Fast rotation of a sub-km-sized near-Earth object 2011 XA_3

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We present lightcurve observations and multiband photometry for the near-Earth object (NEO) 2011 XA_3 [1]. Previous studies had shown that most asteroids with rotation periods of < 2.2 h were smaller than 200 m in diameter [2]. The fast-rotating asteroids have structurally significant tensile strength (so-called monolithic asteroids) because such asteroids need to overcome their own centrifugal force. On the other hand, the slow-rotating asteroids larger than 200 m in diameter maintain themselves by their gravity or the cohesive force of bonded aggregates [3], which generally take on a rubble-pile structure [4]. According to a numerical simulation, the fast-rotating asteroids are provided by the collisional disruptions of parent bodies [5]. In-situ observations of the Rosetta spacecraft have revealed that the size frequency distribution of the boulders on (21) Lutetia become shallower in a region of < 150 m in size [6]. When we regard that the size frequency distribution of > 150 m-sized boulders is corresponding to that of the impact ejecta, some ejecta of < 150 m in size may escape from the parent body and likely become small and fast-rotating asteroids. To confirm this hypothesis, we must accumulate more observational data of such asteroids.

The purpose of our study is to obtain the rotational period and taxonomic class of the NEO 2011 XA_3. The absolute magnitude $H = 20.402 \pm 0.399$ (JPL Small-Body database) of 2011 XA_3 implies the asteroid to be a subkilometer-sized one. The orbital parameters, $a = 1.48$ au, $e = 0.93$, $i = 28°$, $\Omega = 273°$, and $\omega = 323°$, are apparently similar to those of the NEO (3200) Phaethon, $a = 1.27$ au, $e = 0.89$, $i = 22°$, $\Omega = 265°$, and $\omega = 322°$, though indicating a somewhat large difference in the orbital energy. Phaethon is a B/F-type asteroid and probably the main body among the Phaethon-Geminid complex (PGC). The NEOs 2005 UD (F-type) and 1999 YC (C-type) are the other candidates of the PGC along with the Geminid meteor stream [7,8]. We also investigate whether or not 2011 XA_3 is an additional member of the PGC, judging by the taxonomic classification using multiband photometry and long-term orbital analyses.

The observations were conducted using the 1.0-m f/3 telescope and the 0.5-m f/2 telescope at the Bisei Spaceguard Center. The lightcurve observations were mainly carried out on December 19, 2011 using the 0.5-m telescope. At the same time, the multiband photometry was conducted using the 1.0-m telescope with the Sloan Digital Sky Survey (SDSS) g', r', i' and z' filters.

The lightcurve has shown a periodicity of 0.0304 ± 0.0003 d ($= 43.8 \pm 0.4$ min). The fast rotation shows that 2011 XA_3 is in a state of tension (i.e., a monolithic asteroid) and cannot be held together by self-gravitation. The multiband photometric analysis indicates that the taxonomic class of 2011 XA_3 is S-complex, or V-type. Its estimated effective diameter is 225 ± 97 m (S-complex) and 166 ± 63 m (V-type), respectively. Therefore, 2011 XA_3 is a candidate for the second-largest fast-rotating monolithic asteroid behind 2001 OE_{84} [9]. Unfortunately, the S-complex or V-type taxonomic classification and the long-term orbital computation conflict with the idea that 2011 XA_3 is a member of the PGC.

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