ON THE TERMINATION OF ASYMPTOTIC GIANT BRANCH EVOLUTION

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ABSTRACT

The evolution of planetary nebula (PN) nuclei has been studied at masses of 0.60, 0.70 and 0.76 $M_\odot$, and for the ejection of the PN at various phases of a helium shell flash cycle. The evolution at high luminosities takes longer for nuclei resulting from PN ejection at shell flash peak than it does for those resulting from ejection in the interflash phase. Comparison of our calculations with various observational results does not allow us to reach any definite conclusions regarding the phase of the shell flash cycle at which PN ejection occurs.

1. INTRODUCTION

The means by which asymptotic giant branch (AGB) evolution is terminated for low mass ($M \lesssim 5M_\odot$) stars is generally assumed to be PN ejection, but the nature and duration of the ejection process are at present very speculative. There is a widely held belief that stars such as the OH/IR stars, which have high mass loss rates, are in the phase of PN ejection, but the cause of the high $\dot{M}$ is not known. One suggested cause is a switch in the mode of pulsation of a Mira variable from first overtone to fundamental, the large amplitude of the latter mode driving the high mass loss rate (Wood 1974; Tuchman, Sack and Barkat 1979). Such a mode switch would be expected to occur when the luminosity of the star first exceeds some critical value. Since any specific AGB luminosity is first attained during the surface luminosity rise associated with a helium shell flash (e.g., Wood and Zarro 1981), PN ejection by the above process should be initiated at a helium shell flash peak rather than in the quiescent interflash phase of lower surface luminosity. The purpose of the present study is to examine the evolution of PN nuclei in two cases, (i) when the ejection occurs at a helium shell flash, and (ii) when it occurs midway between flashes. A comparison with observational data for PN nuclei might then distinguish between the two possibilities.

A. Maeder and A. Renzini (eds.), Observational Tests of the Stellar Evolution Theory, 179–182.

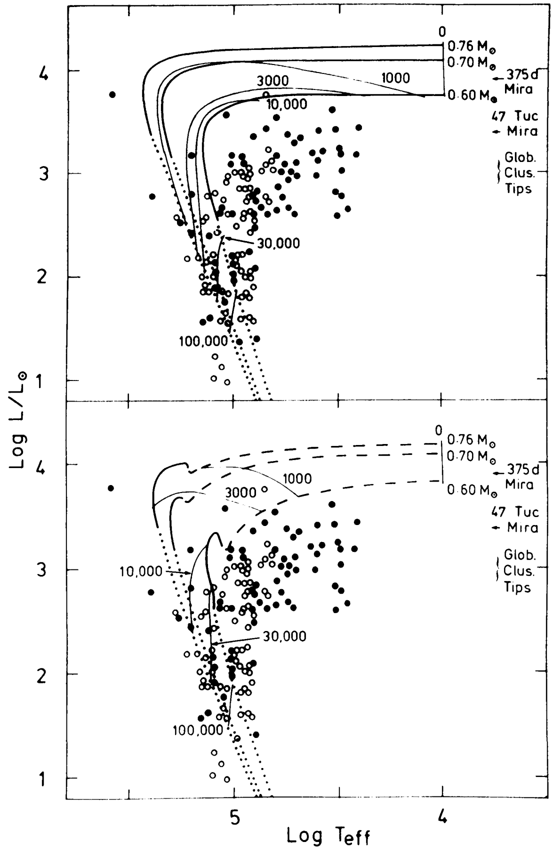

Fig. 1 Evolutionary tracks of PN nuclei of the masses shown when PN ejection occurs midway between helium shell flashes (top), or at the peak of a shell flash (bottom). Hydrogen burning phases are shown as thick lines, helium burning phases as broken lines, and gravitational contraction phases as dotted lines. The thin lines display equal intervals of time since log T_{eff}=4.0. The observational PN positions of Pottasch (1983) (dots) and of Kaler (1983) (open circles) are also shown, as are the luminosities of globular cluster red giant tips, 47 Tuc Miras and typical Galactic disc Miras.

2. RESULTS

Fig. 1 shows evolutionary tracks for PN nuclei of mass 0.6, 0.7 and 0.76 $M_{\odot}$ for both the ejection possibilities under consideration. In both series of tracks, mass loss at the rate of 3×10^{-5} $M_{\odot}$ yr^{-1} was applied until the star's effective temperature had increased to log T_{eff} = 3.8; thereafter $\dot{M}$ was set to zero. The main effect of ejection at a helium flash is to prolong the evolution at high luminosities, particularly for the higher mass cores. A similar result has been noted by Iben (1983).

3. DISCUSSION

Also shown on Fig. 1 are the observationally derived luminosities and T_{eff} values for PN nuclei from Pottasch (1983) and Kaler (1983); in some cases the Kaler points represent only limiting positions for the nuclei. These results, particularly those of Pottasch, indicate that the bulk of PN nuclei should have masses $\lesssim 0.6\ M_\odot$ based on their positions relative to the evolutionary tracks. In fact the bulk of these observations indicate evolution away from the AGB at luminosities less than those characteristic of globular cluster giant branch tips (in particular the luminosities of the 47 Tuc Miras) and much less than those of a typical Mira variable with P=375 days. Since the bulk of the PN near the Sun come from stars more massive than stars presently on the globular cluster giant branches, and probably come from stars similar to a typical Mira variable, it is difficult to see how any meaningful conclusions can be drawn at present from a comparison of observation and theory using the HR diagram plane alone. Indeed, we would suggest that the present observational estimates of luminosities of PN Nuclei are too low by an average factor of ~3. An alternative approach is to introduce evolutionary <u>timescales</u> into the comparison by means of the (M_V, time) diagram of Schönburner (1981), and we have experimented with such comparisons using our theoretical results and published observational data. In making such a comparison it has usually been assumed that the zero point of the theoretical timescale can be set at some arbitrarily chosen T_{eff} value, but it seems to us that this is of dubious validity in view of our ignorance of the duration, mass loss rate, etc., of the PN ejection process itself. Once again we have been forced to the conclusion that the (M_V, time) diagram also yields little information on the phase of the flash cycle at which ejection occurs. Full details will be published in Faulkner and Wood (1983, in preparation).

REFERENCES

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DISCUSSION

<u>Cox</u>: In constructing models for pulsation calculations, we found that there is frequently a convective shell even at 10^5 K. This is due to the high stellar material opacity. Do your models have surface convection?

<u>Wood</u>: Not in the high temperature parts of the evolutionary tracks.

Weidemann: These questions have been extensively discussed at the Erice and London meeting by Schönberner and myself, with the result that the observational evidence, especially on the M_V distribution, favours evolution by quick hydrogen- rather than helium-burning. The production of DB white dwarfs by phasing of the shell flashes as investigated e.g. by Iben is also not convincing since the fraction of DB stars is actually smaller (10-12 %) than predicted.

Schönberner: Tomorrow I shall present an HR diagram for central stars which gives better agreement between theory and observations. Now my question: What are the mass loss rates used to get rid of the envelopes?

Wood: $\dot{M} = 1\ M_\odot\ yr^{-1}$ down to an envelope mass of $0.01\ M_\odot$. Then $\dot{M} = 10^{-5}\ M_\odot\ yr^{-1}$ until log T_{eff} had increased to 3.8. From here on, various mass loss rates were used, $\dot{M} = 0$ being the ones discussed in detail here.