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87.

319 LEONA AND 341 CALIFORNIA – TWO VERY SLOWLY ROTATING ASTEROIDS

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An observing strategy for asteroids suspected of being very slowly rotating is described and recommended to all observers. For 319 Leona the synodic rotation period is 430 ± 2 hours, amplitude 0.7 magnitudes, a second tumbling period is 1084 ± 10 hours, color index $V-R = 0.43$, $H=10.46 \pm 0.08$ and $G=0.11 \pm 0.09$ at mean light. For 341 California the synodic rotation period is 318 ± 2 hours, amplitude 0.9 magnitudes, a second tumbling period is 250 ± 2 hours, color index $V-R = 0.53$, $H=11.53 \pm 0.06$ and $G=0.18 \pm 0.05$ at mean light.

For very slowly rotating asteroids the most productive observing strategy is to obtain a short session 15 to 20 minutes every clear night except when the Moon is very close in the sky for several months before and after opposition. Solar colored comparison stars with Sloan r' magnitudes from the CMC15 catalog (VizieR web site) should be used to measure all CCD frames. The internal consistency of the CMC15 catalog is usually within 0.05 magnitudes over the entire sky. The r' magnitudes read off the CMC15 catalog may be converted to the standard Cousins R magnitudes system by $R=r'-0.22$ (Dymock and Miles, 2009).

Lightcurves from all sessions are then composited with no adjustment of instrumental magnitudes. A search should be made for possible tumbling behavior. This is revealed whenever successive rotational cycles show significant variation, and quantified with simultaneous 2 period software. In addition, it is useful to obtain a small number of all-night sessions for each object near opposition to look for possible small amplitude short period variations.

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 a clear filter. All measurements were calibrated from CMC15 r' values to Cousins R magnitudes for solar colored field stars. Photometric measurement is with MPO Canopus software. To reduce the number of points on the lightcurves and make them easier to read, data points on all lightcurves constructed with MPO Canopus software have been binned in sets of 3 with a maximum time difference of 5 minutes between points in each bin.

Twenty images in both R and V filters were obtained alternately on 2016 September 10 for 319 Leona and 341 California. The same solar colored comparison stars with Sloan r' , J, and K magnitudes read from the CMC15 catalog (VizieR web site) were used to measure both image sets. For the R filter images, conversions to Cousins R magnitudes are by $R=r'-0.22$. For the V filter images conversions to Johnson V magnitudes are by $V=0.9947*r'+0.6278*(J-K)$. Both conversion procedures are from Dymock and Miles (2009). The magnitudes thus converted for each color are shown together. The V magnitude data points can be adjusted upward to obtain the best fit between R magnitude and V magnitude overlapping sessions. The amount of the adjustment is then the color index V-R. For each session R magnitudes were estimated at maximum, mid, and minimum light for the rotational cycle. Each measured R magnitude was converted to its corresponding V magnitude by adding V-R. The H-G calculator function of MPO Canopus then drew the phase diagram for H and G at maximum, mid, and minimum light, respectively, in the Johnson V magnitude system.

Number	Name	2016 mm/dd	Pts	Phase	LPAB	BPAB	Period(h)	P.E	Amp	A.E.	P2	P.E.
319	Leona	08/04-12/06	3193	17, 1, 20	4	0	430.	2.	0.5	0.1	1084	10
341	California	06/03-12/07	3793	34, 1, 26	12	-4	318.	2.	0.5	0.1	250	2

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first date, minimum value, and last date. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). P2 is the second period of tumbling.

319 Leona. Previous published rotation periods and amplitudes are by Behrend (2006), 9.6 hours, 0.03 magnitudes; and by Alkema (2013), 14.9 hours, 0.10 magnitudes. A total of 82 sessions, most of them about 15 minutes, were obtained 2016 Aug. 4 – Dec. 6. A single period lightcurve was constructed with *MPO Canopus* software with best fit to a period 430.66 ± 0.18 hours (Fig. 1). The small formal error is unrealistic because for tumbling asteroids systematic errors are much larger than formal errors. A fit with the 2nd order 2 period Fourier series (Fig. 2) finds a main period 430 ± 2 hours, amplitude 0.7 magnitudes, and candidate second period 1084 ± 10 hours. This fit is done in flux units, not magnitudes. The strongest signals are in the frequencies $2/P_1$ and $1/P_2$ with their flux amplitude ratio 1:0.22. Use of higher orders is not justified by the data limitations for the very long second period. A raw lightcurve of 319 Leona fitted to the 2 period Fourier model is shown in Fig. 3. Individual rotational cycles and their changes in successive cycles due to tumbling are clearly perceived. Raw lightcurves are also shown for the intervals 2016 Sept. 23-25 on the descending branch of the lightcurve (Fig. 4) and 2016 Sept. 27-29 on the ascending branch (Fig. 5). Within the ± 0.05 magnitude internal consistency of the CMC15 catalog, the all-night lightcurve of the middle night has a slope that fits the slope defined for all three nights. No short period variation is seen. Fig. 6 shows alternating R and V filter magnitudes separated by $V-R = 0.43$ magnitudes. Fig. 7 shows the V magnitude H-G plot for 319 Leona at maximum light, mid light, and minimum light, respectively.

341 California. Previous published rotation periods and amplitudes are by Behrend (2005), 8.74 hours, 0.07 magnitudes; Behrend (2008), 8.74 hours, 0.02 magnitudes; and Skiff (2014), 317 hours, 0.75 magnitudes. A total of 117 sessions, most of them about 15 minutes, were obtained 2016 June 3 – Dec. 7. A single period lightcurve was constructed with *MPO Canopus* software with best fit to a period of 317.88 ± 0.06 hours (Fig. 8). The small formal error is again unrealistic for a tumbling asteroid. A fit with the 4th order 2 period Fourier series (Fig. 9) finds a main period 318 hours, amplitude 0.9 magnitudes, candidate second period 250 hours, both ± 2 hours. Again in flux units, the strongest signals are in the frequencies $2/P_1$ and $2/P_2$ with flux amplitude ratio 1:0.21. A raw lightcurve of 341 California fitted to the 2 period Fourier model is shown in Fig. 10. Individual rotational cycles and their changes in successive cycles due to tumbling are clearly perceived. Raw lightcurves are also shown for the intervals 2016 Oct. 3-5 (Fig. 11) and 2016 Oct 9-11 (Fig. 12), both on descending branches of the lightcurve. Within the ± 0.05 magnitude internal consistency of the CMC15 catalog, the all-night lightcurve of the middle night has a slope that fits the slope defined for all three nights. No short period variation is seen. Fig. 13 shows alternating R and V filter magnitudes separated by $V-R = 0.53$ magnitudes. Fig. 14 shows the V magnitude H-G plot for 341 California at maximum light, mid light, and minimum light, respectively.

References

- Alkema, M. S. (2013). "Asteroid Lightcurve Analysis at Elephant Head Observatory: 2013 April-July." *Minor Planet Bull.* **40**, 215-216.
- Behrend, R. (2005, 2006, 2008). Observatoire de Geneve web site. http://obswww.unige.ch/~behrend/page_cou.html.
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Harris, A.W., Young, J.W., Scaltriti, F., Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmena and 444 Gyptis." *Icarus* **57**, 251-258.

Skiff, B. (2014). Posting on CALL website <http://www.minorplanet.info/call.html>.

VizieR (2016). <http://vizier.u-strasbg.fr/viz-bin/VizieR>.

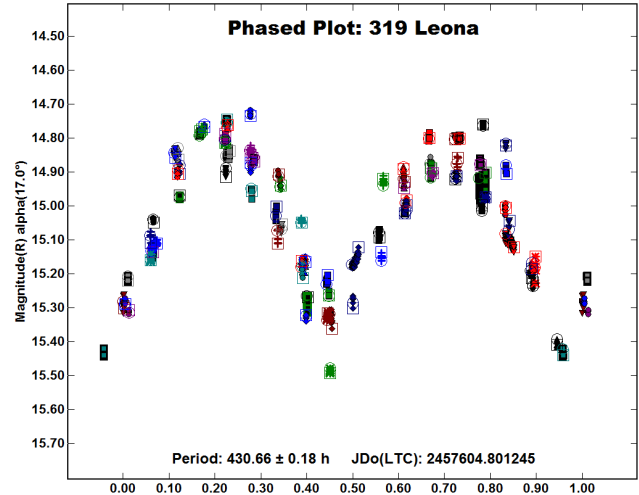


Figure 1. Single period lightcurve of 319 Leona based on 82 sessions 2016 Aug. 4 - Dec. 6 in R band magnitudes, corrected for changes in phase angle and geocentric and heliocentric distances and prepared by *MPO Canopus* software.

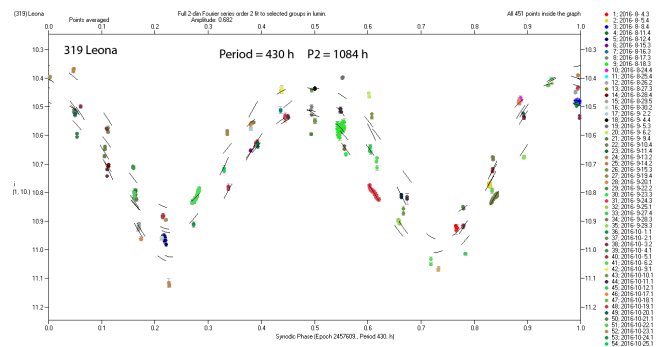


Figure 2. Second order 2 period Fourier series lightcurves of 319 Leona.

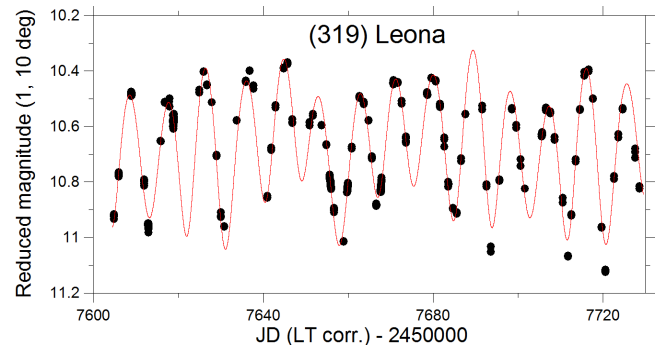


Figure 3. Raw lightcurve of all sessions of 319 Leona fit to a 2 period Fourier model.

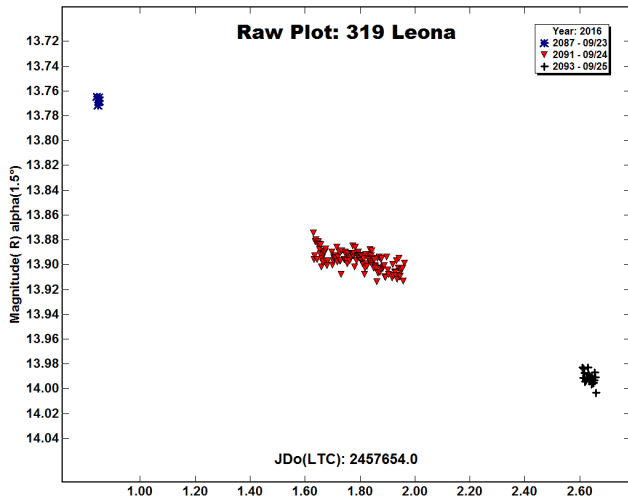


Figure 4. Raw lightcurve of 319 Leona for the interval 2016 Sept. 23-25.

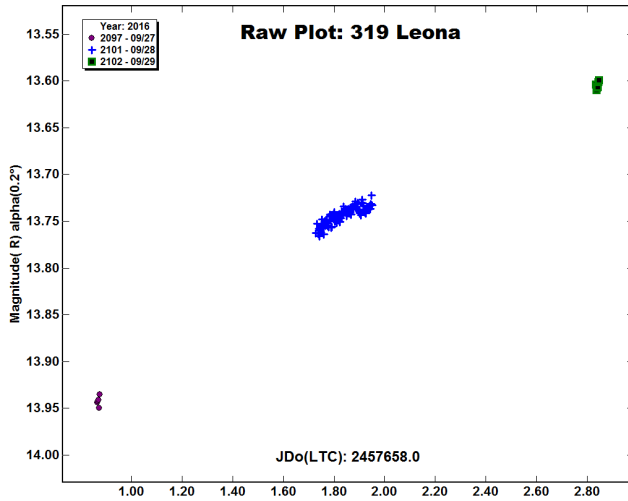


Figure 5. Raw lightcurve of 319 Leona for the interval 2016 Sept. 27-29.

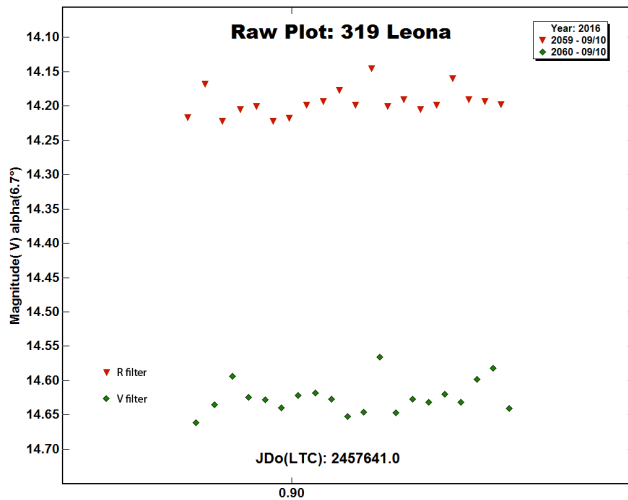


Figure 6. Observations of 319 Leona 2016 Sept. 10 in R and V magnitudes.

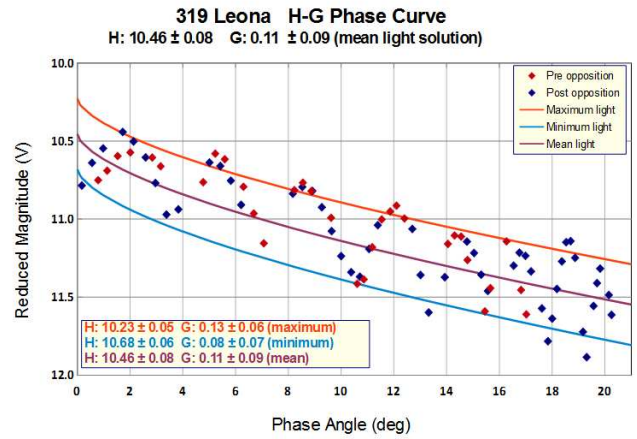


Figure 7. H-G plots for 319 Leona for maximum, mean, and minimum light data points, respectively.

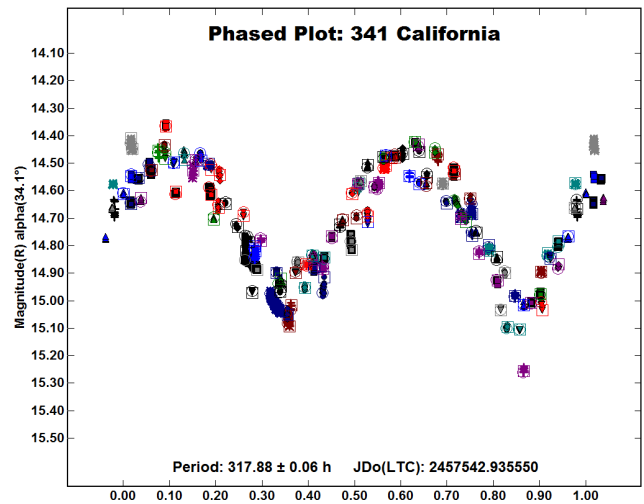


Figure 8. Single period lightcurve of 341 California based on 117 sessions 2016 June 3 - Dec. 7 in R band magnitudes, corrected for changes in phase angle and geocentric and heliocentric distances and prepared by MPO Canopus software.

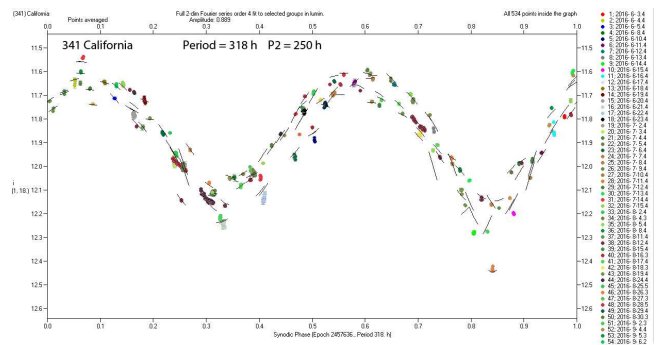


Figure 9. Fourth order 2 period Fourier series lightcurves of 341 California.

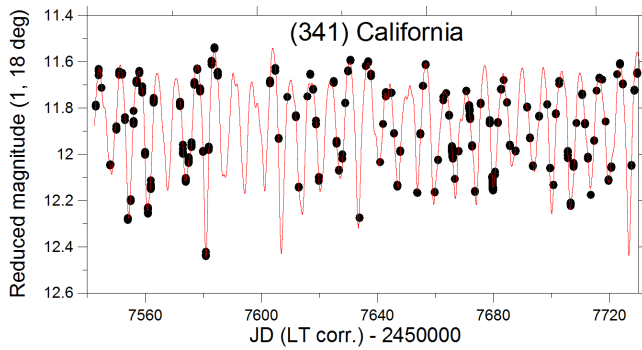


Figure 10. Raw lightcurve of all sessions of 341 California fit to a 2 period Fourier model.

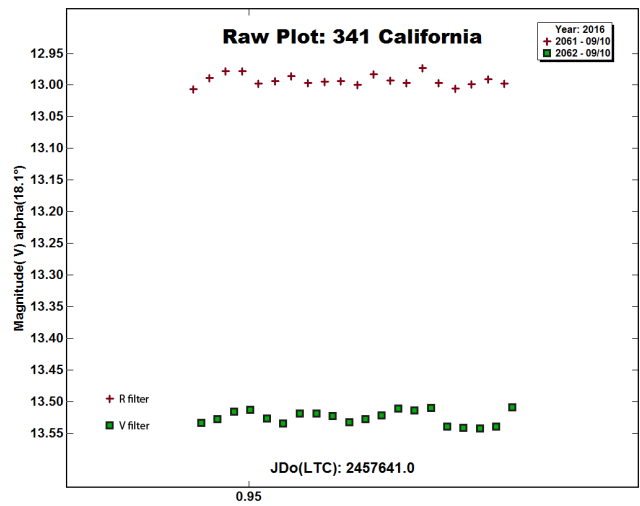


Figure 13. Observations of 341 California 2016 Sept. 10 in R and V magnitudes.

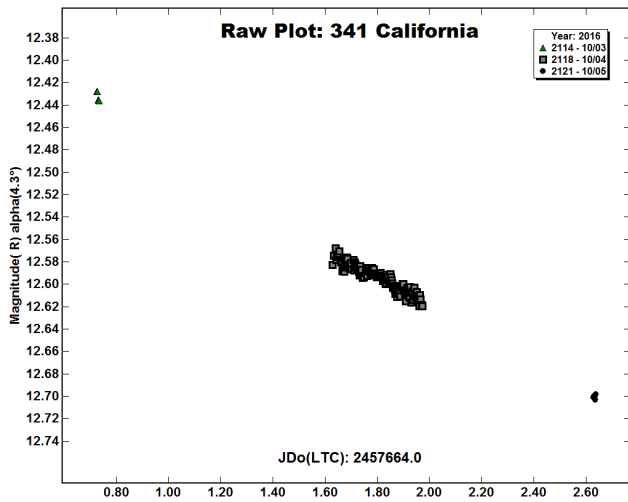


Figure 11. Raw lightcurve of 341 California for the interval 2016 Oct. 3-5.

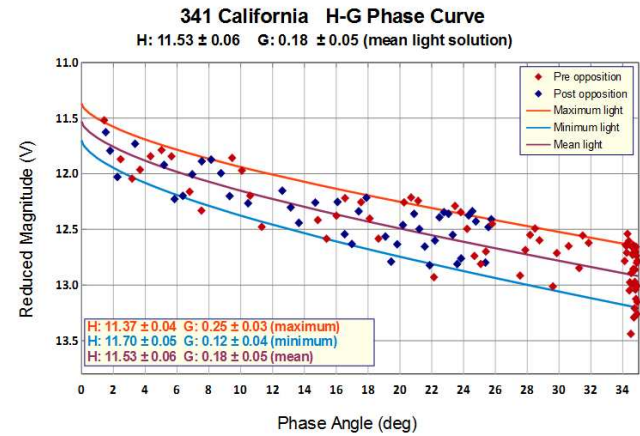


Figure 14. H-G plots for 341 California for maximum, mean, and minimum light data points, respectively.

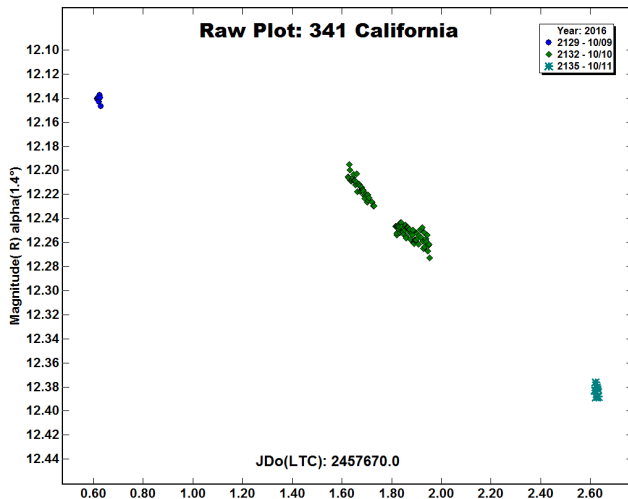


Figure 12. Raw lightcurve of 341 California for the interval 2016 Oct. 9-11.

CALL FOR OBSERVATIONS

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Observers who have made visual, photographic, or CCD measurements of positions of minor planets in calendar 2016 are encouraged to report them to this author on or before 2017 April 15. This will be the deadline for receipt of reports which can be included in the “General Report of Position Observations for 2016,” to be published in *MPB* Vol. 44, No. 3.