# Origin of main-belt comets: In-situ formation vs. implanted interlopers from the outer Solar System

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Since the recognition of the main-belt comets (MBCs) as a new cometary class in 2006 [1], the origin of these objects and the mechanism of their activation have been the subject of intense debate. Much of the interest in this subject is due to the implication that the comet-like activity of MBCs is driven by the sublimation of water ice, presenting these bodies as probable candidates for the delivery of a significant fraction of the Earth's water. An analysis of the dynamics of the first three detected MBCs favored the in-situ formation as a more probable scenario for the origin of these objects [2]. Similar analysis for other MBCs suggests that these bodies were likely formed in the asteroid belt and were scattered from their original positions to their current orbits [3–6]. Despite these analyses, the real origin of MBCs is still unknown.

One quantity that may shed light on the origin of these objects is their Tisserand parameter with respect to Jupiter ($T_J = a_J/a + 2[(1-e^2)a/a_J]^{1/2}\cos i$). This parameter is frequently used to distinguish between asteroids ($T_J > 3$) and comets ($T_J < 3$). An interesting characteristic of MBCs is that while similar to comets, they have comae and dusty tails, they resemble asteroids, dynamically (i.e., their $T_J > 3$). To determine the extent to which the value of $T_J$ can be used as an indicator of the origin of MBCs, we integrated the orbits of a large number of small, test bodies with semimajor axes ranging from 1 au to 5.204 au, eccentricities of 0 to 0.99, and with $2.8 < T_J < 3.2$. Results indicated that, as expected, $T_J$ is not a hard boundary between asteroids and comets, and that we can expect to find objects that are dynamically stable with $T_J < 3$ as well as objects that are dynamically unstable with $T_J > 3$. Test objects close to the canonical $T_J = 3$ boundary between asteroids and comets are even seen to cross that boundary multiple times over the course of the integrations (Fig. 1). Considering the region of orbital-element space occupied by the main asteroid belt, we find that 80 percent of the objects with $2.8 < T_J < 3.2$ are dynamically stable over the course of our simulations. Considering the $T_J$ range where most MBCs reside, the fraction of stable bodies with $3.1 < T_J < 3.2$ increases to 86 percent, with the majority of ejected particles originating near major mean-motion resonances with Jupiter. These results strongly suggest that objects found within the orbital element ranges of the main asteroid belt that are not near major mean-motion resonances, like nearly all MBCs known to date, are generally stable over timescales longer than those typically attributed to Jupiter-family comets or Halley-type comets, and are therefore highly unlikely to be recently implanted interlopers from the outer solar system.

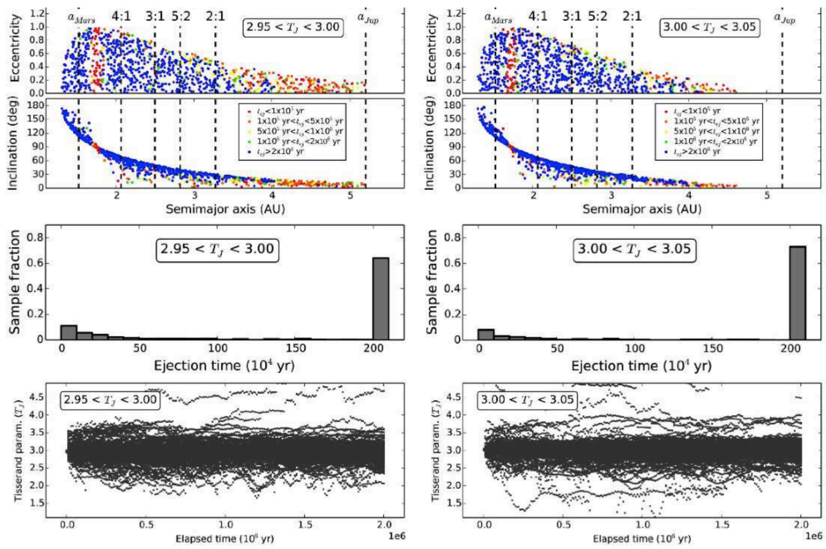


**Figure:** Initial orbital elements, distribution of survival times, and Tisserand parameter of test objects.

**References:** [1] Hsieh, H. H. & Jewitt, D. 2006, Science, 312, 561. [2] Haghighipour, N. 2009, MAPS, 44,1863. [3] Jewitt, D., Yang, B. & Haghighipour, N. 2009, AJ, 137, 4313. [4] Hsieh et al., 2012, AJ, 143, 104. [5] Hsieh et al., 2012, ApJ, 748, L15. [6] Hsieh et al., 2013, ApJ, 771, L1.