THE INITIATION OF CHONDRITE ACCRETION AFTER CHONDRULE FORMATION BY DRAG HEATING

John A. Wood
Harvard-Smithsonian Center for Astrophysics, Cambridge MA 02138

Recently I have suggested that the various classes of chondritic meteorites were formed from discrete parcels of dust-enriched interstellar material which fell into the solar nebula during solar system formation (1). Aggregates of interstellar dust were heated and melted by aerodynamic drag as they streaked through the nebula, forming chondrules (2,3,1).

The highly simplified model discussed by (1) assumed the nebular gas to be a static, passive medium. This is a reasonable assumption if the solids/gas mass ratio is small, but (1) contemplates systems in which solids/gas is concentrated to 100x or more the cosmic ratio, and in this case the mass of solids $\gtrsim$ the mass of the gas. Passage of such large amounts of solid material through the gas would accelerate and heat it significantly.

A more comprehensive computational model has been developed, which attempts to relate particle motions and temperatures to motions and state parameters of the nebular gases. Typical results appear in Fig. 1, which shows profiles of particle density and velocity, and gas density, pressure, temperature, and velocity in the nebula 62 days after a volume of interstellar material containing 100x the cosmic complement of solids (in the form of 1-mm protochondrules) began to encounter the nebula at a velocity of 21.3 km/sec. Particle temperatures in the system have not yet been formally treated.

It can be seen that a buildup of particle (chondrule) density and gas velocity, density, and pressure develops $\sim 7 \times 10^6$ km inside the surface of the nebula. The pileup of particles, which causes the other increases, occurs where particle velocities have become small, for the same reason that automo-

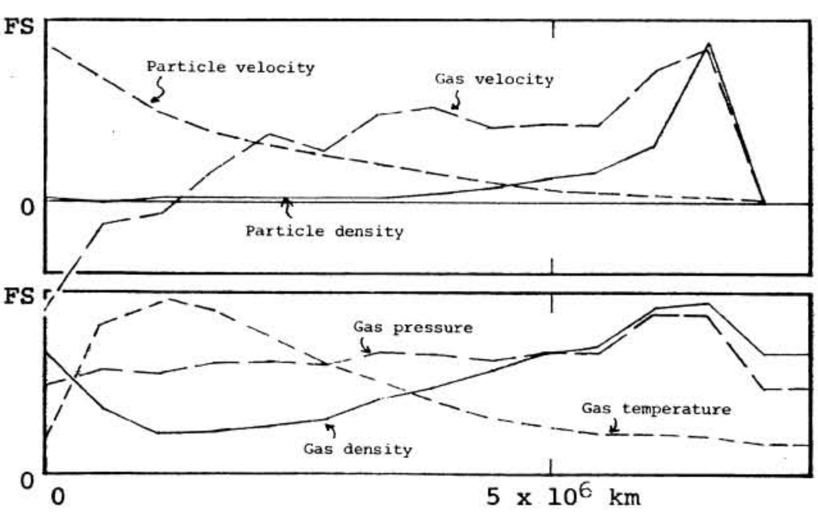

Figure 1. Profiles of various parameters near the nebula surface (see text). FS (full scale) corresponds to: Particle velocity, 25 km/sec; Gas velocity, 0.4 km/sec; Particle density, 1.5×10^{-13} g/cm^3; Gas pressure, 1.5×10^{-8} atm; Gas temperature, 600K; Gas density, 2.5×10^{-12} g/cm^3.

biles draw closer together when the traffic slows down. The density peak shown actually only partly restores the original pre-nebular solids/gas mass ratio, which was diminished by $\sim 10^{-3}$ at the nebular surface because the gas was compressed by that factor when it encountered the nebular shock front, while the spacing of particles remained the same. The solids/gas mass ratio approaches its original value as the particle velocities relative to the gas approach zero.

A crucial question is, does the pre-nebular solids/gas ratio set a limit on the density of particles that can be reached in this particle-rich zone (PRZ) as it moves through the nebula? Or would the particle density tend to build up to much higher values, for reasons other than the simple attenuation of velocities referred to above? The coarse space resolution of the computational model prevents it from reproducing such a process. Factors that might promote such a concentration are:

(a) Early-arriving particles tend to accelerate the gas between the nebula surface and the PRZ, making the passage of later particles easier (less drag deceleration), so they arrive at the PRZ with more residual velocity than early particles did, and can close with (and pass) them.

(b) A moving shock front probably develops in the PRZ, since the sound speed in particle/gas mixtures is very small (4). Particles that moved forward through the shock front would encounter a regime of higher ($V_{particle} - V_{gas}$), and would be slowed by it and eventually overtaken by the shock front and reabsorbed by the PRZ.

(c) If particle density in the PRZ increases above $\sim 10^{-11}$ g/cm^3, the mean free path between particles becomes small enough that an object would suffer multiple collisions while trying to pass through the PRZ, causing it to be decelerated and absorbed by the zone.

These considerations are important because if particle densities in the PRZ come to exceed a value of very approximately 10^{-9} g/cm^3, the PRZ would become unstable against fragmentation and self-gravitational collapse into planetesimals. It is possible that the accretion of chondritic planetesimals was initiated in this way. This would be consistent with the promptness of accretion after chondrule formation that is called for according to (5). It would also explain the striking uniformity of chondrite textures on a large scale, which is inconsistent with the Goldreich-Ward (6) mode of initiation of accretion.

REFERENCES

1. J. A. Wood (1984), *Earth Plan. Sci. Lett. 70*, 11-26.
2. J. A. Wood (1984), *Proc. Eighth Symp. Antarctic Mets. (Tokyo)*, 84-92.
3. J. A. Wood (1984), *Lunar Planet. Sci. XV*, 933-934.
4. A. C. Thompson and D. J. Stevenson (1983), *Lunar Planet. Sci. XIV*, 787-788.
5. J. A. Wood (1985), in *Protostars and Planets II* (Ed. D. C. Black), Univ. Arizona Press, in press.
6. P. Goldreich and W. R. Ward (1973), *Astrophys. J. 183*, 1051-1061.