Measuring the spin period of a rare magnetic white dwarf

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1 DDT Justification

We propose to observe a white dwarf binary to search for rotation induced flux modulation with a period of ~ 20 minutes. DDT allocation is required as the evidence for the fast rotation was not found until after the Cycle 3 deadline.

2 Scientific Justification

Cataclysmic Variables (CVs) are comprised of a white dwarf accreting material from a main-sequence companion via Roche lobe overflow. Roughly one third of the white dwarfs in CVs are magnetic, with field strengths ranging from 100s of kG (Intermediate Polars) to tens of MG (Polars) (Pala et al., 2020). CVs evolve from Post Common Envelope Binaries (PCEBs), close white dwarf-main sequence binaries that lose angular momentum to gravitational wave radiation until the secondary overflows its Roche lobe. As PCEBs are the direct progenitors of CVs, we would expect them to have the same $\approx$ one third incidence of magnetic white dwarfs. Nothing could be further from the truth: of the several thousand detected PCEBs known, fewer than twenty have detected magnetic fields, mostly pre-Polars (Schmidt et al., 2005). Only two pre-Intermediate polars are known (Sion et al., 1998; Parsons et al., 2013). Most proposed mechanisms for the formation of magnetic fields in white dwarfs require them to form either before or during evolution through the giant stages, so the lack of magnetic PCEBs is a complete mystery (Liebert et al., 2005).

Using data from *HST*, we have detected a white dwarf in a PCEB with a ~ 700 kG magnetic field, the third known pre-Intermediate polar. We request *TESS* 2 minute cadence observations to complete our characterisation of this extremely rare object by measuring its rotation period.

CC Cet is a PCEB consisting of a low mass white dwarf and an M 4.5 companion (Saffer et al., 1993). *HST* Cosmic Origins Spectrograph (COS) ultraviolet spectroscopy of the system revealed deep metal absorption lines in the spectra of the white dwarf. As the white dwarf has an otherwise pure hydrogen atmosphere, the metals must be accreted from the stellar wind of the companion. Surprisingly, these lines are Zeeman split, demonstrating the presence of a magnetic field. Figure 1 shows the Si IV lines in our two spectra, clearly Zeeman split in comparison with a non-magnetic object. The splitting allows us to measure a magnetic field of $\approx$700 kG, making this system only the third known pre-Intermediate Polar. We also found that the lines are velocity broadened well beyond the instrumental broadening. We measure a $v \sin i$ of $\approx$40 km s^{-1}, implying a rotation period of ≈ 20 minutes, depending on the inclination.

Furthermore, the line profiles in the two COS spectra are subtlety different, resulting in different best-fit magnetic field strengths. This shows that the wind is not accreting uniformly onto the white dwarf surface, but is instead being channelled down the magnetic field lines onto the magnetic poles

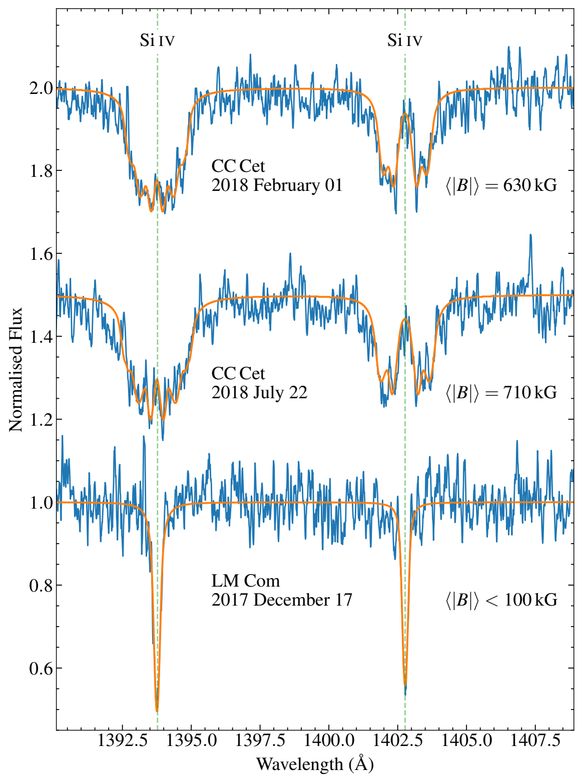

Figure 1: Silicon Si IV lines in the two *HST*/COS spectra of CC Cet, along with a spectrum of LM Com, another PCEB with a similar $T_{\rm eff}$ and $\log g$. The difference between the Zeeman split lines in CC Cet and the non-magnetic LM Com is readily apparent. The orange line shows the best-fit magnetic model to the lines, and the dashed vertical lines show the rest wavelengths. The date and best-fit mean field modulus are given under each spectrum. The absorption lines of CC Cet are broadened by rotation and vary between the spectra, implying that the white dwarf has an imhomogenous surface and is rapidly rotating. 2 minute cadence *TESS* data will allow us to precisely measure the spin period.

of the white dwarf. As the surface of the white dwarf is therefore inhomogenous, the rotation of the white dwarf should be detectable with high-precision photometry from *TESS*.

CC Cet was observed with *TESS* in Sector 4, but unfortunately only 30 minute cadence data was returned, placing the $\approx$ 20 minute spin period above the Niquist frequency. CC Cet will be observed again in Sector 31, thus we request 2 minute cadence data to measure the spin period. Coupling a rotation period with our measured $v \sin i$ will provide the inclination of the system and the mean phase of our *HST* observations, placing stronger constraints on the magnetic field strength and configuration. As the variation will be a direct result of a magnetic field, its detection would validate a search for more magnetic white dwarfs in binaries using *TESS* photometry.

3 Target Justification and Feasibility

The target is a white dwarf/M dwarf close binary. The white dwarf has a $\approx$20 minute rotation period that should be detectable due to an inhomogeneous surface. The binary period, as measured in 30 min Sector 4 data, is 6.8815 ± 0.00057 hours, easily discernible from the spin period. Using the web viewing tool we estimate that we will obtain sub-percent level precision in the *TESS* bandpass.

References

Pala, A. F., Gänsicke, B. T., Breedt, E., et al. 2020, , 494, 3799

Liebert, J., Wickramasinghe, D. T., Schmidt, G. D., et al. 2005, , 129, 2376

Saffer, R. A., Wade, R. A., Liebert, J., et al. 1993, , 105, 1945

Schmidt, G. D., Szkody, P., Vanlandingham, K. M., et al. 2005, , 630, 1037

Sion, E. M., Schaefer, K. G., Bond, H. E., et al. 1998, , 496, L29

Parsons, S. G., Marsh, T. R., Gänsicke, B. T., et al. 2013, , 436, 241