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High resolution UV spectroscopy of two hot (pre-) white dwarfs with the Hubble Space Telescope*

KPD 0005+5106 and RXJ 2117+3412

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Abstract. High resolution UV spectra of KPD 0005+5106 and RX J 2117+3412 have been obtained with the Goddard High Resolution Spectrograph aboard the Hubble Space Telescope. The data were subject to a non-LTE model atmosphere analysis.

For KPD 0005+5106, the hottest known helium-rich white dwarf, the C and N abundances as well as an upper limit for O have been determined (log (C/He)=-3, log (N/He)=-6, log (O/He)<-5.5, by number), improving results from previous studies. These abundances are severely at odds with diffusion/radiative forces theory. They are possible primordial relics of their ancestral progenitor in the post-AGB phase. Besides the photospheric lines with a velocity shift of +35 km s^{-1} we find a distinct interstellar/circumstellar absorption line system shifted by -15 km s^{-1}.

Difficulties are encountered with line profile fits to the spectrum of RX J 2117+3412, an extremely hot hydrogen-deficient (PG 1159-type) central star. Some of the strong C IV and O VI lines are too narrow to match the observations. Either the neglect of wind-effects in our models or the lack of reliable line broadening data may be responsible for this. A weak O V 1371Å line is detected which suggests, that the effective temperature is higher than thought before ($T_{\rm eff}$=170 000 K). This means that RX J 2117+3412 is the hottest known PG 1159 star together with H1504+65. Interstellar and photospheric line spectra are clearly separated, with shifts of -19 and +23 km s^{-1}, respectively.

Both stars exhibit a strong O VIII emission line near 2977Å, which cannot be of photospheric origin but probably arises from shock fronts along a stellar wind. The line widths are of the order of 150 km s^{-1}. In addition, KPD 0005+5106 shows another, equally strong emission feature near 2982Å which either stems from photospheric N V or from non-photospheric C V.

Key words: stars: atmospheres – stars: evolution – stars: individual: RX J 2117+3412 – stars: individual: KPD 0005+5106 – white dwarfs

1. Introduction

KPD 0005+5106 and RX J 2117+3412 were selected as targets for high resolution UV spectroscopy with the Hubble Space Telescope (HST) because of previously detected peculiarities in their spectra.

KPD 0005+5106 is the hottest known DO (i.e. helium-rich) white dwarf ($T_{\rm eff}$=120 000 K). Since its discovery by Downes et al. (1985) it has been the subject of many studies, the last one based on a detailed NLTE model atmosphere analysis of optical, UV, and X-ray spectra (Werner et al. 1994, "WHF"). This star is outstanding not only because of its high temperature but also because it is the only white dwarf known to be surrounded by a corona (Fleming et al. 1993) and exhibiting ultrahigh-ionisation emission lines from O VIII (Werner & Heber 1992, Sion & Downes 1992). We speculated that these emissions originate from shock fronts created by mass-outflow. Abundances of C, N, O elements (or upper limits) were interpreted as being determined by diffusion and radiative levitation processes.

RX J 2117+3412 is an extremely hot ($T_{\rm eff}\approx$160 000 K) PG 1159-type central star of a planetary nebula (CSPN). It was

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discovered in the ROSAT X-ray survey and analysed together with optical spectroscopic data (Motch et al. 1993). Then Vauclair et al. (1993) showed that it belongs to the group of non-radial g-mode pulsators. The inspection of our spectra from several PG 1159-type central stars revealed that RX J 2117+3412 does show a prominent O VIII 6068Å emission line, similar in strength compared to KPD 0005+5106. Other PG 1159-CSPN showing this feature are Lo3 and Lo4, but their faintness made RX J 2117+3412 a primary target for a close inspection with HST. Unlike in the case of KPD 0005+5106 we have direct evidence in RX J 2117+3412 that mass-outflow is still on-going – as one would expect for a hot central star (see below). This together with the occurrence of O VIII lines corroborates the suspicion about current mass-outflow from KPD 0005+5106.

Both stars were observed at high resolution in the 2980Å region, because the presence of a strong O VIII line could be expected there. Deeper insight as to the origin of the ultrahigh-ionisation emissions was aimed at. In addition, spectra covering other wavelength regions were also taken in order to complement and improve the previous analyses. Particularly in the case of KPD 0005+5106 exact metal abundance determinations are highly desired as tests for predictions of diffusion theory.

2. Observations

HST observations of RX J 2117+3412 (V=13.2) and KPD 0005+5106 (V=13.3) were performed on May 31st and June 1st 1994, respectively. Each star was recorded with the Goddard High Resolution Spectrograph (GHRS) in the same wavelength regions and with equal exposure times. The spectra cover four wavelength ranges: 1229–1263Å (t_{exp}=13 min), 1274–1308Å (16 min), 1344-1378Å (11 min), 2959–3002Å (31 min). The G160M grating was used which gives a resolution of about 0.08Å, except for the reddest spectrum for which we used the G270M grating with a resolution of 0.1Å. The data were obtained with the FP-SPLIT=FOUR option which results in four subexposures which we co-added in order to reduce the photocathode fixed-pattern noise. The spectra are displayed in Figs. 1–3 and line identifications are listed in Tab. 1. It is obvious that the spectra suffer from flux calibration problems. Particularly in the case of KPD 0005+5106, which is essentially free of broad intrinsic spectral lines, we would expect smooth continuum fluxes. The strong flux increase near the blue end of the RX J 2117+3412 spectrum in Fig. 2b for example cannot be real.

Interstellar and photospheric lines have different radial velocity shifts and are well separated. The average values for KPD 0005+5106 are −15 and +35 km s^{-1}, respectively. The negative velocity shift of the interstellar lines in KPD 0005+5106 is in accordance with earlier measurements from an International Ultraviolet Explorer (IUE) spectrum (−23 km s^{-1}, Downes et al. 1987). However, the shift for the photospheric lines from the IUE data (−13 km s^{-1}) is quantitatively different from ours. This apparent discrepancy is caused by the fact that Downes et al. measured the N V and C IV (and Si IV) resonance lines which according to our much better HST spectra are dominated by interstellar/circumstellar contributions. Thus, they essentially did not measure the photospheric lines. (Their measurement for the He II 1640Å line (−7 km s^{-1}) must be regarded as uncertain because of the broad and noisy profile and blends with C IV lines. It is most probably of photospheric origin.) Fritz et al. (1990) come to the same conclusion and speculate further about evidence for different velocities between non-photospheric high and low ionisation features. They propose that the former originate from an expanding circumstellar H II region. On the basis of our new data we would not claim that such a difference is real. For RX J 2117+3412 we determine the interstellar and photospheric line shifts as to −19 and +23 km s^{-1}, respectively.

The only photospheric features in our HST spectra of KPD 0005+5106 are due to C IV 1230Å, Fe VII 1240Å, and N V (Fig. 1a). The N V resonance doublet is blended by a stronger interstellar component which, however, has a well distinguishable velocity shift. The Fe VII line was detected before in IUE data (Feibelman & Bruhweiler 1990), but see for a comment below. It is important that no oxygen lines are detected, neither O VI near 1290Å nor O V 1371Å. This will be useful to derive a strong upper abundance limit for this species. Most remarkable are the emission features near 2980Å which were discovered by Sion & Downes (1992) and they are here for the first time resolved in two lines separated by about 5Å. The blue component is undoubtedly due to an O VIII transition (wavelength from Garcia & Mack 1965) while the red component cannot be identified unambiguously. While it could be entirely due to C V, one cannot exclude that it contains a N V contribution or that it is even exclusively made up by nitrogen (see below).

As we have expected, the photospheric spectrum of RX J 2117+3412 is richer in spectral lines. Broad and relatively strong absorption troughs and isolated lines due to highly excited C IV and O VI transitions are detectable in Fig. 2. All O VI lines arise from n=5→7 transitions and it is immediately obvious that their observed positions do not coincide with the theoretically predicted wavelengths (from Moore 1970, 1979). A weak O V 1371Å line is present, too. Fe VII 1239.69Å is detectable, like in KPD 0005+5106. Another absorption feature redward by about 1Å can be seen in both stars, but it is probably not due to Fe VI 1240.07Å (contrary to the case of the hot DO PG 1034+001, see Werner et al. 1995a), because the wavelength would indicate a velocity shift significantly higher than for the other photospheric lines. In addition, no other Fe VI lines in the vicinity of O V 1371Å, which we would expect to see, too, are detectable. Instead it may originate from interstellar Mg II, 1239.93 and 1240.39Å, which would mean that also the Fe VII line is at least partially affected by Mg II.

Like all other PG 1159 stars (with the exception of PG 1144+001) RX J 2117+3412 does not show N V lines. Two unidentified absorption features are visible at 1366Å and 1368Å. For the first time we have observed the region around 2976Å where we have expected to see the O VIII emission feature (Fig. 3). It is indeed detected but in contrast to KPD 0005+5106 no other emission at 2982Å is there. We will discuss these differences later.

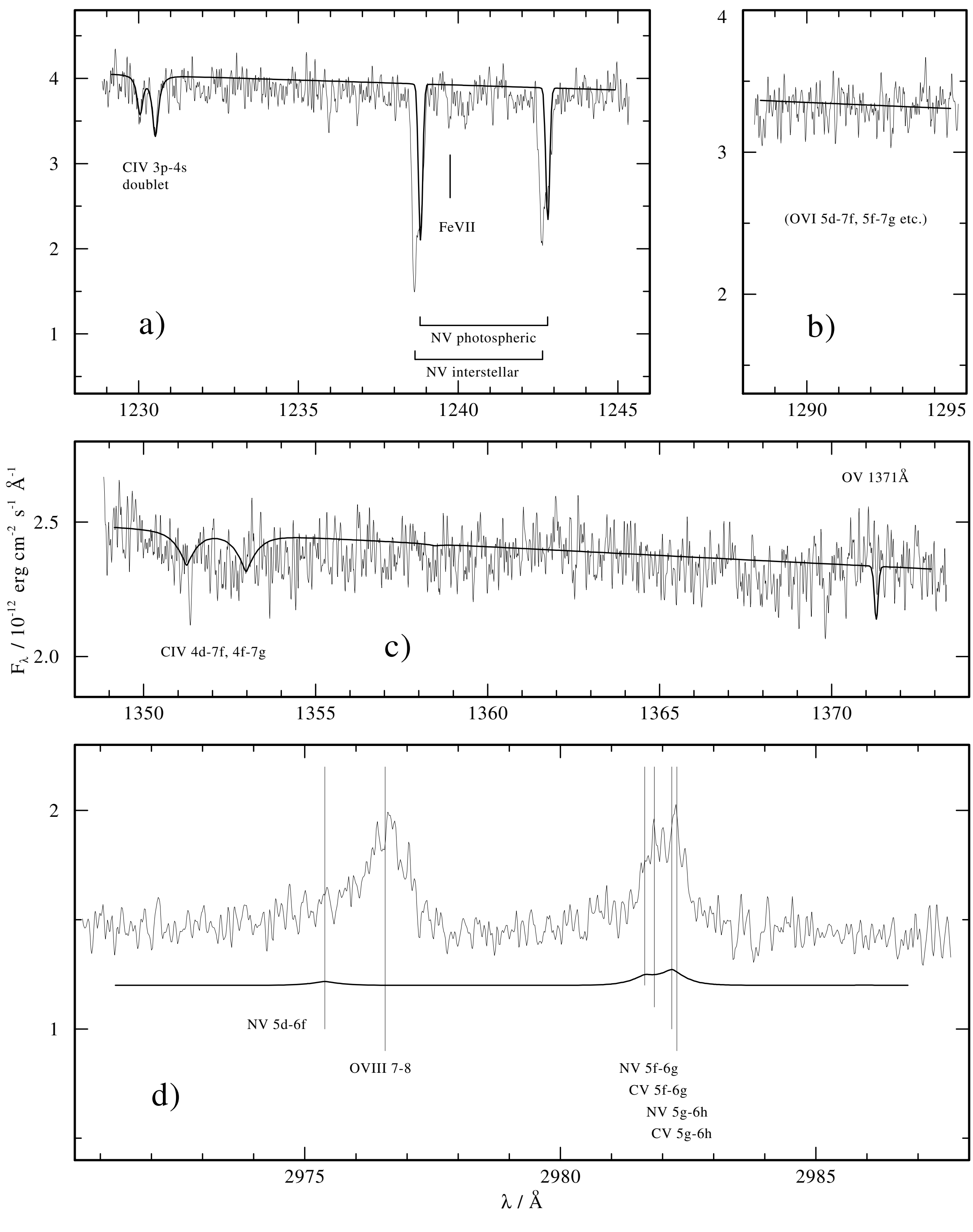

Fig. 1. HST GHRS spectra from the hottest known DO white dwarf, KPD 0005+5106. Overplotted are synthetic spectra. **a)** Photospheric and interstellar N V absorption components are resolved. **b)** No detection of O VI lines. **c)** O V is absent, too. **d)** Two emission features due to extreme ionisation stages, O VIII and C V/N V. Vertical bars indicate the laboratory wavelengths of the labeled lines. The down-shifted model spectrum shows only weak photospheric emissions due to N V. Thus, the observed emission lines are probably of non-photospheric origin. The stellar spectra were shifted to rest wavelengths by 35 km s^{-1}. Model parameters are $T_{\rm eff}$=120 000 K, log g =7, log (C/He)=−3, log (N/He)=−6, log (O/He)=−7 (number ratios), except for d) where we increased $T_{\rm eff}$ by 10 000 K and log (N/He)=−4. All observations were smoothed by a 0.03Å Gaussian and the synthetic spectra by a 0.1Å Gaussian in order to match the instrumental resolution

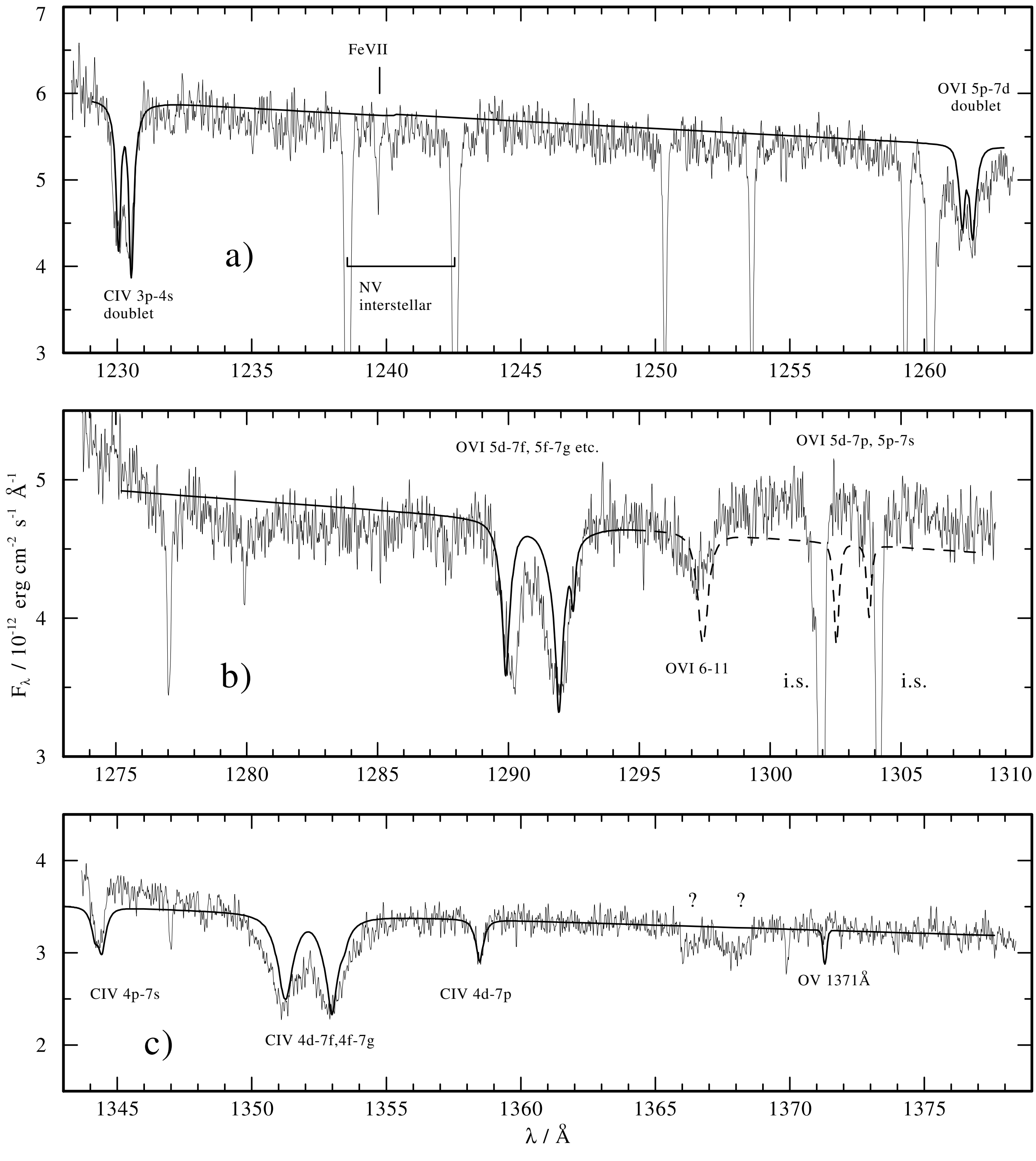

Fig. 2. HST GHRS spectra from the PG 1159-type central star RX J 2117+3412 together with model spectra. **a)** Two strong C IV and O VI doublets. All other absorptions are interstellar, particularly the N V resonance line. **b)** A spectral region with highly excited O VI lines. The mismatch of the observed and computed line positions follows from poorly known level energies. **c)** Strong, highly excited C IV lines appear together with two unidentified shallow absorptions. A weak O V 1371Å line is detectable which puts a tight limit to $T_{\rm eff}$. The stellar spectra were shifted to rest wavelengths by 25 km s^{-1}. Model parameters are $T_{\rm eff}$=170 000 K, log g =6, He/C/O=47.5/23.8/6.2 (number ratios). All observations were smoothed by a 0.03Å Gaussian and the synthetic spectra by a 0.1Å Gaussian in order to match the instrumental resolution

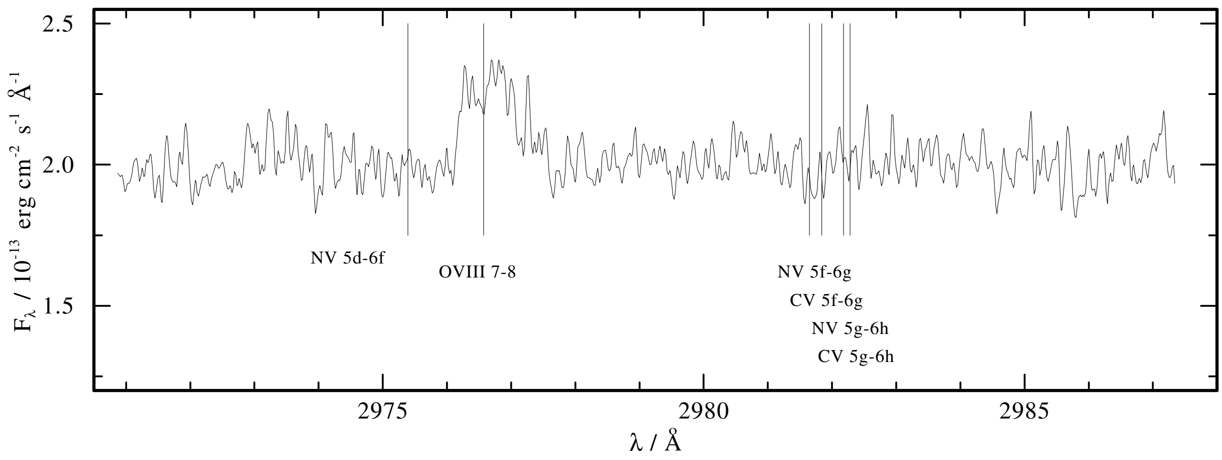

Fig. 3. The O VIII emission line in RX J 2117+3412. In contrast to KPD 0005+5106, no C V/N V emission component at 2982Å is visible. Vertical bars indicate the laboratory wavelengths of the labeled lines. The spectrum was shifted to rest-wavelengths by 25 km s^{-1} and smoothed with a 0.05Å Gaussian.

3. Line profile fits

NLTE model atmospheres and line formation calculations were performed in order to fit the observed line profiles. The model atmospheres are chemically homogeneous, static, plane-parallel, and in radiative equilibrium (Werner & Dreizler 1995).

3.1. KPD 0005+5106

Line profile fits to KPD 0005+5106 were performed using atmospheric models and atomic data as described in detail in Werner et al. (1995a). An additional improvement concerns the inclusion of the Hummer-Mihalas occupation probability formalism (Werner et al. 1995b), generalized to NLTE conditions (Hubeny et al. 1994). With the spectra at hand we are now able to improve the abundance determination of nitrogen and to further constrain the upper limit of the oxygen abundance. Effective temperature and surface gravity are taken from our previous study ($T_{\rm eff}$=120 000 K, log g =7). The WHF carbon abundance log (C/He)=-3.5 ± 0.5 is marginally compatible with the observed strength of the C IV doublet at 1230Å. An increase to log (C/He)=-3.0 gives a perfect fit (Fig. 1a).

Fig. 1a shows our best fit to the photospheric components of the N V resonance doublet. The derived abundance is log (N/He)=-6, a value which is significantly lower than that given in WHF (log (N/He)=-4). The basis for the high N abundance given by WHF was a very weak feature near 1620Å in the FOS spectrum which we attributed to N V. Probably this feature is not real. Furthermore, this high value was compatible with the strong N V resonance line but, as we see now in our high resolution data, interstellar material is mostly responsible for the total equivalent width. Taking into account the uncertainty in $T_{\rm eff}$ ($\pm$10 000 K) we estimate the error for the N/He determination to 0.5 dex.

From the absence of O V 1371Å and O VI lines near 1290Å we can derive an upper limit of the oxygen abundance. The O V 1371Å line is most sensitive to traces of O which might be present in the photosphere. Fig. 1c shows that the model with log (O/He)=-7.0 does predict a barely detectable line at $T_{\rm eff}$=120 000 K. However, the line strength is also very sensitive against variations of $T_{\rm eff}$. At the upper temperature limit of our error range (130 000 K) the line becomes drastically weaker so that a higher oxygen abundance could be possible. We derive log (O/He)=-5.5 as an acceptable upper limit at this temperature. Note that this limit is tighter by almost two orders of magnitude as compared to the WHF analysis of the medium resolution FOS data.

3.2. RX J 2117+3412

Line profile fits to RX J 2117+3412 were performed using models as described in Werner et al. (1991). An extended O V model atom (44 NLTE levels, 86 lines), however, was introduced to ensure a proper accuracy for the calculation of the 1371Å line.

We started the analysis by selecting model parameters close to the values determined by Motch et al. (1993): $T_{\rm eff}$=160 000 K, log g =6, and He/C/O=47.5/23.8/2.7 (i.e. log (C/He)=-0.3 and log (O/He)=-1.2) for the elemental number abundance ratios. From new optical spectra Rauch & Werner (1995) later estimated that the O abundance is twice as high. This is also favored by our present fits. In addition, $T_{\rm eff}$ is slightly higher, based on the O V line, see below. Figure 2 shows the result with our best fit model. Some of the C IV lines fit well (e.g. 1358Å), whereas others are too narrow, see for example the trough at 1352Å. The same holds for the O VI lines (see the 1290Å trough). In the case of O VI lines (which exclusively are 5→7 transitions) we additionally are confronted with the fact that the level energies are not known accurately enough. In one case we artificially shifted the line to the observed position (the 1261Å doublet), but refrained from this procedure in others. Obviously the 1290Å profile is not centered on the observed line position. These problems become particularly serious with the 5d→7p and 5p→7s lines (dotted portion of the calculated

Table 1. Line identifications and velocity shifts in the HST/GHRS spectra of RX J 2117+3412 and KPD 0005+5106. Interstellar and photospheric lines are listed separately. Colons at the rest wavelengths and observed line positions denote uncertainly known atomic data and uncertain measurements due to the lack of a well defined core, respectively. The O VI lines obviously suffer from badly known level energies, hence no velocity shifts are given. The emission feature near 2982Å cannot be resolved and may contain contributions from C V and/or N V

			RX J 2117+3412		KPD 0005+5106		
ion	transition	λ_{rest} (Å)	λ_{obs} (Å)	shift (km s^{-1})	λ_{obs} (Å)	shift (km s^{-1})	remarks
photospheric lines:							
C IV	$3p\,^2P_{1/2}$–$4s\,^2S_{1/2}$	1230.05	1230.15:	+24	1230.17	+29	
	$3p\,^2P_{3/2}$–$4s\,^2S_{1/2}$	1230.51	1230.57:	+15	1230.65	+34	
N V	$2s\,^2S_{1/2}$–$2p\,^2P_{3/2}$	1238.82	—		1238.95	+31	
Fe VII		1239.69	1239.83	+34	1239.85	+39	
N V	$2s\,^2S_{1/2}$–$2p\,^2P_{1/2}$	1242.80	—		1242.92	+29	
O VI	$5p\,^2P_{5/2}$–$7d\,^2D_{5/2}$	1261.77:	1261.48:		—		
O VI	$5p\,^2P_{1/2,3/2}$–$7d\,^2D_{3/2}$	1262.14:	1261.97:		—		
O VI	$5d\,^2D_{5/2}$–$7f\,^2F_{5/2}$	1289.81:	1290.40		—		
	$5d\,^2D_{1/2,3/2}$–$7f\,^2F_{3/2}$	1289.96:	blended		—		
O VI	5f–7g etc.	1291.92:	1292.15		—		
O VI	6–11	1297.90:	1297.35:		—		hydrogenic λ_{rest}
C IV	$4p\,^2P_{1/2}$–$7s\,^2S_{1/2}$	1344.18	blended		—		
	$4p\,^2P_{3/2}$–$7s\,^2S_{1/2}$	1344.41	1344.50:	+20	—		
C IV	$4d\,^2D_{5/2}$–$7f\,^2F_{5/2}$	1351.22	blended		—		
	$4d\,^2D_{1/2,3/2}$–$7f\,^2F_{3/2}$	1351.29	1351.30:	+2	—		
C IV	4f–7g	1352.97	1353.05:	+18	—		
C IV	4f–7d	1353.43	1353.50:	+16	—		
C IV	4d–7p	1358.50	1358.63:	+29	—		
O V	UV 7	1371.29	1371.42	+28	—		
O VIII	7–8	2976.57	2977:	+43	2977:	+43	
N V	5g–6h	2982.18	—		(2982.6)	+41	real? blended with C V?
C V	5g–6h	2982.28	—		(2982.6)	+31	real? blended with N V?
			average:	+23	average:	+35	
interstellar/circumstellar lines:							
N V	$2s\,^2S_{1/2}$–$2p\,^2P_{3/2}$	1238.82	1238.70	−29	1238.77	−12	
Mg II	$3s\,^2S_{1/2}$–$4p\,^2P_{3/2}$	1239.93					blend with Fe VII
	$3s\,^2S_{1/2}$–$4p\,^2P_{1/2}$	1240.39	1240.34	−12	1240.37	−5	
N V	$2s\,^2S_{1/2}$–$2p\,^2P_{1/2}$	1242.80	1242.69	−27	1242.77	−7	
S II	UV 1	1250.58	1250.50	−19	1250.52	−14	
		1253.81	1253.73	−19	1253.73	−19	
		1259.52	1259.43	−21	1259.45	−17	
Si II	UV 4	1260.42	1260.37	−12	1260.40	−5	
C I	UV 7	1277.25	1277.18	−16	1277.17	−19	
C I	UV 5	1280.14	1280.06	−19	1280.04	−23	
O I	UV 2	1302.17	1302.11	−14	1302.12	−12	
Si II	UV 2	1304.37	1304.30	−16	1304.30	−16	
Cl I	UV 2	1347.24	1347.15	−20	1347.18	−13	
Ni II	UV 8	1370.13	1370.03	−22	1369.99	−31	
			average:	−19	average:	−15	

spectrum in Fig. 2b). They are weaker and cannot be identified unambiguously in the observation. There is a possible absorption feature 1Å redward of the 1304Å interstellar Si II line. The other O VI absorption might be hidden within the nearby interstellar lines. The broad and shallow absorption near 1296Å originates from an O VI line with a very high upper quantum number (n=6→11). This confirms our previous identification of the O VI 6200Å n=9→11 transition in RX J 2117+3412 and several other PG 1159 stars (Fig. 11 of WHF).

We found no hint how the parameters for RX J 2117+3412 could be improved in order to yield a better fit than presented here. We tried to change $T_{\rm eff}$ and $\log g$ in order to get broader line profiles – without success. Increasing the surface gravity helps to improve the fits in the far line wings but then the line cores withdraw. We discuss two possible explanations for our difficulties. At first it must be borne in mind that the line broadening theory is still in a very approximate shape (see Werner et al. (1991) for details of the procedure used here), mainly because at the high particle densities relevant here the broadening

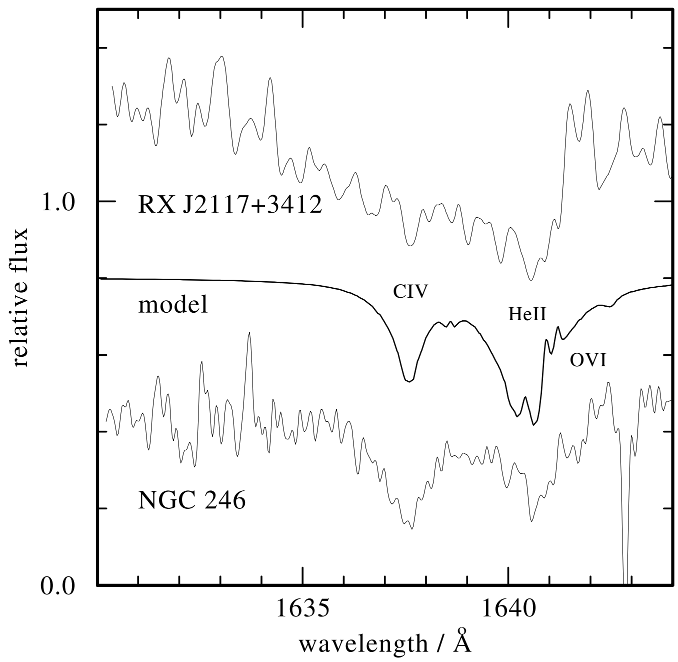

Fig. 4. Comparison of IUE high resolution spectra of RX J 2117+3412 (top) and NGC 246 (bottom), which is another PG 1159-type central star. Placed in between is a model spectrum which indicates that this spectral region around He II 1640Å is crowded with O VI and C IV lines. In RX J 2117+3412 this trough-like absorption feature is triangular shaped indicative for a stellar wind, while in NGC 246 the profile looks more similar to the (static) model atmosphere spectrum (for model parameters see caption of Fig. 2)

is in the difficult regime between linear and quadratic Stark effect. In the case of our O VI lines no data have been published. In the case of C IV lines broadening data were published by Dimitrijević et al. (1991), but since they account for pure quadratic Stark effect only, they result in much too narrow line profiles and cannot be used here. Thus we are left with the possibility that our approximate method is too poor. On the other hand, optical spectra could be fitted quite satisfactorily in the past so that it is not easy to understand the worse fit in the UV region. We therefore look for another explanation.

It is well known that the hottest central stars have fast winds with relatively low mass-loss rates. The PG 1159 central stars are in the regime where the stellar luminosity begins to drop and the mass-loss rate declines. We must face the possibility that a very weak wind does affect the line profiles, which our static model atmospheres do not account for. There is no clear signature in our data that a wind is present, although the line centers within the troughs are not sharp but do show some structure. More evidence for mass-loss comes from two co-added IUE high resolution spectra of RX J 2117+3412 which we have taken in 1993. In Fig. 4 we display the region around the He II 1640Å line in which numerous other lines due to C IV and O VI occur. There is a triangular shaped profile in RX J 2117+3412 which we interpret as the effect of an expanding atmosphere. This becomes evident if we compare this profile with a model calculation and an IUE archival spectrum of NGC 246 which shows essentially symmetric line profiles. From a weak P Cygni profile of C IV 1550Å we know that NGC 246 has a wind (Heap 1982), but probably it is weaker than that of RX J 2117+3412. In analogy there are other hints to mass-loss from RX J 2117+3412 in the IUE data, but a detailed analysis of the complete IUE datasets of RX J 2117+3412 and NGC 246 will be treated in a separate study (Rauch et al. in prep.) which should involve wind models for PG 1159 stars as they were presented recently by Leuenhagen (1995). The IUE data are of worse quality compared to the HST data but they have the advantage that they cover a broader wavelength basis.

Interestingly we can identify a weak O V 1371Å line in our RX J 2117+3412 spectrum and it serves as a sensitive temperature indicator. It can be seen that in the model with $T_{\rm eff}$=170 000 K it is still too strong. A higher temperature is required to weaken it, and it becomes compatible with the observation near 180 000 K. At this temperature the O VI and C IV line cores become weaker than observed, so that we arrive at an acceptable compromise with $T_{\rm eff}$=170 000 K. This very high value slightly exceeds the temperature range in the Motch et al. (1993) study (135 000 –165 000 K) and it is in accordance with the preliminary results of the Rauch & Werner (1995) work (140 000-180 000 K), which employed new optical spectra. This makes RX J 2117+3412 the hottest PG 1159 star together with H 1504+65.

4. The emission lines at 2980 Angstrom

As noted above, the red one of the two emission lines located near 2976Å and 2982Å in KPD 0005+5106 is either due to N V or C V (or both) while the blue emission is undoubtedly from O VIII. As pointed out by WHF this O VIII emission cannot be of photospheric origin because of its very high ionisation potential (871 eV). Since C V has a similarly high ionisation potential (392 eV) it cannot be of photospheric origin either. In contrast, N V has a much lower ionisation potential (98eV) and, therefore, may be formed under photospheric rather than coronal conditions. This is supported by our photospheric model calculations presented in Fig. 1d which indeed predict a N V 2982Å emission, however, it is far too weak to account for the observed line strength. Note that in order to produce a notable emission at all we have increased $T_{\rm eff}$ and the N abundance. Therefore we tend to believe that C V dominates this feature. We may remind the reader that a similar ambiguity was discussed in the context with an optical emission line at 4945Å to which 6→7 transitions of both C V and N V can contribute. In view of the fact that we derived a very tight upper limit for the oxygen abundance in the photosphere it is surprising that such a strong O VIII emission line (compared to the C V component) appears, which we believe to be formed in outflowing material.

The situation becomes even stranger if we compare KPD 0005+5106 with RX J 2117+3412. The very carbon rich PG 1159 star does not show the 2982Å emission which we assumed to be caused by C V. From this fact one can come to an opposite conclusion about the origin of the 2982Å emission.

If it is made entirely by nitrogen in KPD 0005+5106, then this would easily explain its absence in RX J 2117+3412, because the latter is virtually nitrogen free. In this case we must explain why the nitrogen emission in KPD 0005+5106 is so much stronger than predicted by static photosphere models. In WHF (their Fig. 9) we faced a similar problem with the occurrence of a weak emission from the O VI 3s→3p doublet at 3810Å in KPD 0005+5106. For this line we concluded that it may be due to a non-photospheric process similar to the O VIII emission. We can only speculate that the same holds for N V 2982Å. Thus we cannot make a clear decision about this ambiguity until detailed wind modeling is performed.

Measuring the maximum red and blue extensions of the O VIII emission in RX J 2117+3412 results in velocity shifts of +123 and -100 km s^{-1} relative to the stellar rest frame. The profile is slightly asymmetric with a broader red extension. In contrast, the blue emission wing in KPD 0005+5106 is somewhat broader than the red one, we measure +143 and -157 km s^{-1}. There is no indication for a systematic shift of the line centers against the stellar rest frame which has to be compared to the very high terminal velocity of the wind which we expect e.g. for RX J 2117+3412, namely some thousand km s^{-1}. So if the emissions are formed along shock fronts in the wind then this must happen in the acceleration region of the expanding shell, close to the stellar surface.

Alternatively one can interpret the line widths as purely due to thermal Doppler broadening. An observed half-width of 0.8Å implies a kinetic gas temperature of $6 \cdot 10^6$ K corresponding to 520 eV. This is of the order of the C V and O VIII ionisation potentials (392 eV and 871 eV, respectively) which are relevant in order to produce the observed emission lines by recombination cascades from the next higher ionisation stages.

5. Summary and conclusions

Let us summarize and discuss our new results. Thanks to the new high-quality HST data we revealed that the N and O abundances in the photosphere of KPD 0005+5106 are much lower than claimed in our preceding work (WHF) and that the carbon abundance is slightly higher: log (C/He)=-3, log (N/He)=-6, log (O/He)<-5.5. Hence N and O are extremely depleted. We compare these numbers to predictions from diffusion theory (Chayer et al. 1995 and priv.comm.): log (C/He)=-3.45, log (N/He)=-2.87, log (O/He)<-1.91. While the observed C abundance is well predicted, we see that N and O are overestimated by three orders of magnitude. One concludes that either the current state-of-the-art theory wrongly describes the interplay between diffusion and radiative levitation or, alternatively, that the element abundances are essentially determined from previous evolutionary processes. The mass-outflow from KPD 0005+5106, which becomes manifest in the occurrence of O VIII emission lines as well as in the existence of a corona, certainly influences levitation and diffusion processes, should they be acting. Effects of mass-loss on equilibrium abundances are not yet included in the diffusion theory and could be large. Hence it is premature to state that these processes are not determining the observed abundances.

Since the position of KPD 0005+5106 is well within the domain of the PG 1159 stars, which have a strongly different composition (much higher C and O abundances), it seems plausible to assume that KPD 0005+5106 is not a descendant from a former PG 1159 star (WHF). Instead we have proposed that it is a descendant from some other He-rich and metal-poor star, like He-sdO stars (Husfeld et al. 1989) or He-CSPN (LoTr4, K1-27; Rauch et al. 1994, Rauch & Werner 1995). Although metal abundances are low in these objects, too, none of them reflects the abundance pattern in KPD 0005+5106. Therefore we feel that the most reasonable view is that the star has evolved from one of these He-dominated objects and that the metal abundances were changed by diffusion/levitation to the present values. Hopefully, improved diffusion calculations including mass-loss effects will become available soon to check this hypothesis.

We have pointed out the oddity that we see strong O VIII emission lines from the stellar wind of KPD 0005+5106 but at the same time oxygen in the photosphere is extremely depleted, down below the detection limit. This appears even more curious because those metals which we do detect in the photosphere (C, N) are not detectable in the wind by producing emission lines from ions which are isoelectronic to O VIII (C VI, N VII, disregarding the uncertain identification of non-photospheric C V 2982Å). This corroborates our (WHF) rather speculative and naive interpretation: oxygen is pushed upwards and out of the photosphere by radiation pressure while for some reason C and N predominantly remain on the star. That such a selective wind mechanism could be at work in white dwarfs was realized by Vauclair et al. (1979). Interestingly, recent calculations by Chayer et al. (1995) predict that the radiative acceleration on oxygen is strongest among the CNO elements (see above).

On the basis of the detection of a very weak O V 1371Å line we were able to show that RX J 2117+3412 is the hottest known PG 1159 star together with H1504+65 ($T_{\rm eff}$=170 000 K, Werner 1991). Exclusively these are the two PG 1159 stars which were discovered on account of their X-ray emission. The high temperature of the pulsator RX J 2117+3412 indicates a very blue extension of the GW Vir instability strip in the region of high luminosities (Werner et al. 1995c). Our analysis has shown that atomic data for O VI (level energies, line broadening) are poorly known. On the other hand, there are signatures of a fast wind in the UV spectrum, demanding an analysis with expanding model atmospheres to determine, e.g., the mass-loss rate from this PG 1159-type central star. The detection of an O VIII 2975Å emission line which is similar in strength compared to KPD 0005+5106 corroborates our view that this is the most direct evidence for on-going mass-loss from a white dwarf.

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