Pulsational properties of DA white dwarf stars

White Dwarfs from
Physics to Astrophysics

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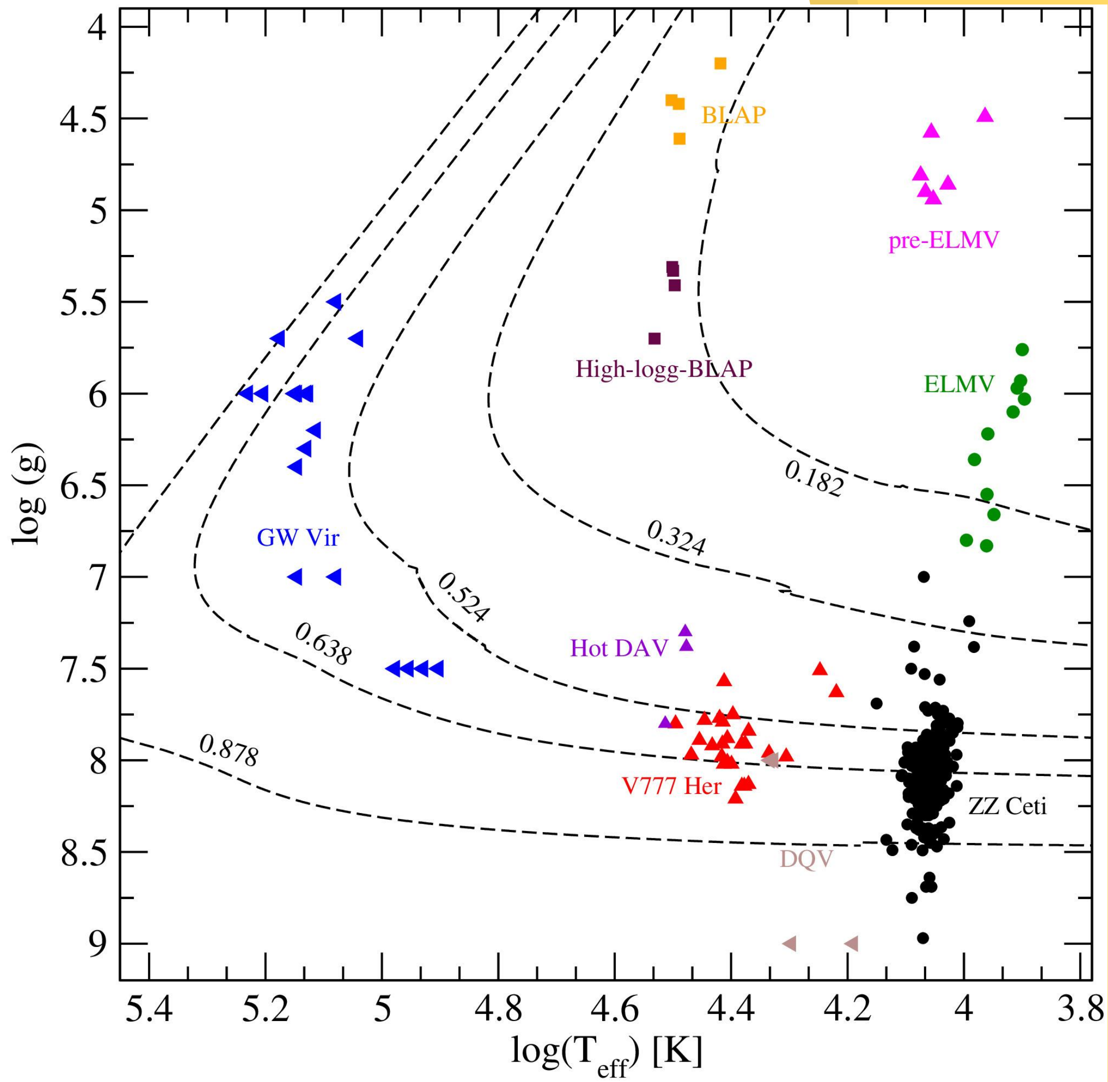
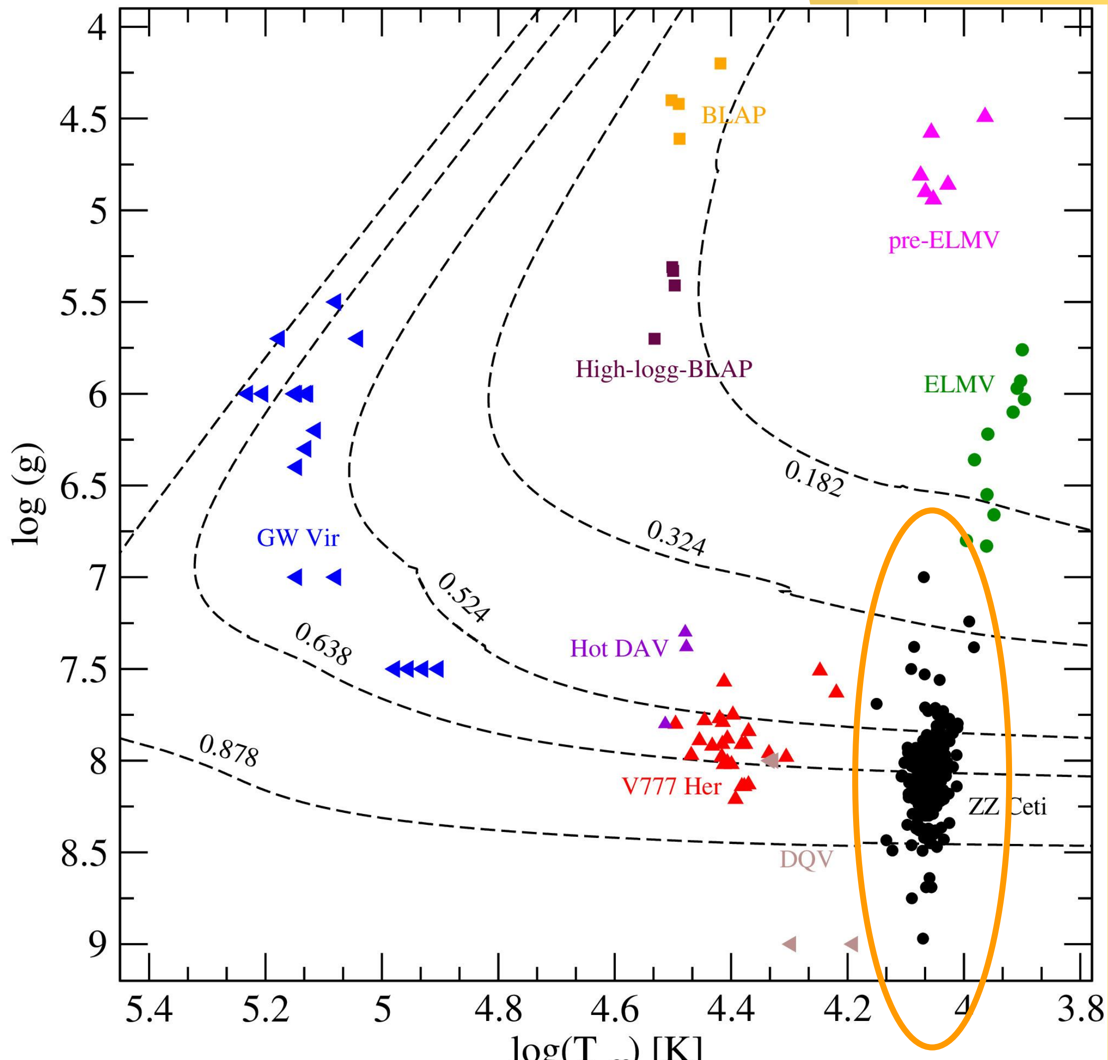
Pulsations in white dwarfs and friends



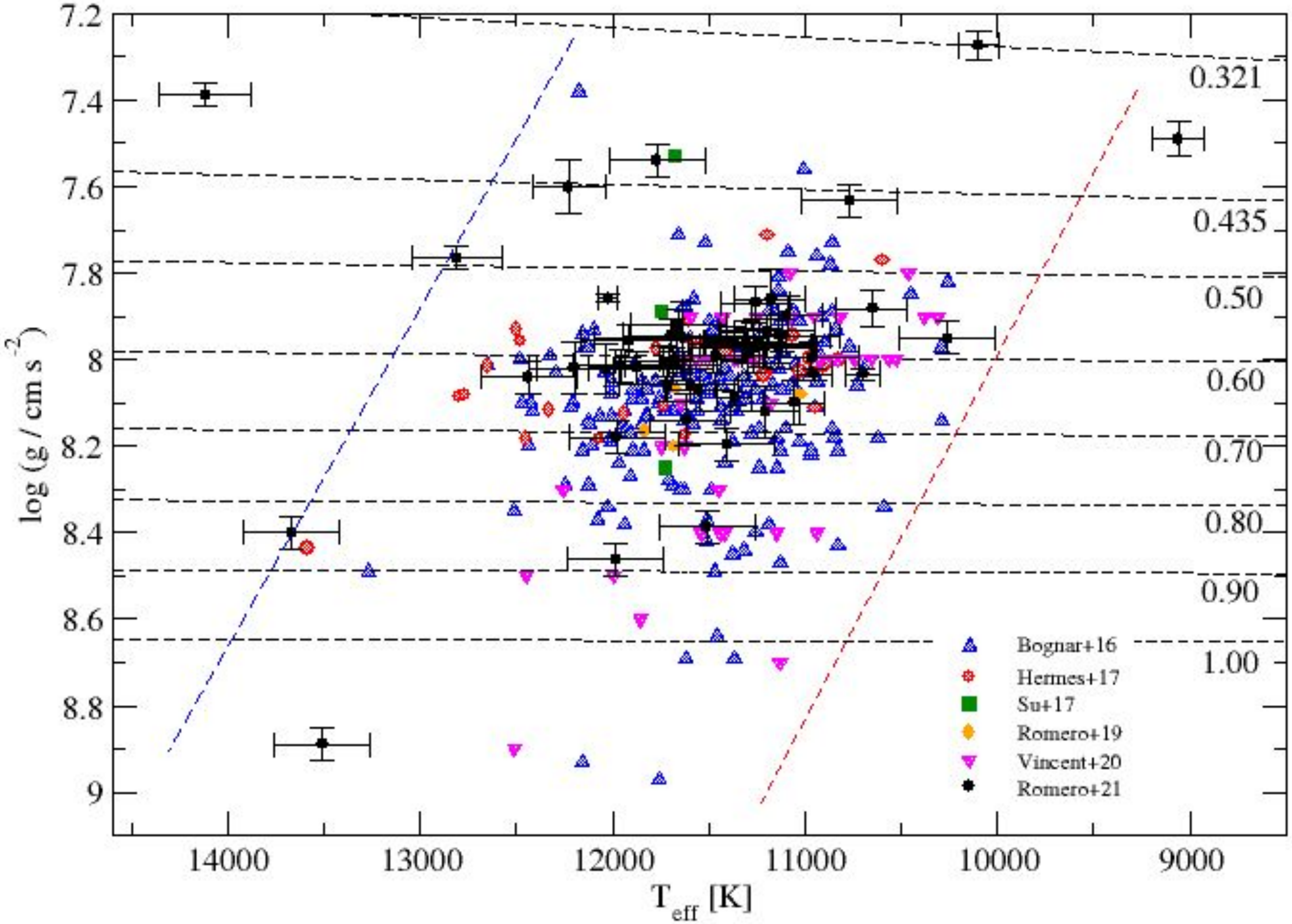
Pulsations in white dwarfs and friends



ZZ Ceti stars: the most populous group of pulsating white dwarfs

ZZ Ceti stars

- ★ T_{eff}= 14000-10400 K, log g = 7.5-9.1
- ★ Period = 70 - 2000 s, 0.01-0.3 mag
- ★ Pure instability strip



Now with ~50 new ZZ Ceti stars from TESS

With ~300 objects we can do some statistics!

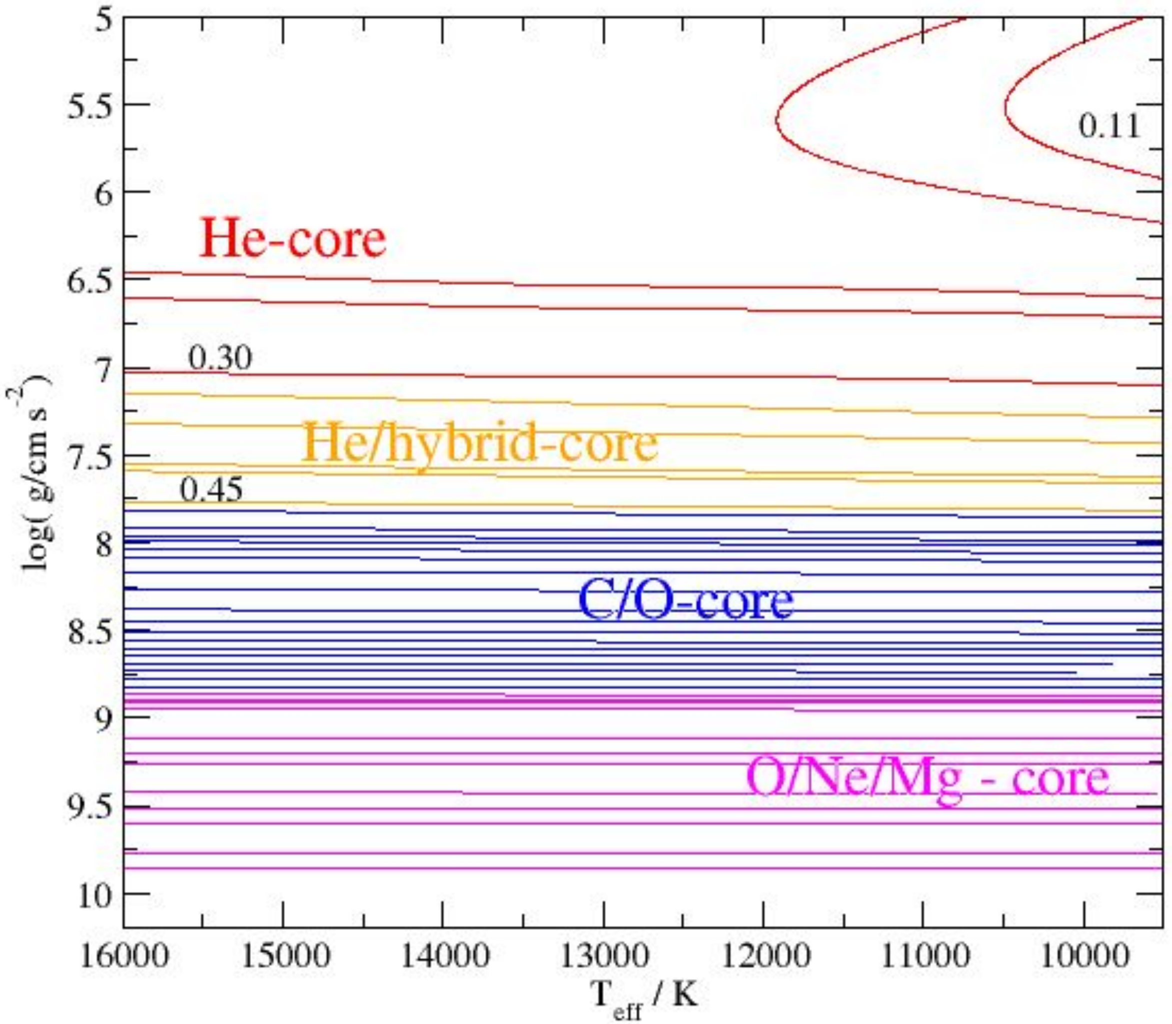
Let's go to the modeling part....

He-core: < 0.3 M_{sun}

He- or Hybrid-core 0.30 to 0.45 M_{sun}

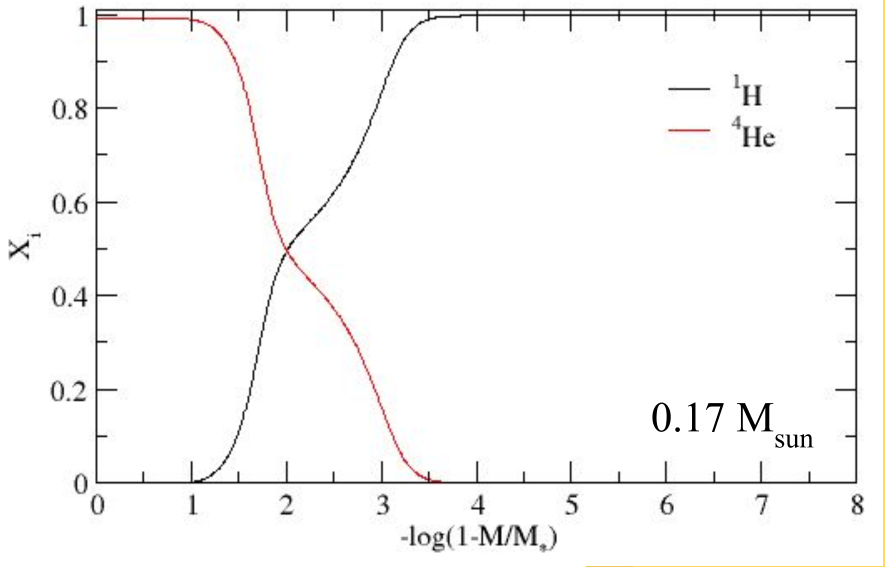
C/O -core: ~0.45 to ~1.05 M_{sun}

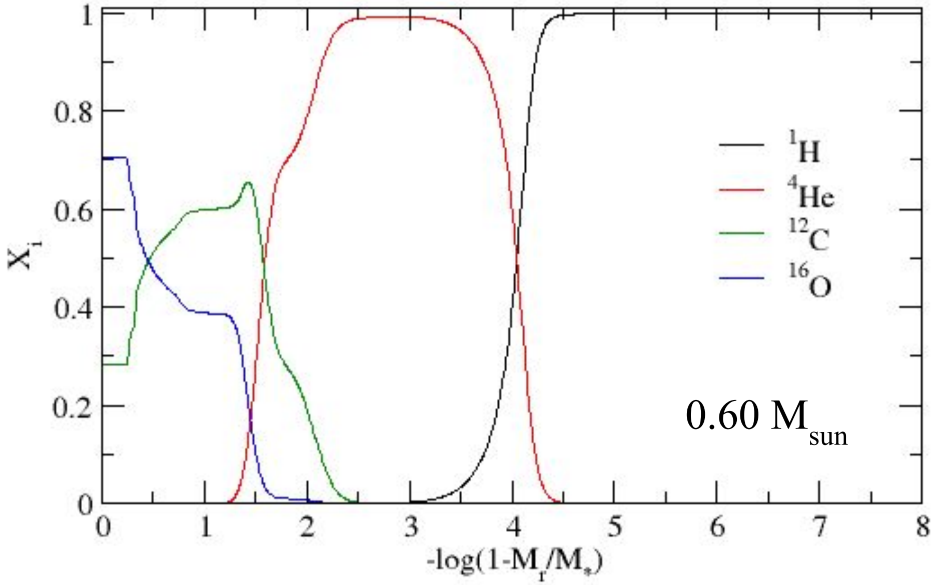
O/Ne/Mg < 1.05-1.10 M_{sun}

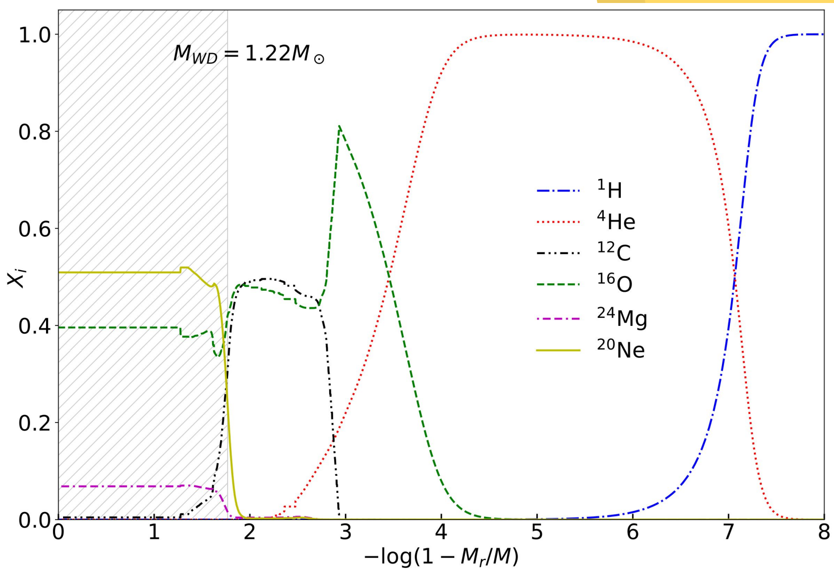


Althaus et al. (2013), Althaus et al. (2009), Romero et al. (2015), Lauffer et al. (2008)

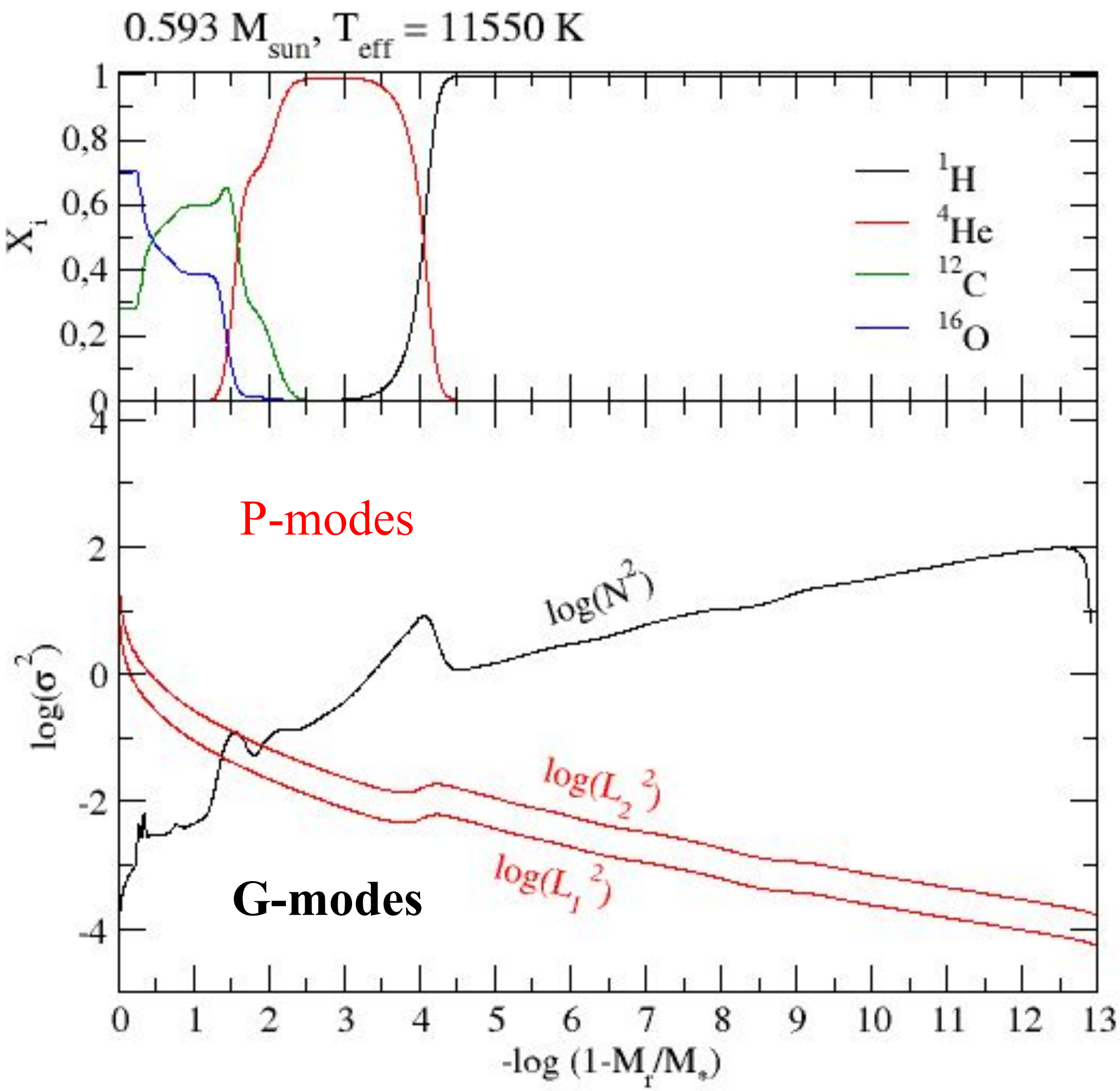
Central composition







Characteristic frequencies



Brunt-Väisälä frequency

$$N^2 = \frac{g^2 \rho}{P} \frac{\chi_T}{\chi_\rho} \left(\nabla_{\rm ad} - \nabla + B\right)$$

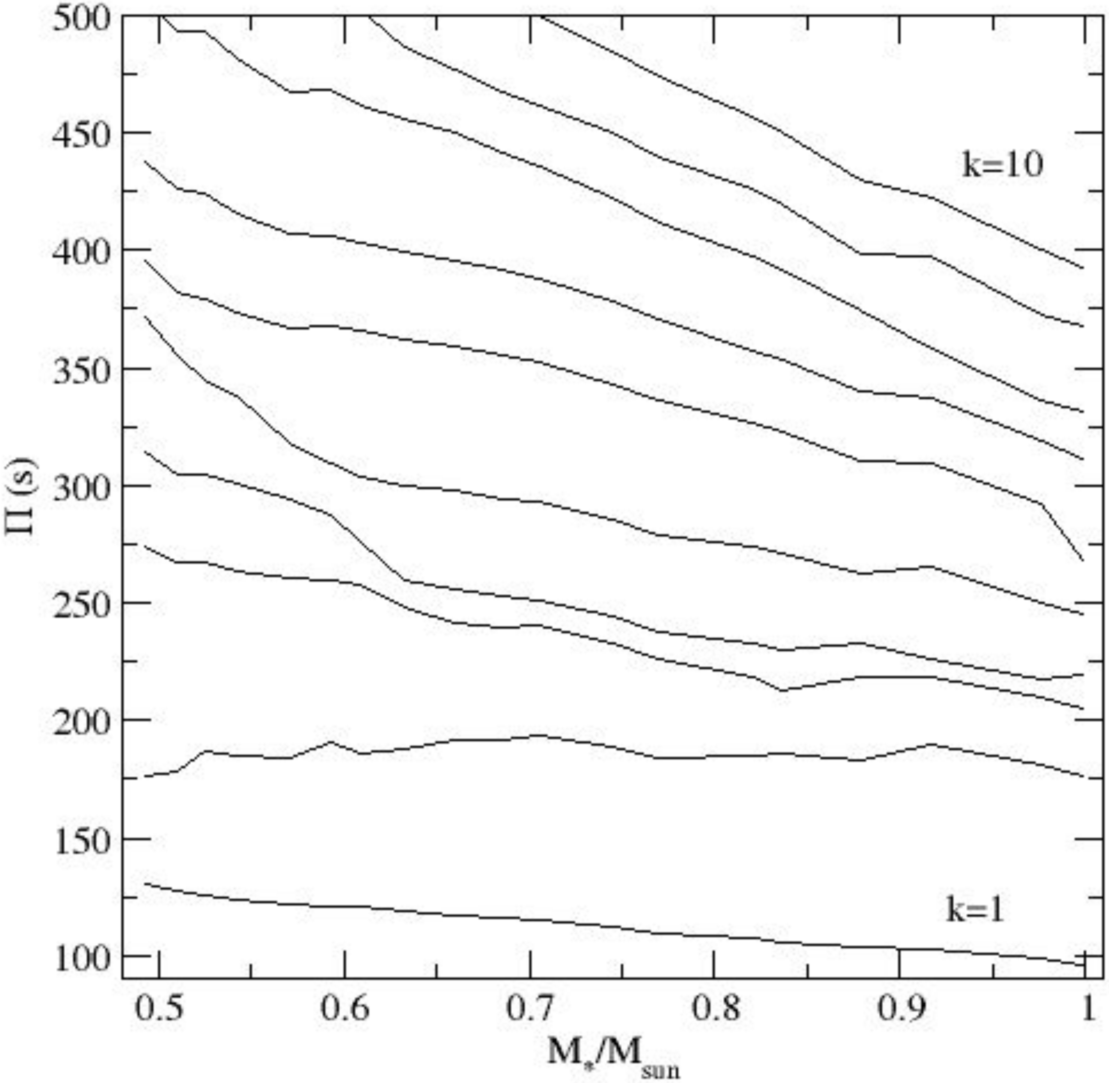
Lamb frequency

$$L_\ell^2 = \frac{(\ell+1)\ell}{r^2} c_S^2$$

Periods vs. stellar mass

Higher mass-> shorter period

$$\Pi \propto 1/N \propto 1/g$$

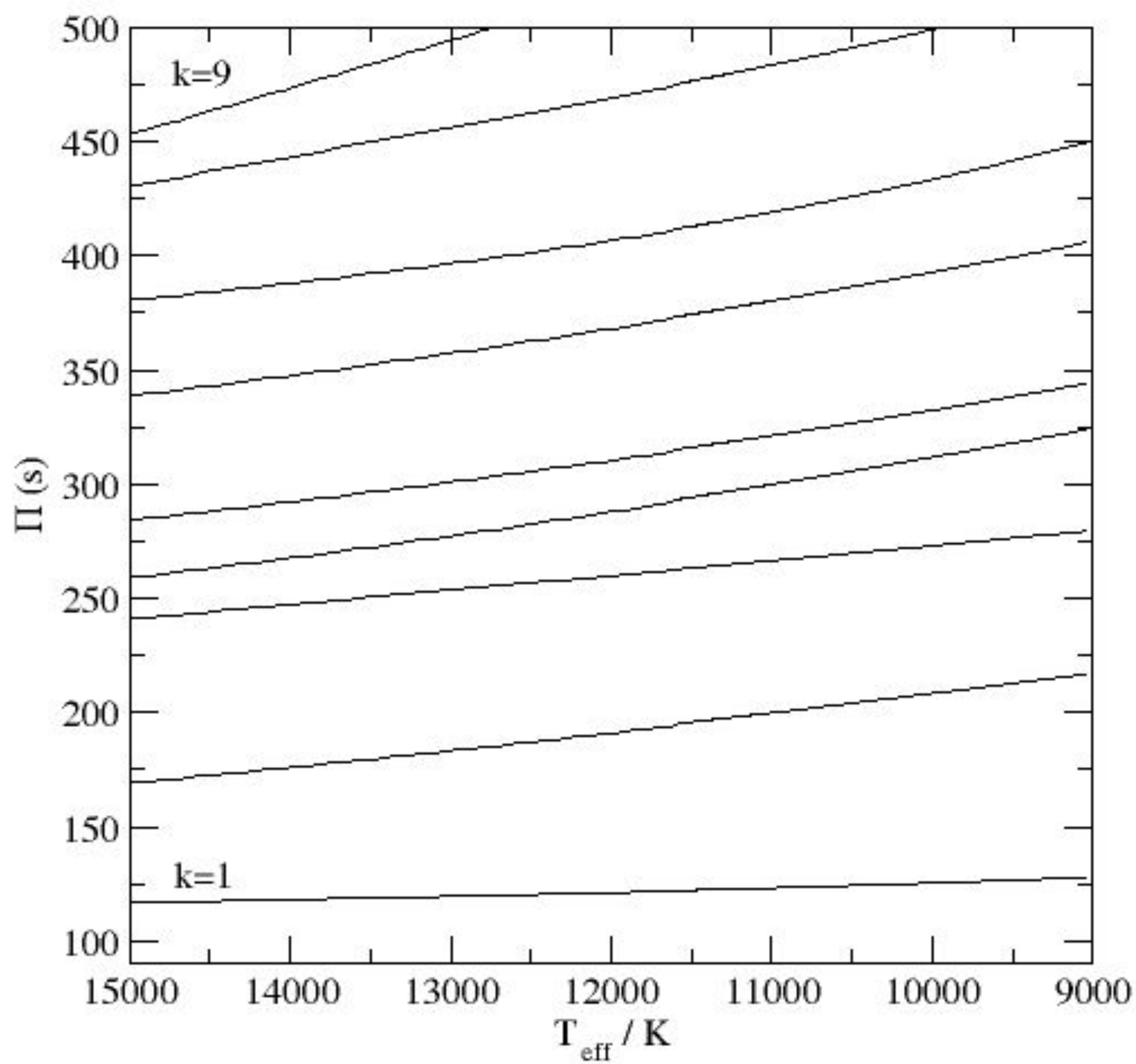


Periods vs. effective temperature

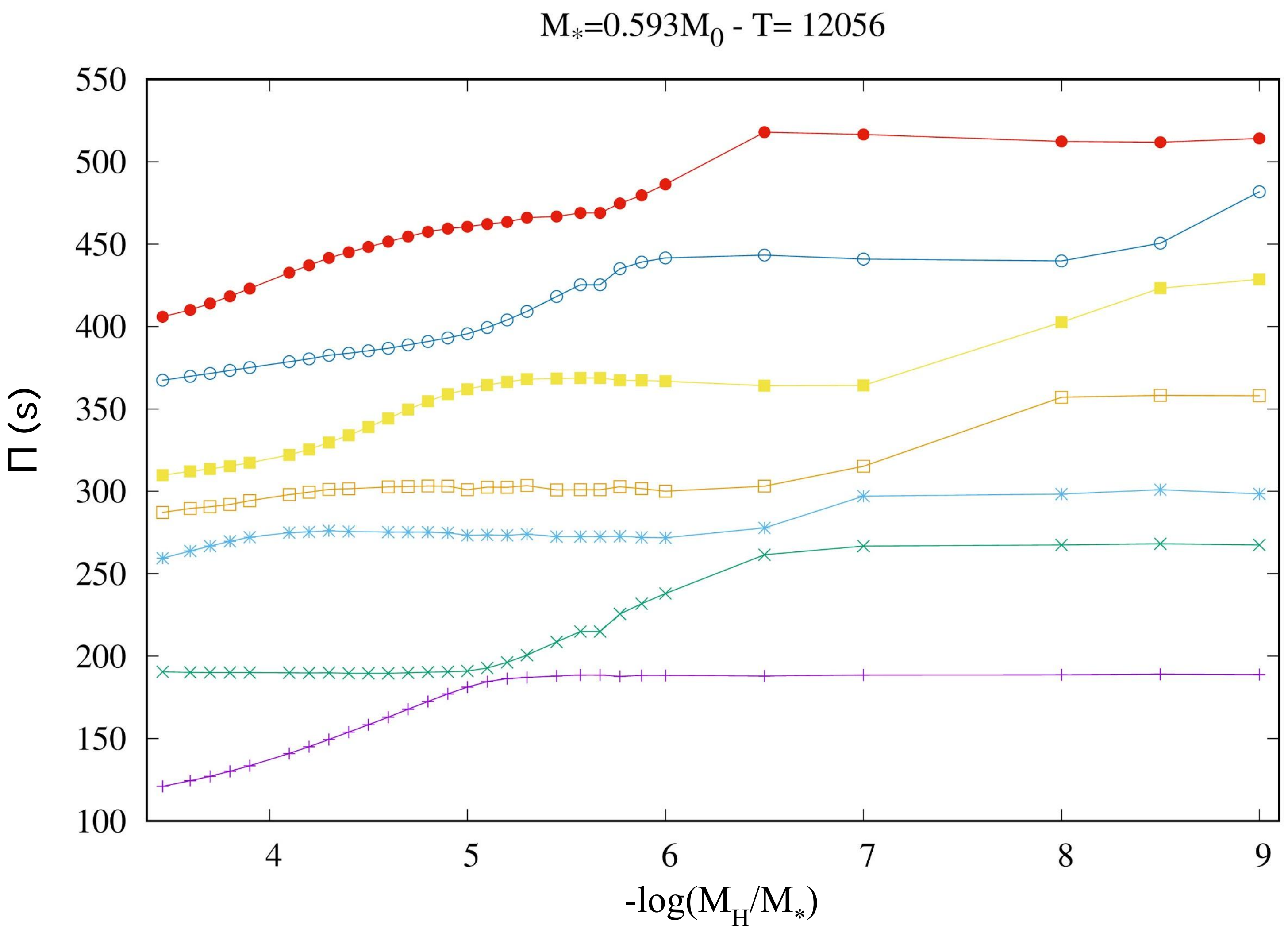
Lower Teff -> longer period

N decreases with degeneracy

$$\Pi \propto 1/N$$



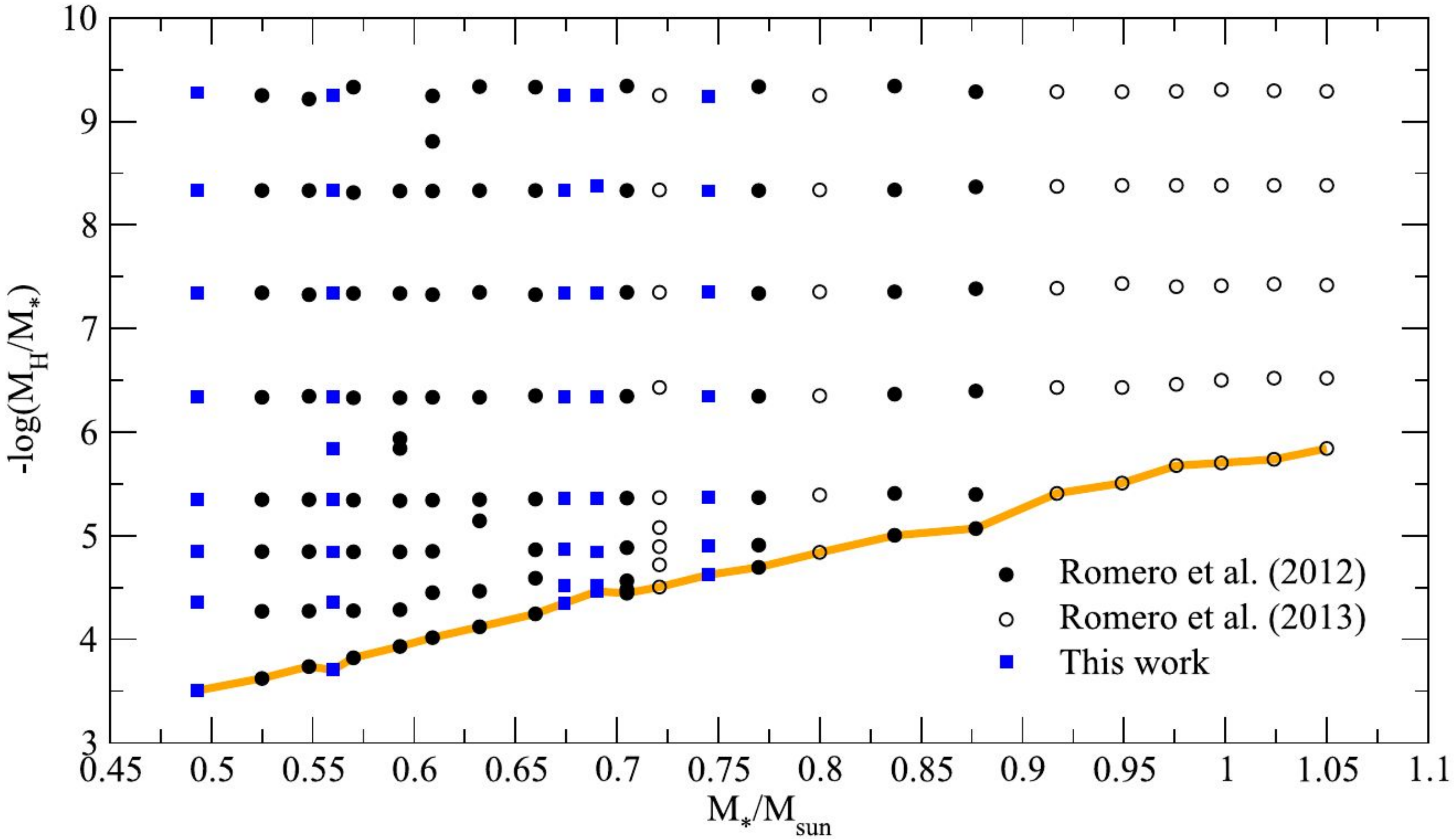
Periods vs. Hydrogen envelope mass



Klippel et al. in prep

Is there a hydrogen-envelope distribution?

Romero et al. (2017)



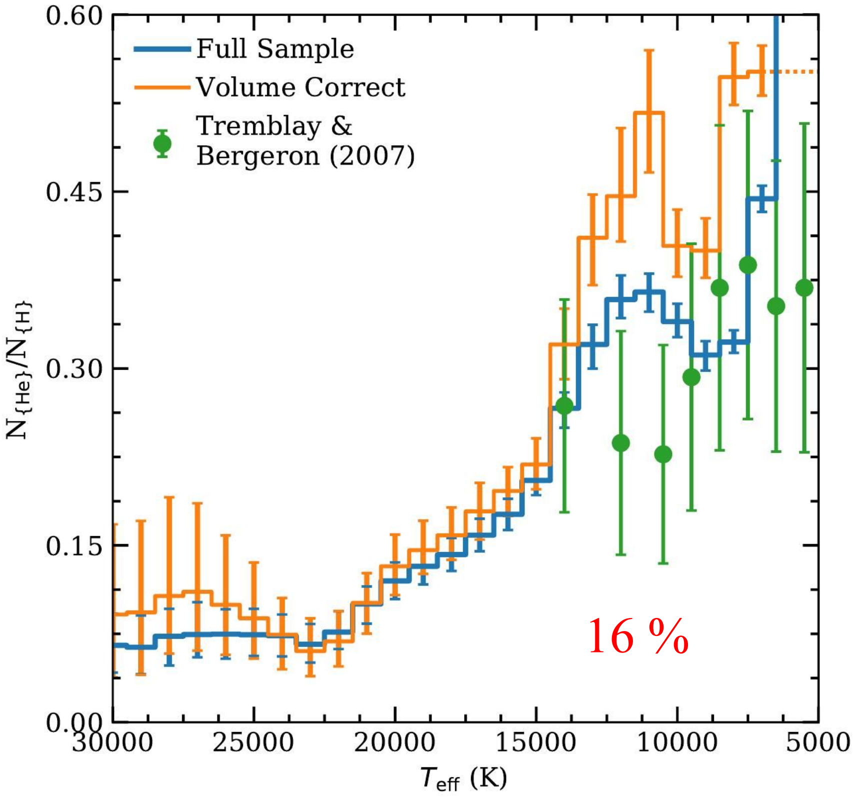
Hydrogen envelope mass decreases with increasing stellar mass

Updated grid in Klippel et al. in prep.

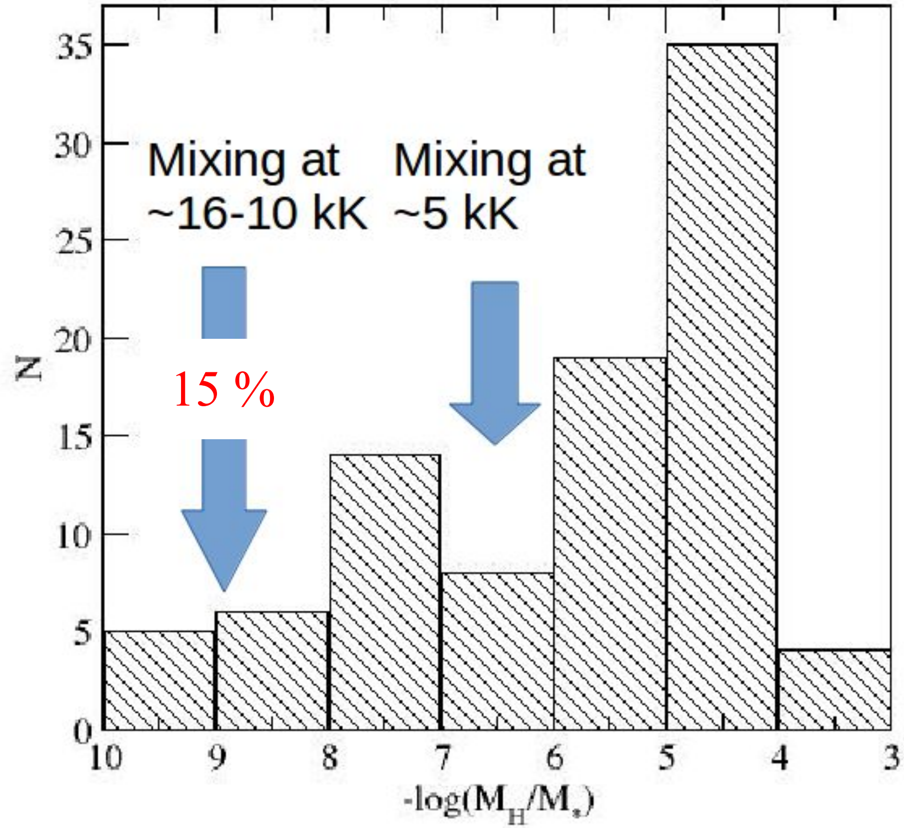
Evidence in favor of a M_H distribution

Romero et al. (2019)

From Spectral evolution and Asteroseismology



Ourique et al. (2019)



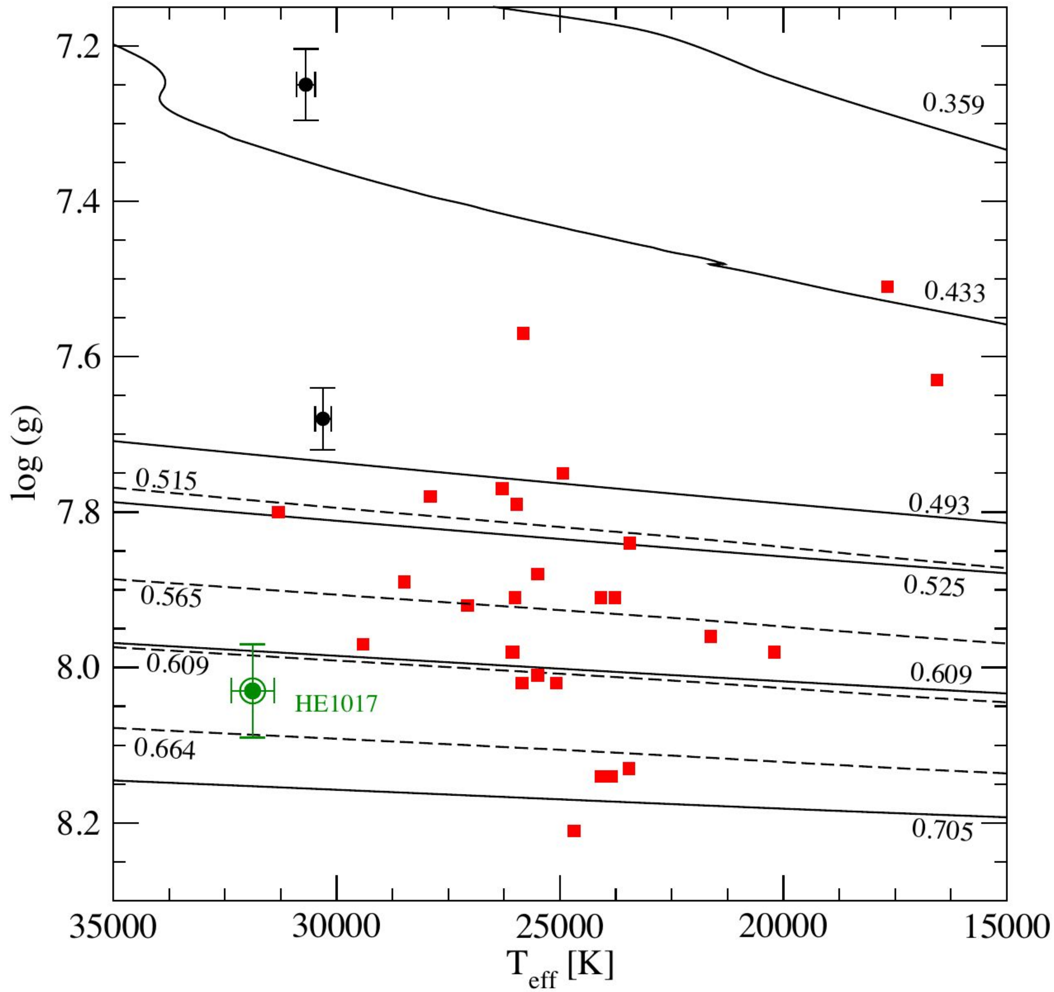
Evidence in favor of a M_H distribution

Confirmation of hot-DAV

HE 1017-1352 (Kurtz+ 2013)
Teff~32000 K

Four pulsation periods:
605 s, 556 s, 508 s and 869 s

Shibahashi (2005, 2007)
$10^{-14} < M_H / M_{sun} < 10^{-12}$



Romero et al. (2020)

Final remarks

Tassoul et al. (1990), Brassard et al. (1992)

- ➔ Periods decrease with increasing stellar mass
- ➔ Periods increase with cooling
- ➔ Periods increase for thinner hydrogen-envelope mass

- ➔ Distribution in H-envelope mass: asteroseismology, spectral evolution, mass-radius relation, existence of hot DAVs, ??
- ➔ Most objects in the ZZ Ceti instability strip have thick H-envelopes (> 10^{-5} M_{sun}), thus we do not need extra physics
- ➔ Thinner envelopes : LTPs? Binary interaction? Increase mass loss?

Thank You
Köszönöm
Mauruuru
Danke
Sagolun
Gracias
Mercé
ありがとう
Спасибо
Merci
Dankjewel
Toda
Tak
Sagolun
Terima Kasih
Mahalo
Xièxie
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Grazie
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Efharisto
Terima Kasih
Danke
Mercé
Rahmat

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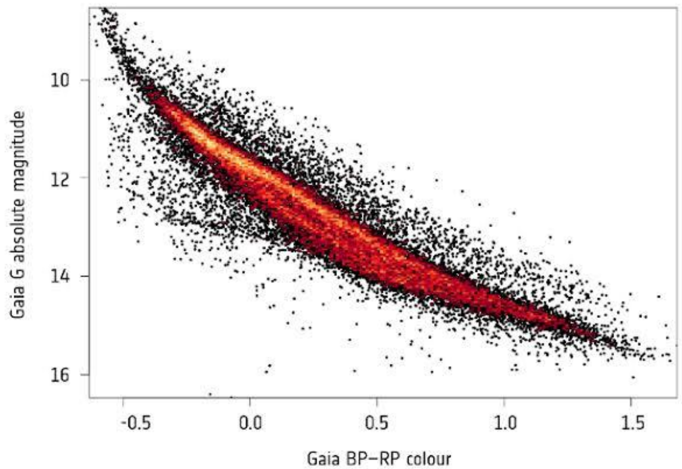
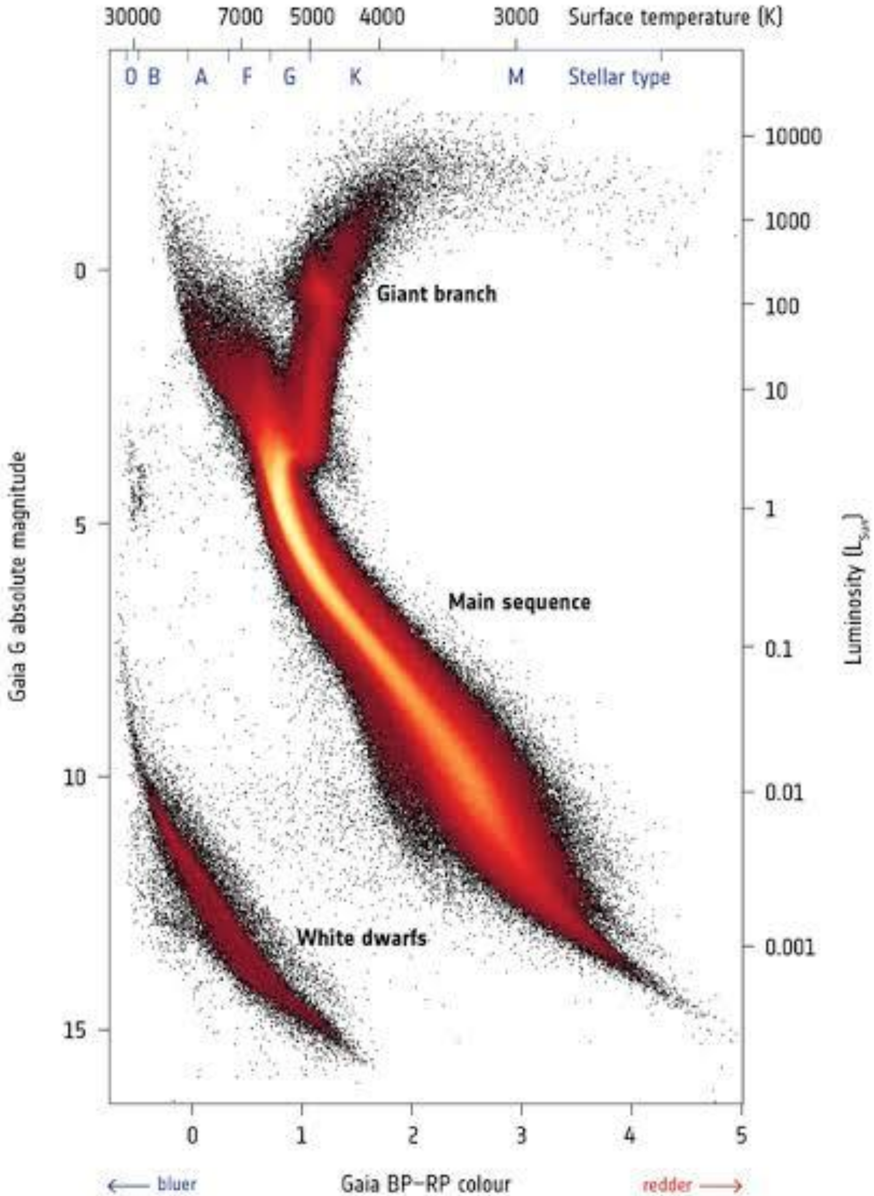
White dwarfs
in the H-R diagram





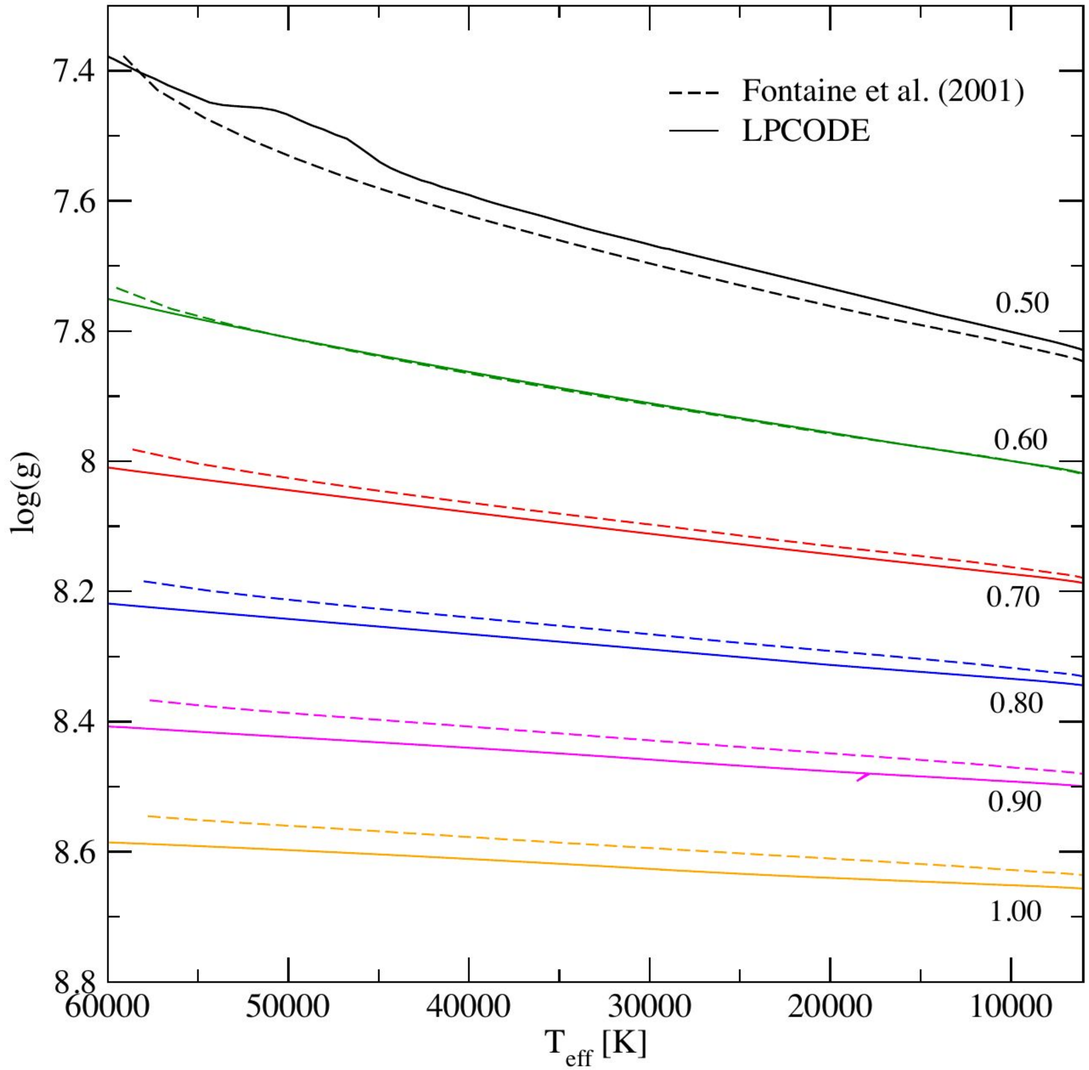
Gaia (ESA)

Is there a hydrogen-envelope distribution?

Less hydrogen mass

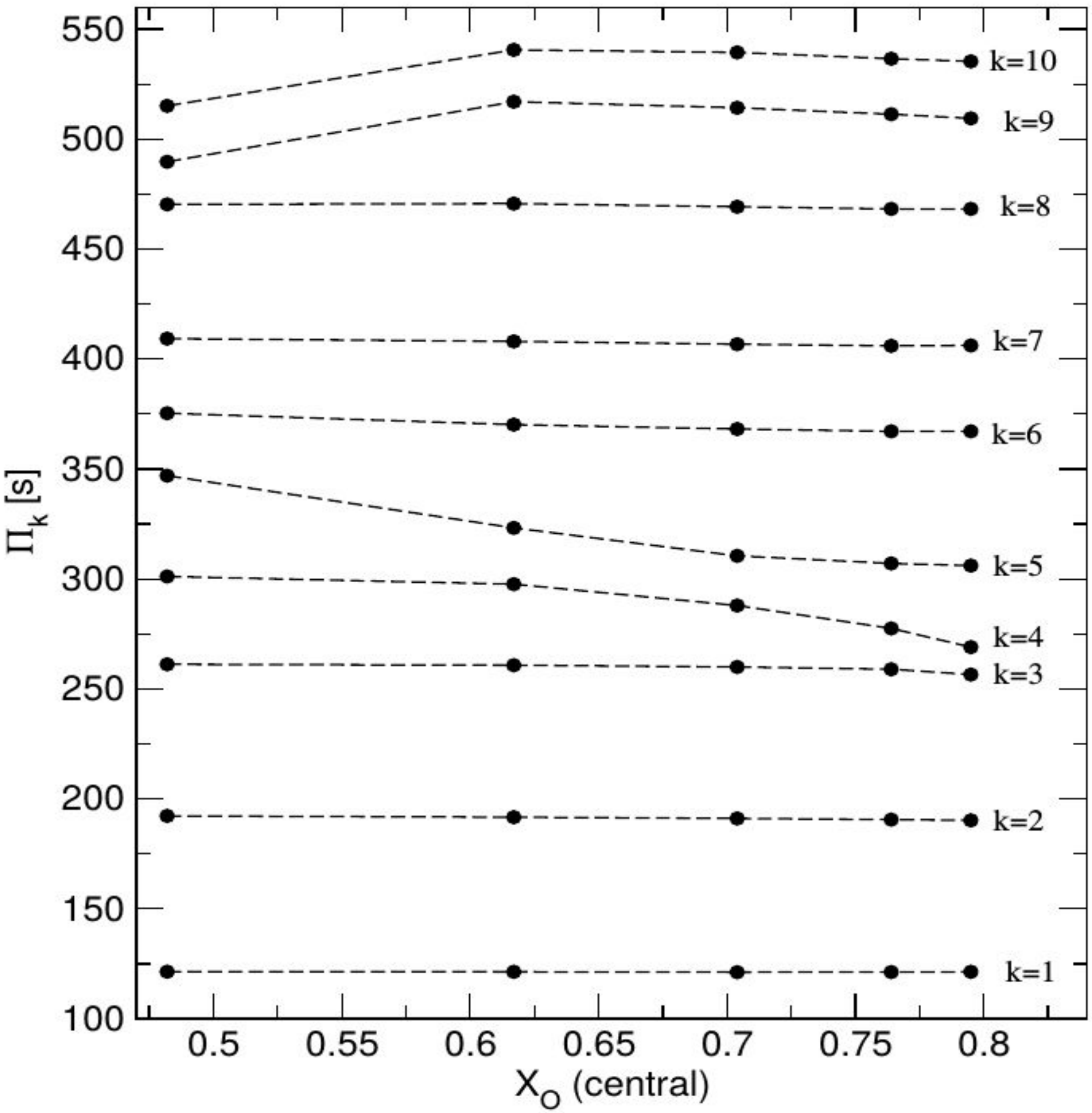
↓

Smaller radius

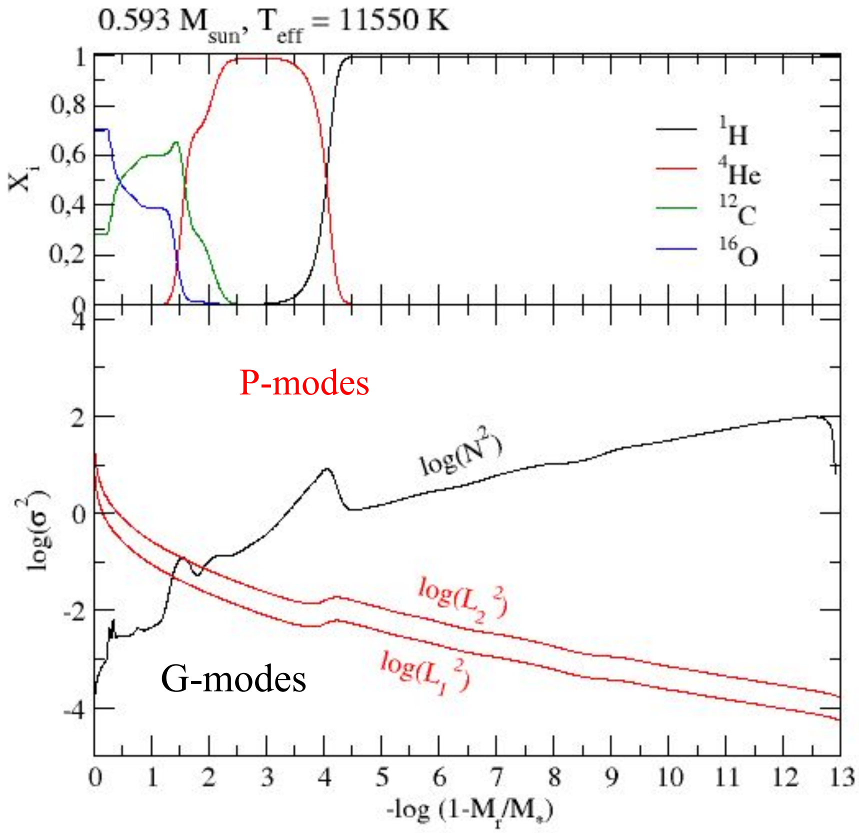


Romero et al. (2019)

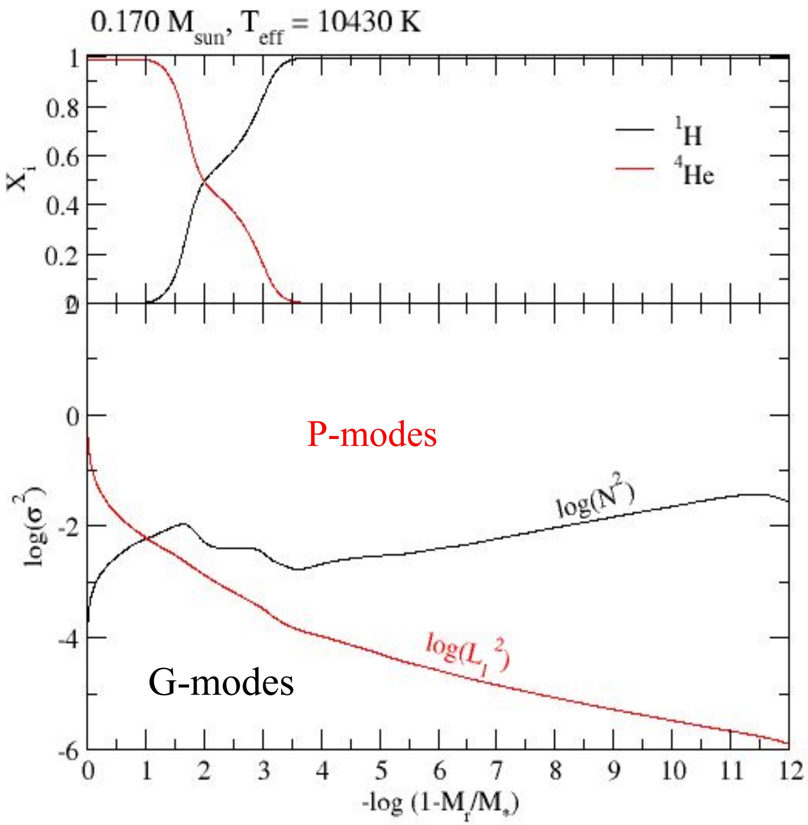
Periods vs. C/O central abundance



Characteristic frequencies



ZZ Ceti star

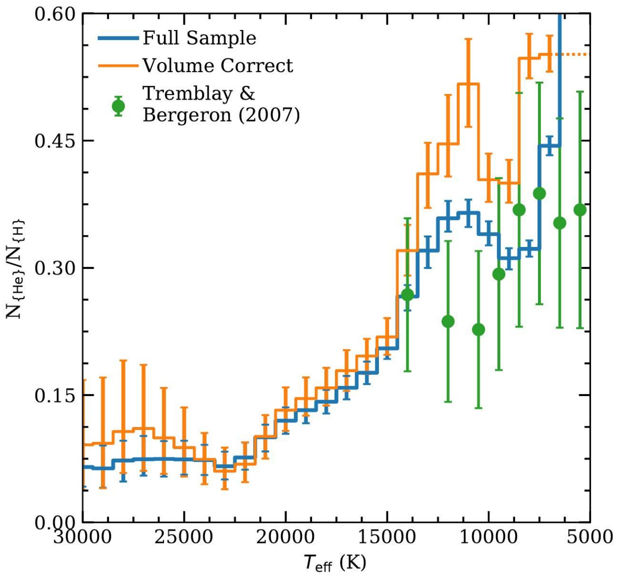


ELMV

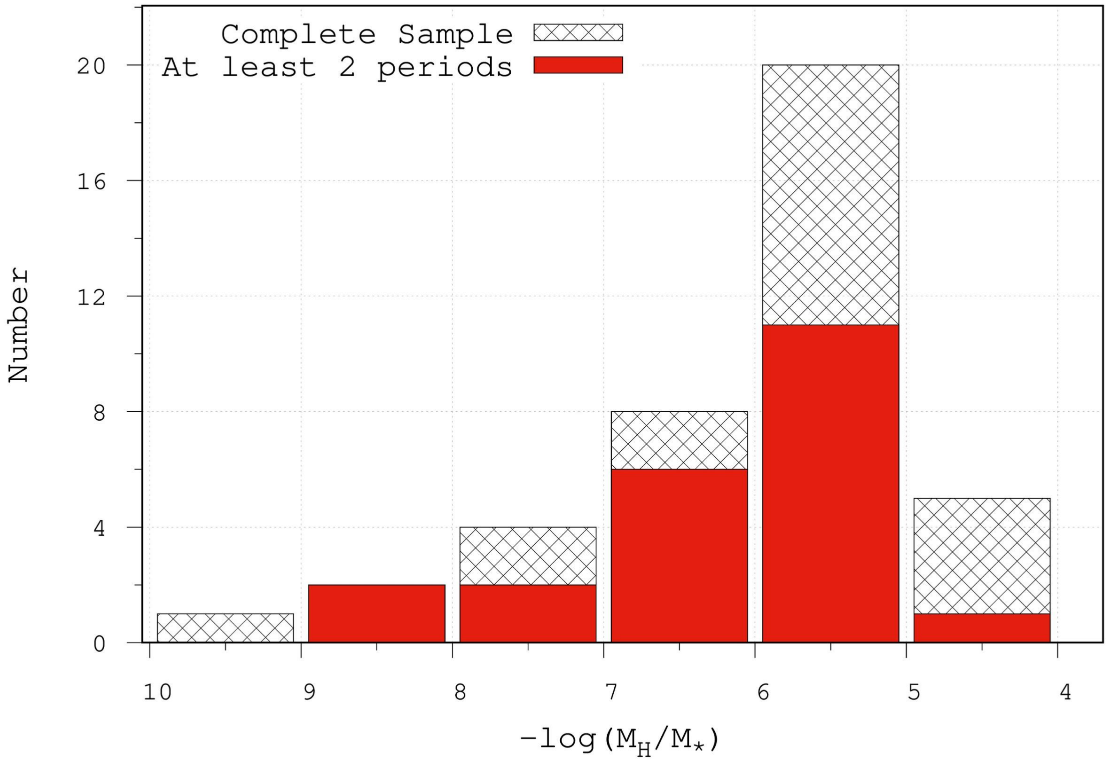
Evidence in favor of a M_H distribution

Klippel et al. in prep.

From Asteroseismology and spectral evolution



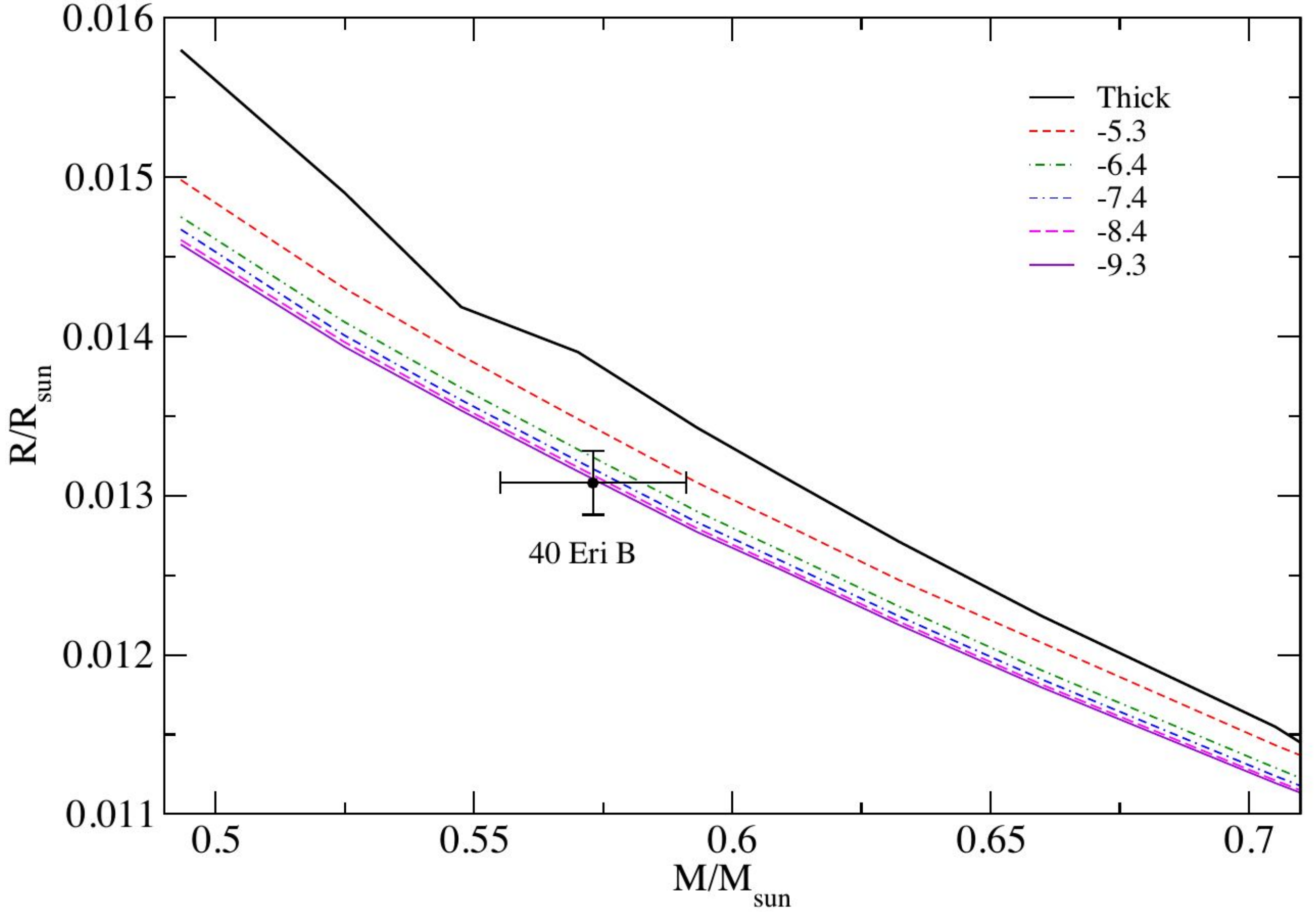
Ourique et al. (2019)



Sample of 40 known ZZ Ceti stars with $M > 0.8\ M_{sun}$

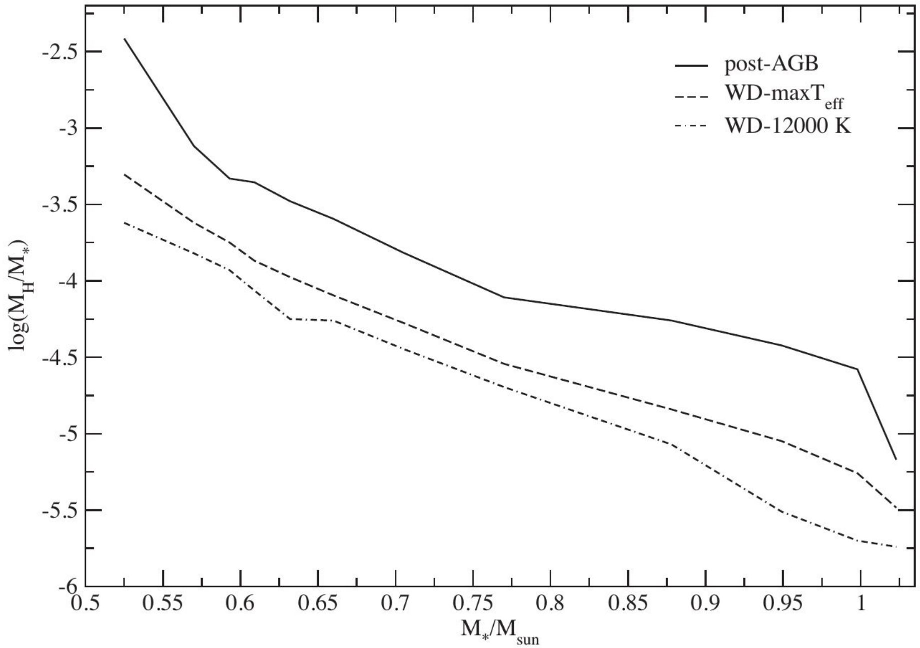
Evidence in favor of a M_H distribution

From mass-radius relation



Romero et al. (2019), Bond et al. (2017)

Is there a hydrogen-envelope distribution?



Evolution previous to the WD cooling curve: M_H decrease for higher core mass.

WD cooling curve: M_H decrease by 2x du to residual burning, independent of the stellar mass