CCD PHOTOMETRIC INVESTIGATIONS OF SMALL BODIES IN THE SOLAR SYSTEM

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Abstract

We present photometric analyses of two high-amplitude minor planets (1627 and 1865) resulting in approximate models of shape and rotation. Three distant (R=5.5–7.2 A.U.) comets are discussed concerning their major morphological parameters*.
KEYWORDS: *solar system: comets, asteroids*

1. Introduction

The new observing strategies using fully automatic telescopes and dedicated large instruments led to regular discoveries of a wealth of relatively bright asteroids, moderately faint comets and other interesting small bodies in the solar system with ambiguous characteristics. With the advent of the CCD era it has become possible to study much fainter objects than previously. The photometric methods of asteroid modelling are based on multi-opposition lightcurves of full phase coverage obtained at very different longitudes (De Angelis (1993), Detal et al. (1994)). We started a long-term observational project in 1998 with the primary purpose of obtaining accurate CCD lightcurves of poorly studied minor planets. The main programme is dedicated to asteroids with available two-opposition lightcurves, where a third lightcurve enables the complex analyis. Additional targets are those asteroids with no previous photometric measurements. The first results have already appeared in Sárneczky et al. (1999) and

*Based on observations taken at the German-Spanish Astronomical Centre, Calar Alto, operated by the Max-Planck-Instiute for Astronomy, Heidelberg, jointly with the Spanish National Commission for Astronomy

Kiss et al. (1999). In the first part of this paper we present photometric analyses of two high-amplitude minor planets resulting in their models of shape and rotation.

The overwhelming majority of cometary studies is based on ground-based or space observations of bright comets around or near to their perihelion. Direct imaging reveals the inner structures of the coma, which usually hides the nucleus itself. There has been a small number of papers dealing with distant ($R \geq 5$ AU) comets (e.g. O'Ceallaigh et al. (1995), Lowry et al. (1999)), and consequently, there is a serious lack of information on the behaviour of these objects. On the other hand, time-series observations may give constraints on the period of rotation and related effects - Jewitt (1992). The main aim of our work is to contribute this topic with new CCD observations of three comets located between 5.5–7.2 AU – C/1999 J2 (Skiff), C/1999 N4 (LINEAR) and C/2000 K1 (LINEAR).

2. Observations

Observations have been made on two different observing sites. Johnson V and R_C filtered CCD observations were carried out at Calar Alto Observatory (Spain) on 10 nights in June–July, 2000. The instrument used was the 123/981 cm Cassegrain-telescope equipped with the SITe#2b CCD camera (2048x2048 pixels giving an angular unbinned resolution of $0.49''$/pixel). The projected sky area is $16' \times 16'$, $10' \times 10'$ unvignetted.

Continuous R_C filtered CCD observations were carried out at the Piszkéstető Station of Konkoly Observatory during 1998-2000. The data were obtained using the 60/90/180 cm Schmidt-telescope equipped with a Photometrics AT200 CCD camera (1536x1024 KAF 1600 MCII coated CCD chip). The projected sky area is $29' \times 18'$ which corresponds to an angular resolution of $1.1''$/pixel.

3. Minor planet photometry

3.1. 1627 Ivar

This Earth-approaching asteroid was discovered by E. Hertzsprung in Johannesburg, on September 25, 1929. Beside a few photometric data series (see references in Kiss et al. (1999)) there is a radar measurement by Ostro et al. (1990). Our observations were made at Piszkéstető only. We have determined a sinodic period of 4.80±0.01 h being in perfect agreement with earlier results.

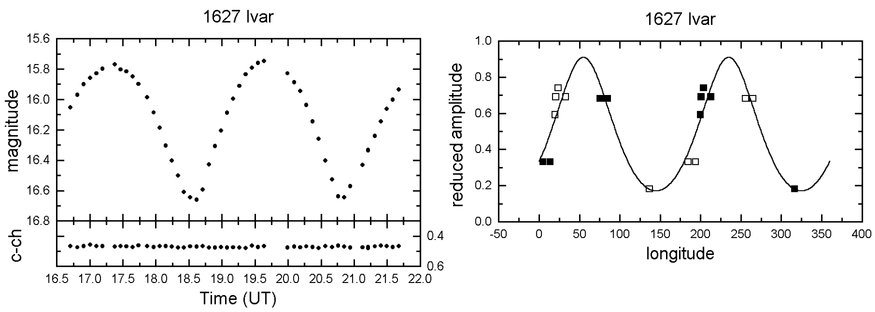

Figure 1: Left: the R lightcurve on Jan. 22, 1999; right: the reduced amplitudes vs. longitudes with the determined fit for 1627 Ivar

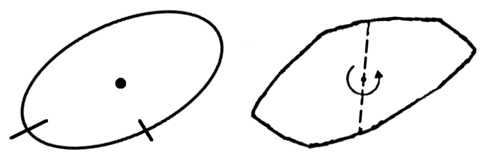

Figure 2: A pole-on view of the photometric model (left) and radar profile (right) of 1627 Ivar.

The amplitude varied between 0.8 and 1.0 mag during the different observing runs (1998 and 1999). A sample lightcurve is plotted in the left panel of Fig.1.

The shape of 1627 was modelled with an AM-method developed by Michałowski (1993). After collecting all available data, the observed amplitudes were reduced to zero solar phase. We have fitted the amplitude variations along the longitude. The resulting parameters of the model triaxial ellipsoid are: a/b=2.0±0.1, b/c=1.09±0.05. The ecliptic coordinates of the spin vector are: $\lambda_p = 145/325 \pm 8°$, $\beta_p = 34 \pm 6°$. The reduced amplitudes with the determined fit is presented in the right panel of Fig.1. The reliability of this model was tested by a direct comparison with radar images of Ostro et al. (1990). The similarity is evident (Fig.2). Therefore, we can rely on this (and similar) simple photometric methods when studying farther minor planets, which are beyond the capabilities of radar measurements.

3.2. 1865 Cerberus

This Near-Earth Asteroid has one of the largest observed amplitudes among all minor planets. Kohoutek discovered it, and the first photometry was discussed in Harris & Young (1989). In Sárneczky et al. (1999) we published the lightcurve in the 1998 opposition. Here we present two lightcurves taken in the 1999 and 2000 oppositions at Piszkéstető and Calar Alto, respectively (Fig.3).

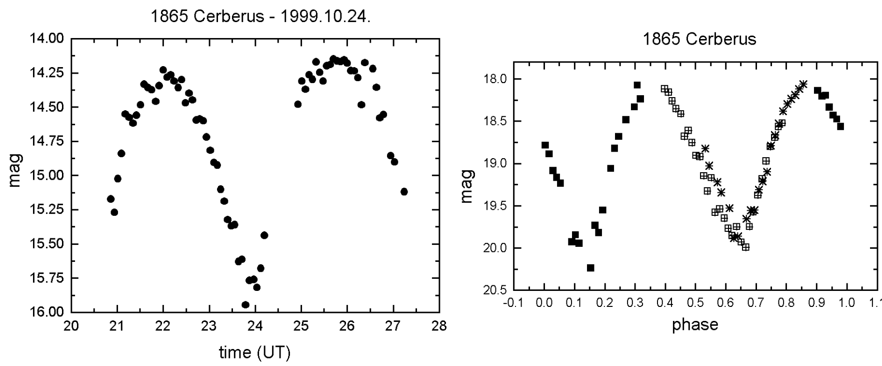

Figure 3: Two lightcurves of 1865 Cerberus: a single-night observation during the 1999 opposition (left) and the composite phase diagram obtained in 2000 (right). Note the 4 mag difference in the mean brightness.

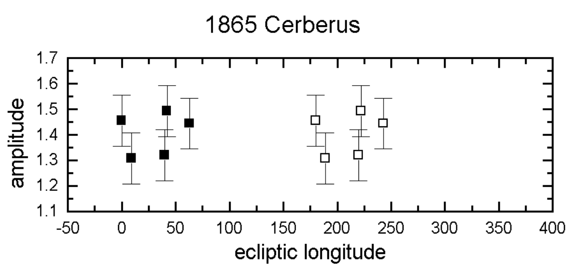

Figure 4: The amplitude-longitude diagram of 1865 Cerberus.

A preliminary analysis is being undertaken addressing the shape and rotation. Unfortunately, the first impressions are confusing, because the amplitude-longitude diagram seems to be unsuited for the AM-method due to the unexpectedly large scatter (see Fig.4). Further analysis is needed to clarify this disturbing situation.

4. Comet morphology

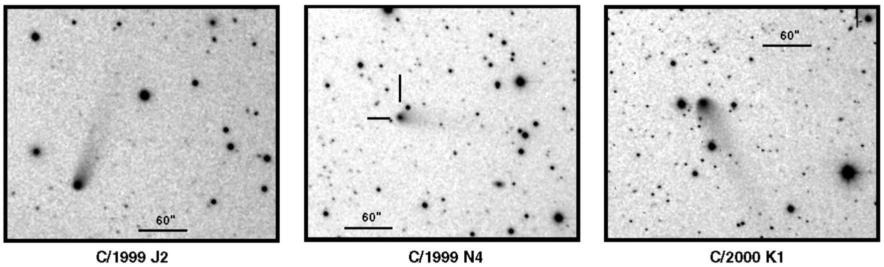

Figure 5: Three distant comets

Three comets located between 5.5–7.2 AU – C/1999 J2 (Skiff), C/1999 N4 (LINEAR) and C/2000 K1 (LINEAR) were observed in July, 2000 at Calar Alto Observatory. Beside the absolute VR_C photometry we took time-series observations in order to detect rotational effects. As can be seen in Fig.5, despite the large solar distances, the observed comets are fairly active. The general appearance is dominated by a small circular coma and a faint, considerably long tail. The presented images were enhanced to emphasize the faint tail extensions. The apparent tails are as long as $2.4'$ (C/1999 J2), $1.0'$ (C/1999 N4) and $3.6'$ (C/2000 K1), though it was impossible to determine the faint ends accurately. The measured position angles (PA) are the following (antisolar directions in parentheses): C/1999 J2 – PA 18° (PA 80°); C/1999 N4 – PA 97° (PA 111°); C/2000 K1 – PA 150° (PA 102°). One can find large difference in C/1999 J2 and a smaller one in C/2000 K1 implying a significant amount of tail curvature in these comets. Neglecting this curvature we calculated the corresponding linear lengths taking into account the projection effect. The results are $7.5 \cdot 10^5$ km (C/1999 J2), $3.2 \cdot 10^5$ km (C/1999 N4) and $12 \cdot 10^5$ km (C/2000 K1), which are far from being typical at such large distances. We note that these values are only order of magnitude estimates because the curvature may alter the real lengths quite seriously at such large distances.

Time-series data revealed only small-amplitude, ambiguous variations, therefore, no firm conclusion could be drawn on the rotation of the nuclei. More results will appear in Szabó et al. (2001).

Acknowledgments

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