Dynamics of coronal loop oscillations

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in cooperation with:
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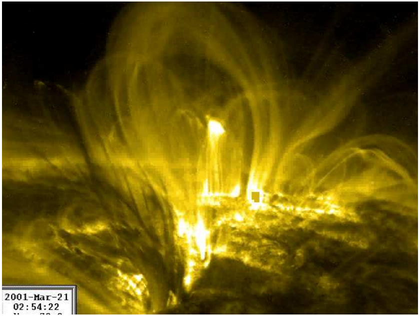
Outline

Outline

Coronal loop oscillations



Standard equilibrium model

- MHD
- static equilibrium
- $g = 0$
- $p = 0$
- cylinder
- $\vec{B} = B\vec{e}_z$
- linear perturbations

free $\rho(r)$

$\longrightarrow$ smoothly varying profile

$\longrightarrow$ allow for resonant absorption

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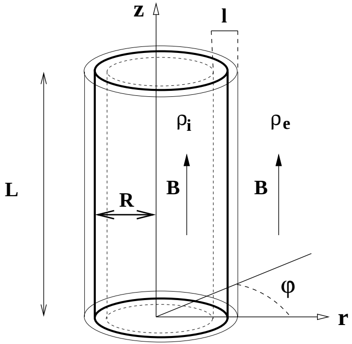

free $\rho(r)$

$\longrightarrow$ smoothly varying profile

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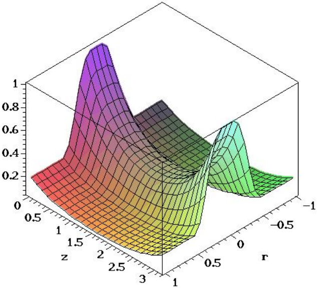
Outline

model

Andries et al. (2005)

$$\rho(r,z) = \rho(r)(1 - \alpha \sin\left(\frac{\pi}{L} z\right))$$



Numerical results

Arregui et al. (2005, accepted by A&A)

Parameter study using POLLUX

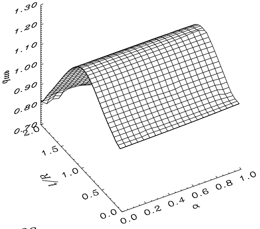
Varying over:

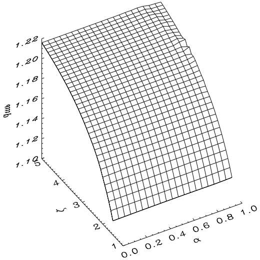
- aspect ratio
- width inhomogeneous layer
- longitudinal stratification
- density contrast

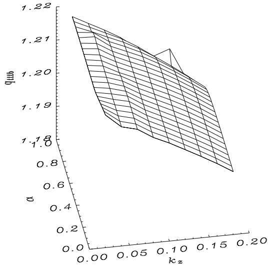
- Finite elements in radial direction
- Spectral discretization in z-direction
- Solved by Jacobi-Davidson (shooting method)

Parallel computation

$$-\frac{\omega_{\mathrm{i}}}{\omega_{\mathrm{r}}} = -q_{TTTB}\frac{1}{4}\frac{l}{R}\frac{\zeta-1}{\zeta+1}$$







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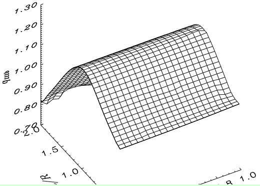
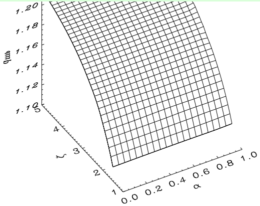
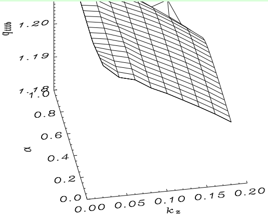
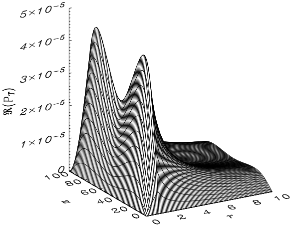
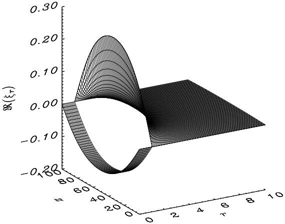


No change in observational parameter τ_{damping}/Period with respect to α.






5×10^{-5}
4×10^{-5}
3×10^{-5}
2×10^{-5}
1×10^{-5}
0
$\Re(P_T)$
100
80
60
40
20
0
z
0
2
4
6
8
10
r


0.30
0.20
0.10
0.00
−0.10
−0.20
$\Re(\xi_r)$
100
80
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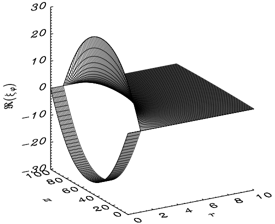
40
20
0
z
0
2
4
6
8
10
r


30
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$\Re(\xi_\varphi)$
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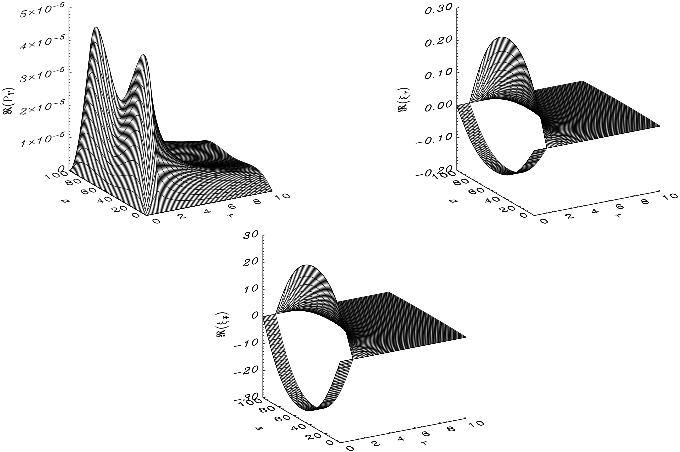
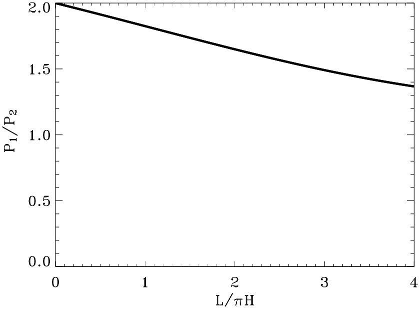


Coupling to other longitudinal mode numbers

Seismology

Assume stratification corona: $\sim \exp\left(-h/H\right)$



$$\text{Verwichte et al. (2005)} \rightarrow P_1/P_2 = \begin{cases} 1.81 \pm 0.25 \\ 1.64 \pm 0.23 \end{cases}$$

Andries et al. (2005)

P_1/P_2	H (in Mm)	confidence interval (in Mm)
1.81 ± 0.25	65	$]-\infty, -190] \cup [27, +\infty[$
1.64 ± 0.23	36	$[20, 99]$

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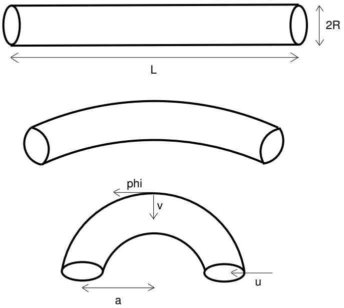
Consistent with observational value of 50Mm

Outline

1. Introduction
2. Density stratification
3. Curvature
   - Model & coordinate system
   - Results
4. Conclusions

Van Doorsselaere et al. (2004)



$$x = \frac{a \sinh u \cos \phi}{\cosh u - \cos v}, \quad y = \frac{a \sinh u \sin \phi}{\cosh u - \cos v}, \quad z = \frac{a \sin v}{\cosh u - \cos v}$$

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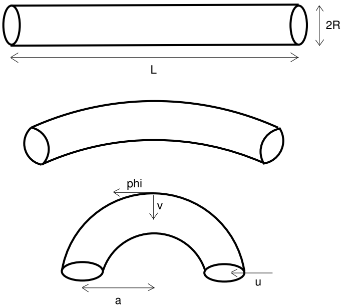

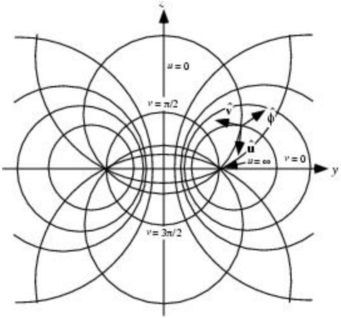

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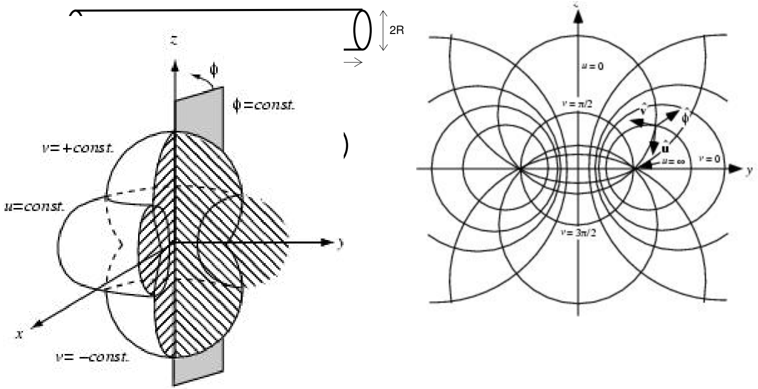

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Force-free magnetic field:

$$B(u,v) = B_{\mathrm{a}} \frac{(\cosh u - \cos v)}{\sinh u}$$

Density:

$$\rho(u,v) = \begin{cases} \rho_{\mathrm{a,e}} \frac{(\cosh u - \cos v)^4}{\sinh^4 u} & \text{for } u < u_0, \\ \rho_{\mathrm{a}}(u) \frac{(\cosh u - \cos v)^4}{\sinh^4 u} & \text{for } u_0 \leq u \leq u_0 + d, \\ \rho_{\mathrm{a,i}} \frac{(\cosh u - \cos v)^4}{\sinh^4 u} & \text{for } u > u_0 + d. \end{cases}$$

Equation & solution

Equation:

$$\nabla^2 \left(\frac{b_\phi}{B} \right) = - \left(\frac{k^2 \omega^2 (\cosh u - \cos v)^2}{\omega_A^2 a^2 \sinh^2 u} \right) \frac{b_\phi}{B}$$

Solution:

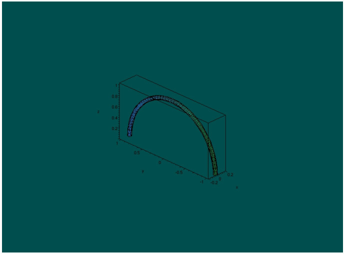
$$\sum_{m=-\infty}^{+\infty} C_{\mathrm{i/e,m}} \sqrt{\frac{\cosh u - \cos v}{\sinh u}} F_{\mathrm{i/e,m}}(u) \exp\left(im(v - v_0) \right)$$

$F_{\mathrm{i/e,m}}(u)$: radial dependance, hypergeometric function
m: poloidal wave number

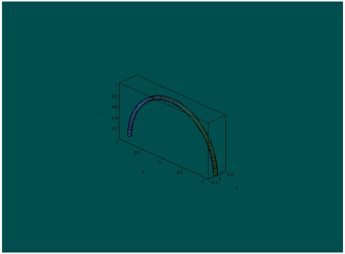
v_0: free phase

Free phase

Horizontal



Vertical



Vertical oscillations

Observed by Wang & Solanki (2004)

No difference between vertical and horizontal oscillations

PROBLEM: observed intensity enhancement can NOT be explained

Outline

Conclusions

- Density stratification
  - Coupling between longitudinal mode numbers
  - Observational parameter τ_{damping}/Period not changed
  - SEISMOLOGY!
- Curvature
  - Vertical oscillations partially explained (Wang & Solanki, 2004)
  - Only coupling to neighbouring poloidal mode numbers $(m \pm 1)$

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