

ASTRONOMY 698 EXAM 1

There are four problems. You must do Problem # 1 and then you can choose two of the remaining three (Problems # 2, 3, and 4). If you answer all four problems, I will grade the first three and give zero credit the last. No exceptions.

For all problems, clearly write out your answers and show your reasoning. Partial credit will be given.

1. You obtain 100 quasar spectra as part of a survey for metal line absorbers. Your survey is very uniform and all spectra have a wavelength coverage 3500 Å to 9000 Å. Consider one of your spectra from a $z_{em} = 3.5$ quasar. For the following show all calculations, or if you use reasoning (which you can do for most of these questions!), *clearly* state your reasoning.

I have provided a list of typical emission and/or absorption lines seen in quasar spectra. The columns have their usual meaning. I have also provided a blank “spectrum” on which you are to mark the locations of features per the below questions.

- (i) Which emission lines do you expect to see in your spectrum? Consider only the Ly β , OVI, Ly α , CIV, and MgII emission lines.
- (ii) What are the approximate observed wavelengths of the emission lines you can detect on this spectrum? (Recall that emission lines are kinematically broadened blends of their doublet components). Mark the locations of each on your plot, if they are detected.
- For this quasar, what are the wavelength ranges over which you can survey for (i) Ly α absorbers, (ii) MgII absorbers, (iii) CIV absorbers, and (iv) OVI absorbers? (HINT: you must capture *both* members of the doublets!) What are the redshift ranges for each of these absorber classes? Mark each of the wavelength ranges on your plot and label the redshift ranges.
- There is a wavelength range over which only the Ly α absorption line is seen and then below this range both Ly α and Ly β lines co-occupy the spectrum. (i) What is the wavelength region over which Ly α -only absorbers lie? To which redshifts does this correspond? Mark the wavelength range on your plot and label the redshift ranges. (ii) What is the wavelength region over which Ly α absorbers co-occupy the spectrum with the Ly β lines of higher redshift Ly α absorbers? To which redshifts does this correspond? Mark the wavelength range on your plot and label the redshift ranges.

2. Consider the Absorption Distance, $X(z)$. The probability of interception per unit redshift along a line of sight, dP/dz , is proportional to

$$dX/dz = \frac{(1+z)^2}{E(z)}.$$

- In qualitative terms of the expansion of the universe, in which non-evolving objects are carried by the Hubble flow, explain the functional form of $dP/dz \propto dX/dz$. In other words, what physically does the term $(1+z)^2$ in the numerator account for with regard to the probability of interception and what does the term $E(z)$ in the denominator account for?
 - You measure some physical property of absorbers as a function of redshift. You then chart these properties as a function the Absorption distance, $X(z)$. What trend do you expected in the properties as a function of X if the properties do not change with redshift (no evolution)? How would you determine if evolution was present?
3. You find a MgII absorber in your spectrum and the FeII lines are clearly present. The mass of magnesium is $24m_p$ and the mass of iron is $56m_p$, where $m_p = 1.67 \times 10^{-24}$ grams. The Boltzmann constant is $k = 1.38 \times 10^{-16}$ erg K⁻¹.
- If the absorbing gas has a temperature of $T = 30,000$ K, what are the Doppler b parameters (in km s⁻¹) of the MgII lines? The FeII lines?
 - When you actually measure the Doppler b parameters, you find that the measured MgII b parameter is $b = 11$ km s⁻¹ and for the FeII lines is $b = 10.5$ km s⁻¹. You attribute this to a turbulent component to the line broadening. What is the value of the inferred turbulent component in km s⁻¹?
4. You have measured the column densities of MgII for several $z \sim 1$ absorbers and find them to lie in the range $11.8 \leq \log N \leq 13.2$ cm⁻². This corresponds to the shaded region on Fig. 2, which shows a grid of photoionization models for $N(\text{MgII})$ vs. $N_H = N(\text{HI}) + N(\text{HII})$ for a metallicity of 0.1 solar.
- (i) In terms of U , and $N(\text{HI})$, what is the range of models that are consistent with the observed $N(\text{MgII})$? (ii) What are the ranges of $N(\text{MgII})$ for clouds that are optically thick to $N(\text{HI})$ for high ionization clouds, i.e., $\log U \geq -2.5$?; for low ionization clouds, i.e., $\log U \leq -2.5$? (iii) What is the mean ionization fraction of hydrogen for a cloud with $\log U = -2$ and $\log N(\text{HI}) = 17$ cm⁻².
 - Answer the same three questions if you assume the clouds have solar metallicity. (HINT: Do you expect there to be more hydrogen per metals or less hydrogen per metals?)