A MULTI-TECHNIQUE ANALYSIS OF THE PARIS METEORITE TO CHARACTHERIZE ITS ORGANIC CONTENT *"IN SITU"*, WITHIN ITS MINERAL MATRIX

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Introduction: The Paris meteorite is the least altered CM2 classified so far [1], and thus, a good witness of the Solar System early history. The first objective of this study is to analyze the mineral and organic composition of a raw chunk of the Paris chondrite without any preliminary preparation or extraction of the sample. The aim is to obtain simultaneous chemical characterization of organic and mineral phases while preserving their spatial distribution within the meteorite fragment. The second objective is to obtain laboratory spectroscopic measurements which can be compared to data obtained by space missions as well as by remote observations of cometary dust and asteroid surfaces.

Materials and methods: This study is carried out by coupling typical remote sensing tools (IR and visible reflectance spectroscopies) to TOF-SIMS (Time-Of-Flight Secondary Ion Mass Spectrometry), a high spatial resolution technique that was embarked on the Rosetta space mission (the COSIMA instrument [2,3,4]), and that is planned to be performed on future collected asteroidal samples [5,6]. Both mid-IR spectroscopy and TOF-SIMS are performed in imaging mode with a spatial resolution of a few micrometers for the first and 1 to 2 µm for the latter. We also add micro-Raman and micro-PIXE measurements of the same sample area as an independent confirmation or clarification of the mineral composition, in order to have a better understanding of the mineralogical context of the organic moieties and components found by TOF-SIMS and IR. The depths of analysis of these different methods are: from a few hundreds of nm to a few µm for the IR and Raman spectroscopies depending on material absorptivity, from 10 to 20 µm for micro-PIXE, the first 10 nm from the surface for static SIMS, and up to a few 100 nm for dynamic SIMS (3D imaging using argon cluster gun).

Results and discussion: The matrix of Paris is found to be as dark as the very dark asteroids Ryugu and Bennu currently visited by Hayabusa2 and OSIRIS-REx [7,8]. By combining the results given by micro-PIXE, TOF-SIMS and IR and Raman micro-spectroscopies, we are able to show the different stages of hydration and amorphization of the amorphous silicate phase dominating the matrix of the analyzed Paris fragment. The infrared signatures of water and hydroxyl groups mapped for a chosen large area (500 x 500 µm²) of the meteorite fragment give a good idea of the circulation of the fluid that partially altered the amorphous silicate phase. TOF-SIMS, one of the rare techniques allowing the simultaneous and micrometric analysis and mapping of organic and mineral mixed phases, gives an interesting insight on the organic matter composition and its systematic spatial association with the partially hydrated amorphous silicate phase and iron under different states. This latter result illustrated in previous studies of other carbonaceous chondrites [9,10] together with the detection by TOF-SIMS of metal-containing organic moieties, emphasizes the important and specific interaction that must take place between the mineral phase and the organic material.

Acknowledgments: We thank B. Zanda and the Museum National d'Histoire Naturelle (MNHN, Paris) for providing us with the Paris meteorite sample. This work has been performed in the frame of the "ANDROMEDE" project funded by the program for future investment EQUIPEX: ANR-10-EQPX-23. The micro-spectroscopy activities are supported by grants from Région Ile-de-France (DIM-ACAV) and SOLEIL.

References: [1] Hewins, R. et al. (2014) *Geochimica et Cosmochimica Acta*, 124:190–222. [2] Kissel, J. et al. (2007) *Space Science Reviews*, 128:823-867. [3] Hilchenbach, M. et al. (2016) *The Astrophysical Journal Letters*, 816:L32. [4] Bardyn, A., Baklouti D. et al. (2017) *Monthly Notices of the Royal Astronomical Society*, 469:S712-S722. [5] Uesugi, M. et al. (2014) *Earth, Planets and Space*, 66:102. [6] Naraoka, H. et al. (2015) *Earth, Planets and Space*; 67:67. [7] Kitazato, K. et al. (2019) *Science*, 364:6437:272-275. [8] Hamilton, V.E. et al. (2019) *Nature Astronomy*, 3:332-340. [9] Le Guillou, C. et al. (2014) *Geochimica et Cosmochimica Acta*, 131:344–367. [10] Le Guillou, C. et al. (2014). *Geochimica et Cosmochimica Acta*, 131:368–392.