Searching the pole solution of NEA 162173 (1999 JU3)

Myung-Jin Kim, Josef Durech, Young-Jun Choi, Masateru Ishiguro, Thomas Müller, Daisuke Kuroda, Sunao Hasegawa, Marco Delbo, Benoît Carry, Yong-Ik Byun

Searching the pole solution of NEA 162173 (1999 JU3)

Myung-Jin Kim[1,2], Josef Durech[3], Young-Jun Choi[2], Masateru Ishiguro[4], Thomas Müller[5], Daisuke Kuroda[6], Sunao Hasegawa[7], Marco Delbo[8], Benoit Carry[9], Yong-Ik Byun[1], and Hayabusa 2 ground-based observation team

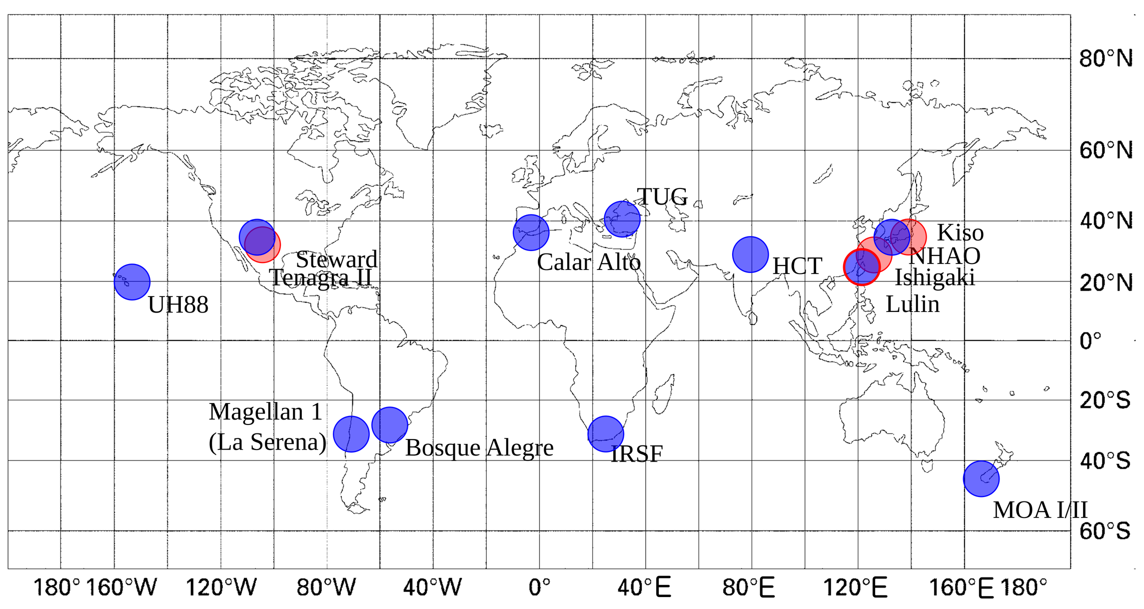
[1]Department of Astronomy, Yonsei University, Korea, [2]Korea Astronomy and Space Science Institute, Korea,
[3]Astronomical Institute, Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic, [4]Seoul National University, Korea,
[5]Max Planck Institut für extraterrestrische Physik, Germany, [6]National Astronomical Observatory of Japan, Japan,
[7]Japan Aerospace Exploration Agency, Japan, [8]Nice observatory, France, [9]IMCCE, Paris Observatory, France

Abstract

Near-Earth asteroid (NEA) 162173 (1999 JU3) (hereafter 1999 JU3) is the primary target of JAXA's Hayabusa 2 mission and also a backup target of NASA's OSIRIS-REx mission, not only because of its accessibility but also because it would be the first C-type asteroid for exploration missions. 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. In order to get the physical properties of 1999 JU3, a total of 75 days ground-based observations at various geometries were carried out during 2007 – 2012 apparitions. Observations in the thermal infrared were also conducted with the Subaru, Akari, and Spitzer telescopes. We have analyzed the optical lightcurve of 1999 JU3, and derived a sidereal rotational period of 7.631 ± 0.001 hour. Using the lightcurve inversion method in conjunction with the thermal physical modeling, we determined a nearly spherical shape with a diameter of 823 ± 38 m, a geometric albedo of 0.058 ± 0.003, and a thermal inertia of 231 ± 76 J m^{-2} s$^{-0.5}$ K^{-1}. Although the pole orientation of 1999 JU3 is not strongly constrained, the best solution we derived is within 30 degree of (103,-20) in the ecliptic reference frame.

Observations

Ground-based observation campaign during 2007 – 2012 was carried out with 14 telescopes for a total of 75 days at various geometries (Fig. 1) : 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).



Observations in the thermal infrared were also conducted with the Subaru, Akari, and Spitzer telescopes.

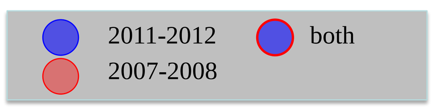


Figure 1. Locations of 14 observatories collaborating for this ground-based observation campaign during 2007 – 2012.

Lightcurve analysis

All the optical 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 discrete Fourier transform algorithm (Lenz & Breger 2005) and the Fast Chi-Squared (Fχ^2) technique (Palmer 2009) were employed.

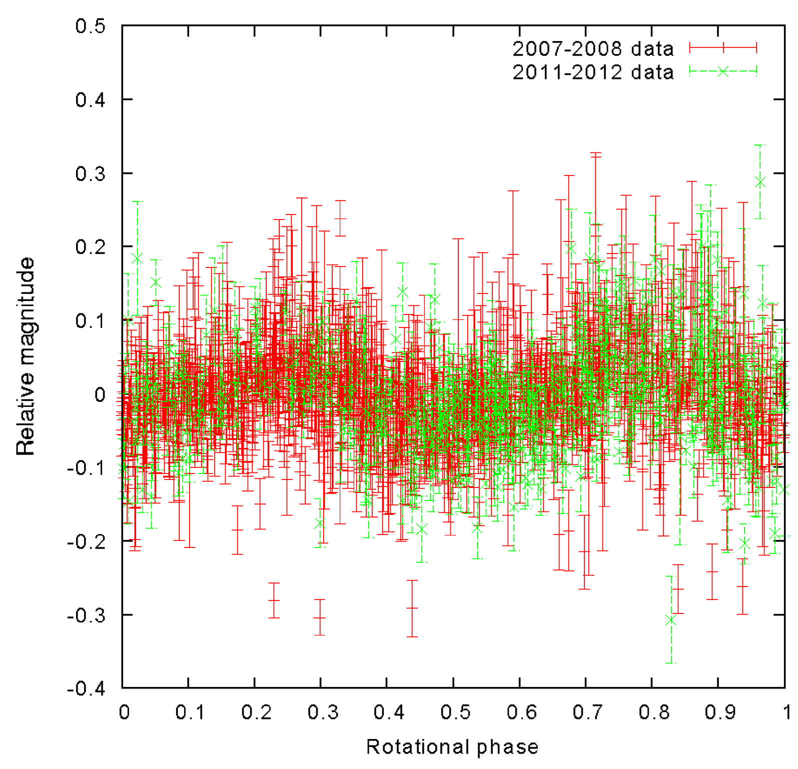


Figure 2. Superposed lightcurve based on the data from 2007-2008 and 2011-2012 apparition, folded with the same best-fit period of 7.6275 hour at the epochs of JD 2454289.97301 and 2455780.00348, respectively.

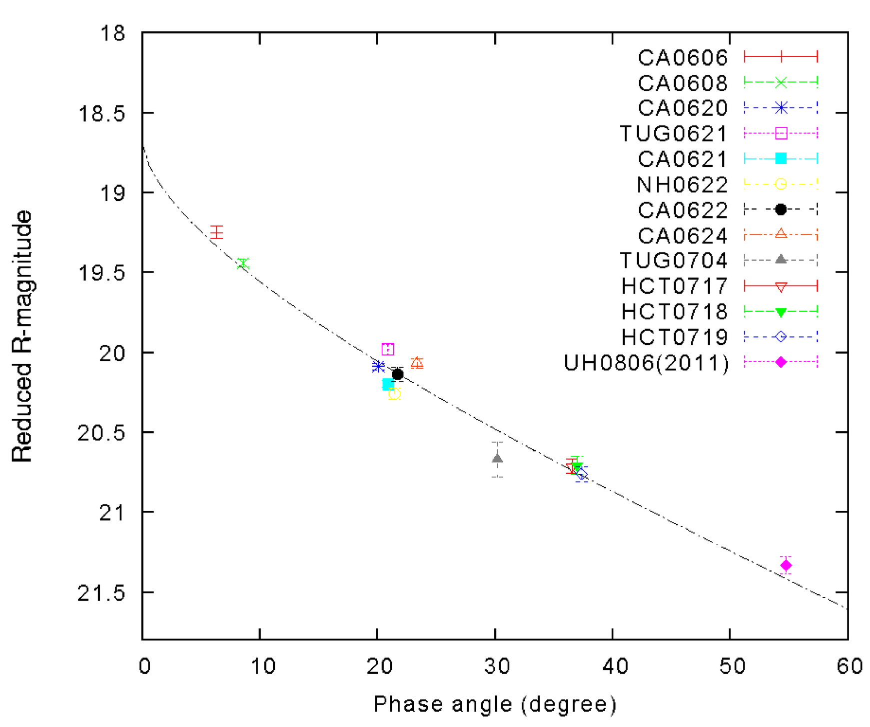


Figure 3. Phase function of 1999 JU3 obtained based on the observations made during the 2011−2012 apparition. Each data point represents the reduced R-band magnitudes at corresponding phase angles. The long dashed dotted line represents the IAU (H,G) phase function fit, where H_R = 18.69±0.07 mag and G = −0.09 ± 0.03.

We obtained the resultant composite lightcurve of 1999 JU3 with whole 2007-2012 data (Fig. 2), which is folded with the same best-fit period of 7.6275 hour at the epoch t_0 of JD 2454289.97301 for 2007-2008 and JD 2455780.00348 for 2011-2012 data. Overall shapes of individual lightcurves look very similar to each other. 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 whole lightcurve data for 2007 - 2012 using the lightcurve inversion method (Kaasalainen & Torppa 2001; Kaasalainen et al. 2001) in conjunction with the thermal physical modeling. However, the spin axis and shape 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. 6).

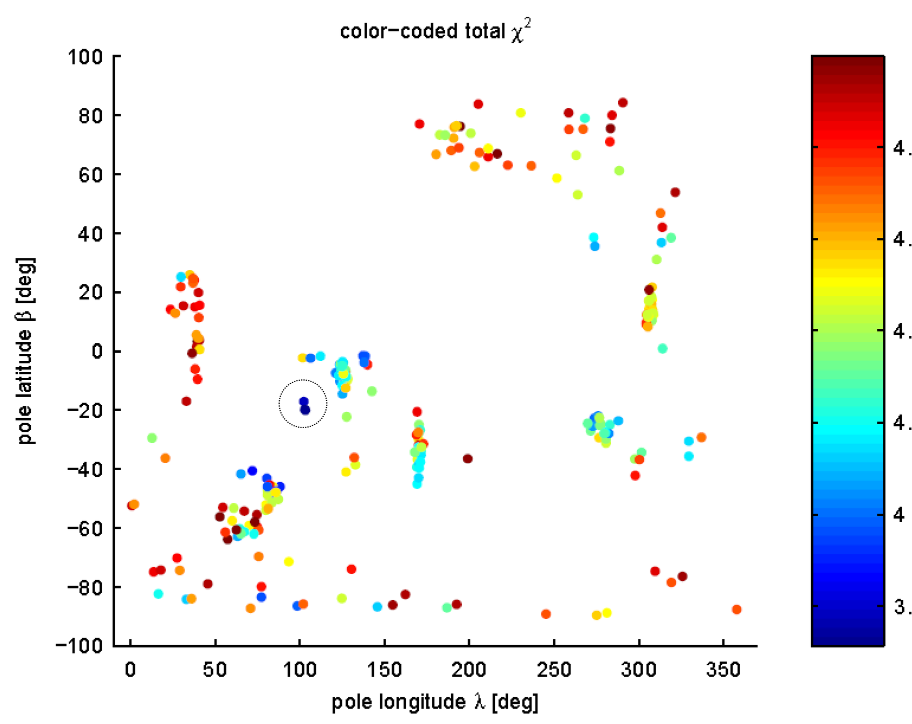


Figure 4. Pole solution distribution of 1999 JU3. Dark blue represents the pole solution with the provisional best solution (lowest ChiSq) of λ = 103° and β = -20° (black dotted circle). The colors move towards red as the solution worsens.

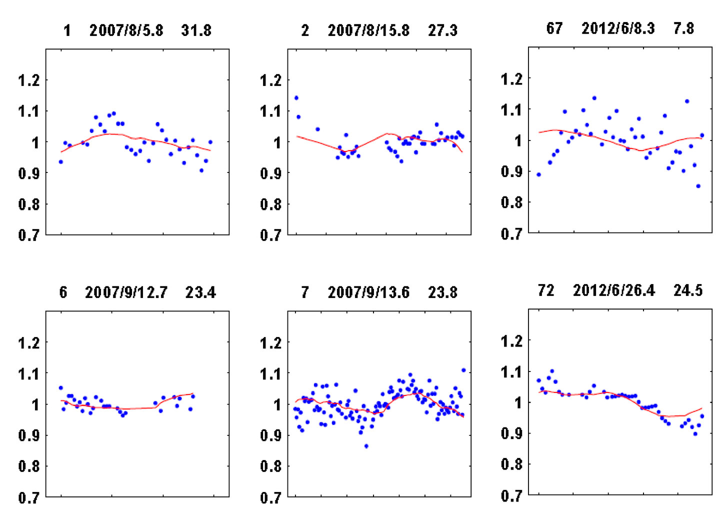


Figure 5. Several examples of 1999 JU3's observed lightcurves (blue point) fitted with the shape model (red line) we derived. The brightness is given in relative intensity units.

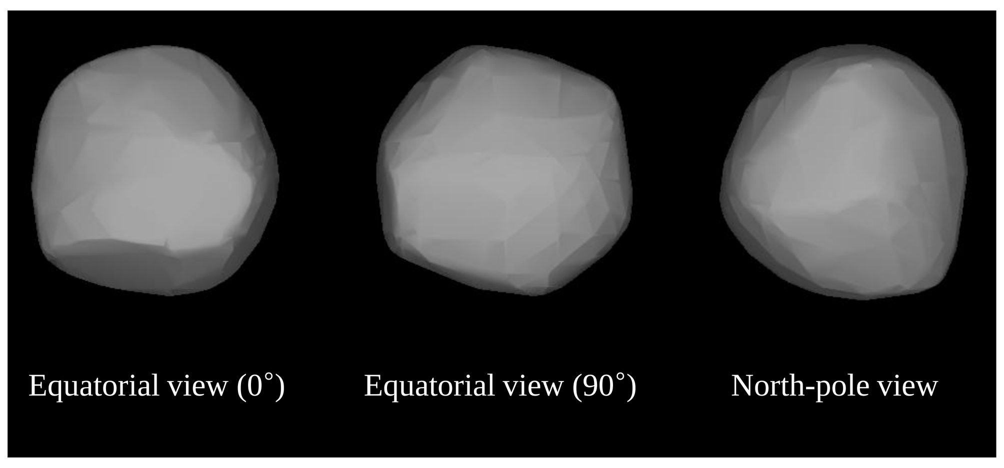


Figure 6. Shape model of 1999 JU3 with a provisional pole solution, which displays the asteroid from three different view.

Conclusions

1. We have analyzed the lightcurve of 1999 JU3 based on the optical observations, and derived a sidereal rotational period of 7.631 ± 0.001 hour, the diameter of 822 ± 38 m, the geometric albedo of 0.058 ± 0.003, a thermal inertia of 231 ± 76 J m^{-2} s$^{-0.5}$ K^{-1}, and nearly spherical shape using the lightcurve inversion method with the thermal physical modeling.
2. The pole orientation and shape model of 1999 JU3 are not clearly determined yet, but the provisional solution is the lambda 103 ± 33 degree and beta -20 ± 24 degree.
3. This result is good agreement with Thomas Müller's solution (priv. communication).

- D_{eff} = 810 (+14/-23) m, p_V = 0.058 (+/- 0.003)
- thermal inertia around 200 (100-300)
- relatively low roughness is favored (rms of surface slopes close to 0.1)

Myung-Jin Kim (skarma@galaxy.yonsei.ac.kr; skarma@kasi.re.kr)