WIDE-FIELD INFRARED SURVEY TELESCOPE
ASTROPHYSICS • DARK ENERGY • EXOPLANETS

Mapping the Milky Way's Dark Matter Halo with WFIRST

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1. Summary

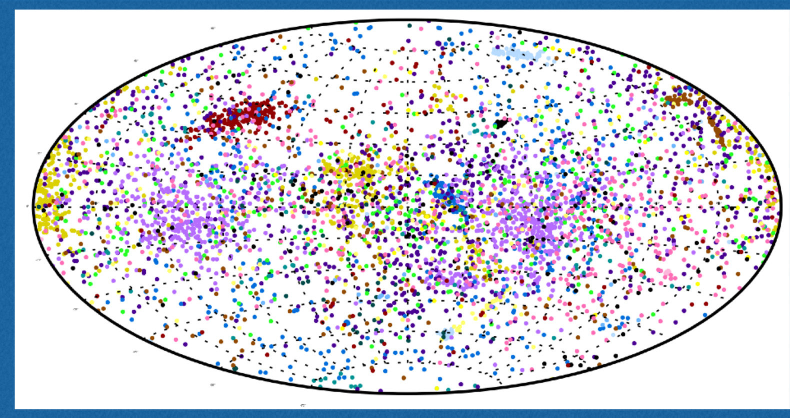
WFIRST provides a unique opportunity to acquire astrometry for stars in the distant Milky Way (MW) halo. These stars can act as probes of the entire MW dark matter halo.

To explore what is possible with WFIRST we simulate observations of RR Lyrae (RRLe) stars in the distant MW halo, asking what we might see, how we can associate stars accreted from the same progenitor galaxy, and how we can use these observations to constrain the potential of the MW halo.

2. Simulating observations of the stellar halo

- Bullock & Johnston (2005) superposed N-body simulations of individual disruptions of dwarf galaxies to build eleven stellar halo models entirely from accretion of satellite galaxies.
- We used the Galaxia stellar population code (Sharma et al. 2011) to construct synthetic all-sky surveys of RRLe from these halo models with an apparent magnitude limit of 24.5 mags (about 562 kpc for RRLe).
- We performed error-convolution on the synthetic surveys to replicate observational errors expected for 2020s-era instruments:

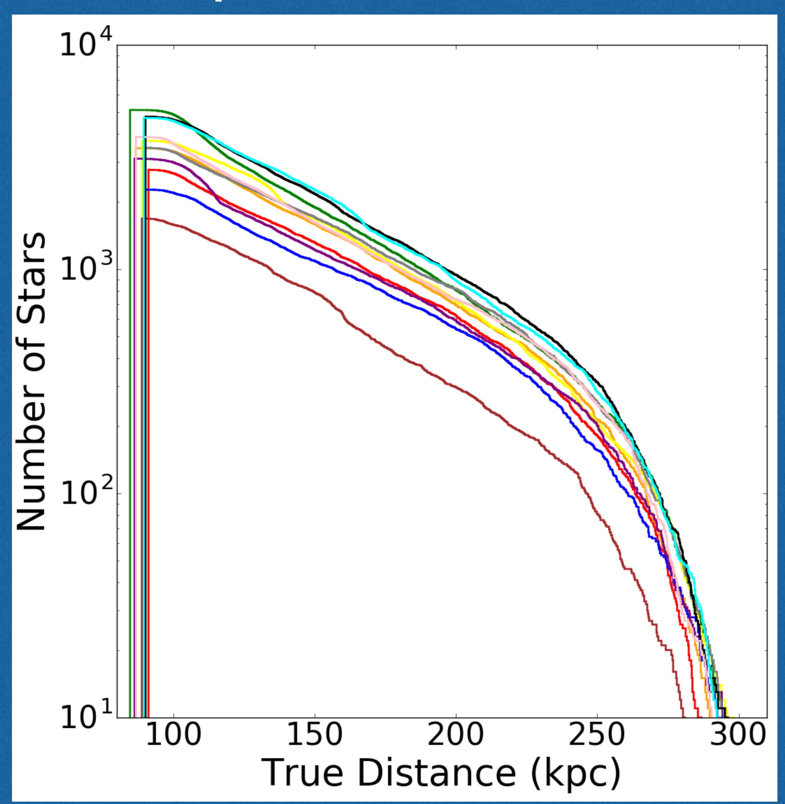
Instrument	LSST	Ground-based spectroscopy	WFIRST	Gaia
Data Acquired	Distances for RRLe brighter than 24.5 mags	Radial velocities	Proper motions of RRLe beyond 100kpc	Proper motions of RRLe within 100kpc
Projected Error	3% distance errors	10 km/s	25 micro-as/yr	End of mission Errors



An all sky view of RRLe beyond 100 kpc color-coded by progenitor galaxy for example mock halo 15.

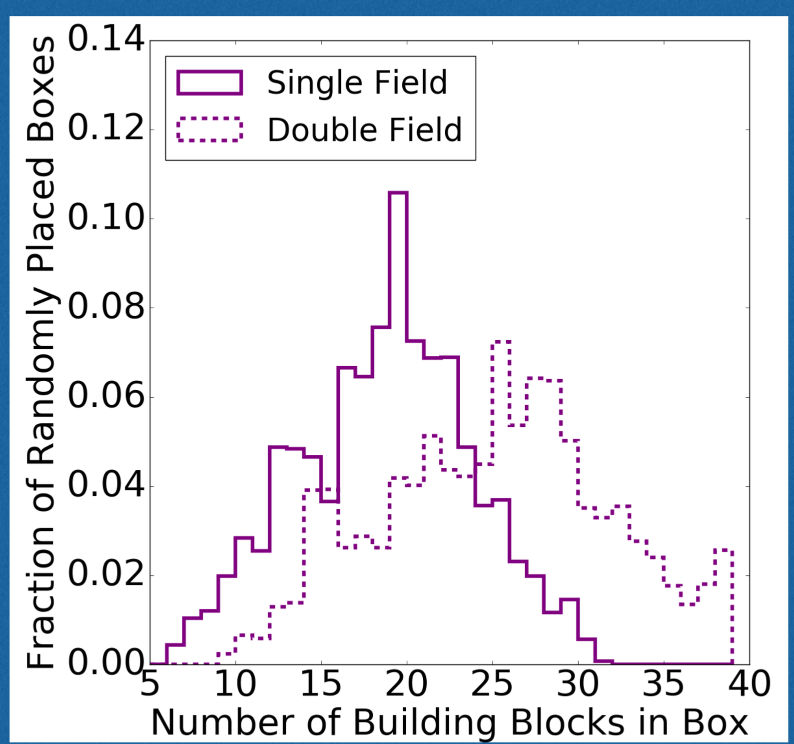
3. What might we see with distant halo surveys?

Thousands of RRLe are beyond 100 kpc for each mock halo.



The number of RRLe beyond each distance. Each line represents a different mock halo.

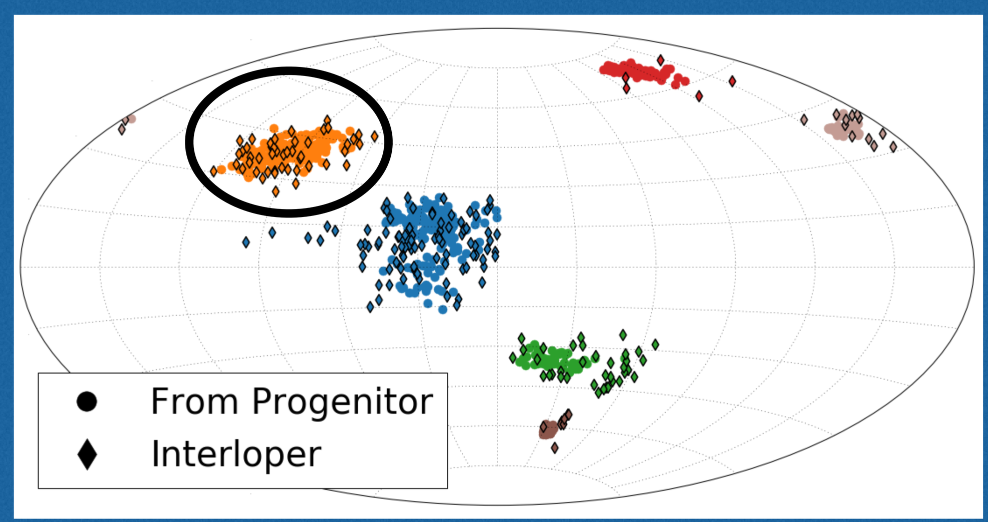
A WFIRST-sized survey should contain tidal debris from more than 5 different disrupted satellites with RRLe beyond 100kpc.



Distribution of the number of different accreted galaxies containing RRLe in a randomly placed WFIRST-HLS-sized (2200 square degree) survey (solid), and a survey twice the size (dashed).

4. What groups might we find in position space?

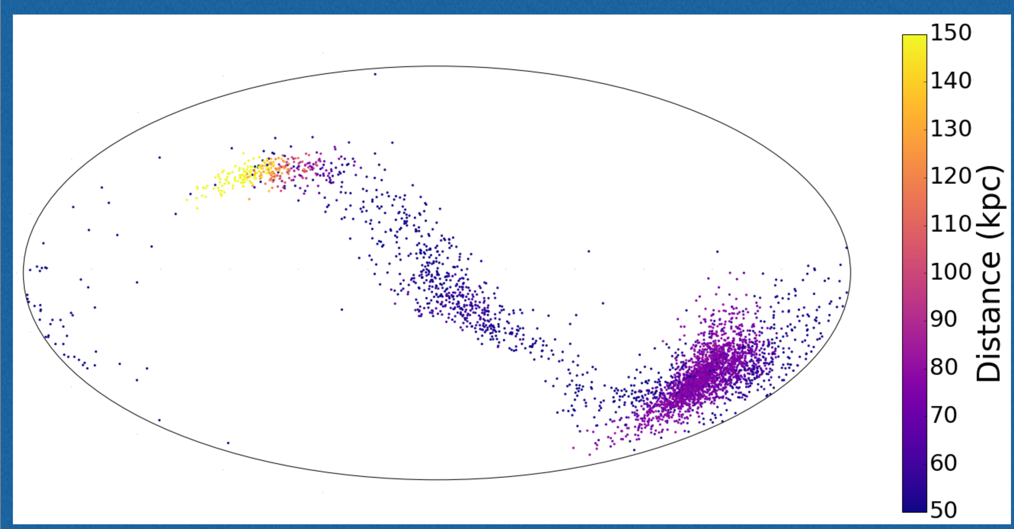
We run the EnLink group finding algorithm (Sharma and Johnston 2009) **on all RRLe beyond 100 kpc for each mock halo. EnLink finds several groups in position space (galactic latitude, galactic longitude, and distance) of RRLe beyond 100kpc in each mock halo.**



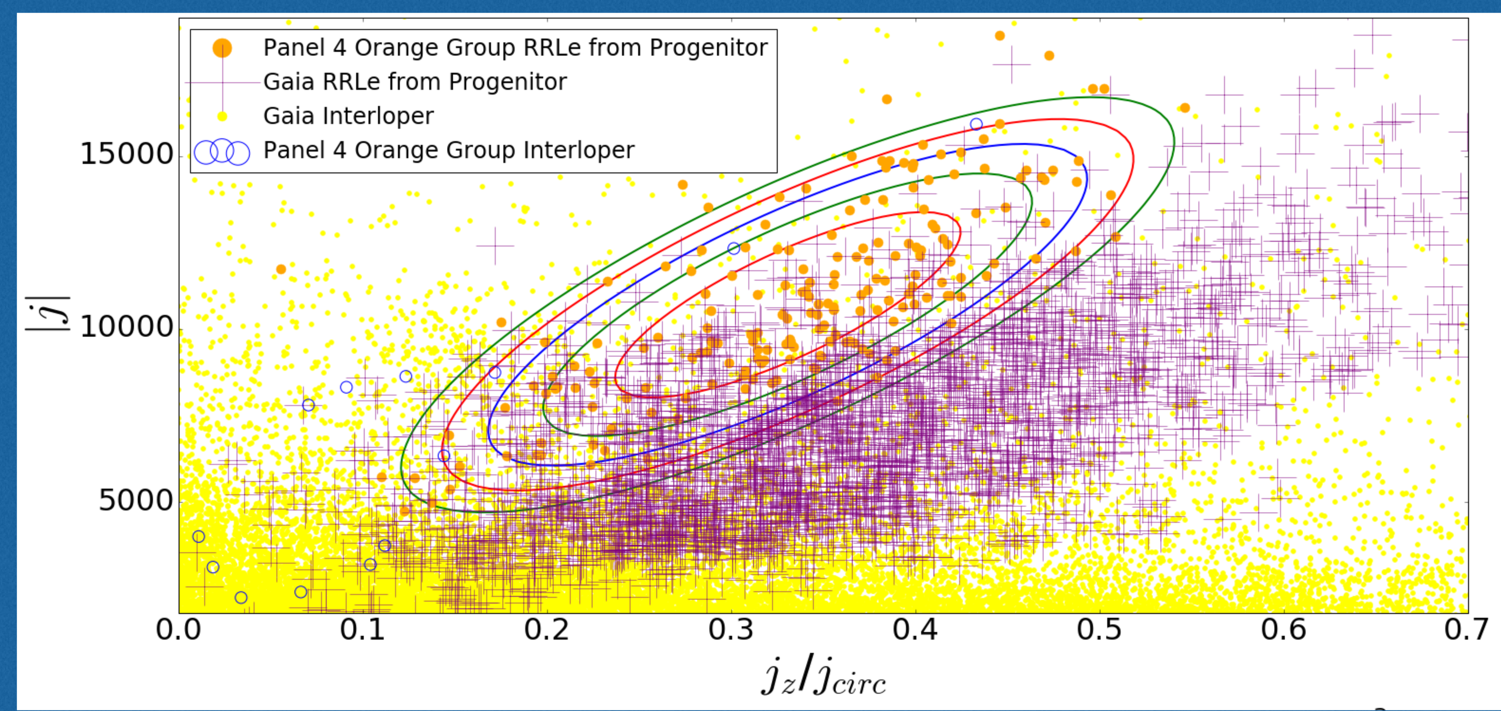
Groups of RRLe beyond 100kpc recovered in position space color-coded by EnLink group ID for the example mock halo. Stars are plotted as diamonds if they are incorrectly identified as group members.

5. WFIRST proper motions help connect halo surveys

Proper motions from WFIRST allow us to look at the angular momenta of RRLe to help identify interlopers in position space groups and associate stars from the same progenitor galaxy that are in Gaia footprint (within 100kpc) even when they are not in the same part of the sky.

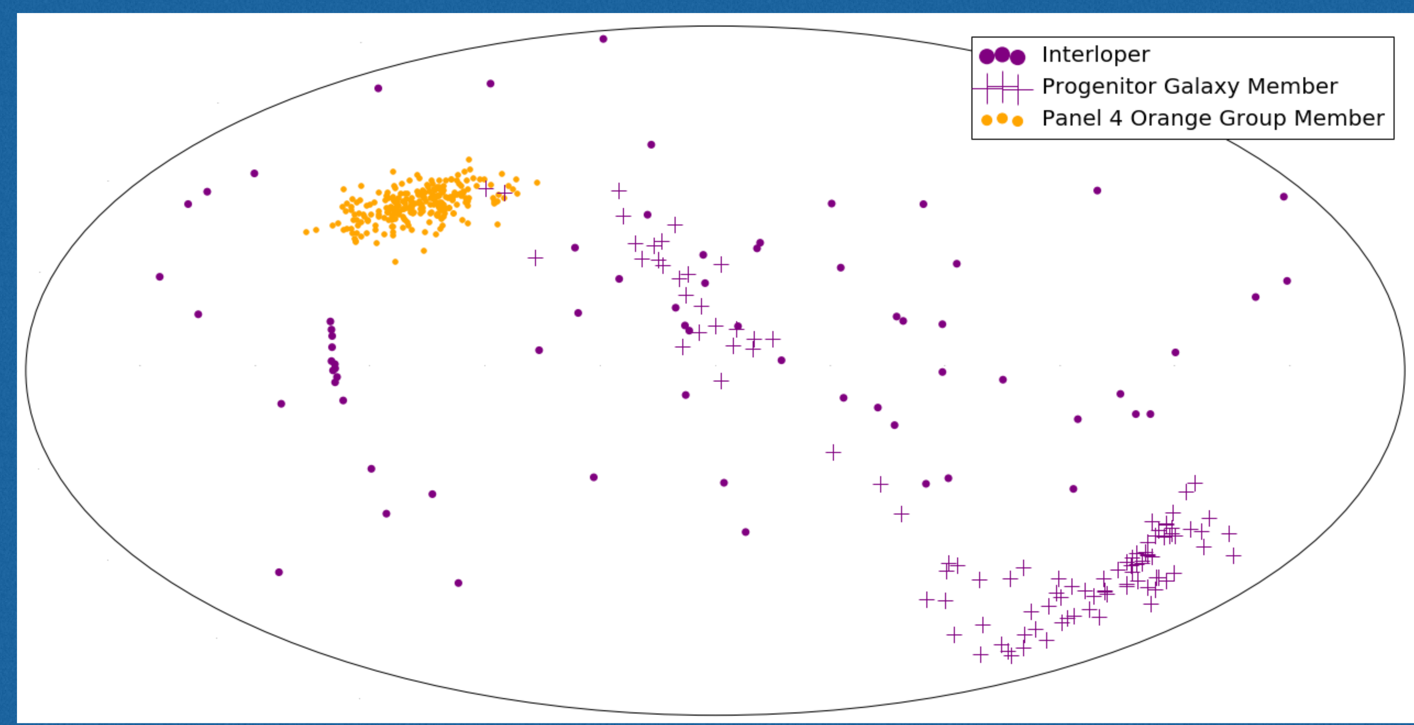


All RRLe from the same progenitor galaxy as the orange group in **Panel 4.**



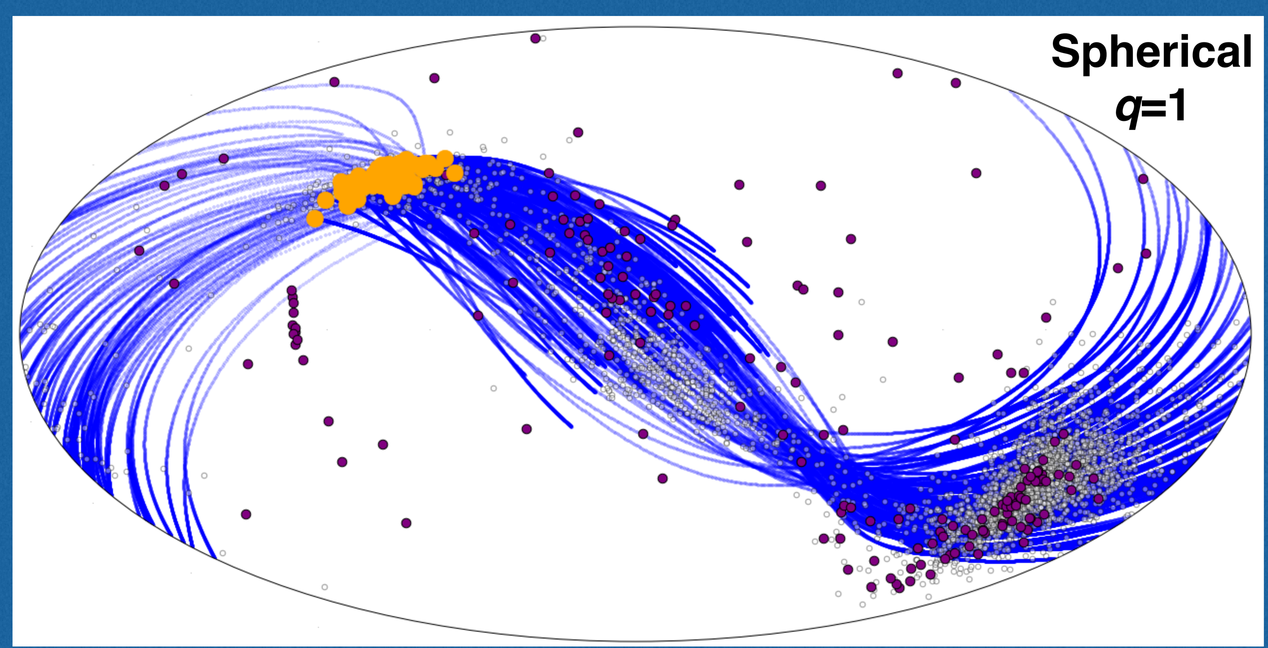
Above: RRLe plotted in |j|-j_z coordinate space. The contours represent standard deviations of the Gaussian distribution of the RRLe that are members of the orange group in **Panel 4**.

Below: Positions on the sky of RRLe that fall within the first contour (one standard deviation) in the figure above.



6. WFIRST proper motions can help constrain the potential of the Milky Way Halo

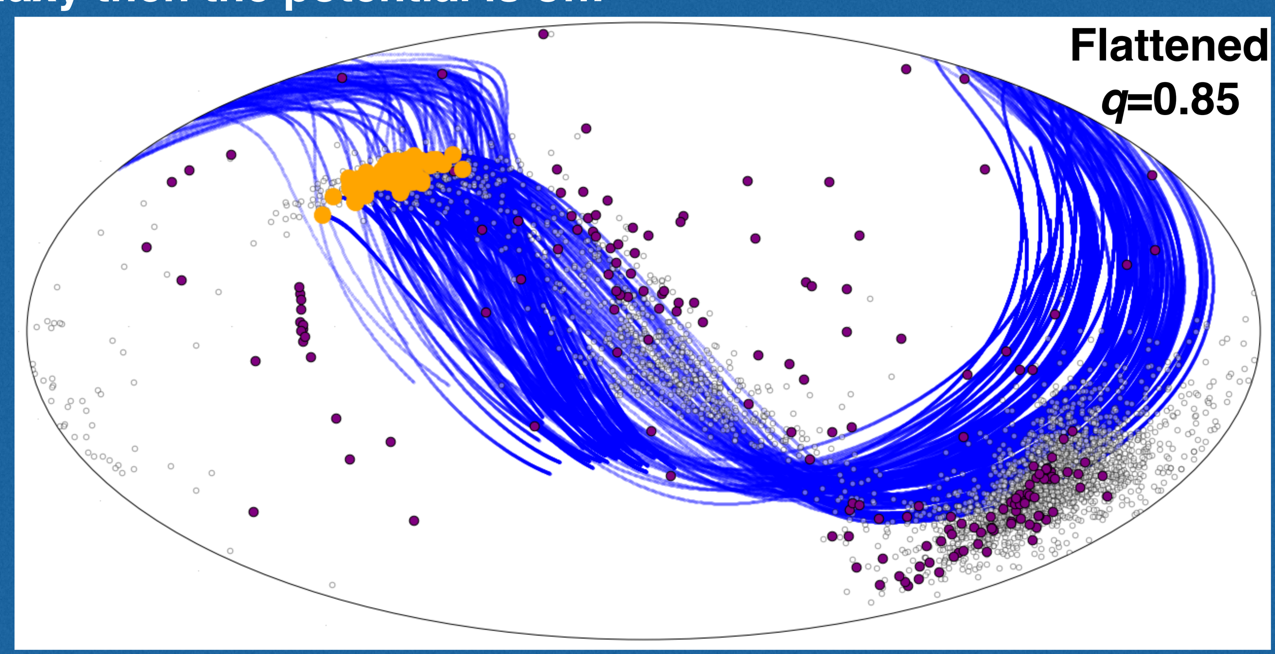
The integrated orbits of the orange group from Panel 4 are very sensitive to changes in potential. If these orbits can't be connected with the positions of the Gaia stars identified in Panel 5 as members of the same progenitor galaxy then the potential is off.



Orbits were integrated in a logarithmic potential (v_a=220 km s^{-1}):

$$\psi = -\frac{v_a^2}{2}\log(R_c^2 + R^2 + z^2 q^{-2})$$

- RRLe from the orange group in **Panel 4** (starting point for integration)
- All RRLe from the orange group's progenitor galaxy
- RRLe within one standard deviation of Gaussian distribution in **Panel 5**
- Orbits of orange RRLe



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Acknowledgments

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