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Backyard Worlds: Planet 9 Discovery of an Unusual Low-mass Companion to an M Dwarf at 80 pc

Austin Rothermich[1], Adam C. Schneider[2,3], Jacqueline K. Faherty[4], Katelyn Allers[5], Daniella Bardalez-Gagliuffi[4], Aaron M. Meisner[6], Marc Kuchner[7], J. Davy Kirkpatrick[8], Dan Caselden[9], and Paul Beaulieu[10]

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Author affiliations

[1] Physics Department, University Of Central Florida, 4000 Central Florida Boulevard, Orlando, FL 32816, USA

[2] US Naval Observatory, Flagstaff Station, P.O. Box 1149, Flagstaff, AZ 86002, USA

[3] Department of Physics and Astronomy, George Mason University, MS3F3, 4400 University Drive, Fairfax, VA 22030, USA

[4] Department of Astrophysics, American Museum of Natural History, Central Park West at 79th Street, NY 10024, USA

[5] Bucknell University; Department of Physics and Astronomy; Lewisburg, PA 17837, USA

[6] NSF's National Optical-Infrared Astronomy Research Laboratory, 950 N. Cherry Ave., Tucson, AZ 85719, USA

[7] NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics Laboratory, Code 667, Greenbelt, MD 20771, USA

[8] IPAC, Mail Code 100-22, Caltech, 1200 E. California Blvd., Pasadena, CA 91125, USA

[9] Gigamon Applied Threat Research, 619 Western Avenue, Suite 200, Seattle, WA 98104, USA

[10] Backyard Worlds: Planet 9

ORCID iDs

Austin Rothermich https://orcid.org/0000-0003-4083-9962

Adam C. Schneider https://orcid.org/0000-0002-6294-5937

Jacqueline K. Faherty https://orcid.org/0000-0001-6251-0573

Katelyn Allers https://orcid.org/0000-0003-0580-7244

Daniella Bardalez-Gagliuffi https://orcid.org/0000-0001-8170-7072

Aaron M. Meisner https://orcid.org/0000-0002-1125-7384

Marc Kuchner https://orcid.org/0000-0002-2387-5489

J. Davy Kirkpatrick https://orcid.org/0000-0003-4269-260X

Dan Caselden https://orcid.org/0000-0001-7896-5791

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Abstract

We present the discovery of CWISE J203546.35–493611.0, a peculiar M8 companion to the M4.5 star APMPM J2036–4936 discovered through the citizen science project Backyard Worlds: Planet 9. Given CWISE J203546.35–493611.0's proper motion (μ_α, μ_δ) = (−126 ± 22, −478 ± 23) and angular separation of 34.″2 from APMPM 2036–4936, we calculate a chance alignment probability of 1.15 × 10^{-6}. Both stars in this system appear to be underluminous, and the spectrum obtained for CWISE J203546.35–493611.0 shows a triangular *H* band. Further study of this system is warranted to understand these peculiarities.

1. Introduction

Low-mass companions to known stars provide an excellent opportunity to better understand the formation and evolution of these objects. Identifying co-moving companions has been made easier through the use of all sky, multi-epoch surveys such as the Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010). Backyard Worlds: Planet 9 (Kuchner et al. 2017) is a citizen science project where volunteers examine WISE images to identify high proper motion objects. Here we report the discovery of CWISE J203546.35−493611.0 (hereafter CWISE J2035−4936) an object at the *M*/*L* spectral type boundary co-moving with a known M4.5 star found through the Backyard Worlds project.

2. Discovery of Companion

The primary of this system, APMPM J2035−4936, was discovered and classified via an optical spectrum as M4.5 in Lodieu et al. (2005). Those authors estimated a distance of 165.8 pc to APMPM J2036−4936 using photometric-spectral type relations, resulting in a tangential velocity estimate of 335 km s^{-1}. Using the parallax measurement for this object from Gaia DR2 (Gaia Collaboration et al. 2018), we find a new distance of 81.5 ± 1.5 pc, resulting in a tangential velocity of 162 km s^{-1}. Using this new distance along with the Gaia DR2 *G* magnitude for APMPM J2036−4936 of *G* = 18.080 ± 0.002 mag, we calculate an absolute *G* magnitude of 13.52 mag. Using the relations described in Kiman et al. (2019), this absolute magnitude plus its colors in Gaia DR2 (BP − RP = 3.738 mag, BP − G = 2.313 mag, G − RP = 1.425 mag) place APMPM J2036−4936 as M7. There is no clear explanation for why the Gaia photometry for APMPM J2036−4936 appears underluminous, suggesting an M7 spectral type using the Gaia color–magnitude relations despite it being classified via its optical spectrum as a normal M4.5. Either this source has highly unusual properties or the wrong target was observed in Lodieu et al. (2005), possibly due to its large proper motion.

The companion, CWISE J2035−4936 was independently found by two citizen scientists: Paul Beaulieu and Austin Rothermich. It was identified by visually inspecting APMPM J2036−4936 using the WiseView tool (Caselden et al. 2018). Given the existing VHS photometry (McMahon et al. 2013) (*J* = 16.810 ± 0.010 mag, *H* = 16.444 ± 0.015 mag, *K* = 16.028 ± 0.0229 mag) and CatWISE 2020 photometry (Eisenhardt et al. 2020) (W1 = 15.742 ± 0.023 mag, W2 = 15.455 ± 0.041 mag) and distance of APMPM J2036−4936, we estimated a spectral type between L2 and L5. The CatWISE 2020 proper motion for CWISE J2035−4936 is (μ_α, μ_δ) = (−126 ± 22, −478 ± 23) mas yr^{-1}, compared to (μ_α, μ_δ) = (−82 ± 0.286, −411 ± 0.279) mas yr^{-1} for APMPM J2036−4936 from Gaia DR2.

3. Spectroscopic Observations

We obtained a near infrared (0.97 − 2.41 μm) spectrum of CWISE J2035−4936 on UT 2019 June 19 using TripleSpec (Wilson et al. 2004) on the Southern Astrophysical Research Telescope. Using an ABBA nod pattern, we observed a total of 12 exposures of 180 s each. Our science observations were taken at an airmass of 1.″11–1.″17 under conditions of scattered high cirrus. Immediately following our observations of CWISE J2035−4936 we observed the A0 star, HD 198546 (8 × 5 s exposures at an airmass of 1.″16) for telluric calibration. We reduced our data using a modified version of Spextool (Cushing et al. 2004), including a correction for telluric absorption following the method described in Vacca et al. (2003). The spectrum of CWISE J2035−4936 compared to various spectral standards is shown in Figure 1.

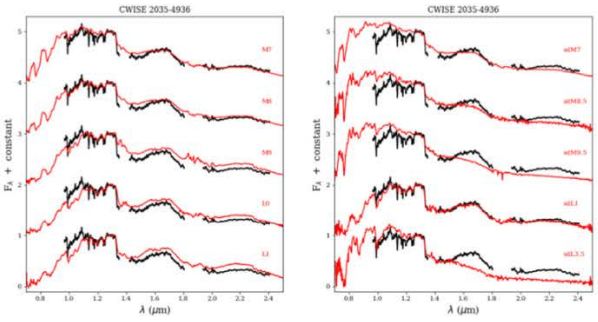

Figure 1. Left: spectrum of CWISE J2035−4936 (black) compared to the spectral standards VB 8 (M7) (Kirkpatrick et al. 2010), VB 10 (M8) (Kirkpatrick et al. 2010), LHS 2924 (M9) (Kirkpatrick et al. 2010), 2MASS 0345+2540 (L0) (Kirkpatrick et al. 2010), and 2MASS 2130-0845 (L1) (Kirkpatrick et al. 2010). Right: CWISE J2035−4936 compared to LHS 377 (sdM7) (Gizis 1997; Greco et al. 2019), 2MASS 0142+0523 (sdM8.5) (Burgasser et al. 2007; Greco et al. 2019), SSSPM 1013 (sdM9.5) (Kirkpatrick et al. 2014), and 2MASS 1756+2815 (sdL1) (Kirkpatrick et al. 2010; Greco et al. 2019), and SDSS J1256-0224 (sdL3.5) (Burgasser et al. 2009; Greco et al. 2019) All spectra were normalized between 1.27 and 1.29 μm and separated by a constant.

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4. Discussion

The spectrum obtained for CWISE J2035−4936 does not fully match any of the spectral standards. When looking at the *J* band portion of the spectrum however, the closest fit is with that of VB 8 (M8), although there are still a few minor features which do not fully match. The *K* band shows some slight irregularities when compared with VB 8, such as slightly lower flux near the blue end. The *H* band of CWISE J2035−4936 however is quite peculiar, appearing to have more of a triangular shape than the *H* band of a standard M8, a feature that has been seen in metal low, sub-dwarf stars (Aganze et al. 2016). This led us to compare CWISE J2035−4936 to sub-dwarf standards as shown in the right panel of Figure

1, which yielded no good fits, though the sdL1 was the closest match. We find no indication that the odd features seen in CWISE J2035–4936 are due to unresolved binarity following the spectral binary template comparison of Burgasser et al. (2010) and Bardalez Gagliuffi et al. (2014). Because the best fit with the normal standards is with that of the M8, we assign CWISE J2035–4936 a near-infrared spectral type of M8 pec. We find that using a very conservative distance range of 67–349 pc, found by using the Gaia absolute magnitude relations in Kiman et al. (2019) for a spectral type range of M7-L2 and the existing Gaia photometry, 166 objects in Gaia EDR3 Gaia Collaboration et al. (2020) match with μ_α and μ_δ both within ±70 mas yr^{-1} of the corresponding CWISE J2035–4936 values (70 mas yr^{-1} ≈ 3× max[σ_{μ_α}, σ_{μ_δ}]). Given the angular separation of 34.″2, this yields a chance alignment probability of 1.15 × 10^{-6}. The angular separation corresponds to a projected physical separation of ~2790 au. Like APMPM J2036−4936, CWISE J2035–4936 also appears to be underluminous, as using our earlier estimates it appeared to be within the range of L2–L5. Due to this apparent underluminosity, the high tangential velocity calculated above, and the triangular *H* band, we do not rule out the possibility of low metallicity in CWISE J2035–4936. Further study of this system is required to understand its peculiarities.

This work has made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.

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