New 'minerals' of the outer solar system - the high-pressure crystallography of methane

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Where on Earth our mineralogy is dominated by silicates, but for both the Uranian and Neptunian systems a different, perhaps simpler, chemistry exists with H_2O, NH_3 and CH_4 the dominant species. Within the interior 'hot ice' layer of these bodies it is thought that interactions between these molecules account for the anomalous magnetic fields generated. Methane's dissociation reactions could also be key to understanding what drives the planet's energy supplies. However studies of at these extremes of pressure and temperature have throw up inconstancies and the way forward is perhaps to understand how the constitute materials behave at room temperature.

In the the suite of outer solar system 'minerals', H_2O, NH_3 to CH_4, methane is the sole organic member and the only one with no hydrogen bonds. Its solid structure instead is determined by van der Waals and stearic repulsive interactions and high-pressure studies can probe the interplay between these forces. The methane tetrahedron exhibits orientational disorder in many phases and the high-pressure behaviour of methane has been discussed in terms of a 'bad rare gas' model [1,2], leading to an assumption that at higher pressures it will adopt structures related the hexagonal closed-packed structure. Further studies have shown that this simplistic view of the molecule was incorrect and that the phase diagram is very complex, with eight distinct solid structures [1].

I will present results from a series of investigations of the room-temperature phases A, B and HP, with data collected using both synchrotron x-ray and neutron diffraction techniques.

[1] R.Bini & G.Pratesi. High pressure infrared study of solid methane: Phase diagram up to 30 GPa. Physical Review B 55, 14800 (1997).

[2] P.Hebert, A.Polian, P.Loubeyre & R.LeToullec. Optical studies of methane under high pressure. Physical Review B 36, 9196 (1987).