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Micro-gravity experiments on the China Space Station reveal the mechanisms of formation and crystallization of chondrule and CAI in the early Solar System

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The Containerless Material Rack (CMR) on the China Space Station (CSS) offers a unique platform for simulating the micro-gravity conditions under which chondrules and Calcium-Aluminum-rich Inclusions (CAIs) formed in the early Solar System (ESS). Understanding the formation mechanism of chondrules and CAIs is fundamental for deciphering the early evolution of the Solar System, yet remains debated (*e.g. [1]*). While experiments conducted on the ground have provided insights into formation mechanisms, the gravity effect is inevitable and immeasurable (*e.g.* [2]). Previous attempts have been made to simulate chondrule formation by heating forsterite using arc discharges in microgravity aboard the International Space Station [2]. However, the short heating durations and limited temperature control hindered effective simulations of ESS circumstances.

Launched alongside the Tianhe core module of the CSS in April 2021, this facility enables the melting and controlled cooling of the samples, allowing for the observation of various metastable phases. Samples were loaded into the experimental chamber with precise position control achieved through electronic field manipulation. The samples were heated using semiconductor or CO_2lasers, enabling the emulation of thermal conditions relevant to the early solar nebula. After the experiments samples were retrieved for further analyses.

Experiments were carried out on sixteen Type I chondrule-like samples at various experimental conditions, including quenching, cooling, and multiple melting cycles. Parallel experiments were conducted in the ground laboratory of Center for Space Utilization, Chinese Academy of Sciences (CAS) to assess the gravitational effects on formation processes such as evaporation, crystallization, and elemental/isotopic behavior. Based on the observation, Type I chondrule-like samples crystallized with the cooling rates of 800K/h and 1200K/h, respectively. Our preliminary results suggest that the presence of gravity may enhance crystallization, although further quantitative analyses are needed. Additionally, experiments involving CAI-like samples are scheduled using the CMR on the CSS. Further analyses are expected following sample retrieval from the CSS in the near future, which will contribute to a more comprehensive understanding of these fundamental processes.

Reference:

[1] Connolly & Jones., 2016, JGR-Planets, 121, 1885

[2] Hewins & Fox., 2004, GCA, 68(4), 917

[3] Spahr et al., 2020, Icarus, 350, 113898