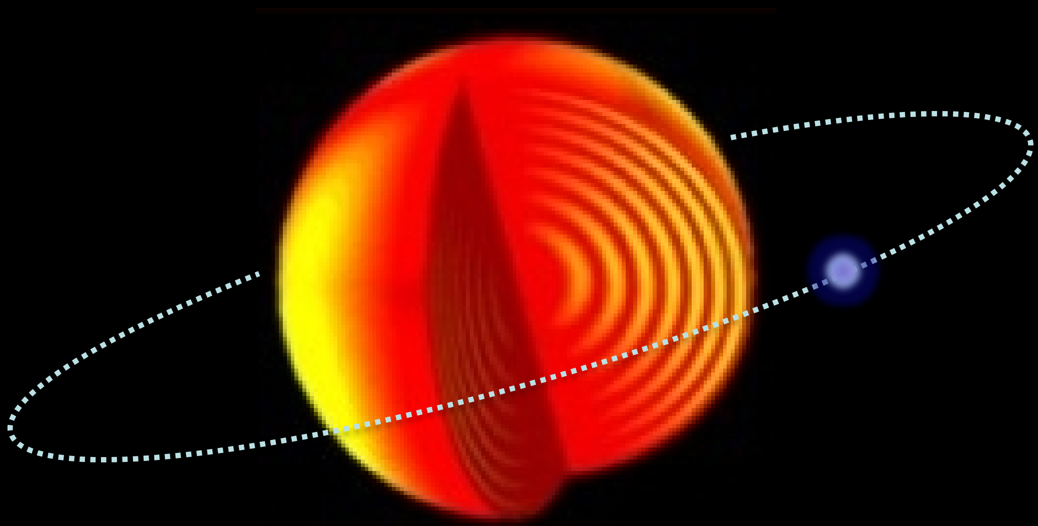
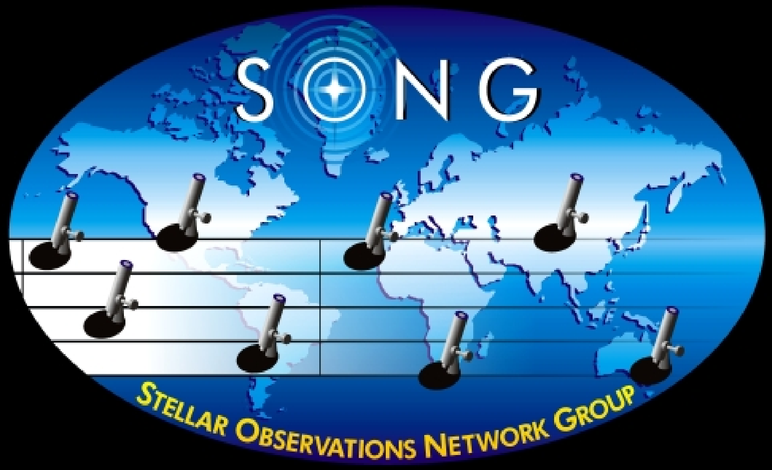
`Massive or not massive that is the question’

Seismology of planet hosting stars with SONG



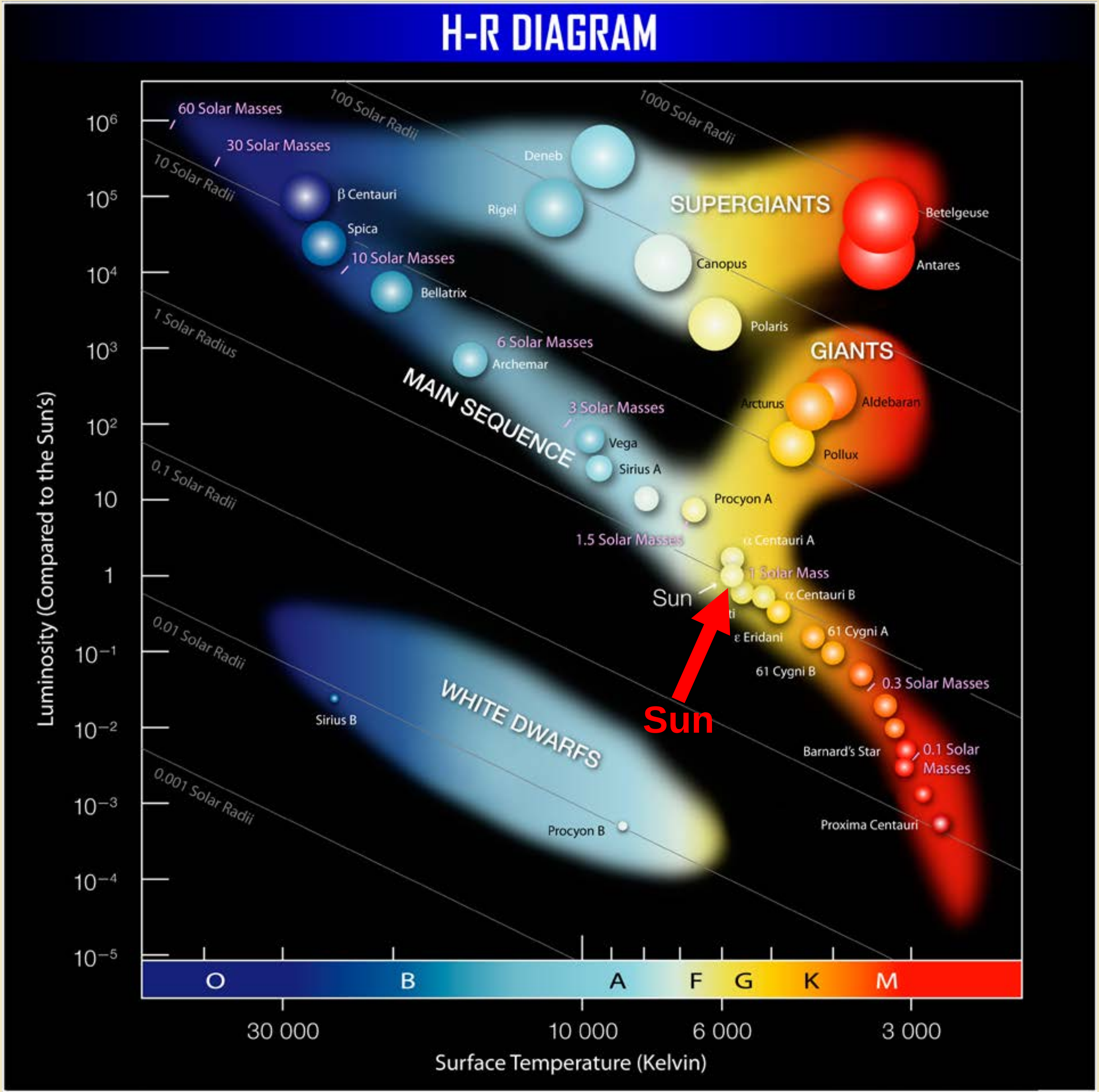


UNSW SYDNEY | Australia's Global University

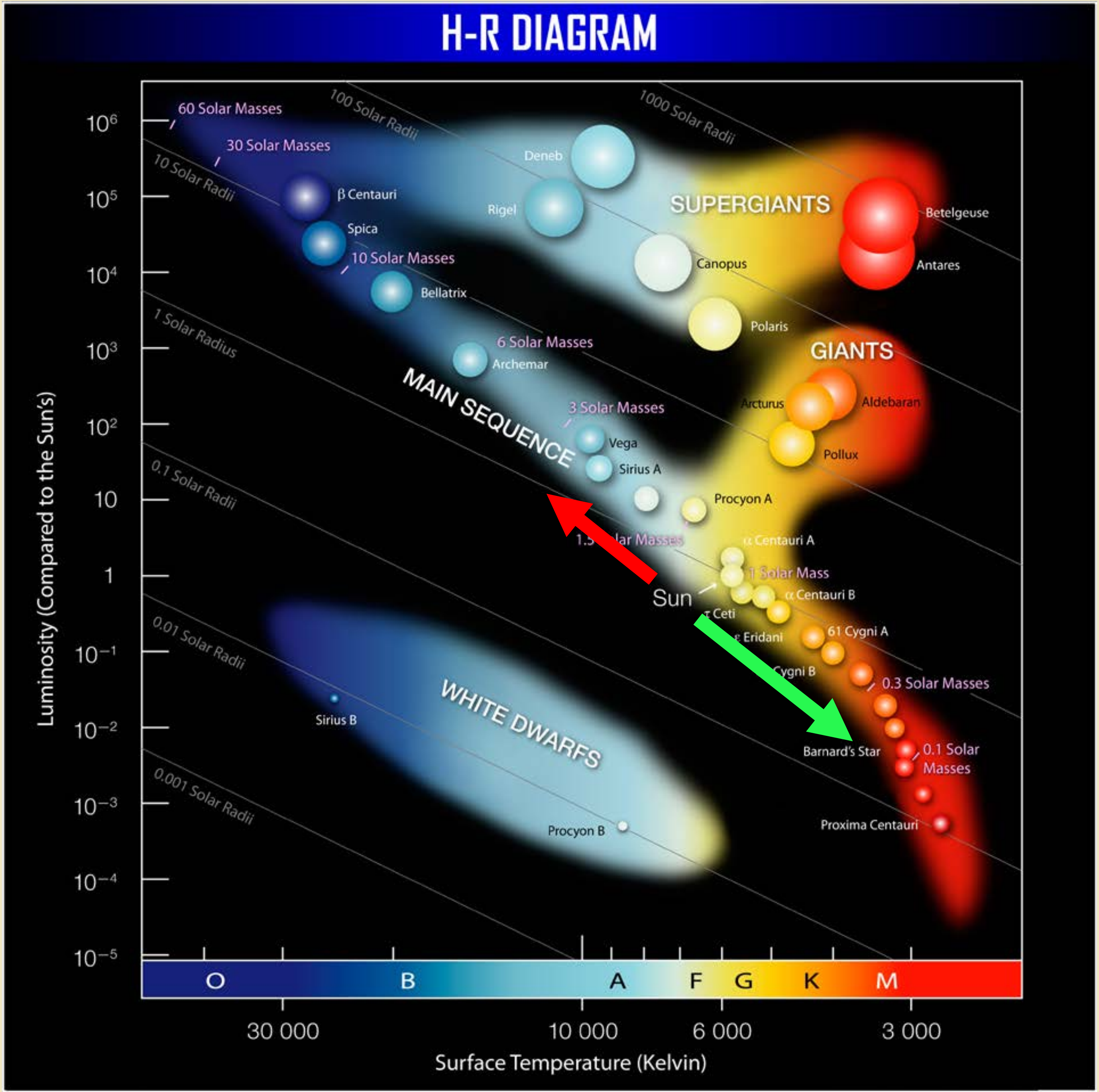
Dennis Stello

My kitchen floor

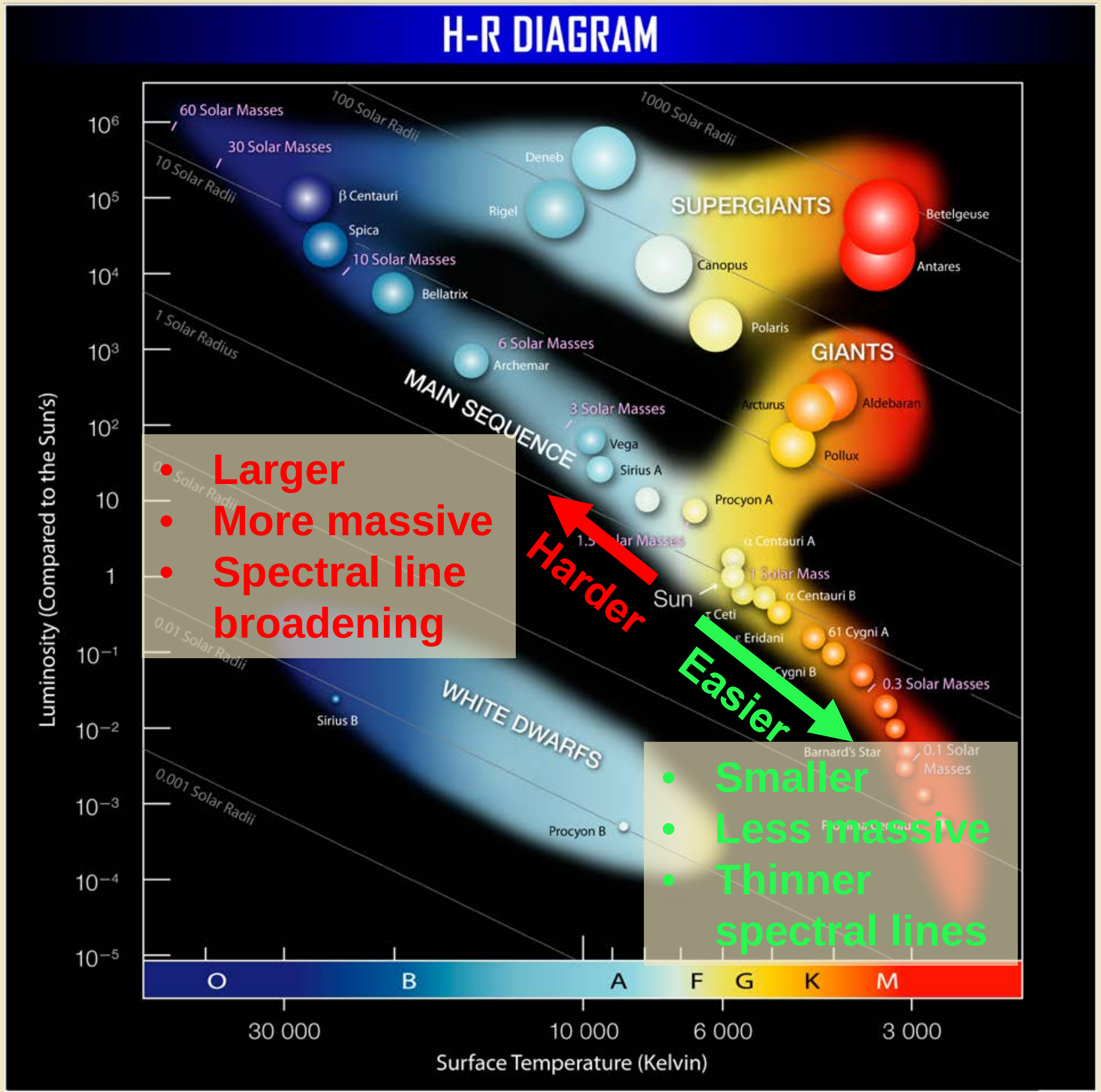
The search for extra solar planets



The search for extra solar planets



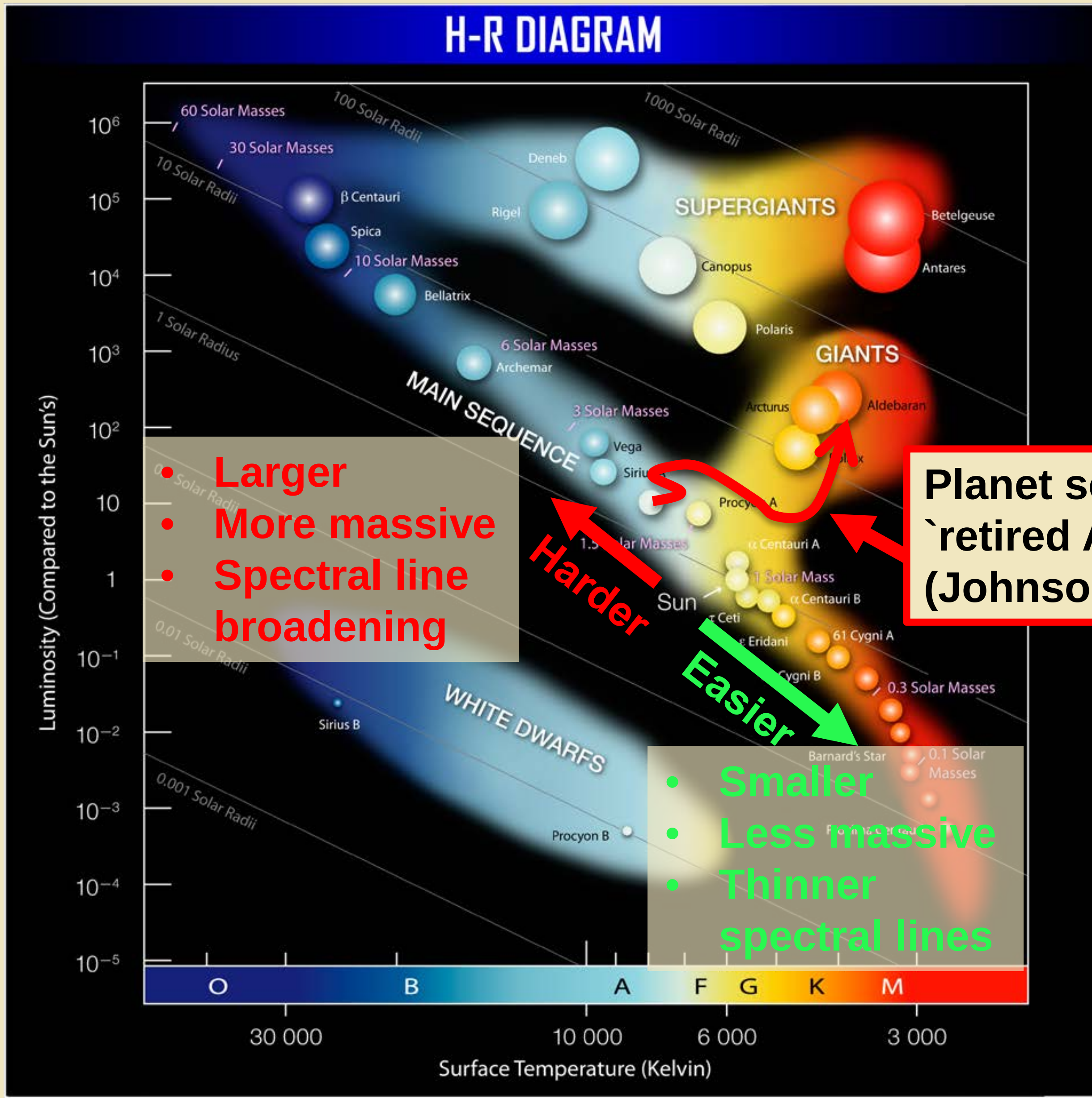
The search for extra solar planets



- Larger
- More massive
- Spectral line broadening

- Smaller
- Less massive
- Thinner spectral lines

The search for extra solar planets



- Larger
- More massive
- Spectral line broadening

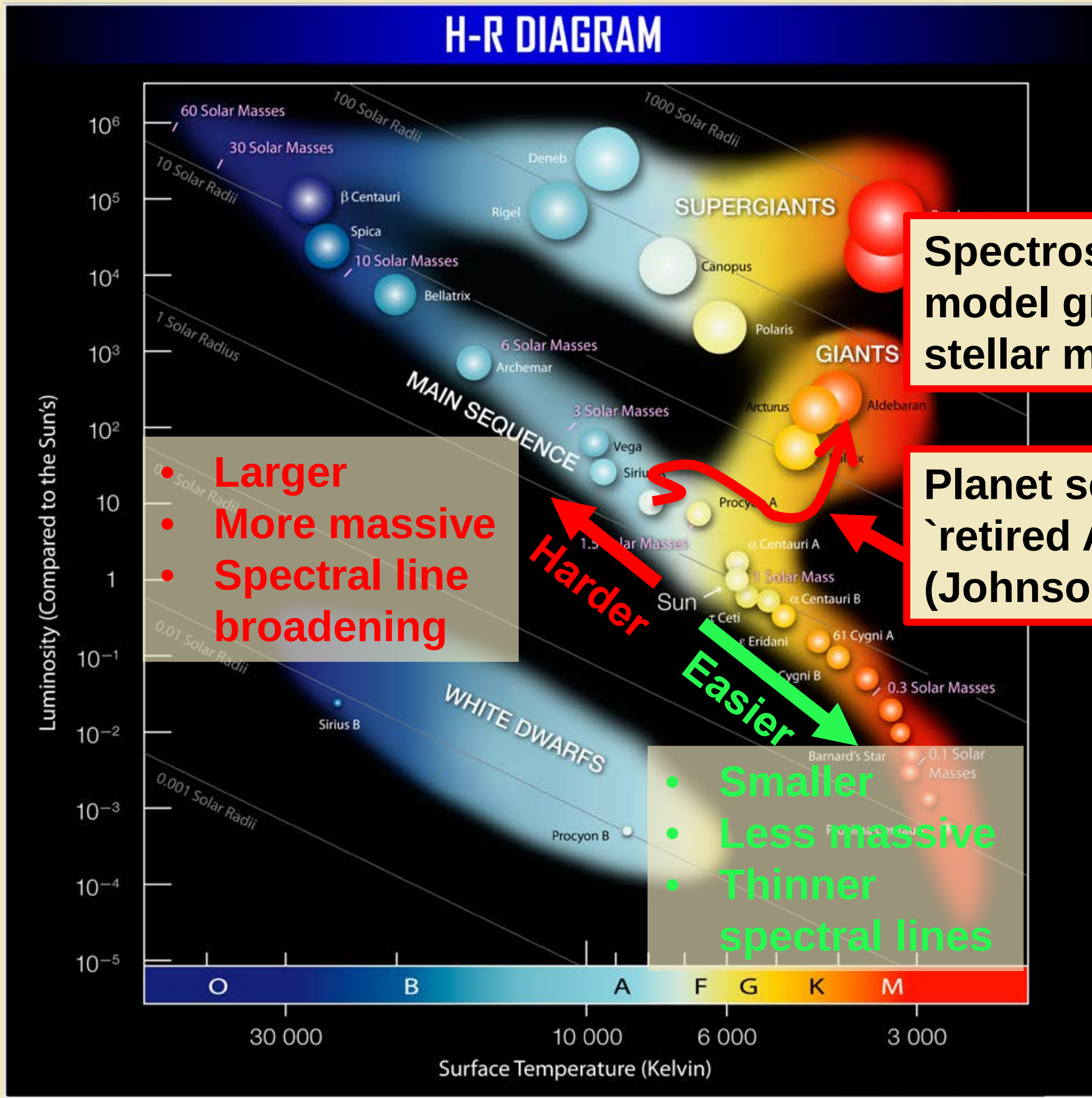
Harder

Easier

- Smaller
- Less massive
- Thinner spectral lines

Planet search around `retired A-stars' (Johnson et al. 2006)

The search for extra solar planets



- Larger
- More massive
- Spectral line broadening

- Smaller
- Less massive
- Thinner spectral lines

Spectroscopy + stellar model grids to determine stellar mass

Planet search around `retired A-stars' (Johnson et al. 2006)

Planets around `retired A-stars'

Johnson et al. (2007a,b) found increased planet occurrence, but fewer short-period planets towards more massive stars.

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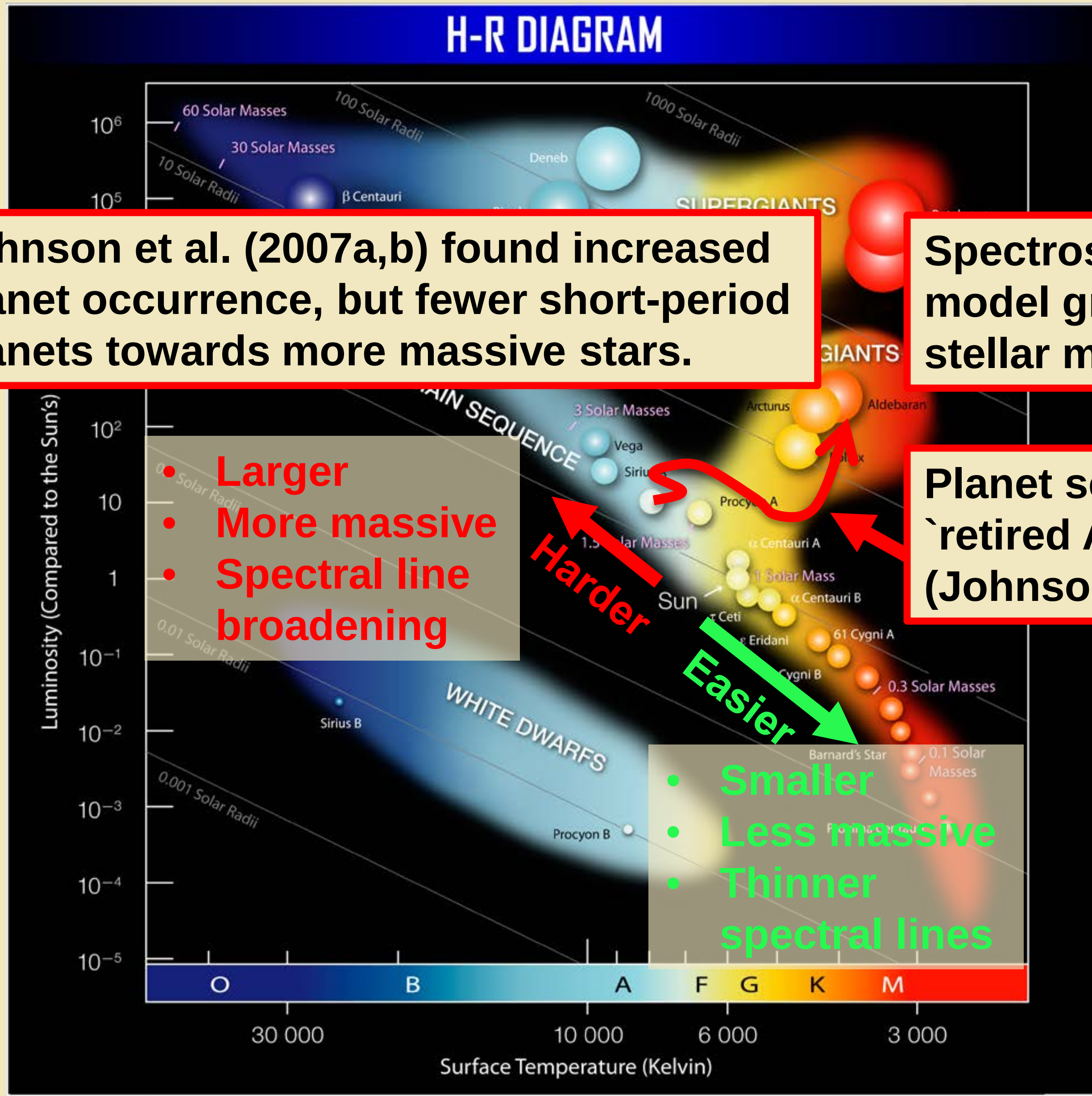

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- Smaller
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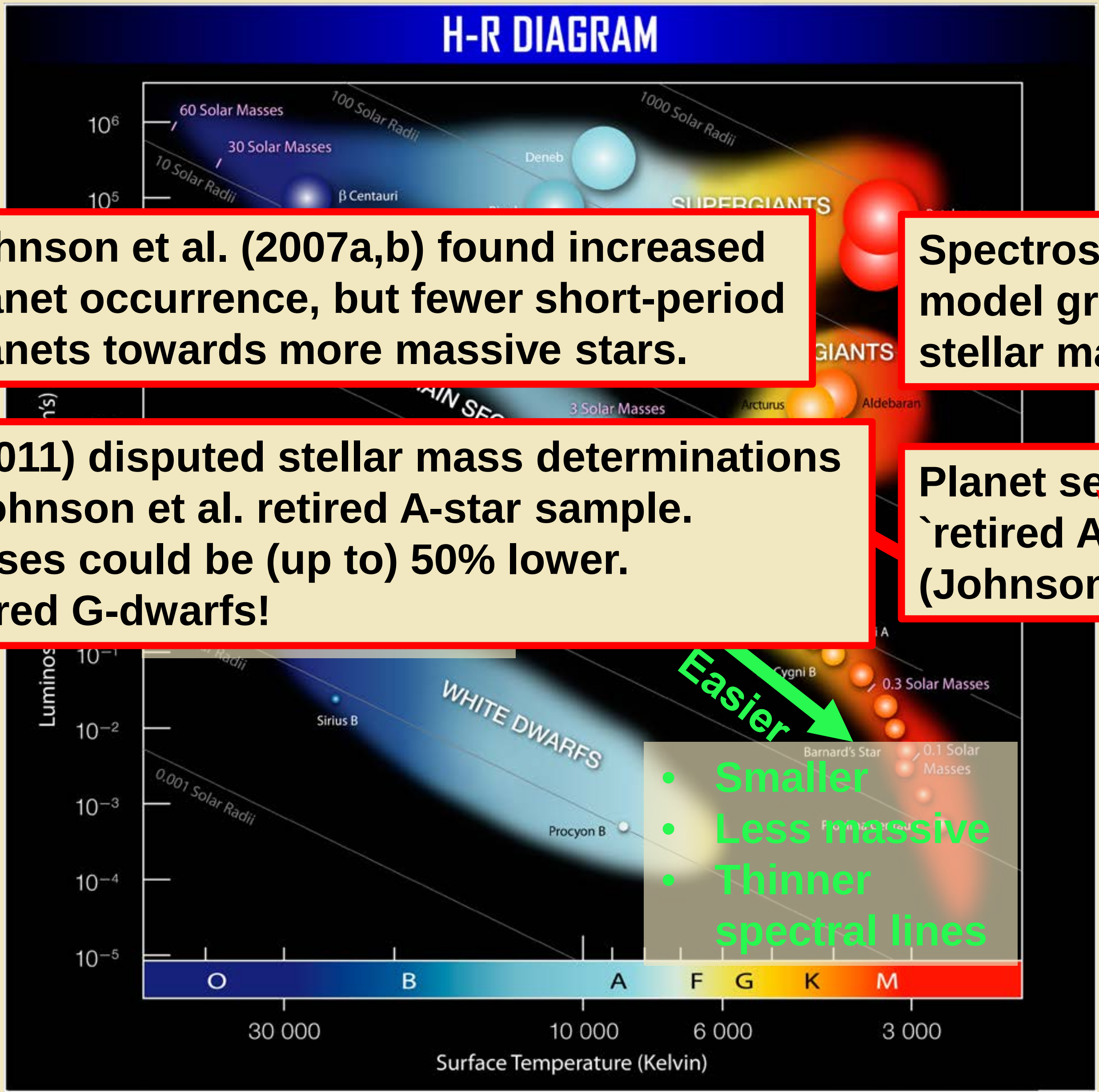
- Thinner spectral lines

Planets around `retired A-stars’



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Spectroscopy + stellar model grids to determine stellar mass

Lloyd (2011) disputed stellar mass determinations of the Johnson et al. retired A-star sample.
➡ Masses could be (up to) 50% lower.
➡ Retired G-dwarfs!

Planet search around `retired A-stars’ (Johnson et al. 2006)

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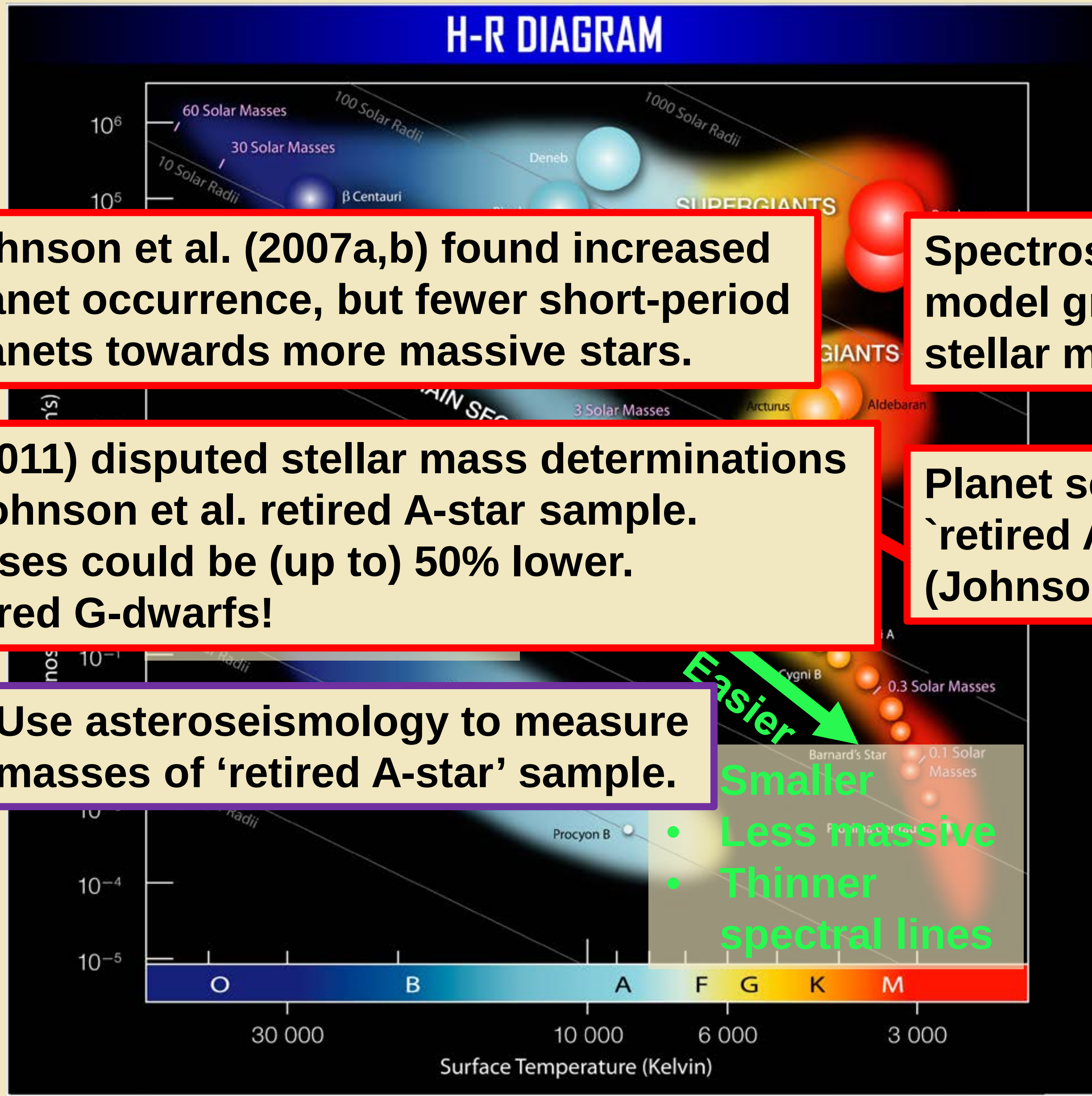
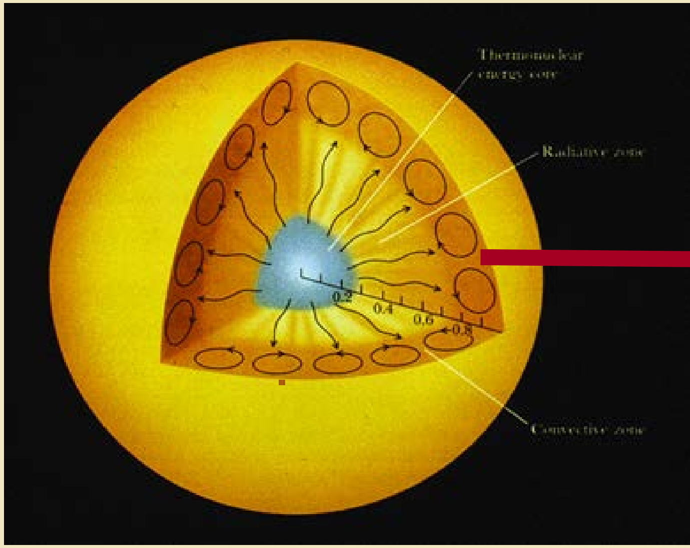
Lloyd (2011) disputed stellar mass determinations of the Johnson et al. retired A-star sample.
➡ Masses could be (up to) 50% lower.
➡ Retired G-dwarfs!

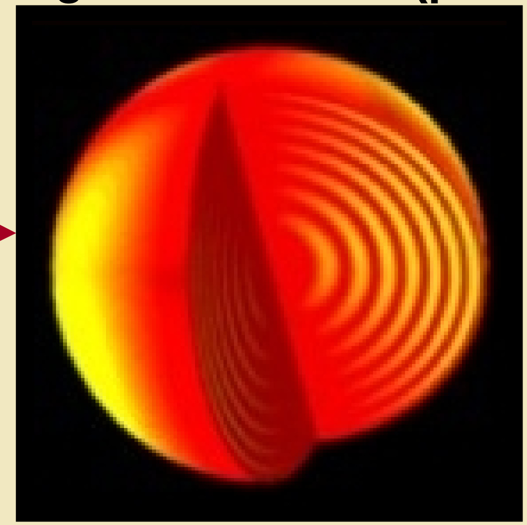
Use asteroseismology to measure masses of 'retired A-star' sample.



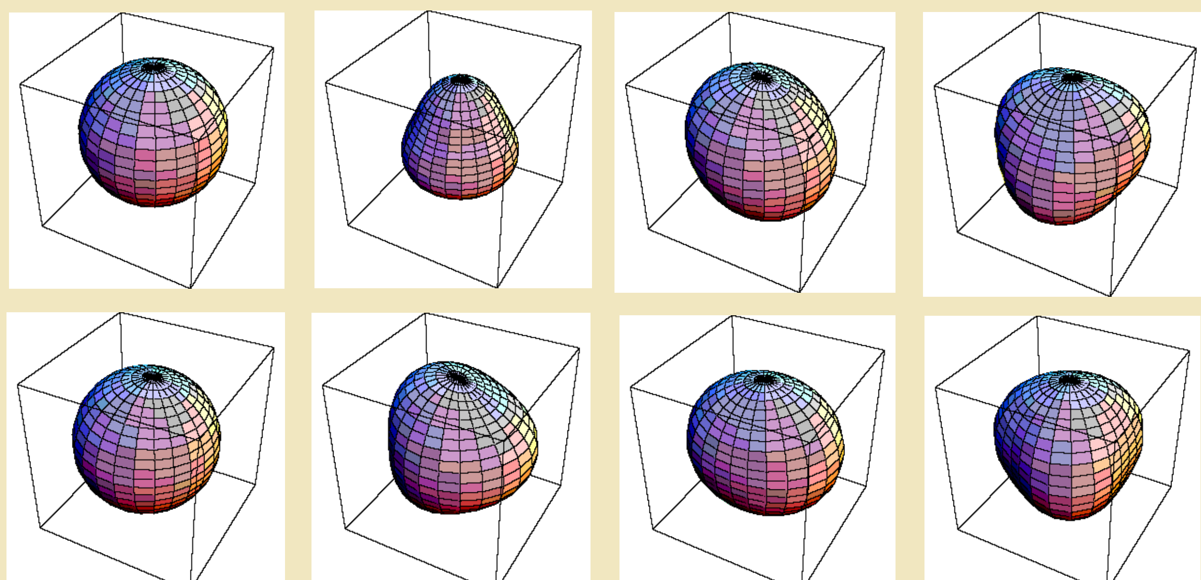
Solar-like oscillations in red giants



Standing sound waves (p modes)



Global oscillation modes



Observing oscillation modes

Light is red/blue shifted (Doppler effect)

Brightness variation

Frequency

↓

Sound speed

↓

Interior properties

The most basic red giant seismology

Power location:

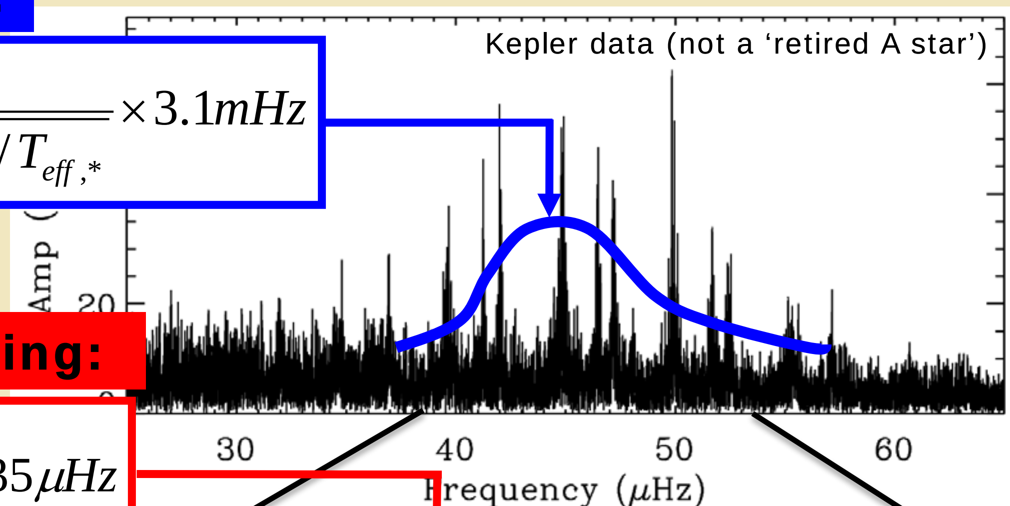
$$\nu_{max} \cong \frac{M/M_*}{(R/R_*)^2\sqrt{T_{eff}/T_{eff,*}}} \times 3.1 mHz$$

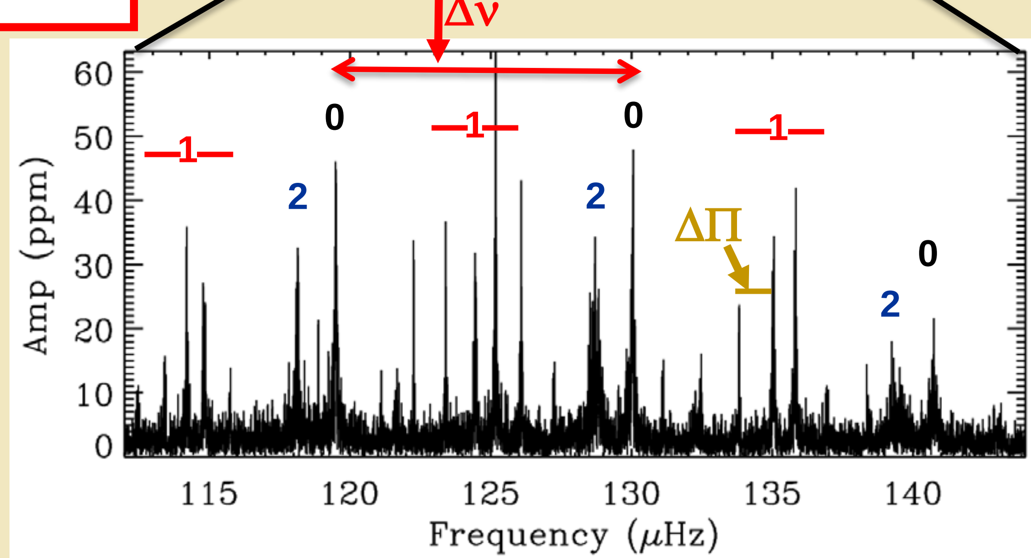
Frequency spacing:

$$\Delta\nu \cong \frac{(M/M_*)^{1/2}}{(R/R_*)^{3/2}} \times 135 \mu Hz$$

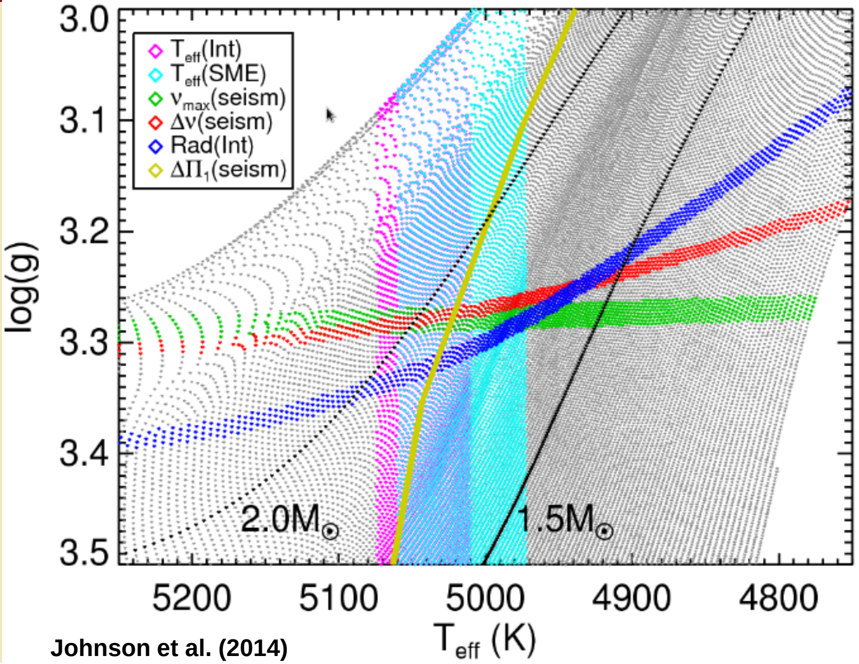
Both relations depend on mass

Fourier transform of photometric time series





One `retired A-star' observed by Kepler



Johnson et al. (2014)

Table 1

In question — 1 — 3 — 4

Stellar Parameter	LTE Spectroscopic Fit + Evolution Model[a]	Asteroseismology Only[b]	Interferometry and SED Fitting	Asteroseismology + Spectroscopy +Evolution Model[c]	Interferometry +Asteroseismology
$R_\star$ ($R_\odot$)	5.07 ± 0.16	5.35 ± 0.20	4.97 ± 0.07	5.27 ± 0.15	...
$\rho_\star$ ($\rho_\odot$)	0.014 ± 0.004	0.0130 ± 0.0003	...	0.0130 ± 0.0003	...
log g (cgs)	3.31 ± 0.06	3.280 ± 0.011	...	3.273 ± 0.014	...
$T_{\rm eff}$ (K)	5016 ± 44	...	5042 ± 32	...	...
[Fe/H]	+0.16 ± 0.04	...	...	...	...
$M_\star$ ($M_\odot$)	1.87 ± 0.07	1.99 ± 0.23	...	1.90 ± 0.15	1.60 ± 0.08

[a] Our LTE synthesis modeling was performed with SME, with log g constrained using the Y^2 stellar evolution models. These models were also interpolated to estimate $R_\star$ and $M_\star$.

[b] Based on $\Delta\nu = 15.4 \pm 0.2$ μHz, $\nu_{\rm max} = 229.8 \pm 6.0$ μHz, and Equations 2 and 3.

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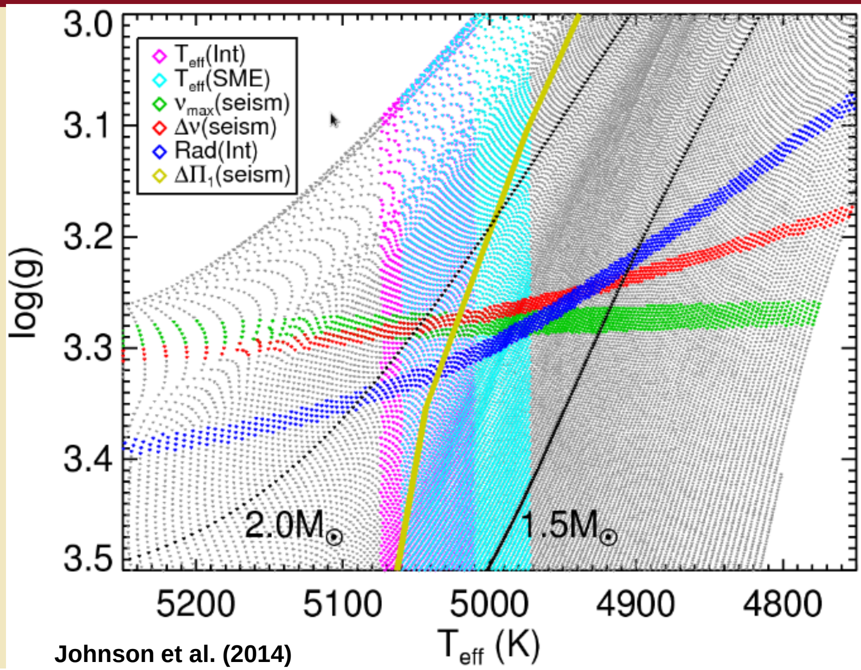

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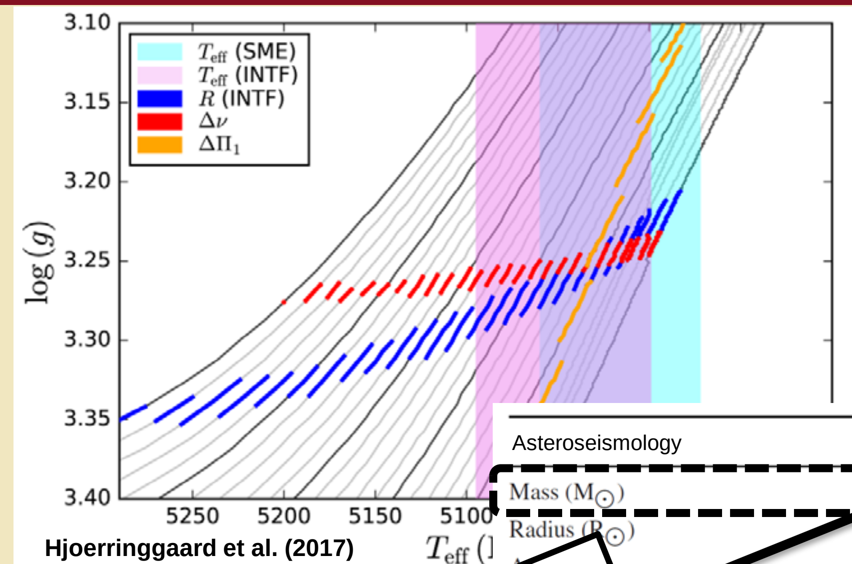

Hjoerringgaard et al. (2017)

Asteroseismology	HD 185351
Mass ($M_\odot$)	$1.58^{+0.04}_{-0.02}$
Radius ($R_\odot$)	$4.92^{+0.15}_{-0.07}$
[illegible]	$2.32^{+0.04}_{-0.07}$
[illegible]	$3.25^{+0.01}_{-0.02}$

Spectroscopic value 15-20% larger than seismic value

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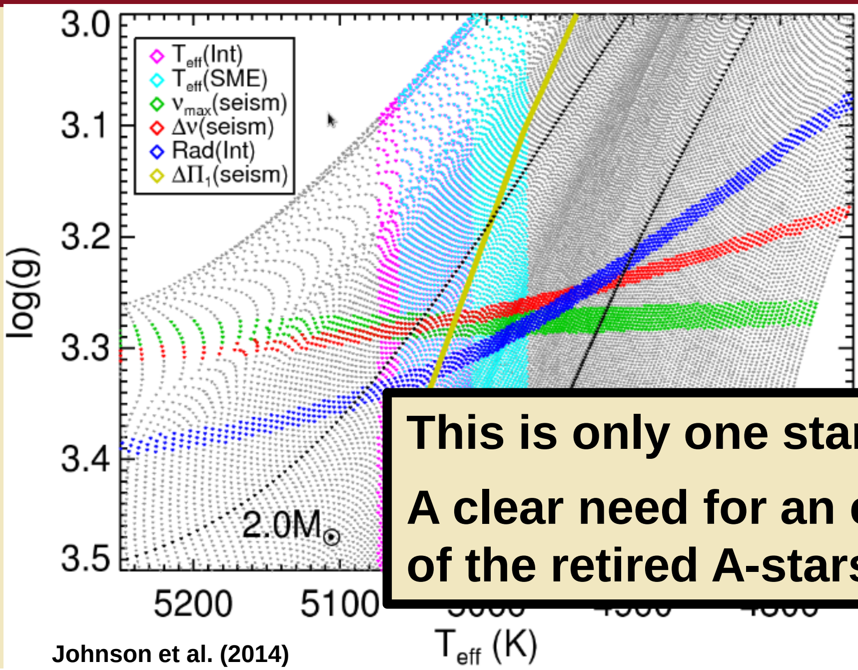

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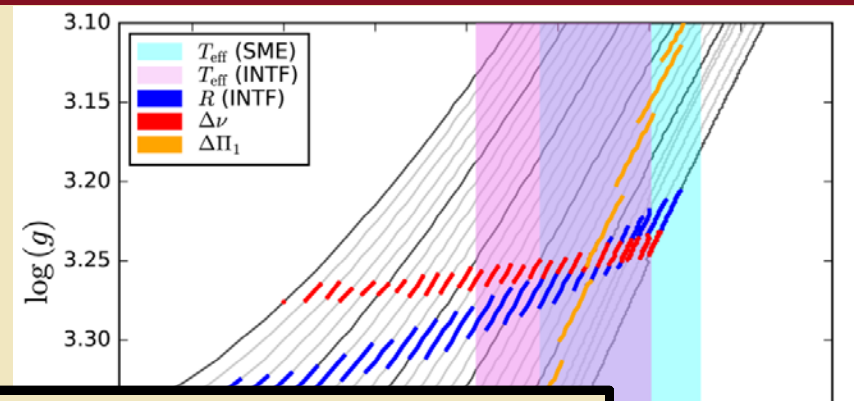

...mology	HD 185351
...)	$1.58^{+0.04}_{-0.02}$
...⊙)	$4.92^{+0.15}_{-0.07}$
	$2.32^{+0.04}_{-0.07}$
	$3.25^{+0.01}_{-0.02}$

This is only one star!

A clear need for an ensample: Are the masses of the retired A-stars *generally* overestimated?

Spectroscopic value 15-20% larger than seismic va...

In question — **1** — **3** — **4**

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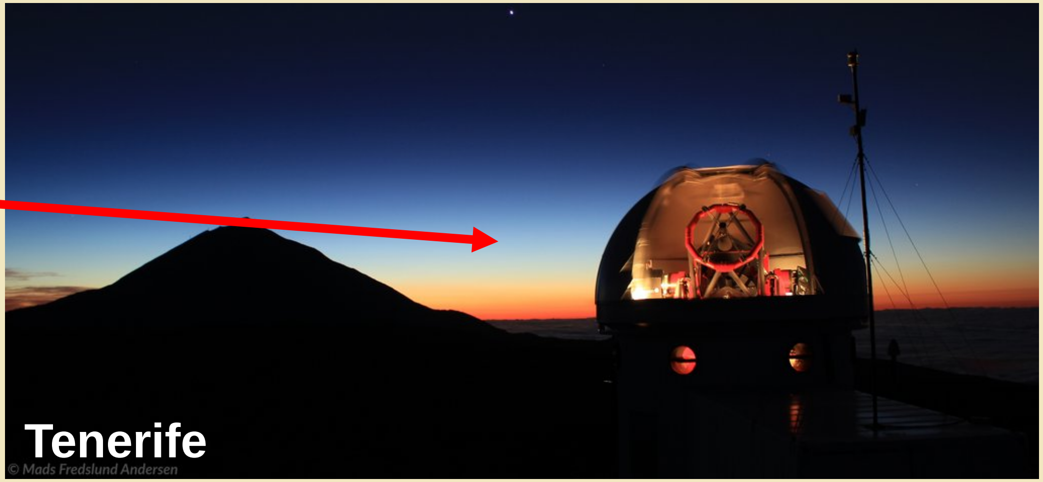
Use the SONG `network’



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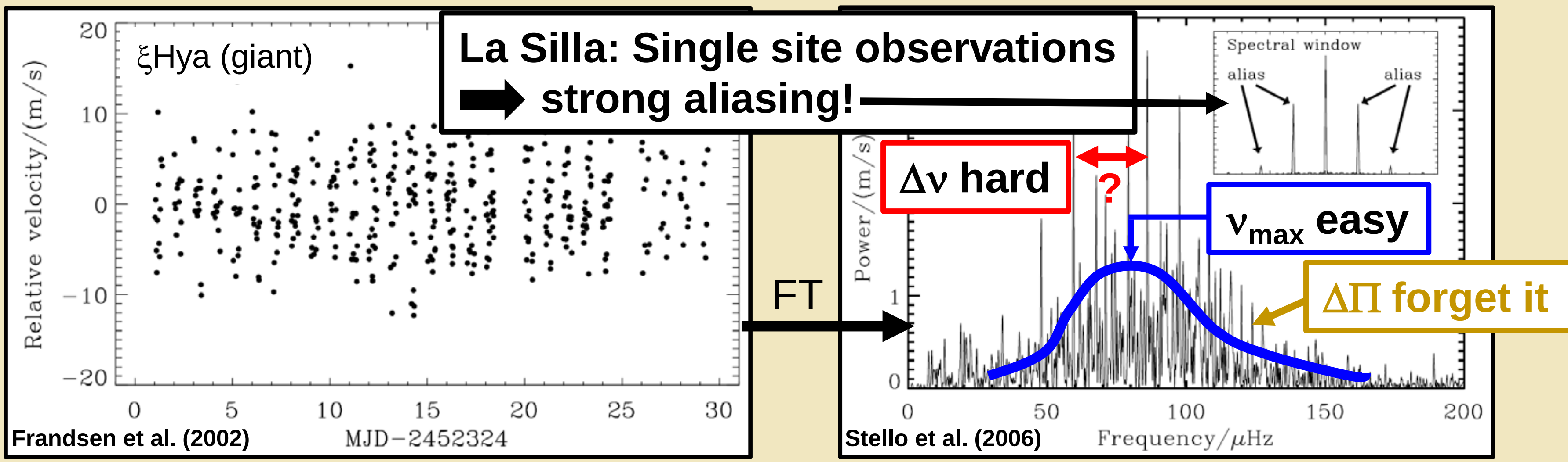

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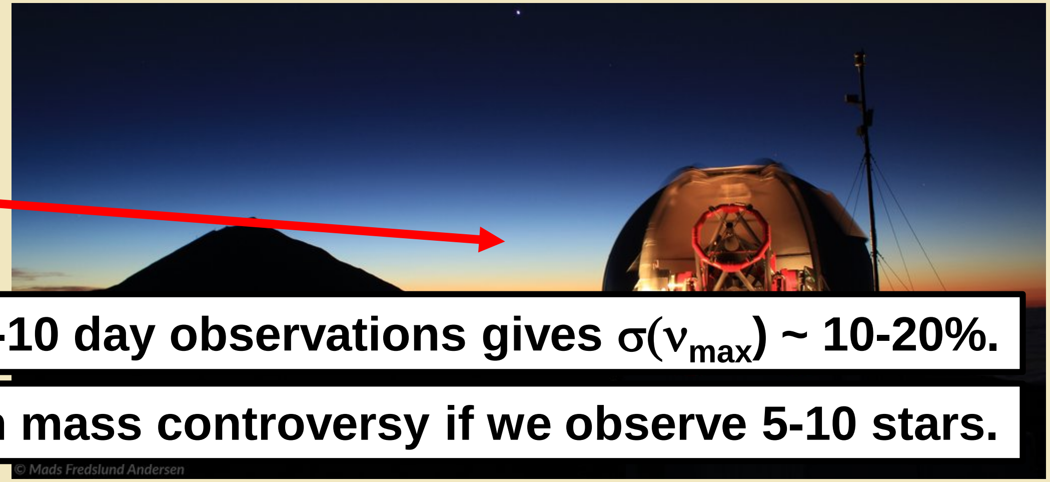
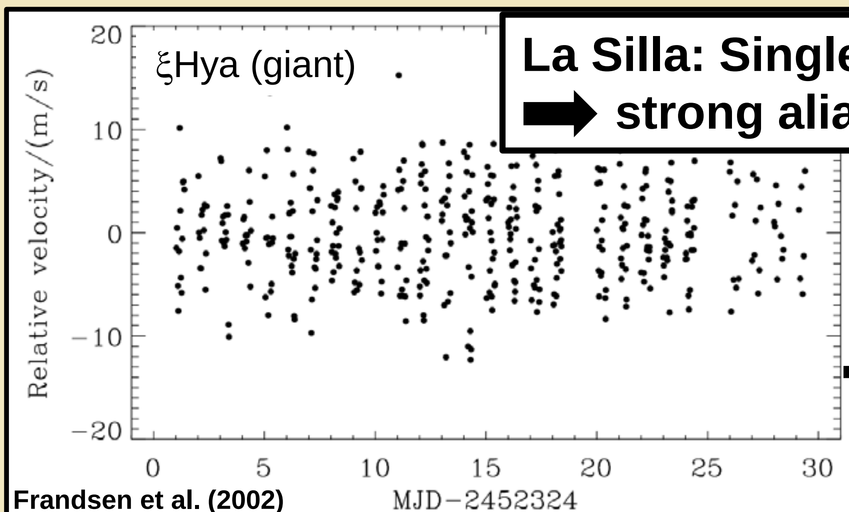


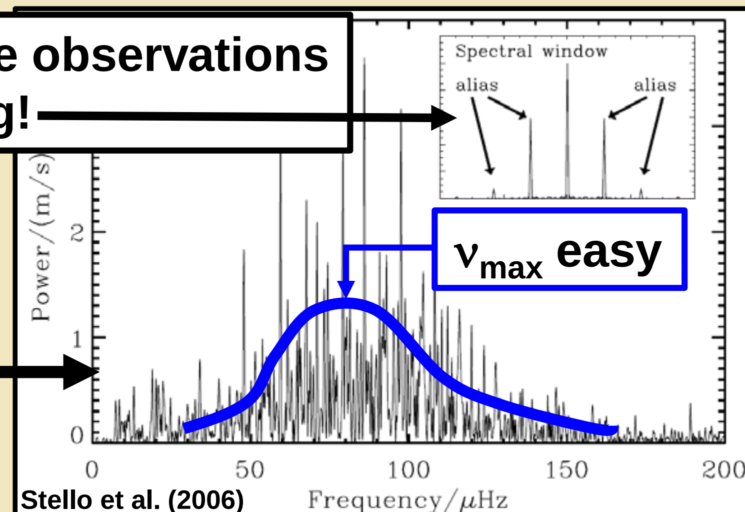
From La Silla ξHya data: 5-10 day observations gives $\sigma(\nu_{max})$ ~ 10-20%.

➡ Robust conclusions on mass controversy if we observe 5-10 stars.



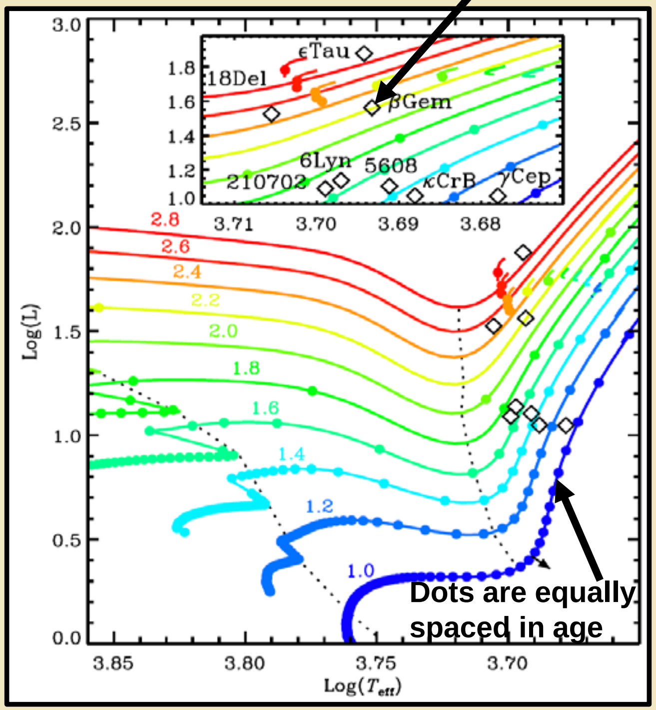
La Silla: Single site observations
➡ strong aliasing!

FT



Our planet-hosting targets

We chose the brightest stars:
1.15 < V < 6.0



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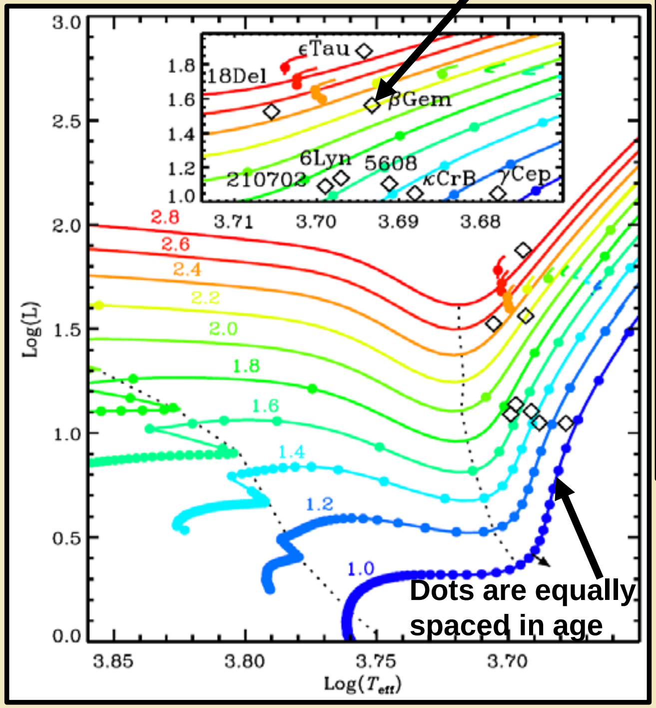
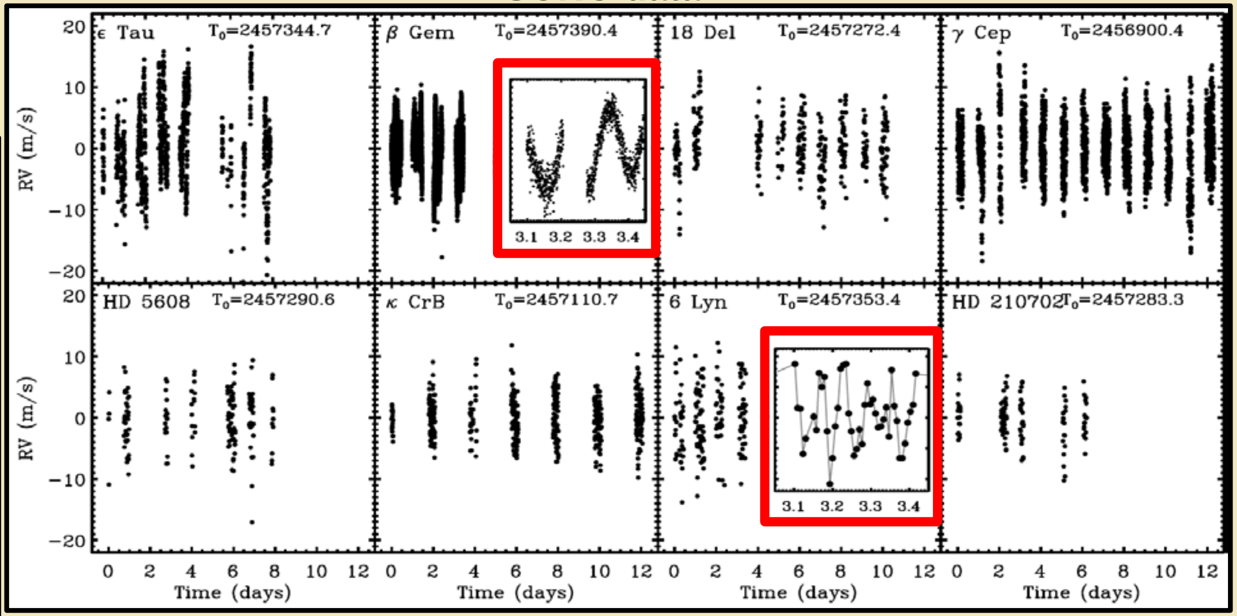
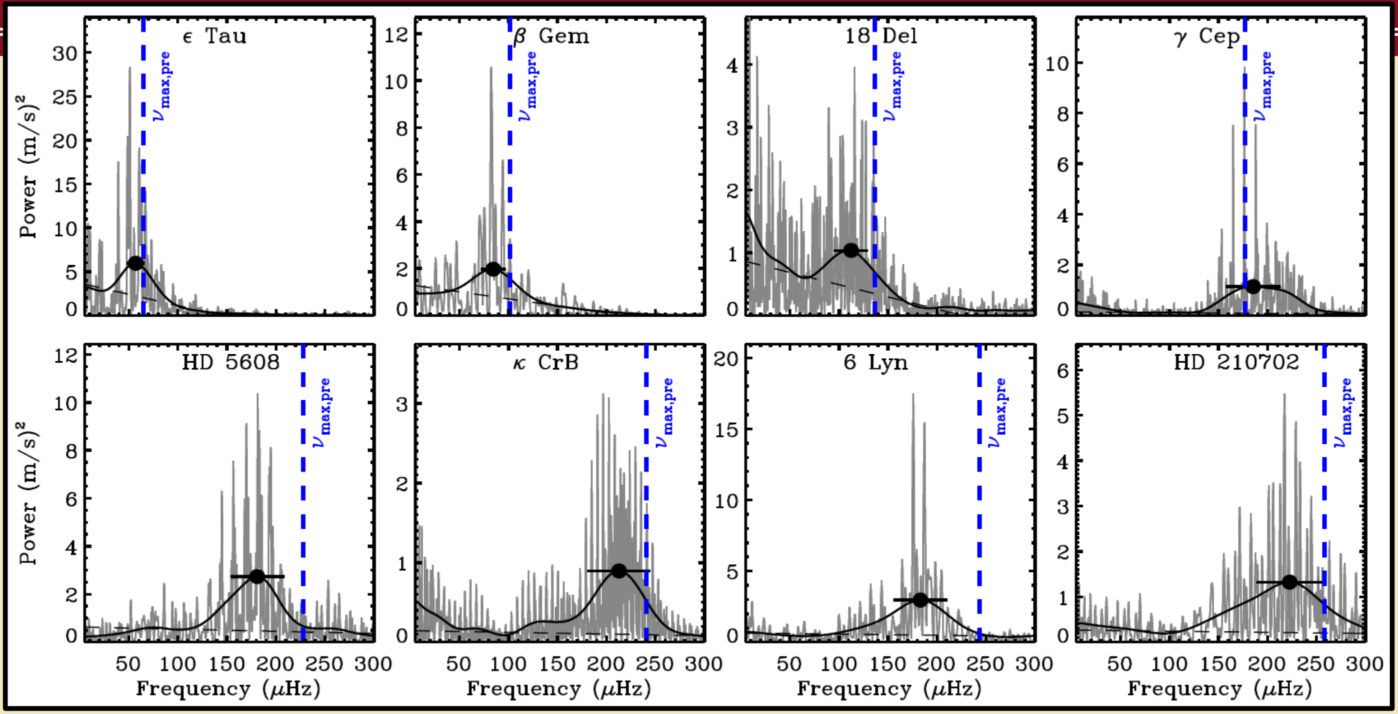


SONG data



SONG results



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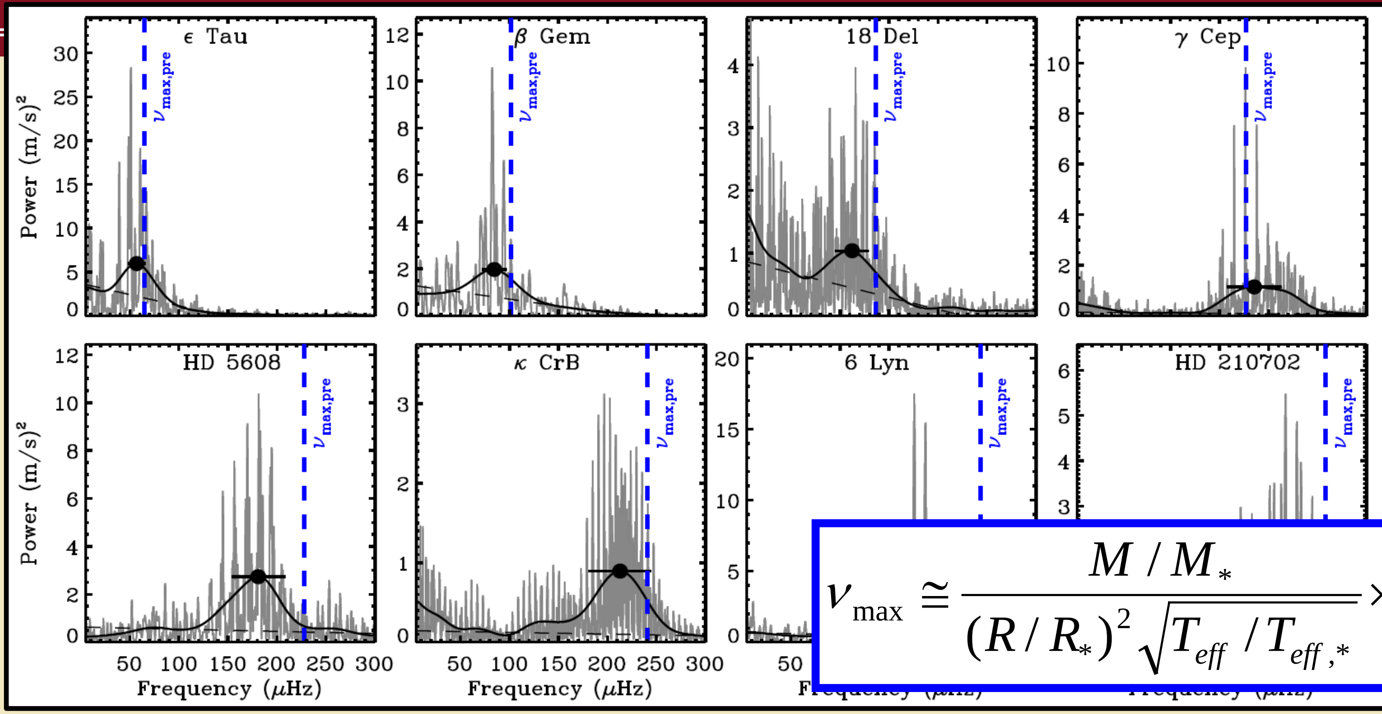
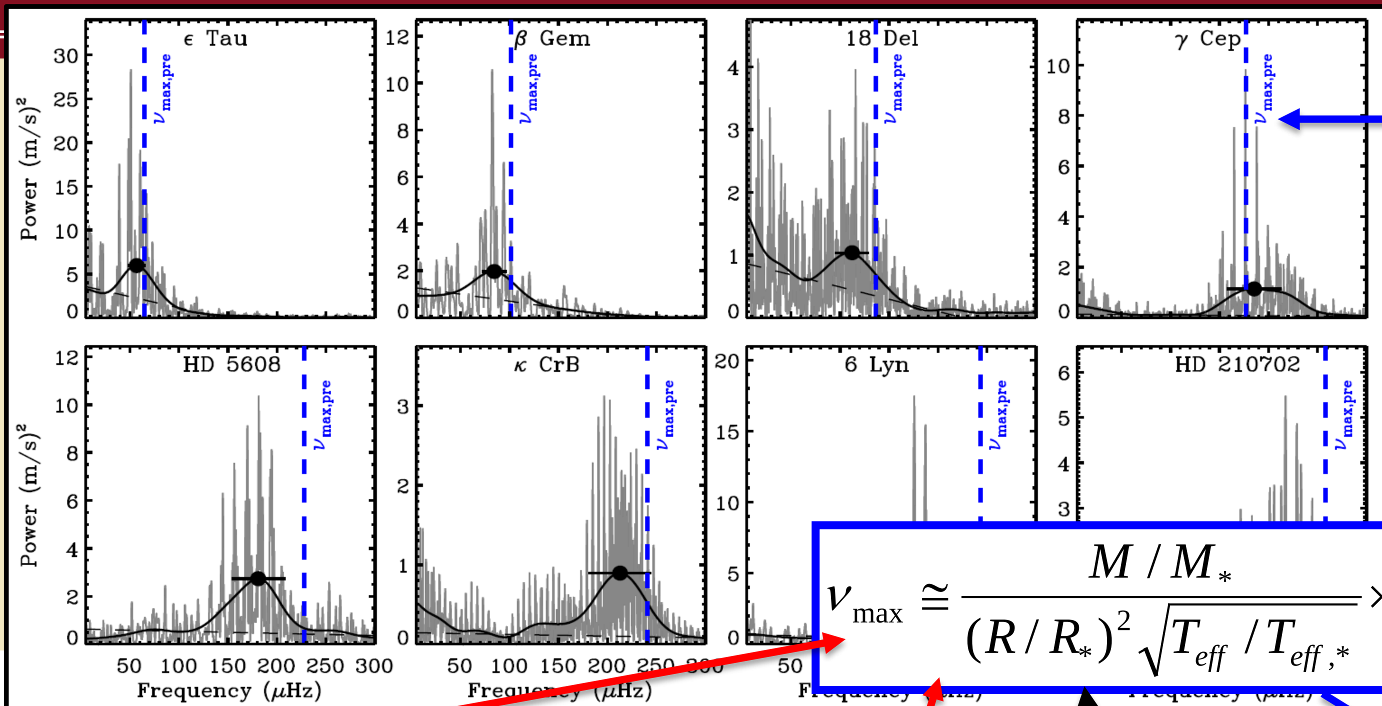


$$\nu_{\max} \cong \frac{M / M_*}{(R/R_*)^2 \sqrt{T_{eff} / T_{eff,*}}} \times 3.1 mHz$$

SONG results



$$\nu_{max} \cong \frac{M / M_*}{(R/R_*)^2 \sqrt{T_{eff} / T_{eff,*}}} \times 3.1 mHz$$

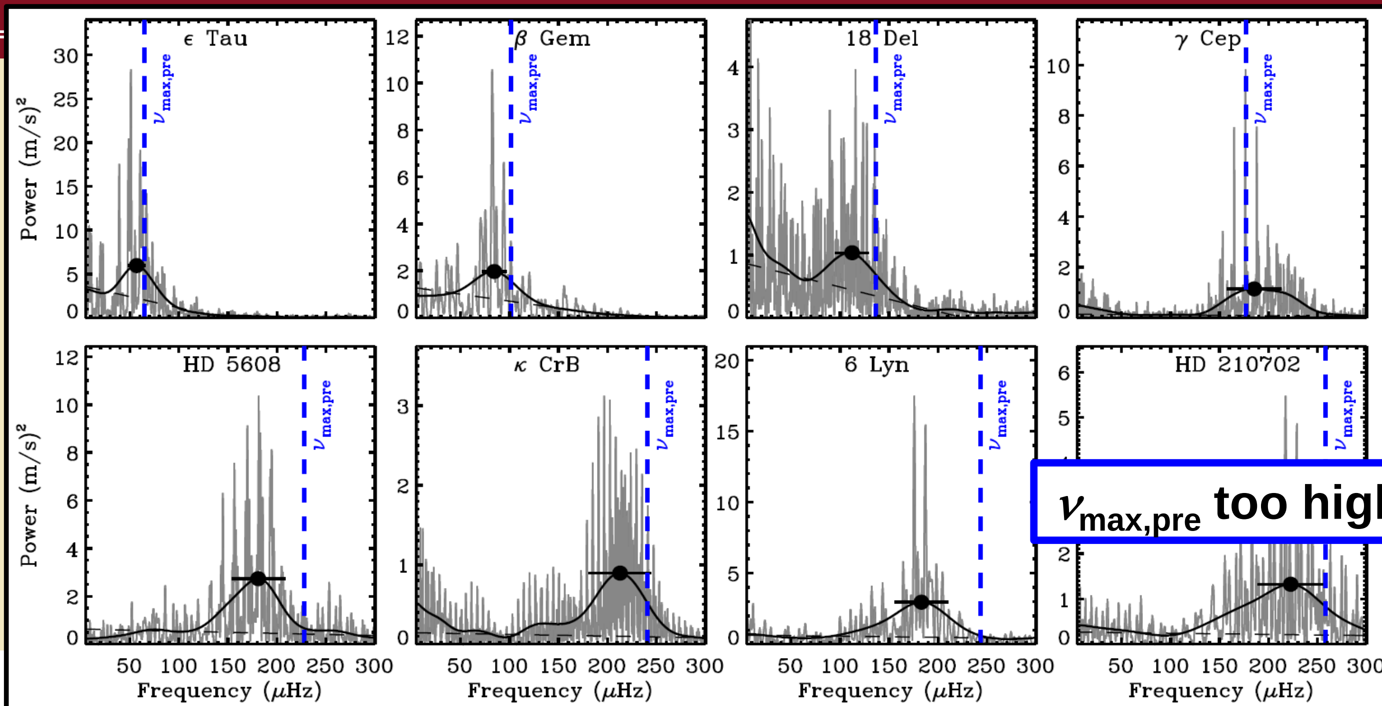
Mortier et al. (2013)

Hipparcos

Star	log g	T_{eff}	[Fe/H]	π	M	Derived R	L	$\nu_{max,pre}$	Aster $\nu_{max,obs}$
	[dex][1]	[K][1]	[dex][1]	[mas][2]	[$M_\odot$][1]	[$R_\odot$]	[$L_\odot$]	[μHz]	[μHz][3]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ϵ Tau	2.62(15)	4746(70)	0.17(6)	22.24(25)	2.73(10)	11.8(5)	75.54(1.80)	64.8(5.4)	56.9(8.5)
β Gem	2.91(13)	4935(49)	0.09(4)	96[illegible](27)	2.08(9)	8.21(37)	36.50(1.69)	101(10)	84.5(12.7)
18 Del	3.08(10)	5076(38)	0.0(?)	13[illegible](31)	2.33(5)	7.51(34)	33.52(1.77)	137(12)	112(17)
γ Cep	3.10(27)	4764(122)	0.13(6)	70[illegible](40)	1.26(14)	4.88(22)	11.17(16)	177(24)	185(28)
HD 5608	3.25(16)	4911(51)	0.12(3)	17[illegible](40)	1.66(8)	4.89(23)	12.74(62)	228(23)	181(27)
κ CrB	3.15(14)	4876(46)	0.13(3)	32[illegible](21)	1.58(8)	4.70(20)	11.20(17)	241(21)	213(32)
6 Lyn	3.16(5)	4978(18)	-0.13(2)	17.92(47)	1.82(13)	5.01(25)	13.74(73)	243(28)	183(27)
HD 210702	3.36(8)	5000(44)	0.04(3)	18.20(39)	1.71(6)	4.68(22)	12.33(52)	258(23)	223(33)

Disputed by Lloyd (2013)

SONG results



$\nu_{max,pre}$ **too high by 15-20%**

$$\nu_{max} \cong \frac{M/M_*}{(R/R_*)^2\sqrt{T_{eff}/T_{eff,*}}} \times 3.1mHz$$

GETS.

Star (1)	log g [dex][1] (2)	T_{eff} [K][1] (3)	[Fe/H] [dex][1] (4)					$\nu_{max,pre}$ [μHz] (9)	Aster $\nu_{max,obs}$ [μHz][3] (10)
ε Tau	2.62(15)	4746(70)	0.17(6)	22.24(25)	2.73(10)	11.8(5)	75.54(1.80)	64.8(5.4)	56.9(8.5)
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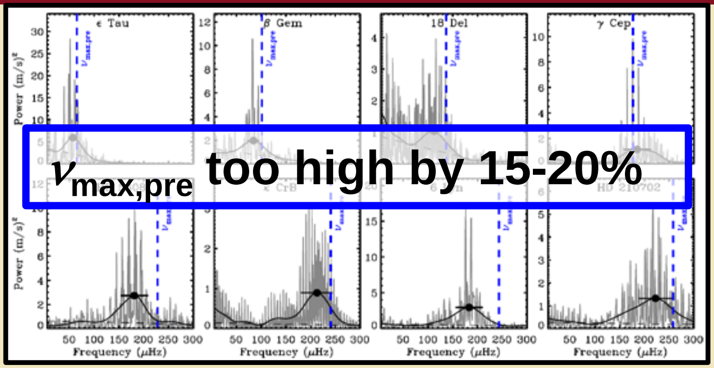
Why are the ν_{max} estimates too high?



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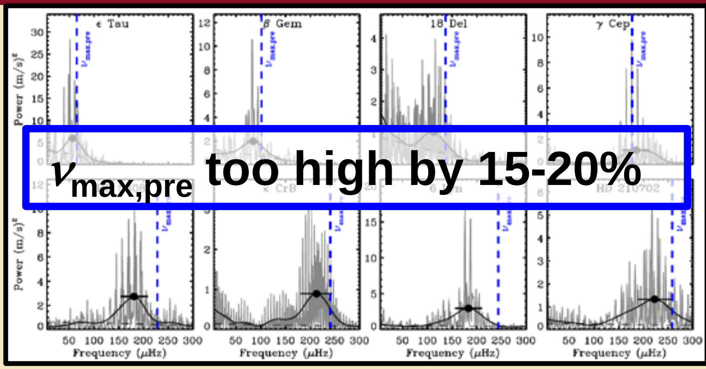

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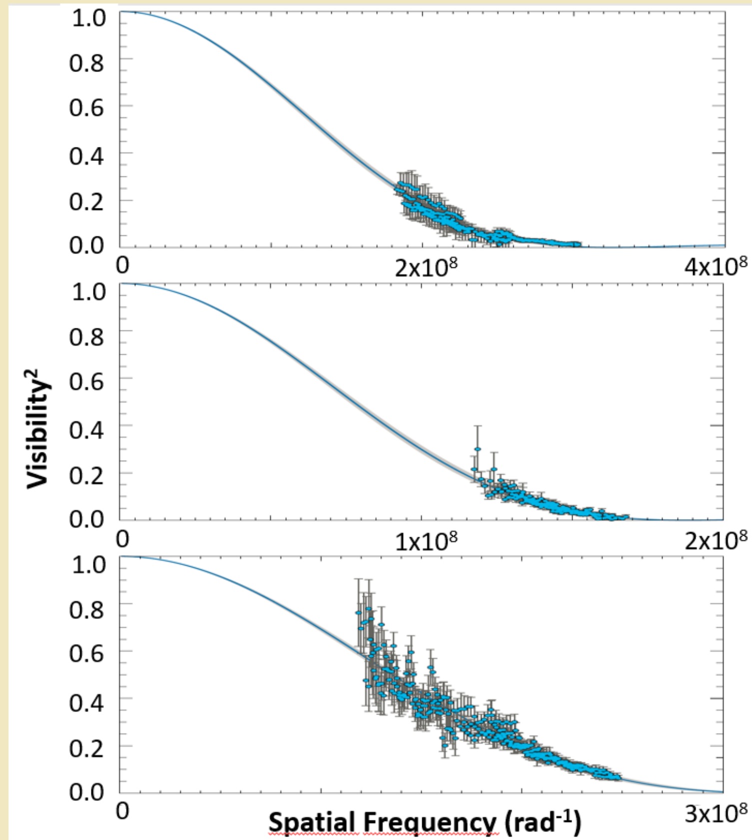
$$\nu_{\max} \cong \frac{M/M_*}{(R/R_*)^2\sqrt{T_{eff}/T_{eff,*}}} \times 3.1mHz$$

- **If T_{eff} is 100-150K too high ➡ No ν_{max} disagreement.**
  But our T_{eff} agrees with interferometry (White et al.)
  ➡ So not very likely (but more interferometry please)



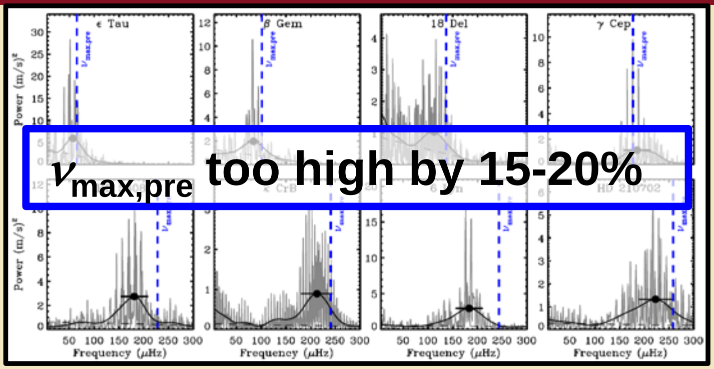
6 Lyn
5.07±0.15 $R_\odot$
4949 ±57 K
(Spec: 4978 K)

κ CrB
4.78±0.08 $R_\odot$
4870 ±48 K
(Spec: 4876 K)

HD 210702
4.91±0.12 $R_\odot$
4950±68 K
(Spec: 5000 K)

White et al. 2018

Why are the ν_{max} estimates too high?



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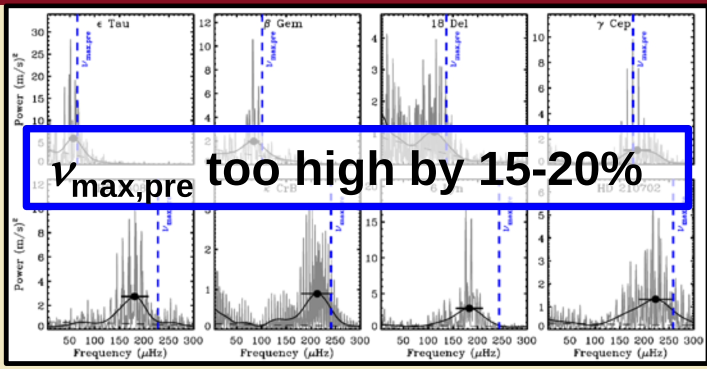
  But our T_{eff} agrees with interferometry (White et al.)
  ➡ So not very likely (but more interferometry please)
- [Fe/H] have only a small effect ➡ Unlikely reason!

Why are the ν_{max} estimates too high?



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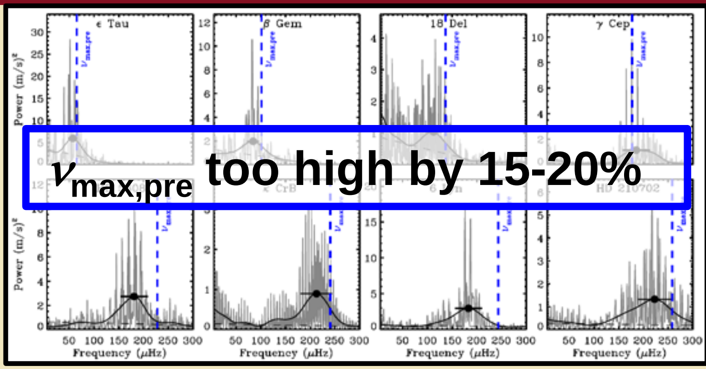

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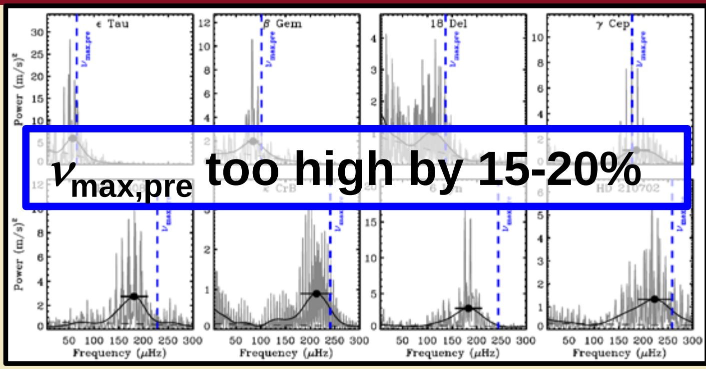

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Spectroscopic masses of planet-hosting `retired A-stars' are 15-20% too high!

Stello et al. 2017

K2: A new opportunity catching retired A-stars

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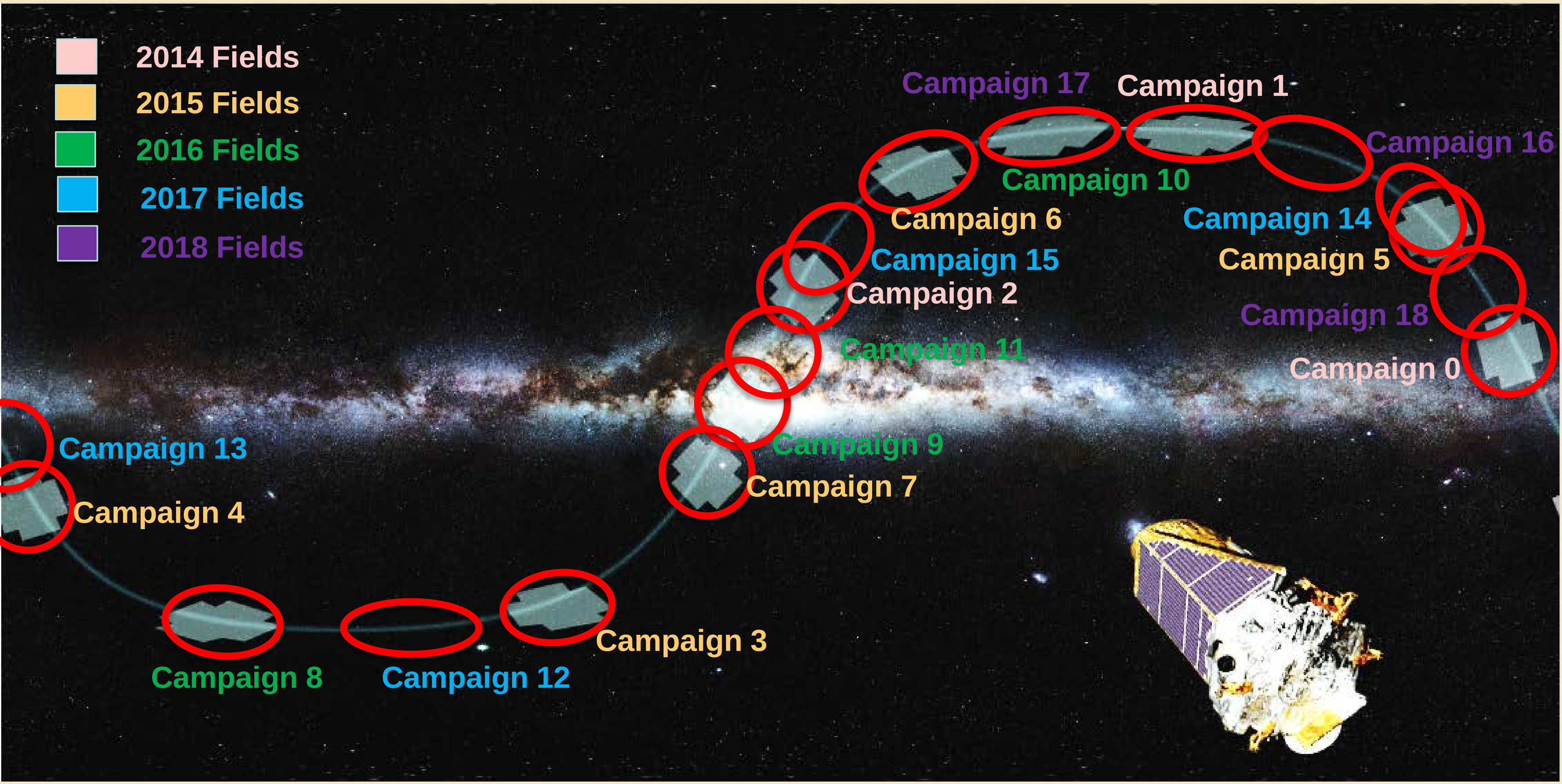

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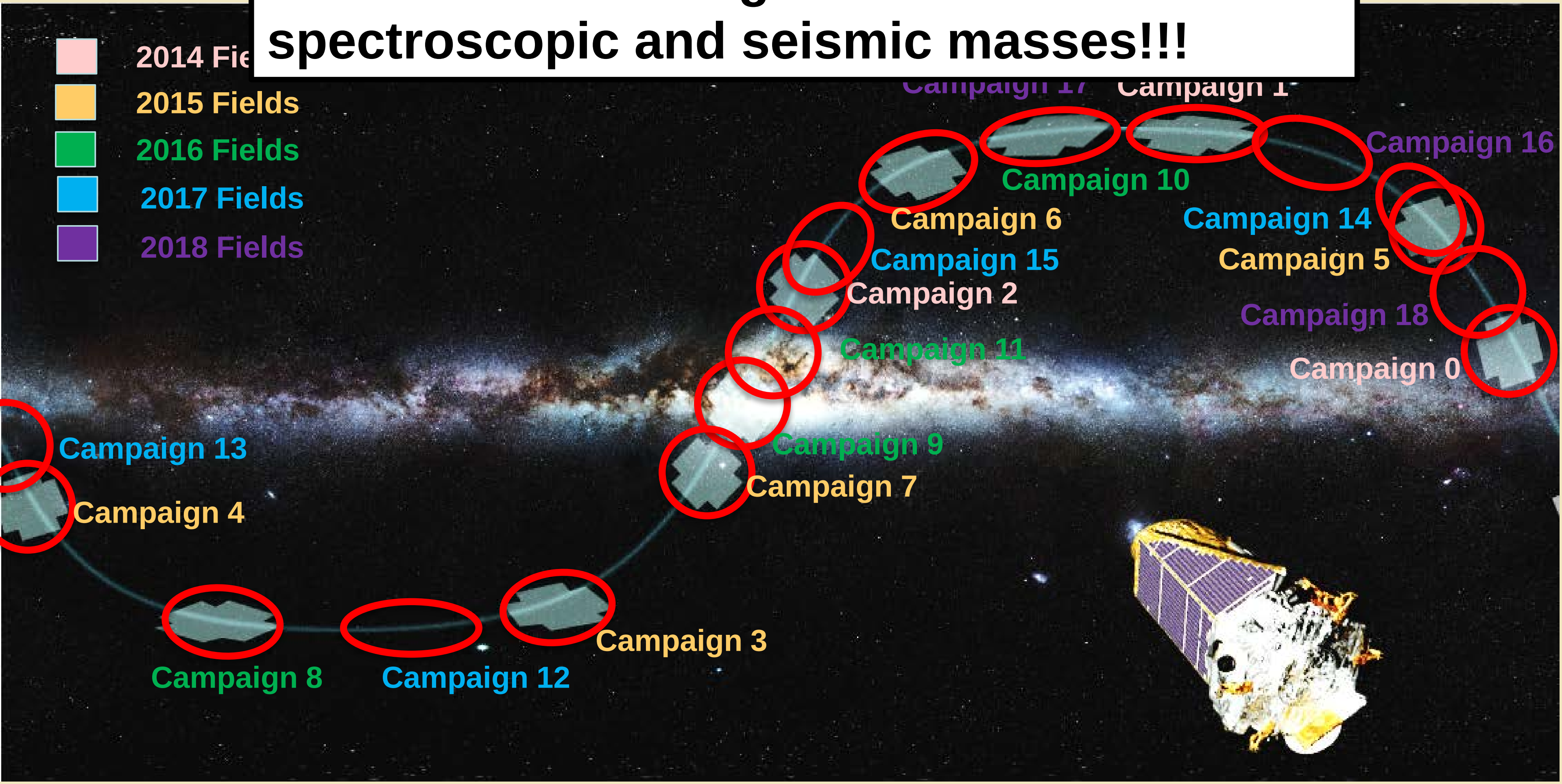
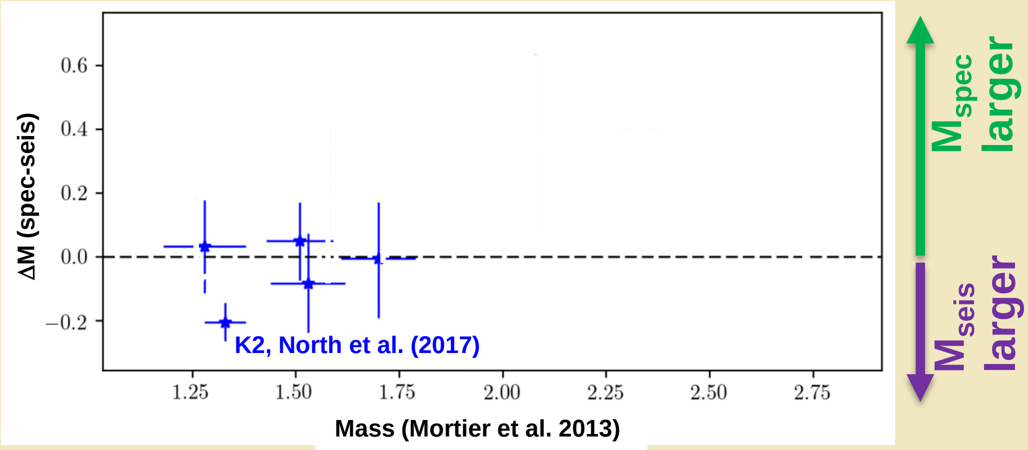
Conclusions: No significant offset between spectroscopic and seismic masses!!!



K2

Plot credit: Thomas North



K2+SONG

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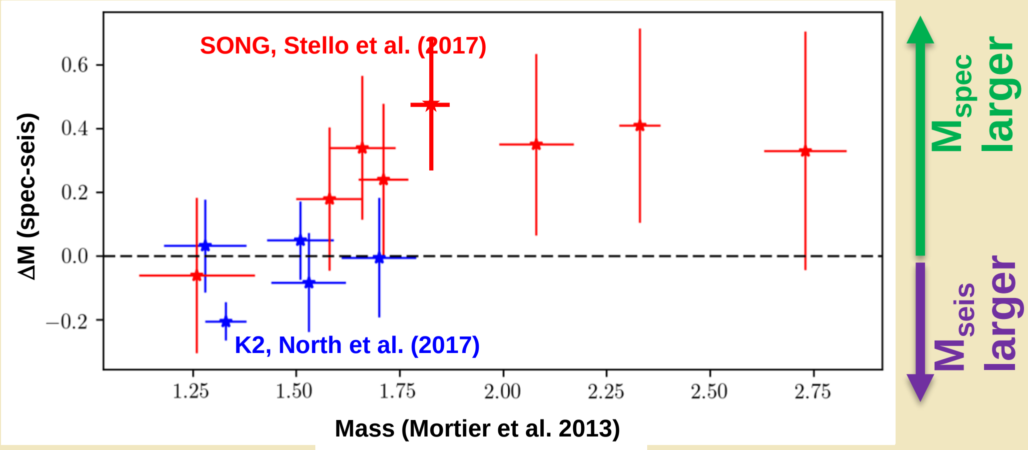

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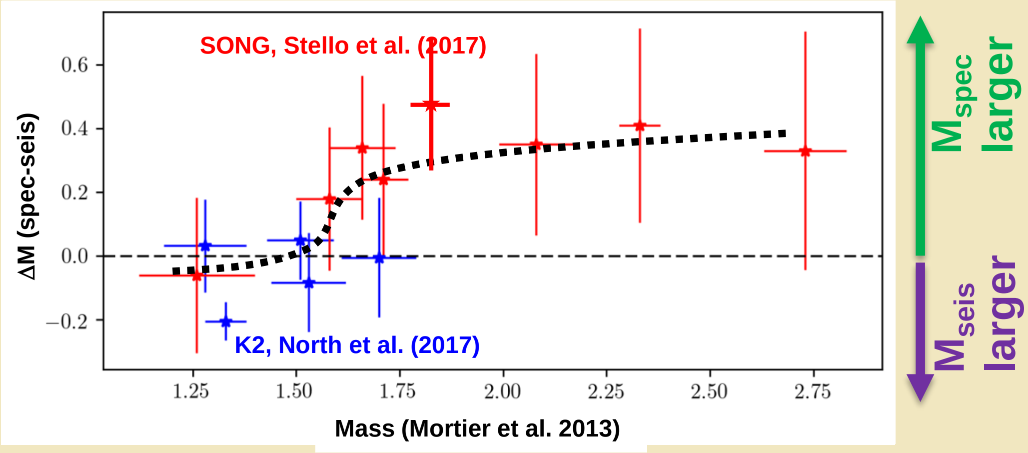

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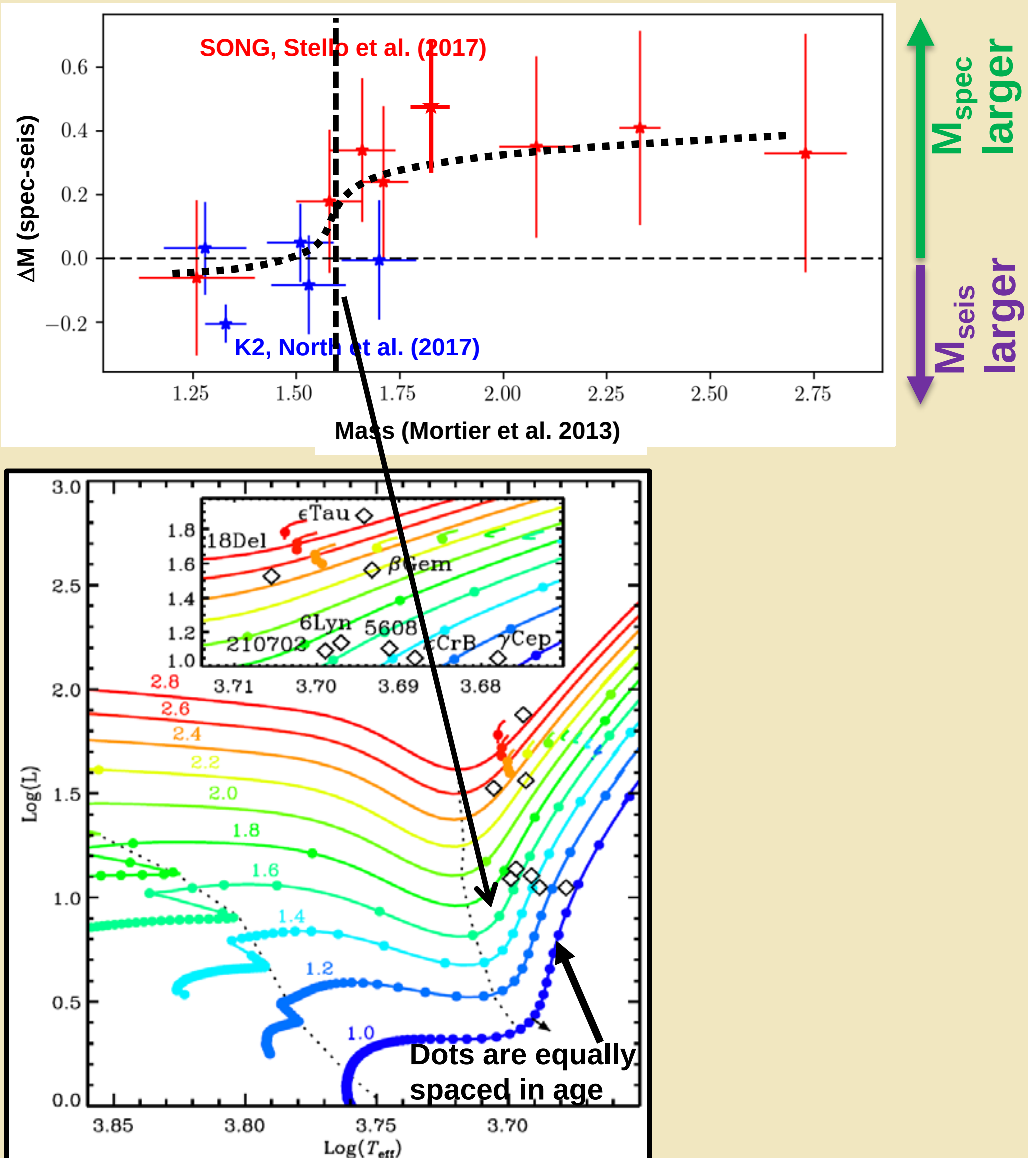

More SONG data: 2018 season

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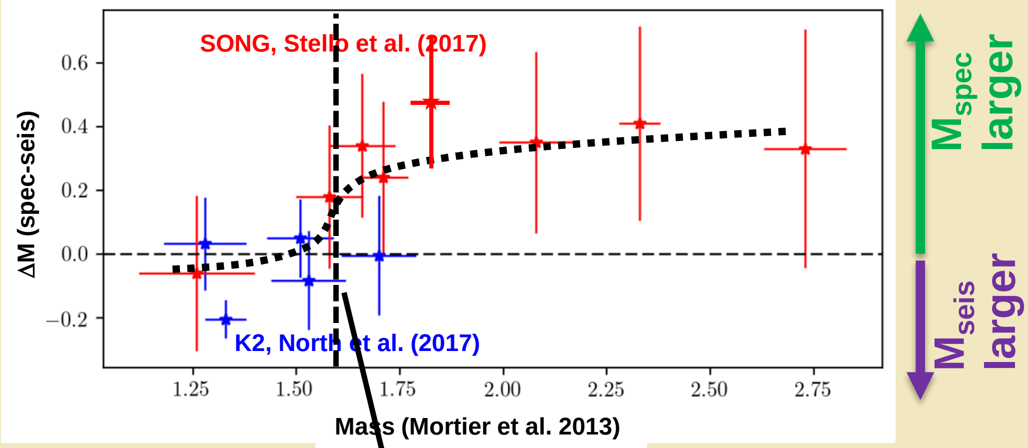

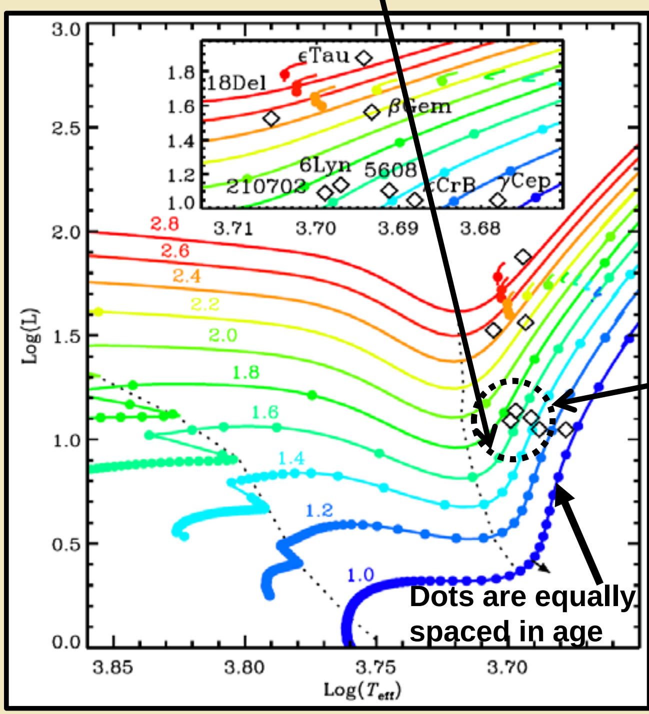

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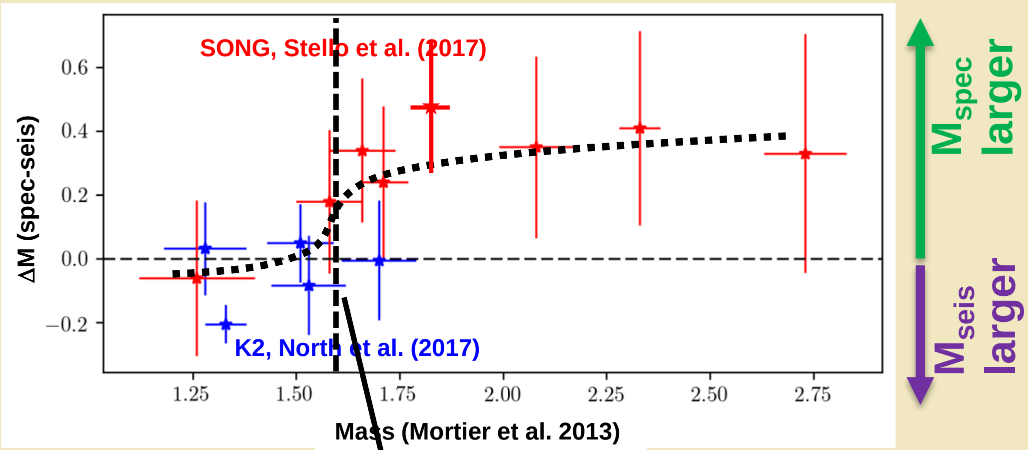

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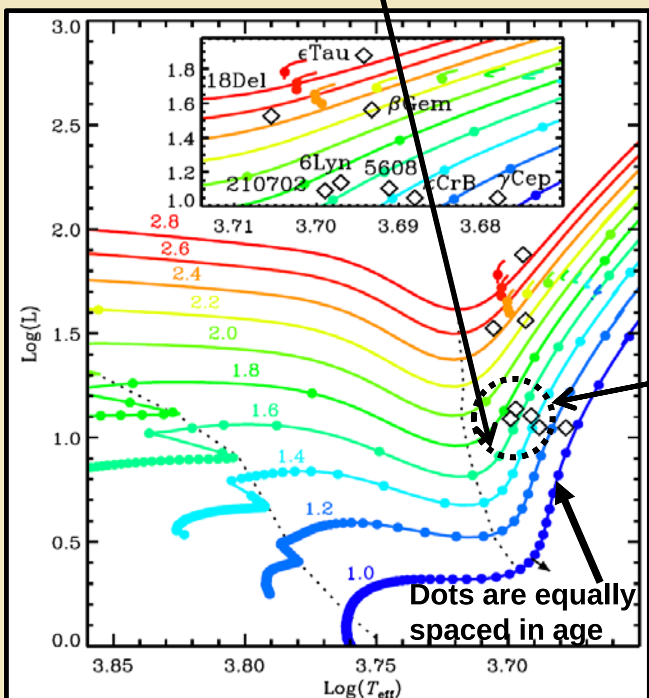

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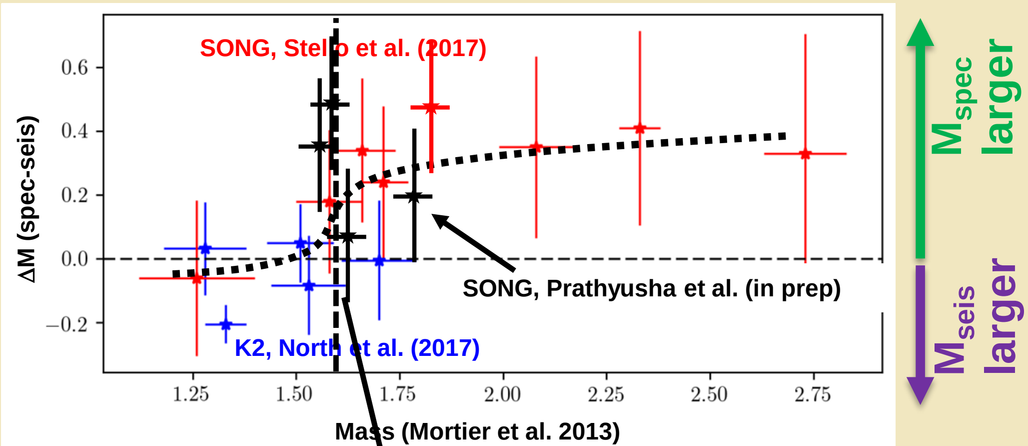

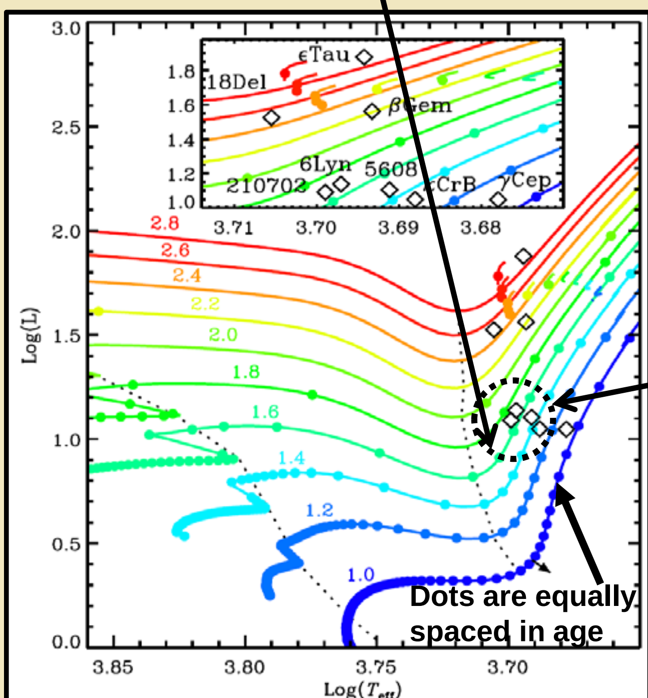

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