**THERMAL HISTORIES OF CHONDRULES IN VERY LARGE PLANETESIMAL BOW SHOCKS: DID MARS MAKE CHONDRULES?**

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**Introduction:** It is widely accepted that the majority of chondrules formed by passage through solar nebula shocks [1,2], but the source of the shocks is debated, with either planetesimal bow shocks [3] or shocks driven by gravitational instabilities [4] favored [5]. Previous studies of bow shock models have indicated that the shocked region would be comparable in size to the planetesimal, ~ $10^3$ km, and so chondrules would necessarily pass through the region in < $10^3$ s, and experience cooling rates > $10^3$ K $hr^{-1}$, inconsistent with the porphyritic textures of most chondrules [6,7]. Additionally, the observed mass of chondrules can be produced only by assuming large numbers of 2000 km diameter planetesimals or other extreme input parameters [7,8].

The majority of extant chondrules formed at ~ 2 Myr after the birth of the solar nebula [9]. Modeling of planetary growth [10] indicates that planetary embryos the size of Mars can grow in ~ 2 Myr, and recent Hf-W isotopic systematics indicate Mars did, in fact, form and differentiate within 2 Myr [11]. If true, then Mars formed in the presence of nebular gas and chondrules. Recent dynamical simulations further suggest Mars formed at <1 AU and by 2 Myr was ejected into an eccentric orbit (e > 0.25) centered near its current orbit at 1.5 AU [12]. A proto-Mars with a=1.5 AU and perihelion 1.0 AU would move at up to 7 km/s relative to local gas at aphelion at 2.0 AU and could drive a bow shock capable of melting chondrules. So did Mars form chondrules?

**Results:** We have conducted preliminary calculations using the methodology of [7], including heating by $H_2$ recombinations [13], to study bow shocks around planetesimals, but assuming a 3400 km radius planetesimal (Mars). We find that chondrule cooling rates are 10-100 K/hr assuming an opacity equal to a solids-to-gas ratio of 0.13 in 300μm radius chondrules (equivalent to a solids-to-gas ratio 0.01 in 20μm particles), so that the optical depths through the shocked region exceed unity. These cooling rates are consistent with the porphyritic textures of most chondrules [14].

**Discussion:** *If* Mars formed as a planetary embryo at 1 AU and was ejected into its present orbit within 2 Myr, it would have driven very large planetesimal bow shocks capable of melting chondrules in a manner consistent with constraints. We note that the presence of a magma ocean on an early-formed Mars (heated by $^{26}$Al) could introduce Na and other volatiles into the gas in the chondrule-forming region around the planet, possibly explaining the high inferred Na vapor pressures during chondrule formation [15]. We estimate that Mars alone could shock ~ $10^{26}$ g of chondrules per Myr. We plan more detailed numerical simulations to test the provocative possibility that Mars formed chondrules.

**References:** [1] Desch, SJ et al. 2011, MAPS submitted. [2] Desch, SJ et al. 2010 ApJ 725, 692. [3] Hood, LL, 1998, MAPS 33, 97; [4] Boss, AP & Durisen, RH, 2005, ApJL 621, 137; [5] Desch, SJ et al., 2005, CPPD 341, 849; [6] Ciesla, FJ et al. 2004, MAPS 29, 1809; [7] Morris, MA et al. 2010, LPSC 31, 293; [8] Hood, LL et al. 2009, MAPS 44, 327; [9] Villeneuve et al. 2009, Science 325, 985; [10] Weidenschilling, SJ 2000, SSRv 92, 295; [11] Dauphas, N & Pourmand, A 2011, LPSC 42, 1040; [12] Hansen, BMS, 2009, ApJ 703, 1131; [13] Morris, MA & Desch, SJ, 2010, ApJ 722, 1474. [14] Desch & Connolly 2002, MAPS 37, 183. [15] Alexander, CMO'D et al. 2008, Science 320, 1617.