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Precision Asteroseismology of DAV (ZZ Ceti) White Dwarf Stars

Paul A. Bradley

Los Alamos National Laboratory, Los Alamos, NM 87545

Abstract. Recently, Clemens suggested that the similarity in period structure of the hotter DAV (ZZ Ceti) stars could be explained if they pulsated in a common set of modes. Here, I use theoretical pulsation periods from a new grid of evolutionary DA white dwarf models to determine the internal structure of G 117–B15A and R 548. Both stars have hydrogen layer masses of $\sim 1.5 \times 10^{-4} M_\star$ and oxygen-rich cores with a composition gradient starting near $0.75 M_\star$.

1. Introduction

In this paper, I derive the structure of G 117-B15A and R 548 by comparing their observed periods to periods predicted by evolutionary white dwarf models. The equilibrium white dwarf models are a subset of those presented by Bradley (1995), so I refer the reader to that paper for additional details about their structure, including the chemical composition profile. Bradley (1995) also presents the general pulsation properties of these models.

I use the effective temperatures and $\log g$ values listed by Koester et al. (1994) and Daou et al. (1990). Both stars have trigonometric parallax data (McCook & Sion 1987) which I use as an independent check on the seismologically predicted distances. G 117–B15A and R 548 have similar pulsation periods (see Table 1), so they should have nearly the same mass and internal structure. A comparison to carbon core models shows the stellar mass is about $0.55 M_\odot$. However, the best fitting carbon core model periods are 215.2 s, 276.5 s, and 341.6 s, so the core cannot be pure carbon. I then try $0.55 M_\odot$ models with various C/O core mass fractions and change the location for starting the switch from a C/O mixture to pure C. These models show close fits when the core is 20:80 C/O, has an inner transition point at $\sim 0.75 M_\star$, and the outer transition point is at $0.90 M_\star$, where the composition is pure carbon. My best fitting model for R 548 has a mass of $0.54 M_\odot$, as opposed to $0.55 M_\odot$ for G 117–B15A. The mass of R 548 is 0.5σ lower than the spectroscopic mass, while the mass of G 117–B15A is 1.3σ higher than the most recent spectroscopic mass. Both stars have a hydrogen layer mass of $\sim 1.5 \times 10^{-4} M_\star$ and a helium layer mass of $\sim 1.5 \times 10^{-2} M_\star$. The seismological distance of R 548 is half the parallax distance, indicating a trigonometric parallax value seriously in error or that R 548 is a binary system. We can rule out a binary model for R 548 because we see no spectroscopic evidence for a companion, and the limits on the rate of period

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change (Tomaney 1987) would correspond to an orbital period of at least 10^5 yr, far longer than the orbital period of any *hidden* companion.

Table 1. Observed Periods of G 117–B15A and R 548

Object	T_{eff} (K)	mode indentity (ℓ, k) (1,2)	(1,3)	(1,4)	Trig. Parallax (mas)	Seis. Parallax (mas)
G 117–B15A	12,350	215.2	271.0	304.4	12.1 ± 5.3	15.9
R 548	12,800	212.9	274.5		14. ± 2.	29.4
		213.1	274.8			

2. Summary and conclusions

If the hydrogen layer mass for G 117–B15A and R 548 is typical for DA white dwarfs, then the standard picture of stellar evolution from the AGB to the white dwarf stage (Iben & MacDonald 1986; D'Antona & Mazzitelli 1991) is at least qualitatively correct. The thick hydrogen layer mass will push the mean mass of DA white dwarfs closer to $0.60M_\odot$ from $0.56M_\odot$ (Bergeron, et al. 1992). Wood (1995) shows that thick hydrogen layers affect the luminosity function and increases the age estimates for the local Galactic disk by about 0.75 Gyr.

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