Physics 785 Problem Set 1

Ben Keller

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1 CGPS Spin Temperatures

For this problem, the spin temperature T_s was calculated using the same equation as Strasser & Taylor 2004:

$$T_s = \frac{T_{boff}}{1 - e^{-\tau}}$$

The error was in this was calculated using the partial derivatives:

$$\delta T_s = \delta T_{boff} \frac{\partial T_s}{\partial T_{boff}} + \delta e^{-\tau} \frac{\partial T_s}{\partial e^{-\tau}}$$

$$\delta T_s = \frac{\delta T_{boff}}{1 - e^{-\tau}} + \frac{\delta e^{-\tau}}{(e^{-\tau} - 1)^2}$$

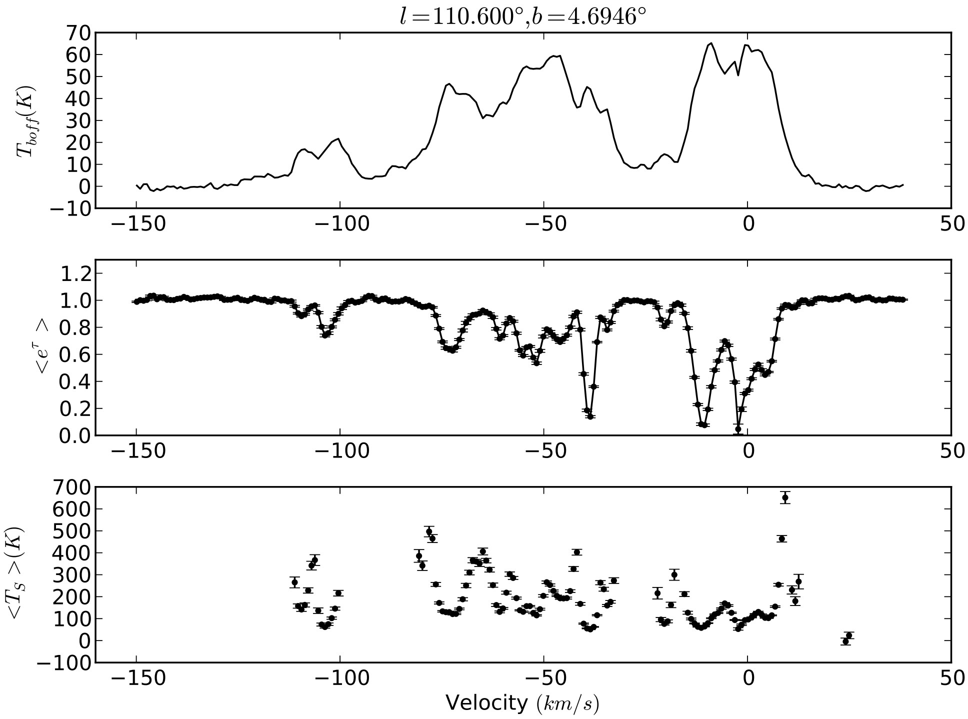
I also calculated a signal-to-noise value comparable to that used in Simon Strasser's MSc thesis, and selected only spin temperatures where this value was greater than 3 (ie, a $> 3\sigma$ detection):

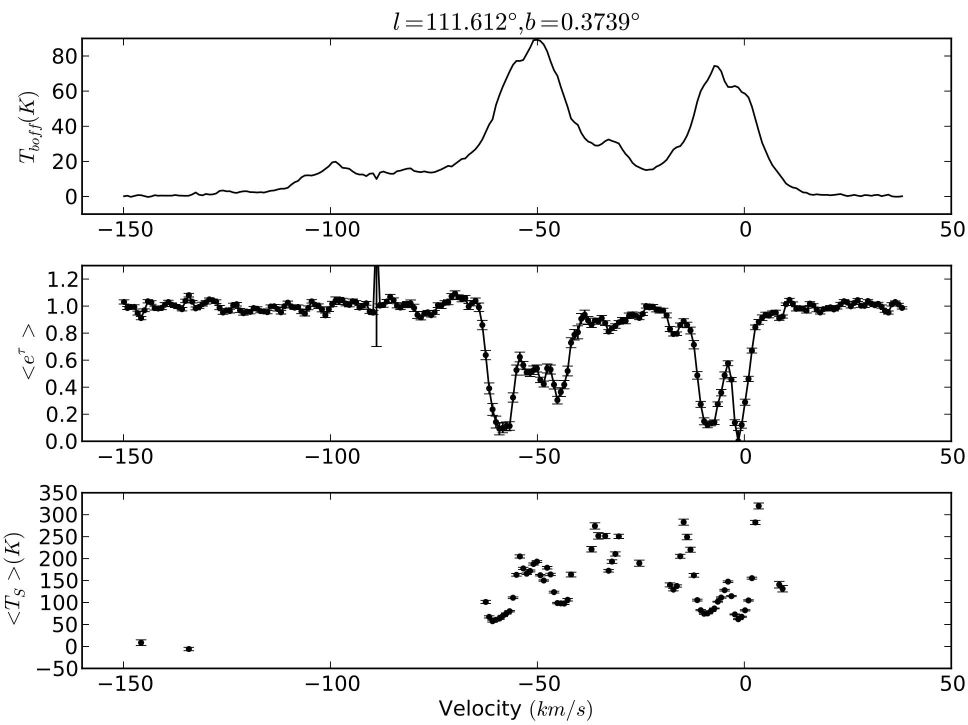
$$SN = \frac{|T_{on} - T_{off}|}{\sqrt{\delta T_{on}^2 + \delta T_{off}^2}}$$

I also calculated the average spin temperature $\bar{T}_s$ of these three lines of sight for all channels that passed the previous criteria in all three lines of sight. I also calculate an error for this average,

$$\delta \bar{T}_s = \sqrt{\delta T_{s1}^2 + \delta T_{s2}^2 + \delta T_{s3}^2} / \sqrt{N}$$

This is shown in Figure 2, and provides a similar picture as Figure 4.7 in the Strasser thesis: since the LSR velocity is primarily a determined by projection of the galactic rotation curve, this figure provides a view of the spin temperature at different depths in the galactic plane.


$l=110.600°, b=4.6946°$
$T_{boff}(K)$
$<e^{\tau}>$
$<T_S>(K)$
Velocity (km/s)


$l=111.612°, b=0.3739°$
$T_{boff}(K)$
$<e^{\tau}>$
$<T_S>(K)$
Velocity (km/s)

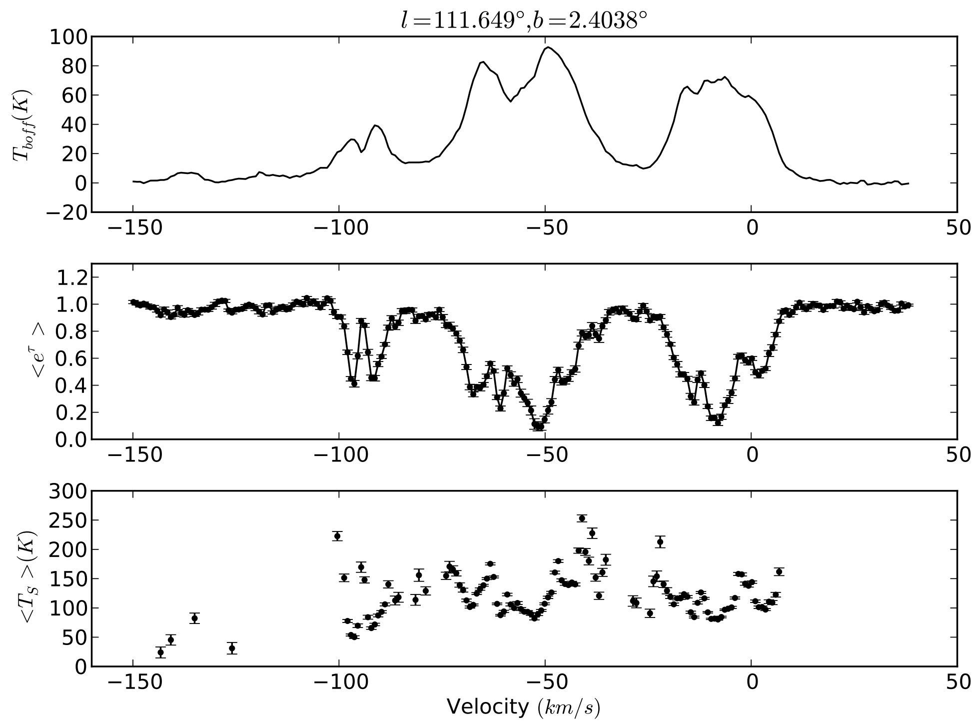


Figure 1: Off-source brightness temperature, exponential optical depth, and spin temperature for three lines of sight

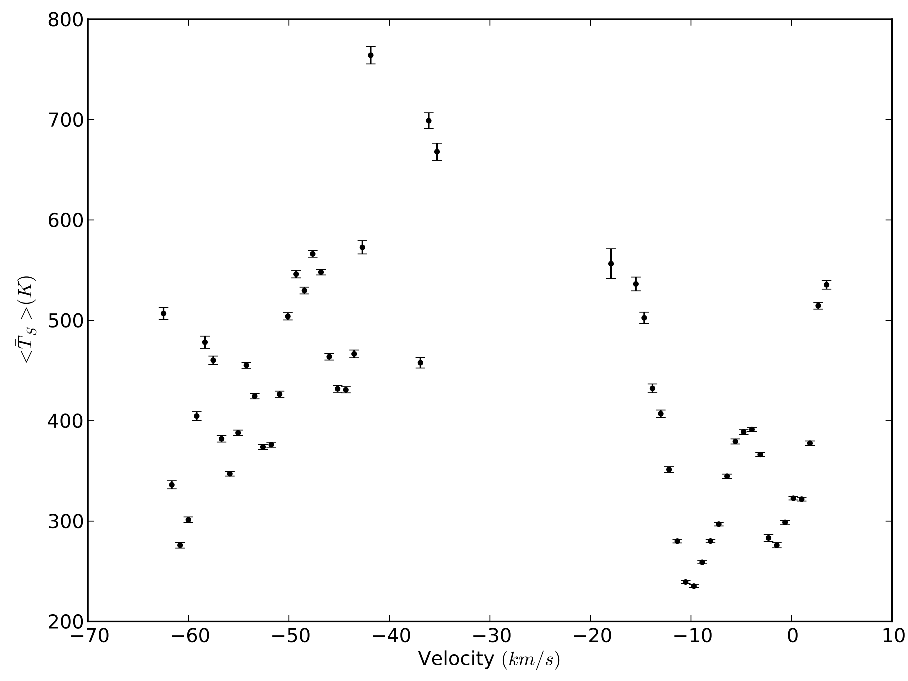


Figure 2: Mean spin temperature as a function of LSR velocity from 3 lines of sight.

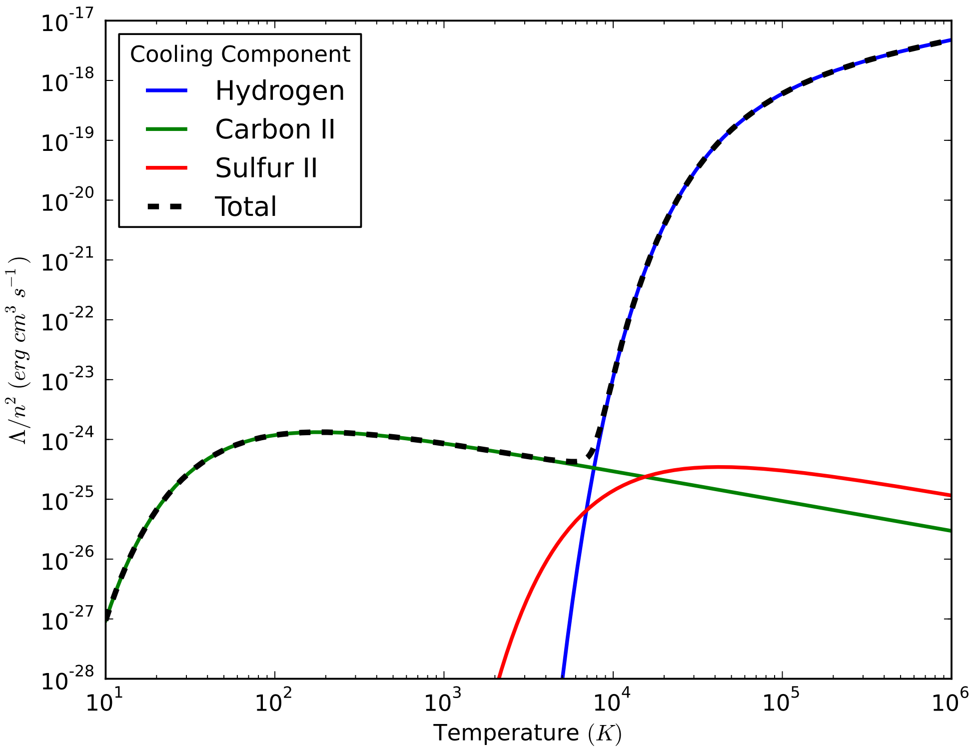


Figure 3: Normalized cooling function for a diffuse ISM composed of Hydrogen, Carbon, and Sulfur with typical abundances

2 Cooling Function

For the construction of a simple 3-component (Hydrogen, Carbon II, and Sulfur II) cooling curve, used the following equations, derived from Dalgarno & McCray 1972 for CII and from Penston 1970 for Hydrogen and SII. The cooling component I included for the two metals was *Electron Impact Excitation* collisions with HI. The mechanism that HI cools in this function is through Lyman-α emission. Each of these functions have had the density normalized out (but for the diffuse ISM, the density can be expected to be $\approx 0.1cm^{-3}$. Also omitted is the fractional ionization, which can become important in regions with large cosmic ray or FUV flux. In Figure 3, note the negative slope in Λ_{total} between $\approx 200-4000$K, indicative of a thermal instability. The abundances for CII and SII were obtained from Table 1 of Dalgarno & McCray 1972. The per-species cooling functions as a function of temperatrue are shown below (f_{CII} and f_{SII} are the fractional abundances of Carbon and Sulfur, and were set to $3.75*10^{-4}$ and $1.4*10^{-5}$ respectively).

$$\Lambda_H(T) = 10.2eV * 3.23 * 10^{-10} T^{1/2}(1 + 17500/T)e^{-118000/T}$$

$$\Lambda_{CII}(T) = f_{CII} * 7.9 * 10^{-20} T^{-1/2} e^{-92/T}$$

$$\Lambda_{SII}(T) = f_{SII} * 8.44 * 10^{-18} T^{-1/2} e^{-21400/T}$$

Note: All calculations and plots were done using attached code

References

Penston, M.V., *Cooling Mechanisms in the Interstellar Gas*, ApJ 162. 1970
Dalgarno, A. & McCray, R.A., *Heating and Ionization of HI Regions*, ARAA 10. 1972
Strasser, S.T., *Properties of HI in the Galaxy*, University of Calgary MSc Thesis. 2002
Strasser, S.T. & Taylor, A.R. *1420MHz Continuum Absorption toward Extragalactic Sources in the Galactic Plane*, ApJ 603. 2004