Alkali Line Profiles in Degenerate Dwarfs

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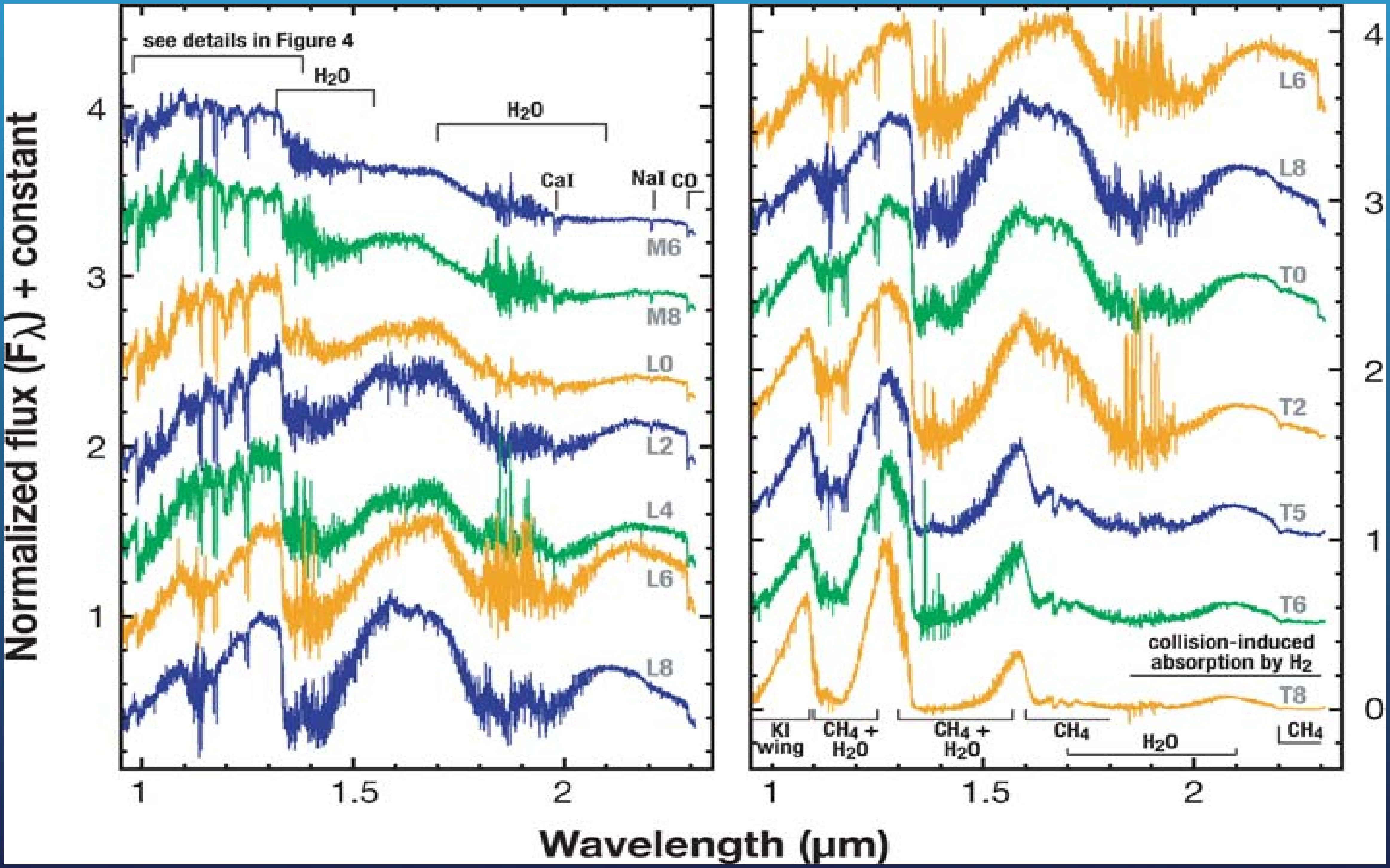
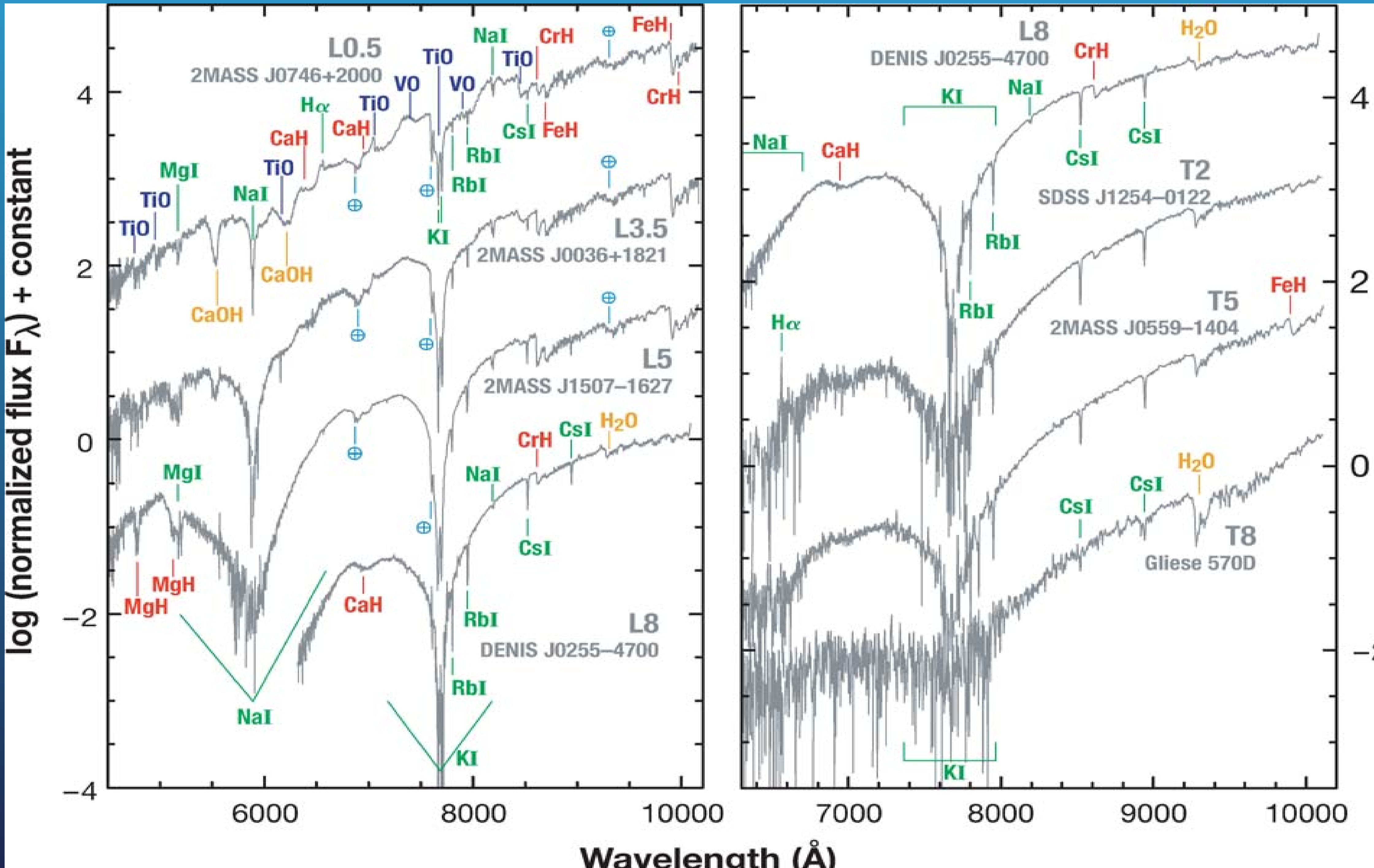
Ultracool Dwarfs



Kirkpatrick 2005

Ultracool Dwarfs



- Extremely reddened optical/near-IR spectrum of late L and T dwarfs ➙ dust or other opacity source?

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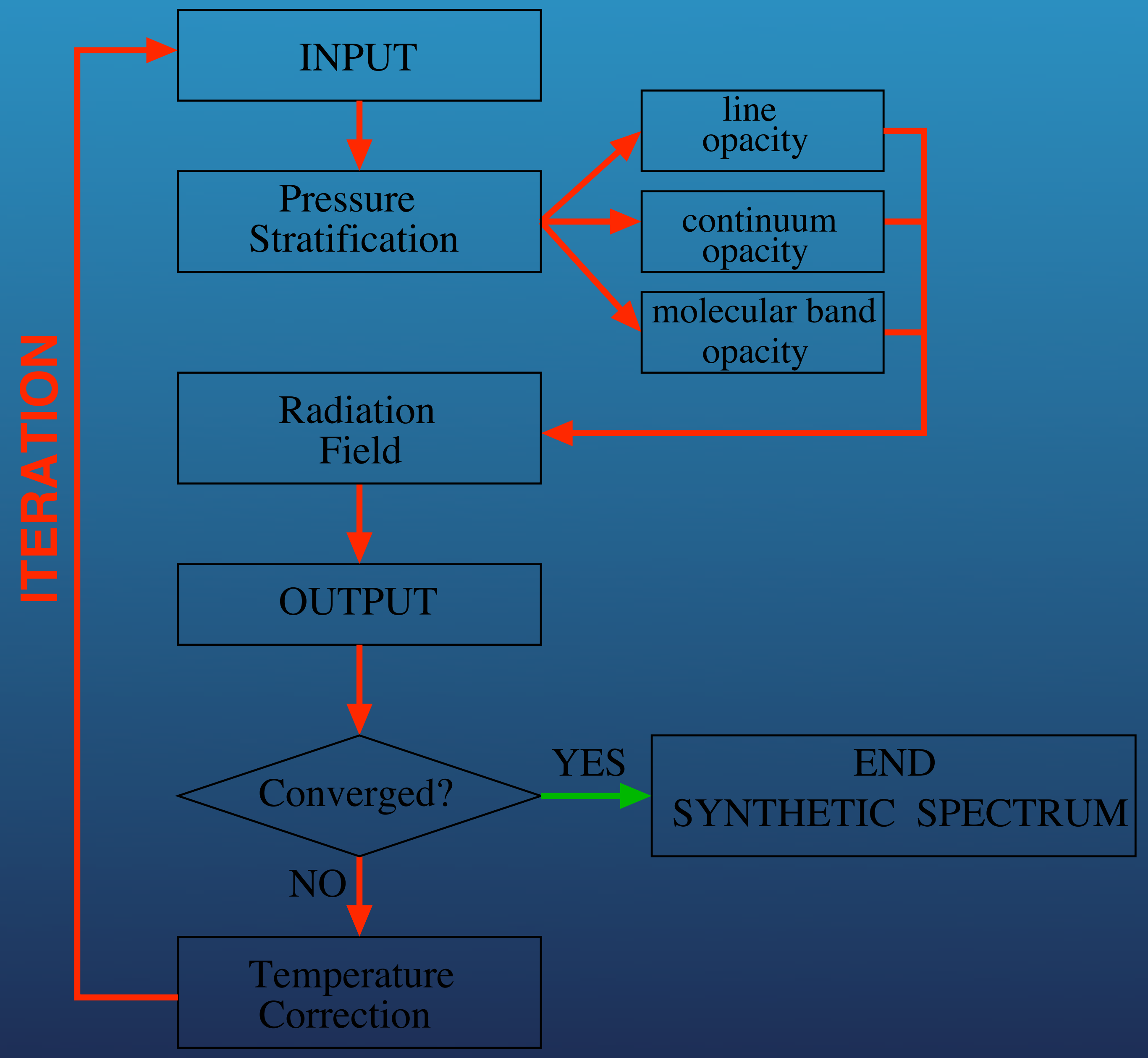
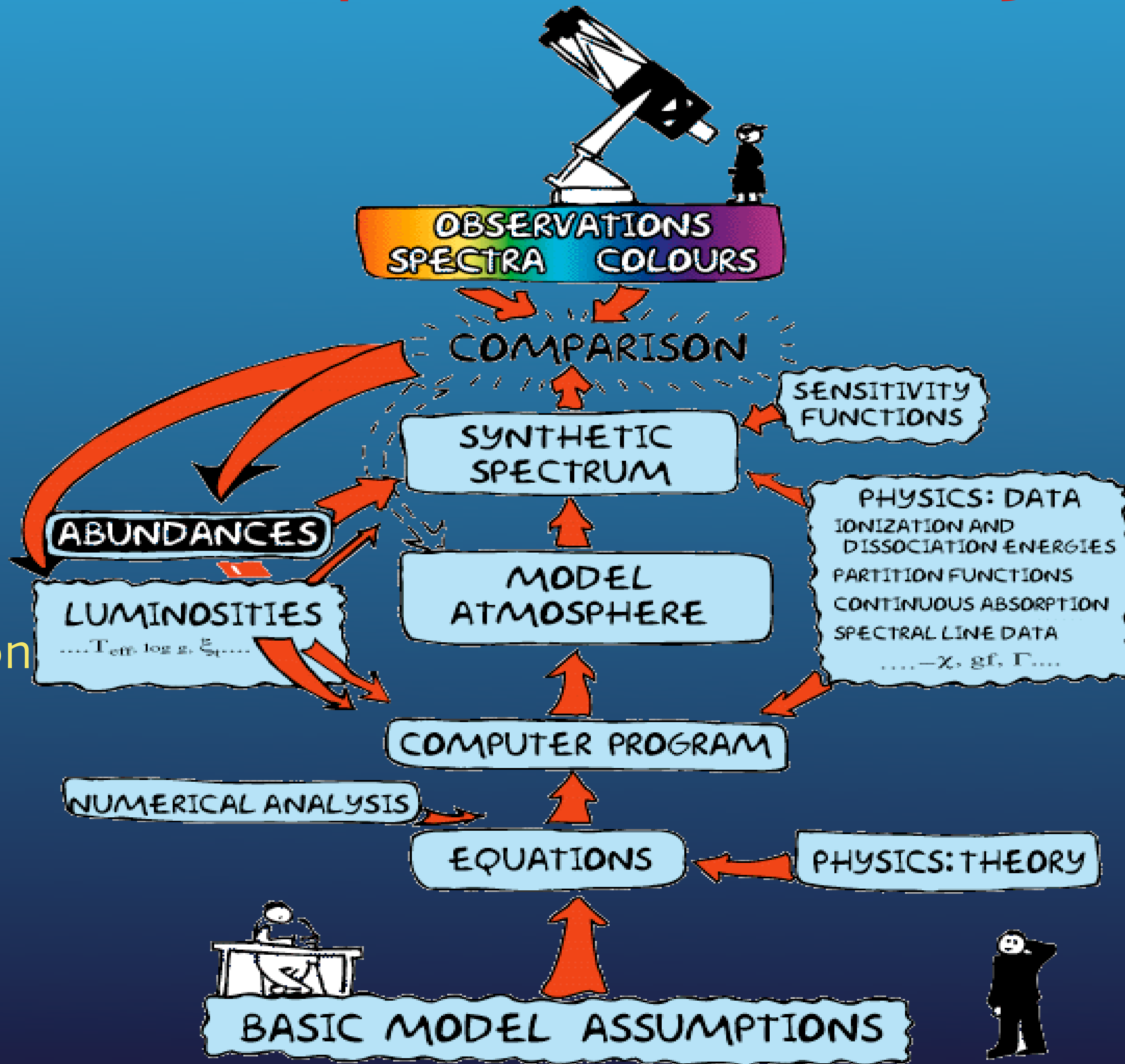
(Sub-)stellar atmosphere modelling

- independent Variables (minimal):
  - effektive temperature T_{eff}
  - surface gravity $g(r) = GM/r^2$
  - mass M or radius R or luminosity $L = 4 \pi R^2 \sigma T_{eff}^4$



(Sub-)stellar atmosphere modelling

- Radiative transfer solution provides thermal structure to determine
  - gas phase physics (ionisation/occupation ratios)
  - chemistry (partial pressures, condensation)



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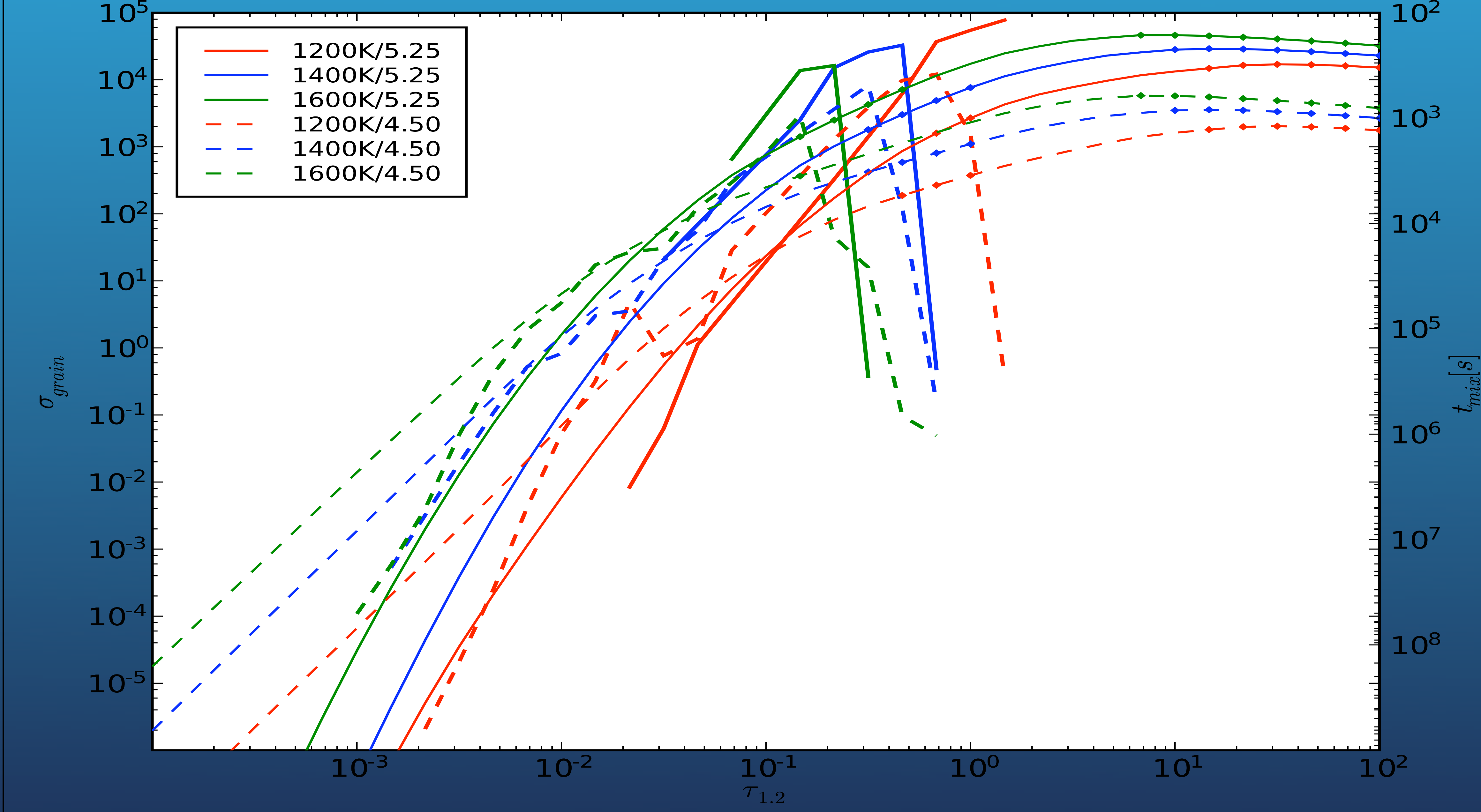
BD Models — Cloud Opacity



- Dust clouds need to be sustained by turbulent mixing.
- Visible clouds have to be supported by convective overshoot.
- Cloud layer recedes from the photosphere in T dwarfs.
- Atomic and molecular lines becoming more important.

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Brown Dwarfs — Line Absorption

- Most atoms in ground state, little contribution at longer wavelengths
- Spectral energy distribution shifts toward IR
- Importance of molecular bands dependent on
  - Line strengths → *gf*, abundances, chemistry
  - Line shapes
  - Line numbers
  - Line distribution
- Bands with complex spectra (polyatomic molecules) produce strongest blanketing effects.

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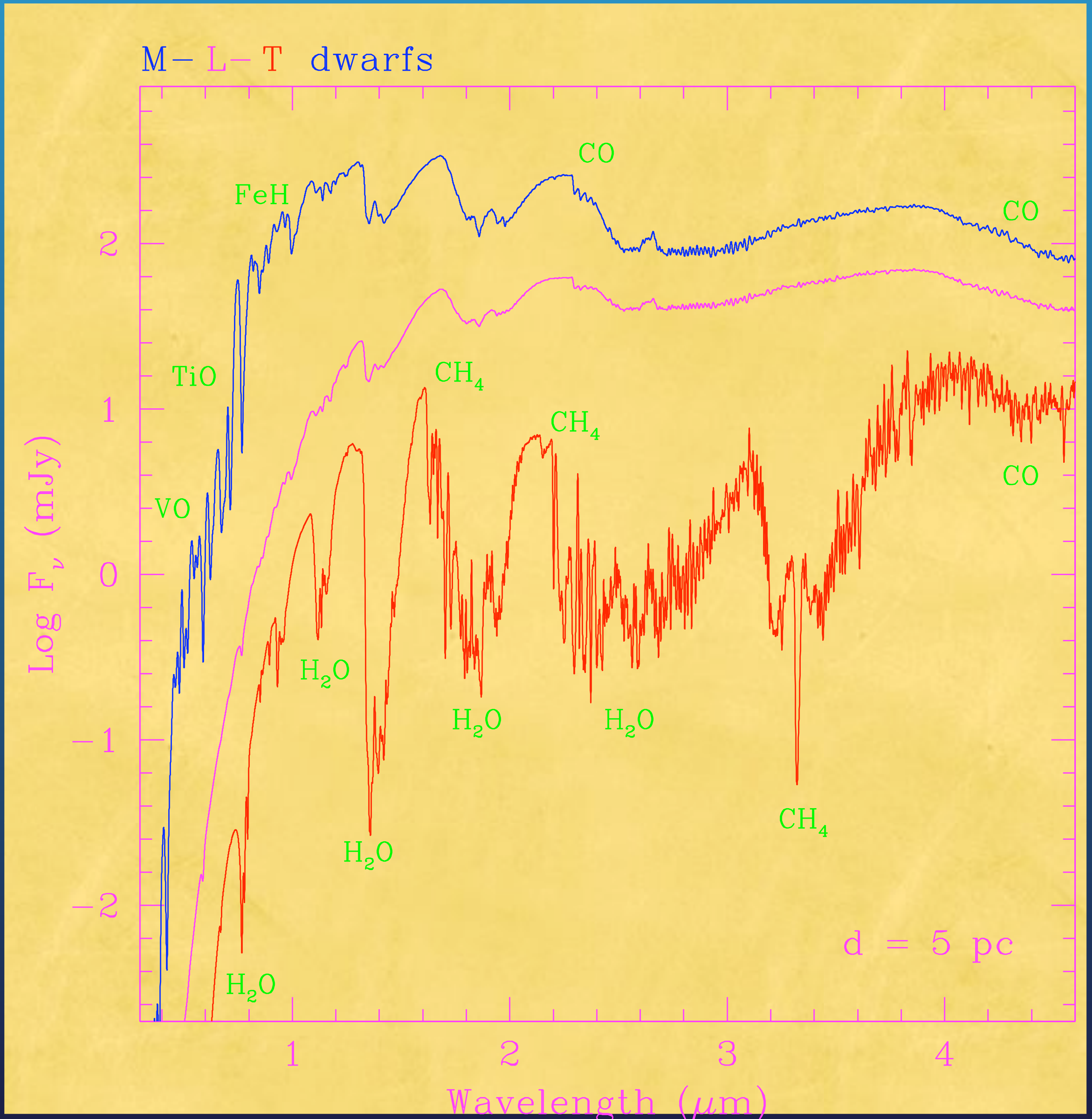
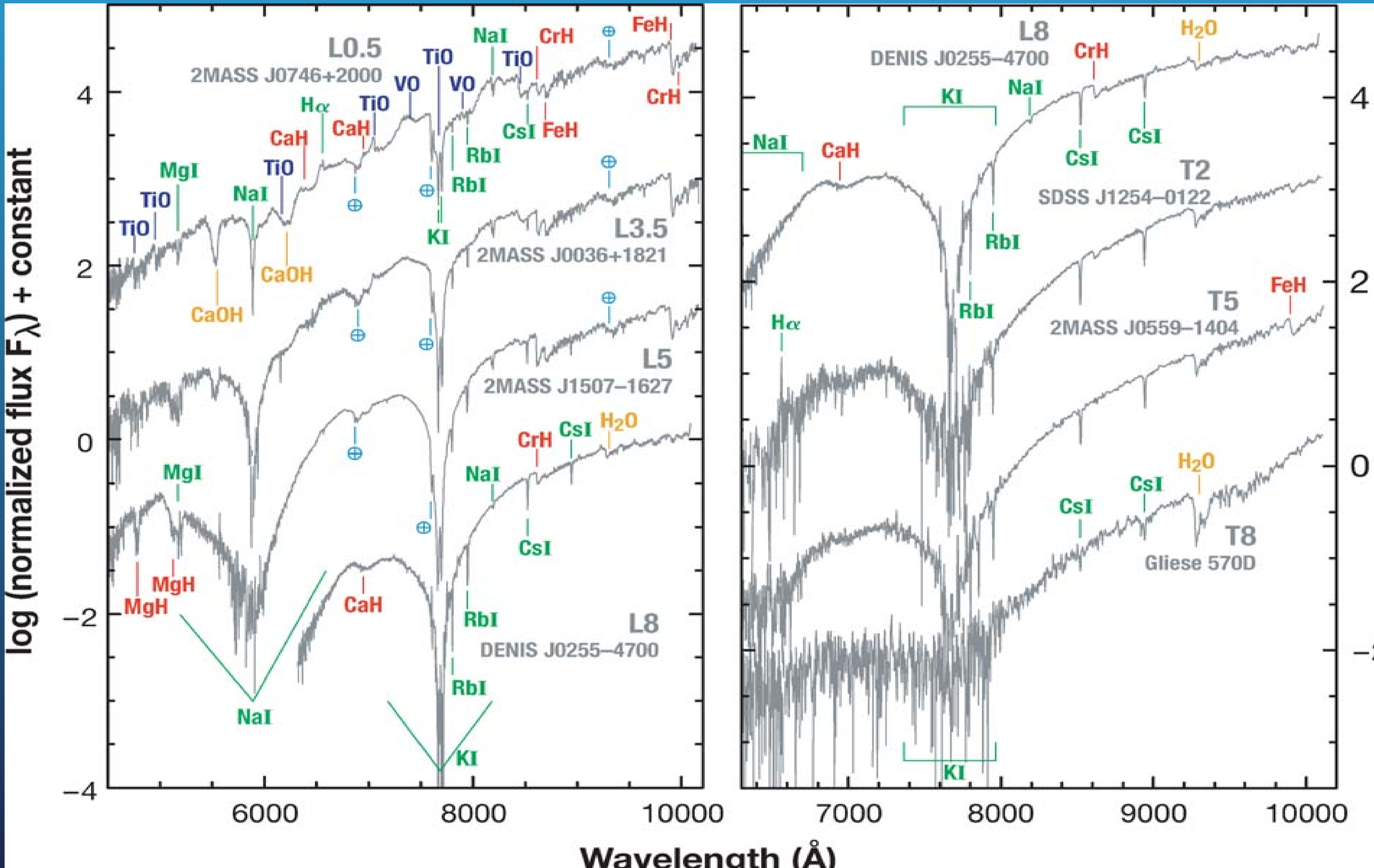
Ultracool Atmosphere Models

- Coming and going of dust clouds explains the M-L-T spectra (Allard et al. 2001)
  - Molecules: 3500-2500 K
  - Dust: 2500-1500 K
  - CH4: 1500-500 K



T Dwarfs — Dust-free atmospheres



- No visible dust → Massive alkali line broadening responsible for optical/near-IR absorption

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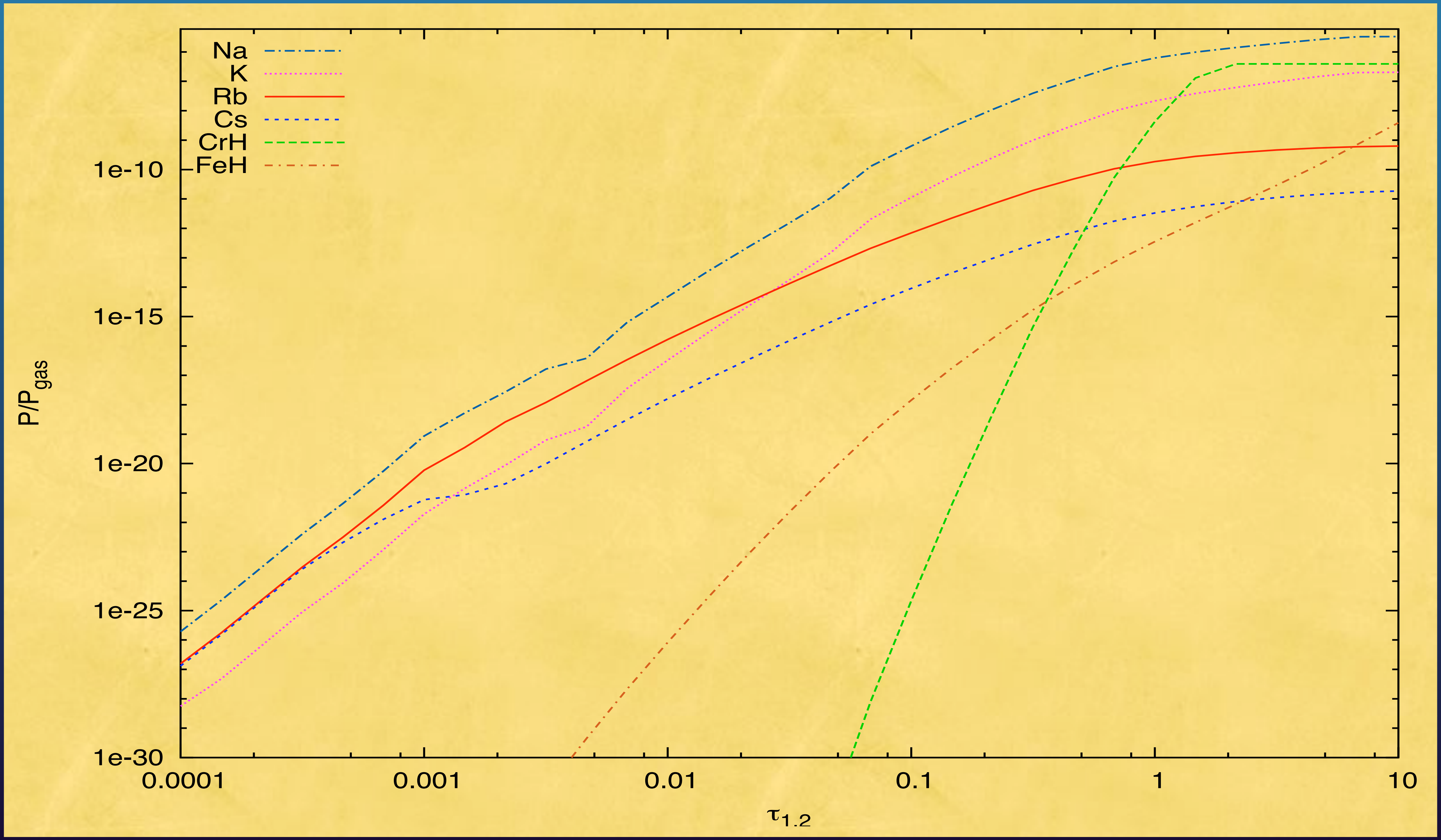
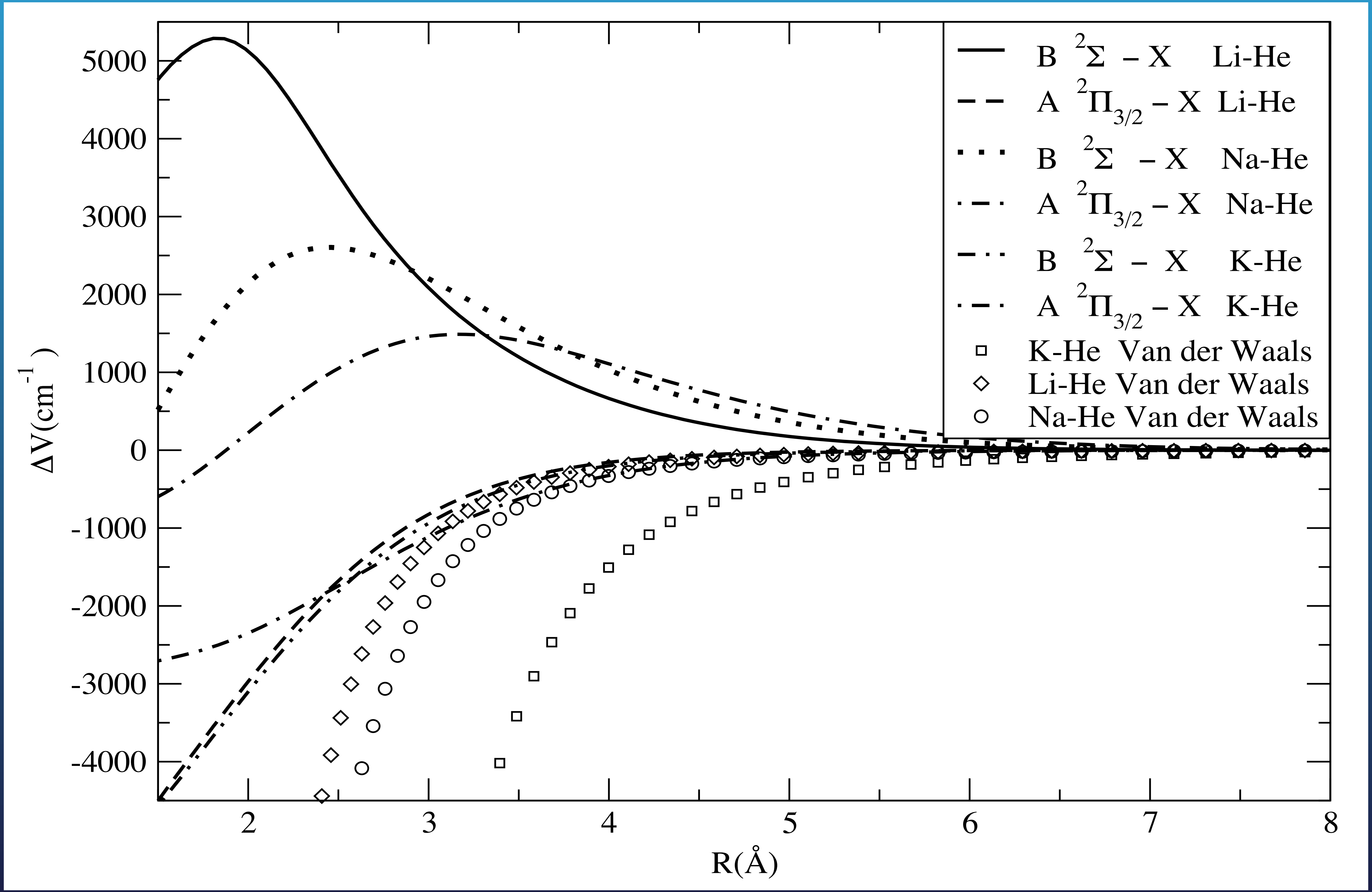
T Dwarfs — Alkali lines

- Depletion of metals due to condensation and sedimentation
- Alkali resonance lines still strong in deep atmosphere layers
- Powerful probe of atmosphere at very different optical depths!



Alkali line profiles



- Impact and single-perturber approximations with accurate inter-atomic potentials (Allard et al. 2005, 2007)

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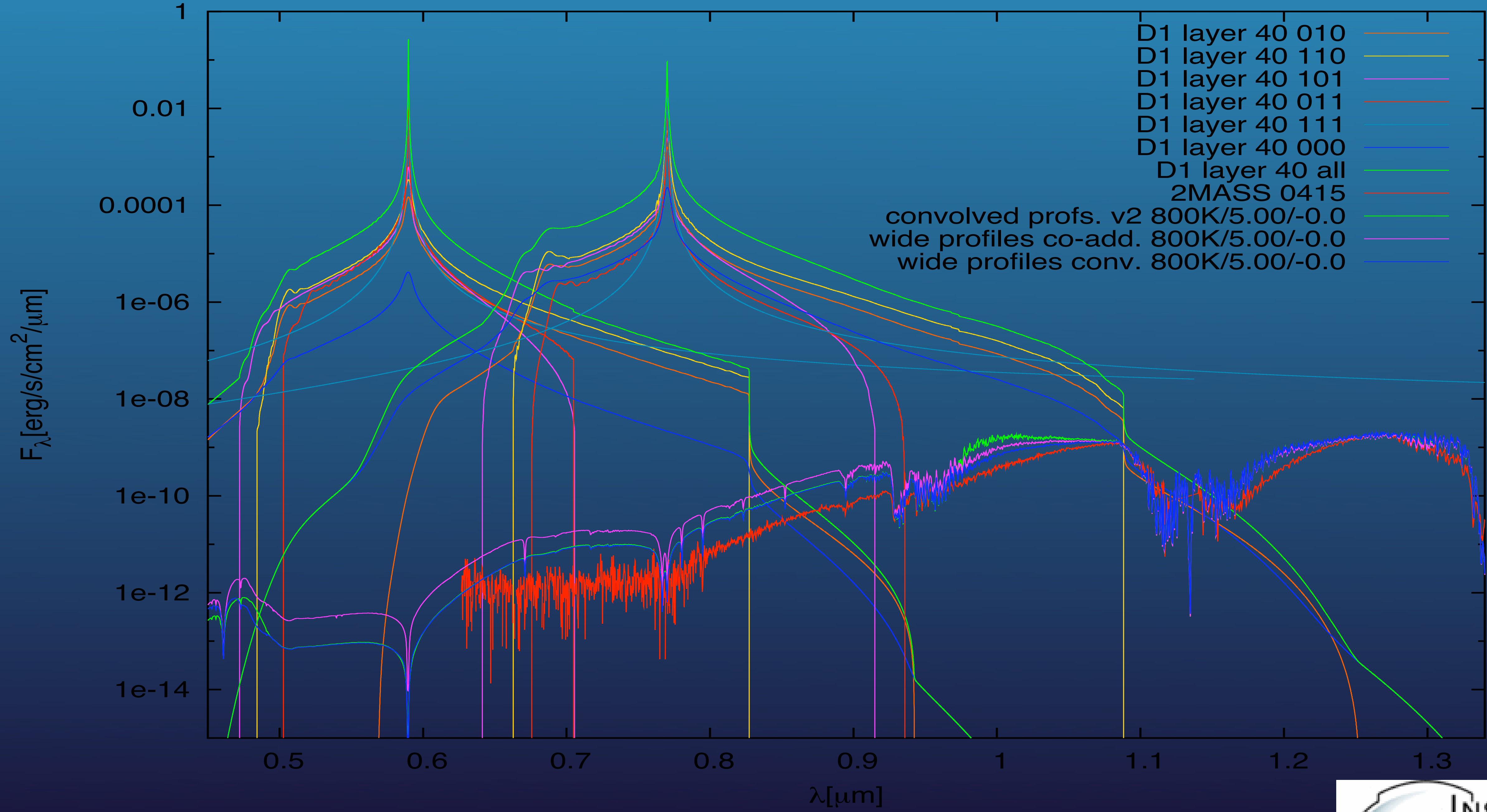
T Dwarfs - Alkali lines

- Broadening by He and H_2 (several geometries)
- Far wings shape spectrum over several µm!



Profiles from Allard, Allard, Hauschildt, Kielkopf & Machin (2003, 2007)

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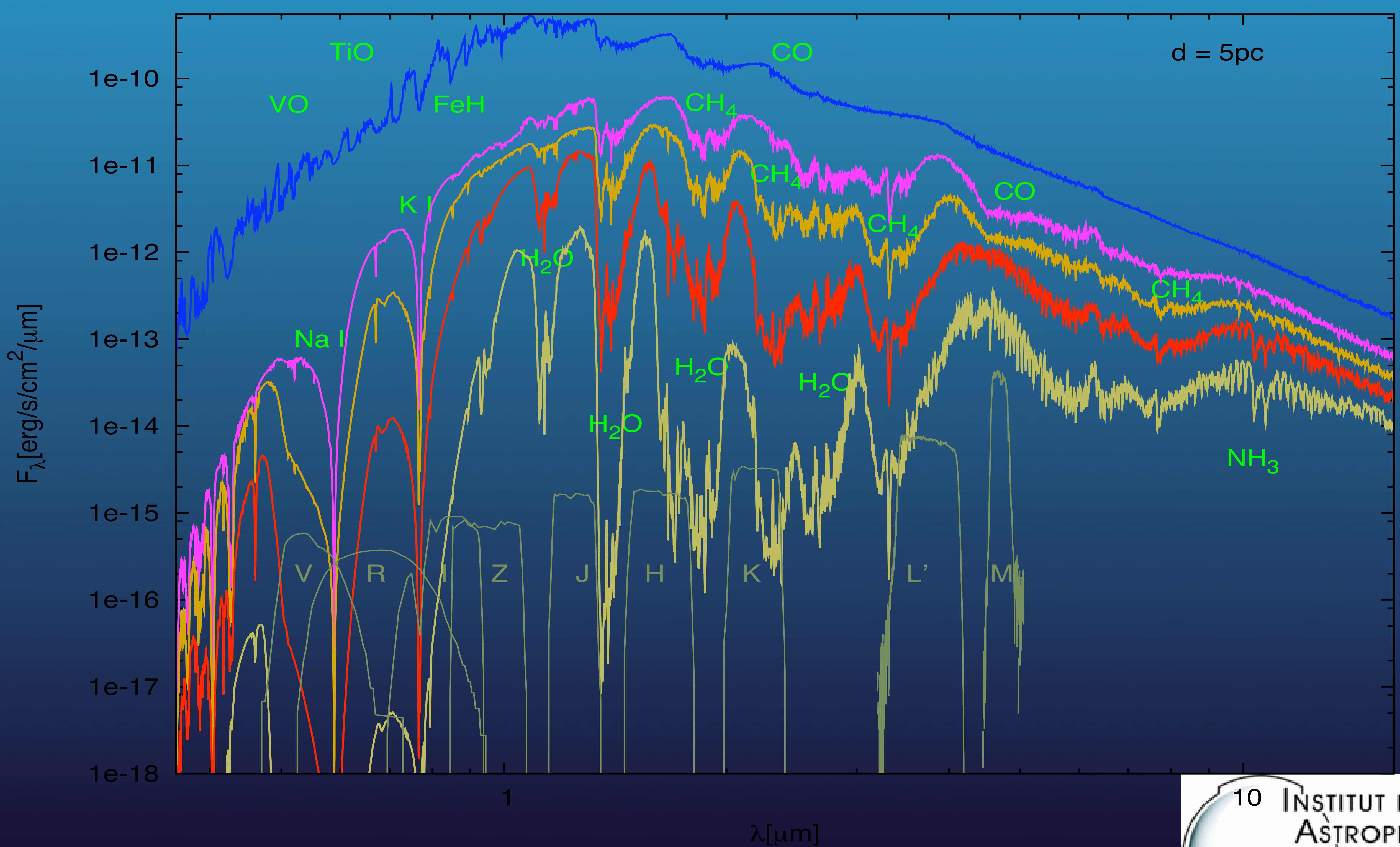
A Unified Set of Model Atmospheres

M-L-T-(Y?)-dwarfs



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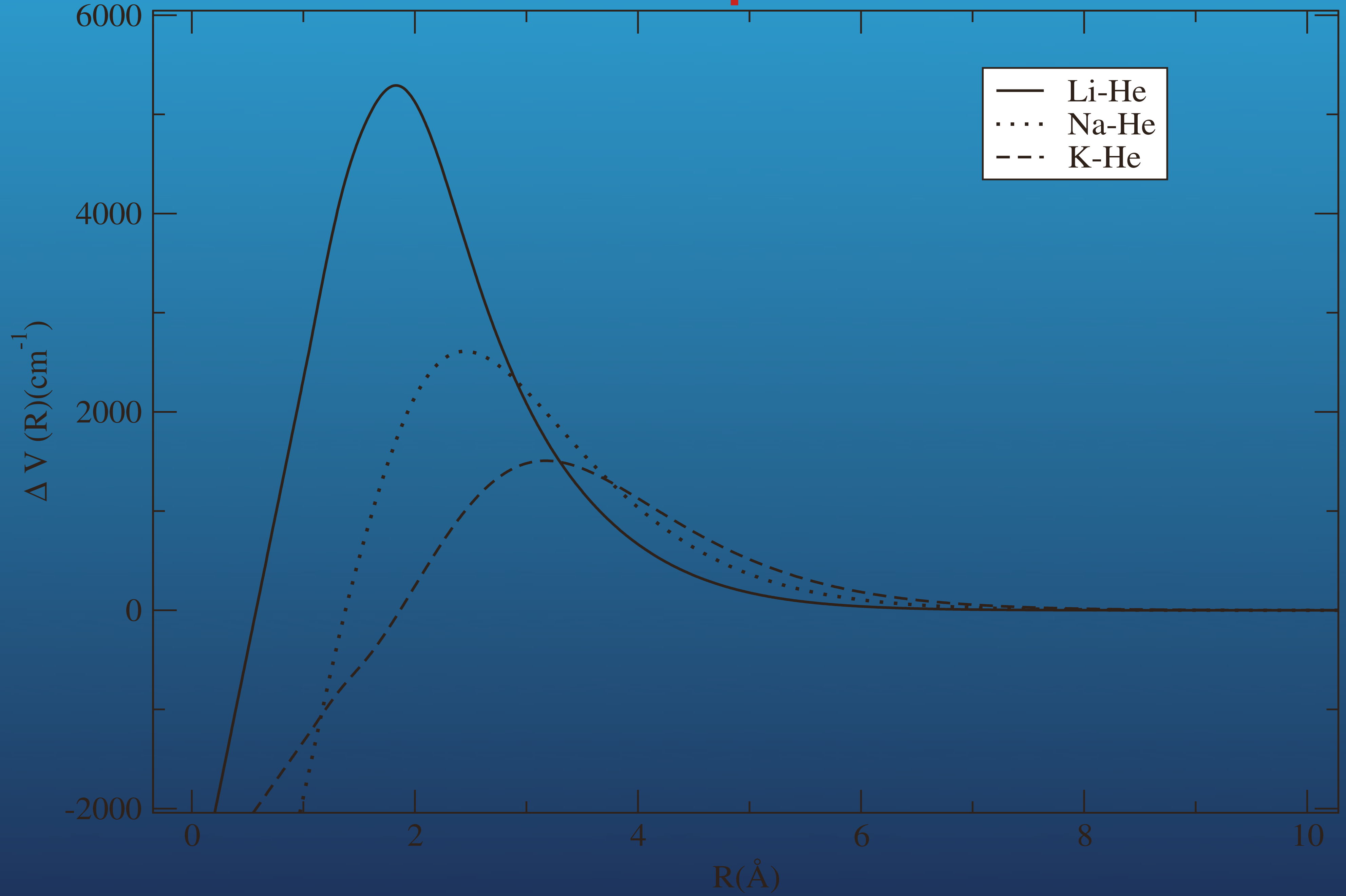
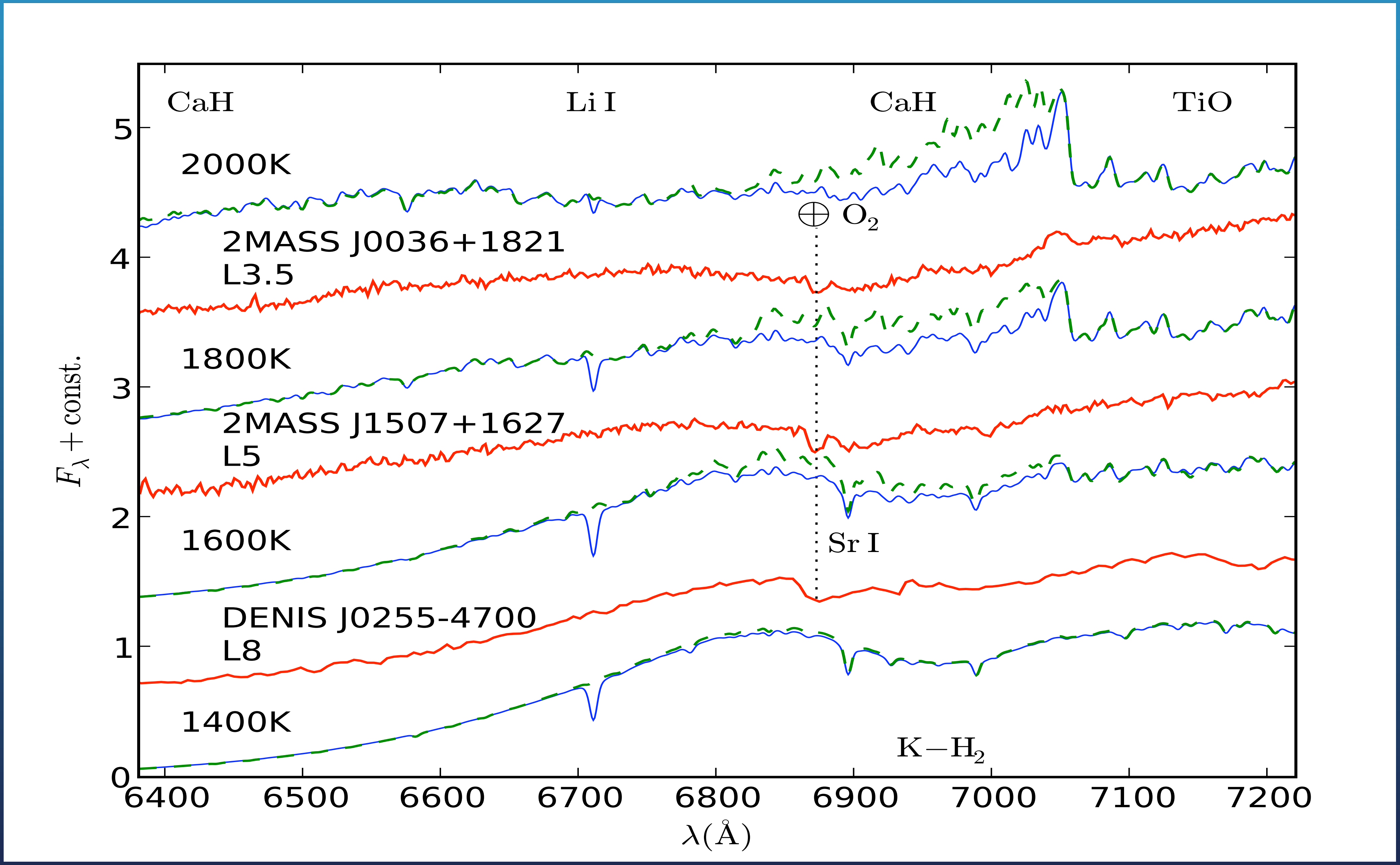
Alkali line profiles



(b) $\Delta V(R)$.

- Interaction potentials show local minimum
  → quasi-molecular resonance in the blue wing

Absorption in the blue wing of K I



- CaH "resurgence" - a molecular band returning or a new absorption feature?

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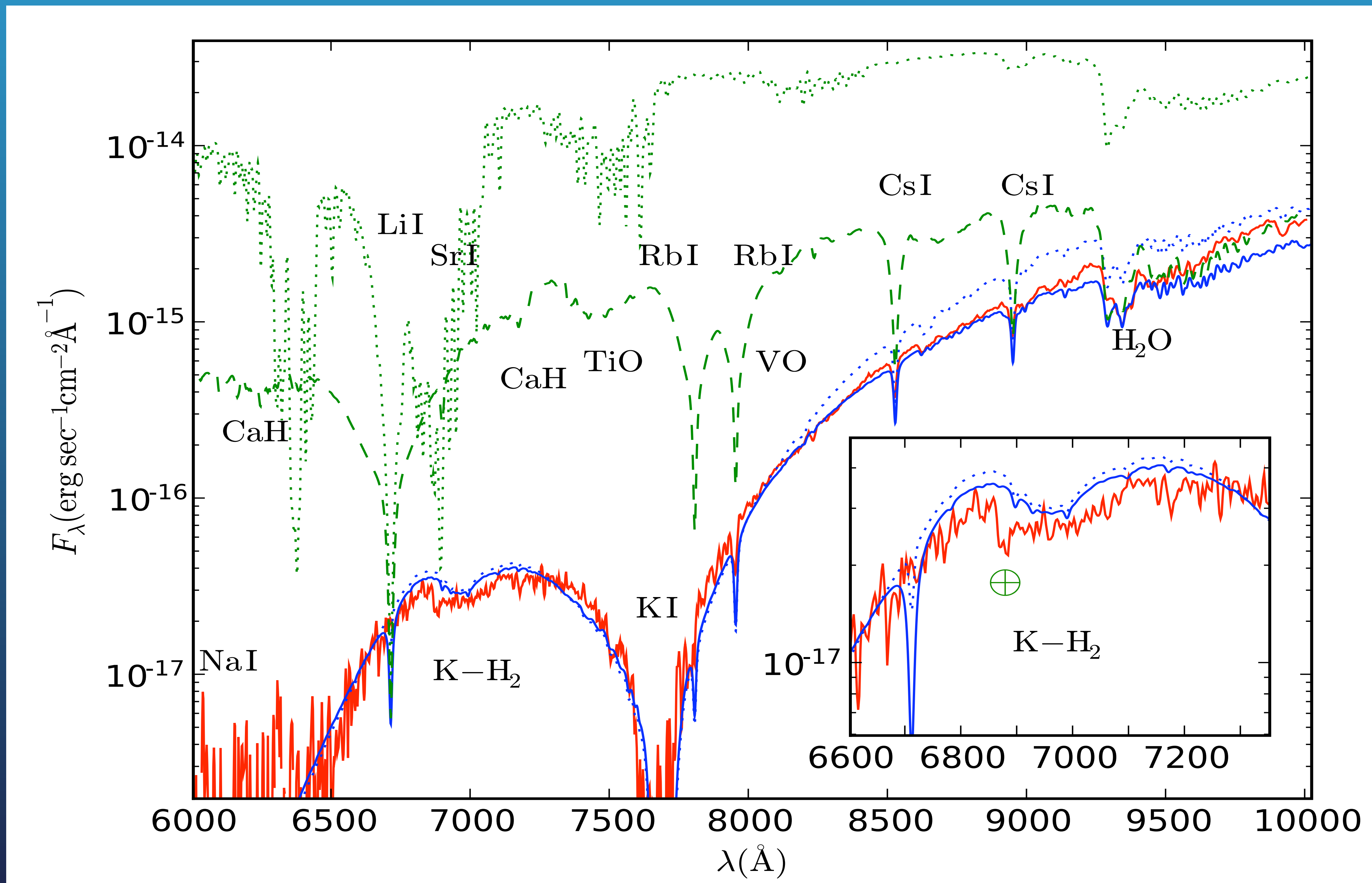
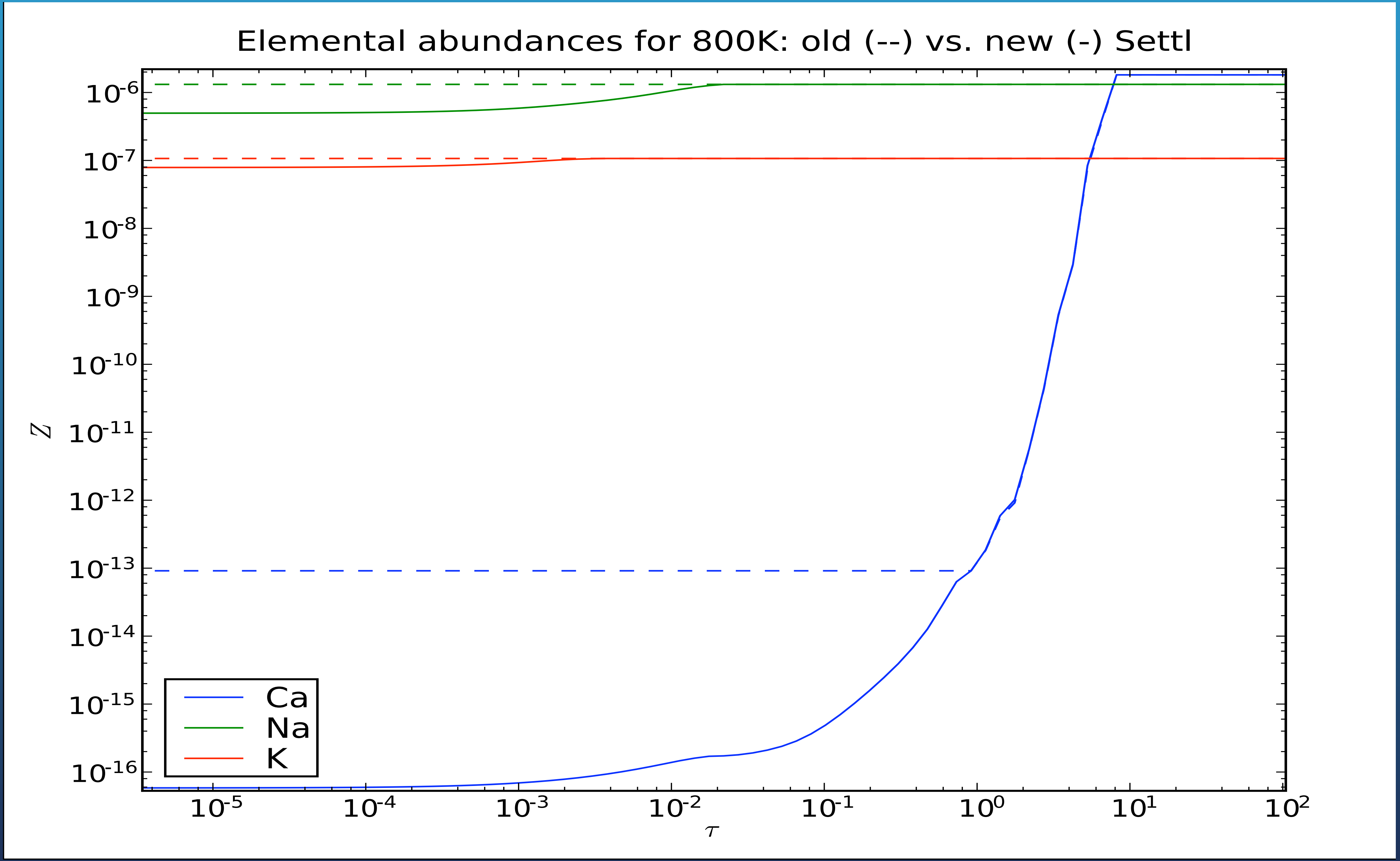
Alkali lines - quasi-molecular satellites!



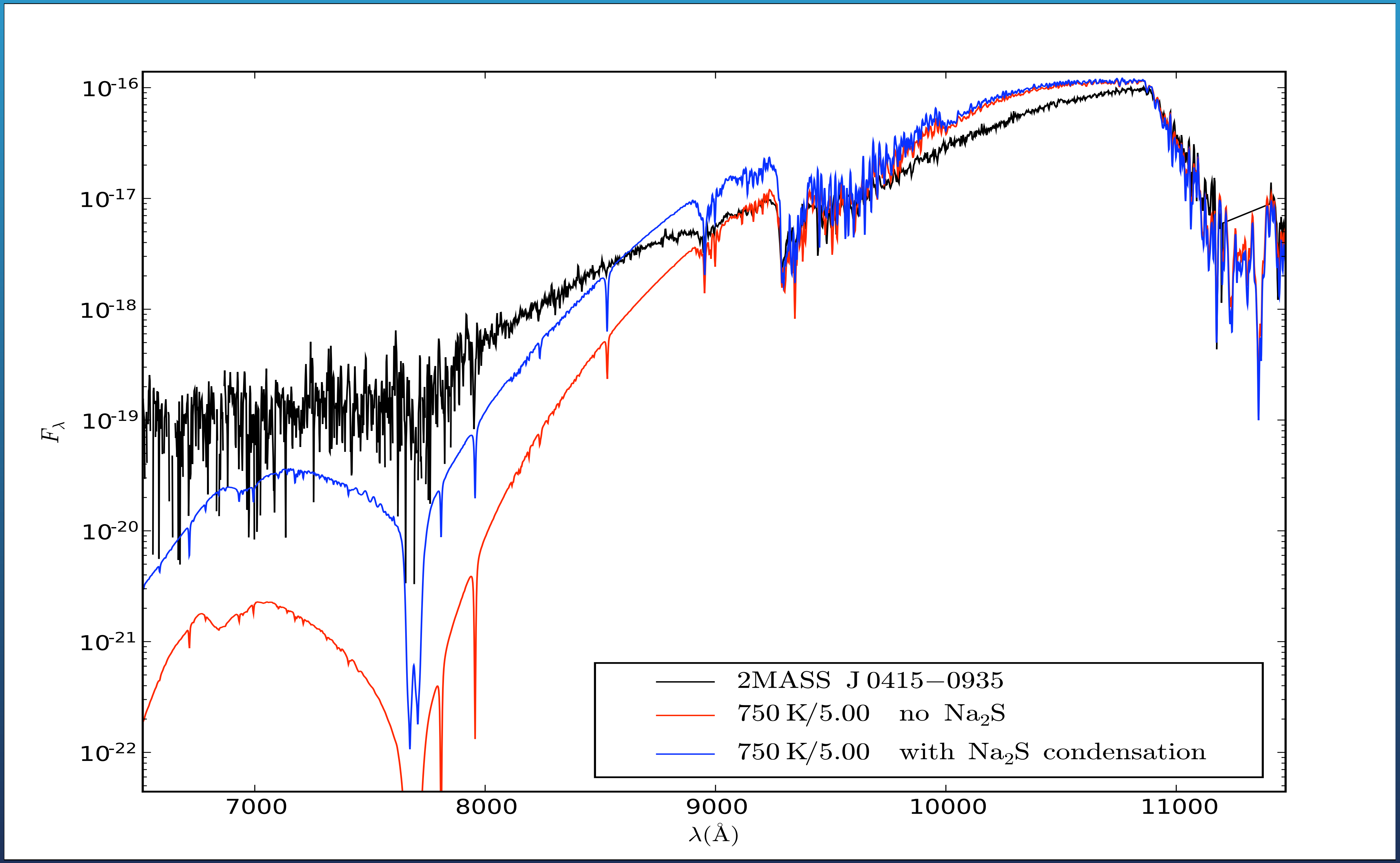
- New profiles by Allard, Spiegelmann & Kielkopf 2007

Challenges - Alkali chemistry



- Depletion of refractory species depends on complex chemical reaction network and mixing properties

Challenges - Alkali chemistry



- Modelling of condensation still important in late T dwarfs!
- Gas density in line-forming region exceeds 10^{20} cm^{-3}
  → single-perturber approximation no longer valid in wings

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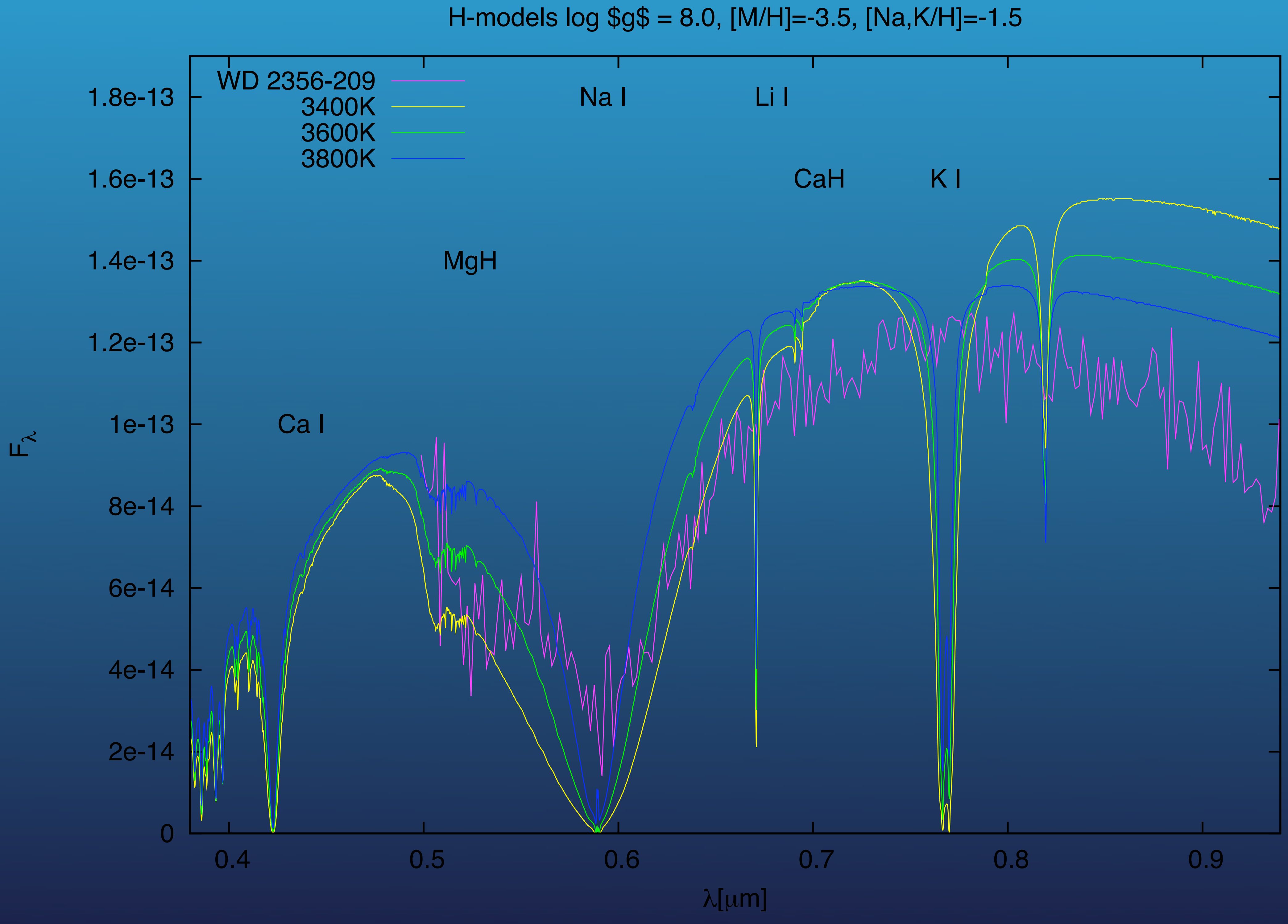
Alkali lines in White Dwarfs



Oppenheimer et al. 2001, Salim et al. 2004 (obs.)
Homeier et al. EuroWD 06

- Strong *V* absorption in metal-rich cool white dwarfs
- Evidence for extremely pressure-broadened Na lines

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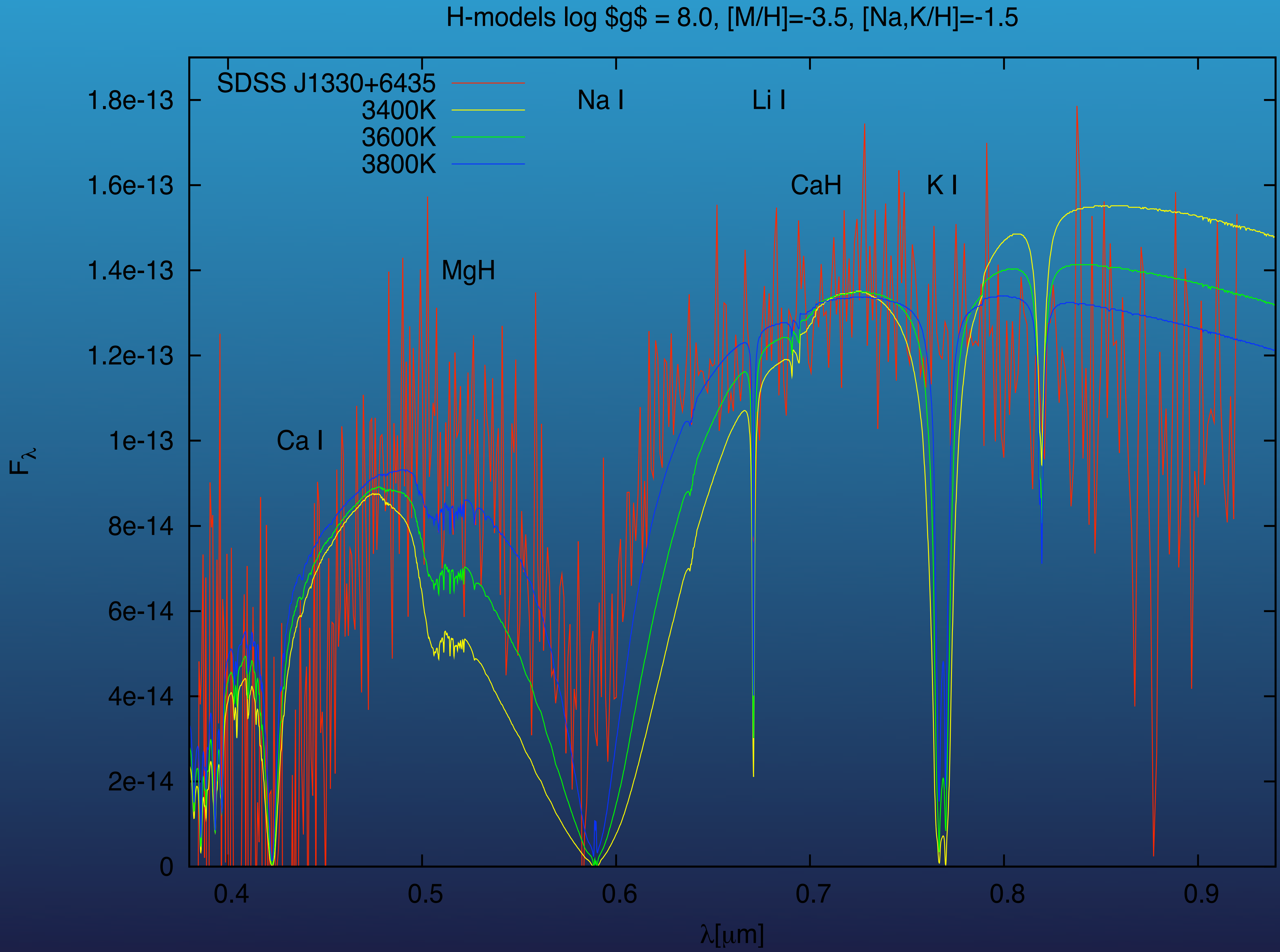
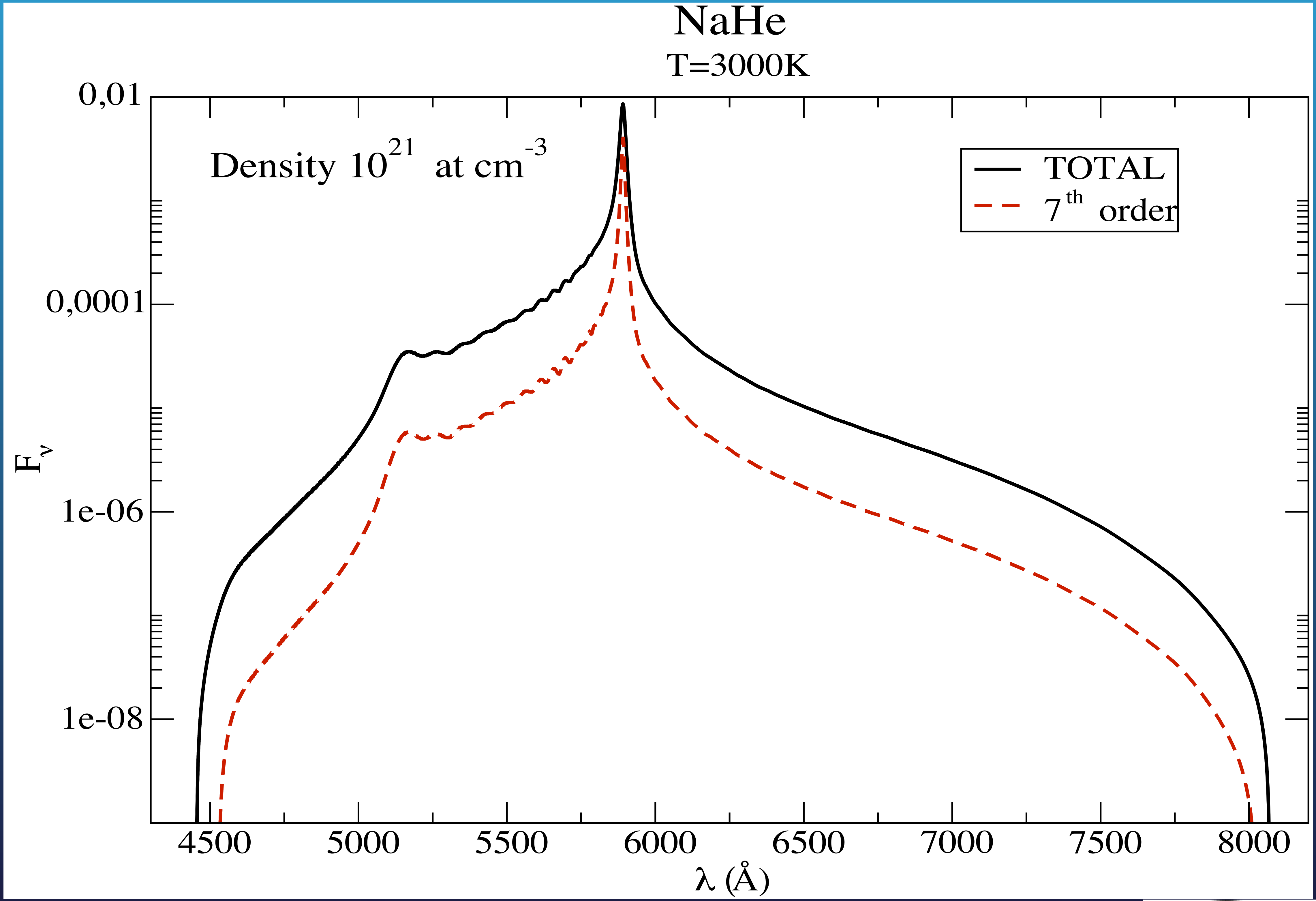
Alkali lines in White Dwarfs



Harris et al. 2003 (obs.)
Homeier et al. EuroWD 06

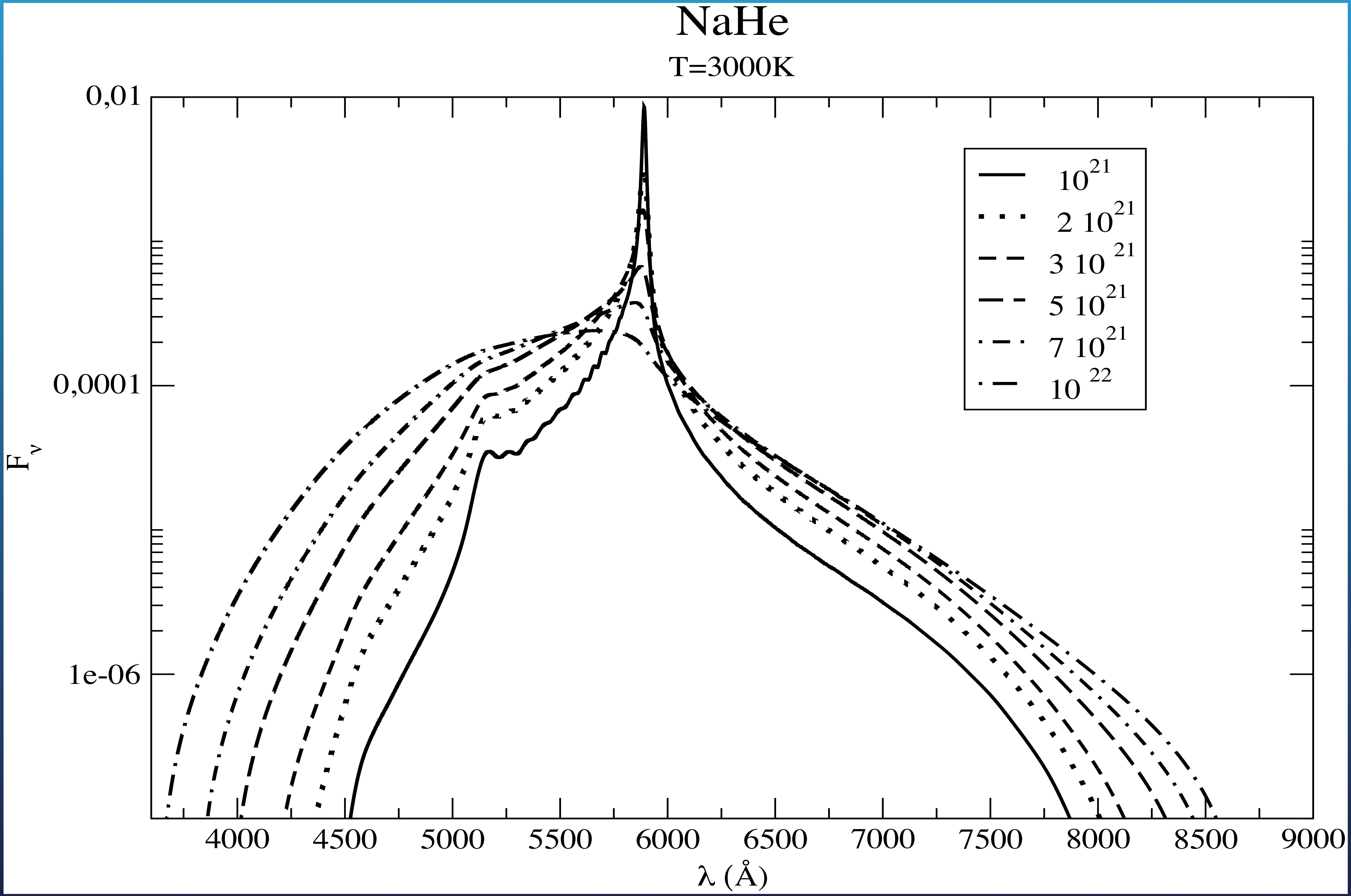
- 2 ultra-cool white dwarfs with strong Na absorption
- Hydrogen- or Helium-dominated atmosphere?

FT Expansion breaks down at high density



- Standard density expansion to 3rd or even 7th order only carries a fraction of the line strength!

FT Expansion breaks down at high density



- Better treatment of far wings by direct calculation required for densest objects!

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Conclusions

- Atmosphere models have made great progress towards understanding substellar objects
- Condensation and depletion of dust species explains the properties of L dwarfs and the transition from L to T
- Line absorption paramount to correctly model T dwarfs
- Few, massively broadened alkali resonance lines shape large regions of brown dwarf spectra
- Next generation of line profiles needed to model atmospheres of still denser objects → Y dwarfs, metal-rich white dwarfs

Thanks for your attention &
Thanks to the organisers!

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