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Photometric Observations of 107P/Wilson-Harrington

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Abstract

We present lightcurve observations and multiband photometry for 107P/Wilson-Harrington by using five small- and medium-sized telescopes. The lightcurve has shown a periodicity of 0.2979 day (7.15 hour) and 0.0993 day (2.38 hour), which has a commensurability of 3:1. The physical properties of the lightcurve indicate two models: (1) 107P/Wilson-Harrington is a tumbling object with a sidereal rotation period of 0.2979 day and a precession period of 0.0993 day. The shape has a long axis mode (LAM) of $L_1:L_2:L_3 = 1.0:1.0:1.6$. The direction of the total rotational angular momentum is around $\lambda = 310^{\circ}$, $\beta = -10^{\circ}$, or $\lambda = 132^{\circ}$, $\beta = -17^{\circ}$. (2) 107P/Wilson-Harrington is not a tumbler. The sidereal rotation period is 0.2979 day. The shape is nearly spherical but slightly hexagonal with a short axis mode (SAM) of $L_1:L_2:L_3 = 1.5:1.5:1.0$. The pole orientation is around $\lambda = 330^{\circ}$, $\beta = -27^{\circ}$. In addition, the model includes the possibility of binary hosting. For both models, the sense of rotation is retrograde. Furthermore, multiband photometry indicates that the taxonomy class of 107P/Wilson-Harrington is C-type. No clear rotational color variations are confirmed on the surface.

1. Introduction

107P/Wilson-Harrington (also know as (4015) Wilson -Harrington, hereafter 107P) is a comet-asteroid transition object and near-earth object (NEO). Though 107P was discovered accompanied by a faint cometary tail at the Palomar Observatory in 1949[1], no cometary activity has been detected since then([2,3,4]). We hypothesize that 107P migrates to the NEO region from the outer main-belt region in which six of seven known main-belt comets (MBCs)[5] inhabit, and impacts with small objects can eject dust and/or expose sub-surface ice that then trigger 107P's cometary activity. In this hypothesis, the impacts' influence would be apparent in the rotational states and/or the surface color variations. We had an opportunity to observe 107P from August 2009 to March 2010. Our long observation campaigns enable us to derive the rotational states, shape model, and rotational color variations. Furthermore, the orbit of 107P makes it accessible by spacecraft. A more advanced sample return mission from a D-type asteroid or an asteroid-comet transition object is envisioned in Japan. One candidate is 107P[6]. Clarification of the physical properties of 107P is important to design the future mission.

2. Observation

We conducted the photometric observation campaigns of 107P with five small- and medium-sized telescopes. The observational circumstances are listed in Table 1.

Table 1: Observation Status.

Observatory	Year/Mon/Day
BSGC[a]	2009/09/6,7,9,10,15,16,19, 2009/10/8,10,28, 20, 2009/11/3,5-7,11,14, 2009/12/5,7-9,17,19,22, 2010/01/3,6-8,14-18,22,23, 2010/02/3-5,7,9,16,18,19, 2010/3/11
OAO[b]	2009/11/7,14,15,18-21,23, 2009/12/1,2,6,7,14,16-21
KISO[c]	2009/8/17,19,20, 2009/12/12
LOT[d]	2009/12/7-10
UH88[e]	2009/12/19

[a] Bisei Spaceguard Center 1.0m telescope
[b] Okayama Astrophysical Observatory 0.5m telescope
[c] Kiso Observatory 1.05m telescope
[d] Lulin Observatory 1.0m telescope
[e] University of Hawaii 2.2m telescope

3. Results

3.1 Rotational states

A period analysis is carried out with a Lomb-Scargle periodgram[7,8]. We conclude that 0.2979 day is the sidereal rotation period of 107P (Figure 1). We focus on the lightcurve has an unusual six peaks. Assuming 107P has a typical double-peak lightcurve, the period of 0.0993 day is the sidereal rotation period. However, the peaks and bottoms in the folded lightcurve with a period of 0.0993 day are overlapped by the three difference amplitudes. Thus, we exclude the period of 0.0993 day as the sidereal rotation period. On the other hand, the period of 0.0993 day may be the precession period. If an object is tumbler, the lightcurve is dominated by two periods: one, P_ψ, for the rotation about the extremal axis of the object, and the other, P_φ, for the precession about the total rotational angular momentum vector[9]. When we assume that P_ψ is 0.2979 day and P_φ is 0.0993 day, the frequency $2\ P^{-1}_\psi = (P^{-1}_\varphi - P^{-1}_\psi) = 6.713\ \mathrm{day}^{-1}$ approximately corresponds to the inverse of one half of our rotational period of 0.2979 day. The existence of periodicity by the linear combination of two frequencies shows a circumstantial evidence for tumbling.

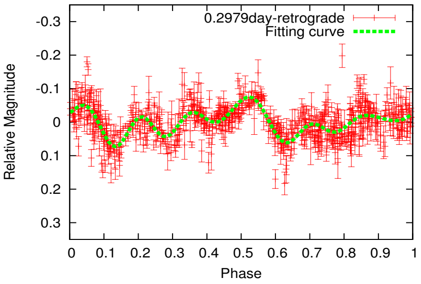

Figure 1: The lightcurve is folded with 0.2979 day. The fitting curve is described by two-order two-dimensional Fourier series.

3.2 Shape model

We estimate the directions of total rotational angular momentum by "epoch methods"[10] and "lightcurve inverse method"[11,12]. Three candidates are found near the direction, A ($\lambda = 310°$, $\beta = -10°$), B ($\lambda = 132°$, $\beta = -17°$), and C ($\lambda = 330°$, $\beta = -27°$). Next, we make the three shape models of 107P for the direction of total rotational angular momentum A, B and C. As an example, the shape model A is shown in Figure. 2. We have found that the normalized axis lengths L1, L2, and L3 are around 1.0, 1.0, and 1.6, respectively. The shape model A indicates a so-called long axis mode (LAM). Assuming a tumbler, the shape model A satisfies Euler's equation. Meanwhile, the shape mode C is a short axis mode (SAM) of L1:L2:L3 = 1.5:1.5:1.0. 107P of the shape model C is not a tumbler.

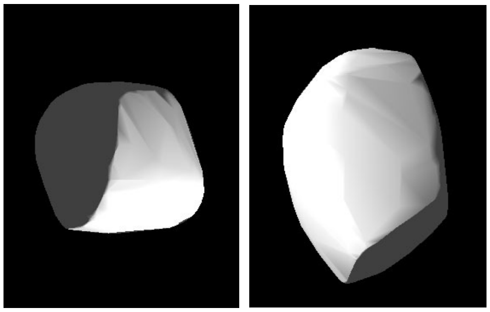

Figure 2: Shape model A. (Left) Pole-on view. (Right) Equatorial view from the right side of the pole-on image.

4. Summary

This study revealed the physical properties of 107P by a photometric observation campaign. We detected the lightcurve periodicity to be 0.2979 day and 0.0993 day with a commensurability of 3:1. We suggested tumbling and non-tumbling model to explain the lightcurve periodicity. Impacts with other small objects might be a cause of tumbling and comet activity.

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