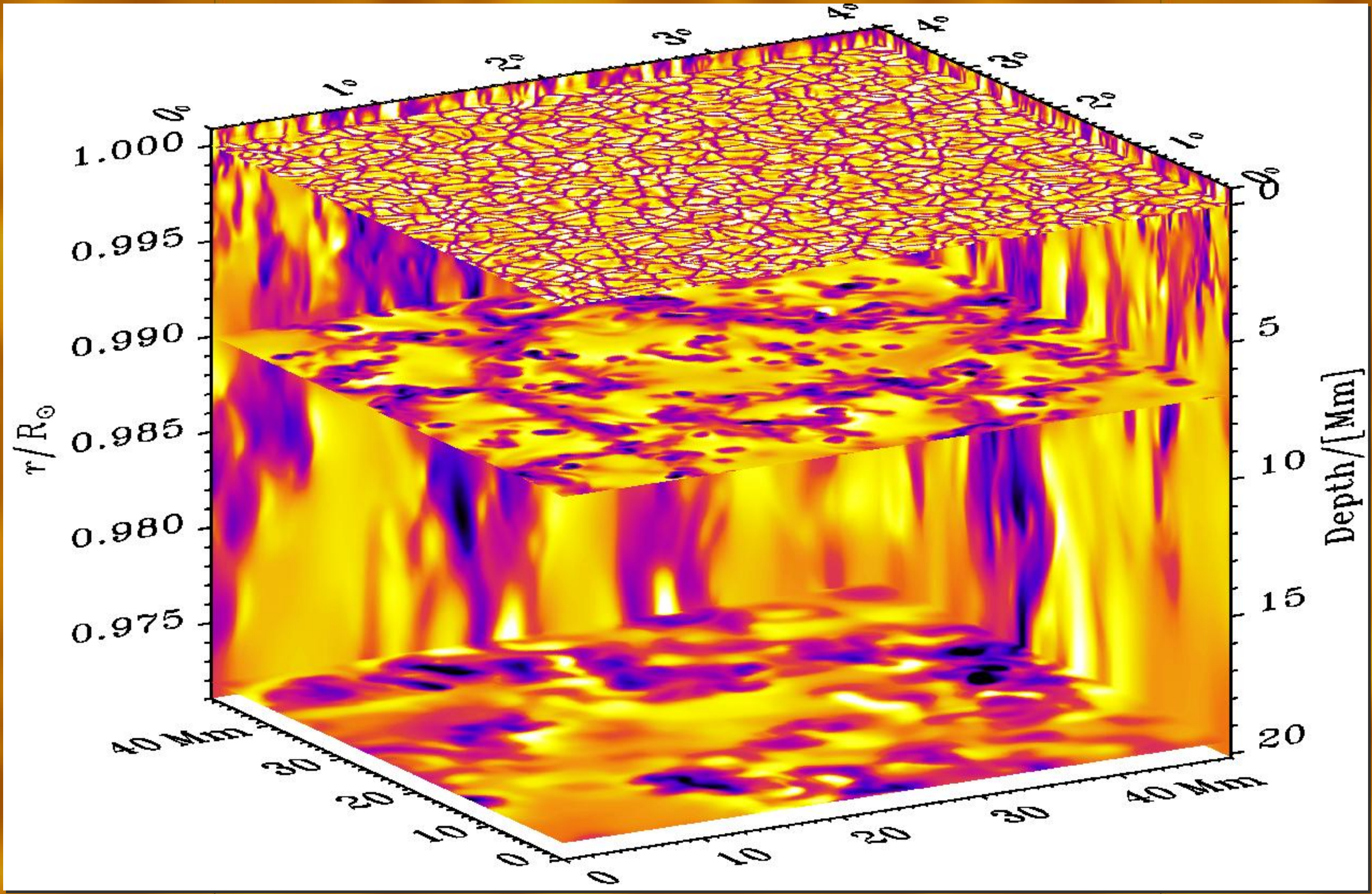
Near-surface convection in solar-like stars – from simulations



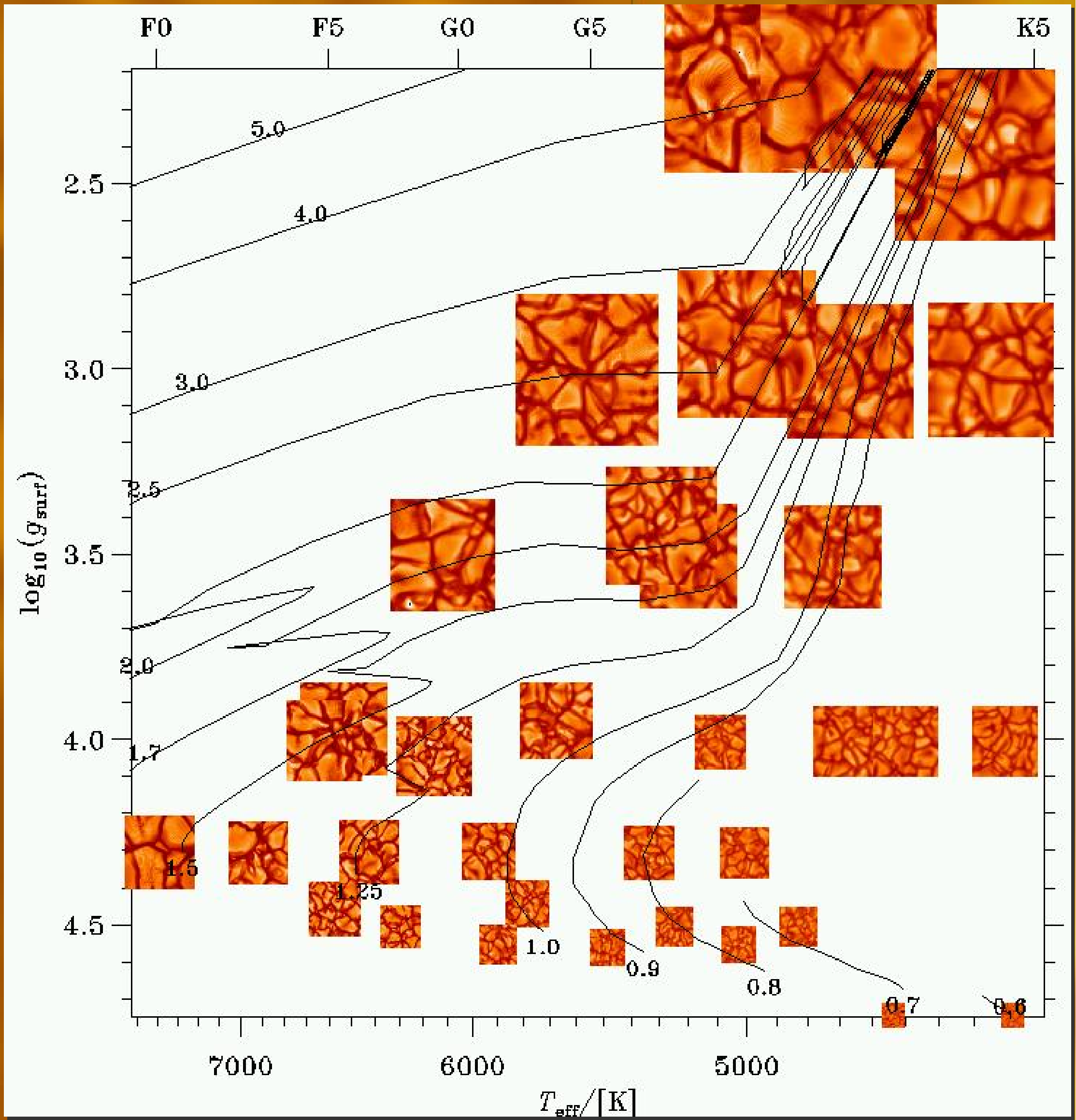
Regner Trampedach

What are 3D Convection simulations Good for?

- Improved stellar modeling
- Improved interpretation of non-seismic observations
- Improved seismic modeling:
  - Granulation background
  - Excitation/damping of modes
  - Surface effects – γ_1 of turbulent pressure
- Teach us what convection is conceptually

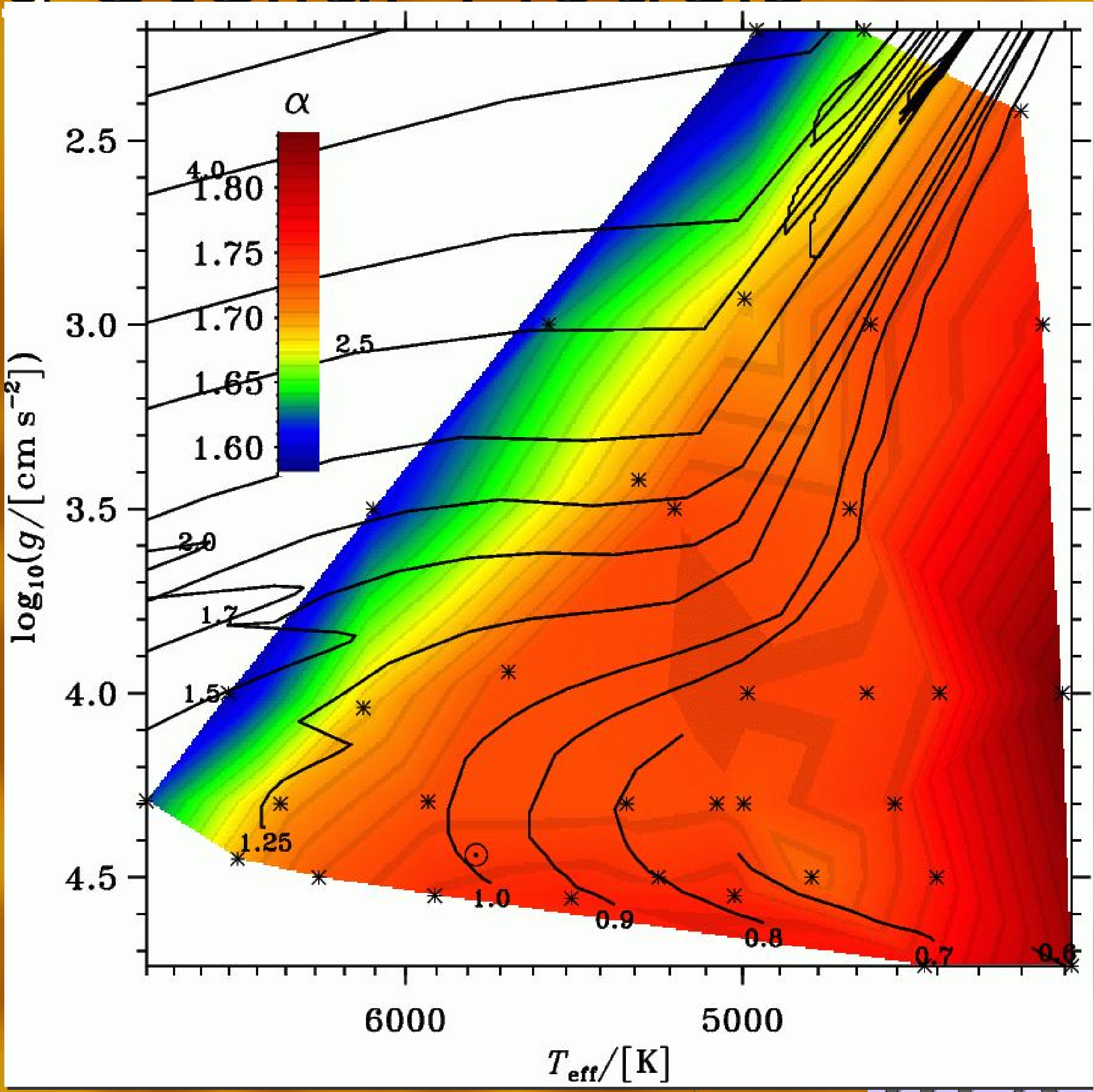
And the 3D convection simulations?

- Grid of 37 sims.
- Realistic EOS, opacities and radiative transf.
- [Fe/H]=0.0 ~GN93



Improving Stellar Models

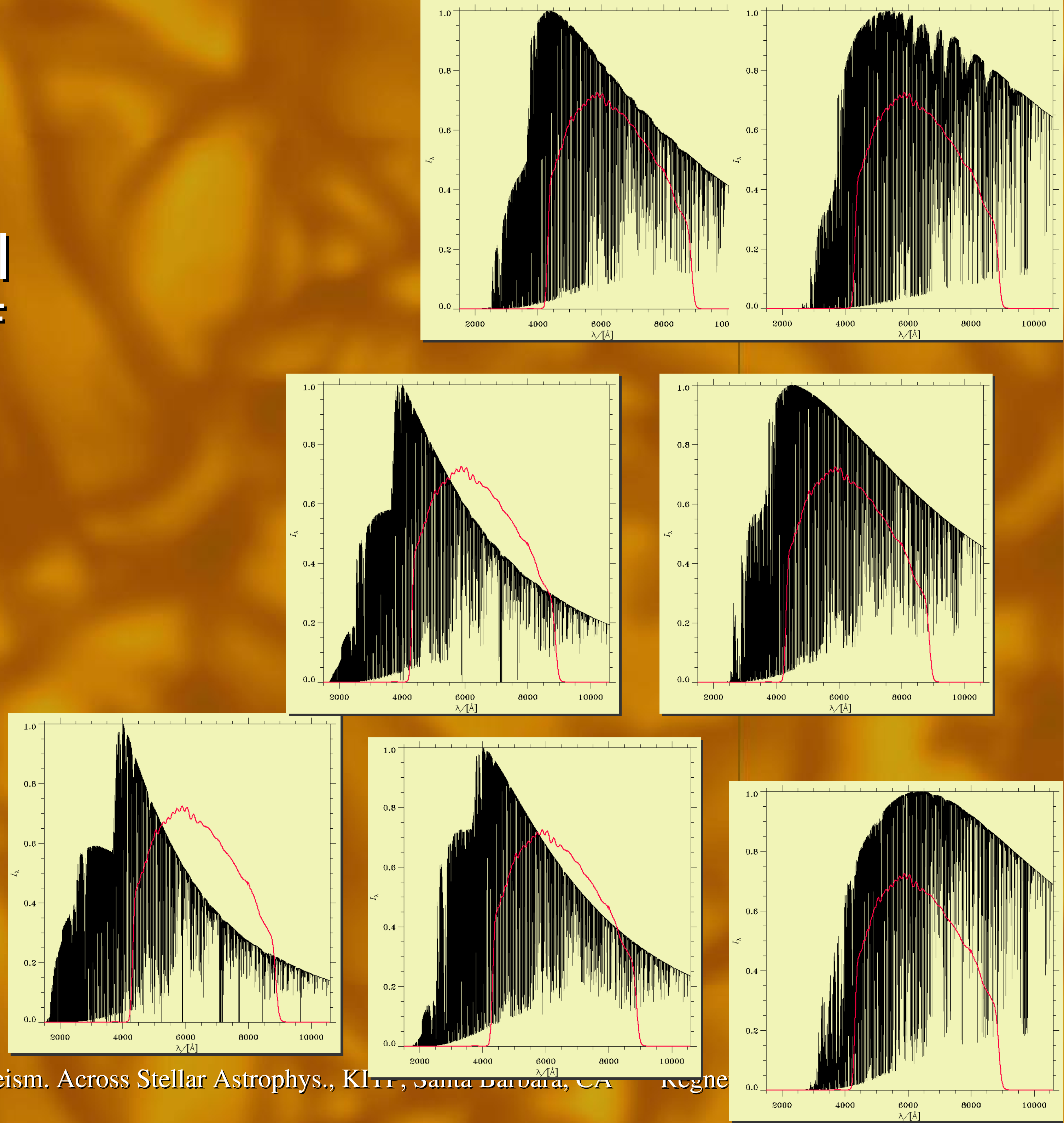
- $T(\tau)$-relations, $q(\tau) + \tau = {}^4/_3(T/T_{\rm eff})^4$
- α-calibration of mixing-length 1D conv.
- = matching 1D envelope to T,P,ϱ at bottom of sim.
- Only conv. differs



Synthetic Non-seismic Observables

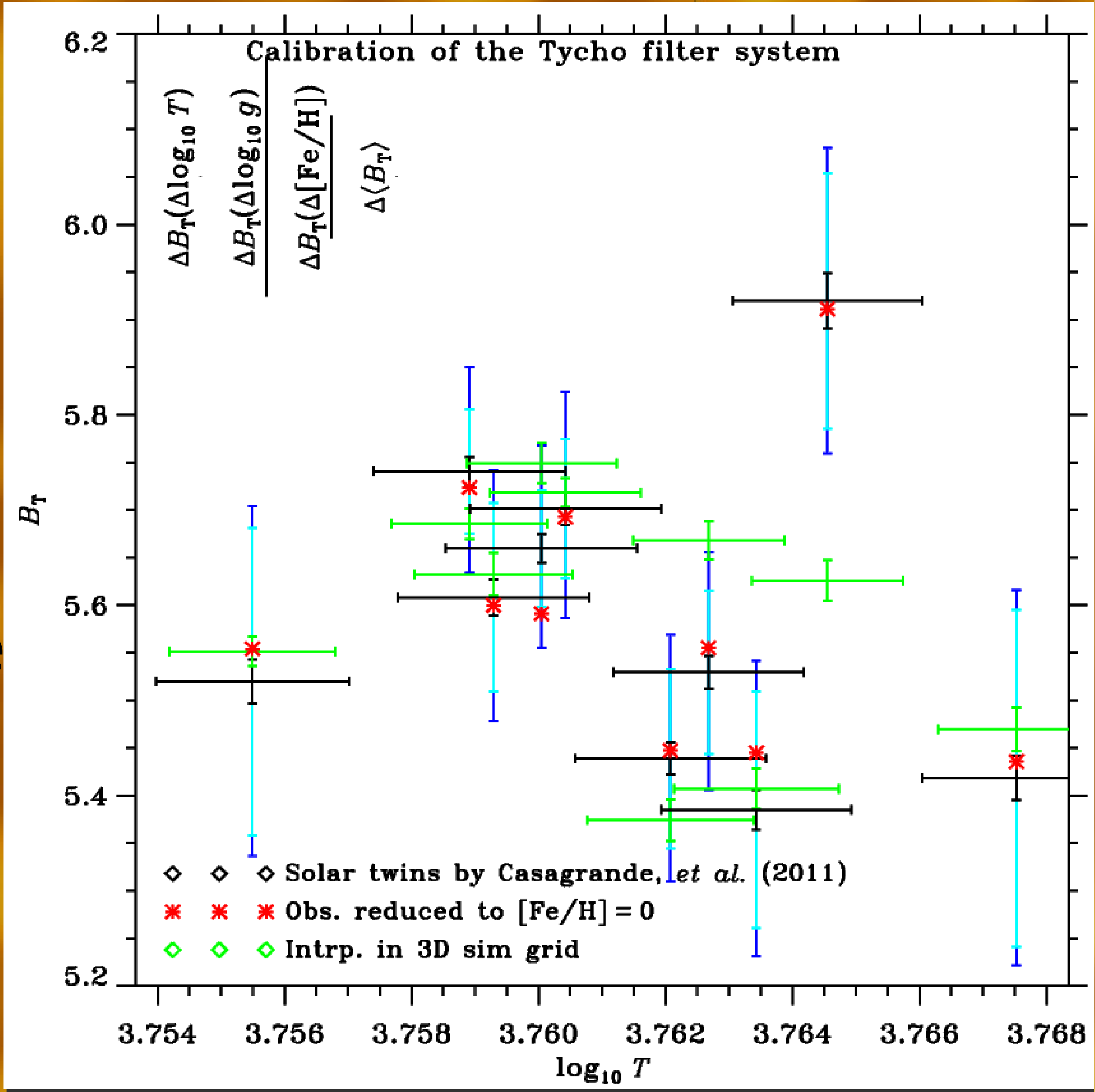
- Broad band fluxes – Incl. Kepler passband
- Limb darkening for relative mode amplitudes and eclipse shape
- Limb darkening factors for interferometry
- ...all for the known T_{eff}, g and [Fe/H] of the simulations

Full (ODF) spectra of all snapshots of all sims., folded w/filters.



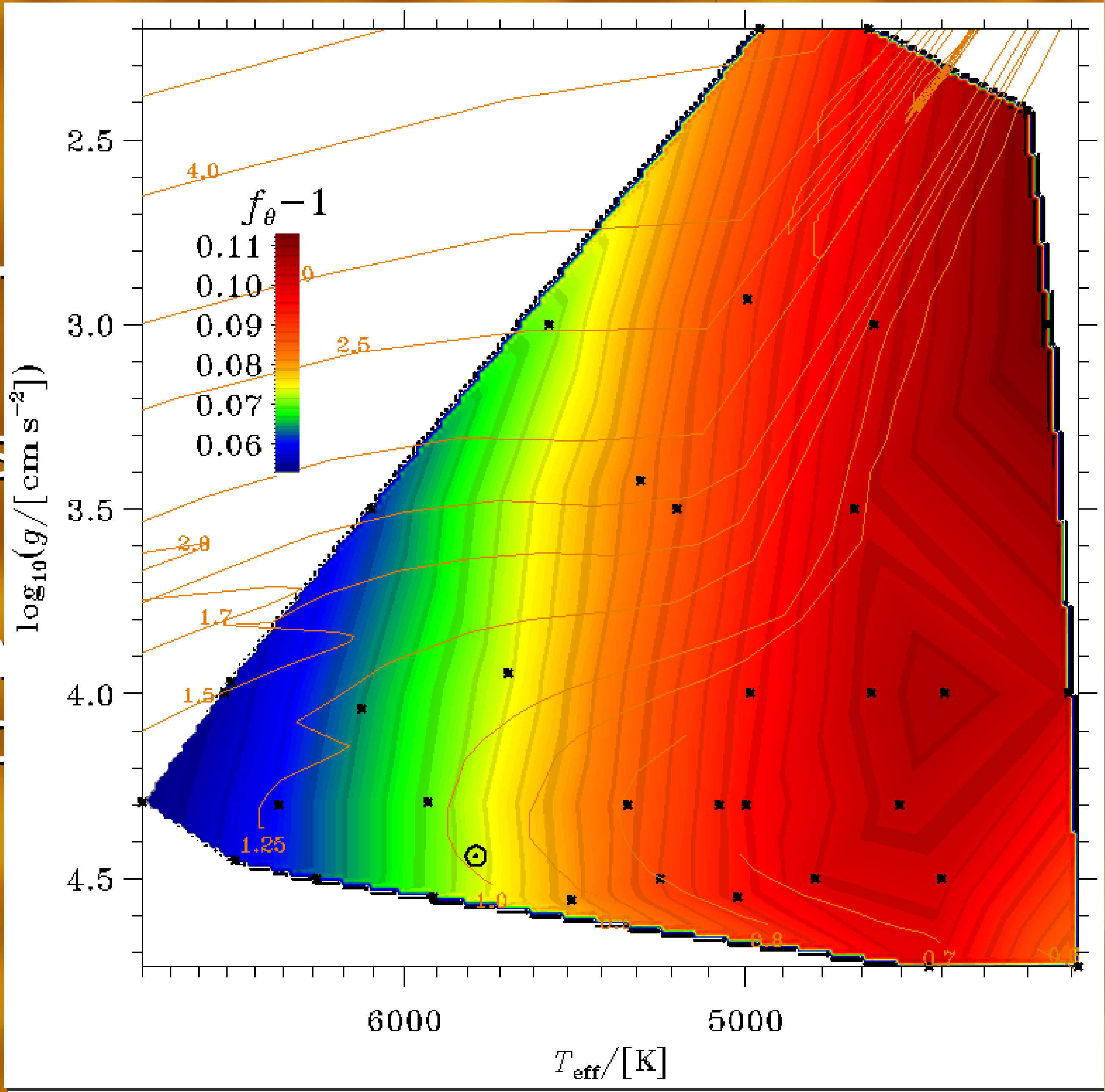
Broad band fluxes

- Calibrated 2MASS and Hipp/Tycho photometry against solar twins
- T_{eff}s from infrared flux method
- Relative abundance determination
- Reduced to [Fe/H]=0 from tri-linear regression



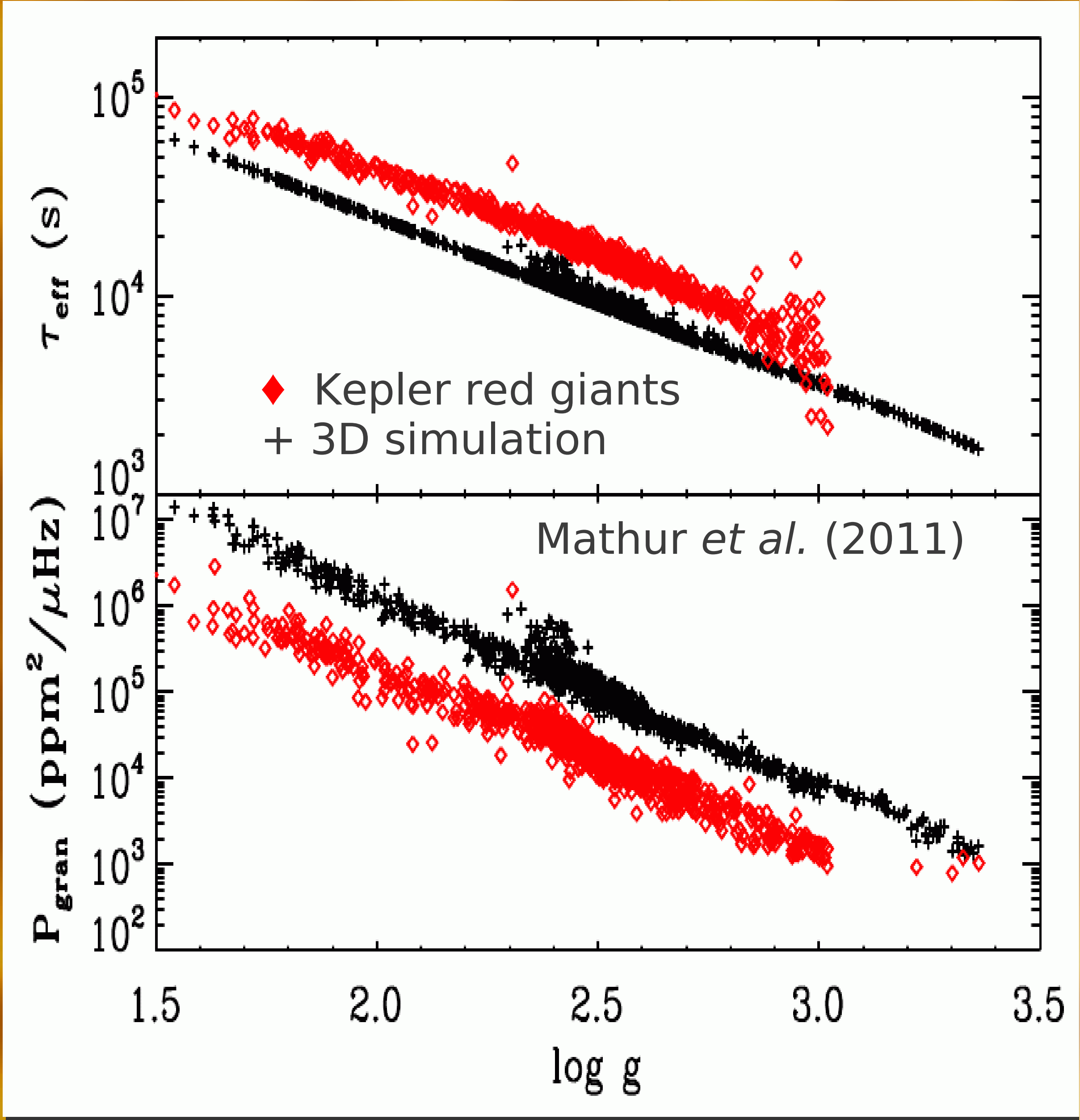
Limb Darkening

- Linear LD is ~~silly~~ rarely adequate...
- Claret (2000) 4-terms ⇒ good fits to all sims.
- Smooth variation with atmospheric params.



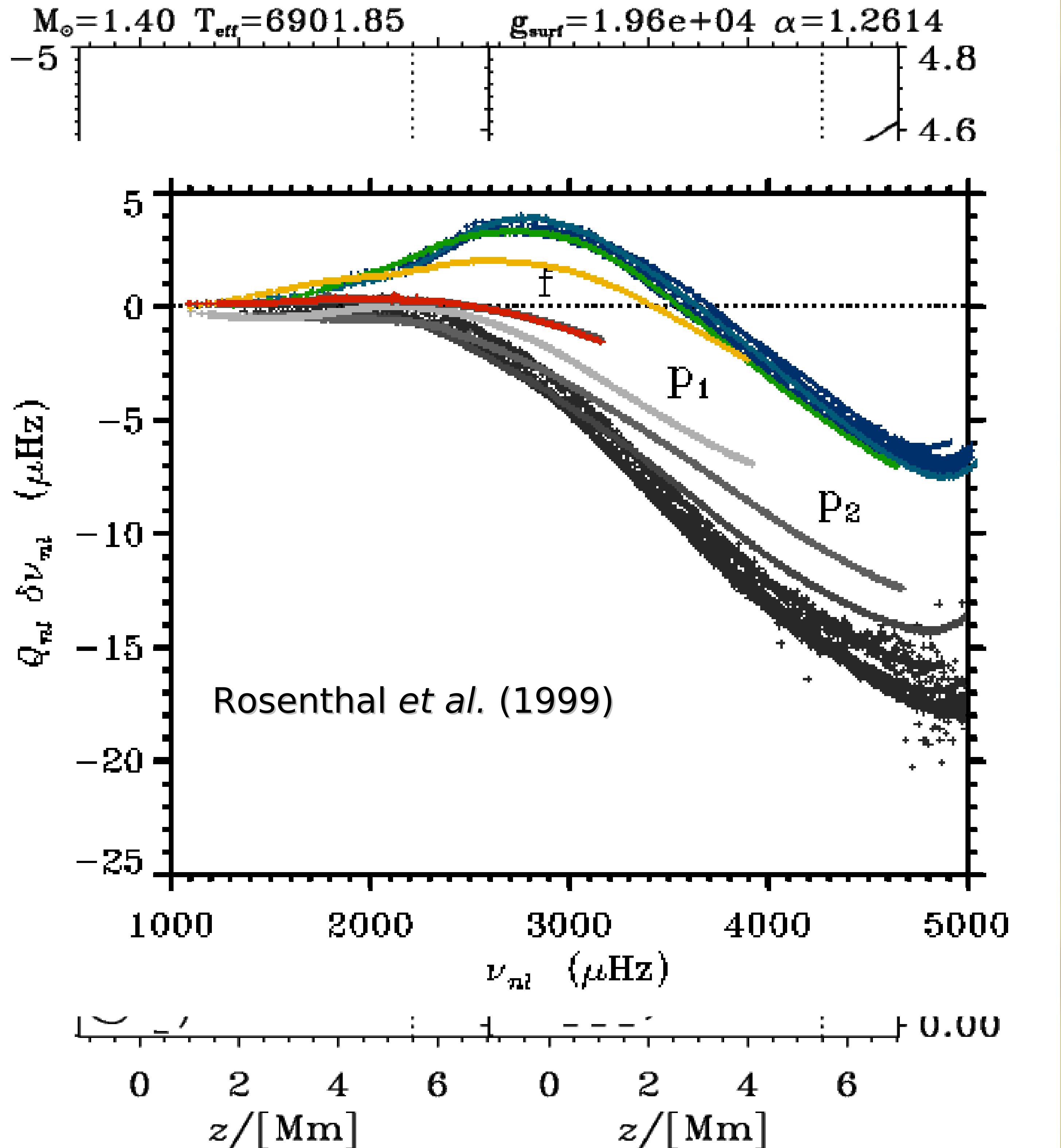
Granulation 'noise' from simulations

- Monochromatic intens.⊗Kepler filter
- ⇒'obs' Time-series
- Fitted granulation spectra
- Predict amplitude and time-scale
- Still looking into cause of difference



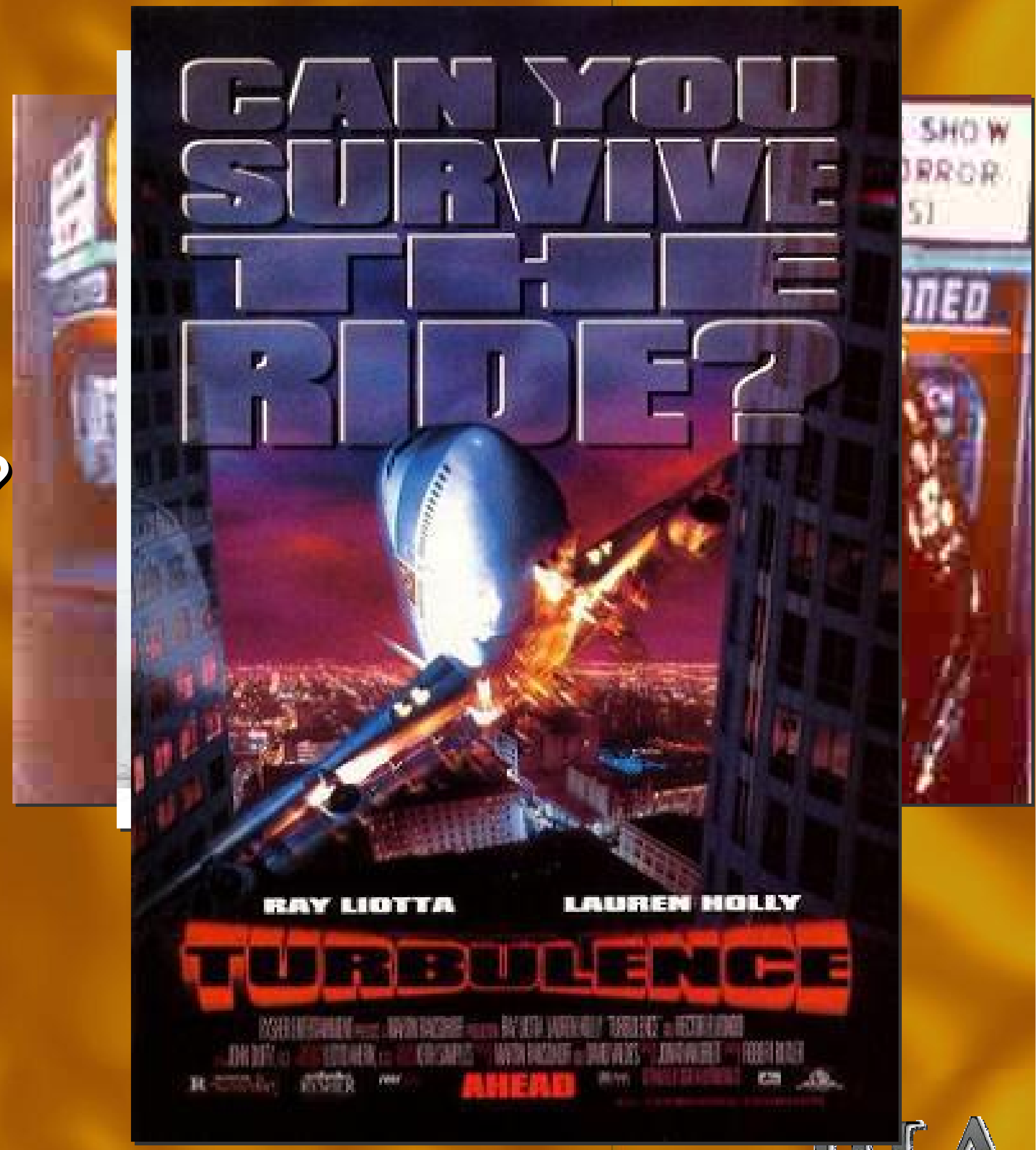
Conv
on

- Three co
  - Atmosp
  - Atm. e
  - Effecti
- Not com
- ...or for



Morphology of Convection

- Is it a blob?
- Is it a convective ~~eddy~~ Eddie?
- Is it all turbulence?



No! It's...

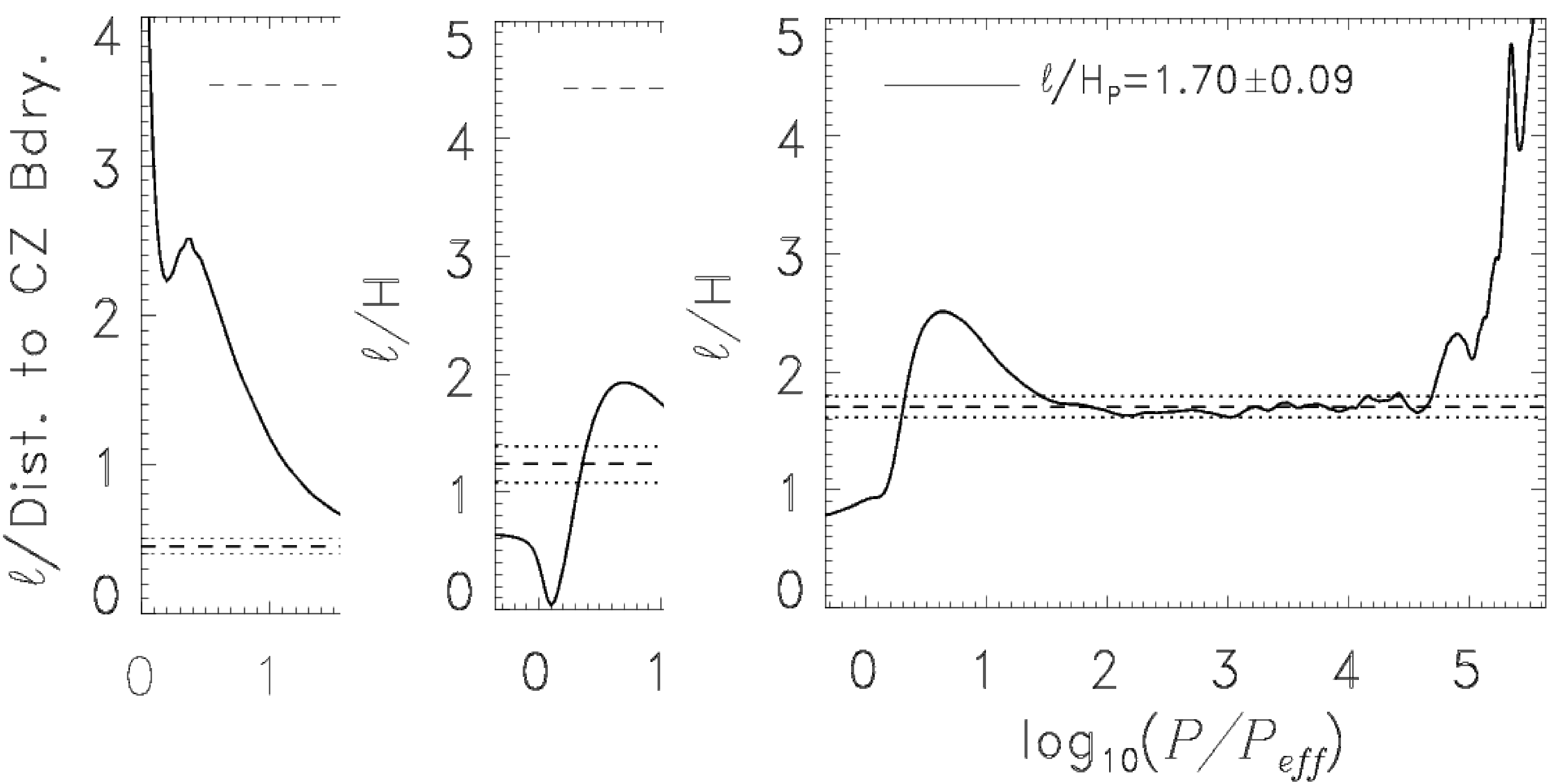
...plasma moving along a density gradient, under the constraint of mass-conservation.

- A fraction of what moves up has to over-turn into the downdrafts to keep $\mathrm{d}\ln\varrho/\mathrm{d}z$.
- Continuous overturning at all heights.
- Mixing length = overturning scaleheight

$$\ell = |\mathrm{d}\ln v_z\varrho/\mathrm{d}r|^{-1}$$

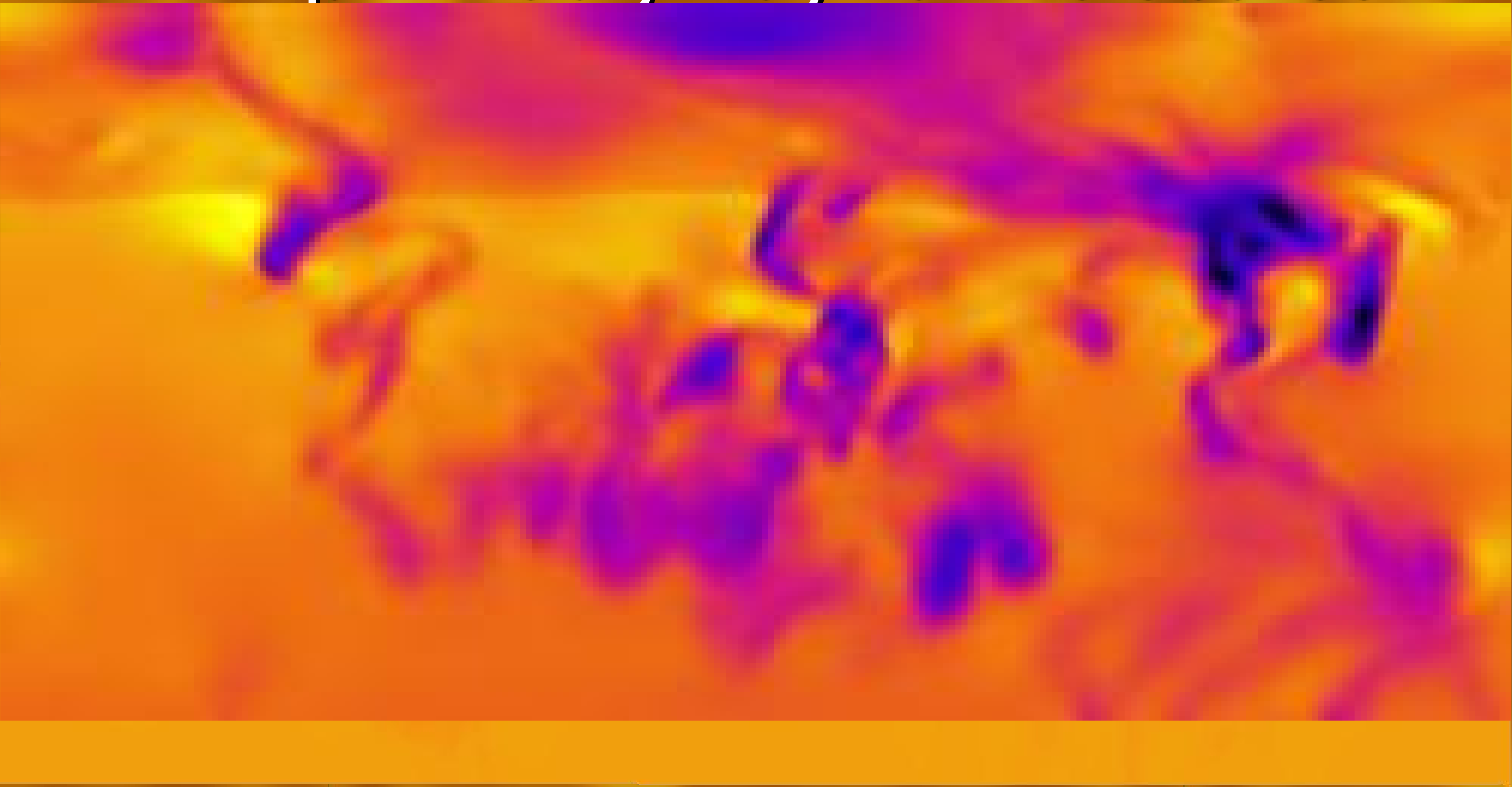
- But up-/down-flows are coherent for many ℓ
- ...and granules last much longer than ℓ/v_z

$\Lambda = z$ or $\Lambda = \alpha H_\varrho$ or $\Lambda = \alpha H_P$ ✓



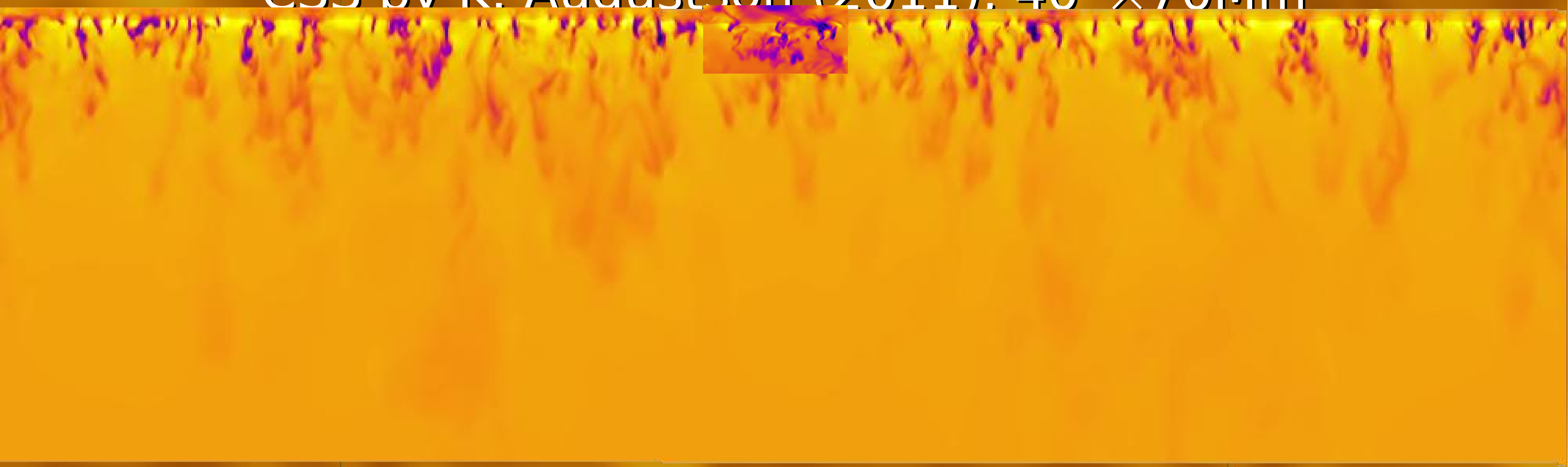
Trampedach & Stein (2010)

A trip through dynamic scales



A trip through dynamic scales

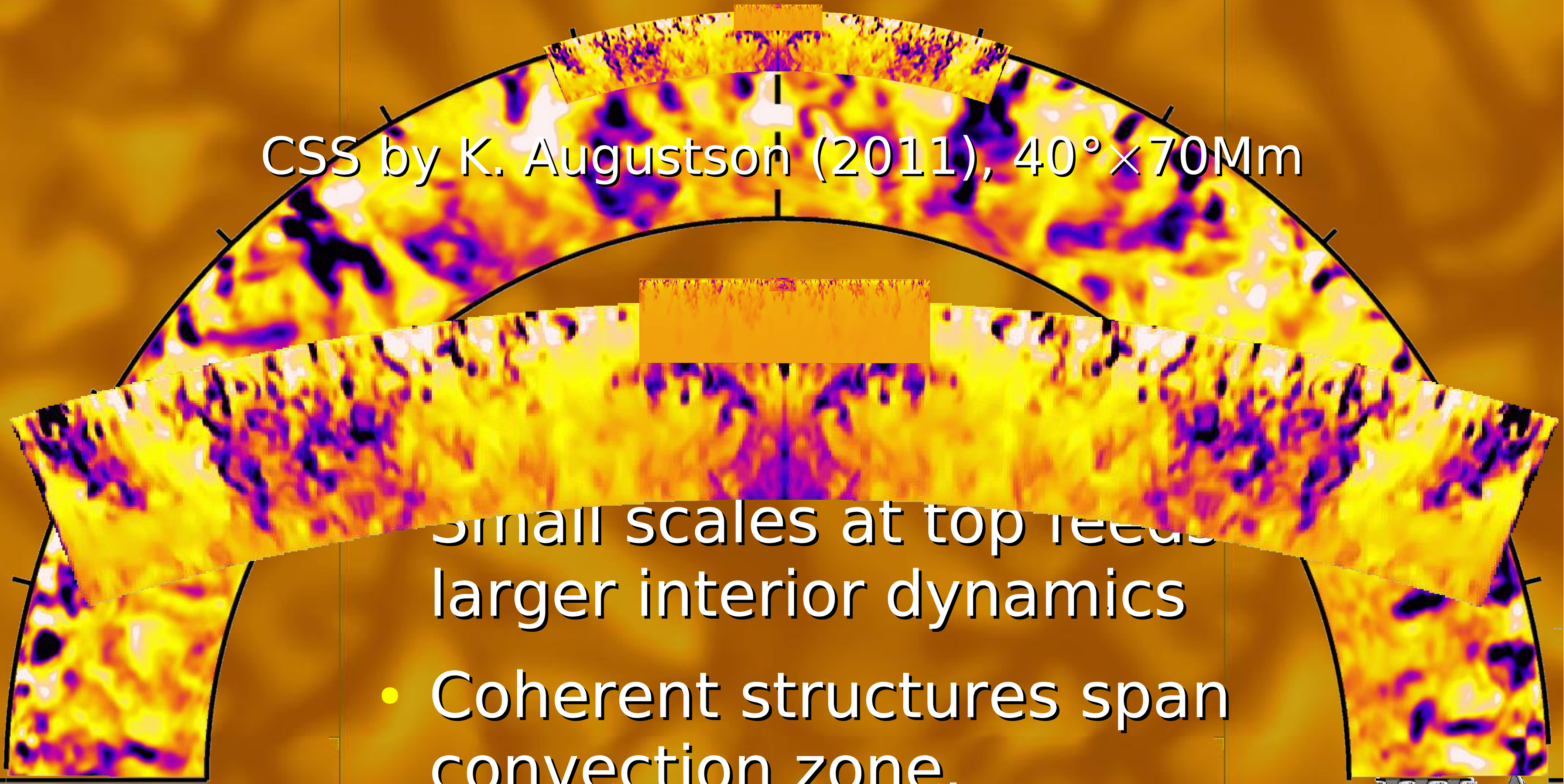
Super granulation by Stein & Nordlund (2009) 96×20Mm
CSS by K. Augustson (2011), 40°×70Mm



A trip through dynamic scales

ASH by Miesch *et al.* (2008), $2\pi R_\odot \times 188$Mm

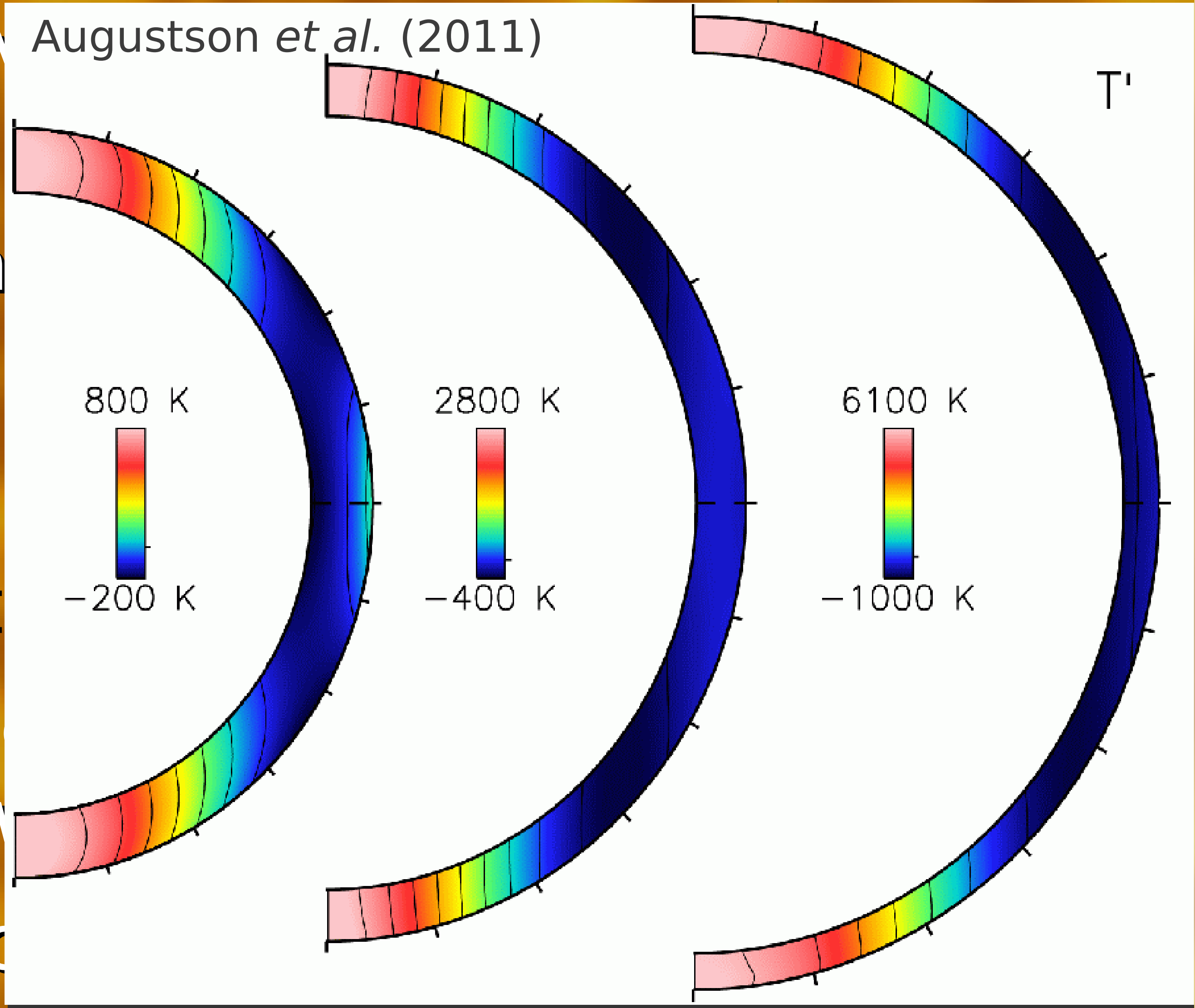
CSS by K. Augustson (2011), 40°×70Mm



- Small scales at top feeds larger interior dynamics
- Coherent structures span convection zone.

Global, AHS simulations and latitudinal effects

- F-stars, thin conv Envelope
- Large differentia rotation
- Meridional flows
- Large T contrast
- Latitude depend boundaries – Ho
- Observable effec



Conclusions

- Convection affects
  - Structure: adiabat, atmospheric expansion
  - Surface layers ⇒ all observables (except ν)
  - Modes through interactions with convection
- Compute the above and intrp between sims
- ...and/or improve our understanding of stellar convection to improve 1D formulations
- And then there are large scale dynamics that just might affect the general stellar structure!