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SSSPM J1549−3544 IS NOT A WHITE DWARF

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ABSTRACT

Spectroscopy and photometry demonstrate that SSSPM J1549−3544 is not a cool white dwarf, but a high-velocity metal-poor halo star.

Subject headings: stars: fundamental parameters — stars: individual (SSSPM J1549−3544) — stars: kinematics — subdwarfs — white dwarfs

1. INTRODUCTION

Cool white dwarfs are typically identified through the combination of proper motion and apparent magnitude called "reduced proper motion" (Liebert et al. 1979; Gizis & Reid 1997; Salim & Gould 2002, 2003; Lépine & Shara 2005). At a given brightness and color, white dwarfs will have larger proper motions than main-sequence stars owing to closer distances from the Earth implied by their small radii.

Metal-poor stars, or subdwarfs, also stand out well in reduced proper motion diagrams due to their lower luminosities (for the same color class) and typically higher velocities. Subluminous main-sequence stars that distinguish themselves in reduced proper motion are kinematic members of the thick disk and halo (Mihalas & Binney 1981; Binney & Tremaine 1987; Binney & Merrifield 1998). Subdwarfs have long been a contaminant in surveys aiming to find cool white dwarfs because both stellar types are mixed in a reduced proper motion diagram at intermediate colors. Cool white dwarfs must be confirmed spectroscopically (Liebert et al. 1979; Gizis & Reid 1997; Salim & Gould 2002; Farihi 2004; Kilic et al. 2004).

Current complete and ongoing large-scale proper-motion surveys are discovering numerous exotic objects, including extreme subdwarfs, brown dwarfs, and cool white dwarfs (see Oppenheimer et al. 2001; Scholz et al. 2004; Lépine & Shara 2005 and references therein). Most if not all of these searches are utilizing available large-scale optical photographic sky survey catalogs. This is potentially problematic for the identification of cool white dwarfs because optical photographic bandpasses do not yield broad color baselines, and photographic photometry has intrinsically large errors. These facts lead to a large overlap in the white dwarf and subdwarf sequences in reduced proper motion diagrams (Salim & Gould 2002). Yet even with spectroscopy, subdwarfs and other weak-lined objects can appear featureless in low-resolution and/or low signal-to-noise ratio (S/N) measurements; they can be potentially mistaken as DC white dwarfs (McCook & Sion 1999; Farihi 2004). Identification of degenerates with $T_{\rm eff} = 4000$–5000 K should include good S/N spectroscopy covering blue-green optical wavelengths (Farihi 2004; Kilic et al. 2004).

This paper presents evidence that contrary to the claim of Scholz et al. (2004), the high proper motion star SSSPM J1549−3544 ($15^{\rm h}48^{\rm m}40\overset{\rm s}{.}23$, $-35°44'25\overset{''}{.}5$; J2000.0) is neither the nearest cool white dwarf nor a degenerate star, but rather a very high velocity halo star passing through the solar neighborhood.

2. OBSERVATIONS AND DATA

Optical *BVRI* photometric data were obtained 2005 February 14 with the Orthogonal Parallel Transfer Imaging Camera (Tonry et al. 2002) on the University of Hawaii 2.2 m telescope at Mauna Kea. Observing conditions were photometric with seeing $\sim 1\overset{''}{.}0$ and some gusty winds 20–40 mph. Three identical exposures of SSSPM J1549−3544 were taken at each bandpass for a total integration time of 12–30 s, yielding S/N > 10 at all wavelengths in a $0\overset{''}{.}7$ aperture radius. A standard Landolt field (Landolt 1992) was observed similarly immediately following the science target.

The images were flat-fielded, cleaned of bad pixels in the region of interest, and combined into a single frame at each wavelength for photometry. Calibration was performed with three stars, and aperture photometry was executed using standard IRAF packages. Calibrator stars were measured in a $1\overset{''}{.}4$ aperture radius, and the science target data were corrected to this standard aperture and adjusted for relative extinction. The results are listed in Table 1.

Optical 4200–10000 Å spectroscopic data were obtained 2005 March 18 with the Double Beam Spectrograph (DBS; Rodgers et al. 1988) on the Australian National University 2.3 m telescope at Siding Spring Observatory. Only the red arm of the spectrograph was operated, with no dichroic in the beam. The 158 line $\rm mm^{-1}$ grating used gave a spectral resolution of 10 Å (2.5 pixels) with the 2″ slit. The seeing was $\sim 2\overset{''}{.}3$ and the sky was clear.

SSSPM J1549−3544 and the flux calibrator LTT 6248 were each observed for 600 s, yielding S/N > 20 over the majority of the science target wavelength shown in Figure 1. The spectral images were flat-fielded and cleaned of bad pixels in the region of interest, and flux-calibrated spectra were extracted using standard IRAF packages. The spectra were trimmed to show the region of interest, while no attempt was made to remove telluric features.

3. RESULTS

The combined optical and near-infrared colors of SSSPM J1549−3544 are consistent with a main-sequence star of $T_{\rm eff} \sim 4200$ K, late K spectral type (Bessell & Brett 1988). The near-infrared magnitudes are too bright for known cool and ultracool white dwarfs (Farihi 2005). For example, the reddest known degenerates have colors that peak near $I - K \lesssim 1.1$,

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TABLE 1
Optical and Near-Infrared Photometric Data

Band	λ_0 (μm)	SSSPM J1549−3544 (mag)
B	0.44	16.13
V	0.55	14.78
R	0.64	14.00
I	0.80	13.20
J	1.25	12.34
H	1.63	11.77
K_s	2.16	11.62

Note.—The uncertainties are all ≤5%. JHK_s data are taken from 2MASS (Cutri et al. 2003).

after which they become bluer again as shown by observation and models (excepting pure helium models at $T_{\rm eff} \lesssim 4250$ K; Bergeron et al. 1995, 2001), while SSSPM J1549−3544 has $I - K_s = 1.58$.

The spectrum in Figure 1 confirms the status of SSSPM J1549−3544 as a nondegenerate star, and the deep MgH feature near 5200 Å indicates that it is metal-poor (Reid & Hawley 2000). Other unlabeled spectral features present include weak Hα and several Fe and Ca lines, plus some weak CaH and TiO. These latter features are difficult to distinguish as they are located, for the most part, within and around the prominent telluric bands (Kirkpatrick et al. 1991) that are also seen in the calibrator star spectrum.

Following the methodology of Gizis (1997), the spectral type and subdwarf class of SSSPM J1549−3544 were estimated by measuring the TiO5, CaH1, CaH2, and CaH3 spectroscopic indices, which are listed in Table 2. Using equations (1)–(3) of Gizis (1997), a spectral type of K5 is found consistently across all three relations, and type sdK5 is found using equation (7) of the same work. However, given the fact that the spectral resolution achieved here is ∼3 times lower than that of Gizis (1997), the spectroscopic measurements may be unreliable but are presented here as a rough guide. There are no distinctions between sdK and esdK stars before spectral type K7, and, combined with the uncertain spectroscopy, it is difficult to say whether or not SSSPM J1549−3544 is an extreme subdwarf without a direct metallicity measurement. The MgH band near 5200 Å is quite strong, and an extreme subdwarf classification might be appropriate (Reid & Hawley 2000).

In order to assess the kinematics of SSSPM J1549−3544, a distance must be estimated. Conservatively assuming that this star lies 2 mag below the main sequence at spectral type K5, it would have $M_V \approx 9.5$ mag (Drilling & Landolt 2000; Reid & Hawley 2000). This would place the star at $d = 114$ pc with a tangential speed of 430 km s^{-1} based on the astrometric data in Scholz et al. (2004). Furthermore, 14 spectral lines (many without high S/N) were used to measure the radial velocity, the crude result being $v_r = +210 \pm 70$ km s^{-1}, corrected for the motion of the Earth along the line of sight on the date of observation. Combining all this data, a Galactic *UVW* space motion was calculated, corrected for the solar motion, $(U, V, W) = (-9, +12, +7)$ km s^{-1} (Mihalas & Binney 1981), relative to the local standard of rest (*U* positive toward the Galactic anticenter, *V* positive in the direction of Galactic rotation, *W* positive toward the north Galactic pole). The result is $(U, V, W) = (-46, -465, +42)$ km s^{-1}, making SSSPM J1549−3544 a halo star (Jahreiss & Wielen 1997; Beers et al. 2000). If we instead assume $v_r = 0$ due to the potential unreliability of the measured radial velocity, the result becomes $(U, V, W) = (143, -392, -10)$ km s^{-1}, which is still consistent with halo membership. Despite a fairly conservative assumption, the 114 pc distance estimate and space motions should be considered preliminary as subdwarfs can span a wide range of absolute magnitudes. If SSSPM J1549−3544 is closer to 150 pc, or around 1.5 mag below the main sequence, it would have a total heliocentric velocity in the range 550–590 km s^{-1}. At 1 mag below the main sequence, or 180 pc, SSSPM J1549−3544 would have a total galactocentric velocity of ∼470 km s^{-1} and would be among the fastest moving stars ever seen (Carney et al. 1988, 1996).

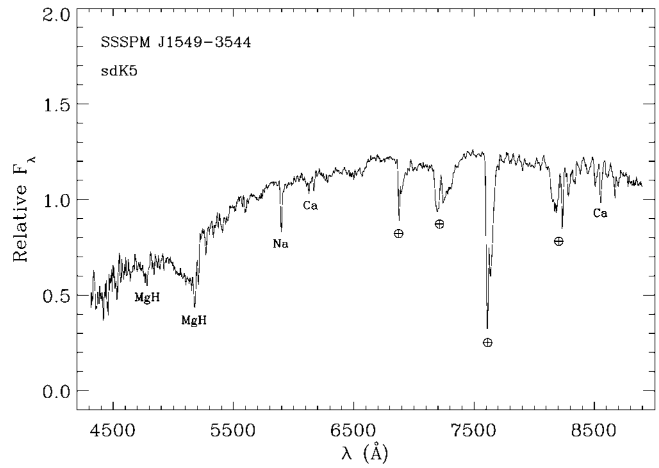

Fig. 1.—Optical spectrum of SSSPM J1549−3544 taken with the DBS on the 2.3 m telescope at Siding Springs Observatory. The data are flux calibrated and normalized near 5500 Å. The most prominent stellar absorption features are labeled, along with telluric O_2 and H_2O bands. The spectral type should be considered preliminary (§ 3).

4. CONCLUSION

The star SSSPM J1549−3544 is shown to be a metal-poor sdK star rather than a cool white dwarf as previously claimed (Scholz et al. 2004). It is possible that this star is an extreme K subdwarf, but in any case it is a very high velocity halo star passing through the solar neighborhood. With many new proper-motion objects being discovered and studied, it is critical to correctly distinguish cool white dwarfs from subdwarf contaminants. There is great science potential in the oldest degenerates.

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TABLE 2
Spectroscopic Measurements

Band	Strength
TiO5	0.986
CaH1	0.983
CaH2	1.034
CaH3	0.997

Notes.—Spectroscopic band measurements of SSSPM J1549−3544, using the method of Gizis (1997). A spectral type of sdK5 is found on the basis of these data.

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