Exploiting JWST to unveil our Icy Universe

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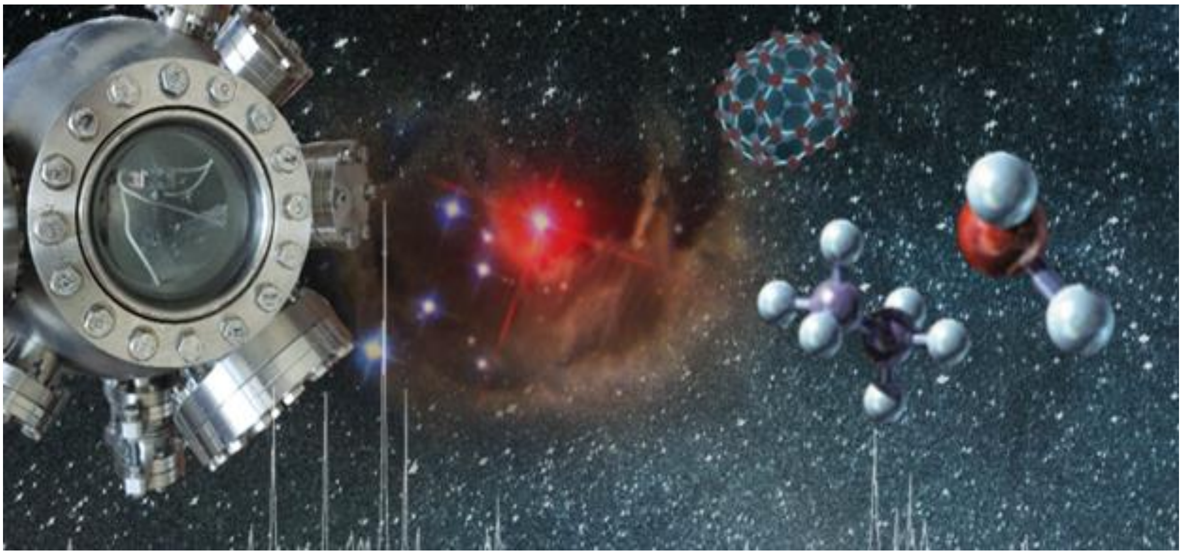

Project highlights:

(a) to map the major, minor, isotopic and ionic interstellar ice species across a range of molecular clouds, probing dense extinct regions, YSOs and their discs as well as cloud edges, to identify their distribution as a function of column density.

(b) to compare ice column densities to gas-phase emission, to test the linkages between gas- and solid-state molecules according to our current astrochemical understanding, and establish ice abundances.

(c) to compare ice abundances with dust emission maps, to test the formation, evolution and destruction of ices as a function of temperature, dust density and local astrophysical conditions.

JWST observations often involve large teams, and this is no exception. We have strong collaborations with a number of worldwide colleagues, particularly at University of Hawaii, STScI in Baltimore USA, Neils Bohr Institute Copenhagen, University of Marseille, Tokyo University and Leiden Observatory. There will certainly be opportunities to travel and work in person with individuals from these institutes / universities during the PhD, learning from the best in the field. Our previous graduates in this field are now either holding academic posts or work in big data applications, showing the skills gained in this PhD field will be highly transferable to many career pathways.

Typically, this PhD would best suit a student with a 4-year integrated Masters level qualification in Physics, Astronomy or Chemistry, experience in Python programming, and an enthusiasm for interdisciplinary research. An interest in astrochemistry, physical chemistry or spectroscopy would certainly be advantageous, as would some past experience (e.g. in a masters research project) of sub-mm or IR observational techniques, including preparing executing reducing and analysing observational data; but most important is an enthusiasm for observational astrochemistry.

Project description:

After hydrogen gas, water ice is the most abundant molecule in the universe. Predominantly the water is found in the form of amorphous ice, in interstellar dense clouds, in combination with many different molecular species, from simple molecules or ions like CO2, CO, SO2, CH3OH, NH3 and OCN-, to the potential presence of complex organic molecules, alongside isotopic ices including 13C and D. The aim of this PhD is to exploit JWST observations of star-forming regions in our own galaxy, to observe the spectra of these ices, and utilise this data to understand the distribution, abundances, formation, evolution and destruction of these solid-state molecules. Ice-mapping (as it is known) is a technique that currently very few groups in the world have attempted, and we previously led the way with the AKARI satellite data. In particular our group studies ices from pre-stellar cores to protoplanetary discs, thereby understanding the chemical "starting points' which set the recipe from which planets moons and atmospheres are formed, probing isotopic ratios and C/O // C/N ratios - to test how the primary elements "for life" C N O (and H) are distributed as the conditions for habitability emerge.

Our group have been working with JWST data since July 2nd 2022! As part of the Early Release Science (ERS) IceAge team, we have focused on NIRCAM WFSS slit-less spectroscopy to probe over 1000 site lines for ice towards the Cha I molecular cloud. We are also involved in two Cycle I proposals looking at ices in Serpens and Oph molecular clouds. Our cycle II data will focus on star-forming regions in Orion as well as follow up from Cha I. Consequently, we have developed skills with the JWST pipelines, and developed our own bespoke software to extract slit-less spectral data. This PhD will build on this development, focusing on the student undertaking ice mapping, in combination with gas-phase sub-mm observations and dust continuum data.

References:

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http://jwst-iceage.org