DUST AND ICE: THE BIRTHPLACE OF NEW MOLECULES IN INTERSTELLAR SPACE

Elena Andra Muntean[1], Tom Field[1], Alan Fitzsimmons[1], Adam Hunniford[1], Pedro Lacerda[2] and Bob McCullough[1]

[1]Department of Physics and Astronomy, School of Mathematics and Physics, Queen's University Belfast, N. Ireland, UK

[2]Max Planck Institute for Solar System Research, Katlenburg-Lindau, Germany

Comets: the time capsules of our Solar System

We all want to know the story of our beginnings and this makes the origin of life one of the biggest questions in science. Comets are small icy bodies which formed alongside the planets and which preserve the record of the material from which the Solar System was born.

Comet 67P/Churyumov–Gerasimenko came into existence at the genesis of our Solar System 4.5 billion years ago. The comet was stored in the outer regions of our Solar System until, recently, it was dislodged by Neptune and began approaching the Sun. The European Space Agency has sent a mission - **Rosetta** - to intercept this comet and study its composition.

How do we replicate extreme conditions in the laboratory?

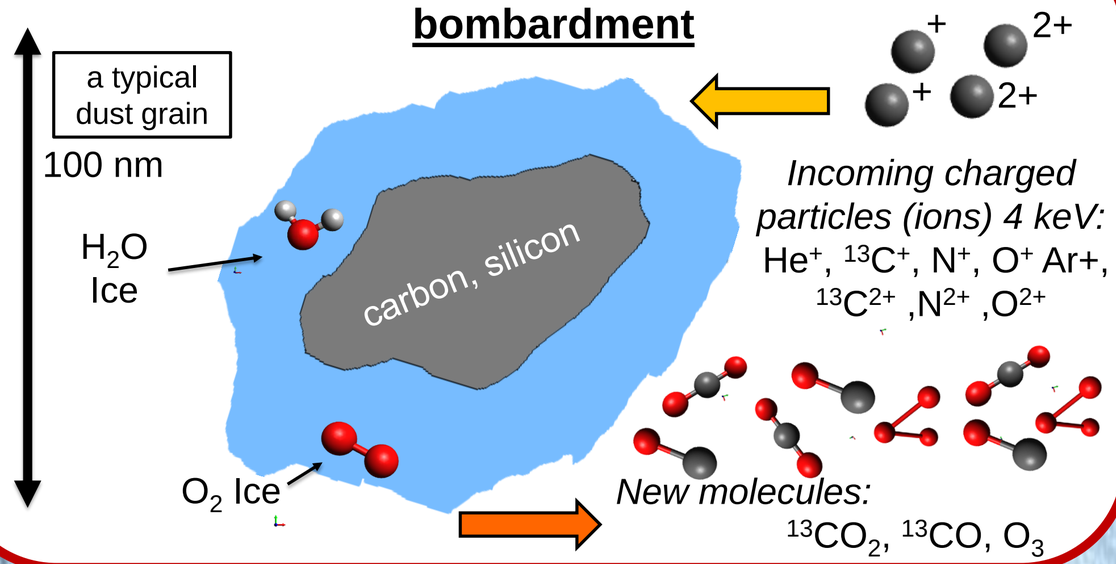
In our lab we have a dedicated experiment that produces ice layers and exposes them to the conditions found in interstellar space:

- *ultra low pressures* (10^{-9} mbar, which is a million times lower than the atmospheric pressure on Earth.)
- *freezing temperatures* of 10 K or -263 ^{o}C

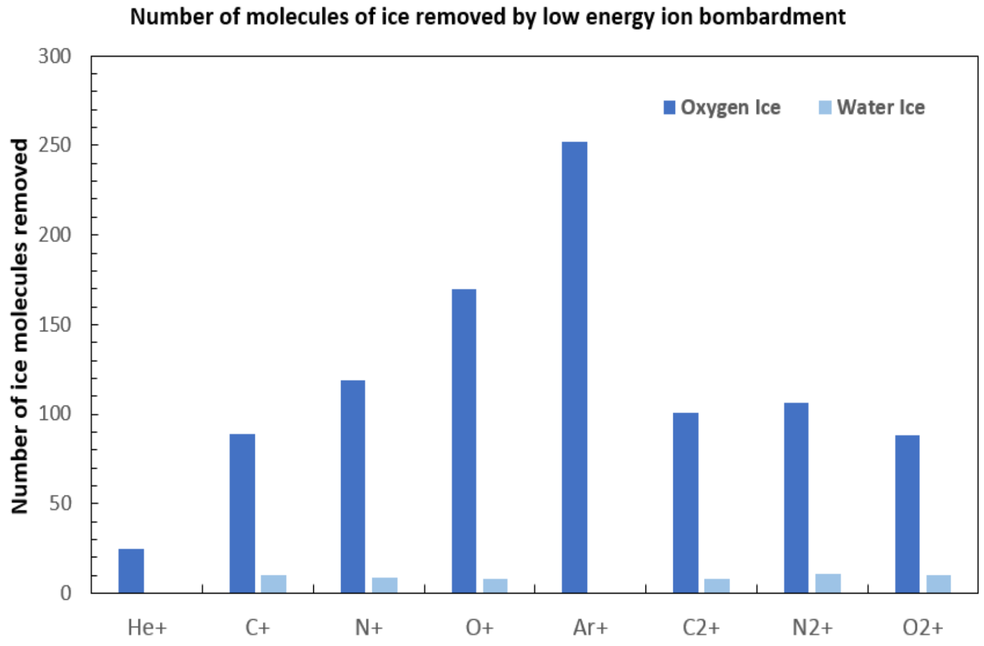
A particle accelerator is used to simulate the cosmic rays and solar wind ions of helium, carbon, nitrogen, oxygen and argon.

- we chose an energy of 4 keV for the charged particles that bombard the water ice and oxygen ice.
- we sometimes remove 2 electrons from these particles, doubling the charge of the particles.

Creation of molecules by bombardment



Yield from oxygen and water ice molecules ejected surfaces by a variety of 4 keV incident ions

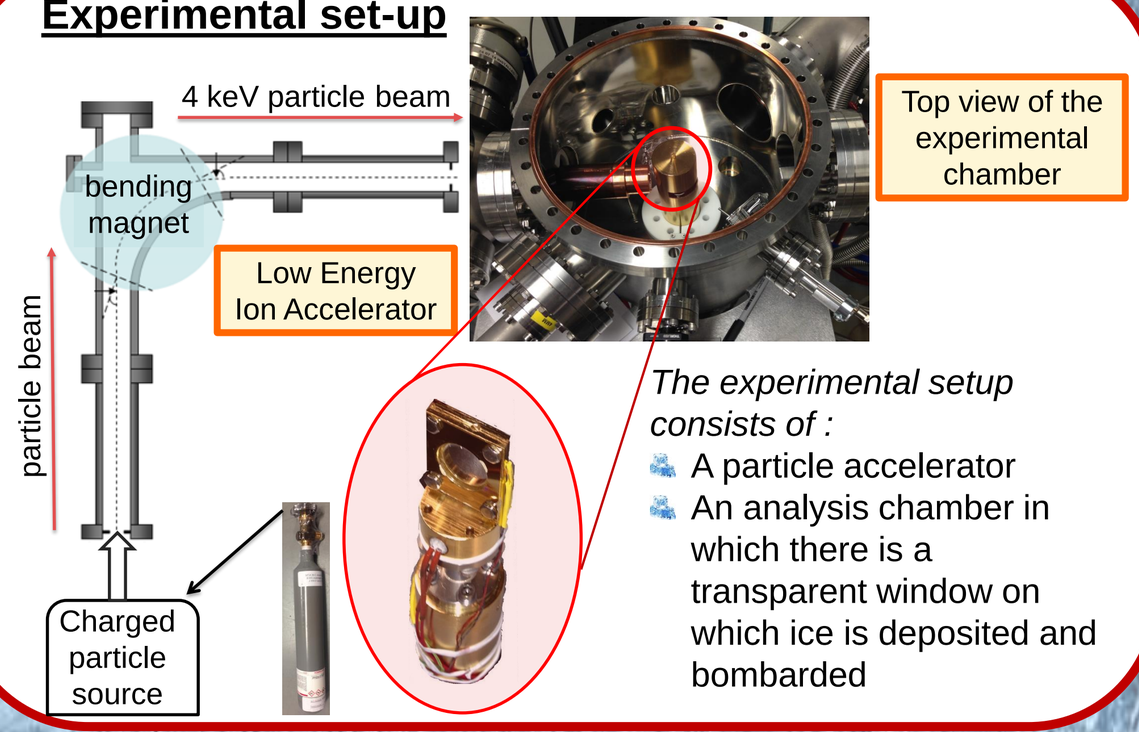


Secrets buried in Ice and Dust

Over 170 chemical species have been detected in space, varying from simple 2-atom molecules to very complex 60-atom structures. A number of these are amino-acids, precursors of DNA, the building blocks of life. This implies remarkable chemistry in regions of space where temperatures are as low as -263 degrees Celsius. **Where did these molecules come from?**

In our search for answers we turned to **ice and dust**. Naturally occurring layers of ice cover planets and their moons, comets, and even small dust particles floating in space. Frozen water is the most common ice, but frozen oxygen is also seen. Mixtures of these different ices are constantly bombarded by various energetic particles due to the solar wind or cosmic rays. Cooked by the incoming particles and heat, this frozen soup becomes the birthplace of new molecules.

Experimental set-up



The experimental setup consists of :

- A particle accelerator
- An analysis chamber in which there is a transparent window on which ice is deposited and bombarded

The results: the formation of molecular stepping stones

Initial results show that bombarding the ice with low energy ions leads to:

1) Molecules being formed as bombardment embeds ions into the ice. Heating -263 ^{o}C oxygen and water ices after bombarding with $^{13}C^+$ or $^{13}C^{2+}$ revealed the formation of O, CO and CO_2. This might explain the presence of these molecules on the surface of moons in the outer solar system.

O_2	+ carbon (+)	⟶	ozone
H_2O	+ carbon (2+)	⟶	carbon monoxide and dioxide
H_2O	+ carbon (+)	⟶	carbon monoxide and dioxide

Thus even at very low temperatures and pressures chemistry can occur and these newly formed molecules are involved in further reactions that may lead to the formation of more complex species, such as amino-acids, the building blocks of life.

2) As shown on the left hand side, a large number of molecules may be ejected from the icy surfaces into space through a process called ***sputtering*.** These ejected molecules may enrich nearby atmospheres, as seen on moons of Saturn and Jupiter. Future work will consist of studying the composition of such sputtered species.

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Queen's University Belfast