Effects of change in the metal mixture on the asteroseismology of β Cep variables
Revised CNO abundances

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Revised CNO abundances

New determinations of the solar photospheric abundances by means of a realistic time-dependent, 3D, hydrodynamical model of the solar atmosphere has led to a downward revision of the abundances of C, N, O and Ne [1,2] We have investigated the effects of this change on the modelling of two β Cephei variables previously studied with a standard metal mixture. The table gives the number abundances used, in the usual logarithmic scale where $\log A_H = 12$.

Element	$\log A$	
	standard	revised
C	8.55	8.41
N	7.97	7.80
O	8.87	8.66
Ne	8.08	7.84

Methodology of our seismic modelling

For both EN (16) Lacertae and HD129929, the frequencies of three modes are known. The degrees ℓ of these modes have been determined by photometric and spectroscopic methods. A number of evolutionary sequences, covering the region of the HR diagram where the β Cep variables are observed, are computed. Each evolutionary track is characterized by a choice of the following parameters : M, X, Z and α_{ov} (overshooting parameter). X was kept constant, X=0.70 (more precisely, our analysis shows that a change in X is more or less equivalent to a change in Z). In the range of observed frequencies, the theoretical frequency spectrum is rather sparse and the radial order n of the observed modes can be determined unambiguously. The fitting of a first frequency determines the age of the model, i.e. a point on each track in the HR diagram. Then the fitting of a second frequency determines a relation between M, Z and α_{ov} (plotted as a relation between M and Z for different α_{ov}). Finally the fitting of the third frequency and the constraints on Z coming from the spectroscopy and the non adiabatic analysis allow us to constrain the mass and possibly the overshooting parameter.

references

[1] N. Grevesse. Revised solar abundances, private communication (2003).
[2] M. Asplund, N. Grevesse, A.J. Sauval, C.A. Priesto, D. Kiselman. Line formation in solar granulation. IV. [O I], O I and OH lines and the photospheric O abundance. A&A, 417, 751–758 (2004).

EN (16) Lacertae

Stellar parameters

$\log T_{eff} \in [4.33, 4.36]$
$\log g \in [3.7, 3.9]$
$Z \in [0.014, 0.030]$
$V_{rot} \in [35, 135]$ km s^{-1}

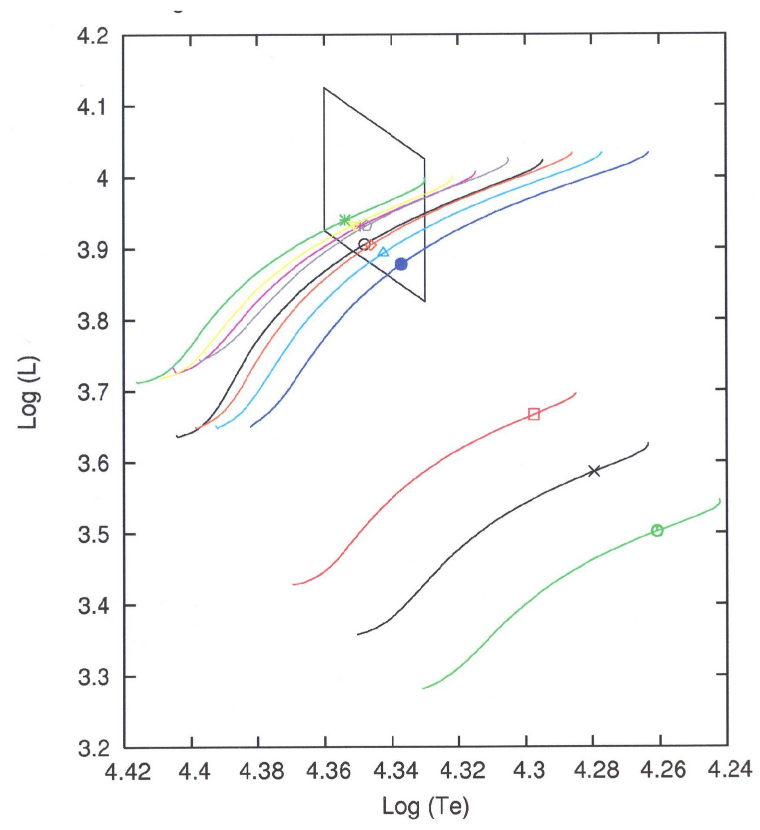
Observed frequencies [1]

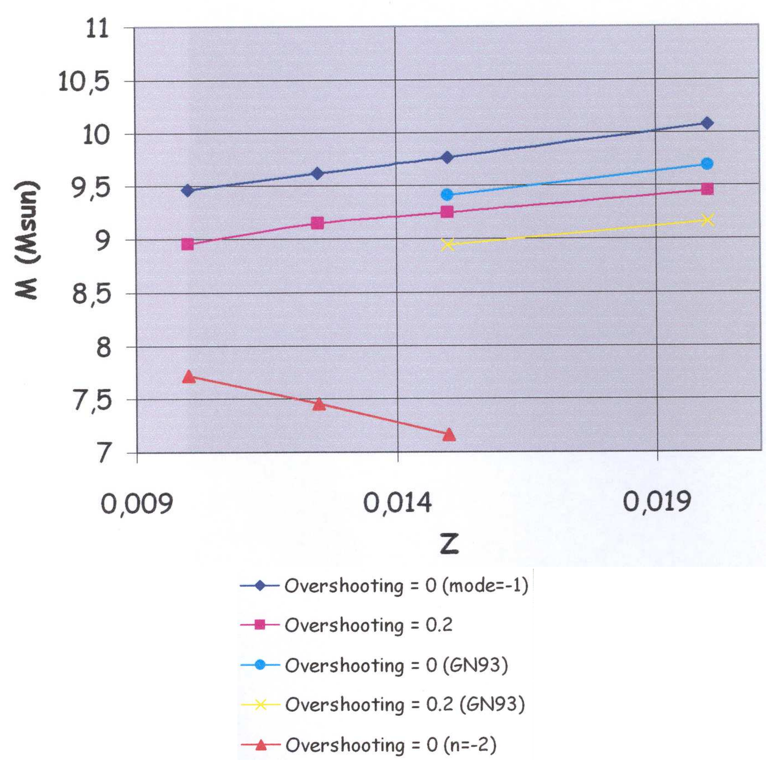
frequency (cd^{-1})	identification
$f_3 = 5.50259$	$\ell = 1,\ m = ?\ \ g_1$
$f_2 = 5.85290$	$\ell = 2,\ m = 0\ \ g_1$
$f_1 = 5.91128$	$\ell = 0\ \ p_1$

Modelling

With the revised metal abundances, two disjoint sets of solutions are obtained when fitting the radial and the $\ell = 2$ modes. In both sets f_1 is fitted to the fundamental radial mode (p_1) but f_2 is fitted to the $\ell = 2$ g_1 mode in the first set and to the $\ell = 2$ g_2 mode in the second set. However the solutions of this second set must be rejected for two reasons : (1) the evolutionary tracks avoid the error box in the HR diagram, (2) at least one of the frequencies f_1 or f_2 is not excited. The main conclusions are summarized in the following table.

Parameter	standard metals	revised CNO
Z	0.015 – 0.020	0.0125 – 0.020
M/M$_\odot$	9.0 – 9.7	8.95 – 10.08





References

[1] C. Aerts, H. Lehmann, M. Briquet, R. Scuflaire, M.-A. Dupret, J. De Ridder, A. Thoul. Spectroscopic mode identification for the β Cephei star EN (16) Lacertae. A&A, 399, 639–645, 2003.
[2] A. Thoul, C. Aerts, M.-A. Dupret, R. Scuflaire, S.A. Korotin, I.A. Egorova, S.M. Andrievsky, H. Lehmann, M. Briquet, J. De Ridder, A. Noels. Seismic modelling of the β Cep star EN (16) Lacertae. A&A, 406, 287–292, 2003.

HD 129929

Stellar parameters

$\log T_{eff} \in [4.35, 4.38]$
$\log g \in [3.87, 3.94]$
$Z \in [0.014, 0.022]$
Slow rotation $V_e \leq 13$ km s^{-1}

Observed frequencies [1]

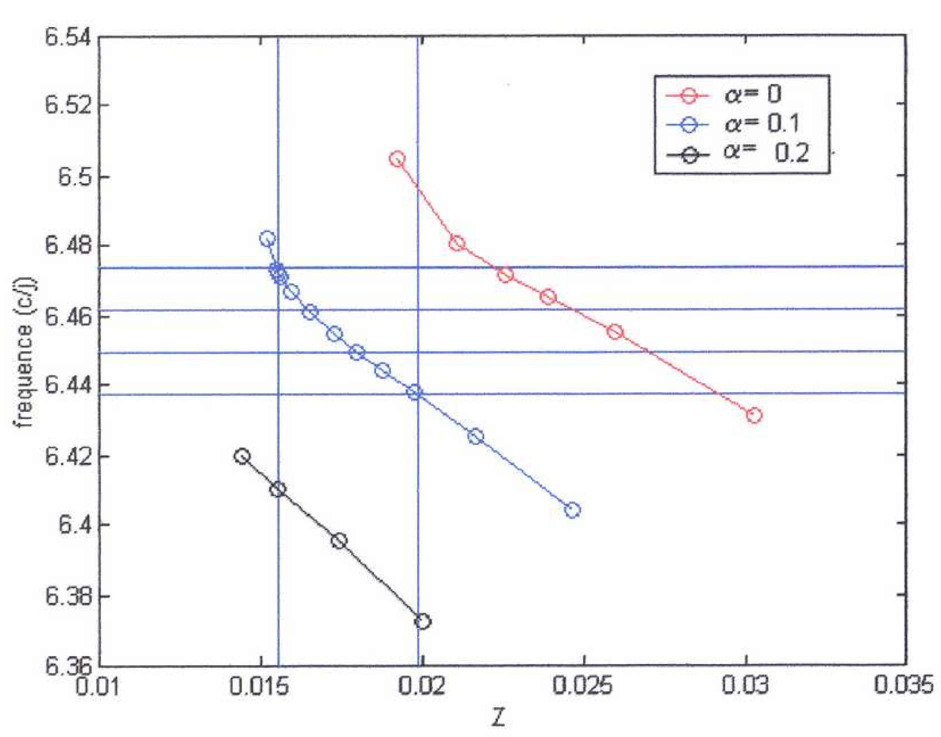
frequency (cd^{-1})	identification
$f_3 = 6.449590$	$\ell = 2,\ m = ?\ \ g_1$
$f_1 = 6.461699$	$\ell = 2,\ m = ?\ \ g_1$
$f_5 = 6.590940$	$\ell = 0\ \ p_1$
$f_6 = 6.966172$	$\ell = 1,\ m = -1\ \ p_1$
$f_2 = 6.978305$	$\ell = 1,\ m = 0\ \ p_1$
$f_4 = 6.990431$	$\ell = 1,\ m = 1\ \ p_1$

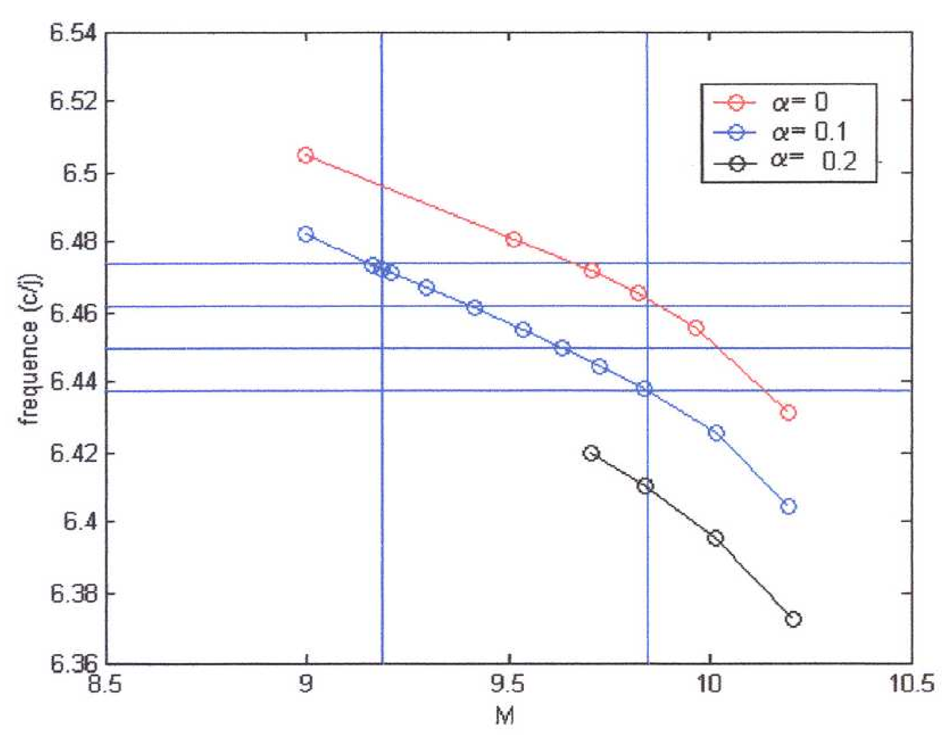
These frequencies give two rotational splittings

Mode	$\Delta\nu$ (c/d)
$\ell = 1,\ p_1$	0.012130
$\ell = 2,\ g_1$	0.012109

Modelling

Modelling with the standard metal mixture provides the constraints $0.017 < Z < 0.022$, $9 < M < 9.5$ and $0.05 < \alpha_{ov} < 0.15$ [2,3]. With the revised CNO abundances, we get a similar range for the metallicity, a slightly different mass range, $9.2 < M < 9.85$ and the same constraint on the overshooting parameter.





Interpretation of the rotational splittings

The kernels for the computation of the rotational splittings do not probe the convective core of the models [2,3]. But they are different enough to give two independent constraints on the behaviour of the rotation curve inside the envelope. We have modelled this behaviour by a linear law. Our conclusions are insensitive to the adopted metal mixture. The table gives the rotation frequency ω_S at the surface and its derivative with respect to $x = r/R$

	ω (c/d)	$d\omega/dx$ (c/d)
standard metal	0.0071334	-0.0185619
revised CNO	0.0072580	-0.0181254

References

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[3] M.-A. Dupret, A. Thoul, R. Scuflaire, J. Daszyńka-Daszkiewicz, C. Aerts, P.-O. Bourge, C. Waelkens, A. Noels. Asteroseismology of the β Cep star HD 129929. II. Seismic constraints on core overshooting, internal rotation and stellar parameters. A&A, 415, 251–257, 2004.