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# Against the biases in spins and shapes of asteroids

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## ABSTRACT

Physical studies of asteroids depend on an availability of lightcurve data. Targets that are easy to observe and analyse naturally have more data available, so their synodic periods are confirmed from multiple sources. Also, thanks to availability of data from a number of apparitions, their spin and shape models can often be obtained, with a precise value of sidereal period and spin axis coordinates.

Almost half of bright ($H \leq 11$ mag) main-belt asteroid population with known lightcurve parameters have rotation periods considered long ($P \geq 12$ h) and are rarely chosen for photometric observations. There is a similar selection effect against asteroids with low lightcurve amplitudes ($a_{max} \leq 0.25$ mag). As a result such targets, though numerous in this brightness range, are underrepresented in the sample of spin and shape modelled asteroids. In the range of fainter targets such effects are stronger. These selection effects can influence what is now known about asteroid spin vs. size distribution, on asteroid internal structure and densities and on spatial orientation of asteroid spin axes.

To reduce both biases at the same time, we started a photometric survey of a substantial sample of those bright main-belt asteroids that displayed both features: periods longer than 12 h, and amplitudes that did not exceed 0.25 magnitude. First we aim at finding synodic periods of rotation, and after a few observed apparitions, obtaining spin and shape models of the studied targets.

As an initial result of our survey we found that a quarter of the studied sample (8 out of 34 targets) have rotation periods different from those widely accepted. We publish here these newly found period values with the lightcurves.

The size/frequency plot might in reality look different in the long-period range. Further studies of asteroid spins, shapes, and structure should take into account serious biases that are present in the parameters available today. Photometric studies should concentrate on such difficult targets to remove the biases and to complete the sample.

## 1. Introduction

Spin and shape parameters of a large sample of main belt asteroids are an important basis for theories describing Solar System formation and evolution, with non-gravitational forces influencing the orbital and physical properties of these minor bodies. It has been recently found that asteroids belonging to the Flora family have preferential prograde rotation, because retrograde rotating objects were moved by the Yarkovsky effect to the $\nu_6$ resonance at the inner main belt and removed (Kryszczyńska, 2013). This fact finds its confirmation in preferential retrograde rotation of Near Earth Asteroids (La Spina et al., 2004). It has also

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been found that the distribution of known spin axis positions of small asteroids shows a trend for them to group at extreme values of obliquities (at high angles from their orbital planes), which can be explained as the outcome of spin evolution under the influence of YORP effect (Hanuš et al., 2013).

However, the available sample of well studied asteroids is burdened with substantial selection effects. There exist well known strong observational biases against small, low-albedo, and distant objects due to limitations of instruments that are most widely used for photometric studies. But there are also other strong selection effects that are connected to photometric studies.

The arithmetic mean of periods in the size range limited by absolute magnitude $H \leq 11$ mag given by Pravec and Harris (2000) was around 9–10 h, with a most extreme value of the mean equal to 12 h in the size range around 100 km. With time the sample of asteroids with known periods substantially grew, and a large number of slow periods was found. Currently the arithmetic mean of rotation periods in this size range is almost 20 h. Median value of all known periods in this sample of main-belt objects with $H \leq 11$ mag (where the period survey is almost complete) is around 11 h. It means that half of the bright main-belt population with known lightcurve parameters have rotation periods considered “long” and are rarely chosen as targets for photometric observations, even though they are easy targets for small telescopes. As a result only 20% of this group has been spin and shape modelled. Along with the bias against asteroids with long periods of rotation (here: $P \geq 12$ h), there is another one, against those with low lightcurve amplitudes (here: $a_{max} \leq 0.25$ mag). Within the set of bright asteroids those with small amplitudes comprise almost half of the whole studied population, while spin and shape models have been determined for around 20% of this sub-population (source: LCDB; Warner et al., 2009, see Table 1). On the other hand two remaining populations (short-period, and high-amplitude objects) have been modelled in 36% each (see Fig. 1). By chance, at such conditions statistics in both groups, divided by period and by maximum amplitude, are very similar and both diagrams look almost identical to each other. For fainter targets these inequalities are much stronger, and the data pool of objects with known periods is highly incomplete. Moreover, the widely known plot showing distribution of rotational frequency vs. asteroid sizes might in reality look slightly different in the lower-right part (Fig. 2).

In the sample of main-belters with $H \leq 11$ mag and with available lightcurves, only 13% of long-period objects with low amplitudes have been spin and shape modelled, while 43% of the comparably numerous group with opposite features (periods shorter than 12 h and maximum amplitudes higher than 0.25 mag) have been modelled (see Table 2 and Fig. 3). It means that almost half of the easily observable population is well studied, while objects more difficult to properly observe and analyse are well studied in a much smaller fraction of their population.

The observational bias against asteroids with small amplitude of brightness variations can influence our knowledge of the asteroid spin axis distribution in space, on their shapes and densities. Since weakly elongated objects always display small lightcurve amplitudes, their periods are hard to determine, and their spin and shape models are very hard to obtain. They become even more difficult for modelling when their spin axes are close to their orbital planes, causing any brightness variations disappear when asteroid is viewed nearly pole-on (Marciniak and Michałowski, 2010). Moreover, data for low-amplitude objects can be lost in the 0.1–0.2 magnitude noise of the sparse data coming from large, astrometric surveys (Hanuš et al., 2011), making them hard to be modelled using such data alone. Photometric data for unique spin and shape modelling of low-amplitude asteroids should be at least an order of magnitude better, with the noise not exceeding 0.01 mag.

Small, kilometer sized asteroids with long periods of rotation can be those that have been spun down by YORP torques (Rubincam, 2000) or can be in tumbling rotational states, showing double periodicity. Thus they are important targets for studies of damping timescales and evolution under thermal effects. Additionally, studies in the small amplitude range can result in possible discoveries of binary systems, because in majority of binaries the components are weakly elongated in shape (Pravec and Harris, 2007).

Summing up, it turns out that at least half of the whole well observable main belt population is studied insufficiently, and the selection effects tend to increase with time. Previously found groupings and depopulations within large number of asteroid spin axis longitudes could have been caused by several overlapping selection effects (Bowell et al., 2014). Also, it has been shown that even precise data from the Gaia satellite will introduce biases in derived asteroid spin and shape models depending on their true pole latitude and shape elongation (Santana-Ros et al., 2015).

## 2. Observing campaign

Motivated by these facts we started a large, long-term observing campaign of a substantial sample of long-period asteroids from those objects (highlighted with rectangular frame in Fig. 2) that additionally displayed small amplitudes of brightness variations, to reduce both selection effects at the same time. Our aim is to obtain spin and shape models of this class of “difficult” objects in order to reduce the increasing biases favouring quickly rotating, elongated asteroids, with extreme values of spin axis obliquity to be prevailingly observed and modelled today. It is caused by the fact that the latter objects are easiest to observe and analyse – their short periods allow for a full lightcurve coverage in one or two nights, and large amplitudes make their brightness variations always stand out of the noise even in imperfect observing conditions. On the other hand, obtaining full phase coverage for objects with long periods requires much more telescope time and, if their amplitude is small, data of higher quality. The periods of the order of several dozens of hours have to be determined from fragments

**Table 1**
Numbers of asteroids with $H \leq 11$ mag, for which LCDB (Warner et al., 2009) gives physical parameters. Only lightcurve parameters with period quality code better than or equal to 2− have been included. The total number here is 1230 asteroids, median period is 10.986 h, median $a_{max} = 0.27$ mag. Parentheses give numbers of spin and shape modelled objects within each group.

| Period of rotation | | | Maximum amplitude | | |
|---|---|---|---|---|---|
| Long, $P \geq 12$ h (modelled) | short, $P < 12$ h (modelled) | Undefined | High, $a_{max} > 0.25$ mag (modelled) | Low, $a_{max} \leq 0.25$ mag (modelled) | Undefined |
| 528 (101) | 656 (236) | 46 | 655 (233) | 543 (104) | 32 |