THE PHOTOMETRIC STUDY OF MARS CROSSER (2078) NANKING. Dong-Heun Kim[1,2], Jung-Yong Choi[3], Myung-Jin Kim[2], Hee-Jae Lee[1,2], Josef Durech[4], Anna Marciniak[5], Krzysztof Kaminski[6], Murat Kaplan[6], Orhan Erece[6,7], Hong-Kyu Moon[2], Young-Jun Choi[2,8], Yonggi Kim[1]

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Introduction: A Mars-crossing asteroid (MCA) is defined as an asteroid with a perihelion distance 1.3 AU < q < 1.666 AU, with semi-major axis < 3.2 AU (Ribeiro 2014). These types of asteroids are in a dynamically unstable region between the main belt and the near-Earth populations. Half of MCAs are known to transfer from their orbits to Earth-crossing ones in less than 20 million years (Migliorini et al. 1998).

(2078) Nanking was discovered at the Purple Mountain Observatory in Nanking, China. The orbital elements of this asteroid are a = 2.36 AU, q = 1.480 AU, e = 0.374 and sin i = 0.34. A study of the rotation of Nanking began in the same year by Mohamed et al. (1994, P = 6.50 h), Chernova et al. (1994, P = 6.463 h) and De Sanctis et al. (1994, P = 6.473 h). After that, Warner (2015) and Choi (2016) performed photometric observations and obtained a rotational period of 6.459 h and 6.393 h, respectively.

Observations: Photometric observations of Nanking were conducted during 46 nights from 2014 to 2019 using nine 0.6m - 1.8 m telescopes with CCD detectors. We employed the Sobaeksan Optical Astronomy Observatory (SOAO) 0.6 m and Bohyunsan Optical Astronomy Observatory (BOAO) 1.8 m telescopes in Korea; Lemonsan Optical Astronomy Observatory (LOAO) 1.0 m and Winer Observatory (WO) 0.7 m telescopes in Arizona, USA; Borowiec Astrogeodynamic Observatory (BAO) 0.4 m telescope in Poland; TÜBİTAK National Observatory (TUG) 1.0 m telescope in Turkey; Korea Microlensing Telescope Network (KMTNet, Kim et al. 2016) 1.6 m telescopes in Chile, South Africa and Australia.

Data reduction: We performed data reduction using the Image Reduction and Analysis Facility (IRAF) software package. Instrumental magnitudes of Nanking were obtained using the IRAF APPHOT task. The aperture radii were set to be equal to FWHM of the stellar profile on each frame in order to maximize the S/N (Howell 1989). The standardization was executed using the ensemble normalization technique (Gilliland and Brown, 1988; Kim et al., 1999) with the Pan-STAARS Data Release 1 catalog (PS DR1; Chambers et al., 2016). The magnitude of the SDSS filters of PS DR1 was transformed to the Johnson-Cousins filter magnitude using the transformation equations proposed by Tonry et al. (2012). Data from Borowiec and Winer were reduced using CCLR Starlink Package.

To determine the synodic period of lightcurve, we used VARTOOLS (Hartman & Bakos, 2016). We compared the results of Lomb-Scargle (L-S) and the Discrete Fourier Transform (DFT) to each other.

We used the lightcurve inversion method (Kaasalainen & Torppa 2001; Kaasalainen et al. 2001) to obtain the sidereal period, pole orientation and convex shape of the asteroid. In order to use this method, we need lightcurve data obtained during 3 or 4 apparitions. For this reason, we utilized our observations but also with data available in the literature from the Asteroid Lightcurve Database (LCDB; Warner et al. 2009), Mohamed et al. (1994) and Chernova et al. (1994).

Results: We performed BVRI, R and non-filter photometric observations for a total of 46 nights to obtain Nanking physical properties of Nanking. The color index values obtained from the multi-color observations are B-V = 0.81, V-R = 0.44, and V-I = 0.81. Based on these values, taxonomy of this object is found to be Sq-type using the classification method proposed by Dandy et al. (2003).

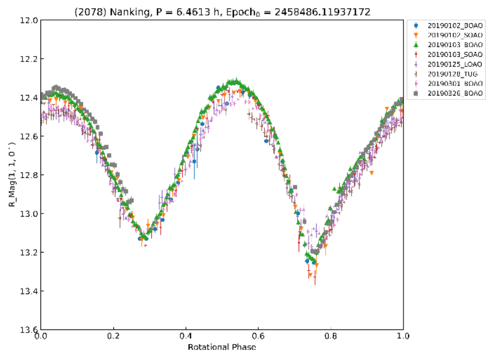

Figure 1. Example lightcurve of Nanking folded with the rotational period of 6.4613 h (2019 apparition).

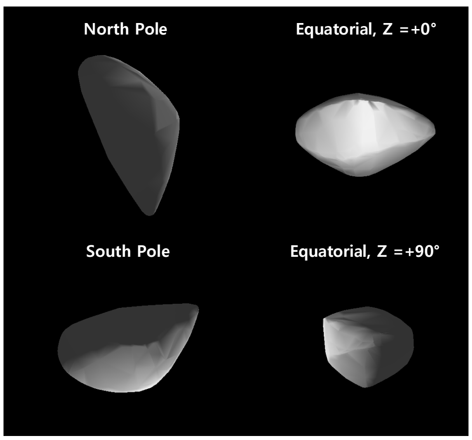

Figure 2. Three-dimensional convex shape model of Nanking.

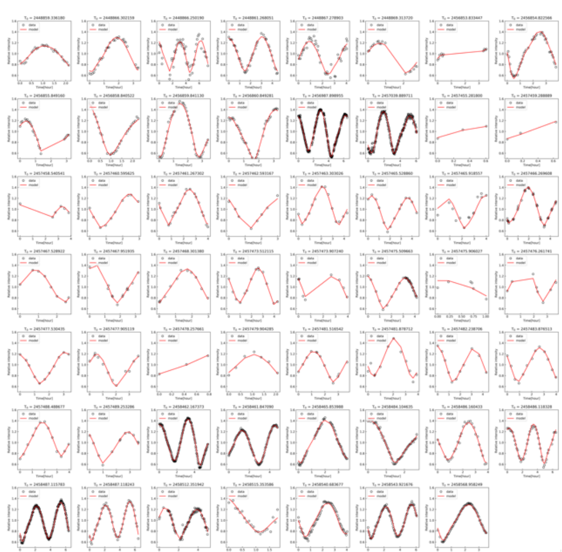

Figure 3. The observed LCs are fitted with the model.

We deduced that the synodic rotation period was 6.4613 ± 0.0004 h (2019 apparition) and sidereal rotation period was 6.461707 ± 0.000002 h. We present the example lightcurve of Nanking in Fig. 1, which folds with the period of 6.46027 h at the epoch t_0 of JD = 2458486.119371. The ecliptic longitude (λ_p) and latitude (β_p) of its pole are $\lambda_p \sim 46$ ° and $\beta_p \sim -60$ °. We present the 3D shape model of Nanking with a sidereal period of 6.461707 h and a pole orientation of (46◦, −60◦; see Figure 2). The model lightcurves are generated with lcgenerator program. The results of model is shown in Fig 3. The shape of 2078 Nanking's light curve shows U-shaped maxima and V-shaped minima that typically appears in light curves of contact binary asteroids. Moreover, the amplitude of the lightcurve is greater than about 1.0 mag and rotational frequency is about 3.714 cycle/day. This is in good agreement with the result of the well-known contact binary Jupiter Trojan 624 Hektor that also displays a U-shaped maximum and V-shaped or notched minima (Sheppard & Jewitt 2004).

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