The DESI Milky Way Survey

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A Disclaimer

This talk is about a MW stellar survey for which the planning is just getting started.

The facility (instrument+) is in progress. Lots of people are working very hard to make it happen.

Take-away message: DESI will be a great opportunity for MW science. This is v0.1 of how we might exploit that.

Lots of people have signed up to a working group to plan the survey, effort just getting started.

Goal: talks on DESI MW science at LG Astrostatistics 2020
Who wants wide-field, massively-multiplexed spectroscopy? We Local Group enthusiasts do!

MW substructure is big on the sky and diffuse
want large area + target density

SDSS DR8
11,000 sq. deg.

Bonaca et al. 2012

PAndAS MW Streams
Red→Blue
Martin et al. 2014
17 <d< 32 kpc
DESI
(Dark Energy Spectroscopic Instrument)

The US entry in the next generation of massively multiplexed, wide-field spectrographs on 4m telescopes

- 5000 fibers
  - 10.4 mm pitch, 12 mm patrol diameter, 1.5 arcsec, < 120 s to reconfigure
- 8 square degree FoV
- 10 spectrographs, 360 - 980 nm
  - 3 arms, R = 2000 (blue) - 5000 (red)
- for RGB stars, system model predicts S/N 20 per Δλ in 1 hr for λ > 600nm, r = 19
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(Dark Energy Spectroscopic Instrument)

DOE experiment to learn about Dark Energy
5-year survey on the KPNO 4m Mayall telescope

LBL + big partnership, NOAO will run the 4m Cosmology Project: galaxy redshifts for clustering statistics
On sky commissioning starts early 2019

Other 4m survey projects, cosmology+MW:

**WEAVE @ WHT**
R = 5000 + 20,000
1000 fibers, 3 deg. sq.
t₀ in 2018

**4MOST @ VISTA**
R = 5000 + 20,000
2400 fibers, 4.25 deg. sq.
t₀ in 2019
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GMOS-N
5 x 5 arcmin FoV
~30-60 objects

3º, 5000 fibers
DESI will do a Milky Way Stellar Survey, too

- 14,000 square degrees
- 1 million+ stars
- expect S/N 25 per $\Delta \lambda$ at $r = 17$
- metallicity, $[\alpha/Fe]$
- RVs to $r \sim 20$ @ the Gaia limit

DESI planned footprint
Cosmology survey and Milky Way + Bright Galaxy Survey
Equatorial coordinates imaging for blue and yellow regions in progress

DECaLS DR1! http://legacysurvey.org/dr1

Shared focal plane with a low-z galaxy survey, time too bright for the DE project. All data will be released
Lots of MW Halo Info in Spectroscopy. We Want More.

An example: Substructure in the MW halo

SDSS + SEGUE data

- Excess of close pairs: halo stars are clustered
- RGB stars more clustered than BHBs (also Xue+ 2011, Cooper+ 2011, Deason+ 2011: comparisons of BHB substructure to simulations)

Things to note:
- Numbers help: 50x RGB sample size is better

Measured using 4-distance (Starkenburg+ 2009): X,Y,Z,RV

Ratio of cumulative $N_{\text{pairs}}$ closer than $D_{4d}$ to $N_{\text{pairs}}$ in a smooth halo

Lots of MW Halo Info in Spectroscopy. We Want More.

An example: Substructure in the MW halo
SDSS + SEGUE data

Great! Halo substructure is stellar pop. dependent (Robertson+ 2005, Font+ 2006, Johnston+ 2008, Cooper+ 2011, ...)

BUT: the leap to [Fe/H] - mass, [α/Fe] - accretion time of MW progenitors is complicated:

- BHBs are found in old and/or metal-poor populations. Not known how N(BHB) depends on either one
- these RGBs are color- and (crudely) PM-selected. Otherwise hopeless: evolved stars are rare, same colors as dwarfs
DESI

What can we do with 1 million+ stars over 14,000 square degrees to $r = 20$?

Photometric metallicity map
SDSS MSTO stars
calibrated with SDSS spectroscopy

Gaia RVS: RVs to $V \sim 15.2$
  - at the MSTO, that’s $d \sim 1.5$ kpc

Adding DESI spectroscopy:
  - PM + RV + parameters to $d \sim 4$ kpc
  - PM + RV to $d \sim 15$ kpc

With a DESI MW survey, we can make this map with spectroscopic $[\text{Fe/H}]$
More with DESI+Gaia:

GDR3 early 2018: all-sky PM
- at $V \sim 20$, 5800 K MS star, Gaia
  $\sigma_{PM} = 330 \mu$arcsec/year
  - that’s 16 km/s at $d = 10$ kpc

Compare SEGUE:
- 2750 sq. degrees vs. DESI 14,000 sq. deg
- $\sigma_{PM} = 4600 \mu$arcsec/year (SDSS+USNOB)

DESI can survey the MW in a qualitatively different way:
Target (some of) *everything*, still get substantial numbers in the distant MW halo (c.f. Hogg)

Breddels et al. 2010
3d velocities for RAVE stars
$d < 1$ kpc
Use Gaia PM info to weight survey to larger distances:

- At $r = 20$, brightest RGBs are at distances $100+ \text{kpc}$
- Stars on the RGB at the same $r$, $g-r$ are $10x+$ more distant than giants

But we can still get everything in the survey: With area + numbers, good sampling of the full PM distribution.

No need for color, pm cuts to escape the local disk

Breddels et al. 2010
3d velocities for RAVE stars $d < 1 \text{kpc}$
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DESI MW Survey: basic parameters (v0.1)

- 14,000 square degrees
- 1 million+ stars
- expect S/N 25 per Δλ at r = 17
- RVs to r ~ 20 @ the Gaia limit
- Should be an exciting facility for MW science