Exchange processes from the deep interior to the surface of icy moons

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Space exploration provides outstanding images of planetary surfaces. Galileo spacecraft around Jupiter, and now Cassini in the saturnian system have revealed to us the variety of icy surfaces in the solar system. While Europa, Enceladus, and maybe Titan present past or even active tectonic and volcanic activities, many other moons have been dead worlds for more than 3 billions years. Composition of ices is also complex and it is now commonly admitted that icy surfaces are never composed of pure ices. Water ice can be mixed with salts (Europa?), with hydrocarbons (Titan?) or with silicates (Callisto).

The present surfaces of icy moons are the results of both internal (tectonic; volcanism; mantle composition; magnetic field; ...) and external processes (radiations, atmospheres, impacts, ...). Internal activity (past or present) is almost unknown. While the surfaces indicate clearly that an important activity existed (Ganymede, Europa, Titan, ...) or still exists (Enceladus, Titan?, ...), volcanic and tectonic processes within icy mantles are still very poorly understood. This project proposes some key studies for improving our knowledge of exchange processes within icy moons, which are:

1) Surface compositions: Interpretation of mapping spectrometer data. It addresses the interpretation of remote sensing data. These data are difficult to understand and a debate between people involved in Galileo and those who are now trying to interpret Cassini data might be fruitful. As an example, interpretation of Galileo data on Europa are still controversial. It is impossible to affirm that the “non-icy” material which does not present the classic infrared signature of pure ice is due to the presence of magnesium hydrates, sodium hydrates, magnesium sulfurs, “clays”, or even altered water ice. Discussion on the subject are still needed. On Titan, the presence of the atmosphere impedes to link IR data from Cassini to the composition of the surface.

2) Past and present dynamics of icy surfaces: erosion, tectonics and cryovolcanism. This second topic is devoted to the description of the surface features. A synthesis of what has been seen in the jovian system and a presentation of what is now discovered in the saturnian system might be useful.

3) Internal processes: dynamics of icy mantles. Many works have been done specifically for icy moons (rheology of icy mantles, heating modes, effect of ice composition, internal activity of small moons, internal oceans,...). Icy mantles present so many dif-

ferent convective processes, depending on parameters such as the ice composition, the heating mode, . . . , that a full review of the recent progress on the subject is required.

4) Physics and chemistry of ices: experimental constraints on hydrates, clathrates and organics. Nothing can be done without experimental data. Thermodynamical constraints, phase diagrams, but also mechanical properties of icy materials are required for constraining all models. Many progress have been made these last five years, especially for clathrate structures so important in the case of Titan. A review of these progresses is required.

5) Earth analogs: a tool for understanding surface/ internal features. Tectonic and volcanic features on icy moons are sometimes confronted to Earth structures. This procedure is very interesting. While materials are different (on Earth the melt is lighter than the rock, but on icy moons it is the contrary), tectonic and volcanic features can be very similar. Our good understanding of the Earth can be very useful for describing the processes responsible of tectonic/volcanic features on the moons.

Discussing around the five themes described above may provide some constraints on open questions such as the characteristics of liquid layers within icy moons, the cryovolcanism on Titan, the resurfacing of Europa, the composition of Titan's surface, and the activity on Enceladus.