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Young Brown Dwarfs as Giant Exoplanet Analogs

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Abstract. Young brown dwarfs and directly-imaged exoplanets have enticingly similar photometric and spectroscopic characteristics, indicating that their cool, low gravity atmospheres should be studied in concert. Similarities between the peculiar shaped H band, near and mid-IR photometry as well as location on color magnitude diagrams provide important clues about how to extract physical properties of planets from current brown dwarf observations. In this proceeding we discuss systems newly assigned to 10-150 Myr nearby moving groups, highlight the diversity of this uniform age-calibrated brown dwarf sample, and reflect on their implication for understanding current and future planetary data.

Keywords. Astrometry– stars: low-mass– brown dwarfs

1. Introduction

Despite different formation mechanisms, brown dwarfs and giant exoplanets share many physical properties, including overlapping temperature regimes and condensate clouds in their atmospheres. Recent studies have revealed a striking resemblance between observations of directly imaged giant exoplanets and young low-temperature brown dwarfs (e.g. Faherty *et al.* 2013). Both populations deviate significantly from older, equivalent temperature objects, and it has been proposed that thick clouds present in the young objects but not in the old ones could explain anomalous observables (Barman *et al.* 2011, Madhusudhan *et al.* 2011). While only a handful of planetary systems can be directly studied with current technology, young brown dwarfs are relatively numerous, bright, and isolated in the field. As such, they are readily accessible to ground-based facilities and lend themselves to detailed, extensive studies not currently possible for exoplanets (Cruz *et al.* 2009, Rice *et al.* 2010ab, Faherty *et al.* 2012, 2013, Allers *et al.* 2013).

2. Assigning Ages to Low-Gravity Brown Dwarfs

We have identified 65 low-surface gravity brown dwarfs with spectroscopic, photometric, luminosity, and/or kinematic properties that make them excellent candidates for an age calibrated sample. Many of these sources are coincident with the locations of individual members of nearby moving groups (e.g. Argus–30-50 Myr, β Pictoris–12-22 Myr, Tucana Horologium–10-40 Myr, AB Doradus–50-120 Myr; Malo *et al.* 2013). To conclusively assign membership, we require precise astrometric measurements. Consequently, as part of the Brown Dwarf Kinematics Project (BDKP–Faherty *et al.* 2009, 2010, 2011, 2012), we have prioritized collecting parallax, proper motion and radial velocity data on the low-surface gravity brown dwarfs. We have enough information on our sources to compute space velocity, positions, and preliminary membership in nearby moving groups.

3. Diversity of Young Brown Dwarfs

Using estimated UVW velocities and XYZ positions in combination with a convergent point and Bayesian analysis (Rodriguez *et al.* 2013) we deduce membership for 30 low-surface gravity brown dwarfs. We assign two sources to Argus, four to AB Doradus, 12 to β Pictoris and 12 to Tucana Horologium. We see a diversity among the spectral gravity classifications within each group. For instance, β Pictoris has eight γ (very low gravity) and four β (intermediate gravity) sources. The diversity that is emerging among equal age sources is not surprising. Faherty *et al.* 2013 discuss the optical γ sources and find that this subpopulation shows a large range in the extent of red photometric color (in both the NIR and the MIR). For those sources with parallax measurements we find that the M dwarfs are overluminous in the NIR whereas the L dwarfs are normal to underluminous in the NIR regardless of the age calibration. We postulate that this diversity among the age calibrated sample is due to atmospheric chemistry which can differ between sources.

4. Discussion: Connection to Exoplanets

The estimated T_{eff} of the directly imaged planetary-mass companions 2M1207b (TW Hydrae $\sim$ 8-20 Myr; Chauvin *et al.* 2004) and HR8799b (Columba $\sim$ 10-40 Myr; Marois *et al.* 2010) are ~1100K and 1600K, respectively, corresponding to mid L and early T spectral types (e.g. Barman *et al.* 2011). Detailed studies of their near-IR spectra and photometric data reveal that both planets (1) are 1-2 mag underluminous on color-magnitude diagrams, (2) have unusually red near-IR colors, and (3) display sharply peaked H-band spectra. Our population of 30 brown dwarfs, now kinematically associated with 10-150 Myr groups share in these deviations from field brown dwarfs. Emerging as the most probable explanation for these features are enhanced clouds induced by gravity effects. Understanding in detail the variations in observable features of the plethora of data available for young brown dwarfs that can be attributed to gravity and/or atmosphere features is critical for interpreting future exoplanet data.

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