Discovery of Three Faint Brown Dwarfs with HST/NICMOS

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Abstract

We report the discovery of a T1 dwarf, HD68456C (**F165M** = 15.63), approximately 4" from the main sequence star HD 68456 (F5V), an L4 dwarf, SLB01 (**F165M** = 17.2), and a T3 dwarf, SLB02 (**F165M** =17.63) in the field near to HD 155826 (G0V). All were found during an observing program of HST/NICMOS coronagraphy of stars potentially harboring planetary companions. Multi-filter medium band photometry (F165M, F171M, F180M, F207M) of 35 candidate objects from the program was used to find objects with unusual 1.72–1.8 µm and 1.65–2.08 µm colors. Photometric comparison of the new objects to the spectral classification scheme of L and T dwarfs of Leggett *et al.* shows a close match to their L/T brown dwarf spectra, with a decrease in flux versus a Rayleigh-Jeans stellar spectrum due to methane absorption at 1.65 µm and a much deeper fall off at 1.8 µm due to water absorption. Since HD 68456 and HD 155826 are known spectroscopic binaries, we speculate that the substellar objects may form widely separated multiple systems; if true, then HD68456C represents the first brown dwarf companion to an F-star.

1. Introduction

The discovery from the ground of the first confirmed brown dwarf substellar companion, Gl229B, by Nakajima *et al.* (1995) marked the birth of a new field in contemporary astronomy. Brown dwarfs are objects that have a mass below ~0.08 M_{solar} and are more massive than a giant planet (~0.013 M_{solar}). The age and mass of a brown dwarf are usually determined using the age of the associated stars and theoretical models of brown dwarf evolution (Burrows *et al.* 1997). A brown dwarf cannot sustain nuclear fusion once its convective accretion phase is over and it reaches the main sequence. However, a brown dwarf is massive enough to fuse deuterium, available in limited quantities, leading to a period of time for the brown dwarf on the main sequence of the H-R diagram. While the deuterium is quickly depleted early in its evolution, early dwarf types can thus be confused with hydrogen burning M-dwarfs in broad-band color-color diagrams (Burrows *et al.* 1997). Post-deuterium burning, a brown dwarf evolves by cooling towards an asymptotic temperature as stellar contraction continues. The youngest brown dwarfs, slightly cooler than the M dwarfs, have been classified as spectral type

"L" (Kirkpatrick *et al.* 1999a). The L-class brown dwarfs have temperatures with 1300 < T_{eff} < 2000 K, but unlike M-dwarfs, have characteristic absorption features in their spectra due to CO and H_2O. "T-class" brown dwarfs have effective temperatures of T_{eff} < 1200-1300 K (Fegley and Lodders 1996, Burrows and Sharp 1999; Kirkpatricke *et al.* 2000), and are cool enough to exhibit not only CO and H_2O absorption features, but also CH_4 features at 1.6 and 2.2 µm in their infrared spectra (Oppenheimer *et al.* 1995; Kirkpatrick *et al.* 1999b); hence their secondary appellation as "methane brown dwarfs".

The discovery of a new T-class brown dwarf is important, as few are known to exist in binary or multiple stellar systems. Brown dwarfs evolve past the deuterium burning stage without reaching thermal equilibrium, through the L dwarf phase, and eventually into a T dwarf, with the rate of evolution depending on the dwarf mass. Despite this, of the discovered brown dwarf population, companion or otherwise, T dwarfs are especially rare, most likely due to selection effects – they are also the faintest dwarfs due to their cool temperatures. Recent massive sky surveys have detected hundreds of brown dwarfs in the field, including the Deep Near-Infrared Survey (DENIS) (Tinney, Delfosse, and Forveille 1997), 2 µm All-Sky Survey (2MASS; Skrutskie *et al.* 1997), and the Sloan Digital Sky Survey (Strauss *et al.* 1999; Tsvetanov *et al.* 2000). Of these, only about 20 have been classified as methane brown dwarfs, including the L/T transition objects.

Many observers have searched nearby stars for ultracool companions with modest success (Becklin and Zuckerman 1988; Henry and McCarthy 1990; Nakajima *et al.* 1994; Simons, Henry and Kirkpatrick 1996; Schultz *et al.* 1997; Golimowski 2001; Lowrance *et al.* 1999; Schneider 1999; Schroeder *et al.* 2000; Oppenheimer 2001, Golimowski et al. 2004). Substellar companions to primary stars with wide separations offer the potential to obtain a dynamical mass given good astrometry, while spectroscopic observations of brown dwarfs with good age estimates provide evolutionary constraints on temperatures, surface gravities, and compositions. Searches for substellar companions are needed to study the frequency of these systems as well as the evolution of these objects. Despite the ~50% probability of a companion for a Milky Way star, only a mere dozen or so brown dwarfs have been found to exist in multiple-star systems. Radial velocity searches for extrasolar planets are also sensitive to more massive sub-stellar companions, but have detected very few. This lack of brown dwarf detections has been termed, the "brown dwarf desert" (e.g. Halbwachs et al. 2001; Armitage & Bonnell 2002). Oppenheimer *et al.* (2001) unsuccessfully examined 200 stars from the ground for evidence of substellar companions. Golimowski *et al.* (2001), using the Near-Infrared Camera and Multi-Object Spectrometer (NICMOS) onboard the Hubble Space Telescope (HST) to search for companions of 79 targets of type G, K, and M within 10 pc of the Sun, discovered that Gliese 54 was a binary pair of M dwarfs. The HST-NICMOS Instrument Definition Team (IDT) reported finding substellar companions of HR 7329 and of TWA 5A following their search of 29 similar targets (Lowrance *et al.* 2000). Recently, Golimowski et al. 2004 reported the detection of low-mass companions to five M and L dwarfs within 10 pc of the Sun using the HST/NICMOS. Currently, it appears that perhaps 1-2% of stars have brown dwarf companions.

We report here the results of an HST companion search program around 14 nearby main sequence stars using the NICMOS Camera 2 imaging coronagraph. Gl229B was observed as a calibration target and its NICMOS photometry provided a bench mark against which the photometry of candidate ultracool dwarfs were compared. Targets were imaged in the 1.6 μm methane absorption band (filters F165M and F171M), the 1.85 μm water absorption band (filter F180M), and the continuum (filter F207M). Photometry was obtained for all objects in the fields surrounding the targets. Placing the detected faint objects on a color-color diagram, three stand out as being highly deviant from main sequence colors. One object, hereafter termed HD68456C, appears to be a candidate companion to HD68456. Two other objects, hereafter termed Schultz+Lisse+Bennum (SLB) SLB01 and SLB02, were found in the field near HD155826. By comparing the photometry of the candidate companions to representative infrared spectra of L and T dwarfs (S. Leggett, private communication of UKIRT dwarf spectra, http://www.jach.hawaii.edu/~skl/LTdata.html), we tentatively identify HD68456C as a T1 dwarf, SLB01 (J2000 17H15M36.5S, -38D35'27.9") as an L4 dwarf, and SLB02 (J2000 17H15M36.8S, -38D35'33.3") as a T3 dwarf.

2. Observations

The observing characteristics of the NICMOS Camera 2 (NIC2) coronagraphic observing mode are ideal for companion searches of nearby bright stars (Krist *et al.* 1998). The NIC2 coronagraphic observing mode is provided by a small hole in the optical relay mirror on the Field Divider Assembly (FDA) outside the dewar, combined with a cold mask at the entrance to the dewar. On board software locates the image of the hole and target on the detector and slews the telescope to move the image of the hole over the target. The image of the hole is offset from the center of the NIC2 detector and located in one quadrant of the detector near an edge. Thus, the coronagraphic search space around any given star positioned in the hole has an inner radius of ~0.5" and an ~20" outer radius. The coronagraph allows detection of objects, depending upon the magnitude of the primary star, up to 15 magnitudes fainter than the primary star (Fraquelli *et al.* 2004).

Fourteen target systems were observed with NICMOS coronagraphy. Seven targets were acquired using the Mode-1 coronagraphic real time acquisition, and seven targets were acquired with the onboard Mode-2 acquisition. The observations were obtained using the MULTIACCUM mode with 16 spaced non-destructive reads in a 144 second integration (SAMP-SEQ=STEP16,NSAMP=15) using the F165M, F171M, F180M, and F207M filters. Gl229B was similarly observed with the 4 target filters and with the F204M filter for 96 seconds, but without the coronagraph, as it was distant enough from Gl229A so that it could be imaged separately without the need for coronagraphic suppression of the primary's emission. Target systems were selected as potential companion systems due to their measured infrared excesses (Aumann *et al.* 1984, Aumann 1985), and they have a wide variety of spectral types (A2V to K1V). With the exception of HD 155826, the fields within 2" of each target were free of foreground or background objects. HD 155826 resides within 3^{o} of the galactic plane and its images were thus crowded with unassociated stars. Gl229B was observed as a calibration target, and is used as a check of our absolute calibration and of our method of classifying the new objects as T dwarfs. Table 1 presents the VJHK magnitudes, spectral types, and distances in parsecs for the target systems.

Table 1. Magnitudes, spectral classifications, and distances for the 14-program stars†

Target	V	J	H	K	Spectral Type	Distance (pc)	Reference
HD10476	5.20	3.73	3.35	3.28	K1V	7.5	1
HD10700*	3.50	3.62	3.29	3.23	G8V	3.6	1
HD18978*	4.10	3.78	3.68	3.68	A4V	26.4	2
HD27290*	4.20	3.60	3.49	3.47	F0V	20.3	3
HD38678*	3.60	3.33	3.32	3.31	A2Vann	21.5	3
HD39060*	3.80	3.55	3.49	3.47	A5V	19.3	3
HD48682	5.27	4.19	3.97	3.93	G0V	16.5	3
HD68456	4.76	3.93	3.70	3.66	F5V	21.4	4
HD84117	4.94	3.94	3.64	3.59	G0V	14.9	4
HD87696	4.48	4.10	4.03	4.02	A7V	28.0	3
HD102647*	2.14	2.27	1.94	1.93	A3V	11.1	3
HD128167*	4.46	3.68	3.53	3.50	F2V	15.5	3
HD155826	5.96	4.93	4.64	4.58	G0V	30.7	5
HD218396	5.99	5.46	5.30	5.28	A5V	39.9	5
Gl229B	22	15.6	15.7	15.8	T	5.78	6

* - Targets requiring a Mode-1 real time acquisition. † - Stars observed in program 7835, with G1229B as a calibrator. Values of V, Spectral Type, and Distance were obtained using SIMBAD, CDS Strasbourg, France. JHK magnitudes are from the literature, or as for HD68456 and HD84117, from the 2MASS catalogue. References: (1) Alonso, Arribas, & Martinez-Roger 1994; (2) Carter 1990; (3) Aumann & Probst 1991; (4) Backman, D. 1998, private communication; (5) Sylvester *et al.* 1996; (6) Matthews *et al.* 1996.

The NICMOS filter central wavelengths and bandpasses are given in Table 2.

Table 2. NICMOS Camera 2 Filters and Bandpasses Used.

Filter	Central Wavelength (microns)	Bandpass (microns)
F165M	1.65	1.55-1.75
F171M	1.72	1.68-1.75
F180M	1.80	1.765-1.835
F204M	2.04	1.9-2.09
F207M	2.08	2.0-2.15

3. Data Reduction

The coronagraphic data were retrieved from the HST Archive and recalibrated using the latest version of the STScI NICMOS calibration software **"calnica"**. Standard calibration reference files, except for darks, were used for calibration. For dark current removal, temperature-dependent darks were created using the STScI NICMOS web tool and the measured NIC2 focal plane temperature at the time of observation. It must be noted that versions 2.0 and later of **calnica** includes a calibration step, known as **"zsigcor"**, which attempts to correct NICMOS MULTIACCUM mode data for signal detected in the initial "zeroth" read of a multiply sampled MULTIACCUM on-target integration. This correction was applied to the data and is important for coronagraphic data because observations of bright sources will often contain detectable signal in the 0.203-second readout time of the "zeroth" read. **calnica** version 4.0 and later include a temperature-dependent dark correction.

IRAF/STSDAS tools were used to remove ghost artifacts, anomalous pixels, and cosmic ray hits. The Image Display Paradigm 3 (IDP3) software developed by the NICMOS IDT was used to scale, align, and subtract images (Lytle *et al.* 1999). Removal of any residual DC bias in the images was performed by measuring the median background near the targets in 11 x 11 pixel boxes followed by subtraction of a constant from the images.

The brown dwarf Gl229B was observed directly with NIC2 (0.072"/pixel) as a calibration target. The telescope was slewed to move the primary star Gl229A out of the NIC2 field-of-view (FOV) leaving the scattered light from two diffraction spikes and wings of the PSF in the imaging field along with the brown dwarf. The primary star was modeled with the “Tiny Tim” model PSF (Krist and Hook 1997) for each filter image. After alignment and scaling, the respective model was subtracted from the appropriate filter image to remove the two diffraction spikes and wings of the PSF. The resulting images retained a slightly higher noise than expected which we attribute to light scatter from the edges of the Lyot stop and aperture.

4. The Suspected Brown Dwarfs

Broad water and methane absorption bands dominate the infrared spectra of the late M, L, and T dwarfs. The water absorption band increases in strength from spectral type M through mid-type L dwarfs (Martin *et al.* 1999, Reid *et al.* 2001), where it saturates. From the mid-L to the late T-types, the methane absorption becomes more and more pronounced, until it also saturates. Methane-rich objects will be fainter when observed with the F165M and F171M filters than with the F207M filter. We thus exploited the NIC2 medium band filter set in our program to image our targets in a novel fashion: in the 1.6 μm methane absorption band (filters

F165M and F171M), the 1.85 μm water absorption band (filter F180M), and the continuum (filter F207M). This program would have been highly difficult to perform from the ground at the sensitivities we achieved, ~ 18th magnitude at H and K, due to the abundance of water and methane in the intervening terrestrial atmosphere.

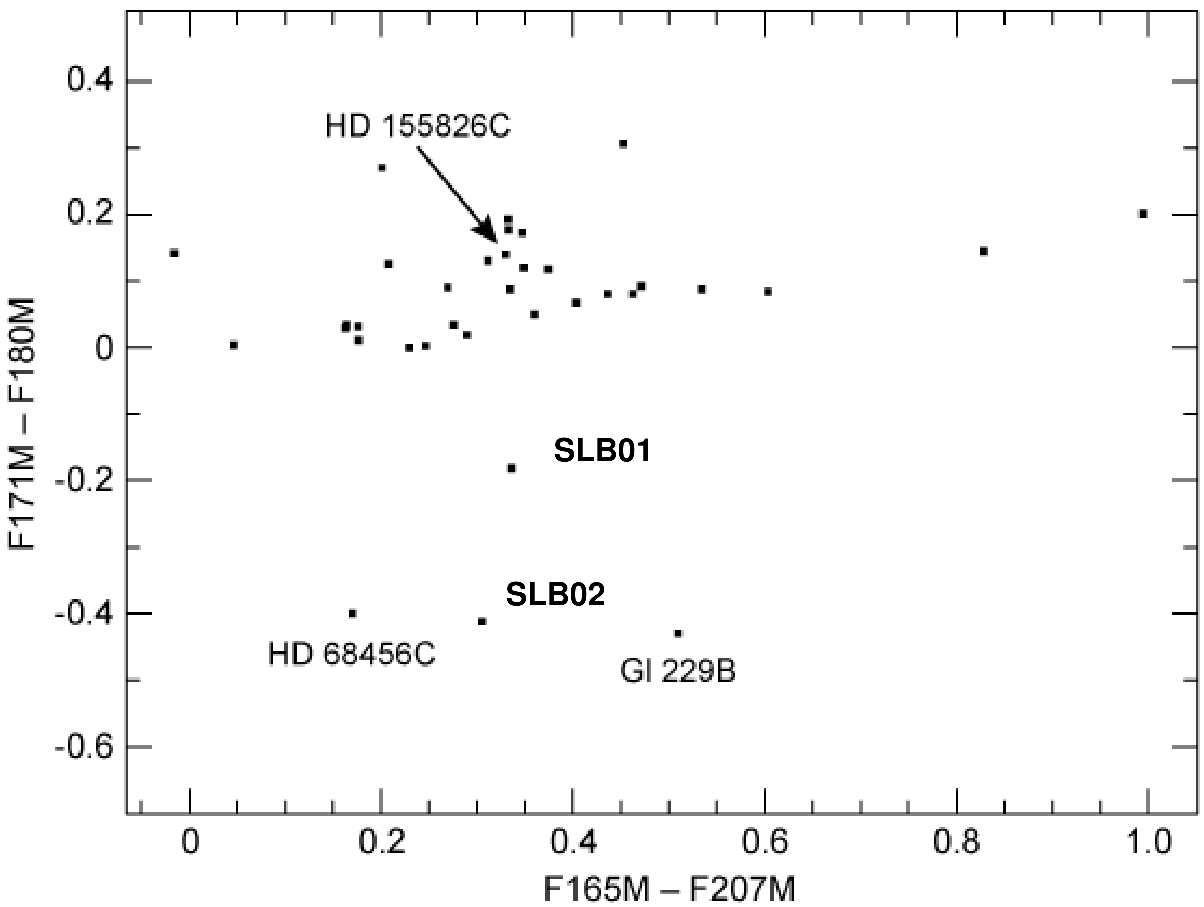

Figure 1 - F165M-F207M (1.72-1.8 μm) versus F171M-F180M (1.65-2.08 μm) color-color diagram. The three T dwarfs are found at large negative values of F171M-F180M. HD 155826C, a faint object found within 4" of HD155826, is associated with the Main Sequence objects.

Using photometry of the field stars in the HD155826 images and the candidate close faint companions to HD68456 and HD155826, we have created a (F165M-F207M versus F171M-F180M) color-color diagram (Figure 1). The former color is a measure of the effective temperature, with hotter objects at more negative color values, while the latter is a measure of the water absorption feature strength, with increasing water absorption at more negative values. We find a continuum of main sequence objects with Rayleigh-Jeans colors at F171M-F180M >

0, and four outlying objects exhibiting strong water and methane absorption. The three objects at F171M-F180M = -0.4 are, from left to right in Figure 1, the T dwarfs HD68456C, SLB02, and our brown dwarf calibrator Gl229B**.** The fourth object, at F171M-F180M = -0.18, is the L dwarf SLB01.

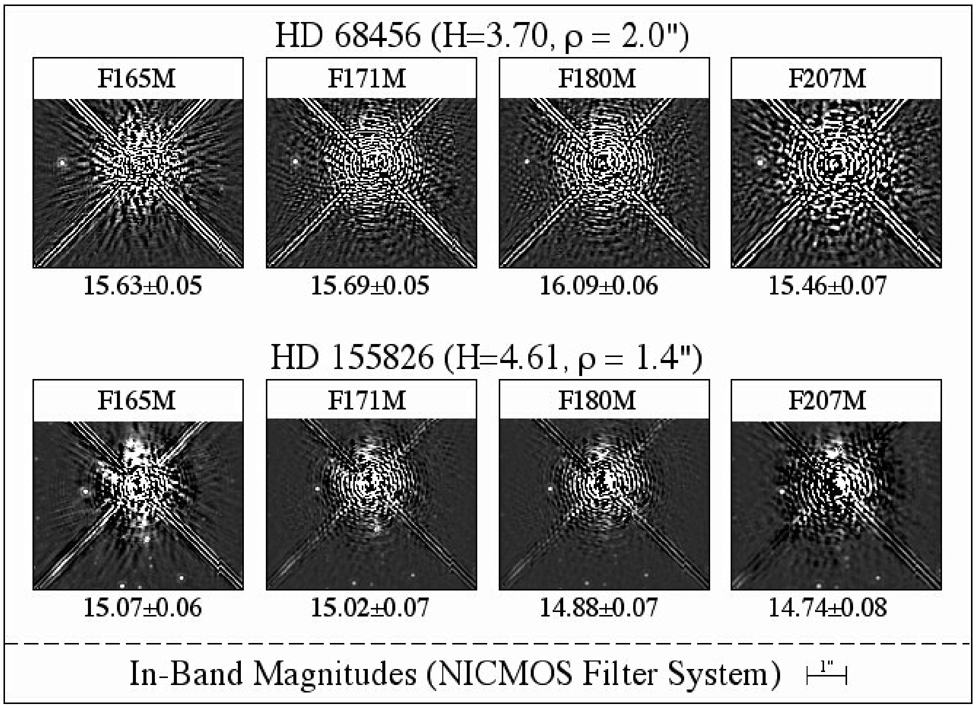

Figure 2 – NICMOS PSF-subtracted images of HD68456 and HD155826 in the four observing filter bandpasses. HD68456C is visible to the left of the star, within 4", and HD155826D and E are found below the star, at 10" and 12" separation. HD155826C is the object within 3" of the primary.

PSF subtracted images of HD68456 and HD155826 are presented in Figure 2, and the NICMOS photometry for the objects in Table 3. HD68456 was observed by HST/NICMOS on September 12, 1998 and HD155826 on September 3, 1998. Gl229b was observed on October 15, 1998. The suspected T dwarf HD68456C is the white dot to the center left of the PSF residuals in the top frames. SLB01 and SLB02 are not shown. HD155826C (F165M=15.07±0.06) is the small white dot to the left of the PSF residuals in the bottom frames. The NICMOS photometry for HD155826C, however, indicates that it is a main sequence star, most probably an M dwarf. While potentially an interesting faint low mass star and possible companion to HD155826, it is clearly not a brown dwarf, and we will use it only for comparison purposes in the remainder of this paper.

Table 3. NICMOS photometry of Brown Dwarfs HD68456C, SLB01, SLB02, and Gl229B.

Target	Filter	Magnitude	Separation (arcsec)	PA (degrees)
HD68456C	F165M	15.63 ± 0.05	4.00" (122.7 AU)	93.19
	F171M	15.69 ± 0.05		
	F180M	16.09 ± 0.06		
	F207M	15.46 ± 0.07		
SLB01	F165M	17.20 ± 0.06	12.24"	29.40
	F171M	17.14 ± 0.07		
	F180M	17.32 ± 0.07		
	F207M	16.86 ± 0.08		
SLB02	F165M	17.63 ± 0.06	10.95"	61.22
	F171M	17.52 ± 0.07		
	F180M	17.93 ± 0.07		
	F207M	17.32 ± 0.08		
Gl229B	F165M	14.34 ± 0.02	7.78" (44.9 AU)	163
	F171M	15.15 ± 0.06		
	F180M	15.58 ± 0.08		
	F204M	14.02 ± 0.03		
	F207M	13.83 ± 0.02		

N.B.: HD68456C and HD155826C photometry extracted with the Image Display Paradigm 3 (IDP3) software via PSF fitting. SLB01, SLB02, and Gl229B photometry extracted using IRAF via aperture photometry.

As a final step in our classification, we have obtained representative spectra of M, L, and T dwarfs from Leggett *et al.* (2002, 2003). Our Gl229b photometry closely matches the Leggett T6 spectrum, and the published Gl229b spectrum of Geballe *et al.* (1996), giving us confidence in our classification of these objects.

Scaling the NICMOS photometry to the representative spectra, we find matches for the brown dwarf objects as follows: L4 for SLB01; T0 to T1 for HD68456C; T3.5 to 4.5 for SLB02; and T6 to T7 for Gl229b (a known T6) (Figure 3). The spectrophotometry for the objects HD68456C, SLB01, and SLB02 clearly do not match that of Gl229b, but are close to earlier type brown dwarf spectra with shallower water and methane absorptions. The four objects represent three different stages of post deuterium-burning brown dwarf evolution, with SLB01 the youngest and warmest, and Gl229b the oldest and coolest.

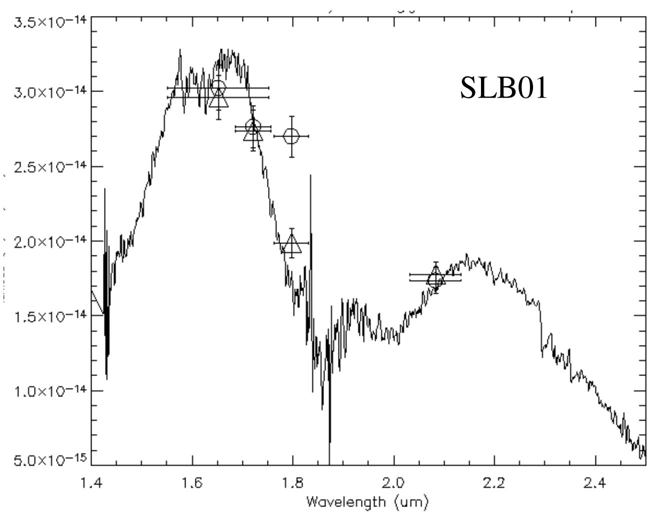

Figure 3a

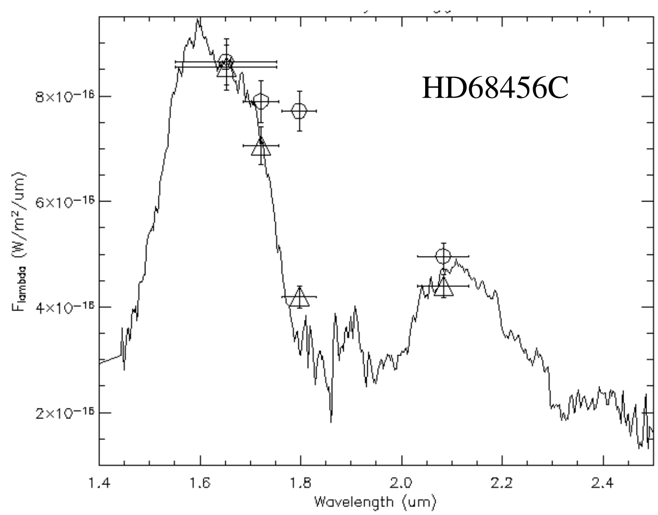

Figure 3b

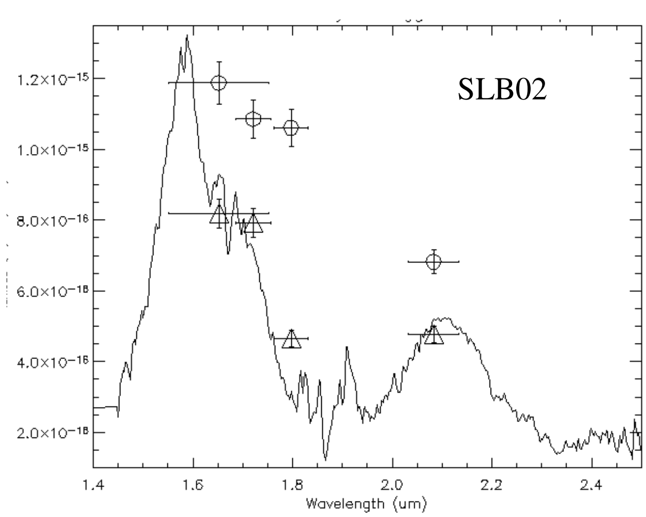

Figure 3c

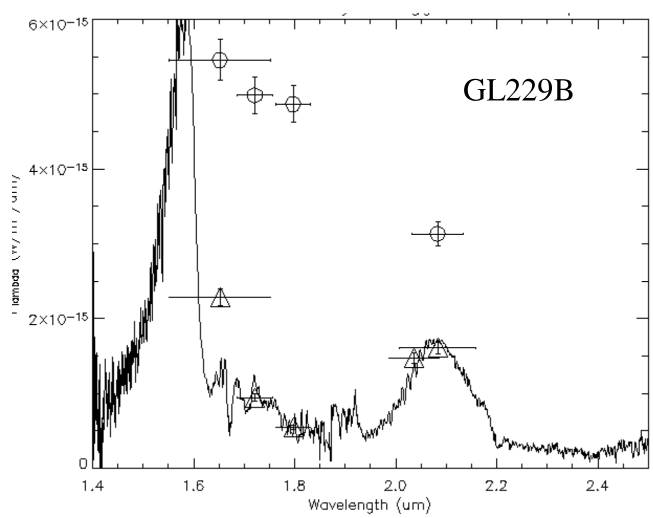

Figure 3d

Figure 3 – Comparison of NICMOS photometry and literature brown dwarf spectra. a) SLB01 photometry, in units of F_{lambda} (W m^{-2} um^{-1}), versus a representative L4 dwarf spectrum from Leggett *et al.* **b)** HD68456C photometry versus representative T1 dwarf spectrum from Leggett *et al.* **c)** SLB02 photometry versus representative T3 dwarf spectrum from Leggett *et al.* **d)** Gl229B photometry versus representative T6 dwarf spectrum from Leggett *et al.* In each plot the NICMOS photometry for HD155826C, a possible M dwarf, has been included for comparison (circles).

5. Discussion

The observed photometric brightness (Table 3) is high for brown dwarf objects at the distance of the systems (HD68456 at 21 pc and HD155826 at 31 pc), judging by scaling Gl229b (5.77 pc distance) to these distances. We are somewhat limited, however, in our understanding of the association of the brown dwarfs with the HD68456 and HD155826 systems without follow-up observations. Both systems exhibit high proper motion so that the association of the new objects with the bright primaries can be easily tested using milli-arcsecond astrometry.

5.1 The Parent Systems.

The HD155826 system has nearly identical magnitude G0V components, A and B (Finsen 1960). Inspection of the HD155826 NIC2 ACQ ACCUM F187N filter acquisition image showed that the two stars were separated by ~0.17 +/- 0.01" with a position angle of PA = 193.9 +/- 3.3^{o}. Originally thought to be a leading candidate for circumstellar material due to a large 12-60 um IRAS color (Aumann 1985). Lisse *et al.* (2002) have reported the detection of a new bright far-IR source, LSF1, ~7" southwest (P.A. 217 ^{o}) of HD155826. As LSF2000 would have been confused with HD155826 in the large IRAS beam, and can totally account for the excess IRAS long-wavelength emission from HD155826, there is no reason now to suspect HD155826 of excess circumstellar dust or ongoing planetary formation. The object HD155826C found in this study may be an additional trinary companion object. While the trinary nature of the system argues for a possible association of the new L and T dwarfs SLB01 and SLB02, the crowded low galactic latitude field and large angular separations of 10" and 12" argue for a serendipitous alignment of the objects.

HD68456A, an F5V star, has a 0.2 M_{solar} mass companion with a period P = 8993 +/- 0.4 days (Murdock and Hearnshaw 1993). This companion, HD68456B, is most probably an M5 dwarf. No positive determination using NICMOS acquisition images could be made for the components of HD68456; i.e., they appear as a spectroscopic binary in our images. This system is not in a crowded field, and the 4" distance of HD68456C from the primaries is small enough for the objects to be gravitationally bound. If HD68456C is indeed associated with the

F5V star, this would make it one of only 3 brown dwarfs known to be associated with an early-type main sequence star.

5.2 Other Brown Dwarf Companions. There are 30 known brown dwarf systems in which members form a close binary, triple, or quartet system (Table 4). The majority of these multiple systems (19) are composed of a very low mass type M (primaries later than M8), L, and T dwarfs. Only about dozen of these systems are stellar binaries with the primary earlier than M8. HD68456C would increase the number of stellar binaries by one, while representing the first brown dwarf found about an F-star. The number of known very low mass binaries is biased towards detection since there has been an effort to search for binaries when a field brown dwarf is discovered. On the other hand, the number of brown dwarf containing stellar binaries with primaries earlier than M8 is biased against detection in most surveys, because of the difficulty of detecting the faint dwarf companion against the bright primary. In the survey presented here, the selection effects are greatly reduced by the utilization of the HST coronagraph.

Table 4. Characteristics of Known Brown Dwarf Companions to Date.

Brown Dwarf	Angular. Separation	Projected Separation	Temperature	Mass	Primary Type/System Age	Ref.
	(")	(AU)	(K)	(M_{JUP})		
PPL 15AB unresolved	0.002	0.3	~ 2300	60, 70	M6+M7/115 Myr	1
J05185995-2828372	unresolved	-	-	-	L6+T4/ -	2
V471 TauC unresolved	0.02-0.26	0.02-11.2	1370	<0.07	K0+?/625Myr	3
HD137510B unresolved	0.044	1.85	-	26	G0IV+?/3.4 Gyr	4
J15344984-2952274AB	0.065	1.0	1100	65+65	T5.5+T5.5/ 5 Gyr	5
J0920122+351742AB	0.070	3.2	-	68	L6.5+L7.0/-	6
HD97334BC	0.070	1.5	-	-	G0V+L4.5+L5.5/-	7
J0920122+351742AB	0.07	1.6	-	68+68	L6.5+L6.5/ -	8
GJ569BC	0.08	0.90	-	69+59	M8.5+M9/300 Myr	9
GJ 1001BC	0.087	0.8-1.3	1750	0.06-0.75	L4.5+L4.5/10 Gyr	10
Gl569B (triple system)	0.1	<0.1	1985	~50	M8.0-9.5/300 Myr	11
J07464256+2000321AB	0.12-0.22	1.5-2.7	1900-2000	85+66	L0.0+L1.5/ -	8,12
HD130948BC	0.134	2.4	1950	40-70	G1V+L4+L4/ <0.8 Gyr	13
J1426316+155701AB	0.152	3.6	1900	83+75	M8.5+L1/0.8 Gyr	14
J2140293+162518AB	0.155	3.7	-	87+75	M8.5+L03.0 Gyr	15
J0850359+105716AB	0.16	4.4	-	50+40	L6+t?/ -	8

J2206228–204705AB	0.168	4.1	-	90+88	M8+M8.5/3.9 Gyr	15
LHS2397aAB	0.21	3.0	2630+1470	90+68	M8+L3/ 7.2 Gyr	16
DENIS 1228-1547AB	0.27	4.9	<1700	60+60	L5+L5/ -	17
J12255432-2739466AB	0.282	3.17	1000+800	40+60	T6+T8/ 5 yr	5
J1146+2230AB	0.29	7.6	-	60+60	L3+L3/ -	8
GJ 1245AC	0.293	1.33	-	74	M5.5V+?/ -	18
DENIS 0205-1159AB	0.51	9.2	-	50+50	L7+L7/ -	17
J2331016–040618AB	0.573	14.4	-	91+62	M8+L3/5.0 Gyr	15
HD209100BC	0.732	2.6	1276+854	47+28	K4.5V+T1+T6/1.3 Gyr	19
HD190406B	0.79	14	1510-1850	55-78	G1V+L4.5/<3 Gyr	20
Gl86B	1.7	40	1300	40-70	K1V+?/ -	21
TWA 5B	2	100	2600	20	M1.5V+M8/10 Myr	22
Gl229B	7.7	40	960	20 - 50	M2V+T6/<5 Gyr	23
GD 165AB	~4	120	1900	72 - 75	WD+M?/<5.5 Gyr	24
HR7329B	~4	190	2600	20 - 50	A0V+M7-8/<30 Myr	25
HD68456C	~4	122.7	-	-	F5V+T1/ -	26

References: (1) Basri and Martin 1999, (2) Cruz et al. 2004, (3) Guinan and Ribas 2001, (4) Endl et al. 2004, (5) Burgasser et al. 2003, (6) Reid et al. 2001a, (7) Kirkpatrick et al. 2000, (8) Reid et al. 2001b, (9) Lane et al. 2001, (10) Golimowski et al. 2004, (11) Kenworthy et al. 2001, (12) Bouy et al. 2004, (13) Goto et al. 2002, Potter et al. 2002, (14) Close et al. 2002a, (15) Colse et al. 2002b, (16) Freed et al. 2003, (17) Koerner et al. 1999, (18) Henry et al. 1999, (19) McCaughrean et al. 2004, (20) Liu et al. 2002, (21) Els et al. 2001, (22) Lowrance, P.J. et al. 1999, (23) Nakajima et al. 1995, (24) Kirkpatrick et al. 1999b, (25) Lowrance et al. 2000, (26) this paper.

Current accretion and fragmentation models (Reipurth & Clarke 2001; Bate et al. 2002) predict the ejection of low mass cores (brown dwarfs and possibly giant planets) from accretion regions and thus explain the < 5% brown dwarf binary fraction in mature stellar systems. Demonstrating an association between the young T1 dwarf HD68456C and HD68456AB is thus highly desirable to improve the statistics for brown dwarf systems. Once association is demonstrated, it becomes a good target for high angular resolution imaging photometry or coronographic spectroscopy in the near-infrared, which will provide a measure of the effective surface temperature. Once established as a brown dwarf companion, HD68456C should provide additional strong data for improving models of brown dwarf structure and evolution, and quite possibly help address the question of brown dwarf and planetary formation.

6. Summary

We report NICMOS coronagraphic results for 14 targets. No candidate companions were detected about 12 targets within ~2" to a limiting magnitude of H ~16.8 (F165M). Possible companions were discovered about HD68456 and HD155826. Photometry of two of the objects (HD68456C, SLB02) exhibit the colors of brown dwarfs due to methane and water vapor absorption similar to that observed in the photometry of Gl229B, strongly suggesting these are also ultra-cool T dwarfs, although with higher temperatures (i.e., younger) than Gl229B. A third object SLB01, in the field near HD155826, is identified as an L4 dwarf. We classify a fourth object HD155826C (sep.=2.7", PA=321^{o}) as a M dwarf. Verification of these objects as viable companions and not unassociated background objects will have to await follow-up coronagraphic or AO observations.

These discoveries highlight the success in searching for low mass companions in a discovery space easily accessible with NICMOS that is difficult, but not impossible, from the ground. We have also demonstrated the unique capability of NICMOS Camera 2 medium band filter imaging and the associated color-color diagram to identify field brown dwarfs. This capability is a powerful tool to locate, identify, and classify brown dwarfs at a much fainter infrared magnitude than previously achieved.

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