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The Spin Rates of Small Near-Earth Asteroids

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Abstract

Rotation periods or lower limits have been obtained for a sample of > 80 small Near-Earth Asteroids (NEAs) with nominal diameters smaller than 800 m, using the 2.4 meter Hiltner telescope at the MDM Observatory. The observational strategy is designed to be particularly sensitive to periods between 2 minutes and 2 hours, which defines the "fast rotator" regime. The numbers of detected fast rotators are debiased (corrected for incompleteness) using simulated lightcurves for Gaussian random spheres. The results show a sharp drop in the fraction of fast rotators at a nominal diameter of 150 m (absolute magnitude $H > 21.6$), and do not indicate a smooth increase in the maximum spin rate with decreasing size.

1. Introduction

The rotation rate distribution of Near-Earth Asteroids (NEAs) shows a surprising difference between objects larger and smaller than ~ 150 meters. Objects larger than this are nearly all slow rotators, with periods longer than the 2.2 h rubble-pile limit. Objects smaller than this show a significant population of faster rotators, with periods down to, and even less than, 1 minute. The fast rotators are under centrifugal tension, and must be dominated by material strength; but whether this strength is that of solid monolithic rock or merely weak cohesion binding a loose aggregate is a matter of some debate [1]. NEAs smaller than 1 km in diameter are likely to have had their spins significantly modified by the YORP effect. Hence the detailed distribution of spin rate as a function of size is a potentially important constraint on both material properties and the role of radiation-recoil torques in asteroid evolution.

2. Observations

We have obtained R-band photometry of approximately 85 NEAs with nominal diameters between 20 and 800 meters, using the 2.4 meter Hiltner telescope at the MDM Observatory. In this program, targets are chosen from the ESA Spaceguard System's "Priority List" and the Minor Planet Center's list of newly discovered objects having $H > 19$ and $V < 20$ at the time observation. Typically we observe each object over a 4-hour window, with 30 second exposures at 90 to 100 second cadence, with random delays inserted to eliminate aliasing problems. Experience and simulations show that this strategy can reliably detect rotation periods between 2 minutes and 2 hours with light curve amplitudes larger than 0.05 magnitudes, in good observing conditions. As these are small bodies, when bright and close they have large proper motions, up to several arcseconds per minute. We track at the sidereal rate and guide on stars, allowing the asteroid's image to be trailed.

3 Reduction and Analysis

The data are reduced using standard techniques and photometry obtained by point-spread function (PSF) fitting. The PSF derived from the stars in each image is convolved with the known motion of the asteroid to yield a trailed PSF, which is fitted to the asteroid's image to derive its flux. Relative flux calibration is "bootstrapped" from the full ensemble of stars observed. Periods are derived (or limited) using phase-dispersion minimization and periodogram analysis.

To correct for incompleteness, the observed fast-rotator fractions are debiased using simulated lightcurves. The thermophysical code TACO [2] is used to calculate model light curves for a large sample of Gaussian random spheres [3] with properties consistent with shapes of known objects with well-modeled light curves in the literature. The model light curves are folded through our full observational strategy, including cadence, exposure times, and photometric errors, in order to determine our detection sensitivity as a function of period and amplitude. The result of these simulations is a probability density for the actual fraction of fast rotators (here defined as having periods under 2 hours) for a given subsample.

4 Results

Figure 1 shows the results of this analysis, in the form of probability density functions (PDFs) for the fast-rotator fraction in two subsamples: small objects ($H > 21.6$) and "transition objects" ($21.6 > H > 18$). The transition objects occupy the region where models of cohesive rubble piles [1] predict a gradual increase in maximum spin rate with decreasing diameter. There is an obvious and striking difference between the subsamples, with the fast rotator fraction differing by a factor > 3 at $> 95\%$ significance, and most probably by a factor ~ 6.

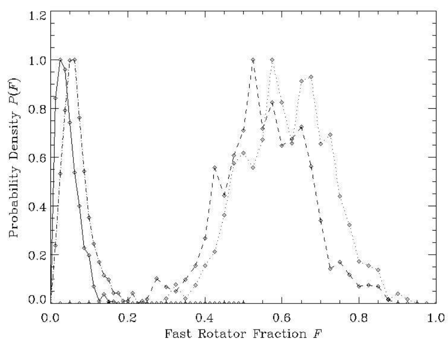

Figure 1: Probability density functions for the fast-rotator fraction (fraction of objects with rotation periods under 2 hours) for (narrow peaks, left) transition objects (150 to 800 meter diameter) and (broad peaks, right) small objects (under 150 meter diameter). Doubled curves indicate ± 1 object ambiguity in the observed samples.

5. Summary and Future Work

The rotation rate distribution of NEAs smaller than 150 meters is starkly different from that of larger objects. The sharpness of the division, and what constraints it places on cohesive rubble-pile models, will be quantified in a more detailed analysis, which will be described in our presentation at the meeting.

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References

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