

Hale COLLAGE 2017 Problem Set #2 (Due Mar 1)

For problems 2–4 explain/justify how you obtained your answer. This will help us determine your understanding of the problem whether or not you got the correct answer. In the event of an incorrect answer, we can still try to give you partial credit based on the explanation you provide.

1. In this problem, we will modify (simplify) the configuration in Problem 1, with the magnetic field generated by a bipole of strength λ at the position in the $y - z$ plane $(\pm b, 0)$, λ, b both being positive, and a line current I at the position $(0, h)$, and its mirror current $-I$ at $(0, -h)$. This produces a simple 2-dimensional flux rope with an X-point below the flux rope (the center of which is the line current) with an appropriate sign of the current I . With this toy model, we will predict observational measurements, reconnection rate and coronal dimming, as the flux rope rises.

(a) As the flux rope rises, we assume that the current I in the flux rope is constant, and reconnection at the X-point below the rope is always very efficient so that a current sheet never forms there. With such a configuration, find the reconnection flux as a function of the flux rope height h . For a high-lying rope $h \gg b$, and also given $\lambda = 2I/c$, find the leading term of your solution.

(b) The measured CME velocity near the Sun often exhibits a time evolution that may be described by a hyperbolic function

$$v = \frac{v_0}{2} \left[\tanh \left(\frac{t - 2\tau}{\tau} \right) + 1 \right],$$

where t is time, τ is a time constant, and v_0 is the peak velocity the CME attains. Use the following set of parameters, $v_0\tau = b$ and $h(t = 2\tau) = 5b$, for two different values of the time constant $\tau = 50, 150$ sec, respectively, plot the reconnection flux ψ_R versus time together with the velocity, with the time range from 0 to 1000 sec.

(c) Find and plot the reconnection rate $\dot{\psi}_R = d\psi_R/dt$ and rope's acceleration. Evaluate the time difference between the peak acceleration and peak reconnection rate for the two values of the time constant τ .

(d) As the rope rises, when we look down upon the rising rope, we may observe coronal dimming. Suppose that the rope is truly 2-dimensional with reconnection injecting bubble field lines into the rope, and the axial flux (which is along the x-direction in

this 2d model) is conserved, but is somehow bent and firmly attached to the surface at two locations. Suppose that coronal mass along this axial direction is conserved and the total length of the axial flux tube grows proportionally with h , for a uniform adiabatic expansion, calculate and plot the time evolution of the density (n), temperature (T), and total emission measure (EM) along this axial flux tube compared with their initial values. You may treat the coronal mass as an ideal gas with the ratio of specific heats $\gamma = 5/3$.

(e) The coronal temperature before the eruption is 1.5 MK. Suppose that we observe the feet of the flux rope with the Fe XII line at 193Å, and the temperature response of the instrument for this line is given by a Gaussian

$$G(T) = \exp \left[-\frac{(T - T_0)^2}{2T_w^2} \right],$$

where $T_0 = 2T_w = 1.5\text{MK}$. The observed counts is an integral along the line of sight with the effective length scale $l_{eff} \propto h$. Find and plot the time sequence of the observed data counts normalized to the pre-eruption data counts (aka, coronal dimming) at this line. Evaluate the extent of dimming when the flux rope is twice as high as its initial height.

2. Use a coronal and heliospheric electron density model $n_e(R)$ from the literature to calculate the plasma frequency as function of the distance R from the Sun, and try to reproduce the curve $\nu_p(R)$ shown in slide #29 of Lecture 7 (from Gary & Hurford 2004). For each density model you use, please provide a reference. Please include a figure with good quality and clear labels (as if it appears in a journal article). Does your result match the curve? If not, why?
3. Fig. 1 shows some typical type III radio bursts observed by STEREO/WAVES on June 26, 2014. Assuming fundamental plasma radiation, use an appropriate solar wind density model to reproduce the frequency drift feature of type III radio bursts (in the STEREO/WAVES frequency range). Note this only gives you a single curve. Why do the type III bursts appear “fatter” (in other words, having longer durations) at lower frequencies? You need to provide references in the literature to support your discussions. Find either a theoretical or empirical relation of the frequency-dependent type III duration to reproduce the general appearance of these bursts in the dynamic spectrum (you do not have to worry about the absolute flux).
4. At what frequency (or frequency range) does each radio spectrum shown in Fig. 2 become optically thin, say where $\tau \lesssim 1$? Why?

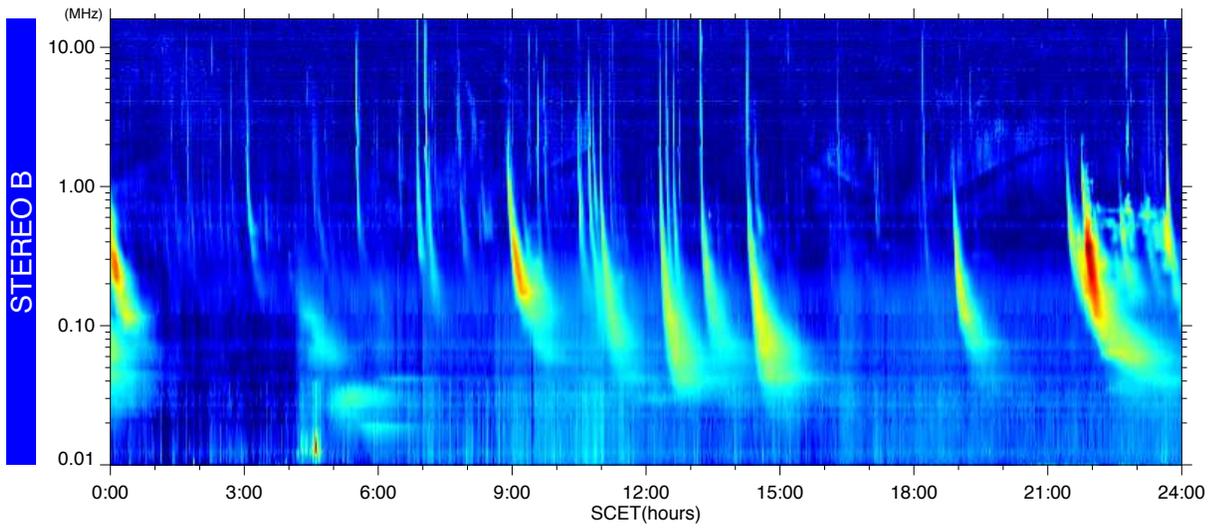


Figure 1: A dynamic spectrum from STEREO/WAVES.

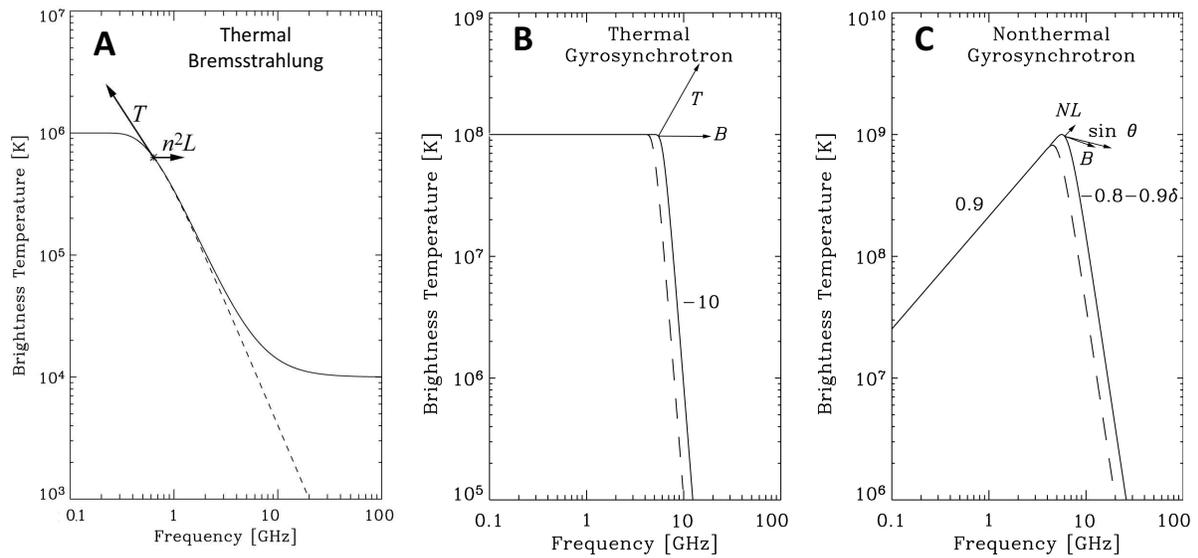


Figure 2: Some typical radio spectra.