CHONDRULES: NEBULAR PRECURSORS BUT STILL NEBULOUS PROCESSES

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Despite two centuries of research, little consensus attends even the broadest outlines of chondrule formation contexts, e.g. "nebular" versus "planetary" [1]. We [2] performed LA-ICP-MS trace element and SIMS O isotope analyses of chondrules and refractory inclusions in the CM-related ungrouped chondrite NWA 5958 [3]. We found that 3 chondrules out of 26 show unequivocal subdued group II-like Rare Earth Element patterns with anomalies way outside the range of bulk *chondrite* anomalies (e.g., [4]). This and not so uncommon similar findings in the past literature (e.g., [5-7]) indicate that chondrule compositions cannot represent broad averages of planetary materials as would be predicted by most planetary-style scenarios [8] and rather call for models where stochastic assemblages of variously refractory condensates were melted, as in the nebular "flash-heating" scenarios.

Yet we cannot stick our heads in this protoplanetary sand and ignore evidence for enhanced solid/gas ratios in chondrule-forming regions (e.g., [9]). In fact, not only do nebular models struggle to reproduce them, but these may be physically fatal to part of them. This we found [10]—but will emphasize anew—is particularly true for the shock wave model, arguably the leading *nebular* model [11]. Indeed the initial heating relies on the drag experienced by solids after the gas velocity jump, but this drag should decelerate differently sized particles differently, hence high relative velocities. Then, increasing the solid/gas ratio will increase the probability of destructive collisions; in fact solar values may be already fatal to most "protochondrules" because of sandblasting. Thus, while we favor processing of primitive nebular solids for chondrules, a suitable robust mechanism is yet to be found.

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