Research Experience for Teachers at NRAO-GB
Measuring the Opacity of the Sky at 86 GHz

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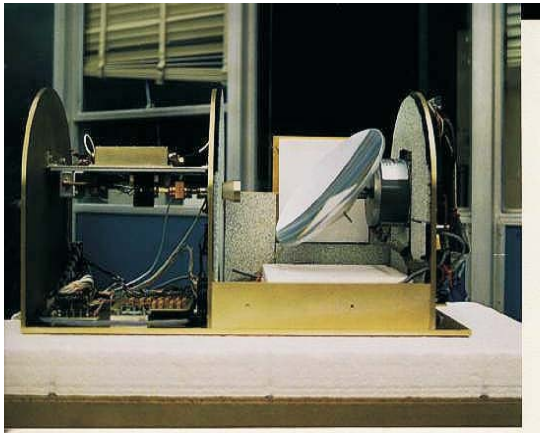
Abstract

An important factor in making decisions about when to observe at millimeter wave lengths is the opacity of the sky to high frequency radiation. To support future observations with the Green Bank Telescope (GBT), NRAO at Green Bank has developed a tipper to measure the atmospheric opacity at 86 GHz. The tipper uses a rotating mirror which reflects radiation from the blank sky onto a radiometer. By plotting the voltage reading from the radiometer against the angle of inclination and then fitting these points to a curve, we find tau, the opacity. My RET project was to update the curve-fitting algorithm and compute tau from the archived tipper data. These tau values, along with weather data from the Green Bank site, are used to characterize the site for high-frequency observing and will be used to predict when favorable observing conditions exist. My 7th and 8th grade math classes continued this research by receiving data in real time from Green Bank, plotting the voltages vs. the angles of inclination and drawing a best-fit line through the data points. The students estimated the atmospheric opacity by measuring the slope of the line. With the tau values they computed they attempt to answer, "When is it a good time to observe on the GBT at high frequencies?" The students are actively involved in real scientific research while learning how to analyze data.



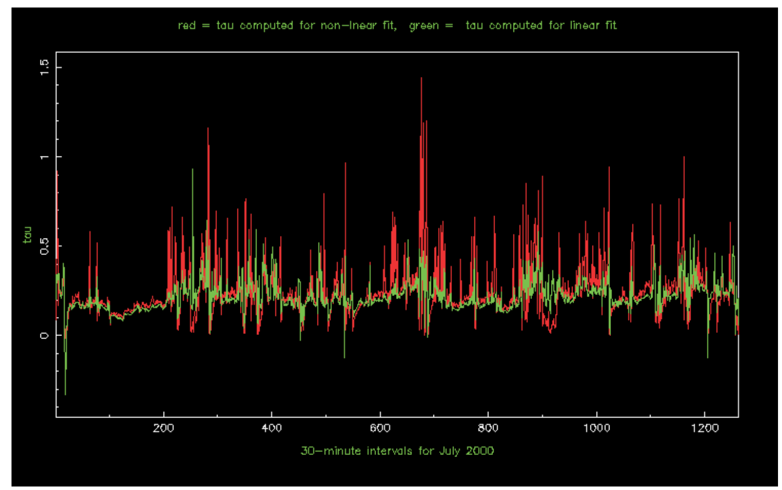

The tipper hardware

SUMMER RESEARCH

I worked with data collected from the tipper at NRAO in Green Bank, West Virginia. A tipper is a device which measures the opacity of the atmosphere by recording the radio background of the sky as a function of elevation. My job was to calculate the opacity of the sky (tau) by processing raw voltage readouts from the tipper hardware. This was done using fitting software developed in AIPS++. We produced a database of opacity values which could then be compared to data available from the weather stations at the observatory. The ultimate goal is to be able to find a correlation between the good opacity times and a particular weather pattern, thereby establishing some criteria for predicting the best times for observing at high frequencies.

The data from the tipper is processed with scripted procedures as it is collected, and the results are available on the NRAO web site. However, the data presented on the web page had been incomplete for two reasons. First, there are times when the computer which processes the tipper data is not up and functioning. This accounts for extended gaps seen in the plots of cumulative results. Second, if the program could not fit a tipper scan using a simple 1-layered atmospheric model, that data was left out of the plot. These combined holes in the database have made a significant impact on the statistics of observing conditions in Green Bank, and so it was important to fill them where possible. To fill the extended gaps caused by computer down time, I retrieved the archived tipper data and wrote programs in Glish, the scripting language used by AIPS++, to process the data. In analyzing the losses due to bad fits, we noticed that many resulted from a random bad point in the data readings. Tipper data is taken once per minute, but the tau values are recorded only every 30 minutes. By using an adjacent minute's data in place of the bad fit data, we are able to mostly eliminate these losses. For the few gaps which still remained, I interpolated tau values between the adjacent 30-minute solutions. These gaps occurred when tau was quite high, that is, when conditions were unfavorable for high frequency observing.

Sample Results from tau Calculations

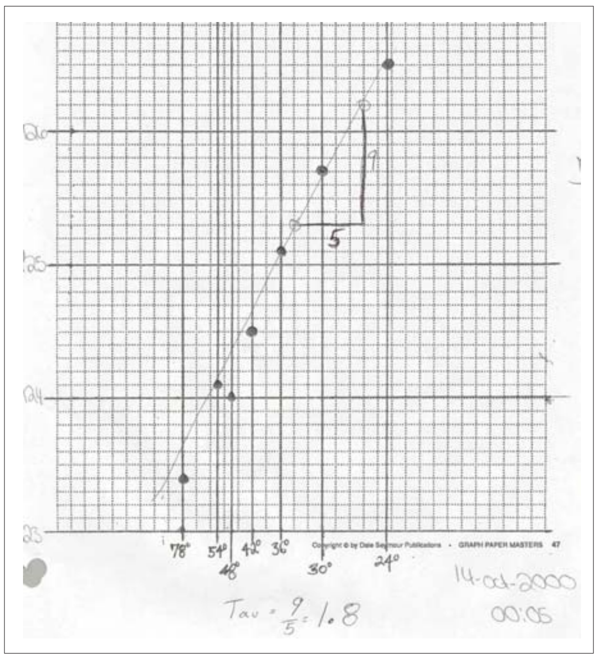


One of the parameters used to compute tau is the ambient temperature. In the early stages of the tipper design, there was to be a temperature sensor included in the hardware. Until the sensor was to be installed, a temporary arrangement allowed for temperatures to be deduced from the voltage readings against an eccosorb material inside the tipper box. I found that the temperatures against the eccosorb were not closely associated with ambient temperature readings available from the weather stations at the observatory. I obtained archived records of the weather station data and we adjusted the Glish program to incorporate the ambient temperature from those sources. This made significant changes in the tau values, at the 10% level, but it did not affect the overall patterns.

THE CLASSROOM PROJECT

An important part of the RET program is taking the research back to my school and incorporating it into the curriculum. This project was ideally suited for use in my 7th and 8th grade classes of general math. Not only did it provide the students with the opportunity to be involved in real scientific research, but it provided a method of teaching some of the objectives which are required for those grade levels. Using an open-ended research model held the students' interest and generated a genuine enthusiasm for doing the work. No one complained by asking, "Why do we have to learn this stuff?"

We used our school's Internet access to learn about the tipper and the need for interpreting its data to make informed decisions about observing at millimeter wavelengths on the GBT. We wanted to answer the question, "When will be the best time to use the GBT to observe at very high frequencies?" We made arrangements with Jim Braatz to receive data from the tipper in pseudo-real time. With this data, my students were able to compute the tau values for the month of October 2000. They accomplished this by graphing the voltage readings from the tipper against the cosecants of the angles of inclination from which they were read. The students then drew a "best fit" line through the points and computed the slope of that line. The students learned to graph points on a coordinate plane, and they learned about slope and how to calculate the slope of a line.



Student's plot of best-fit line to tipper data

After graphing the data for each 30 minute interval for the month of October, we compiled the results from each of the student's calculations. While looking for trends in the tau values over various time intervals, the students gained an appreciation for the difficulties in finding patterns. We concluded that we would need to look at more data and perhaps even incorporate other variables, such as weather conditions, in order to properly evaluate the high frequency observing prospects at the site.

Research on the Internet

Plotting Tipper Data

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