THE EFFECTS OF ABERRATION AND ADVECTION IN PLANE-PARALLEL AND ABSORBING MEDIA

(Letter to the Editor)

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Abstract. We have calculated the changes that would occur in mean intensity due to the presence of aberration and advection terms in radiative transfer equation. We have considered an absorbing medium with velocities 1000, 2000, 3000, 4000, and 5000 km s^{-1} ($\beta = 0.0033, 0.017$, where $\beta = V/C$, V is the velocity of the medium and C is the velocity of the light). Calculations have been done in a comoving frame with monochromatic radiation field. We have calculated the deviation in mean intensity defined as $\bar{J} = \{[J(V = 0) - J(V > 0)]/J(V = 0)]$, where J is the mean intensity. We have taken two types of absorbing media (1) with a source of constant emission and (2) with emission source. As the emission decreases as $1/n^2$ where n is the number of layer, where $n = 1$ corresponds to $\tau_{\max}$ and $n = N$ corresponds to $\tau = 0$.

We find that for a total optical depth of one, the maximum change is about 2% when $B(r) = 1$ and about 6%, when $B(r) \propto 1/n^2$ where $B(r)$ is the Planck function. When the optical depth increases to 5 the maximum change in the case of the constant source function falls to 1.5%, where as in the other case in which the Planck function changes as $1/r^2$ the maximum changes remains at 6%. Further increase of the optical depth will reduce the changes to less than 2%. The amplification factor in the case of the Planck function varying as $1/r^2$ is more than when the emission sources are constant.

1. Introduction

In two papers we have studied the effects of aberration and advection on radiation field (Peraiah, 1987; Peraiah and Srinivasa Rao, 1989). In those two papers we have included the scattering of radiation by the medium and we have found that scatteirng would enhance the effects of aberration and advection while the medium with both scattering and absorption would not change the radiation field as much as when there is pure scattering. In this paper we shall try to investigate how the medium with only absorption will change the radiation field.

2. Results and Discussion

There is no scattering of radiation by the medium, therefore, source function is replaced by the Planck function and we solve the equation of transfer given by

$$(\mu + \beta)\,\frac{\partial I(z, \mu)}{\partial z} + \frac{\mu(\mu^2 - 1)}{C}\,\frac{\partial v}{\partial z}\,\frac{\partial I(z, \mu)}{\partial \mu} + \frac{3\mu^2}{C}\,\frac{\partial v}{\partial z}\,I(z, \mu) =$$

$$= K[S - I(z, \mu)]\,, \tag{1}$$

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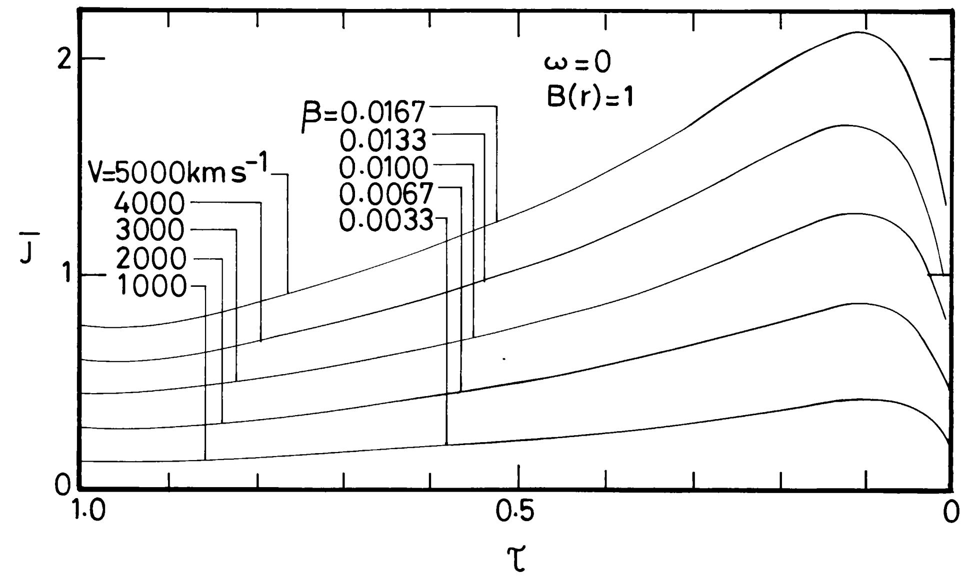

Fig. 1. The changes in the mean intensity optical depth of 1.

where $\mu = (\mu' - \beta)/(1 - \mu'\beta)$ and $\mu' (0 \leq \mu' \leq 1)$ is the cosine of the angle made by the ray with the Z-axis; $\beta = V/C$; V is the velocity of the fluid and C is the velocity of light; $I(z, \mu)$ is the specific intensity of the ray; K is the absorption coefficient; and S is the source function. In this case it is given by

$$S = (1 - \omega)B(z) , \tag{2}$$

where B is the Planck function.

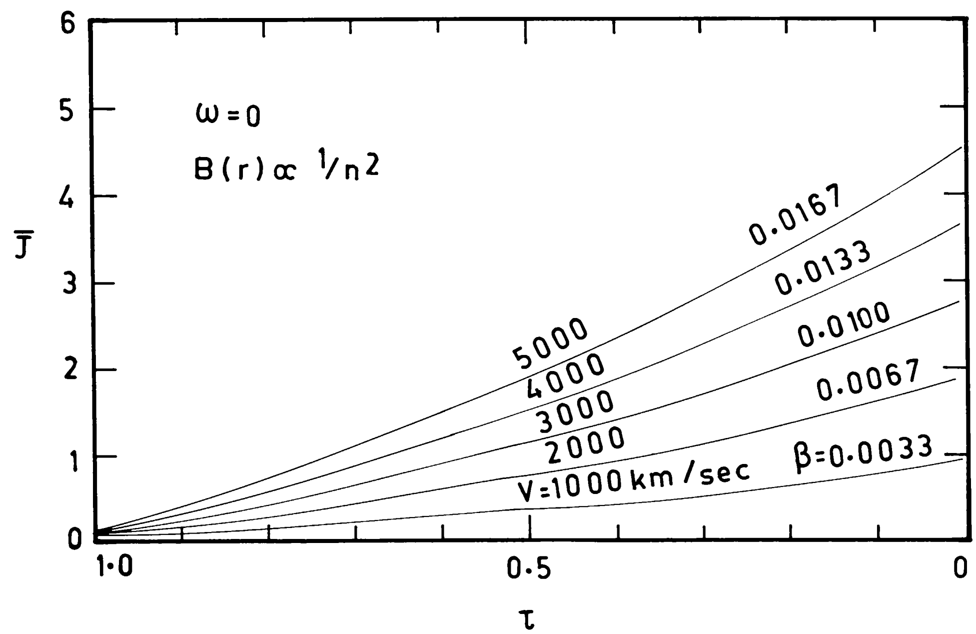

Fig. 2. Same as in Figure 1.

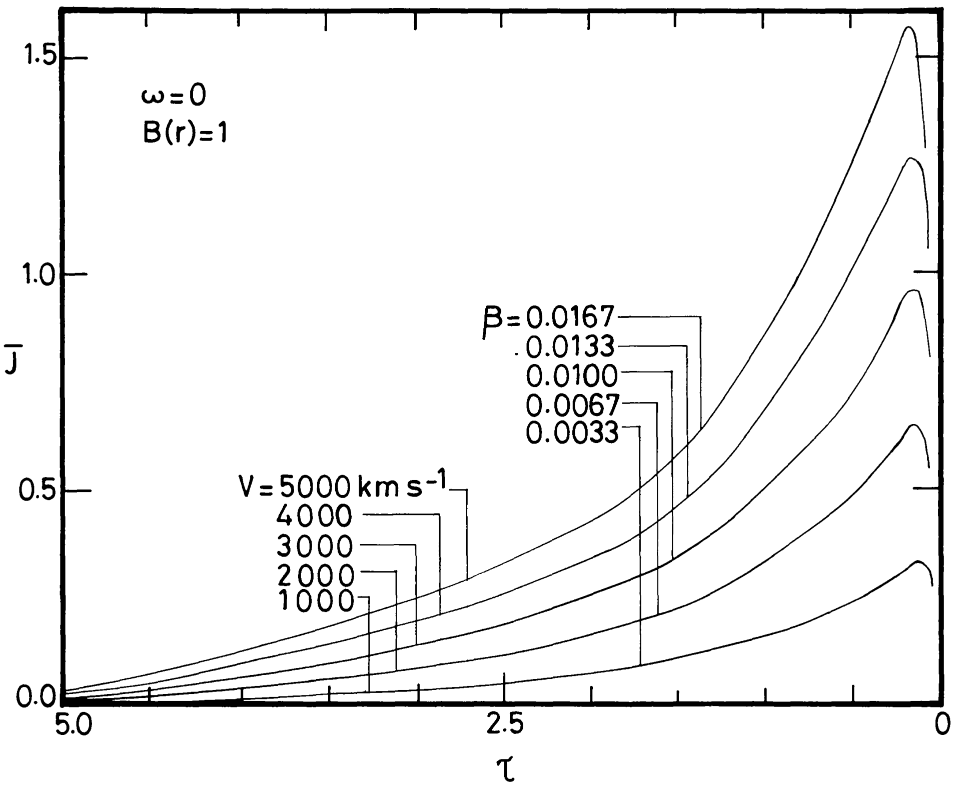

Fig. 3. The changes in the mean intensity optical depth of 5.

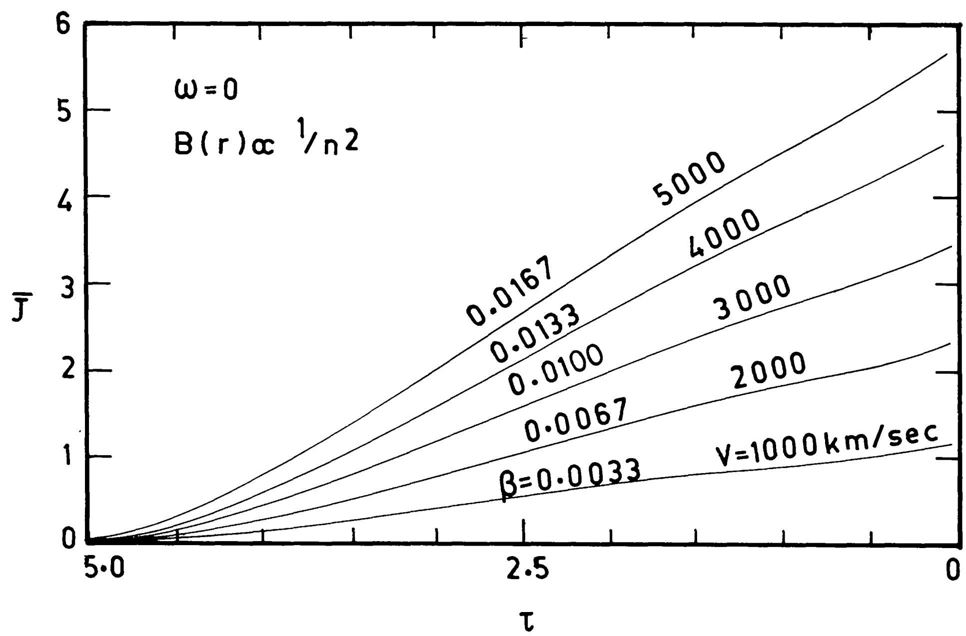

Fig. 4. Same as in Figure 3.

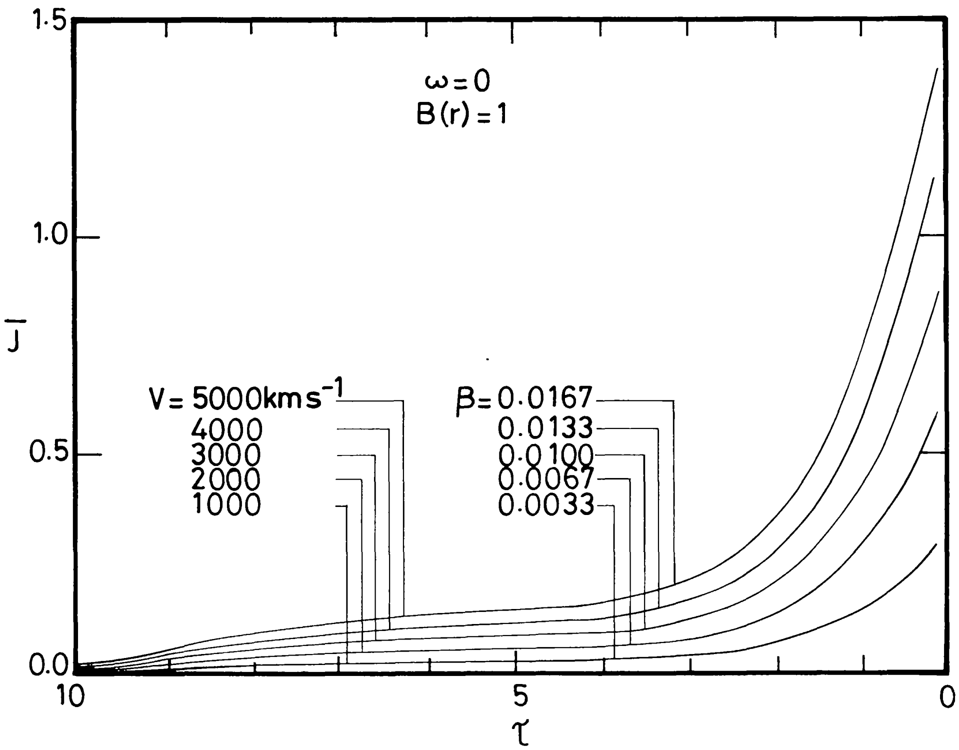

Fig. 5. The changes in the mean intensity optical depth of 10.

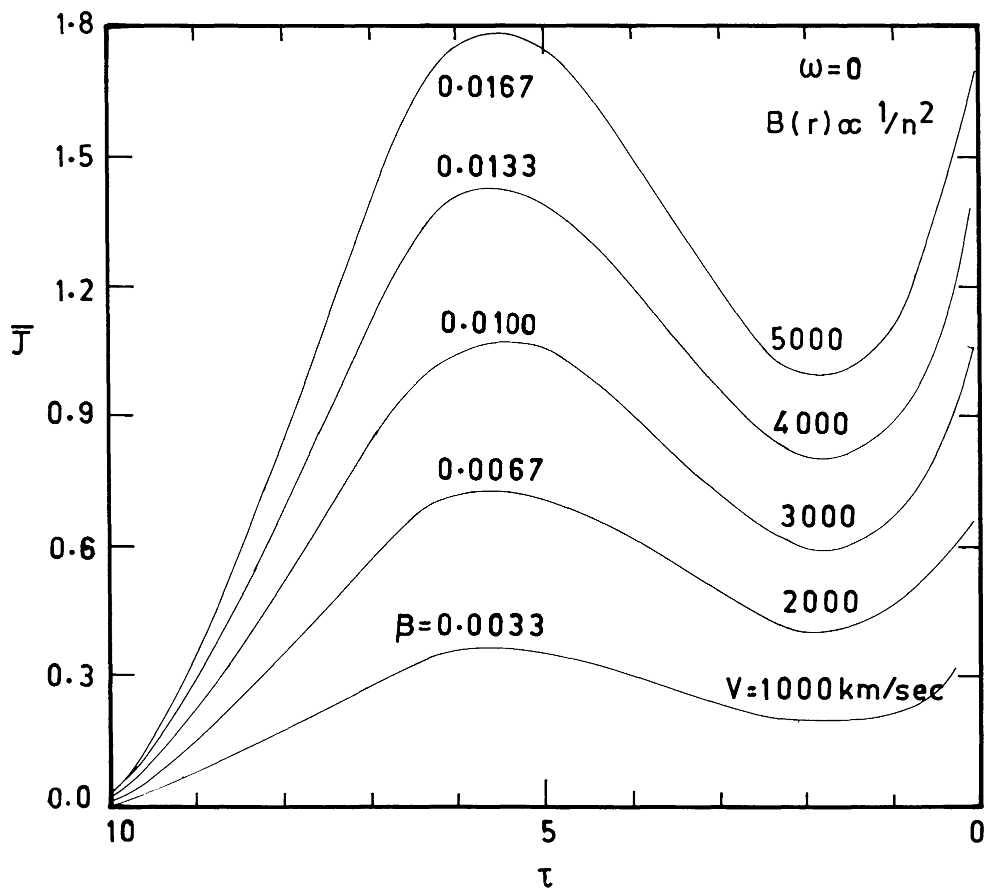

Fig. 6. Same as in Figure 5.

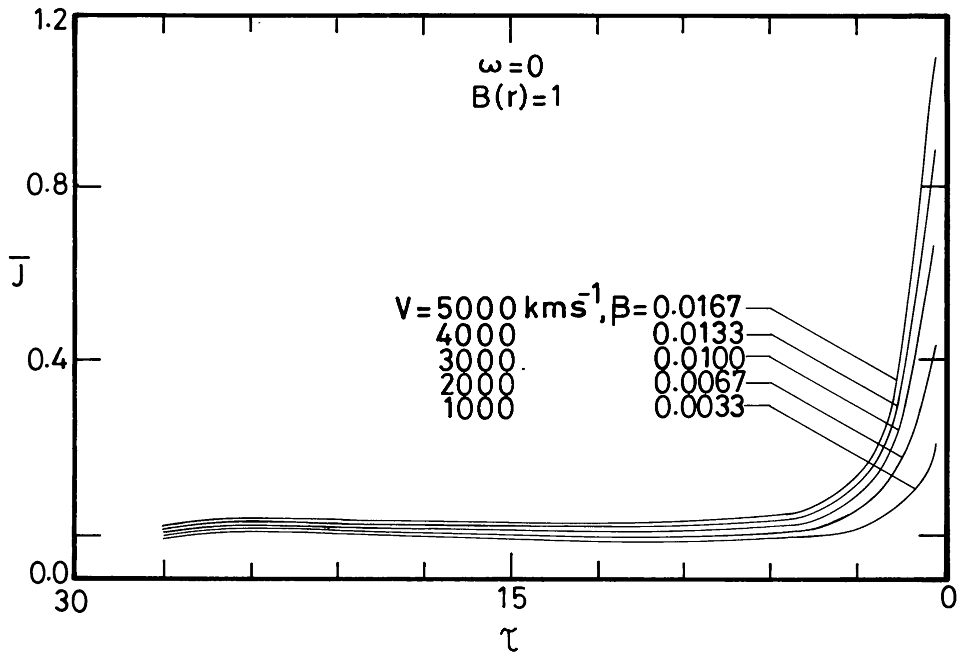

Fig. 7. The changes in the mean intensity optical depth of 30.

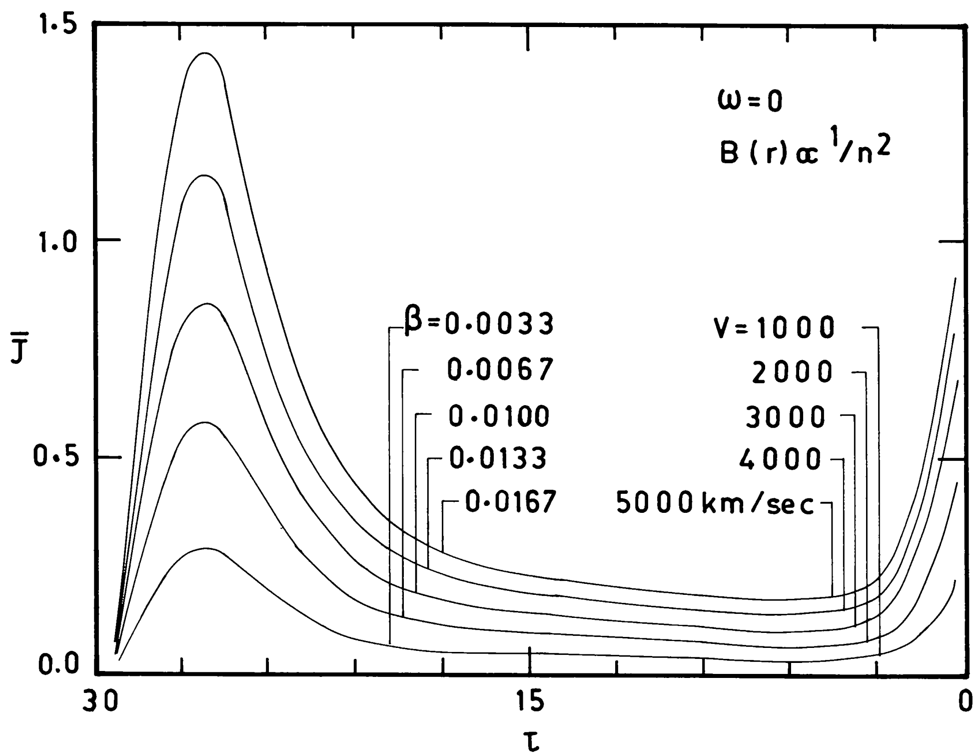

Fig. 8. Same as in Figure 7.

The above equation has been solved as described in Peraiah (1987) and we have set ω, the albedo for single scattering equal to 0.

The medium is absorbing and emitting with the boundary conditions:

$$I^-(\tau = \tau_{\max}, \mu_j) = 0\,, \tag{3}$$

$$I^+(\tau = 0, \mu_j) = 0\,. \tag{4}$$

The physical meaning of Equations (3) and (4) is that we do not irradiate the slab at $\tau = \tau_{\max}$ and at $\tau = 0$. The velocity gradient $dV/d\tau$ is constant: i.e.,

$$V(\tau = \tau_{\max}) = 0\,, \tag{5}$$

$$V(\tau = 0) = V\,; \tag{6}$$

where

$V = 0\ \mathrm{km\ s^{-1}}$ $(\beta = 0)$, $1000\ \mathrm{km\ s^{-1}}$ $(\beta = 0.0033)$, $2000\ \mathrm{km\ s^{-1}}$ $(\beta = 0.0067)$, $3000\ \mathrm{km\ s^{-1}}$ $(\beta = 0.01)$, $4000\ \mathrm{km\ s^{-1}}$ $(\beta = 0.013)$, $5000\ \mathrm{km\ s^{-1}}$ $(\beta = 0.0167)$.

The optical depths $\tau_{\max}$ are taken to be

$$\tau_{\max} = 1,\ 5,\ 10,\ 30,\ \text{and } 50\,. \tag{7}$$

Mean intensities are computed from

$$\bar{J} = \frac{1}{2}\int_{-1}^{+1} I(\mu)\, d\mu\,. \tag{8}$$

The changes in J due to velocities compared to those calculated without velocities are estimated. Thus

$$J = \frac{\Delta J}{J(V = 0)} \times 100\,, \tag{9}$$

where

$$\Delta J = J(V = 0) - J(V > 0)\,. \tag{10}$$

3. Description of Figures

In Figure 1 we plotted $\bar{J}$ agianst total optical depth, is equal to 1 for the velocities shown in the figure. The medium has a constant source function. Now here the maxima differences in the mean intensity is about 2%, where as in Figure 2, in which the source function changes as $1/r^2$, the maximum change is 6%. It seems that the radiation field is effected more by the medium in which there is less emission and high velocity. In Figures 3 and 4 we have plotted the mean intensity differences for the optical depth 5.

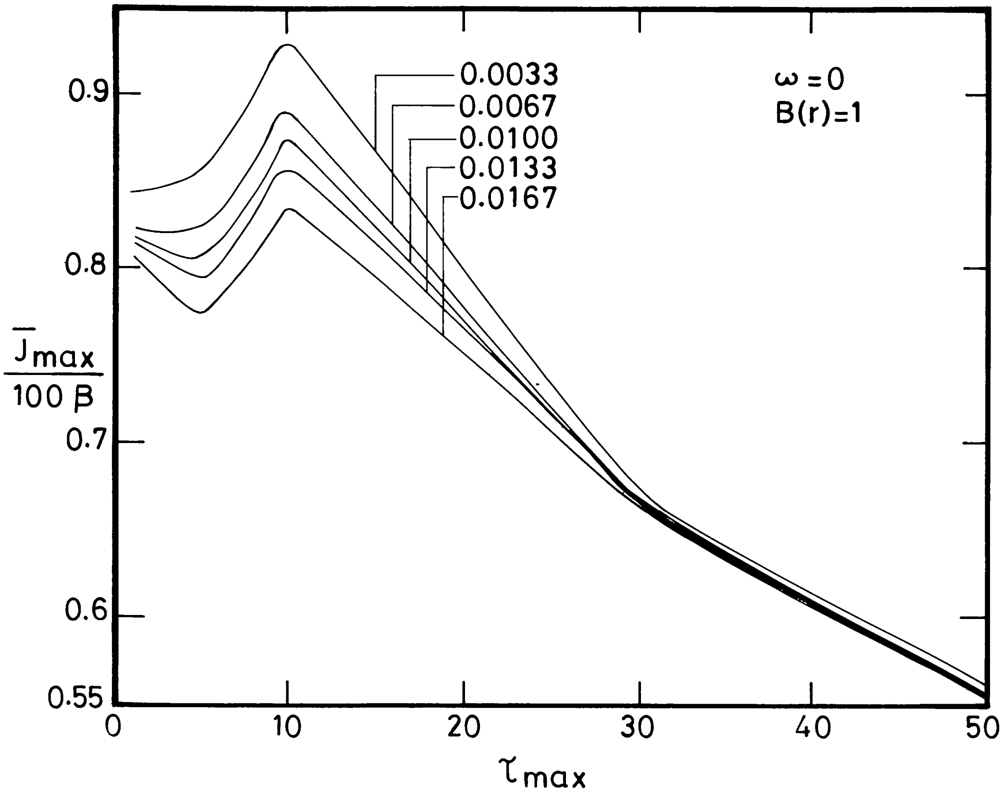

Fig. 9. The amplification factor.

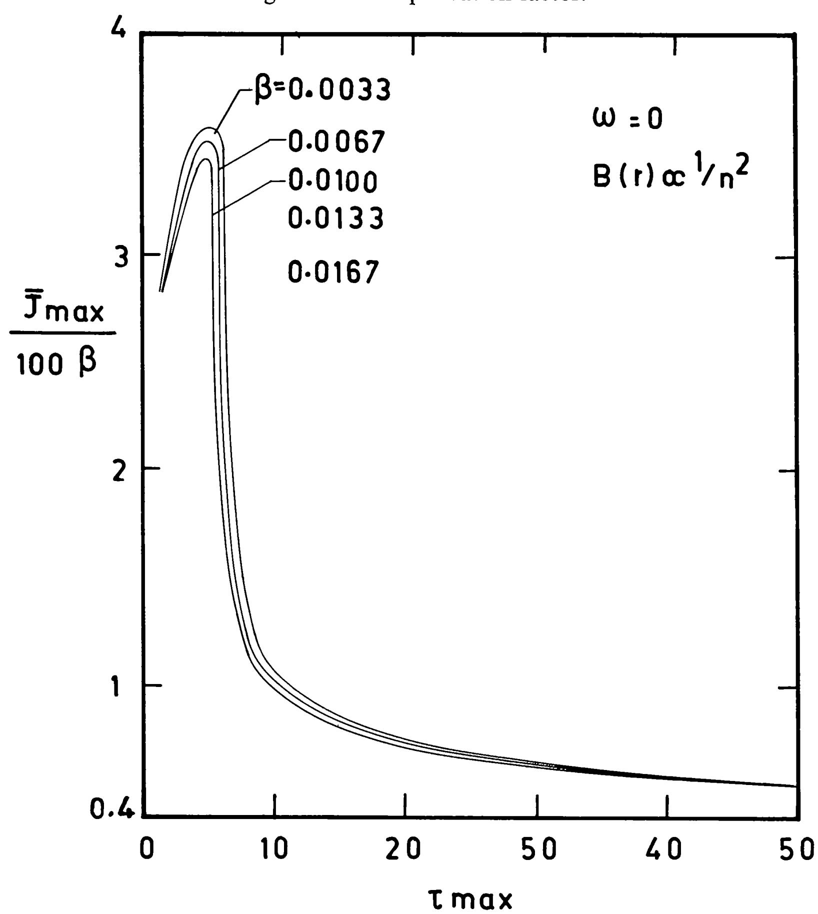

Fig. 10. The amplification factor.

These are similar to those in Figures 1 and 2. In Figures 5, 6, 7, and 8 the optical depth is taken to be 10 and 30 and the changes in the mean intensity come down to less than 2%. The amplification factor for both cases are given in Figures 9 and 10. Again the amplification seems to be high in the case of medium in which the source function varies as $1/r^2$.

References

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