

The primary 3D chemical composition of CM chondrules from micro-CT and fs-LA-ICPMS imaging

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Chondrites are sedimentary layers of asteroidal bodies that have remained relatively unaltered since their accretion from the gaseous protoplanetary disk, providing crucial insights into the earliest evolution of our Solar System, particularly during the planet formation period. Chondrules, once molten spherical objects that form a major component of chondrites, have formation ages that span the entire lifetime of the disk [1]. Consequently, chondrules are considered key building blocks in the accretion of asteroids, and their significance in planetary pebble accretion models has recently been emphasized [2]. In this context, understanding all aspects of chondrules—their precursor material, their formation process, and their role as planetary building blocks—is crucial.

Significant challenges in unraveling these processes are incomplete understanding of the chemical composition of chondrules, as they vary greatly in sizes and textures across different chondrite groups [3], along with technical and time constraints involved in analyzing a statistically significant sample of bulk chondrules [4].

In this study, we analyze the chemical composition of type I chondrules from three of the most pristine CM chondrites: Maribo, Paris, and Asuka 12236. We present scanning electron microscope (SEM) analyses (Globe Institute, University of Copenhagen) combined with high-resolution X-ray micro-CT imaging (DTU), processed using ImageJ. This methodology enabled us to analyze thousands of slice images per chondrule to calculate the bulk mineral phase distributions within each. Additionally, we obtained 2D femtosecond laser ablation RQ iCAP ICP-MS (Globe Institute, University of Copenhagen) maps of each chondrule and their fine-grained rims, providing data on major, minor, and trace element compositions at a range of 50% condensation temperatures. This data was then extrapolated into a 3D chondrule composition, yielding a representative composition for each chondrule.

As a result, we present a comprehensive analysis of the primary chemical signatures of bulk CM chondrules, enabling us to interpret their formation history and significance as planetary building blocks.

[1] Bollard, J. et al. Sci. Adv. 3, e1700407 (2017)

[2] Johansen, A. et al. Sci. Adv. 7, eabc0444 (2021)

[3] Scott, E. and Krot, A. Meteorites and Cosmochemical