THE 2MASS WIDE-FIELD T DW ARF SEARCH. II. DISCOVERY OF THREE T DWARFS IN THE SOUTHERN HEMISPHERE

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ABSTRACT

We present the discovery of three new southern hemisphere T dwarfs identified in the Two Micron All Sky Survey. These objects, 2MASS 0348–6022, 2MASS 0516–0445, and 2MASS 2228–4310, have classifications T7, T5.5, and T6.5, respectively. Using linear absolute magnitude/spectral type relations derived from T dwarfs with measured parallaxes, we estimate spectrophotometric distances for these discoveries: the closest, 2MASS 0348–6022, is likely within 10 pc of the Sun. Proper motions and estimated tangential velocities are consistent with membership in the Galactic disk population. We also list southern hemisphere T dwarf candidates that were either not found in subsequent near-infrared imaging observations and are most likely uncataloged minor planets, or have near-infrared spectra consistent with background stars.

Key words: infrared radiation — solar neighborhood — stars: individual (2MASS J03480772–6022270, 2MASS J05160945–0445499, 2MASS J22282889–4310262) — stars: low-mass, brown dwarfs

1. INTRODUCTION

T dwarfs are substellar objects whose near-infrared spectra exhibit characteristic signatures of H2O and CH4 (Burgasser et al. 2002; Geballe et al. 2002). They make up the coolest class of brown dwarfs currently known, with effective temperatures $T_{\text{eff}} \lesssim 1300$–1500 K (Burgasser et al. 2002; Dahn et al. 2002, and references therein). Their atmospheric properties are therefore quite similar to class III and IV extrasolar giant planets (EGPs; Sudarsky, Burrows, & Pinto 2000) but are more easily studied without the obscuration of a bright host star. Indeed, EGP atmospheric models have advanced in parallel with isolated brown dwarf models, since the latter differ only in the absence of an external radiating source (Seager & Sasselov 1998; Seager & Sasselov 2000; Sudarsky et al. 2000; Baraffe et al. 2003). The observed properties of T dwarfs have served to constrain these models. The currently known collection of nearby T dwarfs are also useful for studies of the substellar population in the solar neighborhood and the substellar initial mass function (Burgasser 2001). Finally, since these objects do not significantly process their initial hydrogen supply to heavier metals,4 they may be used as a tracer population of the chemical history of the Galaxy, as long as temperature, gravity, and metallicity diagnostics can be disentangled.

We have initiated a wide-field search for T dwarfs in the Two Micron All Sky Survey (2MASS; Skrutskie et al. 1997), as described in Burgasser et al. (2003b, hereafter Paper I). We find that this survey, which covers the entire sky, is ideal for finding T dwarfs in the solar neighborhood, since their spectral energy distributions peak in the $J$, $H$, and $K_s$ photometric bands sampled by 2MASS. The optical/near-infrared colors of T dwarfs are also extremely red ($R$–$J \gtrsim 9$; Golimowski et al. 1998); hence, photographic plate surveys, which also cover the whole sky, cannot detect T dwarfs much farther than a few parsecs from the Sun (Scholz et al. 2003). 2MASS is particularly useful for finding T dwarfs in the southern hemisphere, since it is more sensitive than the Deep Near-Infrared Survey of the Southern Sky (Epchtein et al. 1997), and there is as yet no equivalent to the Sloan Digital Sky Survey (SDSS; York et al. 2000) at southern latitudes.

In this article, we present the discovery of three new T dwarfs in the southern hemisphere, 2MASS 0348–6022, 2MASS 0516–0445, and 2MASS 2228–4310.5 In § 2, we review the identification of these T dwarfs through confirmation imaging and spectroscopic observations obtained using the Ohio State InfraRed Imager/Spectrometer (OSIRIS; Depoy et al. 1993), mounted on the CTIO 4 m Blanco Telescope. In § 3, we analyze the spectra of these and three other previously identified T dwarfs, 2MASS 0243–2453, 2MASS 0415–0935, and SDSS 0423–0414 (Burgasser et al. 2002; Geballe et al. 2002), also observed with OSIRIS. Including the latter sources into a suite of spectral standards, we classify the new T dwarfs and estimate their spectrophotometric distances. We also examine the kinematics of the three discoveries. Results are summarized in § 4.

2. OBSERVATIONS OF T DWARF CANDIDATES

2.1. Imaging Observations

Selection of T dwarf candidates from the 2MASS Working Point Source Database (WPSD) are discussed in detail in Paper I. Our color constraints—$H$–$K_s \lesssim 3$ or $H–K_s \lesssim 0$, and no optical counterpart in the USNO A2.0 catalog (Monet et al. 1998) or visible on Digitized Sky Survey (DSS)

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4 Exhaustive deuterium and lithium burning occur in solar metallicity brown dwarfs more massive than 0.013 and 0.065 $M_{\odot}$, respectively (Burrows et al. 2001).
5 Throughout the text, we adopt shorthand notation for 2MASS and SDSS sources, 2MASS/SDSS hhmm±ddmm. Full designations are listed in Tables 1–3.
plates—result in some contamination by asteroids, as discussed in Burgasser et al. (2002). We specifically exclude objects associated with known minor planets in the 2MASS catalog, but uncataloged minor planets are likely to be present. To eliminate these sources, we imaged a subset of our candidate pool with OSIRIS in the J band during 2002 September 20–24 (UT). Conditions during this period ranged from clear and dry (September 20 and 24) to light cirrus and clouds (September 21–23), and seeing was poor ($\gtrsim 1''$) on September 20 and 23, but excellent ($\lesssim 1''$) on the remaining nights. Pairs of 15 s integrations were obtained for each object, dithered $10''-20''$ between exposures. The sensitivity of these images was verified to be greater than that of 2MASS, which has a J-band S/N = 10 completeness limit of 15.8 (Cutri et al. 2003), implying that any stationary sources should have been recovered.

As in Burgasser et al. (2002), a number of sources were not seen in the OSIRIS images; these are listed in Table 1, with updated designations and photometry from the 2MASS All Sky Data Release (2MASS ADR; Cutri et al. 2003). A few sources were identified as unflagged image artifacts arising from electronic feedback in the quadrant readout of the 2MASS NICMOS3 detectors ("star echo"; see § IV.7 in Cutri et al. 2003). Eleven sources were subsequently identified as known minor planets by searching a $30'' \times 30''$ region around the positions of each unconfirmed source at the corresponding epoch of observation in the Small Body Catalog maintained by the Jet Propulsion Laboratory Solar System Dynamics Group. We note that about half of these 2MASS asteroid detections precede their discovery. It is logical, therefore, that most of the remaining unconfirmed sources are uncataloged minor planets, given that their near-infrared colors closely match those of known asteroids (Sykes et al. 2002) and that they are generally found at low ecliptic latitudes. Curiously, a handful of these probable minor planets are found at relatively high ecliptic latitudes, $25'' \lesssim |\beta| \lesssim 40''$. We cannot rule out the possibility of any of these sources being eruptive or otherwise variable events.

2.2. Spectroscopic Observations

For sources that reappeared in the OSIRIS images, we obtained spectra during the same run using the OSIRIS cross-dispersed gratings. Use of the single diffraction grating blazed at 6.6 $\mu$m with the 120 lines mm$^{-1}$ grating and f/2.8 camera provides simultaneous, moderate resolution ($\lambda/\Delta \lambda \sim 1200$) spectroscopy from 1.2 to 2.35 $\mu$m in four orders: J (fifth and sixth), H (fourth), and K (third). Resolution on the 0.430 pixel$^{-1}$ chip ranges from 4.4 to 8.8 A pixel$^{-1}$.

Table 2 summarizes the observations, which also included three known T dwarfs: 2MASS 0243–2453, 2MASS 0415–0935, and SDSS 0423–0414 (Burgasser et al. 2002; Geballe et al. 2002). Targets were acquired in imaging mode and placed into a $1''2 \times 30''$ slit. Observations were made in sets of five exposures dithered $4''.5-5''$ along the slit, with individual integrations of 300 s per exposure. B and A dwarf stars, chosen for their lack of metal lines at moderate resolution, were observed near the target objects for flux calibration and telluric corrections. Spectral lamps reflected off of the 4 m dome spot were observed each night for pixel response calibration, and a series of dark frames with identical exposure times as the spectral flats were also obtained to remove detector bias.

Data reduction consisted of initially trimming the science images to eliminate vignetted regions; dividing by a normalized, dark-subtracted flat field (constructed from a median combination of the spectral lamp and bias exposures); and correcting for bad pixels by interpolation, using a mask created from flat-field and bias frames. Images were then pairwise subtracted to eliminate sky background and dark current. Curvature of the dispersion lines was determined by tracing the spectra of the standard stars, and this trace was used as a template for the target spectra. Both standard and object spectra were extracted by summing eight to 12 columns (depending on seeing conditions) along each row after subtracting off the median background in that row. Individual spectra from each order were then scaled by a multiplicative factor and combined by averaging, rejecting $3\sigma$ outliers in each spectral bin. Wavelength calibration was done with the telluric OH lines, using identifications from Olivia & Origlia (1992). A telluric correction was computed for each target/standard pair by interpolating over H$_2$O absorption features in the standard-star spectra and ratioing these spectra with the uncorrected standard spectra. A smoothed flux correction was then calculated by interpolating over hydrogen Paschen and Brackett lines in the telluric-corrected standard spectra and multiplying by the appropriate blackbody (Tokunaga 2000). Finally, the flux-calibrated spectral orders were combined by first scaling each order to match overlap regions (typically 1.28–1.30, 1.53–1.55, and 1.95–1.97 $\mu$m) and then correcting the combined spectra to

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6 See http://www.ipac.caltech.edu/2mass/releases/allsky/doc/explsup.html.

7 Asteroid identifications were made using the Small-Body Search tool (http://ssd.jpl.nasa.gov/cgi-bin/sb_search).

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Fig. 1.—The 2MASS near-infrared color-color diagram for observed T dwarfs and T dwarf candidates, with photometry from the 2MASS ADR. Small points indicate objects absent in follow-up OSIRIS images; open circles indicate background sources based on spectroscopic observations; large filled circles indicate the three new T dwarfs and the known T dwarfs 2MASS 0243–2453, 2MASS 0415–0935, and SDSS 0423–0414 (identified). Dwarf (bottom) and giant (top) tracks from Bessell & Brett (1988) are indicated by gray lines. Note that many of the background sources have revised 2MASS ADR colors outside of our original WPSD search constraints (dashed lines). The revised colors are consistent with their spectroscopic identifications as late-type background stars.
2MASS \( H \)-band magnitudes. Note that the overlap between the \( H \)- and \( K \)-band orders falls within the 1.9 \( \mu \)m \( H_2O \) band; because of this, we generally applied the same scaling corrections to both orders.

The majority of sources observed appear to be late-type (KM) background stars based on the presence of weak \( H_2O \) absorption and relatively featureless \( H \)-band spectra. This is consistent with their positions on the near-infrared
### TABLE 2

| Object          | J(1)   | J−Ks(2) | UT Date  | J(3) | Air Mass | Calibrator | SpT(5) | Identification |
|-----------------|--------|---------|----------|------|----------|------------|--------|---------------|
| 2MASS J00231718–3346366......| 16.01 ± 0.08 | 0.61 ± 0.23 | 2002 Sep 23 | 1500 | 1.00     | HD 6619    | A1 V   | Late-type star |
| 2MASS J02053685–0853442......| 15.89 ± 0.06 | 0.73 ± 0.17 | 2002 Sep 20 | 1500 | 1.09     | HD 13936   | A0 V   | Late-type star |
| 2MASS J02431371–2453298......| 15.38 ± 0.05 | 0.16 ± 0.17 | 2002 Sep 24 | 1500 | 1.04     | HD 20293   | A5 V   | T dwarf  |
| 2MASS J02485536–4951573......| 16.14 ± 0.12 | 1.13 ± 0.19 | 2002 Sep 22 | 1500 | 1.14     | HD 17098   | B9 V   | Reddened star |
| 2MASS J02521393–3842100......| 15.95 ± 0.08 | 0.78 ± 0.19 | 2002 Sep 22 | 1500 | 1.03     | HD 17098   | B9 V   | Late-type star |
| 2MASS J02560785–4311108......| 15.69 ± 0.06 | 0.75 ± 0.17 | 2002 Sep 24 | 1500 | 1.04     | HD 20293   | A5 V   | Late-type star |
| 2MASS J03164047–6202104......| 15.85 ± 0.08 | 1.02 ± 0.14 | 2002 Sep 22 | 1500 | 1.19     | HD 22252   | B8 V   | Late-type star |
| 2MASS J03480772–6022270......| 15.32 ± 0.06 | -0.28 ± 0.24 | 2002 Sep 24 | 1500 | 1.19     | HD 24863   | A4 V   | T dwarf  |
| 2MASS J04143647–6916594......| 15.72 ± 0.07 | 0.89 ± 0.16 | 2002 Sep 24 | 1500 | 1.31     | HD 37935   | B9.5 V | Late-type star |
| 2MASS J04151954–0935066......| 15.70 ± 0.06 | 0.27 ± 0.21 | 2002 Sep 24 | 1500 | 1.08     | HD 28763   | A2/3 V | T dwarf  |
| 2MASS J19343857–0414033.5......| 14.47 ± 0.03 | 1.54 ± 0.04 | 2002 Sep 23 | 1500 | 1.29     | HD 30321   | A2 V   | T0 standard |
| 2MASS J05160945–0445499......| 15.98 ± 0.09 | 0.50 ± 0.22 | 2002 Sep 21 | 1500 | 1.12     | HD 33948   | B5 V   | T dwarf  |

- **Notes:**
  - a Photometry from the 2MASS ADR; note that some objects have revised photometry outside of our original WPSD search constraints.
  - b Candidate young brown dwarf in the Orion A complex (Strom, Strom, & Merrill 1993; Carpenter 2000).
  - c This object appeared much fainter at J band when imaged with OSIRIS than as observed by 2MASS. It is possible that the 2MASS source is a chance alignment with an uncataloged minor planet, or that this source is intrinsically variable.

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The color-color diagram in Figure 1 (which plots revised photometry from the 2MASS ADR), within the substantial color uncertainties; cf., the M dwarf and giant tracks of Bessell & Brett (1988). Furthermore, their faint magnitudes (15.5 ≤ J ≤ 16) imply optical/near-infrared color limits (R−J > 4.5, based on no detection in DSS photographic plates; Reid et al. 1991) consistent with late-type stars. In some cases, these identifications were confirmed spectroscopically by comparison to near-infrared data of known M dwarfs obtained in prior OSIRIS campaigns (Burgasser et al. 2002). None of the brighter background objects appear to be L dwarfs based on similar companions. Adequate spectral comparison for many of the spectra was not possible, however, due to low signal-to-noise ratio (S/N) data (~5−10 at J band in the worst cases), although it is clear that these faint objects are not T dwarfs. We forego detailed classification of background sources, since it is beyond the scope of this paper, and identify them simply as late-type stars. We do, however, identify one candidate, 2MASS 2005−1056, as LHS 483, a DC9 white dwarf (McCook & Sion 1999, and references therein) with substantial proper motion (μ = 1.08 yr−1; Luyten 1979). This object was not initially recognized as a background proper-motion star because of the small epoch difference between the available DSS plates (2.1 yr). A second source, 2MASS 0533−0633,
appears to be a reddened, mid- to late-type M dwarf based on its somewhat stronger H$_2$O bands, weak 1.23 μm FeH absorption, 1.25 μm K i doublet lines, and red near-infrared spectral slope. This source is also aligned with a small molecular clump just south of the Orion Nebular Cloud (ONC; Bally et al. 1987; Carpenter 2000). Its late-type dwarf spectrum and proximity to the 1–2 Myr ONC star-forming region (Hillenbrand 1997) suggest that it could be a young brown dwarf.

3. NEW T DWARFS

3.1. Spectral Analysis

We spectroscopically confirm three objects as T dwarfs: 2MASS 0348–6022, 2MASS 0516–0445, and 2MASS 2228–4310. Astrometric and photometric properties are listed in Table 3, and 2MASS and DSS images of each source (5′ × 5′ field) are shown in Figure 2. Calibrated spectral data are shown in Figure 3, along with data for 2MASS
Note that data for 2MASS 0348−6022 and 2MASS 0516−0445 have been combined from multiple nights to improve the S/N. All six T dwarfs show distinct CH$_4$ bands at 1.1, 1.3 (blue and red slopes of the 1.27 μm J-band peak), 1.6, and 2.2 μm; H$_2$O bands at 1.3 and 1.7 μm; and K $\lambda$ absorption lines at 1.2432 and 1.2522 μm. The spectrum of SDSS 0423−0414 shows some indication of CO absorption at 2.3 μm. The strength of the CH$_4$ and H$_2$O bands in the three new discoveries are consistent with late-type T dwarfs (Burgasser et al. 2002; Geballe et al. 2002).

Figure 4 displays the 1.19–1.33 μm region of the spectra in Figure 3, highlighting the 1.2432/1.2522 μm K $\lambda$ doublet lines. These lines are prominent in early- and mid-type

### Table 3

| Object                        | Type | J    | J−H  | H−K$_s$ | $d_s$ a | μ (arcsec yr$^{-1}$) | θ (deg) | $V_t$ (km s$^{-1}$) |
|-------------------------------|------|------|------|---------|---------|--------------------|--------|--------------------|
| 2MASS J03480772−6022270 ........ | T7   | 15.32 ± 0.06 | −0.24 ± 0.16 | −0.04 ± 0.28 | 9 ± 4 | 0.77 ± 0.04 | 201 ± 3 | 32 ± 14 |
| 2MASS J05160945−0445499 ........ | T5.5 | 15.98 ± 0.09 | 0.26 ± 0.19 | 0.24 ± 0.27 | 34 ± 13 | 0.34 ± 0.03 | 232 ± 5 | 55 ± 21 |
| 2MASS J22282889−4310262 ........ | T6.5 | 15.66 ± 0.08 | 0.30 ± 0.14 | 0.07 ± 0.24 | 12 ± 4 | 0.31 ± 0.03 | 175 ± 15 | 17 ± 6 |

* Estimated spectrophotometric distance based on spectral type and 2MASS JHK$_s$ photometry (see § 3.3).

0243−2453, 2MASS 0415−0935, and SDSS 0423−0414. Note that data for 2MASS 0348−6022 and 2MASS 0516−0445 have been combined from multiple nights to improve the S/N. All six T dwarfs show distinct CH$_4$ bands at 1.1, 1.3 (blue and red slopes of the 1.27 μm J-band peak), 1.6, and 2.2 μm; H$_2$O bands at 1.3 and 1.7 μm; and K $\lambda$ absorption lines at 1.2432 and 1.2522 μm. The spectrum of SDSS 0423−0414 shows some indication of CO absorption at 2.3 μm. The strength of the CH$_4$ and H$_2$O bands in the three new discoveries are consistent with late-type T dwarfs (Burgasser et al. 2002; Geballe et al. 2002).

Figure 4 displays the 1.19–1.33 μm region of the spectra in Figure 3, highlighting the 1.2432/1.2522 μm K $\lambda$ doublet lines. These lines are prominent in early- and mid-type
T dwarf spectra (as well as late-type M and L dwarfs), peaking in strength around spectral type T5–T5.5, then fading in the later dwarfs (Burgasser et al. 2002). We measured pseudo-equivalent widths\(^1\) (pEW’s) for these lines by integrating over the line profiles; see Burgasser et al. (2002). Results are listed in Table 4. Values decrease monotonically from roughly 12 to 4 \(\AA\) for the 1.2432 \(\mu m\) line and 16 to 6.5 \(\AA\) for the 1.2522 \(\mu m\) line over spectral types T5.5 to T7, consistent with previously observed trends. Upper pEW limits of roughly 2 \(\AA\) are found for the \(K\) lines of the latest type T dwarf 2MASS 0415–0935.

3.2. Classification

We derived spectral types for the three discoveries using the classification scheme of Burgasser et al. (2002). The top of Table 5 lists spectral ratio values of observed T dwarf standards, including new measurements for 2MASS 0423–0414, 2MASS 0243–2453, and 2MASS 0415–0935 (our T0, T6, and T8 standards, respectively), and measurements using OSIRIS data for 2MASS 1254–0122 (Leggett et al. 2000).

\(^1\) The presence of overlying opacity throughout the near-infrared prevents the measurement of “true continuum” for computing equivalent widths; hence, the reported measurements are relative to the local, or “pseudo”-continuum.

### Table 5
Spectral Ratios and Classification on the Burgasser et al. (2002) Scheme

| Object        | \(H_2O\)-B | \(CH_4\)-A | \(CH_4\)-B | SpT\(^a\) |
|---------------|------------|------------|------------|-----------|
| SDSS 0423–0414 | 0.689      | 0.985      | 0.916      | T0        |
| SDSS 1254–0122 | 0.559      | 0.943      | 0.826      | T2        |
| 2MASS 0559–1404 | 0.456      | 0.789      | 0.383      | T5        |
| 2MASS 0243–2453 | 0.369      | 0.648      | 0.229      | T6        |
| 2MASS 0727–1710 | 0.332      | 0.509      | 0.133      | T7        |
| 2MASS 0415–0935 | 0.267      | 0.429      | 0.062      | T8        |

**Standards**

**Discoveries**

Distance estimates for our new discoveries can be made using their spectral types, 2MASS photometry, and the absolute magnitudes of T dwarfs with measured parallaxes. We first compared 2MASS MJ, MH, and MK\(^{\ast}\) versus spectral type (SpT) for T dwarfs typed T5 and later using parallax data from Dahn et al. (2002), Tinney, Burgasser, & Kirkpatrick (2003), and F. Vrba (2002, private communication). Excluding the known binaries 2MASS 1225–2739AB and 2MASS 1534–2952AB (Burgasser et al. 2003c) and Gliese 229B (Nakajima et al. 1995; not detected by 2MASS), we derive the following linear relations over the range T5–T8:

\[
M_J = (10.00 \pm 0.12) + (0.84 \pm 0.02)SpT, \\
M_H = (9.60 \pm 0.18) + (0.88 \pm 0.03)SpT, \\
M_K = (8.7 \pm 0.3) + (0.98 \pm 0.05)SpT, \\
\]

where SpT(T5) = 5, SpT(T8) = 8, etc. Based on these relations, we derived distance estimates for each source in each band assuming spectral type uncertainties of \(\pm 0.5\) subclasses. The mean distances and standard deviations are 9 ± 4, 34 ± 13, and 12 ± 4 pc for 2MASS 0348–6022,

et al. 2000, T2), 2MASS 0559–0414 (Burgasser et al. 2000b, T5), and 2MASS 0727+1710 (Burgasser et al. 2002, T7) from Burgasser et al. (2002). We make use of the \(H_2O\)-B, \(CH_4\)-A, and \(CH_4\)-B indices only, due to the wavelength limits of the spectral data (obviating the \(H_2O\)-A index), poor S/N at \(K\) band (obviating the \(CH_4\)-C, and 2.11/2.07 indices), and possible uncertainties in the individual band calibration (obviating the \(H'\)/\(J\) and \(K'\)/\(J\) color indices). As can be seen in Table 5, the three remaining indices are monotonic with spectral type for the standards.

Spectral ratios of our discoveries are listed at the bottom of Table 5. For each ratio, we assigned a whole or half subtype based on the closest match to the standard values. Final subtypes were derived from the average of these individual ratio types, which for each object differ by less than \(\pm 0.5\) subclasses. Furthermore, individual spectra for 2MASS 0348–6022 and 2MASS 0516–0445 obtained on separate nights yield identical types within \(\pm 0.5\) subclasses. Therefore, we assert that our classifications are accurate to within 0.5 subclasses despite the limited suite of spectral ratios employed. Derived spectral types are T7 for 2MASS 0415–0935, T5.5 for 2MASS 0516–0445, and T6.5 for 2MASS 2228–4310. These mid- to late-type classifications are consistent with their relatively blue near-infrared colors.

3.3. Distance Estimates

Distance estimates for our new discoveries can be made using their spectral types, 2MASS photometry, and the absolute magnitudes of T dwarfs with measured parallaxes. We first compared 2MASS MJ, MH, and MK\(^{\ast}\) versus spectral type (SpT) for T dwarfs typed T5 and later using parallax data from Dahn et al. (2002), Tinney, Burgasser, & Kirkpatrick (2003), and F. Vrba (2002, private communication). Excluding the known binaries 2MASS 1225–2739AB and 2MASS 1534–2952AB (Burgasser et al. 2003c) and Gliese 229B (Nakajima et al. 1995; not detected by 2MASS), we derive the following linear relations over the range T5–T8:

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where SpT(T5) = 5, SpT(T8) = 8, etc. Based on these relations, we derived distance estimates for each source in each band assuming spectral type uncertainties of \(\pm 0.5\) subclasses. The mean distances and standard deviations are 9 ± 4, 34 ± 13, and 12 ± 4 pc for 2MASS 0348–6022,
2MASS 0516–0445, and 2MASS 2228–4310, respectively. It is not surprising that the first object, which has the latest classification and brightest apparent magnitude, is likely to be less than 10 pc from the Sun, unless it is an unresolved multiple system. However, parallax observations are required to verify these rather uncertain estimates.

3.4. Proper Motions

Proper motions for the T dwarf discoveries were measured between the 2MASS and follow-up OSIRIS images following the technique of Burgasser et al. (2003a). First, astrometric calibrations of each OSIRIS field, of the form

\[ \alpha = \alpha_0 + Ax + By, \]

\[ \delta = \delta_0 + Cx + Dy, \]

(\(x\) and \(y\) are pixel coordinates on the OSIRIS images) were made by linear regression using the 2MASS coordinates of six to eight background sources within 2.5 of each T dwarf. Background sources were verified to show consistent positions between the two epochs (which span 3.1–4.1 yr) to within 3 times the astrometric fit uncertainties, roughly 0.05–0.11. Positions for the T dwarfs on the OSIRIS images were then calculated and compared with the original 2MASS coordinates.

Results are listed in Table 3. As expected from their relative proximity, all of these sources have statistically significant proper motions. Their tangential velocities \(V_t\) are relatively modest, however, ranging from 17 to 55 \(\text{km s}^{-1}\); Reid & Hawley 2000) and comparable to or less than the median for field late-type M and L dwarfs (22 km \(\text{s}^{-1}\); Gizis et al. 2000). Hence, the kinematics of these three T dwarfs are consistent with, but not restricted to, membership in the Galactic disk.

4. SUMMARY

We have identified three new southern T dwarfs using 2MASS. These objects are important additions to the sample of nearby stars and brown dwarfs; indeed, one object, if it is single, is likely to be closer than 10 pc from the Sun. Spectroscopic observations yield classifications ranging from T5.5 to T7 and measured \(\text{K}_p\) support the observed trend of decreasing line strength with spectral type for mid- to late-type T dwarfs. All three objects have small to moderate proper motions and tangential velocities, consistent with membership in the Galactic disk. With roughly 70% of the southern hemisphere portion of our 2MASS T dwarf search sample now completed and 13 T dwarfs so far identified (Burgasser et al. 1999, 2000a, 2000b, 2002), we expect to uncover another five to six mid- to late-type T dwarfs over the remaining portion of this part of the sky to \(J = 16\).

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