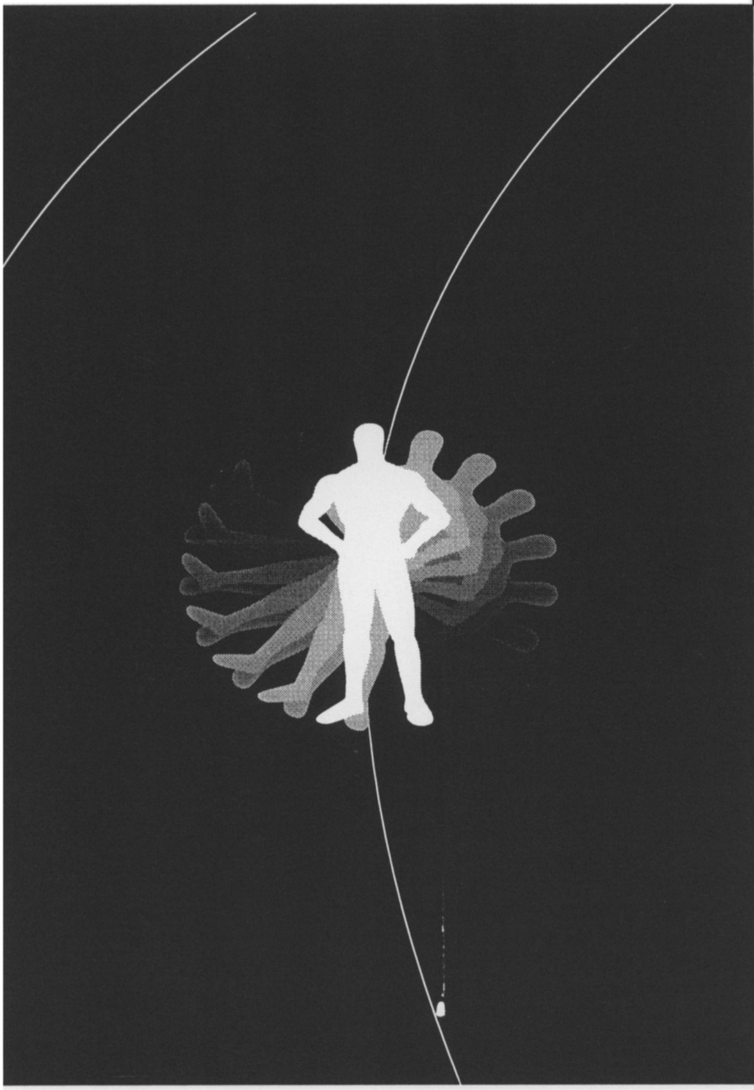

ROTATION of SOLAR SYSTEM OBJECTS

ASTEROID SPINS:
FROM THE VERY FAST TO THE VERY SLOW

A. W. HARRIS
Jet Propulsion Laboratory, California Institute of Technology
Pasadena, California, USA

AND

W. Z. WISNIEWSKI
University of Arizona
Tucson, Arizona, USA

The application of CCD photometry to monitoring the light variations of very small asteroids has led to an explosion of data available, and perhaps as importantly, has made it possible to probe fainter, and hence smaller asteroids. In this paper, we review several new results from the analysis of such lightcurve data, much of it taken by the late W. Z. Wisniewski, a native of Poland who studied at Poznan University (Wisniewski *et al.*, 1997).

At the time of the last close pass of the asteroid 4179 Toutatis by the Earth in 1992, it became apparent from radar observations that the asteroid was in a bizarre rotation state, and that the rotation rate was extremely slow. Harris (1994), re-evaluating the work by Burns and Safronov (1973) found that very small and slowly rotating asteroids can have a time scale of damping into a principal-axis rotation state which is long compared to their expected collisional lifetime, or for that matter, the age of the solar system:

$$P^3 \approx 17D^2\tau,$$

where P is the rotation period in hours, D is the asteroid diameter in km, and τ is the damping time scale in billions of years. Figure 1 is a plot of rotation period vs. diameter for approximately 700 asteroids with known rotation periods, with diagonal lines corresponding to solutions of the above relation, for τ = 100 my, 1 by, and 4.5 by. Clearly quite a few asteroids fall in a regime where "tumbling" rotational motion is expected – including Toutatis, which lightcurve and radar results confirm is indeed in

I. M. Wytrzyszczak, J. H. Lieske and R. A. Feldman (eds.),
Dynamics and Astrometry of Natural and Artificial Celestial Bodies, 265, 1997.

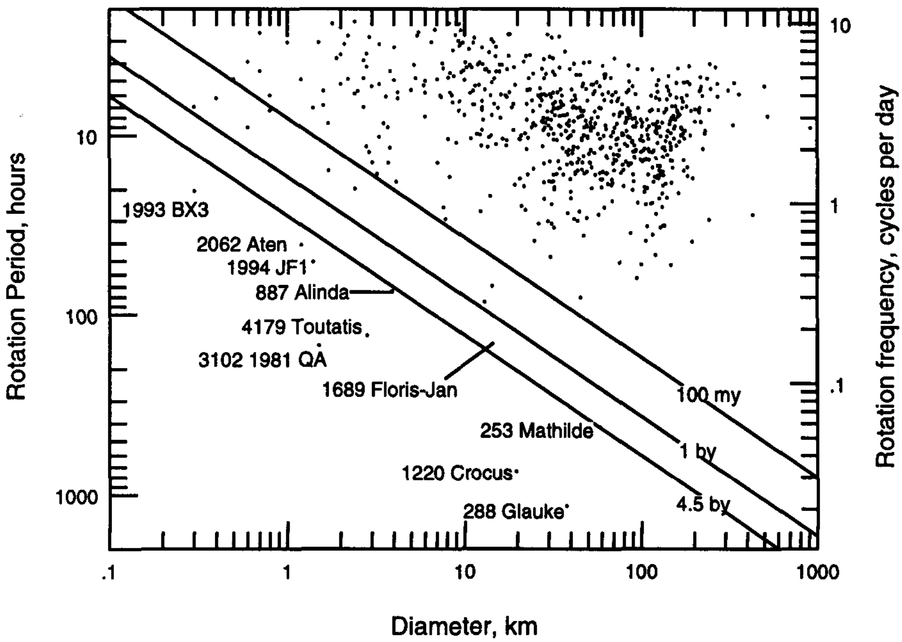

Figure 1. Rotation period vs. diameter for 688 asteroids. The diagonal lines are lines of constant damping time scale of non-principal axis rotation. Objects below the lines are expected to be in a "tumbling" rotation state.

such a rotation state. Lightcurve observations of several other small Earth-approaching asteroids indicate that they too are in "tumbling" rotation states. Perhaps most interesting among these is the asteroid 253 Mathilde (Mottola, *et al.*, 1995), which is a flyby target of the *Near-Earth Asteroid Rendezvous* (*NEAR*) space mission. As yet, we have no understanding of why some asteroids have such very slow spins (with rotation periods of many days or even weeks). Perhaps the *NEAR* flyby may reveal some clue.

At the other end of the rotation rate spectrum are some small asteroids which are spinning so rapidly that they are nearly in a state of tension, with centrifugal acceleration at the equator nearly equal to the self-gravitational acceleration. Harris (1996) recently re-analyzed the distribution of spin rates of small (<10 km diameter) asteroids. With the benefit of the larger data set now available, it appears that the distribution of spins is *truncated*, rather than smoothly decreasing to zero (population) with decreasing spin period, with the threshold being at a period of ~2 1/4 hours (Figure

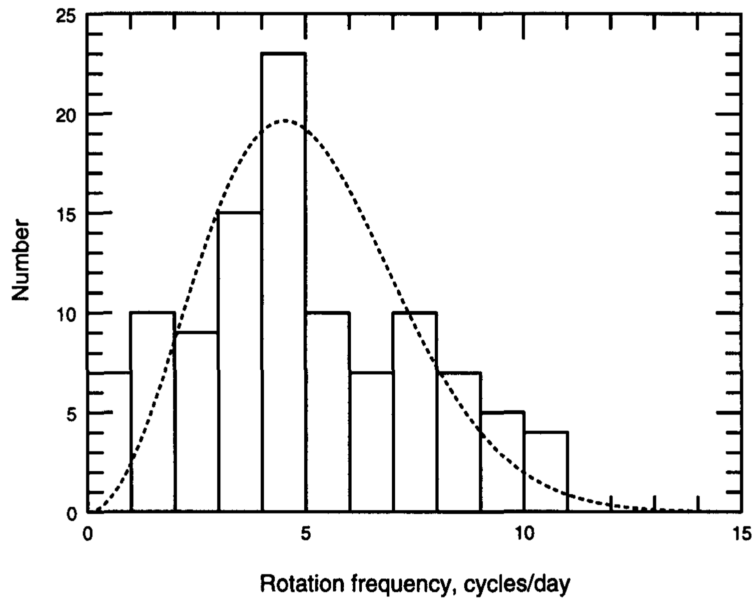

Figure 2. Histogram of rotation frequency for 107 asteroids smaller than 10 km in diameter. Note the abrupt truncation of the distribution beyond 11 cycles per day, compared to an expected smooth decline.

2). This suggests that indeed the spin rate of asteroids is limited by the rate at which the body would become in a state of tension, which in turn implies that even such small asteroids are not monolithic bodies. Furthermore, the threshold spin rate implies that the bulk density of these asteroids is ~2.5 g/cm^3, which corresponds to significant porosity for silicate rock. Thus we infer that most small asteroids are "rubble piles", rather than single rocky bodies.

A third investigation which has resulted from observations by Wisniewski does not involve rotations, but rather the population of near-Earth asteroids. Wisniewski obtained photometric observations of many asteroids recently discovered by photographic methods, as well as by his colleagues using the *Spacewatch Camera* with a CCD detector. In comparing the carefully calibrated magnitudes observed by Wisniewski with the discovery estimates (Table 1), we find that the magnitudes from photographs are underestimated by an average of 0.7 magnitudes, while the *Spacewatch* magnitudes are quite accurate. We suggest that this has led to a bias in the NEA population statistics. The very largest NEAs (>3 km) have for the most part been re-observed by photometric techniques, so magnitudes

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TABLE 1. Comparison of discovery vs. photometric magnitude estimates for near-Earth asteroids.

	Spacewatch discoveries	Photographic discoveries
Number of NEAs in sample	7	14
Mean absolute magnitude, H	19.3	17.2
Mean diameter	0.4 km	1.0 km
H(photometric) − H(discovery)	−0.07	+0.70

used to estimate populations have been corrected from their discovery reports. The very smallest asteroids (<0.3 km) have mostly been discovered by *Spacewatch*, thus again the magnitudes are correct. In the mid range, however, most discoveries have been made by photography and have not been re-observed with electronic detectors, so many of the magnitudes still contain the average bias mentioned above. This leads to an over-estimation in the size range $3 > D > 0.3$ km. In comparing with published population curves of NEAs, we find a "bump" in exactly this range, and thus suggest that it is an artifact of the observational bias which we have found.

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