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Triggering photochemical processes in frozen extraterrestrial worlds by soft X-rays

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Synopsis We presents and experimental investigation on the effects produced by broad band soft X-rays (combined with a small fraction of vacuum ultra violet photons and possibly secondary electrons) on the surface of three moons of giant planets: Europa, Titan and Enceladus. Such environments are constantly exposed to space ionizing agents (UV and soft X-rays photons, electrons and ions) allowing photodissociation processes, surface photochemistry and prebiotic chemistry. The processing of such spatial ices have promoted an enhancement in the chemical complexity, similar what may have happened in the early earth triggering the arising of life.

In this work, we investigate the effects produced mainly by broad band soft X-rays (and X-ray-induced secondary electrons) in ice mixtures that simulates the surface of three moons of giant planets: Europa, Titan and Enceladus. Such environments are constantly exposed to space ionizing agents (UV and soft X-rays photons, electrons and ions) allowing photodissociation processes, surface photochemistry and prebiotic chemistry.

The experiments have been performed using a high vacuum portable chamber from the Laboratório de Astroquímica e Astrobiologia (LASA/UNIVAP) coupled to the SGM beamline in the Brazilian Synchrotron Light Source (LNLS) at Campinas, Brazil. The beamline was operated in off-focus and white beam mode, which produces a wide band spectral range of photons, mainly from 6 eV up to 2000 eV, with the total average flux at the sample of about 1E14 photons cm^{-2} s^{-1}.

Briefly, the samples were produced by the adsorption of a gaseous mixture at 12 K and following by slowly heating to the temperatures in which the irradiation occur, simulating this way the frozen surface of an specific moon of a given giant planet: a) H_2O:CO_2:NH_3:SO_2 (10:1:1:1) at 90 K for Europa, moon of Jupiter; b) N_2:CH_4 (19:1) at 12 K for Titan, moon of Saturn, and c) (H_2O:CO_2:CH_4:NH_3) (10:1:1:1) at 80 K for Enceladus, another moon of Saturn. For experiment b, we simulate the effect of incoming radiation in the aerosols in the upper atmosphere of Titan. *In-situ* sample analyses were performed by Fourier transform infrared (FTIR) spectrometer. Complete experimental description is given elsewhere [1].

The spectral analysis of the processed samples shows several new bands associated with the formation of organic molecules, including nitriles, hydrocarbons, acids and other organic compounds. The dissociation cross sections of parental species were in the order of 10^{-18}-10^{-19} cm^2. Half-lives of the parental species extrapolated to the astrophysical scenario was determined. In case of Europa´s experiment, we observe the presence of H_2O_2, H_3O^+, SO_3, CO, and OCN^- among the new species produced. For the experiment simulation aerosols in Titan, we identify the formation of HCN, HNC, CCCN, NH_3 and C_2H_2. Such molecules possibly will be deposited into the ground and increase the chemical complexity of the surface with time. The irradiation of Enceladus like surface shows as daughter species, OCN^-, H_2CO and CO among others

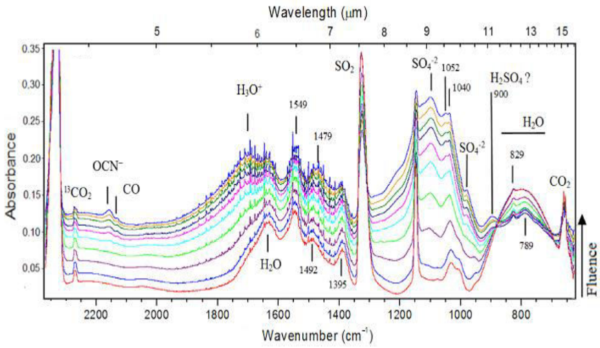

Figure 1. Evolution of IR spectrum of the simulated Europa´s surface at 90 K during the irradiation. Bottommost curve is the unirradiated spectrum. Adapted from [1].

References

[1] Pilling S. & Bergantini A., 2015, *MNRAS, Submitted.*

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