Solar-like oscillations in a Kepler δ Scuti star

V. Antoci*, G. Handler, T. Campante, A.O. Thygesen, A. Moya, T. Kallinger, D. Stello, A. Grigahcene, H. Kjeldsen, T. Bedding, T. Lüftinger, J. Christensen-Dalsgaard, G. Catanzzaro, A. Frasca, P. De Cat, K. Uytterhoeven, H. Bruntt, G. Houdek, D. Kurtz, P. Lenz, A. Kaiser, J. Van Cleve, C. Allen, B.D. Clarke, 2011, Nature

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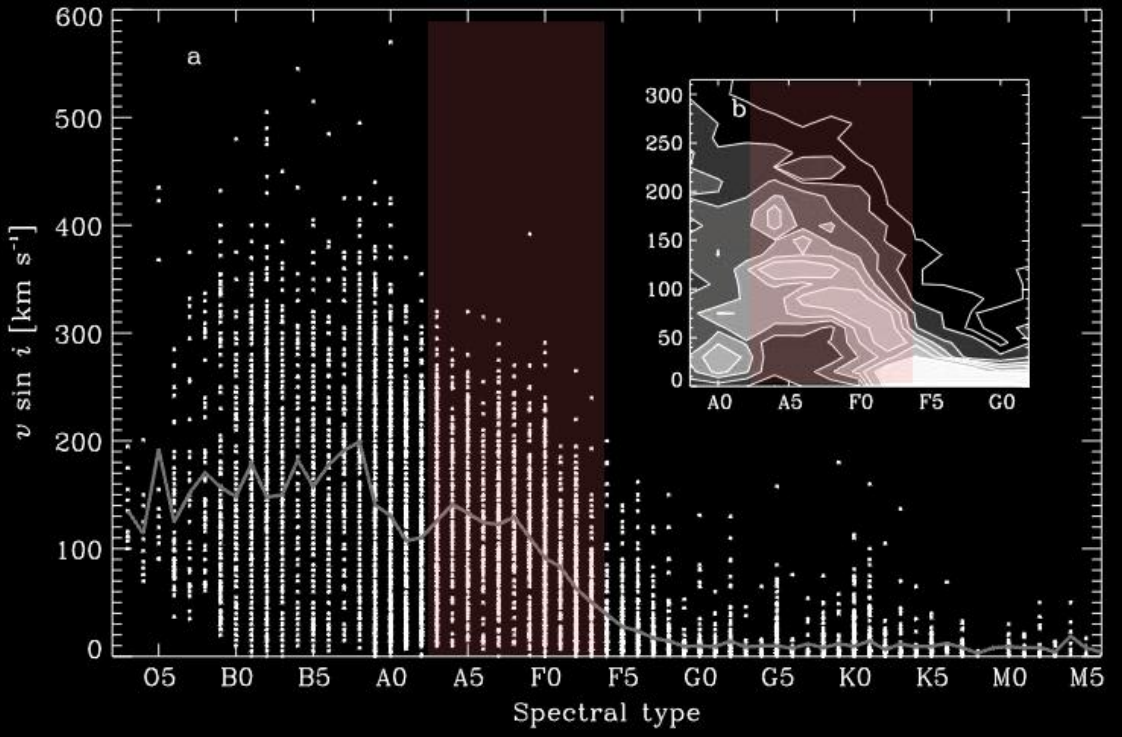
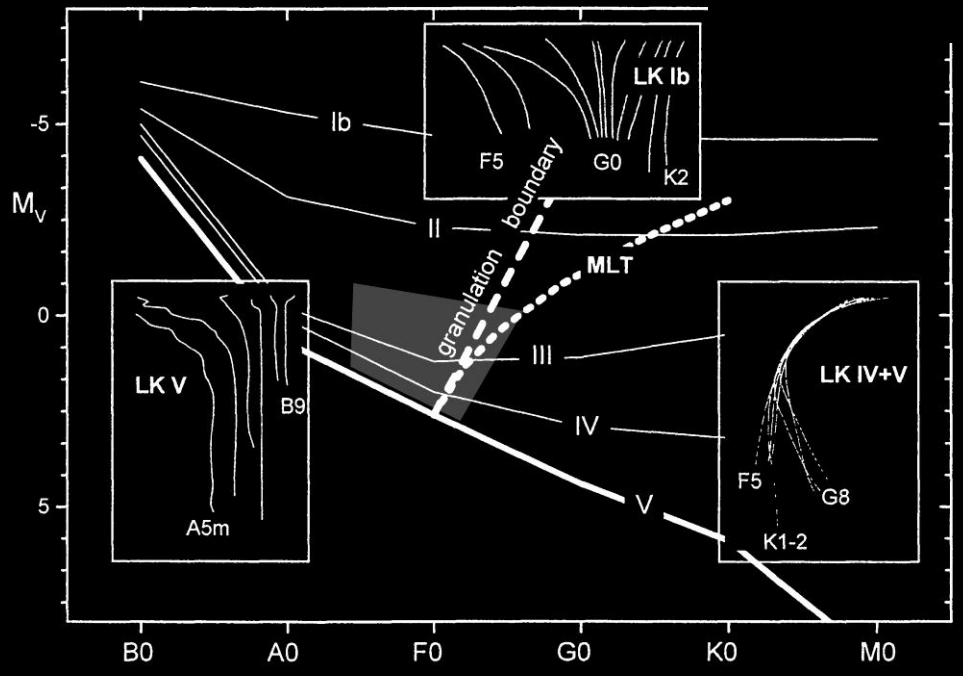
Why is the classical instability strip so important?



Royer 2009

Rotation boundary



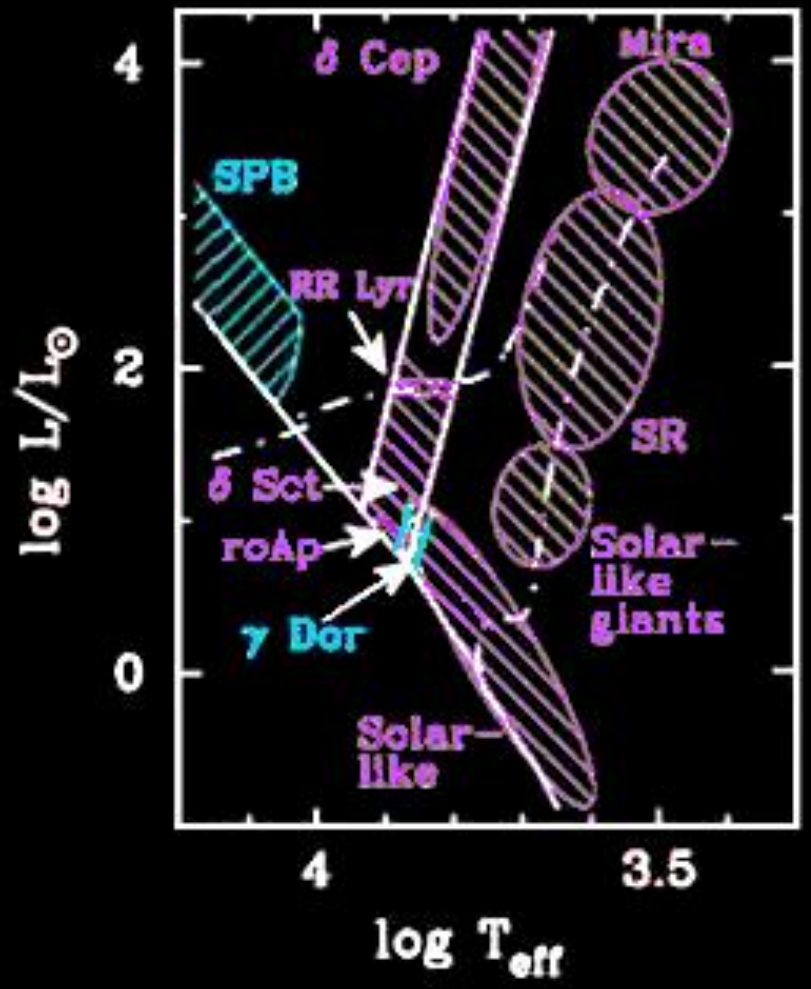
Granulation boundary

Kupka

δ Scuti

Solar -like pulsation predicted to be excited at the red border of the instability strip by Houdek et al. (1999) and Samadi et al. (2002)

Granulation noise as suggested by Kallinger & Matthews (2010), supported by convective motion in the the atmospheres of A and Am stars (spectroscopy, Landstreet et al. (2009)



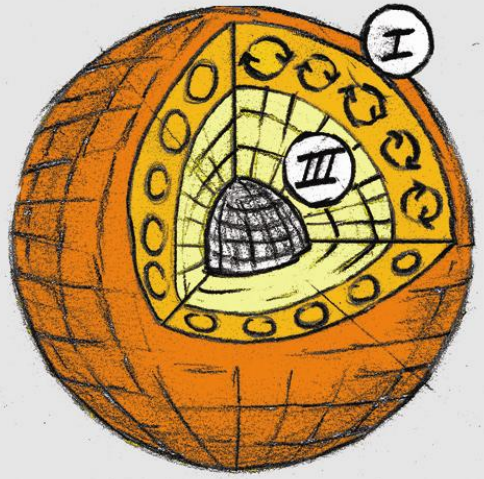
stellar structure

(not to scale)

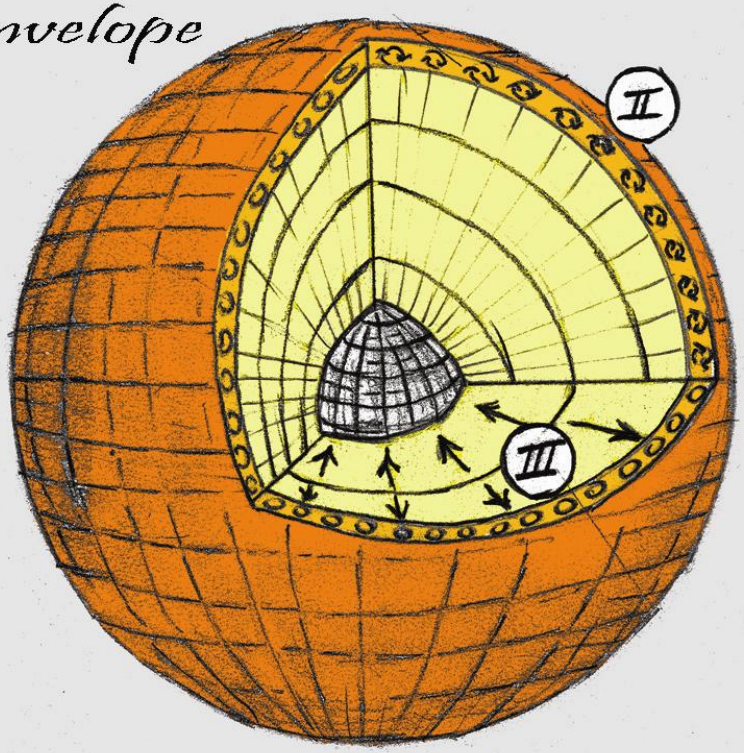
I... 30% convective envelope

II... ~1% convective envelope

III... radiative zone

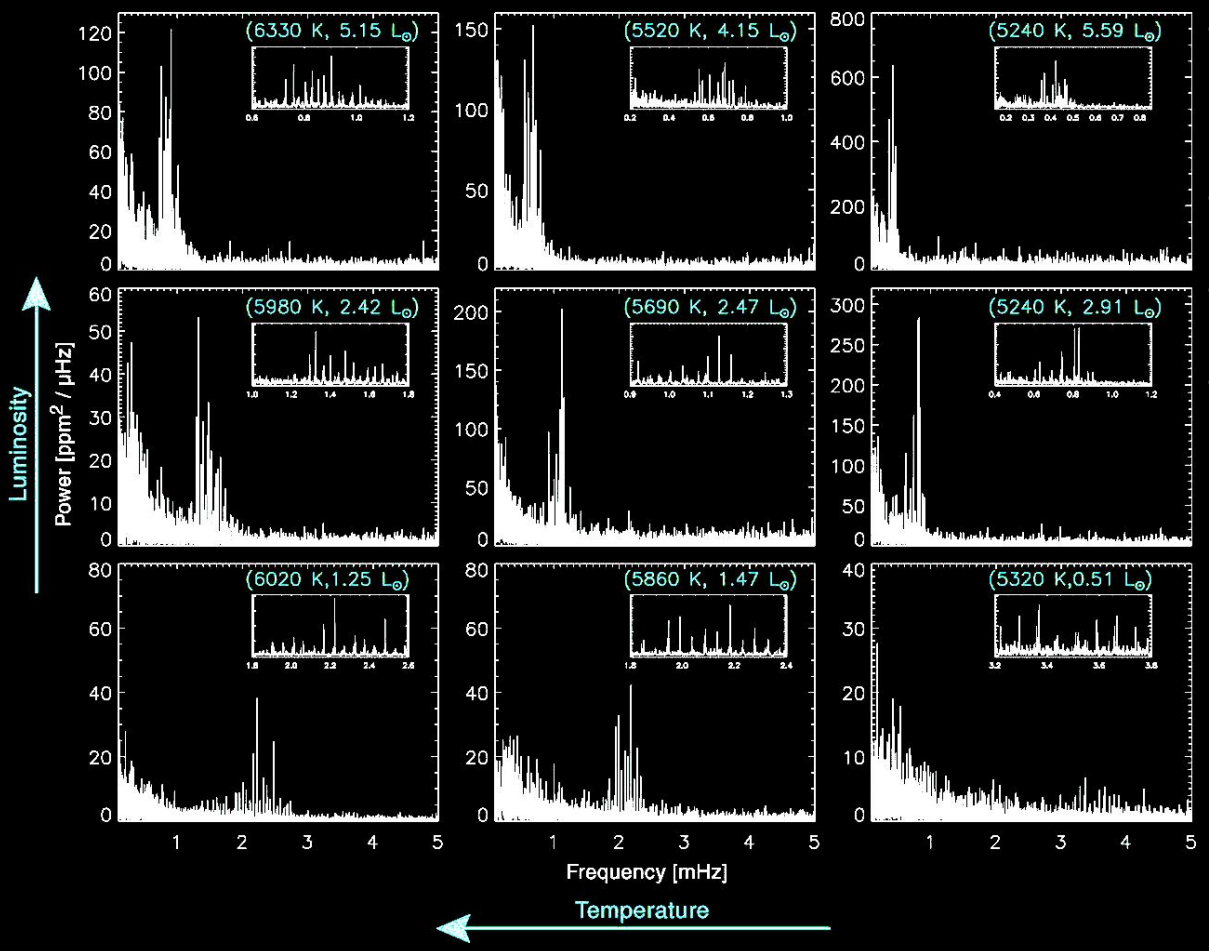


Sun



Delta Scuti star

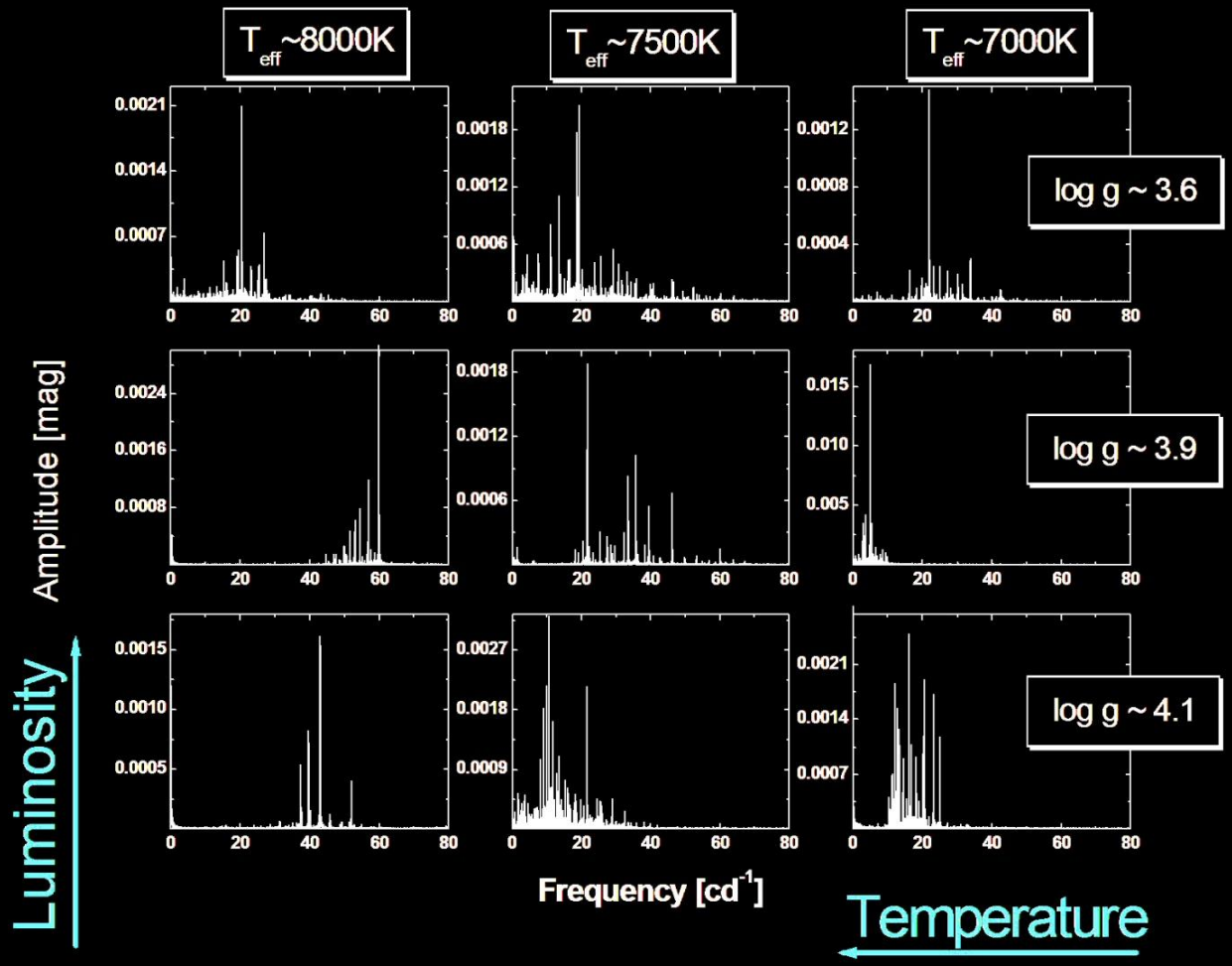
Ensemble Asteroseismology of Solar-type Stars



- Efficiency of convection in envelope
- Mode ID
- Evolutionary stage
- Radius, Mass, ...

Chaplin et al. 2011

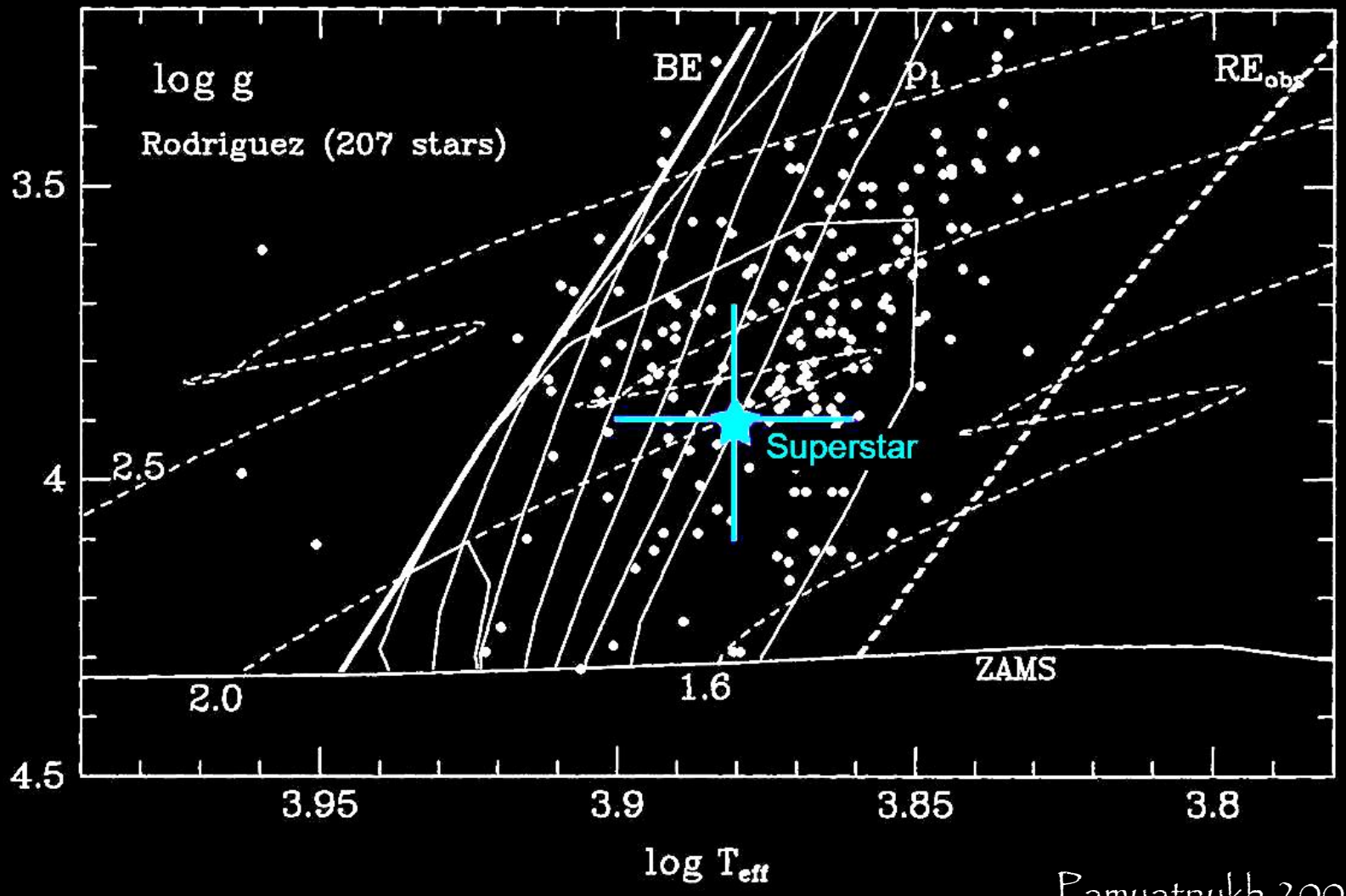
Ensemble Asteroseismology of δ Scuti Stars?



- No $\Delta\nu$ and no ν_{max}
- No mode ID from pattern recognition
- Large error in M, R, Teff, ...
- Long observing campaigns needed.

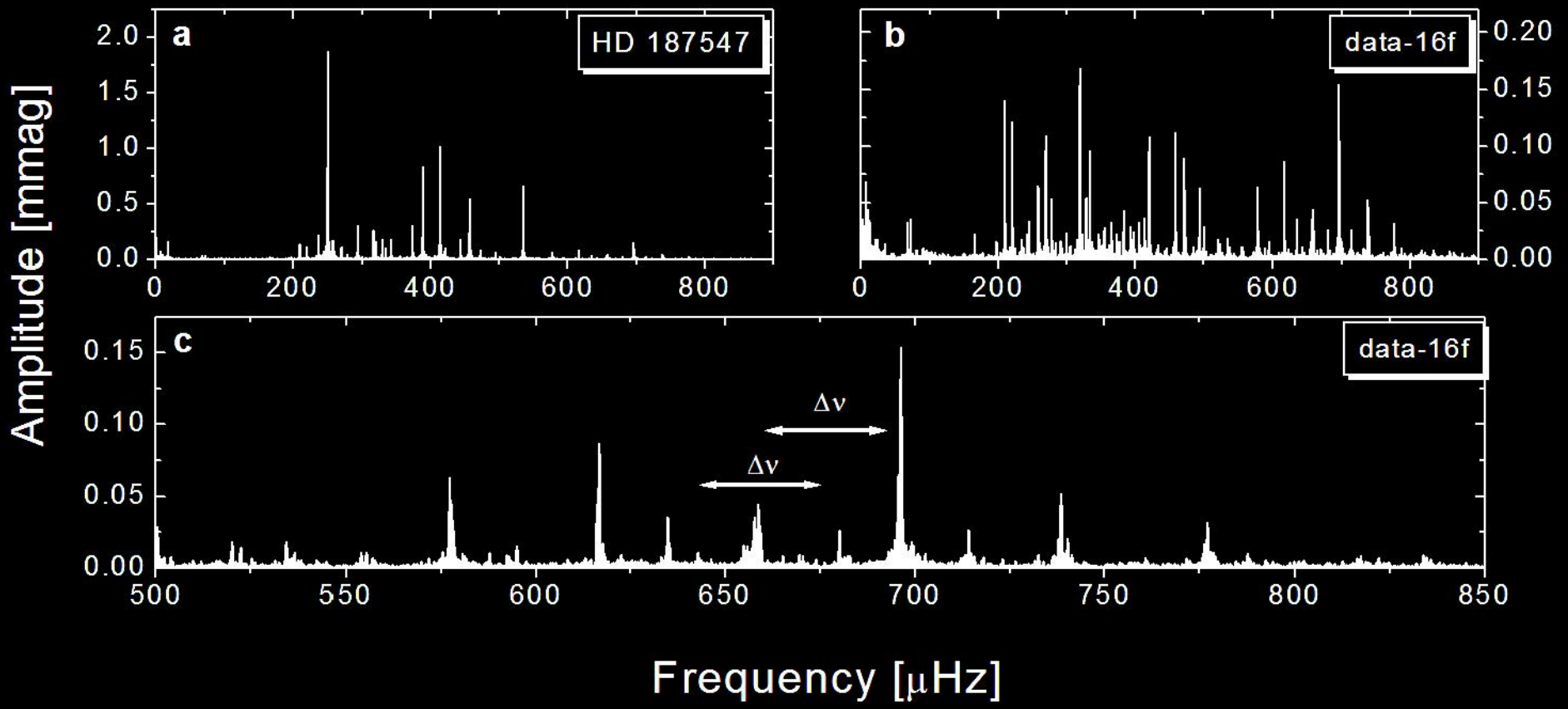
...this is where Kepler came into play

HD 187547 a.k.a. Superstar

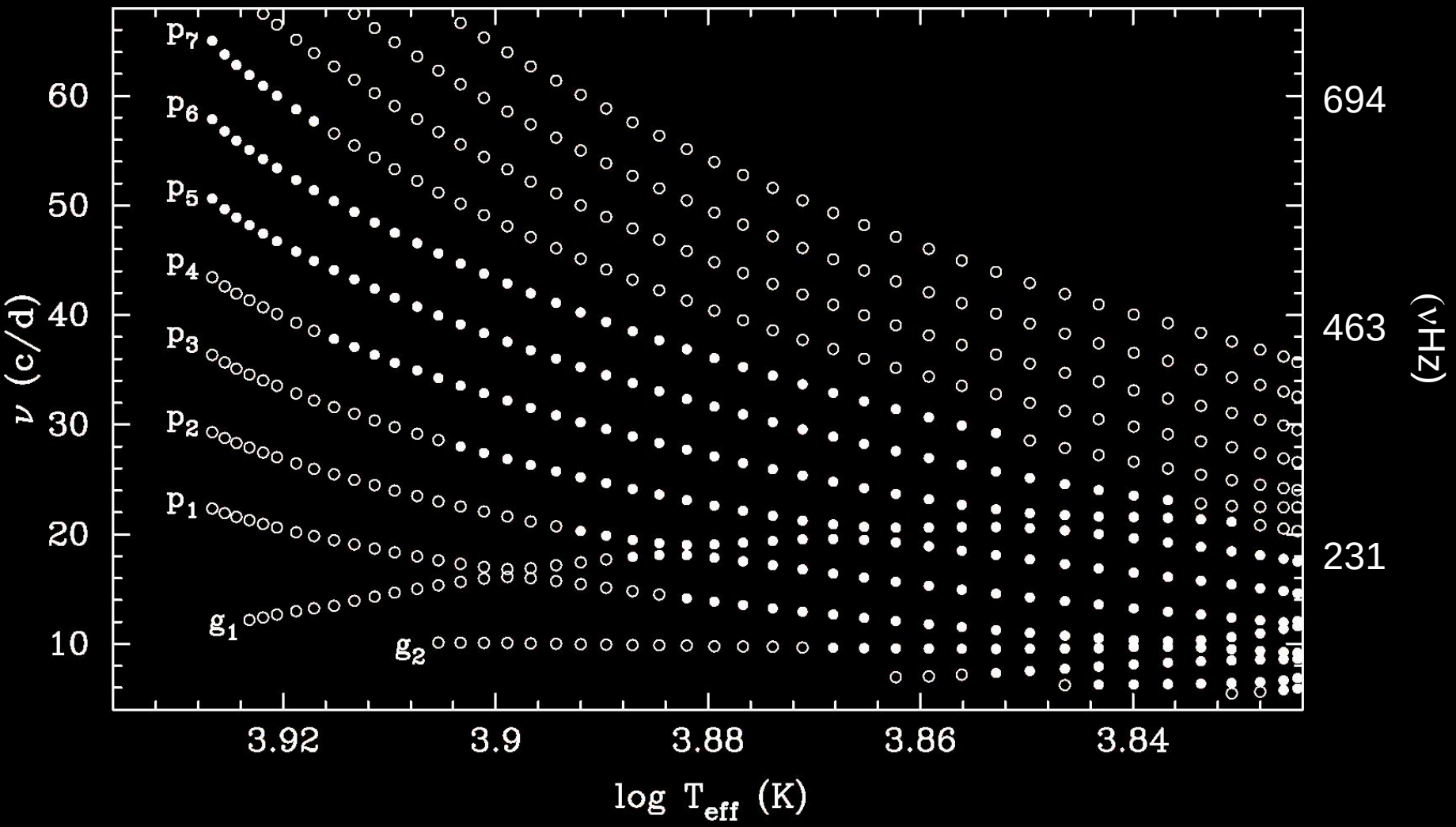


Pamyatnykh 2000

Superstar

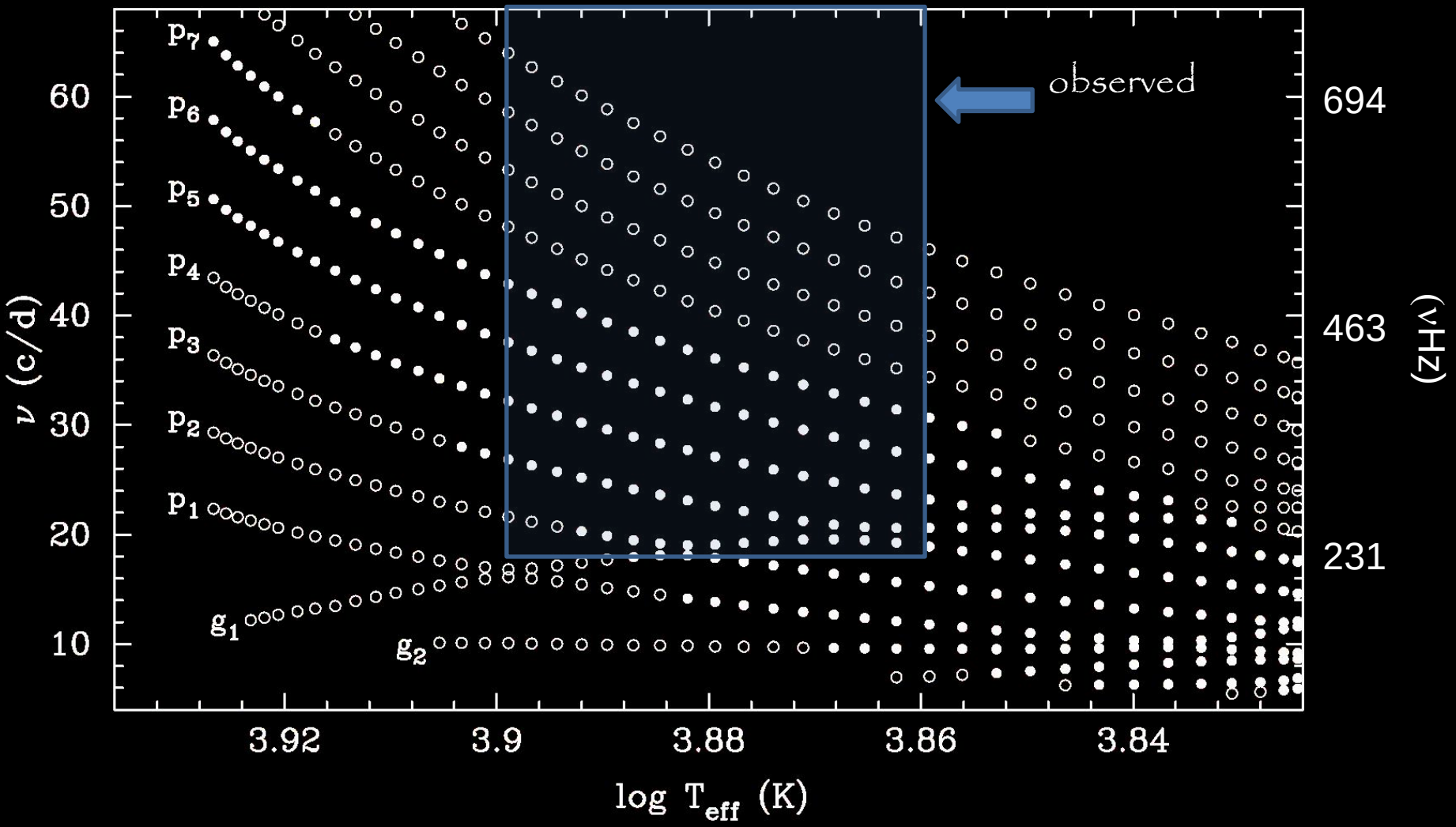

a
HD 187547
b
data-16f
c
data-16f
Δν
Δν
Amplitude [mmag]
Frequency [μHz]

Can the K-mechanism continuously excite the range 180-800 μHz (18-70 c/d)?



K-mechanism excited l=1 modes | G. Handler

K-mechanism excited l=1 modes



G. Handler

κ-κ hybrid?

- Am star (atmospheric under-abundances in Sc and Ca, over-abund. in Ba, Sr, Y).
- No large scale magnetic fields in Am stars (Auriere et al. 2010)

  => no roAp/δ Sct hybrid. (roAp stars also show equidistant patterns in the Fourier spectrum due to alignment of pulsation axes with strong magnetic fields.)

Pulsation from companion?

- Peaks between 500 and 850 μHz from a „classical“ stochastically oscillating companion ?

  unlikely because ν_{max} points toward an F star

⇒companion would be visible in spectrum, which is not.

- δ Scuti pulsation from companion?

  would to be an A or F star => visible in spectrum, which is not.

- Contamination from other star <1.5%
- From RV (7 spectra in 153 days) no indication of binarity either.

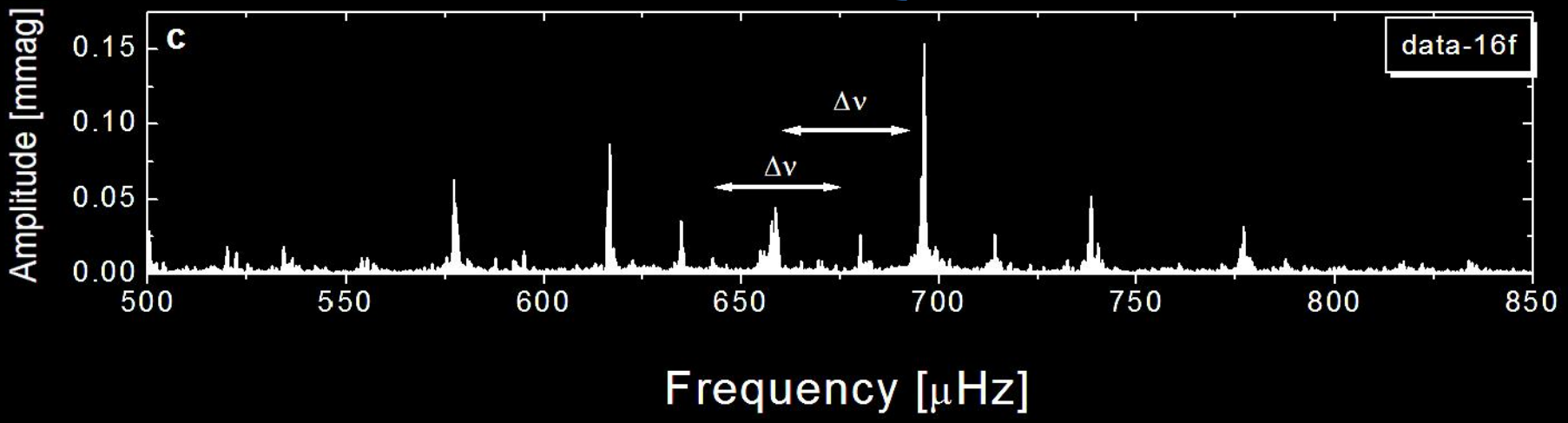
Superstar

- No combination frequencies =>
  high radial overtones as expected for solar-like oscillations.

... but is the driving really the convection in the outer layers?

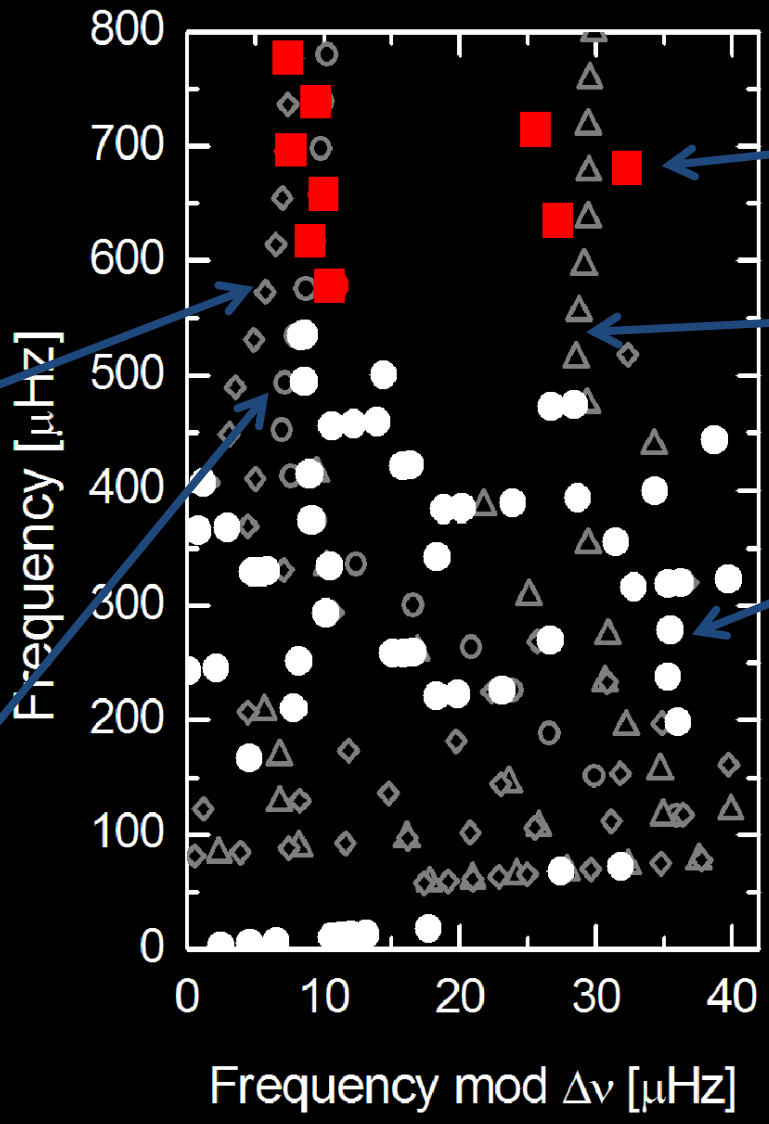
- $\Delta\nu \approx 40.5$ μHz (3.5c/d) ~ $\nu_{max} \approx 578 - 729$ μHz (50-63 c/d)

(using the scaling relation from Stello et al. 2009)



Echelle diagram

Compared to model to guide the eye:
M=1.85Msun,
T_{eff}=7500K,
logg=3.8



Supposed stochastic oscillations

L=1 (model)

L=2 (model)

observed δ Sct modes

L=0 (model)

Amplitude & mode lifetimes

Observed: A_{bol}= 67+/-3 ppm; mode lt.=5.7+/- 0.8 d
Kjeldsen & Bedding 2011: A=14+/- 9 ppm;
Chaplin et al. 2009: Mode lt. < 1 day

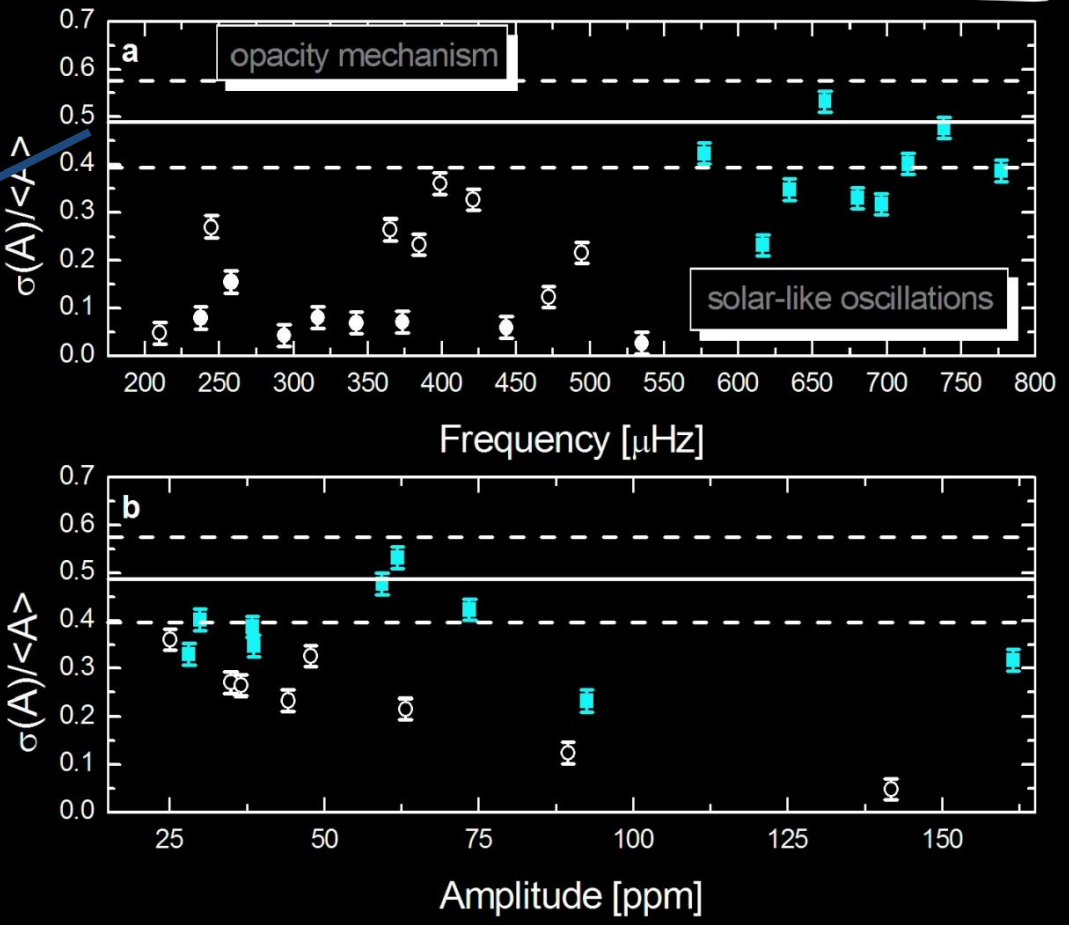
not in agreement BUT

- Scaling relations for stars with significantly diff. Teff.
- Superstar photospheric metallicity : Z= 0.017
  (Z_{Sun}=0.134; Asplund 2009)
- Power of mode directly prop. to lifetime, provided the energy supply rate over the mode inertia is constant.
  => Ampli. higher and mode lt. longer than predicted.
- Am peculiarity

The ultimate test?

- From statistical properties of stochastically excited oscillations (Chang & Gough 1998): $\sigma(A) \simeq 0.52\langle A \rangle$.
- successfully applied by Christensen-Dalsgaard et al. (2001) for semiregular variables

σ(A)/<A> determined from 50000 Monte-Carlo simulations 0.48+/-0.07

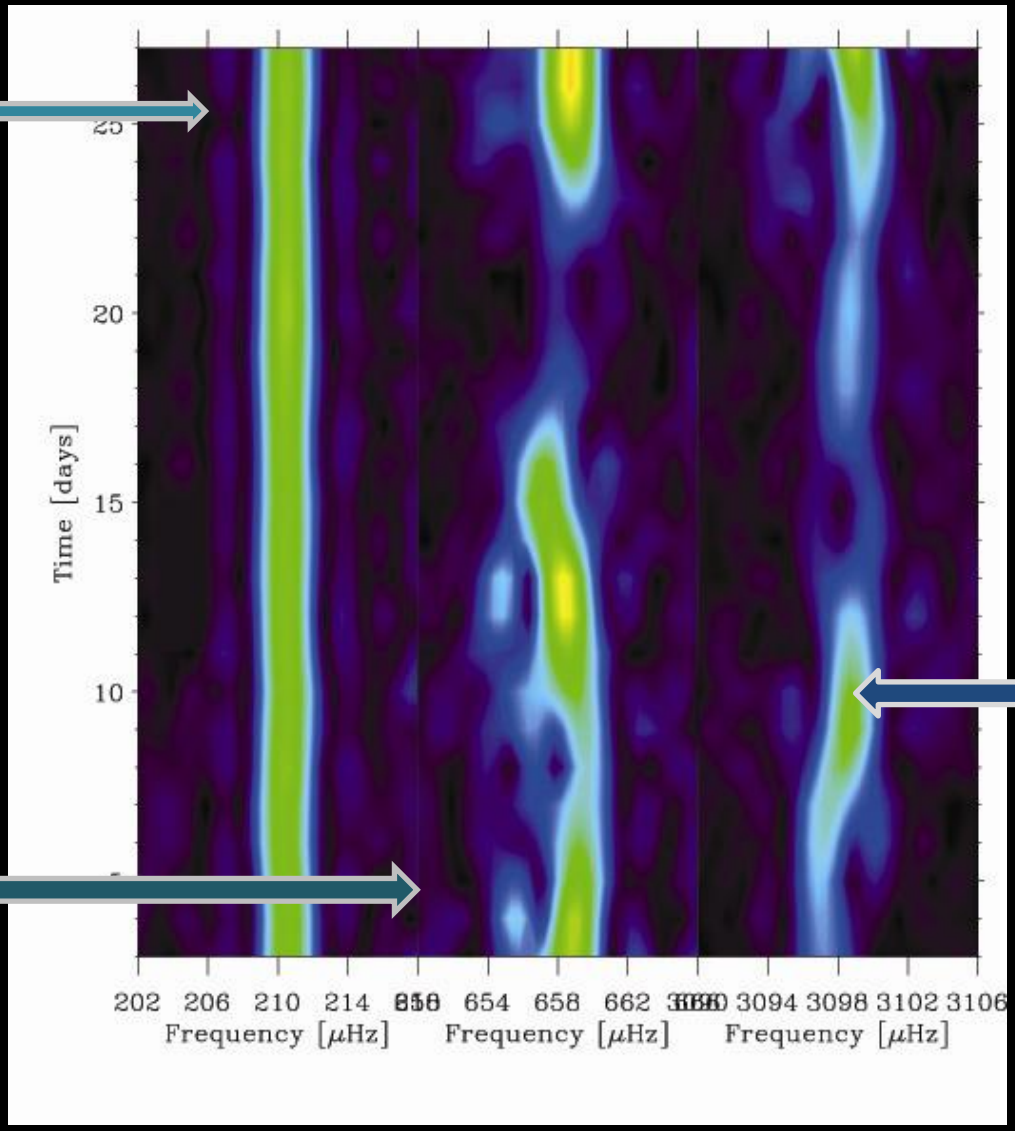


- All δ Sct modes below 1σ

Full circles: high amplitude δ Sct modes | empty circles: low amplitude δ Sct modes

Time-Fourier spectrum

δ Sct mode



Sun

Solar-like mode in Superstar

D. Stello

SOLAR-LIKE OSCILLATIONS

do exist in (this) δ Sct star(s)

Houdek et al. (1999) and Samadi et al. (2002)

Superstar

the perfect astrophysical laboratory!

- test convection in A type stars
- Am phenomenon –> diffusion + pulsation
- convection + κ mechanism
- model δ Sct stars
- ...

Thank you!