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Accretion, Early Thermal State and Differentiation of Icy Satellites

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Differences in composition and internal structure exist between the major icy satellites of Jupiter and Saturn and suggest distinct accretionary histories [1, 2, 3]. Callisto's accretion was probably slower than Ganymede's [1, 4], reducing the internal temperature increase and the volume of melted ice while Ganymede's differentiation may be the result of a catastrophic event following a thermal runaway a few hundred million years after its accretion [2]. Gravity measurements performed by the Cassini Radio Science Experiment [5] suggest that Titan's internal structure is probably intermediate between Ganymede and Callisto. The moment of inertia inferred from the gravity field suggests either that the segregation of rock and ice is not complete in the deep interior or that the rocky core is mostly composed of highly hydrated minerals [6, 7]. Whatever the exact degree of ice-rock segregation, melting of outer icy layers is expected to have occurred during the late stage of the accretion[8, 9]. The most recent models even suggest that a second melting process via impacts may have occurred during the late heavy bombardment 700 Myr after the system's formation [10].

For a better understanding of the thermal evolution of a growing icy satellite and of the conditions under which melting may occur, we developed a three-dimensional numerical model based on the Oedipus code, initially developed to solve the equations of thermal convection in a spherical geometry [11]. This numerical model characterizes the thermal evolution of an icy satellite during its accretion from a variety of plausible impactor population. For each impact, we consider the thermal effects due to the dissipation of the impactor's kinetic energy: After an impact, temperature locally increases deep in the impacted growing object and within the shallow ejecta blanket. As the icy moon grows, gravitational forces increase and impacts become more and more energetic. As the temperature increases below the impact site is proportional to the impact velocity, melting events areexpected tooccur at the end of the accretion once the icy moon reaches a critical size. In order to constrain this critical size, we simulate the growth and thermal evolution of icy bodies from a kilometer-size initial undifferentiated body to a size of order 2500 km from various populations of undifferentiated icy impactors and by assuming different orbital configurations for the growing body and different accretion rates. Preliminary results will be presented.

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