

## Formation of complex molecules on cold surfaces

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Interstellar Complex Organic Molecules (iCOMs) are considered as the building blocks of more complex pre-biotic compounds. In particular, formamide (NH<sub>2</sub>CHO), widely observed in different astrophysical media, is thought to be the starting point of some emblematic metabolic and genetic species (Saladino et al. 2012). Formamide formation through Gas Phase route exists (Barone et al 2015, Codella et al 2017), even if it is still debated, but solid-state chemistry should also be a vector of the molecular complexity observed in later phases of the matter evolution, such as in comets and meteorites.

Our group aims at understanding how the molecular complexity may increase on cold surfaces, from atoms or molecules, without the help of others external energetic agents (photons, electrons, ions...). During the last few years we have developed a new experimental facility (named VENUS) to study the different non-energetic pathways of solid-state astrochemistry.

During my presentation I will show how we can constrain the penetration depth of H and O through molecular ices (e. g. H<sub>2</sub>O, NO, H<sub>2</sub>CO). Penetration actually occurs at a negligible rate in comparison with other surface processes (diffusion and self reaction) (Minissale et al, Sow et al in prep.). Thus, I will present evidence that formamide can also be formed very efficiently following solid-state chemical pathways (Nguyen et al, in prep.).

Finally, I will give few example of how we can nowadays determine the chemical networks (including the evaluation of barriers, and type of reaction) of specific chemical solid state systems, such like the hydrogenation of NO (Nguyen et al, in prep.), combining complete sets of experiments with state-of-the-art calculations of quantum chemistry.