PB-PB AND HF-W ISOTOPIC EVIDENCE FOR EARLY DIFFERENTIATION OF THE IVA ASTEROID

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Introduction: Tungsten and silver isotope systematics strongly suggest that iron meteorites are very old differentiated objects. However, the limiting precision on W and Ag ages of, respectively, ~2 and ~4 Ma, and the current range of 1.6 Ma on the age of CAIs used to anchor both the ^{182}Hf-^{182}W and ^{107}Pb-^{107}Ag chronometers, stand in the way of finding out precisely how old. Contrary to extinct radioactivities, the Pb-Pb chronometer defines an absolute time scale rendering it independent of CAI age constraints. In addition, the precision of the Pb-Pb chronometer is potentially better than 1 Ma, even for ages as old as that of the Solar System. We therefore set out to date troilite inclusions in Muoniolusta, an iron meteorite belonging to the IVA group. The extreme depletion in volatile elements relative to chondrites of this group of rocks [1] holds promise of high U/Pb ratios that over time would produce Pb radiogenic enough to allow for precise and accurate dating of its host.

Results: As suggested by Ulff-Møller [2], the IVA iron meteorites accumulated from magmas produced by melting of a small chondritic asteroid, which broke up some 400 Ma ago [3, 4]. Using LA-ICP-MS, we found that the Muoniolusta troilite, as expected, is indeed highly depleted with very low abundances of Pb, U, and Th of the order of ppt to ppb, but with apparent μ (^{238}U/^{204}Pb) values of up to 1000. While the bulk of the nine troilite samples that we analyzed from Muoniolusta using solution chemistry and MC-ICP-MS scatter to some extent with a mean age of 4.57 Ga, one of the samples with ^{206}Pb/^{204}Pb > 1000 gives a statistically significant ^{207}Pb*/^{206}Pb* age of 4565.3 ± 0.1 Ma (MSWD = 0.08) consistent with the ^{182}Hf-^{182}W age of 2.4 ± 2.0 Ma that we measured on the iron located next to the troilite inclusion in question. This is the oldest age obtained to date for a differentiated planetary body in our Solar System.

The error on the Pb-Pb age was constrained by a new code with a least-square solution to linear alignments that considers the coordinates as lognormal variables. The so far commonly used normal variable assumption often leads to error ellipses lying partially within the negative half-space.

Discussion: The precise age obtained for Muoniolusta from the combined Pb-Pb and Hf-W isotopic evidence can be used in conjunction with the assumed closure temperature for Pb of 300°C and numerous cooling rate estimates acquired for this group of meteorites over the last 15 years [5, 6, 7] to infer that the IVA parent body accreted within 1 Ma of CAI formation and had cooled down to Pb closure within 2-3 Ma of time zero. The results presented here demonstrate that the IVA asteroid formed within the first million years of the Solar System, i.e., before the debris disk had cleared up [8].

References: [1] Wasson J. T. and Richardson J. W. 2001. *Geochim. Cosmochim. Acta* 65:951-970. [2] Ulff-Møller F. et al. 1995. *Geochim. Cosmochim. Acta* 59:4713-4728. [3] Voshage H. 1967. *Naturforsch.* 22a:477-506. [4] Lavielle B. et al. 1999. *Earth Planet. Sci. Lett.* 170:93-104. [5] Rasmussen K. L. et al. 1995. *Geochim. Cosmochim. Acta* 59:3049-3059. [6] Haack H. et al. 1996. *Geochim. Cosmochim. Acta* 60:3103-3113. [7] Yang J. et al. 2007. *Nature* 446:888-891. [8] Wyatt M. C. 2008. *Annu. Rev. Astron. Astrophys.* 46: 339-383.