Cloud Formation in the Atmospheres of Brown Dwarfs and Giant Planets

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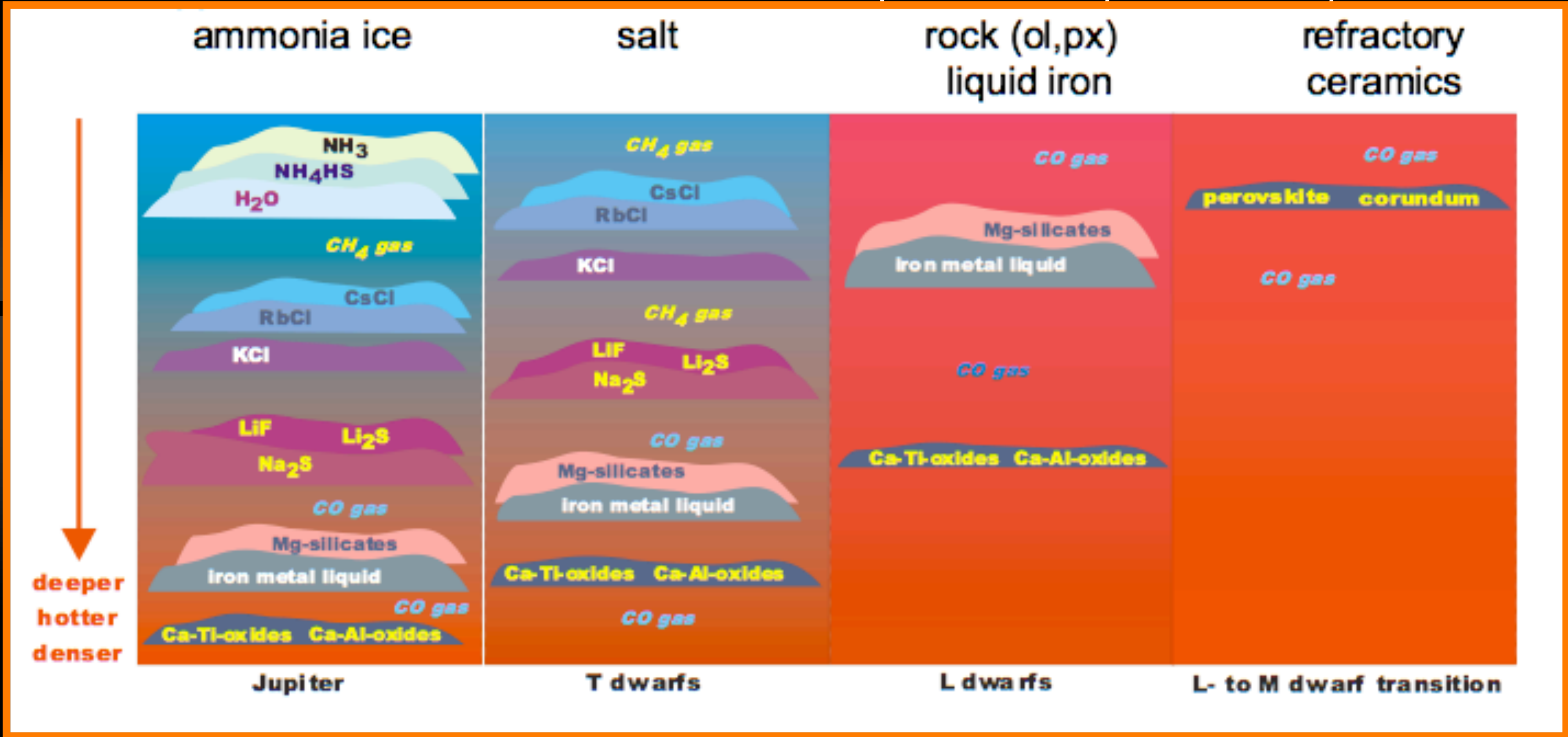
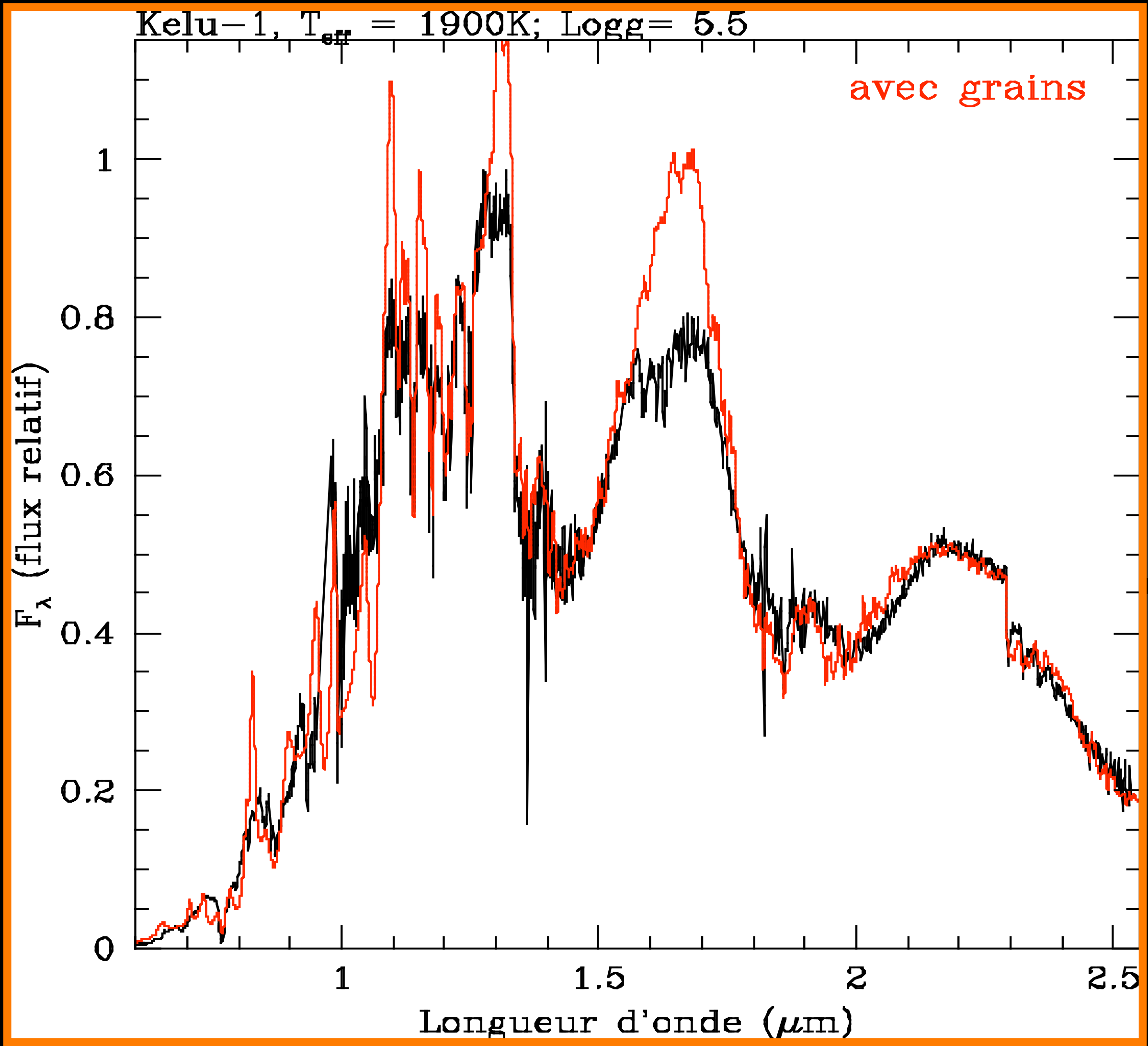
Clouds in brown dwarfs

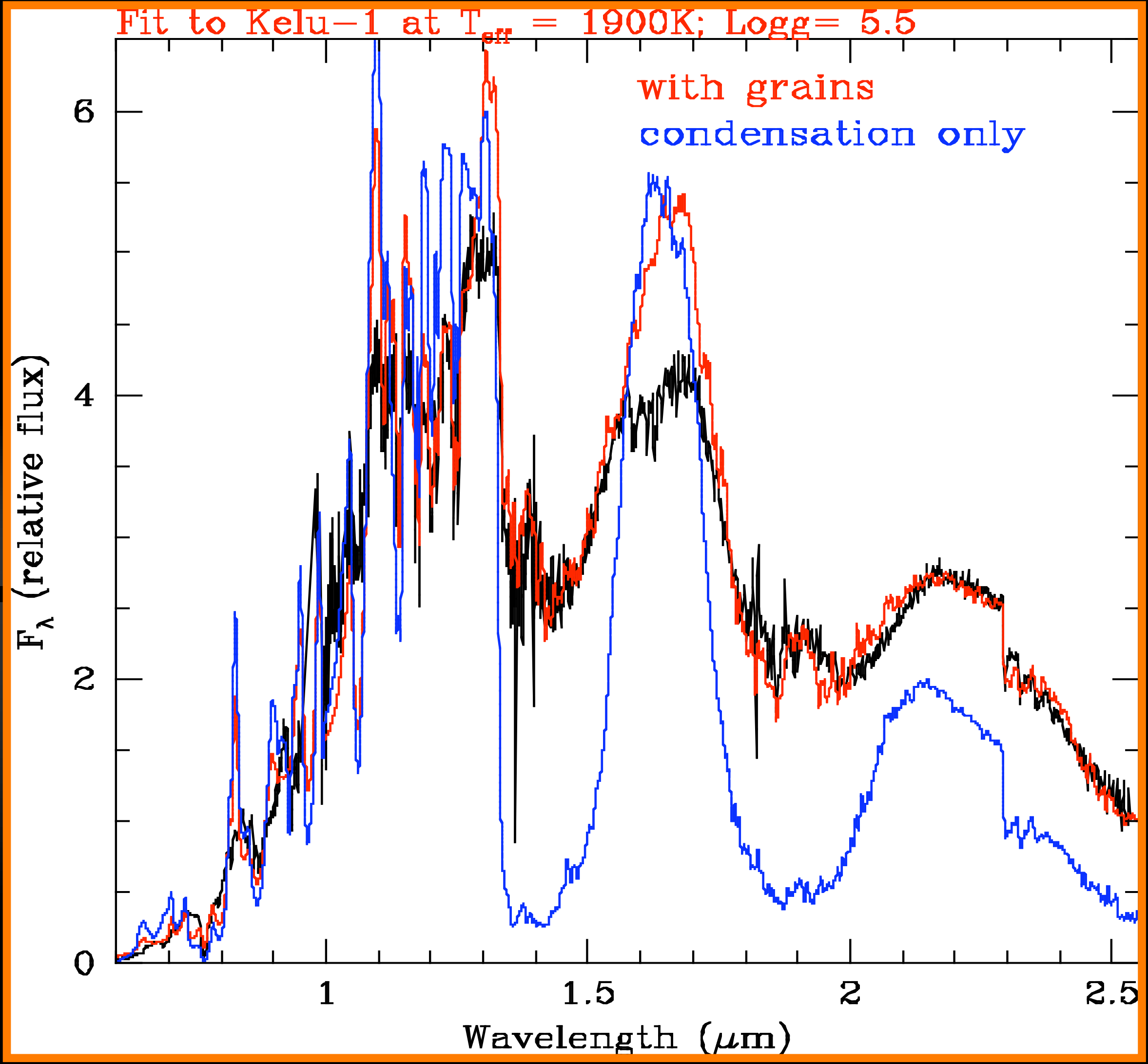
http://arxiv.org/abs/*astro-ph/0601381*



Fergley & Lodders, Astrophysics Update 2,
edited by John W. Mason. ISBN 3-540-30312-X.
Published by Springer Verlag, Heidelberg, Germany, 2006, p.1



Ruiz, Leggett & Allard (ApJ 491, L107, 1997)



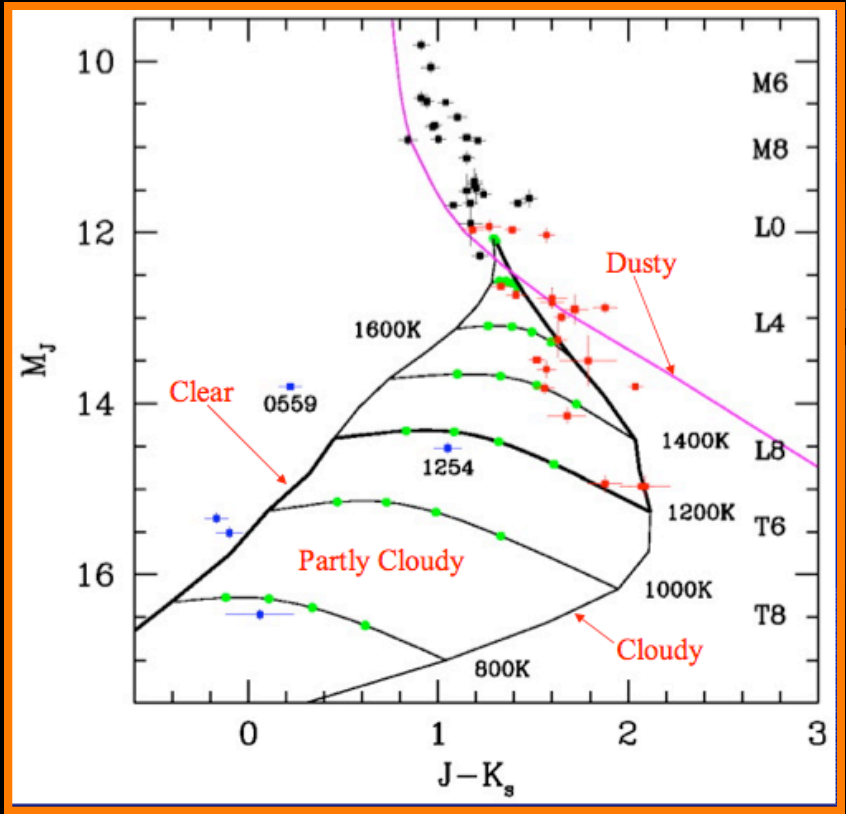
Ruiz, Leggett & Allard (ApJ 491, L107, 1997)

Cloud cover disruption?

Burgasser, Marley, Ackerman, Saumon et al. (ApJ 571, L151, 2002)

Burgasser et al (2002) suggest that the LT transition be due to a gradual break up of the cloud cover here illustrated by Ackerman & Marley (2001) Cloudy and Clear models representing full and none cloud cover respectively.

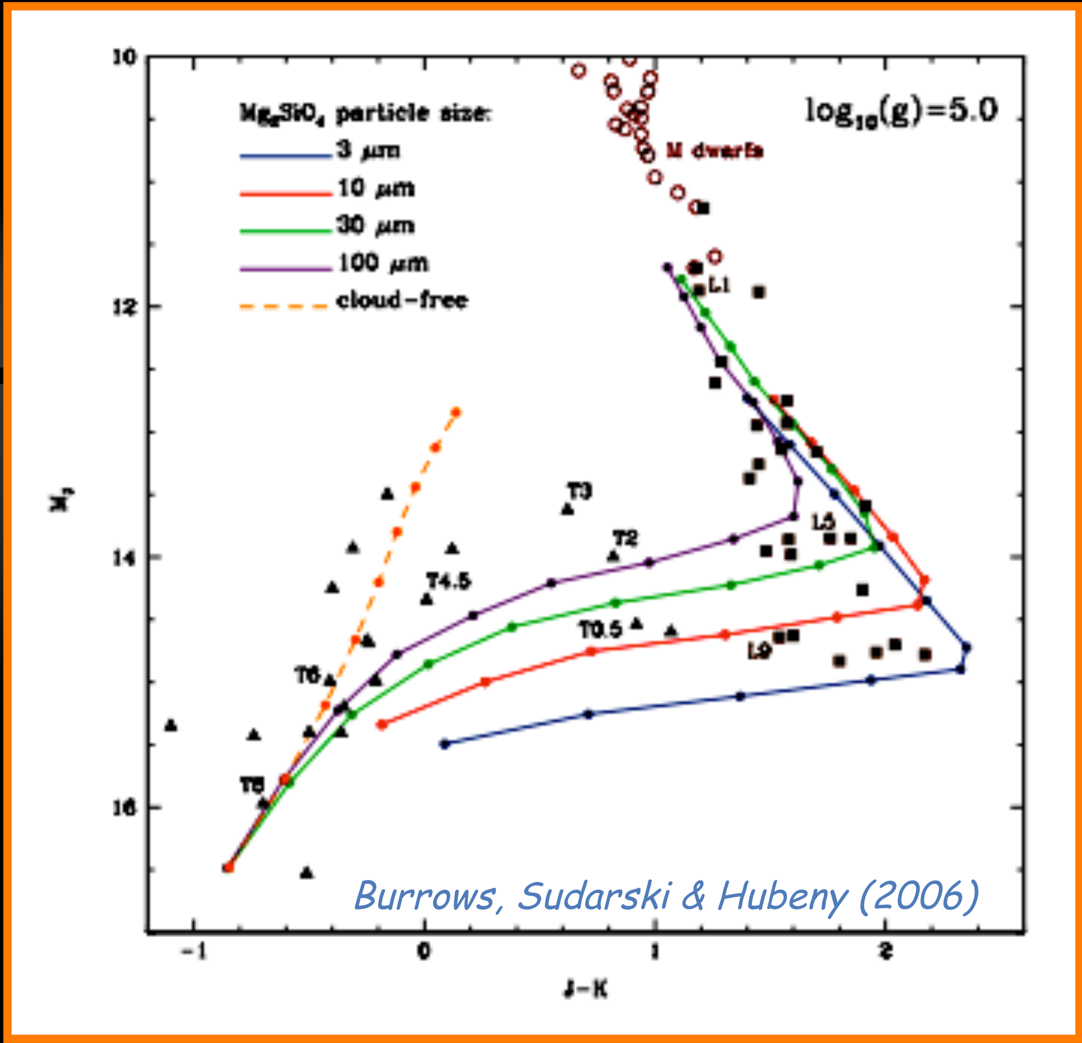
This disruption should lead to variability with rotation if the cloud holes are large enough, i.e. in early T dwarfs.



Effects of particle size

Models based on a single grain size. Here grain sizes are adjusted by hand from 3 to 100 μm to explore the effect on colours of brown dwarfs.

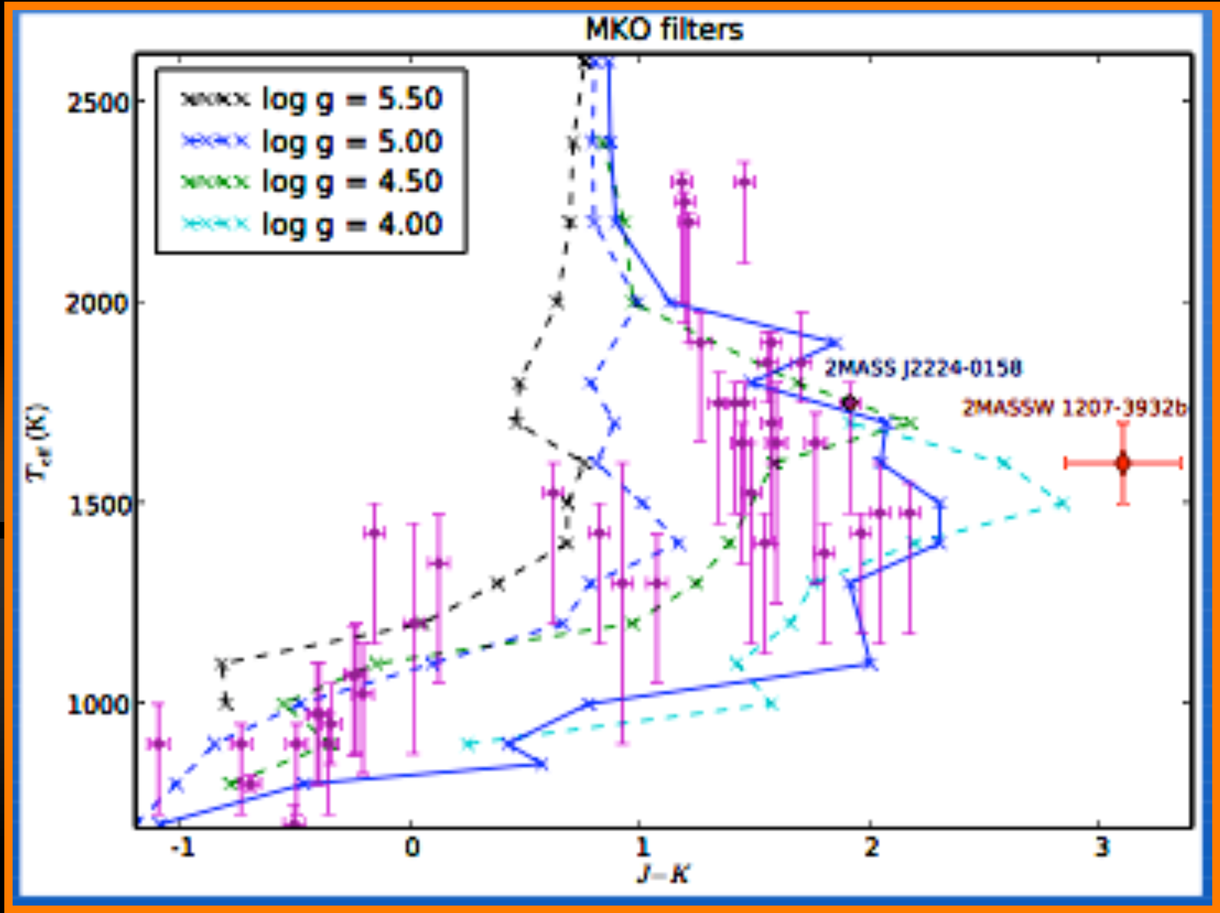
A detailed study by Cooper (2003) assuming that clouds form inside the convection region found grains to have a maximum size of 300 μm



Age, gravity scatter

Homeier & Allard'08

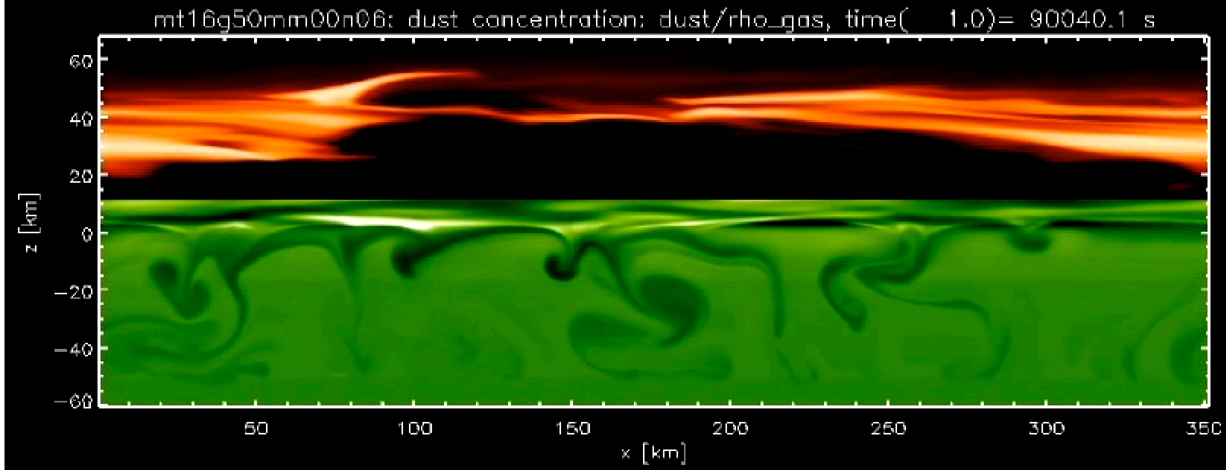
The scatter in the data can be explained by gravity differences tied to age and mass differences between the BDs

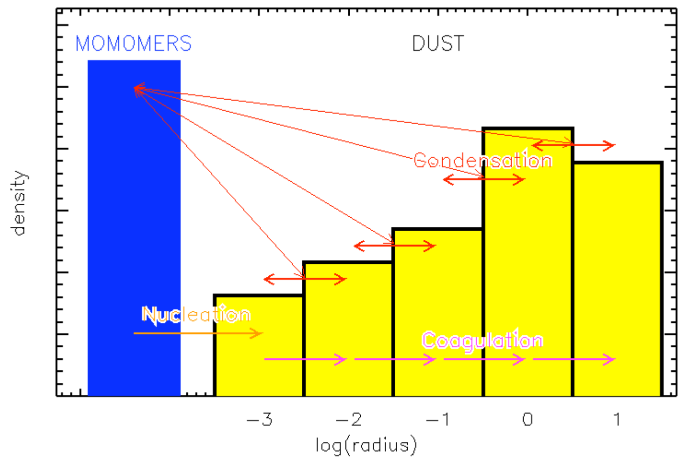


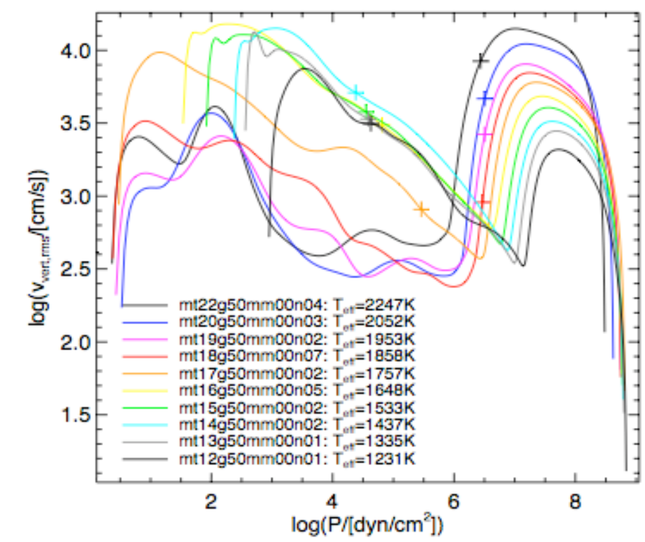
Colour-T_{eff} -diagram of L- and T-dwarfs with theoretical tracks calculated for Settl models without (dashed) and with extra convective instability due to the dust layers included. The known low-mass L dwarf 2MASS J2224−0158 and the new photometry for the planetary mass candidate 2MASS 1207334−393254B (Mohanty et al. 2006) are highlighted.

2D RHD simulations

Gravity Waves !!!







W350 x H80 km² over 36 hours

CO^5BOLD models (Bernd Freytag), gas and grains (Mg_2SiO_4) opacities from Phoenix, cloud model (dust size-bin distribution), nucleation, condensation, coagulation rates, and sedimentation velocity according to Rossow (1978).

Conclusions & Future prospects

- ✓ ***Gravity waves*** are responsible for turbulent mixing and cloud formation in brown dwarf atmospheres
- ✓ ***3D*** RHD simulations accounting for ***rotation*** are necessary to determine the surface distribution of clouds
- ✓ Applications to planets, i.e. accounting for ***impinging radiation***

⇒ see Bernd Freytag's talk Friday 8h30!

Web Simulator

ONLINE!

- Offers synthetic spectra and thermal structures of published model grids and the relevant publications.
- Computes synthetic spectra, with/without irradiation by a parent star, and photometry for:
  - ✓ main sequence stars
  - ✓ brown dwarfs (1 Myrs - 10 Gyrs)
  - ✓ extrasolar giant planets
  - ✓ telluric exoplanets
- Or compute isochrones and finds the parameters (interior/evolution and atmospheric) of a specified star by chi-square fitting to the isochrones
- Rosseland/Planck as well as monochromatic opacity tables calculations

http://phoenix.ens-lyon.fr/simulator

CRA Lyon

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PHOENIX

Star, Brown Dwarf & Planet Simulator

Choose the physics required:

NextGen '99

MODEL SPECTRA

ISOCHRONE χ^2-fitting

These models are available (via the links below with grey backgrounds) and have been published in the following papers:

• NextGen	Gas phase only, valid for $T_{eff} > 2700$ K	Allard et al. '97 Baraffe et al. '97 Baraffe et al. '98 Hauschildt et al. '99
• AMES-Dusty	Dust in equilibrium with gas phase, "valid" for Near-IR studies with $T_{eff} > 1700$ K	Allard et al. '01 Chabrier et al. '00
• AMES-Cond	Same as AMES-Dusty with dust opacities ignored, "valid" for $T_{eff} < 1700$ K	Allard et al. '01 Baraffe et al. '03
• BT-Settl	With a cloud model, valid across the entire parameter range	Allard et al. '07

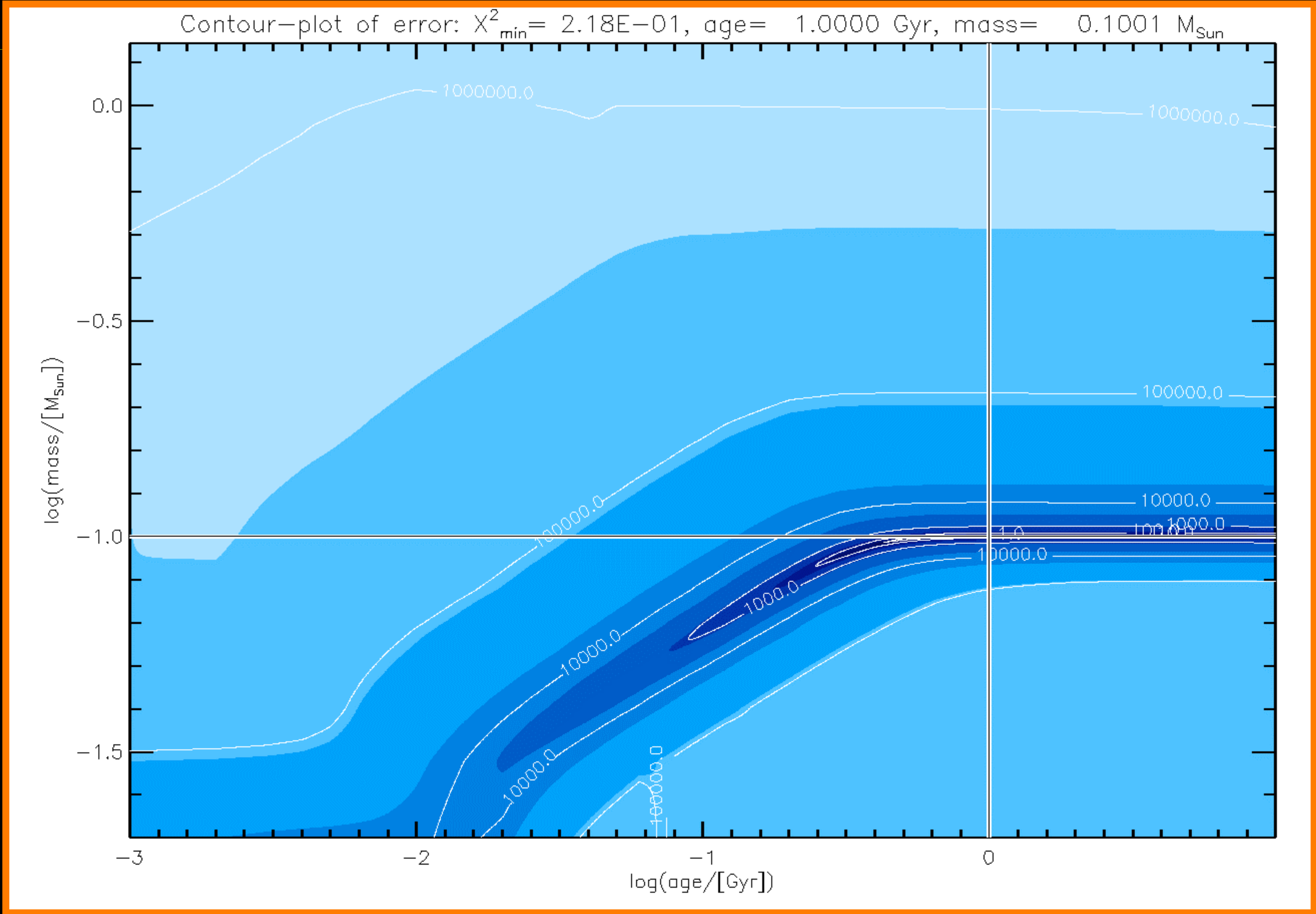
Enstatite ($MgSiO_3$)

Return to France Allard's web page

M dwarf case (2800K)

Using: NextGen (5Gyrs, 0.10$M_\odot$)

I, J and K absolute mags



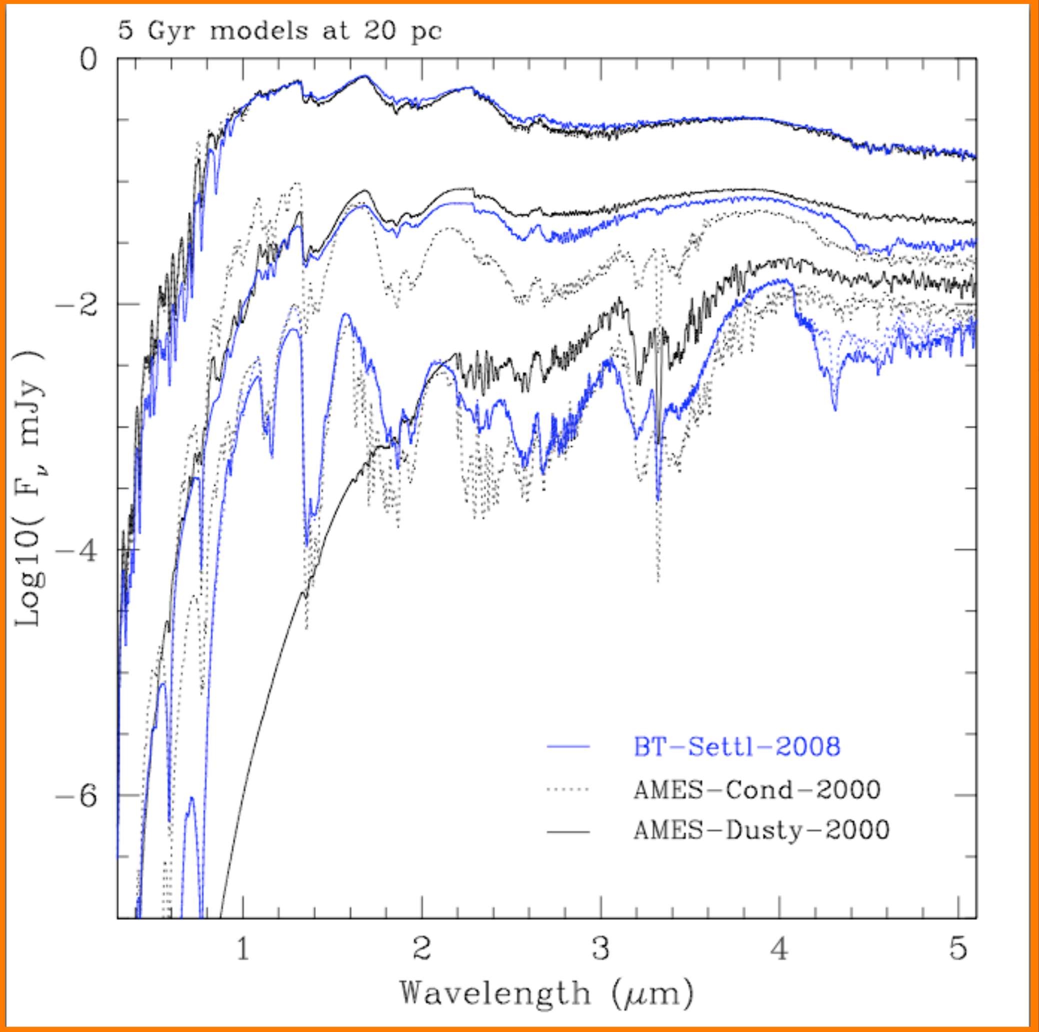
BT-Settl-2008 vs AMES-Cond/Dusty-2001

Opacity updates:

- ✓ BT vs AMES H2O,
- ✓ revised Q(TiO),
- ✓ fels of VO & FeH bands,
- ✓ detailed alkali line profiles,
- ✓ mie scattering of dust
- ✓ cloud model
- ✓ mixing by gravity waves
- ✓ molecular diffusion

Gravity waves yield sufficient mixing (to compensate sedimentation) in the water vapor line forming region of L dwarf atmospheres !

⇒ efficient greenhouse effects

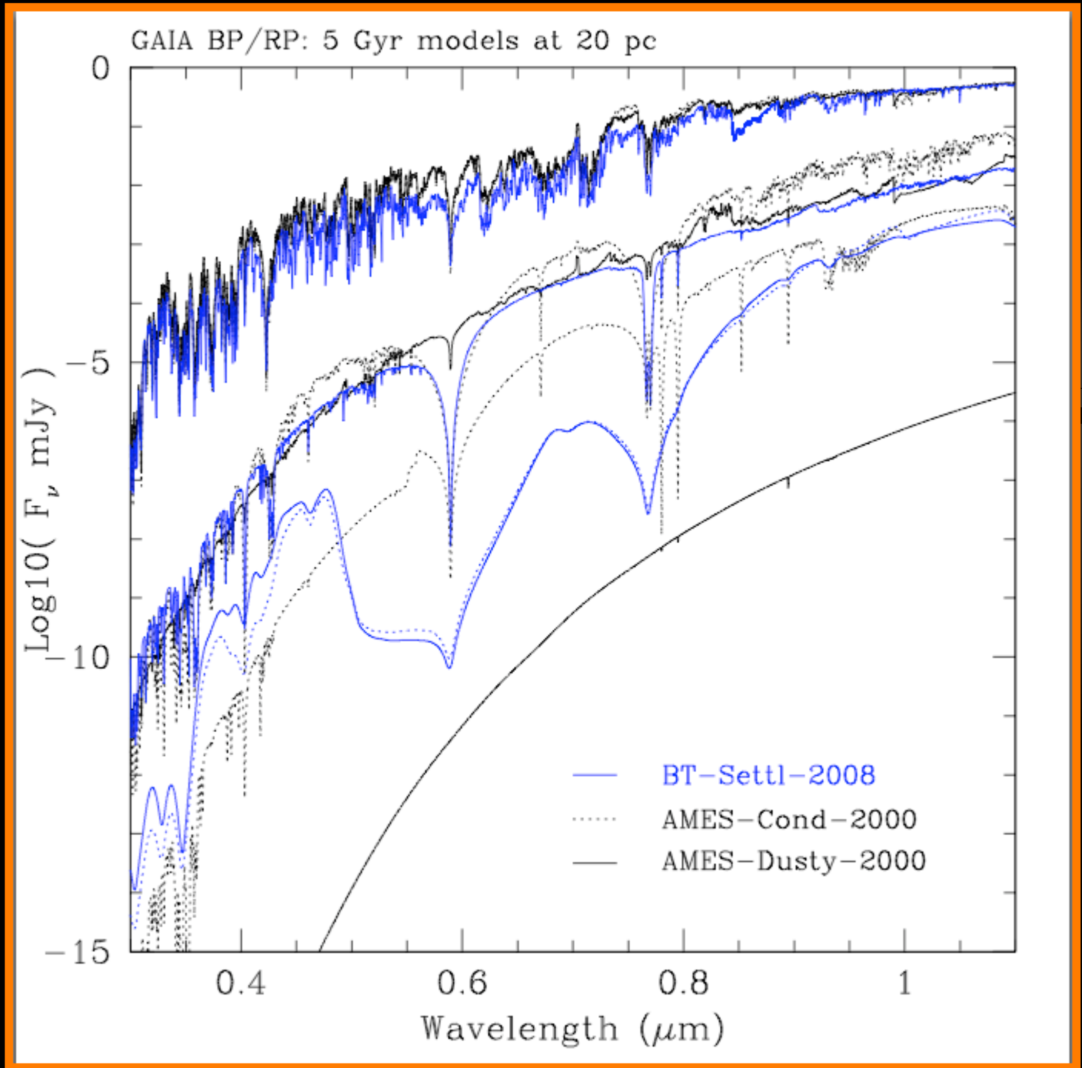


BT-Settl-2008 vs AMES-Cond/Dusty-2001

The upper atmosphere is more depleted in Settl models then in Dusty models, causing

✓ a more transparent line centre forming region similar to Cond model predictions,

✓ a more opaque continuum forming region similar to Dusty model predictions.



Pressure-induced Quasi-molecular K-H_2

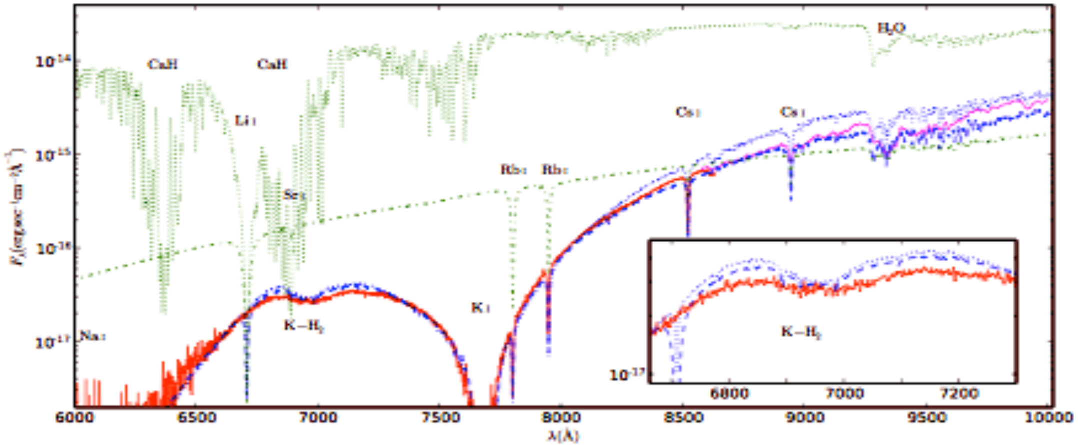
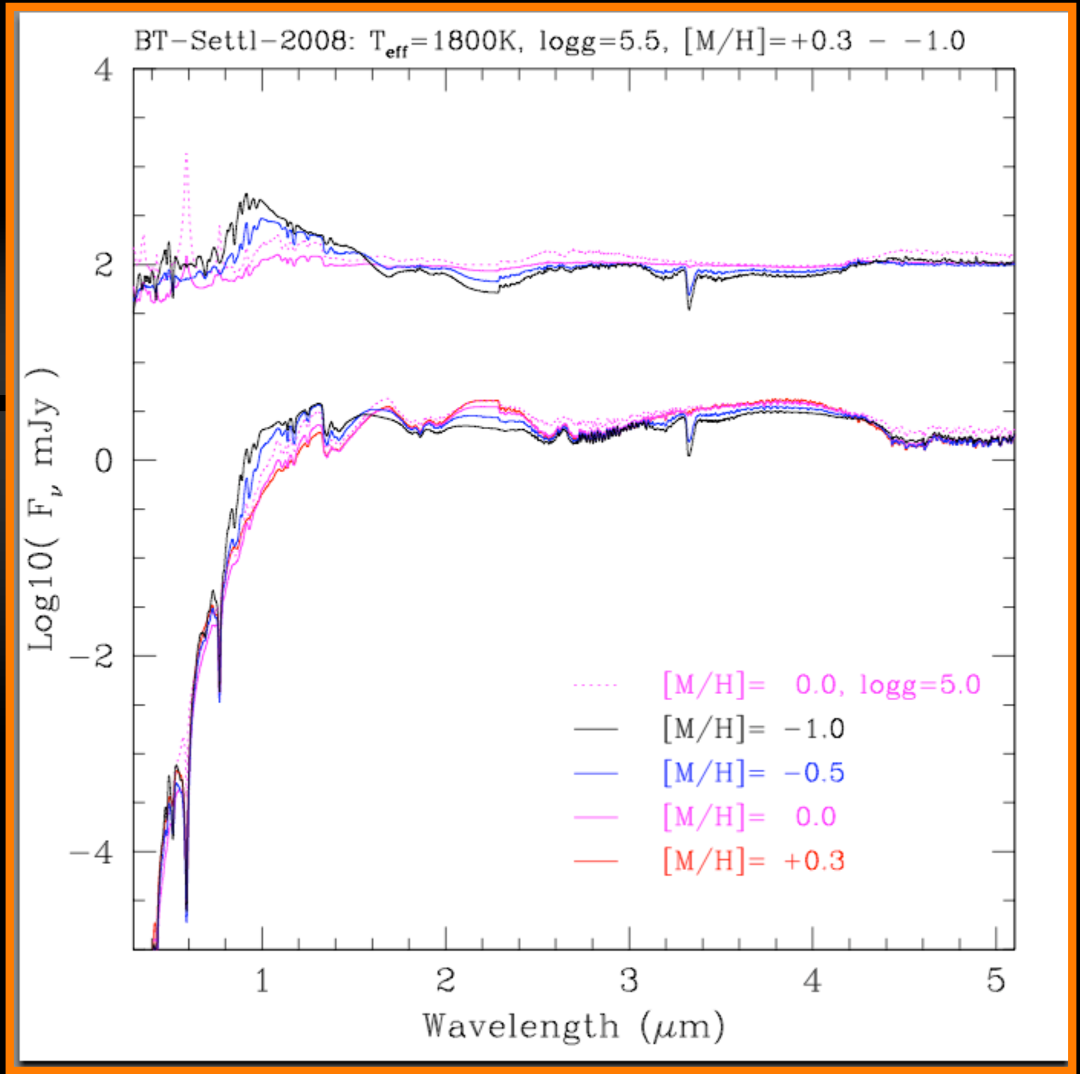


Fig. 1. FORS2 red optical spectrum of the T1 dwarf ε Indi Ba (solid), compared to our synthetic spectra for a 1.3 Gyr (dashed) and 2 Gyr (dotted) model. To highlight the various sources of opacity, spectra obtained when the K and Na D doublets are omitted (dot-dashed), and when dust grains involving Ca and other refractory species are prevented from forming and raining out (upper dotted line) are also shown. All molecular bands but CaH and H_2O have been omitted from the latter spectrum for clarity. The EFOSC spectrum of ε Indi Ba,b is shown from 8600–10 000 Å (light [magenta] solid line) against a composite model of both T dwarfs.

a) Red optical spectrum of the T1 dwarf ε Indi Ba (solid), compared to models for a 1.3 Gyr (dashed) and 2 Gyrs (dotted). Spectra obtained when the K and Na D doublets are omitted (dot-dashed), and when dust grains involving Ca and other refractory species are prevented from forming and raining out (upper dotted line) are also shown. b) Same models where CaH has been remove to show its effect compared to field dwarf spectra from L2 to T.

BT-Settl-2008: metallicity effects

A brightening of the Z and J band flux due to a decrease of dust abondances.



BT-Settl-2008: metallicity effects