Poster session

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Rho Puppis: some spectroscopic results or "The Taming of Rho Puppis"

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Abstract

Basic parameters such as T_{eff} and log g as well as the projected rotational velocity $v \sin i$ for the Delta Scuti star Rho Puppis were redetermined, using high resolution and high S/N spectra from the ESO Science Archive (program ID 60.A-9036(A)). The data were obtained with the HARPS spectrograph attached to the ESO La Silla 3.6m telescope in 2006. For a preliminary analysis of atmospheric parameters and chemical abundances we used a spectral range between 4500 and 5800 Å. Equivalent widths for 33 Fe I and for 8 Fe II lines were measured. The best result for T_{eff} is 6900 $\pm$ 150 K, corresponding to reported values in literature (Burkhart & Coupry 1991). The surface gravity log g resulted in 3.8 $\pm$ 0.2 adjusted from the Fe I and Fe II ionisation equilibrium. The projected rotational velocity $v \sin i$ was found to be 14.0 $\pm$ 1.5 kms^{-1}. For a detailed description of the procedure applied in this work for abundance analysis and for the codes and software packages used, see Stuetz et al. (2006) and Fossati et al. (2008) and references therein.

Rho Puppis was the target of a five night long observing run at the AAT (Anglo Australian Telescope) in January 2008. Using UCLES, we gathered around 1200 high resolution high S/N spectra. Preliminary analysis revealed one frequency at 7.10 c/d, which was identified as the radial fundamental mode[1] (Zima 2008), as already reported by Mathias et al. (1997).

Also significant in the frequency spectrum is the first harmonic, which clearly shows the nonlinear behaviour of the main mode, having a very high amplitude of pulsation. There is evidence for further pulsational frequencies in Rho Puppis, but the time base of our data set is not long enough for more detailed frequency analyses in the Delta Scuti regime.

Rho Puppis, an evolved Fm star eponymous for a whole chemically peculiar subgroup of the Delta Scuti stars, was selected as target for testing the theory predicting solar-like oscillations in cool Delta Scuti stars (Houdek et al. 1999; Samadi et al. 2002). From the observational point of view, no attempts to measure solar-like oscillations in such hot stars have been made so far.

Individual Objects: Rho Puppis

Acknowledgments. This work was supported by the Austrian Fonds zur Förderung der wissenschaftlichen Forschung under grant P18339-N08 and P20526-N16. Partial support for attending the workshop was granted by HELAS and ÖFG (Österreichische Forschungsgemeinschaft).

[1] Mode Identification results obtained with the software package FAMIAS developed in the framework of the FP6 European Action HELAS (http:/www.helas-eu.org).

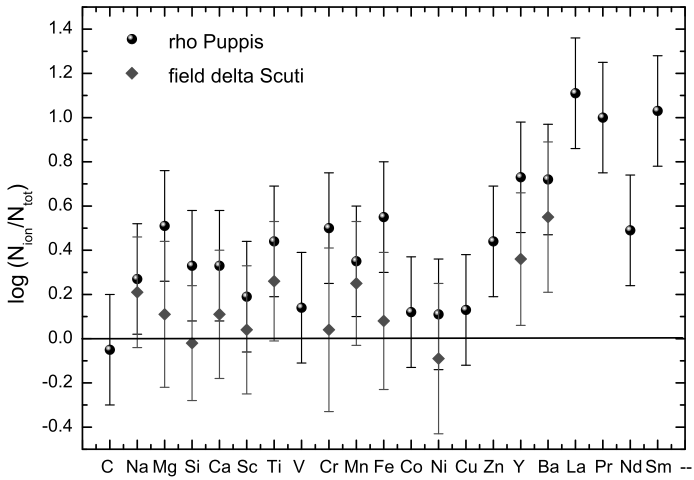

Figure 1: Preliminary results of the abundance analysis of Rho Puppis. All elements found to be under- or overabundant with respect to the Sun (Asplund et al. 2005) are listed. Additionally, we show mean abundances of field Delta Scuti stars computed by Fossati et al. (2008) applying the same procedure as in this work. Compared to the overall abundance pattern of Delta Scuti stars, Rho Puppis clearly shows enhancement of all metals. As expected for Fm stars, our target also shows a strong overabundance of rare earth elements.

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Solar-like stars as seen by CoRoT

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Abstract

For more than a year, photometric high-quality data have been achieved from the CoRoT (COnvection ROtation and Planetary Transits; Baglin et al. 2006, Michel et al. 2008) minisatellite developed by the French space agency (CNES) in collaboration with the Science Program of ESA, Austria, Belgium, Brazil Germany and Spain. The power spectrum of 4 different solar-like stars (stars having sub-surface convective zones showing an acoustic (p) mode spectrum) has been obtained with unprecedented quality allowing the precise study of their seismic properties. These solar-like stars are F stars with masses in the range 1.0 to 1.4 $M_\odot$ and are significantly hotter than the Sun.

Individual Objects: HD 49933, HD 175726, HD 181420, HD 181906

Observations and Data Sets

CoRoT is a 27-cm afocal telescope producing an image of the stellar field into 4 CCDs (composed by a matrix of 2048 x 4096 pixels). Each CCD is working on a frame transfer mode. Two are dedicated to asteroseismology and the other two to exoplanet research. The images on the seismo CCDs are defocused to minimize the effects of the spacecraft jitter. Thus, stellar fluxes are measured every second with a dead time of 0.206s (sampling cycle of 79.4 %).

The data available at this moment for the studies of solar-like stars in the seismology channel are obtained from a run of 156 days of continuous observations (where two stars were observed) and two shorter ones of 60 and 26 days. They correspond to the stars named: HD 181420, HD 181906, HD 49933 and HD 175726 respectively. The duty cycle achieved is, in all the cases, above 93% with most of the data loss being a consequence of the crossing of the South Atlantic Anomaly. The CoRoT Team hopes to reduce the amount of data loss in a future improvement of the ground processing software. The cadence of the light curves is 1 s, regularly resampled every 32 s in the level-2 data released to the scientific community.

* The D.A.T. Team is composed of: T. Appourchaux (chairman), J. Ballot, C. Barban, F. Baudin, O. Benomar, G. Berthomieu, P. Boumier, W. J. Chaplin, S. Deheuvels, Y. Elsworth, R. A. García, R. Garrido, J.-C. Hulot, S. J. Jiménez-Reyes, H. Kjeldsen, E. Michel, B. Mosser, J. Provost, C. Régulo, I. W. Roxburgh, R. Samadi, T. Toutain and G. A. Verner

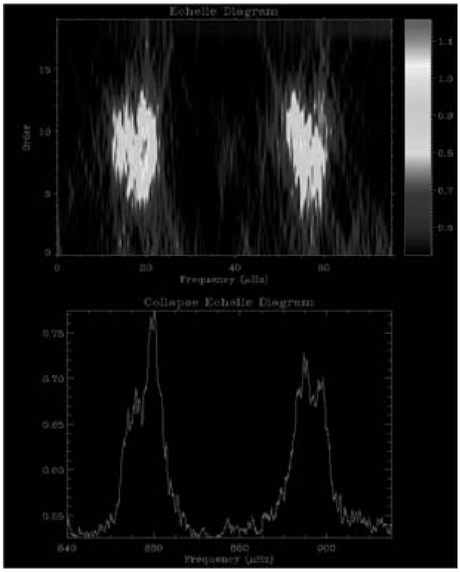

Figure 1: Echelle diagram (top) resulting from lining up the power spectrum in chunks of the large separation after enhancing the contrast using curvelets (Lambert et al. 2006). Bottom: Averaged echelle diagram. A tempting peak tagging can be done from this diagram: the left ridges correspond to the l=0, 2 and the right one to the $\ell=1$

Analysis and Discussion

The power spectral density of the stars with the three longest runs shows the presence of the comb-like pattern due to the p modes excited in those stars (see Fig. 3 in Michel et al. 2008), well above the stellar convective background. Figure 1 shows an example of an echelle diagram for HD 49933 where the two ridges (odd and even modes) are clearly visible.

To identify modes by assigning the proper ℓ, m and n label, we perform a global fitting (see Appourchaux et al. 2008). In this fitting, all free parameters are varied and optimized simultaneously over a large number of orders (depending on the signal-to-noise ratio of the modes) with three modes per order (ℓ=0, 1, 2). The mode peaks are described by symmetric Lorentzian profiles defined by a single height fitted to all modes in each order (the amplitude-height ratio is fixed between modes ℓ1 and ℓ2 compared to the ℓ0), a single linewidth parameter for all modes of the same order and a single splitting for all non-radial modes of all orders. The background was modelled following a Harvey (1985) model.

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Preliminary seismic study of the γ Doradus COROT target HD 49434

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Individual Objects: HD 49434

HD 49434, a new challenge for asteroseismology

HD 49434 is a hot F1V γ Doradus star, selected as a primary target of the CoRoT Nov. 2007/Mar. 2008 long run. This star has been the subject of an extensive ground-based photometric and spectroscopic campaign before and during the space run (Uytterhoeven et al. 2008).

Strömgren indices from GAUDI database and TempLogG package (Napiwotzki et al. 1992, Künzli et al. 1996) give $T_{\rm eff} = 7300 \pm 200$ K, $\log g = 4.21 \pm 0.20$, $[Fe/H] = 0.01 \pm 0.20$. Bruntt et al. (2004) by using 2MASS photometry and H_α line profile obtain the same $T_{\rm eff}$, a higher $\log g$ (4.40 ± 0.45) and a slightly lower metallicity $[Fe/H] = -0.04 \pm 0.21$. On the other hand, a spectroscopic analysis by Gillon & Magain (2006) gives a similar $\log g$ (4.43 ± 0.20) but a value of $T_{\rm eff}$ (7632 ± 126 K) 1σ higher than previous determinations. Given the location of HD 49434 near the blue border of the γ Dor instability strip (IS), an accurate determination of $T_{\rm eff}$ is crucial and further investigations are hence required.

Stellar models and stability computation

Ground-based observations of HD 49434 allowed Uytterhoeven et al. (2008) to classify HD 49434 as a hybrid pulsator, since it shows four frequencies (from 0.2 to 1.7 $\rm d^{-1}$) in the typical domain of g-modes in γ Dor pulsators, as well as six frequencies (from 5 to 12 $\rm d^{-1}$) with values in the range of δScuti p-modes. The simultaneous presence of both p- and g-modes makes this star an extremely interesting target for asteroseismic modelling.

The evolutionary tracks and instability strips we used were computed with the stellar evolution code CLES (Code Liégeois d'Evolution Stellaire - Scuflaire et al. 2008a), the adiabatic oscillation code LOSC (Scuflaire et al. 2008b) and the version of the non-adiabatic oscillation code MAD including the convection-pulsation interaction (Grigahcene et al. 2005). Figure 1 shows that, according to the chosen error box in a ($\log L$,$\log T_{\rm eff}$) diagram, HD 49434 is located either at the blue border of the γ Dor IS or outside the IS. Taking all these observational constraints (global parameters, seismic frequencies) into account, we shall attempt to obtain

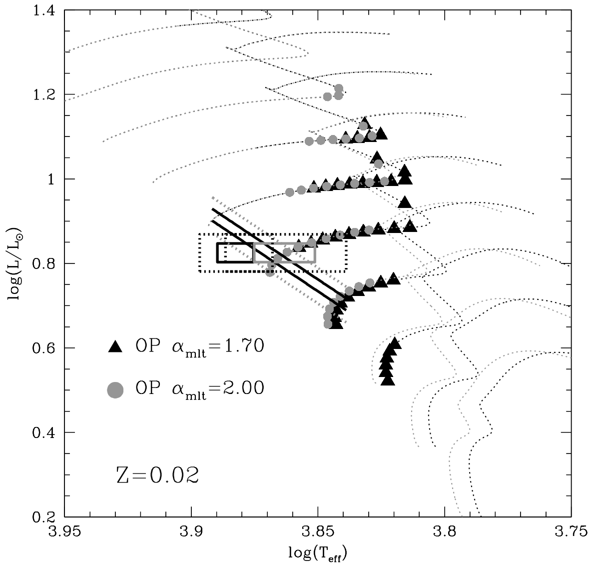

Figure 1: Location of HD 49434 in the (log L, log $T_{\rm eff}$) diagram. 1σ (full lines) and 2σ (dotted lines) error boxes of HD 49434: left/black box for Gillon & Magain (2006) and right/grey one for Bruntt et al. (2004). The diagonal lines show the constraints on the radius of this star (Masana et al. 2006). Points and triangles show the γ Dor IS derived from the Liège Grid of Models.

a best fit for HD 49434 and discuss the uncertainties affecting the models together with their effects on the stability results. Results of this modelling will be presented in a future paper.

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44 Tau: Examination of amplitude variability and combination frequencies

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Abstract

The Delta Scuti Network has observed the slowly rotating δ Scuti star 44 Tau for five seasons during 2000-2006. All ℓ=1 modes exhibit strong annual amplitude variations, while the radial modes have constant (or nearly constant) amplitudes. We examined the probability of different amplitude modulation mechanisms to be responsible for the observed amplitude variability. The amplitudes of the combination frequencies, $f_i + f_j$, mirror the variations of the parent modes. The relationship between the amplitudes of the combination frequencies and their parents is found to be constant (μ=0.003) for the combinations involving the radial fundamental and different ℓ=1 modes.

The details of the results presented in this poster have in the meantime been published (Breger, M. & Lenz, P. 2008, A&A, 488, 643).

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German Data Center for the Solar Dynamics Observatory: A model for the PLATO mission?

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Abstract

The German Data Center for the Solar Dynamics Observatory (GDC-SDO), hosted by the Max Planck Institute for Solar System Research in Germany, will provide access to SDO data for the German solar physics community. The GDC-SDO will make available all the relevant Helioseismic and Magnetic Imager (HMI) data for helioseismology and smaller selected Atmospheric Imaging Assembly (AIA) data sets. This project commenced in August 2007 and is funded by the German Aerospace Center (Deutsches zentrum fuer Luft- und Raumfahrt or DLR) until December 2012. An important component of the GDC-SDO is the Data Record Management System (DRMS), developed in collaboration with the Stanford/Lockheed Joint Science Operations Center (JSOC). The PEGASUS workflow management system will be used to implement GDC-SDO data analysis pipelines. This makes use of the CONDOR High Throughput Computing Project for optimal job scheduling and also the GLOBUS Toolkit to enable grid technologies. Additional information about the GDC-SDO can be found at http://www.mps.mpg.de/projects/seismo/GDC1/index.html. Here, we suggest a similar structure and philosophy should be ideal for the PLATO mission, which looks for planetary transits and stellar oscillations and is being studied by ESA for an M-Mission slot in Cosmic Vision.

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Seismology of ZZ Ceti stars

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Abstract

We used the detected pulsation modes and adiabatic pulsation models to measure the H and He layer masses for 83 ZZ Ceti stars by seismology. The range of H layer is $10^{-9.5} \geq M_H/M_* \geq 10^{-4}$, with an average of $M_H/M_* = 10^{-6.3}$, thinner than the canonical $M_H/M_* = 10^{-4}$, indicating that the stars lose more mass during their prior evolution.

Introduction

White dwarfs are the final evolutionary stage of 95–98% of all stars (e.g., Fontaine et al. 2001). Their evolution is basically dominated by cooling; as they cool, they pass through three distinct instability strips: the hot DOVs, the DBV stars, and the DAV or ZZ Ceti stars, with $12\,400\text{K} \leq T_{\text{eff}} \leq 10\,800\text{K}$.

The ZZ Ceti stars start to pulsate when the partial ionization zone of H deepens into the envelope. They pulsate with a few short periods and small amplitude modes (blue edge). As the stars cool, the depth and size of the convective zone increases, with more modes with longer periods and higher amplitudes excited.

The seismological models

We used the White Dwarf Evolutionary Code (Lamb & van Horn 1975) updated by Don Winget and his group. The transitions between the layers are consistent with time diffusion, following Althaus et al. (2003).

We calculated an extensive adiabatic model grid for the pulsation modes, varying T_{eff}, M, M_{H}, and $M = 0.6\,M_\odot$, with masses from 0.5 to 1.0 $M_\odot$. The T_{eff} varies from 10 600 to 12 600 K. The upper H and He layer mass values are $10^{-4}\,M_*$ and $10^{-2}\,M_*$, respectively. The lower H and He layer mass values are $10^{-9.5}\,M_*$ (the minimum H amount to be detected in a DA white dwarf spectra) and $10^{-3.5}\,M_*$, respectively.

Seismology by groups

First, we searched all periodicities known for all ZZ Ceti stars. We reanalyzed the light curves of the stars observed at the 2.1 m telescope at McDonald Observatory (e.g., Castanheira et al. 2006), at the 4.1 m telescope SOAR and the 1.6 m telescope at Observatório Pico dos Dias (e.g., Kepler et al. 2005). The other ZZ Ceti periods were obtained from the literature.

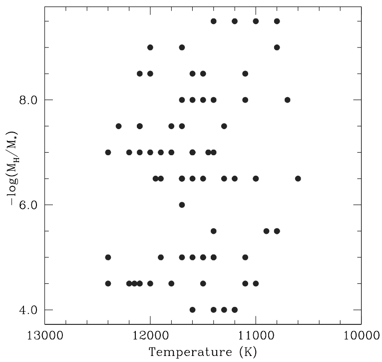

Figure 1: H mass vs. $T_{\rm eff}$, showing that there is no evidence of accretion nor loss of the external layers, as the ZZ Ceti evolves in the instability strip.

We separated the stars according to the excited mode with highest amplitude. We then compared the observed modes with our model grid. We are searching for common properties to characterize a particular group; each group is a specific evolutionary stage in the white dwarf cooling.

We used the external temperature and mass determinations as a guide to search of the best among all the possible families of seismological solutions.

Results and conclusions

The most important result is that the H layer mass is not dependent on temperature (see Fig. 1). There is no evidence for accretion or loss of the external layers, as the H layer mass does not vary univocally with temperature (or age).

The mean value for the H layer mass is $10^{-6.3\pm1.6}\,M_*$, which is lower than the canonical value of $10^{-4}\,M_*$, from evolutionary calculations. This result indicates that white dwarfs might have formed with H mass several orders of magnitude smaller than the predicted value.

We have done the first large seismological analysis of the ZZ Ceti stars as a class, studying 83 stars. Even though we used the spectroscopic determinations as a guide, we only restricted the seismological solution to the range of spectroscopic parameters if there were not enough modes detected, avoiding local minima to be mistaken as global. In our study, we concluded that it is mandatory to use the observed amplitudes in the best model fit, as weights for the periods. It is not acceptable that the best fit does not agree with the highest amplitude mode. After 40 years since the discovery of the first ZZ Ceti star, we finally extracted information about this class as a whole.

Our seismological study of the ZZ Ceti stars is a proof that seismology is really a powerful tool in the study of stellar evolution.

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Contributions of different effects towards the light variations in main sequence pulsators

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Abstract

Nonradial stellar oscillations cause brightness changes, which result from temperature, geometrical and pressure perturbations. The observed values of photometric amplitudes and phases are determined by competition between those three effects whose contributions depend on stellar parameters and on pulsation mode.

I compare the importance of the individual contributions towards the light variations as a function of the spherical harmonic degree, ℓ, and mode frequency, ν, for β Cephei, Slowly Pulsating B-type and δ Scuti star models. All computations are performed in the framework of linear non-adiabatic theory of stellar pulsation neglecting all effects of rotation. Static plan-parallel Kurucz models of stellar atmospheres are used.

Results

Because these results require more space for comprehensive presentations and discussion than allowed in these proceedings, the above abstract is an announcement of the full version paper which will be published in one of next regular issues of CoAst.

Jørgen Christensen-Dalsgaard, Jadwiga Daszyńska-Daszkiewicz and Andrzej Pigulski at the conference dinner.

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HARPS seismic data of the F type star HD 49933 revisited in the light of CoRoT results

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Abstract

Many studies have shown that the identification of pressure modes from line profile variations using the moment method is very efficient for self-excited oscillating stars (Aerts et al. 1992). It has however never been used to identify modes in solar-like pulsating stars. The fact that the velocities of the oscillations are very small compared to the rotational velocity makes it harder to use the moments method. We explore the possibility to adapt this method to the solar-like oscillations. The F type star HD 49933 is a particularly appropriate target, having been observed both in photometry with CoRoT (Baglin et al. 2006) and in spectrometry (HARPS). We use both sets of data to investigate to which extent this method can help in identifying the detected modes.

Individual Objects: HD 49933

Moments method

Balona (1986) proposed a method to identify the oscillation modes observed in nonradially pulsating stars, by analysing the time variations of the first moments of the line profile. For a line profile $F(v)$, described as a function of the velocity v, the n^{th} moment is defined as:

$$\langle v^n \rangle_F \equiv \frac{\int_{-\infty}^{+\infty} v^n F(v)\, dv}{\int_{-\infty}^{+\infty} F(v)\, dv} \tag{1}$$

For given ℓ, m, and mode frequency, the n^{th} moment $\langle v^n \rangle_F$ has a component $\langle v^n \rangle_k$ at the frequency $k\,\nu_{\ell,m}$, for each k between 1 and n. These components depend on ℓ, m, the inclination angle i, the velocity of the mode $v_{\ell,m}$ and the parameters of the star.

For solar-like pulsators, the velocities of the oscillations ($\sim$10 cm s^{-1}) are very small compared to the rotational velocity (a few km s^{-1}). Only the component of the moments at $\nu_{\ell,m}$ (i.e. $\langle v^n \rangle_1$) is accessible, and most of the identification methods cannot be applied to these objects.

There is however a way of identifying the modes, using only this component. Balona proposes to study the ratio $\rho = \langle v^2 \rangle_1 / \langle v \rangle_1$. It has the advantage that for a given (ℓ, m), it depends only on the inclination angle i.

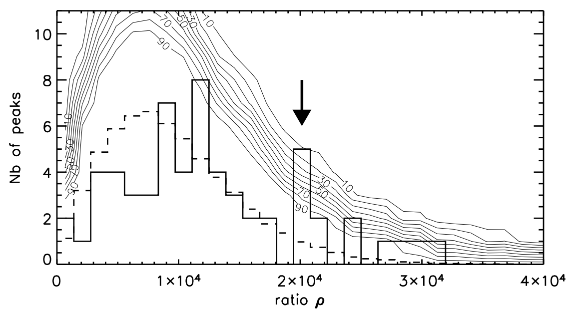

Figure 1: Distribution of the ratio ρ for the selected peaks in the HARPS spectrum, with the superimposition of the false-probability level. The black dashed curve corresponds to the average of the Monte Carlo iterations.

Identification of the modes for HD 49933

Solar-like pulsator HD 49933was observed both with the spectrometer HARPS (Mosser et al. 2005) and in photometry with CoRoT (Appourchaux et al. 2008). We applied a mask on the HARPS spectrum, to keep only the parts which match the frequencies of the modes detected by CoRoT. The ratio ρ was computed for each of them. Since ρ is identical for all (ℓ, m) modes, we expected to find numerous peaks with the same ratio ρ. The obtained values of ρ are shown in a histogram (see Fig. 1).

To determine the significance of the peaks, we used a Monte Carlo technique on the line profiles in order to estimate the false-alarm probability. The histogram contains a peak (pointed by the arrow) which has a probabilty as low as 10% to be due to noise, and therefore 90% chances to be due to signal.

Results and conclusion

According to the values of the period (T$\simeq$ 3.4 days), $v \sin i$ and R, the inclination angle of HD 49933 is estimated at about $i = 29 \pm 3$ degrees.

The relation between ρ and i suggests an identification for the mode detected with a 90% probability: $\ell = 2$, $m = \pm 2$. We obtain the same identification as the one derived from the CoRoT data (Appourchaux et al. 2008).

The application of this method to HD 49933 is still in progress, and the influence of some parameters remains to be studied — for instance the size of the bins in the histogram, the number of highest peaks selected, the dimensions of the mask applied on the HARPS power spectrum.

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Pulsating B and Be stars in the Magellanic Clouds

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The κ-mechanism in β Cephei and SPB stars has an important dependence on the abundance of iron-group elements, and hence the respective instability strips have a great dependence on the metallicity of the stellar environment. Pamyatnykh (1999) showed that the β Cephei and SPB instability strips practically vanish at $Z < 0.01$ and $Z < 0.006$, respectively.

The metallicity of the Magellanic Clouds (MC) has been measured to be around $Z = 0.002$ for the Small Magellanic Cloud (SMC) and $Z = 0.007$ for the Large Magellanic Cloud (LMC) (see Maeder et al. 1999 and references therein). Therefore, it is expected to find a very low occurrence of β Cephei or SPB pulsators in the LMC and no pulsator of this type in the SMC.

Our research has been focusing on a sample of more than 150 stars for the LMC and more than 300 stars for the SMC (photometric time series had been provided by the MACHO project) for which Martayan et al. (2006, 2007) provided accurately determined fundamental astrophysical parameters. Our goal is to map the regions of pulsational instability in the HR diagram for the low-metallicity environments as the MC.

The complete results of the analysis for the SMC data can be found in Diago et al. (2008). Many of the short-period variables have been found multiperiodic and some of them show the beating phenomenon due to the beat effect of close frequencies. In Table 1 we resume the percentages of short-period variable stars compared with the results obtained by Gutiérrez-Soto et al. (2007) for the Milky Way (MW).

In the SMC, all pulsating B stars are restricted to a narrow range of temperatures (see Fig. 1). Moreover, all stars but one have periods longer than 0.5 days, characteristic of SPB stars. Thus, we suggest an observational SPB instability strip at the SMC metallicity shifted towards higher temperatures than in the Galaxy. We propose the hottest pulsating B star in our sample to be a β Cephei variable. The reason is that it has two close periods in the range of the p-mode galactic pulsators, and it is the hottest pulsating star. If it is indeed a β Cephei star, this would constitute an unexpected result, as the current stellar models do not predict p-mode pulsations at the SMC metallicities (see Miglio et al. 2007).

For Be stars in the SMC, most of them are located inside or very close to this region, suggesting that they are g-mode SPB-like pulsators. Three stars are significantly outside the strip towards higher temperatures, all of them multiperiodic, with periods lower than 0.3 days. Therefore, we propose that these stars may be β Cephei-like pulsators.

Table 1: Percentages of short-period variables in the MC and in the MW.

	MW	LMC	SMC
Pulsating B stars	16%	6.9%	4.9%
Pulsating Be stars	74%	14.8%	24.6%

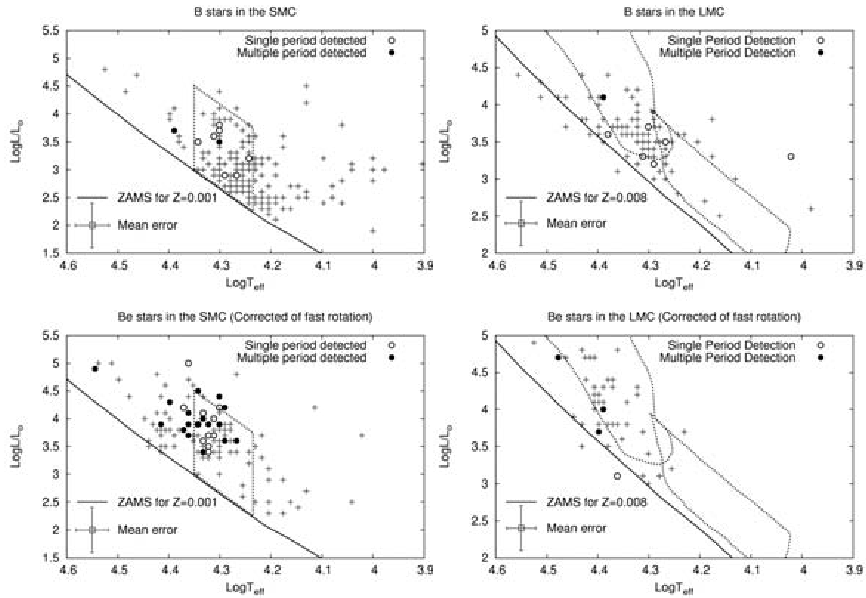

Figure 1: Location of the B (top) and Be (bottom) star samples of the SMC (left panels) and the LMC (right panels) in the HR diagram: single crosses represent stars in our sample, the empty circles represent single period detection and the filled ones multiple period detection. In the left panel (SMC), the dashed line delimits the suggested SPB instability strip for the SMC. In the right panel (LMC) the β Cephei and the SPB boundaries at solar metallicities (Pamyatnykh 1999) are plotted only for reference.

In the LMC the search for short-period variables is more difficult than in the SMC because they show more outbursts and irregular variations that prevent us from carrying the frequency analysis. In spite of this difficulty, we have found 7 short-period variables among the B star sample and 4 among the Be star sample. As in the SMC, the hotter stars are those that are multiperiodic. Our work with the results of the LMC is ongoing.

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Dipole modes of stellar oscillations

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Abstract

We focus on dipole mode stellar oscillations (with l=1) which have been a challenge in identifying the modes. We make use of a new mode identification scheme specific to these oscillations.

Introduction

Nonradial stellar oscillations are governed by a fourth-order system of differential equations which is difficult to treat analytically. Nevertheless, there has been a specific treatment suggested only for dipole-mode oscillations (Takata 2005), which decreases the system of equations from fourth to second order. We apply this new treatment to realistic stellar models and check its validity.

Classification of modes

Stellar oscillation modes are investigated, in a broad sense, under two categories: the acoustic modes (p modes), and the gravity modes (g modes), with the restoring force being pressure and buoyancy, respectively. In most cases, but not for dipolar oscillations, there is also an intermediate fundamental mode, the so-called f mode, which has no radial node (for a detailed discussion; see Christensen-Dalsgaard & Gough 2001). Conventional mode identification is made by analyzing the movement of the phase point on the phase diagram plotted using two variables $(y_1,\ y_2)$, where $y_1 = \xi_r/r$, and $y_2 = \sqrt{l(l+1)}\frac{\xi_h}{R}$, with ξ_r and ξ_h being the radial and horizontal displacements, respectively. The nodes of ξ_r are used to determine the label of the mode together with the direction of the phase point while going around the origin of the phase diagram at the node: it is called a g node (or p node) if the movement is clockwise (or counterclockwise): see Takata (2006) for details. The number of p and g nodes (n_p and n_g) are counted and then a mode is labelled according to the sign of radial order n, where $n = n_p - n_g$. If $n > 0$, the mode is labelled as a p mode, while it is labelled as a g mode if $n < 0$. However, this classification fails to be valid for dipolar modes. Low-order dipolar modes, labelled according to the phase diagram based on the radial and horizontal displacements, change their order as the star evolves, while a proper labelling should be invariant under the evolution. This failure comes from the fact that we can justify the conventional scheme only when we neglect the gravitational potential perturbation (ϕ'), which is not small in the condensed core of the evolved stars. Based on the identity derived by Takata (2005), which takes into account the contribution from ϕ', Takata (2006)

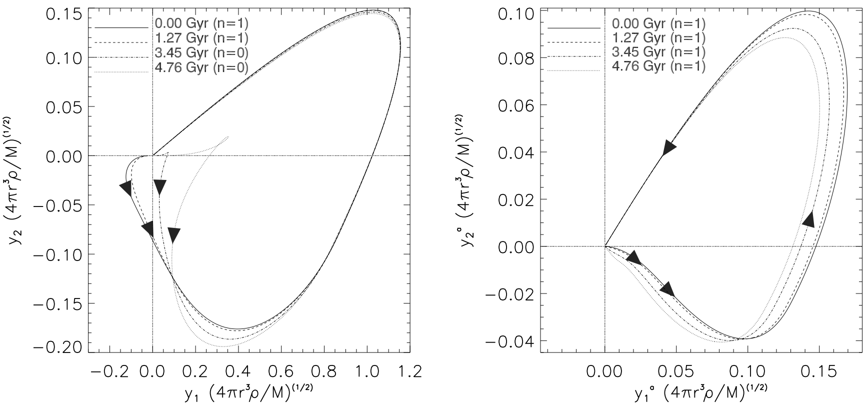

Figure 1: Evolution of an $l = 1$ mode for a model with $M = 1M_\odot$, and metallicity Z=0.02. Starting from the origin, phase points move in the direction of the arrows.

showed that an invariant labelling can be based on the pair of variables (y_1^a, y_2^a), where $y_1^a = \frac{J\xi_r}{r} + \frac{1}{3g}(\frac{\phi'}{r} - \frac{d\phi'}{dr})$, and $y_2^a = \frac{Jp'}{\rho g r} + \frac{1}{3g}(\frac{\phi'}{r} - \frac{d\phi'}{dr})$, with $J = 1 - \frac{4\pi\rho r^3}{3M_r}$. Using these new variables; $n = n_p - n_g$ if $n_p < n_g$, while $n = n_p - n_g + 1$ if $n_p \geq n_g$. The dependence of labelling (as p or g mode) on n is as described before. Fig. 1 shows the phase diagrams plotted using the old (left panel) and the new variables (right panel).

The new definition appears to be a solution to the problem of dipolar mode labelling, at least for stars from the main sequence through the subgiant branch.

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Asteroseismic models for the exoplanet host star HD 19994: A preliminary approach

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Abstract

We present preliminary models for HD 19994, a star which is part of a binary system and also harbors an extrasolar planet. We compute evolutionary tracks with the Toulouse-Geneva evolution code, using four different metallicity values. Large and small separations are computed, and the echelle diagrams are given for a few models. From the currently known spectroscopic data, we found that HD 19994 could be either an overmetallic main sequence star with a mass range between 1.24 and 1.36 $M_{\odot}$ or a less massive subgiant star, with a mass range of 1.18-1.28 $M_{\odot}$ and a solar metallicity. We also found that, in some cases, the small separations can become negative at a given frequency, which is related to the presence of a convective and helium-rich core. This is a preliminary approach: a more precise asteroseismic study of this star, based on recent (November 2007) data from the HARPS spectrograph will be given later.

Individual Objects: HD 19994

Asteroseismology is a powerful tool to study the interior of stars. In the case of HD 19994 we had two motivations for a precise study: this star has an orbiting Jupiter-like planet and also has a binary companion. β Virginis, a "sister" of HD 19994 but with no orbiting exoplanet, has been previously studied using asteroseismology (Carrier et al. 2005; Eggenberger & Carrier 2006). This gives a unique opportunity to compare two similar stars with different environments.

We computed evolutionary tracks using the Toulouse-Geneva evolution code. For the four metallicity values found in the literature, we computed evolutionary tracks for masses ranging from 1.18 $M_{\odot}$ to 1.40 $M_{\odot}$. For each metallicity case, we constructed the corresponding error boxes in the $\log(L/L_{\odot})$ - $\log(T_{\rm eff})$ and $\log(g)$ - $\log(T_{\rm eff})$ planes, according to the observational constraints given by the spectroscopic studies. Finally, we have five error boxes, two of them corresponding to the same metallicity values but to different luminosities, gravities and effective temperatures. In every case we chose a model, in the corresponding track, close to the centre of the error box, in agreement with the observational constraints. We found that, as an overmetallic star, HD 19994 should be a main sequence star with a mass range between 1.24 and 1.35 $M_{\odot}$; otherwise, in case the overmetallicity was due to accretion, it would be a subgiant star with a mass between 1.18 and 1.28 $M_{\odot}$.

We selected ten models to perform the asteroseismic test. Adiabatic oscillation frequencies were computed using the PULSE code (Brassard et al. 1992), for angular degrees from $\ell = 1$ to $\ell = 3$ and radial orders ranging typically from 4 to 30. The azimutal order is always $m = 0$.

We computed the large separations, small separations and we plotted the echelle diagrams. Analyzing our results, the most interesting cases are the models where the lines $\ell = 0$ and $\ell = 2$, and/or the lines $\ell = 1$ and $\ell = 3$ cross, indicating that the small separations change sign at a certain frequency, in contradiction with the asymptotic theory (Tassoul 1980). This is related to the presence of a convective helium-rich core in the star (Soriano & Vauclair 2008).

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Thinking hard about science: Saskia Hekker and Jørgen Christensen-Dalsgaard

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Radiative levitation: a likely explanation for pulsations in the unique hot O subdwarf star SDSS J1600+0748

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Abstract

SDSS J1600+0748 is the only hot sdO star for which unambiguous multiperiodic luminosity variations have been reported so far. These rapid variations, with periods ranging from 60 s to 120 s, are best explained qualitatively in terms of pulsational instabilities, but the exact nature of the driving mechanism remains a puzzle. Models with uniform metallicity are unable to excite pulsation modes in the range of interest as demonstrated most eloquently by Cristina Rodríguez-López in her Ph.D. thesis at the Universidad de Vigo in 2007. We confirm her results here, but also show that the inclusion of radiative levitation in the equilibrium models changes the picture dramatically. We find indeed that *p*-mode pulsations with periods overlapping with the observed ones in SDSS J1600+0748 can be excited in models in which radiative levitation of iron is taken into account. This process provides the necessary boost to the opacity driving mechanism. We conclude that radiative levitation apparently is an essential ingredient of the excitation physics at work in this unique star.

Individual Objects: SDSS J160043.6+074802.9

Woudt et al. (2006) reported the discovery of short-period (from ∼60 s to ∼120 s) multiperiodic luminosity variations in the relatively faint ($g = 17.41$) SDSS object J1600+0748. They also provided a SALT spectrum which clearly showed, even without quantitative analysis, that SDSS J1600+0748 is a spectroscopic binary consisting of a very hot sdO star and, most likely, a late-type main-sequence companion. This came as a bit of a surprise as no driving mechanism able to excite short-period *p*-modes had been found in models of sdO stars as reported by Rodríguez-López in her Ph.D. work (see Rodríguez-López et al. 2006, 2007 for more details).

One piece of physics that can potentially be very important, but was not included in the sdO models built by Rodríguez-López and collaborators, is radiative levitation. In order to investigate that possibility, we followed the same approach as the one proposed by Charpinet et al. (1997) in the construction of their so-called second-generation sdB models. In brief, a state of diffusive equilibrium is assumed between gravitational settling and radiative levitation of iron in the envelope of sdO star models. Prior to that, we secured a high S/N ratio spectrum of J1600+0748, deconvolved it of the light of the G0V companion, and modeled the cleansed spectrum with NLTE H/He synthetic spectra to obtain values of

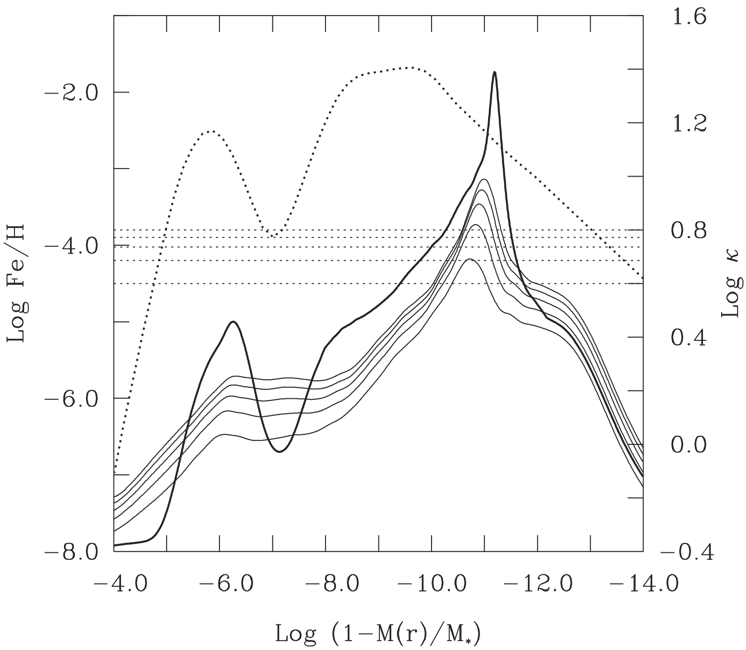

Figure 1: Iron-to-hydrogen number ratio (dotted curve) and Rosseland opacity (solid curve) profile in the envelope of representative stellar models. The thin curves refer to models with uniform metallicity specified by $Z = 0.02$, 0.04, 0.06, 0.08, and 0.10, from bottom to top. The thick curve refer to our reference model that takes radiative levitation into account. The largest bump in the opacity profile for each model is clearly larger and sharper in the latter case and produces pulsational instabilities.

$T_{\rm eff} = 71{,}070 \pm 2725$ K, $\log g = 5.93 \pm 0.11$, and $\log$ He/H $= -0.85 \pm 0.08$. This was an essential step to estimate with some accuracy the atmospheric parameters of J1600+0748 that are needed in the construction of the equilibrium stellar models used in the subsequent pulsation analysis.

With the inclusion of radiative levitation, we find instabilities in models of J1600+0748 that match remarkably well those found in the real star. In contrast, models with uniform metallicity fail to produce unstable modes (see Fig. 1). Details on our results can be found in Fontaine et al. (2008).

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New multisite observations of δ Scuti stars V624 Tauri and HD 23194

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Individual Objects: V624 Tauri, HD 23194, HD 23246

Introduction

The stars V624 Tau (= HD 23156, BD+23^o 495) and HD 23194 (= V1187 Tau, BD+24^o 540) belong to the Pleiades cluster. While the former was identified as a δ Scuti variable by Breger (1972), the latter was classified as a δ Scuti pulsator by Koen et al. (1999). The multiperiodic pulsational behaviour of both stars was established as a result of the STEPHI X campaign in 1999 (Fox Machado et al. 2002). In that campaign 7 frequencies for V624 Tau and 2 frequencies for HD 23194 were unambiguously detected above 99% confidence level. A comparison between the oscillation frequencies and the eigenfrequencies of rotating models of some δ Scuti stars of the Pleiades cluster, V624 Tau and HD 23194 among them, was carried out by Fox Machado et al. (2006). As a result, few solutions with associated ranges of stellar parameters for each star were found suggesting the existence of only p modes, low radial order in all the stars.

In order to increase the number of detected modes in each star, a new STEPHI multisite campaign on V624 Tau and HD 23194 was carried out in 2006. Some preliminary results of these observations are given in this paper.

Observations, data reduction and frequency analysis

Some observational properties of the target stars are given in Table 1. The observations were carried out over the period 2006 November 14–December 3. As has been done in previous STEPHI campaigns, we observed from three sites well-distributed in longitude around the Earth: Observatorio Astronómico Nacional (operated by the UNAM) in San Pedro Mártir, Baja California, Mexico; Xing Long Station (operated by the Beijing Observatory) in Beijing, China; and Observatorio del Teide (operted by the IAC) in Tenerife, Spain. Four-channel photometers with interferometic blue filters were used at all observatories. 232 hours of useful data were obtained during 20 nights of observations from the three sites. The efficiency of observations was 48% of the cycle. The data reduction was obtained following a classical scheme of multichannel photometry and is similar to that reported in previous STEPHI

Table 1: Observational properties of the stars observed in the STEPHI 2006 campaign.

Star	HD	ST	V	$B-V$	$V \sin i$ ($\mathrm{km\,s^{-1}}$)	β
V624 Tauri	23156	A7V	8.22	+0.25	70	2.823
V1187 Tauri	23194	A5V	8.05	+0.20	20	2.881
Comparison	23246	A8V	8.17	+0.27	200	2.773

Table 2: Frequency peaks detected above a 99% confidence level in our target stars. The origin of φ is at HJD 2454040.97. S/N is the signal-to-noise ratio after the pre-whitening process.

Star		ν (μHz)	A (mmag)	φ (rad)	S/N
V624 Tau	ν_{1a}	243.01	3.37	+1.4	5.0
	ν_{2a}	408.96	5.75	−0.1	15.6
	ν_{3a}	413.20	4.15	−0.1	11.5
	ν_{4a}	416.21	1.43	−1.5	3.9
	ν_{5a}	451.80	3.82	−1.4	10.4
	ν_{6a}	489.22	4.38	+2.7	12.7
	ν_{7a}	529.18	1.43	−1.5	4.2
	ν_{8a}	690.92	1.06	−2.9	4.3
HD 23194	ν_{1b}	533.62	6.94	−1.8	14.5
	ν_{2b}	574.85	6.26	−1.8	14.7
	ν_{3b}	615.40	4.50	−0.8	12.2

campaigns (e.g. see Alvarez et al. 1998, Fox Machado et al. 2002). The frequency peaks of the light curves of the target stars were obtained by performing a nonlinear fit to the data. Table 2 lists the peaks detected in each star with a confidence level above 99%. As can be seen, eight and three frequencies were detected in V624 Tau and HD 23194, respectively. A combined analysis of the 1999 and 2006 STEPHI campaigns will be given in a forthcoming paper (Fox Machado et al. 2008).

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Pulsational analysis of the Herbig Ae star HD 140237

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Introduction

The pre-main sequence (PMS) stars of intermediate mass ($1.5 - 8\,M_{\odot}$), called Herbig Ae/Be stars (Herbig 1960), show signs of strong stellar activity (e.g. Böhm & Catala 1995). The origin of this activity is not understood in the frame of current theoretical models of stellar evolution. We have growing evidence that the feeding energy source might be of internal stellar origin. This question still remains open, and it is a major concern for young stellar evolution to study the internal structure of these objects by means of asteroseismology.

HD 104237 is a particularly suitable target for such a study, since it is one of the brightest Herbig Ae stars known ($m_{\rm v} = 6.6$). Moreover, δ Scuti type pulsations have been discovered in this prototype star in the last years (Donati et al. 1997; Kurtz & Müller 2001; Böhm et al. 2004). An asteroseismological study of HD 104237 will enable us to better constrain the PMS instability strip investigated by Marconi & Palla (1998), which covers roughly the same area in the HR diagram as the δ Scuti stars. We have chosen to work with the HD 104237 high resolution spectroscopy data obtained in 1999 at the 1.9m telescope of the South African Astronomical Observatory (SAAO) by Böhm et al. (2004). These authors obtained high quality radial velocity measurements which allowed them to detect for the first time by spectroscopic means multi-periodic oscillations in a PMS star. An accurate analysis of pulsations by high-resolution spectroscopy requires significant Signal-to-Noise Ratios (SNR). In order to make full use of the multiplex gain of more than 500 spectral lines, we work with equivalent profiles taking into account all the informations of the photospheric lines present in the spectrum by using the LSD method (Donati et al. 1997). For each night of the run SAAO 1999, we have computed the LSD profiles corresponding to the different obtained spectra.

Individual Objects: HD 104237

Pulsational tomography of HD 104237

We have classified all photospheric lines following their depth of formation within the stellar photosphere of HD 104237 (LTE approximation) and studied the radial velocity pulsational behaviour of several groups. The detailed frequency analysis revealed the same three main frequencies and associated amplitudes as announced in Böhm et al. (2004). This indicates the absence of radial pulsational nodes within the studied radial area, ie. the absence of high radial order pulsations.

In addition we have gathered photospheric lines in function of different chemical elements, namely Fe (FeI + FeII), FeI, FeII and TiII. The analysis of the pulsational behaviour of these groups of lines indicates that there is no significant difference between the groups, which is not in favour of a chemical stratification of the atmosphere of HD 104237, in opposition to what has been found eg. for roAp stars (eg. Ryabchikova et al. 2002; Kochukohov 2007).

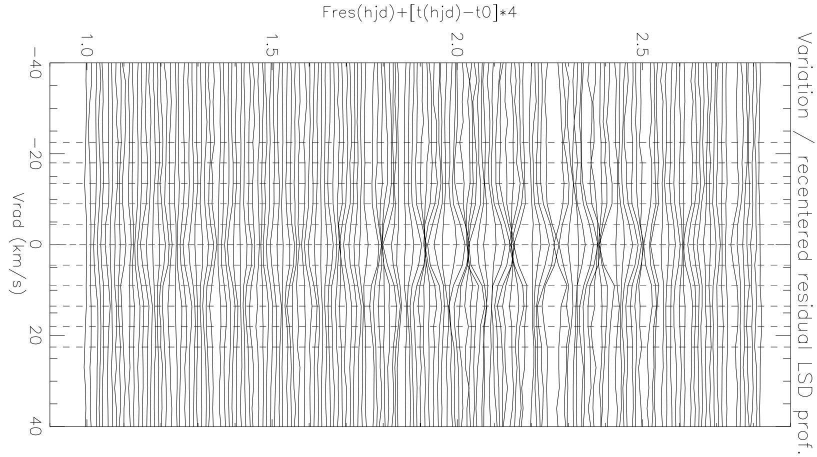

Figure 1: Dynamical spectrum of the HD 104237 LSD residual profiles. Clear indications of nonradial pulsations are observed.

Discovery of nonradial pulsations in HD 104237

In order to search for nonradial pulsations, the LSD profiles have been corrected of their corresponding HJD (Heliocentric Julian Date) radial velocity and recentered on their respective centroid (i.e. all radial velocity movements have been substracted). In order to see the variations in these profiles better, we have substracted a nightly averaged LSD profile (cf. Fig. 1). The variation pattern of the LSD residual profiles shows oscillations in the centroid and the wings, with amplitudes of less than 1.5% of the continuum. For the first time, we have direct spectroscopic indication of the presence of low degree nonradial pulsation in the spectrum of HD 104237. An analysis of 11 velocity bins centered on the individual radial velocity of each profile (from -22.5 km/s to +22.5 km/s) shows a phase opposition between the oscillations of the centroid and the oscillations of the wings of the residual profiles, indicative of nonradial pulsations of low degree ℓ.

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Is HD 163899 really a supergiant star?

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Abstract

According to its spectral type B2 Ib/II (Klare & Neckel 1977; Schmidt & Carruthers 1996), HD163899 is a supergiant star. The star presents p and g-mode pulsations (Saio et al. 2006). In such a post-main sequence (post_MS) star, the helium core is radiative with a very large Brunt-Väisälä frequency which produces a strong damping. The presence of excited g-modes is however possible thanks to an intermediate convective zone (ICZ) which prevents some g-modes from entering the radiative damping core (Saio et al. 2006). We have investigated an alternative solution. We show that MS evolutionary tracks could cross the error box of HD 163899 if a sufficiently large amount of overshooting is taken into account. However, in that case, the spectrum of unstable modes is different from the spectrum of a supergiant star since the Brunt-Väisälä frequency is much smaller.

Individual Objects: HD 163899

HD 163899

HD 163899 is a B supergiant star (B2Ib/II, Klare & Neckel 1977; Schmidt & Carruthers 1996) which has been observed by the MOST satellite (Walker et al. 2003) during 37 days. Saio et al. 2006 reported the detection of 48 frequencies ($\leq$ 2.8 c/d) with amplitudes of the order of the milli-magnitude. The frequency range corresponds to p and g-mode pulsations.

HD 163899 is a supergiant star

The presence of g-mode pulsations in a post-MS star is challenging since those stars present a radiative and contracting core and a low density envelope. The Brunt-Väisälä frequency reaches huge values in the core causing a strong radiative damping. However, an intermediate convective zone (ICZ) located above the core prevents some modes from entering the radiative damping core. In that case the κ-mechanism in the superficial layers is sufficient to excite some g-modes (Saio et al. 2006). Saio et al. (2006) have computed supergiant models in which an ICZ indeed develops in the post-MS phase. They do have excited g-modes and the frequency range corresponds approximately to the observed frequencies.

HD 163899 is a main sequence star with overshooting

MS stars have a convective core surrounded by a radiative envelope: the Brunt-Väisälä frequency is zero in the core and no radiative damping occurs there. The presence of g-modes in such a star is therefore not a problem. Fig. 1 shows evolutionary tracks computed with different overshooting parameters (from 0.2 to 0.5). The black dashed box stands for

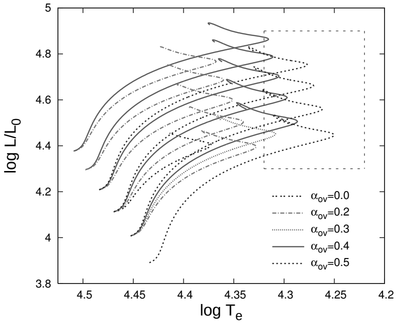

Figure 1: Main sequence evolutionary tracks for masses ranging from $11\mathrm{M}_\odot$ to $16\mathrm{M}_\odot$ computed with different overshooting parameters ranging from 0.2 to 0.5. The dashed box is the error box of HD 163899. Main sequence evolutionary tracks with at least $\alpha_{ov} = 0.3$ cross this error box.

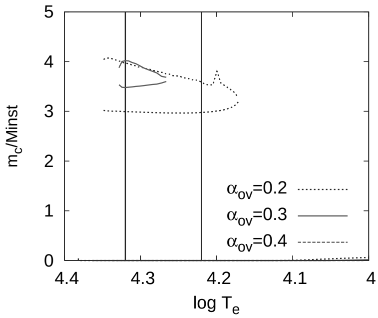

Figure 2: Evolution of the ICZ mass extension during the supergiant phase. The effective temperature decreasing after the MS is shown on x-axis. For a small amount of overshooting 0.2, the ICZ is well develops, it is much smaller for 0.3 and it disappears for 0.4.

the error box of HD 163899 from Saio et al. (2006). We see that when taking sufficiently large overshooting into account, MS evolutionary tracks cross the error box of HD 163899. g-modes can be excited since there is no radiative damping due to the presence of a convective core. However, the frequency range does not represent the observed range as well as in case 1.

HD 163899 is a supergiant star with overshooting

On the post-MS, an ICZ is needed to have excited g-modes. If the overshooting during the MS phase is too large, it can prevent the formation of an ICZ during the post MS and therefore prevent the excitation of the g-modes. The evolution of the convective core and the ICZ in the post MS phase for a sequence of $12\mathrm{M}_\odot$ computed with different overshooting parameters is shown on fig. 2. The ICZ is still well developed for $\alpha_{ov} = 0.2$, it is much smaller for 0.3 and it completely disappears for $\alpha_{ov} = 0.4$. In that case, no unstable g-modes should be observed.

Conclusion

We have investigated three possible solutions for the location of HD163899 in the HR diagram coupled with the presence of excited g-modes. First, if HD 163899 is a supergiant star, an ICZ is needed and for models computed without overshooting the theoretical frequency range closely resembles the observed frequency range. Second, if HD 163899 is still a MS star, a rather large amount of overshooting is needed. However in that case, the agreement between the theoretical frequency range and the observed one is not as good as in case 1. Third, if HD 163899 is a supergiant star with a rather large amount of overshooting during the MS phase, no ICZ is formed and the excitation of g-modes is not possible. These results favour case 1; HD 163899 should be a supergiant star.

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Photometric observations of southern Blazhko Stars

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Abstract

In the years 2004 and 2005, we obtained Johnson B and V photometry of 7 southern Blazhko RR Lyrae stars at the South African Astronomical Observatory (SAAO) and Siding Spring Observatory (SSO), Australia. Using the new data in combination with the ASAS data, Blazhko periods could be determined with unprecedented accuracy.

Individual Objects: AR Ser, RU Cet, RV Cap, V674 Cen, RY Col, SS For, UV Oct

Motivation

Dedicated photometric campaigns of Blazhko stars - i.e., RR Lyrae stars showing a periodic change of their pulsation amplitude and phase - have so far mainly been carried out from the northern hemisphere. Before the results from large-scale surveys such as ASAS and ROTSE-I (Woźniak et al. 2004) came out, there were only few well-established southern field Blazhko stars. We selected some of the brightest and most interesting known Blazhko pulsators in the southern hemisphere and obtained new precise photoelectric measurements. Seven stars were observed in the framework of the campaign. Table 1 lists the targets and the amount of data obtained.

The campaign

Fourteen weeks of telescope time in 2004 and twelve weeks in 2005 were allocated to the project at the South African Astronomical Observatory. Additionally, two of the stars (SS For and UV Oct) were included into a multisite campaign which was carried out in 2005. For these stars, we also obtained data at Siding Spring Observatory, Australia, which led to a great improvement of the spectral window function and made more detailed analyses possible.

	hours	nights	measurements V	measurements B
AR Ser	37.4	18	293	244
RU Cet	17.9	4	123	122
RV Cap	55.9	21	372	254
V674 Cen	77.1	30	469	441
RY Col	58.0	24	293	301
SS For	201.8	50	1218	1218
UV Oct	134.9	47	832	832

	$P_{Pulsation}$(d)	$P_{Blazhko}$(d)
AR Ser	0.57514	110.0 $\pm$ 5.0
RU Cet	0.58628	97.9 $\pm$ 1.0
RV Cap	0.44774	232.6 $\pm$ 5.5
V674 Cen	0.49392	Not determined
RY Col	0.47886	82.4 $\pm$ 0.8
SS For	0.49543	34.9 $\pm$ 0.1
UV Oct	0.54263	143.9 $\pm$ 0.2

Frequency analysis

For the determination of the frequencies we performed a Fourier analysis using the software package Period04 (Lenz & Breger 2005). In order to obtain the most reliable results, we combined our data with the publicly available data from the ASAS survey (Pojmanski 2005). The ASAS observations have a much longer time base, which complements our measurements with their precision and their coverage of large parts of the light curve. This enabled us to determine the Blazhko periods of six stars with unprecedented accuracy:

Amplitude decrease and influence of data sampling

It was noted by Jurcsik et al. (2005) that the amplitudes of the side peaks decrease less steeply from one harmonic order to the next than the amplitudes of the harmonics themselves. We also see this effect in our data. The amplitudes of the harmonics decrease exponentially, while the amplitudes of the modulation components decrease in an almost linear way.

It is well known that data sampling plays an important role in the analysis of RR Lyrae Blazhko stars. Not only the resulting amplitudes depend on the sampling, but due to phase changes also the determined pulsation amplitude may differ from one subset to another. The combination of our data with ASAS data helped to solve this problem and to obtain unambiguous results for both the pulsation and the Blazhko periods (Kolenberg et al. 2008).

Variations at minimum light

In the majority of Blazhko stars the variations around maximum light over the Blazhko cycle are most pronounced. For SS For, strong periodic variations around minimum light were found and analyzed (Guggenberger & Kolenberg 2006). Shock waves passing through the stellar atmosphere are thought to be responsible for the bump in the light curves of RR Lyrae stars. The variation of the bump is hence likely due to a variable timing and intensity of the shock wave. The light curves of some of the other stars in the campaign also show strong changes before minimum light which deserve further analysis.

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Asteroseismology in the young open cluster NGC 3293

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Abstract

This is a progress report on the analysis of our extensive CCD UBV photometry campaign of the open cluster NGC 3293 that contains eleven known β Cephei stars. All of them are multiperiodic with up to seven independent mode periods detected so far. Another group of variables is located near the low-luminosity end of the β Cephei instability strip; it probably consists of rapidly rotating SPB stars. More than a dozen δ Scuti stars have been confidently identified in the field so far. All are new discoveries; about half of them belong to the cluster. To date, we have also discovered five eclipsing variables in and around NGC 3293.

Individual Objects: NGC 3293

Some examples

Figure 1 presents more detailed information on some of the confirmed variables. The first eleven panels contain the amplitude spectra of the known β Cephei stars (GCVS designations) from our B-filter measurements at Siding Spring Observatory, CTIO and part of the SAAO observations. No new β Cephei stars were discovered in the cluster so far. V400 Car was only contained on the CCD frames from Siding Spring, and the SAAO data on V404 Car were not useful. A large variety of pulsational behaviour among the β Cephei stars becomes apparent.

The same comment applies to our SPB candidates (NSV numbers); further analysis is needed to obtain a reliable classification and to understand their behaviour. Finally, a phased light curve of an Algol-type eclipsing binary (NGC 3293 BVC 85, internally named StarC139) is shown. It is hoped that the eclipsing cluster members can be used to obtain additional constraints on the cluster distance.

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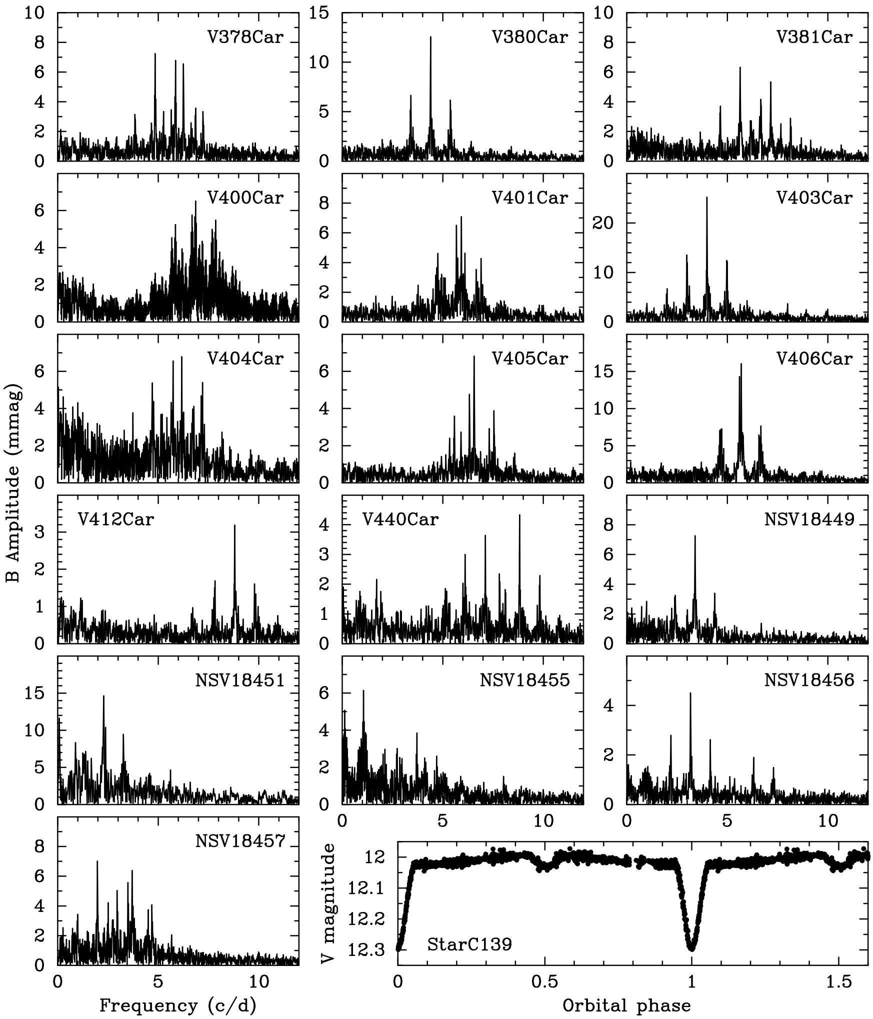

Figure 1: Preliminary amplitude spectra of the eleven known β Cephei stars in NGC 3293 and of five of the presumed SPB stars. The panel to the lower right contains the phased light curve of the brightest of the eclipsing variables newly discovered to date.

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Pulsations, chemical composition and multiplicity in main sequence A- and F-type stars

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Abstract

The region in the HR-diagram where the main sequence intersects the classical instability strip hosts A- and F-type stars exhibiting a rich variety of physical phenomena, such as pulsations on various time scales and chemical peculiarities. We aim to investigate the occurrence of these phenomena among suspected binary systems in this region of the HR-diagram and their mutual interactions.

Introduction

Main sequence A and F stars are interesting since stars in the same region of the HR-diagram show (different types of) pulsations and/or chemical peculiarities. The necessary (different) conditions for these phenomena to occur in stars of similar luminosity and temperature are not yet (well-) known. For a long time it has been thought that chemical peculiarity and pulsations were mutually exclusive (e.g. Breger 1970). Radiative diffusion (gravitational settling of Helium and levitation of other elements in layers which are sufficiently stable against turbulent mixing) in slowly rotating stars can explain the existence of chemical peculiarities as well as the suppression of pulsations due to a lack of Helium in the partial ionisation zone which drives the pulsations. By now, stars possessing both chemical peculiarities and pulsations are observed, which can not be fully understood in terms of the radiative diffusion hypothesis. Only for some subgroups of chemically peculiar pulsating stars theoretical explanations exist. We refer to e.g. Kurtz (2000) for an extensive review.

The aim of our project is to investigate empirically the limits where chemical peculiarity and pulsations can co-exist, where they are mutually exclusive and the role of multiplicity therein.

Sample selection and observations

A sample of poorly studied A and F stars is selected to investigate the mutual interactions between pulsations, multiplicity and chemical abundances in the region where the classical instability strip intersects the main sequence. Stars are selected to be brighter than 8^{th} magnitude in V (Hipparcos catalogue: ESA 1997), have a variability flag in the radial velocity catalogue of Grenier et al. (1999) and only a few references in Simbad.

During three observing runs using the ELODIE spectrograph mounted on the 1.93-m telescope at the Observatoire de Haute-Provence, France, spectra with $S/N \geq 80$ were collected for about 65 stars. To be able to search for pulsations and/or multiplicity, the observing strategy was such that both long- and short-term radial velocity variations could be identified, i.e., several exposures (exposure times $\leq$ 10 min) during a single night and at least one during another night were gathered.

Determination of stellar parameters and chemical abundances

Stellar parameters are determined using GIRFIT, a computer code which performs least squares fitting based on the MINUIT minimisation package (see also Frémat et al. 2007). The radial velocity (RV), projected rotational velocity ($v \sin i$), effective temperature ($T_{\rm eff}$) and surface gravity (log g) are derived in four consecutive steps: (1) RV is determined from the cross-correlation functions; (2) $v \sin i$ is based on metallic line fitting with RV fixed; (3) $T_{\rm eff}$ is derived from H_{α}, with log g equal to 4.0; (4) log g is derived by computing the luminosity using the parallax, V magnitude and $T_{\rm eff}$ and, from these, the mass and radius from stellar evolutionary tracks (Schaller et al. 1992). Because log g depends on $T_{\rm eff}$ the last two steps are performed iteratively.

Determination of abundances is performed for elements with strong spectral lines based on solar abundances in the range 4500 - 5500 Å, using synthetic spectra computed with the SYNSPEC computer code (Hubeny & Lanz 1995) and least squares fitting based on MINUIT. The strategy is as follows: (1) microturbulence is determined from several sensitive isolated lines; (2) iron abundance is determined using strong iron lines (EW $>$ 5 mÅ); (3) abundances of iron peak elements (Ti, V, Cr, Mn, Co, Ni, Cu) are determined from isolated lines or lines blended with iron; (4) using the previous results, iron peak elements are re-determined also allowing blends of several of these elements in the same fitting interval; (5) abundances of other elements with single lines are determined. The abundance determination is performed semi-automatically and optimisation of the procedure is still ongoing.

Current status & future prospects

So far, the cross-correlation functions are computed and checked for indications of pulsations and multiplicity. Indeed, in this rather poorly studied sample of stars binary systems, pulsators and stars without obvious radial velocity variations are present. For the single stars in our sample the determination of stellar parameters is nearly finished. At the moment the abundance determination as described in the previous section is being tested on simulated data as well as on reference stars also observed with the ELODIE spectrograph. Detailed information on the developed procedures and results will be published in subsequent publications.

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Solar-like oscillations in red giants in the CoRoT exofield

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Abstract

Asteroseismic observations from space can provide us with long time series of uninterrupted high quality data for many stars at the same time. The CoRoT satellite (Convection Rotation and planetary Transits) was launched successfully in December 2006 and provides high precision photometery for a large number of stars. Here we present our research on (late G and K) red giant stars observed during the first long run (150 days) of CoRoT with the 'eye' dedicated to exoplanet research.

Introduction

Solar-like oscillations in red giant stars are observed using both spectroscopy (e.g. Frandsen et al. 2002, Barban et al. 2004, De Ridder et al. 2006) and photometry (e.g. Barban et al. 2007, Stello et al. 2007, Kallinger et al. 2008, Tarrant et al. 2008). Results from these observations left room for discussion about the observability of nonradial modes in red giants and the lifetime of the stochastic oscillations. Longer time series of data, such as the 150 day time series from CoRoT, could reveal more details about these phenomena. Here we present the selection and first analysis steps of red giants observed in the CoRoT exofield during the first long run in the direction of the centre of the Milky Way (LRc01).

Selection

In the CoRoT exofield $\sim 12\,000$ stars in the magnitude range 11-16 mag in V are observed during each run with a cadence of 512 or 32 seconds. Although the main focus was on red dwarfs, many red giants were observed. A selection procedure to identify the red giant candidates was developed based on amplitude spectra, using the following criteria: (1) excess amplitude in the frequency range 20 - 120 μHz; (2) width of the excess of at least 20 μHz or several peaks over a similar range; (3) some excess at low frequencies, which is interpreted as granulation. After an automatic selection based on the above criteria, all preselected stars are examined manually. From this selection it became clear that solar-like oscillations in this frequency regime are not observable for stars fainter than 15 mag in V, most likely due to photon noise. Finally, about 400 red giant candidates are selected. An example of a power spectrum of a red giant candidate is shown in Figure 1.

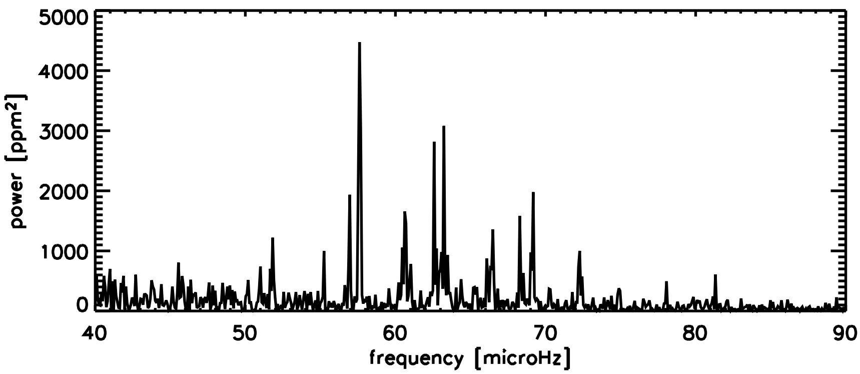

Figure 1: Power spectrum of one of the selected red giant candidates. This star has an apparent magnitude of 12.5 mag in V, while no other parameters are available at the moment.

Data analysis

Although CoRoT delivers high quality data, non-stellar trends and jumps are present in the light curves and need to be corrected. Therefore, a correction using the following steps is performed: (1) subtract a trend modelled by a 2^{nd} order polynomial; (2) detect jumps by comparing mean flux values in adjacent time bins with a width of at least a few times the oscillation period; (3) fit polynomials in all parts separated by the jumps and divide the data by these polynomials.

Currently, a full analysis of the selected candidates is performed in different groups in Belgium, Paris, Tautenburg and Vienna. This includes the search for oscillation frequencies, mode identification, and lifetimes. Details of these analyses and results will be published in subsequent publications.

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Orbital period analysis of some classical Algols with pulsating components

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Abstract

The long-term orbital period variations of the Algol-type binaries with δ Scuti component(oEA) AB Cas, CT Her, and TW Dra are investigated. An upward parabola is seen in all of these systems O-C diagrams, as is expected from the evolutionary scenario of classical Algols. In addition to parabolic variations, the periodic variations on the parabola were explained with light-time effect due to probable unseen components around the eclipsing pairs.

Individual Objects: AB Cas, CT Her, TW Dra

Introduction

The classical Algol type binaries have a hotter main sequence (B-A type) and cooler evolved subgiant or giant (F-G-K) components. Forthese systems, the mass transfer process from the less massive secondary component to the primary one has been expected due to their evolutionary status. In classical Algols, the orbital period should increase, if the mass transfer exists. On the other hand, it is clearly seen in many studies that about 50 percent of Algols shows cyclic orbital period changes (e.g. Soydugan 2008).

All systems in this study are classical Algols including pulsating components. The orbital periods of AB Cas, CT Her and TW Dra are approximatively 1.37^d, 1.79^d and 2.81^d, respectively. The targets clearly indicate orbital period variations (e.g. Kreiner et al. 2001). There are several works for AB Cas and TW Dra, which include O-C analysis (e.g. Abedi & Riazi 2007 for AB Cas, Qian & Boonrucksar 2002 for TW Dra). On the other hand, there is not any published work on the period change of CT Her.

The method for orbital period analysis

AB Cas, CT Her and TW Dra indicate parabolic and cyclic variations in their O-C diagrams. Therefore, we applied a well-known equation, which includes parabolic and periodic (light-time equation given by Irwin 1959) terms to represent O-C variations of these systems. The differential correction method was used to get the fit parameters with standard errors. The details for the method can be found in the work of Soydugan et al. (2003). The O-C diagram with theoretical curves and the residuals can be seen in Fig. 1 for CT Her.

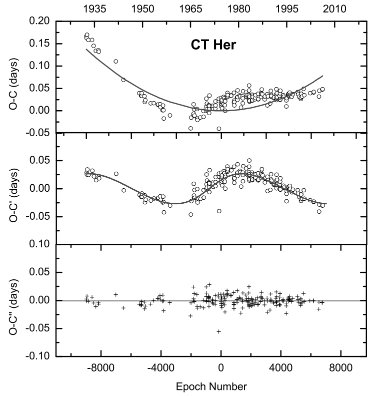

Figure 1: O-C residuals and theoretical fits for CT Her. The upper and middle panels show parabolic and periodic trends of O-C curves. The lower panel shows the residuals from the final theoretical fits.

The results

We have studied the orbital period changes of three oEA type binaries and found that the orbital period of all systems are increasing with a rate of 2.8, 6.0 and 24.7 s/century for AB Cas, CT Her and TW Dra, respectively. Increasing periods must be a result of the mass transfer from the less massive, cooler and Roche lobe filling components to the more massive and pulsating ones. Derived mass transfer ratios of AB Cas, CT Her and TW Dra are 4×10^{-8}, 1×10^{-7} and 5×10^{-7} $M_{\odot}$ yr^{-1}, respectively. The pulsational behaviour, especially the amplitude, of the primary components are expected to change due to the drop of the transferred matter onto their surfaces and/or to the formation of a thin disk or shell around the gainer. This effect has been introduced for the first time in the several year monitoring of pulsational properties of RZ Cas (Mkrtichian et al. 2007). Therefore, following observations of AB Cas, CT Her and TW Dra are strongly encouraged in order to reveal pulsational behavior. In all of these systems, the O-C analysis also shows periodic variations superimposed on parabola, which are expected to be due to the third unseen components around the eclipsing pairs. Minimum masses for these additional bodies are found to be 0.25, 0.26 and 5.8 $M_{\odot}$ for AB Cas, CT Her and TW Dra, respectively.

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Follow-up campaign of the Blazhko star RR Lyr

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Abstract

Stars with changing Blazhko periods challenge the currently proposed hypotheses for the Blazhko effect. RR Lyr, the prototype of the class, is one of the best-studied Blazhko stars but it keeps on surprising its observers. We present the first results from a photometric follow-up campaign in 2006-2007 of the star. Multicolour data were gathered from 4 different observatories in the northern hemisphere. Our analysis focuses specifically on the period behaviour. We confirm the previously reported decrease of the modulation period.

Individual Objects: RR Lyr

Several Blazhko stars are known to have shown changes in their Blazhko period (e.g. XZ Cyg, see LaCluyzé et al. 2004). The prototype of the class, RR Lyr, is also known to have a changing Blazhko period. This was most recently reported by Kolenberg et al. (2006), who discussed photometric data of RR Lyr in 2003-2004 and found a Blazhko period of about 39 days, considerably smaller than the previously known 40.8 days. We kept a close eye on RR Lyrae over the past years.

Our observations were obtained in 2006 and 2007 from Michelbach (Austria), Athens (Greece), Ankara (Turkey), and Wichita (Kansas, US). The new ephemerides are rather different from the one we obtained from our 2003-2004 data, especially for the Blazhko maximum. This may not only be due to a change in the Blazhko period, but also to the start of a new 4-year cycle in RR Lyr.

$$\mathrm{HJD}(T_{\rm max}) = 2453992.591 + 0.566885 \times E_{\rm puls}$$
$$\mathrm{HJD}(T_{\rm Bl.max}) = 2453992.591 + 38.1 \times E_{\rm Blazhko}$$

Using Period04 (Lenz & Breger 2005), we clearly detected the triplet structures typical for Blazhko stars and found in the earlier frequency analyses of RR Lyrae. Compared to our data set from 2003-2004, we obtain different values for the main frequency and the Blazhko frequency. The differences are small but significant. The results obtained with the VSAA (see Kolenberg & Tsantillas, 2008) also confirm our observations of a shorter Blazhko period.

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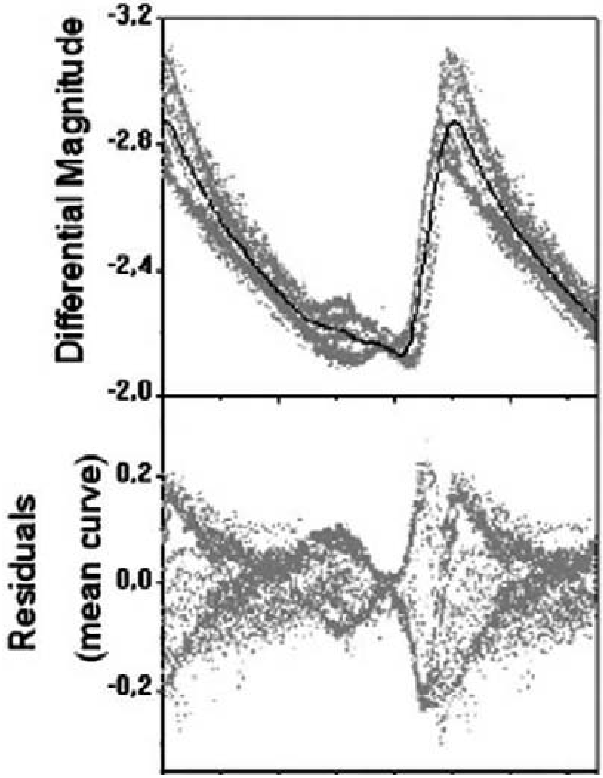

Figure 1: Upper panel: folded light curve of our RR Lyr data in the Johnson *V* filter. The full line represents the mean light curve. Lower panel: residuals after subtracting the mean light curve.

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Spectroscopy of the sdB pulsator HS 2201+2610

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Abstract

We present time resolved echelle spectra of the planet-hosting subdwarf B pulsator HS 2201+2610 and report on our efforts to extract pulsational radial velocity measurements from this data.

Individual Objects: HS 2201+2610, HS 0702+6043

HS 2201+2610 – a planet-hosting pulsating subdwarf B star

Pulsating subdwarf B stars oscillate in short-period *p*-modes or long-period *g*-modes. The sdB star HS 2201+2610 (V 391 Peg) is one of the three known hybrids (Lutz et al. 2008), but it has become famous for different reasons. From its *p*-modes (Østensen et al. 2001, Silvotti et al. 2002), a secular period change due to the star's evolution has recently been measured over a period of 10 years. Furthermore the O–C diagram has revealed a sinusoidal component which is explained by the presence of a planetary-mass companion (Silvotti et al. 2007). To determine the mass of the companion object, the inclination of the orbit needs to be determined. Assuming alignment of the orbital, rotational, and pulsational axes, it should be possible to derive the stellar inclination from a combination of rotational splitting in the photometric frequency spectrum and the projected rotational velocity $v \sin i$ from measured rotational broadening of spectral lines. The measured overall broadening must be corrected for the broadening contribution due to pulsational radial velocities in order to derive the rotational broadening. We therefore initially concentrate on extracting pulsational radial velocities, which requires pulsation phase resolved data.

HET HRS echelle spectra

During two nights each in May and September 2007, spectra of HS 2201+2610 were taken with the HRS echelle spectrograph at the 9m-class Hobby-Eberly-Telescope. The spectra in September were obtained as two series of 95 and 84 20 s-exposures at a resolution of ≈30 000. The resulting signal-to-noise at 5 000 Å is slightly above 3 for individual spectra. When dividing the main pulsation period (349.5 s) into ten phase bins and summing (on average 15) individual spectra corresponding to one phase bin, we obtain a pulsation phase resolved series of ten spectra, each at a signal-to-noise of ≈ 9. A similar data set has been obtained for HS 0702+6043 in January 2008.

Preliminary results and outlook

The series of spectra covers the hydrogen Balmer series from Hβ to Hδ. These observed spectral lines can be cross-correlated with those of an appropriate model spectrum. Our template has been chosen at the spectroscopic parameters $T_{\rm eff}$=30 000 K and $\log\,(g/{\rm cm\,s^{-2}})$=5.5, close to those given by Østensen et al. 2001. From the cross-correlation results for Hβ we do not reliably detect a sinusoidal variation with the phase, and instead give an upper limit of 16 km s^{-1} for the pulsational radial velocity amplitude corresponding to the main photometric period. Results for the other spectral lines and for further pulsation periods are work in progress. This preliminary result, however, already implies that the broadening due to the pulsational radial velocities is small, and it looks like the same is true for the rotational broadening. So while the average of all spectra (including the May 2007 series) will help us to refine the stellar parameters of HS 2201+2610 in a future spectral analysis, it remains a challenge to use them to put constraints on the orbit solution for the planet.

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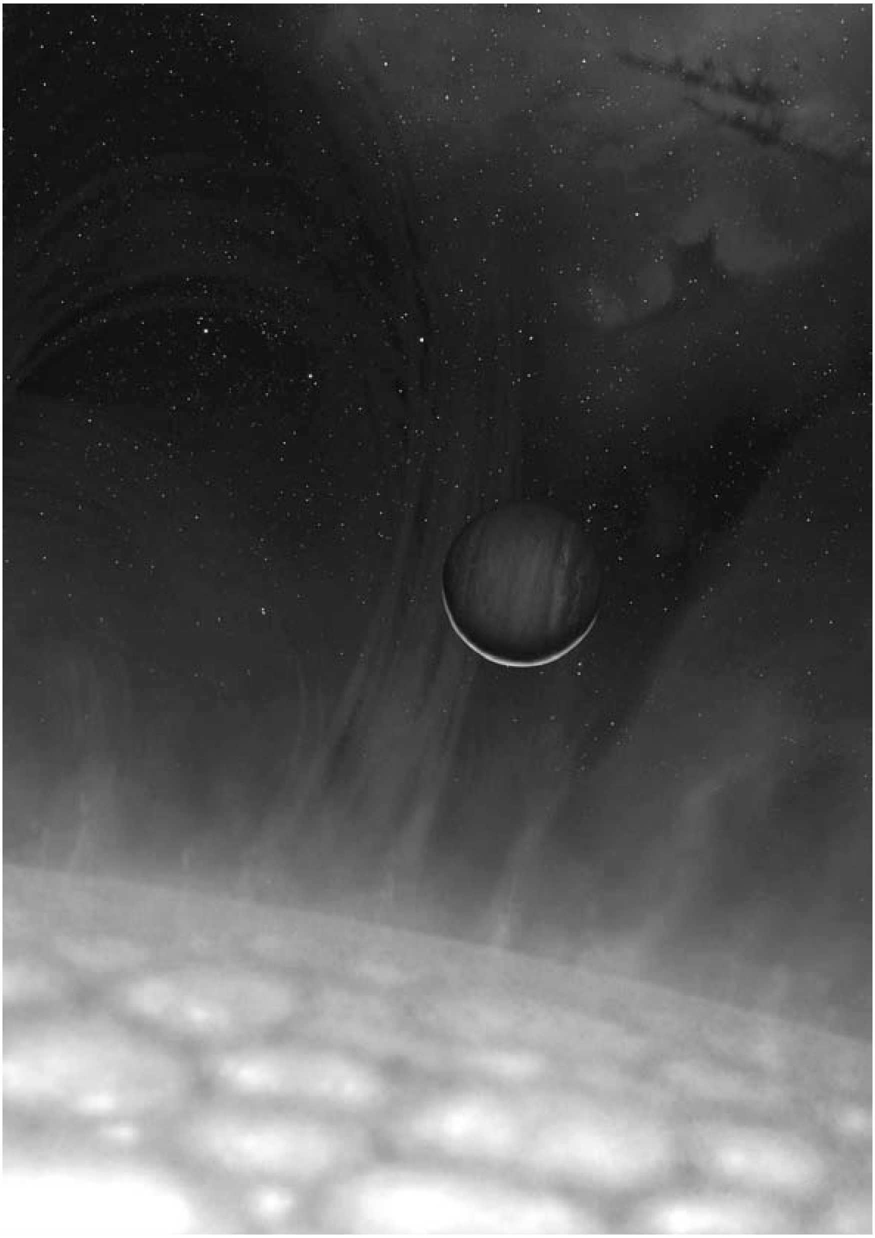

Figure 1: Artist's impression of the HS 2201+2610 system roughly 10^8yrs ago, when the star, at maximum red giant expansion, almost engulfed the planet.

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Frequency analysis of the δ Scuti type pulsations in the semi-detachedeclipsing binary CT Her

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Abstract

We present the latest results of a multisite photometric campaign carried out in 2004-2007 on the Algol-type eclipsing binary system CT Her, the primary component of which is a δ Scuti-type pulsator with a main pulsation period of only 27 min. CT Her belongs to the new class of oscillating Algol-type binary systems. We collected enough data in two passbands to perform a modelling of the light curves using PHOEBE and detected up to 7 significant pulsation frequencies in the frequency range between 45-53 d^{-1}in the B-residual data (independent of the adopted solution for the binary model). The remaining standard deviation of the ca. 7500 B-residuals spread over 4 years is 5.0 mmag.

Individual Objects: CT Her

Objective

From 2004 till 2007 we performed a long-term photometric study of CT Her, a pulsating component of type δ Scuti in a classical Algol-type binary (also called oEA stars, MK04). CT Her is an eclipsing binary of mag 11-12 and spectral type A3V+[G3IV] with a period of 1.7863748 days (SD04). Its primary component pulsates with a main period of 27 min and a total amplitude of 0.02 mag (K04). The science case, the reasons for selection and the results of a first photometric analysis were already described in a previous volume of CoAst (LS07). We report here on the new results obtained after incorporating 2158 additional B-data points collected at the *Observatorio de Sierra Nevada* in the year 2007.

New statistics and progress

The number of useful nights is 18 (filter V) and 47 (filter B). Our data sets now contain slightly more than 1700 photometric measurements in the V filter and over 7500 ones in the (Johnson) B filter.

Table 1: Multi-parameter fit of the B-band residual data of CT Her

Ident.	Freq. (d^{-1})	Formal error (d^{-1})	Ampl. (mmag)	σ_{res} (mmag)	S/N	R (%)
f1	52.936652	0.000012	3.1	5.8	14.1	–
f2	45.702243	0.000026	1.6	5.6	6.3	–
f3	49.203469	0.000016	2.4	5.4	9.9	–
f4	48.571026	0.000028	1.6	5.3	6.5	–
f5	51.249880	0.000021	1.9	5.2	8.2	–
f6	45.435821	0.000032	1.3	5.1	4.9	–
f7	49.642567	0.000038	1.2	5.0	4.9	35

We performed a simultaneous modelling of the data using the programme PHOEBE (version 0.30, PZ05) which is based on the Wilson-Devinney code for solving binary light curves and/or radial velocity data (W90). We used MODE 5 for a classical Algol-type configuration. The surface temperature of the primary component was set to T_1=8700 K (A3V) but T_1=8200 K (A5V) lead to an equally good fit. After subtraction of a consistent solution for both light curves, small-amplitude oscillations with a peak-to-peak amplitude of 0.02 mag were seen in the residual data. We performed the Fourier analysis with Period04 (LB05) and computed successive periodograms after prewhitening of the strongest signal from each previous run. The results of this new analysis are displayed in Table 1. Seven significant frequencies were identified in the largest data set containing 7536 B-band residuals.

Conclusions

The pulsational behaviour of CT Her shows a complex, multiperiodic pattern of frequencies which are all located in the range 45-53 d^{-1}(32-27 min) and appear stable during the years 2004-2007. The binary parameters of CT Her are currently not uniquely determined and radial velocities would be very useful in order to obtain a consistent determination of the absolute parameters of this oscillating Algol-type binary. oEA stars offer the great challenge to study in detail the connection between pulsation and mass transfer between the components of close binary systems, also including the effects of tidal interaction.

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Photometric mode identification methods in eclipsing binaries

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Abstract

We present a comparison of two methods developed to identify modes of nonradial pulsations in eclipsing binary stars. The first method employs the techniques of Eclipsing Mapping (EM), while the second is Direct Fitting of spherical harmonics (DF). Both methods use the effective surface sampling of the eclipses and require photometric data only. The relative merits of the methods are evaluated through tests on synthetic light curves.

Eclipse mapping

The EM method (Horne 1985) is an indirect imaging method used to obtain a best estimate of the original brightness distribution on the stellar surface from photometric data. The best estimate is selected using the Maximum Entropy principle, which chooses the distribution with the least structure (information content) that still explains the observed data. Application of EM to binary systems with pulsating components, explained in more detail by Biro & Nuspl (2005), requires only a minimal set of assumptions about the nature of oscillations and the underlying stellar physics. These include the requirement of axial symmetry for the pulsator (the tidal distortions need to be negligible) and small amplitudes of oscillations (which mustn't affect the shape of the star). We hope to relax these requirements further in future development.

For successful application, the EM method needs detailed knowledge of the eclipsing geometry of the binary, and frequencies of detected pulsations. The result is a reconstructed image of the stellar surface, which can be analyzed quantitatively, based on the properties of spherical harmonics, to estimate l and m.

Direct fitting of spherical harmonics

If the pulsational patterns can be represented as spherical harmonics - which is expected for undistorted, slowly rotating stars - a system of spherical harmonics can be fitted to the light curve directly. The DF method has the advantage of being a linear least squares fitting procedure, thus offering a unique solution. It also requires much less computational effort, since it assumes more about the solution than EM. More importantly, DF may also be used to determine the orientation of the rotation axis using a special transformation property of the spherical harmonics under rotations of the coordinate system:

$$\tilde{Y_{l,m}} = \sum_{m'} \mathcal{D}^{(l)}_{m',m}(\alpha,\beta,\gamma)\, Y_{l,m'} \tag{1}$$

where (α, β, γ) are Euler angles, and $\mathcal{D}$ is the Wigner rotation matrix (Edmonds 1960).

Parameter	Range/value
Base flux	0.3
Amplitude	$0.001 - 0.01$
l	$1 - 4$
Frequency	$0.1 - 0.01P_{orb}$
R_{prim}	$0.1 - 0.5SMA$
R_{sec}	$0.1 - 0.5SMA$
Inclination	$70^\circ - 90^\circ$

Table 1: *The modeling parameters and their scope.*

Reconstruction	l hits [%]		(l, m) hits [%]	
	DF	EM	DF	EM
Single mode	84.3	48.6	61.6	41.7
All modes	70.8	6.9	45.8	4.2

Table 2: The percentages of exact mode *identifications by DF and EM methods for one out of three and all three modes present in the models.*

DF method requires the same input as EM: the light curve, oscillation frequencies and orbital elements of the binary. A mode with given (l, m), looked at from an arbitrary direction, will show up as a linear combination of $2l + 1$ spherical harmonics with the same l: an l-multiplet. The method fits a model of l-multiplets for each mode in the data, and for all possible combinations of l up to a predetermined maximal value. The best l is chosen using χ^2 statistics; then another fitting procedure is used to search for m and the Eulerian angles.

Comparison

We used synthetic light curves with three pulsational modes to test and evaluate both methods. Light curve calculation involves a simple model of the binary system, with spherical stars, circular orbit, monochromatic radiation and linear limb darkening.

We devised a testing scheme allowing us to sample a large parameter space and gather enough results to do statistics, while taking a reasonable amount of computer time. The scheme is set up to randomly select parameters from predefined lists compiled under physical constraints, making a series of unique and unbiased parameter sets. The relevant parameters are given in Table 1, and the results of our tests (based on 70 test cases) in Table 2.

Conclusion

We compared two methods for mode identification in pulsating members of binary systems, both based on photometric data only: the Direct Fitting of spherical harmonics, and the Eclipse Mapping. The methods have been subjected to blind-testing using a grid of eclipsing geometries and pulsation parameters; and while the first results suggest that DF is superior in its ability to retrieve the spherical quantum numbers l and m, it must be noted that the application of this method is strictly limited to *spherical* stars. We continue developing both methods while awaiting for the opportunity to test them on real-life data.

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The oEA star TW Dra - a spectroscopic analysis

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Abstract

We investigate a spectroscopic time series of the oscillating Algol-type star TW Dra to derive basic system and stellar parameters and to prepare for mode identification. From the orbital solution we derive precise masses and get disentangled spectra of the components by using KOREL. For the primary we derive about solar abundance. Computed LSD profiles show a puzzling picture of blue-to-red traveling bumps indicating a rich spectrum of nonradial pulsations. Three pulsation frequencies could be found by using FAMIAS. A first attempt of mode identification indicates that TW Dra shows high-degree modes in the range of l=7-12.

Individual Objects: TW Dra

Observations

TW Dra is a member of the recently established class of the oEA stars (Mkrtichian et al. 2002, 2004), i.e. Algol-type systems with mass transfer where the primary shows δ Sct-like oscillations. Its spectral type is A5 V+K0 III. TW Dra is also part of a close visual binary. The investigation is based on spectroscopic time series taken in 13 consecutive nights in 2007 with the 2-m telescope at TLS. Spectra have a resolution of 33 000 and cover 4 700–7 400 Å.

Analysis

We used KOREL (Hadrava 2004) to derive the orbital solution and to disentangle the spectra of the three components. KOREL also derived the timely varying line strengths (eclipses of TW Dra, third component from the visual binary that contributes to the spectra in dependence on seeing conditions and slit orientation of the spectrograph). From the obtained RV semi-amplitudes and the inclination of the orbit of 86.4° known from photometry, we derived the masses of the primary and secondary to 2.13 and 0.89 $M_\odot$, respectively. The separation of the circular orbit is 12.11 $R_\odot$. Model atmospheres for the hot primary were calculated with the LL-method (Shulyak et al. 2004) and synthetic spectra with the SynthV-method (Tsymbal 1996). The values $T_{\rm eff}$=8150 K and $\log g$=3.88 were taken from the photometric solution and fixed. From an iterative fit of the disentangled spectrum of the primary using the 4895 to 5670 Å range, we derived the micro-turbulence to 2.9 km s^{-1}, $v \sin i$=47 km s^{-1}, and about solar abundance.

We obtained mean line profiles of high S/N by using the least squares deconvolution technique (Donati et al. 1997). Fig. 1 shows the obtained profiles from some of the runs of our time series. The puzzling picture of blue-to-red traveling bumps indicates a rich spectrum of nonradial pulsations. For a first analysis, we only used profiles from out-of-eclipse phases

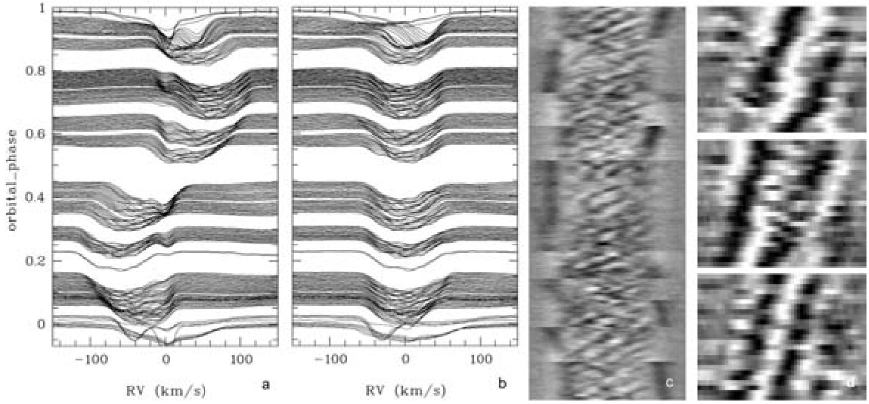

Figure 1: Time series of LSD profiles. a) Original profiles. b) Shifted and corrected for the third component. c) Differential profiles after subtracting the mean profile (in a running order). d) Central parts of profiles ($\pm 50\,\mathrm{km\,s^{-1}}$) averaged into 25 pulsation phase bins. From top to bottom for f_1 to f_3.

which were shifted to the rest frame of the primary and cleaned for the contributions from the second and third component by adjusting rotationally broadened Gaussian profiles (Fig.1c).

We used FAMIAS[1] (Zima 2008) and applied the pixel-by-pixel method and successive prewhitening to determine the oscillation frequencies. We found three modes of f_1=22.90 c d^{-1}, f_2=14.06 c d^{-1}, and f_3=24.72 c d^{-1} but could not detect the 17.99 or 18.95 c d^{-1} found by Kusakin et al. (2001) and Kim et al. (2003) in the photometry. The search in the line profile moments gave no findings. Fig. 1d shows the traveling bumps after averaging the LSD profiles into 25 pulsation phase bins folded with the corresponding period. In this way, the contributions from all other modes are smeared out.

A first attempt to identify the modes with FAMIAS using the FPF method showed that all three modes are high degree modes with l and m in the range of 7 to 12. No unique identification neither in l nor in m could be derived so far. In a next step, we want to improve the mode identification by improving the steps of data reduction to further reduce the influence of the second and third components, using the much more time-consuming multiple frequency analysis in FAMIAS in combination with a light curve analysis, and by modeling the spectra during the eclipses (spatial filtration technique, Gamarova et al. 2003).

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[1] The software package FAMIAS was developed in the framework of the FP6 European Coordination Action HELAS (http://www.helas/eu.org/).

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Observational constraints on intrinsic mode amplitudes of δ Scuti pulsators

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Abstract

Using the azimuthal order, *m*, and the inclination angle, *i*, determined from spectroscopy, the combination of two-color photometry and radial velocity data allows for simultaneous extraction of the spherical harmonic degrees, ℓ, and intrinsic amplitudes, $|\varepsilon|$, of pulsation modes. We present results for the identified modes observed in two well-studied δ Scuti stars: FG Vir and 44 Tau. The correlation between observed photometric amplitudes and intrinsic mode amplitudes is discussed.

Individual Objects: FG Vir, 44 Tau

The method

Daszyńska-Daszkiewicz et al. (2003) proposed a method for inferring the spherical mode degree, ℓ, and the complex parameter, f, which describes the relative bolometric flux variation at the photosphere level, by combining photometric and spectroscopic data. If reliable mode identification is available and the stellar inclination angle is known, this method can also be used to derive intrinsic mode amplitudes, $|\varepsilon| = \langle \delta r/R \rangle_{\rm rms}$.

To apply this method, the photometric and spectroscopic data should preferably be gathered simultaneously to avoid phasing problems. For two well-studied δ Scuti stars, FG Vir and 44 Tau, radial velocity data were aquired during simultaneous photometric campaigns. For both stars, a sufficient number of modes was identified from spectroscopy and the inclination angle was derived (Zima et al. 2006, Zima et al. 2007).

Results for the δ Scuti stars FG Vir and 44 Tau

The derived estimates show that most intrinsic mode amplitudes are around 0.001 for FG Vir, with three modes exceeding this value significantly: ν_1=12.716 c/d (ℓ=1), ν_6=9.199 c/d (ℓ=2) and ν_{13}=12.794 c/d (ℓ=2). In 44 Tau, which is more evolved than FG Vir, the intrinsic amplitudes of most modes are below 0.005. Similar to FG Vir, a few modes have higher $|\varepsilon|$ values: ν_1=6.898 c/d (ℓ=0) and ν_7=7.303 c/d (ℓ=2). More details on these results can be found in Lenz et al. (2008).

In both stars, we find high intrinsic mode amplitudes for the ℓ=2 modes, e.g., in 44 Tau the (ℓ,m)=(2,0) mode ν_7 has an even larger $|\varepsilon|$ than the radial fundamental mode, which is

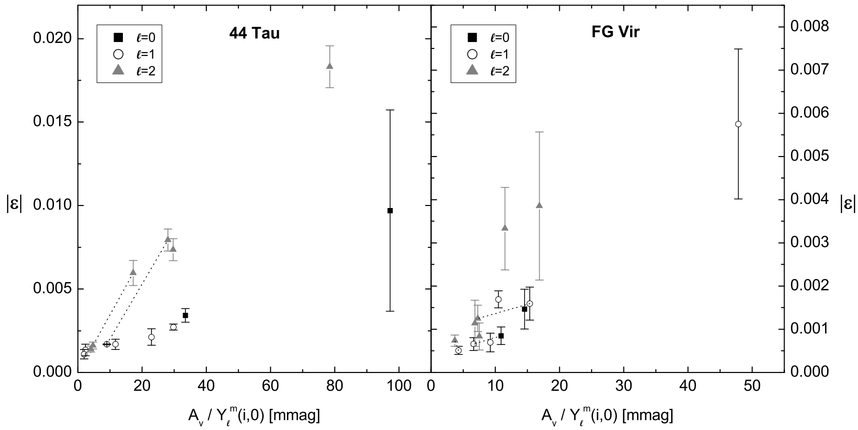

Figure 1: Correlation between derived values of $|\varepsilon|$ and the observed Strömgren y amplitudes divided by the aspect factor of the mode, $Y_\ell^m(i,0)$. The errors of the y amplitudes are smaller than the size of the symbols. If the mode identification is ambiguous, the $|\varepsilon|$ values for all possible (ℓ,m) values are shown and connected by a line.

dominant in photometry. We examined the correlation between intrinsic and photometric amplitudes. To remove the effects of inclination and azimuthal order, the observed Strömgren y amplitudes were divided by the aspect factor of the mode, $Y_\ell^m(i,0)$. Fig. 1 shows that for a given spherical degree, the intrinsic mode amplitude, $|\varepsilon|$, is correlated with the observed value of light amplitudes A_y. The correlation coefficient between $A_y/Y_\ell^m(i,0)$ and $|\varepsilon|$ is 0.70 for FG Vir and 0.76 for 44 Tau. To determine these values, only modes with unique mode identification were used.

Conclusions

Knowledge of the $|\varepsilon|$ values may provide important insights on mode selection in δ Scuti stars and may yield empirical information to test nonlinear oscillation theory. Our results also highlight the importance of obtaining multi-color photometry together with spectroscopy for asteroseismic studies.

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The Algol-type eclipsing binary TZ Eridani: BV photometry and search for pulsations and tertiary component

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Abstract

CCD photometric observations of the Algol-type eclipsing binary TZ Eri have been obtained in B and V filters during 26 nights from December 2007 to February 2008 at the Athens University Observatory. The light curves are analyzed with the Wilson-Devinney code, new geometric and photometric elements are derived, a time series analysis of the observations is applied and a multiperiodic behavior is also discussed. The presence of a third light in the system is considered and our results are compared with those of the O-C analysis for a third body in the system, given by Zasche et al. (2008).

Individual Objects: TZ Eri

Light Curve Analysis and Pulsational Behaviour

The light curves were analyzed with the PHOEBE 0.29D software (Prša & Zwitter 2005) which uses the 2003 version of the Wilson-Devinney code running in MODE 5. The temperature of the primary component and the mass ratio of the system were set as free parameters, using the model of Barblan (1998) as the initial solution while the temperature of the secondary component was fixed in the value derived from the B-V index of the same paper. The contribution of a third light was also considered and the albedo of the secondary component, A_2 was set on 1, with respect to the reflection effect due to the large temperature difference of the two components. The albedo A_1 of the primary component, the gravity darkening coefficients, g_1 and g_2 and the limb darkening coefficients, x_1 and x_2 were set to the theoretical values. The synthetic and observed light curves are shown in Figure 1 (left part), while the derived parameters from the solution are listed in Table 1. The frequency analysis was performed using the data points well outside the primary eclipse, which were substracted from the theoretical light curves using the software PERIOD04 (Lenz & Breger 2005). The results of the frequency analysis are listed in Table 1. Fig. 1 (upper right part) shows the periodogram of the frequencies which are well inside in the range of δ Sct type pulsations. Solution in both filters indicates that the most significant frequency f_1 is about 18.7 c/d while multiple other lower frequencies appear in the periodograms, which are mainly the result of the non-optimal substraction of the binary model and the variations of nightly mean levels not pointed out in the figure. We did not find any reasonable frequency values with amplitudes larger than 2 mmag after prewhitening these frequencies in each filter. Agreement between the solution and the residuals on the longest day is also shown in Fig. 1 (lower right part).

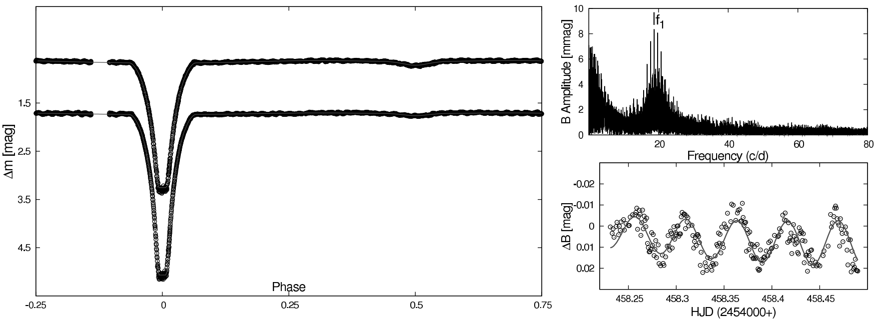

Figure 1: Observational and theoretical light curves (left part) and the periodogram and the frequency analysis on the longest day of observations between the phases 0.405-0.515 (right part).

Table 1: Solution of the light curve and frequency analysis.

Light curve parameters		Pulsational	parameters		
Parameter	Value	Filter	Freq. (c/d)	Amp. (mmag)	S/N
i (degrees)	87.69(7)				
q	0.1773(5)				
T_1, T_2(K)	9307(20), 4562[a]	B	18.7174	8.3	18.2
Ω_1, Ω_2	6.323(12), 2.175		19.6126	3.2	6.7
$[L_1/L_T]_B, [L_1/L_T]_V$	0.9418(14), 0.8892(13)				
$[L_2/L_T]_B, [L_1/L_T]_V$	0.0529, 0.0990	V	18.7177	7.3	11.7
$[L_3/L_T]_B, [L_1/L_T]_V$	0.0053(8), 0.0118(9)		20.6134	2.2	4.1
χ^2	0.499967				

[a] *adopted*
$L_T = L_1 + L_2 + L_3$

Discussion and Conclusions

The present light curve solution shows that TZ Eri is a semi-detached system with the secondary component filling its Roche Lobe. The primary component pulsates with a frequency of 18.7 c/d showing pulsational characteristics very similar to those of a δ Sct star (5-80 c/d, Breger 2000). The contribution of a third light in the system was found to be less than 1% of the total light. The O-C study of the system, showed by Zasche et al. (2008), strongly supports the existence of a tertiary component ($M_{3,min} \sim 1.3 M_{\odot}$) revolving around the eclipsing binary, where mass transfer occurs between the two components. These two independent methods (the O-C analysis and the light curve analysis) come into agreement for the mass exchange between the two components, but not for the existence of the tertiary one. The photometric solution depends on the light contribution of the third body, while the O-C analysis depends only on the period changes. A low luminosity star, having enough mass to affect the binary's orbit might be the connection key between these two methods of analysis. Follow-up observations in other than optical wavelengths are necessary to study the existence and the nature of the additional component.

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The ongoing campaign on the open cluster h Persei (NGC 869)

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Abstract

We present the first photometry and spectroscopy obtained within the ongoing campaign on h Persei (NGC 869).

Individual Objects: h Persei (NGC 869)

Introduction

We have recently increased the number of known β Cephei stars in h Persei (NGC 869) to nine (Majewska-Świerzbinowicz et al. 2008) showing that this cluster is equally a good target for asteroseismic study, as well as its twin, χ Persei (Saesen et al. 2008).

The data and first results

The 2007 Białków photometry was collected on 57 nights between February 17 and November 28 in *UBV* filters using our 60-cm Cassegrain telescope and Andor Tech. DW632 1250 × 1152 CCD camera. Frames were acquired in a sequence through *B*, *V*, and *I* filters. The data were calibrated in a standard way and then reduced using Daophot package (Stetson 1987). A sample light curves for four β Cephei stars, Oo 778, 803, 839, and 1001 (Ooosterhoff 1937), is presented in Fig. 1.

The follow-up spectroscopy for four cluster β Cephei stars (Oo 839, 962, 803 and 1001) was also obtained in 2007 in David Dunlap Observatory (Canada) during 13 nights between September 9 and October 3. The reduction of these data is underway; a sample spectrum of Oo 839 is shown in Fig. 2. The 2007 photometric and spectroscopic data were intended to be the first part of a multisite campaign on this cluster which we are going to carry out in autumn-winter 2008/2009.

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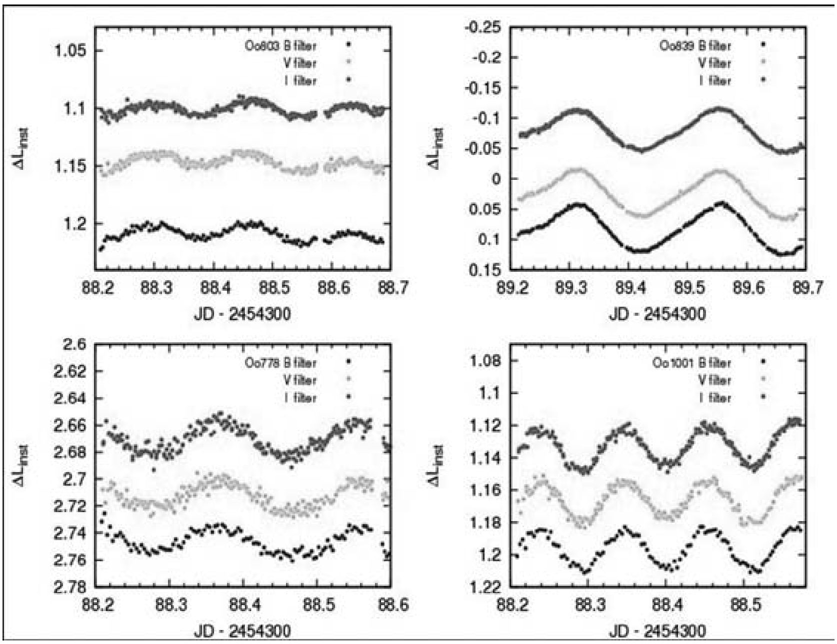

Figure 1: One-night B (top), V (middle) and I (bottom) light curves of β Cephei stars: Oo803, Oo839, Oo778 and Oo1001 in Białków 2007 photometry.

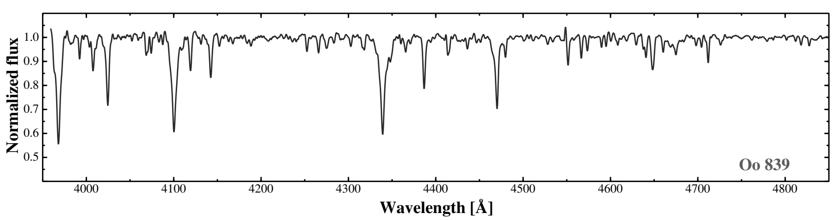

Figure 2: A sample DDO spectrum of Oo839.

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The near-contact system BF Velorum: New BVRI photometry and search for pulsations

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Abstract

A photometric analysis of the short-period eclipsing binary system BF Velorum, based for the first time on complete new BVRI CCD light curves obtained by the authors, is presented. Light variations characteristic of a pulsating component in the system are evident in these light curves. The new photometric solution obtained with the Wilson-Devinney program reveals that BF Vel is a semi-detached (near-contact) system with the secondary star filling its Roche lobe. Absolute elements of the system were calculated, and the evolutionary status of its members was determined. An analysis of the pulsation in the B filter using the Period04 program was also performed.

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A Study of δ Scuti stars in open clusters NGC 1817 and NGC 7062

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Abstract

We report spectroscopic and photometric observations of ten δ Scuti stars and one eclipsing binary from the open cluster NGC 1817, and three δ Scuti stars from the open cluster NGC 7062. For each target, we measure the projected rotational velocity, $v \sin i$, the radial velocity, RV, the effective temperature, $T_{\rm eff}$, and the surface gravity, $\log g$. All stars are found to be moderate or fast rotators. We classify three targets as new single-lined spectroscopic binaries and one target as a double-lined spectroscopic binary.

Individual Objects: NGC 1817, NGC 7062

Observations

The observations were carried out at the Nordic Optical Telescope (La Palma, Canary Islands, Spain). We used the Andalucía Faint Object Spectrograph and Camera, ALFOSC, for spectroscopy, and the ALFOSC/FASU setup with a set of uvbyβ Strömgren filters for photometry.

Analysis and Results

We derived $T_{\rm eff}$ and $\log g$ for each target using the calibration of Napiwotzki et al. (1993) and the Strömgren indices of Balaguer-Núñez et al. (2004) and Peniche et al. (1990) for stars in NGC 1817 and NGC 7062, respectively. We used these $T_{\rm eff}$ and $\log g$, and the ATLAS9 and SYNTHE software (Sbordone 2005, Sbordone et al. 2004) to compute the model atmosphere and the synthetic spectrum for each target.

We measured $v \sin i$ of the stars by comparing the observed spectrum with the synthetic one. We used mainly strong hydrogen lines and, whenever possible, several metallic lines from Table 3 of Rasmussen et al. (2002). We found that all our targets are moderate or fast rotators and therefore difficult targets for asteroseismic analysis.

The radial velocities were computed in two ways: with the cross-correlation method and the fxcor task provided by IRAF, and with the method described by Ruciński (1999). In both cases we used synthetic spectra as templates.

Several stars show indications of variable radial velocity. NGC 1817-V1, -V18 and NGC 7062-V1, we classify as new SB1 systems. In NGC 1817-V4, in the profile of the broadening function we see the evidence of the presence of a secondary component, see Fig. 1, and classify this star as a new SB2 system. The identification numbers of stars in NGC 1817 and NGC 7062 are from Arentoft et al. (2005) and Freyhammer et al. (2001), respectively.

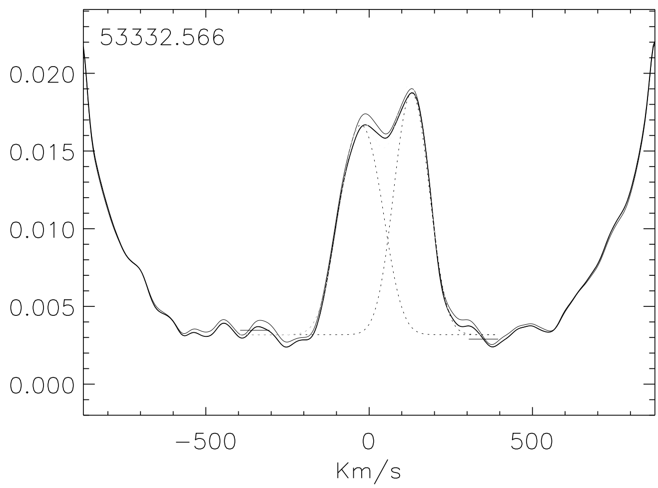

Figure 1: The broadening function of NGC 1817–V04, observed on HJD 2 453 332.566. The two components plotted with dashed lines are clearly visible. The combined fit consists of an instrumental broadening convolved with a rotational broadening profile.

We note that in some cases it was difficult to see the difference between a binary and a fast rotator with the spectroscopic resolution of ALFOSC. Also the observed high spread in *RV* is partially due to the difficulty of measuring precise values of *RV* for fast rotating stars.

Acknowledgments. The data presented here have been obtained using ALFOSC, which is owned by the Instituto de Astrofisica de Andalucía (IAA) and operated at the Nordic Optical Telescope under agreement between IAA and the NBIfAFG of the Astronomical Observatory of Copenhagen. We made use of the SAO/NASA Astrophysics Data System (ADS). J.M.-Ż. thanks the Danish Natural Science Research Council and the HELAS Consortium for the financial support.

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Nonradial modes in classical cepheids

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Abstract

Systematic search for multiperiodicity in the LMC Cepheids (Moskalik et al. 2004) has led to the discovery of low-amplitude nonradial modes in a substantial fraction of overtone pulsators. We present a detailed discussion of this new type of multimode behaviour. We also discuss first detections of nonradial modes in FU/FO double-mode Cepheids.

Individual Objects: LMC

LMC Cepheids: Data and Analysis

Our search for multiperiodic variations in Cepheids of the Large Magellanic Cloud (LMC) was performed with I-band DIA-reduced OGLE-II photometry (Żebruń et al. 2001). The data was analyzed with a standard consecutive prewhitening technique. First, we fitted the data with a Fourier sum representing variations with the dominant (radial) frequency. The residuals of the fit were then searched for secondary frequencies with a Fourier transform.

We analyzed all single mode and double mode Cepheids listed in the OGLE-II catalogs (Udalski et al. 1999; Soszyński et al. 2000), nearly 1300 stars in total. Full results of this survey are presented elsewhere (Moskalik & Kołaczkowski 2008). Here we discuss only our findings concerning the presence of nonradial modes in classical Cepheids.

First Overtone Cepheids

The OGLE-II catalog lists 462 first overtone (FO) Cepheids. We detected residual power in 64 of them. In 42 variables, which constitute 9% of the entire LMC sample, we were able to resolve this power into individual frequencies. (We consider two frequencies to be resolved if $1/\Delta f < 600$ days). Following notation originally introduced for RR Lyrae variables (Alcock et al. 2000), we call these stars FO-ν Cepheids.

In most of the FO-ν Cepheids only one secondary peak was detected, but in several variables two peaks were found. In all cases they have extremely small amplitudes. With the exception of a singe star, the secondary-to-primary amplitude ratio, A_ν/A_1, is always below 0.1, with the average value of 0.048. We note, that secondary peaks detected in the LMC first overtone RR Lyrae stars are typically almost an order of magnitude stronger, with $A_\nu/A_1 = 0.31$ on average (Nagy & Kovács 2006).

It is easy to check, that period ratios measured in FO-ν Cepheids are not compatible with those of the radial modes. This implies, that the secondary frequencies detected in these pulsators must correspond to nonradial modes of oscillations.

The secondary frequencies in FO-ν Cepheids come in two different flavours. In 37 variables they are located close to the primary (radial) frequency, within $|\Delta f| < 0.13$ c/d. In 84% of cases, secondary frequencies are lower than the primary one ($\Delta f < 0$). When two secondary peaks are present, they always appear on the same side of the primary peak. In 7 FO Cepheids a secondary periodicity of a different type was found: a high frequency mode, with the period ratio of $P_\nu/P_1 = 0.60 - 0.64$. Such a period ratio places the nonradial mode just below the frequency of the (unobserved) fourth radial overtone. The two types of nonradial modes are not mutually exclusive. Indeed, in two Cepheids both a high frequency secondary peak and a secondary peak close to the primary frequency were found.

Although the population of FO Cepheids in the LMC extends down to periods as short as 0.4 day, we detected nonradial modes only in stars with $P_1 > 1.2$ day. In fact, the incidence rate of nonradial modes systematically increases with the primary pulsation period, reaching 19% for stars with $P_1 > 3.0$ day. We interpret this behaviour as a selection effect: the Cepheids with longer periods are brighter, consequently it is easier to detect very low amplitude secondary periodicities in their lightcurves. If so, then the true incidence rate of nonradial modes in LMC overtone Cepheids can be significantly higher that 9% derived in this survey.

Fundamental Mode Cepheids

OGLE-II catalog lists 719 fundamental mode (FU) Cepheids. We searched all of them for secondary periodicities. We found no nonradial modes in the FU Cepheids of the LMC.

FU/FO Double-Mode Cepheids

In the course of systematic frequency analysis of OGLE-II Cepheids, we discovered 4 new fundamental/first overtone (FU/FO) double mode pulsators. Together with stars listed in the OGLE-II catalog, this brings the total number of LMC Cepheids of this class to 23. We found nonradial modes in 3 of them. These are the first detections of nonradial modes in the FU/FO double-mode Cepheids. In the following, we call these stars FU/FO-ν Cepheids. In two cases the secondary mode appears very close to the first (radial) overtone. The values of the frequency differences $\Delta f = f_\nu - f_{FO}$ are very similar to those observed in the FO-ν Cepheids. In the third star, the secondary mode was found at a high frequency, with a period ratio of $P_\nu/P_{FO} = 0.623$. This is the same mysterious period ratio, which is frequently observed in the FO-ν Cepheids. Clearly, nonradial modes detected in the FU/FO-ν Cepheids are somehow related to the first radial overtone and their frequencies are drawn from the same distribution as in the case of the FO-ν Cepheids.

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Multiperiodic RR Lyrae stars in ω Centauri

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Abstract

We have conducted a systematic search for multiperiodic pulsations in RR Lyrae-type stars of the globular cluster ω Centauri. Secondary periodicities close to the primary pulsation frequency have been detected in 17 out of 70 studied fundamental mode pulsators (RRab) and in 31 out of 81 overtone pulsators (RRc). Because of the observed period ratios, these newly detected periodicities must correspond to nonradial modes. Their beating with the primary radial pulsation leads to a slow amplitude and phase modulation, commonly referred to as the Blazhko effect. The incidence rate of Blazhko modulation in ω Cen RRab stars ($24 \pm 5\%$) is similar to that observed in the Galactic Bulge. In the case of ω Cen RRc stars, the incidence rate of Blazhko effect is exceptionally high ($38 \pm 5\%$), more than 3 times higher than in any other studied population.

Individual Objects: ω Cen

Results

We have conducted a systematic search for multiperiodic pulsations in RR Lyrae-type stars of ω Centauri. We used data of the Cluster AgeS Experiment published by Kaluzny et al. (2004).

We have detected secondary periodicities close to the primary pulsation frequency in 17 out of 70 fundamental mode pulsators (RRab stars) and in 31 out of 81 first overtone pulsators (RRc stars). The derived period ratios are incompatible with those of the radial modes and must correspond to nonradial modes of oscillations.

In RRab variables two secondary peaks have been detected in most cases. Together with the primary peak, they form an equally spaced triplet of frequencies, centered on the primary peak (RRab-BL stars). In 3 RRab variables only one nonradial mode is present (RRab-ν1 stars). Finally, a more complicated pattern of four nonequidistant peaks has been found in variable V11.

In RRc variables usually only one nonradial mode has been detected (RRc-ν1 stars). Equidistant triplets have been found only in 4 variables (RRc-BL stars). However, more complicated patterns are seen in RRc stars much more frequently than in RRab stars. In 6 variables we have detected nonequidistant triplets of modes. In 4 other RRc stars, even richer frequency patterns with up to seven nonradial modes have been found.

Our findings are summarized in Tables 1. In ω Cen RRab stars the incidence rate of nonradial modes is $24.3 \pm 5.1\%$. This is twice the rate observed in the LMC, but roughly the same as the rate in the Galactic Bulge. For ω Cen RRc stars the incidence rate of nonradial modes is $38.3 \pm 5.4\%$, which is exceptionally high. This is by far the highest rate among all studied RRc populations, being $\sim$3 times higher than in the Bulge and $\sim$4 times higher than in the LMC.

Table 1: Incidence rates of nonradial modes in RR Lyrae-type stars of Large Magelanic Cloud, Galactic Bulge and ω Centauri.

	LMC Alcock et al. (2003)		Bulge Mizerski (2003)		Bulge Collinge et al. (2006)		ω Cen this work	
RRab	6158		1942		1888		70	
RRab-ν1	400	6.5%	243	12.5%	167	8.8%	3	4.3%
RRab-BL	331	5.4%	143	7.4%	282	14.9%	13	18.6%
RRab-other	20	0.3%	86	4.4%	75	4.0%	1	1.4%
All NR	751	12.2%	472	24.3%	524	27.8%	17	24.3%

	LMC Alcock et al. (2000)		LMC Nagy & Kovács (2006)		Bulge Mizerski (2003)		ω Cen this work	
RRc	1143		1161		771		81	
RRc-ν1	24	2.1%	46	4.0%	22	2.9%	17	21.0%
RRc-BL	28	2.4%	53	4.6%	30	3.9%	4	4.9%
RRc-other	8	0.7%	13	1.1%	41	5.3%	10	12.3%
All NR	60	5.2%	112	9.6%	93	12.1%	31	38.3%

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Main sequence pulsating stars in the galactic disk

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Abstract

The analysis of the OGLE-II photometry in Galactic fields revealed variability of about 9500 stars brighter than 17 mag and periods shorter than 5 days. Regarding their amplitudes and periods, we conclude that this sample of variable stars consists mainly of main sequence pulsators, namely β Cephei, SPB, δ Scuti and γ Doradus. However, we cannot exclude that other types of variability e.g. ellipsoidal binaries or low-amplitude W UMa stars contaminate the sample. Since periods and amplitudes alone are not sufficient to make unambiguous classification, we have supplemented the OGLE-II observations with the UBV photometry collected with 1-m telescope in Siding Spring Observatory.

The OGLE-II data analysis

Searches for the new main sequence pulsators in the currently available databases require large computational power and algorithms which can be run in the automated way. Both these needs come from the fact that the databases contain very often photometry of several millions of stars. Currently, we implemented algorithms which require only a small amount of interactive work.

As a continuation of our searches for main sequence pulsating stars in the large photometric databases (Narwid et al. 2006, 2007, Pigulski 2005, Pigulski & Pojmański 2008), we have analysed OGLE-II (Udalski et al. 1997, Szymański 2005) photometry of 3.8×10^5 stars obtained in 21 Galactic fields situated in Carina, Centaurus, Norma and Scorpius. The observations were carried out in the years 1997–2000 and covered roughly 4.6 square degrees in the sky.

Our analysis of OGLE-II photometry consisted of the automatic extraction of up to five terms in Fourier amplitude spectrum and consecutive pre-whitening of the periodicities which were found. At each step of pre-whitening, we checked if the new frequency is a combination, harmonic or subharmonic term. Neural networks were used as a relatively fast and automatic classification method. We have tested ten different architectures of networks (different quantity of hidden layers) for which we used a mixture of periods, amplitudes and optionally colour indexes for known β Cephei, SPB, δ Scuti and γ Doradus stars as training data. This analysis was done for all 380,000 stars brighter than 17 mag found by OGLE-II in the fields mentioned above. We have also supplemented OGLE-II observations with the UBV photometry collected with 1-m telescope in Siding Spring Observatory in 2007. Because the periods and amplitudes we derived are not sufficient to make unambiguous classification, we used the UBV photometry to distinguish between different types of pulsators, especially between β Cephei and δ Scuti stars.

Preliminary results

Using OGLE-II light curves for stars in the Galactic disk, we searched for main sequence pulsating stars, namely β Cephei, SPB, δ Scuti and γ Doradus stars. For this reason, our search was focused on stars that showed well-defined periodic variations with periods shorter than 5 days. In total, we found about 9500 such variable stars. Many of them appeared to be multiperiodic which is a very strong indication of pulsations as a cause of variability. The majority of them (86 %), however, shows mono-periodic variability in brightness. This result is clearly a consequence of not-so-good detection threshold and low amplitudes that are typically observed in main sequence pulsators. The distribution of periods shows many stars with periods in the range between 0.8 and 1.25 d. This range is typical for SPB and γ Doradus stars, but we cannot exclude other types of variability, especially in the case of monoperiodic stars. The distribution we mentioned has another maximum for periods equal to about 0.03 d, which corresponds to δ Scuti type of variability. The amplitudes of the variables are small, typically below 20 mmag, but there are stars with amplitudes up to 0.2 mag.

There are about 150 multiperiodic variables that show both short-period (typical for β Cephei and δ Scuti) and long-period (with periods typical for SPB or γ Doradus) variability. They are good candidates for hybrid β Cephei/SPB stars or δ Scuti/γ Doradus stars. Such stars were discovered recently and are seem particularly interesting targets for advanced seismic studies.

In the instrumental colour-colour diagram, (U−B) vs. (B−V), β Cephei and δ Scuti separate quite well. Therefore, the UBV photometry carried out in the OGLE-II Galactic fields allowed us in most cases to distinguish between β Cephei and δ Scuti stars. However, due to the limiting magnitude of the U-filter photometry, this was only possible for the brightest stars.

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The pulsations of the B5IVe star HD 181231 revealed by CoRoT

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Abstract

We present the first results of the analysis of the light curve of the B5IVe star HD 181231 obtained during a long run (5 months) of the CoRoT mission. The light curve shows clear pulsations and even beating effects. Several frequencies are detected. Ground-based spectroscopic data have also been analyzed and help to determine the rotation frequency and identify pulsation modes.

Individual Objects: HD 181231

HD 181231

HD 181231 is a B5IVe star of magnitude V=8.58 observed by CoRoT during 156 days (see Fig. 1). The fundamental parameters of this star have been determined from 72 high-resolution FEROS spectra (PI Poretti): Teff $\sim$ 13700 K, logg $\sim$ 3.63, vsini $\sim$ 169 km/s. Using an angular velocity of 80 to 99% of the critical angular velocity, this results in i $\sim$ 40 deg and $f_{\rm rot} \sim 0.95$ c.d^{-1}. For $f_{\rm rot}$ to be below 0.7 c.d^{-1} would require extra mixing in HD 181231.

Results

The CoRoT light curve shows variations with a maximum amplitude of 11 mmag (Fig. 1) and a peak-to-peak point scatter due to noise of less than 0.8 mmag. A frequency search provides $\sim$30 frequencies. However, most of the variations, including the clear beating effect, can be reproduced using only 2 independent frequencies, $f_1 = 0.62$ c.d^{-1}, $f_2 = 0.69$ c.d^{-1}, and the first harmonic of f_1.

A study of the line-profile variations in the FEROS data of this star has also been performed. The frequency f_2 is detected in spectroscopy as well. A phase diagram indicates that it corresponds to a pulsation mode dominated by l=3 or 4. Other frequencies observed with CoRoT are not detected in spectroscopy.

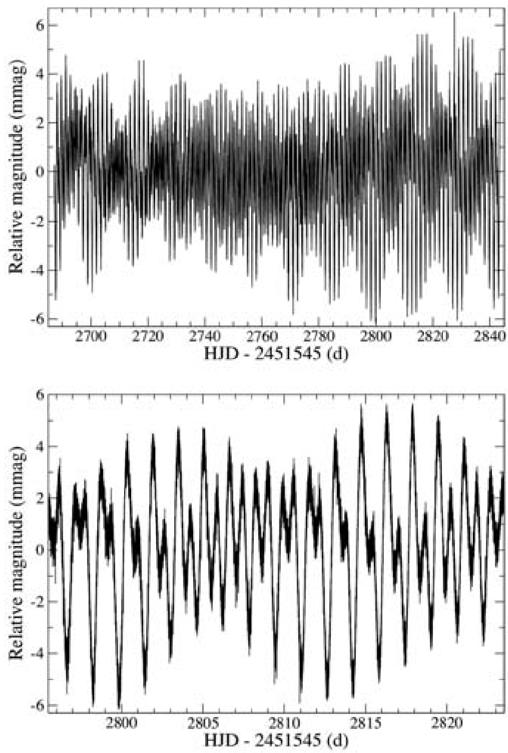

Figure 1: Full 156-day (left) and zoom (right) of the detrended CoRoT light curve.

Discussion and conclusion

The high accuracy of the CoRoT data and the length of the observations (156 days) allows us to detect ∼30 frequencies in HD 181231 with a frequency resolution of 0.006 c.d^{-1} (75 nHz). In particular, two main frequencies are detected: one of them (f_2) corresponds to a pulsation mode with l=3 or 4, as shown from spectroscopy, the other one (f_1 or 2*f_1) could be interpreted in terms of pulsation as well. None of these two frequencies correspond to the rotation frequency as determined from spectroscopy. Harmonics and combinations of these frequencies are also detected. Finally, additional frequencies, probably due to other pulsation modes, are detected with a smaller amplitude and much less impact on the light curve. The identification of these modes will require models taking into account the specificity of Be stars, in particular fast rotation.

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Atmospheric parameters of the β Cephei star HD 167743

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Abstract

We determined the atmospheric parameters and chemical abundances of β Cephei star HD 167743.

Individual Objects: HD 167743

Introduction

HD 167743 = BD -15°4909 = ALS 9453 (α(J2000)=$18^h17^m16^s$, δ(J2000)= 15°27'06", V = 9.59 mag) is the β Cephei variable discovered by Pojmański & Maciejewski (2005) on the basis of ASAS data. The pulsational spectrum of HD 167743 consists of at least three frequencies, indicating that this object is an attractive target for asteroseismology (Pigulski 2005). Seismic modelling of the β Cephei variables is an important tool in understanding the physics of early B-type stars on (or close to) the main sequence. A good knowledge of their atmospheric parameters and chemical abundances is an essential input for correct mode identification and interpretation of internal structure of these stars. Here we present the atmospheric parameters and chemical abundances of HD 167743.

Observations and analysis

Five high-resolution (R = 48000), high signal-to-noise (S/N $\sim$ 100) spectra of HD 167743 were obtained in May 2007 with the FEROS spectrograph at the ESO 2.2-m telescope at La Silla Observatory, as part of the 079.A-9008(A) program. The exposure times ranged from 420 to 1500 seconds. The spectral range extended from 3600 to 9200 Å. All five spectra were normalised, cross-correlated and co-added in order to eliminate the effect of pulsations and to increase the quality of the spectrum.

In order to determine synthetic spectra, we used the hybrid method, that combines the LTE and NLTE approaches. First, hydrostatic, plane-parallel, line-blanketed LTE models of the atmospheres were calculated with the ATLAS 9 code (Kurucz 1996). Then, NLTE population numbers and synthetic spectra were derived using DETAIL and SURFACE codes (Butler 1984). The DETAIL code solves radiative transfer and statistical equilibrium equations, while the SURFACE code calculates the spectrum.

The adopted method of analysis consisted of comparison of high-resolution spectrum $f_{\rm obs}$ with theoretical spectra $f_{\rm teo}$. The shape of the spectrum depends on many parameters, like effective temperature $T_{\rm eff}$, surface gravity $\log g$, chemical abundances of elements $\log \epsilon_{\rm X}$, radial velocity $V_{\rm rad}$, rotational velocity $V \sin i$ and microturbulence ξ. The value of effective

Table 1: Average NLTE abundances $\log \epsilon_X$ (by convention, $\log \epsilon_H = 12$) and He/H value, together with errors : line-to-line scatter (σ_i), variation of abundance for $\Delta T_{\rm eff} = \pm 1000$ K ($\sigma_{T_{\rm eff}}$), the same for $\Delta \log g = \pm 0.1$ dex ($\sigma_{\log g}$) and for $\Delta\xi = \pm 1$ km s^{-1} (σ_ξ). The total error $\sigma_{\rm Tot}$ is calculated as follows: $\sigma_{\rm Tot} = (\sigma^2_{T_{\rm eff}} + \sigma^2_{\log g} + \sigma^2_\xi + \sigma^2_i)^{1/2}$. The number of analysed lines is given between brackets. The last column gives the solar abundances derived from 3D hydrodynamical models (Grevesse et al. 2007).

	He/H (5)	C (5)	N (12)	O (18)	Al (3)	Si (7)	S (1)	Fe (6)
$\log \epsilon_X$	0.144	8.43	7.81	8.75	6.33	7.41	7.27	7.40
σ_i	0.025	0.094	0.141	0.107	0.256	0.247	0.120	0.077
$\sigma_{T_{\rm eff}}$	0.003	0.120	0.025	0.110	0.080	0.045	0.125	0.015
$\sigma_{\log g}$	0.004	0.001	0.015	0.060	0.055	0.030	0.035	0.045
σ_ξ	0.011	0.040	0.030	0.055	0.120	0.035	0.040	0.020
$\sigma_{\rm Tot}$	0.028	0.158	0.147	0.174	0.299	0.255	0.181	0.093
Sun	0.085	8.39	7.78	8.66	6.37	7.51	7.14	7.45

temperature was determined from the analysis of Si lines in different ionization stages. Surface gravity was calculated from Balmer lines. Microturbulence was derived from O II lines of different strength. In order to optimize the other parameters, we used classical least-squares fitting method (LS-method), i.e. we minimized the differences between observed and theoretical spectra, RMS $= \left[\sum(f^2_{\rm obs} - f^2_{\rm teo})\right]^{1/2}$. In the LS-method, the corrections to analysed parameters were determined in each iteration step. The process was repeated untill the best set of parameters in question was obtained.

Results and conclusions

We determined $T_{\rm eff}$ =24500 K, $\log g$ =3.8 dex, ξ =5 km s^{-1} and abundances of chemical elements of new β Cephei star HD 167743. The adopted errors of $T_{\rm eff}$, $\log g$ and ξ result from steps in our grid of theoretical fluxes, and are equal to 1000 K, 0.1 dex and 1 km s^{-1}, respectively. We found moderate rotational velocity, $V \sin i$ =57$\pm$6 km s^{-1}, allowing for abundance analysis. The derived chemical abundances are presented in the Table 1. Eight elements were considered: He, C, N, O, Al, Si, S and Fe. For all but one element (sulphur), more than one spectral line was available. Within the errors, all obtained values are consistent with the solar abundances. Only helium abundance is a little higher than the solar one. The overall metallicity Z =0.014$\pm$0.002 was calculated assuming that all elements not considered in this work have solar abundances as in the paper of Grevesse et al. (2007). All the pulsational and atmospherical characteristics of HD 167743 indicate that this is an interesting object for further observations and seismic modelling.

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Line profile variations in the bright subdwarf B star Balloon 090100001

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Abstract

We have acquired time series of high resolution Echelle spectra for the bright pulsating subdwarf B star Balloon 090100001. The data consist of six nights spanning from August to December, 2006. At least five independent frequencies are retrieved from the frequency analysis, both in the *p*- and the *g*-mode domain. Preliminary results on mode identification for the dominant peak are presented.

Individual Objects: Balloon 090100001

Introduction

The relative faintness of pulsating B-type hot subdwarfs (sdBs, $B \geq 12$) difficults their asteroseismic study, since the required precision for an observational mode identification is extremely demanding. Here we attempt the application of line profile variations analysis for the dominant mode of the pulsating sdB Balloon 090100001. With this purpose, we acquired with FIES@NOT ~1600 high resolution spectra over 6 nights from August until December, 2006.

Frequency analysis

Cross-correlation profiles (ccp's) were produced for each individual frame, merging the information from metal lines into a single profile with higher signal-to-noise. The software package FAMIAS (Zima 2008) was used to compute the amplitude spectrum of the time series ccp's, shown in Fig.1. While a further analysis will be presented elsewhere, we note the dominant peak at 2.80744 mHz (f), and the first confirmed spectroscopic detection of *g*-modes in an sdB star.

Phase folding to the dominant mode

Since f has been accurately determined, frames within the same phase-bin were combined to further increase the signal-to-noise. The equivalent width (EW) and first three moments computed for 25 phase-bins are plotted in Fig.1. The EW and 1st moment vary with a phase shift of $\sim \pi/2$, as expected for adiabatic oscillations. The 2nd moment shows a clear dependence with $2f$, a signature of an $m = 0$ mode (Aerts et al. 1992), in agreement with Baran et al. (2008) and Telting et al. (2008). In a forthcoming paper, we will constrain the

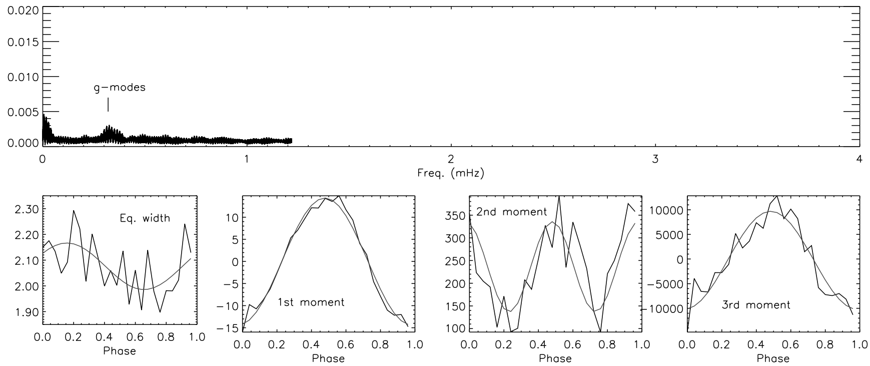

Figure 1: Top panel: amplitude spectrum obtained from the time-series ccp's. Bottom four panels: EW and first three moments computed for 25 phase-folded ccp's, using $f = 2.80744$ mHz. In red, a *sin(f)* fit, *sin(2f)* for the 2nd moment.

dominant peak mode identification (MI) using moments information. MI for other modes will be also explored, as well as the influence of temperature effects on MI.

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Prediciting amplitude variations of physical parameters from spectroscopic modelling of the pulsating sdBV Balloon 090100001

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Abstract

In order to interpret our extensive spectroscopic time-series of the high amplitude sdBV pulsator Balloon 090100001 we have undertaken an extensive exercise to model the variations in effective surface temperature, gravity, velocity as well as photometry throughout the pulsational cycle for different pulsational ℓ and m's. Here we present the results of this modelling demonstrating that the amplitude ratios of temperature and gravity, as determined by classical fitting of observed spectra on model grids, can be used as reliable indicators of the pulsational degree ℓ.

Günter Houdek, Paul Beck, Alosha Pamyatnykh and Patrick Lenz at the conference dinner

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Validity domain of a perturbative approach for rotational effects

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Abstract

Among the methods used to investigate the effect of rotation on oscillation frequencies of stellar pressure modes, we consider here perturbation techniques and direct numerical integrations of a two dimensional eigenvalue system – nonperturbative approach.

Knowing the accuracy of asteroseismic data provided by CoRoT, the issue is to determine whether it is sustainable to take the effect of rotation on stellar oscillations into account with a perturbative approach, or if we should adopt a nonperturbative method that could be much heavier numerically.

The aim of this study is to determine the limits – in terms of rotational angular velocity – of a perturbative approach to model the effects of rotation on both structure and oscillation frequencies.

Until now, 2D nonperturbative oscillation code has only been developed for polytropic models but not for realistic models of stars. Thus, we have used a polytropic model to compare the results of a 2D nonperturbative oscillation code provided by D. Reese, and a 1D second order perturbative one.

For models whose angular velocity of rotation is that of a δ Scuti type star, say 70 – 145 km s^{-1} , we find a relative frequency difference between the results of the two codes of 0.03% to 0.17%. Considering an optimistic evaluation of uncertainties on CoRoT frequency splittings mesurements – 0.2 μHz about 500 μHz: relative frequency uncertainty 0.04% – we can already conclude that the perturbative method seems to be acceptable for a 2 solar radius star up to about 100 km s^{-1} but not further. We expect to push the validity limits of this method a little further taking into account additional corrections such as near-degeneracy coupling – work in progress.

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Physical parameters determination of the RR Lyrae stars RU Psc, SS Psc and TU UMa

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Abstract

Empirical determination of the physical characteristics of RR Lyrae stars is important because their accurate modeling requires knowledge of precise metallicity, effective temperature, surface gravity, luminosity and period of pulsation. Some of these parameters can be estimated from Fourier light curve decomposition (Simon & Clement 1993). Furthermore, *uvby*β photoelectric photometry can also be used to estimate some physical parameters from the comparison with synthetic colours (Lester et al. 1986). Strömgren *uvby*β photometry of the RR Lyrae stars RU Piscium (RRc), SS Piscium (RRc) and TU UMa (RRab) has been acquired. We report the values of $T_{\rm eff}$, M_V, [Fe/H] and $\log g$.

Individual Objects: RU Psc, SS Psc, TU UMa

Observations

The *uvby*β data were acquired in June-July of 1989, 1992, 1995, 2004, 2005 and 2008 at the San Pedro Mártir (SPM) Observatory, Mexico, with a six-channel spectrophotometer attached to the 1.5 m telescope.

Period determination

- **RU Psc**. The period given by Kholopov et al. (1987) and Mendes de Oliveira & Nemec (1988) of 0.390385 d was proved incapable of producing a coherent light curve in our observations. A period analysis of our whole data set of 321 points spanning 2148 days with PERIOD04 (Lenz & Breger, 2005) yielded a period of 0.391299 d $\pm$ 0.000001 d.

- **SS Psc**. Kholopov's period of 0.28779276 d produced small maximum light displacements in several seasons with 133 data points spanning 1090 days. Analyzing both the times of maximum light listed by GEOS (Groupe Européen d'Observation Stellaire) and our times of maxima, we see that the period shows a clear secular decrease.

- **TU UMa**. Wade et al. (1999) have discussed the binary nature of this star and suggest a pulsational period of 0.558 d. The period 0.557659 d is given by Kholopov et al. (1987).

Table 1: Physical parameters from the calibrations for the studied RR Lyrae stars

ID	$[Fe/H]_{ZW}$	$\log T_{eff}$	M_V	$\log L/L_{\odot}$	d (pc)	$< \log T_{eff} >$	$< \log g >$
RU Psc	−1.56	3.86	0.56	1.663	730	3.88	3.5
SS Psc	−0.20	3.88	0.60	1.674	1050	3.88	3.7
TU UMa	−1.78	3.80	0.66	1.650	590	3.88	3.8

Physical parameters

We have used the calibrations of Simon & Clement (1993), Kovács (1998) and Morgan et al. (2007) to determine T_{eff}, M_V and [Fe/H] respectively for the RRc stars and similarly the calibrations of Jurcsik (1998), Kovács & Walker (2001) and Jurcsik & Kovács (1996) for the RRab star. The results are compiled in columns 2-4 of Table 1. The values of [Fe/H] are given in the scale of Zinn & West (1984). We have interpolated the reddening from objects in the vicinity of the program stars to estimate $E(b-y) = 0.1$. Magnitude-weighted magnitudes and colours, when compared with synthetic colours, led to the temperature and gravity values listed as $< \log \; T_{eff} >$ and $< \log g >$

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Perturbation analysis of sdO models

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Abstract

We investigate the effects of perturbing the chemical transition of the Brunt-Väisälä frequency and sound speed in an equilibrium model of a sdO on the trapping and tendency to instability of modes.

Perturbation analysis

sdOs lie in a wide domain in the HR diagram, connecting sdB and post-AGB stars with their final fate as low-mass white dwarfs. The unique pulsating sdO discovered by Woudt et al. (2006) is a very fast multiperiodic pulsator. Our theoretical attempts to find p-mode pulsations in sdO models with uniform metallicity failed (Rodríguez-López et al. 2006, 2007). Fortunately, Fontaine et al. (2008a, 2008b) succeed in driving pulsations in a couple of sdO models which include radiative levitation of iron.

We explore the behaviour of an sdO model ($T_{\rm eff}$=45 000 K, log g= 5.26) which presents an oscillatory behaviour of the growth rate with frequency, both in the g- and p-mode spectrum. The non-uniform distribution of the kinetic energy, and the deviation of the mean period (large frequency) spacing for g-(p-)modes resembles the mode-trapping phenomenon caused by the potential barrier produced by the composition transition regions in Brunt-Väisälä frequency, described extensively for sdBs (Charpinet et al. 2000).

We have investigated the effects of canceling out the He-H and C/O-He chemical transitions of Brunt-Väisälä frequency and sound speed on the mode's tendency to instability (Figure 1). To do this, we wrote the model's variables as function of the perturbations $\delta N^2, \delta c^2$.

We find that g-mode trapping is mainly caused by the He-H chemical transition in the Brunt-Väisälä frequency, while the C/O-He transition has no significant effect. From a non-adiabatic analysis we find that this mode trapping provides a weak selection mechanism, in the way that trapped modes oscillate with lower amplitudes in the innermost damping region of the star. Thus,trapped modes show lower values of the kinetic energy and higher values of the growth rate, and hence more tendency to be driven. The canceling of the He-H and C/O-He transition regions do not have any significant effect on the p-mode spectrum, and in principle, cannot be associated to mode trapping effects.

Acknowledgments. CRL would like to thank HELAS for financial support. She also acknowledges an *Ángeles Alvariño* contract under *Xunta de Galicia*.

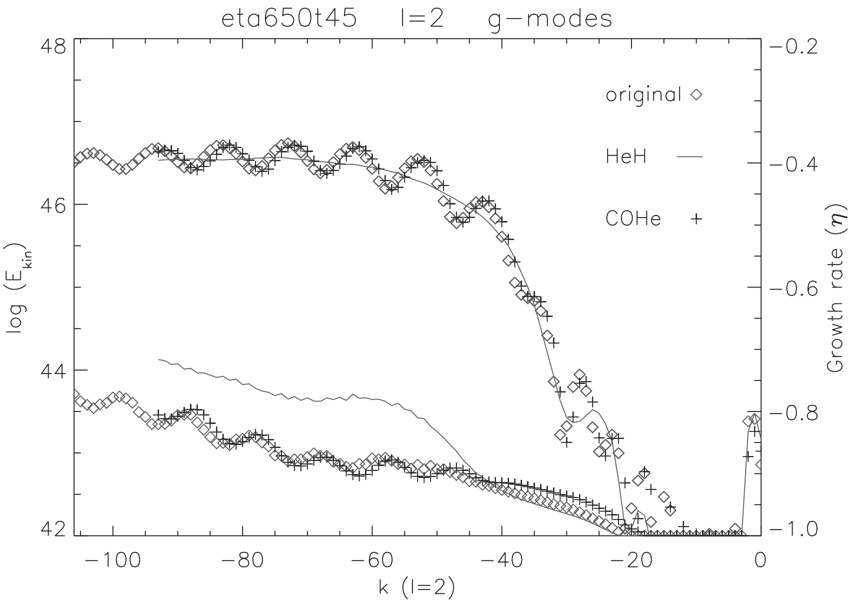

Figure 1: Kinetic energy (up, left axis) and growth rates (down, right axis) vs. radial order for g-modes in the original and perturbed models. When the He-H transition is canceled (solid line), trapped modes vanish, revealing that this region is the main responsible for their occurrence. When the sharpest peak in the C/O-He transition is canceled (plus symbols), we still have the pattern of trapped modes.

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Spectroscopy of pulsating stars at Poznan Spectroscopic Telescope – data reduction and radial velocity measurements

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Abstract

Radial velocity curves obtained with the new Poznan Spectroscopic Telescope (PST) are presented. PST is a small instrument located near Poznań, Poland, equipped with a fibre fed echelle spectrograph. One of the first observed objects was γ Peg, a bright B2IV β Cep type pulsator. It was found to have a period of P= 3.4h and an amplitude of v_{rad} variations of 3.5 km/s. Another star observed at PST, 28 And, is a member of the δ Sct family. For this object a pulsational period of 1.66h could be determined.

Individual Objects: γ Peg, 28 And

Introduction

We present the results of radial velocity measurements for pulsating stars obtained with Poznań Spectroscopic Telescope (PST) operating at Borowiec Observing Station near Poznań. Observations on PST have been performed since August 2007. During the 10 months observational period we accumulated about 700 h of observation, collecting about 1100 stellar spectra. Results of radial velocity measurements with PST so far show a stability down to a level of 100 m/s.

The telescope was built as a small instrument assigned for the medium resolution spectroscopic observations of variable stars. It is a binary telescope with two 0.4 m parabolic mirrors of which only one is currently operational. For the summer 2008, an upgrade to two 0.5 m mirrors is planned. It is expected that from autumn 2008 onwards, both mirrors will be working, acquiring parallel spectra that will be combined during the reduction process.

The optical characteristics of the PST were chosen to fit a double-fibre echelle spectrograph of R= 35 000 resolution, which was built in advance. The spectrograph's optical design is borrowed from MUSICOS (Baudrand J & Böhm T 1992) and the rest is custommade. The spectral range of this instrument covers 64 echelle rows from 4500 Å to 9200 Å.

The PST observing program includes pulsating stars like δ Sct, β Cep, δ Cep and SPB as well as spectroscopic binary stars and, with its limiting magnitude increased soon, extrasolar planetary systems.

Observations and data reduction

The exposure time at PST varies from 150s for the brightest stars to 1800s for stars of 11m, our limiting magnitude. Wavelength calibration is based on the mean of two Th-Ar spectra obtained before and after each object exposure.

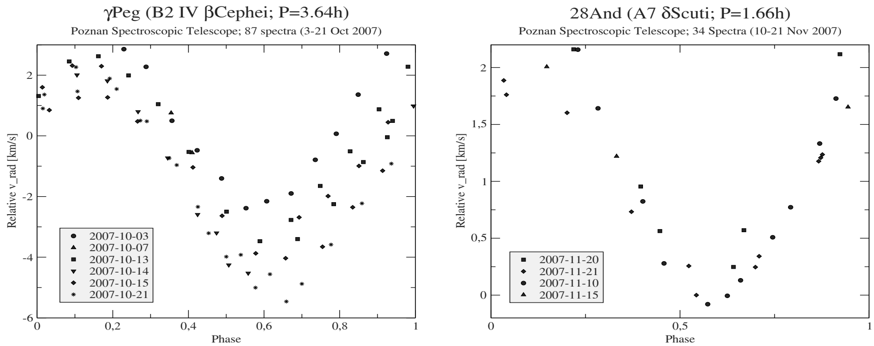

Figure 1: Left panel: Radial velocity curve for γ Peg phased with the frequency of 6.59140 ± 0.00151 c/d Right panel: Observations of 28 And were a good test of PST's capability of observing short-period stars. 600^s exposure covers about 10% of pulsational period for this star.

The data reduction is performed with the Image Reduction and Analysis Facility (IRAF) package. From our spectrum 64 echelle rows are extracted. Either well exposed stellar spectrum or the Tungsten lamp spectrum (in case of faint stars) can be used as a reference for tracing. The spectrum consisting of separated rows is divided by a normalized flat spectrum to remove the fringe patterns. The continuum normalisation is applied before the wavelength calibration. Spectra of the separate echelle rows, obtained this way, are then combined into a single spectrum, which is used in further analysis.

Results

Radial velocity curve for γ Peg is shown in the left panel of Fig. 1. The star is a bright B2IV β Cephei type pulsator. Our results reveal a period of $3.^h4$ and an amplitude of variations about 3.5 km/s.

The data shown in right panel of Fig. 1, were obtained for 28 And (A7III), which belongs to the δ Sct family. The obtained frequency of 14.427 ± 0.004 c/d, corresponds to earlier photometric estimations of 14.429 c/d by Rodriguez et al. (1993).

The radial velocity curves obtained for featured stars show the quality of observations done with PST. Despite the small aperture PST is eligible of resolving low amplitude and short period radial velocity variations, sufficient enough for research of pulsating stars.

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On the excited mode stability in the roAp star γ Equ

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Abstract

Based on both photometric and spectroscopic data analysis, we conclude that in the roAp star γ Equ excited frequencies are stable on the time scale of several years. All observed highest peak frequencies are close to the frequency pair that was first resolved by the Canadian mini-satellite MOST. Observed amplitude modulation in γ Equ and, possibly, in some other slowly rotating roAp stars can be explained by the existence of such closely spaced frequencies.

Individual Objects: γ Equ

γ Equ is the second brightest roAp star and is the most intensively observed one both in photometry and spectroscopy. Kurtz (1983) detected a pulsation period of 12.5 min (1.339 mHz) with an amplitude varying between 0.32 and 1.43 mmag. He suggested a rotation period of 38 days, inconsistent with the magnetic field measurements by Leroy et al. (1994). Aside from rotation, beating with a closely spaced frequency has been proposed as the cause of amplitude modulation. Based on cross-correlation radial velocity (RV) study, Libbrecht (1988) discovered three frequencies at 1.365 mHz, 1.369 mHz and 1.427 mHz. He suggested that the amplitude modulation observed in the spectra of roAp stars may not be due to closely spaced frequencies, but may rather be caused by short ($\sim$ 1 day) mode lifetimes. Martinez et al. (1996) analyzed multi-site 1992 campaign data, 26 nights in total. They also suggested short liefetimes of pulsation modes because different frequencies appeared in their analysis of individual nights.

Continuous 19 day data obtained by the Canadian mini-satellite MOST have allowed to identify 7 frequencies including $f_2 = 1.365411$ mHz that has never been detected before. This frequency is very close to the known frequency f_1=1.364594 mHz. It seems that f_1 and f_2 could not be resolved as individual frequencies before (Gruberbauer et al. 2008). This discovery can explain puzzling amplitude modulation in γ Equ as beating of two closely spaced frequencies.

Spectroscopic and photometric techniques provide information on the boundary zone relevant for any pulsation model and gives access to different modes and hence atmospheric layers. An observed phase lag between luminosity and RV variations is an important parameter for a first step towards modeling the stellar structure. Simultaneous photometric and spectroscopic observations are required to determine this phase lag. Till now, this was only made for two roAp stars: HD 24712 (Ryabchikova et al. 2007) and 10 Aql (Sachkov et al. 2008). For γ Equ we do not have simultaneous photometric and spectroscopic data. But even the data separated by a year (spectral data were obtained in August 19 and 20 and September 11 2003 with the NES spectrometer at the Russian 6-m telescope, photometric data were collected from July 28 to August 16 2004 by the MOST satellite) allow us to check the mode stability

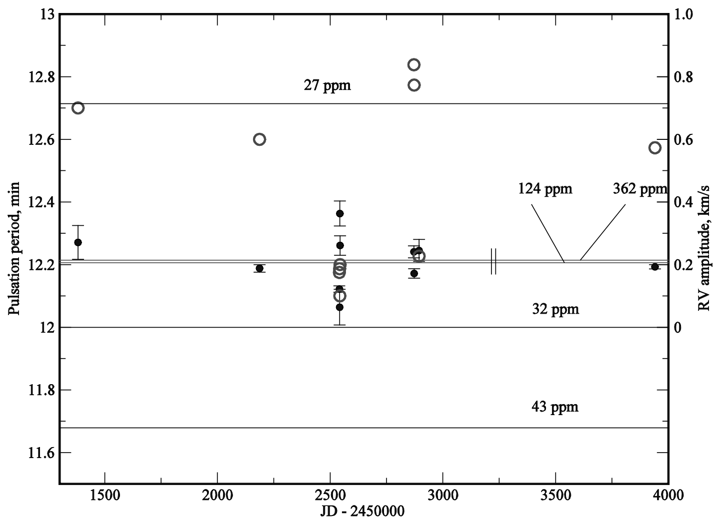

Figure 1: Highest peak frequencies observed in RV data of γ Equ

by answering the question: does the common photometric/RV solution reproduce the amplitude modulation seen in light and RV curves? The positive answer to this question allows us to conclude that in γ Equ excited frequencies are stable on the time scale of several years.

We have also compared the highest peak frequencies that we found on the basis of RV data in 1999-2006. For frequency analysis we used Nd lines. Figure 1 shows the result of this comparison. In all cases, inferred periods (filled circles) are very near to the closely spaced pair of frequencies (lines near 12.2 min). The existence of this pair can easily explain the observed amplitude modulation (open circles, scaled).

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A binary star with a δ Scuti component: EF Herculis

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Abstract

New photometric observations of Algol type binary system EF Her were carried out in B, V and R filters during the 2007 observing season. In the literature, there is not any photometric or spectroscopic study of the system so far. Firstly, the new observations have been analyzed by using the Wilson-Dewinney code and the geometrical and physical parameters of the system are determined. The mass ratio of EF Her was found about 0.21. Periodic oscillations are clearly seen in the maximum, secondary minima and also primary minima of the light curve due to the pulsation of the primary component. The residuals from the computed binary light curves were analyzed with the PERIOD 04 program. As a result of this, only one frequency at 10.07 c/d was obtained.

Individual Objects: EF Her

Introduction

EF Herculis is a semi-detached Algol-type binary system. The orbital period and magnitude in V are given by Kreiner (2004) as 4.729157 d and 11.4 m, respectively. The primary component of the system shows a δ Scuti-type variability (Kim et al. 2004). According to analysis in B filter made by Kim et al. (2004), the pulsational amplitude and period were found to be about 0.06 m and 2.5 h, respectively.

Photometric observations

EF Her was photometrically observed in Johnson B, V and R filters over 18 nights during the 2007 observing season at the Çanakkale Onsekiz Mart University Observatory using the 30-cm Schmidt-Cassegrain telescope equipped with a SBIG-10MXE CCD camera. GSC 1525 1000 and GSC 1525 856 were selected as comparison and check stars, respectively. Standard errors were calculated to be about $\pm$ 0.014 m, 0.011 m and 0.012 m in B, V and R filters, respectively.

Photometric analysis

We analyzed the B, V and R light curves with the 2003 version (van Hamme & Wilson 2003) of the Wilson-Dewinney (W-D) code (Wilson & Devinney 1971), simultaneously. The lowest value of ΣW(O-C)^2 was around $T_1 = 9327$ K, which respond to A2V, was taken from de Jager and Nieuwenhuijzen (1987). According to W-D solution, $i = 77.83$, $T_2 = 4767$ K, $\Omega_1 = 6.232$, $\Omega_2 = 2.555$, $q = 0.21$, $r_{1mean} = 0.166$, $r_{2mean} = 0.289$ were found. The observational points and the computed light curve in V filter are shown in Figure 1.

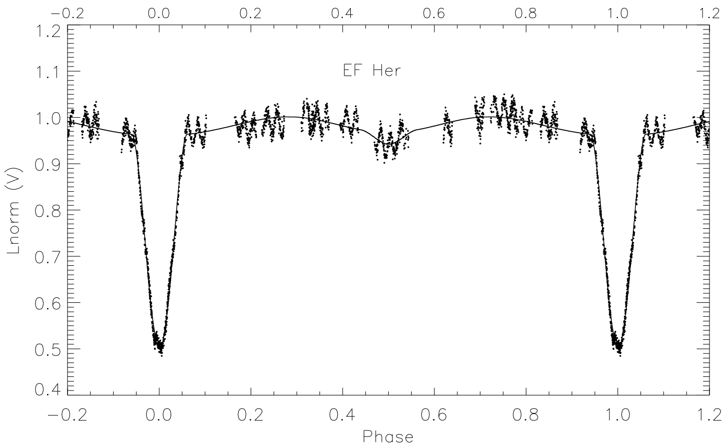

Figure 1: Observational points and computed light curves of EF Her in V filter. The solid line represents the fit to the data.

Frequency analysis of the photometric data for pulsations

The frequency analysis was made on the residual light curves using PERIOD 04 (Lenz & Breger 2005) program. As a result of this, one frequency was found to be as the same value about 10.07 c/d in B, V and R filters. The pulsation amplitudes in B, V and R filters were determined 0.069 m, 0.051 m and 0.040 m, respectively.

The results

We have used new photometric observations of EF Her to determine the geometric and physical parameters of this binary system, including the properties of the primary component. Our pulsation period of 2.38 m and the amplitude of 0.069 m in the B filter do not with agree with those reported by Kim et al.(2004), who found 2.5 h and 0.06 m for the respective parameters.

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Seismic signatures of convective and/or helium cores

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Abstract

The $\ell = 0$ - $\ell = 2$ small separations can become negative in a certain frequency region during the evolution of solar-type stars. This specific behaviour can be used to characterize the convective and the helium stellar cores, and to obtain constraints on the possible extent of the overshooting at the core edge.

Theoretical analysis

The small separations, defined by $\delta\nu_{n,\ell} = \nu_{n,\ell} - \nu_{n-1,\ell+2}$, are very sensitive to the deep stellar interior (Roxburgh & Vorontsov 1994). Soriano et al. (2007) have shown that they could become negative, which was in contradiction with the "asymptotic theory" developed by Tassoul (1980). This phenomenon was related to the presence of a convective core or a helium core with a sharp edge.

Taking into account the fact that not all the modes travel through the same stellar regions, we found a new expression for the small separations:

$$\delta\nu_{n,\ell} \propto I(r) = \int_{r_t}^{R} \frac{1}{r}\frac{dc}{dr}dr \qquad (1)$$

where r_t is the internal turning point of the waves.

A rapid variation in the sound speed profile can create a significant change in the integral and the sign reversal of the small separations.

Results

We performed a study of this phenomenon in the general case of solar-type stars (Soriano & Vauclair 2008), and we found that all stars go through a stage in their evolution where their small separations change sign and become negative. This peculiar stage could be near the end of the main sequence or at the beginning of the subgiant branch. This phenomenon is clearly related to the high-helium content of convective or helium cores.

During the lifetime of a star on the main sequence, its core develops, and its helium abundance increases. A sharp discontinuity in the chemical composition and in sound speed appears at the edge of the core (Fig. 1, left panel). This induces a change in the integral $I(r)$ and the small separations become negative below 3.5 mHz (Fig. 1, right panel). When the star reaches the subgiant branch, a helium core remains, with sharp boundaries. There is still an important discontinuity in the sound velocity profile, and the small separations

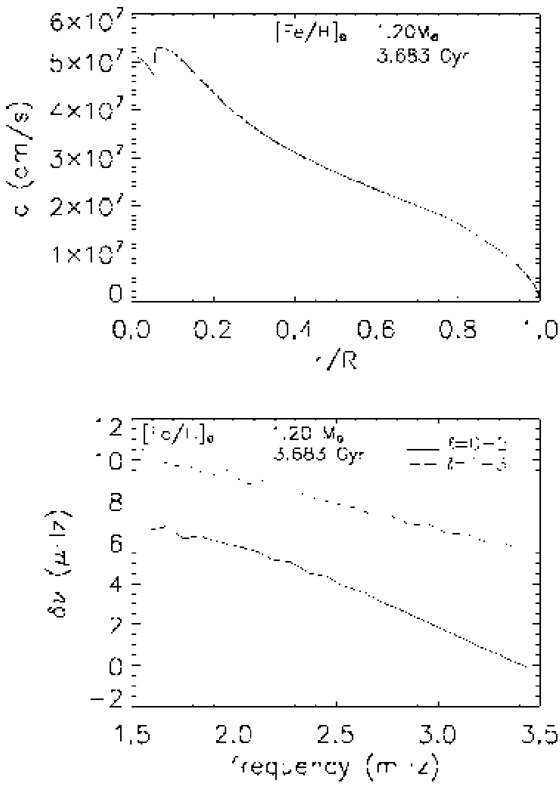

Figure 1: Sound speed profile (top panel) and small separations (lower panel) for a solar metallicity model ($[Fe/H]_{\odot}$) of 1.20 $M_{\odot}$, 3.683 Gyr, without overshooting.

become negative at lower frequencies than for less evolved models. While the star continues its evolution on the subgiant branch, the frequency at which the small separations become negative goes on decreasing.

This special behaviour can be used to characterize the convective and the helium cores, and also to give constraints on overshooting.

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Fourier analysis of gapped time-series

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Abstract

In asteroseismology, gaps in the time series complicate the data analysis and hamper the precise measurement of stellar oscillation parameters, e.g. the frequencies, amplitudes, phases, and mode lifetimes. In the Fourier domain the convolution of the stellar signal with the Fourier transform of the temporal window function introduce data correlations between the different frequencies. We developed a method to derive Maximum Likelihood Estimates (MLE) of mode parameters where these data correlations are explicitly taken into account. Using simulated realisations of noisy time series with gaps, the MLE of the mode parameters of solar-like oscillations obtained with our new fitting method are more precise and less biased than the MLE determined based on the unfounded assumption of uncorrelated frequency bins.

Saskia Hekker and Torsten Stahn discussing a poster

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Radius determination from the large frequency separation

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Abstract

We report on the recent 2nd AsteroFLAG hare-and-hound exercise aimed at determining radii of F-K stars that are on or near the main sequence. Based on the large frequency separation, obtained from simulations of 4 year data from the Kepler mission (1st AsteroFLAG exercise; astroph/08034143), we have been able to correctly determine the stellar radii. The various methods used by each independent hound all agree, which gives strong confidence that radii estimation can be performed to the 1% level on a routine basis using automatic pipeline reduction.

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PMS δ Scuti stars in the region of Carina Nebula

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Abstract

We present the results of the photometric search for pulsating stars in the region of Carina Nebula which contains a very young population of stars and several open clusters. In total, the time series for about 16,000 stars were obtained and analysed. We found about 150 pulsating stars in this region, mainly of δ Scuti-type. At least a dozen of them can be members of young open clusters at the pre-main sequence (PMS) stage of evolution.

Individual Objects: Trumpler 14, Trumpler 15, Trumpler 16

Open clusters in the center of the Carina Nebula

The center of Carina Nebula contains two open clusters: Trumpler 14 (Tr 14) and Trumpler 16 (Tr 16). Both clusters are very young, having age of 2 and 5 Myr, respectively (Carraro et al. 2004). Another open cluster, Trumpler 15 (Tr 15), is located about 25′ north of Tr 14 and Tr 16. It is also very young; its age was estimated for 6 Myr by Feinstein et al. (1980).

Observations and reductions

Observations of the central part of Carina Nebula were carried out with the Wide Field Imager (WFI) attached to the MPG/ESO 2.2-m telescope in La Silla (Chile) during 7 nights between January 18 and 24, 2006. We used a set of standard $UBV(RI)_C$ filters. The observed field covered the area of $35' \times 35'$. In total, about 16,000 stars have been detected and their photometry analysed using classical Fourier techniques.

The results

As a result of the analysis, about 600 variable stars were found. At least 150 of them are δ Scuti-type pulsating stars. They are mostly multiperiodic. In addition, we detected about twenty eclipsing binaries. The remaining stars are long-period variables, irregular variables or simply stars that have periods much longer than the time interval covered by our observations.

The main purpose of our project was the detection of pulsating δ Scuti stars in the PMS stage of evolution. At least a dozen of the 150 pulsating stars that we identified as δ Scuti stars are located in the fields of the three clusters we mentioned above. They are plotted in the colour-magnitude diagrams of these clusters, separately for each cluster, in Fig. 1. These diagrams were corrected for differential extinction which is quite large in this area. This is not a surprise, as the region of Carina Nebula is known as a place of violent star formation and there is still a lot of interstellar matter in the surroundings of the clusters. We also plotted the

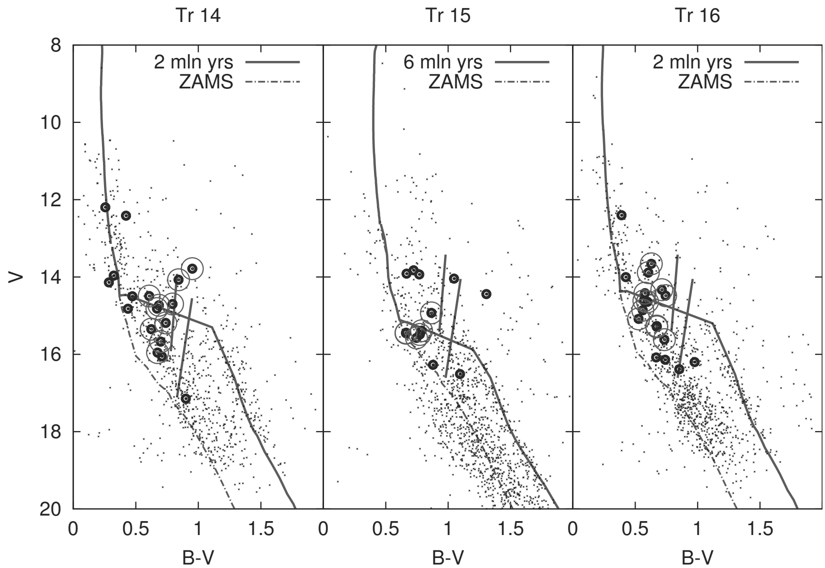

Figure 1: The colour-magnitude diagrams for Tr 14, 15 and 16, the three clusters in the region of Carina Nebula. The δ Scuti stars in the fields of clusters are marked by dots. Those, which are most probable members, are encircled. ZAMS and PMS isochrones, taken from Siess et al. (1997) are indicated by solid and dashed lines. We also show the instability strip for PMS δ Scuti-type stars from Marconi & Palla (1998); it is shown with dotted lines.

isochrones in Fig. 1, for five different ages for each cluster, indicating the best fit by a thick line. It is clear that all clusters are very young: from the location of PMS stars, we estimate the age of Tr 14 and 16 for 2 Myr. Tr 15 is slightly older, the 6-Myr isochrone seems to fit the colour-magnitude diagram best. Despite the large contamination by field stars, we may conclude that some δ Scuti stars we detected are members of these clusters. Consequently, they are very good candidates for PMS δ Scuti stars. Those best candidates are encircled in Fig. 1.

Acknowledgments. These observations have been funded by the Optical Infrared Coordination network (OPTICON), a major international collaboration supported by the Research Infrastructures Programme of the European Commission's Sixth Framework Programme. We are grateful to the EC for the establishment of the European Helio- and Asteroseismology Network HELAS, which made our participation at this workshop possible.

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About the pulsational status of ϵ Oph

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Abstract

We tackle the problem of the existence of nonradial modes in giants. We present the results of numerical computations of oscillation properties of a model of ϵ Oph based on 54 frequencies observed by MOST. Many issues, such as mode identification and position of ϵ Oph in HR-Diagram, are pointed out.

Individual Objects: ϵ Oph.

Results and conclusion

We calculated radial and nonradial pulsation frequencies of models distributed along the evolutionary track of a 2.03 $M_\odot$ stellar model on the giant branch of the HR Diagram and located in the uncertainty box of ϵ Oph. The models were constructed with the CESAM2k_V2 stellar evolutionary code, adopting the OPAL2001 equation of state and Yveline opacities in the interior. Diffusion of helium and heavy elements was not included. The model eigenspectra were generated by ROMOSC linear, nonradial, nonadiabatic stellar pulsation code. In our analysis, we only considered radial modes and strongly trapped unstable (STU) nonradial modes (Dziembowski et al. 2001) with mode degree l up to 3. We set the initial hydrogen and metal mass fractions to (X, Z)=(0.71, 0.01). The mixing length parameter was set to 1.74 (Kallinger et al. 2008). The best fit model matches 15 photometric frequencies in $\pm 1\sigma$: 4 to radial p - modes, 3 to l=1, 3 to l=2 and 5 to l=3. The best model fit to 25 photometric frequencies in $\pm 2\sigma$ (7 to radial p - modes, 5 to l=1, 7 to l=2 and 6 to l=3) and 33 in $\pm 3\sigma$ (9 to radial p - modes, 6 to l=1, 10 to l=2 and 8 to l=3).

Table 1: Fundamental stellar parameters for ϵ Oph as found in the literature and for our best fitting model (M1) and for the best fitting model found by Kallinger et al. (2008) (M2).

	Literature	M1	M2
Effective temperature ... [K]	4877 ± 100	4899	4892
Luminosity ... [$L_\odot$]	59 ± 5	59.13	60.13
Radius ... [$R_\odot$]	10.4 ± 0.45	10.76	10.82
Mass ... [$M_\odot$]		2.03	2.02
log g ... [g cm s^{-2}]	2.48 ± 0.36	2.68	2.674
Age ... [Gyr]		0.73	0.77
Mixing length parameter ... [Hp]		1.74	1.74
Metallicity ... [Z]	0.01	0.01	0.01

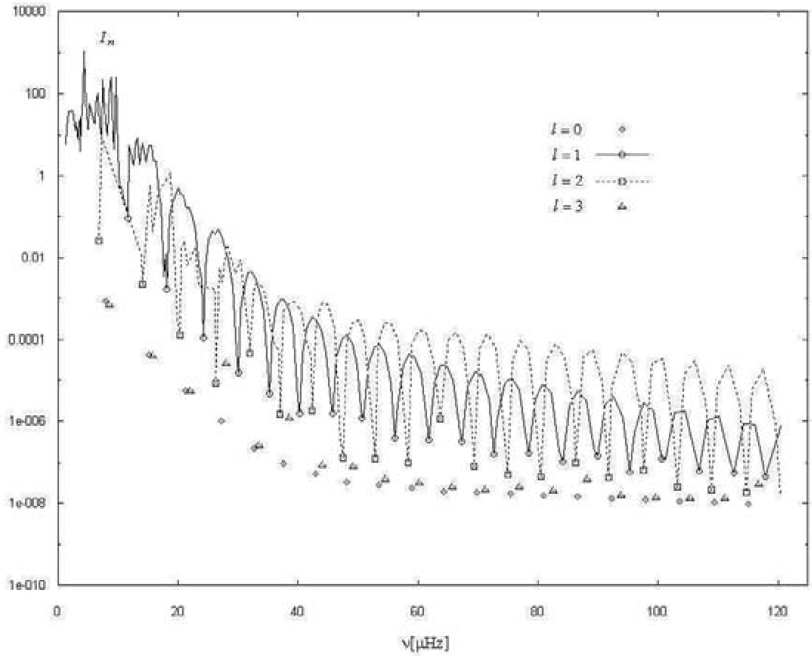

Figure 1: Modal inertia in units of $3MR^3$, plotted against frequency. The symbols are displayed only for those modes that are locally most trapped. In our analysis, we ignored the first five frequencies of the 59 frequencies observed by MOST (Kallinger et al. 2008) because the corresponding theoretical frequencies have high inertia, due to the damping effect in the outer layers.

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The driving mechanism of roAp stars : effects of global metallicity

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Abstract

We have investigated the influence of global metallicity on the excitation mechanism of roAp star pulsations. Our computations show that the opacity in the driving region of the roAp modes is strongly sensitive to the metal content but surprisingly the roAp theoretical instability strip is only weakly affected by metallicity changes.

Context

Up to now several studies have been dedicated to the excitation of pulsations in roAp stars (e.g. Dolez & Gough 1982, Dziembowski & Goode 1996, Gautchy et al. 1998, Balmforth et al. 2001, Cunha 2002). Standard as well as non-standard models have been proposed to account for the roAp properties but they did not suceed in reproducing the right position and extent of their instability strip. These previous studies did not however investigate the effects of metallicity variations.

Recent observations show that the surface metallicity of magnetic A stars increases with their effective temperature (e.g. Ryabchikova et al. 2004). As no roAp star hotter than 8700K is detected, this could suggest a relation between the excitation mechanism of roAp modes (supposedly the κ-mechanism acting in the H ionization region) and their heavy element distribution. With this in mind we have investigated the effects of global metallicity variations on the driving of roAp modes to test if nonsolar metallicities could explain the extent of the roAp instability strip.

Computations and results

We have computed grids of stellar evolutionary models adequate for roAp stars using the code Clés (Scuflaire et al. 2007). The metal mixture used is the solar one (Asplund, Grevesse and Sauval 2005) with X=0.71. Each grid is computed with a different [Fe/H] value (between -0.89 to +0.83). The opacity tables (computed with the AGS05 mixture) are those of OPAL96 (Iglesias & Rogers 1996) completed at low temperature with tables based upon calculations from Ferguson et al. (2005). As outer boundary conditions, Kurucz atmospheres (Kurucz 1998) are joined to the interior at an optical depth equal to 1. We computed standard models with fully radiative envelope, assuming that the convection is suppressed by the magnetic field (following Balmforth et al.2001). The stability of these models has been computed using the non-adiabatic pulsation code MAD (Dupret 2002).

Our results show that the so-called "H-opacity bump" (where the pulsations are driven) of our models is strongly sensitive to the global metal content of the star: the larger the

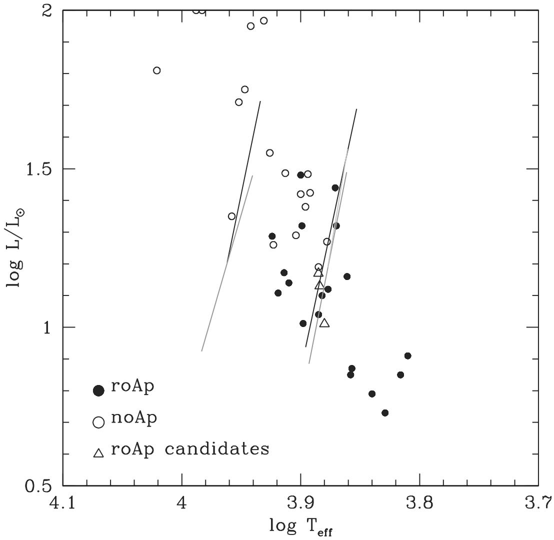

Figure 1: Theoretical instability strips for models with different metallicities (black lines : [Fe/H]= 0.00, grey lines : [Fe/H]= +0.89, -0.83). Observational points are from Kochukhov & Bagnulo (2006) and North et al. (1997).

metallicity, the larger the opacity bump. Surprisingly, the theoretical instability strip is only weakly affected by these changes (see fig.1). These results, which will be discussed in details in a forthcoming paper (Théado, Dupret and Noels 2008), show that global metallicity effects could not help solving the question of the roAp modes excitation in cool roAp stars.

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Spectroscopic solution for the oEA star RZ Cas using the SHELLSPEC code

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Abstract

Reinvestigations of the short-period oEA star RZ Cas by using the "SHELLSPEC" code confirm most of the system parameters obtained by Lehmann & Mkrtichian (2008). Results from spectra obtained in 2001 point to a transient phase of rapid mass transfer and to the existence of dense circumprimary matter of disk-like structure, while results from spectra obtained in 2006 show that the system was in a quiet state during this period and can be modelled very well by two stars of which the secondary component fills its Roche lobe. The brightness distribution over the surface of the secondary can be described by a gravity darkening law that assumes two different exponents for hemispheres of different stars.

Individual Objects: RZ Cas

Introduction

RZ Cas is one of the best investigated oEA stars (i.e. Algol-type systems where the mass-accreting primary shows δ Scuti-like oscillations; Mkrtichian et al. 2002, 2004) of which extended photometric (Mkrtichian et al. 2007; Rodriguez et al. 2004) and spectroscopic (Lehmann & Mkrtichian 2004, 2008) investigations exist. As a result, the following facts were established: RZ Cas is a short-period Algol-type system (P = 1.1952595 d; A3 V/K0 IV spectral type) that shows an orbital period change of the order of seconds within decades, a very pronounced Rossiter effect during primary minimum and amplitude modulation of nrp (non-radial pulsation) modes with an orbital phase in which a strong enhancement of the amplitudes during the primary eclipse can be seen (so-called spatial filtration effect). A different asymmetry of the Rossiter effect and different strengths of the nrp-amplitude modulation in different epochs of observations have been observed.

Spectroscopic modelling and results

We obtained high-resolution spectra with the Coude-Echelle-Spectrograph at the 2-m telescope at the Thüringer Landessternwarte Tautenburg in 12 runs in 2001 (951 spectra) and in 8 runs in 2006 (512 spectra). Based on these spectra, we reinvestigated the RZ Cas system by using the modern code "SHELLSPEC" (Budaj & Richards 2004; Budaj et al. 2005) for the synthesis of composite line profiles from binary systems. The program computes the Roche geometry of the secondary; effects like gravity darkening for the secondary, accretion disk and gas stream are also taken into account. Composite spectra can be obtained for all orbital phases, including eclipse mapping. Starting values for atmospheric parameters for both components like abundances, T_{eff} and $v sin\, i$ have been obtained from the analysis of the disentangled spectra derived with the KOREL program (Hadrava 2004) while the starting values for the system parameters like radii and masses of the components, orbital inclination and separation were taken from the Wilson-Devinney solution and from the radial velocity analysis (Lehmann & Mkrtichian 2004, 2008). After the masses, T_{eff}, $v sin\, i$ and limb darkening coefficients for both components were fine-tuned by using SHELLSPEC, we tried to adjust the gravity darkening exponent for the secondary using the spectra from 2006. We found that the brightness distribution over the surface of the secondary can be described very well if we apply a gravity darkening law with two different exponents for the two hemispheres of the secondary pointing towards ($\beta = 0.5$) and away ($\beta = 0.1$) from the primary. The obtained ultra-large value of $\beta = 0.5$ cannot be interpreted in terms of gravity darkening. Their interpretation is that it reflects the existence of a large dark spot on the surface of the secondary near to Lagrangian point one. This is in line with findings by Unno et al. (1994), where authors reported about an ultra-large gravity darkening exponent of 0.53 for the secondary of RZ Cas. The interpretation was that as a result of mass-outflow from the secondary, spots on the front and back sides of the secondary towards the primary are formed.

In a next step, the model obtained from the 2006 spectra was applied to the spectra taken in 2001 without changing any of the parameters. Results showed a strong attenuation of the primary line profile for most orbital phases, pointing to the existence of dense circumprimary matter of a disk-like structure. This result confirms the hypothesis of a transient phase of rapid mass transfer during the 2001 observational period as given by Lehmann & Mkrtichian (2004, 2008). Finally, we did a very first attempt to include a disk-like circumprimary matter in our model and found that the system in 2001 can be better described in this way, but we have to assume a complex angular density distribution of the disk.

Conclusions

RZ Cas shows different behaviour in 2001 and 2006 observation periods. Whereas in 2006 the observed line profiles can be very well modelled by two stars only, the more complex model with a dense disk of circumprimary matter should be applied to the spectra from 2001. We found that this disk must have a complex angular density distribution. In a further step, we want to model the system by using 3D-hydrodynamical simulations of the mass-transfer to improve our solution.

Acknowledgments. We would like to thank J. Budaj for providing us with the SHELLSPEC code.

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The preliminary results of the eclipsing binary system EW Boo with a δ Scuti component

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Abstract

We present the first ground-based photometric observations and results of EW Boo. The V light curve obtained over 12 nights in 2006 was analyzed by using the Wilson-Dewinney code. We also found that the primary component of the system shows δ Scuti-type variability.

Individual Objects: EW Boo

Introduction

EW Boo (HIP 73612, V=10.27 m), discovered by the Hipparcos satellite (ESA 1997), is an Algol-type binary system with an orbital period of 0.906336 d. The spectral type of the system has been given as A0 (ESA 1997). There is not any published work about the system. This system also has taken part in the catalogue of close binaries located in the δ Scuti region of the Cepheid instability strip reported by Soydugan et al. (2006a). So, It may be shown as candidate system to the pulsations in that catalogue.

In this work, we present the first photometric observations of the close binary star EW Boo, obtained at Çanakkale Onsekiz Mart University Observatory. Preliminary results of photometric analysis and pulsational properties of the hotter component for the system are also given.

Photometric Analysis

Before starting light curve (LC) solution, we have used a few spectra taken at Catania Astrophysical Observatory during 2004 season to obtain radial velocities (RV) of the components. We have made preliminary analysis of RV curves to estimate the absolute parameters of the components. We analyzed V light curve with the 2006 version (van Hamme & Wilson 2003) of the Wilson-Dewinney (W-D) code (Wilson & Devinney 1971), simultaneously. Firstly, (B-V) the color taken from Hipparcos (ESA 1997) was recalculated extracting interstellar reddening and we found $(B\text{-}V)_0$ as 0.19 m, which responds to about A6V spectral type (Pickles 1998). Using the tables of deJager & Nieuwenhuijzen (1987), we estimated the surface temperature of the primary component to be 8179 K, which was used in the Wilson-Devinney code as a fixed parameter. In the solution, the common way is followed to obtain the best LC solution

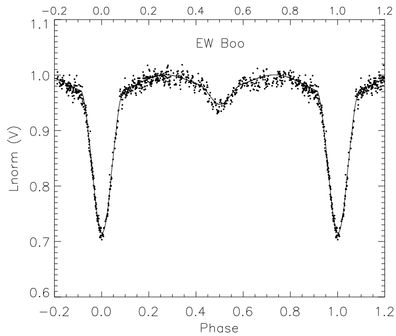

Figure 1: Observational points and computed light curve of EW Boo in V filter.

in V filter (e.g. Soydugan et al. 2003). The mass ratio of the system was found to be about 0.217. The V light curve and theoretical representation according to LC solution can be seen in Fig.1. The pulsational variation on the light curve is very clear in this figure.

Frequency Analysis of The Photometric Data for Pulsations

The frequency analysis was made on the residuals light curves, which are extracted from the theoretical fit applied observed light curves, using PERIOD 04 (Lenz & Breger 2005) program. As a result of this, pulsational period and amplitude were found to be about 30 minutes and ~ 0.02 m, respectively. The preliminary analysis indicates that the system probably has more than one pulsational frequency.

The results

We have presented preliminary LC solution of EW Boo in V filter for the first time. In the first frequency analysis using 2006 data in V filter, two meaningful pulsational periods are obtained. The location of EW Boo in the diagram agrees well with the correlation between orbital and pulsation periods of eclipsing binaries given by Soydugan et al. (2006b). The detailed analysis of the system will be published elsewhere.

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Detection of line-profile variations in high-resolution VLT/UVES spectroscopy of the subdwarf B pulsator PG 1336−018 (NY Virginis)

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Abstract

We present an analysis of about 400 high-resolution time-resolved VLT/UVES spectra of the eclipsing subdwarf binary system PG 1336−018 - a rapidly pulsating subdwarf B primary in a short orbit with an M5 companion. We analysed the spectra of PG 1336−018 with the aim to detect the pulsational signal of the primary in line-profile variations. After removing the dominant radial-velocity component inherent to the orbital motion, we computed cross-correlation functions for each individual spectrum and assumed these to approximate the average line profile. The dominant pulsation mode is detected in the cross-correlation functions and may lead to the first spectroscopic mode identification for this star.

Individual Objects: PG 1336-018

Frequency detection

We have calculated the Fourier amplitude spectrum of the time series of the cross-correlation profiles. For each wavelength (velocity) bin, the amplitude as a function of frequency is plotted in Fig. 1. In the frequency domain where the most pulsation power of PG 1336−018 is detected in photometry (Kilkenny et al.2003) we find a frequency at which variations are clearly seen. This frequency at 5435 μHz is the main pulsation mode seen in the ULTRACAM data set (Vučković et al. 2007) and is found in all photometric data sets on PG 1336−018 (Kilkenny et al. 1998, 2003; Reed et al. 2000). This is the first time that variation in the line profiles of PG 1336−018 has been detected. Our aim, like in any asteroseismic study, is to identify the modes of the pulsation. Such a study is currently under way. In the follow-up paper of this work, we will present the analysis of the character of this mode.

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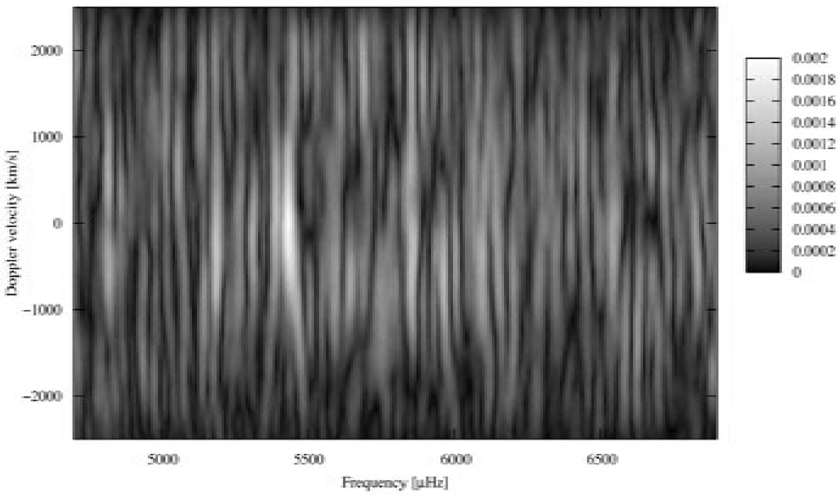

Figure 1: Two dimensional Fourier amplitude spectrum of all the out-of-eclipse PG 1336−018 spectra.

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Rotation and pulsation in g-mode main sequence pulsators

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Abstract

The lack of well-identified modes is one of the major problems preventing an in-depth asteroseismic study of gravity-mode (*g*-mode) main sequence pulsators. Since several of the currently available spectroscopic mode identification techniques have been developed for, or only extensively tested on pressure-mode pulsations, we started an investigation to improve them for the high radial order *g*-modes observed for slowly pulsating B (SPB) and γ Doradus (γ Dor) stars. A few high quality spectroscopic timeseries are being obtained for a selection of the most promising members of these groups with a large spread in projected rotational velocity that will serve as testbeds. These data will also enable us to study any observational relationship between the observed *g*-modes (degree *l*, azimuthal number *m* and/or pulsation amplitude) and the rotation of these non-radially pulsating stars.

Individual Objects: QW Puppis

So far spectroscopic mode identification for SPB and γ Doradus stars has been a limited success. This study uses the recently developed Fourier Parameter fit (FPF) method (Zima 2006) which has produced excellent results on the large spectroscopic data sets for some β Cephei and δ Scuti stars (e.g. Zima et al. 2006). The method generates synthetic data to match to the zero point profile and the phase and amplitude distribution across the line profile. However, difficulties have been encountered when applying the method to *g*-mode pulsating stars (Zima et al. 2007).

Using 179 observations obtained at the South African Astronomical Observatory (SAAO) on the 1.9m (Radcliffe) telescope and at the Mount John University Observatory (MJUO) of the γ Dor star QW Puppis, periodic profile variability is clearly observed and a few clear frequencies were extracted. After an FPF analysis of the first two strongest frequencies the fit to the zero point profile and phase change across the profile is good, however the amplitude distribution is not well matched. A better fit to this data cannot be obtained with the models used in the FPF software. From this it is surmised that either the frequencies determined may be misidentified, since aliasing is a strong problem for these stars, or, more likely, that the assumptions made to produce the synthetic data used for the fit are not valid for this star.

To adapt the FPF method to be usable on the SPB and γ Dor stars, this research will carry out a large-scale study of spectral line synthesis in a manner similar to that of Schrijvers & Telting (Schrijvers et al. 1997; Telting & Schrijvers 1997a; Telting & Schrijvers 1997b). This will focus on stellar models considered more suitable for *g*-mode pulsation by including effects such as the Coriolis force. By confronting our multisite campaign data with the spectral line synthesis improvements a greater knowledge of the effects of the assumptions made can be obtained. Further, interesting results from more complex stellar models such as the equatorial wave trapping due to rotation (Townsend 2003) or mode amplitude damping may be able to be investigated as high quality spectroscopic SPB and γ Dor datasets increase.

To enable more of these detailed studies of line profile variability in the SPB and γ Dor type stars, there is also ongoing work on candidate SPB and γ Dor stars to determine their projected rotational velocity ($v \sin i$) and whether they show clearly varying spectral line profiles. This allows better characterisation of these populations and will provide a larger selection of good multisite campaign targets with a variety of properties to be available for future studies.

Acknowledgments. This paper uses observations made at the South African Astronomical Observatory and the Mount John University Observatory.

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Can opacity changes help to reproduce the hybrid star pulsations?

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Hybrid stars like ν Eri and 12 Lac show two different types of pulsations: (i) low-order acoustic and gravity modes of β Cephei type with periods of about $3 - 6$ hours, and (ii) high-order gravity modes of the SPB type with periods of about $1.5 - 3$ days. Seismic models of ν Eri (Pamyatnykh et al. 2004, Dziembowski & Pamyatnykh 2008) using both OPAL (Iglesias & Rogers 1996) and OP (Seaton 2005) opacity data reproduce the observed range of short-period low-order pulsations of the β Cep type well and also show a tendency to instability of long-period high-order gravity modes. With the OP data, the instability of the quadrupole ($\ell = 2$) high-order gravity modes was found, but at slightly shorter periods than those observed. Trying to reproduce both short and long period ranges of the ν Eri pulsations, we tested the effects of artificial 50 % opacity enhancement around the metal opacity bump at $\log T \approx 5.3 - 5.5$, as it is shown on Fig. 1. Models were computed using the OP opacities

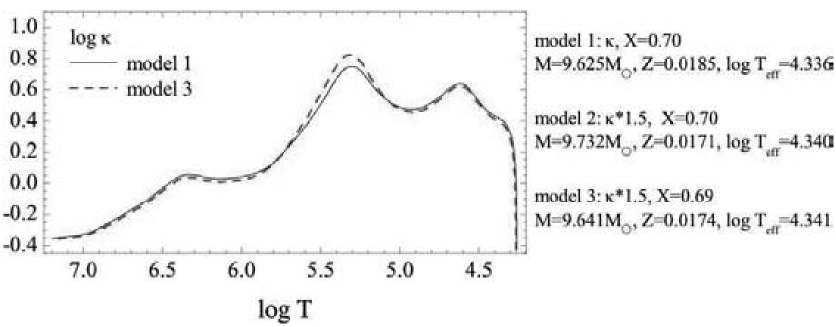

Figure 1: Opacity behavior inside non-modified (1) and modified models (2, 3). Model 2 follows the line of Model 3, for clarity it was not shown.

and new solar proportions in the heavy element abundances (A04, see Asplund et al. 2005). In all models, the frequencies of radial fundamental and two dipole modes (g_1 and p_1) were fitted to the observed values with accuracy better than 0.0005 c/d. As we may see, in Fig. 1, the opacity enhancement in the modified models is less than 50 %, because the fitted models differ in metal abundances and other parameters.

As a result of the opacity enhancements, Model 3 is very close to having unstable dipole high order gravity modes at the observed frequency range (Fig. 2). Also, the range of the unstable short period modes is in better agreement with the observations. In addition, a small decrease of the hydrogen abundance ($X = 0.69$ instead of $X = 0.70$) allows to achieve also a good frequency fit of the $\ell = 1$, p_2 mode to the observed value of 7.898 c/d.

We note however that the required opacity increase, by 50 % in the Z bump, appears larger than allowed by uncertainties in current opacity calculations. A similar improvement in

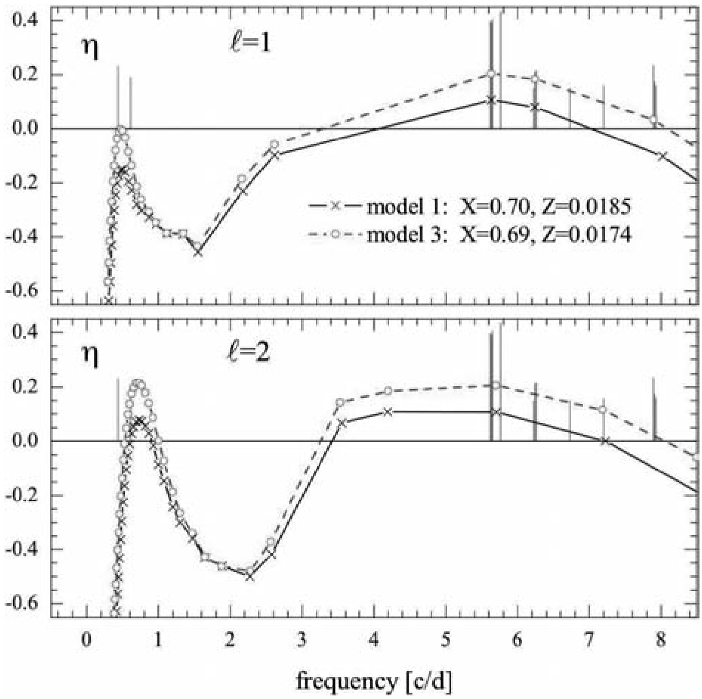

Figure 2: The normalized growth rates, η, of $\ell = 1$ and $\ell = 2$ modes as a function of mode frequency in seismic models of ν Eri ($\eta > 0$ for unstable modes). Vertical lines mark the observed frequencies (Jerzykiewicz et al. 2005), with amplitudes given in a logarithmic scale. In all models, the frequencies of radial fundamental and two dipole modes (g_1 and p_1) fit the observed values at 5.763, 5.637 and 6.244 c/d, respectively. In Model 3, one more dipole mode (p_2) fits the observed value at 7.898 c/d (with the accuracy 0.001 c/d). Model 2 nearly follows the line of the Model 3, for clarity it was not shown.

the fit may be achieved with a more modest (few percent) modification of the opacity bump at $\log T = 6.3$. We plan to examine this option in future.

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FAMIAS - A userfriendly new software tool for the mode identification of photometric and spectroscopic times series

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Abstract

FAMIAS (Frequency Analysis and Mode Identification for AsteroSeismology) is a collection of state-of-the-art software tools for the analysis of photometric and spectroscopic time series data. It is one of the deliverables of the Work Package NA5: Asteroseismology of the European Coordination Action in Helio- and Asteroseismology (HELAS[1]).

Two main sets of tools are incorporated in FAMIAS. The first set allows to search for periodicities in the data using Fourier and non-linear least-squares fitting algorithms. The other set allows to carry out a mode identification for the detected pulsation frequencies to determine their pulsational quantum numbers, the harmonic degree, ℓ, and the azimuthal order, m. For the spectroscopic mode identification, the Fourier parameter fit method and the moment method are available. The photometric mode identification is based on pre-computed grids of atmospheric parameters and non-adiabatic observables, and uses the method of amplitude ratios and phase differences in different filters. The types of stars to which FAMIAS is applicable are main-sequence pulsators hotter than the Sun. This includes the Gamma Dor stars, Delta Sct stars, the slowly pulsating B stars and the Beta Cep stars - basically all pulsating main-sequence stars, for which empirical mode identification is required to successfully carry out asteroseismology.

The complete manual for FAMIAS is published in a special issue of *Communications in Asteroseismology, Vol 155.* The homepage of FAMIAS[2] provides the possibility to download the software and to read the on-line documentation.

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Contents of Communications in Asteroseismology, Volume 155

- FAMIAS User Manual: Zima, W. 2008, CoAst, 155, 17
- DAS (HELAS Database for Asteroseismology): Østensen, R. 2008, CoAst, 155, 7

You can retrieve this volume through ADS or simply download the complete PDF file from CoAst homepage.

[1] http://www.helas-eu.org
[2] http://www.ster.kuleuven.be/∼zima/famias

Communications in Asteroseismology (CoAst), which incorporates the former Delta Scuti Star Newsletter, is a refereed journal, commissioned by the Austrian Academy of Sciences. CoAst is distributed in printed form and can also fully be retrieved online via ADS and Simbad References. You can find more information on our homepage *http://www.univie.ac.at/tops/CoAst/*.

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