## Ay 216: THOSE INCREDIBLY USEFUL OPTICAL/UV ABSORPTION LINES!

The interstellar absorption spectrum of interstellar gas in the line of sight to the star $\zeta$ Oph has been well-studied in both the optical and the UV. An excellent classic that has aged well is the detailed, physically motivated paper by Morton (1975 *Ap. J.* **197**, 85). Before starting this problem, take a look at the actual data in Figures 1 and 2a-b. These are from the first astrophysical satellite, called the *Copernicus* satellite. It obtained the first high-quality (excellent velocity resolution, good accuracy) UV spectra of interstellar absorption lines seen against stars. It worked with a single detector; a motor drove the grating so that the detector scanned the wavelength range one resolution element at a time. CCDs didn't exist back then; the detector was (I think) a photomultiplier tube.

First, take a look at §VI and Table 7. Also look at the section on velocities, §IIIc. And you will want to consult the summary, §IX. (In other words, you don't have to read the whole paper!)

1. From the measured column densities of Ca I and Ca II, calculate the electron volume density in the –14.4 km $s^{-1}$ cloud. Do three cases:

   (a) Use the rates given by Morton, using his adopted $T = 56$ K. How was this temperature derived?

   (b) Use the Morton rates for $T = 18$ K.

   (c) Use the Draine rates (Table 13.1 and fitting for temperature in Table 14.6) for $T = 18$K.

   If you peruse the beginning sections of this article, you will find that Morton had to go to considerable effort to find reasonably accurate atomic constants. This was back in the days when good measurements were rare.

2. How can you estimate the ratio $n_e/n_{HI}$? What's the result? Combine this with the electron density derived above (for Draine 18 K) to obtain the total H-nuclei volume density (i.e., $n(HI) + 2N(H_2)$).

3. From the observed column densities of C I, C I$^*$, C I$^{**}$, calculate the kinetic temperature in the cloud. *Hint:* Look at your derived values of electron and H I volume densities. Compare with the critical densities for these fine-structure transitions (see Draine). This makes it easy! Note the ambiguity in the temperature—18 vs 56 K. I don't know the resolution of this difference.

   Suppose that these were your data and you wanted to combine the three level populations to obtain the best possible values for the total column density and the temperature. If the errors are Gaussian-distributed, you would use least-squares. How would you formulate this problem in a statistically proper way?

4. By comparing column and volume densities, calculate the total path length along the line of sight $L_{los}$ occupied by the cloud. Do you think that this cloud is spherical, planar, or filamentary? Why (see section IX)?