# NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2019 JULY-SEPTEMBER

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Lightcurves for 28 near-Earth asteroids (NEAs) obtained at the Center for Solar System Studies (CS3) from 2019 July to September were analyzed for rotation period, peak-to-peak amplitude, and signs of satellites or tumbling. 2059 Baboquivari, (90403) 2003 YE45, and 2016 AU130 are candidates for membership within the *very wide binary asteroids* class. The 2019 data led to a seemingly unambiguous period of 4.7906 h for (441987) 2010 NY65, which overturned previous results that have now been updated.

CCD photometric observations of 28 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies (CS3) from 2019 July to September. Table I lists the telescopes and CCD cameras that are combined to make observations.

Up to nine telescopes can be used for the campaign, although seven is more common. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales ranged from 1.24-1.60 arcsec/pixel.

| Telescopes | Cameras |
|---|---|
| 0.30-m *f*/6.3 Schmidt-Cass | FLI Microline 1001E |
| 0.35-m *f*/9.1 Schmidt-Cass | FLI Proline 1001E |
| 0.40-m *f*/10 Schmidt-Cass | SBIG STL-1001E |
| 0.40-m *f*/10 Schmidt-Cass | |
| 0.50-m *f*/8.1 Ritchey-Chrétien | |

Table I. List of available telescopes and CCD cameras at CS3. The exact combination for each telescope/camera pair can vary due to maintenance or specific needs.

All lightcurve observations were unfiltered since a clear filter can cause a 0.1-0.3 mag loss. The exposure duration varied depending on the asteroid's brightness and sky motion. Guiding on a field star sometimes resulted in a trailed image for the asteroid.

Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Comp star magnitudes were taken from ATLAS catalog (Tonry et al., 2018), which has Sloan *griz* magnitudes that were derived from the GAIA and Pan-STARR catalogs, among others. The authors state that systematic errors are generally no larger than 0.005 mag, although they can reach 0.02 mag in small areas near the Galactic plane. BVRI magnitudes were derived by Warner using formulae from Kostov and Bonev (2017). The overall errors for the BVRI magnitudes, when combining those in the ATLAS catalog and the conversion formulae, are on the order of 0.04-0.05.

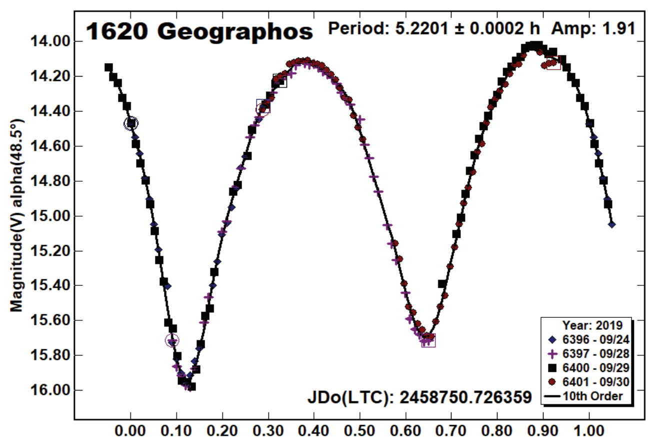
Even so, we found in most cases that nightly zero point adjustments of no more than 0.02-0.03 mag were required during period analysis. There were occasional exceptions that required up to 0.10 mag. These may have been related in part to using unfiltered observations, poor centroiding of the reference stars, and not correcting for second-order extinction terms. Regardless, the systematic errors seem to be considerably less than other catalogs, which reduces the uncertainty in the results when analysis involves data from extended periods or the asteroid is tumbling.

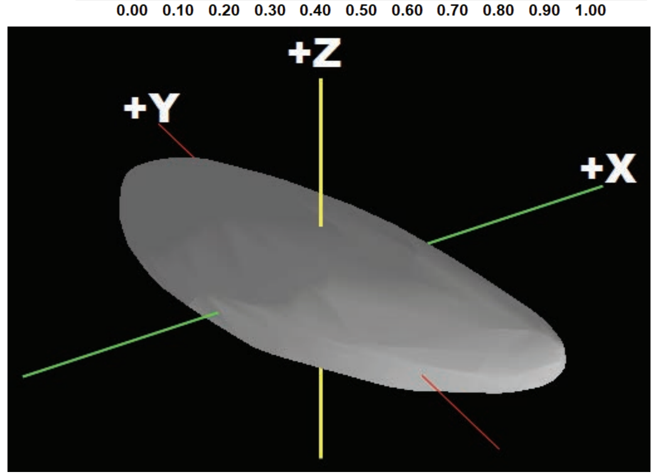
The Y-axis of lightcurves is labeled "Reduced Magnitude" or "Magnitude." Unless otherwise indicated, the values are Johnson V. The latter are sky magnitudes while "Reduced Magnitude" are sky magnitudes corrected to unity distances by applying $-5*\log(r\Delta)$, with r and Δ being, respectively, the Sun-asteroid and the Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses using $G = 0.15$. The X-axis rotational phase ranges from –0.05 to 1.05.

If the plot includes an amplitude, e.g., "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

Our initial search for previous results started with the asteroid lightcurve database (LCDB; Warner *et al.,* 2009) found on-line at *http://www.minorplanet.info/lightcurvedatabase.html*. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB.

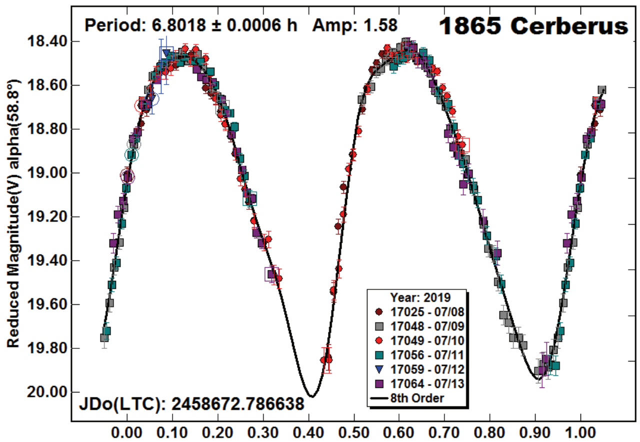
1620 Geographos. Numerous observations and subsequent data analysis have been carried out over the years for this 2-km NEA.



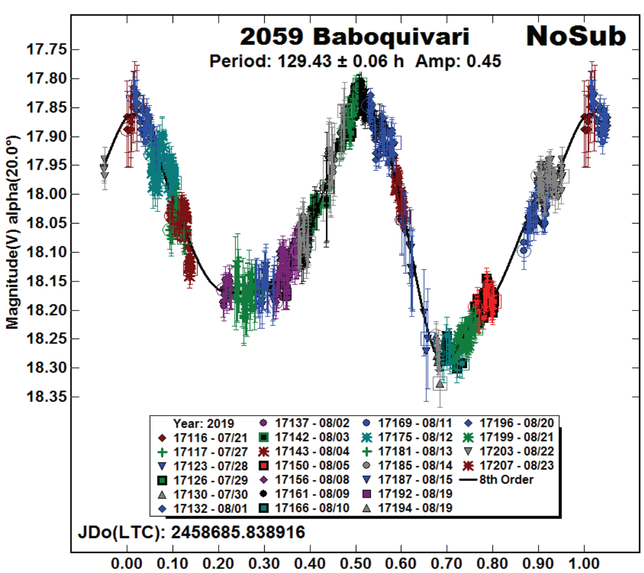
Durech et al. (2008) found that the YORP effect (Yarkovsky–O'Keefe–Radzievskii–Paddack; Rubincam, 2000) was causing the asteroid's rotation period to increase. The model above used data from the DAMIT site Durech et al. (2010) imported into *MPO LCInvert*. From the model, it's easy to see why the lightcurve amplitude is always large, 0.95-2.03 mag.

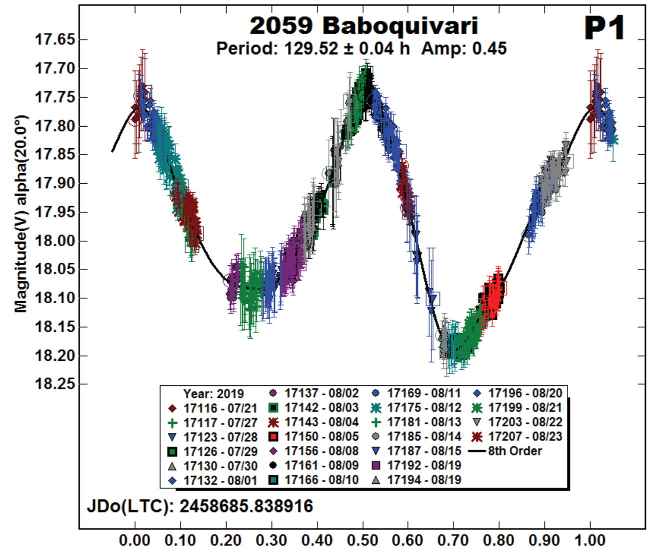
1865 Cerberus. Our result is in good agreement with numerous previous results, e.g., Skiff et al. (2012) and Warner and Stephens (2019a).

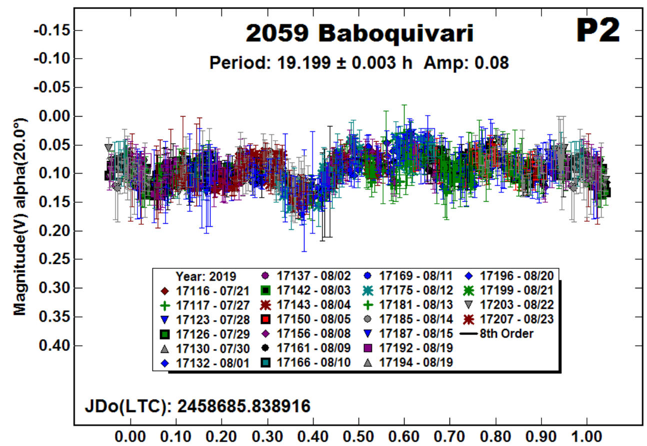



2059 Baboquivari. This 2-km NEA had no previous results listed in the LCDB. Our analysis found a basic period of 129.43 h. However, as seen in the "NoSub" plot, the fit to the Fourier curve showed some deviations. The long period and amplitude made this a possible member of the *very wide binary asteroids* class (see, e.g., Warner, 2016a) or a tumbler with a low amplitude component, and so we used *MPO Canopus* for a dual-period search.

This led to finding a second period ("P2") of 19.199 h with a maximum amplitude of 0.08 mag. If the P2 lightcurve had a simple monomodal or bimodal shape, tumbling could not be formally excluded. However, there is an obvious deviation near 0.4 rotation phase and maybe one at 0.9. This is typical in a small binary asteroid as the satellite and primary undergo occultations/eclipses (*mutual events*).

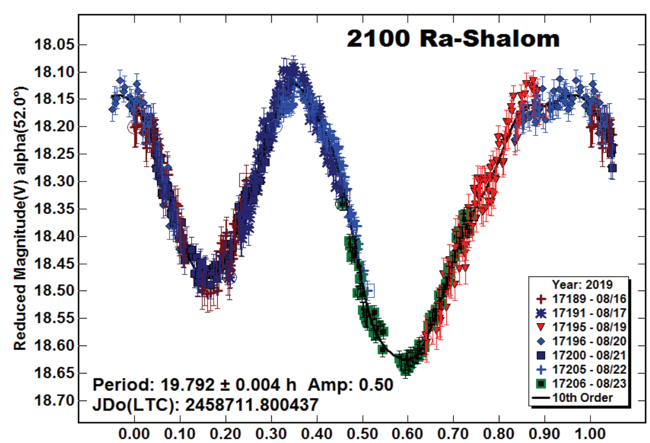



If there was a third period that represented the independent rotation of a satellite, its lightcurve was buried in the noise after subtracting the two periods given here. We urge observers, especially in a coordinated campaign, to work this asteroid in the future.

2100 Ra-Shalom. This is another asteroid where the rotation rate was being affected by YORP (Durech et al., 2018). In this case, the effect is decreasing the period. Our result agrees with previous ones such as Harris et al. (1992; 19.79 h), Pravec et al. (1998; 19.797 h), and Shepard et al. (2008; 19.793 h).

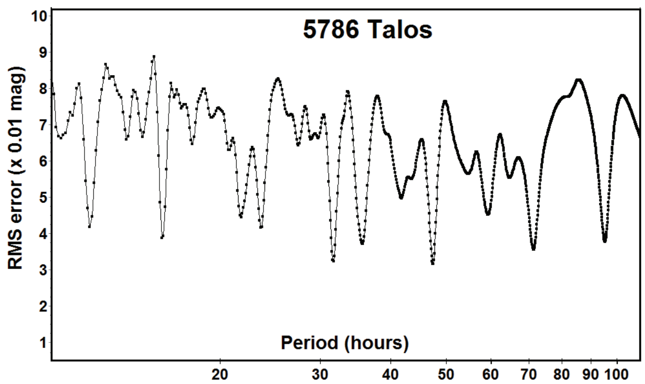


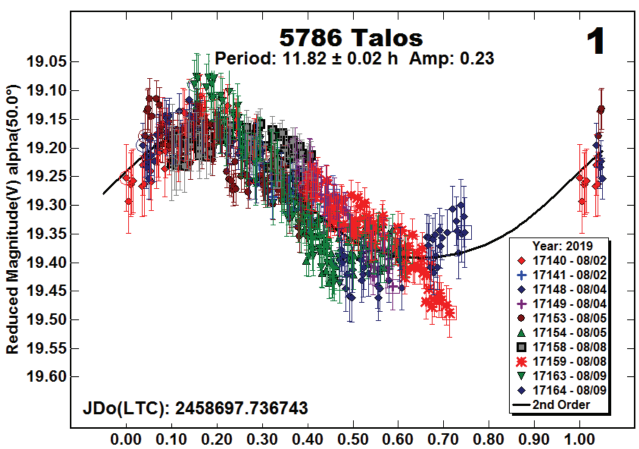
<u>5786 Talos</u>. Pravec et al. (2001) found a period of 38.52 h for the 900-m Talos. That was the only previous listing in the LCDB.

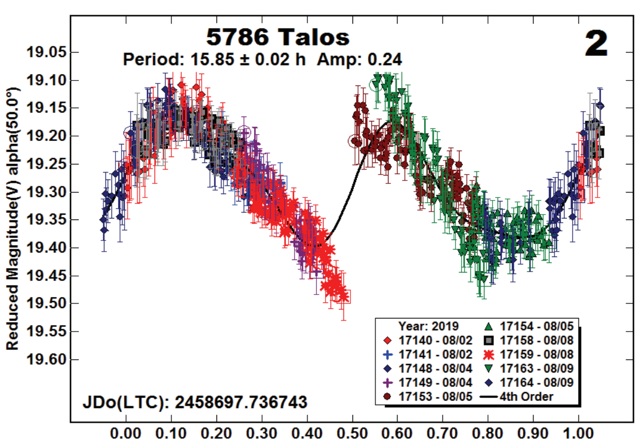
We observed it for a week in 2019 August and obtained 613 useable data points for analysis. The period spectrum showed several possibilities, the more prominent ones being close to commensurate with an Earth day. Lightcurves are shown for the several possible solutions. Each one has its own problems.

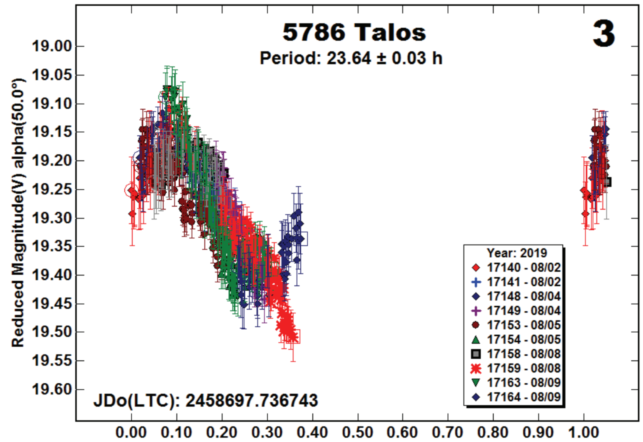
In the end, we adopted a period of 23.64 h based on a half-period of 11.8 h and double period of 47 h. However, we note that it's possible that the asteroid is tumbling (Pravec et al., 2014; 2005). This would explain why some sessions don't fit the Fourier model in each solution.

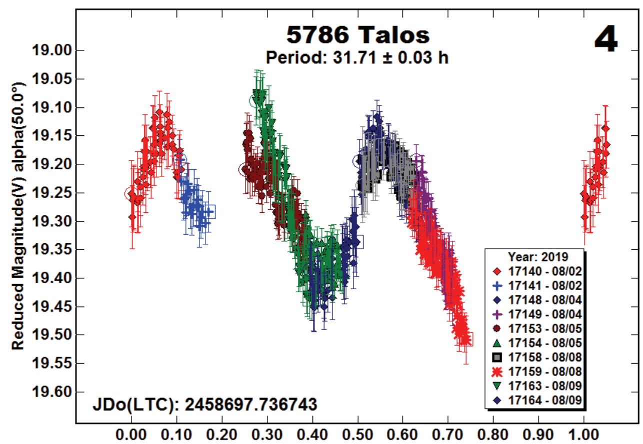
*MPO Canopus* does not handle tumbling asteroids very well and so our solutions may be the dominant periods of tumbling but they also be the sum or difference of the fundamental periods.

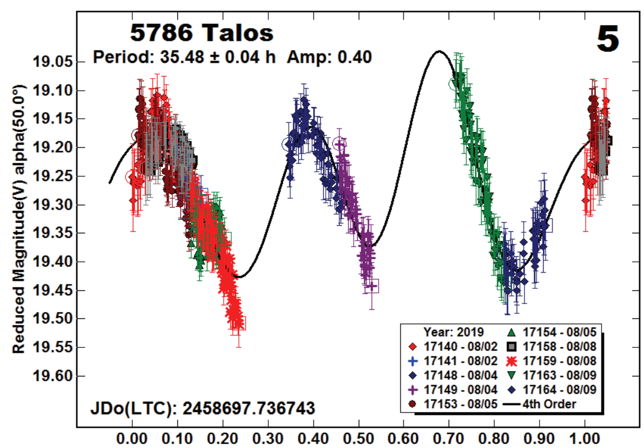


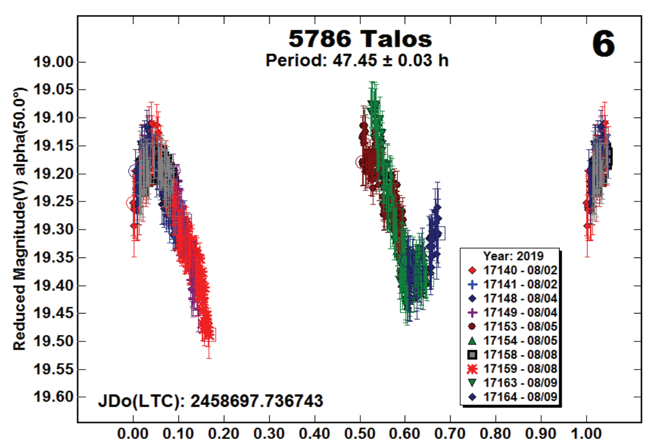



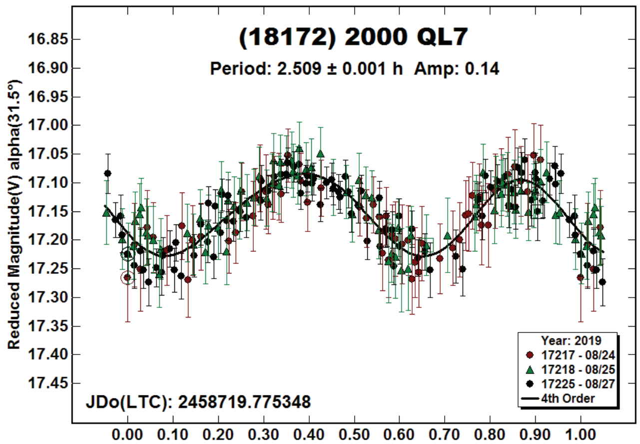



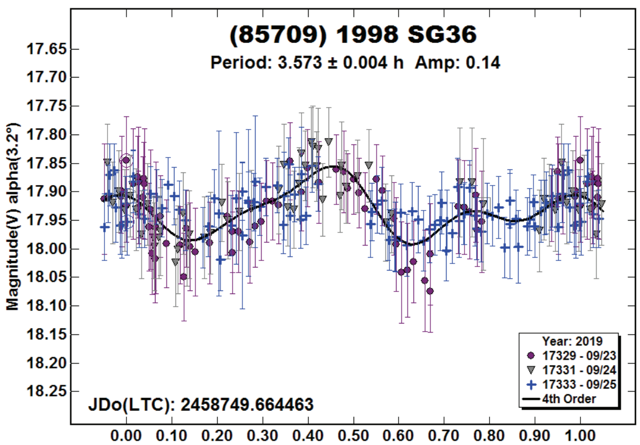



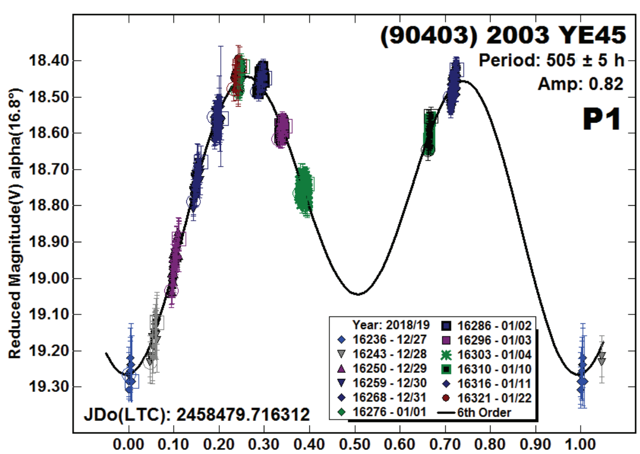
(18172) 2000 QL7, (85709) 1998 SG36. Ours appear to be the first reported lightcurve periods for these two asteroids. Both have a diameter of about 2 km.

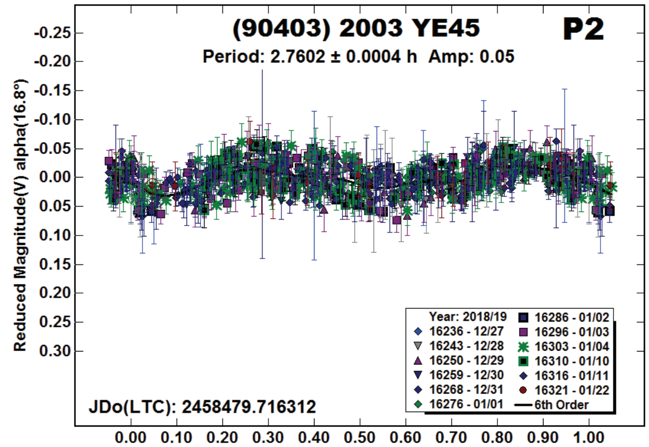


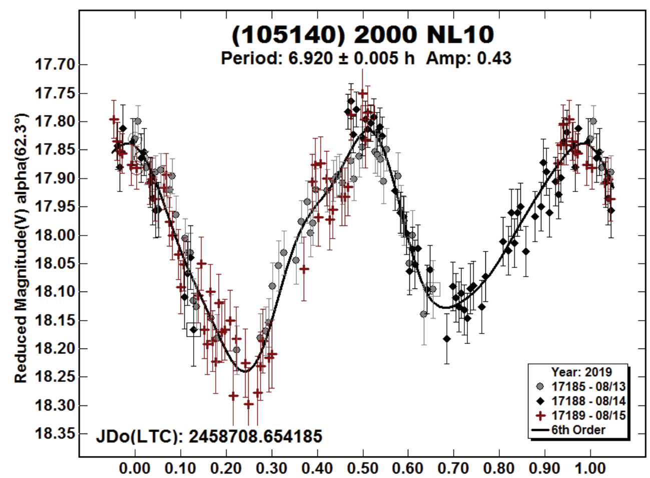

(90403) 2003 YE45. We first reported a solution of 500 h (Warner and Stephens, 2019b) and pointed out that it might be a tumbler because the slopes of some session didn't follow the Fourier model curve.

Even though *MPO Canopus* cannot handle tumbling asteroids, we took another look at the data with a dual-period search. This led to finding a weak asymmetric bimodal lightcurve with a period of 2.76 h. Whether or not this is tied to a fundamental period of tumbling or just "garbage collection" by the Fourier algorithm is not clear. Either way, the asteroid is still likely a tumbler.



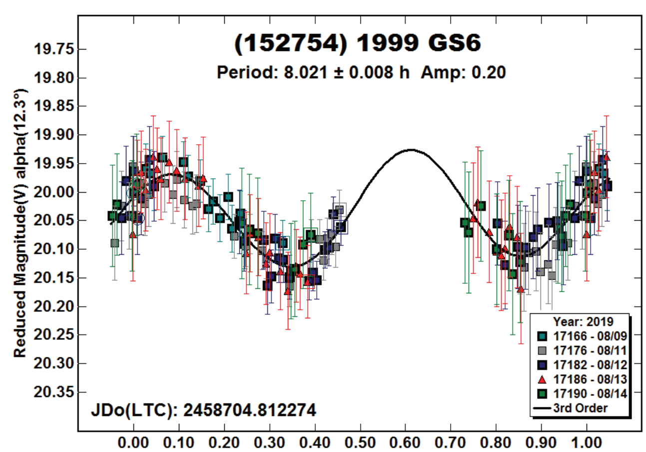



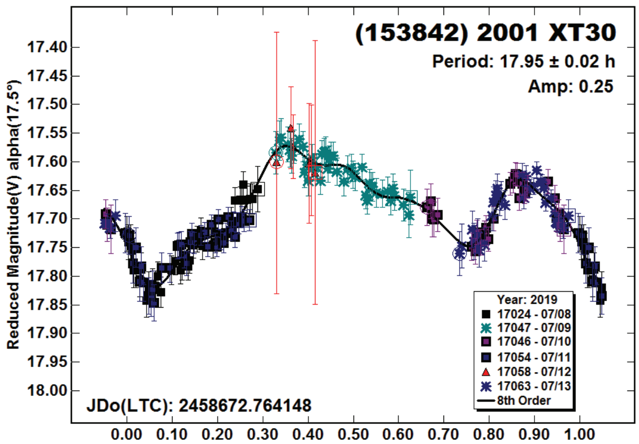

(105140) 2000 NL10. Pravec et al. (2002) first reported a period of 6.927 h. This was followed with 6.9269 h by Polishook (2012). Our result is in good keeping with theirs.



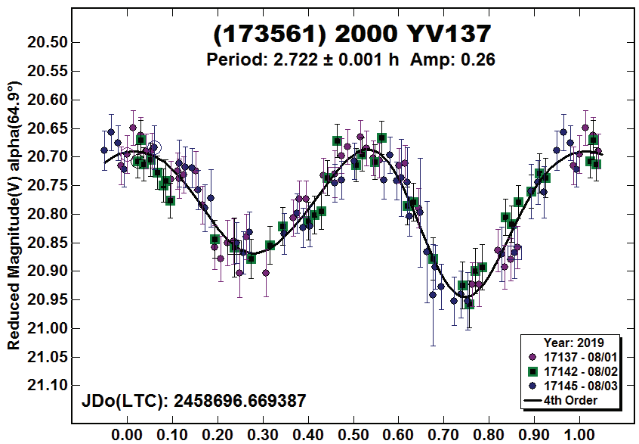

(152754) 1999 GS6, (153842) 2001 XT30. These are both new rotation period entries into the LCDB. Our solution of 8.021 h for 1999 GS6 is based on finding a good fit to its half-period. Even so, the large gap allows only U = 2 in the LCDB.

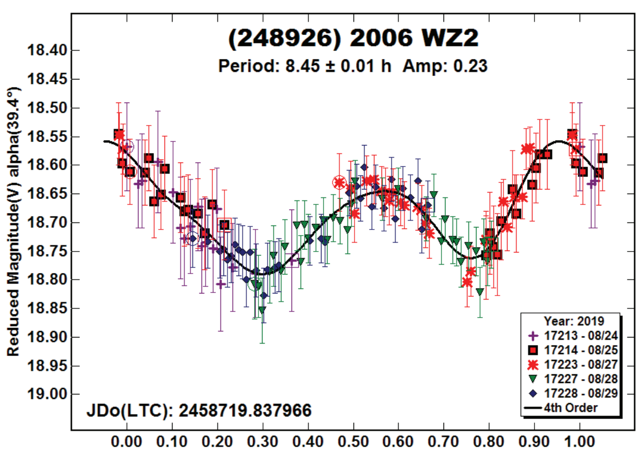
The unusual shape of the lightcurve and lack of double coverage of all segments for 2001 XT30 puts some doubt in our period of 17.95 h. No other solution provided a plausible fit to the data.





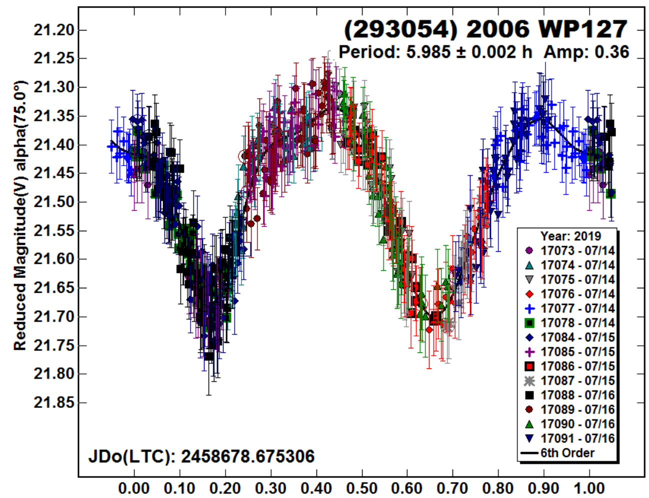

(173561) 2000 YV137, (248926) 2006 WZ2. There were no previous rotation period listings in the LCDB for either of these NEAs. The estimated diameter of 2000 YV137 is only 680 m but 2006 WZ2 is almost double that at 1300 m.



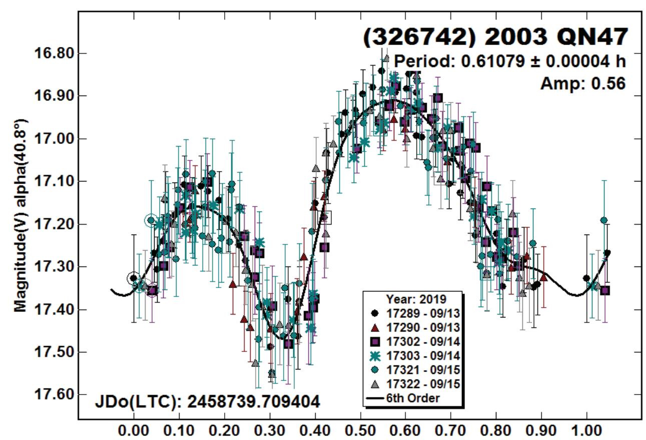

(293054) 2006 WP127. Behrend (2015) reported a period of 12 h for this 650-m asteroid. However, it's rated only U = 1 (probably wrong) in the LCDB.

We observed it on three nights in 2019 July when the phase angle was ~75°. This can be problematic because of deep shadowing effects on the lightcurve. More so, the period is very close to one-quarter of an Earth day. Even so, we believe our solution to be secure.

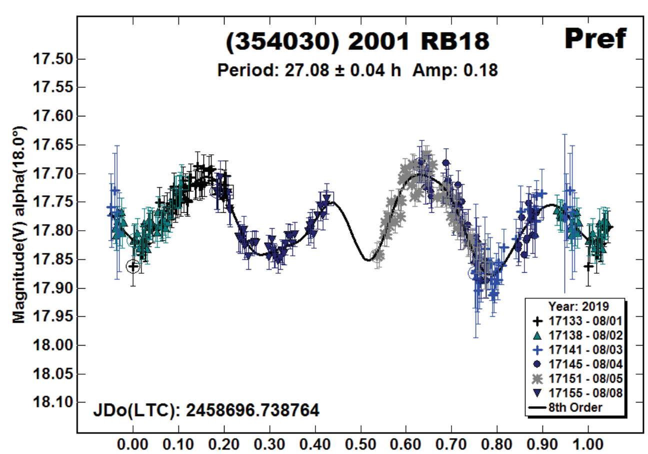



(326742) 2003 QN47, (354030) 2001 RB18, (405212) 2003 QC1, (429733) 2011 LX10. There were no rotation periods given in the LCDB for these four asteroids. The estimated diameters are, respectively, 750 m, 600 m, 750 m, and 1500 m.

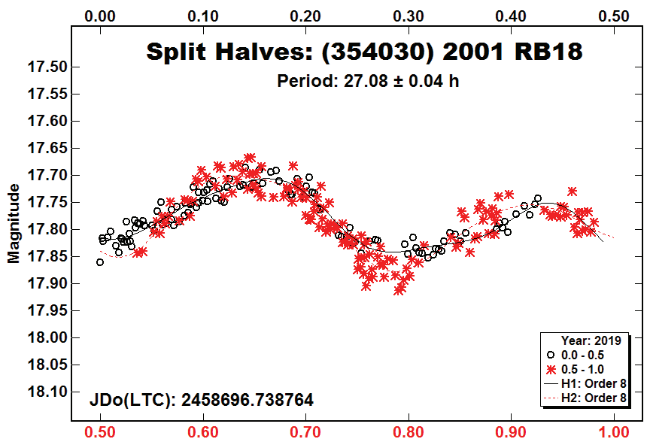
2003 QN47 is a super-fast rotator with a period of about 36.6 minutes. The unusual shape may be due in part to shadowing effects at the large phase angle. The period is a bit unexpected given the size. Of all entries rated U ≥ 2– in the LCDB, only 14 have $0.2 < D < 1.0$ km and $0 < P < 1.0$ h.

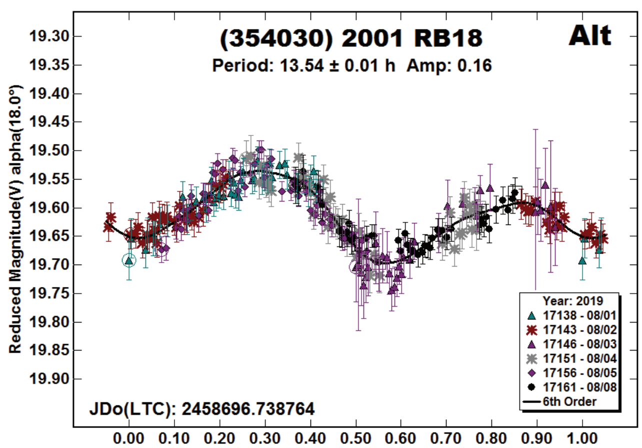


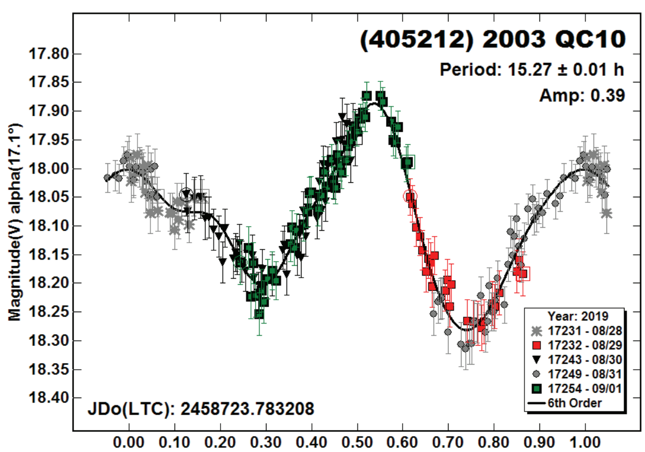

Initial analysis indicated a period of about 13.5 h for 2001 RB18, but the period spectrum showed a nearly as strong solution at 27 h.



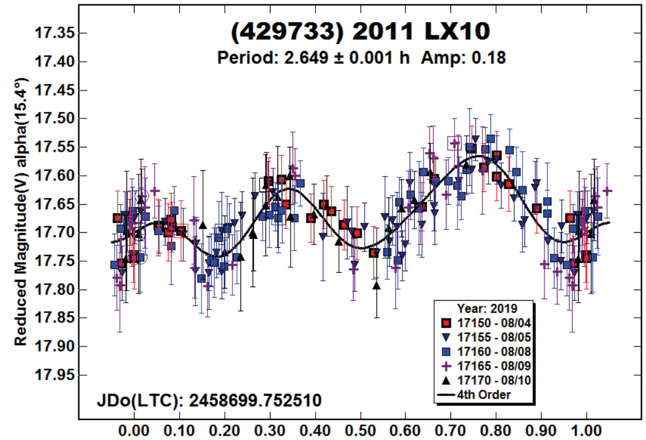
While writing this paper, Pravec et al. (2019) reported that observations by Don Pray indicated that the longer period was preferred. Pravec's period was 26.755 h. The difference is probably due to the longer date range for the Pravec data set. The CS3 data were reanalyzed and the split-halves plot seemed to indicate that the longer period should be preferred. However, our solution of 13.54 h cannot be formally excluded and so our result is considered ambiguous.



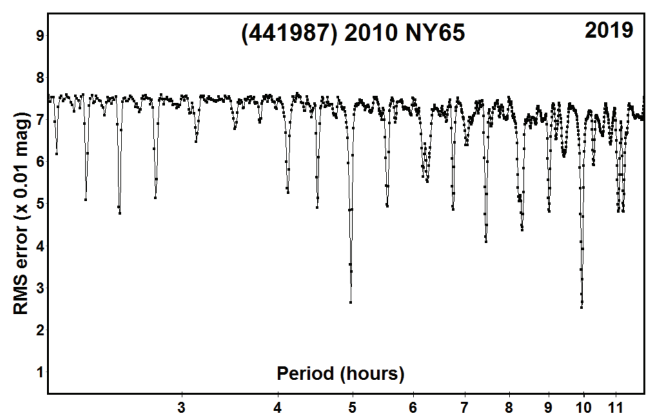

The trimodal shape of the lightcurve for 2011 LX10 is not uncommon at low amplitudes and phase angles (Harris et al., 2014).

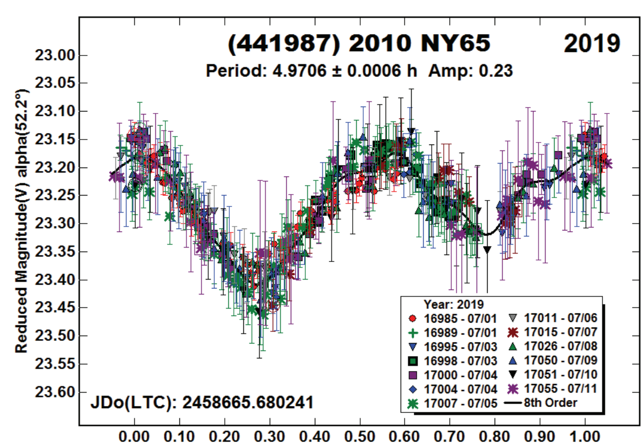


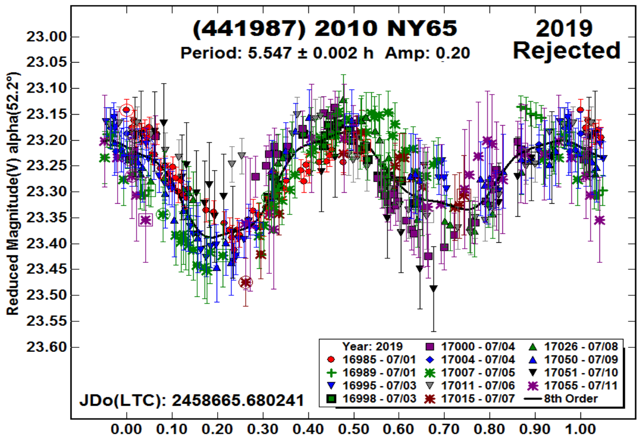

(441987) 2010 NY65. Among the data sets from 2016-2019, the one from 2019 had the most data points and covered a substantially larger range of dates. This was important because previous efforts to find a secure period were suspect.

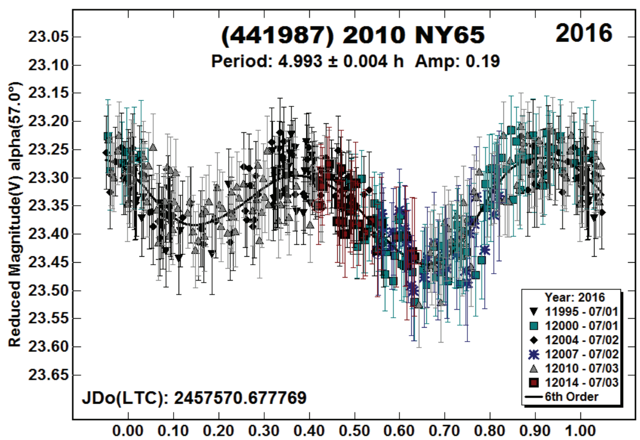
Warner (2016b; 2017) reported a period of about 4.97 h. After we obtained data in 2018 (Warner and Stephens, 2019a), a solution near 5.5 h was found. This prompted another look at the data from 2016 and 2017 and solutions near 5.5 h could be found but they were not secure.

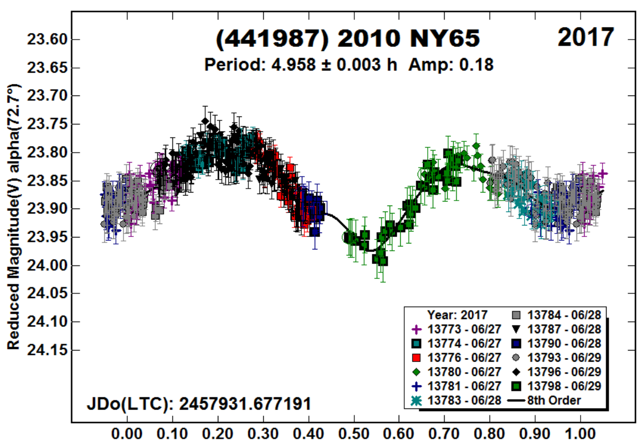
From the 2019 data, a secure solution of 4.9706 h was found. The period spectrum showed a significantly weaker solution near the previously adopted longer period of 5.5 h. The fit to that longer period ("Rejected") is clearly wrong and so we again reviewed the data from 2016-2018. The results were similar (4.958 h to 4.99 h).

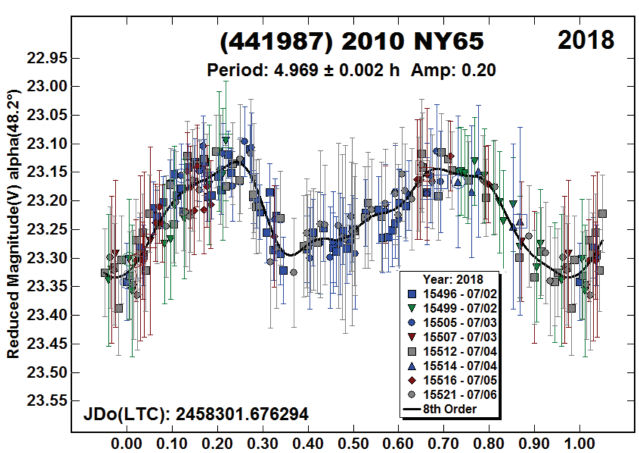




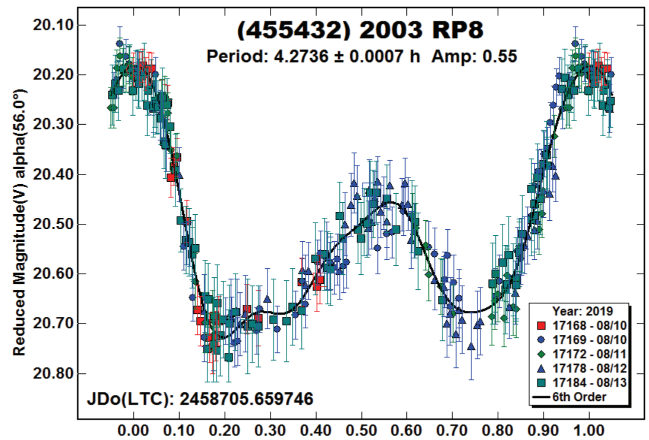



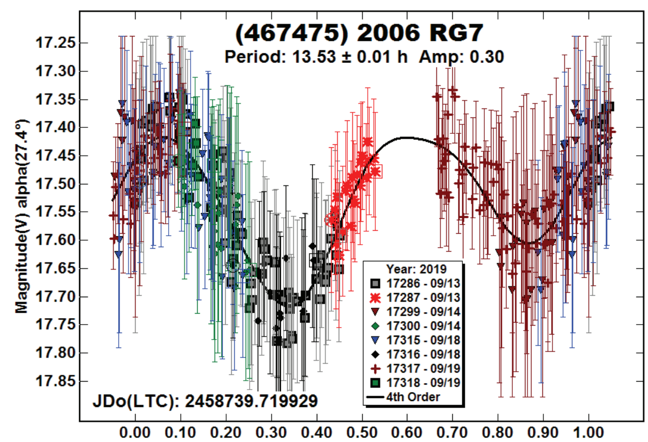



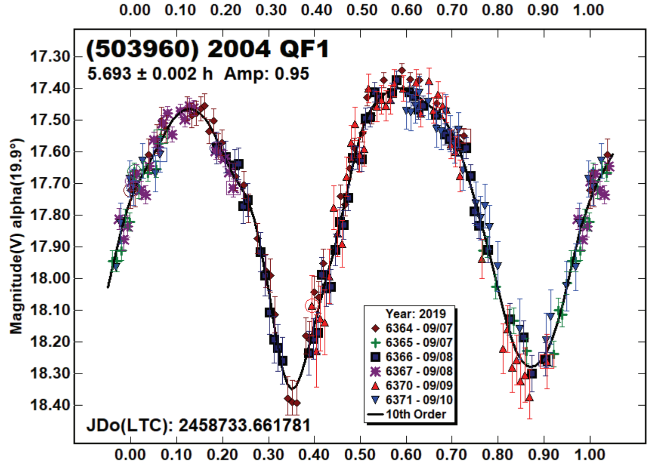

(455432) 2003 RP8, (467475) 2006 RG7, (503960) 2004 QF1. There were no previous rotation period listings in the LCDB for these three NEAs with diameters of 680 m, 520 m, and 650 m, respectively. For 2003 RP8, the solution is bimodal but highly asymmetrical. This may be due to shadowing effects at the large phase angle.

Despite the large error bars, we were able to find a mostly reliable solution for 2006 RG7. The SNR was lower than we'd expect for V ~17.5; it's possible that exposures of only 120 s and a full moon had something to do with the lower quality.

On the other hand, the data for 2004 QF1 are of much better quality even though a waxing gibbous moon (0.59 – 0.85 lit) was in the sky. Fortunately it was about 75° away.

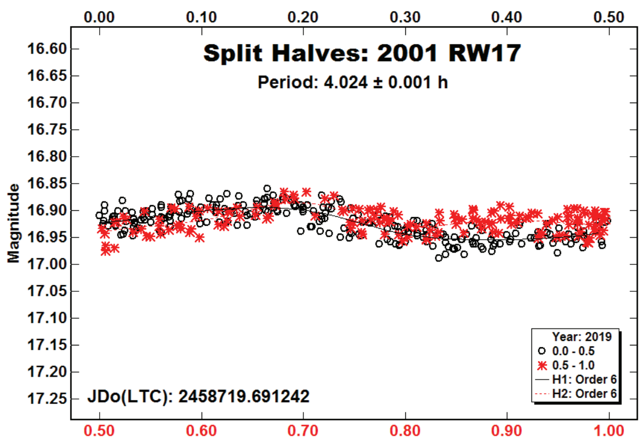


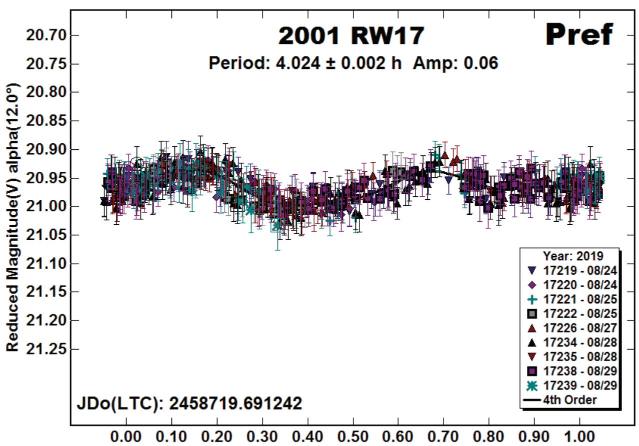



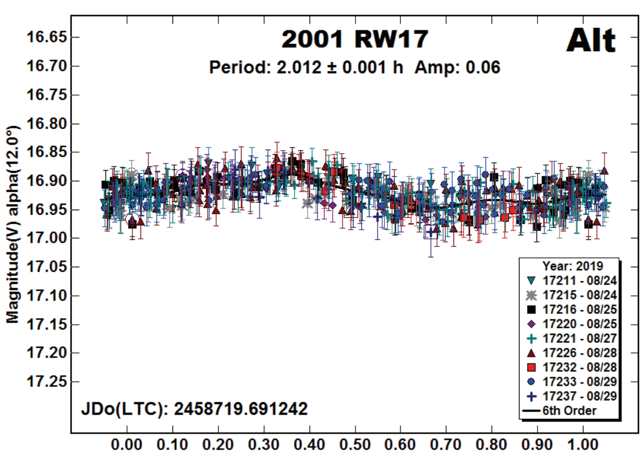



2001 RW17. There were no previous period listings in the LCDB for 2001 RW17, which has an estimated diameter of 260 m. The low amplitude and low phase angle made a monomodal and bimodal (or higher) lightcurve possible (Harris et al., 2014). We assumed that the lightcurve would not be more complex than bimodal.

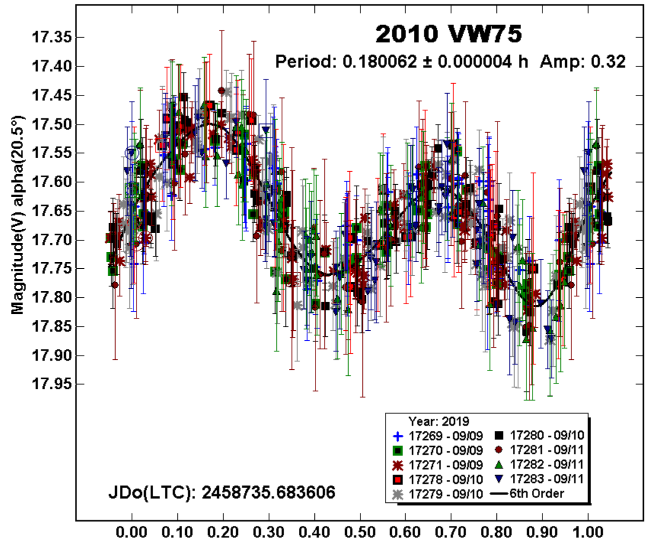
The bimodal solution of 4.024 h had nearly complete coverage, which removes some doubt about a *fit by exclusion*. This is where the Fourier analysis finds a local rather than global RMS minimum by reducing the number of overlapping data points. The split-halves plot for 4.024 h had just enough asymmetry for us to adopt the longer bimodal solution. However, neither can be formally excluded. Future observations when, hopefully, the lightcurve amplitude is larger, may resolve the ambiguity.



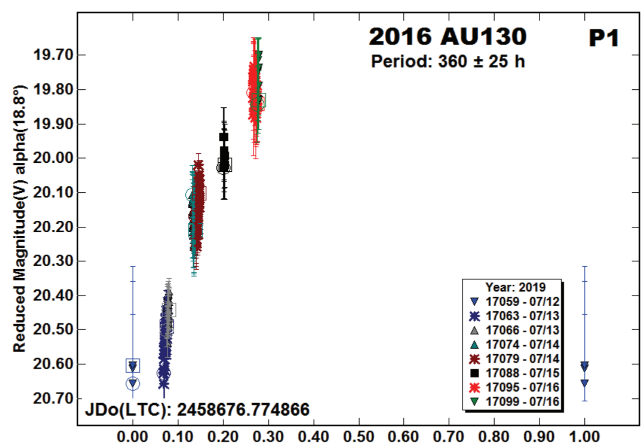



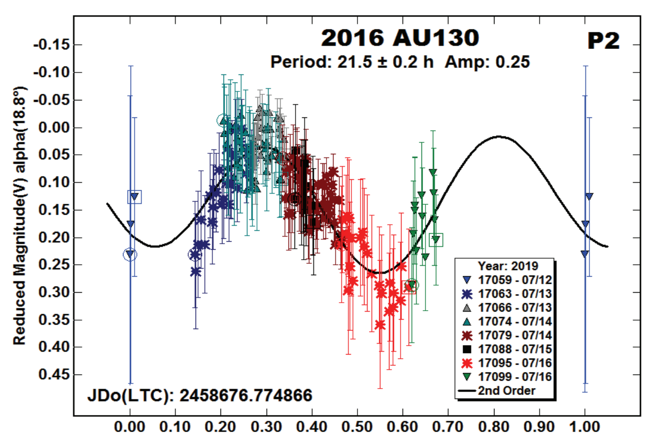




2010 VW75. Based on the LCDB as of 2019 October 8, this appears to be the first reported lightcurve analysis result for this 130-m asteroid that has a rotation period of only 10.8 min.



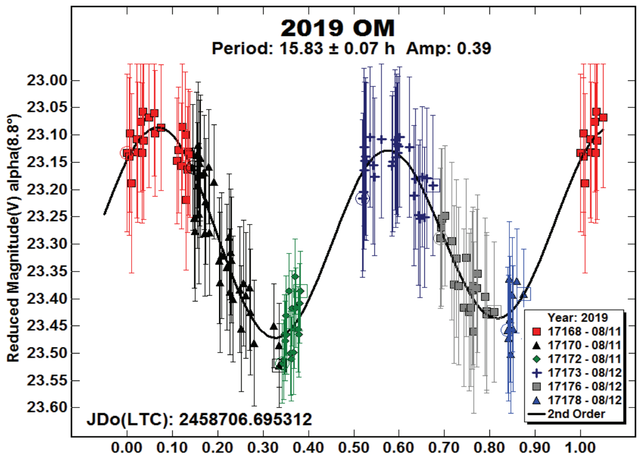

2016 AU130. This 540-m NEA could be observed for only a short period in 2019 July. Bad luck had that it appears to have a very long period. The adopted period of 360 h is based on the assumption that the data went from a minimum to a maximum of a bimodal lightcurve. Further assuming a symmetrical shape, the rise from minimum to maximum would be about 0.25 of the adopted period. A half-period solution supported our result.

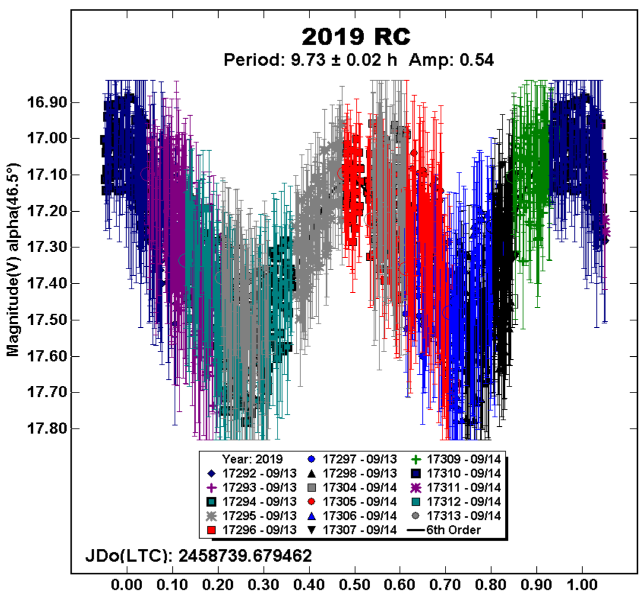


The individual nights show trends that indicated a somewhat long second period. Our dual-period search with *MPO Canopus* found a solution of about 21 h where the amplitude was large enough to overcome the large error bars. Both periods are suspect but, if real, could be due to a satellite or be the dominant periods of tumbling.

2019 OM, 2019 RC. There were no previous LCDB listings for either asteroid. The diameters are 90 m and 130 m, respectively.



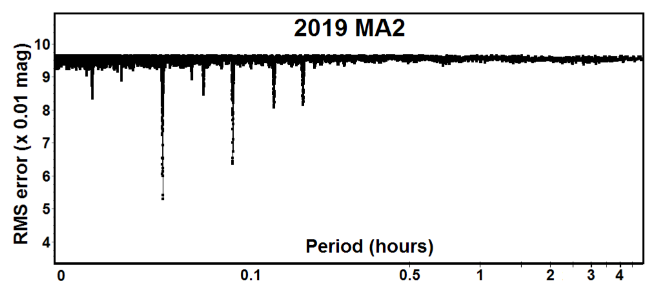



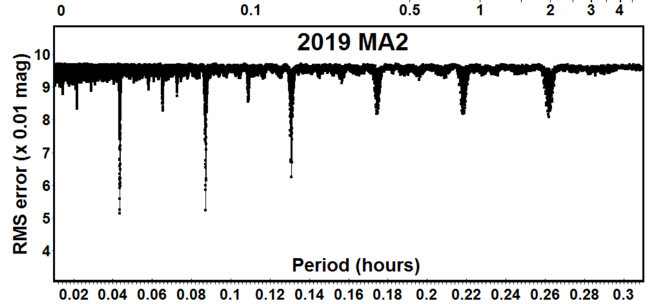

2019 MA2. The estimated diameter is only 490 m (some estimates are > 1.5 km). On first look at the raw data for each night, the plots looked like random, noisy data points. However, in some cases, there is something to be found by looking at very short periods with very high precision.

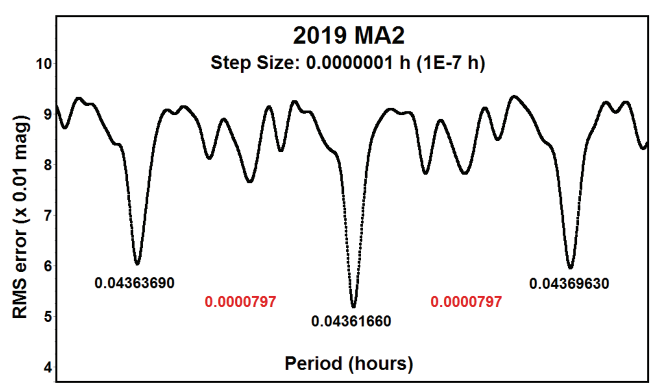
Using some noise filtering and binning data points led to a period of just over 2 minutes (0.0436166 h, 0.27 mag)! If this is true, it makes 2019 MA2 an extraordinary object, as seen by its location in the frequency-diameter plot from the LCDB. Such an object would have to be strength-bound or, if a rubble pile, have an extreme density. Given the extraordinary claim, we asked Alan Harris (formerly JPL, now MoreData!) to comment on the finding. We offer his response nearly in full.

> *Density can't be important; it would have to [be] several thousand gm/cc to be held together by gravity. But strength is no problem. As has been pointed out by Dan Scheeres and others, the strength needed to hold a rock together at such a spin rate is modest, so there is nothing un-physical about a rock that size spinning at that rate; it's just uncommon. I have said many times in meetings and such that the fact that that part of the spin-diameter plot* [seen below] *is mostly empty doesn't reflect [the] impossibility of ordinary rocks being there; it's just that nature doesn't work that way for the majority of bodies, i.e., they're mostly strengthless rubble piles. Exceptions are not prohibited, they're just rare.*
>
> *All that being said, your [solution] is only marginal, for the reason (as I've also said frequently) that if you search the period spectrum down to such short periods, the number of possible independent solution frequencies becomes very large, and seeing 2 or 3 sigma apparent solutions is expected and may be just noise – or not. So I'd go with the solution you plot […] but give it at most a U = 2 rating, maybe even 2–. Including a noise-frequency spectrum to show level of uniqueness would be good.*

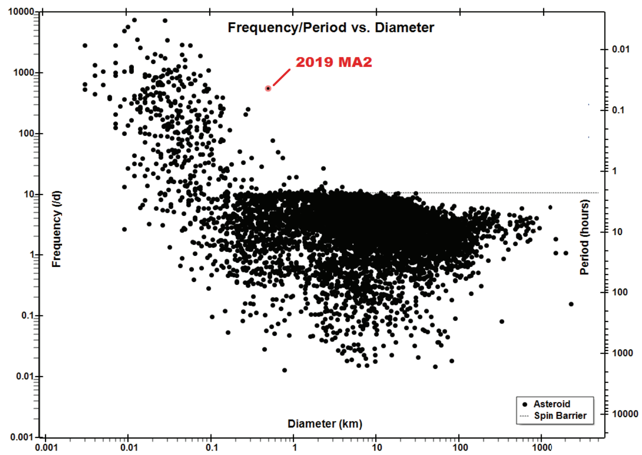
We searched several ranges that covered 0.01 h to 100 h. *Based on our data set and analysis*, it appears that there is very little or no chance for a solution of $P > 0.05$ h. The first period spectrum shown here covers a range of 0.001 h to 5 h. The second shows a range of 0.02 h to 0.3 h and concentrates on the extremely short period section. The third period spectrum shows a very narrow range centered on the adopted period of 0.04361660 h and the local minimums on either side that could not be seen in the first two spectra.

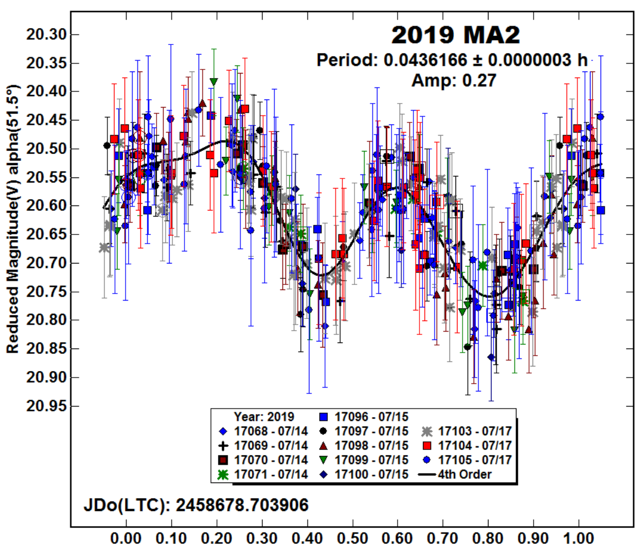


The third spectrum shows some of what Harris meant by the large number of independent solutions. The periods for the two most prominent "sidebands" differ from the adopted period by 0.0000797 h. Even if we tripled our period error to 1E-6 h, the sidebands are about 80-sigma removed from the best period. We used the high period precision (3E-7 h) because it wasn't until the search step size reached 1E-7 h that the error was more than one unit in the last decimal place.




A search of the Internet and a full text search on the ADS found no reported rotation period. If there are sufficient data for period analysis available, we would be grateful to get those data and try to confirm our result with an independent data set. Otherwise, it will be a long wait for more data. The asteroid returns in 2023 but will be V~19.3. It's not until 2046 July (V~15.9) that those with small ($D \leq 1.0$ m) telescopes have an opportunity.

## Acknowledgements

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| Number | Name | 20xx mm/dd# | Phase | $L_{PAB}$ | $B_{PAB}$ | Period(h) | P.E. | Amp | A.E. |
|---|---|---|---|---|---|---|---|---|---|
| 1620 | Geographos | 09/24-09/30 | 48.5,46.3 | 331 | 11 | 5.2201 | 0.0002 | 1.91 | 0.01 |
| 1865 | Cerberus | 07/08-07/13 | 58.9,55.4 | 334 | 32 | 6.8018 | 0.0006 | 1.58 | 0.03 |
| 2059 | Baboquivari | 07/16-08/23 | *21.2,15.8 | 322 | 17 | 129.52 | 0.04 | 0.45 | 0.02 |
| | P2/NPAR | | | | | 19.199 | 0.003 | 0.08 | 0.02 |
| 2100 | Ra-Shalom | 08/16-08/23 | 52.0,45.9 | 3 | 9 | 19.792 | 0.004 | 0.50 | 0.03 |
| 5786 | Talos | 08/02-08/09 | 50.0,33.3 | 339 | 21 | 23.60 | 0.05 | 0.30 | 0.05 |
| 18172 | 2000 QL7 | 08/24-08/27 | 31.5,31.3 | 14 | 9 | 2.509 | 0.001 | 0.14 | 0.02 |
| 85709 | 1998 SG36 | 09/23-09/25 | 3.2,2.0 | 4 | 3 | 3.573 | 0.004 | 0.14 | 0.03 |
| 90403 | 2003 YE45 | 18/12/28-01/22 | *15.8,18.3 | 111 | -1 | 500 | 10 | 0.81 | 0.05 |
| | P2 | | | | | 2.7602 | 0.0004 | 0.05 | 0.01 |
| 105140 | 2000 NL10 | 08/13-08/15 | 62.2,60.3 | 292 | 59 | 6.920 | 0.005 | 0.43 | 0.03 |
| 152754 | 1999 GS6 | 08/09-08/14 | 12.4,6.6 | 326 | 1 | 8.021 | 0.008 | 0.20 | 0.03 |
| 153842 | 2001 XT30 | 07/08-07/13 | 17.5,15.3 | 303 | 7 | 17.95 | 0.02 | 0.25 | 0.02 |
| 173561 | 2000 YV137 | 08/01-08/03 | 64.9,66.0 | 276 | 30 | 2.722 | 0.001 | 0.26 | 0.02 |
| 248926 | 2006 WZ2 | 08/24-08/29 | 39.4,38.8 | 11 | -3 | 8.45 | 0.01 | 0.23 | 0.03 |
| 293054 | 2006 WP127 | 07/14-07/16 | 74.0,61.0 | 291 | 39 | 5.985 | 0.002 | 0.36 | 0.03 |
| 326742 | 2003 QN47 | 09/13-09/15 | 40.8,39.7 | 17 | 16 | 0.61079 | 0.00004 | 0.56 | 0.05 |
| 354030 | 2001 RB18 | 08/01-08/08 | 18.0,17.0 | 321 | 10 | 27.08 | 0.04 | 0.18 | 0.02 |
| | Alternate | | | | | 13.54 | 0.01 | 0.16 | 0.02 |
| 405212 | 2003 QC10 | 08/28-09/01 | 17.1,13.6 | 350 | -3 | 15.27 | 0.01 | 0.39 | 0.03 |
| 429733 | 2011 LX10 | 08/04-08/10 | 15.4,13.9 | 323 | 17 | 2.649 | 0.001 | 0.18 | 0.02 |
| 441987 | 2010 NY65 | 16/07/01-07/03 | 56.6,51.9 | 259 | 21 | 4.993 | 0.004 | 0.19 | 0.03 |
| | Revised | 17/06/27-06/29 | 71.2,58.3 | 257 | 29 | 4.958 | 0.003 | 0.18 | 0.02 |
| | Revised | 18/07/02-07/06 | 48.2,43.3 | 268 | 22 | 4.969 | 0.002 | 0.20 | 0.03 |
| | Revised | 19/07/01-07/11 | 52.1,41.5 | 268 | 21 | 4.9706 | 0.0006 | 0.23 | 0.02 |
| 455432 | 2003 RP8 | 08/10-08/13 | 56.1,59.6 | 306 | 36 | 4.2736 | 0.0007 | 0.55 | 0.03 |
| 467475 | 2006 RG7 | 09/13-09/19 | 27.4,23.2 | 12 | 2 | 13.53 | 0.01 | 0.30 | 0.05 |
| 503960 | 2004 QF1 | 09/07-09/10 | 19.9,19.2 | 355 | 13 | 5.693 | 0.002 | 0.95 | 0.02 |
| | 2001 RW17 | 08/24-08/29 | 11.9,4.8 | 334 | 5 | 4.012 | 0.002 | 0.06 | 0.01 |
| | Alternate | | | | | 2.012 | 0.001 | 0.06 | 0.01 |
| | 2010 VW75 | 09/09-09/11 | 20.7,23.1 | 358 | 7 | 0.180062 | 0.000004 | 0.32 | 0.04 |
| | 2016 AU130 | 07/12-07/16 | 18.7,11.2 | 301 | 5 | 360 | 25 | 0.8 | 0.1 |
| | P2/NPAR | | | | | 21.5 | 0.2 | 0.25 | 0.04 |
| | 2019 OM | 08/11-08/11 | 8.7 | 318 | 5 | 15.83 | 0.07 | 0.39 | 0.05 |
| | 2019 RC | 09/13-09/14 | 46.4,46.2 | 12 | 14 | 9.73 | 0.02 | 0.54 | 0.05 |
| | 2019 MA2 | 07/14-07/17 | 52.6,79.9 | 259 | 18 | 0.0436166 | 0.0000003 | 0.27 | 0.04 |

Table II. Observing circumstances. # The year is 2019 except when a two digit year is at the start. The year is for the first date and may be the following year for the last date. The phase angle (α) is given at the start and end of each date range. If there is an asterisk before the first phase value, the phase angle reached a maximum or minimum during the period. $L_{PAB}$ and $B_{PAB}$ are, respectively the average phase angle bisector longitude and latitude (see Harris et al.,1984). Some asteroids have more than one line. If the additional lines have "Alternate", the result is ambiguous. The first line is the period adopted for this work and the additional lines give alternate solutions. If "P2" is the second line, it is a secondary period that is due to a confirmed or suspected satellite. "NPAR" indicates that the line has the second period of a tumbling asteroid. If P2 and NPAR both appear, it's not possible to confirm which is correct. "Revised" indicates a new period using a previous data set that is based on the period adopted in this work.


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## LIGHTCURVES AND ROTATION PERIODS OF 33 POLYHYMNIA, 206 HERSILIA, 395 DELIA, 400 DUCROSA, 900 ROSALINDE, AND 1066 LOBELIA

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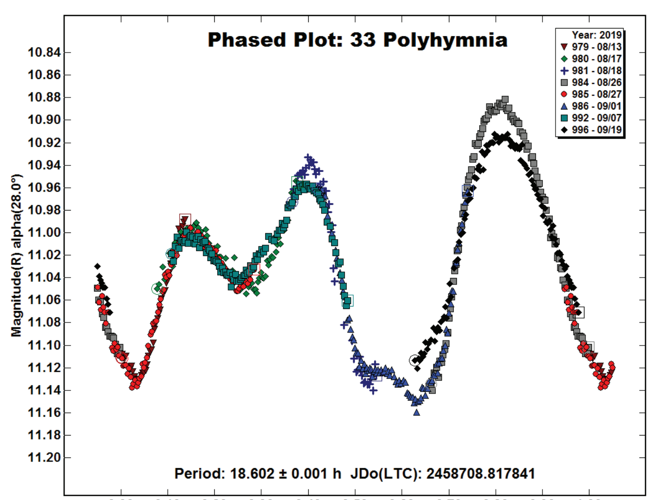
Synodic rotation periods and amplitudes are found for 33 Polyhymnia: 18.602 ± 0.001 h, 0.25 ± 0.02 mag; 206 Hersilia: 11.113 ± 0.002 h, 0.17 ± 0.01 mag; 395 Delia: 19.681 ± 0.001 h, 0.16 ± 0.02 mag; 400 Ducrosa: 6.8678 ± 0.0001 h, 0.57 ± 0.03 mag; 900 Rosalinde: 16.689 ± 0.001 h, 0.29 ± 0.02 mag; and 1066 Lobelia: 5.0176 ± 0.0001h, 0.42 ± 0.02 mag.

Observations to obtain the data used in this paper were made at the Organ Mesa Observatory with a 0.35 meter Meade LX200 GPS Schmidt-Cassegrain (SCT) and SBIG STL-1001E CCD. Exposures were 60 seconds, unguided, with an R filter for the very bright 33 Polyhymnia and clear filter for all other targets. Photometric measurement and lightcurve construction were with *MPO Canopus* software. To reduce the number of points on the lightcurve and make them easier to read, data points have been binned in sets of 3 with a maximum time difference of 5 minutes.

33 Polyhymnia. Six previously published periods in the Asteroid Lightcurve Data Base (LCDB; Warner et al., 2009) all lie in the range from 18.601 to 18.610 hours. New observations on eight nights 2019 Aug 13 to Sep 19 provide a good fit to a lightcurve with three unequal maxima and minima per cycle phased to 18.602 hours. This is within the range of previous determinations. The lightcurve shows that the amplitude of 0.25 mag from Aug 13 to Sept 1 at phase angles 28 to 22 deg had decreased to 0.20 mag from Sept 7-19 at phase angles 20 to 15 deg. In this interval, the phases at which the maxima and minima occurred did not change perceptibly. This decrease of amplitude with phase angle is commonly found for many asteroids.




206 Hersilia. Previously published periods are by Shevchenko et al. (1992, 7.33 h), Willis (2004, 11.11 h), Behrend (2008, 11.135 h), and Behrend (2013, 11.122 h). New observations on six