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The Effect of Volatiles on the Existence of Deep Liquid Layers within Icy Moons

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Since Voyager mission, it has been established that the surfaces of icy moons of Jupiter and Saturn differ very strongly, suggesting different internal structures and thermal histories. Galileo has brought new insights on the internal structure of the largest moons of Jupiter. Magnetic data and moment of inertia measurements provided valuable constraints on the core sizes and possible activity, but also on the degree of differenciation. Cassini has possibly detected a cryovolcano on Titan, and maybe internal activity on Enceladus. Our current understanding of the deep interior of large and medium icy moons is that the icy material surrounds an inner silicate shell and eventually an iron-rich inner core (for the largest moons). The main uncertainty about the internal structures concerns the possible existence of a deep liquid layer below an ice I shell for both large and medium satellites. The possible existence of such layers depends on three independent factors which are the total amount of internal heat, the efficiency of heat transfer through the ice I shell, but also the chemistry of the liquid layer. After a brief review of our understanding of the two first factors, this work will mainly focus on the effect of the chemistry.

Both abundance measurements on cometary ices and composition measurements from Galileo and Cassini spacecrafts suggest that ices are volatile-rich. These compounds influence the existence of deep liquid layer because of their ability to decrease the melting temperature of ices. In this respect, ammonia is the most important, but other compounds such as sulphuric acid or salty materials can be considered. Being the most illustrative and best understood, the effect of ammonia will be shown. The water rich region of the ammonia - water phase diagram presents six solid polymorphs. The three main characteristics of the diagram are: i) the melting temperature of ices decreases strongly when ammonia is added; ii) there is a peritectic curve corresponding to the reaction L + Ice ↔ Dihydrate; iii) the eutectic curve (L ↔ Dihydrate + Monohydrate) is located at very low temperature.

Based on this phase diagram, the effect of ammonia on the existence of liquid layers can be inferred. Both basic principles and main results of numerical simulations conducted in the last five years for large and medium-size satellites will be presented. In addition, several implications of these simulations for explaining the putative cryovolcanism occurring on Titan will be discussed.