The case of the missing Ceres family

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Most of the largest asteroids in the main belt are associated with an impact-generated dynamical family. The Vesta family dominates the inner asteroid belt with its numbers [1,2], and was a critical piece of evidence in tying the HED meteorites to Vesta. In addition to Vesta (the third-largest asteroid), Pallas (the second-largest asteroid), Hygiea (the fourth-largest asteroid), and the largest S-class asteroid, (15) Eunomia, all have dynamical families [3–6]. In total, ten of the 14 known 250+ km bodies in the past or present asteroid belt are associated with dynamical families, either of the smaller "cratering" type, dominated by a major body and relatively small fragments, or large disruptions that indicate gravity-dominated catastrophic events. It is curious, then, that the very largest body in the asteroid belt, Ceres, is missing from this list of parents. Ceres is unassociated with any sort of family at all as far as we know [4]. This alone is perhaps not sufficient to draw any conclusion, but motivates us towards the considerations we make here. We will use relevant published works to demonstrate that Ceres' collisional history is very likely to include large enough impacts to create a family [8–10], that a Ceres family would be found if extant [2], and that a Ceres family would not be easily erased once created if it is like the rocky bodies comprising "typical" asteroid families [7]. There is observational and model evidence that Ceres is a differentiated body, with an icy mantle atop a rocky core [11–13]. However, the surface of Ceres is too warm to maintain ice for significantly long periods of time (save very near the poles), and the retreat of ice does not effectively halt until it reaches a depth of rough order 100–1000 m (depending upon latitude and surface temperature) beneath an insulating lag deposit [14,15]. To first order, an icy Ceres family is subject to the same sublimation rates as Ceres itself. Can its members have simply sublimed away? An order-of-magnitude argument shows that sublimation may have been a powerful force in erasing an icy Ceres family — this simplified model very likely understates the case for sublimation. We hope to show that the lack of a family has implications for Ceres' internal structure, and further hope to encourage research beyond the scope of this work — geodynamical, chemical, and collisional modeling — that can provide additional firm constraints.

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References: [1] Binzel R. P. and Xu S. (1993) Science, 260, 186–191. [2] DeMeo F. and Carry B. (2013) Icarus, 226, 723–741. [3] Gil-Hutton R. (2006) Icarus, 183, 93–100. [4] Nesvorny D. (2012) NASA Planetary Data System. [5] Carruba V. (2013) Mon. Not. Royal Ast. Soc., 431, 3557–3569. [6] Mothé-Diniz T. et al. (2001) Icarus, 152, 117–126. [7] O'Brien D. P. and Greenberg R. (2005) Icarus, 178, 179–212. [8] de Elía G. and Di Sisto R. (2011) arXiv preprint 1109.2523. [9] Li J.-Y. et al. (2006) Icarus, 182, 143–160. [10] Carry B. et al. (2008) Astron. Astroph., 478, 235–244. [11] Thomas et al., (2005) Nature, 436, 366–369. [12] McCord T. B. and Sotin C. (2005) JGR, 110, 5009–5011. [13] Castillo-Rogez J. C. and McCord T. B. (2010) Icarus, 205, 443–459. [14] Fanale F. P. and Salvail J. R. (1989) Icarus, 82, 97–110. [15] Schorghofer N. (2008) Ap. J., 682, 697–705.