Worries and a wish when linking 1D and 3D models

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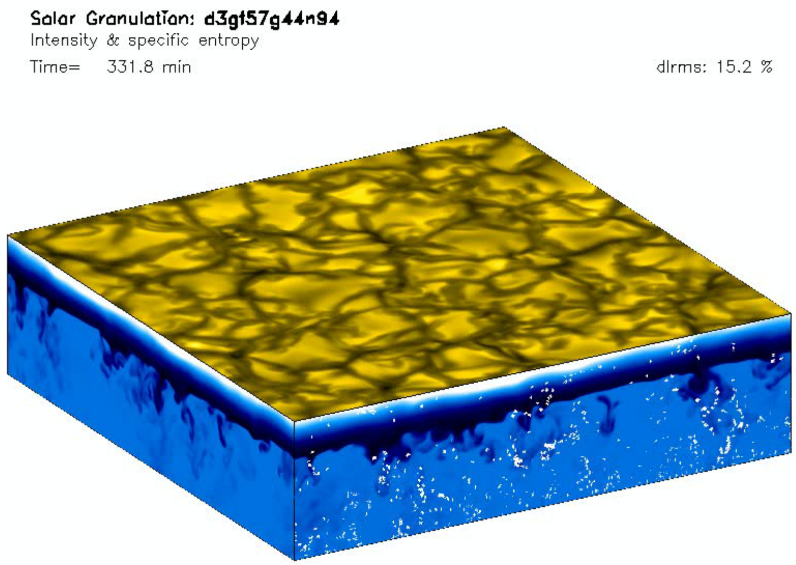
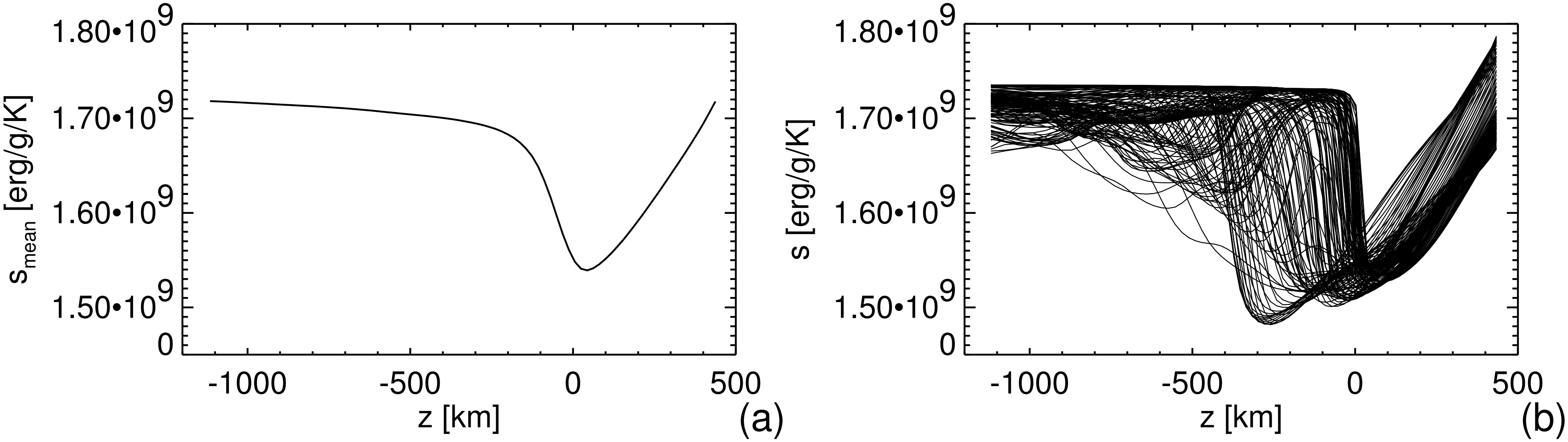
Overview

- Worry 1: turbulent pressure and calibrating the mixing-length parameter
- Worry 2: how to patch 3D surface models to 1D interior structures
- Both points above related to quasi-stationary background structure
- Wish: learning how to calculate mode excitation rates
  - related to dynamics, oscillation-convection interaction
  - brought two 3D models of different extent in depth, otherwise identical



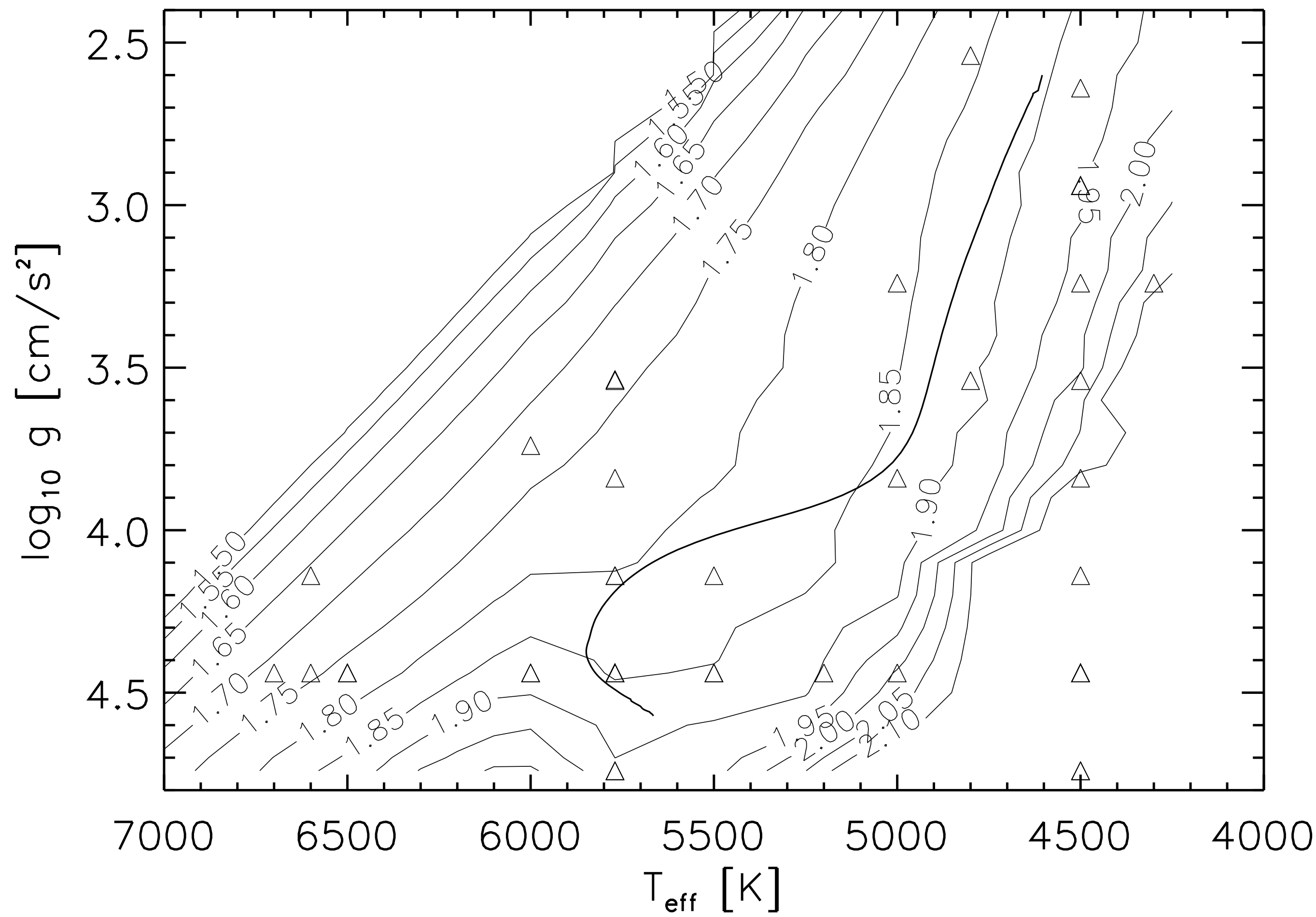
Calibration of the mixing-length parameter α_{MLT}



“Historic” figure from SCORe96 proceedings; left: mean entropy; right: spatially resolved profiles

- Horizontal mean entropy profile superadiabatic in subphotospheric layers
- Spatially resolved profiles exhibit entropy plateau, value s_{env}
  - identified with asymptotic value of the (almost) adiabatically stratified part of the convective zone
- Entropy value matched by choosing α_{MLT} in mixing-length models
- Side point here: also depends on assumed atmospheric $T(\tau)$ relation

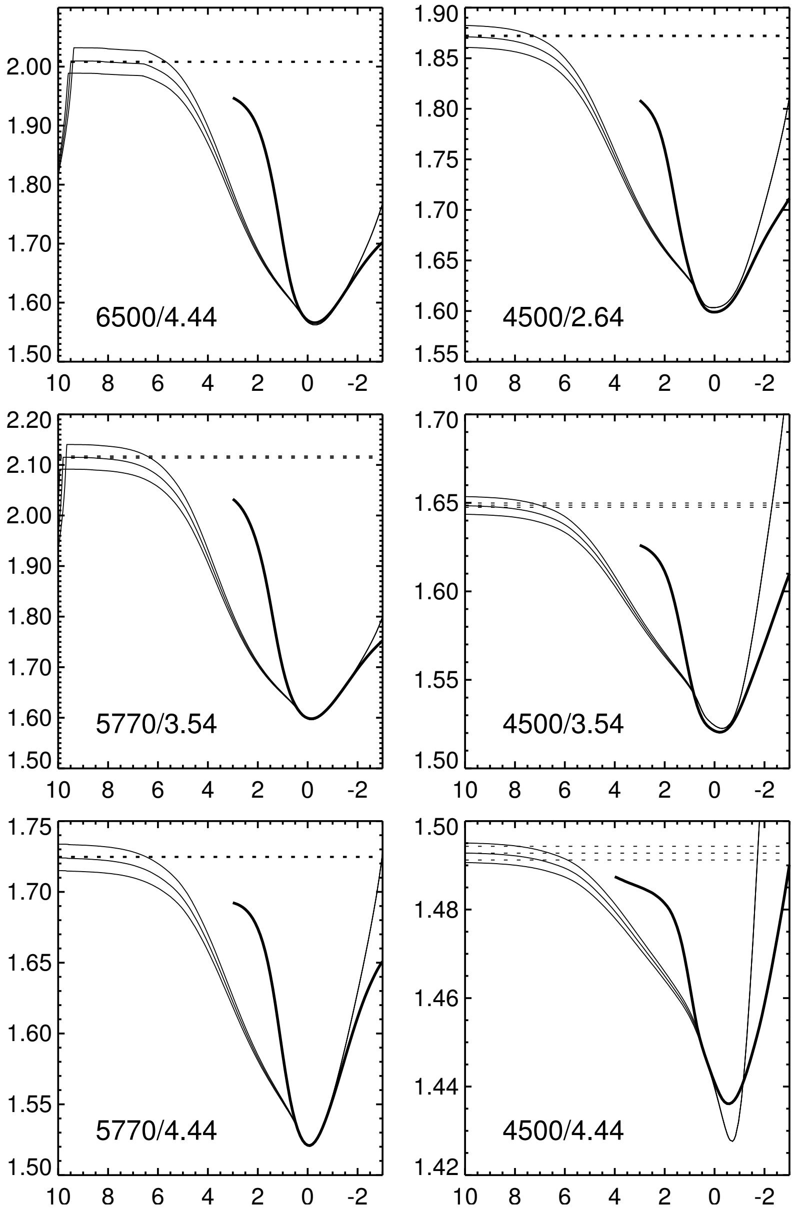
Calibration of the mixing-length parameter α_{MLT}



From SCORe96 proceedings; triangles: 2D models; solid line: solar evolutionary track using calibration

- Grossly, functional dependence withstood the test of time
- HRD coverage increased, metallicity dependence investigated, $T(\tau)$-relation refined

Are mean 3D and calibrated mixing-length model similar?



Specific entropy vs log optical depth (Ludwig et al. 1999)

- Thick solid lines: τ-averages of entropy of hydro model
- Thin solid lines: calibrated MLT model with uncertainties
- Dotted lines: s_{env}
- Main point: entropy minimum matched, correspondence in deeper layers is so-so
- τ-averages suitable / relevant?

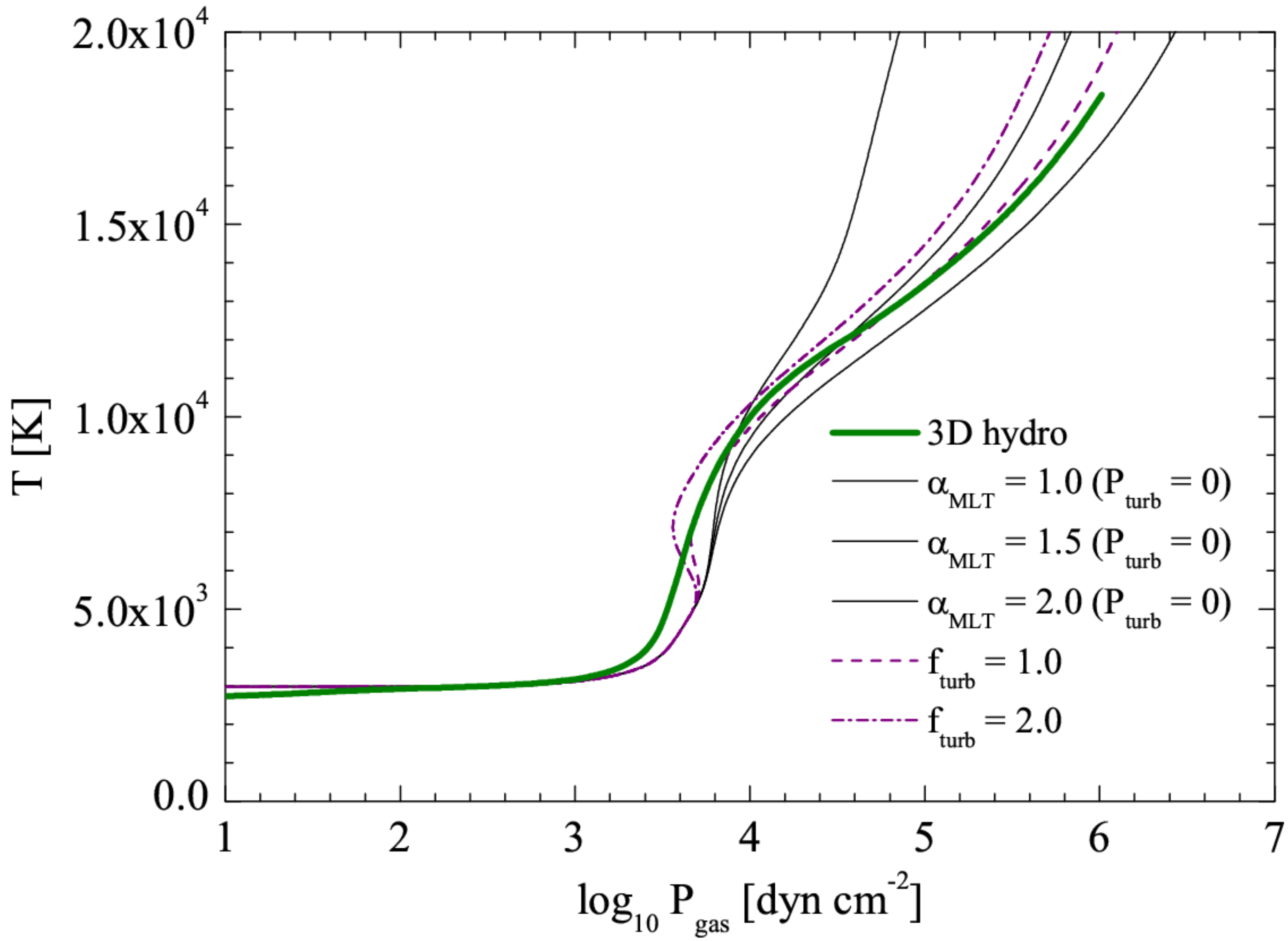
Rationale for calibrating 3D against 1D models based on MLT

- Why not simply provide a table of entropy jumps as function of stellar surface parameters? (I. Roxburgh, H. Spruit, ...)
  - thin surface layer does not matter, discontinuous jump is sufficiently accurate description (M. Schwarzschild?)

- Asteroseimic answer: nowadays we want a detailed description of the superadiabatically stratified surface layers $\rightarrow$ "surface effects"

- Another answer: physics put in MLT allows us to make more robust inter- and extrapolation of the thermal structure
  - provided: the mixing-length parameter is not rapidly varying
  - provided: MLT based models give a reasonable match to mean 3D structure

Turbulent pressure trouble

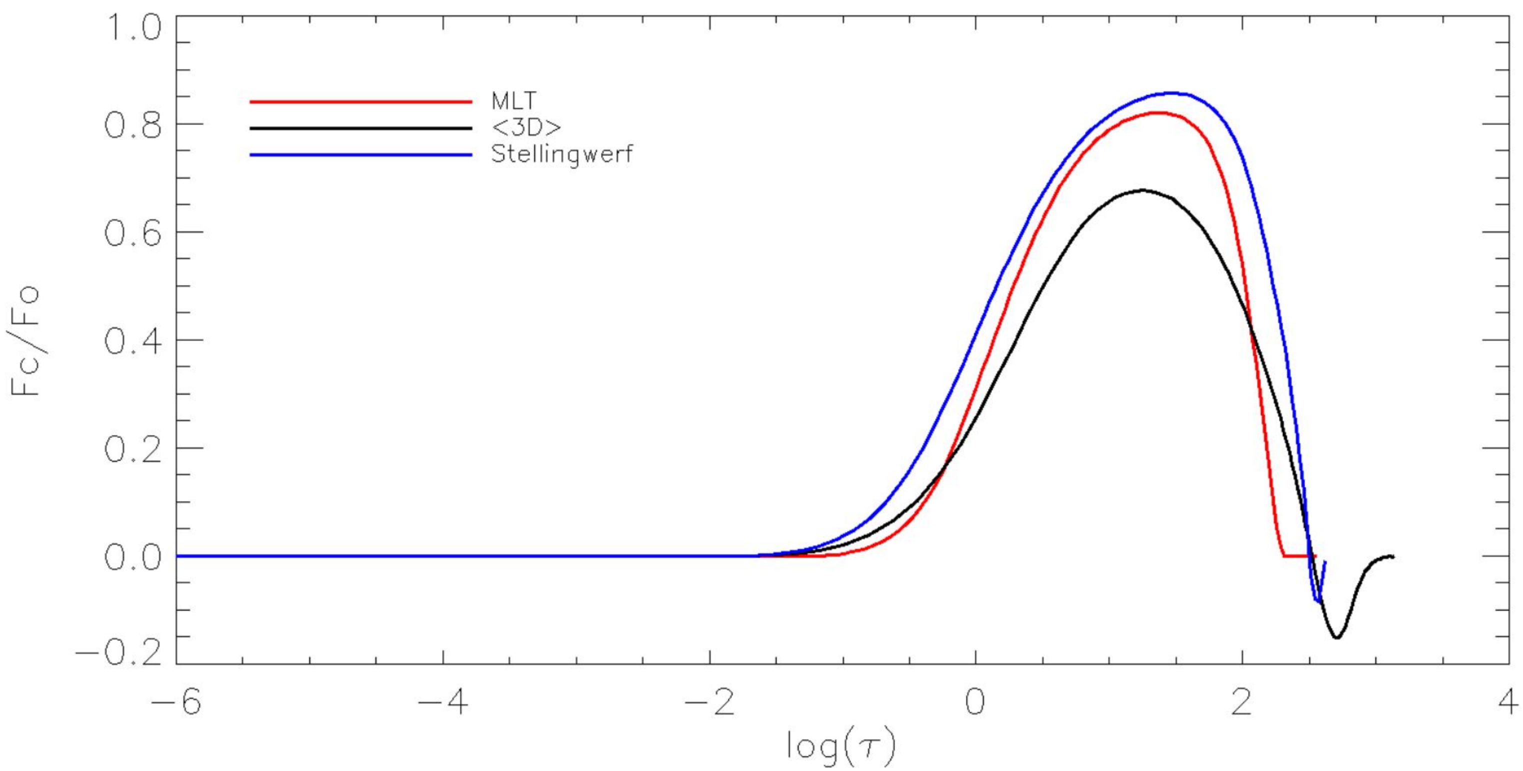


(Figure courtesy A. Kucinskas)

- Red giant model, $T_{\rm eff}$=3600K, $\log g$=1.0, [M/H]=0, $P_{\rm turb} = f_{\rm turb}\, \rho v_{\rm conv}^2$
- Principal difficulty to match 3D structure → meaning of $\alpha_{\rm MLT}$-fit?

Need for more sophisticated standard convection model

- Convection model necessary including effects of overshoot and turbulent pressure
  - should be widely accepted (or acceptable)
  - reasonably simple
  - sufficiently flexible to be able to match detailed calculations
  - able to capture convection-oscillation interaction?



(Figure courtesy V. Vasilyev)

(DA white dwarf models with $T_{\rm eff} = 12\,100\,{\rm K}$; complete convective envelope embedded in model)

Envelope matching – the classical procedure

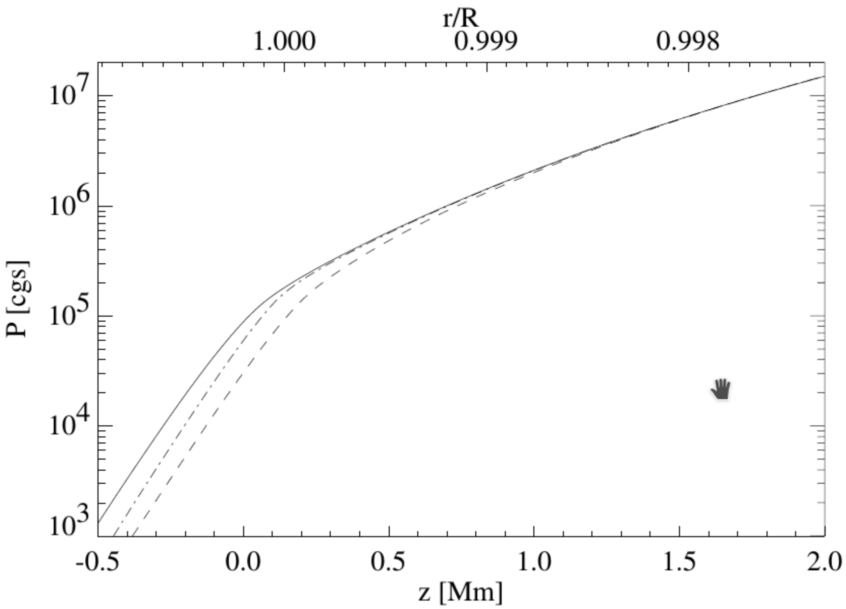


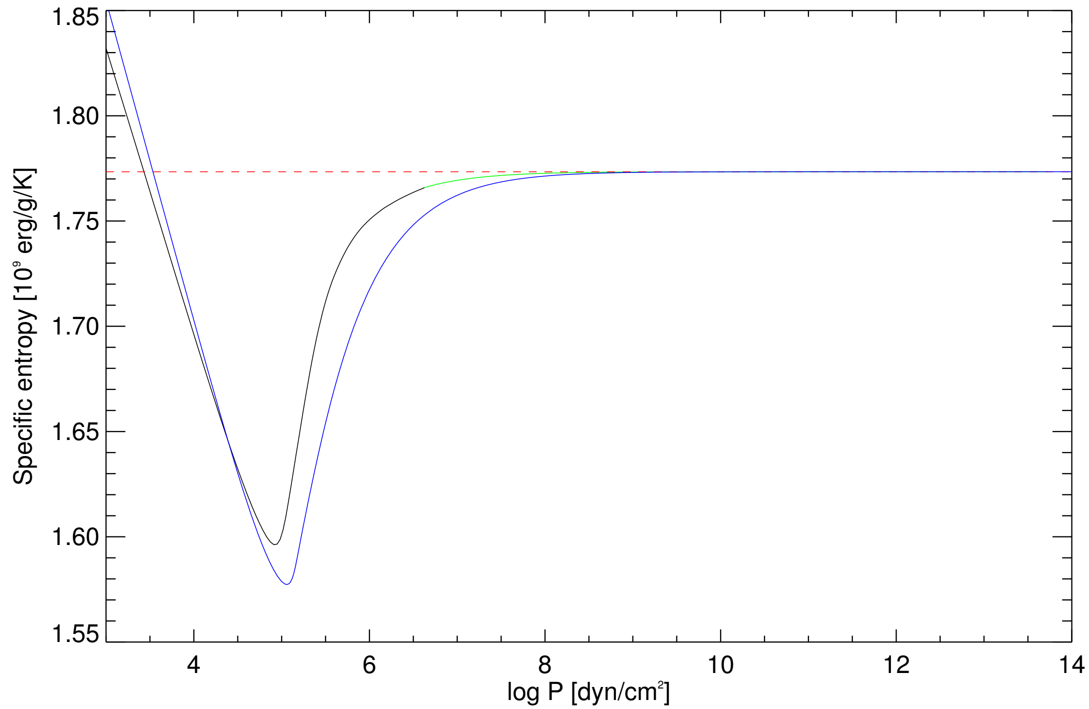
Fig. 7. Pressure as a function of depth for an averaged 3-D model (full drawn), and for the comparison standard envelope (SEM) model (dashed). The dashed-dotted curve shows the pressure stratification of a 3-D model where the gradient of the turbulent pressure has been artificially removed from the vertical pressure balance. The upper abscissa shows the corresponding position in a complete model, in terms of the fractional radius r/R

(From Rosenthal et al. 1999)

- Matching procedure:
  - take full stellar structure model
  - remove surface layers above a selected matching point
  - replace the removed part by suitably averaged 3D structure
  - matching criteria: continuity and smoothness
- Roughly: 3D structures make acoustic cavity larger which results in lower frequencies

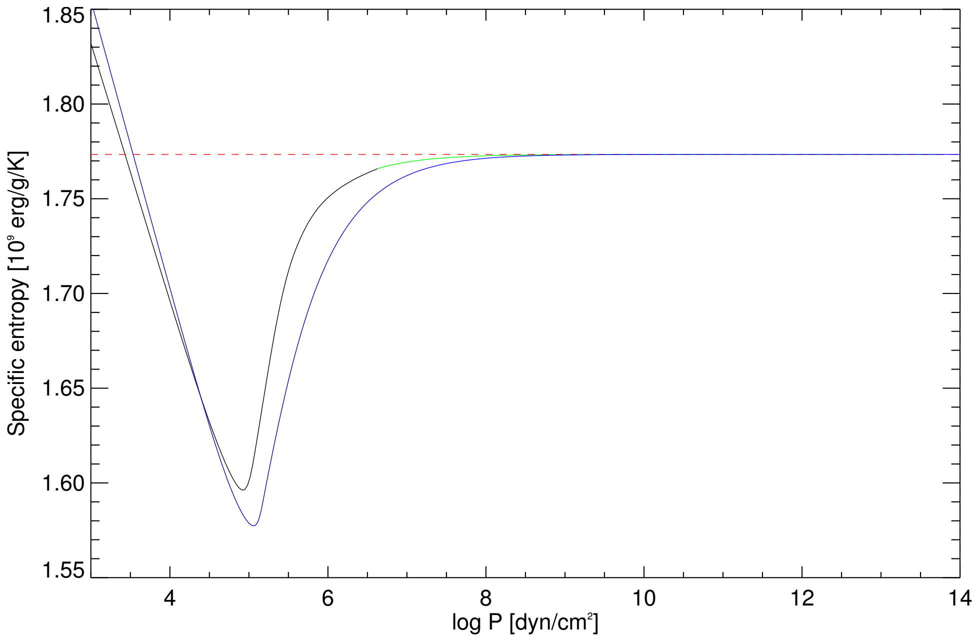
- Is this what one should do? What about requiring a prescribed radius?
- $\rightarrow$ solar MLT calibration: match solar luminosity and radius at given age

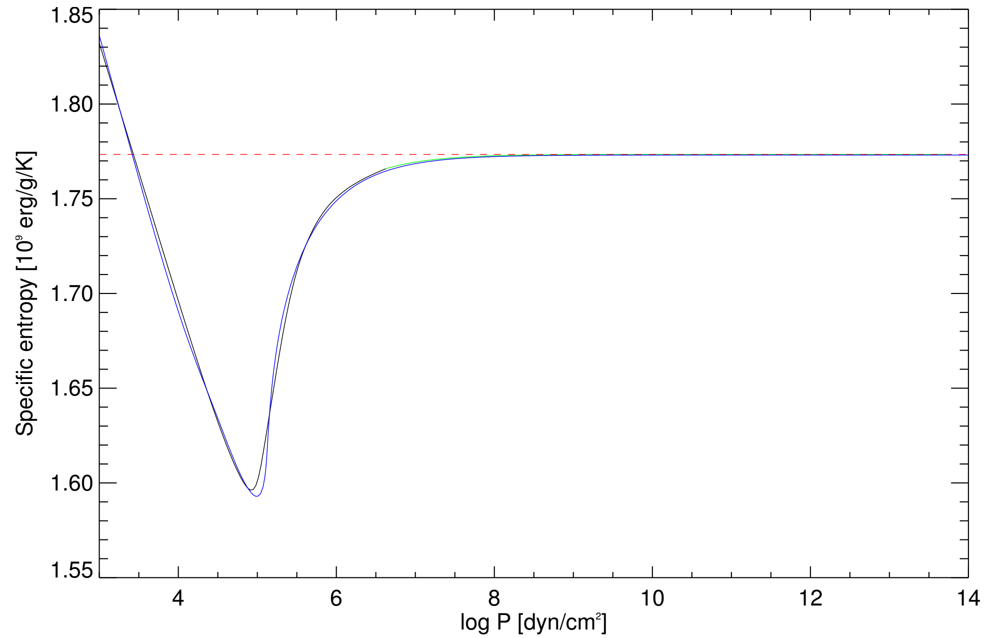
Side note 1: Including s_{env} when matching $\langle 3\mathrm{D} \rangle$ to 1D structures



- Red: Asymptotic entropy s_{env}
- Blue: MLT model, gray Eddington $T(\tau)$ relation, $\alpha_{\mathrm{MLT}} = 1.7$
- Black: Mean (geometrical scale) 3D model
- Green: MLT extrapolation of 3D model, $\alpha_{\mathrm{MLT}} = 3.6$
- MLT dialect a la Mihalas, no turbulent pressure considered

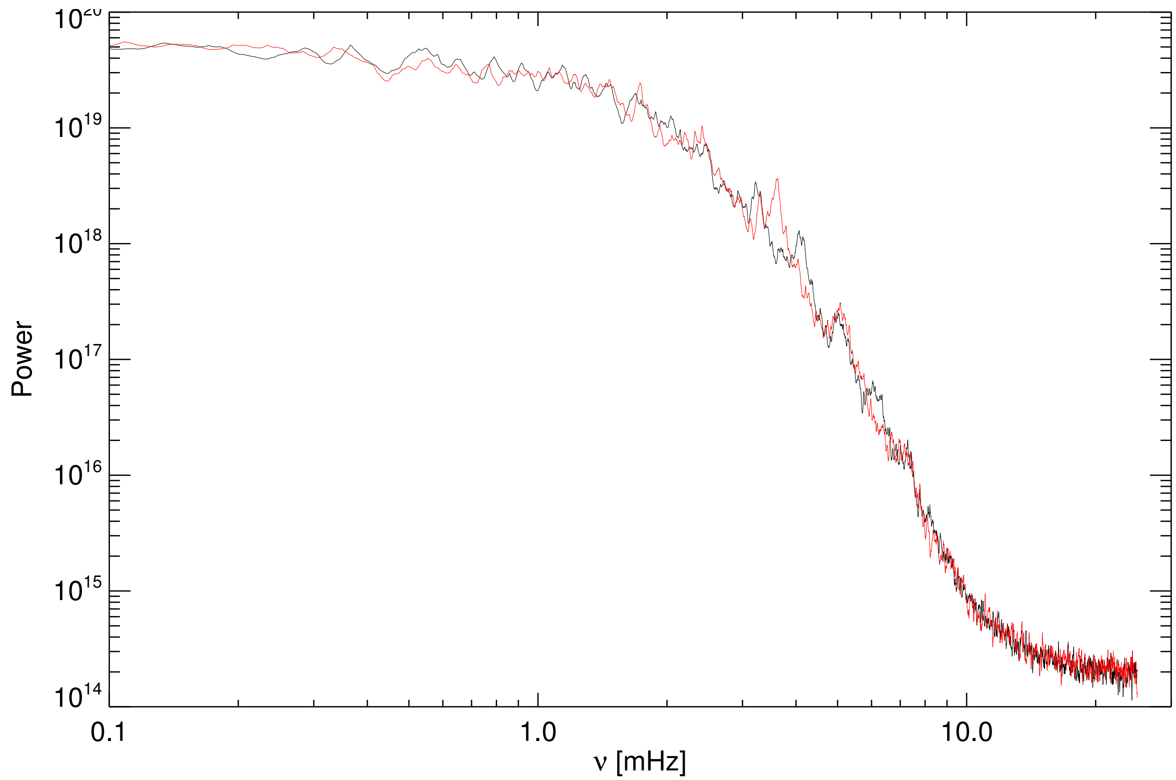
Side note 2: Canuto-Mazzitelli provide better match to $\langle 3\mathrm{D} \rangle$ structure for the Sun





- Left: MLT based solar model; right: theory of Canuto & Mazzitelli (1991)
- Vernazza $T(\tau)$-relation (courtesy Jørgen) used in right plot
- Jørgen as well as Antia & Basu were pointing this out at SCORe96 workshop

Mode excitation and damping



Powerspectra of flux of two solar 3D models, 3.7 and 8.4 Mm vertical extent

- How do I calculate the mode excitation rates in a 3D model?
- Can we get hold of the damping rates to predict mode amplitudes?
- Can we at least predict relative mode amplitudes? ($\rightarrow$ Regner?)