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Rotation Velocities of DA White Dwarfs with Convective Atmospheres

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Abstract. The sharp Hα NLTE line cores of hydrogen rich (DA) white dwarfs allow their projected rotational velocities to be determined. High resolution optical spectra of 22 stars obtained with the Keck I telescope are matched by synthetic spectra computed from a grid of NLTE model atmospheres. We concentrate preferentially on hydrogen-rich white dwarfs with convective atmospheres, i.e. with $T_{\rm eff} < 14\,000$ K. Previous analyses found DA white dwarfs hotter than 14 000 K to be very slow rotators and rarely show any spectroscopically detectable rotation. For 19 of our program stars we were able to derive projected rotational velocities or upper limits. Combining our results with those from two similar studies (Heber et al 1997, paper I and Koester et al. 1998, paper II), we have obtained information of 56 DA white dwarfs. The fraction of rotating DA white dwarfs whose line profiles can be matched for a vanishing projected rotation velocities is high for hot white dwarfs with radiative atmospheres (25 out of 28) with upper limits ranging from $1\,{\rm kms}^{-1}$ to $24\,{\rm kms}^{-1}$, whereas amongst the cool white dwarfs with presumably convective atmospheres only for a few stars (8 out of 22) no additional line broadening has to be invoked to explain their observed Hα line profiles resulting in upper limits to $v \sin i$ of $7\,{\rm kms}^{-1}$ to $35\,{\rm kms}^{-1}$.

1. Introduction

Since white dwarfs are compact remnants of low and intermediate stars, they should be very fast rotators if angular momentum is conserved during stellar evolution. However, recent studies (papers I and II) found that white dwarfs rotate rather slowly. Particularly, previous analyses dealt with hot white dwarfs with radiative atmospheres. In addition to the former studies we therefore expanded the sample to cooler objects having convective atmospheres. This analysis is based on spectra taken by I.N. Reid at the at the Keck I telescope equipped with HIRES (Reid 1996).

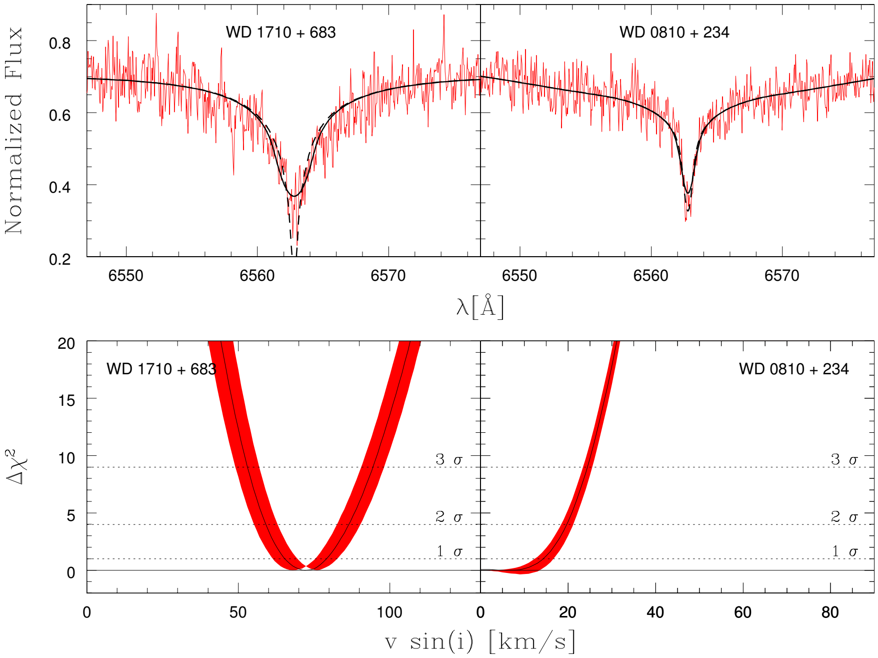

Figure 1. Sample spectra (upper panel) and run of χ^2 (lower panel) for a rotating (WD 1710+683) and a non rotating (WD 0810+234) DA white dwarf. The dashed lines display synthetic spectra without rotation, while solid lines display the most probable v sin i (WD 1710+683), respectively the upper limit at a 3σ level (WD 0810+234).

2. Projected Rotational Velocities

The technique for the rotational - analysis of the Hα line profiles is described in paper I. Briefly, the NLTE synthetic Hα line profiles are interpolated from a grid of model spectra. Using the rotation profile for line broadening, we computed a set of synthetic spectra for each object by varying v sin i. Finally, these sets were matched to the innermost parts of the observed Hα line cores (about ± 20 Å) by calculating the χ^2 deviations (Napiwotzki et al. 1999). Subtracting the minimum χ^2 we obtain a relation of $\Delta\chi^2$ with $v \sin i$ (see Fig. 1).

Projected rotational velocities for 19 of our 22 program stars have been determined. For three stars no reasonable fit could be obtained. For seven stars of our sample the best fit was achieved for vanishing rotation (v sin i = 0 within the error limits), whereas another twelve stars showed extra broadening.

3. Results

Fig. 2 displays all 56 stars from our own analysis as well as the stars from the papers I and II in a $T_{\rm eff}$ - log g diagram.

We divide the complete sample at a borderline at $T_{\rm eff} = 14\,000$K into a hot one with radiative atmospheres and a cool one with presumably convective atmospheres. There are, however, six stars with $T_{\rm eff}$ close to the borderline,

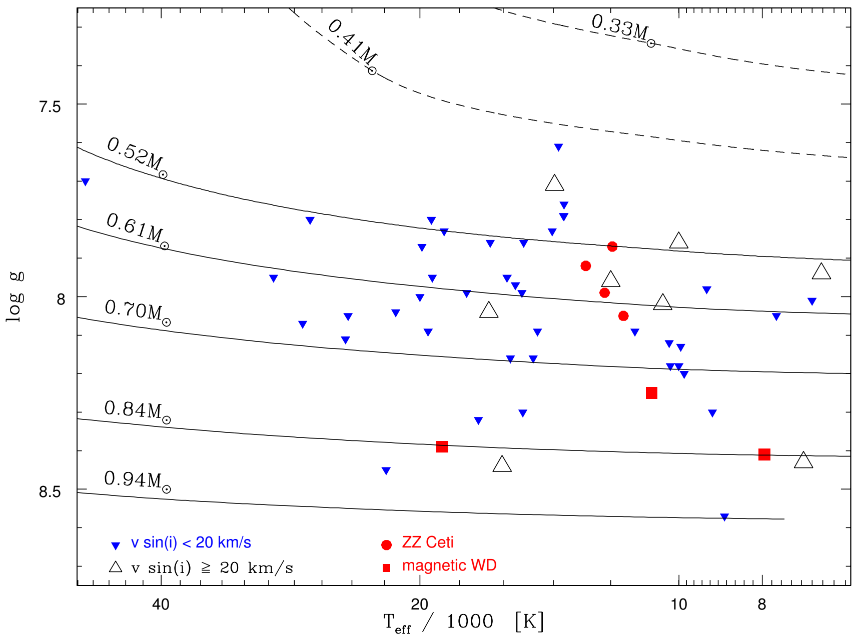

Figure 2. $T_{\rm eff}$ - $\log g$ diagram for DA white dwarfs from paper I and II and this paper. Also shown are evolutionary tracks for white dwarfs (Blöcker 1995, solid lines and Driebe et al. 1998, dashed lines) labeled with the stellar masses.

i.e. in the transition zone from radiative to convective atmospheres. Therefore we consider a group of hot white dwarfs consisting of all program stars with $T_{\rm eff} = 14\,600$K or higher and a group of cool white dwarfs with $T_{\rm eff} = 12\,800$K or less.

- **Hot stars:** For all but three of our 28 stars with $T_{\rm eff} \geq 14\,600$K there is no hint of rotation and upper limits ranging from $1\,{\rm km\,s^{-1}}$ to $24\,{\rm km\,s^{-1}}$. However, the line broadening is more likely to be due to magnetic fields in one object (see paper II). Therefore only two rotating object are found in the hotter temperature range, which are amongst the fastest rotating DA stars known.

- **Cool stars:** For lower temperatures we find no hint of extra broadening in 8 out of 22 stars with upper limits to the projected rotational velocities ranging from $7\,{\rm km\,s^{-1}}$ to $35\,{\rm km\,s^{-1}}$. For the remaining stars extra broadening has to be accounted for. Again the broadening is probably caused by magnetic fields in three cases.

- **ZZ Ceti stars:** For the four ZZ Ceti variables the line profiles are not well matched by rotational profiles (see paper II).

4. Summary and Discussion

By means of rotationally broadened NLTE synthetic spectra we analyzed the high-resolution Hα line profiles of 22 hydrogen rich white dwarfs (DA) observed with HIRES at Keck. A χ^2 minimization method was used to determine projected rotational velocities for 19 of our 22 program stars. We combined our measurements with data from previous analyses (Heber et al 1997, Koester et al. 1998) which were based on similar spectra and model atmospheres to derive a homogenous set of v sin i measurements of 56 DA white dwarfs. This sample contains four ZZ Ceti variables and four probably magnetic white dwarfs. In the latter cases the widening of the line core is caused by Zeemann splitting.

As already noted in paper II the results for hot stars with supposedly radiative atmospheres differ significantly from those for the cooler stars with supposedly convective atmospheres. Our sample contains 28 hot und 22 cool DA stars totally. Excluding the magnetic white dwarf from the hot sample, it was possible to match the observed profiles with the synthetic spectra well for the remaining 27 stars. Only in two cases significant rotation was detected. For all other hot stars the spectral analysis did not reveal any rotation.

For more than half of the cooler DA stars, however, the Hα profile did show evidence for additional broadening. The spectra of ten cool stars were consistently matched by line profiles with projected rotation velocities between $23\,\mathrm{km\,s^{-1}}$ and $72\,\mathrm{km\,s^{-1}}$. Close inspection of the line profiles revealed significant deviations from the rotational profile for the four ZZ Ceti stars, however.

All four ZZ Ceti stars in our sample show evidence for peculiar line broadening. In principle, the rotation velocity of a ZZ Ceti star can be determined independently by measuring the rotation induced splitting of the pulsation modes. The low rotation periods ($\approx$ 1 day) derived from asteroseismology are at variance with the spectroscopic results. Hence the line broadening can not be caused by rotation and other broadening mechanisms have to be invoked. In view of the ZZ Ceti results, it may be premature to conclude that the extra broadening that we see in the non-variable cool DAs is due to rotation. Since the average rotation velocities in a sample of hot white dwarfs should be the same as in a sample of cool white, we conjecture that the physics of Hα line formation in convective white dwarf atmospheres is not yet sufficiently well understood. A larger sample is provided by the ESO SPY project (Napiwotzki et al. 2003, and this volume), allowing precise measurements of the Hα profile for hundreds of white dwarf. This will also improve our knowledge of white dwarf rotation.

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