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UNDERSTANDING ASTEROID COLLISIONAL HISTORY THROUGH EXPERIMENTAL AND NUMERICAL STUDIES.

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It has long been known that the present size distribution of asteroids can collisionally evolve from many starting populations (Dohnanyi, 1969; Chapman and Davis, 1975; Davis *et al.* 1979). However, collisions affect other aspects of the asteroids (formation of dynamical families, exposure of M-type asteroids as the metallic cores of differentiated parent bodies, etc). Further understanding of asteroid collisional history came by identifying those initial populations that not only evolved to the present size distribution, but also produced the observed number of dynamical families and preserved the basaltic crust of Vesta (Davis *et al.*, 1985). Another major feature of the asteroids that has been significantly affected by collisions is the distribution of asteroid spin rates. We, in association with Italian colleagues, embarked on a project to develop a numerical code that would treat the collisional evolution of both the size and spin distributions simultaneously. Previous work on the collisional modification of asteroid spins dealt only with cratering impacts (Harris 1979; Dobrovolskis and Burns 1984). However, collisional disruption, rather than cratering, has been the dominant process acting on the asteroids over most of solar system history, but no one had developed a model for the spin rates of fragments or "rubble piles" formed by shattering collisions. Our initial application of this code to study the collisional evolution of asteroids could not produce the spindown observed in asteroids ~100 km in diameter (Davis *et al.*, 1989). Further work on the physics of asteroids that are shattered, but which partially reaccumulate due to gravity showed that such bodies can lose angular momentum due to what we termed the "splash" effect (Cellino *et al.* 1990), the analog to the "drain" effect of Dobrovolskis and Burns (1984) for cratering impacts; Figure 1 illustrates how asteroids 70-150 km in diameter can be spun down due to this effect.

In the past year we applied our numerical code with the "splash" effect incorporated to study the simultaneous evolution of asteroid sizes and spins; this work is described in a paper submitted to *Astronomy and Astrophysics* (Farinella *et al.*, 1991). We present results on the spin changes of asteroids due to various physical effects that are incorporated in our model. The goal in this paper was not to fit the observed spin distribution of asteroids (that will come next), but rather it is to understand the interplay between the evolution of sizes and spins over a wide and plausible range of model parameters. This work uses a single starting population for both the size distribution and the spin distribution of asteroids and calculates the changes in the spins over solar system history for different model parameters. We show that there is a strong coupling between the size and spin evolution, that the observed relative spindown of asteroids ~100 km diameter is likely to be the result of the angular momentum "splash" effect. An interesting problem arises in that this algorithm predicts a larger spinup of small asteroids than exists in the limited observational data now available. However, this "problem" arises only when the spinup rates of fragments derived from laboratory-scale impacts are used. Perhaps significantly lower spinup occurs when properly scaled to asteroidal sized bodies, or perhaps there is a yet unrecognized process which despins small asteroids, such as the formation of binary objects.

Our collisional evolution studies to date have employed a particle-in-a-box algorithm to calculate collision rates and mean asteroid orbital elements to calculate impact speeds. However, collision rates and impact speed can vary significantly throughout the asteroid belt and these variations can produce different amounts of collisional evolution. We developed a computer program to study the variation of the collision rate and mean impact speed throughout the asteroid belt using the algorithm developed by Wetherill (1967) and the proper elements for the orbits of 682 asteroids larger than ~50 km diameter, a sample which is essentially complete (we assume that smaller asteroids have similar distributions of orbital elements). The Wetherill algorithm was selected over other more exact algorithms due to its ease of implementation and the fact that the differences are generally not significant for our study. We find that the mean collision speed for our sample asteroids is closer to 6 km/sec than the 5 km/sec usually quoted, and that it does not vary significantly across the asteroid zone (Fig. 2(a)). However, the mean collision rate does decrease by nearly a factor of 2 in going from the inner belt to the outer belt (Fig. 2(b)). A manuscript describing this work is currently in preparation.

We used this computer code to investigate the collisional lifetime of asteroid 951 Gaspra, the target of Galileo's October 1991 flyby. We found that the mean time between shattering collisions for a Gaspra-sized asteroid is probably (1-2.5)x10^8 years, using a basalt-like impact strength and the Housen and Holsapple (1990) scaling theory. However, if Gaspra, an S-type asteroid, has a stony-iron composition, then its strength could be considerably higher and its lifetime correspondingly lengthened. We also calculated the probability that Gaspra was a fragment from parent bodies of different sizes; Fig. 3 shows this distribution.

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Figure 1. Ratio of final to initial spin rates in a shattered collision plotted as a function of the preimpact target diameter D.

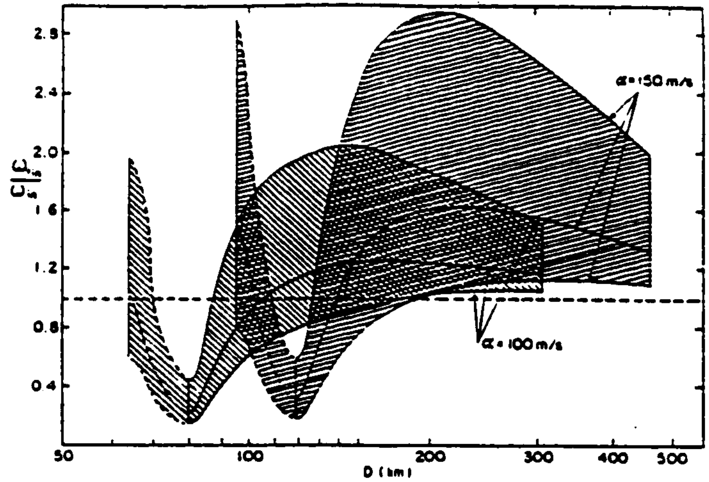


Figure 2(a). Variations of the running box mean impact speed with semimajor axis.

Figure 2(b). Variation of mean intrinsic collisional rate with semimajor axis.

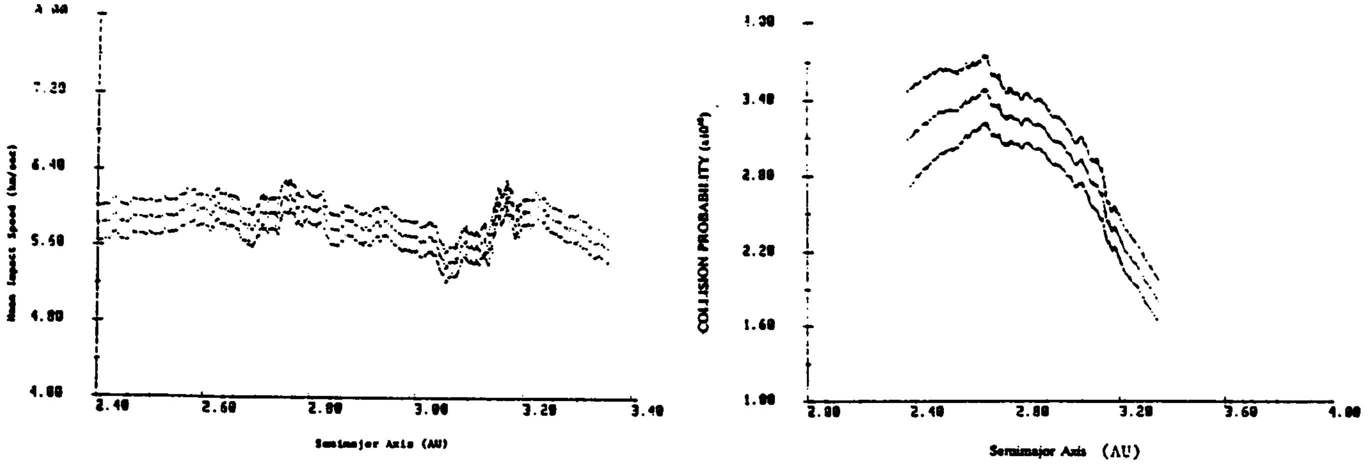
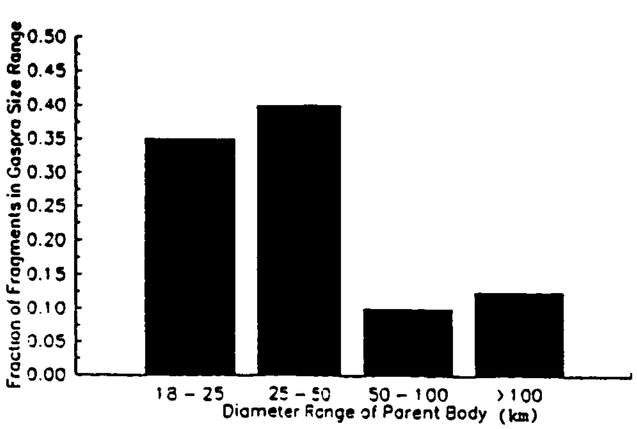


Figure 3. Distribution of parent body sizes for Gaspra-sized asteroids



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