# Report on the outcomes of a Short-Term Scientific Mission[1]

**Action number:** **CA21126**

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## Details of the STSM

Title: Raman measurements of carbonaceous chondrite meteorites and comparison to organic refractory residues.

Start and end date: 20/01/2026 to 30/04/2026

## Description of the work carried out during the STSM

Description of the activities carried out during the STSM. Any deviations from the initial working plan shall also be described in this section.

The research conducted during my staying at the Center for Astrochemical Studies (CAS) of the Max Planck Institute for Extraterrestrial Physics focuses on the analysis of ORRs and CCs using Raman spectroscopy. The Center for Astrochemical Studies is directed by Prof. Paola Caselli. The work I carried out, as part of this research group, was supervised by Dr. B. M. Giuliano, and Prof. P. Caselli.

Raman spectroscopy enables the study of the carbonaceous structural order of the samples, exploiting the inelastic scattering of a monochromatic light source (laser). Amorphous carbon (αC) presents a Raman active band at 1560 cm-1 (*Ferrari & Robertson 2000*). The αC band is a resonant band, its profile depends on the excitation laser wavelength. Using a laser operating in the visible range (488 and 532 nm in our case), the αC band profile is mainly sensitive to the ordering of sp2 bonds and only indirectly on sp3 bonds.

Raman measurements of several αC-bearing ORRs and CCs were acquired with the 488 nm Raman laser at the Center for Astrochemical Studies of the Max-Planck Institute for Extraterrestrial Physics (Garching, Germany). Raman spectra of ORRs and CCs were acquired on several spots on each sample with low laser power (P=0.1 mW, 50x objective) to prevent possible laser-induced alteration.

[1] This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the Grant Holder Manager to verify the grant documents compliance and proceed with the payment.

ORRs were formed at the Laboratory for Experimental Astrophysics (LASp) at INAF-OACT (Catania, Italy), after 200 keV ion irradiation (~120 eV/16u irradiation dose) of icy mixtures, deposited in a UHV chamber (on KBr or MgF2 inert substrate, P≤10-9 mbar, T=18 K), and subsequent warm-up to room temperature (*Germanà et al., under revision on MaPS*). Such as formed ORRs were further irradiated at room temperature. These ORRs differ in the initial icy mixture (consisting of N2, CH4 and CO) and/or irradiation processing (energy dose and/or irradiating ion), mimicking the conditions on TNOs and comets in the Oort cloud (*Baratta et al., 2015*). Before leaving for Germany, I collected Raman measurements of the same αC-ORRs with the 532 nm Raman laser at the Laboratory for Experimental Astrophysics (LASp) at INAF-OACT (Catania, Italy). Then I acquired acquire Raman measurements of the CCs Allende, Murchison, Orgueil and Tagish Lake using both 488 and 532 nm excitation lasers, the latter being widely employed in literature.

To quantitatively characterize this band profile modification, I performed a fitting analysis on the αC band detected across the Raman spectra of the samples. The fitting model consists of three components: a Lorentz (for the D line), a Breit-Wigner-Fano (for the G line) and a 2$^{nd}$ order polynomial (for the fluorescence continuum). By means of the fitting procedure I was able to find the parameters (FWHM Γ, peak position ω, peak intensity I) for D and G lines, useful to monitor the variation of the αC band profile obtained from the two different excitation laser wavelengths, i.e. 488 and 532 nm.

## Description of the STSM main achievements and planned follow-up activities

Description and assessment of whether the STSM achieved its planned goals and expected outcomes, including specific contribution to Action objective and deliverables, or publications resulting from the STSM. Agreed plans for future follow-up collaborations shall also be described in this section.

This study extends previous investigations and aims to have a better characterization of carbonaceous extraterrestrial particles, such as carbonaceous chondrites. In particular, the multiwavelength Raman approach employed in this work provides a wider view into carbonaceous properties. A key objective is also to improve our understanding of the astrochemical evolution of complex organic compounds throughout the Solar System and the role of metamorphic processes, such as ion irradiation, experienced by the parent bodies of carbonaceous extraterrestrial particles.

As a result of the experiments, the αC band of both ORRs and CCs exhibits slight profile variations (i.e. dispersion) when moving from 488 nm to 532 nm excitation. Although only a few similar studies are available in the literature, the results presented here are consistent with previous works that have investigated the dispersion effects of a multiwavelength Raman approach on aC-bearing samples (*Ferrari & Robertson 2001*), including some carbonaceous chondrites (*Starkey et al., 2013*). Nevertheless, the heterogeneity detected in the CCs considered in this study exhibit a larger intensity than the dispersion induced by the two different laser excitation wavelengths (i.e. 488 and 532 nm). In general, different excitation laser wavelengths used in Raman measurements are differently sensitive to specific $sp^2$ carbon bond clusters within a cluster distribution. In addition, despite the dispersion of the αC band parameters, which depends on the degree of carbonaceous order, the overall interpretation of the carbonaceous properties of extraterrestrial particles, in terms of metamorphic processes, remains unchanged. In conclusion, the αC band is resonant in nature, and the general understanding derived from visible green lasers (mainly 514 or 532 nm, commonly used in the literature) cannot be straightforwardly extended to Raman measurements acquired at different excitation wavelengths (e.g., 488 nm).

The results obtained through this STSM allows to achieve the planned goals. These scientific results can contribute to have an improved awareness on the Raman spectroscopy of carbonaceous extraterrestrial samples, that represents a key analysis to planetary science community.

As a future development of this work, additional carbonaceous extraterrestrial samples may be investigated through Raman analysis using a multiwavelength approach, possibly employing also excitation laser wavelengths different from those employed here.

This work will soon be submitted as a peer-reviewed paper and presented to the planetary science community at forthcoming meetings.

20/05/2026, Catania (Italy) the grantee

