Probing the halo of the Milky Way beyond 100 kpc with RR Lyrae stars

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Why distant RR Lyrae stars?

• Outer halo should contain *lots* of faint dwarf galaxies
• Every dwarf that has been searched contains at least one RR Lyrae star
• Stellar density of the halo probes the accreted population of satellites
• Mass modeling of the Milky Way is constrained most strongly by the outermost probes
Models predict that the Milky Way should have accreted and subsequently tidally destroyed hundreds of low-mass galaxies in the past $\sim 12$ Gyr.

Simulated (accreted) stellar halos at $d > 100$ kpc

Model halos made from accreted satellites; Building blocks color-coded separately

Sanderson+2017 (MNRAS, 470, 5014)
Simulated (accreted) stellar halos

Expect ~2,000-10,000 RR Lyrae stars between 100 < d < 282 kpc:

- All substructures
- Excluding bound satellites

Stars in bound satellites will be ~1 arcmin from nearest star

Sanderson+2017 (MNRAS, 470, 5014)
Simulated (accreted) stellar halos

Using Aquarius model stellar halos; ~1,000-6,000 RR Lyrae expected at d>100 kpc

Baker & Willman 2015 (AJ, 150, 160)
Gaia DR2 orbits of MW satellites: More dwarf galaxies found near pericenter than apocenter – many more to be discovered?

Fritz+2018 (arXiv:1805.00908)
The slope of the halo density profile is sensitive to the host’s mass and its accretion history.

Based on Illustris simulations
Pillepich+2014 (MNRAS, 444, 237)
Measuring the MW halo density profile

~44,000 RR Lyrae from PanSTARRS1

Hernitschek+2018 (arXiv:1801.10260)
Measured slope of the MW halo density profile


MW mass estimated using globular cluster orbits

Gaia DR2 globular cluster orbits (R_{GC} < 40 kpc)
(see also Posti & Helmi 2018 (arXiv:1805.01408)
Searching for outer halo RR Lyrae stars

- DECam’s FOV makes mapping large areas efficient
- Started with archival data from the HiTS supernova survey (Förster+2016)
- ~20-30 epochs per field
- Have been awarded 7 nights (3 in 2017B, 4 in 2018A) via NOAO/CNTAC proposals (PIs: Carlin, Muñoz)
HiTS:
- 2015 analysis in progress

New DECam observing program (PIs Carlin, Muñoz):
- 2017B: 16 DECam fields, 20-30 visits
- 2018A: 24 DECam fields, ~20 visits

Status of survey/data
~120 deg$^2$
~110 deg$^2$
~50 deg$^2$
~70 deg$^2$
TOTAL: ~350 deg$^2$
RESULTS:
“Serendipitous” (re-)discovery of Leo V dSph with HiTS (2014) RR Lyrae stars


173 RR Lyrae stars, including 18 at d > 90 kpc

- RR Lyrae to $<g> > 22$ ($d > 200$ kpc)

- Sextans dSph
- Leo V dSph
- Leo IV dSph
- Leo V dSph

In the diagram:
- $d > 100$ kpc

Histogram showing distribution of $g$ values with peaks at 21 and 22.
Of course we found RR Lyrae in Leo V – all dSphs have them!*  

Sextans dSph: 65 RR Lyrae stars (46 prev. unknown)
Measured slope of the MW halo density profile: $n = -4.17$

Similar to predictions from Illustris for MW-mass galaxy; Pillepich+2014 (MNRAS, 444, 237)

The Large Synoptic Survey Telescope
will again revolutionize our picture of our own cosmic backyard

(i) an 8.4-meter optical telescope, a 3.5-degree diameter field-of-view, a 3.2 billion pixel camera, and 6 broad-band, optical filters that will observe more than half the sky hundreds of times over 10 years

(ii) a data facility that will process, archive, and distribute survey images, associated transient alerts, and calibrated catalogs.
LSST will open \( \sim 1,000 \) times the volume for studying the Local Universe with resolved stars compared to SDSS.
Conclusions:

• We (Medina+2017, 2018) have discovered the most distant known RR Lyrae in the Milky Way, with many more to come.

• Serendipitous finding of Leo V RR Lyrae stars: RRLs can be beacons of distant ultra-faint dwarfs.

Next steps:

• HiTS 2015, DECam 2017B, 2018A results soon!

• Spectroscopy (velocities)

• Time-series to more completely fill phase curves.

• Deep imaging (are the distant RRLs in dSphs?)

• Survey a larger area?

THANK YOU!

J. Carlin; DECam Community Science Workshop, Tucson, AZ, May 2018
DECAM-NFC 2018

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Workshop: Near-Field Cosmology with the Dark Energy Survey’s DR1 and Beyond

http://kicp-workshops.uchicago.edu/decam-nfc2018/