Hobby-Eberly Telescope
University of Texas
Phase I Observing Time Request
UT21-3

Proposal Title: Exploring the many modes of white dwarf gas disc variability with HET

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Abstract

Gaseous emission from planetary debris discs has been detected around a growing number of white dwarfs. The emission varies in both strength and line morphology, providing insights into the structure and dynamics of post-main sequence planetary systems. In some systems, the emission reveals a fixed, precessing disc structure, where time series spectroscopy can be used to generate detailed Doppler images of the disc. In others, the emission varies dramatically on short time scales, indicative of asteroid impacts onto the discs. Here we propose to monitor the gaseous emission at four white dwarfs on a monthly timescale with HET. The four systems all have different emission behaviour. In one system the flux is slowly declining over years, in contrast to the rapid declines seen at other systems. In another, the disc emission is unusually narrow, and may be indicative of ring-like structures. A third system shows large infrared flux variations, and we will see if they are matched by changes in gas emission. The final system shows a steady variation with a roughly year long period. None have been observed on monthly time scales before, so this program will provide a new observational constraint on the varied behaviour of these fascinating systems.

2. Observing Request Summary

TELESCOPE REQUEST

Total Time Requested: 10.3 hrs

Suggested Priority Allocation: p0(0) p1(0) p2(10.3) p3(0) hrs

Pr4 Time Usable: hrs

Total Visits Requested: 16

Collaborative Proposal: no

Instrument Requested: LRS2

SPECIAL CONSTRAINTS

Time Critical Observation: no

Synoptic Observations: no

Moving Target: no
Moon Constraints: any
Sky Transparency Constraint: S - Spectroscopic (50-90%)
Target of Opportunity: no
Special Calibrations Needed: no
Seeing Constraint: 1.8 arcsecs
Other Constraints: Each of 4 targets should be observed approximately monthly.

3. Graduate Students

Data for Graduate Students: no

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 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 Keplerian 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 and most-studied 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 1, 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 weakening over a long time scale, a hitherto unforeseen behaviour. 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 tentaive 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. 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 disc, yet has narrow emission lines implying a small 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 1, 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.

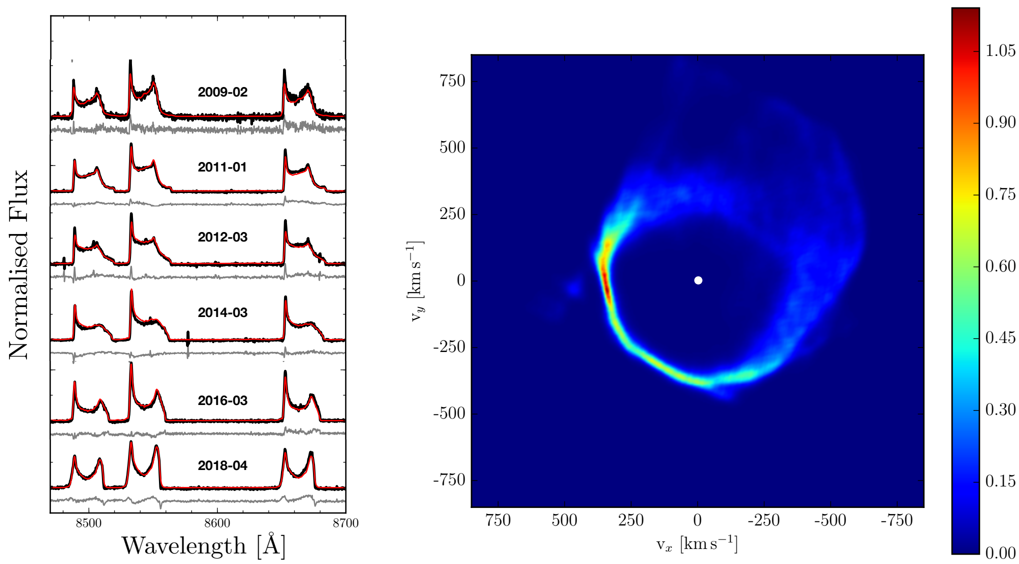

Figure 1: Left: The morphological variation of the Ca II triplet profiles (black) for the debris disc around the prototypical system SDSSJ 1228+1040, fit (red) by the Doppler map (right) with residuals (gray) also shown. Right: The Doppler map of the debris disc around SDSS J1228+1040 constructed from the multi-epoch spectra shown left. The method used is analogous to that used for CT scans in hospitals, where multiple 1D attenuation images are obtained and combined to produce a 2D image/slice of the patient. Here we use spectra giving 1D radial velocity images to combine into a 2D velocity image.

References

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Gänsicke, B. T., Schreiber, M. R., Toloza, O., et al. 2019, , 576, 61. doi:10.1038/s41586-019-1789-8

Trevascus, D., Price, D. J., Nealon, R., et al. 2021, , 505, L21.

Malamud, U., Grishin, E., & Brouwers, M. 2021, , 501, 3806.

5. Description of Observations & Justification of Exposure Times

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 25, 10, 10 and 22 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.