Unveiling the power spectra of δ Sct stars with TESS.

The temperature, gravity, and frequency scaling relation

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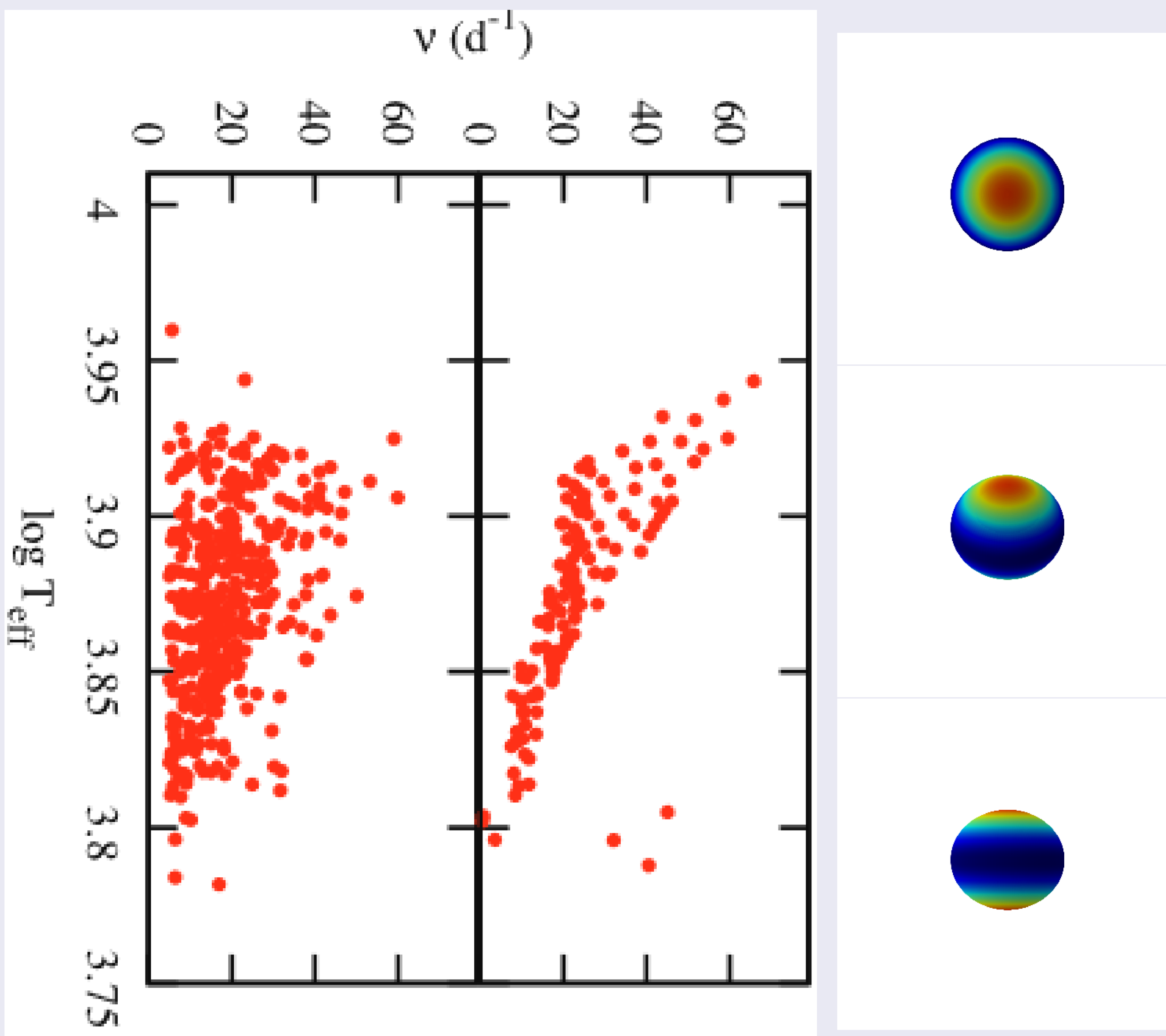
Abstract

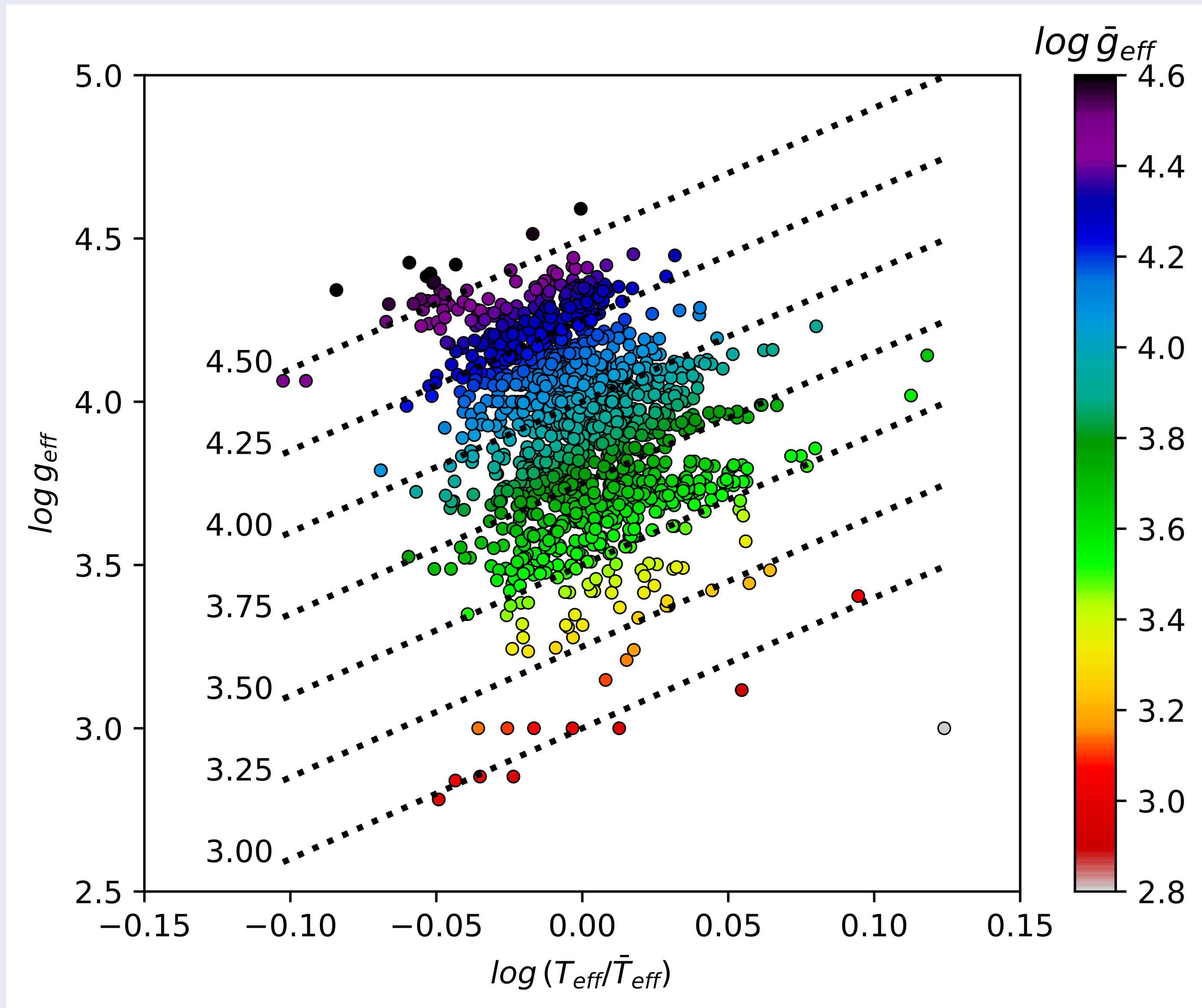
Thanks to high-precision photometric data legacy from space telescopes like *CoRoT* and *Kepler*, the scientific community could detect and characterize the power spectra of hundreds of thousands of stars. Using the scaling relations, it is possible to estimate masses and radii for solar-type pulsators. 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 ($\nu_{\max}$) 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.

Introduction



Balona & Dziembowski 2011 shows the diffences between the observed and predicted relation between the temperature and the frequencies of δ Scuti stars (left and central panels, respectively). Barceló Forteza et al. 2018 suggested that the dispersion on the observations may be produced by gravity-darkening effect. A high rotation rate modifies the shape of the star from a sphere to a spheroid. In that way, the temperature at the poles is higher than the temperature at the equator.The value of the departure of temperature is positive (negative) for inclinations lower (higher) than mid-latitudes ($i \sim 55^\circ$, see right panels).

Data & methodology



We make our study with a sample of 2400 A-F stars with frequencies within δ Scuti regime. Using an iterative method, we corrected the temperature and the surface gravity from gravity-darkening effect. In addition, this method allows us to study the dependence of the parameters of the scaling relation with the evolutionary stage, splitting our sample in several groups of different surface gravity. This Figure shows the mean surface gravity (color and dashed lines) versus the ratio of temperatures and the observed surface gravity.

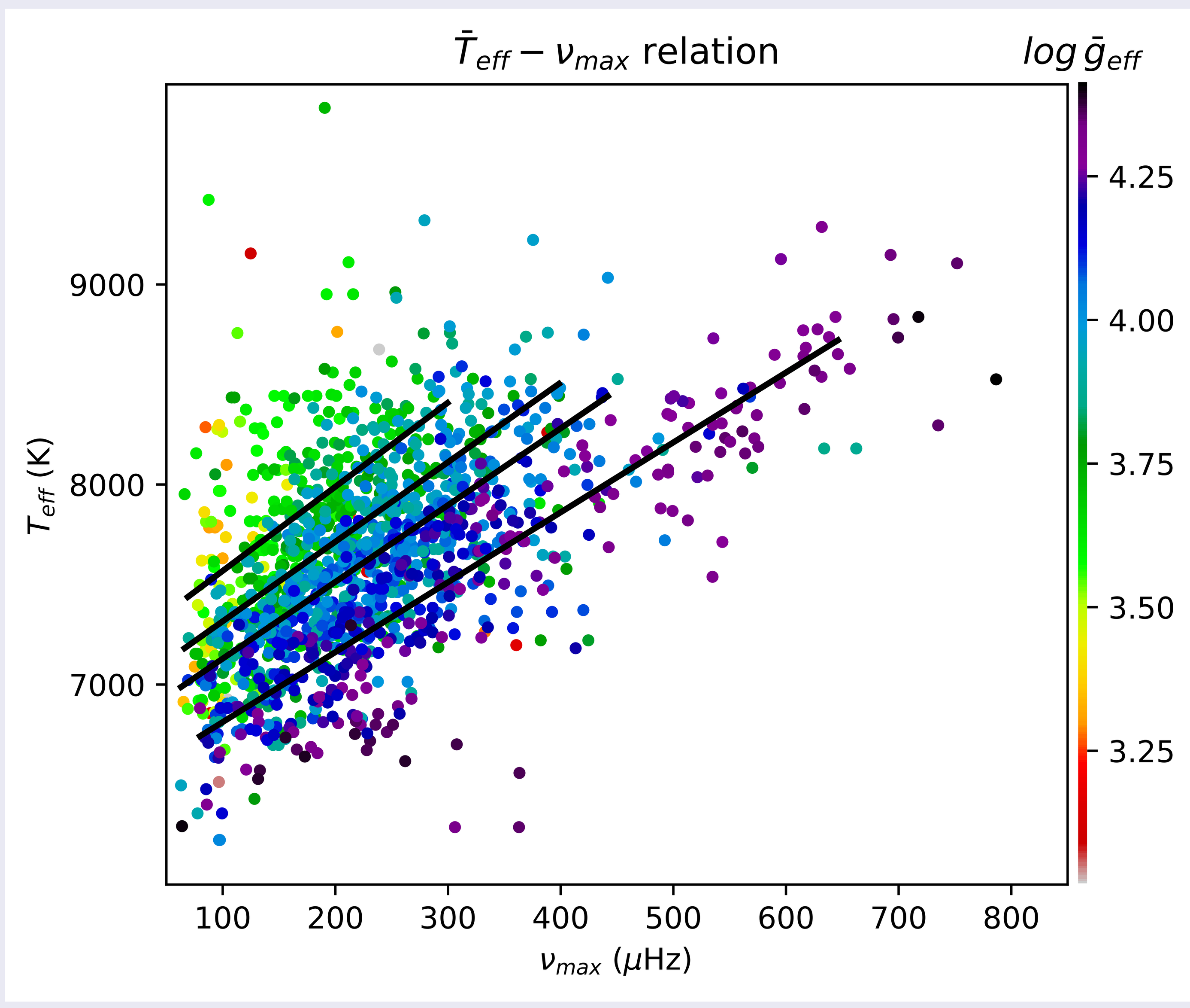
Scaling relation

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

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

The temperature, gravity, and frequency scaling relation. First (Last) column show the obtained values taking into account the frequency at maximum power (highest amplitude mode). We point that the highest amplitude mode could be more affected by resonances. **Therefore, we suggest the frequency at maximum power as a seismic index since it is a proper indicative of the mean temperature and surface gravity of the star. This seismic index do not depend on rotation or inclination unlike photometric or spectroscopic techniques that may be significantly affected by gravity-darkening effect or extinction. Thus, it is possible to improve the distance, age, and habitable zone measurements for δ Scuti stars.**

Gravity-darkening effect & Evolutionary stage



We detected higher frequency modes for higher mean temperature δ Scuti stars (black solid lines). We also observed that old stars with low surface gravity present lower frequency ranges, just as opposite than young δ Scuti stars. This is in agreement with predictions too (Christensen-Dalsgaard 2000). Therefore, the evolutionary stage affects the scaling relation and it must be taken into account to find the intrinsic parameters of these kind of stars. Moreover, the observed dispersion of the scaling relation and its decrease with gravity suggests that ageing stars may decrease its rotation slowly than its density, making them closer to its break-up frequency.

References:

Balona, L. A., & Dziembowski, W. A., 2011, MNRAS, 417, 591
Barceló Forteza, S., Roca Cortés, T., et al., 2018, A&A, 614, A46.
Christensen-Dalsgaard, J. 2000, ASPCS, 210, 187

More details in
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