What can be done with the icy moons?

Three bodies of interest:
- Europa
- Titan
- Enceladus *(maybe too new)?*

State of the Art—what do we have?
- Visible images (low/high resolution)
- Hyperspectral analysis of the surfaces (low resolution)
- Geophysical data (poor but it exists)
- Laboratory experiments on ices (rheology, spectroscopy, chemistry of ices, …)

Where are we now?
- Surface Composition are still unknown (even for Europa)
- Interior-surface exchanges not really understood
1) Constraining the composition of Europa’s ices

Blue surface: pure ice

Red lines and spots: material from the deep interior
2) The tectonics of Europa (exchange between the surface and the interior…)

**EUROPA — Surface-feature examples**

Description of data is easy BUT
INTERPRETATION of data is very difficult

Comparison with planetary analogs is difficult:
- « New » features (triples bands, chaos,…)
- Known features (craters, faults)
- Need for analogic models …
3) The use of Earth analogs – example of compressional features

- Crust extension
- Crust compression?
3) The use of Earth analogs – example of compressional features

Fusion sous pression

Compressional features on Earth require topography.

Melting under pressure a new process which does not imply topography.

dans des zones d'anomalies thermiques
4) A review of the data requirements

**Implications:**
- Morphology description
- Description of tectonic activity
- Surface datation (craters)
- ...

**Requirements:**
- Analogic models are missing for icy materials…
- Topography measurements
- Data system providing detailed mapping of icy surfaces on Earth, Mars, icy moons
- Classification of tectonic features in the solar system (maybe it exists???)
The case of Titan – do we have volcanoes?

1) VIMS data showing a cryovolcano
The case of Titan – Volcanic processes

2) Constraining the composition of Titan ices - cryolcanism

- **Requirements:**
  - Spectral signature of clathrates on Titan
  - The effect of ammonia on clathrate stability has not been considered

- **Dissociation of methane seems difficult...**

- **Previous works (but difficult to find):**
  - Oil engineers works (60s)
  - Research studies (chemistry ...)

- **Graph:**
  - Temperature (K) on the x-axis
  - Pressure (MPa) on the y-axis
  - THERMAL PROFILE (based on HP experiments)
  - CLATHRATE DISSOCIATION CURVE

- **Legend:**
  - ice I
  - liquid layer
  - HP ices
  - rock and iron core
## The case of Titan – Volcanic processes

### 3) A review of the data requirements (experimental)

<table>
<thead>
<tr>
<th>Pure ices:</th>
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<tbody>
<tr>
<td>✤ thermodynamic properties (EOS, thermal conductivity, heat capacity, …)</td>
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<tr>
<td>✤ Rheology</td>
</tr>
<tr>
<td>✤ Melting curves at very high pressures (exoplanets)</td>
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</tbody>
</table>
What is required for going further?

- New laboratory experiments (no interest here)
- Catalog(?) of existing laboratory experiments on ices and silicates (IR-Raman) (DWG 3/5/9/8/ any other?)
- Catalog(?) of observed tectonic and volcanic features