DISRUPTION AND REACCUMULATION OF MIRANDA

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We present results of numerical simulations on the breakup of Miranda by a high velocity impact of a large cometary body and its subsequent reaccretion from the ring of fragments. Our goal is to examine the evolution of the size and orbital distribution of the ring debris as a function of time in order to derive a timescale for the reaccumulation of the satellite.

The heavily cratered surfaces of the largest Uranian satellites and the unusual surface geology of Miranda suggested that Miranda and other Uranian satellites were catastrophically disrupted by collision and then reaccumulated over solar system history (Smith et al. [1], Mckinnon et al. [2]). The large Population I craters (produced by Uranus–Neptune planetesimals or short period comets of the Uranus family) recorded on Oberon imply an estimated impact rate of projectiles on Miranda capable of breaking–up and reaccreting the satellite perhaps several times.

To simulate the breakup of Miranda we have used the model of Marzari et al. [3] developed to study the size and orbital distribution of fragments generated from the impact catastrophic–disruption of an asteroidal body. The pre–breakup Miranda parent body is assumed to have the same orbit and the same mass 7.2×10^{22} g of the present Miranda and a bulk density of $1.3\ \mathrm{g/cm^{-3}}$. The fragmentation of the satellite produces a ring of bodies around the planet whose size distribution and spatial distribution (projected on the satellite orbital plane) are shown in Figs. 1 and 2. The largest fragments are concentrated around the orbit of the parent body because they are ejected with lower velocities with respect to the smaller ones. As a consequence these bodies have also lower orbital eccentricities and inclinations.

The reaccumulation of Miranda from the ring of fragments has been modeled using the numerical algorithm of Spaute et al. [4]. This spatially resolved accretion algorithm treats the simultaneous accumulation of bodies in many interacting planetocentric distance zones. For this reason it is very suitable for describing the accumulation process in a swarm of bodies generated by the disruption of Miranda where the size and orbital distributions of the population vary significantly with distance from Uranus. In Figs. 3 and 4 we show the size and spatial distributions of the swarm at a model time of 300 y. The rapid growth of large embryos in the inner zones of the ring and the consequent depletion of small bodies, accumulated by the embryos, is favoured: a) by the presence in the initial distribution of larger fragments in these zones b) by the lower values of eccentricity of bodies in orbits close to the parent Miranda orbit c) by the shorter orbital periods. The residual population of small bodies is concentrated in an outer ring which is slowly accreted by the inner embryos. In the last stage of the re-accretion process, the growth slows down due to the dynamical isolation of the large embryos. In Figs. 5 and 6 we show the spatial distribution of the ring after 1.2×10^5 y. Most of the mass at this time is concentrated in 4 big bodies. The largest one has a mass of 4.8×10^{22} g, about 60 % of the initial satellite mass and its radial distance from the planet is almost the same of the present Miranda. The subsequent evolution of these large bodies cannot be described by our model based on large number statistics but has to be computed via numerical integration. The orbits of these bodies intersect with one another so we expect that they will coalesce into a single body on a short timescale.

Our numerical simulations show that: 1) reaccretion of Miranda occurs on a timescale of the order of 10^5 y, 2) the pre–breakup Miranda should not have been significantly more massive than the present satellite, 3) the reaccumulated body is located at the same distance from the planet in spite of the initial large dispersion of the ring debris.

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REACCUMULATION OF MIRANDA: F. Marzari, V. Vanzani, S. Weidenschilling, D. Davis