(Astro)Physics 343 – Spring 2010
Lab # 2: Measuring the Telescope's Aperture Efficiency and Assessing Solar Variability

Observations: week of 15 February 2010

Reports due: 1 March 2010

Purpose: In addition to the width of a telescope's beam, a key parameter is its *aperture efficiency*, which describes how much less than ideal is the telescope's response to an astronomical source (specifically, to a *point source* that is smaller than the beam). We write this efficiency as η_A; for a perfect telescope, we would expect $\eta_A = 1$. To measure η_A, we need to observe a source whose flux density is *already known* and compare that known flux density to the observed antenna temperature– the goal of the first part of this lab.

For the SRT, we can treat the Sun as a point source in doing this exercise; its flux density at 1.4 GHz is updated on a daily basis at

`http://www.swpc.noaa.gov/Data/`

(see the "Solar Radio Flux Values" link under "ASCII Text Lists", specifically the Sag Hill measurement that occurs at noon in our time zone). However, an important caveat is that to measure η_A, we also need to know that we are correctly scaling raw data counts to antenna temperature in units of Kelvin. Ideally, we would verify this by inserting objects of known temperatures (i.e., a "hot load" and a "cold load") into the beam of the telescope in order to calibrate the response. For now, we will assume that the assigned value of the "calcons" calibration constant (i.e., $0.12\,\mathrm{K\,counts^{-1}}$) relating raw counts to antenna temperature is correct.

For the second part of the lab, you will prepare observations of the Sun over multiple epochs during the next week in an effort to quantify and characterize any variability in its radio emission. The most recent solar minimum, which occurred in 2007, was one of the deepest and most prolonged on record. Solar activity (i.e., the number of sunspots) is now on the upswing, although it may still not be observable with the SRT. Your assigned slots for these observations (during which your particular script fragment will be executed every day from Friday through Tuesday, inclusive) are EST

10:00am: Salmon
10:30am: Tsimaras
11:00am: Conklin
11:30am: Mauriello
12:00pm: Halstead
12:30pm: Morris
1:00pm: Eskow
1:30pm: Vargas
2:00pm: Zahid
2:30pm: Hahn
3:00pm: Patel

Before the lab period: Prepare command files that do the following:

- Open a data file, record observations of the Sun at 1418 MHz (using receiver mode 1) at 25 offsets in azimuth ranging from $-12°$ to $+12°$ in steps of $1°$, and close the data file. This is a script that can be used to measure the telescope's aperture efficiency.
- Beginning *at the start of your designated slot*, open a data file; take 30 seconds of data at an offset of $-30°$ relative to the Sun; determine pointing offsets on the Sun with a 5×5 raster scan; take 60 seconds of data on the Sun; take 30 seconds of data at an offset of $+30°$ relative to the Sun; and then close the data file. (These observations should also be done at 1418 MHz using receiver mode 1.) This is the script fragment that will be used to assess solar variability.

Procedure:

1. **During your lab period**, you and your teammates should merge your prepared scripts for measuring η_A into a single consensus script, and run it. The peak antenna temperature at the position of the Sun will be the sum of the brightness temperature of the Sun and the noise (a.k.a. "system") temperature. The data points off the position of the Sun can be used to determine T_{sys} alone, making it possible in your offline analysis to estimate T_b and therefore η_A. Note: be sure to make an `npoint` observation first, and be careful to adjust the offsets in your script based on the `npoint` results! If the data prove for some reason to be unusable for analysis, please let the instructors know before the end of the week, and we will endeavor to get you a better dataset.
2. Also during your lab period, the two or three members of your team should run your scripts for the solar variability experiment in simulation mode, before leaving working copies of the scripts in the `srt` directory. The instructors will merge these into a master script, which we'll run each of the next five days. You'll receive a service mode report at the end of the observations.

Analysis:

For the measurement of η_A, each of you should do the following on your own (based on your team's shared dataset):

1. Find the mean antenna temperature (and its uncertainty) for each of the 25 offsets in your azimuth scan. (Yes, this is very similar to Lab # 1!)
2. Determine the system temperature of the telescope/receiver combination, and its uncertainty, based on the observations during your scan.
3. Determine the peak brightness temperature of the Sun.
4. Look up the flux density of the Sun as measured at noon on the day of your observations.

5. Determine the aperture efficiency η_A and its uncertainty. (You may treat the flux density of the Sun as a measurement having infinite precision– i.e., ignore any contribution this term makes to the uncertainty in η_A.)

6. We've assumed throughout this analysis that the calibration constant is 0.12 (Kelvin per raw count). It's possible that this value is incorrect, but what limit can we *definitely* place on it as a result of the requirement that $\eta_A \leq 1$?

For the measurement of solar variability, each of you should do the following on your own during and after the acquisition of your data:

1. Make a note of the weather conditions (temperature, wind, rain, snow, etc.) near the time of your observations, and check whether the GOES X-ray satellite data stream at

   `http://www.swpc.noaa.gov/Data/`

   indicates that a solar flare has occurred (since this might also show up in the radio).

2. Consider the path of the Sun through the sky: did the Sun's elevation at a fixed (universal) time change during the week? If so, describe the change(s) and explain the reason(s) for any change(s).

3. Within each of your five blocks of data, calculate the mean brightness temperature of the Sun (and its uncertainty) as a function of time from the central channels across the band. (You'll want to delete some number of end channels, which have a reduced response to incident radiation.) What if any evidence of variability *within* each block do you see? Is the variation (if you see any) consistent with pointing errors creeping in?

4. Now consider whether there is any evidence for variability *between* your five blocks of data, by calculating the mean (and its uncertainty) for the brightness temperature of the Sun over each of the five blocks. What evidence for variability do you see? Is there any evidence that changes in the measured radio flux density of the Sun are correlated with flare events seen in the X-ray, or with changes in terrestrial weather conditions?

5. As a further consistency check, compare your measurements of the Sun with the "Sag Hill" measurements on the same day. If this comparison suggests that certain of your data are flawed, how (if at all) would your conclusions about solar variability change?