DISCOVERY OF A VERY YOUNG FIELD L DWARF. J. D. Kirkpatrick¹, C. G. Tinney², A. J. Burgasser³, M. R. McGovern⁴, I. S. McLean⁵, and P. J. Lowrance⁶ ¹Infrared Processing and Analysis Center, Caltech (davy@ipac.caltech.edu), ²Anglo-Australian Observatory, ³Massachusetts Institute of Technology, ⁴Antelope Valley College, ⁵University of California, Los Angeles, ⁶Spitzer Science Center, Caltech

Introduction: During the course of follow-up of southern L dwarf candidates selected photometrically from the Two Micron All-Sky Survey, we uncovered an unusual object designated 2MASS J01415823-4633574. It is unique among the 404 L dwarfs now archived [1].

Evidence of Youth: Its optical spectrum exhibits very strong bands of vanadium oxide but abnormally weak absorptions by titanium oxide, potassium, and sodium (Fig. 1). Morphologically such spectroscopic characteristics fall intermediate between old, field early-L dwarfs ($\log(g)$=5) and late-M giants ($\log(g)$=0), leading us to favor low gravity as the explanation for the unique spectral signatures in this L dwarf (Fig. 2). Such a low gravity can be explained only if this L dwarf is much lower in mass than an old field L dwarf of similar temperature and is still contracting to its final radius. These conditions imply a very young age. Further evidence of youth is found in the near-infrared spectrum, which exhibits a triangular-shaped H-band continuum (Fig. 3) reminiscent of young brown dwarf candidates discovered in the Orion Nebula Cluster [2].

Comparison to Theory: Using the above information along with comparisons to brown dwarf atmospheric and interior models [3], our current best guess is that this L dwarf has an age less than ~50 Myr and a mass below ~15 $M_{\text{Jup}}$. Although the lack of a lithium detection (pseudo equivalent width <1 Å) might appear to contradict other evidence of youth, we suggest that lithium becomes weaker at lower gravity like all other alkali lines and thus needs to be carefully considered before being used as a diagnostic of age or mass for objects in this regime.

Member of a Young Association?: The location of 2MASS J0141-4633 on the sky coupled with the above age estimate and a distance estimate of ~40 pc suggests that this object may be a member of the Tucana-Horologium Association of age ~30 Myr. Distance as determined through trigonometric parallax (underway) and a measure of the total space motion are needed to test this hypothesis.

Young L Dwarfs in the Larger Context: Objects of similar temperature but of even younger age and lower gravity should exhibit even more pronounced spectroscopic departures from normal field L dwarfs. The purported low mass (>15 $M_{\text{Jup}}$), early-L dwarfs of the ~3-Myr-old α Orionis cluster, for example, have a more ordinary spectral appearance [4,5]. This strongly suggests that those objects are not true low-mass members of the cluster but are instead merely higher mass, foreground objects. (See also [6,7].)


Fig. 1: The far red optical spectrum of 2MASS J01415823-4633574 (red) compared to a sequence of normal field late-M and early-L dwarfs (black). All spectra were taken with the Low-Resolution Imaging Spectrograph (LRIS) at the 10-m W. M. Keck Observatory. Atomic absorption by alkali metals (green), and molecular absorption by oxides (blue) and hydrides (magenta) are marked. Telluric absorption and intrinsic Hα emission are also marked.
(cyan). Note the weak or absent TiO, strong VO, weak alkali lines, and notable Hα emission in the spectrum of 2MASS J0141-4633.

Fig. 2: Far red optical spectra of a normal L1 field dwarf GJ 1048B (top, black), the peculiar L dwarf 2MASS J0141-4633 (center, red), and the very late-type M giant IRAS 14303-1042 (bottom, black). All spectra were taken with LRIS on Keck. Color coding of features is the same as in Fig. 1. In the spectrum of 2MASS J0141-4633, the strength of the sodium and potassium lines falls intermediate between the strengths seen in the dwarf and the giant. The alkali lines have long been known to be gravity-sensitive, leading us to suspect a low-gravity explanation for this unusual L dwarf. At face value the strengths of the oxide bands are harder to interpret, but nonetheless point to low gravity as well: The vanadium oxide strengths of 2MASS J0141-4633 fall intermediate between the high- and low-gravity objects whereas the titanium oxide strengths are very similar to those of the dwarf and quite unlike those of the giant. Both of these oxide molecules disappear along the late-M/early-L dwarf sequence due to condensation, TiO disappearing first and VO at somewhat colder values of Teff [8]. A lower gravity tends to inhibit condensation, in the sense that condensation does not occur until even colder temperatures are reached [9]. (At their very low gravities, late-M giants never reach temperatures low enough to trigger the formation of TiO- and VO-bearing condensates. Because the weakening and disappearance of these two molecules is the hallmark of the M/L transition, that explains why there is no such thing as an “L giant.”) 2MASS J0141-4633 can therefore be understood as a low-gravity object with a Teff low enough to have already triggered the formation of TiO-bearing condensates but not yet low enough to trigger VO-bearing condensation.

Fig. 3: Near-infrared spectra of normal field late-M and early-L dwarfs (black, [10]) and the peculiar L dwarf 2MASS J0141-4633 (red). All spectra were taken with SpeX on the 3-m NASA Infrared Telescope Facility. Most notable in the spectrum of 2MASS J0141-4633 is the triangular-shaped appearance of the H-band spectrum, a feature also seen in the spectra of low-mass brown dwarf candidates in the Orion Nebula Cluster. Also notable are two deep molecular bands centered near 1.06 and 1.18 μm that are not present in spectra of the normal late-M/early-L dwarfs. These bands are produced by VO and are present in 2MASS J0141-4633 for the same reason that strong VO bands are seen in its optical spectrum – VO-bearing condensates have not yet begun to form. As can also been seen in this figure, the near-infrared spectrum of 2MASS J0141-4633 is much redder than spectra of normal late-M/early-L dwarfs. Its 2MASS color of J-Ks =1.74±0.05 is significantly redder than the average color of J-Ks≈1.40 found for normal, field L0 dwarfs [11].