Dating the formation of Jupiter using the genetic heritage and isotopic ages of meteorites

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Gas-giant planets, including Jupiter, likely formed through the growth of large solid cores, followed by the accumulation of gas onto these cores [e.g. 1]. Thus, the gas-giant cores must have formed before dissipation of the solar nebula, which likely occurred within less than 10 Ma after Solar System formation. Although such rapid accretion of gas giant cores has successfully been modelled [e.g. 1], until now it has not been possible to date their formation. Prior work revealed a fundamental genetic dichotomy distinguishing between carbonaceous (CC) and non-carbonaceous (NC) meteorite reservoirs [2]. If this dichotomy reflects the spatial separation of materials accreted inside (NC) and outside (CC) the orbit of Jupiter [3,4], then the formation of Jupiter can be dated by determining the formation time and lifetime of these reservoirs. In this study we use the W and Mo isotope signatures of iron meteorites for this purpose.

The iron meteorites analysed here and in prior work [4,5] reveal a dichotomy in their nucleosynthetic Mo and W isotope signatures. Thus, similar to chondrites [3,4], iron meteorites derive from two genetically distinct NC and CC nebular reservoirs. As the Hf-W core formation ages for both the NC and CC iron meteorite indicate parent body accretion within <1 Ma after CAIs, the NC and CC reservoirs must already been separated by this time. Chondrite parent bodies in both reservoirs accreted later, between ~2 and ~4 Ma after CAIs, indicating that the NC and CC reservoirs remained spatially separated until at least ~4 Ma after CAIs. The most plausible mechanism for this efficient separation is the formation of Jupiter, opening a gap in the disk and preventing the exchange of material between the two reservoirs [6]. As such, our results indicate that Jupiter's core grew to ~20 Earth masses within <1 Ma, followed by a more protracted growth to ~50 Earth masses until at least ~4 Ma after Solar System formation.

[1] Pollack J.B. et al. (1996) *Icarus* 124, 62–85. [2] Warren P.H. (2011) *EPSL* 311, 93-100. [3] Budde G. et al. (2016) *EPSL* 454, 293-303. [4] Burkhardt C. et al. (2011) *EPSL* 312, 390-400. [5] Kruijer et al. (2014) *Science* 344, 1150-1154. [6] Morbidelli A. et al. (2016) *Icarus* 267, 368-376. Work was performed under the auspices of the U.S. DOE by LLNL under Contract DE-AC52-07NA27344.