New constraints on the formation and settling of dust in the atmospheres of young M and L dwarfs

Elena Manjavacas

Max Planck Institut für Astronomie

25th March 2014

Results: Manjavacas et al. 2014

Collaborators:

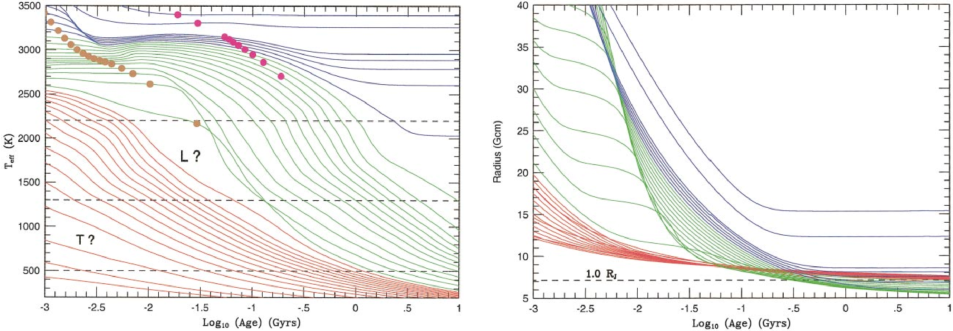
M. Bonnefoy, J. E. Schlieder, F. Allard, B. Goldman, P. Rojo, T. Henning,

G. Chauvin, N. Lodieu, D. Homeier

Introduction

Brown dwarfs (BDs) are substellar objects unable to burn H

Formation and evolution of brown dwarfs



Burrows et al. 2001

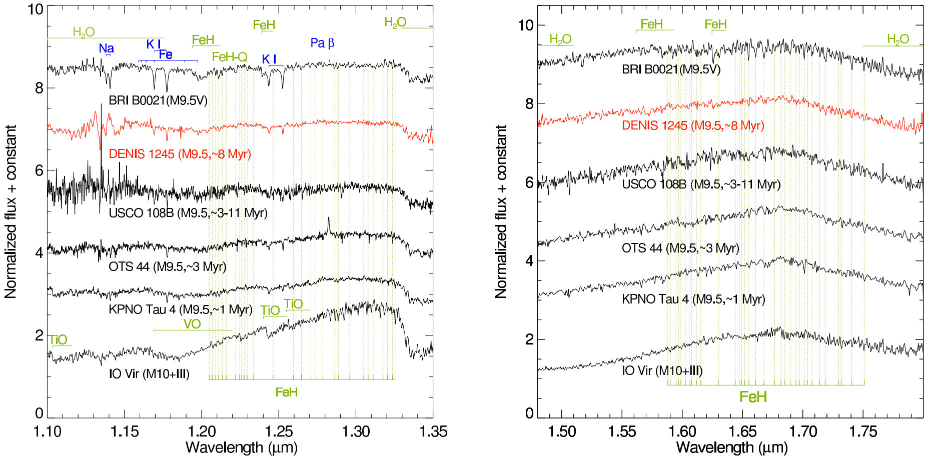
Observations & data

- VLT/ISAAC spectra of 5 young BDs candidates + 2 BDs members of young clusters and associations
- NIR spectra in J, H and K (Resolution = 1500 - 1700)
- Targets:
  - **Optical** spectral types: M9.5 - L3
  - Previously studied in the optical

Objectives

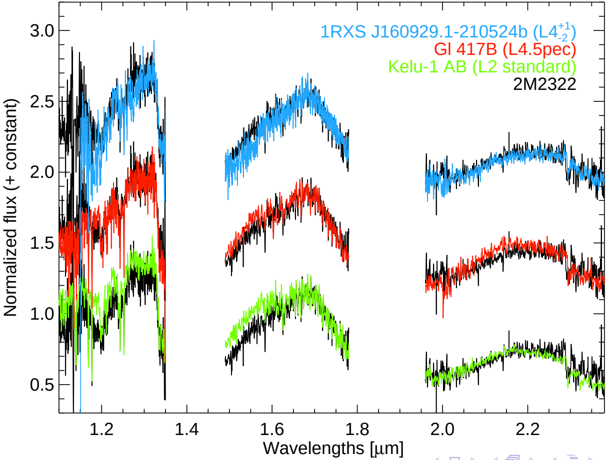
- NIR spectral typing of our targets
- Confirm their low surface gravity
- Test BT-Settl 2010 & 2013 in the M-L transition

Age-sequence M9.5 SpT objects



Empirical Analysis

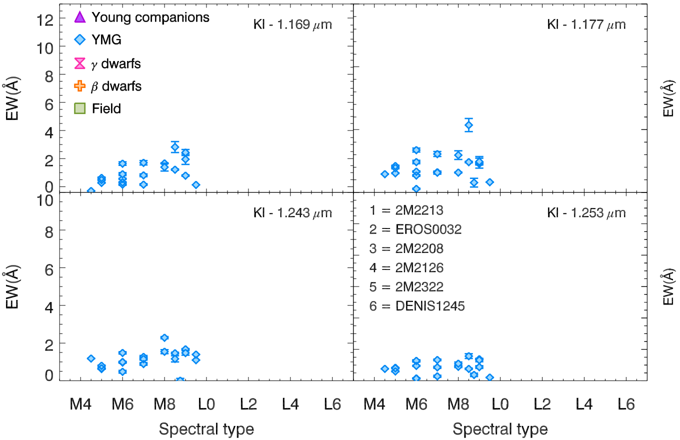
- We compare spectral features of our objects in the NIR to brown dwarfs found in the literature.
- χ^2 statistic to decide the best fit + visual inspection



Equivalent widths

Gravity sensitive K I lines at: 1.169 μm, 1.177 μm, 1.243 μm and 1.253 μm.

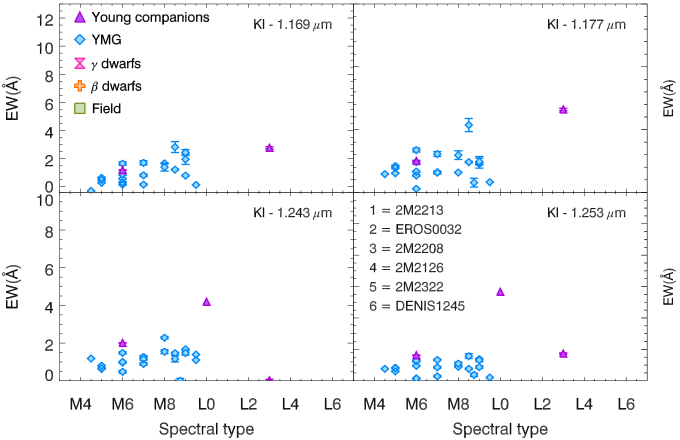
γ = very low gravity features; β = intermediate gravity features



Equivalent widths

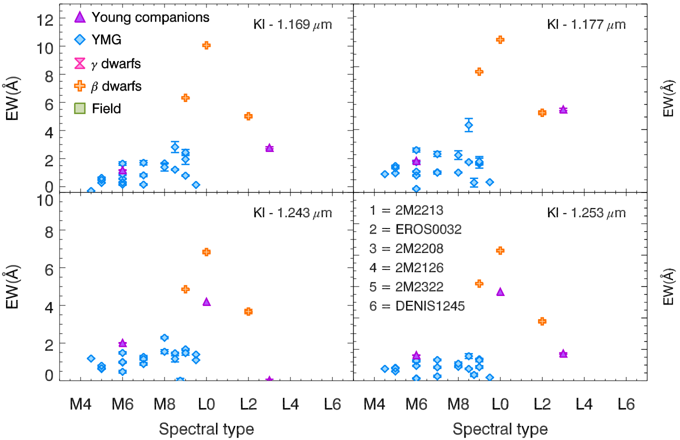
Gravity sensitive K I lines at: 1.169 μm, 1.177 μm, 1.243 μm and 1.253 μm.

γ = very low gravity features; β = intermediate gravity features



Gravity sensitive K I lines at: 1.169 μm, 1.177 μm, 1.243 μm and 1.253 μm.

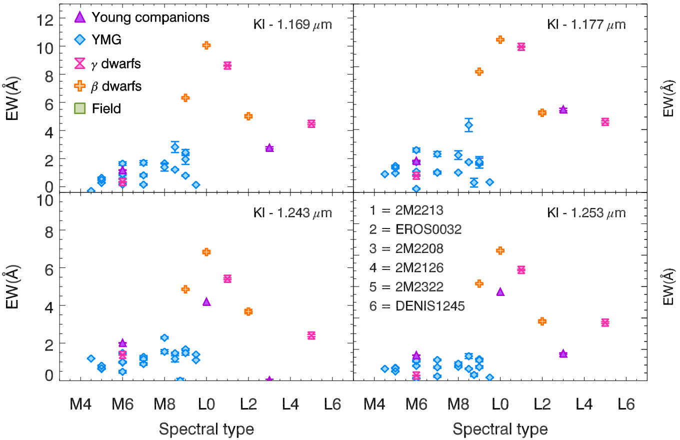
γ = very low gravity features; β = intermediate gravity features



Equivalent widths

Gravity sensitive K I lines at: 1.169 μm, 1.177 μm, 1.243 μm and 1.253 μm.

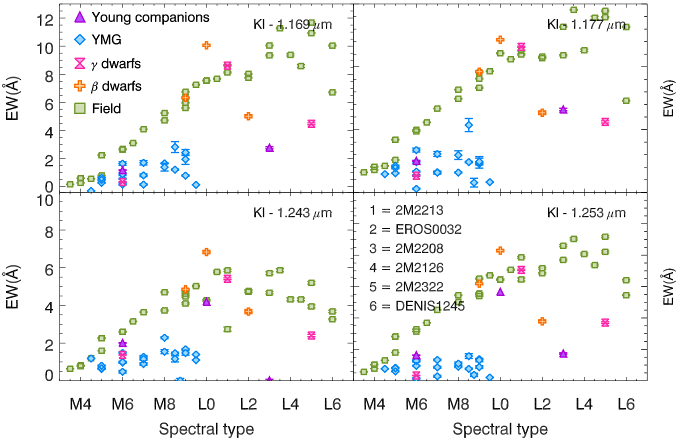
γ = very low gravity features; β = intermediate gravity features



Equivalent widths

Gravity sensitive K I lines at: 1.169 μm, 1.177 μm, 1.243 μm and 1.253 μm.

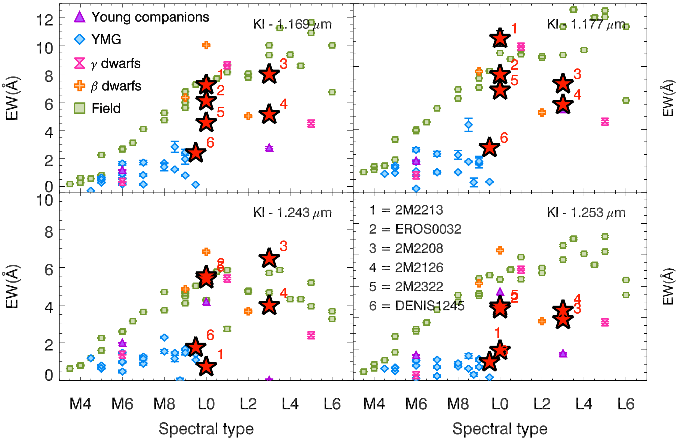
γ = very low gravity features; β = intermediate gravity features



Equivalent widths

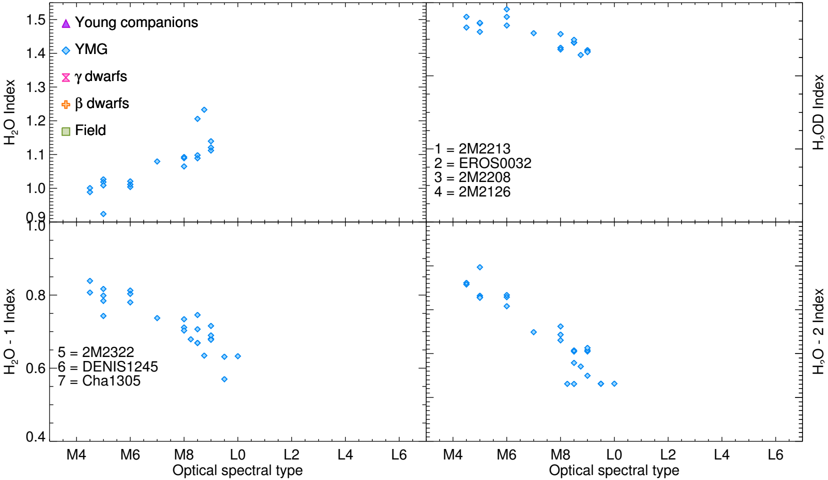
Gravity sensitive K I lines at: 1.169 μm, 1.177 μm, 1.243 μm and 1.253 μm.

γ = very low gravity features; β = intermediate gravity features



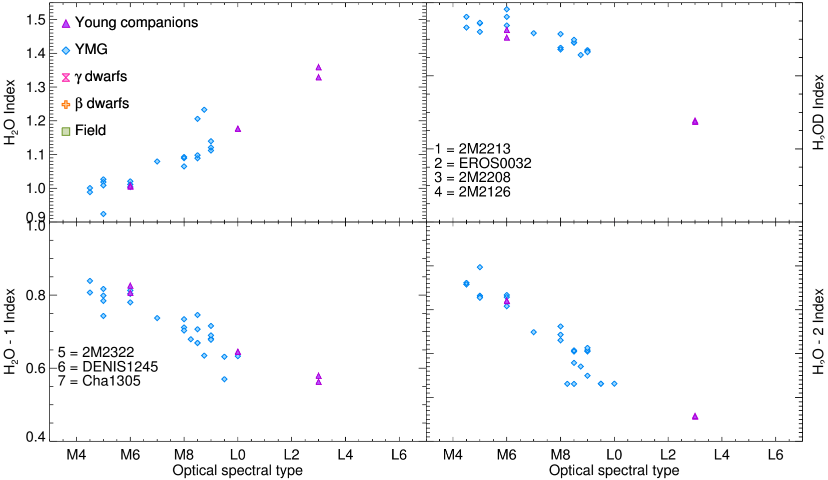
Spectral indices: NIR spectral typing

H_2O, H_2OD, H_2O-1, H_2O-2 (Allers et al. 2013)

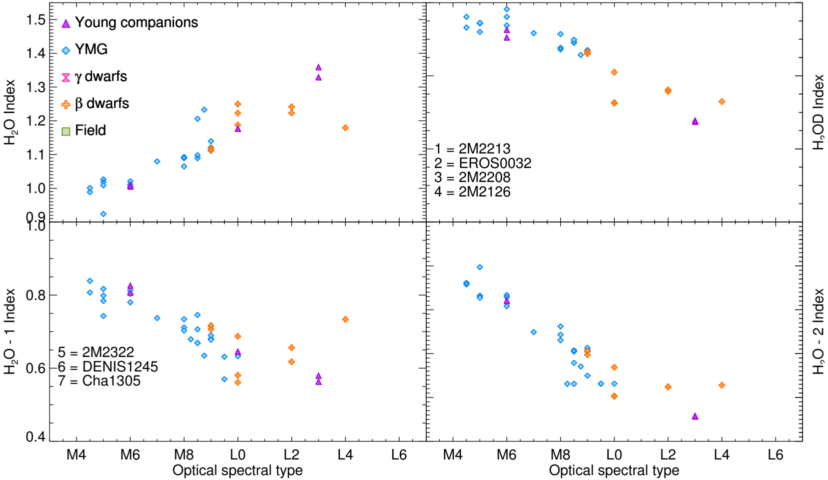


Spectral indices: NIR spectral typing

H_2O, H_2OD, H_2O-1, H_2O-2 (Allers et al. 2013)

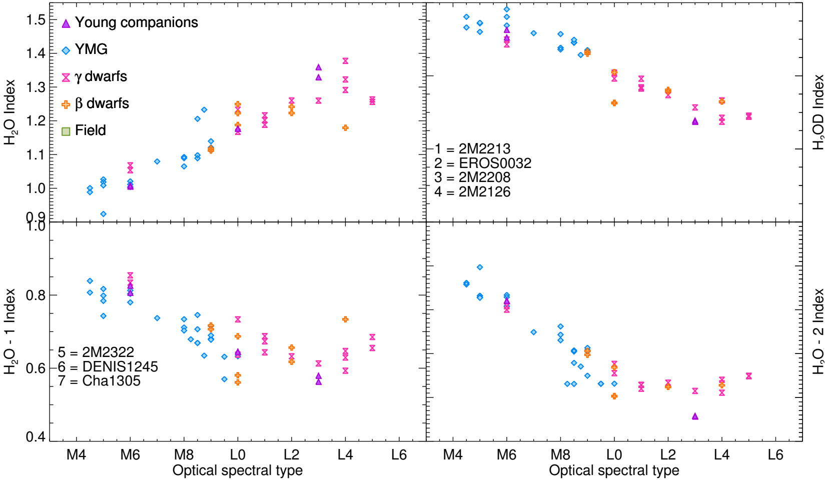


H_2O, H_2OD, $H_2O - 1$, $H_2O - 2$ (Allers et al. 2013)

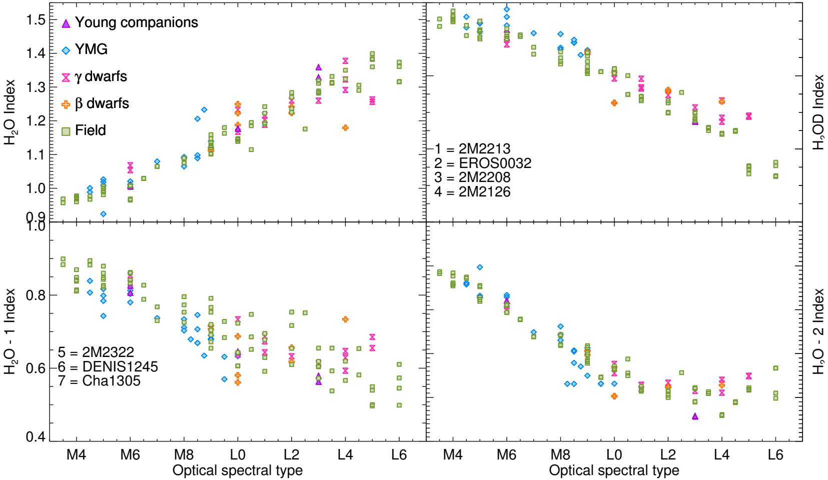


Spectral indices: NIR spectral typing

H_2O, H_2OD, H_2O-1, H_2O-2 (Allers et al. 2013)

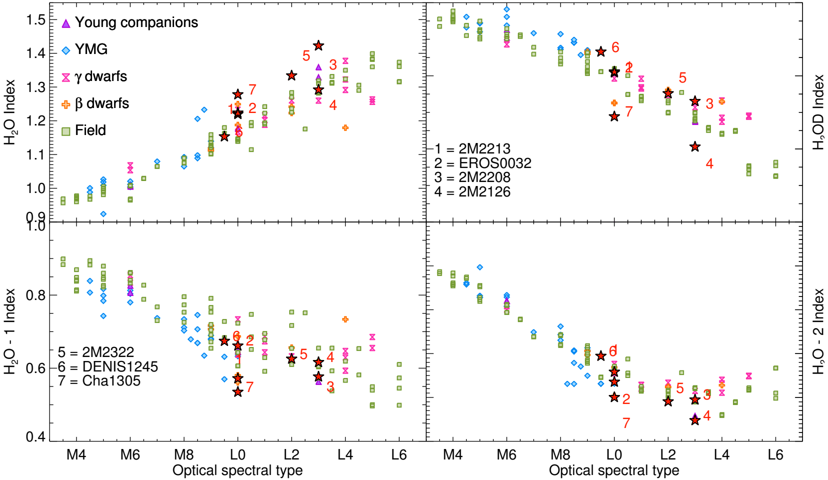


H_2O, H_2OD, H_2O-1, H_2O-2 (Allers et al. 2013)



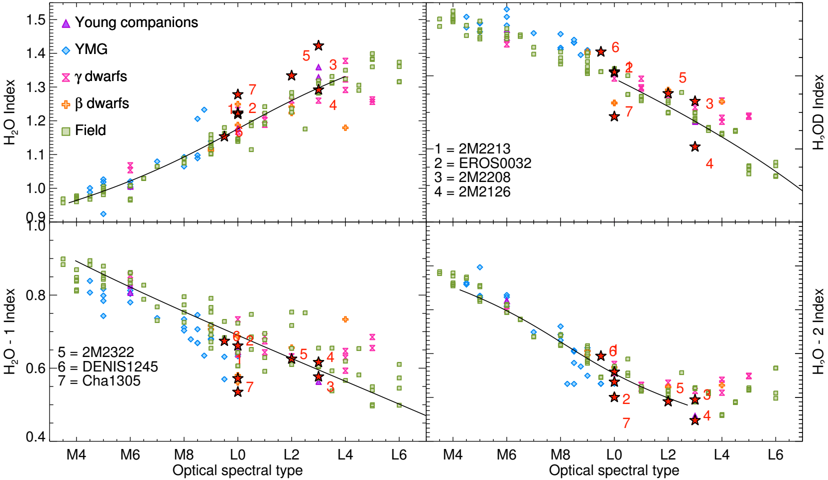
Spectral indices: NIR spectral typing

H_2O, H_2OD, H_2O-1, H_2O-2 (Allers et al. 2013)



Spectral indices: NIR spectral typing

H_2O, H_2OD, H_2O-1, H_2O-2 (Allers et al. 2013)



Estimation NIR SpT

Table : Estimation of NIR spectral types

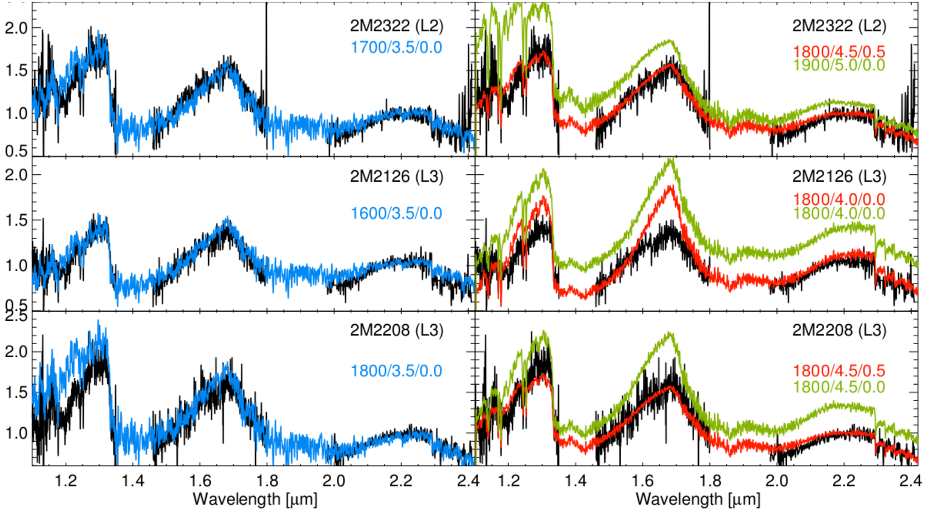
Name	Opt SpT	Emp. SpT	**SpT final**
DE J1245	M9.5	M9	**M9.5±1.0**
EROS J0032	L0γ	L1	**L0.5±0.5**
2M J2213	L0γ	L0	**L2.0±1.5**
Cha J1305	L0	L1	**L3.5±1.5**
2M J2322	L2γ	L2	**L2.0±1.0**
2M J2126	L3γ	L3	**L3.0±1.5**
2M J2208	L3γ	L1	**L3.0±2.0**

Spectral synthesis

- We compare our NIR spectra with preditions of BT-Settl 2010 & 2013
- Some differences:
  - Different reference for solar abundances:
    2010: Asplund et al. (2009); **2013**: Caffau et al. (2011)
  - **BT-Settl 2013**: atmospheres enriched with C, O, Fe, K compared with 2010 (FeH, CO, H_2O, K)
  - Improved opacities
- Grids:
  1000 K$\leq T_{eff} \leq$ 3000 K; 3.0$\leq$log g$\leq$5.5; [M/H]=0
  For 2013 also [M/H]+0.5
- We derive T_{eff}, log g & [M/H]

Comparison with synthetic NIR spectra

BT-Settl 2010
BT-Settl 2013



Comparison with SED

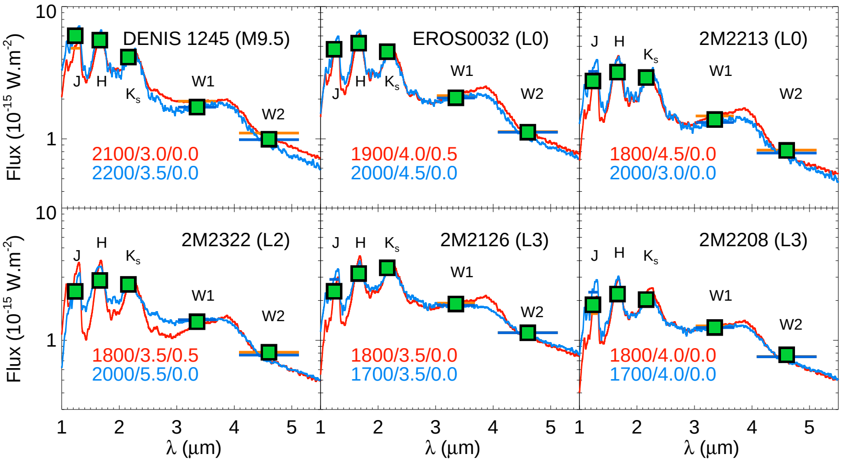
- We build SED of the objects using published photometry: 2MASS & WISE
- We look for the best fit in of BT-Settl 2010 & 2013.
- We exclude Cha 1305 as it has NIR excess (disk) (Allers et al. 2006b)
- We do not include optical photometry because the models are really inaccurate (Bonnefoy et al. 2013b).
- We use the parameters derived from the SED fit to compare synthetic spectra & observational spectra

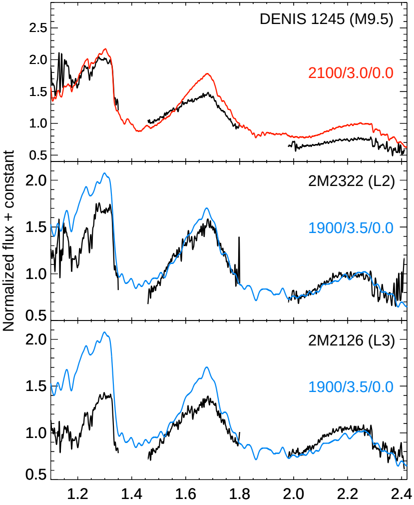
Comparison with SED

SED fitting

BT-Settl 2010

BT-Settl 2013





BT-Settl 2010

BT-Settl 2013

Comparison of the syntethic spectra corresponding to the best SED fitting

Why do the models fail?

Supersolar metalicity models fit better -> suggest a problem with the amount of dust

- Missing opacities?
- Amount of dust in the atmosphere: **condensation rate**?
- Dregde-up effect: convection

Revised properties

Table : Physical properties of the objects with known distance.

Object	Age (Myr)*	Membership	BANYAN I**	BANYAN II***
DENIS 1245	10^{+10}_{-7}	TW Hydrae	95%	93.3%
Cha1305	4 ± 2	Chamaleon II		
EROS J0032	30^{+20}_{-10} ?	Tuc/Hor	92%	
EROS J0032	120 ± 20 ?	AB-Dor	8%	
EROS J0032	21^{+4}_{-13}	β Pic	1%	91.8%

* Evolutionary models from Chabrier et al. (2000)
** Malo et al. 2013
*** Gagné et al. 2014

Conclusions

- **BT-Settl 2013 models underpredict dust on young brown dwarfs atmospheres**
- SED is well reproduced by BT-Settl 2010 & 2013
- We confirm the youth of our targets and we estimate their spectral types in the NIR
- The spectra help to **confirm the membership of photometricaly-selected candidates in star-forming regions**
- The spectra help to **understand directly image exoplanets**

- Accurate distances will give absolute luminosities to constrain ages of these objects using evolutionary models
- Accurate distances will allow to study the kinematics of young brown dwarfs and they potential membership to moving groups