DENSITY DEPENDENCE OF THE LINE SOURCE FUNCTIONS IN SCATTERING MEDIA

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Abstract. We have calculated source functions in a scattering medium in which the density changes according to the law of $N_e(r) \sim r^n$ where n takes the value from -3 to $+3(1)$ and $N_e(r)$ is the electron density. We have assumed that the media consist of electrons and we have also considered a geometrically extended media in which the outer radii are 2, 3, 5 times the inner radius. The source functions obtained are completely due to electron scattering. It is found that the source function varies considerably for different variations of density changes from $n = -3$ to $+3$. In the case of density variation with $n = -3$ and -2, the source functions do not increase with optical depth considerably, but when $n = -1, 0$, they rise slowly with the increase in optical depths and when $n = 1$ to 3 there is a steep rise in the source functions with the optical depth increasing towards the center of the star.

1. Introduction

The calculation of source functions is essential in estimating the line profiles emerging from the stellar atmospheres. The extreme outer layers of many stars scatter radiation. Therefore, it becomes very essential to obtain the source functions in such a scattering media. We assume that the medium consists of electrons and calculate the source function by solving the radiative transfer equation. We also assume that the electron density varies as $\rho \sim r^n$ with $-3 \leq n \leq 3$.

2. Results and Discussions

We have solved the radiative transfer equation given by

$$\mu \frac{\partial I}{\partial r} + \frac{1-\mu^2}{r} \frac{\partial I}{\partial \mu} = k_x \int J_x \phi_x \, \mathrm{d}x - K_x I_x \,, \tag{1}$$

in which the frequency-dependent absorption coefficient is

$$K_x = \sigma N_e \phi_x \,; \tag{2}$$

where ϕ_x is the Doppler profile, here I is the specific intensity of the ray making an angle of $\cos^{-1} \mu$ with radiation, J_x is the the mean intensity, σ is the Thomson scattering coefficient, N_e is the electron density and X is the frequency by

$$X = (\nu - \nu_0)/\Delta \,, \tag{3}$$

where Δ is the same standard frequency. We essentially consider the case for $\varepsilon = 0$, $\beta = 0$, which means pure scattering medium with no line emission. The above equation

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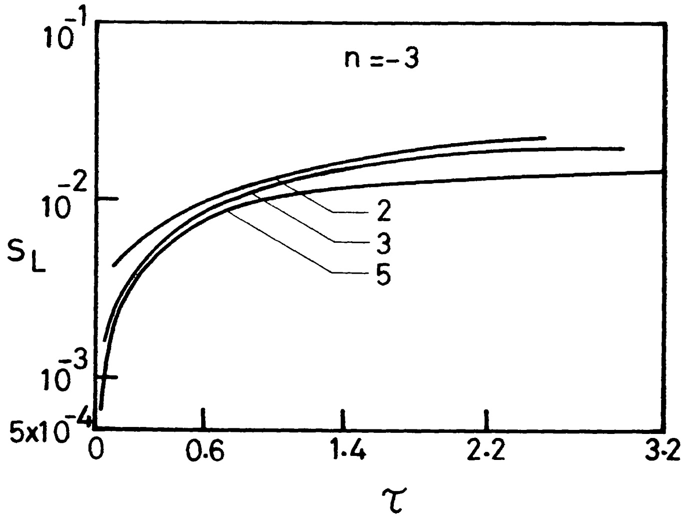

Fig. 1. The source function S_L is plotted against optical depth. The numbers 2, 3, 5 represent the value of B/A with $n = -3$.

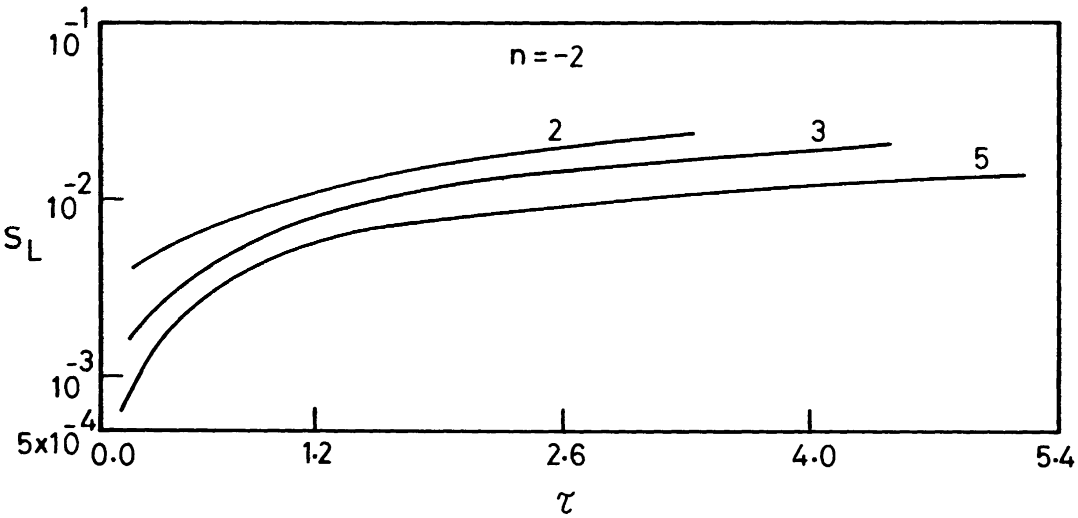

Fig. 2. Same as those given in Figure 1, with $n = -2$.

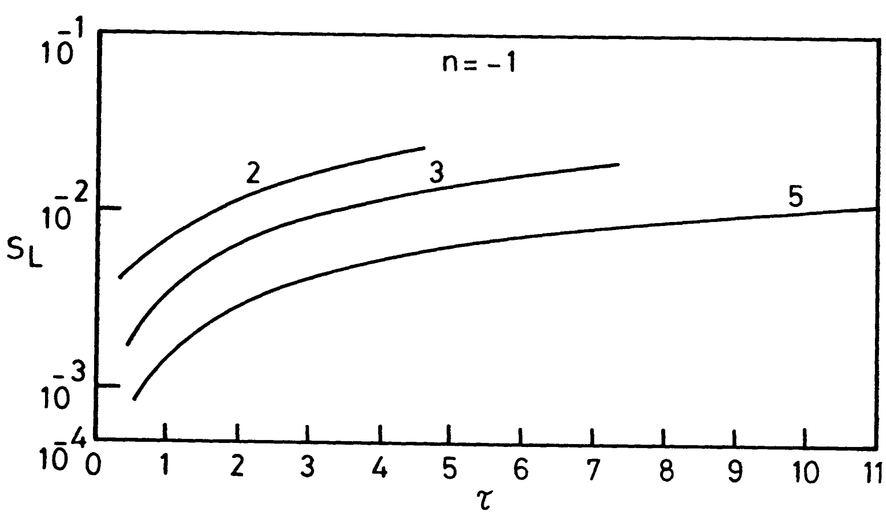

Fig. 3. Same as those given in Figure 1, with $n = -1$.

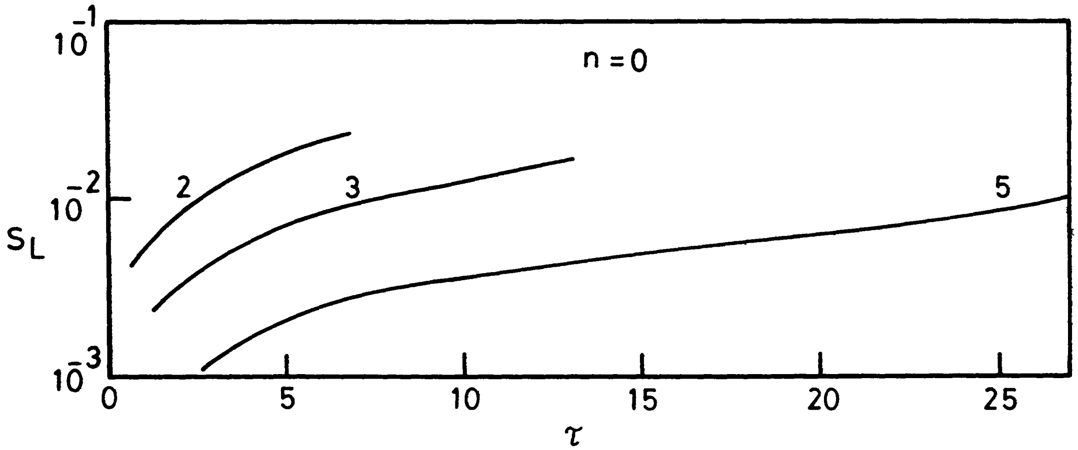

Fig. 4. Same as those given in Figure 1, with $n = 0$.

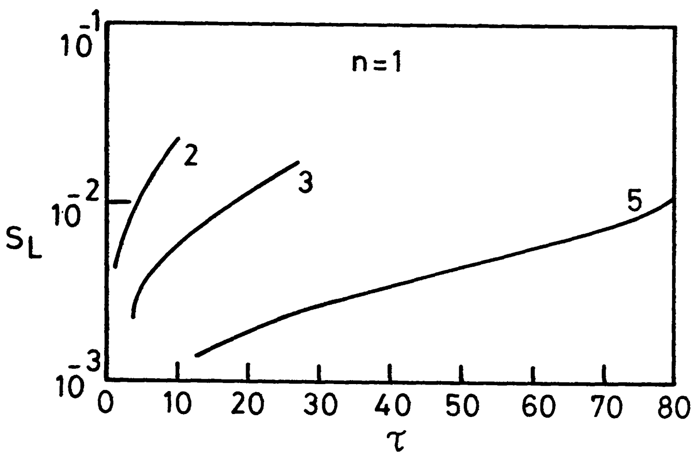

Fig. 5. Same as those given in Figure 1, with $n = 1$.

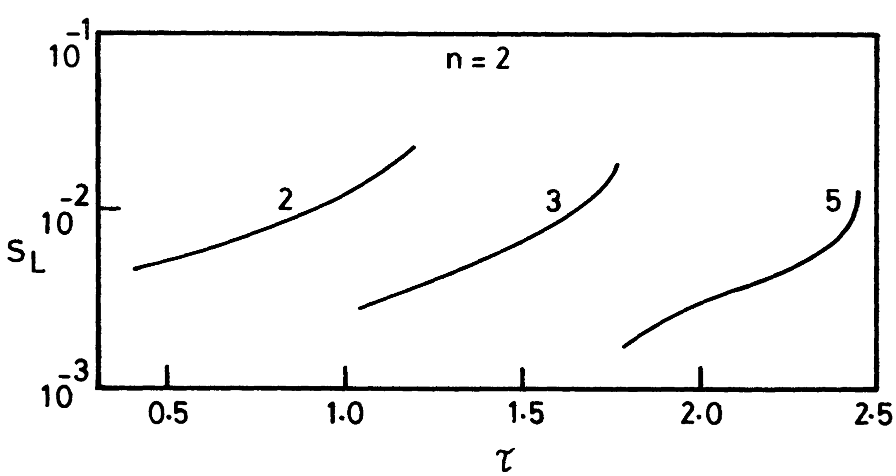

Fig. 6. Same as those given in Figure 1, with $n = 2$.

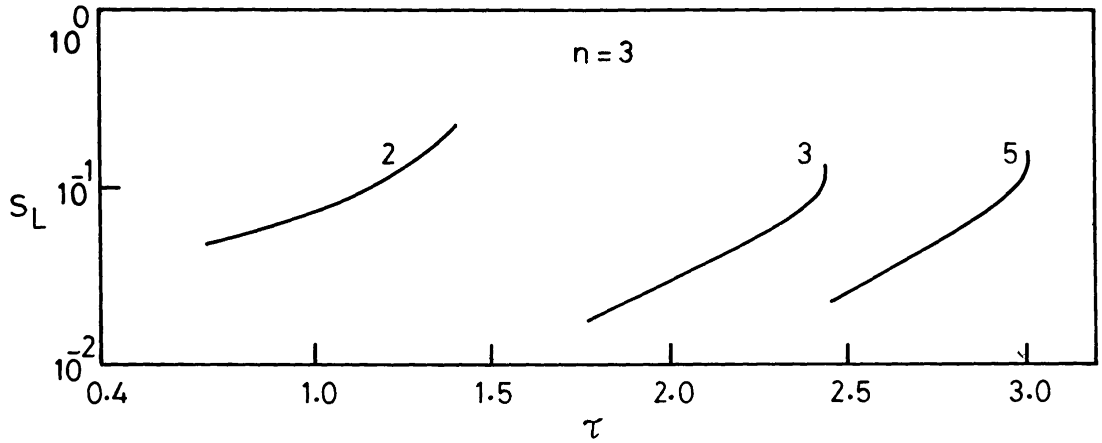

Fig. 7. Same as those given in Figure 1, with $n = 3$.

has been solved in Grant and Peraiah (1972) for the case of spherical symmetry. We have assumed atmospheres with different geometric extensions: 2, 3, 5 times inner radius of the atmosphere. The inner radius is taken to be 10^{12} cm (R_{in}). We have assumed electron density at R_{in} equal to 10^{13} cm^{-3} and variation of the density is taken to be $N(r) \sim r^n$ where $-3 \leq n \leq 3$. The maximum optical depth for $n = -3$ is 3.2 and for $n = 3$ is 1000 for the quantity $B/A = 5$ where B/A is the ratio of the outer and inner radii of the atmosphere. We have described this result in Figure 1 to Figure 7. In all these figures we have plotted the line source function, given by

$$S_L = \int J_x \phi_x \, \mathrm{d}x \,, \tag{4}$$

with respect to the optical depth in the atmosphere. In Figure 1 the quantity S_L is plotted against τ for $n = -3$. We notice that optical depth at $B/A = 2$ is slightly larger than that at $B/A = 3$ and this is larger than that for $B/A = 5$. The source functions rises steeply from optical depth $\tau = 0$ up to an optical depth, $\tau = 0.6$ then the rise becomes slow and from 0.6 to 3.2 it becomes almost flat. In Figure 2 the source functions are given against τ for $n = -2$. In this case the source function rises slightly up to $\tau = 1$ and then becomes almost flat with the same characteristics shown by the source function for $n = -3$ given in Figure 1. The source function for smaller value of B/A is correspondingly high. The optical depths corresponding to different geometrical depths change considerably. In Figure 3 we have given source function for $n = -3$ and these source function show essentially the same features as shown by those in Figure 1 and Figure 2. However, the values of the source functions for smaller geometrical extensions are much larger than those computed for larger geometrical extensions. The curves in Figure 4 show the same characteristics shown by those in Figure 3. In Figure 5 we have drawn the source function for $n = 1$ and we can see that source function for $B/A = 2$ is much larger than that for $B/A = 3$ which in turn is slightly larger than that for $B/A = 5$.

The variation of source functions from one law of density variation to another is considerable. We have a flat variation of source functions for the indices $n = -3, -2, -1$, and 0. With $n = 1$ there is a steep rise in the source function with respect to the optical depth. The curves in Figures 5, 6, 7 corresponding to $n = 1, 2$, and 3, respectively, show very similar characteristics. Here the source functions rise considerably towards the higher optical depths. With higher values of n, the optical depth in the outermost shells are quite high and, therefore, the source functions in these cases, start at large optical thicknesses.

Reference

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