How low can we go?

Ursa Major III/UNIONS 1, the faintest known satellite of the Milky Way

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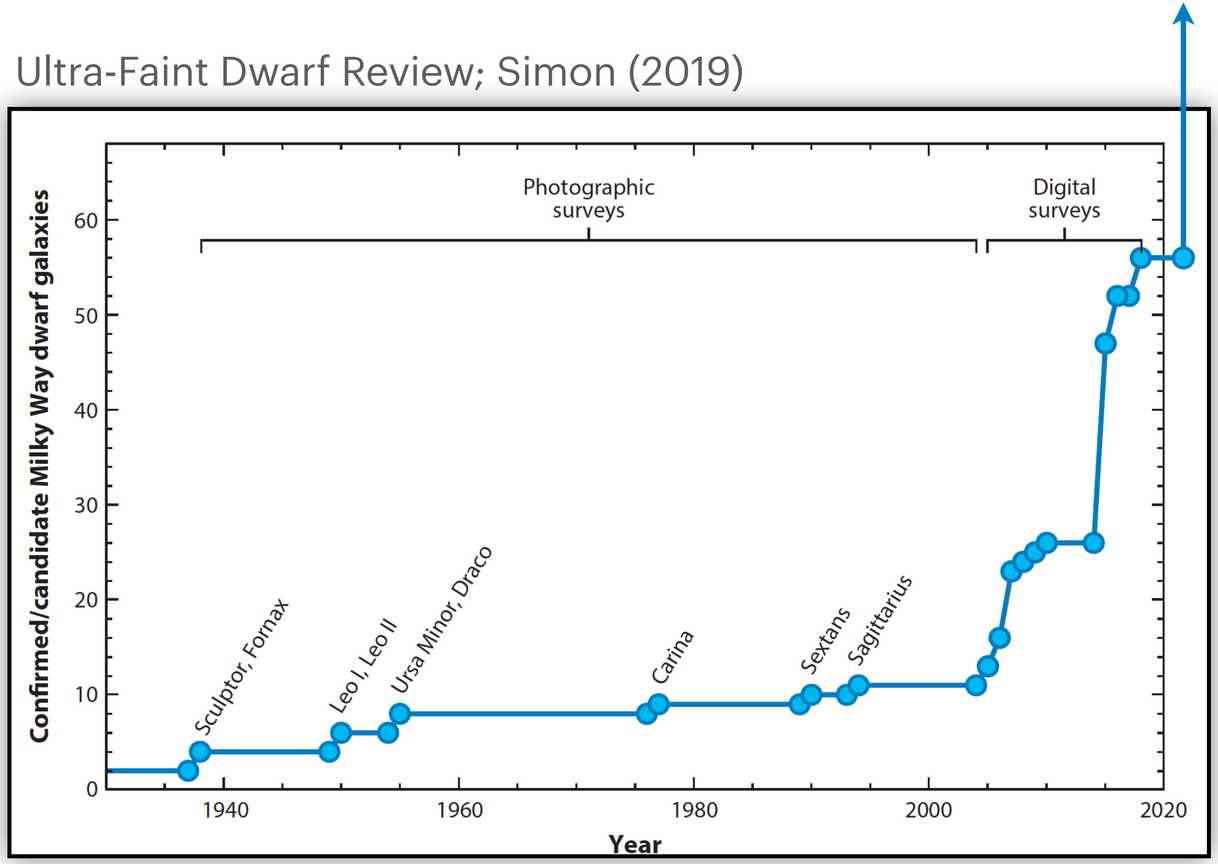
Dwarf Galaxies, Star Clusters,
& Streams in LSST Era

In collaboration with: **Will Cerny, Marla Geha, Ting Li, Raphael Errani**, as well as Alan McConnachie, Jaclyn Jensen, Christian Hayes, Julio Navarro, Stephen Gwyn, and the UNIONS Team

Dwarf Galaxy Discovery

A Brief History

Ultra-Faint Dwarf Review; Simon (2019)



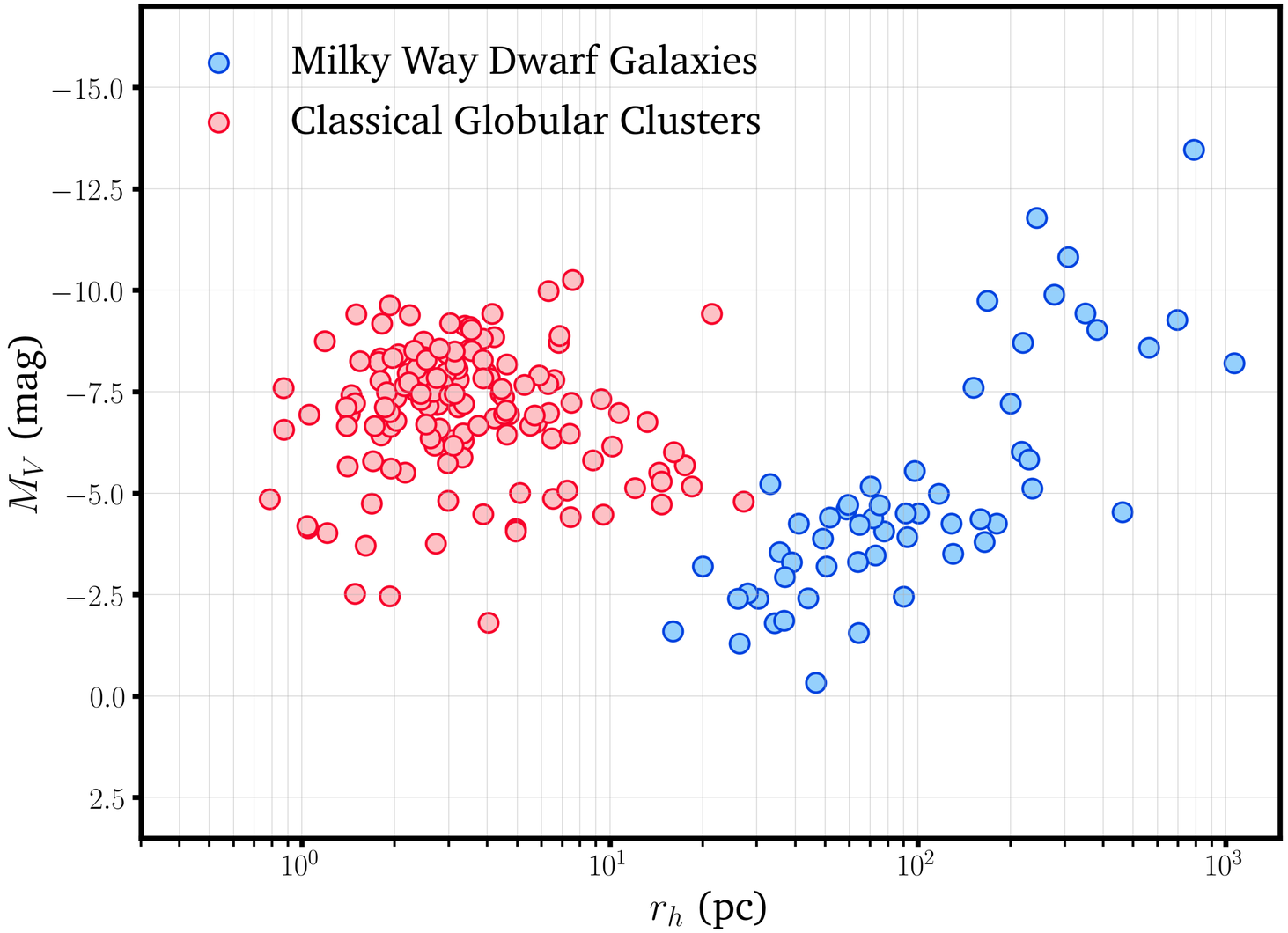
Digital Surveys:
SDSS, PAndAS, Pan-STARRS, DES, DELVE, the DESI Legacy Imaging Survey, HSC-SSP, KiDS, and now UNIONS have each contributed to this growing catalogue of faint systems

13 new LG dwarf galaxies discovered since I started grad school 3 years ago

Martínez-Delgado+ (2022), Collins+ (2022), Cerny+ (2022, 2023), Sand+ (2022), Smith+ (2023, 2024), McQuinn+ (2023, 2024), Homma+ (2024), Gatto+ (2024)

Dwarf Galaxies vs. Globular Clusters

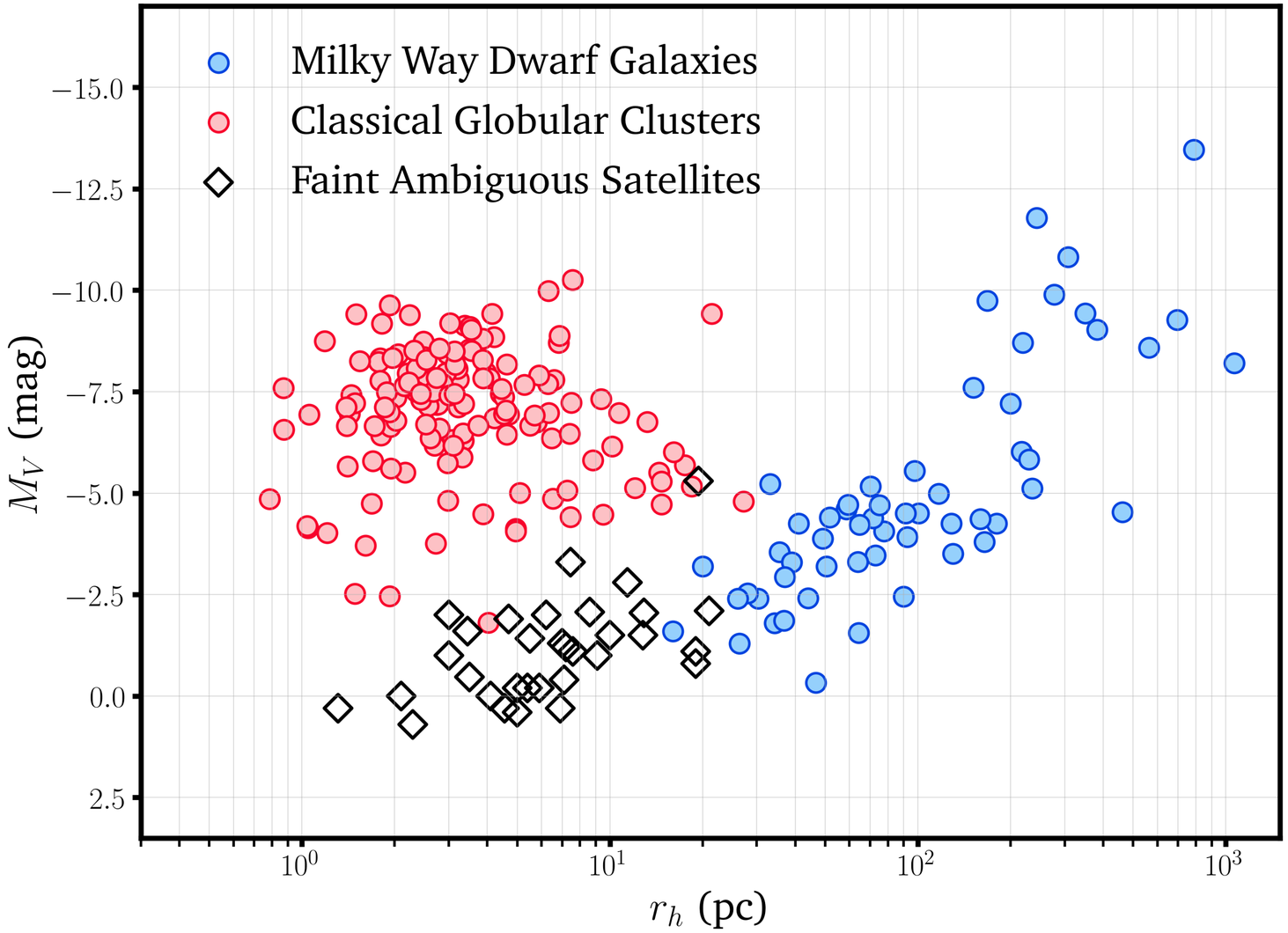
A question of dynamics



- Globular clusters (Harris 2010)
  - Dyn. M/L ratios ~ 1 – 4
  - Dominated by matter
- Dwarf galaxies (McConnachie 2012)
  - Dyn. M/L ratios > ~100s — 1000s
  - Not explainable by baryons alone
    - Dominated by dark matter?
- Well resolved velocity dispersions are the key observable, additional evidence from metallicity spreads (Willman & Strader 2012)

Dwarf Galaxies vs. Globular Clusters

A question of dynamics



- Faint ambiguous satellites (compiled)
  - ~30 systems lacking strong dynamical evidence either way
  - For most, no deep imaging or spectroscopy
  - Typically assumed to be a star cluster unless demonstrated to be a dwarf
- Presumably, each will prove to be either a star cluster or a galaxy
- Incredibly hard to confirm…

UNIONS

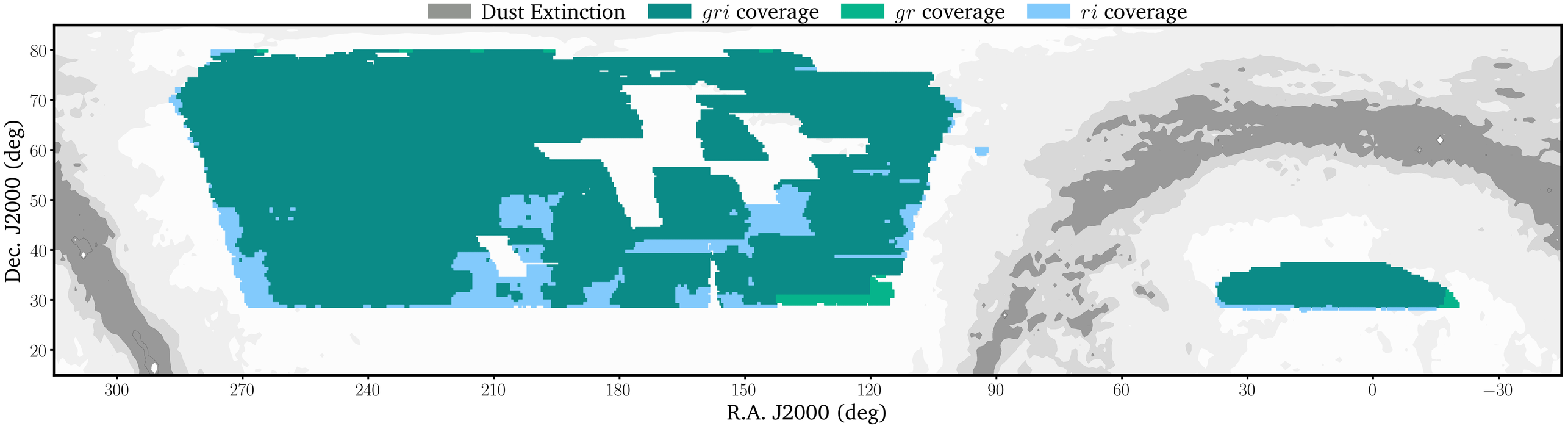
The deepest photometric survey of its scale

UNIONS The **U**ltraviolet **N**ear **I**nfrared **O**ptical **N**orthern **S**urvey

- A collaboration of four wide field imaging surveys using telescopes based in Hawai'i
  - **CFIS**: Canada-France Imaging Survey (u = 24.5, r = 24.85) *[all 5-sigma point source depths]*
  - **Pan-STARRS**: Panoramic Survey Telescope And Rapid Response System (i = 24.3, z= 24.1)
  - **WISHES**: Wide Imaging with Subaru HSC of the Euclid Sky (z = 24.1)
  - **WHIGS**: The Waterloo-Hawaii-IfA G-band Survey (g = 25.2)
- Mapping ~4800 square degrees of the extragalactic sky (dec>30)
- Supporting Euclid (photometric redshifts) in the North
- Will benefit from Euclid star/galaxy separation
- Roughly the depth of LSST DR1!

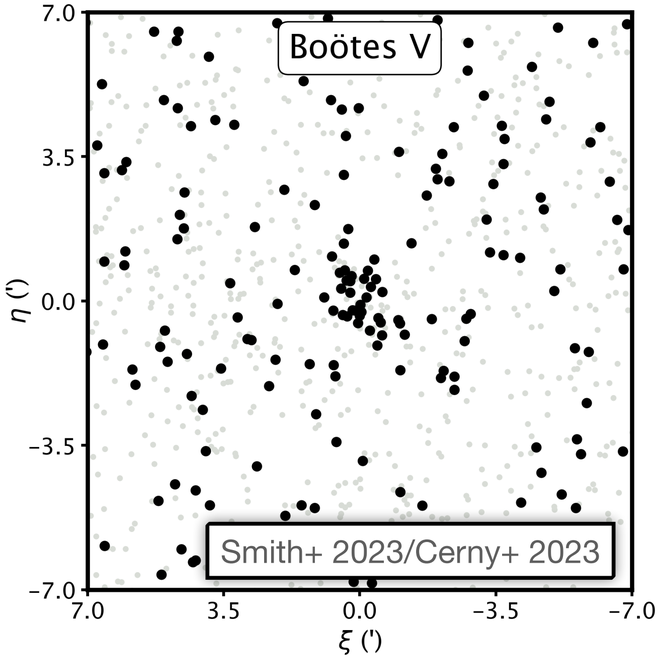
UNIONS

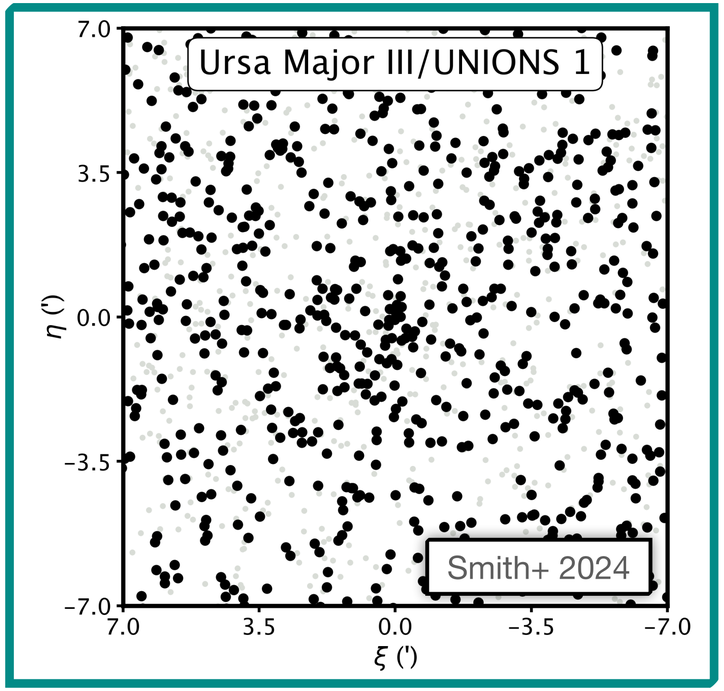
Current *gri* coverage

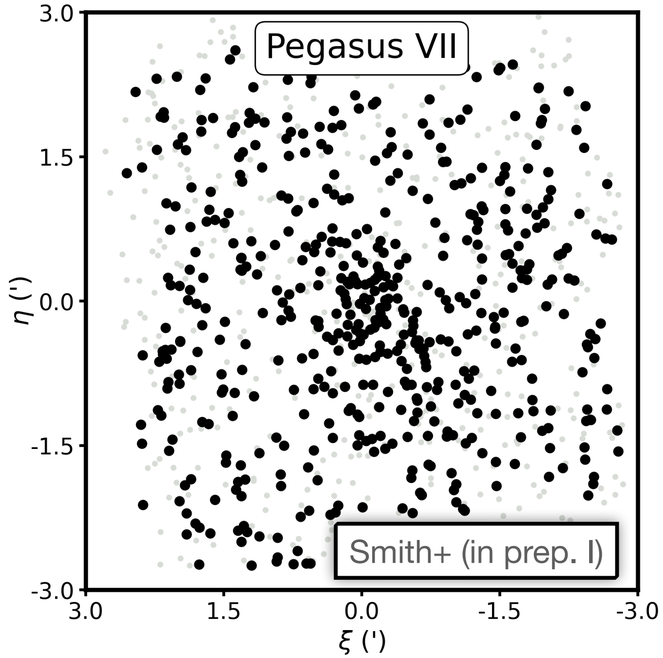


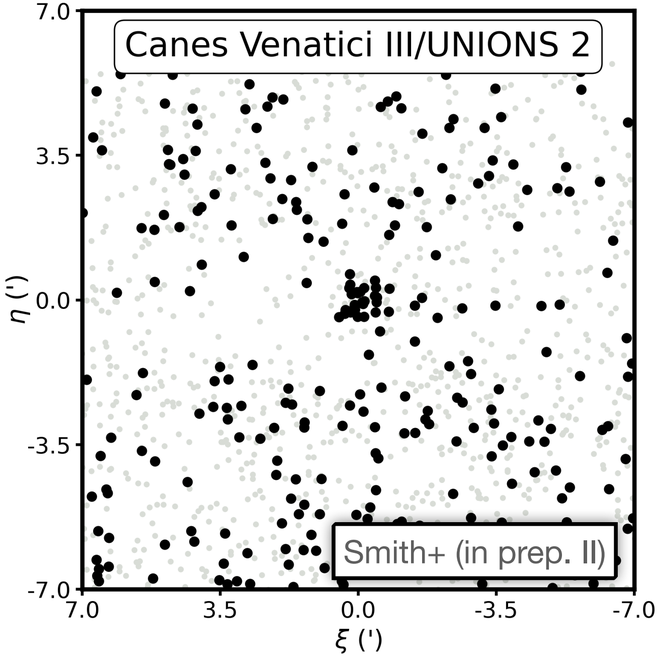
- Stand-alone science (outside of Euclid) resulting from outstanding seeing (IQ ~ 0.7” in *r*) and depth
- Major contributions in Galaxy Evolution, Weak Lensing, Data Analysis/Techniques, etc.
- And… Galactic Archaeology

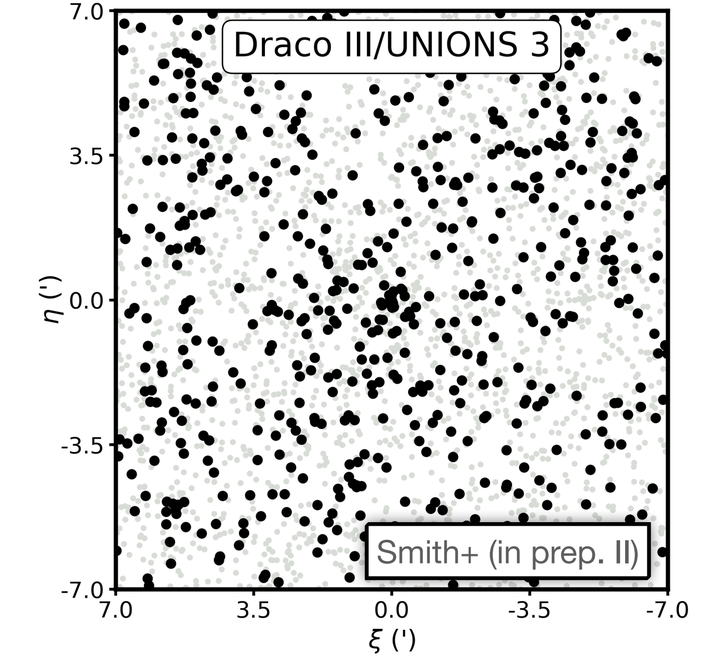
- Testbed for the discovery space of LSST?
- How small a galaxy/satellite can there be?
- What will we learn from extreme systems?

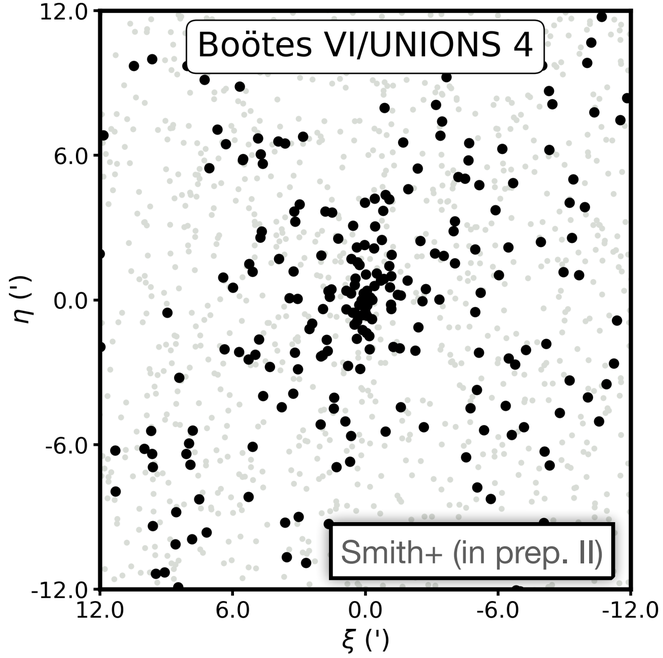

Boötes V
Smith+ 2023/Cerny+ 2023
η (')
ξ (')


Ursa Major III/UNIONS 1
Smith+ 2024
η (')
ξ (')


Pegasus VII
Smith+ (in prep. I)
η (')
ξ (')


Canes Venatici III/UNIONS 2
Smith+ (in prep. II)
η (')
ξ (')


Draco III/UNIONS 3
Smith+ (in prep. II)
η (')
ξ (')

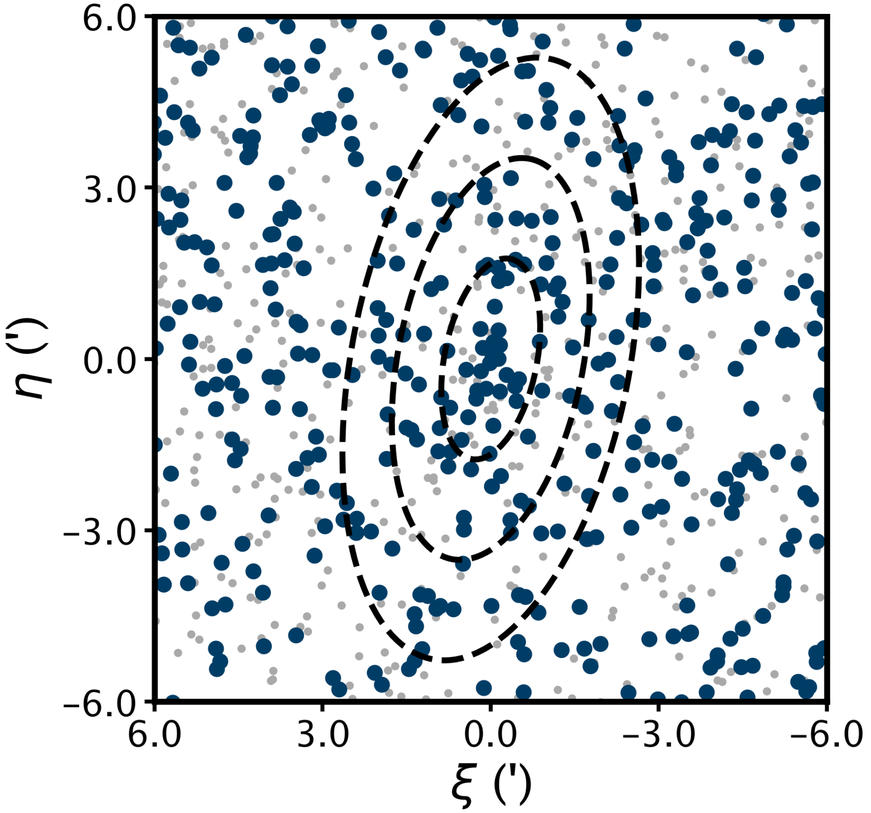

Boötes VI/UNIONS 4
Smith+ (in prep. II)
η (')
ξ (')

Ursa Major III/UNIONS 1:

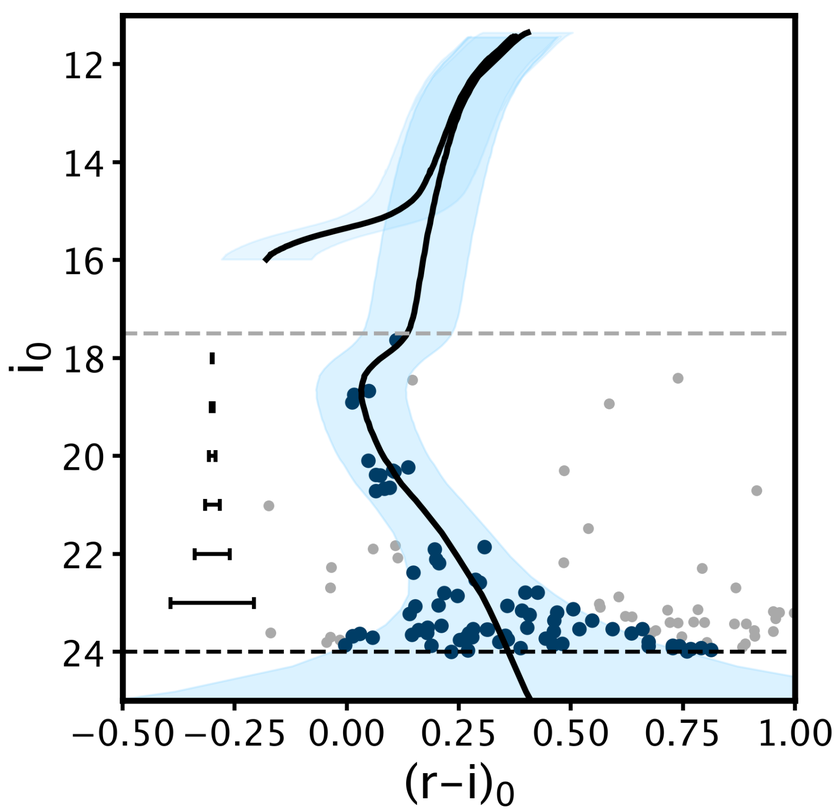
The faintest known Milky Way satellite

Half-light radius (r_h) = 3 ± 1 pc, Distance = 10 ± 1 kpc

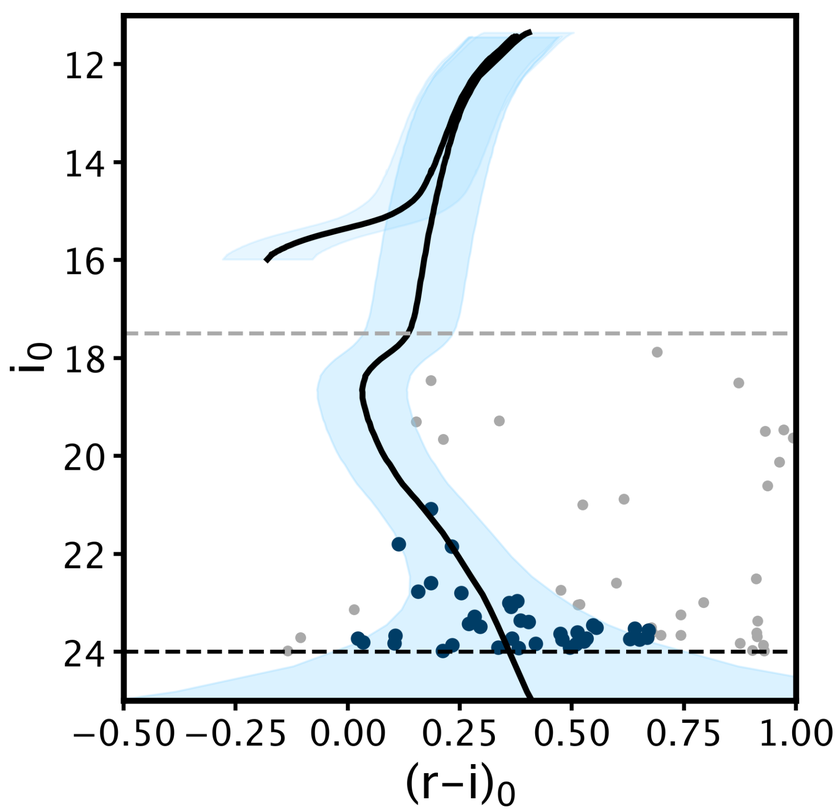
Shown: 2, 4, 6 x r_h



Within 4 x r_h

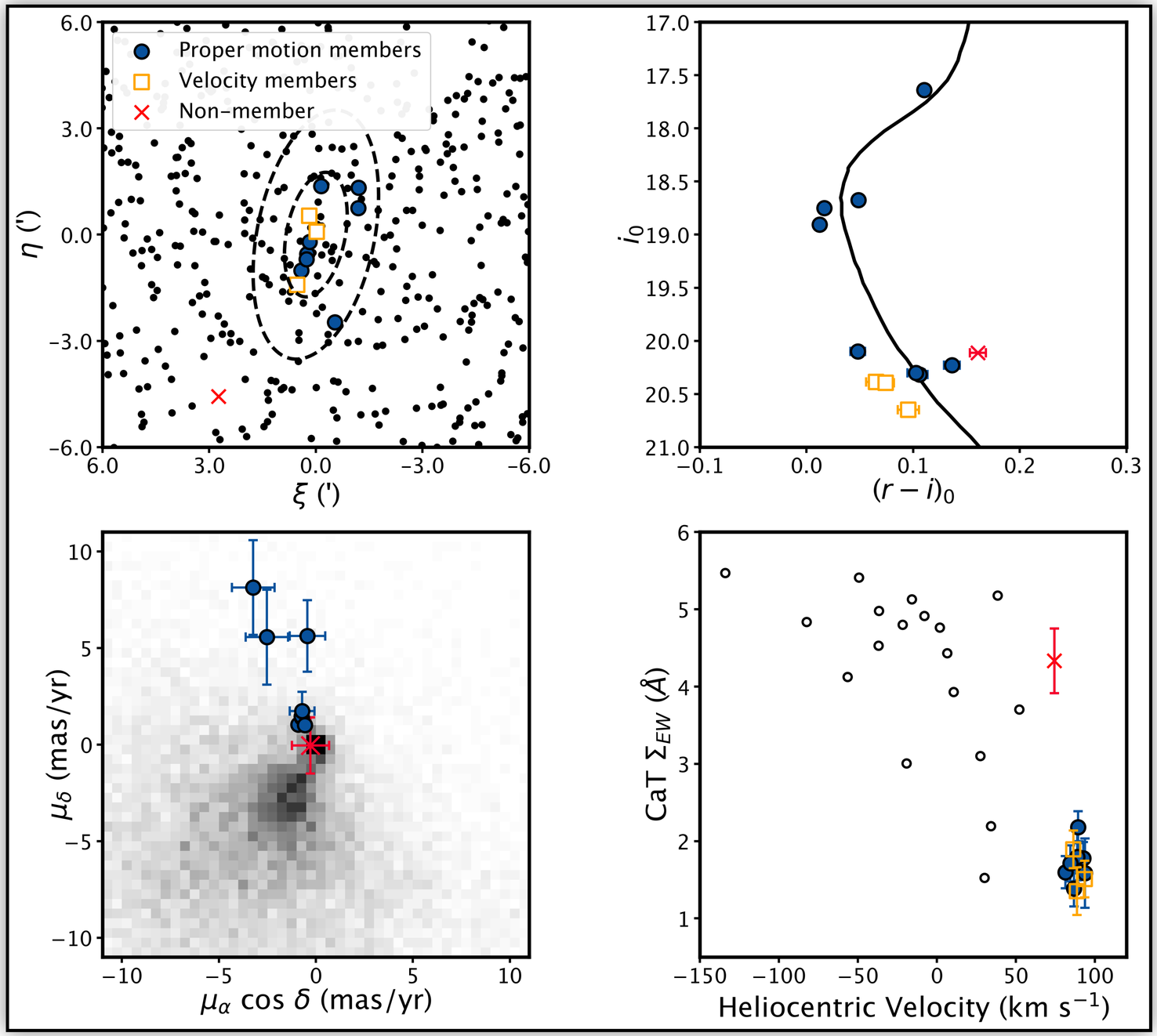


Offset field



An incredibly sparse stellar population...

Gaia proper motions, Keck/DEIMOS velocities —> stars are co-moving (McConnachie & Venn 20a,b; Jensen+ 24)



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Total stellar mass is estimated from:

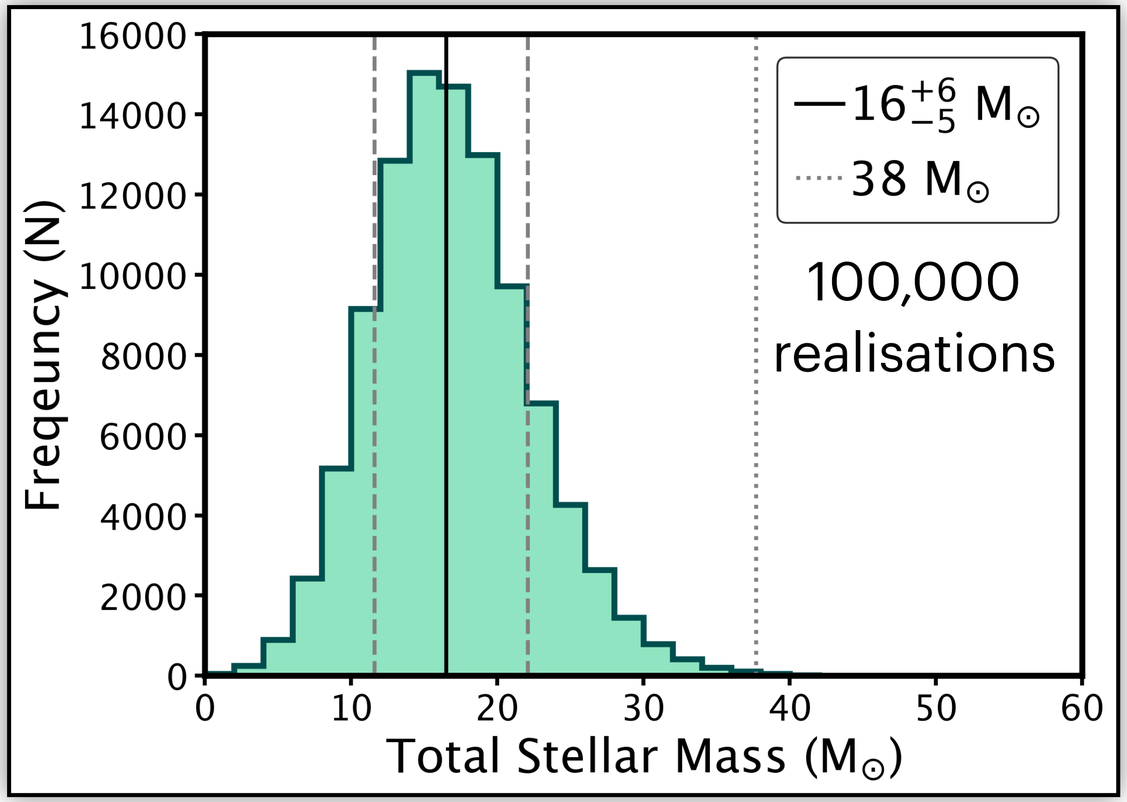
- Best-fit isochrone (12 Gyr, [Fe/H] = -2.2)
- Assumed IMF (Kroupa)
- Measured distance (10 ± 1 kpc)
- N stars at *i* < 23.5 mag (21 ± 5.5)

$$M_* \sim 16\,M_\odot$$

$$M/L \sim 1.4\,M_\odot/L_\odot$$

$$M_V \sim +2.2\,\mathrm{mag}$$

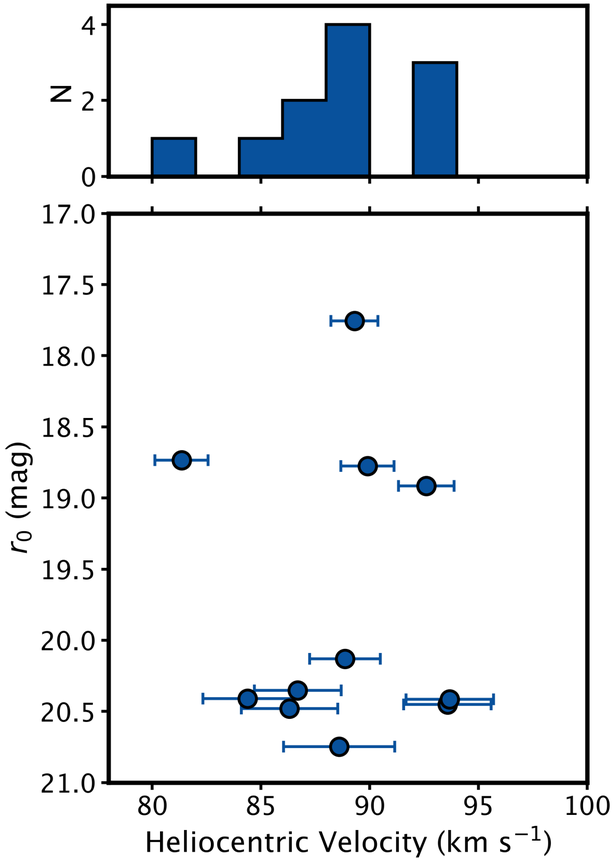
Expected velocity dispersion: 50 m/s!



Ursa Major III/UNIONS 1:

The faintest known Milky Way satellite

Intrinsic line-of-sight velocity dispersion measurement



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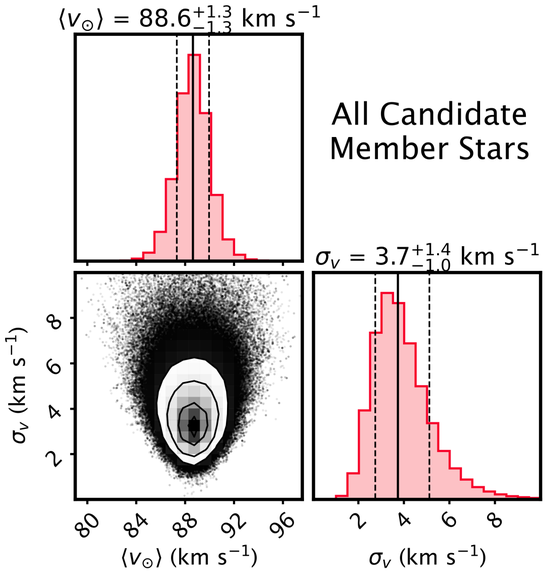

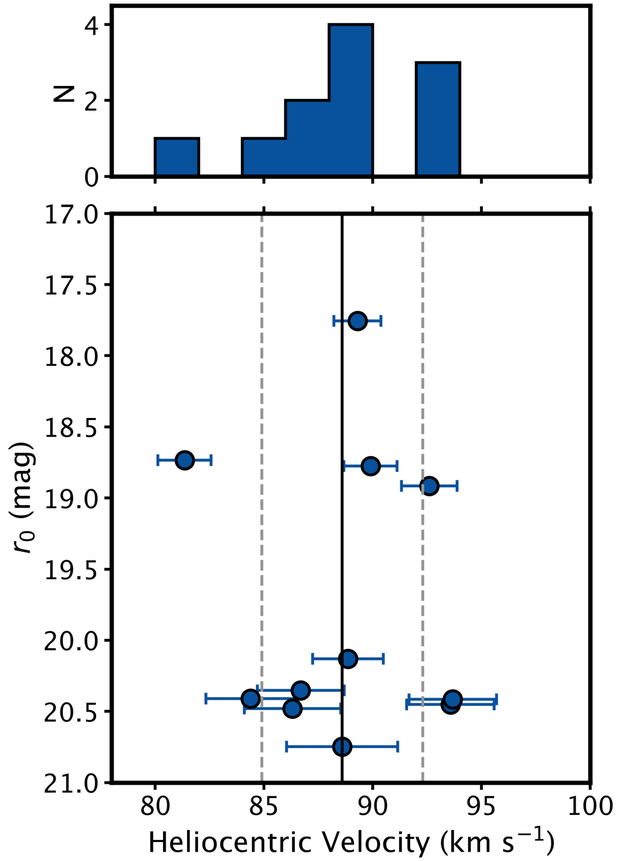

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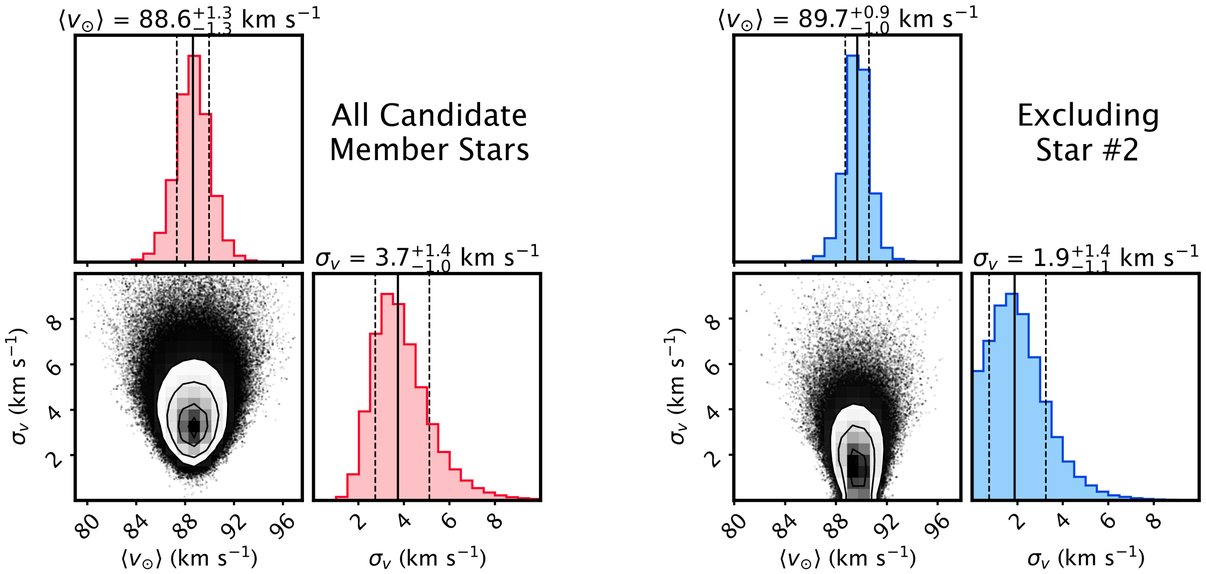

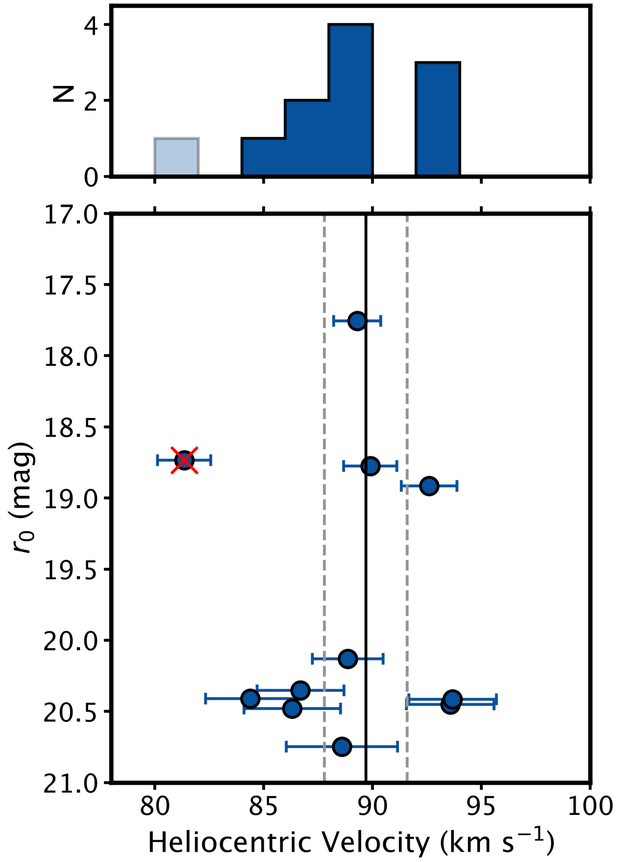

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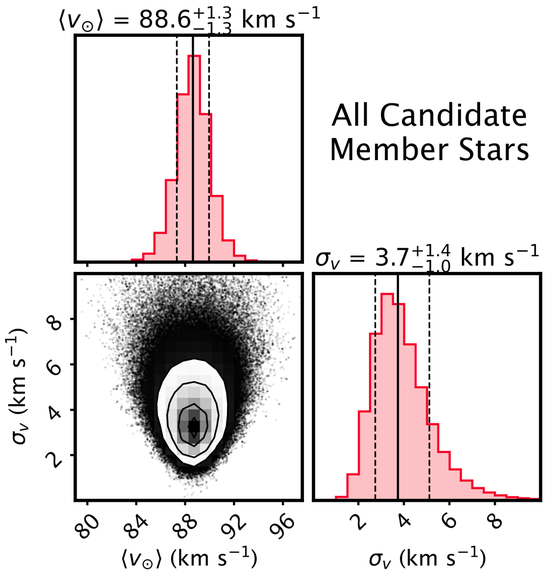
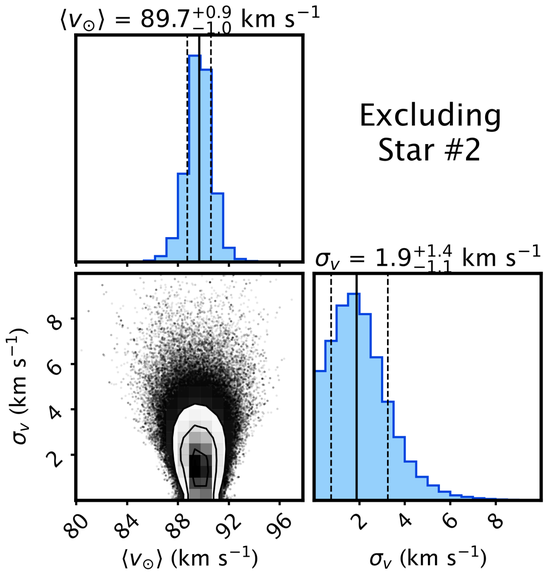
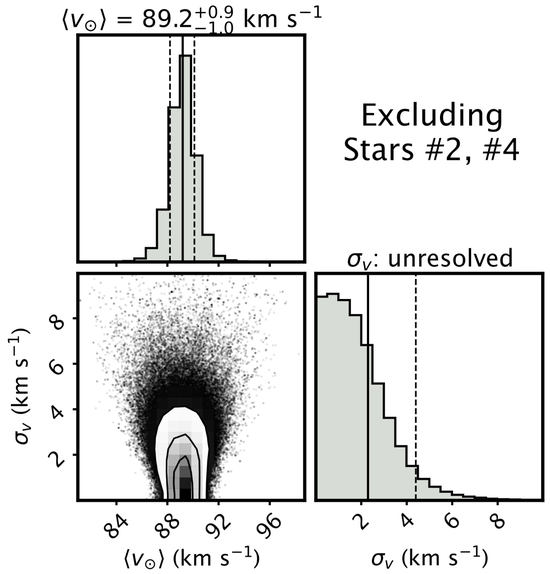
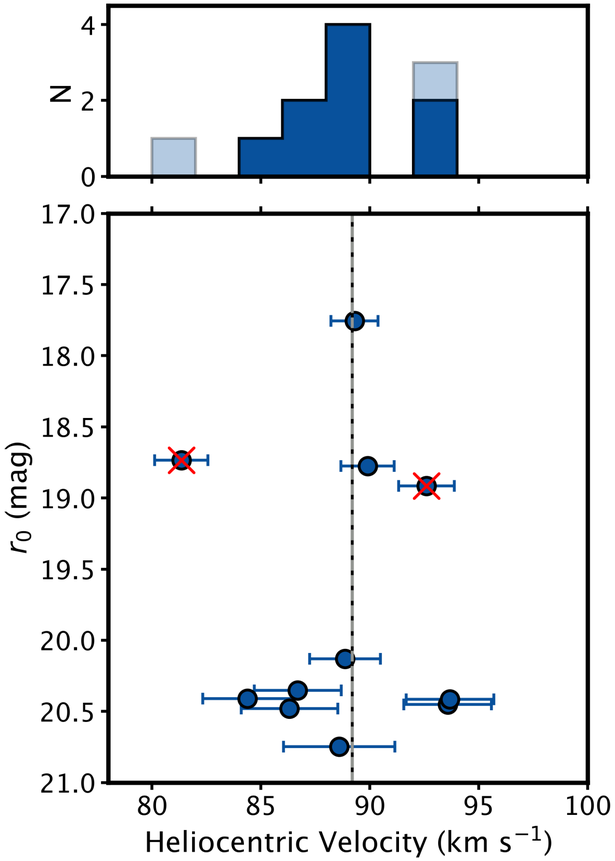
Intrinsic line-of-sight velocity dispersion measurement

Complicating factors: binary stars, dynamical equilibrium, rv uncertainties









Extremely sensitive, cannot confidently resolve dispersion: **Faint Ambiguous Satellite**

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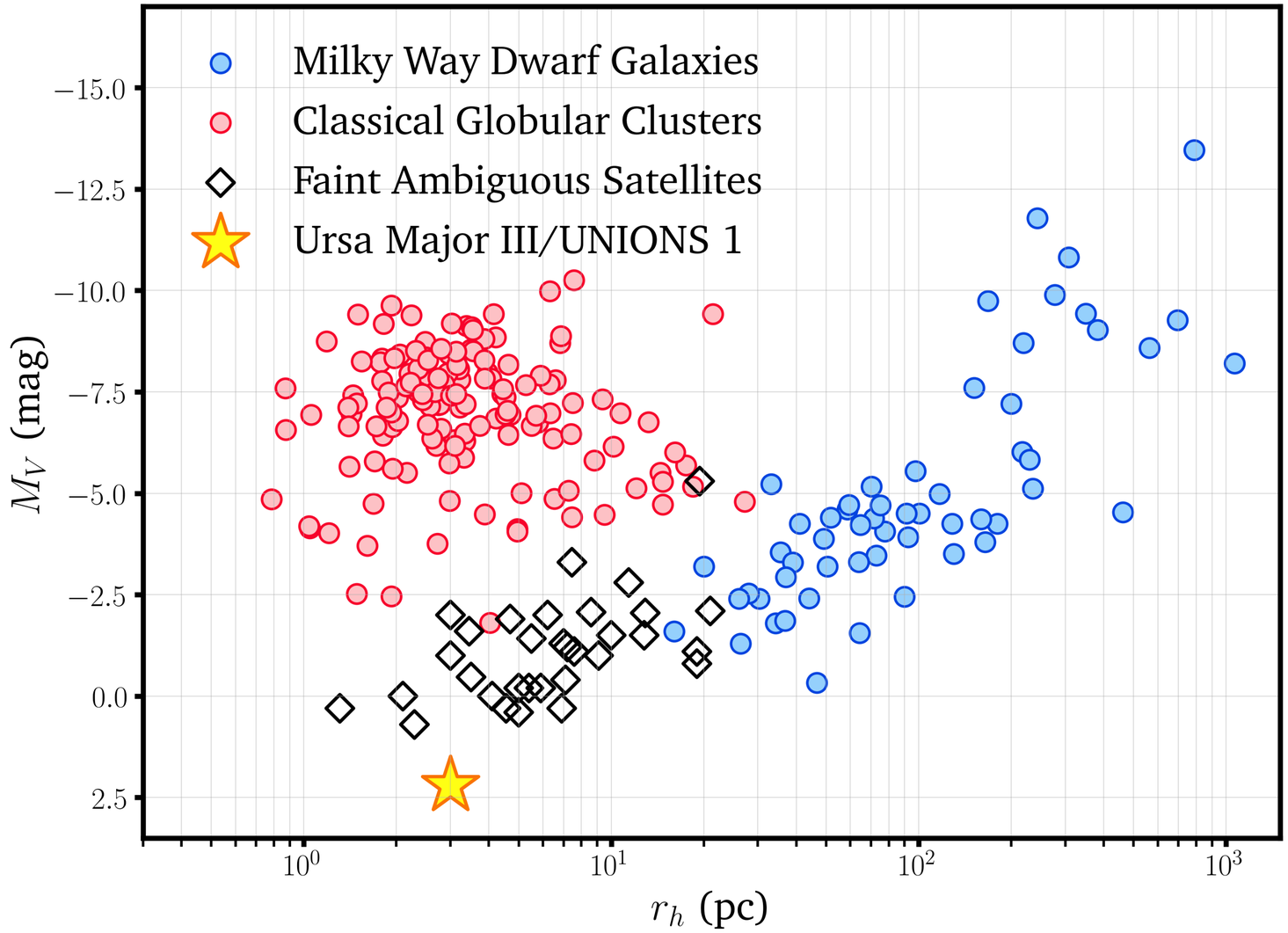

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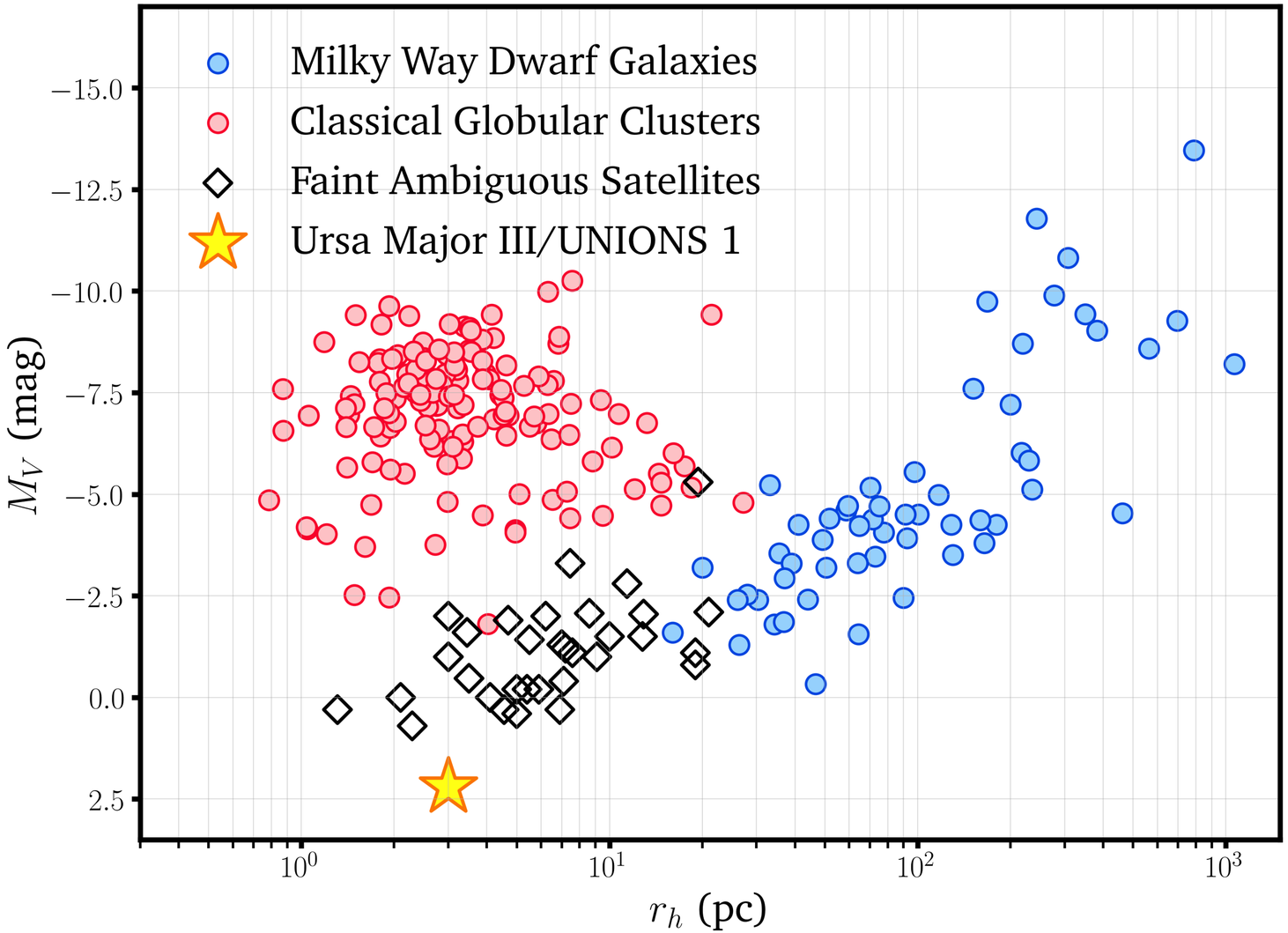
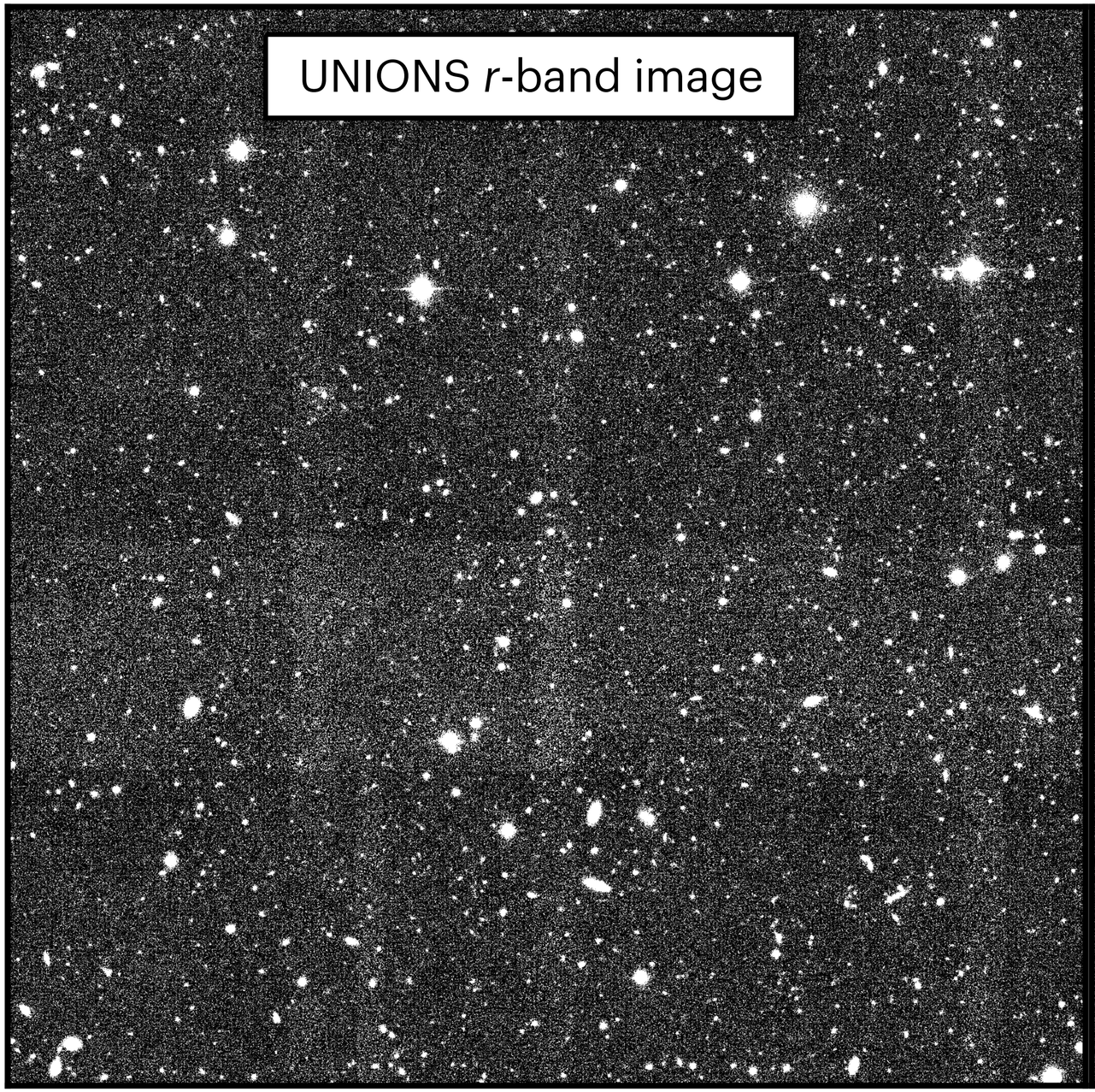
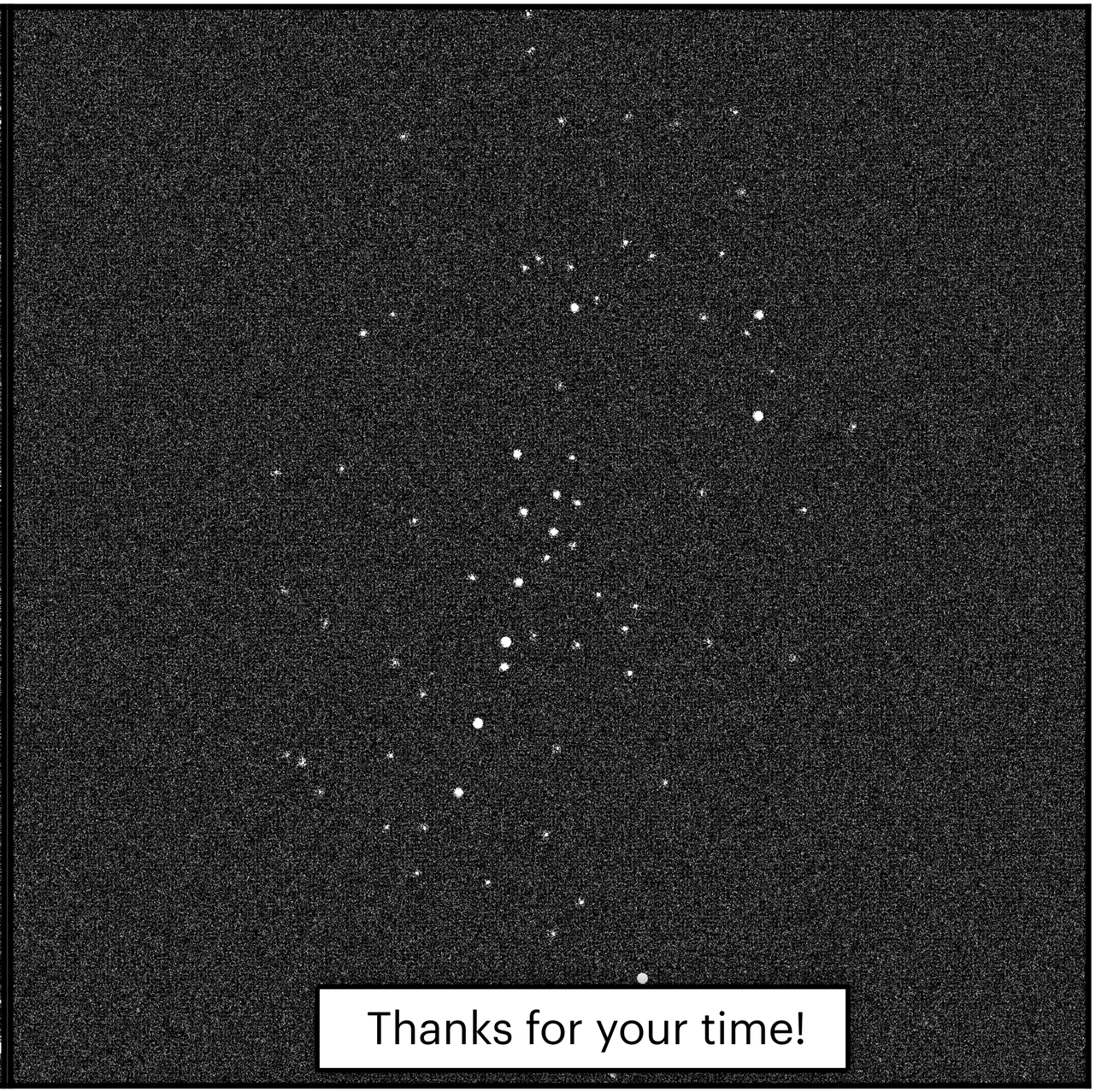


Takeaways

- Ursa Major III/UNIONS 1 is incredibly small (M_V ~ +2.2, 3 pc) and it is real!
- Current medium-res spectroscopy cannot definitively classify this object; its dark matter content remains unknown
- Each ambiguous system deserves spectroscopic follow-up to get a handle on this regime
- The depth and breadth of UNIONS is letting us do LSST DR1 science now!


UNIONS *r*-band image


Thanks for your time!