EPSC Abstracts
Vol. 14, EPSC2020-950, 2020
https://doi.org/10.5194/epsc2020-950
Europlanet Science Congress 2020

Ion and electron impact studies on astrophysically relevant ices: a new laboratory at Atomki in Debrecen

Péter Herczku[1], Zoltán Juhász[1], Sándor T. S. Kovács[1], Béla Sulik[1], Sergio Ioppolo[2], Nigel J. Mason[3], Duncan V. Mifsud[3], Alejandra Traspas-Muina[3], Máté Czentye[3], Zuzana Kanuchová[4], Béla Paripás[5], and Robert W. McCullough[6]

[1]Institute for Nuclear Research, Atomic and Molecular Physics, Hungary (herczku.peter@atomki.hu)
[2]Queen Mary University of London, Mile End Road, London E1 4NS (UK)
[3]School of Physical Sciences, The University of Kent, Canterbury, CT2 7NH (UK)
[4]Astronomical Institute of the Slovak Academy of Sciences, 059 60 Tatranska Lomnica (The Slovak Republic)
[5]University of Miskolc 3515 Miskolc-Egyetemváros, Hungary
[6]School of Mathematics and Physics, Queen's University Belfast, University Road, Belfast, BT7 1NN (UK)

Understanding how complex organic molecules (COMs) form, survive under space conditions and are then delivered to planetesimals in Solar-like systems is a key step to unravelling the origin of the life on Earth [1]. From dedicated laboratory studies it has become clear that the large molecular inventory observed in space cannot be formed efficiently in the gas phase. Interstellar dust grains provide surfaces on which gas-phase species can accrete, collide and react, and to which they can donate excess energy. Therefore, in dense interstellar clouds, icy dust grains act both as a molecular reservoir and as sites for catalysis [2]. For decades, surface complex molecule formation has been thought to be triggered largely by energetic processing, e.g. photon, electron and cosmic ray bombardment of ice dust grains [3]. Similarly, the rich inventory of molecules found by the Rosetta mission in the surface ices of comet 67P/Churyumov–Gerasimenko [4] and the increasing studies of composition of ices on planetary bodies (e.g. Saturnian and Jovian moons, Pluto, Charon and Kuiper belt objects) all suggest molecular synthesis by irradiation by ion bombardment. However, comprehensive laboratory studies of such ice analogues systematically exposed to a wide range of ions and energies remain fragmentary and often contradictory. Further laboratory work is therefore pivotal to our understanding of the chemical and physical processes in the ISM and on planetary bodies of the Solar System to interpret data from past, present and future space missions (e.g. JWST, JUICE).

At Atomki in Debrecen, Hungary, we have recently commissioned a new ion beamline dedicated to exploring the processing of complex molecular ices found in the interstellar medium and Solar System. It is a Transnational Access facility for the EUROPLANET 2024 Research Infrastructure Project and is therefore open to the international research community (https://www.europlanet-society.org/europlanet-2024-ri/ta2-dplf/ta2-facility-11-atomki-ice-chamber-for-astrophysics-astrochemistry-ica/). High current beams can be provided from H to a wide range of heavy ions with the kinetic energy of 0.2 – 20 MeV. The Ice Chamber for Astrophysics/Astrochemistry (ICA) at Atomki is designed to investigate the effect of ion irradiation of astrophysically relevant ices deposited on a series of cold substrates (20-300 K) vertically mounted on a copper holder connected to a closed cycle cryostat, a 360° rotation stage and a z-linear manipulator. The ice layers are created through background deposition of gases, both pure and mixed, which are prepared in a high vacuum dosing-line and introduced in the main chamber by means of an all leak metal valve not facing the sample holder. The ice structure can be crystalline or amorphous depending on the chosen temperature during deposition. The apparatus is currently being upgraded in order to study cold layers of more complex organic molecules produced by an effusive evaporator.

The ice composition grown on an infrared transparent substrate and the physico-chemical changes induced upon ion irradiation are monitored by a FTIR spectrometer in transmission mode. Using metallic substrates, reflection mode is also possible. Ions of different species and charge states mimicking the effects of cosmic rays and stellar wind are produced by a Tandetron accelerator. The ICA chamber is also equipped with an electron gun, which provides electron beams of a few microamps in the 5 eV – 2 keV energy range. Sequential and/or simultaneous irradiation by ions and electrons is an available option for studying radiation synergies. Temperature programed desorption (TPD) studies can be performed on both non-irradiated and irradiated ices. The desorbed molecules during irradiation and TPD experiments are monitored by a quadrupole mass spectrometer, while chemical and morphological changes in the ice can be followed "in situ" by using the FTIR spectrometer. At the conference, we will present the preliminary results of the e^-, H^+ and S^{2+} impact on pure methanol ice and some other ice mixtures deposited at 20 K as a function of a wide range of energies and beam fluxes. We will further discuss how the induced chemical changes strongly dependent on the studied parameters.

Acknowledgment Europlanet 2024 RI has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871149. The enthusiastic help from the Atomki Tandetron accelerator staff both in preparation and experiments is gratefully acknowledged.

References

[1] E. Herbst, and E. F. van Dishoeck, Complex organic interstellar molecules,Annu. Rev. Astron. Astrophys. **47** (2009), 427-480

[2] A. C. A. Boogert, P. A. Gerakines, and D. C. Whittet, Observations of theicy universe, Annu. Rev. Astron. Astrophys. **53** (2015), 541-581

[3] M. A. Allodi, R. A. Baragiola, G. A. Baratta, M. A. Barucci, G. A. Blake,Ph. Boduch, J. R. Brucato, C. Contreras, S. H. Cuylle, D. Fulvio, M. S.Gudipati, S. Ioppolo, Z. Kanuchová, A. Lignell, H. Linnartz, M. E. Palumbo, U. Raut, H. Rothard, F. Salama, E. V. Savchenko, E. Sciamma-OBrien, G.Strazzulla, Complementary and emerging techniques for astrophysical icesprocessed in the laboratory, Space Sci. Rev., **180** (2013) 101

[4] Altwegg, Kathrin; et al. (27 May 2016). Prebiotic chemicals—amino acid and phosphorus—in the coma of comet 67P/Churyumov-Gerasimenko. Science Advances. 2 (5): e1600285. Bibcode:2016SciA....2E0285A. doi:10.1126/sciadv.1600285. PMC 4928965. PMID 27386550.