Research project: Physics and Chemistry on the surface of interstellar grains

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Hosting institute: LERMA-CERGY Lab, Cergy-Pontoise University

Dr KAMEL GADALLAH has been invited to work on his post-doc research project during this interval with the LERMA team « Reactivity on Cold surfaces » located in the University of Cergy Pontoise. https://lerma.obspm.fr/spip.php?article48

SAMMARY of the project

Now in laboratory astrophysics, we have the instruments that enable us to determine how molecular complexity grows up in space, at its first stages. It is very important to understand where molecules come from? How and where did they form? What do they tell us about stars and planets formation? And last, but not least, atoms and molecules are the remote thermometers and barometers, as their observed line spectra can and are used to extract a mine of precious and often unique information. In the complex tree of the chemical evolution of the Universe, starting from the core of stars to our planetary biosphere, our project focus on the small link of the transformation of atoms into molecules, such like complex organic molecules (named COMs by astronomers).

Unfortunately, the birth-place of the molecular complexity remains almost invisible, as complex molecules are possibly synthesized and likely frozen on the surface of micron-sized cold dust particles, veritable nano-factories of our molecular Universe. Therefore, only laboratory astrophysics can help to understand this frozen micro/nano world.

There are at least two possibilities to explain the observed molecular complexity in the interstellar medium (ISM): either COMs are formed on the gas or they are synthesized on the grain surfaces (e.g. Garrod & Herbst 2006; Balucani et al. 2015). Very likely, both mechanisms are important even though in different stages and for different molecules, and the permanent exchange between solid and gas phases is also central (Dulieu et al. 2013). The dust grains have very cold surfaces where gaseous species can accrete, diffuse and react, and have some specific catalytic properties, but the release of solid species in the gas phase is the key of many observations like for comets or star forming regions. Our project focusses on the solid-state chemistry, and its exchanges with the gas phase, were molecules are more easily observed, and/or can generate new chemical branches starting from molecules released from the solid phase. It is devoted to laboratory astrophysics and its link with the models and observations.

Methanol is chosen as one of the complex molecules in space to show the physical and chemical complexity of such a complex molecule on cold grain surface. We aim to study the reactivity of Methanol on different surfaces at low temperatures as one of the complex molecules deposited on icy dust grains in space. It has an important role in the surface chemistry on ice-dust surface in space during the formation and deformation processes of other complex molecules. Its role can be explained by studying several points of research, we consider only two points of them.

i) ***the sticking of methanol on ice surfaces***; It was necessary to know how much molecules of methanol can stick on the cold surface, how long they stay on the surface during the thermal desorption which is considered as one of the physical mechanisms taking place on ice in space. For this point we plan to study the sticking of methanol as a function of the surface temperature (7-40 K) in ultra-high vacuum on different underlayers of gold surfaces and ice layers of CO and H_2O when these layers work as underlayer surfaces to mimic the case in space. In which, the mantle of dust grain ice contain water mixed with a lot of CO and others.

ii) ***Hydrogenation or H-irradiation of methanol on ice surfaces:*** It is another process that occurs of the solid methanol molecules in space. In the ISM, the ice dust mantle that contains a reservoir COMS is the reactive surface that hold the chemical complexity of COMs and it works a substrate layer of their reactivity. Many experiments will be conducted to simulate this process. It is expected that the H-irradiation of methanol has an impact on the amount of the desorption of methanol after hydrogenation as a function of the surface temperature on different cold surfaces of gold, ^{13}CO and water ice layers.

To achieve this work, LERMA lab at Cergy Pontoise Univesity has two very interesting ULTRA-HIGH vacuum systems (VENUS and FORMALISM). VENUS system is used to conduct our experiments. The apparatus of this system is connected to several operating system such as heating, cooling, and pumping systems in addition to several devices such as the QMS and IR spectrometer. it is possible to reach suitable physical conditions of the ULTRA-HIGH vacuum. In this system, there are five lines of the gas injections into the vacuum chambers where the beam lines pass throughout three chambers to reach the sample holder. These lines were formerly calibrated for each beam and background lines before doing the deposition of Methanol.

Physically, both the TPD and RAIRs measurements will be used to follow the desorption of methanol molecules under the conditions of mechanisms of the sticking and H-irradiation. These two mechanisms have an impact on the chemistry of COMs in interstellar space and hence on their enrichments into the gas phase chemistry in relevance to their depletion.

References

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