Curation of Extraterrestrial samples in France and the future center for extraterrestrial materials in Paris.

J. Duprat[1], J.-C. Viennet[1], M. Roskosz[1], B. Doisneau[1], S. Pont[1], M. Verdier-Paoletti[1], S. Bernard[1], M. Gounelle[1], J. Aléon[1], P. Sans-Jofre[1], B. Zanda[1], G. Avice[2], F. Moynier[2], R. Brunetto[3], C. Pilorget[3], F. Poulet[3], C. Engrand[4], L. Delauche[4], E. Dartois[5], J. Gattacceca[6], C. Maurel[6], L. Piani[7], Y. Marrocchi[7], A. Barucci[8], L. Bonal[9], L. Lemelle[10], A. Simionovici[11], G. Libourel[12]

[1]IMPMC, CNRS-MNHN-Sorbonne Université, UMR 7590, 57 rue Cuvier, Paris, France ; [2]Université Paris Cité, Institut de physique du globe de Paris (IPGP), CNRS, Paris, France ; [3]IAS, Université Paris-Saclay, CNRS, UMR 8617, Orsay, France ; [4]IJCLab, Université Paris-Saclay, CNRS/IN2P3, Orsay, France ; [5]ISMO, Université Paris-Saclay, CNRS, Orsay, France, [6]CEREGE, Aix-Marseille Université, CNRS, INRAE, IRD, Aix-en-Provence, France, [7]CRPG—CNRS 15 rue Notre Dame des Pauvres, BP 2054501 Vandœuvre-les-Nancy, France, [8]LESIA-Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Université de Paris Cité, 92195 Meudon Principal Cedex, France, [9]IPAG, Université Grenoble Alpes; 38000 Grenoble, France, [10]LGL-TPE, CNRS, UCBL, ENS de Lyon, [11]ISTERRE, CNRS, Université Grenoble Alpes, 38058 Grenoble, France, [12]Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, LAGRANGE, France.

The coming decade will witness important developments in curation facilities dedicated to pristine samples from space missions. The return of samples from asteroid Bennu by the OSIRIS-REx NASA-led mission [4] is imminent and, on a longer term, samples will be returned from the Martian moon Phobos by the MMX JAXA-led mission [5]. After 2030, samples from the Martian surface are expected to be returned to Earth by the NASA/ESA Mars Sample Return (MSR) mission [6]. Advanced curation studies are on-going [9, 10] in major curation facilities at JAXA and NASA [7-9] while others facilities are currently into construction, such as the SAL in Berlin [see e.g. 11 and this meeting]. Many laboratories in France have experience in handling samples from spatial missions or from existing collections of extra-terrestrial materials (meteorites, micrometeorites, IDPs…). These experiences cover a whole range of expertise from curation itself to dedicated samples handling (e.g. micromanipulation, fragmentation…), first-order characterization by non-invasive or non-destructive techniques and dedicated sample preparation (e.g. thin and ultra-thin sections, polished sections, …) in clean-room environments.

The CNME project was launched in 2022 to build a national curation facility for extra-terrestrial materials at MNHN. This project is supported, at the national level, by the French spatial and scientific research agencies (CNES and CNRS) and will be supported locally by the National Museum of Natural History (MNHN), Sorbonne University and the Institut de physique du globe de Paris (IPGP). This project will benefit from the local experience in curation of existing collection of meteorites and micrometeorites and from expertise developed in other French laboratories. A key objective of CNME will be to ensure the long-term curation of a fraction of samples from the future MMX JAXA-led mission [5]. As a result of on-going agreements between JAXA and the French space agency CNES and ESA, a fraction of Phobos (MMX) samples are expected to be transferred to the CNME at MNHN and after the period of initial description at JAXA-ISAS sample receiving laboratory and after the first scientific analysis by the MMX Science Sub-Teams (i.e. after 2030). In the long-term, the CNME will be designed to allow the reception of un-restricted samples from MSR mission, i.e. once they will be out of the Sample Receiving Facility.

The design of CNME will be modular to allow flexible configuration of different environments for the curation of samples from different space missions. The CNME clean-room infrastructure will be divided in separated modules (ISO7 to ISO5 [24]) environments, together with a laboratory dedicated to sample preparations. It will contain secured cabinets and glove boxes under controlled atmospheres (dry and purified N_2, Ar, vacuum, …). In the long-term perspective of MSR, the CNME team is involved in the MARCUS project to study, under the supervision of CNES, a dedicated apparatus for small sample (solid and gas) handling in clean and bio-contained (BSL4-like) environment. The CNME will include a dedicated space for rehearsal activities on the MARCUS apparatus (before operation in BSL4-like laboratories). Instrumentation in CNME will focus on acquisition of the basic properties on samples with sizes going from µm up to cm scales, including optical 2D and 3D microscopy and imaging, weighting, magnetic susceptibility measurements, scanning electron microscopy, XRD, Raman and infrared (IR)

micro-spectroscopy with a dedicated suite of instruments, to achieve initial characterization and cataloguing of samples. The control of terrestrial contamination within CNME cleanrooms will be achieved by real-time monitoring of inorganic, organic and biological contamination.

The CNME will include instruments and advanced storage facilities developed by several French laboratories. The magnetic environment of the samples and the magnetic properties of the handling tools will be monitored to ensure preservation of the original paleomagnetic record of the samples. The CNME will develop research programs to improve existing curation techniques and new technological solutions for the mid to long-term curation of volatile elements contained in samples collected by future space missions, e.g. ice and gas from cometary objects or planetary atmospheres (see G. Avice et al. this meeting). A specific setup will be developed at IAS in order to allow a multi-scale (from mm down to µm) IR reflectance micro-imaging characterization of samples. The analysis will be fully non-destructive and non-invasive with no need for specific sample preparation, it will be performed within a dedicated bench in a controlled atmosphere (e.g., N_2). Other setups for samples preparation and/or first-order charaterization are currently in study in French laboratories with the aim to built a national network of experts in curation-related activities. At the international level, the CNME team will develop in-depth collaboration with other teams currently managing major curation centers in Europe and on a world-wide scale (see A. Hutzler et al this meeting).

The CNME will ensure the long-term curation of the MNHN historical meteorite collection that include a rich panel of Martian samples (Shergottites, Chassignites, Nakhlites) [17] and several emblematic primitive chondrites (e.g. Orgueil CI-chondrite). The MNHN meteorite collection is actively used for cosmochemistry research projects and is constantly growing with new additions every year, thanks to collections performed by a joint team from CEREGE and MNHN in Atacama Desert (see e.g. [14]). The CNME will also have the responsibility for the long-term curation of micrometeorite collections recovered from both Greenland and Antarctica [15] including the Concordia micrometeorites collection (currently in a dedicated curation cleanroom at IJCLab) that contains thousands of micrometeorites with minimal terrestrial weathering [16]. Beside these collections, CNME will also ensure the long-term curation of samples from the Chinese mission Chang'e5 recently donated to France.

In this presentation, I will summarize the general landscape of curation activities in France and present the current status of the CNME project.

Acknowledgement: The CNME is a joint project supported by MNHN, IPGP, Sorbonne University, University Paris Cité, CNES and CNRS. The curation-related instruments and apparatus currently under development benefit from funding by Région Ile de France (DIM-ACAV$^+$ contract C^{3}E), CNES, CNRS, MNHN and ANR contract (COMETOR 18-CE31-0011). The collection of micrometeorites benefited from the pluri-annual funding by IPEV and PNRA (Program #1020)

References: [1] Brownlee D. (2014) *Ann. Rev. Earth Planet. Sci.* **42**, 179-205. [2] Yano H.*, et al.* (2006) *Science* **312**, 1350-1353. [3] Watanabe S.*, et al.* (2019) *Science*, eaav8032. [4] Lauretta D.S.*, et al.* (2017) *Space Sci. Rev.* **212**, 925-984. [5] Kuramoto K.*, et al.* (2022) *Earth, Planets and Space* **74**, 12. [6] Beaty D.W.*, et al.* (2019) *Meteorit. Planet. Sci.* **54**, S3-S152. [7] Yada T. *et al. Meteorit. Planet. Sci.* **49**, 135-153 [8] Evans C.*, et al.* (2018) **42**, B4.2-49-18. [9] McCubbin F.M.*, et al.* (2019) *Space Sci. Rev.* **215**, 48. [10] Hutzler A. et al. *EURO-CARES D7.1 Final technical Report*. [11] Helbert J.*, et al.* (2020), EPSC2020-250. [12] ISO 14644-1 [13] Caillet Komorowski C.L.V. (2006) *Geol. Soc. London Spec. Pub.* **256**, 163-204. [14] Gattacceca et al. (2011) *MAPS* 46, 1276-1287, Hutzler et al. (2016) *MAPS* 51, 468-182 [15] Maurette M.*, et al.* (1986) *Science* **233**, 869-872. Maurette M.*, et al.* (1991) *Nature* **351**, 44-47. Duprat J.*, et al.* (2007) *Adv. Space Res.* **39**, 605-611. Rojas J.*, et al.* (2021) *Earth Planet. Sci. Lett.* **560**, 116794. [16] Duprat J.*, et al.* (2010) *Science* **328**, 742-745.