PROPERTIES OF THE NEARBY BROWN DWARF WISEP J180026.60+013453.1

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ABSTRACT

We present new spectroscopy and astrometry to characterize the nearby brown dwarf WISEP J180026.60+013453.1. The optical spectral type, L7.5, is in agreement with the previously reported near-infrared spectral type. The preliminary trigonometric parallax places it at a distance of 8.01 ± 0.21 pc, confirming that it is the fourth closest known late-L (L7–L9) dwarf. The measured luminosity, our detection of lithium, and the lack of low surface gravity indicators indicates that WISEP J180026.60+013453.1 has a mass 0.03 < M < 0.06 M⊙ and an age between 300 million and 1.5 billion years according to theoretical substellar evolution models. The low space motion is consistent with this young age. We have measured the rotational broadening (ν sin i = 13.5 ± 0.5 km s⁻¹), and use it to estimate a maximum rotation period of 9.3 hr.

Key words: brown dwarfs – solar neighborhood – stars: individual (WISEP J180026.60+013453.1)

1. INTRODUCTION

The closest stars to the Sun make up a uniquely valuable sample for astronomical studies. Nearby L dwarfs are especially significant due to their relative rarity and low intrinsic luminosities. Kirkpatrick et al. (2012) list 243 stars and brown dwarfs in 182 systems within 8 pc of the Sun, including just three L dwarfs. Discoveries of additional nearby very-low-mass stars and brown dwarfs (Bihain et al. 2013; Luhman 2013, 2014; Cushing et al. 2014; Pérez Garrido et al. 2014; Scholz 2014) have continued. Of these, WISE J104915.57-531906.1A (Luhman-16A) is a late-L dwarf at ~2 pc (Burgasser et al. 2013; Kniazev et al. 2013; Luhman 2013). Additionally, WISE J072003.20-084651.2 (Scholz 2014) is a low-mass binary system with a combined-light optical classification of L0 ± 1 (Ivanov et al. 2015) and component near-infrared classifications of M9.5+T5 (Burgasser et al. 2015). Although currently 6 pc distant, it likely passed within 0.25 pc from the Sun in the last 70 kyr (Mamajek et al. 2015).

WISEP J180026.60+013453.1 (hereafter W1800+0134) was discovered by Gizis et al. (2011) using the Wide-field Infrared Survey Explorer (Wright et al. 2010) and Two Micron All-sky Survey (Skrutskie et al. 2006). We classified W1800+0134 as an L7.5 dwarf in the near-infrared and estimated its distance as 8.8 ± 1.0 pc. In this paper, we present additional observations and analysis of this brown dwarf, including a preliminary trigonometric parallax that places it at 8.01 ± 0.21 pc, confirming that it is the fourth nearest late-L (L7–L9) dwarf.

2. OBSERVATIONS

2.1. Spectroscopy

Optical (far-red) long-slit spectra were obtained with the Gemini-North telescope (Gemini program GN-2012B-Q-105) on UT Date 2012 September 14 with the GMOS spectrograph (Hook et al. 2004) using grating R831. Four 600 s exposures were taken during cloudy conditions. The wavelength coverage was 6340–8460 Å with a resolution of ~2 Å. The seeing (full width at half maximum) was 0.64 arcsec, and W1800+0134 appears single in the z-band finder image. The spectrum was reduced with the Gemini GMOS IRAF package and is shown in Figure 1. The signal-to-noise ranges from ~8 at the blue end to ~80 at the red end. Comparing to the Kirkpatrick et al. (1999) spectral standards, we find that the spectral type is L7.5 ± 0.5, midway between the L7 and L8 standards. We caution that our spectrum does not include the 8460–10000 Å region necessary for a definitive optical spectral type, but it is consistent with the near-infrared L7.5 spectral type reported in the discovery paper. Lithium absorption is present with an equivalent width (EW) of 2.7 Å. No Hα emission or absorption is detected (EW < 0.5 Å).

W1800+0134 was observed in clear and dry conditions on UT Date 2011 July 6 with the Keck II NIRSPEC near-infrared echelle spectrograph (McLean et al. 2000), as part of an ongoing search for radial velocity variables among nearby L dwarfs (Burgasser et al. 2012). The source was observed using the high-dispersion mode, N7 filter and 0″432 × 12″ slit to obtain 2.0–2.39 μm spectra over orders 32–38 with λ/Δλ = 20,000 (Δv = 15 km s⁻¹) and dispersion of 0.315 Å pixel⁻¹. The two 120 s exposures were obtained in nobs separated by 7″ along the slit, and a nearby A0 star was observed for telluric calibration. The resulting near-infrared spectrum was reduced using an adaptation of the REDSPEC package (described in McLean et al. 2007), then compared to a family of theoretic BT-Settl models (Allard 2014) using a Markov-chain Monte Carlo (MCMC) adaption of the forward-modeling method described in Blake et al. (2010) and Burgasser et al. (2015). The solar atlas of Livingston & Wallace (1991) was used to model telluric absorption, and both radial shift and rotational line broadening were simulated in the theoretical models. Figure 2 shows the best-fit model from our MCMC chain. Marginalizing over all fits, we infer a radial velocity of v_rad = −5.1 ± 0.7 km s⁻¹ and projected equatorial rotational velocity v sin i = 13.5 ± 0.5 km s⁻¹.

2.2. Astrometry

W1800+0134 was added to the U.S. Naval Observatory’s near-infrared parallax program (Yrba et al. 2004) in 2011 July. Astrometric observations were obtained in J-band using the
reconstructed ASTROCAM camera, the optically identical original of which is described by Fischer et al. (2003). The preliminary results presented here are derived from data obtained through May of 2015 and consist of 96 frames obtained on 31 nights. The relative trigonometric parallax is 122.45 ± 3.18 mas with a proper motion of 424.7 ± 2.1 mas yr⁻¹ at position angle 153°.8 ± 0°.2. The correction to absolute parallax for the 14 reference frame stars was determined to be 2.44 ± 0.62 mas based on 2MASS photometry and the homogenized infrared colors of Kenyon & Hartmann (1995); giving an absolute parallax of 124.89 ± 3.24 mas. This object continues on the USNO parallax program and we expect to obtain a considerably improved parallax based on a full analysis of the final data set in approximately

![Figure 1](image1.png)

**Figure 1.** The optical spectrum is consistent with a type of L7.5. Note the detection of lithium in absorption and the absence of any Hα feature. Also shown are the Kirkpatrick et al. (1999) spectra of the L7 dwarf standard DENIS-P J0205.4-1159 (blue, scaled by a factor 1.51 to match W1800+0134) and the L8 dwarf standard 2MASSW J1632291+190441 (red, scaled by a factor of 7.6). Each standard is offset vertically to allow comparison, but we caution that the Kirkpatrick et al. (1999) spectra were taken with lower resolution which affects the appearance of the narrow atomic lines.

![Figure 2](image2.png)

**Figure 2.** The NIRSPEC spectrum of WISEP J180026.60+013453.1 with the best fit model. The data are shown in black, the model of the intrinsic spectrum in red, and the model including telluric absorption is in green. The $v_{\text{rad}}$ and $v_{\sin i}$ reported in Table 1 are the best-fit values from our MCMC analysis.
three years. We obtain the luminosity by applying a K-band bolometric correction of $3.19 \pm 0.07$ mag (Golimowski et al. 2004; Cushing et al. 2006) and the $U$, $V$ and $W$ components of space motion from the astrometry and radial velocity. The measurements are listed in Table 1.

### Table 1

| Parameter | W1800+0134 |
|-----------|------------|
| $v_{rad}$ km s$^{-1}$ | $1.75 \pm 0.5$ |
| $\pi_{rel}$ (mas) | $-5.1 \pm 0.7$ |
| $\theta_{ast}$ (mas) | $122.45 \pm 3.18$ |
| $\mu$ (mas yr$^{-1}$) | $24.89 \pm 3.24$ |
| $\mu$ (mas yr$^{-1}$) | $424.7 \pm 2.1$ |
| $\theta$ (deg) | $153.79 \pm 0.14$ |
| Distance (pc) | $8.01 \pm 0.21$ |
| $U$ km s$^{-1}$ | $2.6 \pm 0.6$ |
| $V$ km s$^{-1}$ | $-9.5 \pm 0.4$ |
| W km s$^{-1}$ | $-13.8 \pm 0.4$ |
| $M_f$ (2MASS) | $14.78 \pm 0.07$ |
| $M_g$ (2MASS) | $13.60 \pm 0.07$ |
| $M_Ks$ (2MASS) | $12.90 \pm 0.06$ |
| $L/L_\odot$ | $-4.53 \pm 0.04$ |
| Age$^a$ | $300-1500$ Myr |
| Mass$^a$ | $0.03-0.06$ $M_\odot$ |

**Note.**

$^a$ Model dependent, see text.

### 3. DISCUSSION

All late-L dwarfs are brown dwarfs below the hydrogen-burning limit, but our observations further constrain the properties of W1800+0134. The presence of lithium requires this source to have a mass less than 0.06$M_\odot$ (Magazzu et al. 1993). Theoretical evolutionary models predict that an object with luminosity $L/L_\odot = -4.5$ with lithium must be $\sim$1.5 billion years old or younger (Burrows et al. 1997; Baraffe et al. 2003; Saumon & Marley 2008). W1800+0136 does not show any signs of low surface gravity in its near-infrared spectrum, and it lies within the field dwarf locus in the Dupuy & Liu (2012) near-infrared color–magnitude diagrams. These imply that $\log g \geq 4.7$ and therefore the age is $\geq 300$ Myr and mass $\geq 0.03 M_\odot$ according to the same evolutionary models. The space motion is consistent with the young thin disk, and W1800+0134 has a 100% chance of being a field object and a 0% chance of belonging to any known moving group according to the model of Gagné et al. (2014). As discussed in the discovery paper, there is no spectroscopic evidence of an unresolved companion; in Huélamo et al. (2015)’s survey, W1800+0134 did not show any companion down to 0.3 arcsec in the H-band. The apparent magnitudes and parallax are consistent with a single L7.5 dwarf. The rotational period should be $\sim 9.3$ hr or less, based on the model predictions of a radius of $\sim 0.10 R_\odot$ and our measurement of $v \sin i = 13.5 \pm 0.5$ km s$^{-1}$.

Overall, W1800+0134 is a typical L7.5 dwarf. With its relatively large parallax and position near the celestial equator, it is well suited for additional follow-up and detailed study by ground-based telescopes in either hemisphere. For example, its classification at the start of the L dwarf/T dwarf transition, proximity, and relatively dense surrounding starfield, makes W1800+0134 a potentially interesting target for variability studies. While its potentially long rotation period may challenge experimental designs, Apai et al. (2013) and Burgasser et al. (2014) have argued that such long-period rotators may have larger spot features, and hence more pronounced variability, if spot size correlates with the atmospheric Rhines scale, which is itself proportional to the rotation period. Indeed, the highly variable T1.5 dwarf 2MASS J21392676+0220226, which exhibits $\sim 30\%$ variability amplitude in the infrared, has a rotation period of 7.7 hr (Radigan et al. 2012; Khondrika et al. 2013). Based on the observed parallax, W1800+0134 is a confirmed member of the 10 pc sample and may be a member of the 8 pc sample. Assuming a normal distribution for the uncertainty, the probability that W1800+0134 has a distance less than 8.0 pc is 48.6% if no priors are applied, or 46.6% if we apply our prior belief that the probability should be proportional to the volume sampled. Until a much more precise parallax is available, W1800+0134 could be included with this weight in statistical studies of the 8 pc sample such as Kirkpatrick et al. (2012).

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