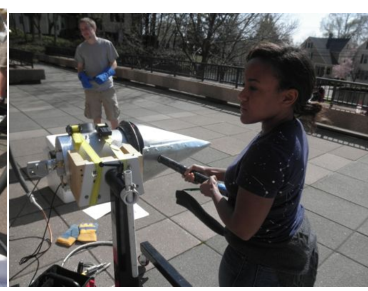
ASTR 240: CMB Lab

Part 1: Experimental setup

Describe the different pieces of equipment that we used and the purpose of each piece of equipment. Include a description of the hot and cold loads and how we determined their temperatures, the metal cone that we attached to the front of the telescope and its purpose, the feed, and the basic electronic components of the receiver on the back of the telescope. Be sure to include a description of the readouts you were looking at. With what precision did you make your measurements? Compare and contrast our experimental setup with that described in the Wilson reading. What are the pros and cons of the different frequencies of observation? How does calibrating in front of the antenna simplify the measurement?

Also consider the features of the loads that we used. The foam inside the cones was made of a material called Eccosorb. What properties of this material do you think are important to ensure that the temperature measurement is accurate? (Think particularly about absorption vs. emission efficiency.) Why was the load shaped like a cone? (Think about the potential for reflections and the path that a light ray might travel through the cone.)

Part 2: Calibration


Describe the calibration procedure and its purpose. What is the “responsivity” of the system (i.e., the factor that allows you to turn voltage measurements into temperature measurements)? Discuss any assumptions you make in deriving the responsivity: why did we assume that the voltage is linearly proportional to the temperature? Present your measurements of system temperature, and discuss the stability of the receiver with time. Be sure to discuss the two nearly contemporaneous measurements as well as the measurements before and after the skydip. When we pointed the antenna straight overhead, what was the voltage? What is the equivalent temperature, T_{zenith}?

Part 3: Beam

The zenith temperature that you measured above was probably quite high. Discuss the different sources of temperature that contribute to this measurement. Be sure to consider the size and shape of the beam (including sidelobes), the atmosphere, and any cosmic sources of radiation.

Describe how we checked the contribution from the sidelobes, with and without the cone. Did the voltage readings change when there were people standing near the telescope? By how much, and why? Was the change roughly at a level you might have expected?

Report the zenith temperature measurement with the cone. By how much did it differ from the measurement without the cone? What accounts for this difference?

Part 4: Sky dip

Describe how a sky dip can help you separate atmospheric emission from the cosmic microwave background radiation. Present the data neatly in a spreadsheet, and plot the temperature you measure (with receiver temperature subtracted) as a function of the airmass (sec(z)). Fit a line to the data and describe the meaning of the slope and y-intercept. Describe the reasons why you decided to space out your elevation measurements as you did (because you saw them in the template spreadsheet is not a good reason…).

An important part of this analysis will be understanding the sources of error in our data and determining whether our measurements are consistent with the accepted value of the temperature of the cosmic microwave background radiation. What was the precision of your measurements in K? How might your assumptions about the temperature of the loads, the size of the beam and its sidelobes, the stability of the receiver, and other factors influence the measurements? Estimate the zenith opacity, and discuss the attenuation of the cosmic microwave background radiation due to that opacity. How does the atmospheric temperature contribution compare to what you expect from the CMB? Given the estimated size of the beam, how high would Exley have to be to contribute significantly to our measured zenith temperature, using your best estimate for the distance of the apparatus from the base of the building? How does this compare to the actual height of Exley (or your best estimate)? Discuss errors that come from approximations in the model you are using, and do your best to estimate the magnitude of these errors (or at least their direction). Some examples include: the assumption of a plane-parallel atmosphere (flat earth, temperature linear with airmass), the assumption of constant temperature with time and height above the ground, the assumption of negligible sidelobes over the elevation range across which you measured the skydip, the Rayleigh-Jeans approximation, etc.

Play with the data to determine whether there are some ranges of time/elevation that seem to show the expected trend. What is the best measurement / upper limit you can put on the temperature of the CMB? Mid-range elevations may be best for this purpose, since they are the least likely to pick up contributions from the building (high elevation) or ground (low elevation).

Finally, here are some sample measurements from a previous run of this experiment with the same telescope. Perform the same analysis on these data: what temperature do you measure for the CMB?

Measured Elevation Angle	**Tmeas (K)**
89.8	5.701503799
72.2	5.866262766
64.7	6.101632718
59.3	6.101632718
56.5	6.337002671
49.7	6.572372623
45.9	6.807742575
39.8	7.513852433
36.6	7.984592338
32.9	8.808387171