Photometric and Spectral Analysis of Blue and Red L Dwarfs

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Abstract. We explore the photometric and spectral properties of unusually blue and red L dwarfs using multi-resolution near-infrared spectra and 2MASS photometry to probe their underlying atmospheric and physical properties. The analysis is anchored by optical spectra (as a proxy for effective temperature) and benchmarks such as confirmed young objects, subdwarfs, and L dwarf spectral standards. This is the largest, most diverse observational dataset of red and blue L dwarfs assembled to date.

1. Introduction

L dwarfs have a range of near-infrared colors at a given optically-defined spectral subtype (Faherty et al. 2013). L dwarfs of the same spectral subtype are thought to have similar surface temperatures, but the presence of extreme near-IR colors in some L dwarfs suggests that parameters other than temperature influence their spectra (Kirkpatrick 2008). Such extreme near-IR colors have been variously attributed to differences in gravity (Cruz et al. 2009), metallicity, and dust/cloud properties (Burgasser et al. 2008).

For a limited number of these objects, diagnostic spectral features indicate the cause of extreme near-IR color. Low surface gravity red L dwarfs have characteristic weak Na I doublets and FeH absorption bands, but strong VO features (Cruz et al. 2009), and are known to be young. Subdwarfs have bluer $J-K_s$ colors and low metallicity spectral features

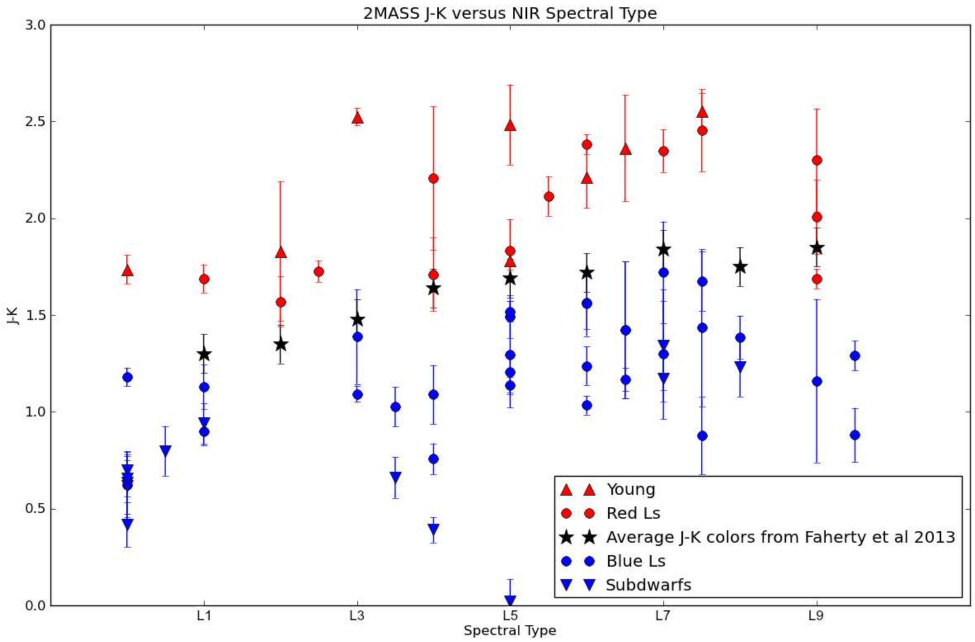

Figure .1: $J - K_s$ color as a function spectral type for our L dwarf sample. The black stars represent the $(J - K_s)_{avg}$ colors (Faherty et al. 2013) for each spectral subtype. Known young objects and confirmed subdwarfs are shown in red and blue triangles, respectively. Red and blue photometric outliers are shown in circles of the corresponding color.

such as greater H_2 absorption, stronger metal hydride bands, and enhanced TiO absorption (Burgasser et al. 2008). The absence of Li I absorption in the optical spectra of subdwarfs (Burgasser et al. 2008) is characteristic of high surface gravity and thus old age. For most objects, however, the underlying physical cause of the extreme color is unknown. This project focuses on understanding objects whose extreme colors remain widely unexplained by the absence of diagnostic spectral features indicating age, gravity and metallicity.

1.1 Identifying Color Outliers

We constructed a sample of unusually blue and red L dwarfs using objects in the Brown Dwarfs in New York City (BDNYC) database, the Brown Dwarf Spectroscopic Survey (BDSS) archive (McLean et al. 2003, 2007), and the literature. Candidacy for blue and red color outliers was based on the $(J - K_s)_{avg}$ average values (Faherty et al. 2013) for each spectral subtype. Faherty et al. (2009) details the method for defining the average $J - K_s$ color for spectral bins using all known ultracool dwarfs taken from from the M, L, T, and Y dwarf compendium housed at DwarfArchives.org. This method designates photometric outliers as objects whose deviation from the $(J - K_s)_{avg}$ is more than twice the standard deviation of the color range for a given spectral bin.

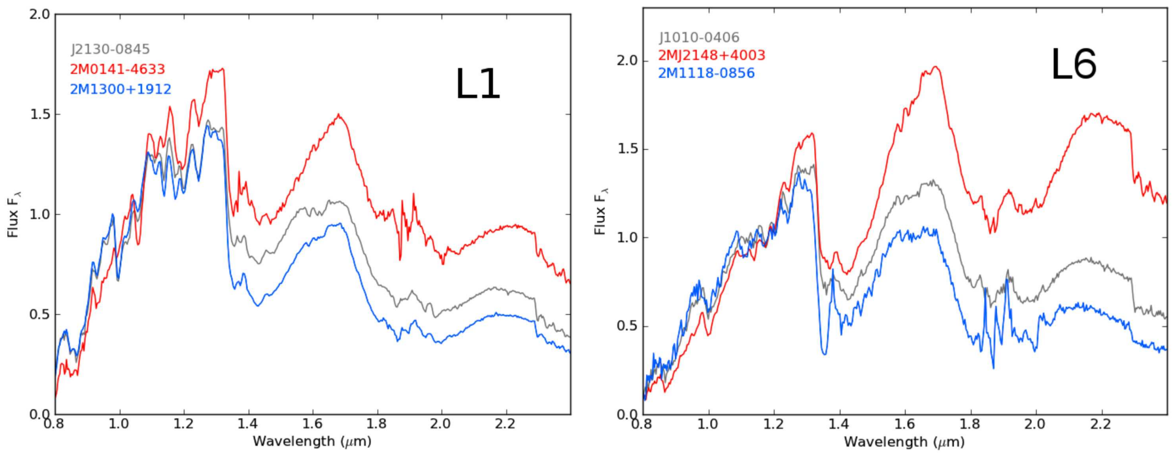

Figure .2: Low-resolution spectral comparisons of blue, red and standard L6 and L1 type L dwarfs, normalized at 1.1 μm.

2. Multi-resolution Spectral Comparisons

Observational trends among red, blue, and standard L dwarfs at a given spectral subtype can elucidate underlying atmospheric properties that may be the cause of their extreme near-IR colors. This warrants the need to compare multi-resolution near-infrared spectra of these objects for a detailed exploration of their spectral features.

We overplotted for comparison low-resolution SpeX-IRTF spectra for blue, red and standard objects of the same near-IR spectral type, as shown in Figure 2.

Such low-resolution spectral comparisons reveal the “fanning out” of the spectra in the K-band (Cruz and Núñez, 2012), and accurately show the range of $J - K_s$ colors that L dwarfs have at a given spectral subtype. Spectral comparisons in higher resolution, however, are needed to probe the unknown physical properties that could be the cause of these extreme near-IR colors.

Medium and high-resolution J-band spectra from the NIRSPEC BDSS (McLean et al. 2003, 2007) further reveal differences in the spectral features of these normal and unusual L dwarfs. Comparisons of medium-resolution spectra (see Figure 3) reveal differences in the strengths of the KI absorption lines (1.17 μm and 1.25 μm), the FeH bandhead (1.20 μm), and the H_2O band (1.30 μm). These spectral features are stronger for blue L dwarfs when compared to standard and red objects of the same spectral subclass. High-resolution BDSS spectra confirm this trend. As shown in Figure 4, blue L dwarfs have broader and deeper absorption features relative to similarly spectral-typed red and standard objects.

This project will focus on identifying quantitative differences in the KI absorption lines among L dwarf color outliers and standards since medium- and high-resolution NIRSPEC spectra resolve the two sets of neutral potassium doublets at 1.1773 μm/1.1776 μm and 1.2436 μm/1.2525 μm (see Figure 3).

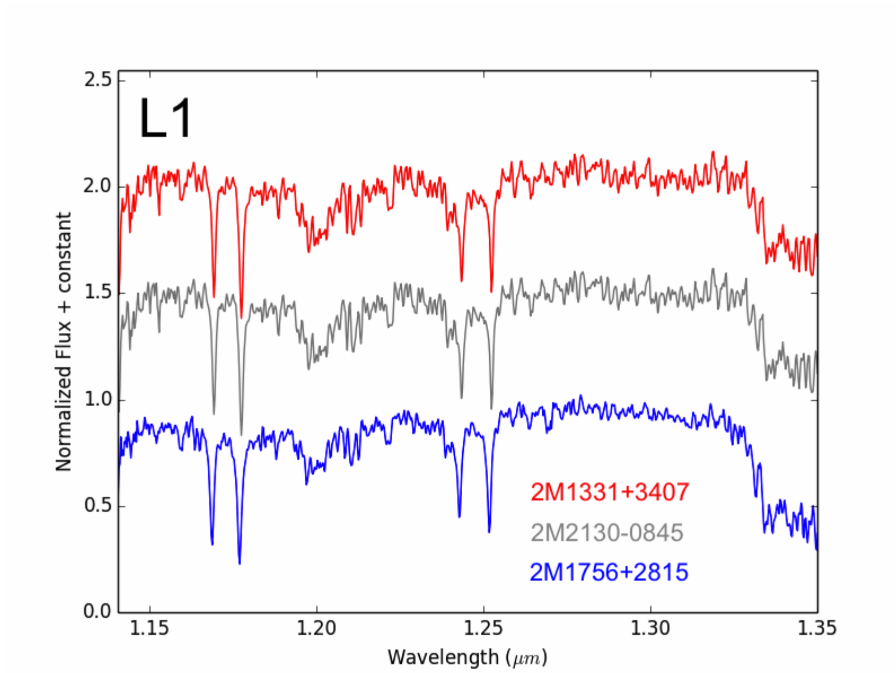

Figure .3: Medium-resolution spectral comparison of red, blue, and standard L dwarfs. For comparison, spectra are offset vertically by an arbitrary constant.

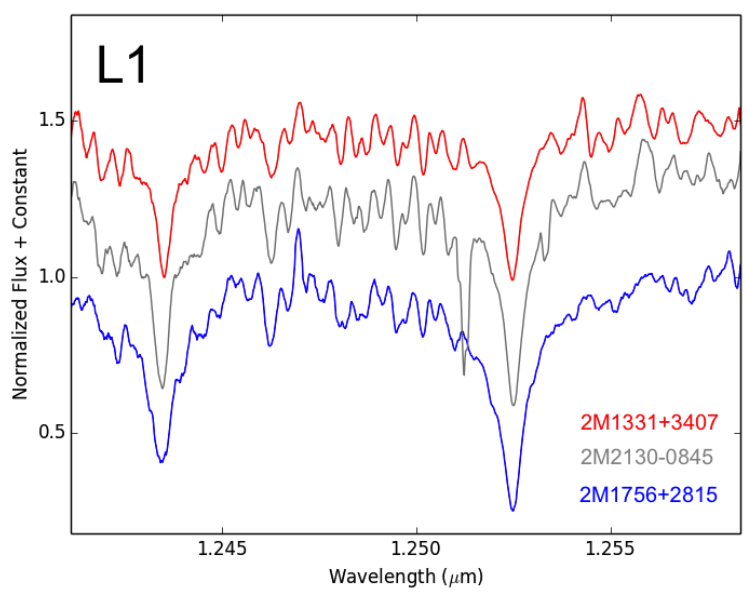

Figure .4: High-resolution spectral comparison of red, blue, and standard L1 dwarfs. Spectra are smoothed and offset vertically by an arbitrary constant. Note the broader, deeper KI lines for the blue L dwarf, 2MASS 1756+2815.

3. Ongoing Work

Although we can use high-resolution spectra from the NIRSPEC BDSS to visually compare the strengths, shapes, and depths of different spectral features, this data can be used further still to uncover more information about the atmospheric and physical properties of the unusually red and blue objects in our L dwarf sample. We can use high-resolution BDSS data to measure equivalent widths, FWHM, and line depths for the KI absorption lines in the J-band to compare the strengths of these spectral features.

This data can also be used to investigate, for example, the rotational velocities of the red and blue color outliers to test hypotheses regarding the correlation between color and viewing angle. Kirkpatrick et al. (2010) suggested that observational dust properties may cause some L dwarfs to appear either red or blue, citing pole-on viewing as a possible cause for the red phenomenon and equator-on viewing as the cause for the blue phenomenon. Comparing *vsini* values for similarly spectral-typed L dwarfs could thus shed light upon the validity of this claim.

Such quantitative spectral line analysis will allow us to probe diagnostics of physical parameters to explain observational trends. This type of analysis directly brings us back to the underlying physics in the atmospheres of these objects, and is thus integral in our understanding of these unusually red and blue L dwarfs.

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Emily Rice and Lil' Brown Dwarf taking a break.