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CPD –20 1123 (ALBUS 1) IS A BRIGHT He-B SUBDWARF

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ABSTRACT

Based on photometric and astrometric data it has been proposed that Albus 1 (also known as CPD –20 1123) might be a hot white dwarf similar to G191-B2B or, alternatively, a hot subdwarf. We obtained a series of optical spectra showing that CPD –20 1123 is a bright He-B subdwarf. We analyzed the H I Balmer and He I line spectra and measured $T_{\text{eff}} = 19,800 \pm 400$ K, $\log g = 4.55 \pm 0.10$, and $\log N(\text{He})/N(\text{H}) = 0.15 \pm 0.15$. This peculiar object belongs to a family of evolved helium-rich stars that may be the products of double-degenerate mergers, or, alternatively, the products of post horizontal- or giant-branch evolution.

Subject headings: stars: atmospheres — stars: chemically peculiar — stars: individual (Albus 1) — subdwarfs

1. INTRODUCTION

Albus 1 is a blue star ($B_T = 11.75 \pm 0.07$ mag) but its true nature remains to be established. It was first recorded as CPD –20 1123 (Gill & Kapteyn 1896) with a photographic magnitude $m_p = 10.6$ mag but it did not attract much attention until Caballero & Solano (2007) proposed that the star might be a nearby ($d \sim 40$ pc) hot white dwarf, or, alternatively, a hot subdwarf. They noted that the star stands out as the bluest of over a thousand objects investigated in an area of ≈ 18 deg² and covered by the Tycho-2 and 2MASS catalogs. The object is also known as TYC 5940 962 1 (Høg et al. 2000) and 2MASS J06061339–2021072 (Cutri et al. 2003). Caballero & Solano (2007) located the star at R.A. = $06^{\text{h}}06^{\text{m}}13.39^{\text{s}}$, decl. = $-20^{\circ}21'07.3''$ (J2000.0).

We present in § 2 a series of optical spectra of CPD –20 1123 obtained at the Cerro Tololo Inter-American Observatory (CTIO) which show the star to be a helium-rich B subdwarf. The star appears very similar to another well-studied peculiar subdwarf, PG 0229+064 (Green et al. 1986; Moehler et al. 1990; Ahmad & Jeffery 2003), but with markedly stronger optical He I lines. Hot subdwarf B (sdB) stars are core helium burning stars that lie at the hot end of the horizontal branch, i.e., the extreme horizontal branch stars. These stars cover a narrow mass range around $0.5 M_{\odot}$ and have very thin hydrogen ($< 0.02 M_{\odot}$) envelopes (Heber 1986). They possibly evolved via two main branches. The first is through single-star evolution where the star fails to ascend the asymptotic giant branch and loses most of its mass via extensive mass loss (D’Cruz et al. 1996). The second is through binary-star evolution, with one proposed scenario involving the merger of two helium white dwarfs (Iben 1990; Saio & Jeffery 2000). Han et al. (2002, 2003) conducted population syntheses of sdB stars and showed that most should have evolved in binary systems. Helium-rich subdwarfs (He-sdB) have a higher abundance of helium and a systematically lower surface gravity compared to most sdB stars (Ahmad & Jeffery 2003). The origin of He-sdB stars is

still uncertain, but Ahmad & Jeffery (2004) consider that a white dwarf merger is the most likely case. We complete our investigation of CPD –20 1123 with a model atmosphere analysis in § 3, and we conclude in § 4.

2. OBSERVATIONS

We have obtained three spectra of CPD –20 1123 (Table 1) using the R-C Spectrograph attached to the CTIO 4.0 m Blanco Telescope. We employed the KPGL2 grating in the first order and centered at 5109 \AA , resulting in a dispersion of $1.992 \text{ \AA pixel}^{-1}$. We also used the order-sorting filter WG360 which provided us with an effective coverage from $\lambda = 3700$ to 7200 \AA . We observed at the parallactic angle and the slit width was set at $1.5''$ which resulted in a resolution element 4 pixels wide and a FWHM $\approx 8 \text{ \AA}$. Finally we obtained a HeNeAr comparison arc after the series of exposures. We calibrated the spectrometer response with the flux standards EG 131 and Feige 110. However, the spectra of CPD –20 1123 were obtained at a high air mass under poor seeing conditions, and with possible obstruction by clouds near the horizon which resulted in considerable light losses. Nonetheless, the relative flux spectrum is of good quality with a signal-to-noise ratio of ≈ 150 , although we could not secure the absolute flux scale. All data were reduced using standard procedures within IRAF.⁵

Figure 1 shows the summed spectrum. The hydrogen Balmer line series and numerous He I lines are evident. The He I lines appear stronger than in ordinary B subdwarf or main-sequence stars. The object bears similarities with a sample of He-rich subdwarf B stars studied by Ahmad & Jeffery (2003). The spectrum of CPD –20 1123 is also compared to a spectrum of the hot white dwarf EUVE J0230–479 ($T_{\text{eff}} = 64,800$ K, $\log g = 7.72$; Vennes et al. 1996) obtained with the same setup on 2007 July 14. The white dwarf EUVE J0230–479 and the prototypical DA G191-B2B share similar properties but Figure 1 shows that CPD –20 1123 is not a hot white dwarf.

3. ANALYSIS AND DISCUSSION

The peculiar helium line spectrum clearly indicates an evolved star. Figure 2 compares CPD –20 1123 and PG 0229+064 (Green et al. 1986; Moehler et al. 1990; Ahmad & Jeffery 2003). We obtained the spectrum of PG 0229+064 from the Isaac Newton Group Archive. The spectrum was originally

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⁵ IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

TABLE 1
CTIO OBSERVATION LOG

Date and Time (UT)	Exposure Time (s)	Air Mass
2007 July 12 10:19	120	2.83
2007 July 12 10:25	120	2.70
2007 July 12 10:29	120	2.60

obtained by Ahmad & Jeffery (2003) using the ISIS double-beam spectrograph attached to the 4.2 m William Herschel Telescope. The helium lines appear somewhat weaker in PG 0229+064 than in CPD -20 1123 which may indicate that the helium abundance is somewhat higher in the latter. Following a strict application of the subdwarf classification scheme proposed by Drilling et al. (2003) CPD -20 1123, much like PG 0229+064, would be listed as a sdB3V:He15, where a classification index of He15 implies a deeper H γ line over the He I λ 4471 line. The absence of He II is consistent with a relatively low temperature compared to other helium-rich subdwarf stars. In order to find out whether or not the atmosphere is helium-rich it is necessary to perform a model atmosphere analysis.

We computed a series of non-LTE model atmospheres using TLUSTY version 200 and SYNSPEC version 48 (Hubeny & Lanz 1995). The three-dimensional grid points are located at $T_{\text{eff}} = 18000, 20000, \text{ and } 22000$ K, at $\log g = 4.5, 5.0, \text{ and } 5.5$, and at the helium abundance $\log N(\text{He})/N(\text{H}) = -0.5, 0.0, \text{ and } 0.5$. We fitted the Balmer line spectrum (from H α to H9) and the He I line spectrum ($\lambda\lambda$ 4026, 4471, 4713, 4921, and 5015) of CPD -20 1123 using χ^2 minimization techniques. Table 2 lists the atmospheric parameters T_{eff} , $\log g$, $\log N(\text{He})/N(\text{H})$, and M_V (see below) of CPD -20 1123 from this study, and the parameters of PG 0229+064 (note that $n_{\text{He}} = N(\text{He})/[N(\text{H}) + N(\text{He})]$) from Ahmad & Jeffery (2003). We also estimated the absolute magnitude M_V of PG 0229+064 using parameters from Ahmad & Jeffery (2003). The helium-to-hydrogen abundance ratio is a factor of ≈ 7 larger in CPD -20 1123 than in PG 0229+064, and it is comparable to abundance ratios measured in a few He-sdB stars studied by Ahmad & Jeffery (2003).

The stellar parameters of CPD -20 1123 place it on an extreme horizontal branch track at $M = 0.49 M_{\odot}$ (Dorman et al. 1993). We obtained the evolutionary tracks at $M = 0.471, 0.480, \text{ and } 0.490 M_{\odot}$ with a solar abundance ($Y = 0.288, [\text{Fe}/\text{H}] = [\text{O}/\text{Fe}] = 0.0$) using the VizieR database at the Centre de Données de Strasbourg. We then located CPD -20 1123 near the track at $M = 0.49 M_{\odot}$ in the $\log g$ versus T_{eff} plane. Adopting a gravity of $\log g = 4.55$, this mass implies a radius of $0.62 \pm 0.07 R_{\odot}$. Next we calculated the absolute V magnitude using the solid angle subtended by the star at 10 pc, $\Omega = 2 \times 10^{-18}$, and the model flux at 5500 Å. Based on the apparent optical magnitude from the All Sky Automated Survey (ASAS-3; Pojmanski 2002) $V = 12.08 \pm 0.04$, and the calculated absolute magnitude $M_V = 2.55 \pm 0.24$, we estimate a distance of $d = 800^{+100}_{-80}$ pc. Therefore, a proper motion of 19 mas yr^{-1} (Høg et al. 2000) corresponds to a tangential velocity of $72^{+9}_{-7} \text{ km s}^{-1}$ characteristic of an old population in the thin disk or possibly in the thick disk (Thejll et al. 1997; Altmann et al. 2004). A detailed kinematical study awaits high-dispersion spectroscopy and accurate radial velocity measurements. On the other hand the location of CPD -20 1123 in the $\log g$ versus T_{eff} plane also sits well with the He-He merger

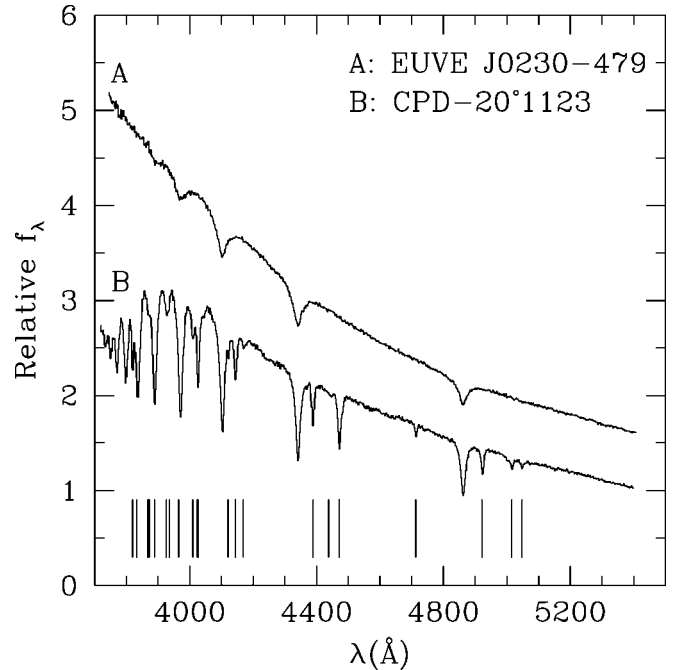


FIG. 1.—Summed CTIO spectrum of CPD -20 1123 normalized at $\lambda = 5500$ Å and a spectrum of the DA white dwarf EUVE J0230-479 also normalized at 5500 Å but shifted up by 0.5 units. He I lines are marked with vertical lines.

tracks of Saio & Jeffery (2000) displayed by Ahmad & Jeffery (2003).

The 2MASS measurements do not support the presence of a cool companion to CPD -20 1123 (Caballero & Solano 2007). Infrared excess is a common feature among subdwarf stars and has often been used to infer the presence of a cool companion (Thejll et al. 1995). Although the C II λ 4267 line is clearly present in PG 0229+064, it is not detected in CPD

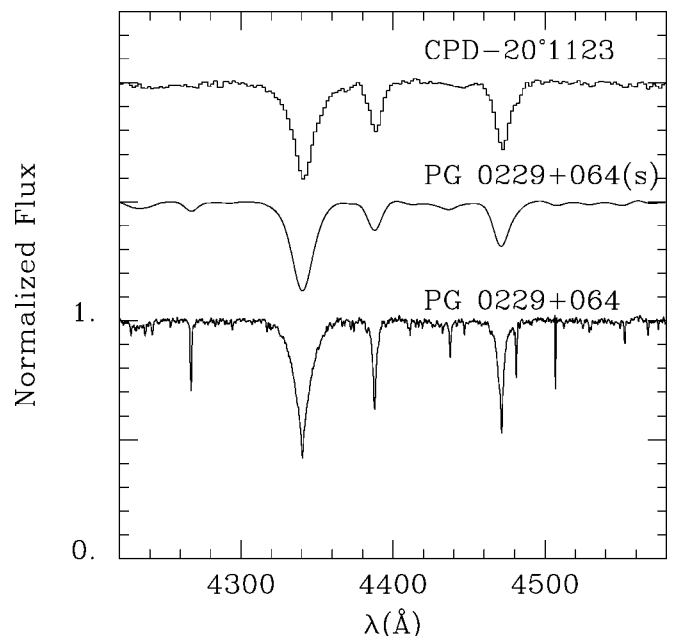


FIG. 2.—Comparing CPD -20 1123 (shifted up by 1.0 unit) and PG 0229+064. The spectrum of PG 0229+064 is presented at the nominal resolution of 0.8 Å as well as degraded to a resolution of 8 Å (labeled “s” and shifted up by 0.5 units).

TABLE 2
STELLAR PARAMETERS

Star ^a	T_{eff} (10^3 K)	$\log g$	M_V (mag)	$\log N(\text{He})/N(\text{H})$	n_{He}
CPD –20 1123	19.8 \pm 0.4	4.55 \pm 0.10	2.55 \pm 0.24	0.15 \pm 0.15	0.6 \pm 0.1
PG 0229+064	19.70 \pm 0.15	4.2 \pm 0.1	1.70 \pm 0.24	–0.66 \pm 0.03	0.18 \pm 0.01

^a Parameters for CPD –20 1123 from this study and parameters for PG 0229+064 from Ahmad & Jeffery (2003).

–20 1123. The detection of weaker lines will be best achieved in the future with the acquisition of high-dispersion spectra. Abundance of trace elements offers clues to the origin of these objects. In the present instance, the absence of carbon would support a He-He white dwarf merger origin. Overall, the origin of CPD –20 1123 remains an open question.

4. CONCLUSIONS

We show that CPD –20 1123 is a He-sdB. The spectrum shows strong He I lines along with the hydrogen Balmer line series. The atmosphere is dominated by helium, but high-dispersion spectra are required to carry out a detailed abundance analysis. Present evidence indicates that CPD –20 1123 may

be the result of He-He white dwarf merger, although post horizontal- or giant-branch evolutionary scenarios cannot be excluded.

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