LABORATORY STUDIES OF CRYOGENIC OUTER SOLAR SYSTEM MATERIALS AT THE NORTHERN ARIZONA UNIVERSITY ASTROPHYSICAL ICES LABORATORY. J. Hanley¹, W. Grundy¹, S. Tegler², G. Lindberg². ¹Lowell Observatory, Flagstaff, AZ (jhanley@lowell.edu), ²Northern Arizona University, Flagstaff, AZ.

Introduction: The Physics and Astronomy Department at NAU hosts the Astrophysical Ice Laboratory, which is dedicated to studying ices under controlled temperatures and pressures [1-5]. Simple molecules like CH₄, H₂O, N₂, CO, CO₂, O₂, CH₃OH, C₂H₆, and NH₃ are important geological materials in the cold, outer regions of the solar system. Their mobility and distinct material properties enable geological activity and produce a spectacular variety of exotic landforms, even at extremely low temperatures. But frustratingly little is known of the basic mechanical and optical properties of these volatile ices, and especially of their mixtures.

Many outer Solar System bodies exhibit interesting phenomena that indicates active processes on geologically recent timescales. For instance, New Horizons imaged what appears to be flows of nitrogen ice on Pluto (Figure 1 top), possibly created through convective cells of buoyant nitrogen ice. How does nitrogen ice behave at these temperatures and pressures? What happens when it is mixed with other species, such as carbon monoxide or methane? On Titan, we see lakes and seas of liquid hydrocarbons, as well as geologic features related to them such as river channels and shorelines (Figure 1 bottom).

The Astrophysical Ices Laboratory: Our cryogenic laboratory setup at Northern Arizona University (NAU) allows us to explore various properties of cryogenic materials at temperatures and pressures relevant to the outer Solar System.

Within the laboratory setup (Figure 2 top), volatile ices are condensed as thin ice films on a cold mirror, or within an enclosed cell (Figure 2 inset). Cooling is provided by closed-cycle helium refrigerators, within vacuum chambers for insulation. Samples can be cooled to 6 K on the thin film side, and ~30 K on the enclosed cell side. Cryogenic ice samples are studied via various analytical techniques including visible and infrared transmission spectroscopy, photography, and Raman spectroscopy (Fig 2 bottom). Mass spectrometers are capable of monitoring changes in composition.

Figure 1. Top: In the northern region of Pluto’s Sputnik Planitia, swirl-shaped patterns of light and dark suggest that a surface layer of exotic ices has flowed around obstacles and into depressions, much like glaciers on Earth. Image and caption credit: NASA/JHUAPL/SwRI
Bottom: Hydrocarbon seas on Titan. Image credit: NASA/JPL-Caltech/Agenzia Spaziale Italiana/USGS.

Figure 2. Top: Photo of laboratory setup. Inset: Schematic of the cell. Bottom: Schematic of Raman optics.
Further exploring at what pressures and temperatures these effects occur.

Understanding the freezing points of combinations of these species has implications for not only the lakes on the surface of Titan, but also for the evaporation/condensation/cloud cycle in the atmosphere, as well as the stability of these species on other outer solar system bodies. These results will help interpretation of future observational data, and guide current theoretical models.

**Future Goals:** The ices that can be created in the lab are useful to a variety of outer solar system bodies. For instance, mixtures of CO and N$_2$ are found on both Pluto and Triton, and spectral features acquired in the lab may aid in their identification [5]. We intend to continue to characterize the ternary of methane-ethane-nitrogen. We will also add other hydrocarbons and materials likely in Titan’s atmosphere and surface to determine how their presence effects stability and spectral properties.

We would like to be able to study not only the spectroscopic properties of these materials at low temperatures, but the physical properties as well. These include density, viscosity, speed of sound, vapor pressure, refractive index, compressibility, thermal and electrical conductivity, and diffusion rates.

Computational modeling of the interactions of these species is underway and will provide parameters such as ΔH-vaporization, heat capacity (const. P), diffusion constant, static dielectric constant, thermal-expansion coefficient, isothermal compressibility, shear viscosity, hydrogen bond lifetime, melting points and bulk moduli.

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**References:**