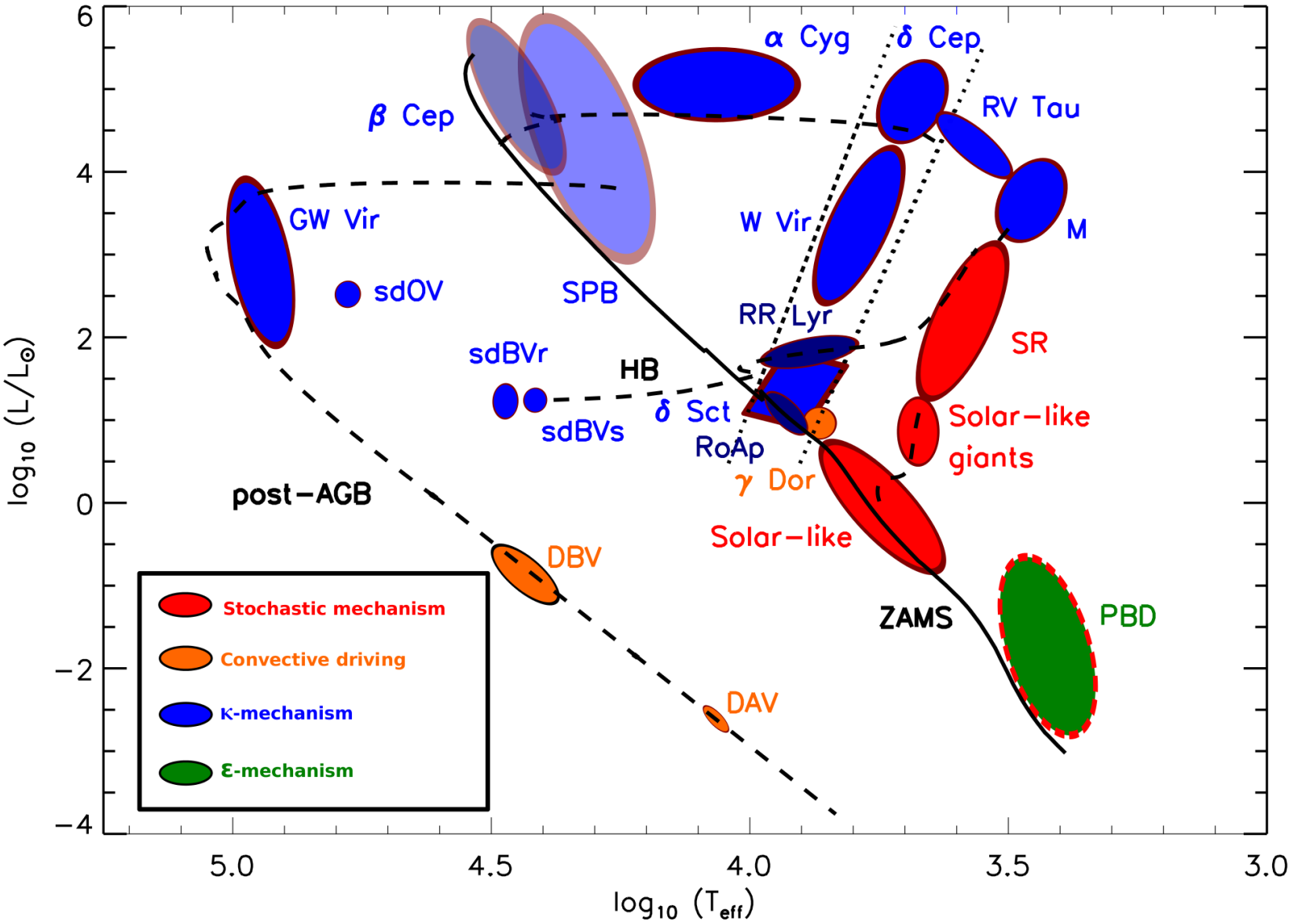

α Cyg
δ Cep
β Cep
RV Tau
GW Vir
W Vir
M
sdOV
SPB
RR Lyr
SR
sdBVr
HB
δ Sct
sdBVs
RoAp
Solar−like
giants
γ Dor
post−AGB
Solar−like
DBV
ZAMS
PBD
DAV
Stochastic mechanism
Convective driving
κ-mechanism
ε-mechanism
log10 (L/L⊙)
log10 (Teff)
6
4
2
0
−2
−4
5.0
4.5
4.0
3.5
3.0

The envelope of the power spectra of over a thousand δ Scuti stars

Sebastià Barceló Forteza

24 October 2018

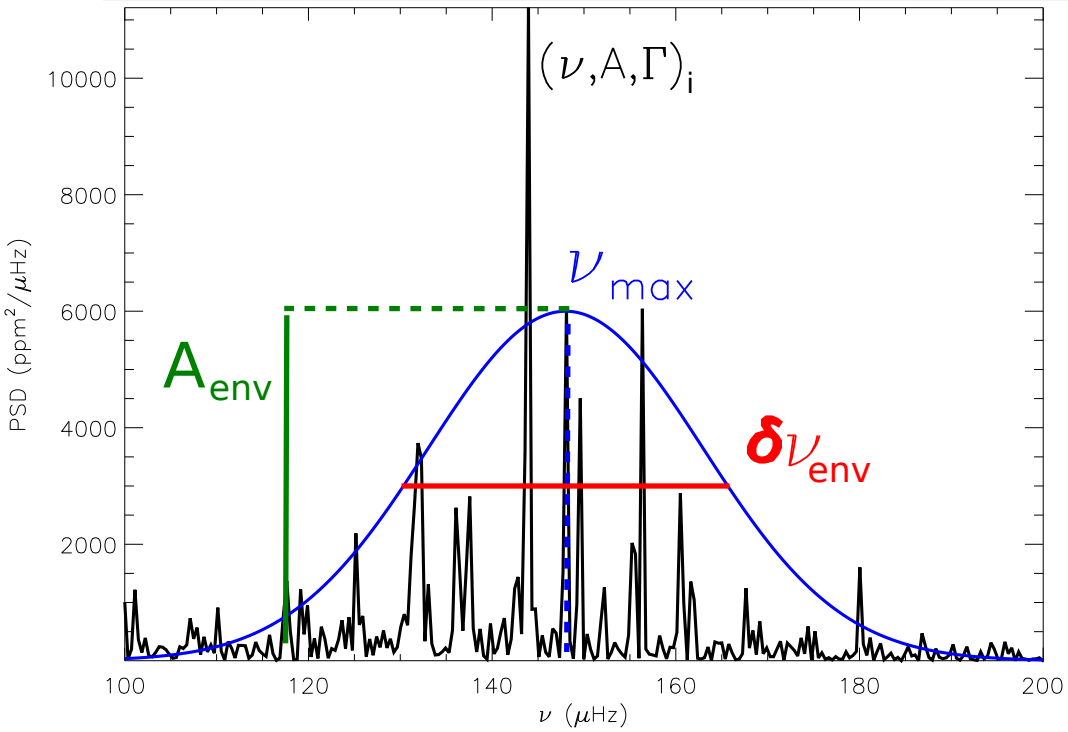
CENTRO DE ASTROBIOLOGÍA
ASOCIADO AL NASA ASTROBIOLOGY INSTITUTE
CSIC INTA

Contents

The envelope

Definition:

- Power spectrum structure $\rightarrow$ modes $\rightarrow$ M, R, $T_{\rm eff}$
- $\nu_{\rm max}$, $A_{\rm env}$, $\delta\nu_{\rm env}$, α



How to calculate:

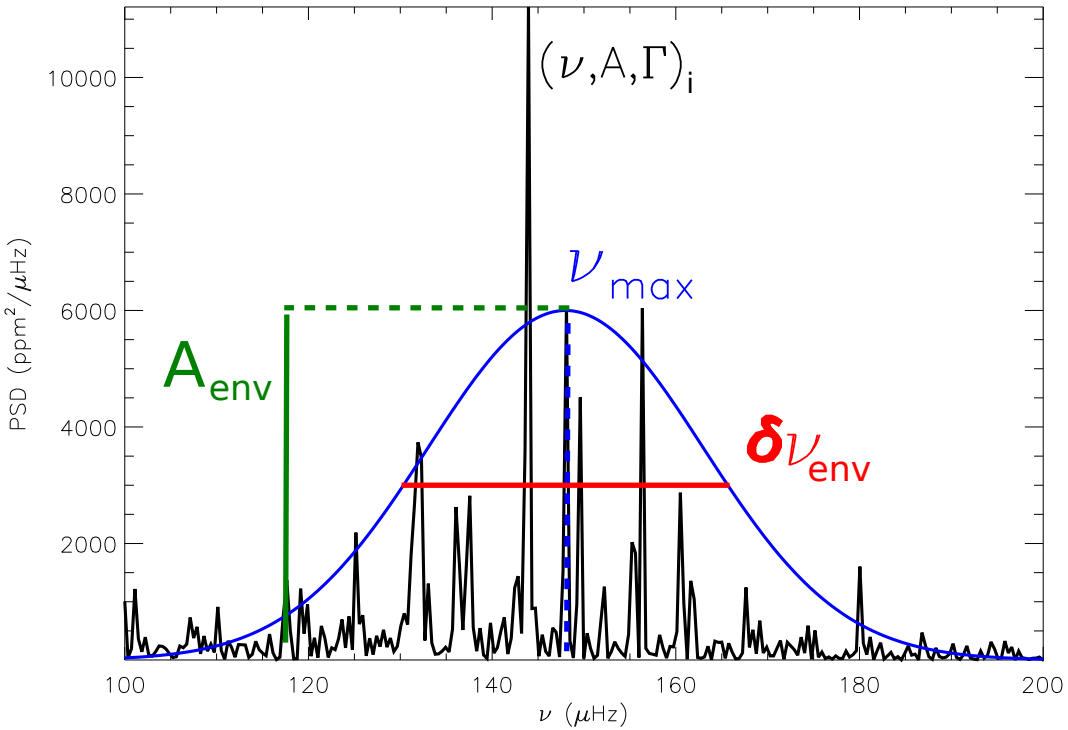
1. Gaussian fit
2. Kallinger et al. (2010):
$$\nu_{\rm max} = \frac{\sum A_i \nu_i}{\sum A_i}$$

Envelope of the red giant KIC 5701829.

The envelope

Solar-like pulsators:

- Kjeldsen & Bedding (1995): $\nu_{\max} \propto MR^{-2}T_{\rm eff}^{-0.5}$
- Kallinger et al. (2010): $\alpha \lesssim 3\%$



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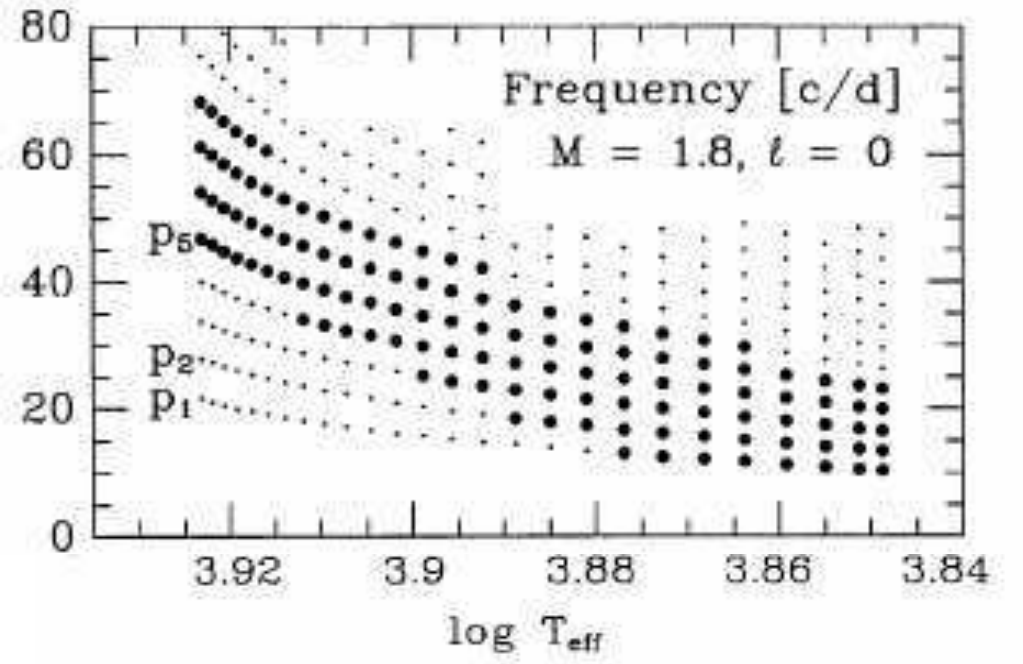
δ Scuti stars:

- κ-mechanism (Chevalier 1971; Xiong et al. 2016)
  - $M \in [1.5, 2.5]\ M_\odot$
  - $T_{\rm eff} \in [6000, 9000]$ K
  - $\Omega \lesssim \Omega_K$
  - $\nu \in [60, 930]\ \mu$Hz



Scaling relation?

1. Dziembowski (1997): $T_{eff} \propto \nu_i$
2. Kallinger et al. (2010): $\nu_{\rm max} = \frac{\sum A_i \nu_i}{\sum A_i}$

Excited modes of a δ Scuti model from Dziembowski (1997).

The envelope

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- κ-mechanism (Chevalier 1971; Xiong et al. 2016)
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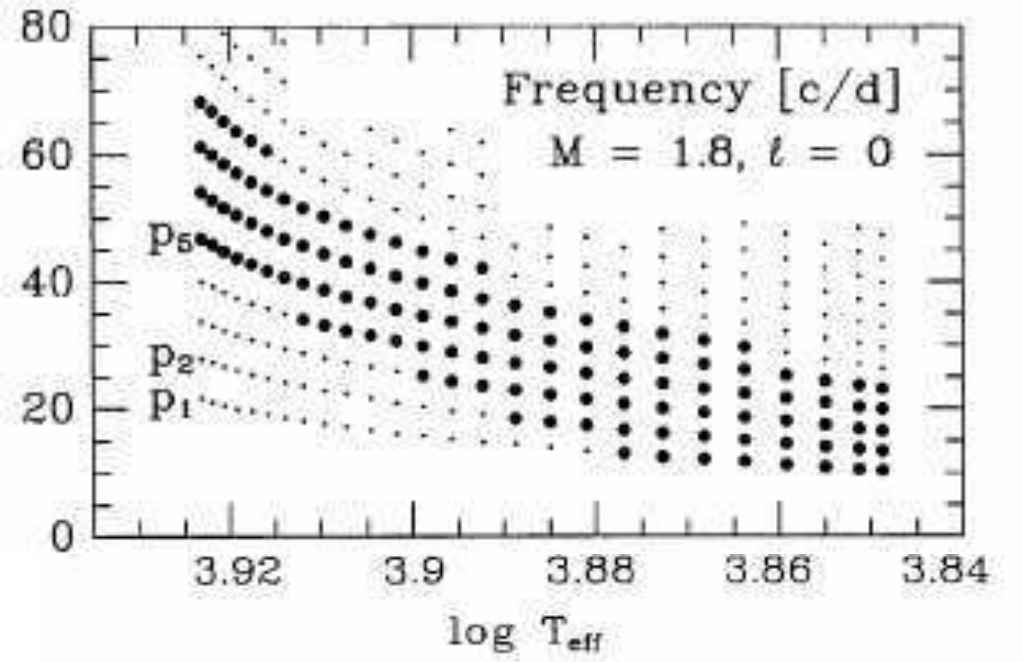

Scaling relation?

- $T_{eff} \propto \nu_{\rm max}$

Excited modes of a δ Scuti model from Dziembowski (1997).

Gravity-darkening effect

Rotation

$$g_{eff}(i) \approx g - R(i)\Omega^2 \sin^2\{i\}$$

$$T_{eff}(i) \propto g_{eff}^{\beta/4}(i) \rightarrow \beta \approx 1 \text{ (von Zeipel 1924)}$$

$$\delta \bar{T}_{eff}(i) \equiv \left(T_{\rm eff}(i) - \bar{T}_{\rm eff}\right) / \bar{T}_{\rm eff}$$

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$\Omega/\Omega_K = 0$

$|\delta \bar{T}_{eff}(i)| = 0$ %

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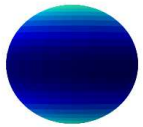

$\Omega/\Omega_K = 0$

$|\delta \bar{T}_{eff}(i)| = 0$ %

$\Omega/\Omega_K = 0.7$

$|\delta \bar{T}_{eff}(i)| \lesssim 4.1$ %

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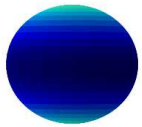
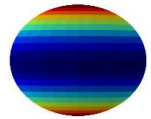


$\Omega/\Omega_K = 0.7$

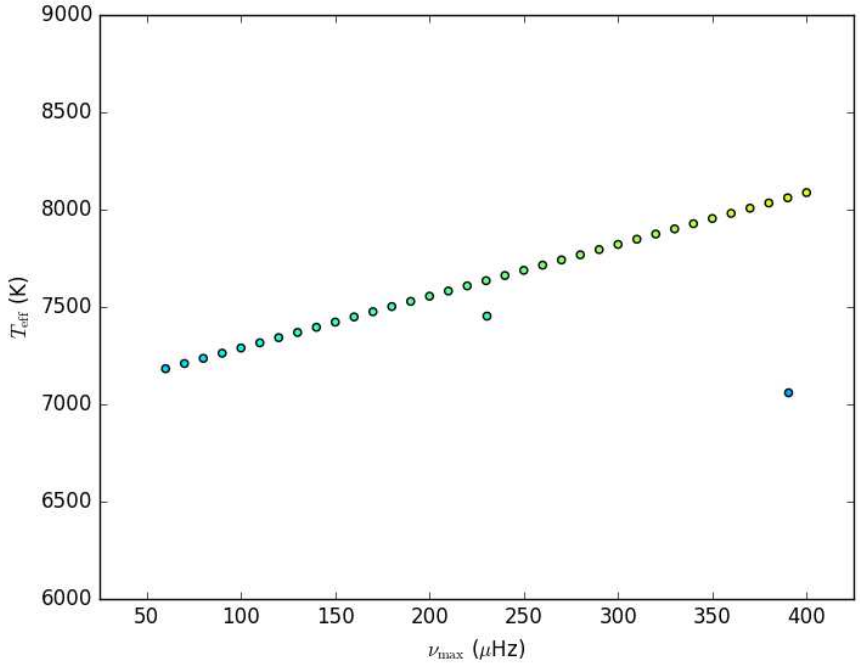
$|\delta \bar{T}_{eff}(i)| \lesssim 4.1$ %



$\Omega/\Omega_K = 1$

$|\delta \bar{T}_{eff}(i)| \lesssim 12.4$ %

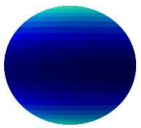
Gravity-darkening effect



$i \approx 90^\circ$

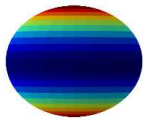
$\Omega/\Omega_K = 0$

$\delta\bar{T}_{eff}(i) = 0$ %



$\Omega/\Omega_K = 0.7$

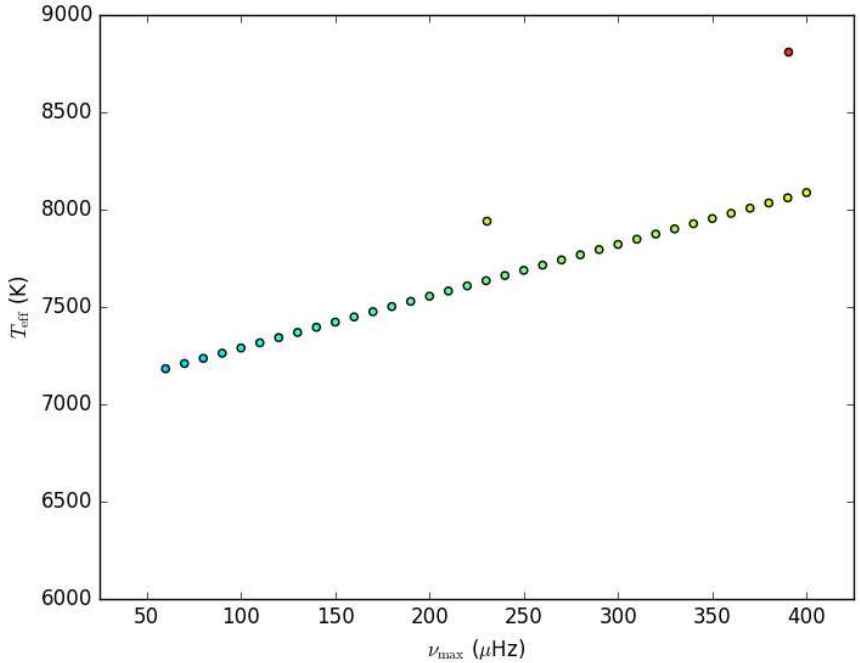
$\delta\bar{T}_{eff}(i) \approx -2.4$ %



$\Omega/\Omega_K = 1$

$\delta\bar{T}_{eff}(i) \approx -12.4$ %

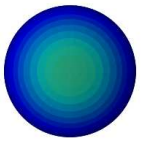
Gravity-darkening effect



$i \approx 0^\circ$

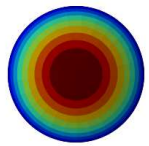
$\Omega/\Omega_K = 0$

$\delta \bar{T}_{eff}(i) = 0$ %



$\Omega/\Omega_K = 0.7$

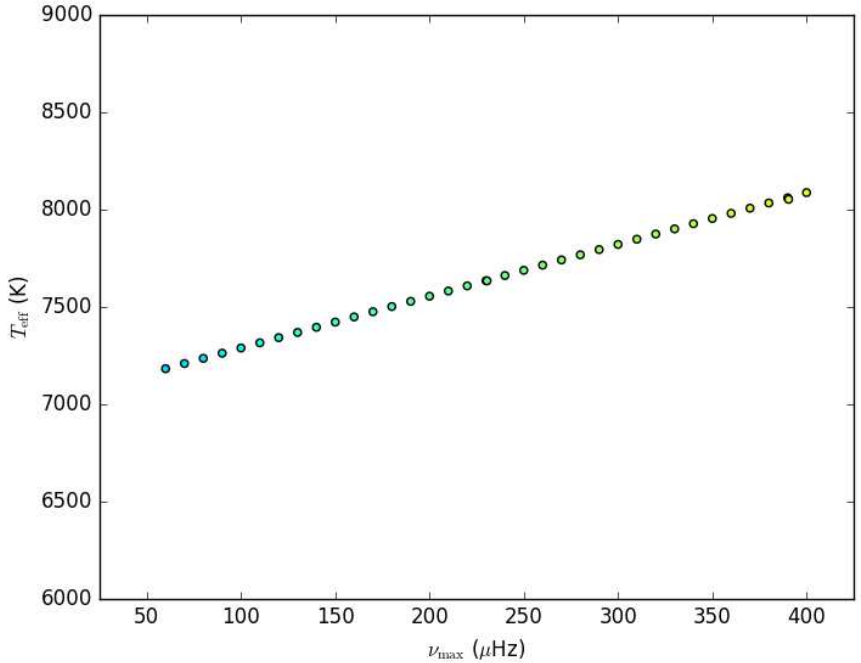
$\delta \bar{T}_{eff}(i) \approx 4.1$ %



$\Omega/\Omega_K = 1$

$\delta \bar{T}_{eff}(i) \approx 9.4$ %

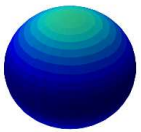
Gravity-darkening effect



$i \approx 55°$

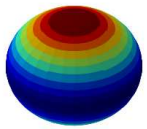
$\Omega/\Omega_K = 0$

$\delta\bar{T}_{eff}(i) = 0\ \%$



$\Omega/\Omega_K = 0.7$

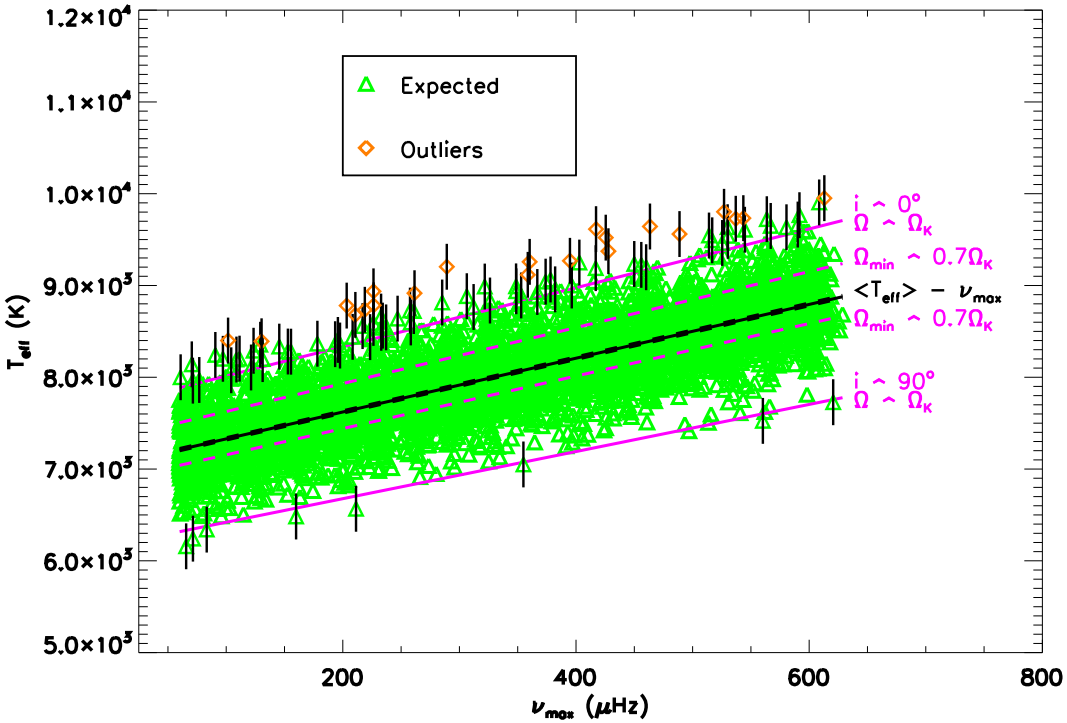
$\delta\bar{T}_{eff}(i) \approx 0\ \%$



$\Omega/\Omega_K = 1$

$\delta\bar{T}_{eff}(i) \approx 0\ \%$

$T_{\rm eff} - \nu_{\rm max}$ DIAGRAM



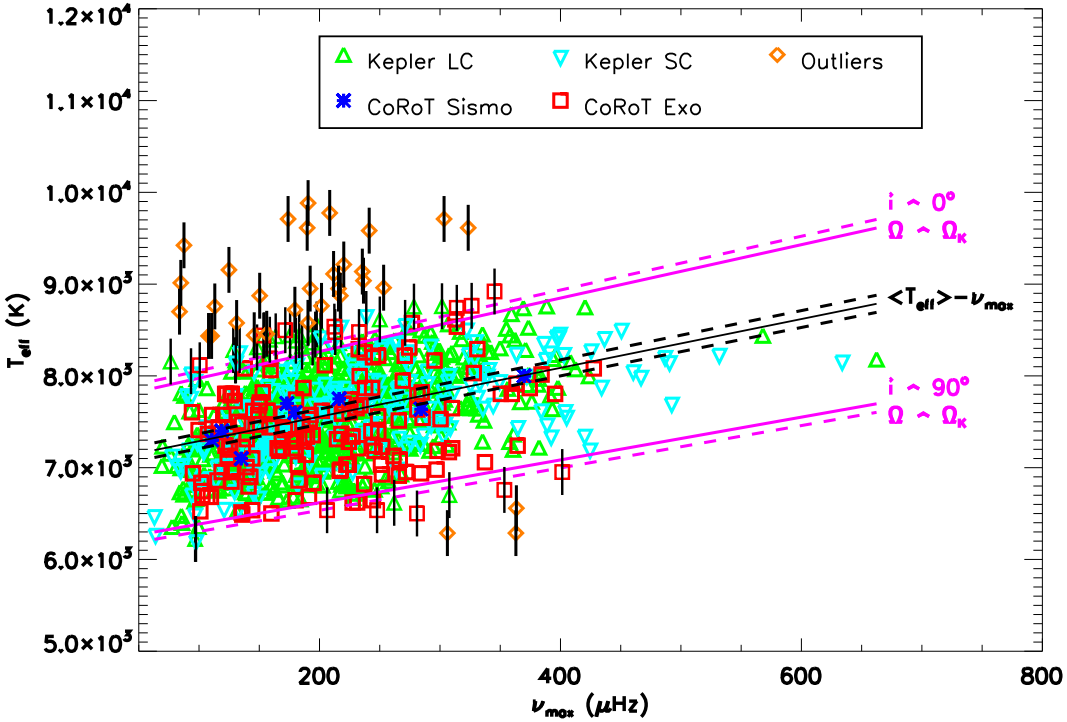
Barceló Forteza et al. (2018)

$$T_{\rm eff} = \bar{T}_{\rm eff}\left(1 + \delta\bar{T}_{\rm eff}(i)\right)$$

1. $\nu_{\rm max} \rightarrow \bar{T}_{\rm eff}$
2. $\delta\bar{T}_{\rm eff}(i) \rightarrow \{\frac{\Omega}{\Omega_K}, i\}$

Predicted temperatures of over 5000 δ Scuti star models with $\forall\ \{\nu_{\rm max}, \frac{\Omega}{\Omega_K}, i\}$ including the *Kepler* $ET_{\rm eff} \approx 250$ K

Data sources



Measured $\{\nu_{\max}, T_{\rm eff}\}$ values of over a thousand δ Scuti stars.

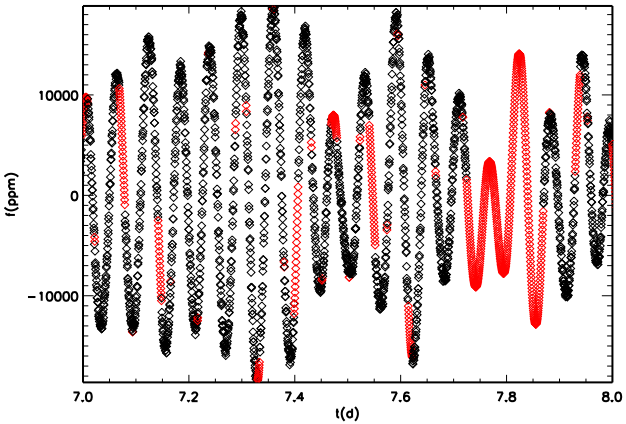
$\{\nu_{\max}, T_{\rm eff}\}$

- $\nu_{\max} \rightarrow \delta$SBF pipeline
- $T_{\rm eff} \rightarrow$ CATALOGUES

  Brown et al. (2011)

  Debosscher et al. (2009)

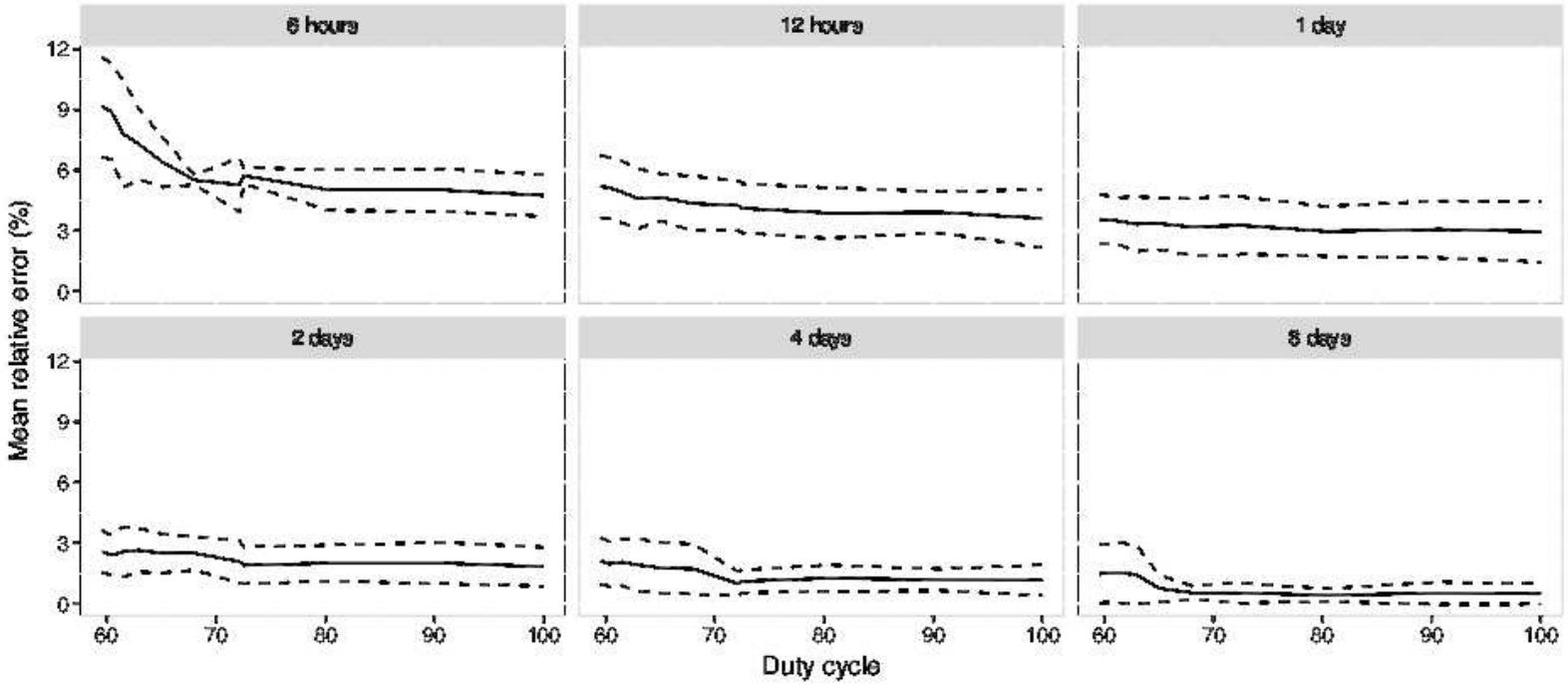
δ Scuti Basics Finder



Barceló Forteza et al. (2015)

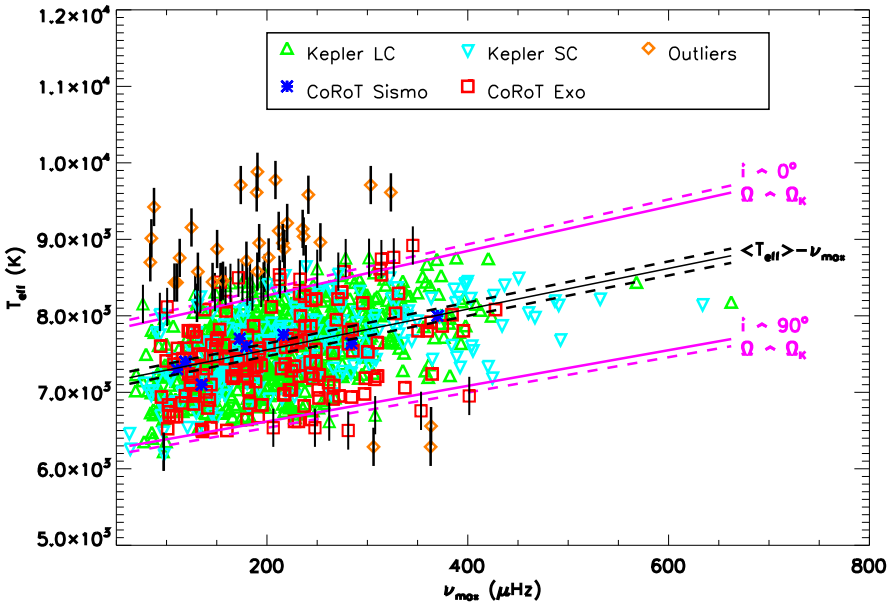
$$F(t) \rightarrow \{\nu_i, A_i, \phi_i\} \rightarrow \nu_{\max}$$

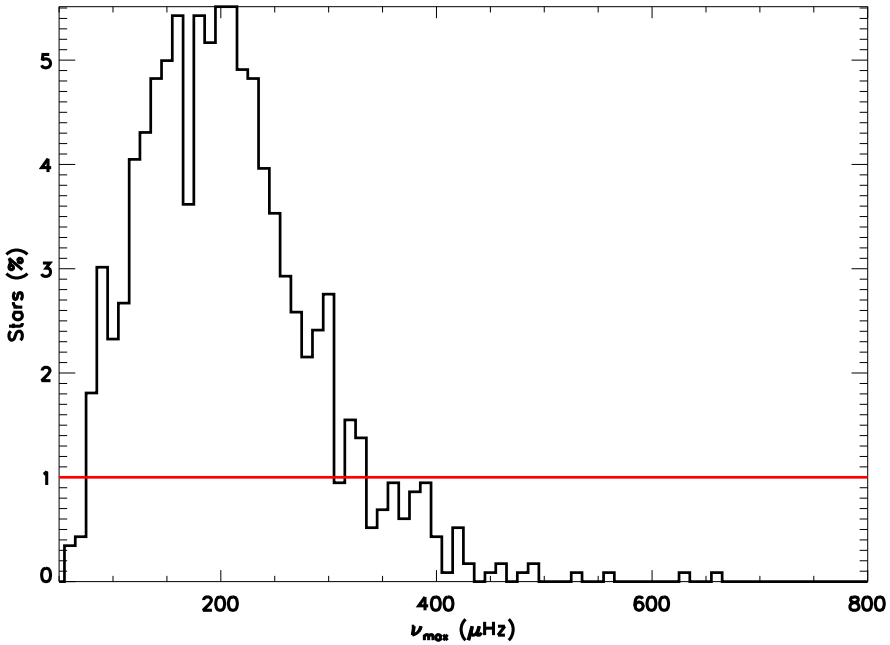
Detail of the light curve of CID 546. Different colours point to the observed and estimated data



Accuracy of $\nu_{\max}$ determination using δSBF for different run length and duty cycle from Moya et al. (submitted)

Method 1: Linear fit

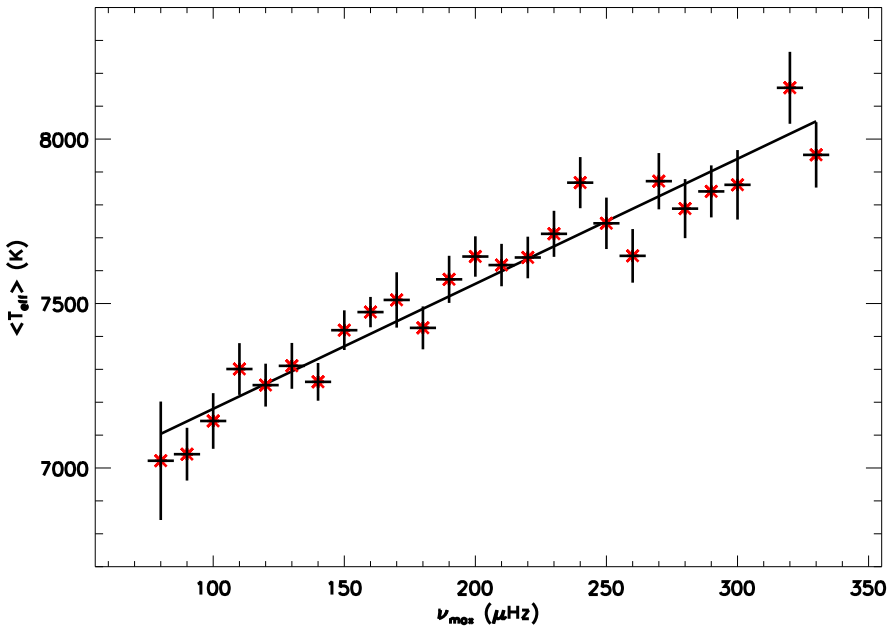


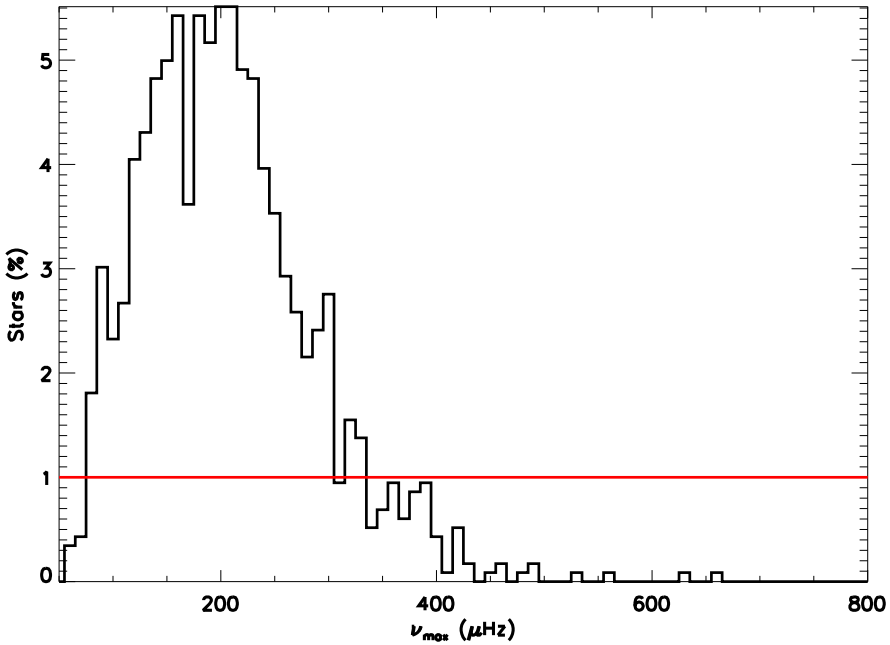


$$\bar{T}_{\rm eff} \approx a \cdot \nu_{\rm max} + b$$

a (K/μHz)	3.8 $\pm$ 0.2	σ (%)	6.67
b (K)	6800 $\pm$ 40	N_{in} (%)	97
R	0.964	N_{out} (%)	3

Method 1: Linear fit





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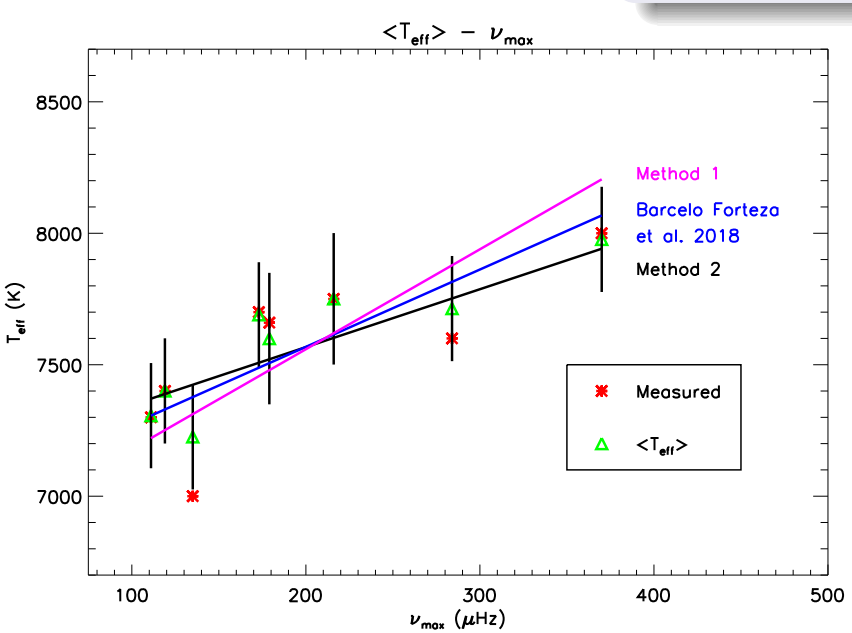
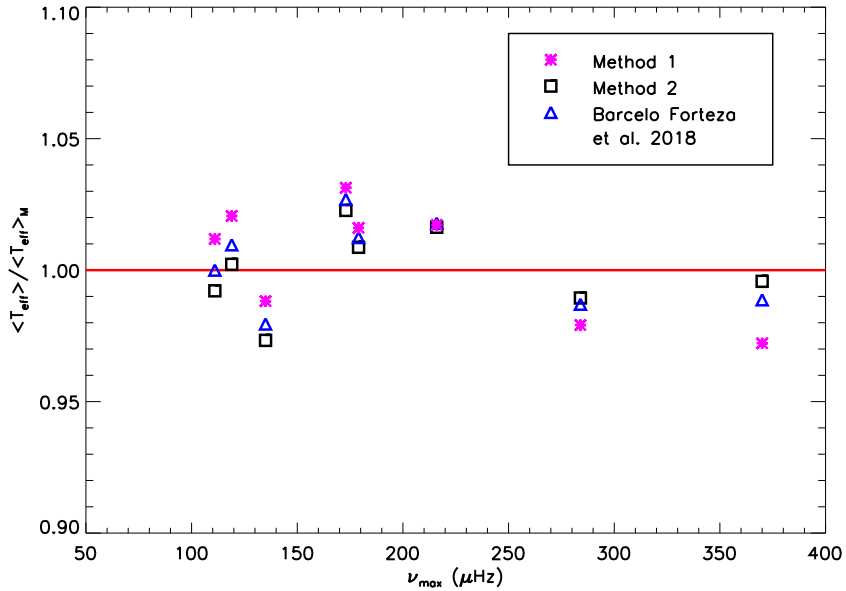
b (K)	6800 $\pm$ 40	N_{in} (%)	97
R	0.964	N_{out} (%)	3

Method 2: Known δ Scuti stars

$$\{T_{\rm eff}, \frac{\Omega}{\Omega_k}, i\} \rightarrow \bar{T}_{\rm eff}$$





$$\bar{T}_{\rm eff} \approx a \cdot \nu_{\rm max} + b$$

a (K/μHz)	2.5 ± 0.6
b (K)	7090 ± 120
R	0.882

$$\left| \frac{\bar{T}_{\rm eff} - \bar{T}_{\rm eff,M}}{\bar{T}_{\rm eff,M}} \right| \lesssim E T_{\rm eff}$$

Conclusions

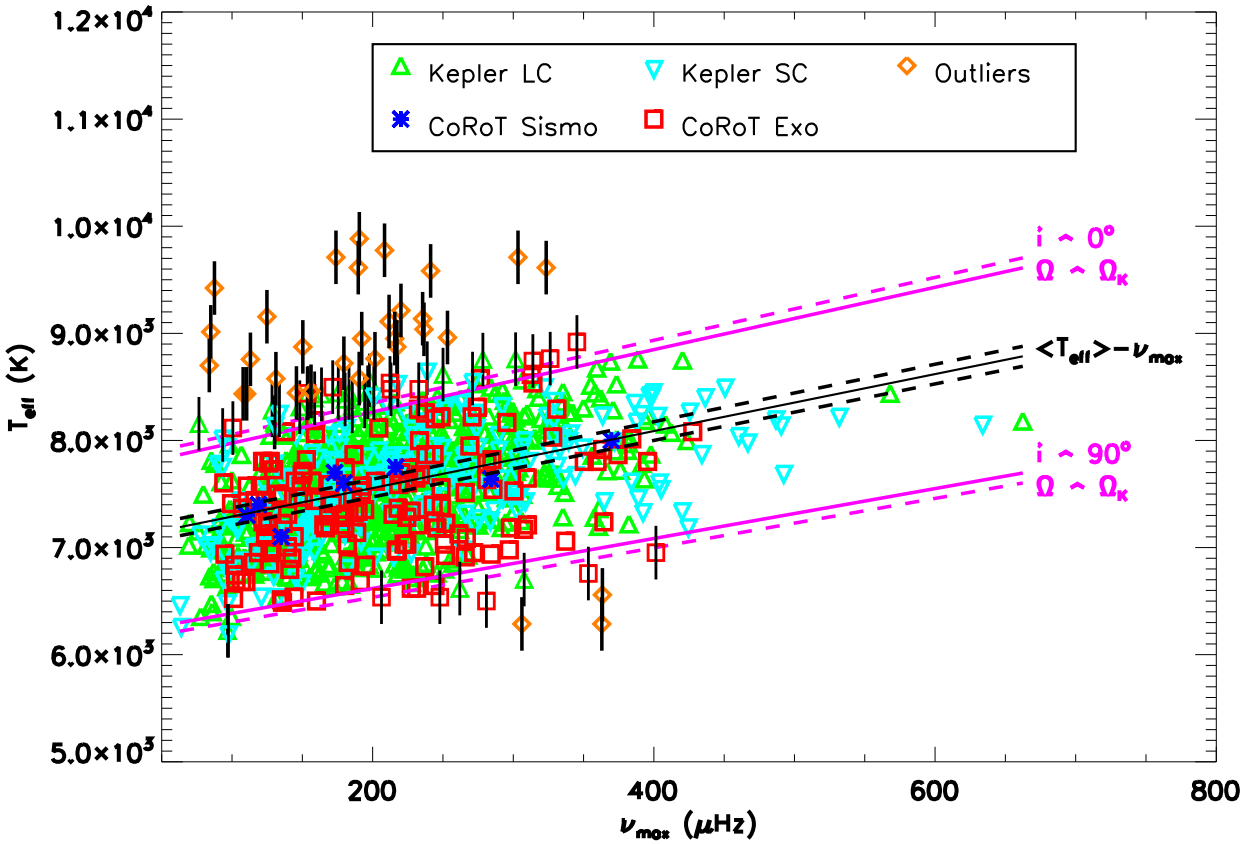
- We suggest a new scaling relation non dependent of $\{\frac{\Omega}{\Omega_k}, i\}$
- We suggest a new method to constrain $\{\frac{\Omega}{\Omega_k}, i\}$

Future work

- Improve $\bar{T}_{\rm eff} - \nu_{\rm max}$ with more data
- Improve $\bar{T}_{\rm eff} - \nu_{\rm max}$ with known δ Scuti stars
- $\neq$ between photometric and spectroscopic data

} { TESS, CHEOPS, **SONG**

Thanks for your attention!



Acknowledgements

- P.L. Pallé, T. Roca Cortés, R. A. García
- J.A. Caballero, E. Solano, A. Moya

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