New Dimensions of Stellar Atmosphere Modelling

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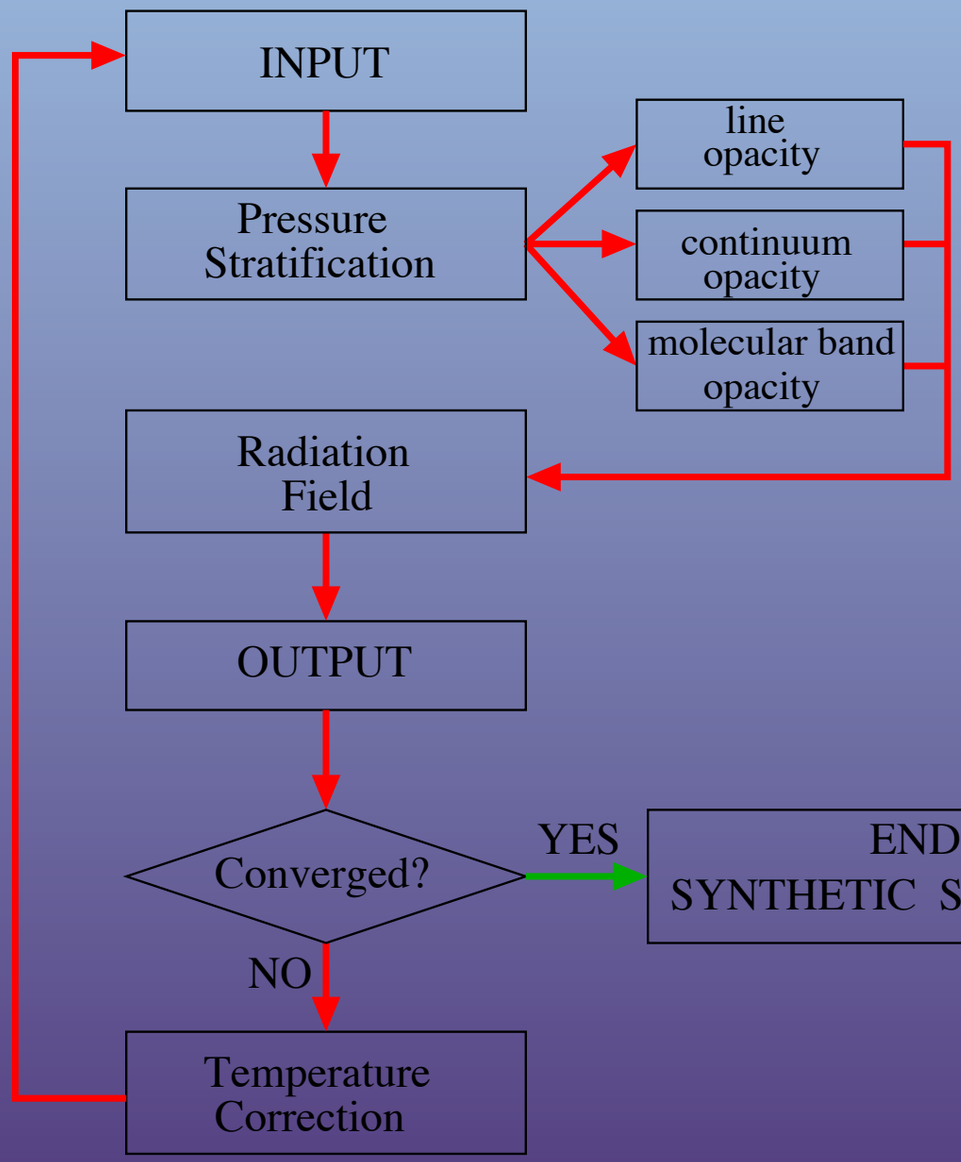
(Sub-) stellar atmosphere modelling

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



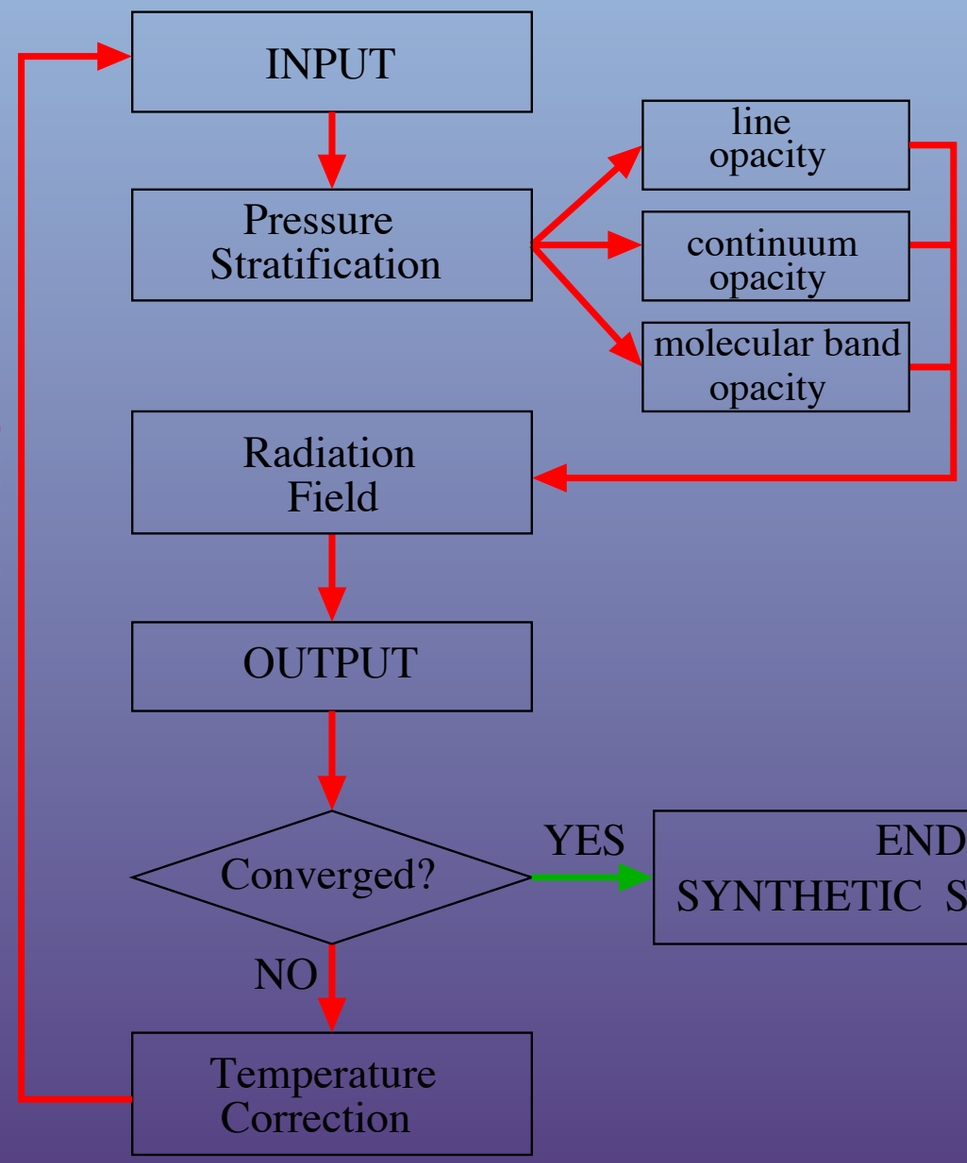
PHOENIX workflow (P. Hauschildt)

(Sub-) stellar atmosphere modelling

★ independent Variables (minimal):

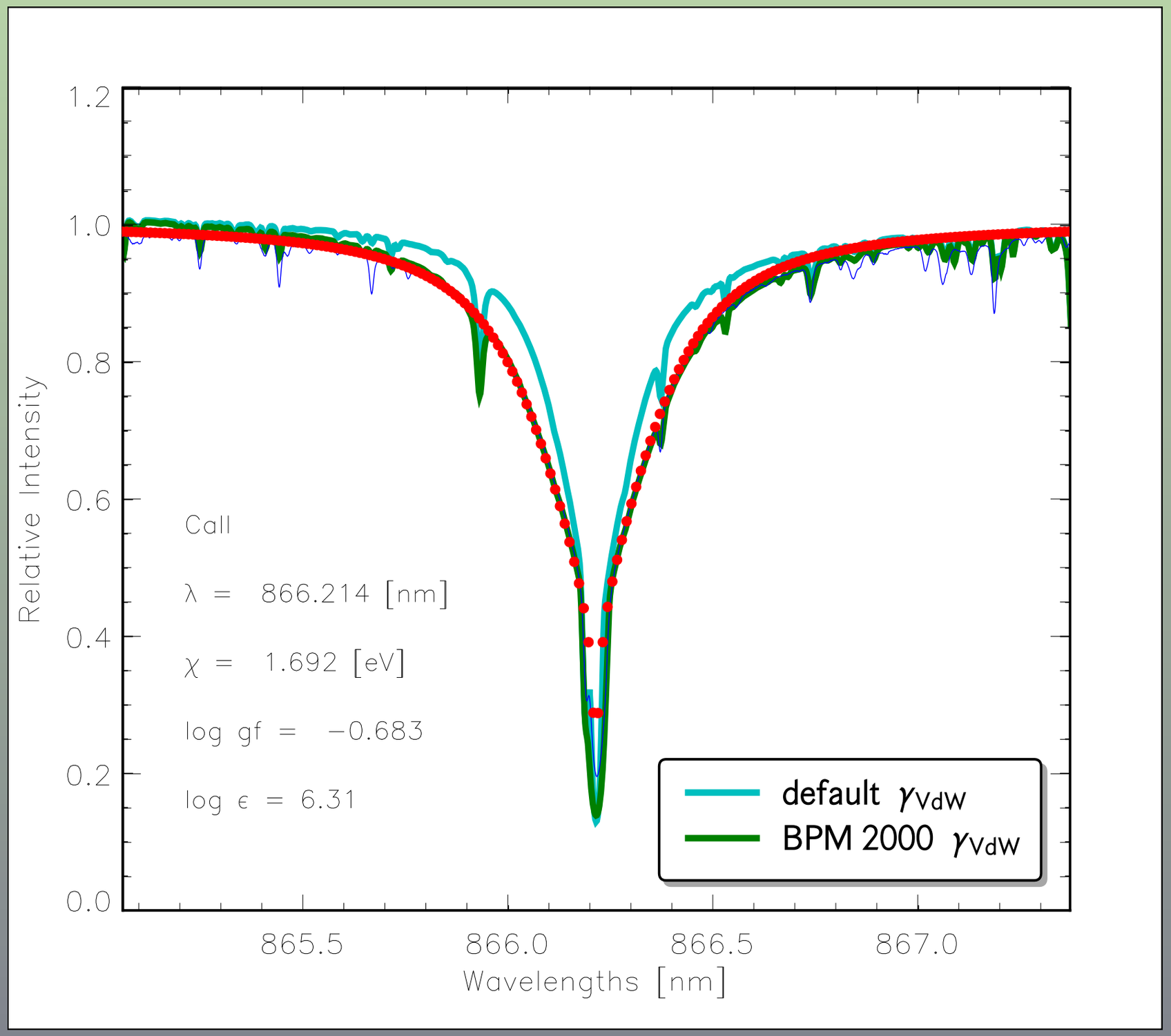
- effective temperature T_{eff}
- surface gravity $g(r) = GM/r^2$
- mass M or radius R or luminosity
  $L = 4 \pi R^2 \sigma T_{eff}^4$
- composition ("metallicity")
- convection ➞
  (micro-) turbulence & mixing
- rotation
- chemical peculiarities
- magnetic fields etc….

➞ adding more dimensions to the modelling problem



PHOENIX workflow (P. Hauschildt)

Model Spectra and Line Synthesis

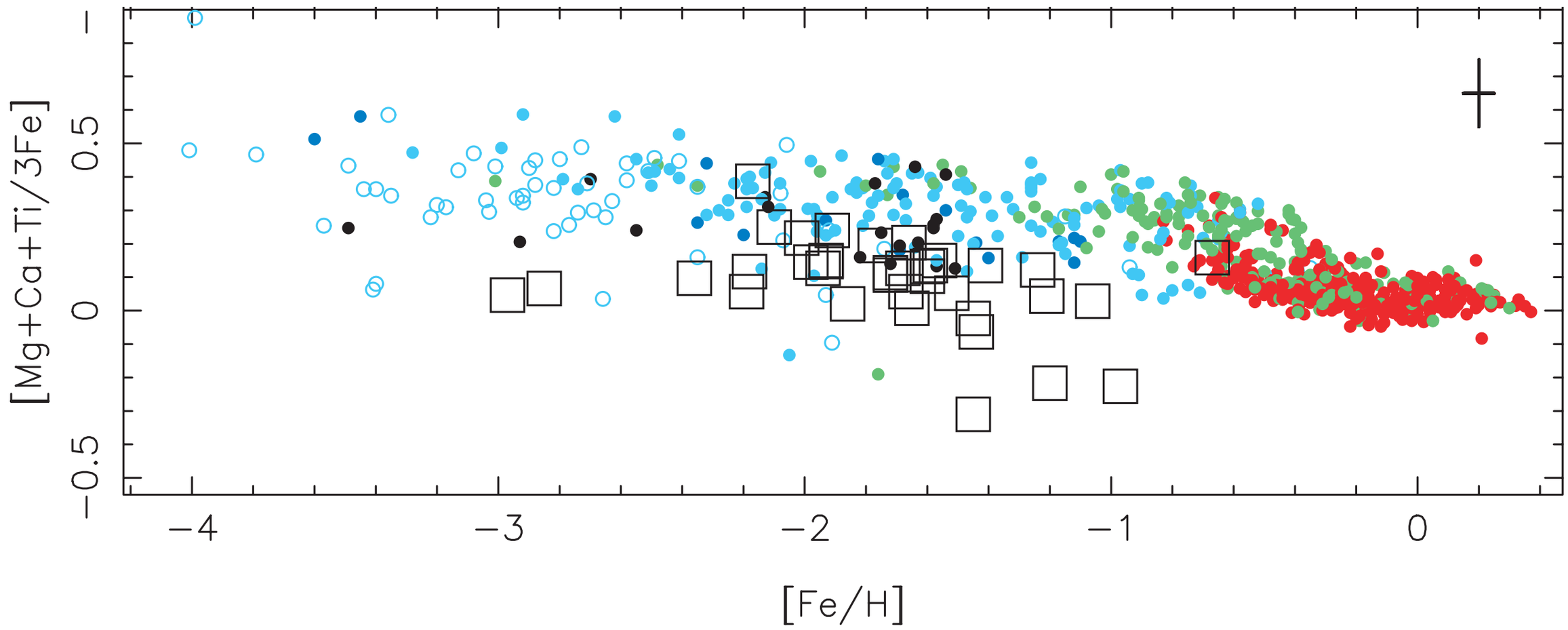


Solar disk-centre spectrum (blue)

3D RHD model with LTE spectrum (red dots) with fitted *gf* from Bigot & Thevenin 2008;

PHOENIX 1D NLTE model (green), same *gf*, γ_{VdW} by Barklem et al. 2000

Atmosphere Models and Turbulence

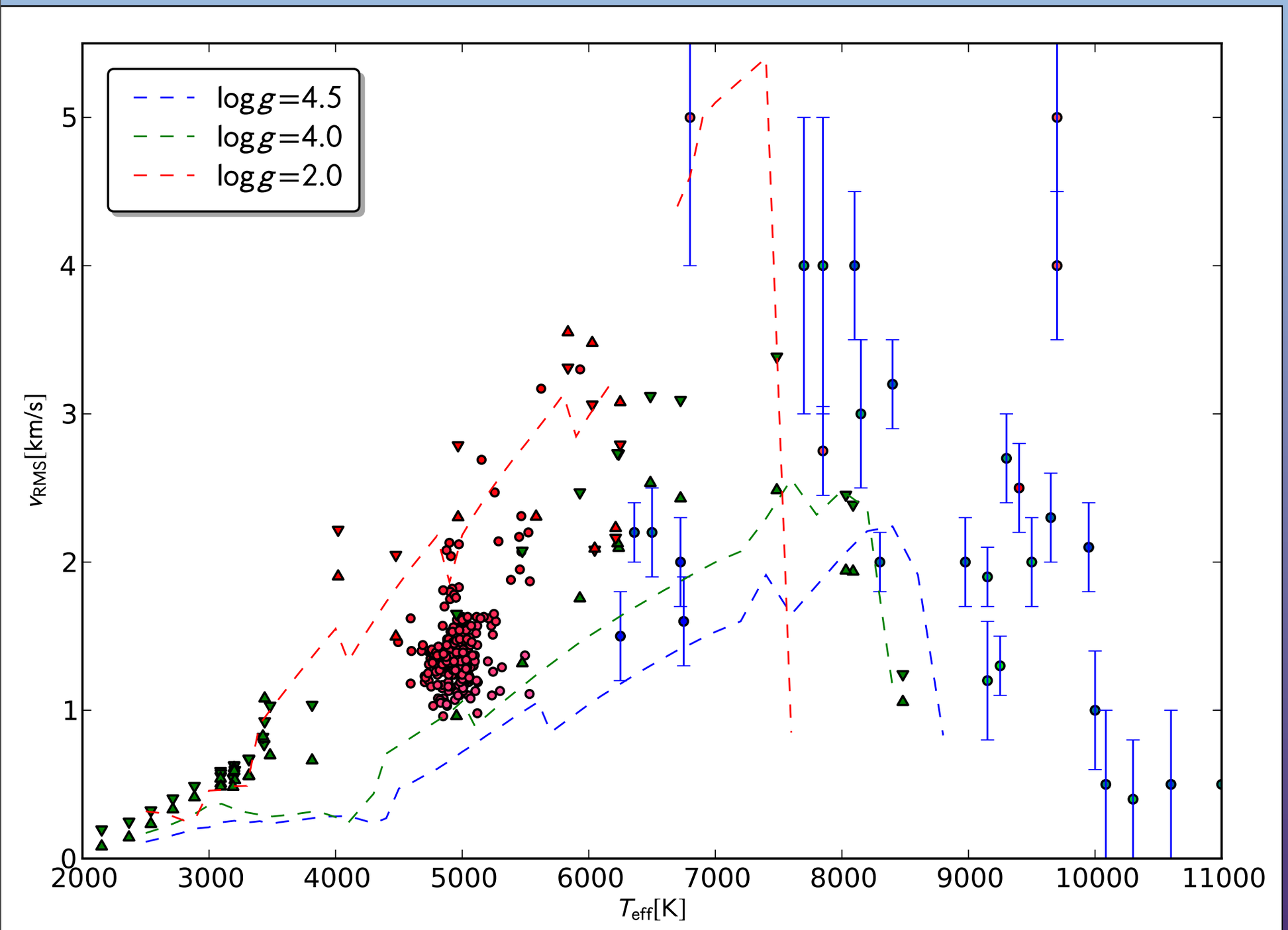


● thin disk ● thick disk ● halo □ dSph galaxies

α-element abundances from Venn et al. (2004)

- No unique relation between metallicity and "α-enhancement" between different populations or even within one population
- at least one additional dimension in chemical composition

Atmosphere Models and Turbulence



Turbulent velocity from

CO5BOLD 2D+3D RHD models (triangles)

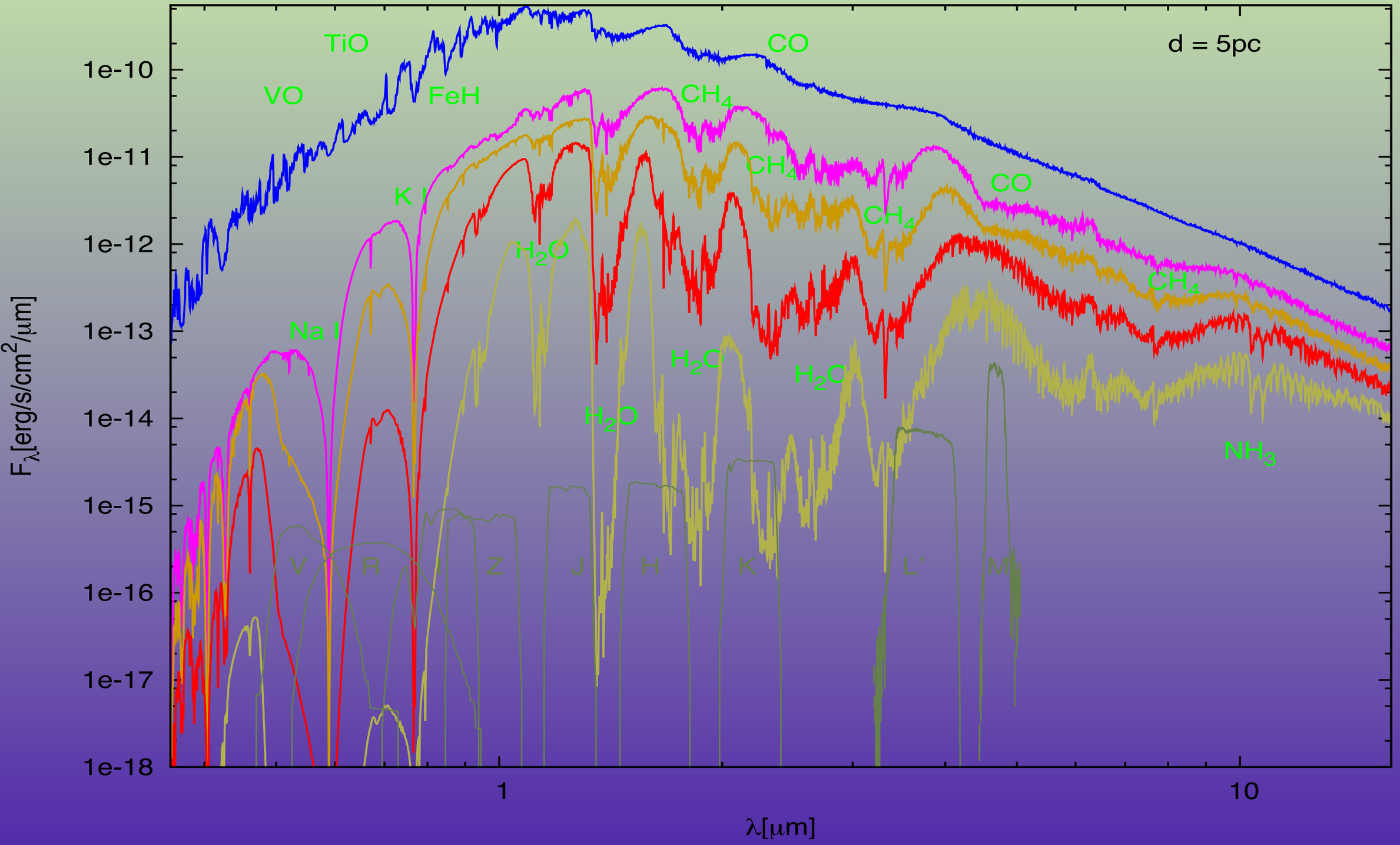
PHOENIX 1D models estimated from MLT (dashed lines)

fitted to observed spectra of B – F dwarfs by Landstreet et al. (2009, errorbars) and G – K giants by Takeda et al. (2008, circles)

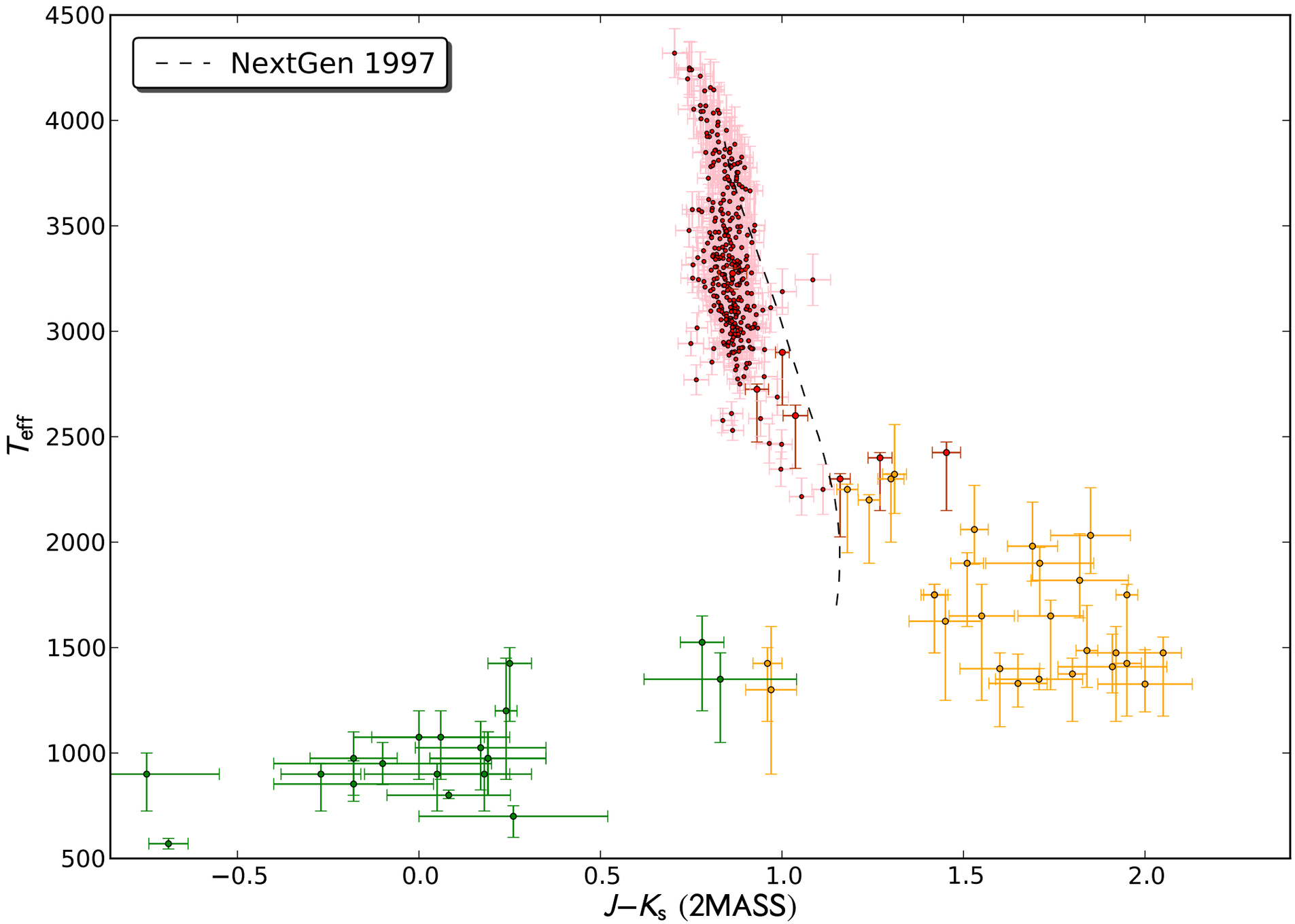
- 1D treatment of convection reproduces trends found in multi-D simulations and empirically fitted "microturbulence"
- Improvements in treatment of convective boundary required!

Spectral Shapes of Cool Atmospheres

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



Model grids for cool and ultracool dwarfs



Allard et al. 1997

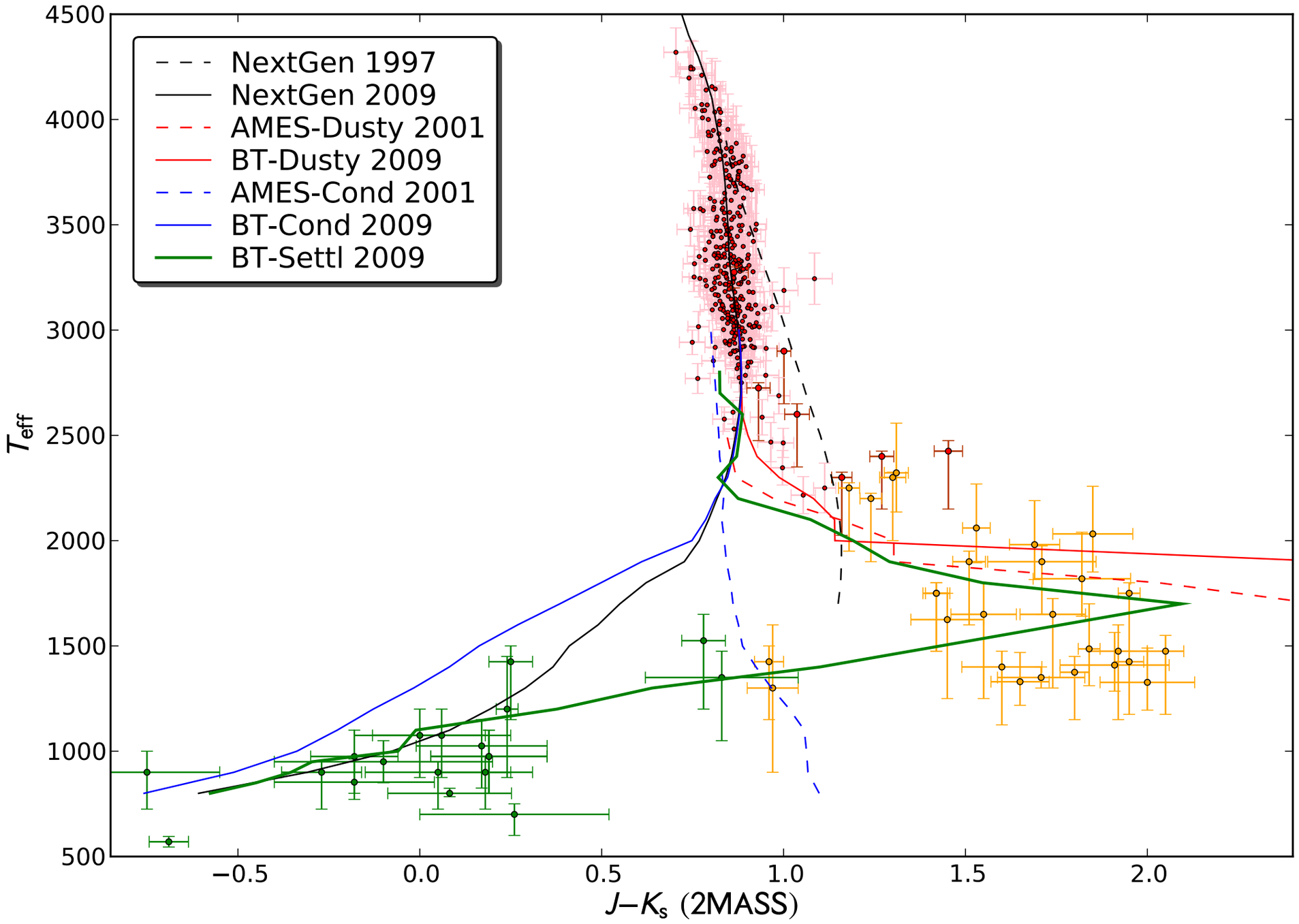
Casagrande et al. 2008

Golimowski et al. 2004

Vrba et al. 2004

- NextGen: molecular line blanketing, no condensation

Model grids for cool and ultracool dwarfs



Allard et al. 1997

Allard et al. 2001

Freytag et al. 2010

Allard et al. in prep.

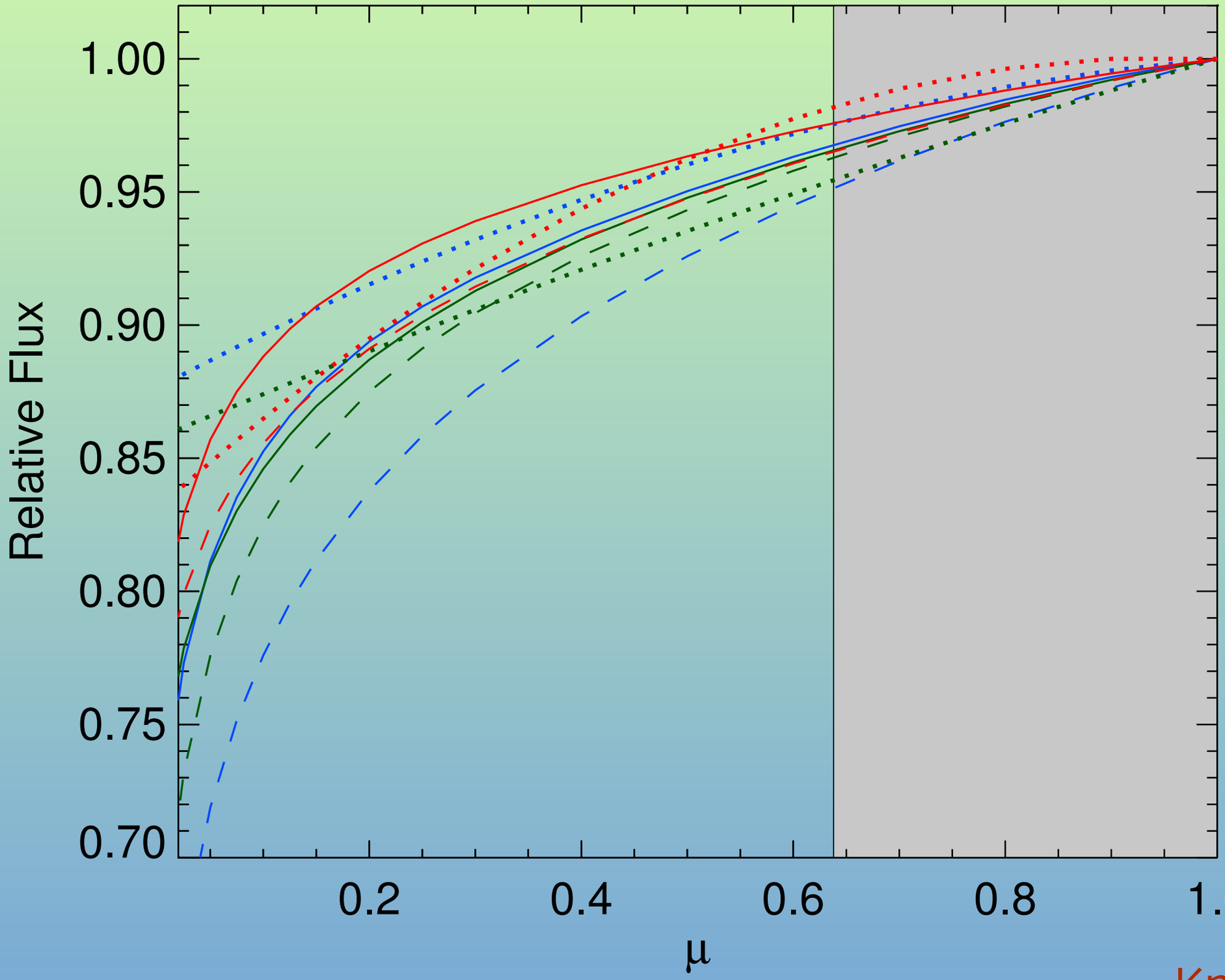
Casagrande et al. 2008

Golimowski et al. 2004

Vrba et al. 2004

- 8 Years after: updated opacities, line profiles, abundances, and a new cloud model!

Model Atmospheres: Limb Darkening



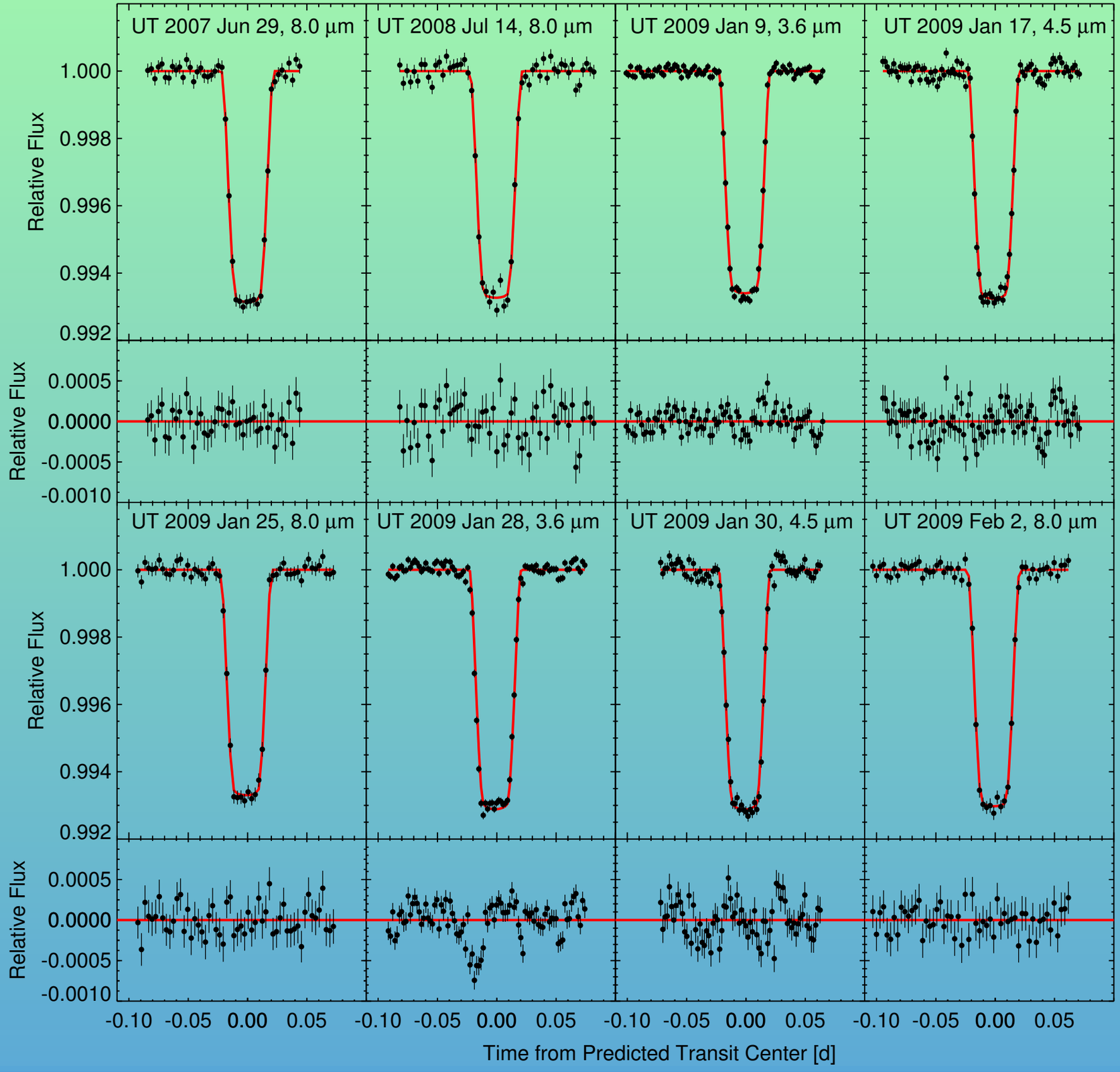
Limb darkening curves of a 3500K M dwarf for IRAC 3.6, 4.5, 8.0 μm bands (blue, green, red):

solid – ATLAS models
dashed – PHOENIX
fully molecular line blanketed models
dotted – free fit

The shaded area is not passed in transit, thus unconstrained by lightcurve fitting

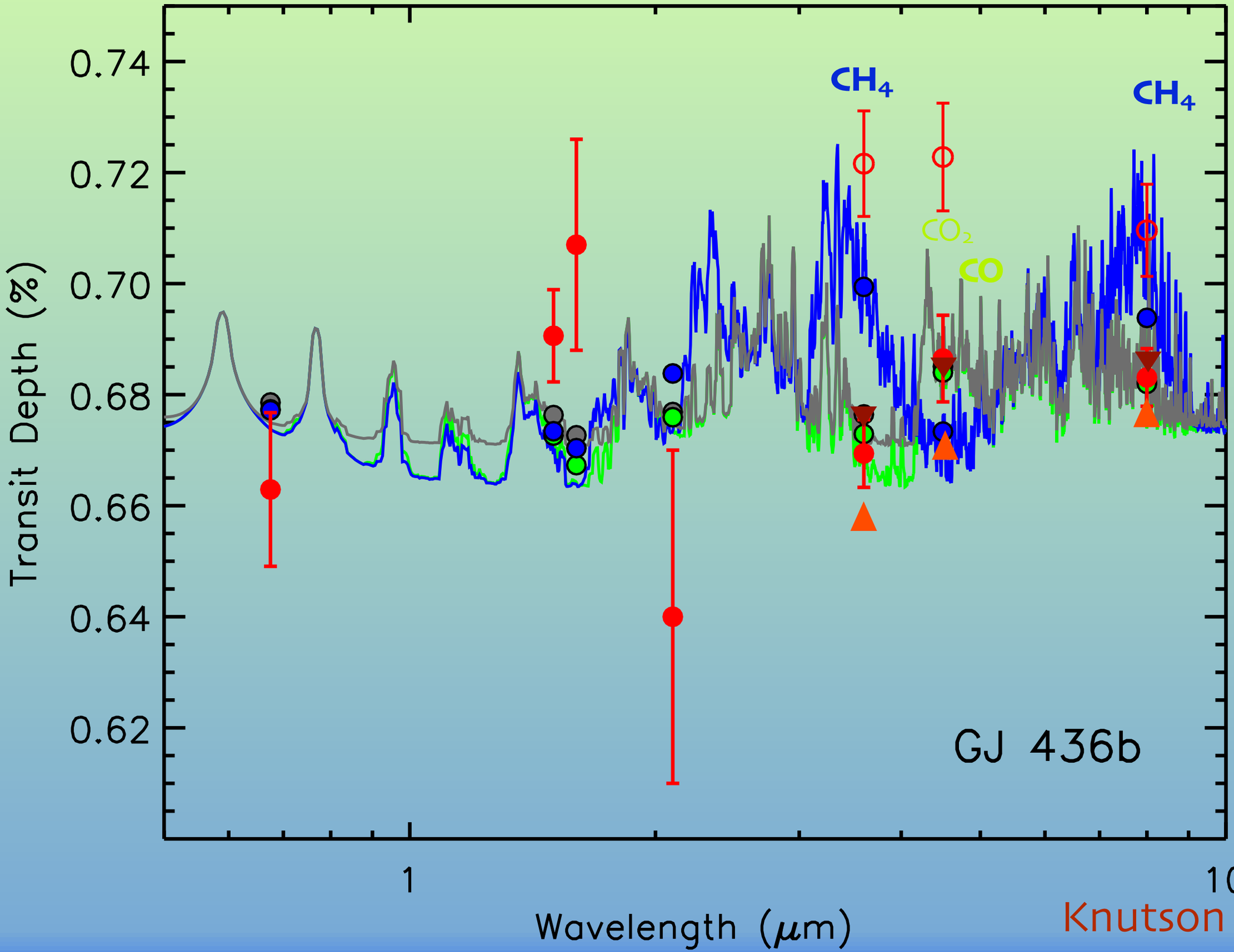
Knutson et al. 2011

Extrasolar planets – Transmission spectroscopy



Multi-wavelength IRAC transit observations of Gl 436b (Knutson et al. 2011)

Limb Darkening and Transmission Spectroscopy



measured transit depths w/ ATLAS limb darkening (red circles)

▼ – PHOENIX limb darkening

▲ – zero limb darkening

blue, green: CH_4, CO-dominated planetary atmosphere models

Knutson et al. 2011

Next Generation of PHOENIX models

- MUSE/BT-Settl (Allard, Homeier & Freytag)
  & ACES-Cond (Husser, Hauschildt et al.) grids
- Super(giants) & main sequence down through brown dwarf into exoplanet regime
- Extensive coverage of metallicities and α-enhancements
- 1D static, but with spherical symmetry
- Close feedback with CO5BOLD RHD simulations
- Detailed limb darkening or intensity output

Hvala

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& for your attention!