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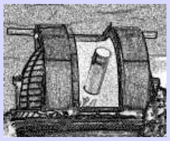

Abstract

We determined rotational velocities of eight hydrogen-deficient (pre-) white dwarfs from high-resolution optical échelle spectra obtained with the Keck telescope (Hawaii) and the NTT (ESO, La Silla, Chile) by comparison to synthetic NLTE model fluxes.
In contrast to previous investigations on hydrogen-rich DA white dwarfs which yield only very small rotational velocities, the values of our programme objects amount up to v•sin i = 80 km/sec.

Introduction

Detailed analyses of the NLTE Balmer line cores of DA white dwarfs have revealed that for the vast majority the rotational velocities are extremely low, so that they cannot be detected, even with high-resolution high-S/N spectra (Koester et al. 1998). This unexpected behavior poses the question how these WDs have lost their angular momentum during previous evolutionary phases. To our best knowledge no one has ever tried a similar analysis on non-DA white dwarfs or hydrogen-deficient pre-white dwarfs. The only exception is the PG 1159-type central star of NGC 246, whose high rotational rate is well known since many years (Heap 1975, Rauch & Werner 1997). High-resolution optical spectra of PG 1159 stars can in principle be used to resolve the narrow line cores (in absorption or emission) of He II, C IV, and O IV and to constrain the rotational velocity.

Observations and Data Reduction

During several observation runs in the recent years we have gathered a number of high-resolution échelle spectra of PG 1159 stars. They were obtained at the 10m Keck telescope (Hawaii) employing the HIRES instrument and at the 3.5m NTT at ESO (Chile) with the EMMI spectrograph. The most difficult step in the data reduction is to determine the stellar continuum, due to the fact that many absorption lines are extremely broad. In many cases normalization of the spectra was performed by comparing them with low resolution long slit spectra, which were obtained during the last 15 years and stored in a spectral database at Tübingen. However, many uncertainties remain in this step, as can be seen on hand of those objects for which we have taken Keck and NTT spectra. In the particular cases of NGC 246 and NGC 7094, however, the differences are regarded as significant, implying spectral variability.

Comparison with Synthetic Spectra

Spectral analyses have been performed by means of NLTE model atmosphere techniques (Tab. 1). Synthetic spectra af these models have be convolved with rotational profiles in order to compare them to the observation (Fig. 1). The results are summarized in Tab. 2.

Table 1. Photospheric parameters (1: Werner et al. 1996, 2: Rauch& Werner 1995, 3: Dreizler & Herber 1998, 4: Dreizler et al. 1995, 5: Dreizler et al. 1997) of our programme stars (sorted by increasing surface gravity g). log g is given in cgs units, the abundances are number ratios.

object	T_{eff}/ kK	log g	H/He	C/He	O/He	Ref
Abell 43	110	5.7	3.33	0.17	0.0	5
NGC 7094	110	5.7	3.33	0.17	0.0	5
NGC 246	150	5.7	0.0	0.5	0.04	2
RX J2117+3412	170	6.0	0.0	0.5	0.13	1
HS 2324+3944	130	6.2	2.0	0.3	0.006	4
PG 1159-035	140	7.0	0.0	0.6	0.1	3
PG 2131+066	95	7.5	0.0	0.3	0.1	3
PG 0122+200	80	7.5	0.0	0.3	0.1	3

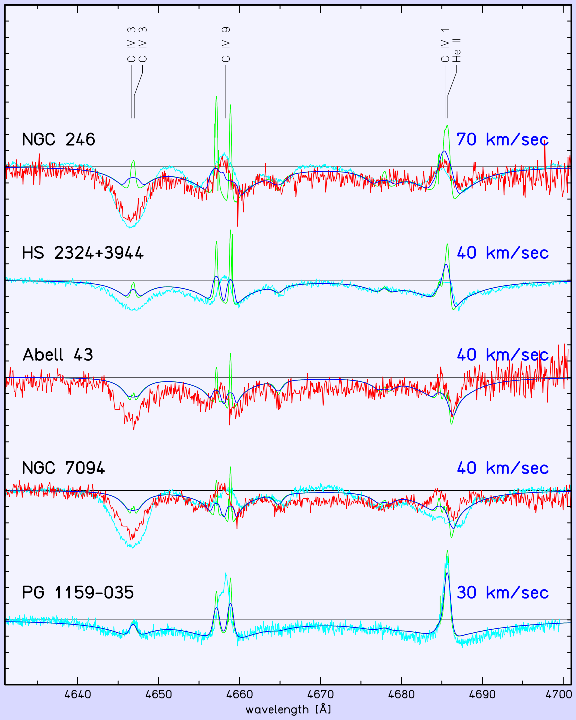

Figure 1. Example for the comparison of observed spectra with synthetic line profiles. The colors denote: NTT spectrum, Keck spectrum, model without rotation, model with rotation. One ordinate tickmark corresponds to 10% of the relative flux.

Depending on the wavelength range and quality of the available spectra, different lines have been evaluated for the determination of the rotational velocity (Tab. 2). However, we are aware of some problems (Köper et al. 2001). E.g. the models fail to explain all observed lines perfectly, most probably due to the lack of reliable atomic data, and emission features are formed in the outer atmospheric layers and tend to be affected by a stellar wind. This concerns particularly the C IV doublet at 5801/5812Å. Thus, care must be taken when interpreting line strengths and profiles.

Table 2. Rotational velocities (v_{rot}•sin i given in km/sec) measured from individual lines: 1: C IV 4441 Å, 2: C IV 4547 Å, 3: C IV 4658 Å, 4: He II 4686 Å, 5: C IV 5018 Å, 6: He II 5412 Å, 7: He II 6560 Å. ^{up} and ^{low} denote upper and lower limits, respectively, "-": line not suited for a reliable analysis, "n": no observation available.

object	1	2	3	4	5	6	7
Abell 43	30^{low}	-	42 ± 13	-	-	30^{low}	-
NGC 7094	30^{low}	-	25^{low}	46 ± 16	-	40^{low}	-
NGC 246	40^{low}	-	77 ± 9	80 ± 20	70 ± 10	-	80 ± 20
RX J2117+3412	45^{low}	-	79 ± 3	60 ± 5	-	25^{low}	65 ± 15
HS 2324+3944	25^{low}	-	63 ± 7	50 ± 10	-	-	37 ± 7
PG 1159-035	-	0^{+15}	0^{+15}	0^{+15}	-	-	-
PG 2131+066	-	-	15^{up}	30^{up}	-	n	n
PG 0122+200	25^{up}	-	-	-	-	n	n

Results and Conclusions

All five low-gravity (i.e. high-luminosity) PG 1159 stars display signatures of rotation in the line cores. There appears a clear evidence that the more massive of these have higher rotational velocities (Fig. 2). The fast rotation of NGC 246 (v_{rot}•sin i = 77 km/sec) is confirmed. The rotational velocities in three luminous hybrid-PG 1159 stars (Tab. 1, with H) are of the order v_{rot}•sin i = 40 km/sec. The slow rotation of PG 1159-035, deduced from asteroseismology, is corroborated.
For a more precise analysis of rotational velocities, however, high-resolution and high-S/N optical and UV spectra are required.

Table 3. Adopted otational velocities of our programme stars. The errors are determined from comparison between observed and synthetic spectra (convolved with rotational profiles of different velocities).

Objekt	v_{rot}•sin i / km/sec
Abell 43	42 ± 13
NGC 7094	46 ± 16
NGC 246	77^{+23}_{-17}
RX J2117+3412	68^{+14}_{-18}
HS 2324+3944	42^{+28}_{-12}
PG 1159-035	0 ± 15
PG 2131+066	15^{up}
PG 0122+200	25^{up}

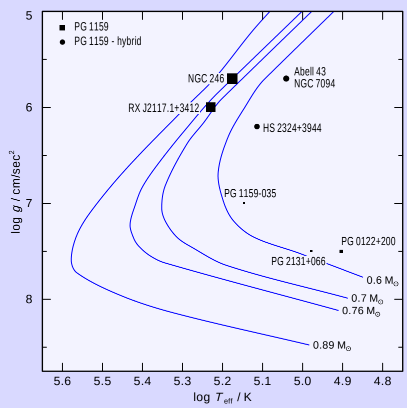

Figure 2. Position of our programme stars in the log T_{eff} − log g plane compared to evolutionary tracks of helium-burning post-AGB stars (Wood & Faulkner 1986, labeled by the stellar core mass). The symbol's size is equivalent to the rotational velocity of the star.

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