Part 1

Population and Evolution

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The Low State Temperature Distribution and First Chemical Abundances of White Dwarfs in Polars

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Abstract.
During the low optical brightness states of AM Her systems (polars) when accretion has declined to a very low value, the underlying magnetic white dwarf photosphere can be modelled without the complication of thermal bremstrahlung and cyclotron emission from the luminous accretion column. The far ultraviolet spectra can be modelled with high gravity Solar composition photospheres. In this way, I present new temperatures and the first chemical abundance estimates for the white dwarfs in three selected polars from the IUE NEWSIPS archive. For the white dwarf in V834 Cen with T_{eff} = 16,000K, Si/H = 0.1 Solar, C/H = 0.5 Solar, for BY Cam, T_{eff} = 17,000K, Si/H = 0.1, C/H = 5 Solar and for RX J1313-32, T_{eff} = 22,000K, Si/H = 0.1 Solar, C/H = 0.1 Solar. The temperature distribution of 24 white dwarfs in polars with known temperatures above and below the period gap is compared with the distribution of the white dwarf temperatures in dwarf novae during quiescence. In both cases, the magnetic white dwarfs in polars are significantly cooler than the non-magnetics. For all CV white dwarfs, magnetic and non-magnetic with $T_{eff} <$ 12,500K, 91% of the objects (10 out of 11) are magnetics in polars. This suggests that long term accretion heating and cooling of white dwarfs in polars differs from the effects of long term accretion in non-magnetic disk accretors.

1. Introduction

The physics of magnetic accretion at the highly magnetic white dwarf surface in polars is poorly known. We do not yet understand the lateral spread (sideways diffusion) and downward diffusion of accreted matter, and the long term heating of the magnetic white dwarf (compared with the heating due to disk accretion). Yet it is these very systems which offer us tantalizing possibilities for increasing our understanding through studies during their low optical brightness states. This is because, for reasons which remain unexplained, accretion declines to an extremely low rate during these low states and hence the emission contribution from thermal bremstrahlung and cyclotron sources from the accretion column is no longer evident in their far ultraviolet spectra. All that is left to observe is the bare magnetic white dwarf with relatively rapidly cooling polar accretion regions. By using white dwarf model atmospheres to analyze far UV spectra

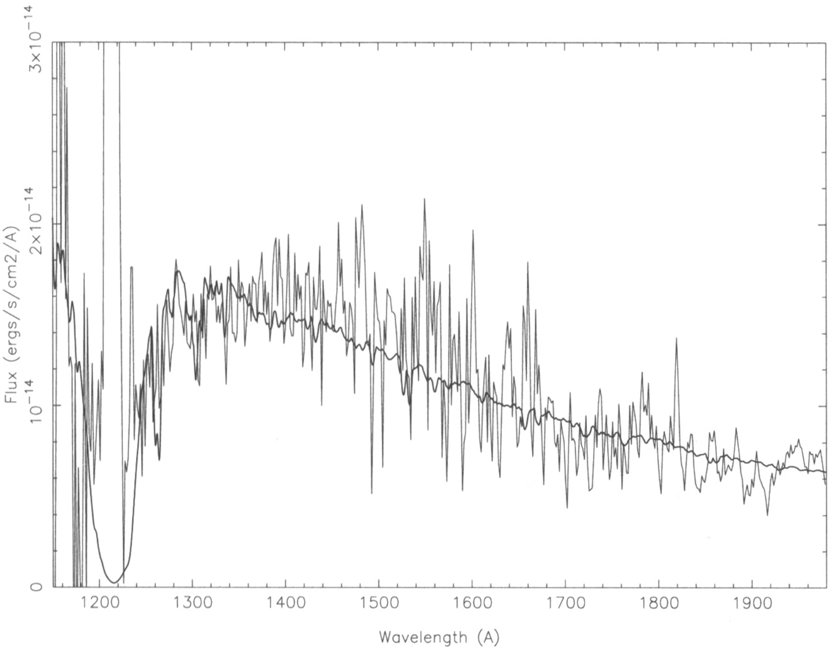

Figure 1. The observed IUE low state spectrum (SWP56879) of RX J1313-32 (flux F_λ versus wavelength (Å)) with the best-fitting white dwarf model atmosphere (thicker black line) having $T_{eff} = 18,000$K, log $g = 8$, with Si/H = 0.1 Solar, and C/H = 0.1 Solar.

obtained with IUE and HST during low states, new insights are possible on all of the above questions.

Here I present the first results on the chemical abundances of the accreted atmospheres of the white dwarfs in polars starting with the prototype AM Her itself, V834 Cen, BY Cam and RX J1313-32. For comparison, the metal abundance derived by Sion et al. (1998) for the magnetic white dwarf in the pre-CV (pre-IP?) V471 Tauri will also be compared. Next, I present the latest information on the low state temperature distribution of the magnetic white dwarfs in polars and compare their temperature distribution with the white dwarf temperatures in dwarf novae. I do this in two ways: number versus T_{eff} distribution histograms and by using the distribution function of magnetic and non-magnetic white dwarf temperatures versus orbital period.

2. Chemical Abundances

Our knowledge of chemical abundances derives from fitting Solar composition high gravity model atmospheres to the low state spectra of polars. and varying the abundances of individual elements until the best fit is achieved. The first

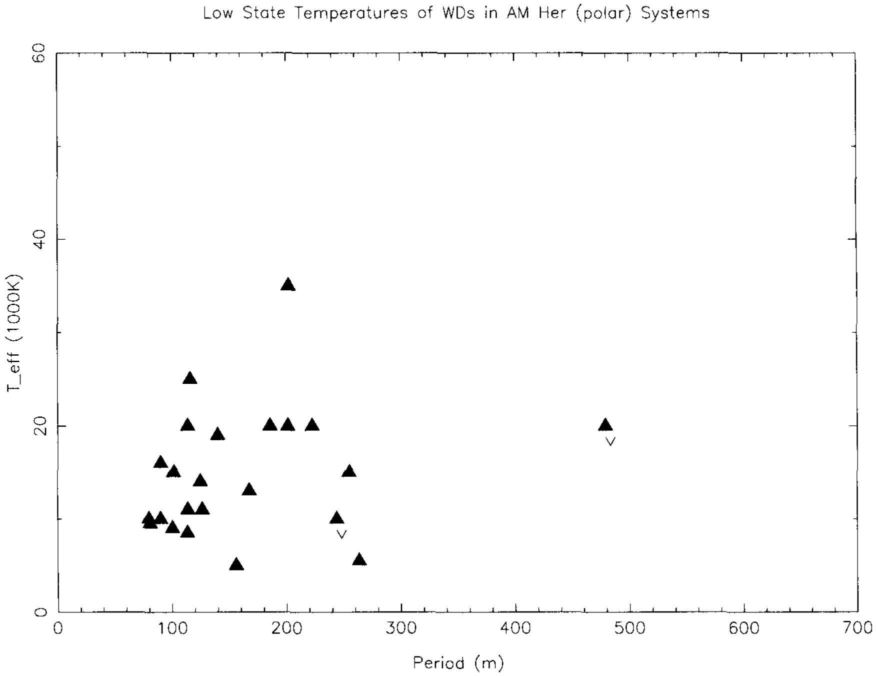

Figure 2. The orbital period (minutes) versus white dwarf T_{eff} (K) diagram for the white dwarfs in polars (triangles) with temperatures determined during their low states.

abundances derived in this way were obtained by DePasquale & Sion (2001) who carried out fits to the white dwarf in AM Her during its low states at different times following the last previous high states. On average, they found that $T_{eff} = 20,400$K at UV minimum (when the field is perpendicular to the line of sight) and 23,500K at UV maximum (when the magnetic pole is facing the observer). These temperatures are close to the values found by Gänsicke (1997). DePasquale & Sion (2001) carried out abundance fits and found Silicon abundances, Si/H, from 14 spectra ranging between 0.001 Solar and 0.05 Solar. There was no apparent difference in abundance with increasing time since the high state nor between spectra at UV maximum and UV minimum. For comparison, Sion et al.(1998) found that Si/H = 0.001 from fitting a detected photospheric Si III (1206) absorption feature in the magnetic white dwarf in the pre-CV V471 Tauri when the large accretion cap is facing the observer (X-ray rotational phase 0.5).

Since polars are very faint during their low states, IUE observations were possible for only a few systems. The archival spectra are quite noisy. A search of the archive revealed three systems with spectra of marginal but sufficient quality for a photosphere analysis, V834 Cen, BY Cam and RX J1313-32. The

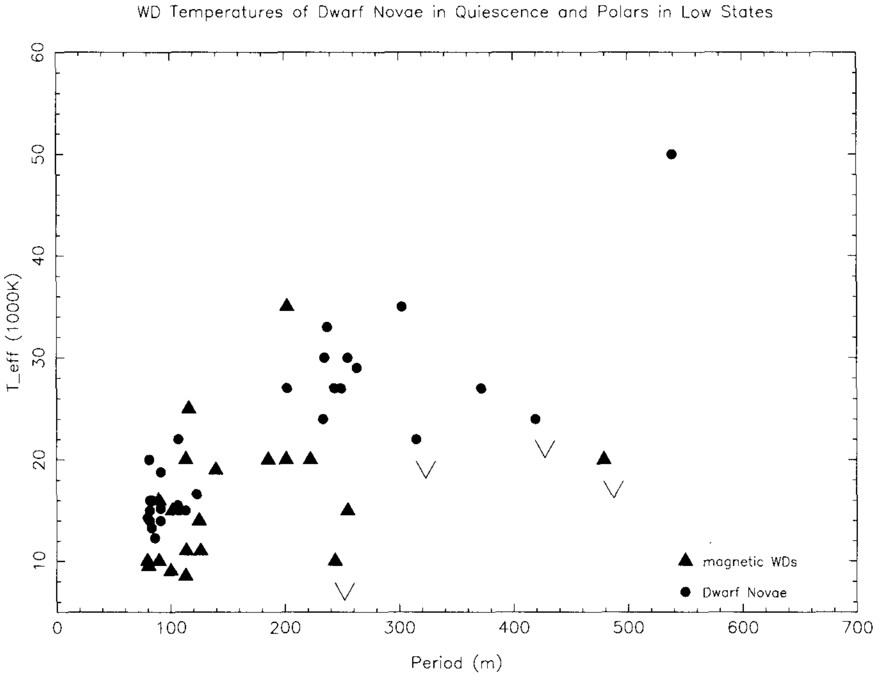

Figure 3. The orbital period (minutes) versus white dwarf T_{eff} (K) diagram for the white dwarfs in dwarf novae during quiescence (filled circles) and the white dwarfs in polars during low states (triangles).

low state temperatures of these systems were first derived by Gänsicke (1997). Here, I present new temperatures and estimate the chemical abundances. For RX J1313-32, the best-fitting model revealed $T_{eff} = 18,000\text{K} \pm 1000\text{K}$, Si/H = 0.1 Solar, C/H = 0.1 Solar. This model fit is displayed in Figure 1. Sinilarly, for V834 Cen, the best-fitting model yielded $T_{eff} = 16,000\text{K} \pm 1000\text{K}$, $\log g = 8$, Si/H = 0.1 Solar and C/H = 0.5 Solar. For BY Cam, the same fitting procedure led to a best-fitting model with $T_{eff} = 22,000\text{K}\pm 1000\text{K}$, $\log g = 8$, Si/H = 0.1 Solar and C/H = 5 Solar.

3. The Low State Temperature Distribution of the White Dwarfs in Polars

Is there a difference in long term heating between the accreting white dwarfs in polars and the accreting white dwarfs in disk systems? If so, does it arise from a difference between a magnetic accretion geometry and disk (tangential) accretion geometry? It was first noted by Sion (1991) that magnetic white dwarfs in polars tended to be cooler, at the same orbital period, than the disk-accreting white dwarfs in dwarf novae and nova-like variables. This conclusion was bolstered by

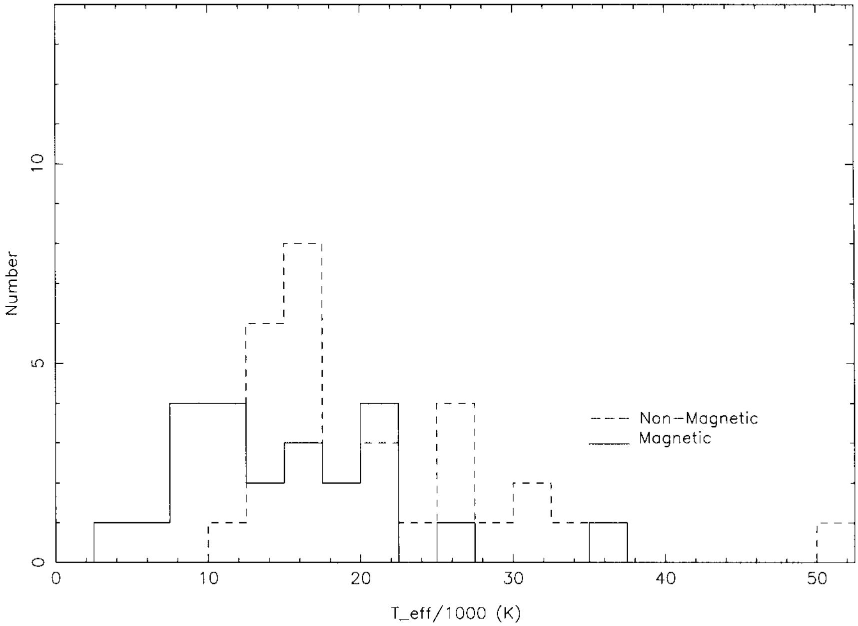

Figure 4. A histogram of number versus T_{eff} for the magnetic white dwarfs in polars during low states (solid lines) in comparison with the white dwarfs in disk-accreting dwarf novae during quiescence (dashed lines). Note that below 12,500K, 98% of the white dwarfs are in polars.

a re-examination of an increased sample of white dwarf temperatures in polars presented in the review by Sion (1999). Here, I discuss a sample size of magnetic accretors one-third larger than in Sion (1999), including 3 new cool magnetic degenerates in polars presented at this meeting (see the papers by Schmidt 2004, Szkody 2004), two of which, SDSS1553+5516 and SDSS13254+0320, were recently discovered in the Sloan Digital Sky Survey (Szkody et al. 2003).

For systems below a period of 2 hours (i.e., below the period gap) the average temperature of magnetic white dwarfs in polars is $< T_{eff} >= 13,710$K while non-magnetic white dwarfs in dwarf novae have $< T_{eff}> = 15,547$K. For the magnetic white dwarfs in polars above a period of 3 hours (i.e., above the period gap), $< T_{eff}> = 17350$K while for non-magnetic white dwarfs in dwarf novae, $< T_{eff} >= 31,182$K. In Figure 2, I display the temperatures (black triangles) of all of the magnetic white dwarfs in polars versus their orbital period in minutes. In Figure 3, I display the temperatures of all of the white dwarfs in dwarf novae during quiescence (filled circles) together with the magnetic white dwarfs in polars (filled triangles).

In Figure 4, I display a histogram of number versus T_{eff} for the magnetic white dwarfs in polars during low states (solid lines) in comparison with the white dwarfs in disk-accreting dwarf novae during quiescence (dashed lines). Note that below 12,500K, 98% of the white dwarfs are in polars. Note that for 11 magnetic and non-magnetic sytems with white dwarf $T_{eff} < 12,500$K, 91% of the objects are magnetic WDs in polars. While we cannot dismiss a possible role for observational selection, we believe the evidence is compelling enough to support our conclusion that magnetic white dwarfs in polars are cooler (and may cool differently) than disk-accreting, non-magnetic white dwarfs in dwarf novae. The effect of long term accretion heating on magnetic white dwarfs in polars may be different than the effect of long term accretion heating in disk accretors.

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