INTRODUCTION

(4660) Nereus is an Apollo asteroid with one of the lowest ΔV requirements for a future sample return mission. The Institute of Space and Astronautical Science (ISAS) in Japan has been planning the world’s first asteroid sample return mission named MUSES-C, of which (4660) Nereus was selected for the target (Kawaguchi et al. 1996, Matsuo et al. 1996). The MUSES-C spacecraft will be launched in January 2002. Arriving at Nereus in April 2003, both remote sensing and in-situ observations of Nereus will be performed during 2 months. After landing and sampling from a few sites on the asteroid surface, in 2006 the spacecraft will come back to the Earth and finally the sample encapsulated in a reentry probe will be retrieved onto the Earth ground with the aid of parachute.

For successful landing and sampling we need the definite information on the rotation of Nereus. At present, however, we have no data for lightcurve of Nereus except for Tholen (1995)’s observation in 1993. He said that the brightness of Nereus gradually increased in about 3 hours in 1993. Nereus is an about 1 km sized asteroid. Binzel (1989) shows that asteroids of less than 100 km in diameter have faster spin rate with decreasing size. He suggests this empirical law may hold up to a few km sized body (Binzel 1992). Most of physical properties of very small asteroids like Nereus, however, are not yet understood. Moreover we can compare the groundbased observational data to in-situ data by spacecraft and verify the justification of the groundbased observation.

OBSERVATION

Photometric observations were performed on 1997 August 2 and 3, through R broadband filter with a CCD at the 2.2m telescope at ESO, La Silla. Nereus was observed for about 8.5 hours on each night. The observation was sometimes affected by field stars since Nereus was near the galactic center during the observation period.

ANALYSES AND RESULTS

IRAF software was used for the aperture photometry of Nereus, comparison stars on the same frame, and the standard stars listed by Landolt (1992) used for determining the apparent magnitude. The derived lightcurve of Nereus was shown in Fig. 1. The errors of the data are typically about 0.05 mag, but some of them become about 0.1 mag since they are needed to subtract the fluxes of field stars closed to Nereus.

Nereus’ position during the observation period was calculated by Fuse (1997). The heliocentric and geocentric distance of Nereus was about 2.01 AU and about 1.02 AU, respectively. The phase angle was about 8.5 degree at the beginning of our observation, and about 9.4 at the end. The absolute magnitude, $H_R(1,1,0)$ was calculated from the apparent magnitude shown in Fig. 1 using the method presented by Bowell et al. (1989) assuming $G = 0.15$. Then the spectrum analysis method by Lomb cited in Press et al. (1994) was applied to $H_R(1,1,0)$. This method is suitable for unevenly sampled data. Fig. 2 shows the obtained periodogram. Note that the abscissa is period.

![Figure 1](image1.png)

**Figure 1.** Observations of (4660) Nereus. The different symbols denote observations on different nights.

![Figure 2](image2.png)

**Figure 2.** Spectral power vs. rotation period of Nereus for $H_R(1,1,0)$ derived from our observations with the Lomb method.
The lightcurve period is found to be approximately 7.55 +/- 0.1 hours from Fig. 2. The error is estimated by changing parameters in the Lomb method. Considering that asteroids usually display 2 maxima and 2 minima lightcurves in 1 rotational period, actual rotational period of Nereus seems to be 15.1 +/- 0.2 hours. Fig. 3 shows the Nereus' lightcurve assuming that the rotation period is 15.1 hours.

**Figure 3.** Nereus’ lightcurve constructed from H$_g$(1,1,0) derived from our observations assuming a rotation period of 15.1 hours. The obtained data is almost full lightcurve coverage (including 2 maxima and 2 minima).

From Fig. 3, the mean H$_g$(1,1,0) is found to be 18.3 mag, and the amplitude of the light variation is found to be about 0.9 mag. This large light variation suggests that Nereus is highly elongated shape.

**DISCUSSION**

About Near Earth Asteroids like Nereus, two sources have been proposed: asteroids from the main belt and extinct or dormant comet nuclei (Binzel et al. 1992, Wisdom 1983, 1985, Wetherill 1988). Binzel et al. (1992) discussed the origins of them using their rotational frequencies and lightcurve amplitudes. Using both their discussion and our results, comet nuclei is more preferred than the main-belt asteroids for Nereus' origin.

Harris (1994) discussed asteroid's wobble. In his paper, smaller and slower rotating asteroid has longer time scale of the wobble motion. From our results, the damping time scale of Nereus' wobble motion is 1 billion years. If we cannot detect the wobble motion on Nereus, Nereus has not been experienced large collision within about 1 billion years ago. Our results however, cannot infer strongly whether Nereus has a wobble motion or not. Two other strong peak in Fig. 2 might show some information about wobble, but more observation and analyses or in-situ observation by spacecraft must need to say about it.

For the MUSES-C Mission, the rotational period of Nereus is a significant information. Since the sampling sequence must be finished within a daytime of Nereus, if its rotational period would be very short, sampling schedule would be very tight. Obtained rotational period, 15.1 hours, is enough slow and preferable to the mission scenario. Rotational axis is also significant, but it is not determined by only our observation. We need more data at another opposition.

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**REFERENCES**


