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Linking main-belt comets to asteroid families

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Abstract

Here we present our results obtained by applying different methods in order to establish a firm link between the main-belt comets (MBCs) and colisionally-formed asteroid families (AFs), i.e, to possibly find additional line of evidence supporting the hypothesis that MBCs may be preferentially found among the members of young AFs.

Linking MBCs to AFs

Main belt comets (MBCs) are objects that are dynamically indistinguishable from main belt asteroids, but which exhibit comet-like activity due to the sublimation of volatile ice [5]. To date, seven such objects have been discovered. MBCs are important because they represent a new reservoir of comets in the solar system, and may give insights into the role of main-belt objects in the primordial delivery of water to the Earth as well as to provide constraints on the composition of the protosolar disk.

Wherever MBCs originate from, their activity is likely triggered by the impact-excavation of subsurface ice [4, 9] because completely exposed surface ice is unstable against sublimation at their heliocentric distances over Gyr time-scales. Thermal modeling shows that buried ice on a main-belt comet can in fact survive over the life of the solar system [13]. However, while thermal devolatization may not preclude the existence of present-day ice (and therefore MBCs) in the main asteroid belt, there is the additional problem of collisional devolatization. Each time an impact triggers activity in a MBC by exposing a small amount of subsurface ice to direct solar heating, that particular area of the surface is effectively devolatilized once that ice has sublimated away. An estimates of the active areas required to produce the activity observed for MBCs, Hsieh (2009) suggests that the observed activity was most likely triggered by meter-sized impactors [6]. Impacts by objects of this size in the main belt should occur roughly every 10^4 yr [2, 1]. Over Gyr time-scales, the cumulative effect of such impacts could be to devolatilize a significant portion of the surface of an ice-bearing asteroid. On the other hand, more deeply buried ice could persist, safe from both thermal and collisional depletion, but would also therefore be inaccessible by activity-triggering impacts. Such asteroids would then be just as unlikely to exhibit activity in the present day and be identified as MBCs as other non-ice-bearing asteroids.

Because of these reasons, it was proposed that MBCs may be preferentially found among the members of asteroid families [11, 6]. Previous analyses showed that three of the seven currently known MBCs (133P/Elst-Pizarro, 176P/LINEAR, and P/2006 VW_{139}) are associated with the large and old Themis family [5, 7], which is thought to have formed in the catastrophic disruption 2.5 ± 1.0 Gyr ago [10]. Additionally, a fourth MBC (238P/Read) is close to the Themis family in orbital element phase space, and may have once belonged to the family [3].

However, assuming 133P is a primordial member of the Themis family, placing its age at $\sim$2.5 Gyr, less than 10% of 133P's surface would be expected to be unaffected by impacts by the present day. For this reason, it is even more important that 133P has been found to belong also to the young Beagle family (embedded in the Themis family), which is thought to have formed less than 10 Myr ago [11]. In the case that 133P is only 10 Myr old (i.e., the age of the Beagle family), 99% of its surface would be expected to remain unimpacted. This possible link between MBCs and young asteroid families is additionally supported by the recent finding that P/2006 VW_{139} belongs to a small family formed about 7.5 Myr ago [12]. Finally, P/2010 R2 (La Sagra) belongs to a small cluster that might have a common collisional origin as well [8] .

The lack of confirmed young family associations for other MBCs does not necessarily undermine our hypothesis. It is possible that many young families remain unidentified due to insufficient numbers of their members simply not yet being discovered. Also, despite being relatively young, some of these groups might be difficult to recognize due to their dynamical evolution since the post-impact situation. As a consequence, it is important to understand the dynamical environment of each MBC and any possible links to recently formed collisional asteroid families, i.e. to continue to search for small clusters of dynamically related asteroids around MBCs. Here we present some of our recent results obtained on this line of research.

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