ON THE EVOLUTION OF THE MAIN BELT ASTEROIDS.
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Introduction: Over the last two decades, there has been a rapid growth of asteroid light curve observations. One of the main benefits of those observations is information on asteroid spins. There are spin data for almost six thousand asteroids from the efforts of observers from all over the world. The present spin of any asteroid is a result of its history. The analysis of that history is the subject of this contribution.

Theoretical Approaches: Figure 1 shows the distribution of asteroid spin versus its diameter. There are some well-described features that are evident in that plot; the most well-known now is the gravity spin limit at the period of about 2.3 h. (We emphasize again that the limit does not imply rubble-pile asteroid structure, a rock asteroid would have that same gravity limit.) Other features still remain puzzling. A common way to understand such a distribution is to construct a theoretical model and run numerical simulations of an artificial population of asteroids and try to reconstruct what we observe. The previous studies that attempted to do so include [1], [2], [3], [4], [5], [6] and others. Here we update those approaches with several important modifications.

The primary elements of the prior studies and of the present one are 1) a population of asteroids in a finite region, 2) a distribution of impact velocities and angles, 3) the efficiency of angular momentum transfer in an impact, 4) the loss or gain of mass and angular inertia, 5) the amount, direction and speed of the cratering ejecta. We note that the characteristics of the ejecta are especially important, firstly identified by [2]. We upgrade the ejecta analysis to include recent results on ejecta scaling ([7], [8]). We use some recent experimental results on the angular momentum transfer efficiency and we also update the asteroid population estimates.

Contrary to the previous studies, we do not average over the distribution of the impact velocities and angles. A key outcome of such averaging is a quadratic accumulation of spin magnitudes from averaged single impacts. We reject that approach for two reasons. First, because of the momentum drain effect, the result of any one impact is not independent of the prior ones. Second, it has been found that the current spin of an asteroid is more likely caused by a very few large impacts and not by an accumulation of random small ones.

Therefore, we performed Monte Carlo analyses of the effects of a large number of impacts into a large number of target asteroids. The outcomes are distributions of spin versus asteroid size, which can then be compared to the actual data. Some of the typical simulations are shown in Figure 2.

Results: First (and as found by others), the spins of the large asteroids cannot have resulted from impacts with the current population. A much larger population is required. Second, both the average spin and the maximum spin at any given size falls off with increasing asteroid size. Third, there may be "average equilibrium spin states", defined by a curve of spin versus diameter. For asteroids spinning faster than that state, the average next impact will always slow the spin; but for an asteroid with a spin below that state the average impact will increase its spin. That is an effect of the preferential ejection of ejecta in the spin direction of the surface.

There are reasonable parameter choices that result in the average equilibrium curve consistent with the average spins, and with the resulting distributions centered along that curve. Then there is also a "maximum equilibrium spin curve" defined as the maximum possible spin an asteroid can attain, again as a function of asteroid size. That bounds the upper limit of asteroid spins, and has a downward power slope of 0.65. The fact that the maximum equilibrium curve intersection with the gravity limit curve occurs right at the 10 km upper bound of the data for binary asteroids strongly suggests that it is collision spin-up and not YORP that creates the spins that result in binaries. Finally, a single large impact into an asteroid with a preexisting average spin can easily reduce its spin to near zero. That may explain the excess of slow spinners (as compared to Maxwellian) for the spin distributions of the asteroids with diameters larger than 10 km.

These results and others will be presented at the conference.

References: [1] McAdoo D. C. and Burns J. A. (1973) *Icarus, 18,* 285–293. [2] Dobrovolskis A. R. and Burns J. A. (1984) *Icarus, 57,* 464–476. [3] Harris A. W. (1979) *Icarus, 40*, 145–153. [4] Davis D. R. et al. (1989) In: *Asteroids II, Proceedings of the Conference, Tucson, AZ,* 805–826. [5] Farinella P. et al. (1992) *Astronomy and Astrophysics, 253*, 604–614. [6] Henych T. and Pravec P. (2013) MNRAS, 432, 1623–1631. [7] Housen K. R. and Holsapple K. A. (2011) *Icarus, 211*, 856–875. [8] Holsapple K. A. and Housen K. R. (2012) *Icarus, 219*, 297–306.

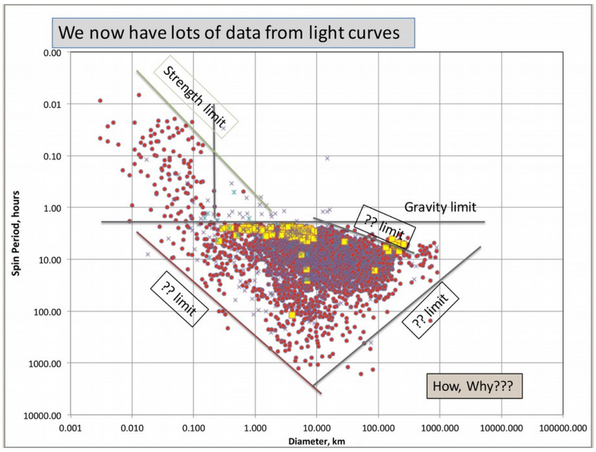

Figure 1. Asteroid spins versus their diameter and some characteristic features of that graph.

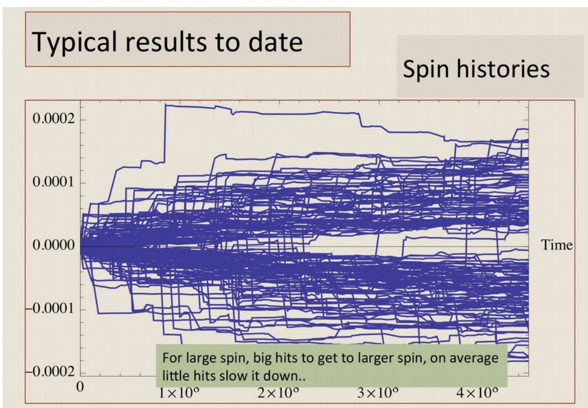

Figure 2. Evolution of spin due to the collisions of a large number of individual asteroids.