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D. Koester, S. Moehler

Identification of a DO White Dwarf and a PG1159 Star in the ESO SN Ia Progenitor Survey (SPY)

K. Werner,[1] T. Rauch,[1,2] R. Napiwotzki,[3] N. Christlieb,[4] D. Reimers,[4] and C. A. Karl[2]

[1]*Institut für Astronomie und Astrophysik, Universität Tübingen, Sand 1, 72076 Tübingen, Germany*
[2]*Dr. Remeis-Sternwarte, Sternwartstr. 7, 96049 Bamberg, Germany*
[3]*Department of Physics and Astronomy, University of Leicester, University Road, Leicester, LE1 7RH, UK*
[4]*Hamburger Sternwarte, Universität Hamburg, Gojenbergsweg 112, 21029 Hamburg, Germany*

Abstract. We present high-resolution VLT spectra of a new DO white dwarf and a new PG1159 star, which we identified in the ESO SPY survey. The PG1159 star is a low-gravity, extremely hot ($T_{\rm eff} = 160\,000$ K, $\log g = 6$) star, having a C/He dominated atmosphere with considerable amounts of O and Ne (He=38%, C=54%, O=6%, Ne=2% by mass). It is located within the planetary nebula nuclei instability strip and pulsations have been discovered. The DO is a unique object. From He I/He II line strengths we found $T_{\rm eff}{\approx}60\,000$ K, however, the He II lines are extraordinarily strong and cannot be fitted by any model.

1. Introduction

The ESO Supernovae Ia Progenitor Survey (SPY) is aimed at finding binary WDs to test the double-degenerate scenario for SN Ia progenitors (Napiwotzki et al. 2001). Here we report on the identification and spectrum analysis of a PG1159 star and a DO WD. HE1314+0018 (B=15.6 mag) and HE1429−1209 (B=15.8 mag) were identified in the Hamburg ESO survey (HES; Wisotzki et al. 2000, Christlieb et al. 2001) as WD candidates and were therefore included in the SPY project. The spectra presented here were taken between April 2000 and July 2002. Their resolution is about $R = 18\,500$. Data reduction was performed with the ESO MIDAS software package. Line blanketed non-LTE model atmospheres were computed using our PRO2 code. The models assume plane-parallel geometry and hydrostatic and radiative equilibrium.

2. The DO Star

The spectrum of HE1314+0018 exhibits lines from neutral and ionized helium, i.e., we have detected a "cool" DO ("hot" DOs show only He II lines). This usually allows an accurate determination of $T_{\rm eff}$ and $\log g$. We also detect the C IV 5801/5812 Å doublet and a very weak feature of this ion close to He II 4686 Å. Surprisingly, we are unable to obtain an acceptable fit to the observed spectrum. Fig. 1 shows the best fit model to the He I lines, which is

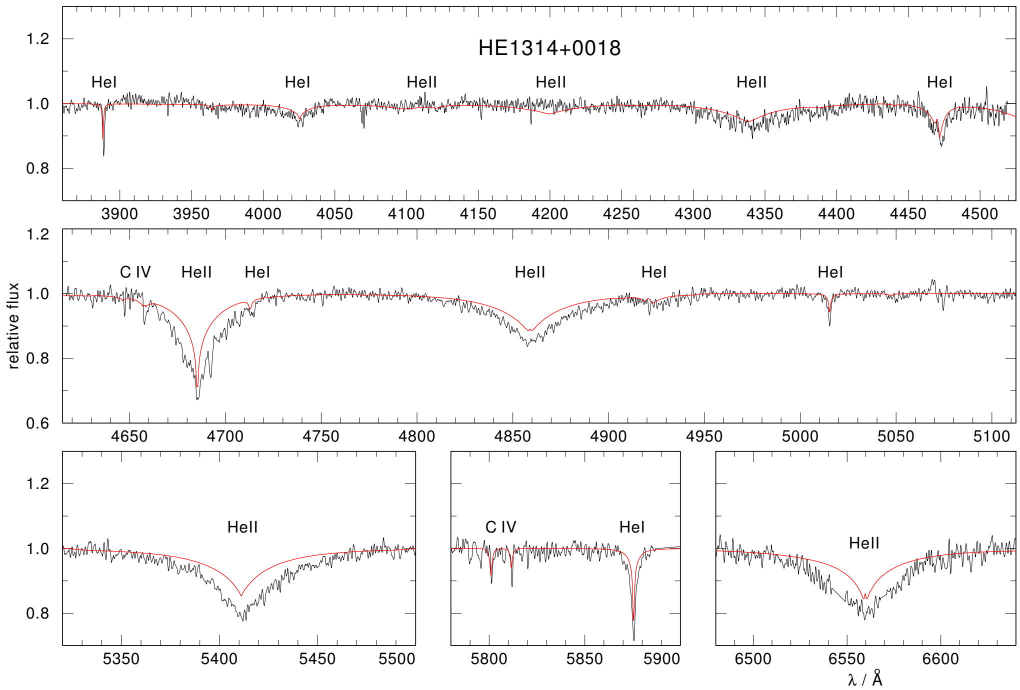

Figure 1. Spectrum of the new DO white dwarf. Overplotted is a model with $T_{\rm eff}$=60 000 K, log g=7.5, and C/He=0.001. The He I lines fit well, but all the He II lines in the model are much too weak. No acceptable fit to the complete spectrum is found.

obtained with $T_{\rm eff}$=60 000 K and log g=7.5. It is obvious that the synthetic He II lines are much too weak compared to the observation. We found no model that can fit the strong He II lines. If we increase $T_{\rm eff}$, these lines become slightly deeper, but never reach the observed equivalent widths. $T_{\rm eff}$>70 000 K can be excluded because the He I lines disappear. $T_{\rm eff}$<55 000 K is excluded because the He I lines become too strong and the He II lines are getting even weaker. A compromise is reached at about 65 000 K in a sense that the relative He I/He II line strengths in the model are similar to the observed ones. But, clearly, lines from both ionization stages are much too weak.

This situation was never encountered before in analyses of cool DOs. However, this problem is reminiscent of what we faced with those "hot" DOs that show signatures of a super-hot wind. We have found that a large fraction (50%) of the hot DOs shows such signatures in the optical spectrum (Werner et al. 1995). These hot stars show high ionization absorption lines of the CNO elements (e.g. C VI, N VII, O VIII, and even Ne X). The high excitation potentials involved require temperatures approaching almost 10^6 K and the triangular shaped line profiles suggest their formation in a rapidly accelerating wind from the WD, reaching a terminal velocity of the order of 10 000 km s^{-1}. At the same time, all He II lines have symmetric profiles and, like in the present case, they are much too strong to be fitted by any DO model. The reason for this simultaneous occurrence of "hot-wind" signatures and too-strong He II lines in hot DOs is unknown.

We have also considered the possibility that HE1314+0018 shows a binary composite spectrum. This can be ruled out because, as already mentioned, the strong He II lines cannot be matched by any DO model, even if we disregard the presence of He I lines.

From the C IV 5801/5812 Å doublet we find a carbon abundance of C/He= 0.003 by number, under the assumption of $T_{\rm eff}$ =60 000 K and $\log g$=8, hence, HE1314+0018 is the coolest DO with a safe detection of a photospheric trace metal.

3. The PG1159 Star

A comparison of the HE1429−1209 spectrum with other PG1159 stars immediately reveals that we have found another very hot, low-gravity PG1159 star which is rather similar to the well known central star of the planetary nebula NGC 246 and the central star RX J2117.1+3412. According to the classification scheme introduced by Werner (1992), the spectral subtype is "lgE" (meaning low-gravity star with emission lines). The spectrum is characterized by lines from highly ionized species (He II, C IV, O VI, Fig. 2), often present as absorption lines with central emission reversals or even as pure emission lines.

We stress in particular the presence of a Ne VII line at 3644 Å and a Ne VII multiplet in the 3850–3910 Å range. We have recently performed a systematic investigation about neon in a large number of PG1159 stars (Werner et al. 2004a) and found that such prominent Ne VII lines are preferentially exhibited by "lgE" subtypes. It has been shown that neon is strongly overabundant (about 20 times solar). For HE1429−1209 we find:

$$\begin{aligned} T_{\rm eff} &= 160\,000\,{\rm K} \pm 15\,000\,{\rm K} \qquad \log g = 6.0 \pm 0.3 \quad [{\rm cm/s^2}] \\ {\rm He} &= 38\% \quad {\rm C} = 54\% \quad {\rm O} = 6\% \quad {\rm Ne} = 2\% \end{aligned}$$

The estimated error for abundances is 0.3 dex. Stellar mass, luminosity, and distance can be derived by comparing the star's position in the $\log g$–$T_{\rm eff}$ diagram with theoretical evolutionary tracks:

$$M/{\rm M}_\odot \;=\; 0.68^{+0.15}_{-0.08} \qquad \log L/{\rm L}_\odot = 4.04^{+0.09}_{-0.05} \qquad d/{\rm kpc} = 5.2^{+1.6}_{-2.2}$$

HE1429−1209 is still very luminous, i.e., on the horizontal part of the post-AGB evolutionary track in the HRD, located within the domain of the hottest central stars of planetary nebulae. It is among the hottest PG1159 stars. It is very similar to six members (having subtype lgE), which also are hot high-luminosity objects. It is thus not surprising that all except one of these previously known lgE-PG1159 stars have associated planetary nebulae, which are rather old and large, but not yet dispersed as is the case for most of the more evolved PG1159 stars (having entered the WD cooling sequence). So we expect that our new PG1159 star could also be surrounded by an extended PN.

In the $\log g$–$T_{\rm eff}$ diagram HE1429−1209 is located within the GW Vir instability strip, close to the PNN variables K 1-16, RX J2117.1+3412, NGC 246, and Longmore 4. And in fact, we could discover pulsations in the new PG1159 star

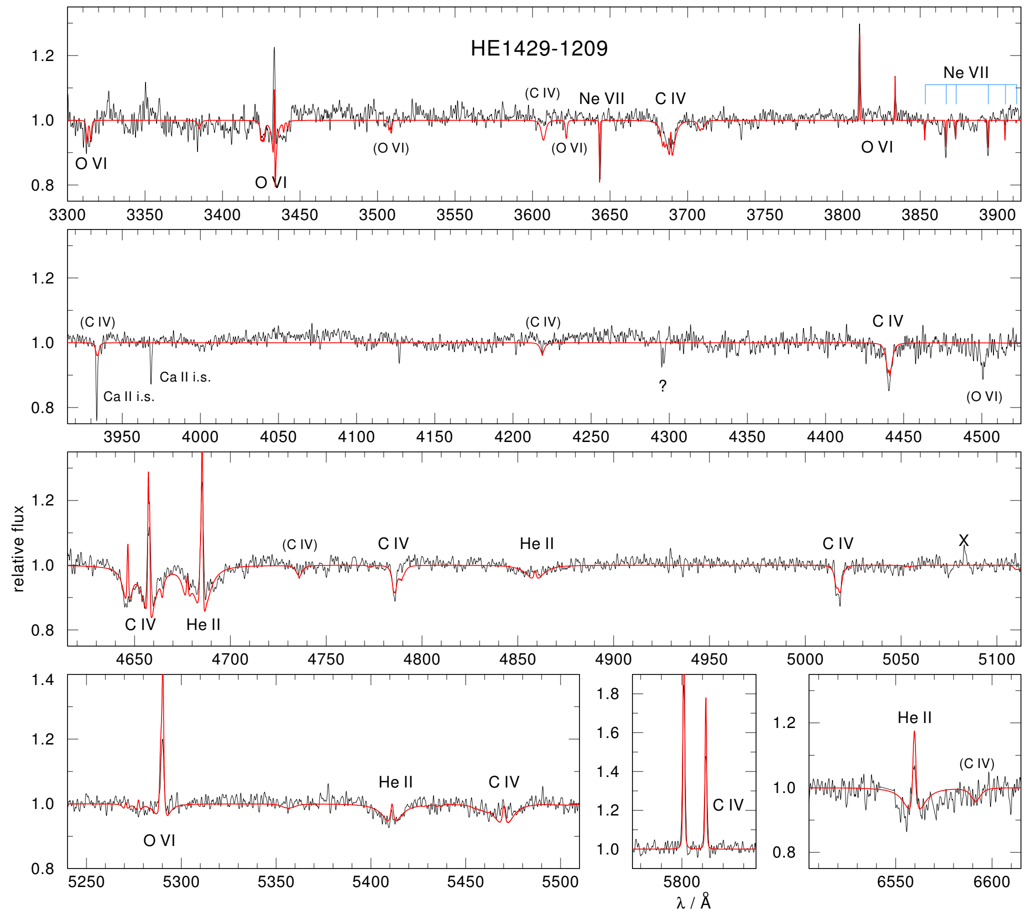

Figure 2. Spectrum of the new PG1159 star with the best fit model overplotted. Note the discovery of a Ne VII multiplet in the 3850–3910 Å range.

(Nagel & Werner 2004). More details on the work described here were published in A&A (Werner et al. 2004b).

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