# Observational Observations of 162173 (1999 JU3) during the 2011-2012

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## Abstract

***Context.*** Near-Earth asteroid 162173 (1999 JU3) is a potential target of two asteroid sample return missions, not only because of its accessibility but also because of the first C-type asteroid for exploration missions. The lightcurve-related physical properties of this object were investigated during the 2011–2012 apparition.

***Aims.*** We aim to confirm the physical parameters useful for JAXA's Hayabusa 2 mission, such as rotational period, absolute magnitude, and phase function. Our data complement previous studies that did not cover low phase angles.

***Methods.*** With optical imagers and 1−2 m class telescopes, we acquired the photometric data at different phase angles. We independently derived the rotational lightcurve and the phase curve of the asteroid.

***Results.*** We have analyzed the lightcurve of 162173 (1999 JU3), and derived a synodic rotational period of 7.625 ± 0.003 hr, the axis ratio a/b = 1.12. The absolute magnitude $H_R$ = 18.69 ± 0.07 mag and the phase slope of G = −0.09 ± 0.03 were also obtained based on the observations made during the 2011−2012 apparition. These physical properties are in good agreement with the previous results obtained during the 2007−2008 apparition.

## Observations

Our photometric observations of 1999 JU3 were carried out for 13 nights during the apparition in the 2011-2012 season, with several 1-2m class telescopes (see Table 1).

**Table 1.** Observatory and Instrument details

| Telescope [a] | Date (UT) | λ [b] | ϕ [b] | Altitude | CCD [c] | Pixel scale | Observer(s) [d] |
|---|---|---|---|---|---|---|---|
| Calar Alto 1.2m | Jun 6-24 2012 | 2:32:45 | +37:13:25 | 2173.1 | e2v 4K | 0.63 | SM |
| HCT 2m | Jul 17-19 2012 | 78:57:51 | +32:46:46 | 4500.0 | SITe 2K | 0.17 | DSW, MI |
| Nish-Harima 2m | Jun 22 2012 | 134:20:08 | +35:01:31 | 435.9 | PL230 2K | 0.32 | JT, MI |
| TUG 1m | Jun 21-Aug 13 2012 | 30:19:59 | +36:49:31 | 2538.6 | SI 4K | 0.62 | MK, MJK, SK, OU, EG |
| UH 2.2m | Aug 6 2011 | 204:31:40 | +19:49:34 | 4212.4 | Tek 2k | 0.22 | MI |

[a] Abbreviations: HCT = Himalayan Chandra Telescope, TUG = Tubitak Ulusal Gozlemevi (Turkish National Observatory), UH = University of Hawaii
[b] Eastern longitude and geocentric latitude of each observatory.
[c] Both e2v 4K CCD and SI 4K CCD were configured with 2×2 binning.
[d] Observer: DSW = D. S. Warjurkar, EG = E. Guzel, JT = J. Takahashi, MI = M. Ishiguro, MK = M. Kaplan, MJK = M.-J. Kim, OU = O. Uysal, SK = S. Kaynar, SM = S. Mottola

Ground-based observation campaign during 2007 – 2012 was also conducted for a total of 75 days at 14 observatories: UH 2.2m (USA), Lulin 1.0m (Taiwan), Ishigakijima 1.0m (Japan), Kiso 1.0m (Japan), Steward 1.55m (USA), TenagraII 0.81m (USA), Bosque Alegre 1.5m (Argentina), Calar Alto 1.2m (Spain), HTC 2.0m (India), Nishi-Harima 2.0m (Japan), TUG 1.0m (Turkey), IRSF 1.4m (South Africa), MOA-II 1.8m (New Zealand), Magellan 6.5m (Chile).

## Analysis and results

All the data reduction procedures were performed using the Image Reduction and Analysis Facility (IRAF) software package. The lightcurve was constructed based on the relative magnitude which is defined as the difference between instrumental magnitude of the asteroid and the average magnitude of each comparison star. In order to find the periodicity, the Fast Chi-Squared (F$\chi^2$) technique (Palmer 2009) was employed.

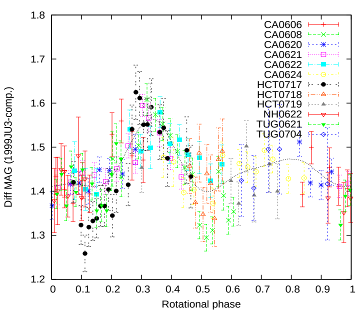


**Figure 2.** Composite lightcurve of 1999 JU3 folded at the period of 7.625±0.003 hr at the zero epoch of JD 2456106.834045 obtained from the 2012 apparition. The dotted line is a fit to the fourth-order Fourier model using the fast chi-squared technique.

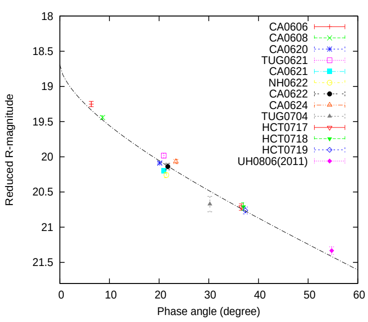


**Figure 3.** Phase function of 1999 JU3. Each data point represents the reduced R-band magnitudes at corresponding phase angles. The long dashed dotted line represents the IAU (H,G) phase function fit, where $H_R$ = 18.69±0.07 mag and G = −0.09 ± 0.03.

We obtained the resultant composite lightcurve of 1999 JU3 (Fig. 2), which is folded with the period of 7.6248 hour at the epoch $t_0$ of JD = 2456106.834045. We also calculated the reduced R-band magnitude of all data points at each phase angle, and computed the best fit parameters of $H_R$=18.756 ± 0.022 magnitude and G = -0.072 ± 0.011 with a linear least squares fit (Fig. 3).

## Results (cont.)

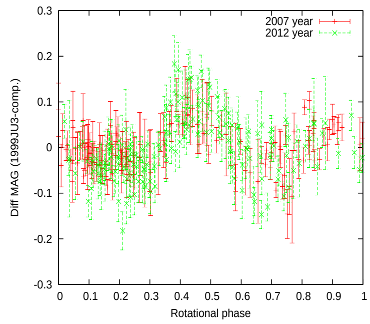


**Figure 4.** Superposed lightcurve based on the data from 2007 and 2012, folded with the period of 7.6275 h at the epochs of JD 2454348.248074 and 2456085.41352, respectively.

In addition, we re-analyzed the 1999 JU3 data obtained in the Subaru-Mitaka-Okayama-Kiso Archive System (SMOKA) (Baba et al. 2002) during the September−November season in 2007, with the same data reduction method. To compare the lightcuves obtained from both apparitions, we overlaid one on the other, with the same best-fit period of 7.6275 hr at the epoch of JD 2454348.248074 for 2007 and 2456085.41352 for 2012. Overall shapes of individual lightcurves look very similar to each other (See Fig. 4). It might be regarded as a clue that we were looking at the asteroid from similar aspect angles during each apparition.

## Searching the pole solution

Kawakami et al. (2010) obtained the pole axis of λ = 331° ± 10° and β = 20° ± 10° while Müller et al. (2011) deduced λ = 73° and β = −62°, where λ and β are the ecliptic longitude and latitude of the pole orientation. In order to find the pole orientation of 1999 JU3, we tried to make shape model with our lightcurve data including the data during Sep. to Nov. 2007 using the lightcurve inversion method (Kaasalainen & Torppa 2001; Kaasalainen et al. 2001). However, the model of 1999 JU3 was not clearly determined yet due to large uncertainties of photometry. Furthermore, it should be regarded as a really spherical body (see Fig. 5).

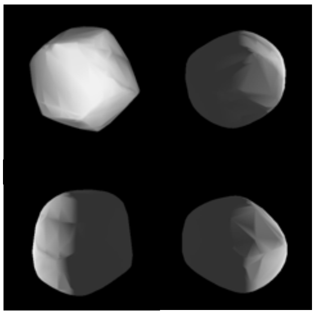

**Figure 5.** Shape model of 1999 JU3 with a provisional pole solution, which displays the asteroid from four different view (North-pole; Equatorial(0°); Equatorial(90°); South-pole view from upper-left in a clockwise direction).

## Conclusions

1. We have introduced the composite lightcurve of 1999 JU3 and found a synodic rotational period of 7.625 ± 0.003 hr. Since the longitude and latitude of the PAB changed little during the period covered by our 2012 observations (about 10 deg and 4 deg, respectively), we used the whole 2012 data set for our analysis. When we compared the period of 7.6272 ± 0.0072 hr derived from the previous study (Abe et al. 2008) with ours, it was found that the precision has been slightly increased.
2. Based on our data, we presented the phase curve of 1999 JU3 encompassing a wide range of viewing geometry, together with the absolute magnitude $H_R$ = 18.69 ± 0.07 mag and the slope parameter G = −0.09 ± 0.03.
3. Knowing the information about spin status, such as rotational period, the ecliptic longitude and latitude of the pole is essential for the design of mission sequence such as the remote sensing observation. We are going to find the possible pole orientation of 1999 JU3 with whole 2007 – 2012 data including the IR data.

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