Can We Constrain Microscopic Diffusion in Solar-like Stars? An Initial Attempt

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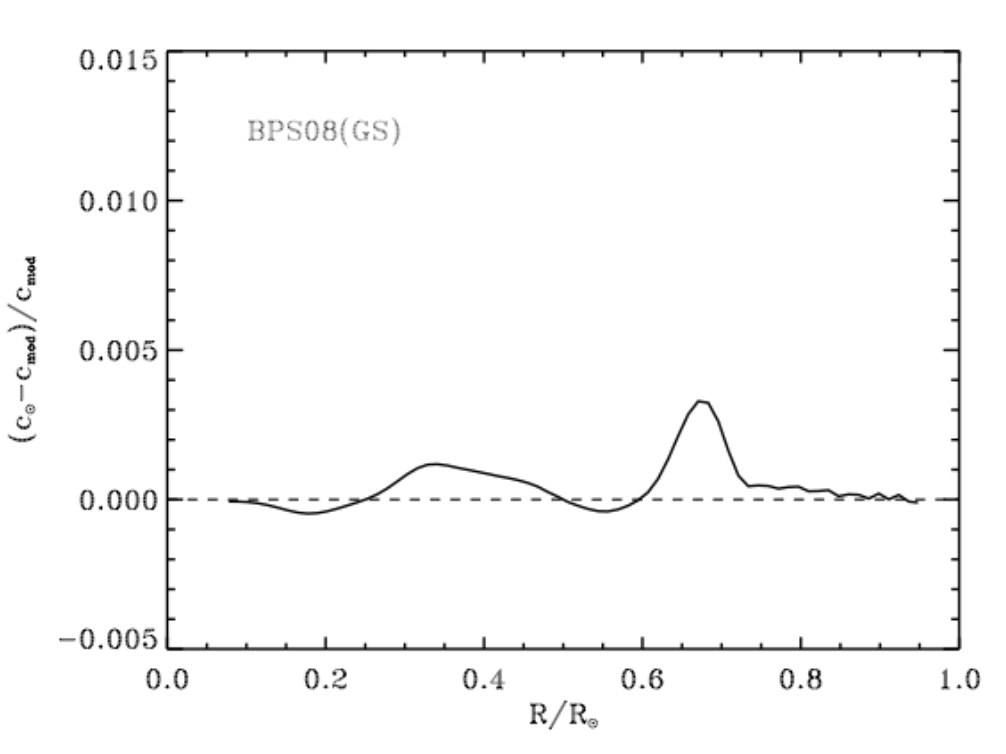
Microscopic diffusion is evident in compact objects

- **DA & DB white dwarfs**
- **sdBs**

However evidence in solar-like stars is scarce

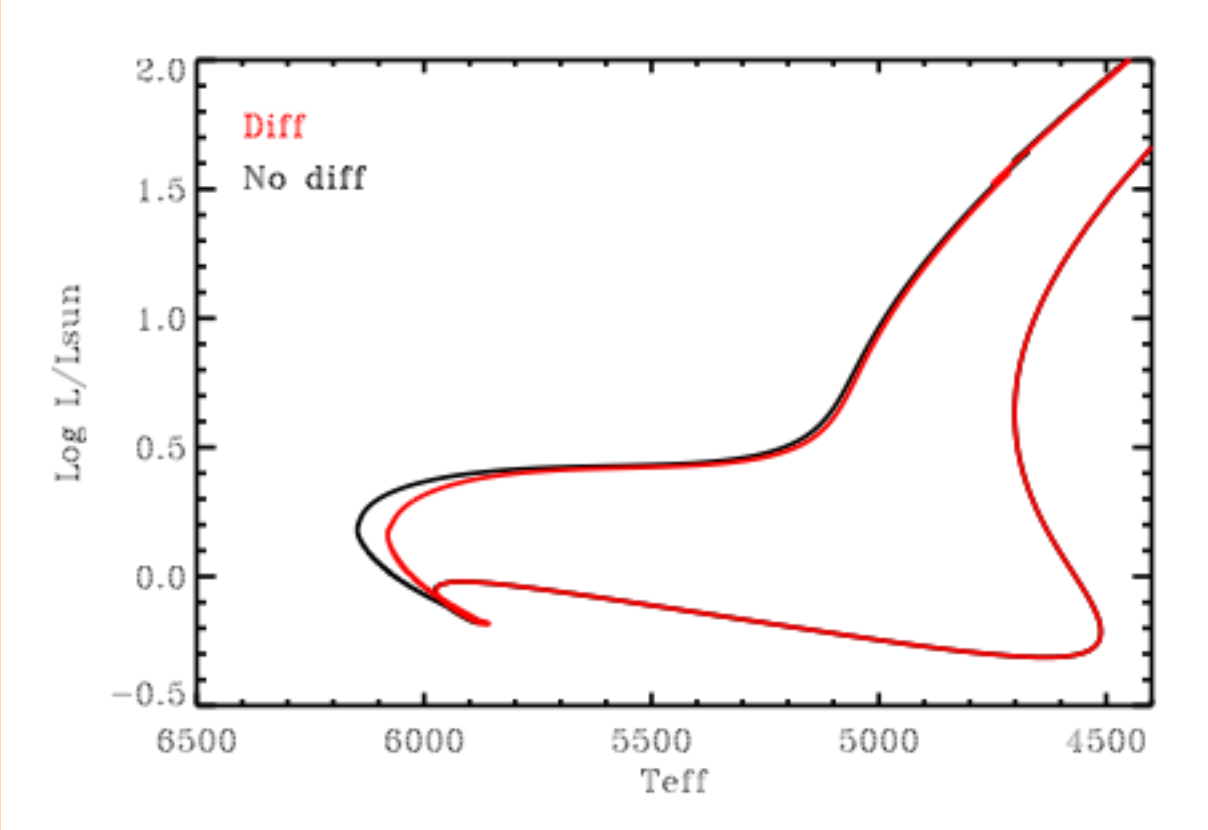
Element diffusion at work in the Sun

necessary for agreement with helioseismology (R_{CZ}, Y_S, $\triangleq c$)

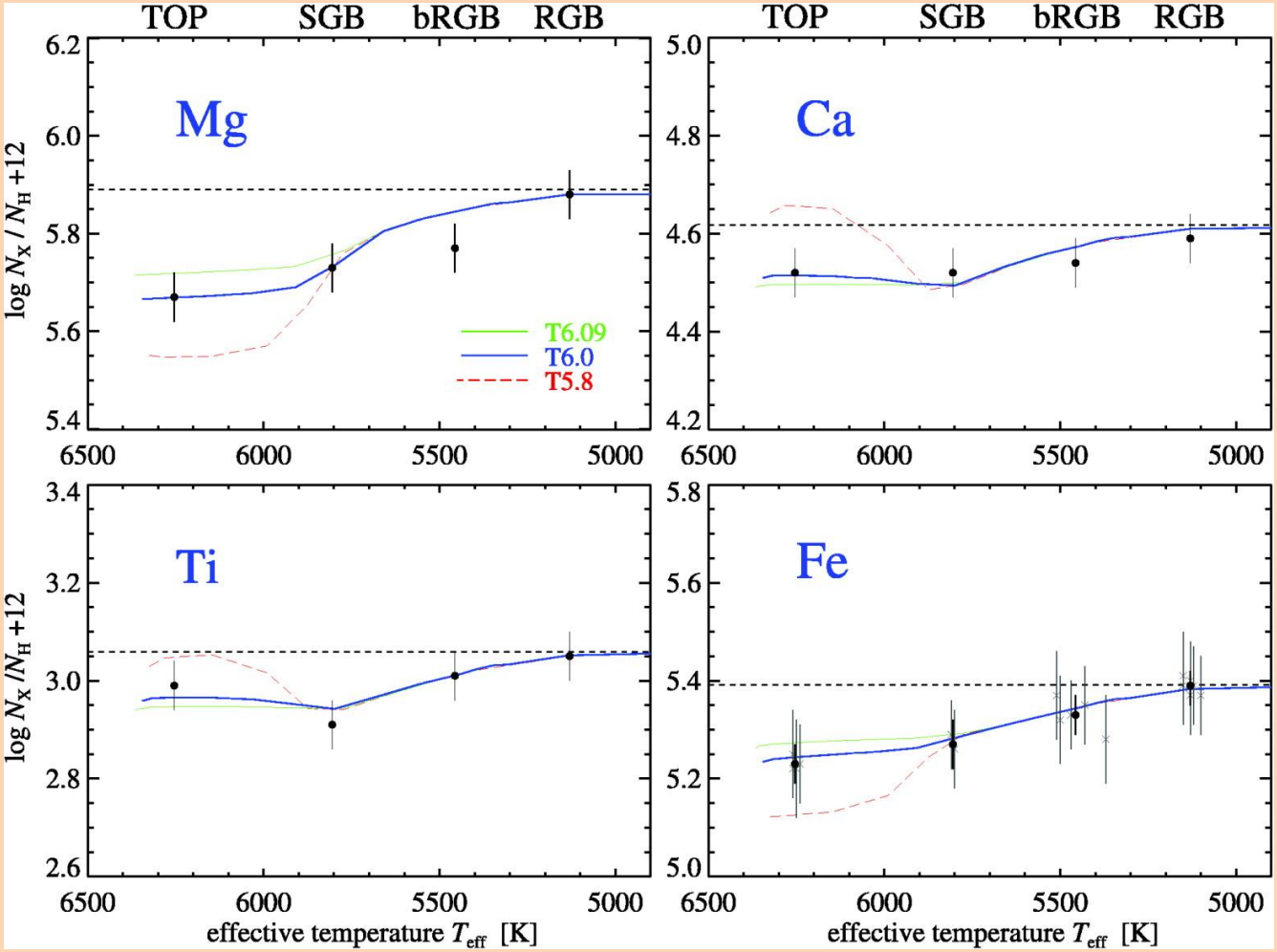


Stellar models somewhat cooler & smaller ages → change in isochrones lead to "younger" clusters in good agreement with age of Universe

M=0.96 – [Fe/H]=-0.5



“Direct” detection of microsc. diffusion in globular cluster NGC 6397?

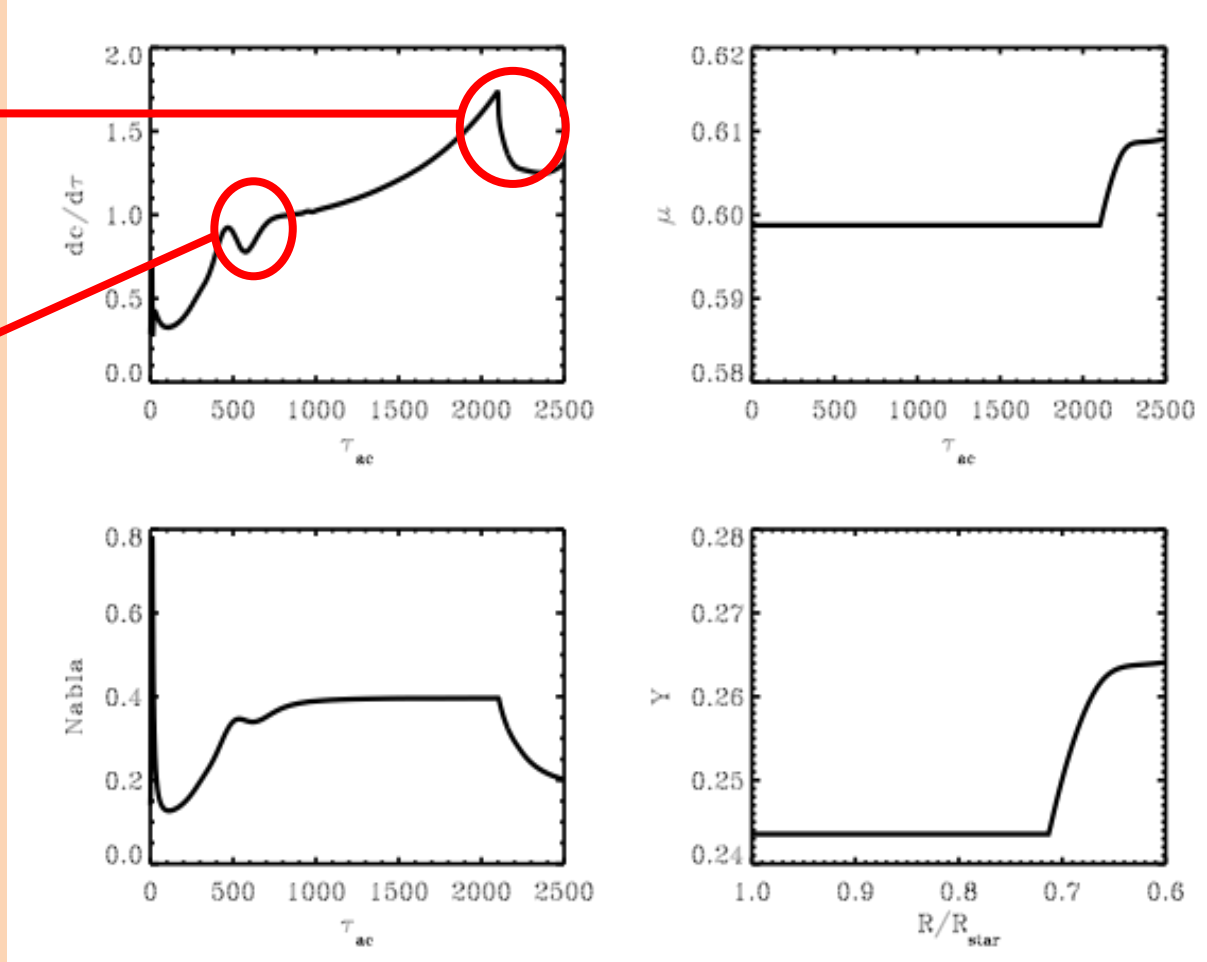


Korn et al. 2007

Basic idea: can acoustic glitches give information on diffusion?

Boundary of CE:
change in transport
+ change in ❍

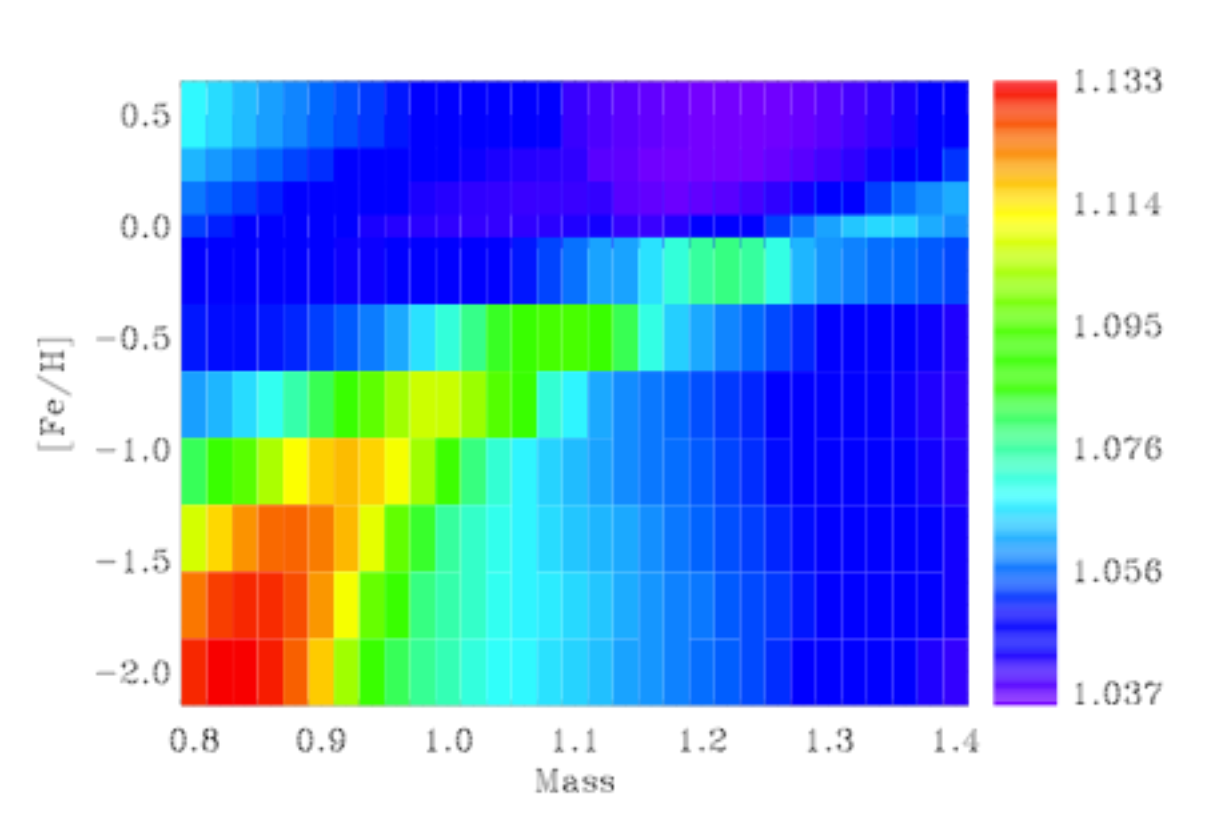
Depression in ☝$_1$
(HeII ioniz.)



Is the added contribution of ❍ change detectable (at least in models)?

Variations in ❍ across the M-[Fe/H] plane

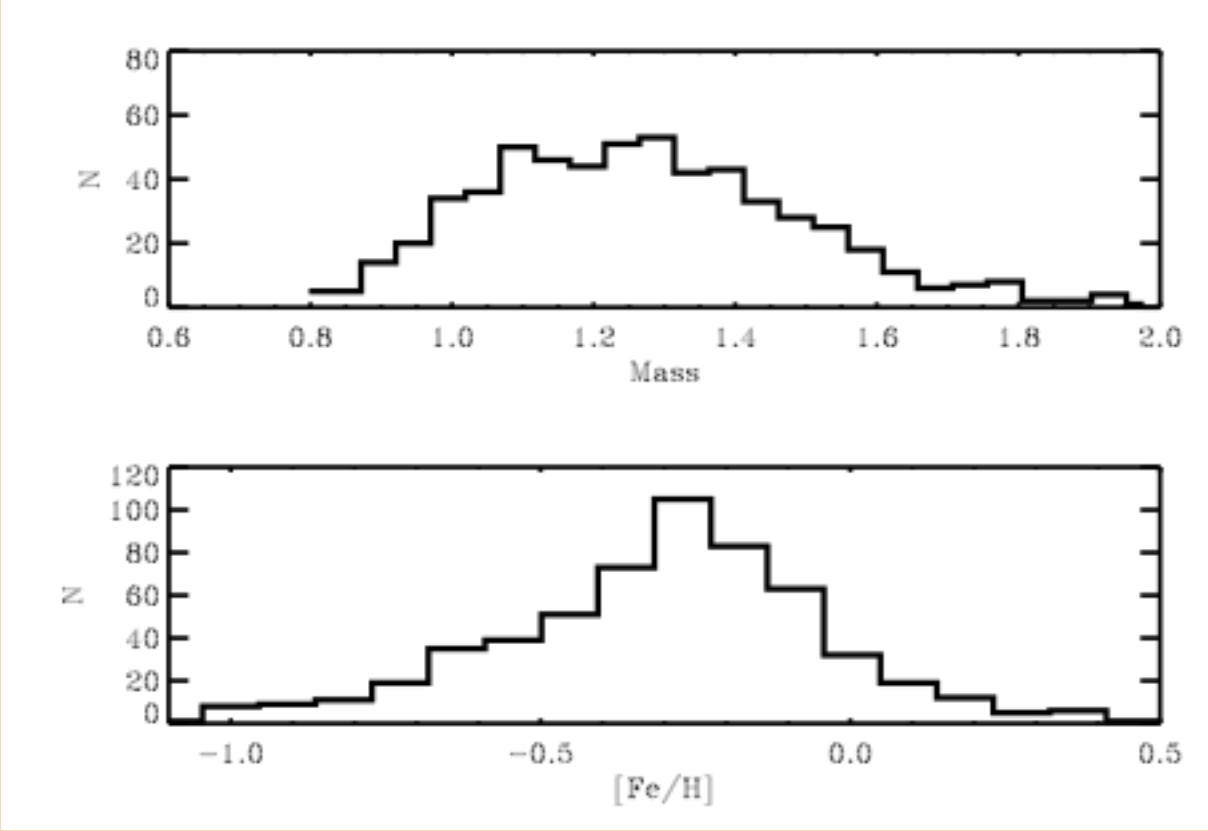
Maximum depletion factor of ❍



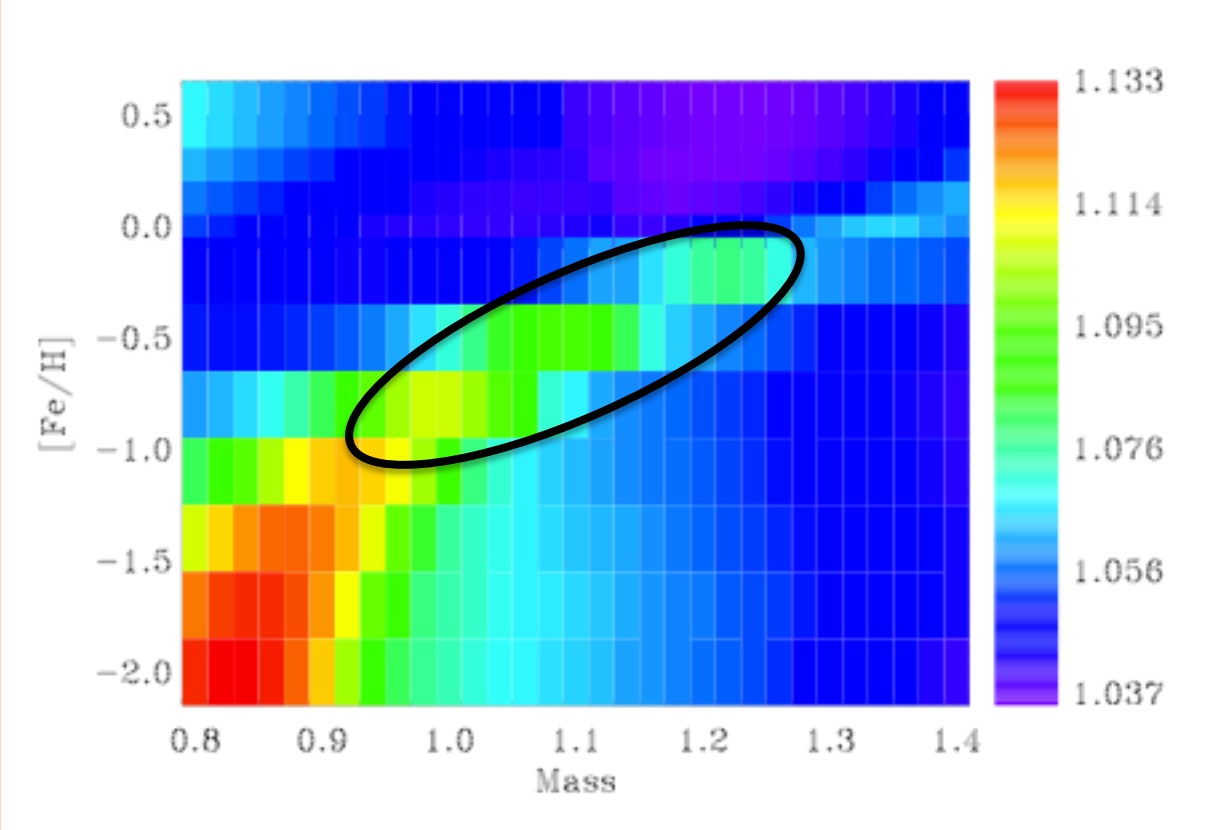
Depletion factor: combination of conv. envelope thickness and evolutionary timescale on MS

Rerefence: for standard solar model is 1.016

Kepler solar-like stars look more or less like this



Restricted parameter space



Two evolutionary sequences:

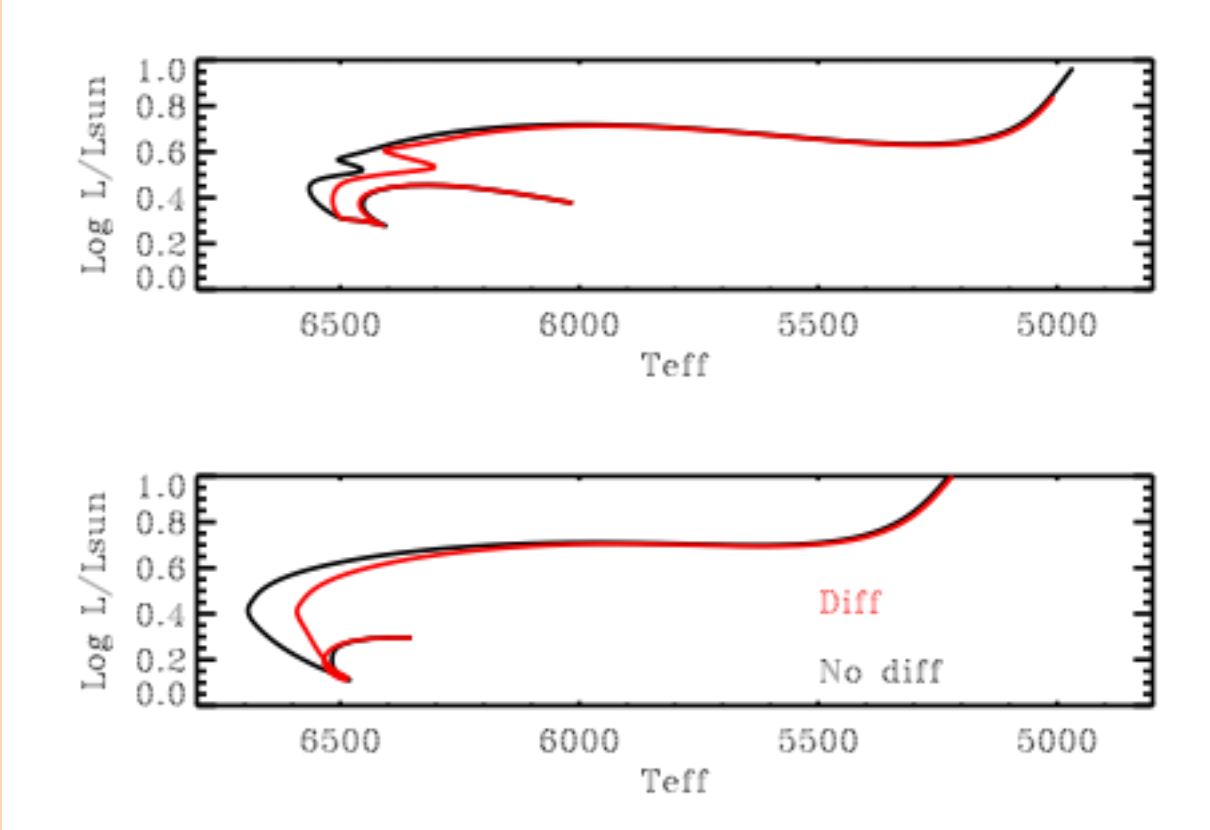
M=1 $M_\odot$ – [Fe/H]= -0.8

M=1.2 $M_\odot$ – [Fe/H]= -0.2

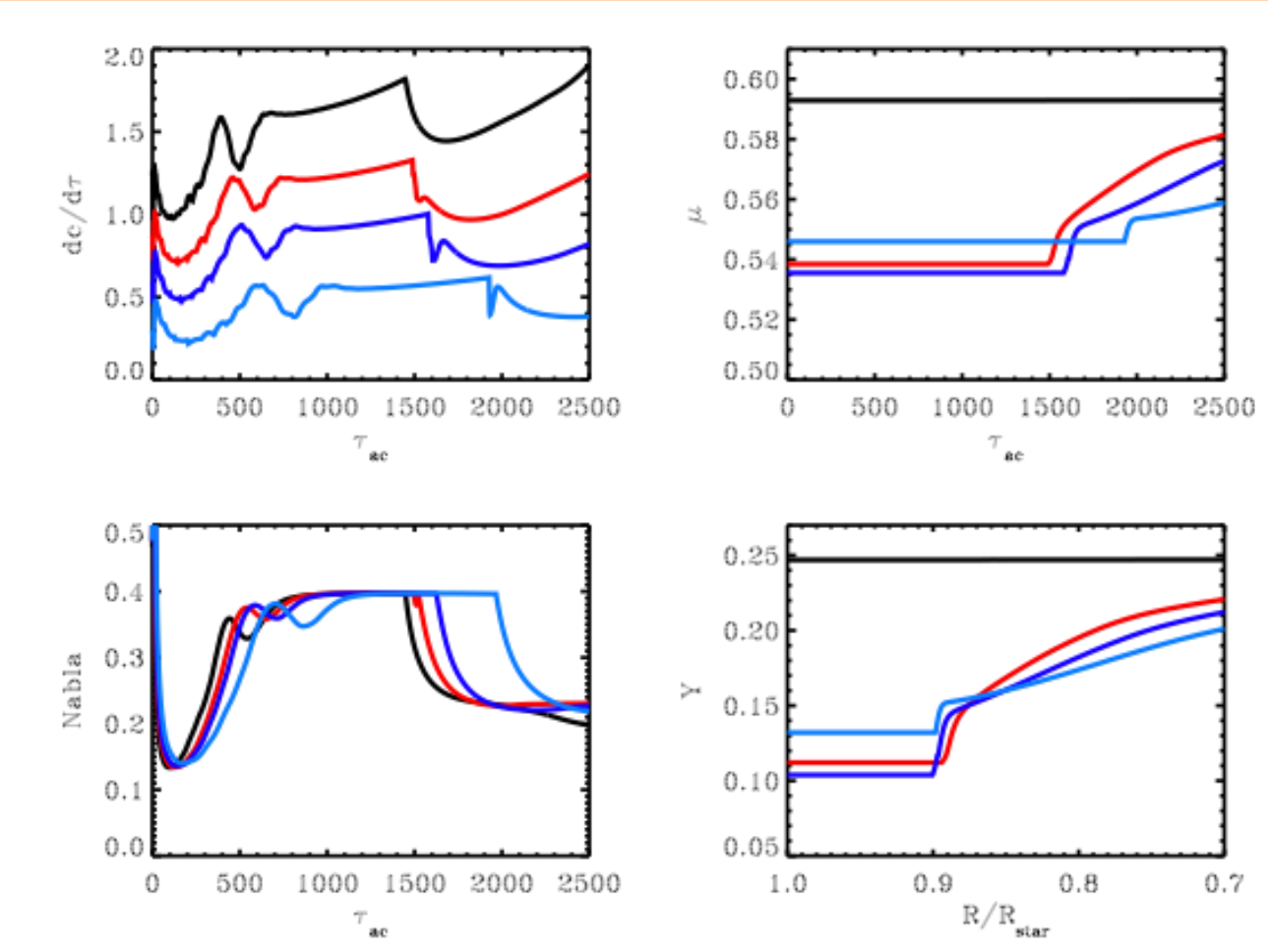
On the HRD

M=1.2 $M_\odot$ – [Fe/H]= -0.2

M=1 $M_\odot$ – [Fe/H]= -0.8

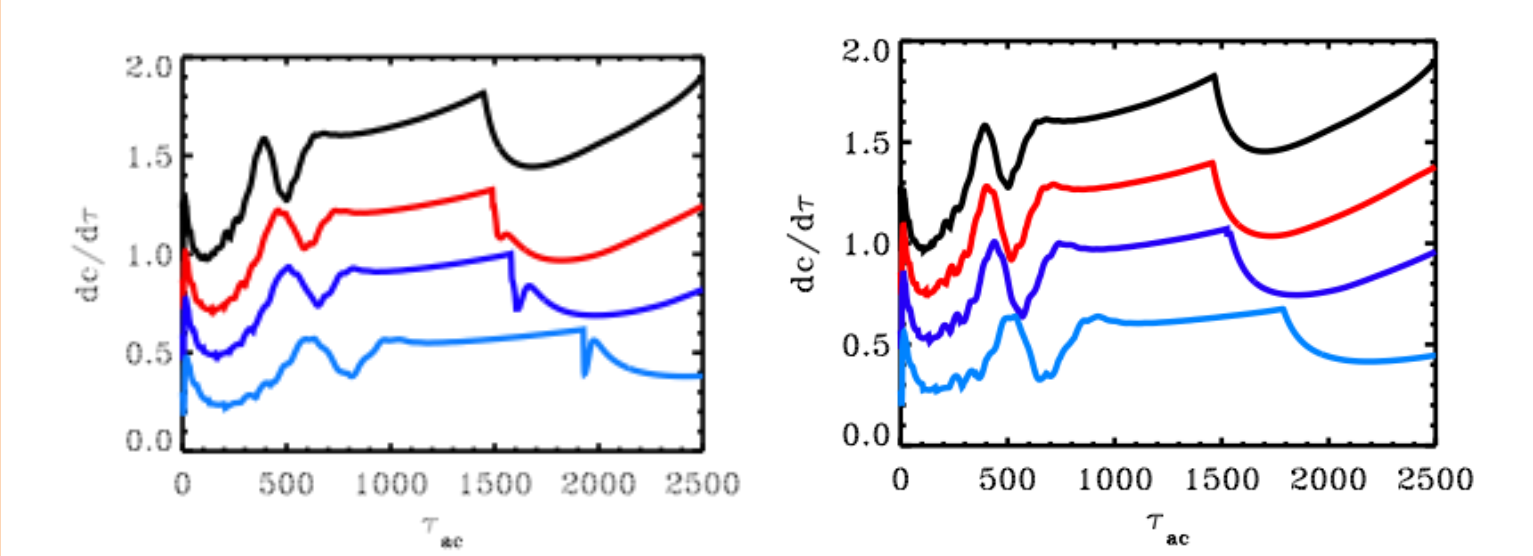


M=1 $M_{\odot}$ – [Fe/H]= -0.8



Even if thinner CE the HeII ion. zone and the BCE are well separated
BCE deep enough → not sensitive to surface effects

M=1 $M_{\odot}$ – [Fe/H]= -0.8



Diffusion **No diffusion**

Differences in the acoustic glitches at base of CE
Tempered effect at the HeII ionization zone (less Y in the envelope)

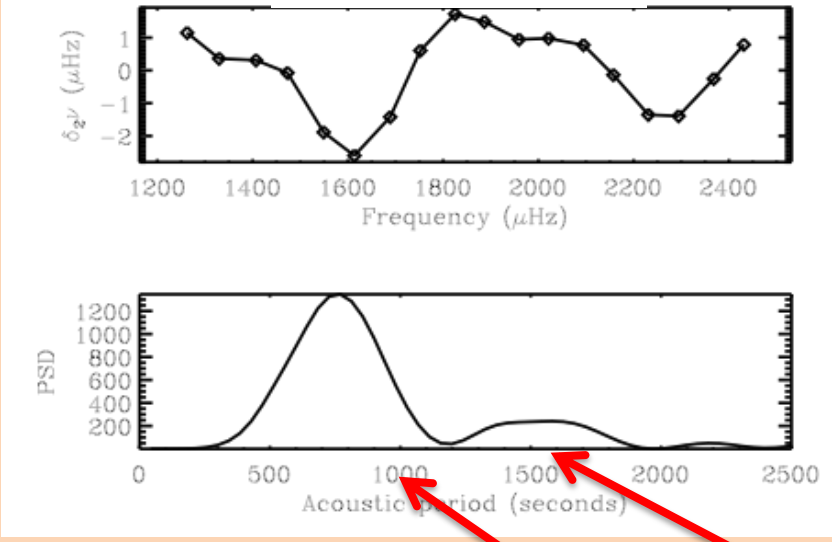
Second order differences: $\Delta_2 \nu_n = \nu_{n-1} - 2\nu_n + \nu_{n+1}$ **(l=0,1,2)**

Fourier analysis after subtraction of slowly varying component

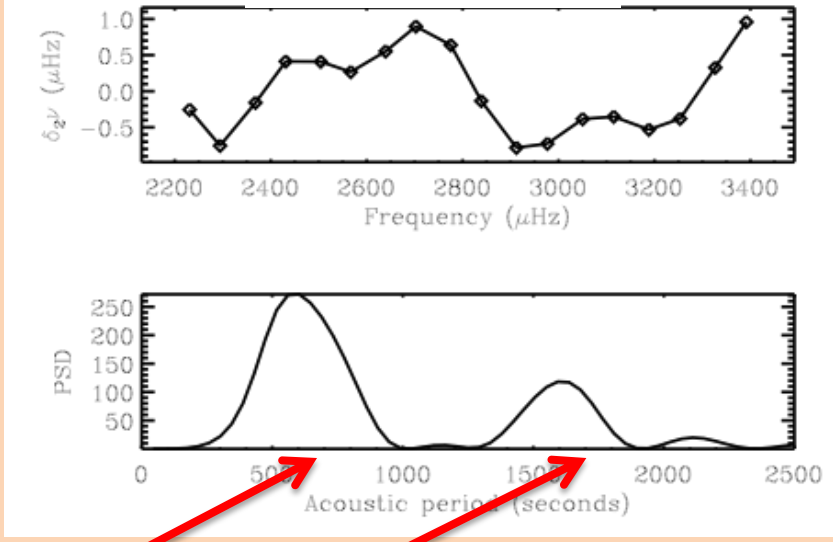
Sensitive to choice of lowest overtone and number of modes available

The two peaks well defined if: $\nu_{min} > 2/3\ \nu_{max}$ **(n>13) & N > 10**

n_{ini}**= 8 – N=11**



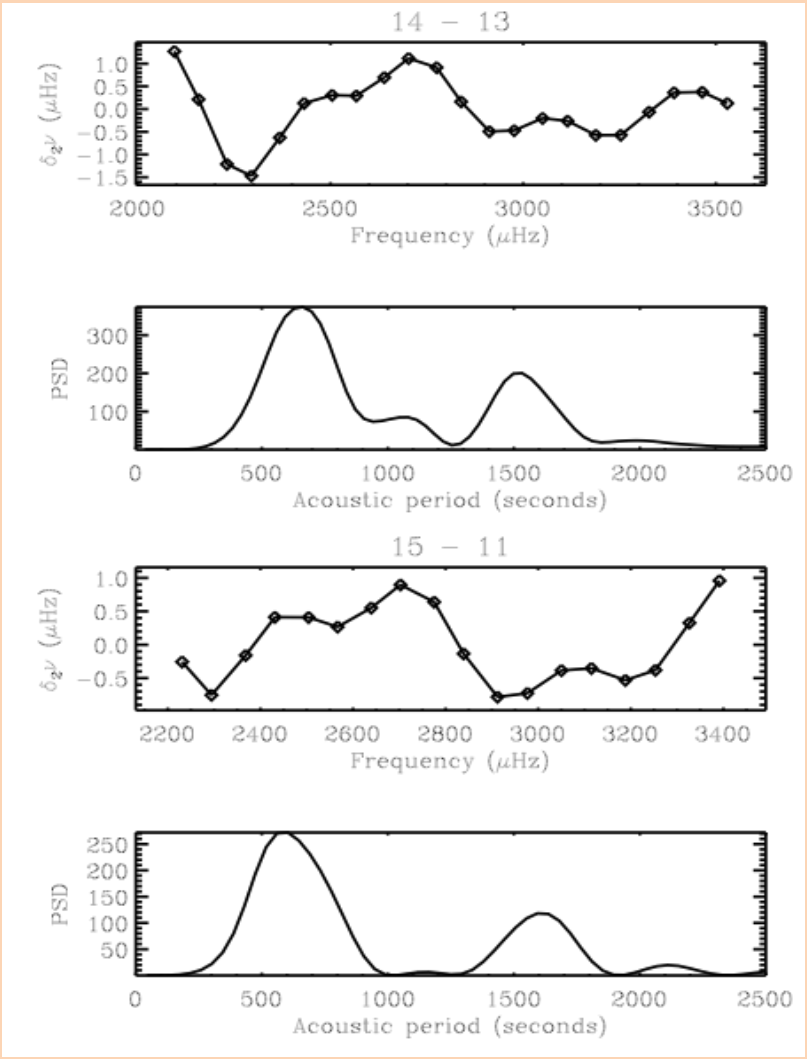
n_{ini}**= 15 – N=11**



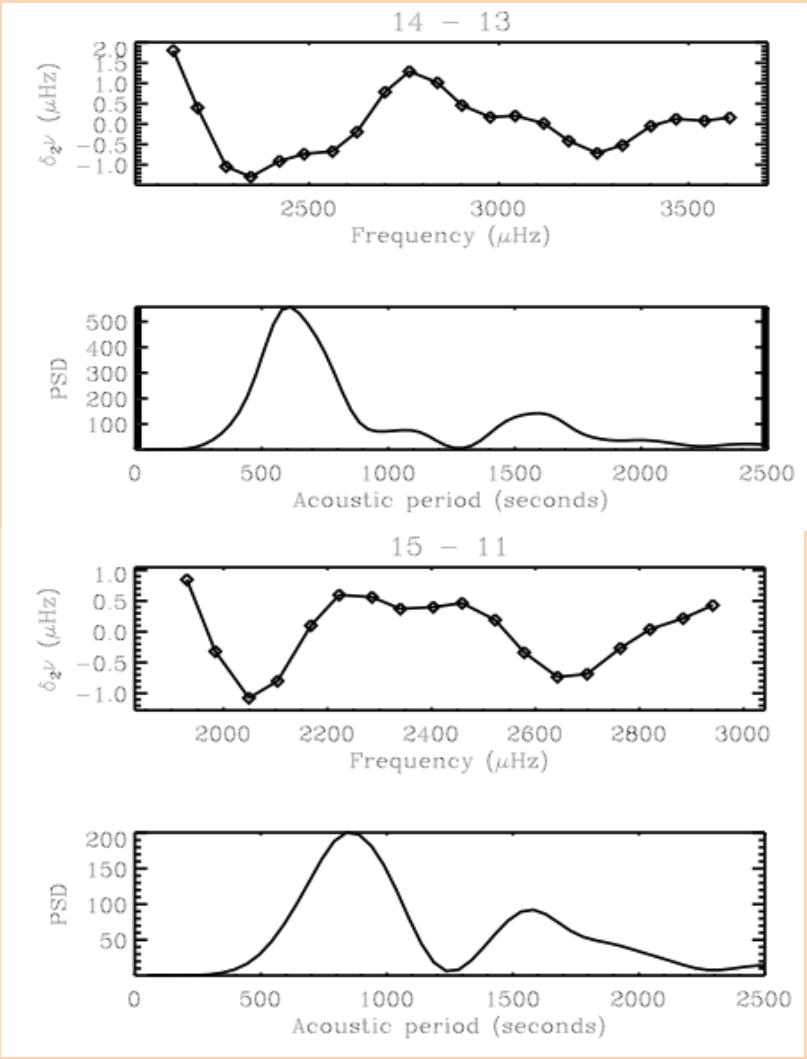
Hell

BCE

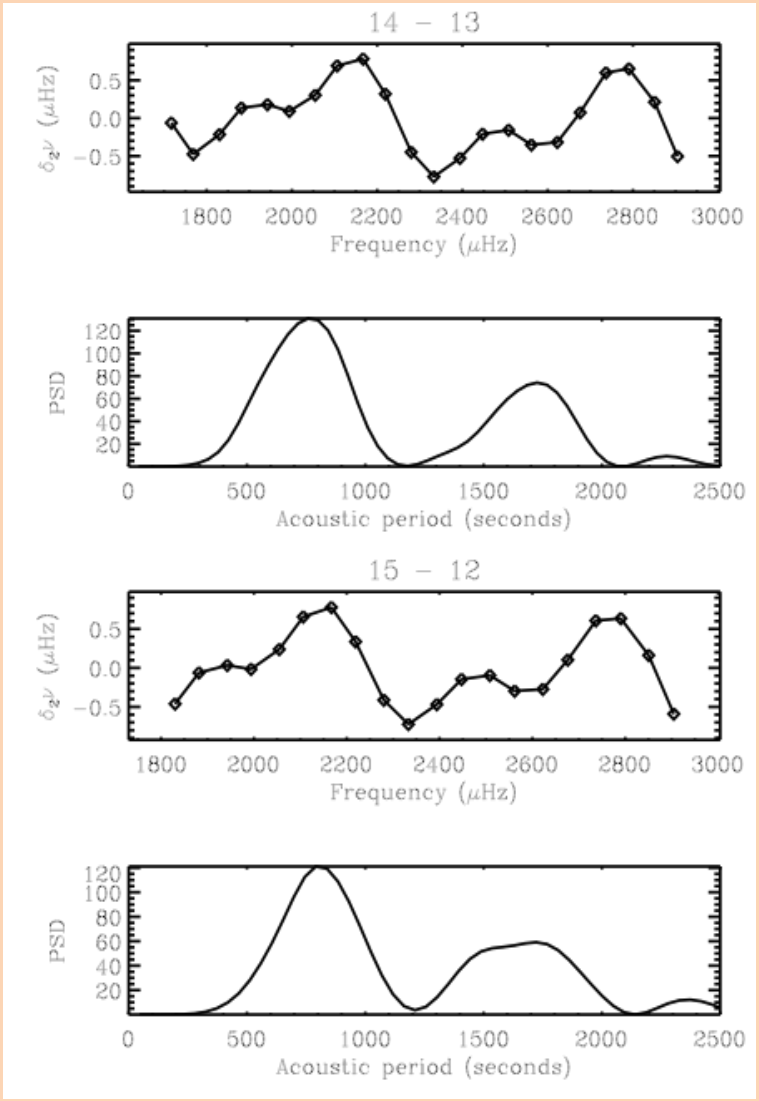
Models with diffusion
Depl. factor 1.04



Models without diffusion



Models with diffusion
Depl. factor 1.10



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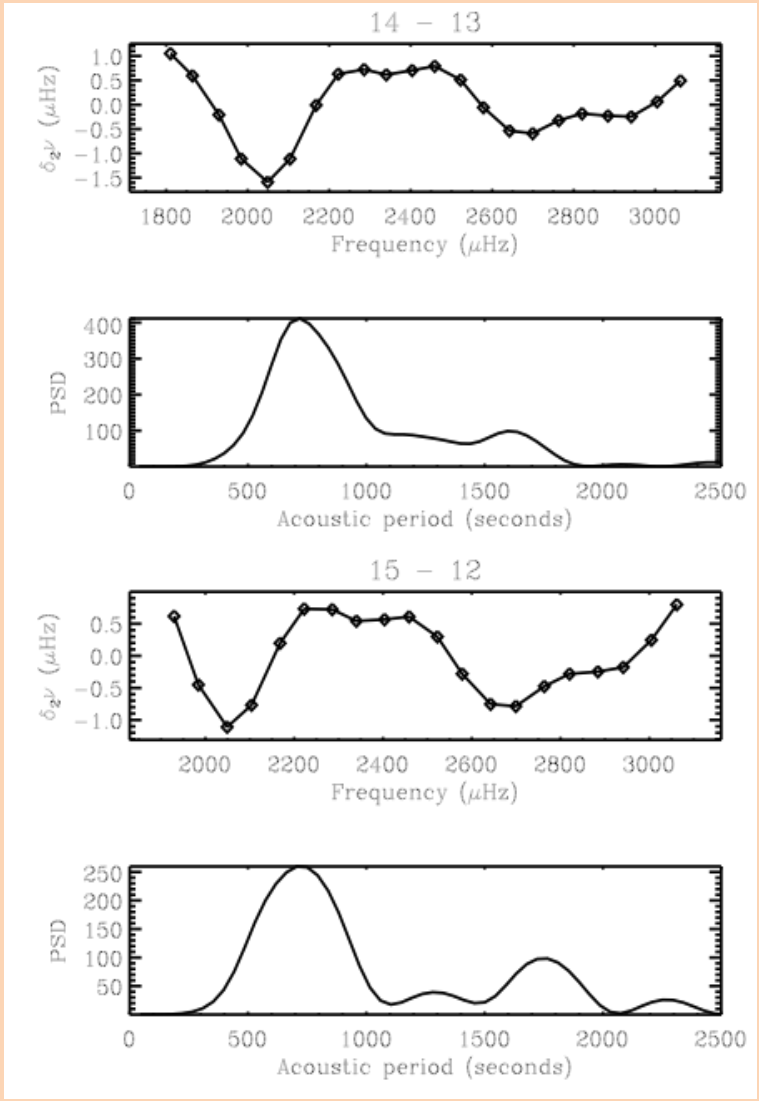
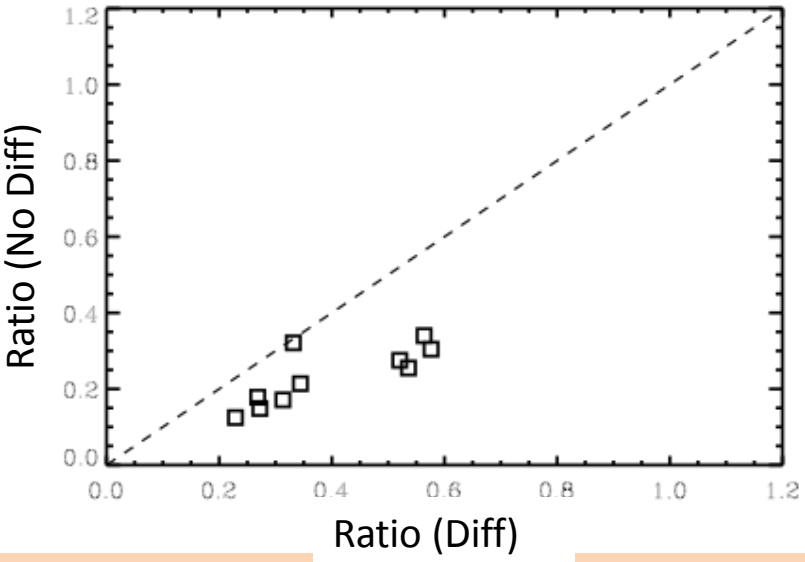


Ratio of maximum power between the two peaks

Depl. factor 1.04



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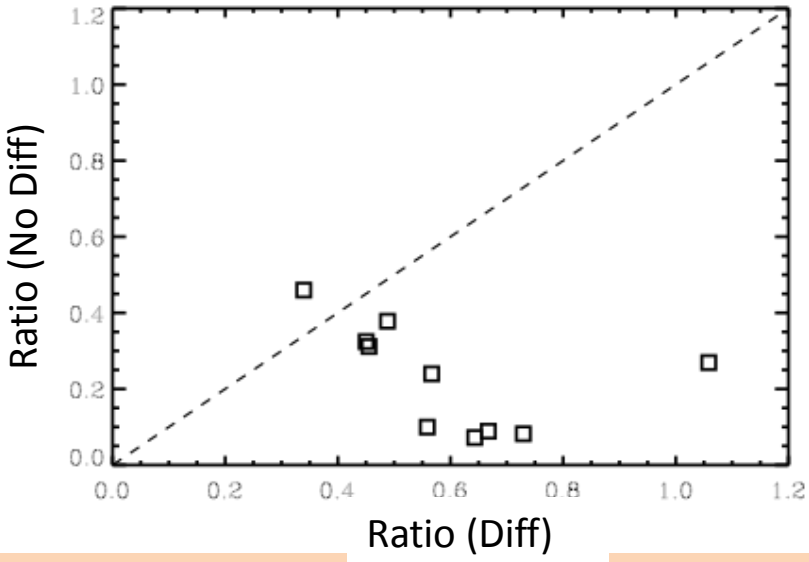

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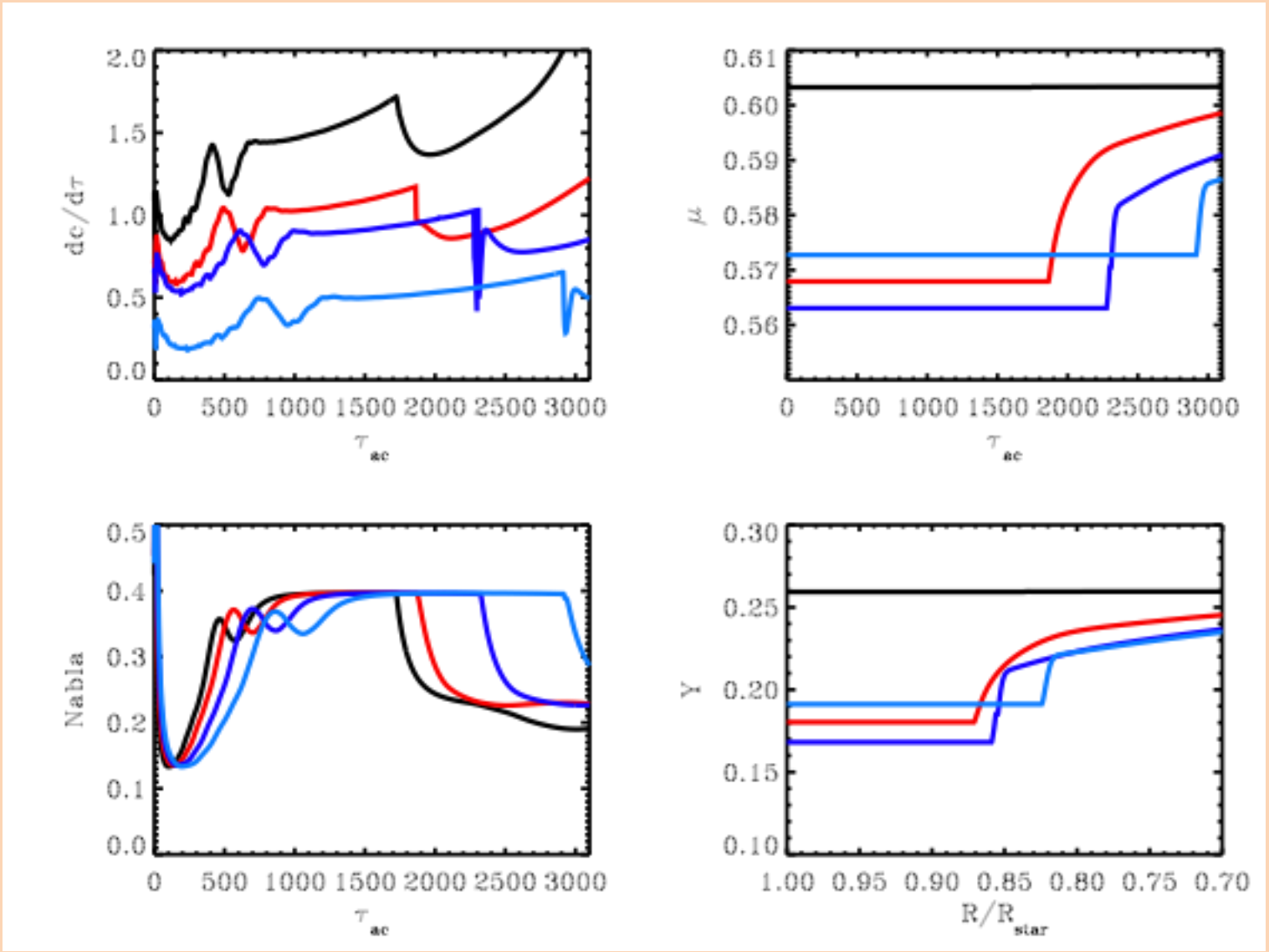

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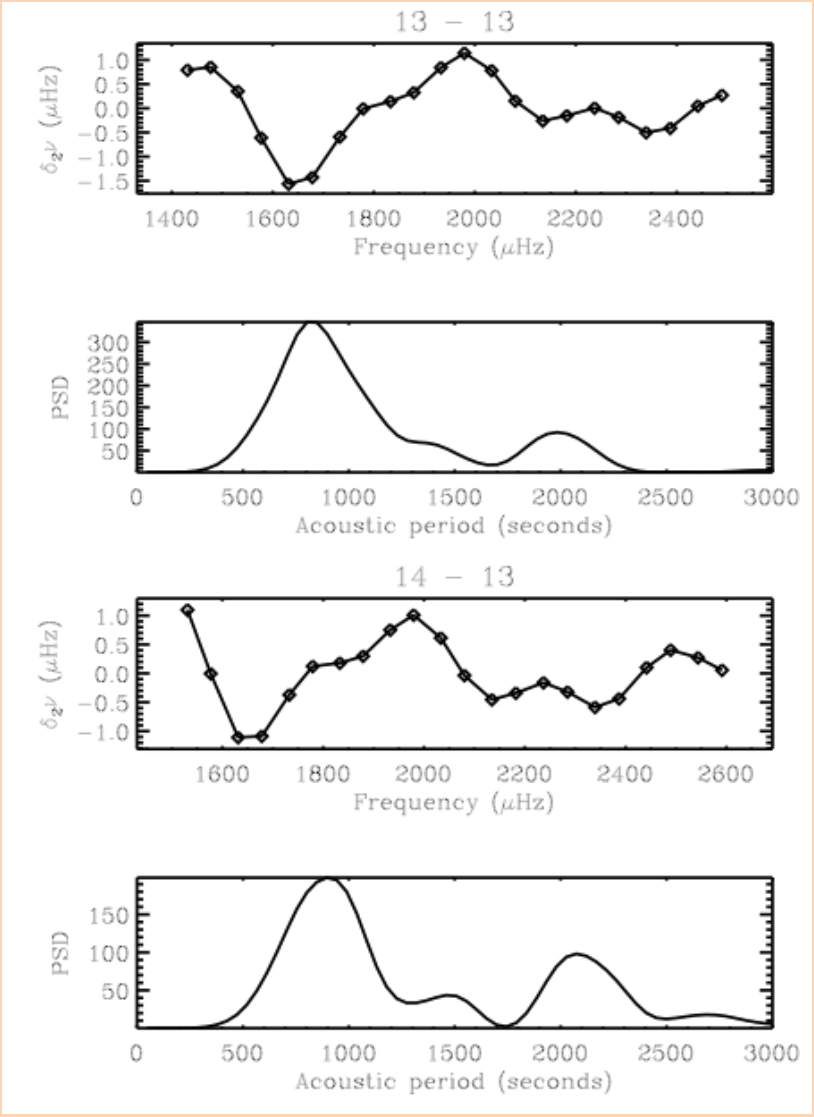

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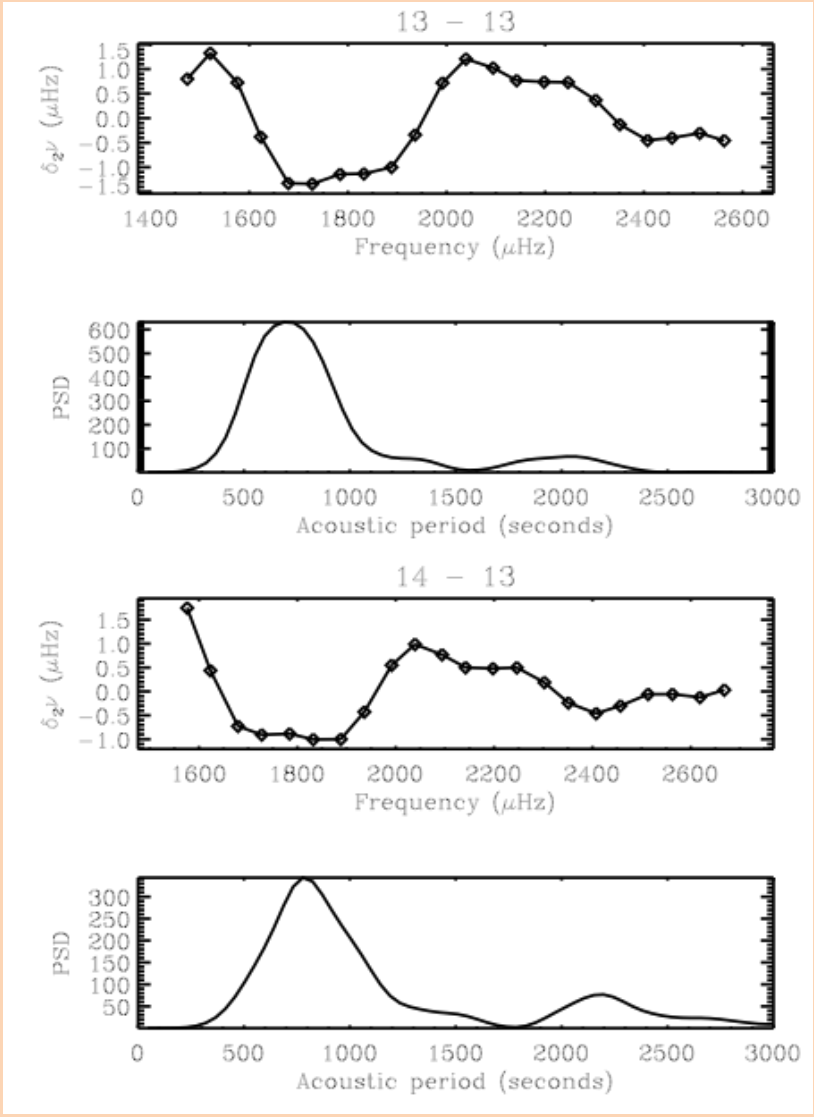

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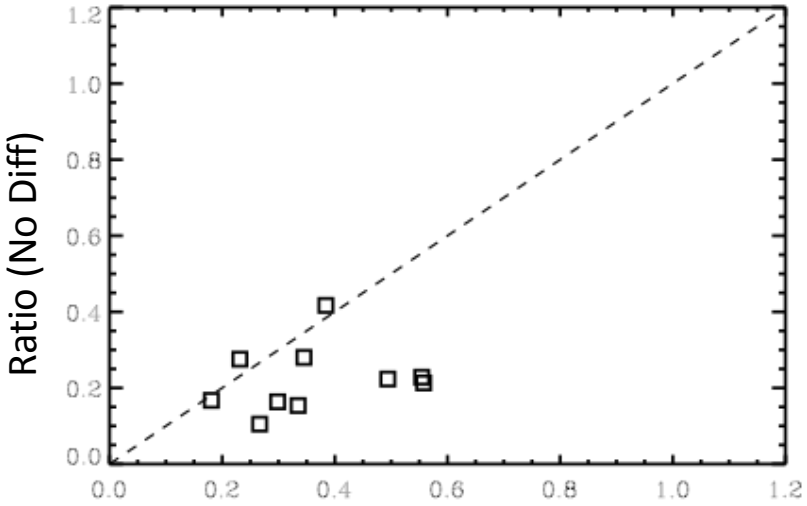
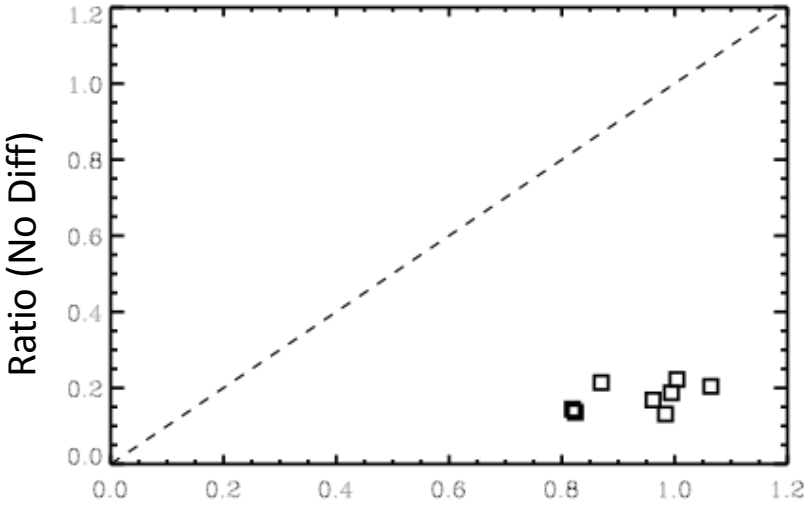


Depl. factor 1.08



Initial tests for effects of element diffusion in acoustic glitches for solar-like stars

First crude analysis in models indicate different power distribution from 2nd order differences in models with and without diffusion

- **– effect of diffusion is double: sharper glitch at BCE and less signal at HeII ion. zone**
- **– however sensitive to modes used in Fourier analysis**
- **– at least 10 modes per ang. degree needed**

Need further work to device a robust indicator of diffusion in models: refined Fourier analysis, optimization in selection of frequencies

No extra-mixing (eg turbulent) considered in models so far

Possibility of application to actual data still very uncertain