Interior Structure And Habitability Of Super-Europas And Super-Ganymedes

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SUMMARY

- Fluid-rock interactions in super Earth oceans are regarded as limited by negatively buoyant high pressure ices V, VI, VII, and VIII.
- Analogous assumption made for large icy worlds Ganymede and Titan: ocean depths up to 800 km create >GPa pressures (>10kaatm). Applying accurate fluid thermodynamics to planetary interiors challenges these assumptions.
- Increased density in highly saline oceans implies possible oceans perched under and between high pressure ices.
- In some model oceans, high-pressure ices become buoyant, implying frazil-like upward snows, interlayered liquids and fluids in direct contact with rock.

REFERENCES


1. Confirmed and candidate Kepler planets with $R < 2.5R_J$.

- Watery Earth-like planets are probably common around other stars.
- (contours: temperature in Kelvin).

2. Mass-radius, planet density vs composition, etc., provide information about internal structure related to habitability.

- Potentially habitable super Europas are notionally in the shaded regions.

3. Interior models for $5M_{\text{Earth}}$ water planets [4], with water oceans with $NH_3$ neglect effects of dissolved species (salts).

4. Watery exoplanets will resemble larger icy satellites in the solar system, with high-pressure ices and salty oceans.

Application of detailed thermodynamics to icy satellites [5,6] reveals strong density and temperature gradients.

How do deep salty oceans affect geodynamic evolution?

5. Pressures in exoplanet oceans span the multi-GPa range of pressures where liquids are possible.

- Pressure (GPa), temperature (°C) profiles in upper mantles of selected objects (as per Ref. 7), beginning at presumed seafloor depth.

- Overlying ocean assumed at a constant temperature.

- Known exoplanets, albeit very hot ones, modeled as super Europas with seafloor depths like Earth’s (10 km), Europa’s (100 km), and Ganymede’s (800 km). [6].

6. Recent EOS and phase measurements for NaCl (aq) indicate ice VII floats at P > 5 GPa.

7. Modern computer processing allows us to apply geophysical methods of regularization to construct optimized “local” fits of thermodynamic properties that easily accommodate new data.

We constructed Gibbs free energies for water [13, 14, Brown et al., in prep., left]. We are using G to develop general thermodynamics of aqueous solutions:

$$\hat{G} = \hat{G}^{\text{H2O}} + \hat{G}^{\text{aq}}$$

Aqueous chemistry separable by contributions from:

- water ($G^{\text{H2O}}$)
- interaction of water with ions
- interaction of ions with each other
- interaction of ions with each other and water

$$\hat{G}^{\text{aq}}(n_x) = \sum_{i} + 2 \sum_{j} \sum_{k} m_i n_{x,j} n_{y,k}$$

We are beginning to estimate Pitzer parameters under planetary conditions.