4. Scientific Justification

Abundant evidence now exists that planetary systems survive the evolution of their host stars into white dwarfs. A common observable in such remnant planetary systems are compact dusty debris discs, detected via excess infrared flux. The discs are formed by tidally disrupted planetesimals, which are scattered in from an outer remnant planetary system, break apart upon reaching roughly one $R_\odot$ from the white dwarf, and circularise into a dusty ring extending inwards to the point where the dust is efficiently sublimated and accreted.

Glowing gas in $\sim 4\%$ (Manser et al., 2020) of these discs forms distinctive double-peaked emission lines, most often from the Ca II 8600 Å triplet, with the emission shifted to the red and the blue by the high Keplarian velocity of the material in the disc (Horne & Marsh, 1986; Gänsicke et al., 2006). Extensive monitoring of these debris discs have shown that the gaseous emission features are highly variable, in both line morphology and strength, over a range of timescales. Such behaviour can be used to probe the structure and dynamics of remnant planetary systems, as well as probing the composition of the accreted debris (Gänsicke et al., 2019), exploring the fates of the vast majority of known planetary systems, including the Solar system. In the prototype system, SDSS J1228+1040, Doppler tomography has been used to map out a fixed pattern in the disc precessing over a ≈ 25 year time scale (Figure 2, Manser et al., 2016), and to infer the presence of a small body orbiting in the disc in a similar fashion to the shepherd moons in Saturn's rings (Manser et al., 2019; Trevascus et al., 2021). Other modes of variation speak to more dynamic events, such as the rapid appearance and disappearance of emission at SDSS J1617+1620 (Wilson et al., 2014) and WD J2100+2122 (Dennihy et al., 2020) thought to have been caused by impacts onto the debris discs (Malamud et al., 2021).

Recently, the first observation of a gaseous disc with HET/LRS2 has confirmed that the emission at one of the most extensively studied white dwarfs, WD J0845+2257 (Wilson et al., 2015) is gradually weakening over a time scale of two decades, a hitherto unforeseen behaviour (Figure 1). This observation confirmed that LRS2 can resolve the emission profiles from the gas discs, and has the sensitively to obtain these observations with relatively short exposures. We now propose more extensive observations of four targets with a monthly cadence. Previous observations have probed time scales of hours or years, with only tentative evidence for $\sim$ monthly time scale variation at a single system (Manser et al., 2019). This program will explore the dynamics of gas discs on a new time scale over multiple systems, as well as contribute to the decades-long effort to monitor and map the discs.

We will observe four systems, selected on the basis of observability and unusual behaviour. WD J0147+2330 has undergone dramatic variation in infrared flux originating in the dusty component of its debris disc (Wang et al., 2019), and our observations will determine if the gaseous component is similarly variable, allowing us to probe the dynamic production and destruction of gas and dust in these systems. The target is relatively bright so we will be able to obtain S/N≈ 100, allowing probes of variability to the $\sim 1\,\%$ level. WD J0845+2257 has slowly fading emission as described above. WD J0846+5703 has the brightest relative infrared excess of any known system, implying a large debris disc, yet modelling of the Ca II triplet emission profiles suggests the gas occupies a significantly smaller and narrower region of the disc (Gentile Fusillo et al., 2021), an observational mis-match that has yet to be reconciled. Finally, WD J0347+1624 shows rapid evolution of its emission lines with a period of order a year (Dennihy et al., 2020). With time series spectroscopy we will be able to map out the structure of the disc as in Figure 2, but also monitor the disc over multiple cycles of variability. This is not available from the longer-period systems such as SDSS J1228+1040, which would require 50 years of observations to monitor for just two cycles.

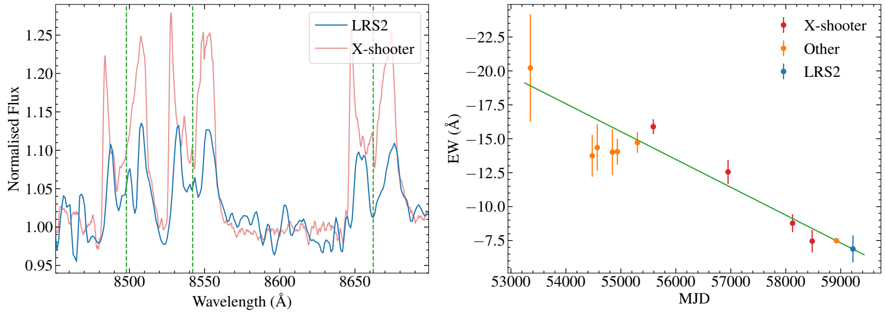

Figure 1: We used unallocated time in a recent semester to observe the Ca II triplet of WD J0845+2257. The observation demonstrated that LRS2 could resolve the double-peaked emission lines (left) and confirmed that the emission strength is decreasing over time (right).

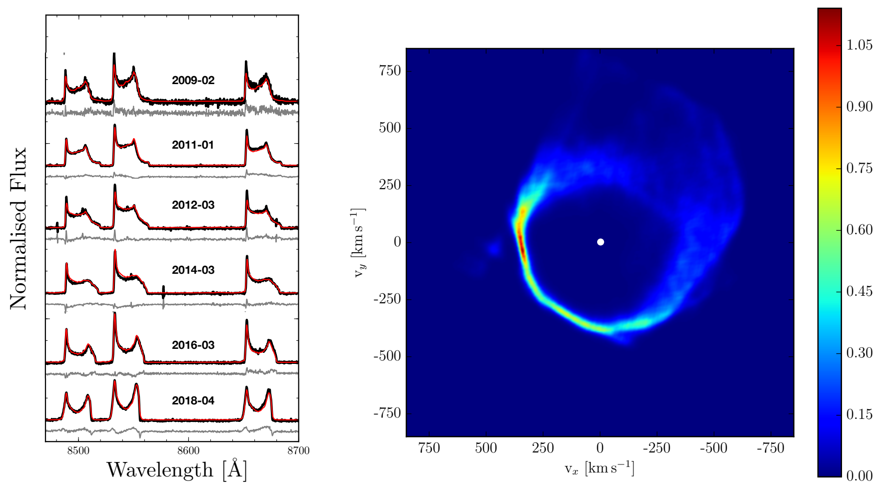

Figure 2: Left: The morphological variation of the Ca II triplet profiles (black) for the debris disc around the prototypical system SDSSJ 1228+1040, fit (red) by the Doppler map (right) with residuals (gray) also shown. Right: The Doppler map of the debris disc around SDSS J1228+1040 constructed from the multi-epoch spectra shown left.

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5. Description of Observations & Justification of Exposure Times

Each target will be observed 4 times with LRS2-R during the semester at roughly one-month interviews, although exact spacing is unnecessary. Exposure times were estimated using the online exposure time calculator, with the previous observation of one of the targets (Figure 1) used to verify that the predicted exposure times returned the desired S/N of 30. For the first target, the required exposure time for S/N 30 was so short in comparison to the overheads that we increased the request to S/N 100, allowing more precise measurements of line variation. This target is also not visible in March, so all four observations should be taken in Dec–Feb.

Object Table

Object Name	# of Objs.	RA (hh:mm)	Dec (±dd:mm)	Mag.	Filter or Wavelength	Acquisition Indentification Method
WD J0147+2339	1	01:47	23:39	14.05	G	Finder Charts
WD J0845+2257	1	08:45	22:57	15.9	G	Finder Charts
WD J0846+5703	1	08:46	57:03	16.81	G	Finder Charts
WD J0347+1624	1	03:47	16:24	16.65	G	Finder Charts

Exposure Table

Object Name	S/N per resolution element	λ of S/N calc.	# of Visits	Overhead (#visits x req. Min)	# of Objects	Exposure time/visit (Mins)	Total Time (Mins)	Notes
WD J0147+2339	100	8500 Å	4	60	1	15	120	LRS2-R
WD J0845+2257	30	8500 Å	4	60	1	20	140	LRS2-R
WD J0846+5703	30	8500 Å	4	60	1	30	180	LRS2-R
WD J0347+1624	30	8500 Å	4	60	1	30	180	LRS2-R
Totals			16		4		620 10.33	 Hours

6. Availability of Tracks

Using the availability tool and the exposure time and overhead for each visit, we find 14, 29, 31 and 21 tracks respectively for the targets in the order they appear in the setup tables.

7. Description and Justification of Special Constraints

Visits for each target should be scheduled ≈ 1 month apart to probe monthly time scale variations in emission line morphology and strength as described in the science justification.

8. Status of Data Accquired Under Previous HET Observing Proposals

Data obtained in UT21-1-016 demonstrated that LRS2 could return useful science data for gaseous discs and strengthened the case that the emission from WD J0845+2257 is slowly fading. Observations from this proposal are required to confirm that the decrease has continued (or not) and compare this slow variation with known systems that evolve on faster time scales, providing a sufficiently detailed dataset for publication.