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The Themis asteroid family: A potential comet nursery

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Abstract

Recent work has suggested that some members of the Jupiter family comet population may actually originate in the main belt. This possibility is particularly interesting given various evidence of icy objects in the Themis asteroid family. We report preliminary results from a study aimed at connecting these threads and investigating the possibility that icy Themis family members could escape the main asteroid belt and infiltrate the population of Jupiter family comets. Numerical integrations appear to indicate that such dynamical evolution is indeed possible, primarily due to the influence of the 2:1 mean-motion resonance with Jupiter and terrestrial planet encounters, where collisional disruptions may also play a role in initiating such evolution. These findings raise intriguing questions about how JFC-like objects originally from the Themis family might be identified and studied in greater detail.

1. Introduction

The Themis asteroid family has come to be of particular interest in solar system science in recent years. At least three main-belt comets (MBCs; [1]), which exhibit comet-like activity indicative of sublimating ice, yet have asteroid-like orbits, are members of the family [2]. Water ice frost has also been reported on large members of the family [3, 4, 5]. Since asteroid family members are believed to be compositionally similar, these findings suggest that ice could be widespread within the family.

The past few years have also seen interesting dynamical results related to the main asteroid belt. In one study, a small number of known Jupiter-family comets (JFCs) were found to be significantly more dynamically stable than other JFCs, leading the authors to propose that these objects may originate in the asteroid belt, rather than in the outer solar system [6]. Meanwhile, a study involving numerical integrations of synthetic particles with Tisserand parameters with respect to Jupiter (T_J) close to the canonical $T_J = 3$ boundary between asteroids and comets found that a small number of objects with initially asteroid-like orbits $T_J > 3$ were able to reach JFC-like orbits with $T_J < 3$, leading the authors to reach a similar preliminary conclusion that the JFC population could potentially include objects from the main asteroid belt [7].

2. Dynamical Integrations

If icy Themis family asteroids are able to reach near-Earth JFC-like orbits with $T_J < 3$, they could begin sublimating, and at least at first glance, be physically and dynamically indistinguishable from other JFCs from the outer solar system. In order to investigate this possibility in more detail, we have conducted a study using numerical integrations to investigate potential dynamical pathways from the present-day Themis family to elsewhere in the solar system.

We sampled the Themis family by selecting the 2000 lowest-numbered members identified by [8] and, following the method of [9], generating 4 dynamical clones per object using σ values of $\sigma_a = 0.001$ au, $\sigma_e = 0.001$, and $\sigma_i = 0.01°$ for their semimajor axes, eccentricities, and inclinations, respectively. These σ values were intentionally chosen to be relatively large in order to roughly mimic the effect of large collisional disruptions of each object that could impart one-time impulses to resulting fragments, causing random deviations in their post-disruption orbital elements relative to each parent body. We then integrated each original object and its clones (10,000 test particles in total) forward in time for 100 Myr under the gravitational influence of the 7 major planets other than Mercury using the hybrid integrator in the Mercury N-body integration package [10]. Non-gravitational forces were not included.

3. Results

Figure 1 shows an example of the dynamical evolution undergone by a test particle found to evolve from a Themis-family-like orbit to a JFC-like orbit during our integrations. As with many of the clones found to reach JFC-like orbits (based on T_J

values and perihelion distances, but not necessarily in terms of other orbital elements of real JFCs) in our integrations, this particle starts out close to the 2:1 mean-motion resonance (MMR) with Jupiter. The MMR then causes eccentricity and inclination excitation, eventually driving the particle to comet-like T_J values as its increasing eccentricity causes it to interact more strongly with the terrestrial planets (cf. [7]). We therefore find it plausible that some JFCs may be Themis family members in disguise, raising intriguing questions about how these objects might be identified and studied in greater detail.

In our presentation, we will report on our findings in greater detail, discussing follow-up efforts to confirm these early results, estimates of the rate at which Themis family objects may escape the main belt and the survivability of ice in these objects during the journey to and while in near-Earth space.

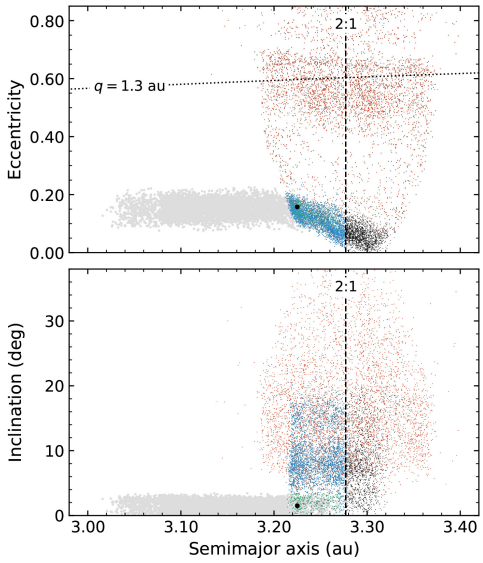

Figure 1: Semimajor axis vs. eccentricity (top) and inclination (bottom) plots of intermediate orbital elements of a dynamical clone of Themis family asteroid (97777) 2000 KG_{16} during our integrations, where the clone's starting orbital elements are marked by a small black circle, small blue and green dots mark main-belt-like orbital elements, red dots indicate JFC-like orbital elements, and light gray circles show the current osculating elements of Themis family members. The 2:1 MMR with Jupiter and the line in *a*-*e* space above which objects are considered near-Earth objects (i.e., have perihelion distances of $q < 1.3$ au) are marked with dashed and dotted lines, respectively.

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