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Thinking outside the ‘ice’ box; grain size changes of solid nitrogen and its effects on the surface of Pluto.

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Abstract

The presence of nitrogen on the surface of Pluto is crucial in understanding surface features and processes, both from a mineralogical and structural standpoint. Observing solid nitrogen in the experimental setting is challenging, yet is necessary to give an insight into phase changes well within Pluto’s temperature range. The plausibility of nitrogen phase changes can be tested more rigorously using various laboratory instrumentation that will ultimately enhance modeling endeavors.

1. Introduction

One of the most striking images from the NASA New Horizons fly-by of Pluto [1], was that of the towering mountains surrounded by seemingly flowing terrain (Figure 1) [2]. The explanation for this terrain has its base in material behaviour, where at 44 K the strength of the hydrogen bond endows water ice with the resilience to build such mountains, while the rotational disorder in methane [3] and nitrogen [4] still allows these materials to flow. These interpretations have been strengthened by the spectral observations that correlate these materials to the respective terrains [5-6]. There is much still to be understood about the interactions and possible new structures that would form under these frigid temperatures, and structural investigations have a key role in this undertaking.

Additionally, in order to accurately model the features on Pluto a number of physical parameters must be well constrained. Thorough investigations on the physical properties of the constituent materials of the Plutonian terrain, water, methane and nitrogen, are currently the best way forward to explaining such features. With this program of research we hope to confirm and extend upon previous determinations of thermal expansivity in these systems [7][8].

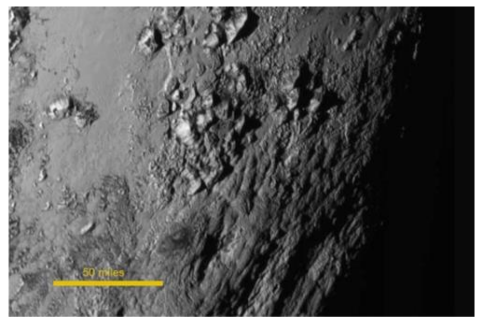

Figure 1: New Horizons LORRI image showing mountains thought to be composed of water ice rising 3,500 meters above seemingly flowing glaciers of nitrogen and methane. Image credit: NASA, John Hopkins University Applied Physics Laboratory and Southwest Research Institute.

Though the crystal structures of nitrogen (as well as water and methane) are well established they have not been investigated by diffraction studies for many years, and none have charted the crystallisation behaviour. We have undertaken an experimental study to chart crystallisation, transformation and structural behaviour of nitrogen at Pluto temperatures, and have sought to relate this to the Plutonian surface.

2. Experimental

We have used neutron diffraction to undertake *in situ* crystallization and structural investigations of solid Nitrogen. High-purity nitrogen was condensed within a vanadium can with gas dosing equipment mounted within an orange cryofurnace set at ~75 K. Once condensed the temperature of the sample was cycled between 16 and 75 K ten times with diffraction patterns collected every 2 K using the high intensity neutron diffractometer (WOMBAT) at the Australian Centre for Neutron Scattering. The WOMBAT instrument is particularly suited to this as it has an area detector that covers a diffracted angular range of

120° and 15° in height, allowing it to monitor both textural and structural changes in crystalline material.

3. Results

Figure 2 shows the nitrogen data from WOMBAT at 2.41 Angstroms. We observed the α-β transition at 38 K, as observed from previous studies of the nitrogen-methane phase diagram [7]. The α phase in the lower temperatures (< 38 K) we have determined to be cubic Pa3 with symmetric ordered molecules. The β phase at relatively higher temperatures has rotationally disordered molecules.

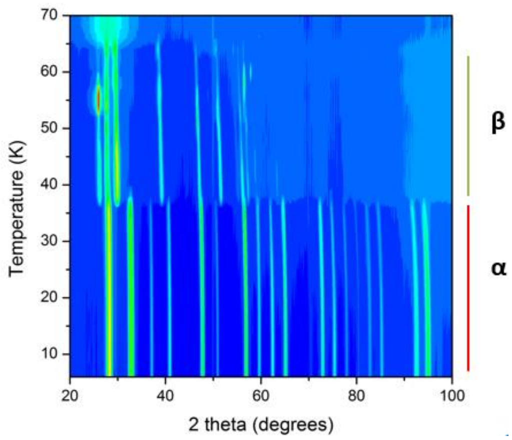

Figure 2: Thermodiffractogram (collected at 1.54 Å) of nitrogen between 6 and 70 K exhibiting the structural change and the variability in the grain size of the β form of nitrogen.

Once the ice sample has reached the phase transition, we observed a large scale change in the grain texture at ~48 K. Understanding this change will be the motivation for future experiments.

Experiments conducted at the Arkansas Center for Space and Planetary Sciences have also confirmed the αalpha-βbeta nitrogen phase change when in a 1:1 binary mixture with methane observed in FTIR mid-IR spectra at 1-2.5 microns. [9].This transition was found at ~35-38 K temperatures [9].

Conclusions

This phase change observation and texture change give insight to the potential of mineralogical changes, localized concentrations of nitrogen (though mixed with methane, carbon monoxide, and water ice), and probable seasonal effects. It is interesting to note that these variations are not observed (i.e. grain size changes) in water ice, and are less clear at this stage with methane mixtures. This preliminary observation will provide crucial support to scientific instrument measurements in various wavelengths and techniques.

Acknowledgements

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