TROJAN COLLISIONAL FAMILIES AS A SOURCE FOR SHORT–PERIOD COMETS

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We have investigated the dynamical evolution of fragments generated by the collisional breakup of Trojan asteroids, in order to study the formation of collisional families in the Trojan clouds and to identify a possible connection between these fragments and the population of Jupiter–family comets.

A relationship between Trojan asteroids and short–period comets is suggested by the spectrophotometric similarity of the D class asteroids, which are predominant among the Trojan asteroids, and inactive comet nuclei. Shoemaker et al. [1], on the basis of this similarity, argued that a mechanism for capturing Jupiter family comets in Trojan–type orbits could be effective. Encounters with Jupiter could drive a small percentage of short period comets into temporary 1:1 libration and subsequently into Trojan–type orbits. Here we show how this process can work also in the reverse direction. The collisional breakup of a Trojan asteroid can inject some fragments into comet–like orbits.

The fact that the Trojan belt is collisionally evolved has been confirmed by the computations of proper elements in the 1:1 resonance with Jupiter by Milani [2,3]. He has proven the existence of small groups of Trojans with very close proper elements which could possibly be the results of collisional events in the Trojan belt. In particular, in the L4 region the Menelaus and Teucer groups have been confirmed as strong candidate collisional families. We intend to prove that the spreading in the orbital element space of the fragments following the breakup of the parent body, can force some of them to escape from the L4 or L5 regions. Repeated close encounters with Jupiter can drive a significant percentage of these fragments into comet–type orbits.

To model the collisional event which generates a Trojan family, we combine in a computer algorithm the semiempirical model of Davis et al. [4], which predicts the size distribution of fragments generated in an individual breakup event, with a mass–velocity distribution for the fragments derived by the experimental work of Nakamura and Fujiwara [5]. Assuming an isotropic distribution of the ejecta velocities, we compute a complete set of post–impact osculating orbital elements for each single fragment. The orbits of the fragments and of the four Jovian planets are then integrated as an N–body system using the Everhart [6] numerical integrator. The integration time span is of the order of 10^5 yr, longer than the periodicity of the variations of Jupiter's eccentricity.

In Fig. 1 we show in the a–e plane a simulated Menelaus family generated by the breakup of a parent body 200 km in diameter as it appears after the breakup (only fragments larger than 20 km are considered). The fragments represented by open circles are in Trojan–type orbits even after $4 \cdot 10^5$ yr. The filled triangles represent fragments escaping from the 1:1 resonance. The distribution in the a–e plane at $t=10^5$ yr is shown in Fig. 2, where the dashed line corresponds to a Tisserand invariant of 3.0, the usual dividing line between comets and asteroids (see Fig. 1 in Weissman et al. [7]). Note that a significant fraction ($\sim 17\%$) of fragments end–up into orbits resembling those of Jupiter–family comets, or of objects such as 944 Hidalgo, 2060 Chiron and 5145 Pholus. Some fragments even end up on hyperbolic orbits, and are ejected from the solar system. Other ones may undergo episodic temporary capture into Jupiter–bound orbits, giving raise to objects such as P/Shoemaker–Levy 9.

Figs. 3 and 4 show the corresponding plots for the Teucer family (parent body 260 km in diameter). In this case 22% of the fragments end up in comet–type orbits, including one 70 km across. The orbital evolution of this body (perihelion distance (full line) and eccentricity (dashed line) vs. time) is displayed in Fig. 5, showing that the orbit is strongly chaotic, and that after some 70,000 yr since the breakup the eccentricity is pumped up to values approaching unity.

A quantitative estimate of the flux of Trojan fragments into comet–type orbits would require a better knowledge of the Trojan size distribution, and a more detailed model for the collisional evolution of the whole Trojan clouds. However, the possibility that at least some objects with cometary dynamics are generated as collisional fragments from asteroidal parent bodies appears well established.

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