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LINES FORMED IN SLOWLY EXPANDING THIN SPHERICAL SHELL

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ABSTRACT

We have investigated how an optically thin spherical shell with small velocities change the profiles and equivalent widths of the lines. We have employed several types of variations in density, velocity of expansion and source functions. In all the cases we find that the line centres are shifted to the blue side almost in proportion to the velocity of expansion. The shells moving with constant velocities shift the line centre the most, irrespective of the density variation. The velocity gradients shift the line centre the least. Maximum velocity of expansion considered is 6 mean thermal units and the total optical depth is taken to be equal to 5.

Key words: spherically symmetric flow—radiative transfer equation—emergent flux profiles.

1. Introduction

Earlier, we have presented results of spectral line profile formed in rotating and expanding spherical shells. (see Peraiah 1980, 1981). Here, we have used large optical depths in the shell. We have allowed the rotation to affect the formation of the lines upto the outermost layers of the shell. However, according to the conservation of angular momentum, the rotational velocities should reduce outward; in systems like Pleione, the outermost shell which is far away may be rotating very slow. Such shells are thinner and are expanding slowly. In this paper, we would like to obtain line profiles which are formed in such shells. Some of the variations of density, and velocity of expansion, need not satisfy the equation of continuity for a spherically symmetric flow.

2. Discussion of the Results

The method has already been described in earlier papers (Peraiah 1980, 1981) and we present only a brief sketch here. The whole line-forming medium is divided into a number of shells. We assume the density at the boundary of each shell. The optical depth is calculated between two shell boundaries in the line of sight because, the emergent intensities are calculated along the line of sight. We assume no incident radiation from outside the medium. The emergent intensity is calculated by the formal solution of the transfer equation and is given by (along the line of sight)

$$I(\tau_s) = \int_0^{\tau_s} s(t) \exp[-(\tau_s - t)]\, dt + I_{\text{incid}}\, e^{-\tau_s}\ , \tag{1}$$

where $s(t)$ is the source function, τ_s the optical depth in the shell, and I_{incid} the incident radiation on the shell. The optical depth is given by

$$\tau_s = \Delta s . k_0\, e^{-x^2} N\ , \tag{2}$$

where Δs is the geometrical distance between two successive shell boundaries, K_0 the absorption coefficient and N the number of absorbing atoms. Here x is the normalized frequency given by

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

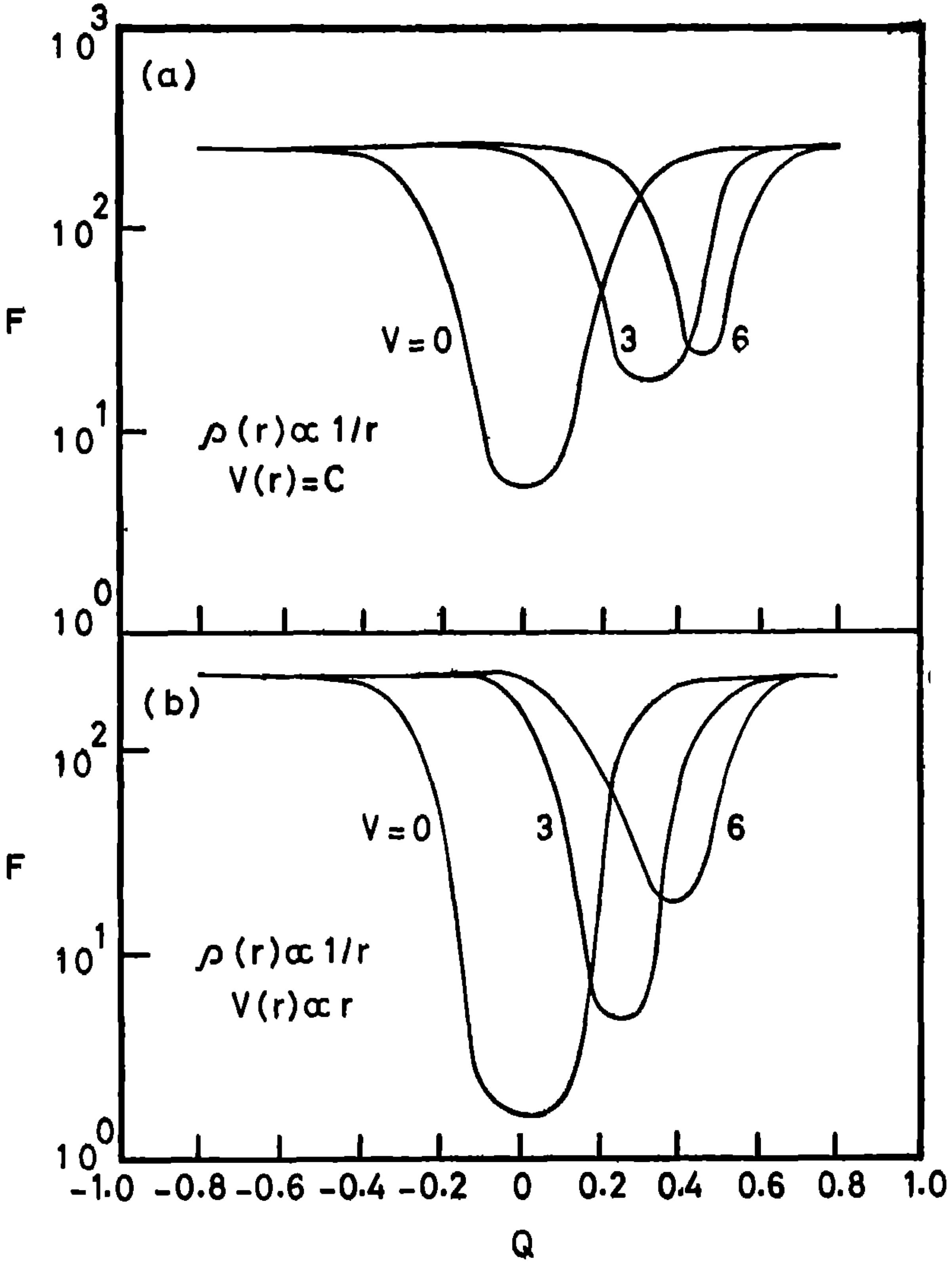

Fig. 1. Line profiles for $\rho \sim 1/r$. $F = F(x)/F(x_{max})$
$Q = x/x_{max}$
(a) V = constant velocity
(b) $V \sim r$

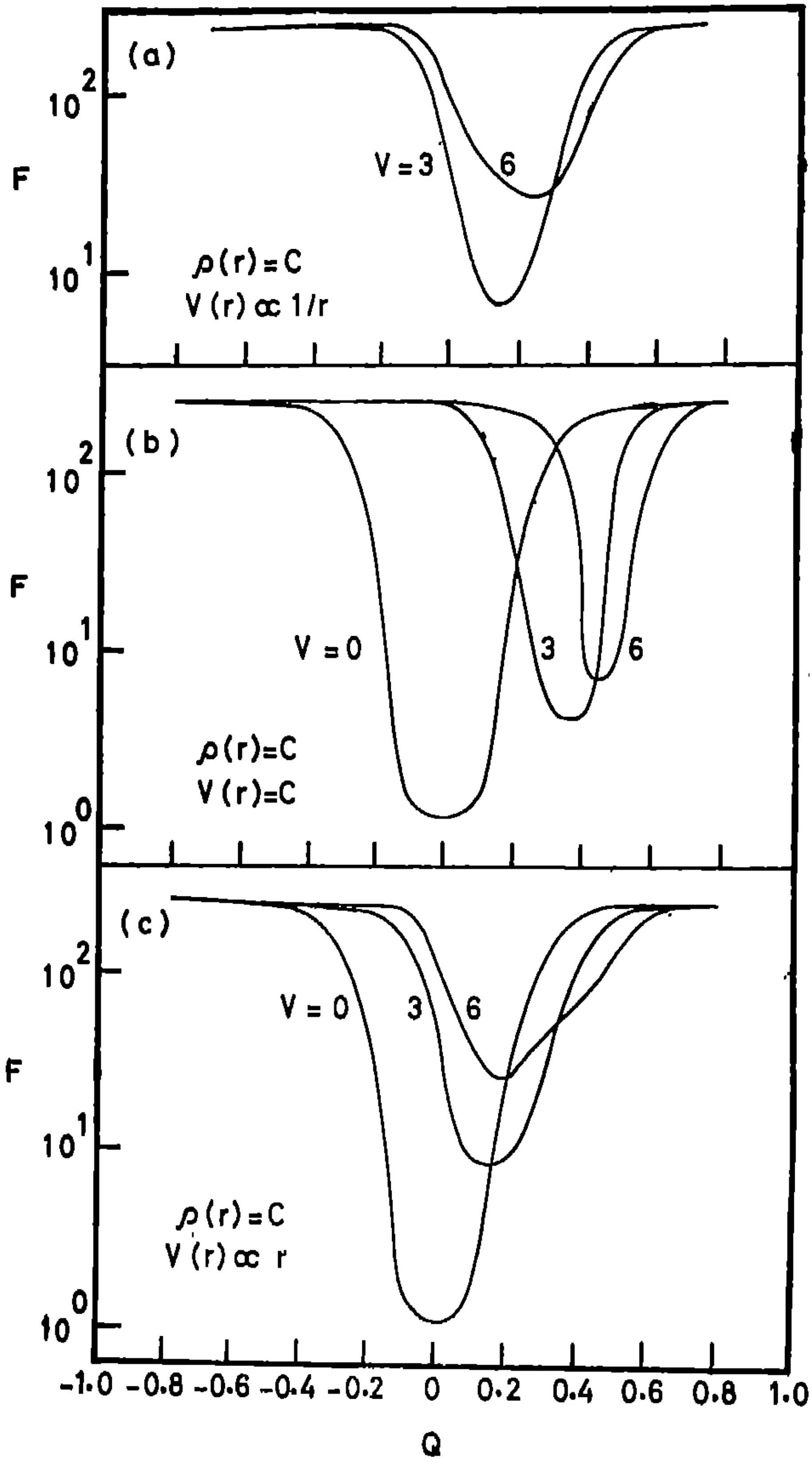

Fig. 2. Line profiles for ρ = const.
(a) $V \sim 1/r$,
(b) $V = c$
(c) $V \sim r$

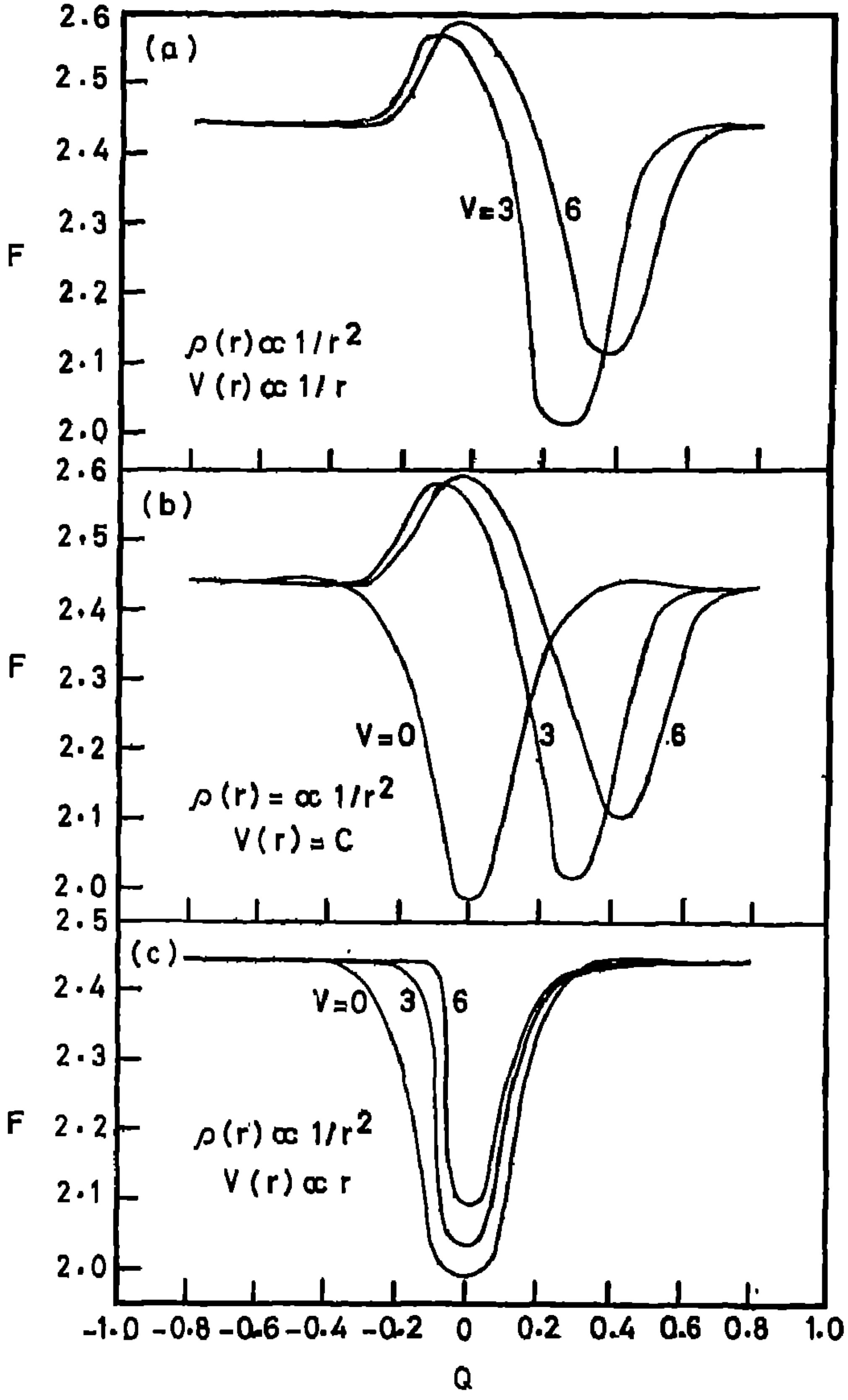

Fig. 3. Line profiles for $\rho \sim 1/r^2$
(a) $V \sim 1/r$
(b) $V = c$
(c) $V \sim r$

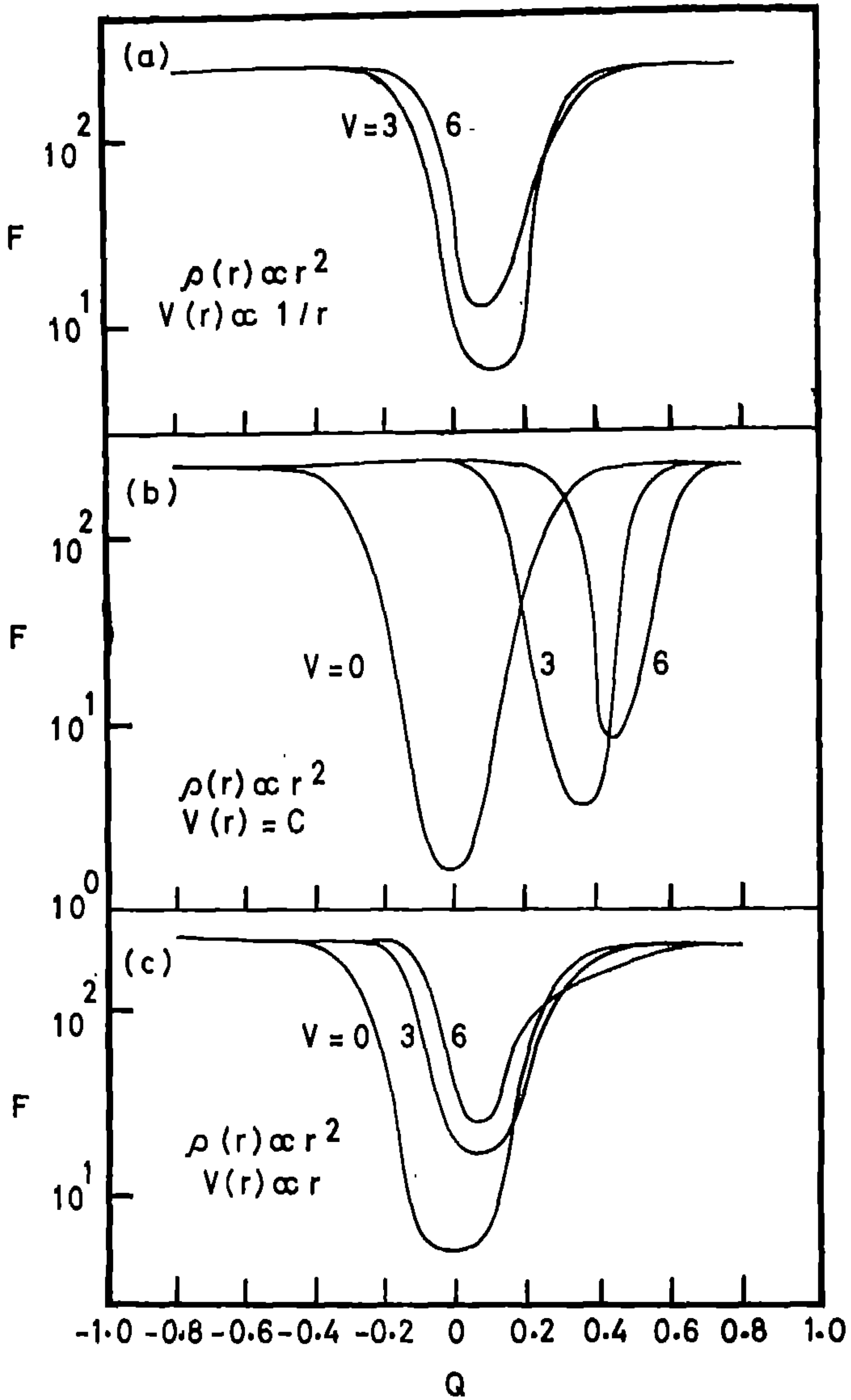

Fig. 4. Line profiles for $\rho \sim r^2$
(a) $V \sim 1/r$
(b) $V = o$
(c) $V \sim r$

where $\Delta\nu_D = \nu_0 V_T / C$. V_T is the thermal velocity. We measure all velocities in terms of mean thermal units (mtu) of velocity. The specific intensity $I(\tau_s)$ is used to calculate the flux F (x) given by

$$F(x) = \int_{r_{in}}^{r_{out}} I(x, p)\, p\, dp \tag{4}$$

where p is the perpendicular distance from the centre of the star to the ray along the line of sight.

We have considered a shell with inner radius 10^{11} cm and an outer radius 1.5×10^{11} cm. The maximum velocities that are treated here are 0, 3, and 6 mtu. The source function is assumed to be varying as $1/r^2$.

The results are presented in Figs. 1 to 4. In all the figures, we have given the flux profiles with $F = F(x)/F(x_{max})$ as ordinates and $Q = x/x_{max}$ as abscissae. The parameters in Fig. 1 (a) are such that the density ρ is changing as $1/r$ and the shell is expanding with constant velocities of 0, 3 and 6 mtu. The lines shift by almost the same number of mtu towards the blue side of the centre of the line. At the same time, there is considerable reduction in their equivalent widths. The shift in the centre of the line is directly due to the outward motion of the shell and in doing so, the density gets reduced and the number of line forming atoms are proportionately reduced. This contributes to the reduction in the equivalent width. The flux profiles in Fig. 1 (b) also exhibit the same variation as those given in Fig. 1 (a). In Figs. 2 (a, b and c), we have presented profiles for a constant density in a shell and $V \propto \frac{1}{r}$, c, and r respectively. When V is decreasing with r, the shift is not appreciable as shown by the profiles in Fig. 2 (a) ; when we introduce constant velocity the shift is almost proportional to the velocity in mtu as shown in Fig. 2 (b). Again with velocity gradients the shift of the centre of the line is quite appreciable but not proportional to the velocity (see Fig. 2c). Figures 3 (a, b and c) show the line profiles for $\rho \sim 1/r^2$, with $V \sim 1/r$, c and r respectively, where c is the constant velocity shown in the graphs. Similarly in Figures 4 (a, b and c) we have presented the line profiles for $\rho \sim r^2$. These two sets of profiles do show similarities with those given in Figs. 1 and 2. However, the profiles for the case with density decreasing as r^2, we obtain a small amount of red emission and blue absorption.

References

Peraiah, A. 1980, *J. Astrophys. Astr.*, 1, 17.
Peraiah, A. 1981, (in press).