Waves in the atmospheres of strongly magnetic stars

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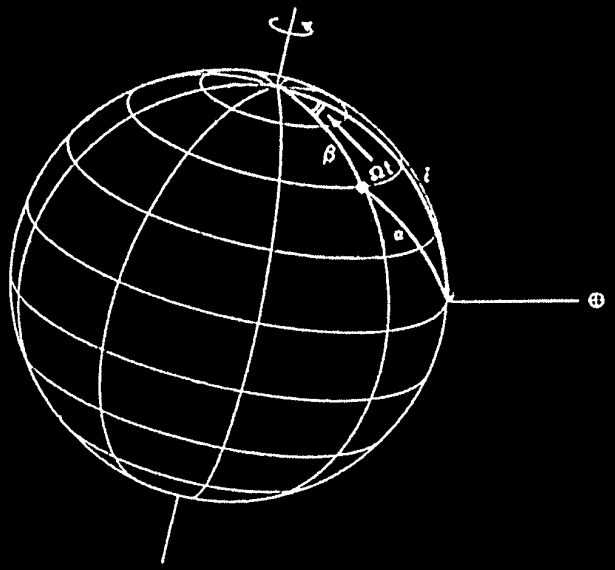
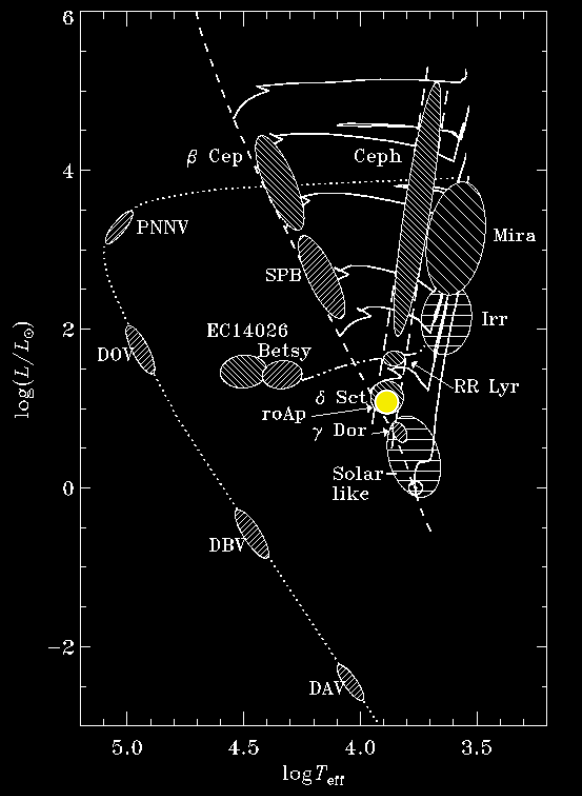
Margarida S. Cunha
and
Joana Sousa



Centro de Astrofísica
da Universidade do Porto

Christensen-Dalsgaard



What's so special about chemically peculiar magnetic stars?

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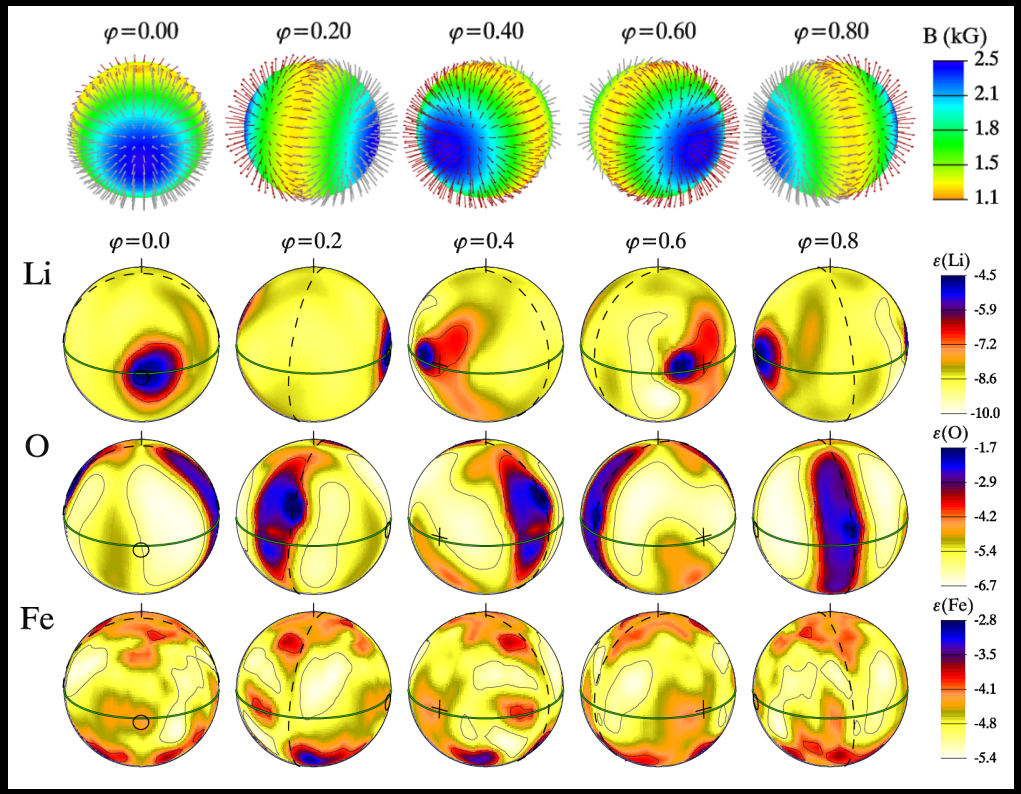
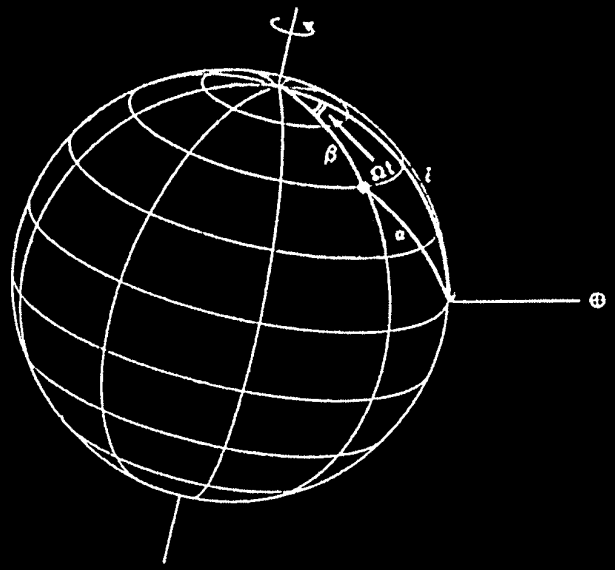
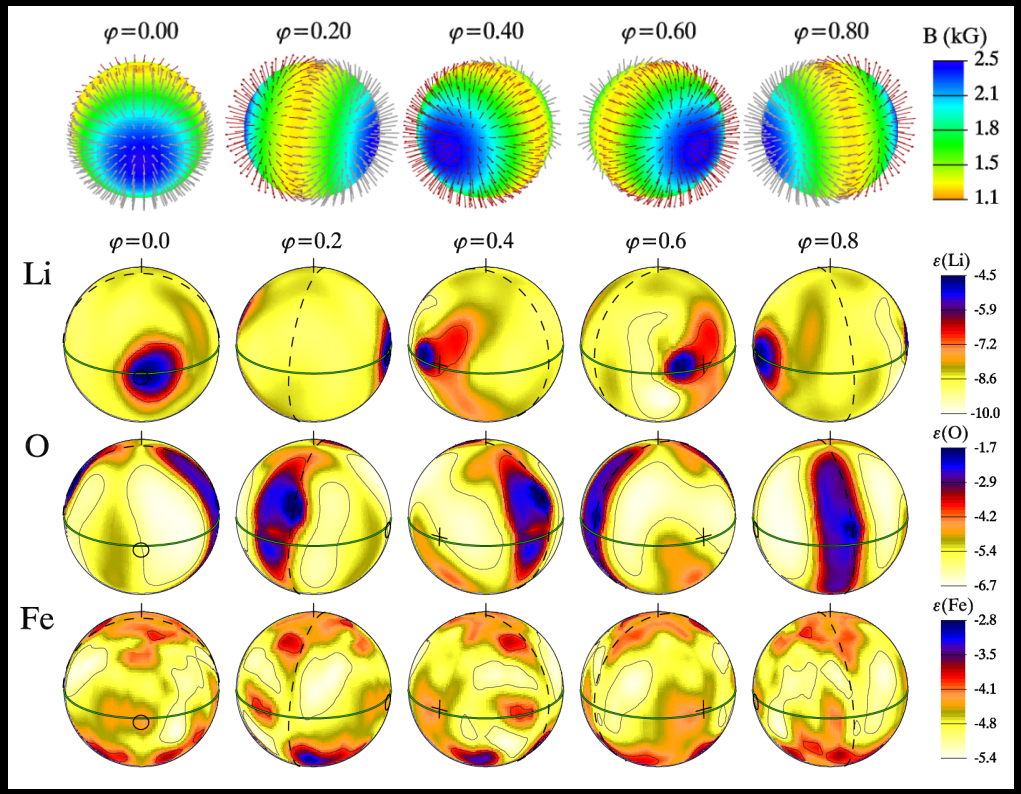
Kochukhov et al. (2004) - - HR 3831



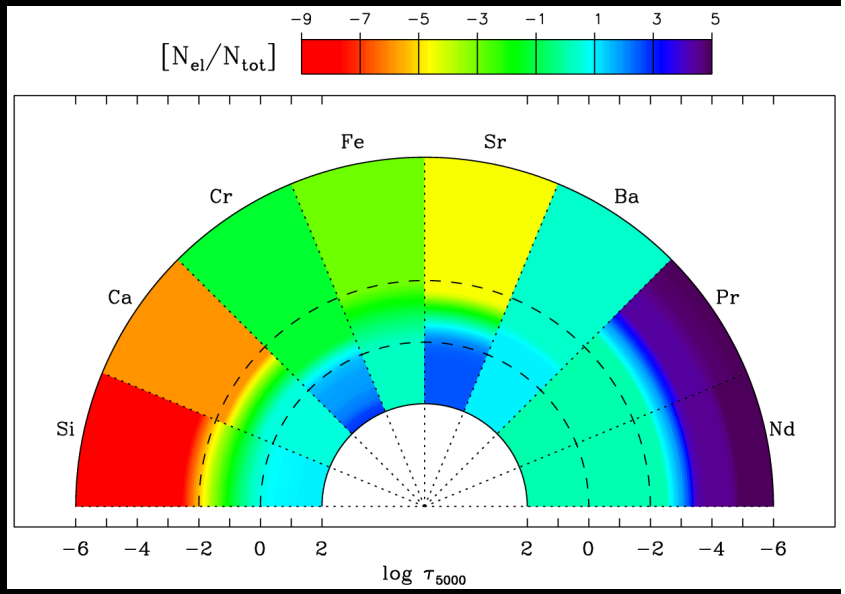


What's so special about chemically peculiar magnetic stars?

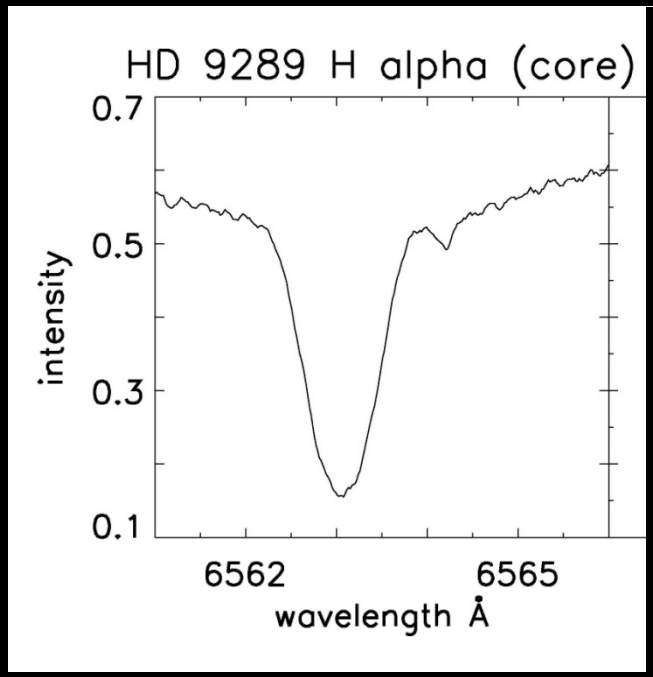
Kochukhov et al. (2004) - - HR 3831



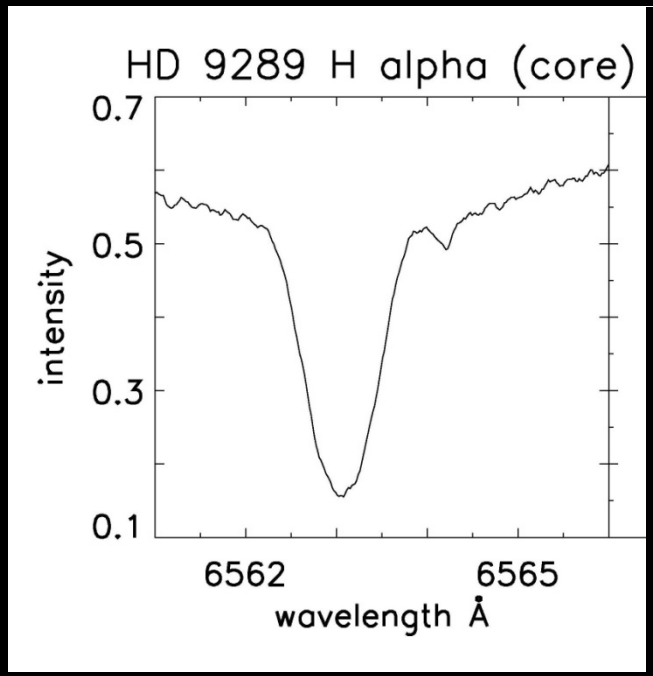
Shulyak et al. (2009) -- HR 1217



Pulsations: Exciting observations



Pulsations: Exciting observations



r

Fit RV onto:

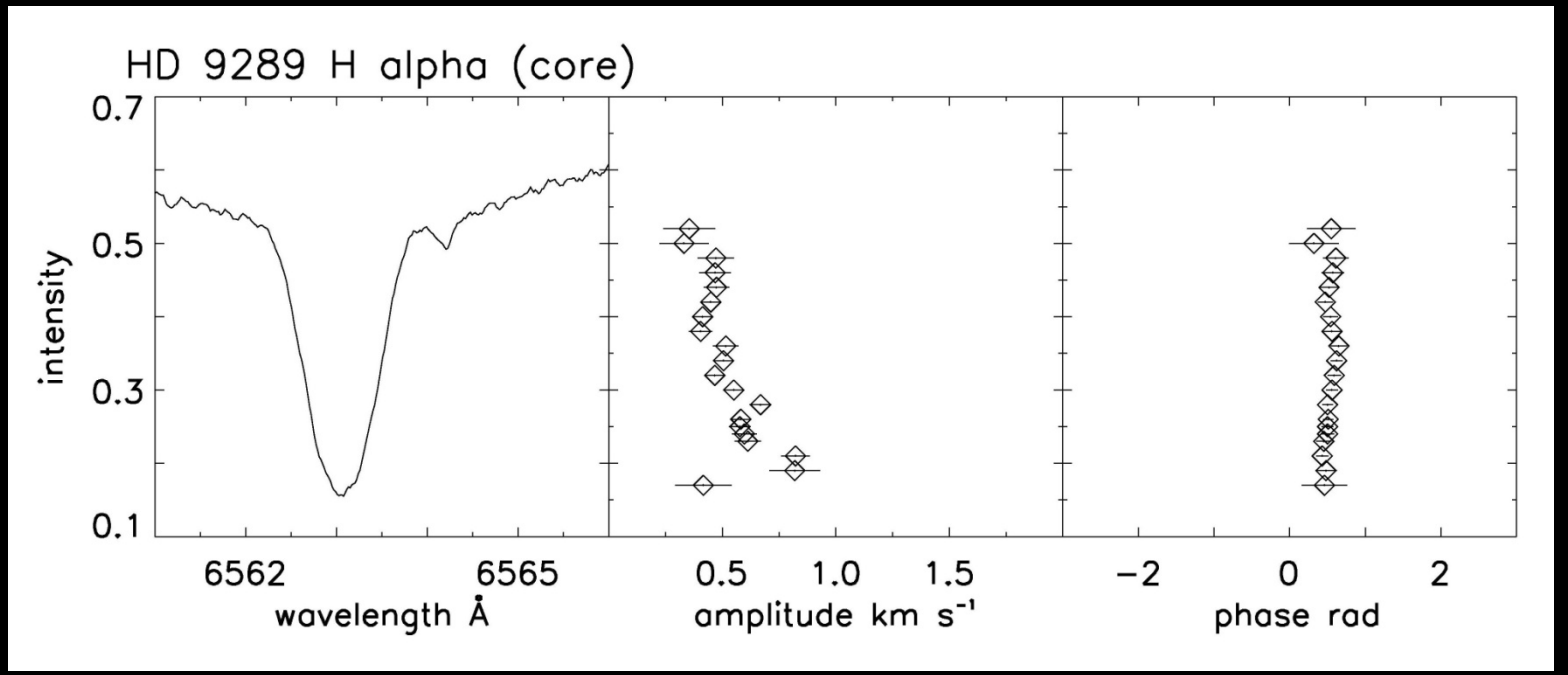
$$A(r)\cos(\omega_r t+\varphi(r))$$

Standing wave => *φ constant*
Running wave => *φ varying*

★ *φ decreases with r for outwardly running wave*
★ *φ increases with r for inwardly running wave*

Pulsations: Exciting observations

Apparent standing running wave

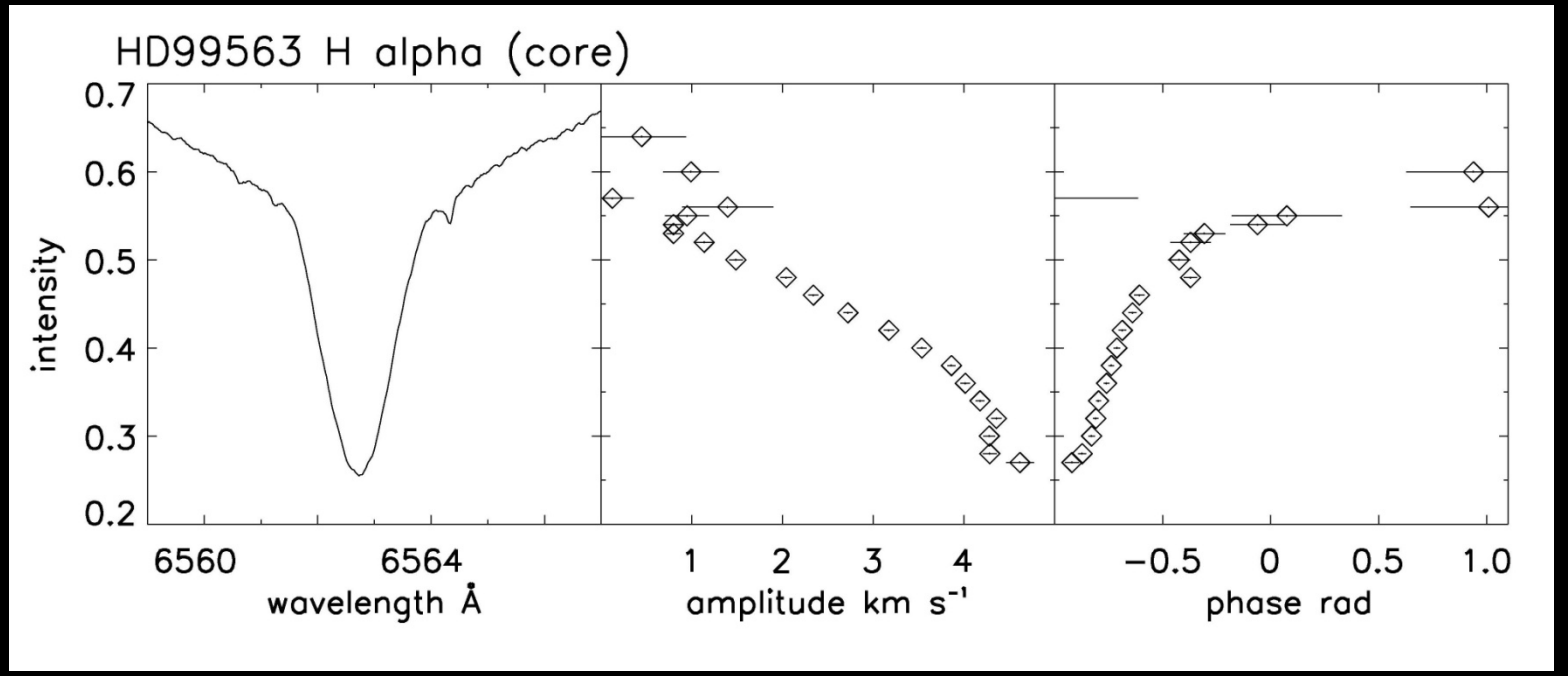


r

(Kurtz et al. 2006)

Pulsations: Exciting observations

Apparent outwardly running wave



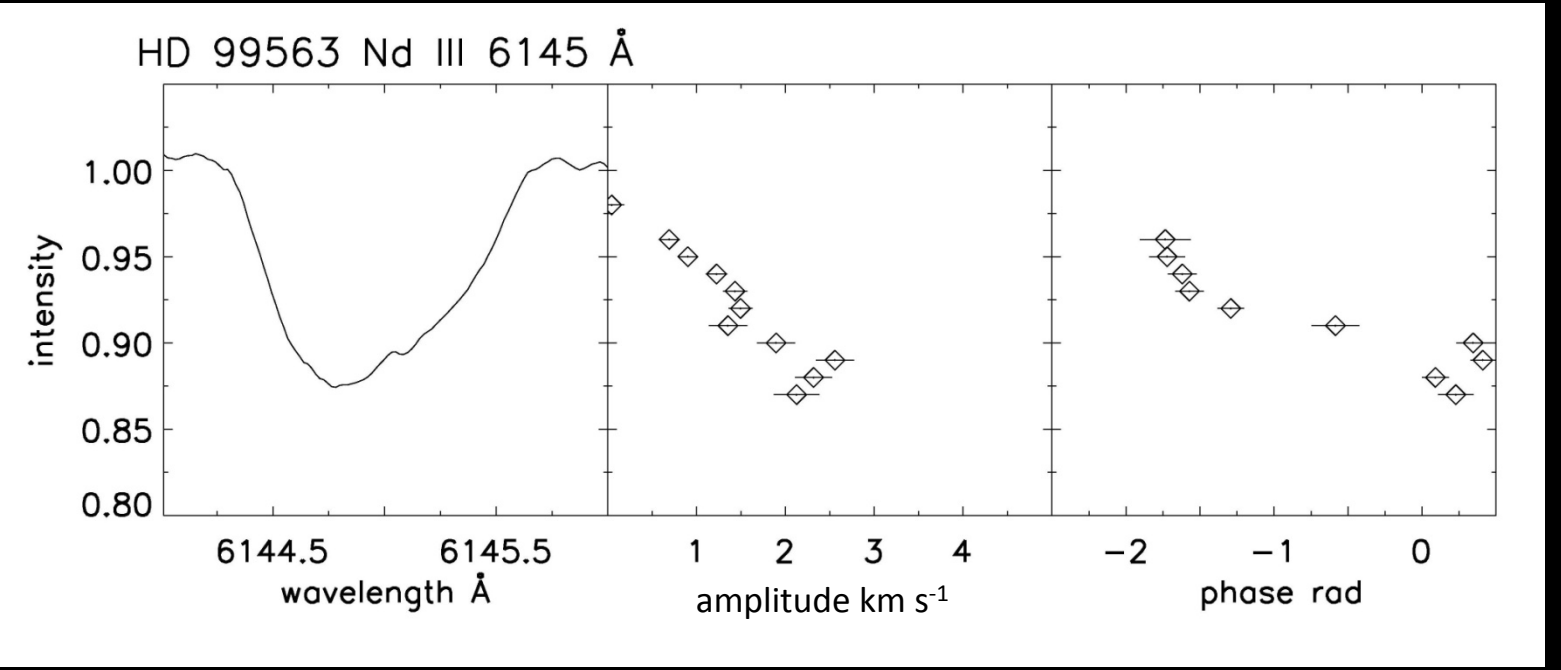
r

(Kurtz et al. 2006)

Pulsations: Exciting observations

Apparent inwardly running wave

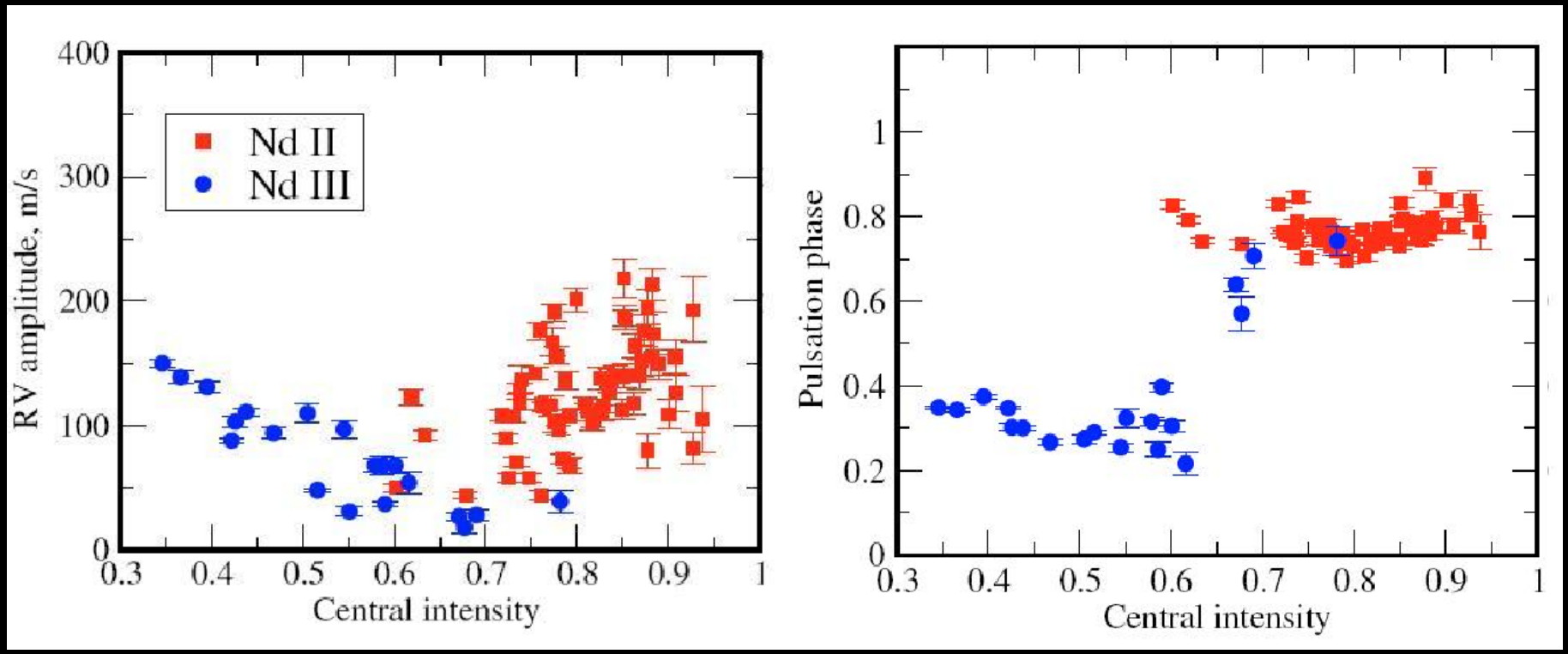
r



(Kurtz et al. 2006)

Pulsations: Exciting observations

Apparent node in a standing wave



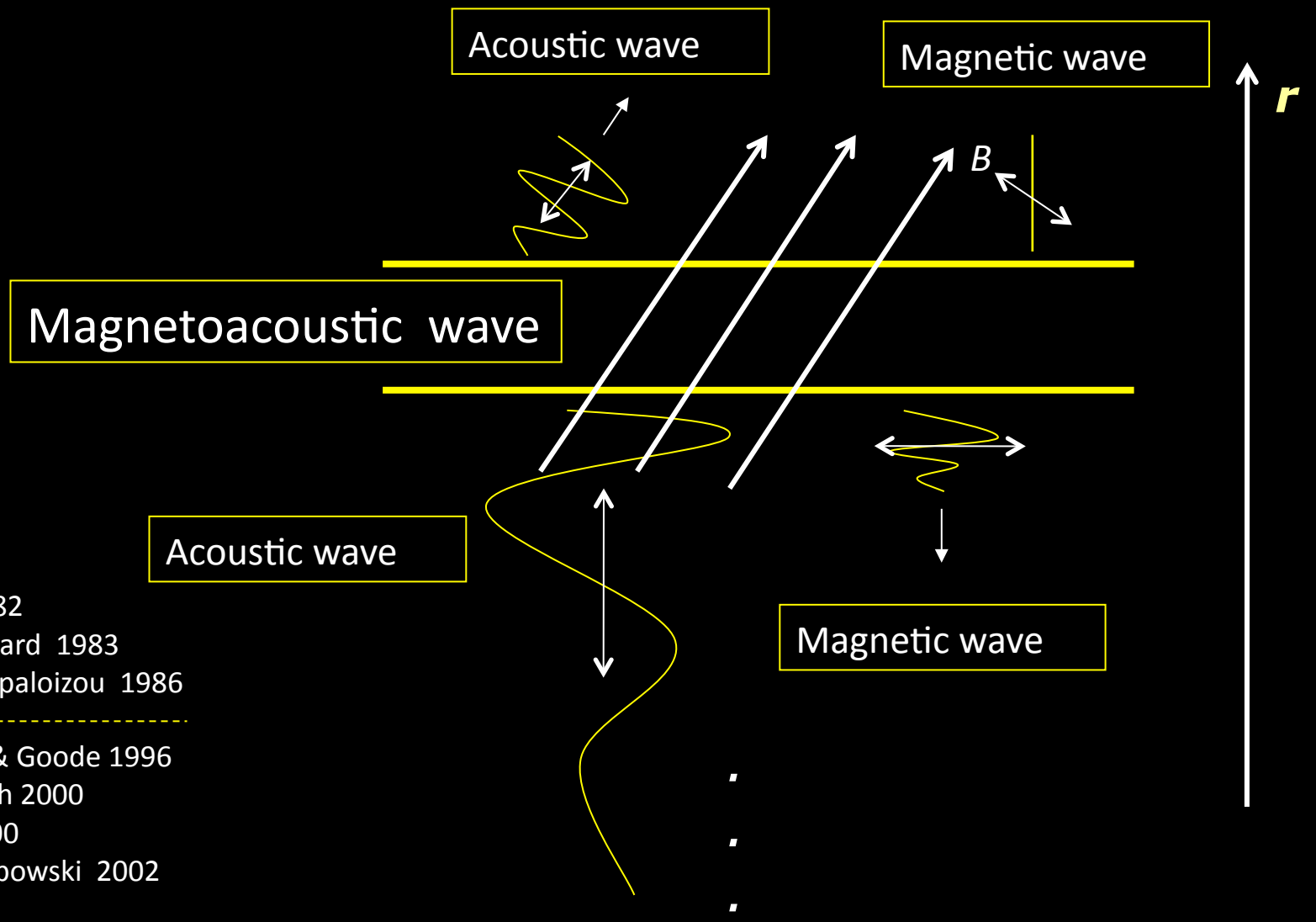
r

(Ryabchikova *et al.* , 2007)

hum… sounds too good to be true!

The interpretation can’t be that simple

Pulsations : Exciting complexity



Biront et al 1982
Roberts & Soward 1983
Campbell & Papaloizou 1986

Dziembowski & Goode 1996
Cunha & Gough 2000
Bigot et al. 2000
Bigot & Dziembowski 2002
Cunha 2002
Saio & Gautschy 2004
Saio 2005
Cunha 2006

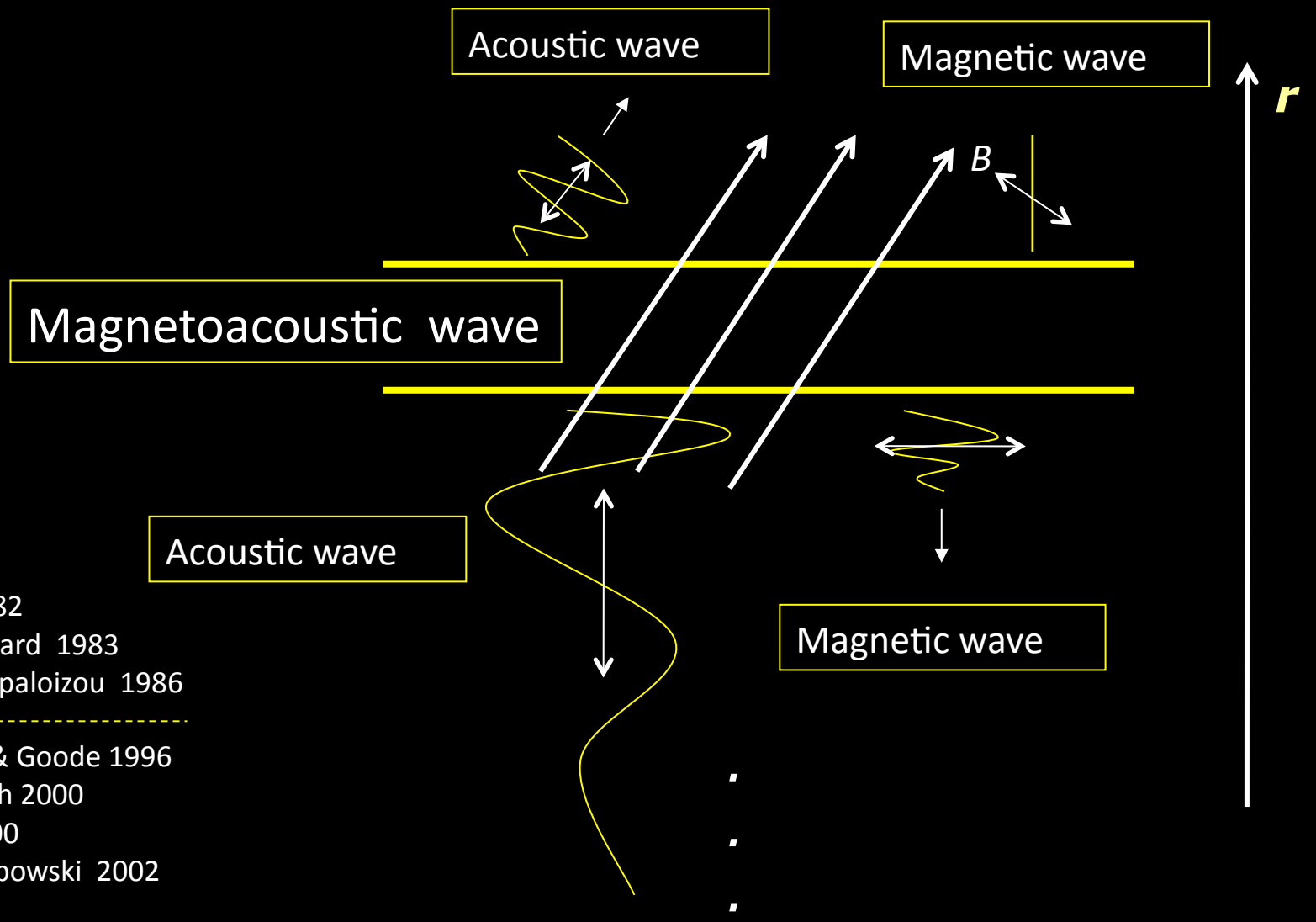
Also, se P. Cally's work over a decade, in the context of the sun

Disclaimer

My understanding of pulsation properties in Ap stars is strongly biased, being influenced by a set of approximations, namely:

- Linear perturbations
- Adiabatic
- Pulsation and magnetic properties varying on large scales only
- Axisymmetry
- Ideal MHD
- Cowling approximation

Pulsations : Exciting complexity



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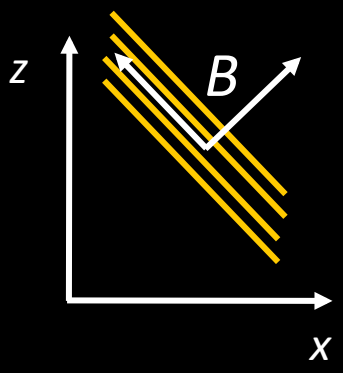
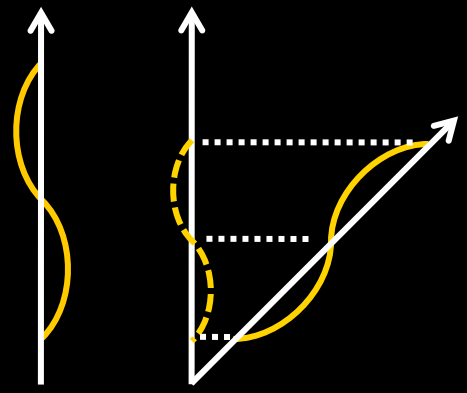
Pulsations : Exciting complexity

Acoustic wave

- Acoustic cutoff frequency





Acoustic wave

Cutoff Varies

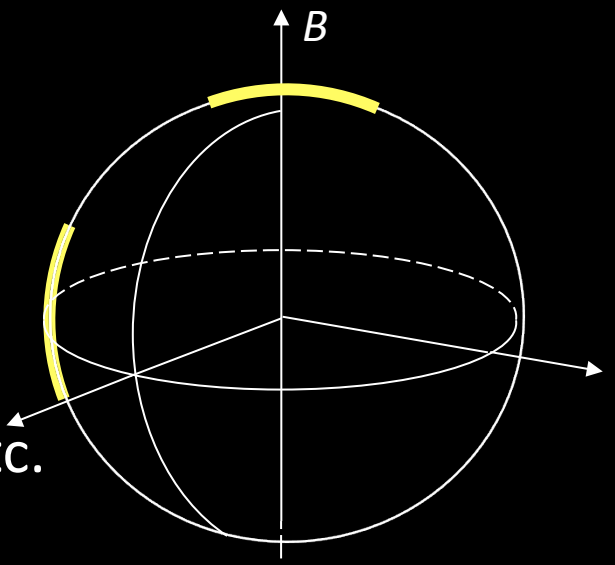
ν_c when ***B*** |||

0 when ***B*** ≡

e.g. Dziembowski & Goode (1996)

Pulsations : Exciting complexity

Observer sees an integral over the disk
of the velocity projected onto his line of sight



- Chemical spots
- Position of observer
- Mode degree, magnetic field topology, etc.
- Acoustic cutoff frequency

Pulsations : Exciting complexity

In practice, in the magnetically dominated region:

$$v_{int}(t,\eta,\delta) = \int_{\theta'_i}^{\theta'_f} \int_{\varphi} \Big[- \frac{|A_s(\theta)|}{p^{1/2}} e^{(-q_e|\breve{k}_{||}|\eta)} \sin(-q_r|\breve{k}_{||}|\eta + \sigma t + \phi_s(\theta)) X_{||}$$

Acoustic component

$$- |A_f(\theta)|\, J_0(2\sqrt{\chi\rho}) \sin(\sigma t + \phi_f(\theta)) X_{\perp}\Big]$$

Magnetic component

$$\times \frac{\sigma}{2C_n} (1 - a(1 - \cos\theta')) \sin(2\theta') d\theta' d\varphi'$$

Pulsations : Exciting complexity

In practice, in the magnetically dominated region:

$$V = \int \int (Va + Vm) \ldots$$

Pulsations : Exciting complexity

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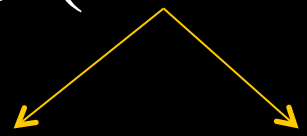
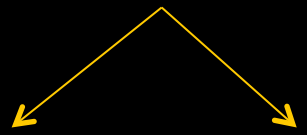


evanescent running

Pulsations : Exciting complexity

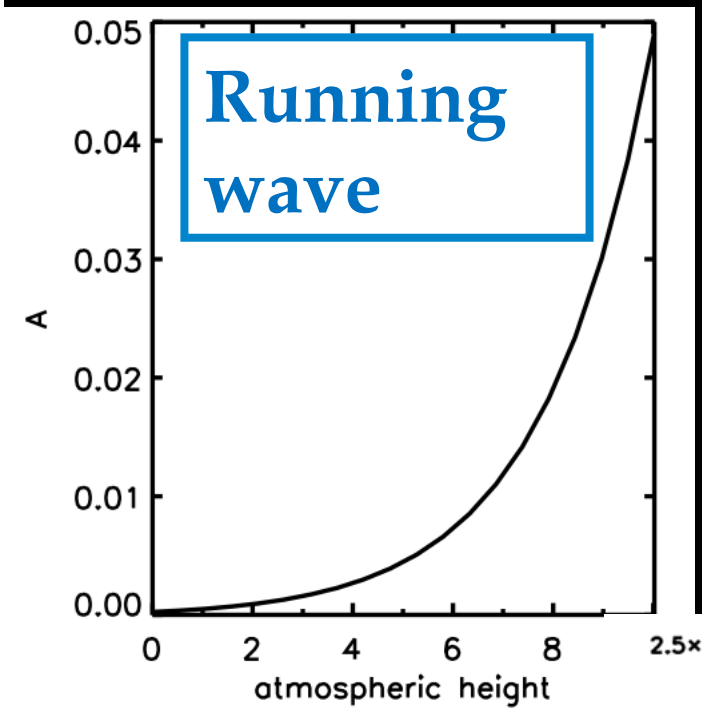
Fit V onto $A(r)\cos(\omega_r t+\varphi(r))$



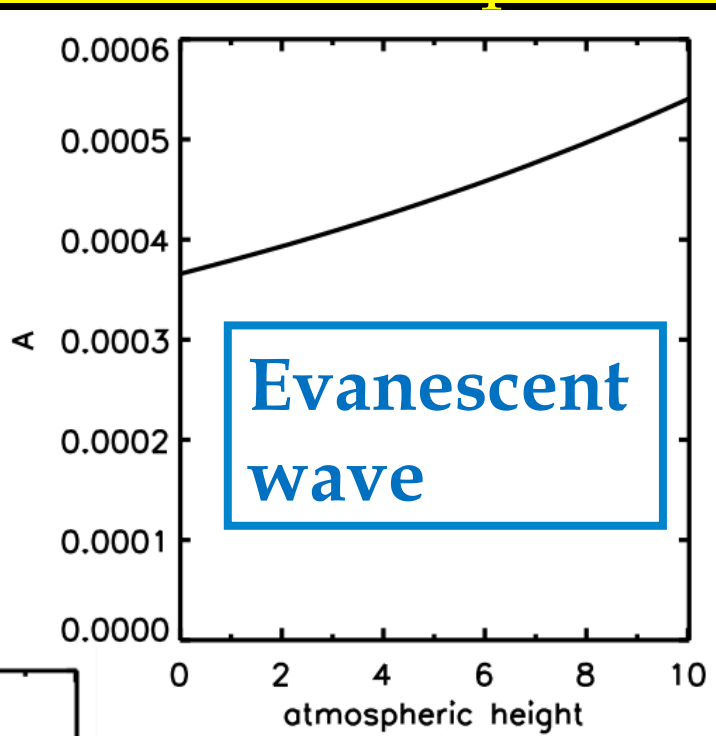
A φ

Results

General behaviour for the Amplitude



(in units of *H*)



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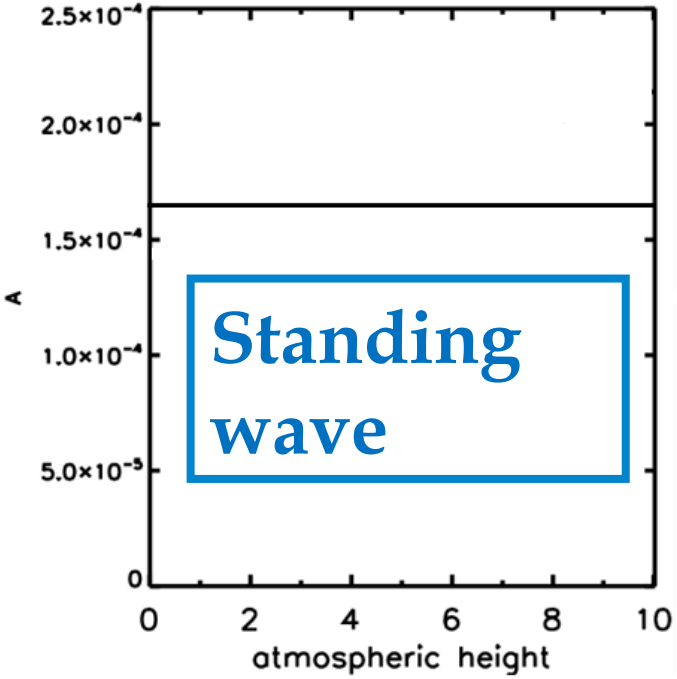
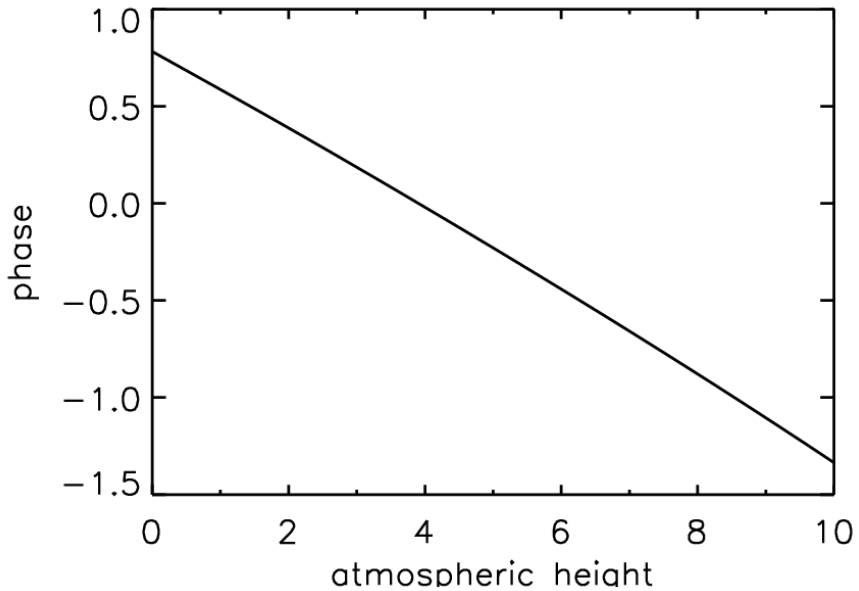


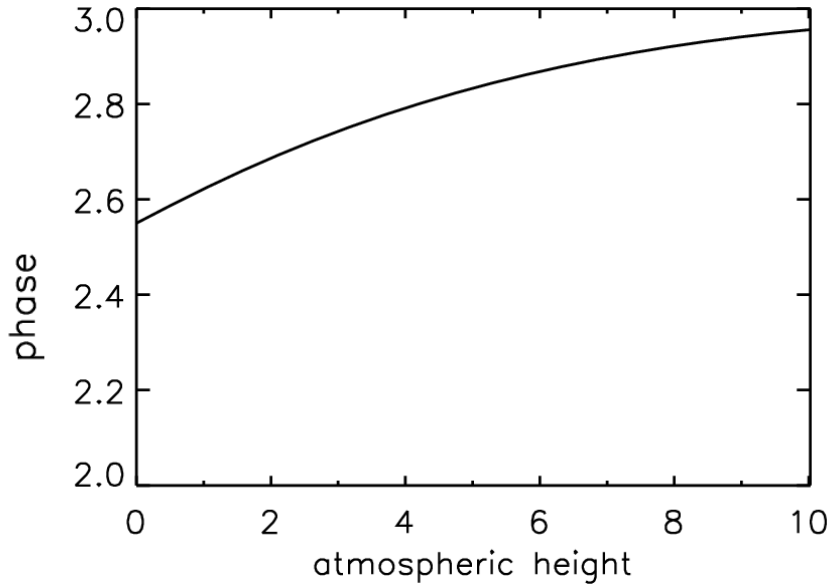
Sousa & Cunha, 2011, MNRAS

Results

Behaviour of Phase



(in units of *H*)



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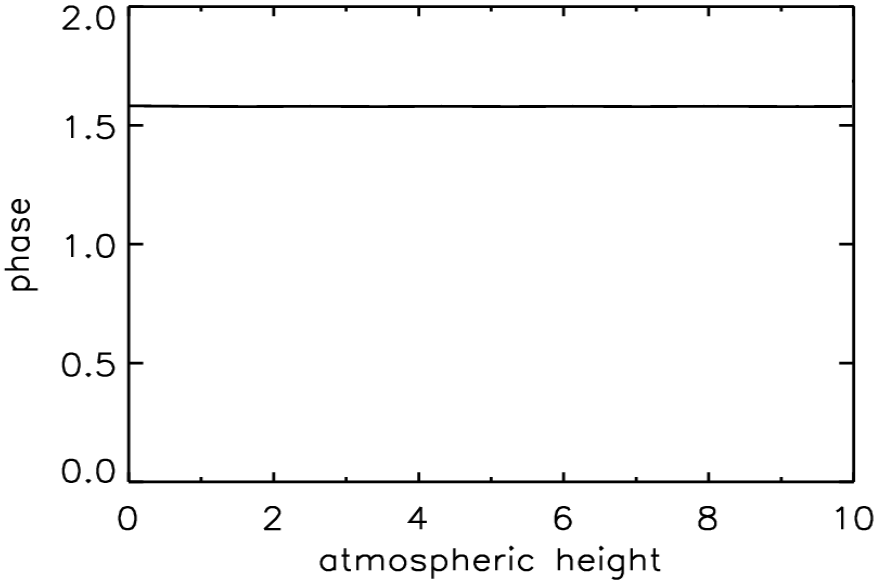
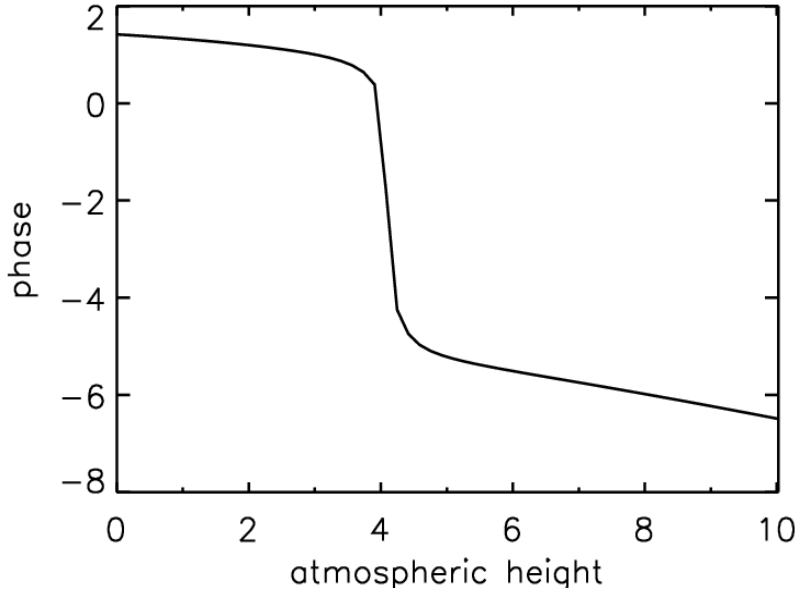


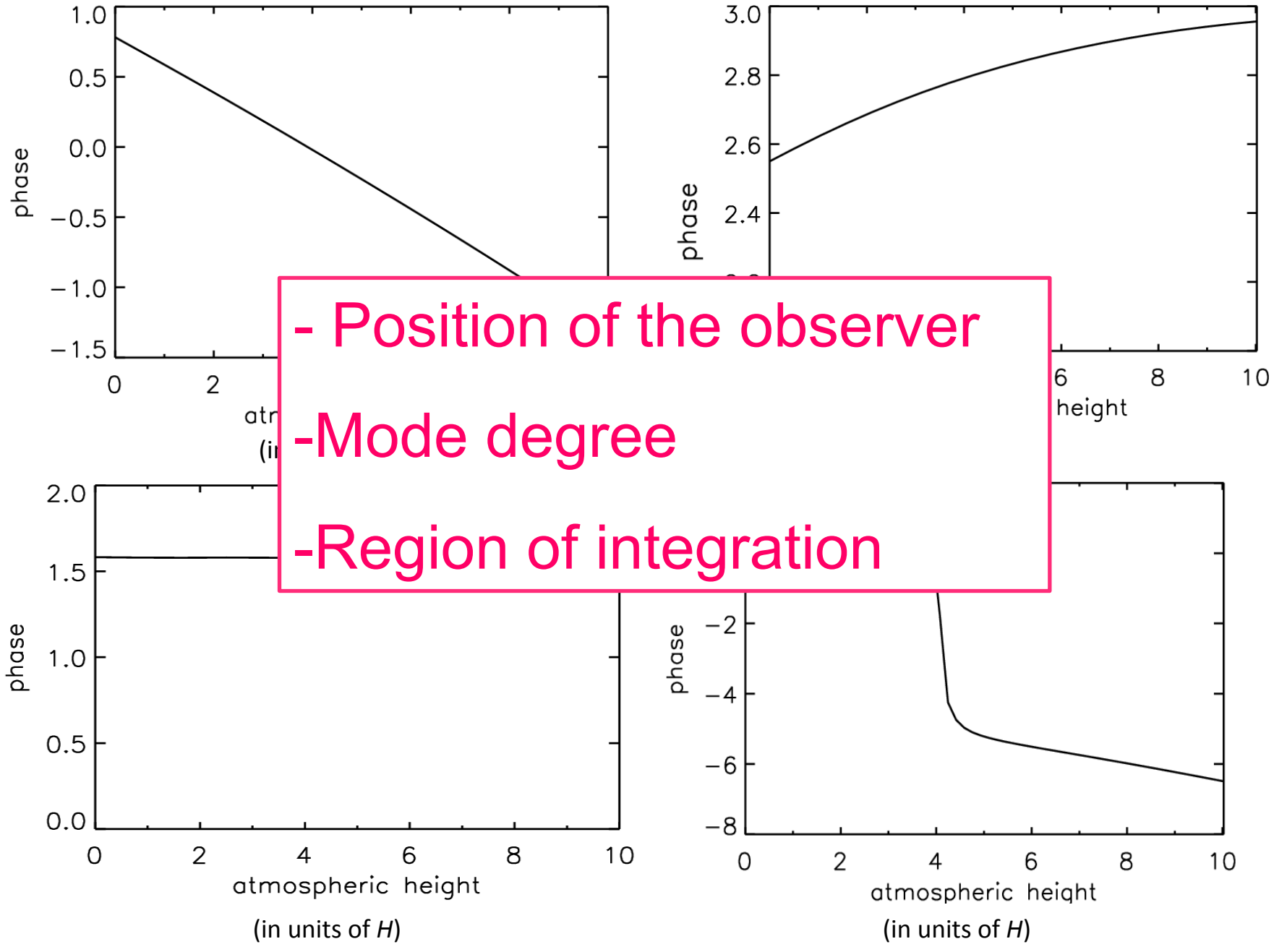
(in units of *H*)



(in units of *H*)

Results

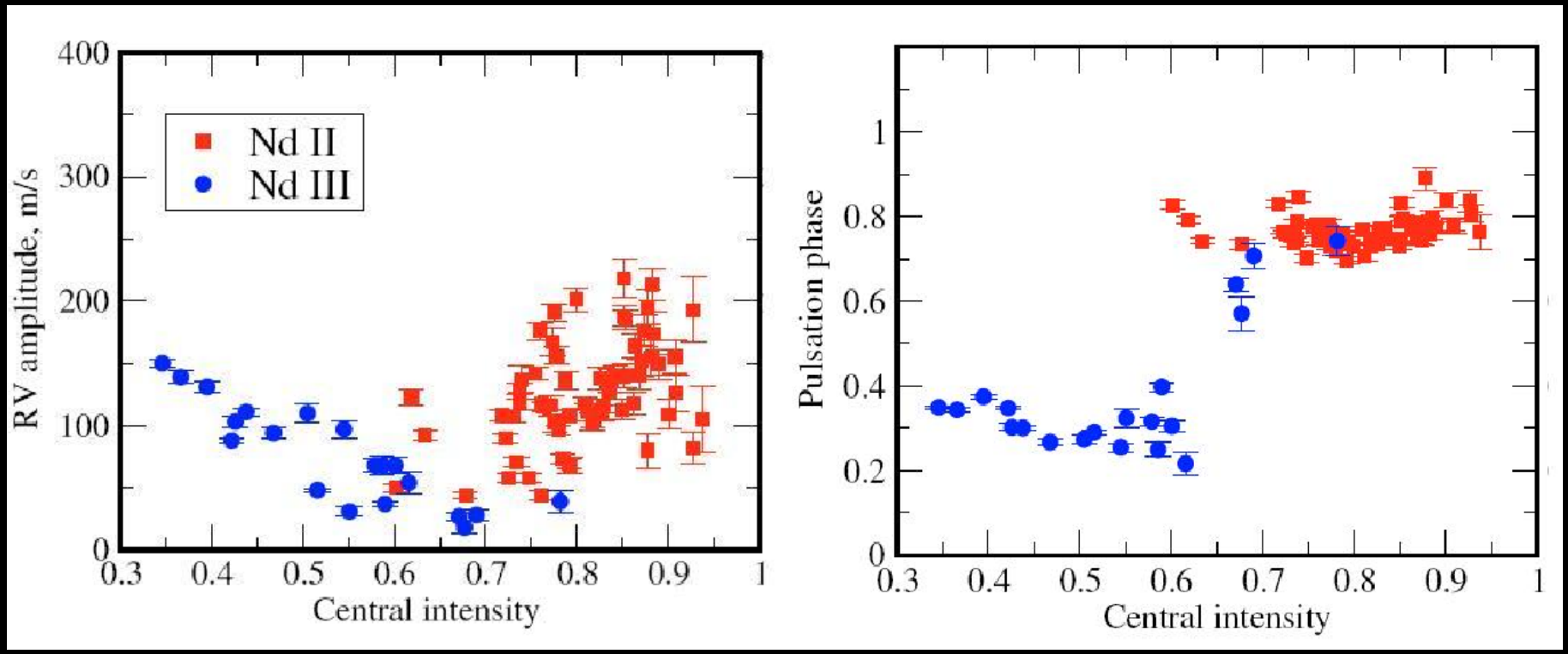
Behaviour of Phase



- Position of the observer
-Mode degree
-Region of integration

Pulsations: Exciting observations

Apparent node in a standing wave



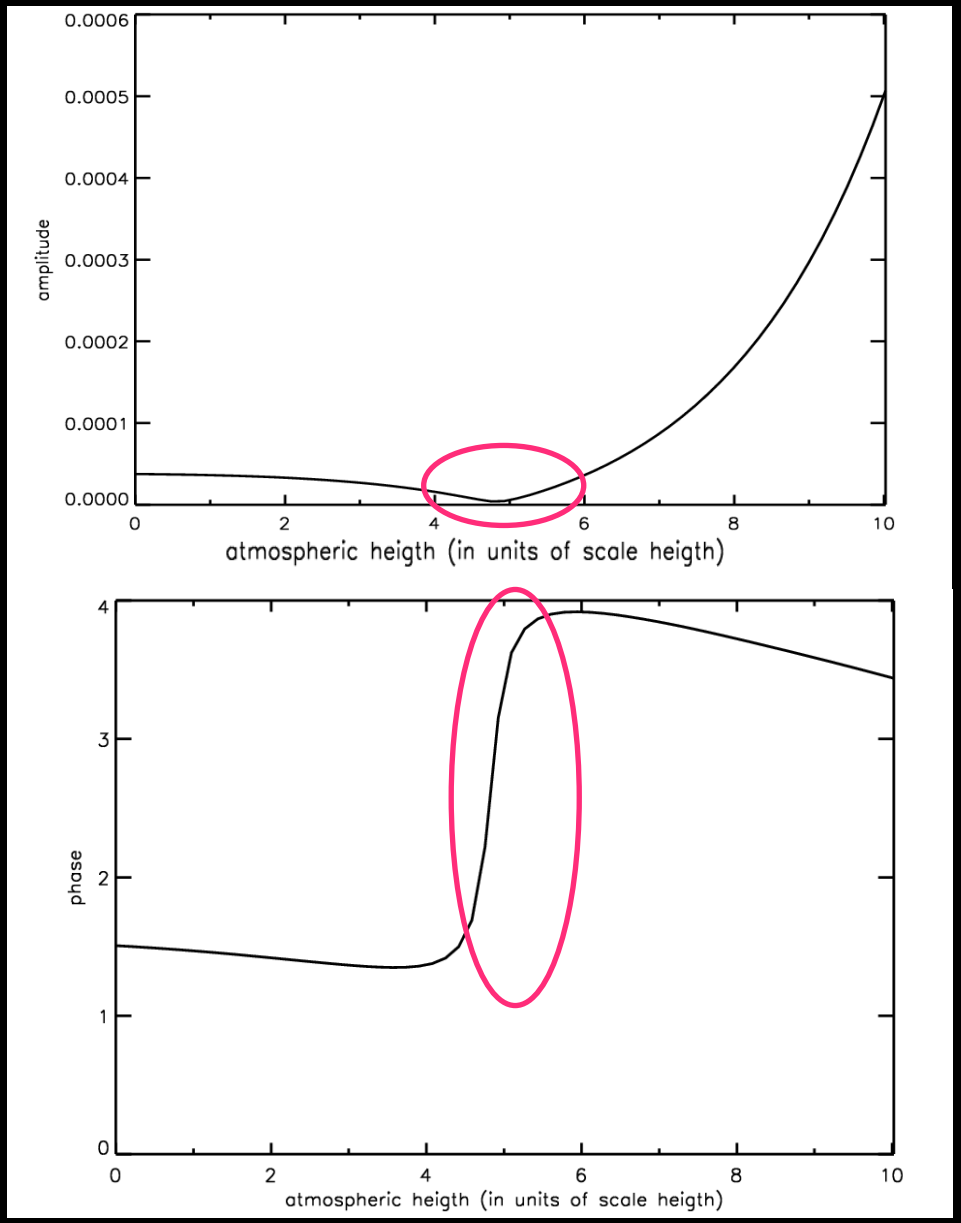
r

(Ryabchikova *et al.* , 2007)

False Node

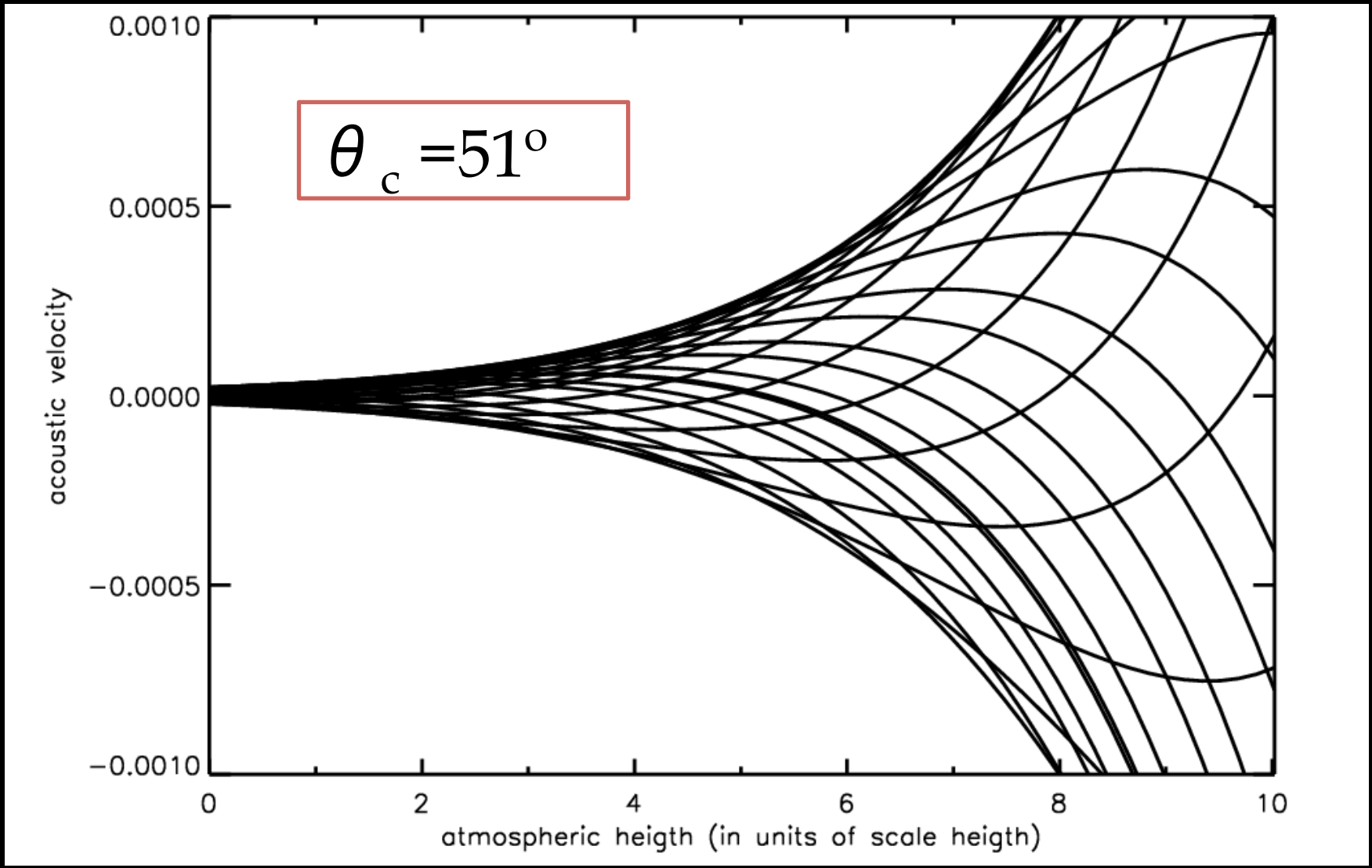
Int region= [50º,80º]

σ = 2.308 mHz



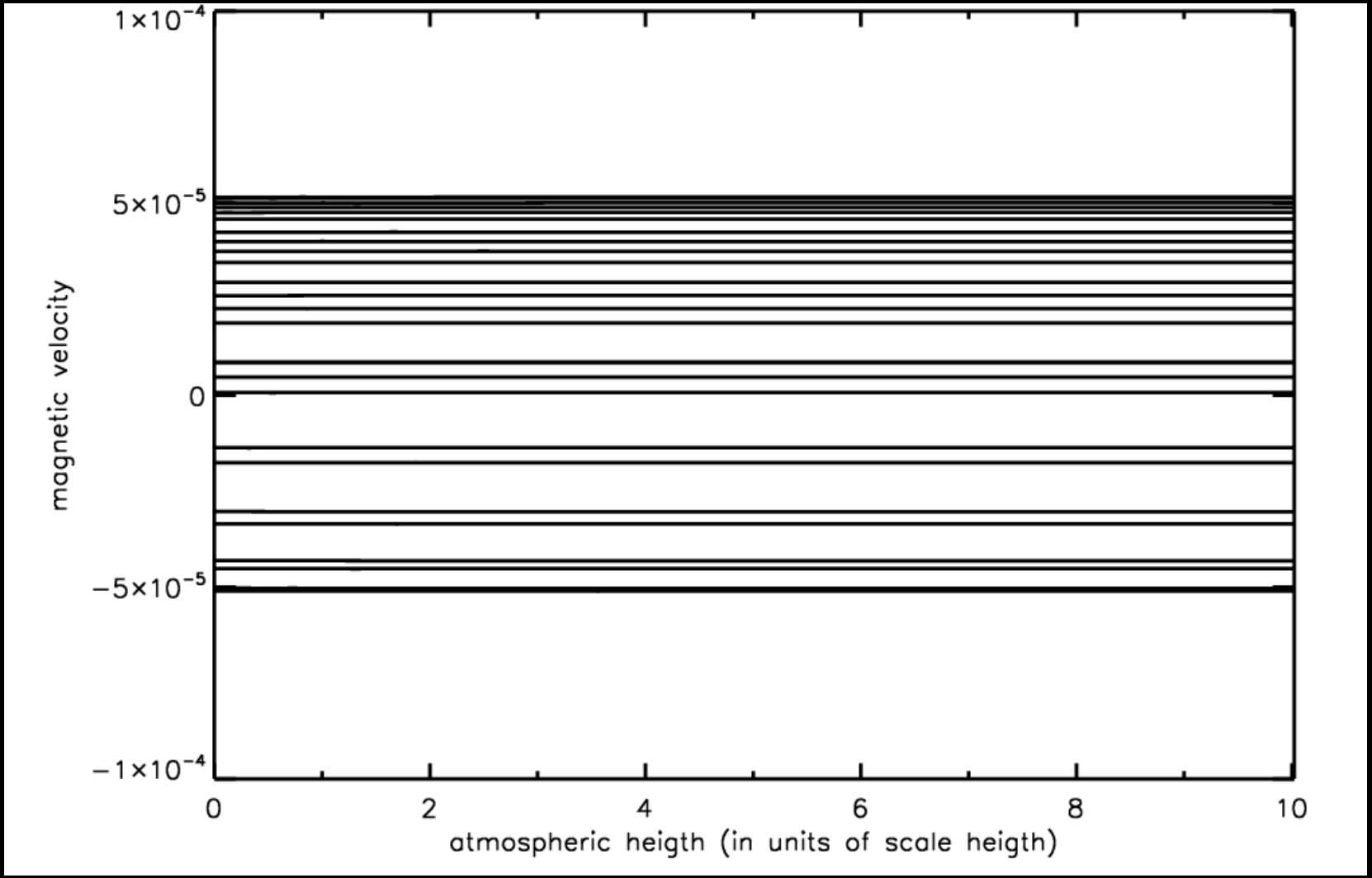
Sousa & Cunha, 2011, MNRAS

Acoustic Component



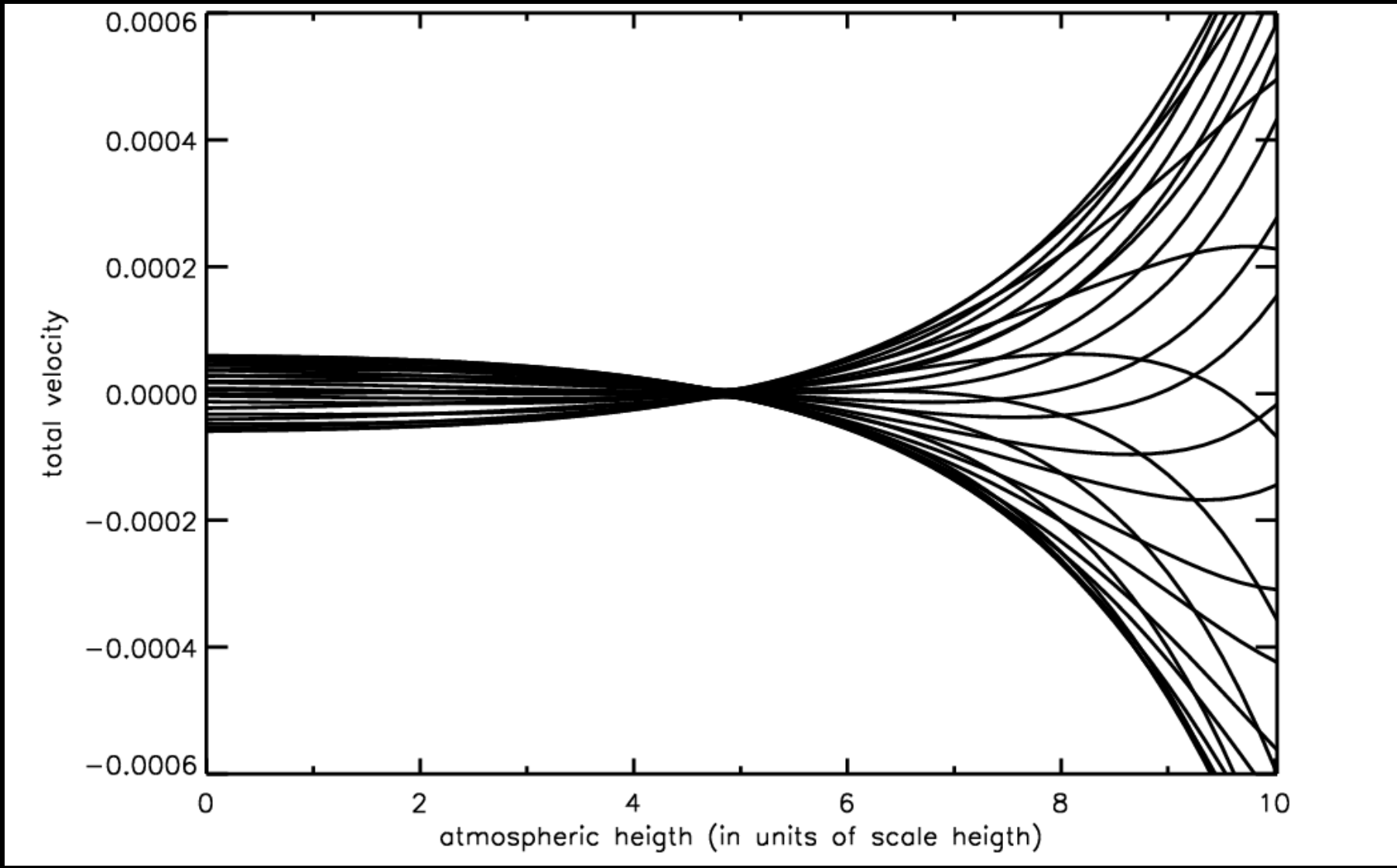
Sousa & Cunha, 2011, MNRAS

Magnetic Component



Sousa & Cunha, 2011, MNRAS

Total Velocity



Sousa & Cunha, 2011, MNRAS

Comparison with results of observations published in the literature

- Amplitude
- Standing and Running waves – *but not always real*
- "Inwardly running" waves - *but not real*
- "Nodes" in the atmosphere – *but not real*

Explain, at least qualitatively the diversity of behaviour observed in high resolution spectroscopic observations

Thank You !!