

A New Population of Young Brown Dwarfs

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Abstract. We report the discovery of a population of late-M and L field dwarfs with unusual optical and near-infrared spectral features that we attribute to low gravity—likely uncommonly young, low-mass brown dwarfs. Many of these new-found young objects have southerly declinations and distance estimates within 60 parsecs. Intriguingly, these are the same properties of recently discovered, nearby, intermediate-age (5–50 Myr), loose associations such as Tucana/Horologium, the TW Hydrae association, and the Beta Pictoris moving group. We describe our efforts to confirm cluster membership and to further investigate this possible new young population of brown dwarfs.

1. Introduction

Until recently, studies of brown dwarfs (BD) have largely focused on two stages of evolution: the very young (~ 1 Myr) and the mature ($\gtrsim 1$ Gyr). Brown dwarfs in young clusters are studied because they are still fairly luminous (typically M type) and the age of the cluster can be adopted for the brown dwarf. In fact, most of the posters presented at this conference about brown dwarfs are studies focused on young clusters: BDs with disks in Upper Sco (Bouy), low-mass binaries in Taurus (Konopacky), new BDs in Orion (Faherty), new low-mass stars and BDs in Lupus (Allen), and new BDs in Trapezium (Riddick). A major drawback of these clusters is their rather large distance from the Sun (~ 100 – 500 pc) and reliably identifying the lowest-mass components of these clusters has proven to be a significant observational challenge.

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The advantage of studying brown dwarfs in the field is that they can be identified in our immediate proximity. Only the lowest-mass, faintest objects (i.e., L and T dwarfs) within ~ 30 pc can be studied in detail. However, only very weak constraints can be made on the age and mass of L and T dwarfs identified in the field. In addition, any protoplanetary disk has long since dissipated and any planetary-mass companions have cooled beyond current detection limits.

We believe that we have uncovered a nearby (~ 30 – 60 pc), juvenile (5–50 Myr) population of brown dwarfs that mediate the current bi-polar situation. The youth of our targets is inferred from the presence of conspicuous low-gravity features in their optical and/or near-infrared spectra not seen in hundreds of other M and L dwarfs; we show two examples in Figure 1. Compared to old field dwarfs of similar spectral type (equivalent temperature), low gravity is indicative of both a lower mass and larger radius—hallmarks of young brown dwarfs still undergoing gravitational contraction. The spectral features present in our targets are similar to those seen in members of very young clusters (e.g., Orion) but since none of our targets are near any tightly bound groups, they are most certainly older than 1 Myr. The upper limit on our age estimate is based on the stronger low-gravity spectral features exhibited in our targets than those seen in members of 100 Myr old clusters (e.g., Pleiades). Additionally, as many of our young candidates appear to be likely members of 8–50 Myr old associations (Figure 2), adopting an age range of 5–50 Myr for similar objects is reasonable.

The prototype of this new population of low-gravity L dwarfs is 2MASS J01415823–4633574 (hereafter 2M 0141–46). This object resembles a L0 dwarf but has spectral features indicative of a very low gravity. The discovery and detailed analysis of this object is presented by Kirkpatrick et al. (2006). Comparing the optical and near-infrared spectra of 2M 0141–46 to both models and dwarfs with known ages, these authors estimate a mass of 6–25 M_{Jup} and an age 1–50 Myr.

Another benchmark object is 2MASS J12073346–3932539 (hereafter 2M 1207–39). This $\sim 25 M_{Jup}$ object has a spectral type of M8, low-gravity spectral features, and is a confirmed member of the ~ 10 Myr old TW Hydrae Association (TWA) (Gizis 2002; Mohanty et al. 2003). Chauvin et al. (2004) detected a ~ 5 – $10 M_{Jup}$ mid-to-late L dwarf companion (hyped as the first direct detection of an exo-planet) with a $\sim 0''.8$ separation from the primary. More recently, evidence has been found that each component has its own disk (Riaz et al. 2006; Mohanty et al. 2006). The 2M 1207–39 system demonstrates not only that juvenile brown dwarfs harbor disks, but that they have a fundamental role to play in the study of star, brown dwarf, and planet formation. (Also see the poster contributions by Riaz and Stelzer on the 2M 1207–39 disks and Kasper on low-mass companions to stars in the Tucana and β Pictoris moving groups.)

We have identified ~ 50 objects similar to 2M 0141–46 and 2M 1207–39. In § 2 we present our spectral observations that indicate low-gravity and youth. The distribution of these objects on the sky and the similarity to the nearby, young associations and moving groups such as AB Doradus and Tucana/Horlogium are discussed in § 3. In § 4 we describe our extensive observational campaign to study this new population. Finally, we summarize our conclusions in § 5.

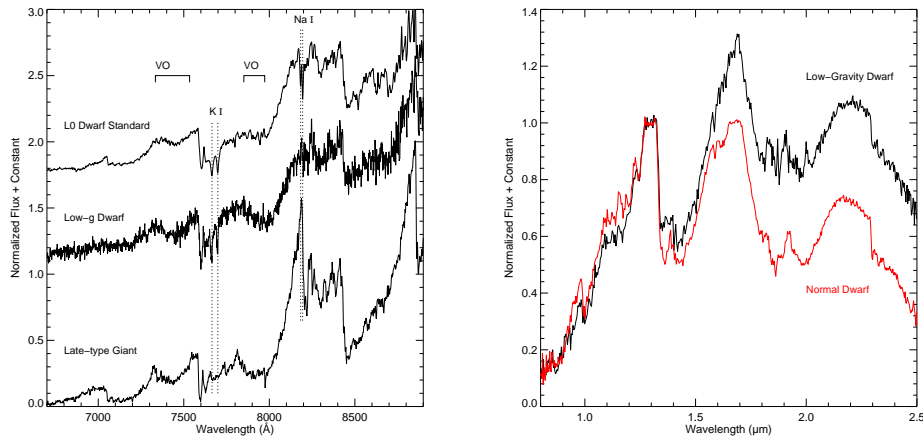


Figure 1. *Left:* Optical spectra of a normal L0 dwarf, a low-gravity dwarf, and a late-type giant (*top-to-bottom*). The VO, K I, and Na I absorption strengths of the low-gravity dwarf are between the normal dwarf and the giant. *Right:* Near-infrared spectra of a normal L5 dwarf (*red/grey*) and a low-gravity dwarf (*thick black*). The low-gravity object is characterized by a red spectral slope and a peak-shaped H band (1.4–1.8 μm).

2. Observations

We have been using data from the Two Micron All Sky Survey (Skrutskie et al. 2006, 2MASS) to undertake extensive, all-sky photometric searches for nearby late-M and L dwarfs (Cruz et al. 2007; Reid et al., in prep.;Looper et al., in prep.). As part of these searches, we have been obtaining both optical (6000–10,000 Å) and near-infrared (0.8–2.5 μm) spectra of candidate nearby L dwarfs. As mentioned in several papers (Cruz et al. 2003, 2007; Kirkpatrick et al. 2006; Reid et al., in prep.; Looper et al., in prep.) this follow-up has uncovered several objects with optical spectral features indicative of low-gravity. In our combined efforts, we have uncovered over ~ 50 late-M and L dwarfs with low-gravity features in the optical and/or near-infrared.

Our optical data have been obtained with NOAO facilities in both hemispheres and the Keck I telescope; these observations are described in detail in Cruz et al. (2003) and Kirkpatrick et al. (1999). The left panel of Figure 1 compares the optical spectrum of a low-gravity L dwarf to spectra of a normal dwarf and a giant.

Near-infrared spectra have been obtained with the SpeX spectrograph on the NASA Infrared Telescope Facility (Rayner et al. 2003). We have used the low-resolution ($R \sim 250$) prism and the cross-dispersed higher-resolution ($R \sim 2000$) modes to cover 0.8–2.4 μm . The right panel of Figure 1 overplots the near-infrared prism spectra of a low-gravity dwarf and a normal dwarf.

The physical origins of the low-gravity spectral features are discussed extensively in Kirkpatrick et al. (2006) and in Kirkpatrick’s contribution to this volume. In addition, in Allers et al. (2007) and in her poster contribution, the gravity-sensitive features present in the near-infrared spectra of young brown dwarfs are described and quantified.

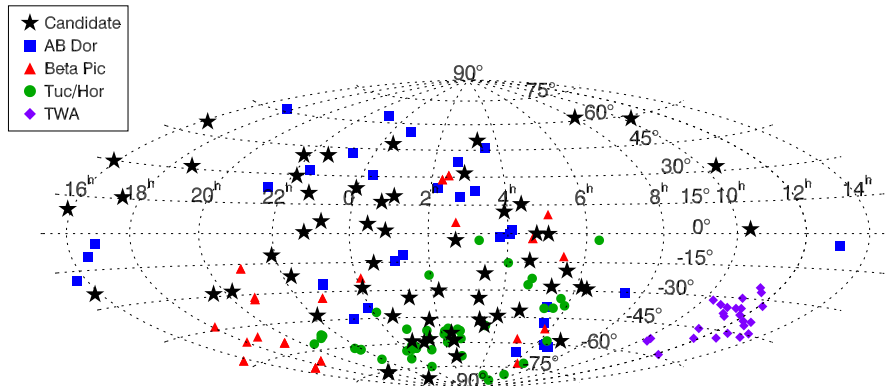


Figure 2. Celestial distribution of young brown dwarf candidates (*five-pointed stars*) on the sky. Also shown are known members of the AB Dor (*blue squares*), β Pic (*red triangles*), Tuc/Hor (*green circles*), and TWA (*purple diamonds*) young stellar associations (Zuckerman & Song 2004).

3. Distribution on the Sky

Figure 2 shows the location of our candidate young brown dwarfs (*five-pointed stars*) with confirmed members of nearby associations AB Dor, β Pic, Tuc/Hor, and TWA as identified by Zuckerman & Song (2004). The spatial distributions of the two populations, widely distributed and clumped in the south, are suggestively similar. This is not too surprising since the age and distance estimates of our young brown dwarfs are consistent with those of the moving groups. It is worth noting here that our searches for nearby late-type dwarfs cover the entire sky and the only major position cut was for the galactic plane. (For a detailed discussion of our sky coverage, see Cruz et al. 2007, Reid et al., in prep.).

Intriguingly, there are several targets that are far removed from the southern young associations. These objects might be the evaporated population of lower mass objects from these young associations, part of some known group that we are unaware of, or could indicate more new young, nearby associations.

4. Follow-up: Present and Future

To confirm our suspicion that our candidates are both young and members of the southerly associations, significant follow-up observations are being undertaken. A rough kinematic association can be estimated with just a proper motion. For the brightest objects, we have used Digital Sky Survey and 2MASS to measure motions of this sample (Schmidt et al. 2007). Second epoch images of the fainter targets are being obtained with AMNH SMARTS access to the CPAPIR wide-field ($35 \times 35'$) near-infrared imager on the CTIO 1.5 m telescope.

Radial velocities and trigonometric parallaxes are required to derive accurate space motions. Radial velocities of our brightest candidates ($J < 15$) are being measured with the optical, high-resolution spectrograph MIKE on Magellan. We are endeavoring to use high-resolution, near-infrared spectrographs

on 8–10 m telescopes (e.g., NIRSPEC on Keck) to measure the radial velocities of our fainter targets ($J > 15$). We are currently using Stony Brook SMARTS access to the ANDICAM near-infrared imager on the 1.3 m telescope at CTIO to measure the parallaxes (and proper motions) of our southerly candidates.

Spectral coverage from 0.8–2.5 μm is needed for all of the young candidates in order to fully study the low-gravity spectral features. Currently, not all candidates have spectral coverage in both the optical and near-infrared and, in some cases, higher signal-to-noise spectra are needed. We have ongoing programs using SpeX on the IRTF to cover the near-infrared and we are hoping to use optical spectrographs on 8–10 m telescopes (e.g., LRIS on Keck, GMOS on the Gemini telescopes) to obtain optical data.

It is now known that it is not unusual for young brown dwarfs to harbor disks (see the splinter session summary of Apai & Luhman, this volume). Our new-found population of brown dwarfs with older ages has the potential to lend insight on disk evolution and planet formation. We are targeting our candidates with Spitzer IRAC and 24 μm imaging to investigate the frequency and properties of brown dwarf disks at intermediate ages.

5. Summary and Conclusions

We have uncovered a new population of young, low-mass brown dwarfs. Based on their spectral appearance and spatial distribution, we conclude that these objects most likely are 5–50 Myr old and $\sim 10\text{--}30 M_{Jup}$.

This juvenile population will enable the quantification and calibration of the age and mass-sensitive features present in brown dwarf spectra. This population also provides an opportunity to study the epoch of disk evolution when planet formation is thought to be ongoing. These objects possibly also harbor brown dwarf companions with masses overlapping the planetary-mass regime providing a laboratory ideal for identifying observational differences between brown dwarfs and planets.

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