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The common origin of family and non-family asteroids: Implications for meteorites and NEAs

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Abstract. The observed size-frequency distributions (SFDs) of the five major asteroid families in the Inner Main Belt (IMB), defined by Nesvorný (2015) using the Hierarchical Clustering Method (Zappala *et al.* 1990), are distinctly different and deviate significantly from the linear log-log relation described by Dohnanyi (1969). The existence of these differences in the SFDs, and the fact that the precursor bodies of the major families have distinctly different eccentricities and inclinations, provides an explanation for the observations that the mean sizes of both the family and the non-family asteroids are correlated with their mean proper eccentricities and anti-correlated with their mean proper inclinations. We deduce from this, and from the fact that the SFDs of the family and the non-family asteroids are almost identical, that the family and most of the non-family asteroids in the IMB have a common origin (Dermott *et al.* 2018).

Keywords. Asteroids, minor planets

1. Observations

Further insight into the origin and evolution of the IMB is gained by separating the asteroids into three groups: (1) family asteroids as defined by Nesvorný (2015); (2) halo asteroids that appear to be closely associated with the family asteroids; and (3) all other non-family asteroids that we designate as non-halo asteroids. The five major families in the IMB (Flora, Vesta, Nysa, Polana and Eulalia) are clearly surrounded by halos of asteroids. While this suggests that these halo asteroids originate from the major families, because of the overlap of the families and their halos in proper orbital element space, use of the Hierarchical Clustering Method Zappala *et al.* (1990) to assign halo asteroids to a particular family is difficult or impossible. However, if we do not attempt to assign a halo asteroid to a particular family, then it is possible to argue that halo asteroids are family asteroids and to separate family asteroids and their surrounding halos from all other asteroids. Note, our chief aim here is not to separate the family and halo asteroids, or to assign a halo asteroid to a particular family, but to define a set of non-halo asteroids that are well separated from the family asteroids and their halos. Some characteristics of the family, halo and non-halo asteroid groups are shown in Figure 1 (Dermott *et al.* 2018).

2. Implications

These new results imply that we must seek explanations for the differing characteristics of the various meteorites and near-Earth asteroids originating from the IMB in

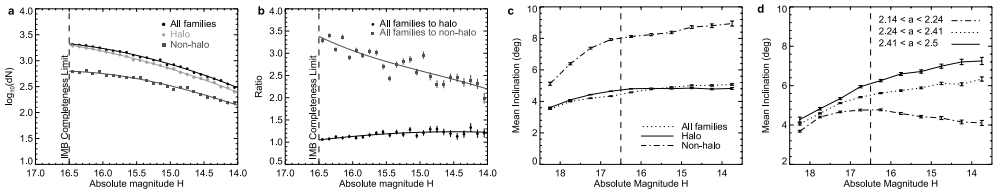

Figure 1. a, Size frequency distributions (SFDs) of the three asteroid groups in the IMB: family, halo and non-halo. b, Ratios of the number of asteroids in a box of width dH=0.1 for all-family to halo, and for all-family to non-halo asteroids. c, Dependence of the mean proper inclination on absolute magnitude for the family, halo and non-halo asteroids. d, Dependence of the mean proper inclination on absolute magnitude for the non-family asteroids in the IMB in three ranges of semi-major axis.

the evolutionary histories of a few, large, precursor bodies. Our findings support the model that asteroids formed big through the gravitational collapse of material in a protoplanetary disk (Johansen *et al.* 2003), but we cannot rule out the formation of very small asteroids as any small primordial bodies would have now been lost from the belt. Our conclusions are based on observations of the present asteroid belt. However, if the initial asteroid belt consisted of a comparatively small number of large bodies formed in a near-coplanar, protoplanetary disk, then even after the excitation of the asteroid orbital eccentricities and inclinations, the initial asteroid collision rate, and the rate of supply of small bodies to the inner solar system, would have been correspondingly low and would only have increased to larger values at a later date. This slow increase in the early asteroid collision rate could have implications for the Late Heavy Bombardment.

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