EPSC Abstracts
Vol. 6, EPSC-DPS2011-429-1, 2011
EPSC-DPS Joint Meeting 2011

Spin-vector distribution of asteroids – the role of the YORP thermal effect

J. Hanuš (1), J. Ďurech (1), M. Brož (1), B. D. Warner (2), D. Higgins (3), J. Oey (4), F. Pilcher (5), R. D. Stephens (6), R. K. Buchheim (7), R. A. Koff (8), D. Polishook (9), V. Benishek (10), J. W. Brinsfield (11), R. I. Durkee (12), and R. Goncalves (13)

(1) Astronomical Institute, Faculty of Mathematics and Physics, Charles University in Prague, V Holešovičkách 2, 18000 Prague, Czech Republic (hanus.home@gmail.com), (2) Palmer Divide Observatory, 17995 Bakers Farm Rd., Colorado Springs, CO 80908, USA, (3) Hunters Hill Observatory, Australia, (4) Kingsgrove, NSW, Australia, (5) 4438 Organ Mesa Loop, Las Cruces, NM 88011, USA, (6) Goat Mountain Astronomical Research Station, 11355 Mount Johnson Court, Rancho Cucamonga, CA 91737, USA, (7) Altimira Observatory, CA, (8) Antelope Hills Observatory, CO, (9) Benoziyo Center for Astrophysics, The Weizmann Institute of Science, Rehovot 76100, Israel, (10) Belgrade Astronomical Observatory, Serbia, (11) Via Capote Observatory, CA, (12) Shed of Science Observatory, MN, (13) Linhaceira Observatory, Portugal

Abstract

More than 300 asteroid shape models were derived by the lightcurve inversion method so far. These models represent the biggest sample of spin-vector parameters of asteroids determined by a single method. We present a simple statistical analysis of spin vectors for these asteroid models. We look for possible correlations between various physical parameters with an emphasis on the spin vector. In order to explain the observed spin-axis distribution, we investigate the bias of the lightcurve inversion method and present a simple theoretical model for the long-term evolution of spins. From this analysis, we find that the latitude distribution of small asteroids ($D < 30$ km) is clustered towards ecliptic poles and can be explained by the YORP thermal effect. On the other hand, the latitude distribution of larger asteroids ($D > 60$ km) exhibits an evident excess of prograde rotators, probably of primordial origin. The distribution of ecliptic longitudes seems to be isotropic.

1. Introduction

The lightcurve inversion method (LI) is a powerful tool that allows us to derive basic physical properties of asteroids (the rotational state and the convex shape) from their disk-integrated photometry (see [1, 2]).

In [3], our first analysis of physical properties of 229 asteroid models derived by the LI was published. Since then, another ~ 80 asteroid models are available.

Our main goal was to investigate the spin-vector distribution, which is still not reliably explained. It was presumed that due to collisional evolution, the spin-vector distribution of Main Belt Asteroids (MBAs) should be nearly isotropic, possibly with a small excess of prograde spins [4]. This is inconsistent with the statistical analyses of observed distributions (see e.g. [5]).

For each asteroid in our statistical sample, we derived its convex shape, sidereal rotational period, spin vector, and parameters of the scattering law; and we adopted diameter, proper elements, family membership, taxonomic type, albedo, and absolute magnitude from several databases available on the Minor Planet Center.

2. Available asteroid models

More than 100 asteroid models were derived during the past decade from dense photometry by several authors. In [6], 24 models based on combined dense and sparse photometry were presented (sparse data were from the US Naval Observatory in Flagstaff). In [3], the authors investigated the sparse photometry produced by several astrometric observatories (these data are available in the AstDyS[1] database), they used only the accurate sparse data in combination with dense photometry and determined 80 new asteroid models. In this study, we also use another ~ 80 asteroid models (see DPS abstract Ďurech et al., 2011).

3. Spin axis distribution

In order to explain the anisotropic latitude distribution, we simulated the bias of the LI and also constructed a

[1] Asteroids – Dynamic Site: `http://hamilton.dm.unipi.it/`

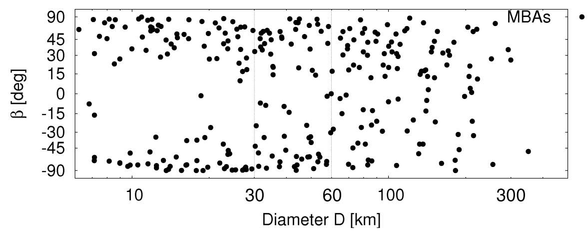

Figure 1: Dependence of the ecliptic latitude β of the MBA's pole directions on the diameter D (plotted in the logarithmic scale).

model for the long-term evolution of spins, where we included the YORP effect, random reorientations by non-catastrophic collisions, and mass shedding after a critical rotation is reached. Asteroids with ecliptic latitudes of the spin axis $|\beta| > 40°$ are derived more frequently than asteroids with $|\beta| < 20°$ by a factor of 1.5–2 (depending on the size). The de-biased observed latitude distribution is still clustered towards higher values. As seen in Fig 1, the so called "ecliptic gap" is prominent only for small asteroids with diameter $D < 30$ km, larger asteroids with $D > 60$ km have spin axes distributed isotropically with a small preference of prograde rotators. The prograde excess is probably of primordial origin. The observed distribution of β for small asteroids seems compatible with our model: the YORP effect is capable of creating such uneven distribution.

4. Summary and Conclusions

We used more than 300 asteroids models derived by the lightcurve inversion in a study of their rotational states.

As expected, the de-biased observed ecliptic *longitude* distribution of asteroid spin vectors is independent of diameter and is compatible with a uniform distribution. The effect of the LI bias on the ecliptic *latitude* distribution is only minor and the global features of the observed *latitude* distribution do not change. The de-biased *latitude* distribution for asteroids with diameters $D > 60$ km shows an excess of prograde rotators in the latitude interval (11°, 90°). This excess is probably primordial. On the other hand, the *latitude* distributions for the entire sample and in particular for asteroids with $D < 30$ km, is strongly anisotropic. The dynamical evolution of asteroid spin states seems to be dominated by the YORP effect and also by collisions and mass shedding for asteroids with diameters $D \lesssim 30$ km. We calculated that YORP (with a small contribution for the LI method's bias) is capable of producing the observed depopulation of spin vectors for small asteroids.

Acknowledgements

The work of JH has been supported by the grant GA UK 134710 of the Grant agency of the Charles University, by the project SVV 261301 of the Charles University in Prague and by the grant GACR 205/08/H005 of the Czech Science Foundation. The work of JH and JĎ has been supported by the grant GACR 209/10/0537 of the Czech Science Foundation, the work of JD and MB by the Research Program MSM0021620860 of the Czech Ministry of Education and the work of MB has been also supported by the Grant Agency of the Czech Republic (grant 205/08/P196). Funding for BW is provided by NASA NNX10AL35G and NSF AST-1032896.

References

[1] Kaasalainen, M., Torppa, J.: Optimization Methods for Asteroid Lightcurve Inversion. I. Shape Determination, Icarus 153, 24-36, 2001.

[2] Kaasalainen, M., Torppa, J., Muinonen, K.: Optimization Methods for Asteroid Lightcurve Inversion. II. The Complete Inverse Problem, Icarus 153, 37-51, 2001.

[3] Hanuš, J., and 14 colleagues: A study of asteroid pole-latitude distribution based on an extended set of shape models derived by the lightcurve inversion method, Astronomy & Astrophysics 530, A134, 2011.

[4] Davis, D. R., Weidenschilling, S. J., Farinella, P., Paolicchi, P., and Binzel, R. P.: Asteroid collisional history – Effects on sizes and spins, Asteroids II, 805–826, Eds: R. P. Binzel, T. Gehrels, & M. S. Matthews, 1989.

[5] Kryszczyńska, A., La Spina, A., Paolicchi, P., Harris, A. W., Breiter, S., and Pravec, P.: New findings on asteroid spin-vector distributions, Icarus 192, 223–237, December 2007.

[6] Ďurech, J., Kaasalainen, M., Warner, B. D., Fauerbach, M., Marks, S. A., Fauvaud, S., Fauvaud, M., Vugnon, J.-M., Pilcher, F., Bernasconi, L., and Behrend, R.: Asteroid models from combined sparse and dense photometric data, Astronomy & Astrophysics 493, 291–297, January 2009.