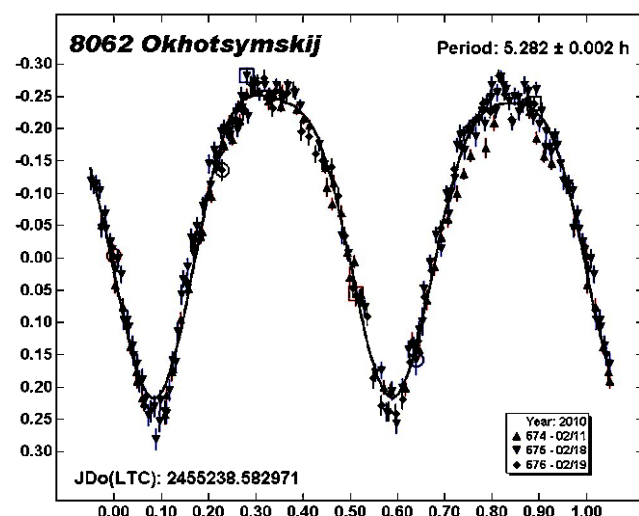
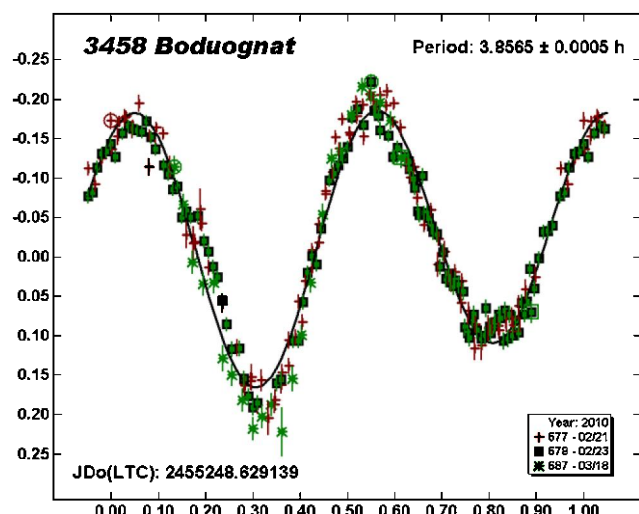




UPON FUTHER REVIEW: I. AN EXAMINATION OF PREVIOUS LIGHTCURVE ANALYSIS FROM THE PALMER DIVIDE OBSERVATORY

Brian D. Warner

Palmer Divide Observatory/Space Science Institute
17995 Bakers Farm Rd., Colorado Springs, CO 80908 USA
brian@MinorPlanetObserver.com

(Received: 25 March)

Updated results are given for ten asteroids previously reported from the Palmer Divide Observatory. The original images were re-measured to obtain new data sets using the latest version of MPO Canopus photometry software, analysis tools, and revised techniques for linking multiple observing runs covering several days to several weeks. Results that were previously not reported or had significantly different periods and/or amplitudes were found for 222 Lucia, 331 Etheridgea, 421 Zahringia, 506 Marion, 586 Thekla, 756 Lilliana, 862 Franzia, 957 Camelia, 1042 Amazone, and 1266 Tone. This is the first in a series of papers that will examine results obtained during the initial years of the asteroid lightcurve program at PDO.

The availability of improved analysis tools and techniques along with the experience gained over more than a decade of asteroid lightcurve photometry have lead to a program to re-examine the early work and results at the Palmer Divide Observatory (c. 1999-2006). In most cases, any changes in the period and/or amplitude as a result of the new analysis were statistically insignificant. However, there were some cases where the new results were significantly different. This paper is the first in a series that reports updated results from the new analysis, giving updates on 10 of the 17 significant revisions. Subsequent papers will complete the list of significant revisions and then those of lesser importance found in the initial stage of the re-evaluation program. Subsequent stages may result in additional updates.

MPO Canopus, developed by the author, is used exclusively at PDO. Since its first version, which did only the most essential functions of photometry, it has undergone a number of revisions. These now include an improved sky background algorithm, a star

#	Name	Original				Revised				
		Per	Amp	U	Ref	Per	PE	Amp	AE	U
221	Lucia				Not previously published	7.6	0.2	0.38	0.02	2
331	Etheridgea	6.82	0.05	2	Warner; MPB 30, 61-64	Long?				1
421	Zahringia	15.5	0.12	1	Robinson; MPB 29, 30-31	6.42 ²	0.01	0.10	0.01	2
506	Marion	10.58	0.35	2	Robinson; MPB 29, 6-7	13.56	0.01	0.30	0.01	2
586	Thekla	10.630	0.24	2	Warner; MPB 27, 20-21	13.68	0.01	0.29	0.01	2+
756	Lilliana				Not previously published	9.37	0.05	0.30	0.02	2-
862	Franzia	15.05 ¹	0.12	2	Warner; MPB 32, 29-32	7.52	0.01	0.13	0.01	2+
862	Franzia					7.65 ³	0.01	0.10	0.02	2
957	Camelia	5.391	0.32	2	Warner; MPB 28, 4-5	150	30	>0.30		1+
1042	Amazone	16.26	0.10	2	Warner; MPB 32, 90-92	540	30	>0.25		2
1266	Tone	11.82	0.12	2	Warner; MPB 30, 61-64	7.4	0.1	0.06	0.01	2

Table I. Summary of original and revised results. The period is in hour and the amplitude is in magnitudes. The U code rating is based on the criteria outlined in the Lightcurve Database (Warner et al., 2009c). Unless otherwise stated, the references are from the *Minor Planet Bulletin* for the original results, with only the volume and page numbers given.

¹ Ambiguous; 7.6 h also given.

² Ambiguous; 12.86 h also possible.

³ Ambiguous; 15.27 h also possible.

subtraction algorithm to remove faint field stars near or merged with the asteroid, Fourier analysis based on the FALC algorithm by Harris (Harris et al., 1989), and use of the 2MASS catalog (Skrutskie et al., 2006) along with formulae to convert the J-K magnitudes to the BVRI system (see Warner 2007; Stephens 2008). These additional features made it worthwhile to review past results, not just by analyzing the original data but generating new data by re-measuring the original images.

Regenerating the data often resulted in data sets that were significantly less noisy, had fewer gaps (i.e., faint stars were removed instead of ignoring images where the asteroid and stars comingled), and could be linked over multiple nights with little or no guesswork due to the 2MASS-BVRI conversions. This last point was probably the most important in assessing the revised data. Without some sort of internal calibration, matching nightly runs could be highly subjective and result in totally incorrect results. For example, without the calibration it was not possible to determine that an asteroid was actually slowly increasing or decreasing in brightness (indicating a slow rotator). Instead, the tendency was to force the individual sessions to overlay one another and try to find a period, often based on what was only noise in the data. In recent years, the discovery of a strong excess of slow rotators among small asteroids (see Pravec, 2008; Warner, 2009b) and the need to understand “tumbling” asteroids (see Pravec, 2005) have made it even more important to provide linked data sets when they span many days or even weeks.

Re-examination of earlier results can prove a little embarrassing but it is better to be sure (as much as possible) of the data and subsequent results. Significant errors (and biases) can affect trend analysis in many ways. Re-examination can also lead to important new discoveries, e.g., going from a long period asteroid to being a probable binary (Warner et al., 2009a). If nothing else, going through the process of reviewing older data and results can further develop one’s techniques and skill in asteroid photometry. That is always a worthwhile effort.

Presentation of the New Analysis

Each paper in this series will give a brief analysis of the new data set and show a lightcurve based on that new data set, even if there is no significant difference in the period. The “improvement” may be a revised amplitude or simply “better data” to be used for modeling in the future (e.g., the U code may have a different rating; see Warner et al., 2009c, for information about the U code rating system). The exact observing details will not be given. Instead, a table will list the original and new results along with a reference to the original paper. The original reference gives data on the equipment used and references to results from other authors and so those will not be repeated here.

The plots show the *R-band* reduced magnitude of the asteroid. This means that the data for each night were corrected to “unity distance” using $-5 \cdot \log(rR)$ where r was the Earth-asteroid distance and R was the Sun-asteroid distance, both in AU. The data were also corrected to the phase angle of the earliest session using $G = 0.15$ (unless otherwise stated).

222 Lucia. Despite the data being obtained 1999 April, the results were never published. The period given in the table is based on a half-period solution (monomodal curve). A better period solution was determined by Stephens (2009).

331 Etheridgea. The raw plot shows a small rise over several days, possibly indicating a long period. However, given the 13-day gap

between the two sessions, it’s entirely possible that they represent parts of a much shorter period lightcurve with an undetermined number of cycles in-between. If the two sessions are forced to overlap, a number of solutions with $P < 24$ can be found.

421 Zahringia. The lightcurve shows the monomodal solution of 6.42 ± 0.01 h. The double period of 12.86 ± 0.01 h, with a bimodal curve, cannot be formally excluded.

506 Marion. This corrects the period derived from the original data set. The new period agrees with subsequent results from this and other authors.

586 Thekla. This corrects the period derived from the original data set. It agrees with subsequent results.

756 Lilliana. The results of the original data set were not previously published. The period of 9.37 ± 0.05 h reported here is based on finding the half-period solution. Given the sparse data set, the period is in reasonable agreement with published results.

862 Franzia. Results from data sets obtained in 2000 and 2004 are reported here. Those from 2000 give a period of 7.52 ± 0.01 h while those from 2004 yield a solution of 7.65 ± 0.01 h or, less likely, 15.27 h.

957 Camelia. The revised data set indicates this to be a slow rotator, with a period on the order of 150 h. The previous result of $P \sim 5.4$ h was derived without the guidance of proper data set linking: the sessions were forced to overlay one another by using arbitrary zero point offsets.

1042 Amazone. This is another case where the arbitrary adjustment of nightly zero points likely lead to a false solution. The derived period of 540 ± 30 h is based on finding a half-period solution. The amplitude of > 0.25 mag makes it probable that the complete curve would be bimodal.

1266 Tone. The plot shows the monomodal solution of $P = 7.4$ h. The double period of 14.8 h cannot be formally excluded.

Acknowledgements

Funding for current observations and research at PDO is provided by NASA grant NNX 09AB48G, by National Science Foundation grant AST-0907650, and by a 2007 Gene Shoemaker NEO Grant from the Planetary Society.

References

- Harris, A.W., Young, J.W., Bowell, E., Martin, L.J., Millis, R.L., Poutanen, M., Scaltriti, F., Zappala, V., Schober, H.J., Debehogne, H., and Zeigler, K.W. (1989). “Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863.” *Icarus* **77**, 171-186.
- Pravec, P., Harris, A.W., Scheirich, P., Kušnirák, P., Šarounová, L., and 15 colleagues (2005). “Tumbling Asteroids.” *Icarus* **173**, 108-131.
- Pravec, P., Harris, A.W., Vokrouhlický, D., Warner, B.D., and 27 colleagues (2008). “Spin rate distribution of small asteroids.” *Icarus* **197**, 497-504.
- Skrutskie, M.F., Cutri, R.M., Stiening, R., et al. (2006). “The Two Micron All Sky Survey (2MASS).” *Astron. Jour.* **131**, 1163-1183.

Stephens, R.D. (2008). "Long Period Asteroids Observed from GMARS and Santana Observatories." *Minor Planet Bul.* **35**, 21-22.

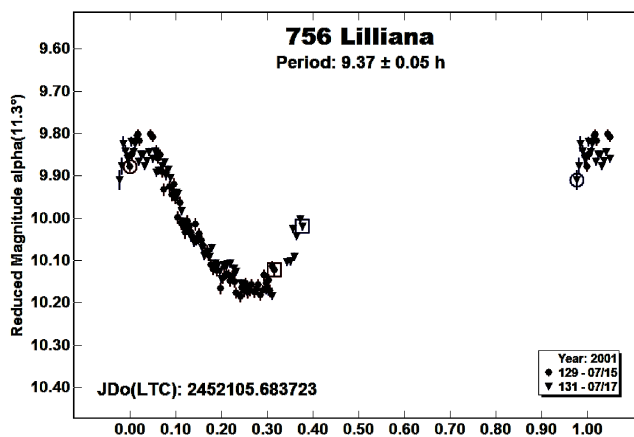
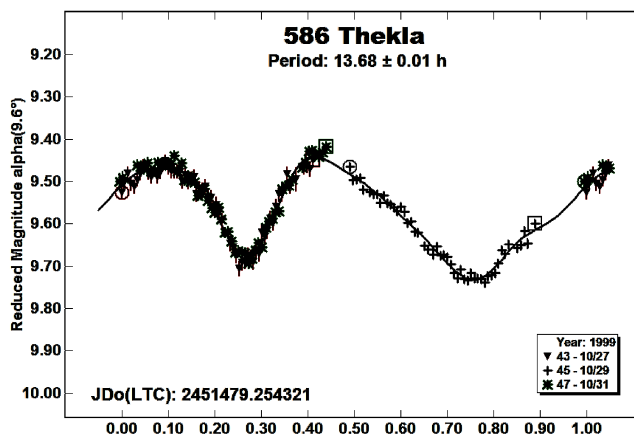
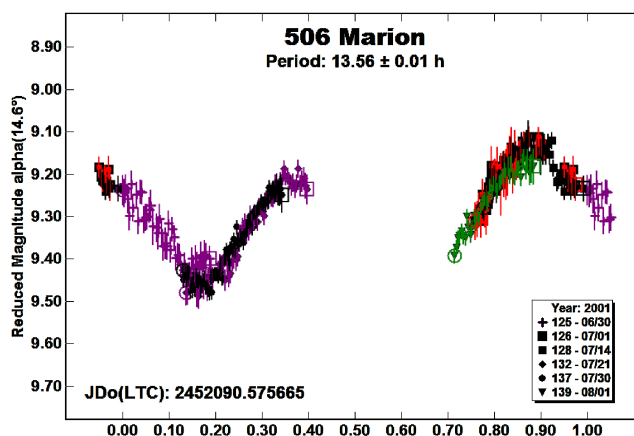
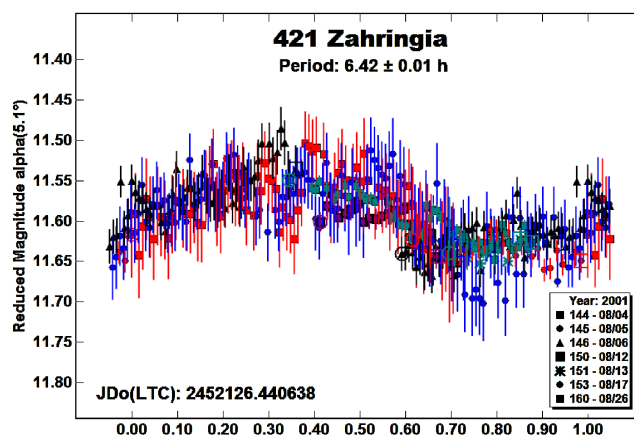
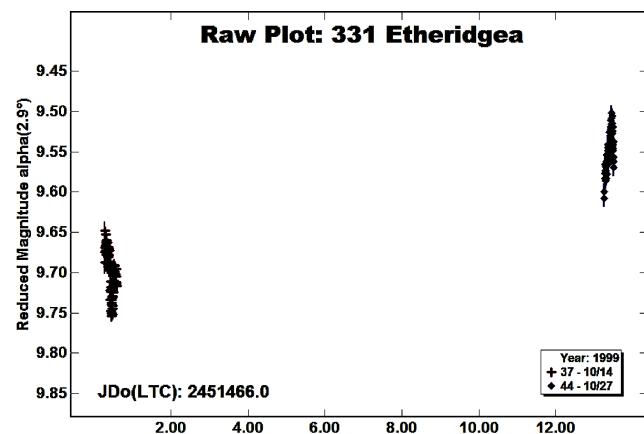
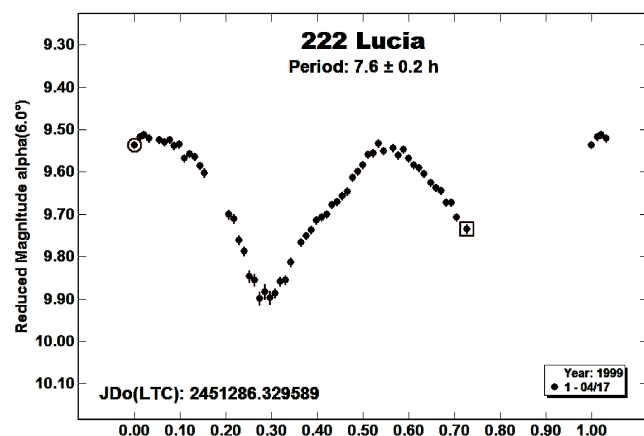
Stephens, R.D. (2009). "Asteroids Observed from GMARS and Santana Observatories." *Minor Planet Bul.* **36**, 59-62.

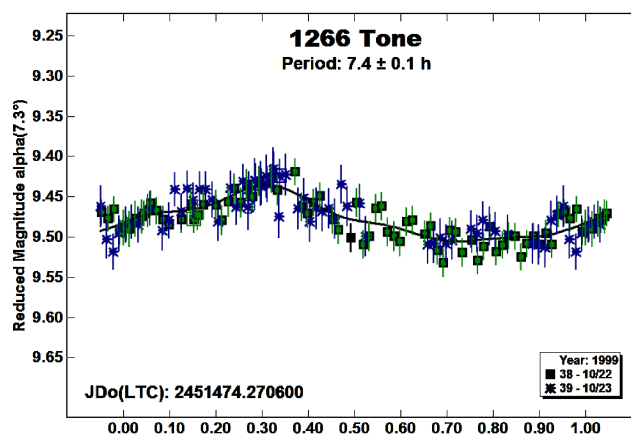
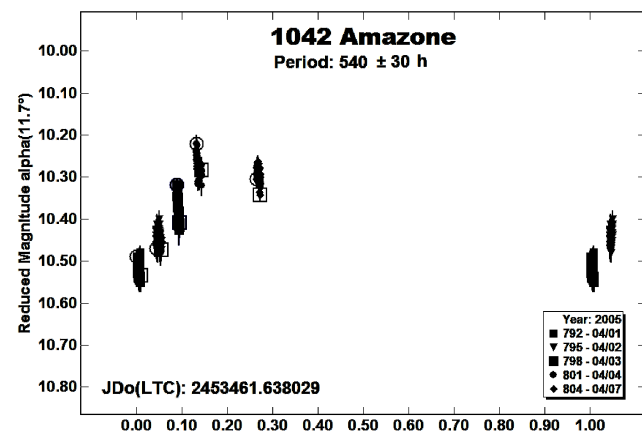
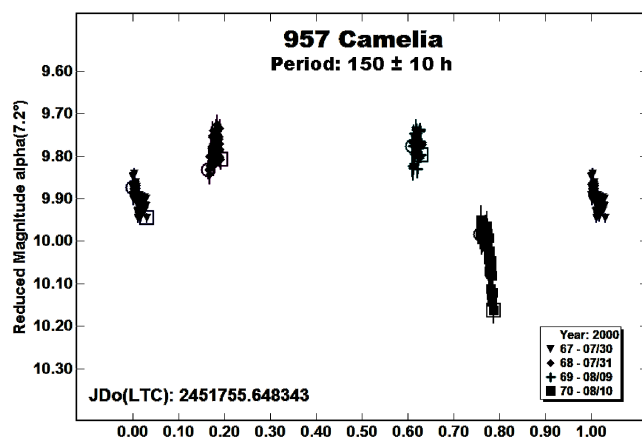
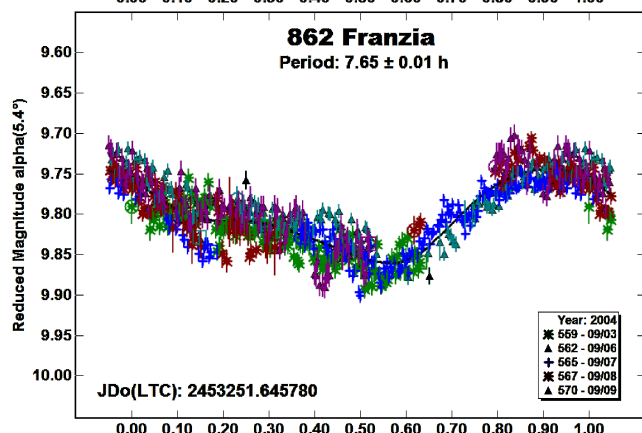
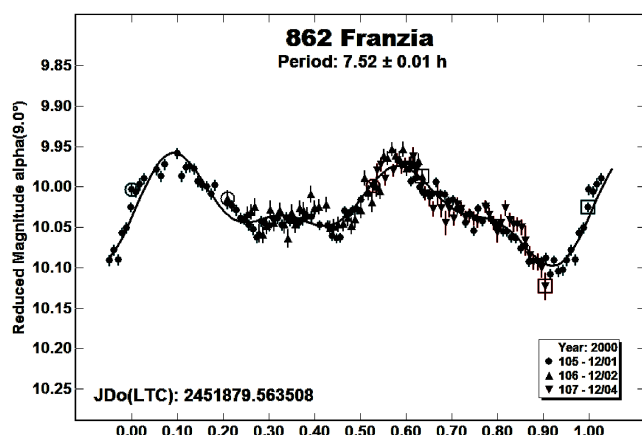
Warner, B.D. (2007). "Initial Results from a Dedicated H-G Project." *Minor Planet Bul.* **34**, 113-119.

Warner, B.D., Stephens, R.D., Harris, A.W. and Pravec, P. (2009a). "A Re-examination of the Lightcurves for 7 Hungaria Asteroids." *Minor Planet Bul.* **36**, 176-178.

Warner, B.D., Harris, A.W., and Pravec, P. (2009b). "An Analysis of Slow Rotators Among the Hungaria Asteroids." *B.A.A.S.* **41**, 34.11, p 1062.

Warner, B.D., Harris, A.W., and Pravec, P. (2009c). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146.





LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2010 JULY - SEPTEMBER

Brian D. Warner
Palmer Divide Observatory/Space Science Institute
17995 Bakers Farm Rd.
Colorado Springs, CO 80908 USA
brian@MinorPlanetObserver.com

Alan W. Harris
Space Science Institute
La Canada, CA 91011-3364 USA

Petr Pravec
Astronomical Institute
CZ-25165 Ondřejov, CZECH REPUBLIC

Josef Durech
Astronomical Institute
Charles University in Prague
18000 Prague, CZECH REPUBLIC
durech@sirrah.troja.mff.cuni.cz

Lance A.M. Benner
Jet Propulsion Laboratory
Pasadena, CA 91109-8099 USA
lance@reason.jpl.nasa.gov

This time we feature several NEAs for radar support that may present some challenges given their fast sky motion, faintness, and/or proximity to the Sun. For more background on the program details for each of the opportunity lists, refer to previous issues, e.g., *Minor Planet Bulletin* **36**, 188.

As always, we urge observations of asteroids even if they have well-established lightcurve parameters, especially if they do not yet have good spin axis or shape models. Every lightcurve of sufficient quality provides valuable information in support of such efforts, which are needed to resolve a number of questions about the evolution of individual asteroids and the general population. Furthermore, data over many apparitions can help determine if an asteroid's rotation rate is being affected by the YORP effect, a thermal effect that can cause a smaller, irregularly-shaped asteroid to speed up or slow down. This is done by seeing if a constant sidereal period fits all the data equally well or if a small linear change in the period produces better results. See Lowry et al. (2007) *Science* **316**, 272-274 and Kaasalainen et al. (2007) *Nature* **446**, 420-422.