Improved Parallaxes and Near-Infrared Photometry of L- and T-Dwarfs From the U.S. Naval Observatory Infrared Astrometry Program

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Abstract. We present an update on the status of the USNO infrared astrometry program for low mass stars and brown dwarfs. Selected results from the 2000-2006 program and its accompanying infrared photometry are presented along with an overview of the current astrometry program. Listings of the objects on both infrared programs are given along with a discussion of when the final results from these programs should become available.

1. Introduction

Parallactic distances and proper motions continue to be amongst the most important and sought after fundamental observations of objects comprising the low-mass stellar to brown dwarf transition (L-dwarfs) and continuing to the cooler T-dwarfs with methane-dominated spectra. In 2004 USNO published one of the first comprehensive studies of high-quality parallaxes and proper motions of 40 L- and T-dwarfs based on near-infrared observations obtained with ASTROCAM at the Flagsaff Station's 1.55-m telescope (Vrba et al. 2004). Since then numerous other studies have greatly expanded the number of brown dwarfs with measured parallaxes and proper motions (cf. the results of Dupuy & Liu (2012) and the summary of other studies to that time contained therein). Nonetheless, many brown dwarfs remain without measured parallactic distances and, due to their great importance, all parallaxes should be confirmed by independent studies.

For these reasons and because the Vrba et al. (2004) results were considered to be preliminary in nature due to the short time baseline of observation, USNO continued with additional observations of the original 40 objects, resulting in greatly improved astrometry. Subsequently another 19 objects were added to that program. In this paper we present a preview of these parallax results along with new near-infrared photometry in the form of spectral type versus absolute magnitude and color-color diagrams. A full presentation of our results will be given in a forthcoming paper (Vrba et al., 2015, in preparation).

2. Astrometry

ASTROCAM went into operation in September 2000 as an infrared astrometric instrument employing an ALADDIN 1024 InSb array and using purely reflective optics for re-imaging (Fischer et al. 2003). Astrometric results covering approximately the first 1.7 years of observations are those reported in Vrba et al. (2004). However, observations continued through mid-June 2006 when ASTROCAM was destroyed in an unfortunate cryogenic explosion ultimately caused by a local forest fire. Table 1 shows the improvement in both parallax and proper motion astrometic quality between the earlier published results and those based on the full data through June 2006. All numbers are for the original 40 objects and show the mean number of nights observed, the mean time baseline of the observations, and the mean parallax and proper motion errors. The 19 objects which were added to the program have astrometric errors appropriate for obsevational time baselines typically of about four years.

Table .1: Comparison of Preliminary and Final Astrometry.

Results	No. of Nights	ΔT (yrs)	$\sigma(\pi)$ mas	$\sigma(\mu)$ mas/yr
Vrba et al. (2004)	24	1.72	4.31	6.56
Final	71	5.27	1.73	1.09

The 59 objects from the 2001-2006 program are listed in Table 2, where we have used somewhat abbreviated forms of their full designations. All objects were discovered either from the 2 Micron All Sky Survey (2MASS) (Skrutskie et al. 2006) or the Sloan Digital Sky Survey (SDSS) (York et al. 2000). The objects are listed along with their current spectral classifications from the literature where we have chosen to use optical spectral types for L-dwarfs and near-infrared spectral types for T-dwarfs, based on general classification availability. Eight of the objects are in resolved binaries, bringing the total to 67 objects in 59 systems. Note, however, §4 where we argue that many other brown dwarfs may be in multiple systems.

3. Photometry

In addition to astrometry, we also embarked on an extensive campaign of new JHK photometry on the CIT system (Elias et al. 1982) using ASTROCAM. This was prompted by the fact that several of the objects had poor or non-existent photometry available in the literature and that we felt it important to obtain photometry on a single photometric system. During 2003 and 2004 we obtained all-sky photometry referenced to the CIT JHK standards of Guetter et al. (2003). This was supplemented by additional ASTROCAM observations during 2013 and 2014 by using in-frame 2MASS Point Source Catalog stars as local standards transformed to the CIT system (Carpenter 2001). Typically an object was observed on 3 or 4 independent nights using either one or both of these techniques and in all cases gave results which are both self-consistent and consistent with quality photometry in the literature. This work while nearly complete is on-going, which is the reason the preview results given in the next two sections are not considered final.

4. M_J versus Spectral Type Diagram

Figure 1 displays the absolute J-band magnitude (M_J) versus spectral type diagram based on spectral types from the literature, as described above, and the combination of our new parallaxes and infrared photometry. In addition, we display as open points the results for this diagram from the Dahn et al. (2002) USNO optical parallax program for generally earlier spectral type objects not on the infrared parallax program. We also identify the only known brown dwarf subdwarf in these studies, 2MASS J053253+8246 (Burgasser et al. 2007), which is over-luminous compared to the normal dwarfs.

The figure clearly shows the J-band luminosity "bump" for early- to mid-T objects first identified by Dahn et al. (2002) and well-documented by Vrba et al. (2004). We have purposely not split the fluxes for the eight known spatially resolved binary systems in this figure. These objects are plotted in red and identified in Table 2. For mid-L and earlier spectral types and mid-T and later spectral types the slopes in this diagram are so steep as to make multiple systems hard to identify. Even a significant flux excess can be interpreted as a natural width to the spectral type versus M_J distribution. However, the relative flatness of late-L to mid-T dwarfs due to the J-band "bump" allows multiple systems to stand out. The figure suggests the possibility of a significant number of near equal spectral type unresolved multiple systems at late-L and early- to mid-T. Since the luminosity "bump" becomes less apparent in H-band and even less so at K-band (neither shown here) we suggest that the spectral type versus M_J diagram is well-suited for identifying spatially and/or spectroscopically unresolved multiple systems for this spectral type range.

5. (J−K) versus (J−H) Diagram

Figure 2 shows the (J−K) versus (J−H) photometry obtained to this point for the 59 objects or systems in this study, where objects of various spectral type and the resolved multiple systems are identified by color. The sole subdwarf is again identified. The L-dwarfs form a fairly tight locus with more dispersion for T-dwarfs and a saturation of (J−H) for the latest T-dwarfs. The resolved multiple systems are known to have near equal spectral type members and are thus not identifiable by these colors. As suggested by their placements in

Figure 1, the suspected multiple systems are also likely near-equal spectral types and thus are also not identifiable in this diagram.

6. Future USNO Brown Dwarf Infrared Astrometric Work

The full parallax, proper motion, and photometry results from the 2001-2006 program will be submitted for publication in fall 2014, once the final photometry is completed (Vrba et al., 2015, in preparation). ASTROCAM has been repaired and was returned to astrometric work in May of 2011. It is in its third year of a program currently consisting of 64 additional L and T-dwarfs which are listed in Table 3. Included in these are additional subdwarfs and objects thought to be young. Results from this program should be available in 2016.

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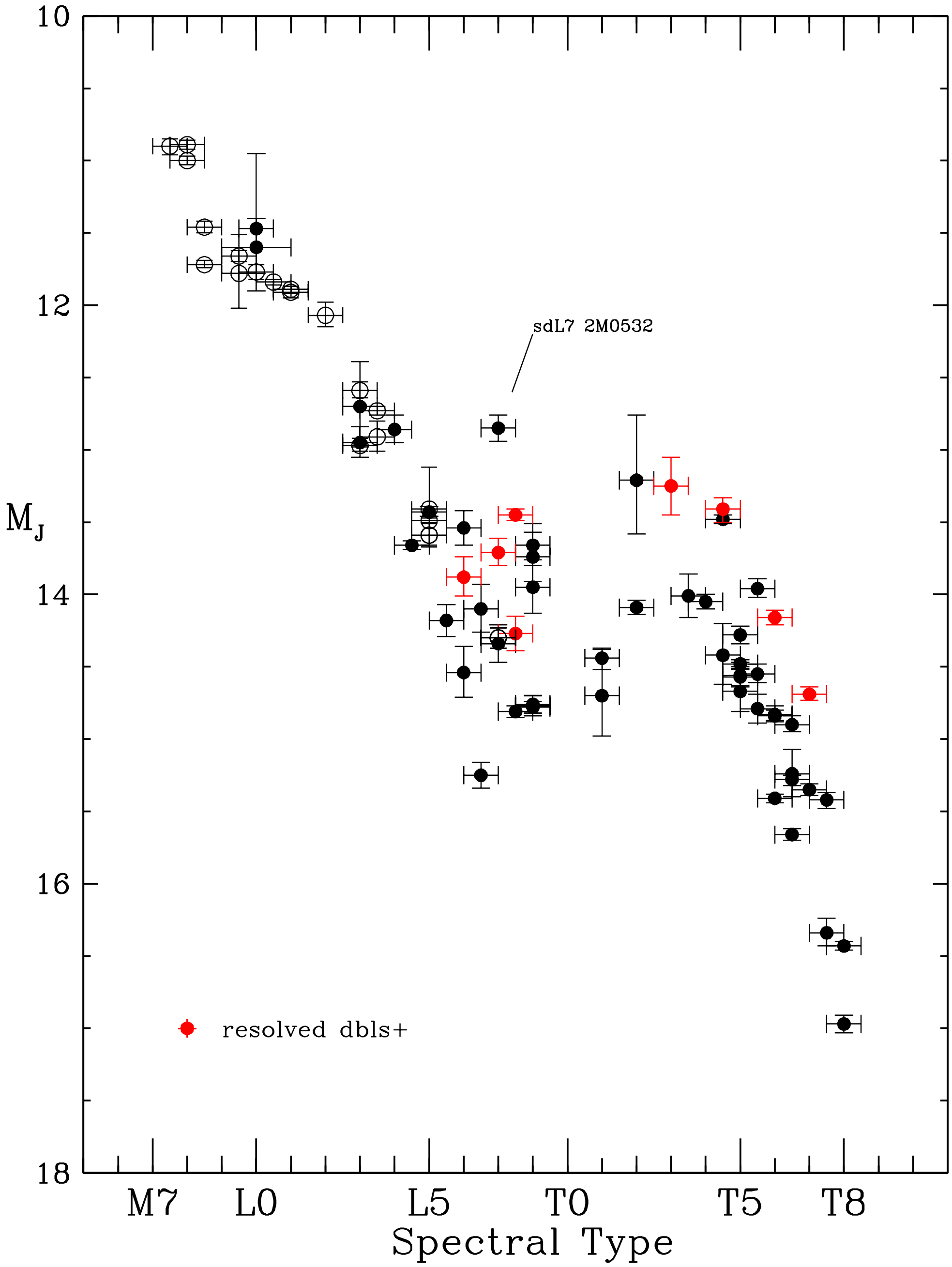

Figure .1: M_J versus spectral type diagram for objects on this program (filled points) and previously published USNO optical parallaxes (open points). Known multiple systems are shown as red points. The only brown dwarf subdwarf in this study is identified.

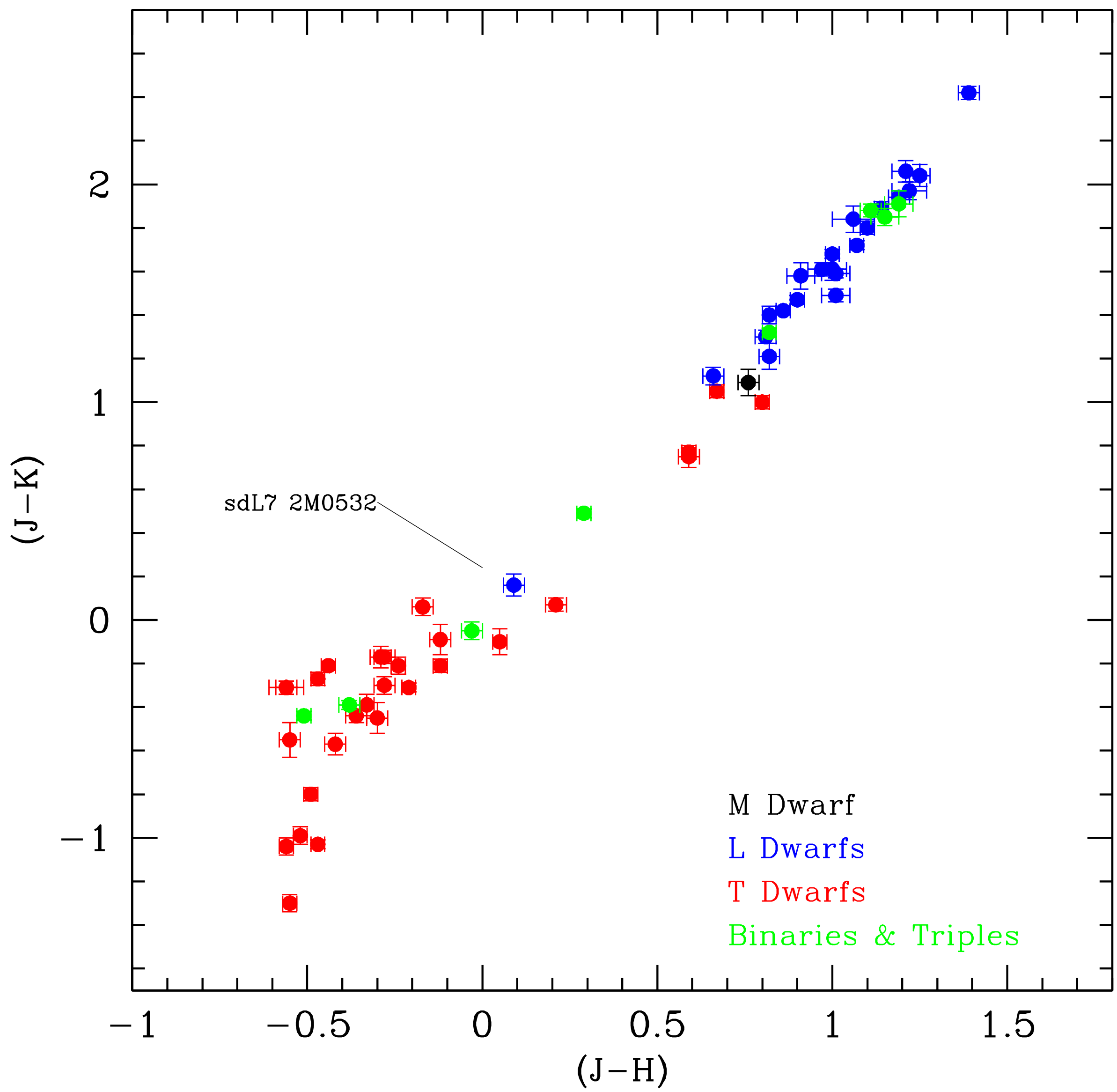

Figure .2: (J−K) versus (J−H) photometry on the CIT system for the objects in this study. Spectral types, multiple systems, and the sole subdwarf in this work are identified in the legend.

Table .2: Objects on the USNO 2000-2006 ASTROCAM Program

Object	SpT	Object	SpT
SDSS J003030-1450	L7	2MASS J122554-2739AB	T6+T8
SDSS J003259+1410	L8	2MASS J123739+6526	T6.5
SDSS J010752+0041	L8	SDSS J125453-0122	T2
SDSS J015141+1244	T1	SDSS J132629-0038	L5.5
SDSS J020742+0000	T4.5	SDSS J134646-0031	T6.5
2MASS J024313-2453	T6	SDSS J143517-0046	L0
SDSS J030953-0753	M9	SDSS J143535-0043	L3
2MASS J031059+1648	L8	SDSS J144600+0024	L6
2MASS J032842+2302	L8	2MASS J150319+2525	T5
2MASS J041519-0935	T8	2MASS J152322+3014	L8
SDSS J042348-0414AB	L6+T2	2MASS J155302+1532AB	T7+T7
2MASS J051609-0445	T5.5	SDSS J162414+0029	T6
2MASS J053253+8246	sdL7	2MASS J163229+1904	L8
SDSS J053952-0059	L5	2MASS J171145+2232	L6.5
2MASS J055919-1404	T4.5	2MASS J172811+3948AB	L7+L8
2MASS J072718+1710	T7	SDSS J175024+4222	T2
2MASS J075548+2212	T5	SDSS J175032+1759	T3.5
2MASS J082519+2115	L7.5	SDSS J175805+4633	T6.5
SDSS J083008+4828	L8	2MASS J184108+3117	L4pec
SDSS J083717-0000	T1	2MASS J190106+4718	T5
2MASS J085035+1057AB	L6+L8	2MASS J210115+1756AB	L7.5+L8
SDSS J092615+5847AB	T4.5+T4.	SDSS J212413+0100	T5
2MASS J093734+2931	T6p	2MASS J2224-0158	L4.5
2MASS J093935-2448	T8	2MASS J224253+2542	L3
2MASS J095105+3558	L6	2MASS J224431+2043	L6.5
SDSS J102109-0304AB	T1+T5	2MASS J225418+3123	T4
2MASS J104753+2124	T6.5	SDSS J225529-0034	L0:
SDSS J111010+0116	T5.5	2MASS J233910+1352	T5
2MASS J111451-2618	T7.5	2MASS J235654-1553	T5.5
2MASS J121711-0311	T7.5		

Table .3: Objects on the Current USNO ASTROCAM Program

Object	SpT	Object	SpT
SDSS J000013+2554	T4.5	WISE J131141+3629	L5pec
WISE J000849-1739	T6	WISE J132004+6034	T6.5
2MASS J003451+0523	T6.5	WISE J132233-2340	T8
2MASS J004121+3547	sdM9	PSO J132407+1906	T3.5
2MASS J004521+1634	L2beta	WISE J134806+6603	L9
WISE J004928+0441	L9	2MASS J140753+1241	L1::
WISE J015010+3827	T0	WISE J145715+5815	T7
WISE J020625+2640	L9pec	WISE J150649+7027	T6
2MASS J025114-0352	L3	2MASS J150654+1321	L3
WISE J025409+0223	T8	2MASS J154614+4932	T2.5:
WISE J030533+3954	T6	PSO J162541+1528	T4.5
2MASS J035523+1133	L5gamma	2MASS J162620+3925	sdL4
2MASS J040708+1514	T5	WISE J162725+3255	T6
WISE J041054+1411	T6	PSO J162918+0335	T2
2MASS J050021+0330	L4	WISE J164715+5632	L9pec
WISE J051317+0608	T6.5	WISE J174124+2553	T9
WISE J060738+2429	L8	SDSS J175024+4222	T2
WISE J061407+3912	T6	2MASS J175610+2815	sdL1
WISE J062542+5646	T6	SDSS J175805+4633	T6.5
WISE J065609+4205	T3	WISE J180026+0134	L7.5
2MASS J070036+3157AB	L3.5 binary	2MASS J182128+1414	L4.5
SDSS J074201+2055	T5	WISE J183058+4542	L9
SDSS J075840+3247	T2	WISE J185215+3537	T7
WISE J082131+1443	T6.5	WISE J190624+4508	T6
2MASS J083542-0819	L5	WISE J190648+4011	L1
SDSS J085758+5708	L8	WISE J195246+7240	T4
2MASS J091534+0422AB	L7 binary	SDSS J212413+0100	T5
2MASS J093935-2448	T8	WISE J221354+0911	T7
WISE J101905+6529	T6	2MASS J224253+2542	L3
2MASS J111451-2618	T7.5	WISE J232728-2730	L9
WISE J112254+2550	T6	WISE J234026-0745	T7
2MASS J123147+0847	T5.5	WISE J234841-1028	T7