Homework 3: Solar Wind

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1 Hydrostatic Corona [From A. Kosovichev]

Chapman (1957) presented a model of corona in hydrostatic equilibrium.

(a) The energy equation contains only thermal conduction. In spherical coordinate, it reduces to

$$\frac{d}{dr}\left(r^2\kappa\frac{dT}{dr}\right)=0, \tag{1}$$

where r is radius, and T is temperature. The conductivity κ satisfies $\kappa=\kappa_0 T^{5/2}$, where k_0 is a constant.

Assuming at the solar surface ($r=R_\odot$, solar radius) there is $T=T_0$, and toward infinity ($r\to\infty$) there is $T\to 0$, **SOLVE** Eq. (1) for $T=T(r)$.

(b) Consider the hydrostatic equilibrium:

$$\begin{aligned}\frac{dp}{dr}&=-\frac{GM_\odot\rho}{r^2},\\ p&=\rho RT,\end{aligned} \tag{2}$$

where p is pressure, ρ is density, G is the gravitational constant, $M_\odot$ is the solar mass, and R is the specific gas constant.

Assuming at the solar surface ($r=R_\odot$, solar radius) there is $p=p_0$, $\rho=\rho_0$, **SOLVE** Eq. (2) for $p=p(r)$.

(c) **COMMENT** on the behavior of $p(r)$ for $r\to\infty$ in context of Parker's solar wind solution.

2 Solar Wind Order-of-Magnitude [From G. Howes]

Given an average solar wind, **ESTIMATE** how much (a) mass, (b) linear momentum, and (c) energy is lost by the Sun per unit time. If the solar wind were constant in time, (d) **ESTIMATE** how long it would take to lose all the solar mass at this rate (in years). (e) **COMPARE** the fluxes of kinetic energy, thermal energy, and magnetic energy due to the outflow of the solar wind from the Sun: which one dominates?