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Space weathering influence on Ryugu's IR signature: insights from nanoscale vibrational spectroscopy in the STEM

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JAXA's Hayabusa2 mission brought back 5.4 g of material from the surface of the carbonaceous asteroid Ryugu. Some grains show evidence of a modified surface attributed to space-weathering effects [1], which result from solar-wind irradiation and/or micrometeoroid bombardment. In collaboration with the Hayabusa2-Initial-Analysis Min-Pet Fine Team and the Hayabusa2-Initial-Analysis core, their study should allow to investigate, for the first time, how a C-type, hydrated asteroid surface evolves when subjected to space weathering. Alongside, the recent development of monochromated electron microscopes dedicated to high resolution EELS makes it possible to reach the Mid-IR spectral range (~40 cm^{-1} spectral resolution at best) [2]. It thus opens the possibility for comparison with bulk IR studies with the advantage of the TEM spatial resolution. Here, we study the modified surfaces and underlying matrix of several small Ryugu grains, originating from both touchdown A and C [3]. Surfaces modified by space weathering were first identified by SEM and FIB sections were prepared.

The main product of space weathering is glassy and vesiculated layer likely resulting from the melting of Ryugu materials due to micrometeorite impacts. Our results show that it is possible to distinguish the spectral signature of both space weathered melt layers and underlying preserved matrix. In particular, we evidence the loss of the H_2O and -OH vibrational modes in the melt layers. It could explain why the 2.7 µm band, corresponding to hydroxyl groups in phyllosilicates, is twice less intense in NIRS3 spectra than in the returned samples ones [4]. We also observe that the organic modes are absent in the melt layers, in agreement with the EDS data. We thus demonstrate that space weathering strongly modifies the IR signature of hydrated and C-rich airless bodies, and may lead to the underestimation of their water and carbon content when analyzed by remote sensing.

[1] Noguchi et al. (2022) Nature Astronomy

[2] Colliex (2022) The European Physical Journal Applied Physics

[3] Yada et al. (2021) Nature Astronomy

[4] Nakamura et al. (2022) Science