Kepler Limits on Variability Near the ZZ Ceti Instability Strip

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White dwarf (WD) stars with hydrogen-dominated atmospheres pulsate when they reach a sufficient effective temperature to generate a hydrogen partial-ionization zone that efficiently drives global stellar oscillations. This range of temperatures for DAVs (aka, ZZ Ceti stars) empirically spans roughly 12,600 − 11,100 K for canonical-mass ($0.6\,\mathrm{M}_{\odot}$), $\log g = 8.0$ WDs (Gianninas et al. 2011, ApJ, 743, 138). Pulsating WDs provide an important glimpse into the interior of the future of the vast majority ($> 97\%$) of all stars in our Galaxy, including our Sun. The blue edge where pulsations turn on is fairly well predicted by theory, and has been successfully estimated by both convective period arguments (Brickhill 1991, MNRAS, 252, 334) and full non-adiabatic calculations (e.g., Winget et al. 1982, ApJ, 252, L65). However, a theoretical understanding of how pulsations shut down remains elusive (e.g., Van Grootel et al. 2012, A&A, 539, A87).

Better defining the boundaries of the ZZ Ceti instability strip helps us to understand the driving conditions for WD pulsations, and refines the selection criteria for future searches for DAVs. In the past, variability has been assessed by relatively short (2 − 3 hr) observations, generally to limits of $0.2 - 0.6\%$. Some ZZ Cetis pulsate at lower amplitude, many with maximum pulsation amplitudes of $0.1 - 0.3\%$, and several WDs "not-observed-to-vary" (NOV) have later been confirmed to pulsate with further observations (e.g., Castanheira et al. 2010, MNRAS, 405, 2561).

Our team discovered all DAVs in the original *Kepler* mission (e.g., Greiss et al. 2014, MNRAS, 438, 3086). We have applied the same photometric selection methods to Field 1, and have identified more than a dozen WDs on silicon with colors consistent with the empirical ZZ Ceti instability strip. Our selection recovered two of the three previously known DAVs in this field, and additionally, two of our candidates (J1151+0525 & J1149−0147) were confirmed to vary from ground-based observations; these targets have been submitted in a companion proposal of confirmed pulsating WDs.

We propose here *K2* observations of 9 candidate WDs that we either could not observe for variability before the Field 1 deadline or our NOV limits are not better than 0.6%. Our 9 candidate DAVs span a range of magnitudes ($16.3 < K_p < 18.4$ mag) and effective temperatures, all likely within 1000 K of the empirical ZZ Ceti instability strip. *K2* observations will provide an unparalleled opportunity to assess variability in these WDs. To orient: KIC 10198116, a $K_p = 16.4$ mag WD observed in the original *Kepler* mission, proved NOV to 112 ppm in 31 d of Q4.1 observations. Assuming a factor of four degradation in photometry for *K2*, we should thus be sensitive to pulsations with amplitudes as low as 300 ppm (0.03% rel. amplitude) using 75 d of data on similarly bright WDs, an order-of-magnitude improvement from the ground.

We have high confidence in our selection: Our candidates are $> 95\%$ probability DAs which were also discovered by Girven et al. (2011, MNRAS, 417, 1210), who found temperatures for all of our objects within 1000 K of the ZZ Ceti instability strip using SDSS photometry. Two of our photometrically selected targets are already confirmed WDs with spectroscopically derived atmospheric parameters: J1139+0310 (EPIC 201671806 , $T_{\rm eff} = 13{,}530 \pm 130$ K, $\log g = 7.93 \pm 0.02$) has high-resolution UVES spectra (Koester et al. 2009, A&A, 505, 441), and J1141+0420 (EPIC 201741620) has a spectrum from SDSS, with $T_{\rm eff} = 13{,}530 \pm 420$ K, $\log g = 7.39 \pm 0.08$ (Tremblay et al. 2011, ApJ, 730, 128). Another WD has a composite WD+dM spectra that misses our color selection but falls in the empirical instability strip: J1127−0028 (EPIC 201431734), with $T_{\rm eff} = 11{,}220 \pm 500$ K, $\log g = 8.35 \pm 0.03$ (S.O. Kepler 2014, priv. comm.).

With typical pulsations ranging from 100 − 1400 s, we require **short-cadence** observations of these 9 WDs. Four have $K_p < 17.8$ mag, which we prioritize in our target list. Minute-cadence *K2* observations have the added benefit of catching transits/eclipses of the WD, revealing any unresolved double-degenerate binaries or even planetary companions.

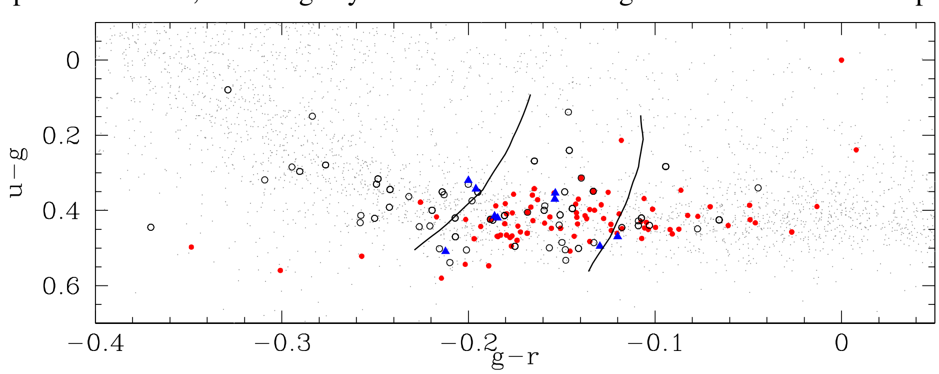

Figure 1: Our u-g, g-r photometric selection criteria for candidate ZZ Ceti stars. The blue triangles are our candidates, the red points are confirmed DAVs from Mukadam et al. (2004, ApJ, 607, 982), and the larger open circles are non-variable WDs from that same work, to median limits of 0.4% relative amplitude. The black lines roughly trace the empirical instability strip. The gray points are spectroscopically confirmed WDs from SDSS (Kleinman et al. 2013, ApJS, 204, 5).