Formation of complex molecules on cold surfaces

F. Dulieu¹, T. Nguyen¹, E. Congiu¹, S. Baouche¹, A. Sow¹, M. Minissale¹,² J.C. Loison³, D. Talbi⁴.

¹LERMA, Université de Cergy-Pontoise, Sorbonne Université, Observatoire de Paris, PSL University, CNRS, LERMA, F-95000, Cergy-Pontoise
²PIIM, Institut Fresnel, Aix-Marseille Université, F-13013 Marseille
³ISM – Université de Bordeaux – CNRS, UMR 5255, F-33405 Talence Cedex,
⁴Laboratoire Univers et Particules de Montpellier, UMR 5299 - Université Montpellier 2, F-34095 Montpellier cedex 05

Interstellar Complex Organic Molecules (iCOMs) are considered as the building blocks of more complex pre-biotic compounds. In particular, formamide (NH₂CHO), 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. H₂O, NO, H₂CO). 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.