RR Lyrae Stars in the Galactic Bulge

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Scientific justification

RR Lyrae stars play a crucial role in many fields of astrophysics. They are excellent distance indicators and tracers of the structure and evolution of the Galaxy. They play an important role in testing stellar evolution and pulsation theories. *Kepler* observations of RR Lyr stars have revolutionized our knowledge about these stars, leading to several new discoveries concerning the Blazhko effect or excitation of additional modes, both radial and non-radial.

For this proposal we benefit from extensive observations of the Galactic bulge by the OGLE project, which allowed us to select a few tens of particularly interesting RR Lyr stars of all flavours, fundamental mode pulsators (RRab), first overtone pulsators (RRc) and double-mode stars (RRd).

Our high priority targets include three RRd stars with Blazhko modulation and peculiar period ratios, members of the recently discovered class (Smolec et al. 2015), never observed from space thus far. We also include three RRc stars in which additional variability of long period, likely corresponding to gravity mode pulsation, is present (Netzel et al. 2015a). So far only one star of this type was observed by *Kepler* and our knowledge about this class is scant. We hope that precise space observations will shed more light on the nature of these new forms of RR Lyr variability. Several tens of RRc/RRd stars with the peculiar 0.61 period ratio are also included, some with features that were not extensively studied from space yet (simultaneous excitation of two/three non-radial modes, Netzel et al. 2015b). Precise observations of these stars will help to verify the theories proposed to explain this peculiar form of pulsation (Dziembowski, 2015, in prep.).

The targets include the RR Lyr binary candidates that were recently identified by Hajdu et al. (2015) using O-C analysis, as well as some unpublished candidates. Although the inferred binary periods are much longer than the time-span of the K2 observations, detection of additional modes could indicate that the observed phase modulation is not due to the light-time effect (e.g. Irwin 1952), but is caused by the Blazhko effect (Benkö & Szabó 2015). This way, K2 can be instrumental in selecting the bona-fide binary candidates for long-term follow-up.

The OGLE survey discovered many stars with peculiar modulation properties. We listed several examples, such as stars where the amplitude and phase modulation are not correlated, or both show very strong variations. A particularly large sample of modulated RRc stars is included. While many modulated RRab stars were already observed from space, the sample of modulated RRc stars is still scarce. Several stars have Blazhko periods much shorter than the expected campaign length, therefore temporal variations in the modulation can also be followed. Important question we will answer is whether and how the Blazhko RRc stars differ from Blazhko RRab stars; are period doubling, additional modes and strong irregularities also present in these stars?

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Targets and technical feasibility

Targets were selected based on their ASAS and OGLE light curves. We selected 68 high-priority targets that are critical for the success of this study. These are the brightest stars and/or stars with the highest expected scientific return. We also listed an additional 132 stars in the proposal whose observations are needed for a thorough analysis and to fully meet all goals we set out.

Given the distance to the bulge and the interstellar extinction, most of the targets we propose are relatively faint, with an estimated brightness of Kp ~14-17 mag (in the target table we use the I band brightnesses where we cannot match EPIC ID and Kp brightness to the targets). Nevertheless, despite the severe blending and contamination issues, we expect that with proper methods, such as differential image photometry, we will be able to extract useful data for these large-amplitude pulsators. A successful application of that method was presented by Molnár et al. (2015) for much fainter, blended RR Lyrae stars within the galaxy Leo IV.

Relevance and legacy

RR Lyr stars populate the bulge in large numbers. The extensive OGLE and ASAS observations were used to select two hundred of the most promising stars, all with interesting or peculiar forms of pulsation. Thus, we have a great opportunity to significantly increase the *Kepler*+K2 sample of RR Lyr stars with all known forms of pulsation, also with members of classes that were never or scarcely observed from space. The 3-month K2 light curves will be extended by and will benefit from the synergy with the OGLE and ASAS projects, which provide several-year long multicolor photometry. This will allow the characterization of the long-term behavior of these stars, to put the three month long K2 observations into context. Conversely, the K2 observations provide high-precision snapshots, which complement the ground-based surveys. A simple procedure for computing [Fe/H] values has also been established for the Kp band (Nemec et al. 2013). K2 observations of the bulge targets will strongly increase the scientific outcome of our Guest Observer RR Lyr proposals. These observations allow us to study phenomena that have never been studied from space before. Furthermore, we emphasize that the majority of our targets belong to the bulge; these observations will address in a statistical way whether the modulation properties differ from the RR Lyr observed by *Kepler* in the thick disk and halo populations. We expect a significant improvement in our understanding of multi-mode and modulated pulsation of RR Lyr stars. The K2 light curves will serve as benchmarks for stellar pulsation models. The processed light curves will be released to the public.

References

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