Readings and Exercises for White Dwarf Evolution and Pulsation

Readings

Mestel (1952) produced the first seminal work on white dwarf (WD) evolution. In particular, section 4 of his paper has the first reasonable treatment of the temperature evolution of WD stars. Concerning pulsation, Winget et al. (1991) made the first successful case study of a pulsating WD; their analysis introduces most of the major asteroseismological aspects of these pulsators.

In addition, there have been many recent reviews of the field. Althaus et al. (2010) treat all aspects of WD evolution and pulsation, while Montgomery (2009), Winget & Kepler (2008), and Fontaine & Brassard (2008) examine WD pulsations, and Fontaine et al. (2001) review WD evolution. Full references to these papers are given at the end in the **References** section.

Exercises

1. A simple, analytical theory of white dwarf (WD) cooling has been developed by Mestel (1952). He treated the WD as composed of a degenerate, isothermal core surrounded by a radiative envelope having a large temperature gradient. From this, he derived

$$t_{\rm cool} \approx \frac{10^8}{A}\left(\frac{M/M_\odot}{L/L_\odot}\right)^{5/7} \text{years}, \tag{1}$$

where L is the luminosity of the WD, $t_{\rm cool}$ is its age as a WD, and M is its mass. We can test this relation with MESA.

We will use models located in ~/mesa/data/star_data/white_dwarf_models/ of your MESA installation. Typical WDs have $M \sim 0.6 M_\odot$, so use model `0.611_from_2.5_z2m2.mod`, along with the following settings in your inlist file. Set the following in `&star_job`:

```
load_saved_model = .true.
saved_model_name = '0.611_from_2.5_z2m2.mod'
```

and in `&controls`:

```
do_element_diffusion = .false.
Teff_lower_limit = 3000
```

Using the output in the `star.log` file plot log t versus log L for this sequence. You can use your own plotting program or you may want to experiment with the `nugrid` python tools (http://www.astro.keele.ac.uk/nugrid/releases-and-software-downloads/python-tools). Examine how well the trend in equation (1) compares to the MESA calculations. What additional physics may account for the discrepancies?

2. For a variety of reasons extremely low mass (ELM) WDs, defined as having masses $\lesssim 0.2 M_{\odot}$, are beginning to attract attention. A cheesy and not-self-consistent way of producing models of these stars is to evolve, for example, a $0.2 M_{\odot}$ star off the main sequence assuming zero mass loss. Using MESA, evolve such a model from the pre-main sequence onto the WD cooling track. At what point in the $\log L$–$\log T_{\rm eff}$ plane do you consider the object to become a WD? Give one powerful reason that this is not a possible formation scenario for present-day ELMs, i.e., How many orders of magnitude are we off by?

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