MAPPING EMISSION LINE FEATURES IN CVS

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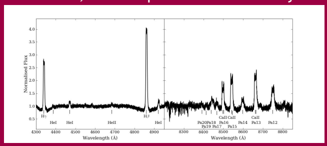
Accreting binaries containing white dwarfs provide crucial benchmark populations for stellar and binary evolution models and are thought to be the progenitors of Type 1A super nova explosions. Using the previously ignored CaII emission lines in the I-band we are probing new diagnostic tools in the search for system parameters of low mass ratio systems near the period bounce as their donors are faint and few system parameters are known.

METHOD with GW Lib as test case

Spectral Features

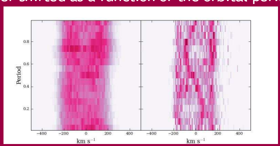
Strong and broad emission features are a common observational feature in CVs. Sources include the accretion disc, the hot spot and the secondary star.



The figure shows normalised spectra of GW Lib. The traditional wavelength range around the Balmer series on the left and on the right the additional coverage of the I-band, showing the strong CaII triplet lines in emission.

Time-Resolved Spectroscopy

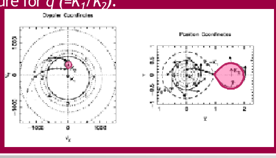
Taking successive spectra, motion due to the rotation of the binary is revealed as emission lines are Doppler shifted as a function of the orbital period.



Trailed spectra for Hbeta (left) and CaII 8662A (right). Where the Balmer line shows little structure, the CaII line shows a third emission peak on top of the double peaked profile from the accretion disc.

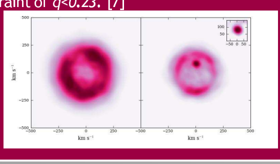
Maximum Entropy Mapping

Knowing the Doppler shift as a function of the orbital period allows us to make a velocity-velocity map (Doppler Tomogram via MEM [1,3]) of the system. The different components (disc, WD, donor and stream) all project to unique positions in the map giving us an indirect tool to measure their projected radial velocities (K_1, K_2, K_{disc}) which provide an independent measure for q ($=K_1/K_2$).



Results

Using the trailed spectra for GW Lib we constructed Doppler maps for Hbeta (left) and CaII (right). Where the Hbeta map shows only a broad disc, the CaII map not only has a finer structure in the disc, but also reveals the donor star in emission for the first time. From the measure of K_2 and K_1 (from the centre of the disc) this provides a first ever dynamical mass constraint of $q<0.23$. [7]



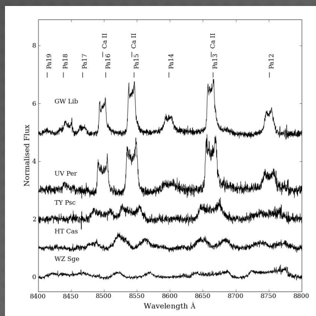
Binary evolution at short orbital periods

According to binary evolution models, the majority of the CV population should have evolved towards short orbital periods, at ~ 80 minutes. However due to the faintness of the depleted donors and the rare outburst, few of these systems have been found. Recent studies, such as the Sloan Digital Sky Survey (SDSS), are finally unearthing short-period systems in larger numbers [5]. Although the orbital period is an important diagnostic, reliable mass estimates are needed for the donor stars (M_2) to place a CV on its evolutionary track. The faintness of the low mass donor star in comparison to the WD and the accretion flow means that very few solid mass constraints are known in this regime. Only in 2006, the first secure CV with a brown dwarf donor was identified thanks to the tight mass constraints made possible because the system is eclipsing [2]. In contrast, the more typical candidates such as WZ Sge remain difficult to constrain conclusively [6]. Patterson [4] has identified several potential low mass ratio ($q = M_2/M_1$ with M_1 the WD mass) candidates, but his method, which is based upon tidal instabilities of the disc, is indirect and poorly calibrated exactly at the small mass ratios which are of the most relevant. If properly calibrated, it would offer mass ratio estimates for many systems.

CaII survey

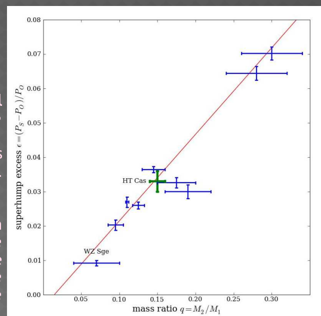
The CaII triplet offers advantages that more than make up for its relative weakness compared to the Balmer lines, namely it has a lower ionisation energy than either hydrogen and helium and is thus capable of being excited even by cool sources of radiation, and its thermal width and pressure broadening are much smaller than for hydrogen leading to sharper, more easily detected spikes of emission. CaII is therefore a promising, but so far neglected, avenue for emission line studies of CVs.

We have initiated a spectroscopic survey of short orbital period CVs, simultaneously covering the traditional Balmer series and the CaII lines. Within this survey we have observed several CVs with unknown parameters but also the eclipsing system HT Cas as this will allow us to verify our method as eclipse mapping has provided an independent measure of q.

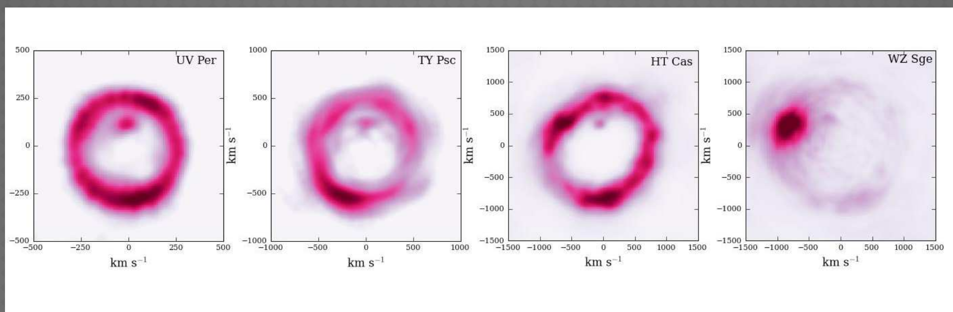


Left: Orbital average spectra for several objects within our survey. Our prototype system, GW Lib, shows relatively strong CaII lines, but even those with weak features prove to potentially have the power to reveal the donor start in emission.

Right: Pattersons empirical relation between the superhump excess and the mass ratio. The extreme low mass ratio end hinges on the badly determined mass ratio of WZ Sge. Once properly calibrated this relation will provide mass ratios for a large number of CVs.



Below: CaII Doppler maps for the same systems as above. UV Per, TY Psc and HT Cas all reveal the donor star in emission combined with clear structure in the disc, emphasising the diagnostic power of our method. Unfortunately, not all observed systems manifest CaII emission lines or clear donor features when CaII is present. For example, WZ Sge only shows the stream impact point on the disc.



Within our survey, we observed 16 short orbital period systems so far. Encouragingly, in 11 systems significant CaII emission was detected and a minimum of 5 systems reveal an emission spot from the donor star in Doppler tomograms, illustrating the diagnostic advantages of these lines. The measure of the disc and donor orbital velocities, in combination with emission models, will provide a measure of q for these systems. Importantly, only one precise measure of a low q system is needed to calibrate Pattersons relation, unlocking the mass ratios of ~100s CVs and providing a vindication of our binary evolution models.

References

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[5] Southworth et al, 2007, MNRAS, 382, 1145
[6] Steeghs et al., 2007, ApJ, 667, 442
[7] van Spaandonk et al, 2009, MNRAS , arXiv:0909.3991

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