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Scarlet Spectra: Two Red L Dwarfs Revealed by SOAR

Grady Robbins [1,2] Aaron M. Meisner [2] Adam C. Schneider [3] J. Davy Kirkpatrick [4] Dan Caselden [5] Adam J. Burgasser [6] Jacqueline K. Faherty [5] Marc J. Kuchner [7] Federico Marocco [4] Jonathan Gagné [8] Sarah Casewell [9] The Backyard Worlds: Planet 9 Collaboration, and The Backyard Worlds: Cool Neighbors Collaboration

[1] *Department of Astronomy, University of Florida, 201 Criser Hall, Gainesville, FL 32611*
[2] *NSF's National Optical-Infrared Astronomy Research Laboratory, 950 N. Cherry Ave., Tucson, AZ 85719, USA*
[3] *United States Naval Observatory, Flagstaff Station, 10391 West Naval Observatory Rd., Flagstaff, AZ 86005, USA*
[4] *IPAC, Mail Code 100-22, California Institute of Technology, 1200 E. California Blvd., Pasadena, CA 91125, USA*
[5] *Department of Astrophysics, American Museum of Natural History, Central Park West at 79th Street, NY 10024, USA*
[6] *Center for Astrophysics and Space Science, University of California San Diego, 9500 Gilman Drive, La Jolla, CA 92093, USA*
[7] *Exoplanets and Stellar Astrophysics Laboratory, NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD 20771, USA*
[8] *Planétarium Rio Tinto Alcan, 4801 Pierre-de Coubertin Ave, Montreal, Quebec H1V 3V4, Canada*
[9] *School of Physics and Astronomy, University of Leicester, University Road, Leicester, LE1 7RH, UK*

ABSTRACT

We present the analysis of two unusually red L dwarfs, CWISE J075554.14−325956.3 (W0755−3259) and CWISE J165909.91−351108.5 (W1659−3511), confirmed by their newly obtained near-infrared spectra collected with the TripleSpec4 spectrograph on the SOAR Telescope. We classify W0755−3259 as an L7 very low-gravity (VL-G) dwarf, exhibiting extreme redness with a characteristic peaked H-band and spectral indices typical of low-gravity late-type L dwarfs. We classify W1659-3511 as a red L7 field-gravity (FLD-G) dwarf, with a more rounded H-band peak and spectral indices that support a normal gravity designation. W1659−3511 is noticeably fainter than W0755−3259, and the rounded H-band of W1659−3511 may be evidence of CH_4 absorption.

Keywords: L dwarfs, Brown dwarfs, Spectroscopy, Near-infrared spectroscopy, Low-gravity dwarf, Field-gravity dwarf

1. INTRODUCTION

The Backyard Worlds projects (Kuchner et al. 2017; Humphreys et al. 2020) aim to discover new substellar objects in the solar neighborhood by applying citizen science to find potential moving objects. CWISE J075554.14−325956.3 (hereafter W0755−3259) and CWISE J165909.91−351108.5 (hereafter W1659−3511) were identified as part of the Backyard Worlds project by citizen scientist Dan Caselden. Both objects were determined to have significant proper motions in CatWISE2020 (Marocco et al. 2021). Photometric distance estimates suggest that each of these objects may be within ∼25 pc of the Sun, and were both flagged for follow-up spectroscopy.

2. OBSERVATIONS

Near-infrared spectra of W0755−3259 and W1659−3511 were obtained using the TripleSpec4 near-infrared spectrograph (Schlawin et al. 2014; Herter et al. 2020) located at the 4.1m Southern Astrophysical Research (SOAR) telescope. Observations were taken in queue mode on April 17, 2023 (UT) and April 29, 2023 (UT), respectively. Using a slit width of 1.″1, Triplespec4 returns simultaneous spectra across six cross-dispersed orders covering the 0.8–2.4 μm range with a resolving power of ∼3500. 180-second exposures were taken at different nod positions, with 16 nods obtained for W0755−3259 and 20 nods obtained for W1659−3511.

Spectral extractions and telluric corrections were performed with a modified version of the SpeXtool package (Vacca et al. 2003; Cushing et al. 2004) using A0 stars taken just after the target. W0755−3259 is a previously known source discovered in Scholz & Bell (2018), but its spectrum has not yet been analyzed and the parallax for this source has not yet been used to investigate moving group membership. Both of these objects are located in crowded fields, with W0755−3259 (l, b) ∼ (249, -2) and W1659−3511 (l, b) ∼ (349, +5).

3. ANALYSIS OF W0755-3259 SPECTRUM

The spectra for W0755−3259 and W1659−3511 were compared to M, L, and T spectral standards, as well as VL-G, intermediate-gravity (INT-G), and FLD-G spectra contained the SPLAT Python library (Burgasser & the SPLAT Development Team 2017). The spectra were Gaussian-smoothed to the resolution of the standards ($\Sigma = 5$) and normalized between 1.27 and 1.29 μm.

Using the J-band classification method referenced in Kirkpatrick et al. (2010), W0755-3259 visually best matched the spectrum of the L5 dwarf standard 2MASS J08350622+1953050 discovered in Chiu et al. (2006) and recommended by Kirkpatrick et al. (2010) (see Figure 1). However, it is important to note that despite being the closest match among the standards, W0755−3259 remains unusually red compared to any dwarf standard. The J-band exhibits noticeable differences, suggesting that this object would be classified as L5 (pec) if based on the standards alone.

When comparing to INT-G and VL-G dwarf spectra in the SPLAT library (Burgasser & the SPLAT Development Team 2017), a close visual correlation was found between the J- band and H-band of W0755−3259 and the L7 VL-G dwarf WISEA J114724.10−204021.3 (Schneider et al. 2016) (see Figure 1), so we assign a classification of L7 VL-G even though the K-band of W0755−3259 is still redder.

Determining the gravity type of these objects through non-visual means is challenging, as many methods of gravity classification are designed for dwarfs with spectral types earlier than L7 (e.g., Allers & Liu 2013; Cruz et al. 2017). For L7 and later, one of the few accurate methods is measuring the H-cont index of the blue side of the H-band, as discussed in Allers & Liu (2013). The H-cont index for W0755−3259 is 1.00±0.04, a value expected for VL-G dwarfs with H-cont ≈ 1. Another gravity index is the K-band $H_2(K)$ index described in Canty et al. (2013). W0755−3259 has $H_2(K) = 1.03\pm.04$ between 2.17 and 2.24 μm, whereas VL-G dwarfs have $H_2(K) \leq 1.045$ (Schneider et al. 2014). Additionally, the spectrum exhibits the characteristic triangular shape in the H-band often seen in VL-G dwarfs, further confirming the classification of W0755−3259 as L7 VL-G.

Using the parallax and proper motion determined in Kirkpatrick et al. (2021), we find a 98.6% probability of membership in the Carina-Near Association (Zuckerman et al. 2006) according to the BANYAN Σ classification algorithm (Gagné et al. 2018). A radial velocity measurement for this source would help to firmly determine moving group membership.

4. ANALYSIS OF W1659−3511 SPECTRUM

For W1659−3511, the L7 standard 2MASSI J0825196+211552 discovered in Kirkpatrick et al. (2000) and recommended by Cruz et al. (2017) is a close match in the J-band (see Figure 1), while noticeable differences are again observed in the H- and K-bands. Note that we used the L7 spectral standard recommended by Cruz et al. (2017) for W0755−3259 instead of the recommended Kirkpatrick et al. (2010) L7 standard due to inconsistencies of the Kirkpatrick et al. (2010) L7 standard, yielding various results for spectral and gravity types when analyzed separately (see Faherty et al. 2012 and Allers & Liu 2013).

When comparing W1659−3511 to INT-G and VL-G dwarf spectra in the SPLAT library, a close H-band and acceptable K-band correlation is found for the L7 INT-G dwarf WISEP J004701.06+680352.1 (Gizis et al. 2012). While the H- and K-bands show greater similarity for WISEP J004701.06+680352.1 than the L7 standard, the J-band exhibits a poorer match. Because of our classification method, the L7 standard spectrum is determined to be more accurate and we assign W1659−3511 a classification of L7 (red).

We identify W1659−3511 as a likely FLD-G L7 dwarf using the previous H- and K-band analysis methods. To determine a stable H-cont and $H_2(K)$ index for this object, the spectrum is smoothed with $\Sigma = 20$ to reduce error. H-cont = 0.95±0.02 for W1659−3511, which is expected for FLD-G dwarfs of H-cont < 0.96. $H_2(K) = 1.25\pm0.33$, which is consistent with FLD-G dwarfs that have $H_2(K) > 1.05$. The H-band shape of W1659−3511 does not have the triangular peak seen in most VL-G dwarfs as well, which may be attributed to CH_4 absorption. Through analysis of J-, H-, and K-bands, we classify W1659−3259 as L7 FLD-G (red). Some reasons for the red nature of this field dwarf could be from a dusty atmosphere (Hiranaka et al. 2016) or inclination angle (Vos et al. 2017).

Using the best-available proper motion from Marocco et al. (2021) with BANYAN Σ, we find that W1659−3511 does not match any known nearby young association.

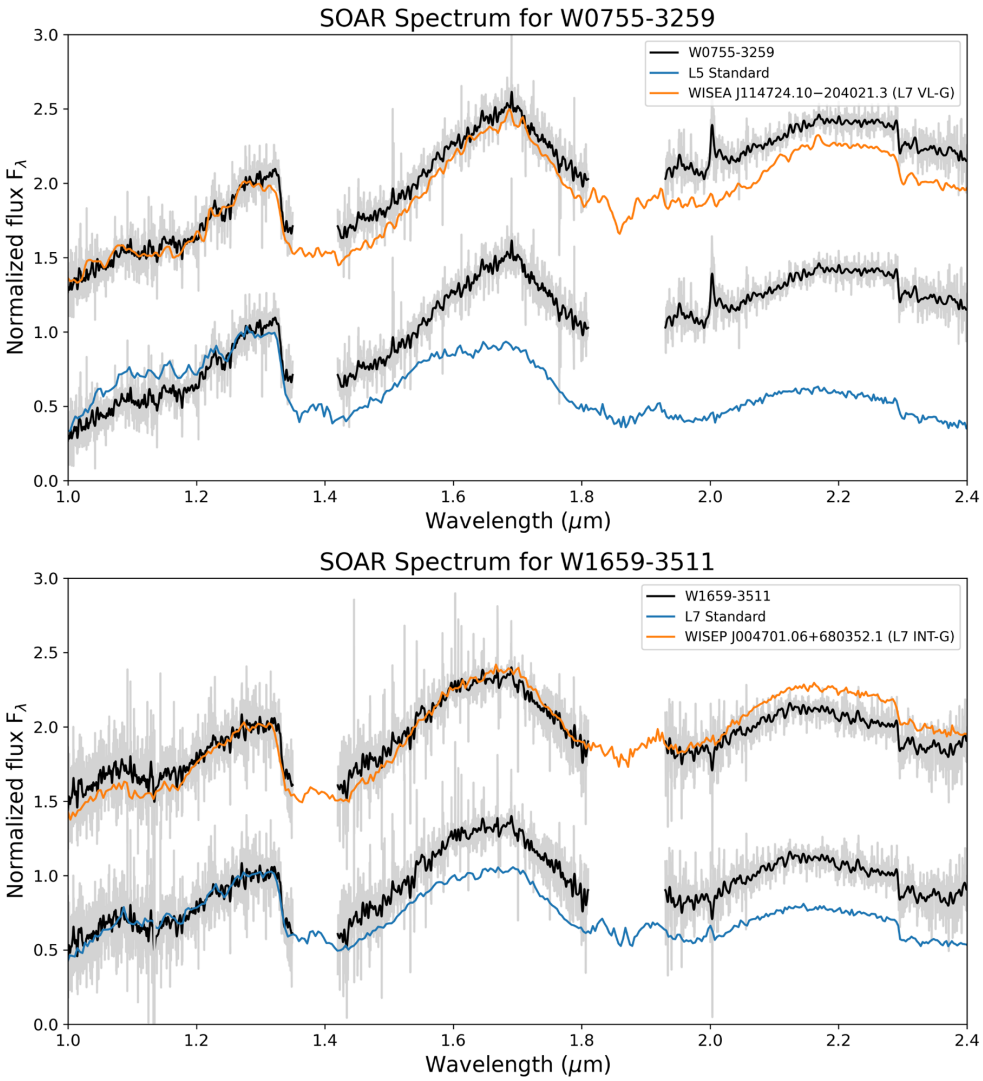

Figure 1. Top panel: The full resolution near-infrared spectrum of W0755−3259 (grey) and smoothed (black) compared to the L5 near-infrared spectral standard SDSS J083506.16+195304.4 (Chiu et al. 2006; Kirkpatrick et al. 2010) and L7 VL-G dwarf WISEA J114724.10−204021.3 (Schneider et al. 2016). Bottom panel: The full resolution near-infrared spectrum of W1659−3511 (grey) and smoothed (black) compared to the L7 near-infrared spectral standard 2MASSI J0825196+211552 (Kirkpatrick et al. 2000; Cruz et al. 2017) and L7 INT-G dwarf WISEP J004701.06+680352.1 (Gizis et al. 2012). All spectra are normalized between 1.27 and 1.29 μm.

5. DISCUSSION

From our analysis of near-infrared spectra, we determine that W0755−3259 is a new L7 very low-gravity dwarf and that W1659−3511 is a new L7 field-gravity dwarf. Due to the redder color and striking resemblance of W0755−3259 with WISEA J114724.10−204021.3 in the J-band, as well as the combination of a high H-cont index, a low $H_2(K)$ value, and a triangular H-band peak, there is clear evidence that W0755-3259 is an L7 VL-G dwarf. W1659−3511 has similar support in its classification as a likely L7 FLD-G dwarf due to the similarities in the J-band to the field L7 spectral standard, as well as a lower H-cont index with no peak and a high $H_2(K)$ value. Notably, W0755−3259 is redder than the L7 VL-G dwarf it shared similarity to in the H- and K-bands. The unusual nature of these red L dwarf spectra emphasizes the importance of further research on these objects to advance our understanding of their atmospheres, gravities, and ages.

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Software: SPLAT (Burgasser & the SPLAT Development Team 2017), WiseView (Caselden et al. 2018)

Facilities: SOAR, WISE

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