Space- and ground-based asteroseismology

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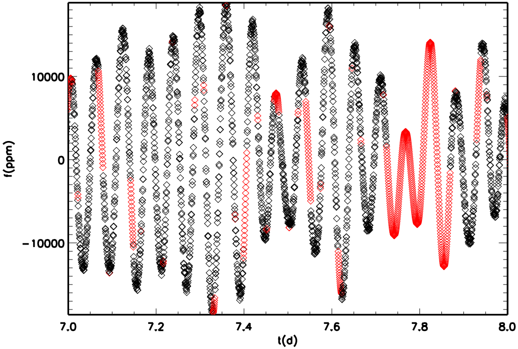
21 February 2019

Asteroseismology

Why?

- LC
- LV

$$\left.\begin{array}{l}\text{LC}\\\text{LV}\end{array}\right\} \rightarrow \mathsf{PSD} \rightarrow \{\nu,\, A,\, \Gamma\}_i \rightarrow \nu_{\mathrm{max}} \rightarrow T_{\mathrm{eff},\star} \rightarrow T_{\mathrm{eff,P}}$$



Observed from

1. **Ground**: CARMENES, SONG
2. **Space**: CoRoT, Kepler, TESS

Observed and estimated data of CID 546 light curve.

Asteroseismology

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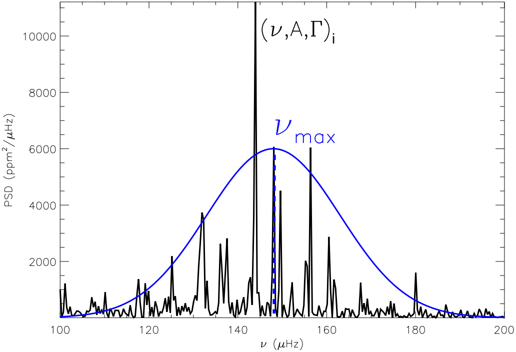

How to calculate:

1. Gaussian fit
2. Kallinger et al. (2010):

$$\nu_{\max} = \frac{\sum A_i \nu_i}{\sum A_i}$$

PSD of the red giant KIC 5701829.

Asteroseismology

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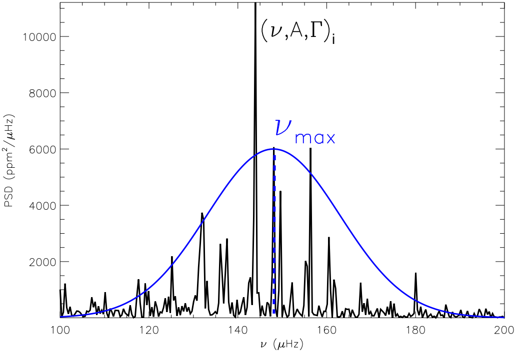
$$\left.\begin{matrix}\text{LC}\\ \text{LV}\end{matrix}\right\} \rightarrow \text{PSD} \rightarrow \{\nu,\, A,\, \Gamma\}_i \rightarrow \nu_{\max} \rightarrow T_{\mathrm{eff},\star} \rightarrow T_{\mathrm{eff,P}}$$



Scaling relations

- Kjeldsen & Bedding (1995):

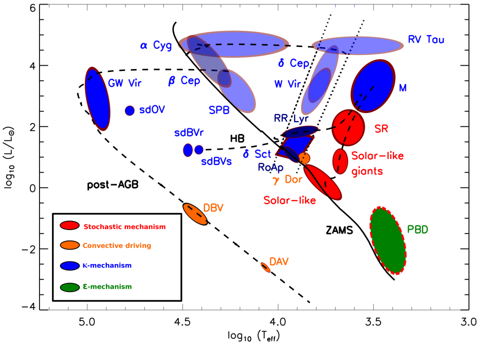
  $\nu_{\max} \propto M R^{-2} T_{\mathrm{eff}}^{-0.5}$
- $\left(\frac{T_{\mathrm{eff,P}}}{T_{\mathrm{eff},\star}}\right)^2 = \frac{R_\star}{2a}$

PSD of the red giant KIC 5701829.

δ Scuti stars

Characteristics:

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



Scaling relation?

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

Pulsators in the HR diagram (Barceló Forteza et al., submitted).

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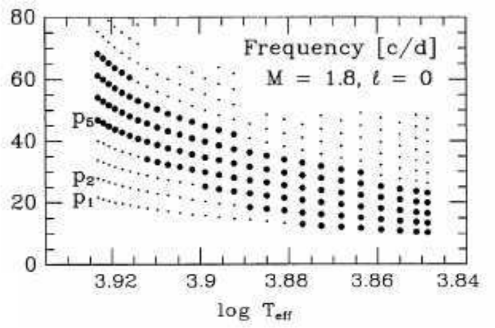

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Excited modes of a δ Scuti model from Dziembowski (1997).

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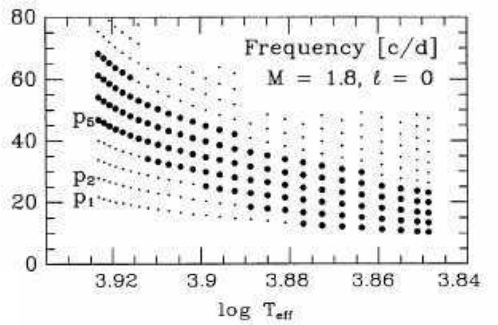

Scaling relation?

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

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

Gravity-darkening effect

Rotation

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

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

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

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$\Omega/\Omega_C = 0$

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

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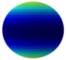

$\Omega/\Omega_C = 0$
$|\delta \bar{T}_{eff}(i)| = 0$ %

$\Omega/\Omega_C = 0.7$
$|\delta \bar{T}_{eff}(i)| \lesssim 5.9$ %

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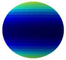

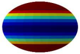

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$|\delta \bar{T}_{eff}(i)| = 0$ %

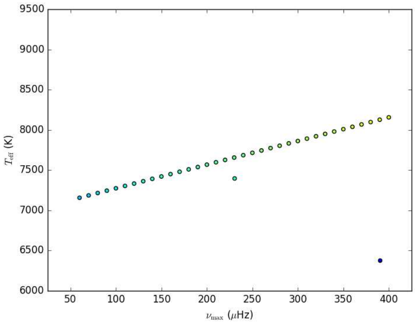
$\Omega/\Omega_C = 0.7$

$|\delta \bar{T}_{eff}(i)| \lesssim 5.9$ %

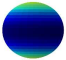
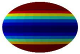
$\Omega/\Omega_C = 1$

$|\delta \bar{T}_{eff}(i)| \lesssim 21.5$ %

Gravity-darkening effect



$i \approx 90^\circ$

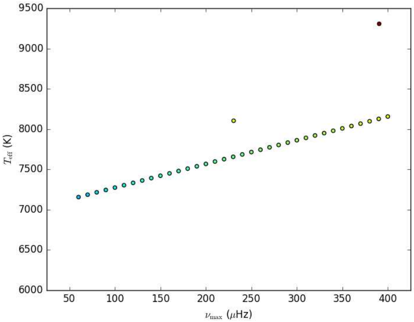




$\Omega/\Omega_C = 0$
$\delta \bar{T}_{eff}(i) = 0$ %

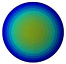
$\Omega/\Omega_C = 0.7$
$\delta \bar{T}_{eff}(i) \approx -3.3$ %

$\Omega/\Omega_C = 1$
$\delta \bar{T}_{eff}(i) \approx -21.5$ %

Gravity-darkening effect



$i \approx 0^\circ$

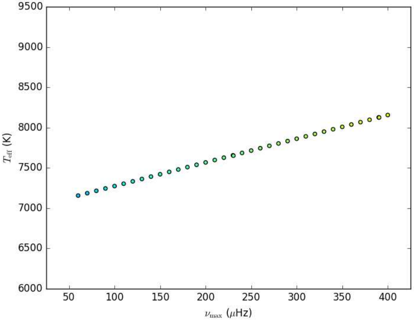


$\Omega/\Omega_C = 0$
$\delta \bar{T}_{eff}(i) = 0$ %

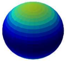
$\Omega/\Omega_C = 0.7$
$\delta \bar{T}_{eff}(i) \approx 5.9$ %

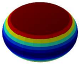
$\Omega/\Omega_C = 1$
$\delta \bar{T}_{eff}(i) \approx 14.5$ %

Gravity-darkening effect



$i \approx 55^\circ$



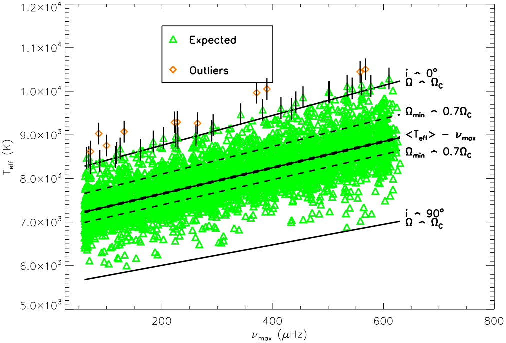


$\Omega/\Omega_C = 0$
$\delta \bar{T}_{eff}(i) = 0$ %

$\Omega/\Omega_C = 0.7$
$\delta \bar{T}_{eff}(i) \approx 0$ %

$\Omega/\Omega_C = 1$
$\delta \bar{T}_{eff}(i) \approx 0$ %

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



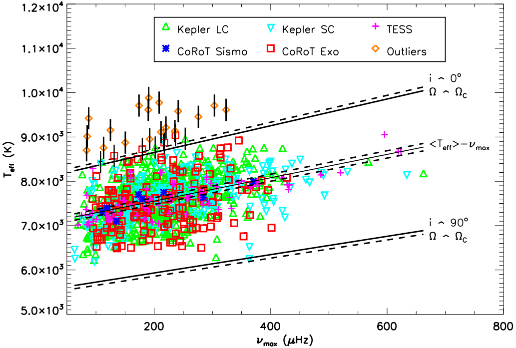
Barceló Forteza et al. (2018)

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

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

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

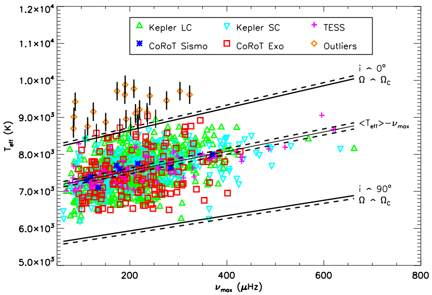
  Barceló Forteza et al. (2015)

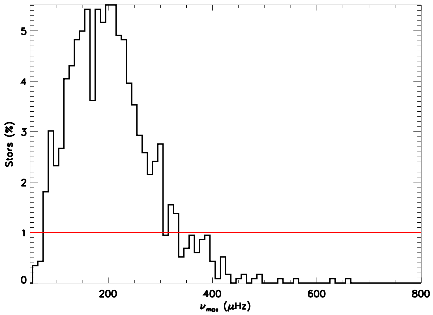
- $T_{\rm eff} \rightarrow$ CATALOGUES

  Brown et al. (2011)

  Debosscher et al. (2009)

METHOD 1: LINEAR FIT

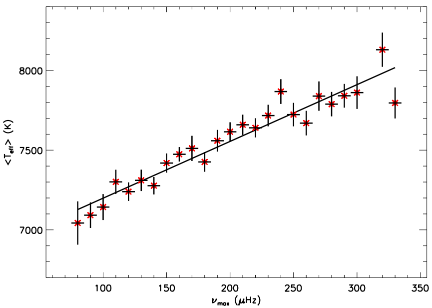


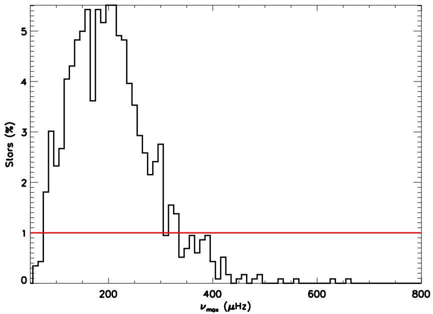


$\bar{T}_{\mathrm{eff}} \approx a \cdot \nu_{\mathrm{max}} + b$

a (K/μHz)	3.56 ± 0.23	σ (%)	6.52
b (K)	6840 ± 50	N_{in} (%)	99
R	0.954	N_{out} (%)	1

Method 1: Linear fit



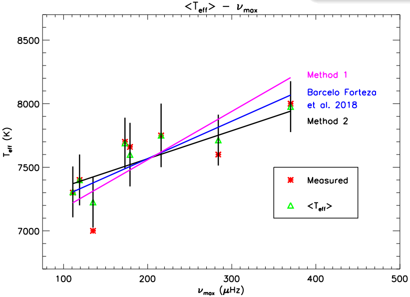


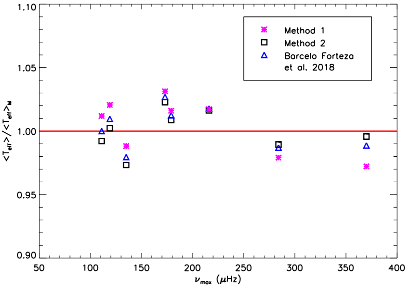
$\bar{T}_{\mathrm{eff}} \approx a \cdot \nu_{\mathrm{max}} + b$

a (K/μHz)	3.56 ± 0.23	σ (%)	1.08
b (K)	6840 ± 50	N_{in} (%)	98
R	0.954	N_{out} (%)	2

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 ± 0.5
b (K)	7090 ± 120
R	0.882

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

Conclusions

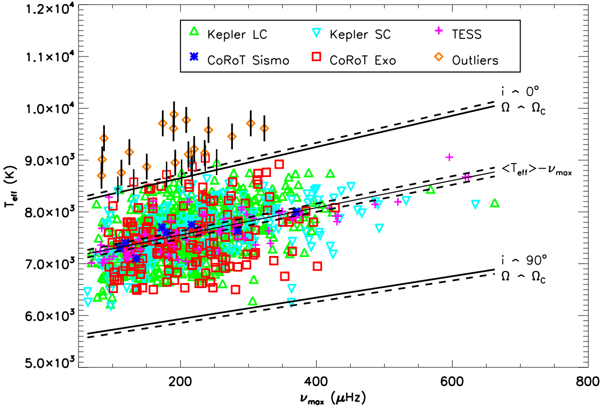
- We suggest a new scaling relation $\bar{T}_{\mathrm{eff}} - \nu_{\mathrm{max}}$ for δSct
  - non dependent of $\{\frac{\Omega}{\Omega_k}, i\}$
  - find $T_{\mathrm{eff,P}}$ and H.Z.

Future work

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

TESS, CHEOPS
CARMENES
SONG

Thanks for your attention!



Acknowledgements

- J.A. Caballero, E. Solano, C. Rodríguez-Lopez

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