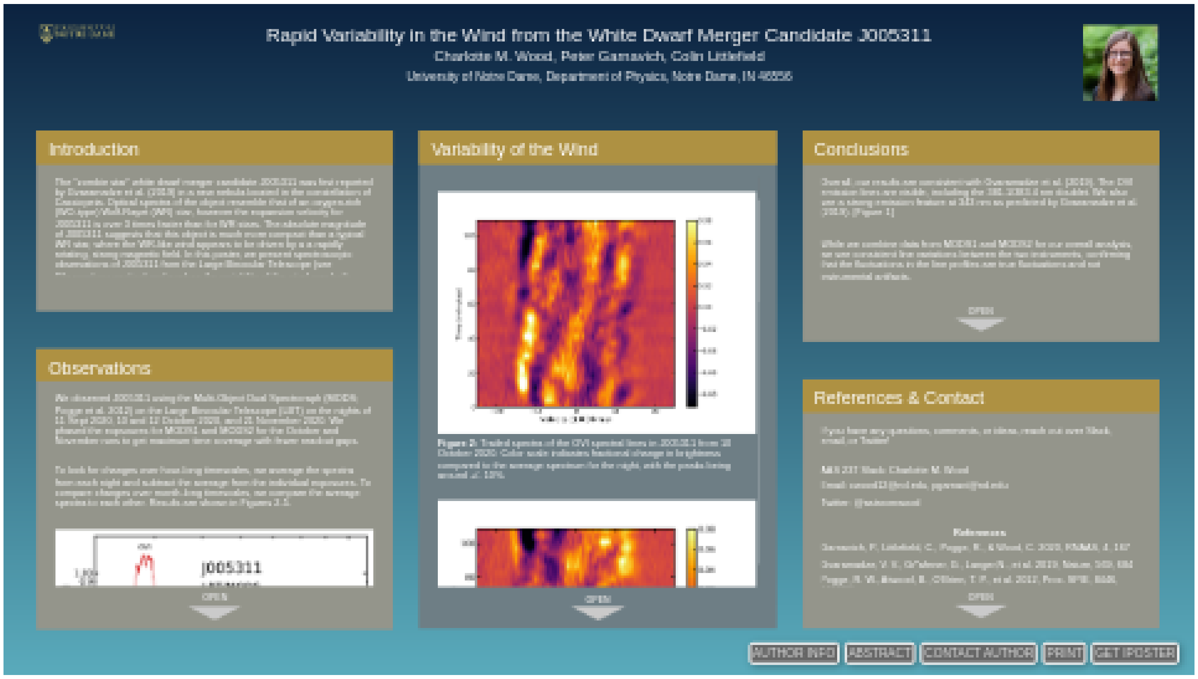
Rapid Variability in the Wind from the White Dwarf Merger Candidate J005311



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INTRODUCTION

The "zombie star" white dwarf merger candidate J005311 was first reported by Gvaramadze et al. (2019) in a new nebula located in the constellation of Cassiopeia. Optical spectra of the object resemble that of an oxygen-rich (WO-type) Wolf-Rayet (WR) star, however the expansion velocity for J005311 is over 3 times faster than for WR stars. The absolute magnitude of J005311 suggests that this object is much more compact than a typical WR star, where the WR-like wind appears to be driven by a a rapidly rotating, strong magnetic field. In this poster, we present spectroscopic observations of J005311 from the Large Binocular Telescope (see Observations section) and analyze the variability of the wind over both hours- and months-long timescales (see Variability and Conclusions sections).

OBSERVATIONS

We observed J005311 using the Multi-Object Dual Spectroraph (MODS; Pogge et al. 2012) on the Large Binocular Telescope (LBT) on the nights of 11 Sept 2020, 10 and 12 October 2020, and 21 November 2020. We phased the expsoures for MODS1 and MODS2 for the October and November runs to get maximum time coverage with fewer readout gaps.

To look for changes over hour-long timescales, we average the spectra from each night and subtract the average from the individual exposures. To compare changes over month-long timescales, we compare the average spectra to each other. Results are shown in Figures 2-5.

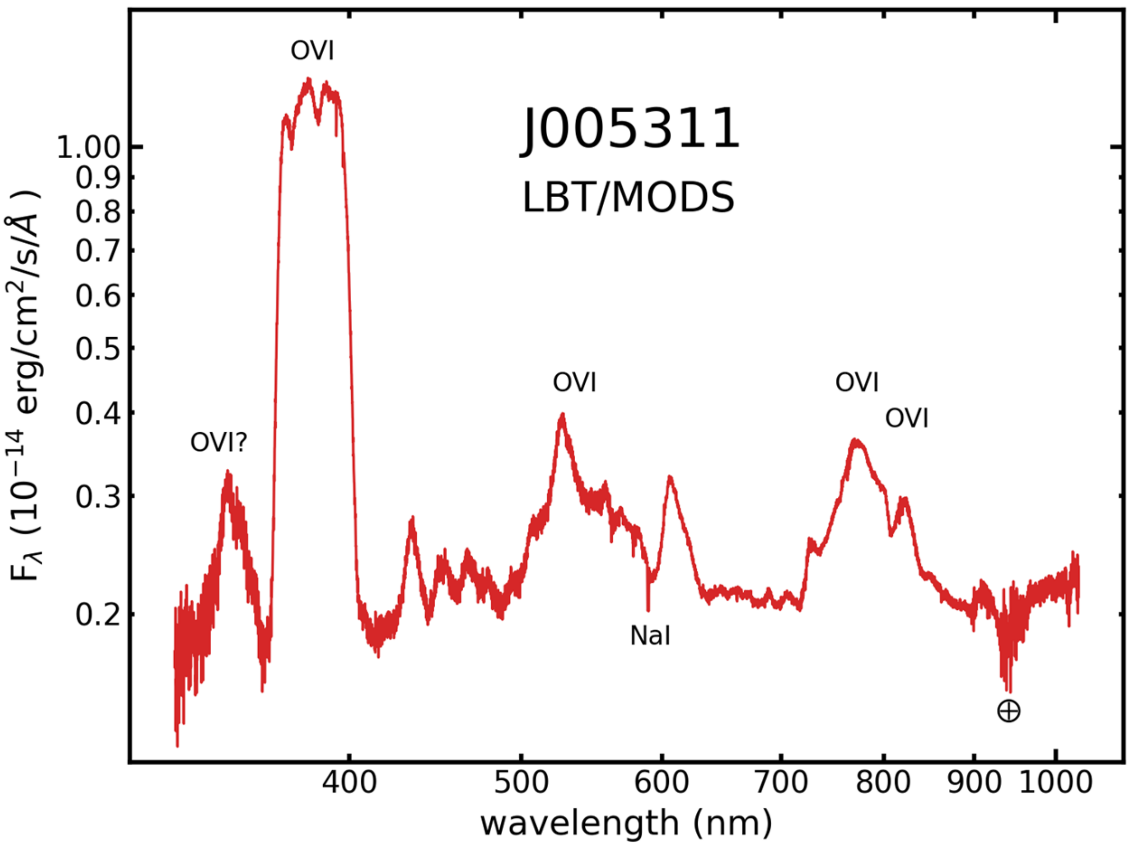

Figure 1: The full spectrum of J005311, averaged over five exposures from 11 Sept 2020 using MODS on the Large Binocular Telescope. Several of the OVI lines identified by Gvaramadze et al. (2019) are labeled. Narrow interstellar/circumstellar NaI and CaII (H+K) lines are also visible (top panel of Fig. 1 in Garnavich et al. (2020)).

VARIABILITY OF THE WIND

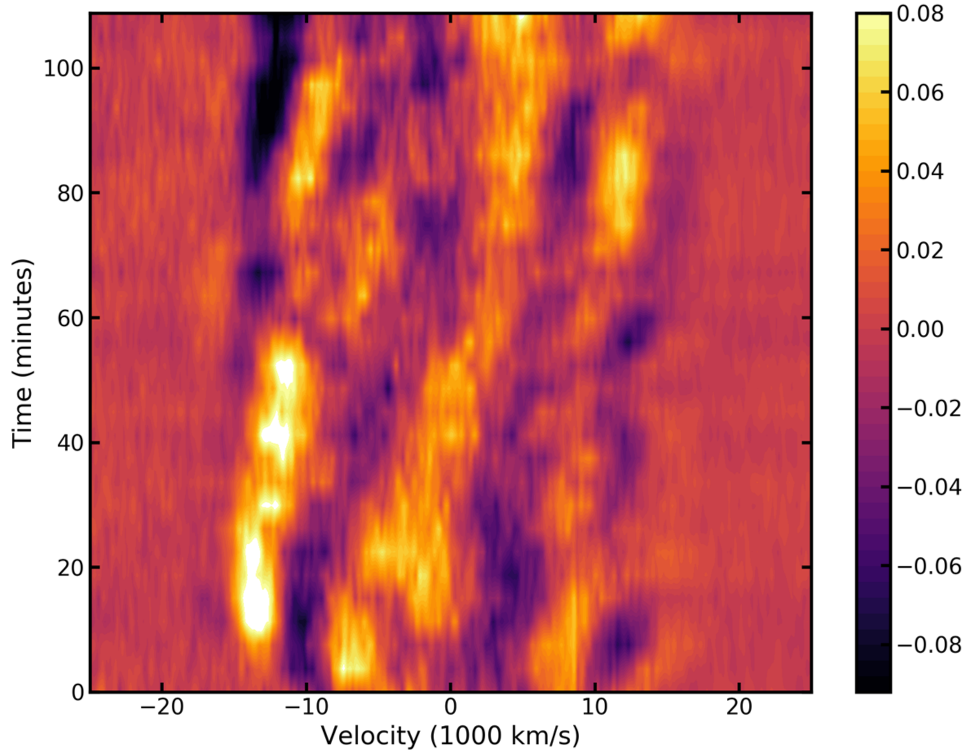

Figure 2: Trailed spectra of the OVI spectral lines in J005311 from 10 October 2020. Color scale indicates fractional change in brightness compared to the average spectrum for the night, with the peaks being around +/- 10%.

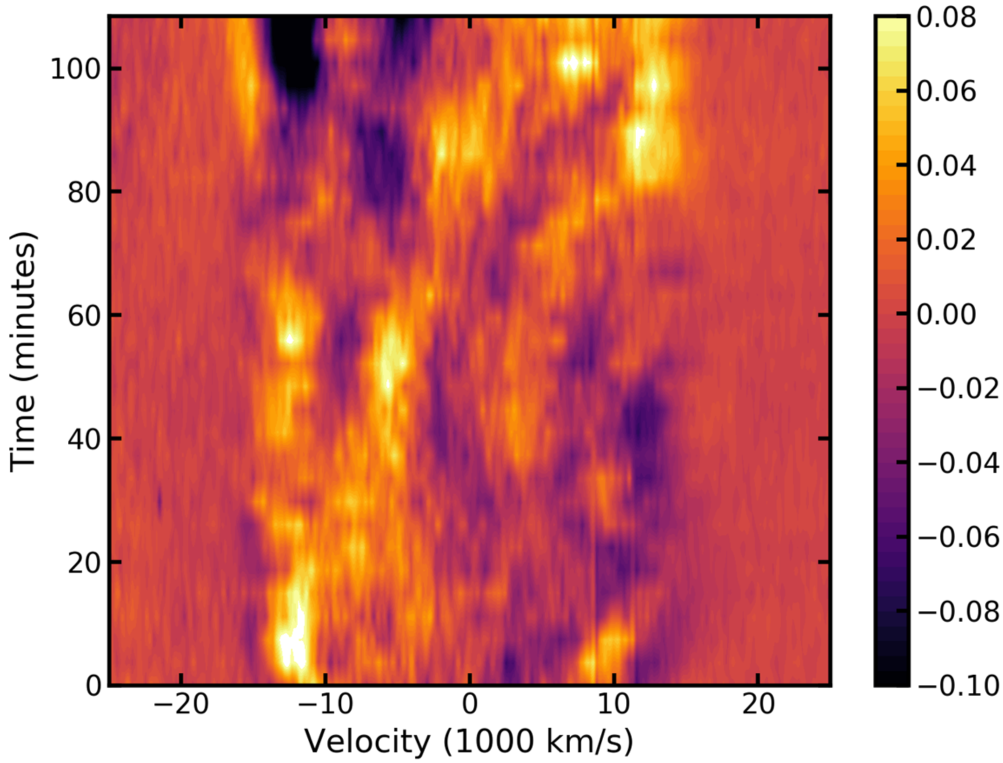

Figure 3: Trailed spectra of the OVI spectral lines in J005311 from 21 November 2020. Color scale indicates fractional change in brightness compared to the average spectrum for the night, with the peaks being around +/- 10%.

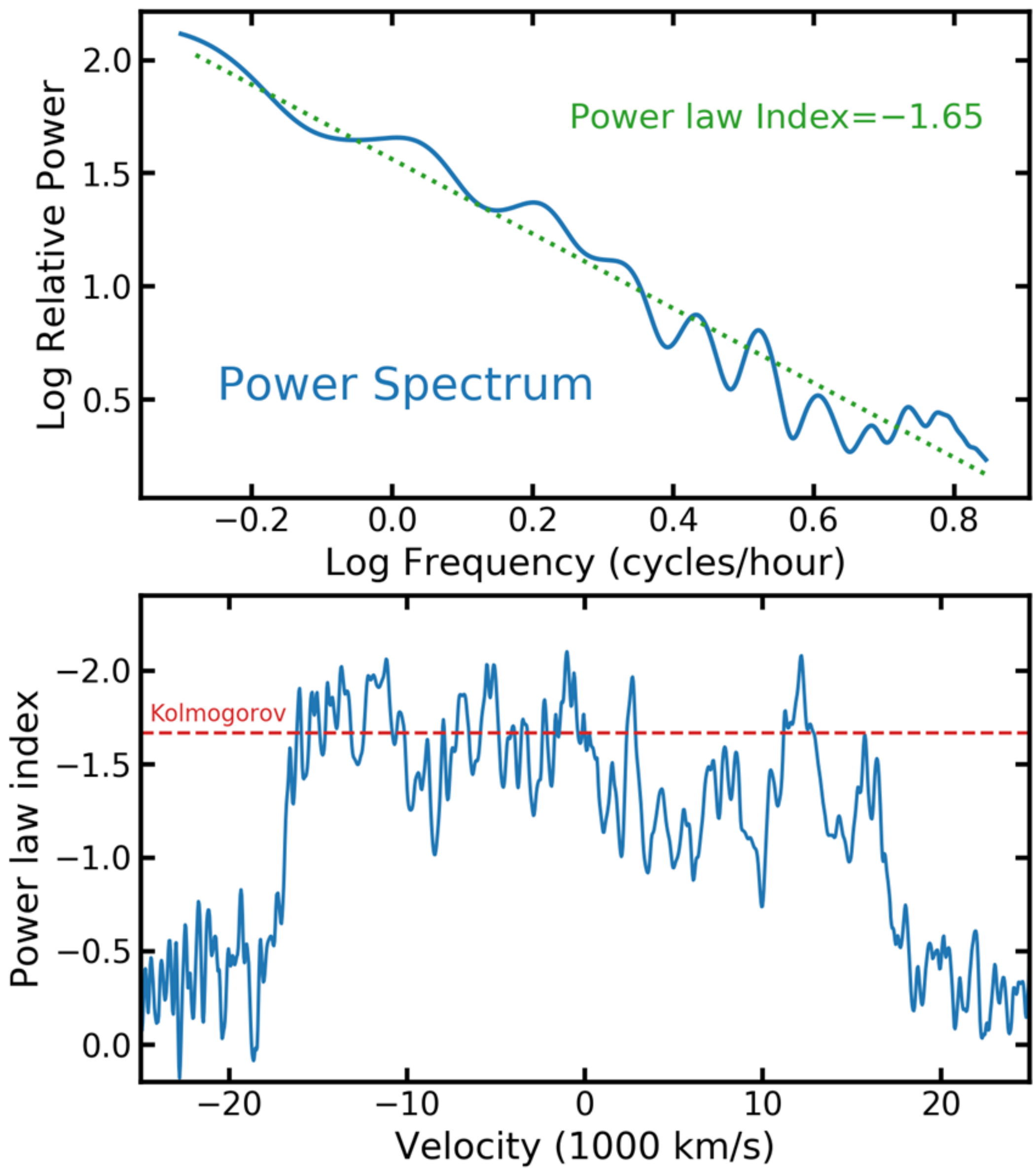

Figure 4: *Top:* Flux power spectrum averaged between -15000 and -10000 km/s. The dotted green line is a linear fit to the power spectrum showing an index of -1.65. This index is close to the Kolmogorov turbulence spectrum index of -5/3. *Bottom:* The power-law index measured at each wavelength over the OVI emission line. The blue-shifted side of the line has an index close to -5/3, but the redshifted side generally has a flatter index close to -4/3.

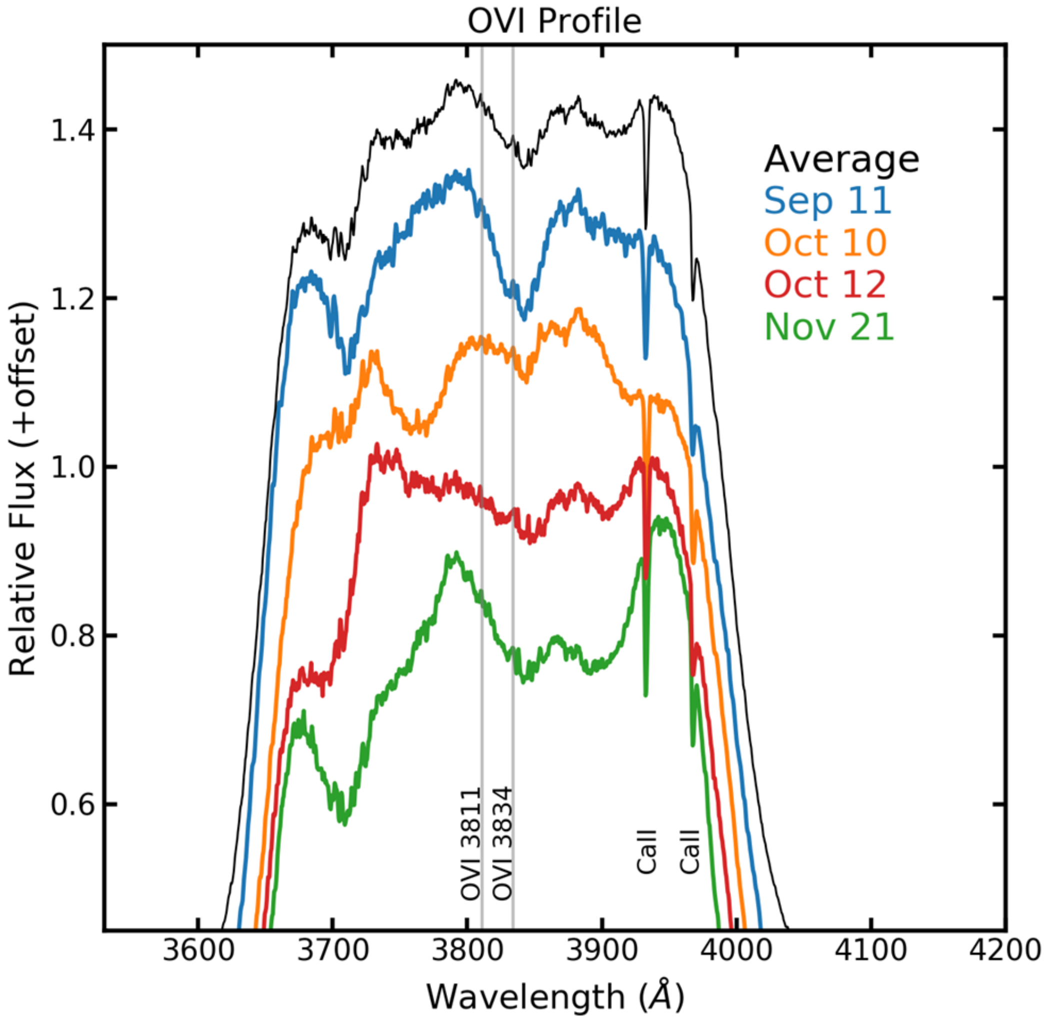

Figure 5: Average OVI line profile for each night of observation and the overall average. The OVI 3811 & 3834 angstrom lines are marked, as well as some CaII lines. The absorption of the OVI lines varies greatly between each observation.

CONCLUSIONS

Overall, our results are consistent with Gvaramadze et al. (2019). The OVI emission lines are visible, including the 381.1/383.4 nm doublet. We also see a strong emission feature at 343 nm as predicted by Gvaramadze et al. (2019). [Figure 1]

While we combine data from MODS1 and MODS2 for our overall analysis, we see consistent line variations between the two instruments, confirming that the fluctuations in the line profiles are true fluctuations and not instrumental artifacts.

Two-hour long time-series combining MODS1 and MODS2 shows rapid fluctuations in the line profiles with peak-to-peak amplitudes of nearly 20%. The largest variations in flux occur at the highest velocities, near the edges of the broad OVI emission feature. Unlike in some WR stars, The variability in the line profile of the 381.1/38 does not show clear, coherent clumps moving to higher velocities over time. [Figures 2 & 3]

The flux power spectrum is well fit by a power law. On the blue-shifted side of the line the power law index is close to -5/3, but on the red-shifted side, the index is less steep. The origin of this difference is not clear. [Figure 4]

With several data sets distributed over several weeks, we see the average OVI line profile varies significantly across timescales of months. [Figure 5]

REFERENCES & CONTACT

If you have any questions, comments, or ideas, reach out over Slack, email, or Twitter!

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ABSTRACT

The optical spectrum of the "zombie star" white dwarf merger candidate J005311 is similar to that of WO-type Wolf-Rayet (WR) stars; however the maximum expansion velocity for J005311 is more than three times faster than for WR stars at 16,000 km/s. The absolute magnitude of the star suggests that this object is much more compact than a typical WR star, where the WR-like wind appears to be driven by a rapidly rotating, strong magnetic field. We observed J005311 with the twin Multi-Object Dual Spectrographs (MODS) at the Large Binocular Telescope (LBT) to search for emission line profile variations and derive statistical properties of its wind. Time-resolved spectra were obtained at three epochs in September and October of 2020 with the blue spectrographs out of synchronization to increase time resolution. We detect significant variability in the strong OVI 381.1/383.4 nm emission with amplitudes as high as 10% of the average flux. This variability likely corresponds to density fluctuations in the stellar outflow. Other variations in the emission profile are seen to change over a range of times-scales from days to minutes. Full widths of the coherent features are approximately 2000 km/s and appear to drift by as much as 8000 km/s over an hour.