THE STRUCTURE OF PLANETARY ICES: HOW LABORATORY DIFFRATION METHODS CAN SUPPORT ASTRONOMICAL OBSERVATIONS. D.F. Blake[1], [1]MS 239-4, NASA Ames Research Center, Moffet Field, CA (dblake@mail.arc.nasa.gov).

Introduction: Solar system ices – water ice, water ice clathrates and frozen gases – are major players in the physical and chemical processes that occur in and on outer solar system bodies. An understanding of the physical chemistry (including such things as condensation and volatilization temperatures, structure states and stability, extent of solid solution with other elements and compounds) of outer solar system ices is key to unraveling the past, present and future behavior of these bodies. Remote observations of outer solar system ices, in particular of highly processed bodies such as Kuiper Belt Objects are extremely difficult to make because of their great distance from Earth and their low albedo. Occasionally, one sees dramatic brightening of a cometary apparition due to anomalous outgassing of (presumably) a solid icy material, but the underlying cause of the outgassing remains speculative. Likewise, direct observation of meteoritic materials (including interplanetary dust) may suggest the prior presence and action of frozen volatiles or of water ice, but only indirectly. In such cases, it is abundantly clear that laboratory simulation and analysis of solar system ice analogs will help our understanding.

With regard to condensed phases, it is well known in mineral chemistry that the structure of a crystalline material controls all other observed characteristics. Thus, the study of the sructure of a solid ice and its transitions – amorphous to amorphous, amorphous to crystalline and of one crystalline phase to another, will control all other detected or predicted properties.

Caveats for Laboratory Analog Studies: It is tempting to suggest that laboratory analog investigations are a panacea for planetary ice studies. However, as usual there are limitations to each technique (no one knows this better than the experimentalist!). What does one need to be aware of in order to properly study the behavior of an icy material in the laboratory?

- It is important to know the phase diagram of the material (this of course doesn't apply to amorphous materials). This is especially true for low-temperature studies in which a material approaches stability sluggishly or not at all. One can arrive at the wrong conclusion, if laboratory data are extrapolated to solar system time scales without knowing the phase relationships!
- One must be sure that the experimental protocol (mode of observation, method of growth of the ice, geometry or scale length of the experiment, etc.) is not influencing the structure or properties of the ice. For example, is the electron or photon beam processing the material in some unknown way? Will bulk ice behave in a similar fashion to the thin film that is being measured? There is never any completely satisfactory way to validate a laboratory experiment that is intended to be analogous to a planetary satellite-sized body.
- Experiments in pure end-member systems may not be representative of the dilute solutions or mixed chemistries that exist in nature; in fact, they probably aren't.

Adventures with Laboratory Analogs: Despite the caveats, many noble souls choose to enter into the labyrinth of experimental laboratory ice studies. It is implicit in any laboratory study that those experimentalists who conduct them and those astronomers who who read and apply them to observations of solar system ices, understand the value (and the limitations) of laboratory results. Experimentalists should explicitly state the limitations of their results, and observationalists should read and understand the minutia of the experiments that could limit or invalidate the experimental result for their particular application.

A case study of the structure of water ice: Some rather dated experiments by the author on the structure of vapor-deposited water ice and dilute water solutions will be shown as a case study.[1-4] Results will be shown of a transmission electron microscope study of vapor-deposited water ice and dilute water ice solutions from 10-170K in controlled warming experiments in vacuum. Comparisions will be made with IR experiments, and molecular dynamics / montecarlo simulations of ices deposited and warmed under similar conditions.

References:

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