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Research Article

DENIS-P J1901391-370017: IS A YOUNG VERY LOW-MASS STAR OR A LOW-MASS BROWN DWARF IN CORONA-AUSTRALIS?

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ABSTRACT

DENIS-P J1901391-370017 has been identified as a low-mass brown dwarf in the Corona-Australis cloud. This paper presents our mass estimate of this brown dwarf. The dereddened spectral energy distribution of the source indicates that DENIS-P J1901391-370017 is a very low-mass star, not a low-mass brown dwarf, as previously reported. We also reconfirm that DENIS-P J1901391-370017 is diskless, as previously mentioned in the literature.

Keywords: brown dwarfs; circumstellar matter; photometry; spectroscopy

1. Introduction

Rocky planets have been found orbiting very low-mass (VLM) stars (masses below ~0.35 M_{Sun}) more frequently than solar-type stars. Detecting young VLM stars and studying circumstellar disks around them is essential to understanding how rocky planets form around these stars.

Nearby young star-forming regions, within 500 parsecs of the Sun and with different ages from 1 Myr to 100 Myr, are excellent laboratories to study young VLM stars, brown dwarfs (BD) with masses below 75 M_{Jup} (M_{Jup} is the mass of Jupiter), and free-floating planetary mass objects. The *Gaia* data release in 2023 (DR3, Gaia Collaboration et al. 2023), which contains about 1.8 billion sources with very high-precision trigonometric parallaxes (i.e., very high-precision distances) and proper motions, is an excellent resource to identify new members of nearby star-forming regions.

DENIS-P J1901391-370017 (hereafter, DENIS1901-3700) was identified as an M8 dwarf in the Corona Australis (CrA) molecular cloud complex by Martín et al. (2010). DENIS1901-3700 was then classified as a planetary-mass object with spectral type L6 (Bouy et al., 2022).

In this paper, we use the dereddened photometry and the dereddened spectral energy

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distribution (SED) of DENIS1901-3700 to determine the mass and age of the source. Our results, contrary to the recent reports, suggest that DENIS1901-3700 is a VLM star rather than a low-mass BD. We also confirm again that this VLM star is diskless. The rest of the paper is arranged as follows. Section 2 presents dereddened photometric data and discusses our estimates of the mass and age of DENIS1901-3700. Section 3 summarizes the results.

2. Determination of mass, age, and surface gravity of DENIS1901-3700

Up to date, only a few BDs have been identified in the CrA region. To determine basic parameters DENIS1901-3700, such as mass, age, and surface gravity $\log g$, we first determined again its membership in CrA with *Gaia* data. DENIS1901-3700 has a *Gaia* trigonometric parallax of 6.4316$\pm$0.4883 mas (or about 155.5$\pm$11.8 pc), a proper motion with μRA = 4.431$\pm$0.545 mas yr^{-1} and μDE = -26.482$\pm$0.498 mas yr^{-1} (DR3[2], Gaia Collaboration et al. 2023). Based on the Gaia data and the Bayesian analysis tool BANYAN Σ[3] (Gagné et al. 2018), we found that DENIS1901-3700 has a membership probability of 99.9% for CrA. Therefore, DENIS1901-3700 is a member of CrA as previously identified in the literature (e.g., Martín et al., 2010).

Based on the optical spectrum of DENIS1901-3700, Martín et al. (2010) estimated its spectral type of M8.0$\pm$0.5. The low value of Na I equivalent width (an indicator for surface gravity) of DENIS1901-3700, 2.6$\pm$0.6 Å, also implies a low surface gravity, thus the youth of DENIS1901-3700. With a low surface gravity and a late spectral type of M8, Martín et al. (2010) suggested that DENIS1901-3700 is a BD in CrA. Based on the SpeX near-infrared spectrum of DENIS1901-3700, Bouy et al. (2022) estimated its spectral type of L6 that corresponds to a planetary mass in the range from 4 M_{Jup} to 13 M_{Jup}. One should note that based on optical and near-infrared spectroscopic observations, Esplin and Luhman (2022) determined a spectral type of M6.5 for DENIS1901-3700. The significant difference in estimating the spectral type of DENIS1901-3700 by those authors is probably due to the reddening effect. The reddening effect occurs because interstellar dust in star-forming regions absorbs blue and visual light waves more than red and near-infrared light waves from stars. This effect makes stars appear redder than they are. Therefore, using spectral indices at different wavelengths to determine spectral type may give different results since the reddening effect depends on wavelength.

To determine the mass of DENIS1901-3700, we first dereddened photometric data and then used the dereddened photometry and theoretical models to estimate its age and mass. Table 1 lists the DENIS, 2MASS, and WISE photometric data of DENIS1901-3700. The source was not detected in WISE W3- and W4-bands. Using the extinction law with $R_V = 3.1$ (Mathis, 1990), we found the visual extinction A_V by searching its value in the range from 0 to 10 minimizing the χ^2 between the dereddened observational photometry and BT-

[2] https://vizier.cds.unistra.fr/viz-bin/VizieR?-source=I/355
[3] https://www.exoplanetes.umontreal.ca/banyan/banyansigma.php

Settl atmospheric models (Baraffe et al. 2015). The A_V value is obtained from the best fit of BT-Settl atmospheric models to DENIS *I*-band, 2MASS *J*-, *H*-, and *K*-band magnitudes. We did not include WISE infrared photometry because the infrared flux from circumstellar dust disk (if any) may affect the best fit.

Table 1. *DENIS I-, 2MASS JHK-, and WISE W1W2-band photometric data of DENIS1901-3700*

DENIS name	*I*	*J*	*H*	*K*	*W1*	*W2*
1901-3700	17.94 ±0.16	14.257 ±0.029	13.045 ±0.033	12.296 ±0.026	11.875 ±0.026	11.514 ±0.023

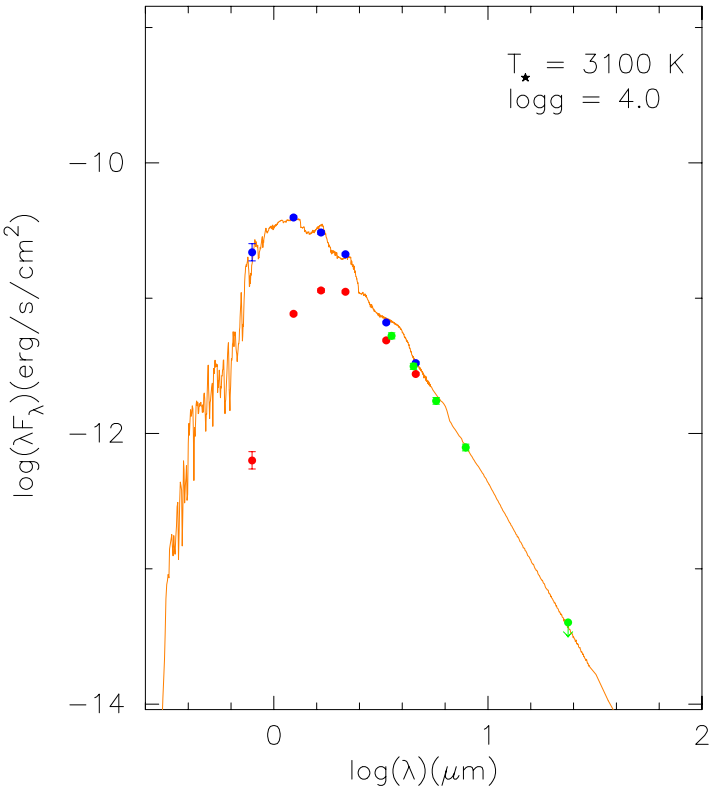

Figure 1. *Dereddened SED of DENIS1901-3700. The orange line shows the best fit of BT-Settl atmospheric models. The blue solid circles represent dereddened DENIS I-band, 2MASS JHK-band, and WISE W1W2-band magnitudes. The dereddened Spitzer photometric data from Peterson et al. (2011) are plotted as green circles. The non-dereddened (observed) data are also shown as red circles for comparison.*

Figure 1 shows the dereddened SED of DENIS1901-3700. The best fit of BT-Settl models is obtained with a visual extinction $A_V = 6.14 \pm 0.01$, an effective temperature of $T_\star = 3100 \pm 100$ K and $\log g = 4.0 \pm 0.5$ (g in cm s^{-2}). The dereddened SED also matches with dereddened *Spitzer* data for DENIS1901-3700 from Peterson et al. (2011). The dereddened SED shows no infrared excesses, an indicator of the presence of circumstellar

dust around the source. We therefore confirm again that DENIS1901-3700 is diskless as previously mentioned in the literature (López Martí et al., 2010).

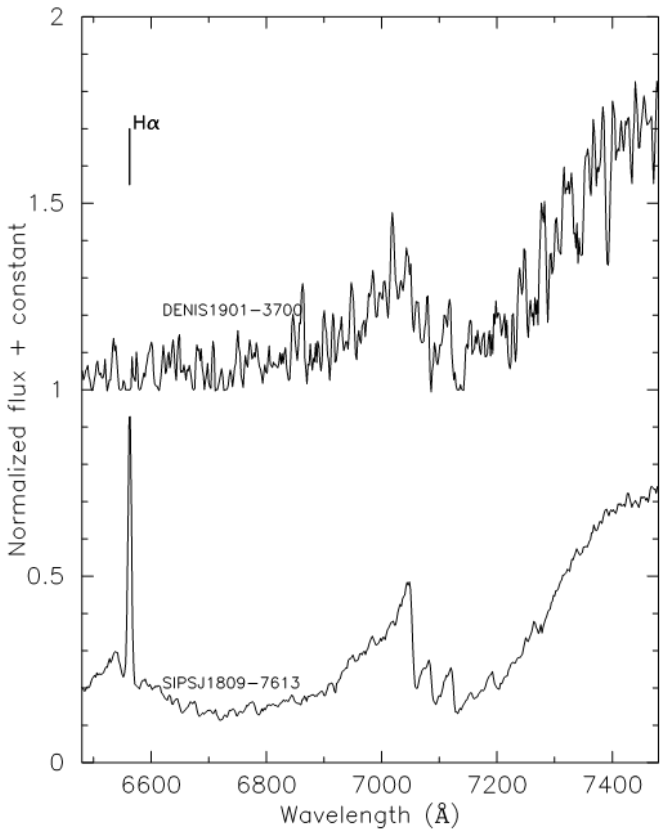

Figure 2. *The optical spectrum of DENIS1901-3700 from Martín et al. (2010). DENIS1901-3700 shows no Hα emission, often observed in young stars. SIPSJ1809-7613, a young M5 dwarf member of the β Pic moving group, exhibits strong Hα emission (Phan-Bao et al., 2017).*

Using $A_V = 6.14$ and the extinction law $R_V = 3.1$ (Mathis 1990), we derived a dereddened color $I - J = 1.62$ (non-dereddened color $I - J = 3.68$, see Table 1). Using the *Gaia* trigonometric parallax $\pi = 6.4316 \pm 0.4883$ mas, we derived a *J*-band absolute magnitude $M_J = 6.52$ ($M_J = J + 5\log\pi + 5$, where π in arcsec). According to the CIFIST2011 BT-Settl models (Baraffe et al. 2015), the dereddened color $I - J = 1.62$ and the absolute magnitude $M_J = 6.52$ of DENIS1901-3700 corresponding to a mass of 132^{+21}_{-18} M_{Jup} and an age of 5 Myr. Our estimated mass of DENIS1901-3700 is consistent with the mass value of 0.13 M_{Sun} estimated by López Martí et al. (2010). However, our estimated age of 5 Myr is younger than their estimate of 8 Myr. With a color $I - J = 1.62$ and a temperature of 3100 K, the spectral type of DENIS1901-3700 is ~M5, which is earlier than the spectral type of M6.5 determined by Esplin and Luhman (2022). We therefore conclude that DENIS1901-3700 is very likely a VLM star, not a low-mass BD.

One should discuss that with a young age of only 5 Myr, DENIS1901-3700 would exhibit Hα emission as often observed in young M dwarfs. However, no Hα emission was seen in this young VLM star. Figure 2 shows the optical spectra of DENIS1901-3700 (from Martín et al. 2010) and SIPSJ1809-7613, a young M5-dwarf member of the β Pic moving group identified in Phan-Bao et al. (2017). The non-detection of Hα emission in DENIS1901-3700 is possibly due to the low signal-to-noise spectrum obtained by Martín et al. (2010). A higher signal-to-noise spectrum of DENIS1901-3700 is needed to detect the Hα emission from the source.

3. Summary

In this paper, we found the visual extinction $A_V = 6.14$ for the young M5 dwarf DENIS1901-3700 in the CrA cloud. Based on the dereddened color $I - J = 1.62$ and the Gaia trigonometric parallax, we estimated a mass of 132^{+21}_{-18} M_{Jup} and an age of 5 Myr for DENIS1901-3700. With our estimated mass, DENIS1901-3700 is a VLM star, not a low-mass BD, as previously reported. The dereddened SED of DENIS1901-3700 reconfirms that the source is diskless. We also show that public data archives, such as *Gaia* for astrometry, DENIS, 2MASS, and WISE for near-infrared and infrared photometry, as well as astrophysical tools, such as the BANYAN Σ, are valuable resources for graduate students and researchers to study Astrophysics and related fields.

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DENIS-P J1901391-370017: MỘT SAO LÙN KHỐI LƯỢNG RẤT NHỎ HAY MỘT SAO LÙN NÂU KHỐI LƯỢNG NHỎ TRONG VÙNG CORONA-AUSTRALIS?

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TÓM TẮT

DENIS-P J1901391-370017 được nhận dạng là một ngôi sao lùn nâu có khối lượng thấp trong vùng hình thành sao Corona-Australis. Bài báo này giới thiệu việc ước tính khối lượng của ngôi sao lùn nâu này của chúng tôi. Phổ phân bố năng lượng đã khử đỏ hoá của ngôi sao chỉ ra rằng DENIS-P J1901391-370017 là một sao khối lượng rất nhỏ, không phải là một sao lùn nâu khối lượng thấp như đã đề cập gần đây. Chúng tôi cũng xác nhận lại rằng DENIS-P J1901391-370017 không có đĩa bụi bao bọc quanh như đã được đề cập trong các tài liệu tham khảo.

Từ khóa: sao lùn nâu; vật chất bao quanh sao; quang trắc; quang phổ