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Identifying Local Group Field Galaxies which have Interacted with the Milky Way

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We distinguish between Local Group field galaxies which may have passed through the virial volume of the Milky Way, and those which have not, via a statistical comparison against populations of massive dark matter haloes in the Via Lactea II (VLII) simulation which have known orbital histories.

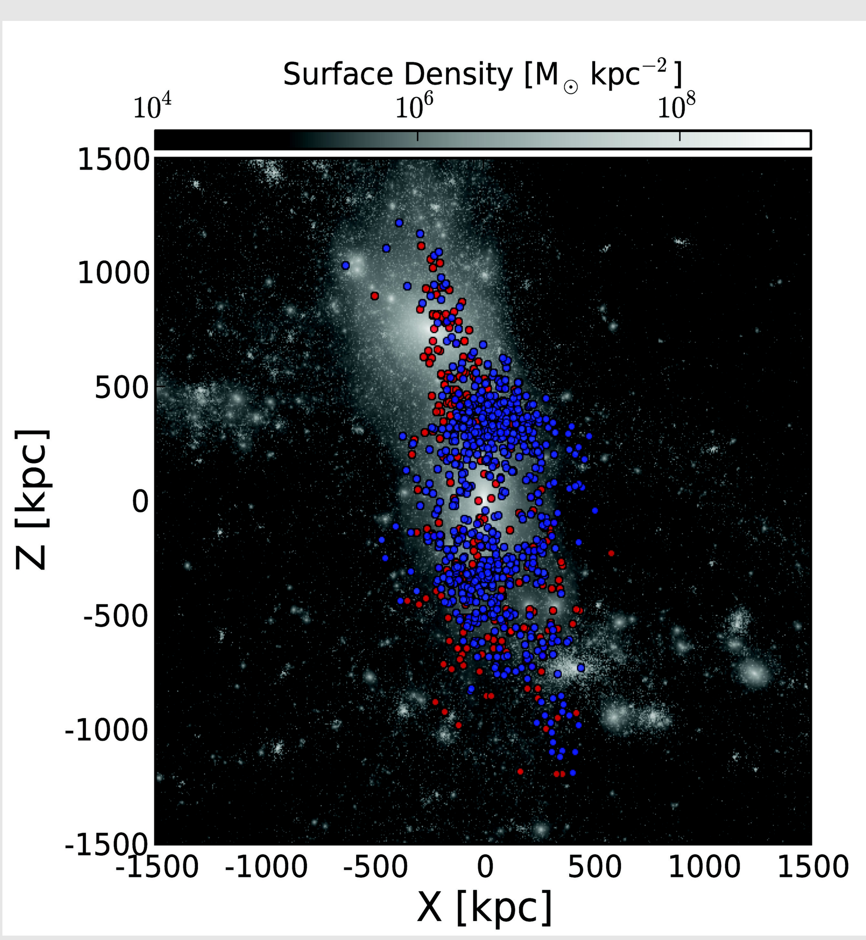
Motivation: Not all Local Group Dwarfs fit the Distance-Morphology Relationship

Dwarfs within the approximate 300 kpc virial radii of the Milky Way and M31 are preferentially small, gas-poor spheroids, compared to their field counterparts, which are typically larger, gaseous, and irregularly shaped (e.g. Grebel03, Einasto74). This position-morphology relationship is attributed to a transformation of gas-rich dwarf irregular galaxies into gas-poor dwarf spheroidals via environmental effects. That the cumulative environmental effects encountered during a passage through a larger potential are sufficient to transform the morphology of a dwarf is very well motivated by simulations (e.g. Kravtsov04, Mayer06).

However, there are objects that do not fit the rough distance-morphology relationship, because they exist outside the virial radius of the nearest large galaxy, but nevertheless exhibit a morphology that suggests strong interactions (e.g. Tucana). Knowledge of orbit and encounter likelihood would help in this regard, and can enhance our understanding of individual objects.

We make connections between dynamically distinct histories for subhaloes seen in a cosmological simulation of structure formation (Via Lactea II, hereafter VLII), and properties of Local Group dwarf galaxies. More specifically, we establish that it is possible to distinguish Local Group field populations which may have passed within the Milky Way from those which have not, using observable properties at z=0 (radial distance, line-of-sight velocity and mass).

Simulation Results I: 13% of the simulated galactic population between 300 and 1500 kpc from the Milky Way Analog has passed within its virial radius, and hence we expect that about 7 of the 54 known Local Group galaxies in that distance range, have likewise passed through the Milky Way



Projection of VLII: subsets of the massive field haloes in blue and red at z=0.

Field haloes which have been within $R_{virial}(z)$ of the Milky Way Analog

Field haloes which have been within .5 $R_{virial}(z)$ of the Milky Way Analog

These field haloes which have passed through the virial radius of the Milky Way Analog fill a triaxial volume of space around it. The maximum distance of a member of this population from the center of the Milky Way Analog is ~1500kpc.

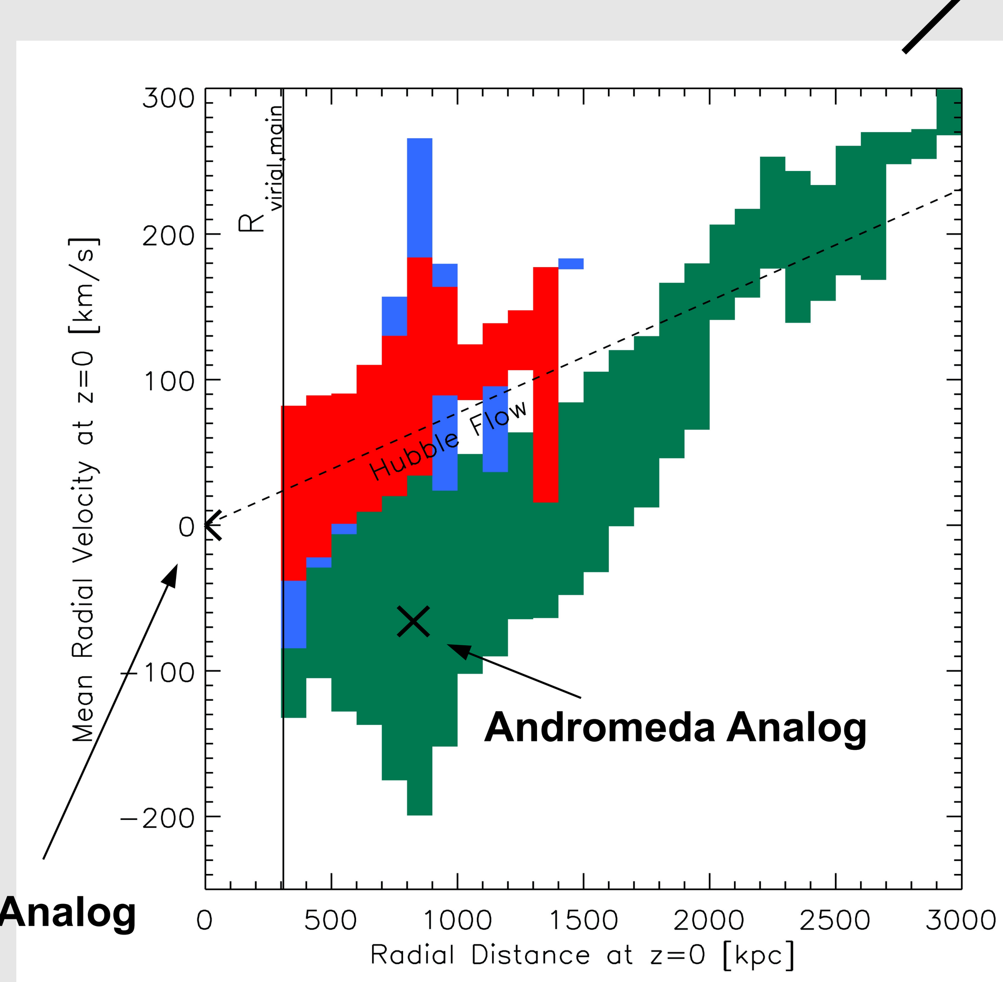
Simulation Results II: This escaped population is expected to generally have positive radial velocities with respect to the Milky Way.

VLII Field Haloe Distributions: Vertical bars show the 1 sigma region above and below the mean radial velocity per radial distance bin for different massive haloe populations in VLII at z=0.

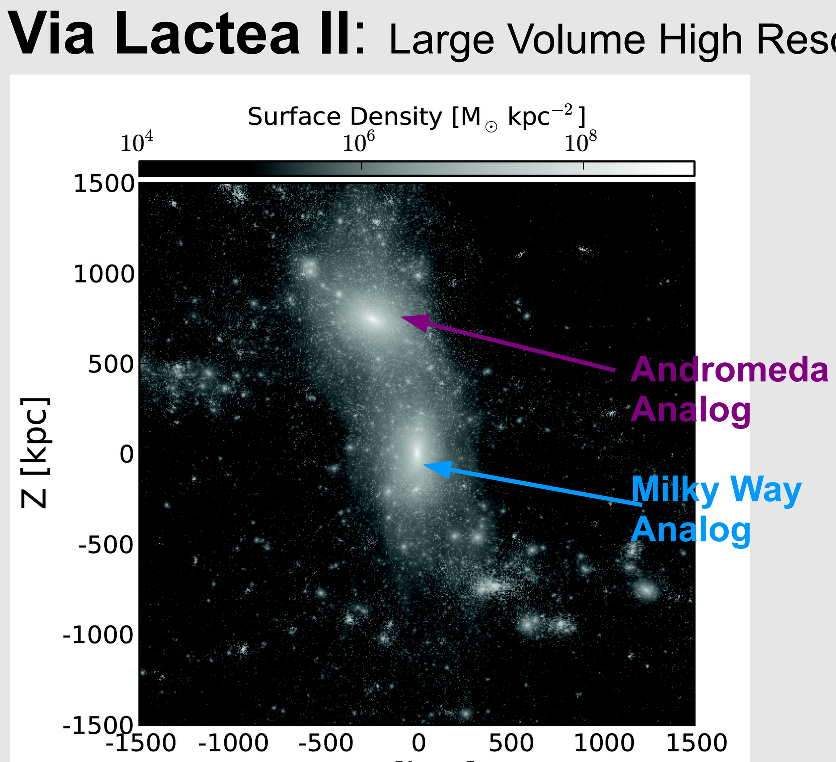
Associated Haloes: Field haloes which have been **within $R_{virial}(z)$** of the Milky Way Analog

Associated Haloes: Field haloes which have been **within .5 $R_{virial}(z)$** of the Milky Way Analog

Unassociated Haloes: Field haloes which **never passed through $R_{virial}(z)$** of the Milky Way Analog



Via Lactea II: Large Volume High Resolution Cosmological Dark Matter Simulation



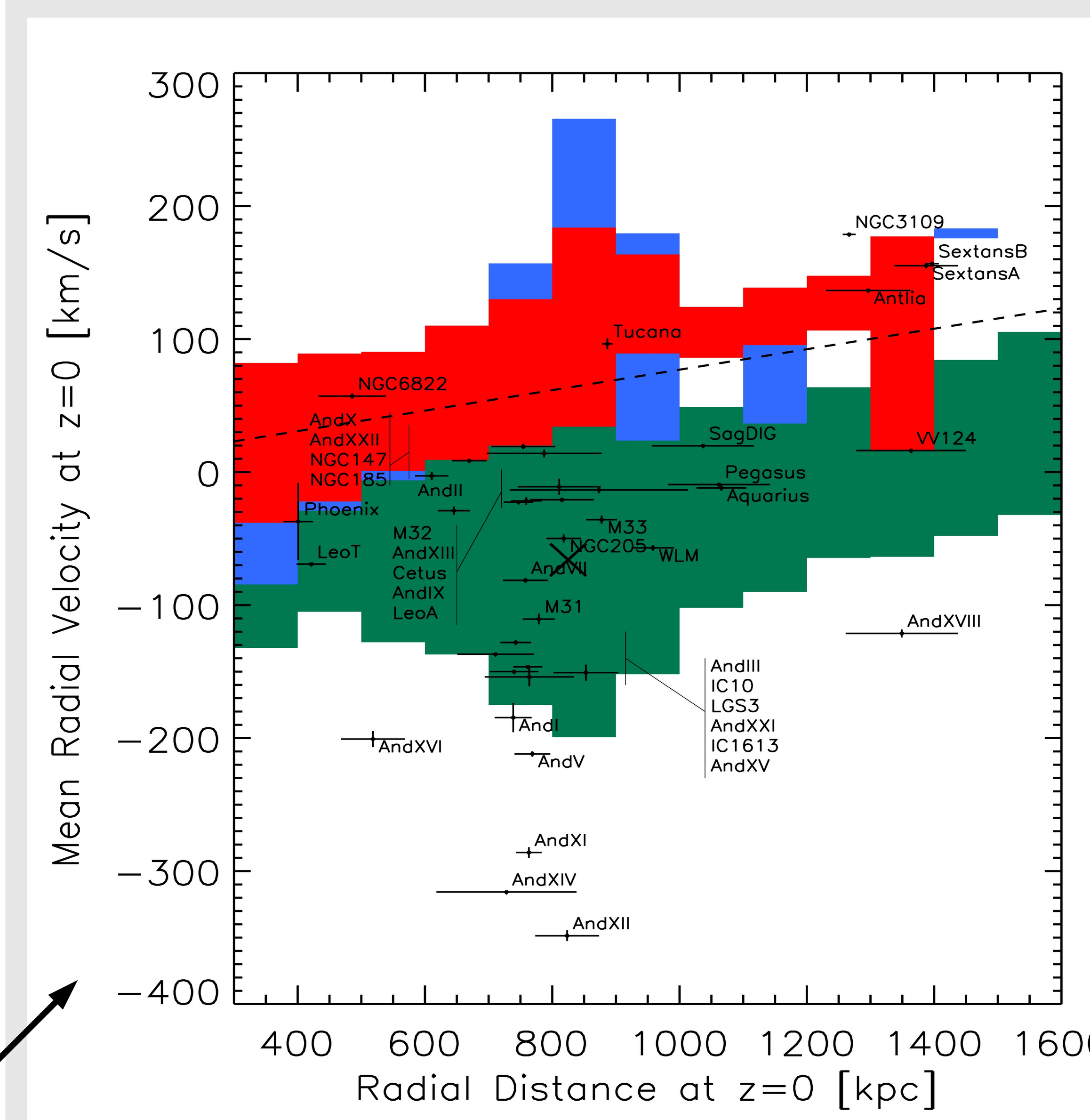
This is a projection of the mass within the inner 3 Mpc of VLII at z=0.

The properties of the VLII simulation make it ideal for our purposes: the small particle mass allows us to follow a large range of haloe masses, and trace haloes through order of magnitude changes in mass; the high frequency of outputs allow an accurate assessment of the subhaloe interactions with the host haloe potential; and the large volume allows us to track subhaloes to large distances beyond the host's virial radius.

The central halo is a Milky Way Analog (z=0 virial mass and radius of 1.7 x 10^{12} $M_\odot$ and 309 kpc), and the second most massive halo is a reasonable Andromeda Analog (z=0 mass of 6.5 x 10^{11} $M_\odot$, radius of 225 kpc and velocity of -60 km s^{-1} toward the Milky Way analog).

Analysis only includes halos massive enough to host baryons.

Simulation vs Observation Results III: There is a strong likelihood that Tucana, Cetus, NGC3109, SextansA, SextansB, Antlia, NGC6822, Phoenix, LeoT, and NGC185 have passed through the Milky Way.



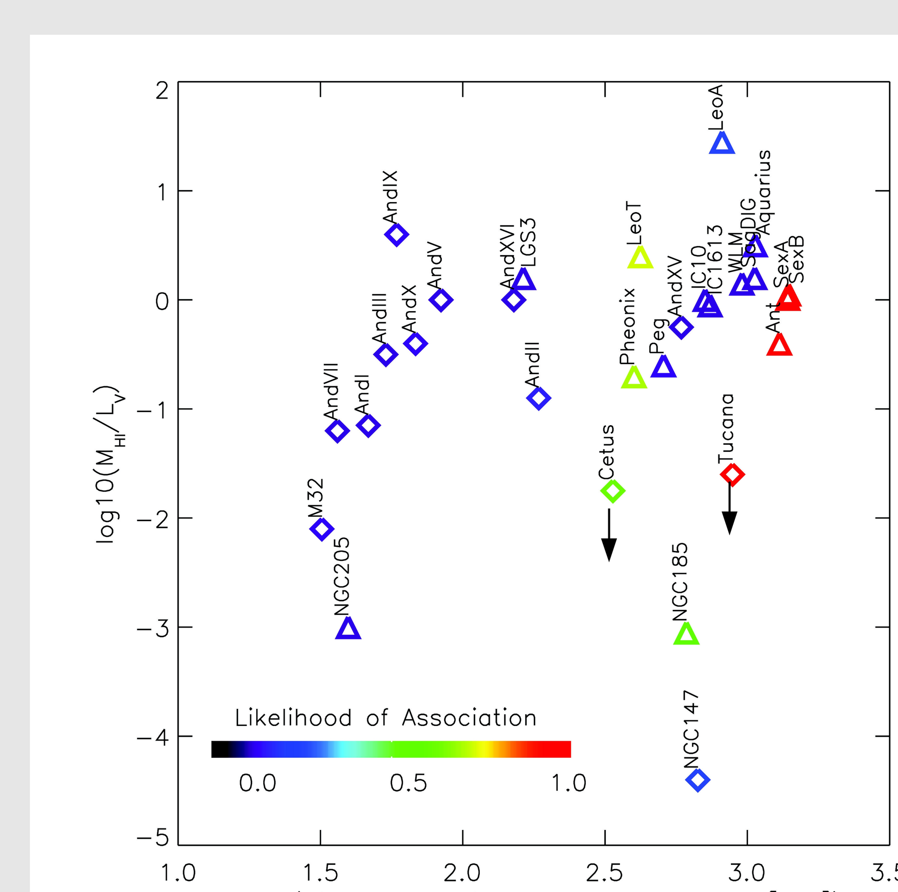
Radius-velocity distributions of VLII populations and measurements of Local Group Galaxies: This Figure illustrates the overlap between VLII populations and Local Group Field Galaxies in the galactocentric radial velocity and distance plane.

To quantify the likelihood that a field galaxy is associated with the Milky Way, we bin the different VLII halo populations with radial velocity and distance; the fraction of each population within a bin provides a rough fractional likelihood that a Local Group galaxy falling in that bin has a history which takes it within the viral radius of the Milky Way.

Several of the galaxies with high likelihood -- especially those with lower masses -- contain signatures in their morphology, star formation history and/or gas content indicative of evolution seen in simulations of satellite/parent galactic interactions.

Trends in Morphology: Here we have color-coded the likelihood that a field galaxy has passed through the Milky Way. It is shown with distance to the nearest massive object, and the fraction of HI mass over V-band luminosity.

We see that **several of the field objects (beyond ~300 kpc) have comparatively low HI mass over luminosity fractions. Several of these also have a high likelihood of a past interaction with the Milky Way.** Therefore, the low HI mass fraction for these objects could be explained by a passage through the Milky Way that stripped their HI gas.



Our results offer strong support for scenarios in which dwarfs of different types form a sequence in morphology and gas content, with evolution along the sequence being driven by interaction history.

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