Seismic Diagrams for β Cephei Stars

A database for COROT

A. Thoul + BAG
Tools

- Stellar Evolution Code: CLES
- Adiabatic oscillation code: OSC
- Non Adiabatic oscillation code: MAD
Grid of models

• Model parameters:
  – Mass $M$: 8 to 11 $M_\odot$
  – Metallicty $Z$: 0.010 to 0.025
  – Hydrogen Abundance $X$: 0.6 to 0.7
  – Overshooting Parameter $\alpha_{ov}$: 0 to 0.2
Excited zone on the Main Sequence: effects of M and Z
Excited zone on the Main Sequence: effect of $X$
Excited zone on the Main Sequence: effects of $\alpha_{ov}$ and $Z$

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Excited zone on the Main Sequence:

Depends mostly on the metallicity $Z$
Which modes are excited?

Degree 1
Order n
Which modes are excited?

\( l=0, \ n=1 \)
Which modes are excited?
\( l=0, n=2 \)
Which modes are excited?
\[ l=0, n=3 \]
Which modes are excited?
\( l=1, n=-1 \)
Which modes are excited?
$l=1, n=1$
Which modes are excited? 
$\ell=1$, $n=2$
Which modes are excited?
\( l=2, n=-4 \)
Which modes are excited?
\(l=2, n=-3\)
Which modes are excited?

$l=2, n=-2$
Which modes are excited?
\[ l=2, \ n=-1 \]
Which modes are excited?
\[ l=2, \ n=0 \]
Which modes are excited?
\[ l=2, \ n=1 \]
Which modes are excited?

$l=2, n=2$
## Excited Modes:

<table>
<thead>
<tr>
<th>$l=0$</th>
<th>$l=1$</th>
<th>$l=2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1</td>
<td>-3</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>-2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Evolution of the Frequencies
Seismic Diagrams

Good approximation for the mass

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Determination of the Stellar Parameters: $<p>$
Determination of the Stellar Parameters: $\langle \rho \rangle$

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Determination of the Stellar Parameters: $\langle \rho \rangle$
An example: HD129929

Observed and identified frequencies:

- $f_1 = 76.28403 \text{ mHz}$ mode: $l=0 \ m=0$
- $f_1 = 80.76742 \text{ mHz}$ mode: $l=1 \ m=0$
- $f_1 = 74.64803 \text{ mHz}$ mode: $l=2 \ m=0$?
An example: HD129929
An example: HD129929

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A. Thoul
An example: HD129929

A. Thoul
An example: 
**HD129929**

<table>
<thead>
<tr>
<th>M</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>NO</td>
</tr>
<tr>
<td>9</td>
<td>NO</td>
</tr>
<tr>
<td>9.5</td>
<td>✔️</td>
</tr>
<tr>
<td>10</td>
<td>✔️</td>
</tr>
<tr>
<td>10.5</td>
<td>NO</td>
</tr>
<tr>
<td>11</td>
<td>NO</td>
</tr>
</tbody>
</table>

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9 < M < 10.5
An example:
HD129929
An example: HD129929
An example: HD129929

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An example:
HD129929

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An example:
HD129929

A. Thoul
An example: HD129929

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An example:

**HD129929**

<table>
<thead>
<tr>
<th>(Z)</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.010</td>
<td>NO</td>
</tr>
<tr>
<td>0.015</td>
<td>NO</td>
</tr>
<tr>
<td>0.020</td>
<td>✔</td>
</tr>
<tr>
<td>0.025</td>
<td>✔</td>
</tr>
</tbody>
</table>

\[0.015 < Z\]
An example: HD129929

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<th>Z</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.010</td>
<td>NO</td>
</tr>
<tr>
<td>0.015</td>
<td>NO</td>
</tr>
<tr>
<td>0.020</td>
<td>✓</td>
</tr>
<tr>
<td>0.025</td>
<td>✓</td>
</tr>
</tbody>
</table>

0.015 < Z
An example:
HD129929

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An example:
HD129929

A. Thoul
An example:
HD129929
An example: HD129929
An example: HD129929

<table>
<thead>
<tr>
<th>$\alpha_{ov}$</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>$=0$</td>
<td>NO</td>
</tr>
<tr>
<td>$=0.1$</td>
<td>✓</td>
</tr>
<tr>
<td>$=0.2$</td>
<td>✓</td>
</tr>
</tbody>
</table>

$0.0 < \alpha_{ov}$
An example:
HD129929
An example:
HD129929
An example: HD129929

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An example:
HD129929

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HD129929: Determination of $\langle p \rangle$
HD129929: Determination of $<\rho>$

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HD129929: Determination of $<\rho>$

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HD129929:  
Determination of $\langle \rho \rangle$  

Mode $l=1$  

$\langle \rho \rangle / \langle \rho_0 \rangle = 0.0520 \pm 0.0008$  

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To be continued…

• Continue to build grids of models
  – β Cephei stars
  – SPBs, δ Scuti, …

• Construct additional seismic diagrams
  – Use combination of frequencies

• Find relations between stellar properties and frequencies
To be discussed...

- Interest from the community
- Format of data
- Access to results
- Comparison with other codes
Asteroseismologist involved in the COROT mission

M = 81±7.9 kg
Chemical composition
O = 0.65
C = 0.18
H = 0.10
<ρ> ~ 1.1
age = 46 ± 2 yrs

«Normal » people