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

Austin Rothermich1, Adam C. Schneider2,3, Jacqueline K. Faherty4, Katelyn Allers5,6, Jillia Bardalez-Gagliuffi1, Aaron M. Meisner6, Marc Kuchner7,8, J. Davy Kirkpatrick8,9, Dan Caselden9, and Paul Beaulieu10

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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 (μα, μδ) = (−126 ± 22, −478 ± 23) and angular separation of 3.2′′ 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.

Keywords

Low mass stars; Binary stars

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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 (Kuehner 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 J203549-4936 as an object at the MC 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. (2020). Those authors estimated a distance of 185.8 pc to APMPM J2035-4936 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 J2035-4936 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. (2018), 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 at M7. There is no clear explanation for why the Gaia photometry for APMPM J2036-4936 appears luminous, suggesting an M7 spectral type using the Gaia standard 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. (2020), possibly due to its large proper motion.

The companion, CWISE J2035-4936 was independently found by two citizen scientists: Paul Beaulieu and Austin Rothenfluh. It was identified by visually inspecting APMPM J2036-4936 using the WISEView tool (Caselden et al. 2013). Given the existing VHS photometry (McMahon et al. 2012) (μv = 16.810 ± 0.010 mag, μr = 16.444 ± 0.015 mag, μg = 16.028 ± 0.022 mag) and CatWISE 2020 photometry (Magain et al. 2020), WISEView photometry (Eisenhardt et al. 2011) (W1 = 15.742 ± 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. 2008) 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 1.27-1.37 under conditions of scattered high cirrus. Immediately following our observations of CWISE J2035-4936 we observed the A0 star, HD 198546 (8 x 5 s exposures at an airmass of 1.16) for telluric calibration. We reduced our data using a modified version of Speftool (Luhman et al. 2008), 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.

4. Discussion
The spectrum obtained for CWISE J2035-4936 does not fully match any of the spectral standards. When looking at the J/H band portion of the spectrum however, the closest fit is with that of VB 8 (M7) (Kirkpatrick et al. 2001), VB 19 (M8) (Kirkpatrick et al. 2001), LHS 2524 (M9) (Kirkpatrick et al. 2001), 2MASS 0345+5540 (L0) (Kirkpatrick et al. 2001), and 2MASS 2130-0845 (L1) (Kirkpatrick et al. 2001). Right: CWISE J2035-4936 compared to LHS 371 (M7) (Gizis et al. 2000), 2MASS 1756+2115 (L0) (Kirkpatrick et al. 2001), SDSS J1256-0224 (L0.5) (Burgasser et al. 2002), Greco et al. (2019), and SDSS 1221-3753 (L0.5) (Burgasser et al. 2003). All spectra were normalized between 1.27 and 1.29 μm and separated by a constant.

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Figure 1: Left spectrum of CWISE J2035-4936 (black) compared to the spectral standards VB 8 (M7) (Kirkpatrick et al. 2001), VB 19 (M8) (Kirkpatrick et al. 2001), LHS 2524 (M9) (Kirkpatrick et al. 2001), 2MASS 0345+5540 (L0) (Kirkpatrick et al. 2001), and 2MASS 2130-0845 (L1) (Kirkpatrick et al. 2001). Right: CWISE J2035-4936 compared to LHS 371 (M7) (Gizis et al. 2000), 2MASS 1756+2115 (L0) (Kirkpatrick et al. 2001), SDSS J1256-0224 (L0.5) (Burgasser et al. 2002), Greco et al. (2019), and SDSS 1221-3753 (L0.5) (Burgasser et al. 2003). All spectra were normalized between 1.27 and 1.29 μm and separated by a constant.

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which yielded no good fits, though the sd1 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. (2015) and Bardalez Gagliuffi et al. (2014). Because the best fit with the normal standards is with that of the MS, we assign CWISE J2035-4936 a near-infrared spectral type of M8. We find that using a very conservative distance range of 67–349 pc, found by using the Gaia absolute magnitude relations in Khan et al. (2012) 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 μJ and μK both within ±70 mas yr⁻¹ of the corresponding CWISE J2035-4936 values (70 mas yr⁻¹ = 3 × max[(o-0), (o-0)]). Given the angular separation of 340, 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.