Near-Infrared Integral-Field Spectroscopy of the Young AB Pic b Companion

M. Bonnefoy[1]

Collaboration: G. Chauvin[1], P Rojo[2], C Dumas[3], A-M. Lagrange[1] , F. Allard[4] and J-L Beuzit[1]

[1] Laboratoire d'Astrophysique de Grenoble. BP 53. F-38041 GRENOBLE Cédex 9. (France)
Email: mbonnefo@obs.ujf-grenoble.fr
[2] Departamento de Astronomia, Universidad de Chile, Casilla 36-D, Santiago, Chile
[3] European Southern Observatory. Alonso de Cordova 3107, Vitacura. Casilla 19001. Santiago 19, Chile
[4] CRAL-ENS. , 46, Allée d'Italie , 69364 Lyon Cedex 07

Planet Formation and Evolution: The Solar System and Extrasolar Planets
-- Tübingen - 03/05/2009 --

Plan

Mickaël Bonnefoy
LAOG
France

- Introduction
- 1. Observations and data reduction
- 2. Spectral type determination
- 3. Atmospheric parameters
- A planet or a brown dwarf ?

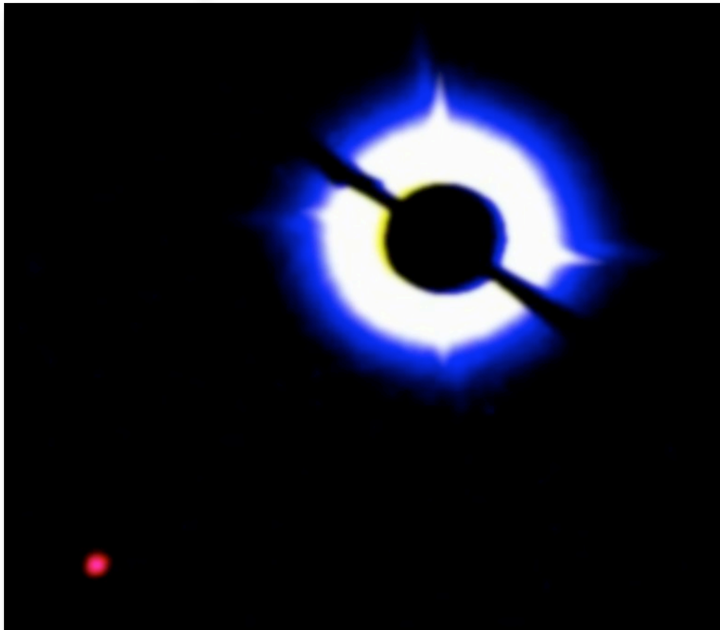
Plan

Mickaël Bonnefoy
LAOG
France

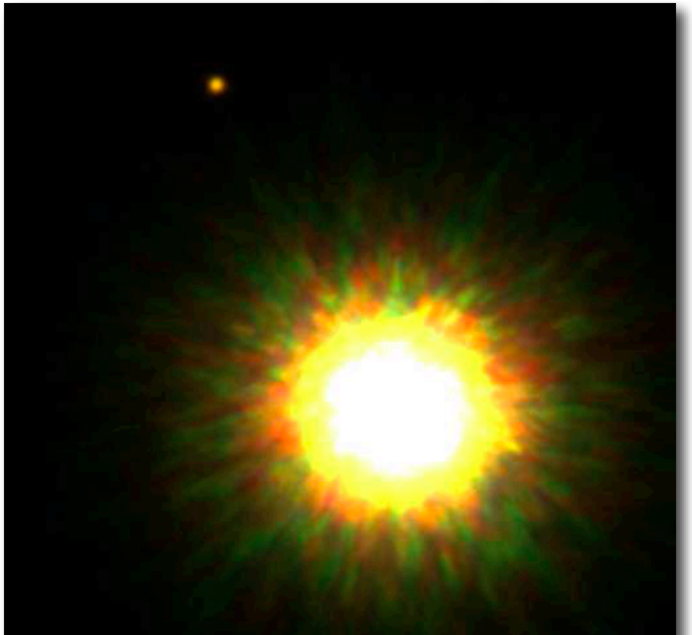
- Introduction
- 1. Observations and data reduction
- 2. Spectral type determination
- 3. Atmospheric parameters
- A planet or a brown dwarf ?

Introduction

Mickaël Bonnefoy
LAOG
France



Chauvin et al. 2005



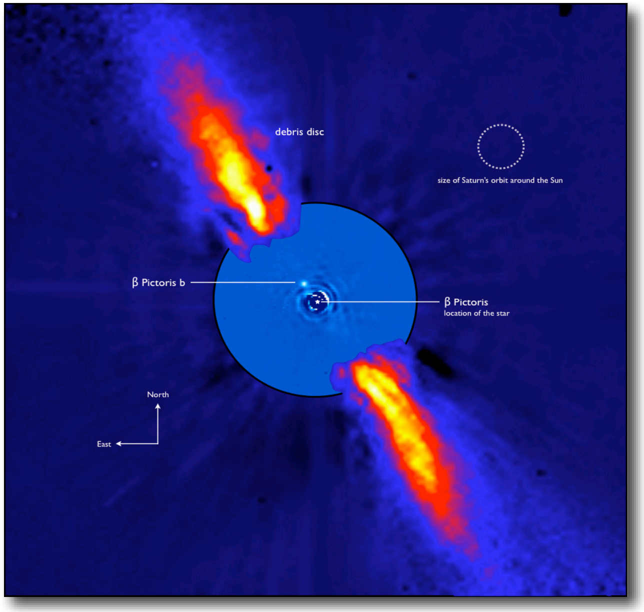
Lafrenière et al. 2008

✓ Today: detection performances allow direct imaging of planetary mass objects at ~10 AU.

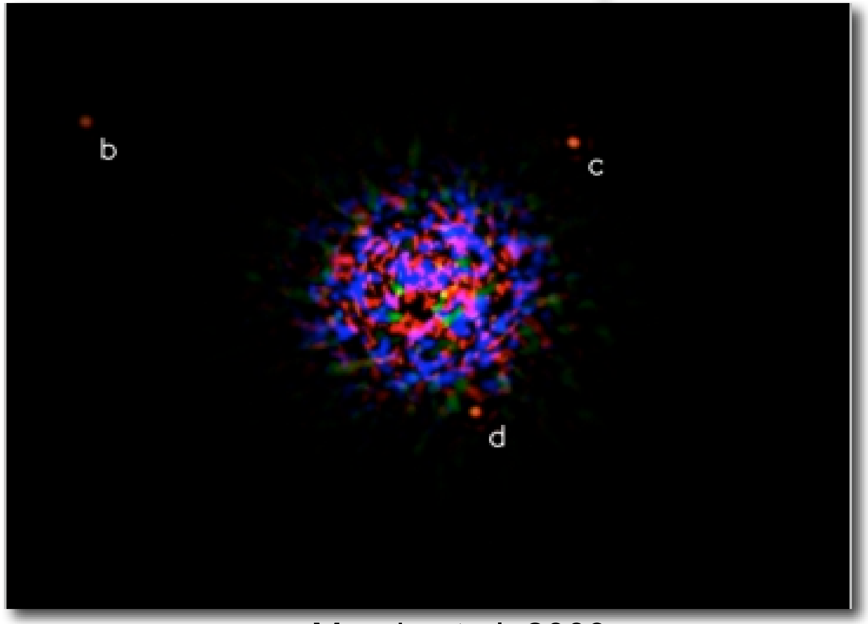
✓ Mass inferred from predictions of evolutionary models.

Introduction

Mickaël Bonnefoy
LAOG
France



Lagrange et al. 2009



Marois et al. 2009

✓ Wide range of separations: different formation mechanisms (initial state) ?

✓ Needs for a full characterization of interesting targets to refine the mass (the status), and to constraint models of formation and evolution.

Introduction

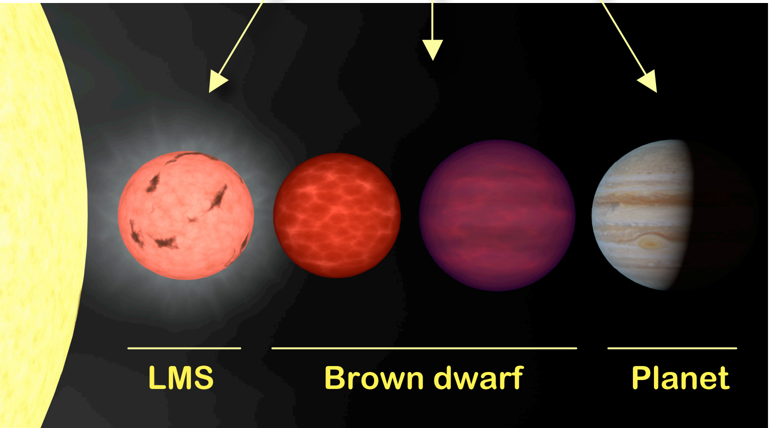
Mickaël Bonnefoy
LAOG
France

Why characterizing atmospheric properties ?

✓ To know the composition of ultra-cool atmospheres under intermediate gravities.

✓ To constrain atmospheric models used in evolutionary models of these objects.

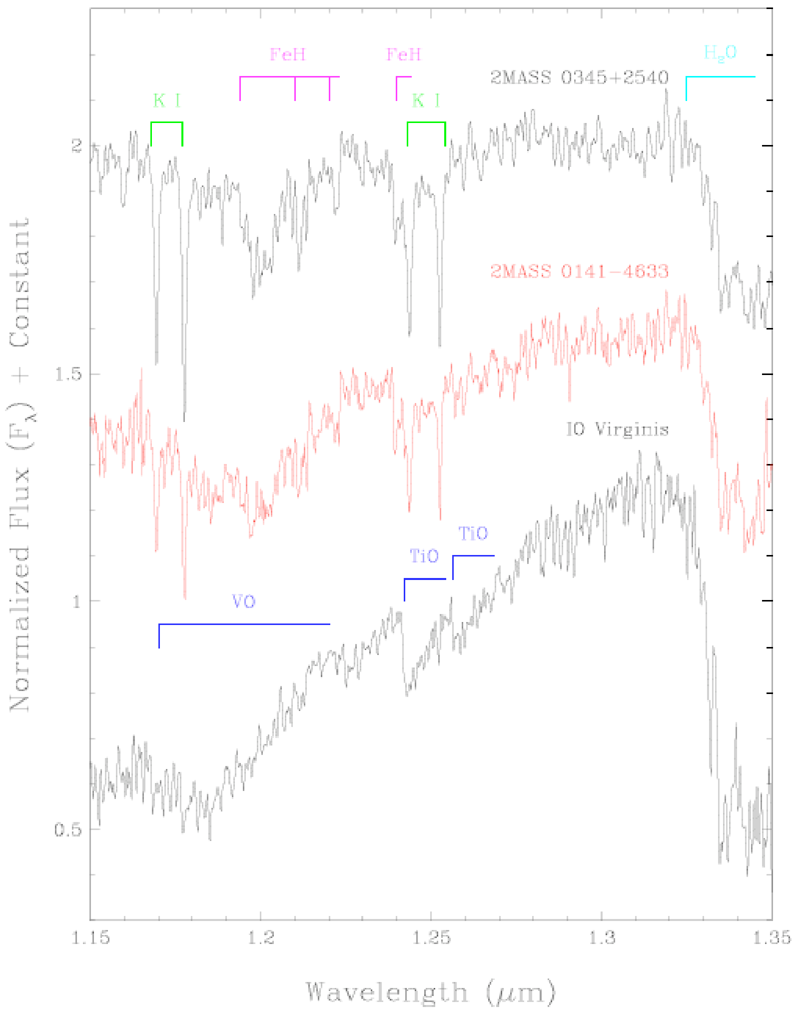
✓ To constrain the mass of the object

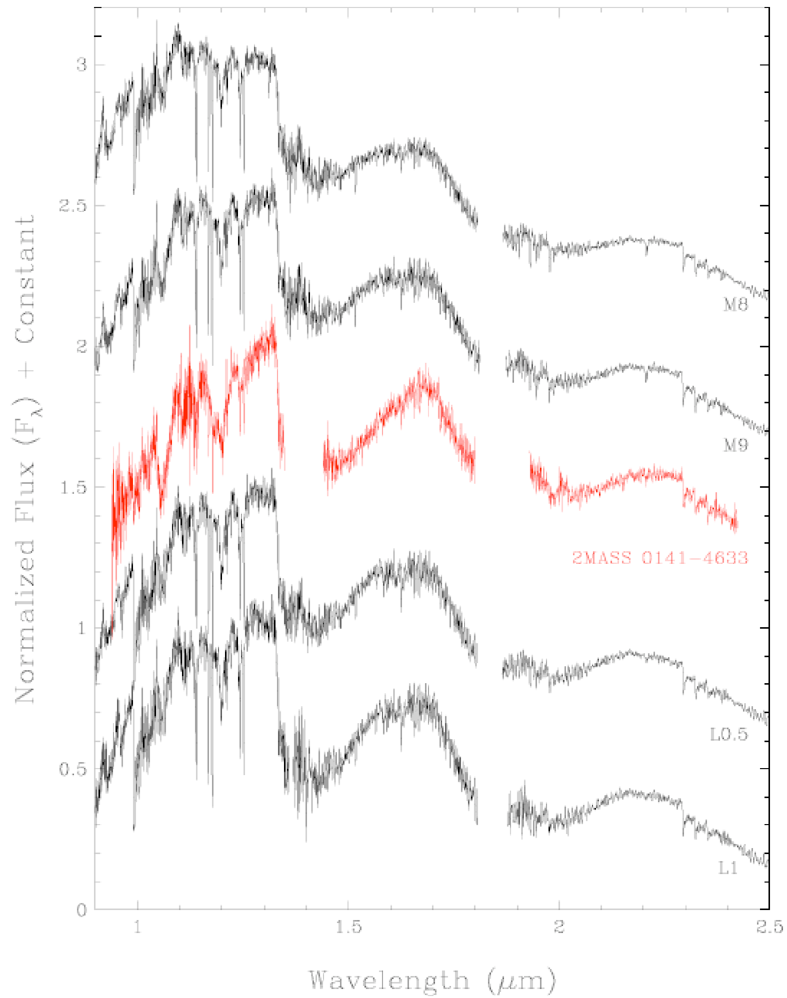


Introduction

Mickaël Bonnefoy
LAOG
France

Looking for cold and young objects in the near-infrared:





Introduction

Mickaël Bonnefoy
LAOG
France

Project: spectral library of young low mass objects in the near-IR:

→ **Finding interesting features:**

✓ **Age indicators…**

✓ **Features to distinguish planets from contaminants (giant stars, low mass stars,…).**

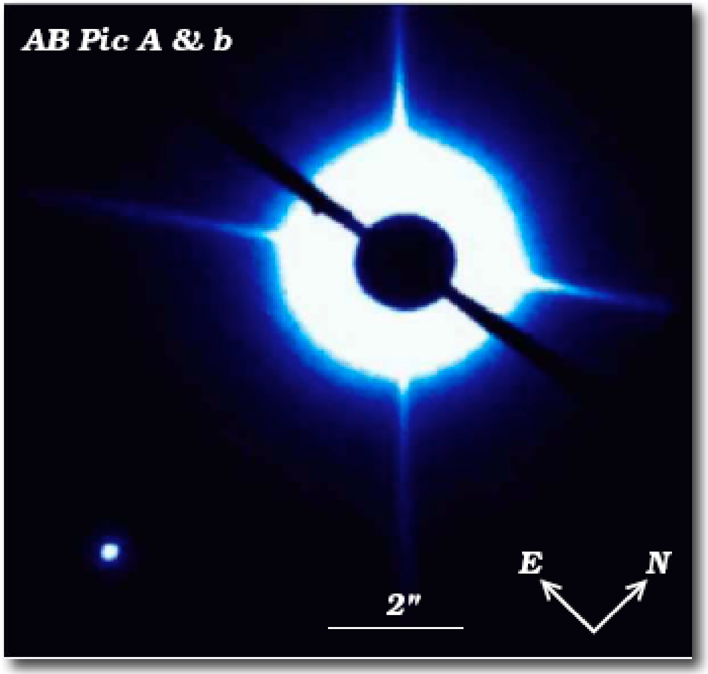
→ **Preparing the surveys for direct detection and characterization of giant planets (Gemini/GPI and VLT/SHERE).**

Introduction

Mickaël Bonnefoy
LAOG
France

Observation and characterisation of AB pic b:

- AB Pic A: K2V Member of Tuc-Hor association (30 Myrs old).
- AB Pic b discovered in NACO coronographic images (Chauvin et al. 2005).
  - ✓ M=13-14 M_{jup}
  - ✓ K-band spectrum: L0-L3.



NACO Ks-band coronographic image

Companion at the planet-brown dwarf boundary at ~260 AU from AB Pic A…

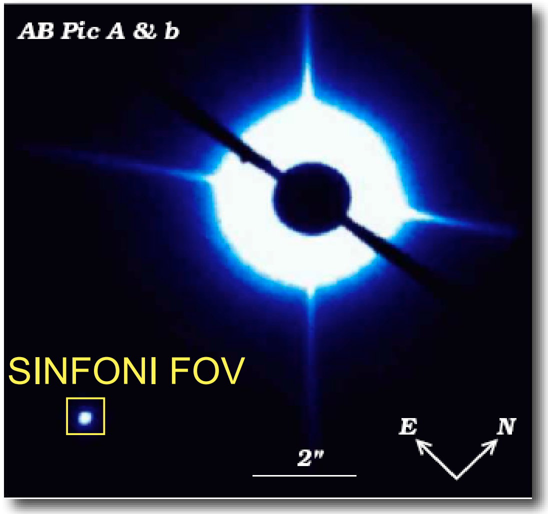
Plan

Mickaël Bonnefoy
LAOG
France

- Introduction
- 1. Observations and data reduction
- 2. Spectral type determination
- 3. Atmospheric parameters
- A planet or a brown dwarf ?

Observations of AB Pic b

Mickaël Bonnefoy
LAOG
France



Ks-band coronographic image of AB Pic Ab.

High contrast configuration: ΔM_J=8.6 !

→ Need for adaptive optic (AO)

Limiting the differential flux losses

→ ~~Long slit Spectroscopy~~

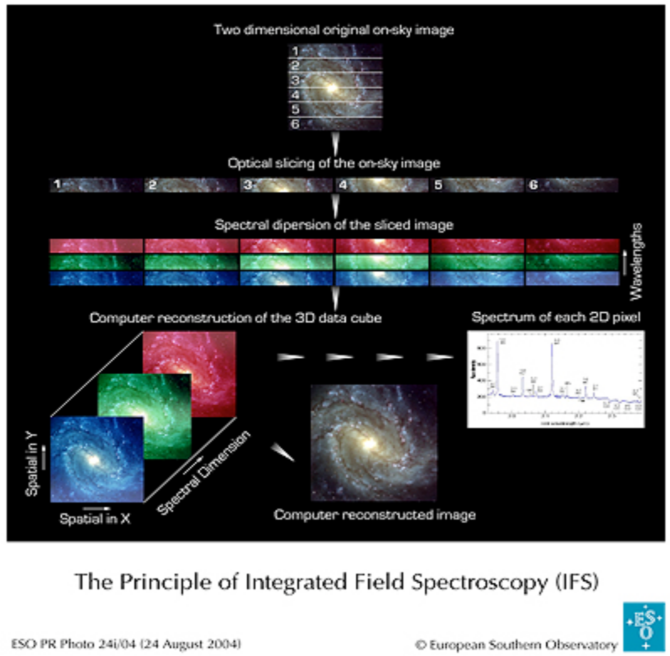
Possible flux halo of the primary

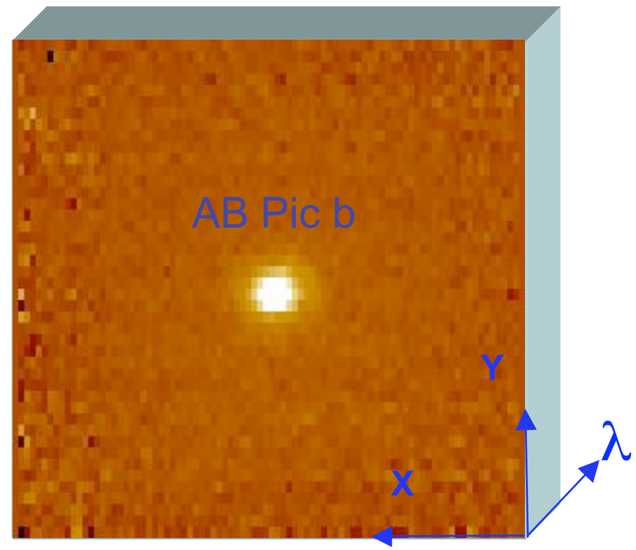
→ Spectral extraction of the residuals

→ Observations with the Spectrograph for INtegral Field Observations in the Near Infrared (SINFONI)

Observations of AB Pic b

Mickaël Bonnefoy
LAOG
France





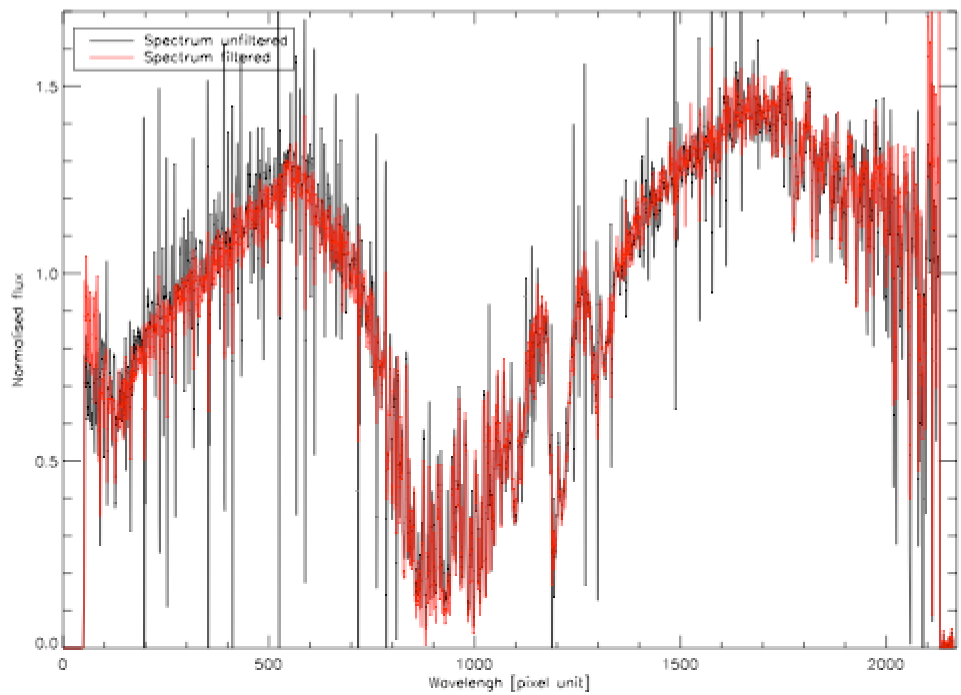
- ✓ Observations: J (R=2000, 1.1-1.35 μm) and H+K (R=1500, 1.5-2.45 μm).
- ✓ Platescale: 25 mas/pixel.
- ✓ No contamination coming from the primary.
- ✓ DIT: 3 × 9 × 300s in J and 9 × 300 s in H+K.

Data reduction

Mickaël Bonnefoy
LAOG
France

Tricky and complex task…

- ✓ ESO Data reduction pipeline version 1.9.8
- ✓ Custom routines for electronic ghost correction, residual bad pixel removal…
- ✓ Optimization of the extraction (refraction correction, optimal radius)

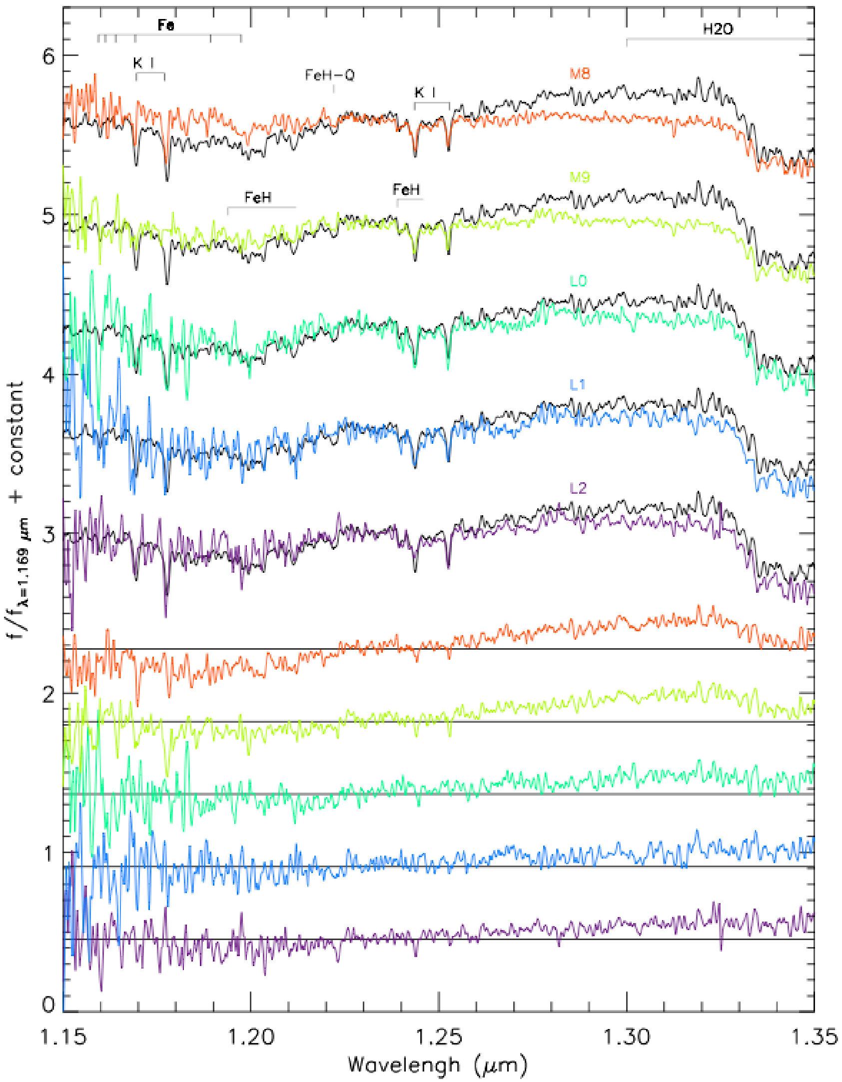


Plan

- Introduction
- 1. Observations and data reduction
- 2. Spectral type determination
- 3. Atmospheric parameters
- A planet or a brown dwarf ?

Spectral type

Mickaël Bonnefoy
LAOG
France



Comparison with the Lodieu et al. 2008 library: young M8-L2 dwarfs spectra at R~1400 from Upper Sco (5Myrs).

- χ^2 minimum for L0 in the 3 bands.
- Comparison of the absorptions

↓

Spectral type: L0 ± 1

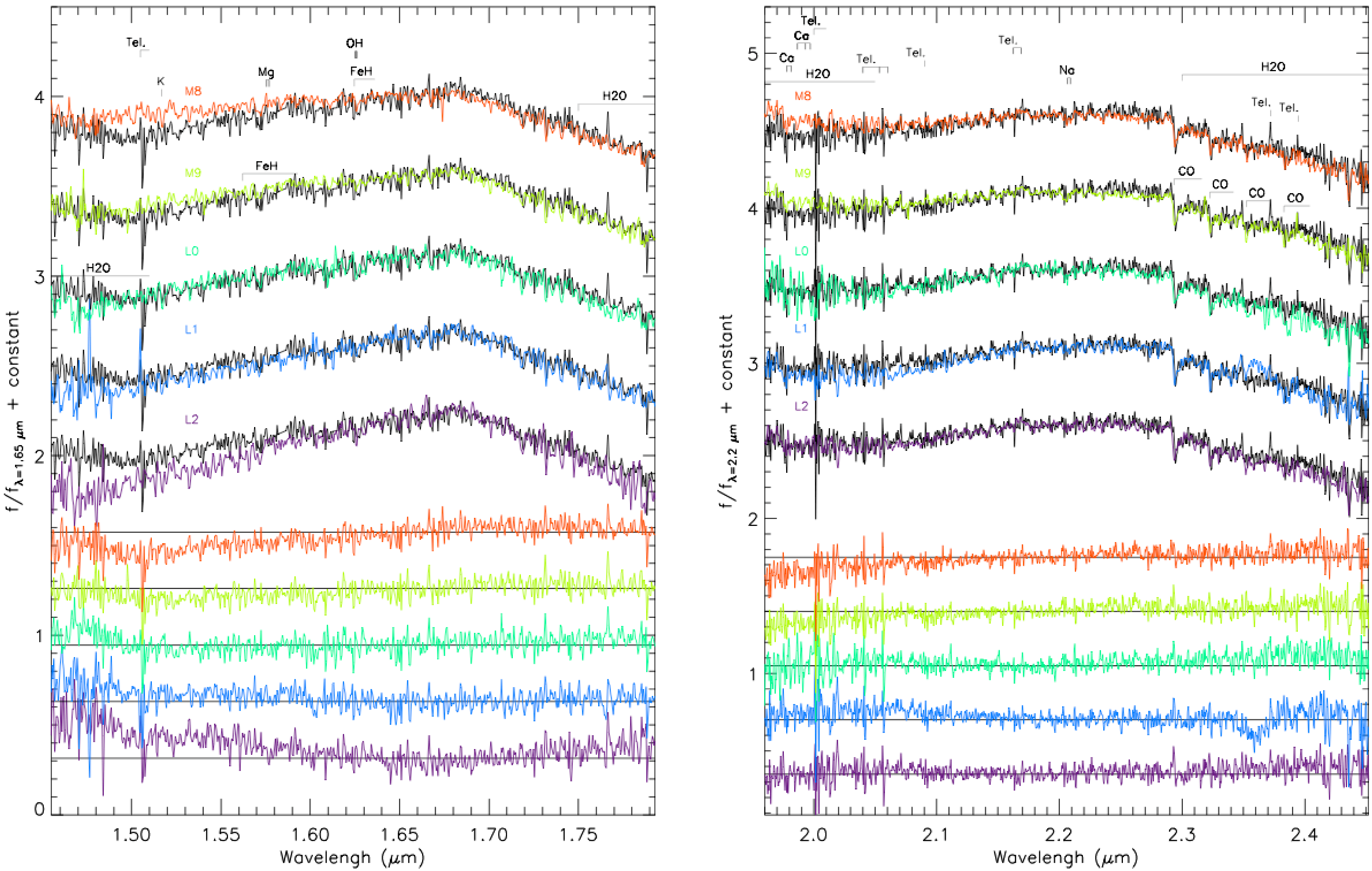
Chauvin et al. (2005): $L1^{+2}_{-1}$

Planet Formation and Evolution

05/03/2009

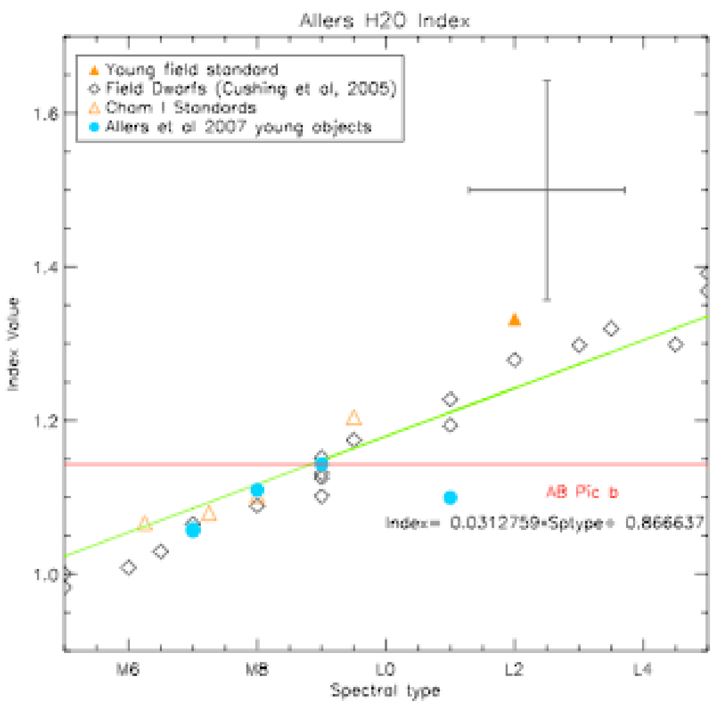
Spectral type

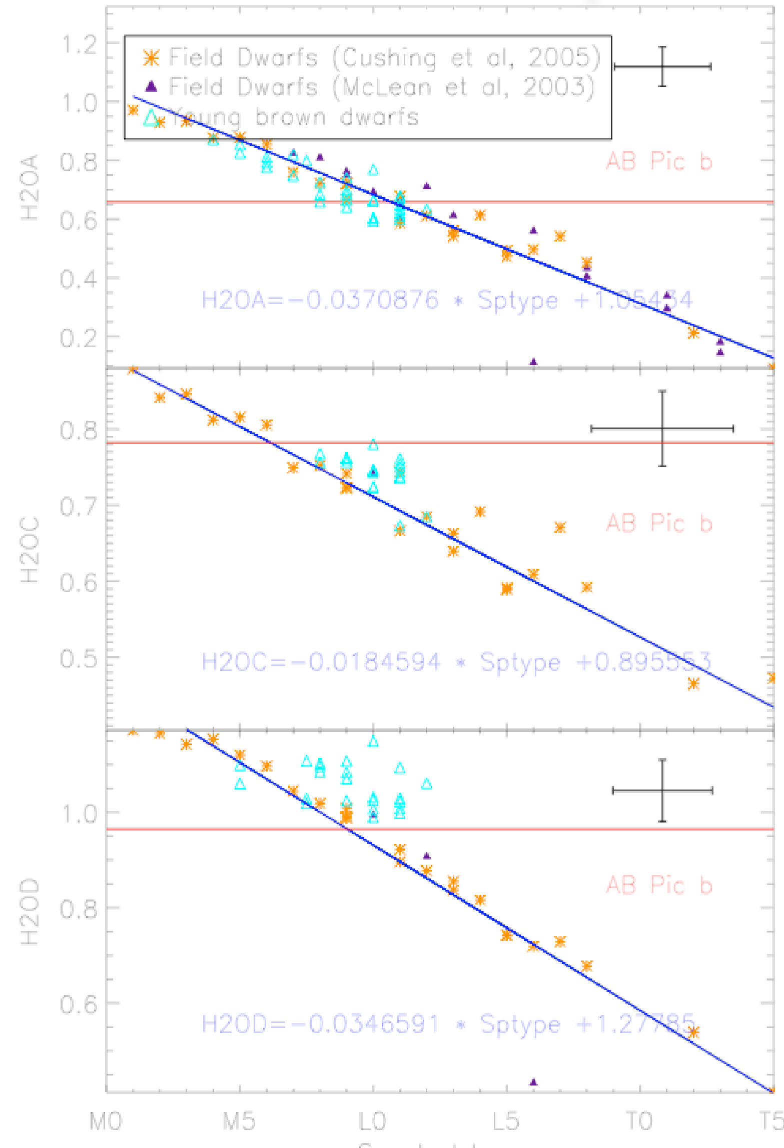
Mickaël Bonnefoy
LAOG
France



Spectral type

Mickaël Bonnefoy
LAOG
France

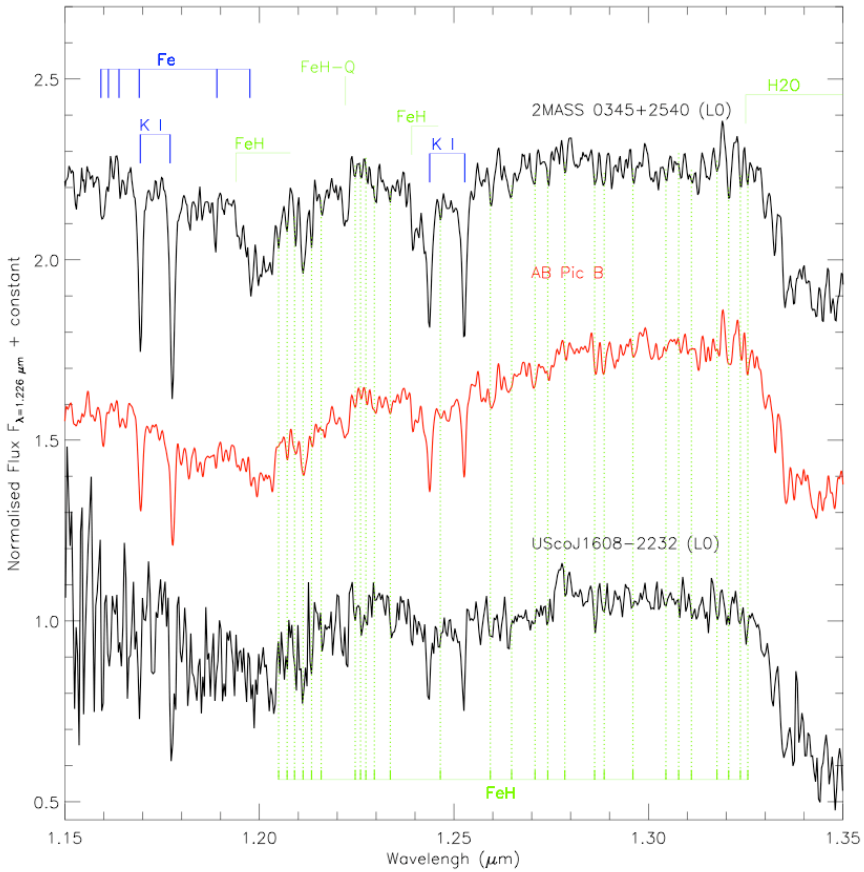




Spectral type

Mickaël Bonnefoy
LAOG
France

Evident signs of youth:



- Triangular shape in the H-band
- Reduced depth of alkalis lines (Na I, K I)
- Reduced depth of FeH absorptions.
- Rounded K-band.

↓

Log(g) < 5-5.5 dex (field dwarfs)

Plan

Mickaël Bonnefoy
LAOG
France

Atmospheric parameters

Mickaël Bonnefoy
LAOG
France

Young L0 dwarf

↓

Comparison to Teff-Spectral type scales predictions:

- Luhman et al. 2003: Teff < 2400 K
- Golimowski et al. 2004: Teff = 2300 ± 100 K.
- Lodieu et al. 2008: 2000 K < Teff < 2400 K
- Kirkpatrick et al. 2006: 2M0141 (L0pec) has Teff=2000 K

Comparison of surface gravities:

- Primary: log(g)=4.69 ± 0.5 dex (Mentuch et al. 2008)
- M dwarfs Upper Sco: 3.5-4 (Mohanty et al. 2004)

Atmospheric parameters

Mickaël Bonnefoy
LAOG
France

Comparison with synthetic spectral grids:

✓ **DUSTY (Allard et al. 2001).**

Log(g)=3.5-6 dex, Δlog(g)=0.5 dex

Teff=1700K - 2700 K. ΔTeff=100 K.

✓ **SETTL08 (Homeier, private com.)**

Log(g)=4.0-5.5 dex, Δlog(g)=0.5 dex

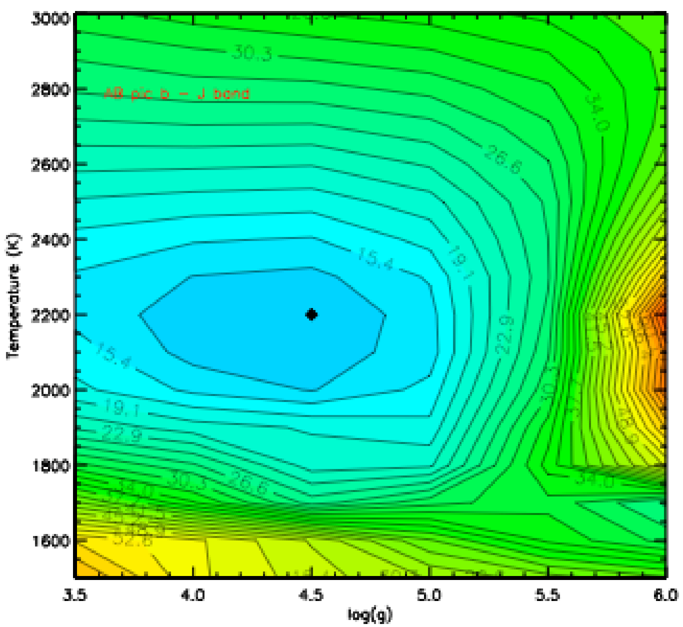
Teff=400K - 2400 K. ΔTeff=100 K.

Atmospheric parameters

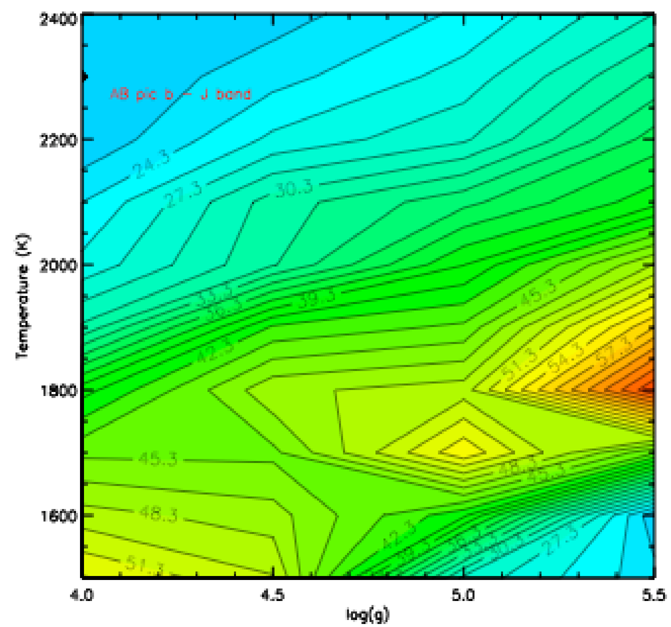
Mickaël Bonnefoy
LAOG
France

Criterions used:

1) Mask on the 1.1-1.32 μm and 1.75-2.2 regions.
2) Fit of the J-band.
3) Confirmation of the surface gravity from the comparison of equivalent width of Na I @ 1.138 μm and K I @ 1.169, 1.177, 1.243 and 1.253 μm.



DUSTY00



SETTL08

Atmospheric parameters

Mickaël Bonnefoy
LAOG
France

Preliminary results:

Teff=2200 ± 100 K and log(g)=3.5-4.5

Comparison to Teff-Spectral scales predictions:

- Luhman et al. 2003: Teff < 2400 K
- Golimowski et al. 2004: Teff = 2300 ± 100 K.
- Lodieu et al. 2008: 2000 K < Teff < 2400 K
- Kirkpatrick et al. 2006: 2M0141 (L0pec) has Teff=2000 K

Comparison of surface gravities:

- Primary : log(g)=4.69 ± 0.5 dex (Mentuch et al. 2008)
- M dwarfs Upper Sco: 3.5-4 (Mohanty et al. 2004)

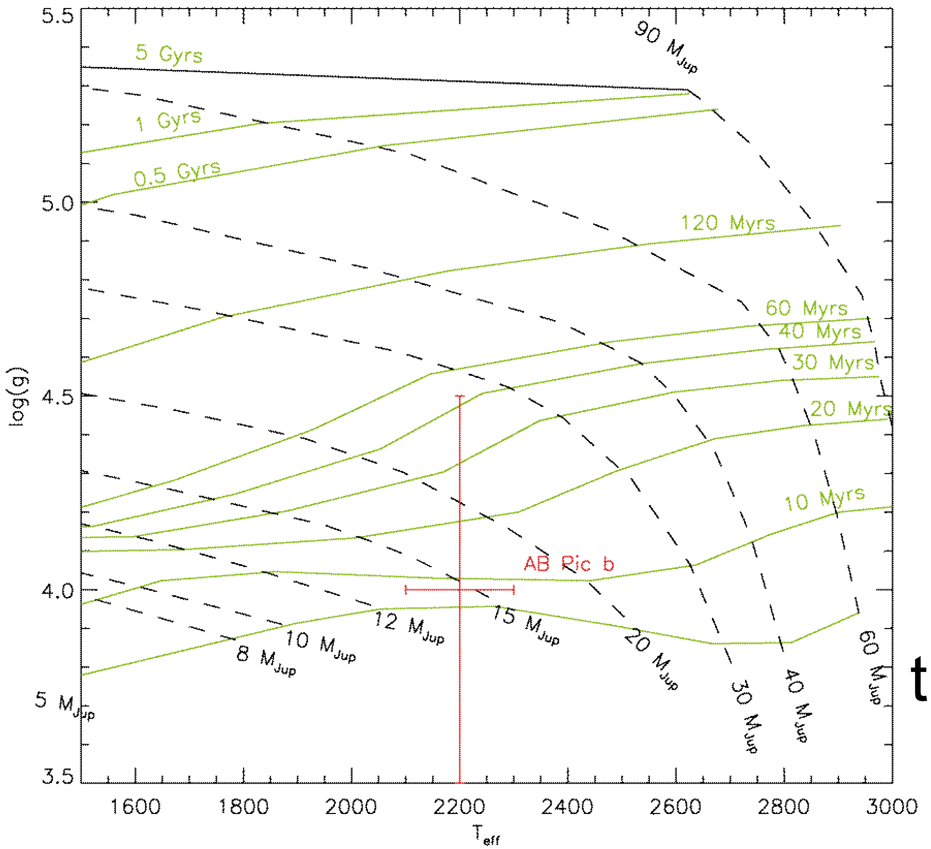
Plan

Mickaël Bonnefoy
LAOG
France

Planet or brown dwarf ?

Mickaël Bonnefoy
LAOG
France

L0 ± 1 ⟶ $\mathrm{Log}(L/L_{\odot})$=-3.68 ± 0.11 dex



Does not allow to refine the status of the source…

But…

Temperature predicted from the photometry 400 K lower than that from our spectral fit…

Results in Bonnefoy et al. 2009, A&A, in prep.

Planet or brown dwarf ?

Mickaël Bonnefoy
LAOG
France

Synthesis:

- ✓J and H band spectra: young object !
- ✓Spectral type: L0 ± 1
- ✓ Log($L/L_{\odot}$)=-3.68 ± 0.11 dex
- ✓ Teff=2200 ± 100 K
- ✓ log(g)=4.0 ± 0.5 dex
- ✓ Mass still in agreement with the 13-14 Mjup mass from J, H, K.
- ✓Teff from photometry 400 K lower that from our spectral fit…

Results in Bonnefoy et al. 2009, A&A, in prep.

Thank you for your attention

For further question: mbonnefo@obs.ujf-grenoble.fr