Exploiting neutron scattering to understand the structure of amorphous solid water (ASW) in interstellar environments

H.J.Fraser,[1] S.Gaertner,[2] T.Headen,[2] T.Youngs,[2] and D.Bowron[2]

[1] *School of Physical Sciences, Open University, UK*
[2] *ISIS Neutron Source, Rutherford Appleton Laboratory, Harwell, UK*

Amorphous Solid Water (ASW) is the most common form of condensed matter in star and planet forming regions. As such, this porous, amorphous, metastable material is the key medium governing chemical reactivity in the solid-state in space, forming the "birthplace" of complex organic materials that are the precursors to life, as well as acting as a gas reservoir for volatiles that may otherwise be key coolants in the astronomical environments. In addition the physical properties of ASW impact on the earliest stages of planet formation, where the structure and amorphicity of the water ice impacts the sticking properties of nano- to cm-sized dust grains.

However, all these chemical and physical behaviors are dependent on the nano- and meso-scale structure of ASW. Alas, ASW is non-conducting and likely to change structure as soon as it is probed – so both direct (TEM STM AFM) and indirect (volumetric analysis, TPD RAIRS) methods of "seeing" the ASW structure still cannot reveal how the structure forms, or changes as a function of time or temperature. In the last few years we have been pioneering the use of neutron scattering methods to non-invasively reveal the nano-scale and meso-scale structure of ASW under pressure and temperature conditions akin to those in star and planet forming regions. Our results have shown that ASw has a significant diffusive interface [1] at the surface, and identified the mechanism for the onset of the glass transition at around 120 – 136 K [2]. Now our work is focused on identifying the pore size, shape and density in the ices as a function of time and temperature during growth and thermal processing (see Figure 1), and linking this back to our understanding of ice observations at the very onset of star-formation [3].

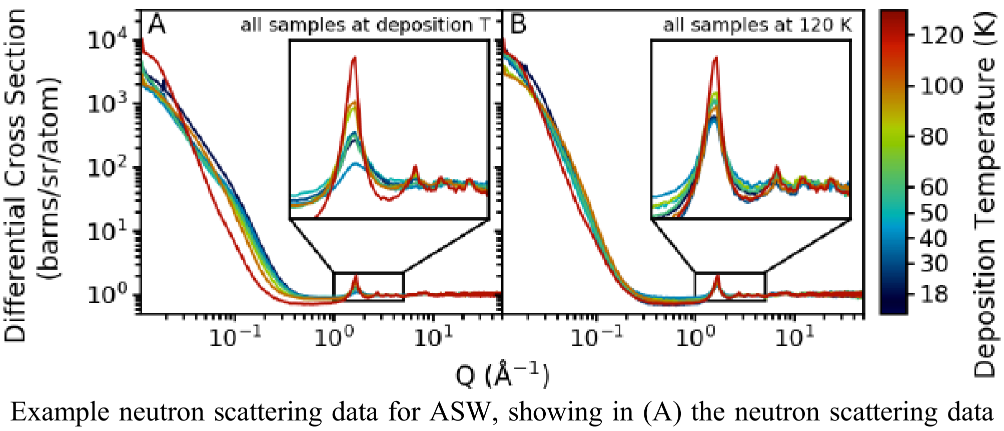

Figure 1: Example neutron scattering data for ASW, showing in (A) the neutron scattering data for ASW immediately after deposition, indicating that both the meso- and nano-scale structure of the ices changes as a function of surface deposition temperature and (B) comparing the neutron scattering data of all deposited samples once heated to 120 K, showing the metastable nature of the ASW, and that the resultant structure is dependent on the thermal pathway.

References

[1] Gaertner S et al (2017) ApJ 848 96
[2] Hill et al (2016) Phys Rev Lett 21 215501
[3] Noble JA et al (2017) MNRAS 467 4753