LIGHTCURVE ANALYSIS OF 10 V-TYPE ASTEROIDS

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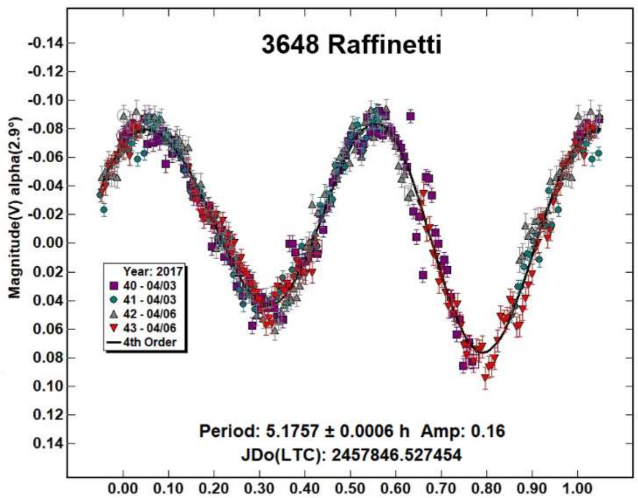
Lightcurves for ten asteroids of taxonomic type V, potential impact debris from 4 Vesta, are presented. This analysis is based on observations conducted from 2016 November through 2017 June.

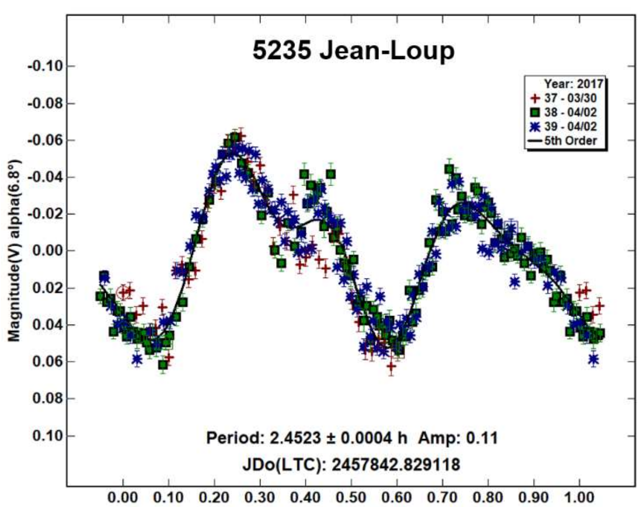
Photometric observations of ten V-type asteroids were performed using three observatories: Stone Edge Observatory (SEO) in Sonoma, CA, USA; Cerro Tololo Inter-American Observatory (CTIO) in La Serena, Chile; and Yerkes Observatory in Williams Bay, WI, USA. Telescope, camera, and image specifications for each of these facilities are presented in Table I. All images used in this analysis were obtained between 2016 November and 2017 June. Data processing and analysis were done with *MPO Canopus* (Warner, 2019).

The targets for this study were selected from a set of asteroids categorized by Carvano et al. (2010) with a V_p-type taxonomic class. This taxonomy was developed based on optical photometric observations from the Sloan Digital Sky Survey (SDSS) Moving Object Catalogue (MOC4) (Ivezić et al., 2010). The V_p-type taxonomic class is so named because of its photometric similarities with 4 Vesta; hence, these asteroids represent a population of potential impact debris from that parent body. Several of the target asteroids for this study were also included in a near-infrared spectroscopic investigation conducted by Hardersen et al. (2014, 2015). The orbital and physical properties of the ten target asteroids are shown in Table II. Table III summarizes the observing circumstances and the results of this study.

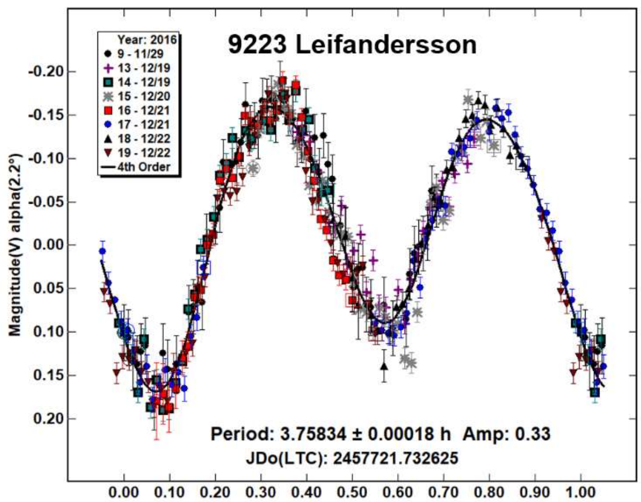
3648 Raffinetti was discovered in 1957 at the La Plata Observatory near Buenos Aires, Argentina. The asteroid was named after Virgilio Raffinetti (1869-1946), the observatory's director from 1889 to 1905. The asteroid was observed using the CTIO-PROMPT6 telescope. Measurements were obtained for a total of approximately 15 hours using exposure times of 120 seconds and an open filter (*i.e.*, no filter). The derived rotational period was $P = 5.1757 \pm 0.0006$ h with an amplitude of $A = 0.16 \pm 0.007$ mag. Galdies (2022) published a similar result of $P = 5.177 \pm 0.001$ h.



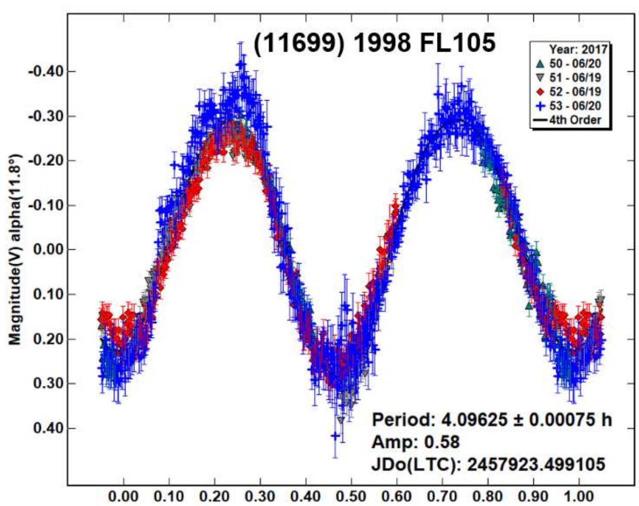
5235 Jean-Loup was discovered in 1990 at the Palomar Observatory, CA, USA. The asteroid was named after French astronaut Jean-Loup Jacques Marie Chrétien (1938-). 5235 Jean-Loup was observed using the CTIO-PROMPT6 telescope. Measurements were obtained for a total of approximately 9.5 hours using exposure times of 120 seconds and an open filter. The derived rotational period was $P = 2.4523 \pm 0.0004$ h with an amplitude of $A = 0.11 \pm 0.006$ mag. Oszkiewicz et al. (2020) published a similar result of $P = 2.4524 \pm 0.0001$ h.



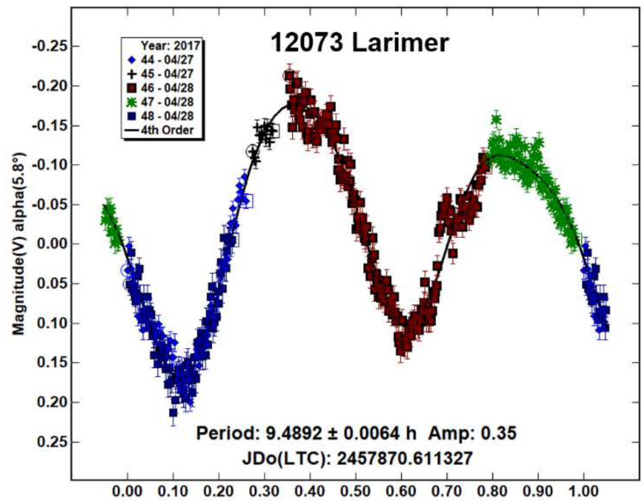
9223 Leifandersson was discovered in 1995 by the University of Arizona's SPACEWATCH group at the Kitt Peak National Observatory, AZ, USA. The asteroid was named after Swedish astronomer Leif Erland Andersson (1943-1979), who calculated the pole orientation of the planet Pluto. 9223 Leifandersson was observed using both the SEO and CTIO-PROMPT6 telescopes. Measurements were obtained for a total of approximately 23 hours using exposure times of (1) 120 seconds and a clear filter for SEO, and (2) 180 seconds and an open filter for CTIO-PROMPT6. The derived rotational period was $P = 3.75834 \pm 0.00018$ h with an amplitude of $A = 0.33 \pm 0.028$ mag. Waszczak et al. (2015) published a similar result of $P = 3.758 \pm 0.0014$ h.



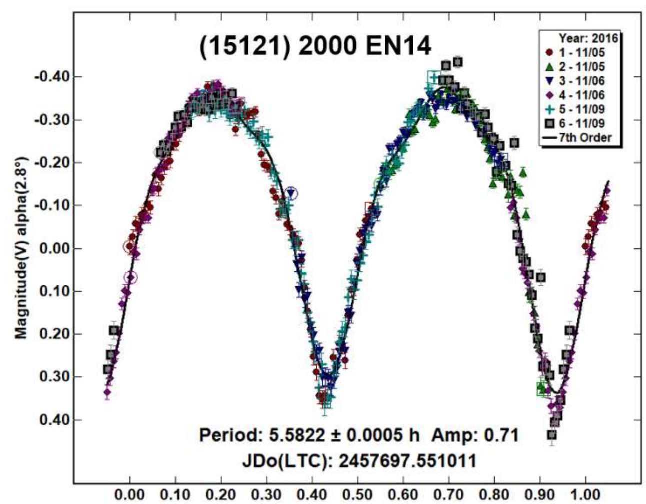
(11699) 1998 FL105 was discovered in 1998 by MIT's Lincoln Near Earth Asteroid Research (LINEAR) program in Soccoro, NM, USA. (11699) 1998 FL105 was observed using both the CTIO-PROMPT3 and CTIO-PROMPT6 telescopes. Measurements were obtained for a total of approximately 15 hours using individual exposure times of (1) 30 seconds and a clear filter for CTIO-PROMPT3, and (2) 80 seconds and an open filter for CTIO-PROMPT6. The derived rotational period was P = 4.09625 ± 0.00075 h with an amplitude of A = 0.58 ± 0.042 mag. A review of the literature found no previously published lightcurve results for (11699) 1998 FL105.



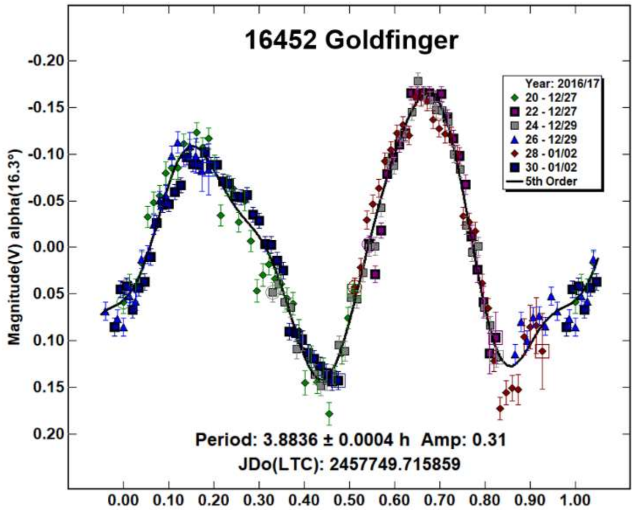
12073 Larimer was discovered in 1998 by LINEAR. The asteroid was named after Curtis James Larimer (1986-), a 2002 awardee of the Intel International Science and Engineering Fair (ISEF). 12073 Larimer was observed using the CTIO-PROMPT6 telescope. Measurements were obtained for a total of approximately 11 hours using individual exposure times of 120 seconds and an open filter. The derived rotational period was P = 9.4892 ± 0.0064 h with an amplitude of A = 0.35 ± 0.019 mag. A review of the literature found no previously published lightcurve results for 12073 Larimer.



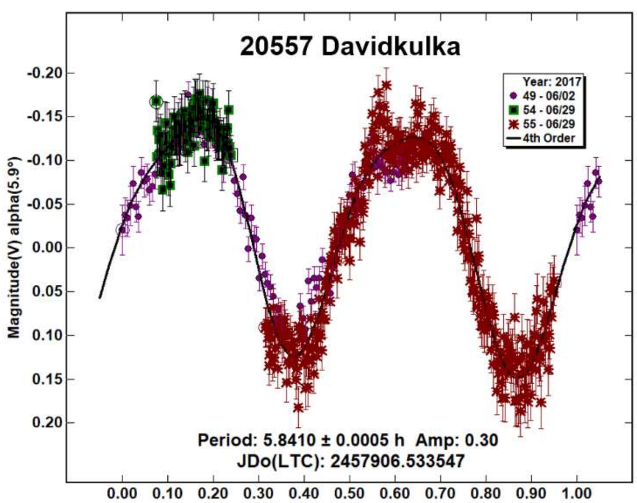
(15121) 2000 EN14 was discovered in 2000 by Korado Korlević at the Višnjan Observatory, Croatia. (15121) 2000 EN14 was observed using the CTIO-PROMPT6 telescope. Measurements were obtained for a total of approximately 15 hours using individual exposure times of 120 seconds and an open filter. The derived rotational period was P = 5.5822 ± 0.0005 h with an amplitude of A = 0.71 ± 0.020 mag. Yeh et al. (2020) estimated a longer period (by approximately 0.22 h or 4%) of P = 5.80 ± 0.06 h based on 14 observations by the China Near-Earth Object Survey Telescope (CNEOST).



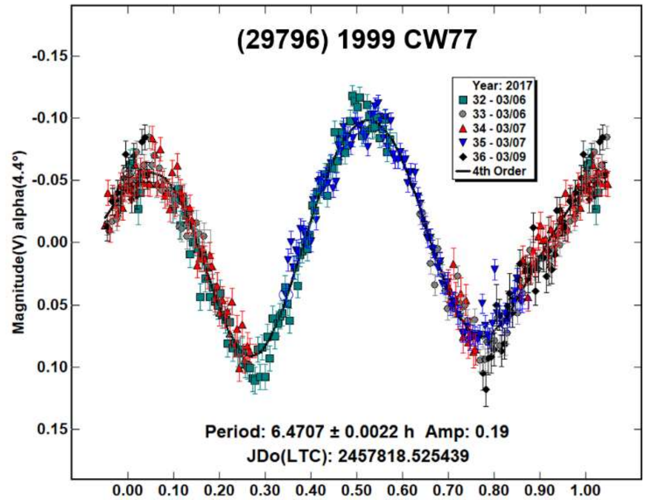
16452 Goldfinger was discovered in 1998 by Carolyn Shoemaker at the Palomar Observatory, CA. The asteroid was named after Pauline J. ("PJ") Goldfinger (1964-), an adaptive-optics operator at the observatory who helped to organize the glass plate archive of the observatory's famous Schmidt Oschin telescope. 16452 Goldfinger was observed using the CTIO-PROMPT6 telescope. Measurements were obtained for a total of approximately 14 hours using individual exposure times of 120 (on 2017 February 27) and 180 seconds (all other dates) and an open filter. The derived rotational period was P = 3.8836 ± 0.0004 h with an amplitude of A = 0.31 ± 0.014 mag. Dose (2021) published a similar result of P = 3.884 ± 0.001 h.



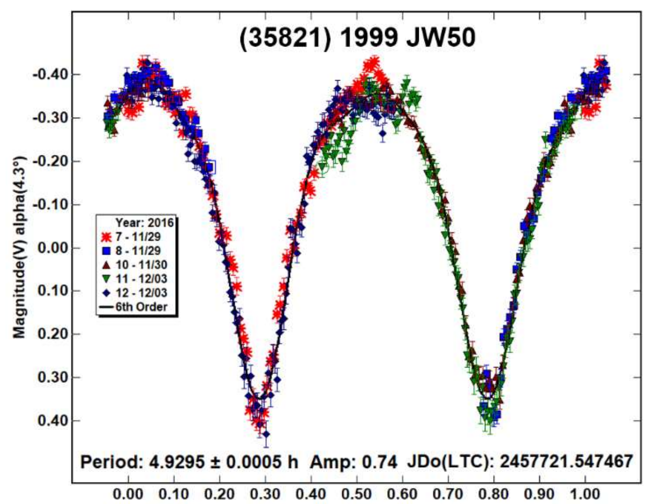
20557 Davidkulka was discovered in 1999 by LINEAR. The asteroid was named after David Kulka, a mentor at the 2004 Discovery Channel Young Scientist Challenge. 20557 Davidkulka was observed using both the CTIO-PROMPT1 and CTIO-PROMPT6 telescopes. Measurements were obtained for a total of approximately 16 hours using exposure times of (1) 35 seconds and a clear filter for CTIO-PROMPT1, and (2) 120 seconds and an open filter for CTIO-PROMPT6. The derived rotational period was P = 5.8410 ± 0.0005 h with an amplitude of A = 0.30 ± 0.028 mag. Durech et al. (2019) estimated a shorter period (by approximately 0.5 h or 9%) of 5.295743 ± 0.000002 h based on photometric data from the Lowell Observatory and the Gaia Data Release 2.



(29796) 1999 CW77 was discovered in 1999 by LINEAR. (29796) 1999 CW was observed using the Yerkes-41 telescope. Measurements were obtained for a total of approximately 16 hours using exposure times of 120 seconds and a clear filter. The derived rotational period was P = 6.4707 ± 0.0022 h with an amplitude of A = 0.19 ± 0.013 mag. A review of the literature found no previously published lightcurve results for (29796) 1999 CW.



(35821) 1999 JW50 was discovered in 1999 by LINEAR. (35821) 1999 JW50 was observed using the CTIO-PROMPT6 telescope. Measurements were obtained for a total of approximately 14 hours using exposure times of 120 and 80 (3 December 2016) seconds and an open filter. The derived rotational period was P = 4.9295 ± 0.0005 h with an amplitude of A = 0.74 ± 0.013 mag. Waszczak (2015) published a similar result of P = 4.931 ± 0.1177 h.



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Observatory	Code	Telescope	Aperture	Focal Ratio	Filter	CCD	Binning	Resolution	Image Scale
SEO	G52	RC	0.51 m	f/8.1	Clear	FLI CG230	2x2	1024x1024	1.50 arcsec/pixel
CTIO-PROMPT 1/3	807	DK	0.6 m	f/6.6	Clear	Alta F47	2x2	512x512	1.34 arcsec/pixel
CTIO-PROMPT 6	807	RC	0.41 m	f/17.3	Open	Aspen CG230	2x2	1024x1024	0.87 arcsec/pixel
Yerkes-41	754	Cass.	1.0 m	f/8.2	Clear	SBIG STL-1001E	1x1	1024x1024	0.61 arcsec/pixel

Table I. Facilities used to perform the observations presented in this paper. Resolution and image scale are provided according to the specified binning.

Number	a (AU)	i (°)	e	H	D (km)	p_V
3648	2.42	7.90	0.11	13.0	5.31	0.609
5235	2.30	4.85	0.14	12.7	7.39	0.301
9223	2.30	3.41	0.07	13.5	4.50	0.381
11699	2.40	5.08	0.08	13.1	6.71	0.227
12073	2.42	6.24	0.09	14.0	2.95	0.465
15121	2.35	3.57	0.16	15.0	3.55	0.169
16452	2.41	6.29	0.08	13.4	4.33	0.344
20557	2.38	6.27	0.10	14.1	3.95	0.179
29796	2.34	7.87	0.07	13.9	4.85	0.248
35821	2.48	5.95	0.13	14.3	N/A	N/A

Table II. Orbital parameters and physical properties for the target asteroids. Diameter (*D*) and visible albedo (p_V) values are from Masiero et al. (2011).

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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
3648	Raffinetti	2017 4/3-4/6	2.9,1.6	198	-2	5.1757	0.0006	0.16	0.007	MB-M
5235	Jean-Loup	2017 3/30-4/2	6.9,5.6	200	-6	2.4523	0.0004	0.11	0.006	Flora
9223	Leifandersson	2016 11/29-12/22	2.1,12.7	63	-1	3.7583	0.0002	0.33	0.028	MB-M
11699	1998 FL105	2017 6/19-6/20	11.8,12.3	248	-5	4.0963	0.0008	0.58	0.042	Vesta
12073	Larimer	2017 4/27-4/28	5.9,5.4	227	+4	9.4892	0.0064	0.35	0.019	Vesta
15121	2000 EN14	2016 11/5-11/6	2.8,2.9	43	-4	5.5822	0.0005	0.71	0.020	MB-M
16452	Goldfinger	2016 12/27-2017 1/2	16.4,14.0	127	+5	3.8836	0.0004	0.31	0.014	Vesta
20557	Davidkulka	2017 6/2-6/29	6.0,13.1	256	+9	5.8410	0.0005	0.30	0.028	Vesta
29796	1999 CW77	2017 3/6-3/9	4.4,4.5	166	-7	6.4707	0.0022	0.19	0.013	MB-M
35821	1999 JW50	2016 11/29-12/03	4.2,5.5	64	-7	4.9295	0.0005	0.74	0.013	Vesta

Table III. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).