Early results from the DECam MAGIC Survey: Mapping the Ancient Galaxy in CaHK

Anirudh Chiti (UChicago)

IAUS 395

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Photo credit: Dark Energy Survey

The DECam MAGIC Survey (**M**apping the **A**ncient **G**alaxy **i**n CaHK) is an approved **54 night** NOIRLab survey to study the **ancient Milky Way**

- **Duration:** Fall 2023 - Spring 2026 **(~1 year of data so far)**

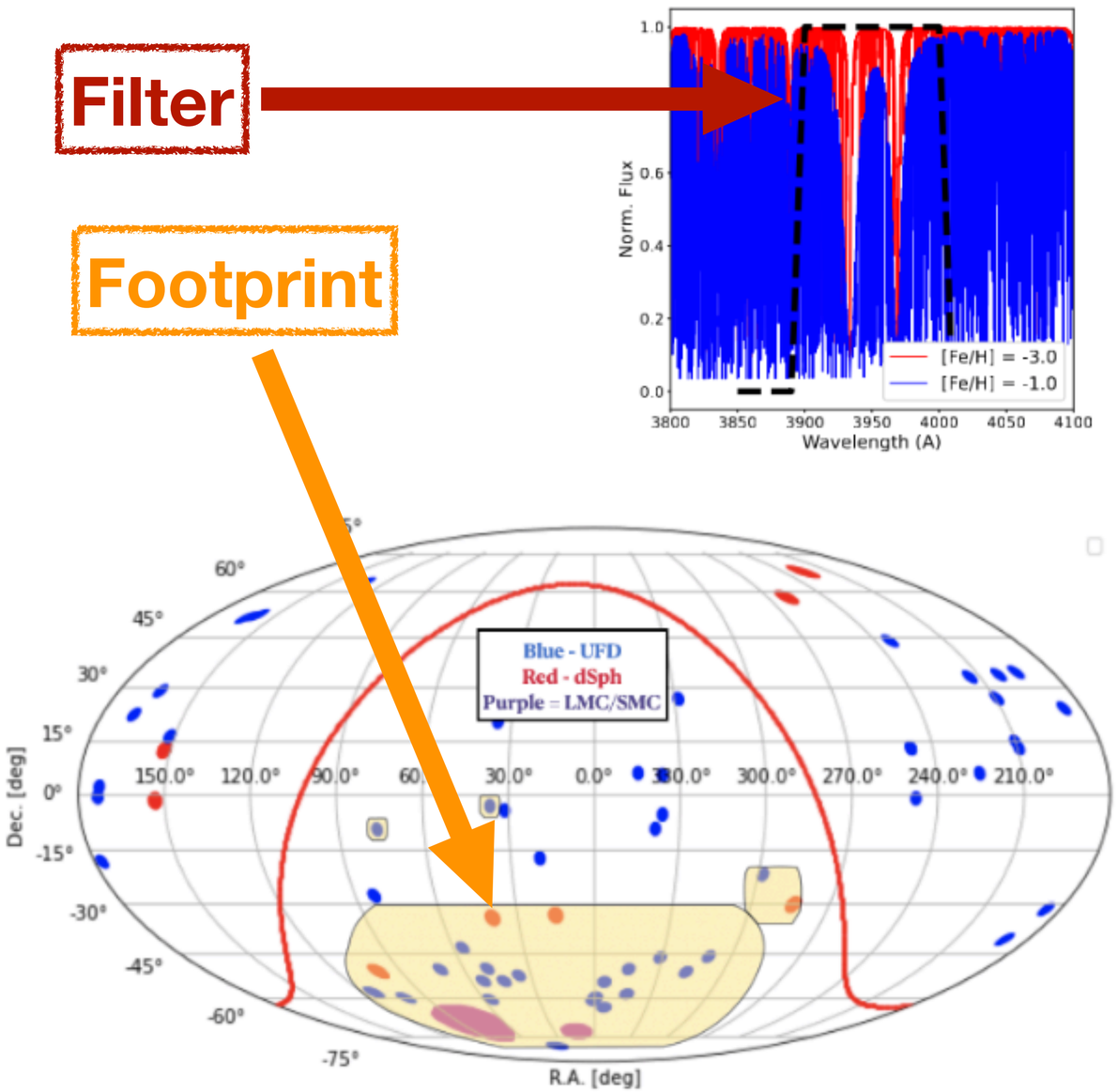
- **Aim: Image a quarter of the southern sky** (~5300 sq. deg.) with a narrow-band filter centered on the Ca II H&K lines

- **Science:** With CaHK photometry, derive photometric metallicities of red giant stars across our footprint

  - **Reliable identification of [Fe/H] < -3.0** red giant stars to **g~18.0 (~hi-res spectroscopy limit)**

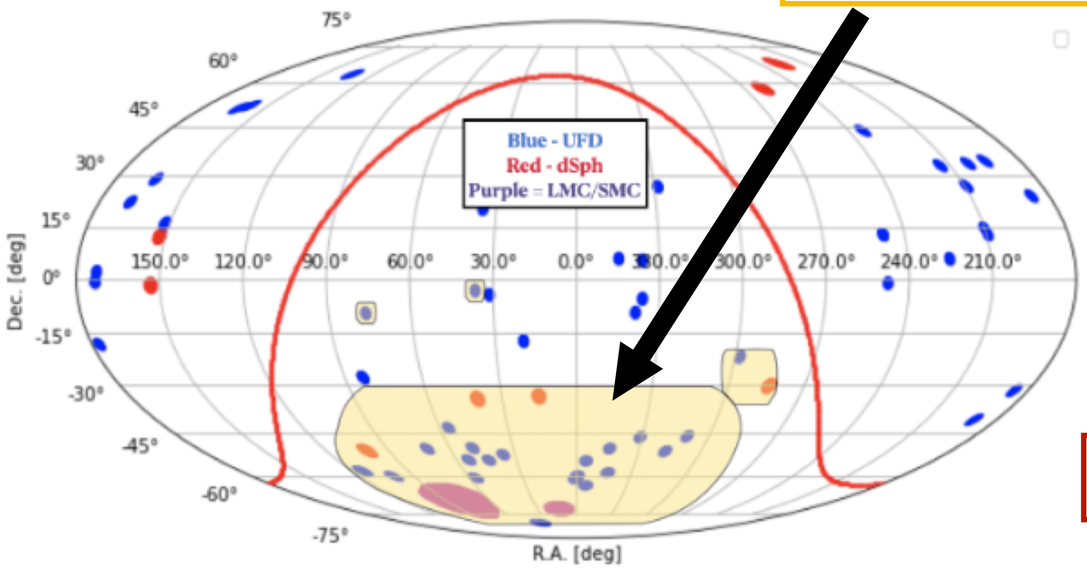
  - **Metallicity precision of ~0.3 dex at [Fe/H] ~ -2.0** down to **g~20.3 (~Gaia proper motion limit)**

- **Context:** Builds on the success of previous CaHK surveys in the southern hemisphere (e.g., S-PLUS, SkyMapper), but extends >2 mags fainter; complements the Pristine survey in the northern hemisphere

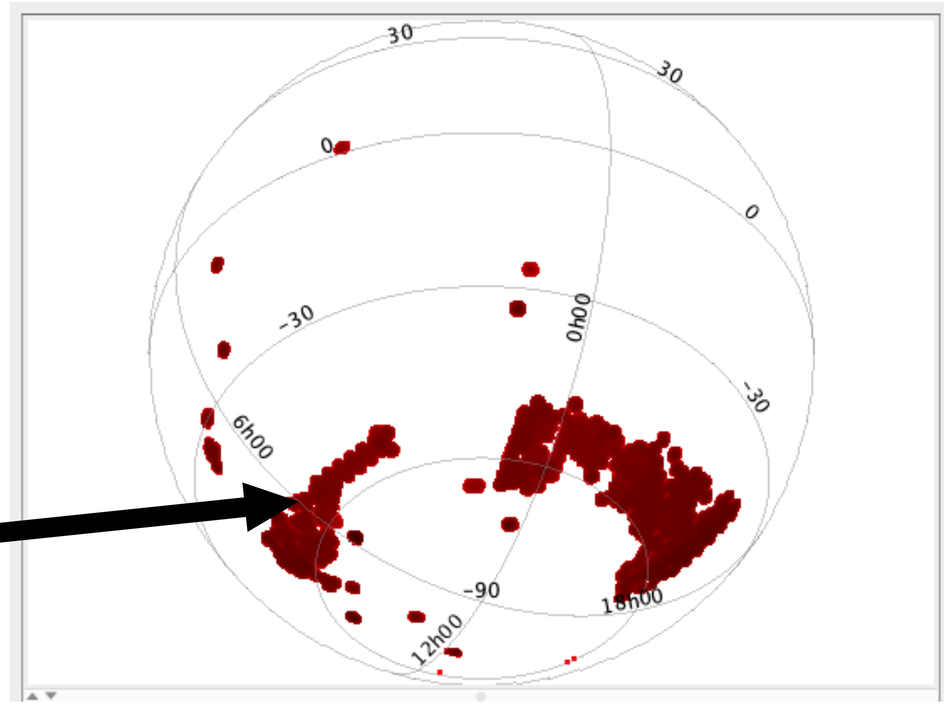


MAGIC Survey progress so far: **Effectively ~10 nights of data**

Proposed footprint



Actual data



- ☑ Survey fields **covering ~1000 sq. deg.** (12 min exposures)
- ☑ Targeted observations (>36 mins):
  - ☑ **>10 star clusters**— P.I. programs led by Julio Carballo-Bello, Clara Martìnez-Vázquez
  - ☑ **>15 dwarf galaxies**— P.I. programs led by Will Cerny and Andrew Pace
- ☑ Proposed P.I. programs targeting additional systems (e.g., Jet Stream— P.I. Ha Do)

Relevant scientific goals of the MAGIC survey

- ☑ Discovery and follow-up of Pop-III enriched (e.g., [Fe/H] < -4.0) stars
- ☑ Characterizing the Metallicity Distribution function (MDF) of the Milky Way and its satellites
- ☑ Probing low metallicity stellar halos/tidal tails around dwarf galaxies
- ☑ Detecting low metallicity substructure in the Milky Way and MCs

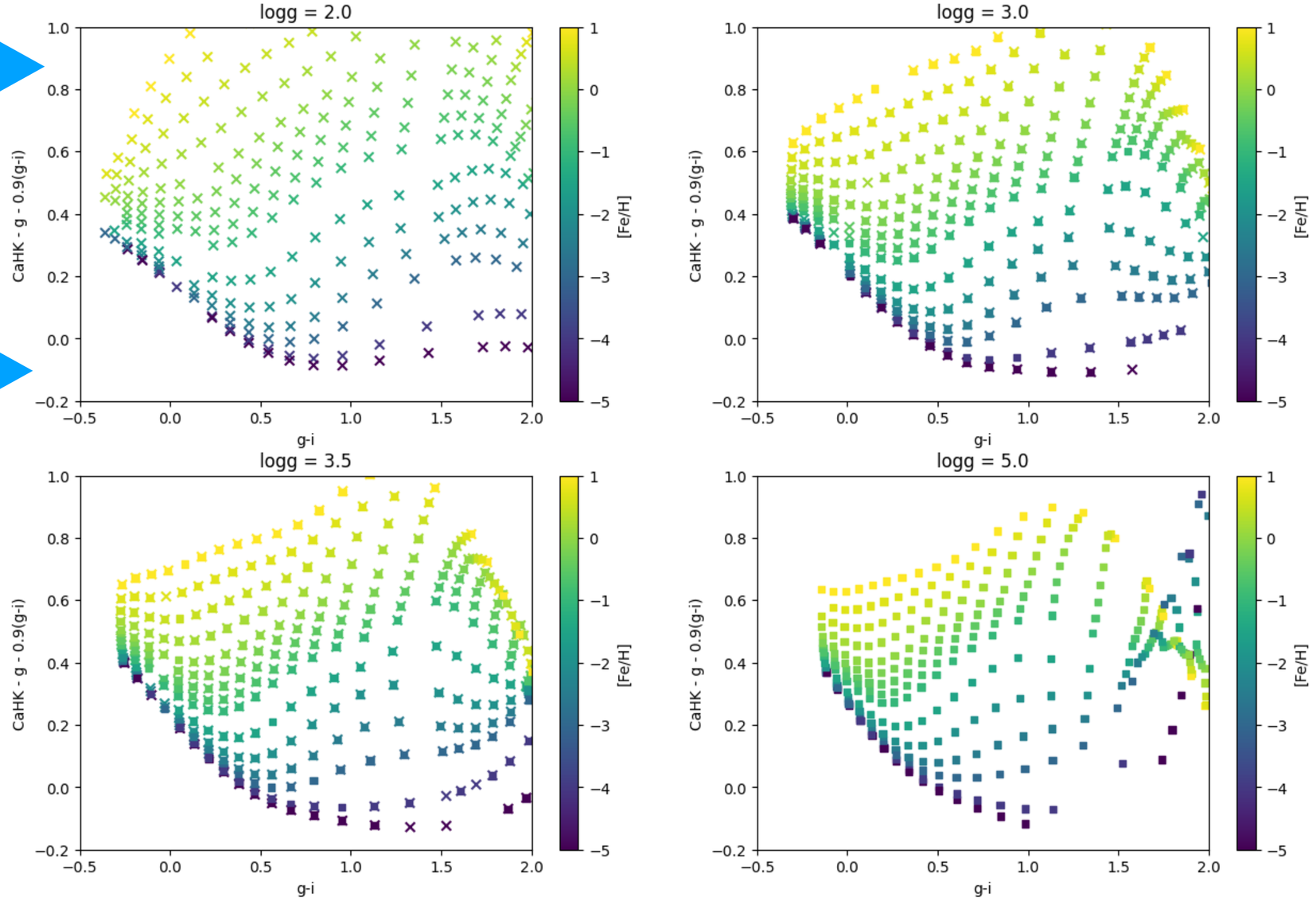
And a number of auxiliary cases: *Star formation histories of the MCs, searches for quenched field dwarf galaxies, metal-polluted white dwarfs, mapping z~2.2 quasars, metallicity-resolved maps in the LMC wake*

Method for deriving CaHK metallicities from photometry—

Comparison to grids of synthetic photometry derived from Turbospectrum-generated spectra

Grids of photometry from synthetic spectra generated by the Turbospectrum code

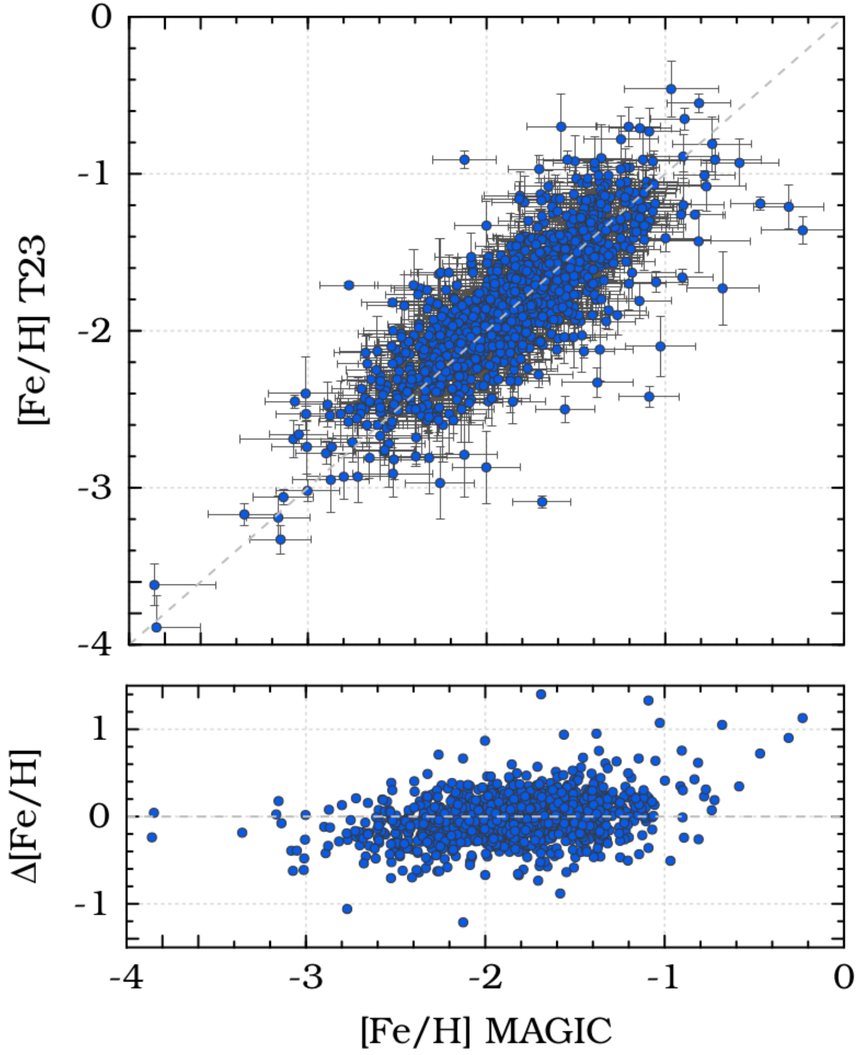
Span a range of:
Teff, logg, [Fe/H]



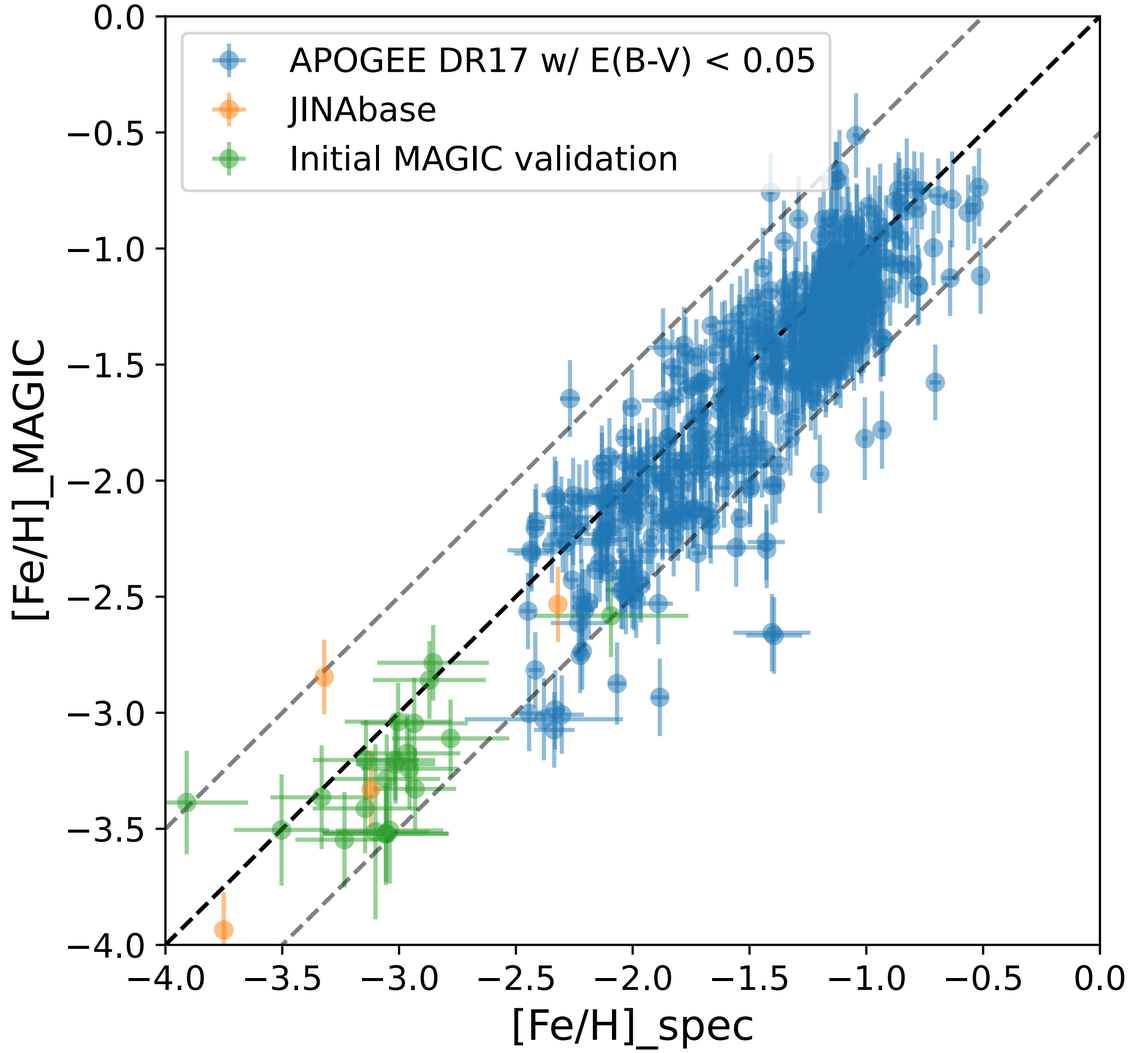
Method: Overlay observed photometry on grids of synthetic photometry —> enables metallicity determination

How are the CaHK photometric metallicities performing in our current data?

In Sculptor dSph (Fabricìa Barbosa)—



Across the survey footprint—



Early science from the MAGIC survey

1.Discovery and follow-up of Pop-III enriched (e.g., [Fe/H] < -4.0) stars

2. Characterizing the Metallicity Distribution function (MDF) of the Milky Way and its satellites

—> **Result 1: Photometric metallicities of stars in the Sculptor dwarf galaxy (Barbosa et al., in prep)**

3.Probing low metallicity stellar halos/tidal tails around dwarf galaxies

—> **Result 2: Uncovering the outskirts of the Sextans & Reticulum II dwarf galaxies (Chiti et al., in prep)**

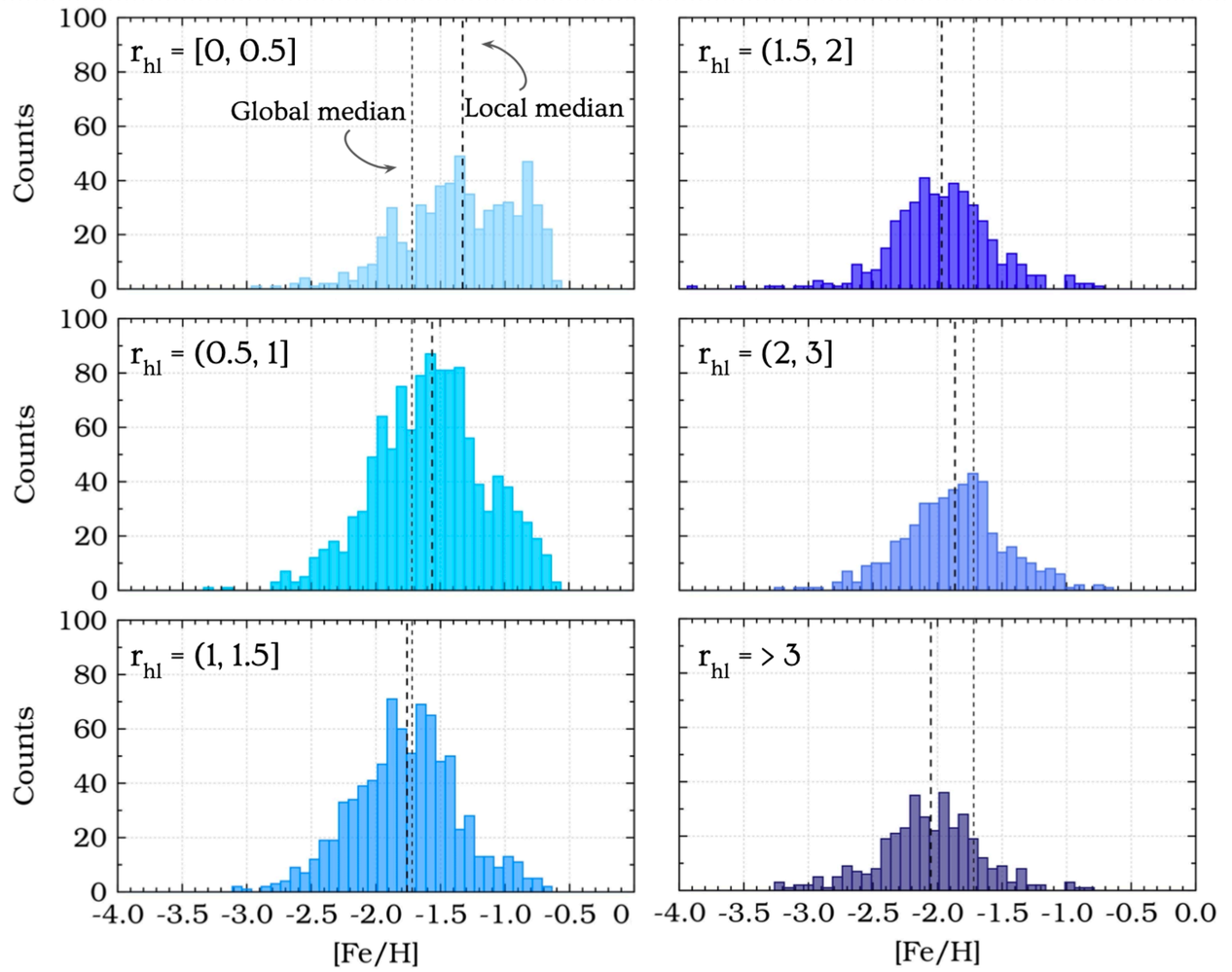
4. Detecting low metallicity substructure in the Milky Way and MCs

—> **Result 3: Recovery of the Jet stream (Do et al., in prep)**

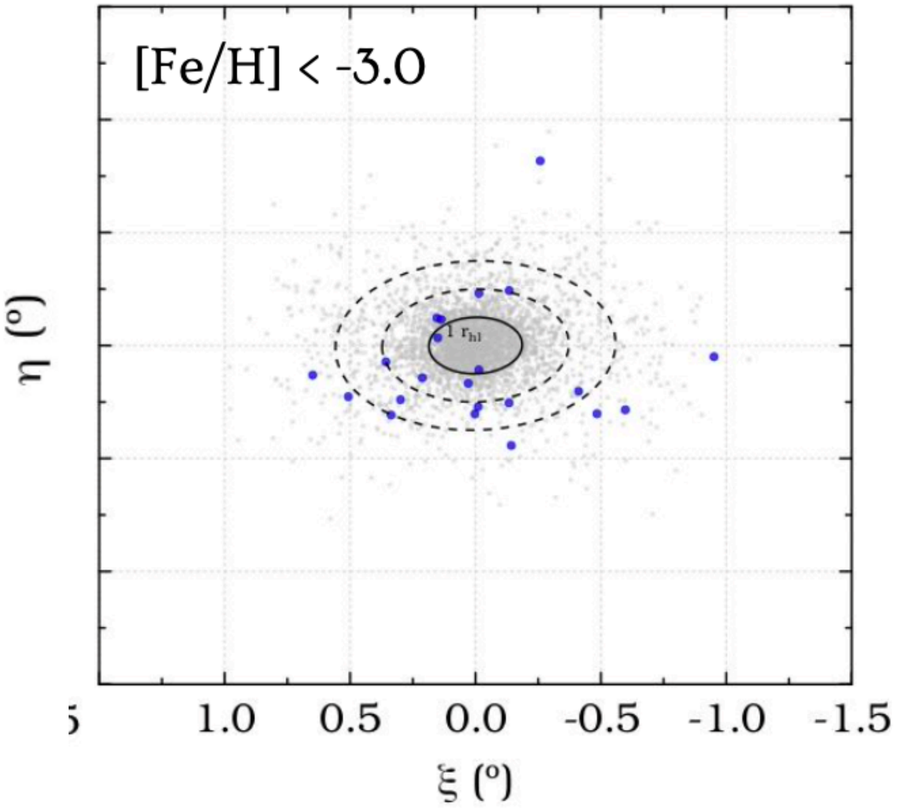
Result 1: A spatially unbiased metallicity study of stars in the Sculptor dSph

—> Fabricìa Barbosa (USP), Guilherme Limberg (UChicago), Silvia Rossi (USP)

N = 3790 stars —> ~3x current literature sample



[Fe/H] < -3.0 stars in Sculptor may be asymmetrically distributed



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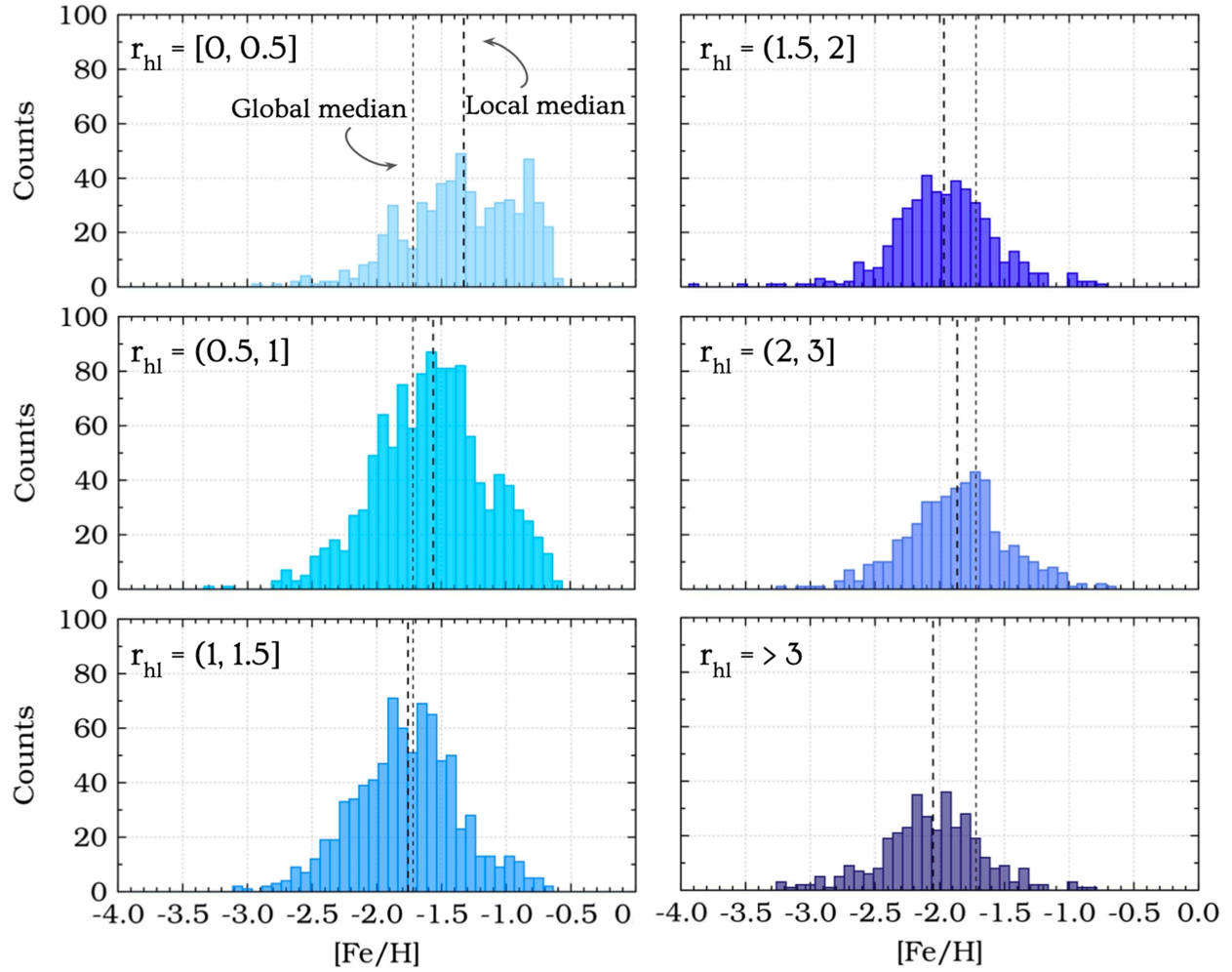

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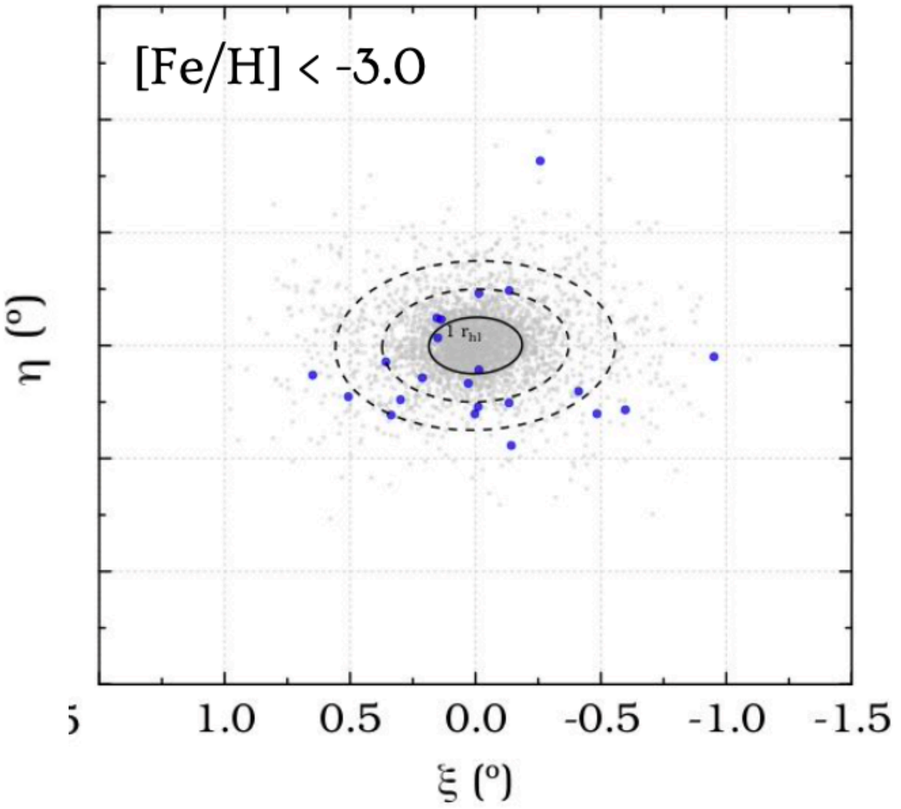
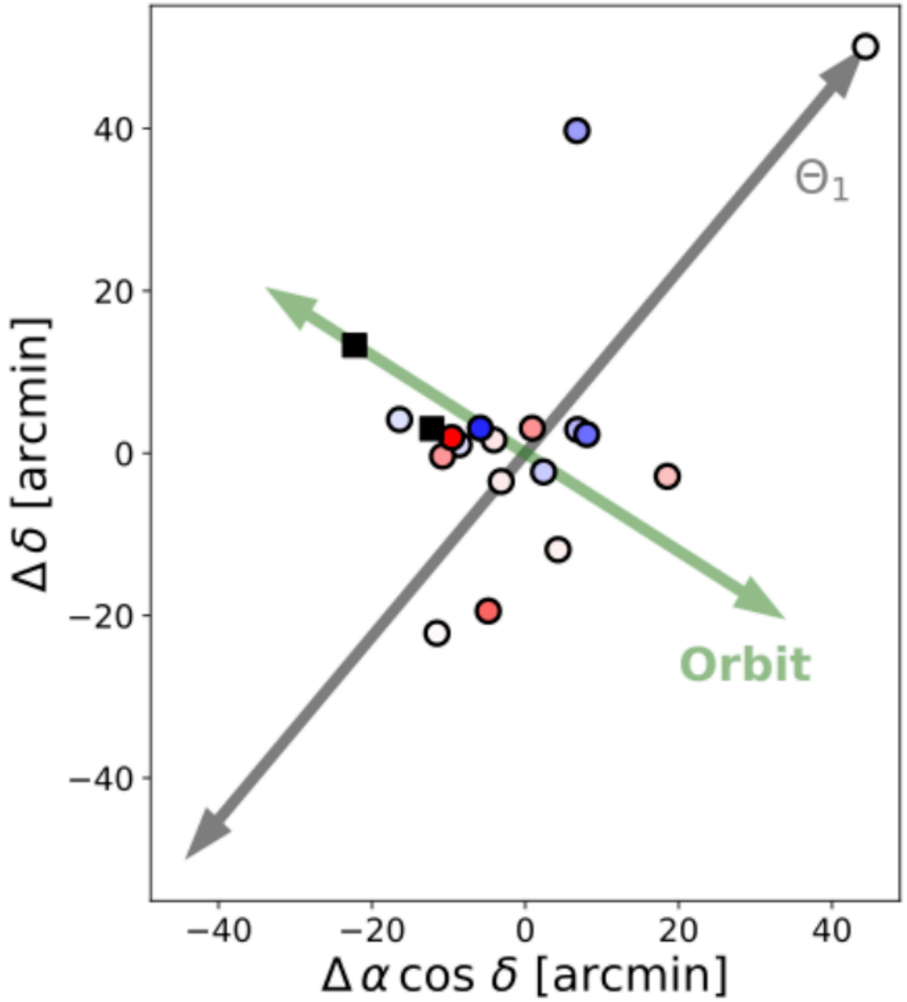


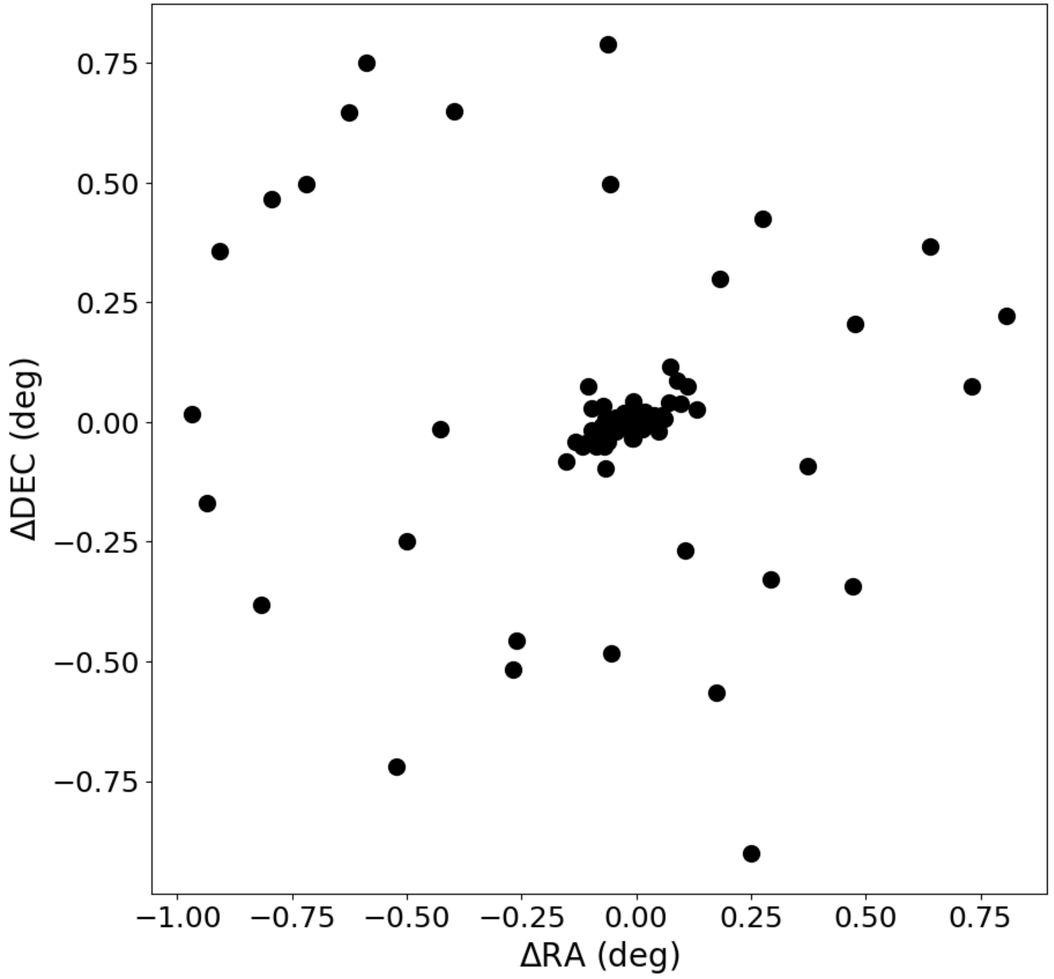
See poster by Fabricìa Barbosa!

<u>Result 2:</u> Does the Reticulum II ultra-faint dwarf galaxy (UFD) host distant members (i.e., an underlying halo, stream)? (Example left: Tucana II UFD)

Previous Tucana II extended halo detection (Chiti+21,23)



Stars with proper motions consistent with the Reticulum II UFD (Pace et al. 2022)



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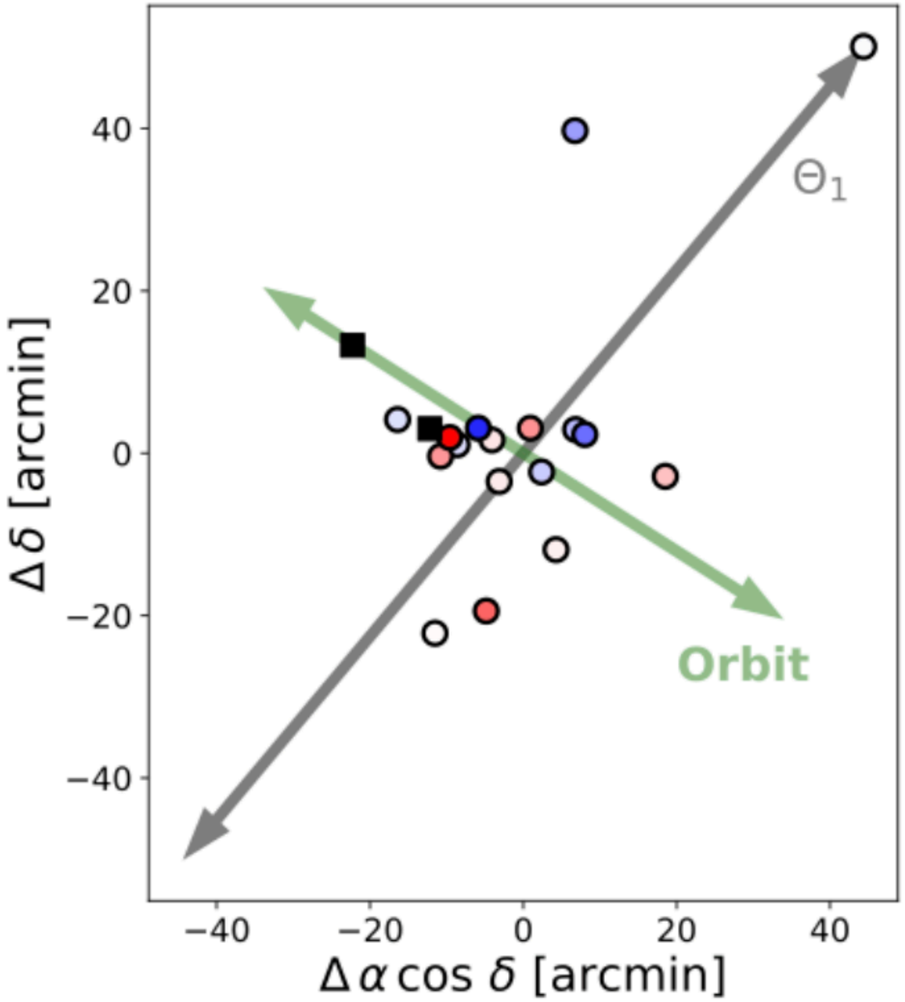
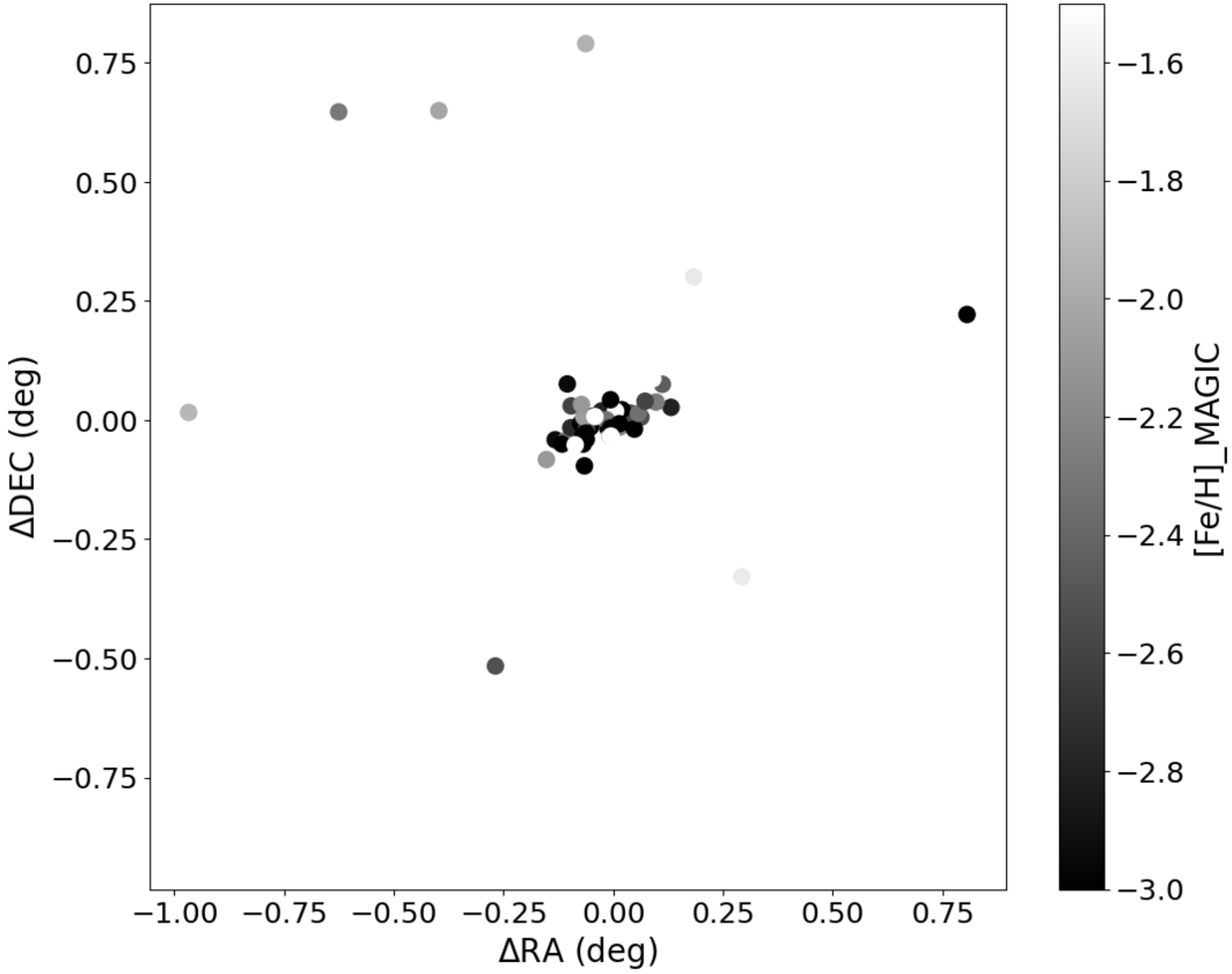


Stars with proper motions consistent with Reticulum II, colored by MAGIC [Fe/H]



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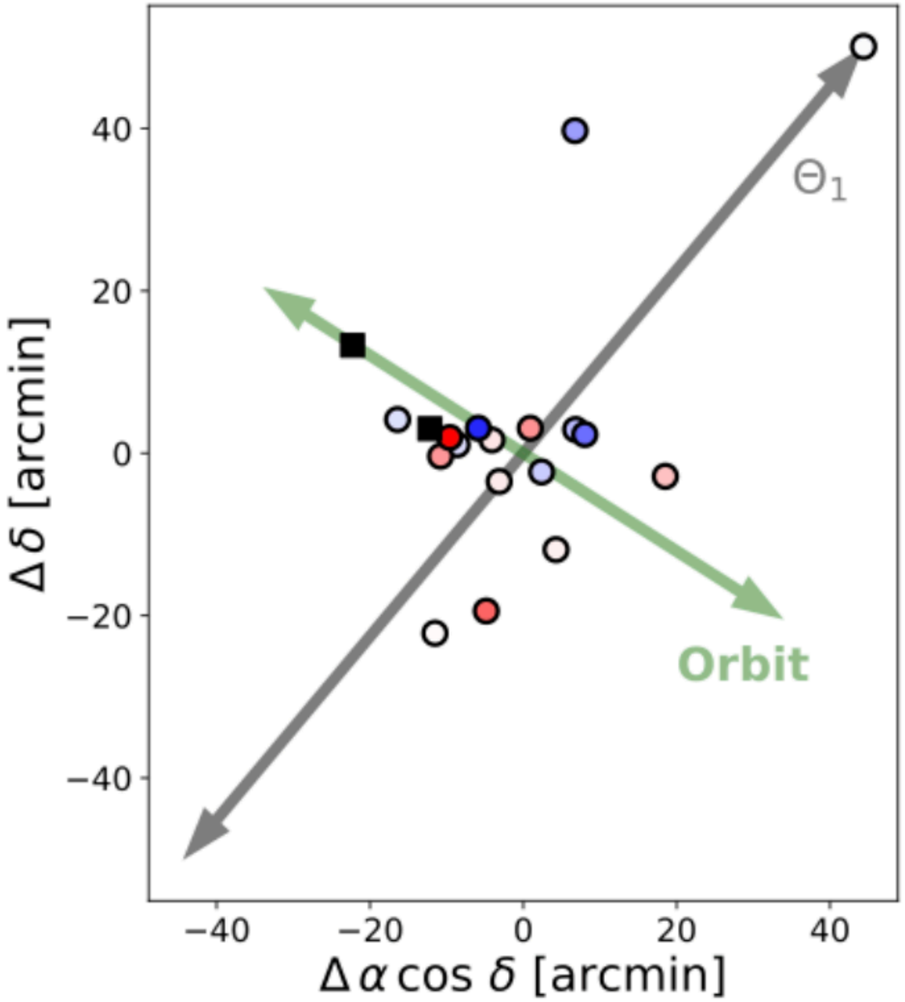

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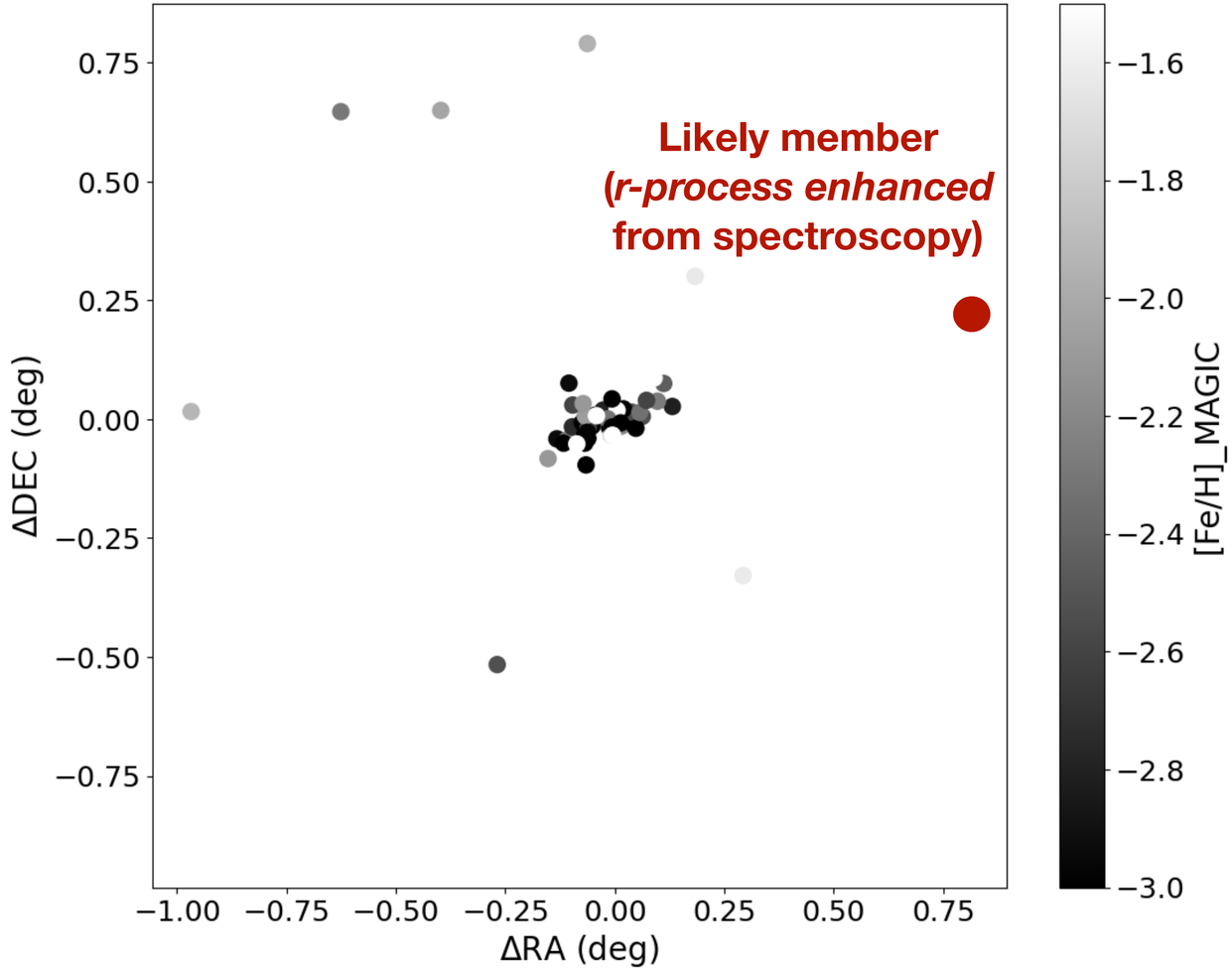

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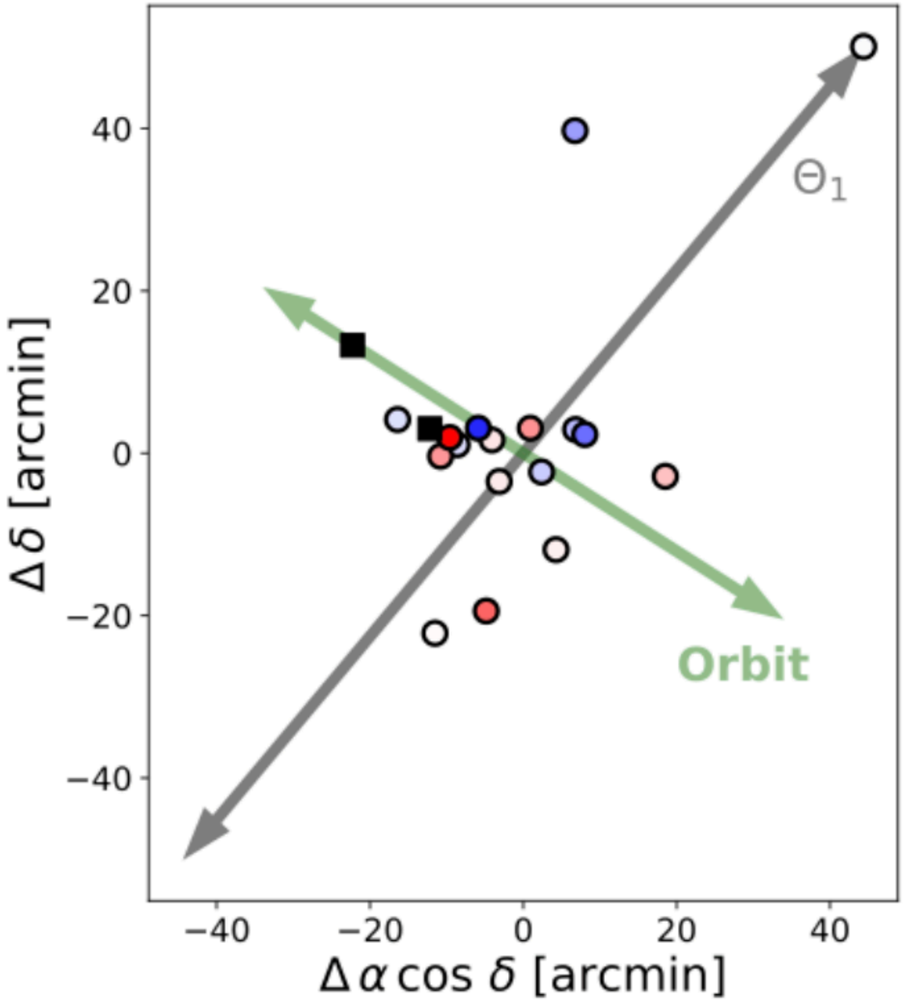

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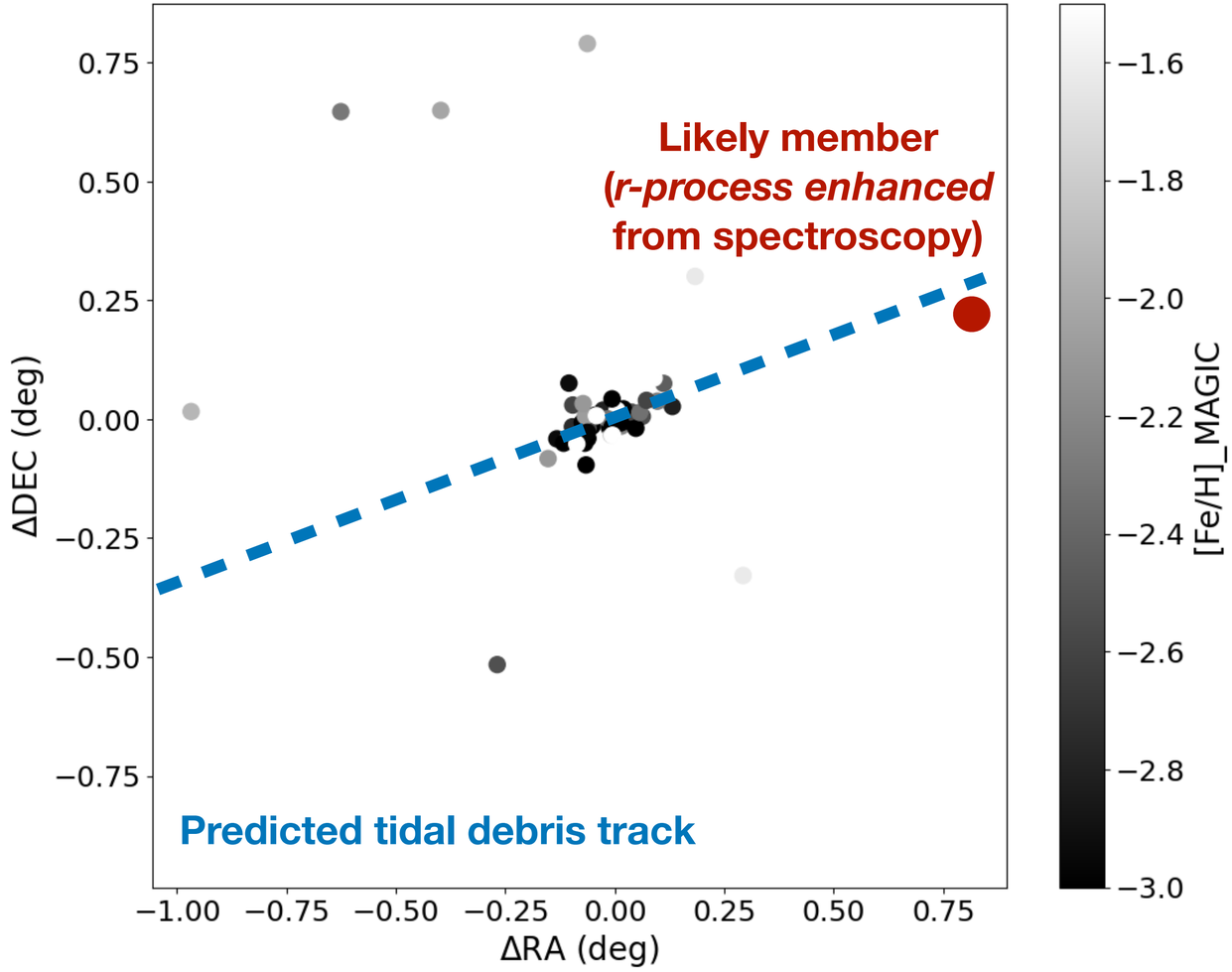
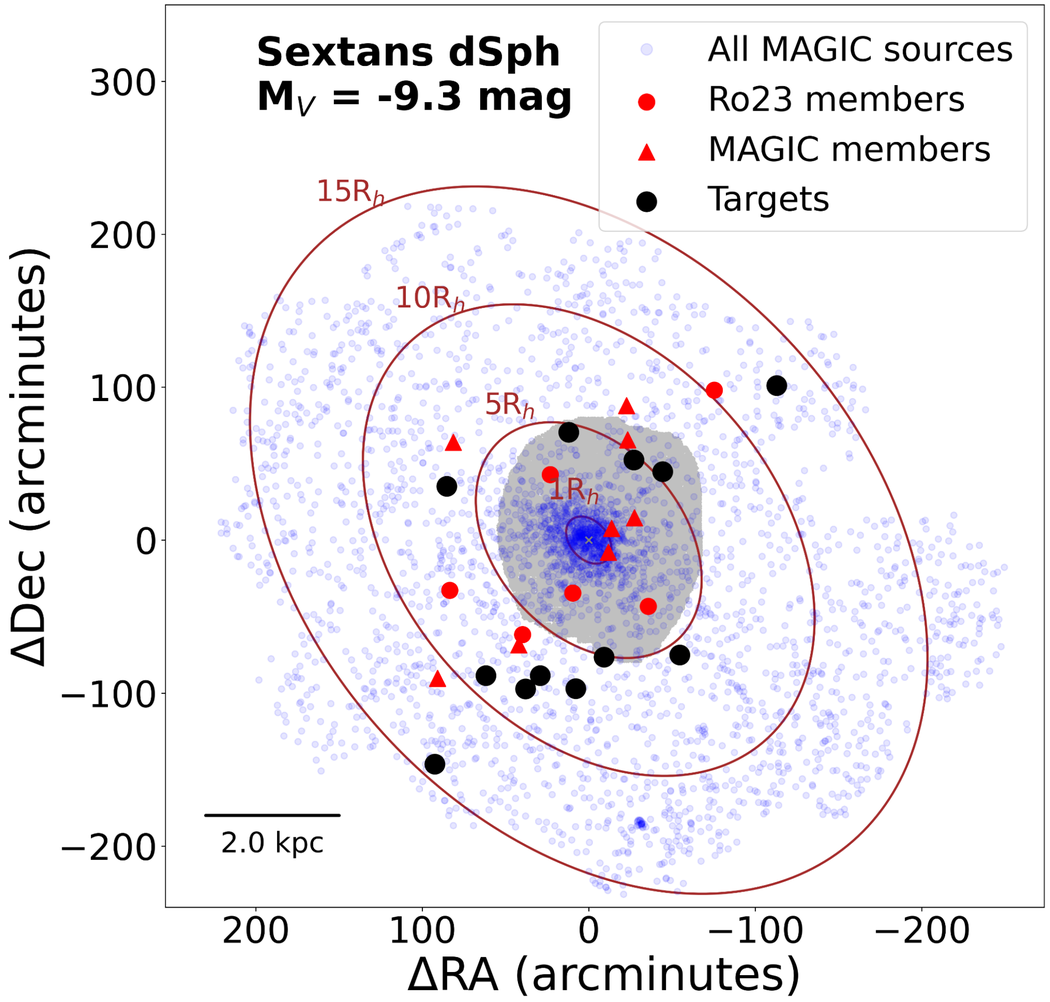


Result 2: Outskirts of other dwarf galaxies in MAGIC (example: **Sextans**)

—> Deepthi Prabhu (Arizona), Andrew Pace (UVa), Will Cerny (Yale)



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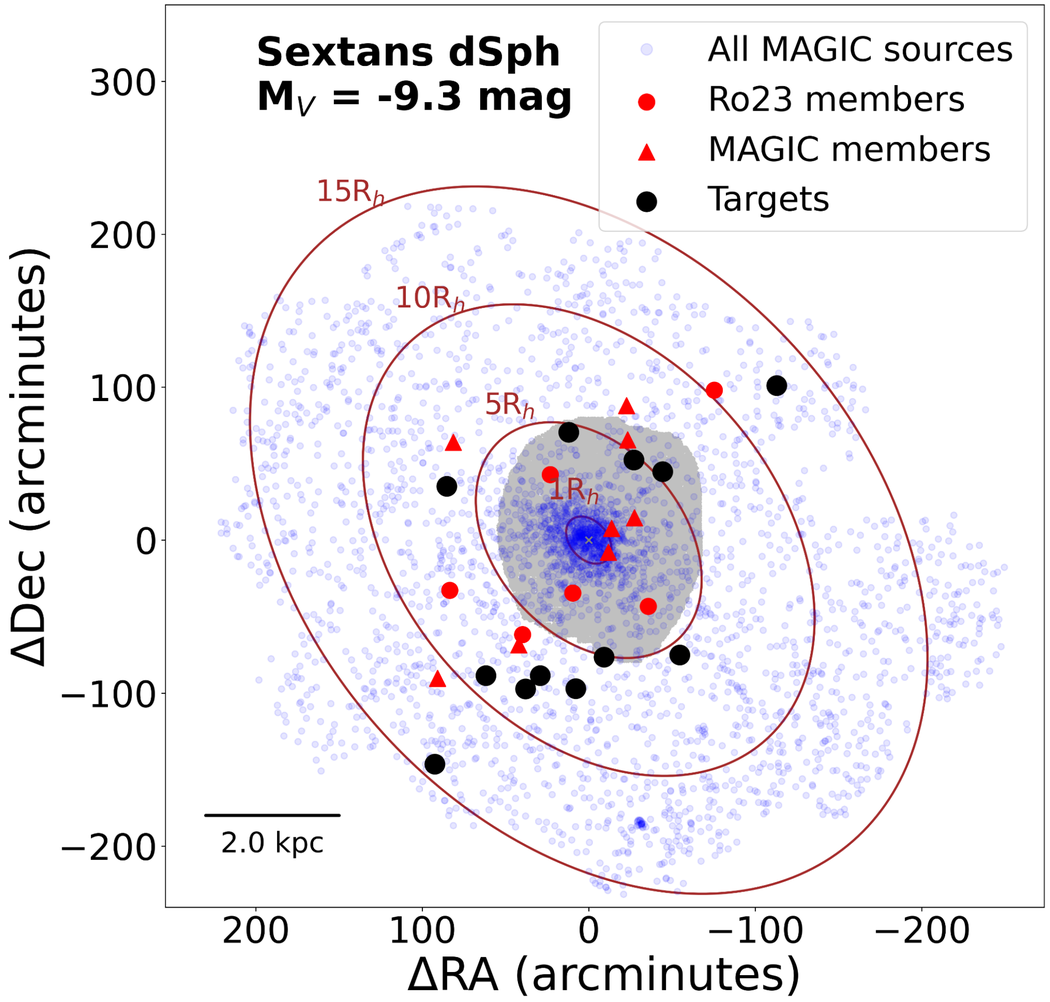

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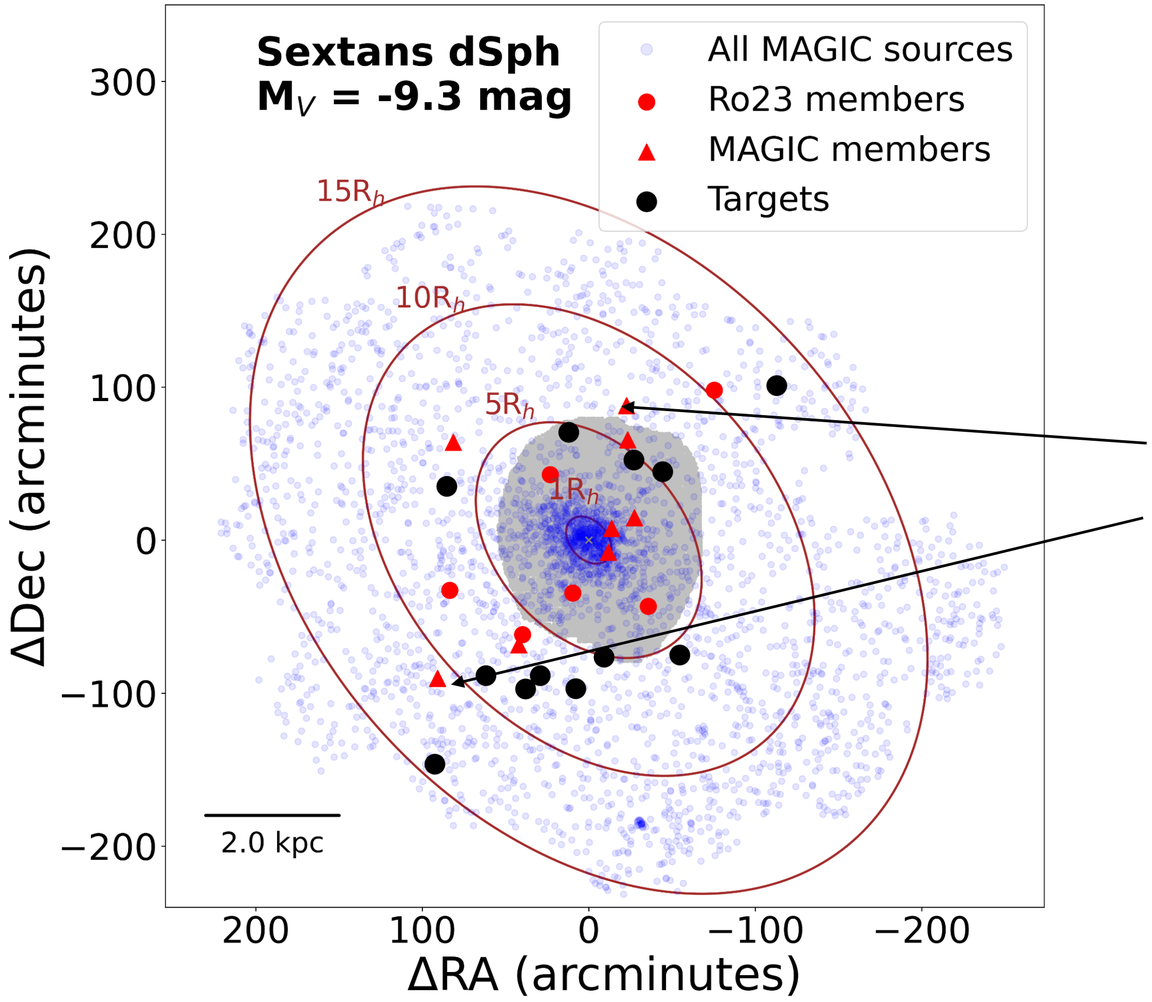
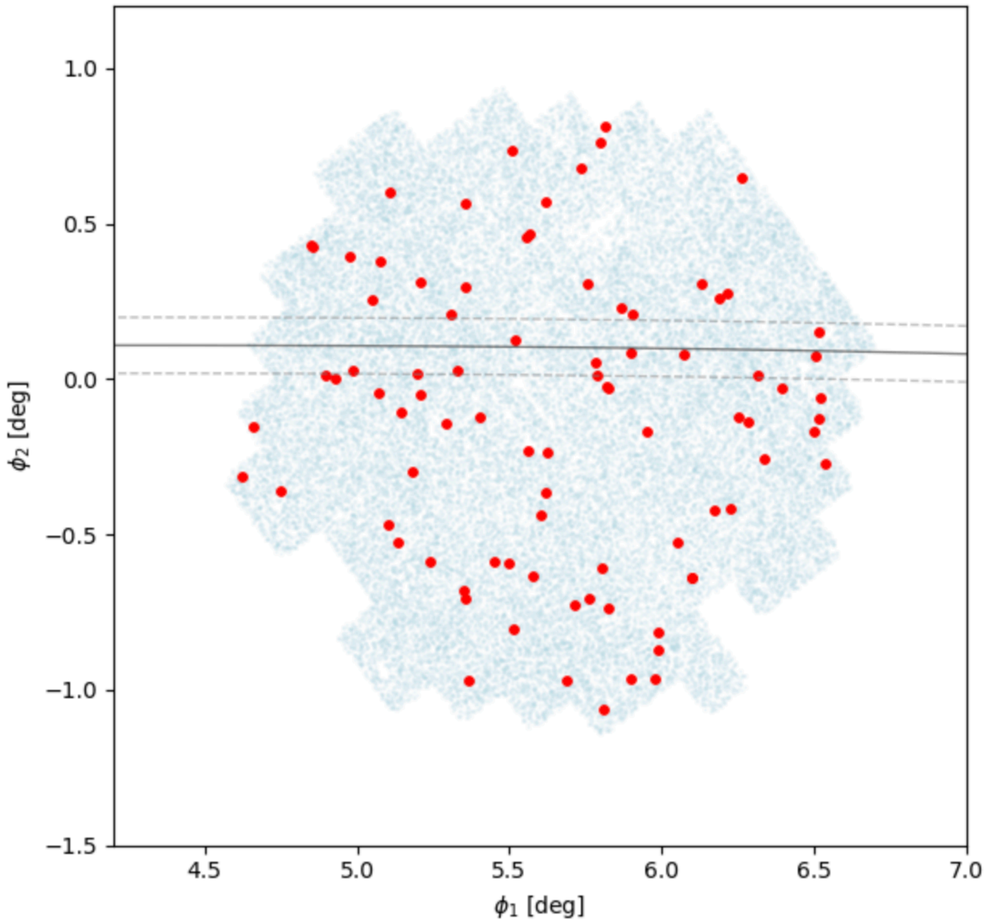


Confirmed membership of 5 stars beyond 5 rh, **distant candidates generally do not align with central ellipticity**

High-resolution MIKE spectra (R~22,000) of these two stars
—> Are the detailed abundances consistent with the central population?
(Test for **in-situ formation,** or **ex-situ origin via merger**)

Result 3: Probing the Jet stream's morphology with a pure sample of members —> Ha Do (UChicago)

Stars with Gaia proper motions consistent w/ Jet



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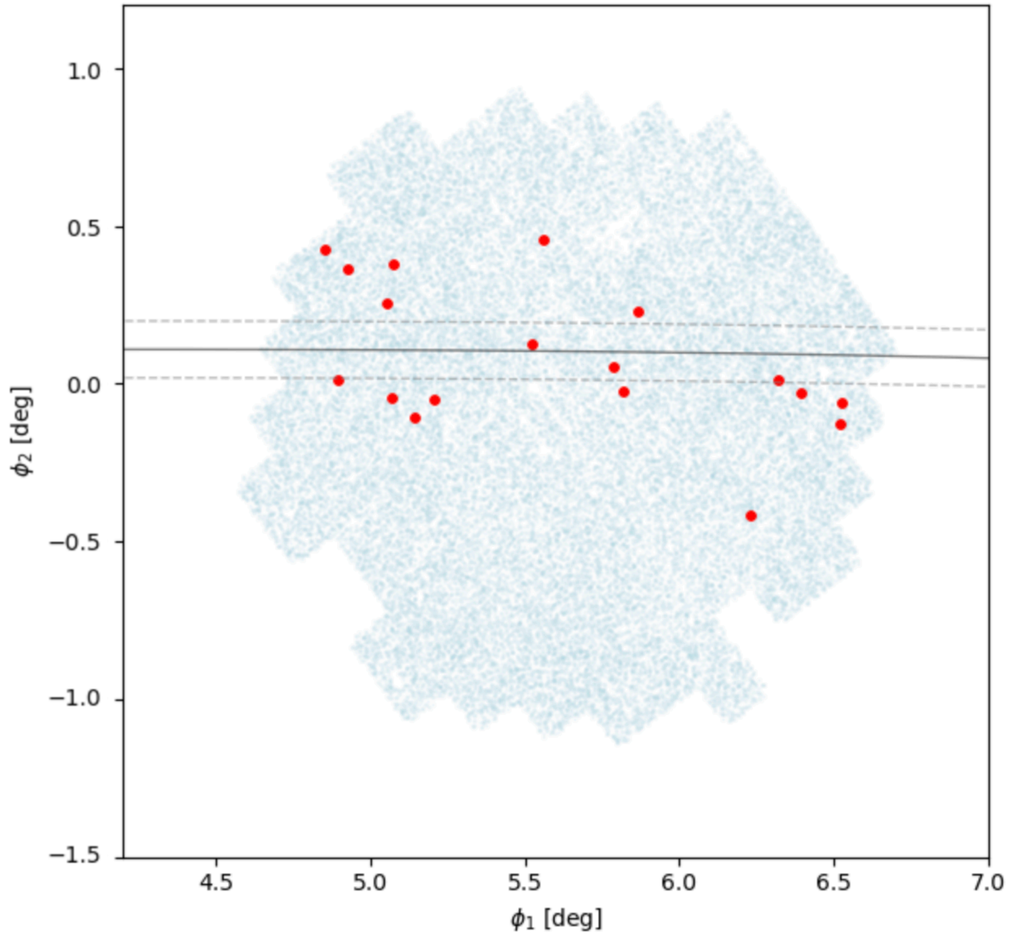
Stars with proper motions +
MAGIC metallicities consistent w/ Jet



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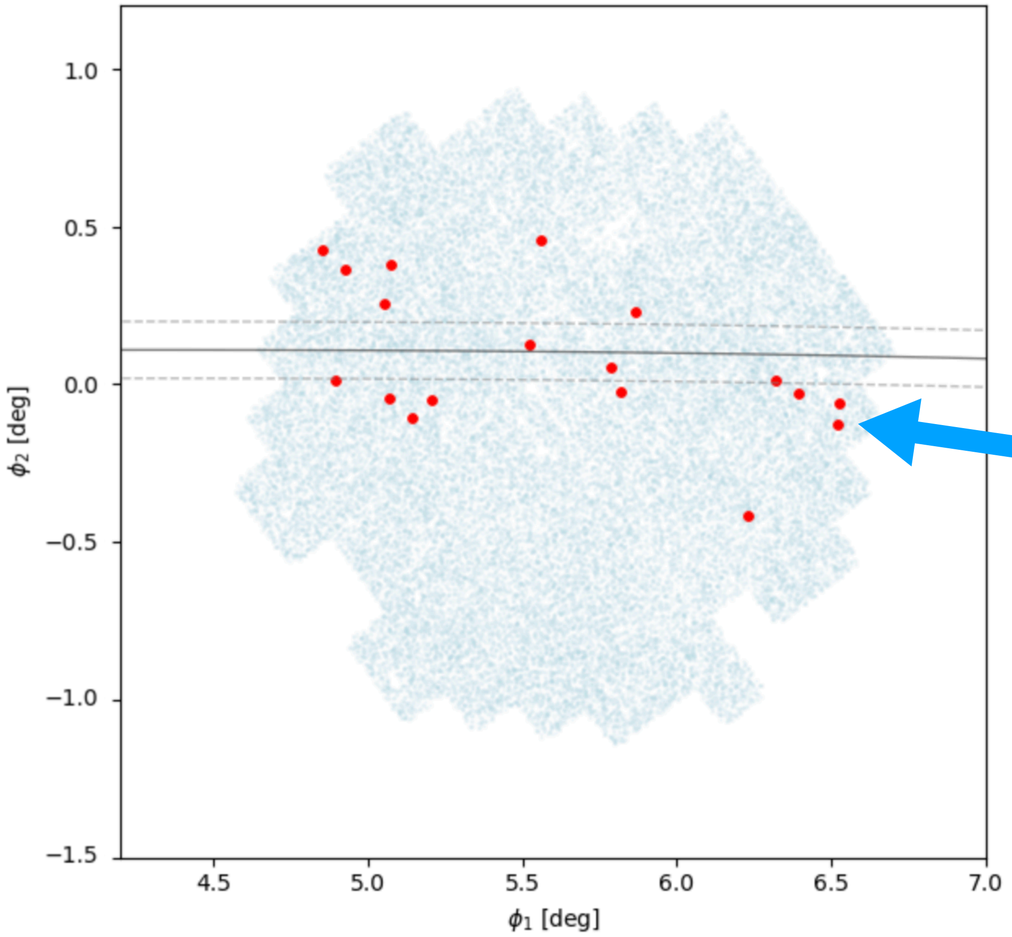
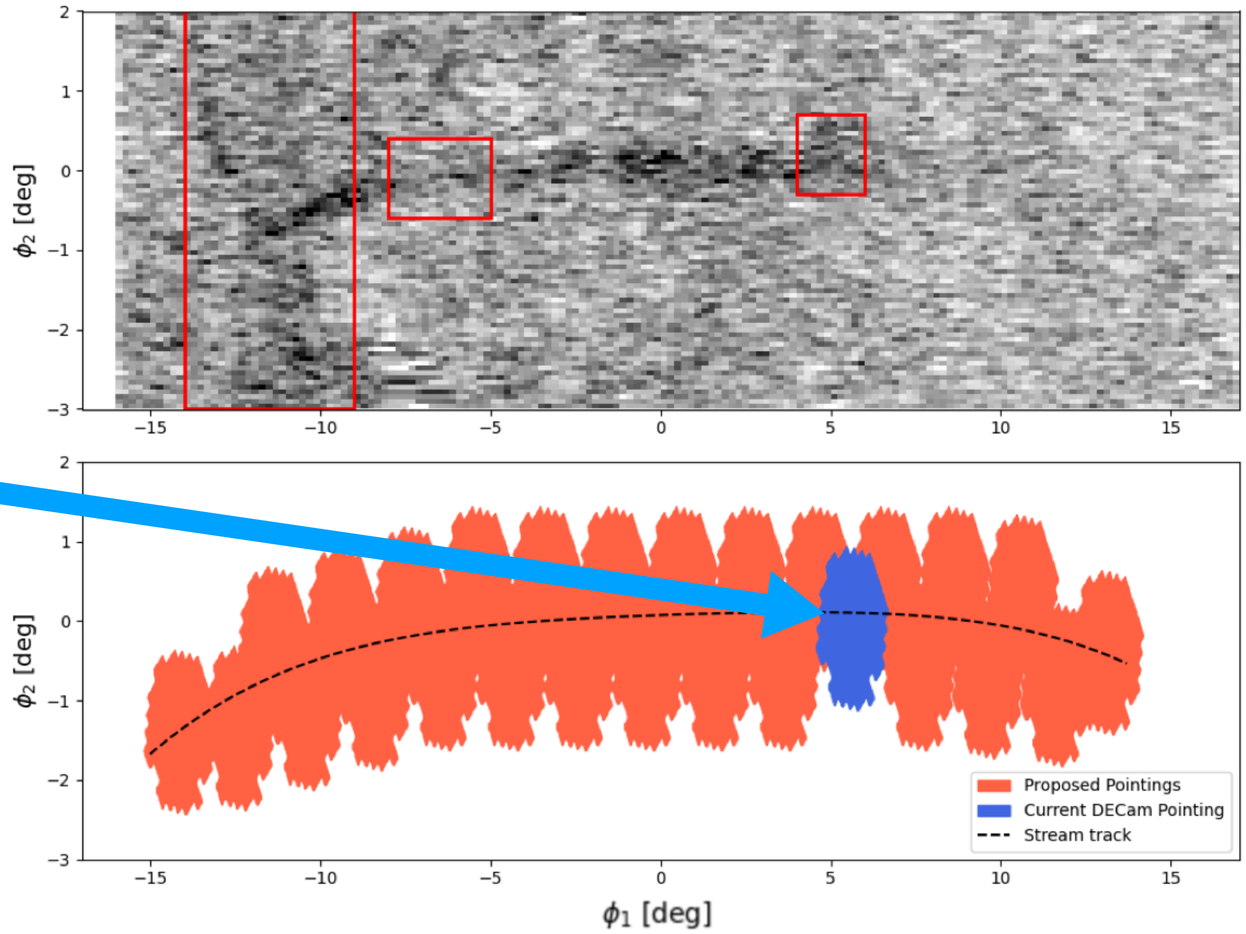
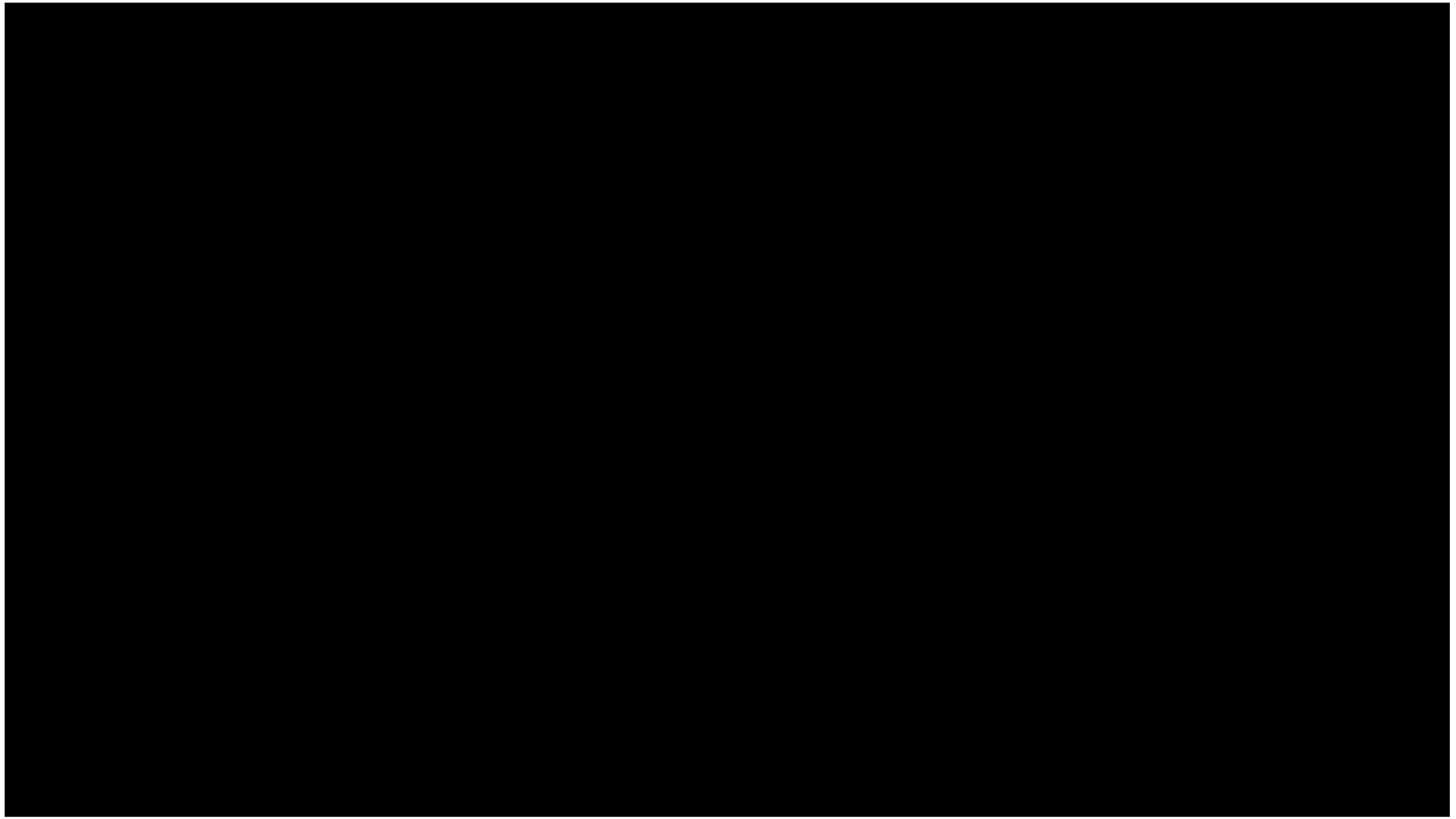


Proposed future data (2025A)



When coupled with all-sky *Gaia* proper motions, MAGIC can potentially probe low metallicity substructure *into the very outer Milky Way halo (>50 kpc)*



Credit: Gaia/ESA

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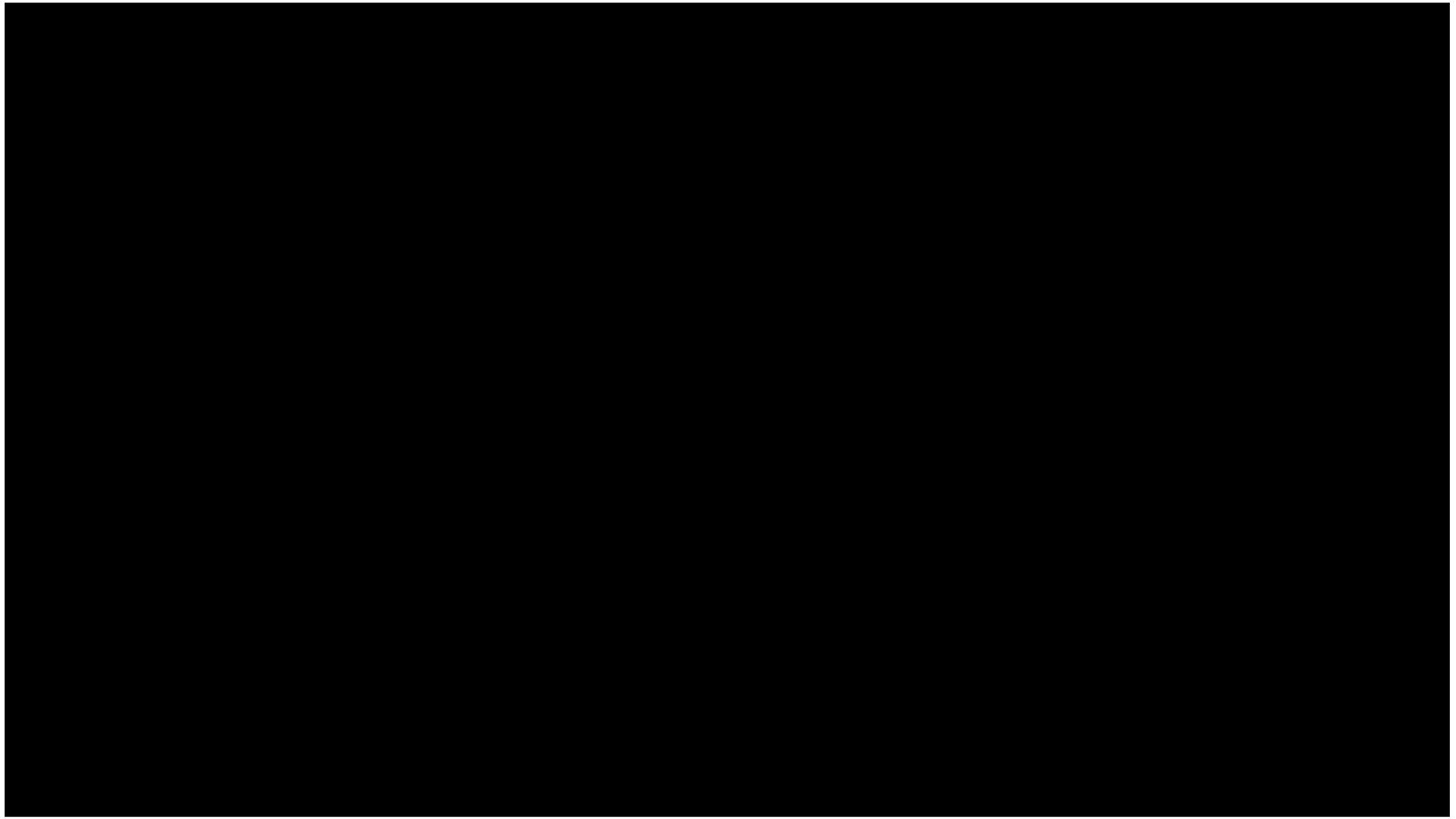

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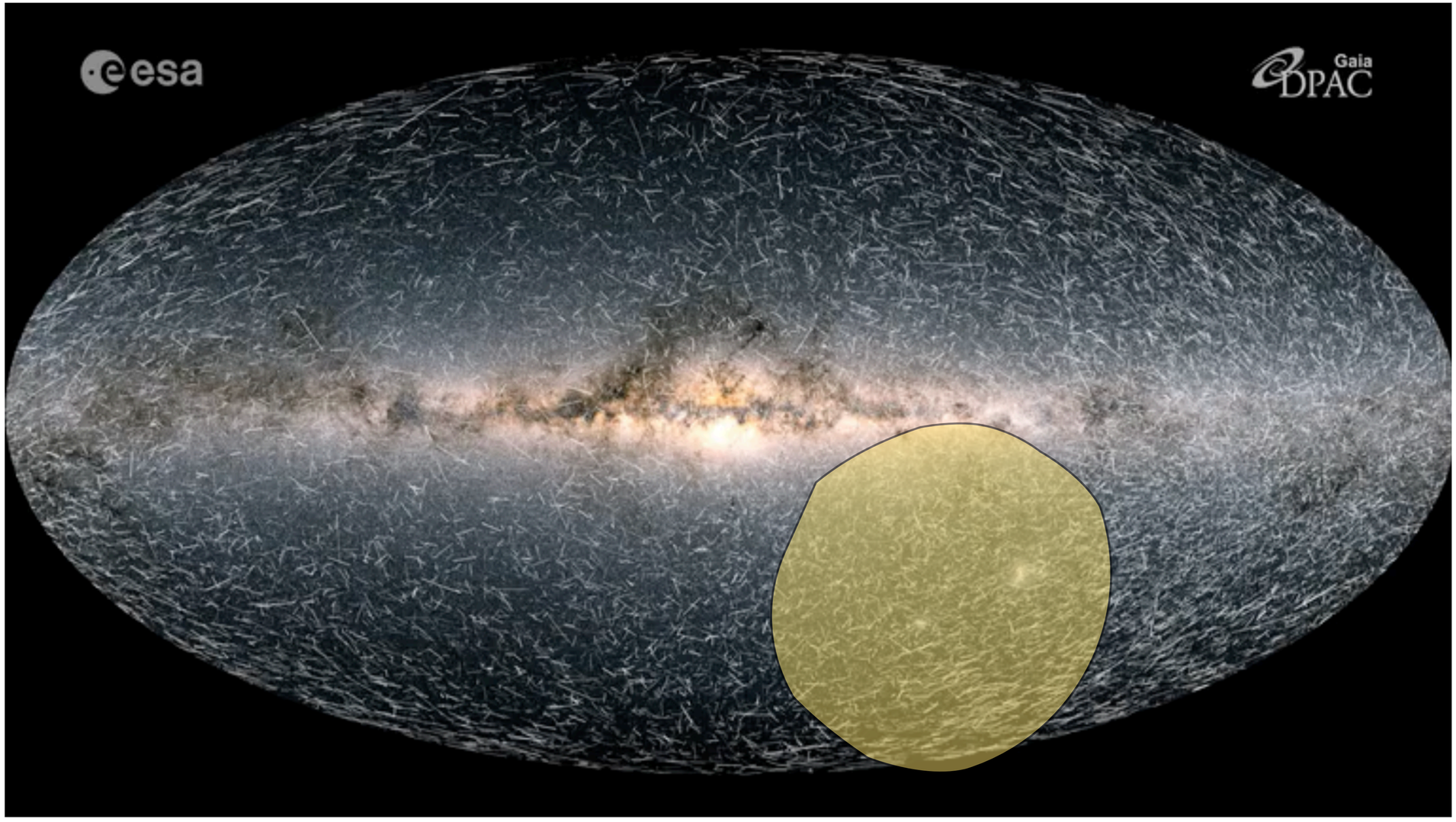

Credit: Gaia/ESA

Main takeaways:

- The DECam MAGIC Survey (**M**apping the **A**ncient **G**alaxy **i**n **C**aHK) will image a quarter of the southern sky (~5300 sq. deg.) with a CaHK filter from **Fall 2023 — Spring 2026**, providing photometric metallicities for red giant stars approaching the *Gaia* proper motion limit

- **Early science results** span several topics and demonstrate the power of MAGIC photometry to study low metallicity, faint stellar populations, including:

  - **(1)—** Spatially unbiased study of >3000 stellar metallicities in the Sculptor dwarf galaxy **(see Fabricìa Barbosa's poster)**

  - **(2)—** Uncovering a faint, distant member in the Reticulum II UFD along its tidal debris track, and a population of distant Sextans members out to ~15 half-light radii

  - **(3)—** Recovering members of the Jet stellar stream, to characterize its morphology

- **Future Investigations** will scale these results across the full MAGIC footprint, in addition to pursuing a number of other science cases targeting the low metallicity regime of the Milky Way

Appendix