BRITE's role in stellar physics

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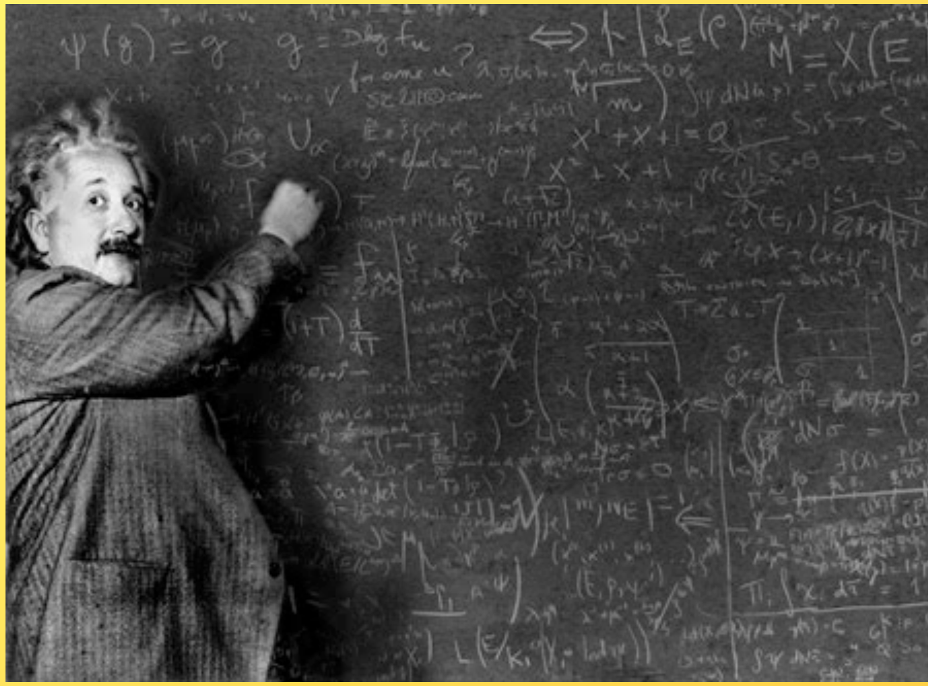
Space Mission Flowchart



"…tell us what we in your opinion can do with this instrument."

(instructions from Gerald)

BRITE-Constellation Flowchart

404: Not Found

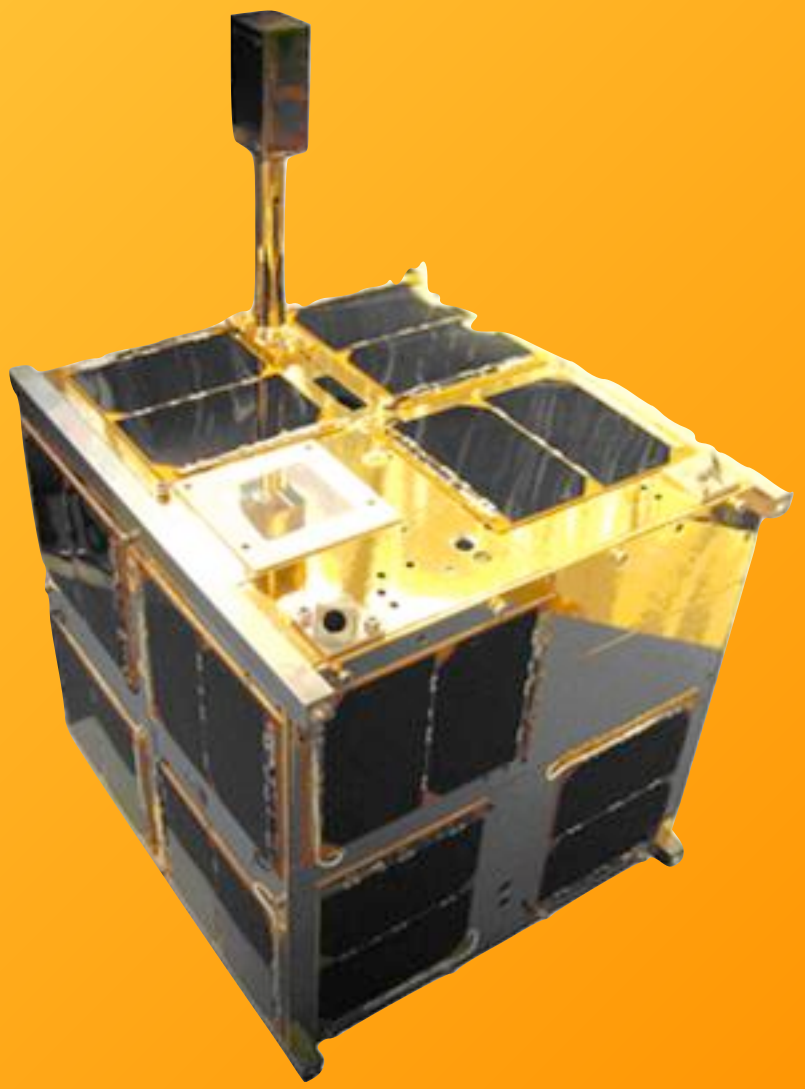
BRITE-Constellation Goals

1. Measure p- and g-mode pulsations to probe the interiors and ages of stars through asteroseismology;
2. Look for varying spots on the stars surfaces carried across the stellar disks by rotation, which are the sources of co-rotating interaction regions in the winds of the most luminous stars, probably arising from magnetic subsurface convection;
3. Search for planetary transits.

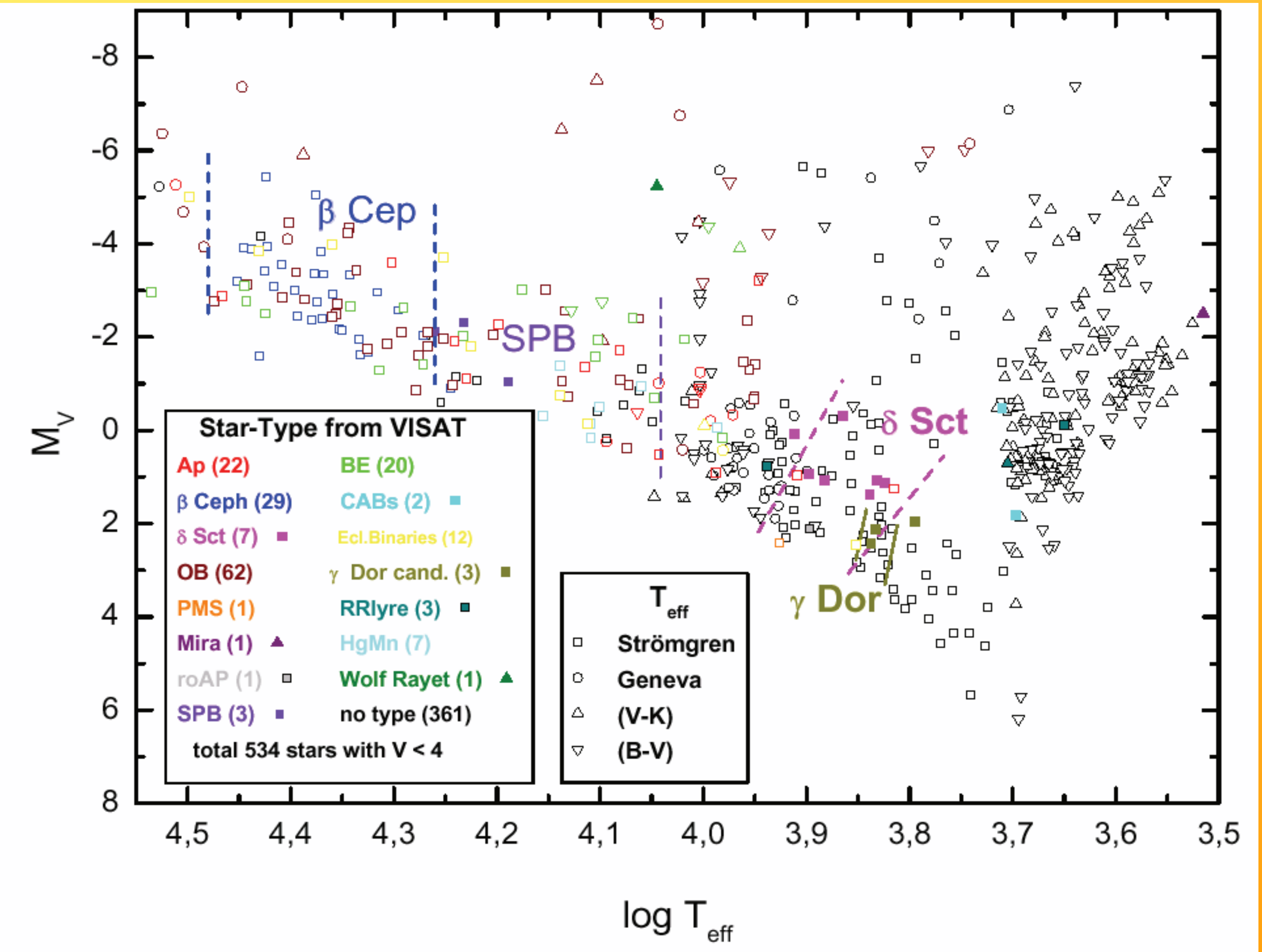
Weiss+2014 (PASJ 126), abstract

BRITE-Constellation Capabilities

- (All) stars brighter than $V = 4$
- Photometric precision @ sub-mmag levels
- Continuous monitoring up to $\approx$ 150 d
- All-sky coverage
- Two filters (red, blue)
- 24deg x 24deg FOV
- Up to 18 targets simultaneously

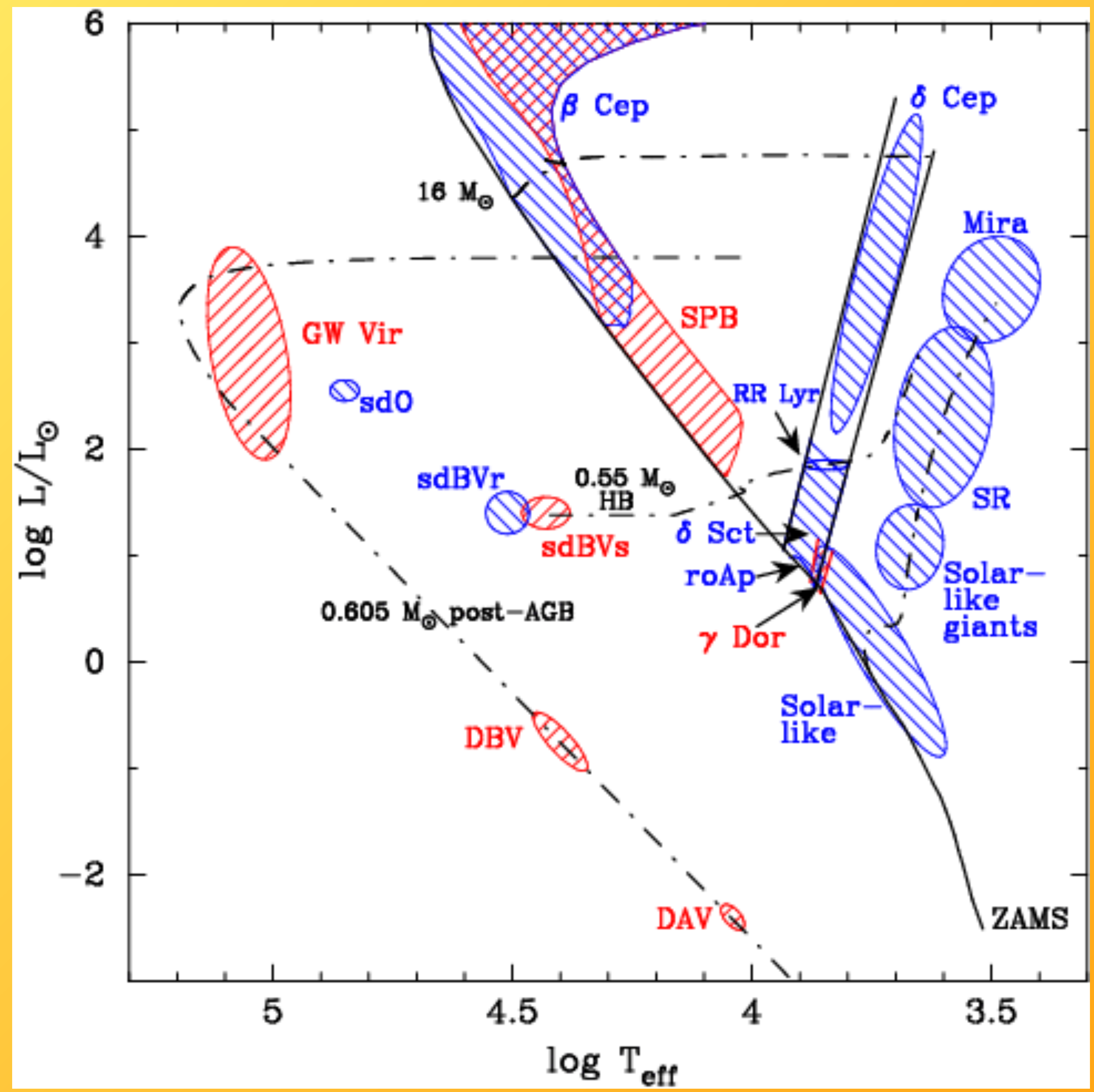


Bright Stars for BRITE



Weiss+2013 (Proc. IAUS 301), fig.1

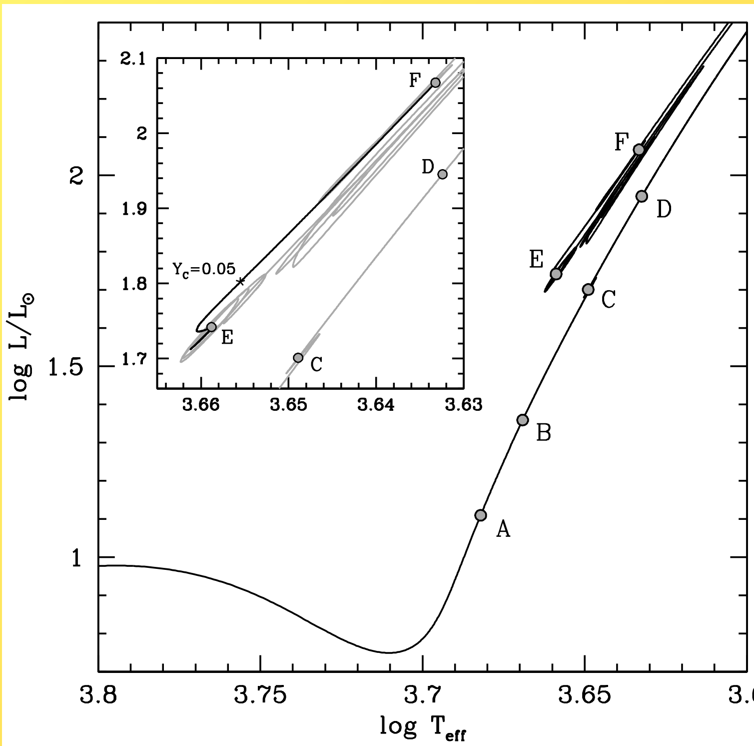
Oscillations Across the HRD

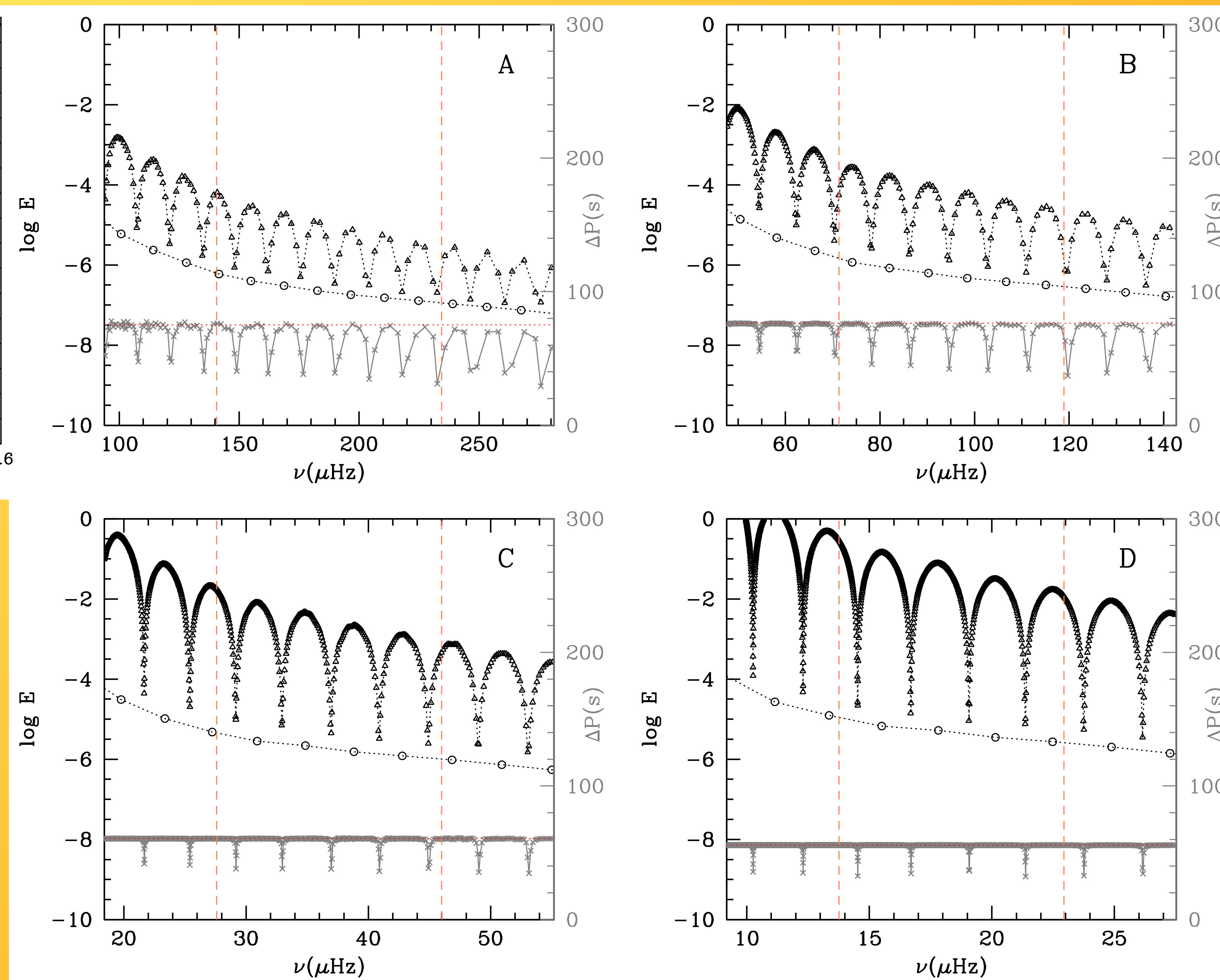


http://www.univie.ac.at/brite-constellation/html/additional_science.html

Stochastic Pulsations

Stochastic Mixed Modes on the Lower RGB

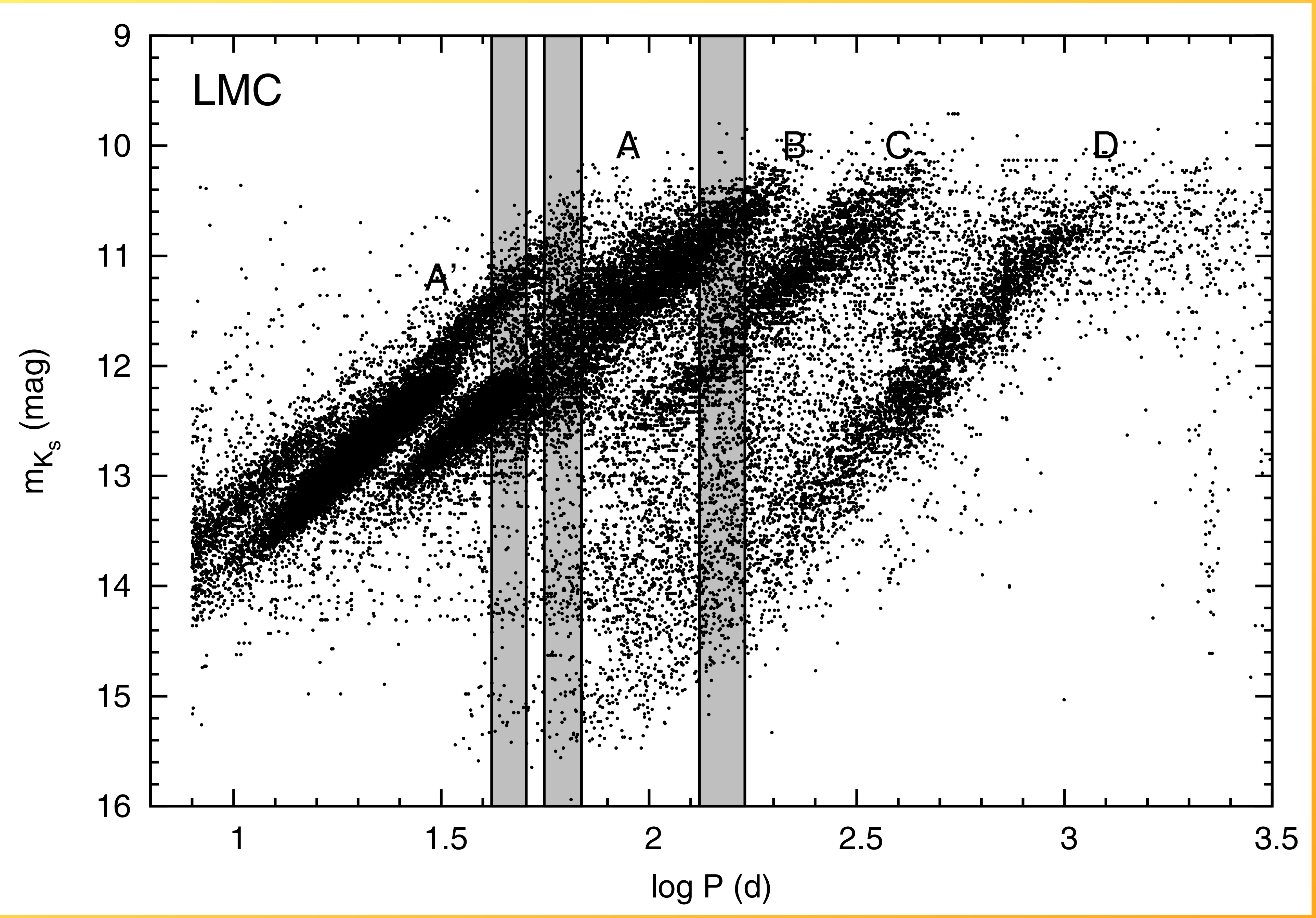




Toward the TRGB, only envelope-trapped low-order modes remain visible

Montalban & Noels 2013 (EPJWC), figs. 2 & 3

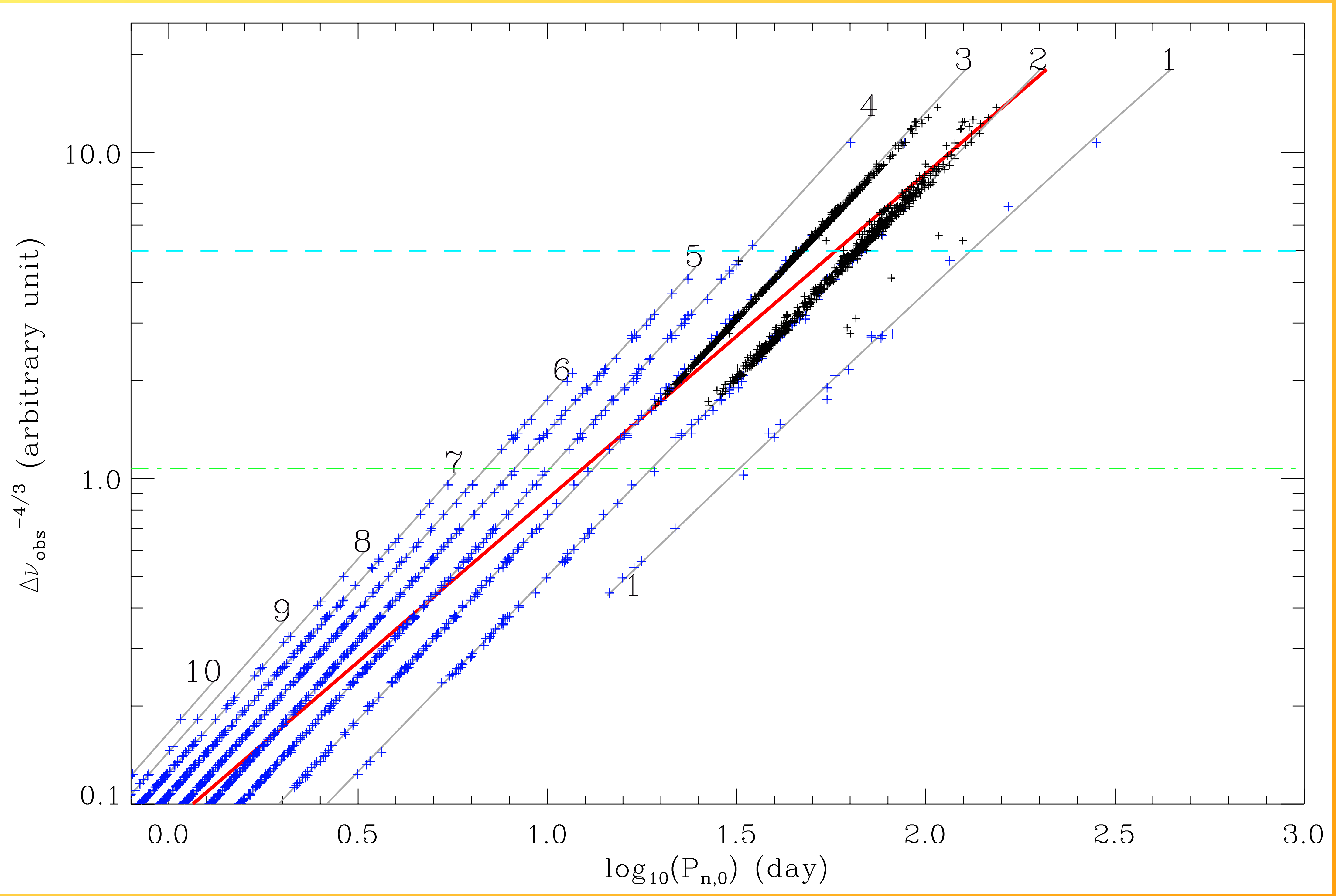
Period-Luminosity Relations Near & Above the TRGB



A - OSARGs
C - SRV/Mira
D - LSP

Tabur+2010 (MNRAS 409), fig. 9

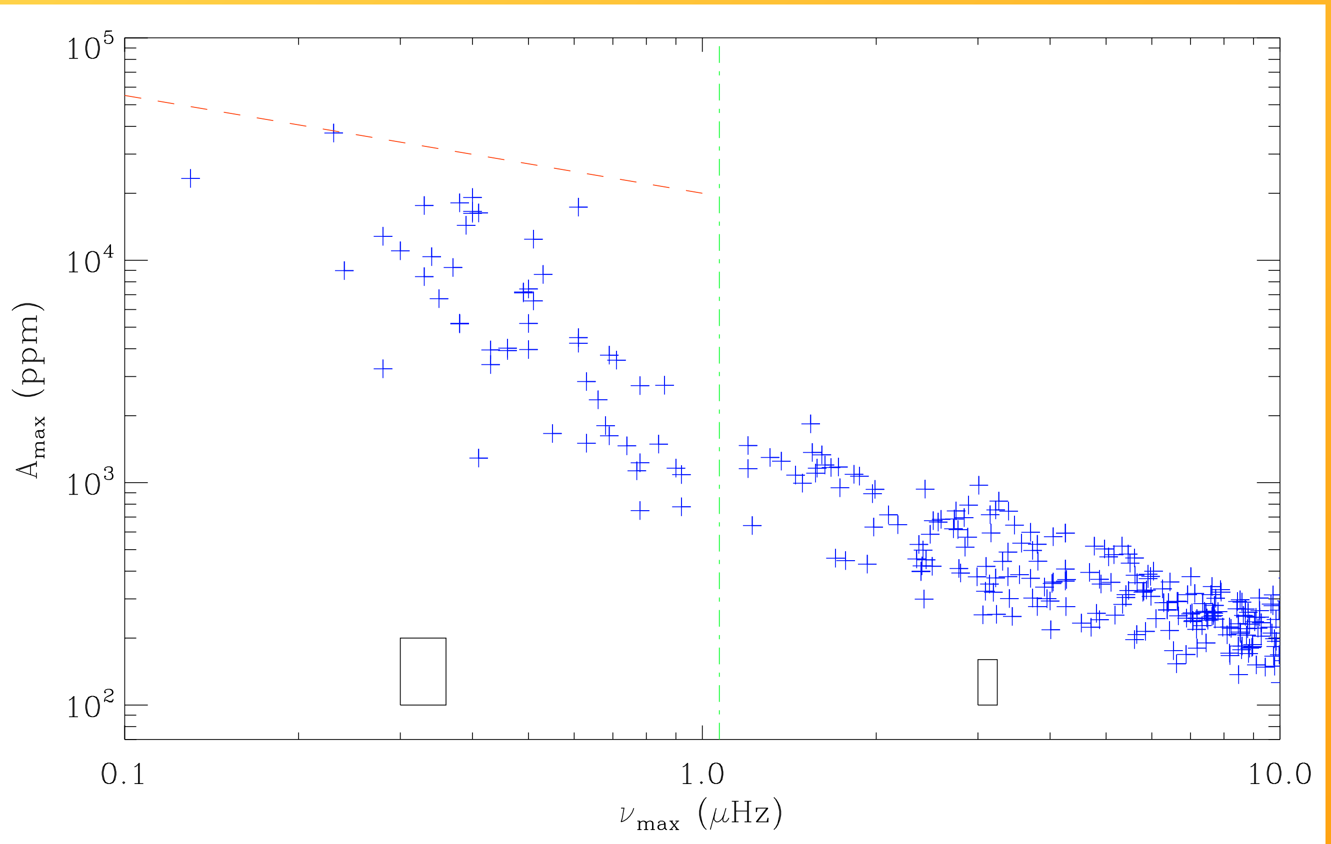
P-L Relations Consistent with Solar-Like Oscillations



Mosser+2013 (A&A 559), fig. 10

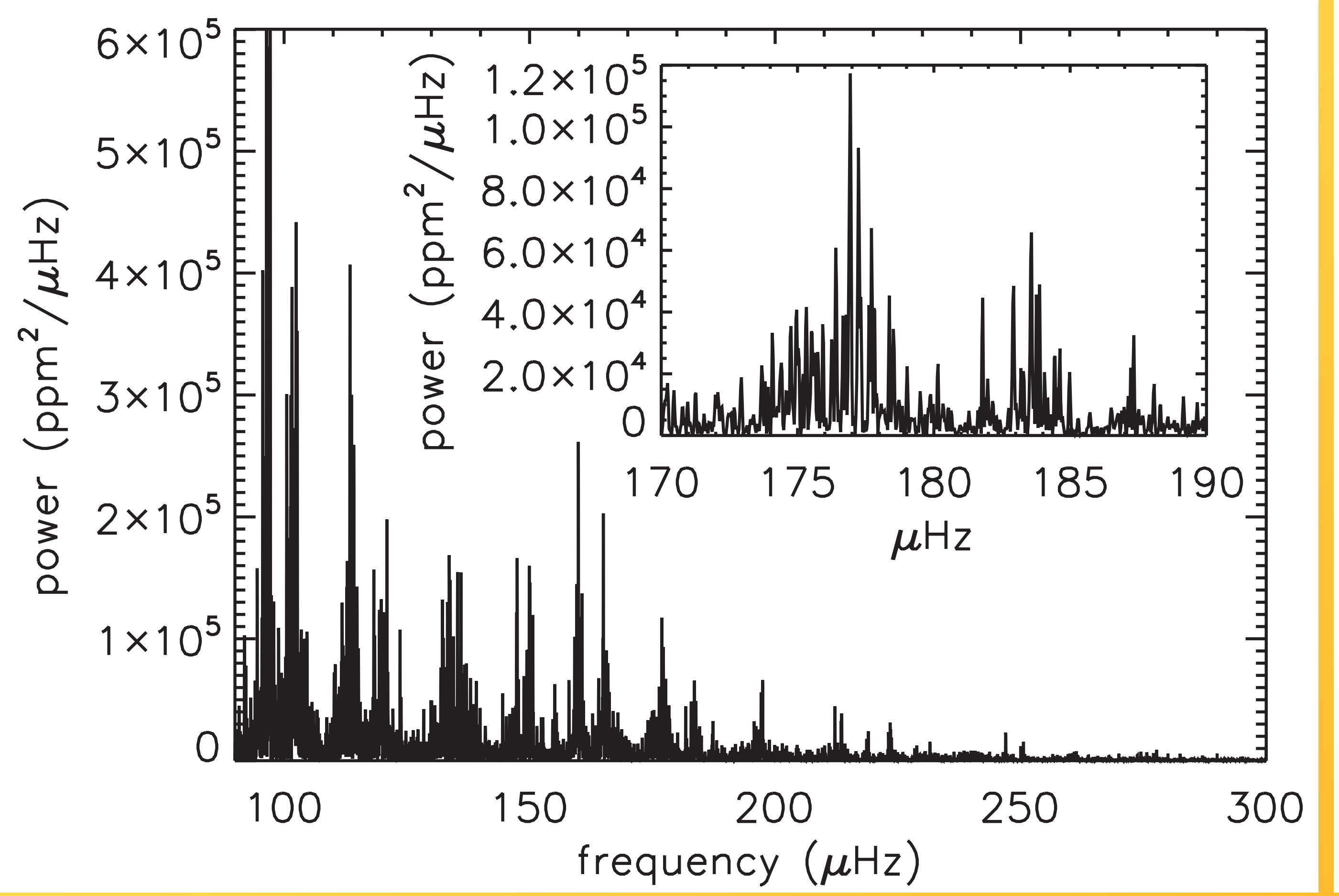
Outstanding Questions

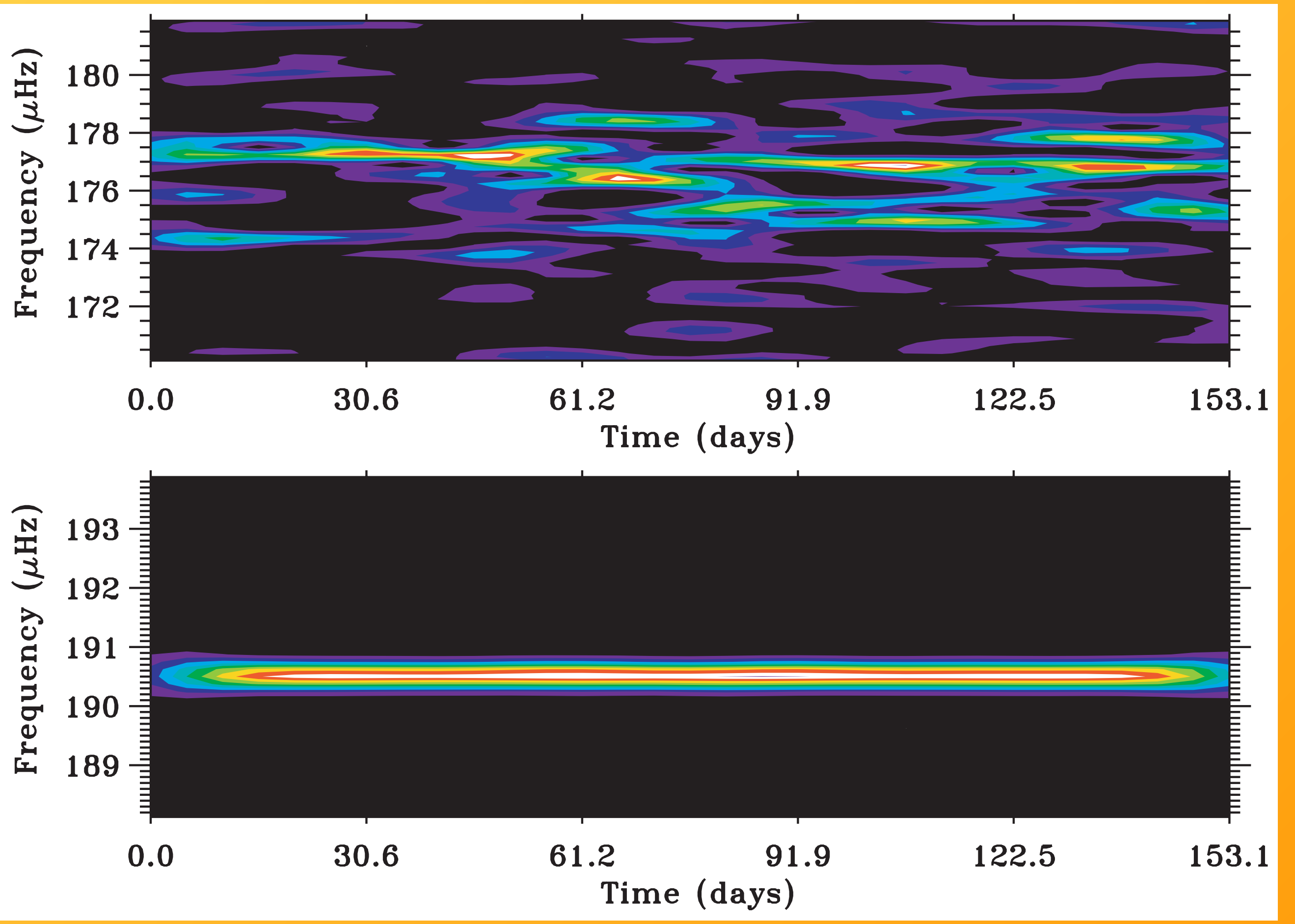
- What causes the change around $\nu_{\max} \approx 1$?
- Can we reliably distinguish between RGB and AGB stars?
- What about other types of variability, e.g. granulation?



Mosser+2013 (A&A 559), fig. 5

Stochastic Oscillations in β Cepheids?





HD 180642

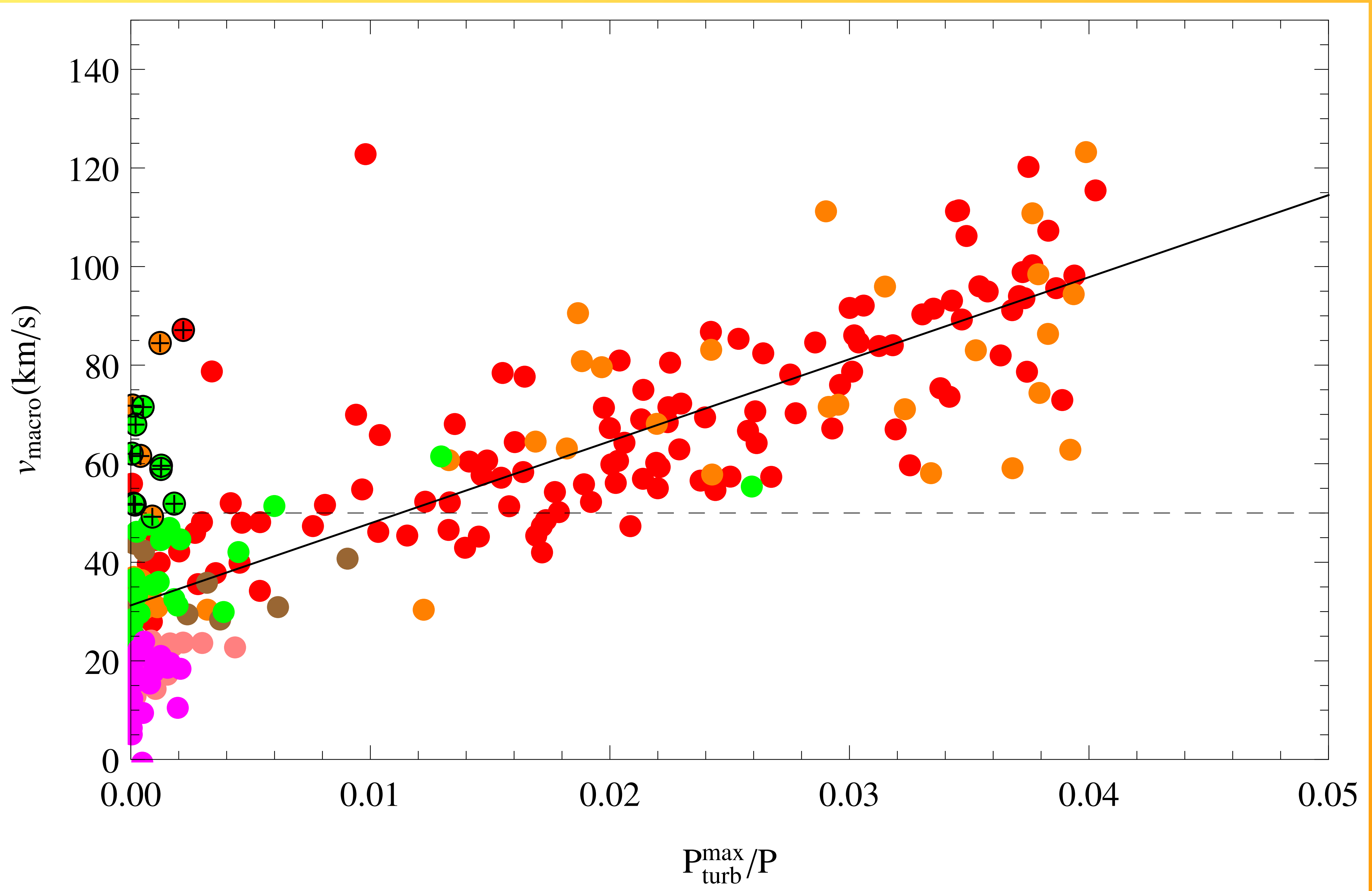
Belkacem+2009 (Science 324), figs. 1 & 2

See also Degroote+2010 (A&A 519)

Theoretical Prognostications

- Belkacem+2010:
  - p modes excited by both core and Fe convection zones
  - amplitudes 10 ppm @ >100 μHz, 100 ppm @ <100 μHz
- Samadi+2010:
  - low-order g modes excited by core convection
  - high-order g modes excited by Fe convection
  - amplitudes 10 ppm @ 3 μHz
- Shiode+2013:
  - g modes excited by core convection
  - <u>ensemble</u> brightness variations 10 ppm @ 10 μHz
- Aerts & Rogers 2015:
  - g modes excited by core convection (2-D hyro)
  - amplitudes 100 ppm @ 3 μHz (may be over-estimated)
  - link with macroturbulence?

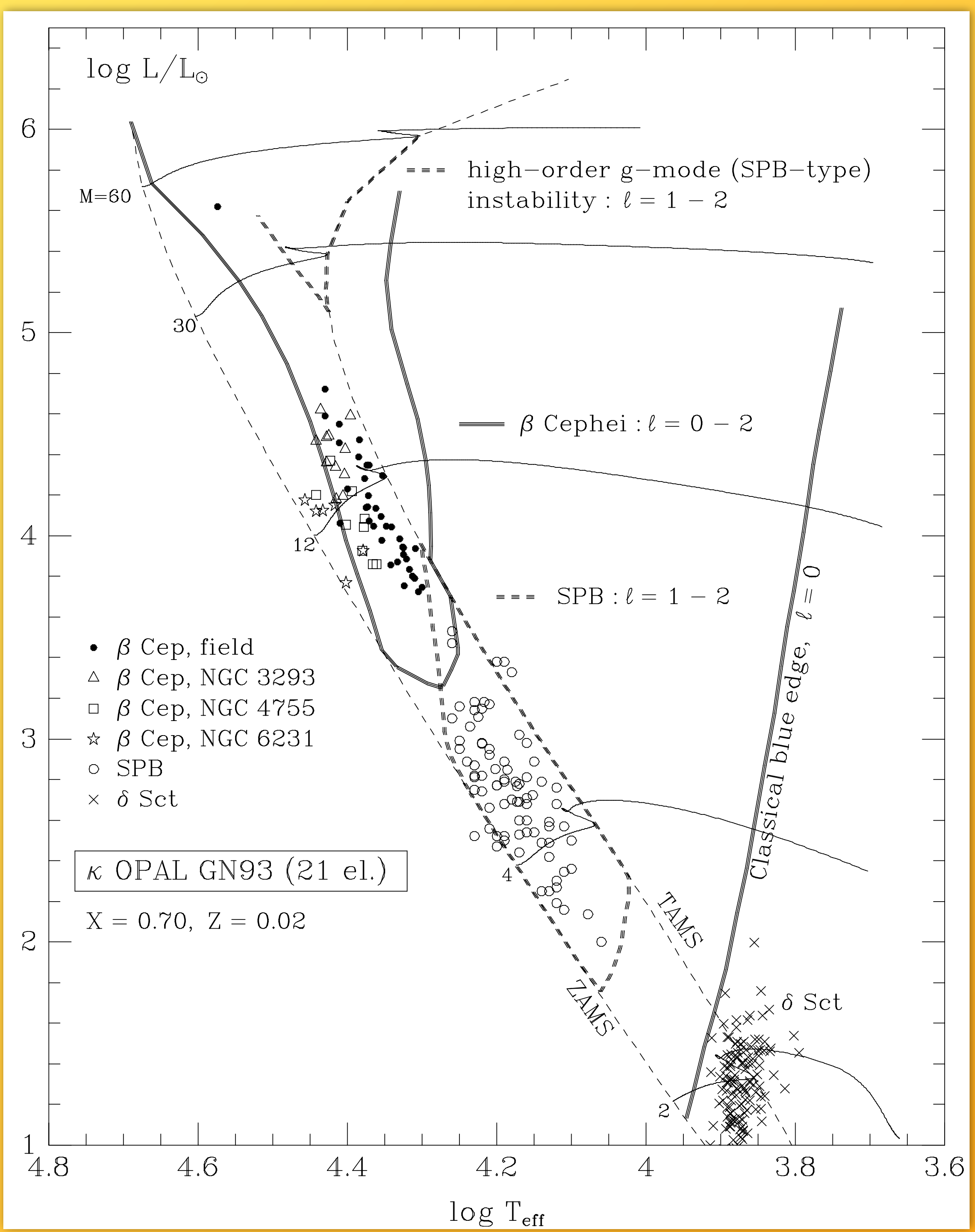
Evidence for a Link with Macroturbulence



Grassitelli+2015 (ApJ 808), fig. 5

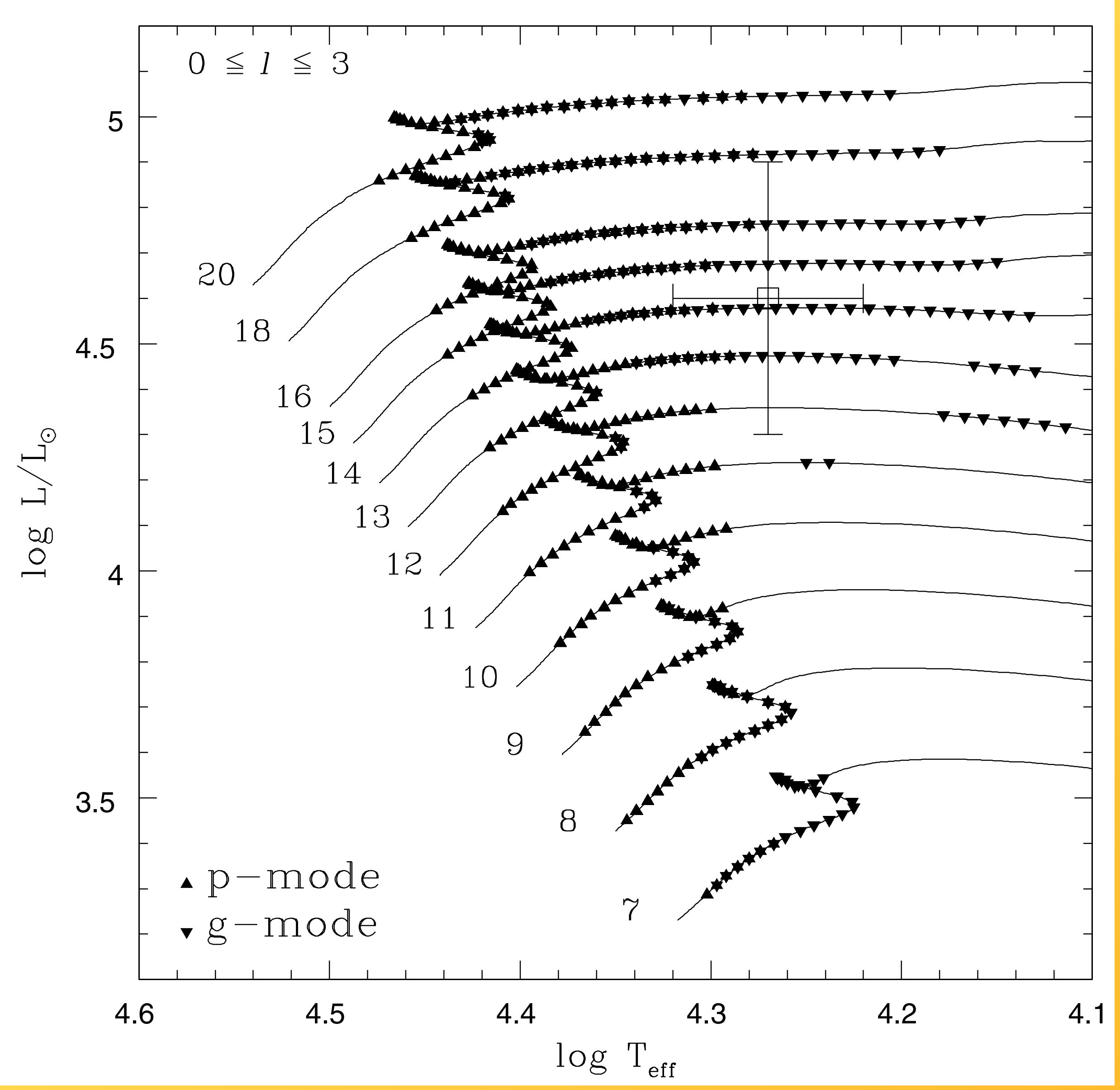
Heat-Driven Pulsations

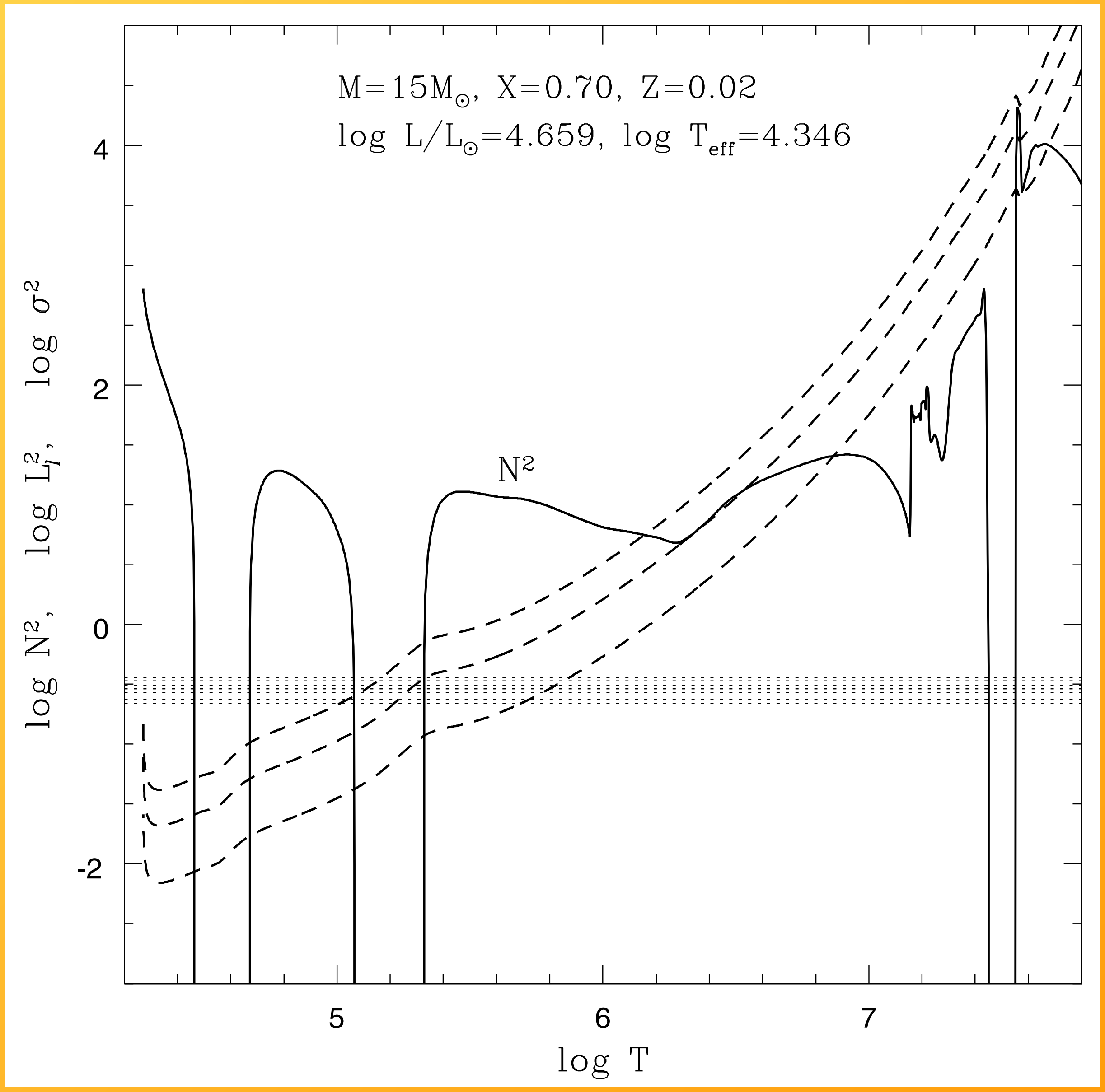
Massive-Star Instability Strips



Pamyatnykh 1999 (Acta Ast 49), fig. 3

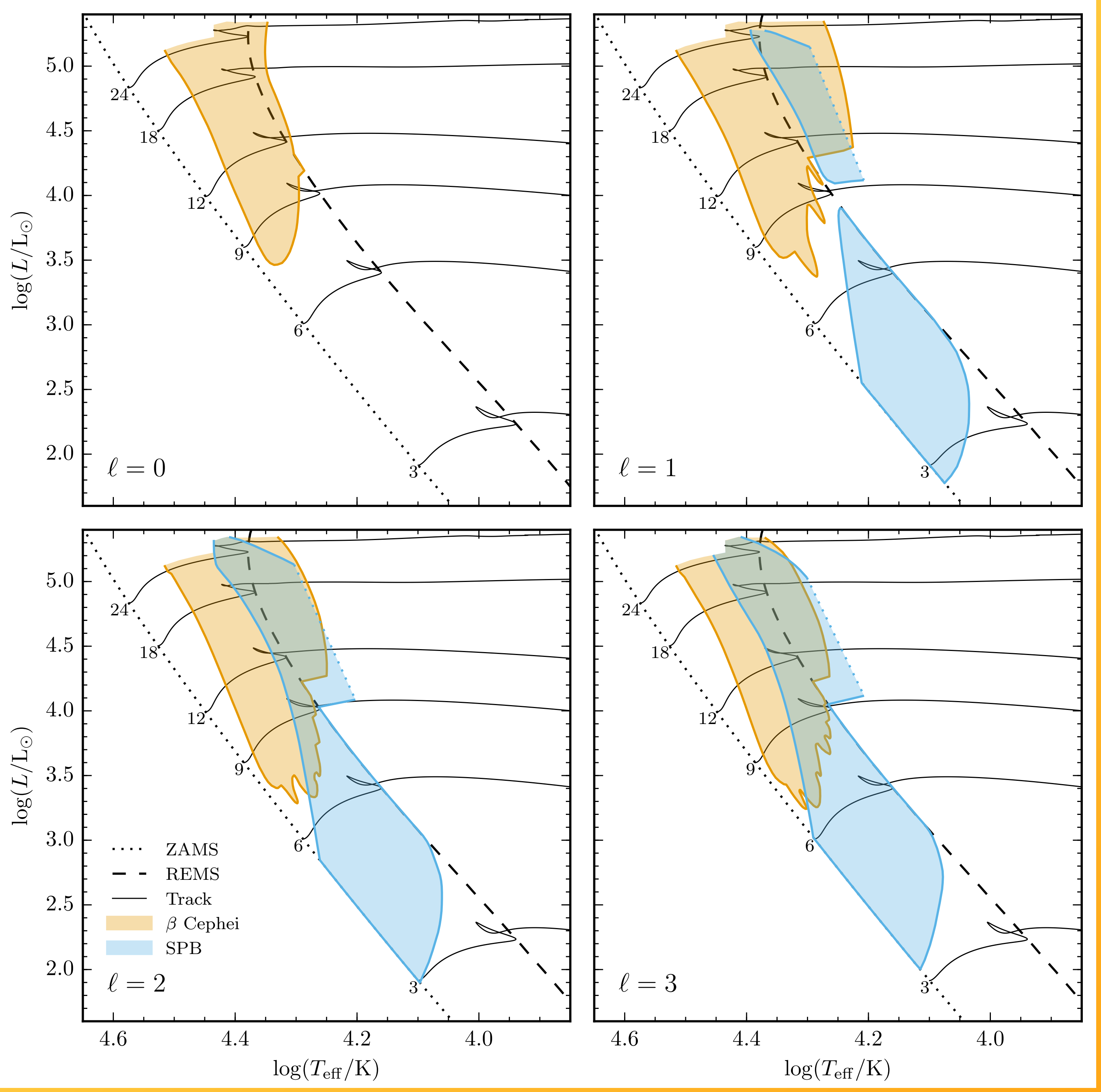
Post-MS Extension of Instability Strips





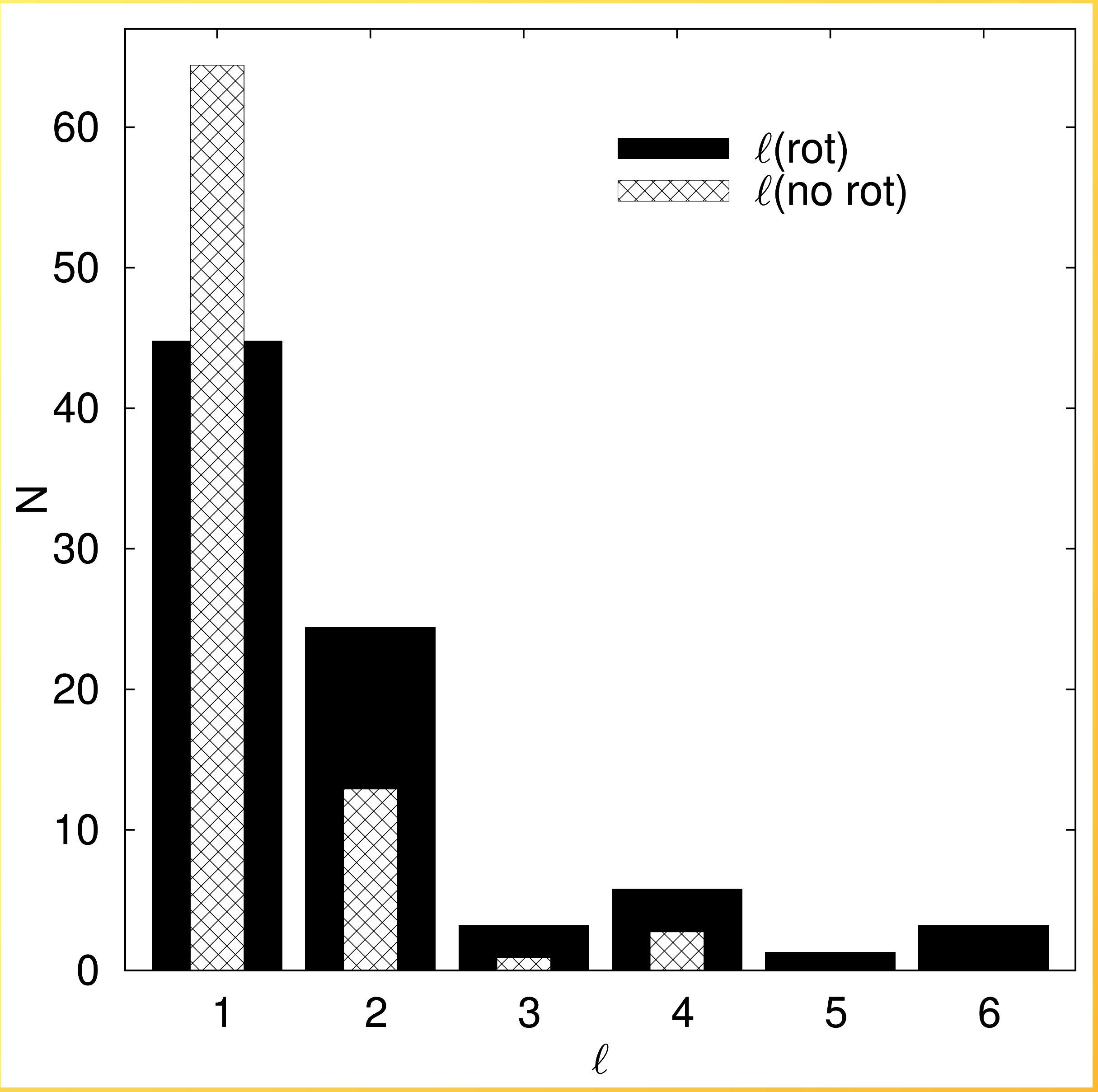
Saio+2006 (ApJ 650), figs. 4 & 7

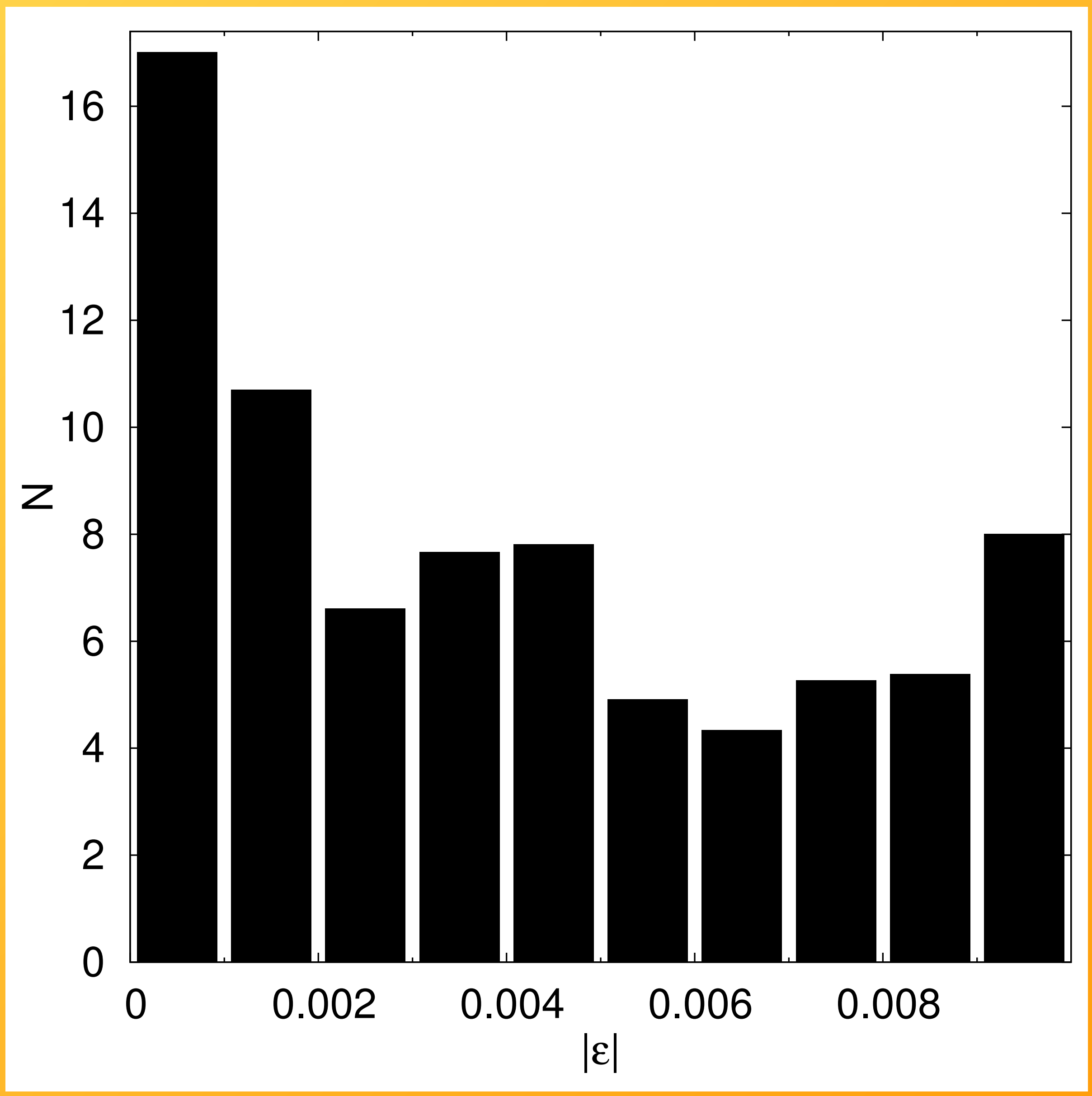
Fine Structure in Instability Strips



Paxton+2015 (ApJS, in press), fig. 9

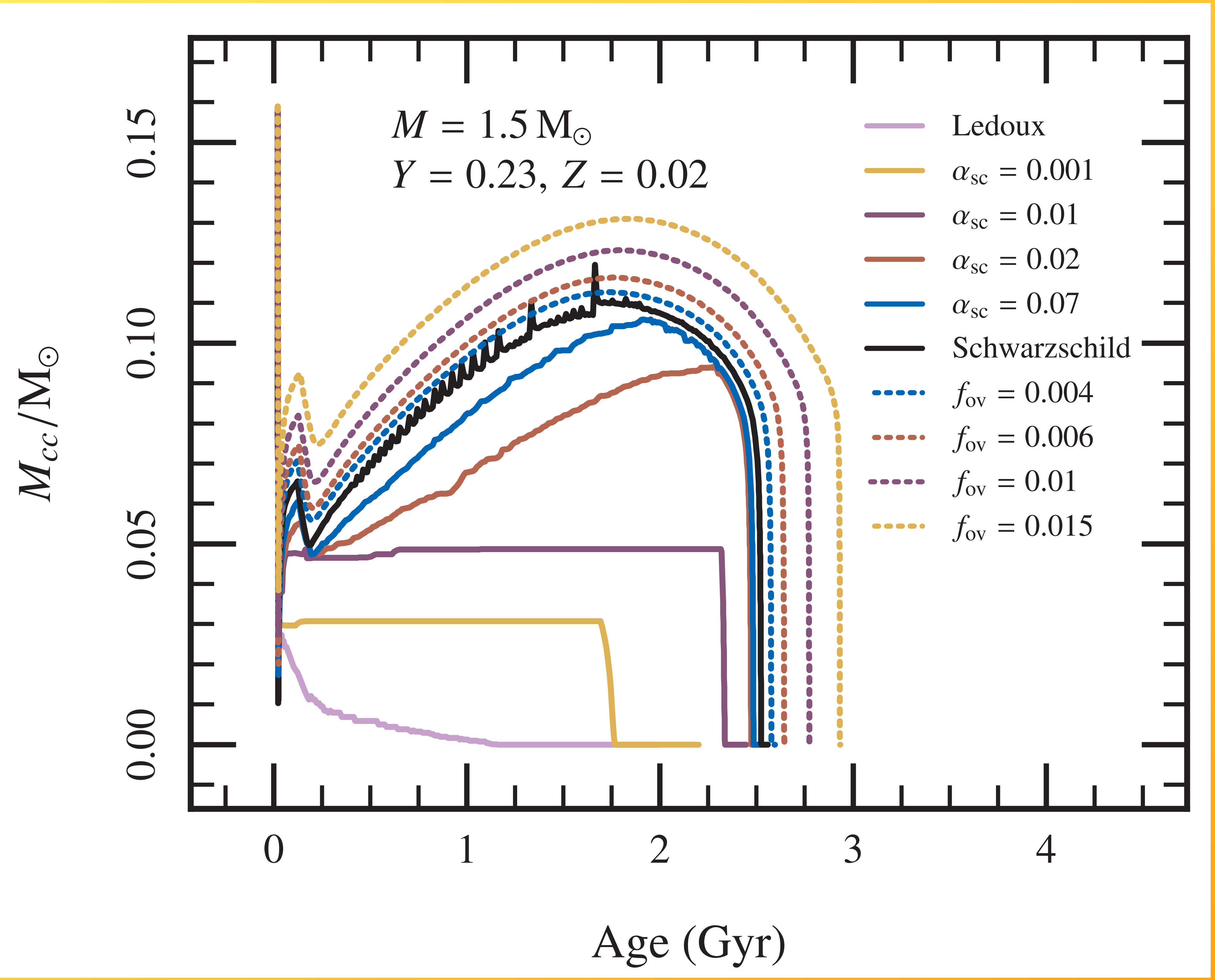
Mode Selection in SPB Stars: Still a Mystery





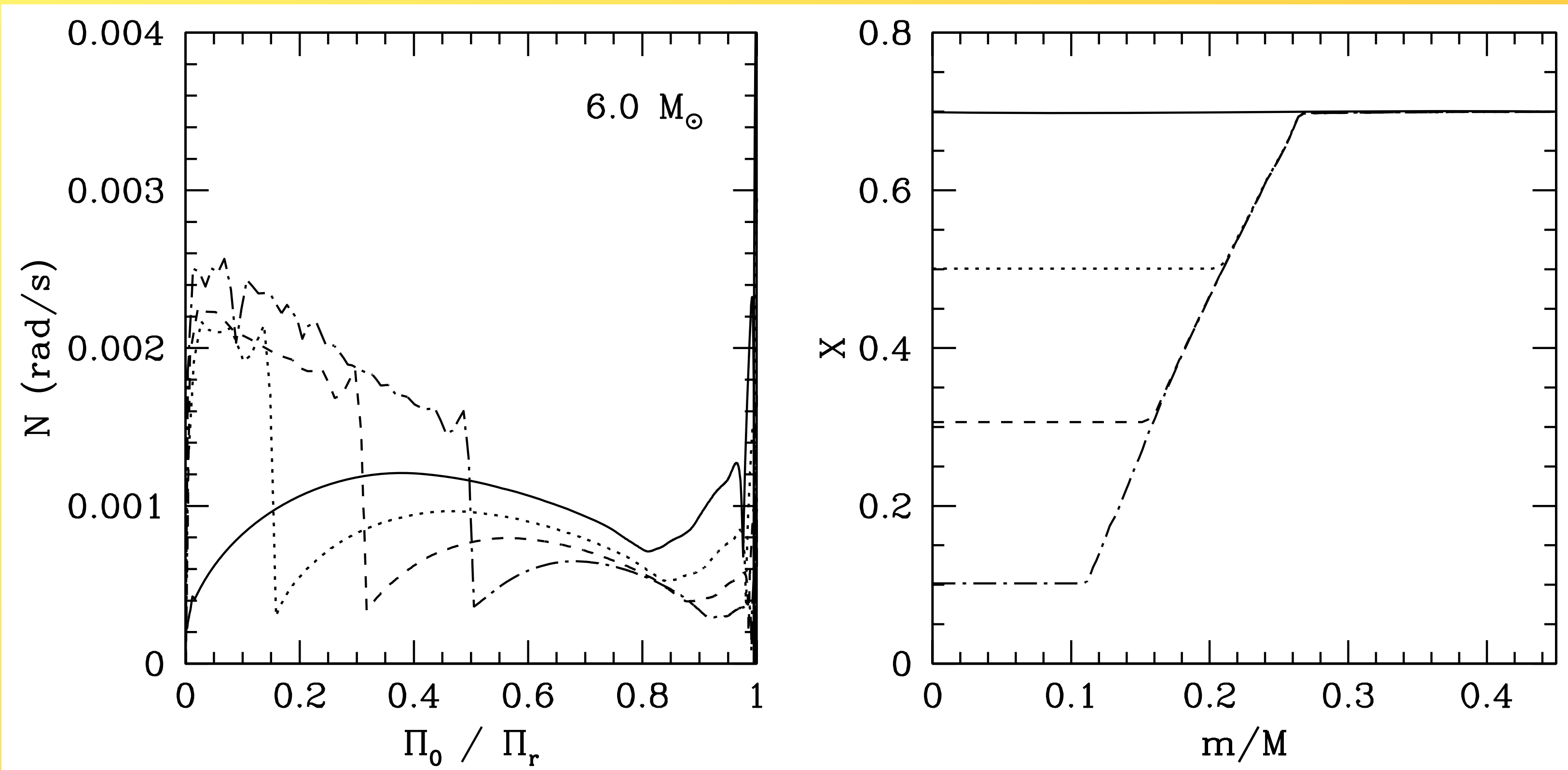
Szewczuk & Daszynska-D. 2015 (MNRAS 450), figs. 5 & 7

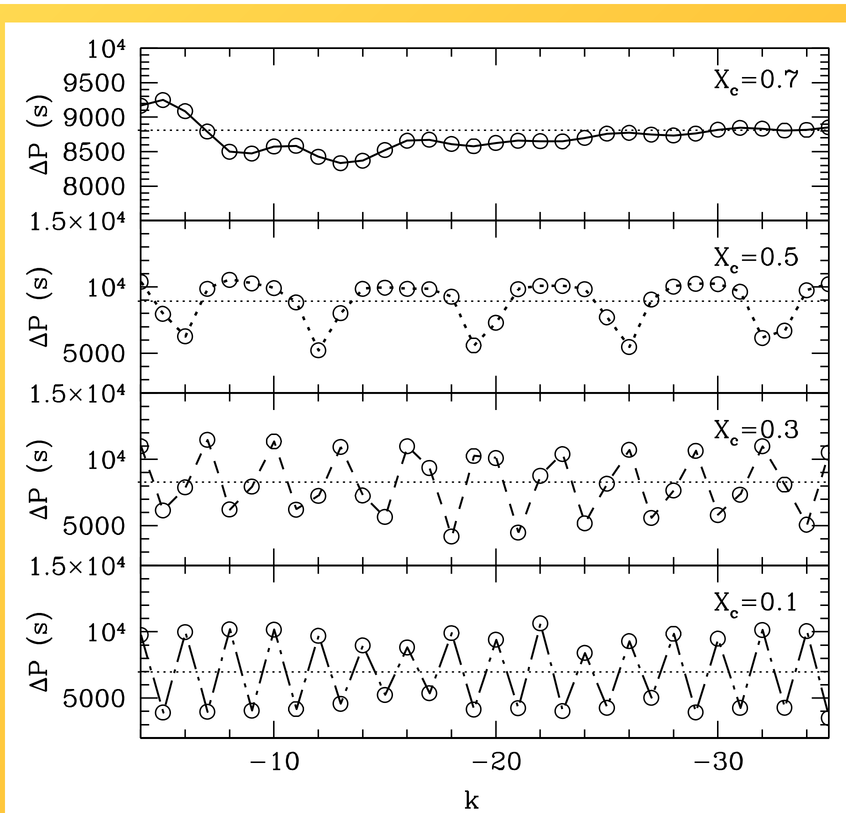
What Sets the Core Boundary?



Paxton+2013 (ApJS 208), fig. 13

Period Spacing Modulation due to Features in the Buoyancy Frequency



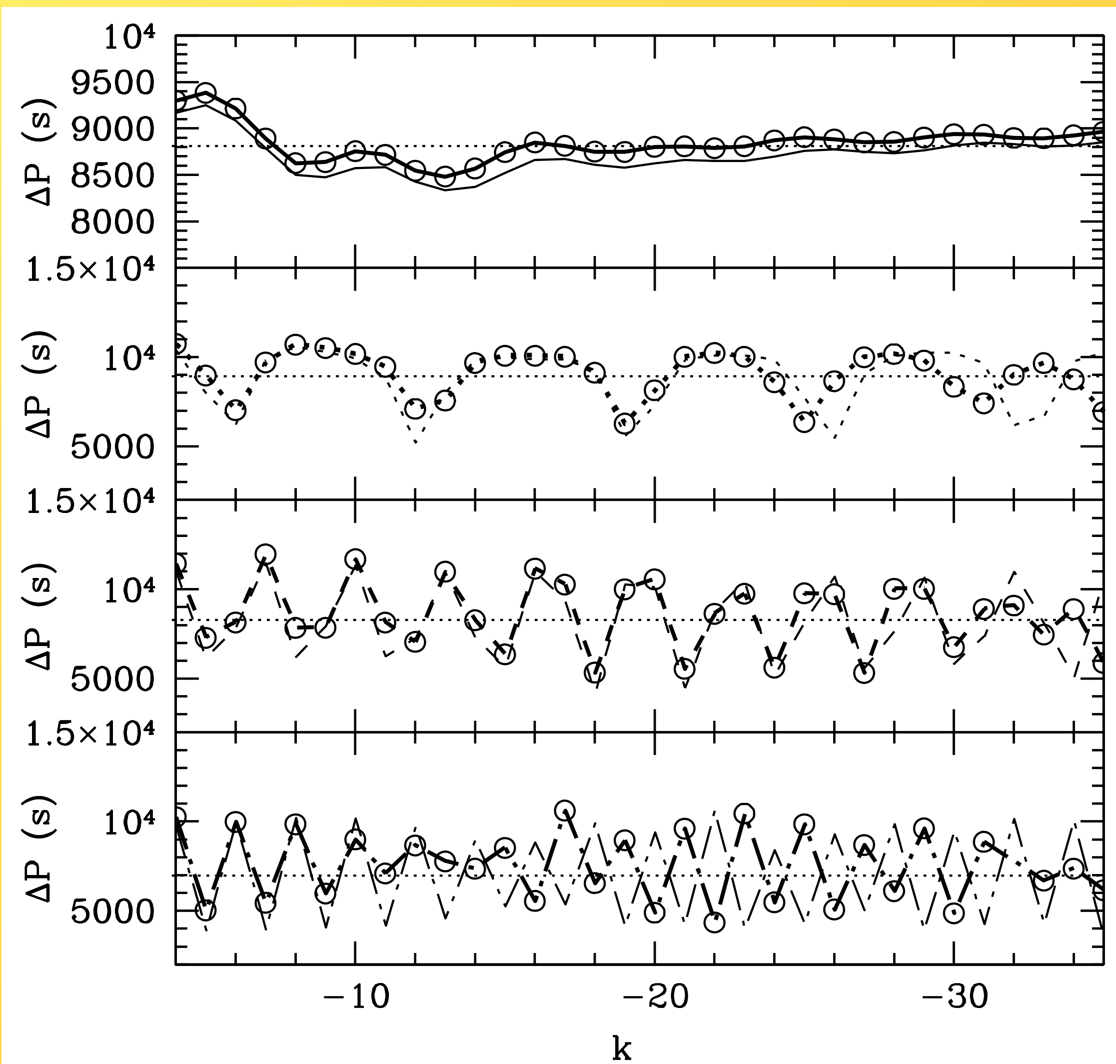


$$\frac{\Pi_0}{\Pi_r} = \frac{\int_0^r \frac{|N|}{r'}\,\mathrm{d}r'}{\int_0^R \frac{|N|}{r'}\,\mathrm{d}r'}$$

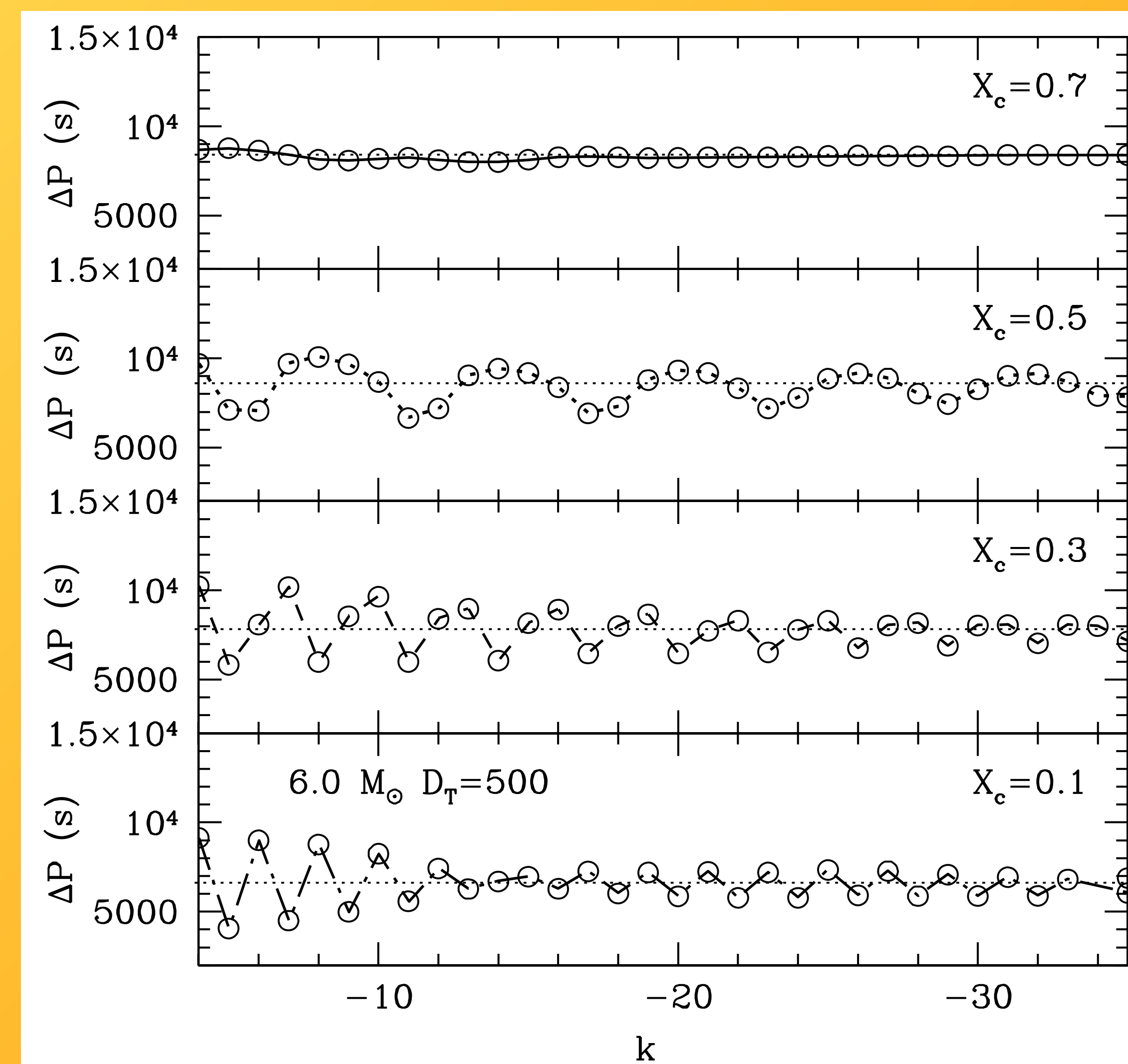
Miglio+2008 (MNRAS 386), fig. 16

Effects of Overshoot & Rotation on PS Modulation

No overshoot (thin)
0.2 H_p overshoot (thick)

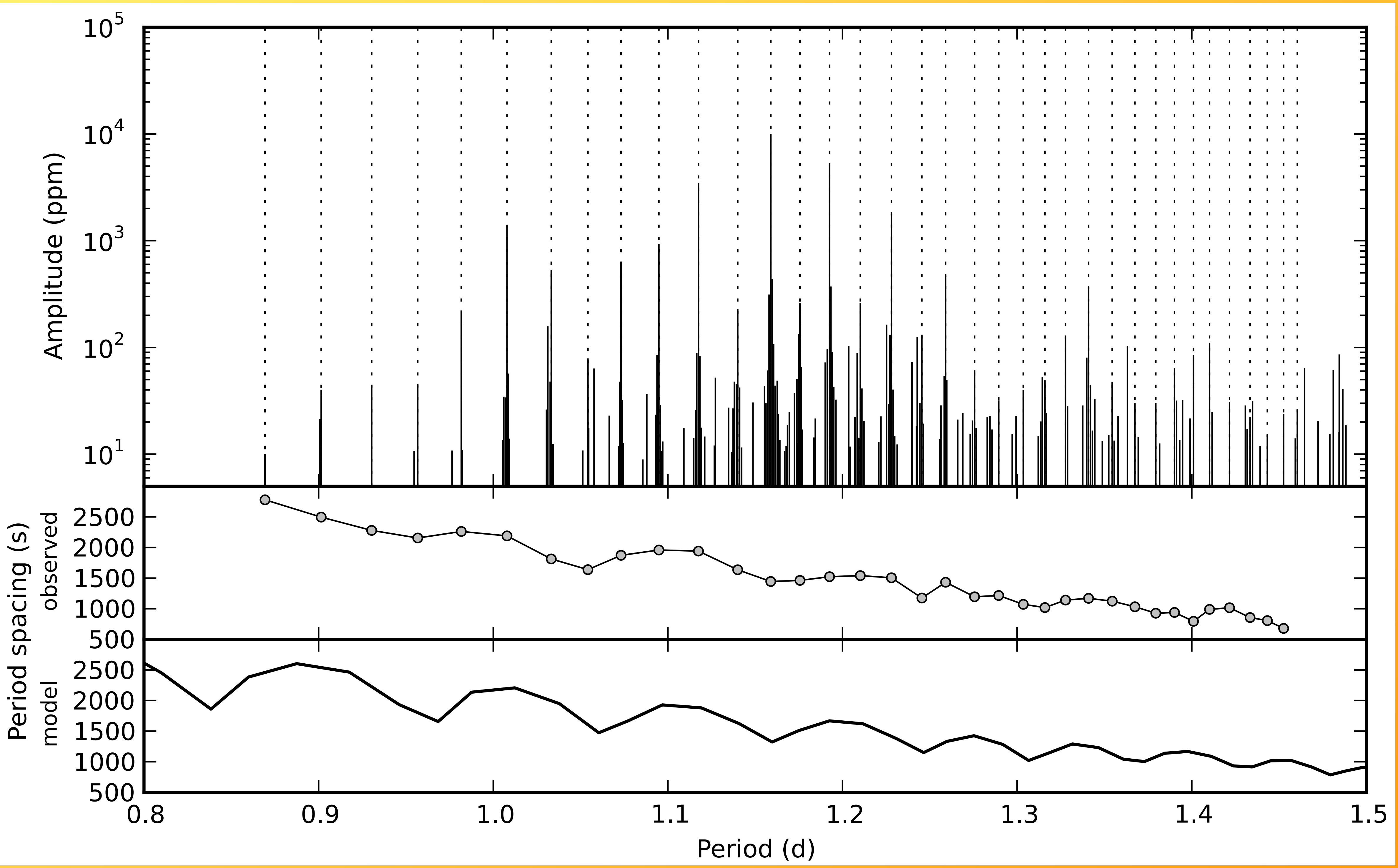


Rotation



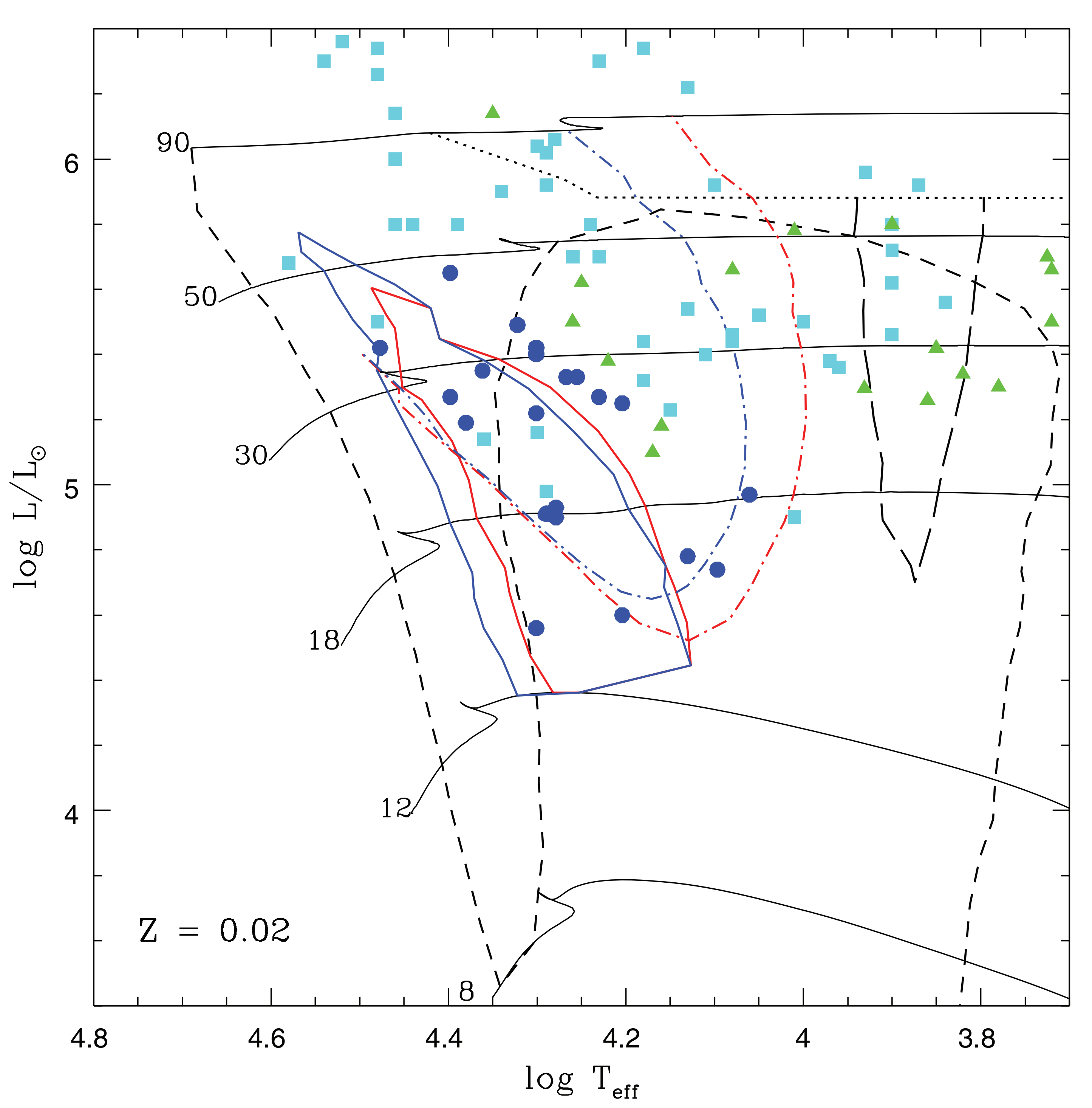
Miglio+2008 (MNRAS 386), figs. 17 & 21

Application to an SPB Star: KIC 7760680



Papics+2015 (ApJ 803), Fig. 4

Overstable Convection Modes



Saio 2011 (MNRAS 412), fig. 1

Diagnostic Techniques

Method of Photometric Amplitudes

Light and Radial Velocity Variations in a Nonradially Oscillating Star

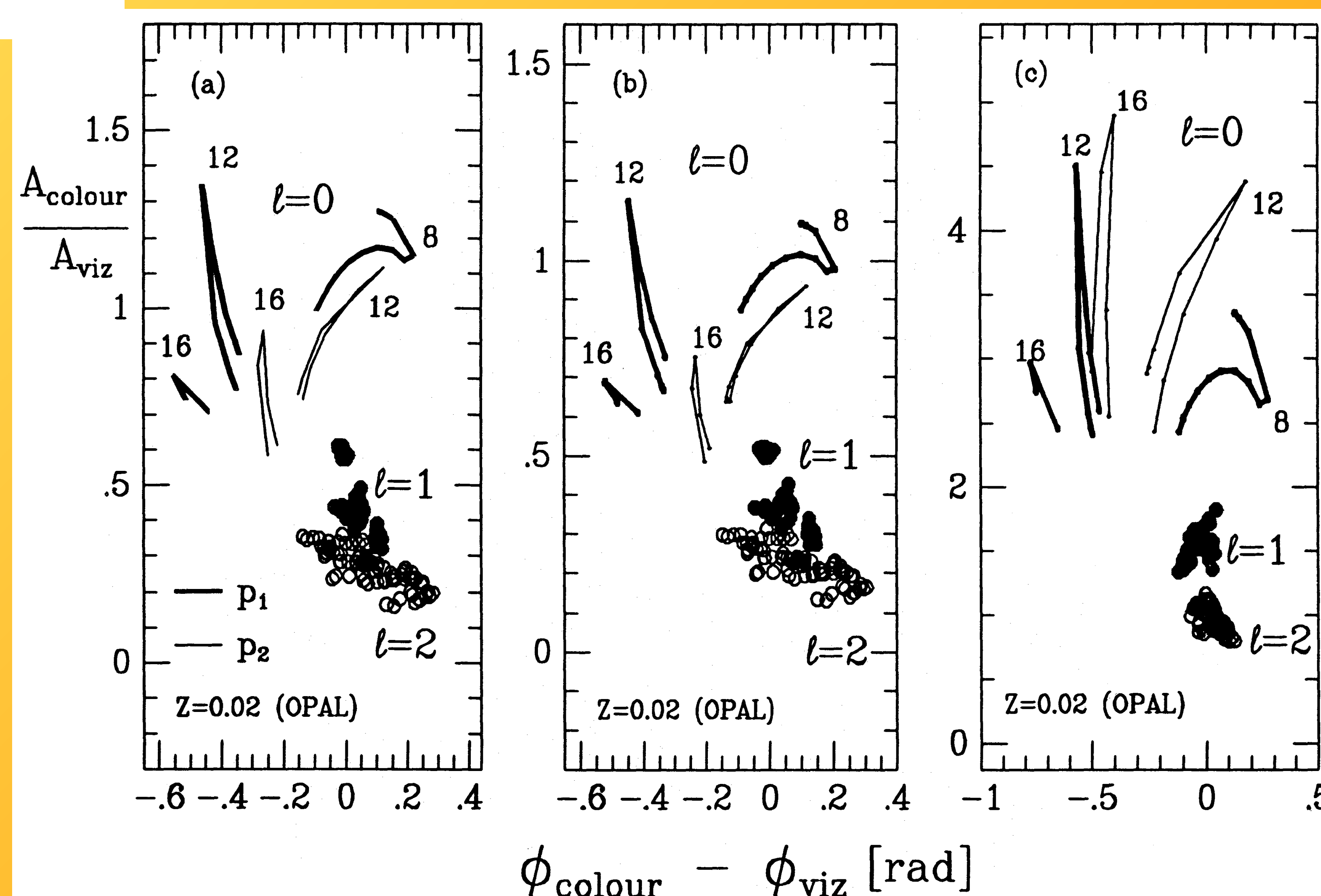
by

W. Dziembowski

Copernicus Astronomical Center, Warsaw

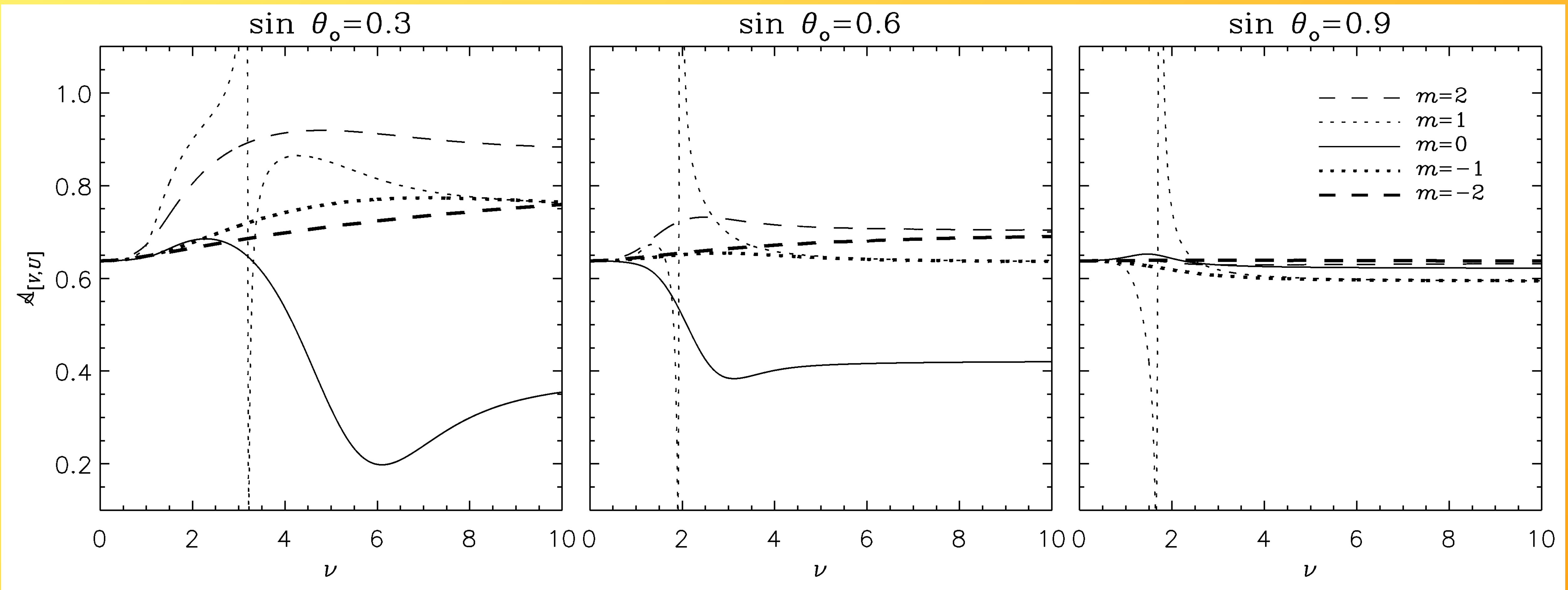
Received March 24, 1977

NB: Phase data require non-adiabatic models



Cugier+1994 (A&A 291), fig. 4

Complication: Rapid* Rotation



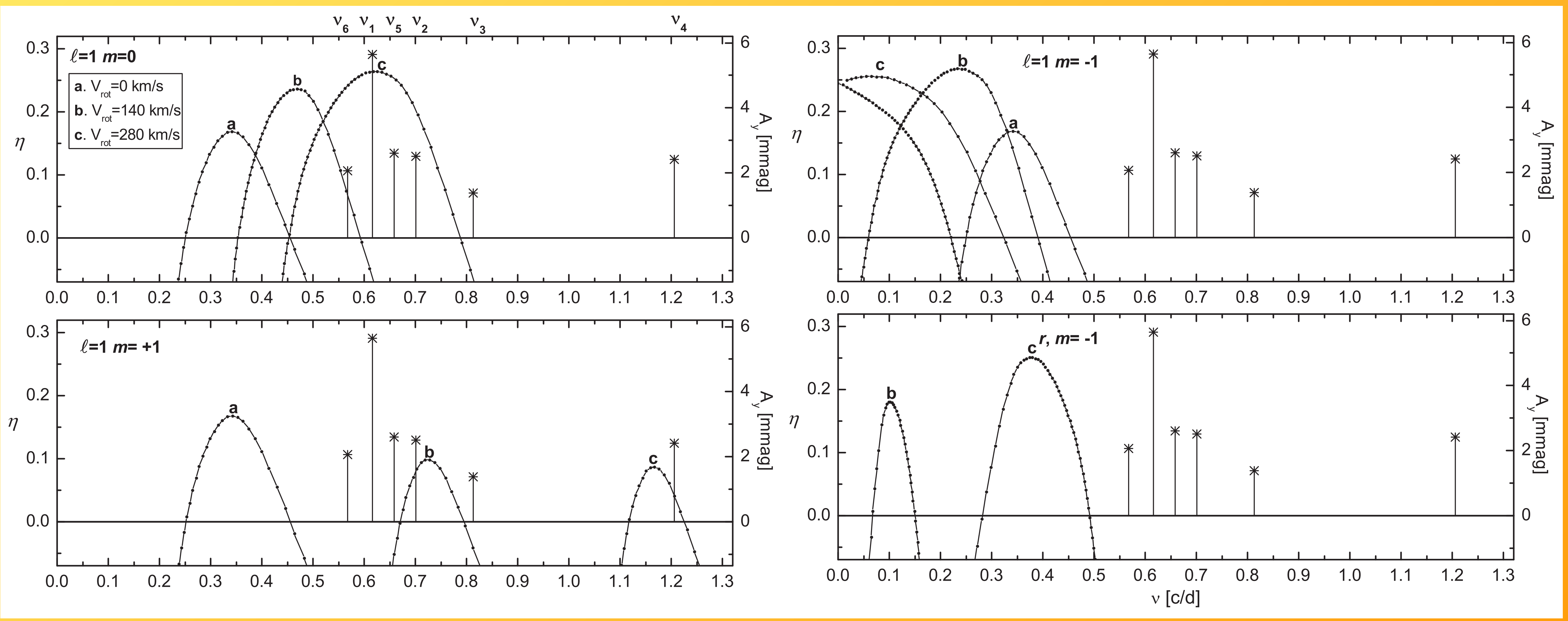
Townsend 2003 (MNRAS 343), fig. 5

"...it will be very difficult to ascertain, from multi-color photometry alone, the identity of modes excited in a given rotating star."

*In the sense that $\nu = 2\Omega/\omega_c > 1$

"Loaded for Bear"

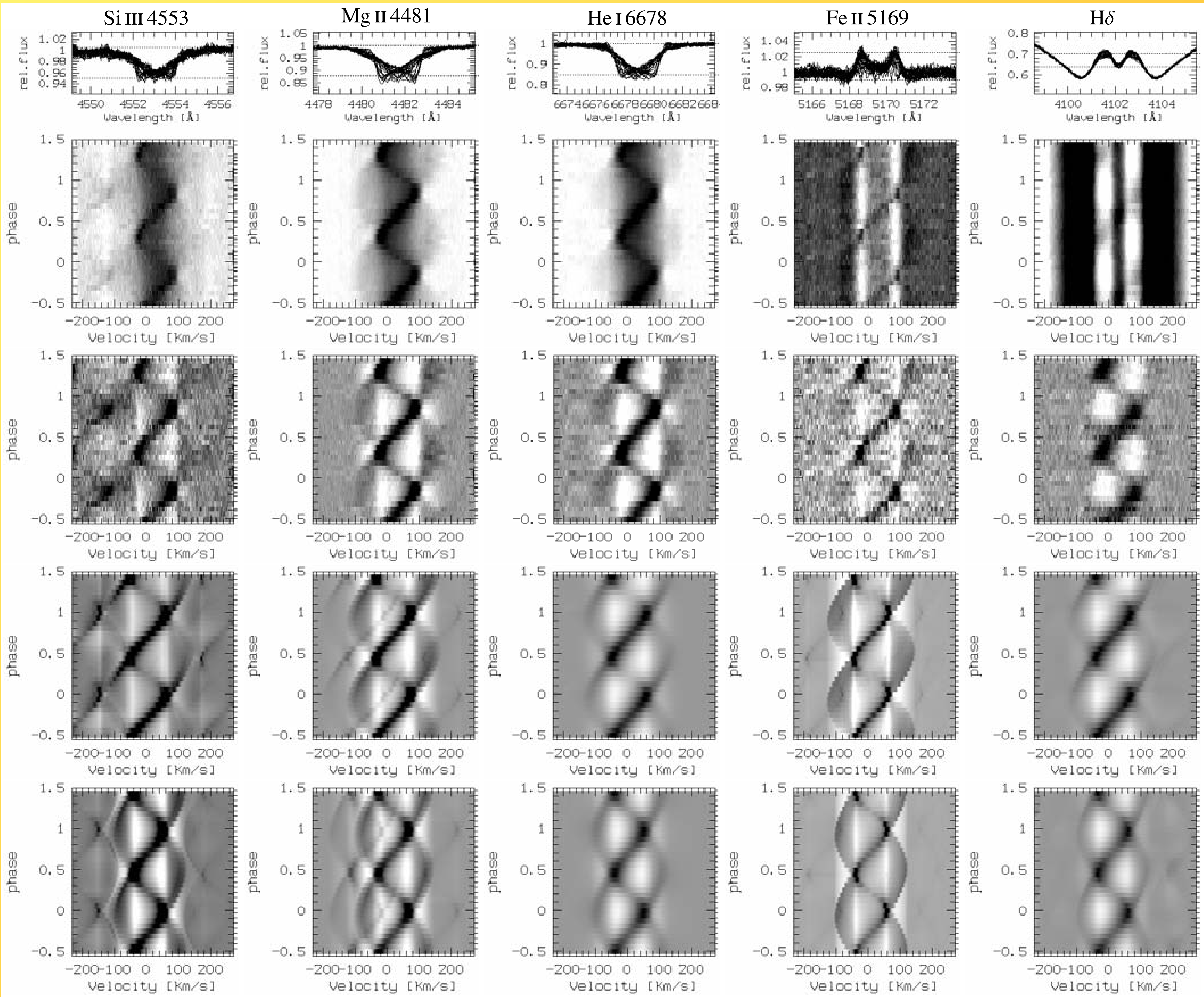
- Fit multiple modes with consistent set of stellar parameters
- Fit radial velocity data in addition to photometry
- Only consider modes which are unstable
- Only consider modes which have reasonable amplitudes



μ Eri

Daszynska-Daszkiewicz+2015 (MNRAS 446), fig. 3

Mode Identification from LPV



Maintz+2003 (A&A 411), fig. 1

- Moment method
- Pixel-by-pixel
- Fourier coefficients
- Direct modeling

Interior Modeling: MESA & GYRE

MESA

- 1-D hydrodynamical evolution
- Comprehensive microphysics
- Modern numerical techniques
- Wide applicability
- High performance
- Extensive test suite

http://mesa.sourceforge.net/

GYRE

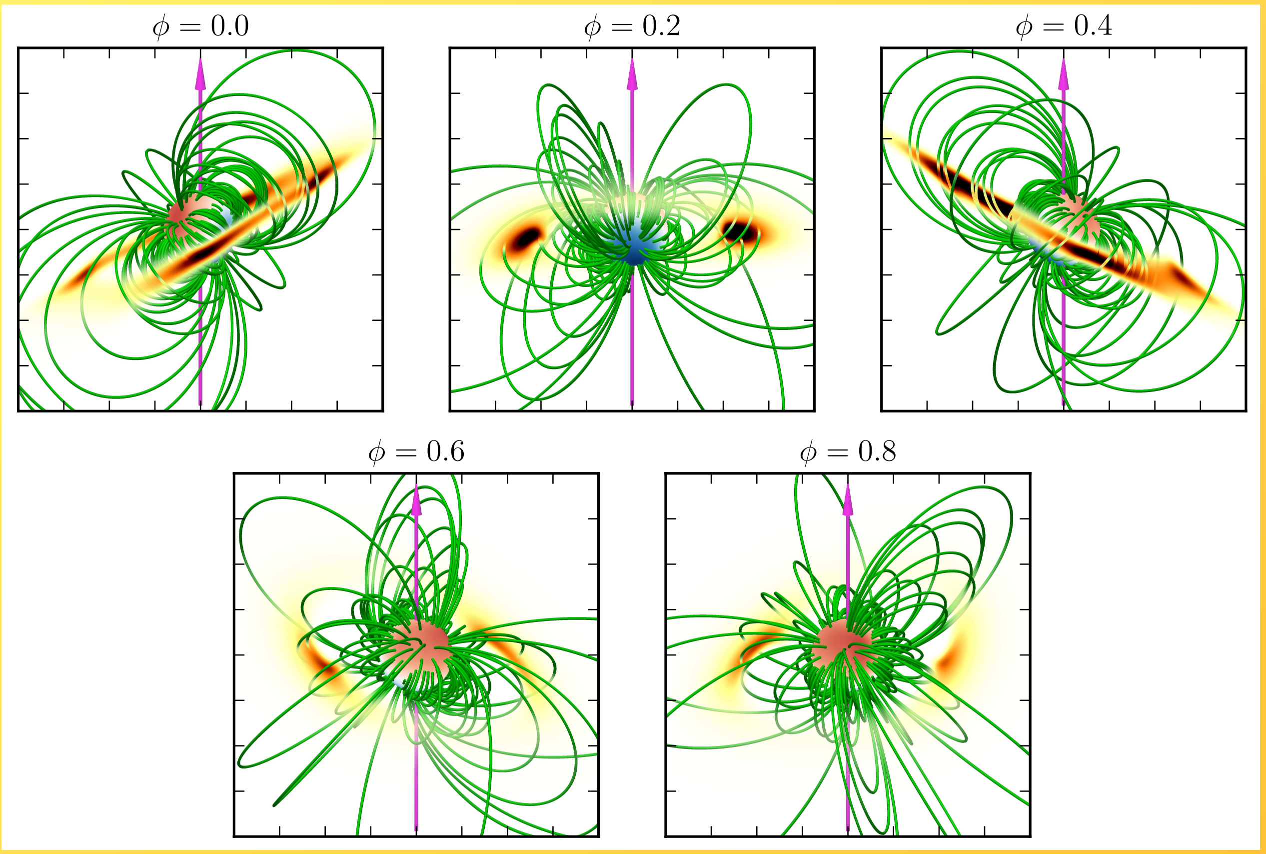
- Adiabatic or non-adiabatic pulsations
- Rotation via traditional approximation
- Reads many model types
- Robust & accurate
- User friendly
- Integrates with MESA for auto-astero

https://bitbucket.org/rhdtownsend/gyre/wiki/Home

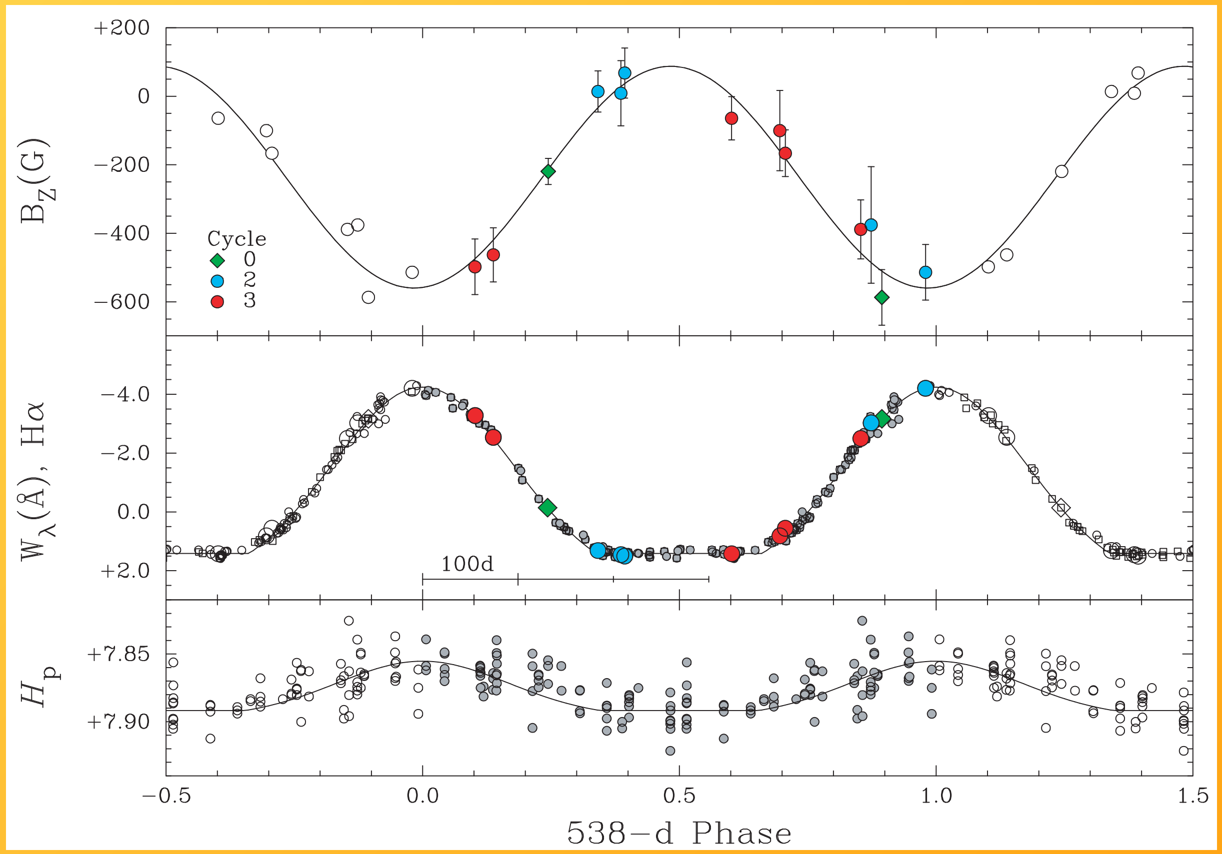
Open Source, Open Knowledge!

Magnetic Fields & Spots

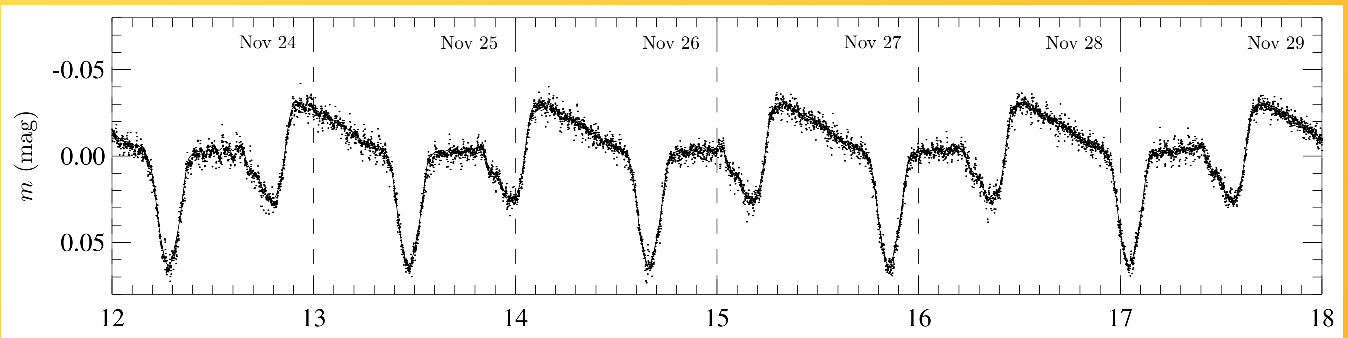
Magnetic OB Stars



Oksala+2015 (MNRAS), fig. 7

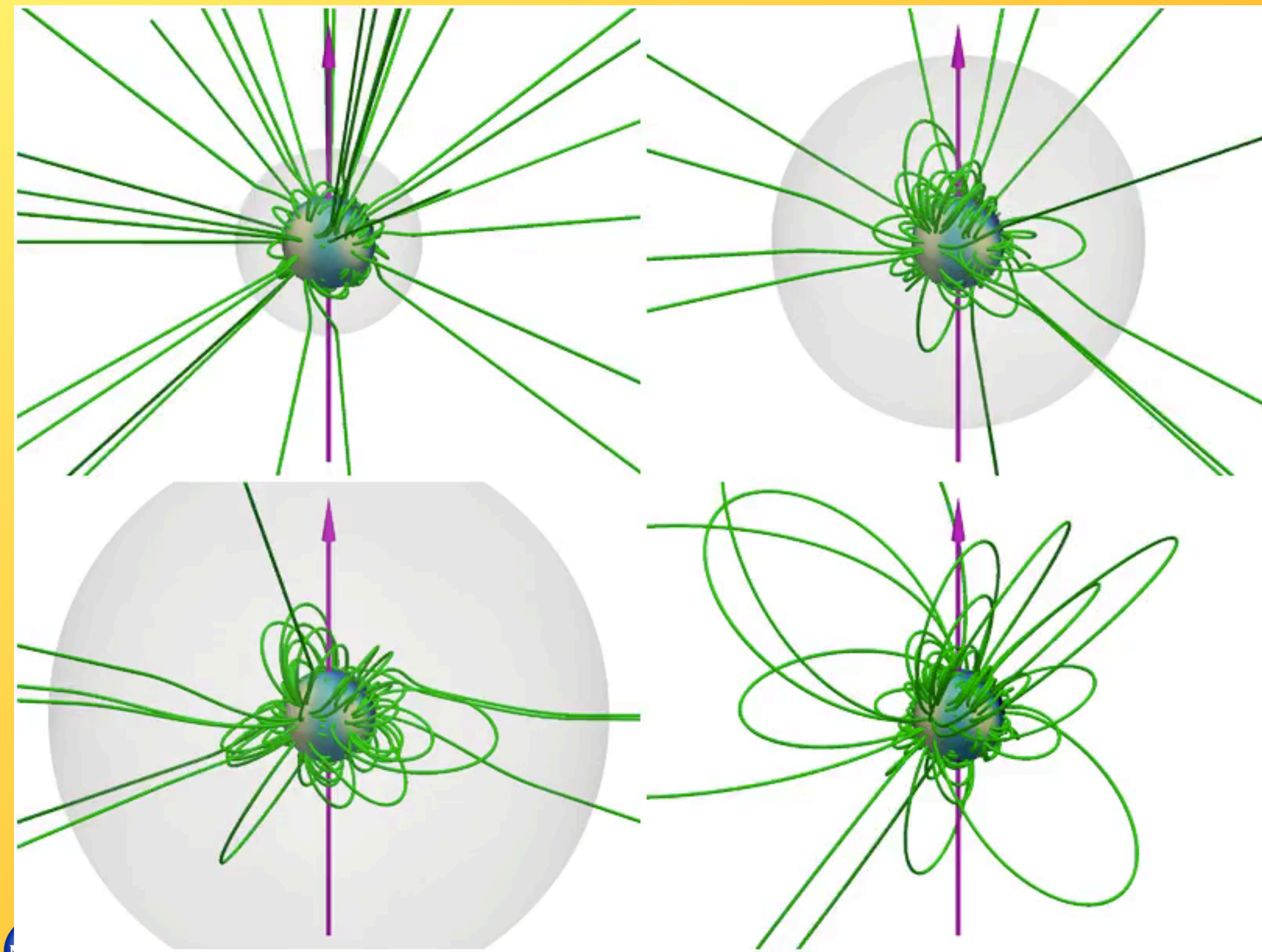


Wade+2011 (MNRAS 416), fig. 3



Townsend+2013 (ApJ 769), fig. 1

τ Sco: Field Extrapolations



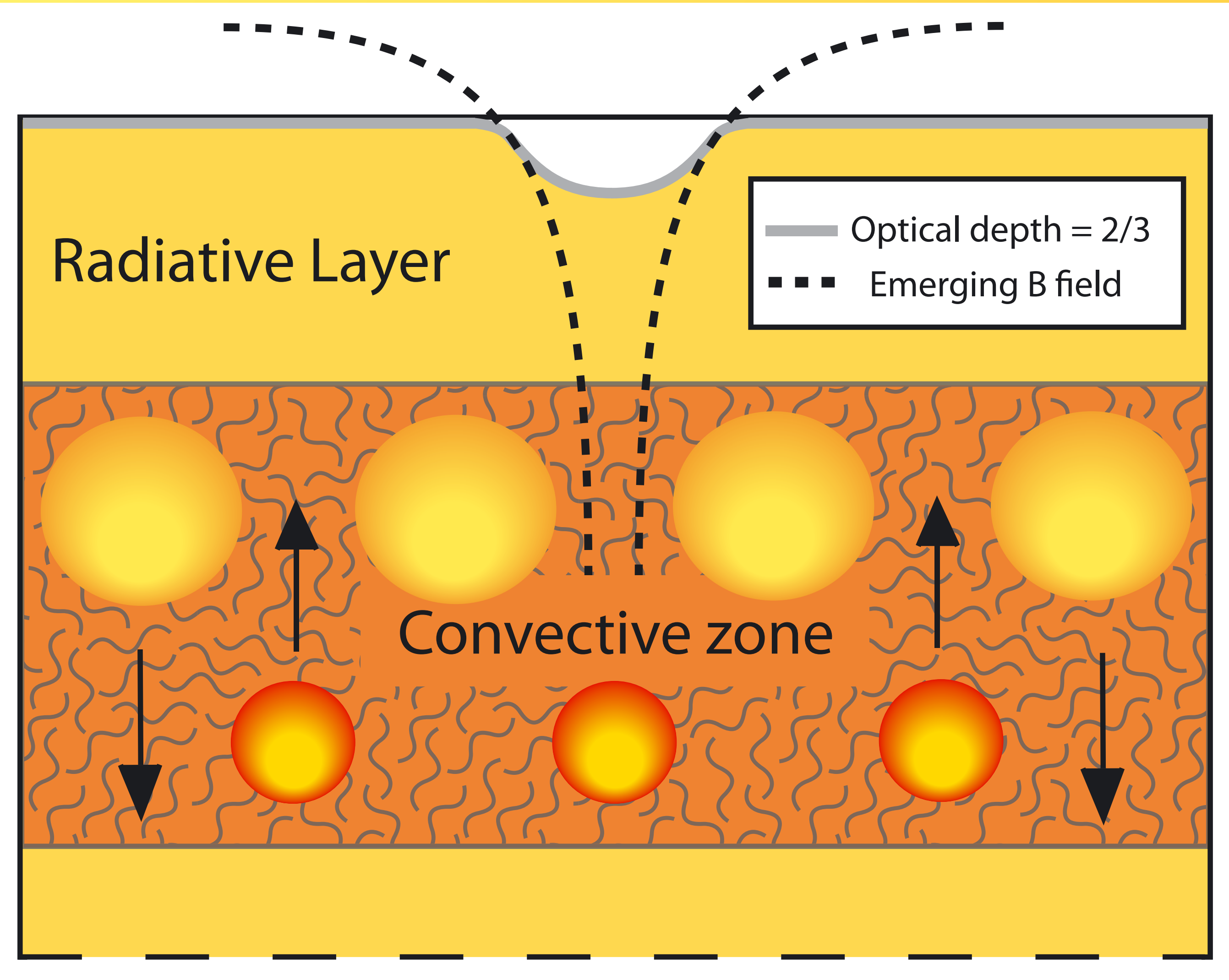
$R_s = 2\,R_*$

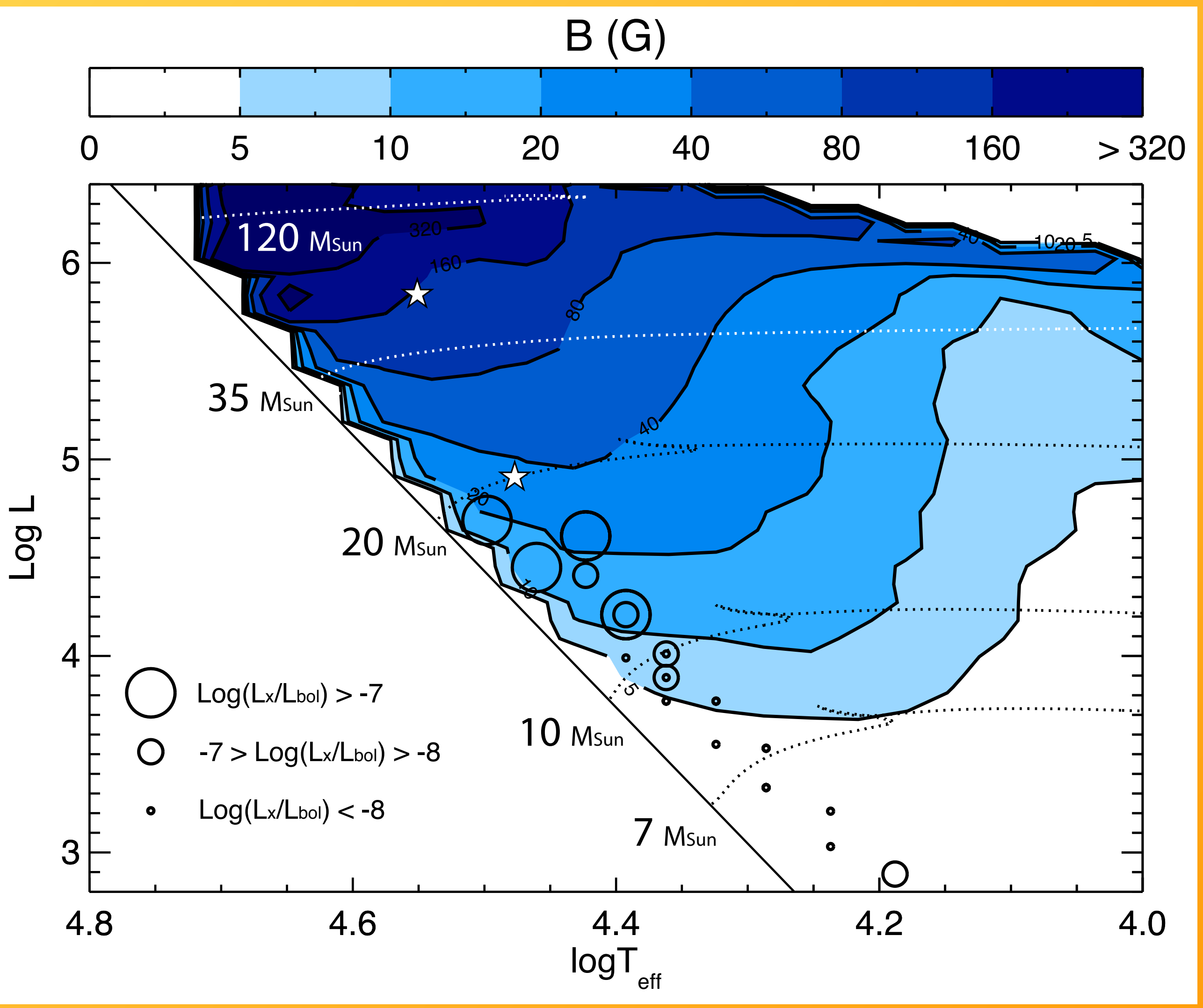
$R_s = 4\,R_*$

$R_s = 6\,R_*$

$R_s = \infty\,R_*$

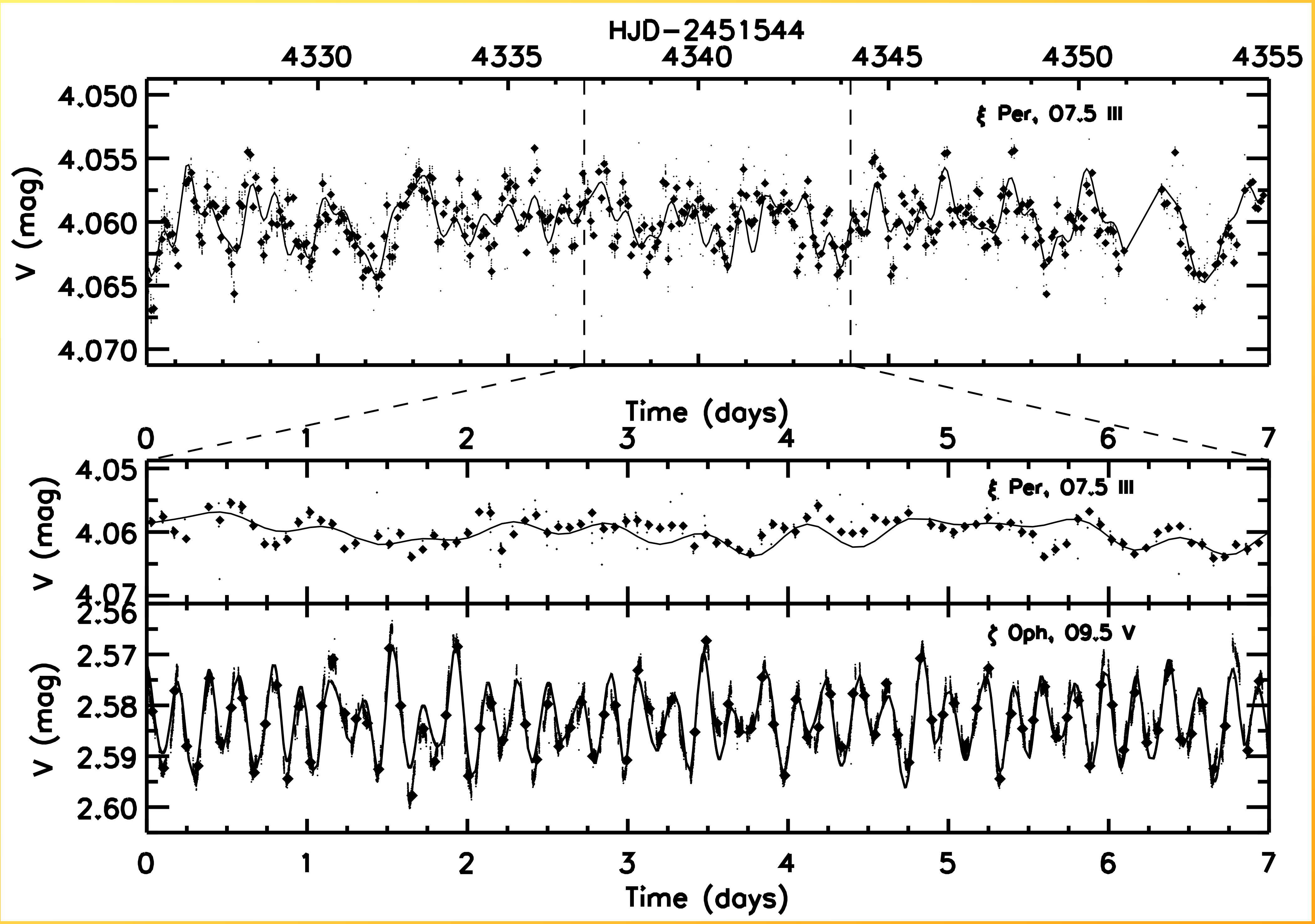
Small-Scale Fields?





Cantiello & Brathwaite 2011 (A&A 534), figs. 2 & 3

Brightness Spots in ξ Per

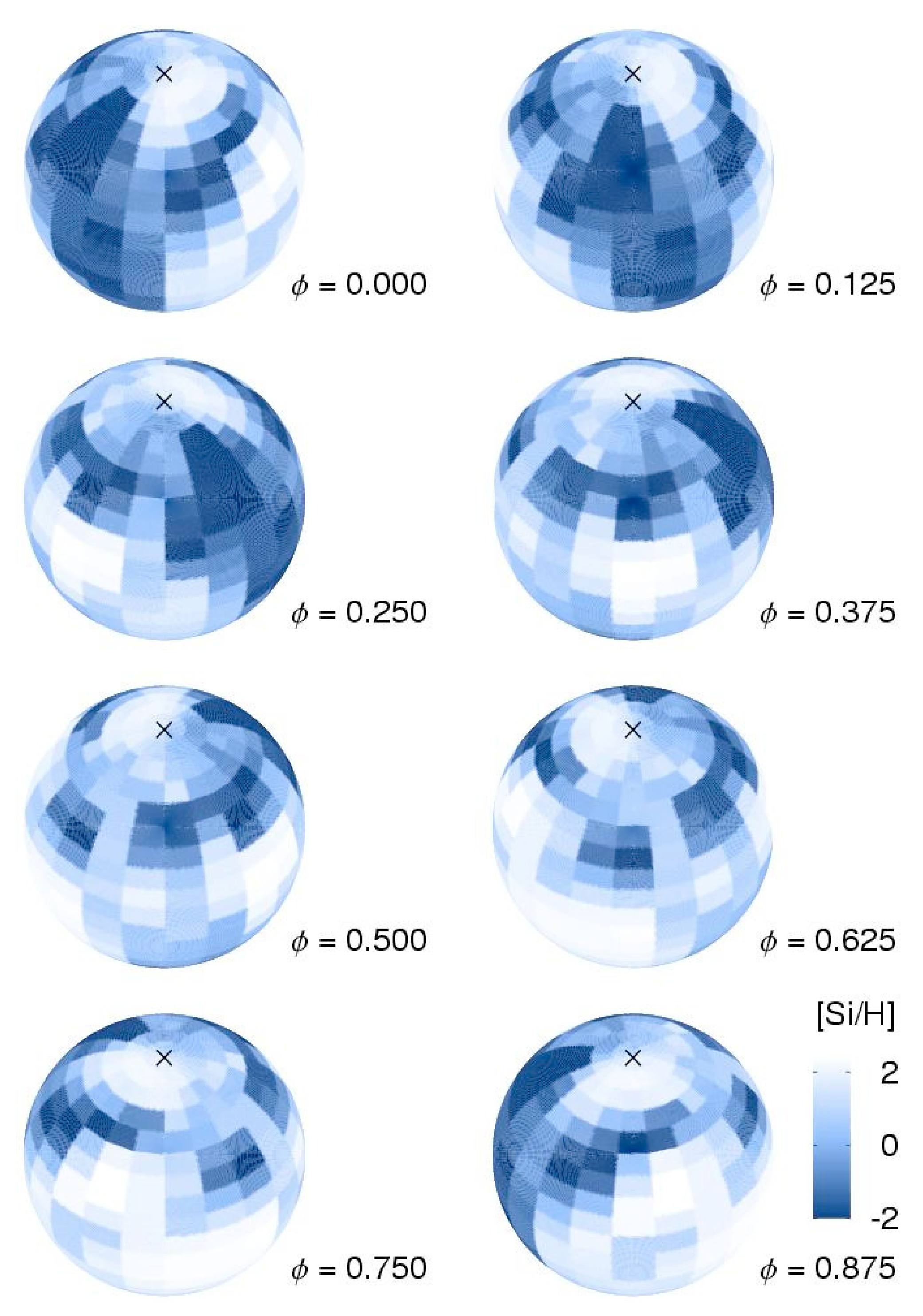


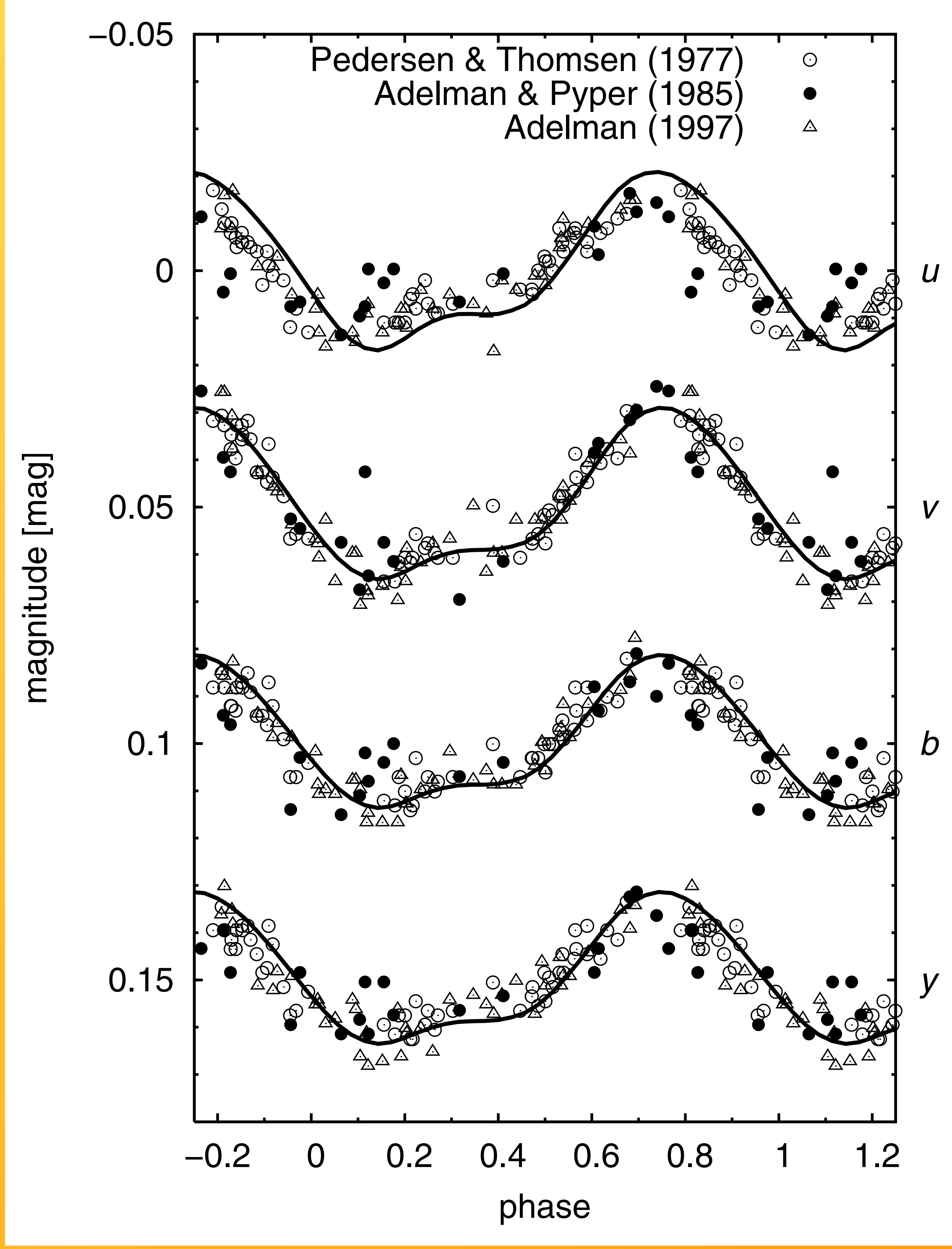
Ramiaramanantsoa+2014 (MNRAS 441), fig. 1

$P_{rot} \approx 4.2$d

$P_{var} \approx 2$d

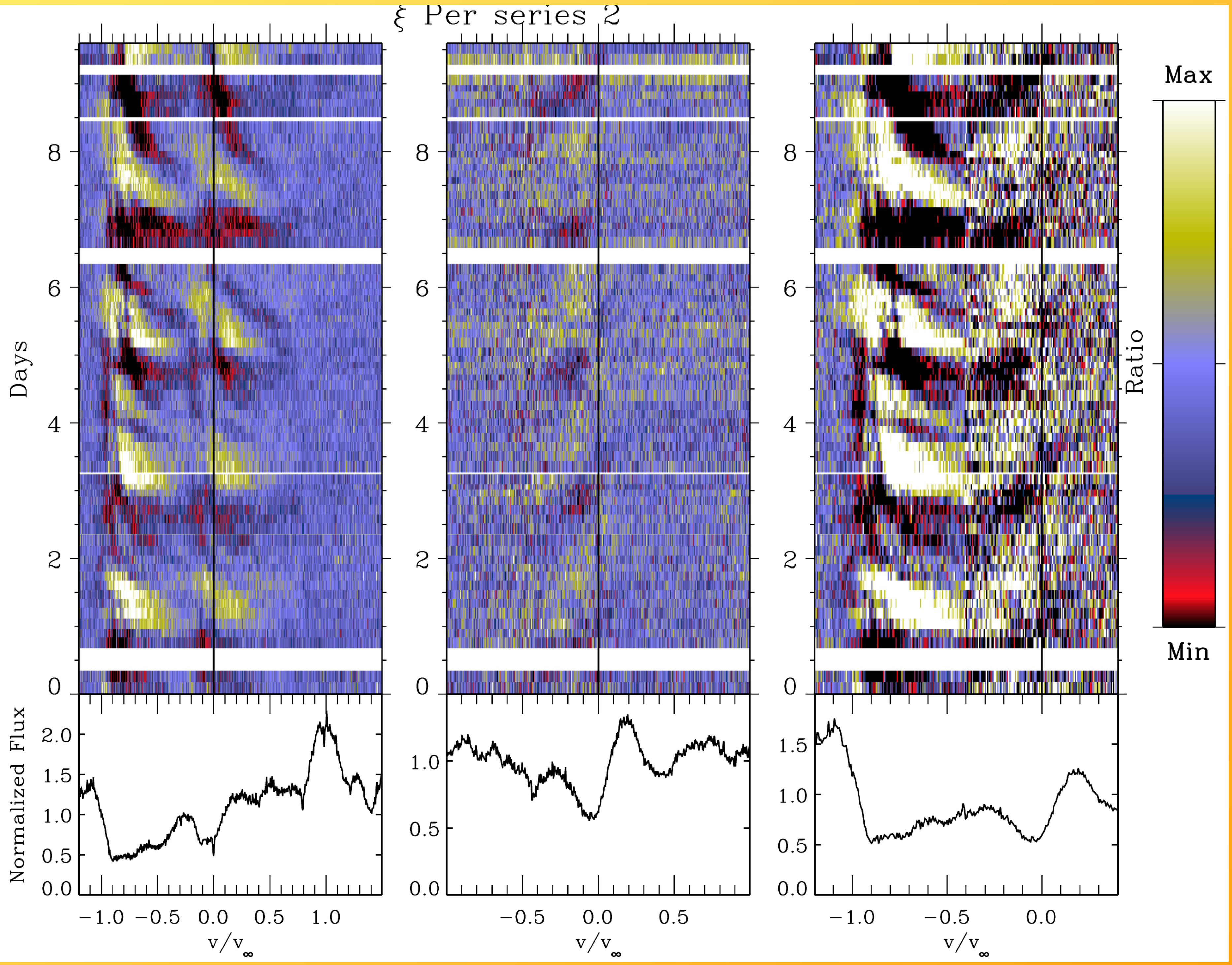
Abundance Spots





Krticka+2007 (A&A 470), figs. 1 & 11

Spots as Seeds of Wind Structure



Massa & Prinja 2015 (ApJ, submitted), fig. 3

Summary: What Can BRITE Do?

- Thermal oscillations in traditional instability strips (β Cep, SPB, δ Sct, γ Dor)
- Stellar spots in abundance(Ap/Bp) & temperature (OB stars)
- Stochastic oscillations of RGB/AGB stars in ‘Goldilocks’ zone: luminous but short periods (maybe)
- Stochastic oscillations of OB stars (maybe)
- All the other stars... (esp. the “constant” ones)