PROBLEM SET 4, ASTRONOMY 216

1. Two identical clouds of density ρ_0, temperature T_0 collide at a relative velocity $2v_r$. Shocks then advance into each cloud at velocity v_s. Assume that the clouds are semi-infinite one-dimensional slabs and that they collide head-on.

a. Assuming that the shocks are strong and nonradiative, and that the gas has a ratio of specific heats $\frac{5}{3}$, find v_s, ρ, T, P between the shocks.

b. Evaluate these quantities numerically for the case $n_0 = 40$ cm^{-3}, $B_0 = 3$ μGauss, and $2v_r = 24$ km s^{-1}.

c. Cooling takes place primarily by radiation in the CII FS line at 158 μm wavelength. You can use Spitzer's rate (equation 6-13); approximate it by a temperature-independent rate to make things easy. How long does the gas take to cool to $T = 100$ K? Neglect heating (this isn't perfectly valid, particularly as the gas gets cooler, but it's good enough for our purposes).

After the gas has cooled to 100 K, what are the density and magnetic field?

Consider: You can use the energy equation with the loss term. Does the cooling take place at roughly constant pressure or constant density? Assume cooling occurs in one of these extremes; in-between cases are harder to handle and don't illustrate any new features of interest.

d. Real clouds aren't semi-infinite. Suppose each cloud has thickness l_0, but does actually extend to infinity in the direction perpendicular to the motion so that all motions are one-dimensional. After both clouds have been completely shocked, they are at a much higher pressure than the ambient medium, and they will expand. Take the initial thickness of the slabs, before the collision, to be l_0. What is the thickness after compression by the radiative shock? If the shocked clouds expand at their Alfvén velocity ($V_A^2 = \frac{4\pi B^2}{\rho}$), how long does it take for the density to drop by a factor of two[1]?

Compare this with the cooling time. Does dynamical expansion occur faster than cooling?

Give numerical values for $l_0 = 1$ pc.

---

[1] If B is in Gauss, then all equations we've written are valid in cgs units.