(Astro)Physics 343 – Spring 2010
Lab # 3: Measuring the Thickness of the Milky Way's Disk

Observations: week of 1 March 2010

Reports due: 22 March 2010 (**note: this is the Monday after Spring Break**)

Purpose: As is also true of most other spiral galaxies, most of the stars in the Milky Way are distributed in one of two structural components: an extended, flattened *disk* and a central, oblate (i.e., hamburger–shaped) *bulge*. (The Milky Way also contains a *thick disk* whose dimensions are intermediate between those of the disk and the bulge, a very extended spherical *halo* of very old stars, and a *bar*.) In contrast to its stars, the vast majority of the Milky Way's gas is located in the disk. The reason is that gas is more dissipative than stars: it's easier for gas clouds to collide with each other and lose energy and angular momentum. For this lab, you will exploit our privileged location within the disk of the Milky Way to measure the *scale height* (i.e., vertical thickness) of the H I component of the Milky Way's interstellar medium. Each of you will obtain spectra at a fixed Galactic longitude (ℓ) and nine different values of Galactic latitudes ($b = \pm 15°, \pm 10°, \pm 5°, \pm 2.5°, 0°$). Your observations will take place at the following assigned times EST on Friday, March 5th (with backup observations later in the week if necessary):

6:00am: $\ell = 20°$, Salmon
6:30am: $\ell = 10°$, Tsimaras
7:00am: $\ell = 5°$, Conklin
7:30am: $\ell = 0°$, Mauriello
9:00am: $\ell = 30°$, Halstead
9:30am: $\ell = 45°$, Morris
11:00am: $\ell = 90°$, Eskow
1:00pm: $\ell = 150°$, Vargas
2:00pm: $\ell = 120°$, Zahid
3:30pm: $\ell = 220°$, Hahn
5:00pm: $\ell = 180°$, Patel

Before the lab period: Prepare a command file that does the following:

- Open a data file at the correct start time in UT, set the frequency to 1420.4 MHz in mode 4 (this gives 156 frequency bins centered at 1420.4 MHz with a spacing of 0.0078125 MHz), record observations in a unique file name, take 10 seconds of data at each of the nine Galactic latitudes for your assigned longitude, and stop recording.

Procedure:

1. **During your lab period**, you and your teammates should test the scripts you have prepared in simulation mode. After confirming that your script executes correctly (and fixing any problems), you should (a) increase the integration time per position to 150 seconds, (b) set the start time as appropriate for your observing slot (see above), and (c) tell your instructor the name of this file so that it can be combined with other students' files into a single master script. (If time and the location of the Galactic plane permit, you may also wish to experiment with *real-time* observations to verify your understanding of Galactic coordinates.)

2. The final scripts will be executed in service mode on Thursday, March 4th in service mode (again later in the week if there are problems with the initial dataset), and the data will be emailed to you.

Analysis:

Each of you should do the following with the data for your assigned Galactic longitude:

1. Produce a baseline–subtracted plot of brightness temperature vs. frequency for each of your nine positions. (Baseline subtraction corresponds to subtracting out an estimate of the system temperature from the antenna temperature; $T_{\rm sys}$ may vary with frequency!)

2. For each pointing, find and report the maximum H I brightness temperature and the frequency of the bin at which this maximum occurs.

3. For each pointing, estimate the *frequency* on either side of the maximum at which the brightness temperature has fallen to half the maximum value. (The H I emission appears at a range of frequencies because of the motion of the gas in the interstellar medium.)

4. Discuss whether and how the shape of the H I spectrum varies with b. Are the nine spectra identical to each other apart from normalization? If not, how do they differ?

5. Plot peak brightness temperature vs. b. Assess whether this plot is symmetric about $b = 0$ (the Galactic plane), and estimate the positive and negative Galactic latitudes at which the peak temperature has fallen to half the value observed at $b = 0$.

6. Calculate the velocity width that corresponds to a single frequency channel in your dataset.

7. For each of your pointings, sum the brightness temperature over all of the frequency bins for which you judge that it is significantly different from zero. This will give you a number proportional to the total amount of H I along that line of sight. Plot this H I integrated intensity (typical units are $\mathrm{K\,km\,s^{-1}}$) against b, assess its symmetry about $b = 0$, and estimate the positive and negative Galactic latitudes at which it has fallen to half the value observed at $b = 0$.

8. Rescale your H I integrated intensity as a function of b to obtain the total hydrogen *column density* along the line of sight as a function of b, via the formula

$$N_{\rm H} = 1.8224 \times 10^{18}\,\mathrm{cm^{-2}} \left(\frac{\int T_{\rm b}\,dv}{1\ \mathrm{K\,km\,s^{-1}}} \right) \quad (1)$$

   and plot the result.

9. Considering the results above, answer whichever of these two questions is appropriate for your assigned Galactic longitude (making sure to discuss the principal sources of uncertainty, both random and systematic):

- For $-10^\circ \leq \ell \leq 45^\circ$, assuming that the H I you have detected lies at a typical distance of $\sim 8\,\mathrm{kpc}$ (i.e., the distance from the Sun to the Galactic Center), what would you estimate to be the FWHM thickness (in pc) of the Milky Way's H I disk?
- For $90^\circ \leq \ell \leq 220^\circ$, assuming that the Milky Way's H I is confined to a layer whose FWHM thickness is $220\,\mathrm{pc}$, what would you estimate to be the typical distance from the Sun of the H I you have detected?