ASTR 605
Homework 4

For this assignment, all electronic data are available on line at

http://astronomy.nmsu.edu/cwc/Teaching/ASTR605/HW4/

1. You observe a nebula for $\Delta t = 3600$ [sec] and detect the Hα emission line using the APO 3.5–meter telescope and the DIS spectrograph configured with the R1200 and B1200 gratings. The average pixel sampling for these gratings is $B_\lambda = 0.62$ [Å pixel $^{-1}$]. The Hα counts are illustrated in the Figure 1 (left panel). The data are in the file "nebula-cnts.txt". You then observe a standard star for $\Delta t = 10$ seconds. The standard star counts are illustrated in the Figure 1 (right panel). The data are in the file "stdstar-cnts.txt".

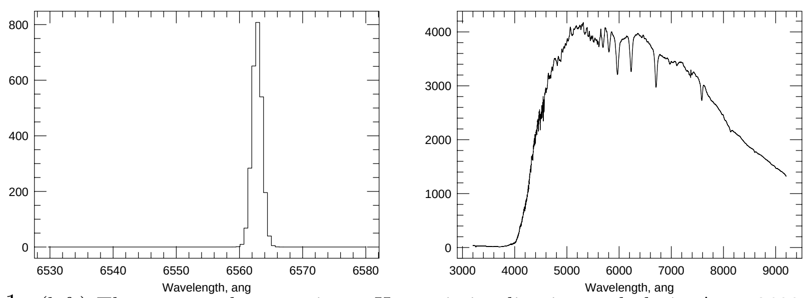

Figure 1: (left) The measured counts in an Hα emission line in a nebula in $\Delta t = 3600$ sec exposure with APO 3.5 meter. (right) The observed counts of a flux standard star in $\Delta t = 10$ sec exposure with APO 3.5 meter.

(a) Re–couch the definition of equivalent width as a summation and write it down. Using your equation, compute the equivalent width of the Hα emission line.

(b) Using the the observed flux density, F_λ, of the standard star provided by the observatory (in file "stdstar-Flam.txt"), compute the sensitivity function, S_λ, for the standard star and plot $\log S_\lambda$ as a function of wavelength. Label your axes and give the units.

(c) Now, calculate the sensitivity function, S_λ, for you nebula observation and plot it on the same figure as the one for the standard star, being sure to label the two curves. Why is this sensitivity function different than that of the standard star (i.e., what is the source of this difference)?

(d) Flux calibrate your spectrum of the nebula and plot its flux density, F_λ, using linear–linear axes (expand the region around the line so it is well resolved). Label the axes and put proper units. Compute the total flux *of the line* (and give the proper units).

(e) If the quantum efficiency of the CCD is 80% in the region of the Hα emission, compute the apparent flux density, $F_\lambda^{(a)}$, of the standard star incident on the detector. Plot $\log F_\lambda^{(a)}$ as a function of wavelength. [HINT: you will first need to determine the function $\epsilon(\lambda)\epsilon_\lambda^{\rm A}(z)$.]

(f) Comment on the various sources causing the dramatic differences between the observed flux density (entering the atmosphere) and the apparent flux density, in particular: What dominates the difference in the far blue?

(g) Which terms within the function $\epsilon(\lambda)\epsilon_\lambda^{\rm A}(z)$ can be time variable and therefore render the sensitivity function less certain?

2. Assume you acquire a second identical spectrum of the standard star, but you place a Sloan r band filter in the light path. The transmission curves for the filter is in the file "Sloan-r.txt". Note that the data are not normalized such that the integral of $R_r(\lambda) \neq 1$. You will need to account for this.

   (a) Starting with the definition of the flux modulate by a filter for the condition that $\int_{-\infty}^{\infty} R(\lambda) d\lambda = 1$, rewrite this equation for the case in which the area under the transmission curve is not unity.

   (b) Using your equation, show (symbolically) that the Sloan r flux, F_r, is invariant to the choice of the flux density (meaning that the integral evaluates to the same numeric value whether the integration is carried out using F_ν or F_λ). [Note that this is true for all filter modulated fluxes, not just Sloan filters and not just for the r band!]

   (c) Re–couch your equation as a summation for discrete data. Write this equation down for flux density in wavelength units, F_λ.

   (d) Using your equation from (c), compute the Sloan r flux, F_r, for your standard star. (Recall that you have the observed flux density, F_λ, of the standard star as provided from the observatory– I am not asking you to flux calibrate again!). What are the units of F_r?

   (e) Using your equation from (c), compute the Sloan r apparent magnitude of the standard star in the Vega photometric system. The flux densities of Vega are provided in the files "Vega-Fnu.txt" and "Vega-Flam.txt". You can chose either one for your calculation, but declare which one you used).

   (f) Using your equation from (c), compute the Sloan r apparent magnitude of the standard star in the AB photometric system. [HINT: to make the calculation easier, think might about the results of part (b) above.]

3. In class, we derived the expression for the classical harmonic oscillator,

$$\sigma(\omega) = \frac{2\pi e^2}{m_e c} \frac{1}{(\omega - \omega_0)^2 + (\gamma/2)^2}. \tag{1}$$

(a) From the relation $\omega = 2\pi\nu = 2\pi c/\lambda$, derive the frequency and wavelength forms, $\sigma(\nu)$ and $\sigma(\lambda)$.

(b) Assuming $\gamma \equiv \Gamma_{mn}$, and using the atomic constant in Table 16.1 (page 367 of the notes), compare the numeric values of the scale parameter, y, of $\sigma(\lambda)$ for Lyα and Lyβ? What is the FWHM of $\sigma(\lambda)$ for Lyα and Lyβ?

(c) Accounting for the scaling with oscillator strength, f_{mn}, what is the peak amplitude of $\sigma(\lambda)$ for Lyα and Lyβ?

(d) For a temperature of $T = 10,000$ K, what is the ratio of the FWHM of $\sigma(\lambda)$ to the FWHM of the thermal Gaussian (related to $\Delta\lambda_{\rm D}$)? If the Gaussian dominates so significantly, then why is it necessary to account for the atomic cross section when determining the relationship between optical depth and column density for a spectral feature (two reasons, actually)?