Toward a better understanding of red giants rotation

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Abstract

Red giants present mixed modes, which behave as pressure modes in the convective envelope and as gravity modes in the radiative interior. This property allows one to probe their very inner core and to study their mean core rotation. Rotation strongly impacts stellar structure and evolution, but only few manual measurements of the mean core rotation of red giants are available, which indicate a very efficient angular momentum transport process from the core to the envelope [1]. The goal of this work is to develop an automated method to measure the mean core rotation in red giants observed by *Kepler*. We validated this new method on 8 red giant stars for which automated measurements are fully consistent with 2012 manual measurements [1]. This work opens the way for core rotation measurements for thousands of red giants.

Method

- Stretching frequency spectra leads to stretched period spectra where mixed modes are nearly regularly spaced with a period spacing close to $\Delta\Pi_1$, carrying information about rotational splittings [2]:

$$\Delta\tau_{\mathrm{m}} = \Delta\Pi_1(1 + m x_{\mathrm{rot}}) \qquad (1)$$

$$x_{\mathrm{rot}} \simeq 2 \frac{\mathcal{N}}{\mathcal{N}+1} \frac{\delta\nu_{\mathrm{rot}}}{\nu_{\mathrm{max}}} \qquad (2)$$

$$\mathcal{N} = \frac{\Delta\nu}{\Delta\Pi_1 \nu_{\mathrm{max}}^2} \qquad (3)$$

- Folding spectra on the $\Delta\Pi_1$ period allows to build échelle diagrams where the different rotational multiplet components of dipole mixed modes are disentangled.
- The automated method first helps identifying the number of components, ranging from one to three depending on the inclination: Figure 1.
- Identifying modes azimuthal order is not necessary: such identification is a by-product of the method.

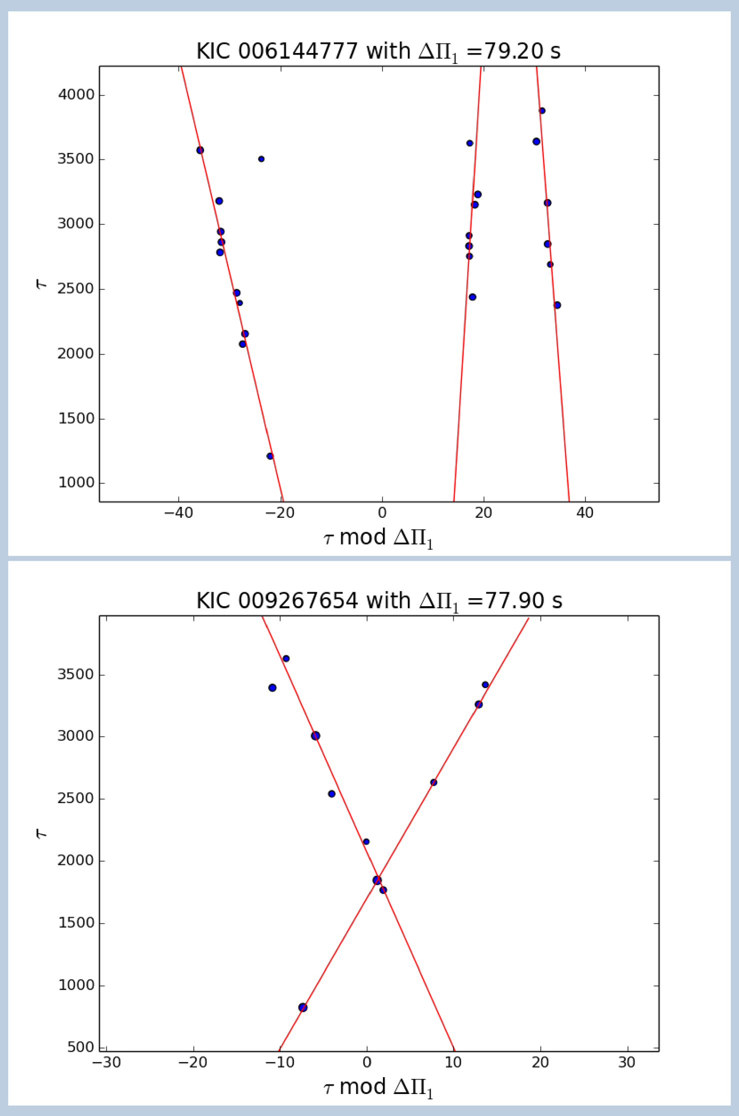

Figure 1: Echelle diagrams representing the stretched period τ as a function of τ modulo $\Delta\Pi_1$.
Top: KIC 006144777 star. Bottom: KIC 009267654 star, with a rotational splitting above the confusion limit.

- The mean core rotation, which is slow, derives from [1]:

$$\delta\nu_{\mathrm{rot}} \simeq \frac{1}{2}\left\langle \frac{\Omega}{2\pi} \right\rangle_{\mathrm{core}} \qquad (4)$$

References

[1] B. Mosser et al. Spin down of the core rotation in red giants. *Astronomy & Astrophysics*, 548:A10, December 2012.

[2] B. Mosser et al. Period spacings in red giants, I. Disentangling rotation and revealing core structure discontinuities. *Astronomy & Astrophysics*, 584:A50, September 2015.

Validation

- We have tested the method on 8 red giants mostly located on the red giant branch and found that automated measurements are fully consistent with the 2012 manual measurements [1]: Figure 2.

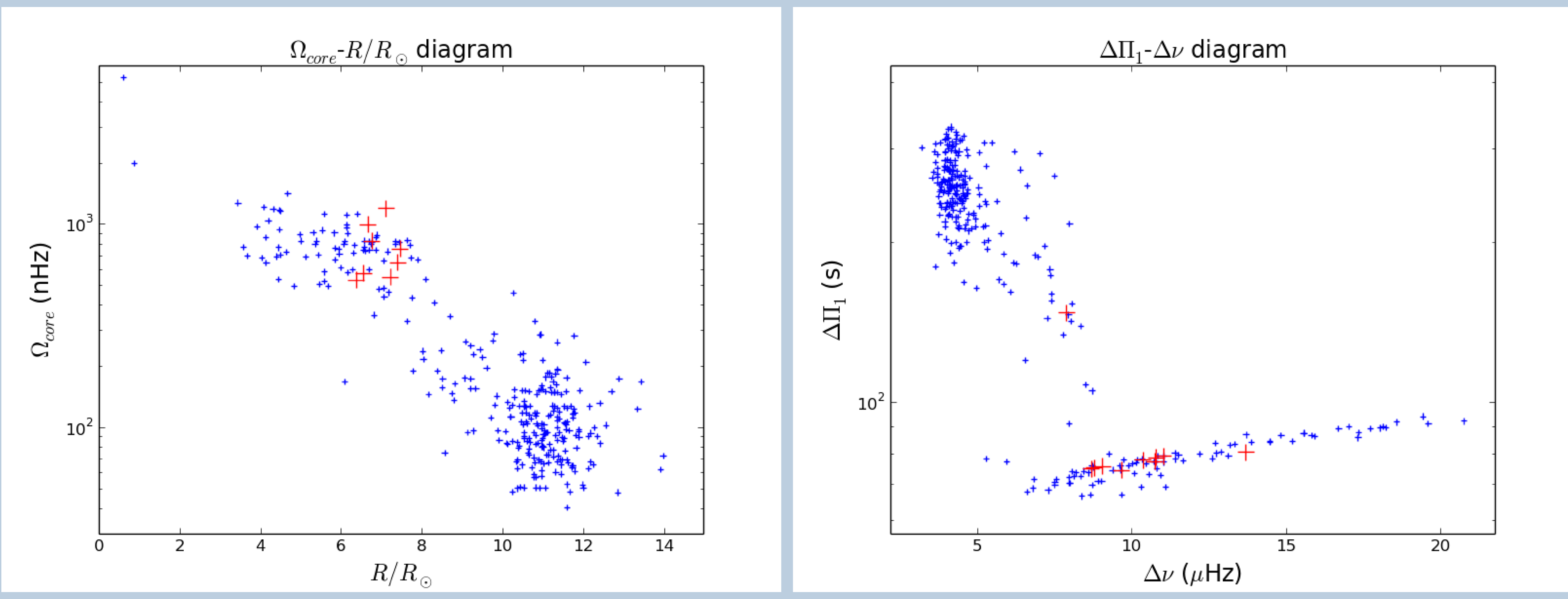

Figure 2: Left: Evolution of the mean core rotation of red giants as a function of their radius. Red crosses: automated measurements. Blue crosses: 2012 manual measurements [1]. Right: $\Delta\Pi_1$-$\Delta\nu$ diagram allowing the identification of stars evolutionary status. Same color code.

- At low frequency, the rotational splittings of RGB stars are as high as mixed-mode frequency spacings, so that measuring core rotation above the confusion limit is challenging [1]: Figure 3.
- We are able to automatically measure core rotation for relatively complicated RGB stars.

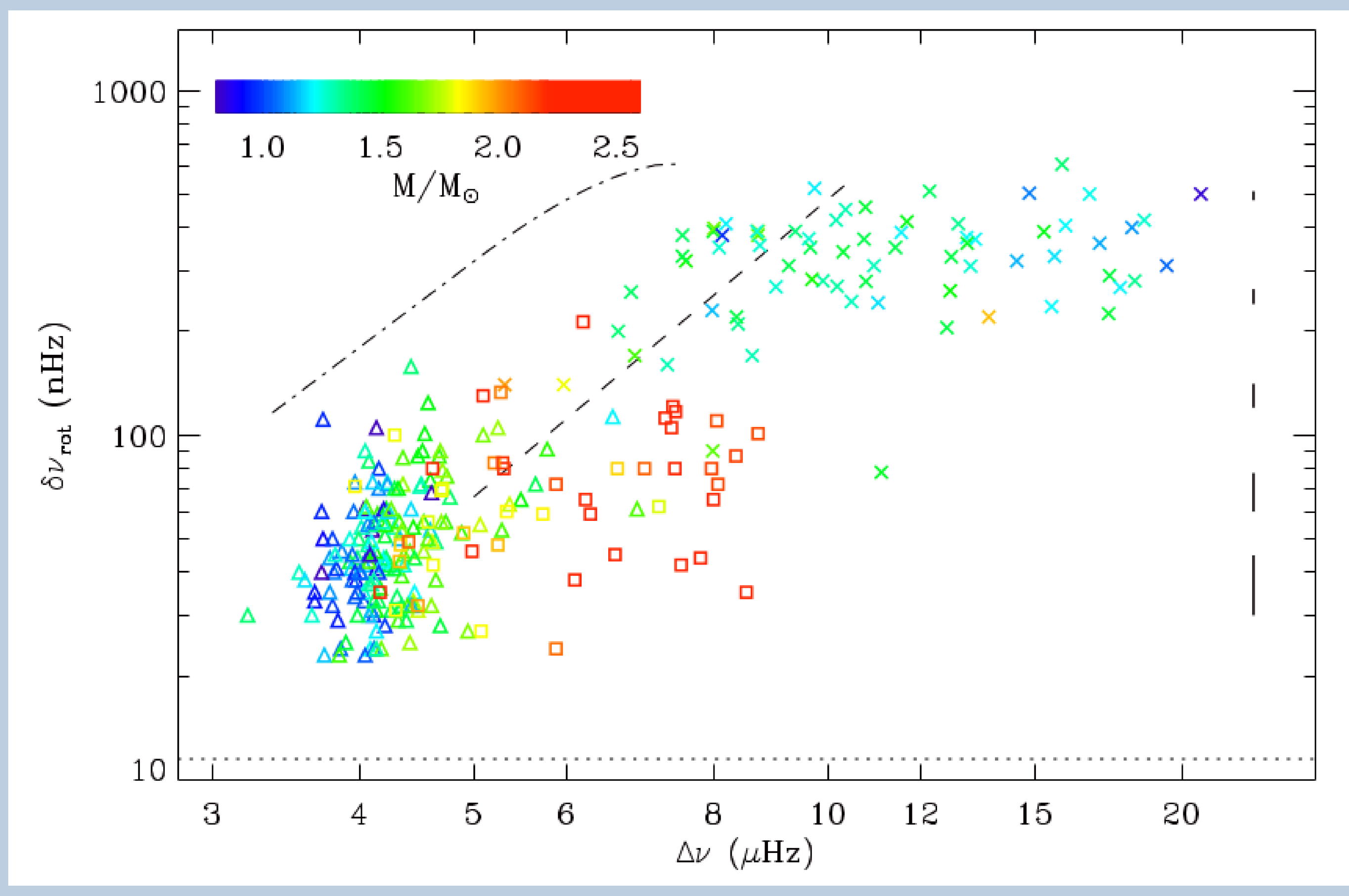

Figure 3: $\delta\nu_{\mathrm{rot}}$-$\Delta\nu$ diagram. Crosses: red giant branch stars. Triangles and squares: *clump* stars. Dashed lines: confusion limit for red giant branch stars. Dot-dashed lines: confusion limit for *clump* stars.

- Our automated method is validated: it is a promising and powerful method to be applied now to thousands of red giants.
- *Clump* stars have a lower core rotation and less complex frequency spectra: mean core rotation automated measurements will be even easier provided we develop another method based on the stretching of frequency spectra to obtain stretched frequency spectra.

Conclusion and perspectives

- Disentangling rotational splittings from mixed modes is now possible:
  - Identifying modes azimuthal order is not necessary to measure core rotation: such identification is a by-product of the method.
  - The entire automation of the red giants core rotation measurement is in progress.
- Our aim is to obtain mean core rotation for thousands of red giants in the near future.
- This work is necessary to prepare the analysis of PLATO data, representing hundreds of thousands of potential red giants.
- It will be possible to study the evolution of red giants core rotation depending on the mass, metallicity or evolutionary status. We will get more information on the physical mechanisms transporting angular momentum.