Building a statistical sample of extremely low mass galaxies

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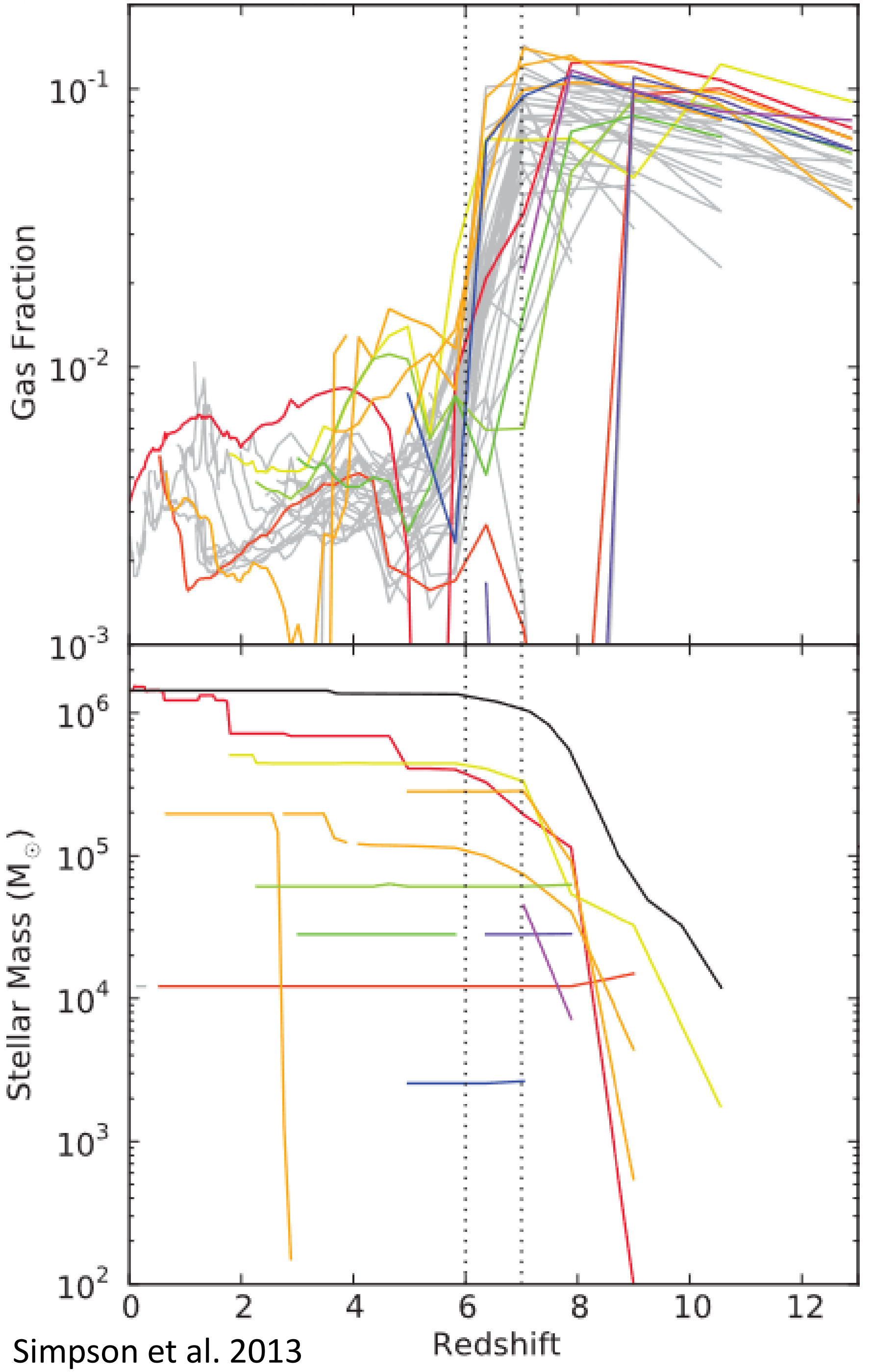
Background image: DECaLS

Reionization quenching

- When the Universe was 0.5-1 Gyr old the epoch of cosmic reionization transformed the IGM.
- The dark matter potential wells of the lowest mass galaxies were too shallow to contain gas dense enough to self-shield (e.g. Benson et al. 2002).
- Their entire gas reservoir was ionized and they would never form stars again.
- These galaxies are commonly called ultra-faint dwarfs (UFDs).

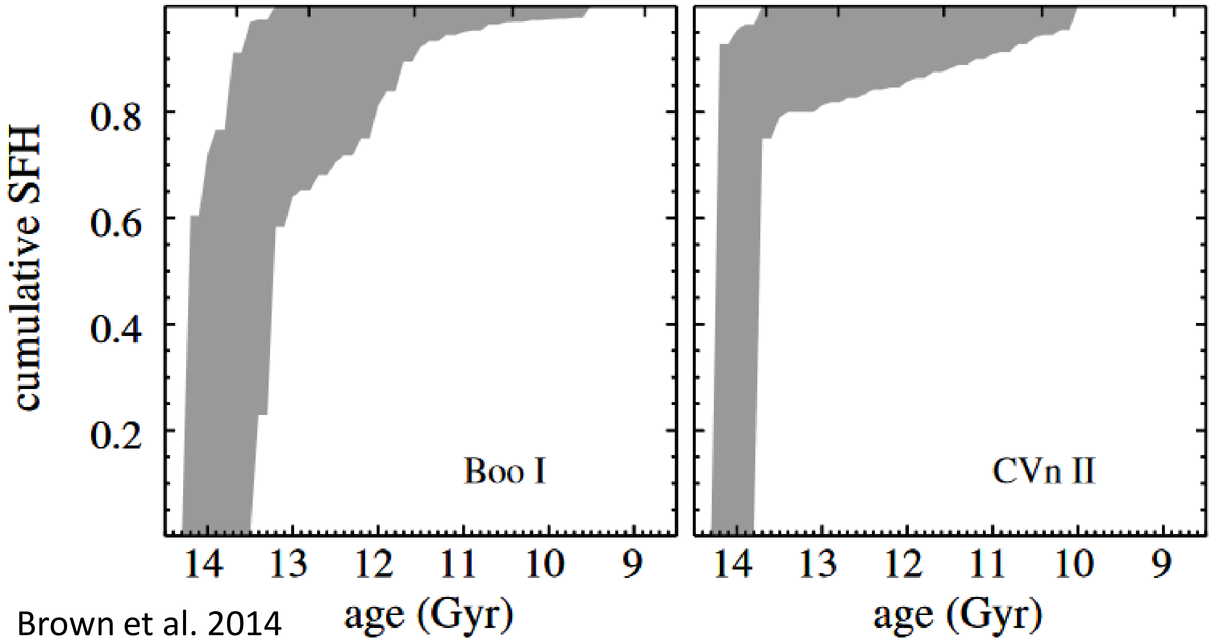


Simpson et al. 2013

Ultra-faint dwarfs in the Local Group

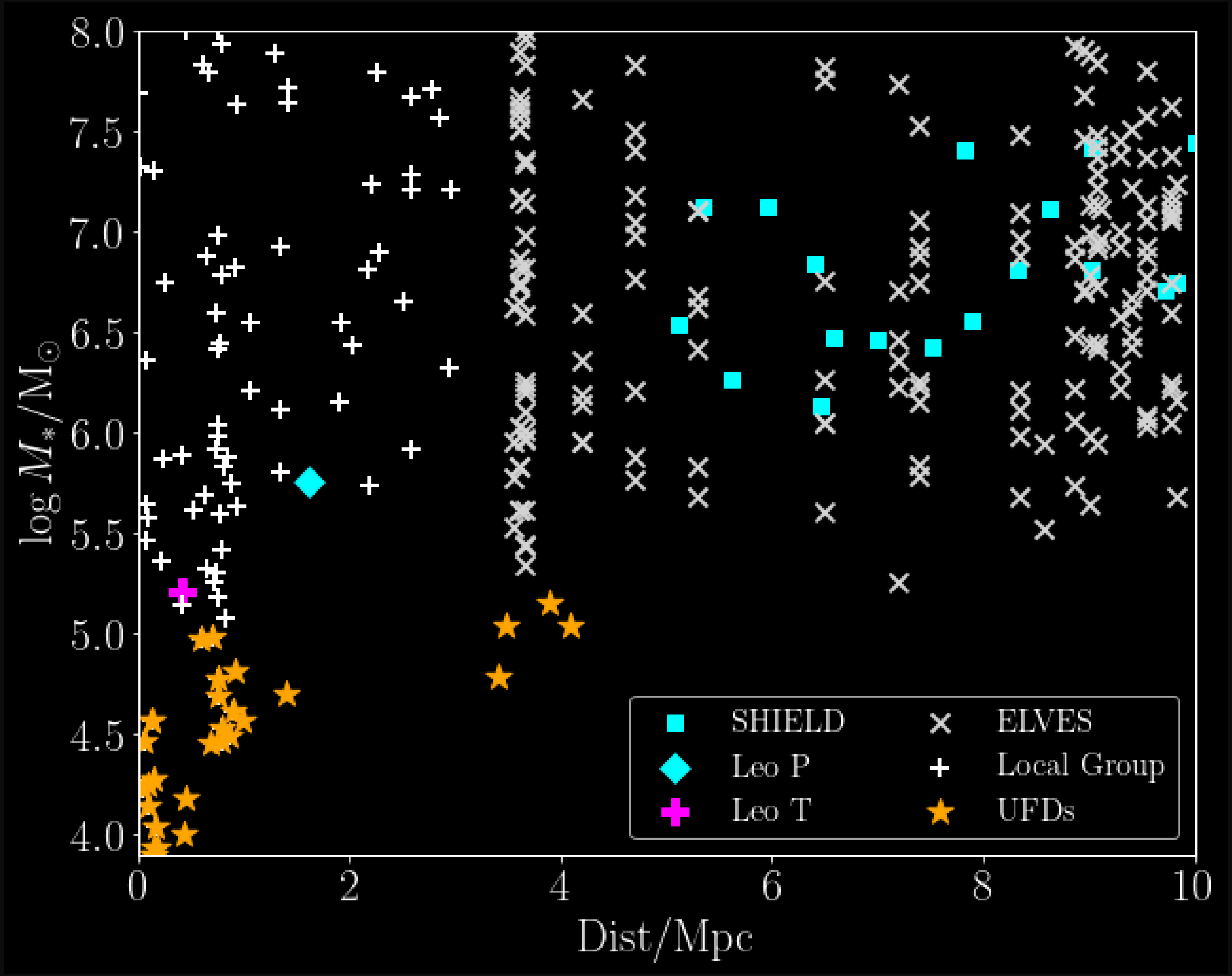
- With HST (and now JWST) it is possible to measure the star formation histories of nearby UFDs.
- Several UFDs within the LG appear to have formed almost all their stars before the end of reionization (e.g. Brown et al. 2014).
- However, how can we confidently separate environmental effects within the LG? Answer: Look at isolated galaxies.

Star formation histories of two UFDs in the LG



Brown et al. 2014

Gaps in the low-mass galaxy population

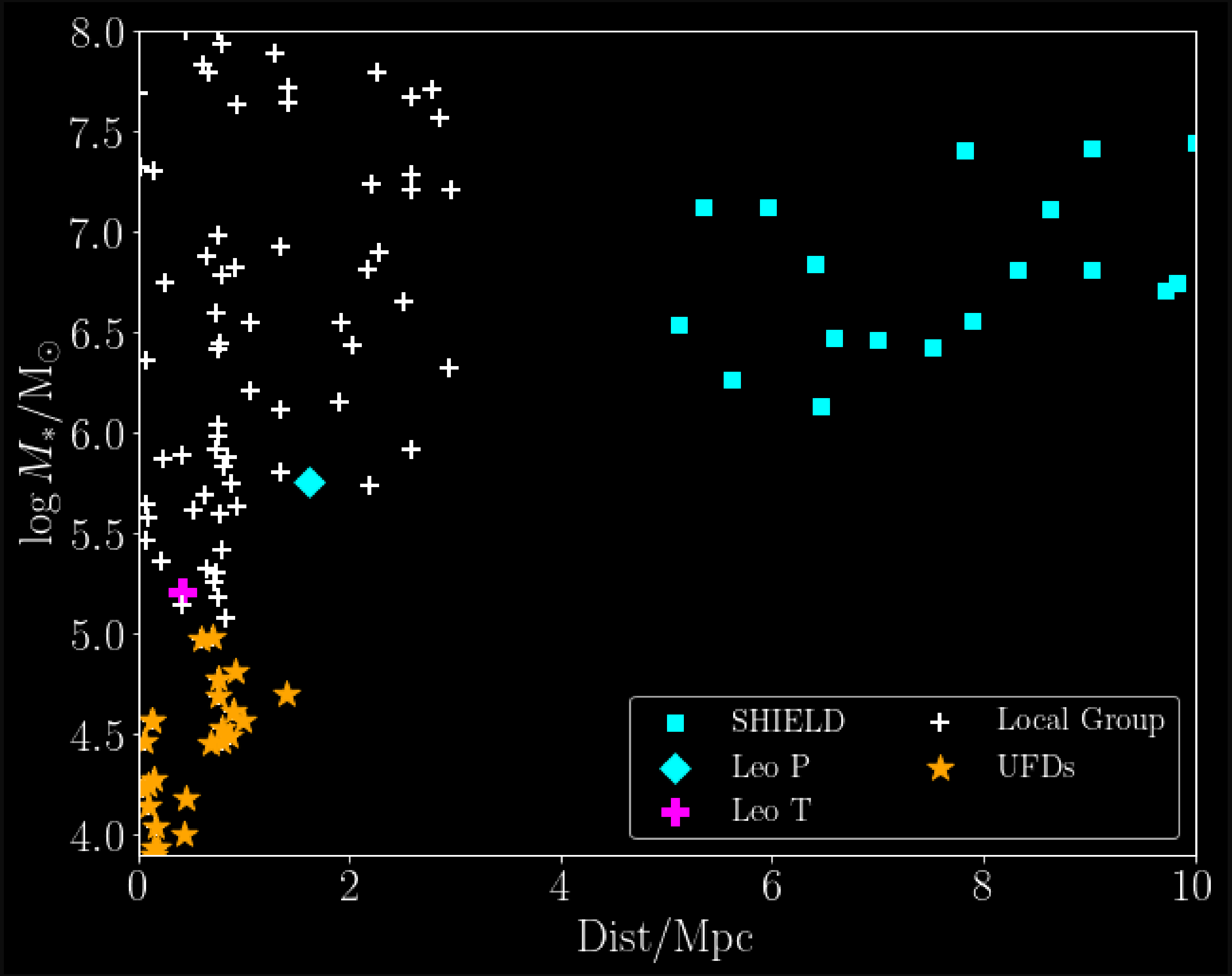


SHIELD:
Cannon et al. 2011,
McQuinn et al. 2014

ELVES:
Carlsten et al. 2022

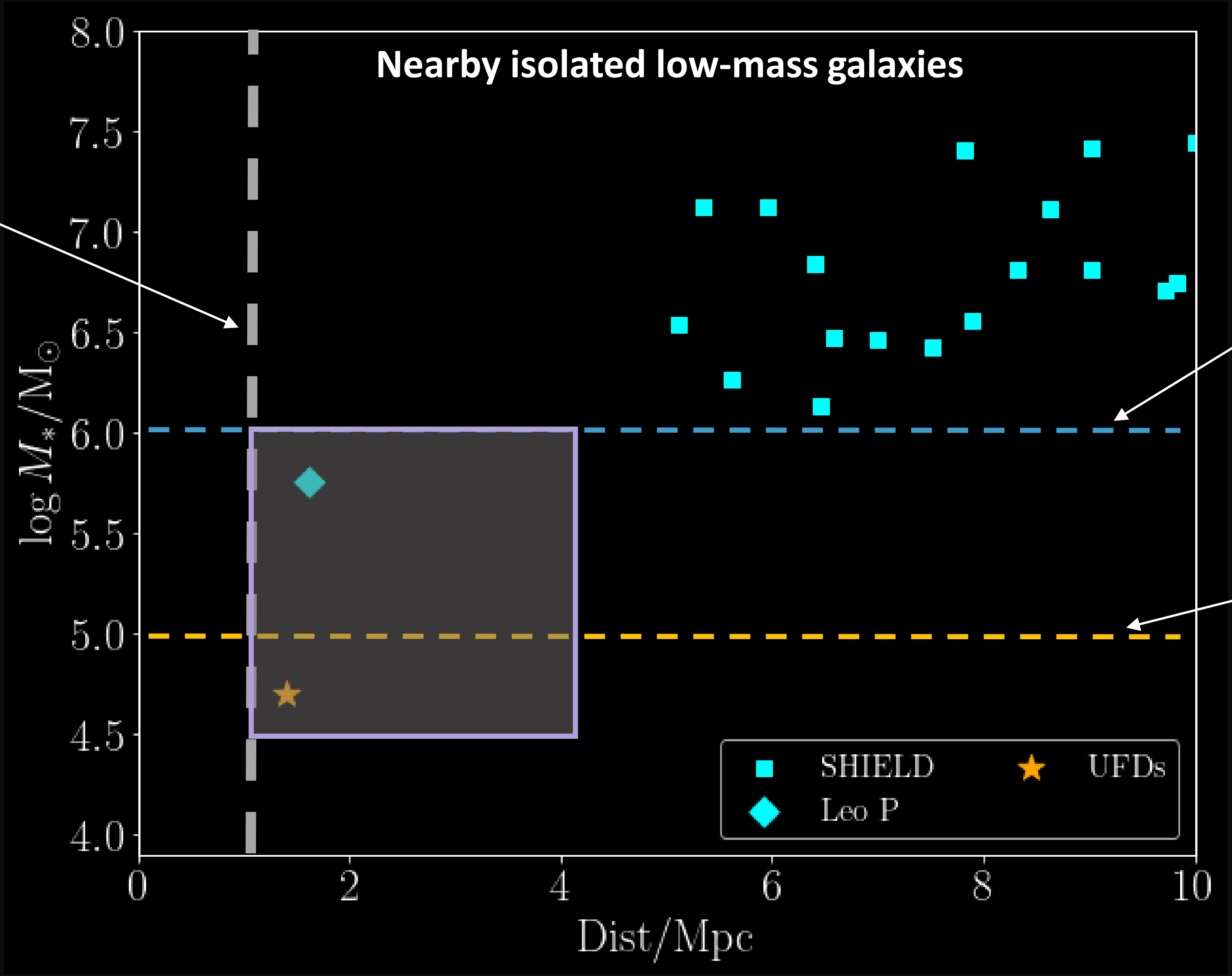
Leo P:
Giovanelli et al. 2013,
McQuinn et al. 2015

Gaps in the low-mass galaxy population



Gaps in the low-mass galaxy population

Too close to the Local Group.

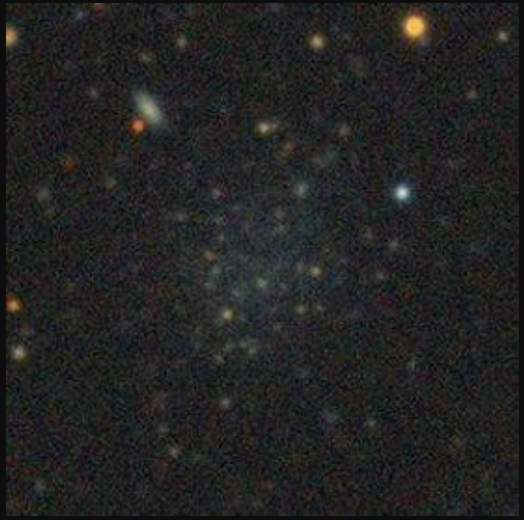


Sensitivity limit of current HI surveys.

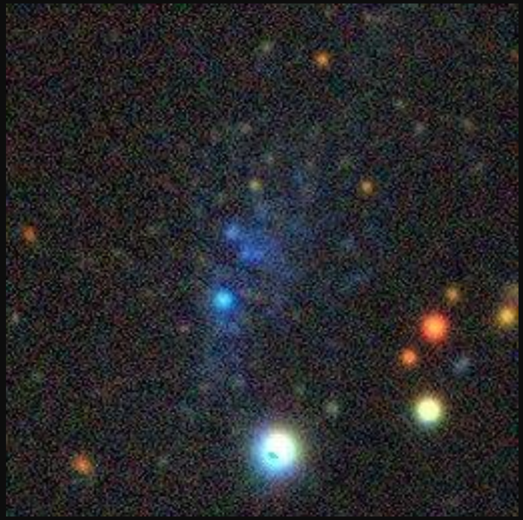
Approximate threshold for UFDs.

Tucana B and Leo P

- Until a year ago, Leo P was the lowest mass star-forming galaxy known in isolation and Tucana B was the most isolated UFD known.
- Established search algorithms (i.e. resolved star searches) did not find these objects, likely because they are semi-resolved.
- We aim to fill in the gap from both sides by finding both Leo P and Tucana B analogs.



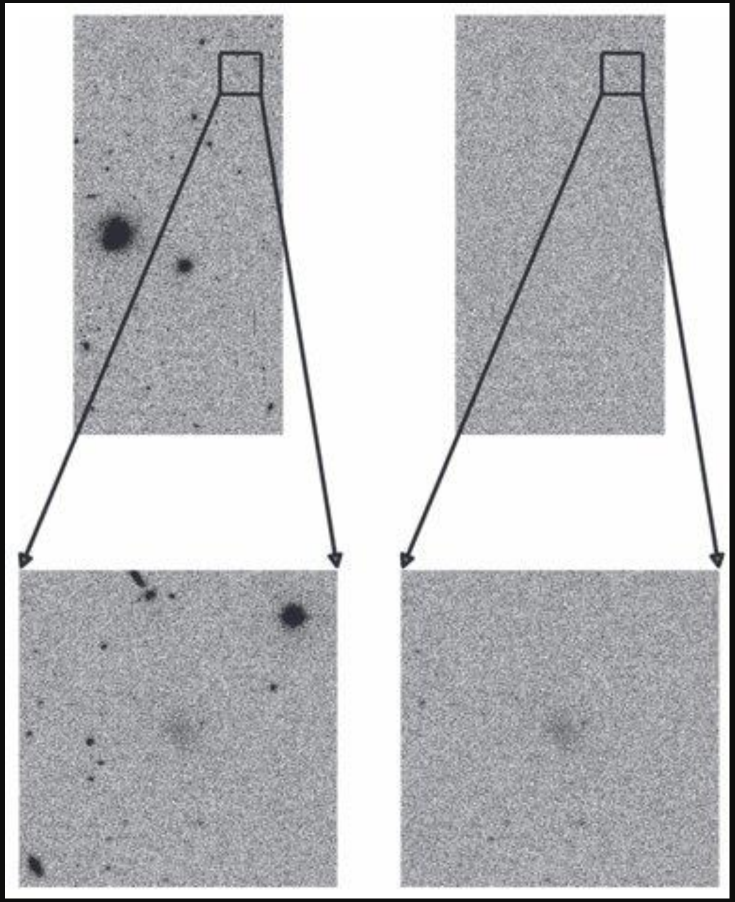
Tucana B – Found "by eye"
(Sand et al. 2022)



Leo P – Found via HI line
(Giovanelli et al. 2013)

SEAMLESS

(SEmi-Automated Machine LEarning Search for Semi-resolved galaxies.)

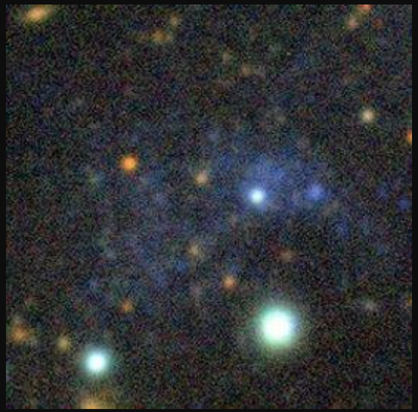


SMUDGes (Zaritsky et al. 2019)

4×10^5 candidates

Retrained CNN classifier:

1314 candidates, including … Pavo!



Jones et al. 2023

Follow-up strategy

Deep imaging:

- Resolve stars
- TRGB dist. (<4Mpc)
- Basic stellar pops

HI synthesis imaging:

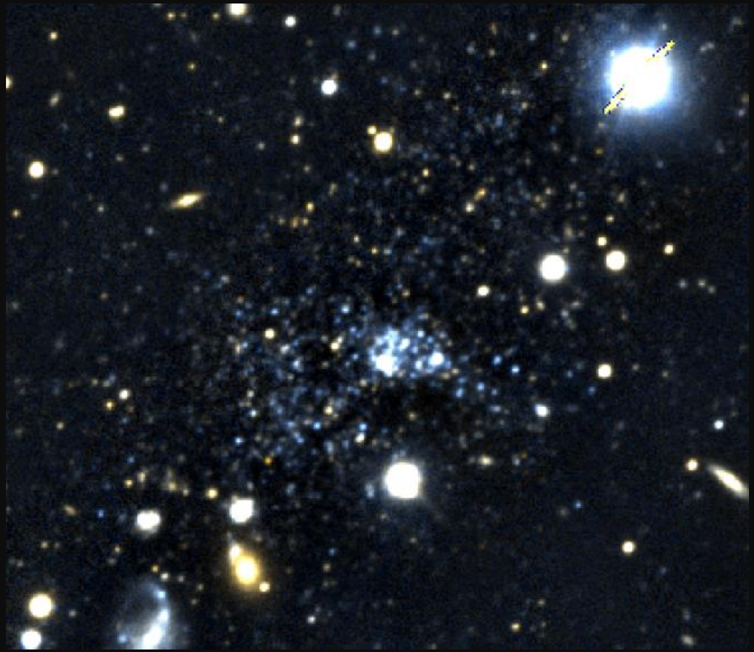
- Gas content
- Radial velocity
- Gas kinematics

HST imaging:

- Better TRGB distance
- No crowding
- Stellar pops/SFH

SEAMLESS: Pavo, Corvus A, and Hydrus

Pavo

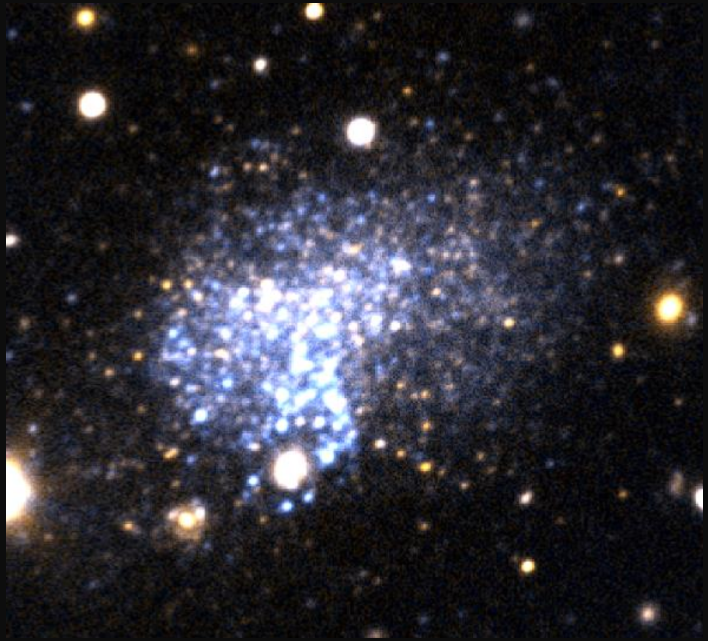


Magellan/IMACS image
(Jones et al. 2023)

- The lowest mass star-forming galaxy currently known in isolation.
- No known neighbor within 680 kpc.
- Young, blue stellar population, but no HII regions.
- Has a gas reservoir, but much poorer than that of Leo P.
- May be in a lull in its SFH (cf. Rey et al. 2022).

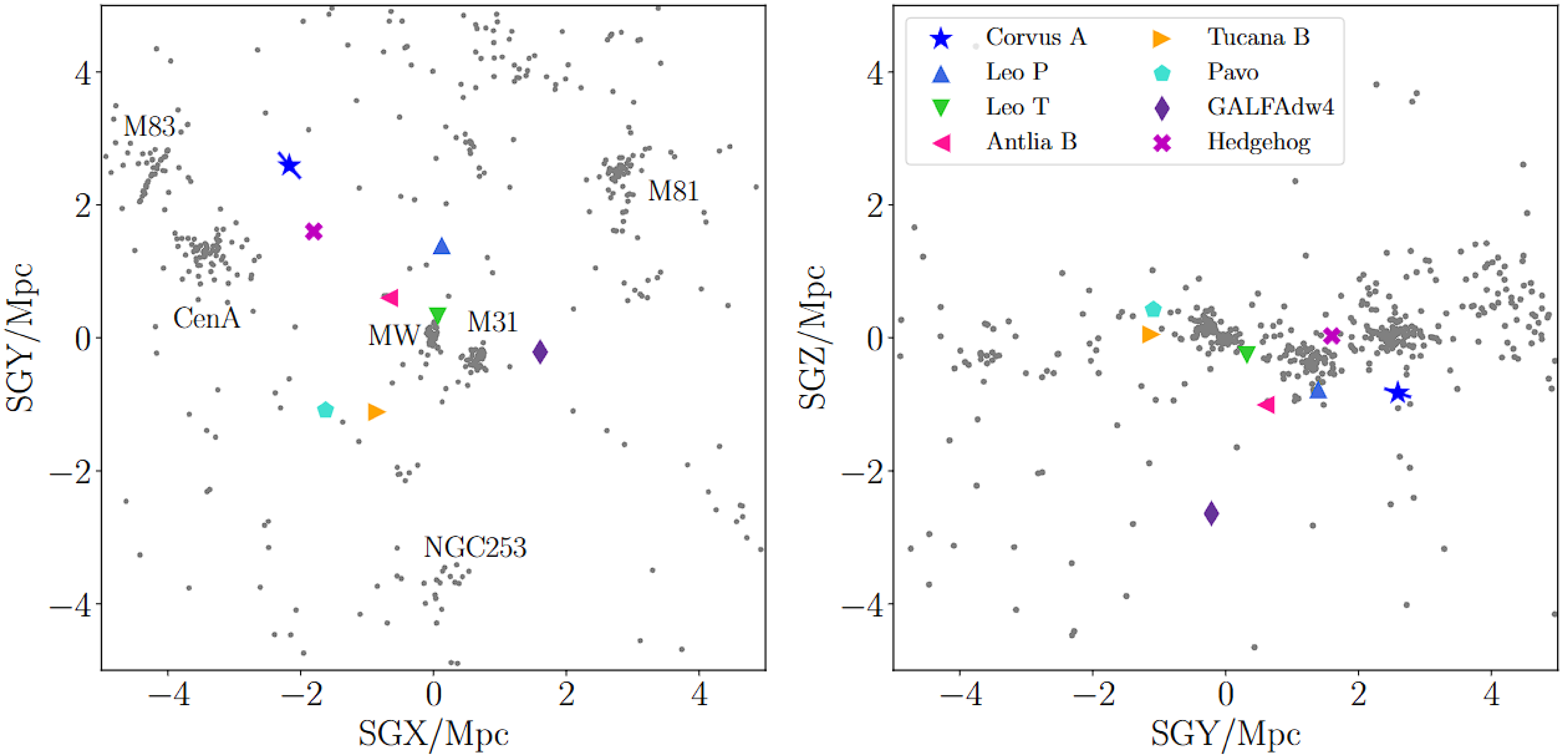
SEAMLESS: Pavo, Corvus A, and Hydrus

Corvus A



Magellan/Megacam image
(Jones et al. 2024)

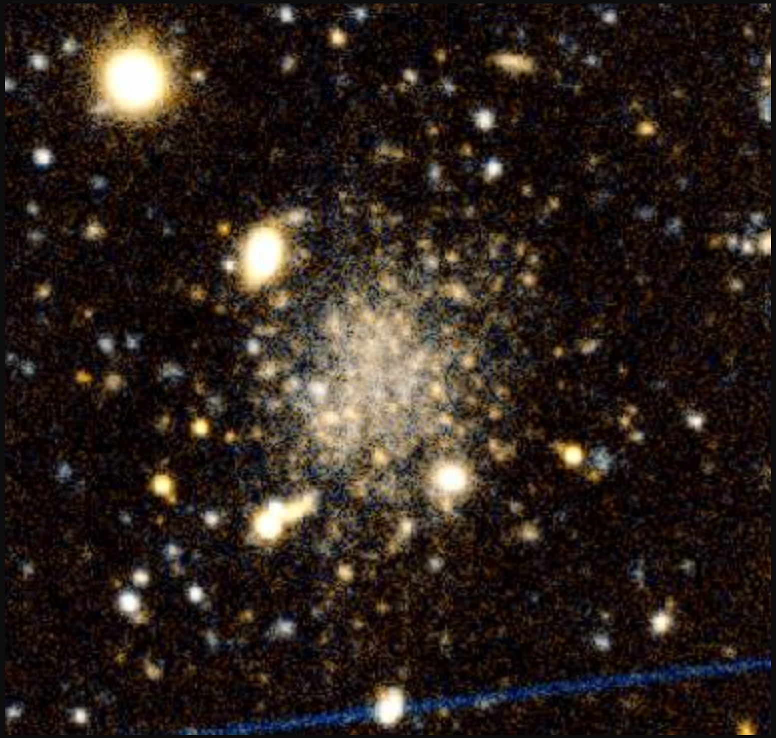
- Intermediate mass between Leo P/Pavo and the SHIELD sample.
- Remarkably isolated, no known neighbor within 1 Mpc.
- Nearly face-on, rich HI distribution.
- Crowded region of blue stars, but no Hα emission.



M83
M81
CenA
MW
M31
NGC253
SGY/Mpc
SGX/Mpc
SGZ/Mpc
SGY/Mpc
Corvus A
Leo P
Leo T
Antlia B
Tucana B
Pavo
GALFAdw4
Hedgehog

SEAMLESS: Pavo, Corvus A, and Hydrus

Hydrus



Magellan/Megacam image
(Fielder et al. in prep.)

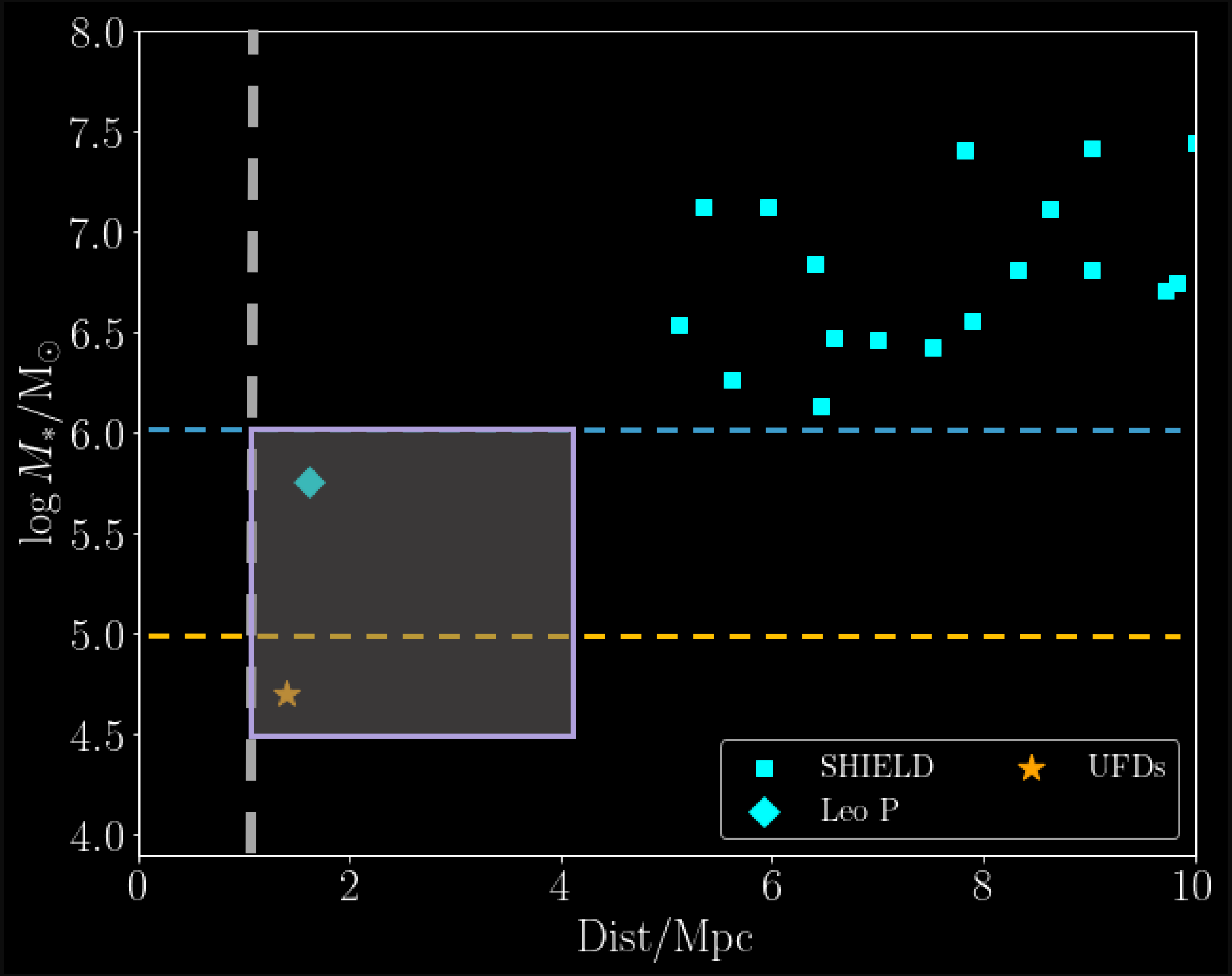
- Quenched and isolated.
- Perhaps slightly more massive than a UFD?
- Still finalizing distance measurement.

Catherine Fielder

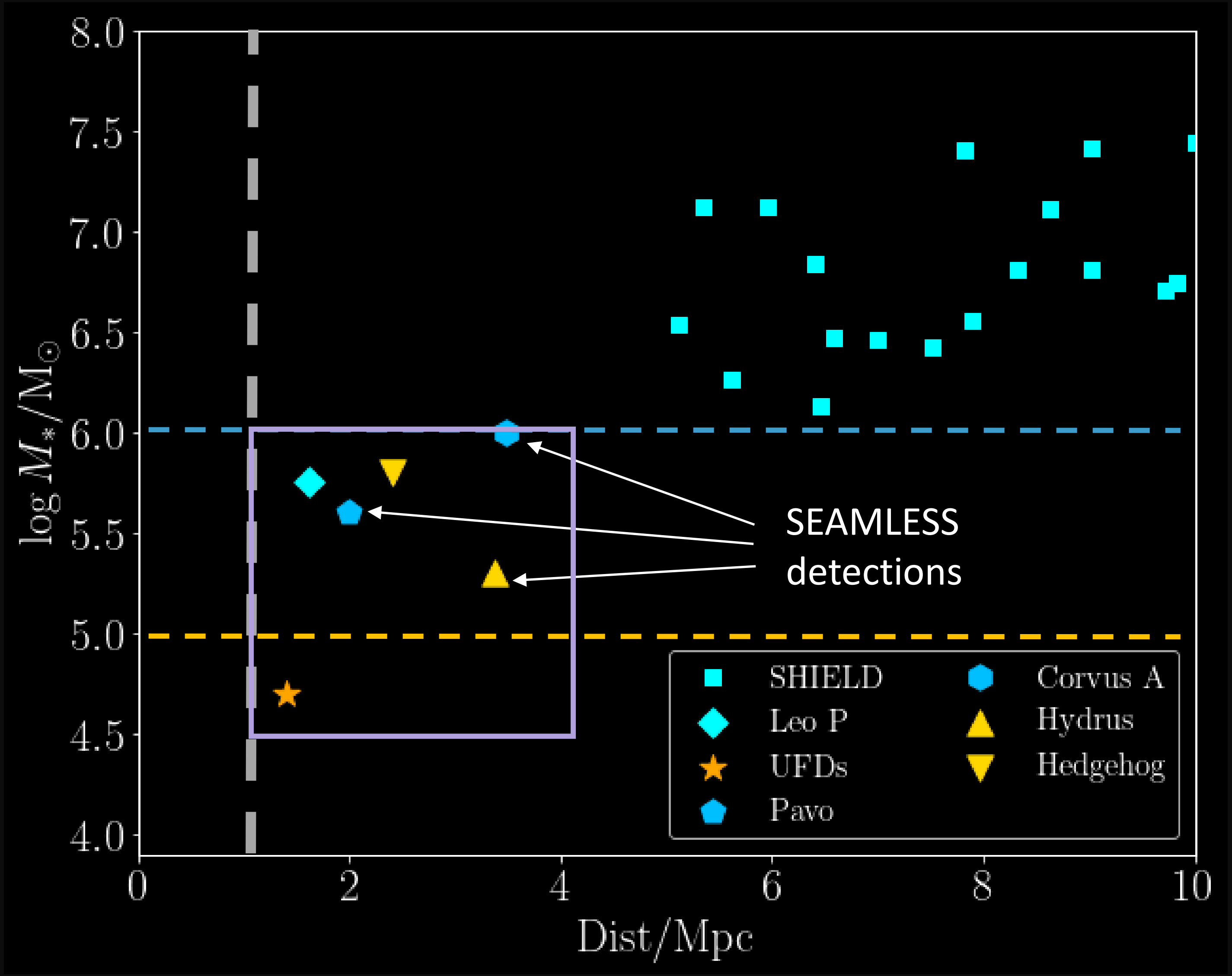
Post-doc at Arizona

Poster on dwarf
galaxy stellar streams

Isolated extremely low-mass galaxies



Isolated extremely low-mass galaxies



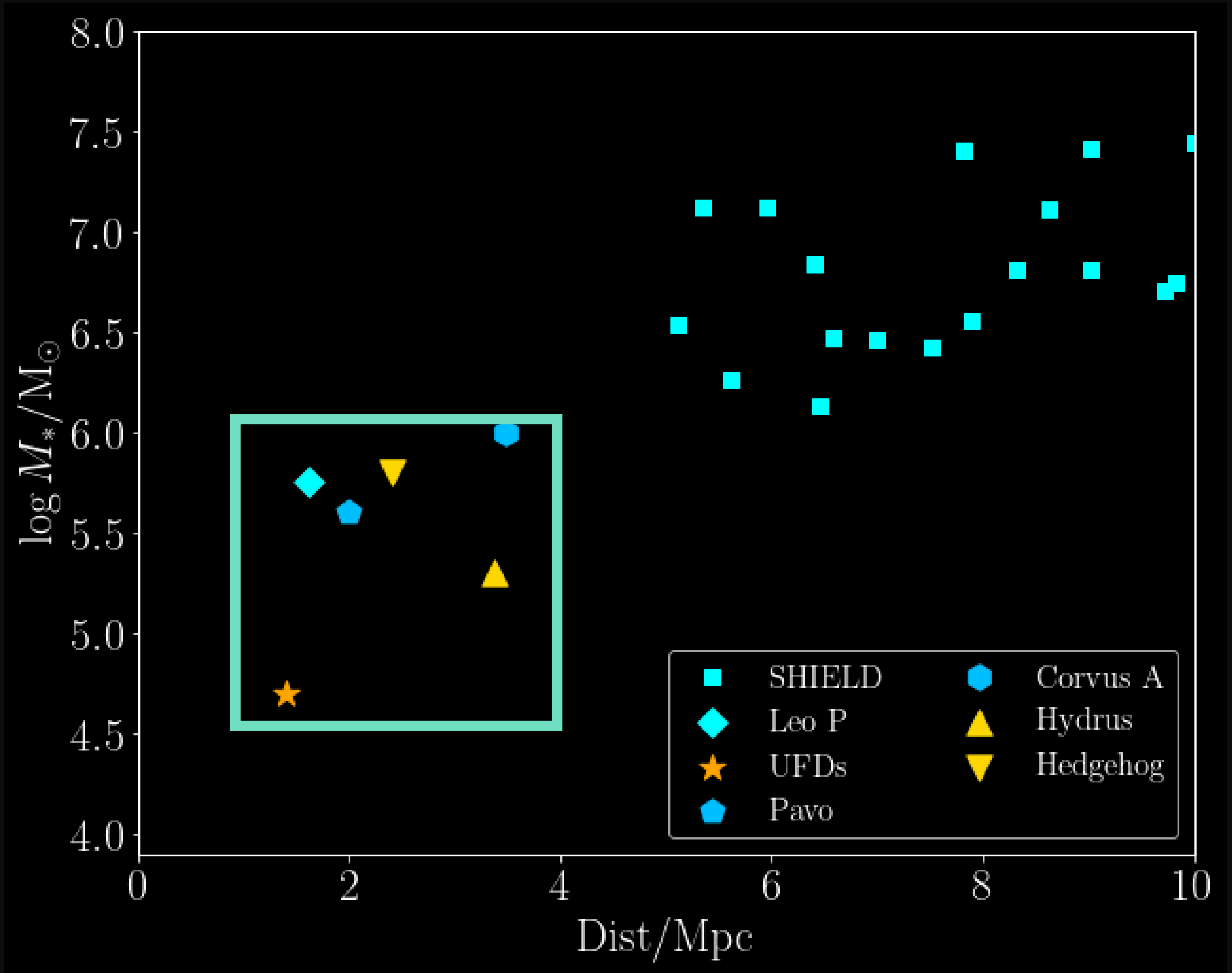
SEAMLESS:
Jones et al. 2023,
Jones et al. 2024,
Fielder et al. in prep.

Hedgehog:
Li et al. 2024

Future: LSST & Roman

Some ballpark numbers:

Resolved	LSST	Roman
Area	18000 deg^2	2000 deg^2
Max dist.	≈4 Mpc	≈10 Mpc
Volume	350 Mpc^3	600 Mpc^3

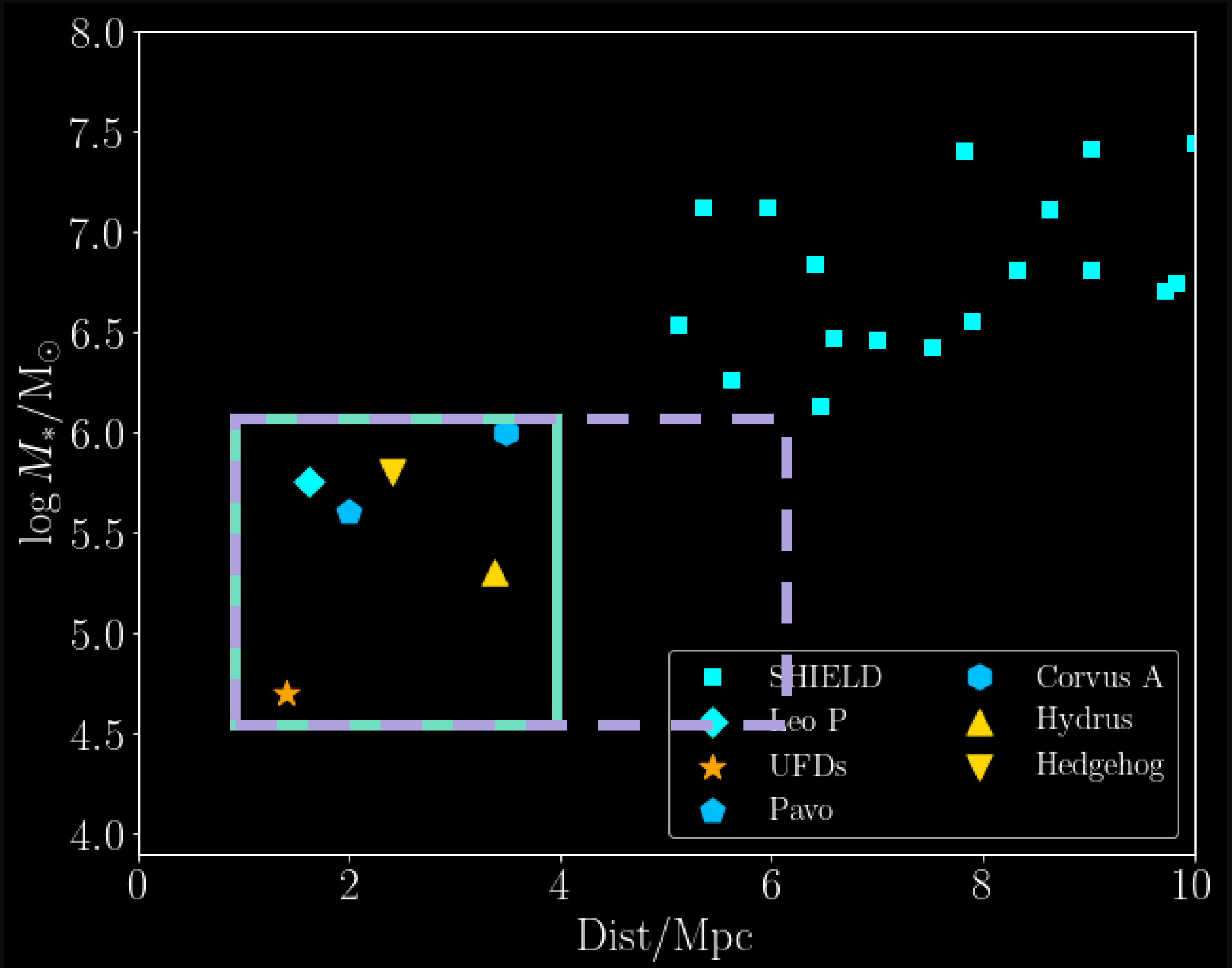


Future: LSST & Roman

Some ballpark numbers:

Resolved	LSST	Roman
Area	18000 deg^2	2000 deg^2
Max dist.	≈4 Mpc	≈10 Mpc
Volume	350 Mpc^3	600 Mpc^3

Semi-resolved	LSST	Roman
Area	18000 deg^2	2000 deg^2
Max dist.	≈6 Mpc	≈15 Mpc
Volume	1200 Mpc^3	2000 Mpc^3



Summary

- SEAMLESS is filling in the extreme low mass ($M_* < 10^6$) regime for isolated galaxies from both sides (quenched and star-forming) in a single search.
- We anticipate discovering/confirming around a dozen galaxies.
- We are currently going through the CNN's "trash" and improving the algorithm (e.g. why we missed Hedgehog).

- Gains in survey volume are much more rapid (and cheap) by extending distance rather than by expanding footprint.
- Pushing low-mass galaxy searches in LSST and Roman into the semi-resolved regime will effectively expand their volumes by factors >3.
- For LSST, and especially Roman, following up candidates will be challenging, this will not be possible from the ground.

Questions?