GRAIN SEDIMENTATION AND MAIN SEQUENCE EVOLUTION

John Lattanzio
Department of Mathematics
Monash University
Clayton, Victoria, Australia

ABSTRACT. Under the assumption that grain sedimentation can lead to an enhancement of heavy elements in the central regions of proto-stars, we present the evolution of stellar models with metal-rich cores. The resulting isochrones can explain the "double-gap" clusters NGC2420 and NGC2506, without destroying the agreement for other clusters.

Previous evolutionary calculations have generally assumed a homogeneous abundance distribution in initial main sequence models. This assumption may not be valid. If theories of grain sedimentation are correct then we may expect an enhancement of grain material in the core of pre-stellar clouds (see Horedt 1973, Prentice 1976, Krautschneider 1977, Flannery and Krook 1978, etc.). Recent collapse calculations have cast doubt upon the ability of the Hayashi phase to homogenize the star (Winkler and Newman 1980, Stahler et.al. 1980a,b). Thus any abundance inhomogeneity caused by grain sedimentation may survive to the ZAMS.

In this study we have followed the evolution of models of various masses. The models have an envelope of $(X,Z) = (0.70,0.02)$ and an inner core of 2% by mass with $Z = 0.10$ and the same X/Y as the envelope. Convective dilution of the core with the lower metallicity surrounds has been followed in detail (see Lattanzio 1983), with opacities taken from the Los Alamos code (Huebner et.al., 1977).

During contraction to the main sequence, CN cycling leads to a convective core covering the inner 20-30% by mass, which reduces the core $Z \simeq 0.025$-0.03, a value maintained throughout subsequent evolution. Details of the evolutionary calculations may be found in Lattanzio (1983), but the main effect is an increase in the time of core H burning. For $M \gtrsim 1.4$ this is due to a hydrostatic readjustment associated with the increased CNO abundances in the core. For lower masses the cause is the larger convective core, due to the higher opacity of the metal-rich material. Figure 1 shows that the resulting H burning lifetimes are no longer monotonic. There are two

A. Maeder and A. Renzini (eds.), Observational Tests of the Stellar Evolution Theory, 109–112.

https://doi.org/10.1017/S0074180900030655 Published online by Cambridge University Press

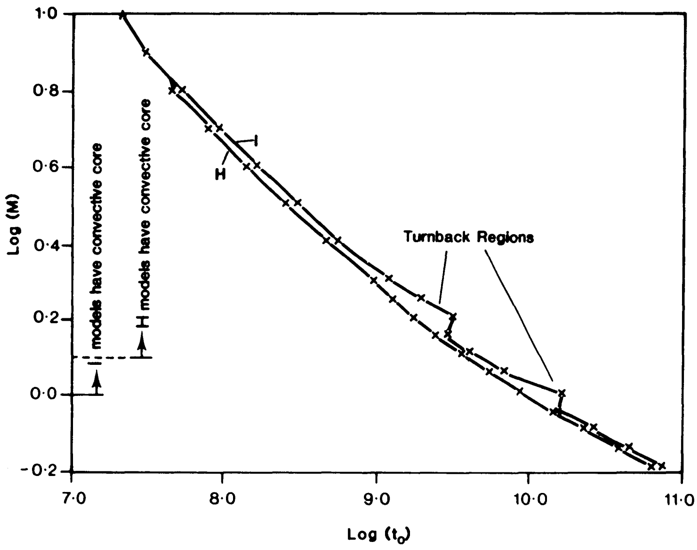

Figure 1. Plot of time of core H exhaustion (t_0) against mass. Crosses show results for both homogeneous (H) and inhomogeneous (I) models.

"turn-back" regions, and the important question is the nature of the isochrones for ages corresponding to these regions. A line of constant time will, in the turn-back region, cross the H exhaustion curve at three places. There will be two regions of the H exhaustion curve that lie to the right of the time line. These regions represent stars burning H in their core, and will thus heavily populate the isochrone. Regions to the left of the time line represent stars having just exhausted core H, and thus will be sparse in stars when plotted in the HR diagram. As there are two such regions we would expect two gaps to appear in the isochrone.

An isochrone for log(age) = 9.45, in the turn-back region, is shown in Figure 2. We do indeed find two gaps in the resultant distribution. Observations of NGC2420 (McClure et. al. 1978) and NGC2506 (McClure et. al. 1981) also show two gaps. These two clusters are metal deficient relative to the models presented. Using the expressions of Patenaude (1978) we can estimate the age at which we would expect two gaps to occur in clusters with the metallicity of NGC2420 and NGC2506. We find log(age) = 9.67, which agrees will with previous age estimates.

Figure 1 also explains the scarcity of "double gap" clusters, as only those with ages in the turn-back region will show two gaps. Finally, a comparison between the gaps in observed colour-magnitude diagrams and in theoretical isochrones has been performed (see Lattanzio 1983) in the manner outlined by Maeder (1974). The discrepancies found by Maeder are found to decrease when recent opacity tables are used, and may further decrease for initially inhomogeneous models.

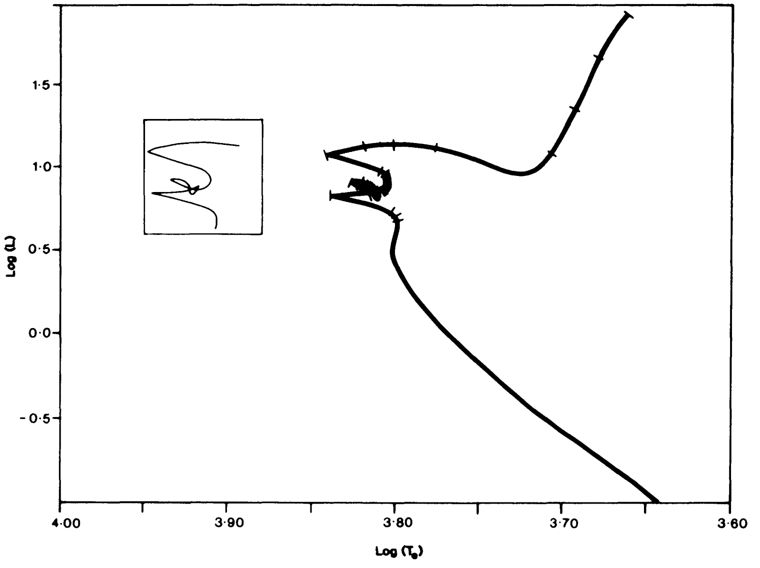

Figure 2. Isochrone for inhomogeneous models at log(age) = 9.45. The thick portion of the line represents a region of high star density. Ticks are placed every 0.005 $M_\odot$ in the region of the gaps. This region is repeated in the inset.

Thanks to the following people for their assistance: A.J.R. Prentice, R.A. Gingold, P.R. Wood, W.F. Huebner and M.F. Argo. Thanks also go to the Ian Potter Foundation and the IAU for support.

References

Flannery, B.P. and Krook, M., 1978, *Astrophys. J.*, *223* p.447.

Horedt, Gp., 1973, *Mon. Not. R. astr. Soc.*, *163*, p.285.

Huebner, W.F., Merts, A.L., Magee, N.H., Jr. and Argo, M.F., 1977. *Astrophysical Opacity Library*, Los Alamos Scientific Laboratory report LA-6760-M.

Krautschneider, M.J., 1977, *Astr, Astrophys.* *57*, p.291.

Lattanzio, J.C., 1983, *Mon. Not. R. Astr. Soc.*, submitted.

Maeder, A., 1974, *Astr. Astrophys.*, *32*, p.177.

McClure, R.D., Newell, E.B. and Barnes, J.V., 1978, *Publs. Astr. Soc. Pacif.*, *90*, p.170.

McClure, R.D., Twarog, B.A. and Forrester, W.T., 1981, *Astrophys. J.*, *243*, p.841.

Patenaude, M., 1978, *Astr. Astrophys.*, *66*, p.225.

Prentice, A.J.R., 1976, *Astr. Astrophys.*, *50*, p.59.

Stahler, S.W., Shu, F.H. and Taam, R.E., 1980a, *Astrophys. J.*, *241*, p.637.

Stahler, S.W., Shu, F.H. and Taam, R.E., 1980b, *Astrophys. J.*, *242*, p.226.

Winkler, K.-H. A. and Newman, M.J., 1980, *Astrophys. J.*, *238*, p.311.

DISCUSSION

R. Cayrel: Have you computed the actual sedimentation of grains during the pre-main sequence stage?

Lattanzio: Those calculations have been performed by Krautschneider (1977), Flannery and Krook (1978) and others. My calculations begin where theirs finish.

Cox: Did you include the pre-main sequence burning of deuterium and He^3? They could lead to convection and mixing.

Lattanzio: No, but the mixing produced by burning deuterium and He^3 will be much less than that resulting from CN equilibration, which was included.

https://doi.org/10.1017/S0074180900030655 Published online by Cambridge University Press