Molecular physics in space: investigating molecular processes and interactions in condensed films and molecular clusters

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Description:
Over 200 molecular species have been identified in the interstellar medium (ISM), many of which are complex organic molecules (COMs). Elucidating the formation of such molecules in astrophysical environments is fundamental to our understanding of the molecular origins of life. It is widely accepted that the molecular building blocks are formed on microscopic icy grains (at temperatures ~ 10 K) in dense molecular clouds from which stars are formed. Subsequent thermal and non-thermal (photon, ion, electron) processing throughout the evolutionally process of star and planet formation, leads to the synthesis of more complex molecules. Most of what we know about the physical and chemical properties of these interstellar ices comes from the direct comparison of observational data from infrared telescopes (ISO, Spitzer, AKARI, VLT) with spectroscopic laboratory data. As such, efforts to elucidate the processes involved in the formation of COMs are hampered by the difficulty of producing suitable laboratory samples that mimic interstellar icy grains and the need for consistent laboratory data that systematically traces the physical and chemical evolution of condensed molecular systems through thermal and non-thermal processing.

This project aims to address key questions applicable to astrochemistry: (1) are the physical and chemical properties of macroscopic condensed molecular films analogous to those of the ices covering microscopic 3D fractal-like particles found in the ISM, and (2) how does thermal and non-thermal induced molecular synthesis depend on the physical and chemical properties condensed molecular samples, down to the level of specific molecular arrangements?

The project will exploit fundamental and novel molecular physics laboratory techniques, to make direct comparisons between the physical and chemical properties and reactivity on *macroscopic* and *microscopic* scales, in condensed molecular films, ice aerosols and molecular clusters. The successful candidate will have the unique opportunity to carry out complementary experiments using a combination of *in situ* infrared spectroscopy, at the Molecular Astrophysics Laboratory (Dawes, School of Physical Sciences) and vacuum ultraviolet spectroscopy (ASTRID2 Synchrotron Facility, Aarhus University, Denmark) using the Portable Astrochemistry Chamber (PAC) – systematically probing the vibrational and electronic states of molecules and reaction products in condensed films (in layers, mixtures and matrix isolation) during thermal and non-thermal (electron and photon) processing, under controlled, reproducible experimental conditions.[1,2] Subsequently, equivalent electron and photon irradiation experiments will be carried out on molecular clusters (typically up to 10 molecules) at the Molecular Clusters Laboratory (Eden, School of Physical Sciences) – with reaction product analysis by mass spectroscopy.[3]

An important application of these investigations is to address the key question in the field of astrochemistry of how to best mimic interstellar icy grains in the laboratory, and to understand the extent to which the macroscopic versus microscopic molecular processes influence the reactivity and formation of COMs. As such, the infrared spectroscopic signatures of macroscopic laboratory molecular films containing COMs will also be compared with those of acoustically levitated microscopic icy aerosol analogues.[4] These data will be valuable for planning and informing observational programmes such as the upcoming 2021 launch of James Webb Space Telescope to probe for COMs in star forming regions.

We seek an enthusiastic and highly motivated candidate with an interest in molecular physics, physical chemistry or astrochemistry and a willingness to learn, develop and integrate a variety of laboratory techniques to acquire and analyse high quality systematic laboratory data. The successful candidate will work in a stimulating and nurturing laboratory research environment within the School of Physical Science and be involved in planning and writing proposals for competitive beam time and participating in experimental runs at international facilities.

References:

1. James, (Dawes) *et al.*, (2020) RSC Adv. 10(61), pp. 37515-37528
2. James, (Dawes) *et al*., (2019) RSC Adv. 9(10), pp. 5453-5459
3. Ghafur, (Eden) *et al.* (2018) J. Chem. Phys. 149, 034301
4. Mason, (Dawes) *et al.* (2008) Faraday Discuss. 137, pp. 367-376

Qualifications required:
The equivalent of a First Class or Upper Second class MSci degree in Physics, Chemistry or related discipline. Previous experience in vacuum technology and experimental techniques such as FTIR and Mass Spectroscopy.