Interstellar Complex Organic Molecules in the NGC 1333 IRAS 4A Outflows.

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The interstellar Complex Organic Molecules (iCOMs) are considered as the small bricks from which more complex and prebiotic molecules may build up. Although iCOMs have been detected in solar-type forming planetary systems since almost two decades [1], their formation is still matter of debate. Two main approaches of the iCOMs formation are invoked [2]: a direct formation on the icy mantle of the dust grains [3], or through the reaction in gas phase of species released from grain frozen mantles [4].

The shocked gas along jet-driven outflows driven by low mass protostars turns out to be a precious environment to study the iCOMs formation. In fact, the grain mantles components are sputtered into the gas phase at the passage of the shock, changing immediately the gaseous chemical composition which evolves towards a new equilibrium. The new gas chemical composition varies as a function of time and species injection, which makes the shocked sites potential chemical laboratories where theories and models can be tested. The method has been successfully applied to the prototypical L1157-B1 shocked site [5], which remains so far unique in its detected chemical richness [6]. In this work, we studied the IRAS 4A multiple outflows in the Perseus NGC 1333 star forming region.

As part of the Large Program IRAM/NOEMA SOLIS (Seeds Of Life in Space: [7]) we imaged the large scale (>1') bipolar outflows driven by the IRAS 4A protobinary system. The new SOLIS observations detected, for the first time in the IRAS 4A outflows, several iCOMs, in particular methanol (CH3OH) and acetaldehyde (CH3CHO). Interestingly, we found a significant chemical differentiation between the outflow driven by IRAS 4A1 and the one of the hot corino IRAS 4A2, with the former being richer in iCOMs than the latter.

In order to understand the origin of this differentiation we used the gas-grain model GRAINOBLE+ (upgraded version of GRAINOBLE, [8]) and compared its predictions with the SOLIS observations. This comparison suggests that the IRAS 4A1 outflow is younger than the IRAS 4A2 one and that acetaldehyde is formed mainly through the gas phase reaction of CH_3CH_2 and atomic oxygen.

Therefore, with this work we confirm the great diagnostic power of multi-line multi-species studies towards protostellar shocked sites.

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