CAPTURING COMETS IN THE OUTER ASTEROID BELT DURING THE LATE HEAVY BOMBARDMENT.
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The *Nice* model [1-3] describes a plausible scenario where the Jovian planets experienced a violent reshuffling event ~ 3.9 Ga. In the Nice model, the Jovian planets are assumed to have formed with a more compact configuration than they have today (all were located between 5-15 AU). Slow planetary migration was induced in the Jovian planets by gravitational interactions with planetesimals leaking out of a $\sim 35M_\oplus$ planetesimal disk residing between $\sim$ 16-30 AU. Eventually, Jupiter and Saturn crossed a mutual mean motion resonance. This event triggered a global instability that led to a reorganization of the outer solar system; planets moved, existing small body reservoirs were depleted or eliminated, and new reservoirs were created in distinct locations.

The Nice model is compelling because it can quantitatively explain the orbits of the Jovian planets [1], the orbits of bodies in several different small body reservoirs in the outer solar system (e.g., Trojans of Jupiter [2] and Neptune [1], the Kuiper belt and scattered disk [4], the irregular satellites of the giant planets [5]), and the occurrence of a late heavy bombardment (LHB) on the Moon and other terrestrial planets ~ 3.9 Ga [3]. These accomplishments are unique among models of outer solar system formation.

The results described above suggest that Jupiter Trojans, irregular satillites, and Kuiper belt objects share a common origin. This idea is supported by the spectral characteristics of these bodies. In particular, Trojans are mainly organic-rich primitive D- or P-type asteroids. They are also a good spectral match to the observed dormant comets. Thus, it is natural to ask whether most known primitive objects followed a similar formation history. The main sticking point with this hypothesis is the presence of D/P-type objects on orbits completely interior to that of Jupiter, which is unexpected for objects that were, at one time, gravitationally scattered by the giant planets (cf. Fig. 1).

To investigate the possible capture of cometary planetesimals into the asteroid belt, we first integrated the orbits of a large number of massless planetesimals initially on Saturn-crossing orbits under the gravitational influence of the Sun, Jupiter and Saturn. The planets were forced to migrate by including a suitably chosen acceleration in the planets equations of motion, so that they reproduced the evolution of the 'fast migration' run in Ref.[2]. The integrations covered 20 Myr. During the first 10 Myr of the simulation, we supplied a steady flux of planetesimals through the Jupiter-Saturn system. These objects represent the planetesimals that originally formed in the trans-planetary disk. At the end of the calculation there were 1270 particles captured into orbits decoupled from Jupiter.

Next, we tracked the long-term evolution of the population of the particles captured during the migration simulations in order to compare it to observations. We integrated the system containing the 1270 particles and the planets for a total of 4 billion years, removing any particle that evolved onto a planet crossing orbit.

Fig. 1 shows that, not only do the above calculations generate reasonable Trojan and Hilda populations, but they cover the range of the orbital elements of the D-type asteroids. Unfortunately, it is not possible to do a direct comparison between the orbital element distribution of our trapped objects and that of the D-types because the observations are biased due to selection criteria, asteroid families, and the like. However, we find noteworthy the fact that the inner edge of both populations are at $a\sim 2.6$ AU.

The next and last step in our analysis is to estimate the total number of primitive objects we expect to find in each population and compare them to observations. To accomplish this, we not only need to account for their long-term dynamical evolution, but for their collisional evolution as well. This issue is addressed in a companion ACM 2008 abstract, Bottke *et al*.

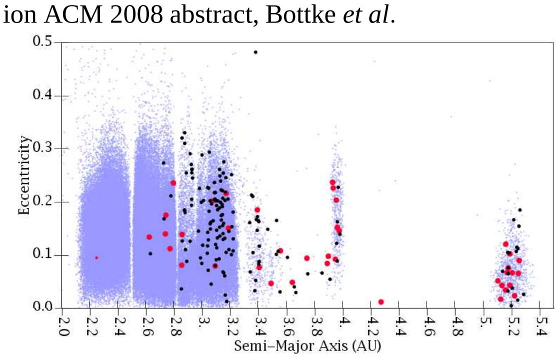

Figure 1: The semi-major axis (a), and eccentricity (e) distribution of asteroids in Hilda, Trojan, and MB populations. The small blue dots show all the numbered objects in the IAU Minor Planet Center database. The red symbols show the D-type asteroids as cataloged by D. Tholen and S. J. Bus. It is important to note that asteroid (336) Lacadiera at $a = 2.25$ AU and $e = 0.1$, which is classified as a D-type by ref. [8], has an unsual spectrum (Campins, pers. com.), and thus is probably a different type of object. Thus, we do not include it in our analysis. The black dots show the location of objects captured during our simulations.

References. [1] Tsiganis *et al*. (2005) *Nature* **435**, 459. [2] Morbidelli *et al*. (2005) *Nature* **435**, 462. [3] Gomes *et al*. (2005) *Nature* **435**, 466. [4] Levison *et al*. (2008) *Icarus*, in press. [5] Nesvorny *et al.* (2007) *AJ* **133**, 1962.