Multi–zone simulations of the collisional evolution of Main Belt asteroids.

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We have adapted the planet building code, a multi–zone code developed to model the evolution of a planetesimal swarm (Weidenschilling et al. [11]), to study the collisional evolution of asteroids in the Main belt. The advantage of the semimajor axis discretization implemented in the code, over the usual single–zone particle–in–a–box approach, is in the possibility of including in a statistical way the effects of resonances and Yarkowski's drift. In this way we can estimate with a reasonable accuracy the flux of bodies into NEO orbits as due to a combination of collisions, Yarkowski's drift and resonance evolution. This would represent an additional constraint to the modeling.

The model

The population of asteroids in the belt is divided in a series of discrete zones in semimajor axis. Bodies in distant zones can collisionally interact if they are on crossing orbits. The initial eccentricity and inclination distributions are properly set to closely match the impact velocity distribution and intrinsic probability of collision as derived for the Main Belt in Bottke et al. [2]. The semimajor axis zones far from resonances are evenly spaced while each resonance (we consider the most prominent ones like the 2:1, 3:2, 3:1, 5:2, 7:3) has its own zone whose width is equal to the average resonance width. A special treatment is reserved to the secular resonance ν_6 since its location in semimajor axis depends on the inclination. In this case the zones in between 2.1 and 2.5 AU are further split in inclination to account for the resonance effects (Knezevic et al. [7]).

Bodies can shift from one zone to a close one either because of a collision or driven by the size–dependent Yarkovski effect. We include both the diurnal and seasonal drifts (treated separately) as described in O'Brien and Greenberg [9]. Both collisions and Yarkovsky are primary mechanisms for the NEO flux since they inject bodies into resonances.

Whenever a body ends up in a resonance zone, we statistically sample a lifetime according to a Poisson-exponential distribution. The dynamical lifetimes in the resonances we include in our model are derived from Gladman et al. [5] (see their Fig. 2). At the end of its lifetime, the body is ejected out of the system. If it comes out from the 3:1 and the ν_6 then it is recorded in a separate bin and it becomes a NEO. In this way we can monitor the NEO flux during the collisional evolution of the Belt. We neglect the contribution from the 5:2 resonance which is closer to Jupiter and its contribution to the NEO flux is small Gladman et al. [5].

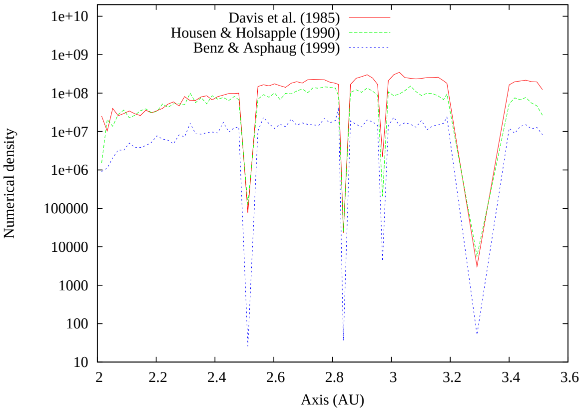

Figure 1: Number density of asteroids as a function of their semimajor axis in AU. The density is computed adding up all bodies from 0.1 to 1000 km in diameter in each zone.

In Fig.1 we show the number density of asteroids as a function of their semimajor axis for 3 different simulations with different scaling laws. The depletion of bodies at the resonances is strong even if they are not fully empty because of refilling due to collisions and Yarkowski. We cannot model the dynamical evolution of stable resonant bodies since our is a statistical approach and, in any case, they are a minority of all asteroids passing through the resonances.

Modeling the collisional evolution

We tested different initial populations and scaling laws in order to reproduce the observed size distribution of asteroids (Bottke et al. [3]). The scaling laws we considered are published in Davis et al. [4], Housen et Holsapple [8] and Benz and Asphaug [1]. In Fig.2 we compare the outcome of our simulations for different scaling laws after 3.9 Gyr of collisional evolution (from the end of the Late Heavy Bombardment, LHB, till today). The model that better fits the observed distribution is that obtained with the Housen et Holsapple [8] scaling even if this might depend on the initial size distribution. However, a large number of different initial distributions have been tested without success.

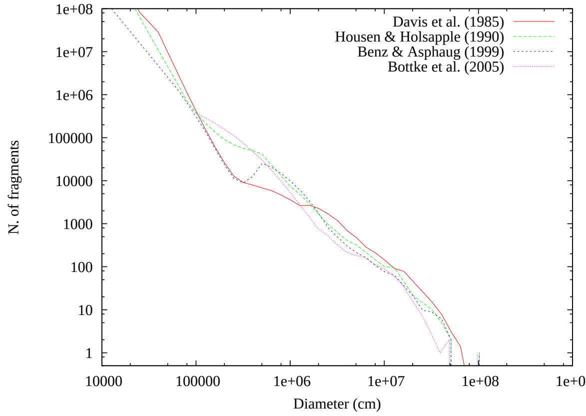

Figure 2: Asteroid size distribution from model with different scaling laws (see labels) but same initial populations, compared to the observed distribution (Bottke et al. [3])

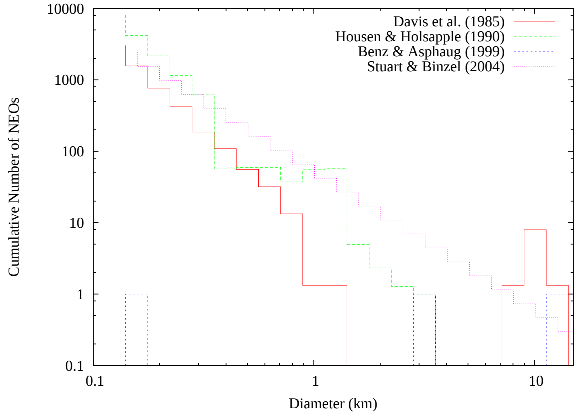

Figure 3: Comparison between the observed present NEO flux (derived from Stuart and Binzel [10]) and that predicted by our models with different scaling laws (see labels in the plot).

The number density is that shown in 1 and reflects the Main belt density as a function of semimajor axis. Since we start our simulations after the LHB we assume that some mechanism like resonance sweeping already partly depleted the inner region of the belt from about 2.1 to 2.8 AU. For this reason we adopt an initial population whose number density slowly declines when the semimajor axis becomes smaller than 2.8 AU.

The NEO flux

In Fig.3 we compare the NEO flux derived from the 3 different models with the observed one. The latter is computed from the present observed size distribution of NEO (Stuart and Binzel [10]) assuming an average lifetime of 10 Myr (Gladman et al. [6]). Even in this case a good agreement is observed between the observed data and the model with the Housen et Holsapple [8] scaling law while in the case of the Benz and Asphaug [1] scaling law the flux of NEOs is underestimated. It is noteworthy that while comparing the model size distributions with observations we not only have to reproduce the observed number but also the slope of the size distribution.

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