THE WFIRST VIEW OF THE MILKY WAY'S STELLAR HALO

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Introduction

Using synthetic RR Lyrae (RRLe) surveys generated from cosmological mock stellar halos, we explore how the surveys of the 2020s will shed new light on the Milky Way's distant stellar halo. Specifically, we examine how upcoming observational data might help to associate stars that were accreted together from the same progenitor galaxy building block.

Methods

- 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. 2011a) to construct synthetic all-sky surveys of RRLe from these halo models with an apparent magnitude limit of 24.5 mags (out to a distance of roughly 562 kpc for RRLe).
- We performed error-convolution on the synthetic surveys to replicate observational errors expected for 2020s-era instruments:

Data Acquired From:	LSST	Ground-based spectroscopy	WFIRST	Gaia
Data Acquired	Distances for RRLe brighter than 24.5 mags	Radial Velocities	Proper Motions	Inner Halo RRLe Proper Motions
Approx. Projected Error	3% distance errors	10 km/s	25 micro-as/yr	End of mission Errors

-To calculate energy we assume an exactly logarithmic potential with a circular velocity of 220km/s. This potential was also used in our orbit integration.

Finding Distant Halo RRLe with LSST

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

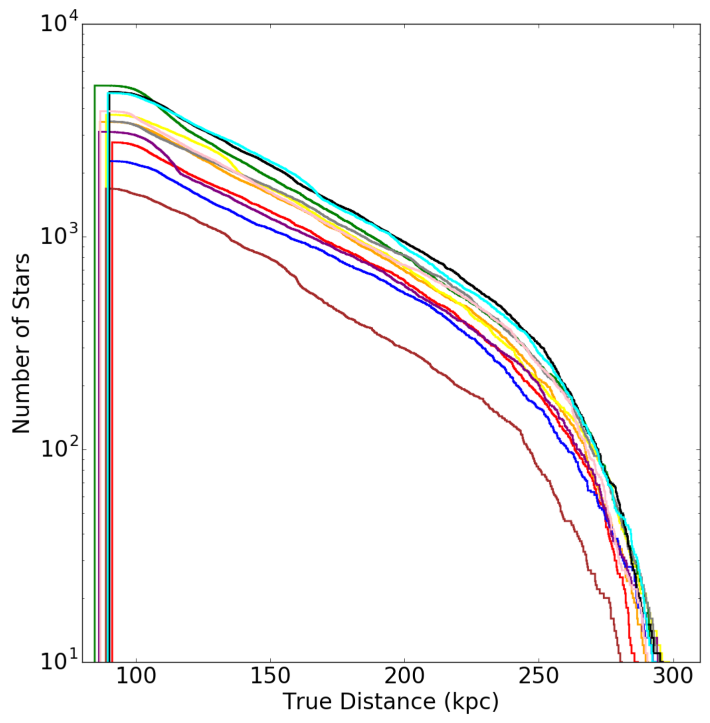


Figure 1: The number of RRLe beyond each distance. Each line represents a different mock halo.

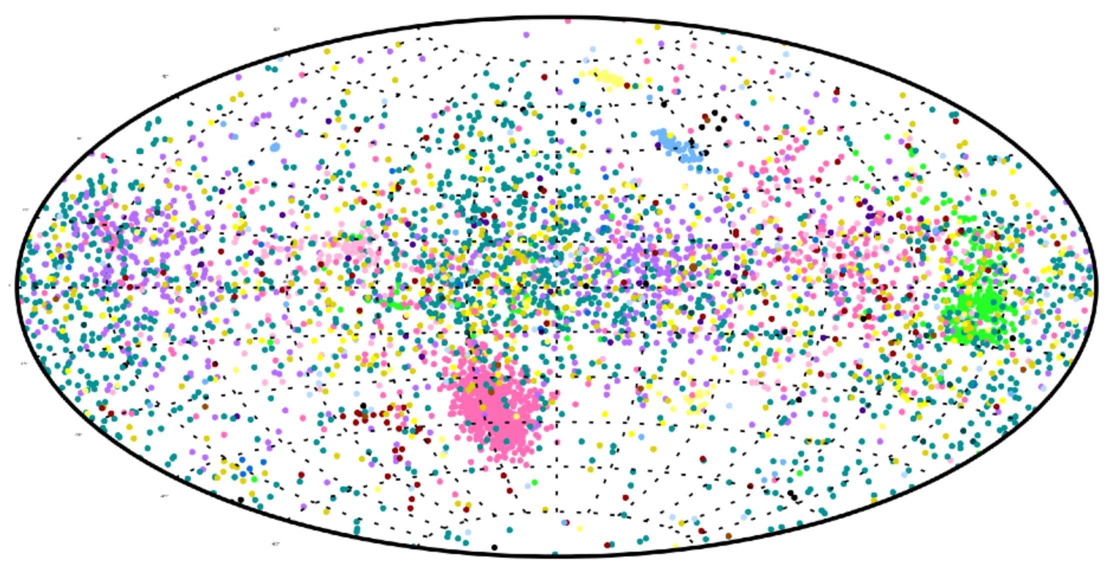


Figure 2: An all sky view of RRLe beyond 100 kpc color-coded by progenitor galaxy for example mock halo 20.

Adding in WFIRST Proper Motions

Having proper motion measurements allows us to make connections between stars in the halo.

What Can We Find With WFIRST-HLS?

A WFIRST-sized survey should contain more than 5 different building blocks with RRLe beyond 100kpc. Roughly 50% of the time there will be multiple RRLe from each building block in one survey box.

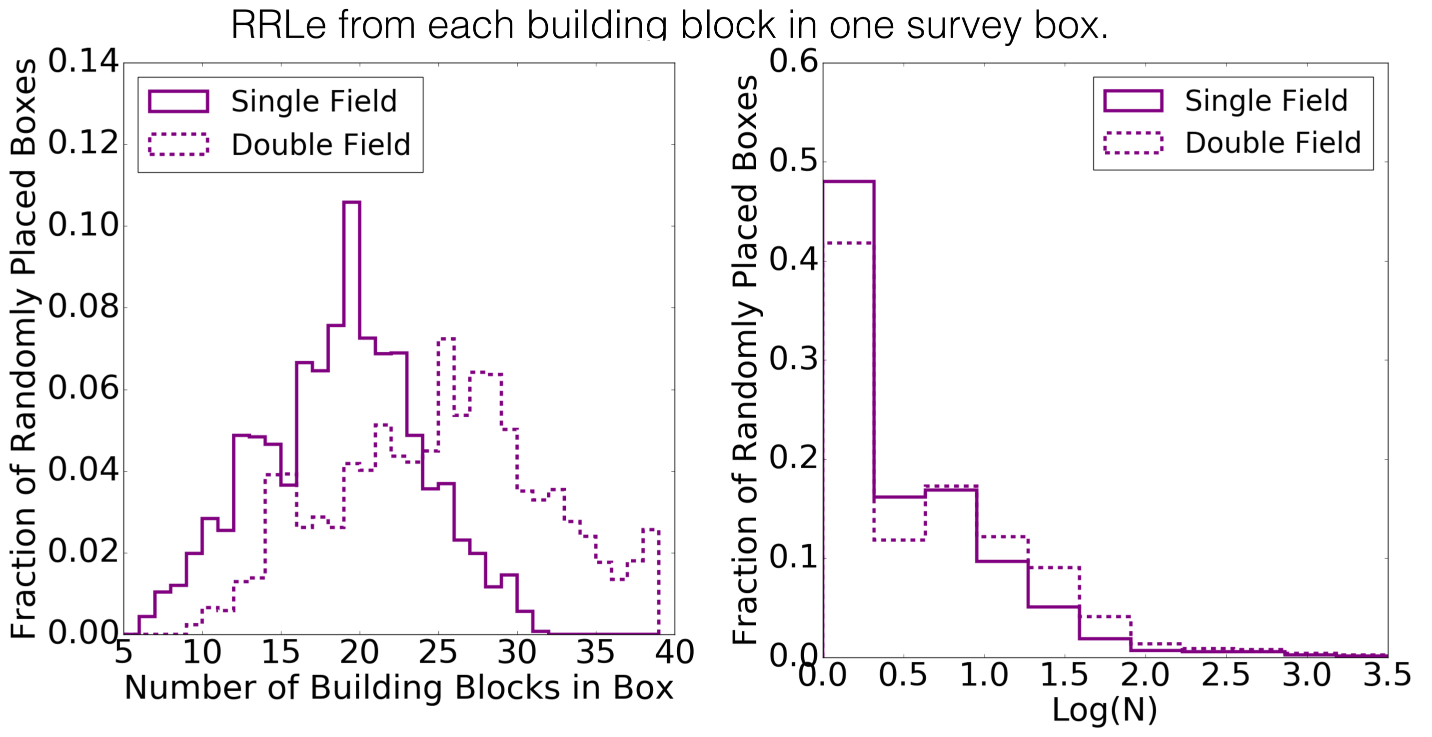
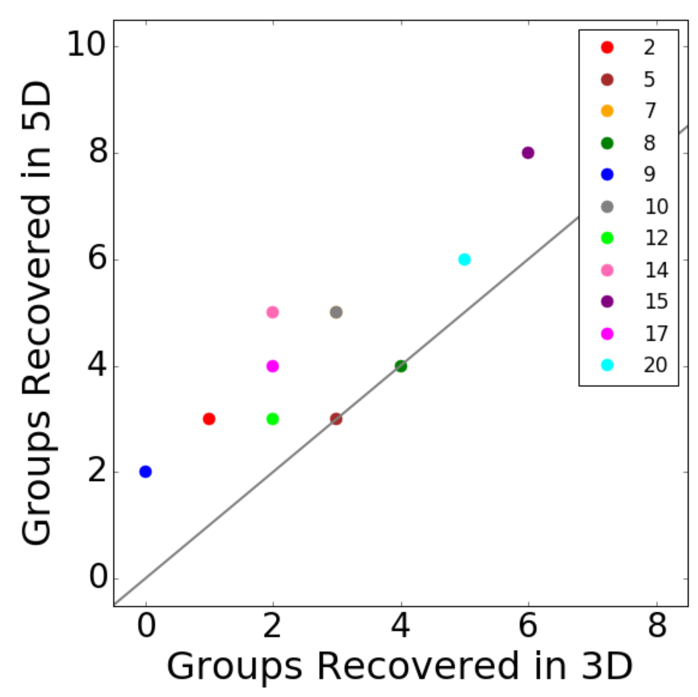


Figure 3: Left: Distribution of the number of different accreted galaxies containing RRLe in a randomly placed WFIRST-HLS-sized (2200 square degree) survey (solid), and a survey twice the size (dashed). Right: Distribution of the number of RRLe from the same building block that fall in a WFIRST-HLS-sized survey (solid), and a survey twice the size (dashed).

Group Finding

The EnLink group finder (Sharma et al. 2011) found more groups with error-convolved proper motions added in (5D) than in position space (galactic latitude and longitude, and error-convolved distance: 3D) alone.

Figure 4: Comparisons of the number of groups found for 11 mock halos over the entire sky when using only position space versus adding in error-convolved proper motions. Only groups with over 50% of stars correctly identified as being from the same building block were considered recovered groups. Labels/colors show the different mock halos.



Orbit Integration

Integrating the orbits of a group that falls within the WFIRST footprint (i.e. has measured proper motions) allows connections to debris that may be on the opposite ends of the Galaxy (and not in the WFIRST footprint). This crude technique works despite using an approximate logarithmic potential potential (see Methods) and having proper motion errors of 25 micro-as/yr. As seen in Figure 6, these groups overlap in energy-momentum space, so one expects them to have similar orbits. You can also determine their relative phases this way.

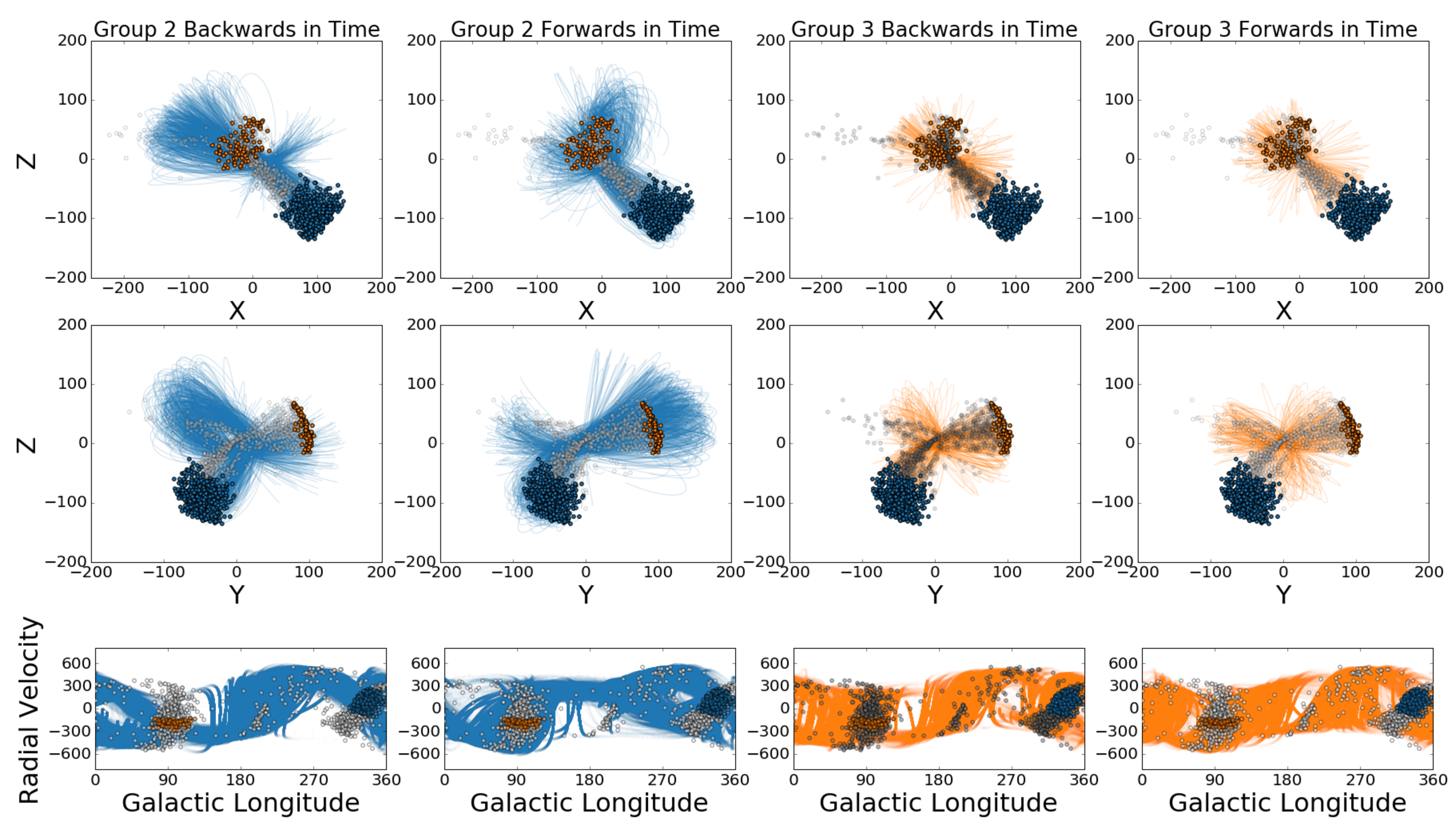


Figure 7: Integrating two groups that are from the same accreted galaxy in Halo 20 forwards and backwards in time, using a flat logarithmic halo potential. Stars marked in blue are members of Group 2 and stars marked in orange are members of Group 3. Clear circles represent stars from all parts of the halo that are from the same accreted galaxy as the groups identified. The orbits are plotted over galactic rectangular coordinates in 2D in the top two panels, and over galactic longitude and radial velocity in the bottom panel.

Energy Momentum Space

Proper motions help identify interlopers in position space groups by looking in energy-momentum space.

Figure 5: Halo 20 groups recovered in position space color-coded by EnLink group ID. Stars are plotted as diamonds if they are incorrectly identified as group members.

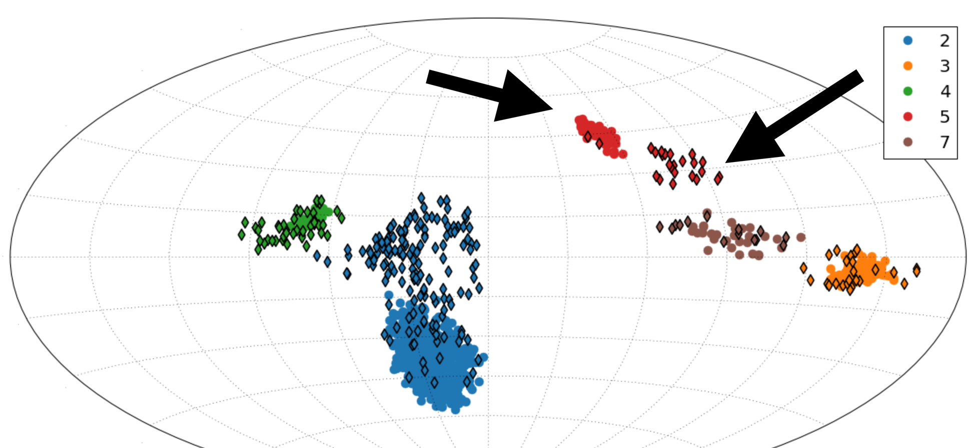
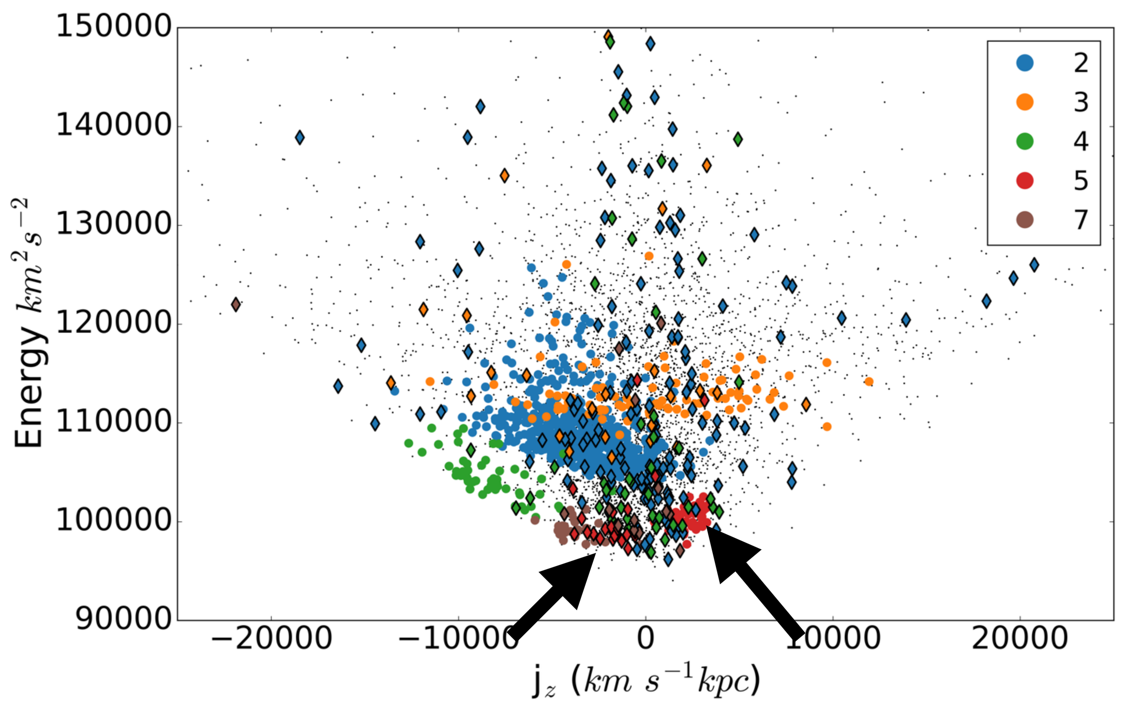


Figure 6: The z-component of angular momentum versus energy. Stars are color-coded by group ID as found by EnLink in position space. Stars are plotted in black if not grouped by EnLink. Stars are plotted as diamonds if they are incorrectly identified as group members. Interlopers in Group 5 (indicated by arrows) separate cleanly from real members in energy space.



Future Work: Adding the Inner Halo with Gaia

Energy-Momentum Space

Gaia stars that fall within a 2D or 3D Gaussian in energy-momentum space fitted to groups in the WFIRST footprint may be members of the same building block

Orbit Integration

Orbits of Gaia stars that fall along the orbits of groups in the WFIRST footprint may be members of the same building block

Bibliography

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