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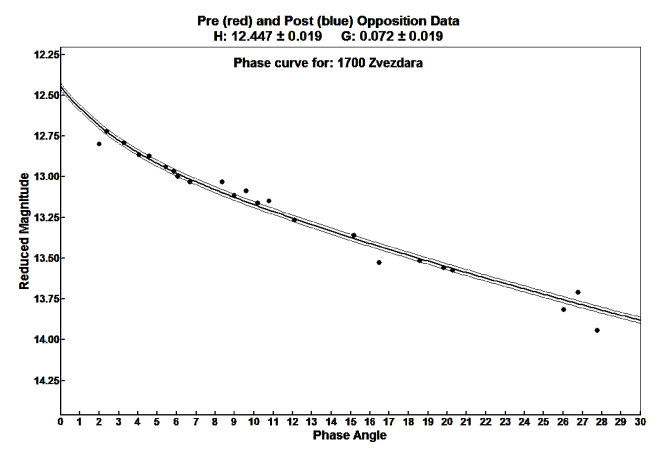
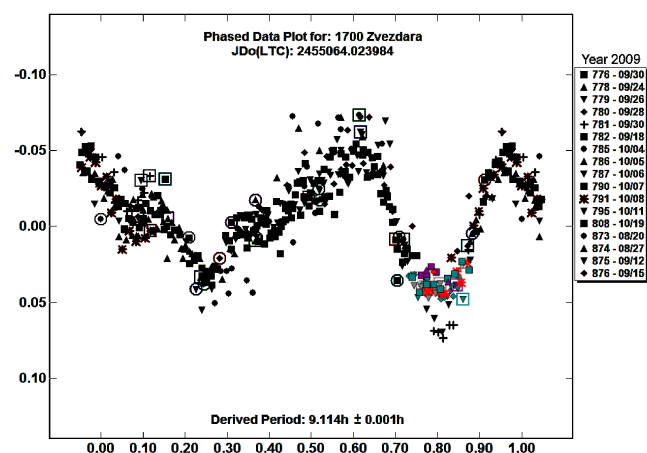
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COLLABORATIVE LIGHTCURVE PHOTOMETRY OF NEAR-EARTH ASTEROID (159402) 1999 AP10

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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.

A separate analysis of the first and second half of the data shows no significant changes in the period or amplitude (within errors), despite the different phase angles, so we used the entire data set for our analysis. However, we found that the amplitude and the synodic period of the October 24 session ($\alpha = 68.6^\circ$, not included in our analysis) changed significantly compared to the other sessions (Fig. 3). For this session we estimate a phase shift of 0.030 ± 0.016 (from 0.798 to 0.828), based on the minimums of Oct. 7 and 24 as determined with a polynomial fit in *Peranso*.

For the lightcurve amplitudes (min to max), we found a value of $A = 0.36 \pm 0.02$ mag by taking the mean values from the several sessions as found by a polynomial fit in *Peranso*. We estimate an approximate lower limit on equatorial elongation of the asteroid as follows. The mean amplitude of 0.36 mag, observed at the mean phase angle of 35 deg, was corrected to zero phase angle using the empirical formula by Zappala et al. (1990):

$$A(0^\circ) = A(\alpha) / (1 + m\alpha) \quad (1)$$

where α is phase angle of observations, and m is a slope parameter. Using $m = 0.03/\text{deg}$, which is the mean value for S-type asteroids (see below), we found $A(0^\circ) = 0.18$. Assuming a triaxial ellipsoid, this gives a lower limit for the (a/b) ratio of $a/b = 10^{(A/2.5)} = 1.2$ (Warner, 2006). Despite the range of phase angles covered, the collected lightcurves were insufficient to do shape modeling from this single apparition.

Color Index, H, and Diameter Estimate

1999 AP10 was observed from OAVdA Observatory in both R and V band, making it possible to estimate the V-R color index. For this purpose, we used the CMC14 catalogue and the method of Richard Miles and Roger Dymock (Miles and Dymock, 2009). In this method, the airmass of comparison and target are the same. The comparison stars are not Landolt stars but stars in the field of view belonging to the CMC14 catalogue with color indices J-K (from the 2MASS catalogue) between 0.3 and 0.7 (near solar values) and not belonging to GCVS (General Catalogue of Variable Stars). We manually selected the CMC14 reference stars with the help of the Aladin Sky Atlas (Bonnarel et al., 2000). Between the r' magnitude of CMC14 (Sloan DSS filter) and R/V standard magnitude, the linear relations are the following:

$$R = r' - 0.22 \quad (2)$$

$$V = 0.6278(r' - K) + 0.9947 r' \quad (3)$$

The standard deviations of the Landolt stars, from which Eq. 2 was obtained, are 0.02/0.04 mag for R and V.

Using (2) and (3), the result is $V-R = 0.46 \pm 0.02$ (mean of 7 values, see Table III), and the individual values are essentially independent from the rotational phase. This value is typical of an S-type asteroid (Shevchenko and Lupishko, 1998). For an S-type asteroid, the mean G value is 0.24 ± 0.01 , while the geometric albedo is 0.20 ± 0.07 (Shevchenko and Lupishko, 1998). With these values, we estimated the absolute magnitude and the diameter, finding $H_V = 16.6 \pm 0.3$ mag and $D = 1.4 \pm 0.3$ km. Unfortunately, there were no V values for small phase angles, i.e., near 0° , which are required for a proper determination of H and G . So, the uncertainty is still quite high, but it is still less than the error given in the JPL Small-Body Database Browser (<http://ssd.jpl.nasa.gov/sbdb.cgi>), $H_V = 15.986 \pm 0.494$ mag.

Observer	Telescope	CCD
L.Franco	SCT 0.23-m f/5.5	SBIG ST7-XME
A.Carbognani	RC 0.81-m f/7.9	FLI PL 3041-1-BB
P.Wiggins	SCT 0.35-m f/5.5	SBIG ST-10XME
B.W.Koehn ¹	ST 0.60-m f/1.8	Loral 4K X 4K
R.Schmidt	CDK 0.32-m f/8	SBIG STL1001E

Table I. Observers and equipment list. 1In the course of the Near-Earth Asteroid Photometric Survey (NEAPS).

#	Date 2009	Observer	Phase Angle	N.Obs	Filter
1	Sept 21	B.W. Koehn	20.1°	22	R
2	Sept 22	B.W. Koehn	21.0°	82	R
3	Sept 23	B.W. Koehn	22.0°	118	R
4	Sept 23	A. Carbognani	22.7°	128	V,R
5	Sept 24	A. Carbognani	23.6°	121	V,R
6	Sept 26	L. Franco	25.7°	278	C
7	Oct 2	P. Wiggins	31.7°	72	C
8,9	Oct 7	P. Wiggins	38.3°	404	C
	Oct 8	R. Schmidt	39.6°	80	R
10	Oct 8	P. Wiggins	39.6°	170	C
11,12	Oct 9	P. Wiggins	41.2°	306	C
13,14	Oct 10	P. Wiggins	42.8°	293	C
	Oct 12	R. Schmidt	45.8°	74	R
15,16	Oct 12	R. Schmidt	45.9°	71	R
	Oct 12	R. Schmidt	46.1°	212	R
	Oct 13	R. Schmidt	47.7°	302	R
17,18	Oct 13	L. Franco	49.1°	323	C
19	Oct 14	A. Carbognani	51.1°	56	V,R
20	Oct 15	A. Carbognani	52.9°	40	V,R
	Oct 24	L. Franco	68.6°	396	C

Table II. Observations list (sessions without ID are not included in the period analysis).

Month/Day	UT	V	R	V-R	α (°)
09 23	20:13	13.63	13.18	0.45	22.62
09 23	20:34	13.63	13.18	0.45	22.63
09 23	22:02	13.67	13.24	0.42	22.69
09 24	21:37	13.38	12.91	0.46	23.67
10 15	19:37	13.14	12.64	0.50	52.78
10 15	20:27	13.12	12.64	0.48	52.84
10 15	20:49	13.10	12.63	0.47	52.87

Table III. The V and R magnitude values, corrected for rotational phase with the 7.908 h period, used for mean color index and H_V estimate. The last column shows the corresponding phase angle (OAVdA Observatory).

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This research made use of the SIMBAD and VIZIER databases with the Aladin Sky Atlas that operates at CDS (Strasbourg, France), of GCVS maintained by Sternberg Astronomical Institute (Moscow, Russia), and of the NASA's Astrophysics Data System.

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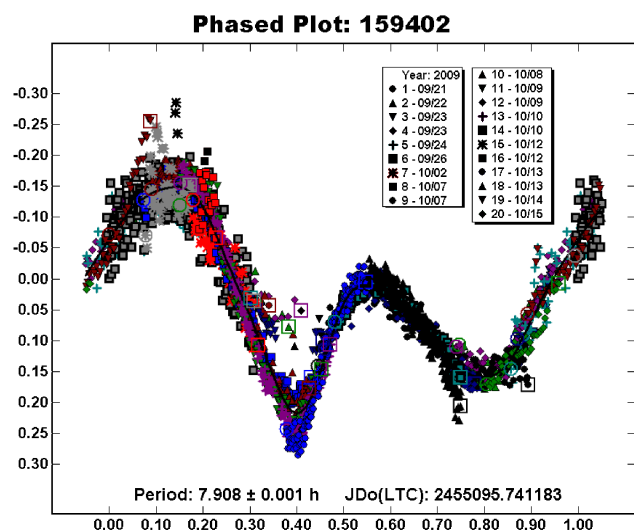


Figure 1. The lightcurve of (159402) 1999 AP10 shows a period of 7.908 h with an amplitude of 0.36 mag.

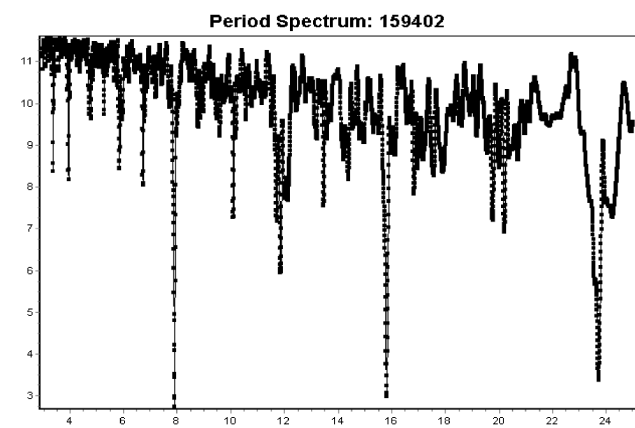


Figure 2. Period Spectrum show the principal period and the harmonics P/2 and P/3.

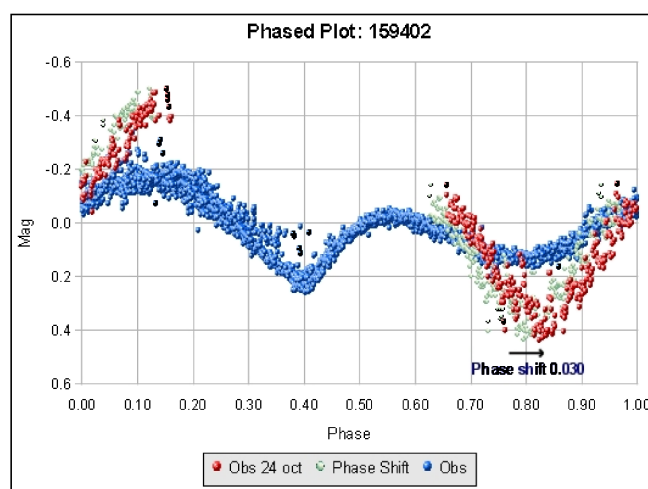


Figure 3. The session of October 24 ($\alpha = 68.6^\circ$) shows amplitude variations and a phase shift estimated as 0.030 ± 0.016 .

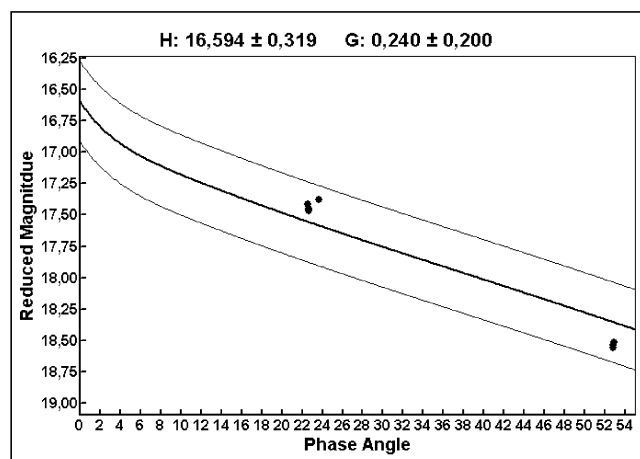


Figure 4. Visual reduced magnitude vs phase angle for Hv estimate with fixed G (OAVdA Observatory).