The red giant cores contract and spin down

Date de mise en ligne : samedi 1er décembre 2012
Usually, investigating directly the core of the stars is not possible. Usually, when a body contracts, its rotation speeds up. With red giants, things are not so simple! A team of astronomers, including researchers from Paris Observatory questions these points, to the benefit of the red giant study.

One of the great achievements of the CNES-led mission CoRoT is undoubtedly the observation of solar-like oscillations in red giants (De Ridder et al. 2009, Nature 459, 398). As in the Sun, they are excited by turbulent convection in the outer layers; in the stellar envelope, these oscillations correspond to pressure waves. Contrary to the Sun, their oscillation spectrum is much more complex. Red giants have a pure helium core that defines a cavity clearly different from the envelope where gravity waves can propagate. For dipole modes, conditions are met to ensure the efficient coupling of pressure and gravity waves. This coupling gives raise to mixed modes with non-negligible amplitudes both at the stellar surface and in the core. These mixed modes are therefore clearly observable and unveil phenomena occurring in the core (Fig. 1).

**Figure 1** Modeling of the pressure waves (red) and gravity waves (blue) which participate to the mixed modes. The zoom on the most internal region provides a focus onto the stellar core with a radius limited to about 1% of the total stellar radius (Goupil et al. 2013)
Click on the image to enlarge it

With Kepler observations, an international team driven by the group Etoile (=star) of the LESIA has put in evidence
The red giant cores contract and spin down

The spinning down of the core of red giants. The monitoring of hundreds of red giants at different evolutionary stages has shown that the period of the core rotation increases when the star ascends the red giant branch, despite the fact that the core contracts (Fig. 2). Without redistribution of angular momentum inside the star, the core rotation should speed up. But seismic measurements prove that the cores rotate slowly. These measurements are derived from the rotational splittings of the mixed modes (Fig. 3). Measuring these splittings is possible only if one can measure the unperturbed mixed modes. This is a recent skill developed at LESIA too. The phenomenological approach for identifying the splittings has also been validated on a theoretical basis by the team.

**Figure 2** Mean period of the core rotation as a function of the stellar radius, in log-log scale. The radii and masses (color code) are estimated from the seismic measurements. Stars on the red giant branch are presented with crosses, clump stars with triangles or squares if their mass exceeds 1.8 solar mass. The dotted line indicates a rotation period varying as $R^2$. The dashed (dot-dashed, triple-dot-dashed) line indicates the fit of RGB (clump, secondary clump) core rotation period (Mosser et al. 2012)

The spinning down governed by the global expansion of a star on the red giant branch indicates that internal angular momentum is redistributed between the different regions, in order to lower the rotation gradients. This spinning down, suspected but never directly observed, can now be precisely measured and modeled.

The new theoretical tools for interpreting the seismic observations prove that mixed modes primarily unveil the core rotation but can also give access to the rotation of the envelope. This rotation is so slow that its measurement is extremely challenging and will highly benefit from the extent of the Kepler mission till 2016.
The red giant cores contract and spin down

Figure 3 Exemple d’ajustement des multiplets rotationnels des modes mixtes d’une étoile de la branche des géantes, dans un diagramme présentant en abscisse une fréquence réduite et en ordonnée l’ordre radial np d’oscillation. Les multiplets, en fait des triplets pour les modes dipolaires, ici le plus souvent réduits à des doublets pour cette étoile, présentent une largeur qui dépend de leur position. Les fréquences indiquées, en microherz, correspondent aux fréquences attendues en absence de rotation. Les tiretés gris définissent un seuil de confiance. Les modes radiaux (en rouge) ne sont pas affectés par la rotation. Les modes quadrupolaires (en vert) et de degré l=3 restent à étudier en détail. (Mosser et al. 2012)

Cliquez sur l’image pour l’agrandir

Références


Previous news related to this subject

• To see the heart of stars rotate
The red giant cores contract and spin down

- Stellar mass loss: the recipe from giant stars
- The age of red giants uncovered by Kepler and CoRoT
- The red-giant oscillation universal pattern

Contact

- Benoit Mosser (Observatoire de Paris-LESIA, CNRS)