The Stagger Grid

A grid of 3D atmosphere models for cool stars

Zazralt Magic

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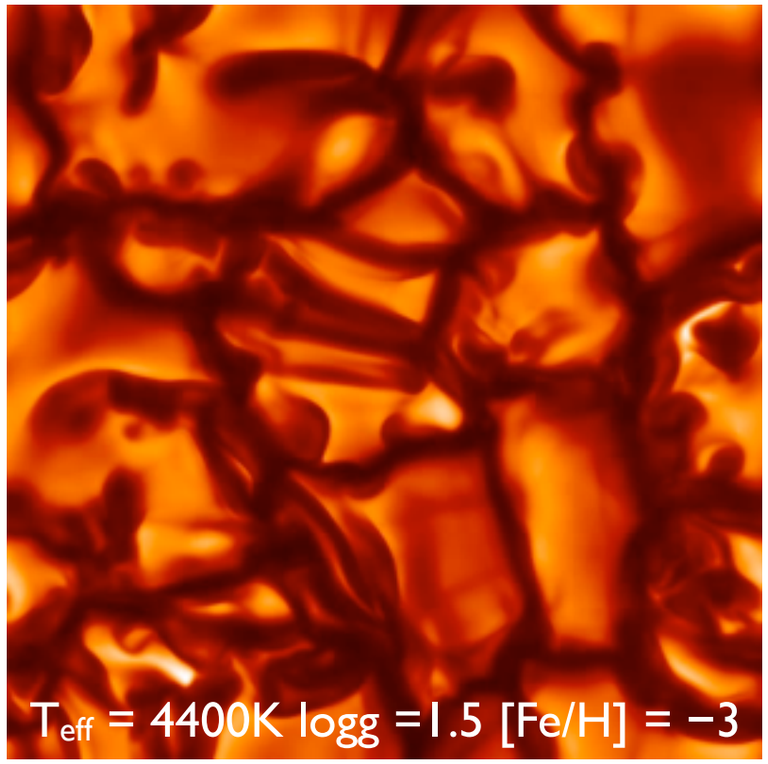
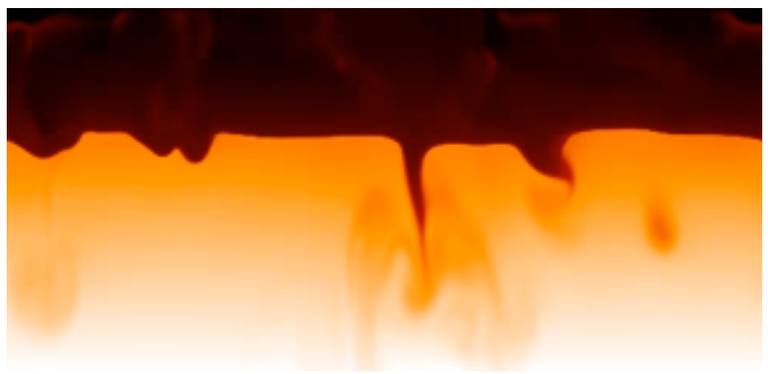
Why 3D RHD?





- Convection:

  Turbulent, non-local phenomena
- Stellar Structure:

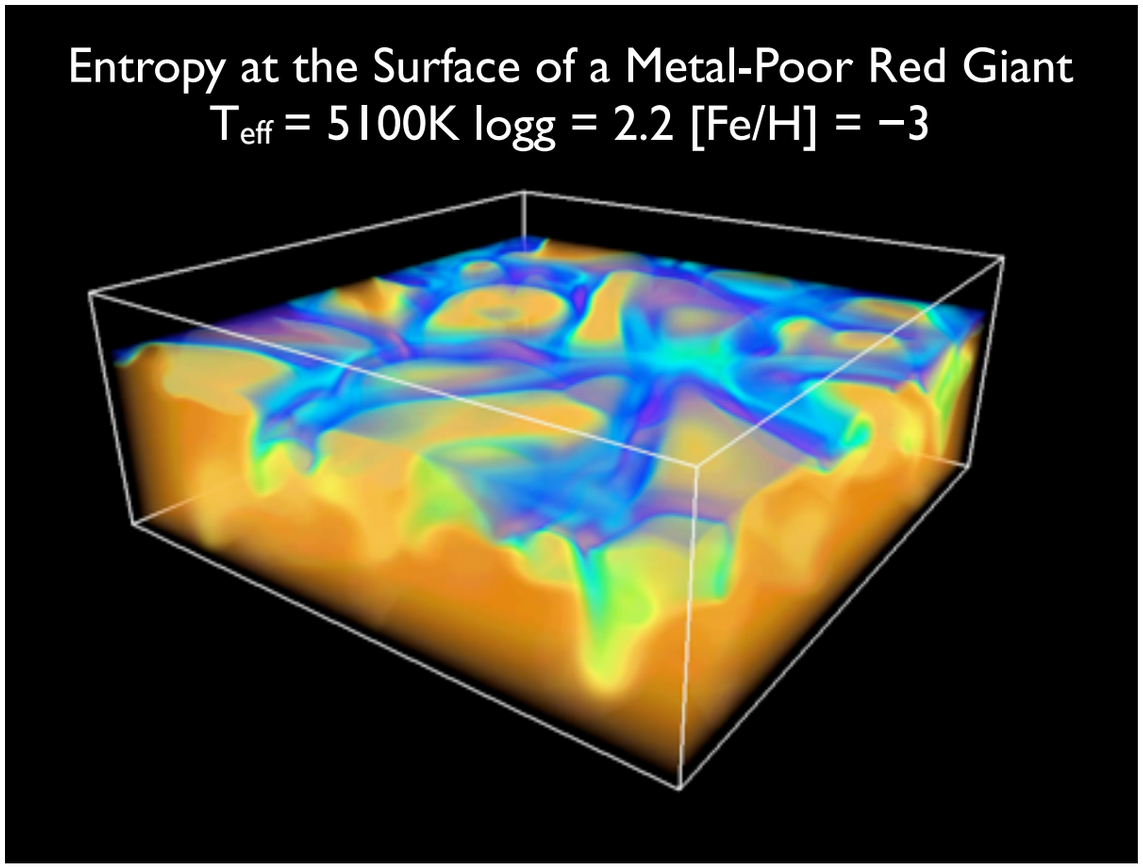
  Outer boundary poorly rendered
- Spectral synthesis:

  Abundances, Stellar parameters
- Helio- and Asteroseismology:

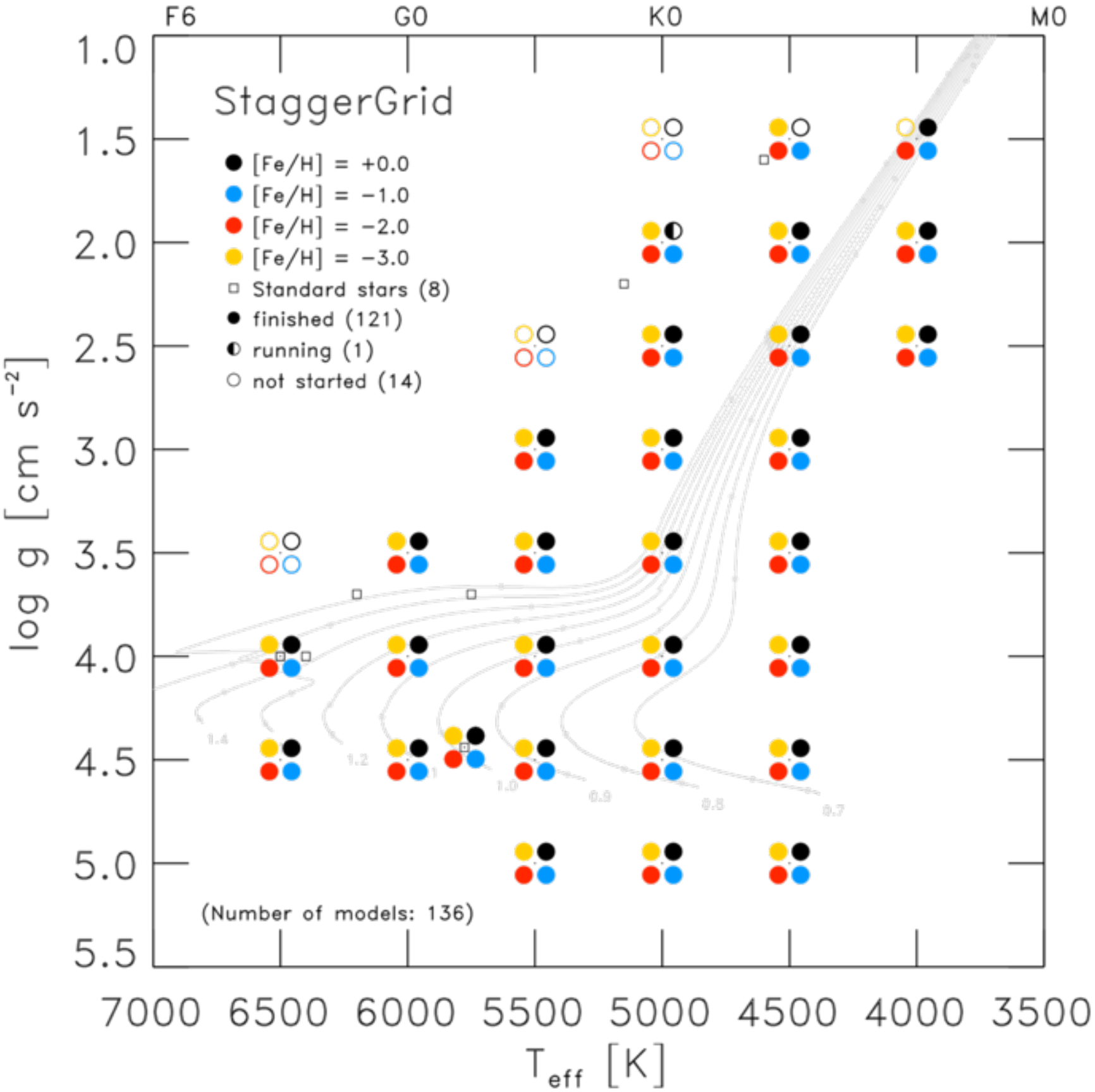
  Excitation of P-modes

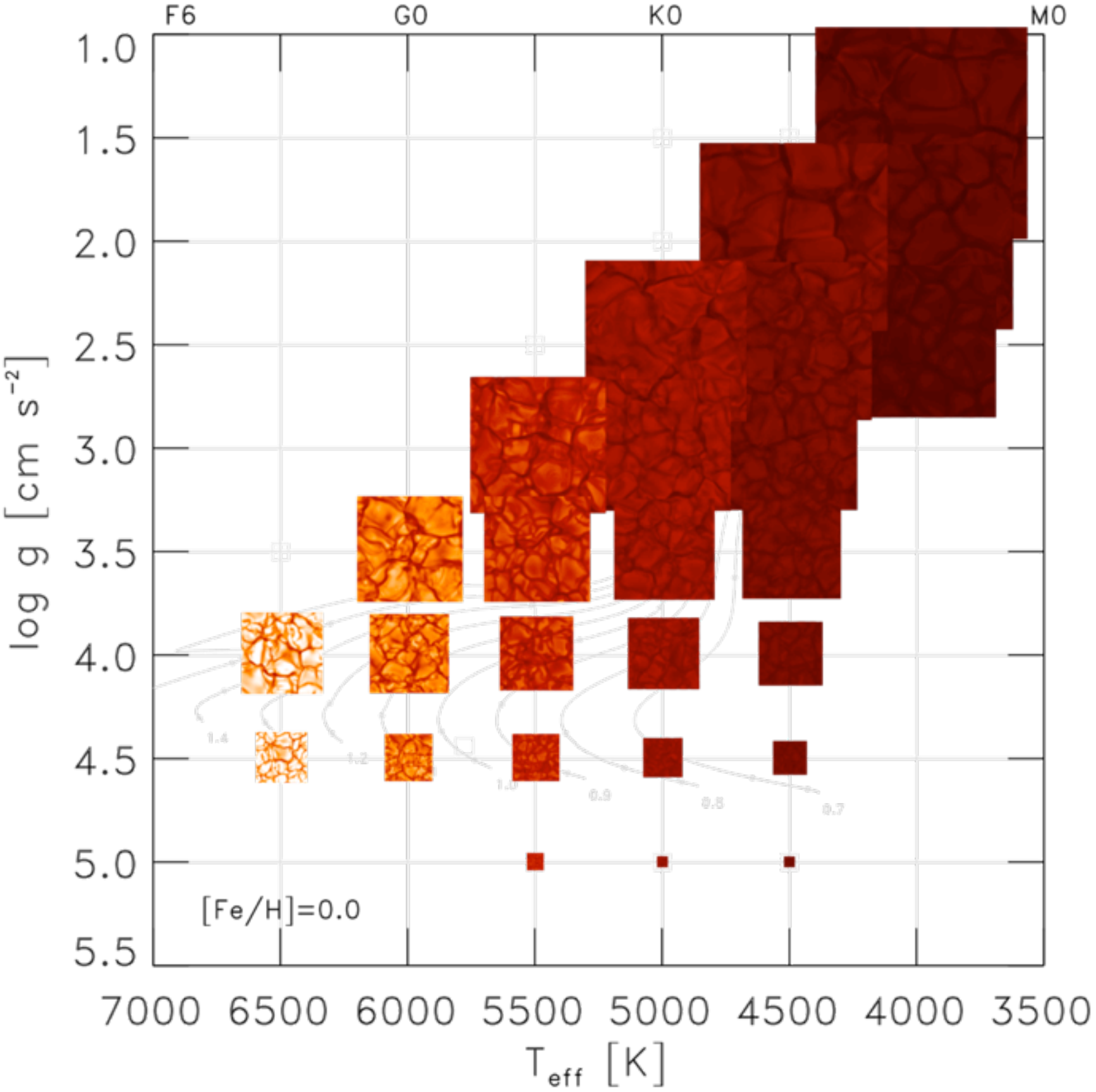
	1D	3D
	Hydrostatic, stationary	Hydrodynamic, time-dependent
Convection	Parametrized MLT, FST	Emergent
Radiative Transfer	10^5 wavelengths	12 opacity bins
Free parameters	α_{MLT}, ξ_{turb}	Essentially no free parameters
Codes	MARCS, ATLAS, PHOENIX, MAFAGS, ...	Stagger, Bifrost CO^{5}BOLD, MURaM, ANTARES, ...

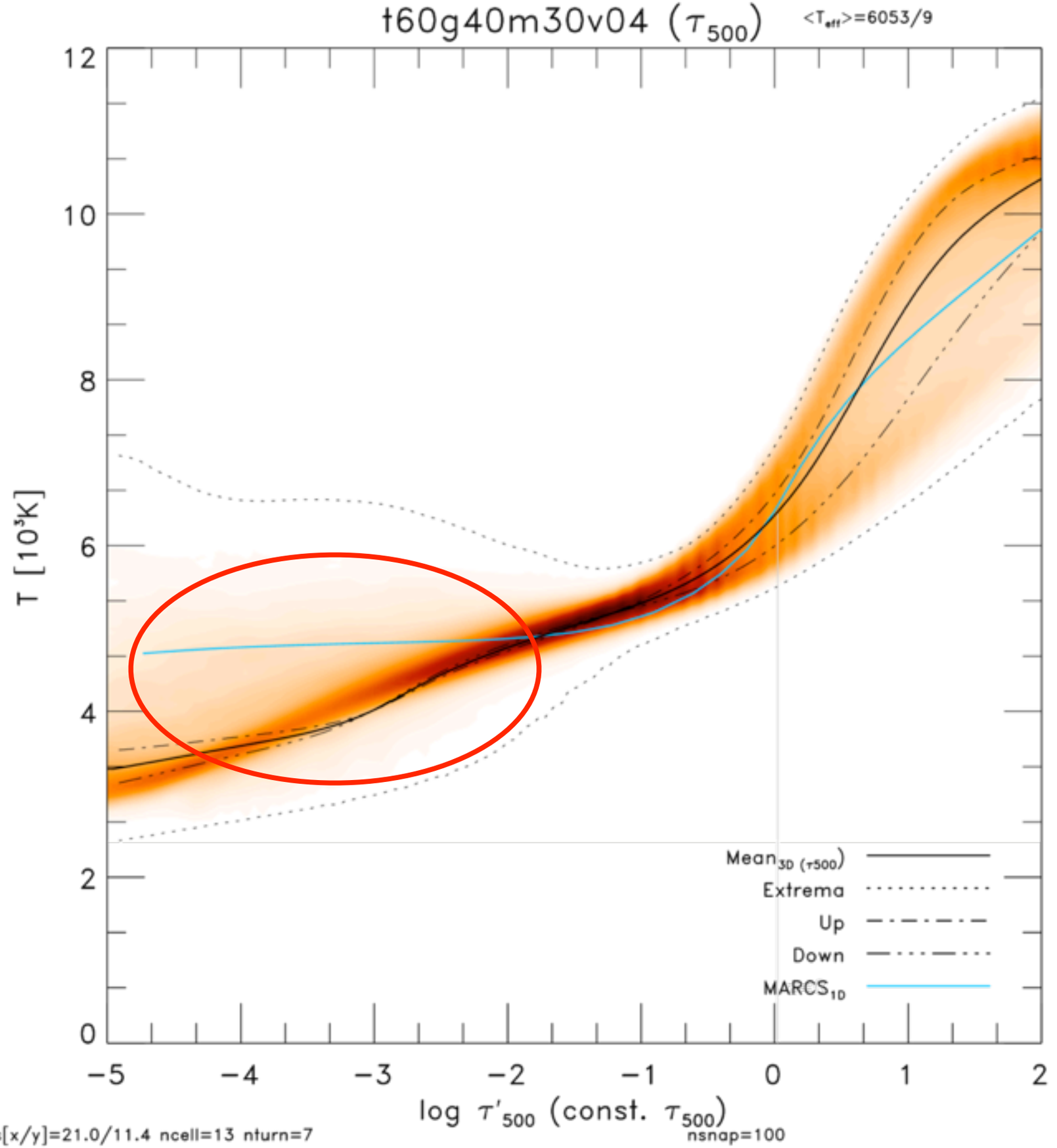
Stagger Grid



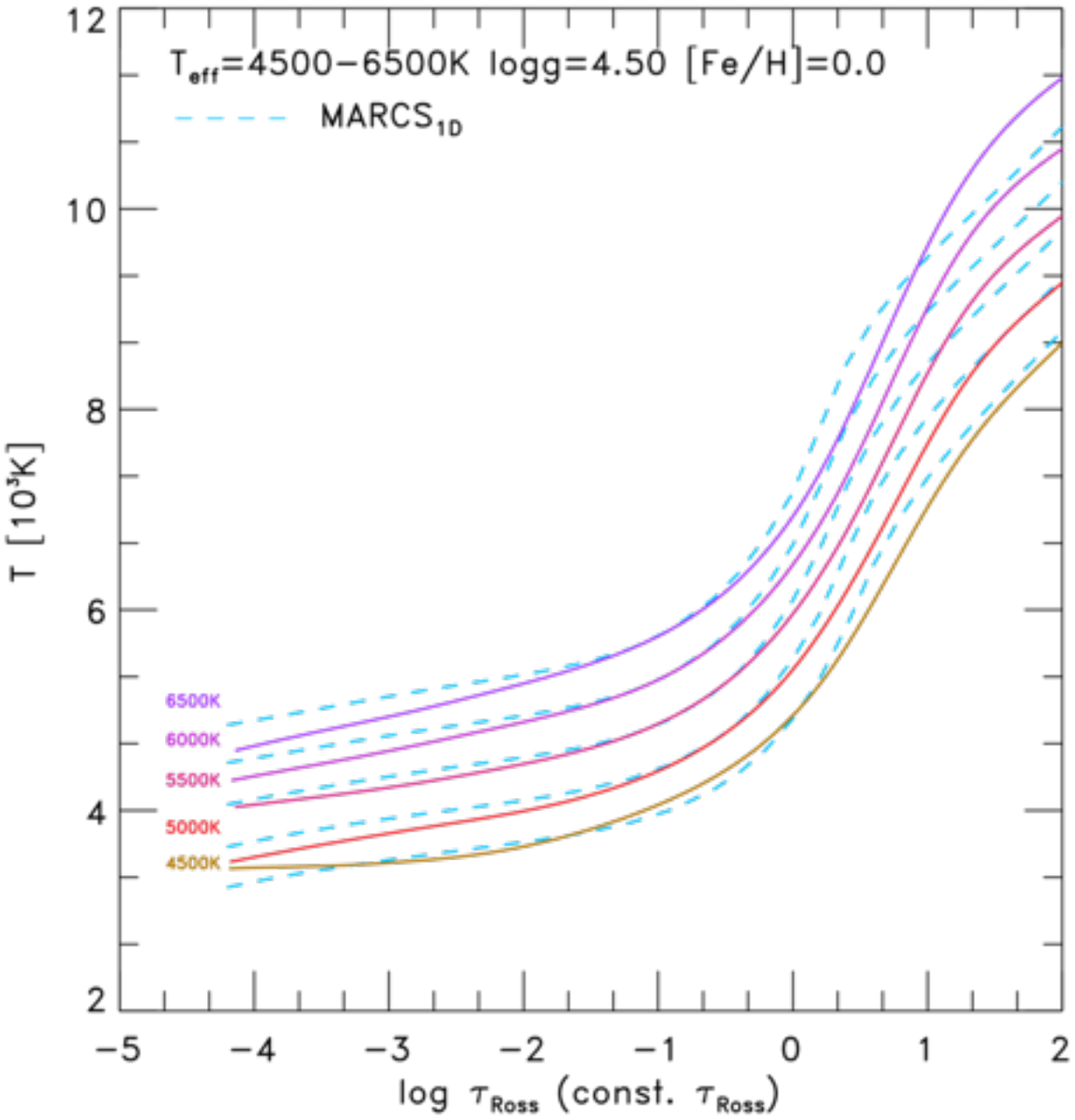
- Stagger Code in pure hydro mode (Nordlund & Galsgaard 1995)
- Box-in-the-star
- Realistic EOS (Mihalas et al.1988) and opacities (MARCS)
- Asplund et al. 2009 composition, α-enhanced for metal-poor stars
- 3D LTE radiative transfer with 9 angles and 6-12 opacity bins
- Resolution: 240^3 covering ~10 granules and ~12 H_P

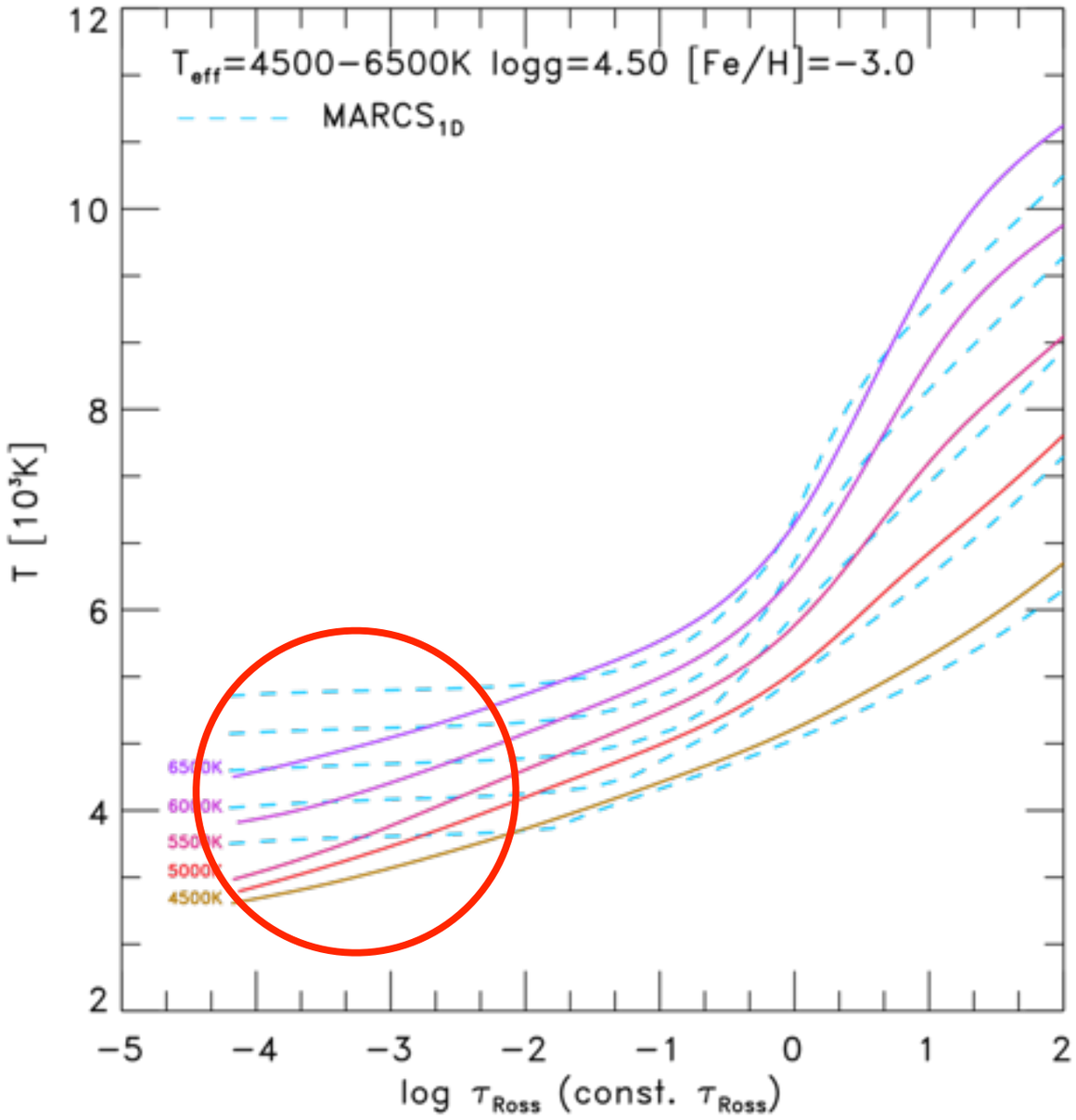

F6
G0
K0
M0
StaggerGrid
[Fe/H] = +0.0
[Fe/H] = −1.0
[Fe/H] = −2.0
[Fe/H] = −3.0
Standard stars (8)
finished (121)
running (1)
not started (14)
(Number of models: 136)
log g [cm s^{-2}]
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
7000
6500
6000
5500
5000
4500
4000
3500
T_{eff} [K]


F6
G0
K0
M0
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
log g [cm s^{-2}]
[Fe/H]=0.0
7000
6500
6000
5500
5000
4500
4000
3500
T_{eff} [K]

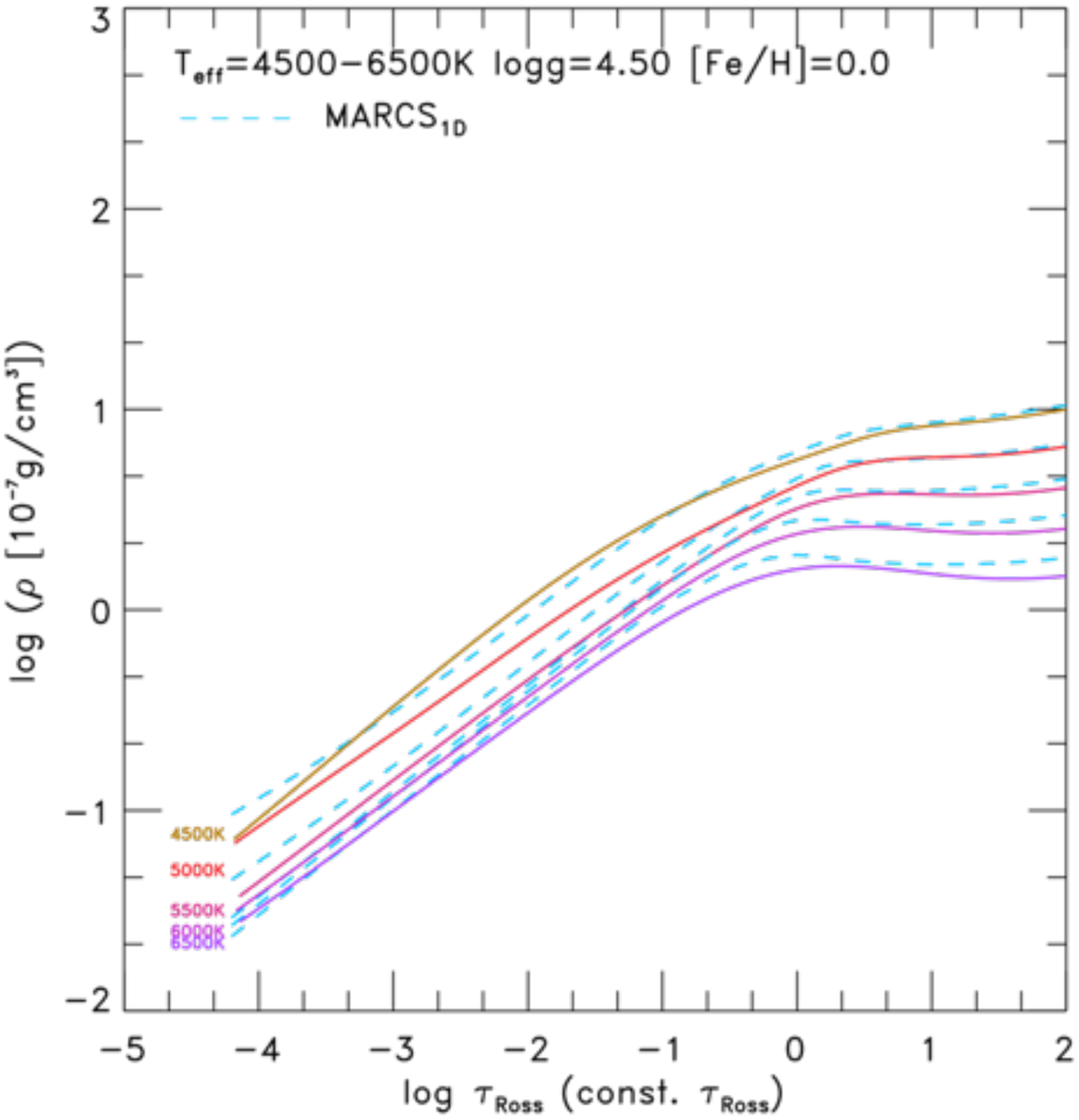

t60g40m30v04 (τ_{500})
<T_{eff}>=6053/9
12
10
8
6
4
2
0
T [10^3K]
−5
−4
−3
−2
−1
0
1
2
log τ'_{500} (const. τ_{500})
Mean$_{3D\ (\tau 500)}$
Extrema
Up
Down
MARCS$_{1D}$
s[x/y]=21.0/11.4 ncell=13 nturn=7
nsnap=100

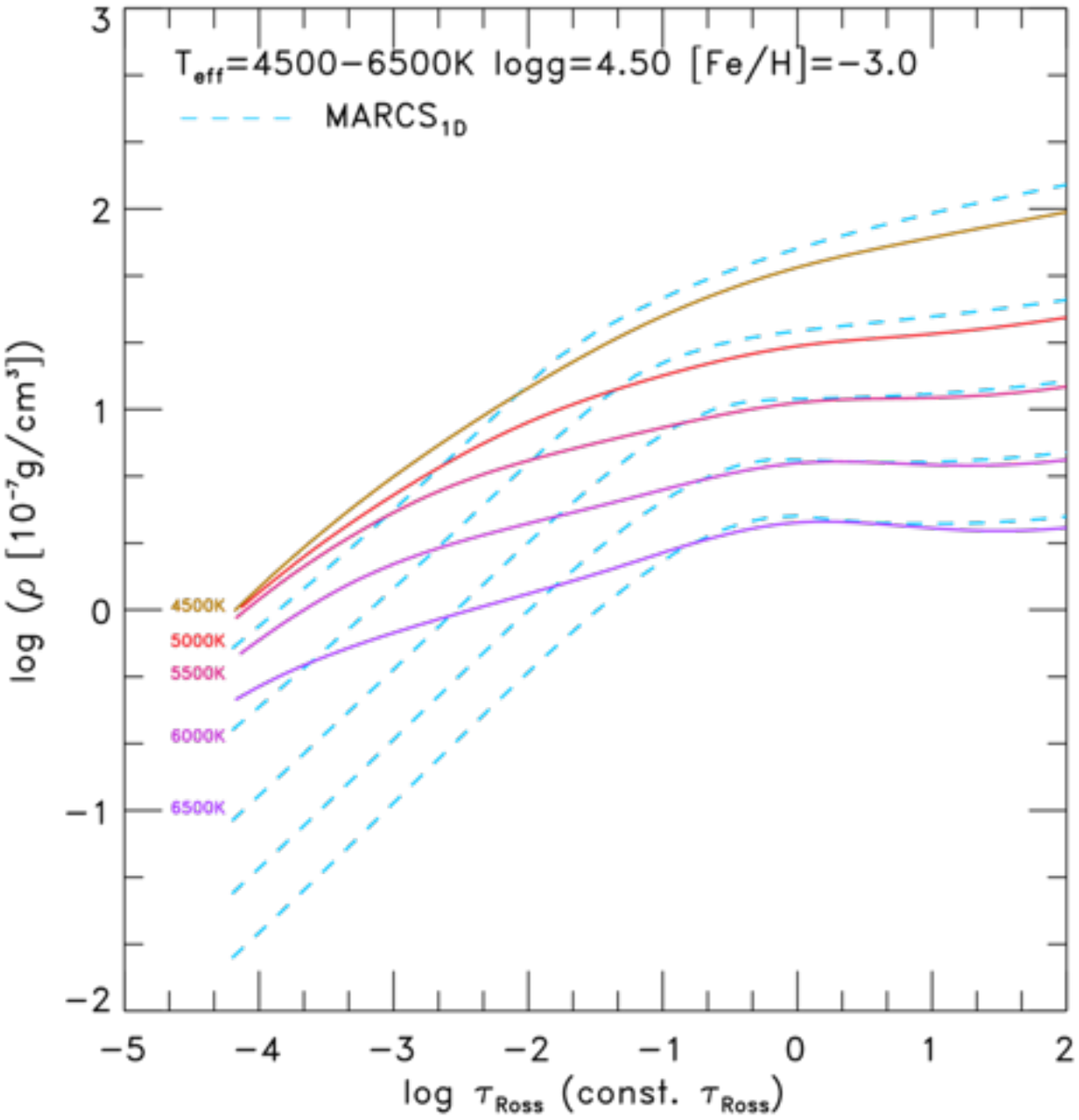
Temperature



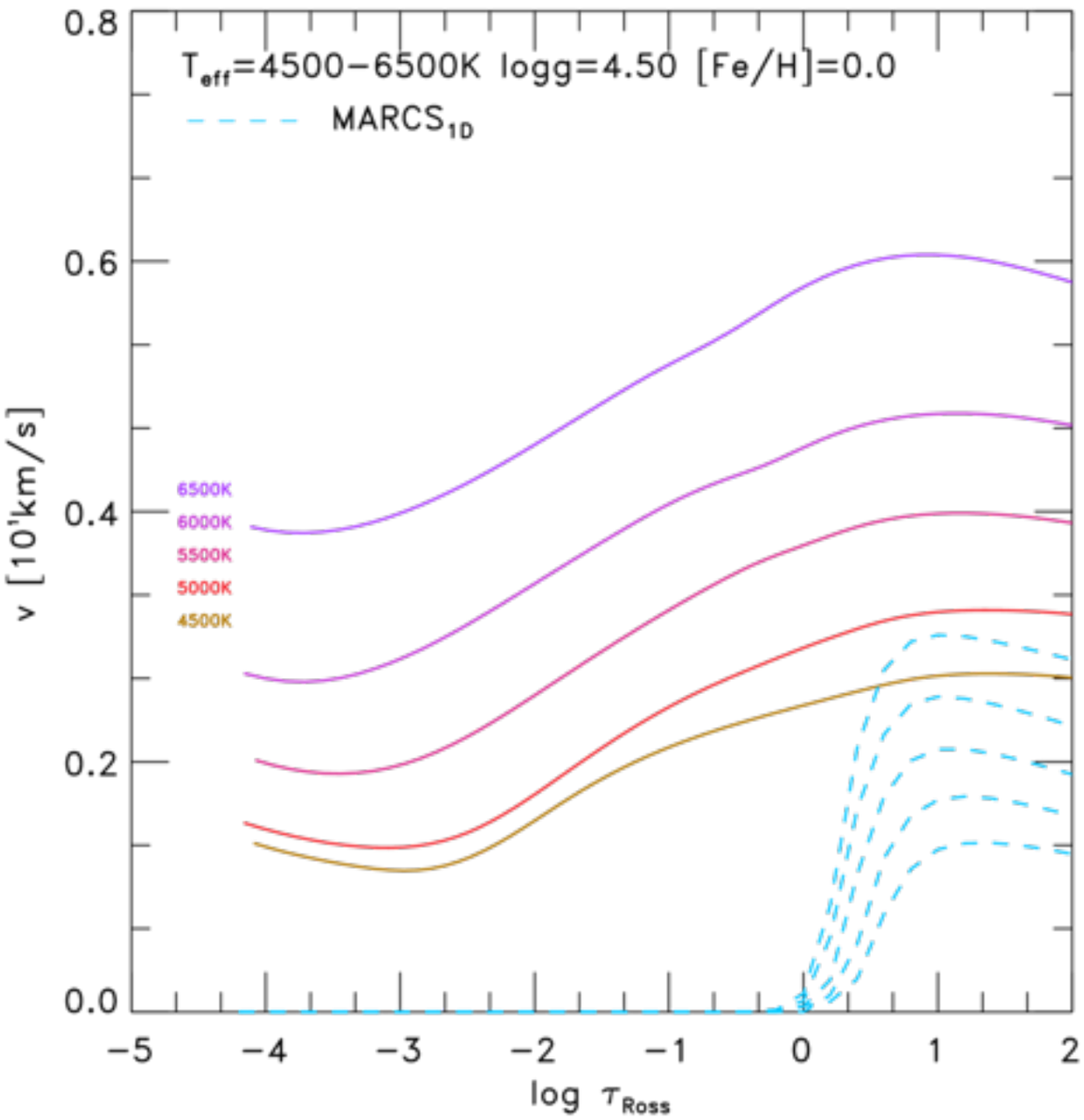


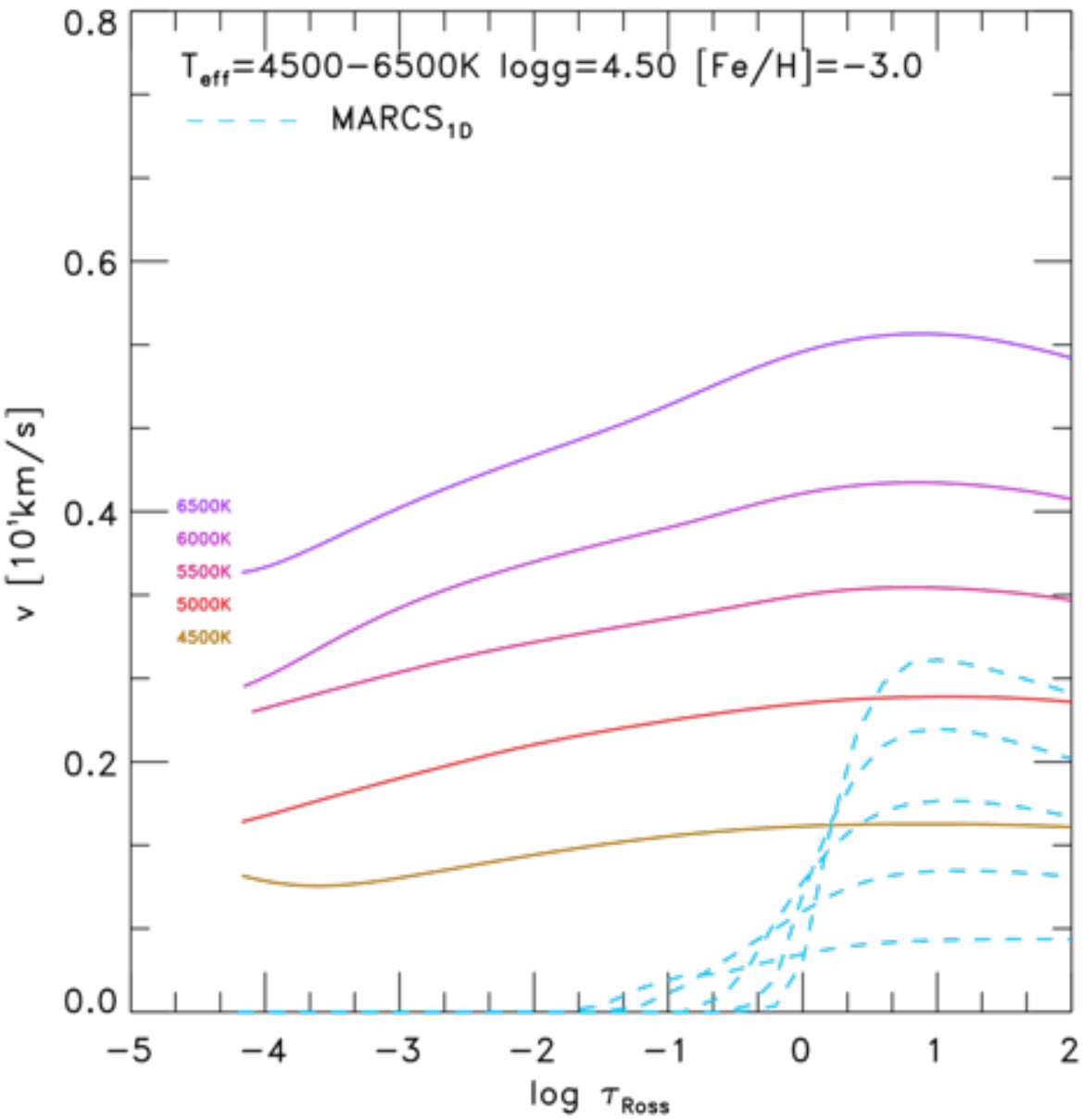
Density


T_eff=4500−6500K logg=4.50 [Fe/H]=0.0
MARCS1D
4500K
5000K
5500K
6000K
6500K
log (ρ [10⁻⁷g/cm³])
log τRoss (const. τRoss)


T_eff=4500−6500K logg=4.50 [Fe/H]=−3.0
MARCS1D
4500K
5000K
5500K
6000K
6500K
log (ρ [10⁻⁷g/cm³])
log τRoss (const. τRoss)

Velocity

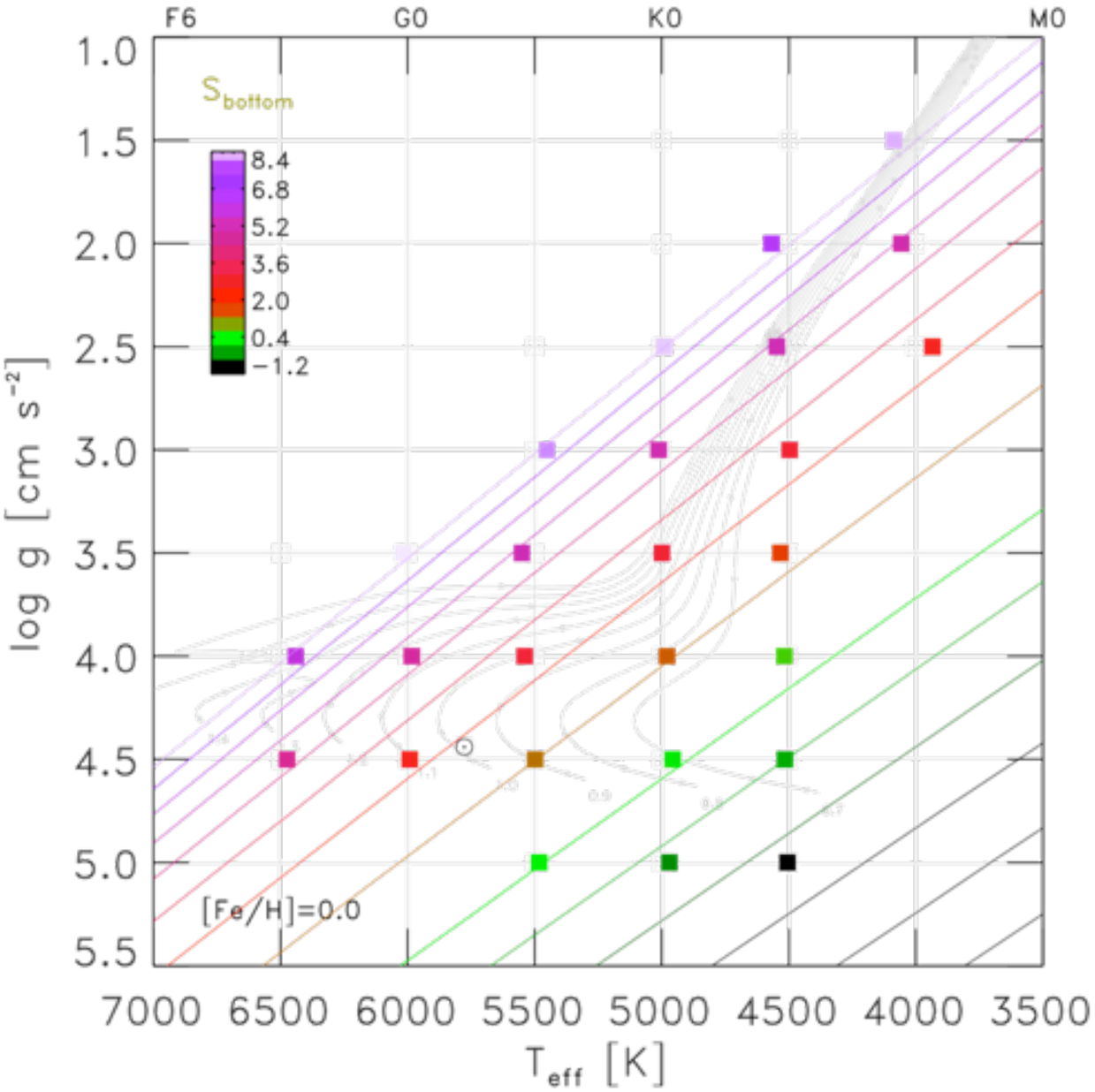

T_{eff}=4500−6500K logg=4.50 [Fe/H]=0.0
MARCS$_{1D}$
6500K
6000K
5500K
5000K
4500K
v [10'km/s]
log τ_{Ross}


T_{eff}=4500−6500K logg=4.50 [Fe/H]=−3.0
MARCS$_{1D}$
6500K
6000K
5500K
5000K
4500K
v [10'km/s]
log τ_{Ross}

Applications

- Stellar abundance analysis
- Stellar parameters determination
- Boundary condition for stellar evolution
- Calibrating MLT
- Oscillation frequencies

Calibrating MLT



- Ludwig et al. 1999:

  α_{MLT}: $\langle S_{2D,bot} \rangle = S_{1D,env}$

- Trampedach 2007:

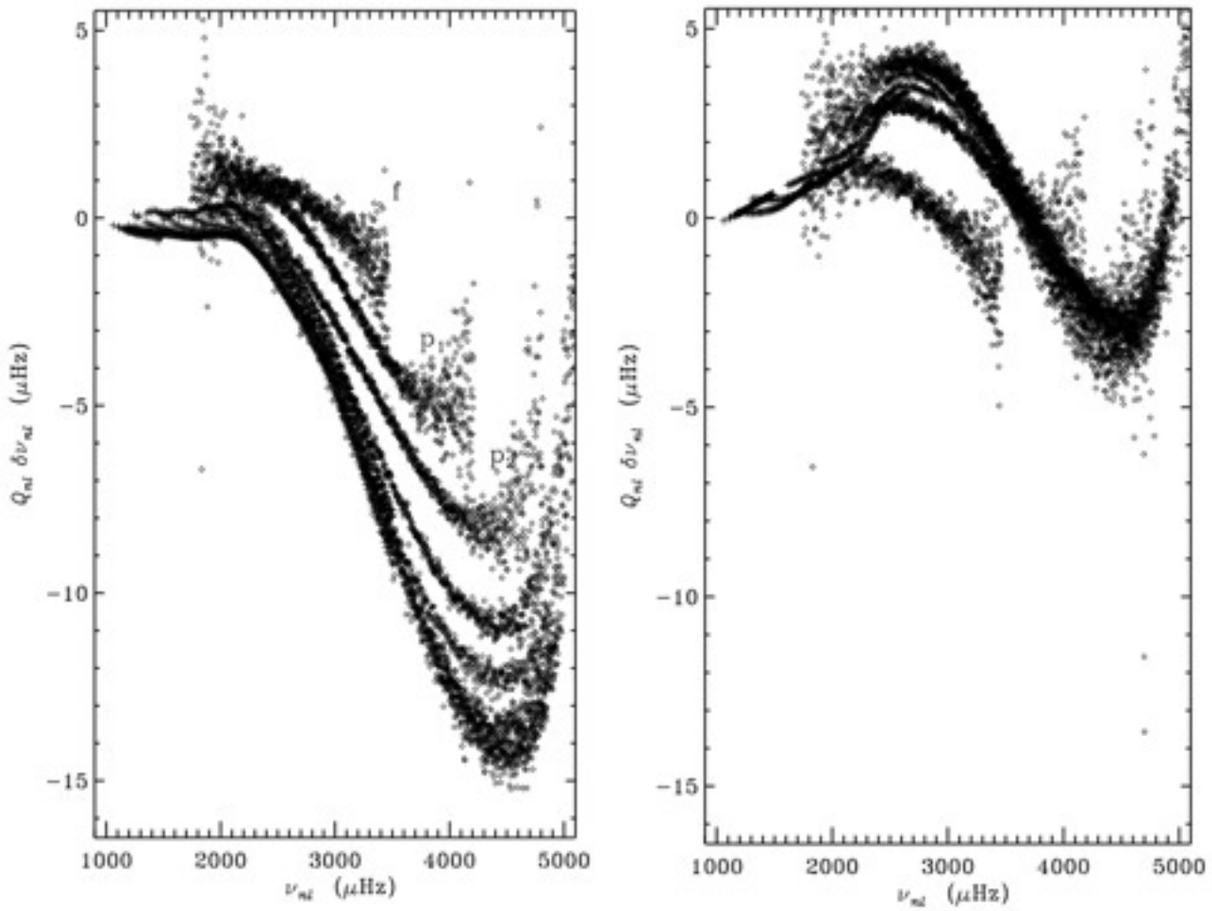
  α_{MLT}: $\langle \rho, T_{3D,bot} \rangle = \rho, T_{1D,env}$

- Trampedach & Stein 2011:
  α_{MLL}: Masss Mixing Length

- Matching Entropy-jump with α_{MLT}

Oscillation frequencies

1D <3D>

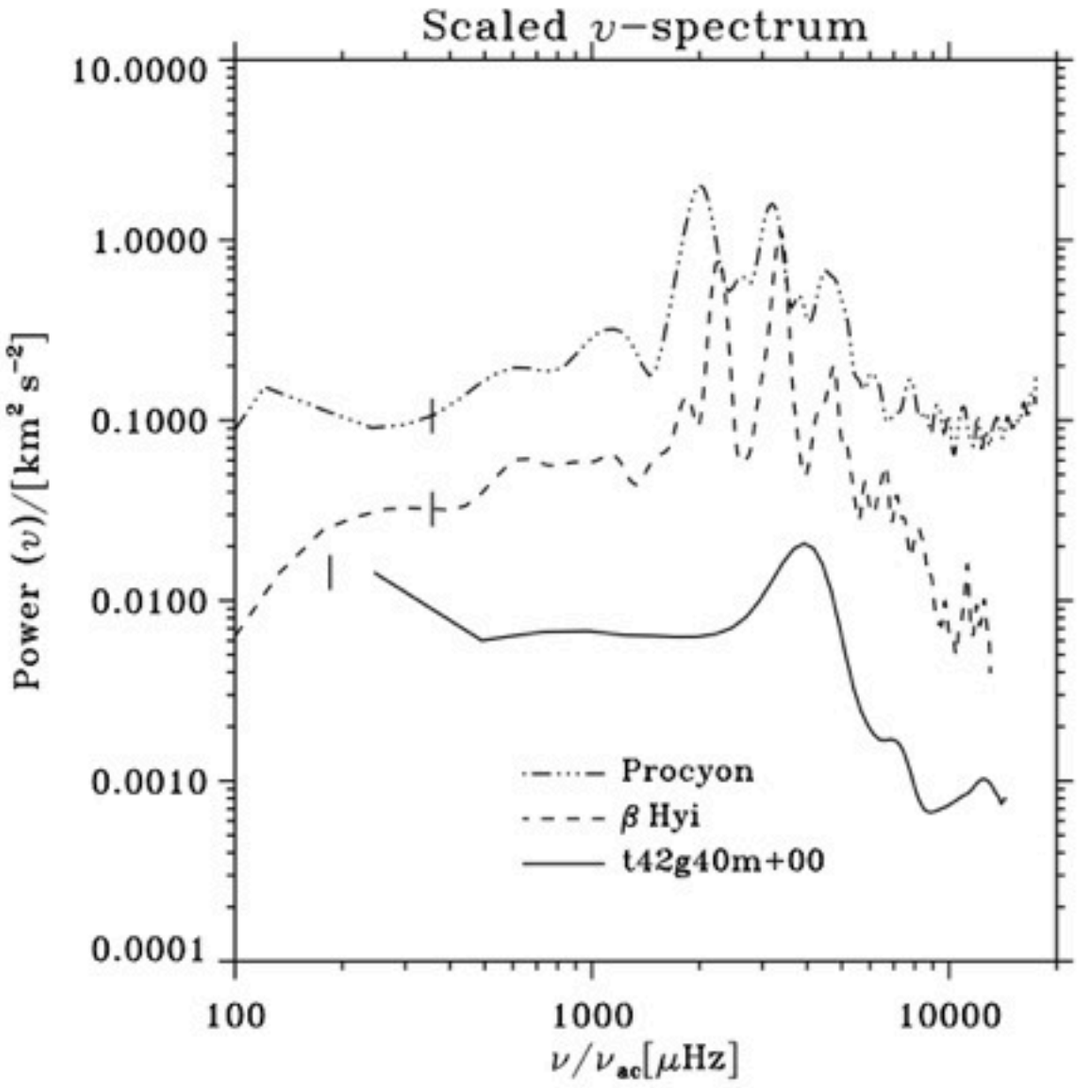


- Rosenthal et al. 1999:

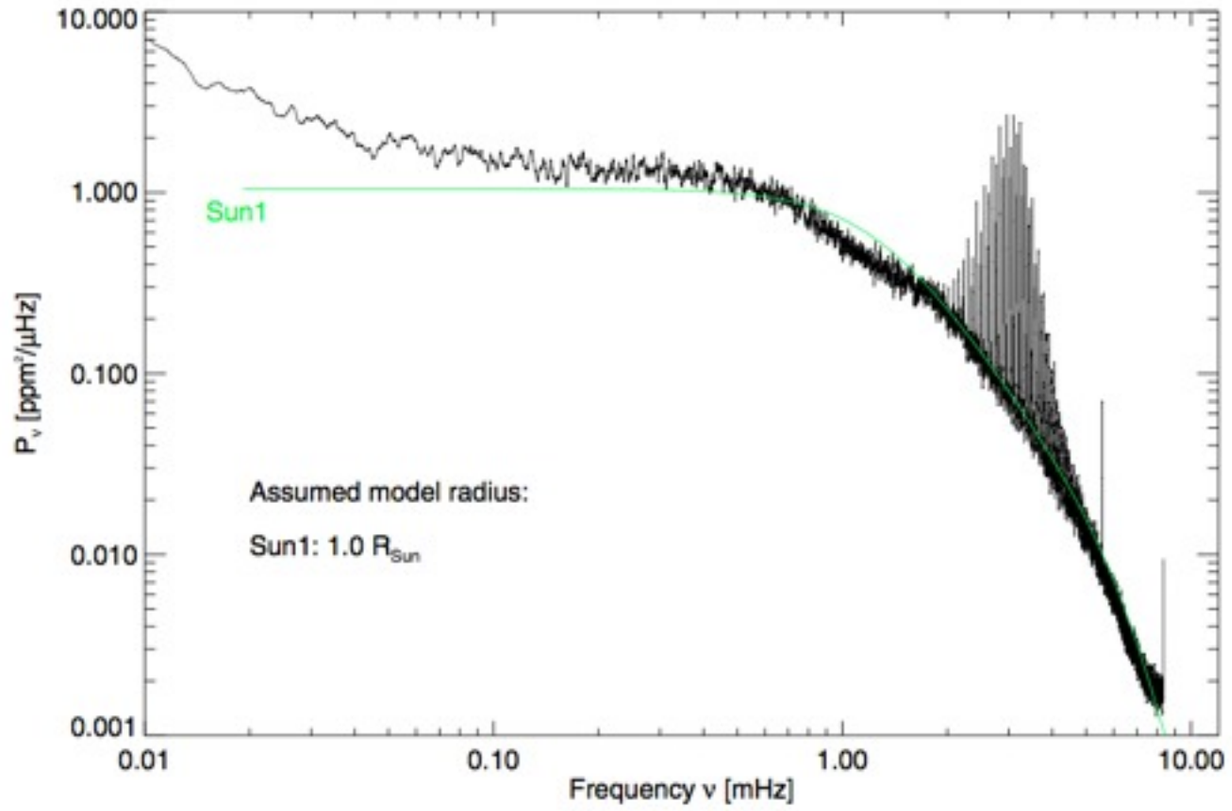
  <3D> atmosphere models extended with 1D stellar envelope models, improvement at higher frequencies

- Nordlund & Stein 2000
- Stein & Nordlund 2001

Oscillation power spectrum



Trampedach 2007



Ludwig et al. 2009

Summary

- Large 3D RHD Grids soon available
- Stagger Grid will be publicly accessible
- Improvement in Stellar Structure models

Thank you.