COMBINING DYNAMICAL AND COSMOCHEMICAL CONSTRAINTS ON THE PROCESSES OF CHONDRULE FORMATION: LAYERED DISKS. A. Hubbard[1] and D. S. Ebel[2], [1]Department of Astrophysics, American Museum of Natural History (ahubbard@amnh.org), [2]Department of Earth and Planetary Sciences, American Museum of Natural History (debel@amnh.org)

Introduction: The field of astrophysics has been making large strides in the understanding of the processes of collisional dust growth, dust transport, concentration and aerodynamical sorting, and planetesimal formation in protoplanetary disks [1,2,3]. Similarly, cosmochemists have been developing an exciting relatively new constraint on the correlation between chondrules and matrix in chondrites known as complementarity [4,5,6]. Combined, these advances make striking predictions about the physical partitioning of protoplanetary disk regions associated with chondrule formation that match well with a standard global picture of protoplanetary disks as accreting through magnetically active surface layers while the midplanes are quiescent [6].

Complementarity: Across a wide range of elements and isotopes, the composition of matrix and chondrules within a given chondrite differ significantly. Further, the ratio of chondrules to matrix varies strongly between chondrites. Nonetheless, the bulk elemental and isotopic abundances of chondritic meteorities are flat across chondrite classes [4,5,6]. This implies that chondrules and matrix within a given chondrite were co-genetic, forming from a single reservoir of near-solar composition. It also implies that parent body assemblage had to have occurred shortly after and spatially near chondrule formation [8].

Spatial sorting: One mystery associated with complementarity is how the chondrules and matrix can have different compositions in the first place. This challenge was made particularly pressing by the recent W/Hf isotope measurements of Budde et al [6]. Separating matrix from their co-genetic chondrule precursor grains would have required strong aerodyanmical sorting [8]. While radial pressure perturbations can concentrate large dust grains and act as a sorting mechanism [2], chondrules are too small to have been easily concentrated in such a fashion.

Planetesimal formation and chondrule size: It has become clear that naked chondrules (on order of 500 micron diameter and smaller) could not have directly proceeded to planetesimal formation, and must have stuck together to form large agglomerations [10]. However, outside of a few rare examples [11], meteorites do not record the thermal processing of such agglomerations. Thus, in tension with complementarity, chondrule formation regions must have been separate (either in space or in time) from the parent body assemblage regions.

Layered disk structure: These challenges and constraints point to a layered disk scenario, where chondrule formation events were restricted to the upper layers, well above a cool midplane. In that case, strong vertical stratification and settling would have allowed the spatial sorting of chondrule precursors and matrix grains. Once the newly formed chondrules settled to the midplane, they could agglomerate without those agglomerations being thermally processed. Further, the low aspect ratio of protoplanetary disks means that this scenario would have required only relatively small vertical distances with concomitantly short transport times. Thus, this scenario would have allowed the matrix and chondrules in a narrow radial annulus to remain co-genetic through the aerodynamical sorting, chondrule formation and parent body formations stages.

This picture is particularly attractive because it meshes well with the conventional astrophysical picture of magnetically accreting layered protoplanetary disks: quiescent, low ionization midplanes and non-thermally ionized, magnetically active surface layers [7]. However, it also places a constraint on chondrule formation models: the mchanism should preferentially occur in the upper reaches of disks. While the dissipation of magnetic turbulence would be consistent with that constraint [12], the strong vertical gradients invoked to allow spatial sorting might have allowed other mechanisms such as lightning [13]: spatial sorting is a mechanism to drive charge separation over large length scales.

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