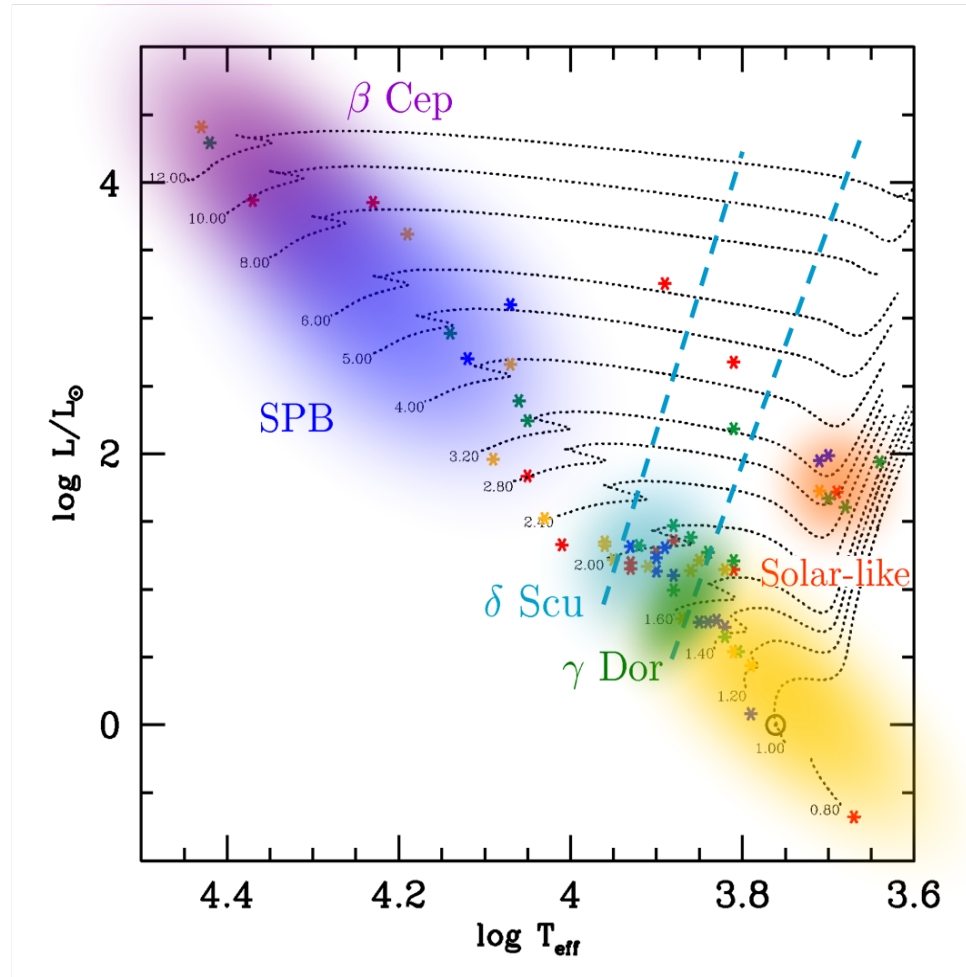


Testing the effects of opacity and the chemical mixture on the excitation of pulsations in B stars

Sébastien Salmon

Collaborators : J. Montalbán, T. Morel, A. Miglio, M-A.
Dupret, A. Noels

Pulsations across the HR diagram



K mechanism

OP / OPAL

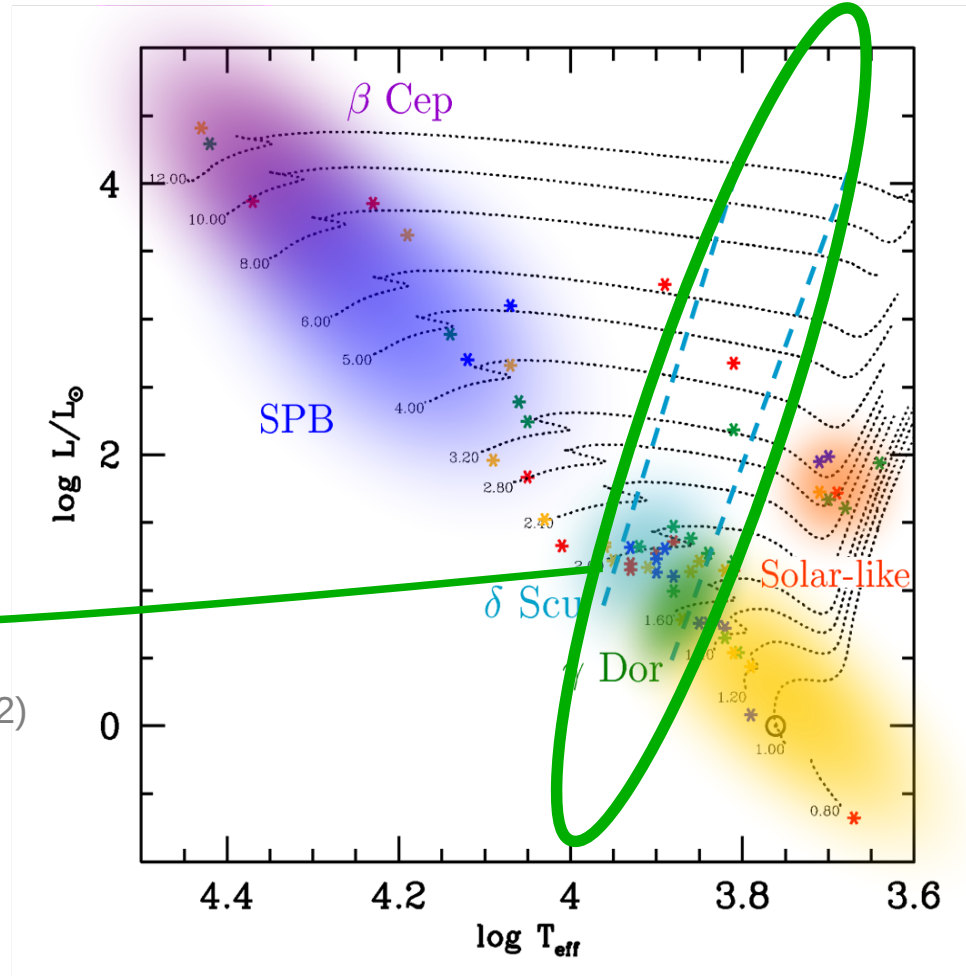
β Cephei - SPB

Ni opacity

The Kappa mechanism

Second He partial ionization zone

(see Zhekavin 1959, Baker & Kippenhahn 1962)



K mechanism

OP / OPAL

β Cephei - SPB

Ni opacity

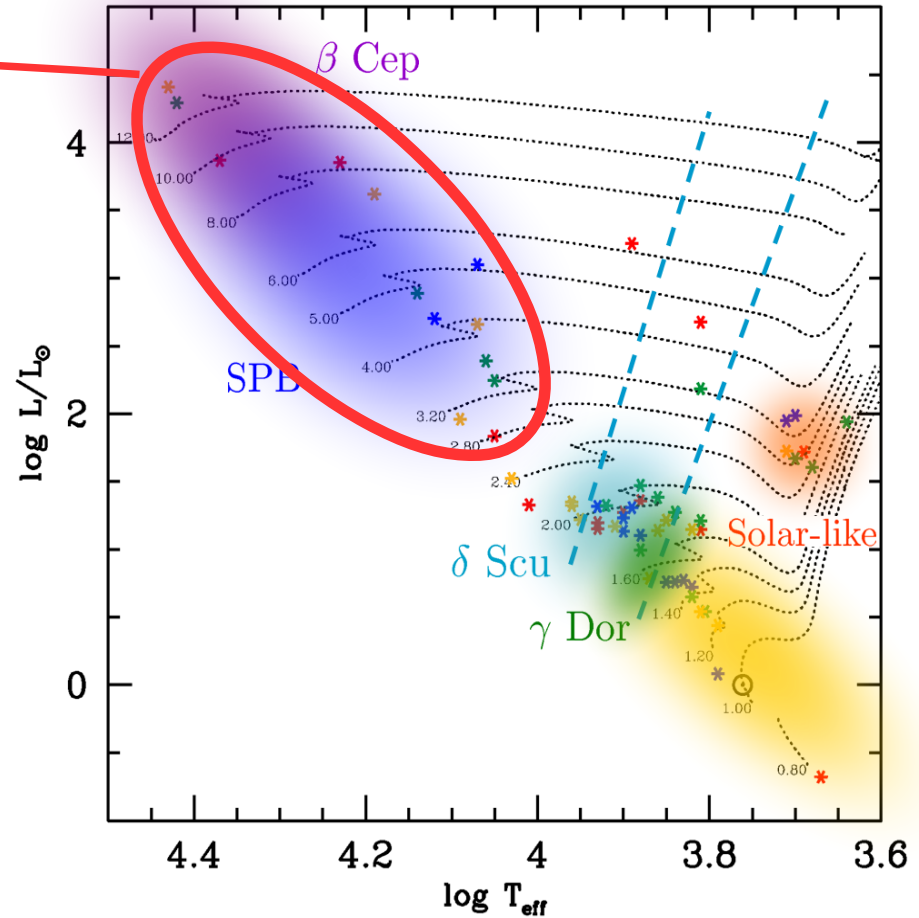
The Kappa mechanism

Iron group opacity bump

β Cephei : main-sequence B stars ;
low-order p and g modes ; $P \sim 2-8$ h

SPB : less massive ;
high-order g modes ; $P \sim 1-3$ d

(see Moskalik & Dziembowski 1992;
Cox et al. 1992;
Dziembowski & Pamyatnykh 1993;
Dziembowski, Moskalik & Pamyatnykh 1993)



K mechanism

OP / OPAL

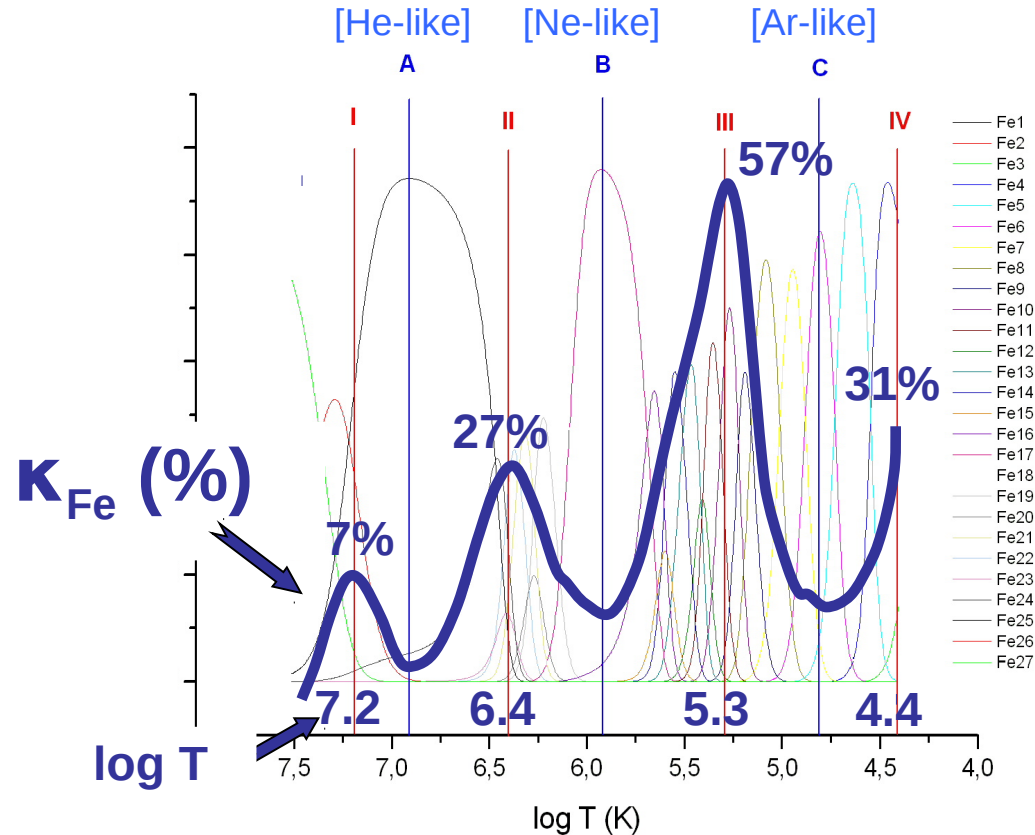
β Cephei - SPB

Ni opacity

The iron bump

Very high number of atomic transitions of iron-group elements

e.g. for Fe



K mechanism

OP / OPAL

β Cephei - SPB

Ni opacity

Historical review...

Group	Date	Chemical elements	Physics input	Result/Trouble
Los Alamos (first release by Cox & Stewart 1965)	Before 1991	12 (H-He-C-N-O-Ne- Na-Mg-Al-Si-Ar-Fe)	Missed bound-bound transitions of heavy elements	Cepheids mass problem
OPAL (Rogers & Iglesias 1991,92)	1991	14 (H-He-C-N-O-Ne- Na-Mg-Al-Si-S-Ar- Ca-Fe)	Bound-bound transitions of heavy elements + spin-orbit interaction	300 % increase of iron bump of opacity : κ mech. of β Ceph / SPBs
OP (Seaton et al. 1994)	1994	17 (OPAL ones + Ni-Cr-Mn)	Iron-group elements	Iron bump \neq from OPAL
OPAL (Iglesias & Rogers 1996)	1996	21 (+ P-Cl-K-Ti-Ni-Cr-Mn)	More elements + improved EoS	
OP (Badnell et al. 2005)	2005	17	New treatment of inner-shell transitions	Iron bump enhanced by 18%

K mechanism

OP / OPAL

β Cephei - SPB

Ni opacity

... also for the chemical mixture

Chemical mixture: from GN93 (Grevesse & Noels 1993) to AGS05 (Asplund & Grevesse & Sauval 2005)

Element	Z	GN93	AGS05
C	6	8.55 ± 0.05	8.39 ± 0.05
N	7	7.97 ± 0.05	7.78 ± 0.06
O	8	8.87 ± 0.04	8.66 ± 0.05
Ne	10	8.07 ± 0.06	7.84 ± 0.06
Na	11	6.55 ± 0.03	6.17 ± 0.04
Mg	12	7.58 ± 0.05	7.53 ± 0.09
Al	13	6.47 ± 0.07	6.37 ± 0.06
Si	14	7.55 ± 0.05	7.51 ± 0.04
P	15	5.45 ± 0.04	5.36 ± 0.04
S	16	7.21 ± 0.06	7.14 ± 0.05
Cl	17	5.50 ± 0.30	5.50 ± 0.30
Ar	18	6.60 ± 0.14	6.18 ± 0.08
K	19	5.12 ± 0.13	5.08 ± 0.07
Ca	20	6.36 ± 0.02	6.31 ± 0.04
Ti	22	5.04 ± 0.02	4.90 ± 0.06
Cr	24	5.67 ± 0.03	5.64 ± 0.10
Mn	25	5.30 ± 0.03	5.30 ± 0.03
Fe	26	7.51 ± 0.01	7.45 ± 0.05
Ni	28	6.25 ± 0.04	6.25 ± 0.04
Z/X		.0244 ± .0014	.0165 ± .001

Abundances are in units of $\log_{10}(A/H) + 12$.

→ C, N, O ↘ 35-45%

→ For a given Z, Fe ↗ 20%

AGS05 in combination with OP enlarges instability strip and domain of frequency (Miglio et al. 2007)

!

K mechanism

OP / OPAL

β Cephei - SPB

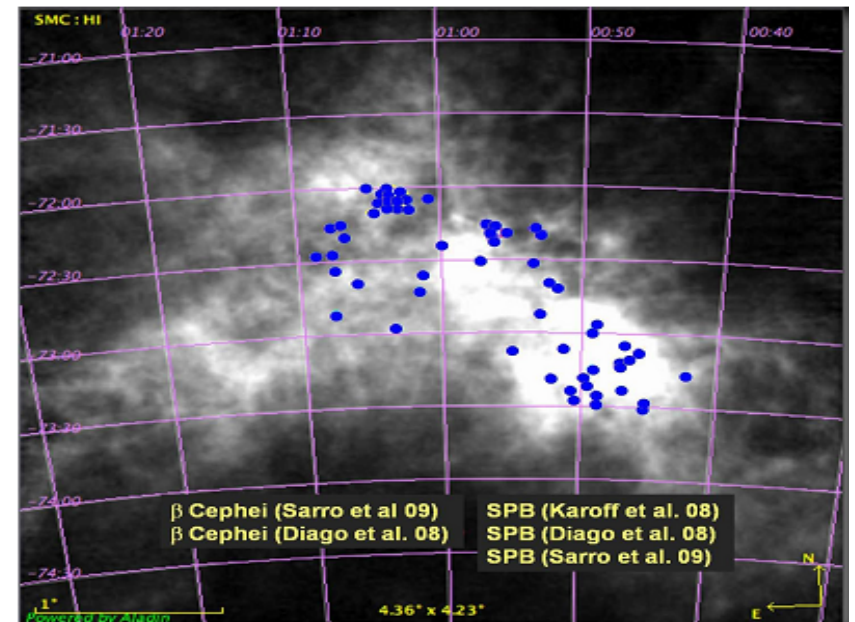
Ni opacity

Pulsating B stars : troubleshooting ?

The answer is no :

- Galactic hybrids (both β Cep/SPB pulsations) => trouble to reproduce high period modes (e.g. Pamyatnykh, Handler & Dziembowski 2004 ; Dziembowski & Pamyatnykh 2008 ; Daszynska-Daszkiewicz & Walczak 2010)
- B-type pulsators in the Magellanic Clouds $Z_{SMC}=0.0027$ and $Z_{LMC}=0.0046$ (metallicities from Buchler 2008)

Z too low for excitation of pulsations !
(e.g. Miglio et al. 2007)



K mechanism

OP / OPAL

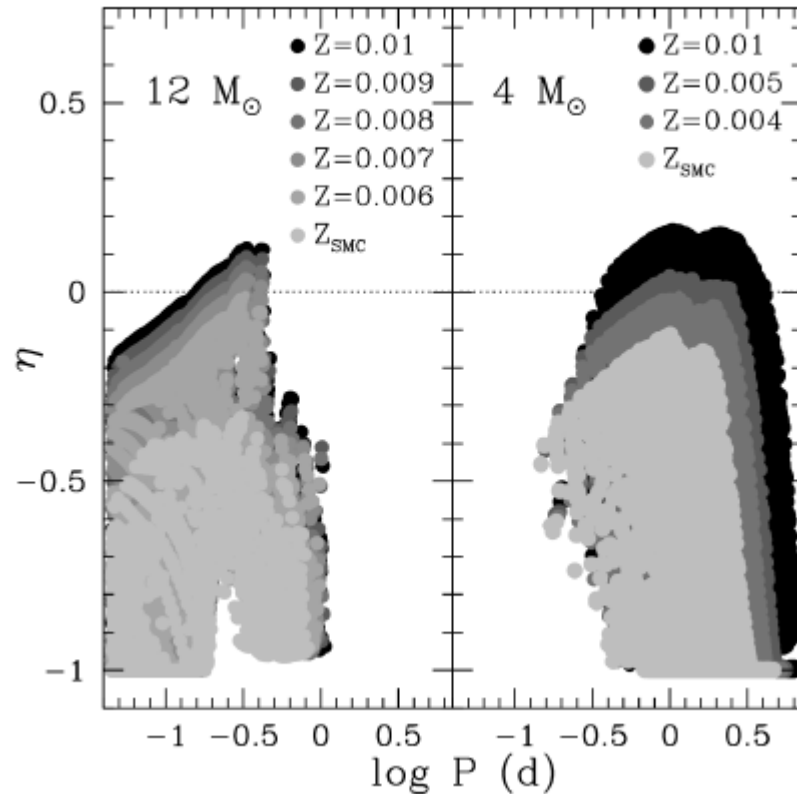
β Cephei - SPB

Ni opacity

Effect of the chemical mixture

We made a compilation (from literature) of chemical abundances of B stars for the SMC (Salmon et al. 2012)

+ a stability analysis of stellar models with that mixture



$Z_{\text{SMC}}=0.0027$

K mechanism

OP / OPAL

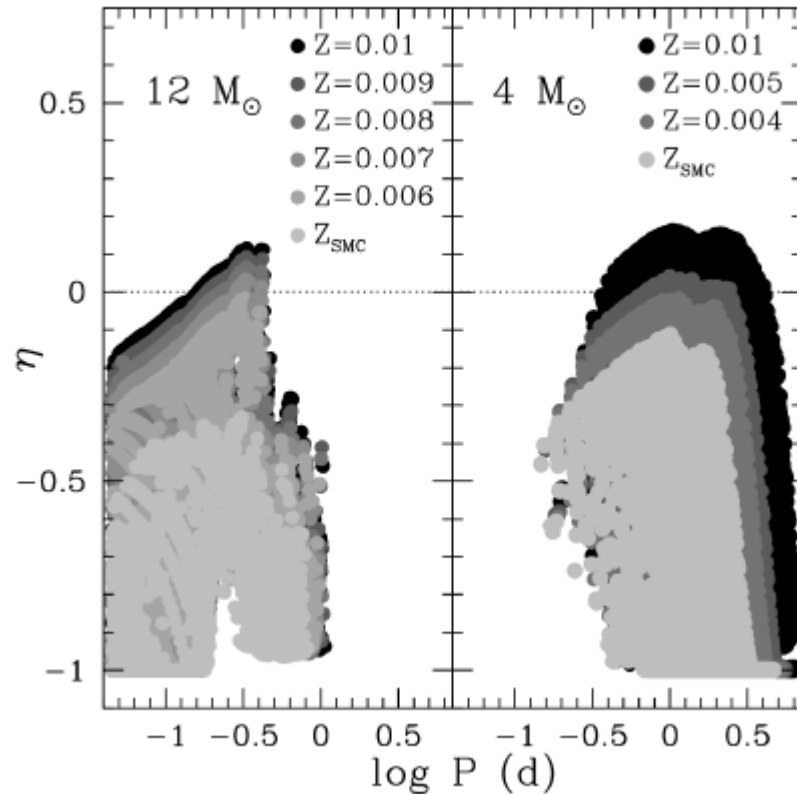
β Cephei - SPB

Ni opacity

Effect of the chemical mixture

We made a compilation (from literature) of chemical abundances of B stars for the SMC (Salmon et al. 2012)

+ a stability analysis of stellar models with that mixture



$Z_{\text{SMC}}=0.0027$

$Z \geq 0.007$ to excite β Cep modes $\sim 2.5 Z_{\text{SMC}}$

$Z > 0.004$ to excite SPB modes $\sim 1.5 Z_{\text{SMC}}$

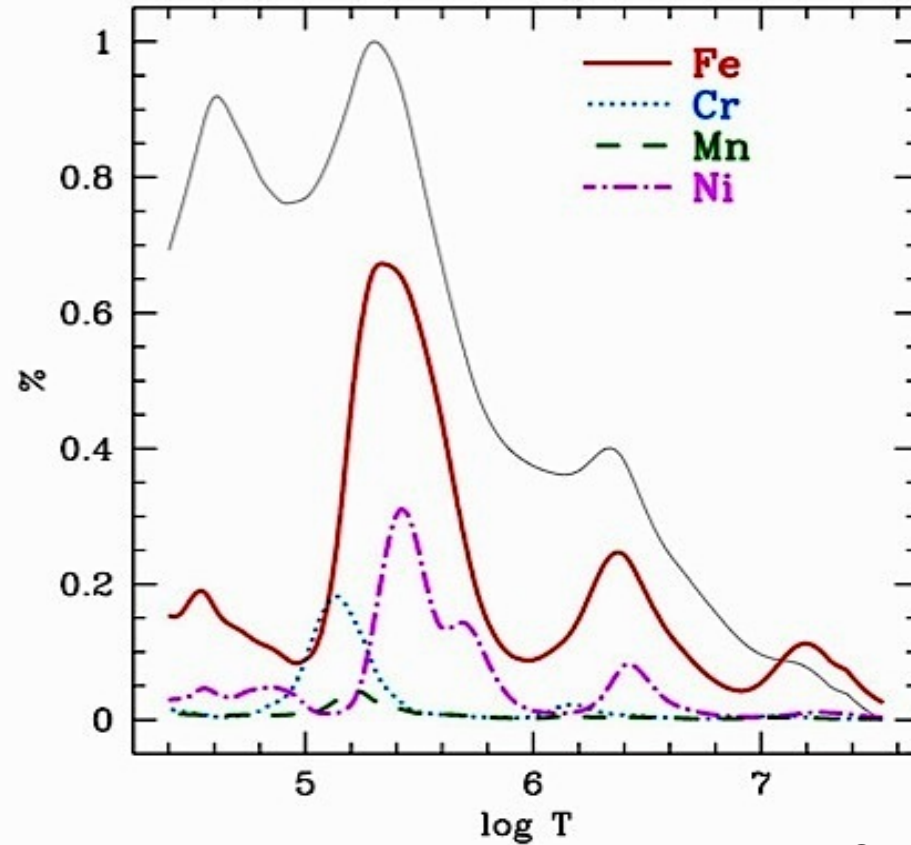
K mechanism

OP / OPAL

β Cephei - SPB

Ni opacity

Increasing the opacity



10 M_{\odot} model

K mechanism

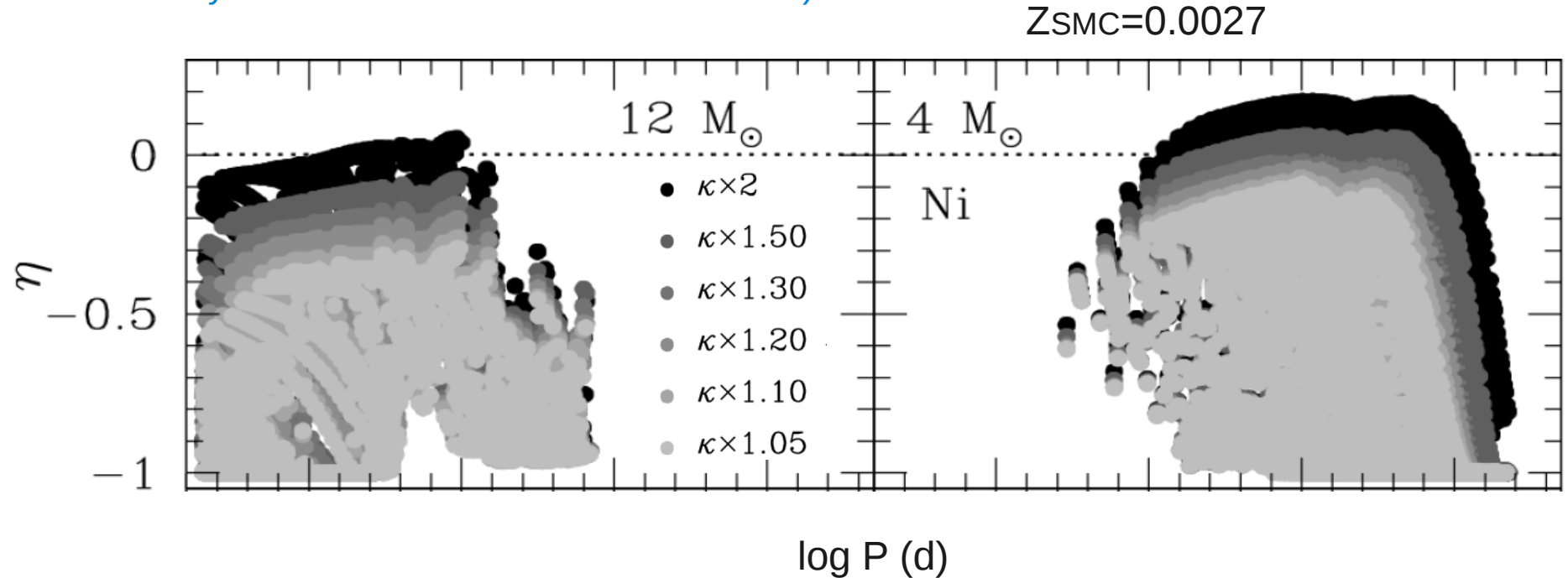
OP / OPAL

β Cephei - SPB

Ni opacity

Increasing the opacity

We made an *ad hoc* increase of the Ni opacity (also of Fe and Cr/Mn opacities, see Salmon et al. 2012 ; see also Jeffery & Saio 2006 in the case of the sdBs)



K mechanism

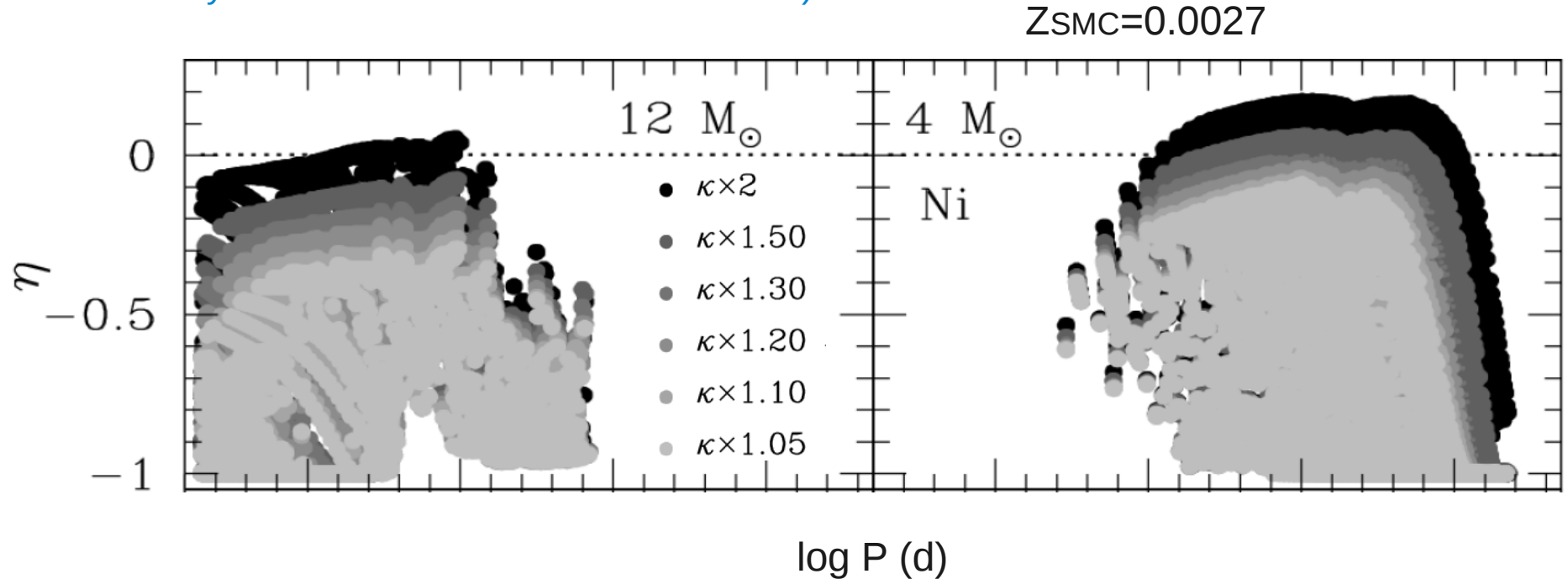
OP / OPAL

β Cephei - SPB

Ni opacity

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$\kappa \nearrow$ by 2 in the Ni region => excitation of both β Cep and SPB modes at Z_{SMC}

K mechanism

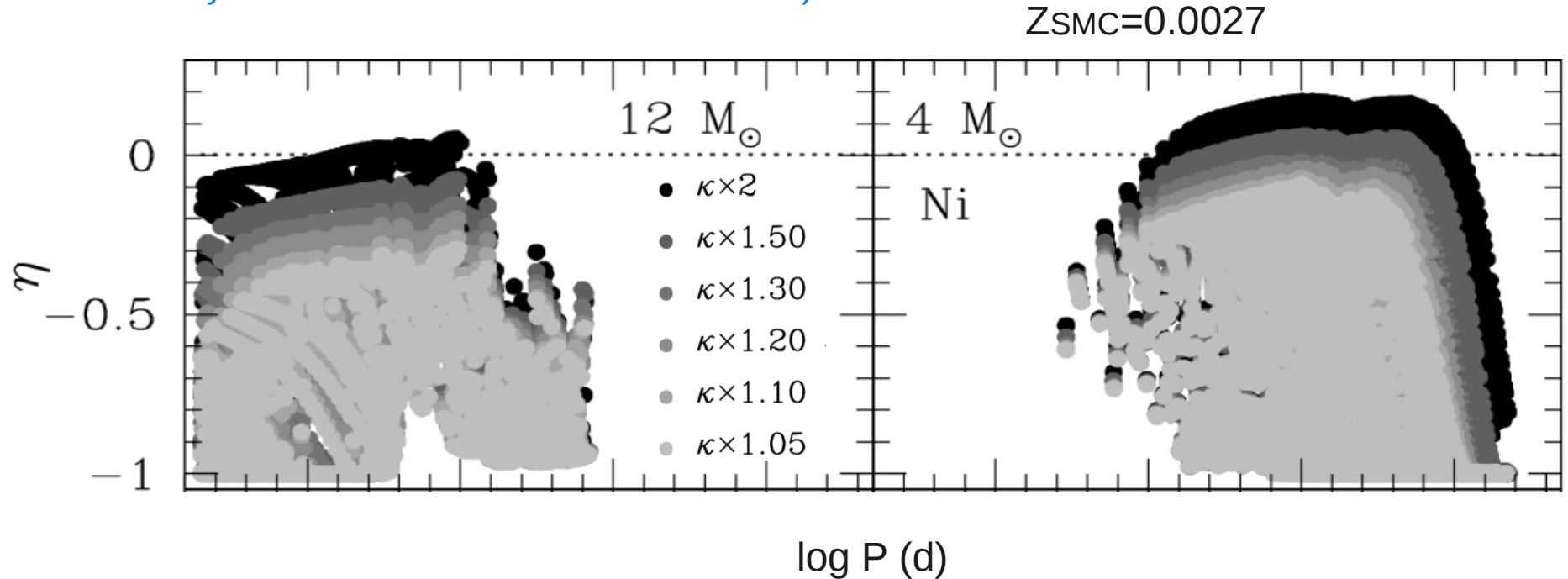
OP / OPAL

β Cephei - SPB

Ni opacity

Increasing the opacity

We made an *ad hoc* increase of the Ni opacity (also of Fe and Cr/Mn opacities, see Salmon et al. 2012 ; see also Jeffery & Saio 2006 in the case of the sdBs)



$\kappa \nearrow$ by 1.5 in the Ni region => increases instability domain to higher periods at
Z_{Galaxy}=0.014 (metallicity from Przybilla, Nieva & Butler 2008)

K mechanism

OP / OPAL

β Cephei - SPB

Ni opacity

Conclusion

An underestimation < 2 of Ni opacity could explain the difficulties encountered for B-type pulsators of the Galaxy and Magellanic Clouds

This is strengthened by the facts :

- Ni opacity is partially extrapolated from Fe opacity in OP computations
- recent results from computations of Ni opacity and plasma laboratory measurements (Turck-Chièze et al., LIAC 2012)

We thus call for a reexamination of Ni opacity computations

K mechanism

OP / OPAL

β Cephei - SPB

Ni opacity