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INSTRUMENT
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DESI and LSST: Milky Way Science

Vera C. Rubin Observatory
Project and Community Workshop
August 11, 2022

Connie Rockosi (UC Santa Cruz, SCIPP)
with the DESI Milky Way Survey Working Group

Outline

- DESI spectroscopy + Vera Rubin Observatory LSST: a great match for Milky Way, Local Group and stellar science
  - Wide field, high sensitivity: dwarf galaxies, streams, MW halo structure
  - Survey speed: large samples of rare, sparse targets like white dwarfs, blue horizontal branch stars
- DESI Milky Way survey: 14,000 sq. deg, large-scale halo properties
- Early science from DESI Milky Way Survey: white dwarfs
- Exploratory programs:
  - DESI Observations in Andromeda, Draco MW dwarf galaxy
- Future prospects for DESI + LSST science

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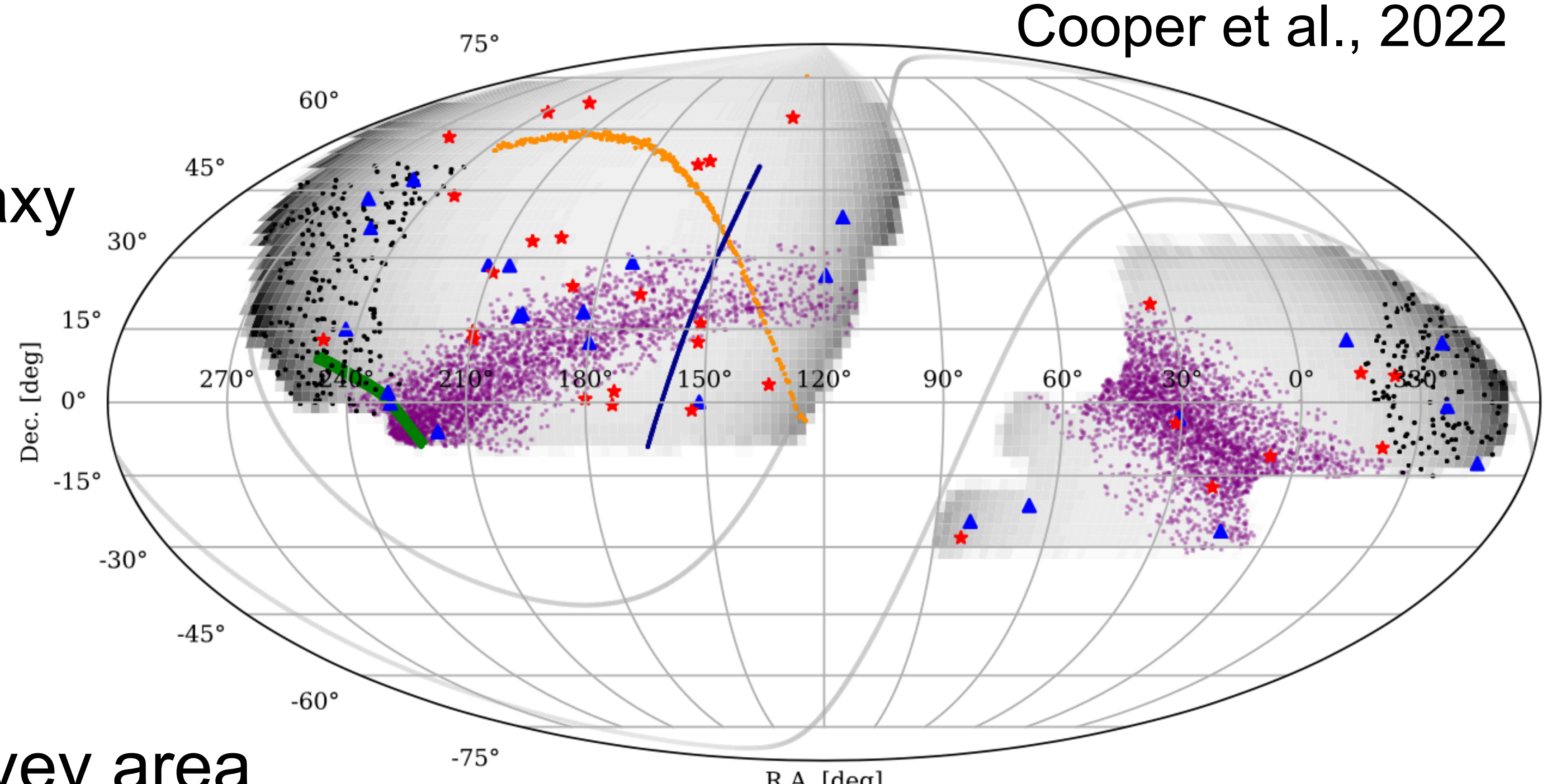
The DESI Milky Way Survey

Science Focus: large-scale spatial and kinematic structure of the Milky Way to 150 kpc

- plus plenty of other great stellar and MW science

- 7 million stars
- 1000 second exposures
- Bright time, with Bright Galaxy Survey
- poor weather bright star backup program

Cooper et al., 2022



DESI Milky Way Survey area

Grayscale: DESI MW survey target density

- Sagittarius
- Pal 5
- GD1
- Orphan stream
- Globular clusters
- Dwarf galaxies
- Her. Aq.

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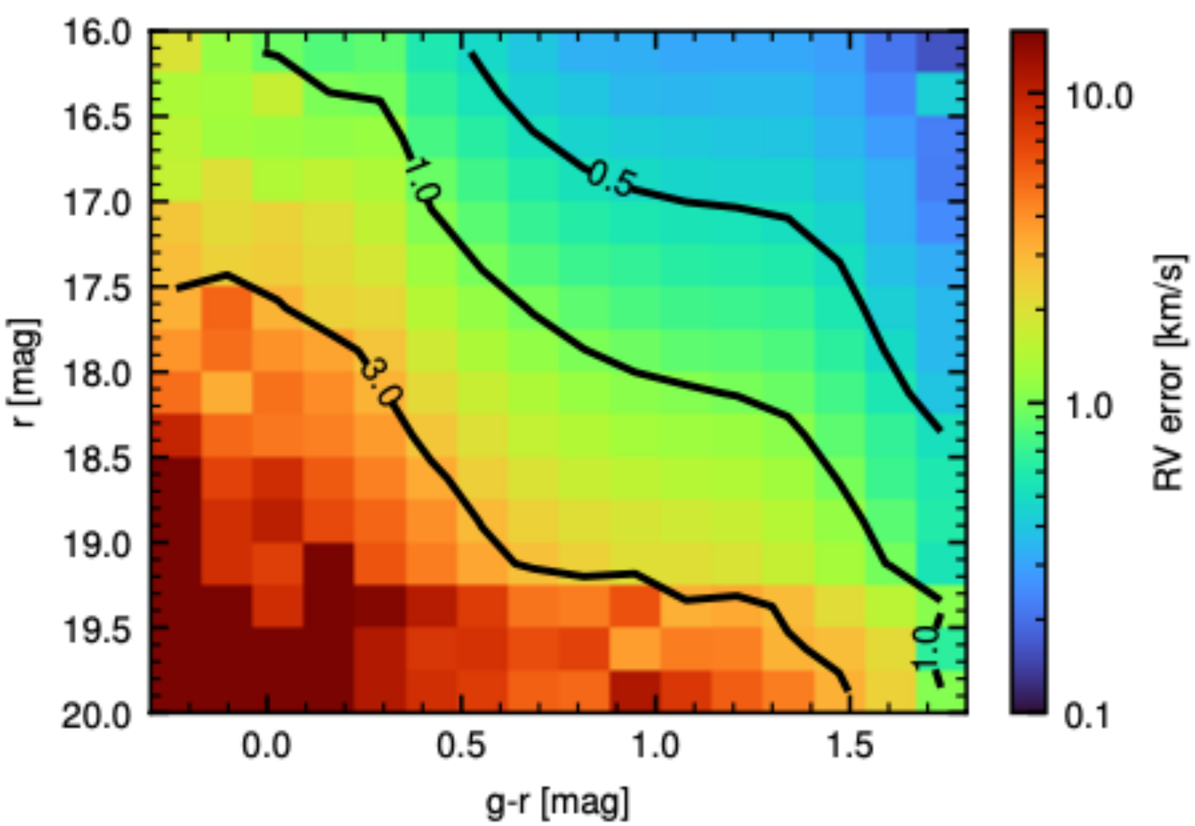
The DESI Milky Way Survey

- r < 19 (20), Legacy Survey photometry
- Prioritize distant MW halo giants with Gaia
- Nearby Stars: Gaia selection highly complete to 100 pc

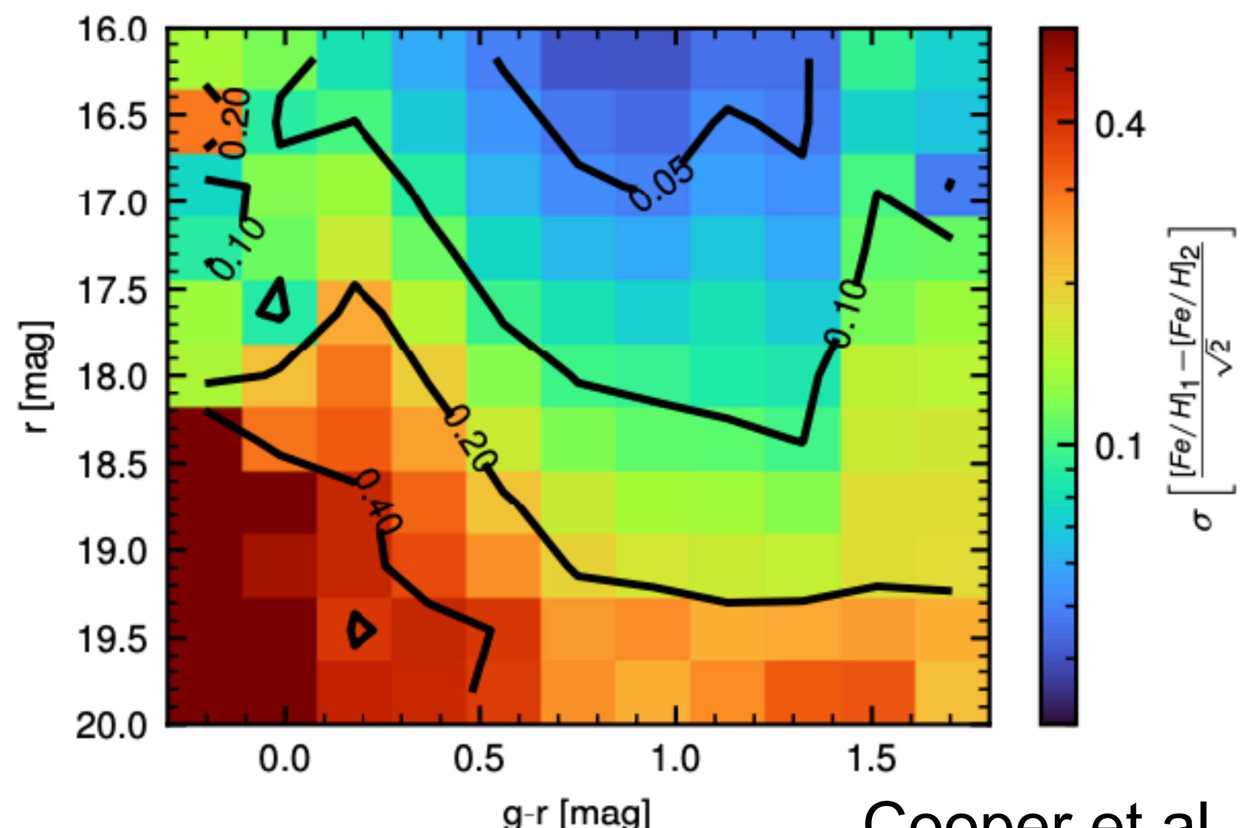
Typical accuracy: RV: 1 km/s

[Fe/H]: 0.2 dex

radial velocity errors



[Fe/H] random errors

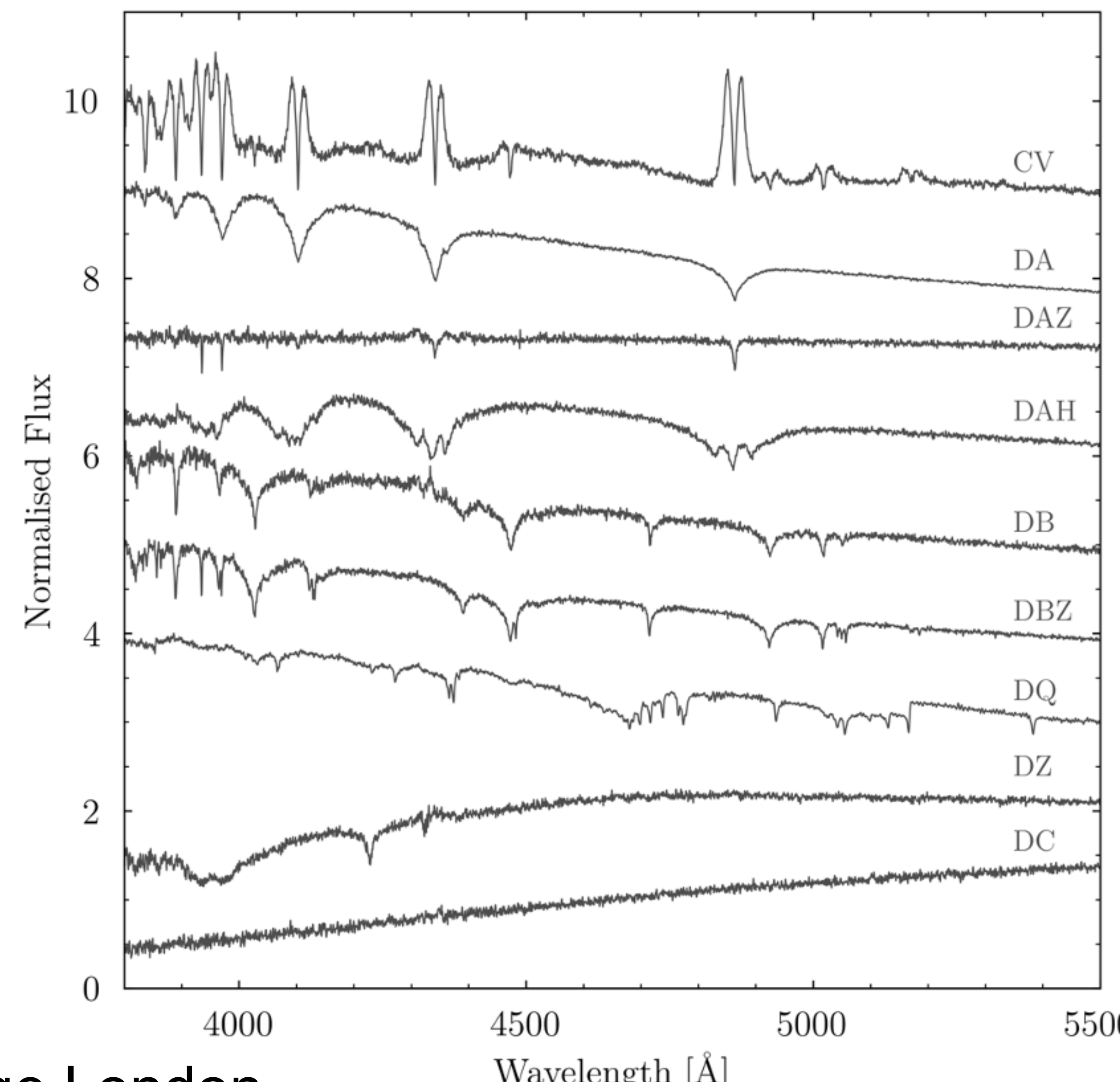


Cooper et al., 2022

White Dwarfs in DESI MW Survey

DESI has survey speed and sky coverage for large samples of rare objects

- 5 per sq. deg.
- Final sample: ~66,000
  - more magnetic WDs than previously known
  - ~1000 accreting planet material
  - > 100 CVs
  - …



Credit: Chris Manser, Imperial College London

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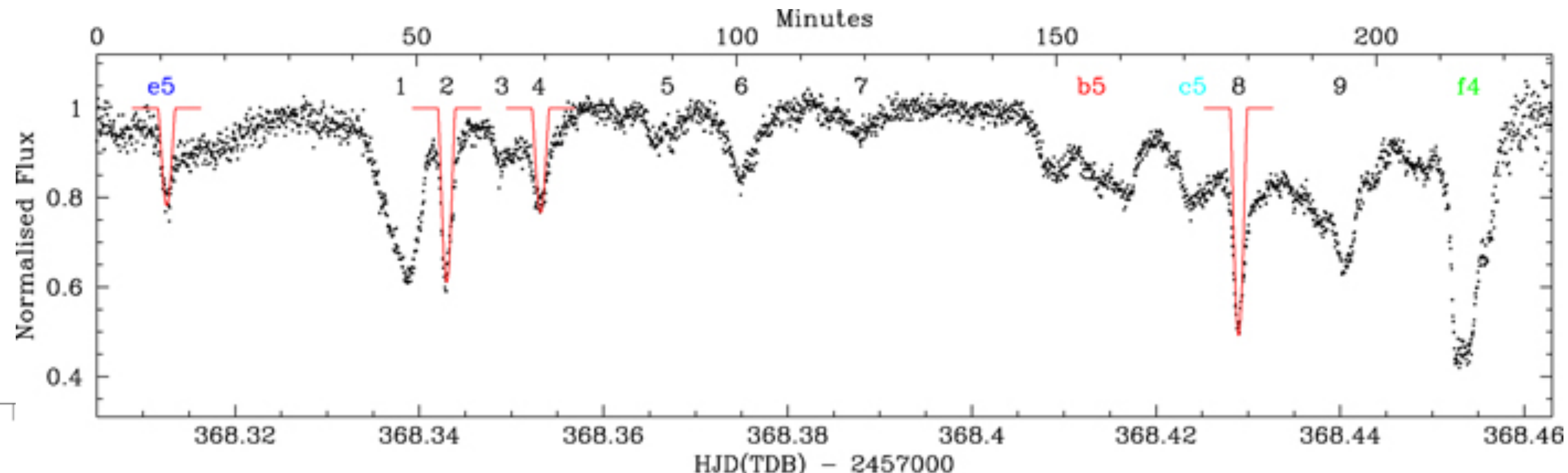
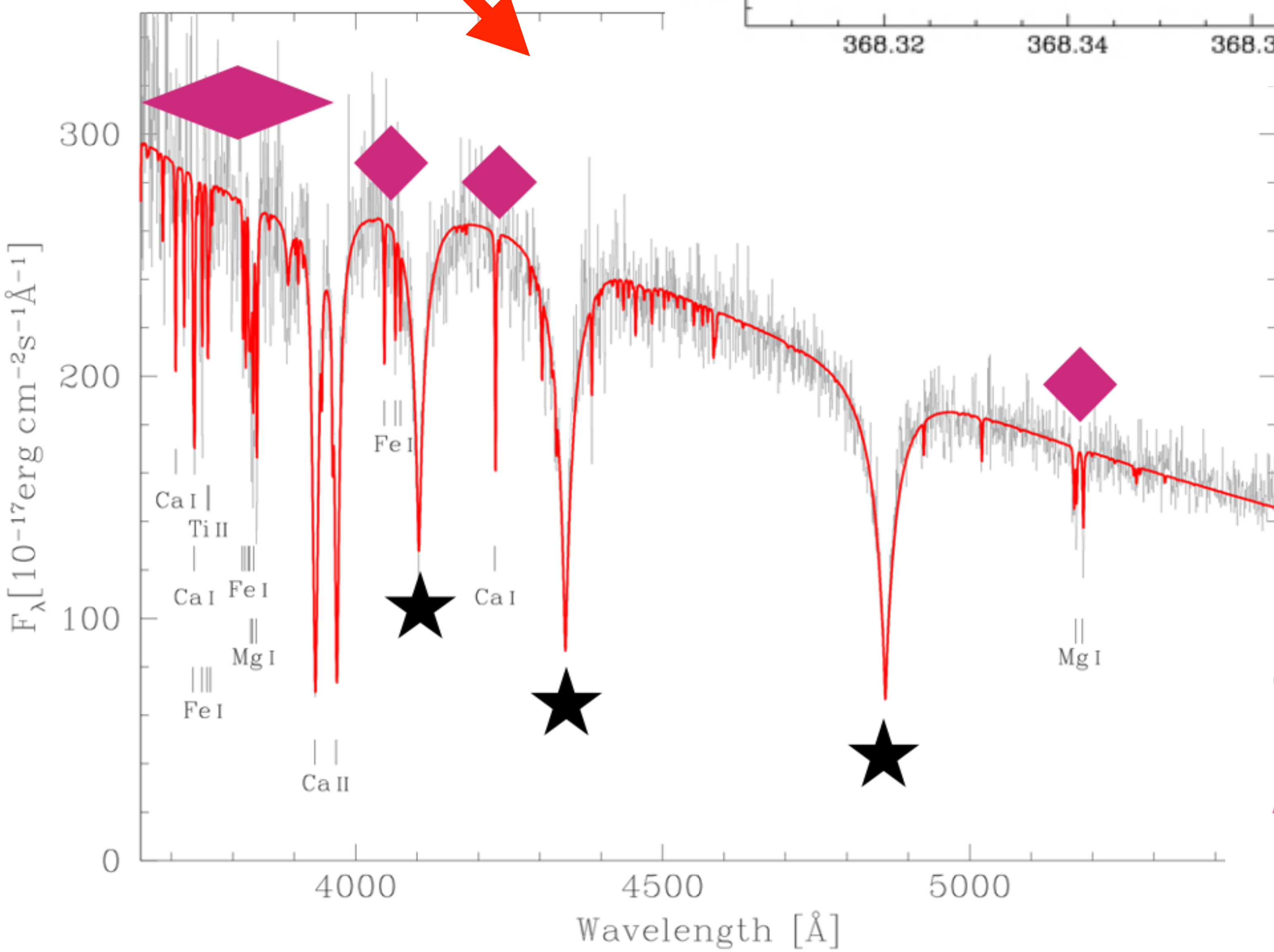
White Dwarfs in DESI MW Survey



Gänsicke et al. 2016
planet-accreting WD 1145+017
light curve

DESI planet-accreting WD Spectrum!



Hydrogen from white dwarf ★

Accreted planetary material ◆

Credit: Boris Gänsicke, U. Warwick, Chris Manser ICL; see Cooper et al. 2022

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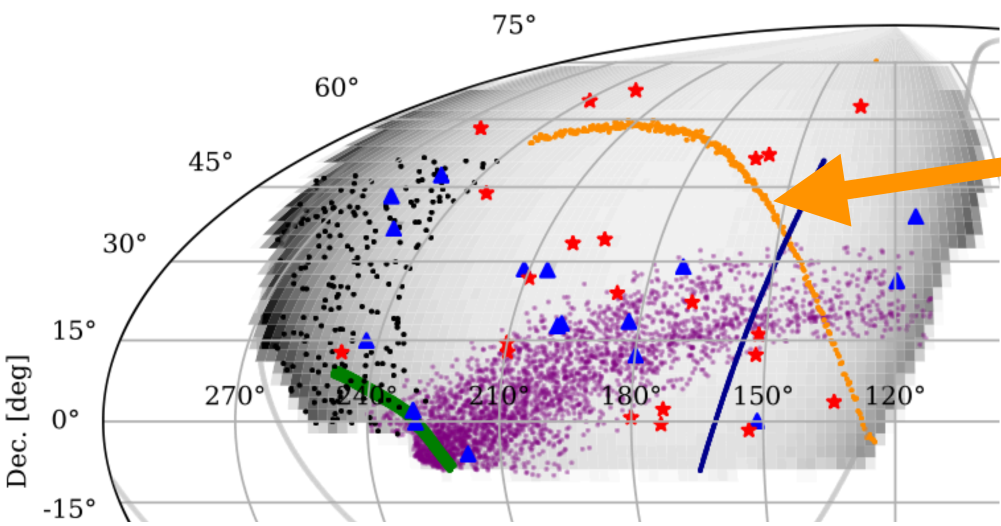
Stellar Streams and Milky Way Substructure in DESI

DESI wide field + sensitivity: MW stellar stream kinematics

- Dark matter subhalo mass function, MW dark matter halo shape

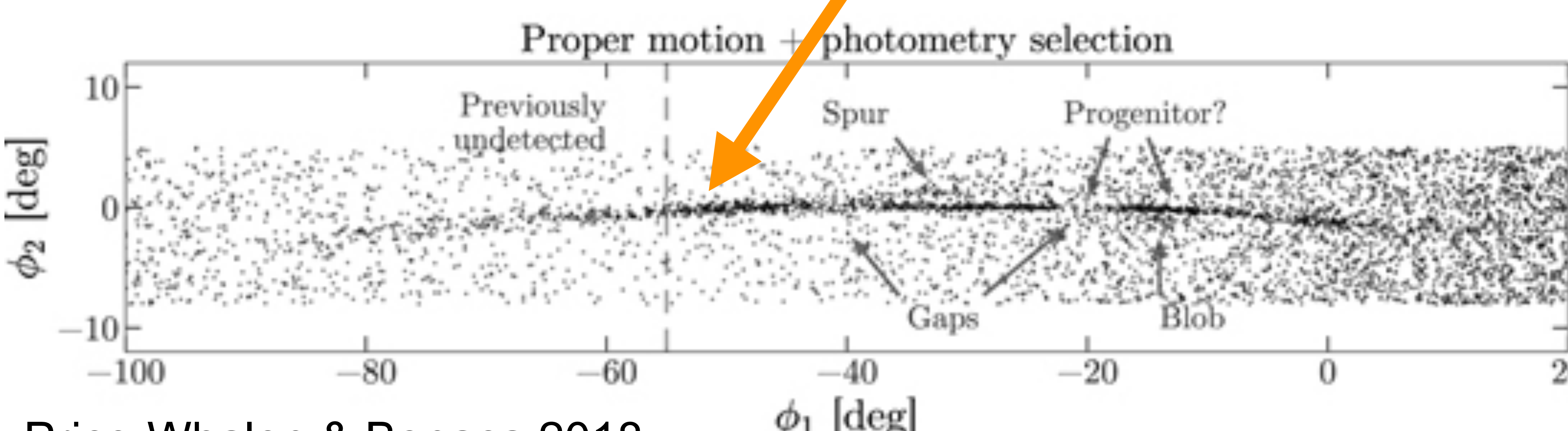


GD-1 MW stellar stream

100°+ long on sky

30 candidates/sq. degree in Gaia

(in 200 sq. deg)



Price-Whalen & Bonaca 2018

Credit: Ting Li (U Toronto)

DESI and the Draco Dwarf Galaxy

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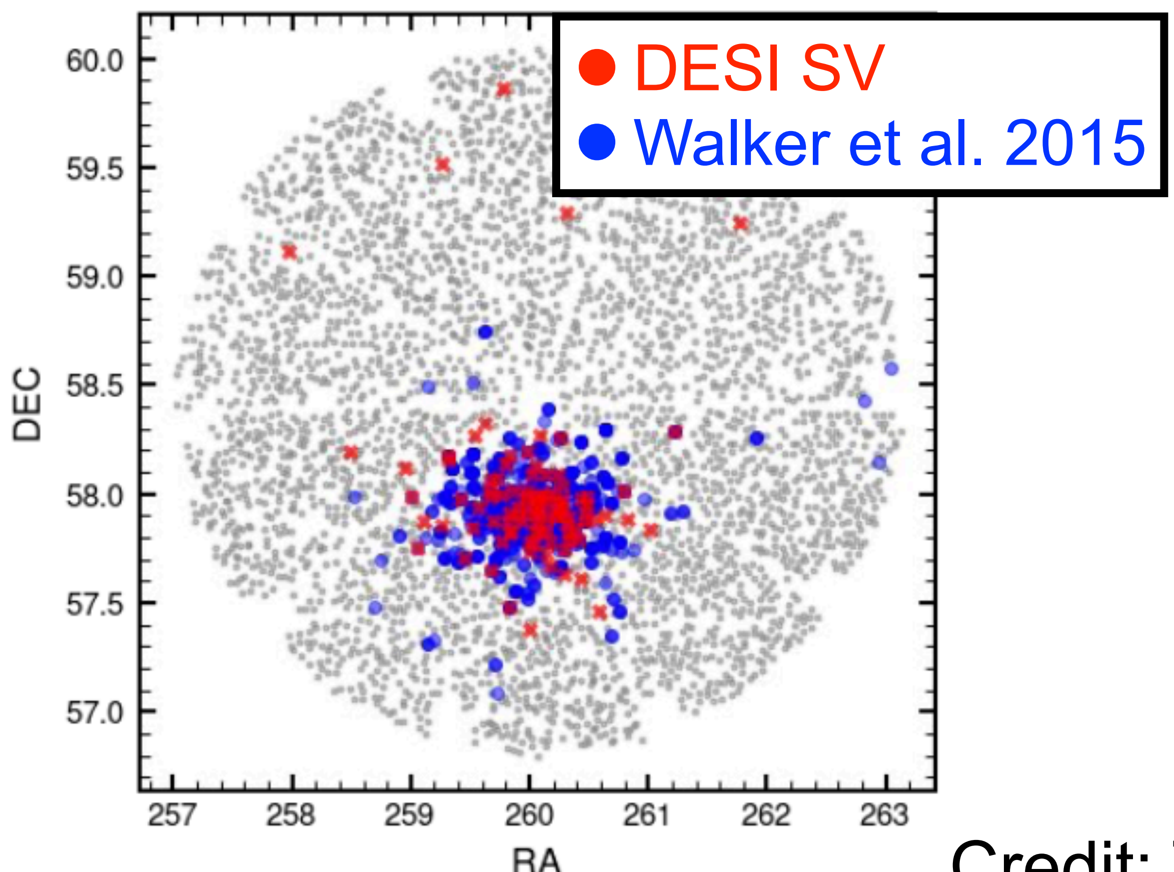
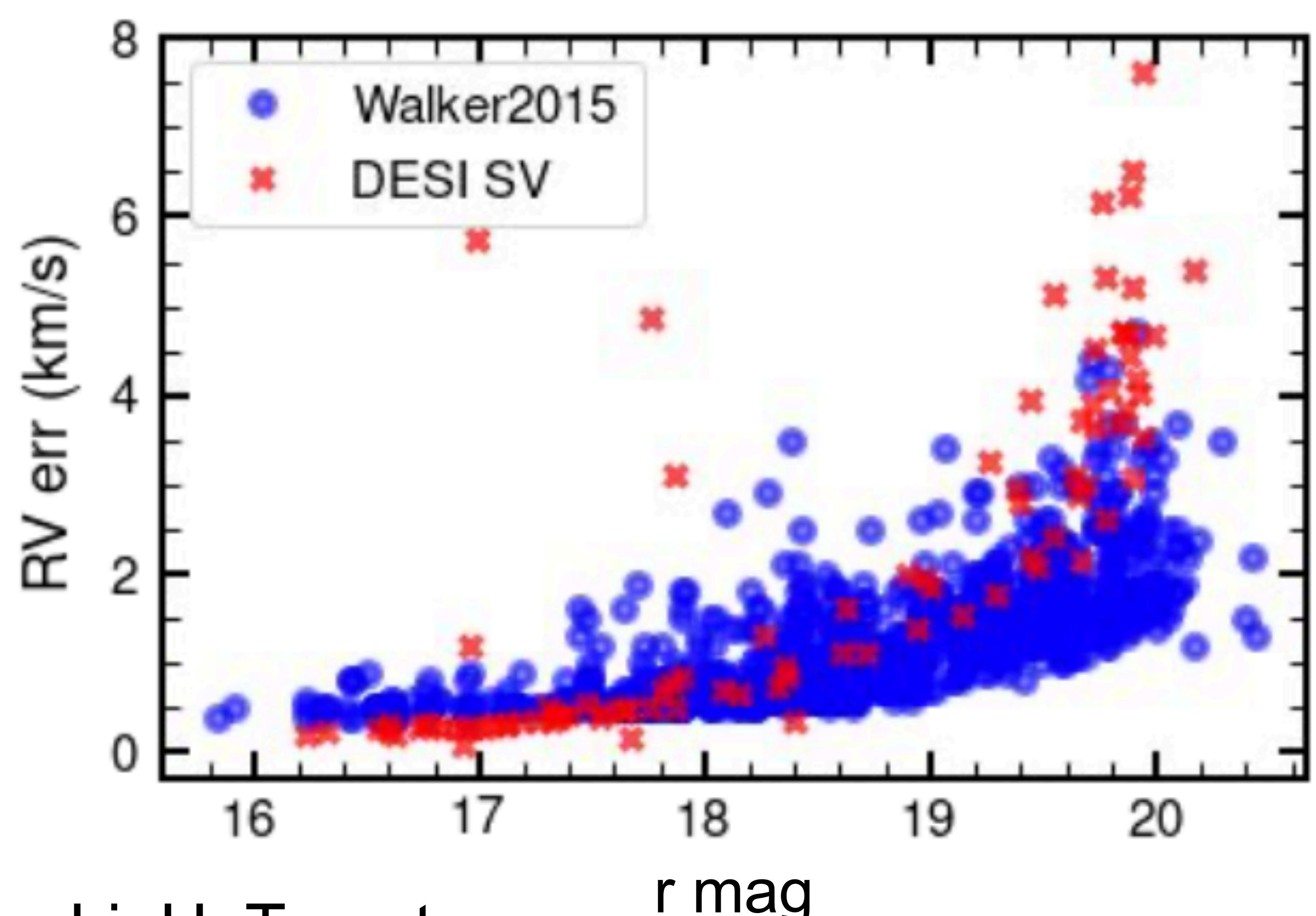
DESI wide field + sensitivity: dwarf galaxy membership, kinematics

- Dark matter subhalo density profile, total mass

DESI RVs for 200 Draco candidates in 45 min (SV observations)
- 5 DESI passes → most Draco member candidates in Gaia
- Comparable to big programs on larger telescopes (Walker et al. 2015)

Draco MW dwarf galaxy field





Credit: Ting Li, U. Toronto

DESI Observations of Andromeda

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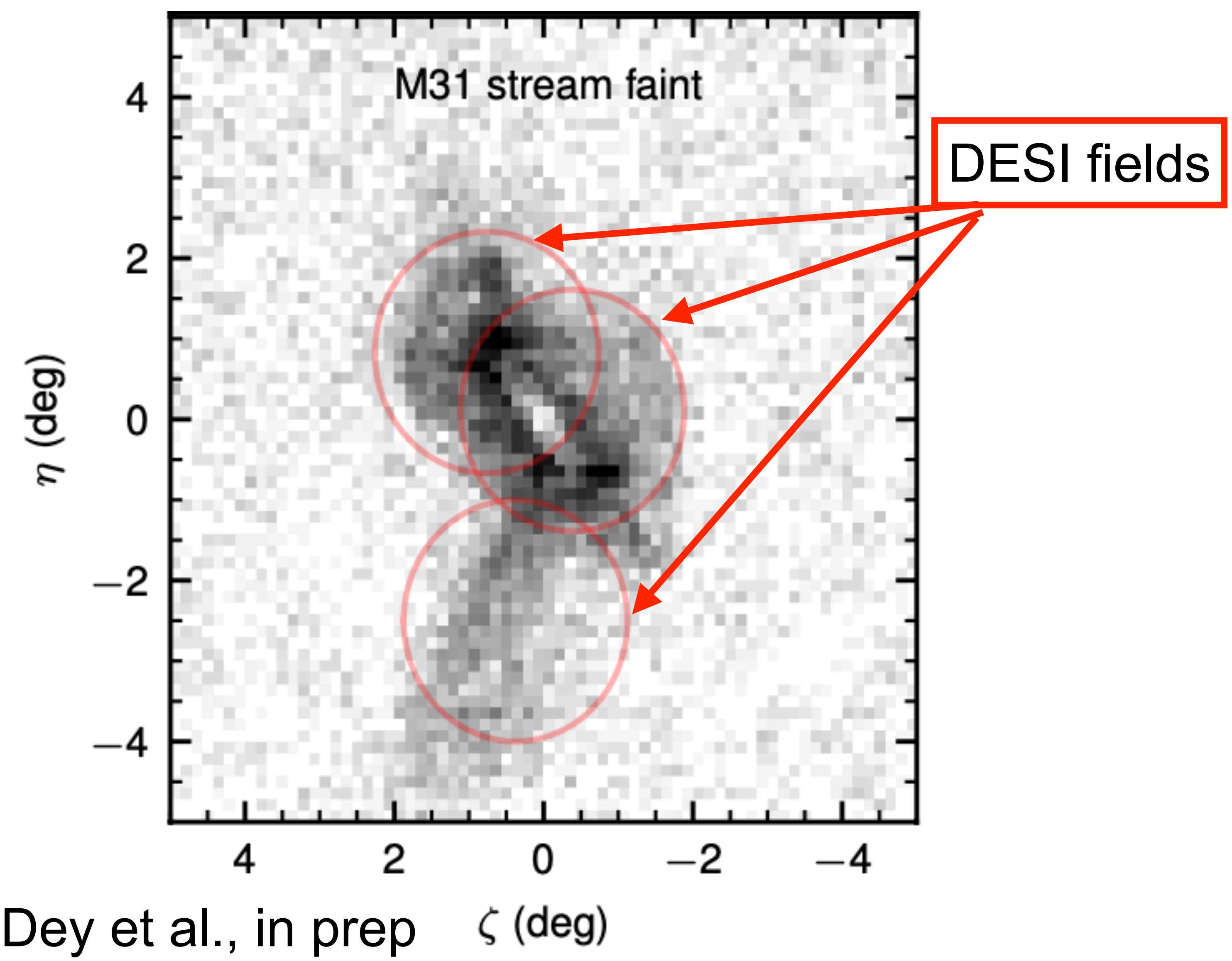
DESI special M31 observations

DESI M31 Giant Southern Stream CMD selection



Dey et al., in prep

PAndAS Map of M31

Martin et al., 2013

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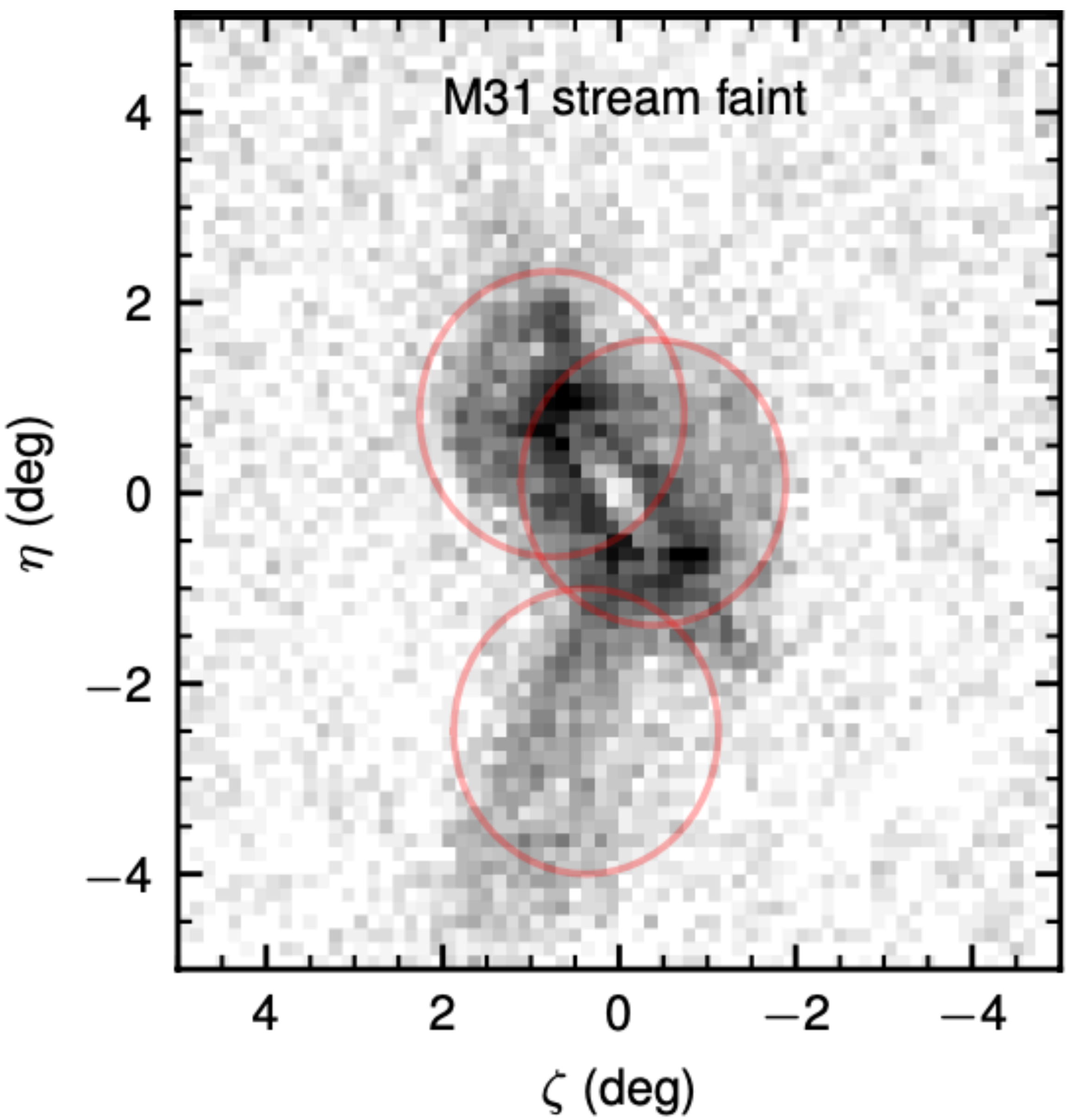
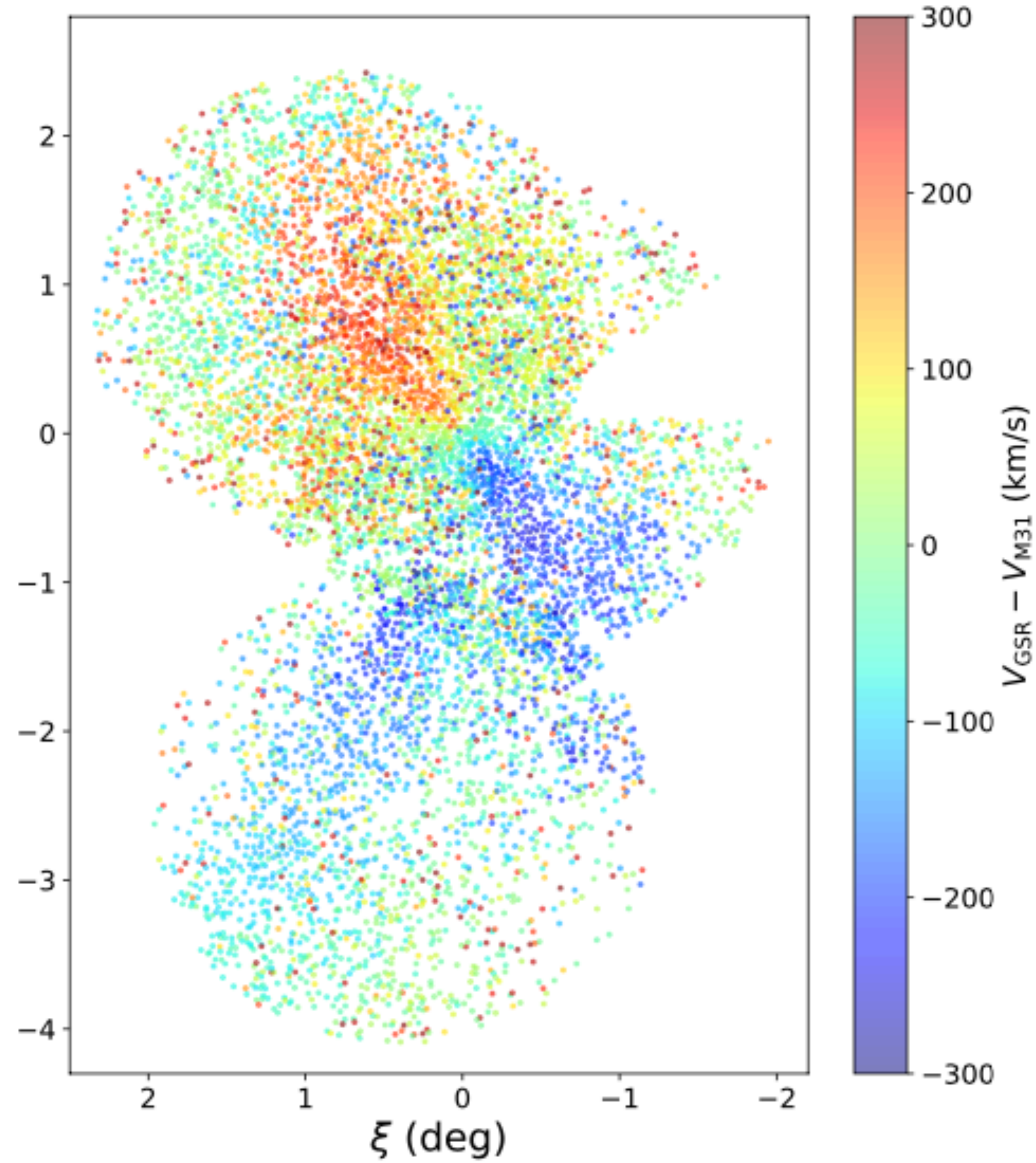
DESI Observations of Andromeda

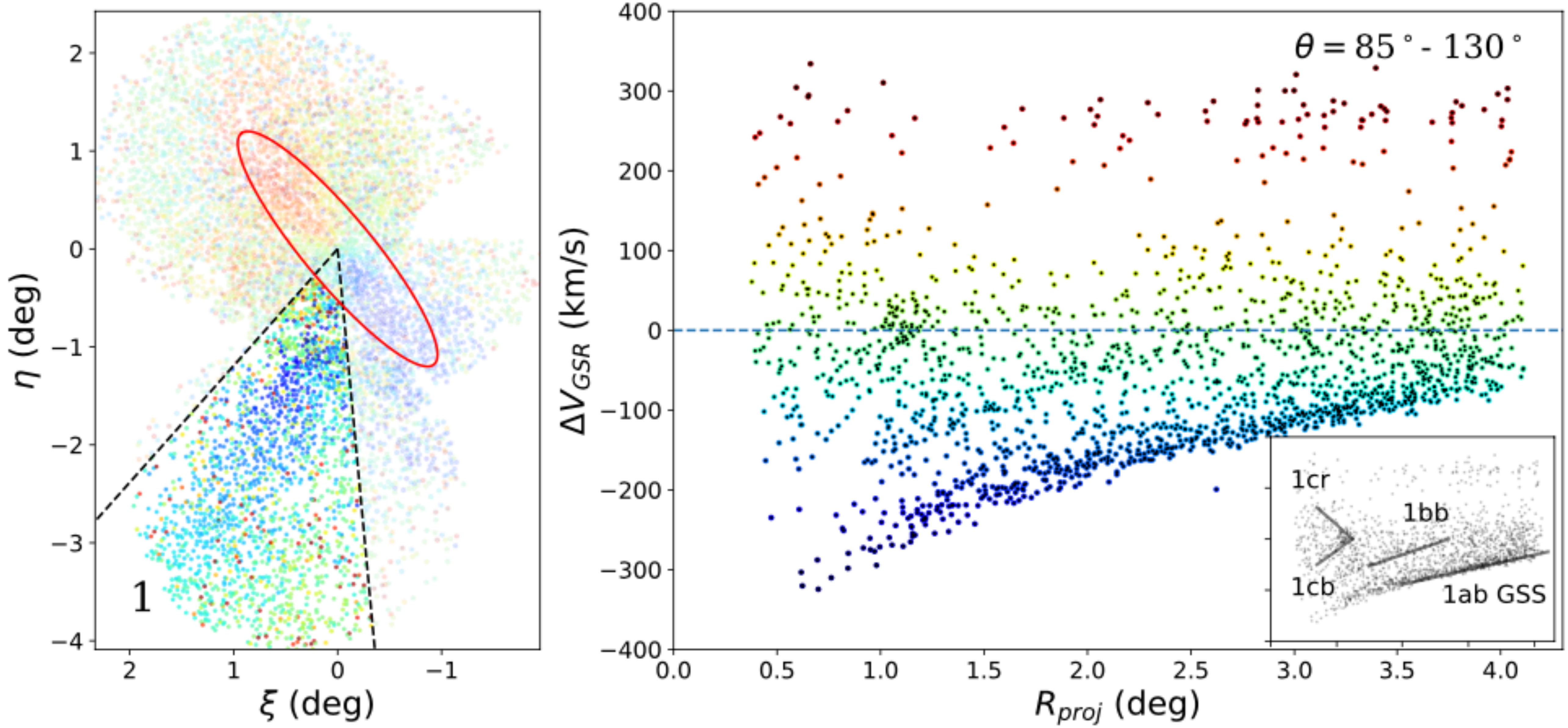
Three (!) DESI fields:
- Halo/stream: 1.5 hours, dark
- Disk: 45 min, dark
- σ_{RV} < 5 km/s @ z < 21.5





Dey et al., in prep

DESI Observations of Andromeda



Dey et al., in prep

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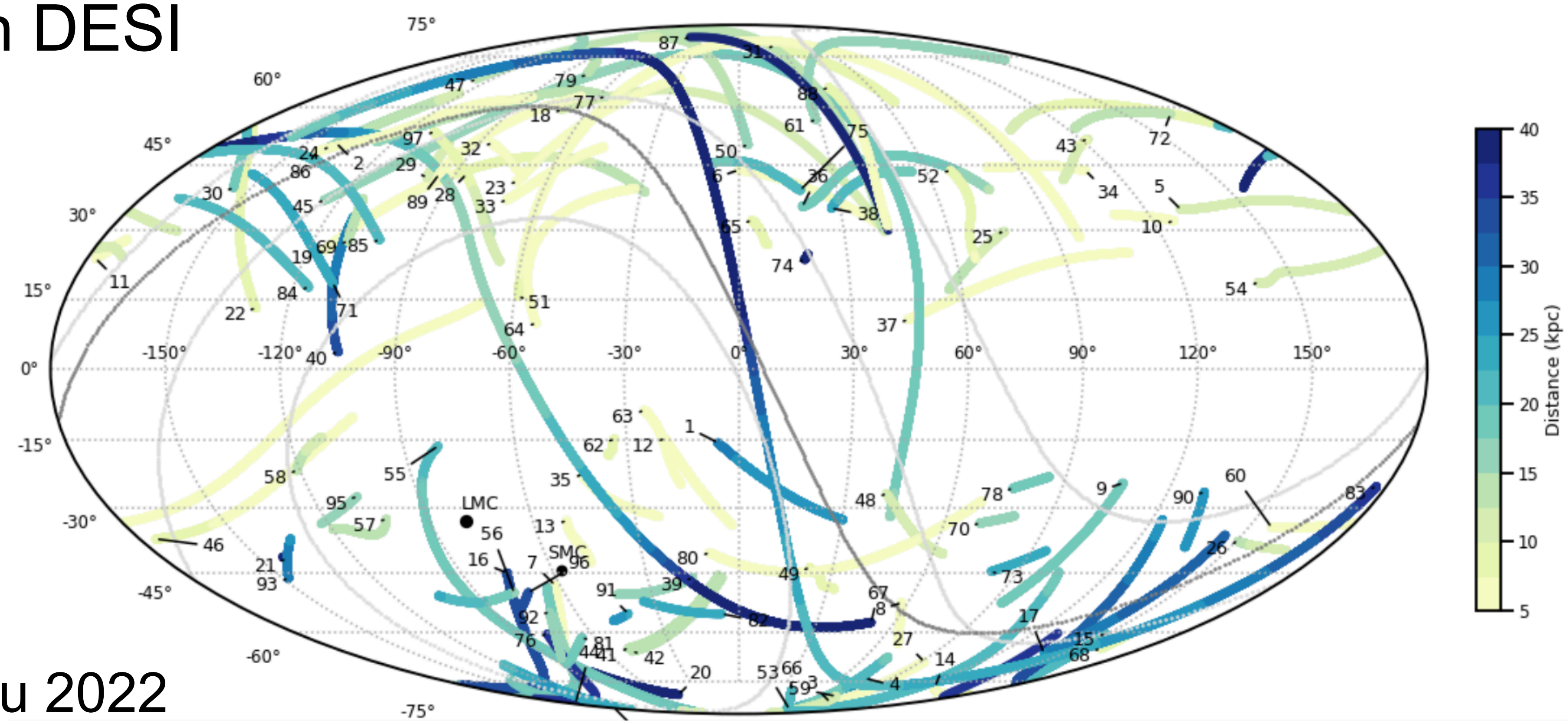
MW Science with LSST + DESI

- DESI spectroscopy can help realize Rubin Observatory/LSST Milky Way and stellar science goals
  - LSST proper motions, parallax, photometry → fainter, deeper DESI targets for stream, dwarf galaxy and halo kinematics
  - Calibrate stellar photometric metallicity relations (u band!)
  - Spectra of variable stars: ID, population characteristics, RVs, etc.
- More science return from larger DESI + LSST overlap, coordinated follow-up of LSST with DESI

Known Milky Way stellar streams, color-coded by distance



Mateu 2022

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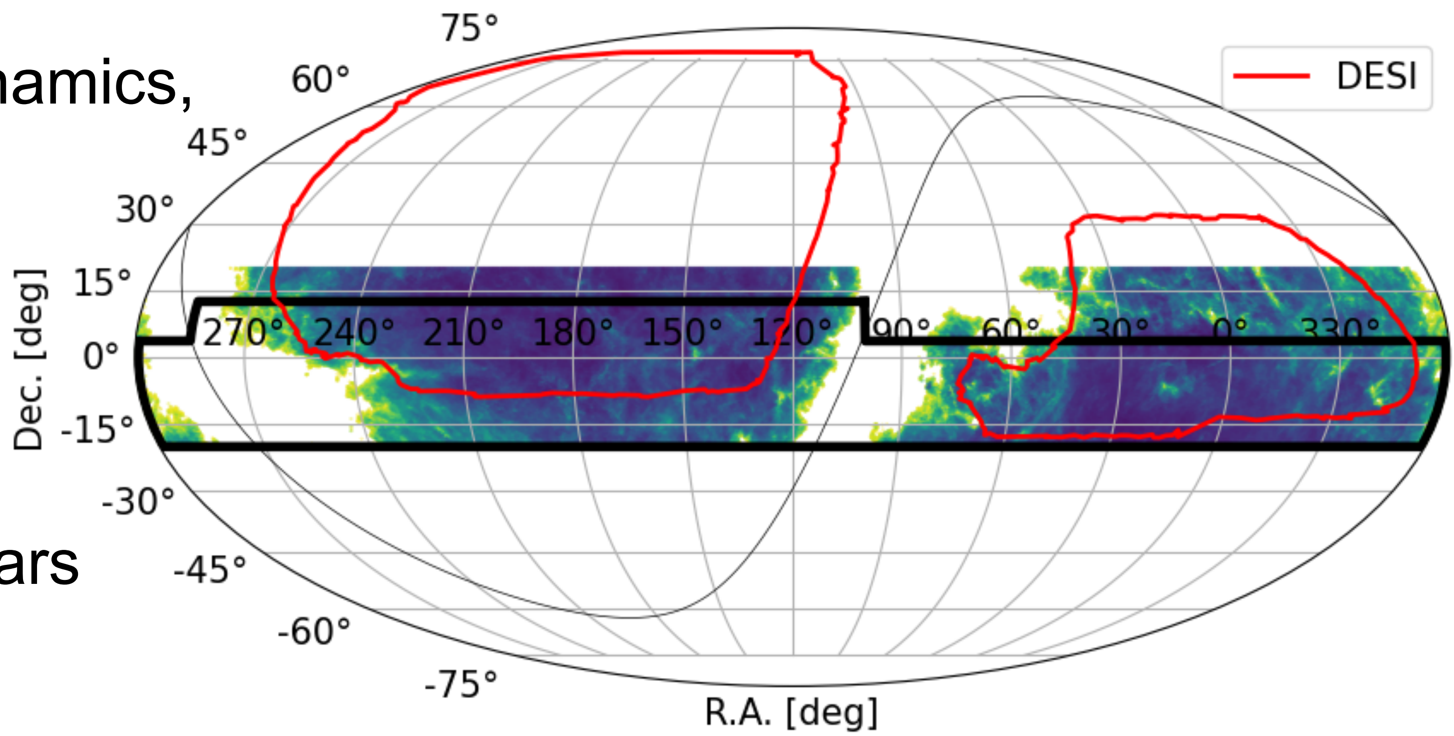
Time for Discussion

A list of science gains with DESI + LSST overlap

(Surely incomplete!)

- galaxy-galaxy lensing
- radial velocities of stars for Milky Way dynamics, streams, dark matter halo LF, MF, profile
- galaxy photo-z calibration
- redshifts of strong lenses
- redshifts in deep drilling fields
- radial velocities, ID, physics of variable stars
- redshifts of GW candidates from LSST
- velocity field for kinematic S-Z calibration
- variable stars in early and late phases of stellar evolution
- redshifts for galaxy intrinsic alignment calibration
- transient host galaxy redshifts (cosmic expansion, velocity field for growth of structure
- stellar metallicities: photometric relation calib., stellar nucleosynthesis, chemical evolution



DESI-2 Footprint