

delay.[†] In fact, even at $n_e \sim 10^6$, recombination delays for hydrogen (~ 100 days, including time dilation) may be detectable. At much lower densities of $n_e \sim 10^4$, hydrogen may not have time to reach equilibrium in the period between continuum changes, thus decreasing the *effective* optical depth of neutral hydrogen.

The character of the change as a function of time will also be very important in identifying this effect; therefore, we wish to solve the non-equilibrium photoionization equation.

3.6.2 : Solution for Two Ion States

Given two ion states, X^{+n} and $X^{+(n+1)}$, let us call the fractional abundances for these states x and x' , respectively. For hydrogen, we have $x+x'=1$. For more complex elements, we can state $x+x' \simeq 1$, as long as the contributions from other ions can be neglected (for the ionization parameter of interest). Referring to figure 3-3, we see that this is approximately true for Carbon if $\log(U) \simeq -1.2$ – a value which is consistent with observations. In this case, nearly all of the Carbon ($\sim 95\%$) is in the form of C^{+3} and C^{+4} .

In the following, we assume n_e is constant, neglect any change in α_R with any changes in T_e , and assume that the gas is in equilibrium at time $t=0$. The time-dependent equation for photoionization/recombination is:

$$\frac{dx}{dt} = n_e x' \alpha_R - \Gamma(t)x \quad ,$$

where

$$\Gamma(t) \equiv \int_{\nu_o(x)}^{\infty} \frac{4\pi J_\nu(t)}{h\nu} a_\nu(x) d\nu \quad ,$$

[†] Unfortunately, there may be problems with measuring changes in the Lyman- α BAL due to scattered light effects. However, variability in this BAL would allow the highest lower limits on n_e (if no recombination time delays are seen) via time-dependent photoionization/recombination analysis.