

Line identification in soft X-ray spectra of stellar coronae by comparison with the hottest white dwarf's photosphere: Procyon, α Cen A+B, and H 1504+65

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Abstract. H 1504+65 is a young white dwarf with an effective temperature of 200 000 K and is the hottest post-AGB star ever analysed with detailed model atmospheres. *Chandra* LETG+HRC-S spectra have revealed the richest X-ray absorption line spectrum recorded from a stellar photosphere to date. The line forming regions in this extremely hot photosphere produce many transitions in absorption that are also observed in emission in cool star coronae. We have performed a detailed comparison of *Chandra* spectra of H 1504+65 with those of Procyon and α Cen A and B. State of the art non-LTE model spectra for the hot white dwarf have enabled us to identify a wealth of absorption lines from highly ionized O, Ne and Mg. In turn, these features have allowed us to identify coronal lines whose origins were hitherto unknown.

Key words. stars: atmospheres – stars: coronae – X-rays: stars – stars: individual H 1504+65

1. Introduction

High-resolution X-ray spectroscopy performed with *Chandra* and XMM-Newton allows very detailed studies of coronae about cool stars. While many individual emission lines were detected for the first time in stellar spectra by the Extreme Ultraviolet Explorer Satellite (EUVE; see, e.g., Drake et al. 1995), the resolving power of $\lambda/\Delta\lambda \sim 200$ of the EUVE spectrographs was quite modest compared with that of present day X-ray observatories. In particular, the unprecedented resolution capabilities of the *Chandra* X-ray Observatory Low Energy Transmission Grating Spectrograph (LETG) in the 30–170 Å range ($\lambda/\Delta\lambda \sim 1000$) that overlaps with the EUVE Short Wavelength spectrometer (70–170 Å), have revealed many more weak spectral lines.

The 25–70 Å region is a relatively uncharted part of the soft X-ray spectrum. Prior to *Chandra*, only a small handful of astrophysical observations had been made at anything approaching high spectral resolution in this range: these were of the solar corona using photographic spectrometers (Widing & Sandlin 1968; Freeman & Jones 1970; Schweizer & Schmidtke 1971; Behring et al. 1972; Acton et al. 1985) a channel electron photomultiplier (Malinovsky & Heroux 1973) and a Geiger-Müller counter (Manson 1972). While these works resulted in identifications for many of the bright spectral lines, a large fraction of the forest of weaker features remains unidentified.

Identification of these features is desirable because they could be used as spectroscopic diagnostics, because they potentially contribute to the flux of diagnostic lines currently employed, and because they contribute to the overall plasma radiative loss.

Two nearby stars that have illuminated the forest of lines in the 30–170 Å range are α Cen (G2V+K1V) and Procyon (F5IV). All three stars exhibit classical solar-like X-ray emitting coronae. Indeed, analogues of the relatively X-ray faint Sun are difficult to observe because they become unreachable with current instrumentation beyond a few parsecs, and α Cen and Procyon represent the nearest and brightest coronal sources with solar-like activity. Only a small fraction of the multitude of lines between 30–170 Å seen in their *Chandra* LETG spectra could be identified based on current radiative loss models (Raassen et al. 2002, 2003). Drake et al. (in prep.) have estimated that these models underestimate the true line flux in the range 30–70 Å in these stars by factors of up to 5 or so.

The “missing lines” are predominantly transitions involving $n = 2$ ground states in abundant elements such as Ne, Mg, Si, S and Ar—the analogous transitions to the Fe “L-shell” lines between ~ 8 –18 Å, together with Fe $n = 3$ (the “M-shell”) transitions (Drake 1996; Drake et al. 1997; Jordan 1996). Some of these lines have been identified based on Electron Beam Ion Trap experiments (Beiersdorfer et al. 1999; Lepson et al. 2002, 2003). In the present paper we approach this problem from a new perspective, namely through a *Chandra*

observation of the photosphere of the hottest white dwarf (WD) known, H 1504+65, and its quantitative analysis by means of detailed non-LTE model atmospheres.

H 1504+65 has an effective temperature of 200 000 K. It belongs to the PG1159 spectral class, which are hot, hydrogen-deficient (pre-) white dwarfs. Their surface chemistry (typical abundances: He = 33%, C = 48%, O = 17%, Ne = 2%, mass fractions) suggests that they exhibit matter from the helium-buffer layer between the H- and He-burning shells in the progenitor AGB star (Werner 2001). This is likely because the PG1159 stars have suffered a late He-shell flash, a phenomenon that drives the fast evolutionary rates of such famous stars like FG Sge and Sakurai's object. H 1504+65 is in fact a peculiar member of this class, because it is also helium-deficient. Its atmosphere is mainly composed of carbon and oxygen plus neon and magnesium (C = 48%, O = 48%, Ne = 2%, Mg = 2%, mass fractions). H 1504+65 is a unique object, considering its high T_{eff} and chemical surface composition, and we have speculated that it represents the naked C/O core of a former red giant (Werner et al. 2004, W04).

Chandra LETG+HRC-S spectra from H 1504+65 have revealed the richest X-ray absorption line spectrum recorded from a stellar photosphere to date. We have recently performed a detailed analysis of this spectrum (W04) and we use in the paper in hand the photospheric spectrum of H 1504+65 together with an appropriate model atmosphere to identify a number of emission lines in the coronae of α Cen A, α Cen B, and Procyon. The difference in particle densities in the WD photosphere and in the coronae amounts to many orders of magnitude (roughly $n_e = 10^{13}$ – 10^{18} and 10^{10} cm $^{-3}$, respectively), however, the temperature in the line forming regions of the WD (up to 300 000 K) is comparable to the low-temperature component of multi-temperature fits to coronae, required to account for the lines of low-ionization stages (e.g. 630 000 K for Procyon; Raassen et al. 2002). As a consequence, numerous lines from O VI, Ne VI–VIII and Mg VI–IX are visible in the soft X-ray spectra of both, the cool star coronae (in emission) and the hot WD photosphere (in absorption). Lines from higher ionization stages are formed in the high-temperature regions of the coronae (T of the order 1–2.5 million K for the stars studied in this paper), hence, their respective absorption line counterparts cannot be formed in the WD photosphere.

In the following, we first introduce briefly the characteristics of the objects studied here. We describe our model atmosphere calculation for the hot WD, concentrating on the atomic data employed. We then perform a detailed comparison of the absorption and emission line spectra and suggest a number of new line identifications for the cool star coronae.

2. Observations

H 1504+65 was observed with the *Chandra* LETG+HRC-S on September 27, 2000, with an integration time of approximately 25 ks. Flux was detected in the range 60 Å–160 Å. The spectrum is that of a hot photosphere, characterized by a continuum with a large number of absorption lines from highly ionized species: O V–VI, Ne VI–VIII, and Mg V–VIII. It rolls off at long wavelengths due to ISM absorption. The maximum flux

is detected near 110 Å. Between 105 Å and 100 Å the flux drops because of photospheric absorption from the O VI edge caused by the first excited atomic level. The edge is not sharp because of a converging line series and pressure ionization. Below 100 Å the flux decreases, representing the Wien tail of the photospheric flux distribution. The complete spectrum with detailed line identifications was presented in W04.

The α Cen A and B observation has been described in detail by Raassen et al. (2002) and we describe it here only in brief. α Cen was observed with the LETG+HRC-S on December 25, 1999 with an exposure time of 81.5 ks, including dead time corrections to account for telemetry saturation during intervals of high background. The observation was designed such that the two stars were maximally separated in the cross-dispersion axis, with the dispersion axis positioned nearly perpendicular to the axis of the binary. At the time of the observation, the stars were separated by 16'' on the sky. The spectra were extracted with the standard CIAO bow-tie region, though the central two background regions interfered with the stellar spectra and only the outer regions were used for background subtraction.

The two Procyon observations studied here were obtained with the LETG+HRC-S as part of the *Chandra* on-orbit calibration programme and Emission Line Project. The observations were executed contiguously beginning on November 6, 1999 at 21:11:32 UT. The second observation began on 1999 November 16:59:48 UT. The effective exposure times for these observations were 69 643s and 69 729s, respectively, including dead time corrections.

Reduction of the HRC-S event lists for all the observations was initially based on standard pipeline products. Events were further filtered in pulse height in order to remove background events. The final reduced first order spectra were co-added in order to maximise the signal. In the case of Procyon, we also co-added the two separate observations.

3. Photospheric model for H 1504+65

We use here a photospheric spectrum from a line blanketed non-LTE model atmosphere constructed for H 1504+65 by W04. Model parameters are: $T_{\text{eff}} = 200$ 000 K, $\log g = 8$ [cm s $^{-2}$], and C = 48%, O = 48%, Ne = 2%, Mg = 2%, (mass fractions). Details of model assumptions and calculations can be found in that reference and we restrict ourselves here to those characteristics which are of immediate relevance in our context. This primarily concerns the NLTE model atoms for neon and magnesium. They comprise 88 and 122 NLTE levels, connected with 312 and 310 radiative line transitions, respectively, in the ionization stages IV–IX. The final synthetic spectrum was computed considering fine structure splitting of levels and multiplets assuming relative LTE populations for levels within a particular term. We have tried to use the best available data for level energies and line wavelengths, compiling them from several sources. For the lines discussed here (Table 1), we used the following databases:

- (i) National Institute of Standards and Technology (NIST)¹;

¹ <http://physics.nist.gov/>

Table 1. List of X-ray multiplets in the wavelength region 69–151 Å observed in both the H 1504+65 photosphere or its model and in the coronae of either α Cen A (“A”), α Cen B (“B”), or Procyon (“P”), as suggested in this paper. In the last column, we note earlier line identifications in either solar spectra (SA = Acton et al. 1985; SB = Behring et al. 1972; SF = Freeman & Jones 1970; SM = Manson 1972; SMH = Malinovsky & Heroux 1973; SW = Widing & Sandlin 1968) or stellar spectra (D = Drake et al. 1995; R = Raassen et al. 2002, 2003). The letter “u” is appended in the case of the feature having been observed but not identified. “N” denotes a new identification suggested in this paper. “N” in combination with other letters means that at least one component of the multiplet is newly identified here. Expressions in brackets denote doubtful cases. The column “Source” gives the reference to the level energies of the transition. After each transition we have marked, if the lower level is a ground state (“G”) or a metastable state (“M”).

$\lambda/\text{Å}$ (H 1504+65 model)	Seen in	Ion	Transition	Source	Remark
69.41, .47, .57	A, B, P	Mg VIII	$2p^2 P^o - 3p^2 D$	G NIST	N, SMu, blend with blue wing of Si VIII 69.63 Å
74.27, .32, .34, .37, .41, .43	A, B, P	Mg VIII	$2p^2 4P - 3d^4 D^o$	M NIST	N, SAu, SMu, broad emission feature
74.78, .81, .87	A, B	Ne VII	$2p^3 P^o - 4p^3 D$	M NIST	N, SAu, SBu, SMu, blend with Mg VIII 74.86 Å
74.86, 75.03, .04	A, B, P	Mg VIII	$2p^2 P^o - 3d^2 D$	G NIST	SA, SB, SF, SM, SMH, SW, R, blend with Fe XIII 74.85 noted by R, and Ne VII 74.87 Å
(78.34), 78.41, 78.52	A, B, P	Mg VII	$2p^3 3P - 3p^3 P^o$	G Kelly	N, SAu, SMu
80.23, .25	A, B, P	Mg VIII	$2p^2 2D - 3d^2 D^o$	NIST	SMu, R
80.95, 81.02, .14	A, (B, P)	Mg VII	$2p^3 3P - 3p^3 S^o$	G Kelly	N, SAu, SMu
81.37	(A), B, P	Ne VII	$2p^1 P^o - 4p^1 P$	Kelly	N
81.73, .79, .84, .87, .94, .98	A, B, P	Mg VIII	$2p^2 4P - 3s^4 P^o$	M NIST	N, SFu, SMu, broad emission, blend with Si VII 81.89 Å noted by R
82.17, .20, .27	A, B, (P)	Ne VII	$2p^3 P^o - 4d^3 D$	M Kelly	N
(82.60), .82	A, B, P	Mg VIII	$2p^2 P^o - 3s^2 S$	G NIST	(SBu, SFu), SM, R, blend with Fe XII 82.84 Å noted by R
83.51, .56, .59, .64, .71, .76	A, B, P	Mg VII	$2p^3 3P - 3d^3 P^o$	G Kelly	N, SBu, SF, SW, SM, D, R, broad emission feature; poss. Si VI contribution noted by R
83.91, .96, .99, 84.02, .09, .11	A, B, P	Mg VII	$2p^3 3P - 3d^3 D^o$	G Kelly	N, SB, SF, SM, SMH, R, broad emission feature
(84.19, .23), .30	A	Ne VII	$2p^3 P^o - 4s^3 S$	M Bashkin	SMu, R
85.41	(A, B, P)	Mg VII	$2p^2 1D - 3d^1 F^o$	M Kelly	N, SBu, SMu, blend with Fe XII 85.46 Å noted by R
86.82	A, B, P	Ne VII	$2p^2 1D - 4d^1 F^o$	M Kelly	N, SBu, SFu, SMu, blend with Fe XI 86.77, Mg VIII 86.84 Å noted by R
86.84, .85, 87.02	A, B, P	Mg VIII	$2p^2 2D - 3s^2 P^o$	NIST	N, SBu, SFu, SMu, R
87.46	A	Ne VII	$2s^2 1S - 3s^1 P^o$	G NIST	N
87.72	A	Mg VII	$2p^2 1D - 3d^1 D^o$	M Kelly	N
88.08, 88.12	A, B, P	Ne VIII	$2s^2 S - 3p^2 P^o$	M NIST	SA, SB, SF, SM, SMH, D, R
88.68	(A), B, P	Mg VII	$2p^2 1S - 3d^1 P^o$	M Kelly	N, SMu
89.64, .65	A, (P)	Mg VI	$2p^3 2P^o - 4s^2 P$	M Kelly	N, SBu
91.56	P	Ne VII	$2p^1 P^o - 4s^1 S$	Kelly	SMu, R
92.13, .32	A, B, P	Mg VIII	$2p^2 2S - 3s^2 P^o$	NIST	N, SMu, SBu, R
92.85	P	Ne VII	$2p^2 1S - 4d^1 P^o$	M Kelly	SMu, R
(93.89), 94.07, .10, (.27)	A, B, P	Mg VIII	$2p^2 P - 3s^2 P^o$	NIST	N, (SAu, SBu), SMu, blend with Fe X 94.012 Å, Mg VII 94.04 Å
94.04, (.17, .24)	A, B, P	Mg VII	$2p^3 5S^o - 3s^5 P$	M Kelly	N, SMu, SFu, blend with Fe X 94.012 Å noted by R, and Mg VIII 94.07 Å

(ii) CHIANTI database (Young et al. 2003)²;

(iii) Kelly Atomic Line Database³.

However, in order to assemble the complete model atoms, other sources were essential, too:

(iv) Opacity Project (OP, Seaton et al. 1994) TOPbase⁴;

(v) University of Kentucky Atomic Line List⁵.

4. Comparison of H 1504+65 with α Cen A, α Cen B, and Procyon

We have performed a detailed comparison of the H 1504+65 photospheric absorption line spectrum with the coronal emission line spectra of α Cen A, α Cen B, and Procyon. We have also used the model spectrum of H 1504+65 for this purpose. It turns out that not all lines predicted by the model, particularly

² <http://www.solar.nrl.navy.mil/chianti.html>

³ <http://cfa-www.harvard.edu/amdata/ampdata/kelly/kelly.html>

⁴ <http://legacy.gsfc.nasa.gov/topbase/home.html>

⁵ <http://www.pa.uky.edu/~peter/atomic/>

Table 1. continued.

$\lambda/\text{\AA}$ (H 1504+65 model)	Seen in	Ion	Transition	Source	Remark
94.26, .27, .30, .31, .36, .39	B	Ne VII	$2p^3\ ^3P^o-3p^3P$	M	Bashkin N, SMu
95.03, .04	B	Mg VII	$2p^3\ ^3D^o-3s^3D$	Kelly	N
95.26, .38, .42, .49, .56, .65	(A, B, P)	Mg VII	$2p^3\ ^3P-3s^3P^o$	G	Kelly N, SBu, SFu, SMu, blend with Fe x 95.338 Å
(95.38, .42, .48)	(A, B, P)	Mg VI	$2p^3\ ^4S^o-3d^4P$	G	Kelly N, SBu, SFu, SMu, R, blend with Mg VII 95.26–.65 Å
95.75, .81, .89, .90, .91, 96.0	A, B, P	Ne VII	$2p^3\ ^3P^o-3p^3D$	M	Bashkin N, SMu, broad emission, blend with Si VI 96.02 Å noted by R
96.08, .09	(A, B, P)	Mg VI	$2p^3\ ^2P^o-3d^2D$	M	Kelly N, SBu, SMu, blend with Fe x 96.12 Å noted by R
97.50	A, B, P	Ne VII	$2s^2\ ^1S-3p^1P^o$	G	Kelly SM, SW, SMH, R
98.11, .26	A, B, P	Ne VIII	$2p^2\ ^2P^o-3d^2D$		NIST SB, SM, SMH, SW, D, R
98.50, .51	B	Mg VI	$2p^3\ ^2P^o-3d^2S$	M	Kelly N, SBu, SMu
99.69	B	O VI	$2s-6p$	G	Kelly N, SMu
100.70, .90	A	Mg VI	$2p^3\ ^2D^o-3d^2F$	M	Kelly N, SBu
101.49, .55	B	Mg VI	$2p^3\ ^2D^o-3d^2P$	M	Kelly N, SBu, SMu
102.91, 103.08	A, B, P	Ne VIII	$2p^2\ ^2P^o-3s^2S$		NIST SM, SMH, SW, D, R
103.09	(A, B, P)	Ne VII	$2p^1\ ^1P^o-3p^1D$		Kelly N, SBu, blend with Ne VIII 103.08 Å
104.81	B, P	O VI	$2s-5p$	G	Kelly SMu, R
105.17	A, (B)	Mg VII	$2p^3\ ^1D^o-3s^1D$		Kelly N, SMu, blend with Fe IX 105.21 Å noted by R
106.03, .08, .19	P	Ne VII	$2p^3\ ^3P^o-3d^3D$	M	Kelly N, SM, SW, D, R
(111.10, .16), .26	A, B, P	Ne VI	$2p^2\ ^2P^o-3p^2D$	G	Kelly N, SBu, SMu, blend with Ca x 111.20 poss. Mg VI contribution noted by R
111.15	(A), B, P	Ne VII	$2p^2\ ^1D-3d^1P^o$	M	Kelly N, blend with Ca x 111.20, Ne VI 111.16 Å poss. Mg VI contribution noted by R
111.55, .75, .86	B, (A, P)	Mg VI	$2p^3\ ^4S^o-3s^4P$	G	Kelly SB, R
(115.33), .39, (.52)	A, B, P	Ne VII	$2p^3\ ^3P^o-3s^3S$	M	Kelly R
115.82, .83	B	O VI	$2s-4p$	G	Kelly SB, SMu, Ru
115.96	B	Ne VII	$2p^2\ ^1D-3d^1D^o$	M	Kelly N
(116.35), .42	B	O VI	$2p-5d$		Kelly N
116.69	B	Ne VII	$2p^1\ ^1P^o-3d^1D$		Kelly SMu, R
116.97, 117.22	A	Mg VI	$2p^3\ ^2D^o-3s^2P$	M	Kelly N, SMu, poss. Mg VI contribution noted by R
(117.33), .40	B	O VI	$2p-5s$		Kelly N
(117.43), .66, (.78)	P	Mg VII	$2p^3\ ^3S^o-3s^3P$		Kelly N, Ru
(117.52), .64, (.81)	P	Mg VII	$2p^3\ ^3P^o-3p^3P$		Kelly N, Ru
120.20, .27, .33, .35, .42, .48	P	Ne VII	$2p^2\ ^3P-3s^3P^o$		Kelly N, blend with O VII 120.33 Å note by R
122.49, .69	B, P	Ne VI	$2p^2\ ^2P^o-3d^2D$	G	Kelly N, SBu, SMu, SMH, D, R
123.59	P	Mg VI	$2p^4\ ^2D-3s^{iv}\ ^2D^o$		Kelly N, SMu, Ru
127.67	B, P	Ne VII	$2p^1\ ^1P^o-3s^1S$		Kelly SMu, R
129.78, .87	A, B, P	O VI	$2p-4d$		Kelly SMH, SB, R
130.31, .64	B	Mg VI	$2p^4\ ^2P-3s^v\ ^2P^o$		Kelly N
130.94, 131.09, .30	A, B, P	Mg VII	$2p^3\ ^3S^o-3p^3P$		Kelly N, SBu, blend with Fe VIII 130.94, 131.24 Å noted by R
132.22, .31	A, B	O VI	$2p-4s$		Kelly N
150.09, .12	B, P	O VI	$2s-3p$	G	Kelly SMH, SB, D, R

the weaker ones, are readily identified in H 1504+65, which is at least in part due to the S/N of the *Chandra* spectrum. Another reason is heavy blending by lines from iron group elements, which are not considered in the model used here. It was shown that identification of weak lines suffers from iron and nickel line blends, which is a problem because the accurate positions of the majority of lines from Fe-group elements in the soft X-ray domain is unknown (W04). The use of our synthetic

spectrum in addition to the H 1504+65 spectrum helps considerably to identify lines in the coronal spectra.

Table 1 summarizes the results of our comparison. Lines from 65 multiplets of O VI, Ne VI–VIII, and Mg VI–VIII are identified in both, H 1504+65 (or its model) and in at least one of the considered coronae. Many of these had already been identified in earlier solar work (Widing & Sandlin 1968; Freeman & Jones 1970; Behring et al. 1972; Manson 1972;

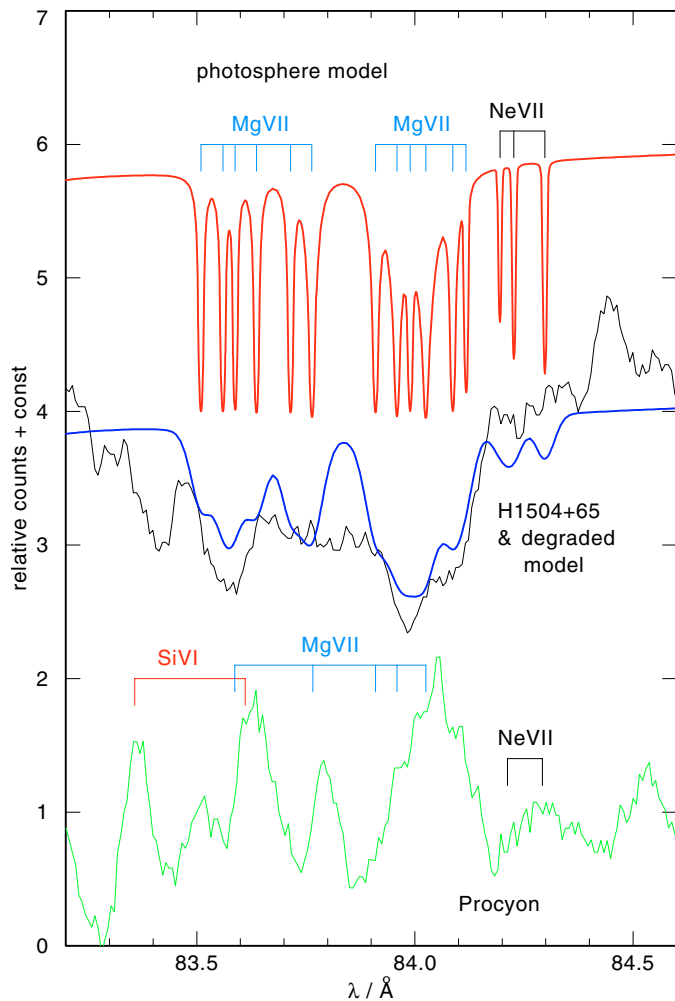


Fig. 1. Comparison of *Chandra* X-ray spectra of H 1504+65 and Procyon. Lines from Mg VII and Ne VII are in absorption in H 1504+65 and in emission in Procyon. *Top:* photosphere model for H 1504+65 with line identifications for Mg VII and Ne VII. *Middle:* degraded model spectrum (i.e. folded with a 0.05 \AA FWHM Gaussian) plotted over H 1504+65 observation. *Bottom:* Procyon spectrum with line identifications from Raassen et al. (2002). *Chandra* spectra were smoothed with a 0.03 \AA boxcar.

Malinovsky & Heroux 1973; Acton et al. 1985) and by Raassen et al. (2002, 2003), but the majority represents new identifications. Table 1 also denotes lines or features seen in earlier solar spectra but which were unidentified in the earlier work. The identifications presented here can then also be applied (either wholly or in part, allowing for blends) to these solar spectra. Many, but not all, of the tabulated lines have lower levels which are either ionic ground states or metastable states (labeled G or M, respectively). As an example how the spectra compare, we show in Fig. 1 the spectra of Procyon and H 1504+65 in a wavelength region where a bunch of lines from two Mg VII and one Ne VII multiplet is located. All three multiplets, or at least some components of them, were identified by Raassen et al. (2002) in Procyon. They are also clearly seen as absorption features in the H 1504+65 spectrum. Over this, we have plotted the model

spectrum, degraded to the *Chandra* spectral resolution, which can qualitatively reproduce the observed line features. Placed at the top of this figure we show the original, non-degraded model spectrum, showing the diverse structure of the multiplets, whose components are not entirely resolved in *Chandra* spectra, neither of H 1504+65 nor of Procyon.

Figure 2 shows a detail from the spectra of Procyon and α Cen A compared to H 1504+65 in another wavelength interval. It displays some new line identifications in the coronal spectra, see for example the 87.46 \AA resonance line of Ne VII in α Cen A. The strongest emissions in α Cen A stem from two Ne VIII and Mg VIII doublets, identified already in Raassen et al. (2003). But note that the Mg VIII 86.84 \AA component is blended with the possibly stronger, newly identified Ne VII 86.82 \AA line.

Some of the newly identified lines do blend with other lines used for coronal diagnostics. The emissivity of the Fe VIII lines at 130.94 \AA and 132.24 \AA in Procyon was computed by Raassen et al. (2002) using a three-temperature model. They stress that these line strengths are strongly underestimated, by factors 6 and 4 compared to the observation. The result of their differential emission measure (DEM) model underestimates the emissivity even more (factors 9 and 6). This can at least partially be explained by the fact that two components of a Mg VII triplet (at 130.94 \AA and 131.30 \AA) can contribute to the Fe VIII line emissivities. A similar explanation may hold for the Fe IX 105.20 \AA line, which also appeared too weak in their model. It is blended with a Mg VII singlet at 105.17 \AA .

Another example is the Mg VIII 74.86 \AA line observed in α Cen A and α Cen B. Raassen et al. (2003) find that the line fluxes from their models are too small by about 40%. We think that the missing flux is contributed by a blend with a new neon line located at almost the same wavelength, Ne VII 74.87 \AA . Detailed emission measure modeling, which is beyond the scope of this paper, is needed to quantify these suggestions. Other blends with previously identified emission lines in the coronae of Procyon and α Cen are indicated in Table 1.

5. Summary

We have performed a detailed comparison of *Chandra* soft X-ray spectra from the photosphere of the hottest known white dwarf, H 1504+65, with the corona spectra of α Cen A, α Cen B, and Procyon. With the help of a detailed model spectrum for H 1504+65 we have found that a large number of lines from multiplets of O, Ne, and Mg are present in both the photospheric absorption line spectrum and the coronal emission line spectra. In the coronal spectra we have newly identified lines from about 40 multiplets of O VI, Ne VI-VII, and Mg VI-VIII. Some of these lines are blends with previously known lines, which are in use for diagnostic purposes, hence, their contribution to the line flux must be considered in detailed spectral analyses.

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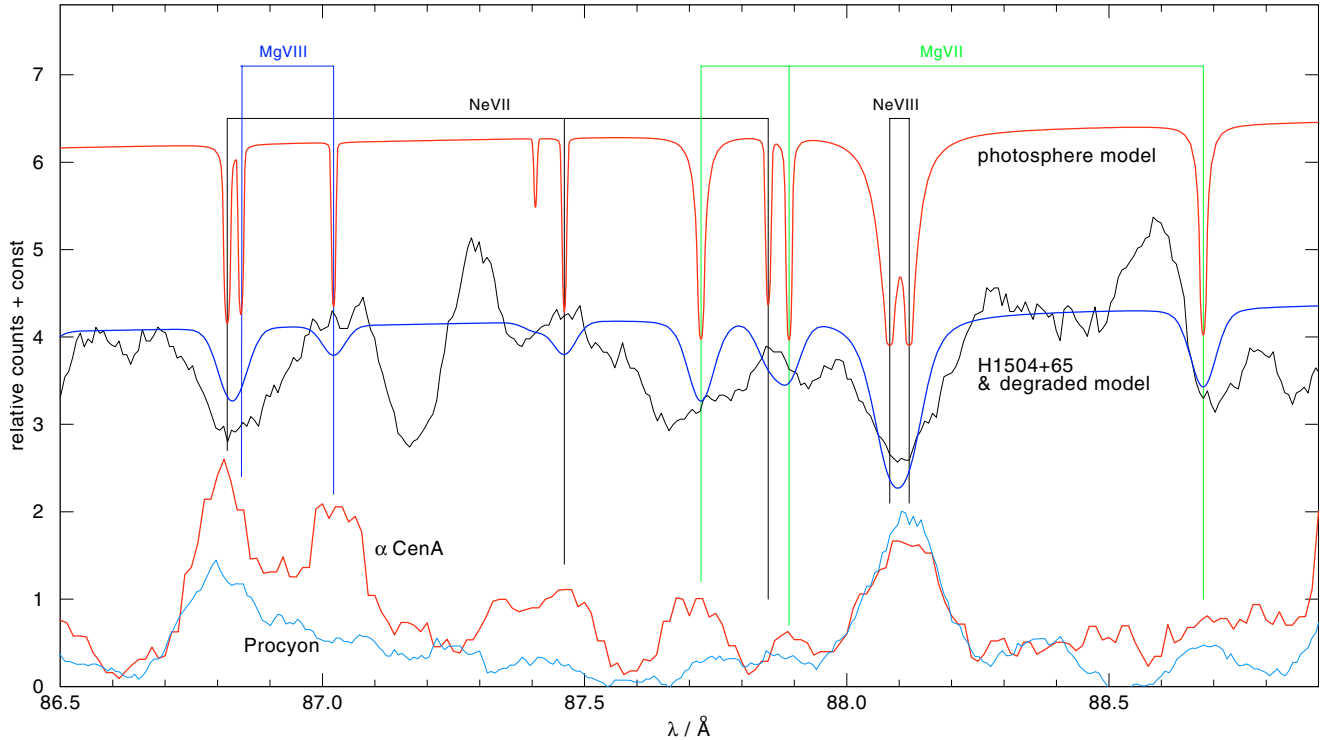


Fig. 2. Comparison of *Chandra* X-ray spectra of H 1504+65 with Procyon and α Cen A, similar to Fig. 1. All shown lines from highly ionized Ne and Mg are identified for the first time in the cool star corona, except for Mg VIII 86.85/87.02 Å and the Ne VIII doublet at 88.1 Å, which were identified by Raassen et al. (2002, 2003). *Chandra* spectra of H 1504+65 and the coronae were smoothed with 0.03 Å and 0.05 Å boxcars, respectively.

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