THE INFLUENCE OF MASS LOSS BY STELLAR WIND ON THE EVOLUTION OF MASSIVE HELIUM BURNING STARS

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Helium burning stars with masses between 10 $M_\odot$ and 40 $M_\odot$ are evolved up to core helium exhaustion including mass loss by stellar wind at rates between 10^{-5} $M_\odot$/yr and 10^{-4} $M_\odot$/yr appropriate for WR stars. Different $\dot{M}$ formalisms were used. It should however be noted that the results presented here are only marginally dependent on this formalism. The initial models contain a small hydrogen shell. The atmospherical hydrogen abundance X_{atm} = 0.2-0.3. These models correspond to primary remnants (with hydrogen ZAMS masses between 30 $M_\odot$ and 100 $M_\odot$) after a case B mode of mass transfer in close binaries, or to stars after a red giant phase of huge mass loss comparable to late case B remnants after Roche lobe overflow. Evolutionary details can be found elsewhere (Vanbeveren, D., Ph.D. Thesis, Vrije Universiteit Brussel) and will not be discussed here. I want to focus on two applications

1. Total mass lost during He burning based on the WN/WC ratio

Due to stellar wind mass loss, the remaining H layers are stripped off and eventually layers which have been in the convective He burning core may appear at the surface. These layers are carbon enhanced due to 3α-processing. It is assumed that from this moment on, the star will be classified as a WC star. Prior to this the star is assumed to be a WN type WR star. By comparing the evolutionary lifetimes of the different stages and the observed WN/WC number ratio it is possible to estimate the total mass lost from the star during the WR phase. If on the average, $\dot{M}$ during the WC phase equals $\dot{M}$ during the WN phase (corresponding to the observations of Barlow, Smith and Willis, this symposium) it follows that for the Galaxy the helium stars should lose on the average half of their mass during the WR phase. For the SMC where WN/WC $\simeq$ 7, it turns out that the He stars should lose about 1/3 of their mass. If the WR phase lasts for the whole core helium burning phase and taking into account that a lower $\dot{M}$ also shortens the He burning lifetime, it follows that on the average SMC Wolf-Rayet stars should have an $\dot{M}$ which is ~30% lower than galactic WR stars. In order

C. Chiosi and R. Stalio (eds.), Effects of Mass Loss on Stellar Evolution, 275–278.

https://doi.org/10.1017/S0252921100094872 Published online by Cambridge University Press

to have a WN/WC ratio ~1 holding for the Galaxy one needs an average $\dot{M}$ equal to ~3.5 10^{-5} $M_\odot$/yr (with a spread of a factor 2) which is very close to the observed $\dot{M}$ values for WR stars given by Barlow, Smith and Willis.
Important is also the fact that once carbon enhanced layers appear at the surface, C_{atm} very soon reaches values larger than 0.1 (by weight). One should thus expect that, with $\dot{M}$ values as large as discussed above, many WC type stars have atmospherical carbon abundances larger than 0.1. Moreover, if indeed the WN phase corresponds to stationary He burning of stars with $X_{atm} \leq 0.2$ and if $\dot{M}$ is more or less constant during the WR phase, one might expect from a theoretical point of view that ~40% to 50% of the WN stars contain hydrogen in their surface layers. The presence of H in the spectrum of a WN star (of any subclass) is therefore a doubtful criterion to prove the binary status of WN stars.

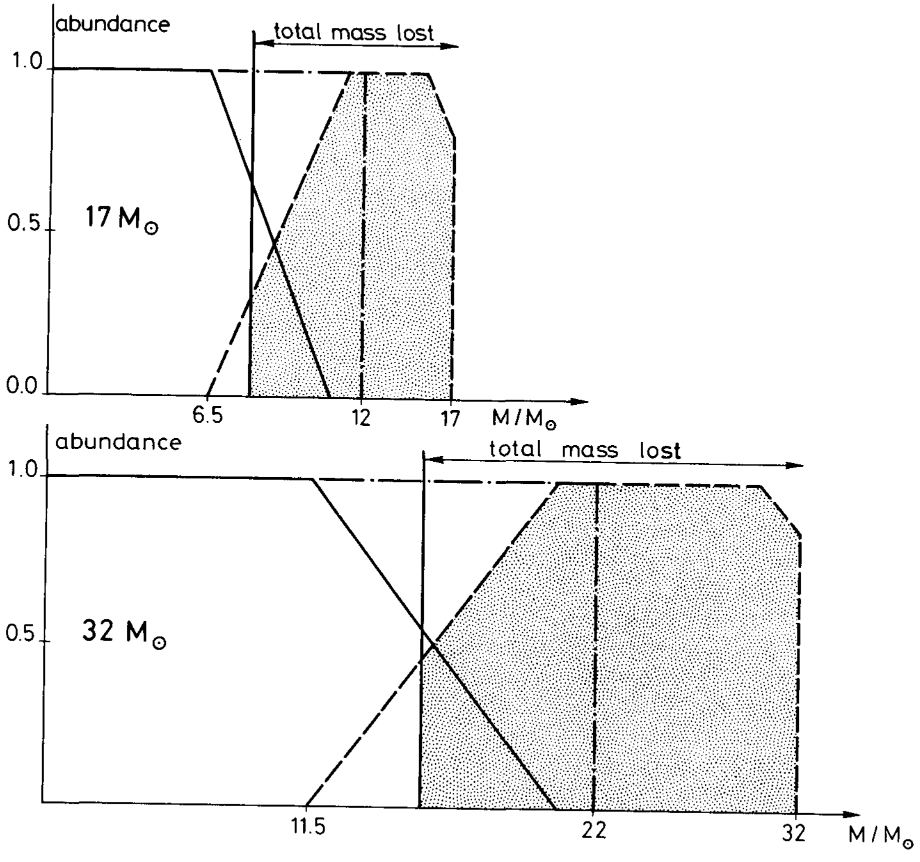

Figure 1. Helium and metal abundance profiles for end core He burning models (Z: full lines; He: dashed lines). The dashed dotted line gives the Z profile without mass loss by stellar wind.

2. The difference in chemical yields due to stellar wind during He-burning

The fact that a helium star with mass between 10 $M_\odot$ and 40 $M_\odot$ can lose on the average half of its mass has two important implications for chemical yield computations :

a. a large mass fraction of almost pure helium is expelled prior to the supernova explosions.

b. the mass fraction of the CO core is considerably lower compared to the case where the mass is constant. In the case of the Galaxy M_{CO} is a factor 2 smaller.

These two points are illustrated for a 17 $M_\odot$ and a 32 $M_\odot$ helium star in Figure 1. For these two stars the helium and metal profiles are shown at the end of core helium burning. They are compared to profiles without stellar wind mass loss.

DISCUSSION

LAMERS: The mass lost by the WR stars is only a very small fraction of the total mass lost by all stars, especially by the very late type stars such as Mira variables (which may have large CNO abundances). Do you think that the enrichment of the overall ISM by mass from WR stars is significant?

VANBEVEREN: One has to take into account that during the WR phase almost pure helium is lost by stellar wind. This means that although the mass lost by a WR star may be small compared to the total mass lost by all stars, the mass fractions of He lost by the WR star may be considerable. In order to get a more certain answer one has to go through chemical yield calculations and this has not been done yet for this process.

SERRANO: With respect to Lamers question, observations indicate that $\Delta Y/\Delta Z \approx 3$, from intermediate mass stars and a conventional 15% of massive stars you already get this value. So you cannot increase very much the production without conflicting with observations.

VANBEVEREN: Before I answer this question I will go through the chemical yield calculations and see how large is the effect.

CHIOSI: Is it possible to apply this kind of analysis also to single stars?

https://doi.org/10.1017/S0252921100094872 Published online by Cambridge University Press

VANBEVEREN: If single stars are reaching a stage where $X_{atm} = 0.2 - 0.3$ at the beginning of He burning after going through a stellar wind mass loss phase during core H burning and in the red giant phase, then these results can certainly be applied to single stars. If $X_{atm} = 0.2 - 0.3$ appears only in the middle of core He burning, then you have to increase the $\dot{M}$ in order to find an analogous WN/WC ratio; the total mass that must be removed however should be of the same order as proposed in this analysis.

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