Peculiar A stars: the phenomenon of rapid oscillation

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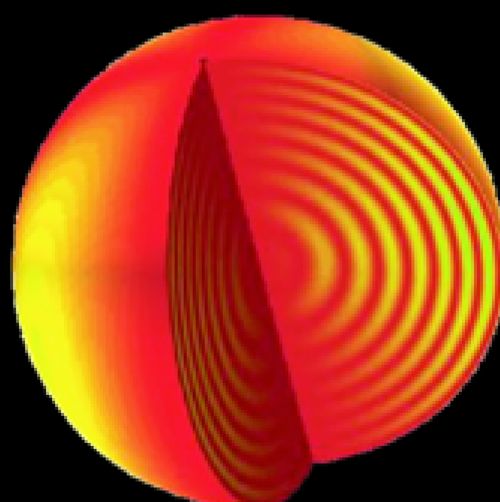
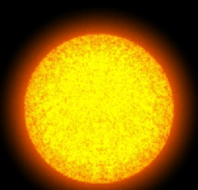
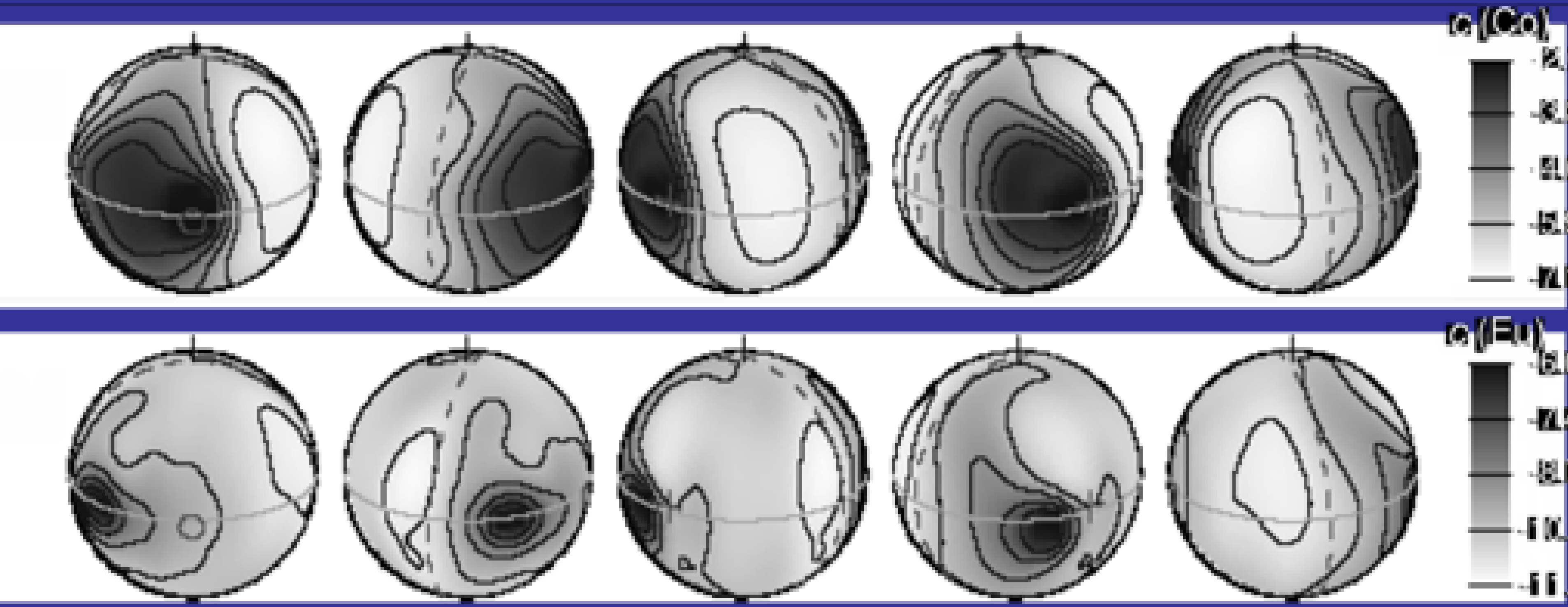
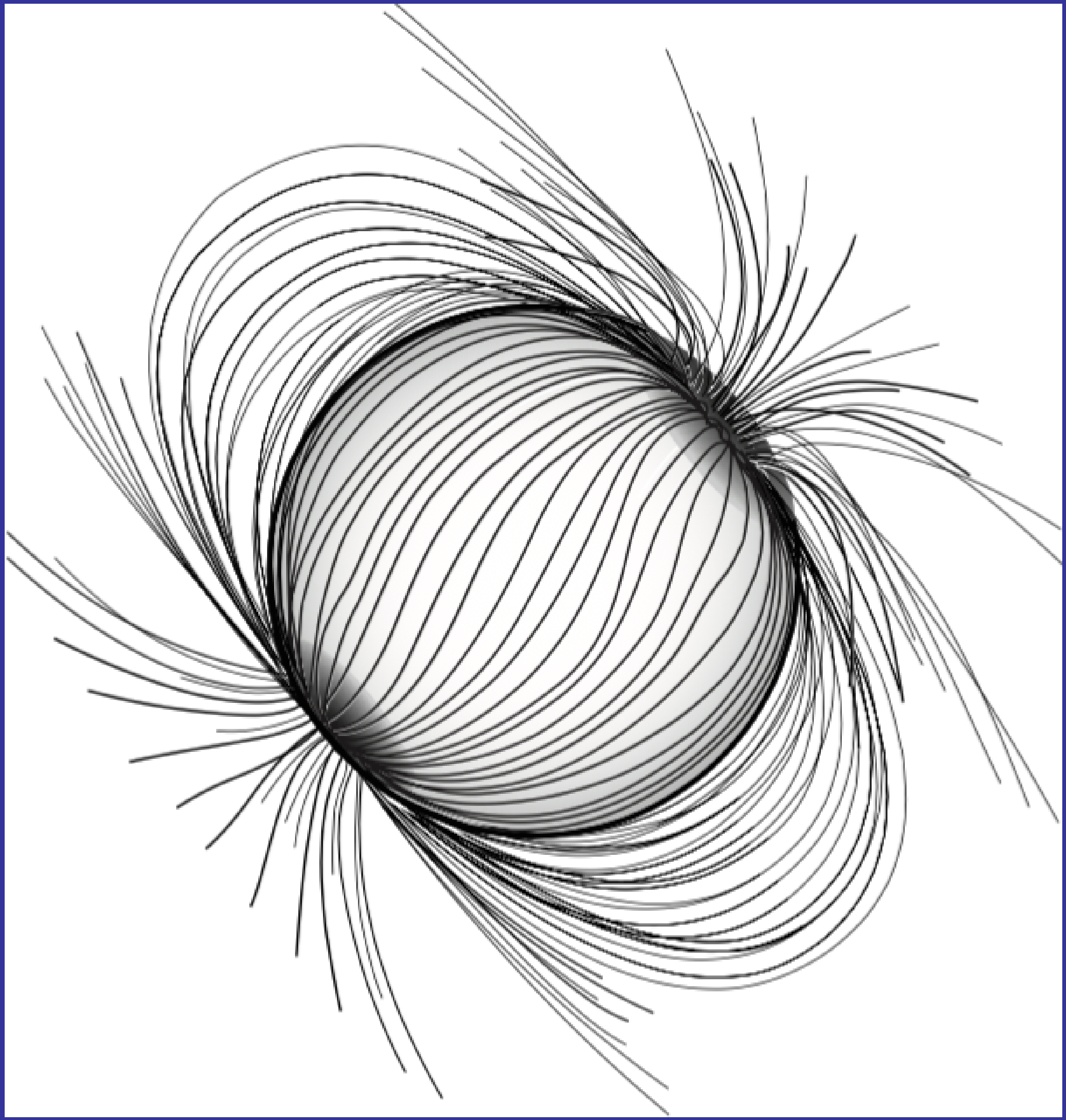
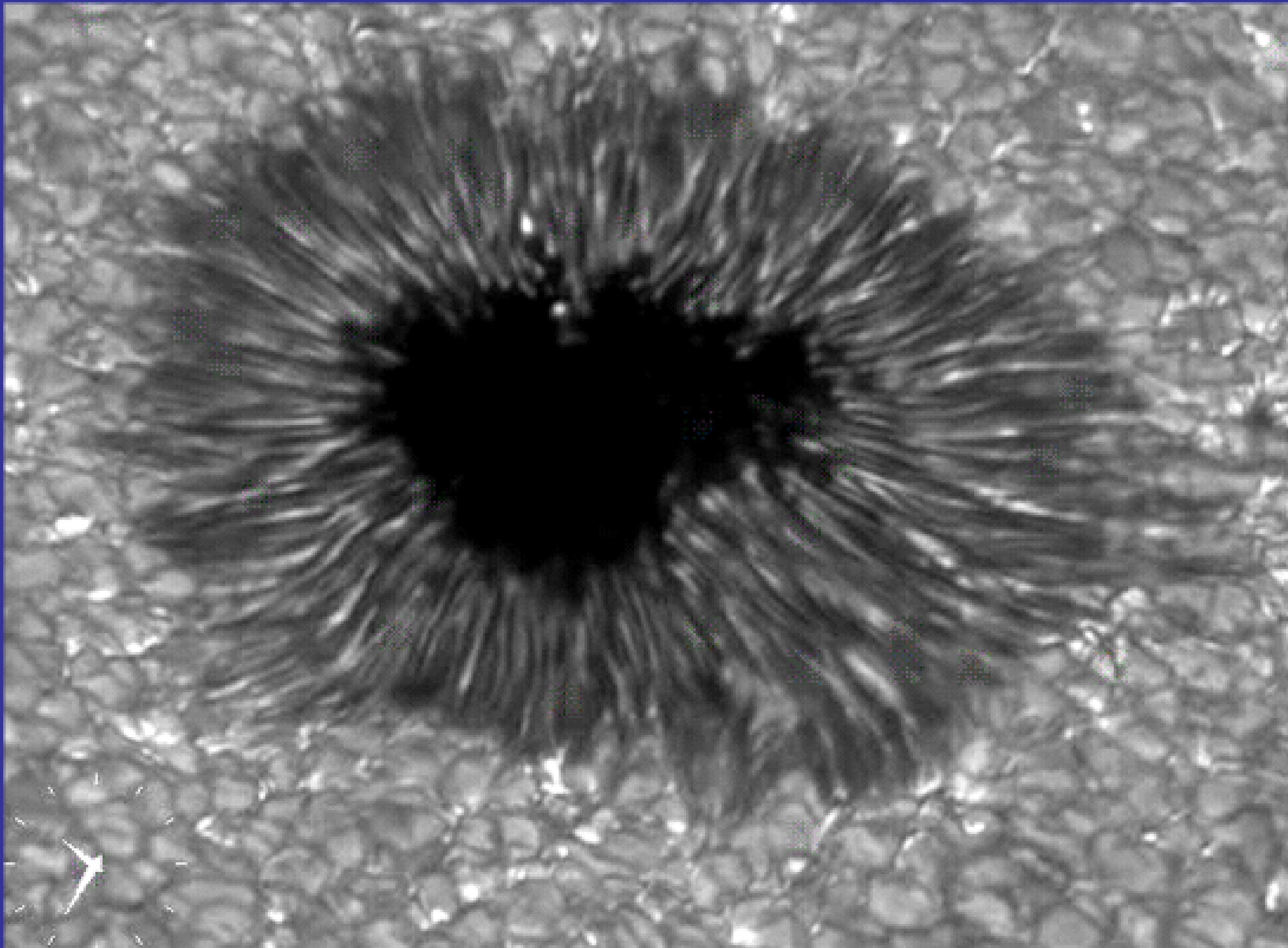


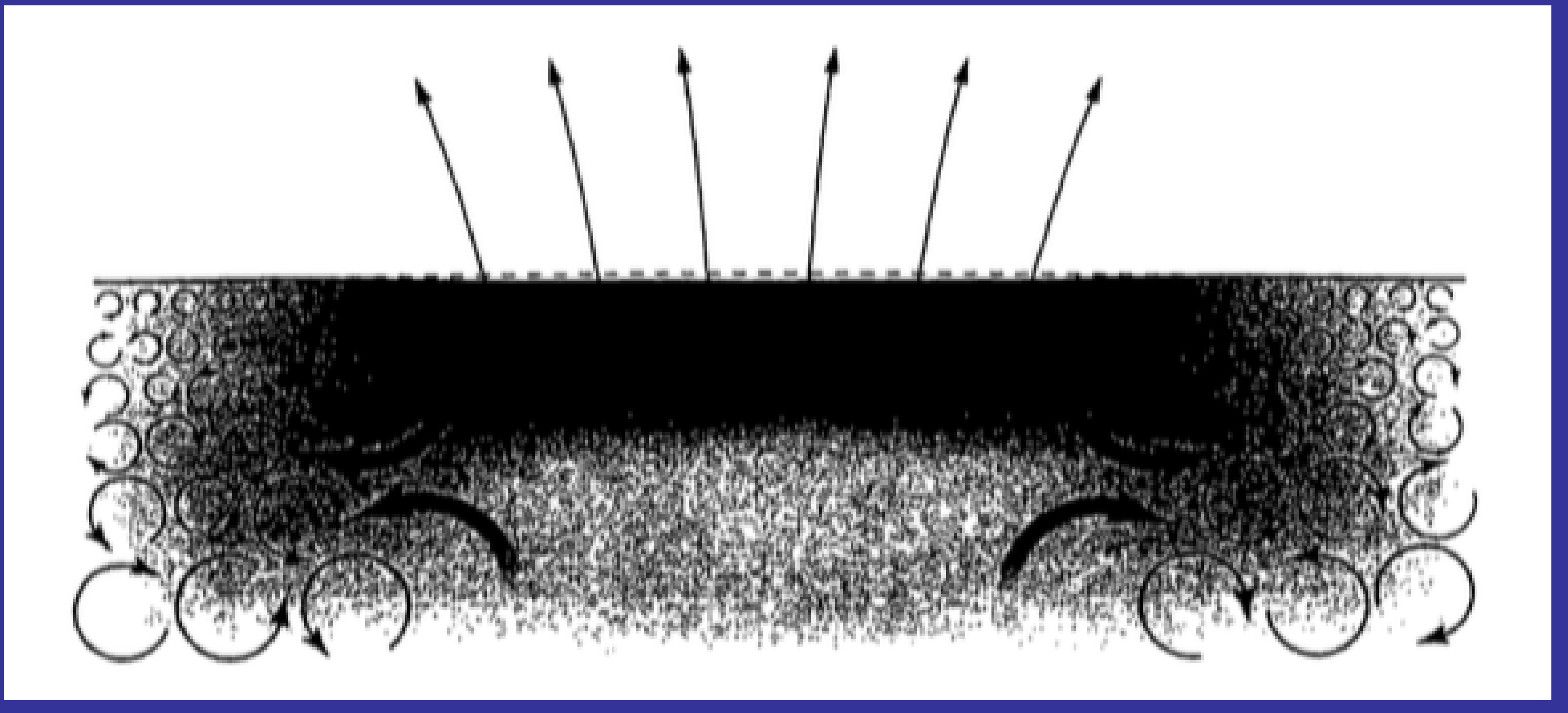


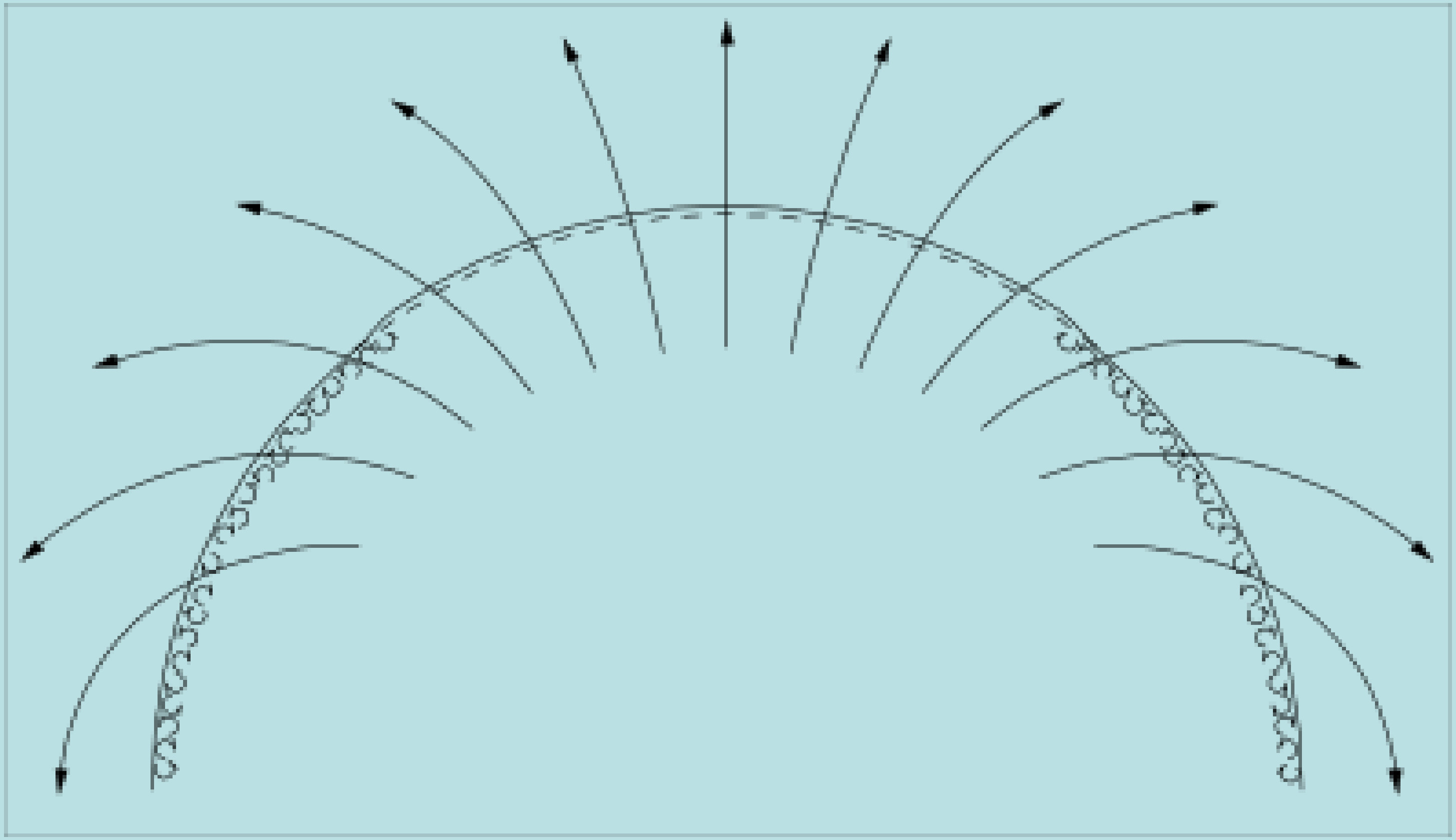
A Doppler-imaged roAp star











Can the magnetic field stabilize the convection?

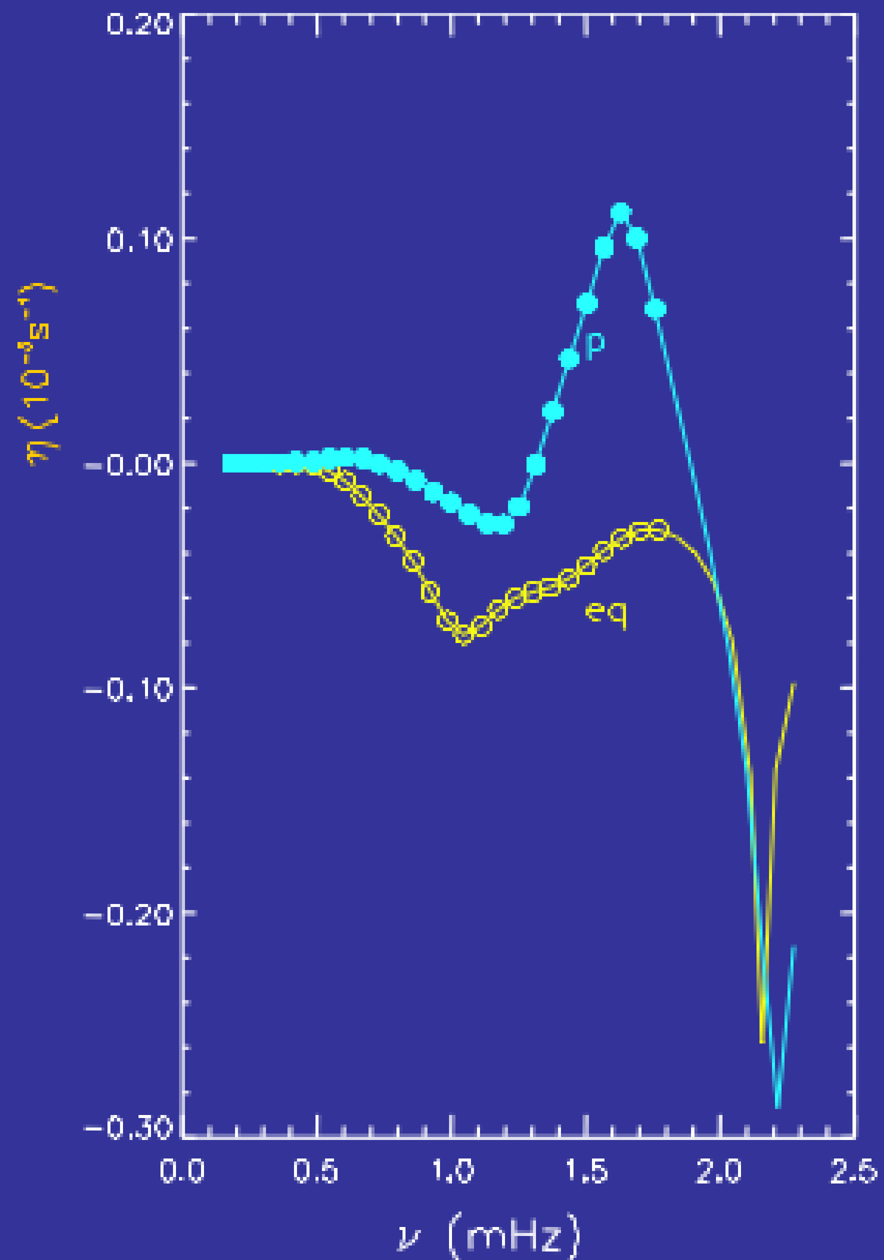
The spot model

- Large-scale magnetic field suppresses convection at the polar region of the star

- Model is composed of two polar regions, in which convection is suppressed, and an equatorial region, where convection is unaffected

- The two envelope models (polar and equatorial) are matched in the interior to assure that they differ only in their surface layers

Contributions to the growth rate η



Is it only the aligned modes that are excited to observable amplitudes?

$$\nabla^2\Psi + \frac{\omega^2}{c^2}\Psi = 0 \qquad \text{in } \mathcal{V}$$

$$\mathbf{n}\,.\nabla\Psi + \alpha\Psi = 0 \qquad \text{on } \mathcal{S}$$

$$\omega^2 = \frac{\int_{\mathcal{V}} |\nabla\Psi|^2 \mathrm{d}V + \int_{\mathcal{S}} \alpha|\Psi|^2 \mathrm{d}S}{\int_{\mathcal{V}} c^{-2}|\Psi|^2 \mathrm{d}V}$$

$$\frac{\Delta\omega}{\omega} = \frac{\int_{\mathcal{S}} \Delta\alpha|\Psi|^2 \mathrm{d}S}{2\omega^2 \int_{\mathcal{V}} c^{-2}|\Psi|^2 \mathrm{d}V}$$

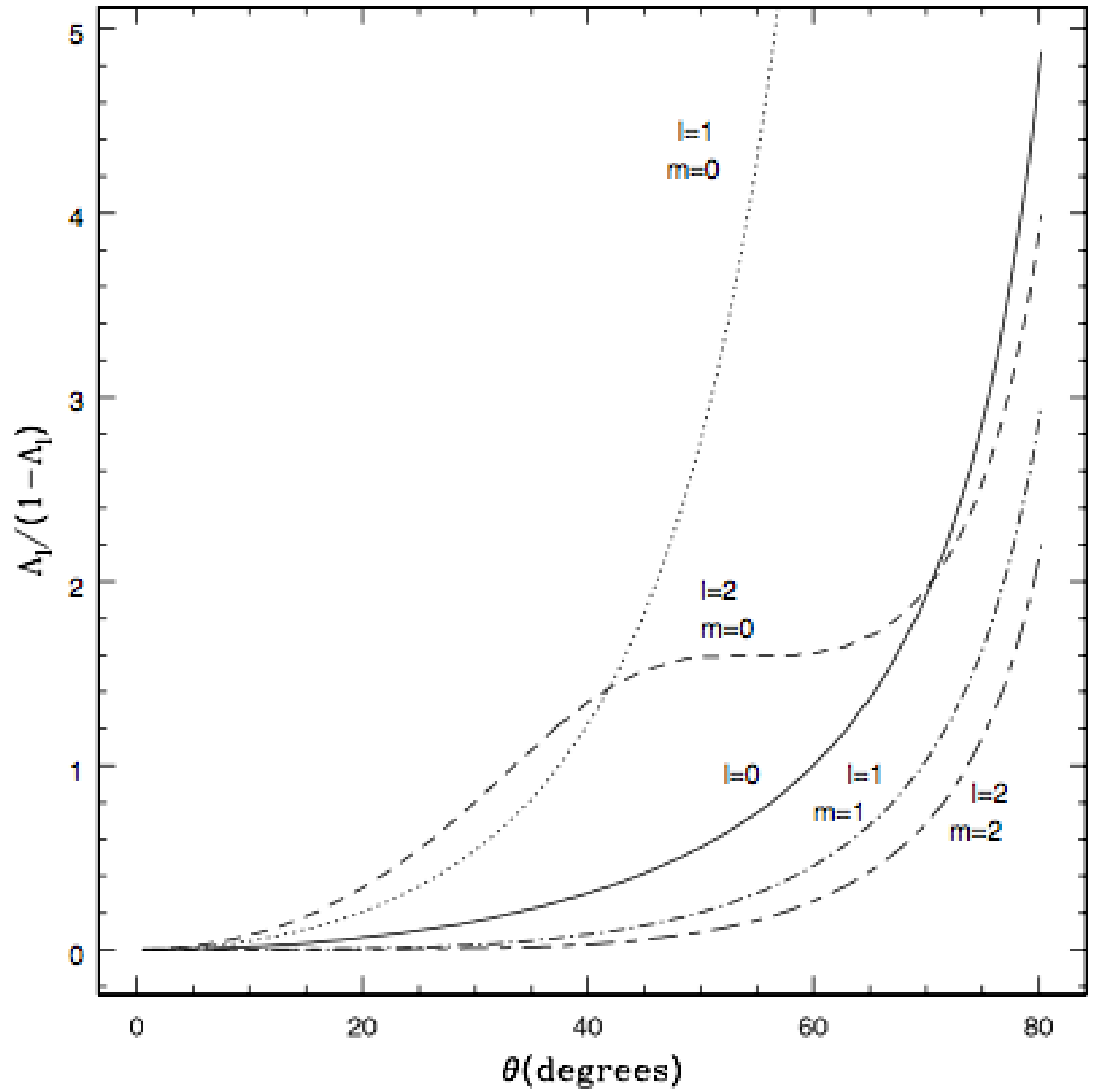
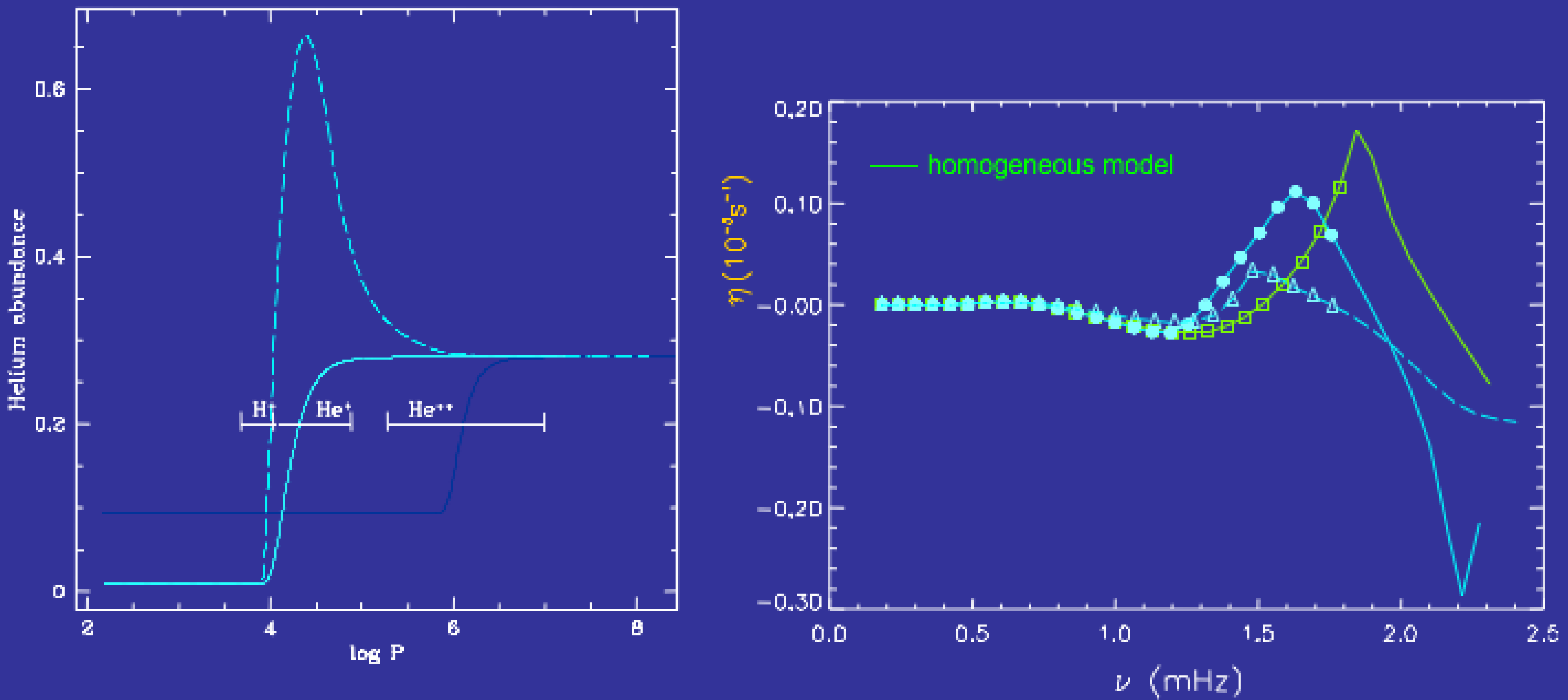
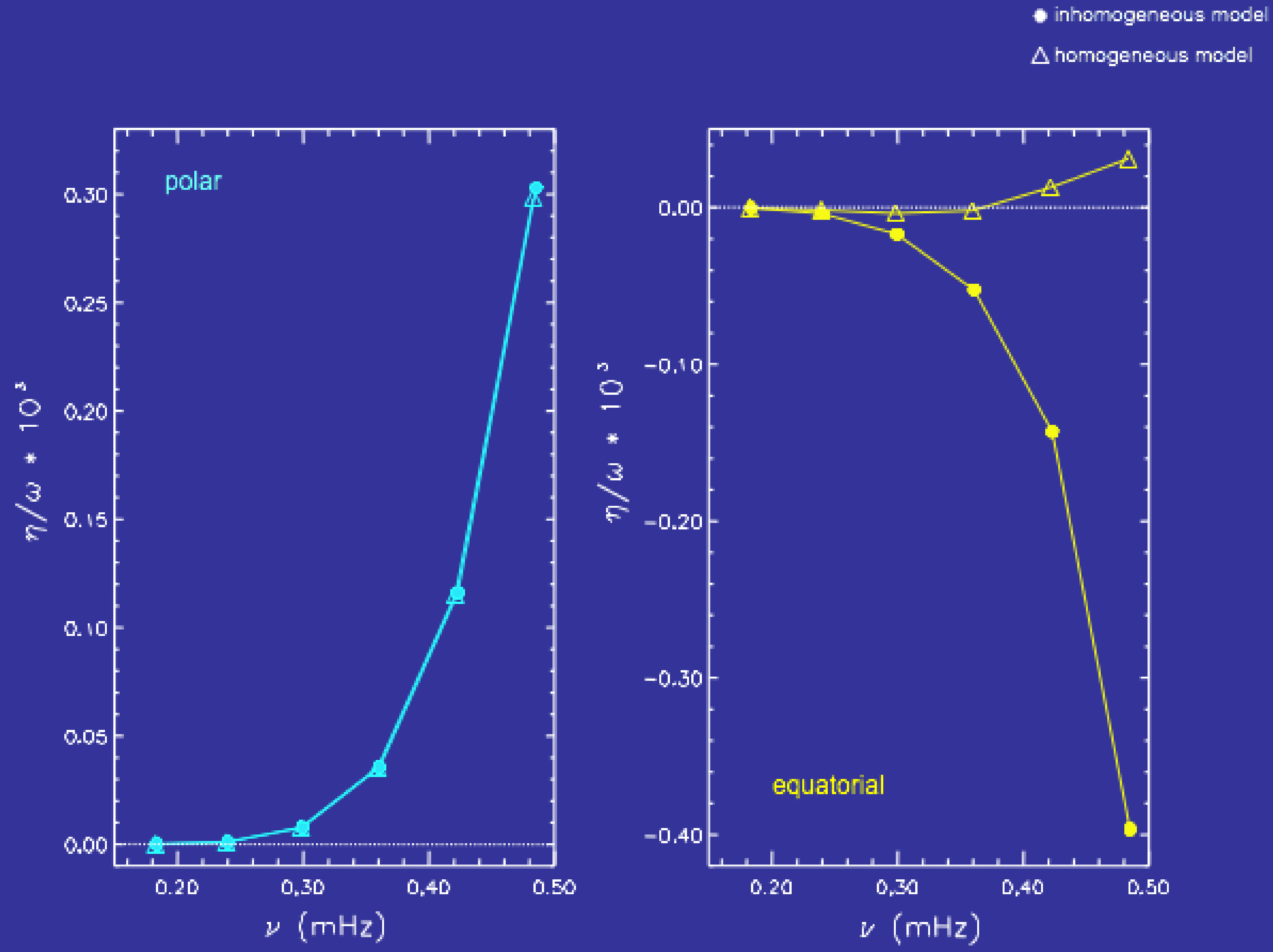


Figure 4. Coefficients $\Lambda_l^m/(1-\Lambda_l^m)$ for modes with $l=0$, $m=0$ (full line), $l=1$, $m=0$ (dotted line), $l=2$, $m=0$ (dashed line), $l=1$, $m=1$ (dash–dotted line) and $l=2$, $m=2$ (short dash–long dash line), versus angular radius ϑ of the polar regions.

Effect of chemical composition on the growth rates of the polar model



Stability coefficients of low-order modes



NoAp stars are systematically more luminous (and more evolved) than roAp stars

More luminous/evolved stars tend to pulsate at lower frequencies

Computations suggest that magnetic suppression of convection is less likely in more evolved stars

Growth rates are predicted to decrease as the stars evolve, so stabilizing processes such as acoustic-wave conversion into slow magneto-sonic waves can more easily suppress pulsations

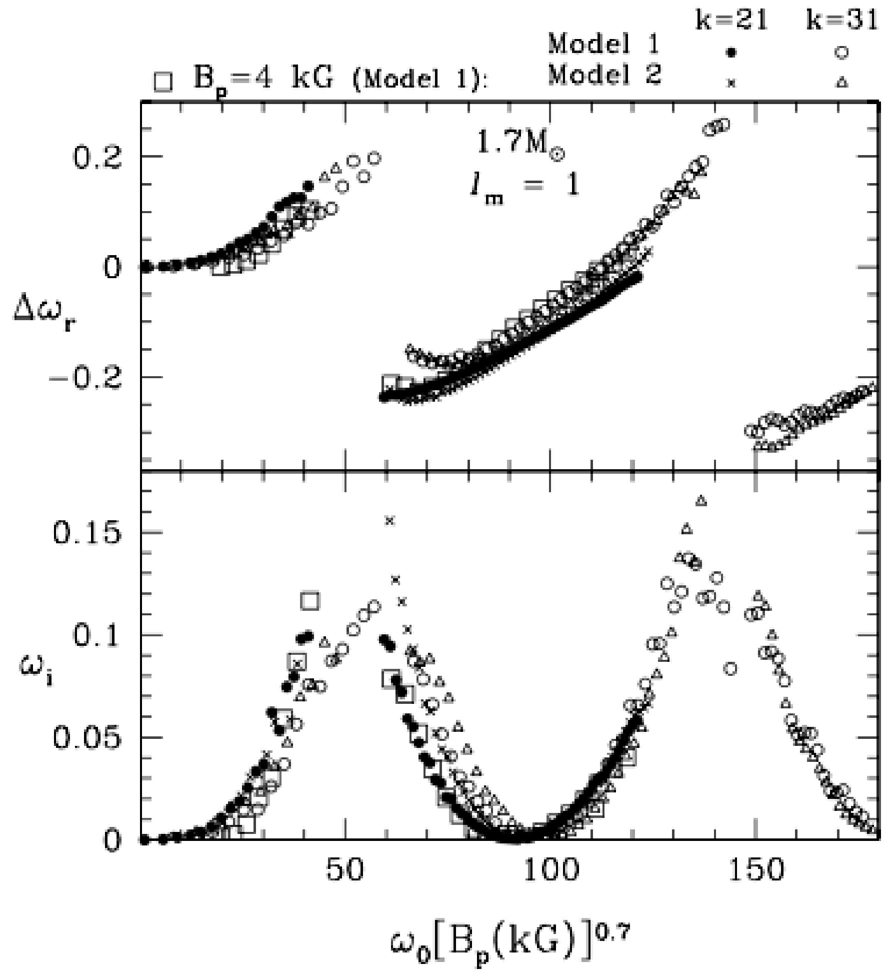


Figure 12. Frequency shift $\Delta\omega \equiv \omega(B_{\rm p}) - \omega_0$ versus $\omega_0[B_{\rm p}(\mathrm{kG})]^{0.7}$ for $\ell_{\rm m} = 1$ modes of Model 1 and 2. The upper panel shows the real part $\Delta\omega_{\rm r}$, the lower panel the imaginary part $\omega_{\rm i} = \Delta\omega_{\rm i}$. Large squares indicate frequencies of various orders of p-modes at $B_{\rm p} = 4$ kG of Model 1. Filled circles depict the 21st ($\omega_0 = 28.26$), and open circles the 31st ($\omega_0 = 41.06$) overtones of Model 1. Crosses stand for the 21st, open triangles for 31st overtone p-modes of Model 2, all at various strengths of the magnetic field.

Discovery of the 'missing' mode in HR 1217 by the Whole Earth Telescope

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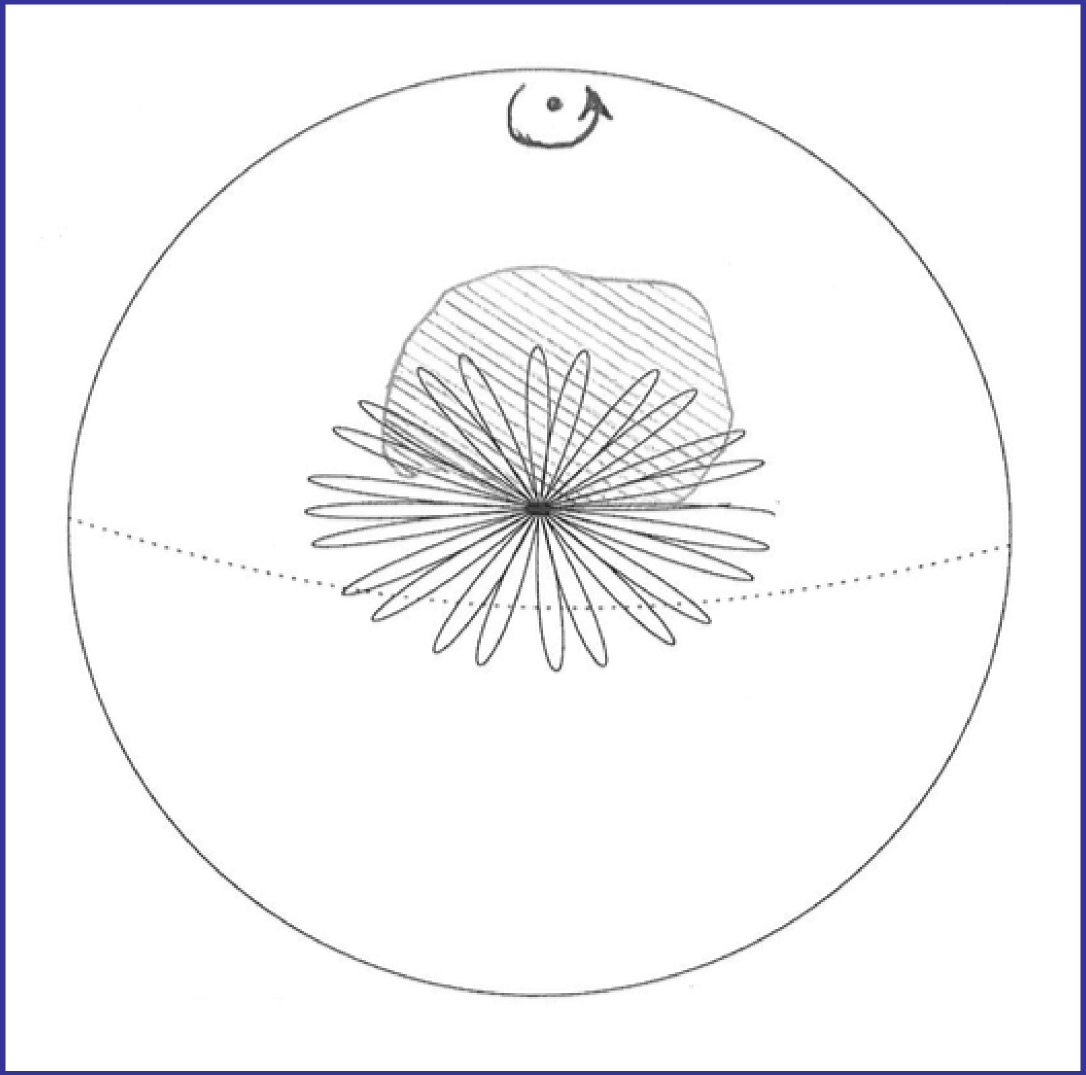
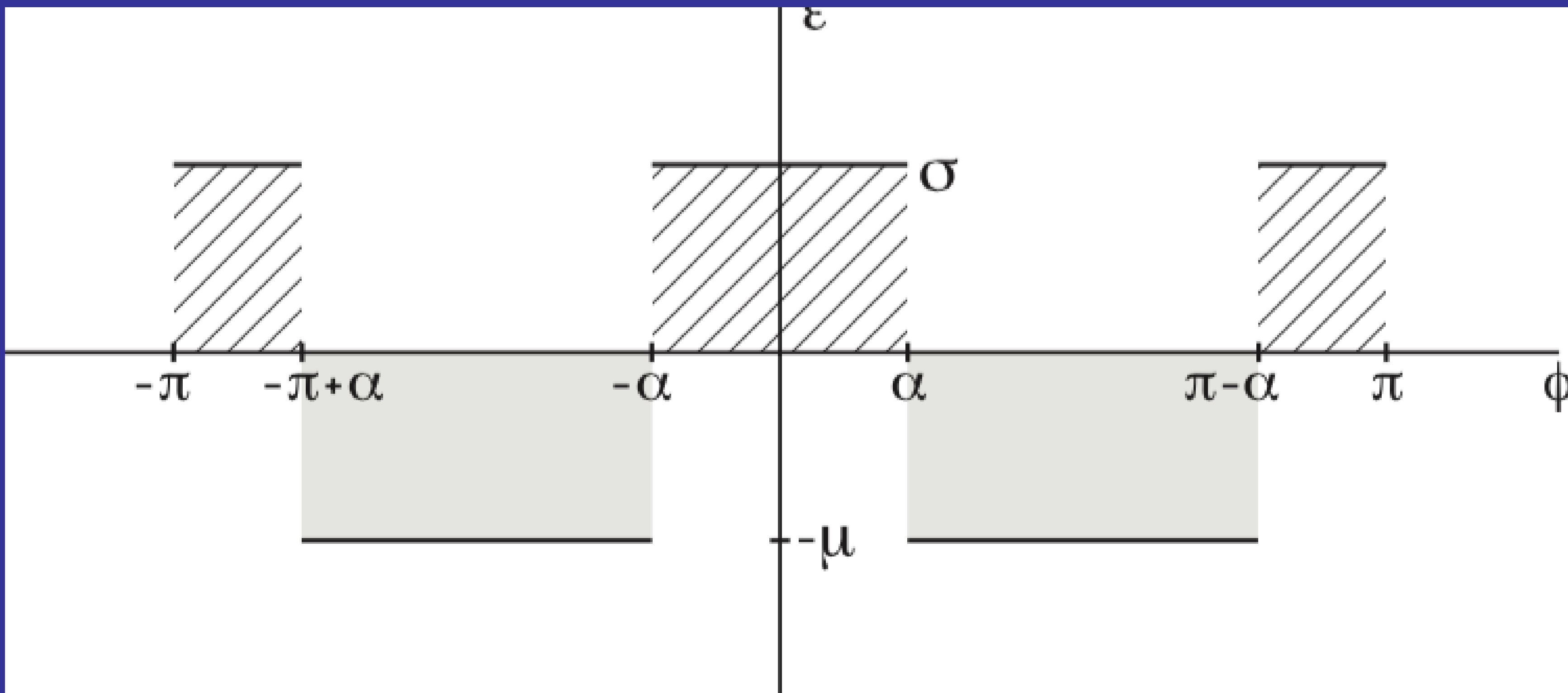
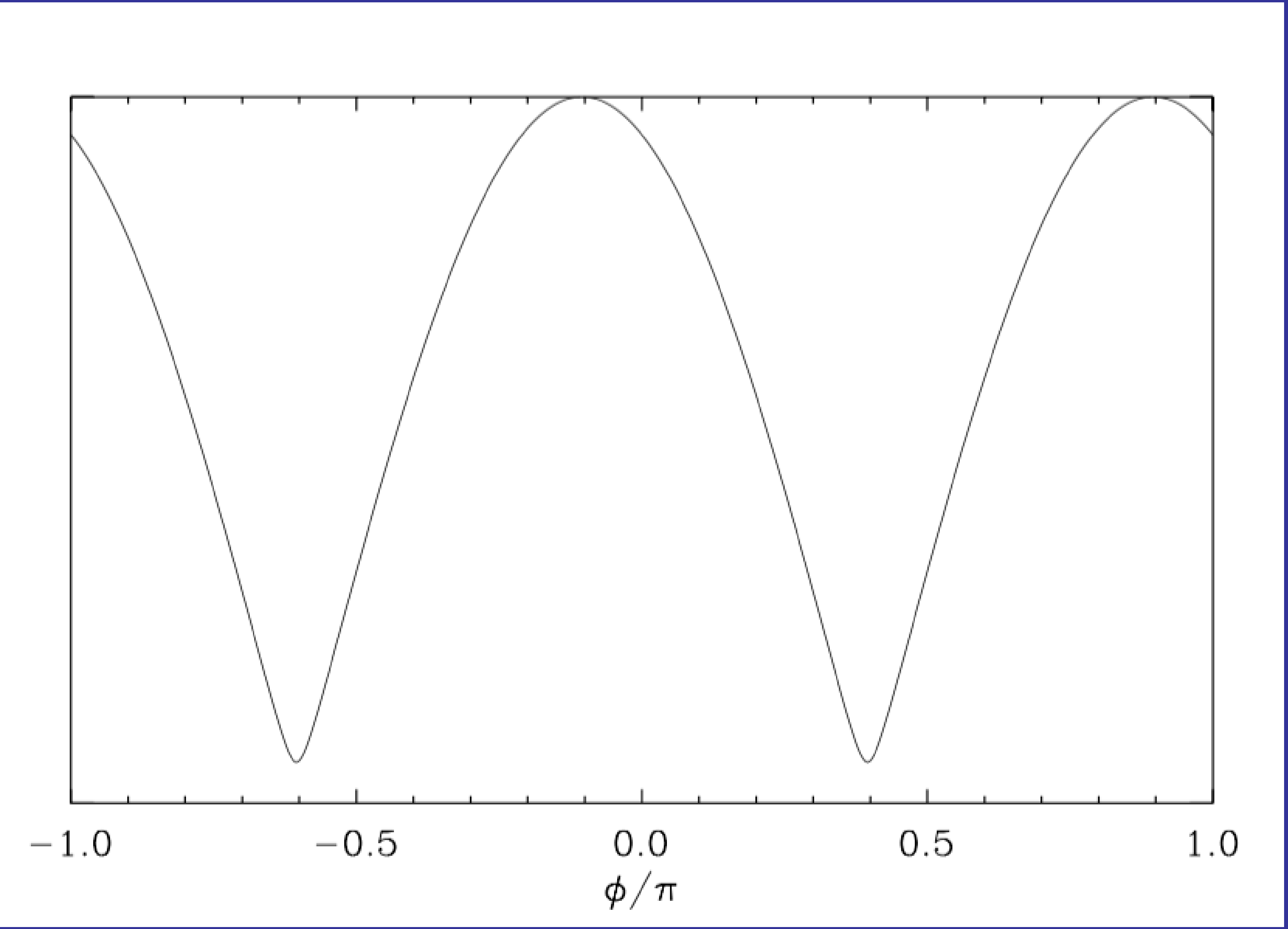
Are there dipole/quadrupole pulsations that are aligned with the spots?

It is convenient to consider 'standing' normal-mode combinations in order to appreciate the physical nature of the oscillations





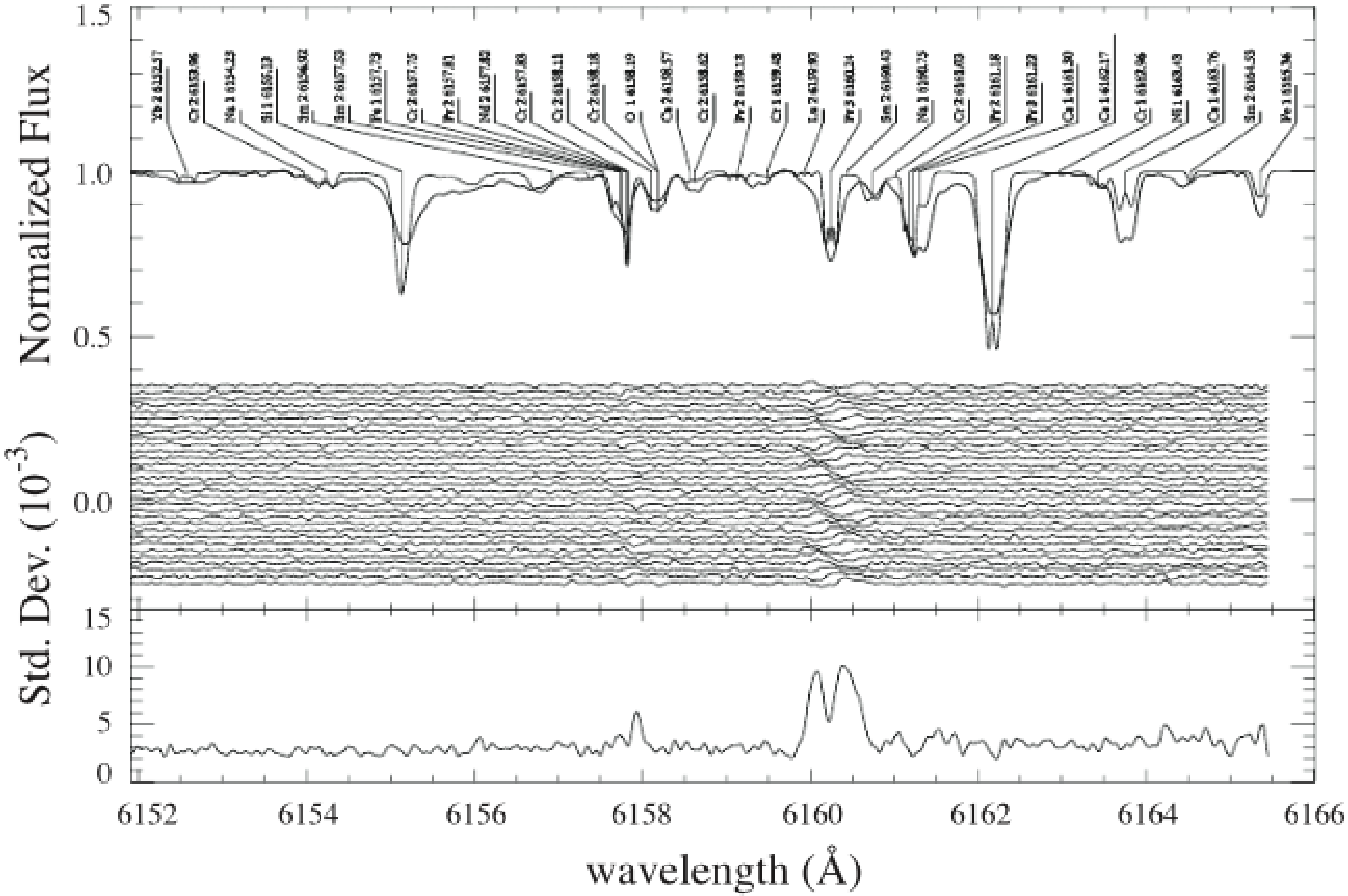
ε
σ
-π
-π+α
-α
α
π-α
π
φ
-μ

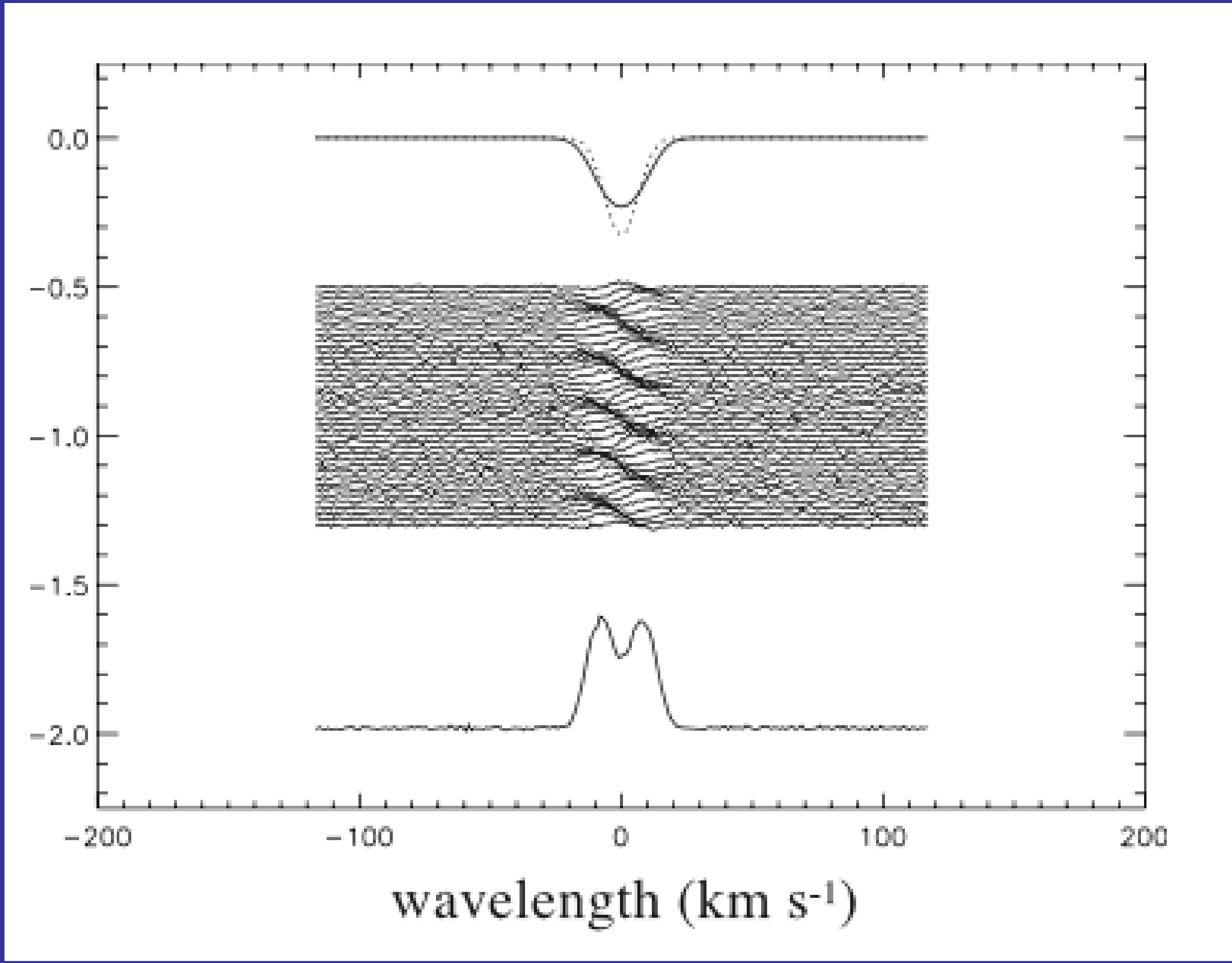


−1.0
−0.5
0.0
0.5
1.0
ϕ/π

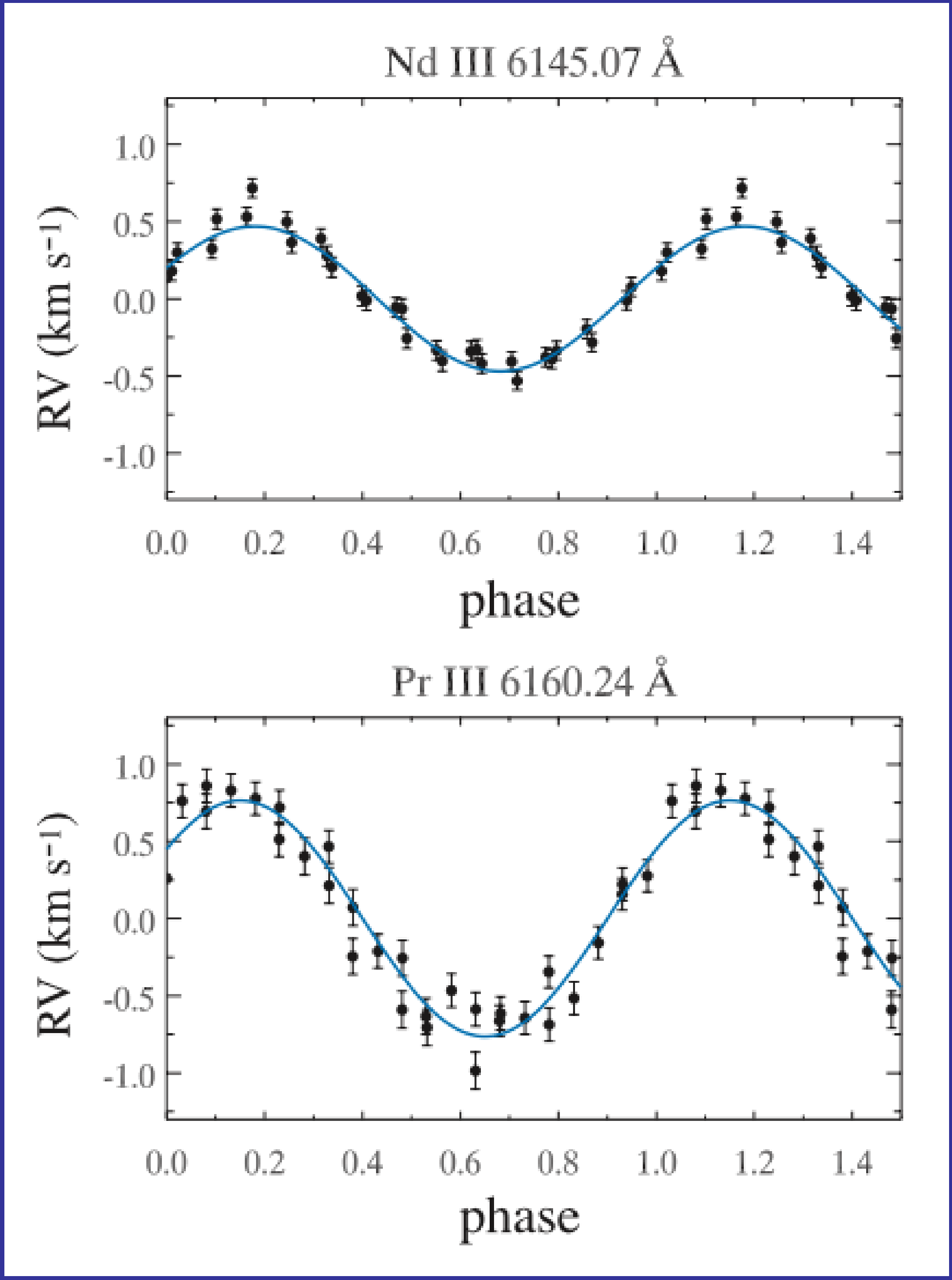
Atmospheric waves

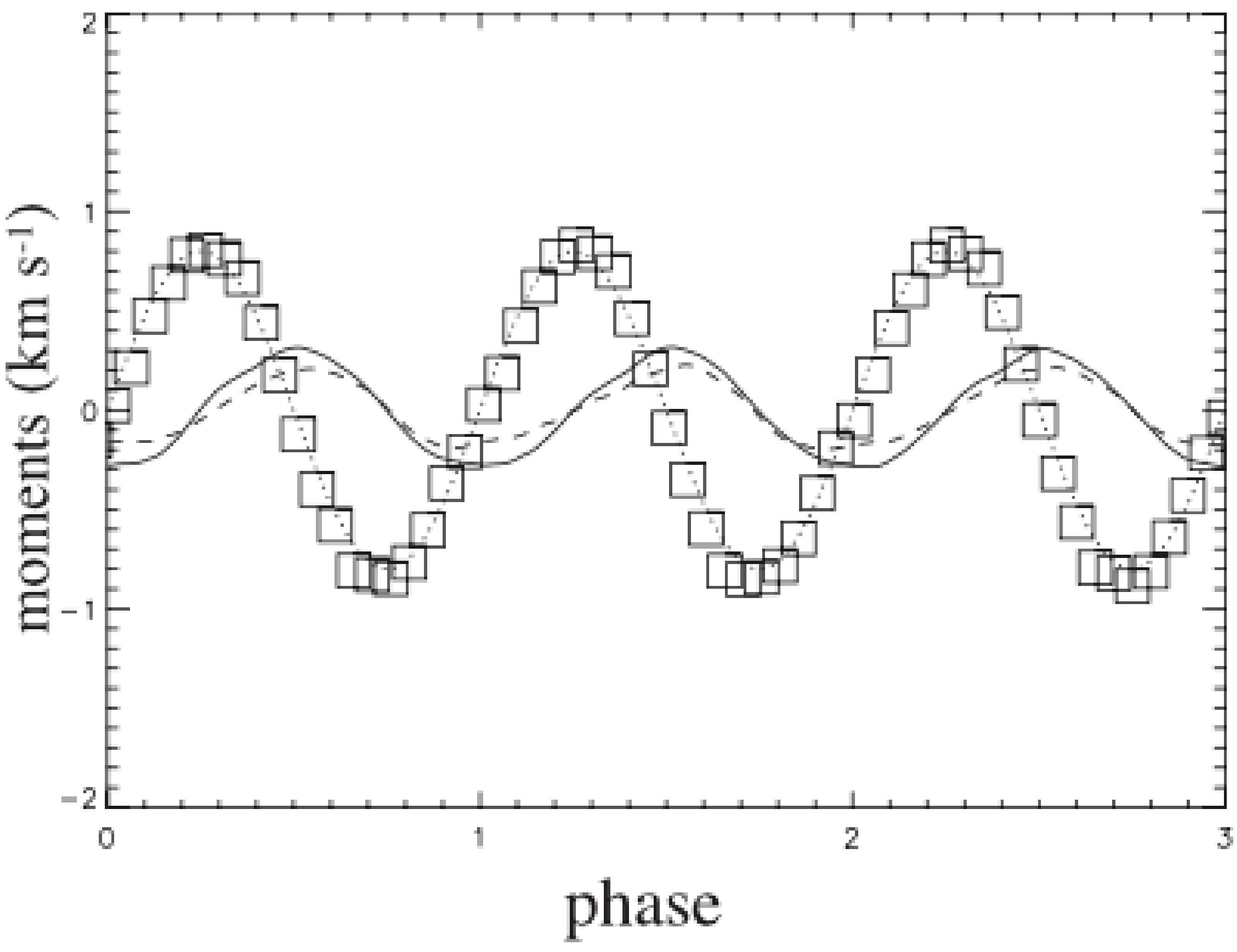
H. Shibahashi et al.





0.0
−0.5
−1.0
−1.5
−2.0
−200
−100
0
100
200
wavelength (km s-1)


Nd III 6145.07 Å
RV (km s⁻¹)
phase
Pr III 6160.24 Å
RV (km s⁻¹)
phase



moments (km s-1)
phase
2
1
0
−1
−2
0
1
2
3

Limiting amplitudes

This presentation, as are all the others at this meeting, is dedicated to the present life's work of Don Kurtz, with thanks for his tremendous scientific contributions and, most importantly, his friendship

We now look forward with great expectations to Don's next life's work