

(139345) 2001 KA67: A POTENTIAL NEA VERY-WIDE BINARY ASTEROID

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Analysis of CCD photometric observations of the near-Earth asteroid (139345) 2001 KA67 show that it may be a very wide asynchronous binary, which features a long primary and short secondary period. The two periods that were found for 2001 KA67, $P_1 = 44.25 \pm 0.05$ h and $P_2 = 6.011 \pm 0.003$ h, are in-line with other potential members of this class.

The formation and states of binary asteroids has been analyzed by several authors (e.g., Pravec et al., 2006, 2010, 2016; Jacobson and Scheeres, 2011). In those works, even so-called “wide binaries” (Jacobson et al., 2014) featured a rapidly spinning primary and a tidally-locked satellite. However, a new class seems to have come to light: the “very wide binary asteroids” (VWBA; Warner, 2016 and references therein).

These systems feature a slowly rotating primary and, presumably, a fully asynchronous satellite with a rotation period usually similar to the primaries of “close” binary asteroids ($P < 5$ hours).

In general, the satellite is lacking just enough mass and its orbit has expanded close to but not beyond the limit where it could decouple from the primary and form an asteroid pair (e.g., Pravec et al., 2010). This leads to 1) the primary being “despun” to a long period and 2) the satellite’s orbit having a very long period. Given these circumstances, the chances of seeing mutual events (eclipses and/or occultations) are very remote and so, thus far, there has been no *absolute* confirmation that any members of the VWBA class exist.

The long period can be attributed to the primary based on the relatively large amplitude. If due to the satellite, the amplitudes would be “diluted” by about a magnitude due to the primary and so require that the satellite be viewed equatorially and have an unphysically great elongation (Alan Harris, private communications).

Observations and Data Reduction

A C-14 0.35-m Schmidt-Cassegrain and FLI Microline-1001E were used to make the observations. Images were unbinned with no filter and had master flats and darks applied. The exposures were 300 seconds. Table I gives the observing circumstances and analysis results.

Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). Night-to-night calibration (generally ± 0.05 mag) was done using field stars from the CMC-15 catalog. The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color.

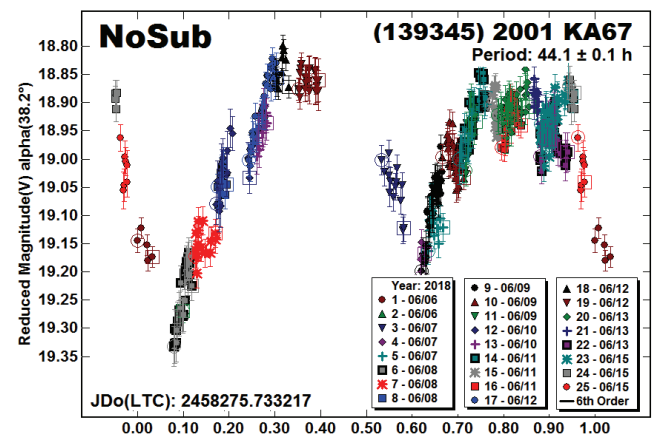
In the lightcurve plots, the “Reduced Magnitude” is Johnson V corrected to a unity distance by applying $-5 \cdot \log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and the Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses using $G = 0.15$. The X-axis rotational phase ranges from -0.05 to 1.05 .

The amplitude indicated in the plots (e.g. Amp: 0.23) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

Data Analysis

Stephens’ initial analysis of the data through June 11 indicated a single period of about 6.9 hours but with other possibilities. In his analysis, nightly zero points were adjusted by 0.4 mag or more, which is usually assumed to be systematic errors in the catalog magnitudes that are RA/Dec dependent. As it turns out, and has likely happened to many times to others, forcing the sessions to fit masked a completely different result.

Warner reviewed the data obtained through June 11, starting by resetting the nightly zero points to 0. When plotting individual nights, the data often showed a steadily increasing or decreasing trend that usually indicates a long period.



Additional data were obtained through June 15 and the nightly zero point adjustments limited to 0.05 mag or less. The initial results of the second analysis found more than one potential period, i.e., a second, shorter period superimposed on the long period lightcurve.

The “No Sub” plot shows the result of finding a single period using the full data set. The fact that the curve did not seem to repeat itself after one cycle is one indication that the asteroid might be “tumbling”, i.e., in non-principal axis rotation (NPAR; Pravec et al., 2005).

The dual-period feature of *MPO Canopus* was used to look for the possibility of one or two secondary periods that would, after subtracting out, give a better fit for the long period. This led to finding two, distinct periods within the data.

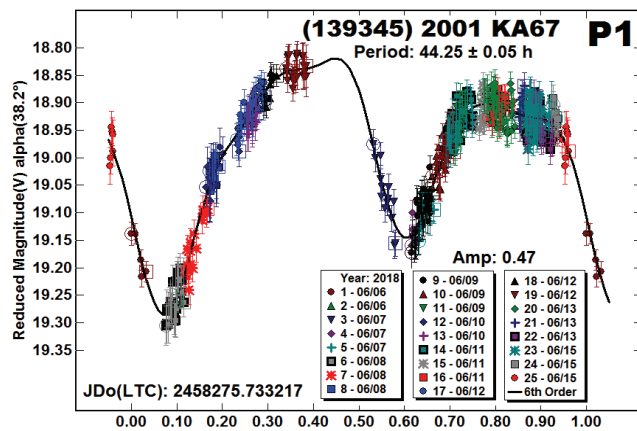
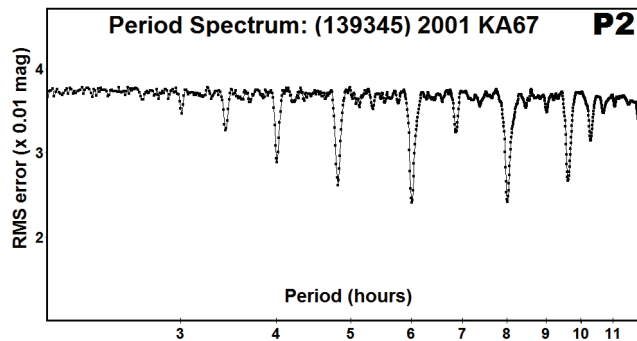
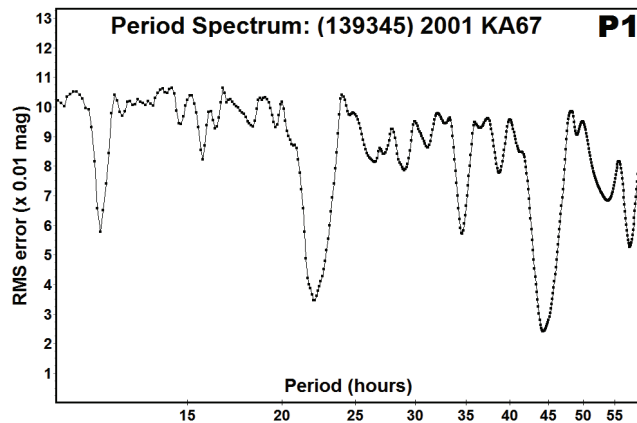
The “P1” period spectrum shows the two dominant long periods, including the adopted one near 44 hours since it produced a bimodal lightcurve with a large amplitude (Harris et al., 2014). The “P2” period spectrum showed a period near 6 hours as most likely. The two strong solutions on either side represent a one

Number	Name	2018 mm/dd	Pts	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.
139345	2001 KA67	06/06-06/15	481	38.6,24.3	271	24	44.25 6.011	0.05 0.003	0.47 0.10	0.03 0.01

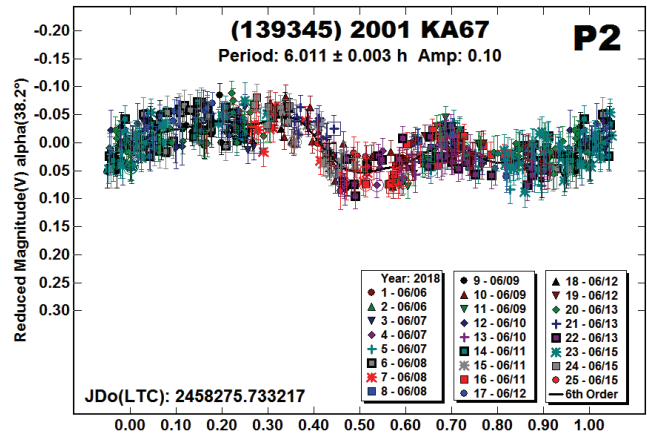
Table I. Observing circumstances and results. The first line is for the primary of the putative binary while the second line is for the presumed satellite rotation period. The orbital period was not determined. Pts is the number of data points. Phase is the solar phase angle for the first and last date. L_{PAB} and B_{PAB} are, respectively, the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984).

rotation per day difference. All three were used against the long period in the analysis.

The final results are shown in the “P1” and “P2” lightcurves which give the best fits of $P_1 = 44.25 \pm 0.05$ h and $P_2 = 6.011 \pm 0.003$ h. Unfortunately, it was not possible to fill in the entire long period lightcurve. However, it is sufficiently well-defined to be certain of the solution.



The period for P_1 is near the short end of those found in other suspected very wide binary candidates (see Table II). It's amplitude of 0.47 mag fits well into the model for these objects, as does the amplitude of the P_2 lightcurve.



Number	Name	P1	P2	Ref
1876	Napolitania	45	2.825	MPB 43, 57-65
2026	Johnmckay	372	2.298	MPB 38, 33-36
15778	1993 NH	113	3.320	MPB 42, 60-66
19204	Joshuatree	480	21.25	MPB 43, 220-222
23615	1996 FK12	368	3.646	MPB 42, 36-42
67175	2000 BA19	275	2.716	MPB 41, 102-112
119744	2001 YN42	624	7.24	MPB 42, 79-83
218144	2002 RL66	588	2.49	MPB 37, 109-111
139345	2001 KA67	44	6.011	This work
2014	PL51	205	5.384	MPB 42,134-136

Table II. List of suspected wide binary asteroids. P_1 is the primary's period (hours). P_2 is the satellite's period, which is not tidally-locked to its orbital period. The orbital period is likely very long.

Number	Name	P1	P2	P1/P2
139345	2001 KA67	44	6.011	7.3
1876	Napolitania	45	2.825	15.9
19204	Joshuatree	480	21.25	22.6
15778	1993 NH	113	3.320	34.0
2014	PL51	205	5.384	38.1
119744	2001 YN42	624	7.24	86.2
23615	1996 FK12	368	3.646	100.9
218144	2002 RL66	588	2.49	236.1
67175	2000 BA19	275	2.716	272.3
2026	Johnmckay	372	2.298	369.7

Table III. The ratios of the primary-to-secondary rotation periods.

What makes this candidate a bit unusual is the ratio of the primary-to-secondary periods. As shown in Table III, the ratio for 2001 KA67 is, by far, the smallest and less than half of the second lowest ratio. There does not seem to be a correlation between the ratio and primary period.

Conclusions

(139345) 2001 KA67 is a strong candidate for the small set of very wide binary asteroids discovered *so far*. We can only speculate on how many more there might be. More of a question is how many might have been overlooked by presuming that large

nightly zero point shifts were systematic errors in the catalogs or measurements.

Perhaps it would be worth a second look by others who have data sets that required large zero point shifts, especially if the result was a lightcurve with a period of less than 5 hours. As shown in Table II, however, this is only a place to start since some secondary curves are much longer.

As before, we encourage more detailed observations when initial results indicate a long period. The oft-used method of obtaining only a few data points each night will not allow finding more candidates for this class. Denser lightcurve coverage may be a strain on telescope time if only one is available. It's never easy balancing priorities and program goals.

Acknowledgements

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