Interstellar ice chemistry from simple hydrocarbon to complex organics in star-forming regions

Chuang, K.-J.,[1]* Santos, J.C.,[1] Jäger, C.[2]
*presenter
[1]chuang@strw.leidenuniv.nl; Leiden Observatory, The Netherlands.
[2] Max Planck Institute for Astronomy, Germany

Cosmic dust grains are crucial in regulating the temperature of interstellar clouds and enriching their molecular content in harsh conditions. Efficient atomic reactions occur on dust surfaces at cryogenic temperatures, forming interstellar ices, including H_2O, CO_2, NH_3, and CH_3OH. These ices are commonly observed toward extremely dark and cold astronomical objects as well as in cometary bodies, implying a molecular inheritance scenario from clouds to planetary systems.

Detecting interstellar molecules, particularly complex organic molecules (COMs) that potentially link to the building blocks of life on planets, raises a fundamental question: How do these species form before the star formation? Experimental and theoretical studies have suggested several possible mechanisms to explain astronomical observations. In this presentation, we report on a series of laboratory experiments investigating the formation of COMs through the simplest alkyne (C_2H_2) interacting with radicals (e.g., H, OH, HCO, NH_2, and SH), which are expectedly present in the ice mantles.

C_2H_2, commonly observed in the ISM, can be formed through the gas-phase ion-molecule reactions, PAH photodissociation, or the solid-state addition reactions of C atoms with scarce H contents.[1] The newly formed or accreted C_2H_2 on dust surfaces readily reacts to form various hydrocarbons (i.e., C_2H_n and C_4H_m) through (non-)energetic processes.[2] As shown in previous theoretical calculations[3], the reactive sp hybridization bond (C≡C) also provides a ready-to-use molecular backbone for complex organics with different functional groups. Experimental results show that several oxygen-/nitrogen-/sulfur-bearing COMs can be efficiently formed through the radical association reactions to C_2H_2 and its chemical derivatives in the interstellar ice at ~10 K upon *thermal* atoms, energetic protons (200 keV H^+) or VUV photons impact. The derived reaction kinetics indicates a preference for hydrogen-saturated species over the evolution of molecular clouds, and its astrochemical implication is further discussed.

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