Mapping the North Polar Spur

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1 Introduction

The final lab combines some of the previous knowledge with a new source to close out the semester. The chosen source was the North Polar Spur and its associated expanding HI shell. The goal was to first write a procedure to automatically take data and calibrate each spectrum to limit post processing, then take data and process it into a useful representation of the North Polar Spur.

Above the galaxy lies a large source of ionized hydrogen and relativistic electrons, called the North Polar Spur. It roughly extends from galactic longitude 200° to 50° (passing through zero), all above the galactic plane from latitude 0° to 90° . The expected HI velocity pattern follows that of an expanding shell.

To measure the spur, the new Leuschner radio telescope was used. The old telescope was replaced with a 5m dish and updated data collection system. The dish can clearly see above altitude 15° . In the east and west directions are partially obscured by a hill and optical telescope dome, respectively. Fortunately, during data acquisition, the spur appeared primarily to the south. A convenient IDL procedure automatically points to a coordinate or can follow an object for a time.

The telescope splits the data into two polarizations. These are separately amplified, filtered, and down-converted to 150 MHz, as seen in Figure 1. While this is not baseband, the system relies on aliasing to finish the down-conversion. The final double sideband spectrum collected has a sampling rate of 24 MHz, or bandwidth of 12 MHz. A tunable LO selects which

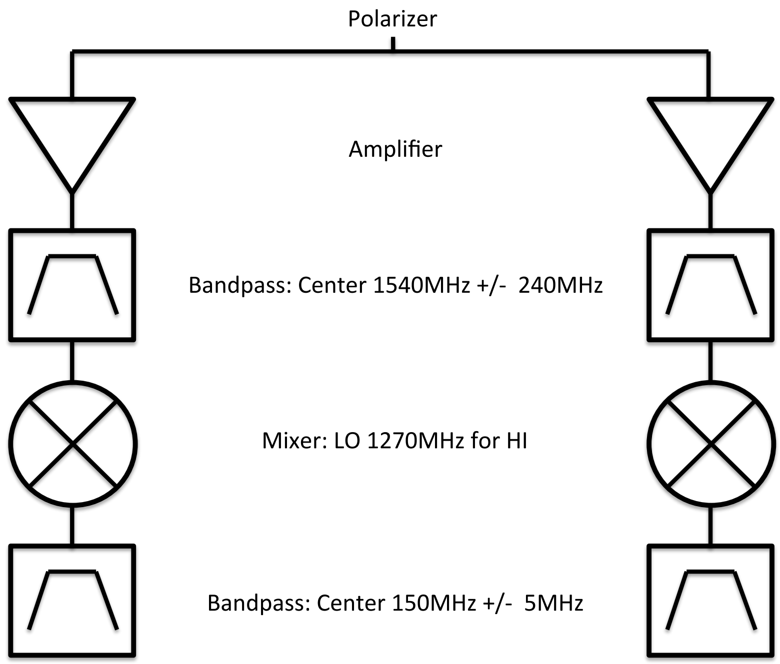

Figure 1: Block diagram of the Leuschner system front-end.

band to measure, and it was set to 1270 MHz to collect HI data. Once collected, the data are passed through a polyphase filter bank, FFT, power, and accumulator block designed in Simulink and placed on a Roach 1 board. Finally, the two polarizations are auto-correlated and cross-correlated. Each spectrum read out represents about 0.8 seconds of data accumulation, which for an 8k spectrum is about 2000 accumulated sepctra.

2 Mapping

A mapping script was written to investigate when and where to collect data. It loops through all the desired coordinates and plots them in altitude-azimuth coordinates. The data points may be manually stepped through time, which tells when certain datapoints are available for measuring. Two versions of this script were written. The first provides a visual representation of the coordinates, as exemplified in Figure 2. Any point above 15° altitude can be collected. The second tells the dish when and where to collect data as the points become available, then collects the data. In general, it sweeps

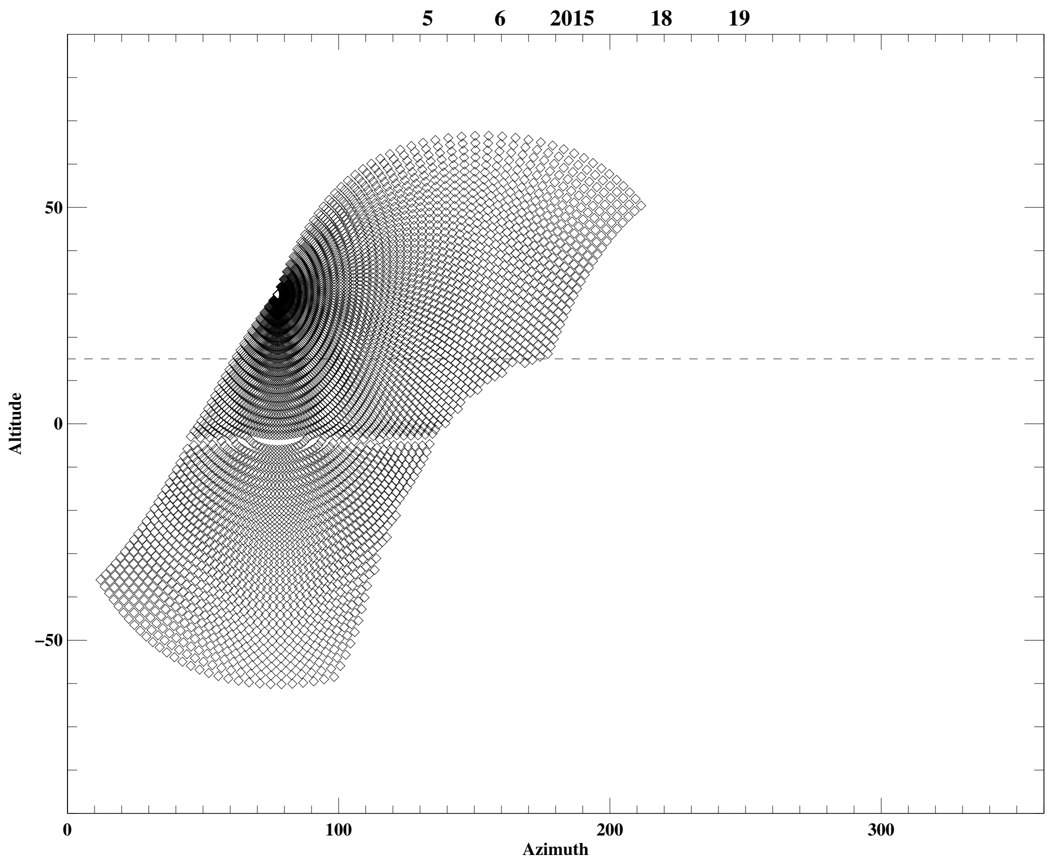

Figure 2: An example map. The axes show the altitude and azimuth at Leuschner. Each point is a coordinate to be measured. The dotted line marks 15° altitude. The title shows the date (month, day, year, hour, minute).

through the galactic longitude values, and collects all latitudes for a given longitude.

3 Data Acquisition

Data were collected for each point over multiple days. For each point, about thirty seconds of data were collected. The LO alternated between 1267.5 MHz and 1272.5 MHz, which placed the HI line approximately in the upper and lower halves of the spectrum. System temperature calibration was not done to save time and because only relative magnitude differences are enough

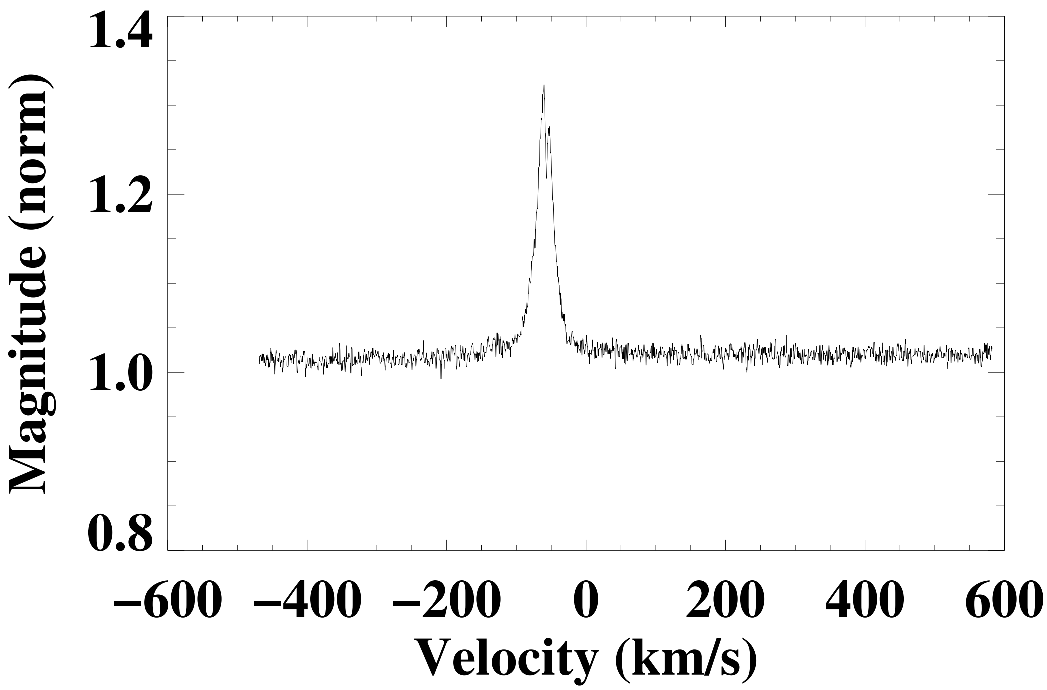

Figure 3: An example calibrated spectrum, clearly showing the HI line.

to show the shell. The output was a large number of FITS files containing these data.

A post-processing script takes in all FITS files, finds the ones with overlapping coordinates, and properly calibrates and combines the spectra. It adjusts the velocity to the local standard of rest. An example calibrated spectrum is shown in Figure 3. For each calibrated spectrum, a slew of information were collected. First, a Gaussian was fitted to the spectrum. The peak, center, and width of the Gaussian roughly give the strength, doppler-shifted velocity, and spread of the HI at that location, respectively. Assuming the location is part of the shell, the spectrum is expected to show two peaks. The stronger peak is the front of the shell, and the weaker is the back of the shell. Thus the peak values on either side of the middle of the Gaussian were calculated to give the strength of velocity of both shell parts. All these and more are shown in the results section.

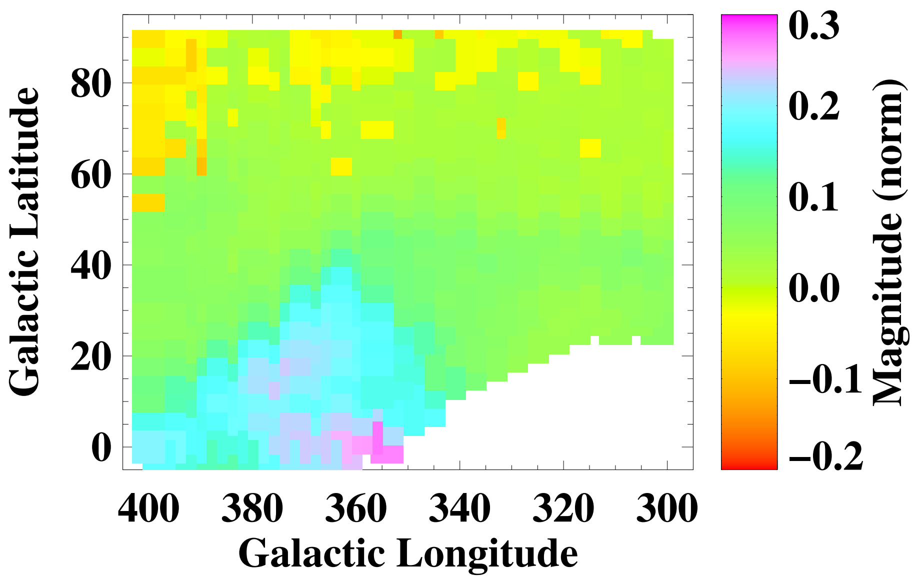

Figure 4: The peak of the spectrum.

4 Results

Figures 4 and 5 show the peak magnitude and the velocity at which the peak spectrum magnitude occurs, respectively. As expected, the galactic plane contains the strongest HI lines. However, the velocity plot shows a bubble-like feature, as seen by the increasing doppler velocity as galactic longitude is decreased. Since negative velocities are approaching, this indicates that the hydrogen is receding at the edge, but approaching as we move to the center. The center appears to be around latitude 15° and longitude 40° . At large latitudes, the HI line is very faint, which leads to noise in the plots.

Figure 6 shows the width of the HI line, as measured by the width of the Gaussian fit to the spectrum. The line appears wider in the galactic plane, but shows little correlation with the North Polar Spur.

As mentioned in the previous section, the spectra are expected to show two peaks. The first peak comes from the approaching side of the shell, while the other comes from the back side. Figure 7 shows the velocity difference between the two peaks.K While the plot contains mostly noise, a large difference does occur at the center of the spur mentioned earlier. The back-side of the shell may be diffuse (weak) or non-existent, leading to just a single peak and a noisy plot.

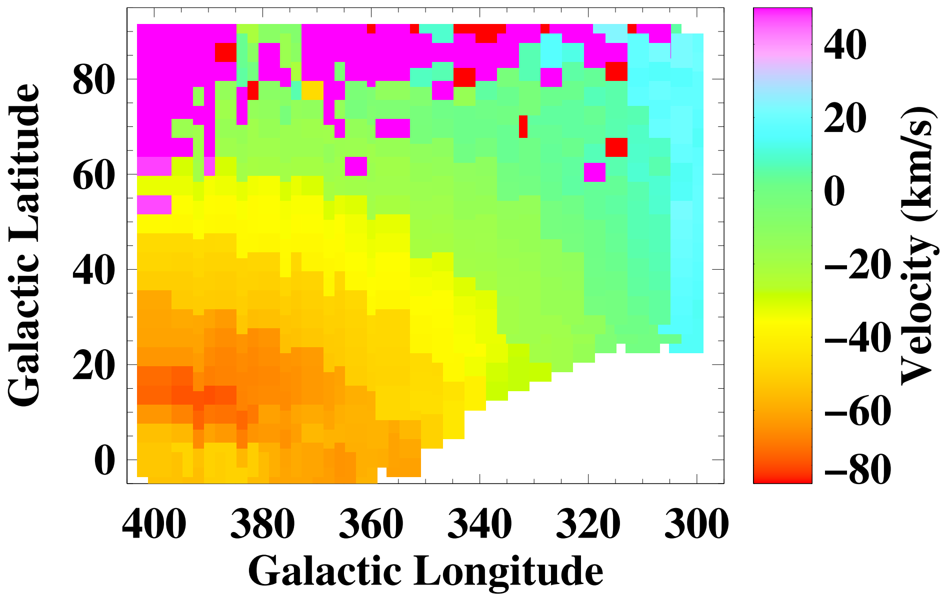

Figure 5: The velocity at which the peak spectrum magnitude occurs.

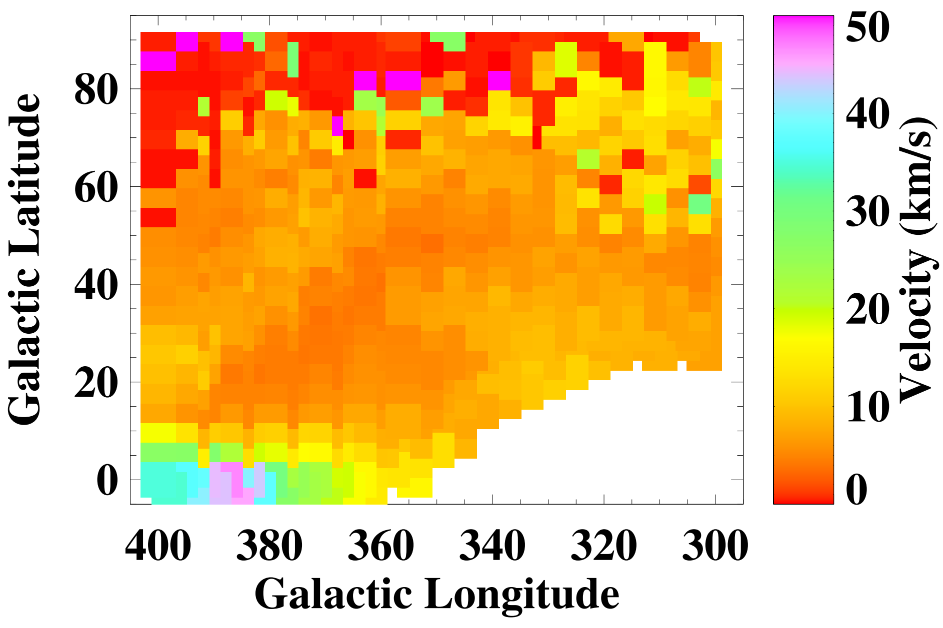

Figure 6: The width of the HI line.

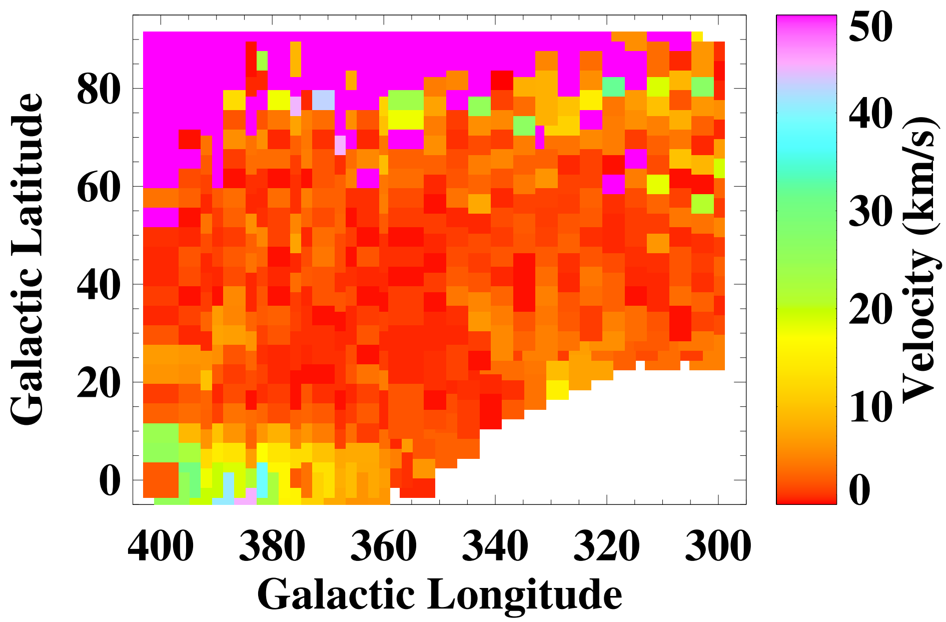

Figure 7: The difference in velocities between the two magnitude peaks.

5 Conclusion

The HI content of the North Polar Spur was measured and presented. This lab relied on the Leuschner observatory, which contains an array of front-end elements followed by an FPGA-based spectrometer back-end. Expected locations are compared with data. The data indicate a bubble centering on latitude 15° and longitude 40° and expanding outward. This location roughly agrees with that mentioned in [1].

References

[1] Taotao Fang and Xiaochuan Jiang. High Resolution X-Ray Spectroscopy of the Local Hot Gas along the 3C 273 Sightline. *Astrophys.J.*, 785:L24, 2014.