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# Observations of 2000 $DP_{107}$ in NAOC: rotation period and reflectance spectrum

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**Abstract**

Photometric observations of a Near-Earth-Asteroid (NEA) 2000 $DP_{107}$ were made on four successive nights during October 2000, 1.4–4.7 with the 0.6-m/0.9-m Schmidt telescope of National Astronomical Observatories, CAS (NAOC). The derived rotation period of 0.1156 day was consistent with that obtained by Pravec et al. (IAU Circular No. 7504, 2000). In addition, the relative reflectance spectrum of the asteroid covering 0.35–0.9 μm was obtained with the NAOC 2.16-m telescope adopting a low-resolution grating (10 Å/pix) on October 2, 2000, which revealed that 2000 $DP_{107}$ is an M-type asteroid.



*Keywords:* Techniques; Photometric techniques; Spectroscopic-minor planets; Asteroids

## 1. Introduction

The NEA 2000 $DP_{107}$ was discovered on February 29, 2000 by LINEAR (Blythe et al., 2000) with orbital elements of $a = 1.37$ AU, $e = 0.38$ and $i = 8.66°$. Radar observations of this object made by Ostro et al. (2000) on September 22 and 23, 2000 using NASA's Goldstone radar in Southern California, revealed that 2000 $DP_{107}$ is a binary system—two separate objects travelling at least a kilometer apart at times. Photometric observation of this object made by Pravec et al. (2000) on nine nights during September 25.2–October 4.2 showed a fast variation with a period of $0.11564 \pm 0.00001$ day with an amplitude of 0.19 mag, and the eclipse/occultation event in the binary system with a period of $1.76 \pm 0.02$ day. Their measured broad band color indices revealed that 2000 $DP_{107}$ is spectrally flat, consistent with a C-type minor planet.

In this paper, we present the result of our own photometric and spectral observations of 2000 $DP_{107}$ in early October 2000 with the NAOC 0.6-m/0.9-m Schmidt and 2.16-m telescopes.

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## 2. Photometric observation and analysis

### 2.1. Observation description and data reduction

The photometric observations of 2000 $DP_{107}$ were made on four nights during 2000 October 1–4 with the NAOC 0.6-m/0.9-m Schmidt telescope using a thick $2048 \times 2048$ CCD with a $58' \times 58'$ field and scale of $1''.7$ pixel$^{-1}$. The BATC i-filter with a central wavelength of 6660 Å and a band width of 480 Å was used during the observation (Fan et al., 1996; Zheng et al., 1999). The reduction of images was performed using APPHOT, a routine of the Image Reduction and Analysis Facility (IRAF) package. Magnitudes of the 2000 $DP_{107}$ and comparison stars were extracted from each image using aperture photometry. By convention, we chose 5 comparison stars in each frame. The most stable one with the minimum standard deviation at RA $22^h\ 11^m\ 45.57^s$, Dec $01°\ 06'50.7''$ with $V$ magnitude 11.226 was adopted as the final standard star to obtain the relative magnitude of the asteroid. The magnitude of the standard star was adopted from the TASS tenxcat catalog (Richmond et al., 2000). The reduced magnitudes of the asteroid were corrected for light travel time and distance (Harris and Lupishko, 1989). The photometric data were analyzed using Phase Dispersion

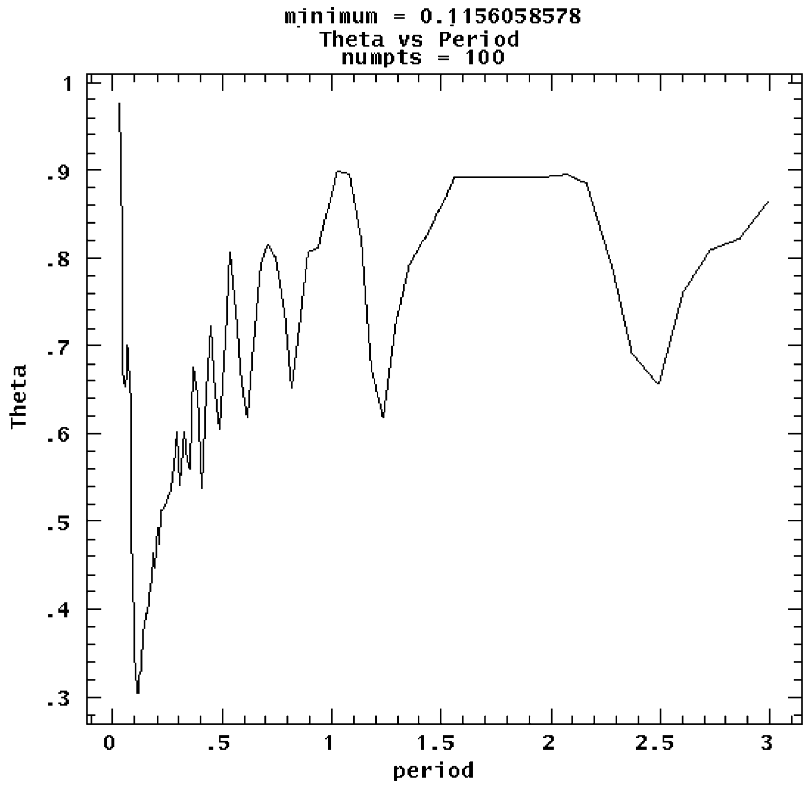


Fig. 1. Theta statistics of data vs. period.

Minimization (PDM), a routine of the IRAF (Stellingwerf, 1978), to obtain the light curve.

### 2.2. Result

The observations were made during nights that were mostly not of good quality. Observations on October 1, 2000 yielded a period of 0.1156 day with an amplitude of 0.21 mag (Fig. 1), which was quite consistent with the results of 0.11564 day by Pravec et al. (2000). The deviation of about 0.1 mag among the data is related to the eclipse/occultation event around October 1.66 as mentioned in Pravec et al. (2000). The dashed line in Fig. 2 was fitted by rejecting those points (marked as "x"). Data from other nights suffered from large photometric errors and could not be used to get reasonable results.

## 3. Spectral observations and analysis

### 3.1. Observation description and data reduction

Spectral observations were made with the NAOC 2.16-m reflector on 2000 October 25 at the same site, adopting a low-resolution grating centered at 6000 Å with 10 Å/pixel dispersion. Spectral data reduction follows the process of the Small Main-Belt Asteroid Spectroscopic Survey (SMASS) (Xu, 1994; Xu et al., 1995). A solar-analog star 16 Cyg B (Hardorp, 1978) was adopted for obtaining the asteroid's relative reflectance spectrum (Luu and Jewitt, 1999). The standard spectrum of 16 Cyg B was adopted from the library of stellar optical spectra by Silva and Cornell (1992). By convention, the reflectance spectrum of 2000 $DP_{107}$ was normalized to 0.55 μm. Some strong absorption bands in the spectra of asteroid and 16 Cyg B were caused by the water and oxygen molecules in the Earth's atmosphere (Cochran and Barnes, 1981), and this telluric feature was removed as well as possible in the final plot.

### 3.2. Analysis and result

The reflectance spectrum of 2000 $DP_{107}$ obtained from our observation is almost featureless and slightly reddish over the 0.4–0.89 μm wavelength region (see Fig. 3(a)). The spectral character is in accord with the characteristics of X-type asteroid spectra described by Bus (2002).

Spline3 function was used to fit the spectrum of the asteroid and to obtain 46 points ranging from 0.44 to 0.89 μm with an interval of 0.01 μm. The '*spectral distances*' between this asteroid with the known spectra of 1341 asteroids from SMASS II (Binzel et al., 2001; Bus, 1999) in the 46-dimensional space were calculated, which is defined as follows:

$$D_x = \sqrt{\sum_{n=1}^{k} (X_n - Y_n)^2},$$

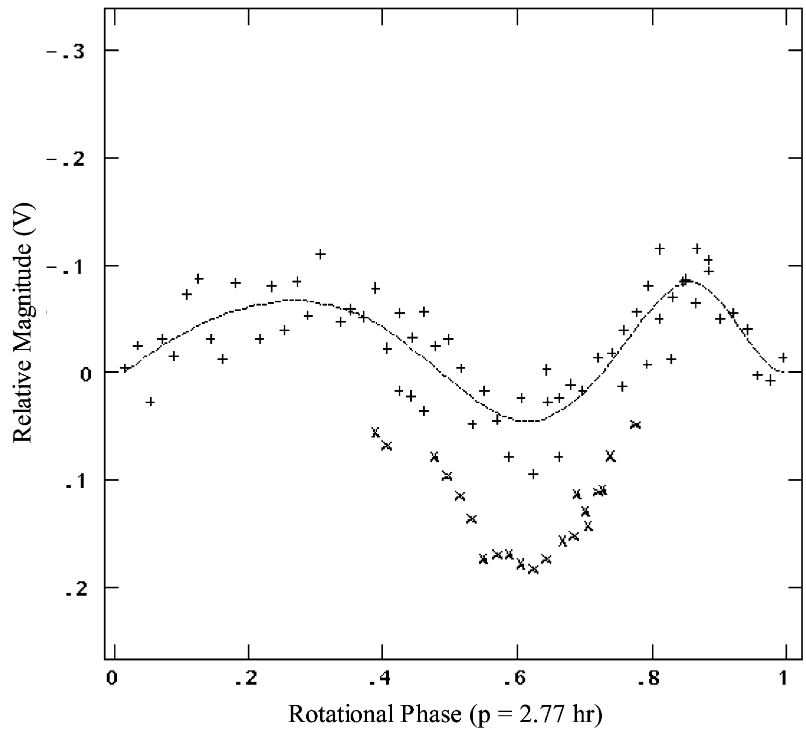


Fig. 2. Fitted light curve of 2000 $DP_{107}$. Zero phase corresponds to UT 2000 October 1.56.

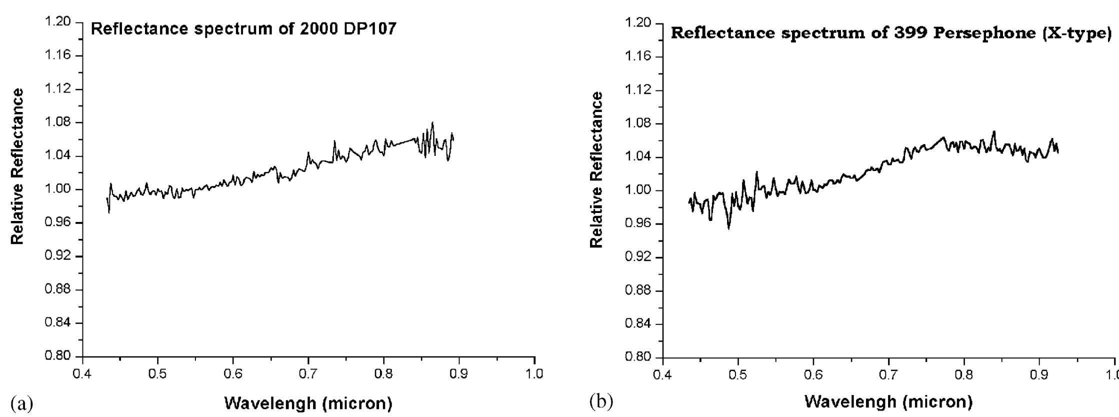


Fig. 3. (a) Reflectance spectrum of 2000 $DP_{107}$ and (b) spectrum of the asteroid (Binzel et al., 2001) with the closest “spectral distance” to 2000 $DP_{107}$.

where $D_x$ is the ‘*spectral distance*’ between the unclassified spectrum $X$ and a classified spectrum $Y$, and $n$ represents the individual channels consisting of the spectrum, where the total number of the channels is $k$. The calculated results are listed in Table 1, where it is clear that the objects with the closest spectral matches are mostly X-type asteroids including successively No. 1–39 (see Fig. 3(b)). Therefore, we classify the NEA 2000 $DP_{107}$ as a member of “X class” (including the E-, M-, and P-types) (Tholen, 1984,1989).

Recent publications of radar observations of this object provide further information (Margot et al., 2002). They estimate a diameter of 800 m of the primary body and of approximately 300 m of the secondary (Margot et al., 2000). In addition, Pravec et al. (2000) give the absolute magnitude $H = 18.08 \pm 0.11$ of this object. Adopting the values

Table 1
Asteroids class with the minimum “spectral distances” to the 2000 $DP_{107}$

| Classification | Minimum distance | Sequence number | Corresponding asteroid |
|---|---|---|---|
| X-type | 0.0705 | 1 | (399) Persephone |
| C-type | 0.1242 | 40 | (551) Ortrud |
| B-type | 0.2487 | 308 | (59) Elpis |
| S-type | 0.2912 | 398 | (1977) Shura |
| Others | $> 0.3300$ | $> 400$ | |

Table 2
Albedos of asteroids with the closest "spectral matches"

| Sequence number | Asteroid | $P_v$ | Source | Classification |
|---|---|---|---|---|
| 1 | (399) Persephone | 0.18 | IRAS | M |
| 2 | (272) Antonia | 0.14 | IRAS | M |
| 3 | (129) Antigone | 0.17 | TRIAD | M |

mentioned above, we derive a mean V-band albedo of this object of 0.15 by the formula (Bowell et al., 1989)

$$\log P_v = 6.259 - 2\log d - 0.4H_v,$$

where $P_v$ is the V-band geometric albedo, $d$ is the diameter of an asteroid in km and $H_v$ is the absolute magnitude of the V-band. Albedos of the first three asteroids with minimum spectral deviation from the object are presented in Table 2. As mentioned above, 2000 $DP_{107}$ should be classified as type "M" based on the moderate albedo and the spectral feature.

## 4. Discussion

For those fast-moving NEAs such as 2000 $DP_{107}$, which approach the earth in a comparatively short period, it is difficult to observe them over a long-time period. However, even if there is only one night of photometry observation, assuming the data are in good precision and the rotation period of the asteroid is short, it is still possible to obtain a credible rotation period at a certain extent, as can be seen from the comparison of our photometric results with those of Pravec et al. (2000).

Although the taxonomic classification of 2000 $DP_{107}$ as an M-type asteroid based on spectrum and albedo is certain, its density of 1.7 $g/cm^3$ from the radar results is at odds with the conventional interpretation that "M" type is dominated by metallic materials and thus has high density.

In this paper, we present a method to derive the spectral type of an asteroid based on a current spectral classification system. The result indicates that asteroid classification based on broad band photometry might not be precise enough, especially for distinguishing between C- and X-type asteroids.

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