TURBULENT SIZE SELECTION AND CONCENTRATION OF CHONDRULE-SIZED OBJECTS: REYNOLDS NUMBER INVARIANCE AND IMPLICATIONS.

J. N. Cuzzi, *Ames Research Center, NASA; Moffett Field, Ca, 94035, USA, cuzzi@cosmic.arc.nasa.gov*, R. Hogan, *Symtech inc., Mountain View, Ca 94035, USA*, A. Dobrovolskis, *Board of Studies in Astronomy, University of California, Santa Cruz, Ca, USA*, J. Paque, *SETI Institute, Mountain View, Ca, USA*.

It is generally agreed that individual chondrules formed as entities in a gaseous nebula prior to being accumulated into a meteorite parent body, within which they incur various forms of modification before arriving in our labs. While there are major unanswered questions about the properties of the nebula environment in which chondrules formed, the process by which the most primitive meteorites are formed overwhelmingly from chondrules must then be an aspect of “nebula processing". Textures in certain fragments of primitive meteorites might be summarized as being primarily chondrules and clastic, chondrule-sized, fragments of other minerals, each covered with a rim of fine dust with physical and chemical properties which are essentially independent of the composition and mineralogy of the underlying chondrule. This (unfortunately rather rare) texture was called “primary accretionary texture" by Metzler et al (1992) to reflect their belief that it precedes subsequent stages in which fragmentation, comminution, mixing, heating, and other forms of alteration occur on the parent body(-ies). The size distribution of these chondrules and fragments, and the properties of their dusty rims, are key clues regarding the primary nebula accretion process. Even in the much more abundant meteorites which have clearly suffered internal mixing, abrasion, grinding, and even mineralogical alteration or replacement (due presumably to the collisional growth and heating process itself), key chondrule properties such as mean size and density remain relatively well defined, and well defined rims persist in many cases.

It has been our goal to infer the key nebula processes indirectly from the properties of these very earliest primitive meteorites by making use of a theoretical framework in which the nebula possesses a plausible level of isotropic turbulence. We have shown that turbulence has the property of concentrating one particular particle size by orders of magnitude, where the preferentially concentrated size depends primarily on the intensity of the turbulent kinetic energy (represented by the Reynolds number of the nebula). Specifically, the preferentially concentrated particle is that which has a stopping time equal to the turnover time of the smallest eddy (Cuzzi et al 1996). The intensity level of turbulence implied by chondrule sizes can be maintained by even a small fraction of the energy released by the radially evolving disk (it must be noted that the details of how this transfer of energy actually occurs remain obscure, however).

We have carried our studies of the turbulent concentration process to a deeper level and have obtained several new and interesting results. Where in our previous results we needed to rely on large extrapolations between computational turbulence regimes and nebula turbulence regimes (5 orders of magnitude in Reynolds number), we now have established that two critical aspects of the process can be described in a way that is Reynolds number *independent* (Hogan *et al.* 1997, in preparation).

Firstly, we have run numerical calculations of particle density fields in turbulence for a range of particle sizes where the initial spatial distribution of each size is uniform. We then determine the distribution of particle sizes only within the high density regions. We show that not only is the shape of the particle distribution resident in dense clumps quite similar to that found in chondrites, it is Reynolds number independent (across the factor of 3-4 in Reynolds number we have mapped so far). That is, chondrule size distributions provided by our numerical models might be expected to persist even at much higher nebula Reynolds numbers. Results will be shown and compared with size distributions from the literature (Hughes 1978) and from our own experiments (Paque and Cuzzi 1997); in the newer data, chondrules are disaggregated so their size and density can be measured separately. This is critical because in the aerodynamic sorting provided by turbulence, the defining parameter is the aerodynamic stopping time, which is proportional to the product of the particle radius and density.

Secondly, we have developed a new way of describing the particle density fields that is also invariant to Reynolds number. The mathematics of fractals has been shown to be particularly appropriate to describe the spatial distribution of certain properties of turbulence, specifically the dissipation rate of turbulent kinetic energy (Meneveaux and Sreenivasan 19??). This means that the spatial distribution of the turbulent energy dissipation rate is scale-independent, and that higher intensities have a different spatial structure, or dimensionality, than lower intensities (*ie*, are concentrated in smaller regions). We have shown that the same mathematics applies to the particle density field when the particle size is close to the preferentially concentrated size (Hogan *et al* 1997, in preparation). The density field (or concentration factor) for these particle sizes can then be described by a probability distribution which has only two elements: a Reynolds number independent scaling function (which we determine in our numerical calculations at three relatively low Reynolds numbers) and the Reynolds number itself. The entire particle density probability distribution can be predicted at any Reynolds number from this universal function. The particle concentrations predicted this way are in general accord with simple extrapolations published previously (Cuzzi et al 1996). We discuss the implications for particle concentration in nebula turbulence, and some remaining uncertainties.

References: Cuzzi, J. N., A. R. Dobrovolskis, and R. C. Hogan (1996); in “Chondrules and the Protoplanetary Disk", R. Jones, R. Hewins, and E. R. D. Scott, eds; Cambridge Univ. Press; Hughes, D. W. (1978); E.P.S.L. 38, 391-400; Meneveau, C. and K. R. Sreenivasan (1991) J. Fluid Mech. 224, 429-484; Metzler, K., H. Bischoff, and D. Stöffler (1992); Geochim. Cosmochim. Acta, 56, 2873-2897; Paque, J. and J. N. Cuzzi (1997); Proc. 28th LPSC