

NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2018 JULY-SEPTEMBER

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Lightcurves for 45 Near-Earth asteroids (NEAs) obtained at the Center for Solar System Studies (CS3) from 2018 July-September were analyzed for rotation period and signs of satellites or tumbling. NEA 13553 Massakikoyama appears to be in non-principal axis rotation, i.e., tumbling. 2011 UA ($D = 0.6$ km) is a super-fast rotator with a period of 0.316391 ± 0.000007 h. The period and size place it well above the spin barrier. The period for 2018 RQ2 is multiply ambiguous, with possible solutions of 4.28 h or 5.17 h (monomodal lightcurve) and 8.58 h or 10.60 h (bimodal lightcurve). 2018 KE3 may be a binary asteroid.

CCD photometric observations of 45 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies (CS3) from 2018 July-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
0.35-m f/11 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. Catalog magnitudes were taken from the APASS (Henden et al., 2009) or CMC-15 (Munos, 2017) catalogs.

The nightly zero points for the APASS and CMC-15 catalogs are generally consistent to about ± 0.05 mag or better, but occasionally reach >0.1 mag. There is a systematic offset between the two catalogs and so, whenever possible, the same catalog is used for all observations of a given asteroid. Period analysis is done with

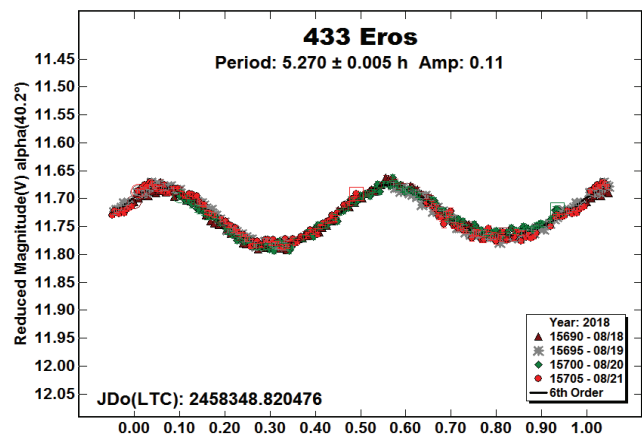
MPO Canopus, which implements the FALC algorithm by Harris (Harris et al., 1989). The same algorithm is used in an iterative fashion if it appears there is more than one period. This works well for binary asteroids but not for tumbling asteroids.

In the plots below, the “Reduced Magnitude” is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distances by applying $-5 \cdot \log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. Unless otherwise stated, the magnitudes were normalized to the phase angle in parentheses using $G = 0.15$. The X-axis is the rotational phase, ranging 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*.

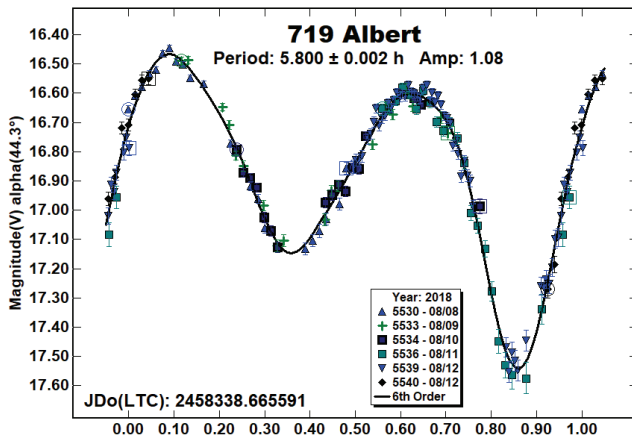
For the sake of brevity, only some of the previously reported results may be referenced in the discussions on a specific asteroid. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner et al., 2009). The on-line version at <http://www.minorplanet.info/lightcurvedatabase.html> allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files of the main LCDB tables, including the references with bibcode, is also available for download. Readers are strongly encouraged, when possible, to cross-check with the original references listed in the LCDB.

433 Eros. The rotation period of Eros had long been determined to be about 5.27 h by numerous observers prior to the visit of the NEAR-Shoemaker spacecraft, e.g., Warner (2017a). The data from 2018 were obtained to help find a more exact value for the change in rotation rate, if any, due to the YORP (Yarkovsky–O’Keefe–Radzievskii–Paddack) thermal effect (Rubincam, 2000).

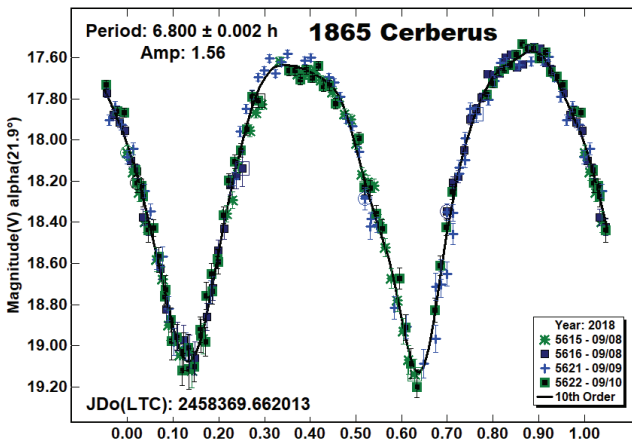


719 Albert. Recovered in 2001 after being lost for several decades, this 2.5 km NEA was observed by Pravec et al. (2001), who found a period of 5.8011 h. However, the 2001 observations were the last to be reported in the LCDB until the results given here.

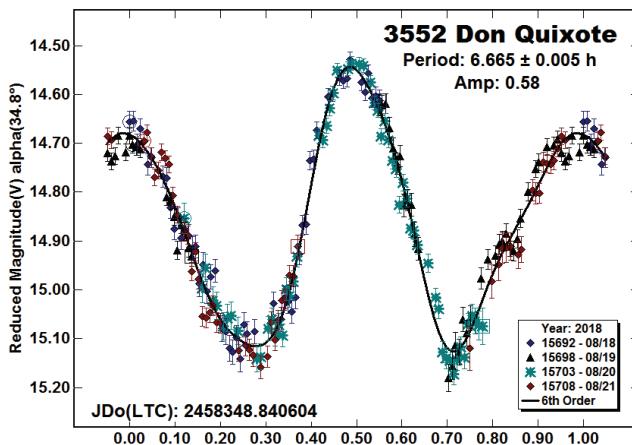
The amplitude in 2018 was 0.52 mag compared to 0.94 mag found by Pravec et al. (2001) at the time of maximum amplitude in their observations (2001 Aug 23). The phase angle bisector longitude (see Harris et al., 2004) was about 2° and the phase angle was 46° . In 2018, the values were 257° and 17° , respectively. From this a rough estimate of the longitude for the asteroid's pole is 250° (or $70^\circ \pm 20^\circ$).



1865 Cerberus. Among some of the previous synodic period results for Cerebus are Pravec et al. (2008; 6.8039 h) and Skiff (2012; 6.804 h). Our results are in good agreement.

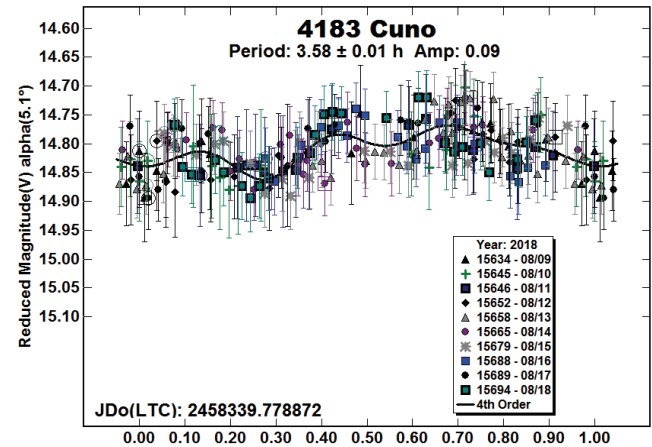


3552 Don Quixote. This NEA has an orbit that is very “comet-like” and it appears that it really is one. Mommert et al. (2018) reported seeing a tail in visible wavelengths for the first time. There were no obvious signs of cometary activity in our observations and the object did not appear “fuzzier” than nearby stars.

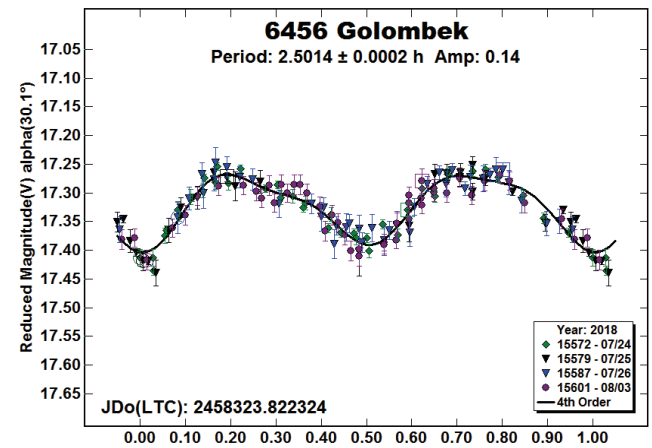


4183 Cuno. Pravec et al. (1997, 2000) reported a period of about 3.56 h. Warner (2015a) found a similar result. These earlier results were obtained when the lightcurve amplitude was at least 0.47 mag. In 2018, the amplitude was only 0.09 mag and the data errors

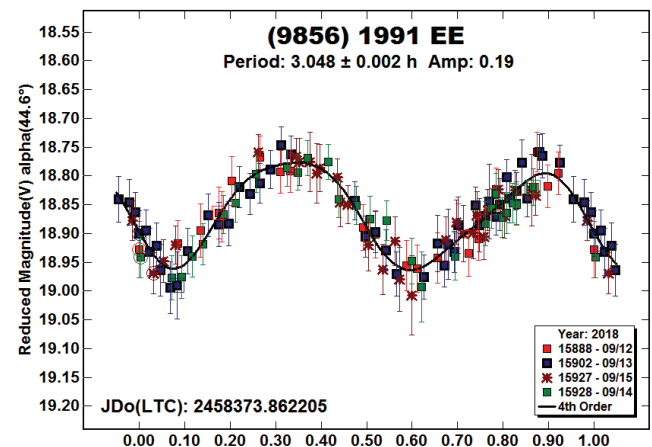
were almost the same level. As a result, there were several possible solutions. We forced a period near the earlier results and found 3.58 h.



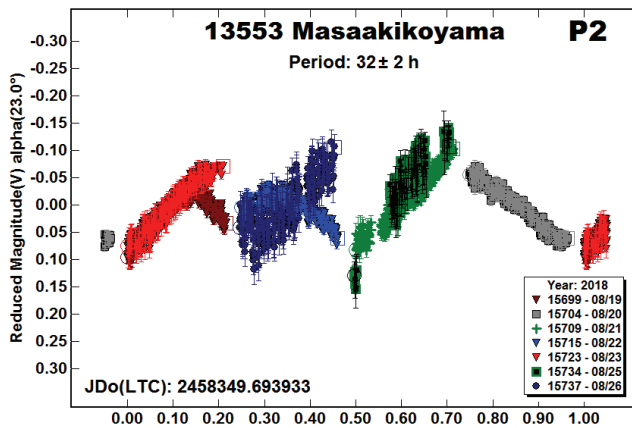
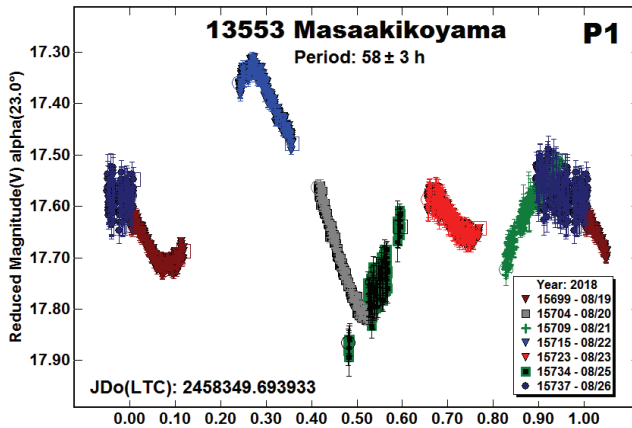
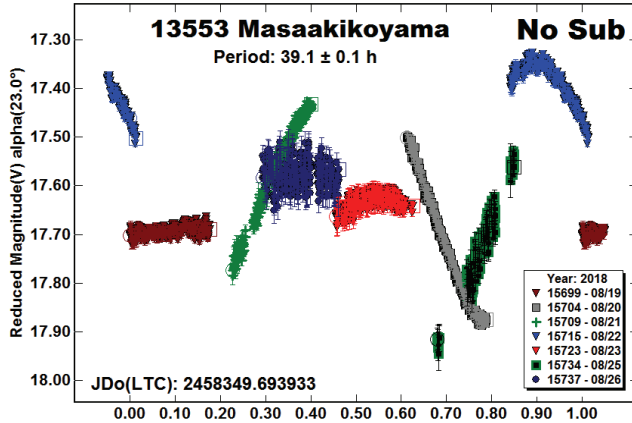
6456 Golombek. Previous results include Pravec et al. (2005, 2.5013 h; 2018, 2.5016 h). Our results are in good agreement.



(9856) 1991 EE. Wisniewski et al. (1997) reported $P = 3.045$ h for 1991 EE. Warner (2018) observed it in 2018 May and found $P = 3.0416$ h, $A = 0.28$ mag. We observed it again in September and found $P = 3.048$ h, $A = 0.19$ mag.

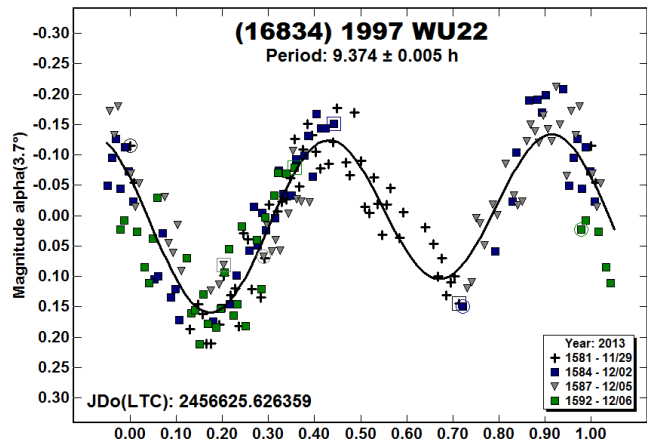
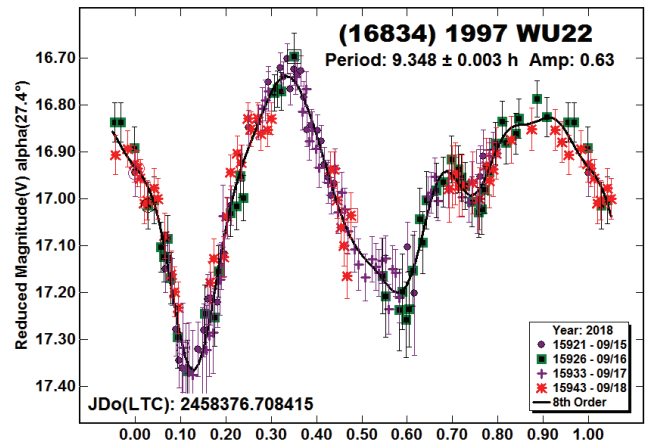


13553 Masaakikoyama. Pravec et al. (2005) found this to be a tumbler, i.e., in non-principal axis rotation. They found a dominant period at about 38 h. Our 2018 data confirm the tumbling state. The data set was insufficient to find the two rotation frequencies even with Pravec's custom software. *MPO Canopus* does not allow simultaneous dual period searches and so we provide two lightcurves, each phased to a period that dominated the period spectrum.

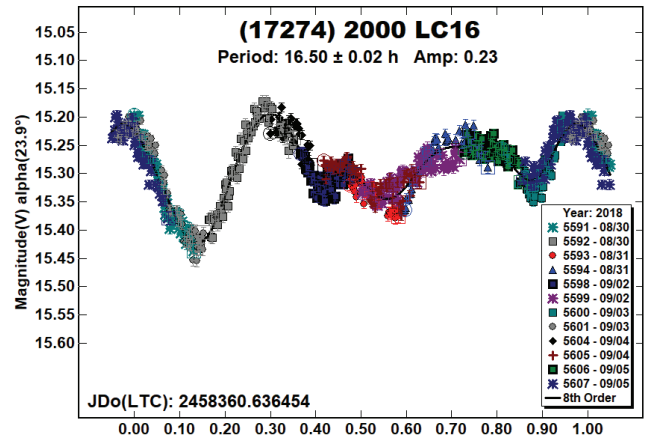


(16834) 1997 WU22. Earlier results include Pravec et al. (2000; 9.345 h), Stephens (2013; 9.374 h), and Warner (2017a; 9.343 h). The Stephens lightcurve is given here since it was not previously published except on the CS3 web site.

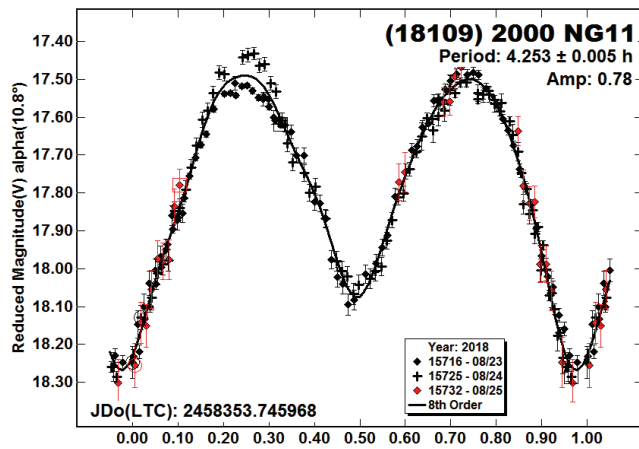
Our 2018 data led to a period of 9.348 h, which is within the formal errors of the previous results.



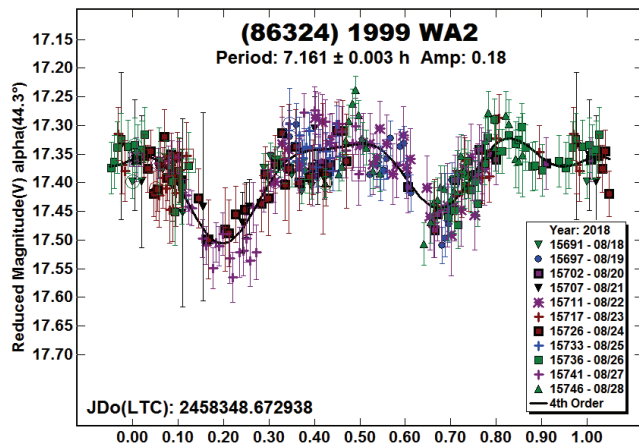
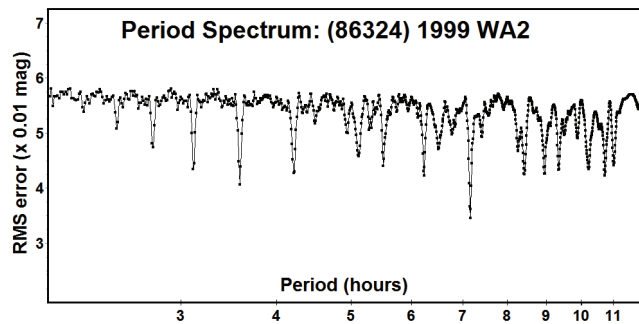
(17274) 2000 LC16. Our result of 16.50 ± 0.02 h agrees with that reported by Pravec et al. (2000). The amplitude of 0.23 mag is in a “gray area” between small amplitudes where multimodal lightcurves are easily possible and larger amplitude lightcurves where, at low phase angles, a bimodal lightcurve is virtually assured (Harris et al., 2014).



(18109) 2000 NG11. This is one of the relatively few NEAs observed by two recent Palomar Transient Factory groups: Waszczak et al. (2015) and Chang et al. (2016). They reported periods of, respectively, 4.258 h and 4.25 h. Previous dense lightcurve results include Pravec et al. (2000; $P = 4.2534$ h, $A = 1.13$ mag) and Warner (2014a; $P = 4.255$ h, $A = 0.89$ mag).

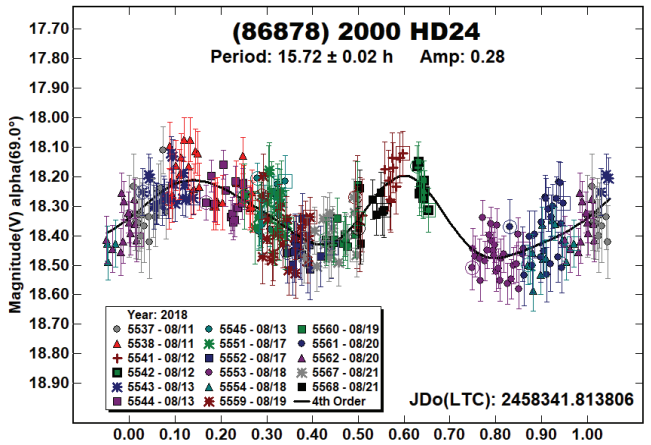
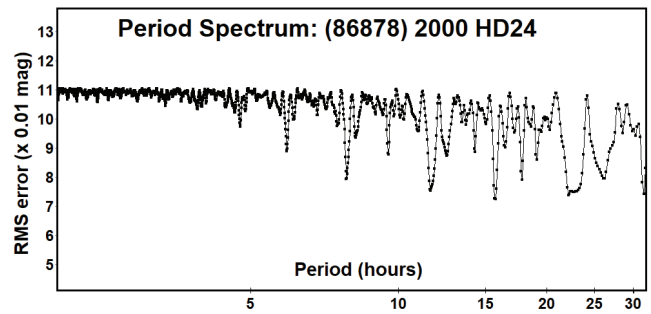


(86324) 1999 WA2. The period spectrum shows a strong preference for the adopted period of 7.161 h. The lightcurve shape is somewhat asymmetrical but, at larger phase angles, shadowing effects can likely explain some of the anomalies in the expected lightcurve shape.



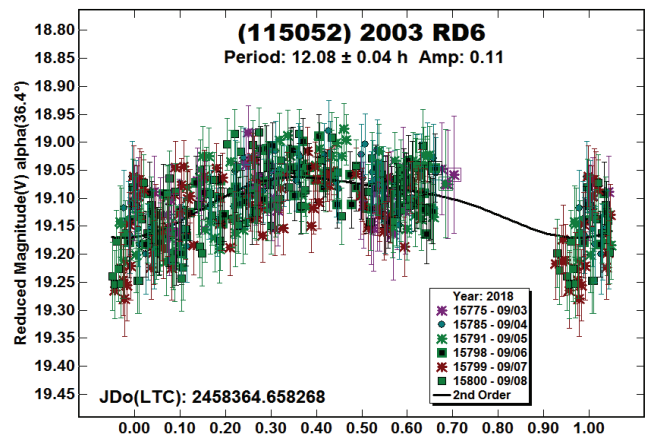
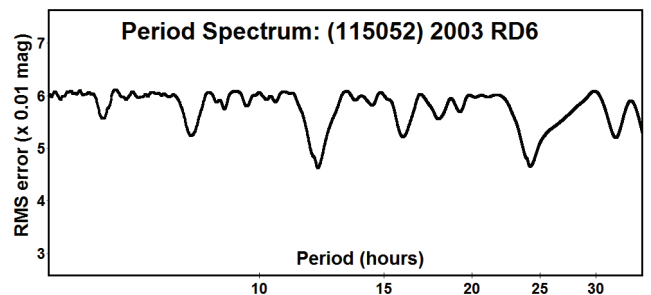
(86878) 2000 HD24. This 900-meter NEA was observed by Warner (2014b), who found a period of 23.1 ± 0.5 h. The 2018 data set was of higher-quality, but it was still not possible to get a precise period solution. Our result of $P = 15.72$ h represents the best fit in the period spectrum, which also includes a nearly equal RMS minimum at about 23 hours. The 2014 data set was reviewed; a reasonable fit of $P = 15.65$ h was found.

It's worth noting that the two periods are very close to an integer ratio of 3:2. This usually indicates a *rotational alias*, which is caused by a miscount of the actual number of rotations over the time span of the data. A rotational alias often occurs with nearly symmetrical lightcurves, where the “wrong half” of a lightcurve is matched to other half.

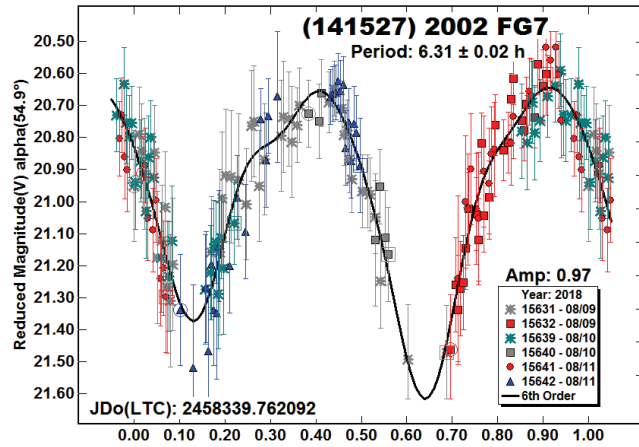


(115052) 2003 RD6. This appears to be the first reported rotation period for 2003 RD6. Unfortunately, it's an ambiguous one. The period spectrum favors two results: 12.08 h and 24.23 h. The lightcurve has been phased to the shorter period. Even a second-order fit for the longer period produced a Fourier model with an amplitude of several magnitudes.

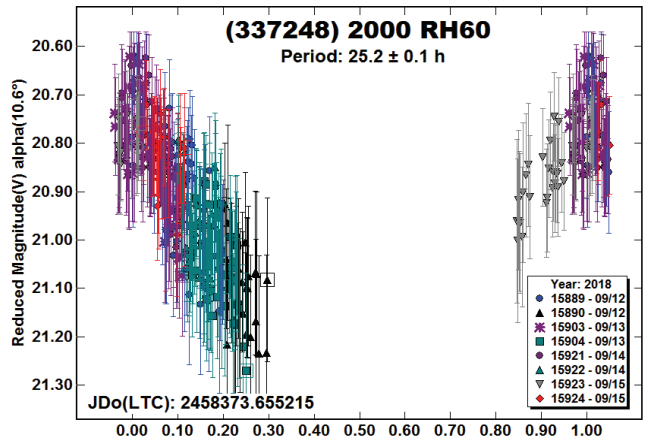
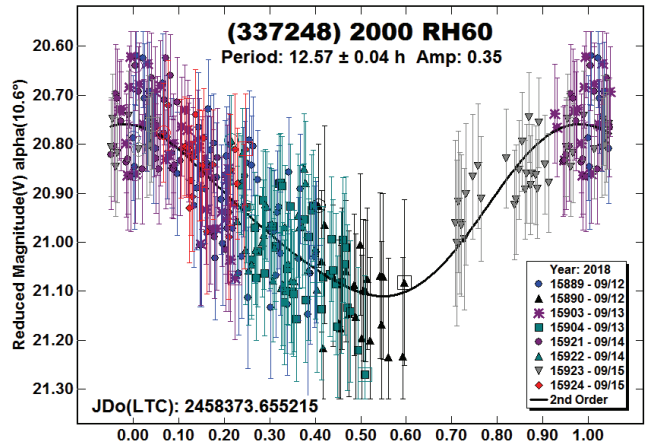
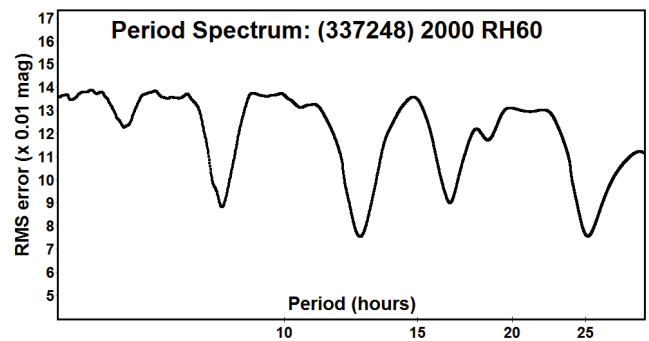
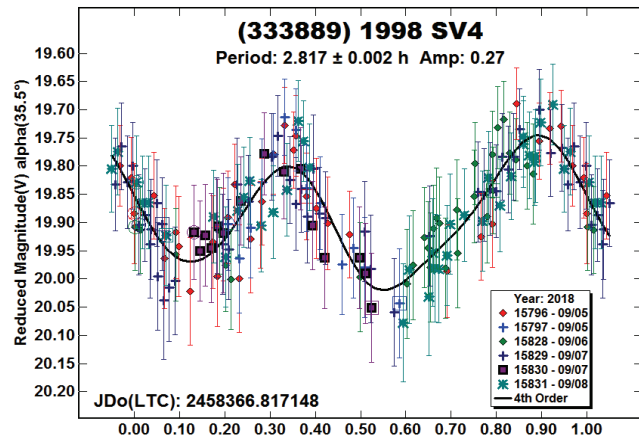
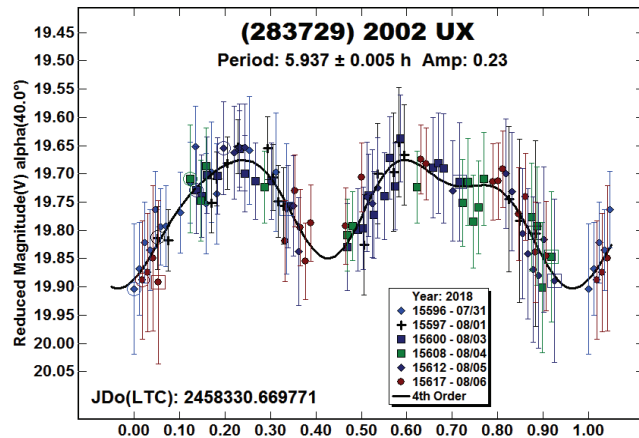
We adopt the shorter period for this paper, but the double period of 24.23 h should be given equal weight.



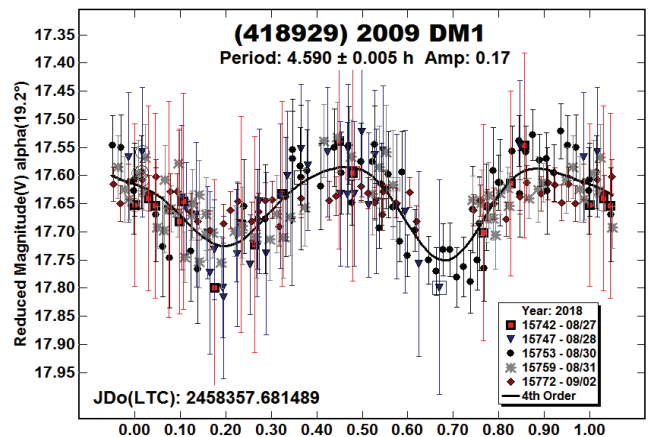
(141527) 2002 FG7. The phase angle longitude in 2018 differed from the one in 2015 (Warner, 2015b) by 175° , meaning that the 2018 view was of the opposite pole. The gap in coverage and only three nights of data in 2018 allowed only 0.02 h precision for the result. This is statistically the same as the earlier result of 6.306 h.



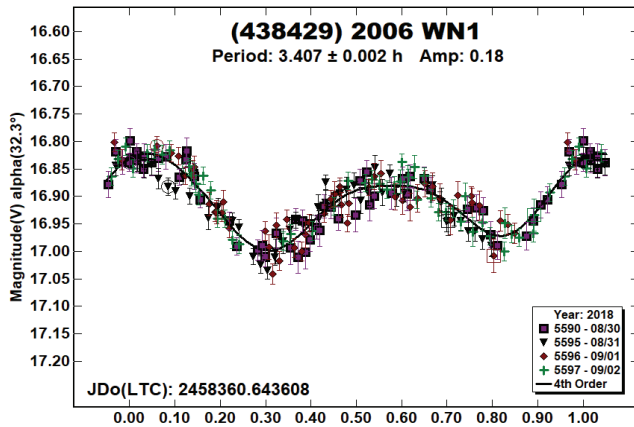
(283729) 2002 UX, (333889) 1998 SV4, (337248) 2000 RH60. These appear to be the first reported rotation periods for these three NEAs. The solutions for 2002 UX and 1998 SV4 are considered secure (at least $U = 2+$ in the LCDB). The solution for 2000 RH60 suffers the fate of being nearly commensurate with an Earth day. Despite this, we consider $P = 25.2$ h to be more likely correct than not because of the lightcurve amplitude and low phase angle (Harris et al., 2014).



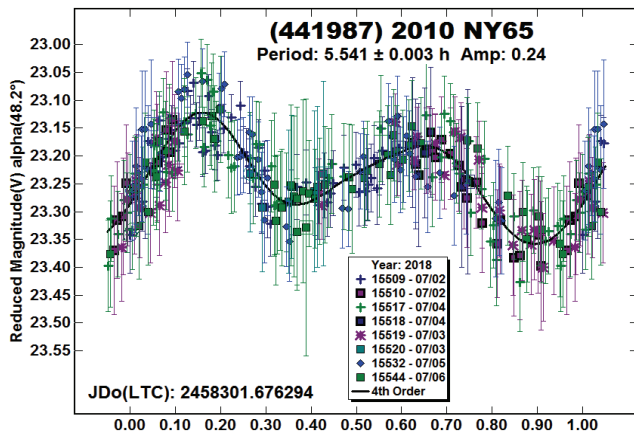
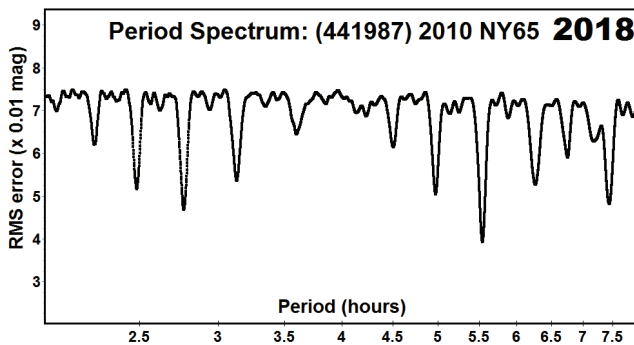
(418929) 2009 DM1. There were no previous rotation period entries in the LCDB. We consider the solution secure.



(438429) 2006 WN1. The LCDB had no previous entries of any kind for 2006 WN1.



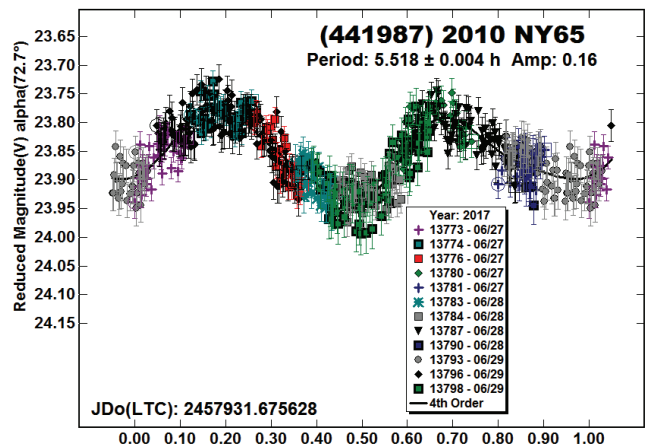
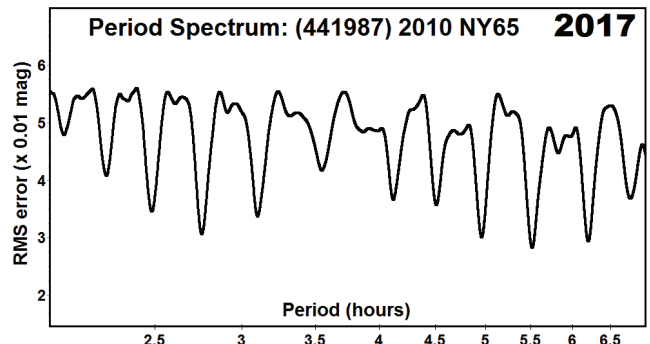
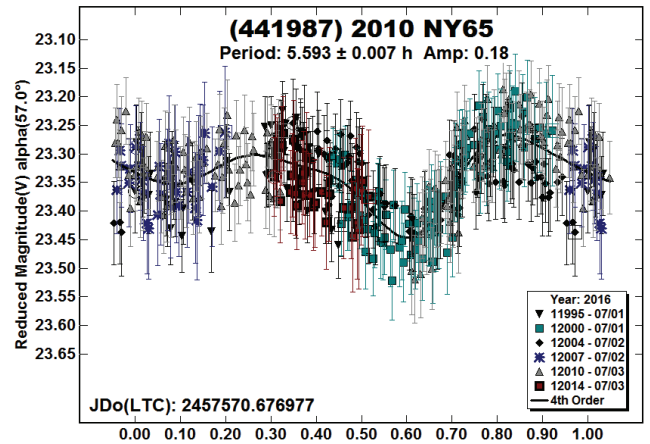
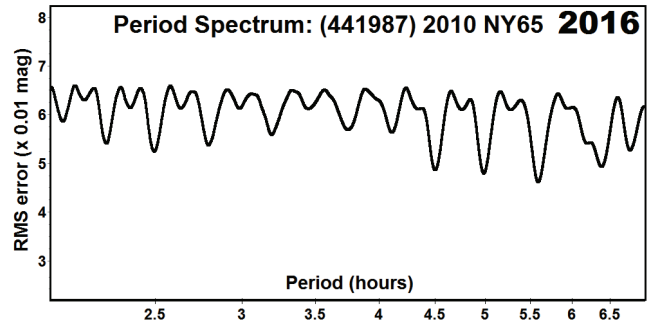
(441987) 2010 NY65. Two previous results are from Warner (2016b, 4.979 h; 2017b, 4.973 h). The period spectrum using the 2018 data strongly favors a period of 5.541 h. When forcing the data to a period near 4.97 h, there was a clear mismatch on two nights that could not be corrected by zero point adjustments.



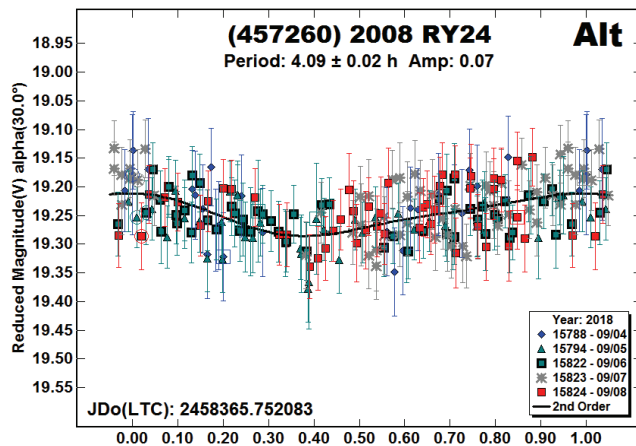
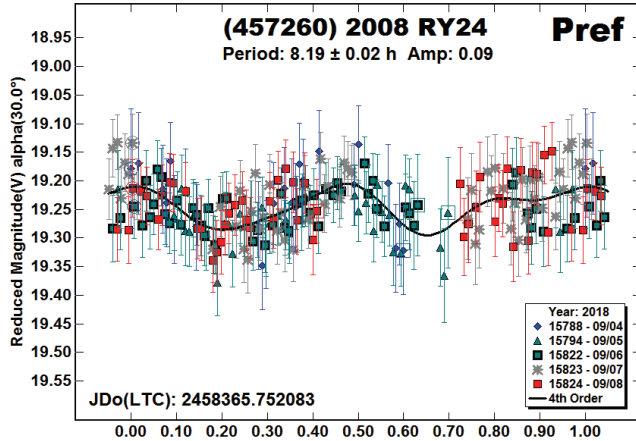
The two periods do not have a simple integer ratio, which helps eliminate a rotational alias. So does the strong asymmetry of the 2018 lightcurve. To see if the discrepancy in periods could be resolved, we took another look at the data from 2016 and 2017. The results did not fully resolve the question.

Forcing the 2016 data to near 5.5 h led to a period of 5.593 h while the 2017 data had a best fit at 5.518 h. These are well outside the limits set by the formal and conservative “10 σ ” errors. The latter is the period difference that results in a 10 $^\circ$ rotation difference over the time span of the data set.

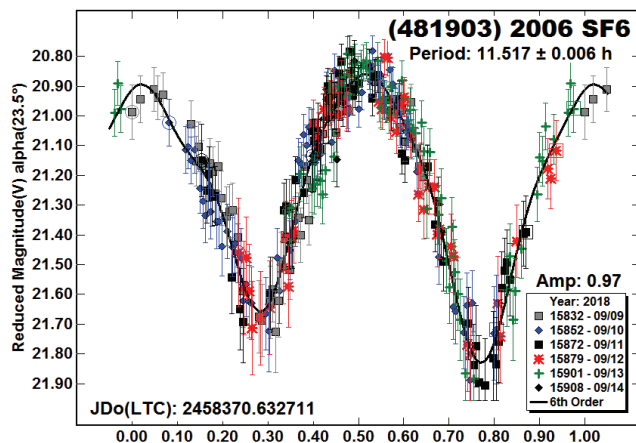
The argument for the longer period is reinforced by noting that the two earlier data sets had data from only three consecutive nights. On the other hand, the 2018 data set had five consecutive nights, covering about nine more rotations.



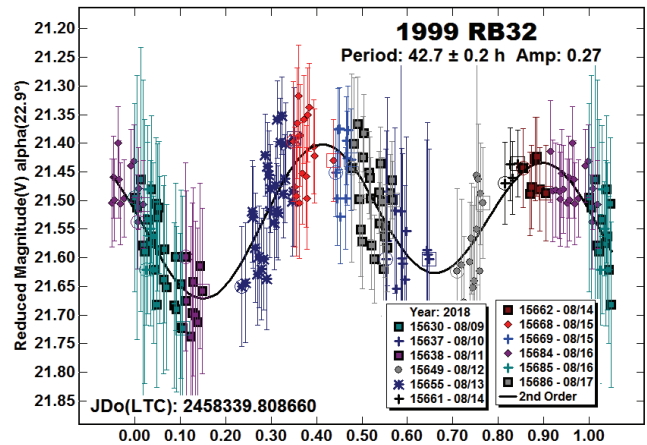
(457260) 2008 RY24. The 2018 data set produced yet another object with a period that was nearly commensurate with an Earth day. The low amplitude and SNR compounded the problem of finding the correct period. The period spectrum favored the longer period of 8.19 h. However this left a gap in the lightcurve at about 0.7 rotation phase. Such gaps are sometimes caused by the Fourier algorithm finding a period that minimizes the number of overlapping data points. The half-period (4.09 h) lightcurve has no gaps and is monomodal. While we have adopted $P = 8.19$ h; this is another case where an alternate period should be given equal weight.



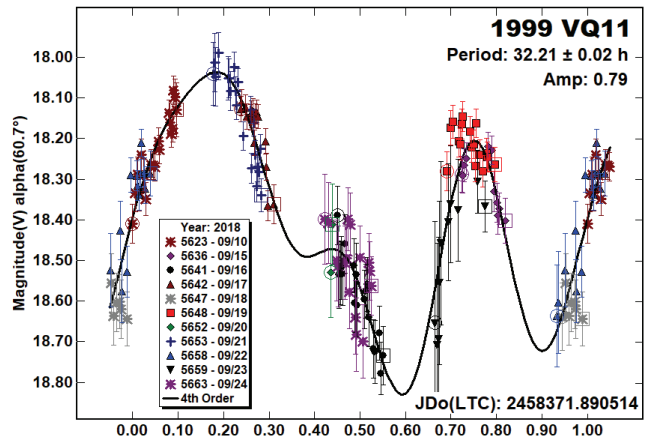
(481394) 2006 SF6, 1999 RB32. Neither of these NEAs had a previous entry of any kind in the LCDB. The period for 2006 SF6 is considered secure. This is not so for 1999 RB32.



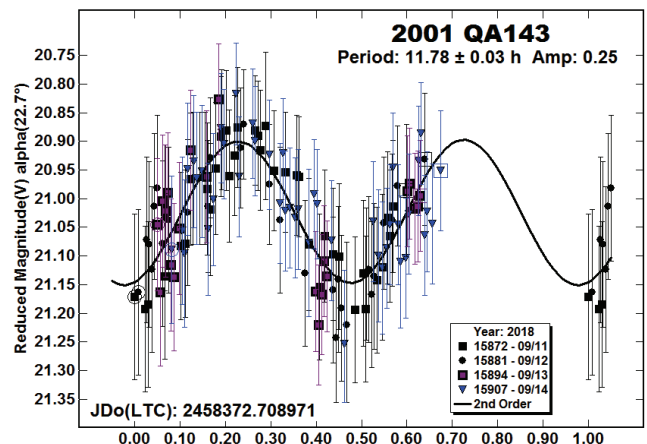
There are significant gaps in the lightcurve and the error bars are nearly the amplitude of the lightcurve. Furthermore, the period is nearly commensurate with an Earth day. A period near 24 hours produced a monomodal lightcurve. Given the apparent amplitude of at least 0.27 mag, the longer, bimodal solution was favored.



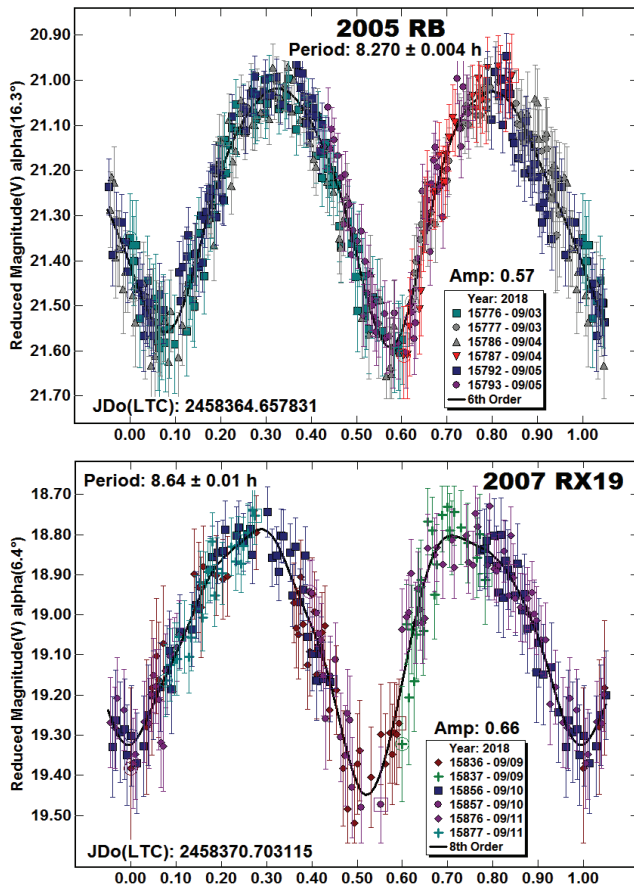
1999 VQ11. The period spectrum gave strong preference to the period of 32.21 h. This could be correct or the result of minimizing the number of overlapping data points. The former theory was adopted but the solution is by no means secure.



2001 QA143. The amplitude of 0.25 mag gave high confidence in the bimodal solution of 11.78 h (Harris et al., 2014) despite missing more than 25% lightcurve.



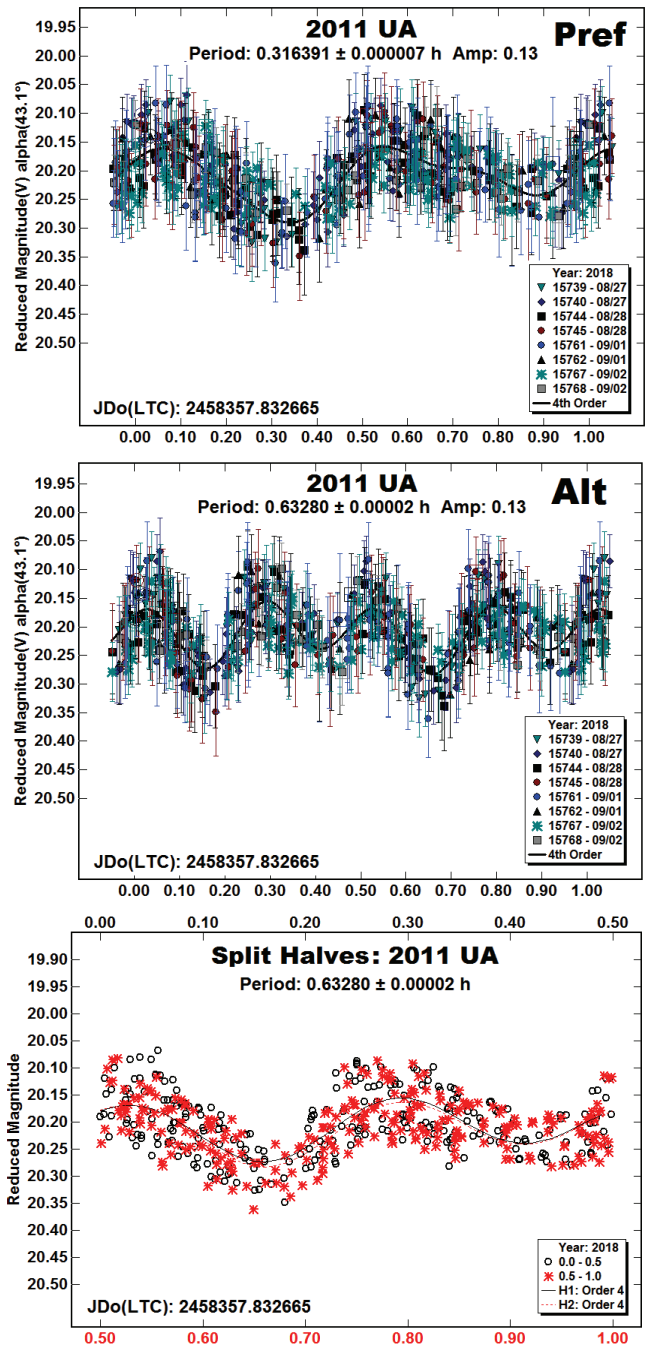
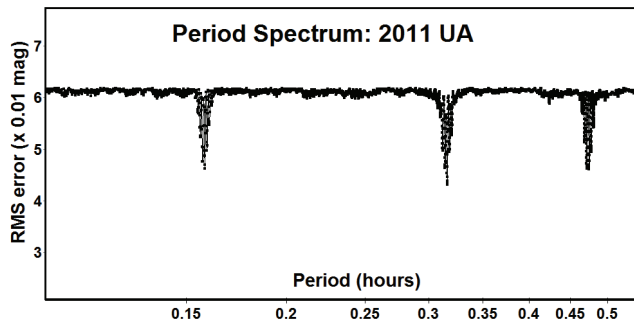
2005 RB, 2007 RX19. The two NEAs had no previous entries of any kind in the LCDB. The solutions are considered secure.



2011 UA. As the period spectrum shows, there are three very strong solutions. Narrowing down the preferred period relied mostly on the symmetry or asymmetry of the lightcurves.

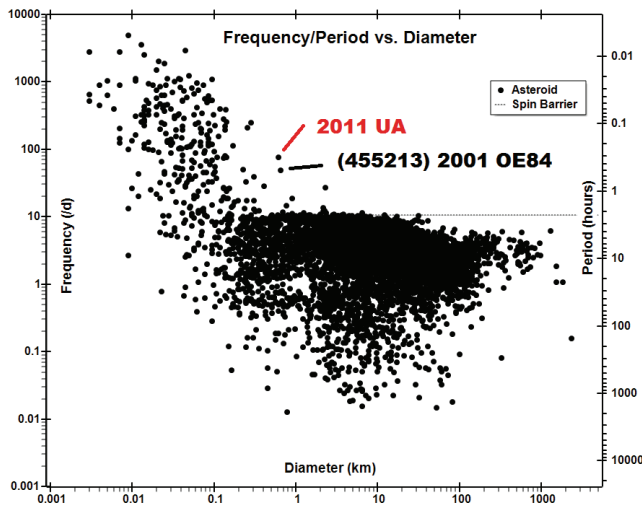
The shortest solution of about 0.15 h produced a monomodal lightcurve. The low amplitude allowed that possibility (Harris et al., 2014), but the slight asymmetry of the bimodal solution at 0.316391 h eliminated the monomodal solution. This meant that either the bimodal or a quadramodal one with a doubled-period was more likely correct.

A “split-halves” plot was made for the longer period of 0.63280 h. This is where the second half of a lightcurve is superimposed on the first half (see Harris et al., 2014). If this results in the two halves being essentially the same, there is a reasonable chance that the half-period is the correct solution. Based on this, a period of 0.316391 h is adopted here.

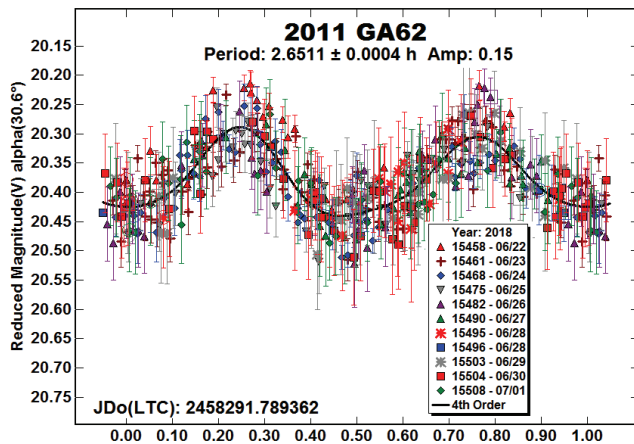


Even if the period of 0.15 h or 0.63 h is correct, this still makes the asteroid somewhat unusual. The frequency-diameter plot based on data from the LCDB shows that the asteroid is well above the spin barrier. It is also to the right of the “ascending branch” which starts at about 0.2 km diameter and *roughly* defines a point where tumbling becomes more possible.

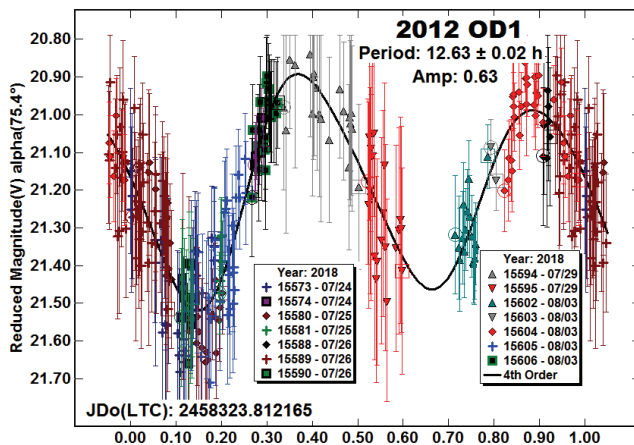
The location on the frequency-diameter plot is very close to the first object discovered (Pravec et al., 2002) in what might be called the “forbidden zone” (the term is ours and not one formally or even informally adopted within the planetary science community). Polishook et al. (2017) did an extensive analysis of the asteroid, including the constraints on the internal structure that would help keep the asteroid from breaking apart given its size and rotation period.



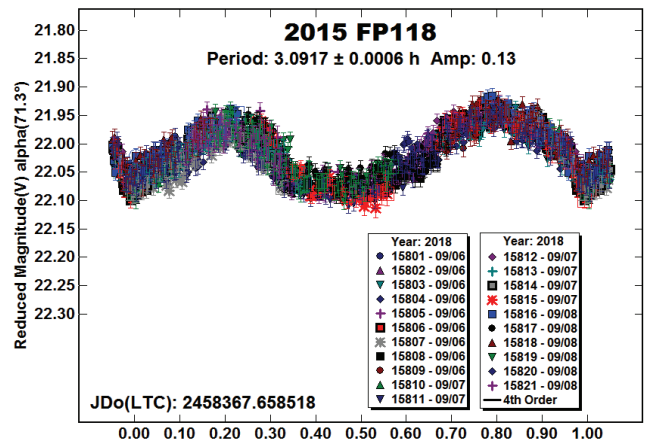
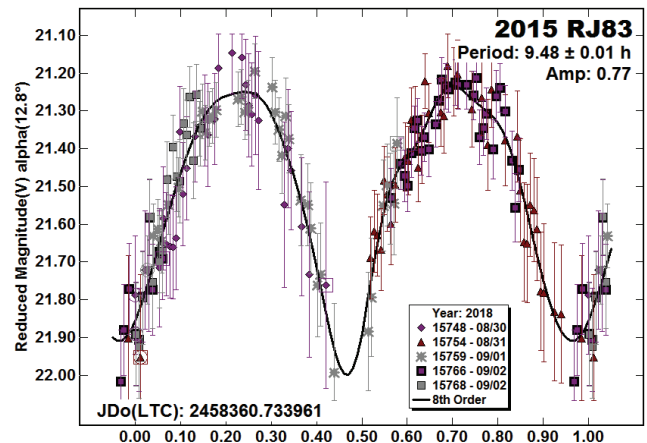
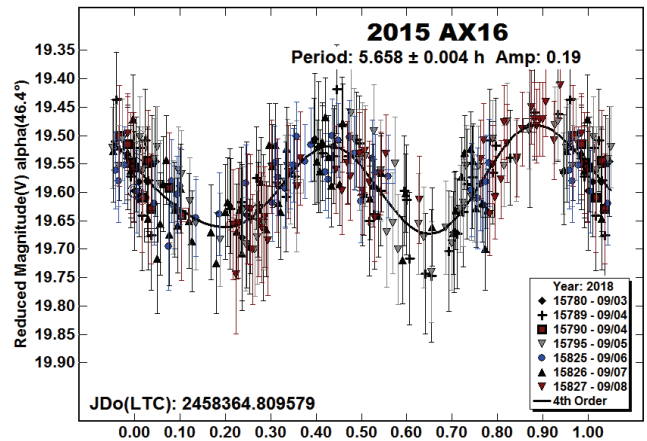
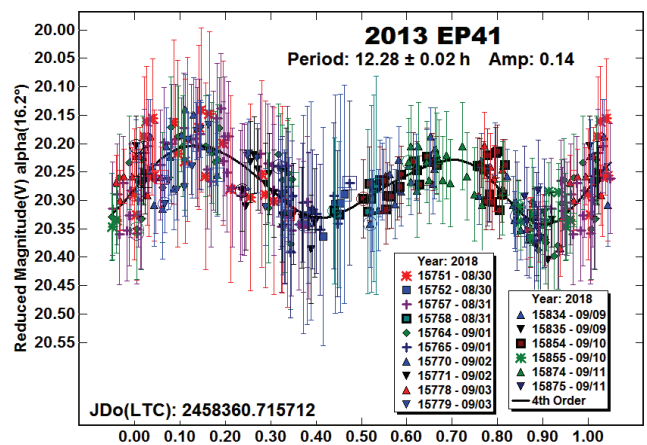
2011 GA62, 2012 OD1. There were no previous rotation periods in the LCDB for 2011 GA62 or 2012 OD1. The solution for 2011 GA 62 is considered fully secure.



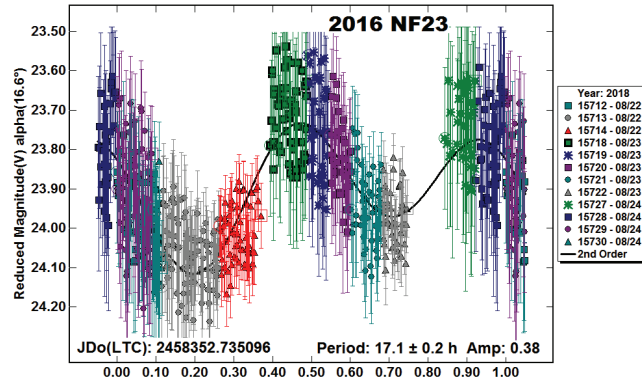
The period for 2012 is not as secure but it is very likely to be close to the correct solution. The large amplitude made this possible despite the large error bars.



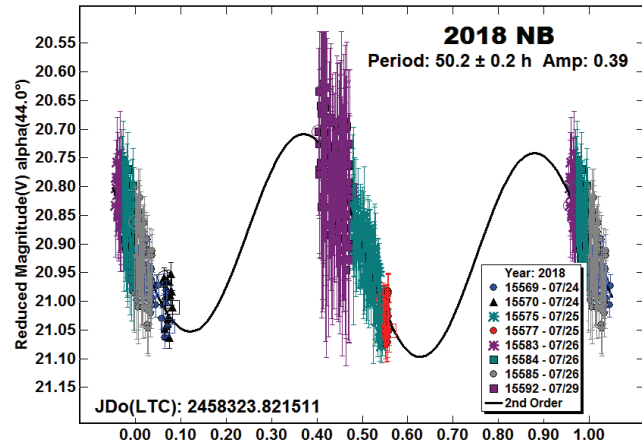
2013 EP41, 2015 AX16, 2015 RJ83, 2015 FP118. These four NEAs are new additions to the LCDB. Of the four, the solution for 2013 EP41 might be the least secure because of the low amplitude and large error bars.



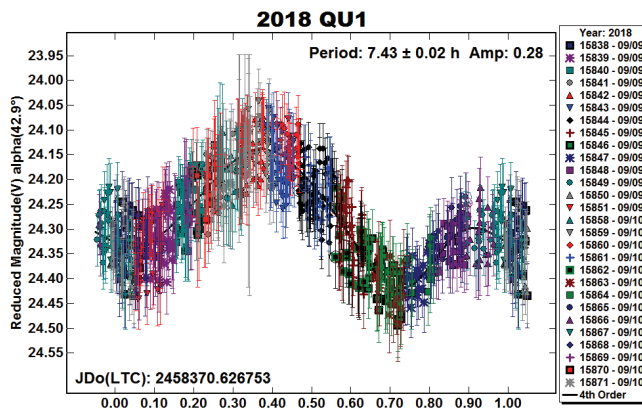
2016 NF23. The adopted period of 17.1 h was the best fit in the period spectrum. The result is supported by the slopes of the lightcurve data and model and an amplitude that makes anything other than a bimodal solution unlikely (Harris et al., 2014)



2018 NB. The period spectrum strongly favored the adopted period of 50.2 h. The half-period, with a monomodal lightcurve, was not considered likely because of the apparent amplitude.

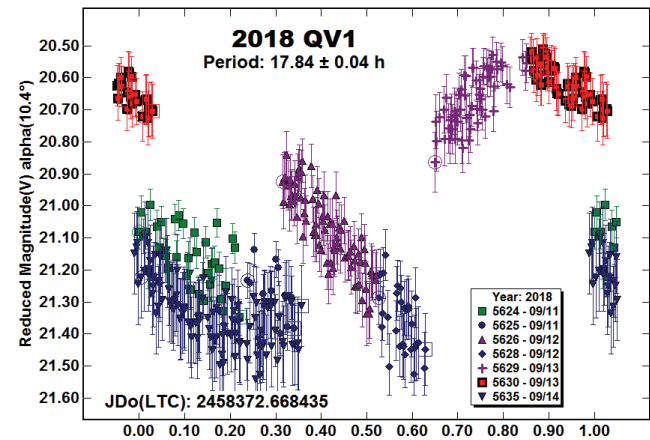
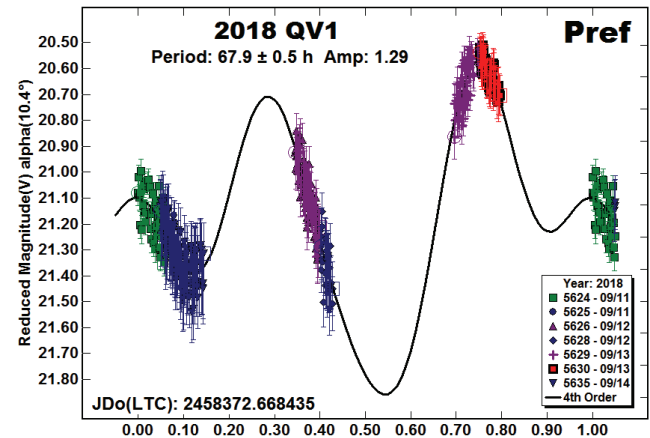


2018 QU1. There were no previous entries of any kind in the LCDB. Despite the large error bars, the solution is considered secure since the scatter in the data is relatively low and, therefore, the data closely follow the Fourier curve.

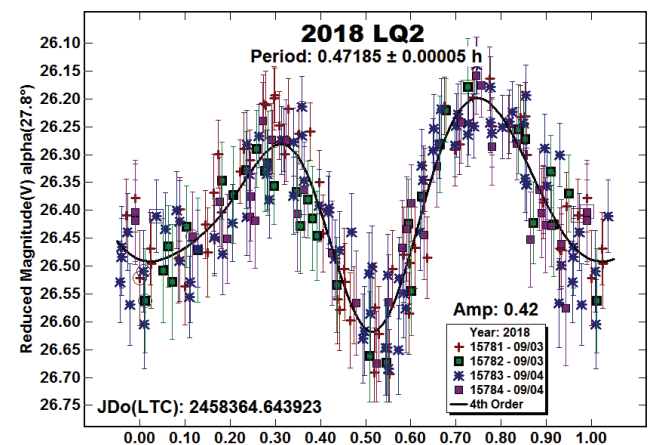


2018 QV1. The period spectrum favored 67.9 h. To be more certain about this, the data were forced to alternates of 34.1 h and 17.84 h. The lightcurve forced to 17.84 h, shown below, is an improbable result. This reinforces the conclusion that 34.1 h is the approximate half-period of the adopted period of 67.9 h.

Unfortunately, confirming observations are not coming any time soon. The 2018 apparition is the only one between 1995 and 2050 where the asteroid is brighter than $V = 18$. The brightest apparition from 2019-2050 is $V \sim 21.3$ in 2049.

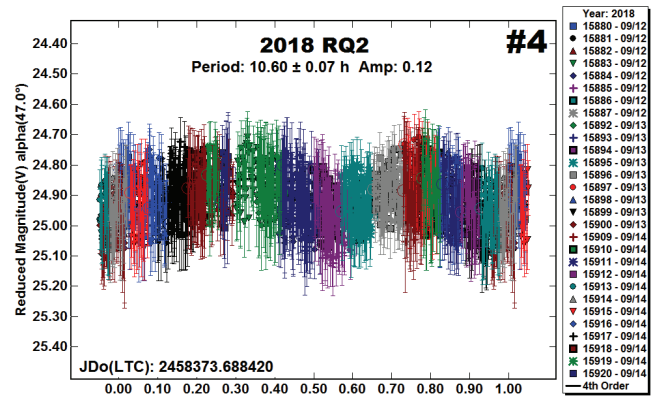
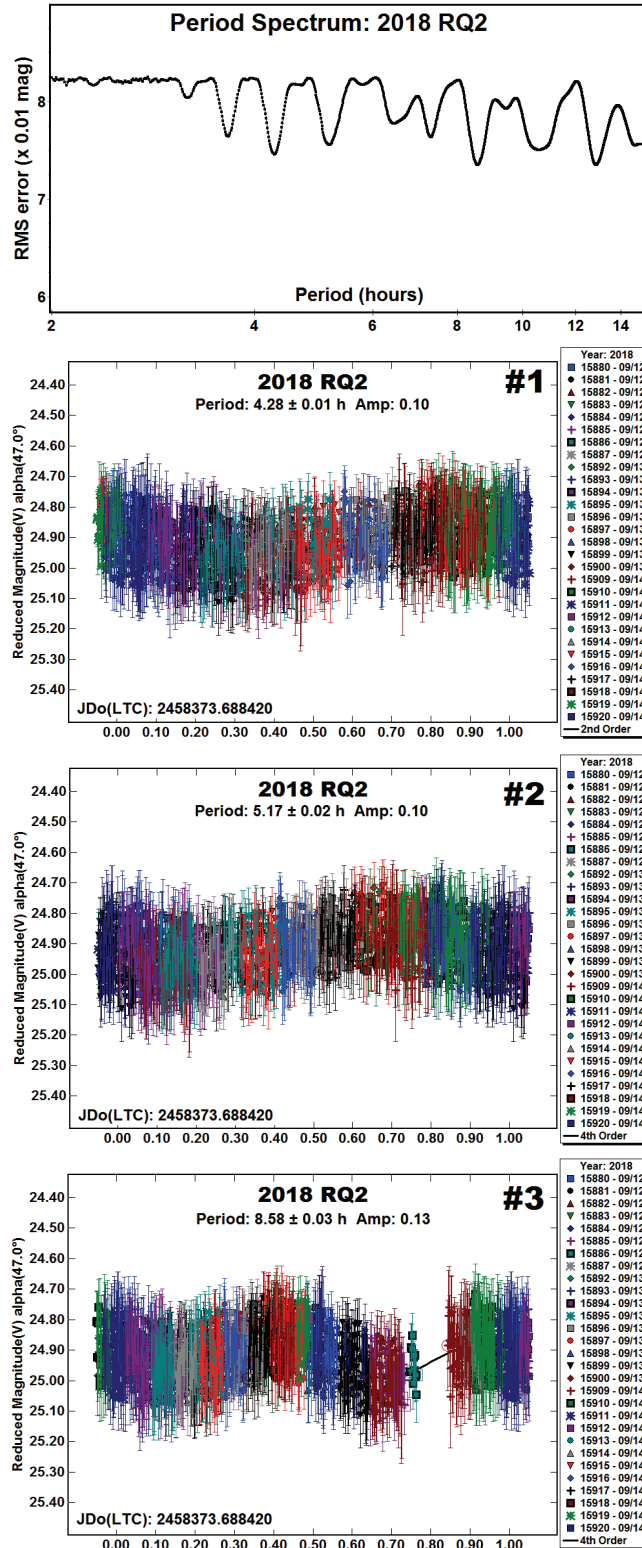


2018 LQ2. There were no previous entries of any kind in the LCDB. The estimated diameter, assuming an albedo of 0.2, is only 30 meters. At such a small size, it was a good candidate for tumbling. There were no signs of that.



2018 RQ2. Finding a single period for this 80-meter NEA, and new addition to the LCDB, wasn't enough. The data fit four nearly likely results. The period spectrum favored 8.58 h (#3), but this had a gap in the bimodal lightcurve that raised concerns that this was a "fit by exclusion" solution, one where the number of overlapping data points is minimized by the Fourier algorithm.

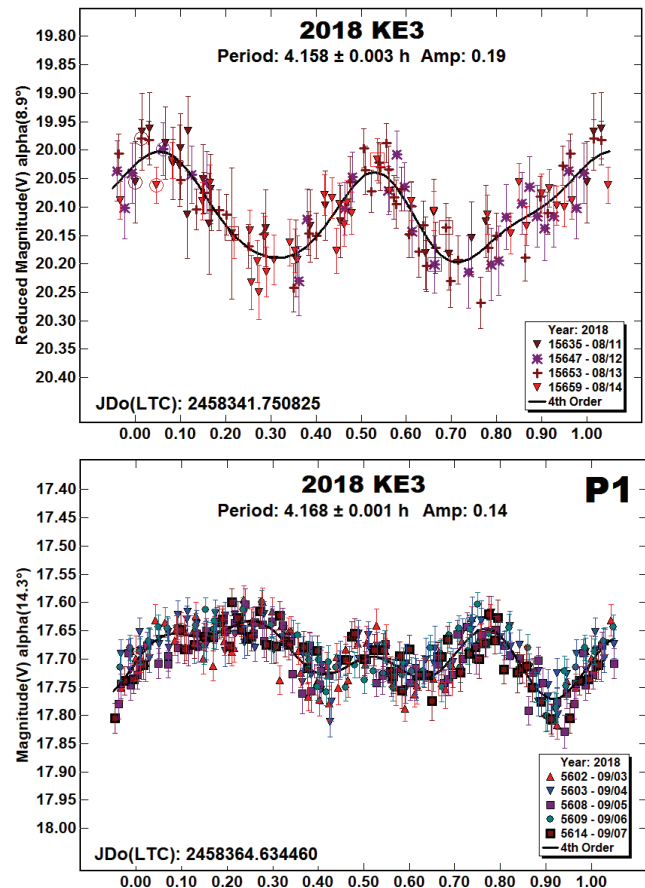
The second more-likely period was the half-period at 4.28 h (#1). However, given the low amplitude and large error bars, a solution of 5.17 h (#2) was examined. This one was chosen over one near 3.8 h because the double period of 10.80 h (#4) produced a bimodal lightcurve with no gaps and had nearly the same RMS fit as the one at 8.58 h. We have adopted $P = 8.58$ h, mostly because it's the most favored in the period spectrum.

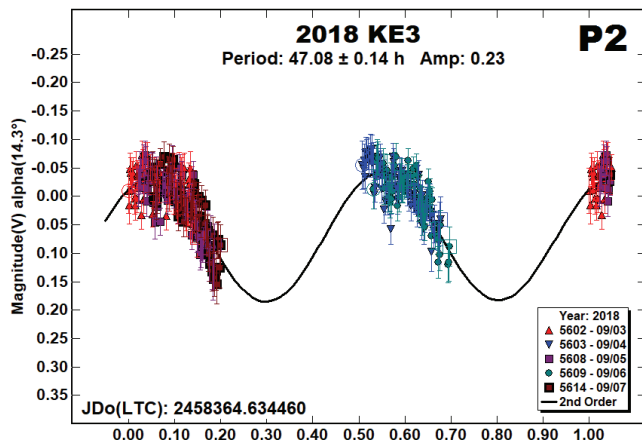


Looking ahead, the only apparition brighter than $V = 19$ is in 2028. As is the case for so many other NEAs, the observations in 2018 were a once-in-a-lifetime opportunity for those with modest telescopes.

2018 KE3. The initial observations were made in 2018 mid-August. These led to a period of 4.158 h with no obvious signs of a second period. The follow-up observations three weeks later told a different story.

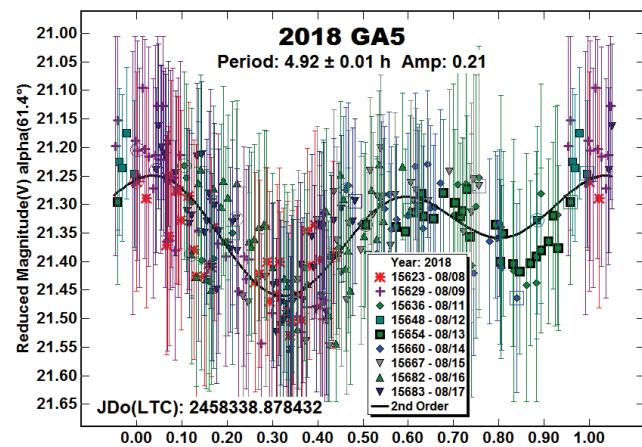
Those new data indicated the possibility of two periods. One was very similar to the earlier result, $P_1 = 4.168$ h. However, this was superimposed on a longer period, $P_2 = 47.08$ h. Shorter periods for P_2 were tried, e.g., ≈ 24 h. That produced a convincing second-order fit to a monomodal lightcurve. We have adopted 47.08 h for P_2 .



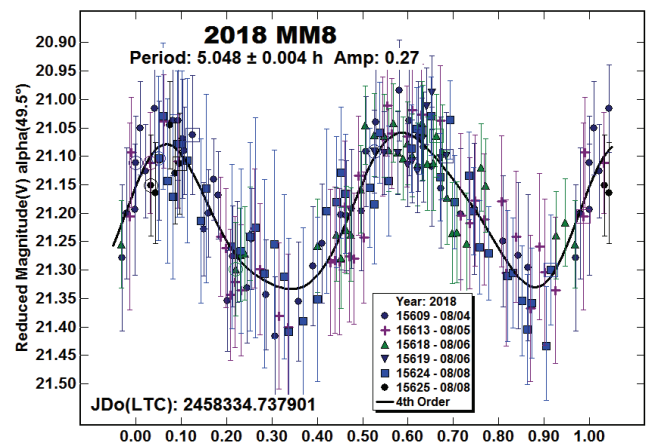
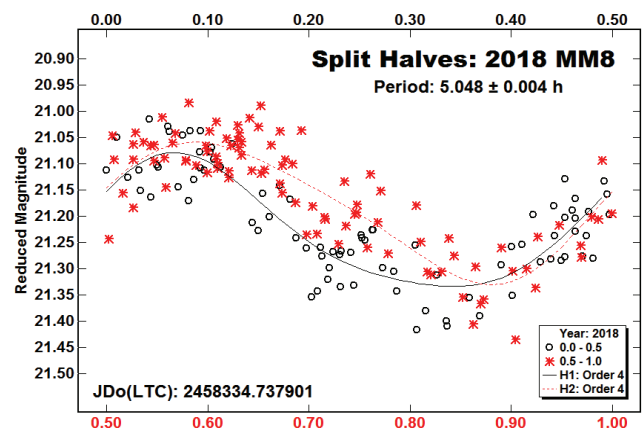


This makes 2018 KE3 a potential new member of the rare class of very wide binaries (see Warner, 2016a).

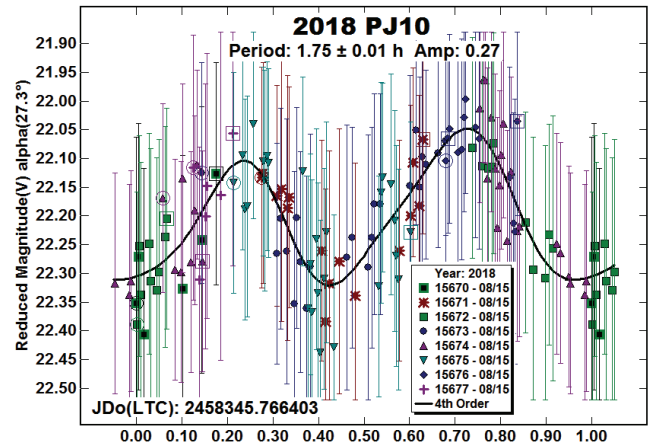
2018 GA5. There were no previous entries in the LCDB for this NEA. The solution is weak because of the large error bars.



2018 MM8. The period spectrum for 2018 MM8 showed several distinct solutions. We used the split-halves plot to try to remove doubt about a period of 5.048 h over one between 2.5-2.9 h. The result showed two distinct halves. Combined with the amplitude of 0.27 mag, $P = 5.048$ h is considered reasonably secure.



2018 PJ10. The period spectrum favored 1.75 or 3.5 h. The shorter period produced a bimodal lightcurve with an amplitude of 0.27 mag. This seemed more likely than a quadramodal solution at 3.5 hours. $P = 1.75$ h puts the asteroid just above the spin barrier in the frequency-diameter plot, but far enough left to be in the ascending branch, making it an “ordinary” and not particularly unusual asteroid.



Acknowledgements

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The authors gratefully acknowledge Shoemaker NEO Grants from the Planetary Society (2007, 2013). These were used to purchase some of the telescopes and CCD cameras used in this research.

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Number	Name	2018 mm/dd	Pts	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.
433	Eros	08/18-08/21	525	40.2, 40.3	26	13	5.270	0.005	0.11	0.01
719	Albert	08/08-08/12	151	44.3, 46.0	276	20	5.800	0.002	1.08	0.02
1865	Cerberus	09/08-09/10	211	21.9, 20.6	3	18	6.800	0.002	1.56	0.02
3552	Don Quixote	08/18-08/21	219	34.8, 34.2	35	18	6.665	0.005	0.58	0.02
4183	Cuno	08/09-08/18	223	5.1, 2.0	326	4	3.58	0.01	0.09	0.02
6456	Golombek	07/24-08/03	152	30.1, 24.7	328	0	2.5014	0.0002	0.14	0.01
9856	1991 EE	09/12-09/15	124	44.7, 41.7	32	-7	3.048	0.002	0.19	0.01
13553	Masaakikoyama	08/19-08/26	2098	23.0, 18.2	337	13	58	3	0.75	0.10
16834	1997 WU22	09/15-09/18	189	27.4, 26.0	27	21	9.349	0.004	0.63	0.03
17274	2000 LC16	08/30-09/05	665	24.0, 25.3	323	8	16.50	0.02	0.23	0.02
18109	2000 NG11	08/23-08/25	200	10.8, 9.7	339	-2	4.253	0.005	0.78	0.02
86324	1999 WA2	08/18-08/28	279	44.4, 51.0	287	20	7.161	0.003	0.18	0.02
86878	2000 HD24	08/11-08/21	277	68.9, 89.1	16	27	15.72	0.02	0.28	0.05
115052	2003 RD6	09/03-09/08	413	36.4, 31.1	360	26	12.08	0.04	0.11	0.02
141527	2002 FG7	08/09-08/10	163	54.8, 56.4	353	18	6.31	0.02	0.97	0.05
283729	2002 UX	07/31-08/06	110	40.1, 43.3	286	28	5.937	0.005	0.23	0.02
333889	1998 SV4	09/05-09/08	169	35.6, 32.3	15	-2	2.817	0.002	0.27	0.03
337248	2000 RH60	09/12-09/15	288	10.5, 8.9	351	7	25.2	0.1	0.35	0.04
418929	2009 DM1	08/27-09/02	204	19.2, 3.5, 18.4	343	15	4.590	0.005	0.17	0.03
438429	2006 WN1	08/30-09/02	208	32.3, 32.1	323	16	3.407	0.002	0.18	0.02
441987	2010 NY65	¹⁶ 07/01-07/03	511	56.6, 51.9	259	21	5.593	0.007	0.18	0.03
441987	2010 NY65	¹⁷ 06/27-06/29	593	71.2, 58.3	257	29	5.518	0.004	0.16	0.02
441987	2010 NY65	07/02-07/06	292	48.2, 43.3	268	22	5.541	0.003	0.24	0.03
457260	2008 RY24	09/04-09/05	214	30.0, 29.9	10	8	8.19	0.02	0.09	0.02
481394	2006 SF6	09/09-09/13	246	23.5, 22.8	348	17	11.517	0.006	0.97	0.04
	1999 RB32	08/09-08/17	170	22.9, 26.5	337	-1	42.7	0.2	0.27	0.03
	1999 VQ11	09/10-09/24	152	60.6, 61.5	47	-3	32.21	0.02	0.79	0.10
	2001 QA143	09/11-09/14	135	22.8, 22.9	2	13	11.78	0.03	0.25	0.03
	2005 RB	09/03-09/05	415	16.2, 13.7	345	10	8.270	0.004	0.57	0.03
	2007 RX19	09/09-09/11	237	6.4, 4.4	353	1	8.64	0.01	0.68	0.04
	2011 UA	08/27-09/02	375	43.2, 35.9	179	-6	0.316391	0.000007	0.13	0.03
	2011 GA62	06/22-07/01	419	30.6, 34.5	293	11	2.6511	0.0004	0.15	0.02
	2012 OD1	07/24-08/03	274	75.5, 60.9	340	29	12.63	0.02	0.63	0.05
	2013 EP41	08/30-09/11	300	16.2, 2.8, 3.1	348	3	12.28	0.02	0.14	0.02
	2015 AX16	09/03-09/08	266	46.4, 48.5	22	1	5.658	0.004	0.19	0.03
	2015 RJ83	08/30-09/01	162	12.8, 10.9	344	5	9.48	0.01	0.76	0.04
	2015 FP118	09/06-09/08	1304	70.6, 59.0	6	27	3.0917	0.0006	0.13	0.01
	2016 NF23	08/22-08/24	572	16.4, 5.7	336	0	17.1	0.2	0.39	0.05
	2018 NB	07/24-07/29	396	43.9, 52.2	330	0	50.2	0.2	0.39	0.04
	2018 QU1	09/09-09/10	721	44.9, 57.4	355	26	7.43	0.02	0.28	0.04
	2018 QV1	09/11-09/14	397	10.4, 13.4	342	4	67.9	0.5	0.85	0.10
	2018 LQ2	09/03-09/04	208	30.2, 28.6	338	15	0.47185	0.00005	0.42	0.03
	2018 RQ2	09/12-09/14	1470	47.2, 56.7	15	9	8.58	0.03	0.13	0.03
	2018 KE3	08/11-08/14	124	8.9, 7.8	326	0	4.158	0.003	0.19	0.01
	2018 KE3	09/03-09/07	326	14.3, 16.1	341	11	^P 4.168	0.001	0.14	0.02
	2018 KE3						47.08	0.14	0.23	0.02
	2018 GA5	08/08-08/17	276	61.5, 54.7	81	-10	4.92	0.02	0.21	0.04
	2018 MM8	12/31-12/31	180	30.2, 0.0, 28.6	0	0	5.048	0.004	0.27	0.03
	2018 PJ10	08/15-08/15	137	27.1, 27.1	338	4	1.75	0.01	0.27	0.04

Table II. Observing circumstances. ^y indicates the data are from 20yy. ^P indicates the period for the primary in a binary system. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. L_{PAB} and B_{PAB} are, respectively the average phase angle bisector longitude and latitude.

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MINOR PLANETS AT UNUSUALLY FAVORABLE ELONGATIONS IN 2019

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A list is presented of minor planets which are much brighter than usual at their 2019 apparitions.

The minor planets in the lists which follow will be much brighter at their 2019 apparitions than at their average distances at maximum elongation. Many years may pass before these planets will be again as bright as in 2019. Observers are encouraged to give special attention to those which lie near the limit of their equipment.

These lists have been prepared by an examination of the maximum elongation circumstances of minor planets computed by the author for all years through 2060 with a full perturbation program written by Dr. John Reed, and to whom he expresses his thanks. Elements are from EMP 1992, except that for all planets for which new or improved elements have been published subsequently in the Minor Planet Circulars or in electronic form, the newer elements have been used. Planetary positions are from the JPL DE-200 ephemeris, courtesy of Dr. E. Myles Standish.

Any planets whose brightest magnitudes near the time of maximum elongation vary by at least 2.0 in this interval and in 2019 will be within 0.3 of the brightest occurring, or vary by at least 3.0 and in 2019 will be within 0.5 of the brightest occurring; and which are visual magnitude 14.5 or brighter, are included. For planets brighter than visual magnitude 13.5, which are within the range of a large number of observers, these standards have been relaxed somewhat to include a larger number of planets. Magnitudes have been computed from the updated magnitude parameters published in MPC28104-28116, on 1996 Nov. 25, or more recently in the Minor Planet Circulars.

Oppositions may be in right ascension or in celestial longitude. Here we use still a third representation, maximum elongation from the Sun, instead of opposition. Though unconventional, it has the advantage that many close approaches do not involve actual opposition to the Sun near the time of minimum distance and greatest brightness and are missed by an opposition-based program. Other data are also provided according to the following tabular listings: Minor planet number, date of maximum elongation from the Sun in format yyyy/mm/dd, maximum elongation in degrees, right ascension on date of maximum elongation, declination on date of maximum elongation, both in J2000 coordinates, date of brightest magnitude in format yyyy/mm/dd, brightest magnitude, date of minimum distance in format yyyy/mm/dd, and minimum distance in AU.

Users should note that when the maximum elongation is about 177° or greater, the brightest magnitude is sharply peaked due to enhanced brightening near zero phase angle. Even as near as 10 days before or after minimum magnitude the magnitude is generally about 0.4 greater. This effect takes place in greater time interval for smaller maximum elongations. There is some interest in very small minimum phase angles. For maximum elongations