Europlanet TA Scientific Report

PROJECT LEADER

Project number: 20-EPN-008	
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TA Facility visited: NanoSIMS 50L-NSIMS at Open University (UK)	

Project Title:

Scientific Report Summary.
(plain text, no figures, maximum 250 words, to be included in database and published)

Oxygen isotopes are a powerful tool to determine the parent bodies of cosmic spherules, which are the entirely melted endmember of micrometeorites. After considering the fractionation processes affecting their original oxygen isotope signatures, >90% of cosmic spherules larger than 200 µm appear to be related to chondrite clans established studying chondritic meteorites. About 10% of cosmic spherules that show clear chondritic major element compositions display unusual ^{16}O-poor oxygen isotopic compositions that are not linked to chondritic material present in present-day meteorite collections. Simultaneously, a subset of porphyritic (Po) cosmic spherules labelled Cumulate Porphyritic Olivine (CumPo) particles exhibits textures testifying to the settling of olivine crystals during atmospheric deceleration. This unusual texture suggests these particles entered the Earth's atmosphere at velocity of ∼16 km s^{-1}, which corresponds to orbital eccentricities >0.3 and is considered higher than most asteroidal dust bands. By establishing a potential link between the CumPo particles and a subset of the ^{16}O-poor spherules and characterizing relict mineral grains in a selection of particles from the Sør Rondane Mountains and Larkman Nunatak micrometeorite collections using the Open University NanoSIMS, a parentage with the newly defined CY carbonaceous chondrite group is proposed. This implies that about 10% of the cosmic spherules reaching the Earth's surface have a near-Earth origin. As such connection is rare in the meteorite collection, demonstrating the importance of fully characterizing the flux of micrometeorites to understand the composition of the Solar System.

Full Scientific Report on the outcome of your TNA visit

We encourage you to add figures to your report, which should be approx. 1 page of text plus figures.

Micrometeorites are extraterrestrial dust-sized (< 2 mm) particles surviving atmospheric entry and representing the main part of the flux of extraterrestrial matter reaching the Earth's surface (~40.000 tons/year). Micrometeorites are classified according to the degree of heating experienced during atmospheric entry [1]. Cosmic spherules, which represent the melted end member, account for ~70% of all micrometeorites. Almost complete melting erases the primary features of the precursors of cosmic spherules (i.e. mineralogy and petrology), thus preventing a direct comparison with other meteoritic materials (e.g.,[2]). One type of silicate cosmic spherules is the Porphyritic Olivine (Po) cosmic spherules that are mainly composed of microphenocrysts of olivine set in glass. Approximately half of these Po cosmic spherules exhibit relict olivine crystals, often Fe-poor, which survived atmospheric entry and retained their original chemistry and isotopic signatures. However, the chemistry of relict olivine alone is not sufficient to identify their parent material, as major and minor element compositions of olivine in different chondrite groups overlap significantly [2].

Recent studies have shown that oxygen isotopes are an efficient tool to identify the parent bodies of cosmic spherules, as well-characterized chondrite groups exhibit distinct $\delta^{18}O$ and $\delta^{17}O$ values (Fig. 1; [3] and references therein). Accounting for atmospheric effects, most cosmic spherules can be deduced to mostly derive from known chondrite groups (Fig. 1). However, approximately 10% are depleted in ^{16}O and show relatively high $\Delta^{17}O$, which is not consistent with known chondritic materials. These particles have been labelled the isotopic Group 4, first established by [4]. Thus, these micrometeorites could represent ^{16}O-poor nebular material from a reservoir that is currently not sampled by meteorites.

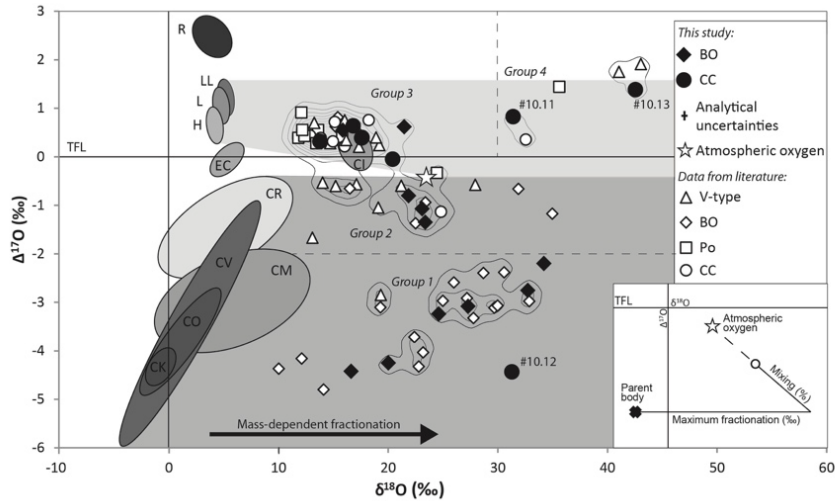

Fig. 1. $\Delta^{17}O$ vs. $\delta^{18}O$ values (in ‰ vs. VSMOW) of individual cosmic spherules from the Atacama Desert and from the Transantarctic Mountains measured by IRMS [3-6]. Analytical uncertainties (2σ) are represented. Density contours are shown. Reference for compositional fields of the potential parent bodies in [2].

About 14% of Po cosmic spherules, named Cumulate Porphyritic Olivine (CumPo) cosmic spherules, exhibit textures showing evidence of settling of olivine crystals during atmospheric deceleration [1]. This unusual texture suggests that these particles entered the Earth's atmosphere at velocity of ∼16 km s^{-1}, which corresponds to orbital eccentricities >0.3, higher than those of most asteroidal dust bands. Using a Cameca IMS 1270 SIMS instrument at the Centre de Recherches Pétrographiques et Géochimiques in Nancy, France we have established a link between the CumPo particles and a subset of the ^{16}O-poor spherules. However, the cesium beam-size used for these analyses (10-20 µm) did not allow us to characterize individual relict olivine crystals (<10 µm), which are essential to determining the undisturbed initial oxygen isotopic composition of the parent material of these particles. Using the NanoSIMS 50L at the Open University in Milton Keynes, United Kingdom during this EuroPlanet project, we have however been able to investigate in more detail the oxygen isotopic signatures of these CumPo cosmic spherules. Focus was placed on relict olivine crystals and neoformed mineral phases (with distinct

MgO/FeO ratios) within 4 selected particles. In total, there were 5 days of analyses plus an additional 2 days of set-up and calibration. Due to the COVID pandemic, this was a virtual visit as agreed to by the EuroPlanet administration. The work was conducted from the 4th to the 13th of October 2021 for the spot measurements and from the 21st to the 22nd of October 2021 for the imaging measurements. In addition, a day of data processing was done by OU staff on the 25th of October.

Based on the NanoSIMS results, a parentage with the newly defined CY carbonaceous chondrite group is proposed here. This implies that about 10% of the cosmic spherules reaching the Earth's surface has a near-Earth origin. As such connection is rare in the meteorite collection, this clearly demonstrates the importance of fully characterizing the flux of micrometeorites to understand the composition of the Solar System. Currently, models are being run to confirm a near-Earth origin. As soon as finalised, all results will be processed and discussed in collaboration with the Open University colleagues and jointly submitted for publication in a journal with a high impact factor (*Geochimica et Cosmochimica Acta, Earth and Planetary Science Letters, Science Advances, Nature Astronomy or Nature Communications*), acknowledging EuroPlanet support (aimed for 2023).

References: [1] Genge et al., 2016. Geophys. Res. Lett. 43, 10646-10653; [2] Van Ginneken et al., 2012. Meteorit. Planet. Sci. 47, 228-247; [3] Van Ginneken et al. 2017. Geochim. Cosmochim. Acta, 293, 313-320; [4] Suavet et al., 2011. Geochim. Cosmochim. Acta 75, 6200–6210; [5] Cordier et al., 2011. Geochim. Cosmochim. Acta 75, 18, 5203-5218; [6] Suavet et al., 2010. Earth Planet. Sci. Lett. 293, 313-320.

- Give details of any publications arising/planned (include conference abstracts etc)

- A first interpretation "A potential origin for 16O-poor cosmic spherules: a near-Earth source and parentage with CY chondrites" was presented by Van Ginneken and coauthors at the RAS specialist meeting - Sources and inventory of cosmic dust: From space to the Earth's surface on Feb. 11 2022 https://ras.ac.uk/sites/default/files/2022-02/RAS-meeting-programme_0.pdf
- Given the importance of these results to the micrometeorite community, as manuscript will be submitted to a high-profile journal (e.g., *Geochimica et Cosmochimica Acta*, *Earth and Planetary Science Letters*, *Science Advances, Nature Astronomy or Nature Communications*) as soon as the modelling component of this project is completed. We expect this to be in September 2022.

- Host confirmation

Please can hosts fill in/check this table confirming the breakdown of time for this TA project:

Dates for travel to accommodation for TA visit (if physical visit by applicant)	Start Date of TA project at facility	Number of lab/field days spent on TA Visit pre-analytical preparation	Number of days in lab/field site for TA Visit	Number of days spent in lab for TA Visit data analysis	End Date of TA project at facility	Dates for travel home (if physical visit by applicant)
No travel due to COVID pandemic	04-10-21	2	5	0	25-10-21	No travel due to COVID pandemic

The host is required to approve the report agreeing it is an accurate account of the research performed.

Host Name	Ian Franchi
Host Signature	
Date	18Aug22

- Project Leader confirmation

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Project Leader Name	Steven Goderis

Project Leader Signature	
Date	18 August 2022