Asteroseismology of β Cephei stars: effects of the chemical composition

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Variable MS stars in the HR diagram



about 200 known β Cephei stars



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Excitation of modes in B stars

Two major updates/uncertainties:

Revised solar metal mixture

Asplund et al. 2005 A&A Cunha et al. 2006 ApJ

Fe, Ni 💦 🦯

 Updated opacities from OP

Badnell et al. 2005 MNRAS



Miglio et al. 2007 MNRAS 375 L21

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Excitation of modes in B stars





Miglio, Montalban, Dupret, 2007 CoAst

Excitation of modes in B stars



- Larger hot wing of opacity bump: Bluer border of SPBs and β Cephei instability strip
- Larger number of hybrid SPB-β Ceph pulsators
- More β Cephei modes excited at Z=0.01
- Red border of SPBs instability strip almost unchanged

Miglio, Montalbán, Dupret, 2007 MNRAS Helas II - Göttingen - August 20075 A. Thoul

Pulsations of β Cephei stars

- Multiperiodic: a few radial and non radial pulsation modes of low degree and low order are excited
 (∽≅ mechanism in iron-group opacity bump around 10000 degrees)
- sparse spectrum
- multiplets are resolved and well separated
- short period pulsators (a few hours)
- p, g and mixed modes info on the internal structure

Asteroseismology of β Cephei stars

- Strategy: Forward modelling
- Parameters: X, Z, α_{ov} , M, age
- Try to fit the observed frequencies
- If problems: try to improve the physics
 - different chemical composition
 - different opacities
 - diffusion and radiative accelerations
 - mixing
 -



A case study: v Eri

- Many observed frequencies (latest results: Jerzykiewicz et al 2005)
- Identified modes and multiplets
- Well-studied by several independent groups (Pamyathnykh et al. 2004, Ausseloos et al. 2004)
- Problematic star: no satisfactory solution

vEri: Observations

Observed spectrum of oscillations: f1=5.7633c/d l=0,m=1

- f2=5.6200c/d l=1,m=-1 5.6372c/d l=1,m=0 5.6539c/d l=1,m=1
- f3=6.2236c/d l=1,m=-1 6.2438c/d l=1,m=0 6.2629c/d l=1,m=1
- f4=7.8982c/d l=1,m=-1 7.9138c/d l=1,m=0 7.9299c/d l=1,m=1

+low-frequency modes: fA=0.433c/d fB=0.614c/d

 \rightarrow v Eri is both a β Cephei and a SPB star

Position in the HR diagram: logT_{eff}=[4.33,4.38] logL=[3.6,4.18]

Metallicity: [0.0083,0.0127] (Morel et al. 2006)

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Fitting of 1 frequency: fixes the age (or X_c) Fitting of two frequencies: for each X, α_{ov} : M-Z relation Fitting of three frequencies: for each X, α_{ov} one M and one Z Fitting of four frequencies: for each X, one α_{ov} , one M, and one Z

The solution(s) has to fit in the error box in the HR diagram and the observed modes have to be excited

Previous studies of v Eri

- Pamyathnykh et al. 2004: fit 3 frequencies
 - Opal opacities, GN93, Opal eq. of state
 - Solution: X=0.70 (fixed), α_{ov} =0 and 0.1 (fixed), Z=0.015, M=9.8 and 9.2
 - Only 2 excited frequencies (I=0 p1 and I=1 g1)
 - Ad-hoc enhancement of iron in excitement region: 4 modes excited
 - Problems remain for the low-frequency high-order g modes
- Ausseloos et al. 2004: fit 4 frequencies
 - Opal opacities, GN93, CEFF eq. of state
 - Solution: X=0.70 (fixed), α_{ov} =0.3, Z=0.016, M=7.8

BUT: Too cold (outside error box) AND none of the four frequencies is excited

New analysis of v Eri

• We re-analyze v Eri using

- new abundances (AGS05)
- Neon from Cunha et al 2006
- OP opacities

• For 2 values of X:

- X=0.7211 (solar calibration with the new abundances)
- X=0.70 (value used in previous studies)

New fitting of v Eri for X=0.7211



X=0.7211
Z=0.021
≃ α_{ov}=0.22

- M=9.1
- Red: I=0
- Green: I=1
- solution: at an avoided crossing

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New fitting of v Eri

- X=0.7211; Z=0.021; α_{ov}=0.22; M=9.1
 Y=0.258
- X=0.70; Z=0.022; α_{ov}=0.22; M=8.9
 Y=0.278



Fitting of four frequencies: for each X, one α_{ov} , one M, and one Z : DONE

The solution(s) has to fit in the error box in the HR diagram and

the observed modes have to be excited



Position of the solutions in the HR diagram



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Fitting of four frequencies: for each X, one α_{ov} , one M, and one Z : DONE

The solution(s) has to fit in the error box in the HR diagram: DONE : OK!

and the observed modes have to be excited



Excitation of the modes

- X=0.70 and X=0.7211:
 - f1 (I=0 p1), f2 (I=1 g1), f3 (I=1 p2) are excited;
 - f4 (I=1 p3) not excited
 - low-frequency high order g modes excited in range 0.55-0.91 c/d (obs: 0.43 c/d and 0.61 c/d)

Fitting of four frequencies: for each X, one α_{ov} , one M, and one Z : DONE

The solution(s) has to fit in the error box in the HR diagram: DONE : OK!

and the observed modes have to be excited DONE: almost OK!



Conclusions

- New abundances and OP opacities help solve the problems of vEri.
- BUT some problems remain:
 - Z higher than observed (diffusion?); independent of X!
 - highest frequency mode not excited (Fe accumulation?)
 - range of excited high-order g modes