Thermal history of Ryugu based on Raman characterization of Hayabusa2 samples

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Introduction: The degree of structural order of the polyaromatic carbonaceous matter present in extraterrestrial samples is a tracer of the thermal history they experienced (e.g., primitive chondrites: [1-4]; micrometeorites: [5-6]). To characterize Ryugu's thermal history (long vs. short thermal heating and extent of thermal heating), we thus perform Raman characterization of several Ryugu particles returned by the Hayabusa2 mission. In order to be fully confident in the obtained data and interpretation, Raman characterization was led independently by two groups of persons in Japan and in France on distinct Ryugu particles. The results were subsequently compared.

Samples and methods: Raman point analyses were performed on several fragments of six particles from Chamber A aggregates (A0108) and six particles from Chamber C aggregates (C0109). To be able to combine in situ IR and NanoSIMS measurements on the same samples, fragments of particles were manually selected under a binocular and pressed onto diamond windows. The Raman spectra were acquired with a 532 nm laser in both Japan and France. Because some Raman bands related to carbonaceous matter are dispersive, data for Ryugu particles and comparison samples have been acquired and analyzed consistently in both Japan and in France. In particular, a Renishaw InVia Reflex equipped with a 1800 l/mm grating at Materials Characterization Central Laboratory was used in Waseda University (Japan). The laser was focused at the sample surface through a 50× objective (spot size around 3-4 μm) and its power was set at 0.24 mW and 1 mW. Each acquisition comprised five integrations of 10 s that were averaged to make the final spectrum. In France, Raman measurements were performed at the Ecole Normale Supérieure de Lyon (Laboratoire de Géologie de Lyon—Terre, Planètes, Environnement) using a LabRam Raman spectrometer (Horiba Jobin-Yvon) equipped with a 600 g/mm grating. The laser was focused through a 100× objective to obtain a <2 μm spot size. The power on the sample was 0.3 mW. Each acquisition comprised six integrations of 15 s that were averaged to make the final spectrum.

Results and discussion: More than 200 spectra were acquired on 12 different particles. The Raman data acquired in Japan and in France are fully consistent. Each acquired spectrum is characterized by a high fluorescence background and by the presence of the Raman D- (~ 1350 cm^{-1}) and G-bands (~ 1580 cm^{-1}), related to the presence of polyaromatic carbonaceous matter. The spectral parameters derived from the mathematical fitting of the individual spectra, that is, the band widths (FWHM-D, FWHM-G), the band positions (ω_D, ω_G), and the band intensity ratio (I_D/I_G) are comparable between particles. No systematic differences have been observed to date between the spectral parameters of Chamber A and Chamber C particles. This point will be further investigated on insoluble organic matter isolated by acid treatment of Ryugu samples.

The Ryugu particles contain polyaromatic carbonaceous matter that is poorly structured, as reflected by the high fluorescence background superimposed to wide D- and G-Raman bands, present at relatively low Raman shifts. The comparison of these spectral parameters with similarly characterized chondrites shows that the structural order of the polyaromatic carbonaceous matter present in Ryugu particles is comparable to that in primitive (type 1, type 2) carbonaceous chondrites. Ryugu thus escaped significant degree of long duration radiogenic thermal metamorphism (as typically experienced by type 3 chondrites), as well as short-duration heating as experienced by some type 2 chondrites (e.g., [4]).

References

[1] Bonal et al. 2006. Geochimica Cosmochimica Acta 70 :1849. [2] Bonal et al. 2016. Geochimica Cosmochimica Acta 189: 312. [3] Busemann et al. 2007. Meteoritics & Planetary Science 42: 1387. [4] Quirico et al. 2018. Geochimica Cosmochimica Acta 241 : 17 [5] Dobrica et al. 2011. Meteoritics & Planetary Science 46 : 1363. [6] Battandier et al. 2018. Icarus 306 : 74.