



Research Article

A SYSTEMATIC SEARCH FOR NEW NEARBY BROWN DWARF CANDIDATES

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ABSTRACT

The data release in 2023 from Gaia, a space astrometry survey, contains about 1.8 billion sources with very high-precision positions, distances, and proper motions. Using the Gaia astrometry and the DENIS photometry, we search for new nearby brown dwarfs over about 13,500 square degrees in the DENIS database. This paper presents our selection criteria of brown dwarf candidates and a preliminary result of 439 candidates with spectral types estimated from M8 to L2 and photometric distances from 30 to 75 pc.

Keywords: brown dwarfs; circumstellar matter; free-floating planetary mass objects; photometry

1. Introduction

Brown dwarfs (BD) with masses below 75 Jupiter masses are very popular in our Galaxy. Depending on the age of a BD, the BD temperature ranges from about 300 K (less than the temperature of a human body) to about 2200 K, corresponding to spectral types later than M8.

Studying BDs has greatly improved our understanding of stellar physics at very low temperatures as well as the formation mechanism of free-floating planets. The existence of free-floating planets challenges the current theory of planet formation because, unlike thousands of exoplanets discovered so far, free-floating planets can form directly from the fragmentation of a molecular cloud, not from the condensation of gas and dust in a protoplanetary disk around a host star.

In the last two decades, many BDs have been discovered by several large-scale near-infrared surveys: the DEep Near-Infrared Survey of the Southern Sky¹ (DENIS, Epchtein 1997) in one optical *I*-band at 0.8 μm and two near-infrared bands, *J*-band 1.25 μm and *K*-

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¹ <https://cdsweb.u-strasbg.fr/denis.html>

band at 2.16 μm ; the Two-Micron All-Sky Survey² (2MASS) in three near-infrared bands *J*-band at 1.235 μm , *H*-band at 1.662 μm , and *K_s*-band at 2.159 μm ; and the Wide-field Infrared Survey³ (WISE) in four infrared bands *W1*-band at 3.4 μm , *W2*-band at 4.6 μm , *W3*-band at 12 μm , and *W4*-band at 22 μm .

The photometric color $I - J$ has been widely used to select BD candidates, as it serves as an excellent indicator of their spectral type. The DENIS survey, which provides us with *I*- and *J*-band photometric data, has been a valuable resource for the systematic identification for BDs. For example, Phan-Bao et al. (2008) carried out the first systematic search for very late-M and L dwarfs in the Galactic plane, and they discovered 20 new nearby L and late-M dwarfs by using the DENIS photometry.

Mass, age, and temperature, which are basic properties of a star, can be determined if the distance to the star is precisely known. *Gaia*⁴ is a space astrometry survey of nearly two billion objects in our Galaxy. The *Gaia* data release in 2023 (DR3, Gaia Collaboration et al. 2023) contains about 1.8 billion sources, including many BDs (e.g., Reylé 2018), with very high-precision positions, distances, and proper motions. Thus, the combination of the DENIS $I - J$ color and the *Gaia* precise distance will be an excellent tool to systematically identify new nearby BD candidates and precisely determine their age and mass.

In this paper, we present our search for new BD candidates using the DENIS photometry. Section 2 presents our selection criteria and the preliminary results of our search. We provide a conclusion and discuss future directions of research in Section 3.

2. Selection criteria and results

Using the DENIS database, we have systematically searched for BD candidates (cooler than M8, $I - J \geq 3.0$, *I* and *J* are apparent magnitudes from the DENIS database) within 30 pc at high Galactic latitude with $|b| \geq 15^\circ$ (Martín et al. 2010; Phan-Bao 2011) and at low Galactic latitude with $|b| < 15^\circ$ (Phan-Bao et al. 2008).

In this paper, we systematically searched for BD candidates with spectral types later than M8, located at distances greater than 30 pc and at high Galactic latitude with $|b| \geq 15^\circ$. We used the same criteria as described in Phan-Bao et al. (2008), except photometric distances > 30 pc. We first selected all DENIS objects with $|b| \geq 15^\circ$ and the DENIS color $I - J \geq 3.0$, approximately spectral types later than M8. To reject distant red giants that may have the same color $I - J$ as BD candidates, we used the color $I - J$ versus color $J - K$ sequence for very late-M and L dwarfs. We only selected candidates within $J - K = \pm 0.52 \text{ mag}$ of the linear fit of BDs from Phan-Bao et al. (2008): $J - K = -0.462 + 0.532(I - J)$. Figure 1 shows our BD candidates and the linear fit of BDs.

² <https://irsa.ipac.caltech.edu/Missions/2mass.html>

³ <https://wise2.ipac.caltech.edu/docs/release/allwise/>

⁴ https://www.esa.int/Science_Exploration/Space_Science/Gaia_overview

We then calculated the J -band absolute magnitude M_J using the $(M_J, I - J)$ relation given in Phan-Bao et al. (2008): $M_J = 130.164 - 124.899(I - J) + 46.948(I - J)^2 - 7.4842(I - J)^3 + 0.4341(I - J)^4$, valid for $3.0 \leq I - J \leq 6.0$. The error on the J -band absolute magnitude M_J estimated using this relation is 0.3 mag, corresponding to a 14% error on photometric distances. The distance d is then calculated using $d = 10^{(J - M_J + 5)/5}$. We retained the candidates with $d > 30$ pc. One should note that these estimated distances are valid only for old BDs of a few hundred million years or a few billion years. If a BD candidate is very young (a few million years), the estimated distance is uncertain.

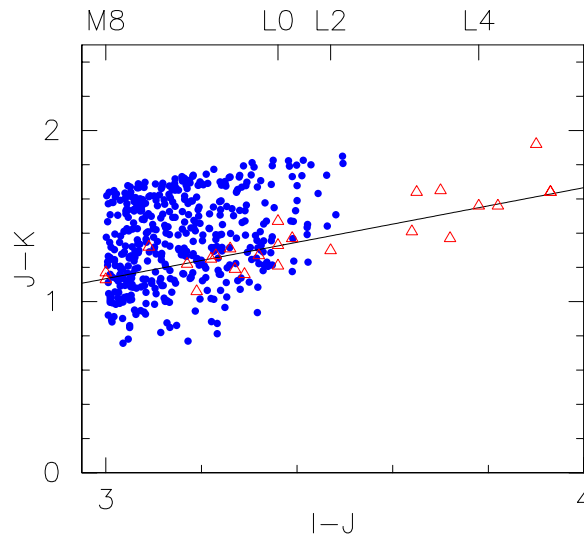


Figure 1. DENIS color-color diagram for 439 BD candidates of M8-L2 (distances > 30 pc), selected over about 13,500 square degrees from the DENIS database. The blue solid circles represent the 439 BD candidates. Well-known late-M and L dwarfs from the literature are shown as red open triangles, and the linear fit (solid line) of the BDs is from Phan-Bao et al. (2008).

In total, we found 439 candidates over about 13,500 square degrees, about 33% of the full sky or 81% of the full DENIS survey, in the DENIS database that match our selection criteria. The photometric distances of the candidates range from 30 to 75 pc. Table 1 lists a sample of six candidates. As shown in Figure 1, the 439 candidates have spectral types in the range of M8-L2. Candidates with spectral types later than L2 are not in our list; probably they are too faint to be detectable by the DENIS telescope. The cross-identification of all the candidates with the Gaia DR3 to determine their trigonometric parallaxes (i.e., very precise distances) and the WISE catalog, as well as the determination of their masses and ages, will be presented in a forthcoming paper.

Table 1. A sample of 439 BD candidates with distances of 30-75 pc and spectral types of M8-L2

DENIS name	<i>I</i> (mag)	<i>J</i> (mag)	<i>K</i> (mag)	Distance (pc)
0004497-424137	17.01±0.10	13.88±0.07	12.88±0.15	32.3
0006491-085244	17.39±0.13	14.14±0.10	13.03±0.16	31.5
0116528-645556	17.91±0.18	14.59±0.10	13.26±0.17	35.2
0130356-444541	17.18±0.11	14.02±0.09	12.75±0.12	33.1
0207184-512943	17.36±0.11	14.28±0.11	13.20±0.11	41.0
0246553-824701	17.91±0.20	14.52±0.12	13.28±0.19	31.0

3. Conclusion and outlook

In this paper, we present a sample of the preliminary list of 439 nearby (>30 pc) BD candidates selected over about 13,500 square degrees from the DENIS database. Based on the DENIS photometry, we estimated the spectral types and distances of the candidates in the range of M8-L2 and 30-75 pc, respectively. The cross-identification of the 439 BD candidates with the *Gaia* catalogue and other available catalogues to determine their precise distances as well as the detailed analysis of related quantities, such as absolute magnitudes, mass, age, and temperature, will be presented in a forthcoming paper.

❖ **Conflict of Interest:** Author has no conflict of interest to declare.

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SẸN TÌM CÁC SAO LÙN NẬU MỚI

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TÓM TẮT

Năm 2023, dữ liệu quan sát bởi kính viễn vọng không gian Gaia chứa dữ liệu của khoảng 1,8 tỉ nguồn với độ chính xác rất cao về tọa độ, khoảng cách và chuyển động riêng. Sử dụng dữ liệu về tọa độ của Gaia và quang trắc của DENIS, chúng tôi săn tìm các sao lùn nâu gần trên khoảng 13.500 độ vuông trong cơ sở dữ liệu DENIS. Bài báo này giới thiệu các tiêu chí để chọn lựa các ứng cử viên sao lùn nâu và kết quả tìm kiếm sơ bộ đầu tiên, với 439 ứng cử viên có kiểu phổ từ M8 đến L2 và khoảng cách từ 30 đến 75 pc.

Từ khóa: sao lùn nâu; vật chất bao quanh sao; các vật thể khối lượng hành tinh trôi nổi tự do; quang trắc