The Art of Modelling Stars in the 21st Century
Proceedings IAU Symposium No. 252, 2008
L. Deng& K.L. Chan, eds.

doi:10.1017/S1743921308022965

"Hot Helium Flashers" – The Road to Extreme Horizontal Branch Stars

O. Yaron[1], A. Kovetz[1,2] and D. Prialnik[1]

[1]Department of Geophysics and Planetary Sciences, Sackler Faculty of Exact Sciences
[2]School of Physics & Astronomy, Sackler Faculty of Exact Sciences, Tel Aviv University, Israel

Abstract. Observational and theoretical investigations, performed especially over the last two decades, have strongly attributed the far-UV upturn phenomenon to low-mass, small-envelope, He-burning stars in Extreme Horizontal Branch (EHB) and subsequent evolutionary phases.

Using our new stellar evolution code – a code that follows through complete evolutionary tracks, Pre-MS to cooling WD – without any interruption or intervention, we are able to produce a wide array of EHB stars, lying at bluer ($T_{eff} \geqslant 20,000$ K) and less luminous positions on HRD, and also closely examine their post-HB evolution until the final cooling as White Dwarfs.

HB morphology is a complex multiple parameter problem. Two leading players, which seem to possess the ability to affect considerably positions of HB, are those of: 1.Helium abundance, and 2.mass-loss efficiency on the first giant branch. We focus here on the latter; thus, EHB stars are produced in our calculations by increasing the mass-loss rate on the RGB, to a state where prior to reaching core He flash conditions, only a very small H-rich envelope remains. The core flash takes place at hotter positions on the HRD, sometimes while already descending on the WD cooling curve. We show preliminary results for a range of initial masses ($M_{ZAMS} = 0.8 - 1.1\ M_{\odot}$) and for metallicities covering both populations I and II ($Z = 0.01 - 0.001$). The [M,Z] combinations have been chosen such that the masses would be above and close to typical MS turnoff masses (e.g. the estimation of $M_{TO} \simeq 0.85$ for NGC 2808), and also so that the ages at HB are of order of 10 ± 5 Gyr.

Keywords. stars: evolution, stars: horizontal-branch, stars: mass loss

1. Numerical Computations

Our new evolution code (Kovetz *et al.* 2008, in prep.) is capable of following through complete evolutionary calculations for a wide range of masses and metallicities. It incorporates up-to-date input physics (EOS, opacities, mass-loss recipes etc...), and, following Eggleton (1971), simultaneously solves the equations of structure and composition with a mass-distribution function, implementing an adaptive mesh.

Mass-loss on the RGB is according to the original Reimers (1975), whereas for post core He-burning stage we have chosen to use one of Bloecker (1995) expressions.

We executed a sequence of runs for each [M,Z] combination; adopting within each sequence increasing values of the mass-loss efficiency parameter – η_{Reim}. In all runs a core He-flash took place, whether normal – at tip of RGB, or delayed – at hotter positions; the end-state of all calculations being a cooling WD.

2. Results

In the left panels of Fig. 1 we show a sequence of evolutionary tracks for a Pop. II $M = 0.9\ M_{\odot}$ model with increasing mass-loss rates. For the lower mass-loss rates, a normal core He flash occurs at the tip of the RGB, whereas for the higher rates – thus smaller M_{env} by the onset of the core flash – we shift to obtaining "Post-Tip-Flashers",

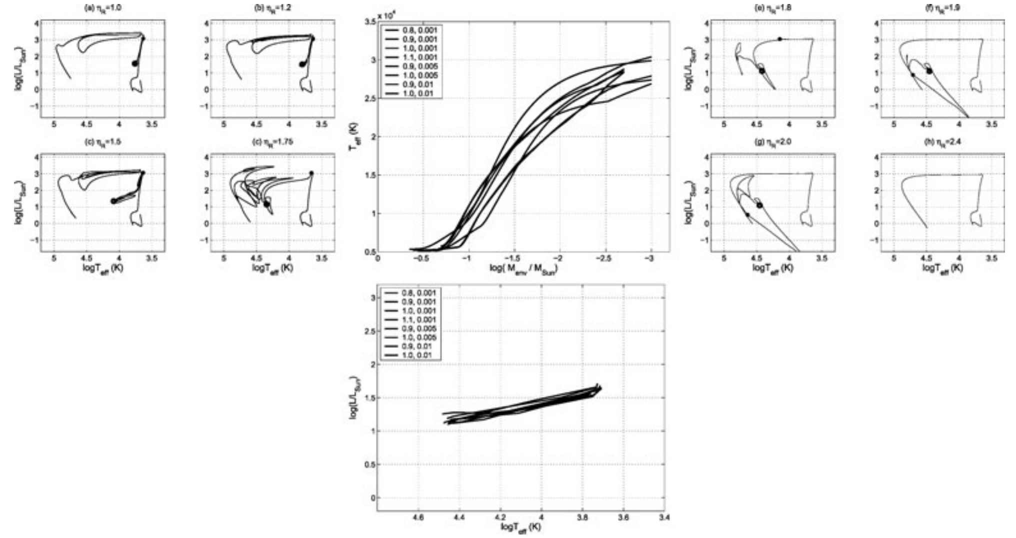

Figure 1. Left: Complete tracks on HRD – $M = 0.90\ M_{\odot}$, $Z = 0.001$, $Y = 0.24$ – for increasing mass-loss rates ($\eta_{Reim} = 1.0 - 2.4$). Red dots mark the onset of core He flash; blue circles mark HB positions. Age at HB is 10.1 Gyr. Bluest HB, obtained in panel (g), is at $T_{eff} = 2.85 \times 10^4$ K. Panels (d),(e) are "Post-Tip-Flashers", (f),(g) are clear "WD-Flashers"; panel (h) – no He-ignition, resulting in a He-WD. Top right: T_{eff} at HB vs. envelope mass M_{env} (at onset of core-He-flash), for the examined [M,Z] combinations (see legend). Bottom right: HB positions on HRD for the [M,Z] combinations, for increasing mass-loss rates, right to left.

followed by "WD-Flashers", till reaching a situation for which He-ignition does not take place. As apparent, the bluest EHB stars do not evolve to normal Asymptotic Giant Branch, but rather immediately to hotter (UV-bright) positions (e.g. "AGB-manque"). In some cases (and dependent on the invoked post-HB mass-loss recipe), an extended set of multiple last shell flashes may take place, before settling on the WD cooling curve.

With close agreement to former studies – e.g. Cruz *et al.* (1996), Brown *et al.* (2001), and based on our yet preliminary set of results, we can conclude the following:

– For both Populations and the examined masses, it is found possible to produce EHB stars by means of increasing the amount of mass that is lost during RGB.

– A transition from normal to delayed core flash occurs for M_{env} around $1 - 2 \times 10^{-2}\ M_{\odot}$.

– As apparent from the top right panel of the figure, envelope masses (at onset of core-flash) of below 0.01 $M_{\odot}$, all yield T_{eff} in excess of $20,000$ K while on HB. (A max. T_{eff} of $\sim 30,000$ K was obtained for Pop. II with M_{env} of 0.001 $M_{\odot}$.)

– For a given initial mass; the lower the metallicity – Z, the higher the mass-loss rate required for obtaining significantly delayed core He flash.

– HB positions of all [M,Z] sequences form a tightly packed thick band, covering the extent of HB from T_{eff} of $\sim 5,000$ to over $\sim 30,000$ K.

References

Bloecker, T. 1995 *A&A* 297, 727
Brown, T. M., Sweigart, A. V., Lanz, T., Landsman, W. B., & Hubeny, I. 2001 *Apj* 562, 368
D'Cruz, N. L., Dorman, B., Rood, R. T., & O'Connell, R. W. 1996 *Apj* 466, 359
Eggleton, P. P. 1971 *MNRAS* 151, 351
Reimers, D. 1975 *MSRSL* 8, 369

https://doi.org/10.1017/S1743921308022965 Published online by Cambridge University Press