COULD CERES BE A REFUGEE FROM THE KUIPER BELT? William B. McKinnon, Department of Earth and Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University, Saint Louis, MO 63130 (mckinnon@wustl.edu).

Introduction: Ceres is a most unusual asteroid. Comprising ~1/3 of the total mass of the present asteroid belt, it is classified as a relatively rare, G type, related to the more abundant carbonaceous C-type asteroids. It resides deep in the main belt, at a semimajor axis of 2.77 AU, at the center of the broad distribution of C types [1]. But it is not a C-type asteroid as usually considered. It is a differentiated dwarf planet, whose water-rich composition indicates a kinship with bodies much farther out in the solar system [2]. Here I explore the idea that Ceres originally accreted in a transneptunian orbit, was dynamically scattered inwards during a Nice-model like reorganization of the outer solar system [e.g., 3], and implanted in a more massive, primordial asteroid belt, where it remains today.

Density: Ground-based and HST imaging/occultations have converged on a picture of Ceres as a large, dwarf-planet-class body in rotational hydrostatic equilibrium, with a mean radius ~470 km and density ~2.2 g cm^{-3} [4] Ceres thus joins an interesting group of outer solar system bodies, the largest KBOs: Triton, 2.061 ± 0.007 g cm^{-3}; Eris, 2.3 ± 0.3 g cm^{-3}, and the Pluto-Charon binary, 1.94 ± 0.09 g cm^{-3} [5]. All these densities agree within uncertainties (and are quite different from Ganymede and Callisto), when self-compression is accounted for. When interpreted in terms of rock/water-ice ratio, such densities imply a ≈70/30 mix, long thought a signature of accretion in the outer solar system [e.g., 6].

The iciness of Ceres contrasts with the much smaller water contents of carbonaceous meteorites [7], the presumed analogues to the C, G, and spectrally related types of asteroids. A model has been proposed in which icy planetesimals drift inwards under the action of gas drag, from beyond 5 AU, to provide the bulk ice (and presumably other volatile) content of Ceres [8]. Were all G and C asteroids originally composed of this much ice? It is curious that Ceres' density ≈matches theoretical predictions/observations for condensation in a kinetically inhibited solar nebula. Otherwise, one must assume it is accidental, a product of both volatile (ice) loss during inward planetesimal drift and initial ice enhancement just beyond the nebular "snow line" [6]. The density and moment-of-inertia of Ceres (the latter indicating central condensation) are not obviously compatible with an ice-poor but *porous* composition [see discussion in 5].

Surface Composition: Ceres' albedo of ~9% hints that its surface is more than intimately mixed silicates and opaques, and frost has been long suspected, at least at some longitudes [e.g., 4,9]. More importantly, hydrated silicates are indicated by a broad 3-μm absorption, and a narrow absorption near 3.05 μm has been attributed to either Fe-rich or NH_4^+-bearing clays [10,11]. Ammonium-bearing phyllosilicates have been noted as unknown in meteorites [11], and for this reason perhaps not as seriously considered, but NH_3 is not unknown in the transneptunian region, having been identified on Charon and in comets [see references in 5]. The early evolution of a dwarf planet TNO would involve eruption of ammonia and methanol-bearing lavas to the surface, even before bulk rock-from-ice differentiation [5], and alteration of silicates by such liquids could be a source for ammonium-bearing clays.

Earlier ideas involving thermal metamorphism of C-type material to yield G-type spectra do not seem obviously relevant to Ceres at least, given the icy nature of its outer layer(s). Nor should Ceres, as an evolved, differentiated KBO, be expected to spectrally resemble its "primitive" D-type asteroid cousins. However, any surface volatiles (NH_3, CH_4, etc.) would have been rapidly lost after its dynamic "resettlement."

Dynamics: The key to Ceres' origin as a KBO is dynamics, and recent work offers a path whereby early solar system populations can migrate [3,12,13]. There has long been a possible link between D-type asteroids and comets, and implantation of asteroid populations is not a new idea [e.g., 14]. For Ceres, in an eccentric, implanted orbit, to end up in a more circular one requires energy and angular momentum exchange with a more massive primordial asteroid belt. Such an early massive, asteroid belt is thought likely [12]. The question is whether enough large (Varuna-class) KBOs were scattered to make a single capture into the primordial asteroid belt statistically likely [13].

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