Amplitude and phase modulation in CoRoT RR Lyrae stars

R. Szabó[1], M. Paparó[1], J. M. Benkő[1], M. Chadid[2], K. Kolenberg[3], E. Poretti[4]

[1]Konkoly Observatory of the Hungarian Academy of Sciences, P.O. Box 67, H-1525 Budapest, rszabo@konkoly.hu
[2]Observatoire de la Cote d'Azur, Université Nice Sophia-Antipolis, UMR 6525, Parc Valrose, 06108 Nice Cedex 02, France
[3]Institute of Astronomy, University of Vienna, Türkenschanzstrasse 17, A-1180 Vienna, Austria
[4]Istituto Nazionale di Astrofisica, Osservatorio Astronomico di Brera, Via E. Bianchi 46, I-23807 Merate (LC) Italy

Introduction

CoRoT (Convection Rotation and planetary Transits) was launched on 27 December, 2006. It is a fantastic instrument that is capable of observing stellar pulsations continuously at an unprecedented accuracy for up to 150 days. This enables us to exquisitely investigate the enigmatic Blazhko-effect in RR Lyrae stars.

For this purpose we studied five RR Lyrae stars found during the first long run toward the Galactic center (LRc01). Four of the 5 stars were found to show amplitude (and phase) modulation. We used the 'white' flux for three of them. The time sampling of these light curves was 512s. For star #544 short-cadence sampling (32s) was collected, as well. Three colors (red, green and blue) are available for this object. We used the 'red' channel of the aperture in the present investigation, because the noise level was most favorable in this case. We removed outlying data points (approx. 2%), the majority of which was taken during the South-Atlantic Anomaly passages. Trend and jump filtering was also applied before the analysis.

Amplitude and phase modulation

Fig.1. shows the folded light curves of the four Blazhko stars. Instantaneous **amplitude** was determined for all stars using the analytic signal method. The method is described in detail in Kolláth et al. (2002). It gives the accurate (time-dependent) amplitude of the signal in a given frequency band. For simplicity, we used it centered on the first harmonic component (A_1). The process provides the instantaneous **frequency**, as well. Periodic variation of the frequency was found in all cases with a period equal to that of the amplitude variation. Hence we interpret the phase variation as period variation throughout the modulation cycle. We computed the phase lag between the amplitude and period modulation ($\Delta\psi$, **Table 2.**). It's interesting to note that the longest period occurs close to the minimum amplitude ($\Delta\psi$=0.50) for all the studied objects. Asymmetry is defined as the phase shift between the maximum of maxima and minimum of minima (ψ_{max}-ψ_{min}). Averaged values are printed in the table, their formal standard deviations are also given. In the case of large amplitude stars (#962, #793) the errors demonstrate the stability of the consecutive Blazhko-cycles, while for the blended stars the scatter is dominated by observational noise.

CoRoT ID	total ampl. of variation	amplitude of modulation	pulsational period P	# of observed puls. cycles
0100689**962**	$0^m.764$	$0^m.392$	$0^d.355990$	399
0101128**793**	$0^m.567$	$0^m.034$	$0^d.471934$	301
0100881**648**	$0^m.091$ (bl)	$0^m.023$	$0^d.607272$	234
0101503**544**	$0^m.021$ (bl)	$0^m.007$	$0^d.605097$	250

Table 1. Pulsational parameters of the CoRoT LRc01 RR Lyrae stars. (bl) denotes low amplitude, blended pulsators.

CoRoT ID	Blazhko-period	asymmetry (ψ_{max}-ψ_{min})	phase modulation $\Delta P/P$	ampl.-per. phase lag $\Delta\psi$
0100689**962**	$26^d.83$	0.132±0.006	0.0137±0.0002	0.390±0.006
0101128**793**	$18^d.66$	0.673±0.020	0.0139±0.0002	0.534±0.053
0100881**648**	$59^d.77$	0.009±0.020	0.00245±0.00006	0.469±0.012
0101503**544**	$25^d.60$	0.045±0.035	0.0040±0.0090	0.507±0.035

Table 2. Modulation parameters. Phase modulation is measured as the relative period variation.

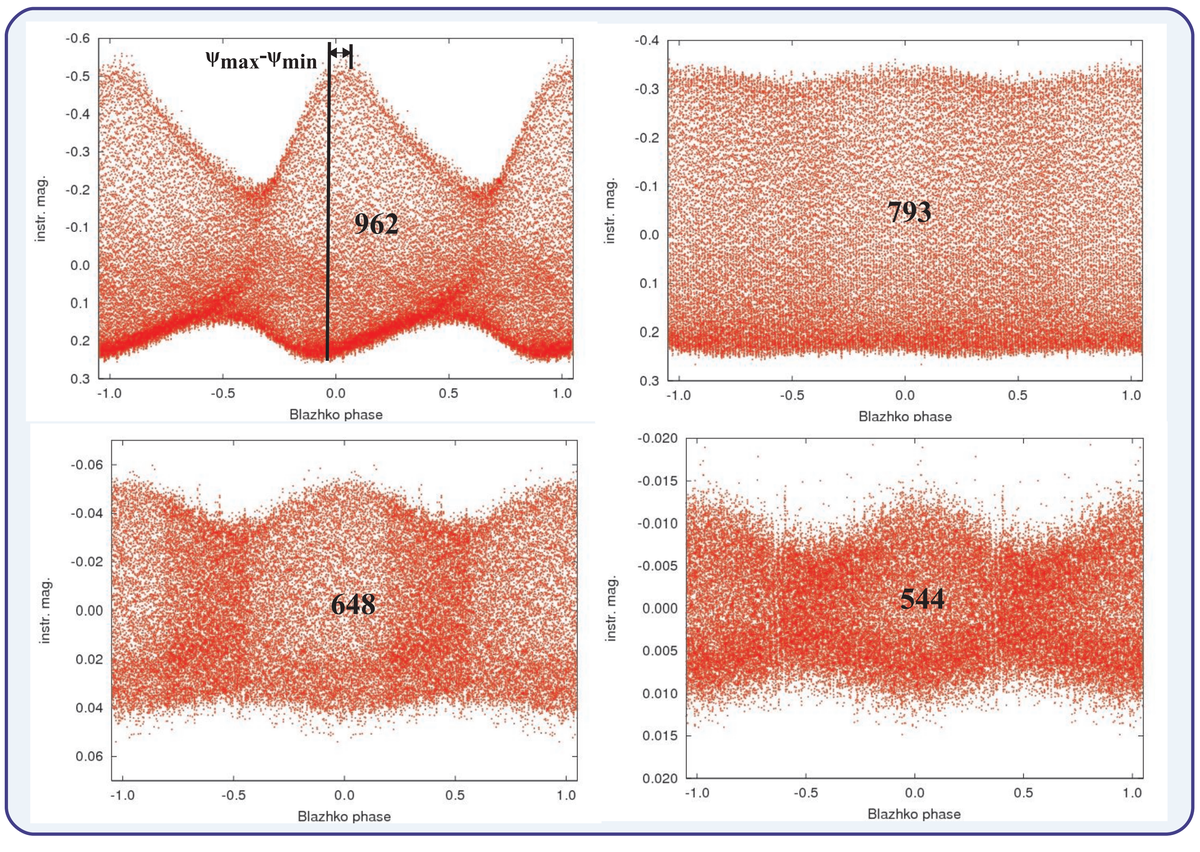

Fig. 1. Phased light curves of the four CoRoT Blazhko RR Lyrae stars, folded by the modulation period. Note the different magnitude scales on the panels.

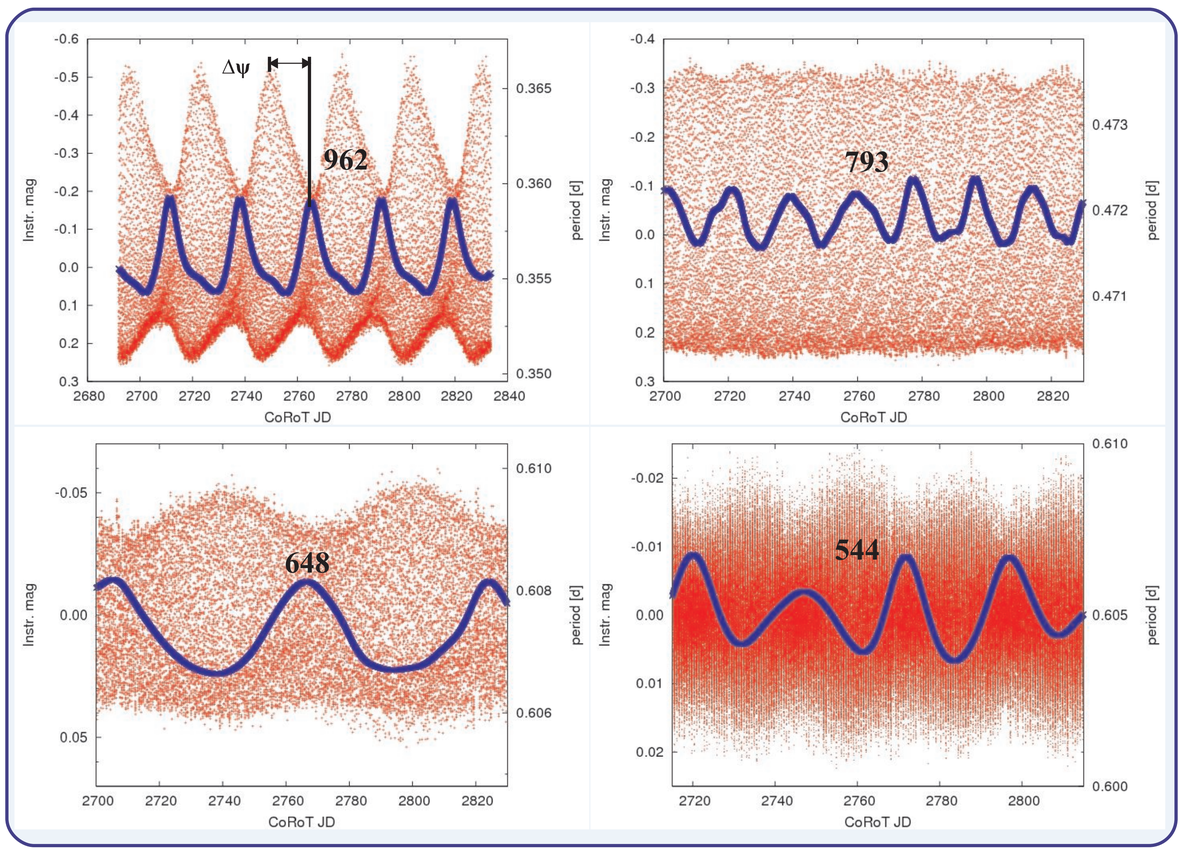

Fig. 2. Light curves of the four Blazhko RR Lyrae stars covering several Blazhko-cycles. Period variation is shown by blue curves. Note the different magnitude and period scales on the panels.

The CoRoT LRc01 RR Lyrae stars

The pulsational properties of the studied objects are listed in **Table. 1**.

962 is identical to V1127 Aql. It shows a strongly modulated light curve, with a high pulsational amplitude and pronounced phase modulation, resembling that of MW Lyr (Jurcsik et al. 2008). However, other properties are markedly different. The modulation is not sinusoidal (as easily seen on the envelope of the maxima), and is asymmetric in the sense, that the maximum of the maxima and the minimum of the minima shows considerable shift (**Table 2**.).

793 shows surprisingly small amplitude modulation ($0^m.034$). The modulation is even more asymmetric than that of 962. This is the lowest modulation amplitude detected so far (Jurcsik et al. 2005.)

648 exhibits an asymmetric RRab light variation diluted by a close stellar companion which is revealed by ground-based imaging with the Konkoly Observatory 1m RCC telescope. The modulation is sinusoidal and symmetric**.**

544 has a typical skewed RRab light curve, diminished to $0^m.021$ overall variation due to blending. The hypothesis that this object is an intrinsically high-amplitude RR Lyrae, is supported by the relatively high modulation ($0^m.007$) compared to the overall light variation amplitude ($0^m.021$). CCD images taken with the Konkoly Observatory 1m RCC telescope confirms the existence of a close companion.

Results

- High incidence rate of Blazhko-effect was found among RRab stars in the CoRoT sample (4 out of 5).
- The easily detected 0.007^m modulation for #544 emphasizes the potential of CoRoT to detect amplitude modulation in the millimag regime. This capability may prove or disprove the existence of a lower limit for the amplitude of the Blazhko-modulation.
- Both sinusoidal and non-sinusoidal modulation shapes occur hinting at a varied manifestation of the modulation process.
- The phase shift between the amplitude and period modulation is confined to a relatively small interval (0.39-0.54) for all studied objects.
- The period variation - common to all Blazhko stars in our sample - points to a spherically symmetric (radial) perturbation of the dominant radial pulsation.

Acknowledgments

MP, RSz and JMB wish to acknowledge the financial support of the ESA PECS project No. 98022. KK thanks the support provided by FWF project T359. EP acknowledges the financial support of the Italian ESS project, contract ASI/INAF/ I/015/07/0, WP 03170.

References

1. Jurcsik, J., Szeidl, B., Sódor, Á. et al.: AJ, 132, 61, 2005
2. Jurcsik, J., Sódor, Á., Hurta, Zs., et al.: MNRAS, 391, 164, 2008
3. Kolláth, Z. Buchler, J. R., Szabó, R. & Csubry, Z.: A&A, 385, 932, 2002