Analysis of RR Lyrae Stars in Milky Way Stellar Streams

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ABSTRACT

RR Lyrae stars (RRL) are old, metal poor pulsating variable stars typically found in discrete stellar populations such as galaxies, globular clusters, and their disrupted remains called stellar streams. Because of their well-calibrated period-luminosity relationship, RRL are excellent distance indicators; and can be used to determine the distance to the stellar populations where they are formed. We searched through RRL discovered by the Dark Energy Survey to potentially find if these stars are associated with various known galaxies and stellar streams. One such stream we evaluated was Indus, and we determined the membership of nearby RRL by analyzing their proper motions from the Gaia space satellite. Further analyzing Indus and other stellar streams will increase our knowledge of dark matter distributions in the stellar halo, improve our distance estimates in the local universe, and shed light on the formation of our own Milky Way galaxy.

INTRODUCTION

Within its first two years, the Dark Energy Survey (DES) has found 16 new ultra-faint dwarf satellite galaxy candidates orbiting the Milky Way (MW) (Bechtol et al. 2015, Drlica-Wagner et al 2015). Using the first three years of data, the DES has found 11 new stream candidates, or the tidally disrupted remains of satellite galaxies and star clusters (Shipp et al 2018). These objects require additional analysis to confirm if they are truly galaxies or streams and to further understand their properties and role in the formation of the MW. Here, we investigate the distances to these objects, which are currently not well constrained.

RR Lyrae stars (RRL) are old, metal poor pulsating variable stars that typically form in galaxies and star clusters. An example RRL light curve, or their brightness as a function of time, is shown in Figure 1. RRL are useful distance indicators because of their well-studied period-luminosity relationship. Using RRL stars found in DES (Stringer et al. in prep) that were also found in the Gaia DR2 data (Clementini et al. 2018), we search for any RRL that are spatially close to the satellite and stream candidates. To assess if these stars are associated with the satellites and streams, we also examine their proper motions, or tangential angular motions across the sky.

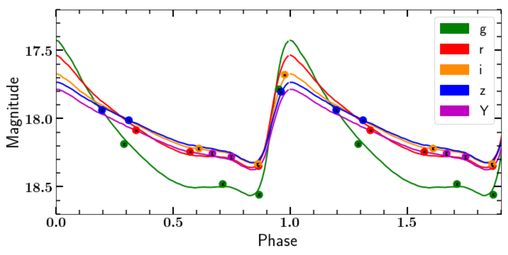

Figure 1. Plot of an RRL's change in magnitude verses time, also known as a light curve.

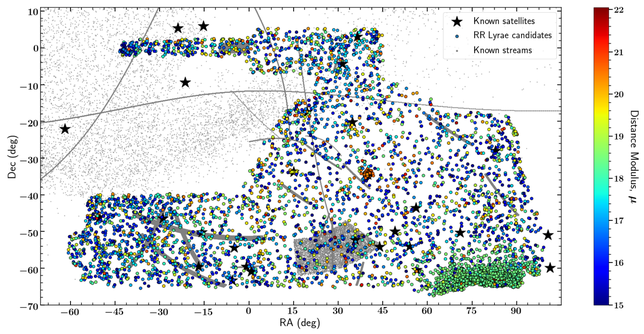

Figure 2. Visually confirmed RRL in DES (Stringer et al. in prep), along with satellite and stream candidates.

ANALYSIS OF NEARBY RR LYRAE

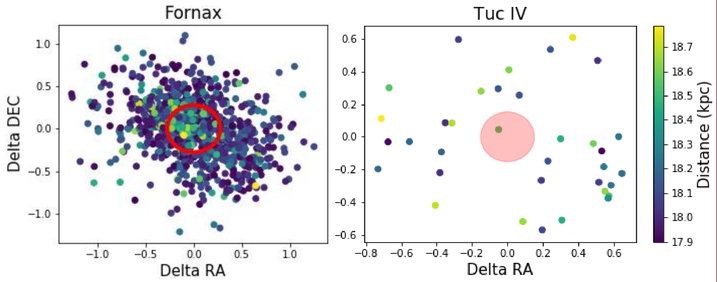

Figure 3. Plots of RRL near two MW satellite galaxies, Fornax and Tuc IV. The red circle denotes the half light radius of each galaxy, and (0,0) is the center of the galaxy. Tuc IV has one RRL within its half light radius, but it has not been visually confirmed (Stringer et al. in prep).

We plotted the sky coordinates of all the DES RRL in Figure 2. Since these coordinates (Right Ascension [RA] and Declination [DEC]) are heliocentric, or centered on the Sun, we first converted them to into a system centered on the satellite or stream candidate ([ΔRA, ΔDec] for galaxies and [Λ,β] for streams.) We then selected RRL within a certain distance of these objects. Figure 3 shows examples of RRL near satellite galaxies and Figure 4 shows examples of RRL near streams. Some objects had many RRL nearby, while others had few to none.

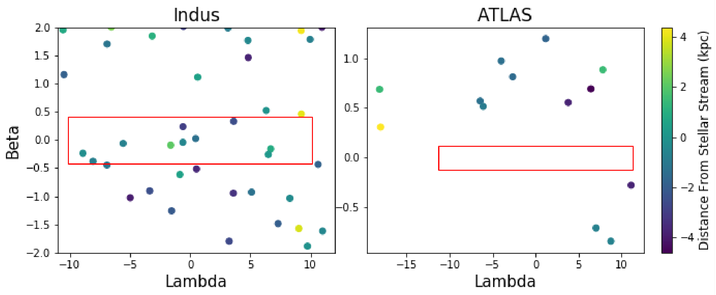

Figure 4. Visually confirmed RRL near two stellar streams in the MW, Indus and ATLAS. The red rectangle denotes the length and width of the stellar stream, where (0,0) is the center of the stream.

INDUS STELLAR STREAM

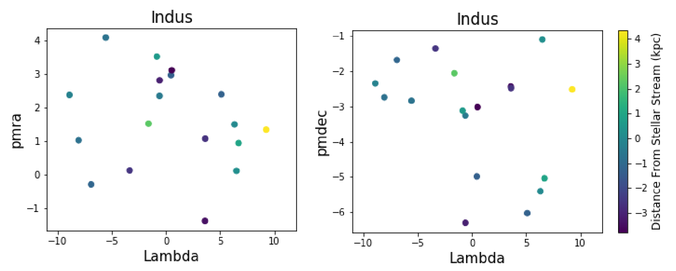

Figure 5. Proper motions of the nearest 18 RRL to the Indus stream plotted against their lambda lateral stream coordinate. See left side of Figure 4.

We chose to analyze the Indus stream (shown on the left side of Figure 4) because it is relatively nearby and has multiple nearby RRL. We found 18 RRL that are approximately in the same region as Indus. To further analyze the association of these stars with the Indus stream we also plotted the proper motions. Figure 5 shows the proper motions of the closest 18 RRL (pmra, pmdec) as a function of their position relative to the center of the stream, Λ (Lambda). It is not clear that these stars are associated with Indus based on the scatter of their proper motions. Further analysis is needed to confirm that these stars are members of the Indus stream.

FUTURE WORK

This work can be extended by examining the proper motions of RRL near other objects. Once RRL are determined to be members of a satellite galaxy or stream, they can be used to improve distance estimates to the object. More precise distance estimates enable more robust studies of dark matter distributions in the stellar halo, and shed light on the formation of our own Milky Way galaxy.

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