HD 43318 — Seismic Interpretation

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We report on the seismic interpretation of the frequencies of the star HD 43318.

Global Parameters of HD 43318

- $T_{eff} = 6280 \pm 100$ K
- $M_{bol} = 2.85 \pm 0.10$
- $[Fe/H] = -0.18 \pm 0.10$
- vsini $= 6 \pm 4$ km/s

- Original model produced by Gabrielle Berthomieu
- Time series produced by Thierry Appourchaux
- Frequencies extracted by Patrick Boumier & Jeremie Lochard

Estimation of acoustic depths of base of CZ and HeII ionisation zone

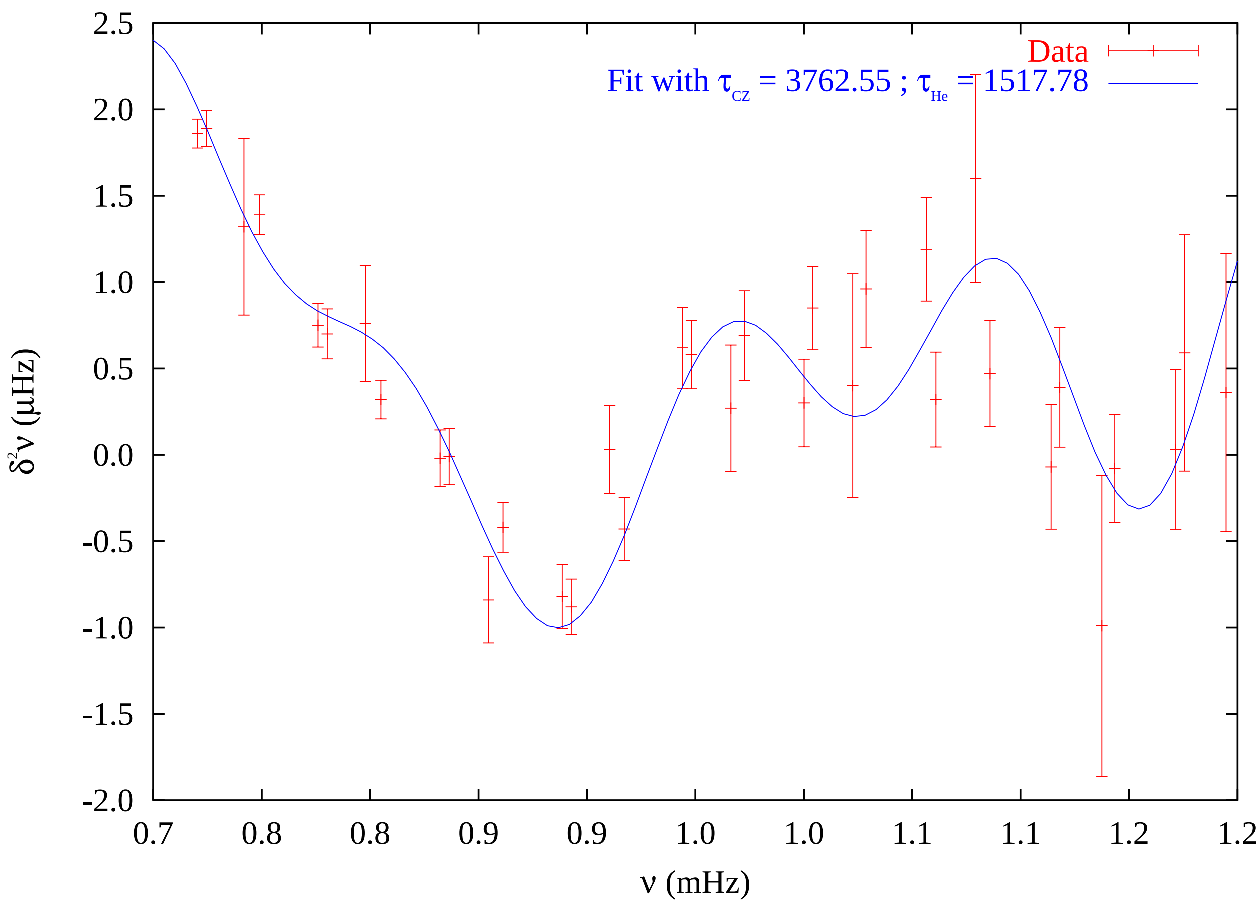
Discontinuities in sound speed derivatives at the HeII ionisation zone and the base of the convective envelope give rise to oscillations in the frequencies.

We fit a function of the form

$$\delta^2\nu(\mathrm{n},\ell) = \left(\mathrm{a}_0 + \frac{\mathrm{a}_1}{\nu_{\mathrm{n},\ell}} + \frac{\mathrm{a}_2}{\nu_{\mathrm{n},\ell}^2}\right)\sin(4\,\pi\nu_{\mathrm{n},\ell}\,\tau_{\mathrm{CZ}} + \phi_{\mathrm{CZ}}) + \left(\mathrm{b}_0 + \frac{\mathrm{b}_1}{\nu_{\mathrm{n},\ell}} + \frac{\mathrm{b}_2}{\nu_{\mathrm{n},\ell}^2}\right)\sin(4\,\pi\nu_{\mathrm{n},\ell}\,\tau_{\mathrm{HeII}} + \phi_{\mathrm{HeII}}).$$

to the second differences of the data, taking into account the errors.

Estimation of acoustic depths of base of CZ and HeII ionisation zone



The fit provides us with values for the acoustic depths of

- the base of the convective envelope: $\tau_{CZ} = 3763 \pm 134$ s
- the HeII ionisation zone: $\tau_{\mathrm{He}II} = 1518 \pm 98$ s

These estimates help to search the closest model.

Stellar Models

Evolutionary tracks were computed with CESAM using

- CEFF equation of state
- OPAL opacities
- NACRE nuclear reaction rates
- MLT convection
- Eddington atmosphere
- No diffusion

Frequencies were computed with ADIPLS.

Variable parameters of models

• Core overshoot (in H_P)	:	d_{ov}	:	0	—	0.2
• Mixing length (in H_P)	:	α	:	1.6	—	1.8
• Metallicity	:	[Fe/H]	:	−0.28	—	−0.08
• Initial Helium abundance	:	Y_0	:	0.25	—	0.28

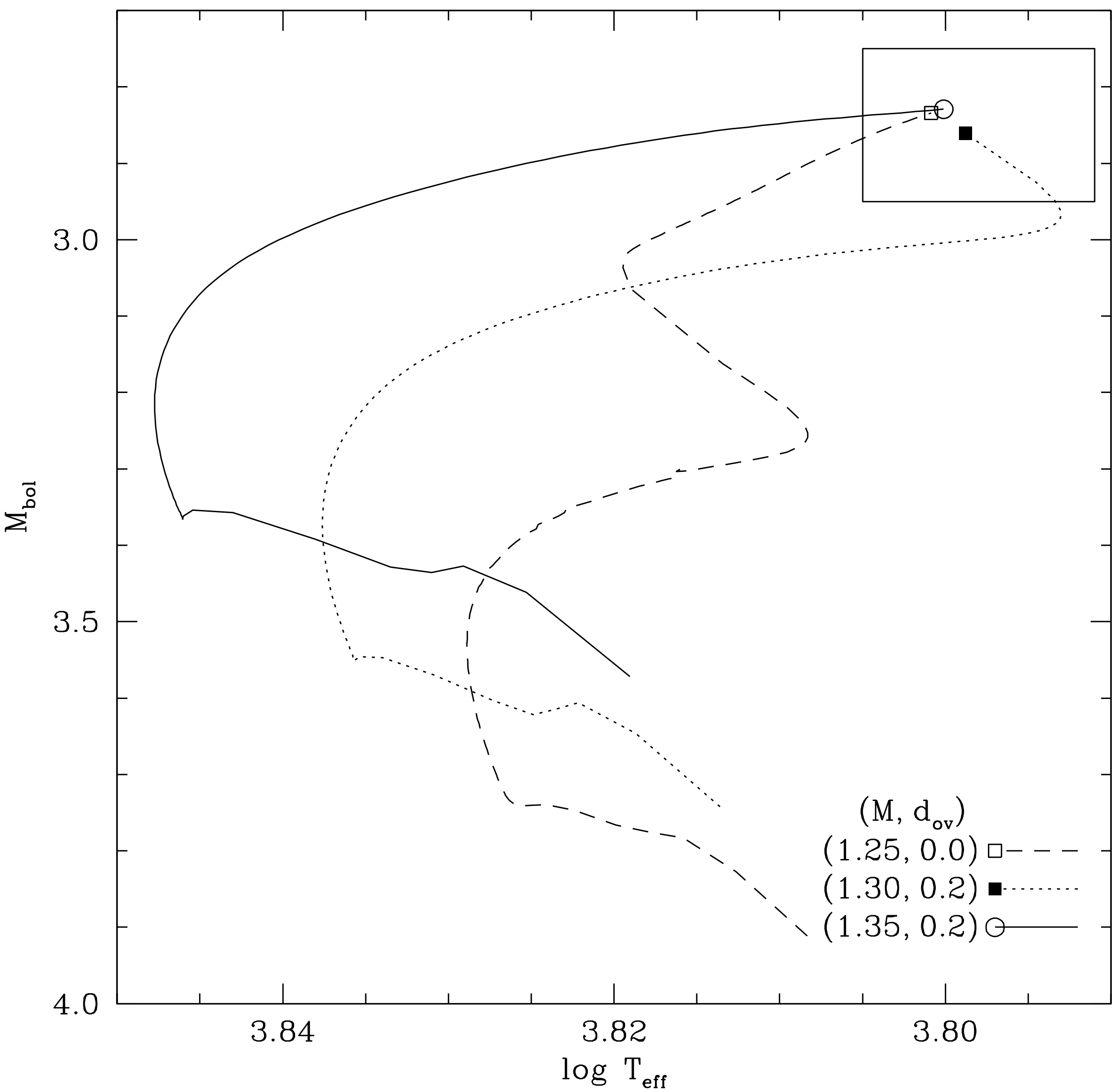
All CESAM models are computed with a "high" precision parameter to avoid irregular features at convective zone boundaries
— more accurate models, but very time-consuming!!

Technique

- For a particular combination of these parameters we vary the mass of the model to check for overlap between main sequence tracks and the global parameters of HD 43318 on the HR diagram.
- Compare large and small separations of the "data" with the computed values to find the closest possible model.

Some preliminary inferences from global parameters

Both MS and post-MS models are possible at the same point within the HD 43318 box on the HR diagram.



Some preliminary inferences from global parameters

- Main sequence models are permissible only for
  - Moderate to high overshoot (0.1–$0.2\ H_P$)
  - Low value of α
  - Higher metallicity ([Fe/H] $= -0.08$ to -0.23)
- Near-end-MS models are possible for
  - Moderate overshoot
- Main sequence models are excluded for
  - Low or zero overshoot
  - Lower metallicity

Table showing overlap of Main Sequence tracks and HD 43318 parameters

Parameters		d_{ov}= 0.0		d_{ov}= 0.1		d_{ov}= 0.2	
[Fe/H]	Y_0	$\alpha = 1.6$	$\alpha = 1.8$	$\alpha = 1.6$	$\alpha = 1.8$	$\alpha = 1.6$	$\alpha = 1.8$
	0.28	—	—	1.35 — 1.41	1.35 — 1.41	1.35 — 1.42	1.34 — 1.40
−0.08	0.27	—	—	1.37 — 1.43	1.37 — 1.43	1.35 — 1.42	1.35 — 1.41
	0.26	—	—	1.39 — 1.45	1.39 — 1.44	1.35 — 1.42	1.36 — 1.42
	0.27	—	—	1.32 — 1.38	—	1.31 — 1.36	1.30 — 1.36
−0.18	0.26	—	—	1.34 — 1.40	—	1.32 — 1.37	1.32 — 1.37
	0.25	—	—	1.36 — 1.42	—	1.35 — 1.40	1.35 — 1.40
	0.27	—	—	—	—	1.27 — 1.32	1.27 — 1.32
−0.28	0.26	—	—	—	—	1.28 — 1.33	1.28 — 1.33
	0.25	—	—	—	—	1.30 — 1.35	1.30 — 1.34

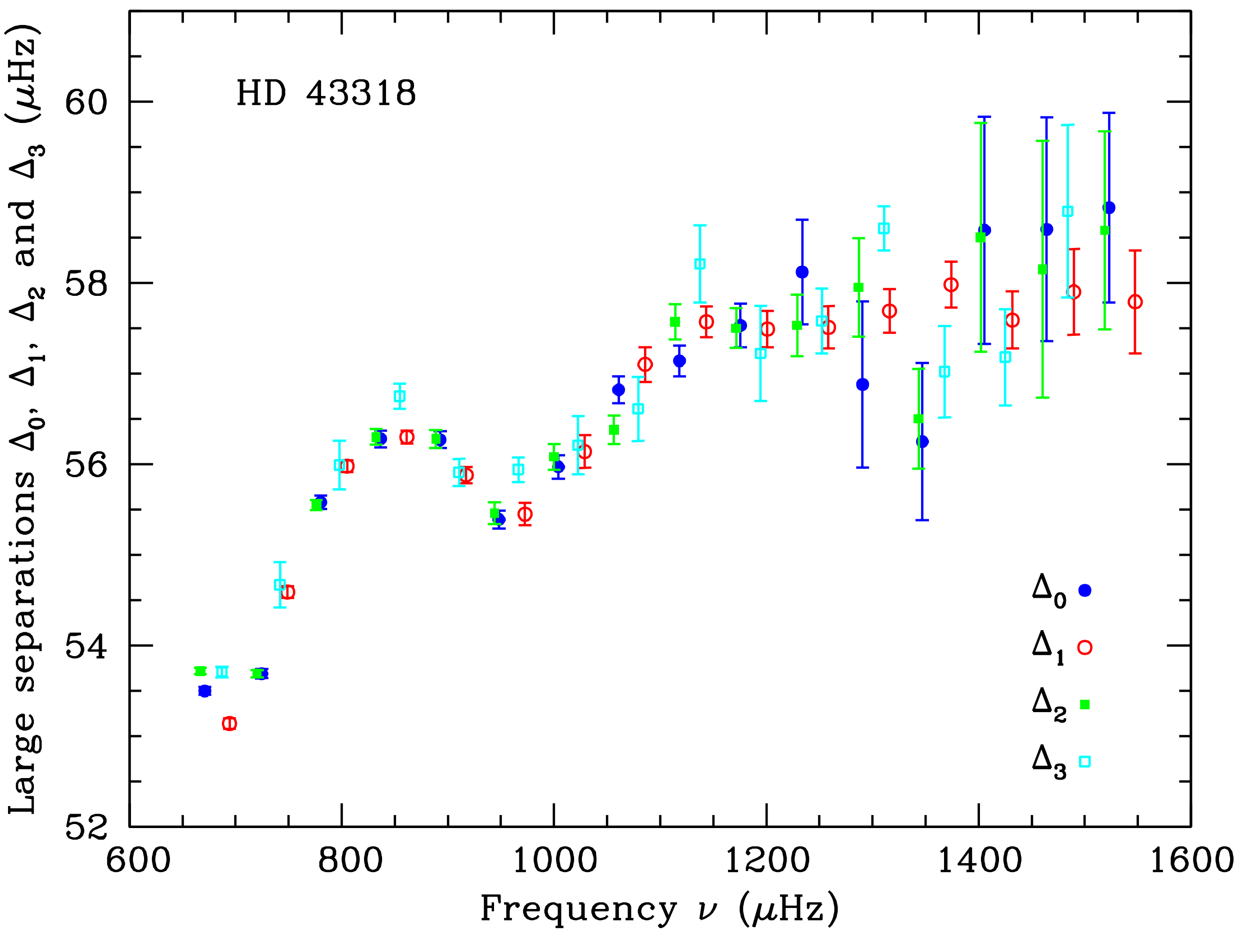
— No Main Sequence stars within HD 43318 box

M_1 — M_2 Main Sequence stars of mass between M_1 and M_2 cover HD 43318 box partially

M_1 — M_2 Main Sequence stars of mass between M_1 and M_2 fully traverse HD 43318 box

Large Separations

$$\Delta_{n\ell} = \nu_{n+1,\ell} - \nu_{n,\ell} \qquad \ell = 0, 1, 2, 3$$

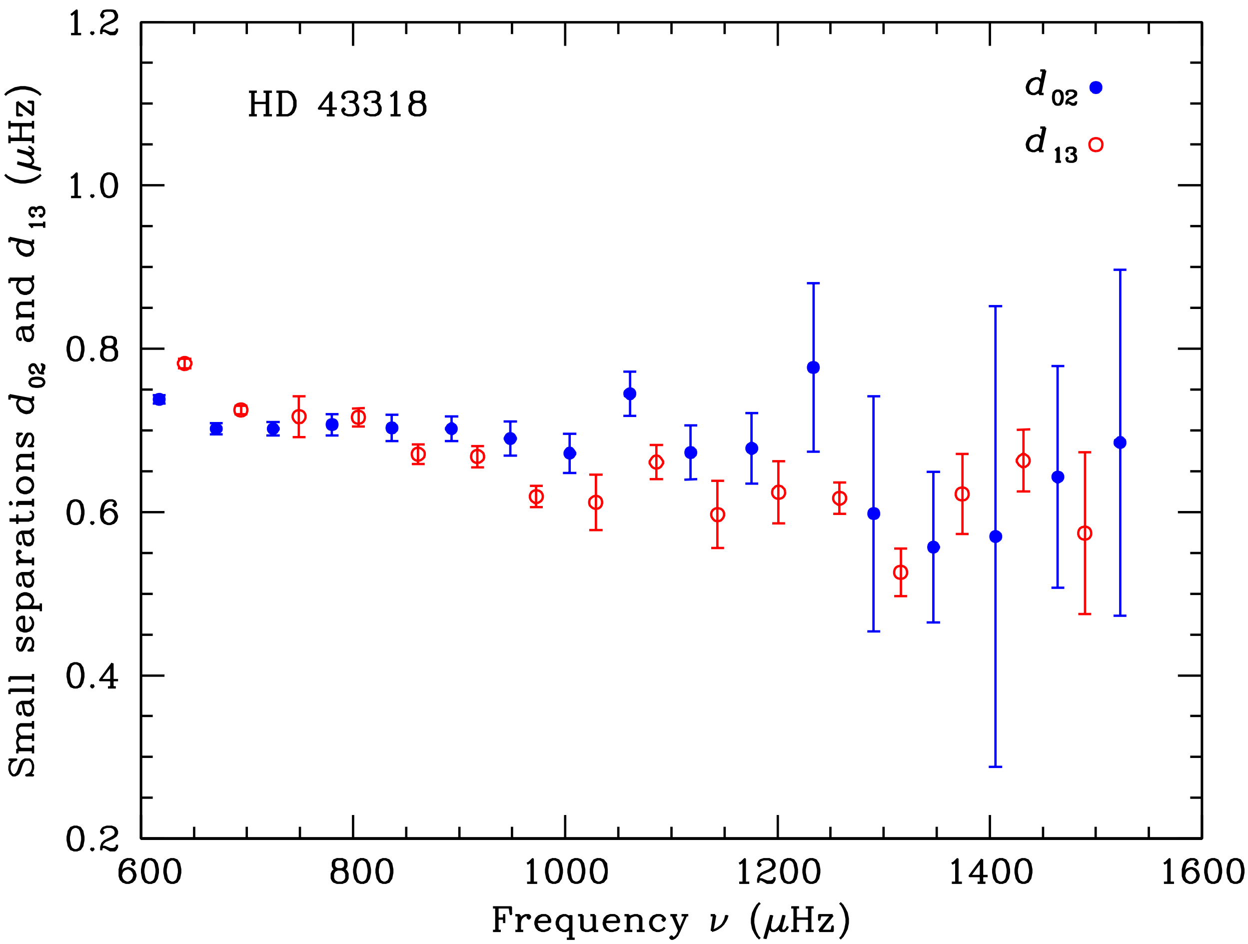


Small Separations

- Between $\ell = 0,\ 2$ modes and $\ell = 1,\ 3$ modes:

$$d_{02} = [\nu_{n,0} - \nu_{n-1,2}]/6$$

$$d_{13} = [\nu_{n,1} - \nu_{n-1,3}]/10$$

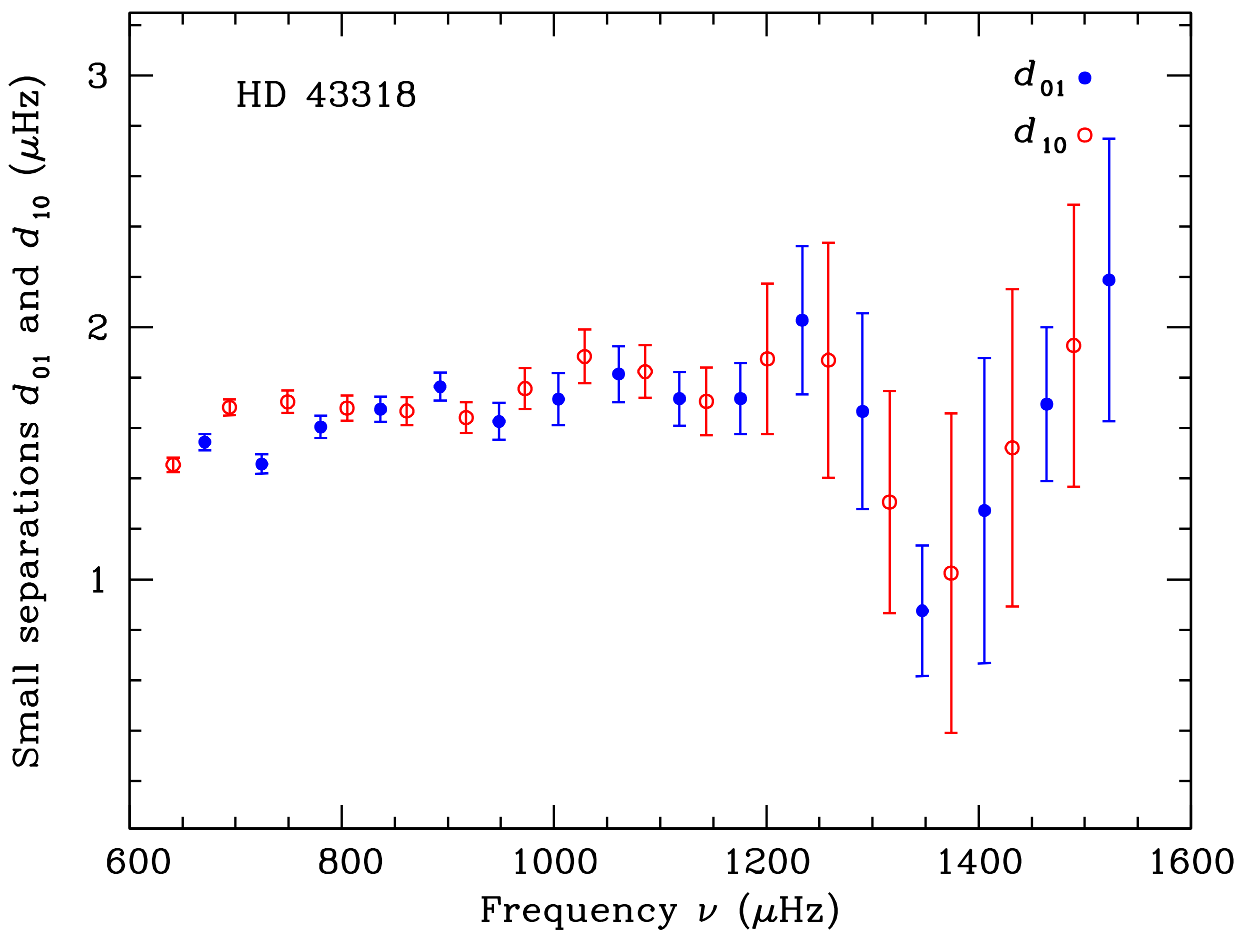


Small Separations

- Between $\ell = 0,\ 1$ modes:

$$d_{01} = \quad [\nu_{n,0} - (\nu_{n,1} + \nu_{n-1,1})/2]/2$$

$$d_{10} = -[\nu_{n,1} + (\nu_{n,0} + \nu_{n+1,0})/2]/2$$



Approaching the closest model

- Average value of large separation provides initial estimate of the mean density of the model:

$$\bar{\rho}/\bar{\rho_\odot} = 0.17$$

- Explore the sensitivity of different features of the large and small separations to the six model parameters:

$$\mathrm{M}, \mathrm{Age}, \mathrm{Y}, [\mathrm{Fe/H}], \mathrm{d_{ov}}, \alpha$$

- Simultaneous matching of large and small separations by tuning these parameters is desirable.
- Several "best case" scenarios are identified, and a comparison of the deviations of the large and small separations of the models from the data is made to select the closest model.

Closest Model

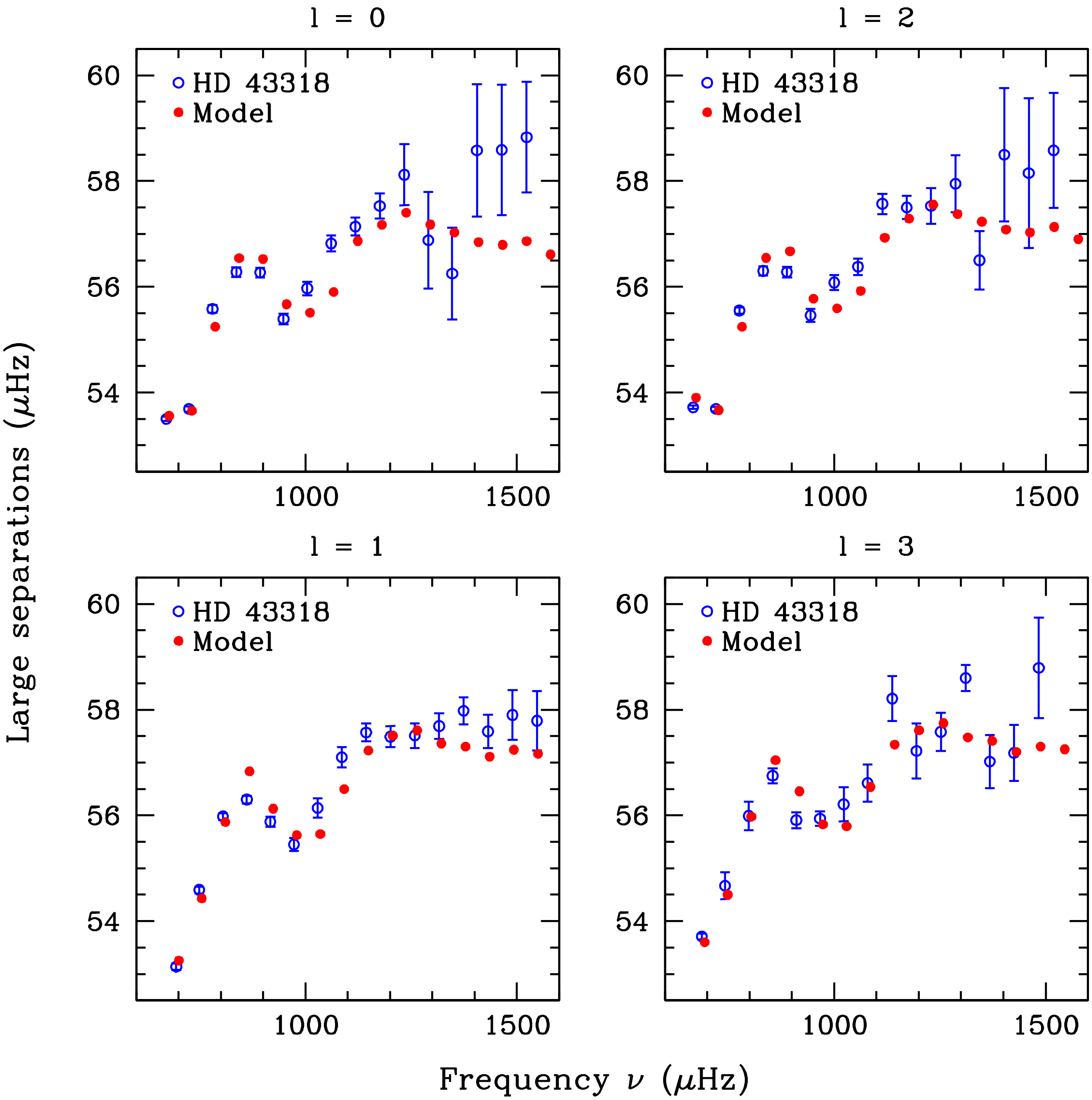
Our closest model for HD 43318 corresponds to

- $M/M_{\odot} =$ 1.38
- $X_c = 0.18$
- $[Fe/H] = -0.08$
- $Y = 0.26$
- $d_{ov} = 0.15$
- $\alpha = 1.6$

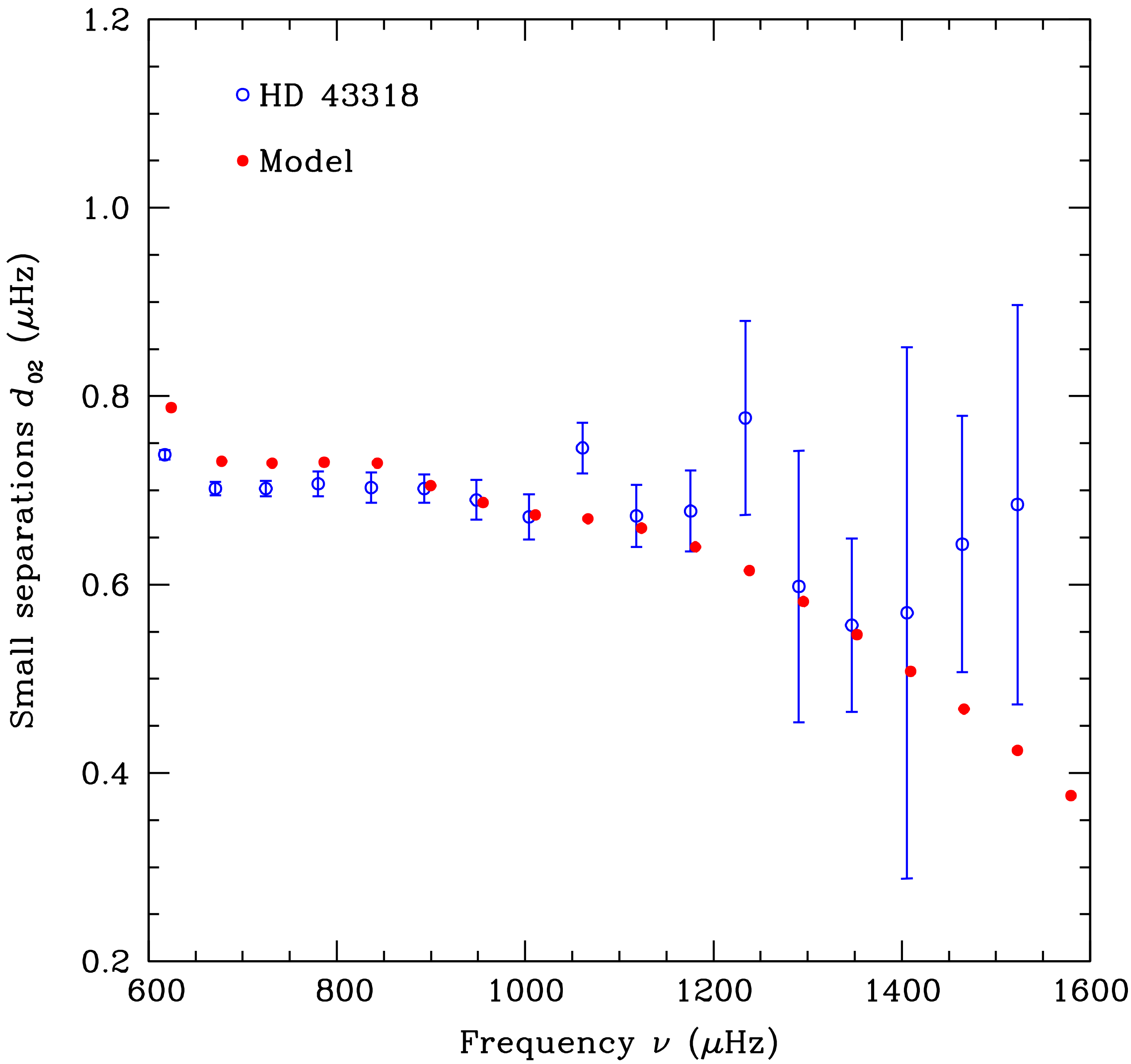
Values for

- $\bar{\rho}/\bar{\rho_{\odot}} = 0.1713$
- $\tau_{CZ} = 3763$ s
- $\tau_{HeII} = 1471$ s

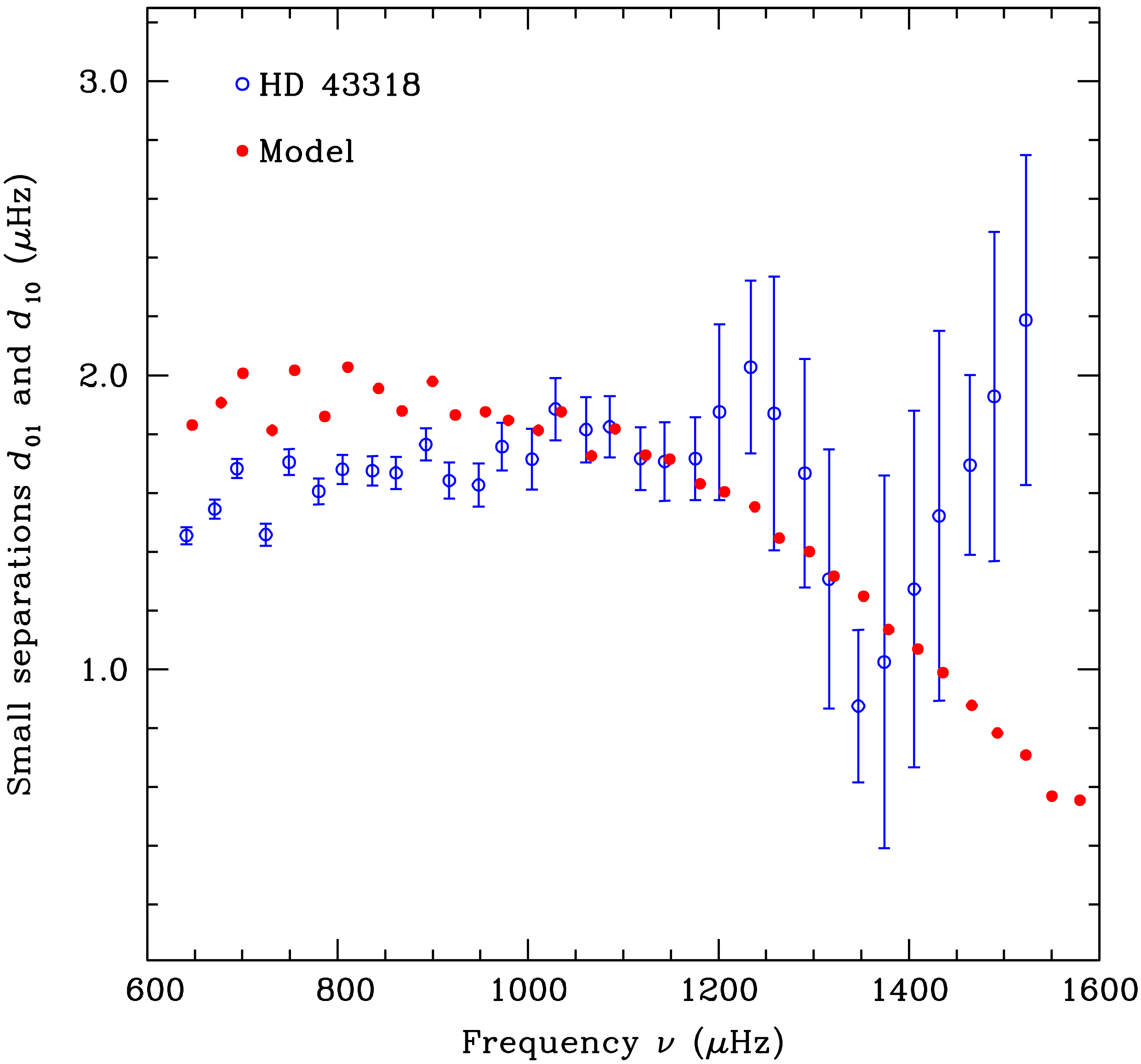
Closest Model



Closest Model



Closest Model



Conclusion

We were able to:

- get an estimate of $\bar{\rho}$ through $\Delta_{n\ell}$
- tune $\mathrm{d_{ov}}$ and $[Fe/H]$ to approach d_{02}

We were not able to:

- reproduce the pattern of large and small separations at all frequencies
- retrieve the behaviour of d_{01} and d_{10}