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Laboratory Study of Halomethanes in Ices to Understand Recent CH_3Cl Protostellar and Cometary Observations

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The recent detection of chloromethane, CH_3Cl, around the low-mass protostar IRAS 16293-2422 using ALMA, and in the coma of comet 67P/Churyumov-Gerasimenko with ROSETTA (Fayolle et al., 2017) has provided some new insights on the extent of the chemical complexity that develop before planet-formation. Halogen interstellar chemistry was until recently limited to atoms and simple species such as HCl, HF,... mostly found in the diffuse interstellar medium but the presence of organohalogens is evidence of the link between halogen and organic interstellar chemistry. The detection of these species around both objects highlights the link between protostellar chemistry and the composition of outer planetary system bodies. It also implies that future CH_3Cl detections in exoplanet atmospheres may not be a biomarker, as previously suggested, since it could be inherited from abiotic formation pathways prior to or during planet formation.

To understand the origin of halomethanes and other organohalogens in protostellar environments and the potential inheritance of these species into planet-forming regions, laboratory studies are needed to measure their spectroscopic signatures and constrain their solid-gas partioning. We experimentally formed halomethane-containing ices by depositing gas mixtures onto a cryogenically microbalance and an IR transparent window adapted into a vacuum chamber. The thicknesses and densities of these ices formed at or brought to various temperatures are measured using laser interferometry with He-Ne lasers (e.g. Westley et al. (1998)). Mid-IR absorption spectra are recorded with an FTIR spectrometer and used to derive band strengths (e.g. Hudson et al. (2017)). The desorption energies are obtained by linearly warming up the ice films onto the microbalance, recording the ice loss, and analyzing the gas composition with a quadrupole mass spectrometer (e.g. Luna et al. (2017)).

Here we present the spectroscopic and desorption data for CH_3Cl, CH_3F and other halomethanes in pure ices, mixed with H_2O, and onto amorphous water ice. The spectroscopic data can be used to search for their presence in interstellar ice observations and the desorption energies can be used as inputs for astrochemical to predict their emission in the gas phase in protoplanetary environments. The desorption energies of CH_3Cl are consistent with its gas phase detection in the lukewarm gas (T 80-100K) around the low-mass protostar. The lower desorption temperature measured for CH_3F implies, if formed onto icy grains, its presence in the gas at lower temperature and in a more extended region around young stellar objects, which is consistent with the upper limit found by the ALMA interferometer. We hypothesize on the formation route of halomethanes in the solid state, and propose future experiments to test the various scenarios. These include halogenation of small organic radicals, reaction of the CH_3 radicals with hydrogen halides (HX) in the solid, or with halogen molecules and salts found in interstellar dust.

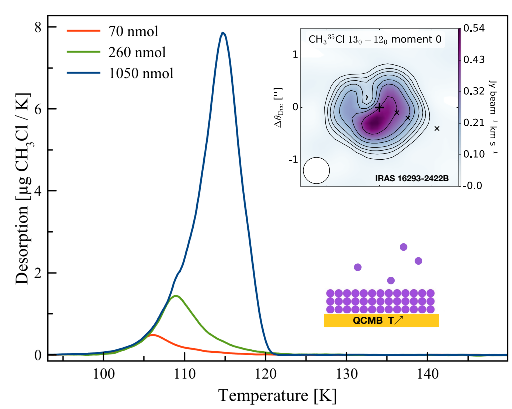

Figure 1: Desorption of pure CH_3Cl ice films measured by a quartz crystal microbalance linearly warmed up at 2 $K.min^{-1}$. The insert shows the emission of a CH_3Cl through one of its rotational line around the low-mass protostar IRAS 16293-2422B.

References

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