Silicate dust surface effects on H_2 formation: rotational temperature and nuclear spin conversion

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We have studied how silicate dust influences the formation of molecular hydrogen and how newly formed molecules are thereby affected by dust. In a joint collaboration, silicate analogs have been produced via laser ablation [1]. These dust grains are then processed to simulate inter- and circumstellar media conditions, providing extremes in: structure (fully crystalline or amorphous grains), and stoichiometry (the forsterite and fayalite end-members of the olivine family) [3-8].

These dust samples are then inserted in FORMOLISM, an ultra-high vacuum setup where they are cryogenically cooled (down to 5 K). Atomic beams are directed at the dust surfaces and the formation of new molecules is studied via REMPI(2+1) spectroscopy. With this technique, we explored the vibrational levels v"= 0 and 4 of the ground electronic state of H_2. These results are compared to those from the first silicate sample used in this setup, prepared by thermal deposition [2].

Surprisingly, the rotational structure of H_2 molecules following scattering on amorphous and crystalline grains is different. These results complement surface science studies usually performed on single crystal surfaces, and hint at the major role of surface structure. In addition, first-of-its-kind experiments have been performed to address the conversion of the nuclear spin of hydrogen on dust. These experiments had only been previously performed on icy surfaces. We deposited hydrogen molecules on both the Mg and Fe- rich dust surfaces and detected nuclear spin conversion in the presence of metallic oxides.

Because gas phase collisions are inefficient to form molecules in space, dust surfaces increase the atomic interaction timescale. We demonstrate that their structure and chemical composition affect the molecules that form on them and interact on their surface. We conclude that the analytic characterization of dust analogs is vital for our further understanding of the internal structure of molecules in space.

References:

[1] T. Sabri, L. Gavilan, C. Jäger, J. L. Lemaire, G. Vidali, and T. Henning. ApJ (2013) *submitted*
[2] Djouadi Z., D'Hendecourt L., Leroux H., Jones A. P., Borg J., Deboffle D., Chauvin N., 2005, A&A, 440, 179
[3] J.L. Lemaire, G. Vidali, S. Baouche, M. Chehrouri, H. Chaabouni, H. Mokrane, ApJ Letters 725 (2010) 156
[4] J.L. Lemaire, Global Journal of Physical Chemistry, 2 (2011) 189
[5] M. Chehrouri, J-H. Fillion, H. Chaabouni, H. Mokrane, E. Congiu, F. Dulieu, E. Matar, X. Michaud, J.L. Lemaire. Phys. Chem. Chem. Phys. 13 (2011) 2172
[6] H. Chaabouni, H. Bergeron, S. Baouche, F. Dulieu, E. Matar, E. Congiu, L. Gavilan, and J. L. Lemaire. A&A 538 (2012) 128
[7] L. Gavilan, J. L.Lemaire, G. Vidal., ScienceJet C 2012, 1:4
[8] L. Gavilan, J. L. Lemaire, G. Vidali. MNRAS (2012) 424 2961
[9] L. Gavilan, G. Vidali, J.L.Lemaire, M. Chehrouri, F.Dulieu, J.H. Fillion, E. Congiu, and H.Chaabouni. ApJ 760 (2012) 35