Science Justification

Hydrogen atmosphere white dwarfs near 11,500 K (DAVs) and helium atmosphere white dwarfs (DBVs) near 25,000 K pulsate (see review by Winget 1998). These pulsations have periods between 100 s and 1100 s and fractional amplitudes from a few tenths of a percent up to 20 to 30%. In general, those with large amplitude pulsations ($\geq 5\%$) show distinctly nonlinear light curves. While seismological models of the *linear* pulsations of white dwarf stars have been used to measure many aspects of these stars' structure, such as stellar mass, $T_{\rm eff}$, or the central carbon/oxygen ratio (e.g., Bradley & Winget 1994; Metcalfe et al. 2000), such analyses have not made use of the important information present in the nonlinearities, which are present in over half of all pulsating white dwarfs. These nonlinear light curves are caused by the interaction of the pulsations with the outer convection zones of these stars (Brickhill 1992; Wu 2001; Montgomery 2005a,b), and are the key to unlocking our understanding of convection in these objects.

We have recently developed a technique for using the observed light curves of these objects to map the instantaneous nonlinear response of their convection zones (Montgomery 2005a,b; 2007a,b). The information we obtain is directly related to the depth and thickness of convection, and thus is a probe of the conditions *at the base* of the convection zone. Other techniques for probing convection, such as measuring photospheric line asymmetries, are complementary to this approach, since they provide information on convection *in the photosphere*. Given the large difference in conditions between the photosphere and the base of the convection zone, both techniques are necessary for fully testing either modern hydrodynamical models of convection or the traditional mixing length theories. This proposal is focused on determining the conditions at the base of the convection zone, which is the supposed seat of mode driving and of the nonlinearities.

The nonlinearities provide a measure of the thermal response timescale (τ_C) of the convection zone, which is directly related to its mass and depth. Simple mixing length theories of convection predict that this timescale should scale like $\tau_C \approx \tau_0 \, (T_{\rm eff}/T_{\rm eff,0})^{-N}$, where $T_{\rm eff}$ is the instantaneous effective temperature, τ_0 and $T_{\rm eff,0}$ are the equilibrium values of τ_C and $T_{\rm eff}$, respectively, and $N \approx 90$ for DAVs and $N \approx 25$ for DBVs. Our results have indeed shown that $N \sim 25$ for the DBVs and $N \sim 90$ for the DAVs (Montgomery 2005a,b; 2007a,b), consistent with these theories, while the derived values of τ_0, together with a spectroscopic temperature determination, have placed constraints on the allowed values of the mixing length parameter α. (see Figures 1a and 1b for preliminary examples). Thus far, two DAVs have been examined using this technique: GD 154 and G29-38. Their nearly identical masses ($\sim 0.70\, M_\odot$) but different effective temperatures (11180 K and 11820 K, respectively; Bergeron et al. 2004) allow us to probe the temperature sensitivity of convection across the DAV instability strip (see Figure 1b).

The target for this proposal, G38-29 (note the different name from G29-38), is a large-amplitude DAV, having a $T_{\rm eff}$ nearly identical to GD 154 but a mass ($\sim 0.55\, M_\odot$) 20% less than that of GD 154. This will allow us to probe the $\log g$/mass dependence of convection. Standard mixing length models predict that τ_C should scale with surface gravity as $\tau_C \propto g^{3.3}$, so G38-29 should have a thermal response timescale less than one-fifth that of GD 154. Given our success modeling the light curves of previous DAVs and DBVs (Montgomery 2005a,b; see also Figure 2) we expect to be able to model this target. It is multi-periodic, with at least four reported periodicities between 900 s and 1100 s, so a time baseline of several days is required. To aid in obtaining frequency resolution and to help with the analysis of this data, a small campaign based around the McDonald 2.1m observations will run using several other small telescopes (e.g., CTIO 0.8m, Mt. John). In addition, the results of this run along with the observed complexity of G38-29's frequency spectrum will allow us to evaluate whether this target is suitable for a Whole Earth Telescope run next year.

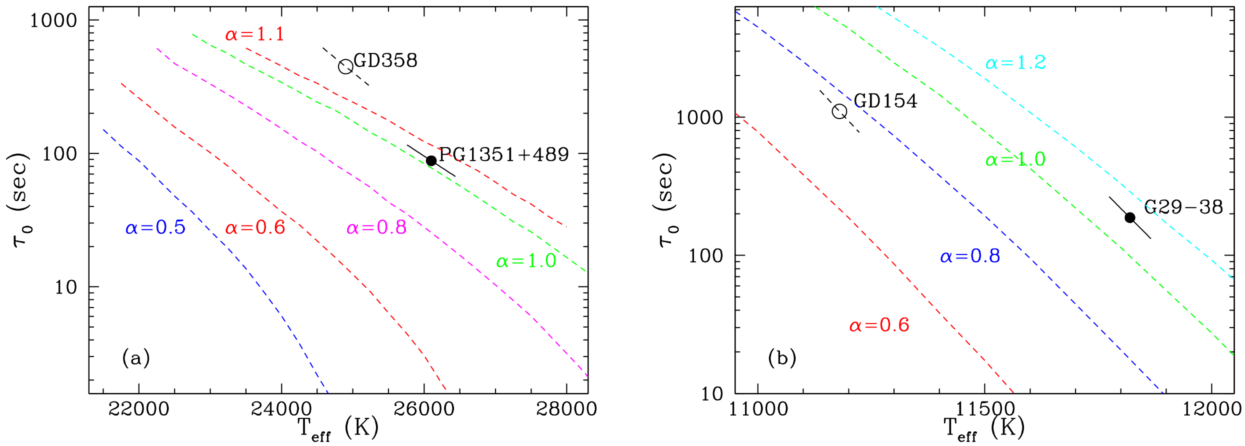

Fig. 1.— (a) The positions of the DBVs GD 358 and PG1351+489 in the $T_{\rm eff} - \tau_0$ plane as derived from light curve fits (Montgomery 2007a,b). The dashed lines show the predictions of mixing length theory labeled by the corresponding values of α. (b) The same as (a) but for the DAVs GD 154 and G29-38 based on data taken in April 2007.

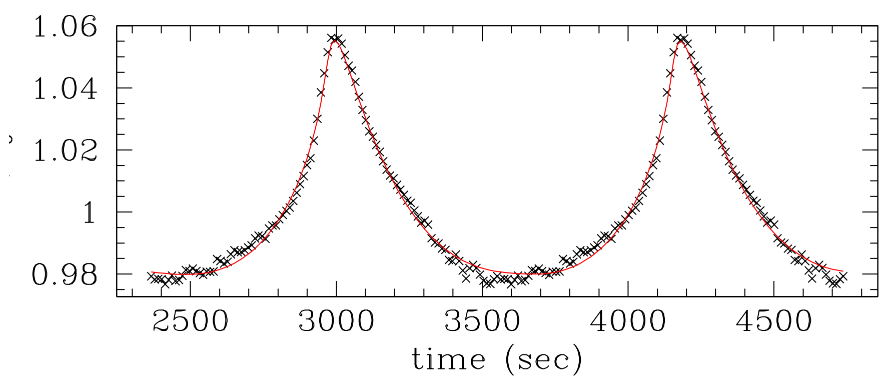

Fig. 2.— A fit (solid line) to the observed (crosses) folded light curve of the DAV GD 154 (data taken in April 2007).

References

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