On the phase-modulation properties of Galactic bulge RRab stars

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Prelude

The properties of Blazhko modulation (e.g., modulation period, strength of the amplitude and phase modulation components, phase relation of the amplitude and phase modulations) do not show any direct, systematic connection with the pulsation and physical properties of RR Lyrae stars. The only systematic feature found is the lack or sparseness of the occurrence of the modulation in long period ($P > 0.65$ d) variables. This was detected both in the Galactic bulge (Prudil & Skarka 2017) and in the globular cluster M3 (Jurcsik, 2019). The analysis of the M3 Blazhko stars gave some hint on that the phase modulation might be week in Oosterhoff type II stars. The OGLE-IV observations of the Galactic bulge RRL stars provide a huge collection of Blazhko stars (Prudil & Skarka, 2017) which is ideal for revising possible differences between the strengths of the phase modulations of the Oosterhoff-type I and II populations.

Analysis

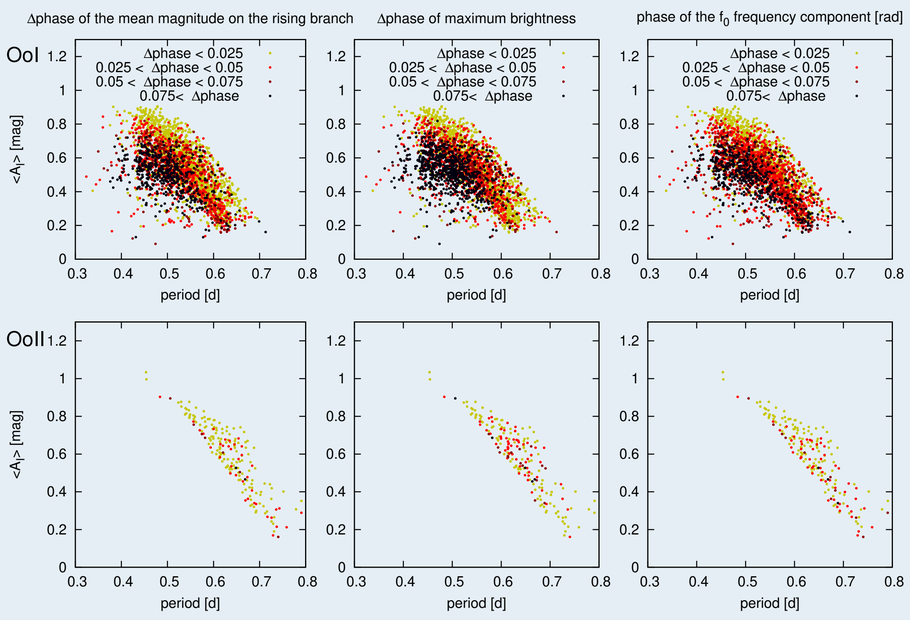
3104 OoI and 199 OoII type Blazhko RRL stars are analyzed. The OoI and OoII types are separated based on their location on the period-amplitude Bailey diagram (see details in Prudil et al. 2019). Pulsation and modulation periods were determined automatically for the whole sample of stars using the Fourier spectra and a nonlinear fitting algorithm (Sódor, 2012). As our aim is to measure the strength of the phase modulation, and period change can mimic long-period phase modulation, we analyze two data sets for each star: a) the full length (seven years) OGLE-IV observations and b) a 3-year segment. If significantly different modulation periods emerged from the two data sets, the results were checked individually. If the amplitude of the period change was larger than the amplitude of the phase modulation than the star was removed from the sample. Stars with modulation periods with similar or longer lengths than the time span of the observations were omitted from the sample, unless amplitude changes parallel with the phase change were detected.

The phase modulation was measured by analyzing the data belonging to six Blazhko phase intervals separately, and its strength was determined as the full range of the phase changes defined by these data sets. Three different definitions of the phase modulation were checked:

- the phase change of the mean magnitude on the rising branch;
- the phase change of the maximum brightness;
- the phase variation of the f_0 Fourier component.

If any of these three measures of the phase modulation has an extreme value or it is significantly different from the others, the star was individually checked. Finally, the removal of all the questionable and false cases resulted in 2936/3019 and 179/193 stars for the OoI and OoII populations using the full datasets and their 3-year segments, respectively.

Results



Comparison of the strength of the phase-modulation of Oosterhoff-type I and II Galactic bulge Blazhko stars. The phase modulation is measured in three different ways and its strength is indicated by the colors of the symbols as explained by the key notes. Results for the 3-year segments of the OGLE data are shown as they are less contaminated by period changes than the full lengths, 7 years long observations. About 25-35% of OoI stars show strong phase modulation (shown in brown and black colors), and about 15-25% belongs to the strongest phase modulation sample (black color). This is true for each of the three different measures of the phase modulation and also for the 7-year and the 3-year data sets. This behaviour is in high contrast with the occurrence rate of strong phase modulation in OoII stars.

Acknowledgements

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References

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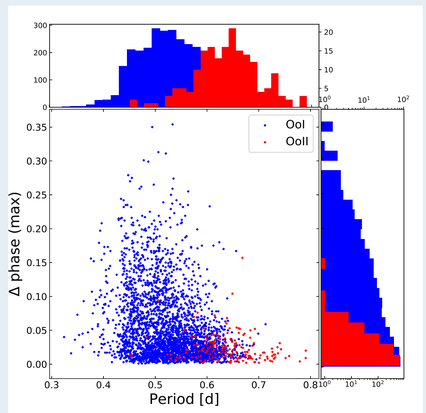
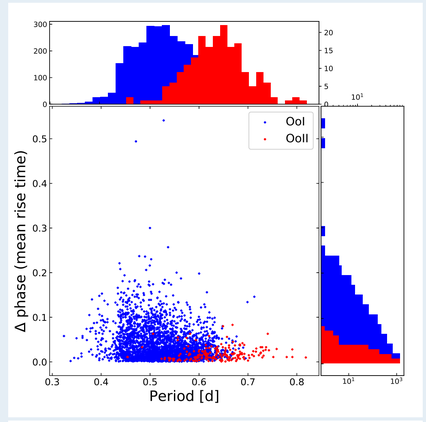
Results

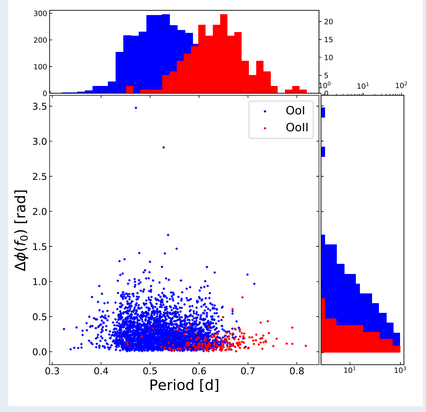
Distribution and statistics of the periods and phase-modulation strengths of the OoI and OoII Galactic bulge Blazhko stars.



Phase change of the maximum brightness determined for the complete OGLE-IV observations.



Phase change of the mean brightness on the rising branch determined for 3 years long segments of the data sets.



Phase change (in radians) of the f_0 frequency component determined for 3 years long segments of the data sets.

Each plot documents that the distribution of the phase-modulation strength is different for the OoI and OoII samples. For the OoI sample the histograms of the phase modulation strength (right side panels in the figures) indicate exponential decrease towards large values (note the logarithmic scale), while it drops sharply for the OoII stars at much smaller values than the possible range of the phase-modulation strength of OoI stars.

Conclusions

Similarly to what was found in M3, the Galactic bulge OoII Blazhko stars display less intense phase modulation as the OoI type stars.

However, there might be some bias in the selection of the OoII sample of Blazhko stars towards skipping variables with reduced mean magnitudes. OoII Blazhko stars were selected based on their location in the *period−mean amplitude* Bailey diagram and the amplitudes of Blazhko stars showing large amplitude phase modulation are suppressed. The low number of OoII type Blazhko stars detected in the bulge seems to support this possibility.

Nevertheless, the strong gradient of the phase modulation strength from small to large pulsation amplitudes at any period (see the panels on the left side) indicates that even if the selection of OoII stars is biased, the reduction of the phase modulation towards larger amplitudes remains a valid feature.