ON THE ROTATION OF COMETARY NUCLEI AND SMALL ASTEROIDS

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ABSTRACT. The spin rate distributions of comet nuclei and small asteroids are compared, and it is shown that Whipple's (1982) finding of a faster average rotation for the asteroid sample was due to observational biases. In fact, the presently available rotational data do not exhibit any clear differentiation among comet nuclei and asteroids, except possibly for a higher abundance of short rotational periods among the Apollo-Amor objects.

Do cometary nuclei rotate (in a statistical sense) like the small asteroids and, in particular, like the Apollo-Amor objects among which a significant fraction of extinct cometary nuclei is widely believed to be present ? Clearly, an answer would represent an important observational test on the theories about the origin and the subsequent physical and dynamical evolution of comets (e.g., see Rickman, 1985). The first attempt to collect and compare systematically the available data on this issue was carried out by Whipple (1982), in the frame of a thorough review of the present knowledge on the rotation of comet nuclei. He showed that for a sample of 47 comets, whose rotational periods were mostly determined by the halo method (Whipple, 1981), the rotation was on the average considerably slower than for a comparable sample of 41 small asteroids (of diameter less than 40 km) extracted from the data set of Harris and Burns (1979). Whipple's tentative conclusion was in the sense of inferring a different origin of comets and small asteroids, i.e., accretion at low relative velocity for comets and collisional fragmentation for asteroids.

We now believe that this conclusion is not justified, because it is vitiated by a strong observational bias affecting the asteroid sample used for the comparison. A substantial part of this sample (more than 2/3 of the objects) was formed by asteroids whose spin period had been determined from photographic observations, which are usually

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carried out on a single night and therefore exclude a priori the determination of periods longer than about 6 hours. For this reason the statistical analyses of asteroid rotation rates performed by Tedesco and Zappala' (1980) and by Farinella et al. (1981), who tried to minimize the most important selection effects, excluded from the samples under scrutiny all the objects observed photographically. Today new lightcurve data obtained by photoelectric photometry has become available for a significant number of small asteroids, mainly as a result of observational programs carefully designed by Harris and Young (1983) and by Binzel and Mulholland (1984) to prevent any bias in favour of short periods. Comparing this new data with the former one, Binzel (1984) has concluded that the photographic technique produces indeed a strong bias against the long periods, thus decreasing artificially the sample variances in the distributions of rotational frequency; as a consequence, photographic and photoelectric data should not be combined in statistical studies, lest the resulting trends are physically meaningless.

We have also to stress that Whipple's results on the spin periods of comet nuclei are affected by several sources of uncertainty. As pointed out by Whipple himself (1982, pp.233-235), a number of ambiguities and faults are unescapable when the halo method is applied to observational data, and quite often the resulting periods can be seen only as reasonable guesses. Moreover the weaknesses of the method are such that in several cases the periods are either quite accurate, or completely wrong (e.g., by a factor two), so that one cannot be confident that statistically the errors average out. In spite of these problems, we think that the importance of the issue for the understanding of comet/asteroid interrelations justifies the attempt to analyse the presently available data in the best possible way, i.e., trying to eliminate at least the known biases.

This consideration has led us to remake Whipple's analysis, by employing an "unbiased" asteroid data set formed only by objects whose lightcurves have been observed photoelectrically; this set has been extracted from the data file on asteroid rotational properties compiled by one of us (V.Z.) at the Turin Observatory (and available on request). Weights have been assigned in the following way : among asteroids, objects whose period is uncertain (or for which only lower limits for the period have been derived from lightcurve data) have been weighed 0.5, while objects with well determined periods have been weighed 1.0; for comet nuclei, we have simplified Whipple's procedure by changing into 0.5 and 1.0 all Whipple's weights $\leqslant$ and $>$ 0.5 respectively. In Figure 1, above the horizontal axis the resulting spin rate distribution is shown for the comet sample, including also a (dotted) histogram referring to comets classified by Whipple (1982) into types III, IV and V, whose shorter orbital periods suggest a longer time of activity;

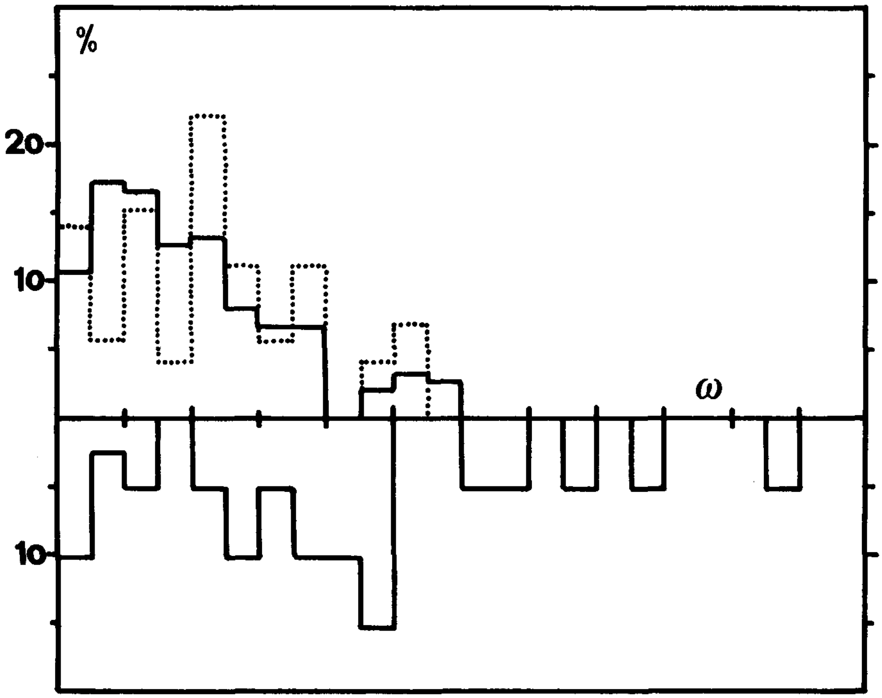

Figure 1. The spin rate distribution is shown for cometary nuclei (above) and for Apollo-Amor asteroids (below). The unit of the horizontal axis is 1 rotation/day, the width of each histogram bin is 0.5 rotations/day, while the vertical axis gives the percentage of objects contained in the different bins. The dotted histogram refres to comets of types III, IV and V according to Whipple's (1982) classification.

below the axis, the corresponding distribution for 21 AA asteroids is shown. In Figure 2, the same comet distribution (above) is compared with that of 68 main-belt asteroids of diameter smaller than 50 km (below); the lower dotted histogram refers to 38 small asteroids which do not belong to dynamical families according to Williams' (1979) classification (we recall that a possibly significant faster rotation of family asteroids has been confirmed by statistical analyses performed by Dermott et al. (1984) and Binzel (1984); this is related perhaps to a different collisional history between the two groups). Surprisingly enough, we can see from the Figures that cometary nuclei and main-belt small asteroids do not display distributions that are impressively different (as in the case of Whipple's comparison), implying that the inference about different origins cannot be drawn by this kind of evidence. On the contrary, the AA asteroids appear to behave in a peculiar way, and in particular they

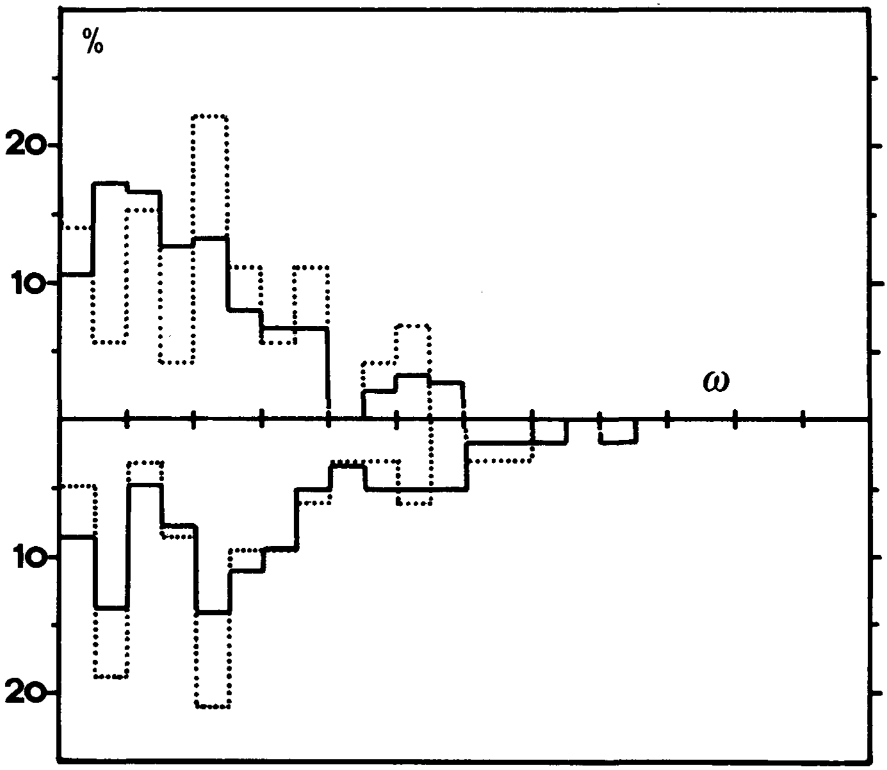

Figure 2. The same comet distribution of Figure 1 (above) is compared with the spin rate distribution for a sample of main-belt, photoelectrically observed asteroids of diameter smaller than 50 km. The dotted histogram in the lower part of the Figure refers to nonfamily asteroids. The units are the same as in Figure 1.

present a tail of fast rotators which has no apparent counterpart either among main-belt small asteroids or among comet nuclei. We recall that the AA objects have also a peculiar distribution of shapes, as deduced from the lightcurve amplitudes, in the sense that they include a significant fraction of very elongated, cigar-like shapes which are very unusual in the main belt and also among fragments from hypervelocity impact experiments (Capaccioni et al., 1984; Catullo et al., 1984). The idea that these peculiar features may be due to some process related to aging of cometary nuclei is attractive, but finds only a weak support from the statistically unsignificant difference between the spin rate distributions of "older" and "younger" comets. On the other hand, few rotational data are available for main-belt asteroids of size comparable to that of the AA objects (typically, of the order of 1 km), so that we cannot exclude that a similar size dependence of the rotational properties is a feature of the whole asteroid population. Indeed, Binzel (1984) has presented some evidence indicating that, even excluding photographic observations, below a diameter of 120 km an inverse correlation between spin rate and size exists in the main belt, so that AA and main-belt objects of the same size might really behave in a similar way. Rotational data are also consistent with the widely accepted "intermediate" hypothesis that we are observing a mixture of two classes of AA objects, one of cometary and one of asteroidal origin.

As a conclusion, we have to stress that at the present stage every result must be taken with caution, because the statistics are poor and because subtle but significant biases could still be present. Moreover, our understanding of the origin and evolution of both asteroid and comet rotation is not such that we can draw any sound inference from the observational data. Our analysis only shows that the presently available data does not exhibit clear differentiations between cometary nuclei and asteroids, except possibly for a higher abundance of short periods among AA objects, a phenomenon of difficult interpretation (if real). Further studies are clearly needed both to make available larger and unbiased samples for the statistics, and to define better the physical mechanisms which, affecting the rotational properties, could be related to any evolutionary relationship or difference between comets and asteroids.

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