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Ion irradiation of astrophysically relevant frozen mixtures with INGMAR-T

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Abstract. Laboratory experiments are essential to support the interpretation of astronomical observations and space mission data. Here we present a new experimental setup to characterize in the Vis-MIR range in both reflection and transmission modes astrophysically-relevant frozen volatiles deposited at low temperature and exposed to ion bombardment.

Keywords. astrobiology, astrochemistry, methods: laboratory, comets: general, solar system: formation, (ISM:) cosmic rays, ISM: molecules

1. Introduction

During their lifetime(s), frozen species in icy grain mantles, cometary and trans-neptunian object surfaces are exposed to cosmic rays, UV photons and solar/stellar winds that modify their chemical composition and physical structure. In fact, energetic processing determines the breaking of molecular bonds, the formation of radicals and unstable species that recombine to form new species (e.g., Rothard et al. 2017). Laboratory experiments allow to investigate the effects of energetic processing (e.g., Strazzulla et al. 2001, Brunetto et al. 2006, de Marcellus et al. 2016, Lantz et al. 2017, Urso et al. 2018). We present the INGMAR-T (from the French acronym *Irradiation de Glaces et Météorites Analysées par Réflectance-Transmittance Vis, near et mid IR*, IAS/CSNSM, Orsay, France) experimental setup that allows to study frozen volatiles at low temperature and the effects of ion bombardment in the Vis-MIR range in both reflection and transmission modes.

2. Experimental methods

Gaseous mixtures are introduced in a vacuum chamber (P$\leqslant 10^{-7}$ mbar) where they condense on a substrate in thermal contact with a cryocooler (15-300 K). To simulate the effects induced by low-energy cosmic rays and solar wind ions on the physical and chemical properties of ices, the frozen films are bombarded with 40 keV ions produced with the SIDONIE ion source (IAS-CSNSM), with doses (i.e., the energy absorbed by the target) between a few and about 100 eV/molecule. After irradiation, samples are warmed-up to about 300 K. Throughout the heating, volatiles sublimate and further reactions take place. Depending on the deposited mixture, an organic refractory material might survive at room T (e.g., Urso et al. 2017). INGMAR-T allows to perform in-situ Vis-NIR reflectance and Vis-MIR transmittance spectroscopy, covering a range between 0.4 and 14 μm (25000-700 cm^{-1}). Figure 1 shows the INGMAR-T setup and a schematic view of the vacuum chamber with the geometry used for the irradiation and spectroscopy.

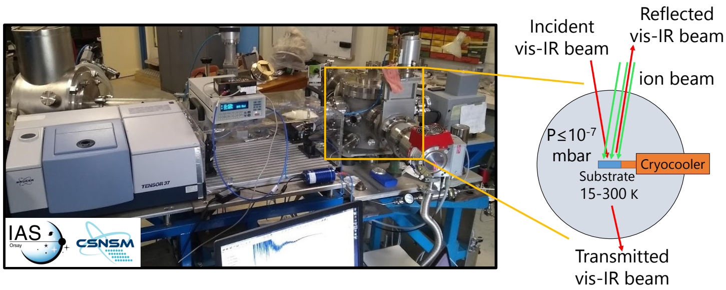

Figure 1. The INGMAR-T setup. Left: FT-IR and INGMAR-T connected to the SIDONIE ion source; right: schematic view of the chamber.

3. Results and future perspectives

To present time, we irradiated and warmed-up mixtures containing H_2O, CH_3OH and NH_3. The ongoing analysis confirms that ion irradiation determines evident changes in the samples and various new features are distinguished after the bombardment, such as those attributed to CO_2 (2340 cm^{-1}), CO (2140 cm^{-1}), and OCN^- (2160-2200 cm^{-1}) together with other bands due to the formation of more complex species. Vis-NIR spectra are acquired to study variations in the samples due to irradiation and warm-up, in order to support the interpretation of observations toward solar system small bodies (Urso, Brunetto et al., in prep.). Furthermore, both punctual analysis and mapping of residues are performed with IR and Raman micro-spectrometers available at the SMIS beamline (Dumas et al. 2006) of the SOLEIL synchrotron (Saint-Aubin, France). The experiments performed with the INGMAR-T setup provide high resolution spectra to support the interpretation of data that will be collected by the James Webb Space Telescope toward star-forming regions and by the instruments on board space probes to solar system small bodies (e.g., Hayabusa-2, OSIRIS-REx, New Horizons).

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