Astrophysics 611 Term Project

Construction and Use of a Radio Spectroscope for HI Line Measurements

23 October 2005

For a term project you will, as a team, construct, measure the characteristics of, and use a spectroscopic receiver for atomic hydrogen line measurements with the 3.7 metre radio telescope. A schematic diagram of the telescope and receiver system up to the point just before digitisation of the signal was handed out separately. This term project consists of three portions.

1) Characterisation of the signal path from the antenna to the digitizer
2) Digitization of the signal and construction in software of a spectrometer
3) Calibration of the telescope to provide output spectra in units of brightness temperature of the sky (Kelvin).
4) Measurement of the strength and shape of an HI spectral line in the direction of a line of sight through the plane of the Galaxy.

The final report of the term project is to be written jointly by the students enrolled in the course and submitted as a web document to be published on the radio astronomy laboratory web site.

1) The receiver signal path

The signal flows from the feed to a "front end" consisting of two RF amplifiers a mixer and an IF amplifier. It then is transmitted to the "back end" in the warm room where it is further amplified down-converted and sent to a sampler and digitizer card within a linux PC. Using a laboratory set up, measure the band-passes and gains of the individual amplifiers and mixer components of the back end, as well as the overall bandpass and gain of the backend. Confirm that the RF signal at 1420 MHz is present within the output bandpass of the final mixer stage. Each of the team should carry out these measurements and mean and standard deviations of the overall gain should be calculated.

As part of the write up describe the signal path components including the LO frequencies, IF frequencies, band passes, and gains.

2) Digitization and Software Correlator

Set up and operate the A/D conversion card and write a program to sample the data stream for a controllable time interval, τ, at a sample rate, Δt. Construct the spectrum either by Fourier transform or auto-correlation. Ideally the program should run continuously: sampling and for τ, creating the spectrum, sampling for another τ, creating the spectrum, then adding this spectrum to the previous spectrum, so that an average spectrum is built up over a long integration time that you specify.

3) Calibration

Using techniques discussed in class, and/or others that you may devise, calibrate the spectrum so that the output units are in units of sky brightness temperature. You can try observing the moon to see if you get a reasonable temperature.

Also confirm that the spectrometer is working as expected. Measure how the noise (rms amplitude about the mean) changes with integration time, and describe your choice of τ and Δt, and how this choice effect the properties of the output spectrum.

4) Use the spectrometer to observe the sky

a) What is the system temperature when observing cold sky?
b) Show a plot of the spectrum of the sky in brightness temperature for a line of sight through the plane of the Galaxy and for another at high Galactic latitude.
c) If an HI line is detected discuss the characteristics of the line and measure the total column density of neutral atomic hydrogen atoms through the Galaxy for the line of sight. You will not be penalized if instrumental problems preclude detection of an HI line. But in that case, discuss the problems that would need to be overcome to allow the line to be detected.

In observational and experimental project such as this technical success in not guaranteed. Even an experiment that does not detect the HI line could receive full marks. The mark will be based on a description that demonstrates correct reasoning and implementation of procedures that are consistent with that reasoning, and the provision of results that are correctly derived and make sense. Also, the clarity and quality of the presentation in the final report will be a factor.

If the HI line is detected, any additional work such as mapping of a region of the sky will generate bonus marks.

Fred Babbot is available to provide technical support and advice for this project. As well Jeff Dever will provide technical and software support for control and operation of the digitizer and visualization of the results. After November 15, I am also available for consultation and discussion.

The final written web report is due on Monday, December 12, 2005. There will be one final grade that will be shared by all. As part of the report please include a description of how you decided to manage the joint execution of the project, how each of you participated in the project itself and in the generation of the final report.

Russ Taylor
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