

New Dimensions of Stellar Atmosphere Modelling

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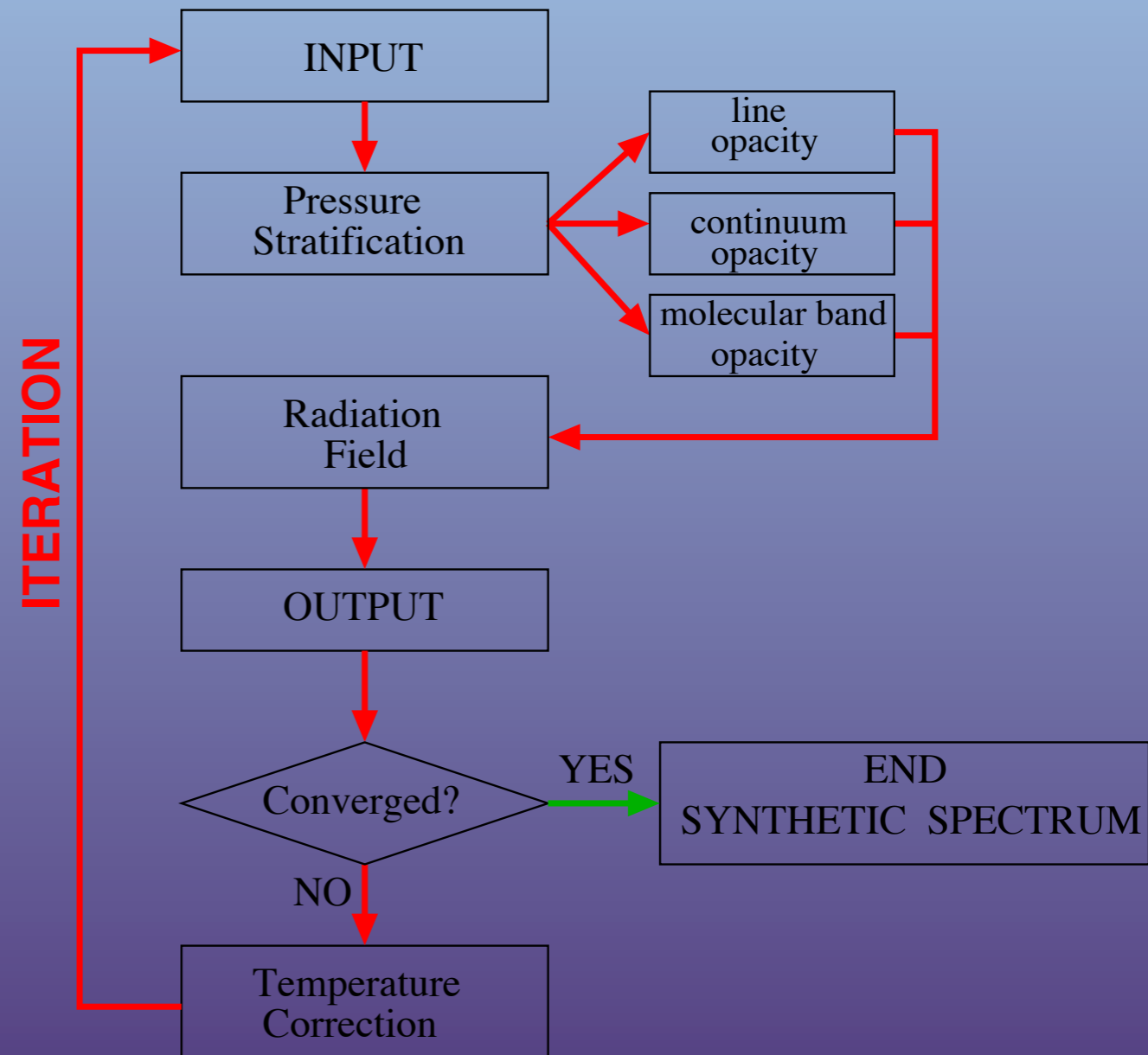
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(Sub-) stellar atmosphere modelling

★ 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

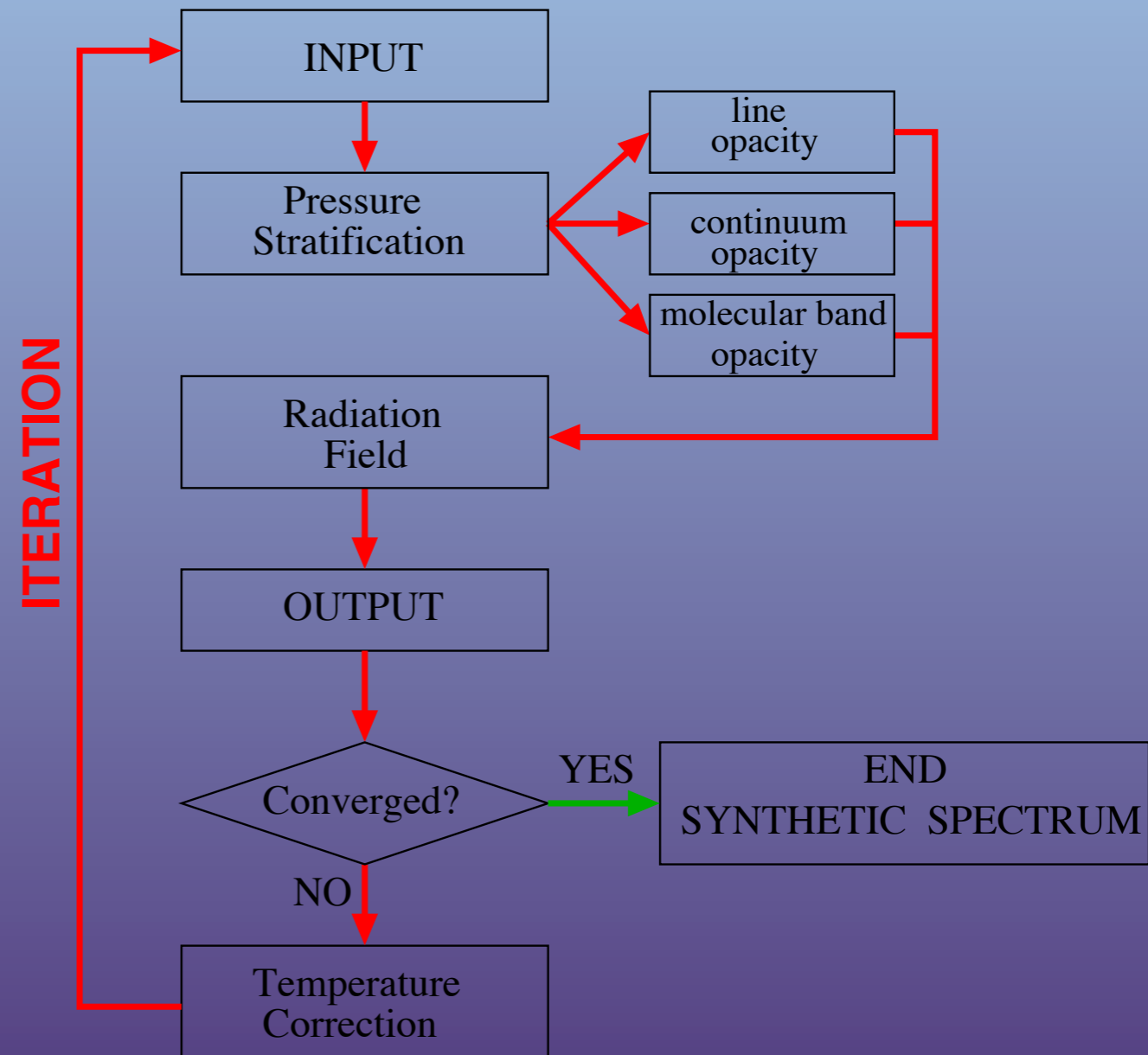
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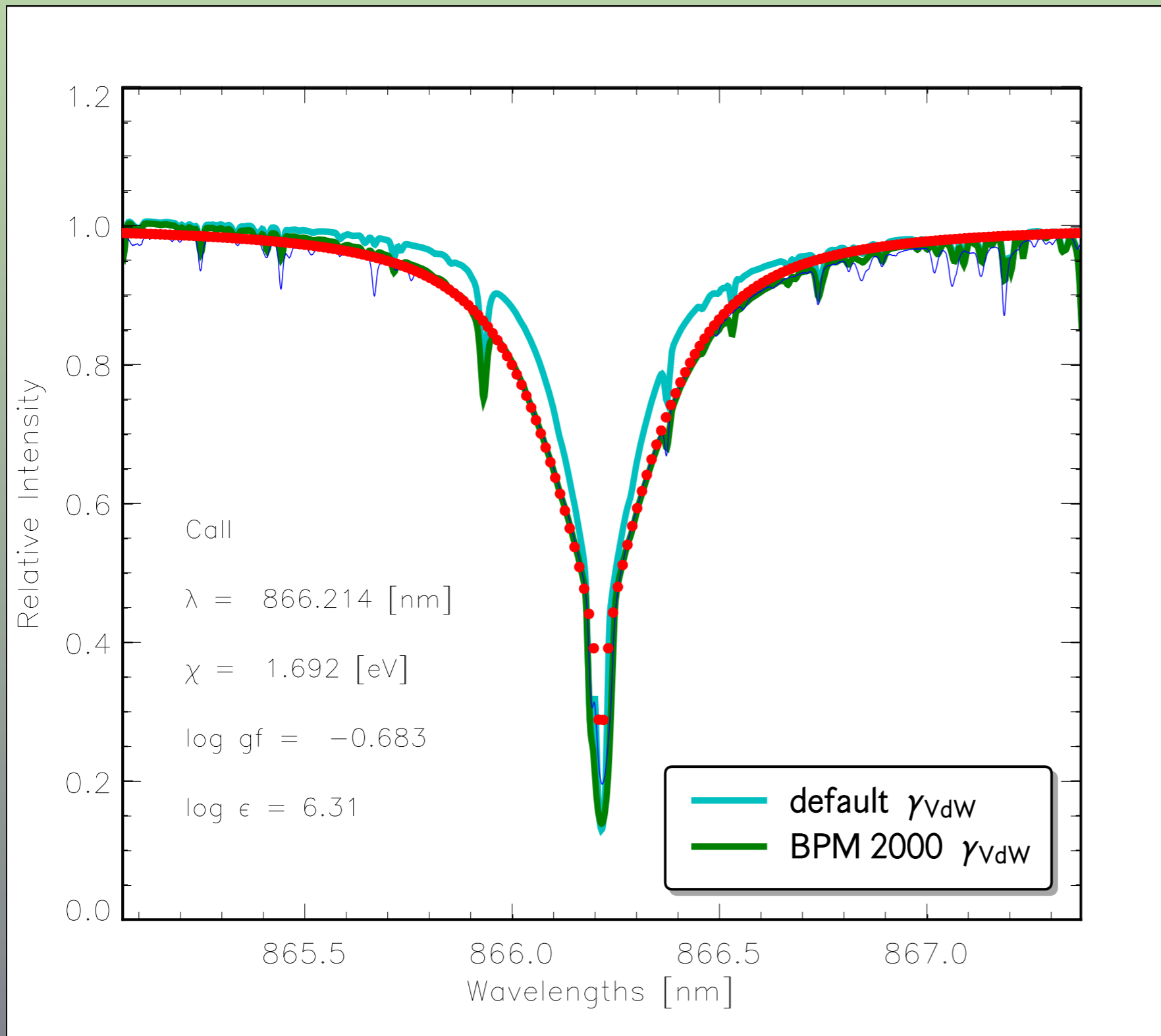
- composition ("metallicity")
- convection → (micro-) turbulence & mixing
- rotation
- chemical peculiarities
- magnetic fields etc....

→ adding more dimensions to the modelling problem



PHOENIX workflow (P. Hauschildt)

Model Spectra and Line Synthesis

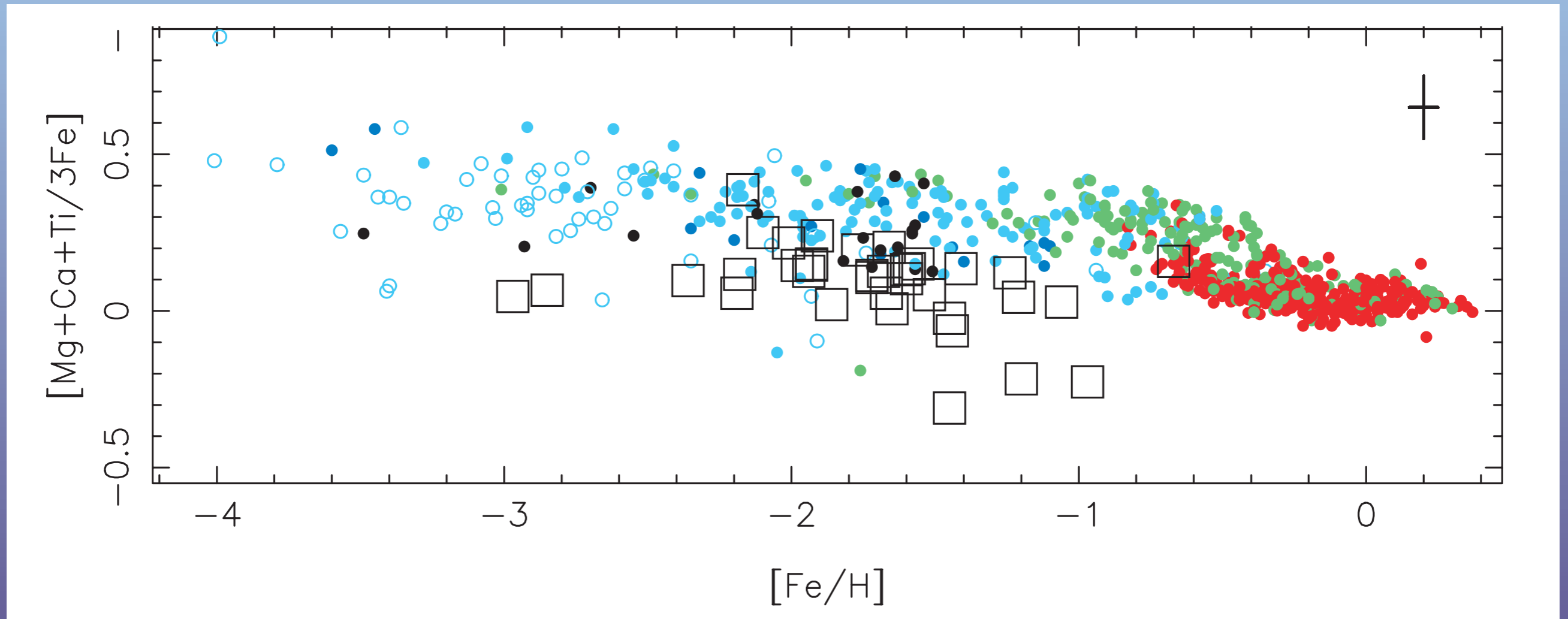


Solar disk-centre
spectrum (blue)

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

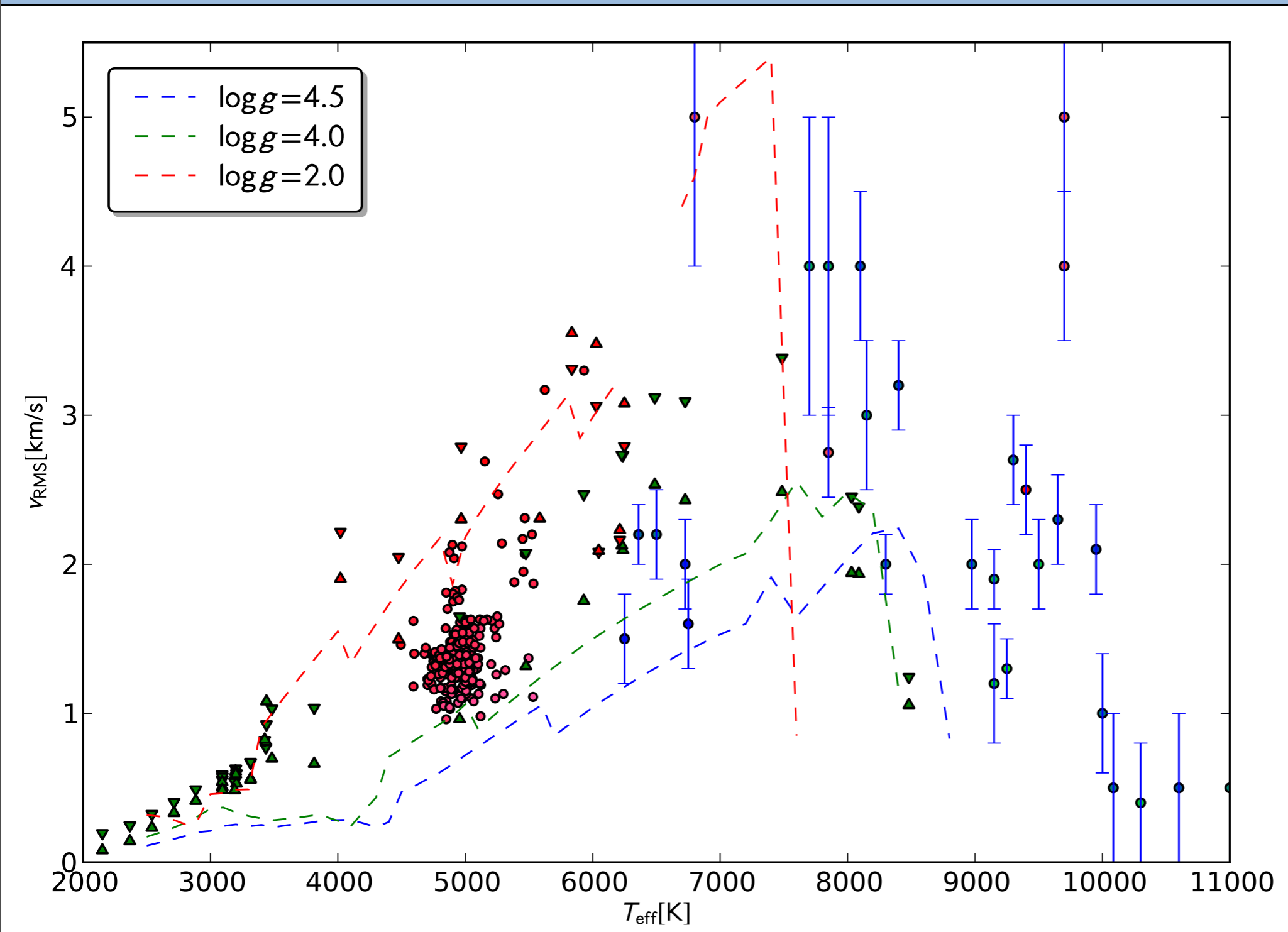
Atmosphere Models and Turbulence



● 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
CO₃BOLD 2D+3D RHD
models (triangles)

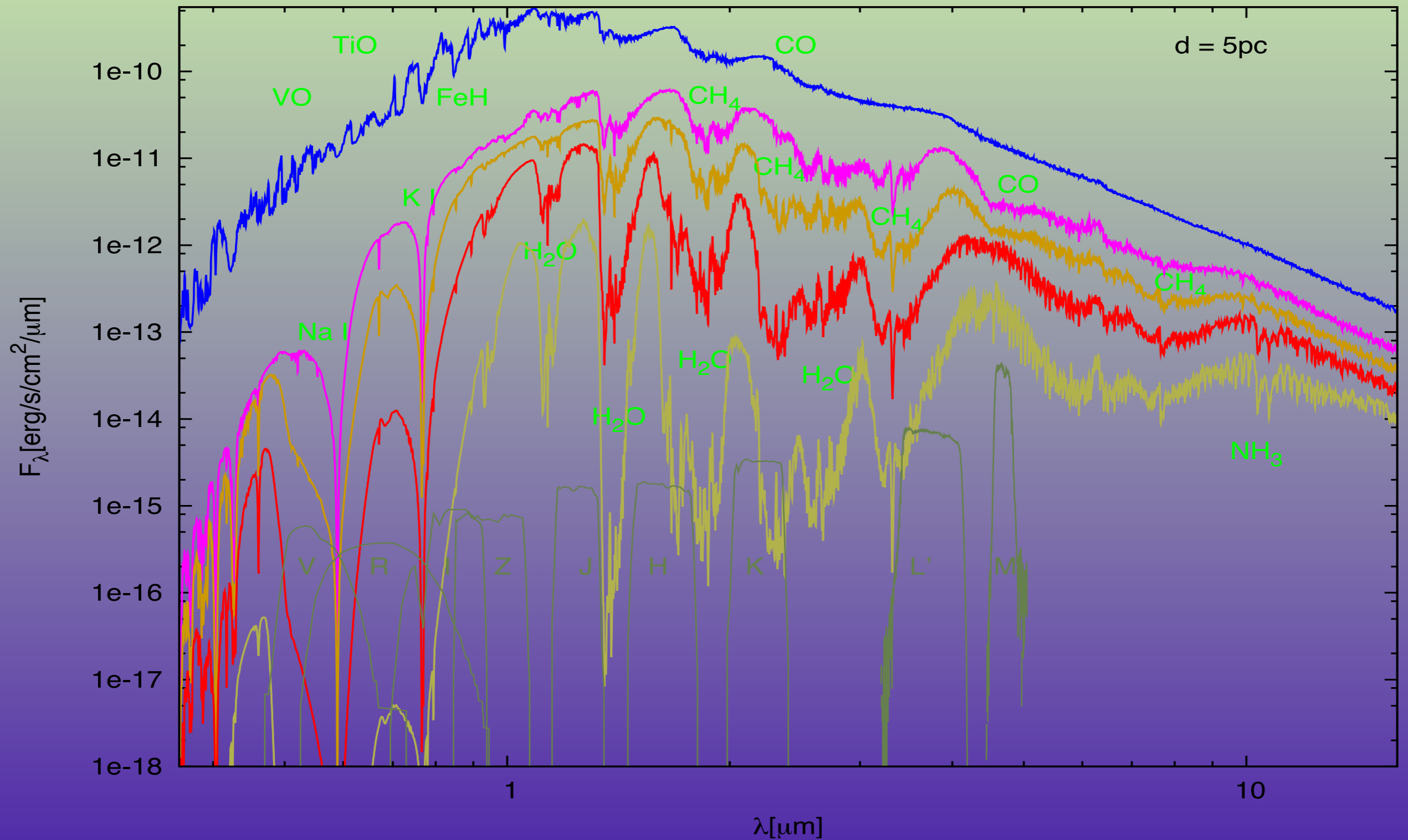
PHOENIX 1D models
estimated from MLT
(dashed lines)

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

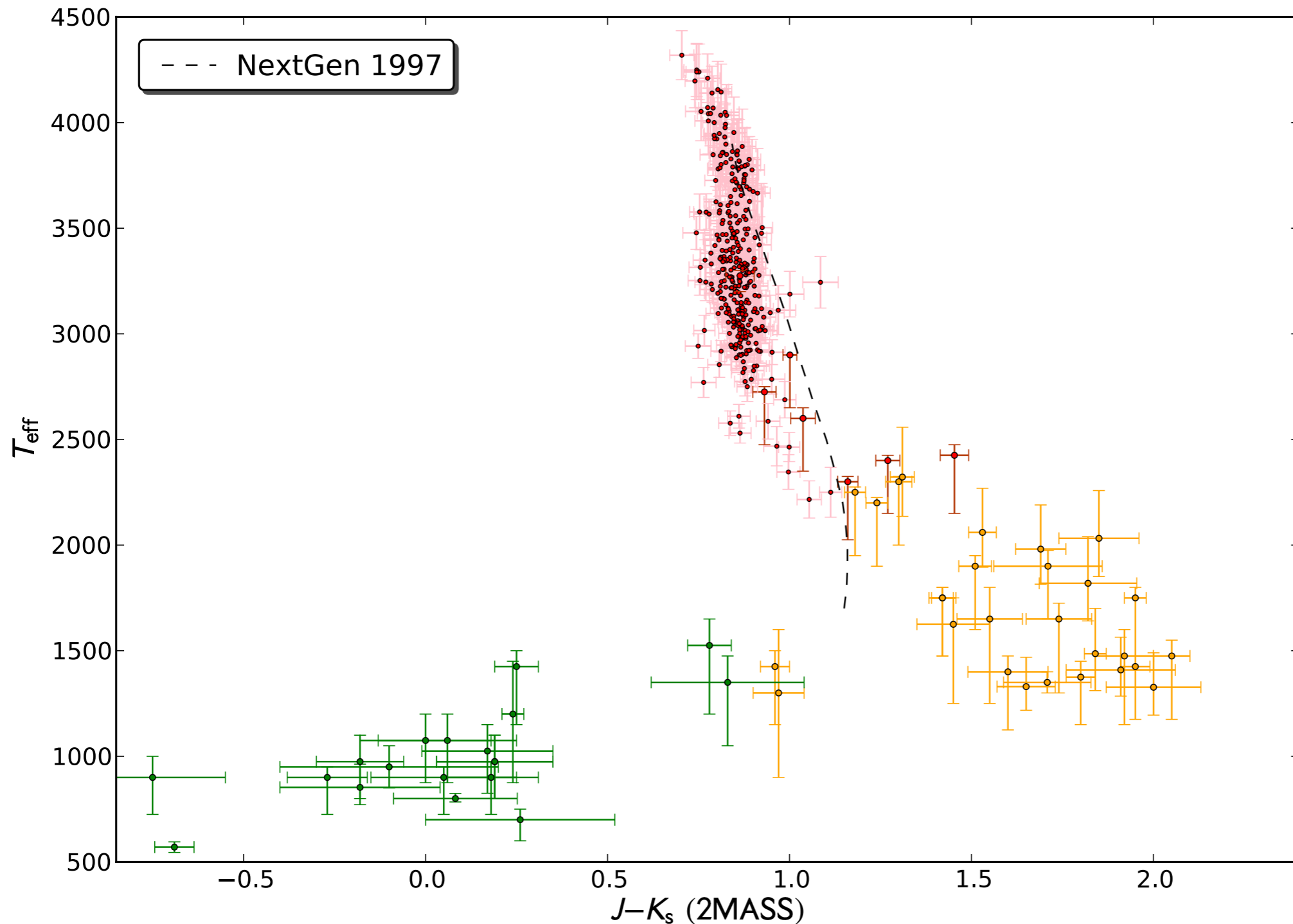
- 1D treatment of convection reproduces trends found in multi-D simulations and empirically fitted “microturbulence”
- Improvements in treatment of convective boundary required!

Spectral Shapes of Cool Atmospheres

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



Model grids for cool and ultracool dwarfs



Allard et al.
1997

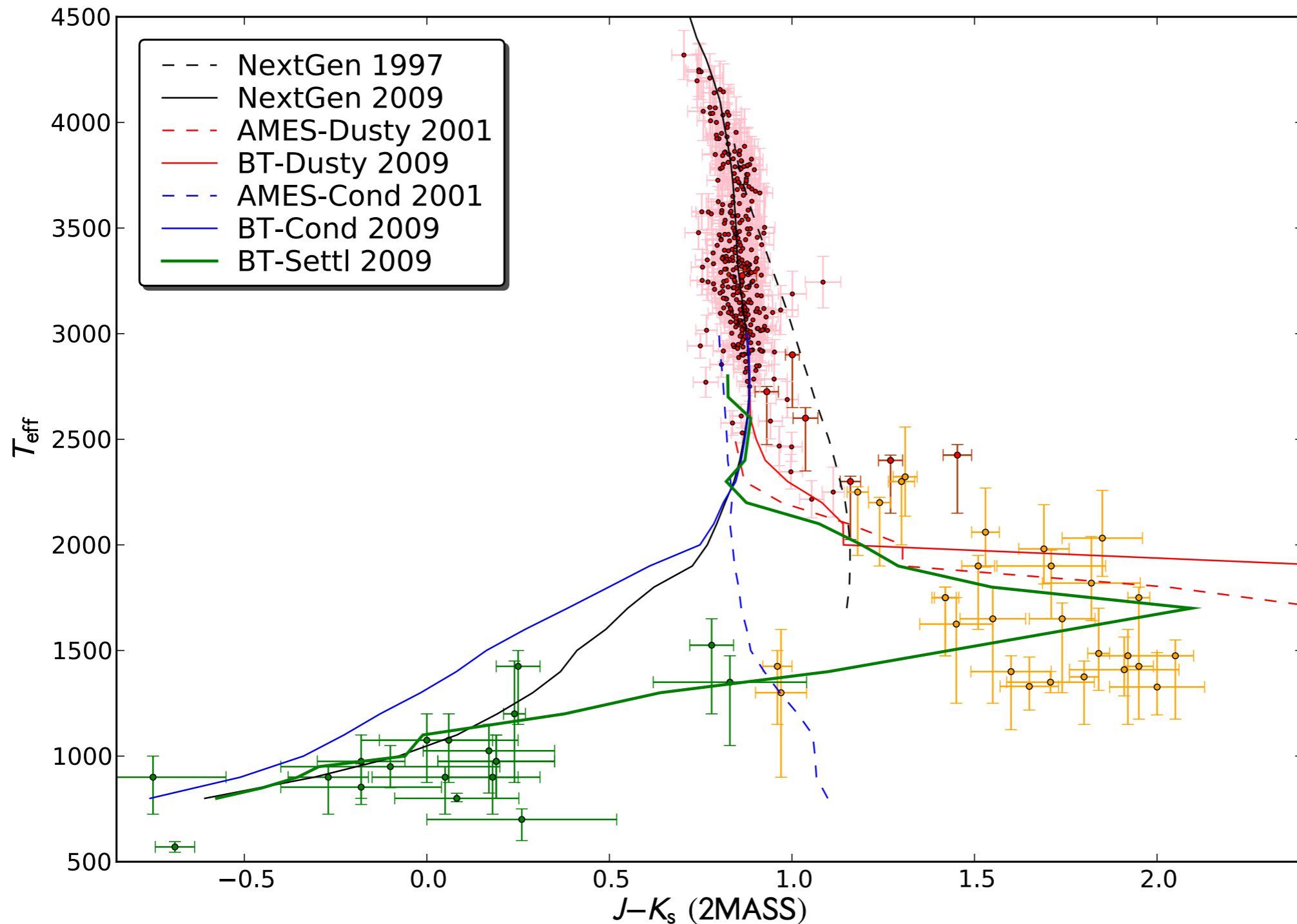
Casagrande
et al. 2008

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.

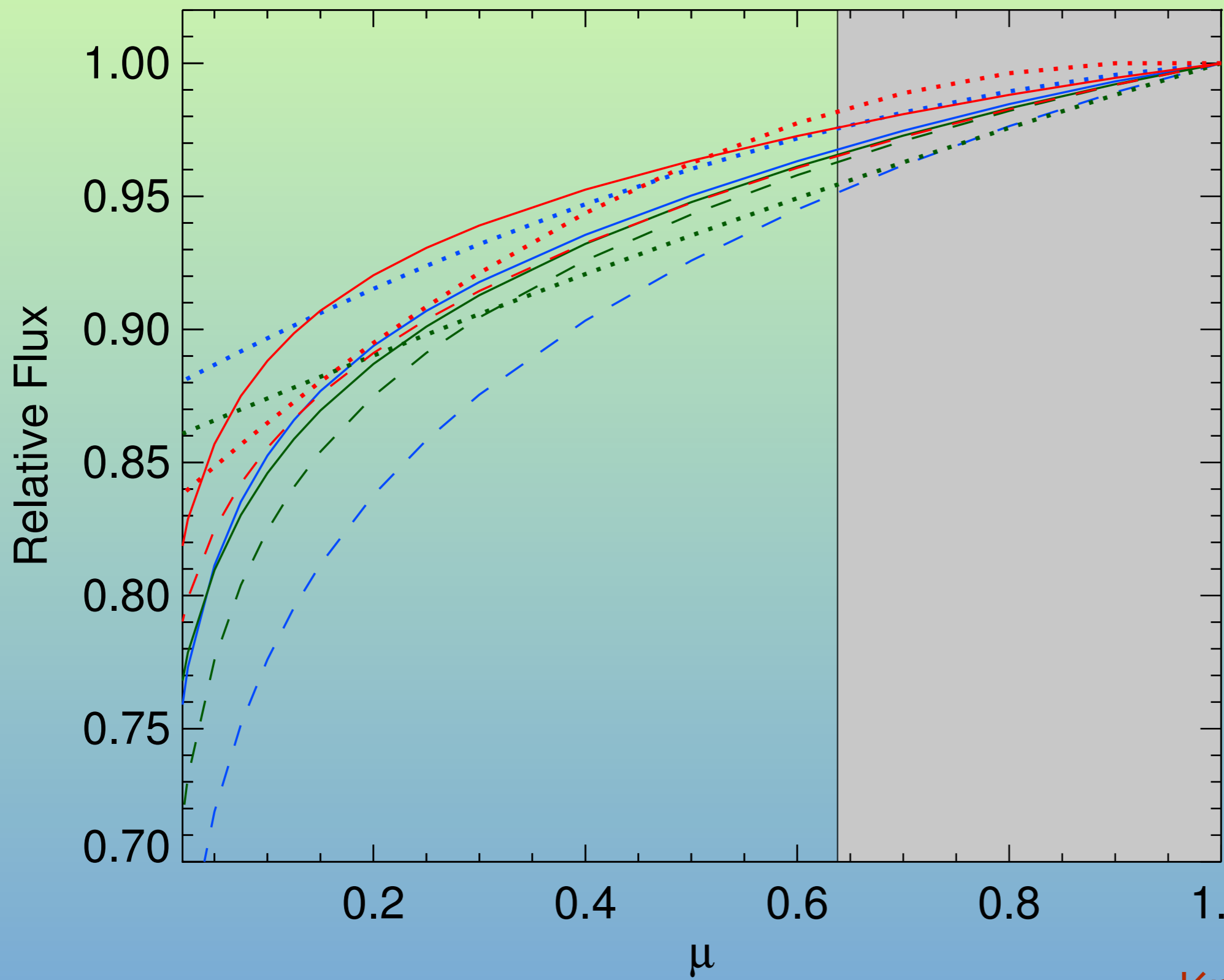
Casagrande
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Golimowski
et al. 2004

Vrba et al.
2004

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

Model Atmospheres: Limb Darkening



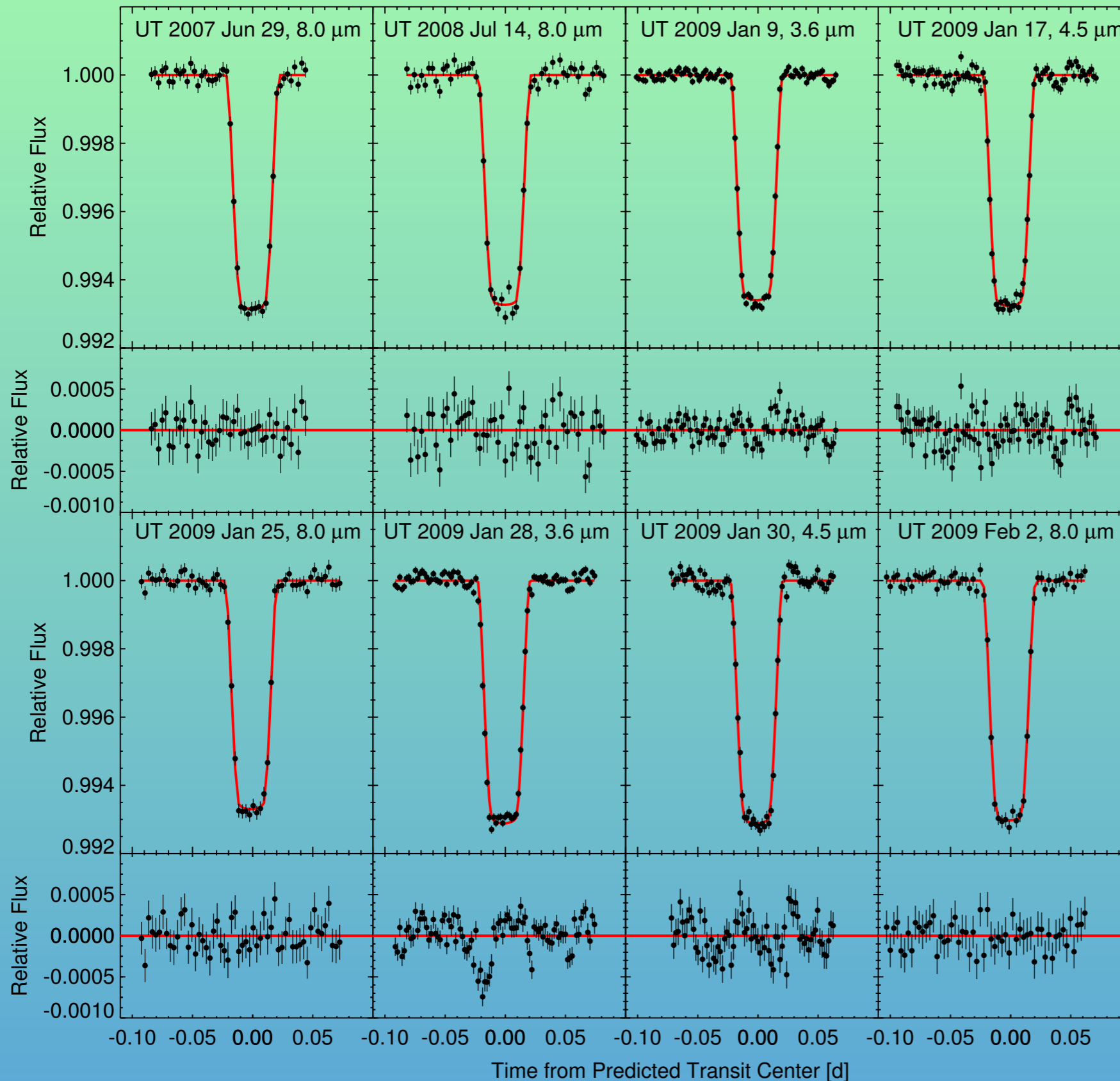
Limb darkening curves of a 3500K M dwarf for IRAC 3.6, 4.5, 8.0 μm bands (blue, green, red):

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

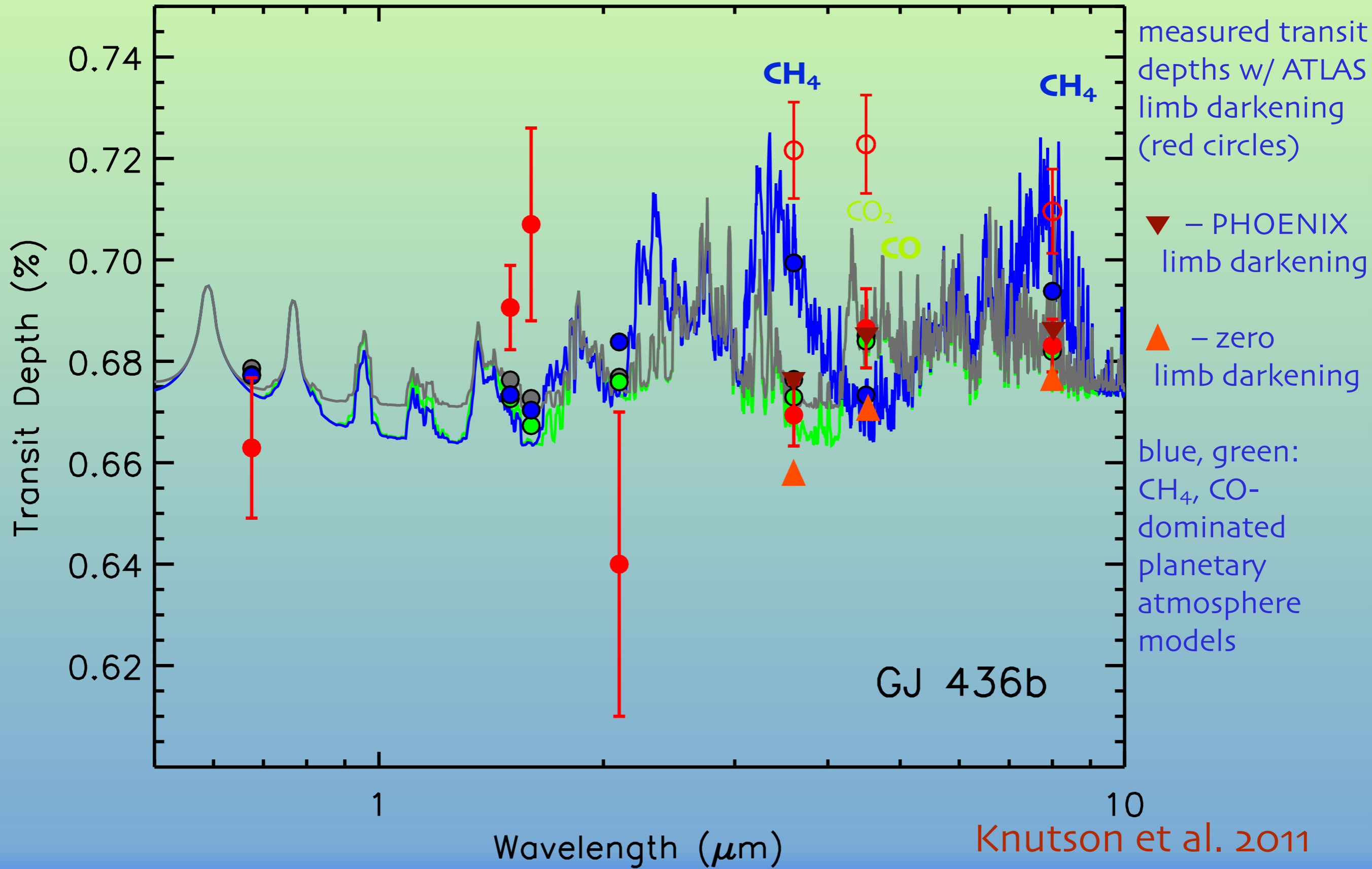
Knutson et al. 2011

Extrasolar planets – Transmission spectroscopy



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

Limb Darkening and Transmission Spectroscopy



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

for funding through the programme

“Astroinformatics: Application of IT in Astronomy and Close Fields” (PI D. Jevremović)

& for your attention!