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

Fe enhanced

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Enhanced Fe abundance

It is well known that iron plays a critical role in the driving mechanism of β Cephei variables. In their study of the β Cephei variable ν Eridani, Pamyatnykh et al. [1] had to invoke an overabundance of Fe in the driving zone of the star. We have investigated the effects of an overabundance of the iron peak elements on the modelling of two β Cephei variables previously studied with a standard metal mixture.

Methodology of our seismic modelling

For the β Cephei stars HD129929 and ν Eridani, several frequencies of oscillation have been detected through long-term monitoring campaigns, and several modes have been identified using photometric and spectroscopic methods. For some of these modes of oscillation, multiplets have been identified. We computed evolutionary sequences, covering the region of the HR diagram where these stars are observed. Each evolutionary track is characterized by a choice of the following parameters : M, X, Z and α_{ov} (overshooting parameter). 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 one 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 value of Z. Thus we have, for fixed values of X and α_{ov}, a relation between M and Z. Finally, we use the additional frequencies to get information on the overshooting parameter α_{ov} and X.

Reference

[1] A.A. Pamyatnykh, G. Handler, W.A. Dziembowski. Asteroseismology of the β Cephei star ν Eridani : Interpretation and applications of the oscillation spectrum. Submitted to MNRAS, astro-ph/0402354.

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]

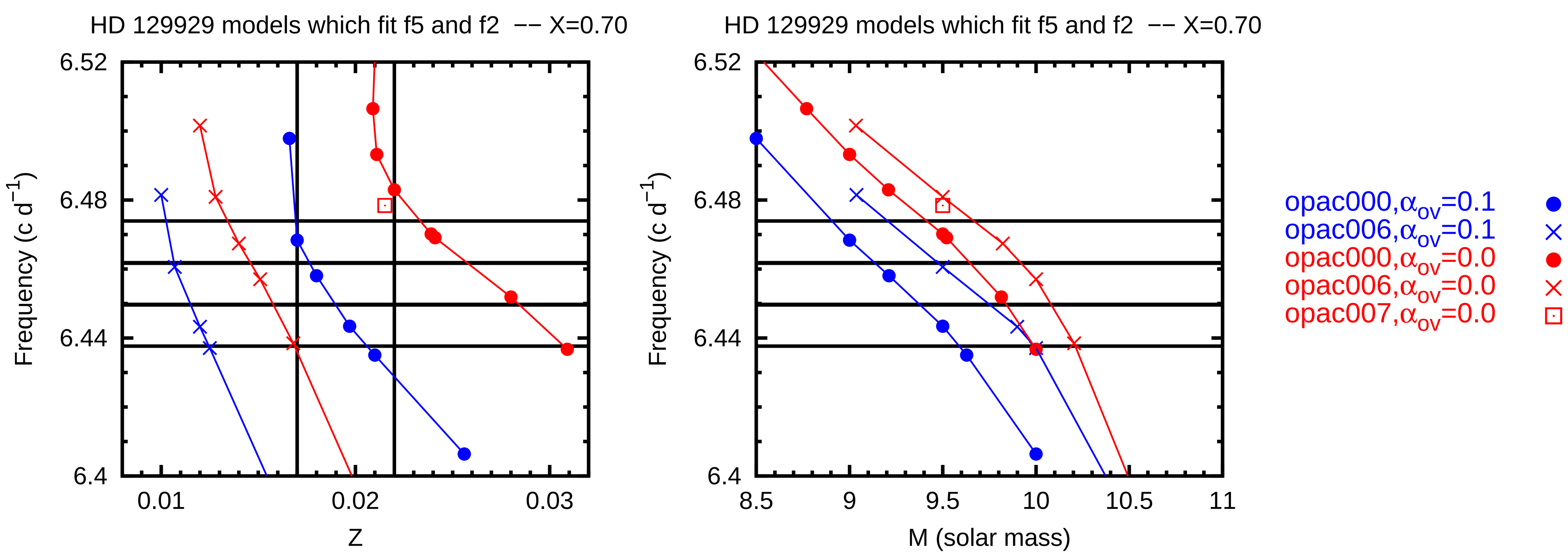
frequency (c d^{-1})	identification	
$f_3 = 6.449590$	$\ell = 2,\ m = ?$	g_1
$f_1 = 6.461699$	$\ell = 2,\ m = ?$	g_1
$f_5 = 6.590940$	$\ell = 0$	p_1
$f_6 = 6.966172$	$\ell = 1,\ m = -1$	p_1
$f_2 = 6.978305$	$\ell = 1,\ m = 0$	p_1
$f_4 = 6.990431$	$\ell = 1,\ m = 1$	p_1

Rotational splittings

The kernels for the computation of the rotational splittings do not probe the convective core of the models. They are however different enough to give two independent informations on the behaviour of the rotation curve inside the envelope. We have modelled this behaviour by a linear law, and we have shown that there is differential rotation in the envelope of the star [2,3]. This conclusion is not affected by changes in the metal mixture ; we get very similar rotation laws in both cases.

Modelling with standard stellar mixture [2,3] (opac000) and with an iron enhanced (factor 5) mixture (opac006)

The constraints we get on the mass and the overshooting parameter using the standard solar mixture are : $0.017 < Z < 0.022$, $9 < M < 9.5$, $0.05 < \alpha_{ov} < 0.15$. Using an iron-enhanced mixture, we get a much lower metallicity, a similar range of masses, and no constraint on the overshooting.



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[1] C. Aerts, C. Waelkens, J. Daszyńska-Daszkiewicz, M.-A. Dupret, A. Thoul, R. Scuflaire, K. Uytterhoeven, E. Niemczura, A. Noels. Asteroseismology of the β Cep star HD 129929. I. Observations, oscillation frequencies and stellar parameters. A&A, 415, 241–249, 2004.
[2] C. Aerts, A. Thoul, J. Daszyńska, R. Scuflaire, C. Waelkens, M.-A. Dupret, E. Niemczura, A. Noels. Asteroseismology of HD 129929 : Core Overshooting and Nonrigid Rotation. Science, 300, 1926–1928, 2003.
[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.

ν Eridani

Stellar parameters [4]

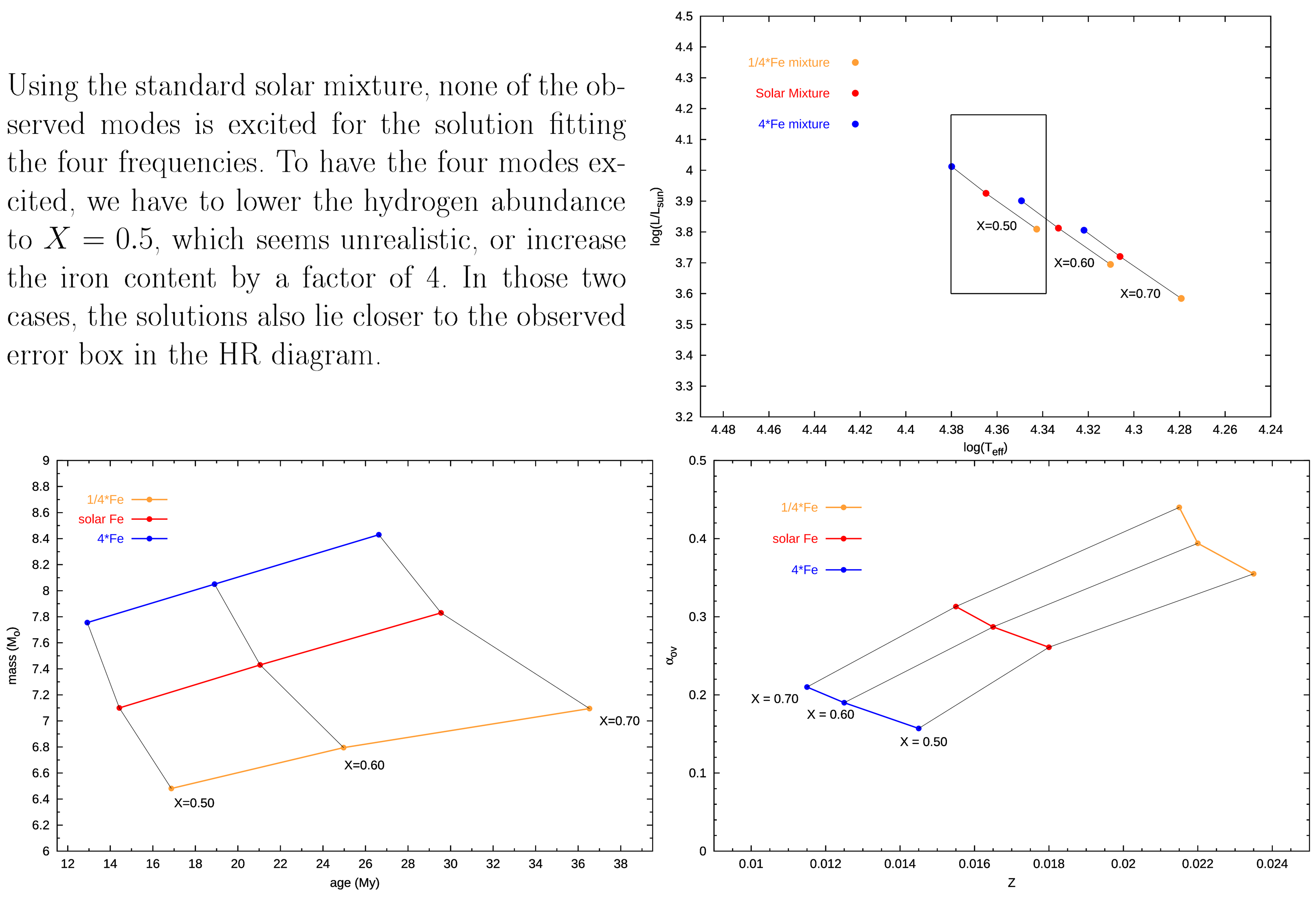
$\log T_{eff} \in [4.34, 4.38]$
$\log L \in [3.6, 4.18]$

Observed frequencies [2,3,4]

	frequency (c d^{-1})	identification	
	5.62006	$\ell = 1,\ m = -1$	
f_2	5.63716	$\ell = 1,\ m = 0$	g_1
	5.65393	$\ell = 1,\ m = 1$	
f_1	5.76327	$\ell = 0$	p_1
	(6.221)		
f_3	6.24408	$\ell = 1$	
	6.26205	$\ell = 1$	
f_4	7.89780	$\ell = 1$	
	(7.914)		

Modelling [5]

Using the standard solar mixture, none of the observed modes is excited for the solution fitting the four frequencies. To have the four modes excited, we have to lower the hydrogen abundance to $X = 0.5$, which seems unrealistic, or increase the iron content by a factor of 4. In those two cases, the solutions also lie closer to the observed error box in the HR diagram.



Mixture	X	α_{ov}	Z	$M(M_\odot)$	age (My)
1/4 Fe$_\odot$	0.70	0.44	0.0215	7.095	36.534
	0.60	0.394	0.022	6.795	24.971
	0.50	0.355	0.0235	6.481	16.868
Fe$_\odot$	0.70	0.313	0.0155	7.83	29.554
	0.60	0.287	0.0165	7.43	21.045
	0.50	0.261	0.018	7.1	14.426
4 Fe$_\odot$	0.70	0.21	0.0115	8.43	26.627
	0.60	0.19	0.0125	8.05	18.904
	0.50	0.157	0.0145	7.755	12.919

Values of the stellar parameters α_{ov}, Z, M and age derived by fitting f_1, f_2, f_3 and f_4 for models with different values of X and Fe.

References

[1] A.A. Pamyatnykh, G. Handler, W.A. Dziembowski. Asteroseismology of the β Cephei tar ν Eridani : Interpretation and applications of the oscillation spectrum. Submitted to MNRAS, astro-ph/0402354.
[2] G. Handler et al. Asteroseismology of the β Cephei star ν Eridani. I. Photometric observations and pulsational frequency analysis. MNRAS, 347, 454–462 (2004).
[3] C. Aerts et al. Asteroseismology of the β Cephei star ν Eridani. II. Spectroscopic observations and pulsational frequency analysis. MNRAS, 347, 463–470 (2004).
[4] J. De Ridder, J.H. Telting, L.A. Balona, et al. Asteroseismology of the β Cephei star ν Eridani. III. Accepted for publication in MNRAS.
[5] M. Ausseloos et al. Asteroseismology of the β Cephei star ν Eridani. IV. Matching stellar models to oscillation data., in preparation.