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The frequency distribution of PG 1657+416, a rapidly pulsating sdB star

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Abstract

We analyse the frequencies shown by the recently discovered pulsating sdB star PG 1657+416. It has at least four frequencies in the range 6.8–7.8 mHz, which are used to constrain the $\log g$ value of the star. Moreover, we derive an estimate of the radial order of the modes on the basis of the observed frequency distribution.

Introduction

PG 1657+416 was discovered to show periodic light variations during a program to search for pulsating sdBs of the V361 Hya type (see Kilkenny 2007). Additional photometric data were acquired in order to undertake a theoretical analysis based on the observed frequencies of the star. The observations, as well as the data analysis and some theoretical results, are described by Oreiro et al. (2006). The frequency spectrum, whose schematic version is displayed in Fig. 1, reveals at least four frequencies showing variable amplitudes, always below 2.7 mma.

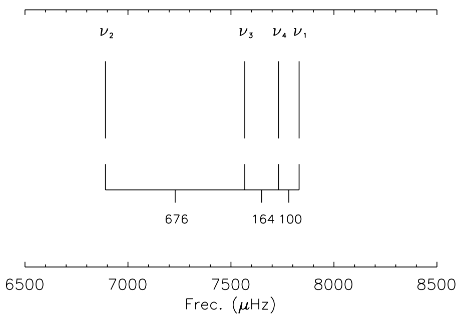

Figure 1: Schematic amplitude spectrum of PG 1657+416. The frequency separations (μHz) between the peaks are also indicated.

Physical parameters from spectrocopic fit

2MASS photometry ($J = 15.8$, $H = 15.64$, $K_S = 15.13$) clearly identifies PG 1657+416 as a system containing a hot subdwarf plus a main sequence star (Stark & Wade 2003). Thus, a line profile fit to the SDSS spectrum was performed only after the companion star contribution was removed (see Oreiro et al. 2006). The spectroscopic fit gives $T_{\rm eff} = 32\,200 \pm 500$ K, $\log g = 5.73 \pm 0.10$ dex.

Physical parameters from seismology

The frequency distribution (Fig. 1), consisting of four peaks in a narrow frequency range (< 1 mHz), allows the possibility of all of them having different ℓ value (considering modes with $\ell \leq 3$. Also, two peaks could have the same degree ℓ with consecutive radial order n. In this case, only three possible cases exist, giving a frequency separation for modes with consecutive n in the range $\Delta\nu = 0.676 - 0.940$ mHz.

Theoretical $\Delta\nu$ separations were computed for acustic modes of a grid of structural models. $\Delta\nu$ is known to be a linear function of the square root of the mean density of a model ($< \rho >^{1/2}$), which is fulfilled by our sdB models, as can be seen in the left panel of Fig. 2. The linear dependence can be fitted to: $< \Delta\nu(\mathrm{mHz}) >= -0.0298 + 0.961 < \rho(\mathrm{cgs}) >^{1/2}$.

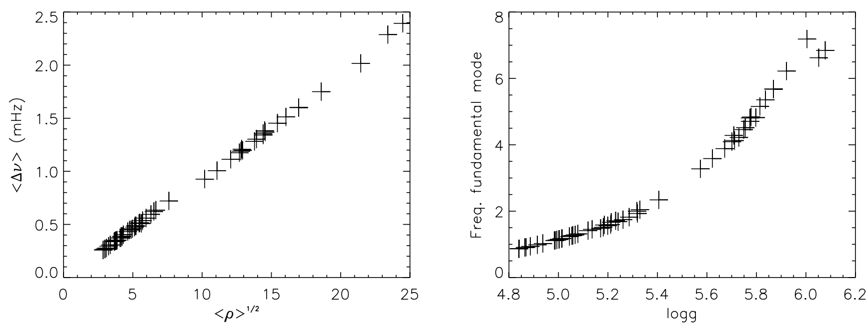

Figure 2: Left: Mean value of the frequency separation between p-modes with the same degree ℓ and consecutive n as function of the $< \rho >^{1/2}$ of the model. Right: frequency of the fundamental mode as function of the $\log g$ value of the model.

The observed frequencies of PG 1657+416 would correspond to a mean density in the range $< \rho >= 54.4 - 102.7$ gcm^{-3} that, assuming a total mass of $0.47\,M_{\odot}$, leads to a possible range in $\log g = 5.38 - 5.57$ dex, relatively lower than the spectroscopic derivation, which would imply either that the four peaks have different ℓ value, or that the errors in the spectroscopic fit are larger than those previously considered.

On the other hand, the frequency of the fundamental mode ($\ell = 0$, $n = 1$) of a given model follows the behaviour shown in the right panel of Fig. 2. Using a second order polynomial, this dependence can be expressed as: $\nu_{\mathrm{fund}} = 85.70 - 35.6 \log g + 3.74 \log g^2$, which would place the fundamental mode of PG 1657+416 in the interval $2.27 - 3.32$ mHz, given the possible $\log g$ range. In this case, the observed frequencies would have radial orders: $4 - 7 \leq n_{\mathrm{obs}} \leq 6 - 9$, where the lower (upper) range corresponds to the possibility with the higher (lower) $\log g$ value.

References

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