Description of the stellar models grid v1.0

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CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

Grid v1.0 for seismology

To be used for PLATO core program stars with seismic data

Provide an initial basis for building fundamental stellar parameters pipeline

Not intended for ‘professional’ PLATO use

limited in parameter space. M, [Fe/H], age

missing (possibly) relevant physics: e.g. radiative levitation, extra mixing, semiconvection
<3D> atmospheres,

better treatment of physics (e.g. overshooting)

Garstec models – 2000 mesh points

ADIPLS (v0.3) oscillations – re-meshed model to 7200 points

Grid v1.0 for seismology

What is available right now

	Range	Step
Mass	[0.6, 2.0] $M_\odot$	0.01 $M_\odot$
[Fe/H]	[-1.0, +0.60] ext. down to -2.5	0.05
Age	70 Gyr (priors later on) logg = 3.1	max step scales as 10Myr/M^3
N. steps & frequencies	2000-2500	ΔT_{eff} < 10-15K in SG
Structures	1/3 cadence	
Storage	190 Gb / 380 Gb 2.4 Tb / 4 Tb (w/structures)	

Physics I

Grey T-τ relation - VAL-C (solar based, empirical, Vernazza et al. 1982, analytic fit – JCD & Sonoi et al.)
intermediate between Eddington and Krishna Swamy
good/decent job on RGB Teff with solar calibration

Solar Fusion II nuclear rates (low 14N+p from LUNA), weak and intermediate e^- screening

Wichita low-T opacities, OPAL opacities, (& Potekhin cond. opacities)

MLT – solar calibrated

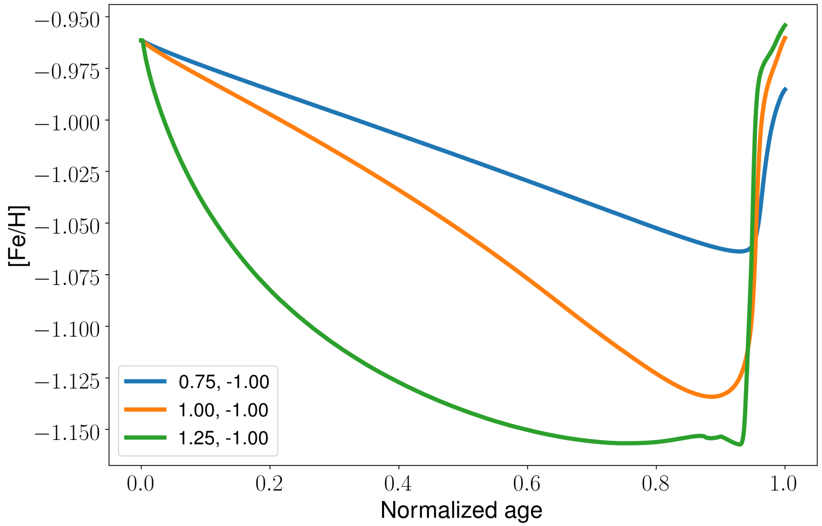
Z/Y from solar calibration → $\Delta Y/\Delta Z$ from SBBN

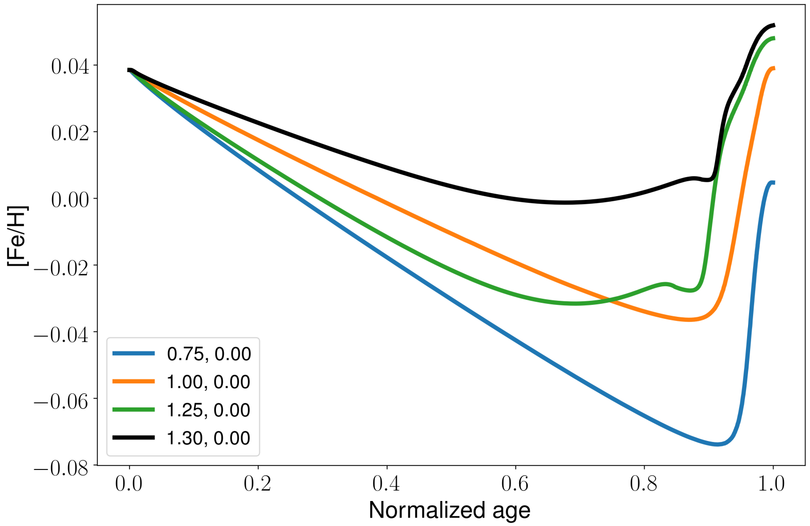
[Fe/H] = 0 @ Z/X= 0.02493 (GN93)

Physics II

Microscopic diffusion – Thoul 1994, fully ionized
switched off smoothly from 1.25 to 1.35 $M_\odot$

Extra mixing below CZ – Vandenberg et al. 2012 (scales with envelope mass)
calibrated to reproduce solar Li and (approximately) depletion in metal poor (globular) clusters





Physics

Overshooting – at all boundaries (CC and CE)

Diffusive approach (Steffen, Herwig, Ludwig) with exponential decay – **$D_C = D_0 \exp(-\Delta r / (f_{ov} H_p))$**

problem for small CC: $Hp > \Delta r$ (→ ∞)

Garstec – geometric cut: **$Hp \rightarrow Hp \times \min[1, (Rcc/Hp)^2]$**

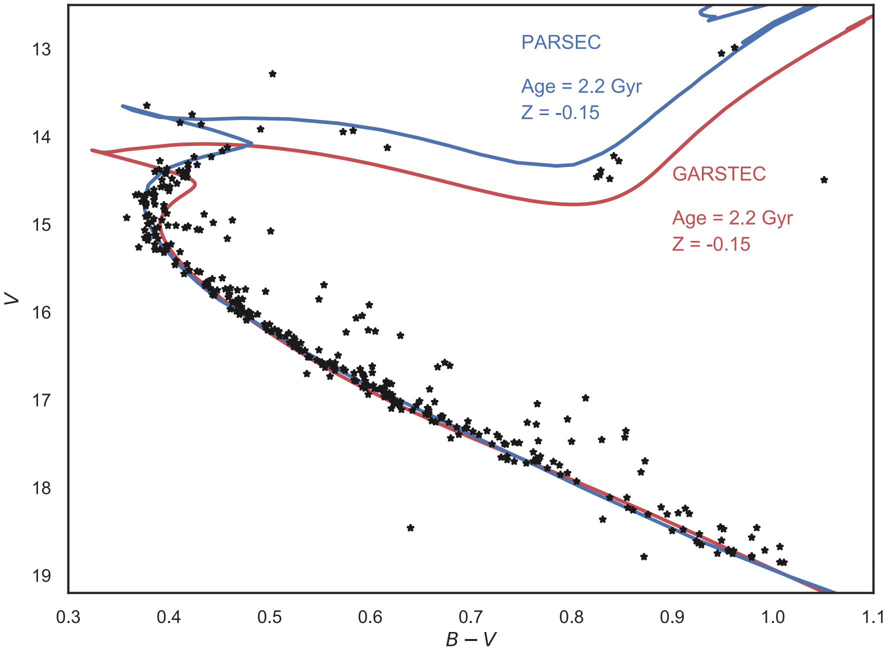
Too restrictive (Higl et al 2018 – HZ Fornacis)

Treatment of OV

Physics

Garstec – geometric cut: Hp → Hp x min[1, $(Rcc/Hp)^2$]

NGC 2420 – Semenova et al. in prep



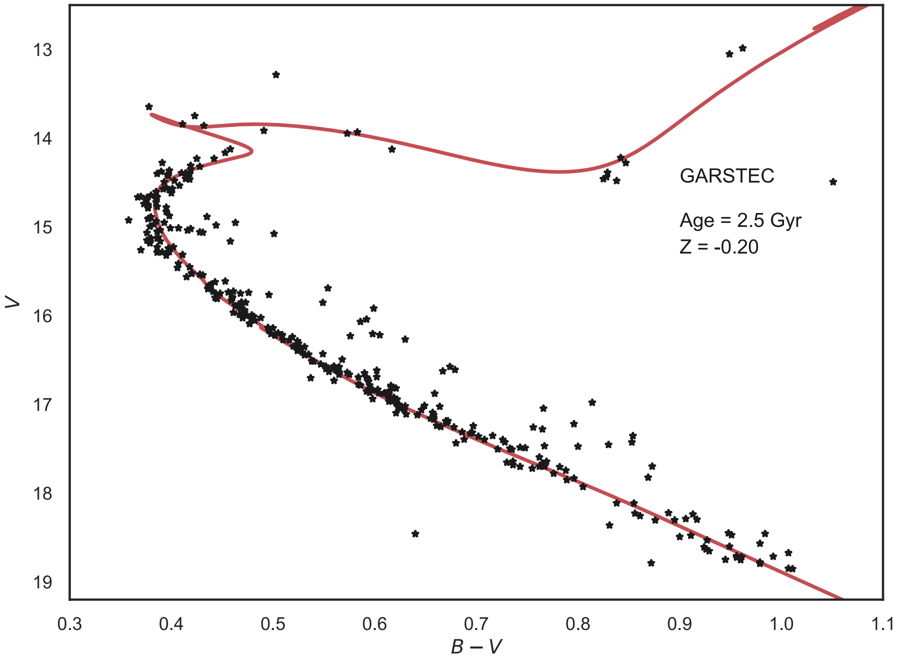
Grid v1.0 for seismology

Physics

Garstec – linear increase in f_{ov} from 1.1 to 1.4 $M_{\odot}$ in H-burning convective cores – geometric cut in other cases

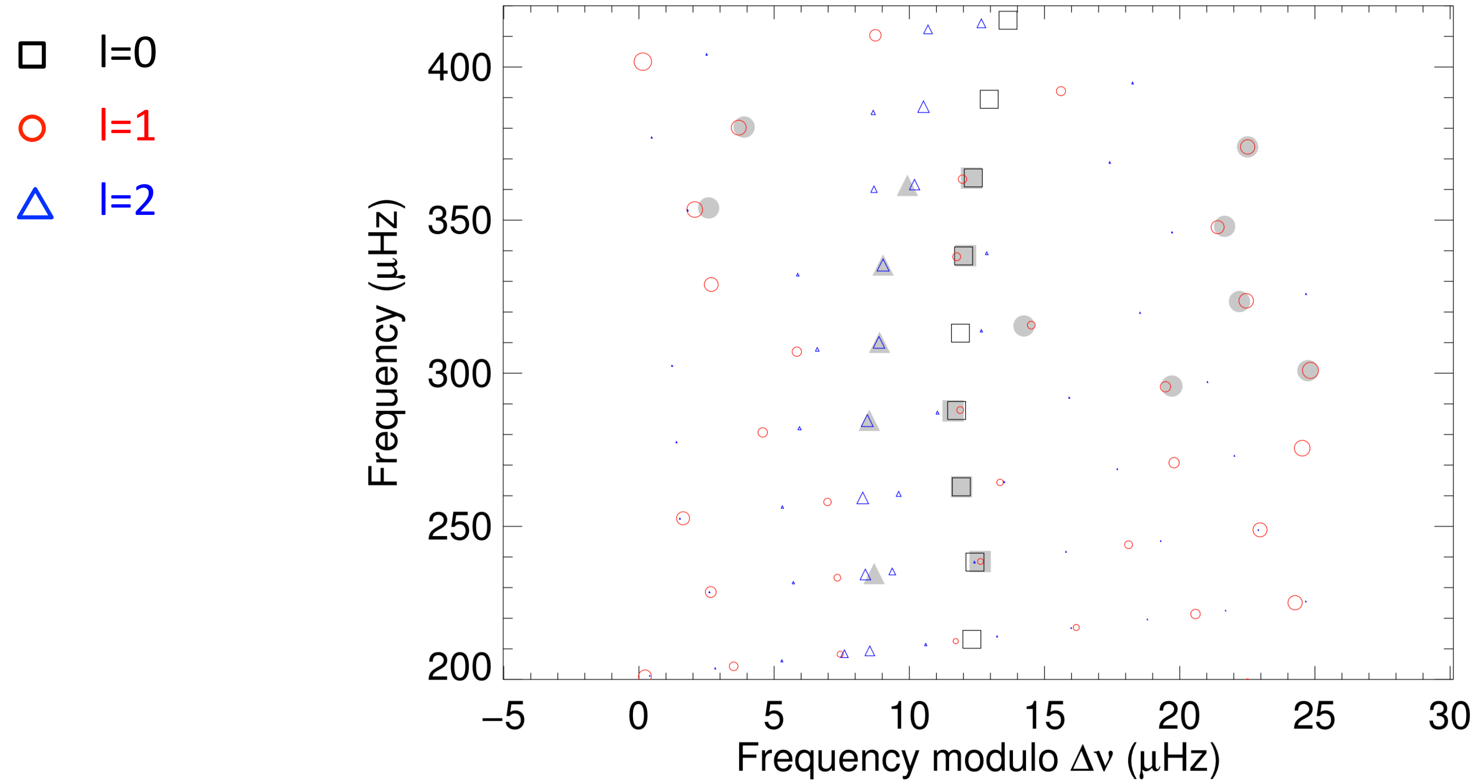
f_{ov} = 0.02 --- 0.20 – 0.25 Hp

NGC 2420 – Semenova et al. in prep



Some tests

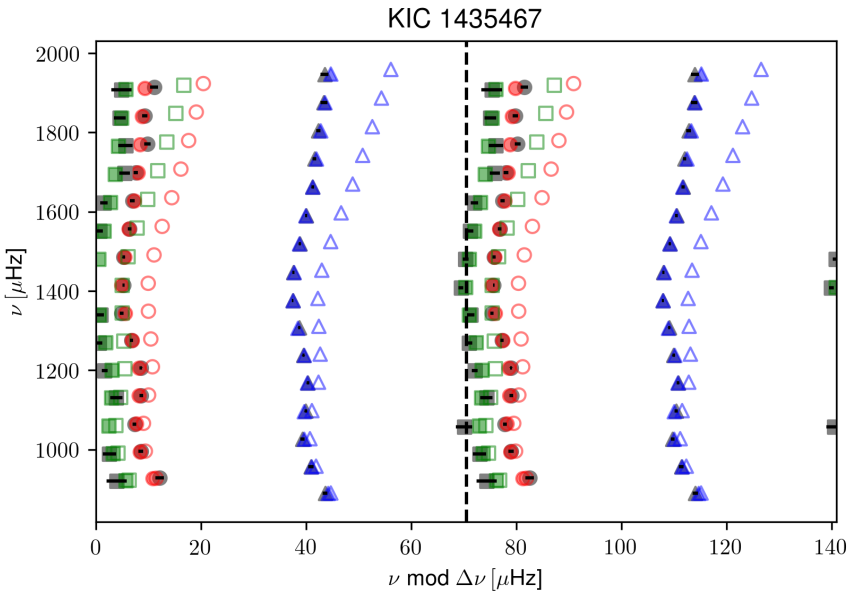
ν Indi, [Fe/H] = -1.50, [α/Fe]= +0.35

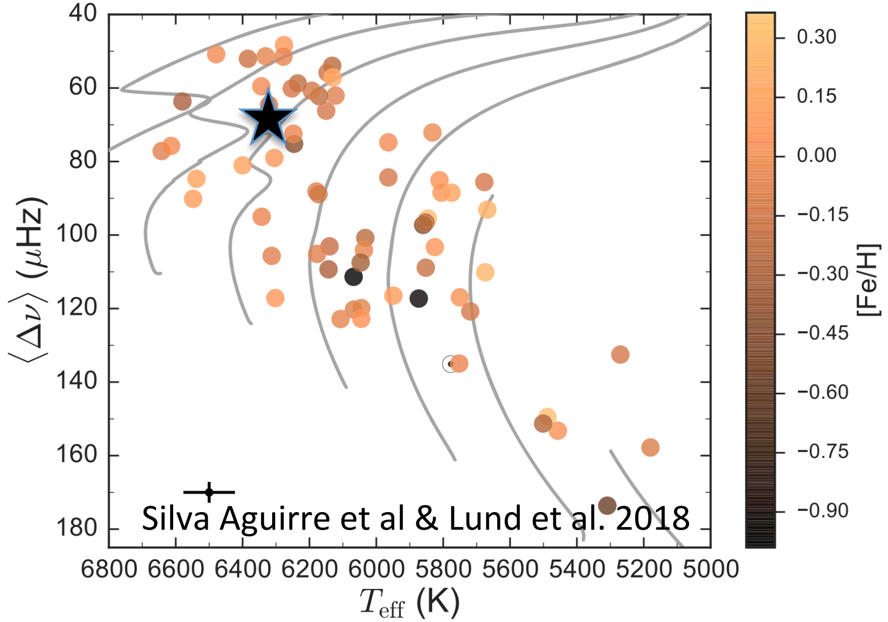


A few Legacy stars

KIC 1435467

M= 1.33 $M_{\odot}$ – [Fe/H]= 0.01 – χ^2= 71 (46) + 2.6

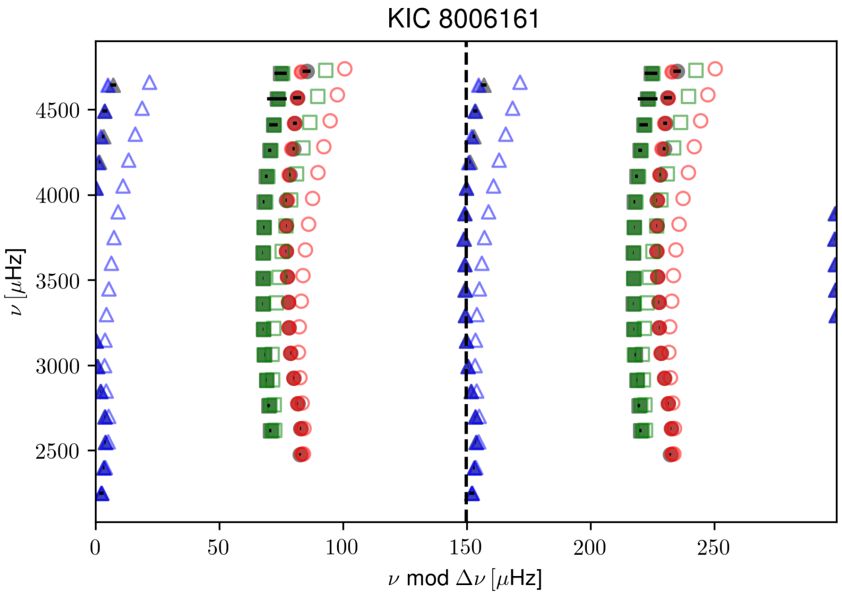


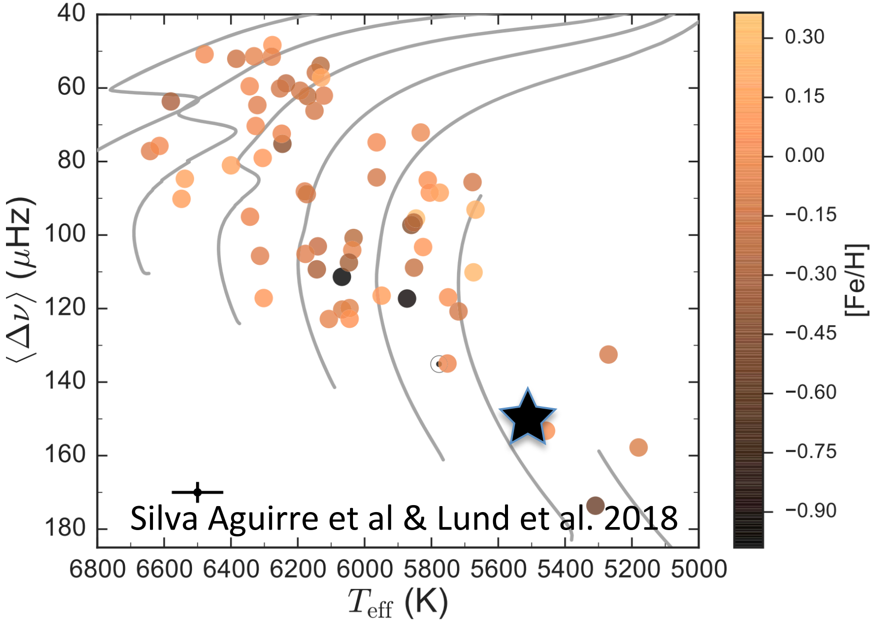


A few Legacy stars

KIC 8006161

M= 0.98 $M_\odot$ – [Fe/H]= 0.34 – χ^2= 100 (48) + 2.4

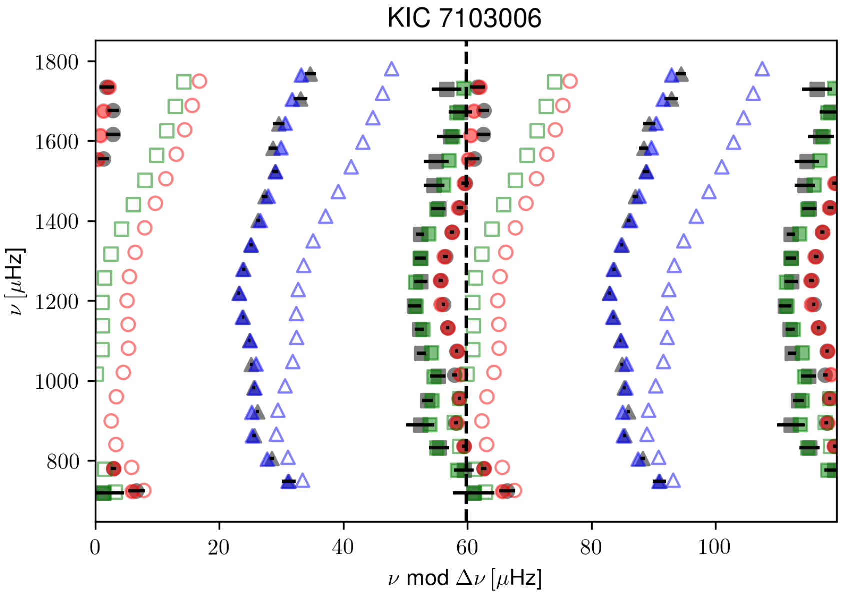


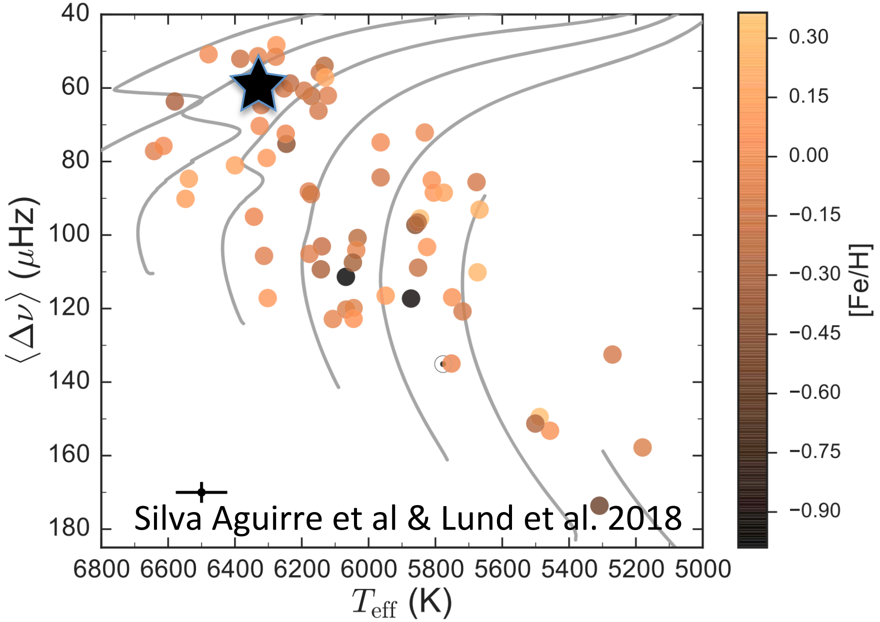


Silva Aguirre et al & Lund et al. 2018

KIC 7103006

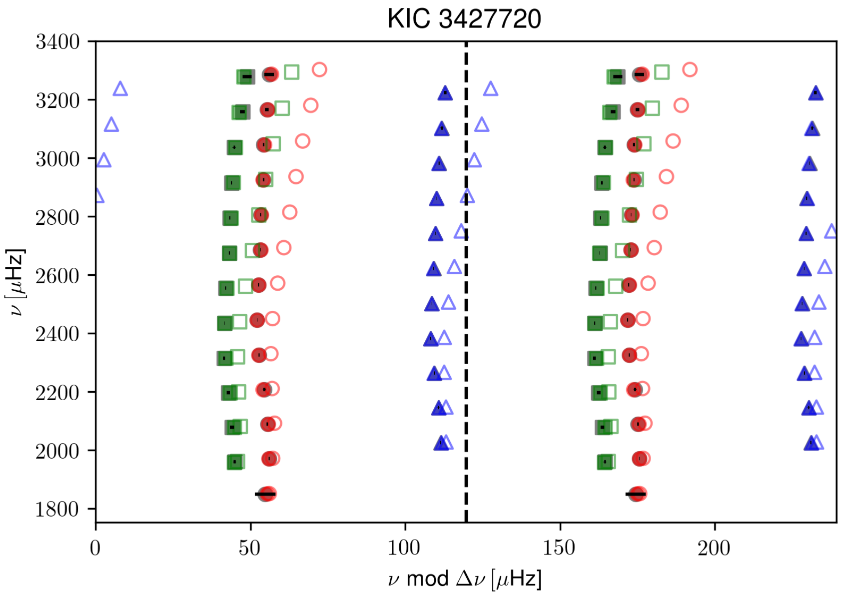
M= 1.41 $M_\odot$ – [Fe/H]= 0.02 – χ^2= 80 (54) + 4.8

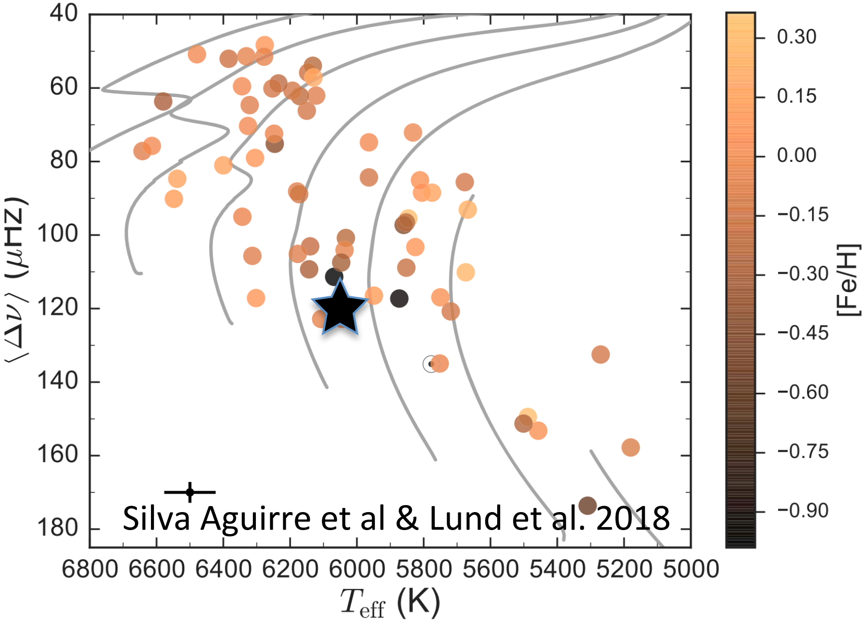




KIC 3427720

M= 1.10 $M_{\odot}$ – [Fe/H]= 0.02 – χ^2= 44 (36) + 1.8

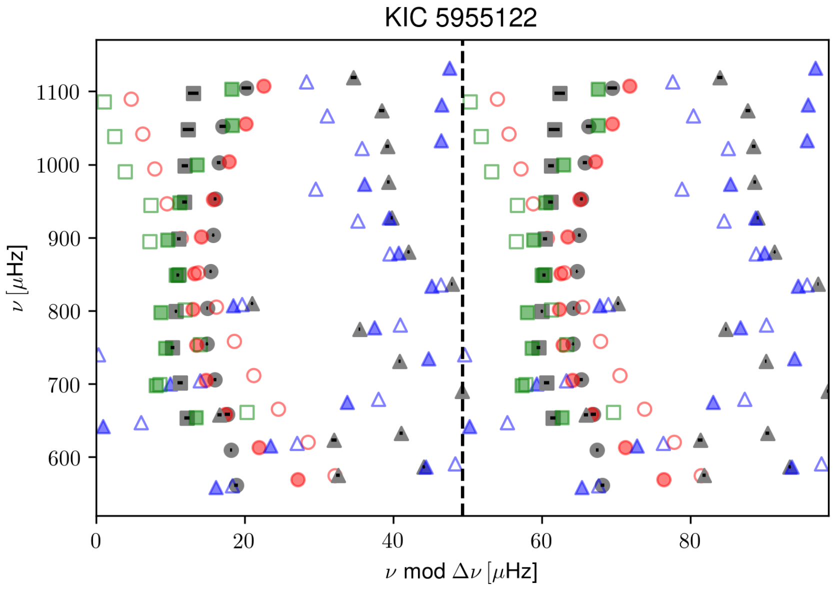




A few subgiants

KIC 5955122 (Appourchaux et al. 2012)

$$M= 1.20\ M_\odot - [Fe/H]= -0.22 - \chi^2= 24818\ (38)$$

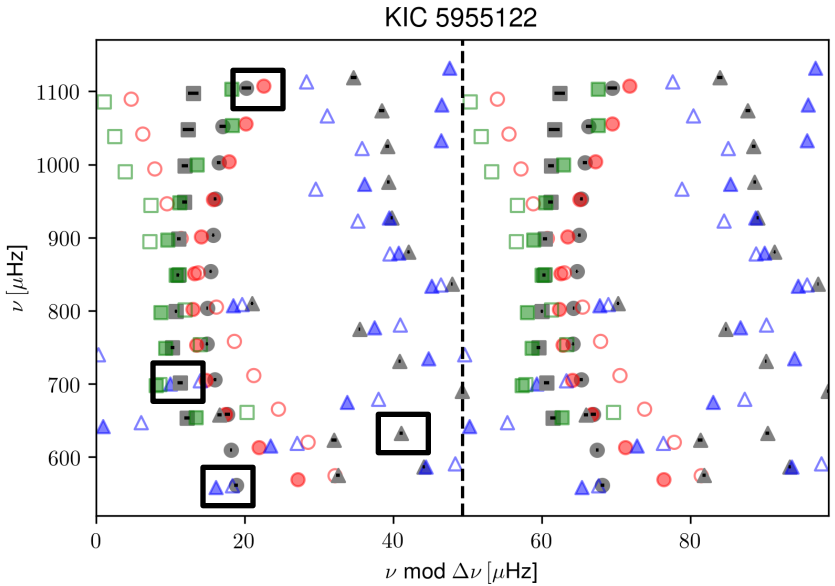


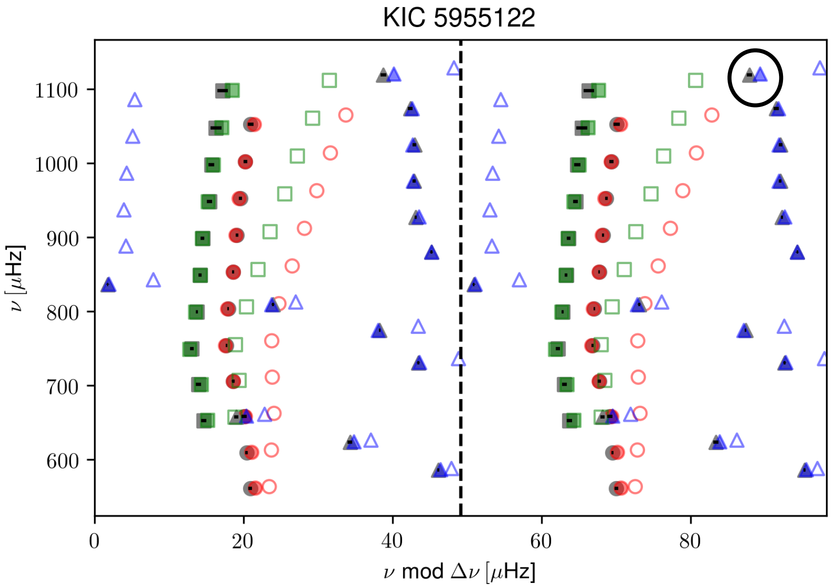
Terrible fit

A few subgiants

KIC 5955122 (Appourchaux et al. 2012)

$$M = 1.20\ M_{\odot} - [Fe/H] = -0.22 - \chi^2 = 106\ (34)$$



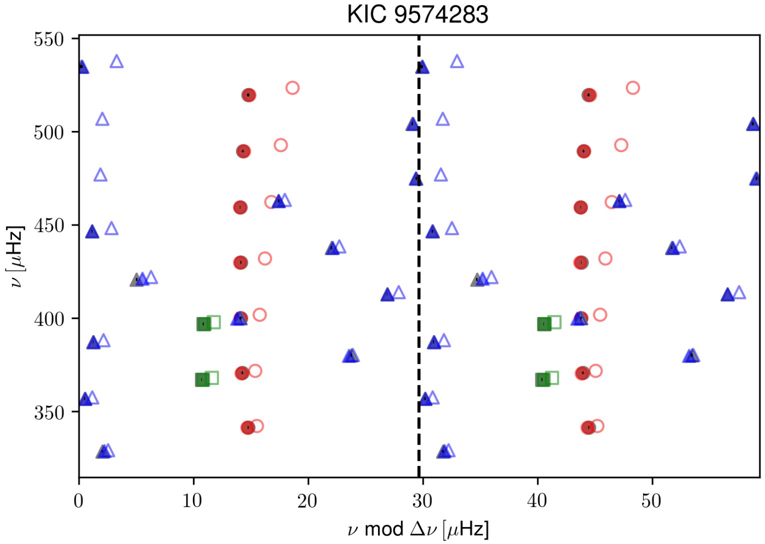


Pretty good fit

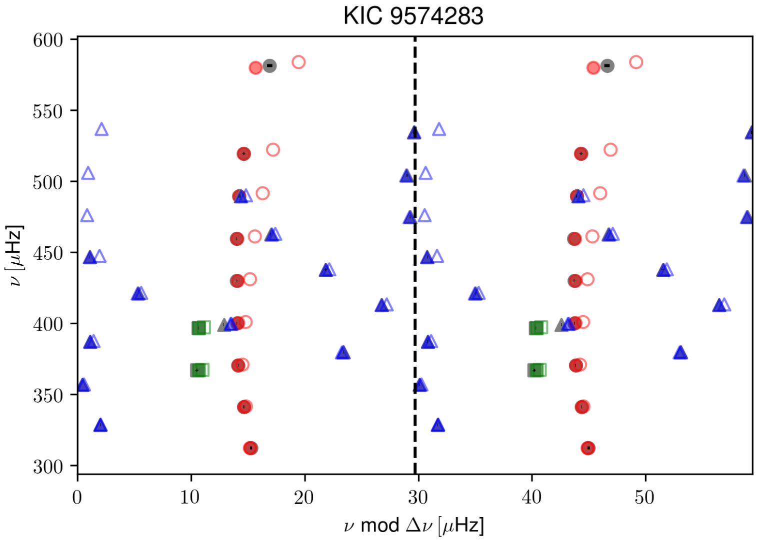
A few subgiants

KIC 9574283 (Appourchaux et al. 2012, Deheuvels et al. 2014)

M= 1.06 $M_\odot$ – [Fe/H]= -0.40 – χ^2= 201 (22)



M= 1.08 $M_\odot$ – [Fe/H]= -0.40 – χ^2= 1305 (25)
<errors> ~ 0.03 μHz

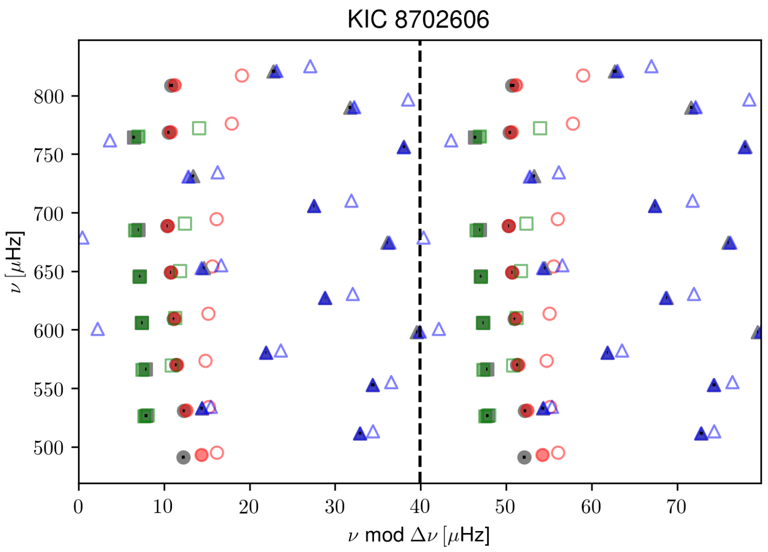


How bad is this model for PLATO's goal?

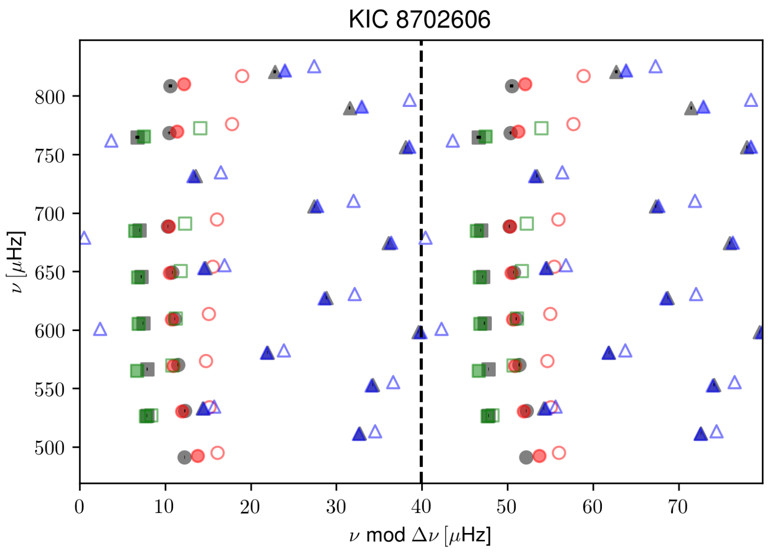
A few subgiants

KIC 8702606 (Appourchaux et al. 2012, Deheuvels et al. 2014)

M= 1.25 $M_\odot$ – [Fe/H]= -0.18 – χ^2= 398 (27)



M= 1.25 $M_\odot$ – [Fe/H]= -0.16 – χ^2= 6685 (27)

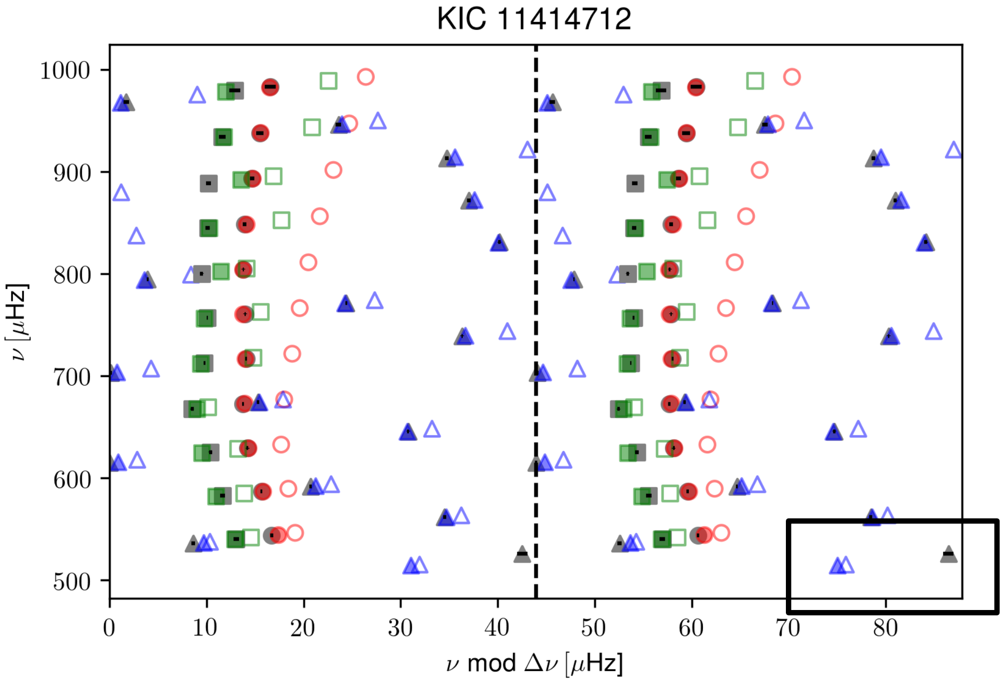


How bad is this model for PLATO's goal?

A few subgiants

KIC 11414712 (Appourchaux et al. 2012)

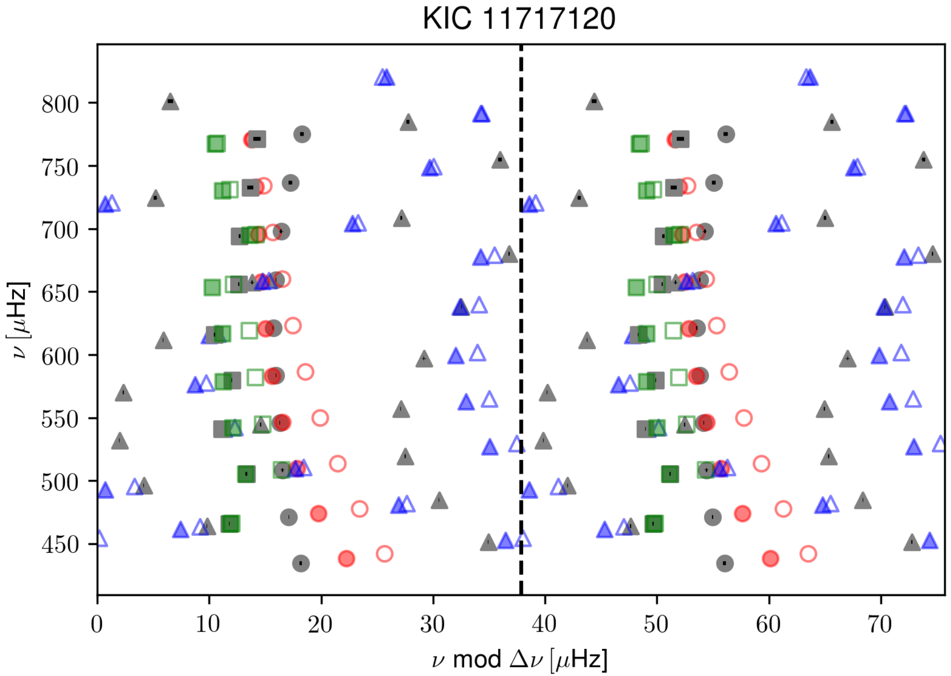
$M = 1.22\ M_\odot$ – [Fe/H]= -0.15 – χ^2= 1123 (38)



A few subgiants

KIC 11717720 (Appourchaux et al. 2012)

M≈ 0.85 $M_\odot$ – [Fe/H]= -0.50 – χ^2= 253000 (38) – more in depth analysis TBD



Summary

- 1st grid based on reasonably ok physics
- So far so good for stars with no mixed modes (but only partial testing)
- Good job for subgiants, generally speaking
- Easy to add synthetic photometry if needed (MARCS and ATLAS)
- For more realistic grids: additional dimensions Z-Y, OV, MLT?

Maybe seismic pipeline should include (given PLATO goals, not for very detailed stellar physics work):

  a criterion of when a fit is a good or bad fit (especially due to one or a few frequencies)
  removal of 'nasty' frequencies? – so maybe iterative seismic analysis

Do Hare & Hounds yield realistic measures of quality?

  Guess is that stellar models do not hold surprises, but actual stars might do