Asteroseismological analysis of the GW Virginis stars SDSS J0349-0059 and VV 47

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Abstract. We present an asteroseismological analysis of the GW Vir stars SDSS J0349−0059 and VV 47. We found good agreement between our mass determinations and previous results. For SDSS J0349−0059, we found a seismological model that provides us with additional information on the star.

1 Introduction

GW Vir stars (or pulsating PG 1159 stars) are very hot H-deficient post-Asymptotic Giant Branch (AGB) stars, that show surface layers rich in He, C and O ([7]). These stars exhibit multiperiodic luminosity variations with periods ranging from $\sim$ 300 to 3000 s due to nonradial pulsation g modes.

In this work, we focus on two GW Vir stars: SDSS J0349-0059 (hereafter J0349), characterized by $T_{\rm eff} = 90\,000 \pm 900$ K and $\log g = 7.5 \pm 0.01$ (cgs, [4]); and VV 47, with $T_{\rm eff} = 130\,000 \pm 13\,000$ K and $\log g = 7 \pm 0.5$ (cgs, [7]). Given the large uncertainty in the $T_{\rm eff}$, this star may be evolving either before or after the "evolutionary knee". We computed adiabatic nonradial g-mode pulsation periods on PG 1159 evolutionary models with stellar masses between 0.515 and 0.741 $M_{\odot}$ that take into account the complete evolution of the progenitor stars through the thermally pulsing AGB phase and born-again episode (that explains their H deficiency; [1, 2, 5]).

2 Analysis and results

The pulsations exhibited by GW Vir stars are produced by g modes with low harmonic degree (ℓ) and high radial order (k). The difference between the periods of modes with consecutive values of k reaches a constant value, known as the asymptotic period spacing ([6]). Given that in GW Vir stars the period spacing mainly depends on the stellar mass, it is possible to constrain the mass of the star by comparing the observed period spacing with the asymptotic period spacing, or with the average of the period spacings computed on a grid of models with different masses and effective temperatures. So, the first step is to search for a constant period spacing (if it exists) in the pulsation spectrum of the star. According to [8], J0349 shows periods in the range 300.93 − 963.48 s. According to [3],

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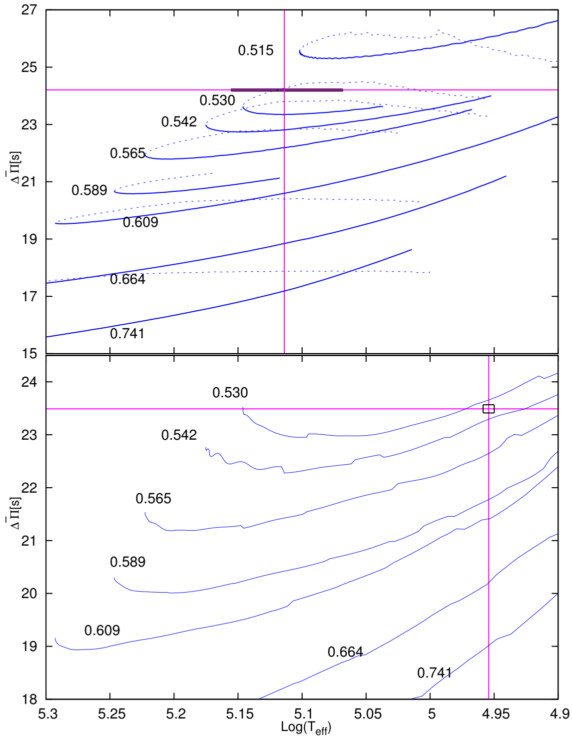

Figure 1. Average of the computed $\ell = 1$ period spacings for VV 47 (upper panel) and J0349 (lower panel) corresponding to our PG 1159 evolutionary sequences in terms of $\log(T_{\rm eff})$. Dashed (solid) lines correspond to evolutionary stages before (after) the "evolutionary knee". Also shown are the observed period spacings and the $T_{\rm eff}$, along with their uncertainties.

VV 47 shows a set of periods in the range 131 − 5682 s. By employing three different and independent significance tests to the periods observed for each star, namely the Kolmogorov-Smirnov, the Inverse Variance and a Fourier Transform based method, we determined a mean period spacing of 23.49 s for J0349 and 24.2 s for VV 47. When we compared these values with the asymptotic period spacing for our models, we obtained $M_* = 0.569\,M_\odot$ for J0349 and $M_* = 0.523\,M_\odot$ for VV 47, which is an average value considering both the cases the star is evolving before and after the "evolutionary knee". When we compared the observed period spacing for each star with the average of the computed period spacings, as shown in Figure 1, we obtained $M_* = 0.535\,M_\odot$ for J0349 and $M_* = 0.528\,M_\odot$ for VV 47 (once again, this is an average value). Next, we carried out period-to-period fits, consisting in search for models that best reproduce the individual observed periods of each star. This is achieved by assessing a quality function that measures the difference between the observed individual periods and the theoretical pulsation periods for our grid of models. We display in Figures 2 and 3 the inverse of the quality function in terms of $T_{\rm eff}$ for J0349 and VV 47, respectively. The model that shows the greatest value of the inverse of the quality function, if it exists, is adopted as the best-fit model. If there is not a unique maximum, we need to employ some external constraint, like the uncertainty in $T_{\rm eff}$. Following this procedure, we found for J0349 a possible solution (within the range of allowed $T_{\rm eff}$) for the model with $M_* = 0.542\,M_\odot$ and $T_{\rm eff} = 91\,255$ K. Once we adopt a model, we have access to theoretical information, such as $\log(g) = 7.488$ (cgs), $\log(R_*/R_\odot) = -1.658$ and $\log(L_*/L_\odot) = 1.475$. For the case of VV 47, as seen in Figure 3, there is no unambiguous asteroseismological solution, not even within the range of allowed $T_{\rm eff}$. Finally, there is another mass determination for the two stars under analysis we obtained using the spectroscopic data given by [4] and [7] combined with our grid of models ([5]). It results in $M_* = 0.543 M_\odot$ for J0349 and $M_* = 0.529 M_\odot$ for VV 47 (average value).

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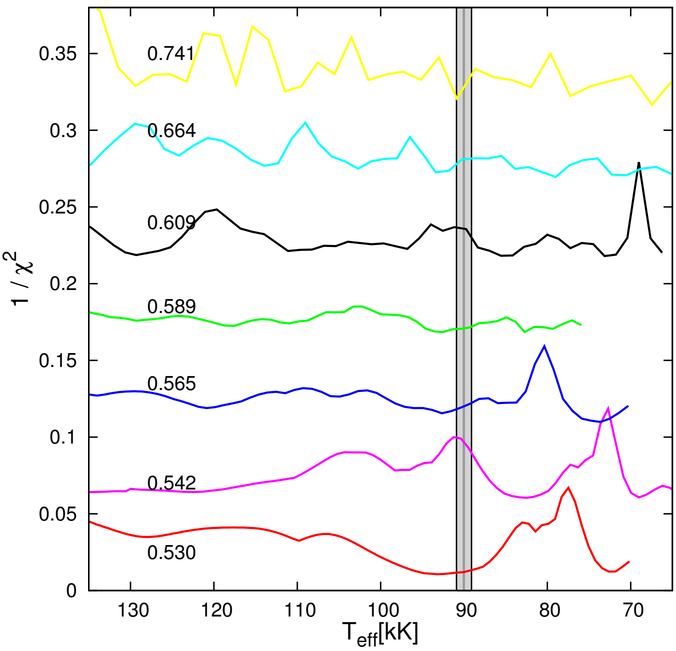

Figure 2. Inverse of the quality function of the period fit considering $\ell = 1$ g modes vs $T_{\rm eff}$ for J0349. The curves have been arbitrarily shifted upward for clarity (with a step of 0.05).

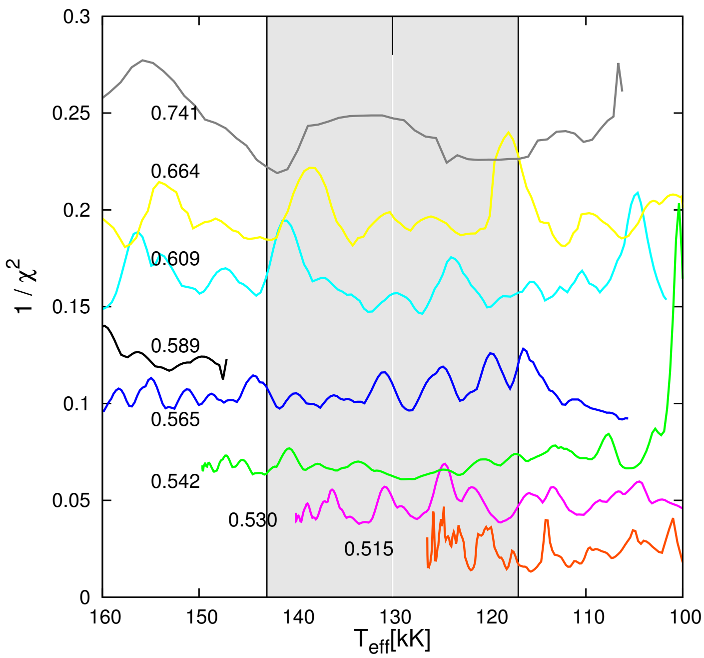

Figure 3. Same as Figure 2 but for VV 47, for the case "before the knee". The curves have been arbitrarily shifted upward for clarity (with a step of 0.025).

3 Conclusions

In this work we employed the photometric and spectroscopic data given for J0349 and VV 47 ([3, 4, 7, 8]), and our computations of adiabatic nonradial g-mode pulsation periods on PG 1159 evolutionary models ([1, 2, 5]), in order to determine the mass and the internal structure of these stars. We found that all the mass estimates we obtained through the different methods employed are in good agreement with each other and also in line with the spectroscopic mass. As we were able to find an asteroseismological model for J0349 that fits the observed periods, we have access to theoretical information that otherwise is not possible to infer by any other methods. Unfortunately, we could not find an unambiguous asteroseismological model for VV 47. It would be really important to have available more accurate spectroscopic determinations for VV 47, in order to be able to choose a seismological model and hence, know more about this star.

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