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Asteroid families versus the Late Heavy Bombardment

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Abstract

In the Nice model, the Late Heavy Bombardment is related to an orbital instability of giant planets which causes a fast dynamical decay of a transneptunian cometary disk [1]. We study effects produced by these cometary projectiles on Main-Belt asteroids.

According to a "standard" model for the size-frequency distribution of comets [2] approximately 100 families with the parent body size $D_{\rm PB} \geq 100\,{\rm km}$ should be created in the Main Asteroid Belt during the LHB. Moreover, we expect many more $D_{\rm PB} \geq 100\,{\rm km}$ families than $D_{\rm PB} \geq 200\,{\rm km}$. Both facts are in a clear contradiction with observations.

The following possibilities seem to be ruled-out:

1. even a shallow SFD of projectiles (comets) with the elbow diameter 50 to 70 km is capable to produce a lot of families.

2. families cannot be simply "hidden" due to an overlapping in the $(a, e, \sin I)$ space.

3. the Yarkovsky drift ${\rm d}a/{\rm d}t$ and chaotic diffusion in e/I due to resonances do not disperse families sufficiently in inclinations.

4. the giant-planet migration (in a jumping-Jupiter scenario) again does not perturb inclinations enough.

We are thus left with five explanations (all of them may actually contribute):

1. disruptions of comets below $q < 1.5\,{\rm AU}$ can decrease the number of families downto ~ 30.

2. the comminution can destroy $D_{\rm PB} = 100\,{\rm km}$ families almost completely, only one tenth of $D \geq 10\,{\rm km}$ fragments survive, while the "cores" of $D_{\rm PB} = 200\,{\rm km}$ families remain more prominent.

3. the SFD of the projectiles (comets) had the elbow at a larger diameter 100–150 km, and the total number of comets was much smaller than 10^9 in the relevant size range $D = 10$ to $70\,{\rm km}$. Such SFD may be also in concert with the cratering record of the Moon, but if comets disrupt often below $q < 1.5\,{\rm AU}$ then the cratering does dot constrain their SFD at all. On the other hand, we may need upto 10^{12} small of comets ($D \simeq 1\,{\rm km}$) to create the Oort cloud which favours steep SFD's.

4. physical lifetime of comets is strongly size-dependent, so $D = 10$ to $20\,{\rm km}$ comets (which serve as projectiles for $D_{\rm PB} = 100\,{\rm km}$) disrupt easily compared to $D = 40$ to $70\,{\rm km}$ bodies (producing $D_{\rm PB} = 200\,{\rm km}$ families).

5. the physics of high-velocity collisions between hard targets and weak projectiles may be somehow different?

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References

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