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Shape models and spins of asteroids derived from ATLAS photometry

Josef Ďurech (1), John Tonry (2), Nicolas Erasmus (3), Larry Denneau (2), Aren N. Heinze (2), Heather Flewelling (2) and Radim Vančo (1)
(1) Astronomical Institute, Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic (durech@sirrah.troja.mff.cuni.cz), (2) Institute for Astronomy, University of Hawaii, Honolulu, HI, USA (3) South African Astronomical Observatory, Cape Town, South Africa

Abstract

We present new shape models and spins of asteroids that we derived by inversion of photometric data obtained by the Asteroid Terrestrial-impact Last Alert System (ATLAS). In total, we reconstructed models for about 2900 asteroids, which significantly enlarged the sample of asteroids with known shape and spin axis direction.

1. Introduction

The Asteroid Terrestrial-impact Last Alert System (ATLAS) is a survey which main purpose is to detect dangerous near-Earth asteroids. It consists of two telescopes (at Haleakala and Mauna Loa, Hawaii) with 0.65cm primary mirror, $f/2.0$, and 7.5° field of view. It covers the whole observable sky in one night with 30 s exposures to ~ 19 mag [8]. The survey is carried mainly in cyan (c, 420–650 nm) and orange (o, 560–830 nm) bandpasses.

2. Inversion of photometry

We used ATLAS asteroid photometry to derive shape models and spins of asteroids. We processed all available photometry from June 2015 to October 2018 for about 180,000 asteroids, most of which was observed in o and c filters. Viewing and illumination geometry of each observation was computed using the Miriade system of IMCCE, the observed brightness was normalized to 1 AU. We removed outliers by fitting a linear-exponential phase function to the data, the same way as [6]. Then we selected 98,000 asteroids with at least 100 individual observations to which we applied lightcurve inversion.

We used the same approach as in [6, 2, 1] – we searched for the best-fit model with the lightcurve inversion method of [7]. The sidereal rotation period was searched on an interval of 2–1000 hr with asteroid shapes being approximated with convex models or ellipsoids. For this time-consuming scan of the parameter space we used the BOINC distributed computing project Asteroids@home [3]. We checked the reliability of the best model with the lowest χ^2 by several tests the same way as in [2]. For example, we tested if the χ^2 value of the best solution was significantly lower than for other minima, if the solution was not dependent on the shape resolution, and if the shape rotated around the shortest inertia axis.

3. Results

From all 98,000 asteroids that we processed, we derived 1274 unique shape and spin models and 929 partial models (where only the ecliptic latitude β of the spin axis was determined, the longitude λ was not constrained). More over, by using the information about rotation periods from the Lightcurve Database (LCDB)[1] of [9] as an a priory constraint to narrow the interval of possible rotation periods, we derived other 330 full and 376 partial models. In total, we have models or partial models for about 2900 asteroids together with their color index $o - c$ and parameters of their phase curves. Out of these, 646 asteroids have independent models derived from other photometry in the Database of Asteroid Models form Inversion Techniques (DAMIT, [4]).[2] Together with the DAMIT database, we now have physical models for about 3900 asteroids, which enables us to study the distribution of shapes and spins in the asteroid population.

[1] http://alcdef.org
[2] http://astro.troja.mff.cuni.cz/projects/asteroids3D

4. Prospects for the future

For most of the asteroids from our sample, ATLAS data were subcritical in the sense that it was not possible to reconstruct a unique spin/shape model. The reasons were: (i) not enough data, (ii) data too noisy, (iii) lightcurve amplitude too small with respect to the noise, and (iv) limited viewing/illumination geometry. While the noise of ATLAS measurements cannot be easily improved, the number of measurements and the viewing/illumination coverage is steadily increasing as ATLAS telescopes continue to observe. We expect that by collecting more ATLAS photometry, other thousands of unique shape/spin models will be reconstructed. Another possibility how to increase the number of models is to combine ATLAS photometry with complementary data, for example with Gaia photometry [5].

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