2.39 \times 10^{18}$ | DEFL   | <a href="#">Goffin (2014)</a>              |
| 95  | Arethusa  | $6.86 \times 10^{18}$ | $8.91 \times 10^{18}$ | EPHEM  | <a href="#">Viswanathan et al. (2017)</a>  |
| 95  | Arethusa  | $7.46 \times 10^{18}$ | $9.30 \times 10^{18}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 98  | Ianthe    | $8.24 \times 10^{17}$ | $2.47 \times 10^{17}$ | EPHEM  | <a href="#">Folkner et al. (2009)</a>      |
| 98  | Ianthe    | $1.47 \times 10^{18}$ | $2.07 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2011)</a>       |
| 98  | Ianthe    | $1.65 \times 10^{18}$ | $2.23 \times 10^{18}$ | EPHEM  | <a href="#">Viswanathan et al. (2017)</a>  |
| 98  | Ianthe    | $1.55 \times 10^{18}$ | $2.02 \times 10^{18}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 104 | Klymene   | $1.79 \times 10^{18}$ | $1.19 \times 10^{18}$ | DEFL   | <a href="#">Goffin (2014)</a>              |
| 104 | Klymene   | $3.78 \times 10^{18}$ | $4.80 \times 10^{18}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 105 | Artemis   | $1.32 \times 10^{18}$ | $3.96 \times 10^{17}$ | EPHEM  | <a href="#">Folkner et al. (2009)</a>      |
| 105 | Artemis   | $2.89 \times 10^{18}$ | $2.53 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2011)</a>       |
| 105 | Artemis   | $6.06 \times 10^{18}$ | $3.81 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2013)</a>       |
| 105 | Artemis   | $2.63 \times 10^{18}$ | $1.82 \times 10^{18}$ | EPHEM  | <a href="#">Viswanathan et al. (2017)</a>  |
| 105 | Artemis   | $1.91 \times 10^{18}$ | $1.82 \times 10^{18}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 106 | Dione     | $3.04 \times 10^{17}$ | $1.08 \times 10^{19}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |
| 106 | Dione     | $4.29 \times 10^{18}$ | $7.92 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |
| 106 | Dione     | $3.52 \times 10^{18}$ | $7.86 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |
| 106 | Dione     | $3.77 \times 10^{18}$ | $1.74 \times 10^{19}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |
| 106 | Dione     | $7.70 \times 10^{18}$ | $2.44 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2013)</a>       |
| 106 | Dione     | $3.58 \times 10^{18}$ | $1.79 \times 10^{18}$ | DEFL   | <a href="#">Goffin (2014)</a>              |
| 106 | Dione     | $1.08 \times 10^{17}$ | $1.62 \times 10^{17}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 109 | Felicitas | $3.20 \times 10^{17}$ | $1.49 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2013)</a>       |
| 109 | Felicitas | $2.21 \times 10^{18}$ | $1.55 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2014)</a>       |
| 109 | Felicitas | $1.65 \times 10^{17}$ | $2.44 \times 10^{17}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 111 | Ate       | $1.99 \times 10^{18}$ | $5.97 \times 10^{17}$ | DEFL   | <a href="#">Krasinsky et al. (2001)</a>    |
| 111 | Ate       | $1.67 \times 10^{20}$ | $1.13 \times 10^{20}$ | DEFL   | <a href="#">Ivantsov (2008)</a>            |
| 111 | Ate       | $1.74 \times 10^{18}$ | $5.22 \times 10^{17}$ | EPHEM  | <a href="#">Folkner et al. (2009)</a>      |
| 111 | Ate       | $2.71 \times 10^{18}$ | $7.47 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |
| 111 | Ate       | $3.42 \times 10^{17}$ | $4.95 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |
| 111 | Ate       | $8.16 \times 10^{17}$ | $4.98 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |
| 111 | Ate       | $8.93 \times 10^{18}$ | $7.05 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2013)</a>       |
| 111 | Ate       | $5.87 \times 10^{17}$ | $5.94 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2014)</a>       |
| 111 | Ate       | $3.05 \times 10^{18}$ | $3.45 \times 10^{18}$ | EPHEM  | <a href="#">Viswanathan et al. (2017)</a>  |
| 111 | Ate       | $3.60 \times 10^{18}$ | $3.15 \times 10^{18}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 112 | Iphigenia | $4.52 \times 10^{17}$ | $6.36 \times 10^{17}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 121 | Hermione  | $9.35 \times 10^{18}$ | $4.77 \times 10^{18}$ | DEFL   | <a href="#">Viateau (2000)</a>             |
| 121 | Hermione  | $5.38 \times 10^{18}$ | $8.94 \times 10^{17}$ | BIMG   | <a href="#">Marchis et al. (2005)</a>      |
| 121 | Hermione  | $4.70 \times 10^{18}$ | $6.00 \times 10^{17}$ | BIMG   | <a href="#">Descamps et al. (2009)</a>     |
| 121 | Hermione  | $5.12 \times 10^{18}$ | $6.66 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |
| 121 | Hermione  | $6.01 \times 10^{18}$ | $5.10 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |
| 121 | Hermione  | $4.58 \times 10^{18}$ | $6.39 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |
| 121 | Hermione  | $6.27 \times 10^{18}$ | $6.84 \times 10^{18}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |
| 121 | Hermione  | $3.18 \times 10^{18}$ | $1.19 \times 10^{18}$ | DEFL   | <a href="#">Goffin (2014)</a>              |
| 121 | Hermione  | $4.77 \times 10^{18}$ | $2.39 \times 10^{18}$ | DEFL   | <a href="#">Kretlow (2014)</a>             |
| 121 | Hermione  | $6.69 \times 10^{18}$ | $7.65 \times 10^{18}$ | EPHEM  | <a href="#">Viswanathan et al. (2017)</a>  |
| 121 | Hermione  | $5.53 \times 10^{18}$ | $3.13 \times 10^{18}$ | EPHEM  | <a href="#">Baer &amp; Chesley (2017)</a>  |
| 121 | Hermione  | $7.29 \times 10^{18}$ | $7.44 \times 10^{18}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 127 | Johanna   | $3.08 \times 10^{18}$ | $4.05 \times 10^{18}$ | EPHEM  | <a href="#">Fienga et al. (2011)</a>       |
| 127 | Johanna   | $1.67 \times 10^{18}$ | $4.14 \times 10^{18}$ | EPHEM  | <a href="#">Fienga (2018, priv. comm.)</a> |
| 130 | Elektra   | $6.60 \times 10^{18}$ | $1.19 \times 10^{18}$ | BIMG   | <a href="#">Marchis et al. (2008b)</a>     |
| 130 | Elektra   | $1.61 \times 10^{19}$ | $2.51 \times 10^{19}$ | DEFL   | <a href="#">Zielenbach (2011)</a>          |

Table D.3. continued.

| #   | Name       | $M$<br>(kg)           | $\delta M$<br>(kg)    | Method | Reference                  |
|-----|------------|-----------------------|-----------------------|--------|----------------------------|
| 130 | Elektra    | $1.00 \times 10^{19}$ | $1.97 \times 10^{19}$ | DEFL   | Zielenbach (2011)          |
| 130 | Elektra    | $6.93 \times 10^{18}$ | $1.93 \times 10^{19}$ | DEFL   | Zielenbach (2011)          |
| 130 | Elektra    | $1.34 \times 10^{19}$ | $3.90 \times 10^{19}$ | DEFL   | Zielenbach (2011)          |
| 130 | Elektra    | $2.19 \times 10^{17}$ | $3.57 \times 10^{17}$ | EPHEM  | Fienga et al. (2011)       |
| 130 | Elektra    | $1.39 \times 10^{19}$ | $4.77 \times 10^{18}$ | DEFL   | Goffin (2014)              |
| 130 | Elektra    | $9.41 \times 10^{18}$ | $6.27 \times 10^{18}$ | EPHEM  | Viswanathan et al. (2017)  |
| 130 | Elektra    | $7.46 \times 10^{18}$ | $6.27 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 130 | Elektra    | $6.20 \times 10^{18}$ | $6.00 \times 10^{16}$ | BIMG   | Yang et al. (2016)         |
| 134 | Sophrosyne | $2.02 \times 10^{18}$ | $2.21 \times 10^{18}$ | EPHEM  | Fienga et al. (2013)       |
| 134 | Sophrosyne | $4.92 \times 10^{18}$ | $3.45 \times 10^{18}$ | EPHEM  | Viswanathan et al. (2017)  |
| 134 | Sophrosyne | $5.68 \times 10^{17}$ | $8.34 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 141 | Lumen      | $8.31 \times 10^{18}$ | $2.80 \times 10^{18}$ | EPHEM  | Viswanathan et al. (2017)  |
| 141 | Lumen      | $3.27 \times 10^{18}$ | $2.80 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 144 | Vibilia    | $4.63 \times 10^{18}$ | $8.52 \times 10^{18}$ | DEFL   | Zielenbach (2011)          |
| 144 | Vibilia    | $5.32 \times 10^{18}$ | $5.58 \times 10^{18}$ | DEFL   | Zielenbach (2011)          |
| 144 | Vibilia    | $4.95 \times 10^{18}$ | $5.55 \times 10^{18}$ | DEFL   | Zielenbach (2011)          |
| 144 | Vibilia    | $4.62 \times 10^{18}$ | $9.18 \times 10^{18}$ | DEFL   | Zielenbach (2011)          |
| 144 | Vibilia    | $1.61 \times 10^{15}$ | $5.97 \times 10^{15}$ | EPHEM  | Fienga et al. (2014)       |
| 144 | Vibilia    | $3.38 \times 10^{18}$ | $1.19 \times 10^{18}$ | DEFL   | Goffin (2014)              |
| 144 | Vibilia    | $4.69 \times 10^{18}$ | $2.49 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 145 | Adeona     | $2.26 \times 10^{18}$ | $6.78 \times 10^{17}$ | EPHEM  | Folkner et al. (2009)      |
| 145 | Adeona     | $1.73 \times 10^{17}$ | $7.17 \times 10^{18}$ | DEFL   | Zielenbach (2011)          |
| 145 | Adeona     | $2.10 \times 10^{18}$ | $8.91 \times 10^{18}$ | DEFL   | Zielenbach (2011)          |
| 145 | Adeona     | $2.04 \times 10^{15}$ | $6.57 \times 10^{15}$ | EPHEM  | Fienga et al. (2014)       |
| 145 | Adeona     | $2.78 \times 10^{18}$ | $1.79 \times 10^{18}$ | DEFL   | Goffin (2014)              |
| 145 | Adeona     | $3.24 \times 10^{17}$ | $4.80 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 146 | Lucina     | $1.18 \times 10^{17}$ | $1.77 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 156 | Xanthippe  | $6.49 \times 10^{18}$ | $2.62 \times 10^{18}$ | EPHEM  | Fienga et al. (2013)       |
| 156 | Xanthippe  | $6.72 \times 10^{17}$ | $9.00 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 159 | Aemilia    | $4.18 \times 10^{18}$ | $1.79 \times 10^{18}$ | DEFL   | Goffin (2014)              |
| 159 | Aemilia    | $5.72 \times 10^{18}$ | $7.59 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 162 | Laurentia  | $3.36 \times 10^{17}$ | $5.01 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 163 | Erigone    | $5.79 \times 10^{17}$ | $7.29 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 168 | Sibylla    | $6.02 \times 10^{18}$ | $2.35 \times 10^{19}$ | DEFL   | Zielenbach (2011)          |
| 168 | Sibylla    | $2.38 \times 10^{18}$ | $1.72 \times 10^{19}$ | DEFL   | Zielenbach (2011)          |
| 168 | Sibylla    | $6.33 \times 10^{18}$ | $7.32 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 176 | Iduna      | $3.36 \times 10^{17}$ | $5.04 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 187 | Lamberta   | $1.57 \times 10^{18}$ | $4.71 \times 10^{17}$ | EPHEM  | Folkner et al. (2009)      |
| 187 | Lamberta   | $5.69 \times 10^{18}$ | $2.35 \times 10^{18}$ | EPHEM  | Fienga et al. (2014)       |
| 187 | Lamberta   | $2.19 \times 10^{18}$ | $2.39 \times 10^{18}$ | DEFL   | Goffin (2014)              |
| 187 | Lamberta   | $2.87 \times 10^{17}$ | $4.14 \times 10^{17}$ | EPHEM  | Viswanathan et al. (2017)  |
| 187 | Lamberta   | $4.93 \times 10^{17}$ | $6.81 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 195 | Eurykleia  | $1.44 \times 10^{17}$ | $2.16 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 200 | Dynamene   | $1.14 \times 10^{18}$ | $4.17 \times 10^{17}$ | EPHEM  | Fienga et al. (2013)       |
| 200 | Dynamene   | $3.98 \times 10^{18}$ | $1.79 \times 10^{18}$ | DEFL   | Goffin (2014)              |
| 205 | Martha     | $1.19 \times 10^{17}$ | $1.78 \times 10^{17}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 211 | Isolda     | $1.99 \times 10^{18}$ | $6.84 \times 10^{18}$ | DEFL   | Zielenbach (2011)          |
| 211 | Isolda     | $2.67 \times 10^{18}$ | $5.34 \times 10^{18}$ | DEFL   | Zielenbach (2011)          |
| 211 | Isolda     | $2.41 \times 10^{18}$ | $5.34 \times 10^{18}$ | DEFL   | Zielenbach (2011)          |
| 211 | Isolda     | $4.16 \times 10^{18}$ | $7.98 \times 10^{18}$ | DEFL   | Zielenbach (2011)          |
| 211 | Isolda     | $7.83 \times 10^{18}$ | $9.39 \times 10^{18}$ | EPHEM  | Fienga et al. (2011)       |
| 211 | Isolda     | $2.98 \times 10^{18}$ | $1.79 \times 10^{18}$ | DEFL   | Goffin (2014)              |
| 211 | Isolda     | $6.36 \times 10^{18}$ | $6.81 \times 10^{18}$ | EPHEM  | Viswanathan et al. (2017)  |
| 211 | Isolda     | $5.40 \times 10^{18}$ | $6.12 \times 10^{18}$ | EPHEM  | Fienga (2018, priv. comm.) |
| 238 | Hypatia    | $4.86 \times 10^{18}$ | $1.25 \times 10^{19}$ | DEFL   | Zielenbach (2011)          |

Table D.3. continued.

| #   | Name        | $\mathcal{M}$<br>(kg) | $\delta\mathcal{M}$<br>(kg) | Method | Reference                  |
|-----|-------------|-----------------------|-----------------------------|--------|----------------------------|
| 238 | Hypatia     | $5.44 \times 10^{18}$ | $9.81 \times 10^{18}$       | DEFL   | Zielenbach (2011)          |
| 238 | Hypatia     | $6.20 \times 10^{18}$ | $9.72 \times 10^{18}$       | DEFL   | Zielenbach (2011)          |
| 238 | Hypatia     | $8.63 \times 10^{17}$ | $2.18 \times 10^{19}$       | DEFL   | Zielenbach (2011)          |
| 238 | Hypatia     | $2.98 \times 10^{18}$ | $1.79 \times 10^{18}$       | DEFL   | Goffin (2014)              |
| 238 | Hypatia     | $4.79 \times 10^{18}$ | $5.67 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 266 | Aline       | $4.23 \times 10^{18}$ | $6.33 \times 10^{18}$       | EPHEM  | Viswanathan et al. (2017)  |
| 266 | Aline       | $1.43 \times 10^{18}$ | $2.08 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 303 | Josephina   | $1.31 \times 10^{17}$ | $1.97 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 345 | Tercidina   | $2.68 \times 10^{18}$ | $3.54 \times 10^{18}$       | EPHEM  | Fienga et al. (2011)       |
| 345 | Tercidina   | $3.53 \times 10^{18}$ | $3.48 \times 10^{18}$       | EPHEM  | Viswanathan et al. (2017)  |
| 345 | Tercidina   | $1.17 \times 10^{18}$ | $1.53 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 350 | Ornamenta   | $2.59 \times 10^{17}$ | $3.87 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 356 | Liguria     | $7.83 \times 10^{18}$ | $4.50 \times 10^{18}$       | EPHEM  | Fienga et al. (2011)       |
| 356 | Liguria     | $8.30 \times 10^{18}$ | $3.45 \times 10^{18}$       | EPHEM  | Fienga et al. (2013)       |
| 356 | Liguria     | $2.78 \times 10^{18}$ | $1.19 \times 10^{18}$       | DEFL   | Goffin (2014)              |
| 356 | Liguria     | $3.98 \times 10^{18}$ | $2.11 \times 10^{18}$       | EPHEM  | Viswanathan et al. (2017)  |
| 356 | Liguria     | $9.05 \times 10^{17}$ | $1.22 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 358 | Apollonia   | $1.60 \times 10^{17}$ | $2.40 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 362 | Havnia      | $1.67 \times 10^{17}$ | $2.51 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 366 | Vincentina  | $1.00 \times 10^{17}$ | $1.50 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 373 | Melusina    | $3.43 \times 10^{17}$ | $5.16 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 377 | Campania    | $1.52 \times 10^{17}$ | $2.28 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 404 | Arsinoe     | $1.25 \times 10^{18}$ | $3.51 \times 10^{18}$       | EPHEM  | Fienga et al. (2013)       |
| 404 | Arsinoe     | $7.87 \times 10^{17}$ | $9.84 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 405 | Thia        | $1.38 \times 10^{18}$ | $4.14 \times 10^{17}$       | EPHEM  | Folkner et al. (2009)      |
| 405 | Thia        | $2.74 \times 10^{18}$ | $1.97 \times 10^{18}$       | EPHEM  | Fienga et al. (2013)       |
| 405 | Thia        | $6.38 \times 10^{18}$ | $1.12 \times 10^{18}$       | EPHEM  | Fienga et al. (2014)       |
| 405 | Thia        | $2.19 \times 10^{18}$ | $2.98 \times 10^{18}$       | DEFL   | Goffin (2014)              |
| 405 | Thia        | $3.13 \times 10^{18}$ | $1.39 \times 10^{18}$       | EPHEM  | Viswanathan et al. (2017)  |
| 405 | Thia        | $2.80 \times 10^{18}$ | $1.28 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 407 | Arachne     | $1.26 \times 10^{17}$ | $1.88 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 410 | Chloris     | $6.11 \times 10^{18}$ | $2.76 \times 10^{18}$       | EPHEM  | Fienga et al. (2011)       |
| 410 | Chloris     | $6.91 \times 10^{18}$ | $3.93 \times 10^{18}$       | EPHEM  | Fienga et al. (2013)       |
| 410 | Chloris     | $5.33 \times 10^{18}$ | $2.58 \times 10^{18}$       | EPHEM  | Viswanathan et al. (2017)  |
| 410 | Chloris     | $1.89 \times 10^{18}$ | $1.79 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 442 | Eichsfeldia | $2.50 \times 10^{17}$ | $3.69 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 445 | Edna        | $4.18 \times 10^{18}$ | $3.57 \times 10^{18}$       | DEFL   | Goffin (2014)              |
| 445 | Edna        | $1.24 \times 10^{18}$ | $1.83 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 481 | Emita       | $1.31 \times 10^{18}$ | $1.87 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 488 | Kreusa      | $2.46 \times 10^{18}$ | $7.38 \times 10^{17}$       | EPHEM  | Folkner et al. (2009)      |
| 488 | Kreusa      | $1.60 \times 10^{19}$ | $1.85 \times 10^{19}$       | DEFL   | Zielenbach (2011)          |
| 488 | Kreusa      | $2.29 \times 10^{18}$ | $1.99 \times 10^{18}$       | DEFL   | Zielenbach (2011)          |
| 488 | Kreusa      | $2.19 \times 10^{18}$ | $2.00 \times 10^{18}$       | DEFL   | Zielenbach (2011)          |
| 488 | Kreusa      | $8.25 \times 10^{17}$ | $4.11 \times 10^{19}$       | DEFL   | Zielenbach (2011)          |
| 488 | Kreusa      | $9.77 \times 10^{18}$ | $8.10 \times 10^{18}$       | EPHEM  | Fienga et al. (2011)       |
| 488 | Kreusa      | $1.03 \times 10^{19}$ | $1.08 \times 10^{19}$       | EPHEM  | Fienga et al. (2013)       |
| 488 | Kreusa      | $8.58 \times 10^{17}$ | $1.01 \times 10^{19}$       | EPHEM  | Fienga et al. (2014)       |
| 488 | Kreusa      | $7.36 \times 10^{18}$ | $2.98 \times 10^{18}$       | DEFL   | Goffin (2014)              |
| 488 | Kreusa      | $4.65 \times 10^{18}$ | $5.58 \times 10^{18}$       | EPHEM  | Viswanathan et al. (2017)  |
| 488 | Kreusa      | $4.63 \times 10^{18}$ | $5.28 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.) |
| 490 | Veritas     | $9.32 \times 10^{18}$ | $1.31 \times 10^{19}$       | DEFL   | Zielenbach (2011)          |
| 490 | Veritas     | $4.48 \times 10^{18}$ | $6.33 \times 10^{18}$       | DEFL   | Zielenbach (2011)          |
| 490 | Veritas     | $4.59 \times 10^{18}$ | $6.30 \times 10^{18}$       | DEFL   | Zielenbach (2011)          |
| 490 | Veritas     | $9.51 \times 10^{18}$ | $1.69 \times 10^{19}$       | DEFL   | Zielenbach (2011)          |
| 490 | Veritas     | $2.02 \times 10^{18}$ | $2.96 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.) |

Table D.3. continued.

| #    | Name        | $\mathcal{M}$<br>(kg) | $\delta\mathcal{M}$<br>(kg) | Method | Reference                                 |
|------|-------------|-----------------------|-----------------------------|--------|---|
| 503  | Evelyn      | $8.28 \times 10^{17}$ | $1.15 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 521  | Brixia      | $7.09 \times 10^{17}$ | $1.01 \times 10^{18}$       | EPHEM  | <a href="#">Viswanathan et al. (2017)</a> |
| 521  | Brixia      | $3.37 \times 10^{17}$ | $4.98 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 554  | Peraga      | $6.59 \times 10^{17}$ | $1.98 \times 10^{17}$       | EPHEM  | <a href="#">Folkner et al. (2009)</a>     |
| 554  | Peraga      | $7.95 \times 10^{17}$ | $5.97 \times 10^{17}$       | DEFL   | <a href="#">Goffin (2014)</a>             |
| 554  | Peraga      | $2.34 \times 10^{17}$ | $3.78 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 602  | Marianna    | $3.20 \times 10^{18}$ | $4.08 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 654  | Zelinda     | $1.35 \times 10^{18}$ | $4.05 \times 10^{17}$       | EPHEM  | <a href="#">Folkner et al. (2009)</a>     |
| 654  | Zelinda     | $6.76 \times 10^{18}$ | $2.98 \times 10^{18}$       | DEFL   | <a href="#">Goffin (2014)</a>             |
| 654  | Zelinda     | $7.41 \times 10^{17}$ | $7.83 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 694  | Ekard       | $1.20 \times 10^{17}$ | $1.78 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 735  | Marghanna   | $7.23 \times 10^{17}$ | $8.94 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 751  | Faina       | $3.27 \times 10^{18}$ | $1.75 \times 10^{18}$       | EPHEM  | <a href="#">Fienga et al. (2011)</a>      |
| 751  | Faina       | $4.53 \times 10^{18}$ | $3.30 \times 10^{18}$       | EPHEM  | <a href="#">Viswanathan et al. (2017)</a> |
| 751  | Faina       | $4.13 \times 10^{18}$ | $3.03 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 776  | Berbericia  | $5.46 \times 10^{18}$ | $1.41 \times 10^{19}$       | DEFL   | <a href="#">Zielenbach (2011)</a>         |
| 776  | Berbericia  | $2.39 \times 10^{16}$ | $9.78 \times 10^{18}$       | DEFL   | <a href="#">Zielenbach (2011)</a>         |
| 776  | Berbericia  | $3.08 \times 10^{17}$ | $9.72 \times 10^{18}$       | DEFL   | <a href="#">Zielenbach (2011)</a>         |
| 776  | Berbericia  | $6.28 \times 10^{18}$ | $2.19 \times 10^{19}$       | DEFL   | <a href="#">Zielenbach (2011)</a>         |
| 776  | Berbericia  | $8.11 \times 10^{18}$ | $6.69 \times 10^{18}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 788  | Hohensteina | $1.85 \times 10^{17}$ | $2.77 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 791  | Ani         | $1.47 \times 10^{17}$ | $2.21 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 914  | Palisana    | $1.97 \times 10^{18}$ | $2.16 \times 10^{18}$       | EPHEM  | <a href="#">Viswanathan et al. (2017)</a> |
| 914  | Palisana    | $4.89 \times 10^{17}$ | $6.87 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.)                |
| 1467 | Mashona     | $2.04 \times 10^{17}$ | $3.06 \times 10^{17}$       | EPHEM  | Fienga (2018, priv. comm.)                |