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The secret to a perfect tan on TNOs: alcohol, water and Sun radiation

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Abstract

The comparison between laboratory experiments and astronomical observations is fundamental to spread light on the properties of frozen surfaces in space. Cosmic rays, solar ions and UV photons induce changes in both the structure and chemical composition of these surfaces, that can be characterized by means of infrared spectroscopy. The irradiation also determines variations in the visible spectra. We carried out various ion irradiation experiments of astrophysical relevant species in order to support the interpretation of spectral observation of small Solar System bodies that exhibit frozen volatiles on their surfaces. Among them centaurs, Kuiper-belt objects (KBOs) and trans-neptunian objects (TNOs) (e.g., [1, 2, 3, 4]).

1. Introduction

In the Solar System, various bodies possess a surface rich in frozen volatiles. Among them, comets and various airless small bodies, such as centaurs, KBOs and TNOs. Frozen volatiles are also observed in the Interstellar medium and towards various young star-forming regions [5]. Since a long time it has been suggested that, to some extent, ices that were present in the presolar cloud might have been trapped in planetesimals and survive up to present time in Solar System small bodies (e.g., [6]). Recently, the flyby of New Horizons of the very primitive TNO (486958) 2014 MU_{69} (Ultima Thule) has revealed the presence of water and methanol ices on its surface[1] similarly to centaur Pholus [1] and TNO (55638) 2002 VE_{95} [4]. The surfaces of these objects are exposed to space weathering, i. e. the bombardment by energetic charged particles (i.e., solar ions, galactic cosmic rays) that modify both their physical structure and chemical composition (e.g., [7, 8]). Moreover, due to the presence of carbon-bearing species, space weathering determines the formation of a complex refractory material that is thought to be responsible for the strong variations in the colors of these bodies ([9, 10]). In particular, it has been suggested that methanol might be responsible for the red color of these bodies, together with by-products of its irradiation [10, 11]. Here we report new laboratory experiments performed to simulate the space weathering of small bodies frozen surfaces, and in particular to interpret the red color observed on water and methanol rich surfaces, as in the case of (486958) 2014 MU_{69}.

[1] http://pluto.jhuapl.edu/News-Center/News-Article.php?page=20190318

2. Experimental methods

The experiments were performed with the INGMAR setup (IAS-CSNSM Orsay, France, [12]). Frozen volatile mixtures containing water and methanol were deposited and then irradiated with 40 keV H^+ at low temperature (about 15 K), up to doses of about 80 eV/16u which correspond to typical astrophysical timescales of about 6×10^9 years at the orbit of Ultima Thule. Furthermore, we warmed up to about 300 K the processed ice. Throughout the experiment we performed in-situ Fourier-Transformed infrared (FT-IR) and visible spectroscopy with the aim to characterize the chemical changes and the color variation induced by ion bombardment. Further analysis were performed on the room-temperature residues at the SMIS beamline of the SOLEIL synchrotron (Saint Aubin, France) by means of micro-infrared and micro-Raman spectroscopy. Complementary experiments were performed including also ammonia in the deposited mixtures.

3. Preliminary results

Ion irradiation determines evident changes in the infrared spectra of the as-deposited mixtures. These changes are due to the formation of both simple and complex species that were not present in the original

frozen mixture. Radicals are also formed and during the further warm-up they recombine and increase the chemical complexity of the ices, while volatile species sublimate. In the visible spectra, a red slope is observed between about 500 nm and 1 μm already at low temperature. At room temperature, a refractory residue is left on the substrate.

4. Conclusions

The experiments we performed confirm that the presence of water, methanol and by-products of space weathering can be responsible for the red slopes observed in the visible spectra of various small bodies and, among them, on the surface of (486958) 2014 MU69. The data analysis that is currently in progress will spread light on the composition of irradiated frozen volatiles and will support the interpretation of spectra acquired on small bodies that exhibit red colors.

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