Fig. 10. Density stratifications (color scale given in cm^{-3}) for model 1 at $t = 3 \times 10^3$ yrs, for an "hr" resolution (top panel); "mr" resolution (middle panel); and "lr" resolution (bottom panel). The axes are labeled in units of 10^{17} cm. The color figure can be viewed online.

Fig. 9. Same as Figure 8 but for models 5, 6, and 7 (top, middle and bottom respectively). The color figure can be viewed online.

the head of the AGBs bow shock. Such stripping, as well as the presence of Rayleigh-Taylor instabilities, produced turbulent clump structures that eventually moved down-stream to the tail of the bow shock. This mechanism, although on a smaller scale, is also present in our simulations (see Figures 3–5).

As we have mentioned earlier, the analytic model assumes that the material of the environment and the jet mix well in a thin shell. Such a situation is more easily met in radiative flows, characterized by a thin cooling layer. However, our simulations with parameters appropriate for the jet of Mira B are basically non-radiative. In order to check what happens with a more radiative flow we ran model 7. In this model, the reverse shock is indeed radiative ($d_c{}^r < R_0 \tan\Theta$) while the cooling distance of the forward shock is of the order of the cross section of the jet ($d_c{}^f \sim R_0 \tan\Theta$) (see Table 1). This model has a 10 times smaller computational domain, and therefore a 10 times larger resolution than the mr models (see § 3). In Figure 11, we overlap the thin layer analytic solution on top of the density and temperature stratifications obtained from model 7 at various times ($v_a = 100$ km s^{-1}, and $v_j = 40\,\mathrm{km\,s^{-1}}$). For this model the stagnation point is $R_0 = 3.48 \times 10^{16}$ cm, and the cooling distances are $d_c{}^r = 0.28\,R_0 \tan\Theta$, and $d_c{}^f = 1.31\,R_0 \tan\Theta$. As can be seen from the time-sequence, a steady state is not reached in this model. The model develops a turbulent structure which is not stable, and the distance from the jet source to the bow-shock oscillates around R_0.

5. DISCUSSION

Motivated by the recently observed bipolar jet from Mira (Meaburn et al. 2009), we study the interaction of a steady bi-conical outflow with a streaming environment. We use this scenario to perform 2D axisymmetrical simulations and an analytical model of such an interaction.

We have studied the particular case in which the bi-conical jets are aligned with the streaming environment (as shown in Figure 1). This of course is an idealization of the situation which could possibly be found in Mira, which is unlikely to have a perfect alignment between the outflow axis and the direction of Mira's motion. It allows, however, simple axisymmetrical analytical and numerical solutions which are useful as a first exploration of the more complex, less symmetric problem of the jet in Mira B.

The proposed "thin shell" analytical solution, based on the momentum equilibrium between the outflow material from the conical jet and the ambient medium, traces the shape of the shock (see