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Methyl formate ice stimulated by X-rays in protoplanetary discs

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Synopsis We study experimentally the processes of photoionization, photodissociation and photodesorption in methyl formate ice due to interaction of soft X-rays at two energy ranges, from 284 to 298 eV and from 528 to 546 eV, around the C 1s→π* and O 1s →π* resonances. The photodesorption ion yield was obtained for some of the desorbed species of the ice surface, like CH^+, HCO^+ and H_3CO+. The extrapolation of these results to an astrophysical environment, as the protoplanetary disc of TW Hydrae star, is presented

Methyl formate, HCOOCH3, is a molecule widely detected in the circumstellar medium. In regions of protoplanetary discs at low temperatures, molecules freeze forming a mantle of ice on surfaces of dust grains. The interaction of radiation emitted by the central protostar with this mantle stimulates ionization, dissociation and desorption favoring the formation of more complex species. The abundance of a given species, ionized or neutral, in these environments depends on the rate of formation, destruction and desorption from the surface of the grains.

We have studied experimentally the photodissociation, photoionization and photodesorption processes of methyl formate ices (130 K) stimulated by X-rays at two energy ranges, from 284 to 298 eV and from 528 to 546 eV, around the C 1s → π* and O 1s → π* resonances, respectively. The experiments were performed at the Brazilian Synchrotron Light Laboratory (LNLS) in the single bunch mode, using the Spherical-Grating Monochromator beamline and applying the time-of-flight mass spectrometry technique. Fifteen ionic fragments were identified in mass spectra, and the more abundant species were H^+, CH^+, CH_3^+, CO^+ and CH_3O^+, corresponding to around 85% of all fragments produced by the irradiation with 270 and 535 eV X-rays; the dissociation pathways were proposed.

These experimental data were then applied to determine the values of relevance to the astrochemistry in the conditions of the protoplanetary disc of the TW Hydrae star. This star has a dense disc and presents X-ray luminosity integrated from 0.2 to 2 keV of 10^{30} erg s^{-1}. The X-ray photon flux of the TW Hydrae disc was evaluated based on the disc density structure, the luminosity of the protostar and considering molecular hydrogen attenuation. For example, a photon flux of 6×10^8 photons cm^{-2} s^{-1} was estimated at 537 eV at a distance of 40 au from the central star [1]. The photodesorption ion yields of the relevant ionic species, H^+, CH^+, CH_3^+, HCO^+, CH_3O+, CH_3OH^+ and $COOH^+$, were extracted, as shown in figure 1. The column densities of these species considering both ions production and destruction rates, were determined and, for instance, the H^+ and HCO^+ column densities compared with values from other protoplanetary discs [2]. The half-life of methyl formate as function of the distance from the central star was determined and, in this context, the survival of the molecule in the circumstellar medium will be discussed.

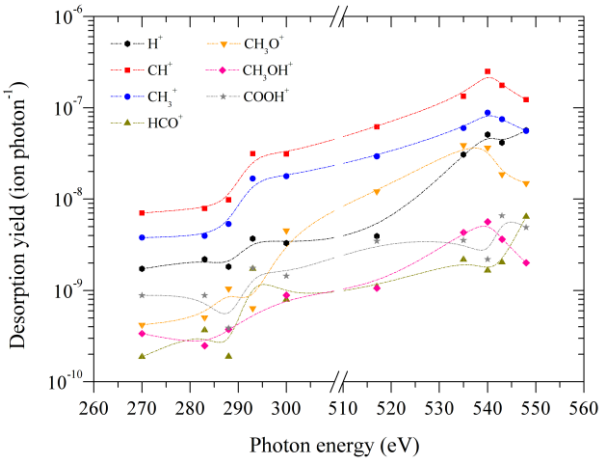

Figure 1. Photodesorption ion yields (ion/photoion) as function of the X-ray energy (eV) around the C1s and O1s edges for H^+, CH^+, CH_3^+, HCO^+, CH_3O+, CH_3OH^+ and $COOH^+$ ions.

References

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