INTERLABORATORY HUB FOR HANDLING AND CHARACTERIZATION OF SAMPLE RETURN AND EXTRATERRESTRIAL MATERIALS

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Introduction: Laboratory measurements of extraterrestrial materials like meteorites and, more recently, materials from sample return missions can significantly enhance the scientific return of the global remote sensing data. Lunar and Martian meteorites were the first extra-terrestrial samples analyzed in dedicated laboratories, followed by micrometeorites and interplanetary dust particles collected in the stratosphere. Apollo and Luna were the first sample return program, and sample return missions add a strong development in XXI century

A big step in sampling and analyzing extraterrestrial materials took place when it became possible to fetch samples at the surface (Moon and asteroid regolith) or in the vicinity (cometary dust) of the sample's parent body.

The exploration of the Solar System started in the 1960s, with the space race between the USA and the former USSR to be the first in space, around the Earth, around and on the Moon. The urge to prepare for the upcoming lunar samples quickly led NASA to fund the development of a prototype instrument specifically dedicated to the analysis of lunar samples. Extraterrestrial samples analysis has made tremendous progress since then.

Sample Return Missions, today:

JAXA/HAYBUSA2: The Hayabusa2 mission (JAXA) investigated the NEA Ryugu from June 2018 to November 2019. On 6 December 2020, 5g of samples from the C-type asteroid 162173 Ryugu were returned to Earth by Hayabusa2 in a hermetically sealed container within the re-entry capsule and transported from South Australia to the Extraterrestrial Sample Curation Center in Sagamihara, Japan. Samples were recovered in a non-destructive manner and under a strict contamination-controlled conditions to perform initial descriptions before delivery to future research worldwide. The Ryugu sample has sizes ranging from ~8 mm, the largest average diameter, down to fine submillimetre dusts, with millimetre-scale particles being the most common. Starting 2022, the Astromaterials Science Research Group (ASRG, ISAS-JAXA) has opened two calls yearly for Ryugu returned samples. Preliminary analyses have already been able to start characterising the material brought back from Ryugu [1,2,3](Yada et al. 2021, Pillorget et al. 2021, Nakamura et al. 2022, Yokoyama et al. 2022). Returned grains show various and different lithologies, with the most common mineralogy containing Mg-rich phyllosilicates, MgCa and MgFe carbonates, hydroxyapatite, Fe sulphides and Fe oxides. Rare fragments also contain islands of anhydrous silicates such as olivine and pyroxene, amorphous silicates, Ca carbonate, phosphide, Fe-Ni oxides and poorly crystalline phyllosilicate. Overall, the major lithology is consistent with a CI chondrite unaltered by terrestrial weathering processes (Fig.1,2).

NASA/OSIRIS-Rex: The OSIRIS-REx mission (NASA) was launched on September 8, 2016, targeting primitive asteroid Bennu. The mission assessed its physical, geological, and chemical properties and successfully collected materials from the surface. The spacecraft delivered more than 70 grams of asteroidal materials back to Earth on September 24, 2023 (figure 2). The OSIRIS-Rex Preliminary Investigation Team has started analysing the returned samples (25% of the total collected mass). Subsequently, 0.5% of the collected sample mass will be delivered to JAXA due to previous arrangements between the Japanese and the American space agencies. Returned samples shall also be available to the international scientific community through future announcements of opportunities.

Sample Return Missions, tomorrow:

In 2024 the Martian Moons eXploration (MMX) mission [4] from JAXA will be launched to the Martian Moons Phobos and Deimos to investigate their nature and improve our understanding about their formation. In 2029 samples from Phobos will be returned back to Earth as MMX is the latest JAXA's sample return mission.

NASA and ESA (European Space Agency) are planning ways to bring the first samples of Mars material back to Earth for detailed study (Mars Sample Return-MSR). The Mars Perseverance rover will collect and cache samples on Mars. A Sample Retrieval Lander would land near or in Jezero Crater, bringing a small rocket on which the samples collected by Perseverance would be loaded. Two Ingenuity-like helicopters would provide a secondary capability to retrieve samples on the surface of Mars. Once the sample cache is launched off the Red Planet, another spacecraft would capture it in Mars orbit, and then bring it to Earth safely and securely in the early to mid-2030s.

The collection of extra-terrestrial returned from mission ignited progress in the transportation, curation and handling of the samples. More sophisticated handling tools and sample preparation and transportation methodologies which preserve samples form terrestrial contamination should be designed and realized in the years to come.

This encouraged three Research groups involved in extraterrestrial and sample return characterization since many years to collaborate to create a interlaboratory Center to study samples returned by asteroids/Moon and Mars. This Research Hub is open to other worldwide Research groups to encompass as much as possible analytical techniques able to characterize these important samples. The objective is not limited to the sample investigation or to the realization of new technologies/methodologies for handling transportation/curation. Skills improvements in this field will be promoted mainly by exchange of Scientists and resources. Another important driver is training of younger generations in order to be ready for Martian Samples in 10-15 years.

The Hub forming Research group are:

- *Analysis and Study ThROugh experimental analysis of returned Grains and mEteorites – Laboratory (ASTROGEM-Lab) at INAF-IAPS, Italy*
- *Centre for Terrestrial and Planetary Exploration (C-TAPE) of University of Winnipeg, Canada*

The Hub is going to be realized within mid-2024 to investigate extraterrestrial materials. It will accommodate a FT-IR spectrometer and a ns-pulsed laser to simulate micrometeorites impacts, both included in a Clean Room ISO7. Its Scientists has been part of the *Hayabusa2 analysis Team for petrology and mineralogy of coarse grains* which performed the very first and restricted analysis on the Ryugu grains before public distribution. The Hub was granted with two Ryugu grains during the AO#2 (see figure 3) with the PRAWNS proposal (PRimitive Asteroid Weathering: New Studies). This investigation will use a multi-technique approach, going from less to more destructive analysis, to assess their weathering state and identify changes in surface texture, morphology and chemical composition. This activity is currently ongoing and supported by INAF up to the mid-2024 (PRESTIGE project).

C-TAPE was established in 2003 as the Planetary Spectrophotometer Facility (PSF, aka HOSERLab) to enable analyses of planetary materials and terrestrial analogues from the micro (lab) to the macro (field) scale. It is dedicated to making acquired data and samples available to the wider planetary community to facilitate planetary exploration.

References: [1] Nakamura et al. (2022), Science, 379.; [2] Yada T, et al., (2021) Nature Astronomy. 2021;6: 214–220. ; [3] Pilorget C. et al., (2021) Nature Astronomy. 021;6: 221–225; [4] Kuramoto, K., et al. (2022). Earth, Planets and Space 74(1).

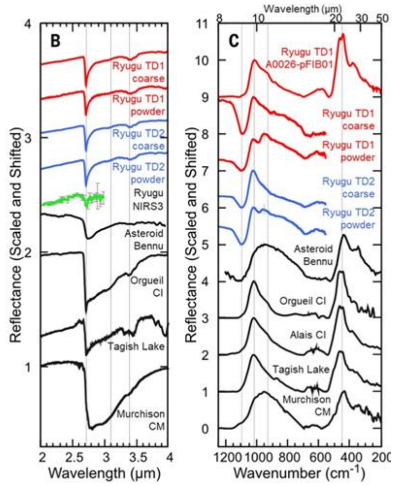

Fig. 1: IR reflectance spectra of coarse and powder samples from the TD1 and TD2 sites on Ryugu, compared with hydrated carbonaceous chondrites, Hayabusa2 remote sensing observations of Ryugu and remote sensing observa-tions of Bennu

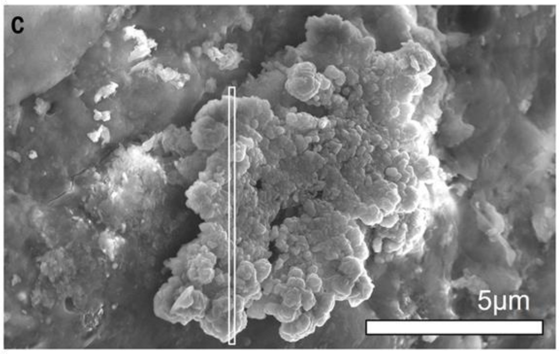

Fig. 2: Secondary-electron image of a tabular coral–shaped CuS object on the flat surface of A0067, formed of a stack of submicrometer-sized disk-like crystals [2].

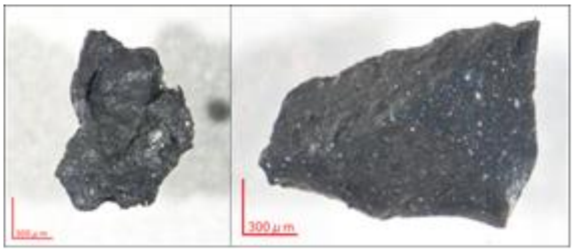

Fig. 3: Grains from C-type asteroid Ryugu allocated at INAF-IAPS: A0226 (left) and C0242 (right).