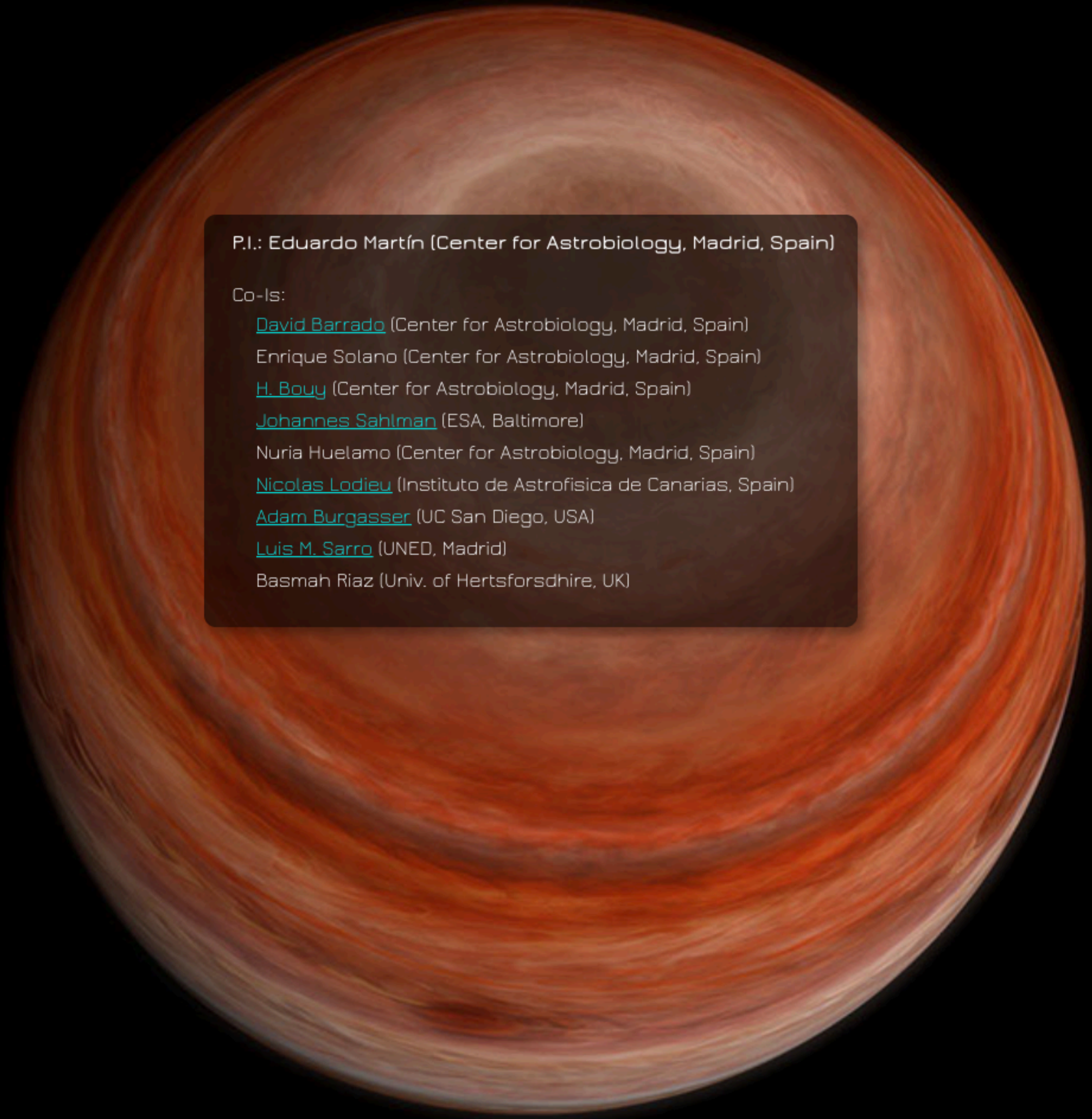
Ultracool dwarfs (UCDs) as potential calibrators for Euclid

ILS UCD team

Presentation at ESAC workshop
March 20th 2016



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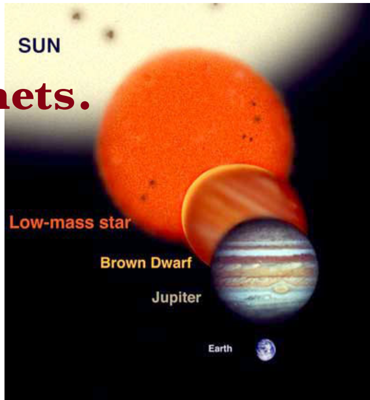
- Scientific Objectives
  - Contributions to Euclid mission
  - Characterization of known UCDs
  - Identification of new UCDs
  - Statistical studies of IMF tail
  - Binaries
  - Subdwarfs

Very low-mass stars; Brown Dwarfs; Ultra-cool Dwarfs; Isolated Planetary-Mass Objects; Free floating Planets; Gaseous Giant Planets

- **Very low-mass (VLM) star= Stars with mass between 0.2 $M_{\odot}$ and the Hydrogen burning mass limit, below 0.072 $M_{\odot}$ ~ 75 M_{jup}** (Kumar 1963, Hayashi & Nakano 1963, Burrows et al. 1997, Chabrier & Baraffe 2000).
- **Brown Dwarf (BD)= Objects unable to fuse hydrogen stably in its interior. Mass below 0.072 $M_{\odot}$ ~ 75 M_{jup}. No lithium depletion below 0.06 $M_{\odot}$** (Magazzu et al. 1993, Rebolo et al. 1996).
- Ultra-cool Dwarf (UDC) **= Objects with dust condensates in atmosphere, SpT > M6, Teff < 2500 K (**Tsuji et al. 1996).
- **Isolated Planetary-Mass Object (IPMO)= Isolated objects unable to burn deuterium. Mass below 0.012 $M_{\odot}$ ~ 13 M_{jup}**

  (Lucas & Roche 2000; Zapatero Osorio et al. 2000)
- **Free Floating Planet (FFP) = Possibly ejected giant planets.**
- **Gaseous Giant Planets (GGP) = Jupiter-like planets.**

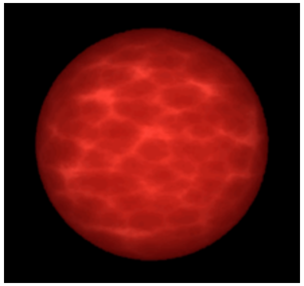
  (Boss et al. 2003)



Ultracool Dwarf types

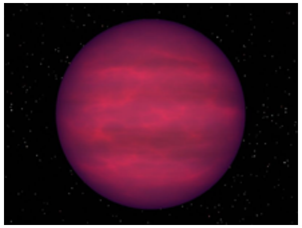
M-type: TiO and VO absorption in the optical and H_2O and CO in the infrared (Delfosse et al. 1999;

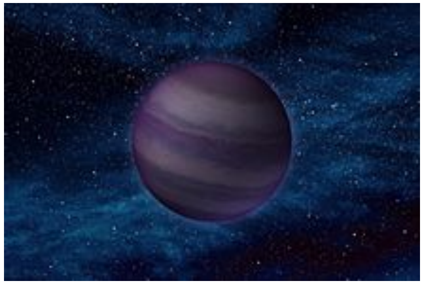
Kirkpatrick et al. 1991, 1999)



L-type: Weaker TiO and VO bands. Strong metal hydride bands (FeH, CrH, MgH, CaH) and alkali metal lines (Na I , K I , Cs I, Rb I). H_2O in infrared. Dust grain condensation (Martin et al. 1997, 1999, 2001)

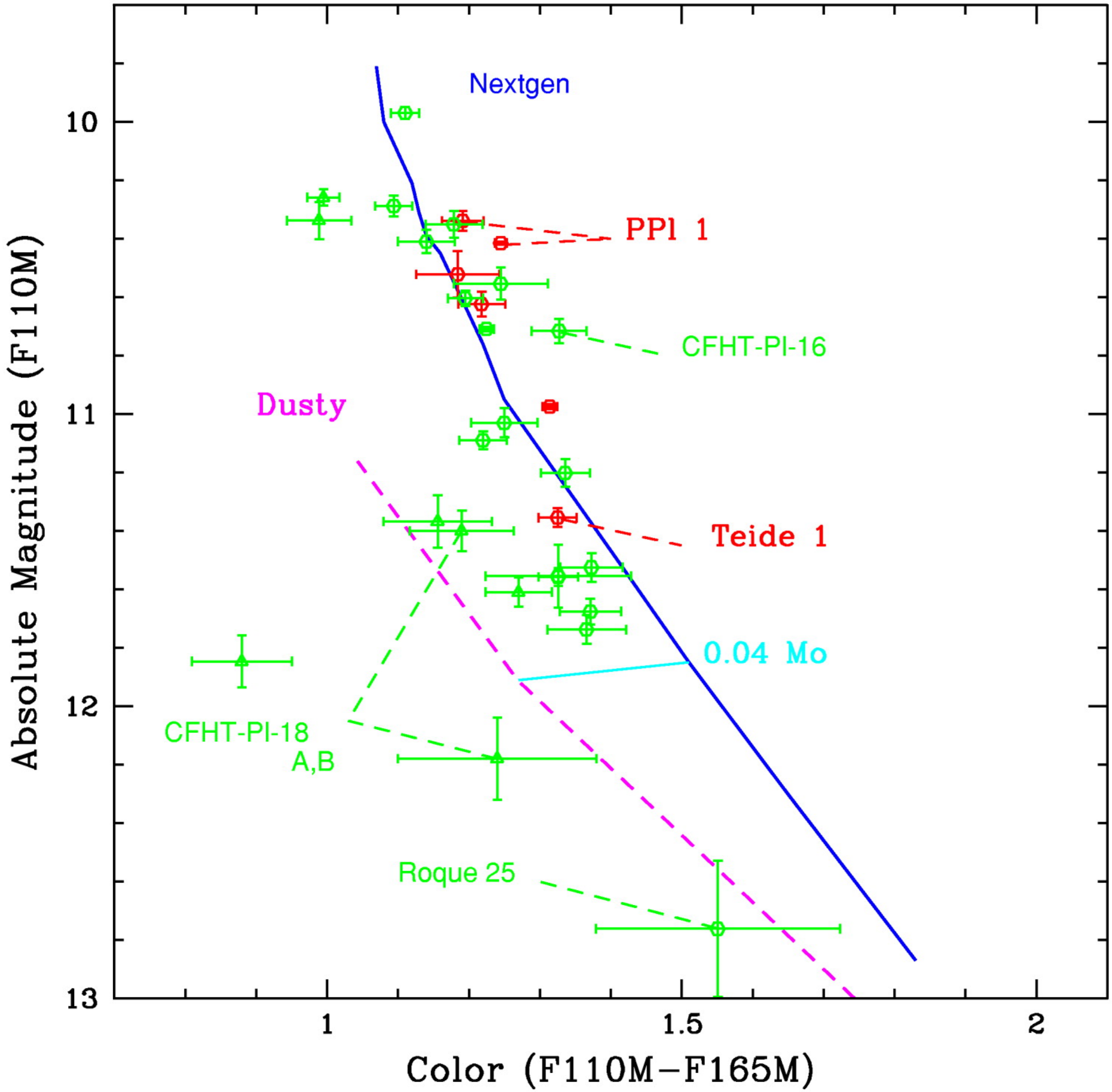
T-type: Appearance of CH_4. Alkalis and hydrures dissapear. Dust deposit below photosphere (Burgasser et al. 2000)





Y-type: Narrower flux in J- and H- band and possible bluer Y- J and redder J-K color, NH_3 in infrared (Cushing et al. 2011).

Clusters as benchmarks



Martin et al. 2000

European Organisation for Astronomical Research in the Southern Hemisphere

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APPLICATION FOR OBSERVING TIME

PERIOD: **99A**

Important Notice:

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of CoIs and the agreement to act according to the ESO policy and regulations, should observing time be granted.

1. Title

Category: **C–7**

Preparing for the Euclid mission: is the IMF in the planetary-mass regime universal?: the case of Blanco 1

2. Abstract / Total Time Requested

Total Amount of Time:

We aim at addressing the question: is the Initial Mass Function (IMF) in the planetary-mass regime universal? To shed light on that issue yet to be answered, we propose to carry out a deep ($J = 23.1$ mag; 5σ; Vega) over 3 deg^2 in Blanco 1 (age=130 Myr; d=209 pc) with VISTA/VIRCAM. Blanco 1 is a Southern open cluster with the same age but slightly further than the Pleiades, the latter being the *only* intermediate-age (50–200 Myr) and nearby (≤ 300 pc) cluster with L/T brown dwarfs with masses near the deuterium-limit confirmed spectroscopically. Our VISTA survey will represent the first epoch observations in preparation of the Euclid mission where Blanco 1 will be the only young nearby cluster part of the Wide Survey (VIS = 24.5 mag, $YJH = 24$ mag, 5σ; AB system). The multi-bands from Euclid will identify photometric candidates while our survey will optimise the selection thanks to the astrometric baseline of >3 years and the ~20 mas/yr motion of Blanco 1.

3. Run	Period	Instrument	Time	Month	Moon	Seeing	Sky	Mode	Type
A	99	VIRCAM	30.6h	any	n	1.2	CLR	s	

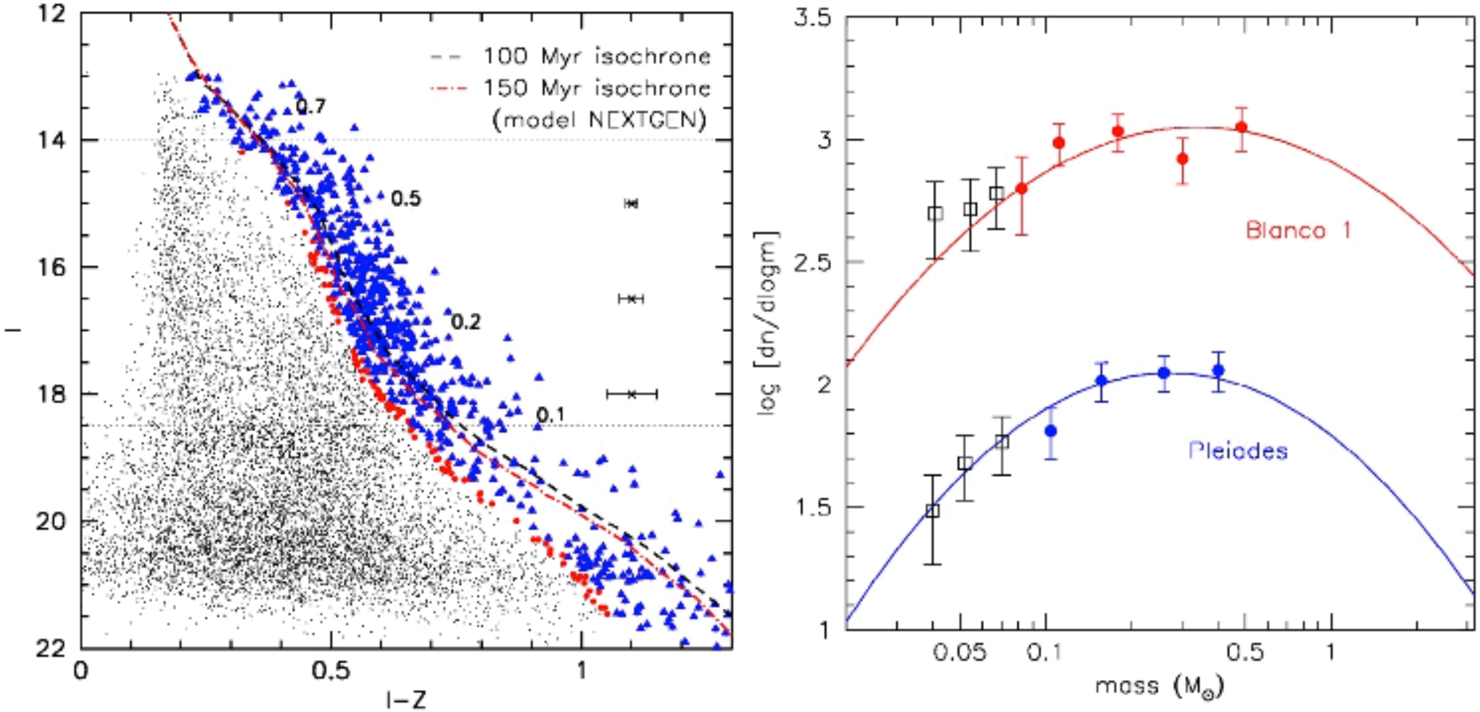
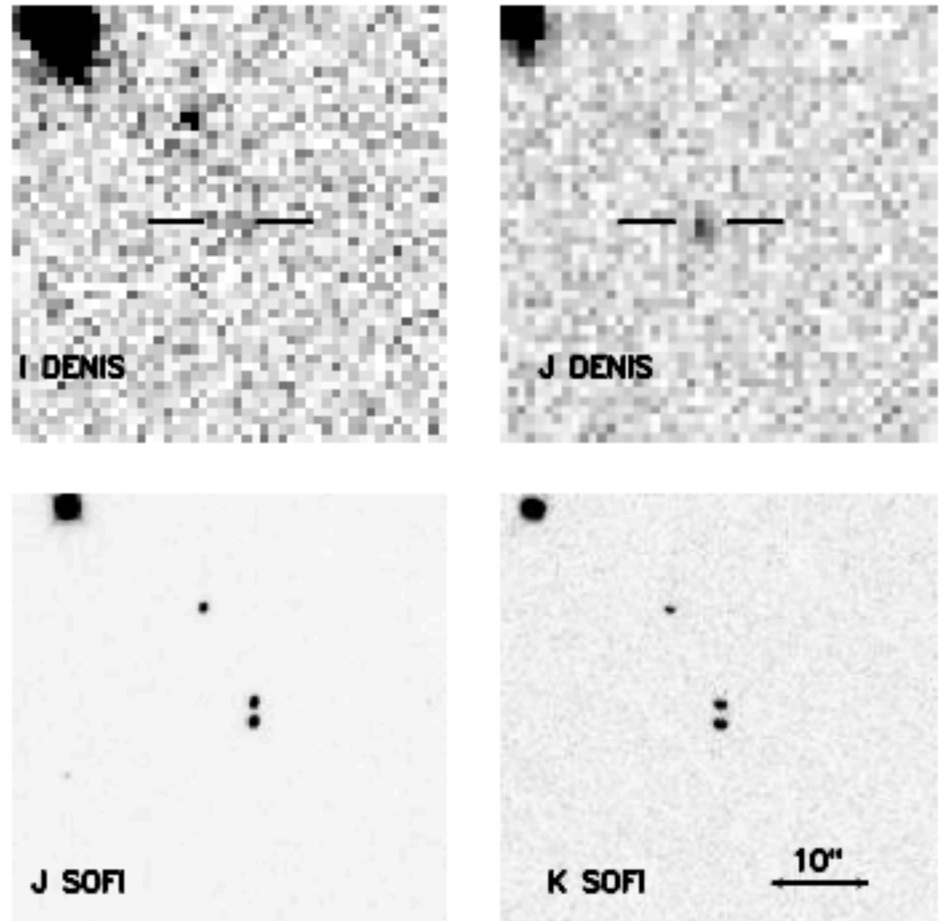


Figure 1: *Left:* $(I-Z,I)$ diagram for 2.5 deg^2 in Blanco 1 imaged with the CFHT wide-field camera. Photometric cluster member candidates are highlighted with isochrones at 100 and 150 Myr are also shown (Baraffe et al. 1998, A&A, 337, 403). *Right:* Mass function for Blanco 1 compared to the Pleiades: both mass functions are similar down to 0.03 $M_\odot$ and best fit by a log-normal function (Moraux et al. 2007, A&A, 471, 499). Our VIRCAM survey will explore the mass domain down to 0.01 $M_\odot$, which extends the shown mass functions down to planetary-mass domain.

A Pleiades-like cluster at high galactic latitude (b=-79 deg.)

UCD binaries as benchmarks



Billeres et al. 2005

Fig. 1. DENIS discovery images in *I* and *J* (top), and SOFI images demonstrating the binary status in *J* and *K* (bottom). North is up and East is left.

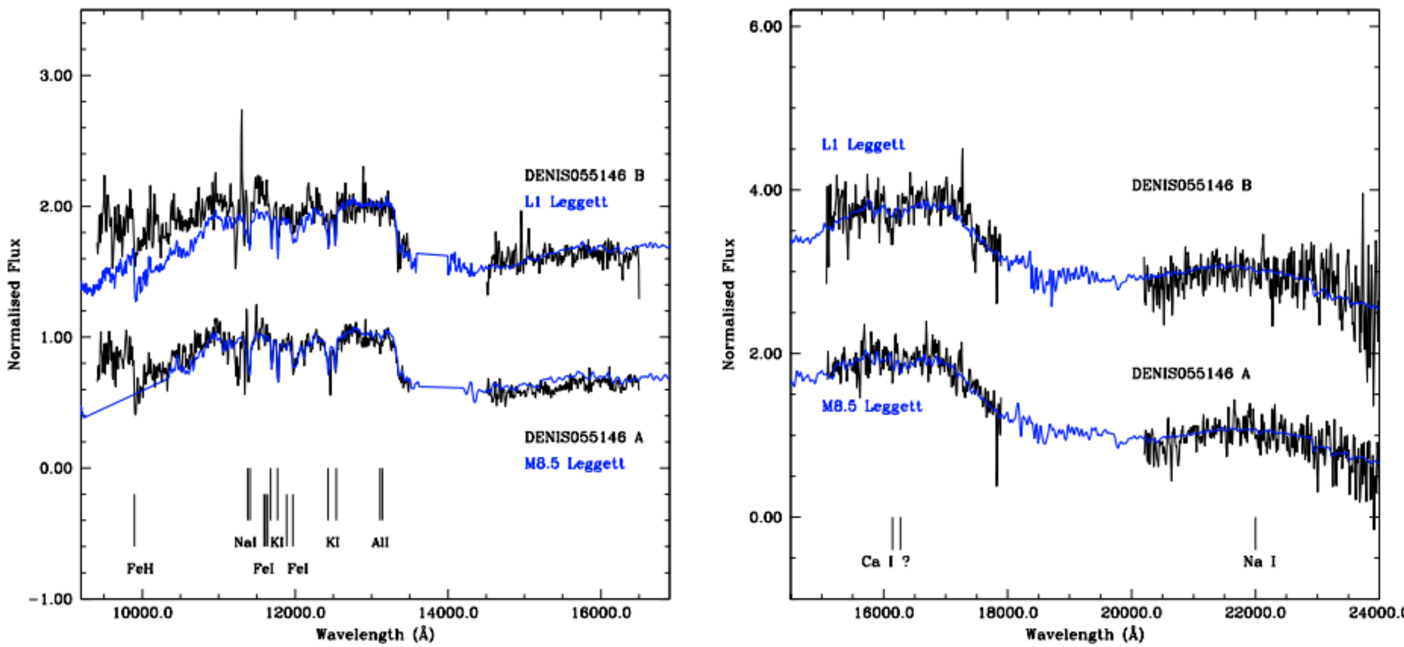


Fig. 2. Blue (left panel) and red (right panel) spectra of the two components of DENIS 0551−44. The blue and red spectra are normalized at respectively 12650 Å and 20800 Å, and vertically shifted for clarity. The blue overlays represent spectra of Leggett spectral templates, with spectral types M8.5 for the primary and L1 for the secondary (the Leggett database does not currently contain an infrared L0 spectrum). The integration ranges of the spectral indices are marked at the top, and several characteristic spectral features at the bottom.

NIR Imaging survey of 250 UCDs indicates 0.34% wide binaries (>100 AU).
Delfosse, Martin et al. (2016, in prep.)

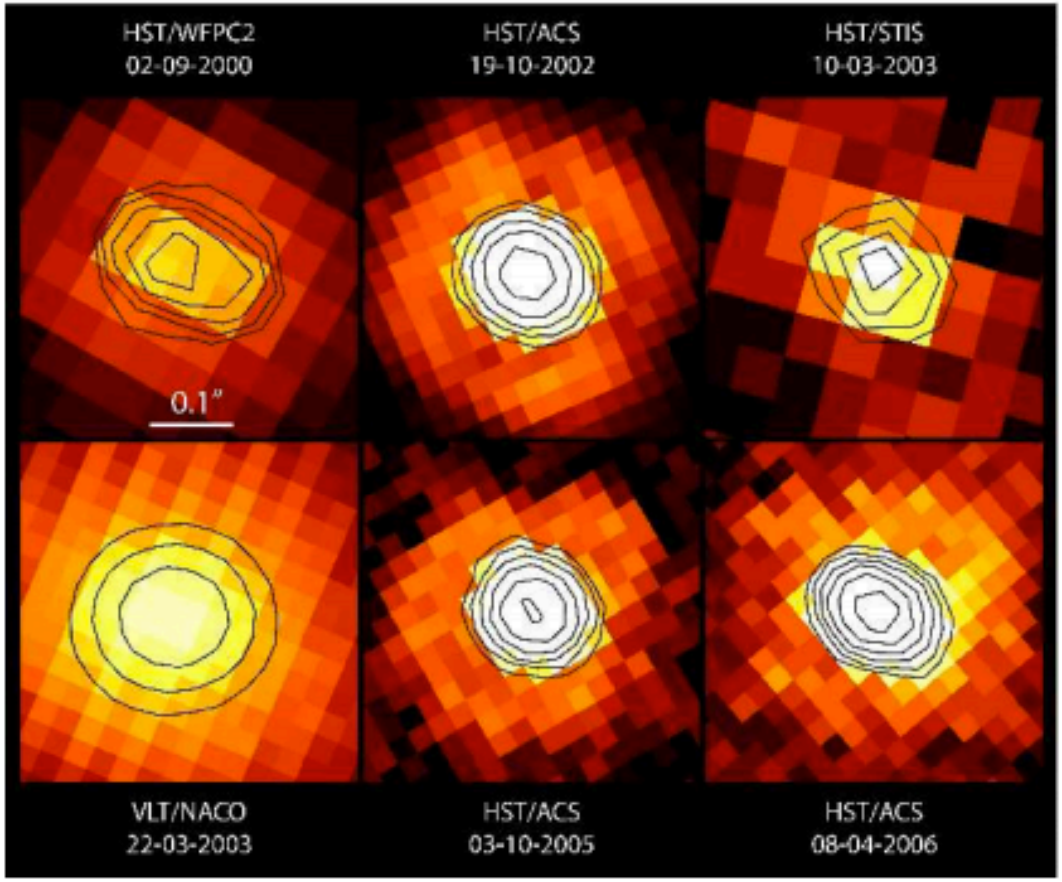


Fig. 1 Mosaic of images of 2MASSW J0920122+351742. The observation date and instrument are indicated. The scale is represented and is the same in each image stamp. Contour plots are over-plotted to illustrate the clear elongation in the first epoch image (Reid et al., 2001), the possible elongation in the last epoch image in the same direction, and the round PSF at the other epochs.

Bouy et al. 2003, 2008: Resolved UCD binary fraction 8%

Euclid photometric sensitivity to UCDs
(assuming 5 sigma J=23.1 Vega system)

SpT	MJ	N (per FOV)	D (kpc)
M5—M9	9--12	20--110	2--7
L	12--15	4--80	0.5--2
T	15--20	2--30	0.3—0.5
Y ?	>20		

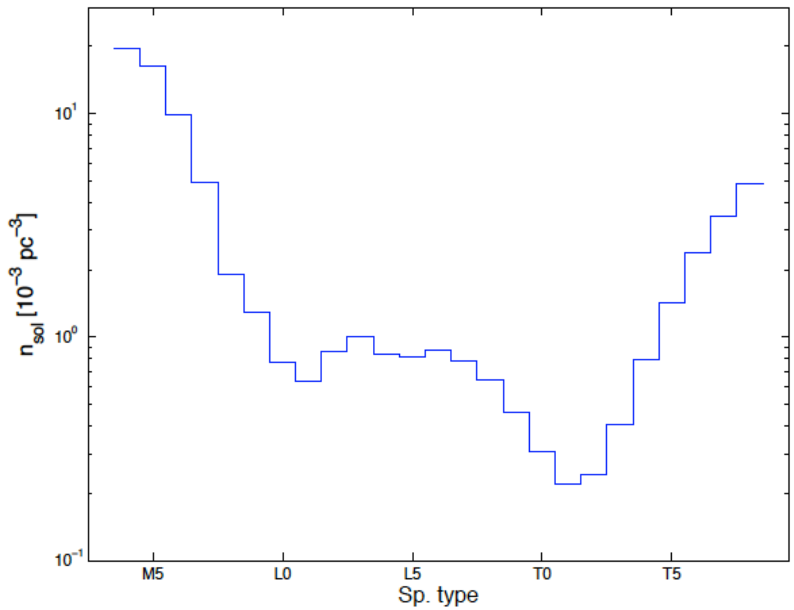
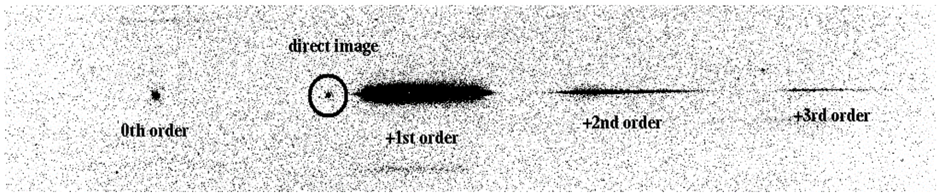
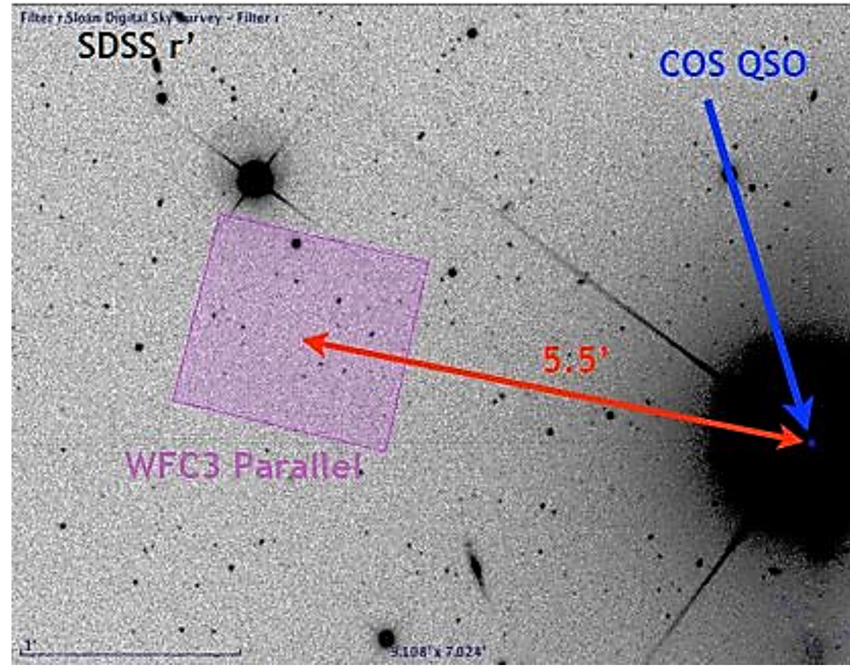


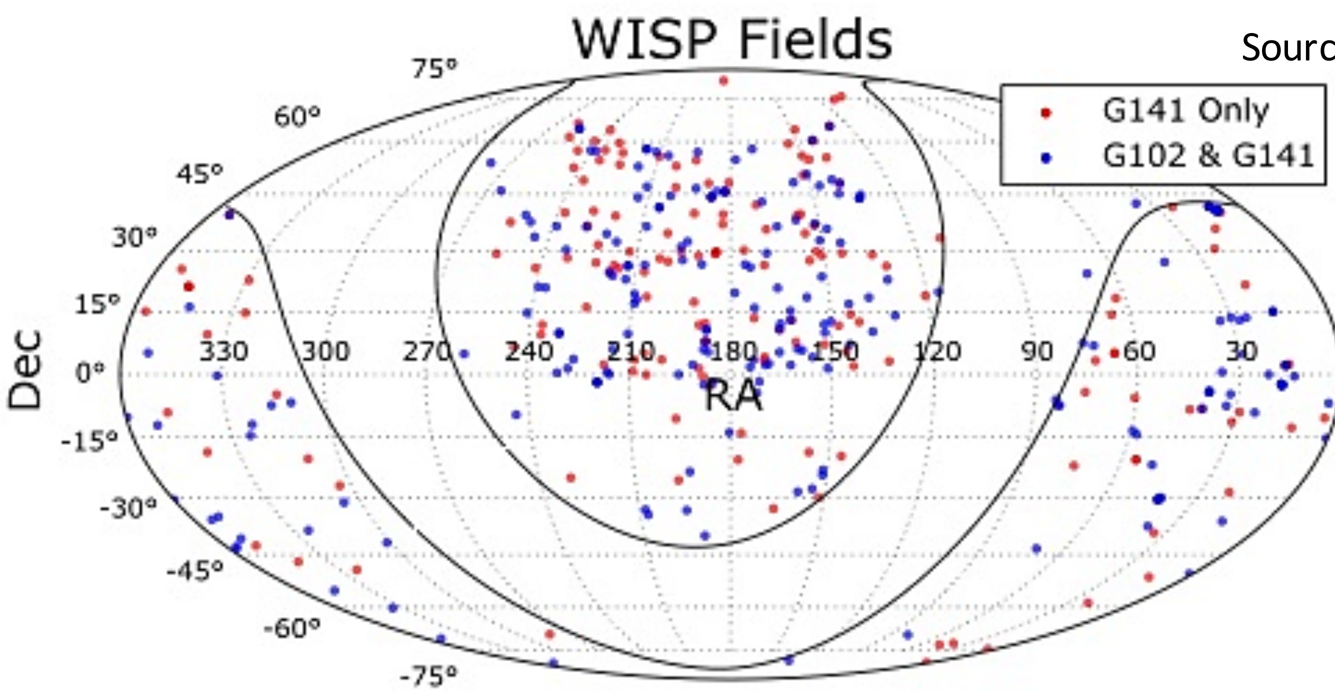
Fig. 3. Local spatial density of ultracool dwarfs as a function of spectral type from the data in Table 3.

Caballero
Burgasser
Klement
2014

WFC3 Infrared Spectroscopic Parallel (WISP) Survey



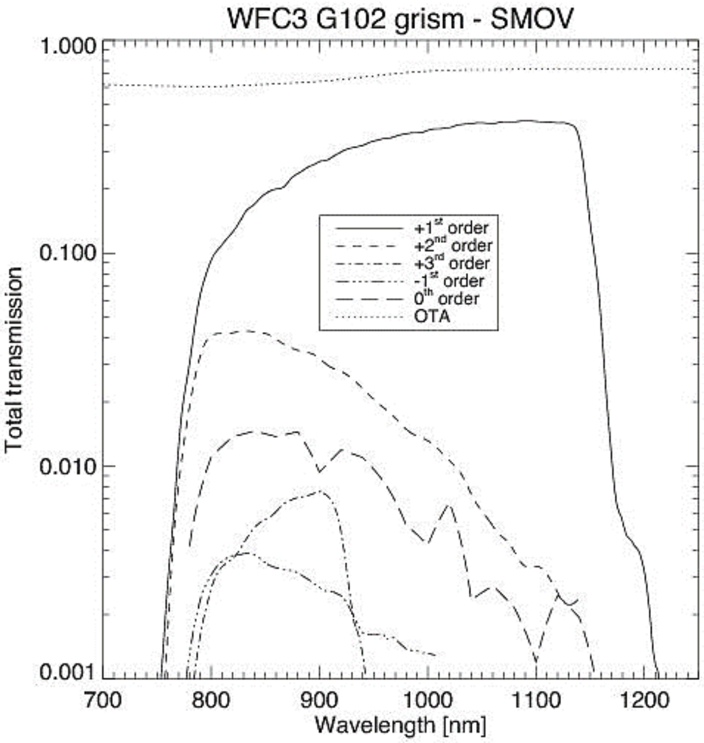


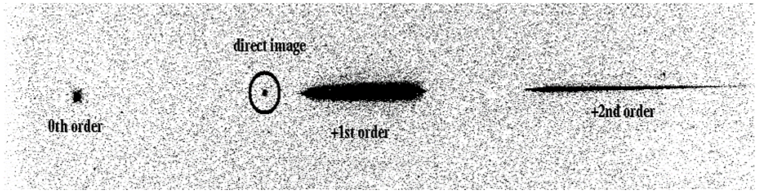


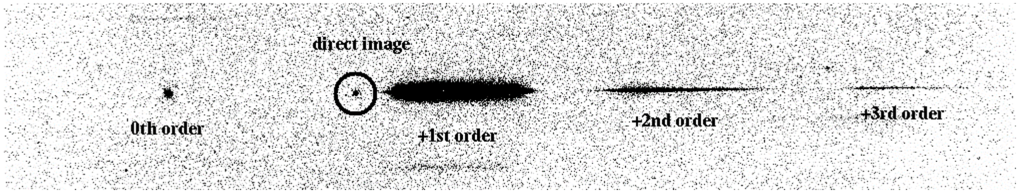
Source: WISP Survey website

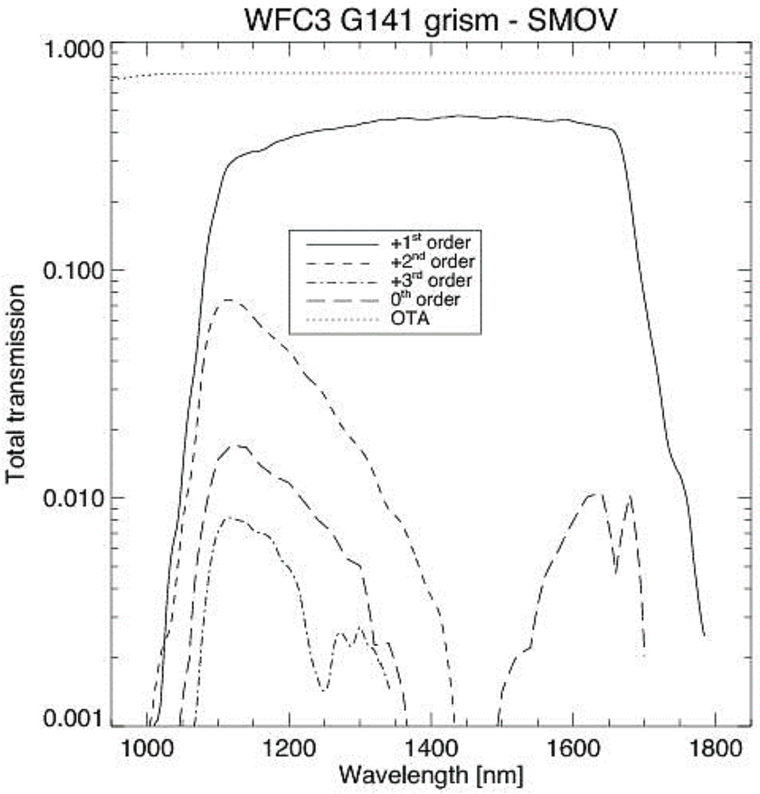
C. Aganze et al. in prep.

G102 VS G1 41 Grisms





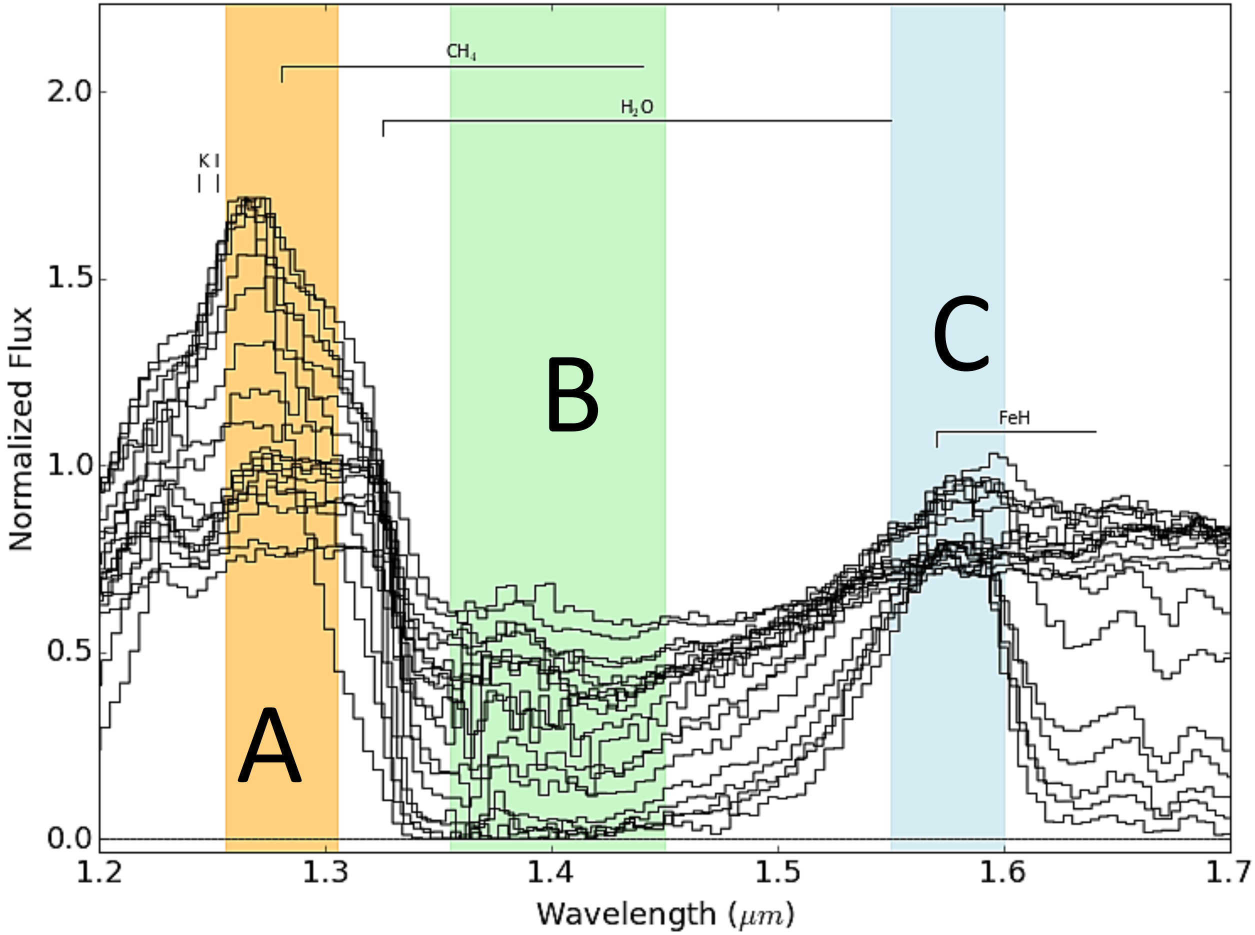




Source : STSCI Website

Method: Spectral Indices

Plot: L and T Spectral Standards from Kirkpatrick et al. 2010



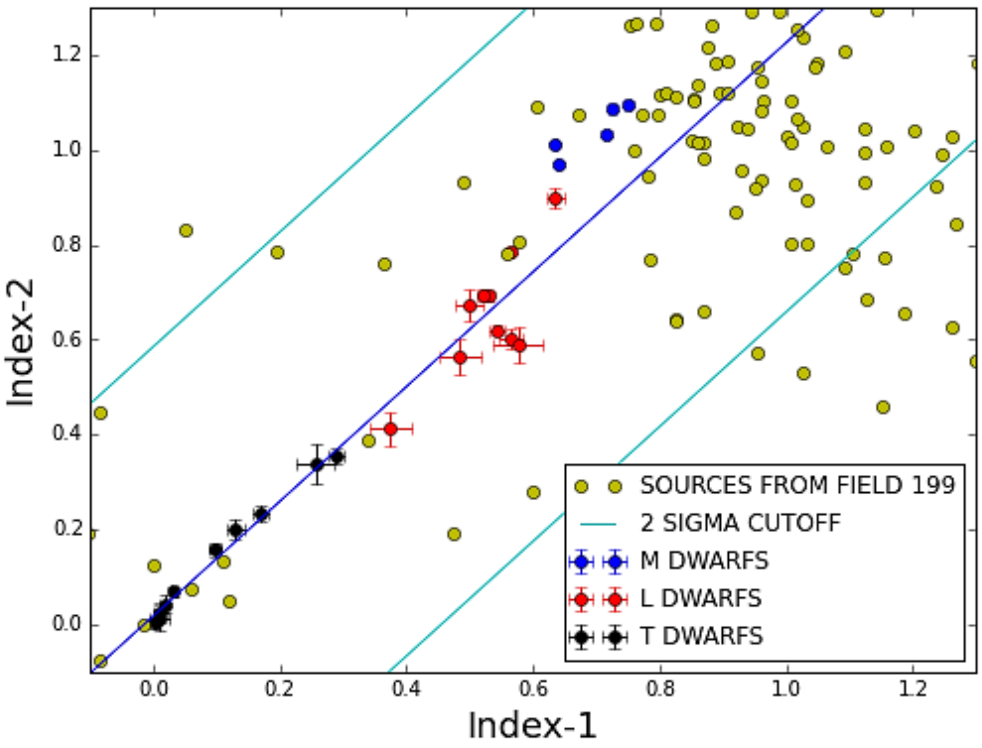
Method: Spectral indices

- Wavelengths ranges:
  - A: 1.256-1.305 microns
  - B: 1.355-1.450 microns
  - C: 1.550-1.600 microns
- Defined indices

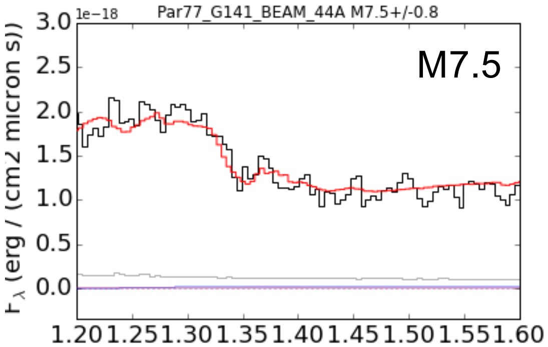
$$Index\text{-}1 = \frac{\mathbf{median}\ F_B}{\mathbf{median}\ F_A}$$

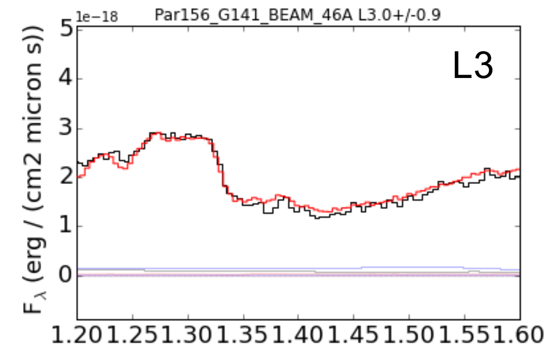
$$Index\text{-}2 = \frac{\mathbf{median}\ F_B}{\mathbf{median}\ F_C}$$

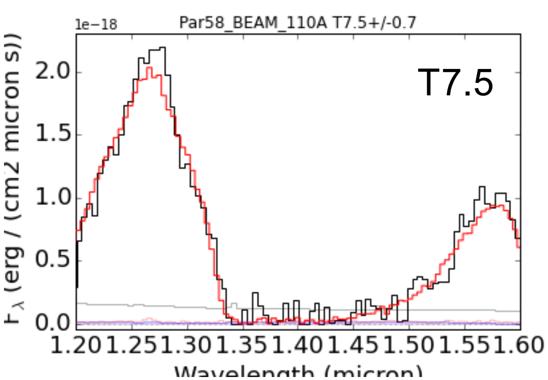
- Uncertainties are calculated by Monte Carlo

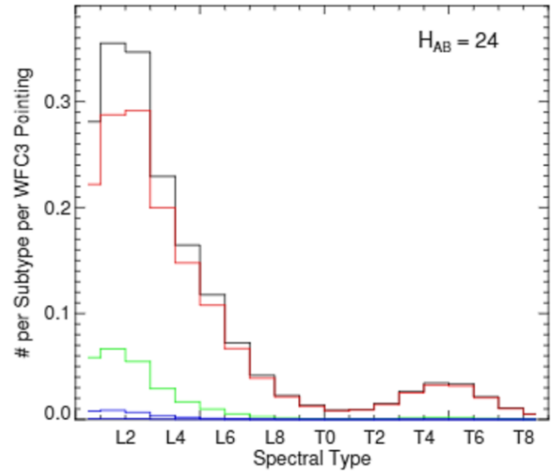


SPL Science: Deep Field Populations

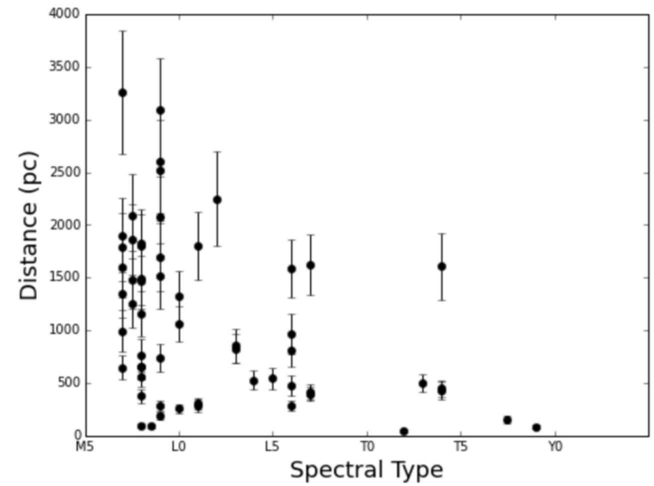








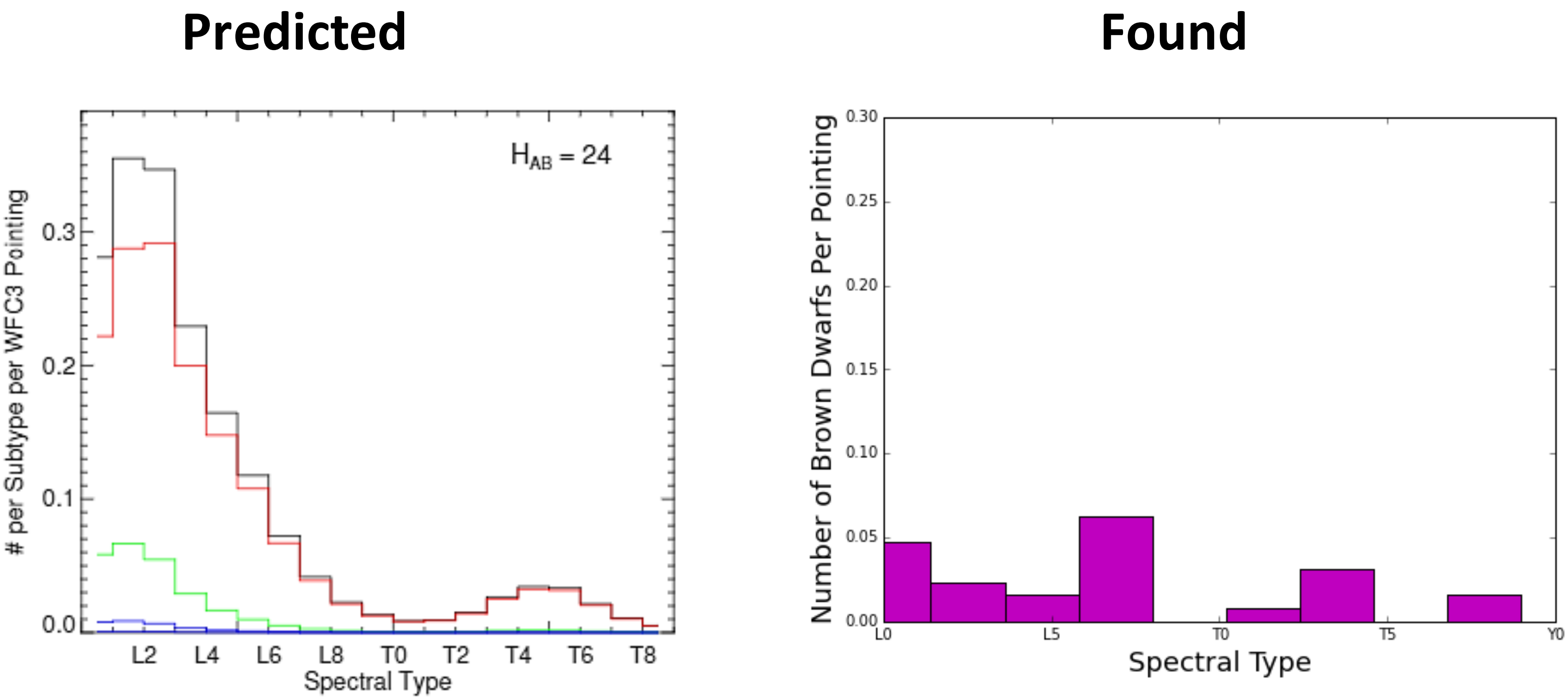
Predicted number of dwarfs per WFC3 pointing based on the population simulations of Burgasser (2004,2007)



Spectral types and distance estimates of MLT dwarfs found in WISPs survey

SPL Templates are being used to identify and classify distant brown dwarfs (up to 3-4 kpc) in the WISPs and HST-3D WFC3 parallel fields (Masters et al. 2012; Aganze et al. in prep.)

Number Density Per Pointing (WFC3 vs NISP)



NISP/WFC3 FOV ratio = 430 ➔ 100 late M dwarfs + 60 L dwarfs + 26 T dwarfs per Euclid pointing

Relative photometric precision

18 M5 – L1 dwarfs

Kepler monitoring

11 < 3%

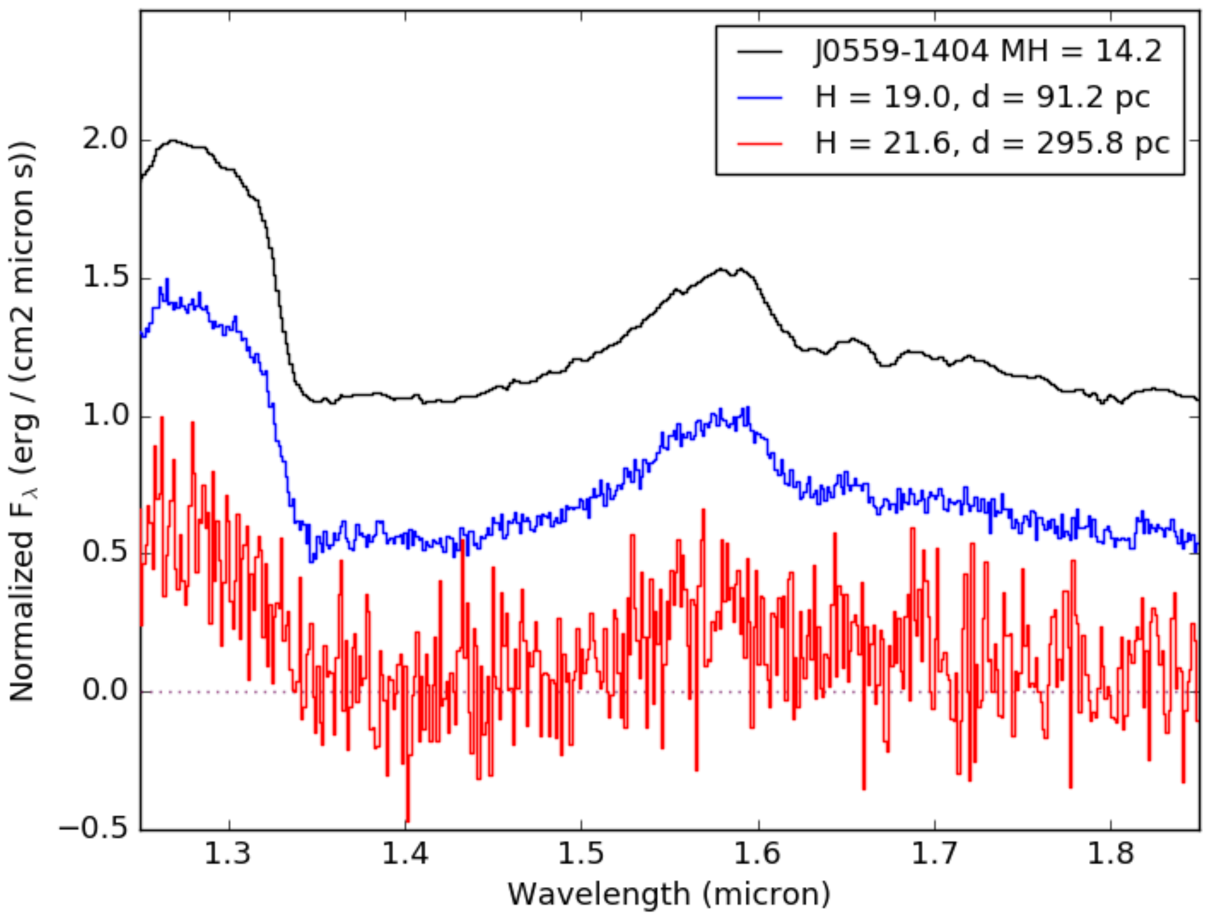
7 > 3%

Martin et al. 2013

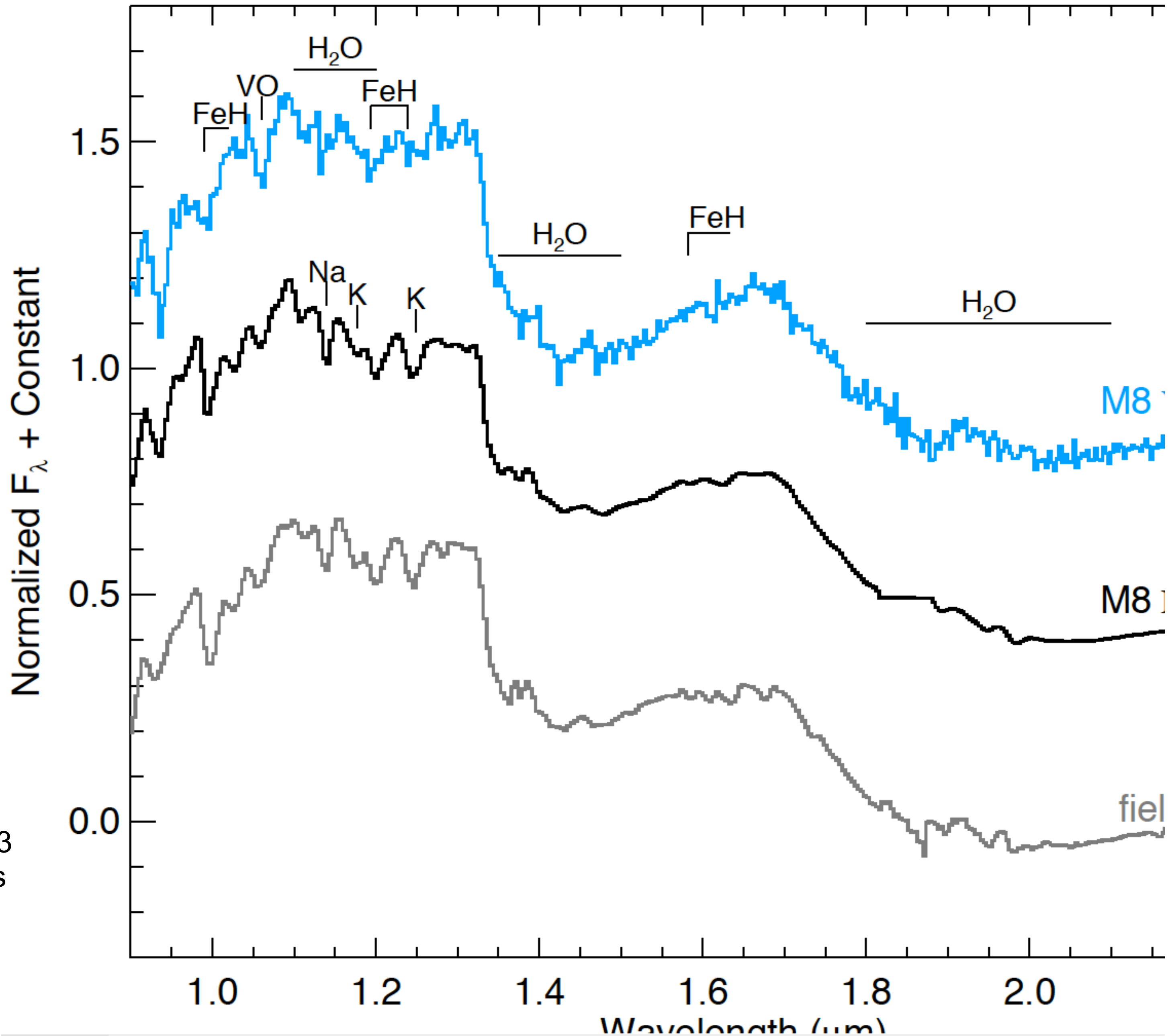
Gizis et al. 2015

Between 15 and 130 UCDs photometrically stable (<3%) per NISP FOV

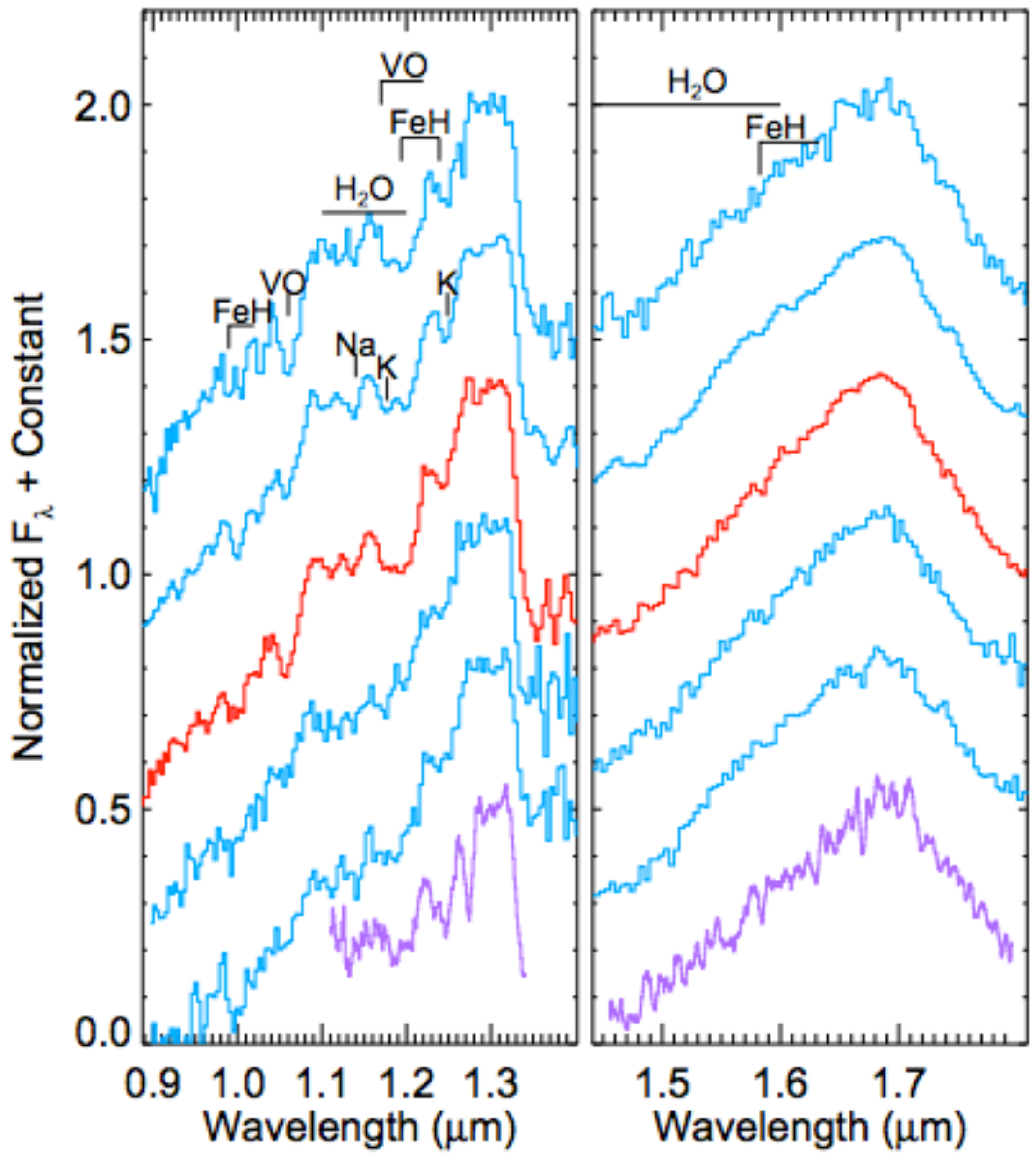
Simulations of Euclid NISP slitless spectra of distant T dwarfs



Allers & Liu 2013 Res. 100

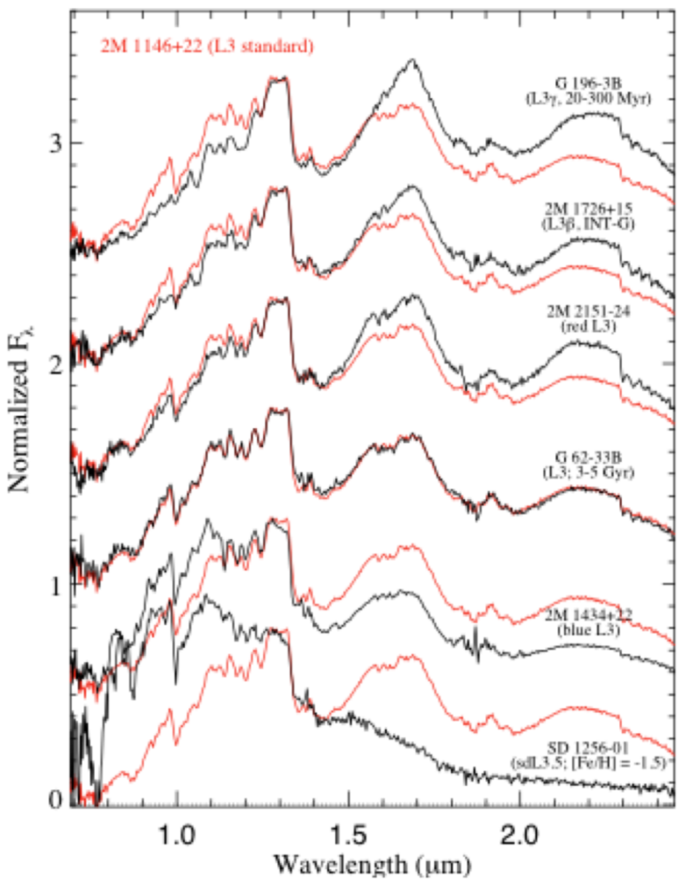


KI 1.253
microns



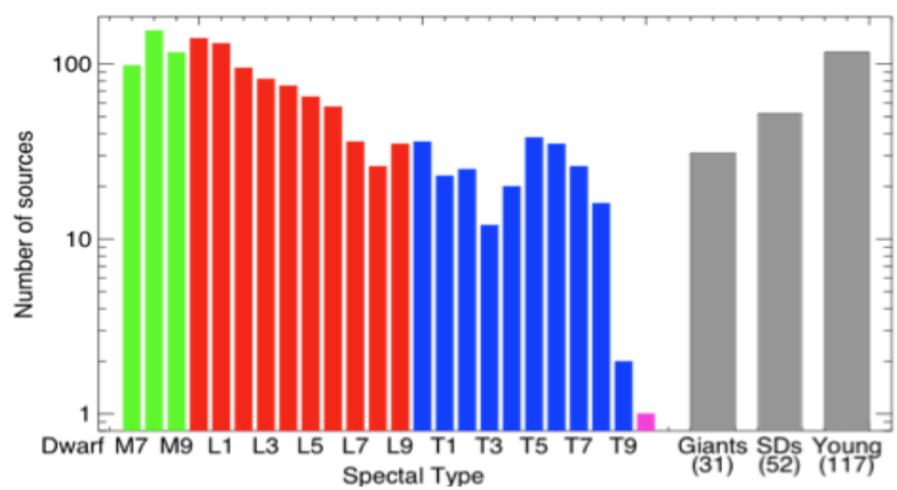
Normalized F$_\lambda$ + Constant
Wavelength (μm)
Wavelength (μm)
VO
FeH
H$_2$O
FeH
VO
K
Na
K
H$_2$O
FeH
0.0
0.5
1.0
1.5
2.0
0.9
1.0
1.1
1.2
1.3
1.5
1.6
1.7

The SpeX Prism Library (SPL)
http://www.browndwarfs.org/spexprism



Roughly 1500 low-resolution (λ/Δλ ≈ 150), 0.7-2.45 μm spectra of late-M, L and T dwarfs, as well as cool giants, subdwarfs, young brown dwarfs, and planets

Used in over 150 studies for source identification classification, binary detection, spectrophotometry, population modeling, etc.

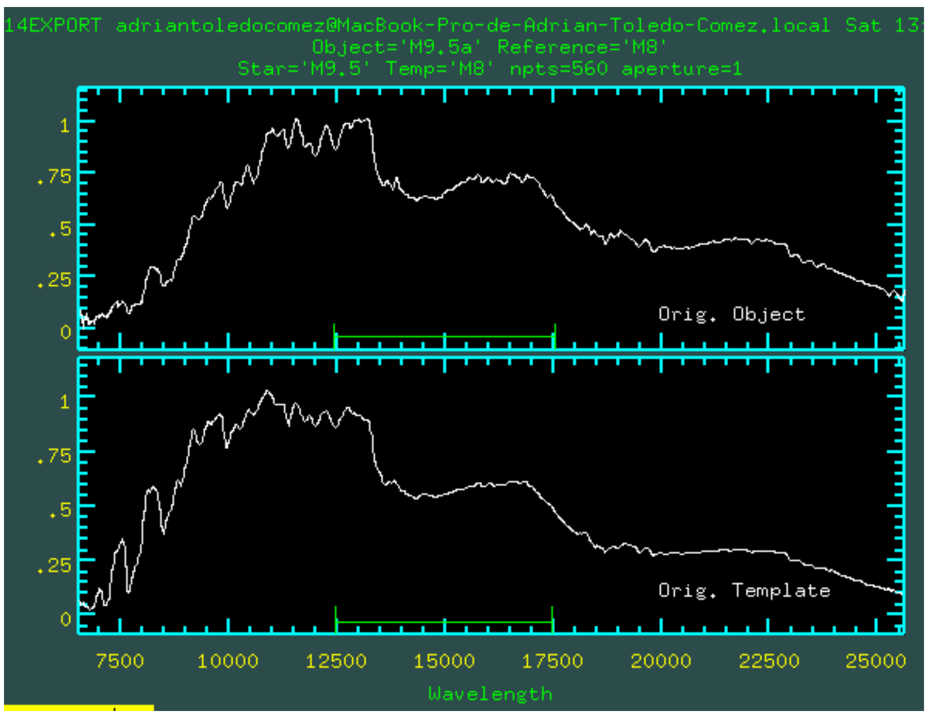


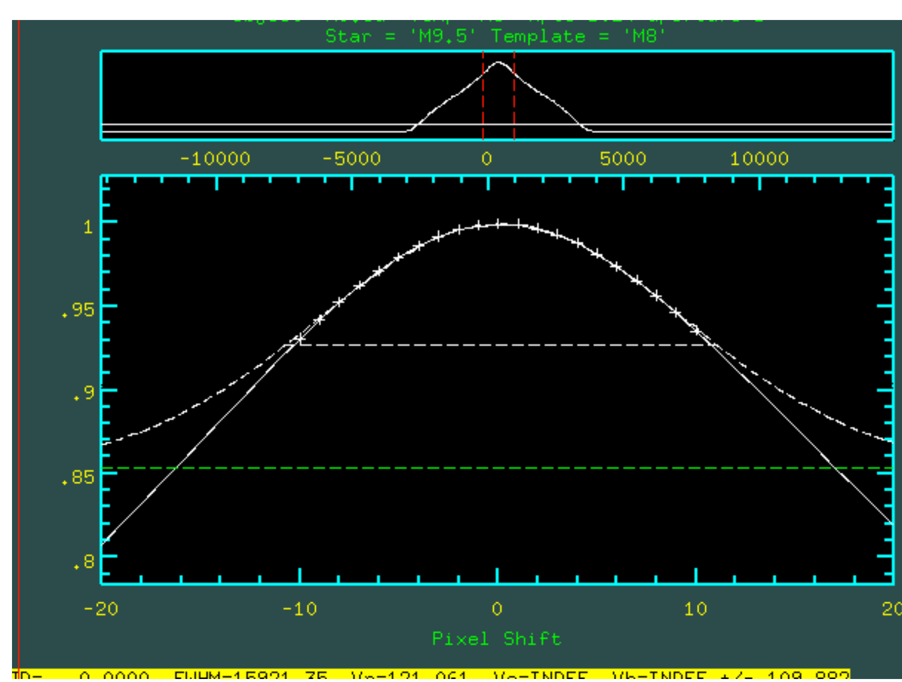
Above: SPL spectra for L3 dwarfs with differing characteristics; Right: distribution of sources in the library

Example M8 vs M9.5 dwarfs

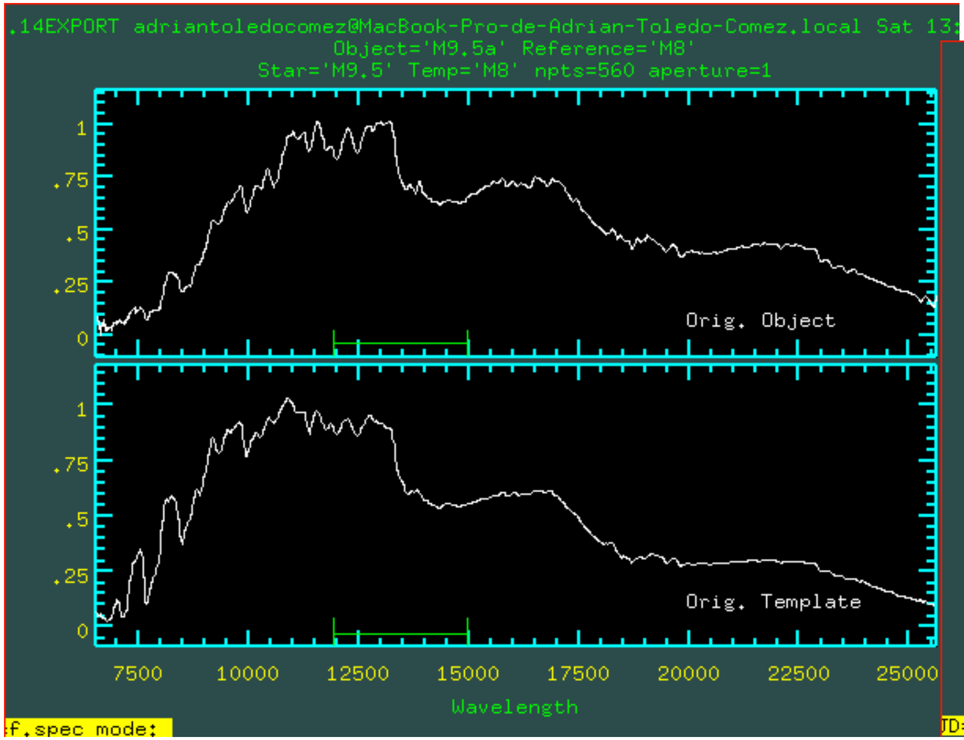
Estimated RV precision (1.25—1.75 microns) 100 km/s

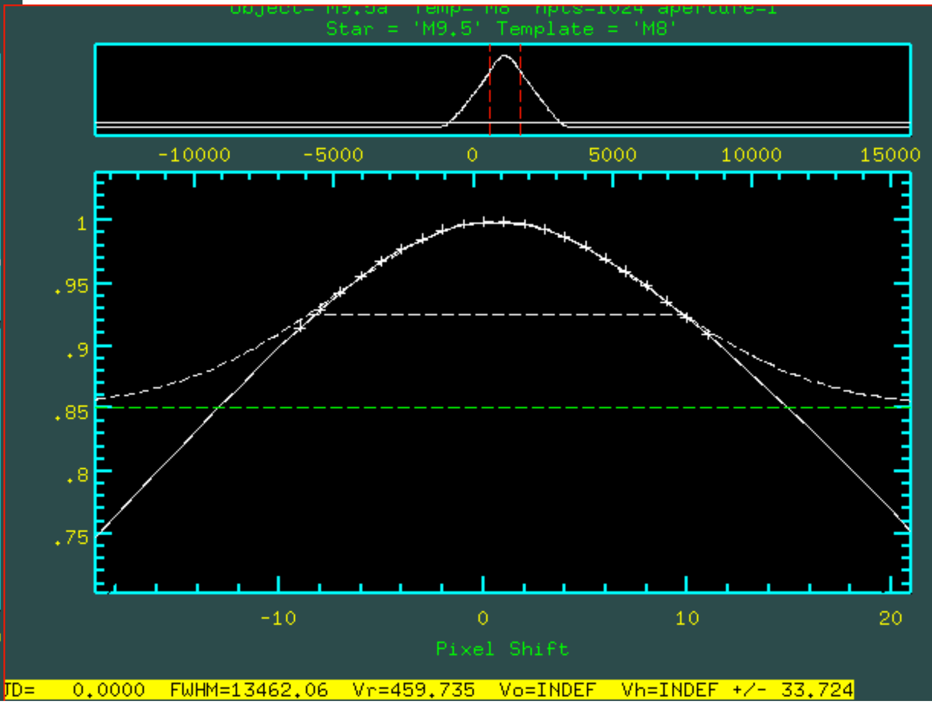
Redshift accuracy 0.00033 < 0.001





Estimated RV precision (1.24—1.5 microns) 33 km/s
Possible improvement in wavelength calibration by a factor 3 by shifting red grating slightly blueward or using blue grating





Lodieu et al. 2016

SDSS vs UKIDSS
New subdwarfs

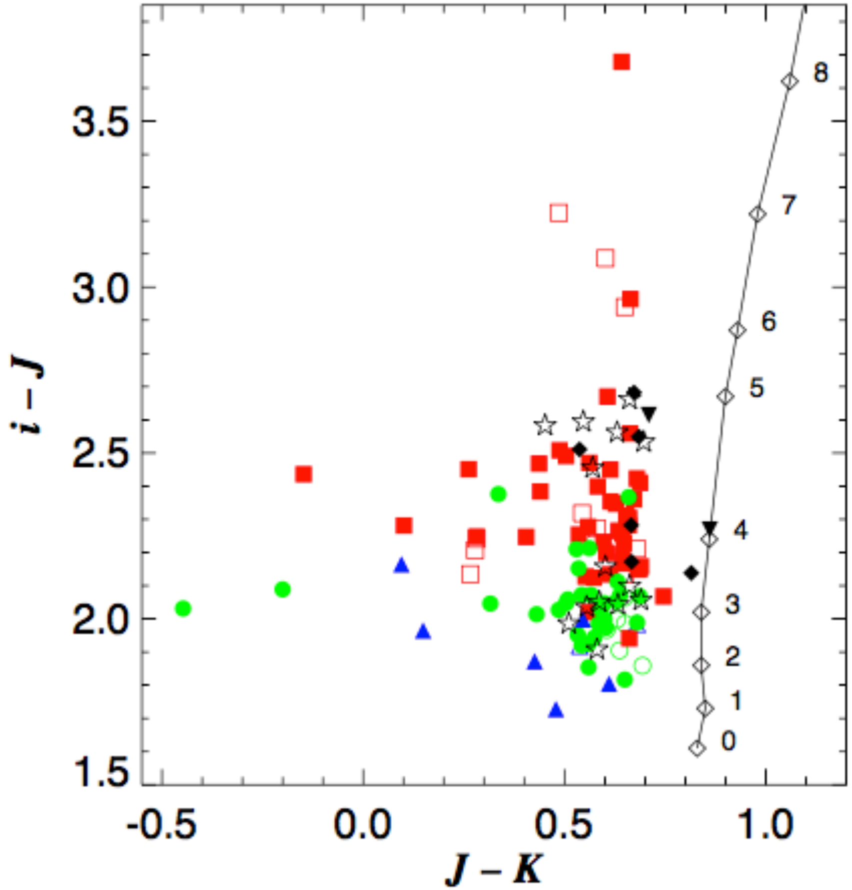
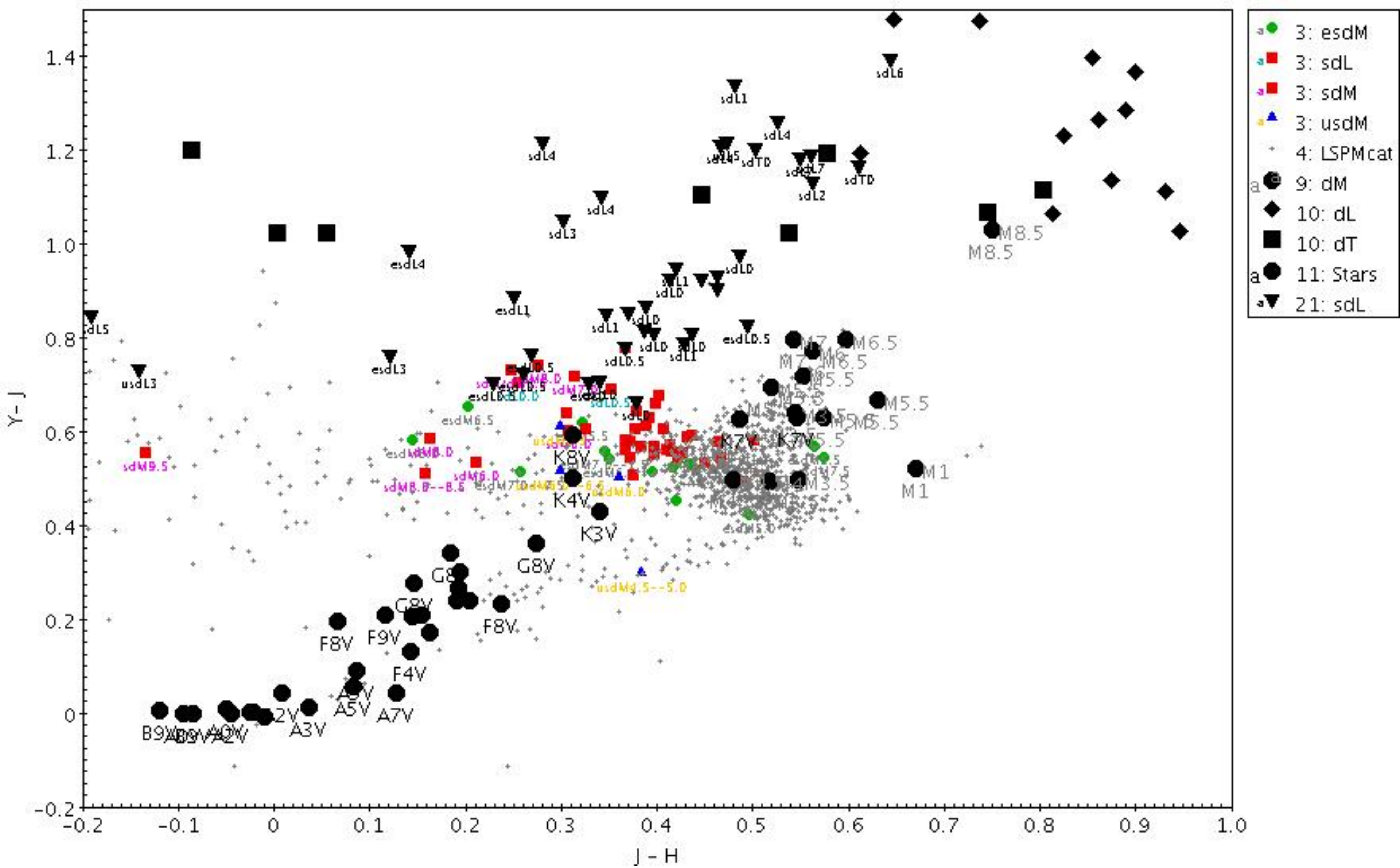


Fig. 1. ($i - J$ vs $J - K$) colour-colour diagram for candidates with optical spectra. Symbols are as follows: sdM/L (filled red squares), esdM (filled green circles), usdM (filled blue triangles), candidates with uncertain class (filled black upside down triangles), and solar-metallicity M dwarfs (filled black diamonds). The empty five pointed stars represent the 14 candidates without optical spectroscopy yet. We also included a few known subdwarfs, extreme subdwarfs, and ultrasubdwarfs published in the literature (empty symbols). The empty diamonds joined with a continuum line in the right part of the diagram are solar-metallicity M dwarfs from West et al. (2008). The J and K magnitudes of candidates with ID = 1–29 are in the UKIDSS Vega system (Hewett et al. 2006), except for objects with ID = 1, 2, 6, 10, 11, and 19, which


Y - J
J - H
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
−0.2
−0.2
−0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
3: esdM
3: sdL
3: sdM
3: usdM
4: LSPMcat
9: dM
10: dL
10: dT
11: Stars
21: sdL

Subdwarf surface densities

SDSS DR9 vs UKIDSS DR10
r=19.6-23.3 J=15.9-18.8 M5-L0.5
0.04 subdwarfs per sq.deg.

Euclid NISP wide survey imaging
subdwarf density estimated at about 1.2
objects per FOV

Potential Uses of UCDs as calibrators for Euclid

Astrometric calibration from known binaries and clusters

Photometric calibration from known photometrically stable UCDs

Wavelength calibration from UCDs with well understood spectra

Assessment of foreground field contamination for distant clusters

Characterization of in-flight filter transmission profiles (transmission edges)