Unveiling the power spectra of δ Scuti stars with TESS.
The temperature, gravity, and frequency scaling relation

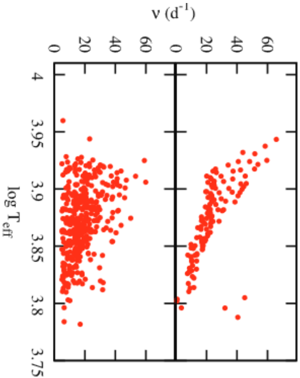
S. Barceló Forteza[1], A. Moya[2,3], D. Barrado[1], E. Solano[1,4], S. Martín-Ruiz[5], J. C. Suárez[5,6], A. García Hernández[5,6]

Barceló Forteza + 2020, A&A V638, A59

Thanks to high-precision photometric data legacy from space telescopes like *CoRoT* and *Kepler*, the scientific community could detect and characterize the power spectra of hundreds of thousands of stars. Using the scaling relations, it is possible to estimate masses and radii for solar-type pulsators. However, these stars are not the only kind of stellar objects that follow these rules: δ Scuti stars seem to be characterized with seismic indexes such as the large separation ($\Delta\nu$). Thanks to long-duration high-cadence *TESS* light curves, we analysed more than two thousand of this kind of classical pulsators. In that way, we propose the frequency at maximum power ($\nu_{\rm max}$) as a proper seismic index since it is directly related with the intrinsic temperature, mass and radius of the star. This parameter seems not to be affected by rotation, inclination, extinction or resonances, with the exception of the evolution of the stellar parameters. Furthermore, we can constrain rotation and inclination using the departure of temperature produced by the gravity-darkening effect. This is especially feasible for fast rotators as most of δ Scuti stars seem to be.

Scaling relations:

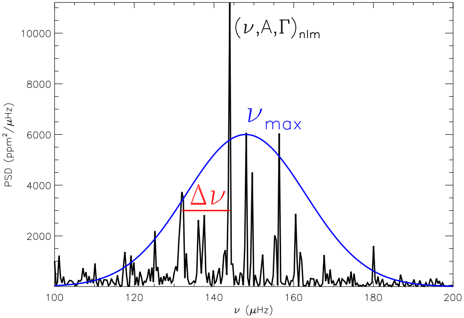
$\Delta\nu \propto \bar{\rho}^{a} \rightarrow$ García Hernández+2015

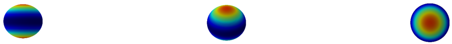


From Balona & Dziembowsky 2011

$\nu_0 \propto T_{\rm eff}$

Higher dispersion than predicted by models



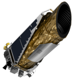


Barceló Forteza + 2018

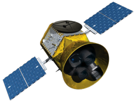
$\nu_{\rm max} \propto \bar{T}_{\rm eff} \neq T_{\rm eff}(i,\Omega) \rightarrow$ Gravity-darkening

Sample:

2372 δ Scuti stars



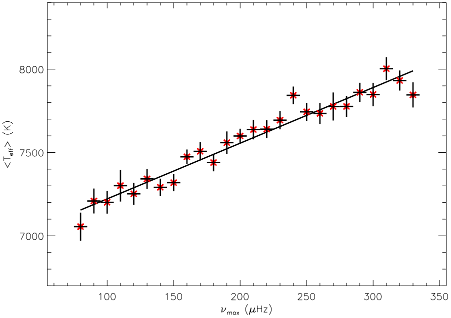
Kepler

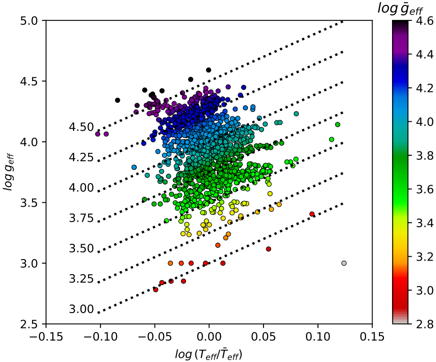


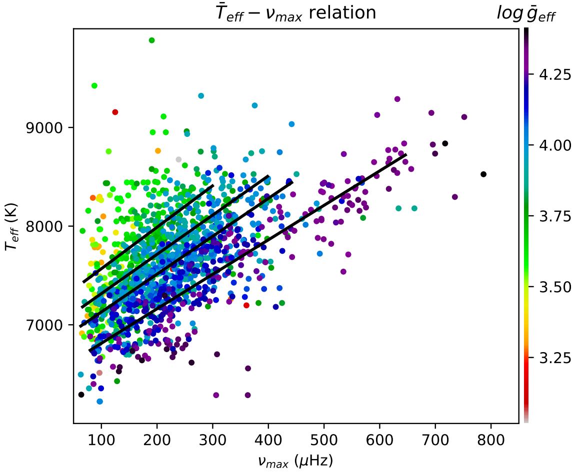
TESS

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

$$T^4_{\rm eff}(i) = C g^{\beta}_{\rm eff}(i)$$







Scaling relation

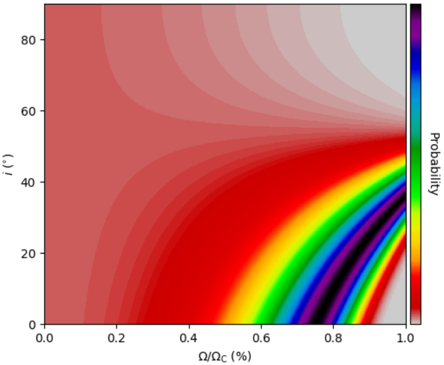
$$\bar{T}_{\rm eff} \approx (a_1 \bar{g}_{\rm eff} + a_2)\, \nu_{\rm max} + (a_3 \bar{g}_{\rm eff} + a_4)$$

	$\nu_{\rm max}$	ν_0
a_1 $\left(\frac{\rm K\,s^2}{\rm cm\,\mu Hz}\right)$	-(46 $\pm$ 5) $\times 10^{-6}$	-(74 $\pm$ 27) $\times 10^{-6}$
a_2 $\left(\frac{\rm K}{\rm \mu Hz}\right)$	4.30 $\pm$ 0.06	3.9 $\pm$ 0.3
a_3 $\left(\frac{\rm K\,s^2}{\rm cm}\right)$	(44 $\pm$ 6) $\times 10^{-3}$	(34 $\pm$ 3) $\times 10^{-3}$
a_4 (K)	7220 $\pm$ 70	7270 $\pm$ 40
σ (%)	1.3	1.0
r	0.701	0.669
P_u (%)	8×10^{-212}	2×10^{-186}

non-continuous $\nu_0(t) \rightarrow$ resonances

Inclination-Rotation Maps

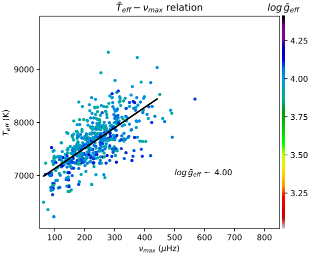
$$\delta \bar{T}_{\mathrm{eff}}(i) \equiv \frac{T_{\mathrm{eff,phot}} - \bar{T}_{\mathrm{eff}}}{\bar{T}_{\mathrm{eff}}} \rightarrow \left(i, \frac{\Omega}{\Omega_C}\right)$$

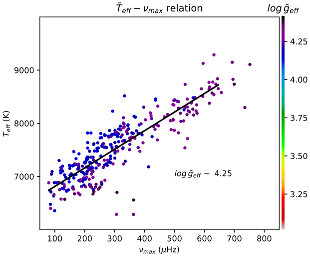


Stellar Evolution

$$\sigma \rightarrow \frac{\Omega_T}{\Omega_C} \propto -\bar{g}_{\mathrm{eff}}$$

$$max\{\nu_{\max}\} \rightarrow \nu_{\mathrm{d}} \propto \bar{g}_{\mathrm{eff}}$$





Lower $\bar{g}_{\mathrm{eff}} \Rightarrow$ higher # resonant modes

$\nu_{\rm max} \Rightarrow$ seismic index for δ Scuti stars

Measure intrinsic parameters $\Rightarrow (\bar{T}_{\rm eff}, \bar{g}_{\rm eff})$

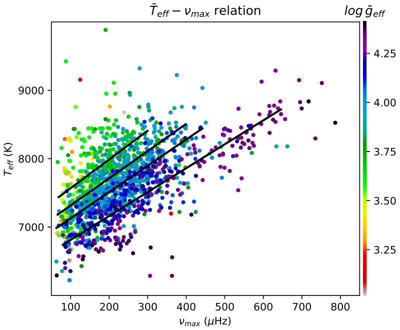
Improved classification $\Rightarrow$ Typical $T_{\rm eff}$ regime

Independent of Ω & extrinsic parameters $\Rightarrow i, A_V$

Not as affected by resonances as ν_0

$\delta \bar{T}_{\rm eff} \Rightarrow$ Constrain $\left(i, \frac{\Omega}{\Omega_C}\right)$

In agreement with stellar evolution predictions



Future work

Standard candles $\Rightarrow$ Improve distance accuracy

Isochrones $\Rightarrow$ Improve age determination

Improve Habitable Zone characterization

References:

Balona, L. A., & Dziembowski, W. A., 2011, MNRAS, 417, 591

Barceló Forteza, S., Roca Cortés, T., et al., 2018, A&A, 614, A46.

García Hernández, A., Martín-Ruiz, S., et al. 2015, ApJ, 811, L29.

Kepler & TESS image credits: ©NASA

More details in
Barceló Forteza + 2020, A&A, V638, A59.