Europlanet TA Scientific Report

PROJECT LEADER

Project number: 20-EPN2-070
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TA Facility visited: TA2.11 Atomki Ice Chamber for Astrophysics/Astrochemistry (ICA), Hungary

Project Title: Formation of Glycine and Alanine upon ion irradiation of space relevant ices

Scientific Report Summary.
(plain text, no figures, maximum 250 words, to be included in database and published)

The experiments initially proposed aimed to investigate the formation and chemical evolution of both glycine and alanine under space relevant conditions. Following a systematic approach, the TA was divided into three projects carried out by a multidisciplinary group of scientist (chemists, biologists, astrophysicists and engineers): looking at (i) experimental insights into the microphysics of molecule destruction and sputtering of CO_2 exposed to cosmic rays analogs; (ii) the formation of methyl formate and its isomers (glycolaldehyde and acetic acid) through the systematic irradiation of H_2CO:CO, H_2CO:CH_4, and H_2CO:CH_3OH ice mixtures with 1 MeV and 200 keV H^+; (iii) and 1 MeV H^+ irradiation of pure Glycine and Glycine:CH_4 interstellar relevant ice mixtures, exploring the survivability and stability of this amino acid in astrophysical relevant environments.

The three projects were designed with incremental molecular complexity to investigate the chemistry of many precursors of simple amino acids. Moreover, the sub-projects were designed to be connected to other awarded TAs either at ICA or AQUILA (PIs: Ivlev, Ioppolo, and Hopkinson) in a synergic manner. For instance, the work of H_2CO completes the systematic study on methyl formate and its isomers, started at this Europlanet facility 2 years ago, trying to improve the understanding of the standing dichotomy on the formation of glycolaldehyde, methyl formate, and acetic acid. All these species are detected in space in star-forming regions and are considered prebiotic molecules.

Full Scientific Report on the outcome of your TNA visit

The molecular universe is composed of species that vary in complexity, going from H_2, N_2, and CO to sugars and amino acids. Being glycine (NH_2CH_2COOH) the simplest and one of the most abundant ones observed in space, amino acids have been detected in different astrophysical environments such as comets, meteorites, and dust particles in the Solar System. Oba et al. (2015) showed that surface hydrogen-atom abstraction occurs on the α-carbon of glycine (Gly) under dark cloud conditions in space. Therefore, glycine can be the potential precursor of larger amino acids relevant to life in interstellar dark clouds. Testing the survivability of glycine under space conditions is key to a correct interpretation of observations (Maté et al. 2015). Moreover, previous work showed that, starting from space relevant ice mixtures, UV photolysis can lead to the formation of several amino acids (Bernstein et al. 2022). To understand the formation pathways of this amino acid and other more complex species, the formation routes of their precursors (acetic acid and the other isomers) were studied. The isomers of methyl formate (MF, $C_2H_4O_2$) have significant astrobiological importance. Glycolaldehyde (GA) plays an important role in study of the origin of life as it is one of the simplest monosaccharide sugars, since sugars participate in the formation of the sugar phosphate backbone of DNA and RNA; acetic acid (AA) is considered one of the precursors in the formation of the simplest amino acid, glycine (NH_2CH_2COOH) (Sorrell 2001); and MF, the most abundant of the three isomers in space, is potentially connected to the formation of acetic acid and other complex organic molecules (COMs). Finally, physicochemical insights into the irradiation of simpler precursor species, like CO and CO_2, will enrich our understanding of energetic processing of interstellar ice analogues (Ivlev et al. 2023). For all the aforementioned reasons, the TA was divided in three projects, generating many transnational collaborations involving scientists from the UK, Hungary, Denmark, Germany, and Slovakia.

The interdisciplinary work carried-out during this TA, with applications in astrochemistry, astrobiology, and planetary science, will advance our chemical understanding of formation and destruction of prebiotics in space, helping to resolve the debate on the origin and distribution of their observed precursors in star-forming regions. Infrared spectra were acquired before and after irradiation of CO_2, H_2CO, H_2CO:CO = 1:1, H_2CO:CH_4 = 1:1, H_2CO:CH_3OH = 1:1, glycine, and glycine:CH_4 = 1:4 (layered ice) (See Fig. 1), all experiments being deposited at 20 K. Pure CO2 was exposed to 1.5 and 2 MeV He^+ and He^{++}, and results were systematically compared. The ion energies used for the MF isomer formation experiments through irradiation of H_2CO and its mixtures were 0.2 and 1 MeV H^+. For Gly, only 1 MeV H^+ was used. Data analysis has shown tentative formation of GA and MF after H_2CO:CH_3OH = 1:1 irradiation with 0.2 and 1 MeV H^+ at fluences of $5x10^{13}$ and 10^{14} H^+/cm^2. However, a more in detail analysis needs to be performed to confirm the formation of MF isomers and to understand glycine destruction and its stability.

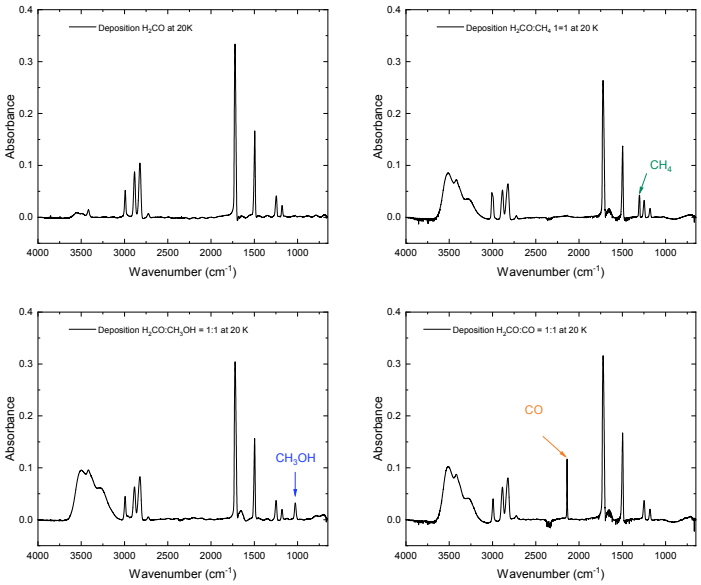

Figure 1: Pure H_2CO and mixed with CO, CH_3OH and CH_4 deposited at 20 K. These ices were irradiated using 0.2 and 1 MeV H^+ up to a fluence of 10^{15} H^+/cm^2.

This data will be used to support the identification of species in the solid phase in space by means of James Webb Space Telescope (JWST). The chemical formation/destruction surface reaction network tested during our research campaign will also help guide and interpret gas-phase observations in the interstellar medium performed by the Atacama Large Millimetre Array (ALMA). All laboratory data generated by the recently carried out research programme will be published in peer-revied high impact journals, and it will be made public and linked to the JWST Ice Age projects (including five other internationally renowned laboratory databases and data compilations) as well as the European VAMDC (http://www.vamdc.org) and the VESPA (http://www.europlanet-vespa.eu/) portals. Spectral data information will be used by the ALMA, JWST, and JUICE astronomy modelling and observational communities to interpret and guide observational data and generate further publications as well as outreach material for the public engagement and awareness of astronomy and space missions (IceAge consortium; McClure et al. 2023).

- Give details of any publications arising/planned (include conference abstracts etc)

Five publications are planned:

- Bombardment of CO_2 Ice by Cosmic Rays. Experimental Insights into the Microphysics of Molecule Destruction and Sputtering
- Electron induced formation of MF and its isomers: a systematic FTIR and VUV spectroscopic study
- Proton induced formation of MF and its isomers: a systematic FTIR spectroscopic study
- A systematic FTIR spectroscopic characterisation of simple and COMs exposed to 1 MeV H+ irradiation
- Glycine stability and survivability in astrophysical relevant environments upon ion and electron bombardment of interstellar relevant ice

- Host confirmation

Please can hosts fill in/check this table confirming the breakdown of time for this TA project:

Dates for travel to accommodation for TA visit (if physical visit by applicant)	Start Date of TA project at facility	Number of lab/field days spent on TA Visit pre-analytical preparation	Number of days in lab/field site for TA Visit	Number of days spent in lab for TA Visit data analysis	End Date of TA project at facility	Dates for travel home (if physical visit by applicant)
Departed: 13/03/2023 Arrived: 13/03/2023	27/02/2023	0	15	0	31/03/2023	Departed: 02/04/2023 Arrived: 02/04/2023

The project was accomplished partly in remote access. Measurements were performed on 27, 28 February and 1, 6, 7, 20, 21, 22, 23, 24, 27, 28, 29, 30, 31.

The host is required to approve the report agreeing it is an accurate account of the research performed.

Host Name	**Dr Zoltán Juhász**
Host Signature	
Date	**08/05/2023**

- Project Leader confirmation

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Project Leader Name	**Alejandra Traspas Muina**
Project Leader Signature	
Date	7/04/2023