MAGNETIC FLOCCULATION: THE METAL-SILICATE SEPARATION
Charles E KenKnight, 3819 Lake Drive, Robbinsdale, MN 55422

The display of magnetic field lines with iron filings on a piece of paper over a bar magnet is familiar. What is not usually emphasized is that the display always succeeds. The field lines are always displayed because a ferromagnetic powder in a strong enough external magnetic field is unstable to the formation of long thread-like chains of particles. The chains avoid each other because they interact like an anisotropic van der Waals gas [1]. In the area outlining the end of the magnet, the 2-D "gas" of filings form threads whose ends at the magnet are all polarized with one sign and therefore avoid the next chains. On a horizontal surface within a coil giving a vertical H-field, the chains stand vertically and roughly equi-spaced. With H of several kGauss the chains form in a fraction of a second. Lifting chains from a dust mixture with a dc H permits little separation of the magnetic and silicate grains; the chains are mantled with the silicates. Use of an ac H tends to shake the silicates loose because the reversal of magnetization is noisy and trembling of the chains follows.

Coagulation of infalling interstellar grains to form aggregates of meter size rapidly enough has been mysterious. I suggest that magnetic fields with H of 1 to 10 Gauss [2] played a role. Ferromagnetic grains of diameter \(a = 10^{-4}\) cm have an alignment parameter \(MH/(kT)\) near \(10^5\). The time for decay of rotation of chains of these grains should be nearly that due to Epstein drag, tens of seconds using the table of nebular parameters given by Weidenschilling [3]. Thus even submicron grains will be continuously aligned with H. Grain-grain collisions with geometric cross-section go slowly. But if the cross-section \(A\) is \(\pi r^2\) in the chance of passing near another dipole, \(n g A k\), where the miss distance \(r\) is obtained by setting the energy per grain \(F = -H^2/(3kT r^6)\) to \(-kT\), one finds from \(r = 1/40\) cm that 2 dipoles will hit in \(10^3\) or so tries, the tries repeating every \(\lambda/v_B = 100\) s; \(\lambda\) is the gas mean free path and \(v_B\) is the Brownian motion speed. These chains follow any movements of the (certainly nonuniform) H field faithfully and should sweep up the silicates on the same short time scale, concentrating both magnetics and non-magnetics in tubes where H is greatest. Chains may grow to length \(r\) or more, so they were effective in blocking the escape of infrared radiation until the temperature \(T\) rose so high that T-driven transport of vapors and smoke caused the formation of larger objects such as chondrules and CAIs. A large number of local relaxation oscillations in T should be expected, so an averaging over volatility effects must be in the rocks we find. A variety of outcomes in reservoirs [4] may be due to T-dependence of Curie points and vapor pressures, plus losses to radial transport above and below the accumulating nebula.


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