Dynamics and evolution of icy satellites

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The Galileo mission (1995-2003) and the Cassini-Huygens mission (2004-2010) in orbit around Jupiter and Saturn, respectively, have revealed that these two giant planets host several very active moons. The magnetic data returned by the Galileo mission suggest that deep salted water oceans are present within three of its biggest moon, Europa, Ganymede and Callisto. Europa exhibits very complex tectonic features, suggesting that liquid water has been recently exposed on its cold surface. Saturn's moon Enceladus also displays in some regions tectonic features similar to Europa. Even more surprising, this tiny moon (only 252 km in radius) is one of the rare solid objects in the solar system to be sufficiently geologically active for their internal heat to be detected by remote sensing. But in contrast to the Earth and Jupiter's volcanic moon Io, the endogenic activity on Enceladus is mainly localized at the South Pole, from which jets of water vapor and ice particles has been observed. The origin of this huge hotspot at Enceladus' South Pole still remains enigmatic.

One of the most intriguing world is probably Titan, Saturn's biggest moon. Titan is the only moon in the solar system hosting a massive atmosphere, mainly composed of nitrogen, methane, and a complex suite of organic molecules resulting from the photolysis of its main atmospheric compounds. Methane, which can be liquid at Titan's atmospheric conditions, plays a role similar to water on Earth, forming lakes and river networks that the Cassini-Huygens mission recently revealed. Measurements performed by the Huygens probe during its descent through Titan's atmosphere on Jan. 14 2005, provided circumstantial evidences that the atmospheric methane is recycled by internal outgassing processes, maybe still operating. More recently, data gathered by the Cassini spacecraft indicate that outgassing processes are probably also operating on other Saturn's moon, Dione, Tethys and Rhea, previously thought to be geologically dead. And this is probably not the last surprise of the Cassini-Huygens mission.

How these small icy worlds have kept such an activity more that 4.5 gigayears after their accretion is enigmatic. Radiogenic heating in these icy bodies is relatively low. Frictional heating owing to solid tides raised by their giant planet on the satellite is probably a major source of energy for several of these moons. Tidal heating associated with their eccentric orbit has long been suspected to play a major role in the thermal evolution of giant planet moons. The surprising activities of Io and now, of Enceladus are the most convincing evidence for tide-generated heat. I will show how the specific rheological properties of water ice make the satellite interior very dissipative, and hence provide a huge source of energy. The effect of tidal heating on the convective instabilities and on coupled thermal and orbital evolution of the satellites will be illustrated. The role of ice composition and grain size will also be discussed. I will expose how tidal heating and thermal convection are strongly coupled in these exotic. This strong coupling could explain the spectacular activity observed on Enceladus, could maintain a global liquid ocean below Europas icy crust and could help recycle Titans atmosphere.