K2 Observations of the Consequences of Common-Envelope Evolution

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We propose an unparalleled opportunity to investigate the consequences of close binary evolution by observing one of the first pulsating white dwarf (WD) stars found a WD+dM system, which has undergone a prior common-envelope event. By taking a detailed census of the pulsation modes of this variable WD, *K2* will allow for the first empirical test of the effects binary interaction has on the remnant WD internal structure and chemical profiles, especially the hydrogen-layer mass. All progenitors of Supernovae Ia, independent of single vs. double-degenerate channel, go through at least one common-envelope phase, so these observations can directly constrain SNe Ia boundary conditions.

To-date, the observed DAV (ZZ Ceti) instability strip for pulsating WDs appears pure; that is, all hydrogen-atmosphere WDs at the appropriate temperature to foster a hydrogen partial-ionization zone are observed to pulsate. Precision asteroseismology, enabled by matching the periods of observed luminosity variations to well-calibrated theoretical models, provides unparalleled insight into the interiors of these WDs (see reviews by Winget & Kepler 2008, ARA&A, 46, 157 and Fontaine & Brassard 2008, PASP, 120, 1043). This technique naturally extends to WDs with detached, close companions, such as those in post-common-envelope binaries (PCEBs), so long as the WD has reached the appropriate temperature.

Our proposed target, **SDSS J1136+0409** (EPIC 201730811, $K_p = 17.15$ mag), is a heretofore unpublished pulsating hydrogen-atmosphere (DA) WD in a PCEB (Pyrzas et al. 2014, in prep.). The spectrum is a composite WD+dM (see Figure 1), but model-atmosphere fits to the WD-dominated part of the spectrum show the WD has an effective temperature of 11600 ± 1200 K and $\log g = 7.99 \pm 0.08$ (Rebassa-Mansergas et al. 2012, MNRAS, 419, 806), placing it in the empirical DAV instability strip. Optical variability was confirmed by ULTRACAM on the 3.5m NTT (right panel of Figure 1), with a period near 277.8 s (0.8% amplitude), and perhaps also a significant period near 181.7 s (0.4% amplitude).

Some wider binaries are initially separated enough to avoid a common-envelope phase but may still show up as composite WD+dM spectra. Such binaries are observed to be separated by > 10 AU (Farihi et al. 2010, ApJS, 190, 275). However, we have observed large-amplitude (> 200 km s^{-1}) RV variations in five epochs of spectroscopy using the Na II lines at 8183.27 Å and 8194.81 Å. This is strong evidence that J1136+0409 has a short orbital period, likely near the mean for PCEBs ($6 - 14$ hr; Nebot Gómez-Morán et al. 2011, A&A, 536, A43), and is most likely a PCEB. We have been awarded 3 hr with FORS2 on the VLT in Period 93 (Apr-Sep 2014) to solve the orbital parameters.

Seismology also affords the opportunity to constrain the rotation rate of the WD if any rotational splittings of the non-radial modes are present. Such observations may constrain how mass- and angular-momentum loss occur after close binary interaction. Given the short-period optical variability, we request **short-cadence** observations of J1136+0409.

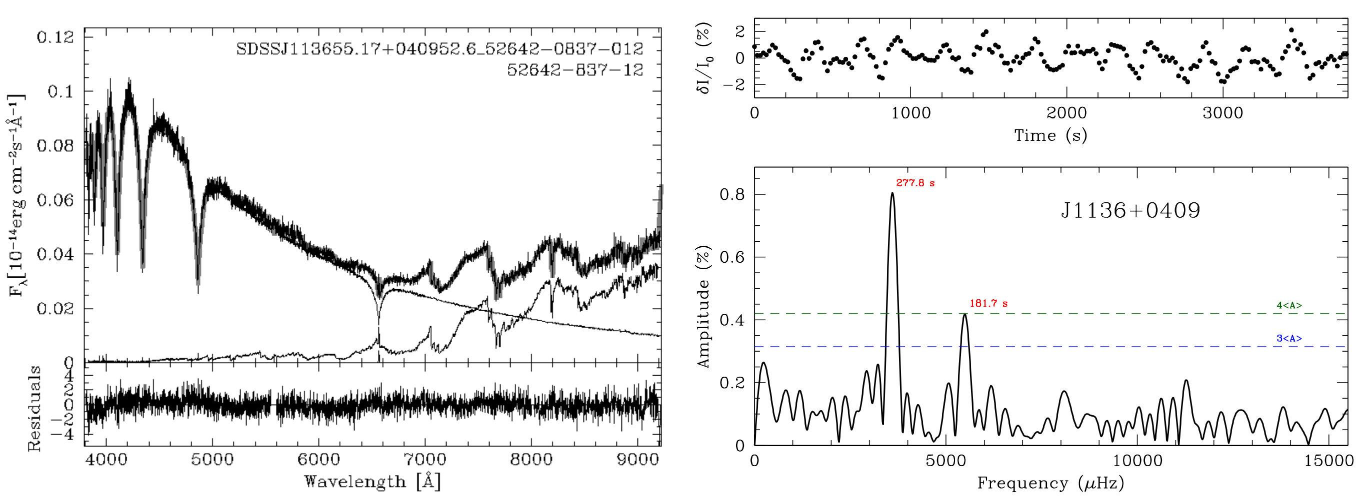

Figure 1: *Left:* The SDSS spectrum of J1136+0409 in thick black, dominated by a white dwarf at the blue end and an M-dwarf redward of 7500 Å. The best-fit composite spectrum in grey matches the observations well, composed of a 11600 K white dwarf blended with an M6 main-sequence companion. Large-amplitude, significant radial-velocity variations confirm this WD+dM system is in a short-period binary, and is thus the descendent of common-envelope evolution. *Right:* Slightly more than an hour of time-series photometry of SDSS J1136+0409 using ULTRACAM on the 3.5m NTT shows significant variability near 277.8 s and 181.7 s. The top panel shows this discovery g'-band light curve, and the bottom displays a Fourier transform of that light curve. The $4\langle \mathrm{A} \rangle$ line marks 4 times the mean noise level in the FT out to 10000 μHz; peaks higher than this value we consider significant.