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BD+48 873b - a brown dwarf companion candidate

R. Jaros[1], **A. Niedzielski**[1], **A. Wolszczan**[2] **and E. Villaver**[3,4]

[1] *Institute of Astronomy, Nicolaus Copernicus University, ul. Gagarina 11, 87-100 Toruń, Poland (E-mail: jaros@doktorant.umk.pl)*

[2] *Department of Astronomy and Astrophysics, Pennsylvania State University, 525 Davey Laboratory, University Park, PA 16802, USA*

[3] *Instituto de Astrofísica de Canarias, 38205 La Laguna, Tenerife, Spain*

[4] *Agencia Espacial Española (AEE), 41015 Sevilla, Spain*

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Abstract. We report the discovery of a brown dwarf candidate around evolved star BD +48 873. Companion is located in eccentric orbit at around 5 AU semi-major axis, which places it in an exciting location at the edge of the theorized brown dwarf desert. We present the radial velocity data analysis results of brown dwarf parameters and the host star's characteristics.

Key words: brown dwarfs – binary – planets

1. Introduction

Pennsylvania-Torun Planet Search (PTPS) project monitored about 1000 objects in the northern hemisphere. Focused mostly on evolved stars, the sample contains a wide range of stars at various evolutionary stages. Here, we present one of the detected potential brown dwarf (BD) candidates orbiting BD+48 873, a giant star in a 5 AU orbit, placing it at the edge of the brown dwarf desert. Brown dwarfs are defined as objects between planets and stars in mass region of 13 - $\sim$75 M_J (Burrows et al. (2001)). Brown dwarf desert is a noticeable lack of those objects in region for orbits $<$ 5 AU(Grether & Lineweaver (2006)). Radial velocity (RV) observations were mostly collected within the PTPS project, using the High-Resolution Spectrograph (HRS, Tull (1998)) at the Hobby-Eberly Telescope (HET, Ramsey et al. (1998)) with later additional follow-up with HARPS-N spectrograph at Telescopio Nazionale Galileo. Keplerian orbital fit parameters were modeled and posterior parameters determined with the RadVel PYTHON package (Fulton et al. (2018)).

2. The star, observations, and the keplerian model

BD+48 873 is a $T_{\rm eff}$= 4830$\pm$ 10 K and $\log g$ = 2.70$\pm$0.03 cms^{-2} [Fe/H]=-0.12$\pm$0.06 intermediate-mass giant star with $logL/L_\odot$ = 1.81$\pm$0.16 and M=

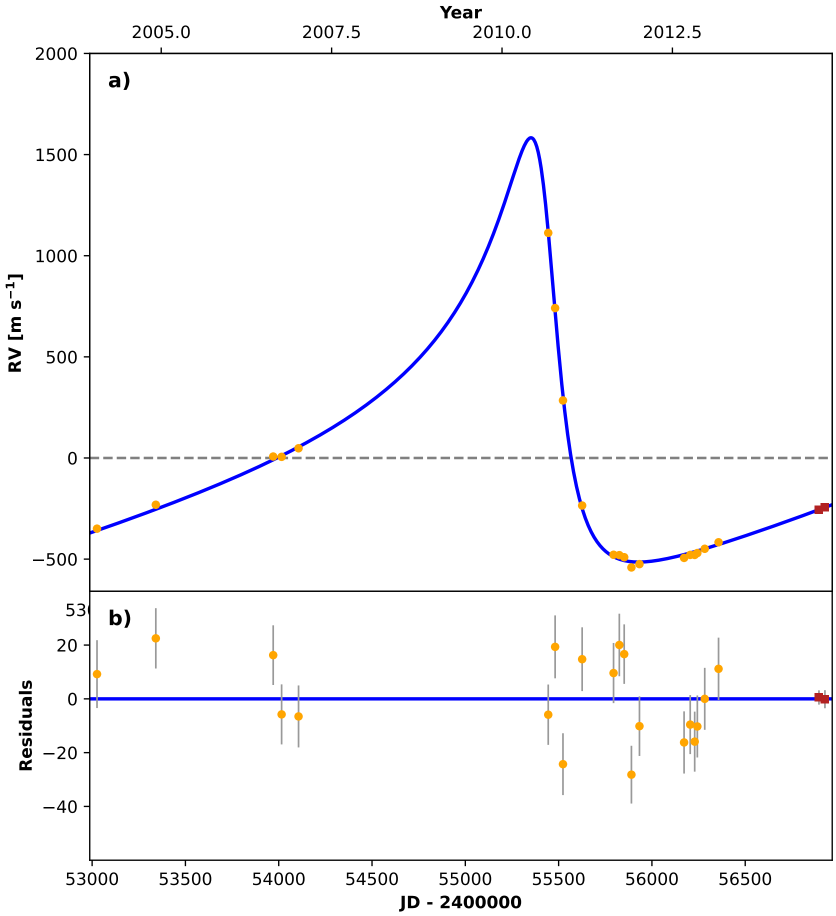

Figure 1. Timeseries with residuals of fitted RV signal for BD+48 873 star.

1.65±0.21 $M_\odot$ with brightness of V=8.31 mag. It belongs to the sample of twelve BD candidates with minimum masses of $m \sin i < 100$ M_J that have been identified in the PTPS sample (Niedzielski et al. (2013)).

Through almost 9 years of spectroscopic observations, 22 epochs have been gathered in total with HET/HRS and two additional epochs with HARPS-N/TNG. Typical uncertainty of HET/HRS data is ∼6 ms^{-1} and ∼3 ms^{-1} in the case of HARPS-N/TNG.

These data show the difference between the highest and lowest points leads to conclusion that real radial velocity amplitude is higher than 1650 ms^{-1}, which is >250 times the HET/HRS uncertainty and a long-term variation.

We modeled these combined data with RadVel and obtained a keplerian orbit of 3686±83 days with a large eccentricity of 0.67±0.01 and semi-amplitude of 1052±43 ms^{-1}. The results are presented in the figure above. The upper panel (a) presents the timeseries of the collected data with modeled keplerian orbit. Yellow dots represent observations made by Hobby-Eberly Telescope. Red squares represent the follow-up observations made with HARPS-N. The lower panel (b) presents the radial velocity post-fit residuals showing the model fit quality. The uncertainties change is caused by stellar jitter fitting, making it bigger to adjust for that possible star effect.

3. Discussion

Table 1. Spectroscopic elements of BD+48 873.

Parameter	Value
P [d]	3686±83
T_c [d]	55498.7±5.3
e	0.67±0.01
ω [rad]	0.86±0.03
K [ms^{-1}]	1052±43
$m \sin i$ [M_J]	83±10
a [AU]	5.52±0.32
σ_{jitter} [ms^{-1}]	16.8±4.3

Presented posterior value results were acquired in the first stage by using the Keplerian model fitting through the likelihood function. The fit was optimized with *scipy* package function *optimize.minimize* for finding the local minimum using Powell's method. For second stage of analysis to extract posterior values and uncertainties, *emcee* package's Affine Invariant Markov chain Monte Carlo (MCMC) Ensemble sampler algorithm was used (Goodman & Weare (2010)).

Within the estimated mass uncertainties, the object could appear to be a brown dwarf as it sits near the maximum of the BD mass region. However, it is highly uncertain about object classification, given the lack of known inclination, naming it instead as a very low mass (VLM) object. From the current estimate of parameters, we can conclude that this object can be categorized as sitting at the outer edge of a BD desert ($\sim$ 5AU). The Keplerian model presented is obviously based on a limited set of data points, not covering evenly the postulated orbit. This adds uncertainty to our detection. It is, therefore, important to collect more observation epochs, specifically around the peak of the RV signal, to straighten the case.

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