Formation, Abundance Distribution and Evolution of Complex Organic Molecules in Starless/Pre-stellar Cores

Izaskun Jimenez-Serra[1], Anton I. Vasyunin[2], Andres Megias-Toledano[1], Silvia Spezzano[3], Paola Caselli[3], Giuliana Cosentino[4], and Serena Viti[5]

[1]*Centro de Astrobiologia (CSIC-INTA), Ctra. de Torrejon a Ajalvir km 4, 28850, Torrejon de Ardoz, Spain*

[2]*Ural Federal University, Kuybysheva st. 48, 620002, Ekaterinburg, Russian Federation*

[3]*Max Planck Institute for Extraterrestrial Physics, Giessenbachstrasse 1, 85748, Garching, Germany*

[4]*Chalmers University of Technology, SE41296, Gothenburg, Sweden*

[5]*University of Leiden, Niels Bohrweg 2, 2333 CA, Leiden, The Netherlands*

Observations carried out toward starless and pre-stellar cores have revealed that complex organic molecules (COMs) are prevalent in these objects (Vastel et al. 2014; Jimenez-Serra et al. 2019; Scibelli et al. 2020). However, it remains unclear what chemical processes are involved in COM formation and at what stage in dense core evolution complex organics form. In this contribution, we will present high-sensitivity observations carried out toward the L1517B and L1498 starless cores. These cores are believed to be at earlier evolutionary stages than the well-known L1544 pre-stellar core, also studied in COM emission by our group. Similarly to what we found in L1544, small O-bearing molecules and N-bearing species are enhanced by factors ~4-14 toward the outer shells of L1498 and L1517B. However, unlike L1544, large O-bearing COMs such as CH3CHO, CH3OCH3 or CH3OCHO are not detected within our sensitivity limits - comparable to the ones obtained for L1544. Surprisingly, N-bearing organics are more abundant toward the outer shells of L1498 and L1517B than in L1544. We have carried out a detailed modelling of the formation of O-bearing and N-bearing COMs in L1498 and L1517B following the model of Vasyunin et al. (2017), which considers both the chemical reactive desorption of COM precursors and their subsequent gas-phase chemistry yielding COMs. The distribution of the COM abundances predicted for L1498 and L1517B nicely matches our observations for both O-bearing and N-bearing COMs in these cores, and reveal that the differences observed between the complex organic content in L1498, L1517B and L1544 are due to the different physical structure of these cores, which in turn is a consequence of their evolution. From our results we conclude that while N-bearing COMs form early in dense core evolution, O-bearing COMs form at a later stage when enough CO has catastrophically depleted onto the surface of dust grains. These results have been published recently in Jimenez-Serra et al. (2021).

References

[1] Vastel, C., Ceccarelli, C., Lefloch, B., & Bachiller, R. *ApJ,* **2014**, 795L, 2V
[2] Jimenez-Serra, I., et al. *ApJ,* **2016**, 830L, 6J
[3] Scibelli & Shirley, *ApJ,* **2020**, 891, 73S
[4] Jimenez-Serra, I., et al. *ApJ,* **2021**, 917, 44J