THE EFFECTS OF BOUNDARY CONDITIONS ON STELLAR EVOLUTION

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ABSTRACT. The effects of using different treatments of the surface boundary conditions are investigated in the context of the mass of He White Dwarfs. We find that since the White Dwarf progenitor is a star with a very extended atmosphere, the results are sensitive to the degree of accuracy implemented in the handling of the boundary conditions.

INTRODUCTION

The influence of mass-loss on the evolution of stars with extended atmospheres has become recognized in the past decade. Several authors investigated mass-loww effects during the RGB phase of the evolution and performed detailed stellar evolution computation.

Practically all mass-loss formulae are empiric and based on some fit to the observed data and expressed in terms which are combinations of L, R and M (the luminosity, radius and mass of the star). The expression given for this purpose by Reimers (1975) for example, is LR/M, which has the dimensions of $\dot{M}$.

The mass-loss rate is proportional to the photospheric radius. At this stage, the luminosity depends mainly on the core mass. The radius, on the other hand, depends on the structure of the very outer envelope. Small changes in the radius lead to small changes in the mass-loss rate. However, its effect is cumulative and the final result may be quite different.

We compare in this paper a simplified treatment with an elaborate and quite accurate method.

THE SURFACE BOUNDARY CONDITIONS

The fast changes in the thermodynamic quantities and the opacities near the stellar surface cause problems in stellar modeling because they demand the introduction of many thin mass shells, which in turn lead to prohibitively small time steps.

The simplest method to implement the boundary conditions is (Sweigart et al., 1974, Aizenman et al., 1969, and Demarque et al., 1968) to apply 'radiative surface conditions', namely the Eddington approximation

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in one form or another and write:

$$L = 4\pi\sigma \; a \; R^2 \; T_b^4 \qquad (1)$$

where a is some function of τ, the optical depth of the grey atmosphere and T_b is the temperature at the base of the atmosphere.

We compared this method (method 1), with a detailed integration of the grey stellar atmosphere equations proposed by Mihalas (1978). By this method (method 2) the boundary conditions are not imposed at $\tau=2/3$ (where their diffusion approximation breaks down), but at rather sufficiently inward mass. At this point the optical depth is much larger than unity. The range from $\tau=2/3$ down to the place where the boundary conditions is imposed is not included in the interior calculations, but integrated independently. The results of this integration are called here the boundary conditions for the evolution computation. The principles of the method are not new, however, the computational scheme, the detailed treatment of the equation of state and the opacities, and the mode of integration render a very flexible method that operates over a very wide range of stellar models and enveloped. A similar method was recently implemented by Van den Berg et al. (1983).

The results of the grey atmosphere calculations were compared with those obtained from model atmospheres and the agreement was excellent.

NUMERICAL RESULTS

Two sequences of evolutionary computation were carried out, for a star of initial mass of 0.7 $M_\odot$. One with the simplified radiative boundary conditions (method 1), where we used for a (in Eq. 1) $a=2./(1+3\tau/2)$, and the second with the detailed integration of the grey atmosphere (method 2). We find that the effective temperatures obtained by method 1 are systematically higher, and the model radii are respectively smaller than those obtained by method 2. In both methods Reimer's formula for mass loss rate was used. The larger radius produces a correspondingly larger mass-loss rate. While the gross feature of the evolution by both methods are essentially similar, the accumulated difference in mass-loss leads eventually to quite different WD mass, when the entire envelope is lost. The effective difference in mass-loss rate is about 10%, and this is also the order of the effect in the remnant mass.

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REFERENCES:

Aizenman, M., Demarque, P., Miller, R.H., 1969, Ap. J. 155, 973.
Demarque, P., Hartwick, F.D.A., Naylor, M.D.T., 1968, Ap. J. 154, 1143.
Iben, I., 1963, Ap. J. 138, 452.
Mihalas, D., 1978, in "Stellar Atmospheres", Freeman, San Francisco.
Sweigart, A.V., Mengel, J.G., Demarque, P., 1971, Ap. J. 164, 317.
Reimers, D., 1975, "Problems in Stellar Atmospheres and Envelopes", p.229, Ed. B. Baschek, W.H. Keggel, G. Tremaine, Springer, Berlin, Heidelberg, New York.
Weidman, V., Koester, D., 1983, Astron. Astrophys. 121, 77.
Van den Berg, D.A., Hartwick, F.D.A, Dawson, P., Alexander, D.R., 1983, Ap. J. 266, 747.