A4410
Fall 2015
Radio Lab 1
Radiometry and Beam Width

Introduction: A radio telescope comprises a basic building block of antenna, receiver, and "backend" signal processor. Whether such a system is used by itself or as part of an array of interferometers, some basic properties of the building block must be known and, typically, these are determined empirically. In this lab you will determine some of the basic properties of the antenna + receiver as a prelude to using the system for spectroscopy in the second lab. In particular, you are to determine the system temperature, the effective temperature of the calibration diode, and the beam width of the antenna. The antenna beam is the angular response to radiation from the sky and is equivalent to the point spread function (terminology from optics). We use the full width at half maximum to characterize the beam width. You should report the FWHM in degrees. For all parameters you estimate, conduct and report a proper error analysis.

1. Estimate the system temperature, $T_{\rm sys}$, and other parameters:

   (a) First be sure the antenna is pointed to as low an elevation as possible; this is so that you can manually hold a slab of electromagnetic absorber in front of the feed antenna at the antenna focus.

   (b) Acquire some data in a time series using the command chart_recorder_rspec. While it is running, make the following events happen:

      i. noise diode on

      ii. noise diode off

      iii. hold absorber between the feed antenna and the primary reflector, as close to the feed as possible but without touching it!

      iv. move absorber away

      v. insert 3dB of extra or less attenuation

      vi. restore the attenuation level to what is was initially.

      vii. *An alternative approach:* instead of using chart_recorder_rspec, which reports the power measured (in digital units) across the entire bandwidth of the receiver, you could use our spectrum data acquisition mode. This would return a spectrum every integration time (e.g. 1 sec), so the data are much more voluminous. What they allow you to do is to use only 'clean' parts of the spectrum that don't have RFI in them. This is a new suggestion. It requires more work in the data analysis but should provide better results and a better understanding of what is going on.

   (c) Move the antenna to a higher elevation so that radiation from the ground (which is at the ambient temperature) does not contaminate the baseline level of the radiometer output (spillover noise). Now make another measurement using chart_recorder_rspec both with and without the noise diode turned on. This can all be done in the same data-taking run as the previous items. The purpose of these measurements is for you to estimate the system temperature when spillover noise is at a minimum.

   (d) From these measurements, you can form at least 4 equations in order to estimate the three unknowns $T_{\rm sys}$, $T_{\rm cal}$ and a proportionality constant g that converts from temperature to voltage (e.g. $V = gT$). The extra equation gives you a check on the linearity of the system.

   (e) In your analysis, calculate the histogram and cumulative distribution of the data points in your time series that exclude the Sun and noise-diode, absorber, and attenuator segments. What shape of distribution do you expect. Compare with what you actually get. You may have to edit out any obvious RFI.

(f) Do a "drift scan" on the Sun and use your result from part (a) to estimate the radiation temperature of the Sun at 1.42 GHz. You will need to take into account that the Sun is not an extended source, as defined in the Radiometry Fundamentals handout and in class. To do so you will need the ratio of the Sun's solid angle as viewed by us to the solid angle of the main lobe of the antenna beam, which you determine in part 2. Note that the one-dimensional angular size of the Sun's optical disk (the photosphere) is about 0.5°. From the drift scan and your other results, you can estimate the radiation temperature of the Sun. Compare your result with those in the article by Zirin et al. on the web site for the course (and other articles that you can find). Be aware of the fact that the Sun's radio flux is highly variable, as indicated in the graphs on the second page, and that at some frequencies, the radiation is from the solar corona, which is much hotter and larger than the photosphere of the Sun. Variability is higher at solar maximum so you should investigate where we are in the 11-yr solar cycle.

2. From the drift scan on the Sun, estimate the beam width of the antenna power pattern. It is conventional to use the points at half of the maximum to define the "full width at half maximum" (FWHM). Compare your result to the diffraction value, which is *approximately* λ/D.

   Be sure to properly convert from time to angular units; take into account the rotation rate of the Earth and the declination of the Sun.

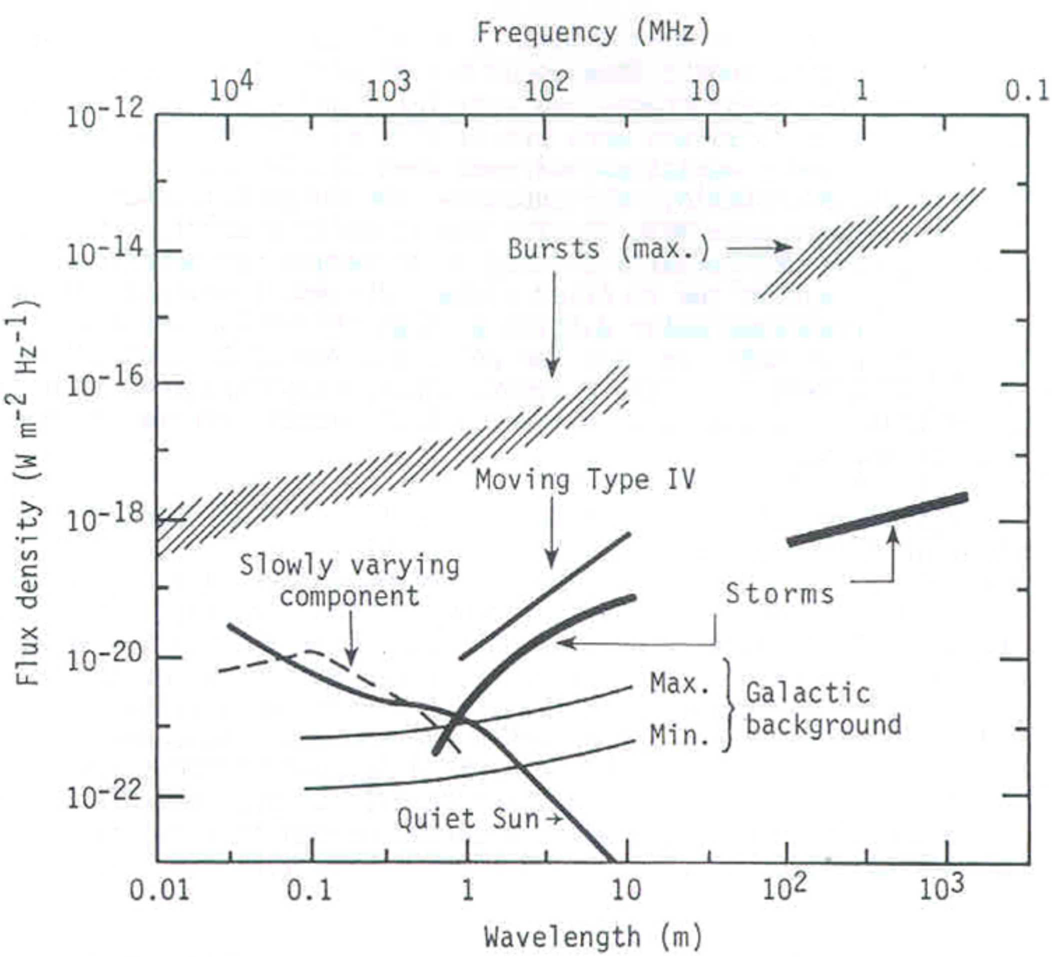

Figure 1: Flux density of the Sun vs wavelength and frequency, showing values for the quiescent Sun and the active Sun. Bursts and other activity are more prominent at lower frequencies and at near the peak of the 11-year Solar cycle.

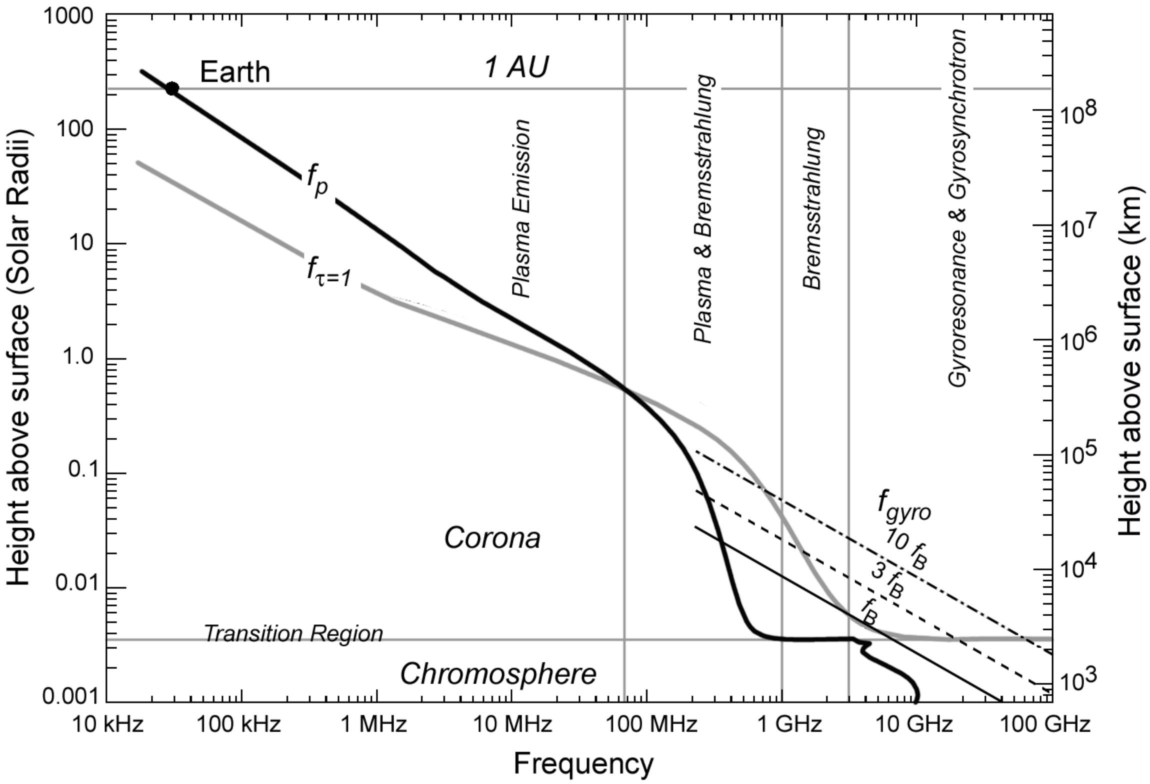

Figure 2: A figure showing radiation processes that are relevant at different frequencies and altitudes above the Sun.