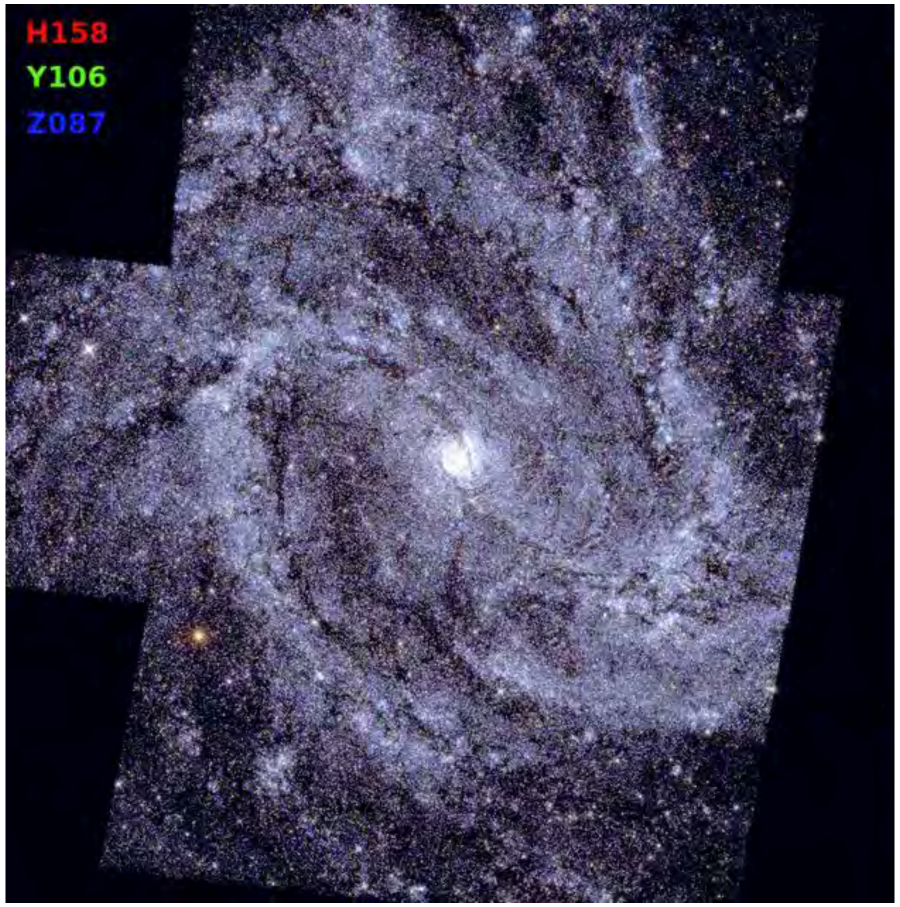
Characterizing Dwarf Satellite Galaxies with Roman



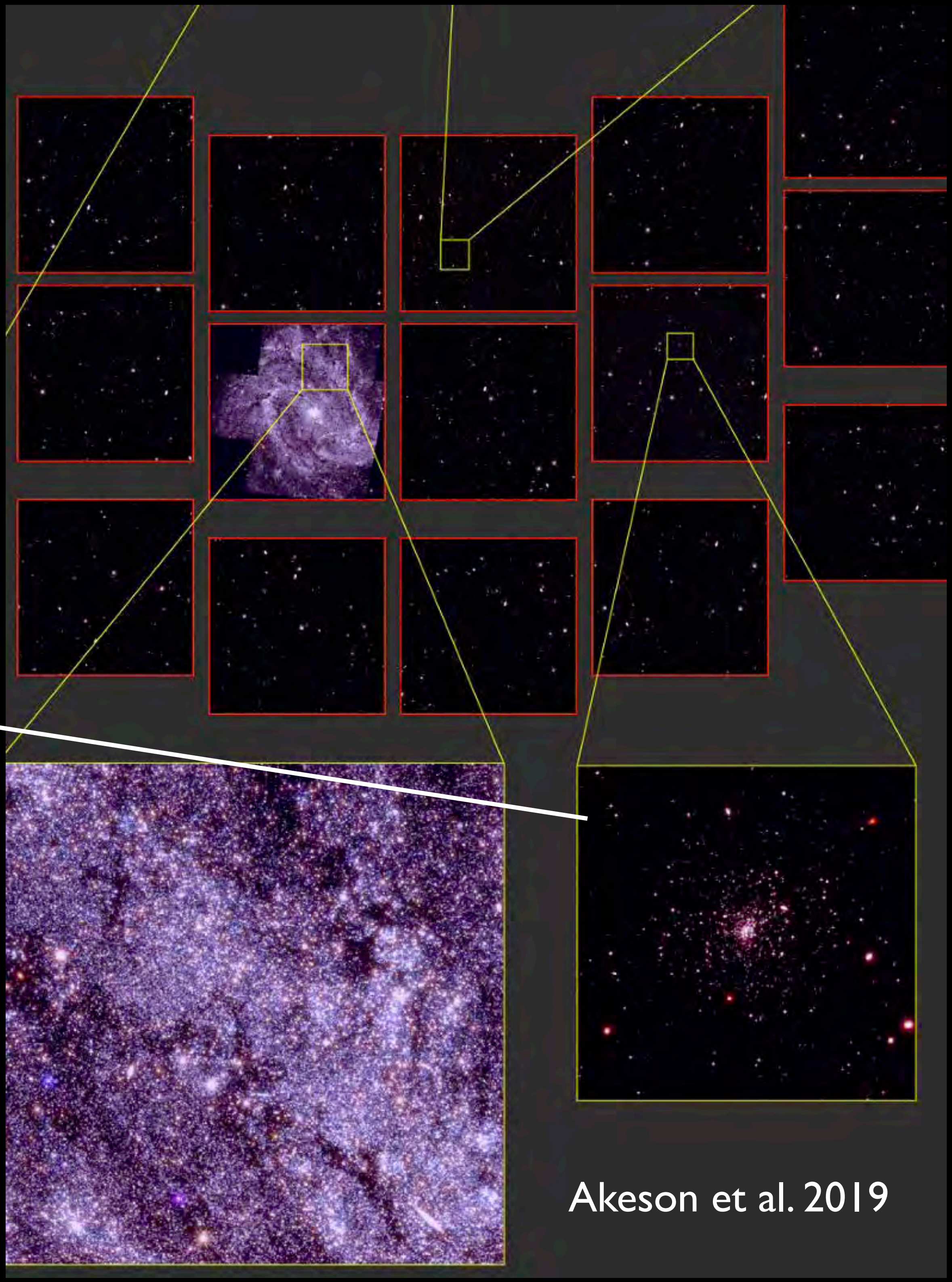
D. Sand (U of Arizona; dsand@arizona.edu)
on behalf of WINGS GO SIT
PI: B. Williams (U of Washington)

E. Bell, J. Carlin, D. Crnojevic, R. Guhathakurta, J. Hargis, B. Mutlu-Pakdil, S. Okamoto, A. Seth, M. Tanaka

A Taste of What is Possible with Roman

Partial view of simulated observation of M83 (4.5 Mpc)

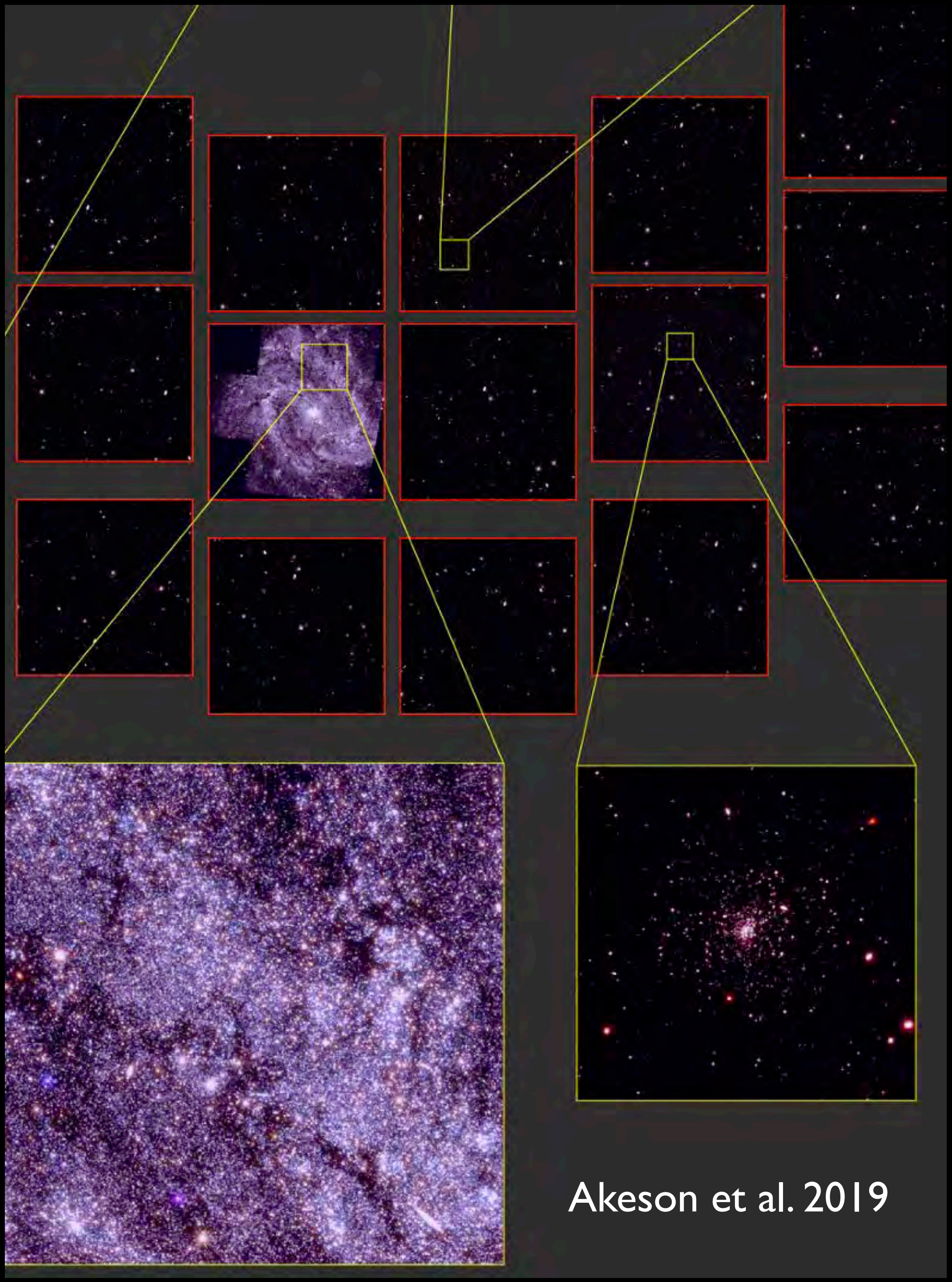
Simulation of a Draco-like dwarf (M_V=-8) at D=4.5 Mpc
H158, Y106, Z087, 1 hr exposure
With STIPS



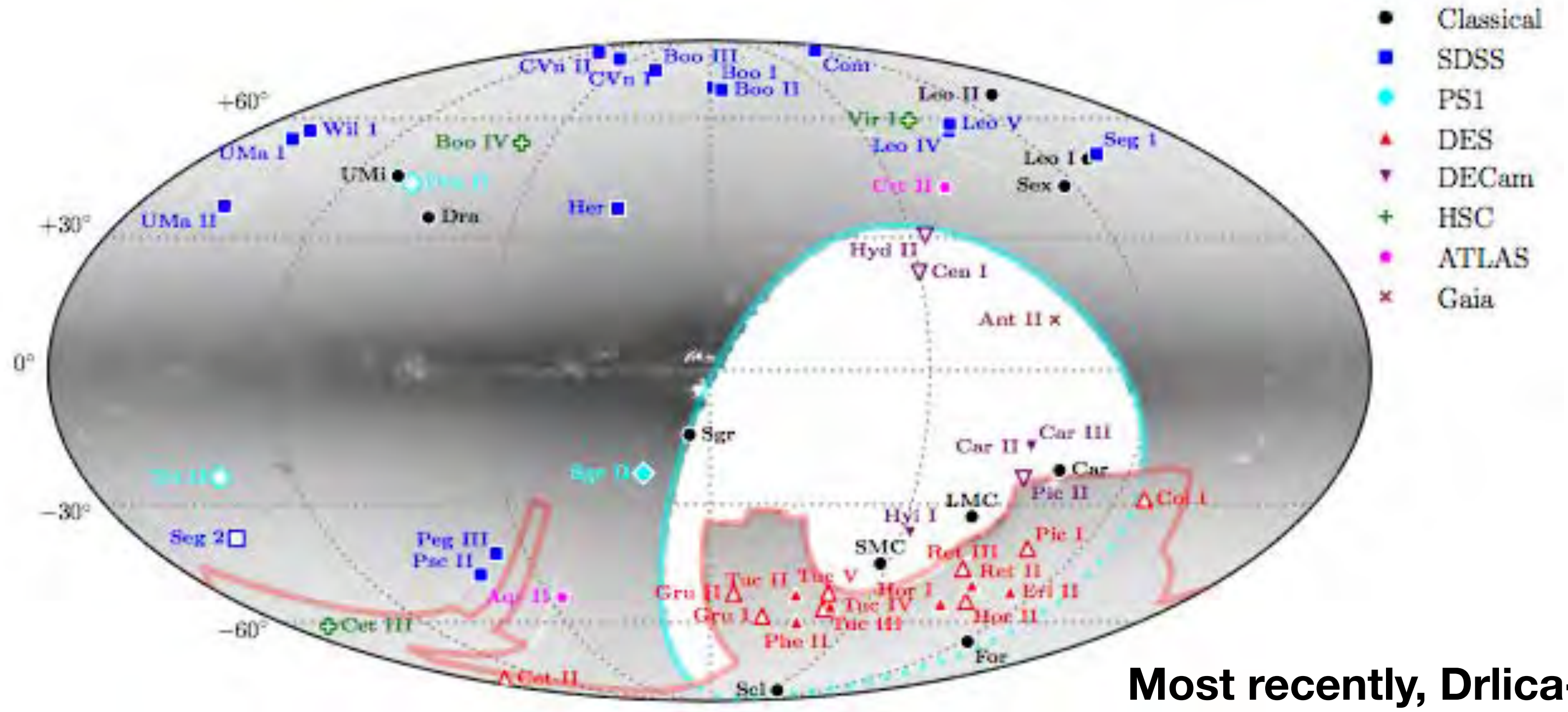
A Taste of What is Possible with Roman

At the point where we can simulate dwarfs

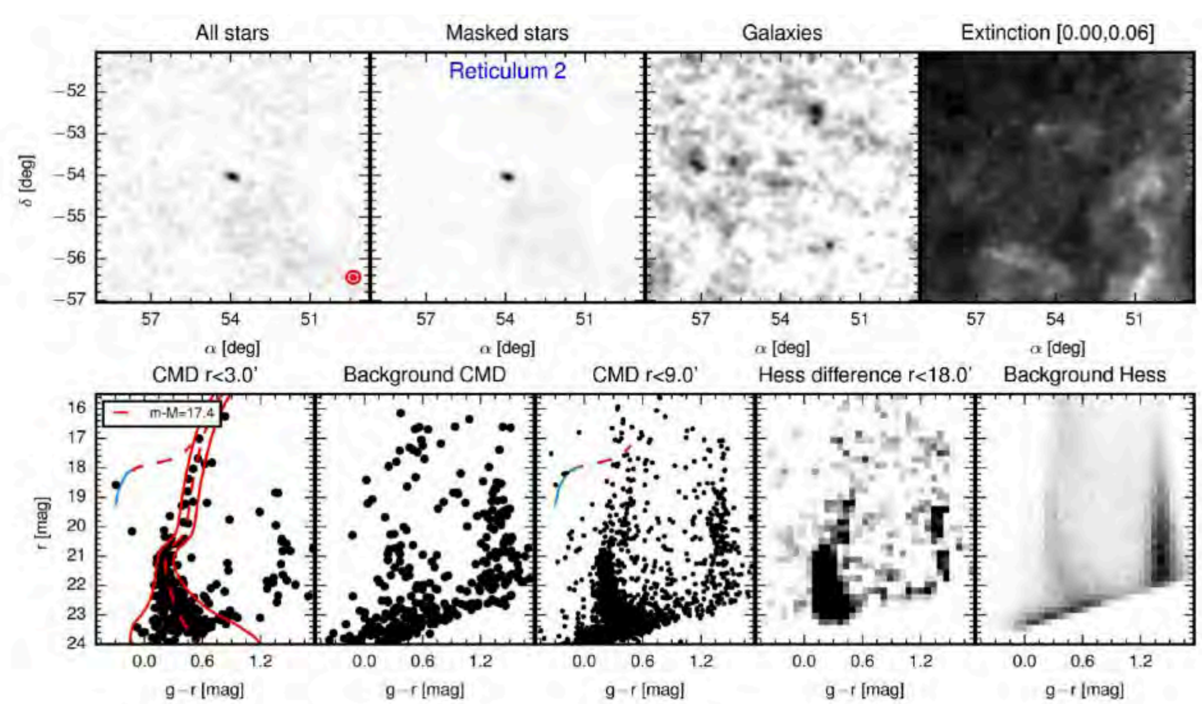
1. Implementing precursor surveys and observations.
2. Demonstrated techniques for doing full image simulations of dwarfs.



Motivation: Dozens of new Milky Way and M31 satellites

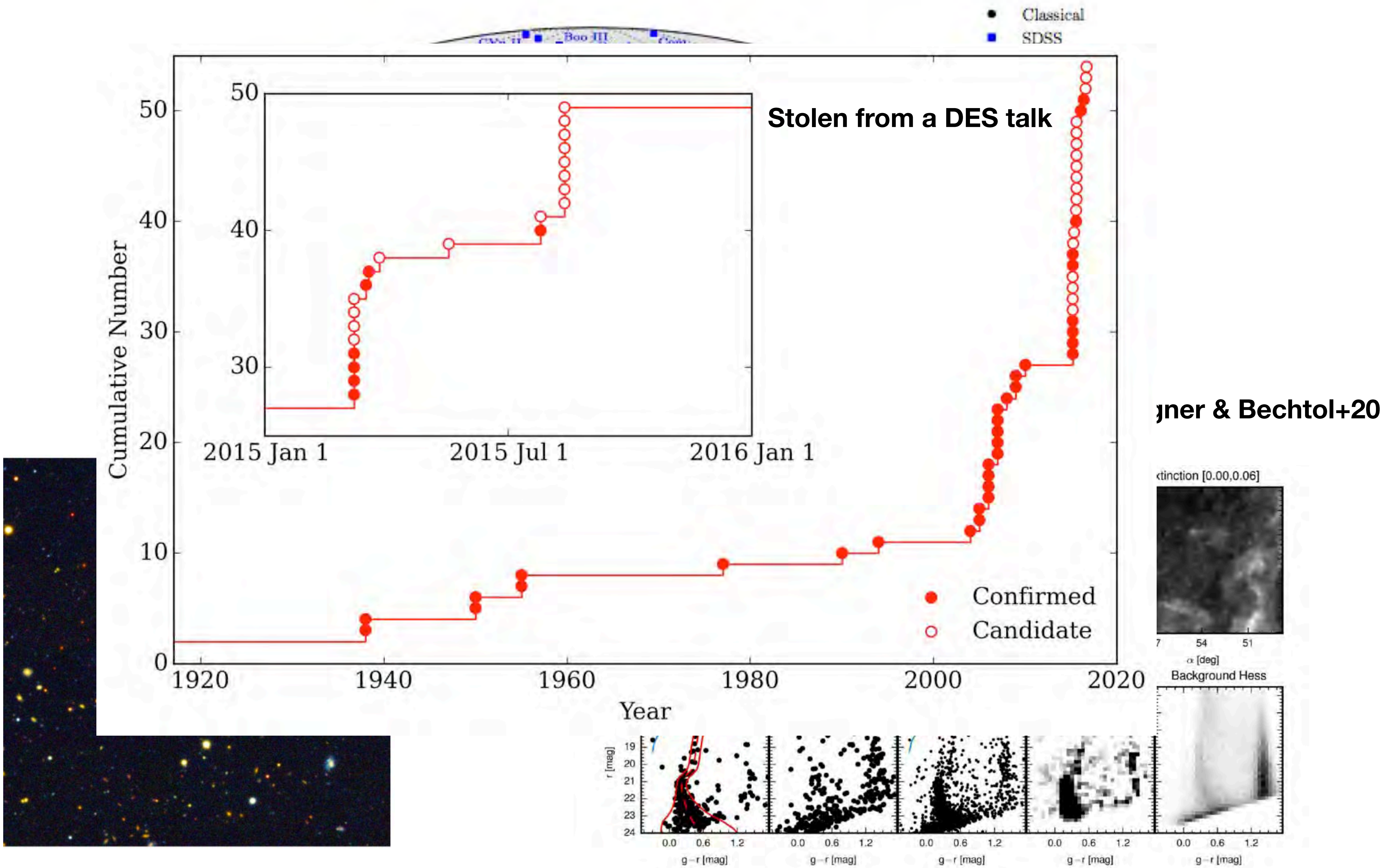


Most recently, Drlica-Wagner & Bechtol+20

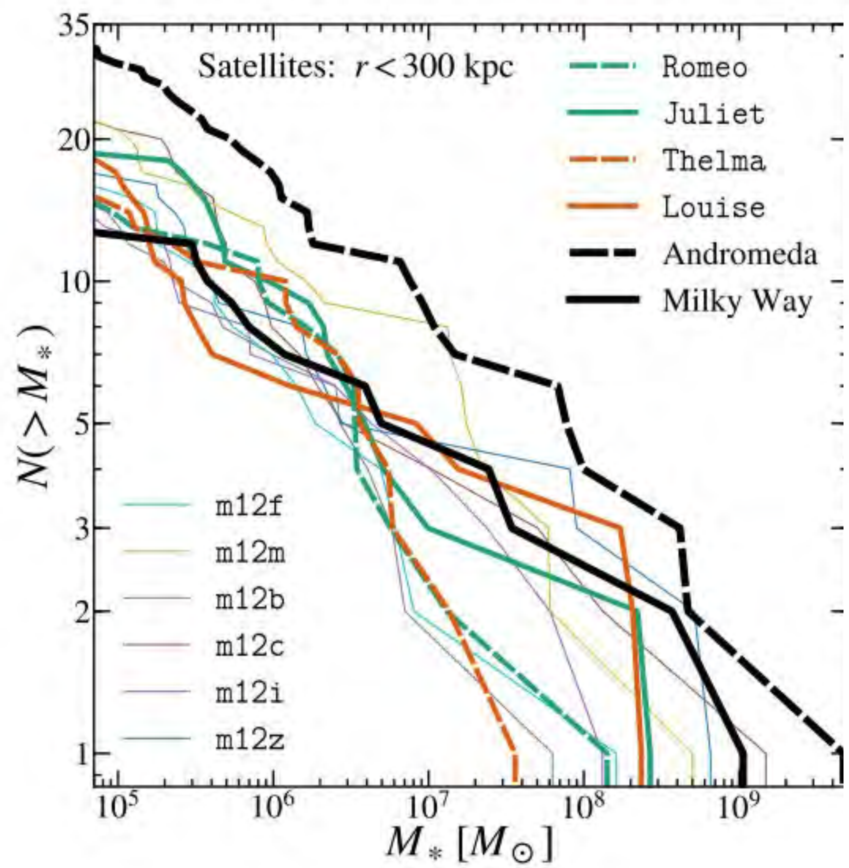


NANCY GRACE ROMAN SPACE TELESCOPE

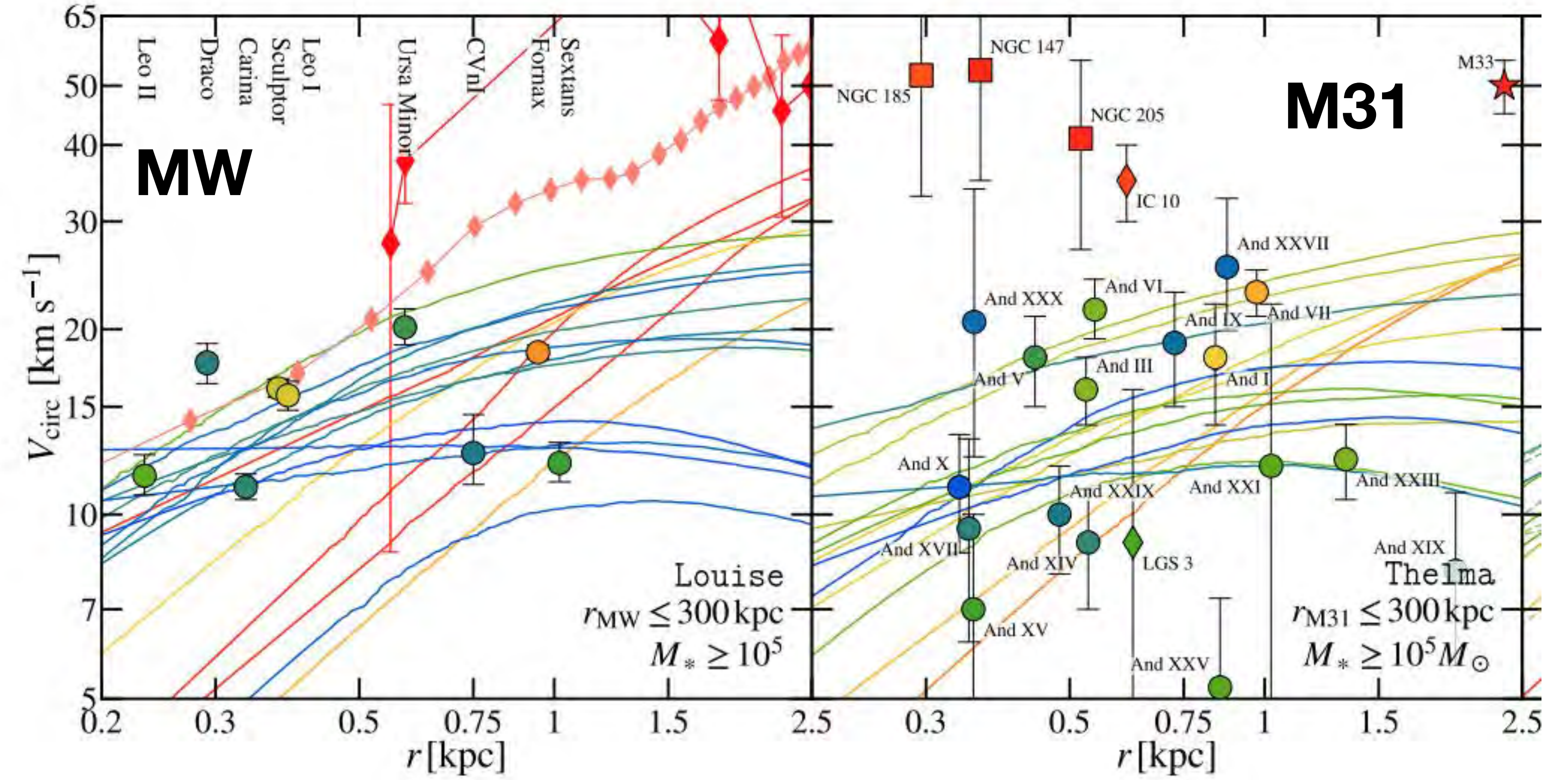
Dozens of new Milky Way and M31 satellites



Realistic inclusion of baryons significantly reduces CDM's 'problems' on sub-galactic scales



FIRE simulations; Garrison-Kimmel+2019



N_{sat} vs Mass

Velocity scale of satellites vs. half-light radius

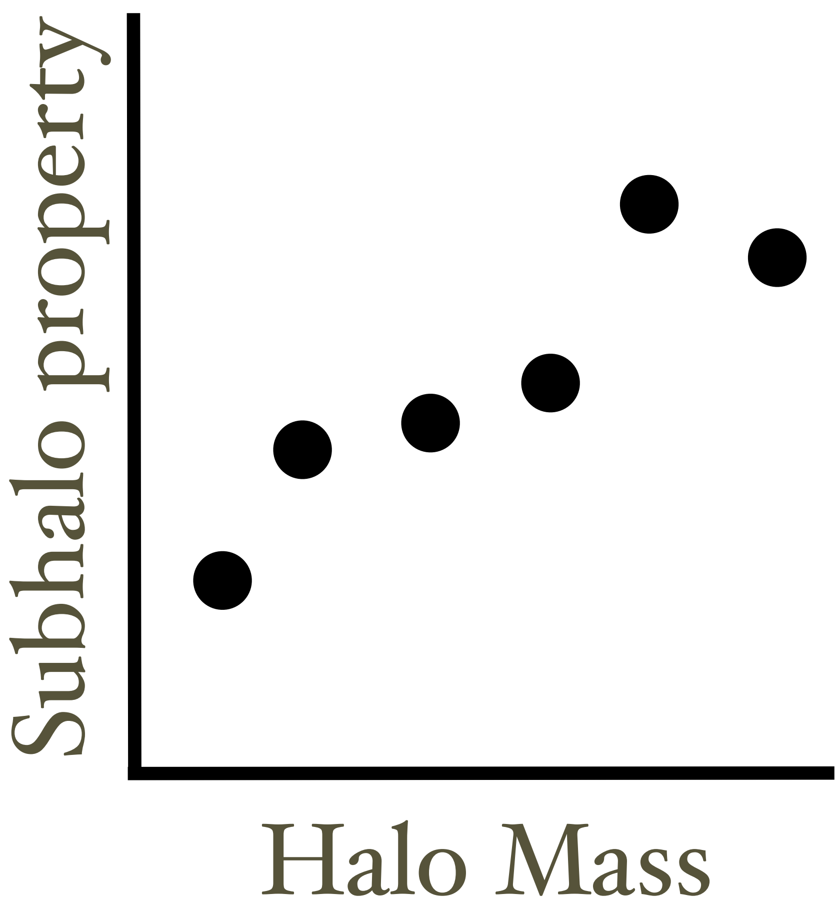
Theory + Observations converging in the Local Group.

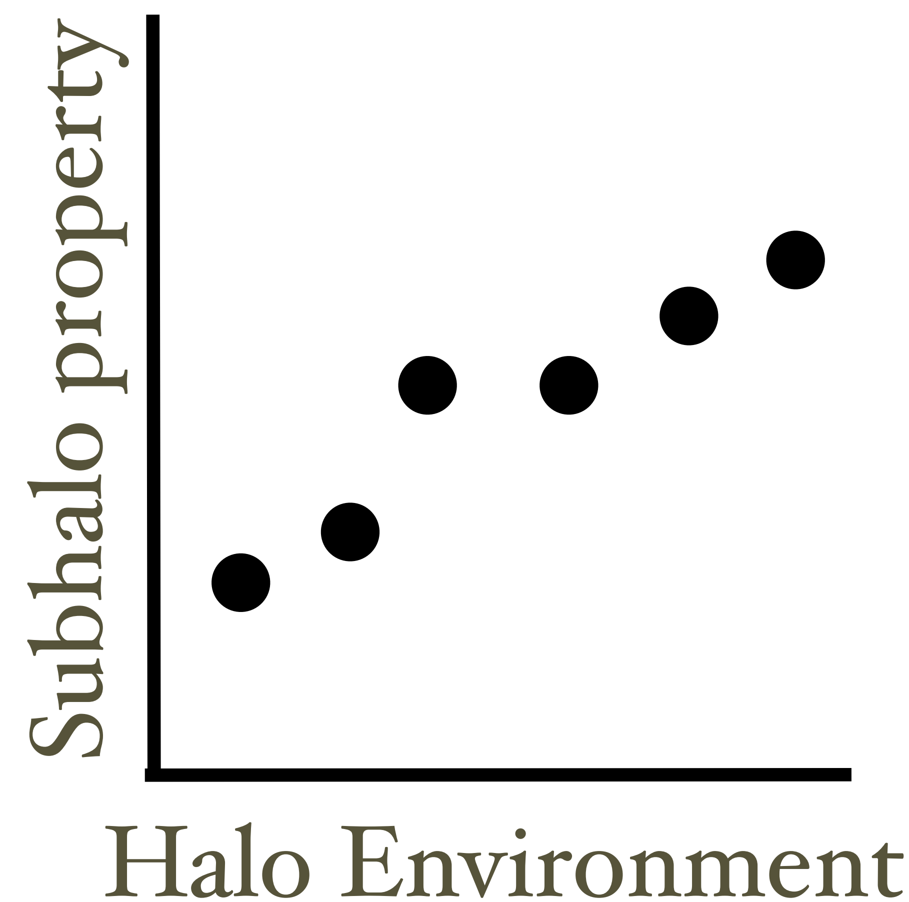
But are we over-tuning our models to reproduce two spiral galaxies in a loose group?

Where do we go from here? The Local Group is nice, but....

- Are our baryonic solutions to the 'Missing Satellites Problem' and 'Too Big to Fail' just tuned to the Local Group?
- Halo to Halo scatter is expected. Can we observationally quantify this? What physically drives the scatter?
- Does parent galaxy morphology matter?
- Environment and formation history?
- Next step is to probe new systems -- our NEXT nearest neighbors.

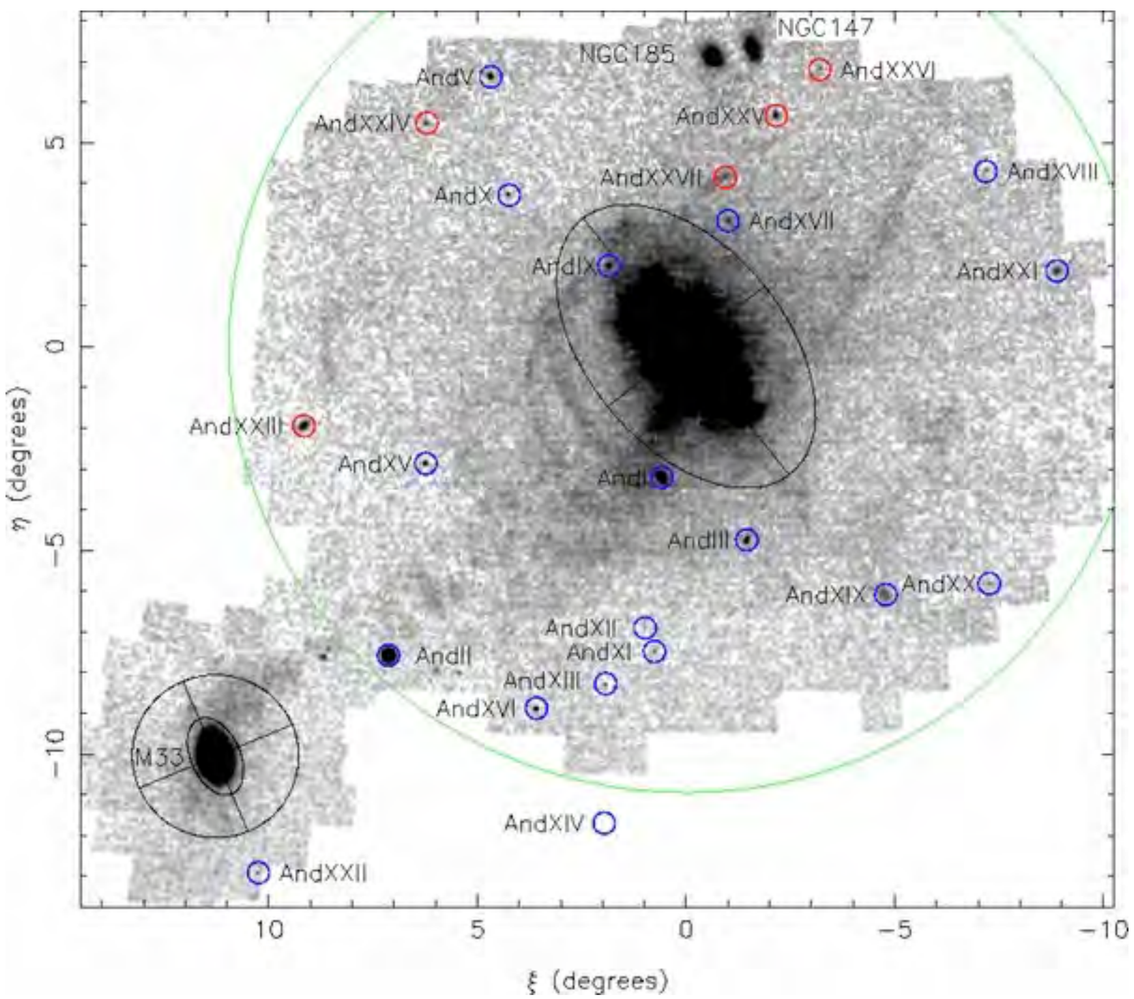
Where do we go from here? The Local Group is nice, but.... What we want:



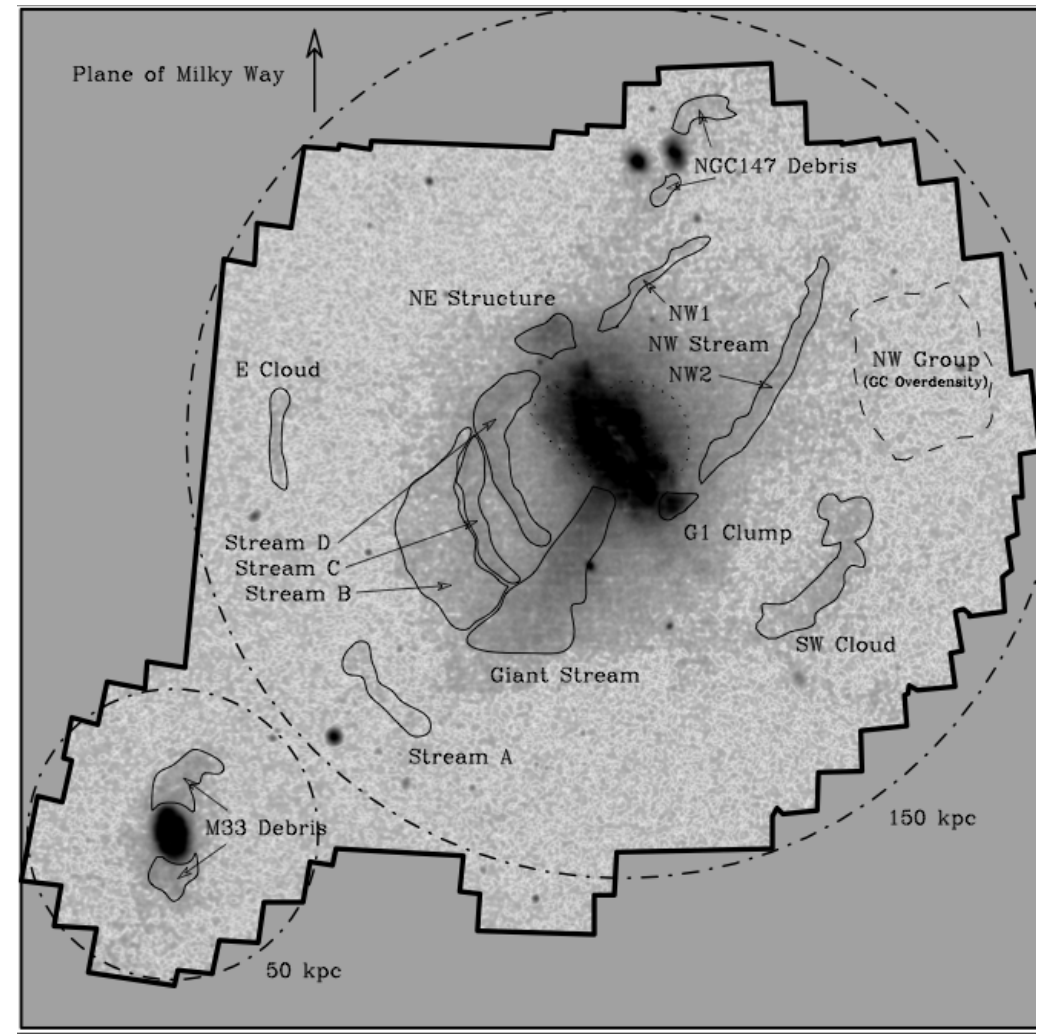


Subhalo property can be dwarf luminosity function, stream richness, you name it.

PANDAS SURVEY OF M31



McConnachie et al. 2009; Lewis et al. 2012, Martin et al. 2013 and MANY more

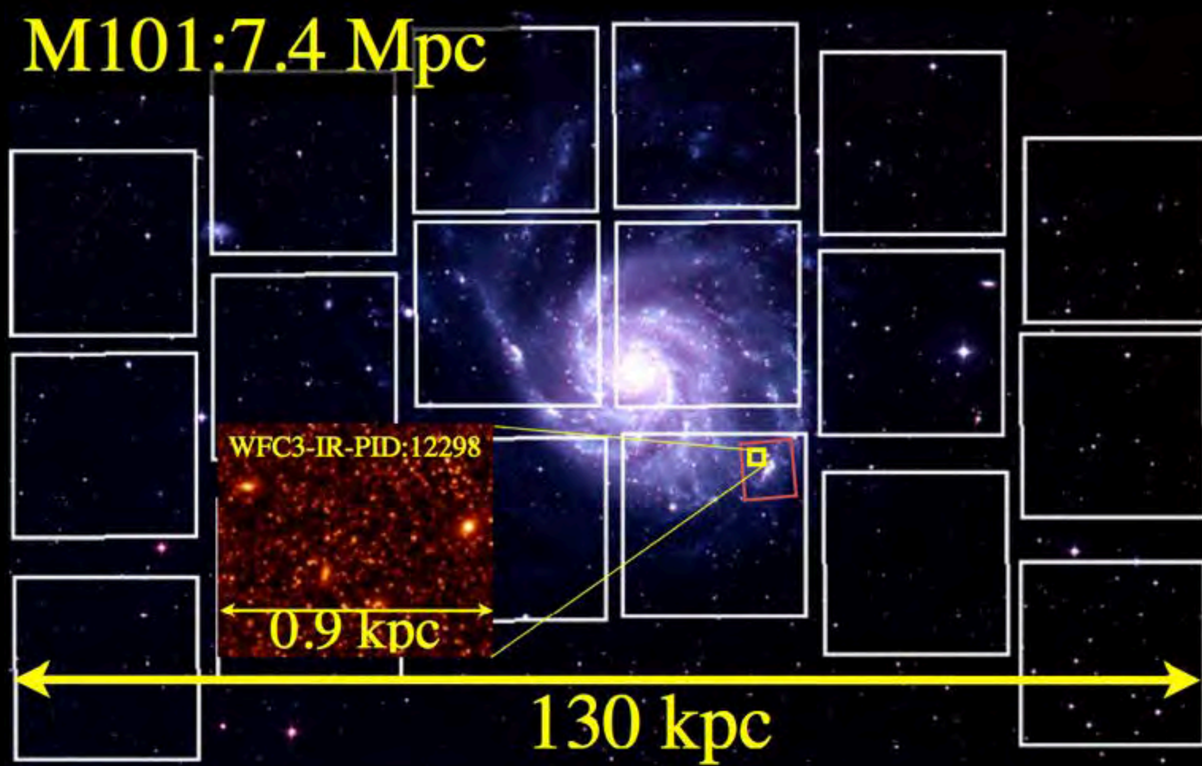


220 HRS OF CFHT/MEGACAM; 400 DEG^2

~2-3 MAGS BELOW THE TIP OF THE RGB

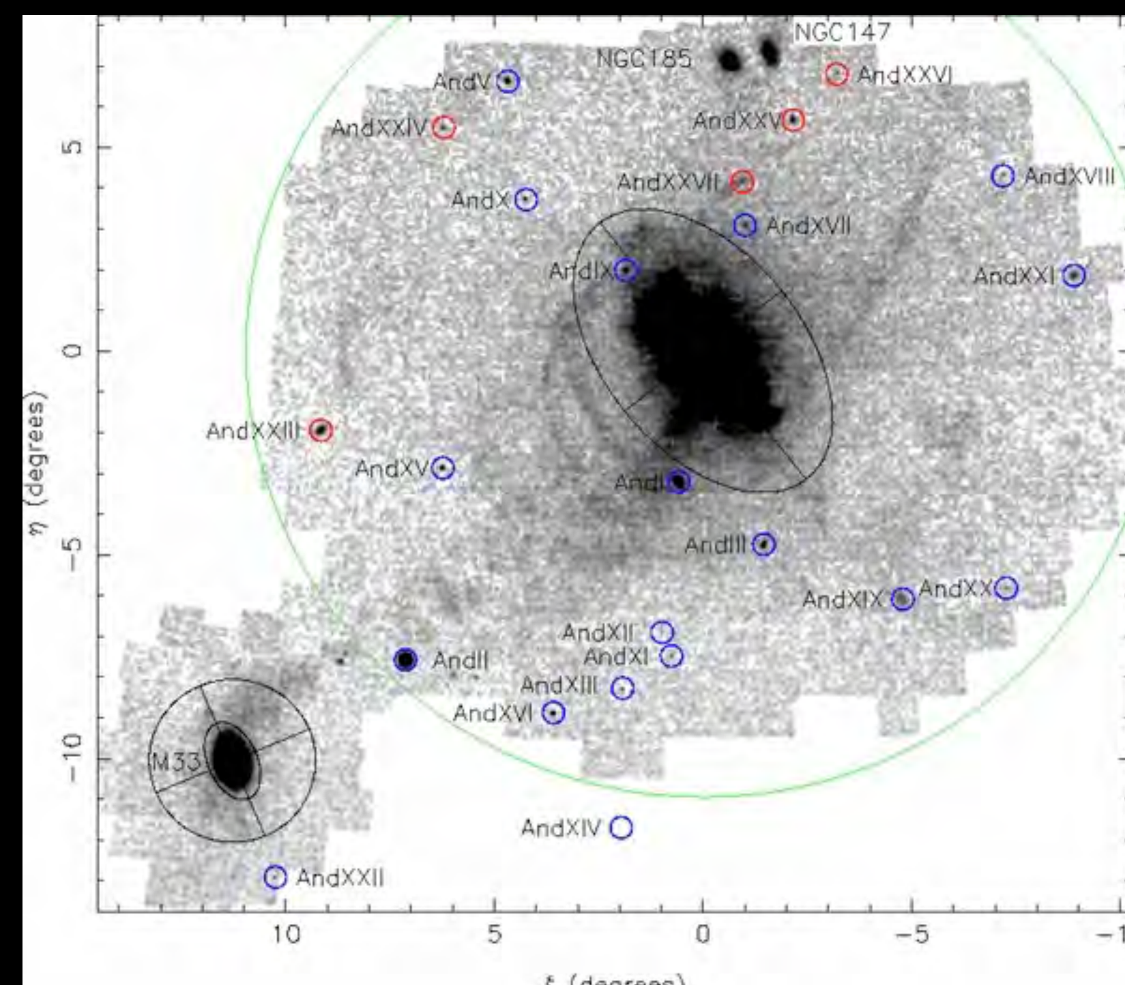
A Taste of What is Possible with Roman

NANCY GRACE ROMAN SPACE TELESCOPE



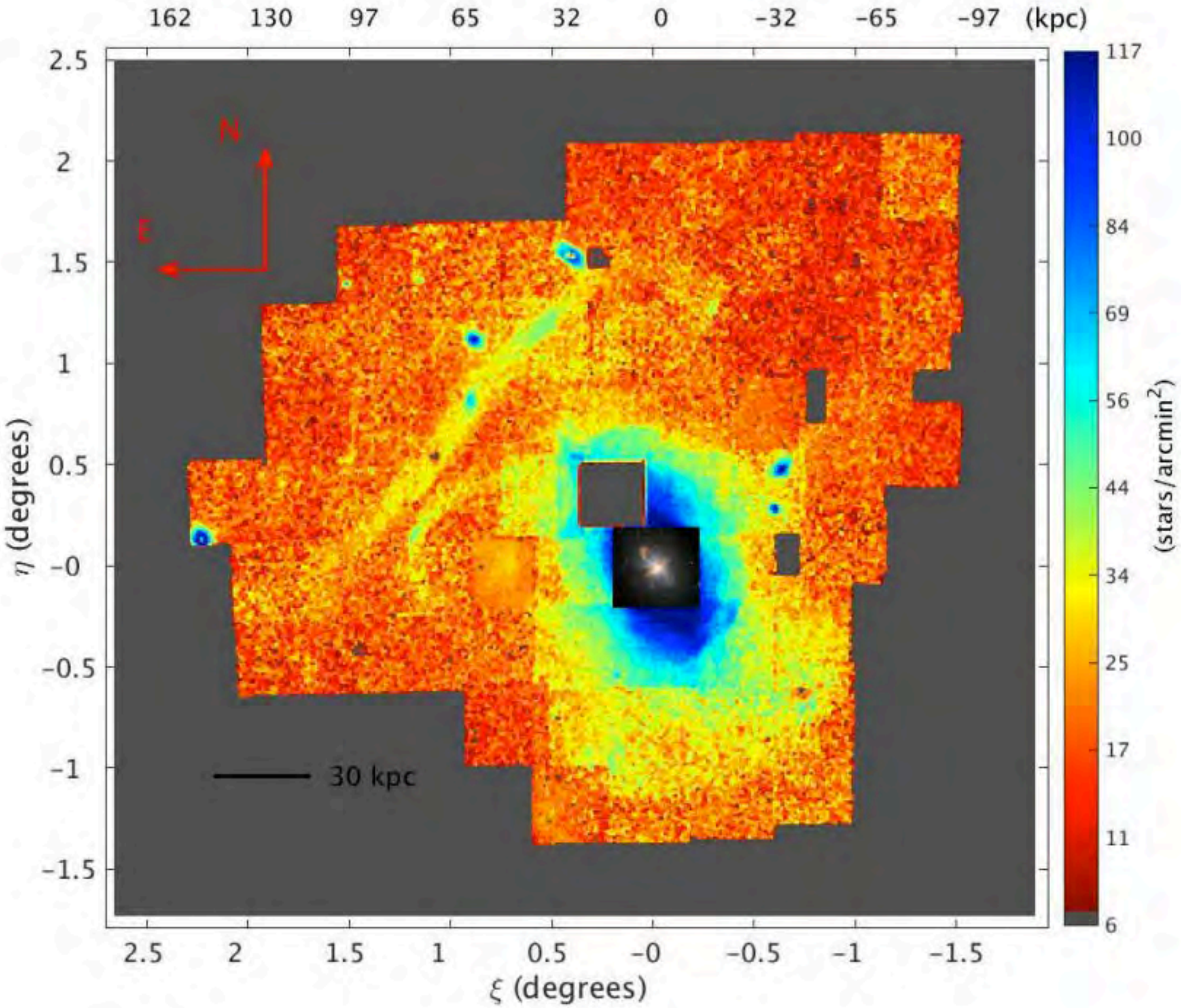
~10 hours with Roman at 10 Mpc

PAndAS Survey of M31



The field of Streams of CenA

D=3.8 Mpc



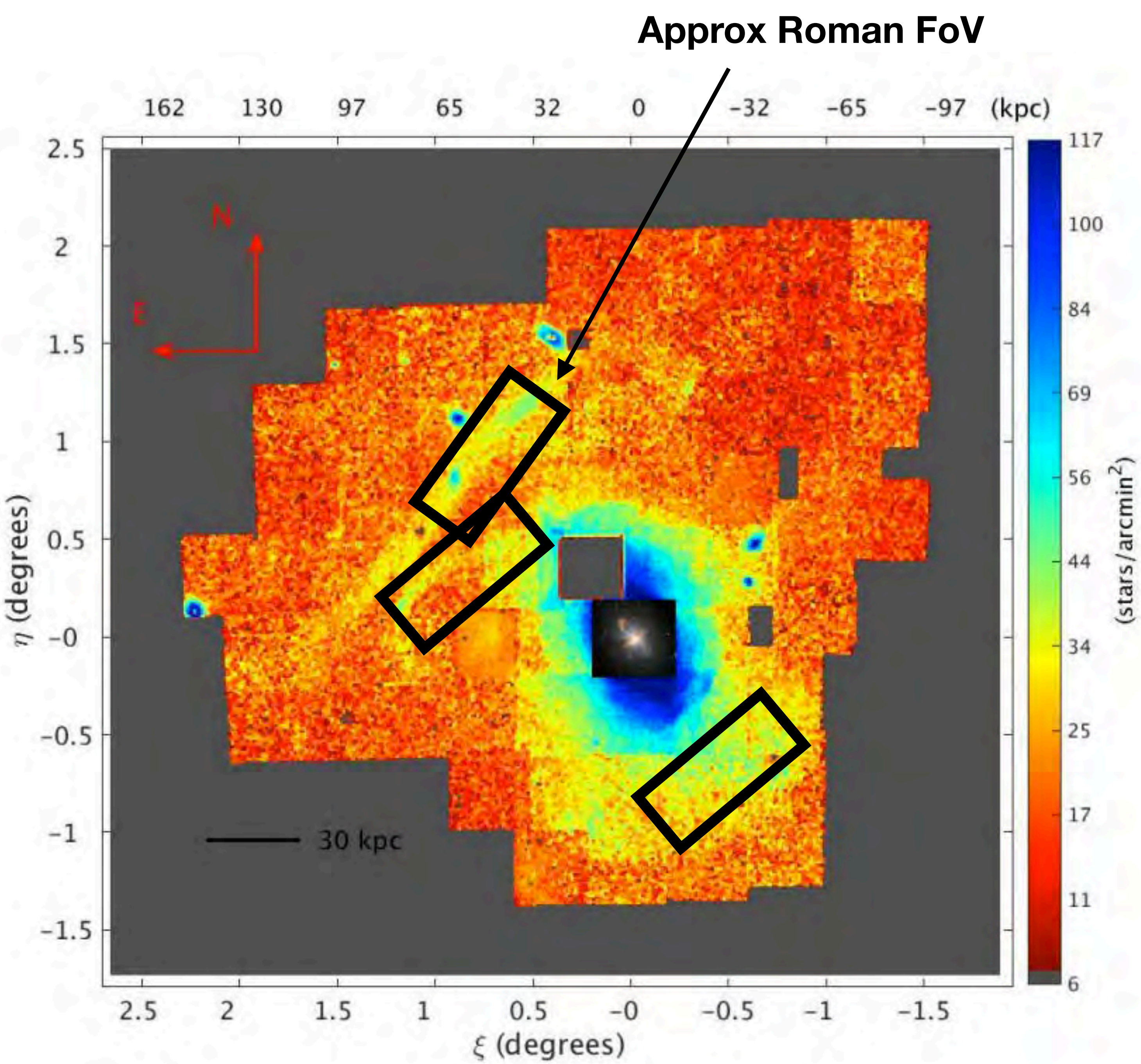
Crnojevic et al. 2016

A disrupting dwarf galaxy -- detected not by low surface brightness measurements but in individual resolved stars!

There are clearly other streams emerging.

All in resolved RGB stars

The field of Streams of CenA



Crnojevic et al. 2016

A disrupting dwarf galaxy -- detected not by low surface brightness measurements but in individual resolved stars!

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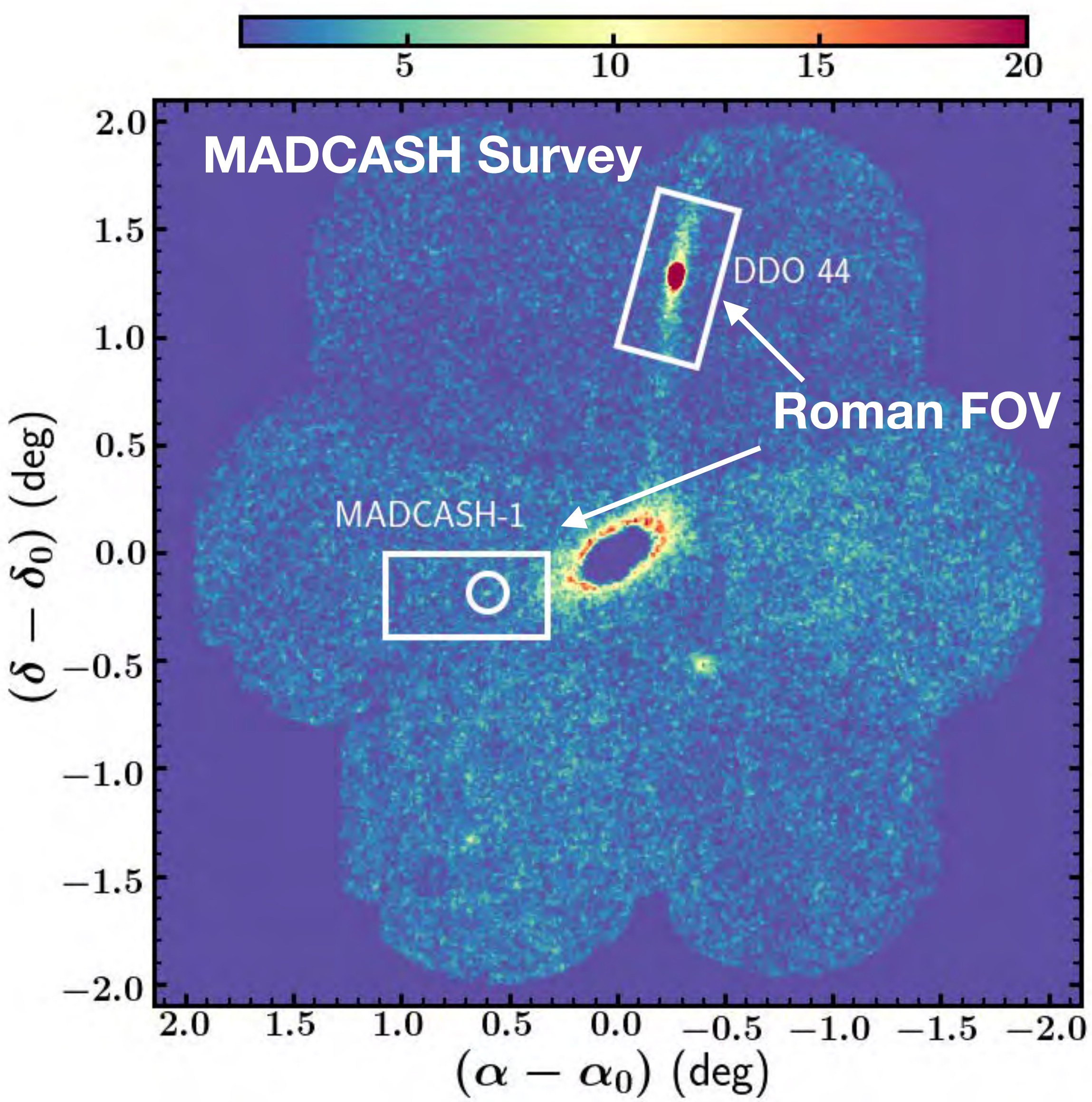
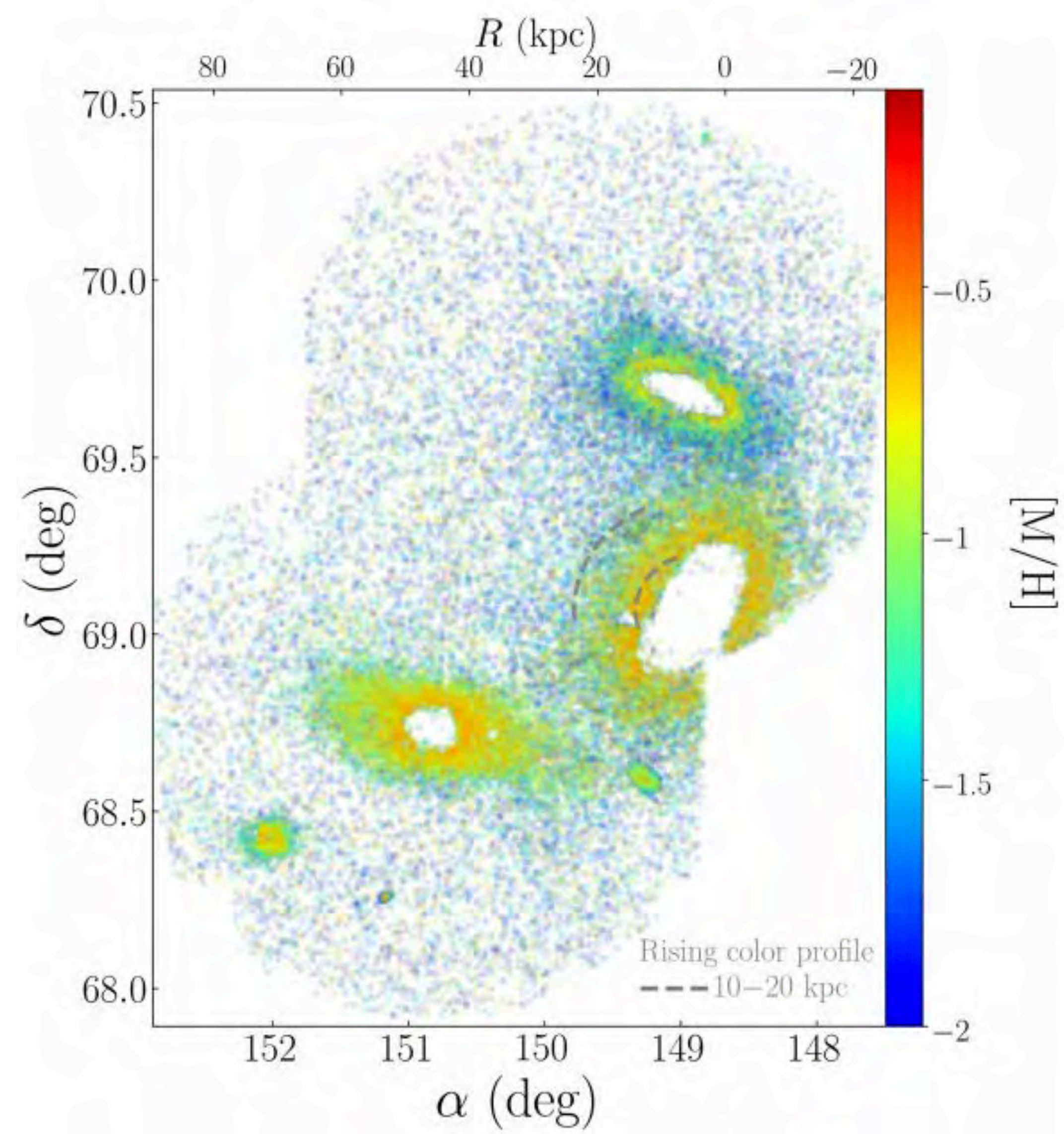
Other RGB maps (not exhaustive)



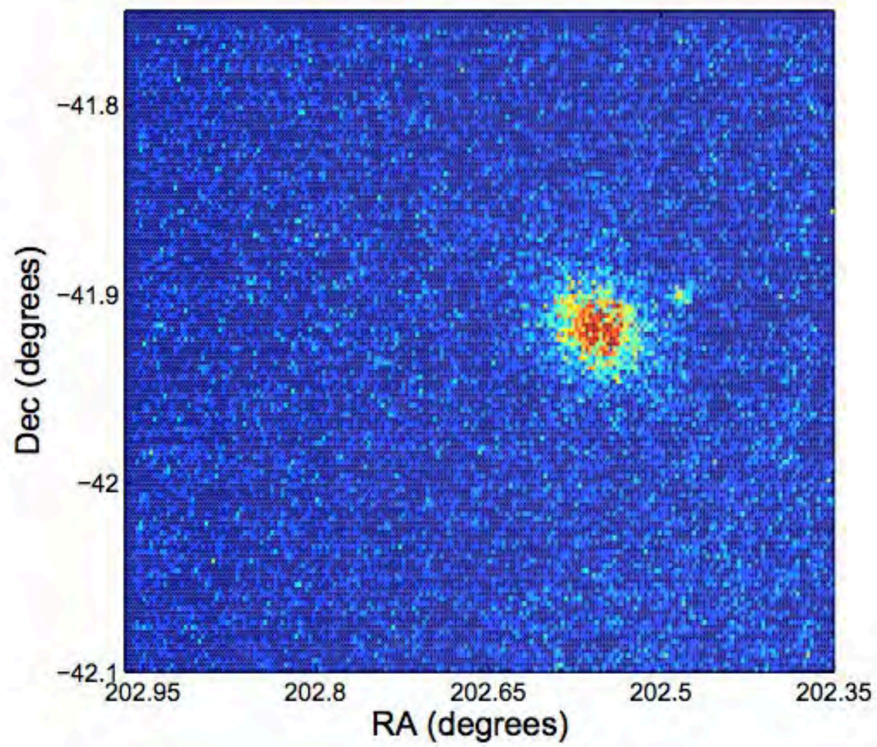
HSC map of RGB stars around NGC2403 (D~3.2 Mpc), showing a stripped DDO 44 satellite (Carlin+16, 19, 20)

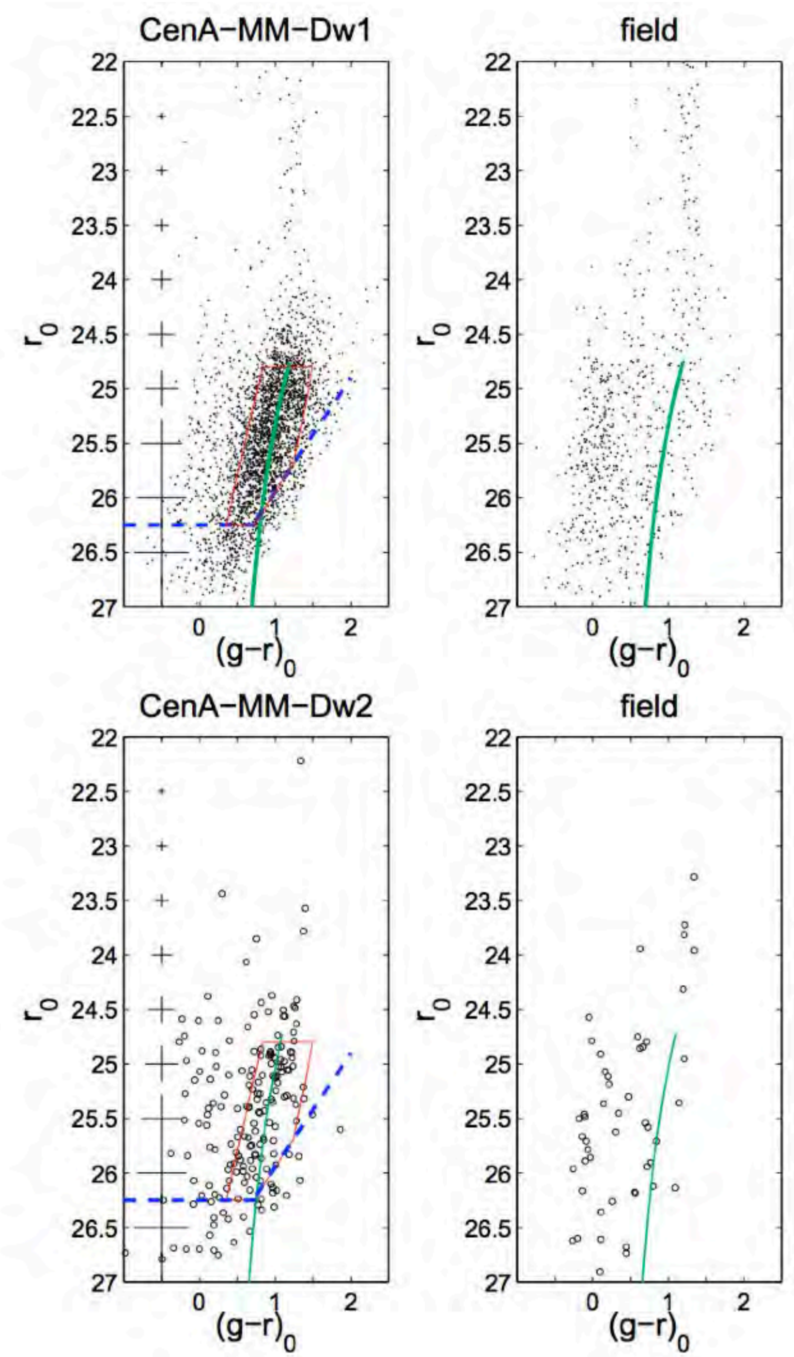


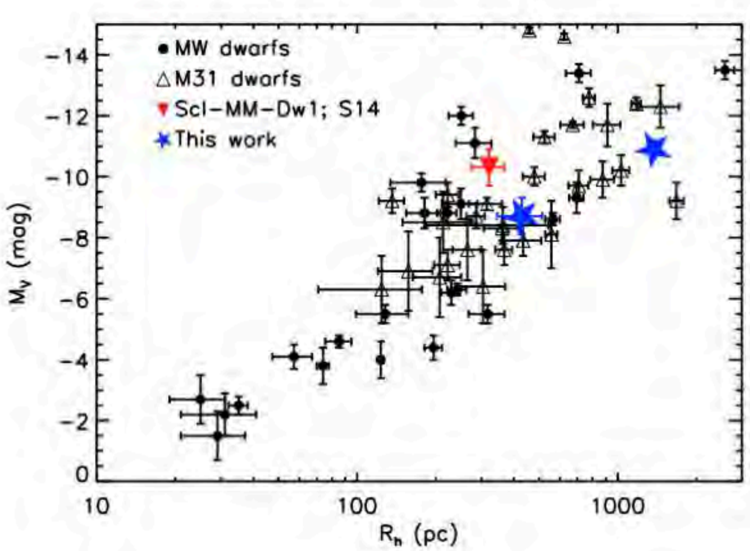
HSC map of RGB stars in the M81 group (D~3.5 Mpc), color coded by metallicity (Smercina+20). See also Okamoto+15.

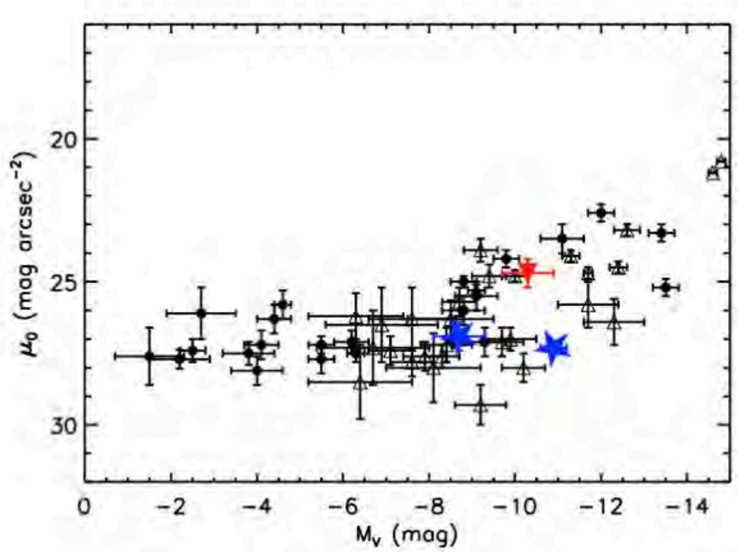
A close pair of satellites

(as an example of ground-space synergy)



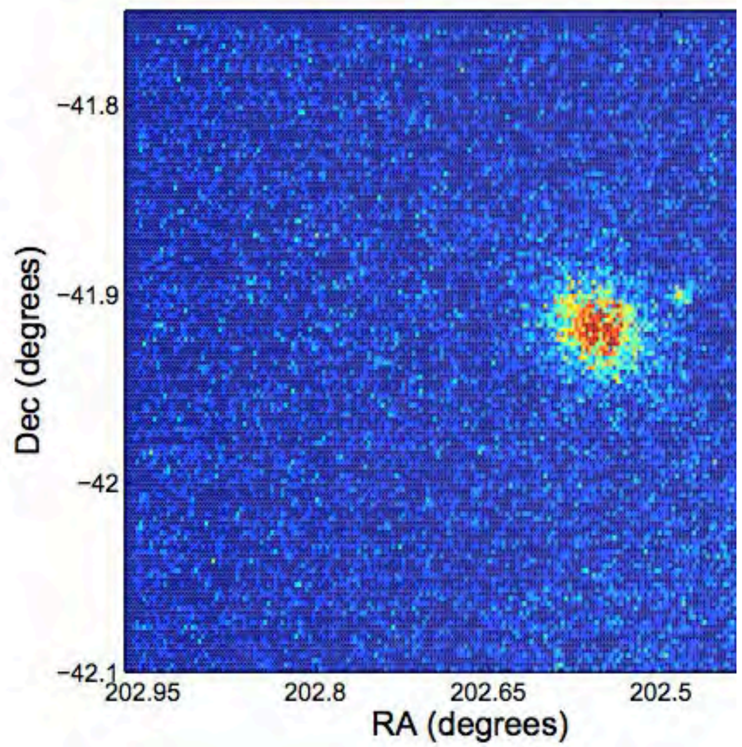


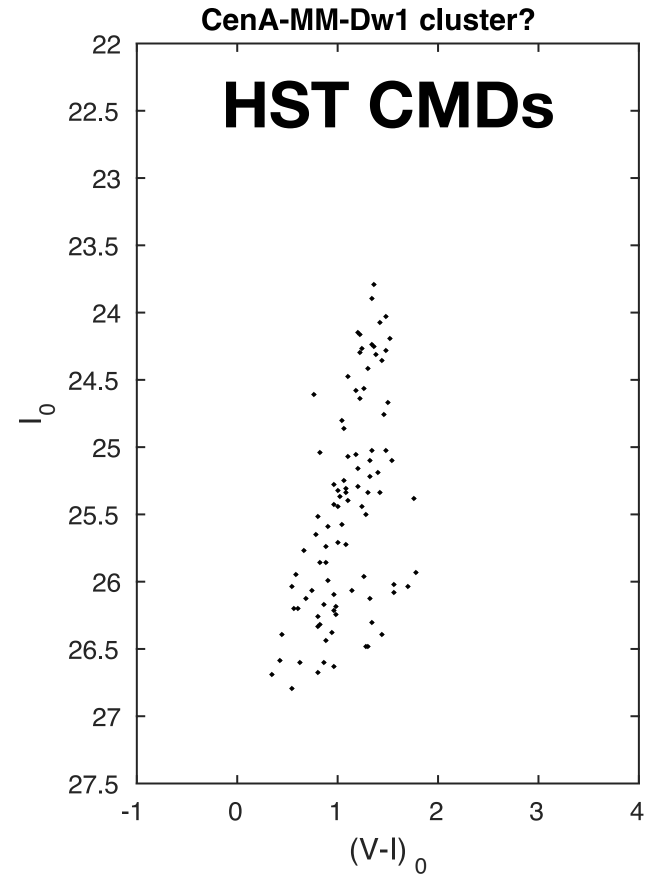


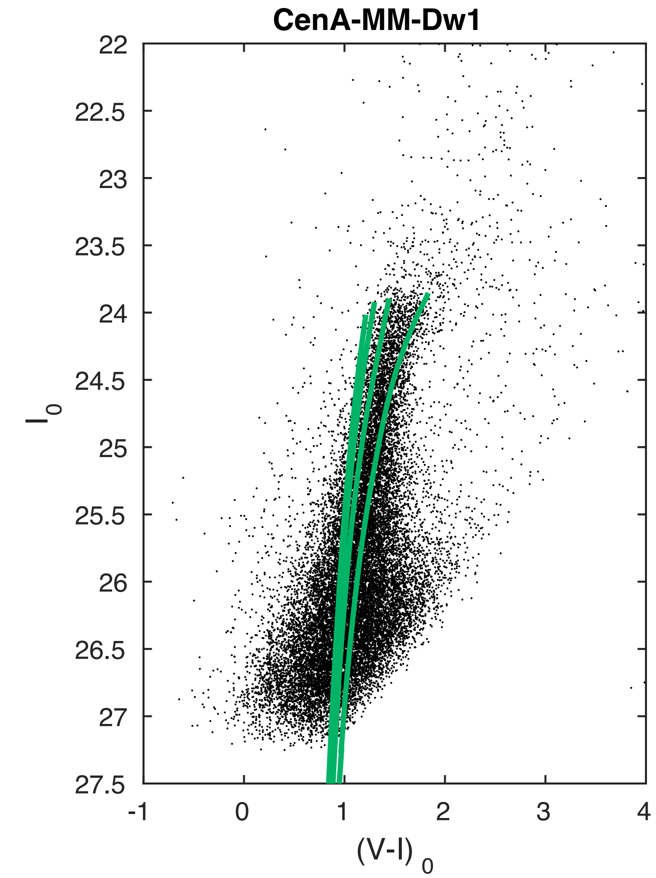


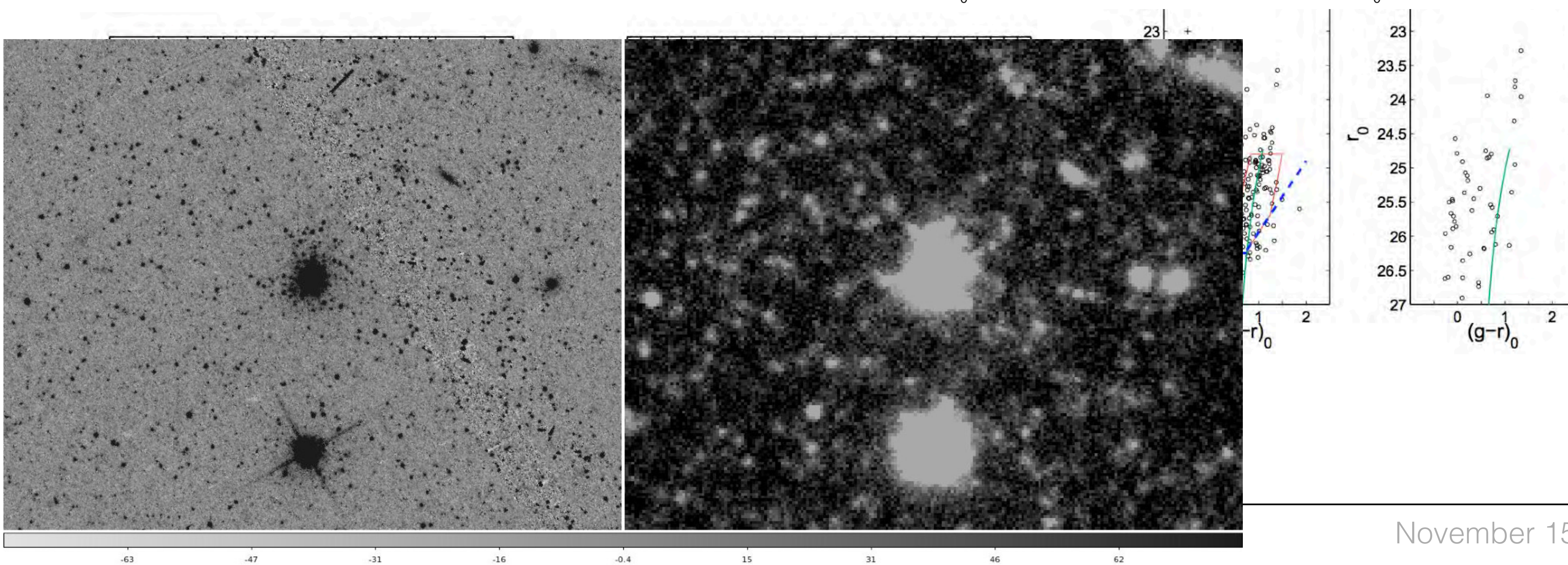
Crnojevic et al. 2014

A close pair of satellites









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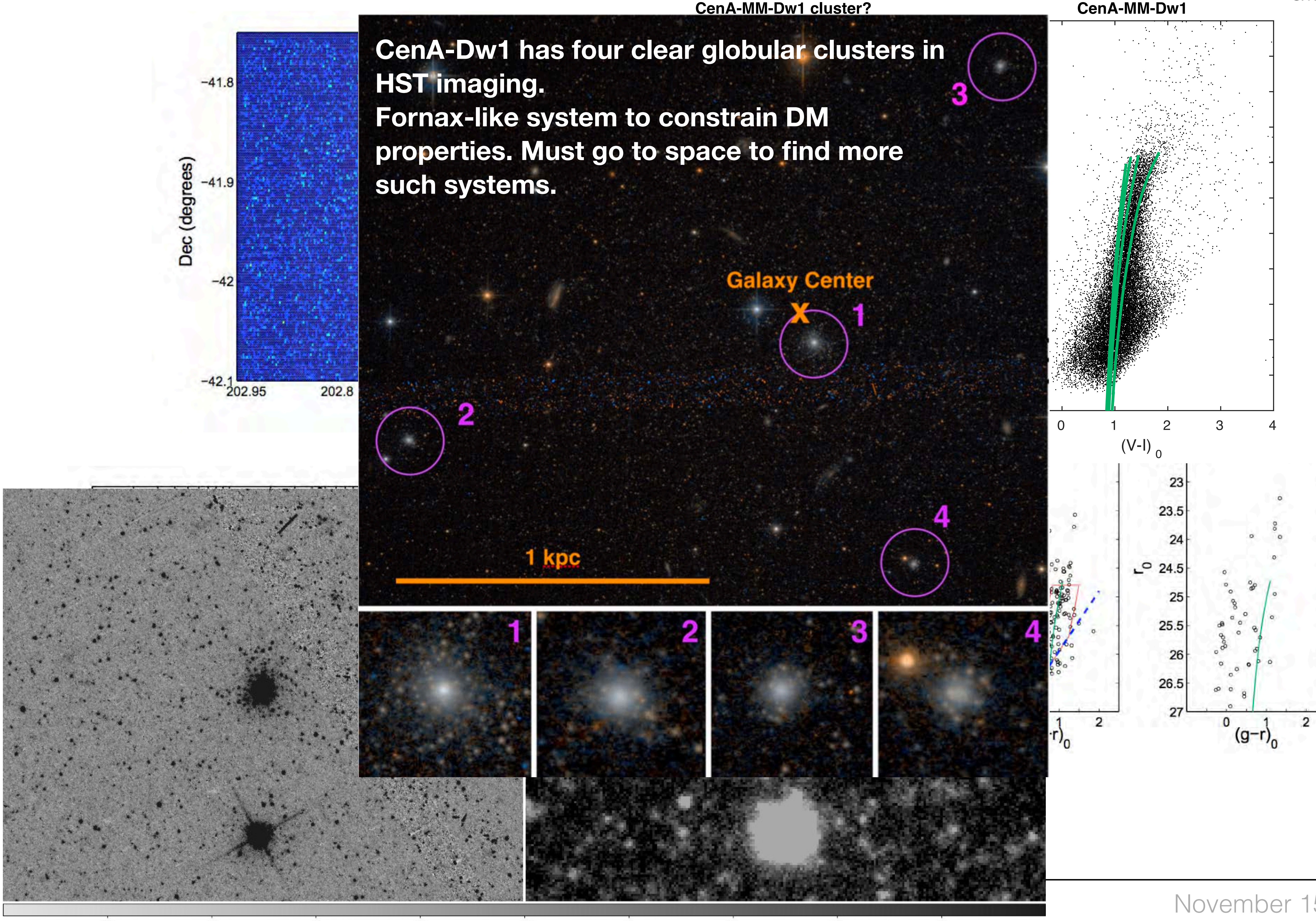
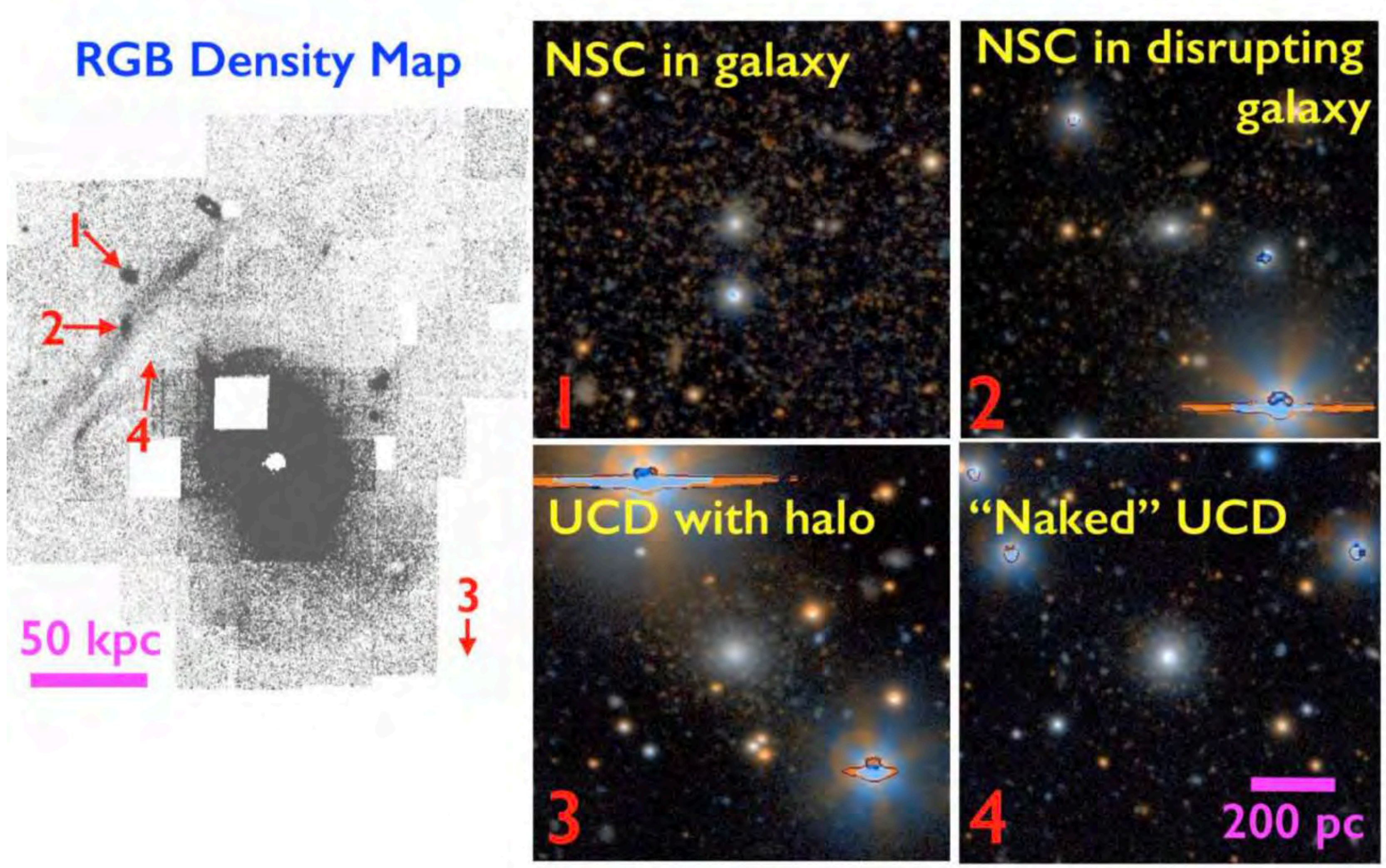


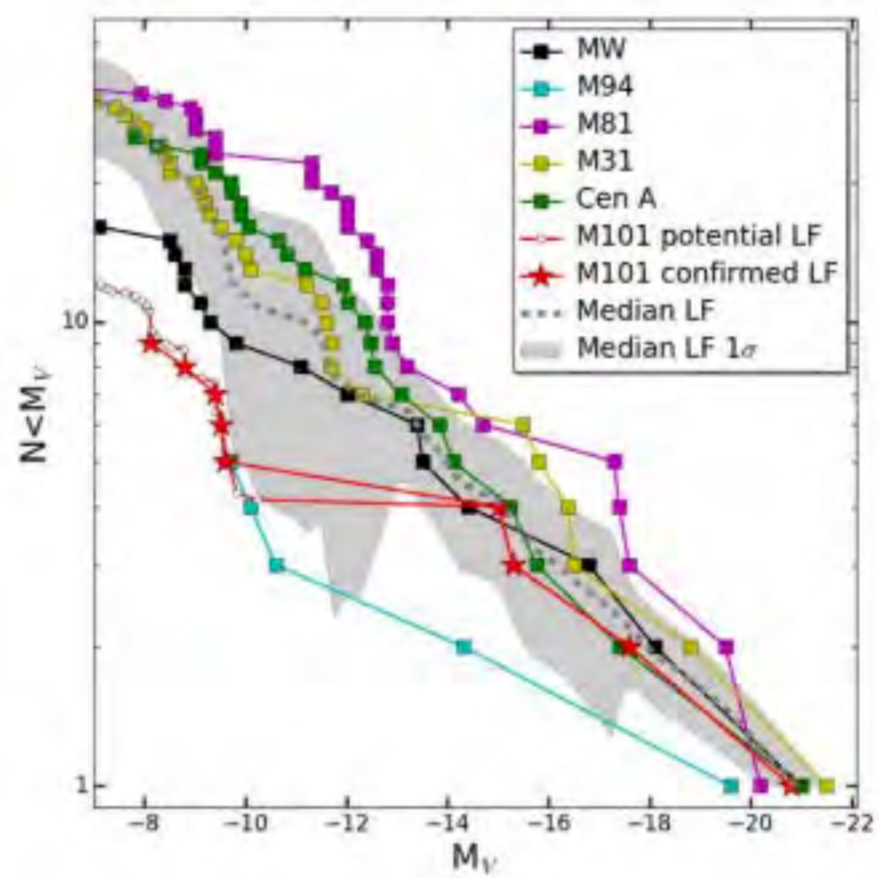
HST followup is revealing a rich variety of star clusters — a preview for Roman

At an average M_V=-7, we can use star clusters to probe kinematics of halo substructures and DM profile of CenA, and other nearby galaxies.

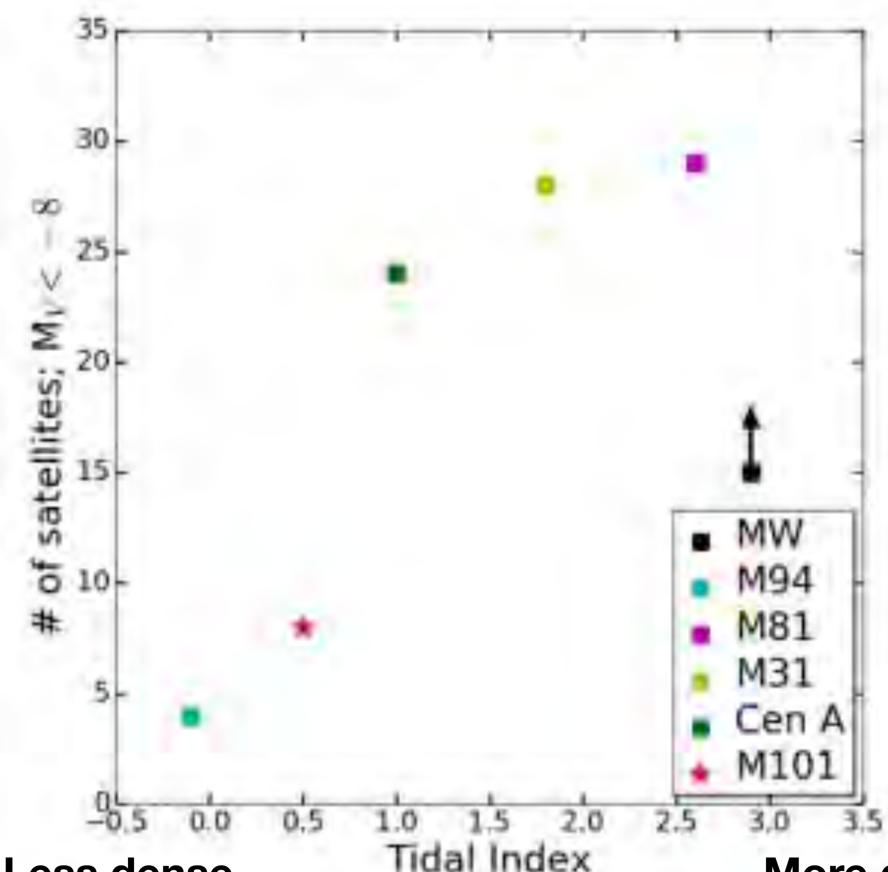


See Voggel et al. 2020

Satellite Luminosity Function of Nearby 'MW-like' Galaxies



Large halo-to-halo scatter. What drives it?
Reproduced in recent simulations; e.g. Samuel et al. 2020; Engler et al. 2021



Less dense Environment **More dense**

Some indication that 'host' halos in denser environments have richer satellite systems. Needs confirmation.

Need to investigate accretion history, feedback, reionization, etc.

Bennet, Sand et al. 2019; see also Carlsten et al. 2020, 2021ab, Geha et al. 2017, Mau et al. 2021

Satellite Luminosity Function of Nearby 'MW-like' Galaxies

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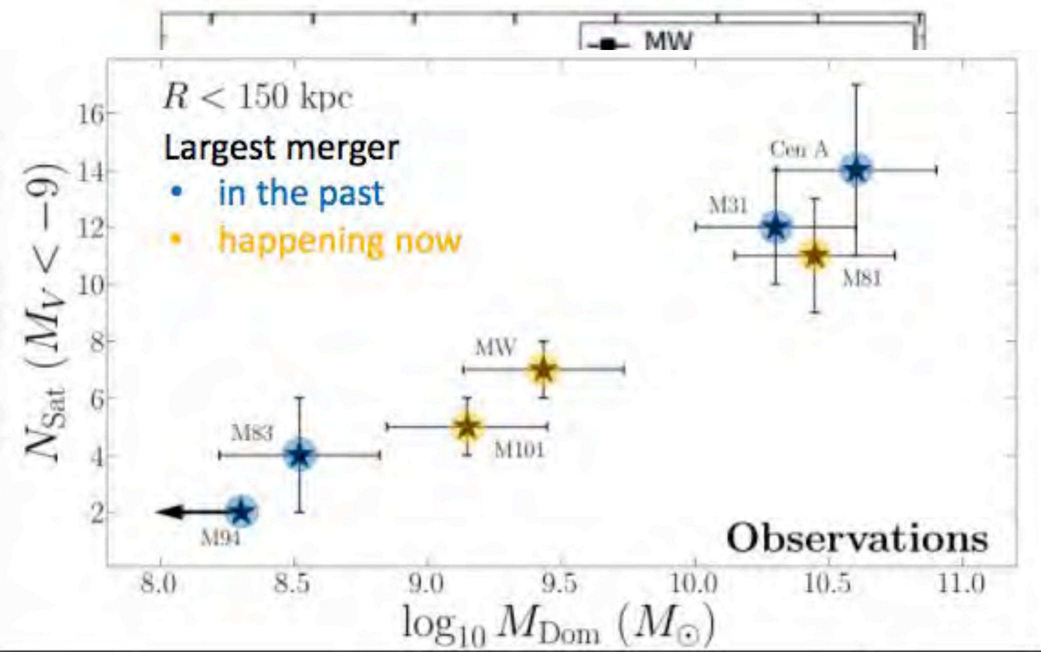
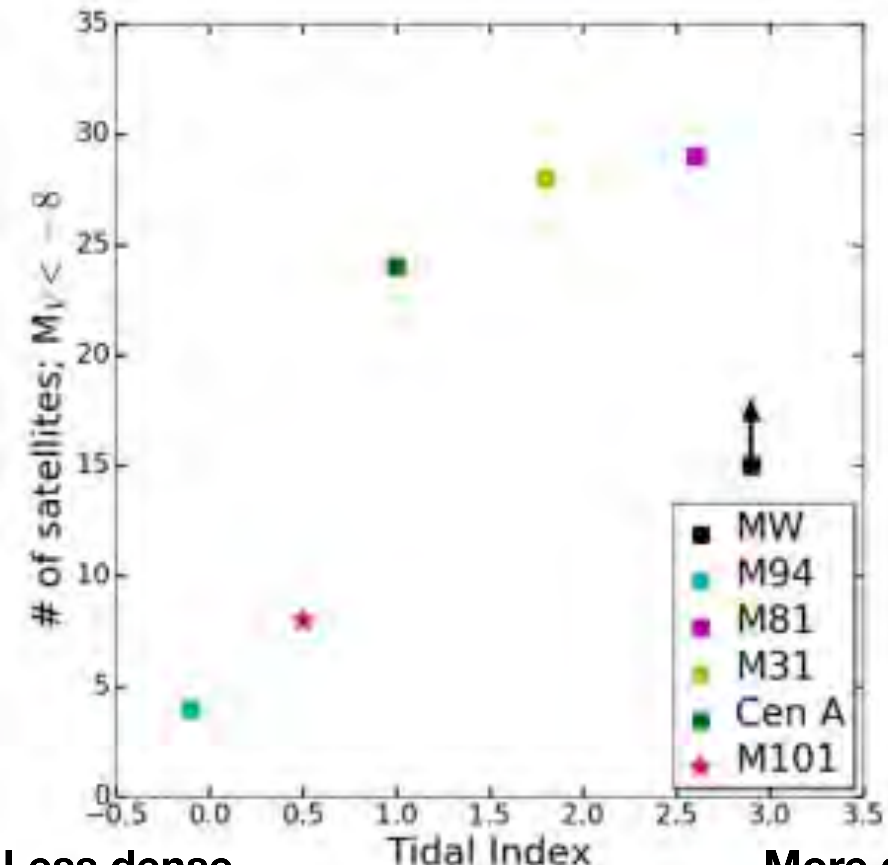


Mass of largest satellite ever accreted
- Still existing or already merged.

Is this driving the scatter in N_{sat} – host mass relations?

Smercina et al. 2021



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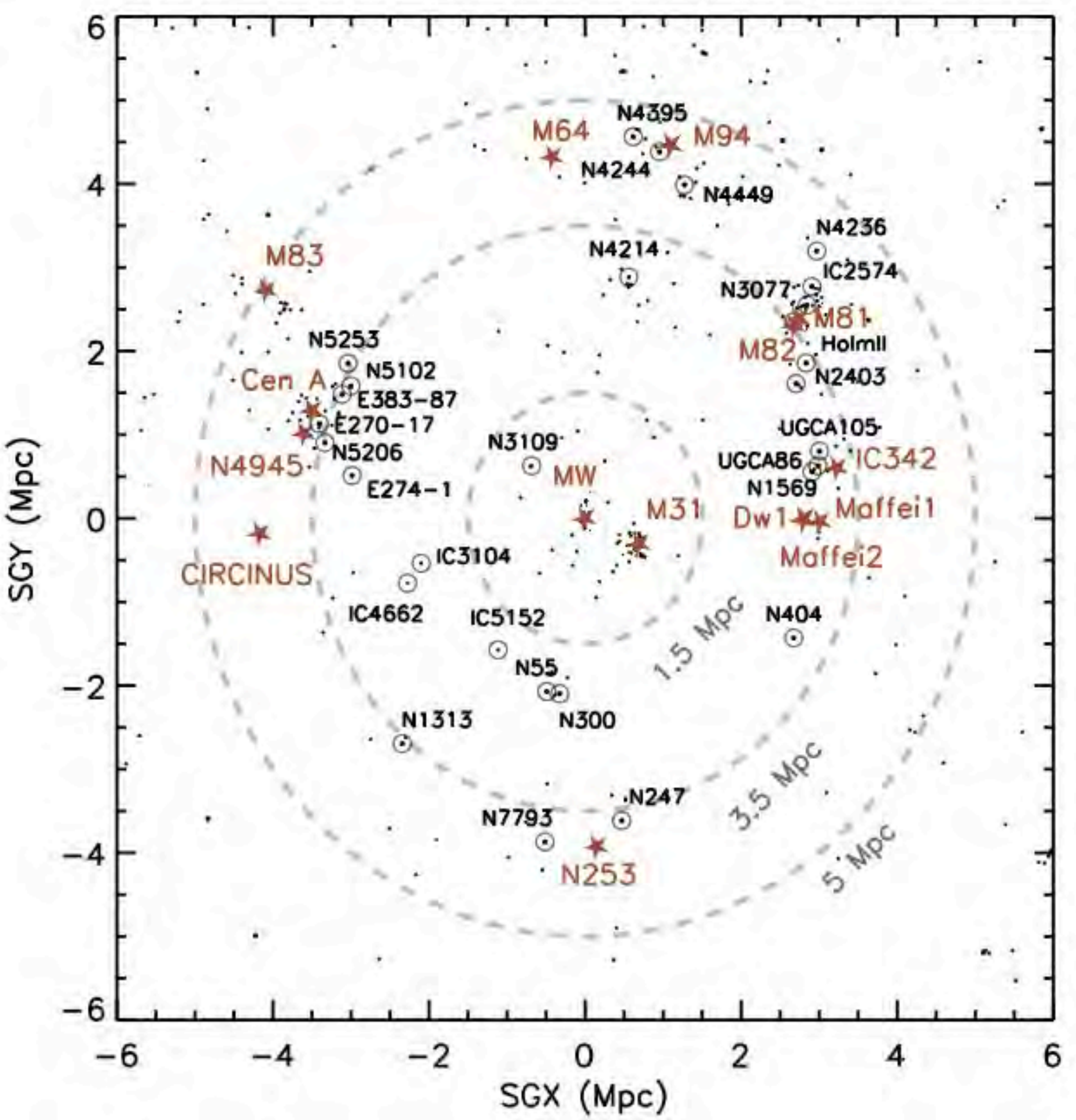
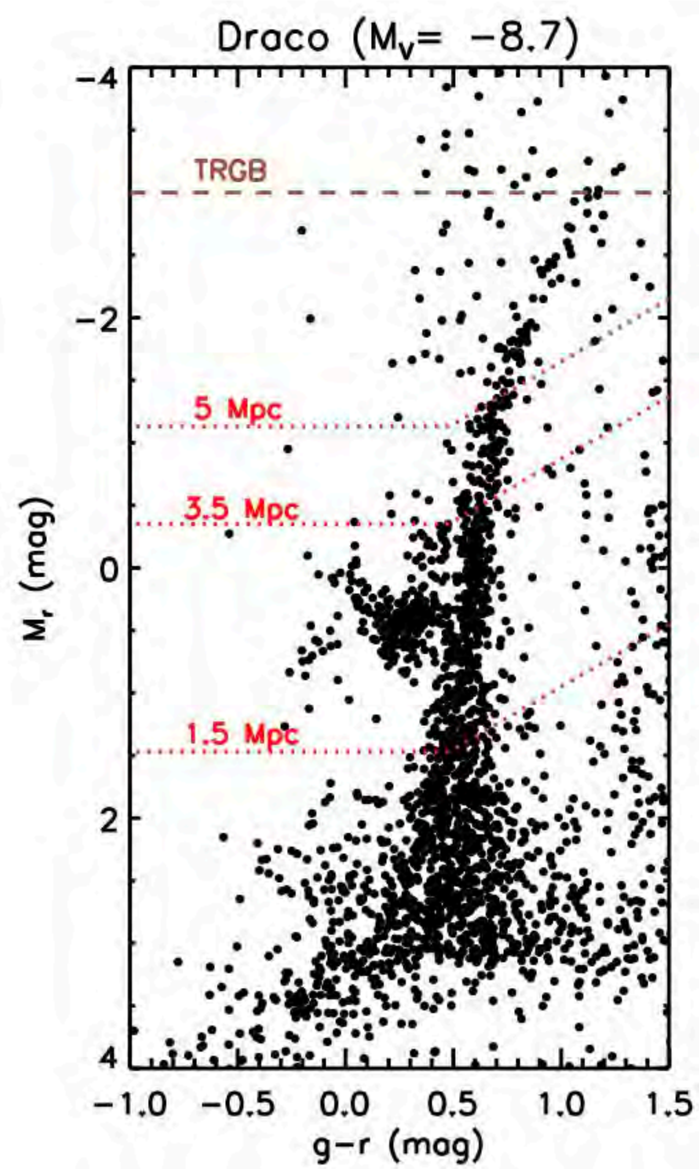
Where Can We Go From Here?
Lets think about resolved stars from the ground with HSC (& VRO)
D<5 Mpc Roughly

NANCY GRACE ROMAN SPACE TELESCOPE



Mutlu-Pakdil, Sand, et al. 2021

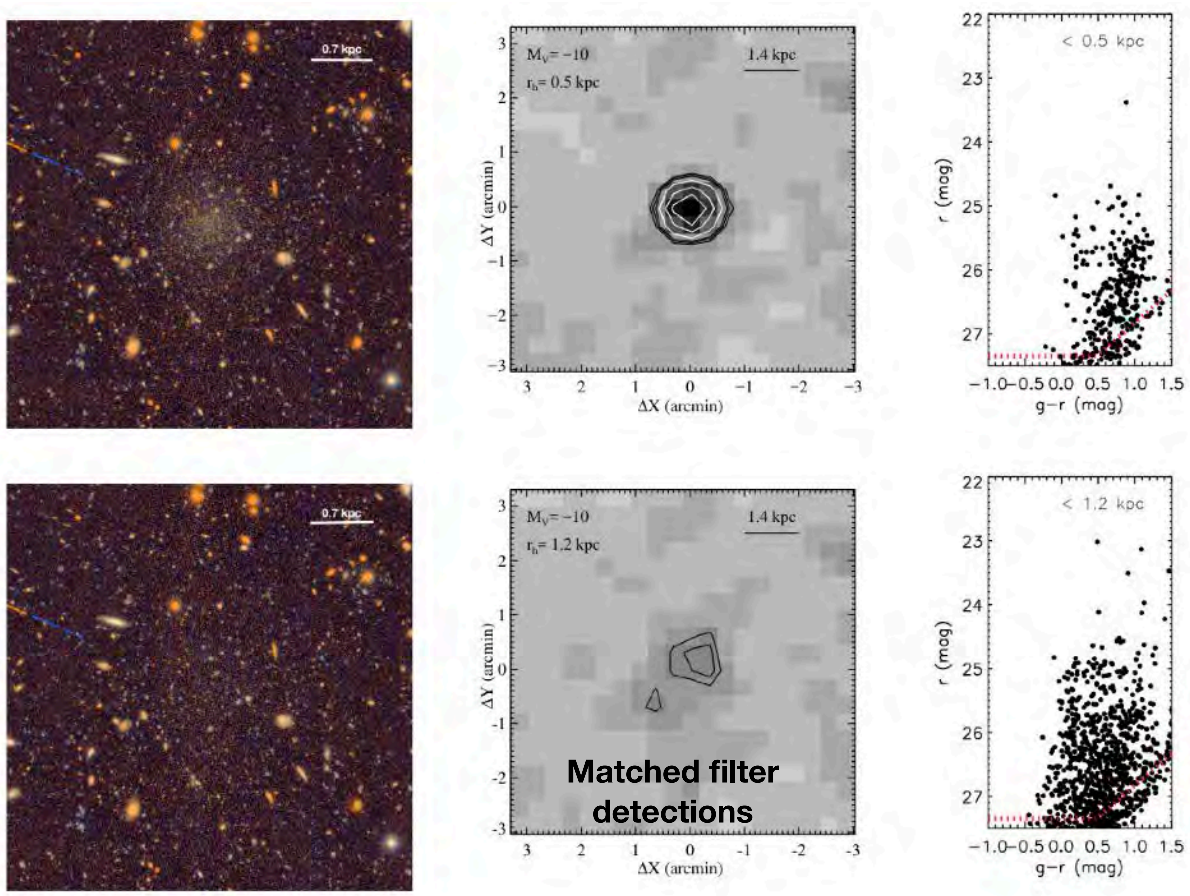


Red corresponds to r~27.4, g~27.8 at 50% comp — close to LSST 10-yr depth HSC data (Carlin et al. 2016, 2019)

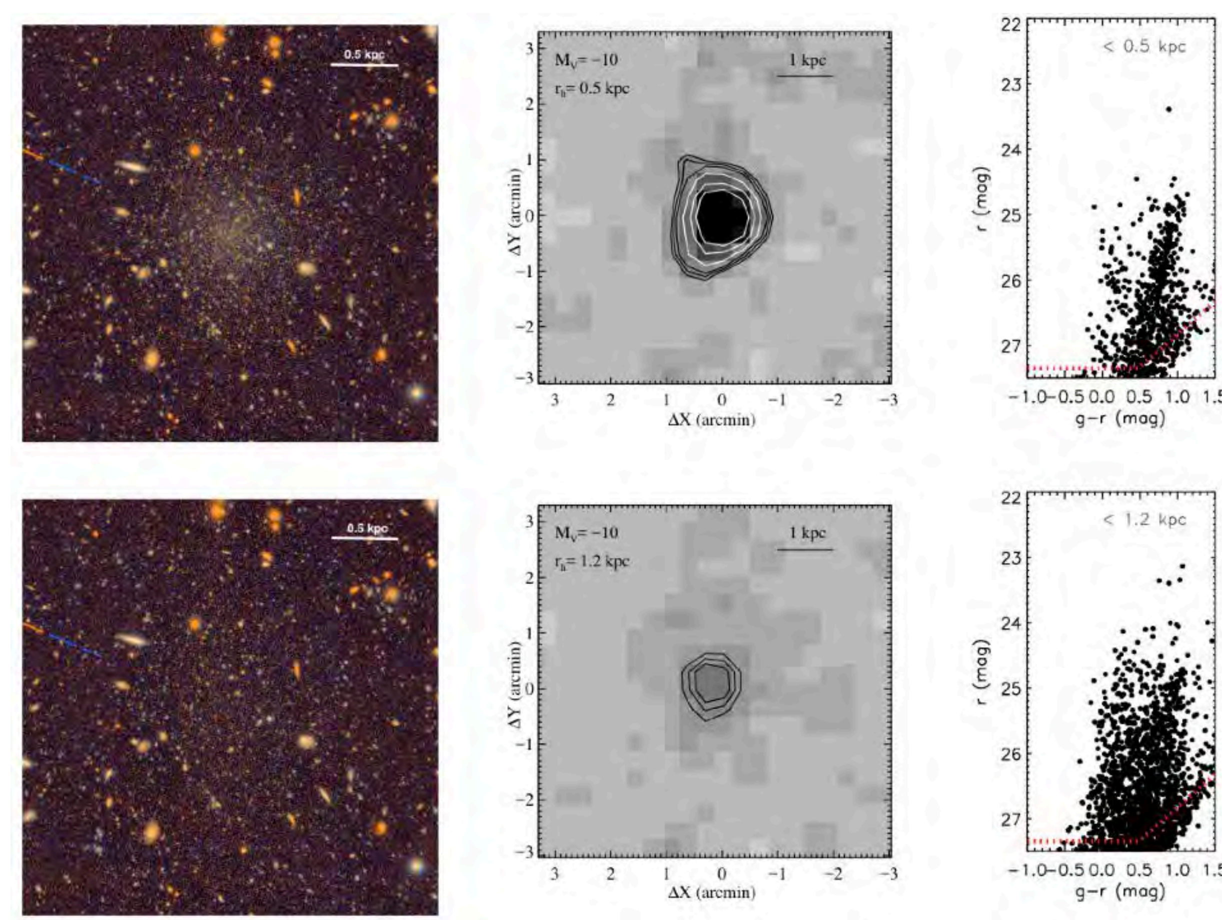
Where Can We Go From Here?
Lets think about resolved stars from the ground with HSC (& VRO)

NANCY GRACE ROMAN SPACE TELESCOPE

D=5 Mpc, M_V=-10, r_half=500pc, 1.2 kpc



D=3.5 Mpc, M_V=-10, r_half=500pc, 1.2 kpc



Implanting simulated dwarfs with a range of size, luminosity, ellipticity, stellar background & galactic latitude to forecast resolved dwarf discovery over the next decade from the ground.
Directly translatable to Roman simulations now.

Mutlu-Pakdil, Sand, et al. 2021

NSF

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Lets think about resolved stars from the ground with HSC (& VRO)

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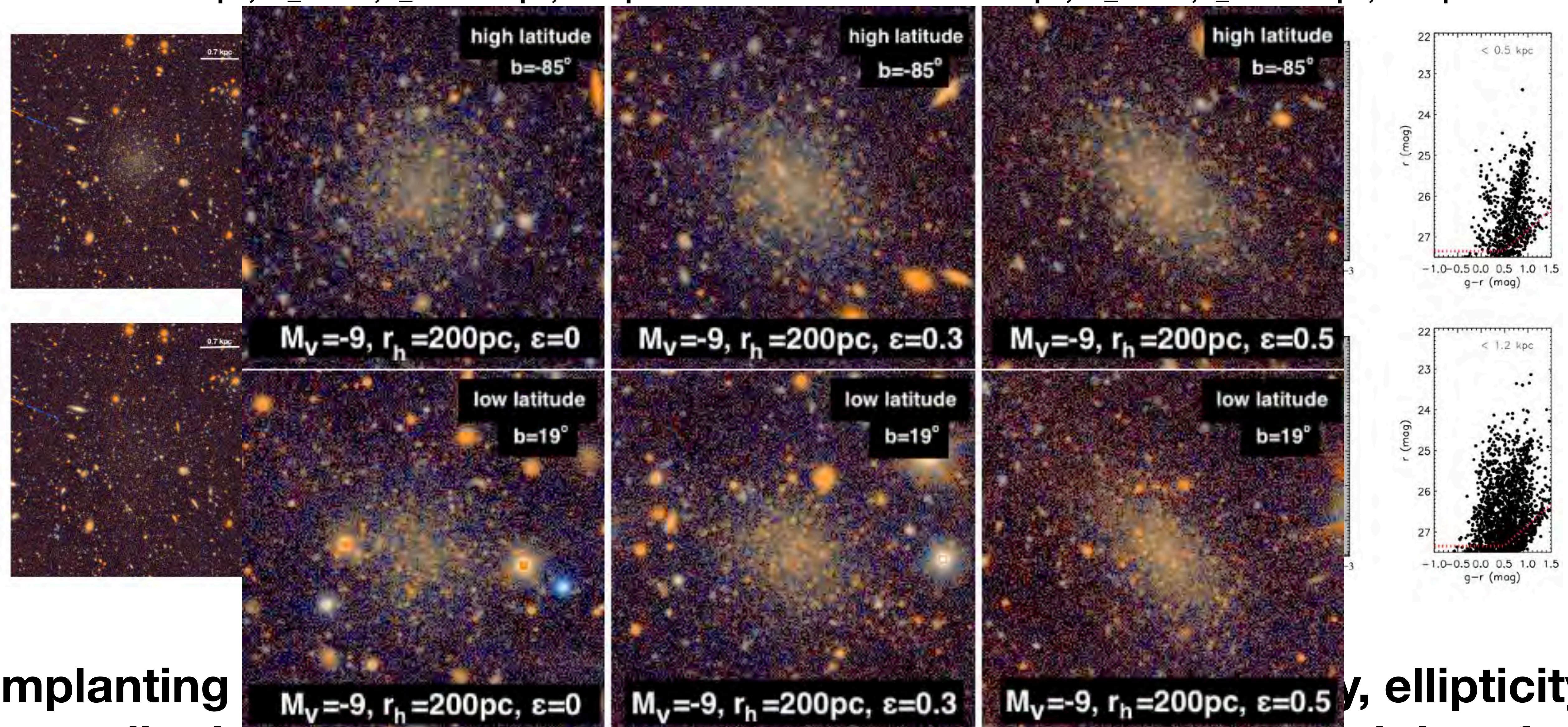

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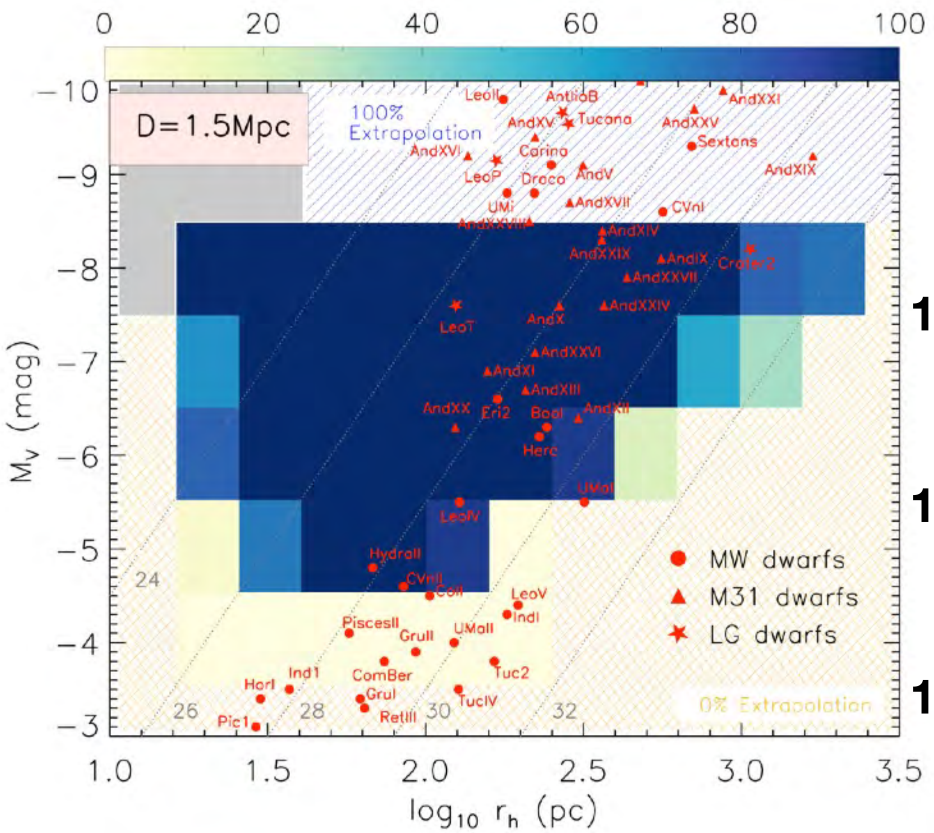
Results at three fiducial distances

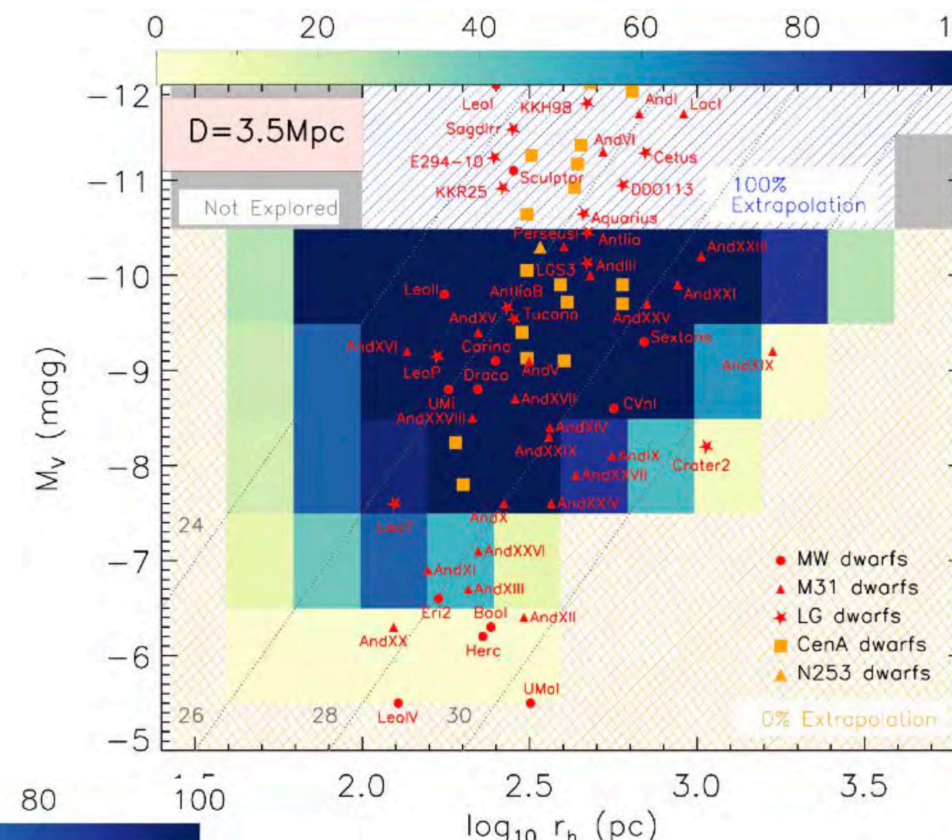


10^5 Lv

10^4 Lv

10^3 Lv

Ultra-faint dwarfs in NGC3109

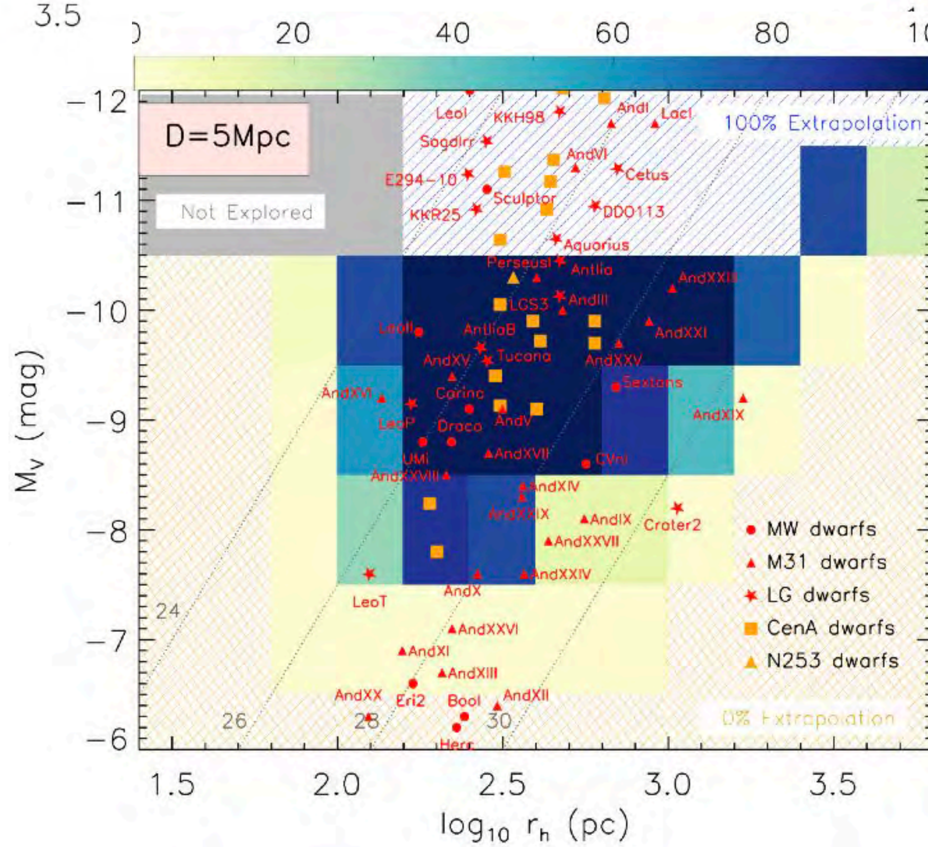


10^7 Lv

10^6 Lv

10^5 Lv

10^4 Lv



Fill out the census at D=3.5 Mpc down to M_V=-7 to -8

M64, M94 and M83 are excellent targets

Mutlu-Pakdil, Sand, et al. 2021

Lets think about resolved stars from the ground with HSC (& VRO)

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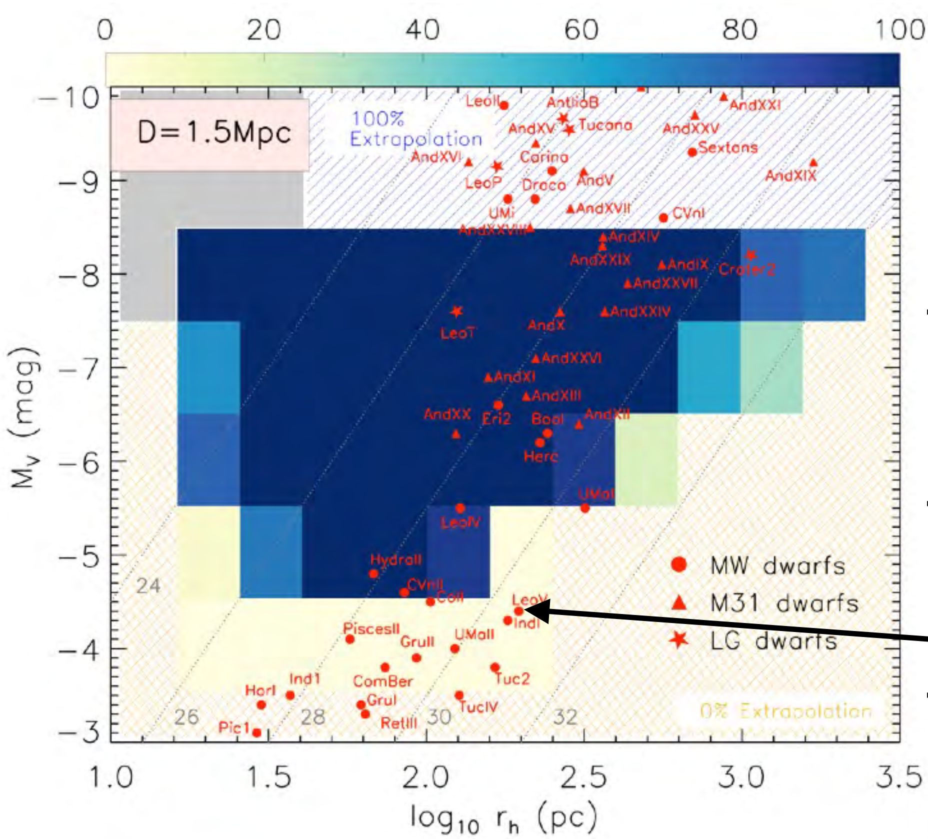


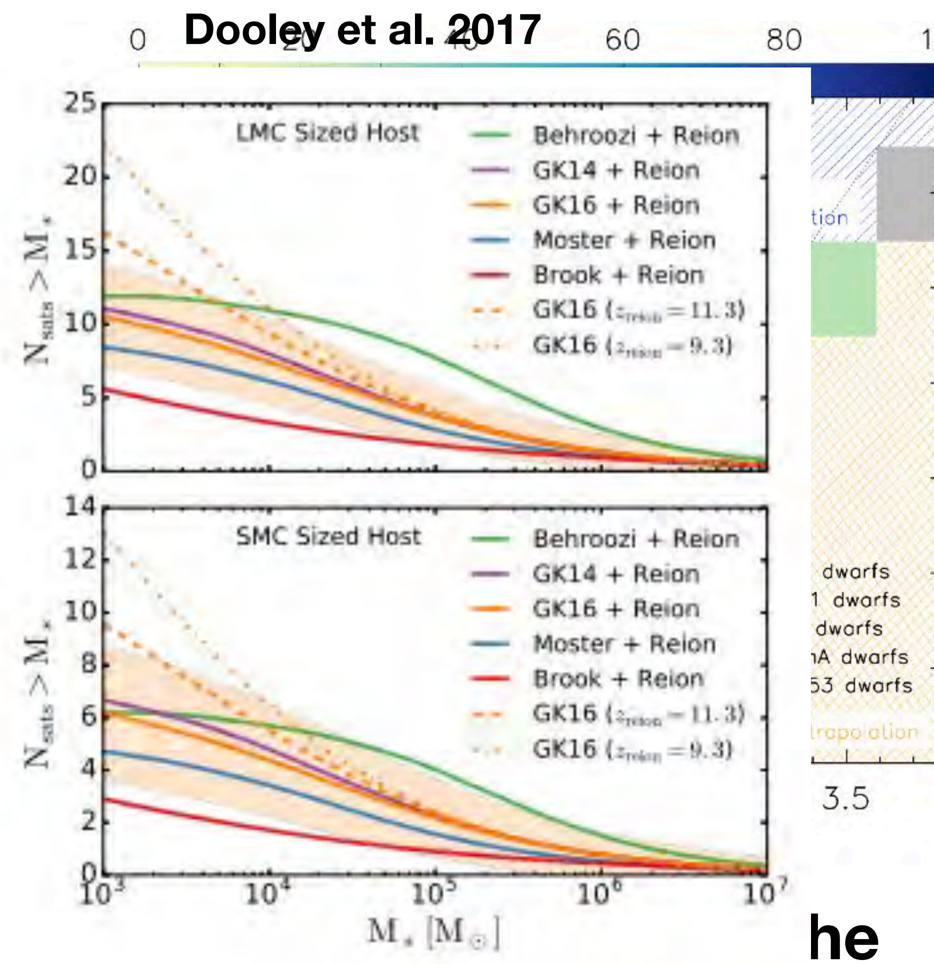
Ultra-faint dwarfs in NGC3109

10^5 L_V

10^4 L_V

10^3 L_V

Dooley et al. 2017



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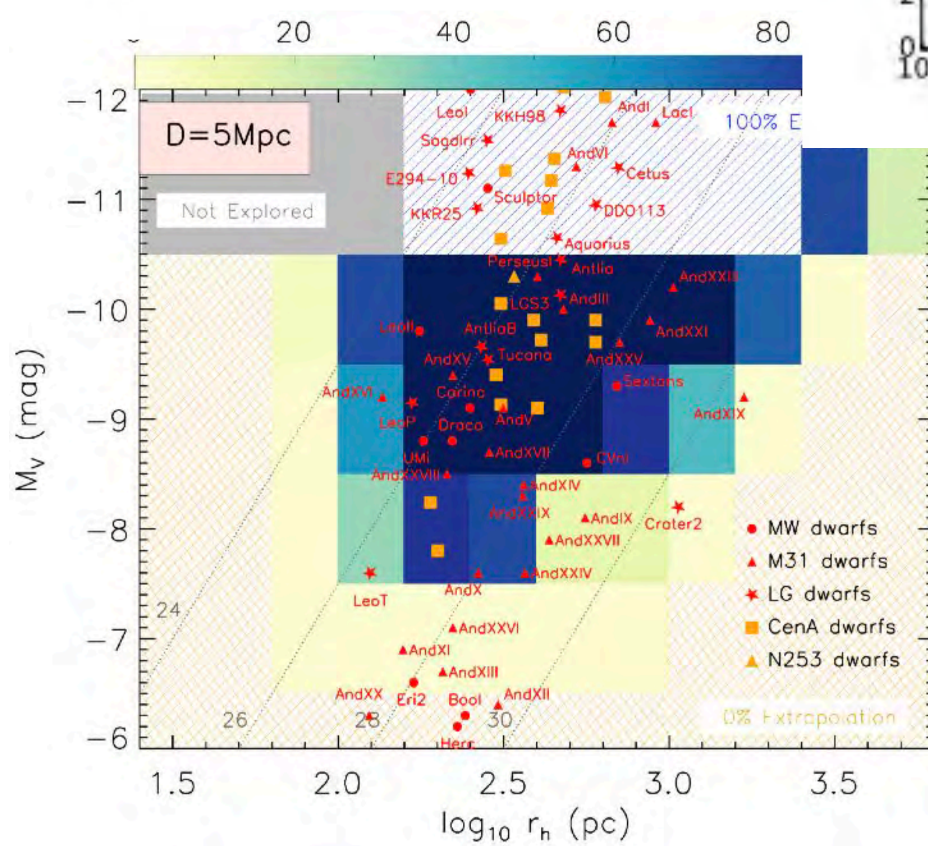

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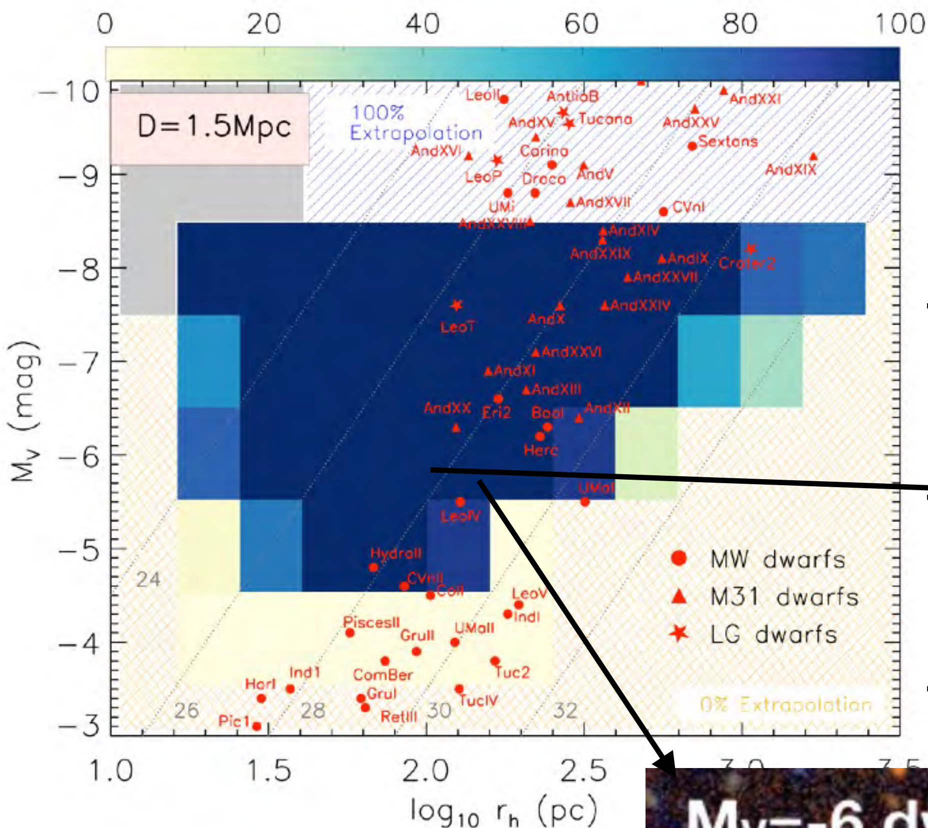

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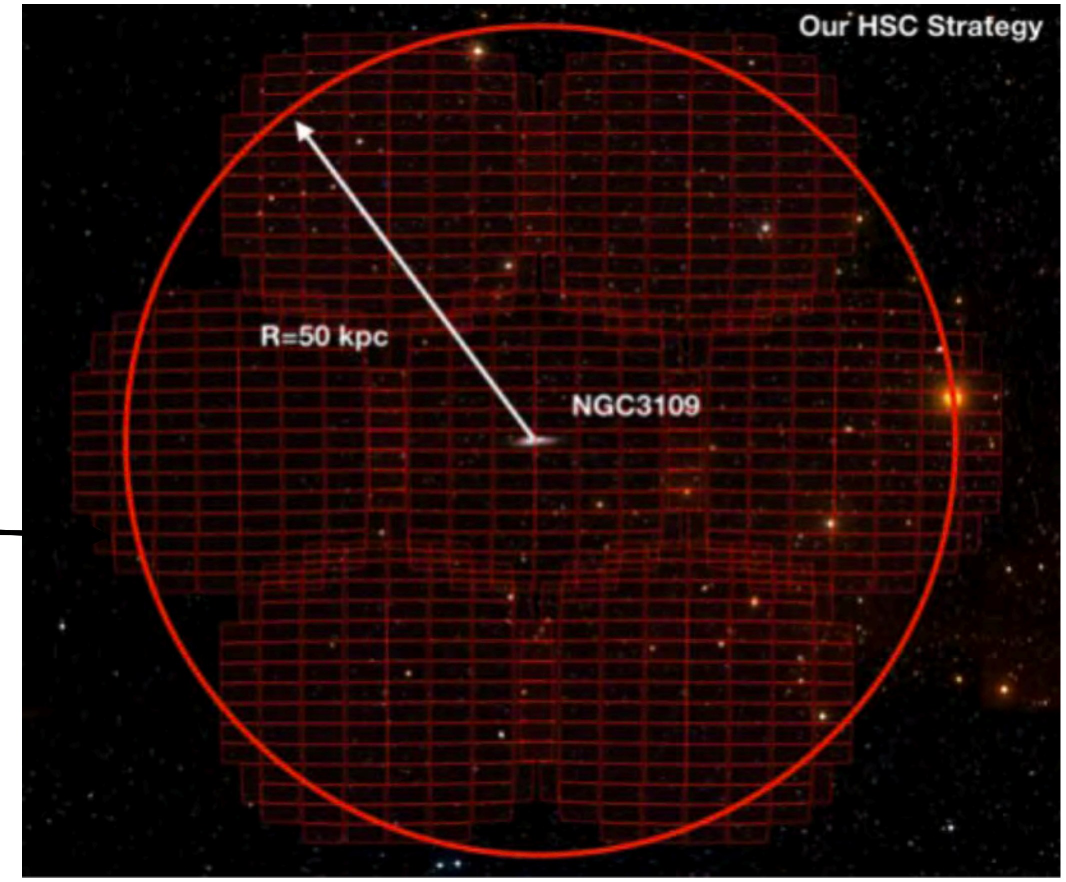
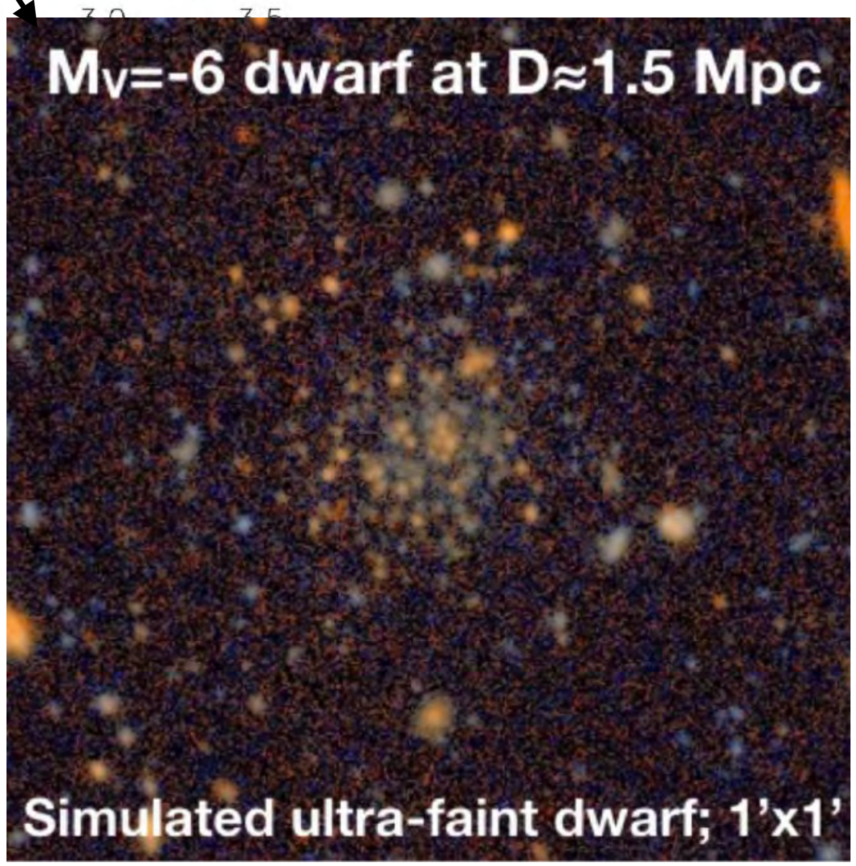
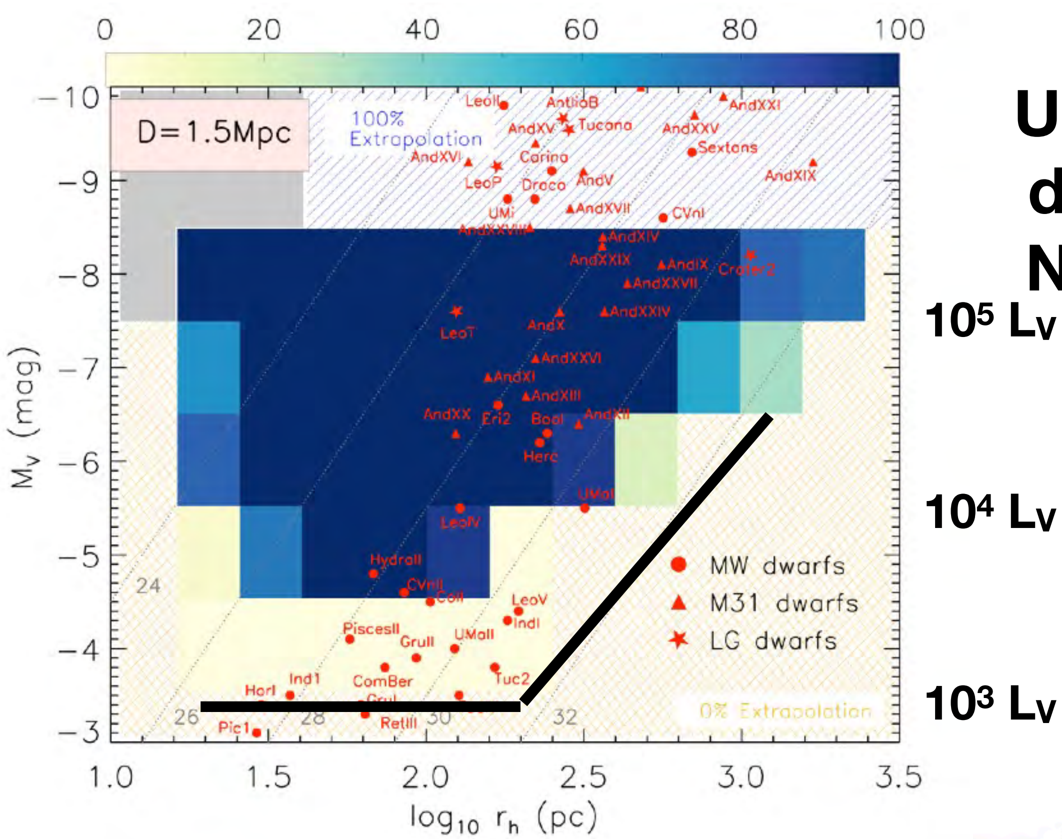


NASA Keck time with HSC awarded as precursor WINGS program



Mutlu-Pakdil, Sand, et al. 2021

Next step: Combine our machinery for dwarf simulations and detection efficiency and apply to Roman/STIPS and plausible nearby galaxy surveys.



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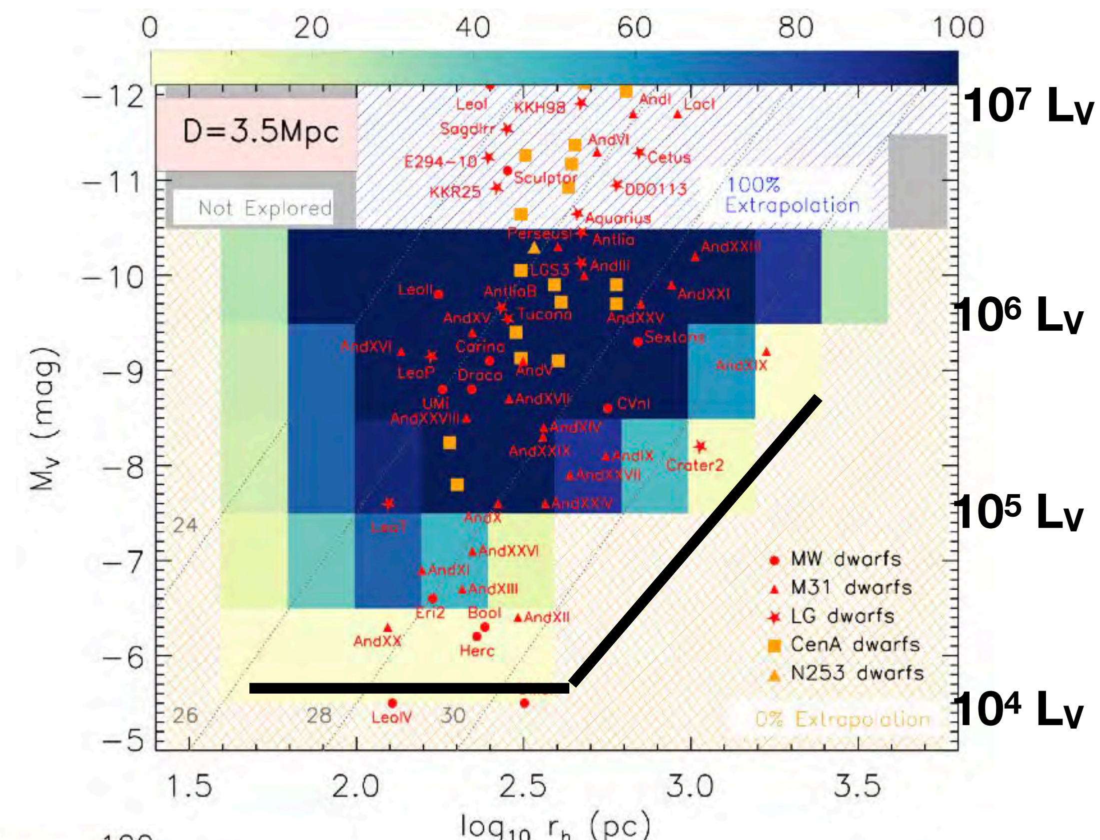

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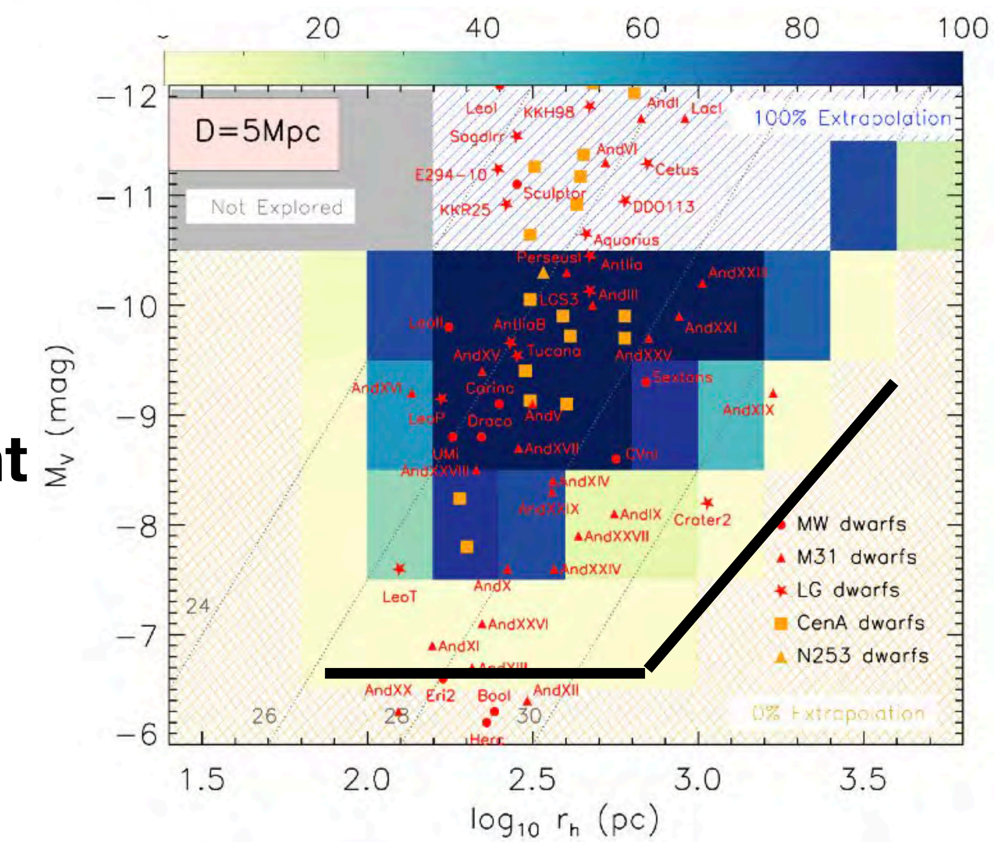

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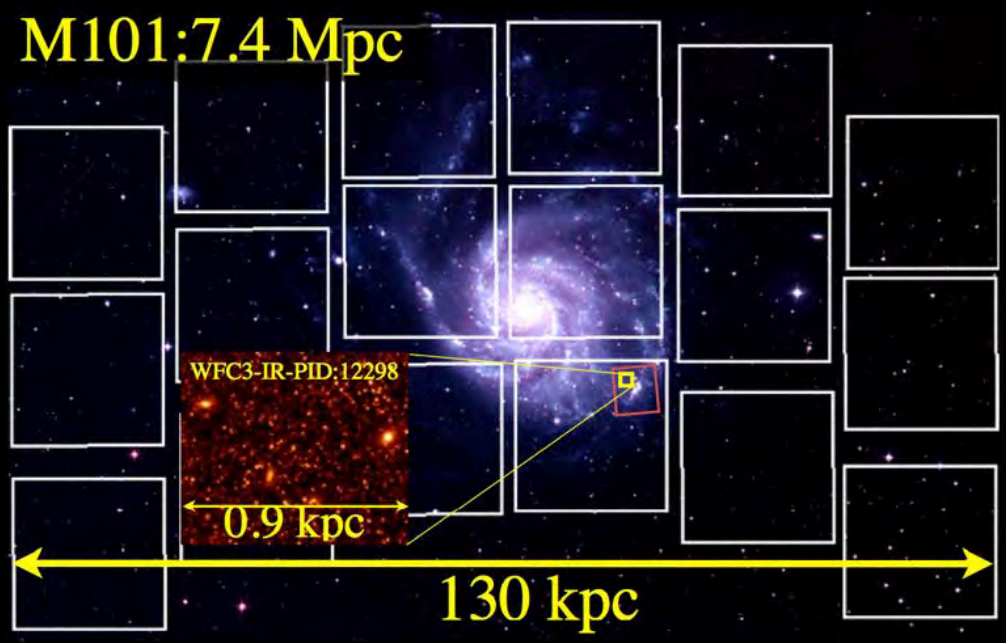
Mutlu-Pakdil, Sand, et al. 2021

Summary



~10 hours with Roman at 10 Mpc

- Roman will do critical work on dwarf galaxies and other substructures to constrain our picture of structure formation on small scales
- WINGS team has begun simulating dwarf galaxies with STIPS.
- Infrastructure in place to do a comprehensive study of dwarf galaxy detection efficiency with Roman.
- Precursor surveys with HSC and other wide-field imagers will provide critical targets for Roman

Thank you