Research Experience for Teachers at NRAO Green Bank: Commissioning the new 100-meter Green Bank Telescope

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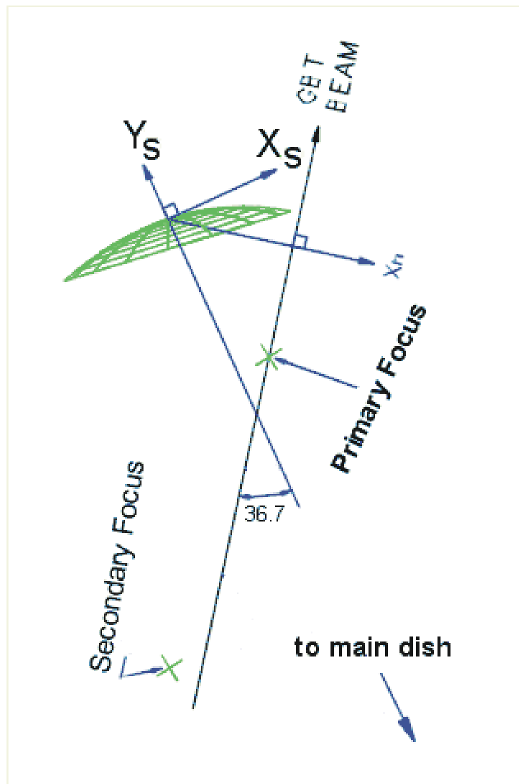
Abstract: As the Green Bank Telescope (GBT) comes on line, the data gathered from a variety of commissioning observations has been filling the computer files daily. The time to thoroughly analyze the data has not always kept pace with the immense amount of data generated. The Research Experience for Teachers (RET) program at Green Bank permitted both the NRAO and the teacher to benefit from time spent analyzing some of the commissioning data. Although the majority of the time was spent working with the commissioning data, the RET experience also involved observing with the GBT, gathering HI data to be used by the teacher's students during the next year.

RET Research Experience

GBT subreflector



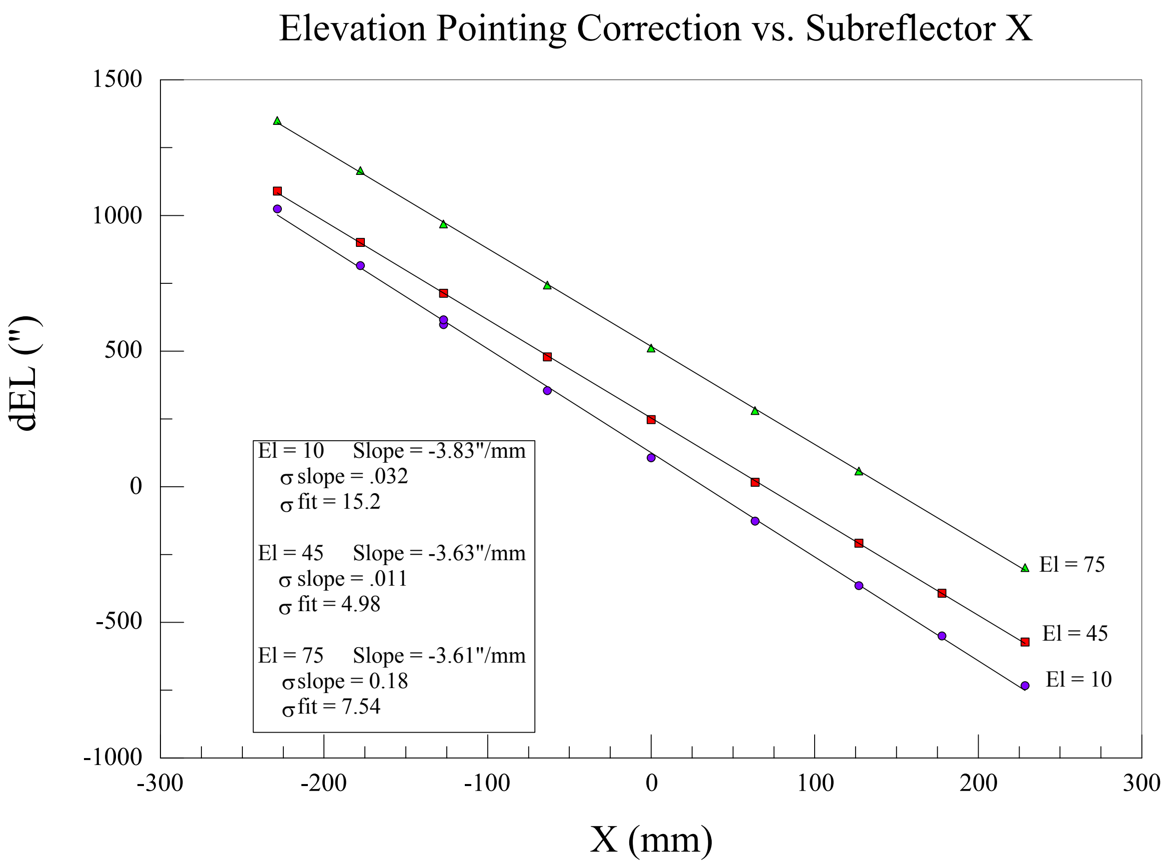
subreflector motions

GBT commissioning data collected from February 23 through March 6, 2001 were studied by Nate Van Wey during his RET appointment. Analysis of the subreflector (above left) motion and the resulting pointing offsets formed the focus of the data analysis.

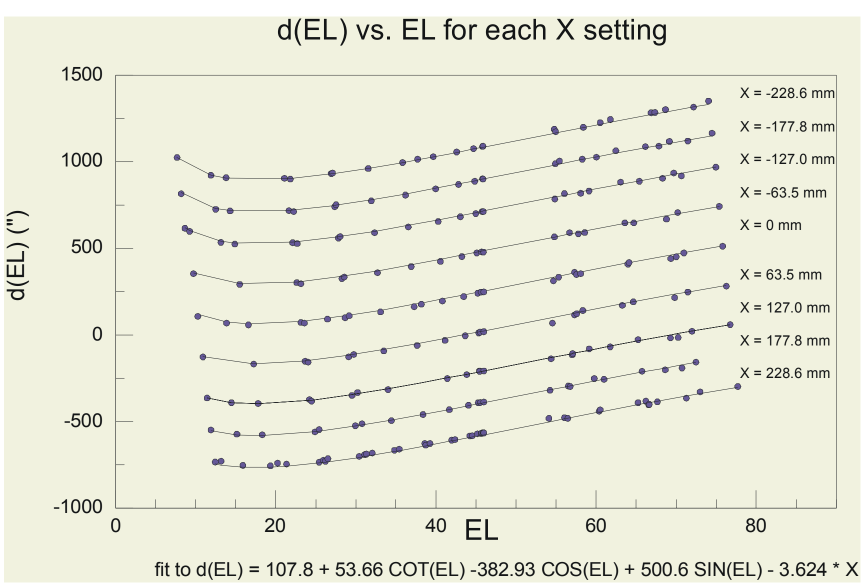
The motion of the subreflector is shown above in the diagram at right. The Y-axis is toward and away from the primary reflector. The X-axis is in the plane bisecting the feed arm and the primary reflector. The Z-axis is perpendicular to both the X and Y axes. Motions of the subreflector in the X and Z directions should produce changes in the elevation of the beam on the sky. Data were taken at a frequency of 2 GHz with a bandwidth of 80 MHz in linear polarization.

Elevation errors as a function of X

We graphed the pointing offset d(El) versus X to show the change in the elevation pointing with the X position, for 3 different elevations. There are elevation dependent effects due to the gravitational deflection of the feed arm and the main reflector.



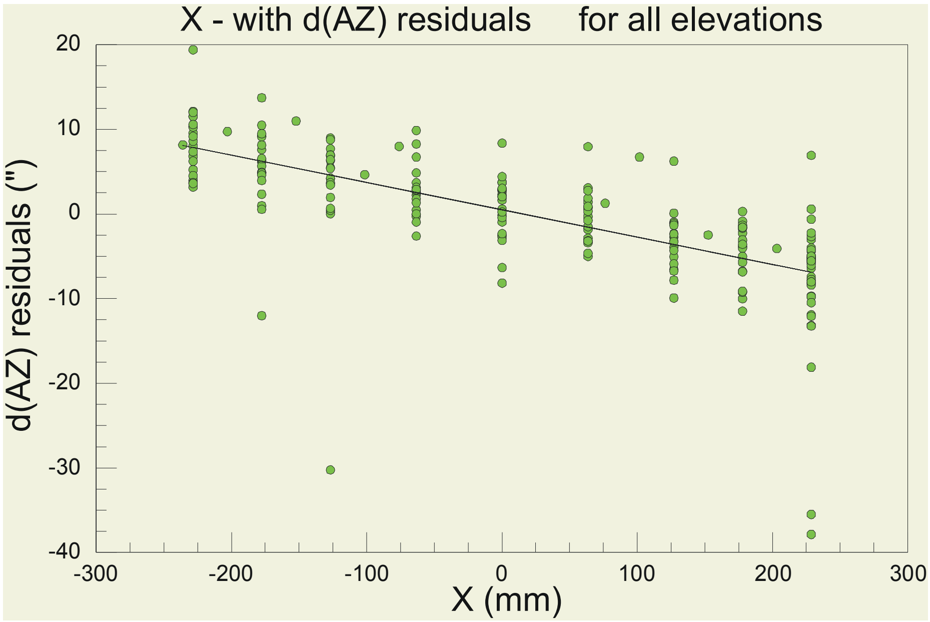
This graph (below) is the data set plotted for each of the X positions. A model was fit to the data set (including a cotangent of elevation related to atmospheric refraction). The plate scale was determined to be ~3.624"/mm. After removing the elevation dependence and the linear plate scale, a non-linear relation between elevation error and X was apparent. This could be due to a non-planar focal surface or from improper transformation between the actuator motion and the subreflector coordinate system.



Azimuth errors as a function of X

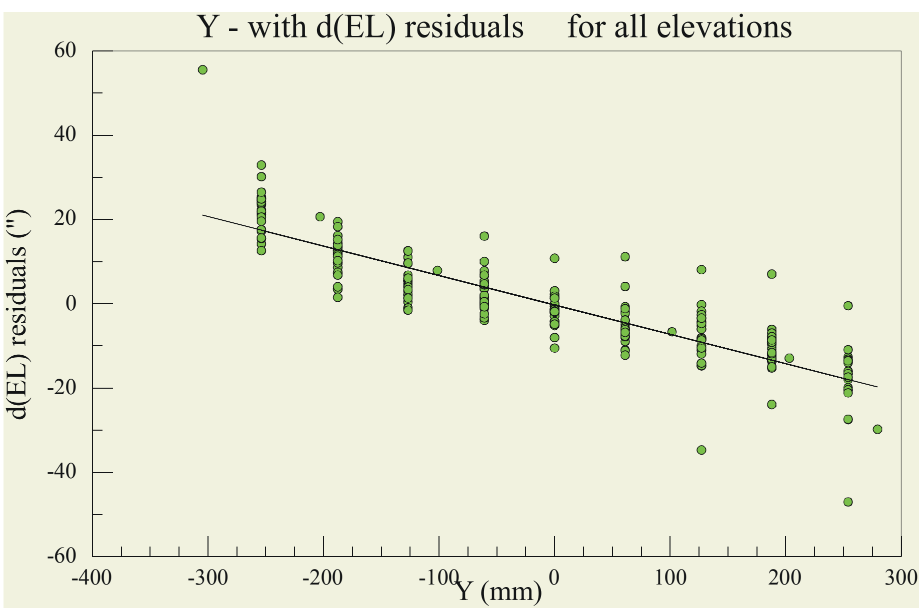
This plot shows the azimuth pointing correction as a function of the elevation for all of the different X settings. There is a small but systematic difference between the various X settings. The plate scale was a small but still significant 0.033"/mm. Moving the subreflector over the entire 500 mm of its motion resulted in a shift of 17". When we graph the residuals of this versus X we find a linear trend. The scatter is less at lower elevations.

A likely explanation is that the X-axis along which the subreflector is moving is not the designed X axis, but is rotated a little. Calculations of the skew are estimated at 0.52degrees, tilted in the Z direction.



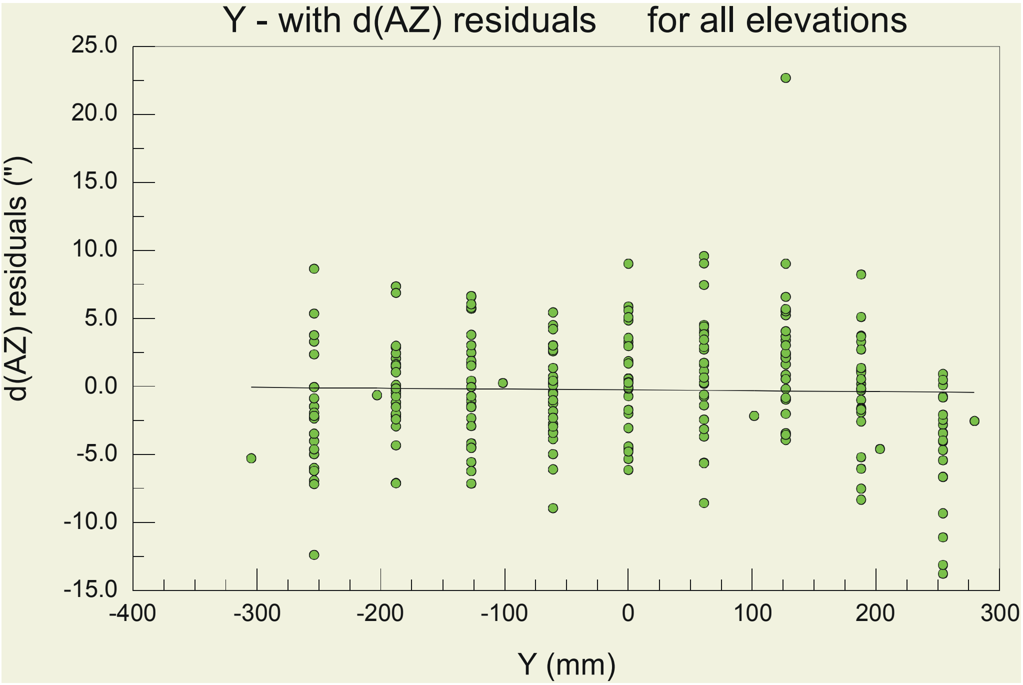
Elevation pointing as a function of Y

The next data set to be studied was that of the pointing offsets with the subreflector moving in the direction of axial focus, the Y-axis. The result showed a small but systematic difference in the different Y settings. The slope of the line of the graph of the residuals shows a line with a slope of ~0.065"/mm. This could be a result of the skew of the Y travel of the subreflector from the ideal Y-axis. An angle was calculated to be 1.05 degrees in the X direction.



Azimuth corrections as a function of Y

A final study was made by examining the azimuth pointing corrections as a function of the elevation at each of the Y settings. The graph here shows the d(Az) residuals as a function of Y. We note little tilting of the Y-axis in the Z direction from the residuals plotted. There was a possible non-linear effect shown in the different ranges of elevation that might be an area of future investigation.



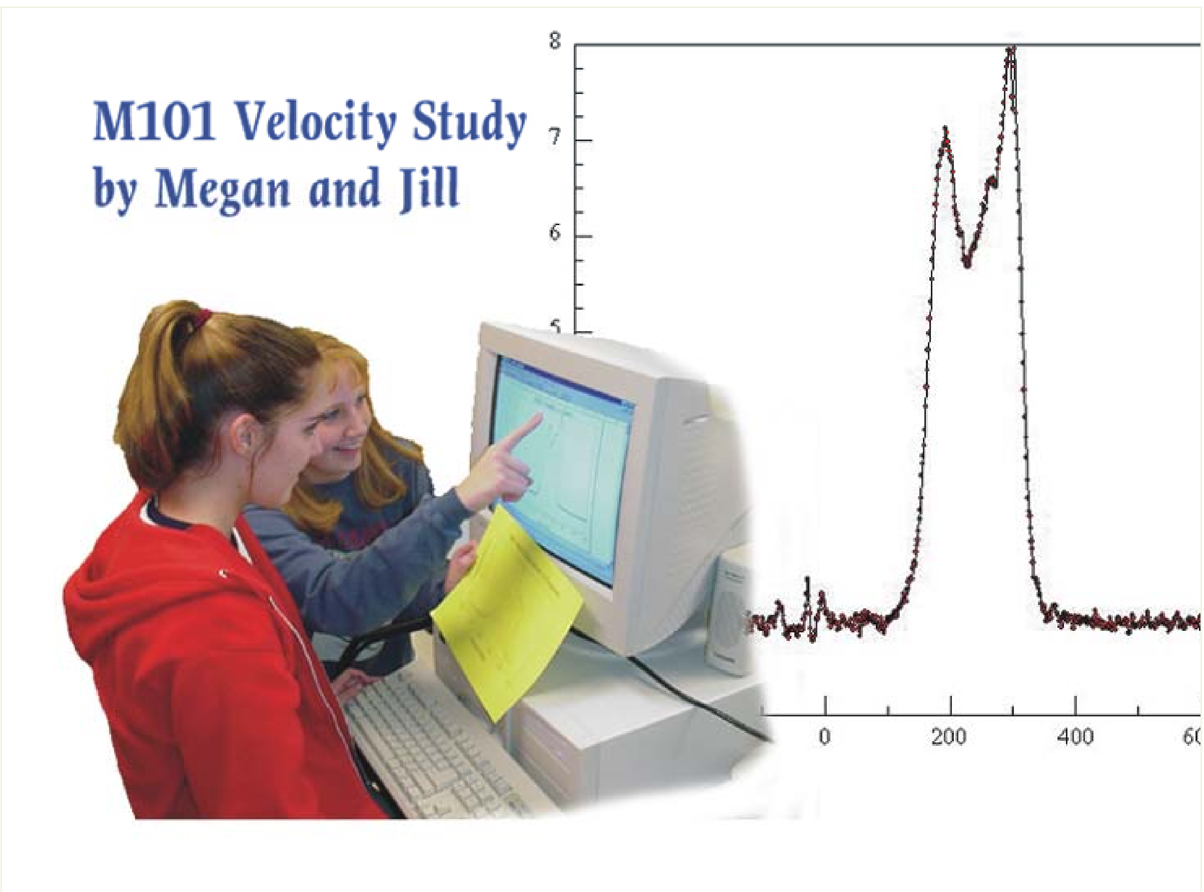
Conclusions

- The X-axis is tilted in the Z direction by about 0.5 deg and the effect may have a slight elevation dependence
- The X-axis plate scale is non-linear, and should be compared with theoretical models. There may be slight elevation dependence.
- The Y-axis is tilted in the X direction by about 1.0 deg, and the effect does not appear to be elevation dependent.

Transfer to the Classroom

The transition from this RET experience to the high school classroom is quite an easy one, and it impacts the students at three different levels.

- The student sees the teacher as more than just a teacher. Because the teacher spent time applying the science that is taught, the students view the material from a different perspective. In this case, real world examples of a variety of physics topics, such as resolution, parabolas and focus, electromagnetic waves, electronics, data analysis, Doppler shifts, torque, and even inertia find their way into the classroom using the GBT. The students' experiences are enhanced by the connection to the Green Bank Telescope, radio astronomy and the specifics of the teacher's RET experience.
- The student also sees the teacher as a life-long learner. Although much lip service is given to this concept in nearly every school district's mission statement, the fact that the students see a teacher who remains current in his field of teaching and who has challenged himself intellectually, as the RET experience does, provides concrete reinforcement of this ideal.
- The student is able to take topics from the classroom lecture and lab and the textbook and apply them to data taken by the GBT. For a student to be given a set of data and be told, “No other student has ever had the chance to work with the data taken by this telescope,” this is an excellent motivator.

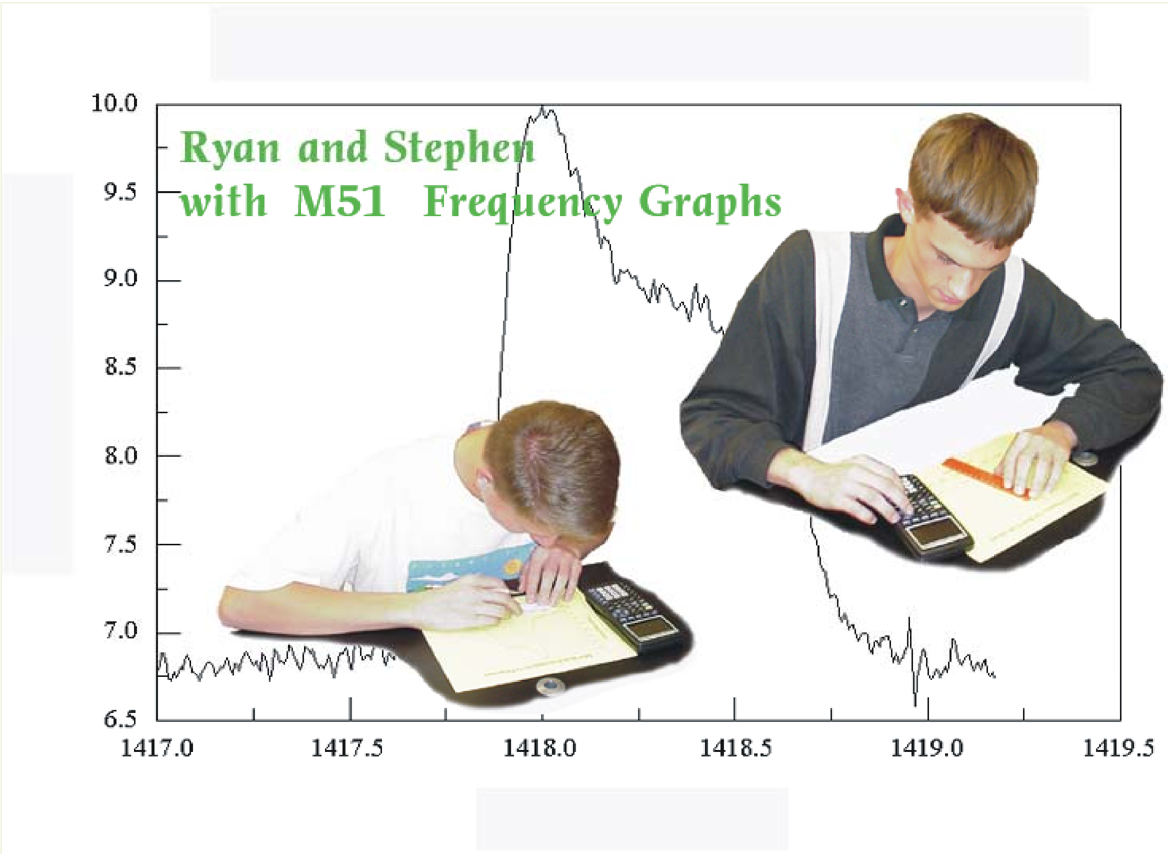


The teacher received time on the GBT to collect data for use in the classroom. Neutral Hydrogen (HI) spectra of two galaxies were taken.

The application of the RET experience into the physics class specifically came after students had covered a unit called “Cosmic Evolution” (designed by the SETI project), electromagnetic waves, and wave properties. Emphasis during the EM waves study was placed on the HI signal and its use by astronomers.

Immediately prior to the analysis of the data from the GBT, students spent a day with the PSiPlot program and a simple data set. The next day students were given the data of one of the galaxies and asked to determine the velocity of the galaxy using the Doppler formula, and then to compare to the velocity in the data table (which lists both f and v).

An additional assignment was this question "looking at your graph, what other information can you measure and what can you infer?" This question was then discussed in the classroom the next day.

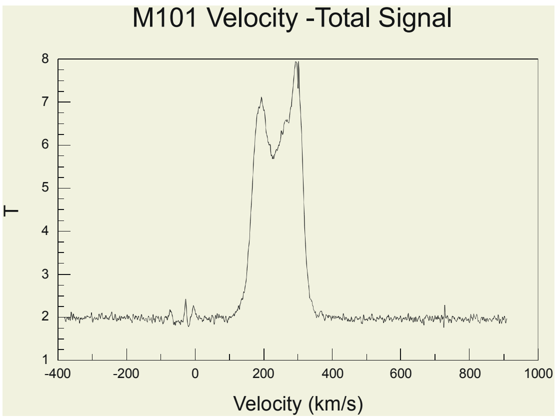


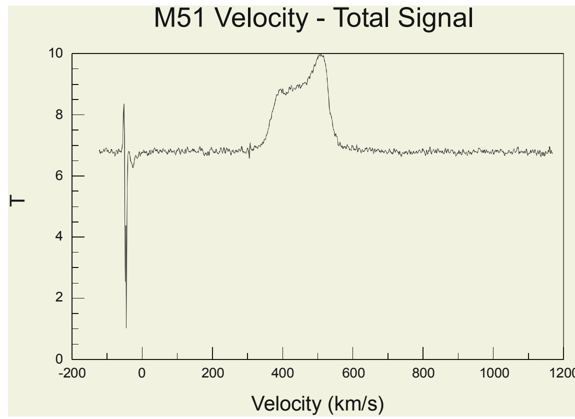
The asymmetry of the plots was a major topic of discussion, with an interesting, wide range of suggestions for the reason. In two of the four classes the question of the inclination of the galaxy and its impact on the shift of the signal was brought up. The large deflection near v = 0 was easily noted on the M51 graph, which led to an interest in the same area on the M101 graph. What initially was thought to be a part of the signal from M51 was, through discussion, recognized to be the signal from local neutral hydrogen. This led to discussions of detection of the HI signal from the Milky Way by other galaxies and the shift in that signal. The students found problems in understanding that their galaxy was entirely in the beam and that the graph represented the different HI velocities and not a scan across the galaxies themselves. As they began to grasp this, their level of understanding jumped appreciably. The students were given the weekend to find out information of their galaxy and be prepared to discuss the graphs based on the known information.

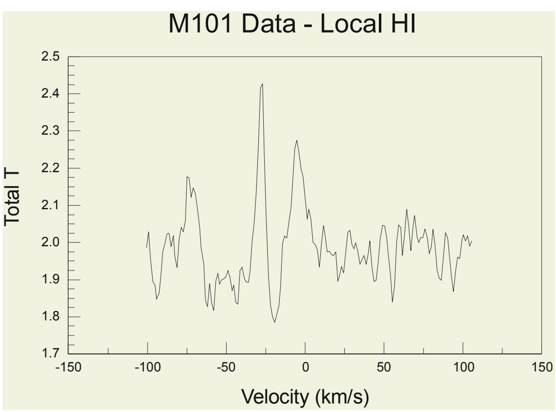
The discussion of the inclination and the asymmetry of the signal led off the next day. As with any class, the information uncovered about the galaxy from different students ranged from paucity to many pages, and the interest level wavered with some students. So, they moved back to the computers to print out graphs and began to look at the width of the signal, the area under the curve, and the structure of their image of the galaxy compared to material they found on line.

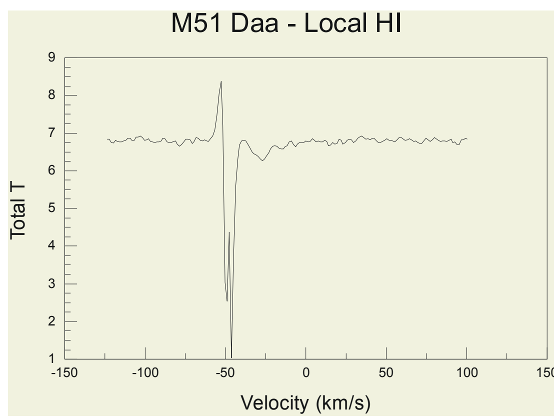
Student generated graphs of M51 and M101 HI data from GBT observations

Students used these graphs to study properties of the galaxies such as velocity of the galaxy and signal width. When interest moved to the local HI signal, the latter two graphs were studied.









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