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ROTATION PERIOD AND H-G PARAMETERS DETERMINATION FOR 1700 ZVEZDARA: A COLLABORATIVE PHOTOMETRY PROJECT

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The main-belt asteroid 1700 Zvezdara was observed from 2009 August - November in order to determine its synodic rotation period (P) and amplitude (A) as well as its absolute magnitude (H) and phase slope parameter (G). The following values were found: P = 9.114 ± 0.001 h; A = 0.10 ± 0.02 mag; H = 12.447 ± 0.019 mag; and G = 0.072 ± 0.019.

The main-belt asteroid 1700 Zvezdara was originally discovered at the Belgrade Astronomical Observatory (BAO) on 1940 August 26 by Serbian astronomer Pero M. Djurkovich using a photo-visual Zeiss refractor with two 16/80 cm photographic cameras. The object is named after Zvezdara hill where the BAO facilities have been located since 1932.

Since no rotation parameters for this object were previously determined, as noted by Warner et al. (2009), our initial intention was to determine a secure rotation period. An exceptionally favorable apparition in 2009 September, with the asteroid reaching $V \sim 13.5$, provided an excellent opportunity for systematic photometric observations using modest instrumentation. Higgins began recording observations on 2009 August 20 at Hunter Hill Observatory equipped with a 0.35-m Schmidt-Cassegrain telescope (SCT) working at f/4 and an SBIG ST-8E CCD. Baker independently initiated observations on 2009 September 18 at Indian Hill Observatory using a 0.3-m SCT reduced to f/6.2 coupled with an SBIG ST-402ME CCD and Johnson V filter. Benishek from the Belgrade Astronomical Observatory joined the collaboration on 2009 September 24 employing a 0.4-m SCT operating at f/10 with an unguided SBIG ST-10 XME CCD. Pilcher at Organ Mesa Observatory carried out observations on 2009 September 30 over more than seven hours using a 0.35-m f/10 SCT and an unguided SBIG STL-1001E CCD. As a result of the collaborative effort, a total of 17 time series sessions was obtained from 2009 August 20 until October 19. All observations were unfiltered with the exception of those recorded on September 18. *MPO Canopus* software (BDW Publishing, 2009a) employing differential aperture photometry, was used by all authors for photometric data reduction. The period analysis was performed using the same program.

The data were merged by adjusting instrumental magnitudes and overlapping characteristic features of the individual lightcurves. Various problems, such as adverse weather conditions and horizon obstructions, cut short many observing runs and so made linking the data sets difficult at times. Fortunately, a few long-duration sessions, such as the one obtained on September 30 by Pilcher, contributed greatly to the construction of the composite lightcurve. We found an initial period and then removed ambiguities associated with the lack of observations and uncertainty of the positioning of some shorter sessions relative to the others. This lead to a bimodal lightcurve with $P = 9.114 \pm 0.001$ h and amplitude $A = 0.10 \pm 0.02$ mag as the most favorable solution (based on the RMS error). In the lightcurve plot, observations are binned into sets of 3 with a maximum time interval of 5 minutes.

Phase Curve and H-G Parameters

1700 Zvezdara reached phase angle of $\alpha = 0.17$ degrees at opposition on 2009 September 21. This provided a very good opportunity to measure the absolute magnitude (*H*) and phase slope parameter (*G*). Although no observations were obtained when $\alpha < 2.0$ degrees, we derived 23 individual phase curve data points. Details for all observations are summarized in Table I. According to the *MPO Asteroid Viewing Guide* (BDW Publishing, 2009b), the asteroid will not appear as bright again for 30 years. The phase curve was constructed with the H-G calculator feature within *MPO Canopus*. The standard V magnitudes for the asteroid and comparison stars were determined using the method derived by Dymock and Miles (2009). Their derived empirical formula calculates standard V magnitudes using the Sloan r' and 2MASS J and K magnitudes for stars in the CMC-14 catalog. Selected images from all observing sessions were measured using *Astrometrica* software (Raab, 2009), including all images recorded on 2009 September 18 with a photometric Johnson V filter.

Although the asteroid's lightcurve amplitude was relatively small, the brightness variance due to the rotation was removed through visual inspection of the lightcurve. The difference in magnitude between a given point on the lightcurve on a given date and the mean magnitude was estimated. The size and direction of the correction was unique for each data point but in all cases the correction was small with a mean correction for all data points of less than 0.02 mag. Although we made no attempt to measure the possible difference in unfiltered chip response among the several cameras, we did apply a constant correction in the amount of 0.04 magnitudes to the observed standard magnitudes from the unfiltered observations. This correction had the effect of forcing the data point from the session recorded with the Johnson V filter to appear exactly on the phase curve line, presumably yielding a more accurate value for the absolute magnitude (*H*). Brightness variance due to changing orbital geometry was removed from the corrected observed standard magnitudes by calculating reduced magnitudes with the formula:

$$\mathrm{Vr} = \mathrm{Vo} - 5.0 \log(Rr)$$

where Vr is the reduced magnitude, Vo is the observed magnitude, *R* is the Sun-asteroid distance, and *r* is the Earth-asteroid distance, both in AU (Warner, 2007).

The absolute magnitude based on our observational data was found to be $H = 12.447 \pm 0.019$. The phase slope parameter was found to be $G = 0.072 \pm 0.019$. Observations were also made with an Ic filter at Indian Hill Observatory on the same night the images in V were recorded. The transformed color index of the asteroid was determined to be $V\text{-}I = 0.796$. The reduced magnitude error estimates are based primarily on the statistics contained in the *Astrometrica* log file (Table I).

A search for previous data in the literature yielded the following references. According to the Planetary Data System (2005), 1700 Zvezdara is a member of the X taxonomic class (Tholen 1989). In the Supplemental IRAS Minor Planet Survey list (SIMPS; Tedesco et al., 2002), the asteroid's absolute magnitude, albedo, and diameter are given as $V = 12.47$, $p_V = 0.0425$, and $D = 20.68$ km. We note that low albedo members of the X class are categorized as type P. Correlation studies of asteroids by Harris (1989) indicate members of the P class typically have albedo values of $p_V = 0.058 \pm 0.004$ and a mean phase slope parameter values of $G = 0.086 \pm 0.015$.

Based on the absolute magnitude derived from our observations and the albedo value from SIMPS, we calculate the diameter of 1700 Zvezdara to be 20.89 kilometers when using the formula:

$$\log D = 3.125 - 0.2H - 0.5*\log(p_V)$$

where *D* is the diameter (km), *H* is the absolute magnitude and p_V is the geometric albedo in the V band (Warner, 2007).

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We wish to thank Brian Warner for his support for asteroid lightcurve collaborations and for the continued development of software that allows efficient data sharing. Thanks also to Richard Miles of the British Astronomical Association for his work in deriving the useful method for determining accurate standard magnitudes from CMC-14 catalog data and for guidance in using the method.

References

BDW Publishing (2009a). MPO Canopus Software, version 10.0.0.4. *http://minorplanetobserver.com*

BDW Publishing (2009b). MPO Asteroid Viewing Guide Software, version 10.0.0.0. *http://minorplanetobserver.com*

Harris, A.W. (1989). "The H-G Asteroid Magnitude System: Mean Slope parameters." *Lunar Planetary Science* XX, 375-376.

Dymock, R. and Miles, R. (2009). "A method for determining the

Date 2009	Mid-UT (hh:mm)	Observer	Time Series (hr)	#Obs	Filter	Phase Angle (deg)	Reduced Magnitude	Error
Aug 20	15:51	Higgins	6.6	37	C	-18.59	13.515	0.049
Aug 27	16:31	Higgins	7.3	55	C	-15.19	13.359	0.040
Sep 11	11:37	Higgins	short		C	-6.69	13.035	0.040
Sep 12	11:49	Higgins	6.6	42	C	-6.05	12.999	0.045
Sep 15	15:25	Higgins	7.9	54	C	-4.08	12.866	0.045
Sep 18	05:21	Baker	5.0	132	V	-2.39	12.750	0.023
Sep 24	22:03	Benishek	3.2	74	C	+2.00	12.823	0.038
Sep 26	21:42	Benishek	3.5	76	C	+3.28	12.815	0.034
Sep 28	21:36	Benishek	3.2	64	C	+4.58	12.910	0.031
Sep 30	06:09	Pilcher	7.3	256	C	+5.45	12.963	0.020
Sep 30	21:33	Benishek	3.3	72	C	+5.86	13.021	0.036
Oct 04	21:11	Benishek	3.5	71	C	+8.37	13.057	0.028
Oct 05	21:24	Benishek	3.2	68	C	+8.99	13.143	0.034
Oct 06	21:27	Benishek	3.2	72	C	+9.60	13.095	0.038
Oct 07	21:17	Benishek	2.7	63	C	+10.20	13.184	0.045
Oct 08	20:59	Benishek	3.1	78	C	+10.80	13.205	0.044
Oct 11	01:57	Baker	1.0	22	C	+12.10	13.295	0.050
Oct 19	01:41	Baker	4.1	76	C	+16.48	13.540	0.120
Oct 26	01:05	Baker	short		C	+19.82	13.580	0.027
Oct 27	02:01	Baker	short		C	+20.29	13.595	0.018
Nov 12	01:43	Baker	short		C	+26.04	13.839	0.067
Nov 14	19:00	Benishek	short		C	+26.79	13.734	0.040
Nov 18	19:45	Benishek	short		C	+27.78	13.964	0.059

Table I. 1700 Zvezdara observation details.

V magnitude of asteroids from CCD images." *Journal of the British Astronomical Association* **119**, 149-156.

Raab, H. (2009). Astrometrica Software, version 4.6.0.381 *http://www.astrometrica.at*

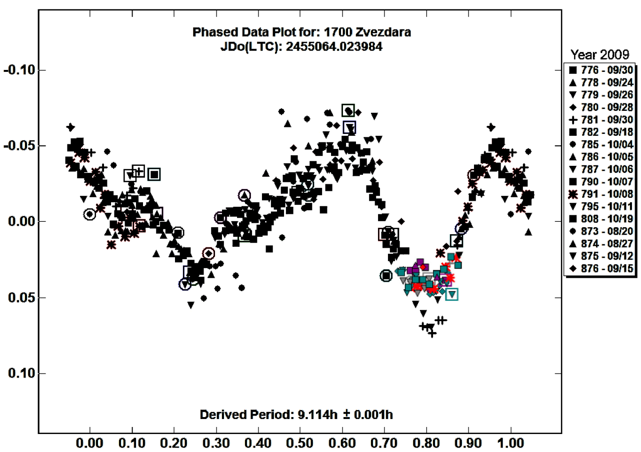
Neese, C., Ed., "Asteroid Taxonomy." EAR-A-5-DDR-TAXONOMY-V5.0. NASA Planetary Data System, 2005.

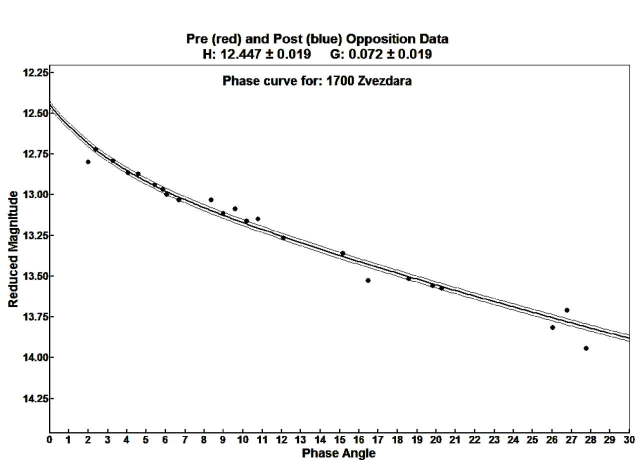
Tedesco, E.F., Noah, P.V., Noah, M., and Price, S.D. (2002). "The Supplemental *IRAS* Minor Planet Survey." *The Astronomical Journal* **123**, 1056-1085.

Tholen, D., (1989). "Asteroid Taxonomic Classifications," in *Asteroids II*, R.P. Binzel, T. Gehrels, M.S. Matthews, ed. pp 1139-1150. University of Arizona Press, Tucson.

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

Warner, B.D., Harris, A.W., Pravec, P., Durech, J., and Benner, L.A.M., (2009). "Lightcurve Photometry Opportunities: 2009 July-September." *Minor Planet Bulletin* **36**, 128-131.





COLLABORATIVE LIGHTCURVE PHOTOMETRY OF NEAR-EARTH ASTEROID (159402) 1999 AP10

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Near-Earth asteroid (159402) 1999 AP10 was observed over fifteen nights in 2009 September-October from several observatories. The resulting synodic period is 7.908 ± 0.001 h with amplitude 0.36 ± 0.02 mag. The V-R color index is 0.46 ± 0.02 mag, while the H magnitude is 16.6 ± 0.3 mag. This suggests an S-type asteroid with a diameter of 1.4 ± 0.3 km.

The near-Earth asteroid (NEA) (159402) 1999 AP10 was reported as a lightcurve photometry opportunity in the *MPB* (Warner et al., 2009a) and selected as a radar target for Arecibo from 2009 Oct 10. On 2009 Sept 23-24, after two sessions in V and R band from OAVdA, the probable rotation period was approximately 12 hours, i.e., in resonance with the Earth's rotation. Observations from different longitudes were required to resolve the period quickly. Following a message on the Minor Planet Mailing List (MPML) sent on Oct 1 by Carbognani, the authors started their collaboration. The equipment used for observations is described in Table I. The observations cover a span of 35 days with 25 sessions, for a total of 3548 data points (see Table II).

Before each session, the observers synchronized the computer's clock via Internet NTP servers to have a timing accuracy of less than one second. All images were calibrated with dark and flat-field frames. Exposure times were chosen to be as long as possible to maximize the overall signal-to-noise ratio (SNR) and to be compatible with the asteroid's sky motion: Max Exposure Time (min) = FWHM (arcsec) / rate of motion (arcsec/min).

Differential aperture photometry was performed with *MPO Canopus* (Warner, 2009b). Period analysis was done using *MPO Canopus* with the FALC analysis algorithm of Harris et al., (1989). Before starting analysis, the best sessions were selected based on signal-to-noise ratio. Sessions were aligned by adjusting the nightly zero point values using the CompAdjust form of *Canopus*. Our analysis shows a synodic period of 7.908 ± 0.001 h (Fig.1). This period is confirmed within error limits by *Peranso* (Vanmunster, 2007) using the ANOVA algorithm (Schwarzenberg-Czerny, 1996). The period spectrum covering 3-24 h (Fig. 2) shows the principal period and its harmonics, 2P and 3P, corresponding to 15.8 h and 23.7 h.