Super-AGB stars
bridging the divide between low-mass and high-mass stars
Carolyne Doherty1, Pilar Gil-Pons2, John Lattanzio3, Lionel Siess3

Abstract & Introduction

Super asymptotic giant branch (super-AGB) stars are in the mass range ~6.5-10 M_	ext{☉} and are characterised by off-centre carbon ignition prior to a thermally pulsing AGB phase which can consist from 10s to even 1000s of thermal pulses (TPs). Their fates are quite uncertain and depend primarily on the competition between the core growth and mass-loss rates. If the stellar envelope is removed prior to the core reaching the mass for electron captures in the core ~1.375 M_	ext{☉} (Nomoto 1984), an ONe white dwarf will remain, otherwise the star will undergo a carbon-core capture supernova leaving behind a neutron star. We briefly describe the factors which influence these different fates, determine their relative fractions and provide mass boundaries.

Pre/Post second dredge-up core mass

After core H, He and C burning, the core mass of the star is reduced due to second dredge-up (2DU) – see Fig 1. This post 2DU core mass is the core mass at the start of the AGB phase, with the final fate of the star determined by the subsequent competition between the growth of the core and mass loss from the stellar envelope.

Rudimentary observations in luminous O-rich AGB stars (e.g. Garcia-Hernandez et al. 2006) are strong evidence for the occurrence of third dredge up (3DU) in the massive AGB and super-AGB stars. In Fig 3, we show the 3DU efficiency λ* as a function of core mass. We examine the important boundaries such as M_{	ext{EC-SN}} (the minimum mass for carbon ignition), M_{\text{mass limit for electron captures in the core}} and mass loss during the TP-AGB phase.

Comparisons

We compare our predictions to observationally derived IFMRs. Large spread in results with maximum WD mass ~7.6 - 10^3 M_	ext{☉}.

Conclusion

We have computed the full thermally pulsing evolution of a large grid of massive AGB and super-AGB stars over a range of metallicities 2\text{\textordmasculine}0-2.0 \text{\textordmasculine}001. Our models with moderate mass loss and efficient 3DU increase their core mass by only ~0.01-0.03 M_	ext{☉} during the TP- (S)AGB phase. Due to this, the majority of our super-AGB star models and their lives as ONe white dwarfs.

Comparison of Observations and other model results

Large variation in model predictions cf. Siess 2010 and Ventura et al. 2013. This is primarily due to differences in treatment of convective boundaries during core He burning.

References

References

Doherty et al. 2010, MNRAS 402, 1470
doherty et al. 2015, MNRAS 446, 2599

Method / Model Descriptions

The evolution of massive AGB and super-AGB stars was calculated using the Monash stellar evolution program (MONSTAR). This program is a 1D hydrostatic evolution program which includes 7 species, H, He, C, O, Ne and Z. For a current review of MONSTAR see Campbell and Lattanzio (2008) & Doherty et al 2010 & 2015. A large grid of models were computed with initial masses ~5-10 M_	ext{☉} over 5 metallicities in the range Z=0.02-0.0001. Our models were run from the zero age main sequence to near the end of the TP-AGB phase. We examine the important boundaries such as M_{\text{EC-SN}} (the minimum mass for carbon ignition), M_{\text{mass limit for electron captures in the core}} and M_{\text{mass limit for electron captures in the core}}.

The mass-loss rate for super- & massive AGB stars is very uncertain, e.g. in Fig 2 we see large variation using different commonly used mass loss expressions. We examine the important boundaries such as M_{\text{EC-SN}} (the minimum mass for carbon ignition), M_{\text{mass limit for electron captures in the core}} and M_{\text{mass limit for electron captures in the core}}.

Due to the fast mass-loss and slow core growth rates our models grew by at most 0.03 M_	ext{☉} during the entire (S)AGB phase.