Calibrating the clock of creation – towards a high-resolution chronology of Solar System formation

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The past three decades have generated remarkable progress in the field of planetary sciences, particularly with the discovery of thousands of extrasolar planets orbiting Sun-like stars. An important discovery emerging from the statistics of exoplanets is the great diversity in composition and structure of these worlds, suggesting that our solar system may not represent the archetype planetary system. Moreover, high-resolution observations of young disks suggest rapid planet formation within ~1 Myr of star-birth. Collectively, these data emphasize that planet formation is ubiquitous in young accreting disks. Better understanding the chronology of events leading to the growth of asteroids and planets in our solar system is thus key to relate its formation history with that of other planetary systems.

The most abundant constituent of chondrites are chondrules, mm-sized spherules formed by transient heating events. High-resolution uranium-corrected Pb-Pb dates indicate that chondrule formation started contemporaneously with the solar system first solids, CAIs, and lasted ~3 Myr [1]. Further, numerical simulations show that the main growth of asteroids results from gas-drag-assisted accretion of chondrules, leading to the formation of planetary embryos <3 Myr [2]. Thus, chondrules represent the precursor material of most asteroids and, by extension, planets. We initiated a study aimed at providing U-corrected Pb-Pb ages for a reference set of individual inclusions from enstatite, ordinary and various classes of carbonaceous chondrites (CV, CR and CK). Chondrule populations from individual chondrite groups show a comparable age range of ~3 Myr, with approximately half of the chondrules having crystallization ages <1 Myr of CAIs. These reference inclusions allow for comparison of the absolute Pb-Pb ages with that of the ^{26}Al short-lived radionuclide as well as tracers of nucleosynthetic variability such as ^{54}Cr. Internal ^{26}Al-^{26}Mg isochron relationships for ten Pb-Pb dated chondrules define ^{26}Al-^{26}Mg ages systematically younger by ~1 to 3 Myr compared to their absolute ages, pointing to a reduced initial abundance of ^{26}Al in the precursor material of terrestrial planets relative to CAIs. I will discuss how these results impact our understanding of mass transport processes in the protoplanetary disk as well as the accretion timescales and formation history of protoplanets.

[1] J. N. Connelly *et al.* (2012) *Science.* **735**, L37. [2] A. Johansen *et al.* (2015) *Science Advances*, in press.