# What is the nature of Neutral Hydrogen tails in the MeerKAT Fornax Survey?

Presented by: **Sambatriniaina Rajohnson**
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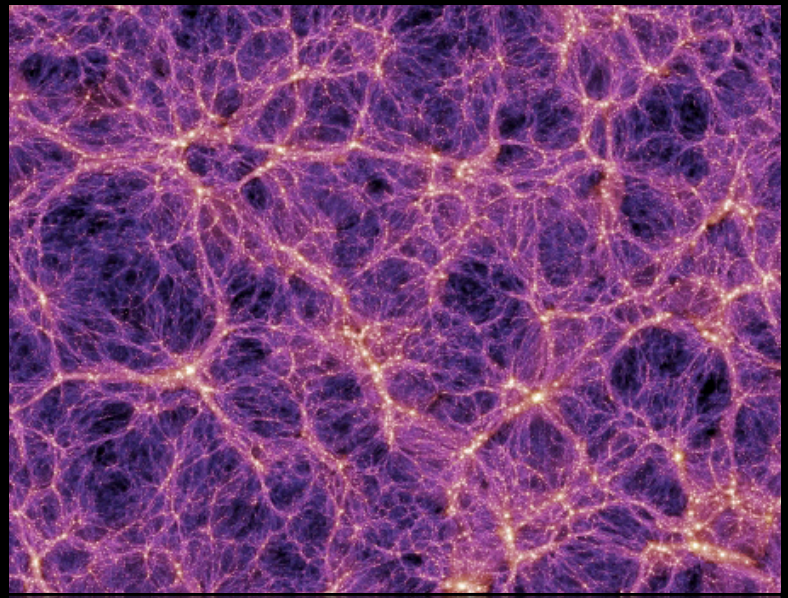
**The Fifth National Workshop on the SKA Project - From precursors to SKAO**

November 26th, 2025

Bologna, Area della Ricerca del CNR, Italy

# Galaxy morphology & environment

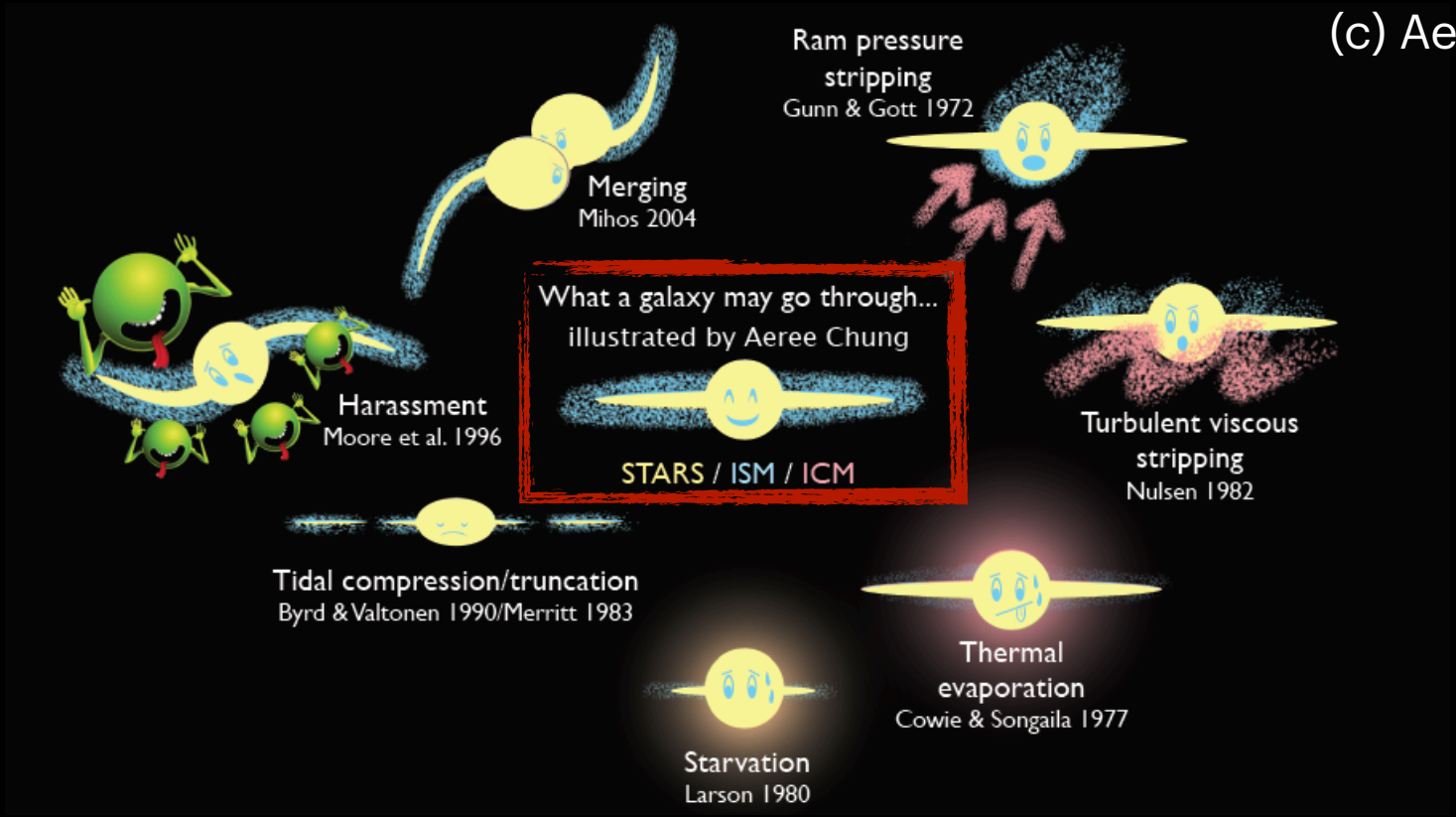


Cosmic web “image” from Springel et al. (2005)

- Galaxy properties influenced by their place in the cosmic web
- Low-density environments: slow decline in SFR
- High-density environments: ISM stripped more rapidly, accelerated quenching

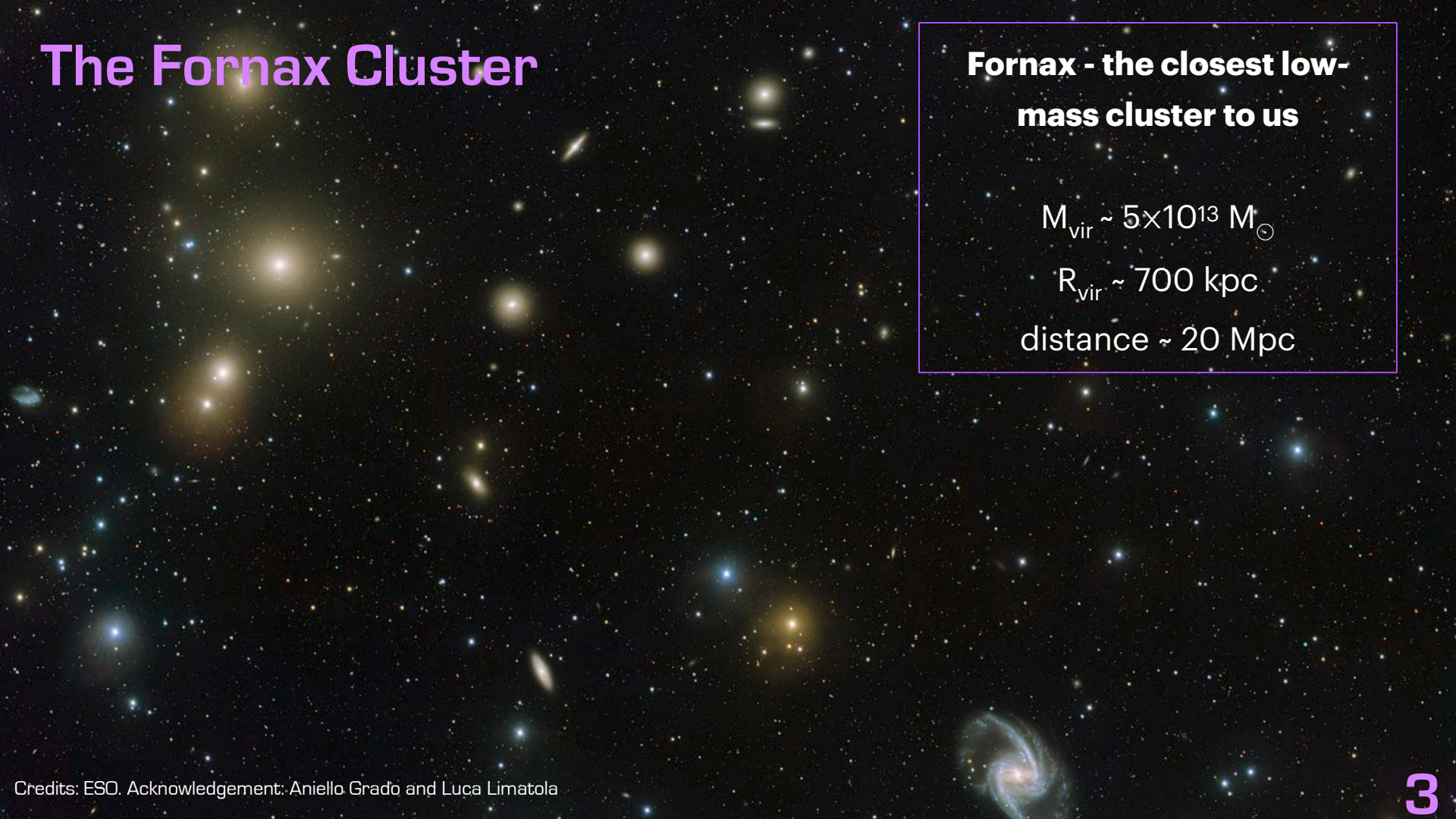
Dressler (1980), Larson (1980), Postman & Geller (1984), Giovanelli et al. (1986), Cappellari et al. (2011), etc.

# Environmental processes in Galaxy clusters




These environmental mechanisms leave observable signatures (especially in the cold gas component)

# The Fornax Cluster



**Fornax - the closest low-mass cluster to us**

$M_{vir} \sim 5 \times 10^{13} M_{\odot}$

$R_{vir} \sim 700$ kpc

distance ~ 20 Mpc

Credits: ESO. Acknowledgement: Aniello Grado and Luca Limatola

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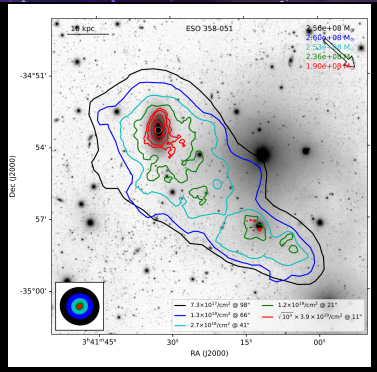
Perfect laboratory for:

- Studying the importance of Hydrodynamical effects that are well established in massive clusters (Gavazzi+78; Dickey+97; Chung+07,09).
- Studying the effects of galaxy interactions which are more relevant in small groups (Hibbard+01, English+10; Serra+13; Lee-Waddell+19).
- Studying the effect and balance between the various environmental processes in dense environments.

Credits: ESO. Acknowledgement: Aniello Grado and Luca Limatola

# What are the physical processes at play in Fornax?

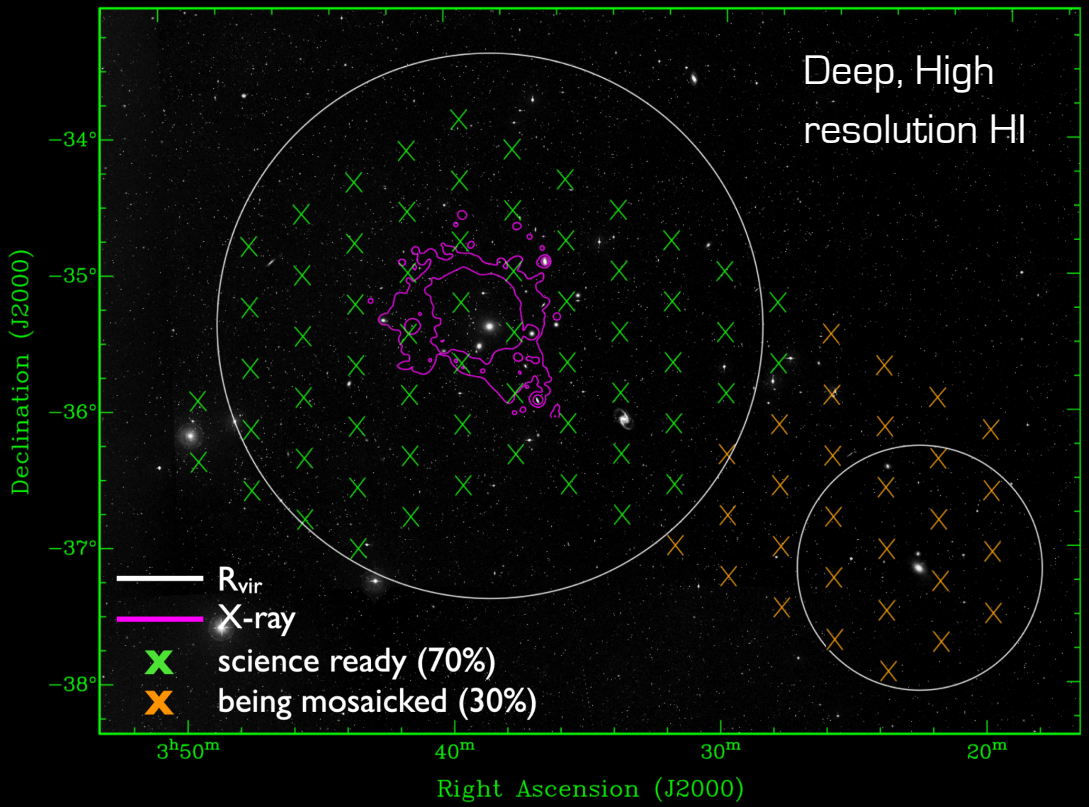
**Insights:** Evidence of galaxies with tails and **two-step ISM stripping** (first tidal then hydrodynamical) in relatively large gas-rich galaxies in Fornax (Serra+23, 24)




**Open questions:**

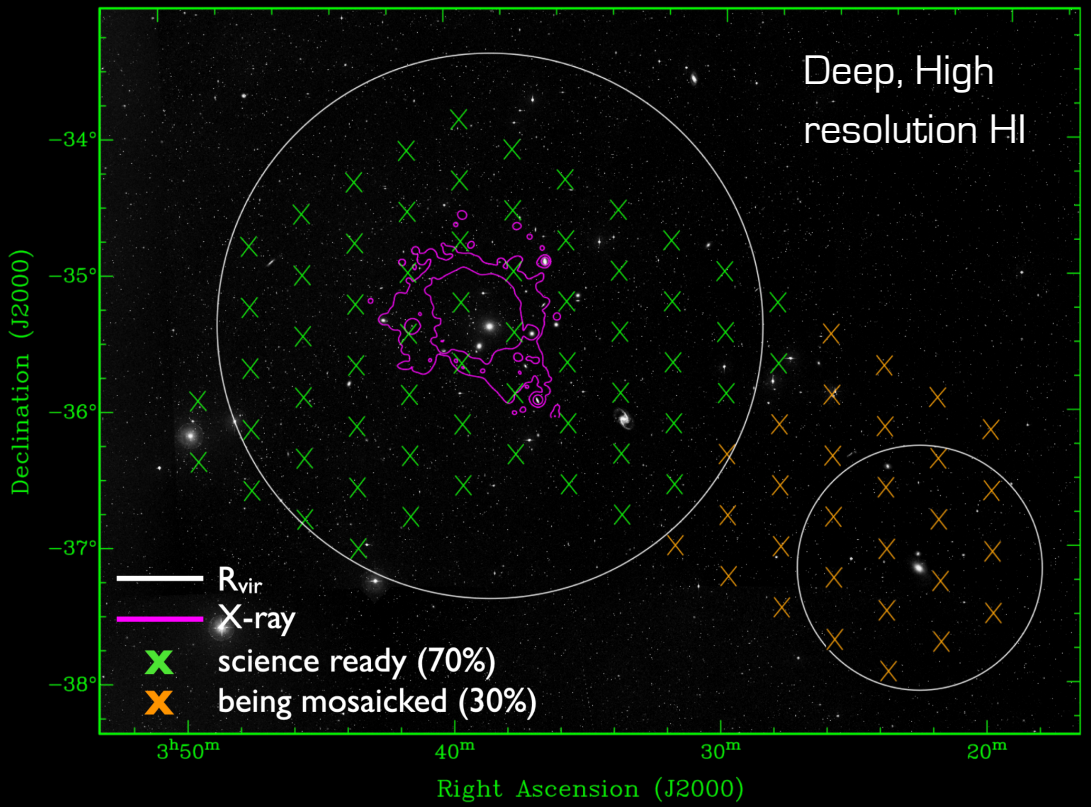
1. What type of interactions are relevant in small clusters like Fornax?
2. Which processes—tidal or hydrodynamical—dominate, and under what conditions? On what timescales?
3. How does the HI content of galaxies with signatures of gas stripping vary with galaxy properties?

# The MeerKAT Fornax Survey




**Why HI?** Component of galaxies ISM, diffuse and extended, the best tracer of environmental interactions.

# The MeerKAT Fornax Survey

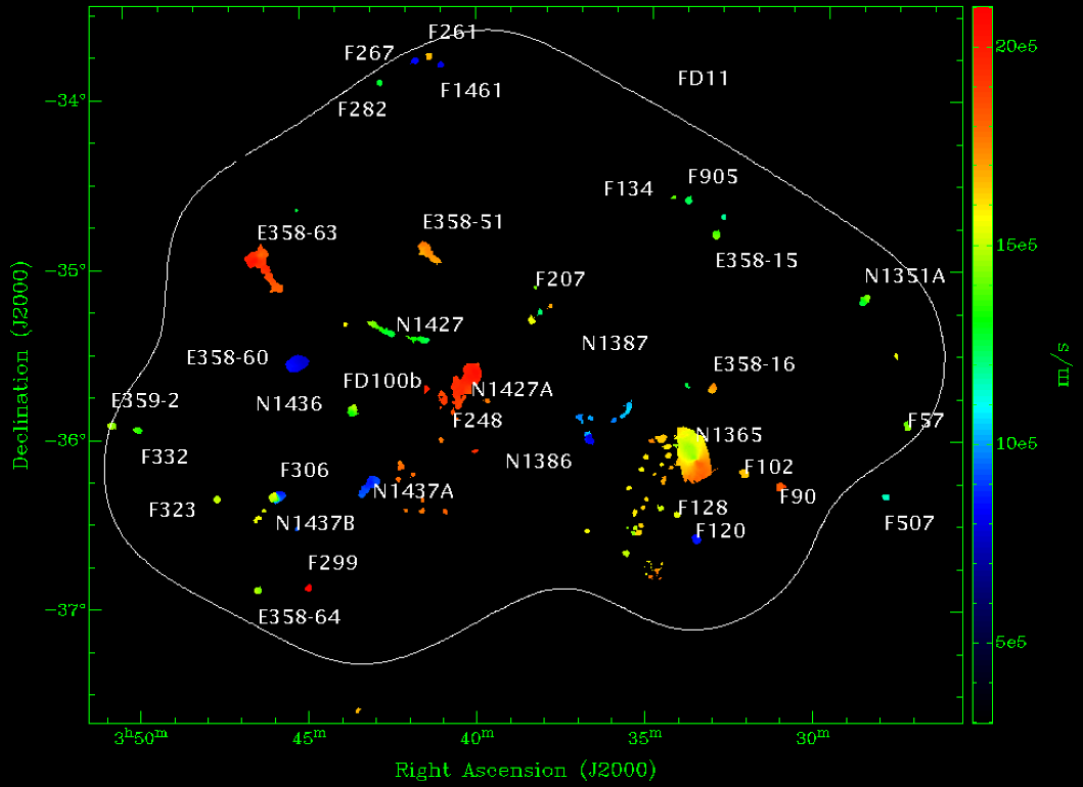



**Why HI?** Component of galaxies ISM, diffuse and extended, the best tracer of environmental interactions.

**Survey Details:**

- 91 fields (this work: 62 fields)
- 30 Hrs/field (total: 1000h)
- 12 deg$^2$ area
- channel width: 1.4 km s$^{-1}$
- resolution: 1, 2, 4, 7, 10 kpc
- $N_{HI}(3\sigma)$: 5x10$^{19}$ - 8x10$^{17}$ cm$^{-2}$
- $M_{HI}(3\sigma)$: 6x10$^5$ $M_{Sun}$

# The MeerKAT Fornax Survey




Velocity field of 35 HI detections seen by MFS

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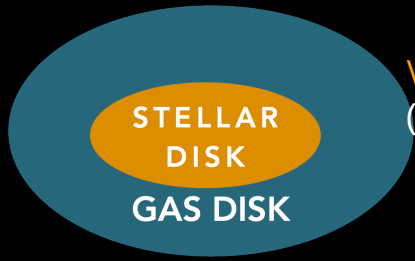
**Published papers:** Serra+19,23,24, Maccagni+20,21, Kleiner+21,23,25, Loi+22,25, Loni+23, Loubser+24, Zabel+24, Kamphuis+25

# Classifying galaxies undergoing gas stripping


VST data (Iodice+16)

MFS data

# Classifying galaxies undergoing gas stripping




VST data (Iodice+16)

MFS data

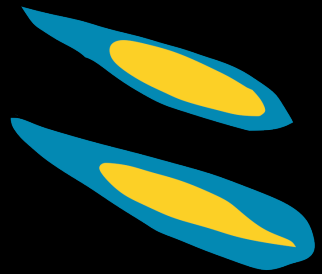
**Yoon et al. 2017 Classification scheme**

Symmetric? Truncated on both or one side? How HI deficient?

**Class 0 - Regular HI**

10/35

**Class 1 - Early Stage**



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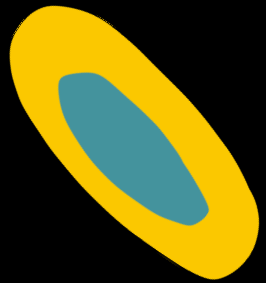
**Class 2 - Ongoing Stripping**

6/35

**Class 3 - Past Stripping**



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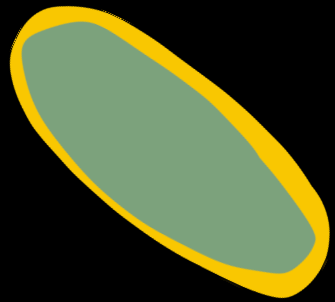
**Class 4 - Slow depletion/Starvation**

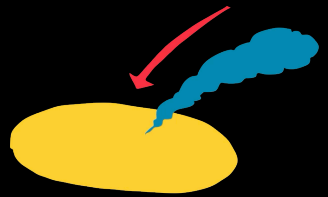


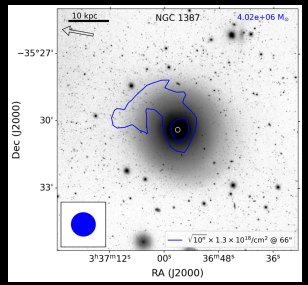
4/35

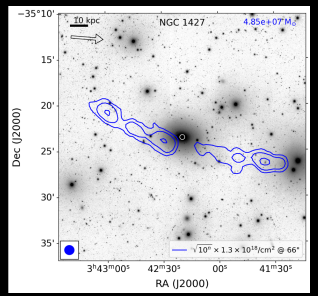
# Classification: additional modifications

## Class 5 - Re-accreting ETs

- Massive Ellipticals not expected to have HI emission
- Unusual HI distribution
- Probably re-accreting gas once they reach the cluster





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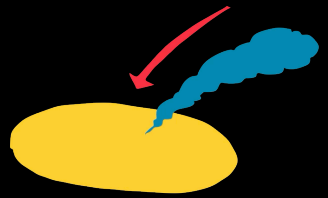
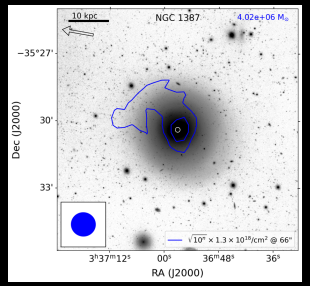
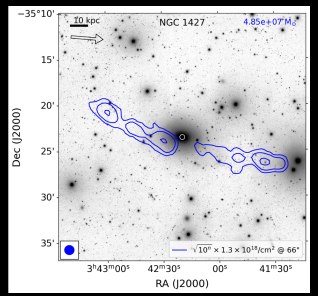
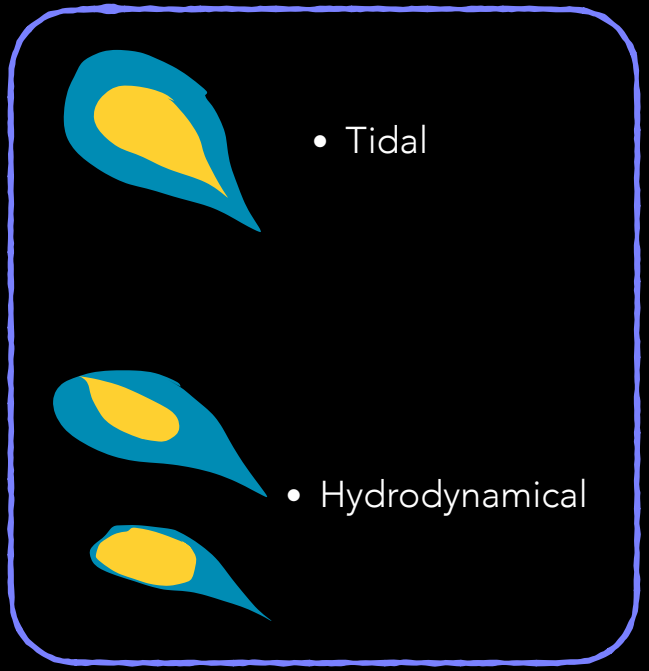





## TIDAL FLAG - is a tail tidal or hydro?



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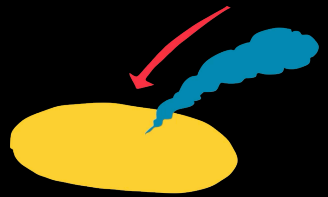

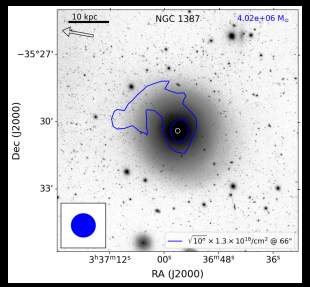


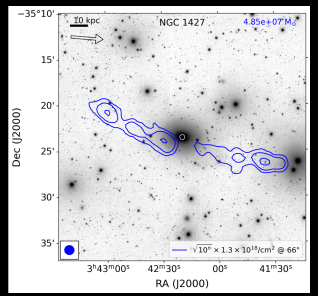


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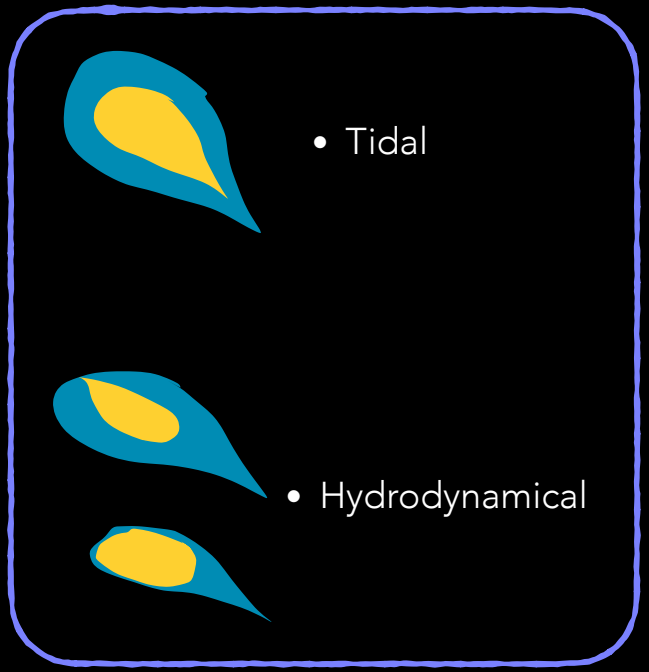
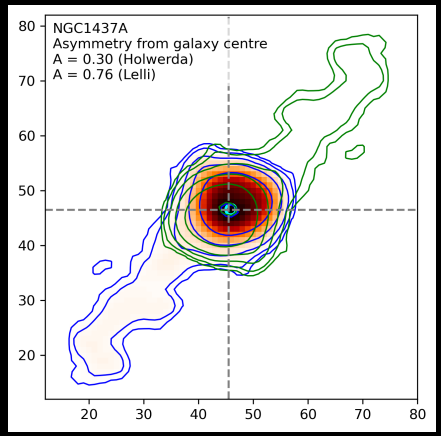
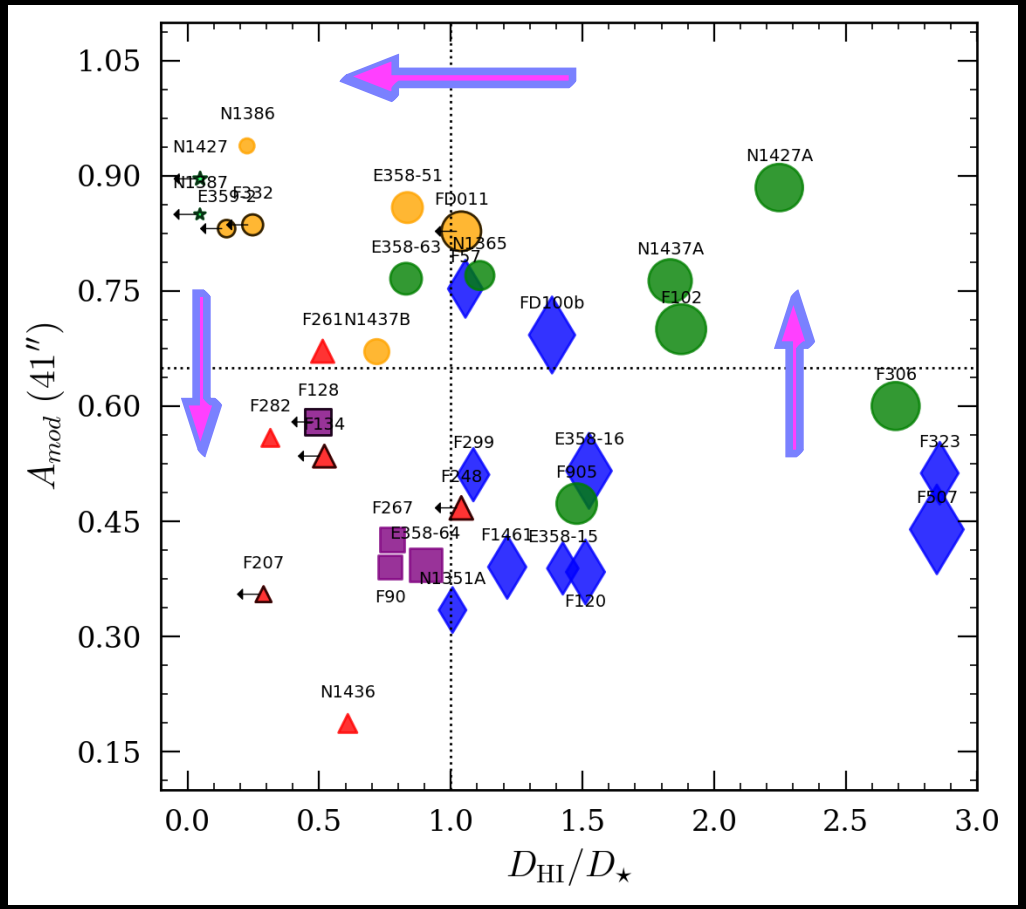



## Quantifying outer asymmetries (Lelli+14)




$$A = \frac{1}{N} \sum_{i,j}^{N} \frac{|I(i,j) - I_{180^\circ}(i,j)|}{|I(i,j) + I_{180^\circ}(i,j)|},$$

# Asymmetry vs. Truncation




Regular HI

Early Stage

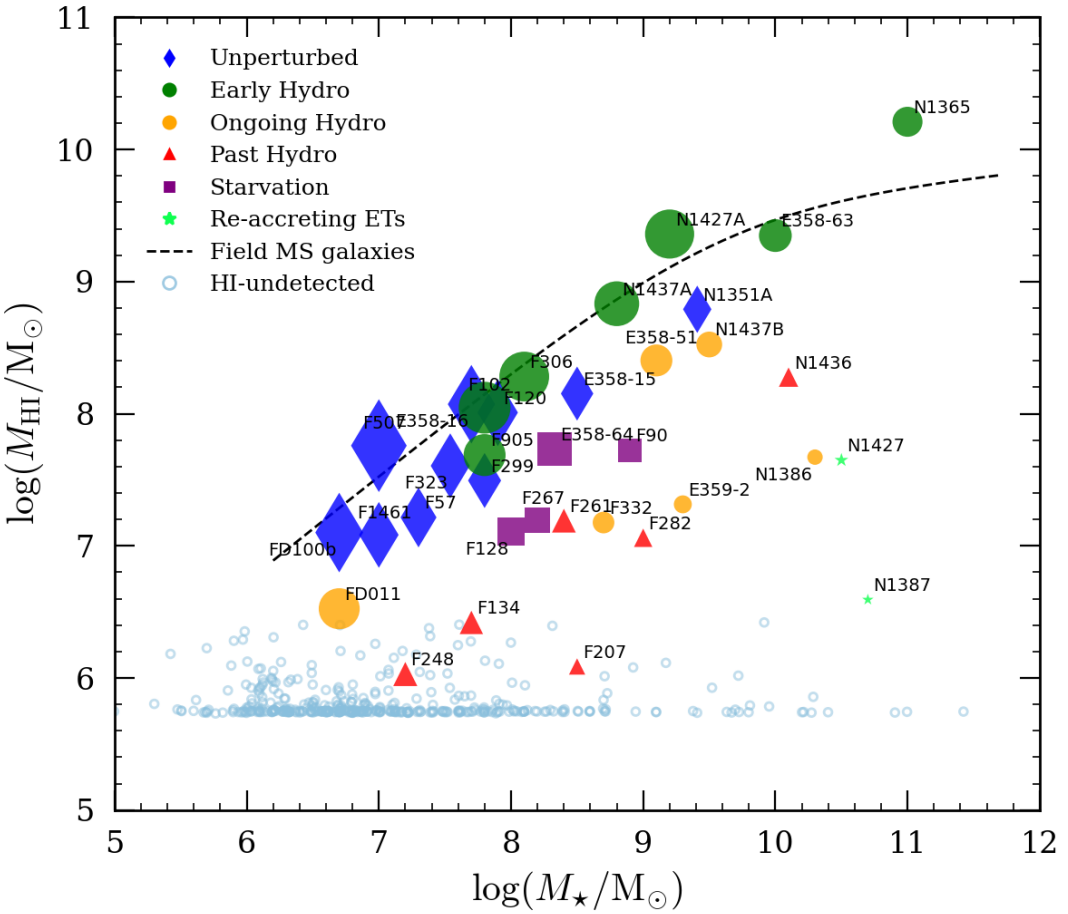
Ongoing Stripping

Past Stripping

Starvation

Re-accreting

# HI mass vs. Stellar mass




- Class 1 (early stage) mostly massive galaxies
- Low-mass galaxies (e.g. dwarfs) are easily affected by gas stripping due to the suggested fast removal of their reservoirs

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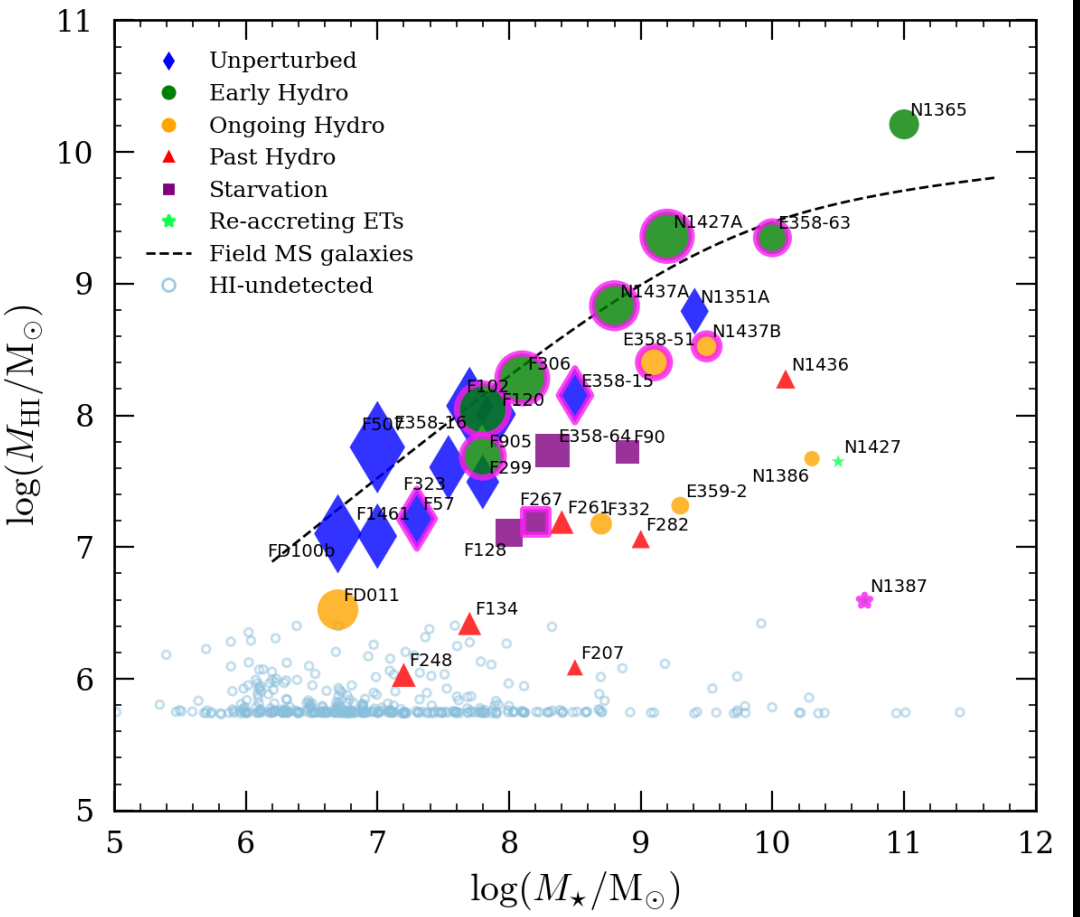
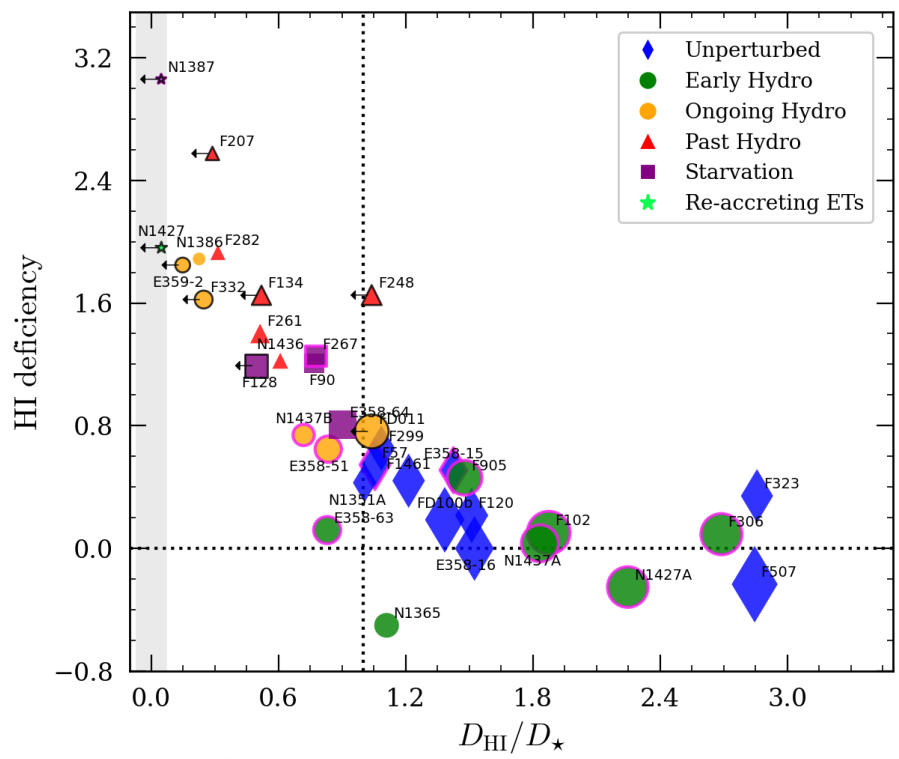


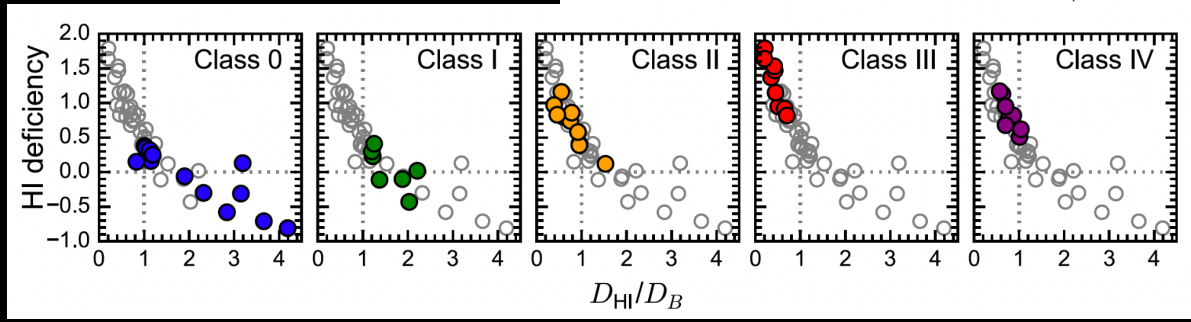

- Class 1 (early stage) mostly massive galaxies
- Low-mass galaxies (e.g. dwarfs) are easily affected by gas stripping due to the suggested fast removal of their reservoirs
- Galaxies with signs of hydrodynamical interactions show signs of tidal interactions the closer they are to the relation.

# Deficiency vs. Truncation

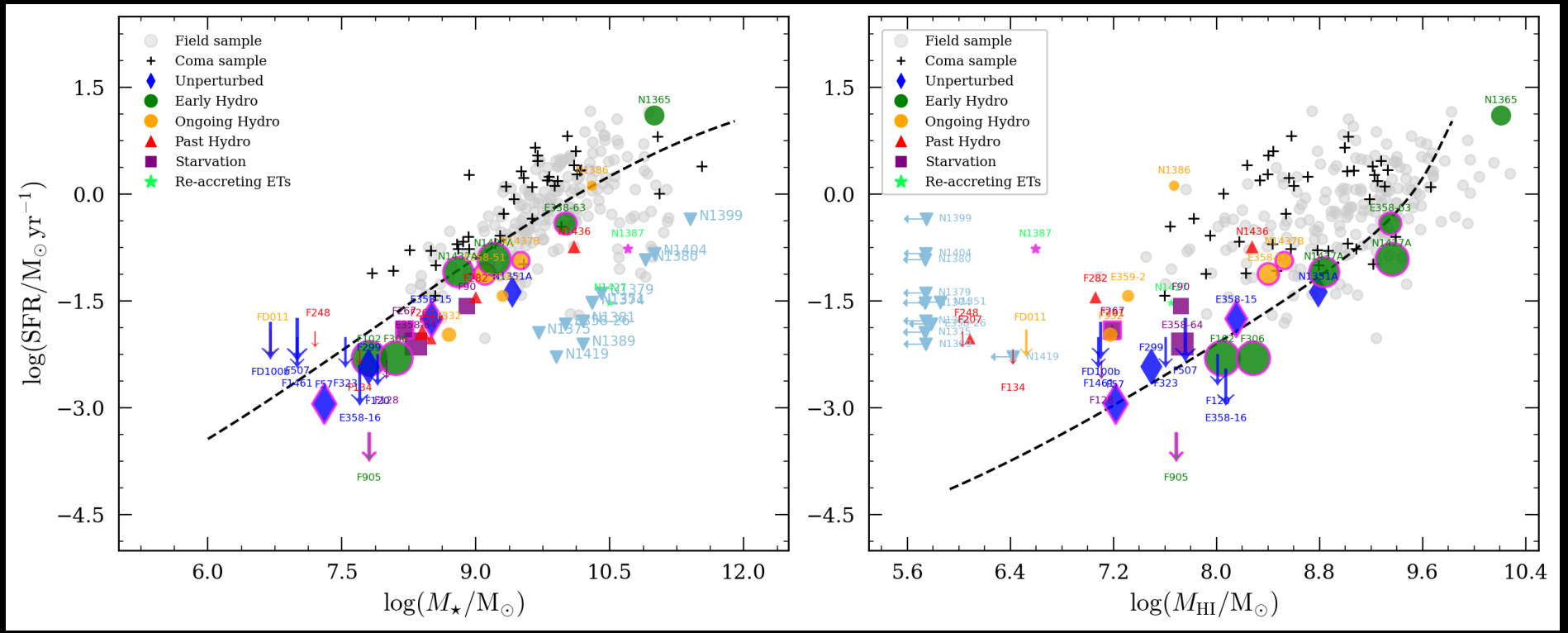
- The more a galaxy undergoes stripping, the more it looses its HI gas and becomes truncated.




Results from Yoon+17 for the **Virgo cluster**



# Gas stripping and Star Formation




Stripping may remove outer H I faster than star formation can respond, leaving the central ISM still capable of sustaining star formation for some time.

# Lessons learned

1- What type of interactions are relevant in small clusters like Fornax?

A. Diversity of gas removal stages revealed from early to past interaction, and starvation

2 - Which processes—tidal or hydrodynamical—dominate, and under what conditions? On what timescales?

A. Combination of tidal + hydrodynamical processes responsible of the observed structures (I.e. a mix of HI stripped from the galaxy then cooled from the ICM)

B. The formation of the largest HI tails requires a tidal interaction to trigger the hydrodynamical effects. However, if the gas has been stripped for a long time, the tidal features may already have faded.

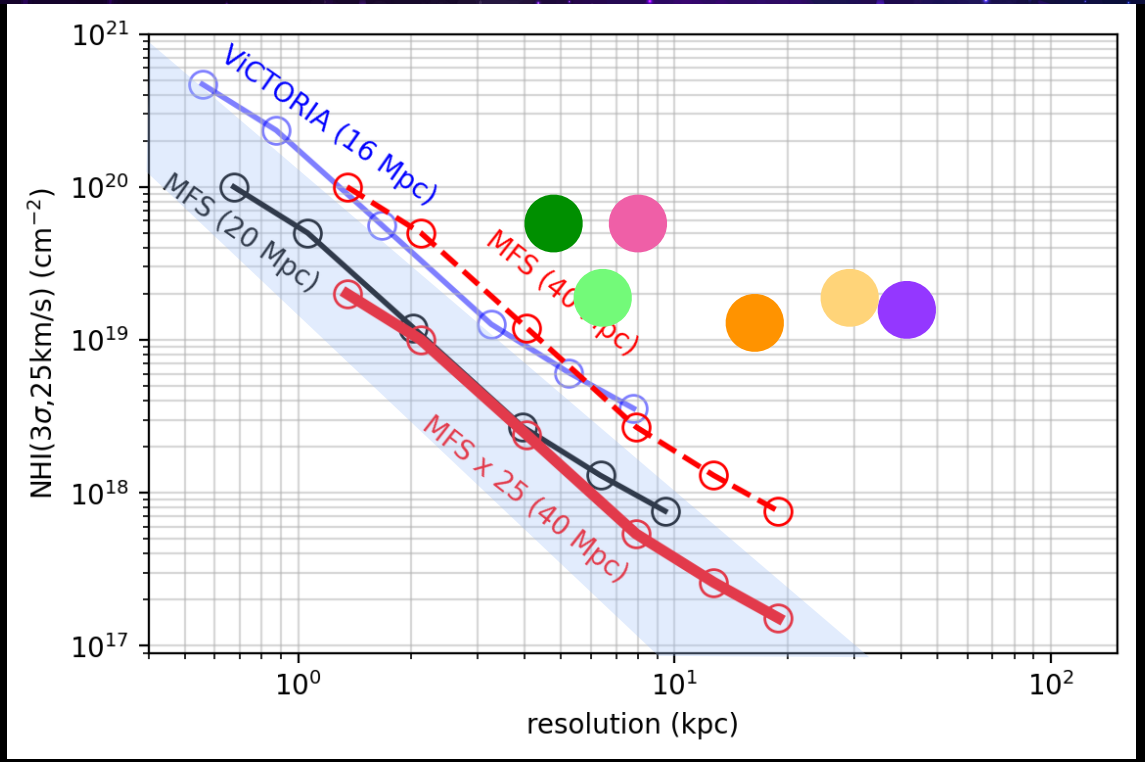
3 - How does the HI content of galaxies with signatures of gas stripping vary with galaxy properties?

A. Strong stripping linked to deficiency, truncation and asymmetry.

B. Although stripped galaxies have lost most of their outer H I gas, their central regions retain enough ISM to prevent the star-formation rate from dropping.

MFS Data products (Cubes, images, etc.) publicly available here →

# Potential with Future SKA surveys




**Expand deep, high-resolution H I imaging** to more targets and wider cosmic-web environments (groups, filaments, cluster outskirts).

**Reach MFS-level depth and resolution** at larger distances.

**Current limitation:** very long integration times needed for the same area (e.g., ~6,000 hr at 40 Mpc).

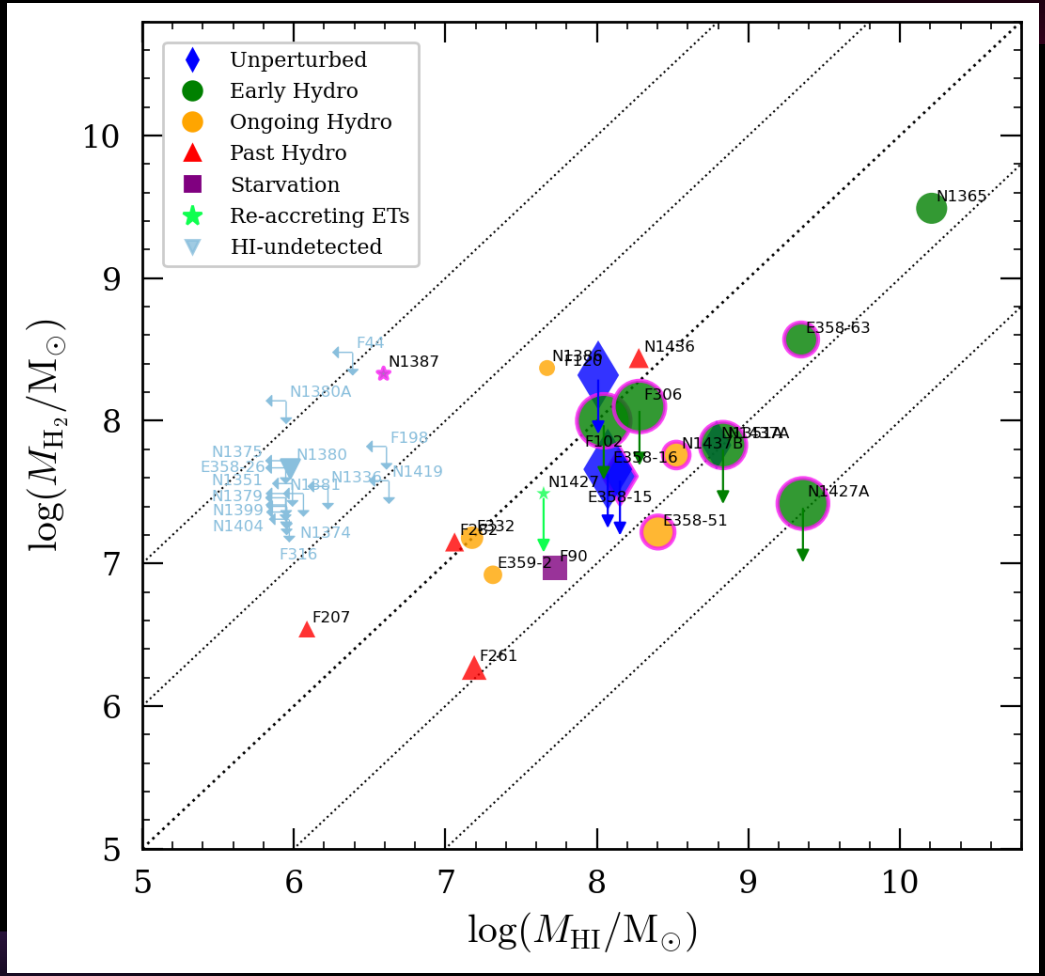
**Solution:** SKA AA*, AA4 will enable this by being **~4.5× faster.**

Apertif-MD$_{70Mpc}$ WALLABY$_{50Mpc}$ MGCLS$_{200Mpc}$

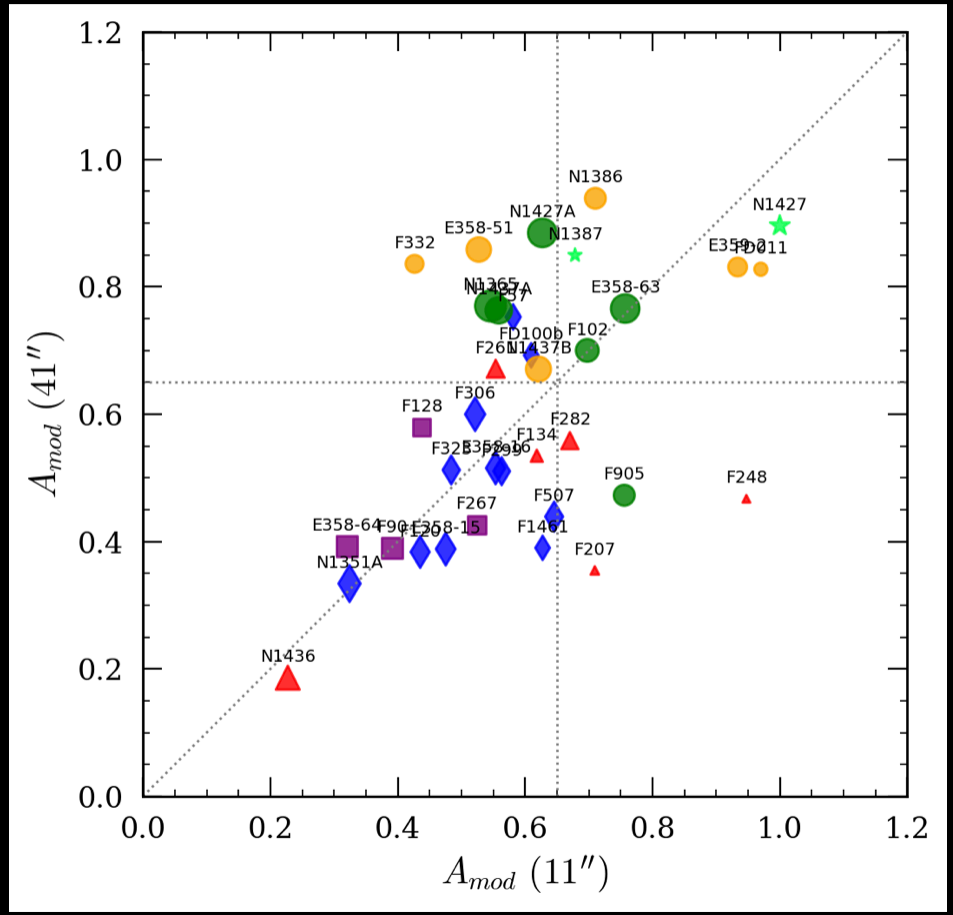
Fornax@ATCA Coma@WSRT DINGO$_{315Mpc}$

# THANK YOU

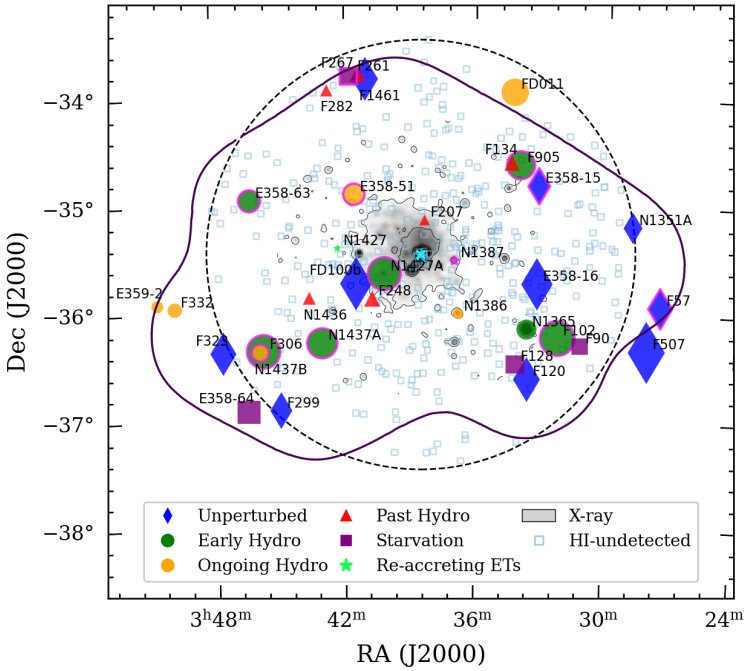
Any questions?

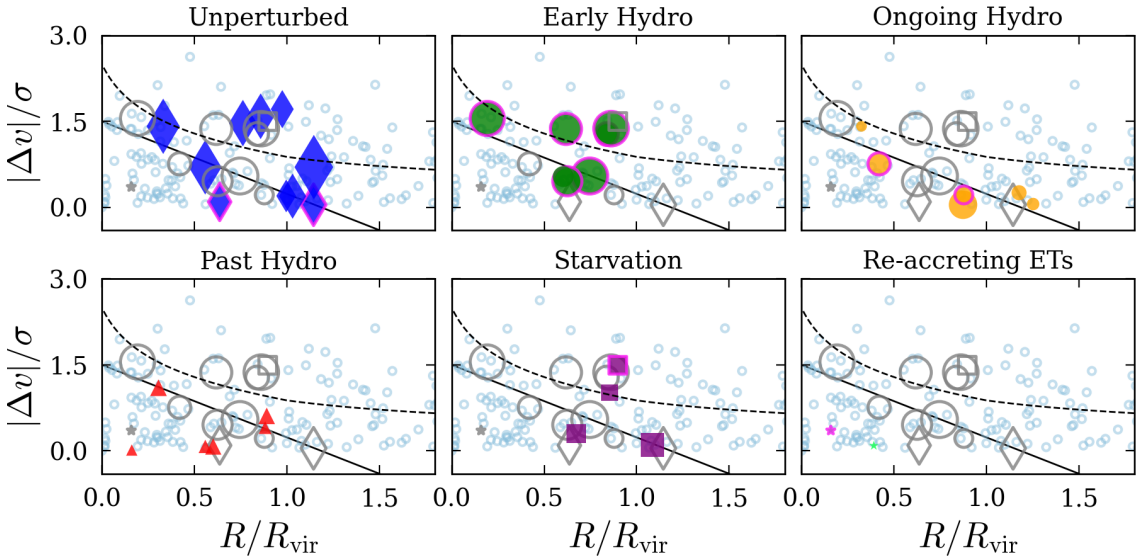

Unperturbed
Early Hydro
Ongoing Hydro
Past Hydro
Starvation
Re-accreting ETs
HI-undetected
$\log(M_{\rm H_2}/{\rm M}_\odot)$
$\log(M_{\rm HI}/{\rm M}_\odot)$
5
6
7
8
9
10
N1365
E358-63
N1436
N1387
N1380A
F306
F102
N1437B
N1427A
E358-16
N1427
E358-15
E358-51
E359-2
F90
F207
F261
F198
N1375
N1380
E358-26
N1351
N1379
N1399
N1404
N1336
N1419
N1374
F44

# ASYMMETRY PLOTS

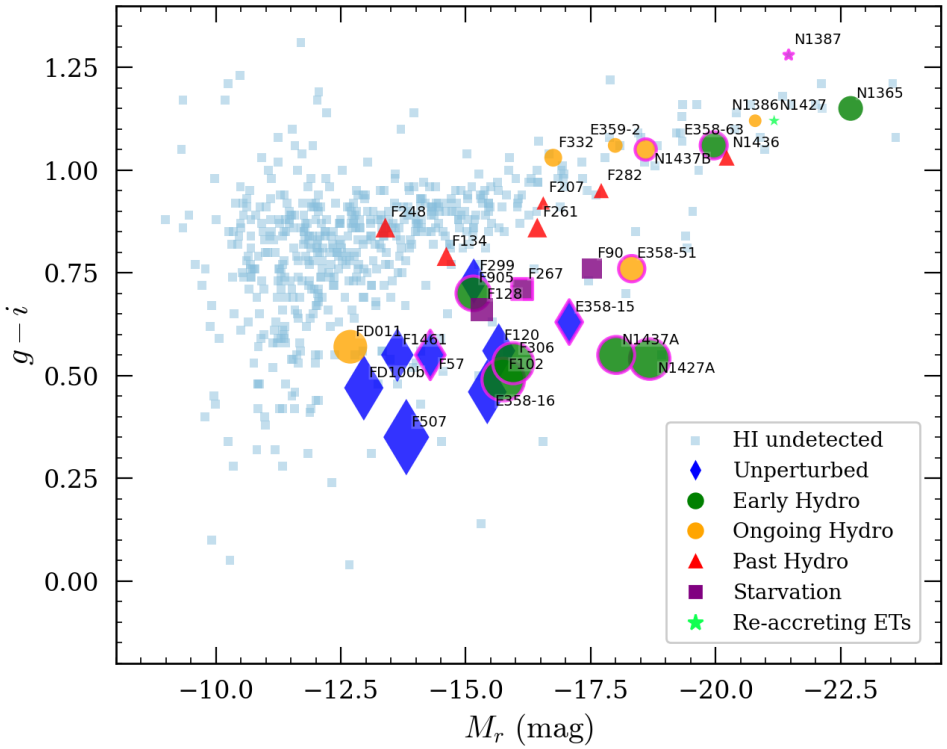


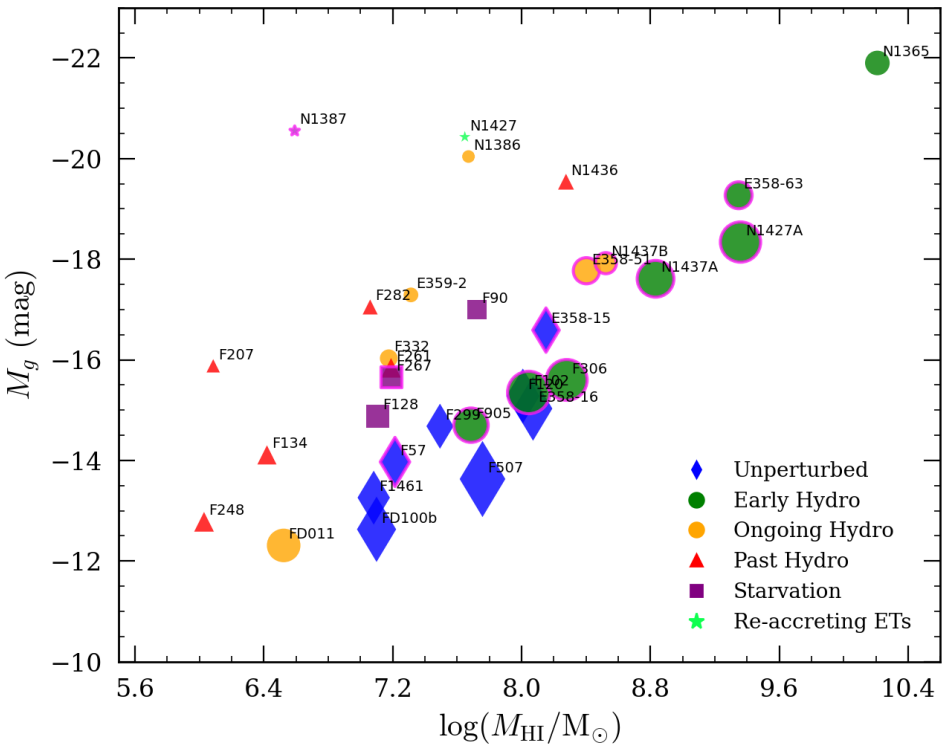
# 2D AND 3D DISTRIBUTION



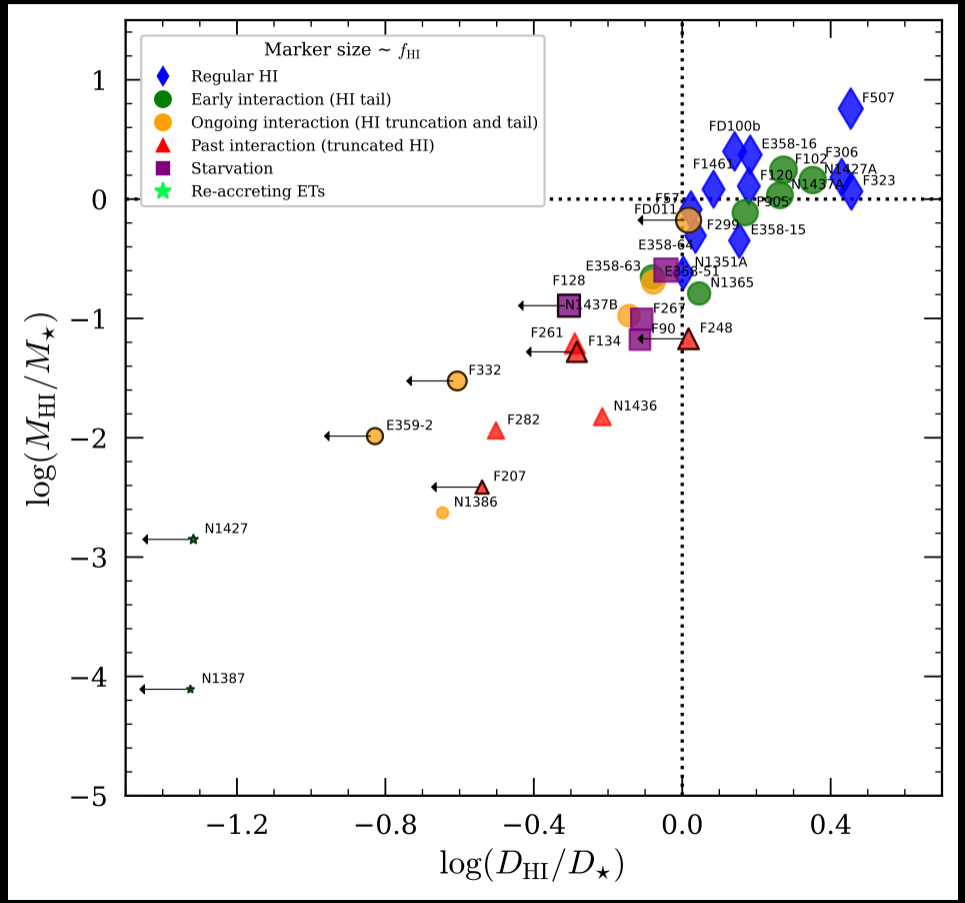



# COLOUR-COLOUR DIAGRAMS

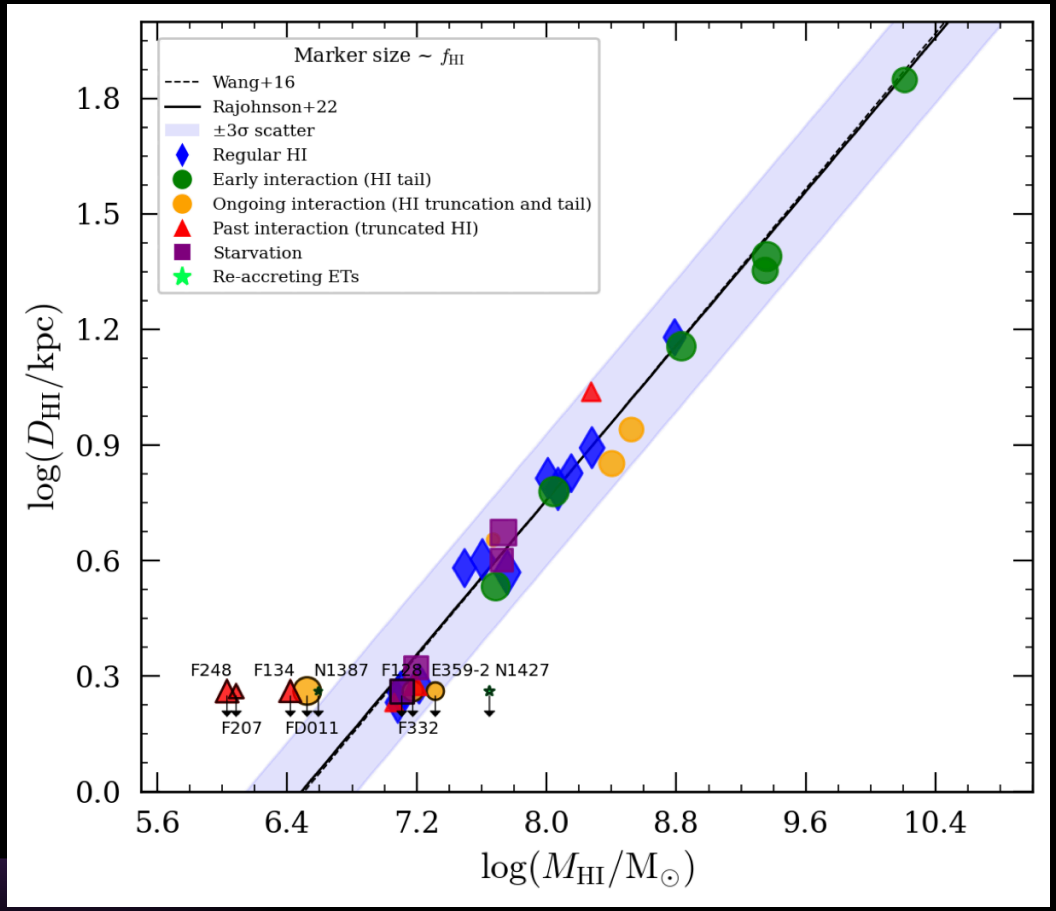


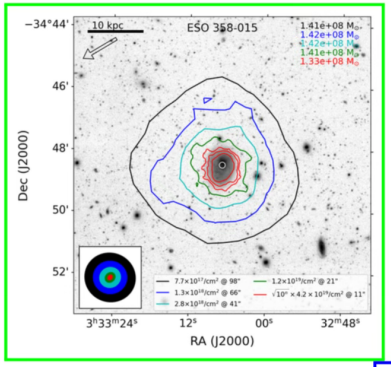
# GAS FRACTION VS. TRUNCATION

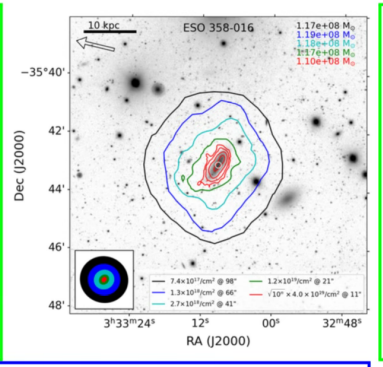


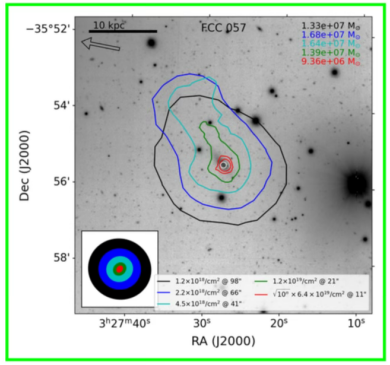
# HI SIZE-MASS RELATION

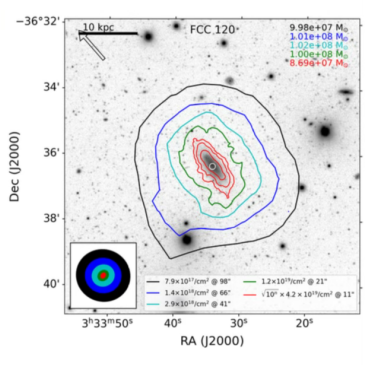


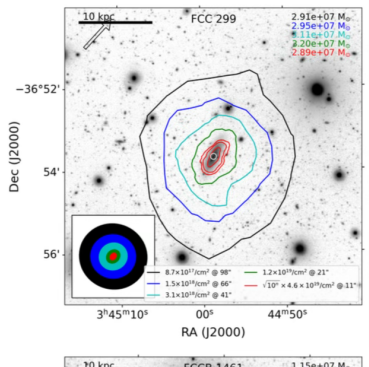
# CLASS 0

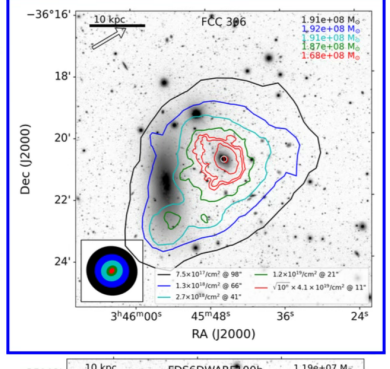

10 kpc
ESO 358-015
1.41e+08 M⊙
1.42e+08 M⊙
1.42e+08 M⊙
1.41e+08 M⊙
1.33e+08 M⊙
Dec (J2000)
RA (J2000)

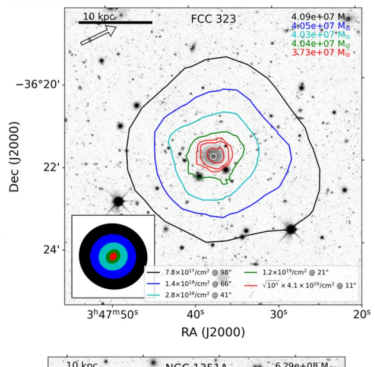

10 kpc
ESO 358-016
1.17e+08 M⊙
1.19e+08 M⊙
1.18e+08 M⊙
1.17e+08 M⊙
1.10e+08 M⊙
Dec (J2000)
RA (J2000)

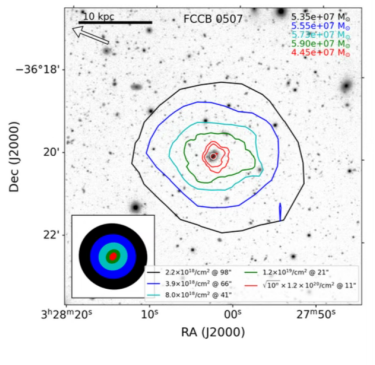

10 kpc
FCC 057
1.33e+07 M⊙
1.68e+07 M⊙
1.66e+07 M⊙
1.39e+07 M⊙
9.36e+06 M⊙
Dec (J2000)
RA (J2000)

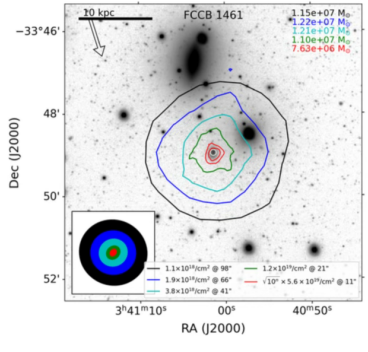

10 kpc
FCC 120
9.98e+07 M⊙
1.01e+08 M⊙
1.02e+08 M⊙
1.00e+08 M⊙
8.69e+07 M⊙
Dec (J2000)
RA (J2000)

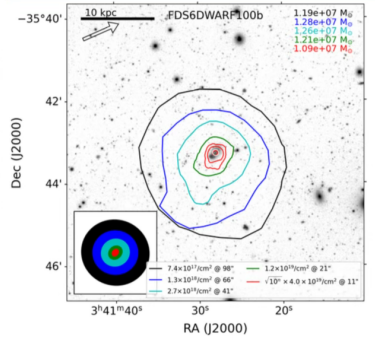

10 kpc
FCC 299
2.91e+07 M⊙
2.95e+07 M⊙
2.20e+07 M⊙
2.89e+07 M⊙
Dec (J2000)
RA (J2000)

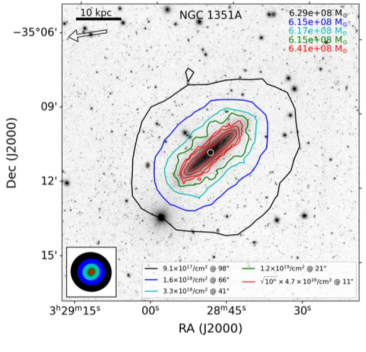

10 kpc
FCC 306
1.91e+08 M⊙
1.92e+08 M⊙
1.91e+08 M⊙
1.87e+08 M⊙
1.68e+08 M⊙
Dec (J2000)
RA (J2000)


10 kpc
FCC 323
4.09e+07 M⊙
4.05e+07 M⊙
4.03e+07 M⊙
4.04e+07 M⊙
3.73e+07 M⊙
Dec (J2000)
RA (J2000)

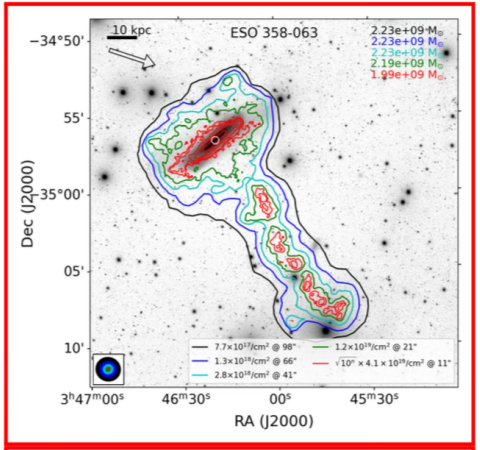

10 kpc
FCCB 0507
5.55e+07 M⊙
5.73e+07 M⊙
5.90e+07 M⊙
4.45e+07 M⊙
Dec (J2000)
RA (J2000)

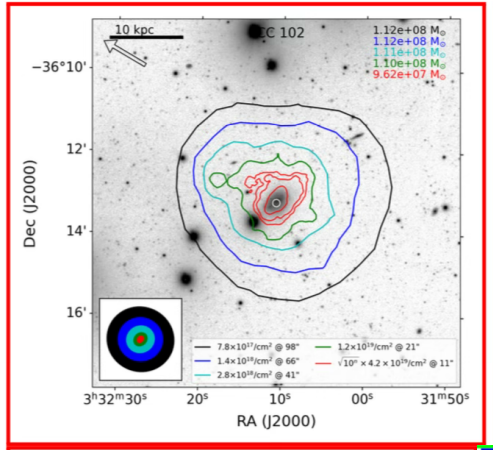

10 kpc
FCCB 1461
1.15e+07 M⊙
1.22e+07 M⊙
1.21e+07 M⊙
1.10e+07 M⊙
7.63e+06 M⊙
Dec (J2000)
RA (J2000)

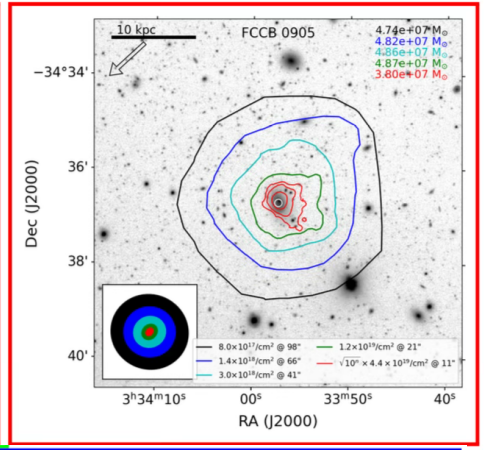

10 kpc
FDS6DWARF100b
1.19e+07 M⊙
1.28e+07 M⊙
1.26e+07 M⊙
1.21e+07 M⊙
1.09e+07 M⊙
Dec (J2000)
RA (J2000)

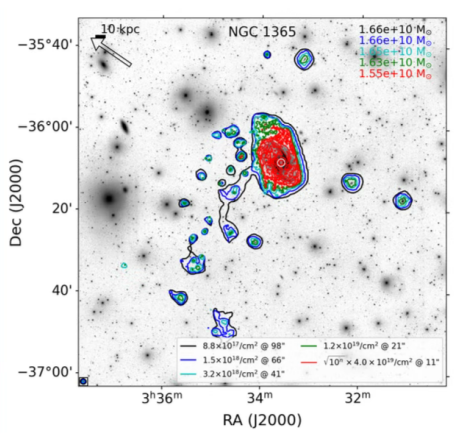

10 kpc
NGC 1351A
6.29e+08 M⊙
6.15e+08 M⊙
6.17e+08 M⊙
6.15e+08 M⊙
6.41e+08 M⊙
Dec (J2000)
RA (J2000)

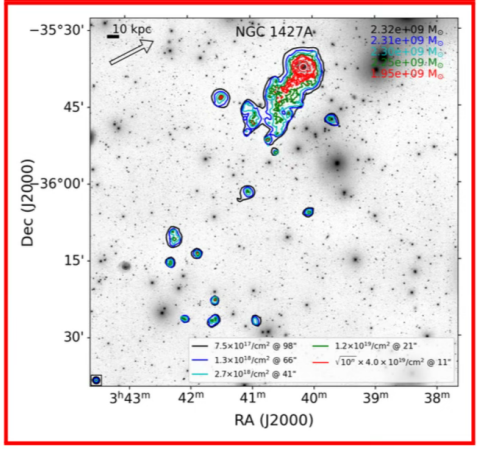
# CLASS 1

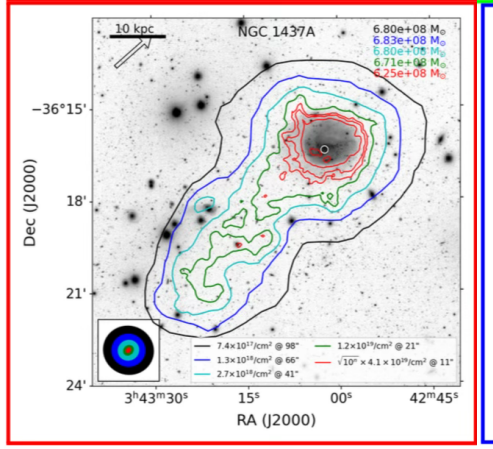

10 kpc
ESO 358-063
2.23e+09 M⊙
2.23e+09 M⊙
2.23e+09 M⊙
2.19e+09 M⊙
1.99e+09 M⊙
Dec (J2000)
RA (J2000)

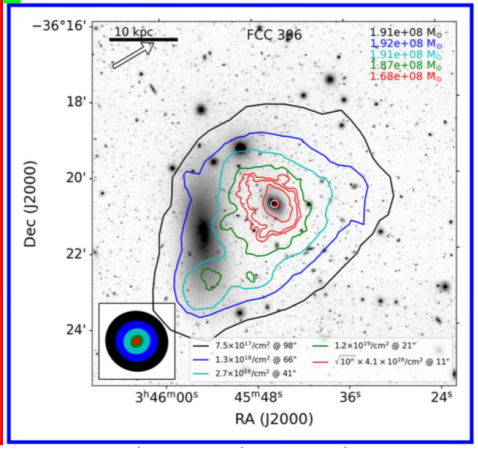

10 kpc
1.12e+08 M⊙
1.12e+08 M⊙
1.11e+08 M⊙
1.10e+08 M⊙
9.62e+07 M⊙
Dec (J2000)
RA (J2000)


10 kpc
FCCB 0905
4.74e+07 M⊙
4.82e+07 M⊙
4.86e+07 M⊙
4.87e+07 M⊙
3.80e+07 M⊙
Dec (J2000)
RA (J2000)

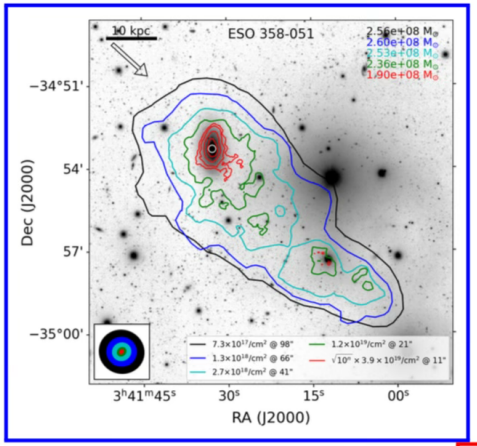

10 kpc
NGC 1365
1.66e+10 M⊙
1.66e+10 M⊙
1.64e+10 M⊙
1.63e+10 M⊙
1.55e+10 M⊙
Dec (J2000)
RA (J2000)

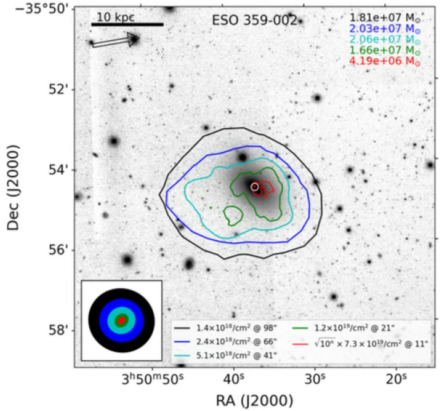

10 kpc
NGC 1427A
2.32e+09 M⊙
2.31e+09 M⊙
2.30e+09 M⊙
2.25e+09 M⊙
2.05e+09 M⊙
Dec (J2000)
RA (J2000)

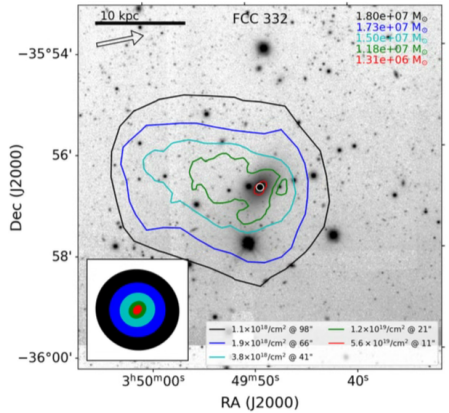

10 kpc
NGC 1437A
6.80e+08 M⊙
6.83e+08 M⊙
6.80e+08 M⊙
6.71e+08 M⊙
6.25e+08 M⊙
Dec (J2000)
RA (J2000)

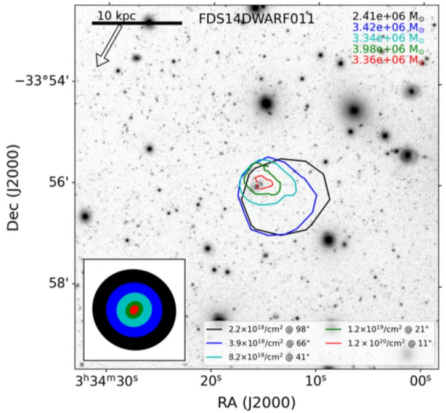

10 kpc
FCC 306
1.91e+08 M⊙
1.92e+08 M⊙
1.91e+08 M⊙
1.87e+08 M⊙
1.68e+08 M⊙
Dec (J2000)
RA (J2000)

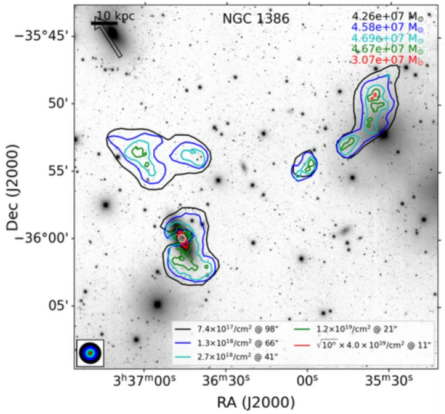
# CLASS 2

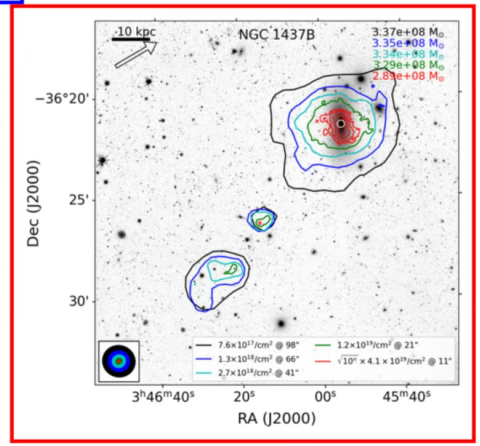

10 kpc
ESO 358-051
2.56e+08 M⊙
2.60e+08 M⊙
2.53e+08 M⊙
2.36e+08 M⊙
1.90e+08 M⊙
Dec (J2000)
RA (J2000)


10 kpc
ESO 359-002
1.81e+07 M⊙
2.03e+07 M⊙
2.06e+07 M⊙
1.66e+07 M⊙
4.19e+06 M⊙
Dec (J2000)
RA (J2000)

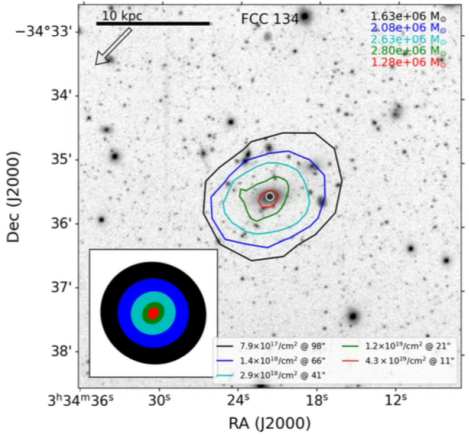

10 kpc
FCC 332
1.80e+07 M⊙
1.73e+07 M⊙
1.50e+07 M⊙
1.18e+07 M⊙
1.31e+06 M⊙
Dec (J2000)
RA (J2000)

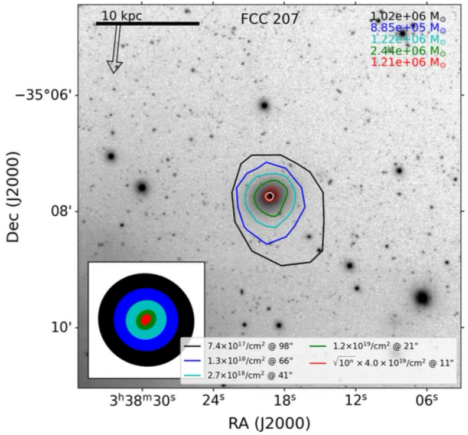

10 kpc
FDS14DWARF011
2.41e+06 M⊙
3.42e+06 M⊙
3.34e+06 M⊙
3.98e+06 M⊙
3.36e+06 M⊙
Dec (J2000)
RA (J2000)

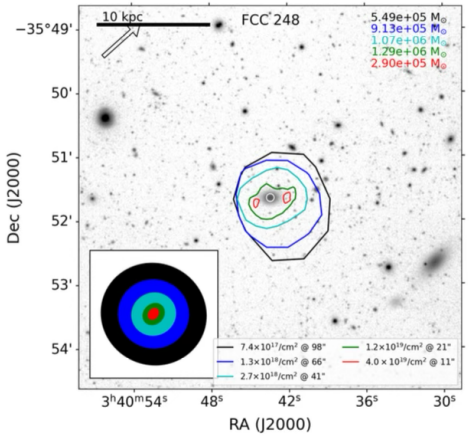

10 kpc
NGC 1386
4.26e+07 M⊙
4.58e+07 M⊙
4.69e+07 M⊙
4.67e+07 M⊙
3.07e+07 M⊙
Dec (J2000)
RA (J2000)

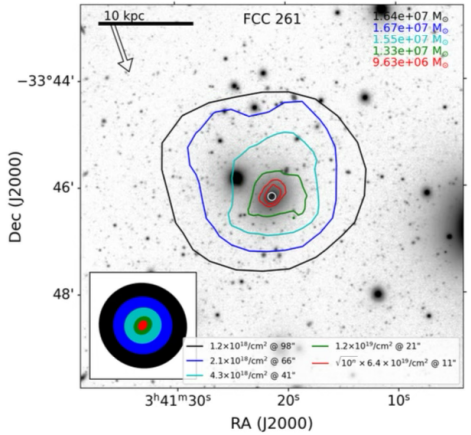

10 kpc
NGC 1437B
3.37e+08 M⊙
3.35e+08 M⊙
3.34e+08 M⊙
3.29e+08 M⊙
2.83e+08 M⊙
Dec (J2000)
RA (J2000)

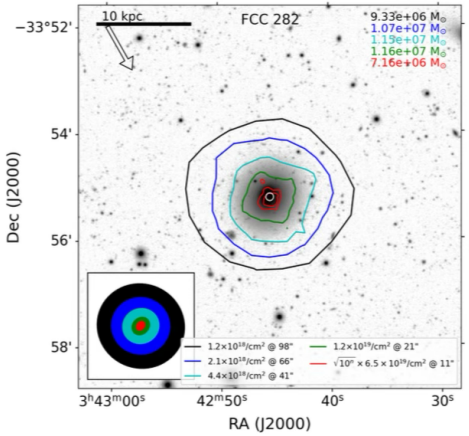
# CLASS 3

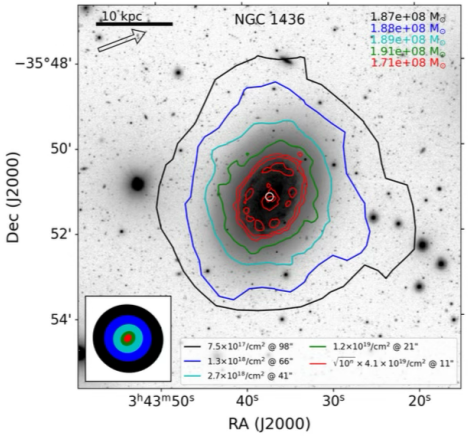

10 kpc
FCC 134
1.63e+06 M⊙
2.08e+06 M⊙
2.63e+06 M⊙
2.80e+06 M⊙
1.28e+06 M⊙
−34°33'
34'
35'
36'
37'
38'
Dec (J2000)
3h34m36s
30s
24s
18s
12s
RA (J2000)
7.9×10^17/cm² @ 98"
1.4×10^18/cm² @ 66"
2.9×10^18/cm² @ 41"
1.2×10^19/cm² @ 21"
4.3×10^19/cm² @ 11"


10 kpc
FCC 207
1.02e+06 M⊙
8.85e+05 M⊙
1.22e+06 M⊙
2.44e+06 M⊙
1.21e+06 M⊙
−35°06'
08'
10'
Dec (J2000)
3h38m30s
24s
18s
12s
06s
RA (J2000)
7.4×10^17/cm² @ 98"
1.3×10^18/cm² @ 66"
2.7×10^18/cm² @ 41"
1.2×10^19/cm² @ 21"
√10" × 4.0×10^19/cm² @ 11"

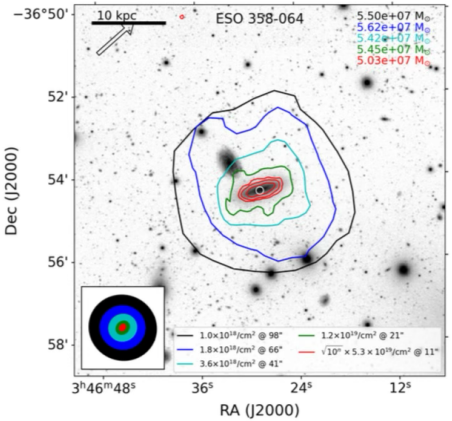

10 kpc
FCC 248
5.49e+05 M⊙
9.13e+05 M⊙
1.07e+06 M⊙
1.29e+06 M⊙
2.90e+05 M⊙
−35°49'
50'
51'
52'
53'
54'
Dec (J2000)
3h40m54s
48s
42s
36s
30s
RA (J2000)
7.4×10^17/cm² @ 98"
1.3×10^18/cm² @ 66"
2.7×10^18/cm² @ 41"
1.2×10^19/cm² @ 21"
4.0×10^19/cm² @ 11"

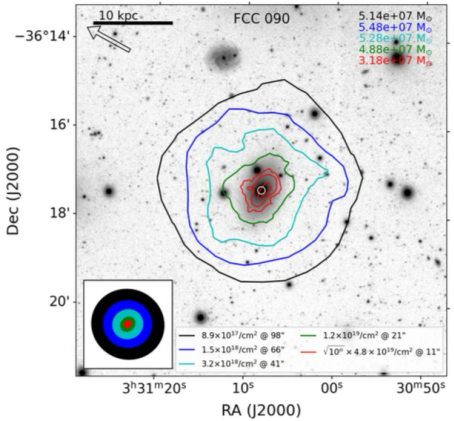

10 kpc
FCC 261
1.64e+07 M⊙
1.67e+07 M⊙
1.55e+07 M⊙
1.33e+07 M⊙
9.63e+06 M⊙
−33°44'
46'
48'
Dec (J2000)
3h41m30s
20s
10s
RA (J2000)
1.2×10^18/cm² @ 98"
2.1×10^18/cm² @ 66"
4.3×10^18/cm² @ 41"
1.2×10^19/cm² @ 21"
√10" × 6.4×10^19/cm² @ 11"

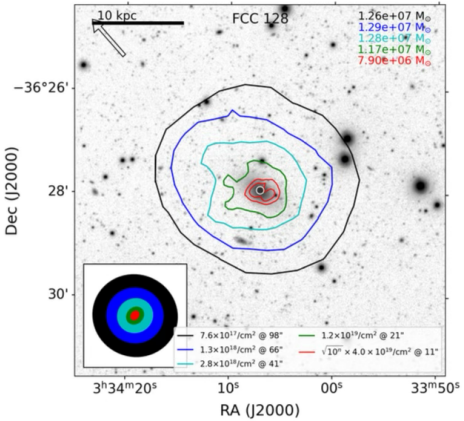

10 kpc
FCC 282
9.33e+06 M⊙
1.07e+07 M⊙
1.15e+07 M⊙
1.16e+07 M⊙
7.16e+06 M⊙
−33°52'
54'
56'
58'
Dec (J2000)
3h43m00s
42m50s
40s
30s
RA (J2000)
1.2×10^18/cm² @ 98"
2.1×10^18/cm² @ 66"
4.4×10^18/cm² @ 41"
1.2×10^19/cm² @ 21"
√10" × 6.5×10^19/cm² @ 11"

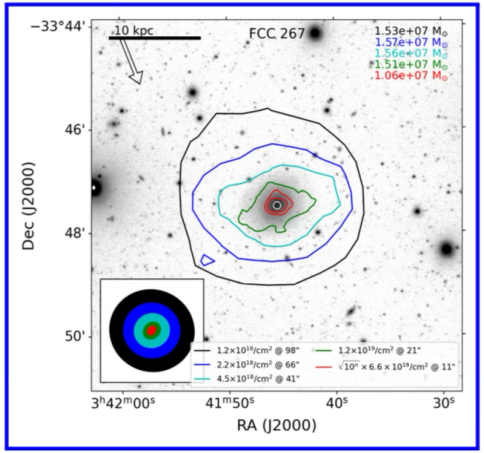

10 kpc
NGC 1436
1.87e+08 M⊙
1.88e+08 M⊙
1.89e+08 M⊙
1.91e+08 M⊙
1.71e+08 M⊙
−35°48'
50'
52'
54'
Dec (J2000)
3h43m50s
40s
30s
20s
RA (J2000)
7.5×10^17/cm² @ 98"
1.3×10^18/cm² @ 66"
2.7×10^18/cm² @ 41"
1.2×10^19/cm² @ 21"
√10" × 4.1×10^19/cm² @ 11"

# CLASS 4

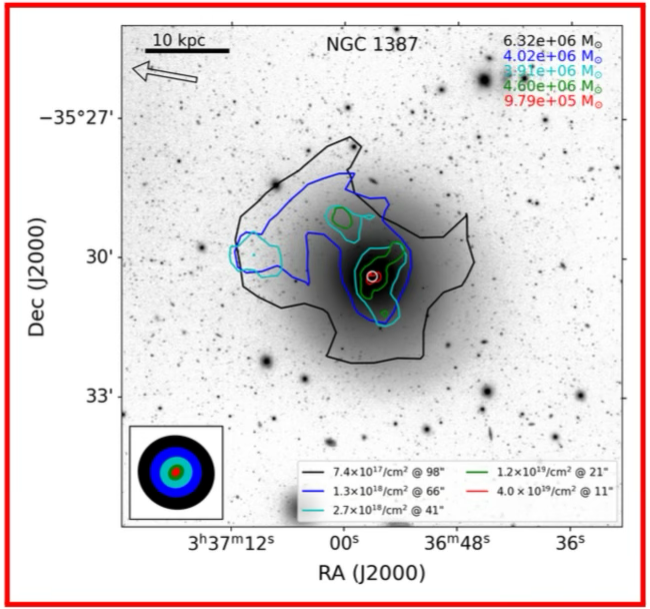

10 kpc
ESO 358-064
5.50e+07 M⊙
5.62e+07 M⊙
5.42e+07 M⊙
5.45e+07 M⊙
5.03e+07 M⊙
1.0×10¹⁸/cm² @ 98"
1.8×10¹⁸/cm² @ 66"
3.6×10¹⁸/cm² @ 41"
1.2×10¹⁹/cm² @ 21"
√10" × 5.3 × 10¹⁸/cm² @ 11"
Dec (J2000)
RA (J2000)

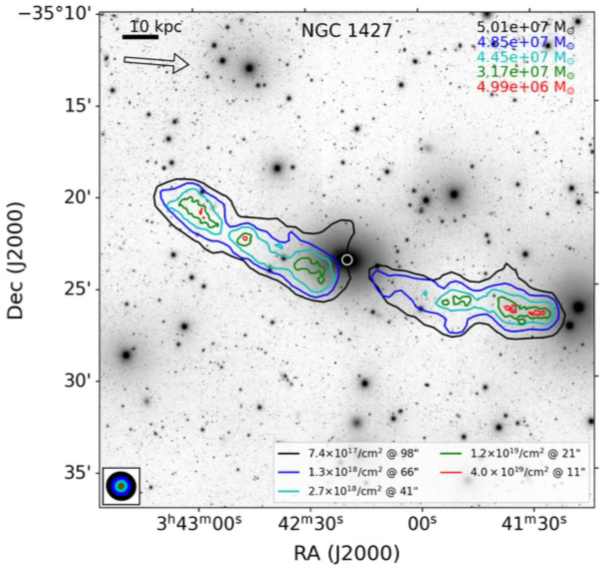

10 kpc
FCC 090
5.14e+07 M⊙
5.48e+07 M⊙
5.28e+07 M⊙
4.88e+07 M⊙
3.18e+07 M⊙
8.9×10¹⁷/cm² @ 98"
1.5×10¹⁸/cm² @ 66"
3.2×10¹⁸/cm² @ 41"
1.2×10¹⁹/cm² @ 21"
√10" × 4.8 × 10¹⁸/cm² @ 11"
Dec (J2000)
RA (J2000)


10 kpc
FCC 128
1.26e+07 M⊙
1.29e+07 M⊙
1.28e+07 M⊙
1.17e+07 M⊙
7.90e+06 M⊙
7.6×10¹⁷/cm² @ 98"
1.3×10¹⁸/cm² @ 66"
2.8×10¹⁸/cm² @ 41"
1.2×10¹⁹/cm² @ 21"
√10" × 4.0 × 10¹⁸/cm² @ 11"
Dec (J2000)
RA (J2000)


10 kpc
FCC 267
1.53e+07 M⊙
1.57e+07 M⊙
1.56e+07 M⊙
1.51e+07 M⊙
1.06e+07 M⊙
1.2×10¹⁸/cm² @ 98"
2.2×10¹⁸/cm² @ 66"
4.5×10¹⁸/cm² @ 41"
1.2×10¹⁹/cm² @ 21"
√10" × 6.6 × 10¹⁸/cm² @ 11"
Dec (J2000)
RA (J2000)

# CLASS 5


10 kpc
NGC 1387
6.32e+06 M⊙
4.02e+06 M⊙
3.97e+06 M⊙
4.60e+06 M⊙
9.79e+05 M⊙
−35°27'
30'
33'
Dec (J2000)
7.4×10¹⁷/cm² @ 98"
1.3×10¹⁸/cm² @ 66"
2.7×10¹⁸/cm² @ 41"
1.2×10¹⁹/cm² @ 21"
4.0×10¹⁹/cm² @ 11"
3h37m12s
00s
36m48s
36s
RA (J2000)


−35°10'
15'
20'
25'
30'
35'
10 kpc
NGC 1427
5.01e+07 M⊙
4.85e+07 M⊙
4.45e+07 M⊙
3.17e+07 M⊙
4.99e+06 M⊙
Dec (J2000)
7.4×10¹⁷/cm² @ 98"
1.3×10¹⁸/cm² @ 66"
2.7×10¹⁸/cm² @ 41"
1.2×10¹⁹/cm² @ 21"
4.0×10¹⁹/cm² @ 11"
3h43m00s
42m30s
00s
41m30s
RA (J2000)

# AVERAGE SURF. DENSITIES VS. DEFICIENCIES