Probing Dark Matter with WISE-Detected RR Lyrae

Carl J. Grillmair, Roc Cutri, Frank Masci, Jeff Rich, & Douglas Hoffman

Introduction

Over the last decade, tidal debris streams have become our most sensitive probes of the mass and shape of the Galactic potential. Twenty one stellar debris streams have now been discovered (Figure 1), including one found in the WISE All-Sky release (Figure 2). The coldest streams (Pal 5, GD-1, $\sigma_v \sim 2$ km/s) are giving us the tightest constraints yet on the mass profile of the Galaxy. The constraints could be tighter still but for the uncertainties in the absolute and relative distances to streams. Distances are typically estimated by adopting values for age and metallicity and then fitting to the color-magnitude distribution of a few hundred stream stars (Figure 3), with uncertainties ranging from 10 to 30%. To improve our knowledge of the density and distribution of dark matter, we need better tracers.

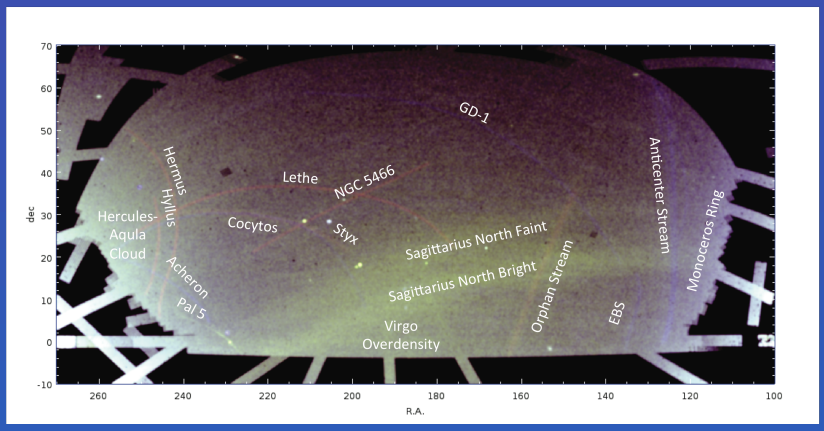

Figure 1. An updated "Field of Streams", showing a subset of the 21 tidal debris streams now known in our Galaxy. All but the Sagittarius streams have been accentuated to make them visible in a single stretch. Nearby streams (< 15 kpc) are shown in blue, while more distance streams are more reddish. Adapted from Grillmair 2014.

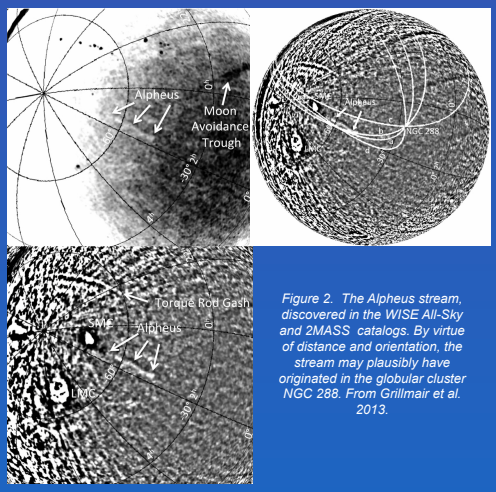

Figure 2. The Alpheus stream, discovered in the WISE All-Sky and 2MASS catalogs. By virtue of distance and orientation, the stream may plausibly have originated in the globular cluster NGC 288. From Grillmair et al. 2013.

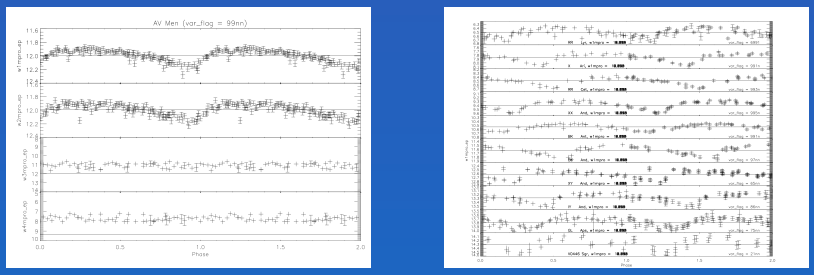

Figure 4. AllWISE photometry of the high-ecliptic-latitude RR Lyra AV Men (left), and of a number of other RR Lyrae over a range of magnitudes (right).

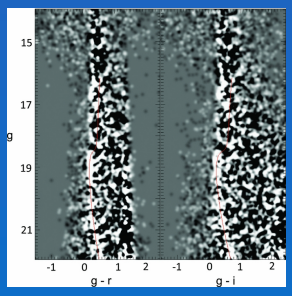

Figure 3 Visible light, background-subtracted, Hess color-magnitude diagrams of the EBS stream. The isochrones shown are fit to the few hundred stars identifiable in the stream to determine age, metallicity, and distance. From Grillmair 2011.

RR Lyrae

RR Lyra stars have long served as our most accurate standard candles. The period-luminosity relation (the Leavitt Law) for these variables is particularly useful in the near infrared (Madore et al. 2013), where the effects of extinction, temperature variations, and metallicity differences are greatly reduced compared with the visible. Thanks to the LINEAR, Catalina, and PTF surveys, some 12,000 RR Lyrae are already known. However, with greater coverage and less sensitivity to dust, WISE should be able to find many more. With a limiting magnitude for RR Lyra detection of W1 ~ 15.2 (Figure 4) and a cadence well suited to detecting variables with periods of ~ 1 day, we expect to find more than 20,000 RR Lyrae out to 16 kpc in the AllWISE catalog. This volume encompasses all but four of the known stellar streams.

Once detected, we need to measure mean magnitudes in the near IR. The Spitzer Space Telescope is currently spending many hundreds of hours measuring mean magnitudes for known RR Lyrae in the Sagittarius and Orphan streams. With no additional investment, AllWISE will give us such measurements for RR Lyrae in most of the remaining streams. These distances will, in turn, become crucial for turning Gaia's proper motion measurements into real velocities.

More Streams?

Stars do not form alone, and all RR Lyrae must once have belonged to larger stellar systems. In a Galaxy as massive as the Milky Way, most RR Lyrae are likely still in stellar debris streams. By finding and measuring 5% distances to all RR Lyrae within 16 kpc, AllWISE may enable us to find new streams, either in regions of the sky not covered by Sloan or Pan-STARRS, or with surface densities much lower than other techniques can reach. As an example, RR Lyrae have been used to extend the length of the Orphan stream well beyond what we could measure with traditional star count methods (Figure 5). More streams, followed further, will be needed if we are to examine the full extent of the dark matter halo, together with all the lumps and bumps along the way.

We are currently in the process of vetting objects classed as variables in the AllWISE release. Automatic classification (Masci et al. 2014) will begin shortly…

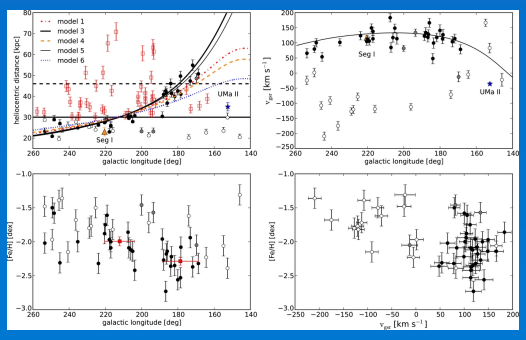

Figure 5. LINEAR and PTF RR Lyrae in the Orphan Stream. RR Lyrae trace the stream out to a Galactocentric radius of 55 kpc and favor a Milky Way with $M < 3 \times 10^{11}\ M_\odot$ to 60 kpc. From Sesar et al. 2013

References

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