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# The search for the most ancient asteroid collisions reveals the original planetesimals of our solar system

**Marco Delbo** (1), Kevin Walsh (2), Chrysa Avdellidou (1), Sonia Fornasier (3), Rogerio Deienno (2), Gerard Van Belle (4), and Alessandro Morbidelli (1)
(1) University Côte d'Azur, Observatoire de la Côte d'Azur, CNRS-Lagrange, Nice, FR. (2) South West Research Institute, Boulder CO, USA (3) LESIA Observatoire de Paris, Paris, FR. (4) Lowell Observatory, Flagstaff, USA.

## Abstract

Hundred years of asteroid family research [1] and new asteroid family identification methods [2, 3, 4, 5, 6] have shed new light on the collisions among asteroids that shaped the main belt. In particular, in the inner portion of the belt – bracketed by the $\nu_6$ secular resonance at $\sim$2.1 au and by the J:3/1 mean motion resonance at 2.5 au – it is now possible to distinguish those asteroids that formed as collisional fragments from the break up of larger and older parents, and those other that are not fragments. This second population, which constitutes those asteroids that formed as planetsiamals by the accretion of dust in the protoplanetary disk, has a size distribution skewed towards bodies with diameters larger than 50 km [4, 17]. This indicates that planetesimals formed big, as previously suggested [7, 8, 9].

## 1. Introduction

Collisions among asteroids are a fundamental processes responsable for sculpting the size frequency distribution of the asteroid population [7]. These collisions have also created families of fragment asteroids that appear to constitute the most populous component of the asteroid main belt population [10, 4]. In a break up process, fragments are launched in space at moderate velocity ($\sim$1 km s$^{-1}$), by which, in the asteroid belt (but not elsewhere), fragments keep orbital elements similar to that of their parent body. But, the orbital elements of these family members diffuse with time due to thermal radiation force by the Yarkovsky effect [11]. This causes (1) different families to overlap in orbital element space, and (2) some of these asteroids to enter regions of instability, leading these bodies to escape from the main belt into the near-Earth space [12] – so collisional asteroid formation can influence the infall of asteroid material on Earth and other planets [13, 14]. Moreover, if one could identify all families and remove from the Main Belt from their members, we would be left out with the survivors of the original asteroids, i.e. those that accreted as planetesimals in the protoplanetary disk. This would allow derive crucial constraints on how planetesimals formed.

## 2. Background

Classically, asteroid families have been identified by the Hierarchical Clustering Methods [15] (HCM) that looks for clusters of asteroids in the orbital element space of semimajor axis, eccentricity, and inclination (a,e,i), with significant contrast with respect to the local background. However, this method appears to have difficulty for the detection of very old and dispersed families [16]. Indeed, Broz et al. [16] showed a lack of families generated by the collisional fragmentation of parent asteroid with D $<$ 100 km and aged by more than $\sim$2 Gyr (Fig. 1, filled symbols with no error bars).

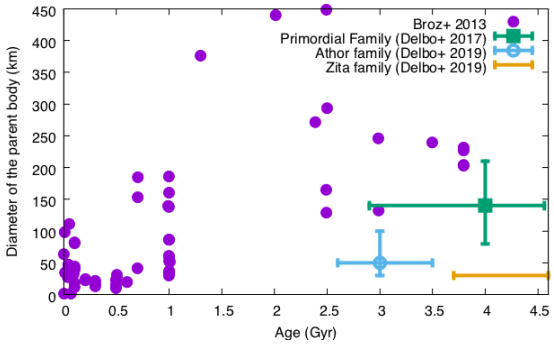


Figure 1: Relation between dynamical ages of families and the sizes of their parent bodies. Adapted from [16]. The data with error bars are from [4, 17]

## 3. Our new method of family identification

We developed a new method of family identification [4, 18, 3, 17] that identifies V-shaped groups of asteroids in $(a, 1/D)$ space, where $D$ is the asteroid diameter and $a$ the proper orbital semimajor axis. A V-shape feature is the expected signature of an asteroid family created by the fragmentation of a single parent body followed by the subsequent drift of the fragments' $a$-value from the family center due to the non-gravitational Yarkovsky force, which occurs at a rate $da/d$t (t is the time) proportional to the inverse diameter, $1/D$. We applied this method and discovered three previously-unknown asteroid families [4, 17] which plot in the age vs parent body diameter diagram of Broz et al. [16] as shown in Fig. 1. It is interesting to note that the families recently discovered by our method are falling in a region of the plot of Broz et al. that was perviously lacking detections.

## 4. Our project

Our search for asteroid families created by the most ancient collisions is currently ongoing using support from the french ANR and the US NSF. We also make use of telescope observations to (1) aid the V-shape finding algorithm to separate overlapping families, (2) study the composition of their newly discovered families, and (3) measure the shape and spin state properties of asteroid family members. We will update on the status of our project at the time of the EPSC/DPS 2019, including the discovery of new families.

## 5. Implications for asteroid and planetesimal formation

We will discuss how the identification of the families presented in Fig. 1 show that that the inner Main Belt contains asteroids of two different origins: (i) those that are collisional fragments of other asteroids and thus members of families and and another population consituted by very few objects that were not created as collisional fragments in the Main Belt and are, therefore, planetesimals accreted directly from the protoplanetary disk. We will show the size frequency distribution of these original asteroids and how this compares with models of planetesimal formation in the protoplanetary disk.

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