First T Dwarf Discoveries from the 2MASS/Lick All-Sky T Dwarf Search

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We use the 3-m GEMINI instrument on the Lick telescope to identify T dwarfs (methane-bearing brown dwarfs) in the Northern Hemisphere which were detected by 2MASS. By surveying a large area of sky accessible from Lick not yet examined for T dwarfs and expanding our color selection, we hope to add at least ten new discoveries to the 30 currently known members of this new spectral class. This work will greatly add to our understanding of this cool class of brown dwarfs, provide better statistics for the derivation of the field substellar mass function, and potentially uncover unique members and/or objects later than type T. We present the first T dwarf discovered by this program, 2MASS 0516-04.

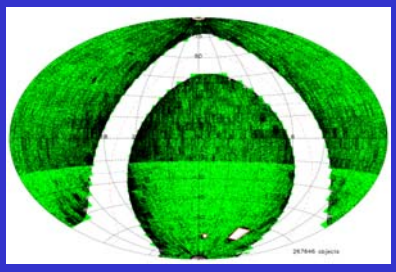

Figure 1: Aitoff projection map of the sky area searched in the sample.

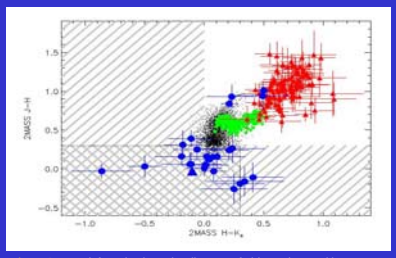

Figure 2: Near-infrared color-color diagram of objects detected by 2MASS.

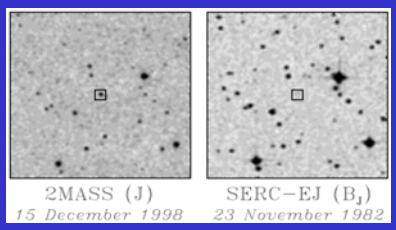

Figure 3: Image of 2MASS 0559-1404 and the corresponding USNO-A2.0 catalog image.

The Sample Coverage & Selection Technique

Our target sample was culled from 2MASS and consists of objects which have passed a selection criterion of $|b| > 15°$, $J < 16$, and $J-H < .3$ or $H-K_s < 0$. There were 267,646 objects that made the first-cut, although the SMC, LMC, and 47Tuc were omitted due to their high background source densities. The total sky area of our sample is 30,531 sq. degrees, more than twice the first search sample in Burgasser et al. 2002. Figure 1 displays an Aitoff projection map of the sky area searched in the sample, where the green boxes represent areas scanned by 2MASS and the individual dots mark the locations of the first-cut candidates selected in this sample.

A near-infrared color-color diagram of objects detected by 2MASS is displayed in Figure 2. Dots are unresolved sources with $J < 15.8$, $H < 15.1$, and $K_s < 14.3$ selected within a 1° radius around R.A. 18^h, decl. 40°. Solid lines trace out the Bessell & Brett (1998) dwarf and giant tracks. L dwarfs (red triangles) and T dwarfs (blue circles) are shown with error bars, based on 2MASS photometry. Colors for Gliese 229B (blue triangle) are taken from Leggett et al. (1999). T dwarfs have blue near-infrared colors due the CH_4, H_20, and H_2 absorption in their atmospheres, placing them in a specific color-color space. The cross-hatched region indicates the color space searched in our original T dwarf sample (Burgasser et al. 2002), while the diagonal lines indicate the expanded color space in our current survey. The expanded color space searched will allow us to detect many more early- and mid-type T dwarfs.

We impose an additional optical/near-infrared color cut by rejecting candidate objects with optical counterparts within 5" of their 2MASS coordinates, using the USNO-A2.0 catalog (Monet et. al 1998). Figure 3 displays the image of 2MASS 0559-1404 (Burgasser et al. 2000) with its corresponding USNO-A2.0 catalog image, displaying a bright T dwarf which still has no optical counterpart. T dwarfs are very cool and the colors of Gliese 229B are R-J ~ 10 (Golimowski et al. 1998), meaning even the brightest T dwarfs will not be detectable in the USNO-A2.0 images.

Lick Observations Using the GEMINI Instrument

The resulting candidate pool is largely contaminated by minor planets, which also have blue NIR colors (Sykes et al. 1999) and lack of an optical candidate due to proper motion. Known minor planets are flagged in the 2MASS database and subsequently eliminated from search samples; however, uncataloged asteroids remain. To remove these objects from our candidate pool, we have conducted a near-infrared reimaging campaign at Lick. Imaging is quick and efficient because the candidates are bright, with $J < 16$. Standards are imaged on particularly clear nights to yield photometric information in addition to our 2MASS data.

Bright candidates that are confirmed by imaging are then observed spectroscopically using the GEMINI grisms. Spectroscopy identifies T dwarfs by the characteristic CH_4, H_20, and H_2 absorption bands in their emergent spectra. We employ the GEMINI instrument to take spectra because the low resolution of 500 is ideal for our candidates, and its two detectors allow for simultaneous J&K or H&K spectra.

Our First T Dwarf Discovery

Of 39 candidates imaged during our first run in February 2002, 4 were absent as likely asteriods in our sample. Nine objects were observed spectroscopically, four of which are unambiguously background stars, while the other four are too faint to clearly identify. The object 2MASS 0516-04 has been identified as a new T dwarf. 2MASS 0516-04 has J-K = 0.5, indicating that it is probably a mid-T dwarf. Figure 4 plots the discovery spectrum of 2MASS 0516-04, compared to the M3 V BD +28 2110 and the T2 V SDSS 1254-0122, all obtained on the same night. The CH_4 and H_20 bands shape the J-band spectra of a T dwarf into sharp peaks, making this region useful for identification. The comparison spectra of the M dwarf shows its continuum emission at the corresponding wavelengths. We observed a number of known M, L, and T dwarfs to use as comparison stars in addition to our targets. **Clearly, this project can successfully identify new members of the T dwarf class.**

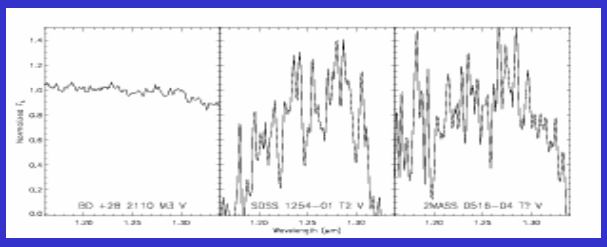

Figure 4: Spectrum of 2MASS 0516-04, compared to the M3 V BD +28 2110 and the T2 V 1254-0122.

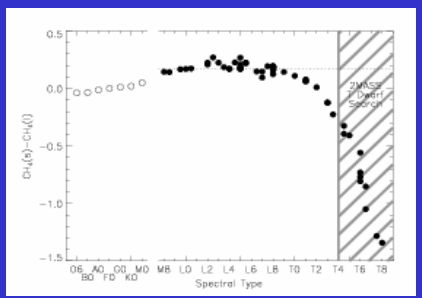

Figure 5: Plot of CH_4 (s) – CH_4 (l) colors synthesized from near-infrared spectra (solid circles) or blackbodies (open circles) as a function of spectral type .

Future Observations

The program at Lick is expected to continue through 2003, as we are planning to observe the entire Northern sky. A similar survey has been proposed to investigate the Southern sky using the CTIO facilities.

A proposal in collaboration with Chris Tinney (AAO) has been submitted to the Anglo-Austrailian Telescope, where a methane filter will be used to identify T dwarfs. This technique obviates the time consuming process of taking a spectra. Figure 5 shows CH_4 (s) – CH_4 (l) colors synthesized from near-infrared spectra (Geballe et al. 2002; solid circles) or blackbodies (open circles) as a function of spectral type. The T subtypes most sensitive to our survey (> T4) are > 0.3 mag bluer in these colors than any type of background star.

Portions of the data presented herein were obtained at the Lick Observatory which is operated as a part of the University of California Observatories. This publication makes use of data from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center, funded by the National Aeronautics and Space Administration and the National Science Foundation. Support for this work was provided by NASA through a Hubble Fellowship grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Incorporated, under NASA contract NAS5-26555.