Precision Pulsation Properties of Bulge RR Lyrae Stars

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Abstract: We propose to obtain precision pulsation properties of 138 bulge RR Lyrae variables (RRLs), a population of RRLs with the widest metallicity distribution in the Galaxy and a population consisting of double-mode stars with characteristics unlike anywhere else in the Milky Way. From spectroscopically surveying ~1000 bulge RRLs, we have found this population has an abundance distribution spanning three orders of magnitude, suggestive of multiple populations within the bulge RRL, which have also been identified by two RRL sequences in the period-amplitude (Bailey) diagram. Our observations have also indicated that the homogeneous population of double-mode RRLs (RR01 stars) found within 10 deg in the bulge, that was previously explained as stars with a common origin (i.e., remnant from a disrupted dwarf galaxy or stellar cluster), in fact *do not* have similar dynamics. Therefore their "clumping" in the RR01 period ratio regime needs to be understood in a different, yet unknown manner. With K2, we can undertake a more detailed investigation of the bulge RRLs by obtaining precise periods, amplitudes and magnitudes. These will allow exquisite measurements of the Bailey diagram to trace multiple populations that exist within this old population. The exact RR01 pulsation properties will also open up the possibility to advance the theory of RRL pulsation, as models of RR01 metallicities and masses can be applied and tested on the bulge RR01 stars, a population occupying a unique (more metal-rich) RR01 period ratio regime.

Science Justification: RRLs are low-mass stars that have evolved away from the main sequence and are burning Helium in their core. Therefore, their progenitors are emphatically ancient (~11 Gyr), so that the bulge RRLs we observe today can be connected to the formation of the oldest datable bulge population. From multi-epoch spectroscopy of ~1000 bulge RRLs we have found the following:

(1) the bulge RRLs appear to have a different origin than the majority bulge stars – the null rotation and hot kinematics of the bulge RRL are consistent with an older, more spheroidal component that formed at high redshift (Kunder et al. 2016).

(2) The bulge RRL spectroscopic metallicities range from -2.5 dex to super-solar, peaking at [Fe/H]~ -1 dex, suggestive of multiple populations (e.g., Lee et al. 2015). The smaller velocity dispersion of the metal-rich RRLs compared to the more metal-poor stars (Fig 1) also indicates there were likely various RRL formation mechanisms in the bulge.

The multiple populations in the bulge RRLs have recently been traced out in two distinct sequences in the period-amplitude diagram (Pietrukowicz et al 2015), which can be explained as the manifestation of two major old bulge populations co-existing in the bulge. ***Long-cadence, uninterrupted, high-precision space photometry, will allow frequency resolution, amplitude derivation and photometric precision to construct an exquisite Bailey diagram, which may reveal additional sequences than the two currently seen.*** Alternatively, the spread in the Bailey diagram may be due to errors in amplitude estimates or by e.g., the Blazhko effect, (which is thought to be more prevalent in metal-rich populations like the bulge RRL). K2 photometry would be crucial to identify and to characterize Blazkho variables and improve photometric precision. For the first time, an understanding of the level of "true" scatter in this diagram can be measured, providing an indication on what scatter is caused by *intrinsic* population differences in the RRLs. We can search then for correlations between the different sequences of RRL in the Bailey diagram and properties such as metallicity, orbital properties, and location in the CMD.

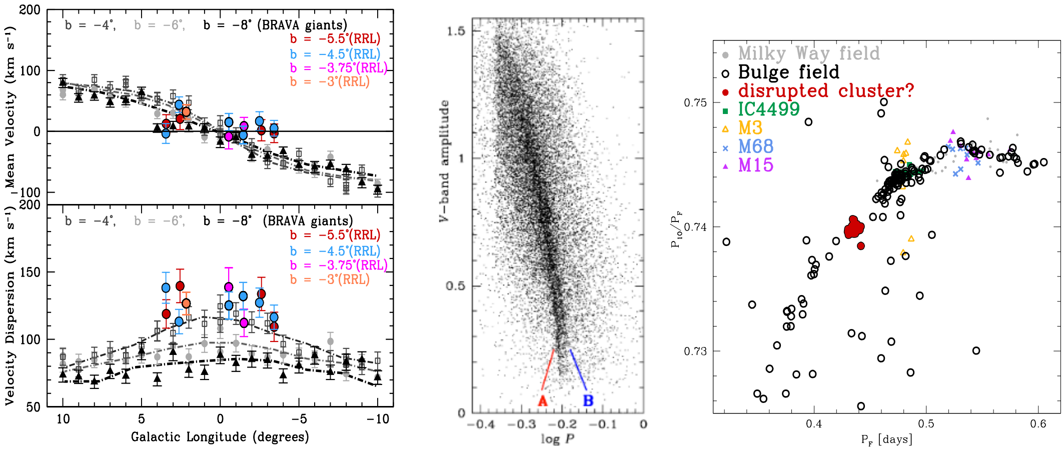

Figure 1 Left: The velocity dispersion profile (bottom) and rotation curve (top) for the RRLs we have already observed compared to that of the BRAVA giants at b = -4, -6, and -8 strips (Kunder et al. 2012). The bulge model of Shen et al. (2010) is shown by the dashed lines. The RRLs have kinematics clearly distinct from the bulge giants, and are the only known non-rotating bulge population (Kunder et al. 2016) Middle: The period-amplitude diagram of OGLE bulge field RRLs. Two distinct sequences, A and B, are visible. Right: All known Milky Way RR01 stars identified so far in globular clusters for which periods are available. RR01 stars have pulsation properties that identify them to specific systems. Also shown are known field stars of our Milky Way and the bulge field RR01 stars. The range in period ratio covered by the bulge RR01 is unique; such a range is not seen in either globular clusters or in dwarf galaxies.

More than 20% of the bulge RR01 stars form a compact group with period ratios of P_{1O}/P_F~0.74 (see Fig. 1), highly suggestive that these stars belong to the same system. Yet, our dynamical results do not indicate this as a plausible formation scenario for these stars. Detailed light curves of the bulge RR01 stars are needed to explain this behavior. ***The RR01 bulge RRL period ratios consist of an extended metal-rich component which no other region in the Galaxy harbors. The bulge is the perfect laboratory to constrain the metallicity dependence of RR01 stars, and K2 will provide the best observations possible.***

Kepler photometry will allow us to remove all the possible period aliases of bulge RRL around 0.5 and 1.0 days. The ~0.5 d regime is where transition between first-overtone (RR1) and fundamental-mode (RR0) type pulsators is, for the more metal-rich high-amplitude, short-period RR0 stars. The 1.0 d regime is the approximate transition between RRL and short period type II Cepheids, for the more metal-poor RRLs.

There are 41 bulge RR01 and 97 bulge RRL with spectroscopic parameters that fall on the K2 silicon; the 97 bulge RRL cover a wide and complete range on the Bailey diagram. These 138 stars are our high priority targets. Any extra pixels remaining could be allocated to as many as possible of the additional 4217 bulge RRLs with high-quality OGLE V and I photometry that fall on the K2 silicon.

No proposal was submitted previously. Spectroscopic data for the bulge field RRLs was collected only in 2014 and 2015, and the link between multiple RRL populations and precision pulsation properties was only published by the OGLE-IV team in 2015.

Kunder, A. et al. 2012, AJ, 143, 57 -- Lee, Y.-W. 2015, MNRAS, 453, 3906 -- Pietrukowicz, P. 2015, AJ, 811, 113 – Shen et al. 2010, ApJ, 720, 72