ASTEROSEISMOLOGY OF K GIANTS

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ABSTRACT

In order to investigate the presence of solar-like oscillations in K giants, as it has been reported in other red giants [3, 21, 22, 23, 14, 27, 19, 11], we have considered the asteroseismic analysis of two K giants, ϵ Leporis (HD32887) and α Hydra (HD81797), selected as suitable targets for recent ESO observational campaigns.

Key words: oscillations; K giants; red giants; solar-like oscillations.

1. INTRODUCTION

It is only quite recently that very precise measurements of radial velocity variations have allowed to establish that G and K giants are pulsating stars showing low amplitude oscillations with periods of about 2-10 days [e.g, 17, 12, 21]. Although several authors have suggested that the oscillatory behaviour of the red giants might be due to solar-like pulsations stochastically excited by turbulent convection [15, 10, 28, 6], the interpretation of the oscillation spectra is still very far from being understood. However, very recently De Ridder et al. [11] and Barban et al. [2] have claimed of having found clear evidence for presence of solar-like oscillations in red giants.

In the 1999, in order to fully understand the complex nature of G and K giants variability, the authors decided to join in a working group dedicated to both the observational and the theoretical study of these stars. Over a sample of more than 100 red giants, observational surveys conducted with FEROS spectrograph at the ESO 1.5m and the MPG 2.2m telescopes and at the Tautenburg Observatory in Germany allowed us to select a large number of targets suitable for seismic analysis. In this paper we study, in particular, the occurrence of solar-type oscillations in K giants, by considering the stars ϵ Lep and α Hya, which have been recently observed with FEROS at the 2.2 m MPG/ESO telescope in La Silla observatory [25, 26].

2. K GIANTS

K giants are cool, low and intermediate mass stars evolved off the main sequence, occupying the RGB, including the red clump and early AGB phases. During our survey, the 90% of the red giants observed have shown multi-periodic variability on large time scales from 1 to 600 days [e.g. 16] and with amplitudes of up to 300 m/s. In particular, short period variations falling in the range of $0.28-10$ days are believed to be due to presence of pulsations while planetary companions and rotational modulations are responsible for long-period radial velocity variations.

Although there are difficulties in the identification of the observed modes and severe problems of theoretical interpretation, Guenther et al. [15] and Dziembowski et al. [10] for α Uma and Teixeira et al. [28] and Christensen-Dalsgaard [6] for ξ Hya succeed to draw important conclusions on the structural and solar-like pulsational properties of red giant stars. They found that observations of these stars are consistent with models in the hydrogen shell-burning phase characterized by a deep convective envelope and a small convective core. Otherwhise, they could also be in the longer lasting phase in which helium burns in the convective core. Since the density in the core is quite large, the buoyancy frequency can reach very large values in the central part, with some maxima rising from the steep changes in the molecular weight. In these conditions, g modes of high frequencies can propagate and might eventually interact with p modes giving rise to modes of mixed character. As a consequence, the spectrum of the red-giant stars is quite complex, with a sequence of peaks uniformly spaced, due to radial modes, which have high amplitude and hence have more probability to be detected, and other series of peaks with low amplitude, due to the non-radial modes of mixed character.

ϵ Lep and α Hya are two K giants whose basic parameters are listed in Table 1. Their luminosity have been calculated on the Hypparcos parallax, adopting the absolute visual magnitude given by da Silva et al. [26] and the bolometric correction by Flower [13]. For the aim of this paper, we assumed the effective temperature T_{eff}, mass M and the metallicity determined by da Silva et al. [26].

Unfortunately the radial-velocity time series which we collected at FEROS during 2004 and 2005 campaigns [25] are not long enough to contain a significant signal to indicate presence of solar-type oscillations. In fact, the theoretical period of oscillations is comparable with the period of observations (about a week). As a consequence, here we present only the theoretical prediction of the frequency spectra for these targets, in view of a comparison with observational data which will come available in the near future.

3. THEORETICAL MODELS

We produced a grid of theoretical structure models for the two stars by using the Aton 3.0 code [20] by including Full Spectrum Turbulence description of the convection [5], by varying the masses and composition in order to match the observed parameters. The models include the OPAL opacities [18] in the interior and the opacities by Alexander & Ferguson [1] at temperatures smaller than 12000 K. The other main physical inputs of the code are described in D'Antona et al. [9].

Three of the resulting evolutionary tracks, obtained for $M = 1.2M_{\odot}$, $M = 2.0M_{\odot}$ and $M = 3M_{\odot}$ with $Z = 0.02$ are plotted in an H-R diagram (Fig. 1). The locations in the H-R diagram indicate that ϵ Lep and α Hya appear to be in the hydrogen-shell burning phase with a degenerate, small core and a very deep convective zone. For α Hya we have also found solutions with models in the helium burning phase. These results have been confirmed by models calculated with the GARSOM 5.0 code [24].

Table 1. Stellar parameters of ϵ Lep and α Hya. The parallax is taken from the Hypparcos catalogue. The effective temperature T_{eff}, the absolute visual magnitude M_v, the mass M, the gravity $\log g$ and the iron abundance $[Fe/H]$ are taken from da Silva et al. [26].

	ϵ Lep	α Hya
Spectral Type	K4III	K3II-III
Parallax (mas)	14.39 ± 0.68	18.40 ± 0.78
M_v	-1.02 ± 0.10	-1.69 ± 0.09
$\log T_{eff}$	3.616 ± 0.07	3.622 ± 0.07
$\log L/L_{\odot}$	2.57 ± 0.05	2.84 ± 0.05
$M/M_{\odot}$	1.70 ± 0.19	3.03 ± 0.36
$\log g$	1.43 ± 0.09	1.48 ± 0.10
$[Fe/H]$	-0.09 dex	0.00 dex

4. CONCLUSIONS

We computed adiabatic oscillation frequencies by using the ADIPLS code [7] for models which match the observed L and T_{eff} of the two targets.

The theoretical results show that solar-like oscillation spectra of these two stars should be characterized by presence of excess of power at very low frequency ($\nu < 5\,\mu$Hz), lying below the theoretical acoustical cut-off frequency at the photosphere. Moreover, we confirm previous results that red giants should show very crowded spectra due to the presence of several high-order g-modes with p-mode character in the outer layers and with frequencies which nearly overlap. Hence even if excited at the surface to appreciable amplitudes, the mixed modes are not easily resolvable. To obtain a rough idea about the modes expected to be visible, amplitudes were estimated, relative to radial modes of the same frequency, such that the modes would have the same total energy [e.g. 8].

As an example, in Fig. 2 we show the results obtained for the models of $M = 2M_{\odot}$ which satisfy observed basic parameters of of α Hya and belong to the evolutionary track represented in Fig. 1. Fig. 2 shows that oscillation frequencies decrease as the star evolves and are located $\nu \leq 5\,\mu$Hz. The large separation for $l = 0$ is $\Delta\nu \sim 0.6\mu$Hz. Modes for $l = 1$ show a very low amplitude, due to their mixed character, to be seen at the surface. A similar figure can be obtained with models of different evolutionary tracks, which satisfy the basic parameters.

We conclude that it is very difficult to be able to interpret

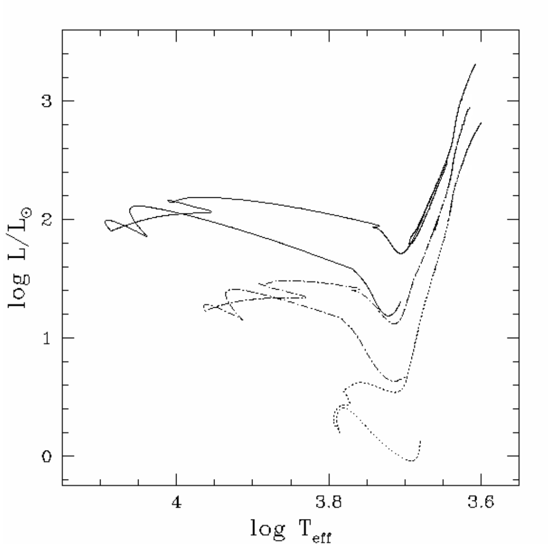

Figure 1. Three evolutionary tracks for fixed masses and solar metallicity ($Z = 0.02$) plotted in an H-R diagram. The dotted line indicate the track for $M = 1.2M_\odot$, the dashed-dotted track for $M = 2M_\odot$, the solid line is for $M = 3M_\odot$.

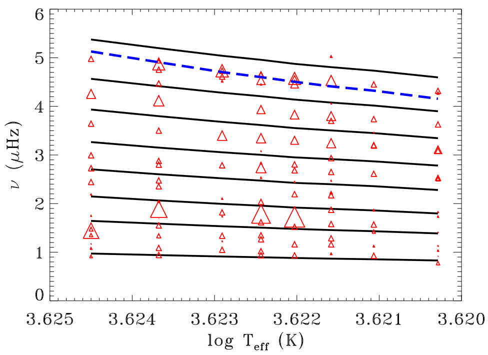

Figure 2. Evolution of adiabatic frequencies with T_{eff} of a model of α Hya computed with $M = 2M_\odot$ (as seen in Fig. 1). The solid lines correspond to p modes of degree l=0 and the triangles to modes with l=1. The size of the triangles is proportional to the relative surface amplitude of oscillation of the modes. The dashed line marks the location of the acoustical cut-off frequency at the photosphere.

the pulsations spectra of K giants obtained with short-term observations in terms of stochastic excitation by turbulent convection. It is evident that only more accurate and long-lasting observing campaign, like the ones which are possible with the MOST satellite and in the future with COROT satellite, will enable to prove the presence of solar-like pulsations in these stars. In fact, there is also the possibility, as suggested by Dziembowski et al. [10] that all, or part of, the observed modes might be self-excited Mira-like pulsations. In the latter case frequencies of oscillations can exceed the acoustical cut-off frequency. Moreover, we cannot exclude, that short-term variability might rise by large-scale granulation [e.g. 4].

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