Available online at www.sciencedirect.com
ScienceDirect
Planetary and Space Science 57 (2009) 1–9
Planetary and Space Science
www.elsevier.com/locate/pss

CCD and photon-counting photometric observations of asteroids carried out at Padova and Catania observatories

D. Gandolfi[a,c], M. Cigna[b], D. Fulvio[a,b,*], C. Blanco[a]

[a]Physics and Astronomy Department, Catania University, via S. Sofia 64, I-95123 Catania, Italy
[b]INAF-Catania Astrophysical Observatory, via S. Sofia 78, I-95123 Catania, Italy
[c]Thüringer Landessternwarte Tautenburg, Sternwarte 5, D-07778 Tautenburg, Germany

Received 11 July 2008; received in revised form 27 September 2008; accepted 29 September 2008
Available online 14 October 2008

Abstract

We present the results of observational campaigns of asteroids performed at Asiago Station of Padova Astronomical Observatory and at M.G. Fracastoro Station of Catania Astrophysical Observatory, as part of the large research programme on Solar System minor bodies undertaken since 1979 at the Physics and Astronomy Department of Catania University. Photometric observations of six Main-Belt asteroids (27 *Euterpe*, 173 *Ino*, 182 *Elsa*, 539 *Pamina*, 849 *Ara*, and 984 *Gretia*), one Hungaria (1727 *Mette*), and two Near-Earth Objects (3199 *Nefertiti* and 2004 *UE*) are reported. The first determination of the synodic rotational period of 2004 *UE* was obtained. For 182 *Elsa* and 1727 *Mette* the derived synodic period of 80.23 ± 0.08 and 2.981 ± 0.001 h, respectively, represents a significant improvement on the previously published values. For 182 *Elsa* the first determination of the $H-G$ magnitude relation is also presented.

Keywords: Asteroids; Photometric observations; Lightcurves; Synodic rotational period; $H-G$ relation

1. Introduction

Photometric observations of asteroids, through the lightcurves collection, allow us to determine their rotational parameters (synodic rotational period, spin axis orientation, sense of rotation, etc.) and physical properties (shape, colour indexes, surface dishomogeneity, taxonomic class, etc.). The knowledge of the rotational characteristics is important to understand the collisional evolution of single minor planets, of families and of the whole asteroidal population. It is also essential to check the action of the so-called Yarkovsky–O'Keefe–Radzievski–Poddak (YORP) effect on smaller asteroids. It seems to become clear that the spin characteristics of super-fast and slow rotators are the result of the torque from solar radiation and re-radiation (Harris, 2006) with the collisional processes determining the excitation of the tumbling motion on slow rotators.

The results reported in this paper are part of the large photometric observational programme of asteroids undertaken since 1979 at the Physics and Astronomy Department of Catania University (Blanco and Catalano, 1979; Di Martino, 1984; Di Martino et al., 1994; Blanco and Riccioli, 1998; Riccioli et al., 2001). The aim of this long-term programme is to increase the number of asteroids with well-known rotational parameters and consequently improve the database necessary for the investigation of the minor planet evolutionary history. Special attention has been devoted to the asteroids with observational constraints and to those with few known lightcurves, in order to obtain the minimum number needed to apply pole coordinates and shape computational methods (Blanco and Riccioli, 1998). Since the study of Near-Earth Objects (NEOs) is important to improve the knowledge of inner Solar System mechanics and physics (resonance mechanisms, smaller bodies dynamics, connection with meteorites, etc.), we have recently expanded our programme to include these objects.

*Corresponding author at: INAF–Catania Astrophysical Observatory, via S. Sofia 78, I-95123 Catania, Italy. Tel.: +39 095 7332325; fax: +39 095 330592.
E-mail address: dfu@oact.inaf.it (D. Fulvio).

0032-0633/$ - see front matter
doi:10.1016/j.pss.2008.09.014

In this paper we present new photometric observations of six Main-Belt asteroids, 27 *Euterpe*, 173 *Ino*, 182 *Elsa*, 539 *Pamina*, 849 *Ara*, and 984 *Gretia*, one Hungaria object, 1727 *Mette*, and two NEOs, 3199 *Nefertiti* and 2004 *UE*.

The values of the synodic rotational period, lightcurve amplitudes, and $B-V$ colour index of almost all the observed asteroids are presented. For 182 *Elsa* and 1727 *Mette*, the rotational periods we derived represent a significant improvement on the previously published values. For 182 *Elsa* also the $H-G$ magnitude relation (Bowell et al., 1989) was obtained. The first observed lightcurve of the small NEO 2004 *UE* might indicate an elongated shape and a possible smooth surface.

The outline of the paper is as follows: we describe our observations and data reduction in Section 2; the results and comments on each single object are reported in Section 3.

2. Photometric observations and data reduction

The photometric observations reported in this paper were carried out at two different observatories using different telescopes and instruments.

CCD imaging photometry was obtained during three observing runs at the Asiago Station of Padova Astronomical Observatory (hereafter PD station), by using the 67/92-cm Schmidt telescope. Unfiltered CCD photometry was performed with the SCAM-1 camera in January and February 2003 with mostly clear and stable weather conditions (mean seeing $\approx 2.0''$). The SCAM-1 camera hosts a front illuminated 2048×2048 LORAL CCD with a 15-μm pixel-size. Taking into account the telescope plate scale ($95.9''$/mm), the resulting projected sky area was about $49' \times 49'$ with an angular resolution of about $1.44''$/pixel. Further CCD photometric observations were carried out using the same telescope equipped with the ITANET camera (Blanco et al., 2004; Gandolfi et al., 2006), hosting a front illuminated 2048×2048 Kodak-KAF 4200 CCD, with 9-μm pixel-size. The observations were performed through V and R Johnson filters in April 2003 and November 2004, under photometric weather conditions with seeing varying between 1.5 and $2.0''$. Taking into account the telescope plate scale and the detector pixel-size, the resulting field of view turned out to be $29' \times 29'$ with an angular resolution of $0.89''$/pixel. The exposure time during both campaigns varied from 2 to 5 min, depending on the asteroid magnitude.

CCD image pre-reduction, including bias, dark, and flat-field correction, was made with standard IRAF[1] routines. Nightly twilight flat-fields were used to correct images for optical vignetting, dust shadow, and pixel-to-pixel sensitivity variation. In order to maximize the asteroid signal-to-noise ratio (especially in cases of elongated images of fast moving asteroids), elliptical aperture photometry was performed using the SExtractor software (Bertin and Arnouts, 1996). A set of comparison stars, each having magnitudes similar to that of the observed asteroid, was selected along the object nightly path. From this set of stars, the non-variable star with the highest signal-to-noise ratio was chosen as the nightly comparison star. Due to a filter wheel technical problem no fields of standard stars were observed during both runs. Therefore only differential photometry was obtained from CCD imaging data.

Photoelectric photometry was carried out in November 1993, December 1996, and July, September, October, and November 2004 at the 91-cm Cassegrain telescope of M.G. Fracastoro Station of INAF-Catania Astrophysical Observatory (hereafter CT station). The observations were performed with the B and V Johnson standard filters. A 1.5-mm diameter diaphragm, limiting the telescope field to about $22''$, and a cooled photon-counting single-head photometer equipped with an EMI9893QA/350 photomultiplier were used. Nearby solar spectral type comparison stars were selected along the asteroid path to neglect the second-order chromatic effects of atmospheric extinction. The B and V linear extinction coefficients were derived each night through the comparison stars. In order to determine the transformation coefficients to the Johnson standard system, several standard stars, selected from Mermilliod et al. (1997), Blanco et al. (1968), and Landolt (1992), were also observed during each night. The observing strategy and data reduction were the same as those already adopted during previous observational campaigns of asteroids (Di Martino et al., 1994).

Both for CCD and photoelectric data, the final error of the single measurements is on average between ~0.01 and 0.02 mag. On the basis of the asteroid aspect data, the time corresponding to each data point was corrected for light-travel time and, when determined, the standard V magnitudes were also reduced to the unit geocentric and heliocentric distances ($V(1,\alpha)$). The value of the synodic rotational period, the composite lightcurve, the mean reduced magnitude $\bar{V}(1,\alpha)$, and the nightly magnitude shifts were obtained by applying the Fourier analysis, as described in Harris et al. (1989).

The nightly aspect data for each asteroid observed at PD and CT station are listed in Table 1. The first column reports the mean universal time (UT) of the nightly observational interval, rounded to a hundredth of a day. The other columns give the heliocentric ecliptic longitude and latitude, asteroid–Sun (r) and asteroid–Earth (Δ) distances, and solar phase angle (α) at the mean UT of each observing night. For the asteroids observed at CT station, the value of the mean reduced magnitude $\bar{V}(1,\alpha)$ are also reported. The filters used and observatory's site are listed in the last two columns.

[1]IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy (AURA), Inc., under cooperative agreement with the National Science Foundation.