EFFECTS OF PARTIAL FREQUENCY REDISTRIBUTION
ON THE LEVEL POPULATION DENSITIES
IN A RESONANCE LINE

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Abstract. We have obtained a simultaneous solution of the statistical equilibrium equation for a non-LTE two-level atom and the radiative transfer equation in the comoving frames by employing the angle-averaged partial frequency redistribution. In the first iteration we have set the population density of the upper level equal to zero and allow it to be populated in the subsequent iterations. The solution converges within two to four iterations. The process of iteration is terminated when the ratios of population densities in two successive iterations at each radial point, attain an accuracy of 1%. The effects of partial frequency redistribution is to increase the population density of the upper level. Radial gas motions do not seem to have significant effects, although in highly extend geometries, velocity gradients change the population densities considerably.

1. Introduction

In a previous paper (Peraiah, 1980; henceforth referred to as Paper I), we have obtained a simultaneous solution of the radiative transfer equation in the comoving frame and the statistical equilibrium equation for a non-LTE two level atom assuming complete redistribution. We have obtained few interesting results in Paper I. The population densities change dramatically when gas velocities are introduced in a spherically symmetric expanding media. The whole process took 2-4 iterations to converge to a consistent solution. However, in that paper, we have used complete redistribution and it will be interesting to study the effects of partial frequency redistribution.

In this paper, we have considered the angle averaged partial frequency redistribution function for zero natural line width ($R_{f-A}$) with isotropic scattering. We have considered a law of linear velocity with the geometrical extension $B/A = 3$ and 10 where $B$ and $A$ are the outer and inner radii of the spherically symmetric extended media. The velocity $v$ is set equal to 0 at $A$, and a maximum velocity at $B$. The maximum velocities set at $B$ are 0, 5, 10, 30, and 60. In the next section, we present a brief description of the computational procedure and discussion of the results.

2. A Brief Description of Computational Procedure and Discussion of the Results

The procedure has been described in detail in Paper I. We shall give a brief sketch of the method here. To solve the equation of transfer we first assume the
population densities of the two levels and calculate the absorption coefficient given by

\[ K_L(r) = \frac{h\nu_0}{4\pi \Delta \nu} [N_1B_{12} - N_2B_{21}] , \]  

(1)

where \( \nu_0 \) is the frequency of the hydrogen Ly line, \( \Delta \nu \) is a suitable frequency width \( B_{12} \) and \( B_{21} \) are the Einstein coefficients. \( N_1 \) and \( N_2 \) are the population densities of the lower and upper levels respectively. The quantities \( N_1 \) and \( N_2 \) are obtained from the solution of statistical equilibrium equation given by

\[ \frac{N_1}{N_2} = \frac{A_{21} + C_{21} + B_{21}\int dx \phi(x)J_x}{C_{12} + B_{12}\int dx \phi(x)J_x} ; \]  

(2)

\( A_{21} \) being Einstein's coefficient for spontaneous emission, \( C_{12} \) and \( C_{21} \) are the rates of the collisional excitation and de-excitation given (Jefferies, 1968) by

\[ C_{12} = 2.7 \times 10^{-10} \alpha_0^{-1.68} \exp (-\alpha_0)T^{-3/2} A_{21} \frac{g_2}{g_1} \left( \frac{I_H}{\chi_0} \right)^2 N_e \]  

(3)

and

\[ C_{21} = 2.7 \times 10^{-10} \alpha_0^{-1.68} T^{-3/2} A_{21} \left( \frac{I_H}{\chi_0} \right)^2 N_e , \]  

(4)

where \( \chi_0 \) is the excitation energy \( E_{12} \), and \( \alpha_0 = \chi_0/kT_e \) being the temperature \( I_H \) is the ionization potential of hydrogen and \( N_e \) is the electron density. In equation (2), \( X \) is the normalized frequency given by

\[ x = (\nu - \nu_0)/\Delta ; \]  

(5)

\( \Delta \) being a standard frequency interval, \( \phi(x) \) is the profile function given by

\[ \phi(x) = \int_{-\infty}^{\infty} R_{I-AI}(x, x') dx' , \]  

(6)

where \( R_{I-AI}(x, x') \) is the angle averaged redistribution function with isotropic scattering given by

\[ R_{I-AI}(x, x') = \frac{1}{2} \text{erfc} \left( |x| \right) \]  

(7)

where

\[ \text{erfc} (x) = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-t^2} dt . \]  

(8)

The symbol \( J_x \) in Equation (2) stands for the mean intensity at the normalized frequency \( x \), given by

\[ J_x = \frac{1}{2} \int_{-1}^{1} I(r, \mu, x) d\mu ; \]  

(9)