From Interstellar Ices to Polycyclic Aromatic Hydrocarbons

A symposium to honor Lou Allamandola's Contributions to the Molecular Universe

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From Observations to the Laboratory: Unravelling the Properties of Interstellar Ices

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When we observe ices in interstellar and planetary regions our key detection tool is infrared spectroscopy. Over the past 40 years IR observations have led us to build an inventory of ice species, based on their identification through functional groups, and comparisons between observed spectral line-shapes and those recorded in the laboratory. Lou, along with many others, pioneered this work, building our understanding of interstellar ice spectroscopy, and the molecular consituents. Such laboratory - observational crossover served us exceptionally well through missions like IRAS and ISO, as well as ground-based observations to compliment our space IR telescopes. It has informed our understanding of gas-grain chemistry in interstellar regions and been the basis of where we are in astrochemistry today. I aim to breifly review this work and Lou's amazing contributions in this field.

Over the last decade the legacy of the SPITZER and AKARI space telescopes coupled with ground-based Keck and VLT observations, has moved our understanding of ices on again. The challenge now is to be able to distinguish all the parameters that might affect an ice spectrum, such as chemical environment, thermal history, non-thermal processing, temperature, local environment and pressure. Given that many of these affect the shapes and nature of ice features - how can we elucidate chemical information from remote observations? Does the prospect exist to use ice as a tracer or probe of astronomical environment, or even a historical chemical clock?

The answer lies in the interdiciplinary interplay between observations, laboratory work and modelling. Based on my groups' novel observations with the AKARI space telescope, I will show how we are now able to map the distribution of ices directly on large and small scales, based on IR ice observations. I'll breifly compare this to the alternatives - mapping gases and infering ice observations from them - and how this leaves still open questions in our understanding (in particular) of non-thermal desorption. I'll present data showing the detection of HDO ice on lines of sight towards background stars, and show the relative abundances of H_2O, CO, CO_2 and CH_3OH ices, observed concurrently towards pre-stellar cores, illustrating for the first time the prevalence of methanol ice in lines of sight towards background sources. This work helps to marry observational and modelling / laboratory pictures of ice evolution. It also raises questions - why does water ice in space exhibit a red wing? Is there a critical extinction before which no ice forms? Again ice mapping has helped us to address these issues and, coupled with novel nano-fabrication techniques to model interstellar grain surfaces, onto which ice cna be grown, offer some solutions. The prospects for ice-mapping with JWST and E-ELT will be discussed.

However, ice ”spectroscopy” has moved beyond the IR. With the advent of HERSHEL SOFIA and ALMA our understanding of ice spectroscopy has been expanded, from the IR to THz. In my group we have developed a novel laboratory technique called THz Desorption Emission Spectroscopy (THz DES) or ”Alma in the Lab”. Sensitive to the species liberated from the ice in the gas-phase, I'll show how this new laboratory astrophysics method could help us to unravel the perennial question on the origns of complex molecules in star-forming regions - I'll show the first data from water and methanol ices.

Finally, perhaps not all our understanding of interstellar ices can be gleaned from spectroscopy with electromagnetic radiation. My group have pioneered the use of neutron scattering as a tool to study and understand ice structure during vapour-deposition growth and thermal processing. Such studies have enabled us to answer some of the very difficult questions which face solid-state astrochemists - cruical to the nature of icy materials in space, but simply impossible to uncover from IR or Thz spectroscopy: are interstellar ices porous, and if so how do the pores collapse? I'll finish this ”tour de force” of ice spectroscopy with a breif look at these exciting new results - and hopefully convince Lou he has founded, and leaves on the occasion of his retirement, an exciting field in good health for many years to come.