Evolutionary Tracks of Low-Mass He-core White Dwarf Stars with Thin H Envelope

Extremely low-mass white dwarf (ELM WD; $M_\star \lesssim 0.18 - 0.20 M_\odot$) stars are supossed to evolve very slowly due to residual H burning, and consequently reach, at most, $T_{\rm eff} \sim 7000K$. However, according to Calcaferro et al. (2018), if these stars were formed with thin H envelope, the resulting cooling times would become very short, making it possible to observe them at very low $T_{\rm eff}$. In this sense, a small reduction in the H envelope, by a factor of two to three, is enough to turn off the H burning, thus leading to a fast evolution.

Here, a sample with four of our computed sequences with an H envelope in the order of 10^{-5}, are found. The sequences are named after the value of the stellar mass (in solar unit), followed by the value of the logarithm of the corresponding H-envelope thickness ($\log(M_{\rm H}/M_\star)$).

For each file it is listed from left to right:

Log(L): logarithm of the surface luminosity in solar unit;
Log(Teff): logarithm of the effective temperature (K);
T_c: logarithm of the central temperature (K) (million degree);
ro_c: logarithm of the central density (gr/cm3);
Hc: central H abundance;
He: central He abundance;
Con_s: outer convection zone;
Con_c: inner convection zone;
Log(tcool/yr): logarithm of the cooling time;
Masa: Stellar mass in solar unit;
...
Log(Lpp): logarithm of luminosity (in solar unit) due to proton-proton burning;
Log(Lcno): logarithm of luminosity (in solar unit) due to CNO burning;
Log(LHe): logarithm of luminosity (in solar unit) due to helium burning;
....
Log(Lnu): logarithm of luminosity (in solar unit) due to neutrino losses;
Log(MHtot): logarithm of the hydrogen content in solar mass;
....
Log(grav): logarithm of surface gravity (cm/s2);
R/R_{sun}: Stellar radius in solar unit.

In order to obtain the age of the WD, from the formation of the progenitor (ZAMS), it is necessary to add to the tabulated tcool, the age of the progenitor. The mass of the progenitor that can lead to the formation of an ELM WD, consistently with the age of the galactic disk (assumming $\sim$ 13.7 Gyr), varies from 1 to 1.5 $M_{\odot}$ if Z=0.01, in which case the age of the progenitor would be $\sim$ 8.6 Gyr and $\sim$ 1.8 Gyr, respectively (if Z=0.001, the mass of the progenitor can be lower, varying from, roughly, 0.9 to 1.5 $M_{\odot}$, being the corresponding ages of the progenitors $\sim$ 8.2 Gyr and $\sim$ 1.3 Gyr, respectively). These values are extracted from BaSTI, Ver. 5.0.1.

In the next figure, some evolutionary sequences with canonical (Althaus et al. (2013)) and thin H envelope, are depicted in the log(g)-$T_{\rm eff}$ plane (see Calcaferro et al. (2018) for details).

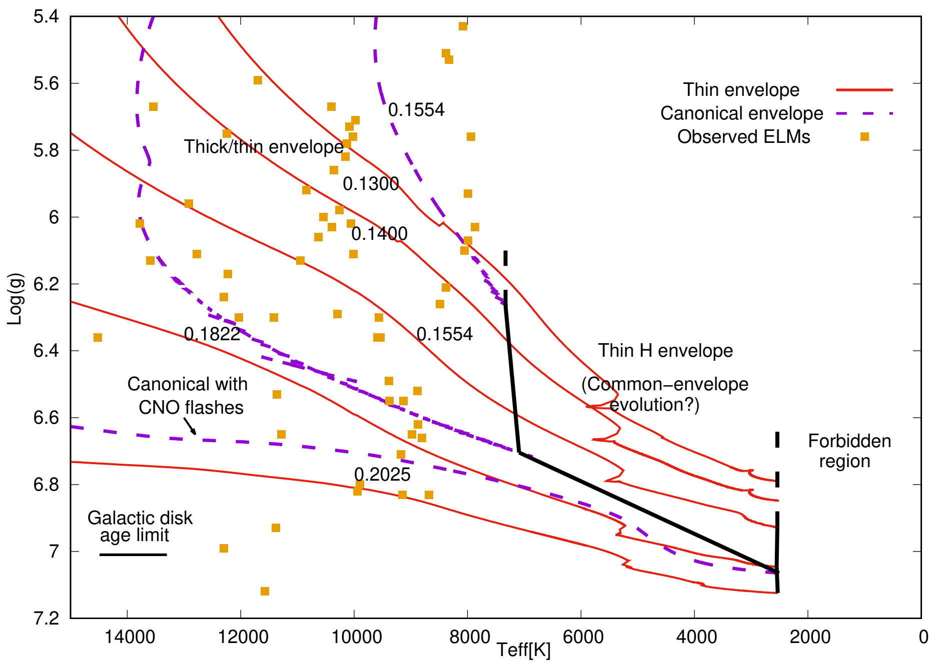

Figure 1: Evolutionary sequences with different mass and thickness of the H envelope (canonical and thin) in the log(g) versus $T_{\rm eff}$ plane. The solid black lines to the left connect points of equal age (13.7 Gyr) for the canonical tracks, while the solid lines to the right connect points of equal age (13.7 Gyr) but for the thin H envelope tracks. The dashed lines also correspond to the galactic disk age limit, and are only marked as projections to delimit the region. Also included are the ELMs observed up until now (including the ELMVs). The progenitor considered has $M_{\star}$ = 1.5 $M_{\odot}$.