ALBUS 1: A VERY BRIGHT WHITE DWARF CANDIDATE

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ABSTRACT

We have serendipitously discovered a previously unknown, bright source ( \( B_V = 11.75 \pm 0.07 \, \text{mag} \) ) with a very blue \( V_r - K_s \) color, which we have named Albus 1. A photometric and astrometric study using Virtual Observatory tools has shown that it possesses an appreciable proper motion and magnitudes and colors very similar to those of the well-known white dwarf G191-B2B. We consider Albus 1 as a DA-type white dwarf located at about 40 pc. If its nature is confirmed, Albus 1 would be the sixth brightest isolated white dwarf in the sky, which would make it an excellent spectrophotometric standard.

Subject headings: solar neighborhood — subdwarfs — white dwarfs

Online material: color figures

1. INTRODUCTION

The three classical white dwarfs were, at the beginning of the 20th century, \( \alpha^2 \) Eri B, Sirius B, and van Maanen’s star. Although \( \alpha^2 \) Eri B had been discovered by Herschel (1785) and Sirius B had been predicted by Bessel (1844), it was not until the 1920s when other great astronomers noticed their oddness (Luyten 1922) and popularized the term “white dwarf” (Eddington 1924). The extreme physical conditions by which the white dwarfs are supported against gravitational collapse could not be understood until the quantum mechanics was properly developed. Since the 1930s, the number of known white dwarfs has exponentially increased, from 18 in 1939 (Schatzman 1958) and over 100 in 1950 (Luyten 1950) to a few thousand at present (McCook & Sion 1999; Eisenstein et al. 2006). See Liebert (1980), Koester (2002), and Hansen & Liebert (2003) for extensive reviews of the general properties of white dwarfs.

The vast majority of the known white dwarfs are very faint, with typical magnitudes in the optical from \( V = 15 \) to 20 mag, or even fainter. Only a few very bright white dwarfs (\( V < 12 \, \text{mag} \) ), including the three classical white dwarfs and Procyon B, are known. Many of them, especially those that are not in double degenerate systems, are extensively used as spectrophotometric stars (see, e.g., the recent catalog by Landolt & Uomoto 2007). Except for rare exceptions, such as the very hot dwarfs and cataclysmic variables found in the Röntgensatellit (ROSAT) all-sky survey of extreme-ultraviolet sources by Pounds et al. (1993), all the very bright white dwarfs were discovered during photometric and astrometric surveys before the early 1970s (e.g., Kuiper 1941; Luyten 1949; Thackeray 1961; Eggen & Greenstein 1965; Giclas et al. 1965; Schwartz 1972). Afterward, and in particular with the advent of the Sloan Digital Sky Survey, the detection of new white dwarfs and blue subdwarfs has been biased toward magnitudes fainter than \( V = 12 \, \text{mag} \). Because of that, the photometry-based discovery of a very bright white dwarf candidate 35 years later would be outstanding. If confirmed, it would yield doubts on the real knowledge that we have of the solar neighborhood and on the completeness of previous and current surveys for white dwarfs.

In this work, we present Albus 1, a previously unknown very bright (\( V_r = 11.80 \pm 0.14 \, \text{mag} \) ) white dwarf candidate.\(^3\) Its finding chart is provided in Figure 1. Albus 1 was serendipitously discovered during an optical near-infrared photometric study by J. A. Caballero & E. Solano (2007, in preparation), devoted to characterize the young stars and brown dwarfs surrounding Alnilam (\( \epsilon \) Ori) and Mintaka (\( \delta \) Ori). As part of this study, they made a correlation between the Tycho-2 (Høg et al. 2000) and the Two Micron All Sky Survey (2MASS) catalogs in ten \( 45^\circ \) radius comparison fields at the same Galactic latitude of the brightest stars of the young Ori OB 1 b association (the Orion Belt; \( b \sim -17.5^\circ \)). The total investigated area was only 17.7 deg\(^2\) (\( \sim 0.04\% \) of the whole sky). Albus 1 has a \( V_r - K_s \) color that clearly deviates from those of the other 1275 investigated sources (see Fig. 2). In particular, while the bluest remaining sources have \( V_r - K_s \sim -0.3 \, \text{mag} \), Albus 1 has a color \( V_r - K_s = -0.95 \pm 0.14 \, \text{mag} \). The Tycho-2 \( B_V, V \) and 2MASS \( JHK_s \) photometry shows that the object is extremely blue at all the wavelengths from 0.4 to 2.2 \( \mu \text{m} \). Given the extreme blueing of Albus 1, we decided to investigate it in detail.

2. ANALYSIS

In this work, we have taken advantage of the tools offered by the Virtual Observatory (VO),\(^4\) which is an international, community-based initiative to provide seamless access to the data available from astronomical archives and services. The VO also aims to provide state-of-the-art tools for the efficient analysis of this huge amount of information. In particular, we have used Aladin,\(^5\) a VO-compliant interactive sky atlas developed by the Centre de Données astronomiques de Strasbourg that allows the user to visualize and analyze astronomical images, spectra, and catalogs available from the VO services.

Albus 1 has an appreciable Tycho-2 proper motion of 19 mas yr\(^{-1}\). Since the comparison fields are relatively close to

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\(^3\) Albus is the Latin term for “white.”
\(^4\) Vizier Online Data Catalog, II/246 (R. M. Cutri et al., 2003).
\(^5\) See http://www.ivoa.net.
\(^6\) See http://aladin.u-strasbg.fr/aladin.gml.
the antapex (the point the Sun is moving away from), the foreground objects in this region have not very large proper motions except for some very nearby stars with large tangential velocities. Indeed, the proper motion of Albus 1 is in the 23rd percentile of the investigated sources (i.e., 77% of the investigated Tycho-2 stars have μ < 19 mas yr⁻¹). This makes Albus 1 a nearby Galactic object.

Apart from the coordinates, proper motion, and \( B_V \) magnitudes from Tycho-2 and the \( JHK_s \) magnitudes from 2MASS, taken from J. A. Caballero & E. Solano (2007, in preparation), we have also collected additional photometric and astrometric data from other catalogs: SuperCOSMOS Science Archive (Hambly et al. 2001), USNO-B1 (Monet et al. 2003), NOMAD1 (Zacharias et al. 2004), and DENIS.³ The data match nicely with Tycho-2 and 2MASS, except for the fact that for very blue objects the Tycho-2 \( B_V \) and photographic \( B_P \) photometry are not comparable. To avoid superfluous, repetitive information in Table 1, we provide only the Tycho-2 and 2MASS information and the \( R_I \) photometric data from USNO-B1.

The search with Aladin concluded that there is no radio (NRAO VLA), mid-infrared (IRAS), ultraviolet (EUVE), or X-ray (ROSAT) source or object discussed in the literature (SIMBAD) at less than 5′ to Albus 1. Spectroscopic information does not exist, nor has photometry in the Johnson passbands been obtained yet.

3. RESULTS

To ascertain the real nature of Albus 1, we must compare its photometry with that of other very blue objects. There is a limited number of Galactic objects with colors as blue

³ Vizer Online Data Catalog, B/denis (DENIS Consortium, 2005).

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**Table 1**

| Parameter | Value | Reference |
|-----------|-------|-----------|
| Name      | Albus 1 | 1         |
| WD number | WD 0604–203 | 1       |
| \( a (J2000.0) \) | 06°06′13.39″ | 2 |
| \( \delta (J2000.0) \) | −20°21′07.3″ | 2 |
| \( \mu_a \cos \delta \) | \( 7 \pm 3 \) mas yr⁻¹ | 2 |
| \( \mu_a \) | \( 18 \pm 3 \) mas yr⁻¹ | 2 |
| \( B_V \) | 11.75 ± 0.07 mag | 2 |
| \( V_V \) | 11.80 ± 0.14 mag | 2 |
| \( R \) | 11.84 mag | 3 |
| \( I_H \) | 11.90 mag | 3 |
| \( J \) | 12.56 ± 0.02 mag | 4 |
| \( H \) | 12.66 ± 0.03 mag | 4 |
| \( K_s \) | 12.76 ± 0.03 mag | 4 |
| Spectral type | DA? | 1 |
| \( d \) | \( \sim 40 \) pc | 1 |

**References.**—(1) This work. (2) Tycho-2 catalog. (3) 2MASS catalog.
as those of Albus 1: white dwarfs, hot subdwarfs, and early-type main-sequence, blue horizontal-branch, and Population II stars. Figure 3 compares the optical near-infrared colors of Albus 1 with those of dwarf and giant stars in the direction to Alnitak and Mintaka. Our blue source is even bluer than the blue horizontal-branch and Population II type main-sequence, blue horizontal-branch, and Population II stars. Besides, such luminous stars are located at long heliocentric distances (kpc), which implies very low proper motions, in contrast with what we have measured for Albus 1. Population II stars are common in the bulge near the center of the Galaxy and in the Galactic halo. Some of the latter cross the solar neighborhood, but only a few of them display extremely blue colors (see, e.g., the recent photometric study of horizontal-branch and metal-poor candidates by Beers et al. 2007). Therefore, Albus 1 is an early-type hot subdwarf or a white dwarf.

The extreme blueing of Albus 1 prevents us from transforming the B_V magnitudes to Johnson BV magnitudes using standard relations and, therefore, from comparing its colors with other white dwarfs tabulated in exhaustive works such as in Bergeron et al. (2001). A new comparison may come, instead, from the available Tycho-2 and 2MASS data. In Table 2, we have compiled the basic data of the brightest white dwarfs and blue subdwarfs identified in the Tycho-2 catalog. We used the white dwarf lists by McCook & Sion (1999) and Holberg et al. (2002), and looked for the Tycho-2 counterparts of the white dwarfs brighter than V = 13.0 mag. Fainter objects were not considered due to their poor photometric accuracy. This list surpasses the sample of white dwarfs observed by the Hipparcos satellite in Vaucul et al. (1997). There are three evident absences: Sirius B, o3 Eri B, and Procyon B (the three brightest known white dwarfs), which are too close to other bright stars and were, thus, not identified by Tycho-2. Among the tabulated objects, there is only one hot subdwarf with blue colors, GJ 3435, which indicates its rarity.

Data in Table 2 is represented in Figure 3. Albus 1 is located in the color-color diagram very close to the well-known white dwarfs G191-B2B (DA1) and GJ 433.1 (DA3), at V_r ~ J ~ K_s = ~0.8 mag, J ~ K_s ~ ~0.2 mag. The resemblance between the spectral energy distributions of Albus 1 and G191-B2B (“the best studied of all hot white dwarfs;” Barstow et al. 2003), shown in Figure 4, is evident. Both of them have the same K_s magnitude within the error bars (Albus 1: K_s = 12.76 ± 0.03 mag; G191-B2B: K_s = 12.76 ± 0.02 mag), but G191-B2B is 0.40 ± 0.11 mag brighter in B_r. It leads us to tentatively classify Albus 1 as an early DA white dwarf slightly cooler than G191-B2B and, therefore, slightly closer to the Sun.
The stellar common proper-motion companion of G191-B2B has an accurate parallax determination by Hipparcos at $d = 46 \pm 4$ pc. Hence, Albus 1 could be located at about 40 pc, which would explain its appreciable proper motion. The probability of Albus 1 being a more distant blue subdwarf is smaller (see Table 2). From the blue $J - K_s$ color in Figure 3, it is deduced, besides, that Albus 1 has no main-sequence close companion or forms part of a cataclysmic variable system.

As shown by Salim & Gould (2002), an optical-infrared reduced proper-motion diagram (e.g., $V + 5 \log \mu$ vs. $V - J$) can be used to classify stars even if no parallax information is available. In particular, white dwarfs and subdwarf stars are easily distinguished from main-sequence stars as they are several magnitudes dimmer at the same color. The position of Albus 1 in the reduced proper-motion diagram in Figure 4 in Gould & Morgan (2003; $V_p + 5 \log \mu = 3.2 \pm 0.6$ mag, $V_r - J = -0.76 \pm 0.14$ mag) agrees with this requirement.

4. CONCLUSIONS

Of the 30 white dwarfs and blue subdwarfs listed in Table 2, only 13 have Tycho-2 $V_p$ magnitudes brighter than 12.0 mag. Albus 1, with $V_r = 11.80 \pm 0.14$ mag, is included in this group. Accounting for the three brightest known white dwarfs not in the table, and discarding the close binary systems BL Psc AB, V841 Ara AB, V3885 Sgr AB, and BD +28 4211 AB, whose spectral energy distributions are affected by the main-sequence close companions, we conclude that Albus 1 could be the 12th brightest white dwarf yet known. Since six of the white dwarfs brighter than it are in multiple systems (the binary status of GJ 127.1 AB claimed by Gill & Kapteyn 1896 is, however, not confirmed), then Albus 1 would be the sixth brightest isolated white dwarf, after the long-known Feige 34, L145-141, BD -07 3632, and HD 340611 (Luyten 1949; Eggen & Greenstein 1965) and the very hot white dwarf and extreme-ultraviolet source RE J2214−49 (Holberg et al. 1993).

Albus 1, although located in the southern hemisphere, is visible from the most important northern observatories. This fact, together with its brightness, makes our blue source an appropriate candidate spectrophotometric standard provided that its white dwarf or hot subdwarf nature is spectroscopically confirmed. Our serendipitous detection has also shown that the $V_p - K_s$ color is a good and simple discriminator to look for very blue, relatively bright objects. A search for new very bright white dwarf candidates using Tycho-2 and 2MASS is currently ongoing.

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Fig. 4.—Spectral energy distributions of Albus 1, the DA1 white dwarf G191-B2B, and the B2 Vp star $\alpha$ Ori E (shifted to a heliocentric distance of 0.5 kpc). The seven passbands ($B, V, R, I, J, H, K_s$) are indicated. [See the electronic version of the Journal for a color version of this figure.]