Galaxy Evolution in Groups and Clusters at 'low' Redshift: Theory and Observations

Schloss Ringberg, 11-15 December 2017

HUNTING DOWN THOSE RESPONSIBLE FOR THE OBSERVED SPATIAL DISTRIBUTION OF GAS IN GALAXIES AT Z=0-0.5

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Context & Outline

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Galaxies in different environments feel different physical processes.

Are we able to characterise each mechanism by studying their impact onto galaxies?

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Spatially resolved gas and star distribution!

- Gas and Star spatially resolved properties in galaxies in low dense environments (isolated, binaries, groups) in the local universe (GASP)
- Gas distribution in galaxies in clusters and field at z~0.5 (GLASS+IllustrisTNG)

GASP:

Low Redshift, Low-Mass Environments

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- 120 hours on MUSE/VLT over 4 semesters
- Besides cluster galaxies, 30+8 galaxies are selected from a field sample (PM2GC, Calvi, Poggianti, BV 2011) - 21 galaxies observed so far

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What is the role of the environment?

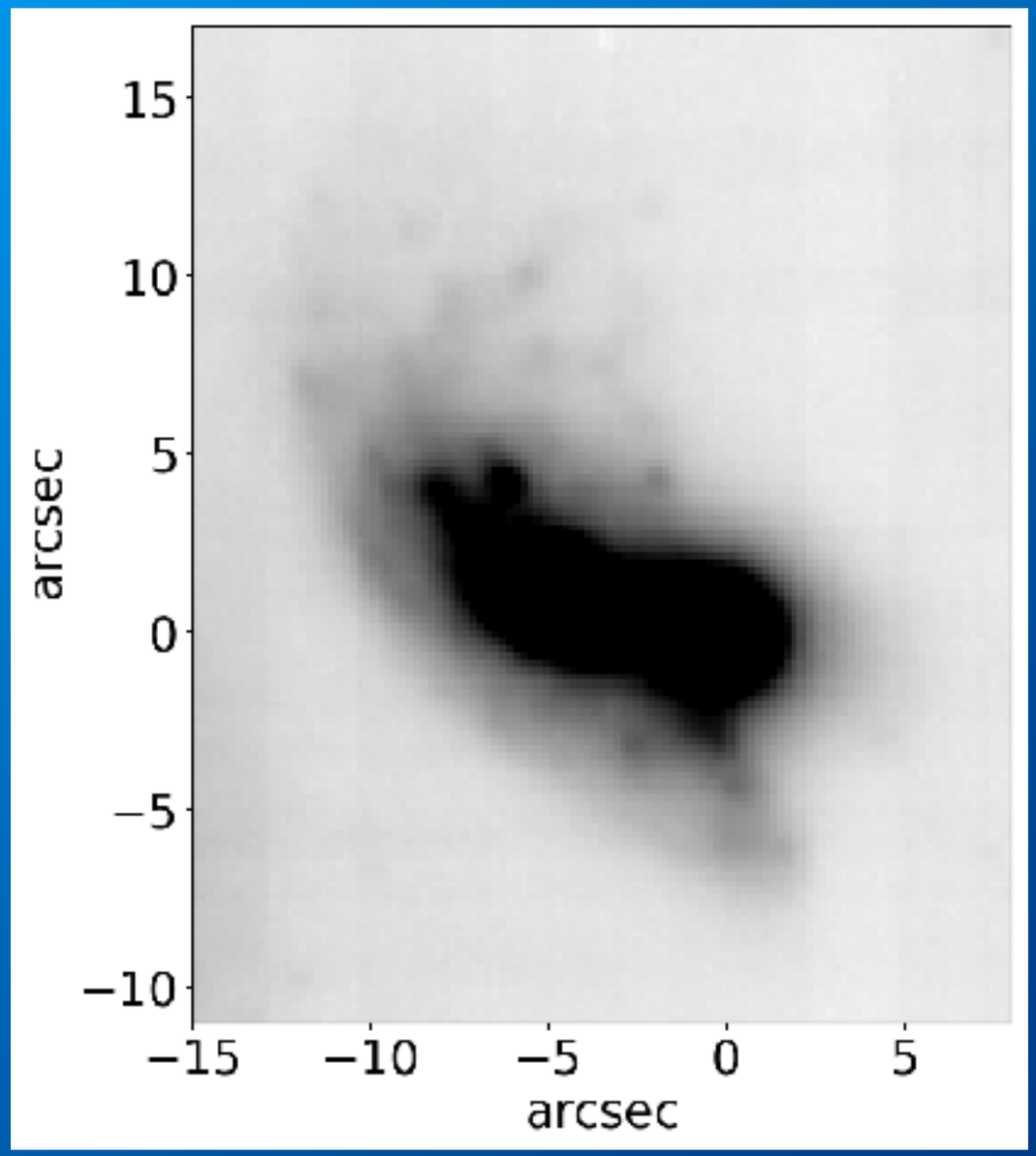
Is ram pressure effective in these environments?

What processes might be responsible for unilateral debris?

Merging system + Formation of a Tidal Dwarf Galaxy

GASP VIII: Vulcani et al. 2017C, ApJ 850, 2

Merging system + Formation of a Tidal Dwarf Galaxy



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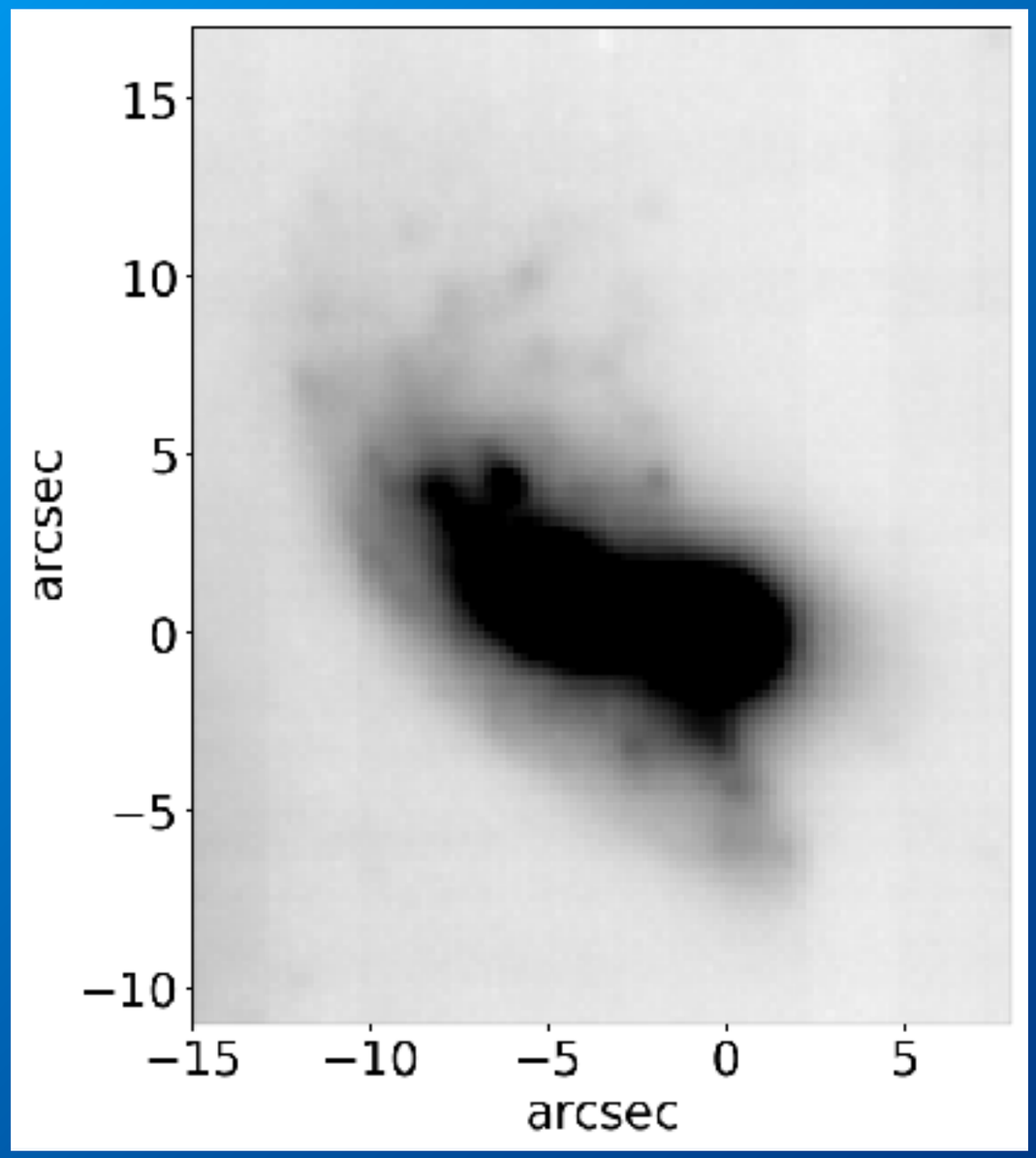

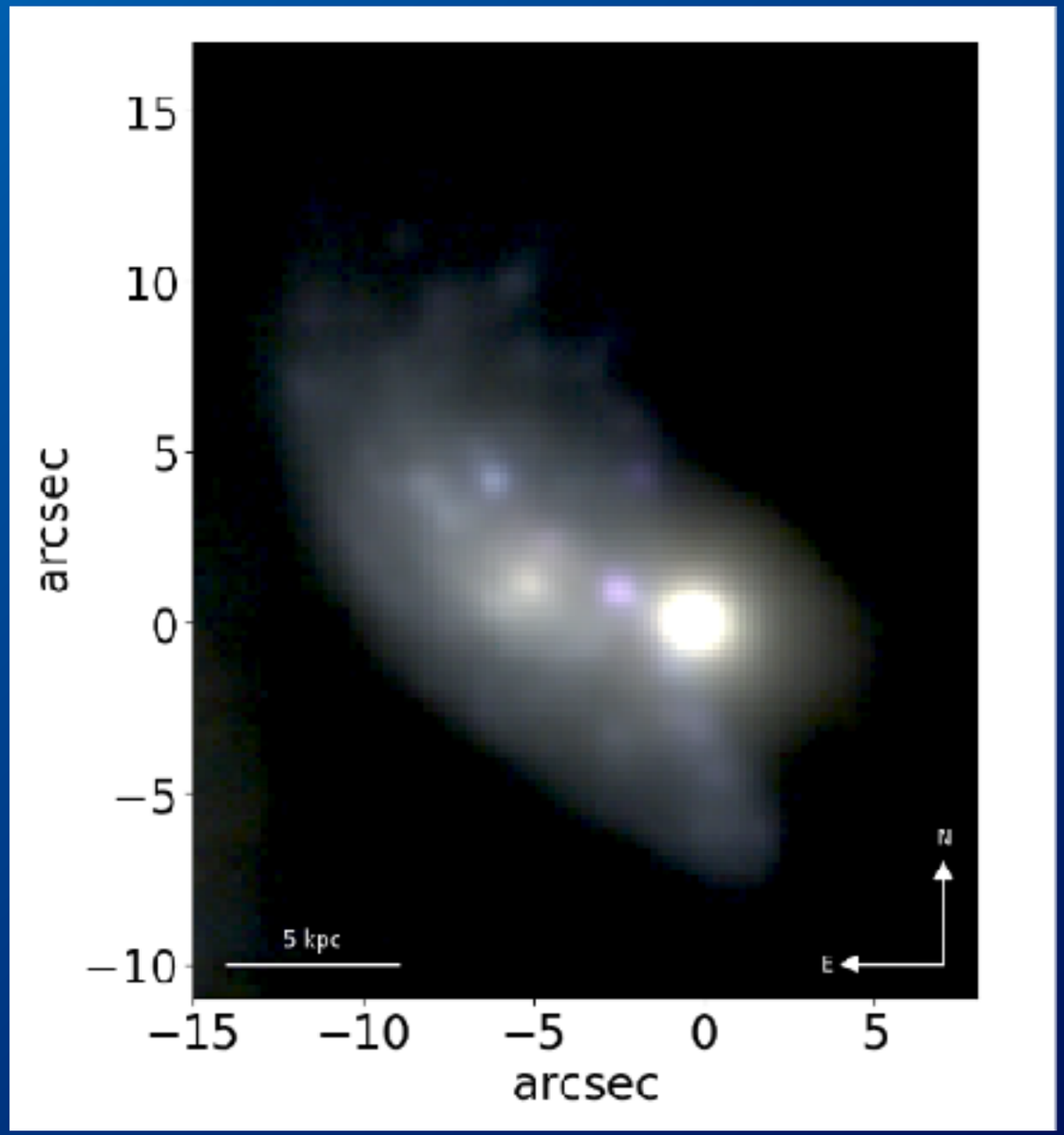

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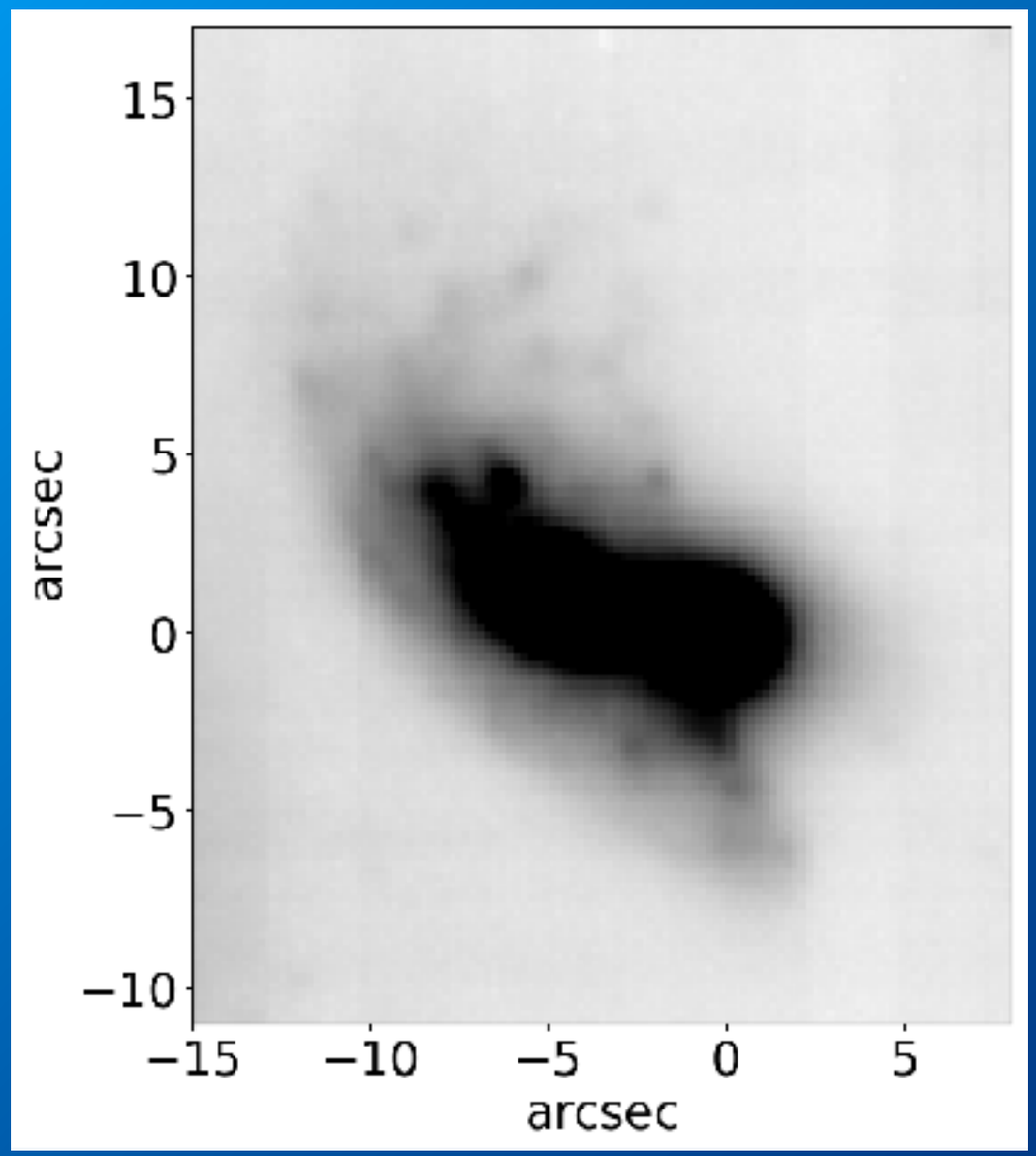
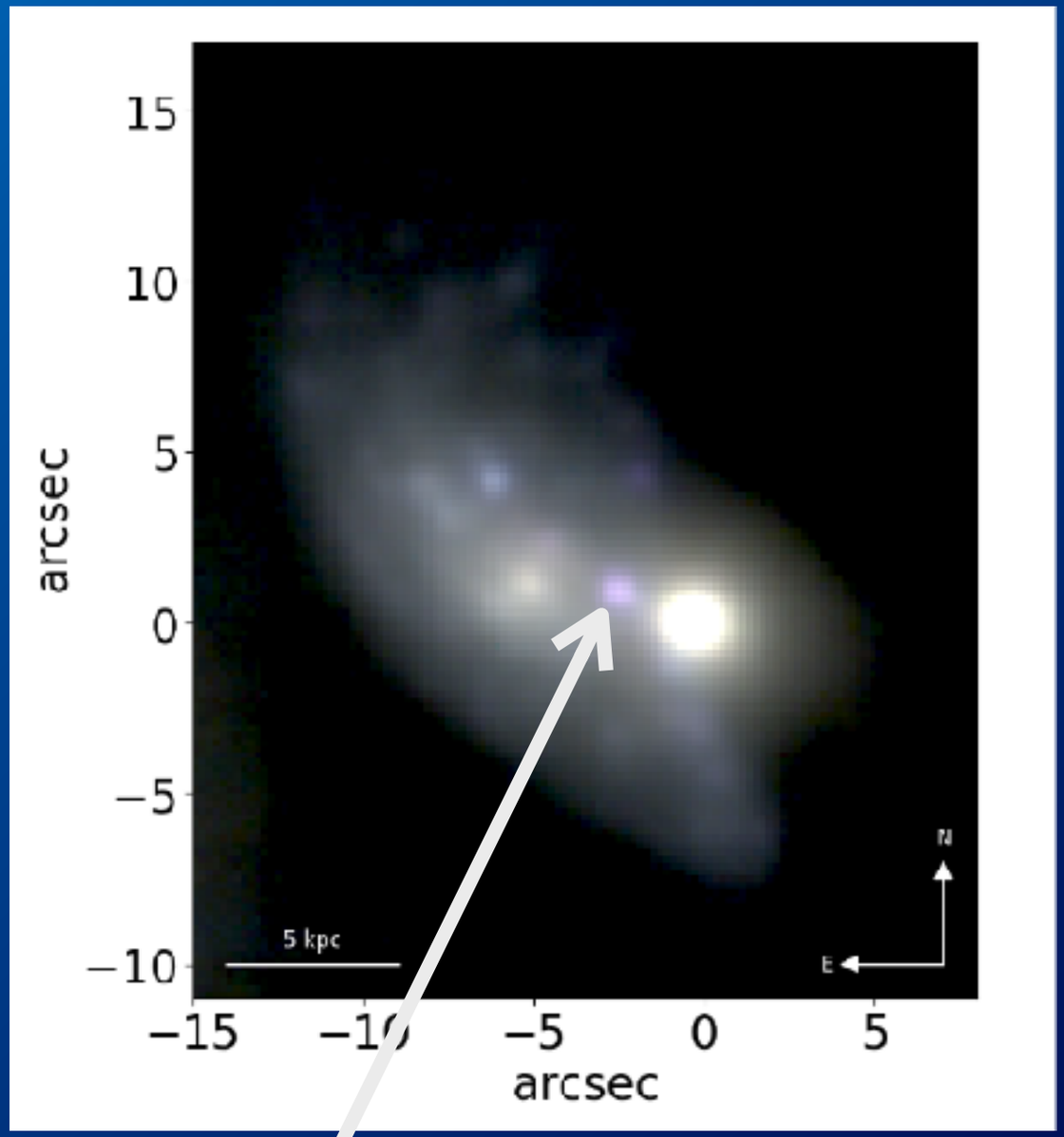
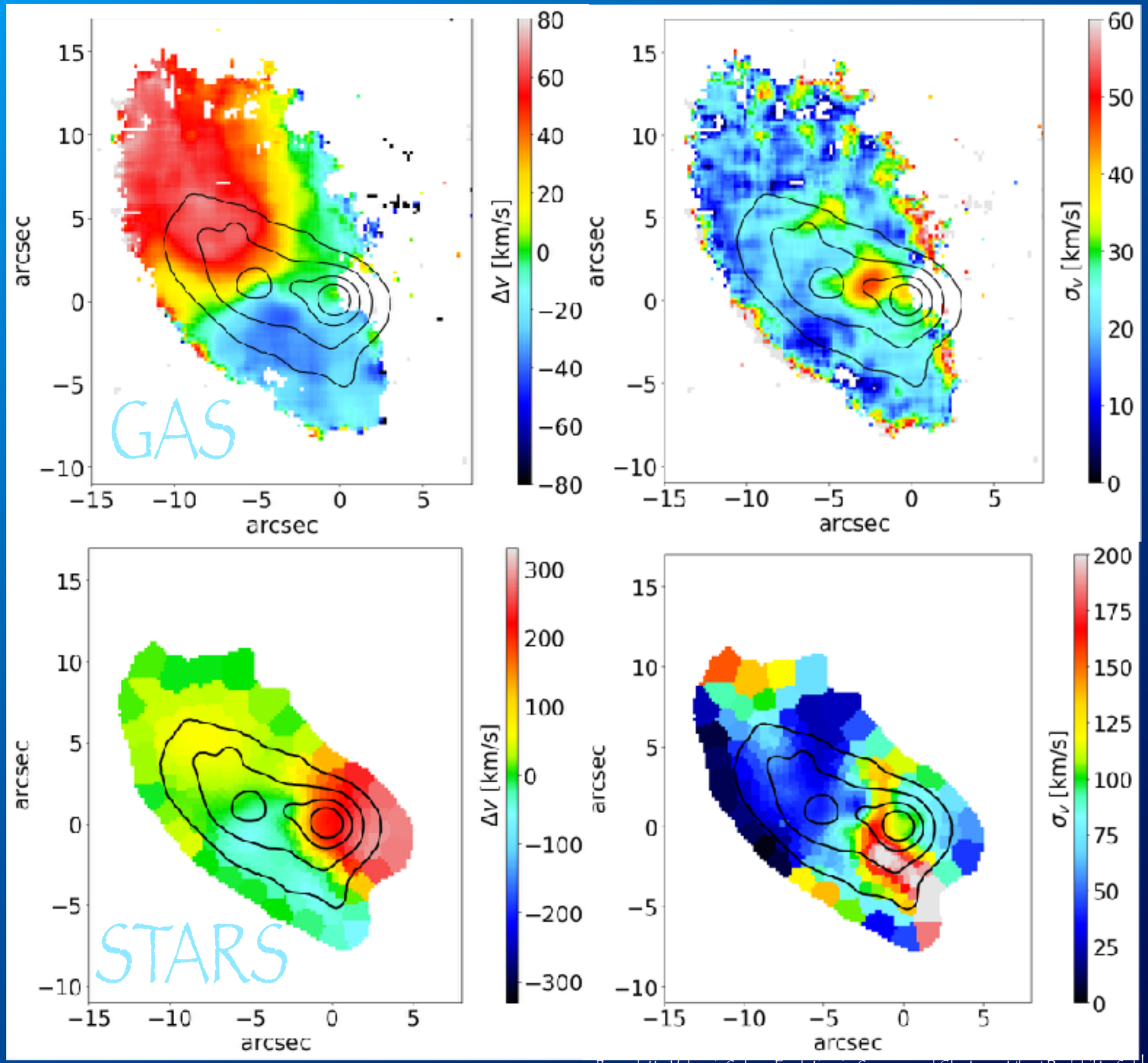
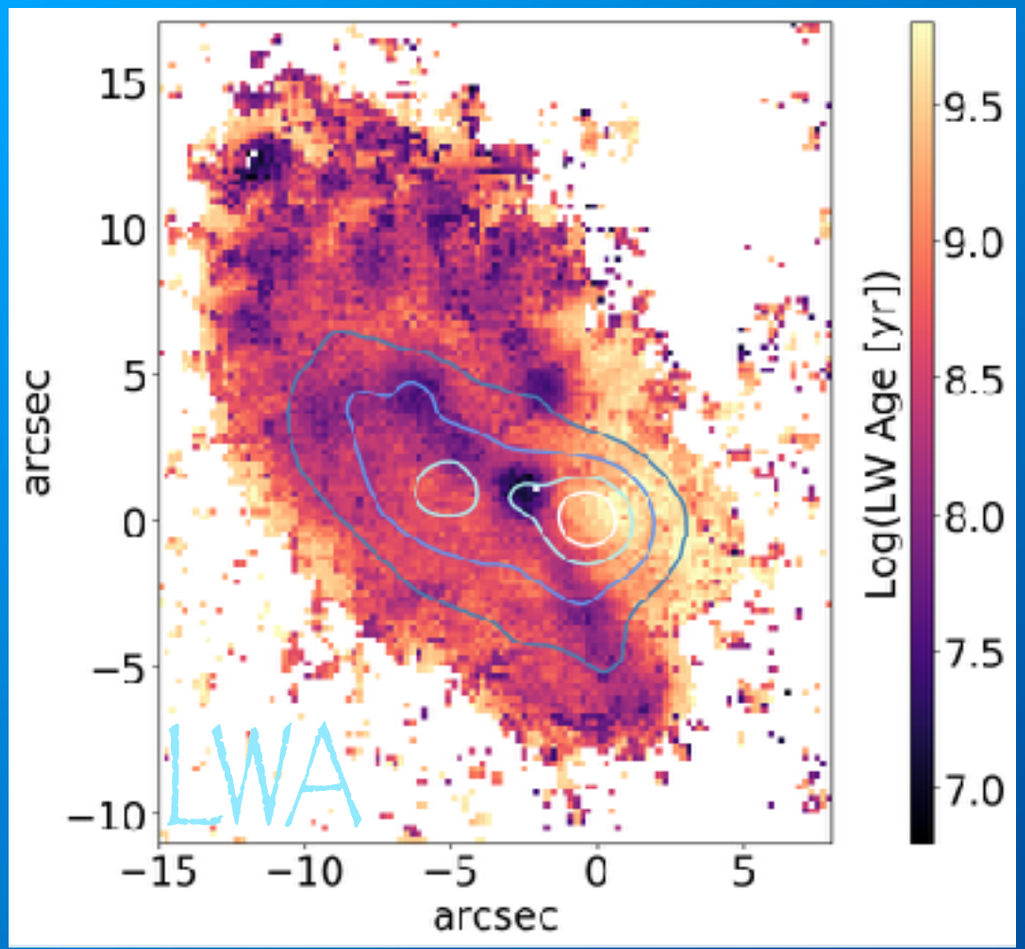


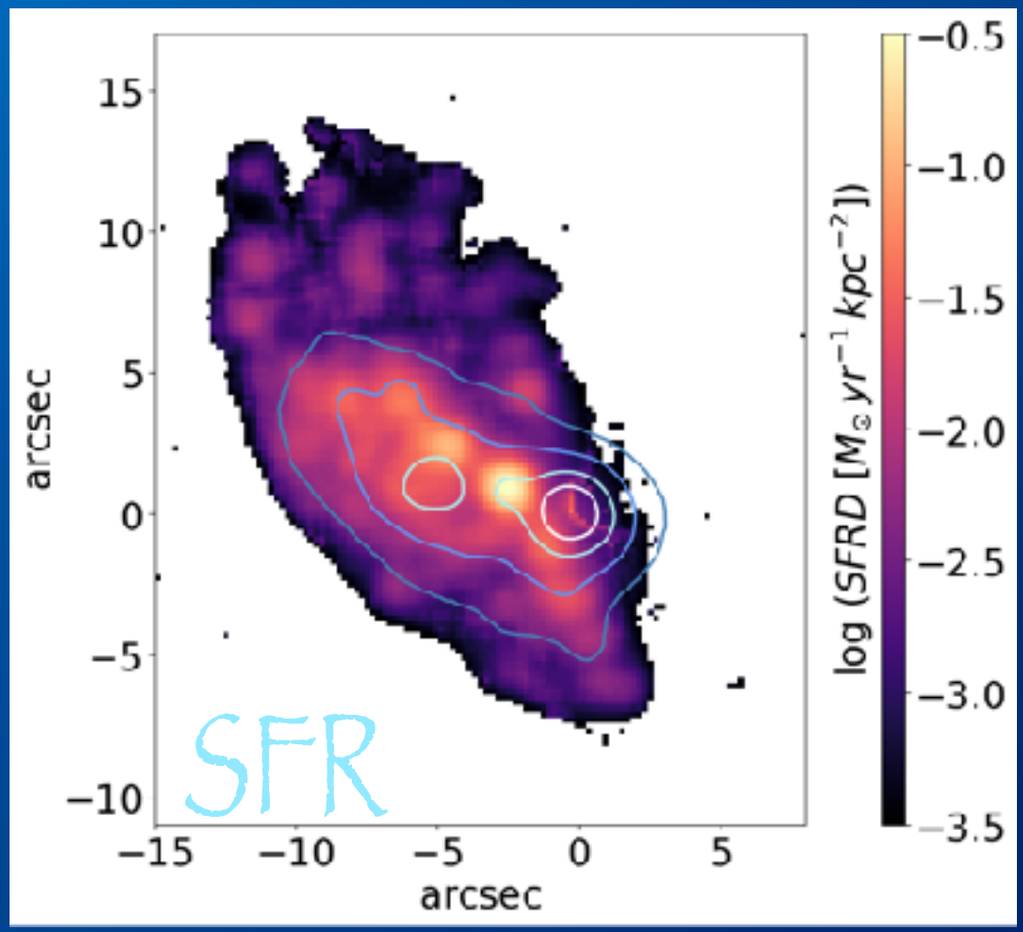


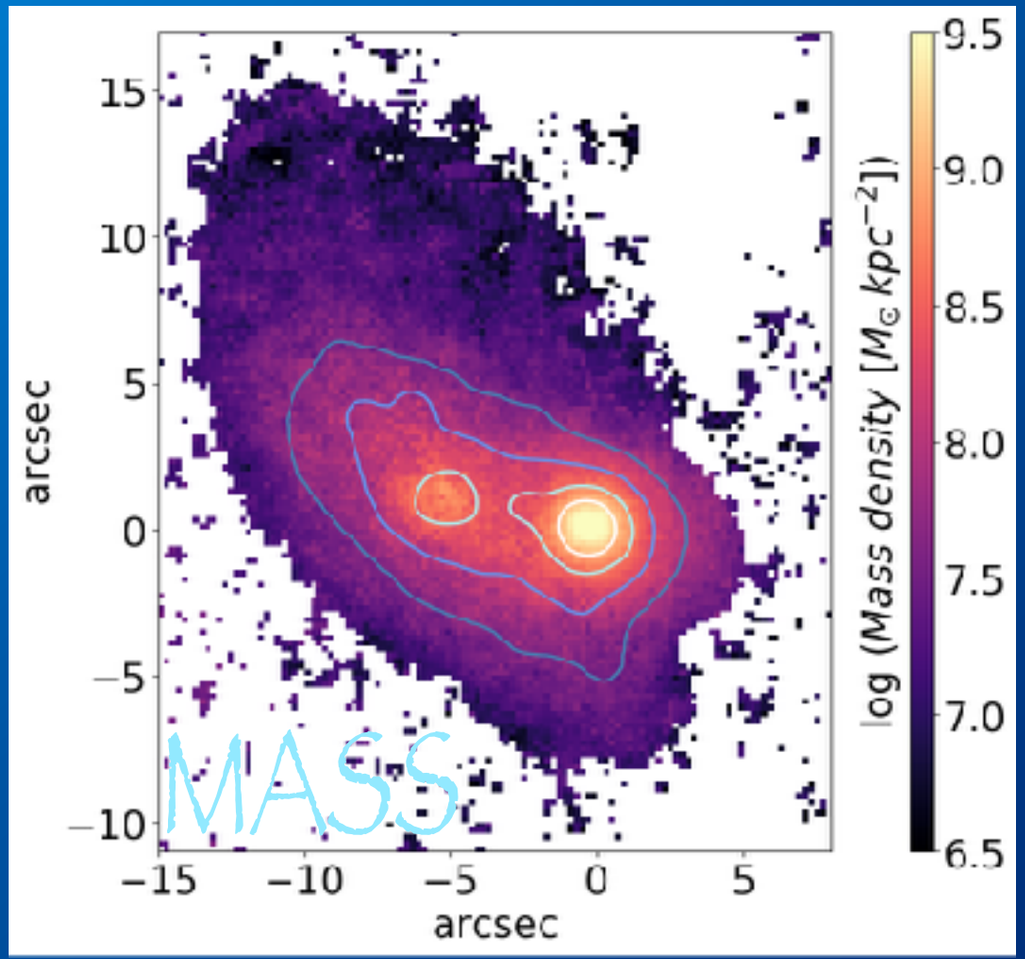
1st detailed characterisation of a TDG candidate beyond the local Universe!

GASP VIII: Vulcani et al. 2017C, ApJ 850, 2


GAS
STARS
arcsec
Δv [km/s]
σv [km/s]







Early-stage 1:1 merger between a LT and ET galaxies

Occurred between 2×10^7< t < 5.7×10^8 yr ago

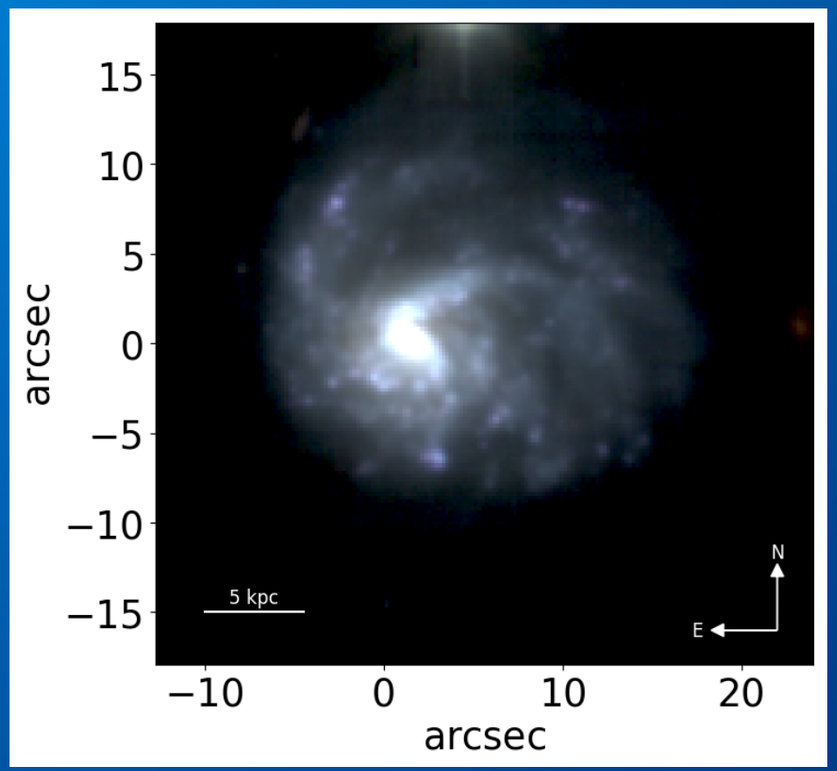
TDG formed in the merger:

Mstar ≈ Mdyn ≈ 6x10^9Msun; r ≈ 2 kpc

Gas Accretion

GASP VII: Vulcani et al. 2017D, ApJ in press

Gas Accretion



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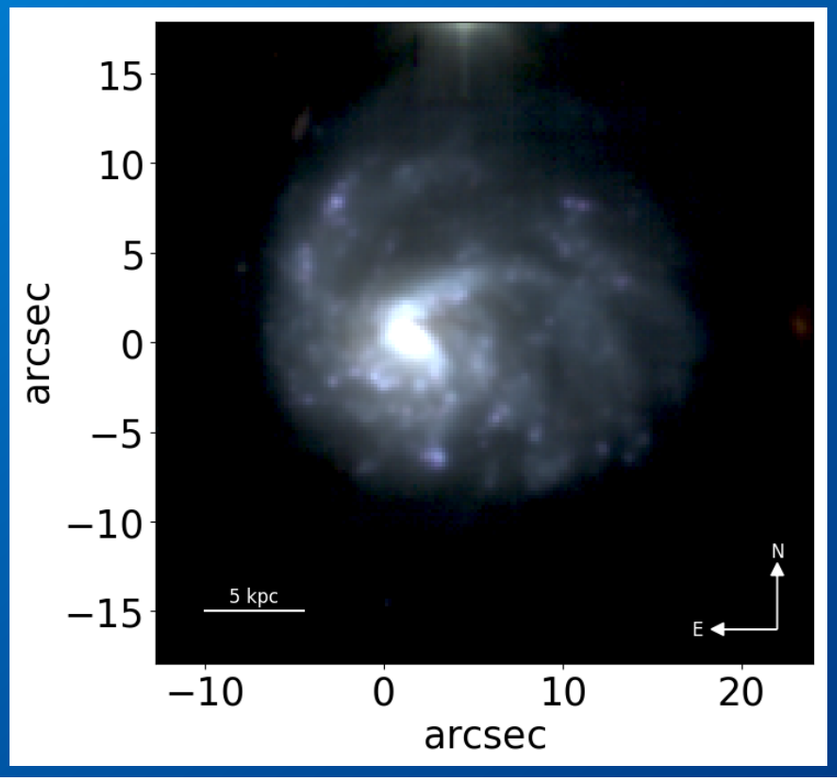
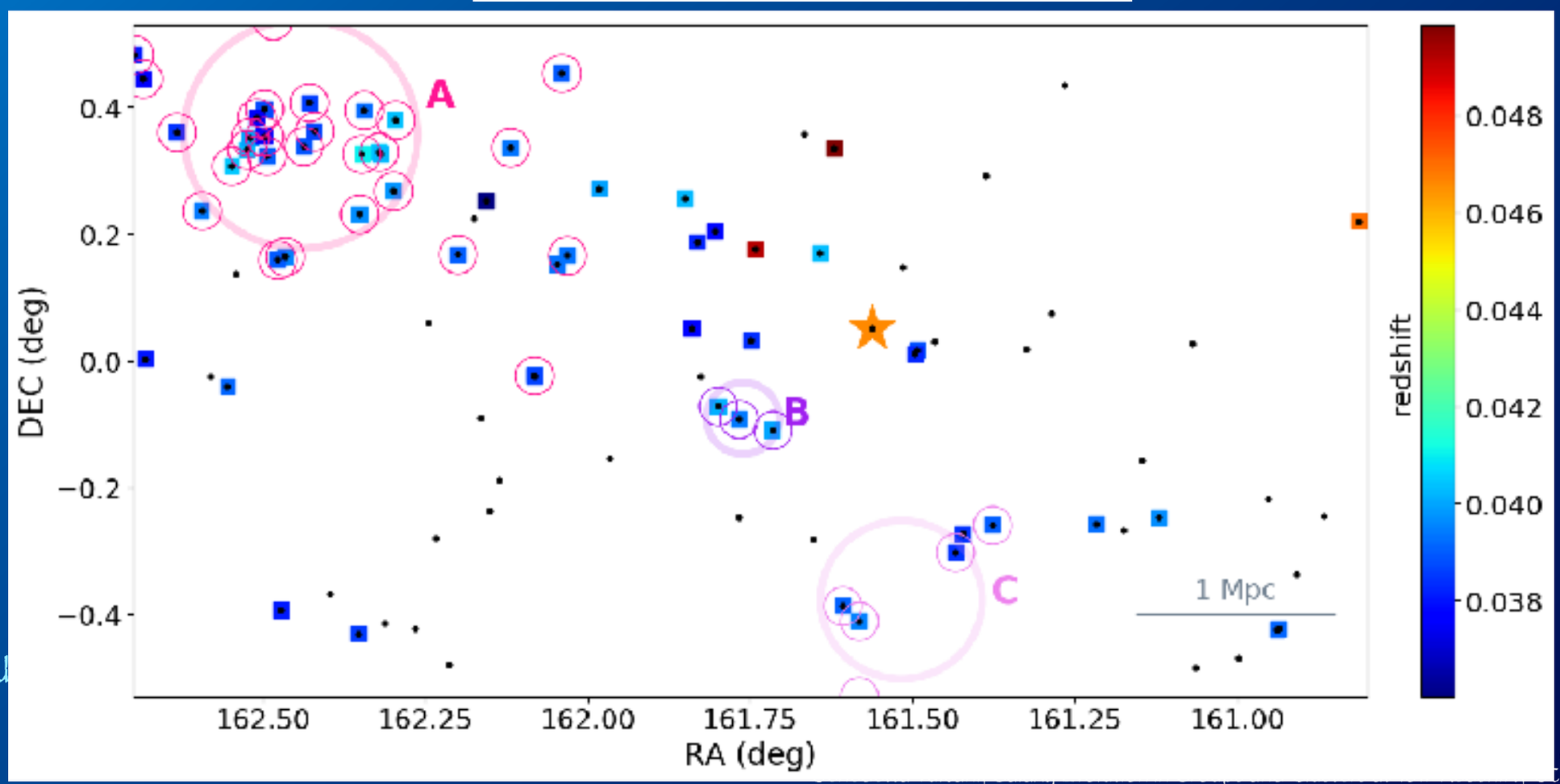
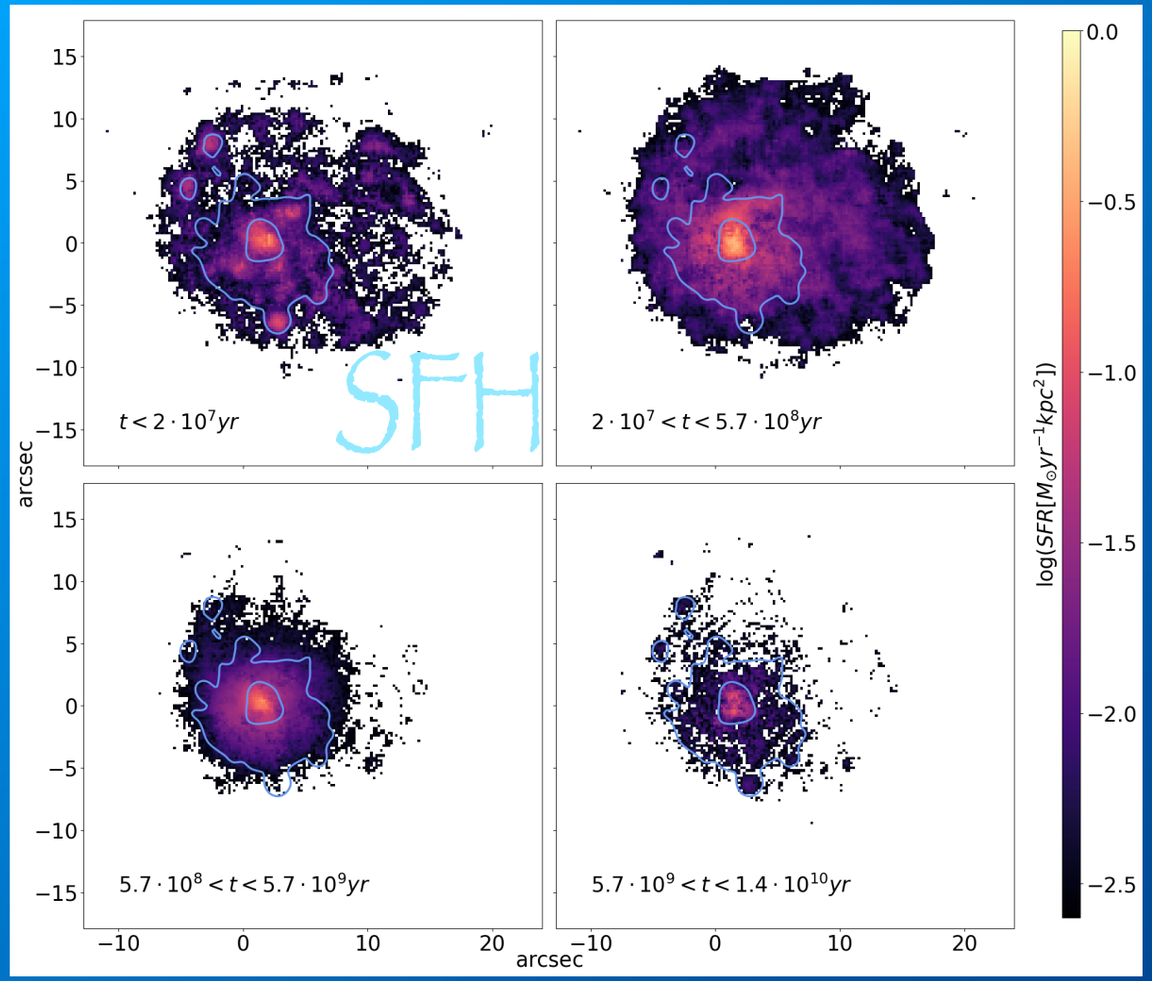
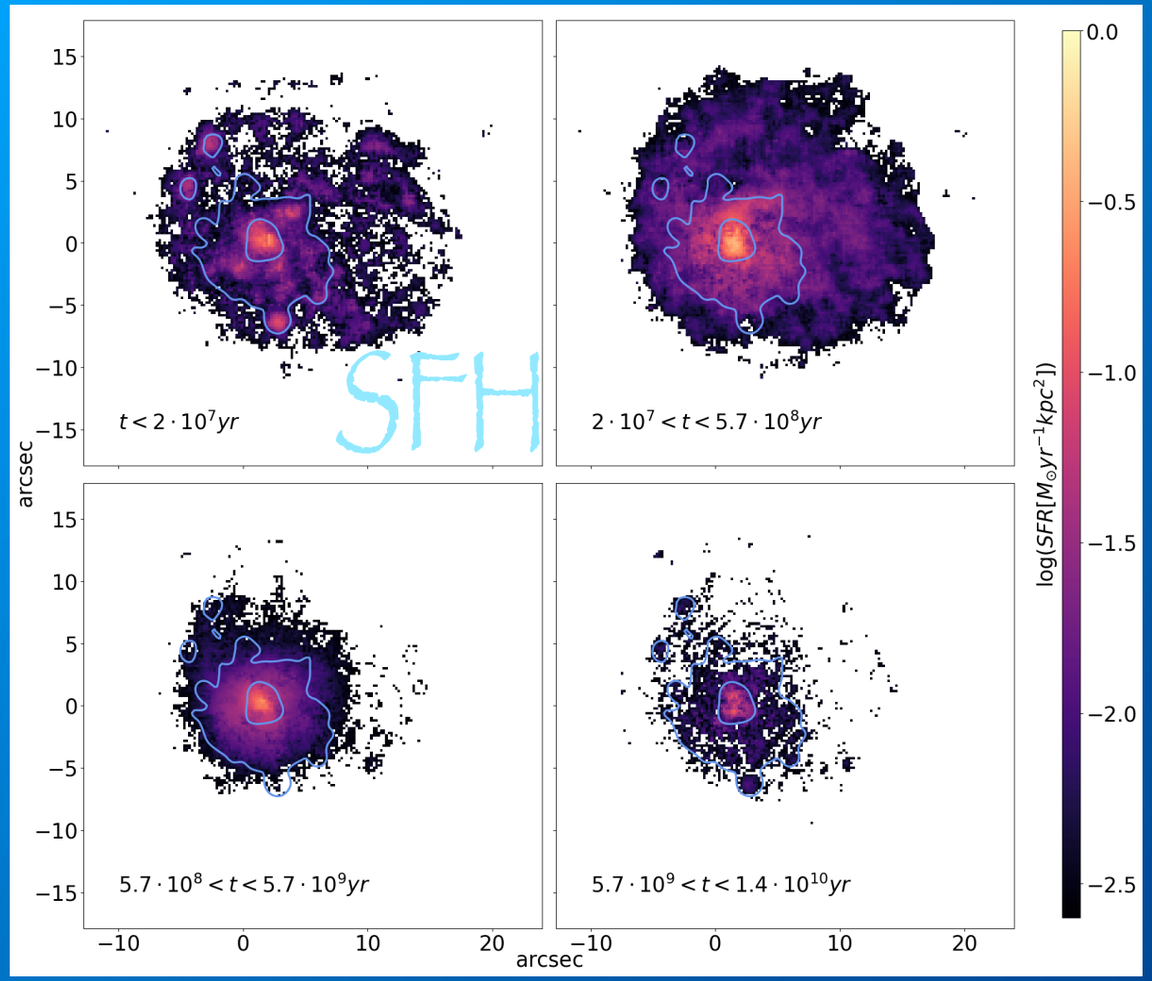




GASP VII: Vu


SFH
$t < 2 \cdot 10^7 yr$
$2 \cdot 10^7 < t < 5.7 \cdot 10^8 yr$
$5.7 \cdot 10^8 < t < 5.7 \cdot 10^9 yr$
$5.7 \cdot 10^9 < t < 1.4 \cdot 10^{10} yr$
arcsec
arcsec
$\log(SFR[M_\odot yr^{-1} kpc^2])$
0.0
−0.5
−1.0
−1.5
−2.0
−2.5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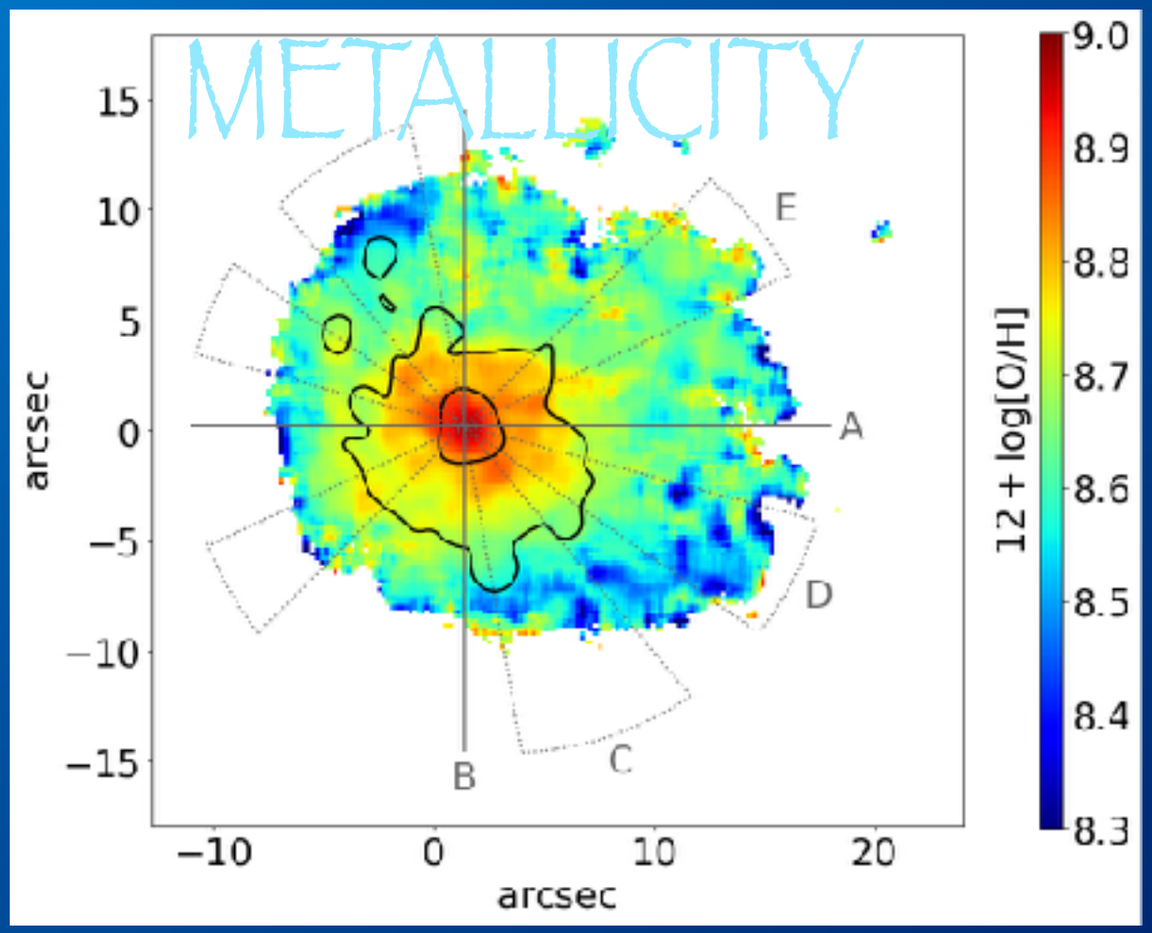
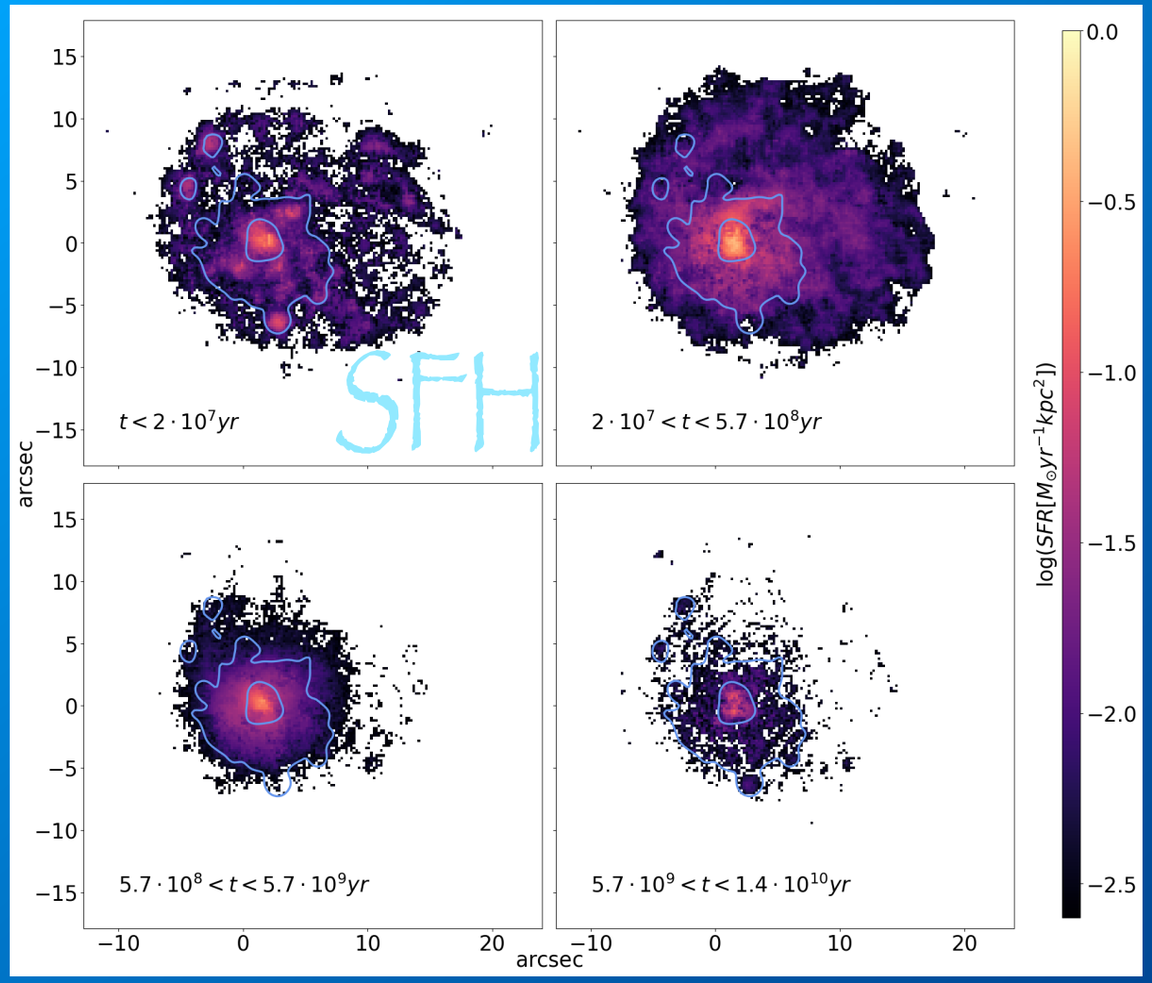

METALLICITY
A
B
C
D
E
arcsec
arcsec
12 + log[O/H]
9.0
8.9
8.8
8.7
8.6
8.5
8.4
8.3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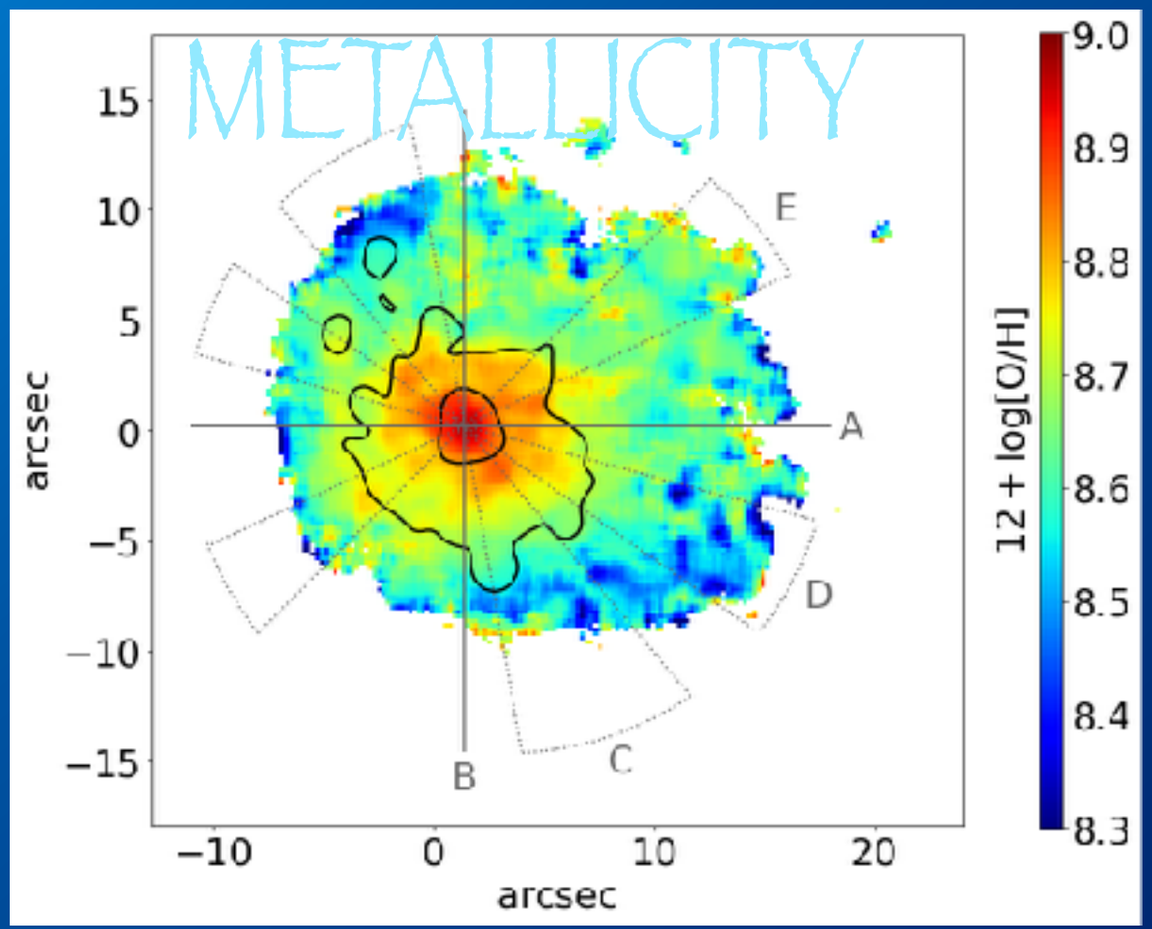
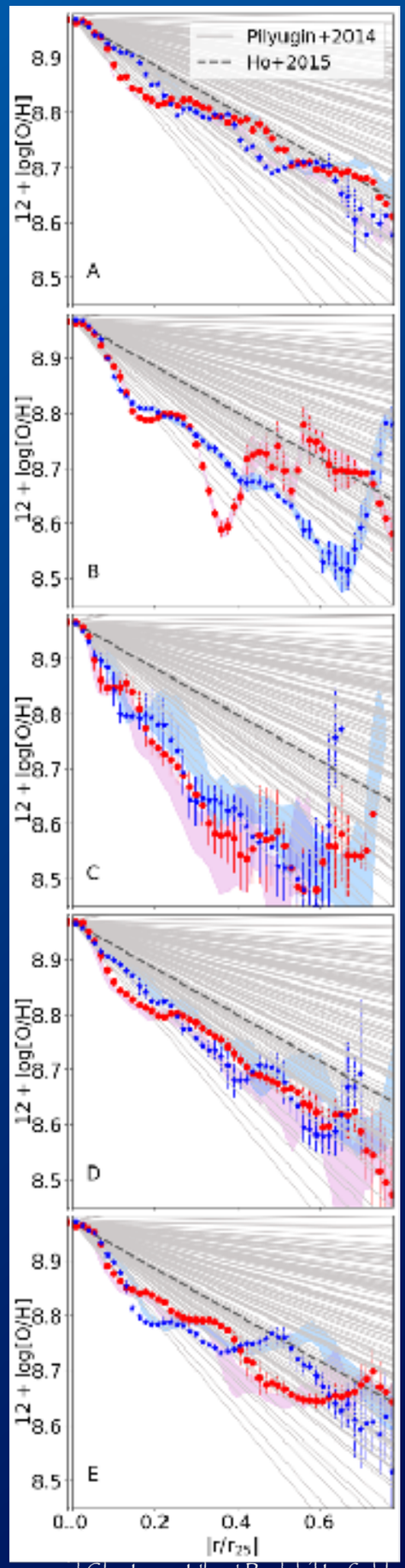
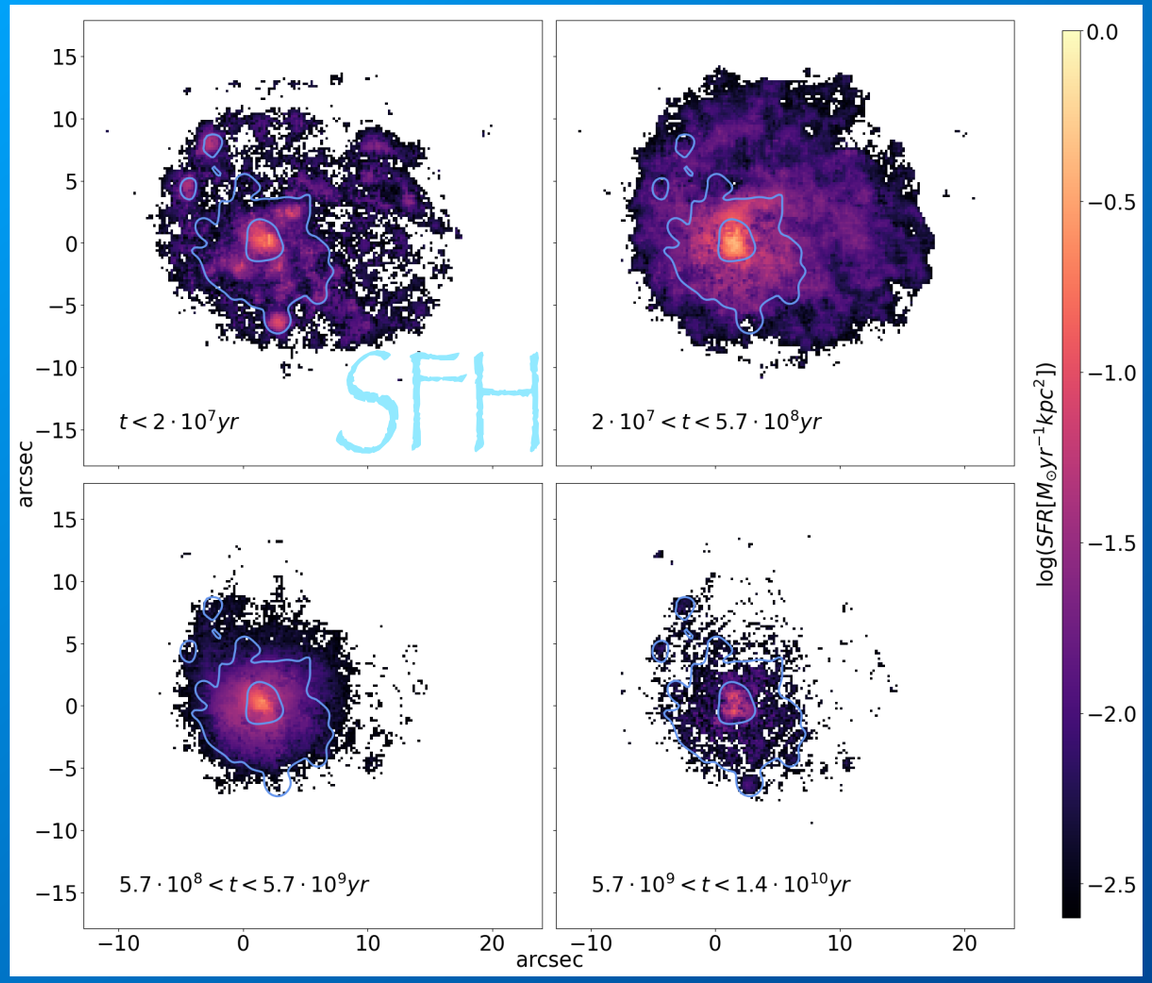
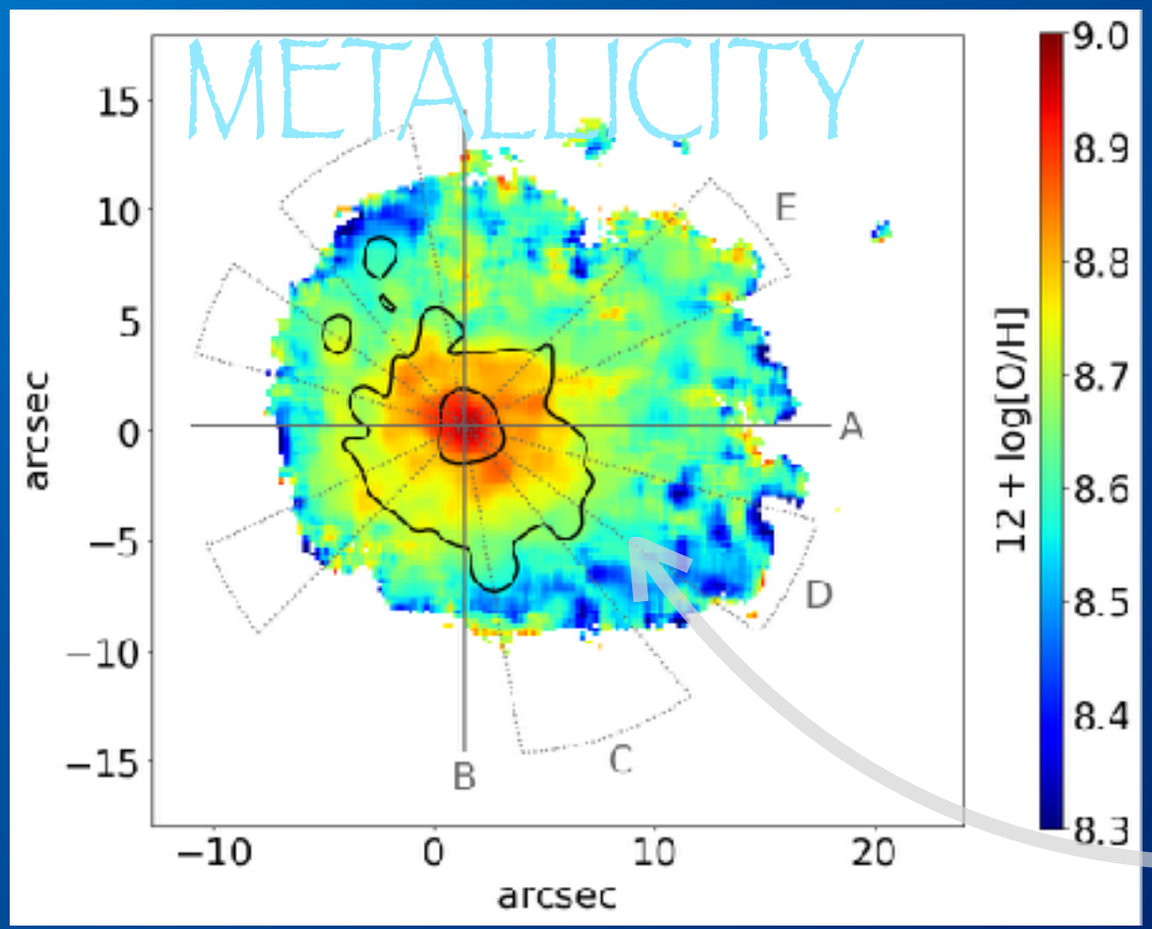
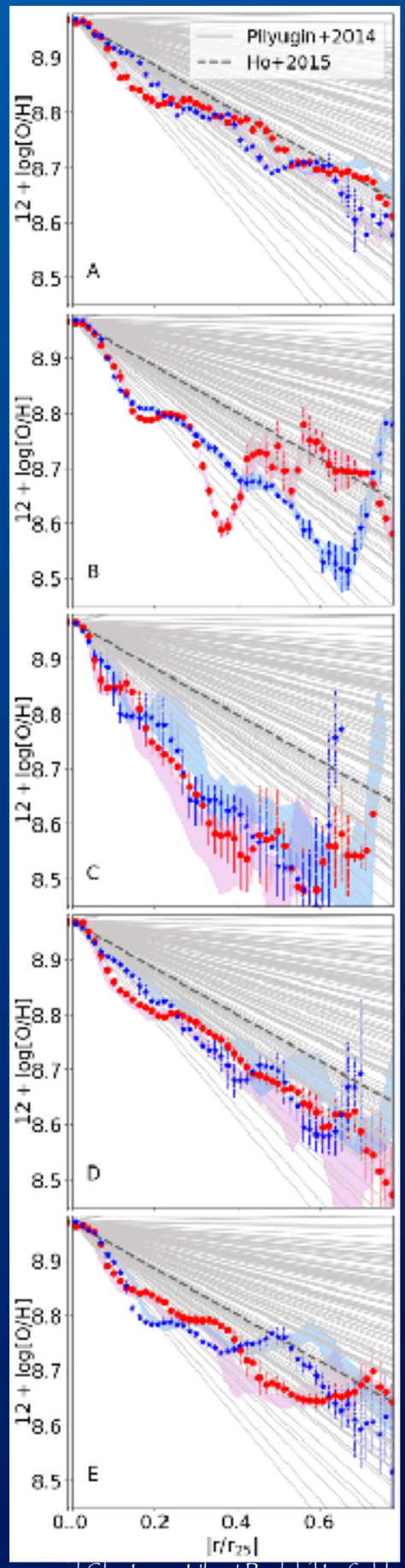

METALLICITY
A
B
C
D
E
arcsec
arcsec
12 + log[O/H]


Pilyugin+2014
Ho+2015
12 + log[O/H]
A
B
C
D
E
$|r/r_{25}|$





inflow of low metallicity gas



Other Puzzling Examples

PRELIMINARY

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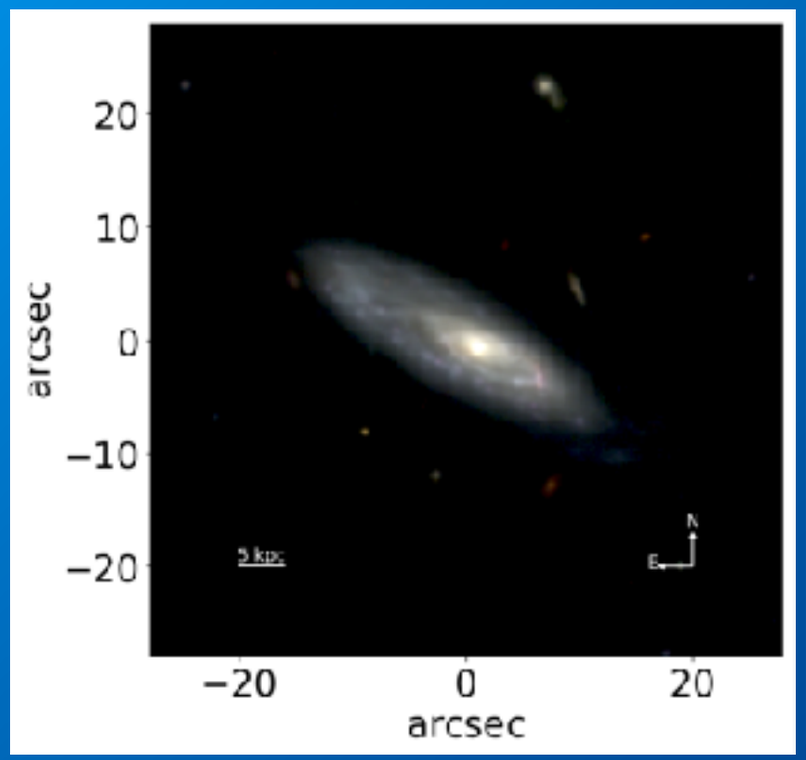
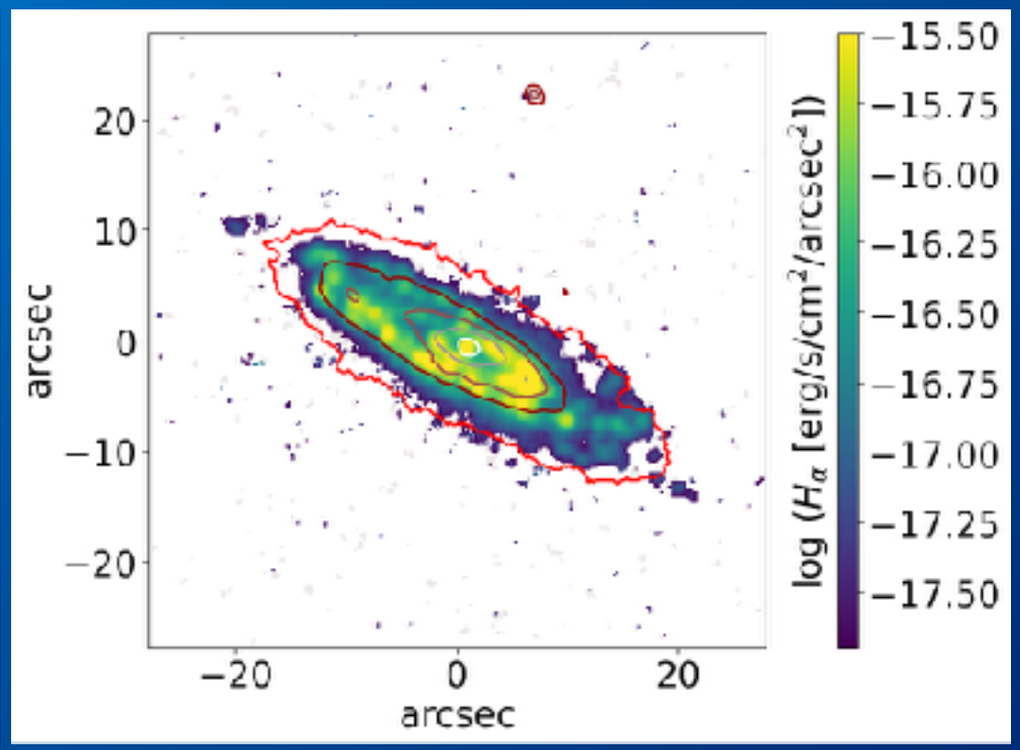




logM*≈ 10^10.75 Msun

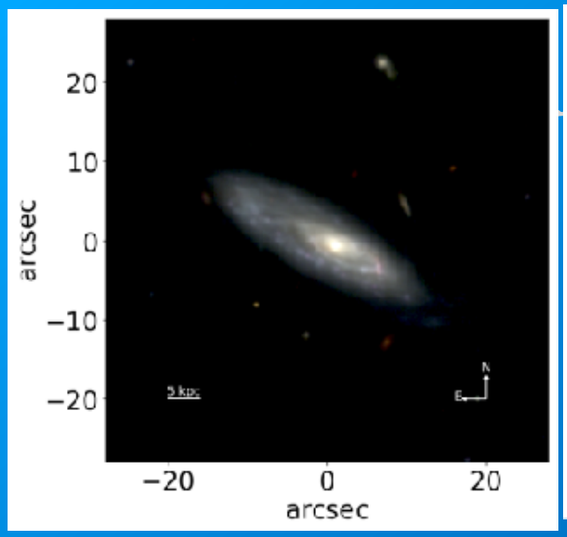
In group of 4 members

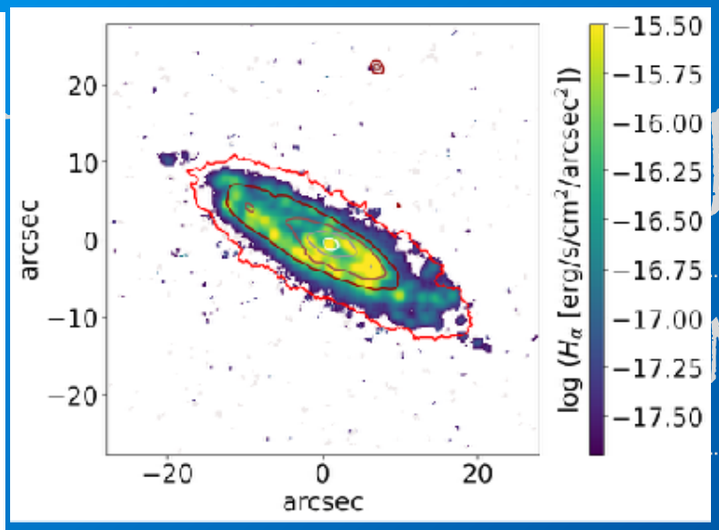
Mhalo≈ 10^11.6 Msun

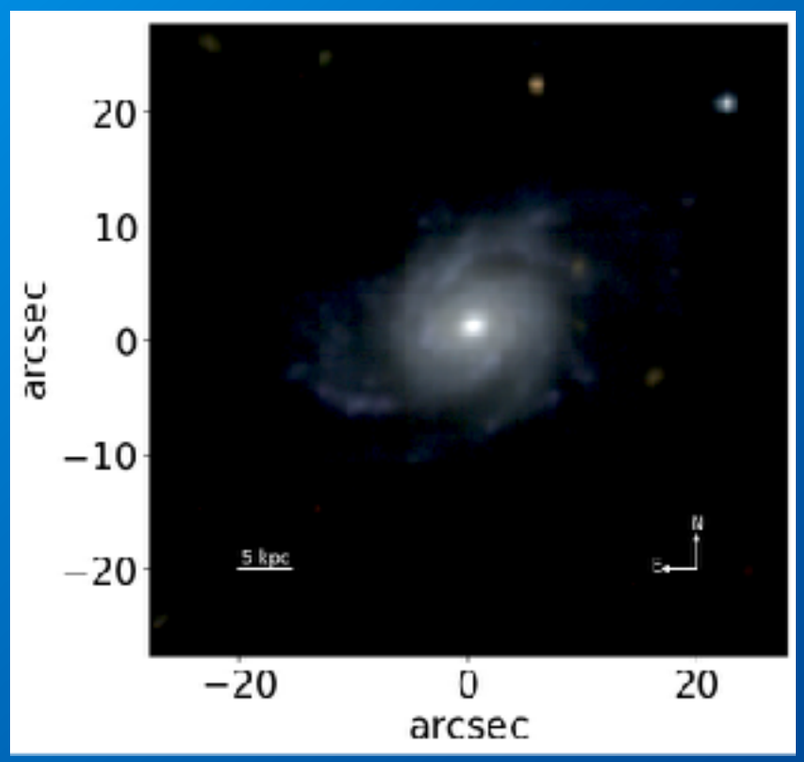
d=0.33 R200

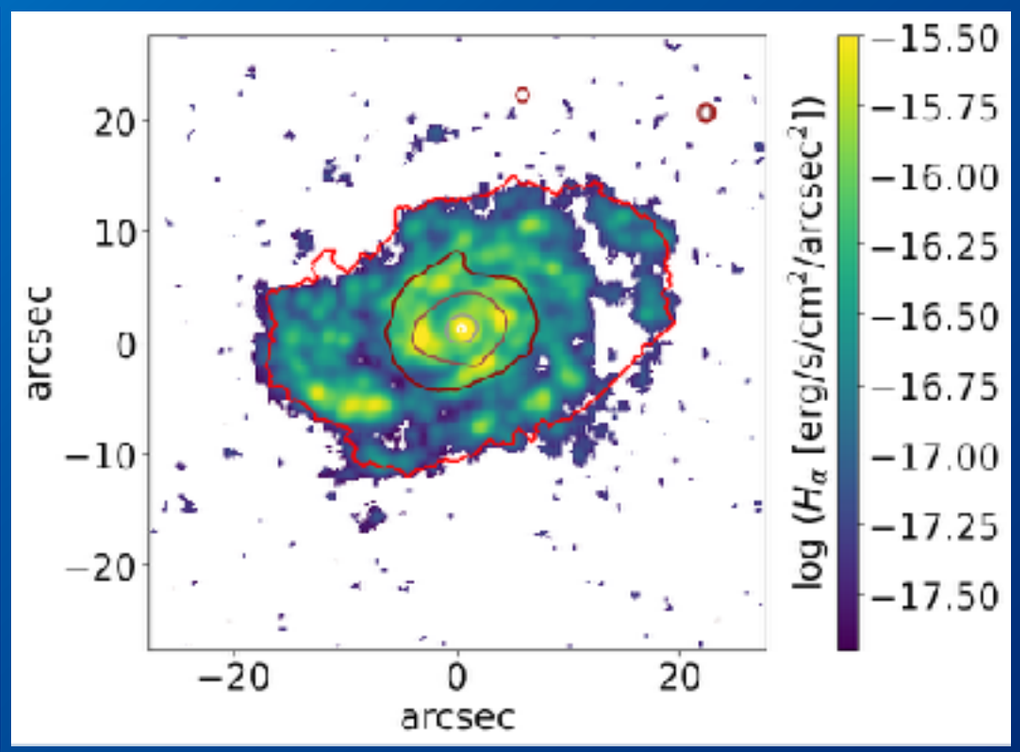
...NG EXAMPLES

...MINARY









logM*≈ 10^10.26 Msun

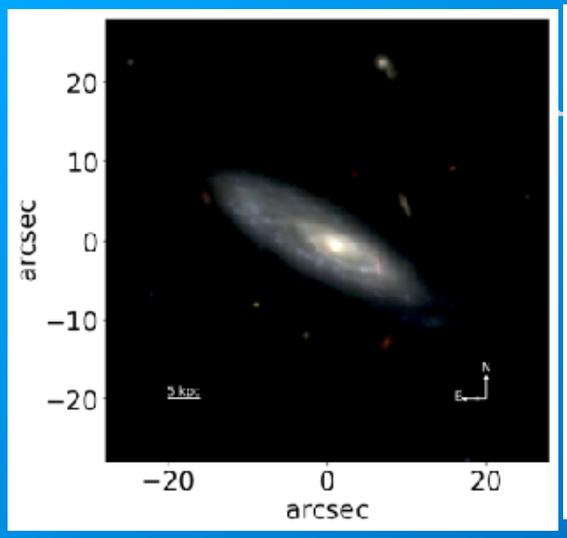
In binary falling onto a system

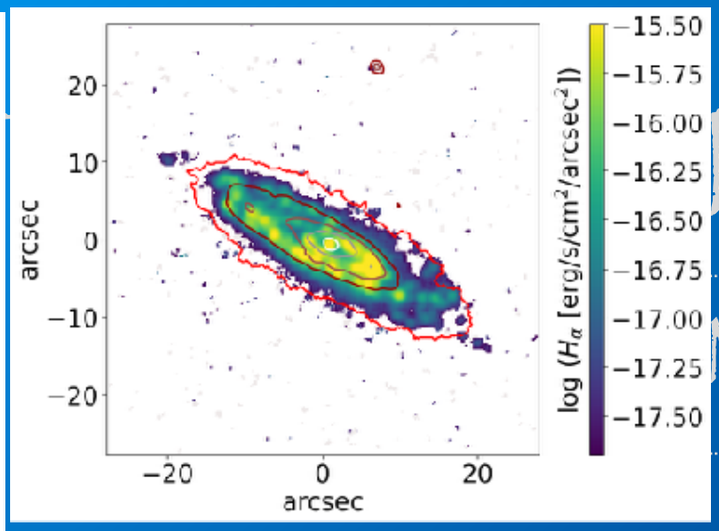
D between galaxies:

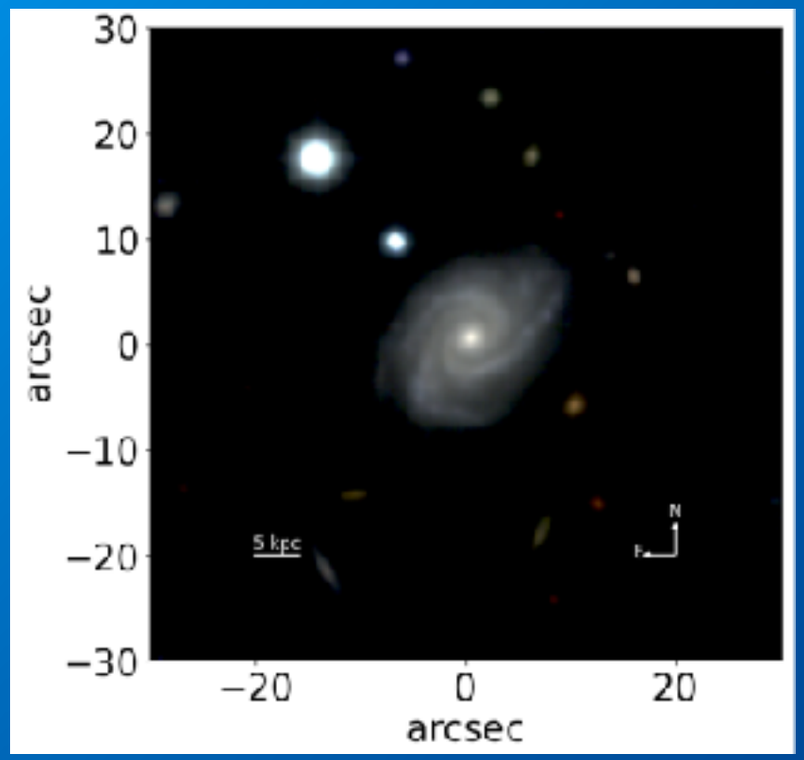
233.5 kpc

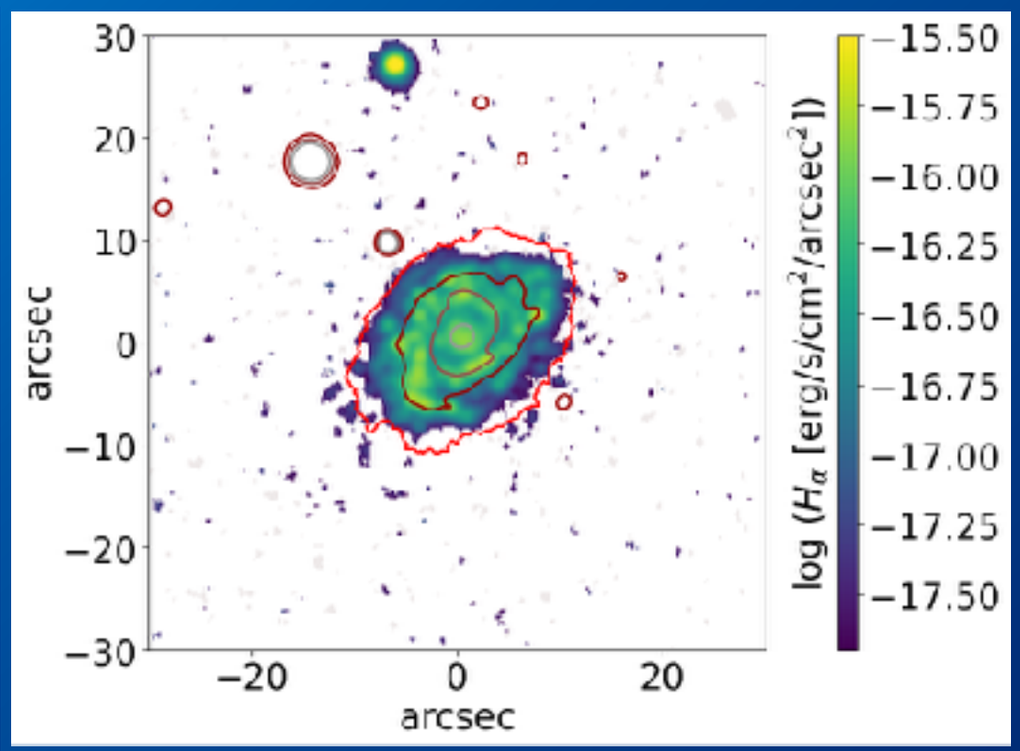
...NG EXAMPLES

...MINARY







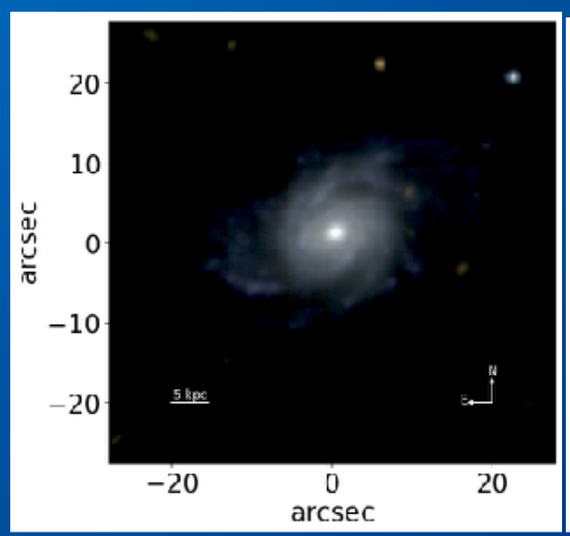


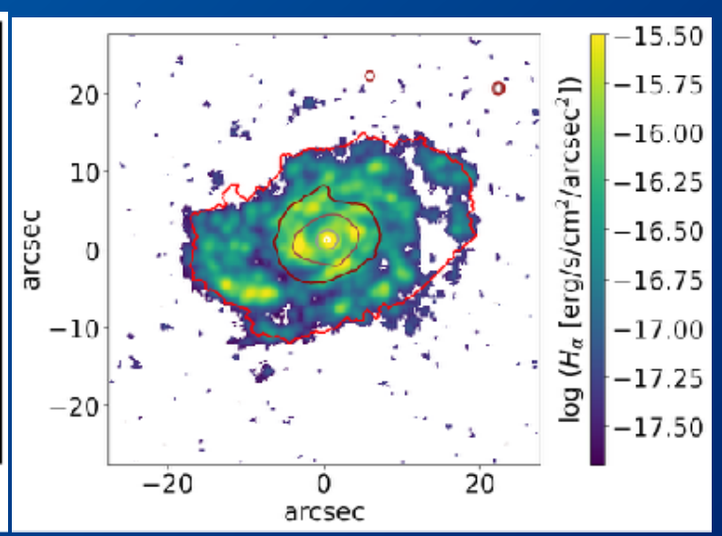
logM*≈ 10^10.46 Msun

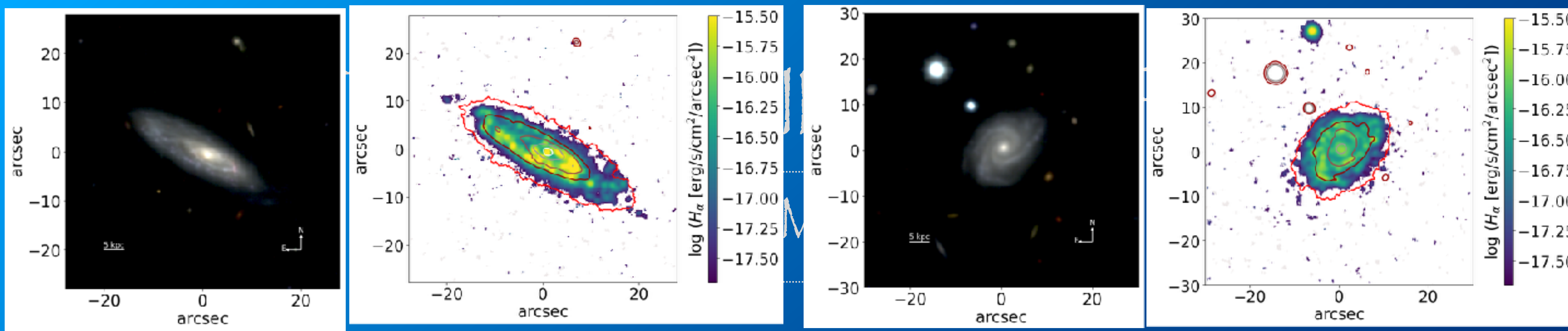
In group of 28 galaxies

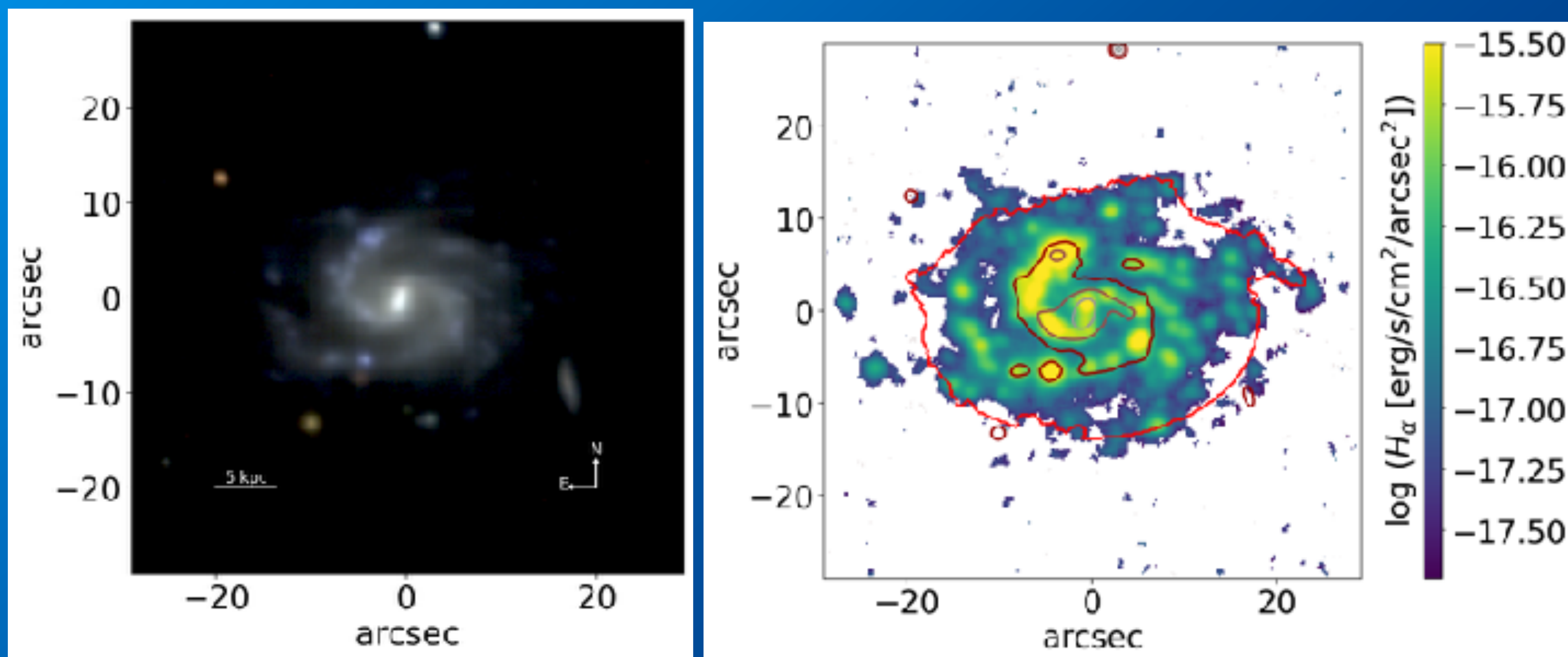
Mhalo ≈ 10^14.12 Msun

d=4 R200







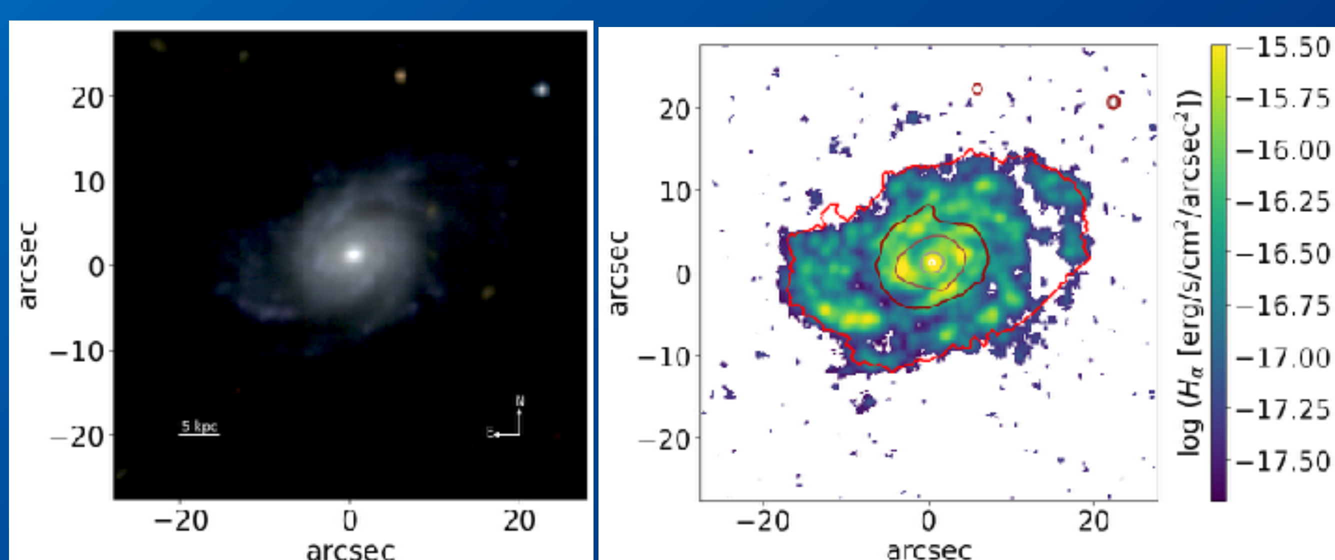


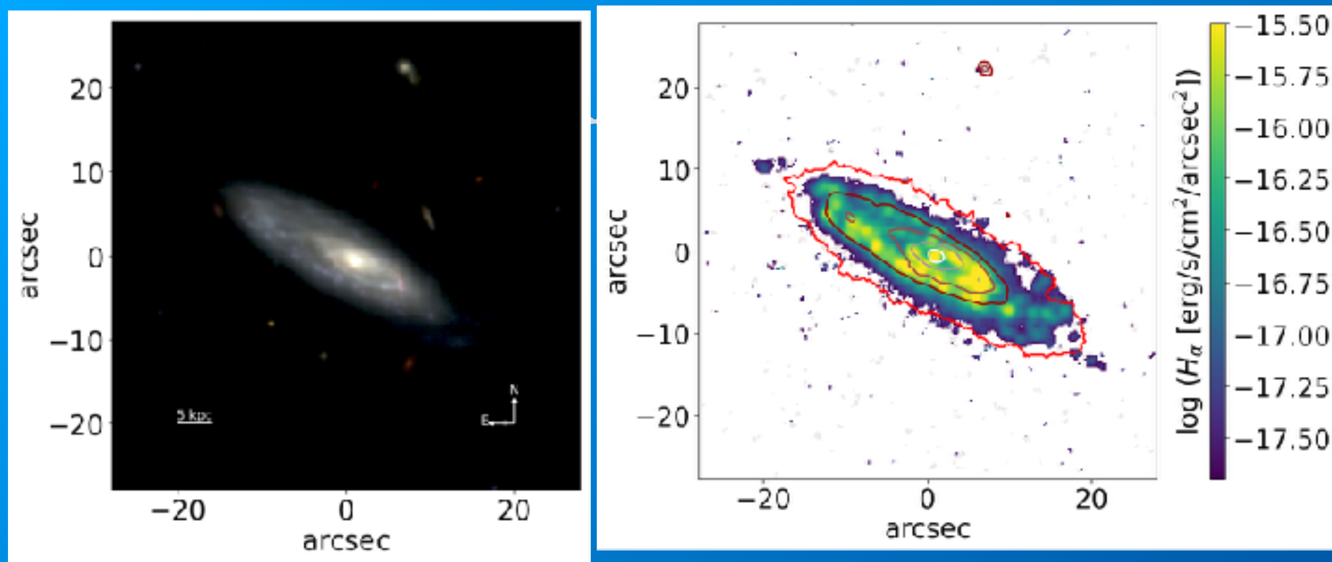
logM*= 10^9.98 Msun

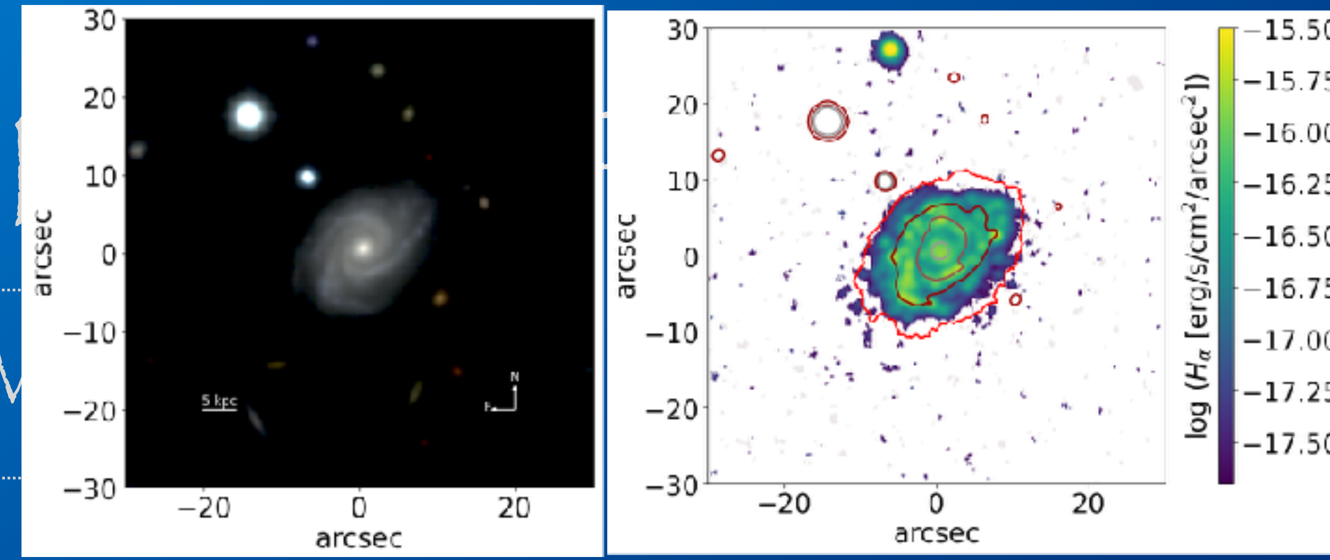
Group of 3 members

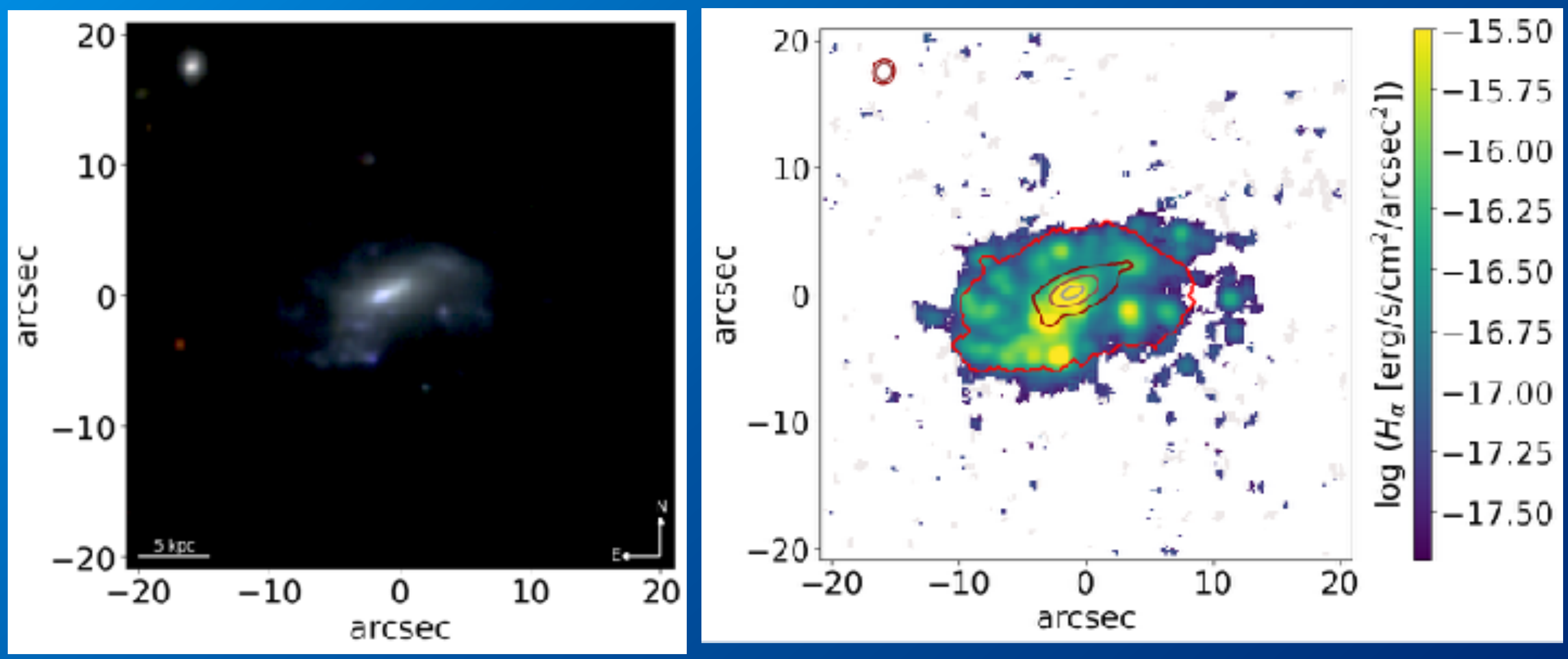
Mhalo = 10^12.6 Msun

D closest galaxy= 193.5 kpc





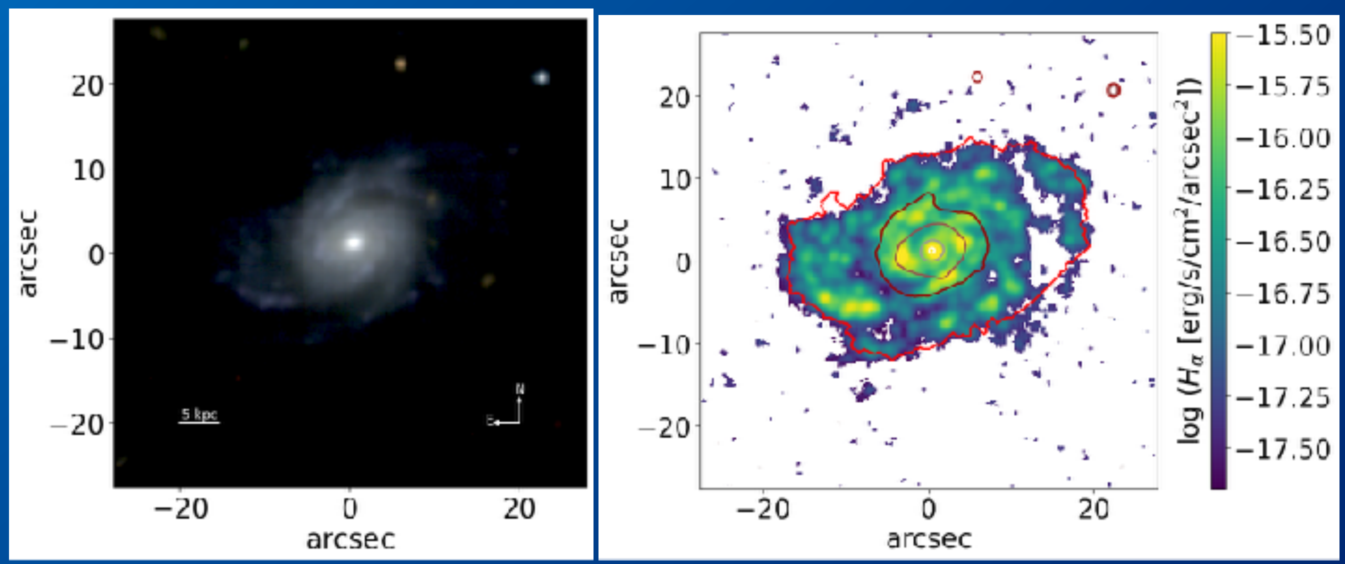


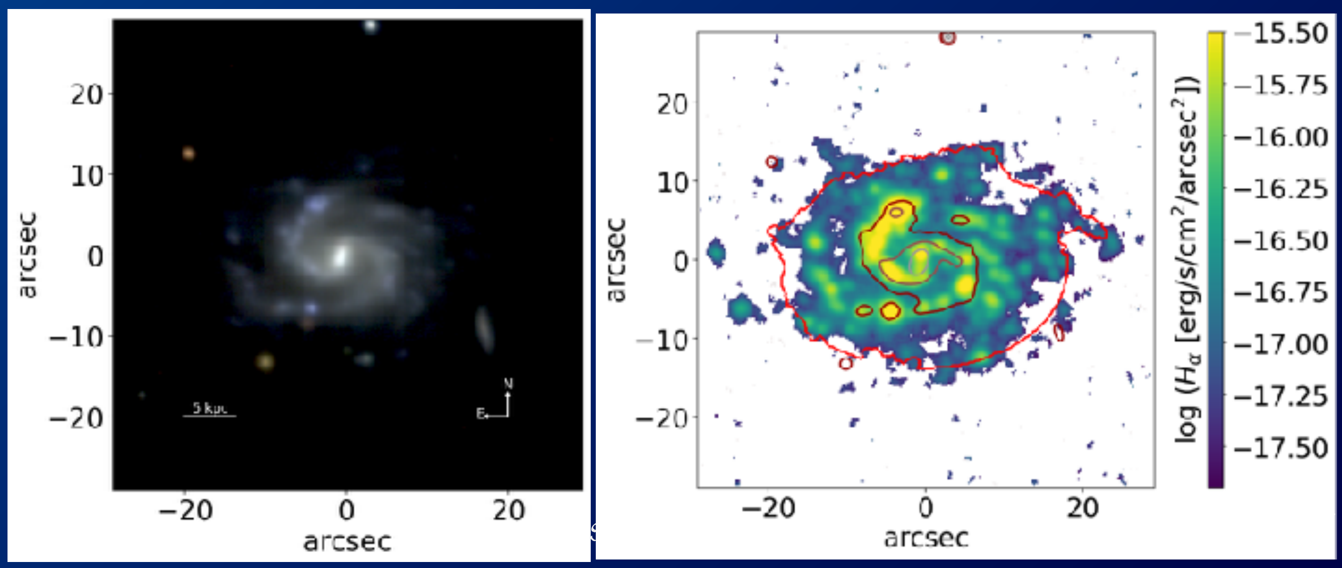


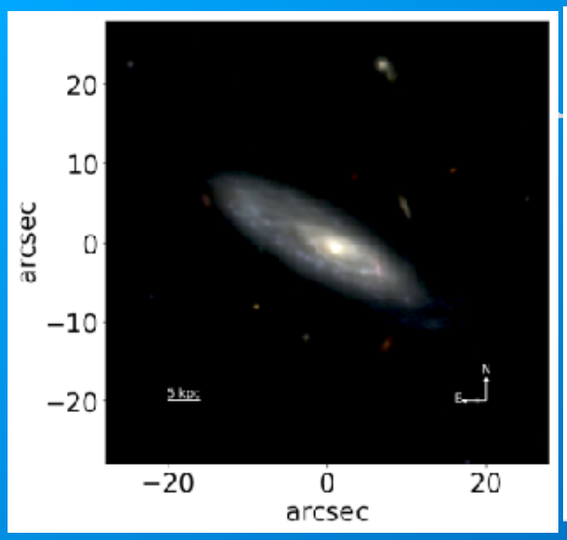
logM*= 10^9.33 Msun

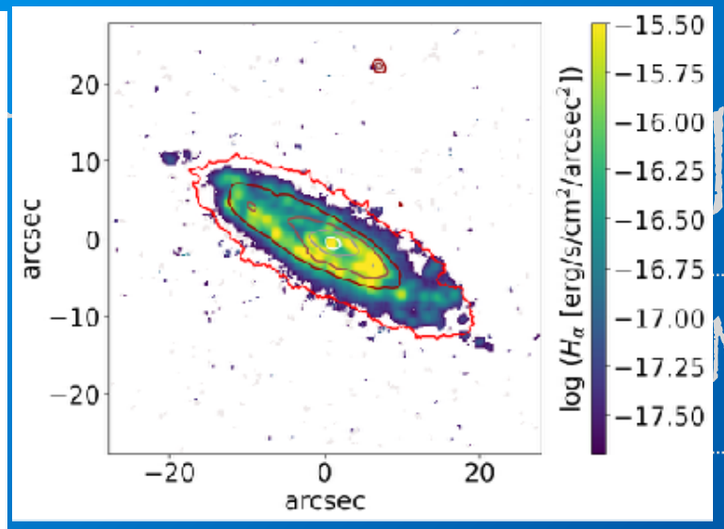
Isolated

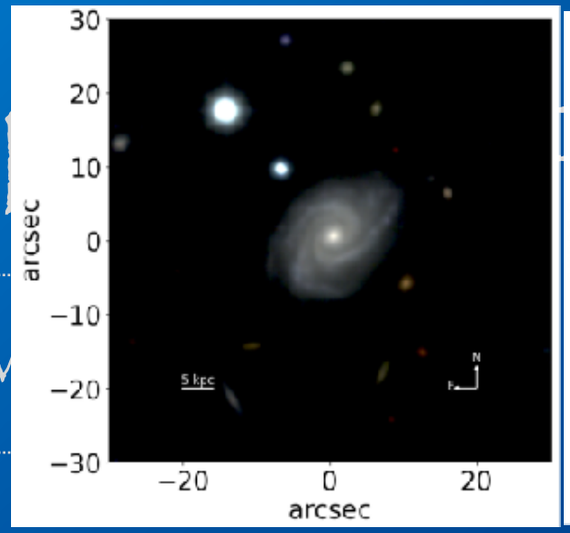
D closest galaxy= 700 kpc

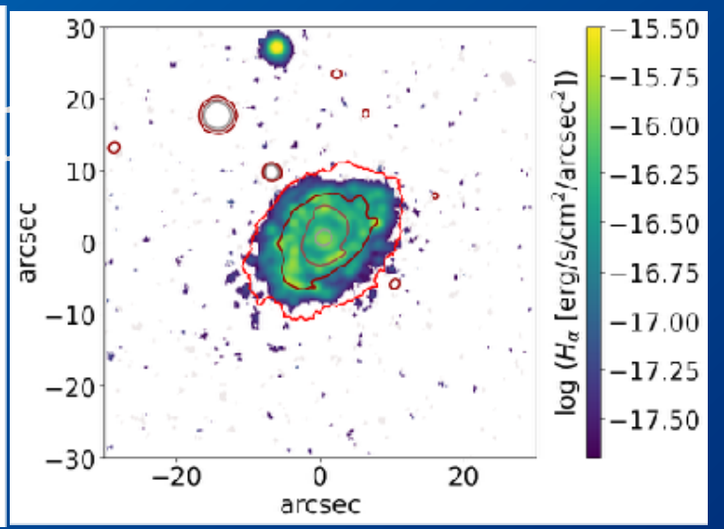


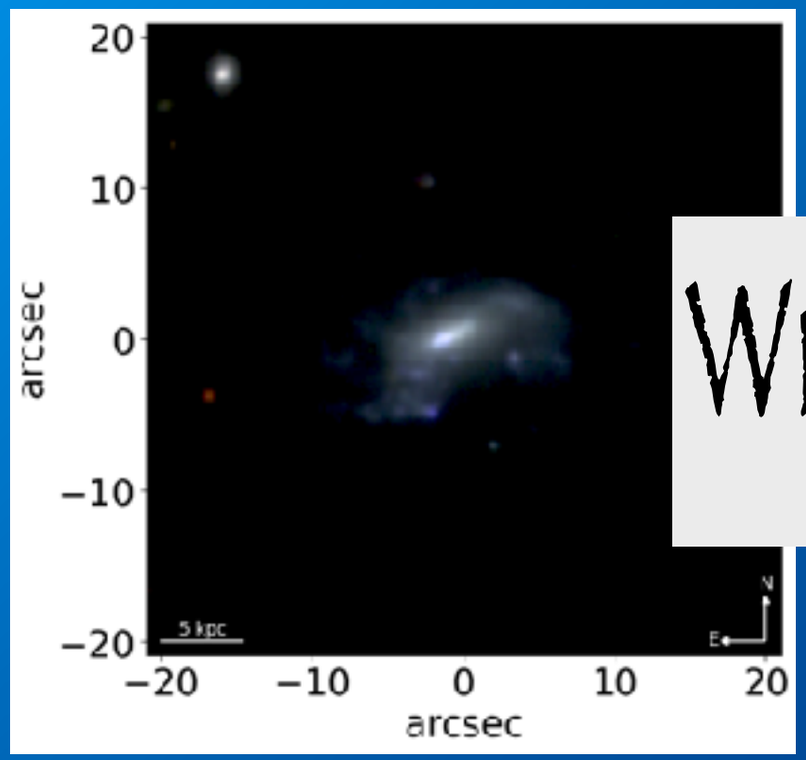


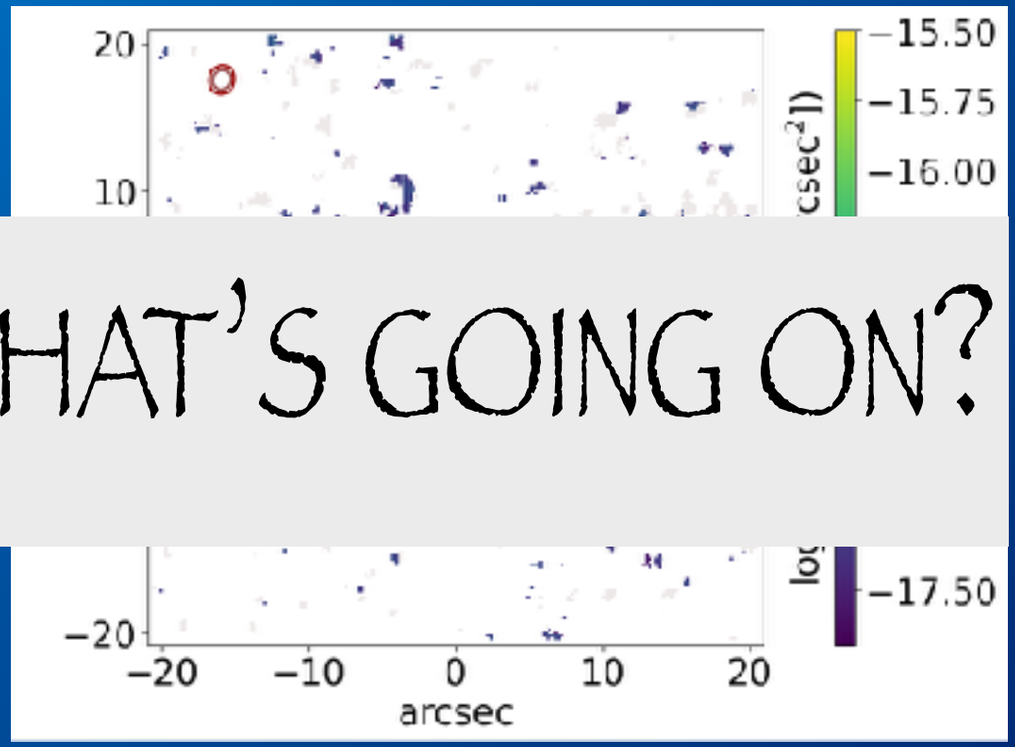










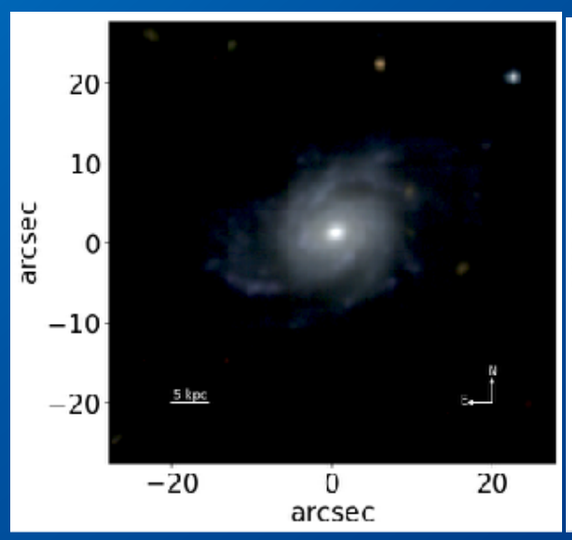


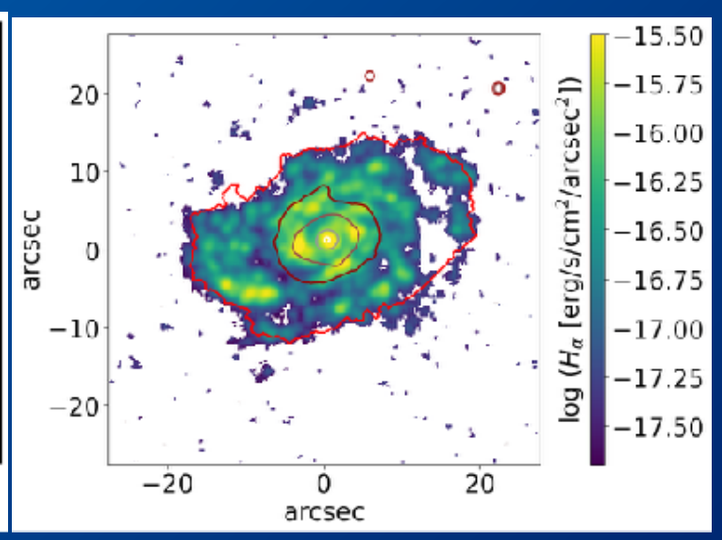
WHAT'S GOING ON?

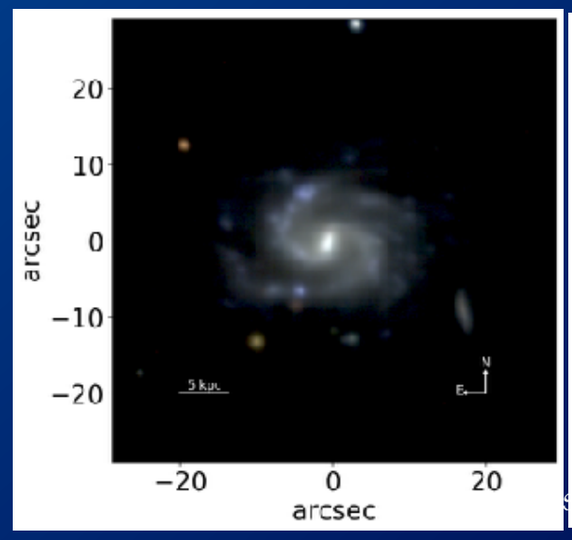
logM*≈ 10^9.33 Msun

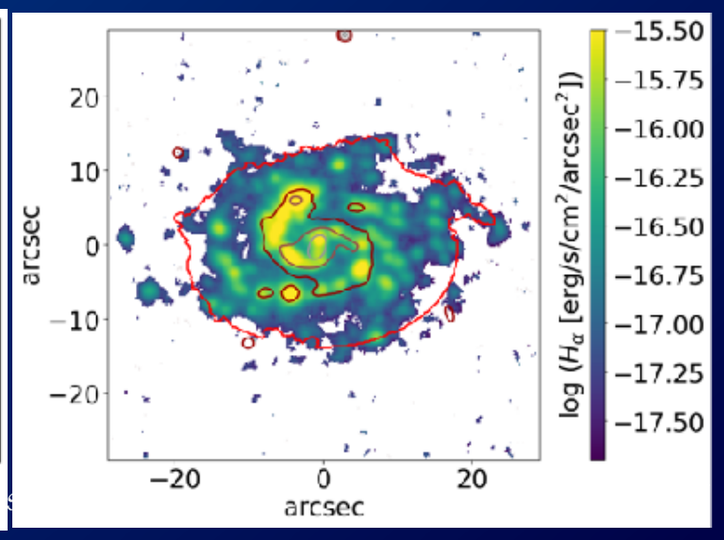
Isolated

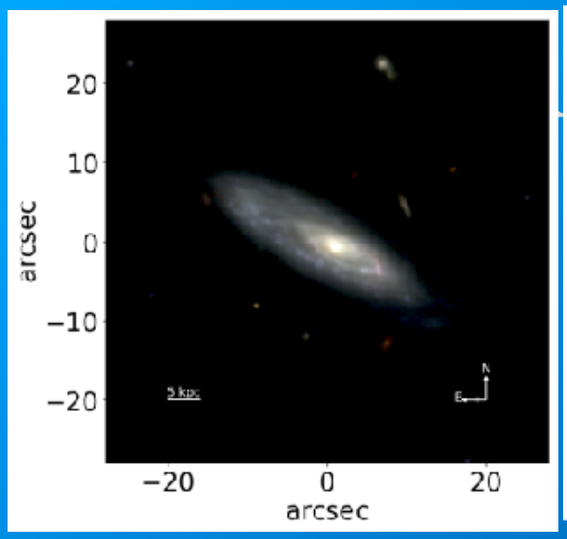
D closest galaxy≈ 700 kpc

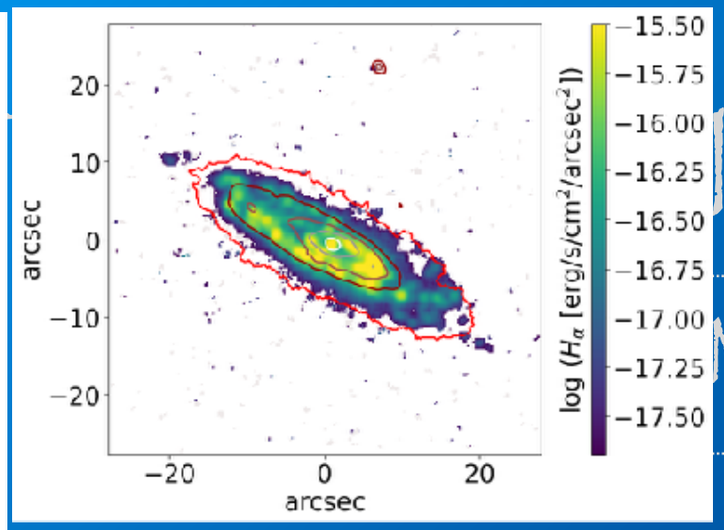


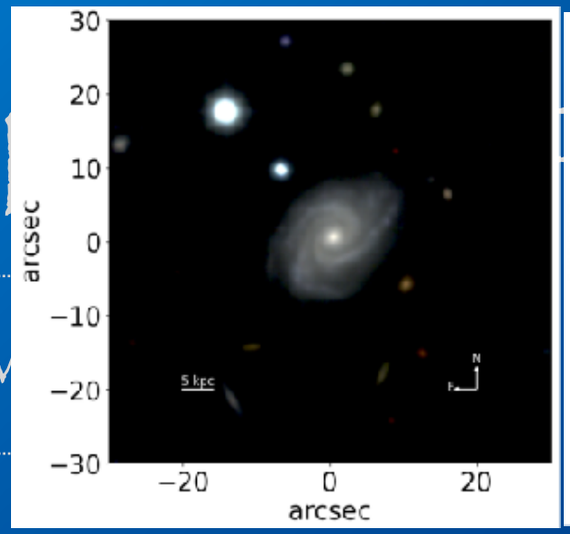


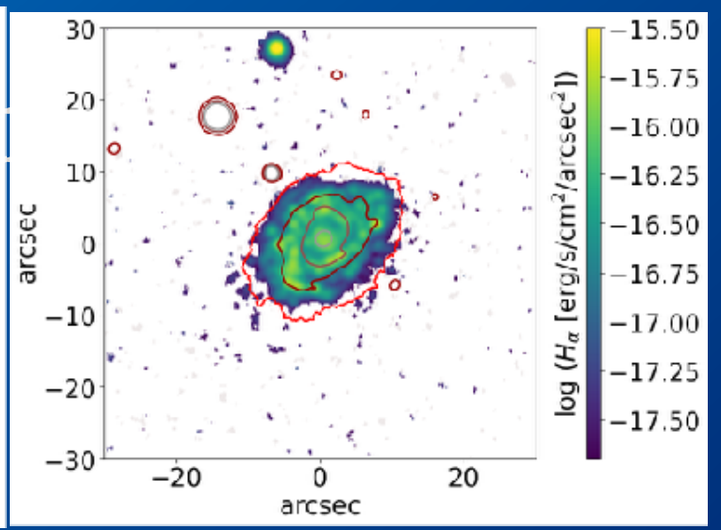


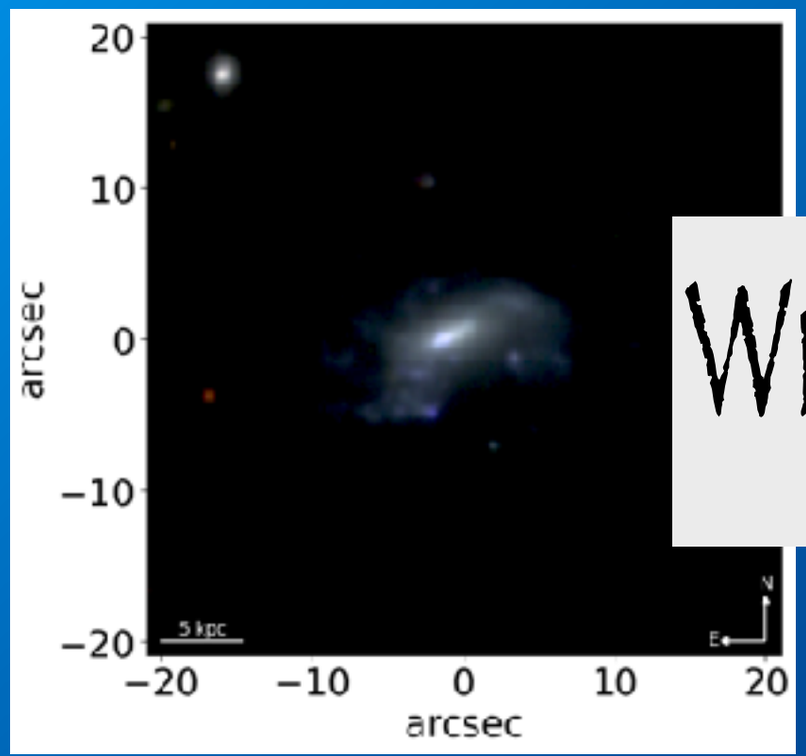












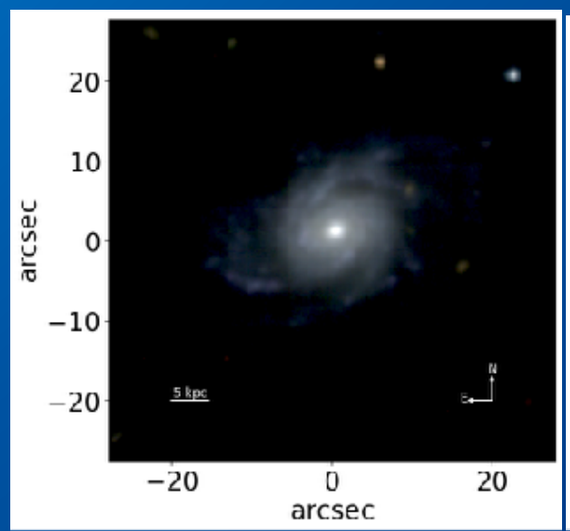
WHAT'S GOING ON?

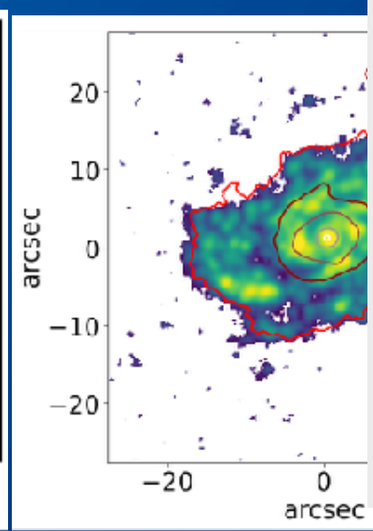
- RAM PRESSURE STRIPPING
- COSMIC WEB STRIPPING
- TIDAL INTERACTIONS
- GAS ACCRETION
- SECULAR EVOLUTION
- INTERACTING GAS-RICH DWARFS
- SECULAR EVOLUTION
- HIGH VELOCITY CLOUDS

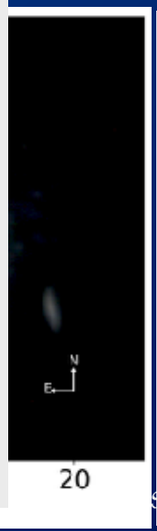
logM*≈ 10^9.33 Msun

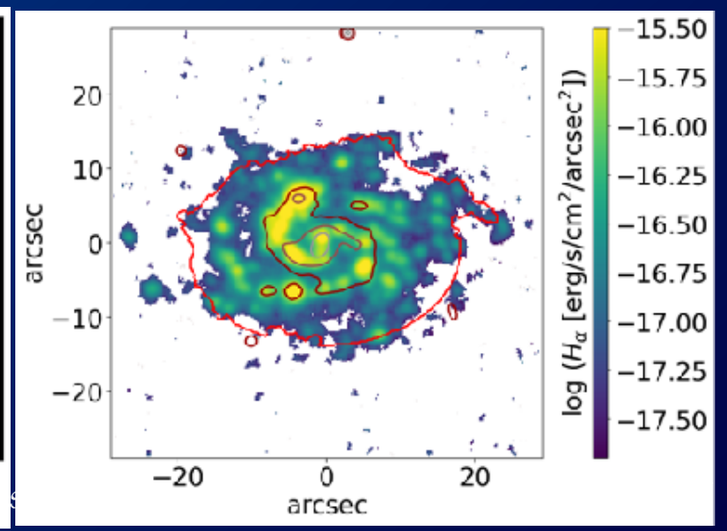
Isolated

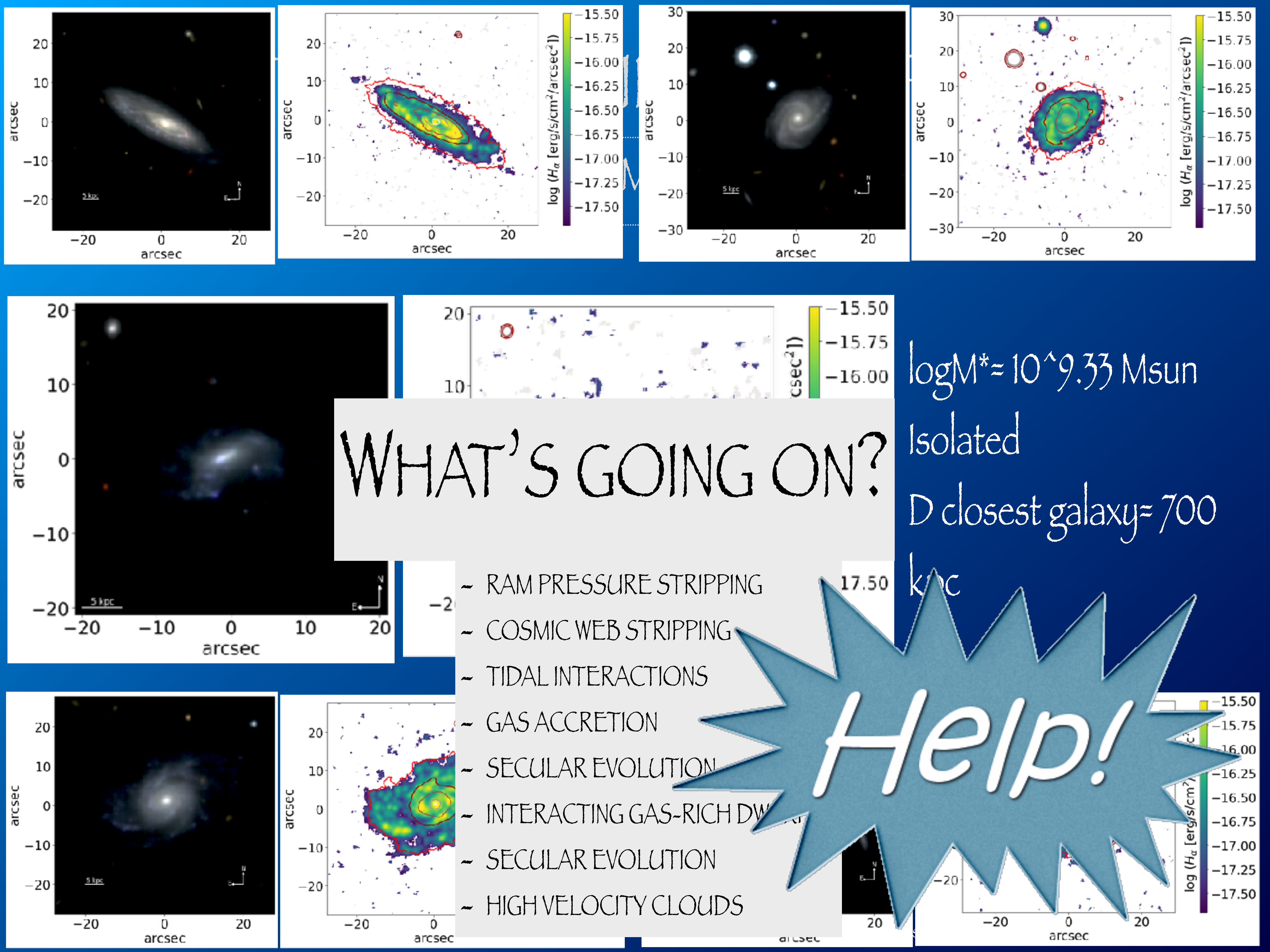
D closest galaxy≈ 700 kpc







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logM*= 10^9.33 Msun
Isolated
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Help!
arcsec
5 kpc
log (H_α [erg/s/cm^2/arcsec^2])

GLASS:

High Redshift, Massive Environments

Schmidt et al. (2014)

Treu et al. (2015)

GLASS:

Schmidt et al. (2014)

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High Redshift, Massive Environments

- The Grism Lens-Amplified Survey from Space (PI T. Treu, UCLA)
- 140 orbits HST grism spectroscopy of 10 massive clusters (Cycle 21)
- 2 orientations per cluster
- Clusters are selected from CLASH and Frontier Field (z=0.3-0.6)
- Spectra for ~20,000 objects (~10,000 down to m_{F140} ~24)

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What is the star formation distribution in galaxies at z~0.5?

Are there any differences between cluster and field galaxies?

Do cluster properties have an impact on the gas distribution?

The Sample

- All galaxies with Qz>2.5 and detected Hα in emission (in G102)
- 74 galaxies with z within ± 0.03 the cluster redshift: CLUSTER MEMBER sample
- 85 galaxies with z outside ± 0.03 the cluster redshift: FIELD sample

Vulcani et al. 2015 ApJ, 814, 161, Vulcani et al. 2016 ApJ, 833, 178, Vulcani et al. 2017A ApJ, 837, 2

The Classification Scheme

- GIGm to classify:
- Broad-band morphology (ellipticals, S0s, spirals, merging, irregulars)
- Hα morphology
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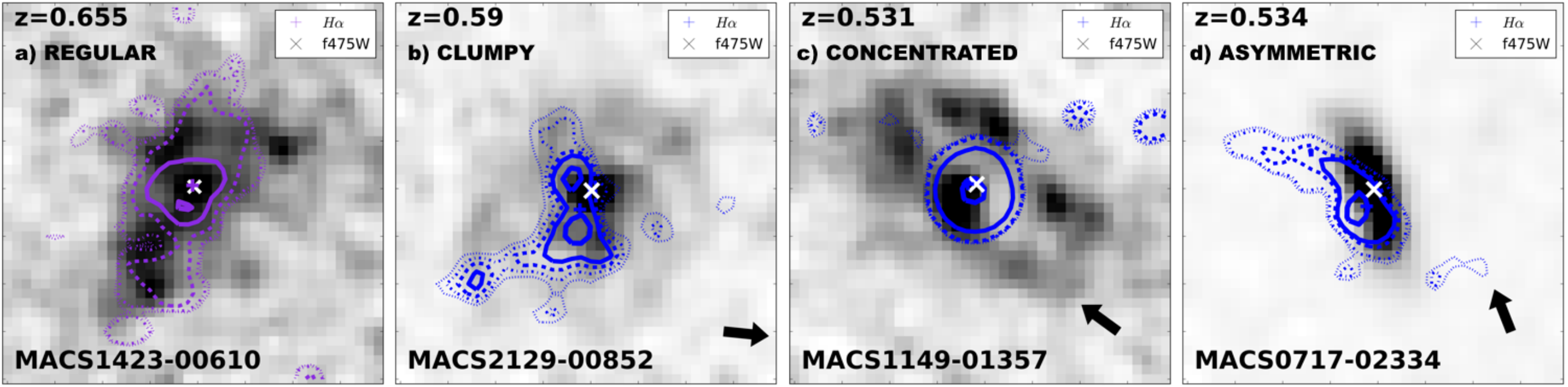

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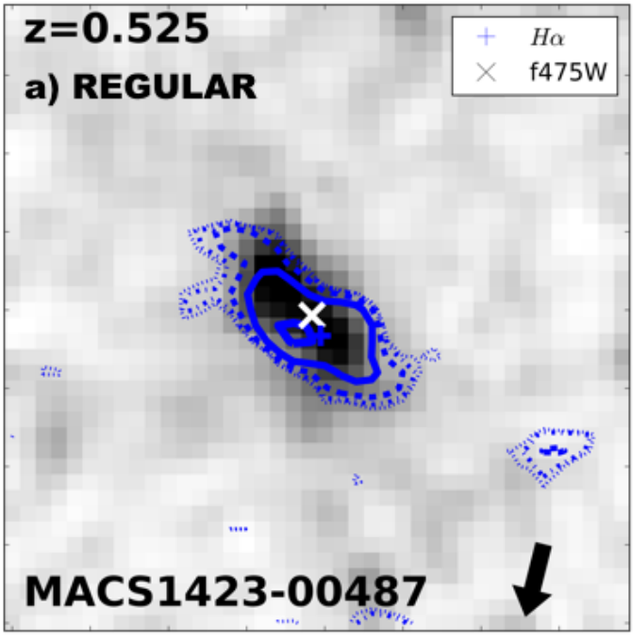
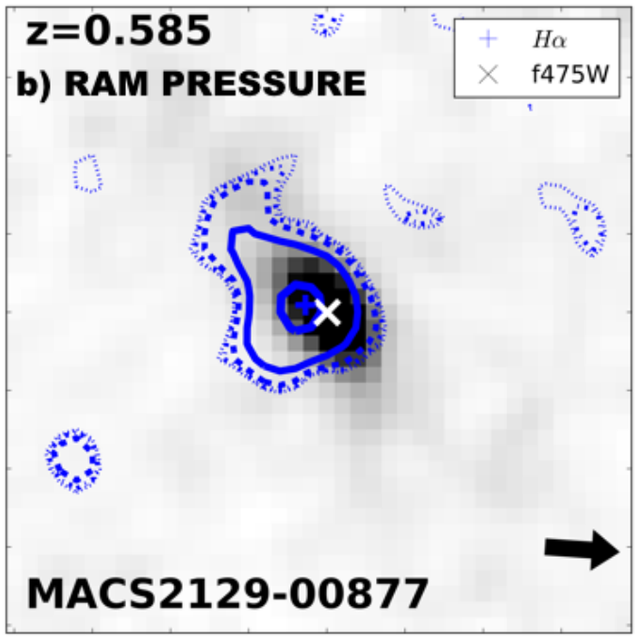
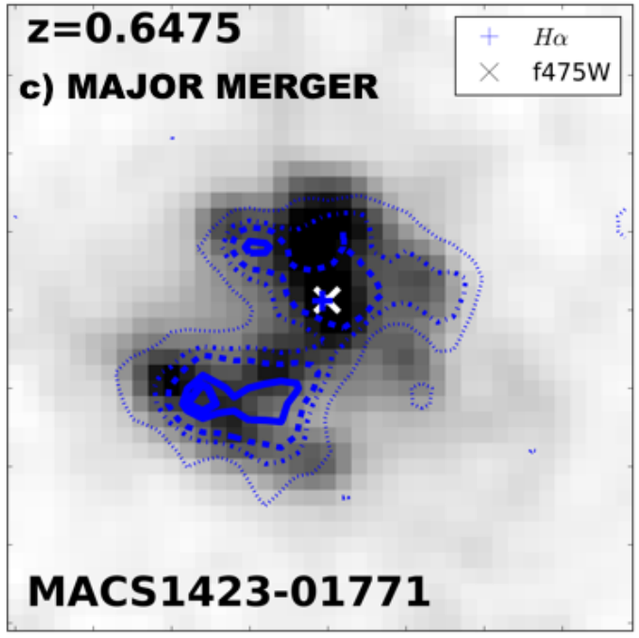
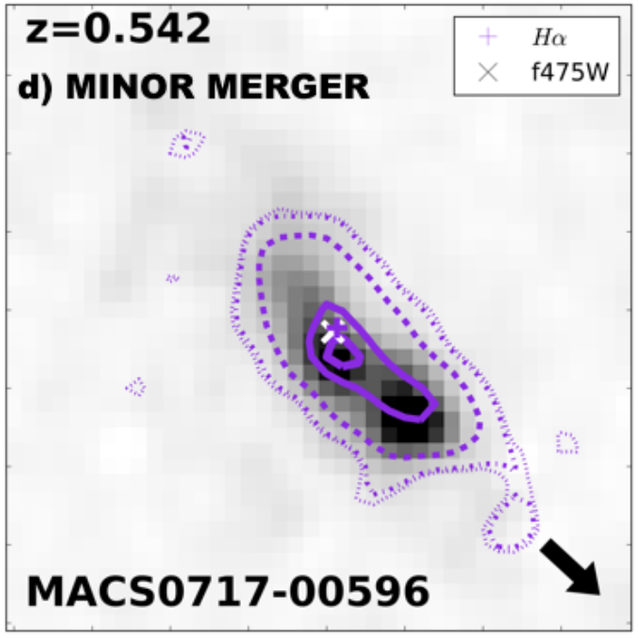








Results

Broad band morphology

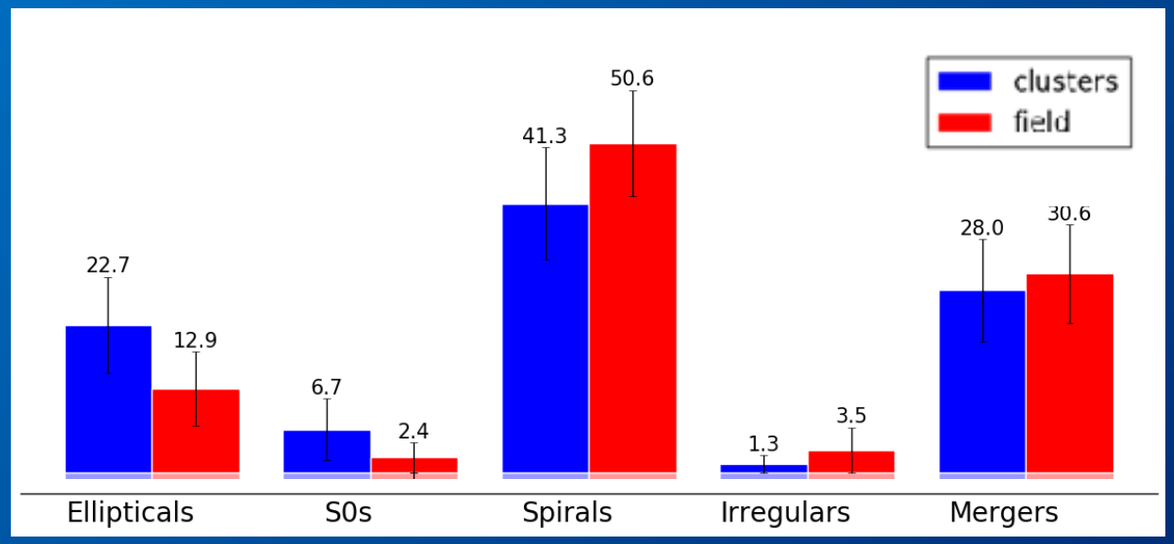
Hα morphology

Physical process

Results

Broad band morphology

most maps are spirals (41.3% in C, 50.6% in F)



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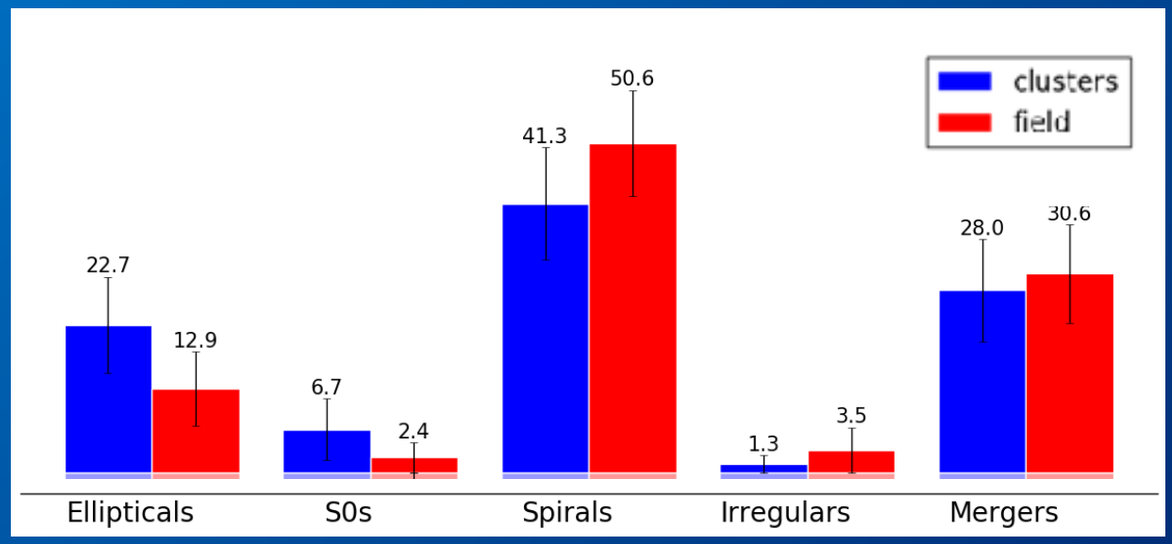

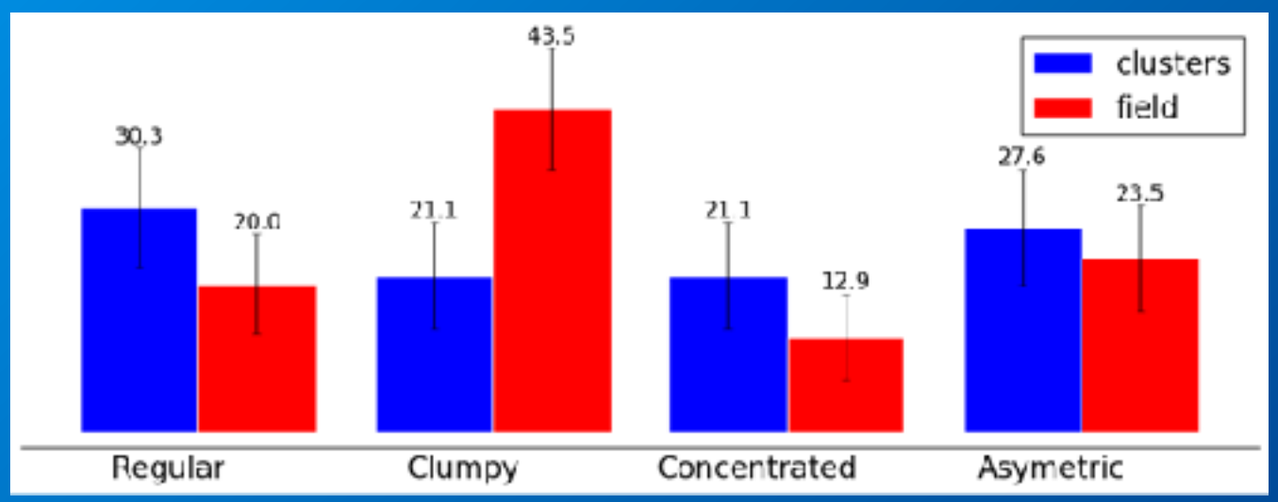

Hα morphology

F: 43.5% clumpy

C: 29.3% regular, 28.0% asymmetric

Physical process

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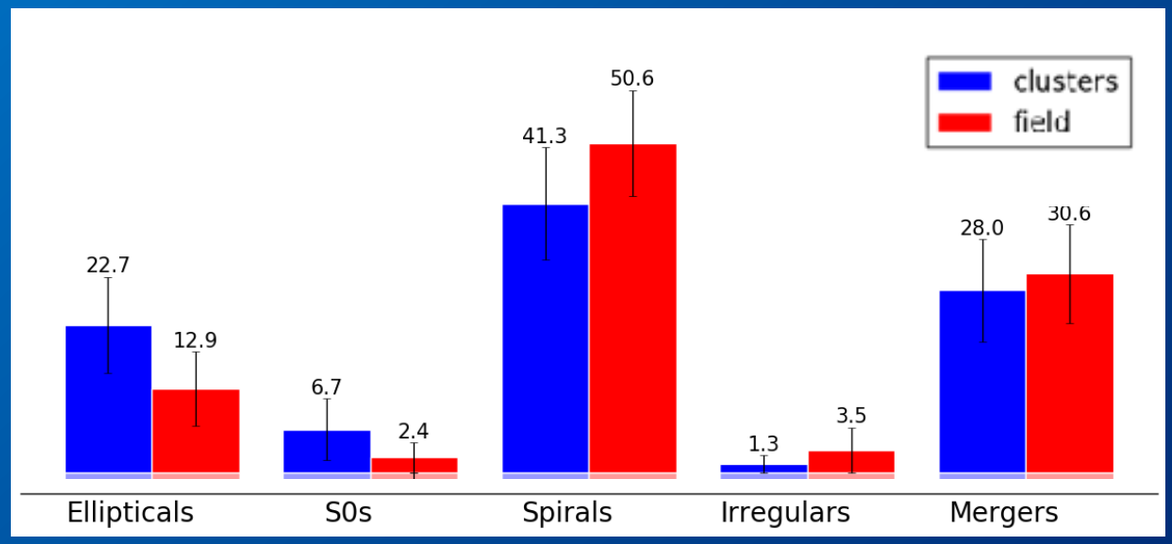

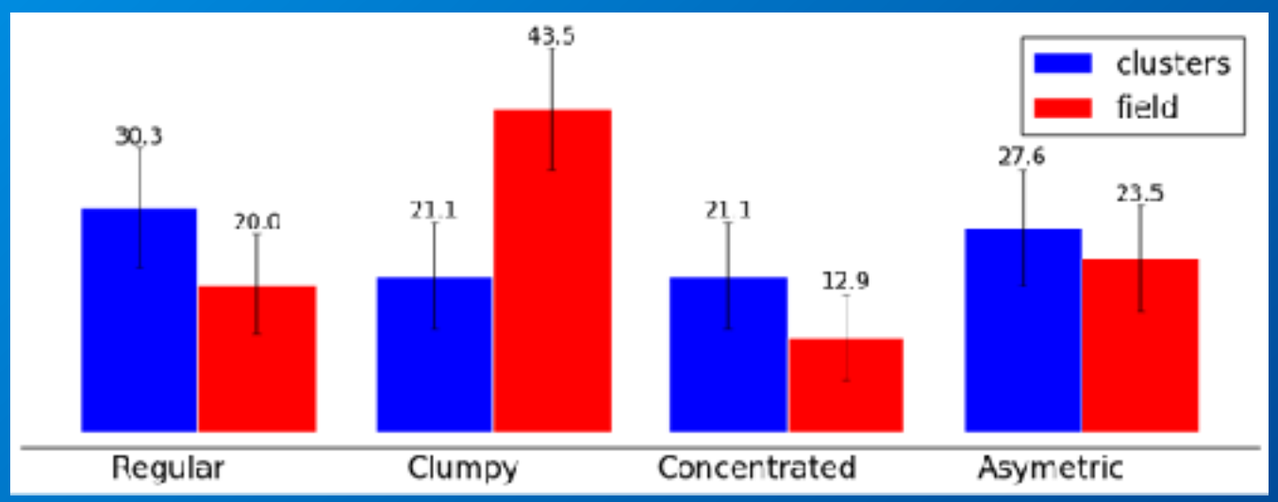

Hα morphology

F: 43.5% clumpy

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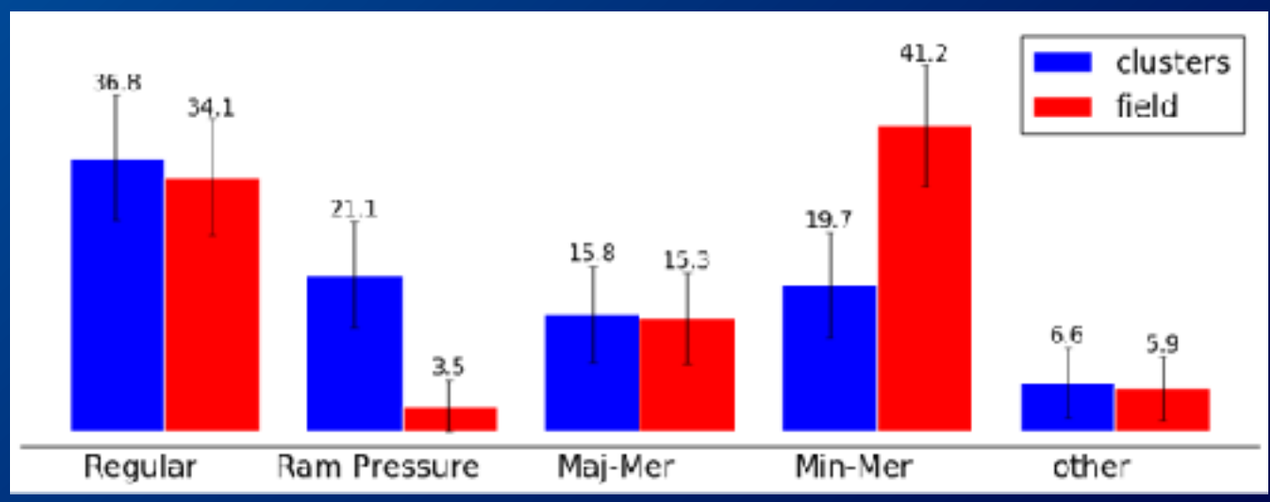
Physical process

F: 41.% Minor mergers

C: 36.8% regular, 21.1% ram pressure



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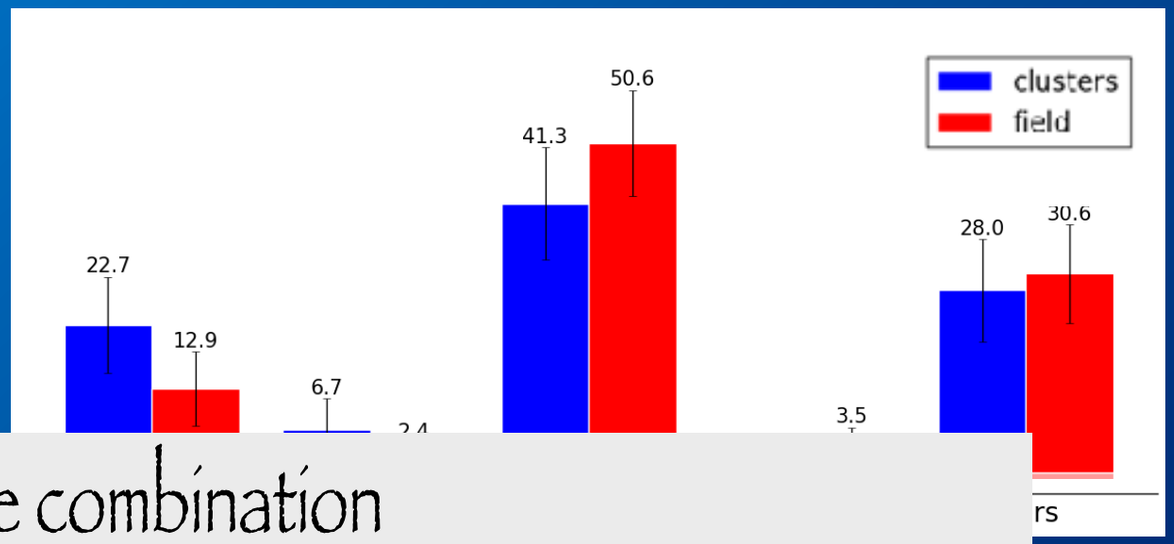
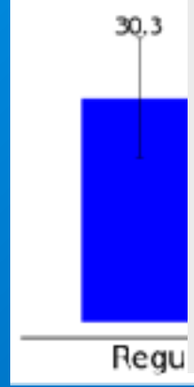
Broad band morphology

most maps are spirals (41.3% in C, 50.6% in F)





The most probable combination

in the field is Clumpy Hα due to Minor Mergers (27%)

in clusters is Asymmetric Hα due to Ram Pressure (19%)

C: 27.7% regular, 20.6% asymmetric

Physical process

F: 41.% Minor mergers

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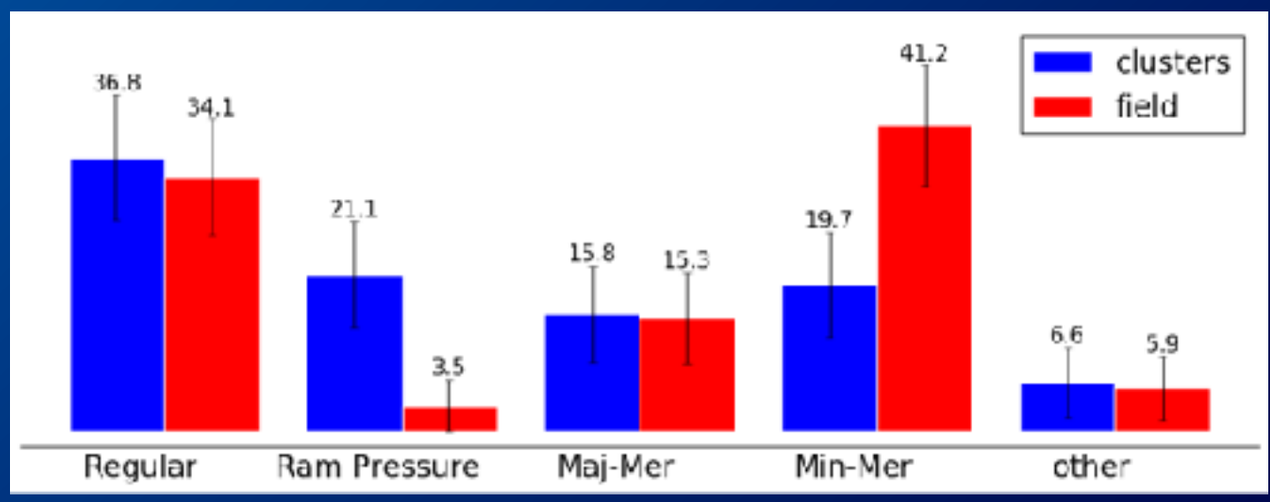

Comparisons to Illustris TNG

PRELIMINARY

What is the star formation distribution in galaxies at z~0.5 predicted by MHD simulations?

What can we actually learn from observations?

Is the environmental history of galaxies in the different environments?

The Sample

- All galaxies at z~0.5 (SnapShot=67)
- Stellar mass range: 9.5<LogMass<11
- Star formation range: 0.5<SFR<100 & LogSSFR>-10.5
- Half mass radius of the star forming gas >0.4 kpc

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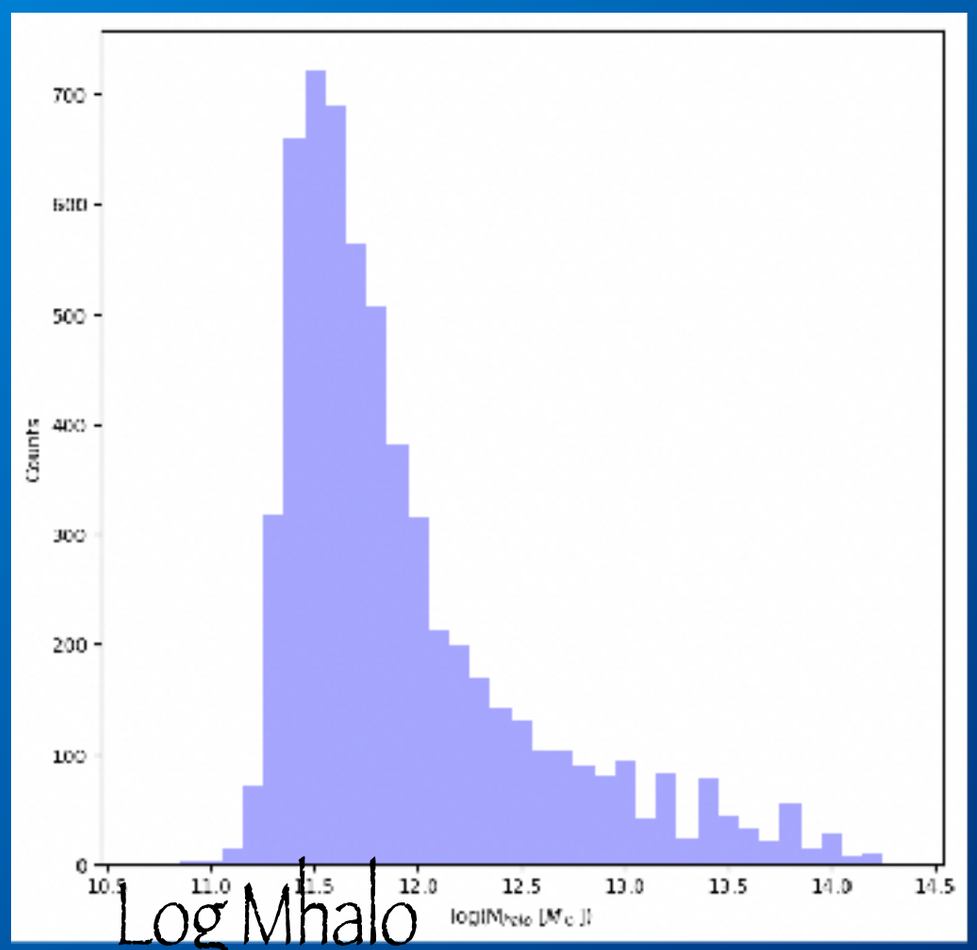

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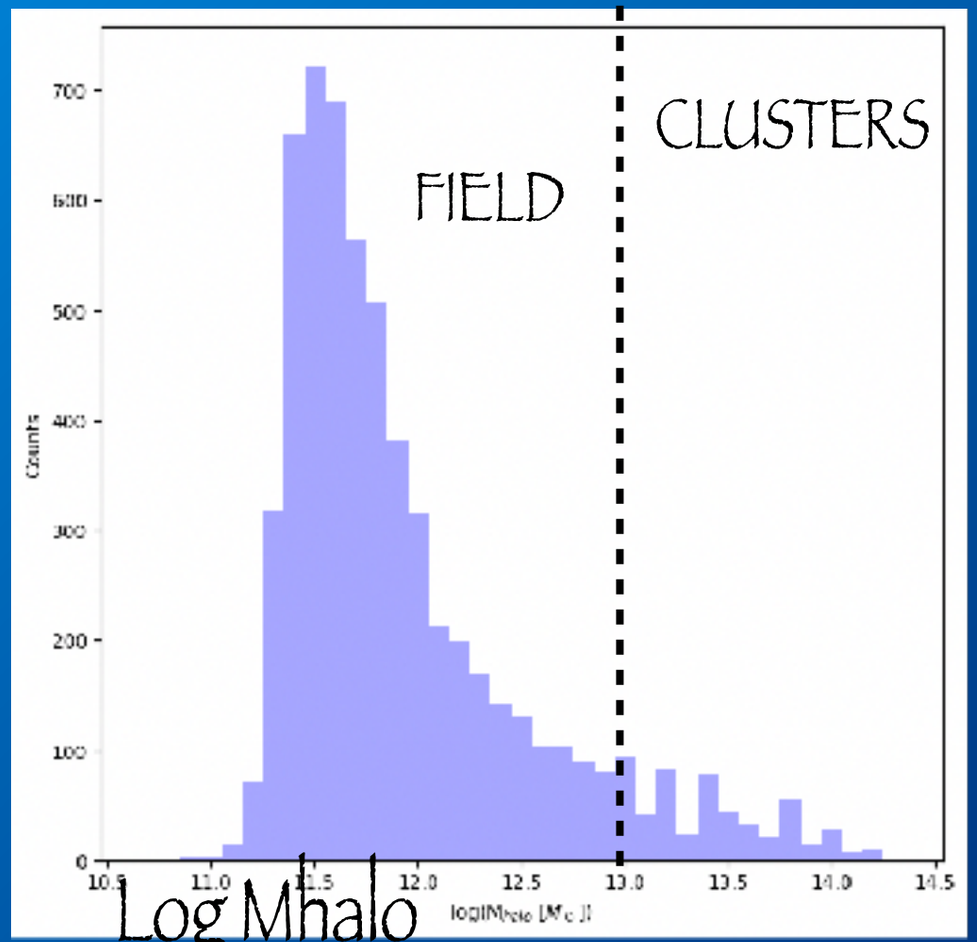
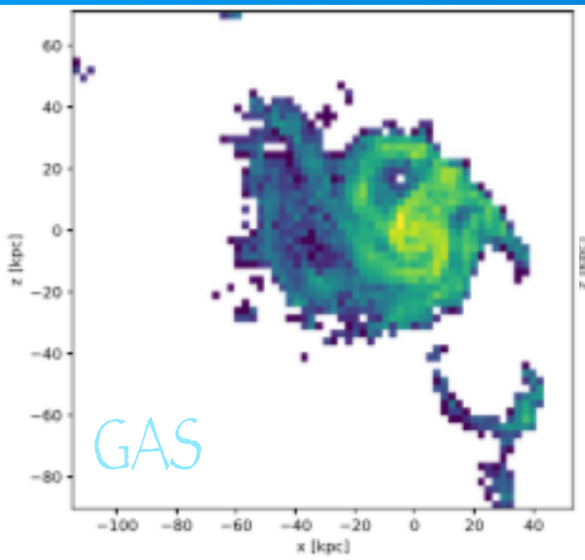
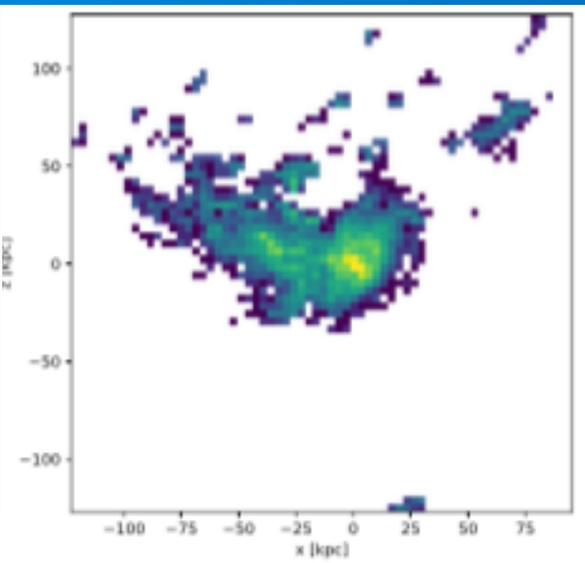
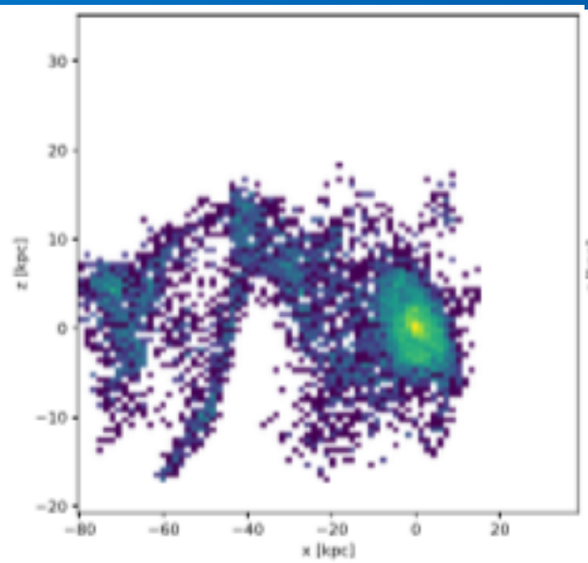
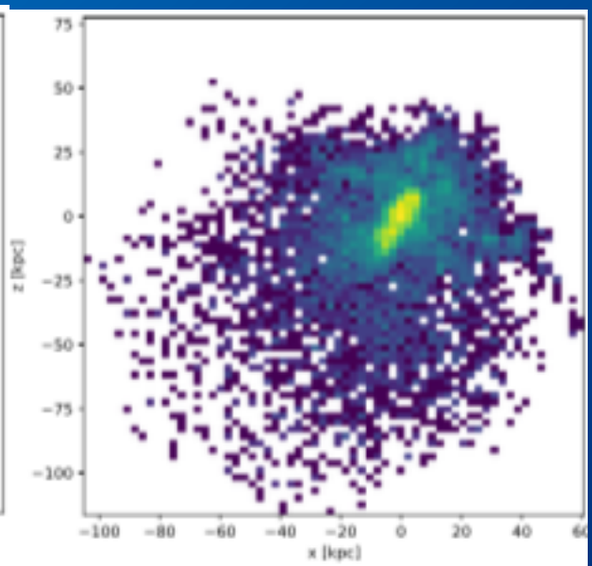


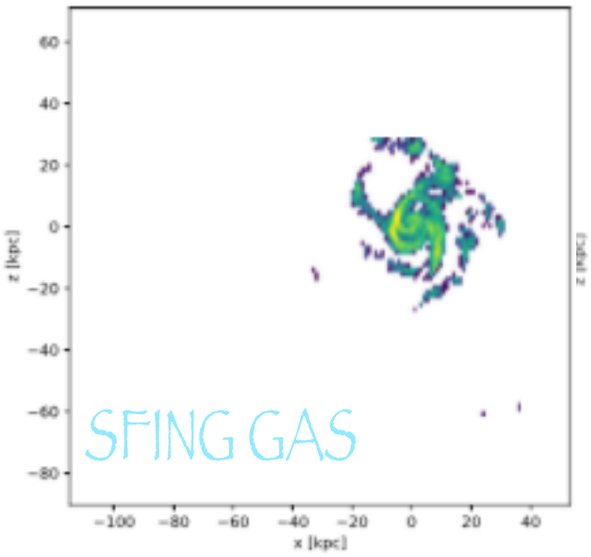
Morphologies Of The SFing Gas

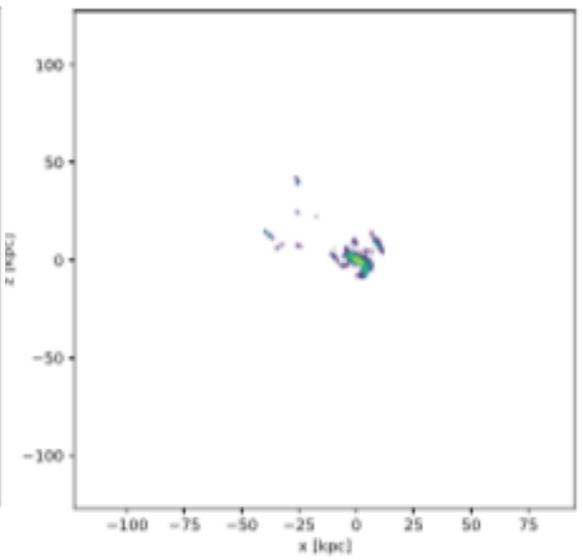


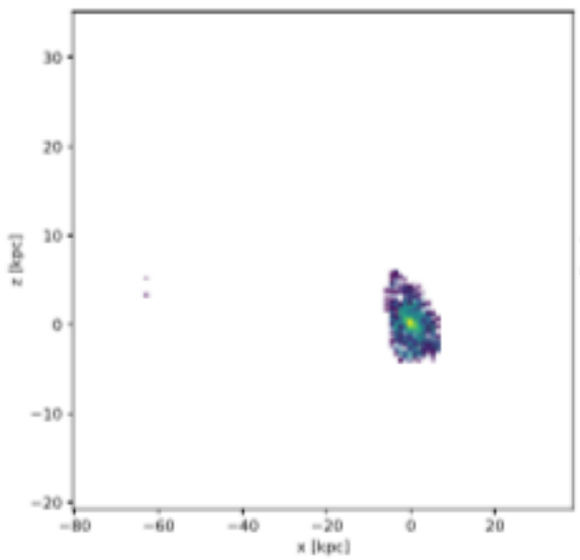


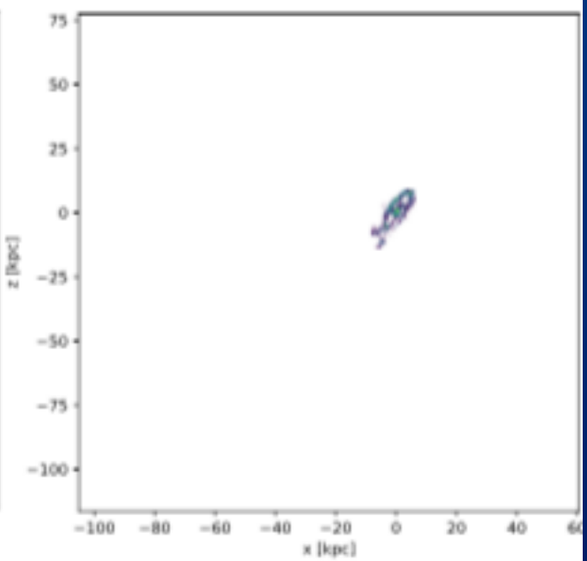


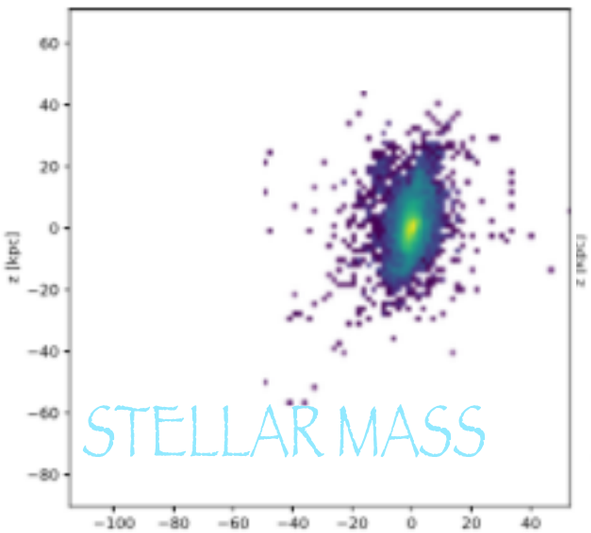


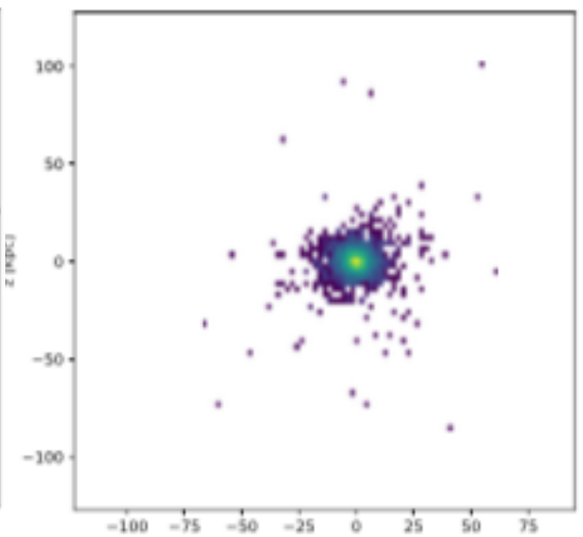


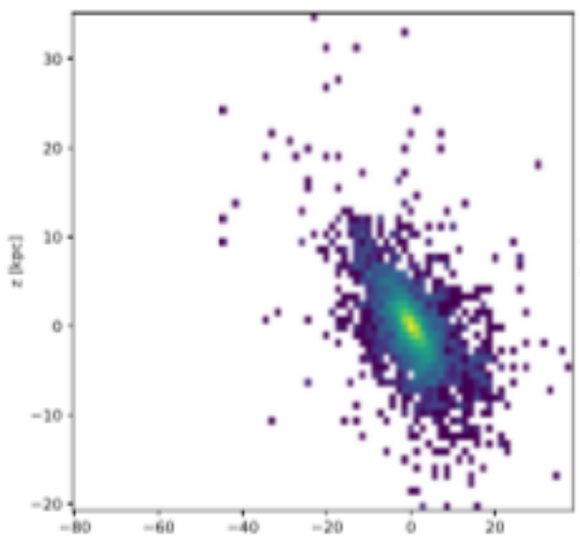


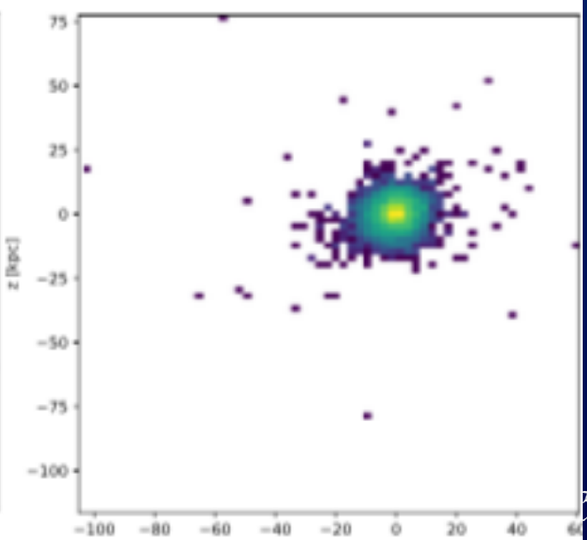












3/12/2017

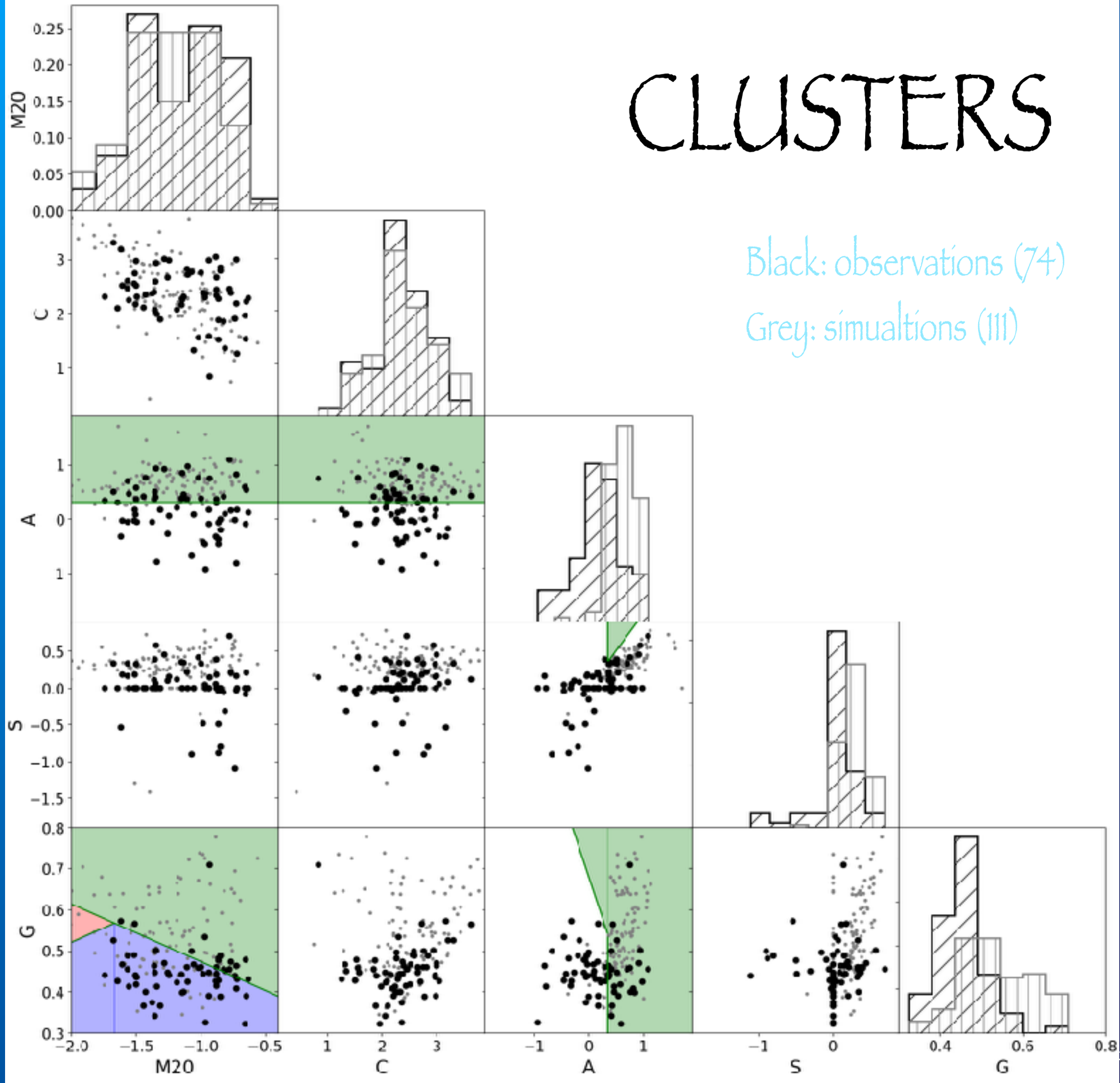
First Comparisons

- Gini, M20, CAS parametrisation on observed (GLASS) and simulated (Illustris TNG - PSF matched) star formation rate maps

CLUSTERS

Black: observations (74)

Grey: simualtions (111)



Next Steps

- Correlate morphological parametrisation to visual classification
- Extract from simulations the environmental history to understand the main physical process responsible for SF distribution

Galaxy Evolution in Groups and Clusters at 'low' Redshift: Theory and Observations

Schloss Ringberg, 11-15 December 2017

THANKS!

Benedetta Vulcani