Helium abundances and Asteroseismology of Exoplanet-host Stars

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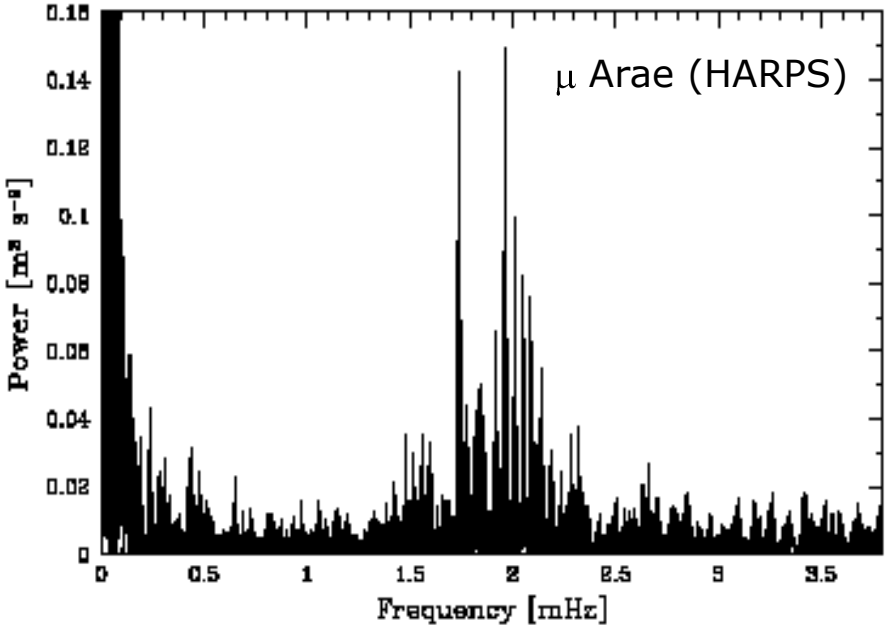
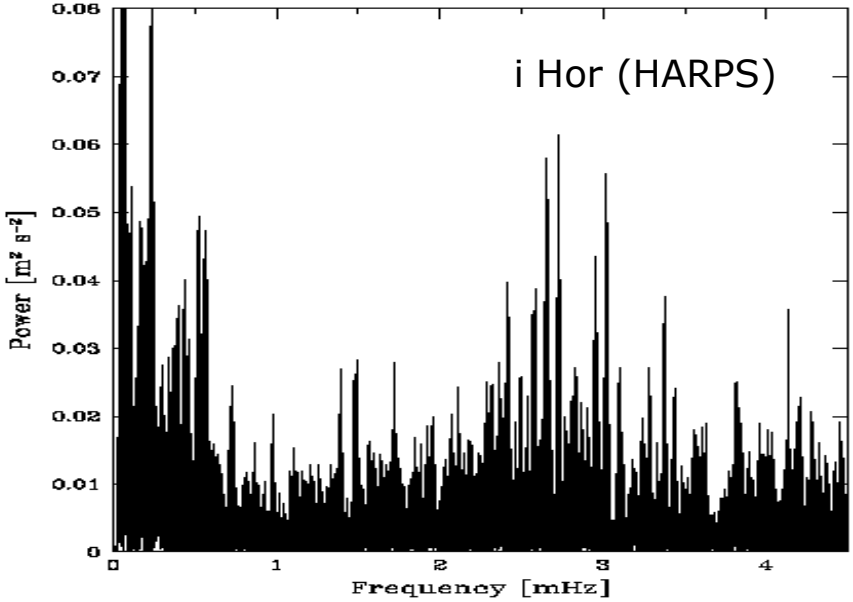
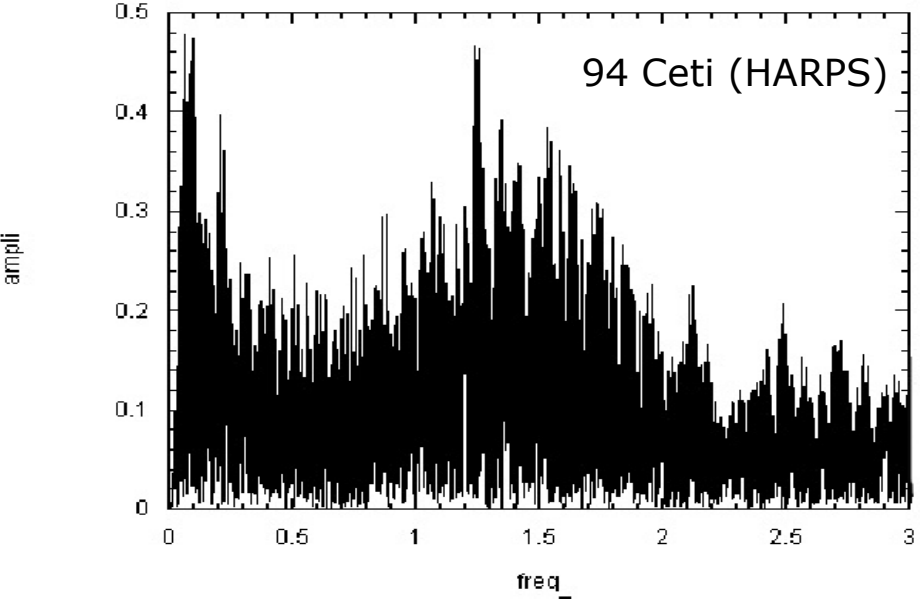
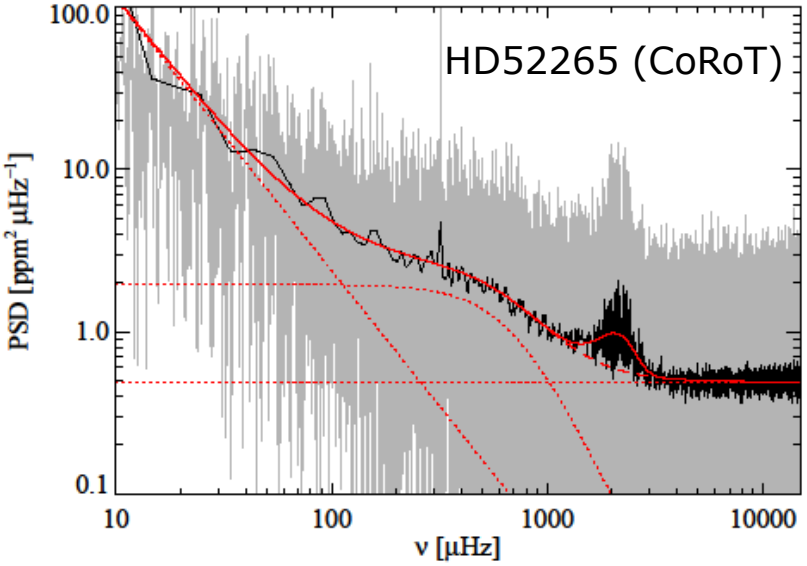

μ Arae (HARPS)
Power [m² s⁻²]
Frequency [mHz]


i Hor (HARPS)
Power [m² s⁻²]
Frequency [mHz]


94 Ceti (HARPS)
ampli
freq_


HD52265 (CoRoT)
PSD [ppm² μHz⁻¹]
ν [μHz]

Generalities

« asymptotic theory » :

$$\nu_{n,l} \simeq \left(n+\frac{l}{2}+\frac{1}{4}+\alpha\right)\Delta\nu_l - \frac{l(l+1)\Delta\nu_l}{4\pi^2\nu_{n,l}}\left[\frac{c(R)}{R} - \int_{r_t}^{R}\frac{1}{r}\frac{dc}{dr}dr\right] - \delta\frac{\Delta\nu_l^2}{\nu_{n,l}}$$

Large separations : $\Delta\nu\,(n,l) = \nu\,(n+1,\,l) - \nu\,(n,l)$

$\Delta\nu_l \sim \Delta\nu_0 \sim 1/2t_a$

characterize average density (→ mass and radius?)

Small separations :

$$\delta\nu = \nu_{n,l} - \nu_{n-1,l+2} \simeq -(4l+6)\frac{\Delta\nu}{4\pi^2\nu_{n,l}}\int_0^R \frac{1}{r}\frac{dc}{dr}dr$$

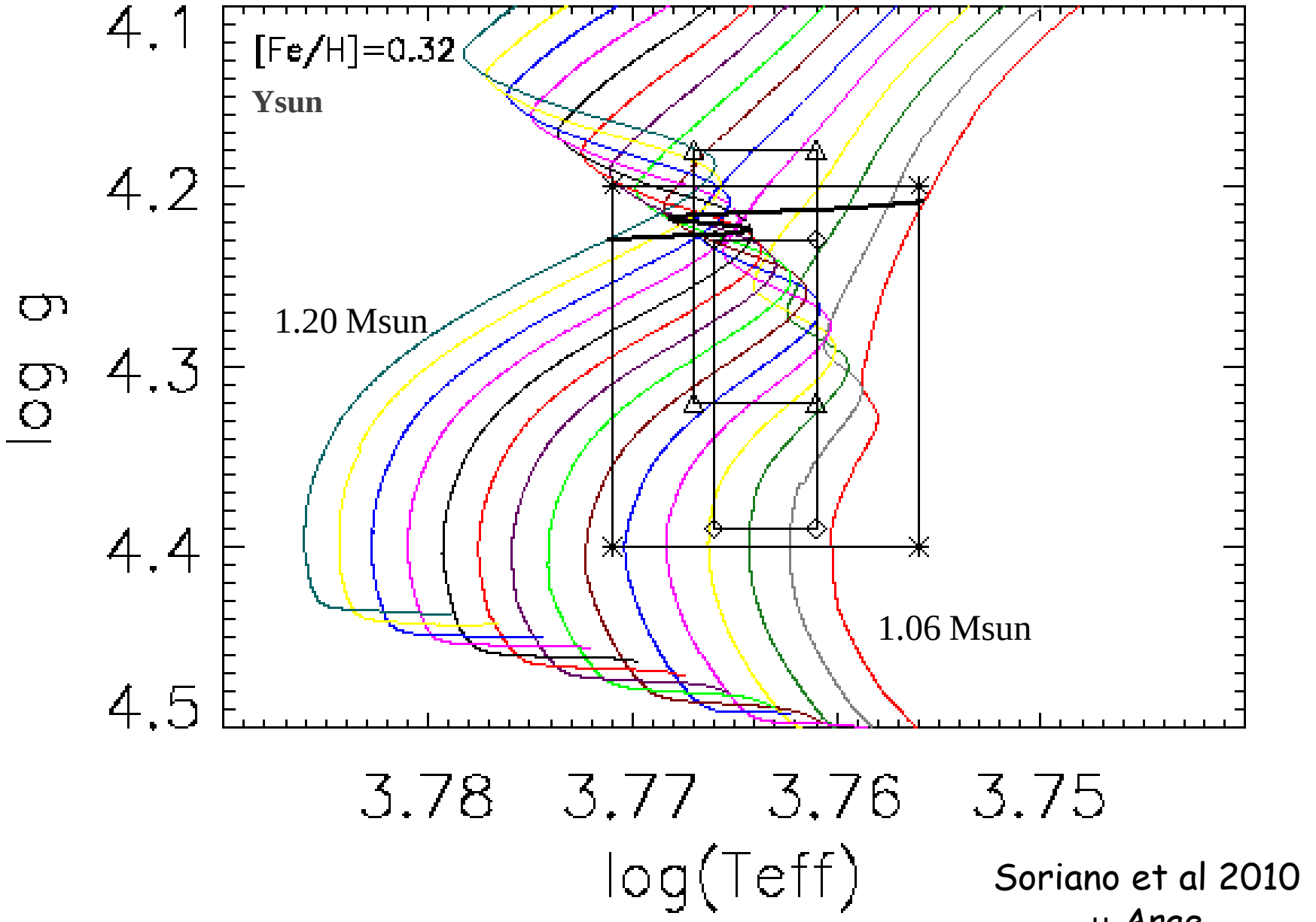
characterize central regions (→ age?)

but… be careful !!!

an elephant in the room !

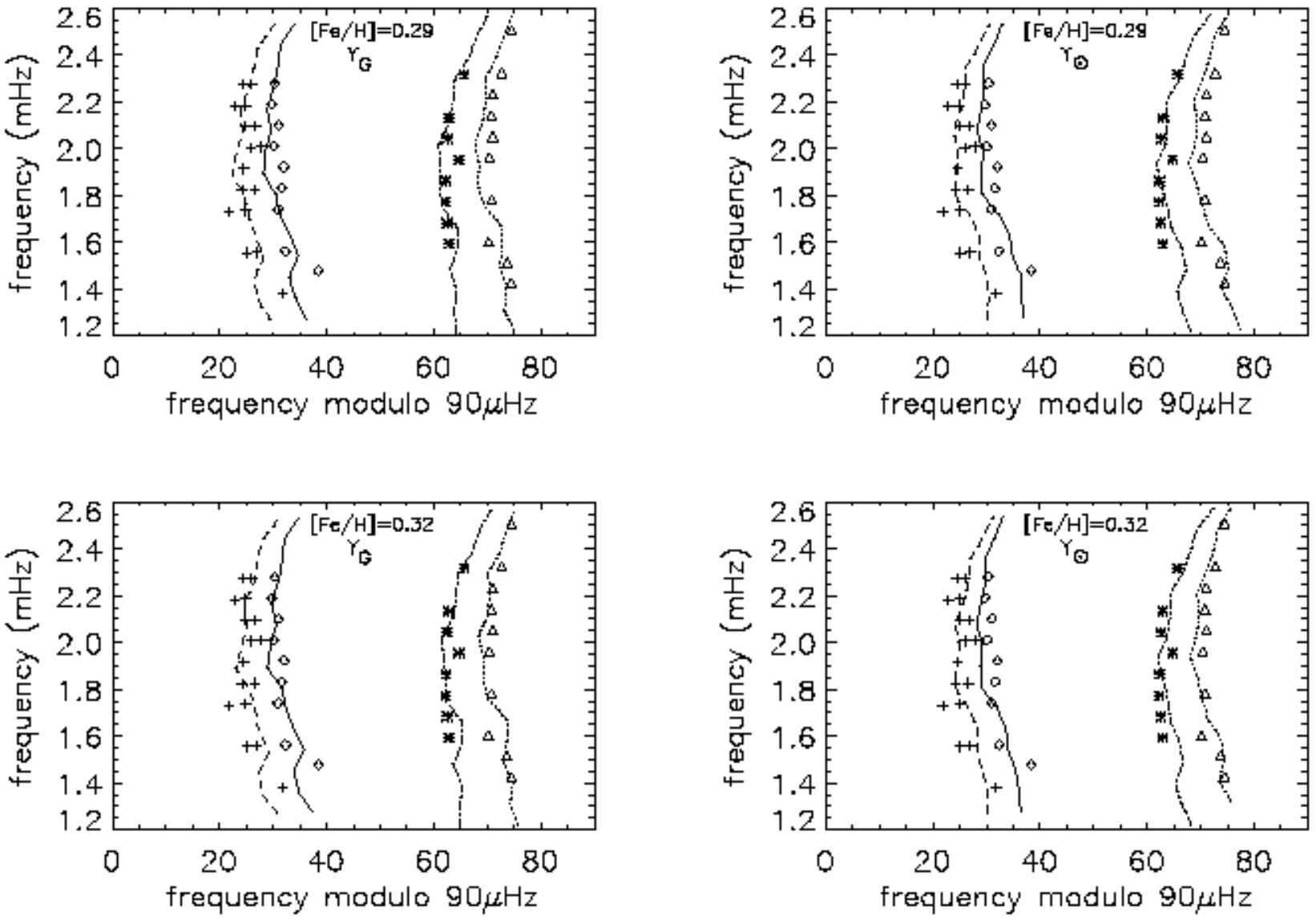
(S. Basu)

the initial helium problem



Soriano et al 2010

μ Arae


[Fe/H]=0.29
Y_G
[Fe/H]=0.29
$Y_\odot$
[Fe/H]=0.32
Y_G
[Fe/H]=0.32
$Y_\odot$
frequency (mHz)
frequency modulo 90μHz
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
0
20
40
60
80

μ Arae

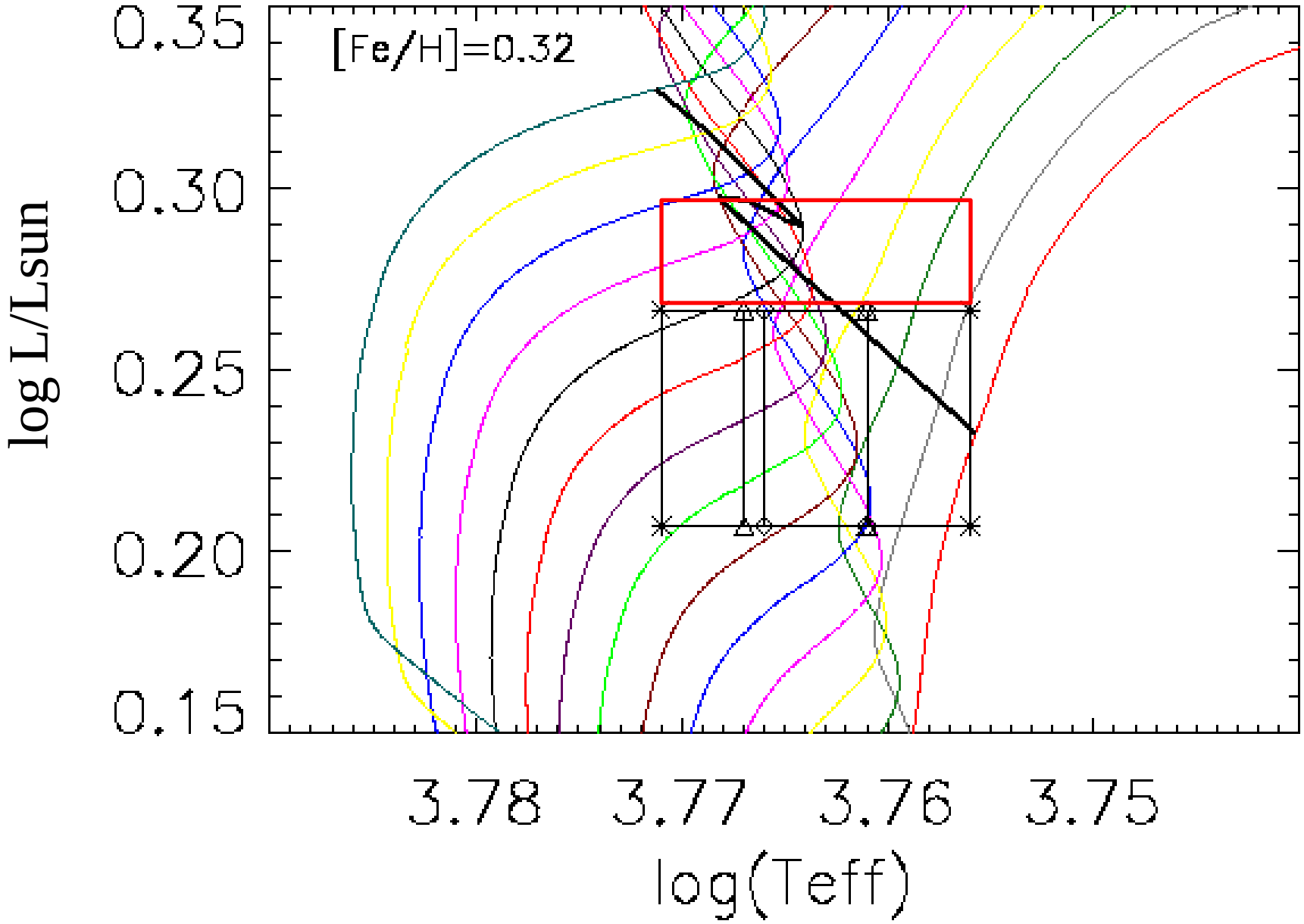

[Fe/H]=0.32
0.35
0.30
0.25
0.20
0.15
log L/Lsun
3.78
3.77
3.76
3.75
log(Teff)

Table 2. Characteristics of some overmetallic models with [Fe/H]=0.32 and Y_G

Mass	Age (Gyr)	log g	log T_{eff}	log $L/L_\odot$	R (x10^{10} cm)	M/R^3	χ^2
1.08	7.112	4.2121	3.7594	0.2519	9.40	2.58	1.700
1.10	6.318	4.2149	3.7644	0.2770	9.46	2.58	1.611
1.12	5.748	4.2172	3.7682	0.2975	9.52	2.58	1.668
1.14	5.387	4.2200	3.7667	0.2967	9.57	2.58	1.742
1.16	4.953	4.2246	3.7642	0.2894	9.61	2.59	1.915

Table 3. Characteristics of some overmetallic models with [Fe/H]=0.29 and Y_G

Mass	Age (Gyr)	log g	log T_{eff}	log $L/L_\odot$	R (x10^{10} cm)	M/R^3	χ^2
1.06	7.916	4.2064	3.7571	0.2371	9.35	2.58	1.734
1.08	7.152	4.2092	3.7607	0.2569	9.41	2.58	1.650
1.10	6.367	4.2152	3.7653	0.2801	9.46	2.58	1.620
1.12	5.716	4.2145	3.7698	0.3039	9.52	2.58	1.737
1.15	5.177	4.2215	3.7672	0.3006	9.60	2.58	2.100

Table 4. Characteristics of some overmetallic models with [Fe/H]=0.32 and $Y_\odot$

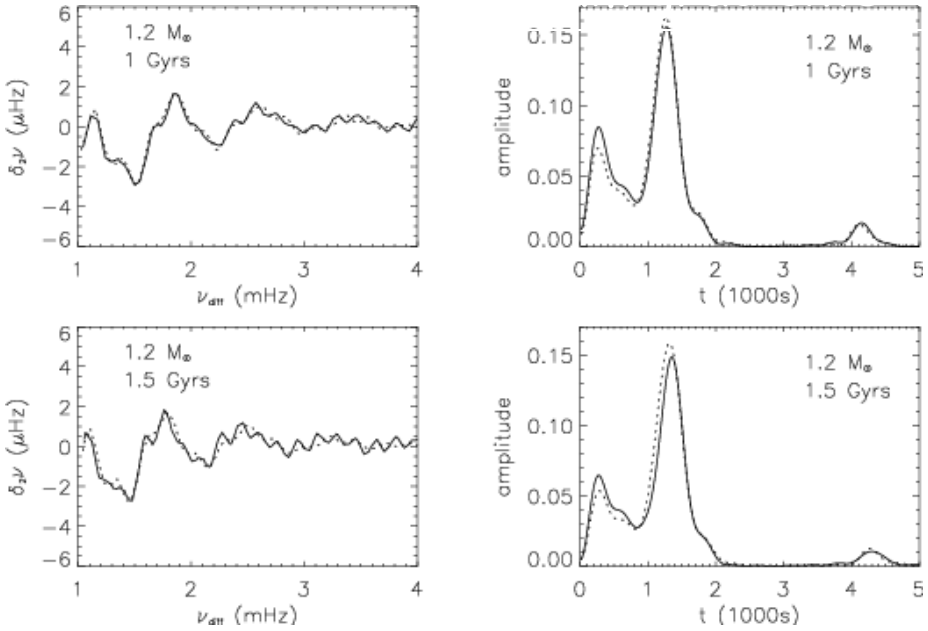
Mass	Age (Gyr)	log g	log T_{eff}	log $L/L_\odot$	R (x10^{10} cm)	M/R^3	χ^2
1.08	9.561	4.2088	3.7459	0.1981	9.41	2.58	1.663
1.10	8.678	4.2120	3.7491	0.2152	9.46	2.58	1.632
1.14	7.002	4.2183	3.7576	0.2589	9.56	2.59	1.670
1.18	6.073	4.2230	3.7562	0.2636	9.68	2.58	2.060
1.20	5.512	4.2281	3.7576	0.2714	9.70	2.60	3.572

Table 5. Characteristics of some overmetallic models with [Fe/H]=0.29 and $Y_\odot$

Mass	Age (Gyr)	log g	log T_{eff}	log $L/L_\odot$	R (x10^{10} cm)	M/R^3	χ^2
1.10	8.559	4.2114	3.7530	0.2319	9.47	2.58	1.627
1.12	7.766	4.2151	3.7566	0.2504	9.51	2.59	1.670
1.14	6.734	4.2179	3.7607	0.2717	9.57	2.58	1.711
1.16	6.227	4.2197	3.7650	0.2946	9.63	2.58	1.762
1.18	5.802	4.2250	3.7590	0.2727	9.65	2.60	1.849

« best » models:
same M, R, g
but different age, Teff, L

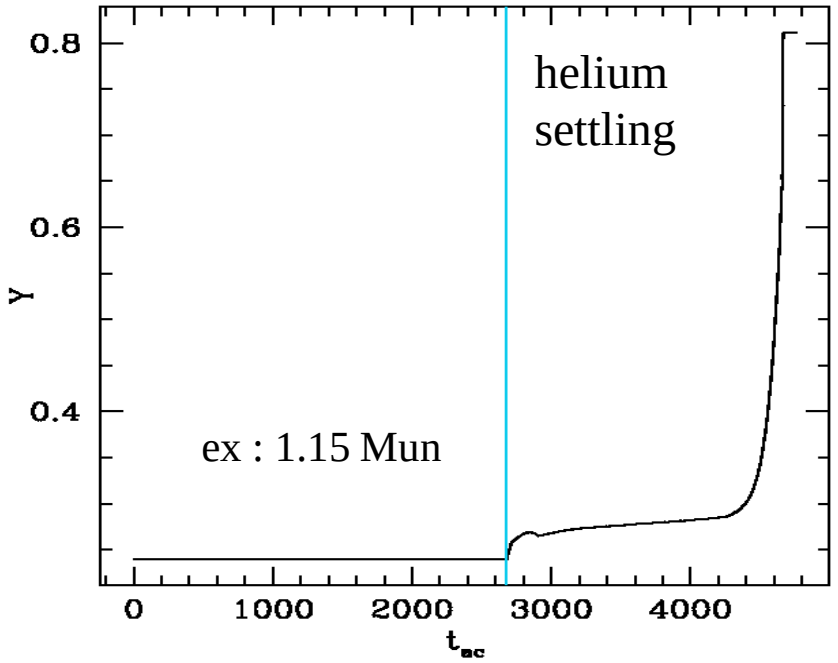
Soriano et al 2010
μ Arae

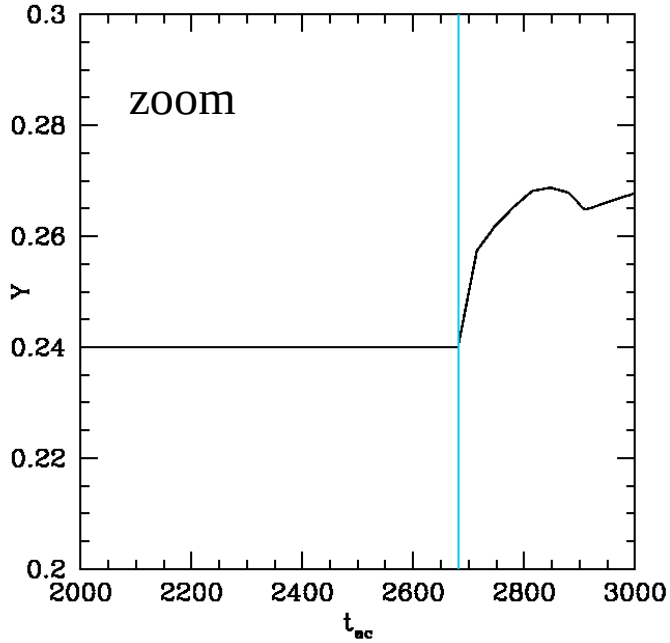


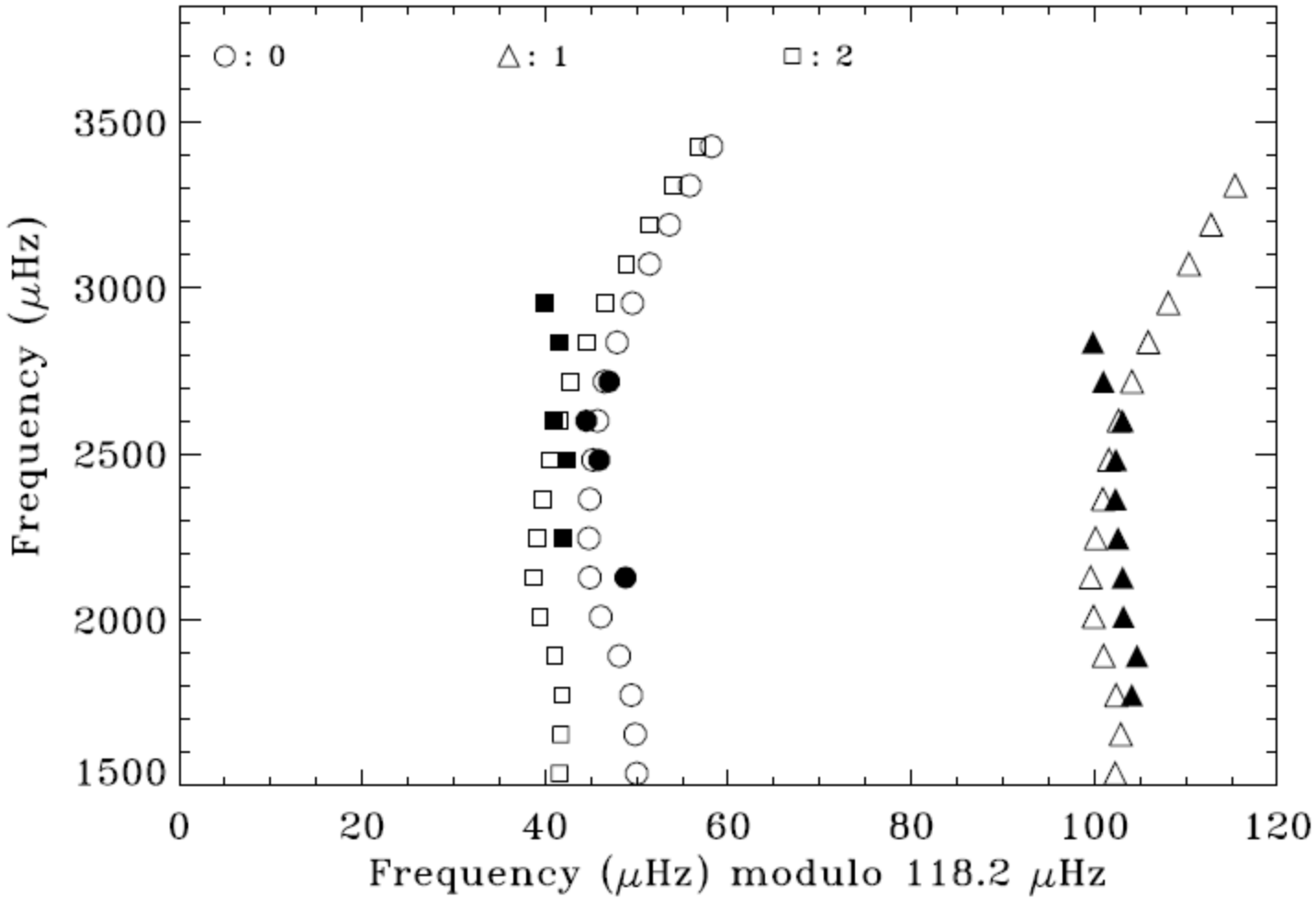
2nd differences or variations of the large separations

But!!!

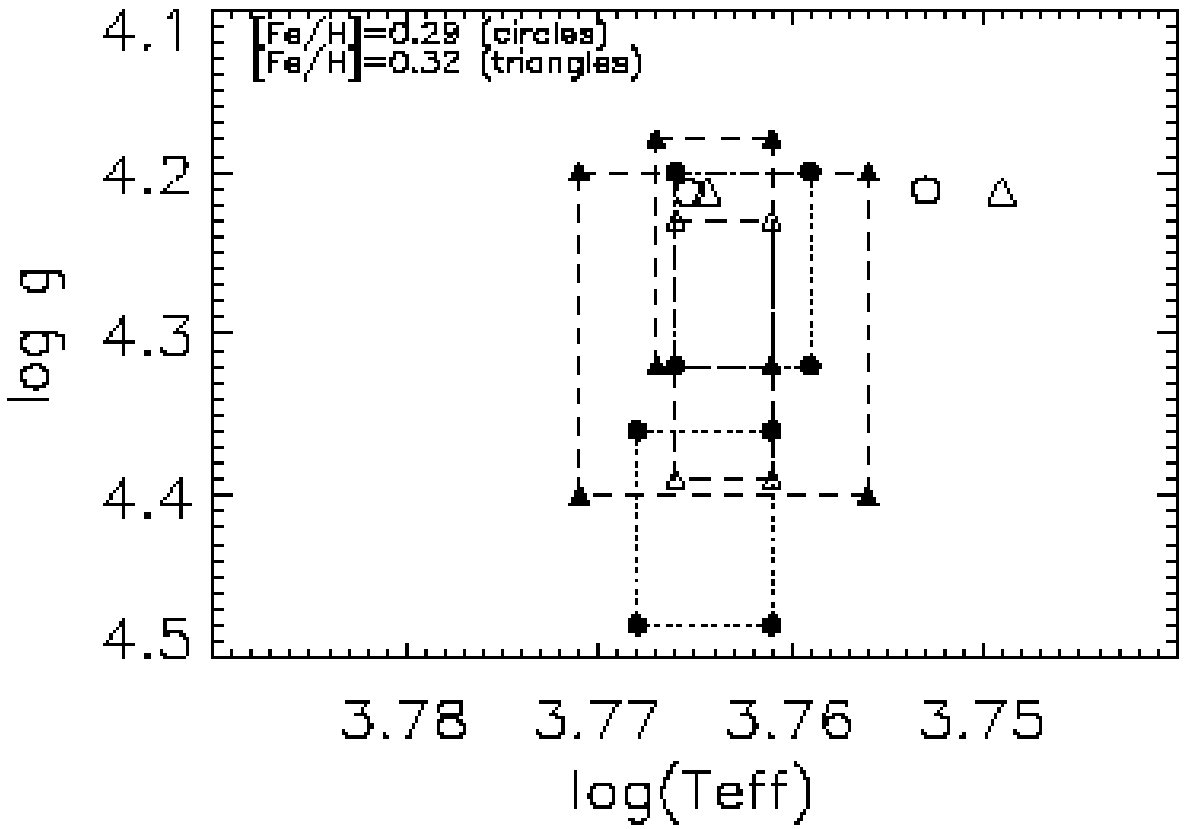
Small number of observed points







Kepler 10b central star (Baralha et al. 2011)



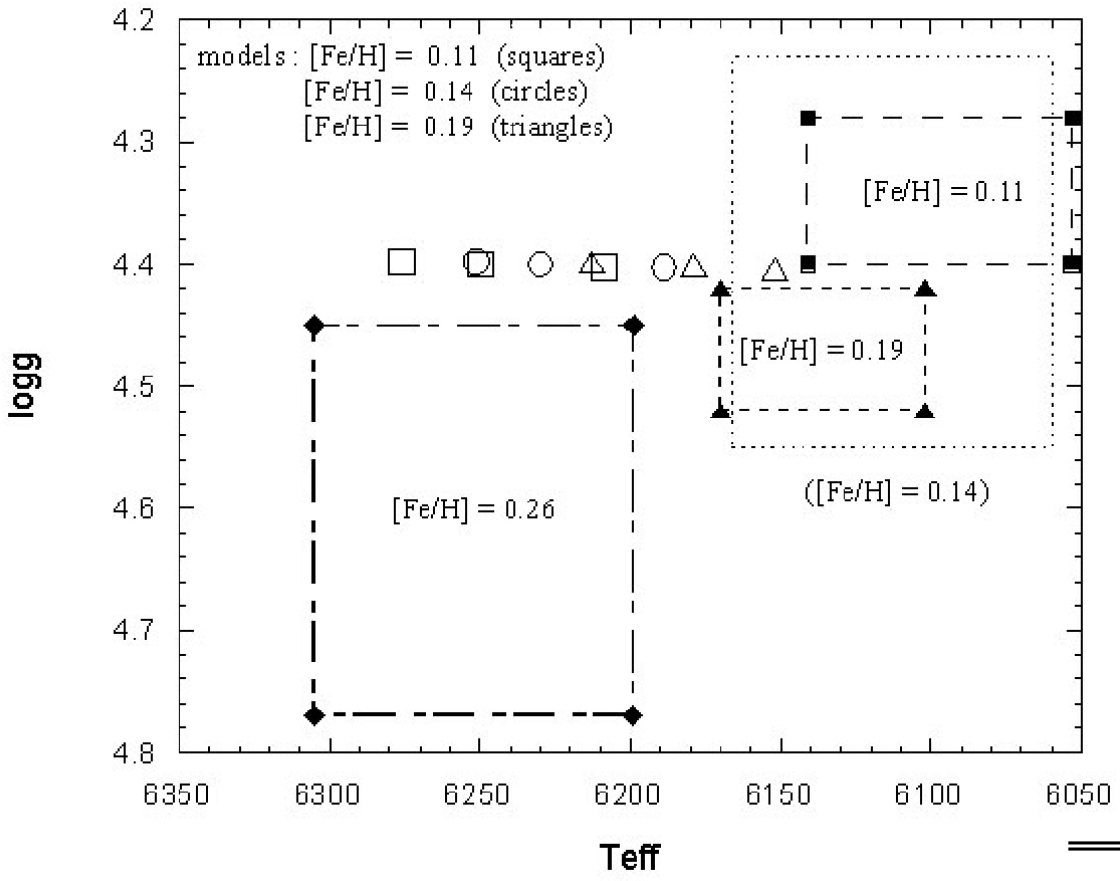
mu Arae

best models for each couple [Fe/H], Y

Y decreases towards right

$M/M_\odot$	1.10 ± 0.01	T_{eff} (K)	5820 ±40
$R/R_\odot$	1.36 ±0.01	[Fe/H]	0.30 ± 0.05
log g	4.215±0.005	Y	0.301 ± 0.01
$L/L_\odot$	1.90 ± 0.10	Age (Gyr)	6.340 ± 0.40

iota Horologii : seismic analysis…

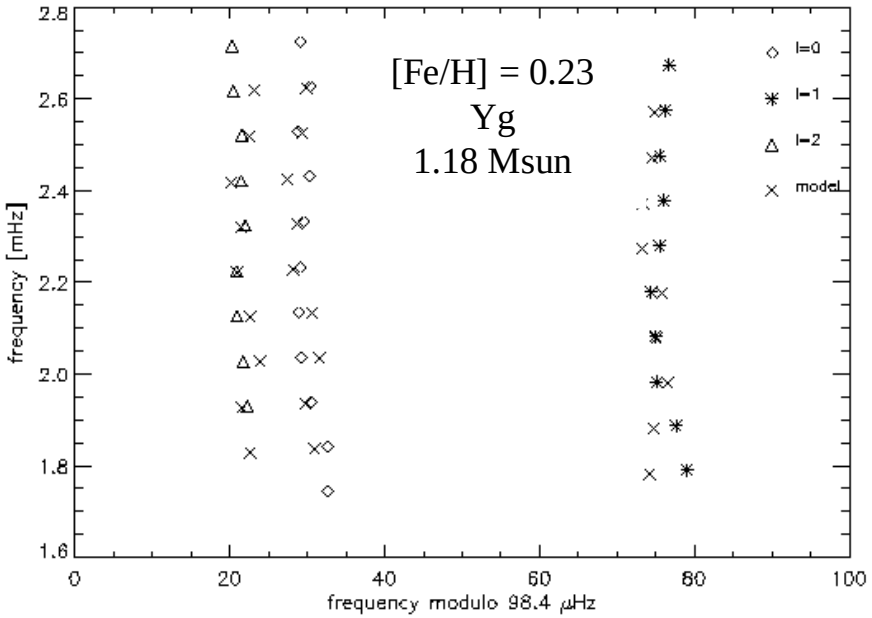


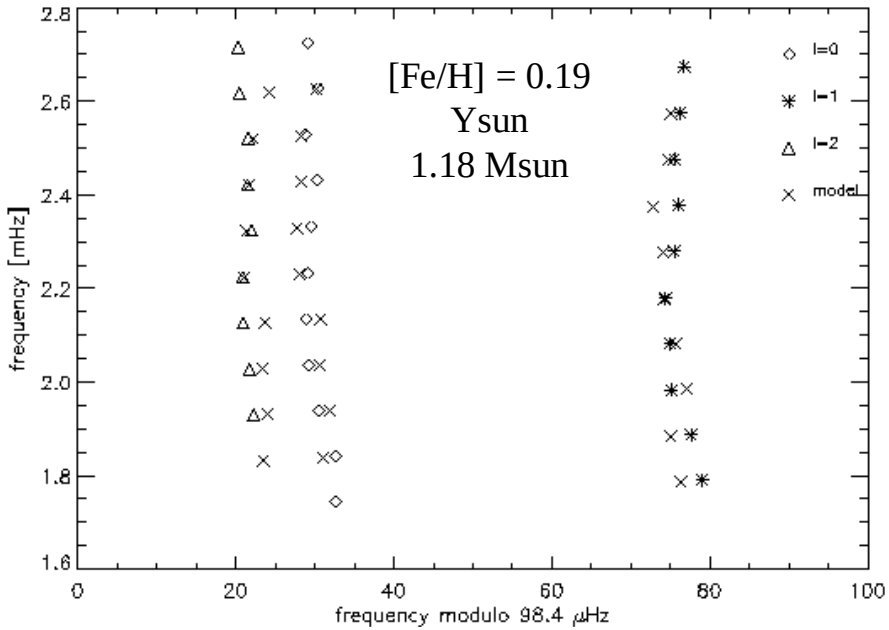
(For each metallicity,
Teff of best model
decreases for decreasing Y)

Vauclair et al. 2008

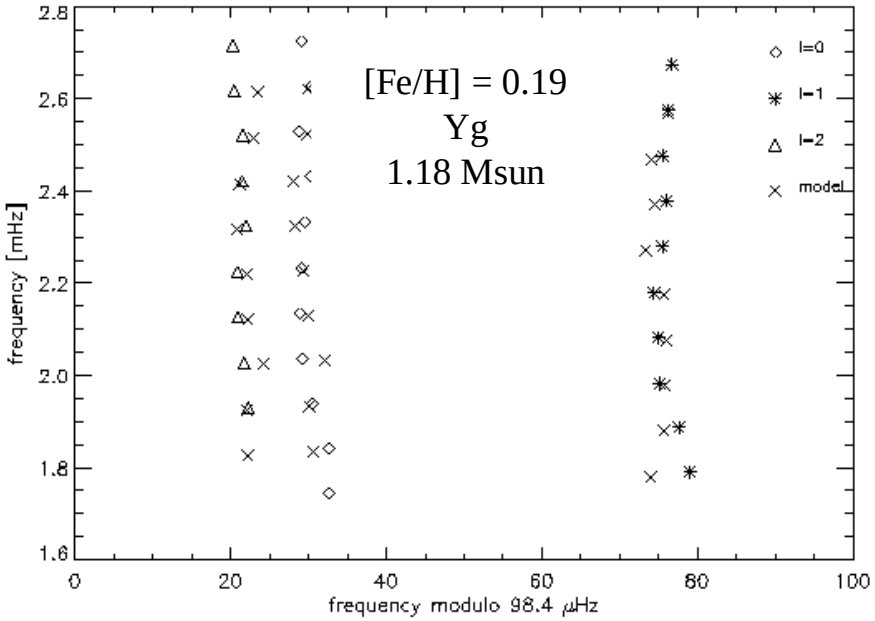
… and best models

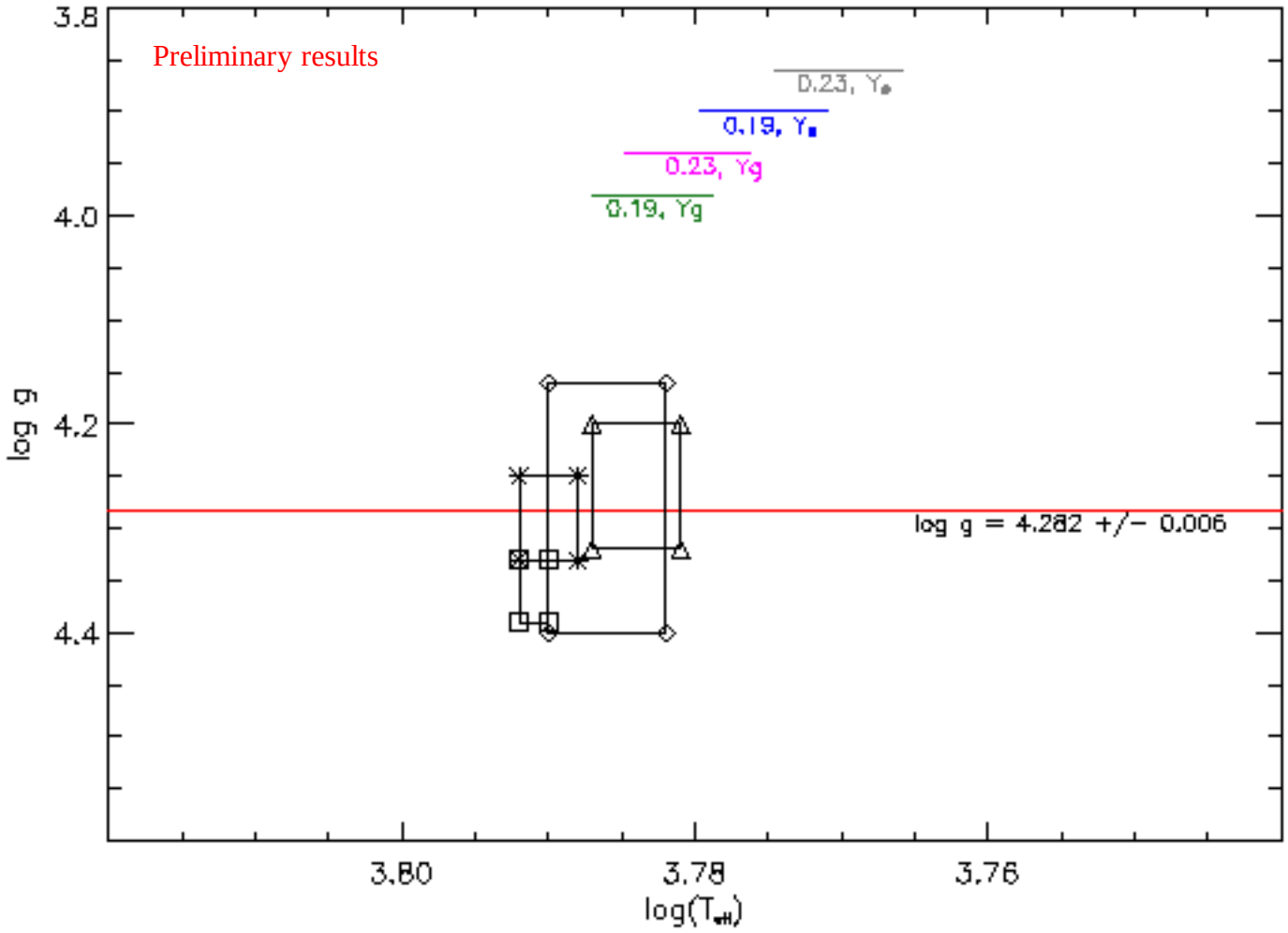
	Best seismic models			Hyades (Lebreton et al. 2001)
[Fe/H]	0.19	0.19	0.14	0.14 ± 0.05
Y	0.271	0.255	0.255	0.255 ± 0.013
age (Myr)	620	627	627	625 ± 25
mass (Msun)	1.24	1.26	1.25	
Teff (K)	6179	6136	6189	
Log g	4.40	4.40	4.40	





HD 52265 :
examples of « good » models




Preliminary results
0.23, Y
0.19, Y
0.23, Yg
0.19, Yg
log g = 4.282 +/- 0.006
3.8
4.0
4.2
4.4
log g
3.80
3.78
3.76
log(T)

Conclusions

- radius, mass : OK

- age : careful ;
  needs precise determination of Teff and/or L

- seismic log g may be used to help
  checking Teff determinations

but: other uncertainties; surface effects?