Radial mode widths in red giant star spectra observed by Kepler

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Introduction

The *Kepler* space mission has observed many solar-like pulsators, and helped to decipher their main characteristics (e.g: mass, radius, rotation). Most of the achievements recently obtained in that domain consist of the analysis of the mode frequency positions. However, unique information on non-adiabatic physics derives from the height and width of the modes. In this study, we aim to measure the mode widths in thousands of *Kepler* red giants and to analyze their behaviour in function of stellar parameters as well as seismic parameters. The results unveil a clear dependence on mass and stellar evolution for the star mode width, thus their mode damping.

Methods

The data set is composed of 3000 *Kepler* red giant stars observed in long-cadence during 44 months (which correspond to Q17). The red giant sample was selected based on the precise determination of the star seismic parameters and their evolutionary states performed in Vrard et al. (2016).

For each of these stars, a first estimate of $\Delta\nu$ and ν_{max} has been obtained with the envelop autocorrelation function (Mosser & Appourchaux, 2009). The large separations are then refined by the use of the universal pattern (Mosser et al., 2011).

We focused our study on radial modes since non-radial modes have a mixed character, hence rapid variations of the mode widths. A first approximation of the position of these modes is achieved using the universal pattern. This guess is then refined with the identification of the doublet l=0 and l=2 modes. After that, we fitted the radial modes with Lorentzians as well as the nearby modes identified around it (like the l=2 modes, see Fig. 1) following the MLE technique described in Barban et al. (2010) and Vrard et al. (2015). The performed fit was composed of a linear background component and several Lorentzians for each modes. The fit being local, a complex modelisation of the background is not necessary. This allows us to extract the frequency, height and width of the radial modes.

For each star, an average mode width (Γ_0) was computed following Appourchaux et al. (2012), obtained from the weighted average of the width of the three radial modes closest to ν_{max}. This way of computing Γ_0 proved to be less sensitive to systematic effects.

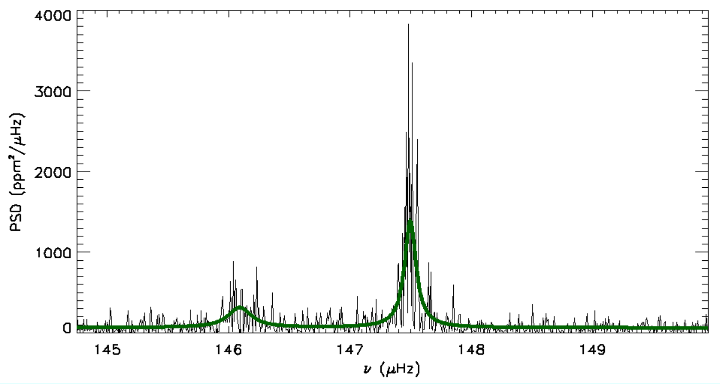

Fig. 1: Power density spectrum (ppm^2/μHz) as a fonction of frequency (ν) (in black). The fit based on Lorentzian is shown with the solid green line. The peak around ν=147.5 μHz is a radial mode and the one on the left is the nearby l=2 mode.

$$P(\nu)=\sum_{k=1}^{Q}\left(\frac{H_k}{1+\left(\frac{2(\nu-\nu_k)}{\Gamma_k}\right)^2}\right)+a+b\nu \qquad (1)$$

Eq. 1 : Lorentzian fit on the modes
Q: number of modes
H_k: height of the modes
Γ_k: width of the modes
ν_k: mode frequency position
ν: spectral frequencies
a,b: background components

Results

A few studies has already been conducted on solar-like pulsators in order to evaluate the dependance of radial mode widths with the stellar parameters and especially with the effective temperature (Baudin et al., 2011 ; Appourchaux et al., 2012 ; Corsaro et al., 2015). For red giant stars, the results obtained by Baudin et al. (2011) showed no dependance with the effective temperature, contrary to the results obtained for main-sequence and subgiants stars. However, Belkacem et al. (2012) pointed out that this observation is in fact consistent with the limited variation of effective temperatures along the low red giant branch. The results obtained with our method seems to be in accordance with this statement (Fig. 2): red giants with higher effective temperature have larger mode widths. However, the difference is not sufficiently significative to assert it definitively.

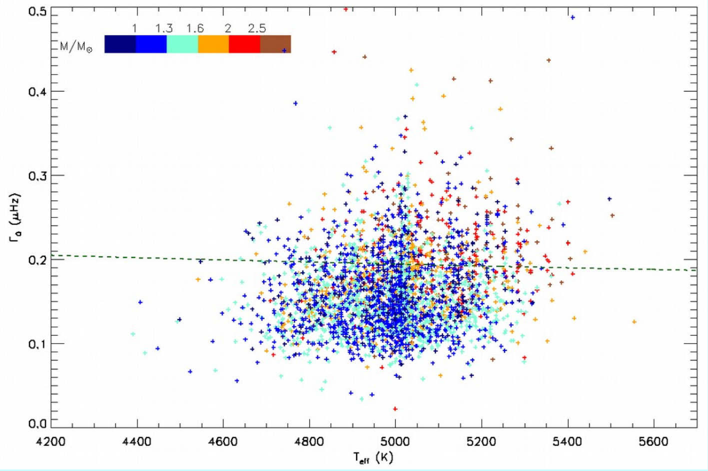

Fig. 2: Radial mode width (μHz) as a fonction of effective temperature (K). The color code indicate the star masses and the green dashed line the width-temperature relation as measured by Baudin et al. (2011)

$$\Gamma_0=\eta_0/\pi \qquad (2)$$

Eq. 2 : Relation between the mode damping and the mode width.
Γ_0: Radial mode width
η_0: damping of the radial modes

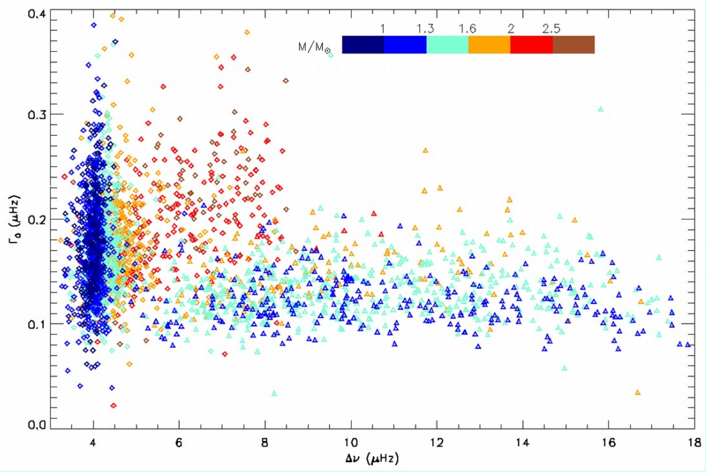

Fig. 3: Radial mode width (μHz) as a fonction of the large separation (Δν). The color code indicate the star masses. ◊ indicate clump stars and Δ RGB stars

Fig. 3 shows the radial mode width plotted against $\Delta\nu$ and put into light a slight but clear mass dependence, regardless the evolutionary state. This is particularly obvious for clump stars (stars wich have ignited helium in their core) since there is much more observed high-mass stars in that evolutionary states, but the mass dependance appears also for RGB stars (stars which burn hydrogen in a shell). Mode width are directly related to the mode damping (Eq. 2) ; this behaviour, which was not previously detected, can then allow a better understanding of mode damping in red giant stars. Recent studies about this parameter suggest that this behaviour correspond to theoretical expectations (Dupret et al., 2009 ; Grosjean et al., 2014), but a complete study about the mass dependance in red giant stars has yet to be conducted in order to confirm it.

Conclusions

In this study, we measured the radial mode width in thousands of red giant stars. The preliminary results we obtained confirmed and extend the previous ones. We also put into light a new mass dependance for the radial mode width present throughout the star evolution. The mode width being directly related to the mode damping, this offers new constraints on this parameter. But, further theoretical studies are needed to fully exploit the results. Meanwhile, the exploitation of the data will continue, especially on the mode height thus on the oscillation excitation mechanism.

References

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