M8.5+M9.5 (Leinert et al. 2001)

M8.5+M9 (Lane et al. 2001; Zapatero Osorio et al. 2004; Simon et al. 2006)

L0+L1.5 (Bouy et al. 2004)

Main-sequence stars
Brown dwarfs

\[ M_J \text{ (mag)} \]

\[ J-K \text{ (mag)} \]

\[ >M6 \]

\[ L \]

\[ T \]

\[ \star = \text{dynamical masses} \]

parallaxes from: Dahn et al. (2002); Tinney et al. (2003); Vrba et al. (2004)
\[ M_{\text{tot}} = \frac{\sqrt[3]{d^3}}{P^2} \]

3% distance error  \rightarrow  9% mass error

\( M_{\text{tot}} = 0.1095 \pm 0.0022 \, \text{M}_\odot \)

Dupuy et al. (2009b)

Kepler
All known ultracool binaries

d \approx 30 \text{ pc} \Rightarrow \text{need} \sim 1 \text{ mas}
CFHT Parallax Program
- WIRCam 20’x20’ FOV
- Mauna Kea seeing
- queue scheduled
Differential Chromatic Refraction (DCR)

\[ \Delta \text{airmass} = 0 \]

\[ \Delta \text{airmass} > 0 \]

Dupuy & Liu (2012)
Correcting for WIRCam's Distortion

1st order

2nd order

3rd order
pixelscale of WIRCam appears constant to within $\approx 3 \times 10^{-3}$

orientation varies by $\pm 0.3^\circ$ from run to run
WIRCam Astrometric Precision

![Histogram showing the distribution of standard errors with a median of 2.8 mas.](image)
DE 2252-17
(Dupuy 2010)

$\pi = 63.2 \pm 1.6 \text{ mas}$

$\Delta \delta \text{ (mas)}$

$\Delta \alpha \cos \delta \text{ (mas)}$

$O-C$

rms $= 8.9 \text{ mas}$

$2007 \ 2008 \ 2009 \ 2010 \ 2011 \ 2012$

Epoch

$\Delta Dec \text{ (mas)}$

$\Delta RA \text{ (mas)}$
References

CFHT: Dupuy & Liu (2012)
CTIO/BDKP: Faherty et al. (2012)
USNO CCD: Dahn et al. (2002)
USNO IR: Vrba et al. (2004)
CTIOPI: Costa et al. (2005, 2006)
Palomar 1.5m: Tinney et al. (1995)
UKIRT: Marocco et al. (2010)
MDM 2.4m: Lepine et al. (2009)
ESO 2.2m: Tinney et al. (1996)
ESO 2.2m/PARSEC: Andrei et al. (2010)
ESO NTT: Tinney et al. (2003)
parallaxes
2004
2012
dynamical
masses
2004
2012

Main-sequence stars
Brown dwarfs

$M_J$ (mag) vs. $J-K$ (mag)

$>M6$

Dahn et al. (2002); Tinney et al. (2003); Vrba et al. (2004)
Dupuy & Liu (2012)
1. late-T dwarf diversity

2. J-band brightening (a.k.a. “bump”)

3. “L/T gap”

M6−L2
L2.5−L9
L9.5−T4
T4.5−T9
rms about the polynomial fit in mags

“second” parameters like metallicity, gravity have bigger effect on T dwarfs than for earlier types…

Dupuy & Liu (2012)
1. late-T dwarf diversity

2. J-band brightening (a.k.a. “bump”)

M6–L2
L2.5–L9
L9.5–T4
T4.5–T9
Dust clearing has an even bigger effect at ≈1.0 mm than at ≈1.2 mm.

Y-band “bump” ≈0.7 mag

J-band “bump” ≈0.5 mag

Dupuy & Liu (2012)
1. late-T dwarf diversity
2. J-band brightening (a.k.a. “bump”)
3. “L/T gap”
The L / T “gap”

Paucity of brown dwarfs at certain $J-H$ and $J-K$ colors, but not $H-K$.

Implies that the last phase of cloud dispersal occurs rapidly.

Dupuy & Liu (2012)
Future / Ongoing Work

Late-T and Y dwarfs
- CFHT (Liu), Magellan (Dupuy)
- VLT (Forveille)
- Young brown dwarfs
  - CFHT (Liu), Magellan (Dupuy)
  - ~10 Myr
  - ~1 Gyr
- ~1 Gyr

Long-term orbit monitoring
- CFHT, Keck AO
- m_1, m_2

Stars
- KOI-961.01
- 961.03 961.02
- Earth
- co-l: Muirhead, Johnson

Observed ≈250 targets total since 2007.
- ≈4× more than any other program targeting ultracool dwarfs
- Vast majority will be too faint to have Gaia parallaxes
Hawaii Infrared Parallax Program

Established CFHT as an excellent infrared parallax platform – no other facility produces such high-quality measurements for objects so faint. (Thank you QSO.)

Distances enable high-precision dynamical masses and absolute magnitudes providing strong tests of substellar evolution models. First discovery of substellar binaries using only astrometric perturbations.

Expanding to new samples for which CFHT is uniquely capable of strengthening the connection between brown dwarfs and exoplanets.