Icarus 000 (2017) 1–9

Contents lists available at ScienceDirect

Icarus

journal homepage: www.elsevier.com/locate/icarus

Shape models of asteroids based on lightcurve observations with BlueEye600 robotic observatory

Josef Ďurech[a,*], Josef Hanuš[a], Miroslav Brož[a], Martin Lehký[a], Raoul Behrend[b], Pierre Antonini[c], Stephane Charbonnel[d], Roberto Crippa[e], Pierre Dubreuil[d], Gino Farroni[f], Gilles Kober[d], Alain Lopez[d], Federico Manzini[e], Julian Oey[g], Raymond Poncy[h], Claudine Rinner[i], René Roy[j]

[a] Astronomical Institute, Faculty of Mathematics and Physics, Charles University, V Holešovičkách 2, 180 00 Prague, Czech Republic
[b] Geneva Observatory, CH-1290 Sauverny, Switzerland
[c] Observatoire des Hauts Patys, F-84410 Bédoin, France
[d] Observatoire de Durtal, F-49430 Durtal, France
[e] Stazione Astronomica di Sozzago, I-28060 Sozzago, Italy
[f] Courbes de rotation d'astéroïdes et de comètes, CdR
[g] Kingsgrove, NSW, Australia
[h] Rue des Ecoles 2, F-34920 Le Crès, France
[i] Ottmarsheim Observatory, 5 rue du Lièvre, F-68490 Ottmarsheim, France
[j] Observatoire de Blauvac, 293 chemin de St Guillaume, F-84570 Blauvac, France

ARTICLE INFO

Article history:
Received 15 January 2017
Revised 2 June 2017
Accepted 12 July 2017
Available online xxx

Keywords:
Asteroids
Rotation
Photometry

ABSTRACT

We present physical models, i.e. convex shapes, directions of the rotation axis, and sidereal rotation periods, of 18 asteroids out of which 10 are new models and 8 are refined models based on much larger data sets than in previous work. The models were reconstructed by the lightcurve inversion method from archived publicly available lightcurves and our new observations with BlueEye600 robotic observatory. One of the new results is the shape model of asteroid (1663) van den Bos with the rotation period of 749 h, which makes it the slowest rotator with known shape. We describe our strategy for target selection that aims at fast production of new models using the enormous potential of already available photometry stored in public databases. We also briefly describe the control software and scheduler of the robotic observatory and we discuss the importance of building a database of asteroid models for studying asteroid physical properties in collisional families.

1. Introduction

The increasing amount of available photometric data for asteroids has led to hundreds of asteroid shape models that have been derived from these data. A common method of asteroid shape reconstruction from disk-integrated time-resolved photometry is the lightcurve inversion of Kaasalainen et al. (2001). The scientific motivation for reconstructing physical models of asteroids can be manifold: increasing the number of models for better statistical studies (Hanuš et al., 2016), debiasing the spin and shape distribution (Marciniak et al., 2015), or studying the spin distribution of collisional family members (Slivan et al., 2009; Hanuš et al., 2013; Kim et al., 2014), to name a few. In order to uniquely determine asteroid's sidereal rotation period, the direction of its rotation axis, and a convex shape approximation of its shape, lightcurves from different viewing and illumination geometries have to be observed. In practice it means that for a typical main-belt asteroid, we need to collect lightcurves from at least three apparitions. So to derive a new asteroid model, one has to either devote a significant amount of time to collect data from more apparitions, choose a near-Earth object that changes its geometry a lot during a single close approach, or use some archived data and combine them with new observations. For the purpose of this paper, we have chosen the last strategy and present new models of asteroids that were obtained by investing only minimum observing time and using mainly archived data.

We present our strategy of concentrating on those asteroids, for which there is a 'subcritical' number of lightcurves available in the archives and adding observations from just one more ap-

* Corresponding author.
E-mail address: durech@sirrah.troja.mff.cuni.cz (J. Ďurech).

http://dx.doi.org/10.1016/j.icarus.2017.07.005
0019-1035/

Fig. 1. Projectsoft BlueEye600 robotic observatory located in Ondřejov, Czech Republic. The alt-azimuth telescope is of Ritchey–Chrétien type with the primary diameter $d = 600$ mm.

parition should lead to a unique model. A list of such candidates is published in every issue of the Minor Planet Bulletin (Warner et al., 2016, for example). We used the BlueEye600 telescope that we briefly describe together with the target selection algorithm in Section 1. In Section 2, we present our results – new or updated shape models of 18 asteroids.

New lightcurves were obtained with the robotic observatory BlueEye600. We have developed an algorithm to assign priorities to individual asteroids, with the aim to maximize the number of new asteroid models that could be derived by adding new lightcurves to archived data. Therefore, we focused on asteroids for which older lightcurves existed and scheduled the observations according to priorities of observable asteroids and observing conditions.

1.1. Instrument description

The observatory is located in Ondřejov, Czech Republic ($\phi = 49°54'34''$, $\lambda = 14°46'48''$, $h = 515$ m, Fig. 1). The telescope itself is a Ritchey–Chrétien system (Officina Stellare), with the primary mirror diameter $d = 600$ mm and the effective focal length $f = 3\,000$ mm, equipped with a 3-lens optical corrector. It produces a diffraction-limited images in a large field of view (50 mm), after a proper alignment; in practice the telescope is seeing limited. Seeing conditions at the site are not exceptional, the average value is about 2–3 arcsec. The secondary mirror also contains a 2nd (raw) focuser.

Instruments are located in the secondary focus, in particular focuser, derotator (Rotofocuser) off-axis guider with a 2nd camera filter wheel (FLI) and the main camera (Mii) using a E2V 42–40 CCD chip, with more than 90% quantum efficiency in VRI bands and the resulting FOV 0.52°.

The alt-azimuth mount (developed by Projectsoft) is of very rigid construction, equipped with torque motors and allows for fast motions with the angular velocity up to 45°/s and angular acceleration up to 45°/s^2.

1.2. High-level control software

The observatory can be controlled using a high-level software with the following basic architecture or parts: Aitel, Aiplan, Aiview, Projectsoft telescope and Projectsoft camera (see the simplified scheme in Fig. 2). All communication between these software components is based on TCP/IP sockets. One can either send commands and their parameters to the lower-level software, specified according to ASCOL, MACOL and other protocols, or serialised objects (most importantly 'cubes', i.e. descriptions of observational blocks). The communication is transparent over the internet, or a secure VPN network, respectively.

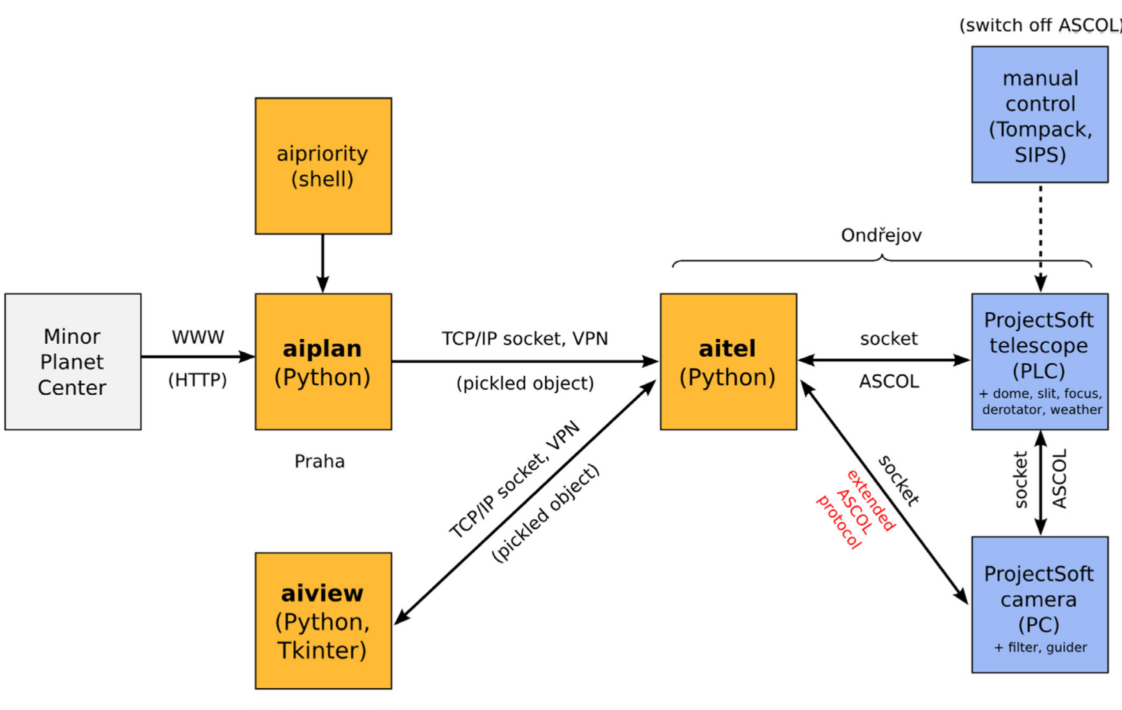

Fig. 2. A concept scheme of the high-level software for autonomous control of the observatory. The basic components are: Aitel (executive part controlling the observatory), Aiplan (automated planner of observations), Aiview (graphical user interface for manual planning of observations). The ephemerides are downloaded from the Minor Planet Center. On the other hand, there is lower-level control software (Projectsoft telescope and Projectsoft camera), which receives commands over TCP/IP according to ASCOL and MACOL protocols. It also allows for a manual control or debugging.

Please cite this article as: J. Ďurech et al., Shape models of asteroids based on lightcurve observations with BlueEye600 robotic observatory, Icarus (2017), http://dx.doi.org/10.1016/j.icarus.2017.07.005