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### NON-DESTRUCTIVE X-RAY, RAMAN AND IR IMAGING OF QUARANTINED MARS RETURN SAMPLES

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**Introduction:** In preparation for the upcoming international Mars Sample Return mission, bringing to Earth samples containing potential biohazards, we have implemented a hyperspectral method of analysis of grains performed in BSL4 quarantine conditions, by combining several non-destructive imaging diagnostics. This methodology was tested on meteorites [1, 2] and cometary grains from the recent NASA Stardust mission [3-6].

**Synchrotron Radiation protocols:** Diffraction, X-ray fluorescence and absorption micro-imaging were performed on chondritic samples using focused beams at the ESRF synchrotron in Grenoble, France. 2D maps of grain composition (down to ppm concentrations) and polycrystalline structure have simultaneously been acquired, followed by XAS on elements of  $Z \geq 26$ . In a future version, absorption micro-tomography will be performed in full-beam mode to record the 3D morphology of the grain followed by fluorescence-tomography in focus-beam mode to complement the picture with a 3D elemental image of the grain.

**Lab-based protocols:** Raman and IR spectroscopies of the few nanometer-thick outer layers of the grains were performed in reflection mode for mineralogical imaging using commercial microscopes. Spatial resolution varied in the 1-10  $\mu\text{m}$  range. Laser spectroscopy allows. Raman mineralogical maps are now routinely acquired at sub- $\mu\text{m}$  scales through the 3 container walls of the holder, followed by IR few-micrometer spot measurements of C-based and potential H<sub>2</sub>O alteration distributions.

**Sample Holder:** A miniaturized sample-holder [7] has been designed and built to allow direct analyses of a set of extraterrestrial grains confined in a sealed container implementing three layers of containment and remotely positioned in front of the X-ray or laser beams of the various setups. The grains are held in several thin walls (10  $\mu\text{m}$ ) ultrapure silica capillaries which are sufficiently resistant for manual/remote-controlled micro-manipulation but semitransparent for the characteristic X-rays, Raman and IR radiations. Miniaturized pressure/temperature sensors located in each container periodically monitor the integrity of the ensemble, ensuring leak proof conditions.

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