

Influence of helium ionisation on red giant oscillation spectra

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Abstract. Since its launch in 2009, the space mission *Kepler* has provided an amount of data of unprecedented quality. In particular, red giants exhibit an oscillation spectrum arranged in a regular pattern called the universal oscillation pattern. Here we analyse and characterize the departures observed from this universal pattern. We measured the deviation for more than one hundred red giants and attribute it to glitches related to the region of second ionisation of helium.

The *Kepler* space mission has observed many red giants and helped deciphering their main characteristics (mass, radius, core rotation) from their oscillation spectra. The red giant oscillation pattern has been depicted, for pressure modes, with a canonical form, called universal red giant oscillation pattern ([1]). In this study, we aim to investigate the deviations from this universal pattern and characterize them as a signature of the second helium ionisation zone.

Long-cadence data from *Kepler* up to the quarter 13 (1120 days) was used for a set of 216 stars for which the evolutionary status was already deduced ([2]).

We focused our study on radial modes since non-radial modes have a mixed character and are, therefore, not pure pressure modes. Modes were fitted with Lorentzian models to adjust their frequency position ([3]). We then calculated the frequency difference between consecutive radial modes, called the local large separation ($\Delta\nu_{\text{obs}}$) and compared these observed values of $\Delta\nu$ with the theoretical ones ($\Delta\nu_{\text{up}}(n)$) provided by the universal pattern ([1]). Deviations from this universal pattern were characterized as glitches.

Glitches correspond to local sound-speed variations induced by inner structure discontinuities of the star. These sound-speed variations produced a shift in the observed frequencies. Glitches in red giants are mainly produced by the structure discontinuity related to the second helium ionisation zone, as shown by [4]. We then adjusted one oscillation component to the modulation observed in the stars frequencies:

$$\delta_g = \mathcal{A}\langle\Delta\nu\rangle \cos\left(\frac{2\pi(\nu - \nu_{\text{max}})}{\mathcal{G}\langle\Delta\nu\rangle} + \phi\right), \quad (1)$$

with, δ_g the difference between observed and theoretical large separation, \mathcal{G} the period of the oscillation, \mathcal{A} the amplitude of the modulation, and ϕ the phase of the modulation centered on the frequency (ν_{max}) of maximum oscillation.

The period of the oscillation is directly related to the acoustic depth T_g of the discontinuity by the relation ([5]):

$$T_g = \frac{1}{2\langle\Delta\nu\rangle} \left(1 - \frac{1}{2\mathcal{G}}\right). \quad (2)$$

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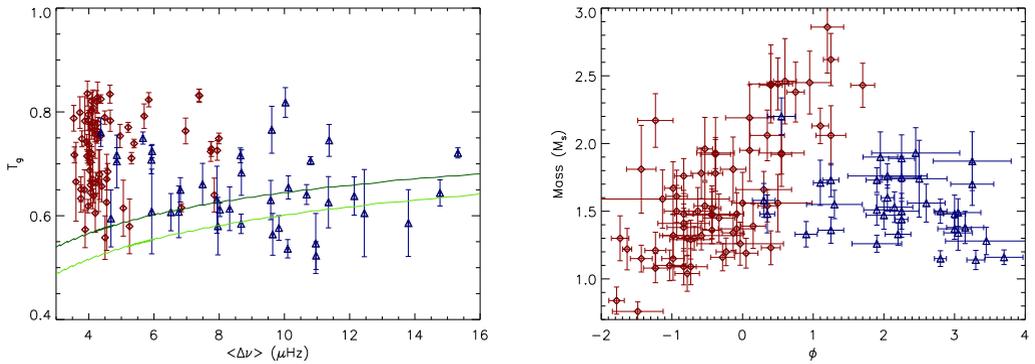


Fig. 1. *Right:* acoustic radius of the discontinuity related to the second helium ionisation zone as a function of the global large separation. Clump stars are indicated by red diamonds and RGB stars by blue triangles. Error bars correspond to $1\text{-}\sigma$ uncertainties. The light green line indicates the theoretical acoustic radius of the second helium ionisation zone for a $1M_{\odot}$ star during the RGB phase. The dark green line gives the same information for a $1.4M_{\odot}$ star. *Left:* stellar masses in function of the phase of the modulation. Error bars correspond to the $1\text{-}\sigma$ uncertainties.

Comparison with modeling (Fig. 1) shows a correct agreement between RGB stars (stars which burn hydrogen in a shell) but not for clump stars (stars which have ignited helium in their core).

RGB and clump stars show very different phase shifts (Fig. 1). We also found a mass dependence of the phase for clump stars. These results have been confirmed by a theoretical study ([6]) though the problem of the mass dependence is not mentioned.

The comparison with recent works ([6],[7]) is encouraging, however these results need further theoretical work to be fully understood. At this stage, they help understanding why RGB and clump stars show a different ε shift in the asymptotic expansion when the large separation $\Delta\nu$ is calculated locally. With a global determination of $\Delta\nu$, the relation $\varepsilon(\Delta\nu)$ does not depend on the evolutionary status.

References

1. Mosser, B., Belkacem, K., Goupil, M.-J., et al., *A&A* **525**, (2011) L9
2. Mosser, B., Goupil, M.-J., Belkacem, K., et al., *A&A* **540**, (2012) A143
3. Barban, C., Baudin, F., Mosser, B., et al., *Astronomische Nachrichten* **331**, (2010) 1016
4. Miglio, A., Montalbán, J., Carrier, F., et al., *A&A* **520**, (2010) L6
5. Mazumdar, A., Monteiro, M.J.P.F.G., Ballot, J., et al., *ApJ* **782**, (2014) 18
6. Christensen-Dalsgaard, J., Silva Aguirre, V., Elsworth, Y., Hekker, S., *MNRAS* **445**, (2014) 3685
7. Broomhall, A.M., Miglio, A., Montalbán, J., et al., *MNRAS* **440**, (2014) 1828-1843