

Complex chemistry in outer solar system bodies

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The outer solar system hosts a variety of bodies whose properties, origins, and history greatly differ from one to another. Due to their remote locations, the information at our disposal mostly comes from remote-sensing data in the visible and near-infrared and from data acquired by instruments onboard a few space probes that revealed the presence of frozen volatiles and refractory materials, including minerals and complex organics [1, 2]. Space mission data also informed on the atmosphere and inner structure of moons of giant planets, revealing the presence of liquid water in the subsurfaces, making these objects a target for the search of life [3,4].

The “Complex chemistry in outer solar system bodies” subgroup of the Working Group “The Pathway to Complexity: From Simple Molecules to First Life” aims to identify the key processes where to focus to make progress in the understanding of the chemistry at work in the outer solar system. In fact, a rich chemistry characterises the atmosphere-less surfaces of the moons of Jupiter and Saturn. The interest in these bodies is evidenced by the efforts of international space agencies in their exploration. In the next decade, the European Space Agency (ESA) Jupiter Icy Moon Explorer (JUICE) mission will explore Jupiter and its moons Ganymede, Callisto, and Europa that host subsurficial oceans. Complex chemical processes are at work also in the thin exospheres of moons and dwarf planets and in the thick atmosphere of Titan, the latter being characterised by clouds and rain of methane, yellow organic hazes, and the presence of liquid hydrocarbons at its surface. To shed light on the chemical networks of these environments will also help us to retrieve information on the alleged presence of life, which in turn requires the strengthening of our capabilities to distinguish between biosignatures and abiotic organic compounds [5].

Complex chemical reactions are at work also beyond the orbit of Neptune. Organic materials are revealed on the dwarf planet Pluto [6] and on various trans-neptunian objects [7], with an open debate regarding their origin, possibly related to the chemistry going on during the solar system formation. In fact, small bodies in the outer solar system are thought to be remnants of the Sun’s protoplanetary disk. As such, they accreted both the refractory and the volatile matter in form of ices present in the early stages of the solar system formation [8]. During their lifetime, these bodies also experienced severe space weathering (e.g. meteorite and micrometeorite impacts, alteration by energetic photons and charged particles) that contributed to increase the bodies’ chemical complexity [9].

The understanding of the chemical processes at work in the very diverse bodies located in the outer solar system help us to shed light on the original composition of the solar system and requires a multidisciplinary approach and the combination of the information coming from observations by means of new-generation telescopes, space mission data, laboratory experiment, and theory.

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