

Ram pressure stripping in local clusters: the GASP perspective

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<http://web.oapd.inaf.it/gasp/>



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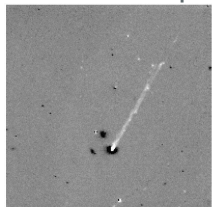
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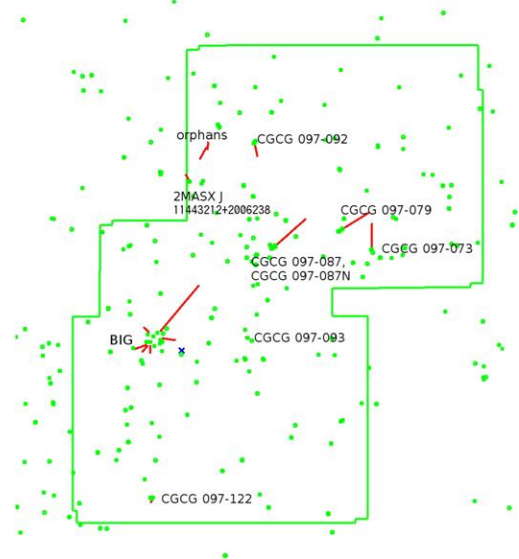
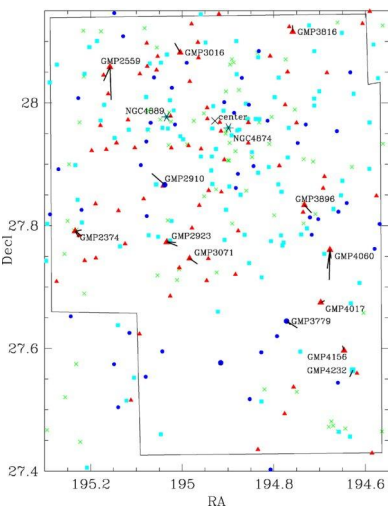
Jellyfish galaxies

“Galaxies with clearly distorted images, with optical data resolving multiple filaments offset asymmetrically from the galaxy” [Smith et al., 2010, UV asymmetry]

+ 60 kpc H α tails in D110 (Coma) [Yagi et al 2007]



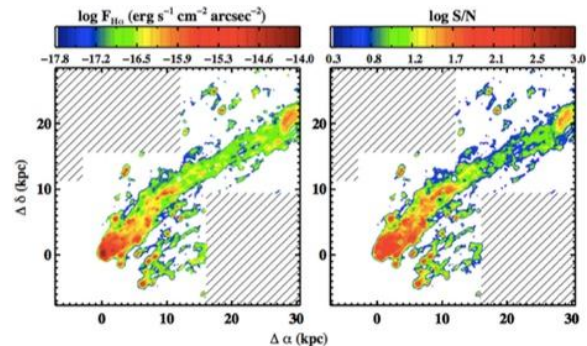
Yagi et al., 2010



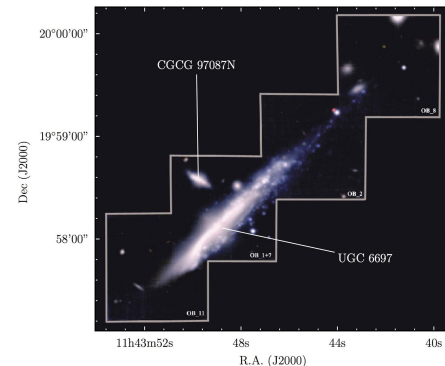
Yagi et al., 2017 A1367

From H α surveys

Fumagalli et al.,
2014, Fossati et
al., 2016
ESO 137-001 in
Norma cluster

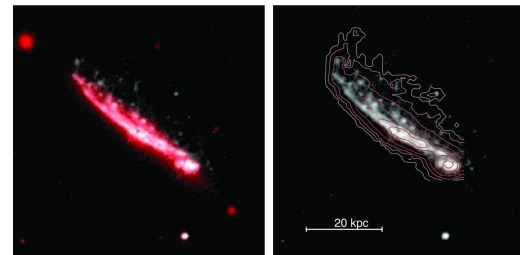


Consolandi et al.,
2017 in A1367



To IFU images

Merluzzi et al.,
2013 in Shapley



The WINGS contribution

→ Started back in 2001 to fill the redshift gap between Virgo/Coma and high-z clusters.

→ Survey of 76 X-rays selected clusters at $z=[0.04-0.07]$ with 30' x 30' FoV: B,V imaging

→ + B, V imaging with OmegaCAM@VST to cover **1 sq. deg** around cluster centers -> beyond R_{200} (46/76 original clusters)

→ 48 clusters have spectroscopic follow-up (~6000 redshifts, ~5300 SFH) and 33/46 clusters have spec. follow up (~18000) with 90% completeness at $V=20$ (7500 new members) over 1 sq. deg

→ Complemented by NIR/U imaging

→ Images and catalogs available (VO tools)

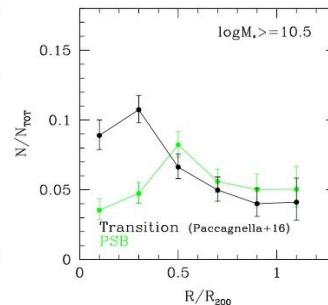
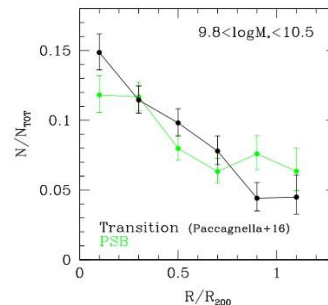
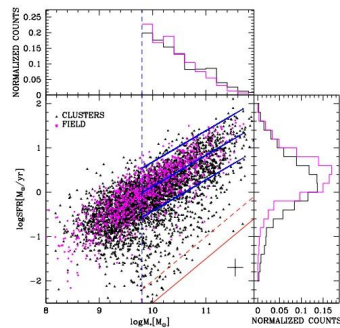
Fasano et al., 2002, Fasano et al., 2006, Moretti et al., 2014, Gullieuszik et al., 2015, Moretti et al., 2017

Quenching related to gas supply/removal

→ RPS, strangulation (fast and slow gas-only removal)

→ mergers, tidal interaction (gas and stars)

→ internal mechanisms (AGN, stellar winds)



Paccagnella et al., 2017

The GASP survey (PI B. Poggianti, ESO MUSE LP)

GAS Stripping Phenomena in galaxies with MUSE

→ Galaxies in different environments (clusters, groups, field+control sample)

→ Galaxies with different masses (from 10^9 to $10^{11.5} M_{\odot}$)

→ Galaxies with different stripping signatures (Jclass 1-5, taken from Poggianti et al., 2016, 344 candidates in clusters+75 in groups)

→ **114** [94+20] gx, 120 hrs, 2700s/pointing, $1e5$ spectra/pointing

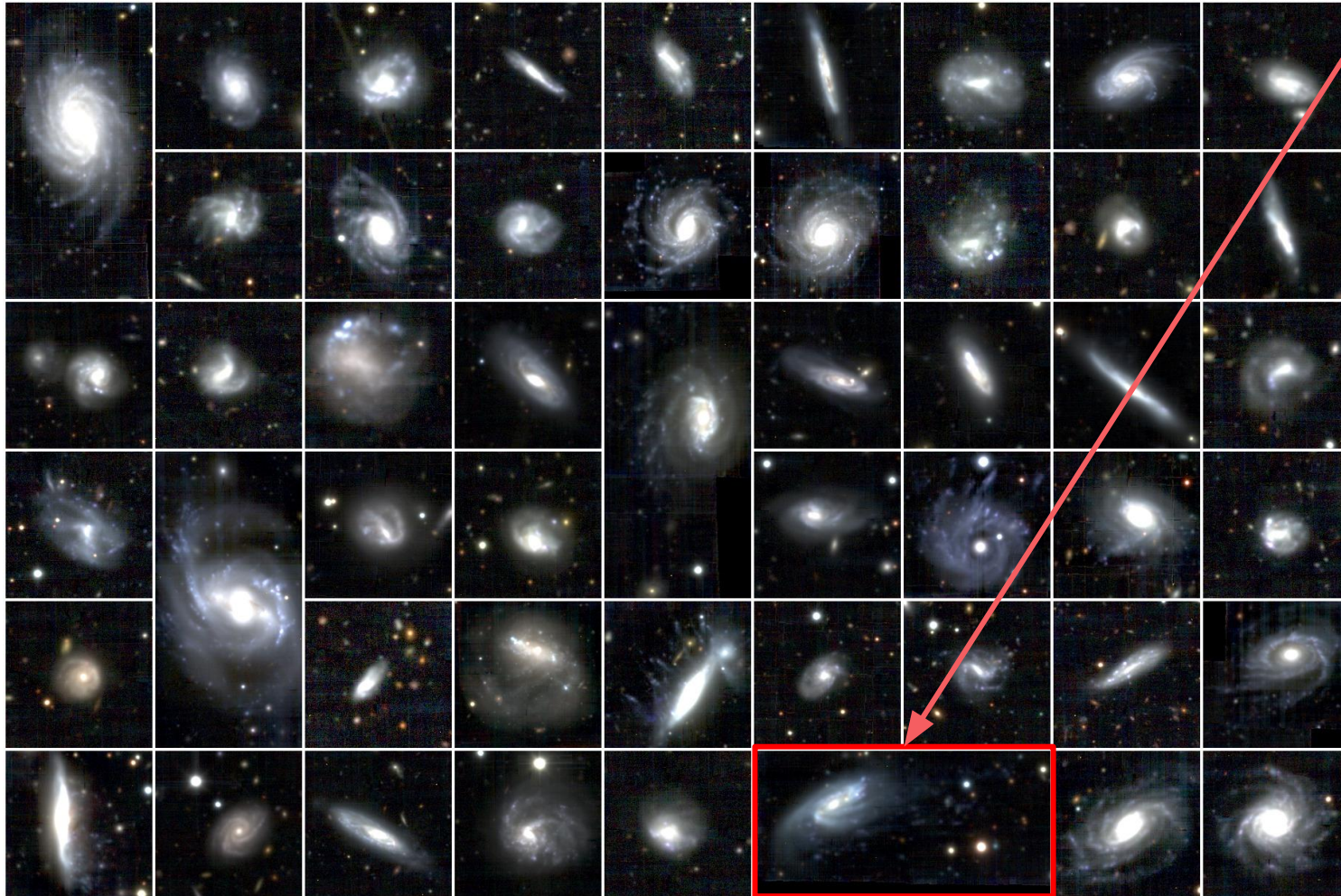
→ 0.2"/px, 2.5 Å FWHM, 4700-9300

→ Started in 2015, ~80% observed [**50% already ESO Phase 3 archive**]

→ Fov (1'x1')~60x60 kpc²

NB Target galaxies selected to have signatures of GAS-ONLY removal processes (no mergers, no tidal interactions)

1. Debris trails, tails or surrounding debris on one side of the galaxy
2. asymmetric/disturbed morphology
3. Distribution of star forming knots/region suggesting induced SF on one side



GASP I :
[arXiv:1704.05086](https://arxiv.org/abs/1704.05086)

GASP II:
[arXiv:1704.05087](https://arxiv.org/abs/1704.05087)

GASP III:
[arXiv:1704.05088](https://arxiv.org/abs/1704.05088)

GASP IV:
[arXiv:1708.09035](https://arxiv.org/abs/1708.09035)

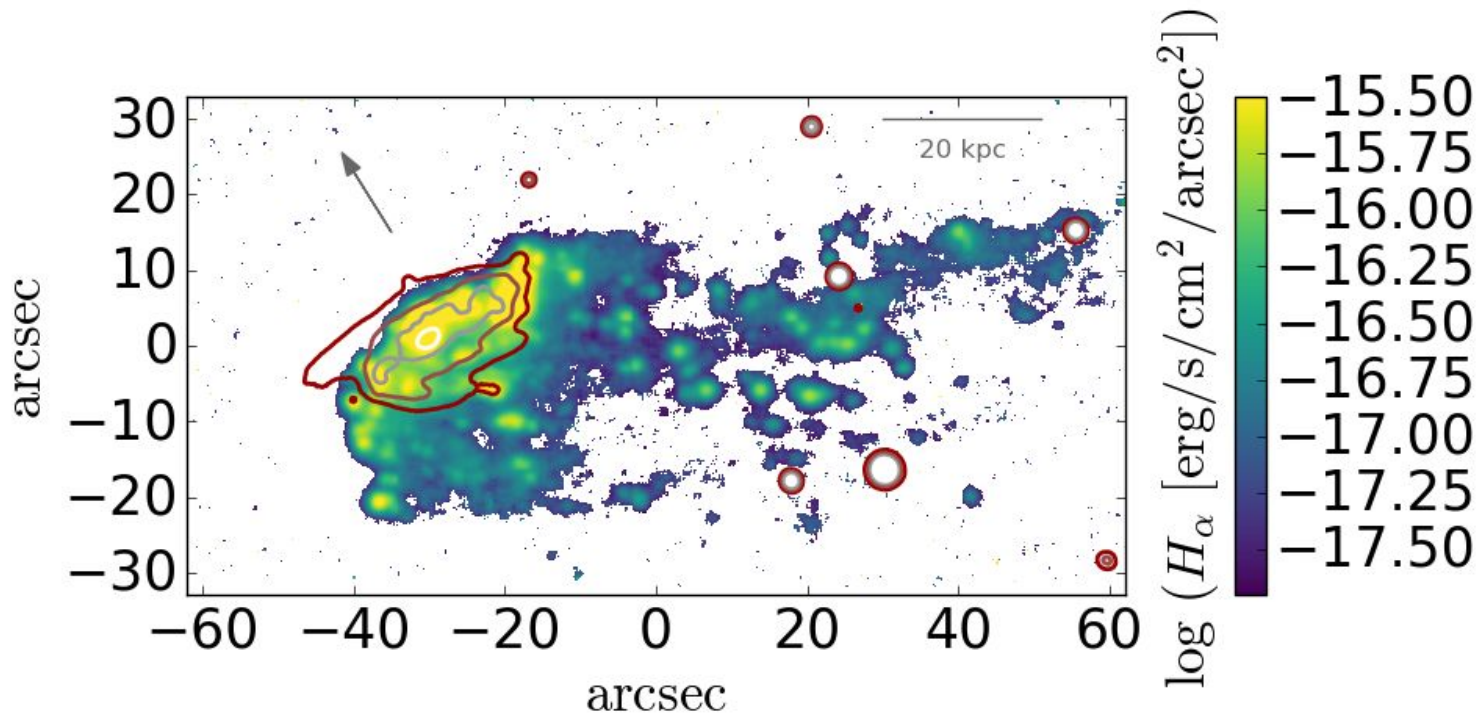
[GASP VI:]
[arXiv:1708.09036](https://arxiv.org/abs/1708.09036)

GASP VIII:
[arXiv:1708.09037](https://arxiv.org/abs/1708.09037)

The GASP survey: JO206, a JF prototype

Gas Stripping Phenomena in galaxies with MUSE

JO206 [8.5e10] in
IIZW108 [1.9e14]
at ~350 kpc
JClass=5

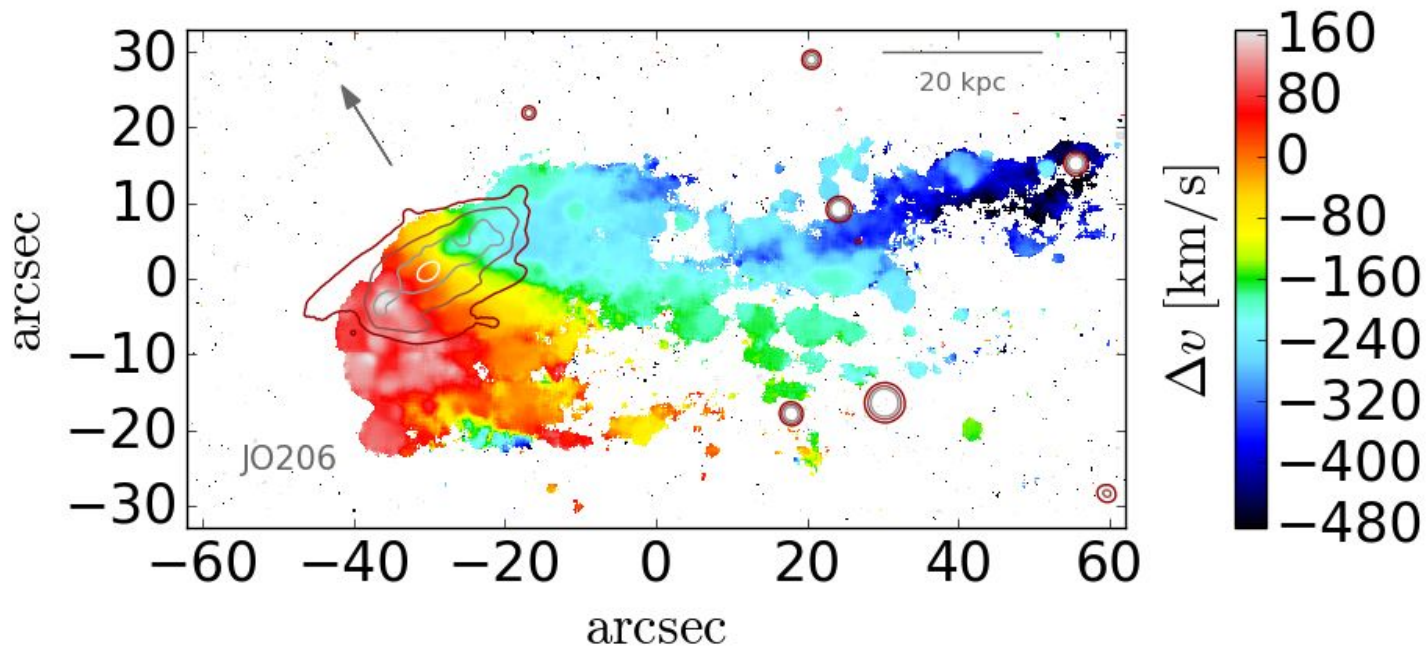


S/N(H α)=5÷50

H α tails out to ~90
kpc (and more?)

The GASP survey: JO206, a JF prototype

GA**S** Stripping Phenomena in galaxies with MUSE



S/N(H α)=5÷50

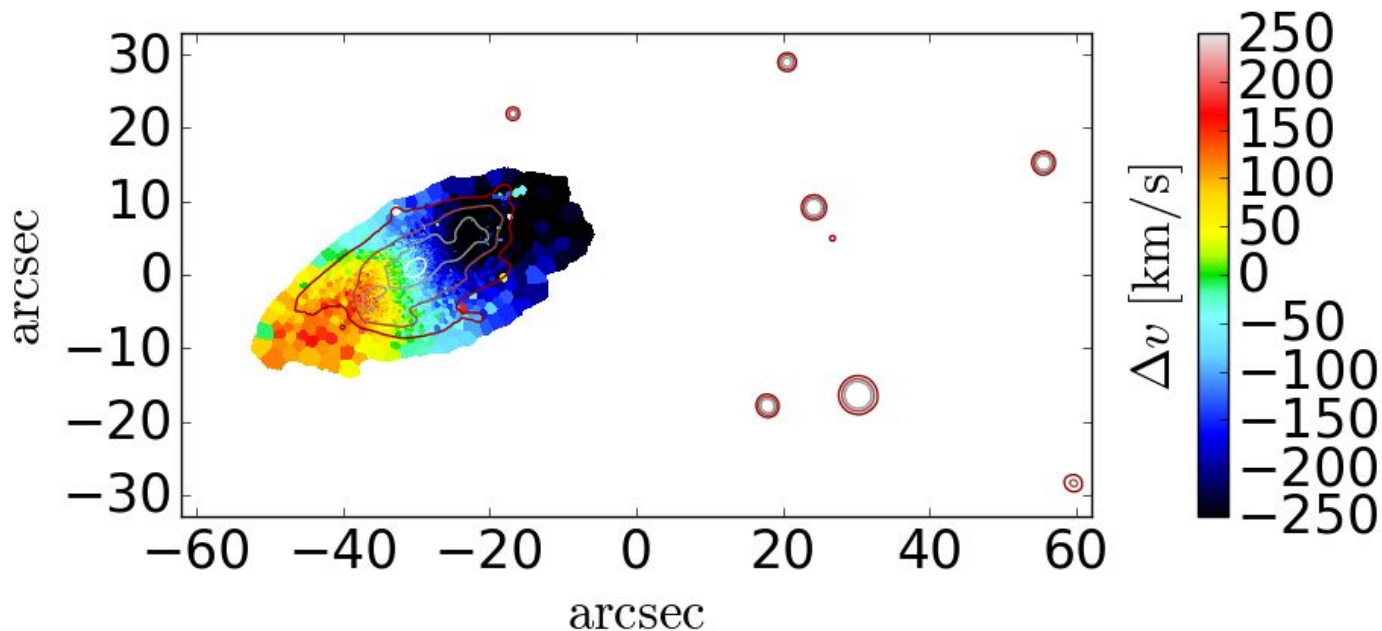
H α tails out to ~90 kpc (and more?)

Stripped gas has coherent rotation

Velocity dispersion generally low (but in the center--AGN)

The GASP survey: JO206, a JF prototype

Gas Stripping Phenomena in galaxies with MUSE



S/N(H α)=5÷50

H α tails out to ~90 kpc (and more?)

Stripped gas has coherent rotation

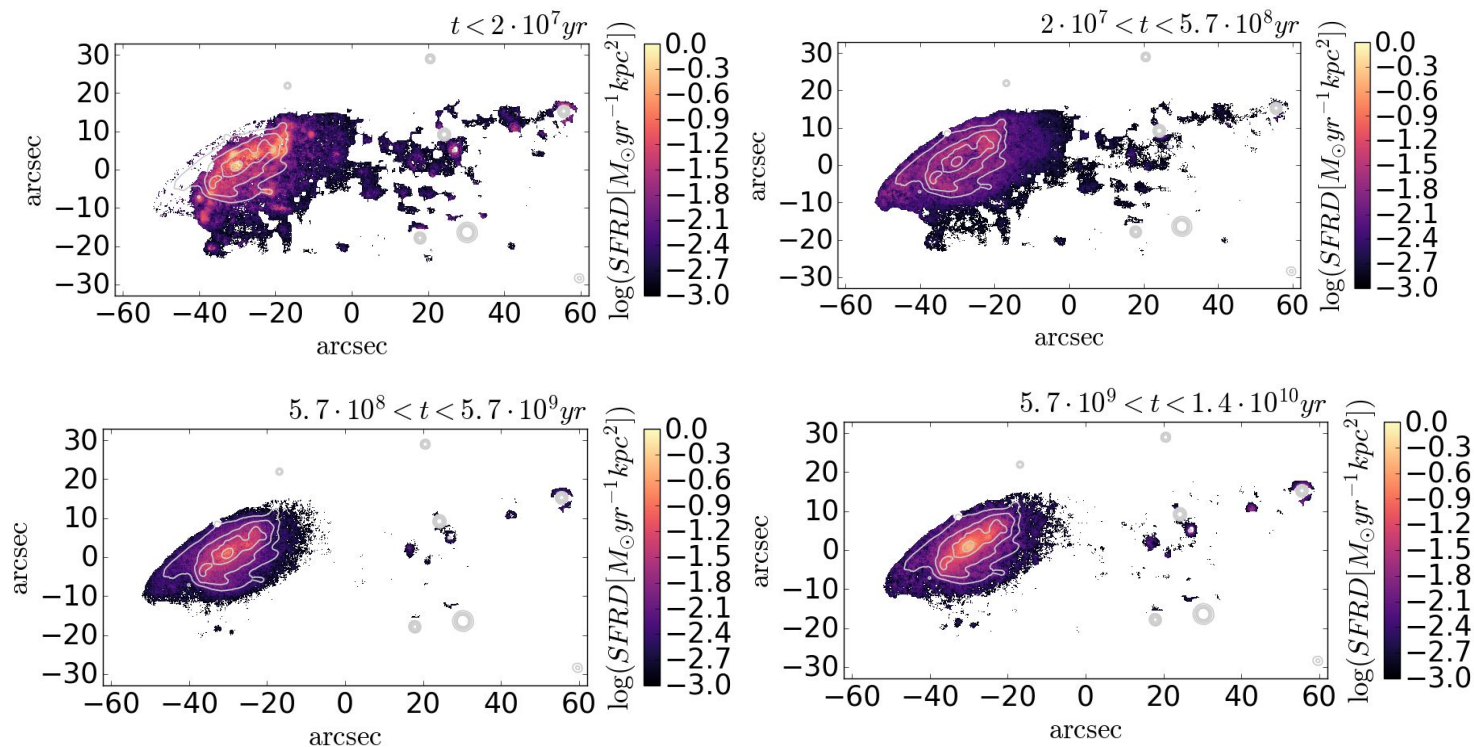
Velocity dispersion generally low (but in the center--AGN)

Regular stellar kinematics

Evidence of ram pressure stripping

The GASP survey: stellar populations

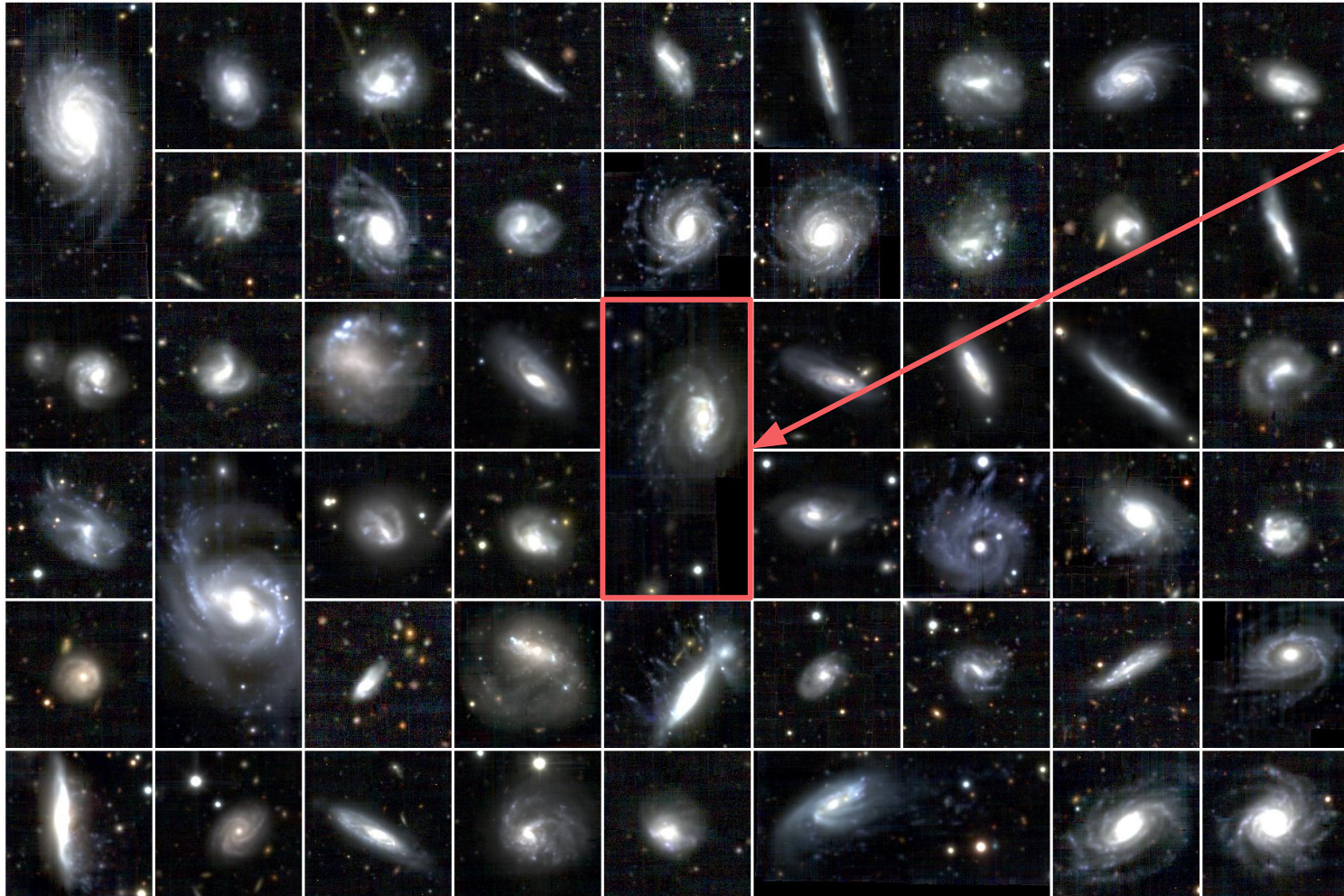
Gas Stripping Phenomena in galaxies with MUSE



Ongoing and recent SF in the tails

Older stars confined to the main galaxy body

SF in the stripped gas started during the last 5×10^8 yrs



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GASP III :
[arXiv:1704.05088](https://arxiv.org/abs/1704.05088)

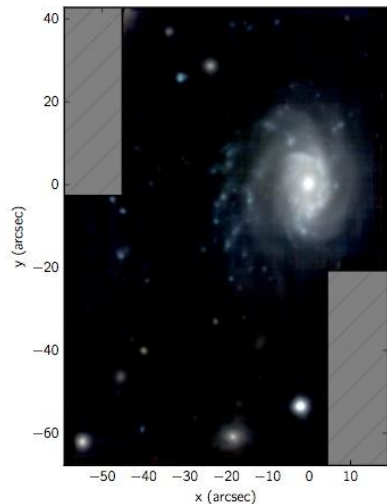
GASP IV :
[arXiv:1708.09035](https://arxiv.org/abs/1708.09035)

[GASP VI:]
[arXiv:1708.09036](https://arxiv.org/abs/1708.09036)

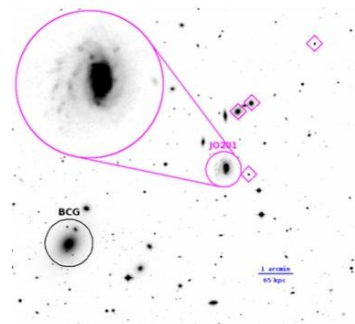
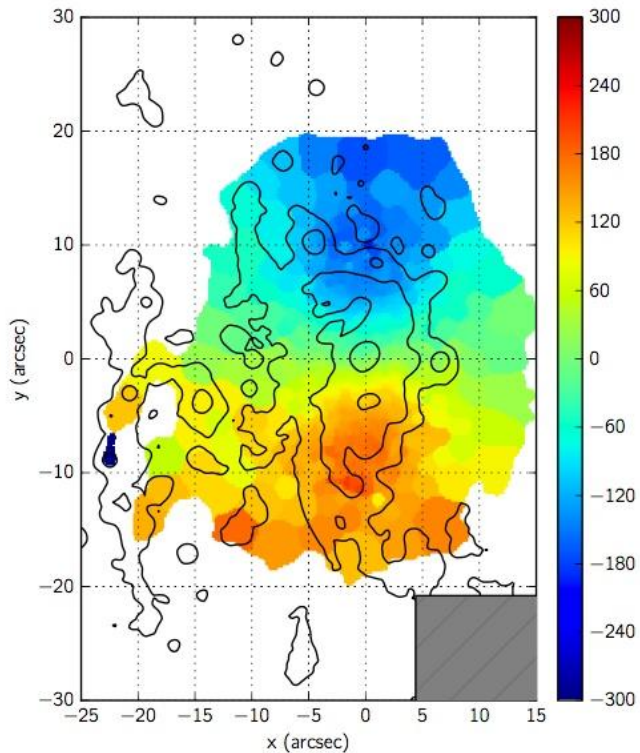
GASP VIII :
[arXiv:1708.09037](https://arxiv.org/abs/1708.09037)

The GASP survey: Galaxy zoo

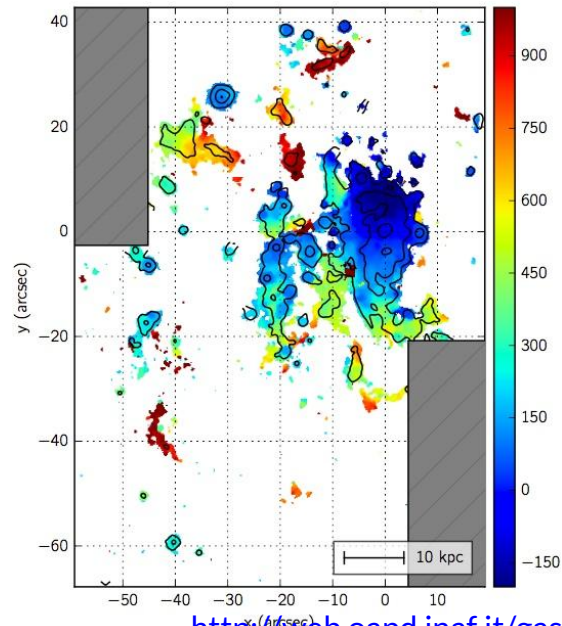
Gas Stripping Phenomena in galaxies with MUSE

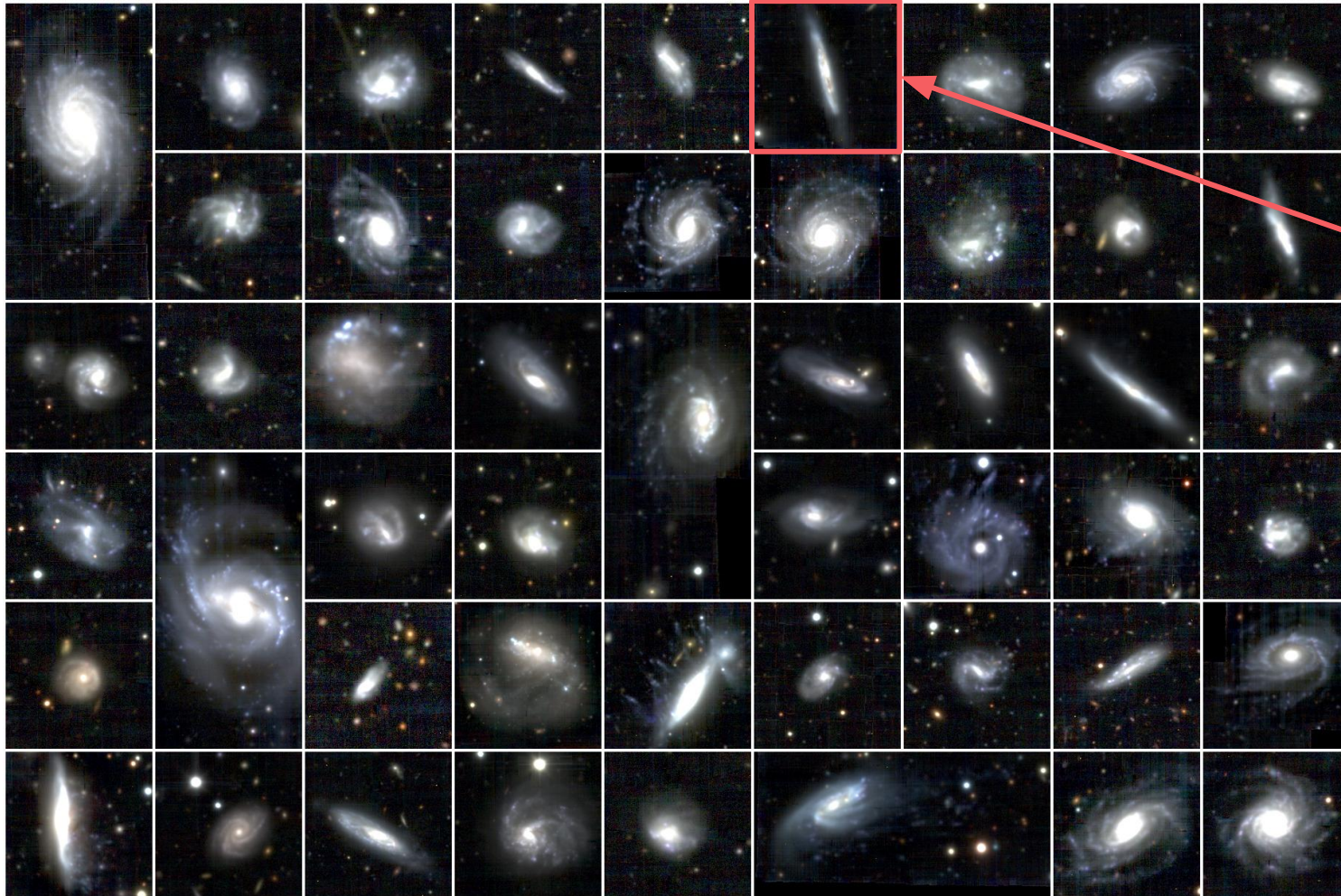


Is RPS causing unwinding arms?
Need for two components fitting: stripping along the line of sight



JO201 [3.5×10^{10}] in
A85 [1.58×10^{15}] at
360 kpc
JClass=5





GASP I :
[arXiv:1704.05086](https://arxiv.org/abs/1704.05086)

GASP II:
[arXiv:1704.05087](https://arxiv.org/abs/1704.05087)

GASP III:
[arXiv:1704.05088](https://arxiv.org/abs/1704.05088)

GASP IV:
[arXiv:1708.09035](https://arxiv.org/abs/1708.09035)

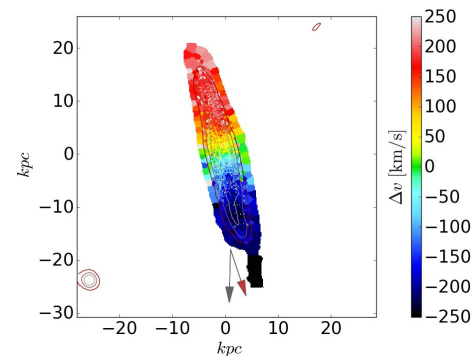
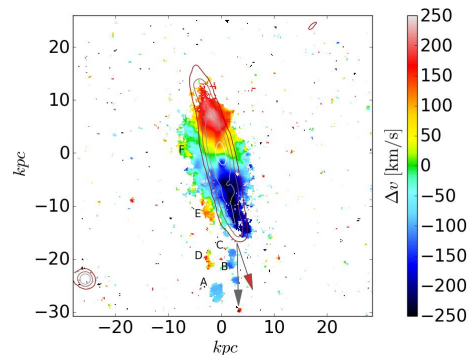
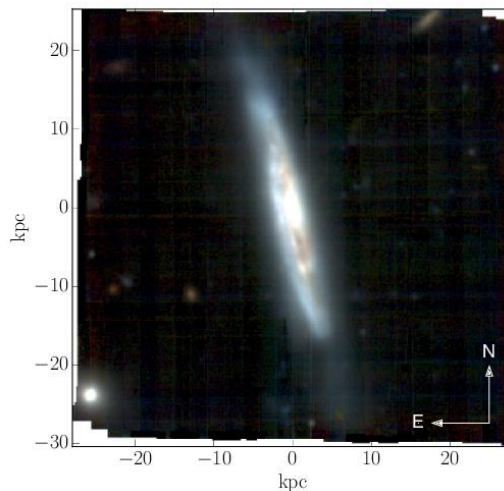
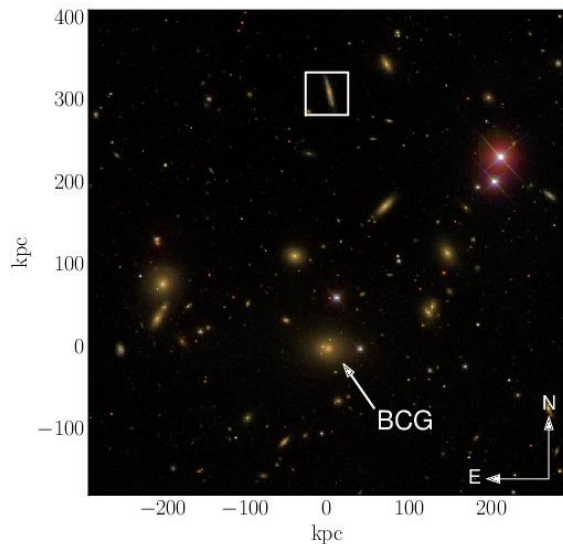
[GASP VI:]
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GASP VIII:
[arXiv:1708.09037](https://arxiv.org/abs/1708.09037)

The GASP survey: Galaxy zoo

Gas Stripping Phenomena in galaxies with MUSE

JO36 [6.5e10] in
A160 [2.9e14] at
310 kpc
JClass=3



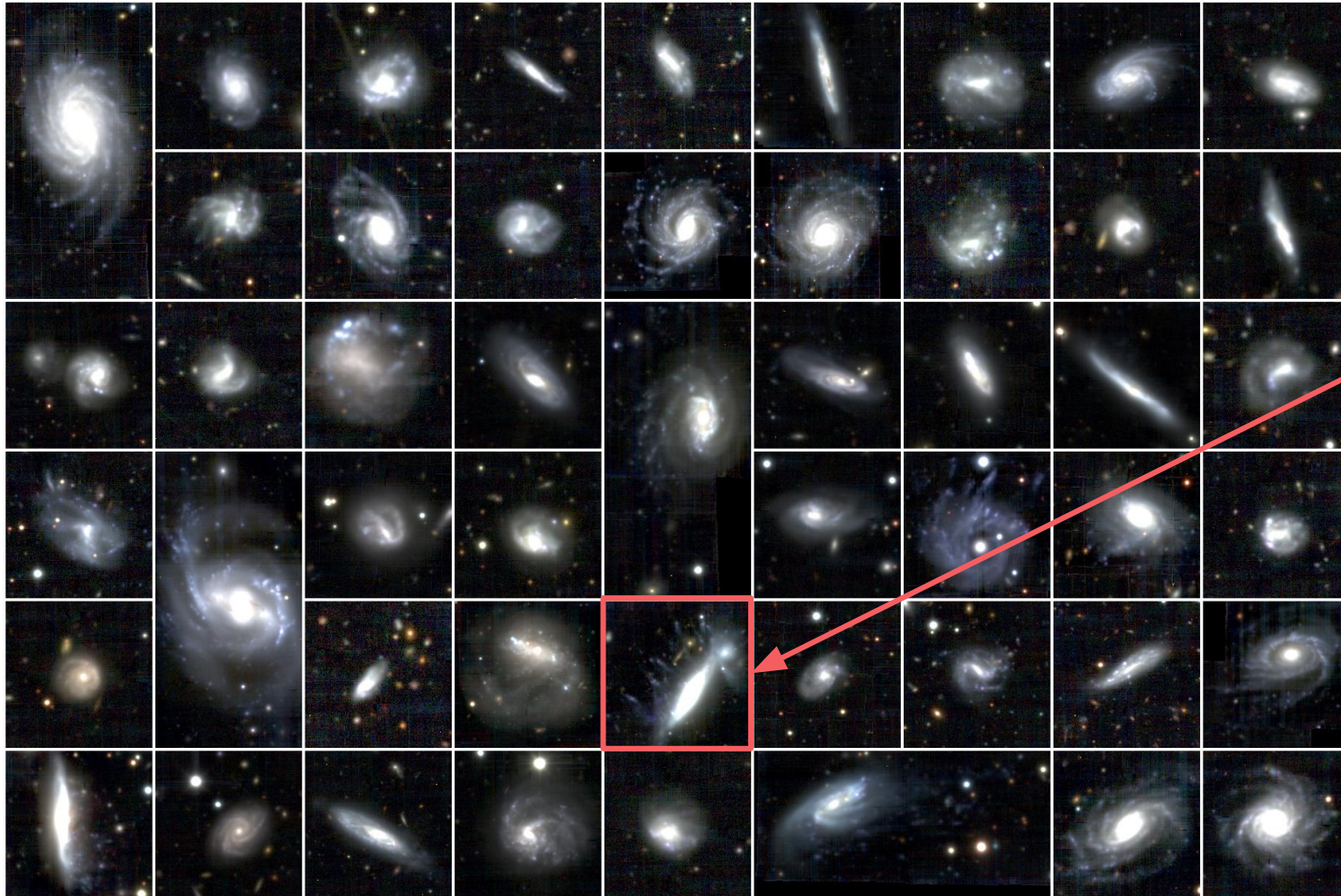
JO36 in A160: truncated H α disk, with probable buried AGN (from Chandra data)

Gas kinematics is disturbed (see also H α blobs)

Stellar tail towards the BCG (due to gravitational interaction)

Inside-out formation

From PPS diagram 21% of gas mass stripped at ~ 13 kpc



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GASP II:
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GASP III:
[arXiv:1704.05088](https://arxiv.org/abs/1704.05088)

GASP IV:
[arXiv:1708.09035](https://arxiv.org/abs/1708.09035)

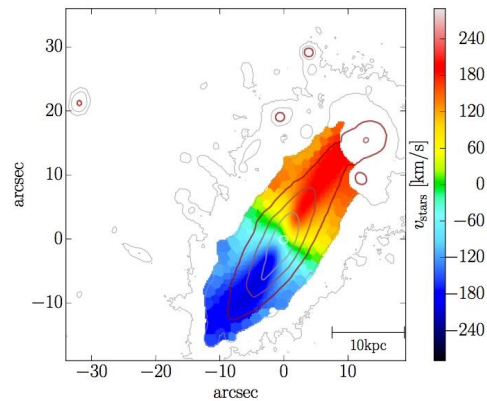
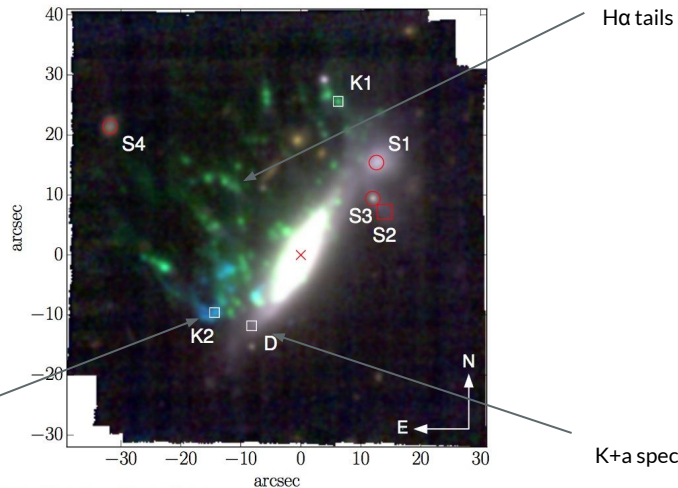
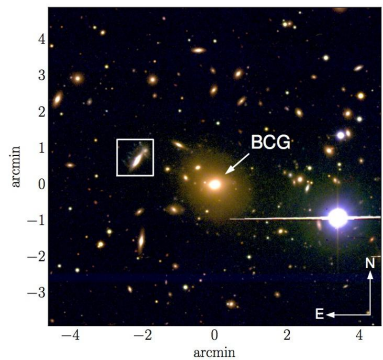
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GASP VIII:
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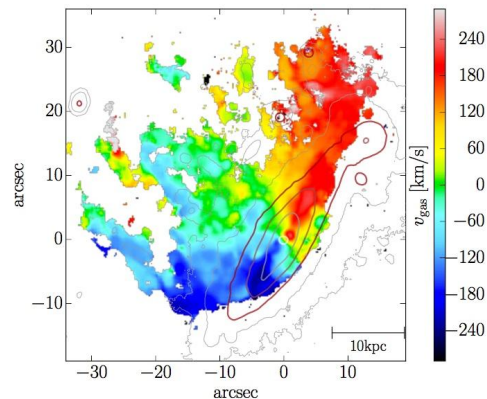
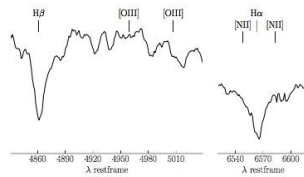
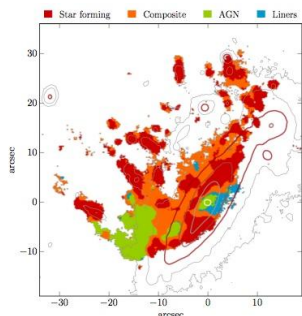
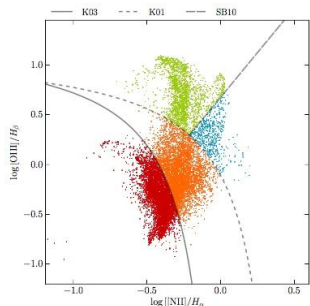
The GASP survey: Galaxy zoo

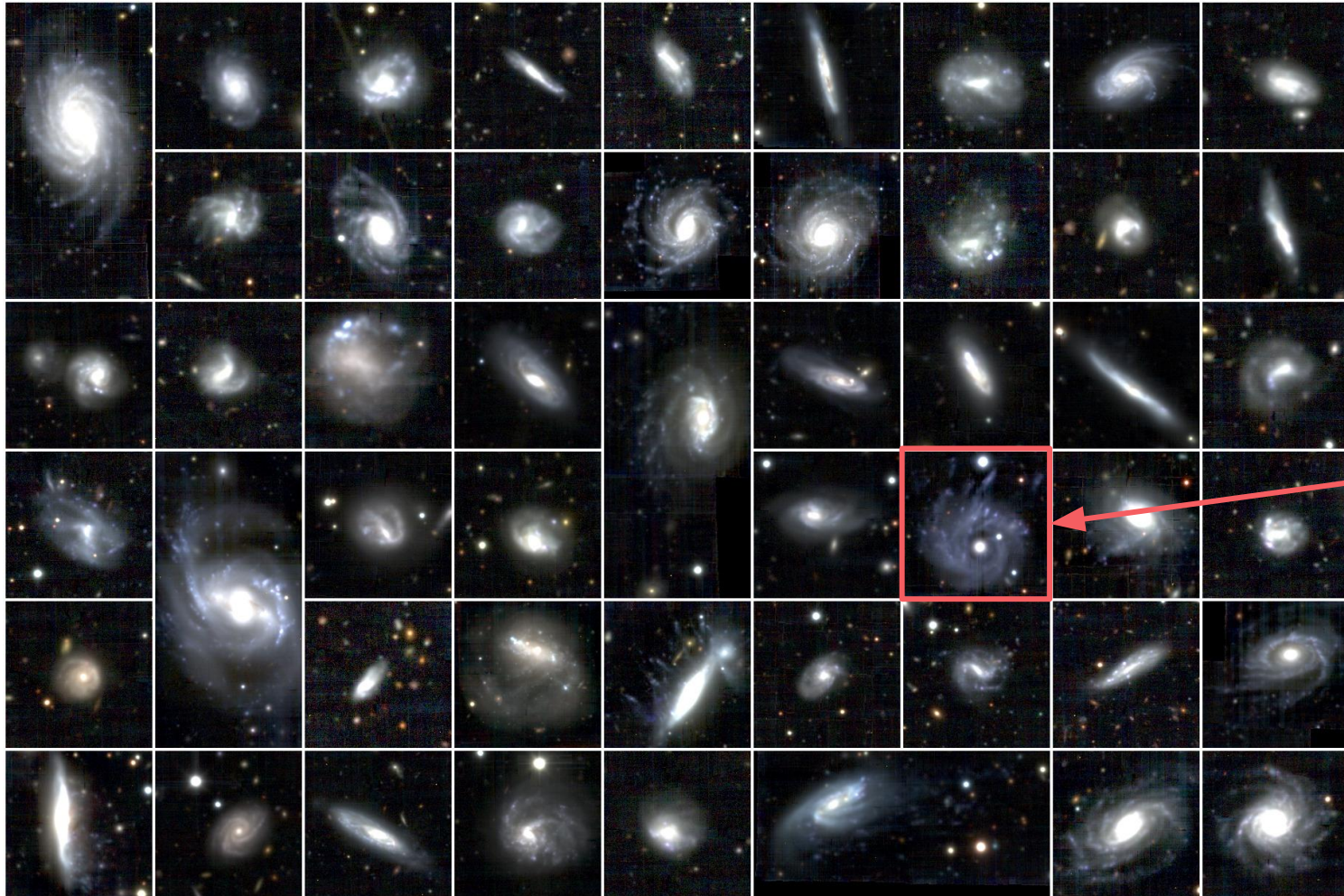
Gas Stripping Phenomena in galaxies with MUSE

JO204 [4e10] in
A957 [4.4e14] at
132 kpc
JClass=5



Strong OIII





GASP I :
[arXiv:1704.05086](https://arxiv.org/abs/1704.05086)

GASP II :
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GASP III :
[arXiv:1704.05088](https://arxiv.org/abs/1704.05088)

GASP IV :
[arXiv:1708.09035](https://arxiv.org/abs/1708.09035)

GASP V
Submitted

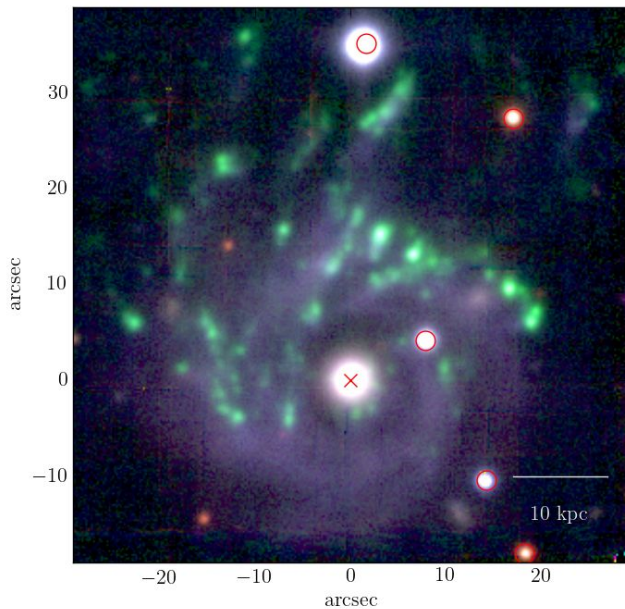
[GASP VI:]
[arXiv:1708.09036](https://arxiv.org/abs/1708.09036)

GASP VIII :
[arXiv:1708.09037](https://arxiv.org/abs/1708.09037)

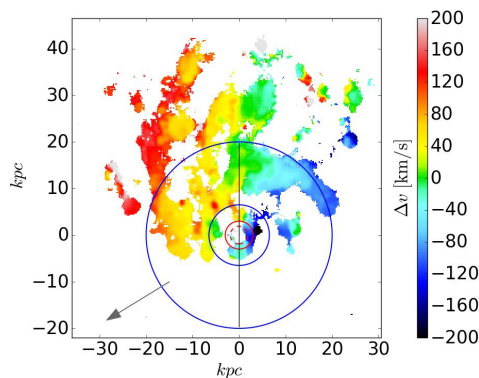
The GASP survey: Galaxy zoo

Gas Stripping Phenomena in galaxies with MUSE

JO171 [3.4e10] in
A3667 [1.7e15] at
1.38 Mpc
JClass=5



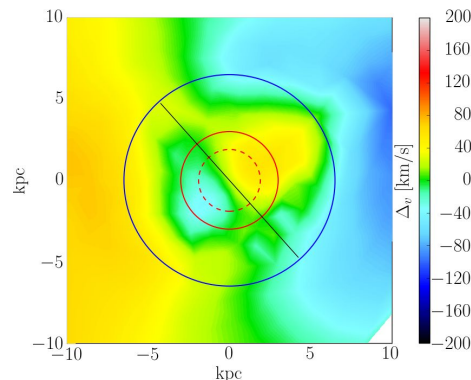
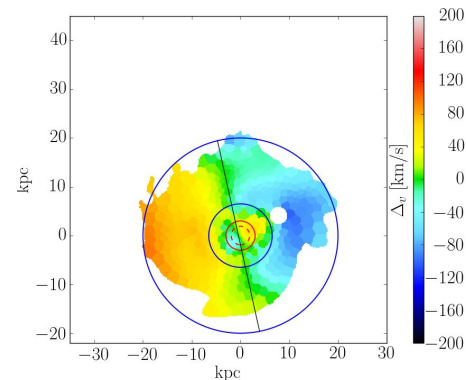
JO171 RGB image (I, H α ,B) resembling Hoag's galaxy: central spheroid+empty corona+gas ring (being stripped)

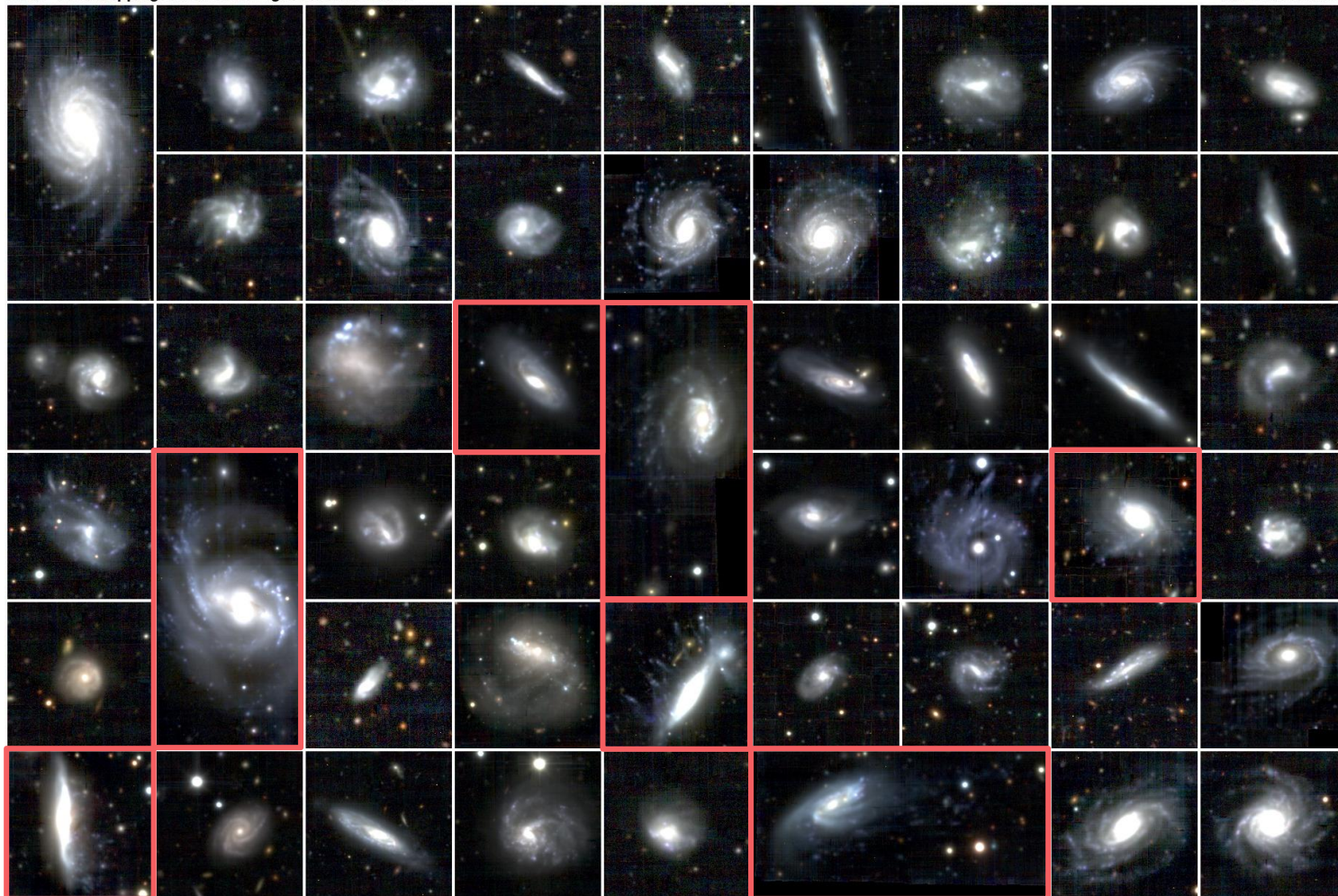


Gas only in the north region
Stars uniformly distributed
+
Counter-rotation!

No merger remnant, no bar

→ gas accretion? merger?





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GASP III:
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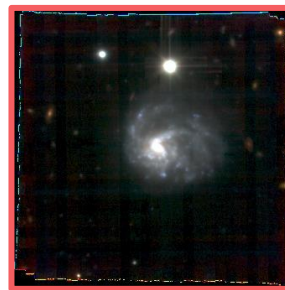
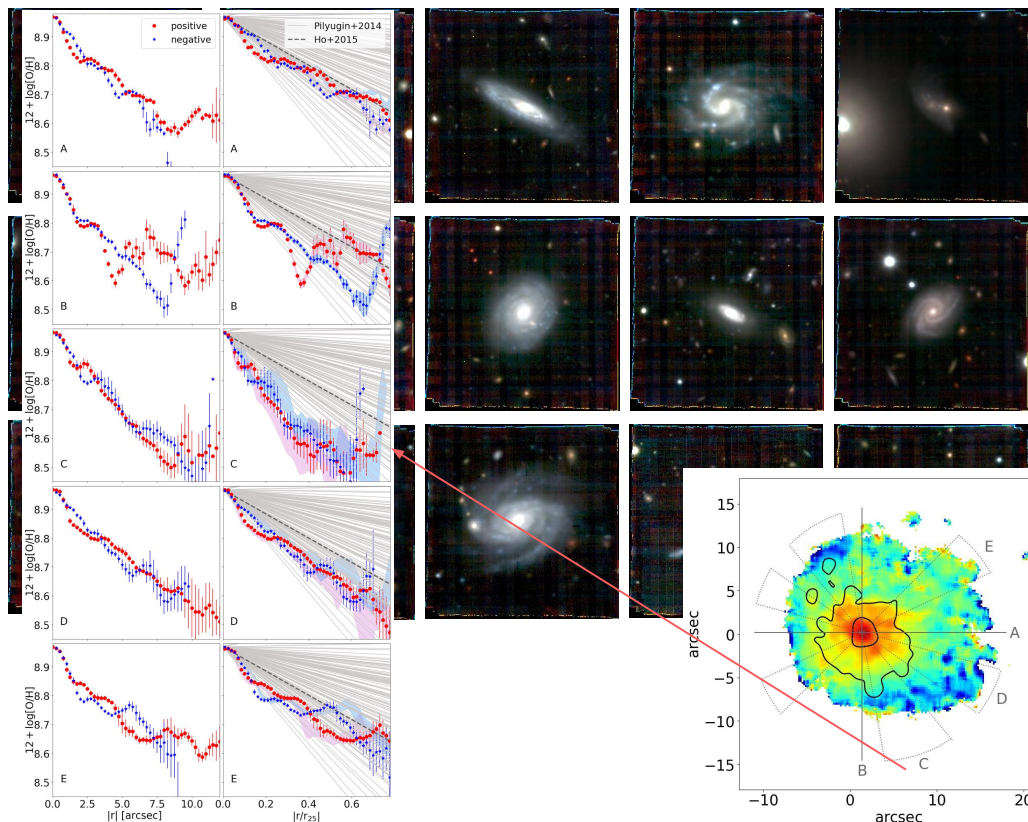
GASP IV:
[arXiv:1708.09035](https://arxiv.org/abs/1708.09035)

[GASP VI:]
[arXiv:1708.09036](https://arxiv.org/abs/1708.09036)
[see M. Gullieuszik talk]

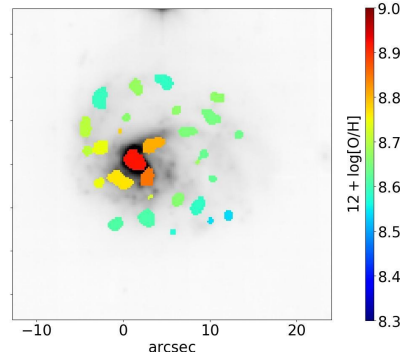
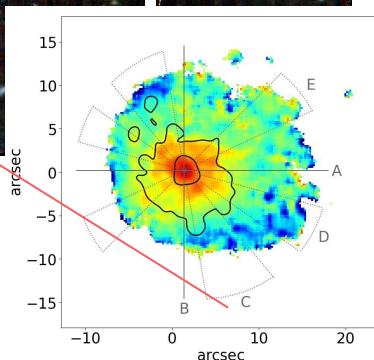
GASP VIII:
[arXiv:1708.09037](https://arxiv.org/abs/1708.09037)

The GASP survey: observed galaxies [groups/field]

Gas Stripping Phenomena in galaxies with MUSE



Gas accretion in an isolated lopsided galaxy



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GASP III:
[arXiv:1704.05088](https://arxiv.org/abs/1704.05088)

GASP IV:
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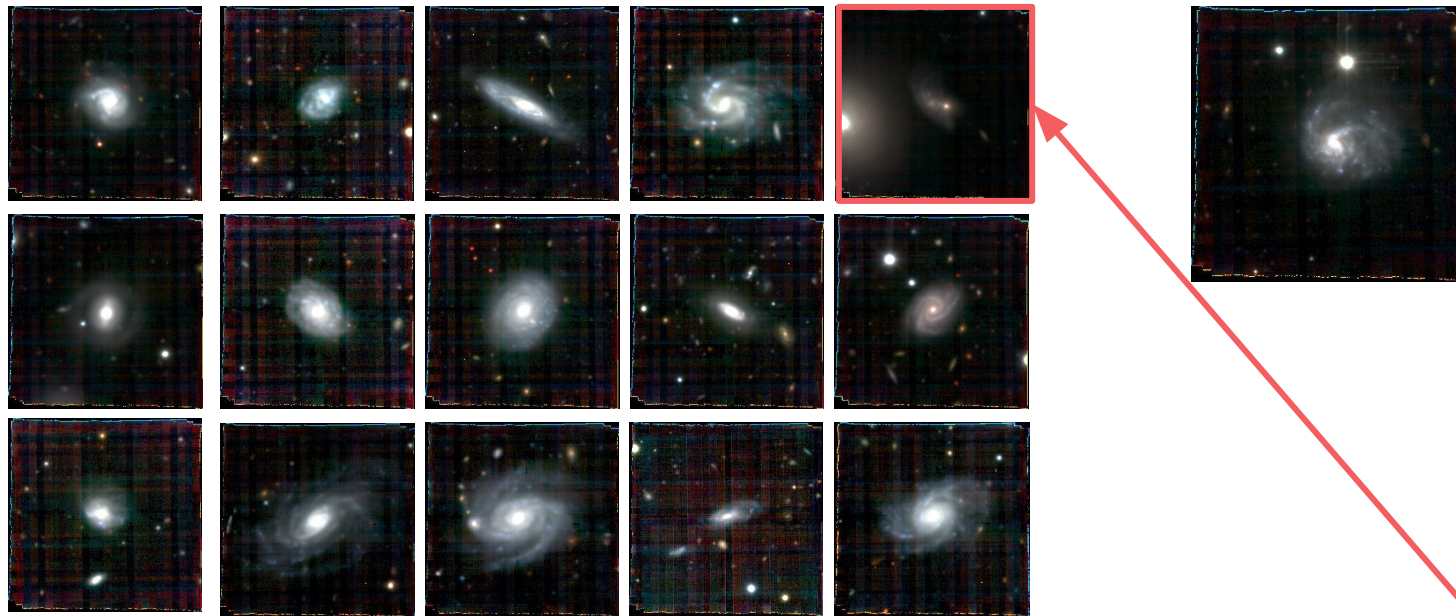
[GASP VI:]
[arXiv:1708.09036](https://arxiv.org/abs/1708.09036)

GASP VII
Submitted

GASP VIII:
[arXiv:1708.09037](https://arxiv.org/abs/1708.09037)

The GASP survey: observed galaxies [groups/field]

GAs **S**tripping **P**henomena in galaxies with MUSE



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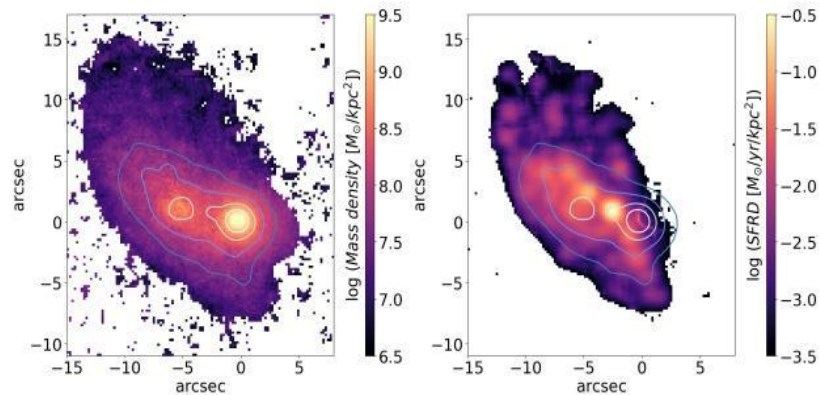
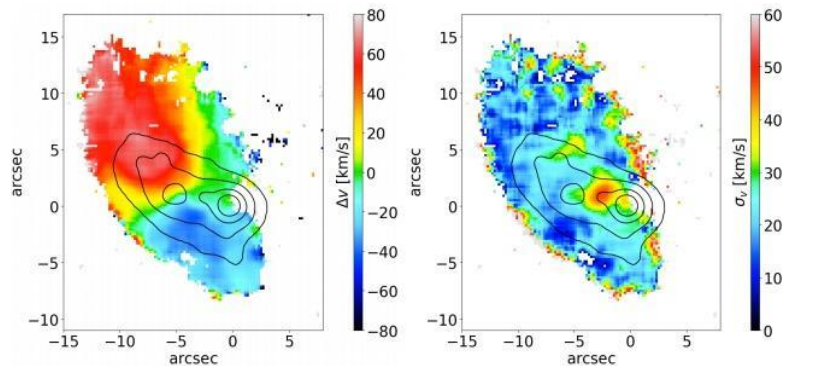
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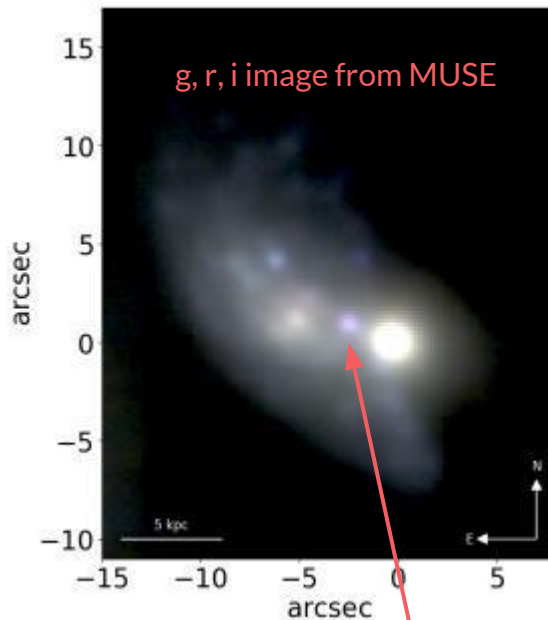
The GASP survey: observed galaxies [groups/field]

GAS Stripping Phenomena in galaxies with MUSE



Mass density

SFR density



Capturing the birth of a tidal dwarf galaxy at $z=0.05$

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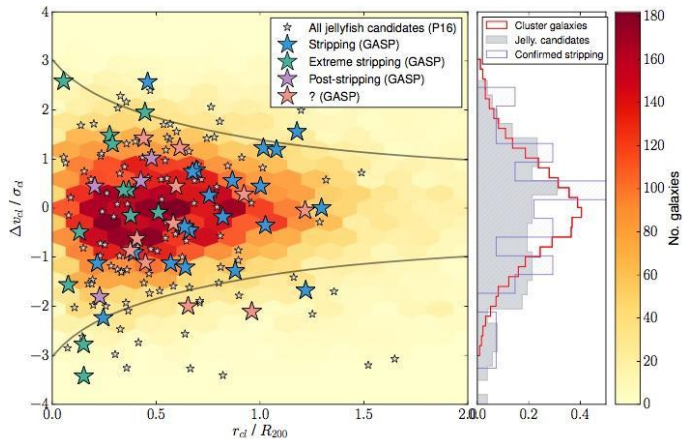
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[GASP VI:]
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Submitted

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JF in phase space



→ Extreme stripping galaxies are high mass galaxies in both low and high mass clusters, located where RPS is more intense, i.e. consistent with peak stripping

→ Mild stripping galaxies are low mass galaxies in low mass clusters outside the intense RPS zone: still retaining more than 90% of their gas?

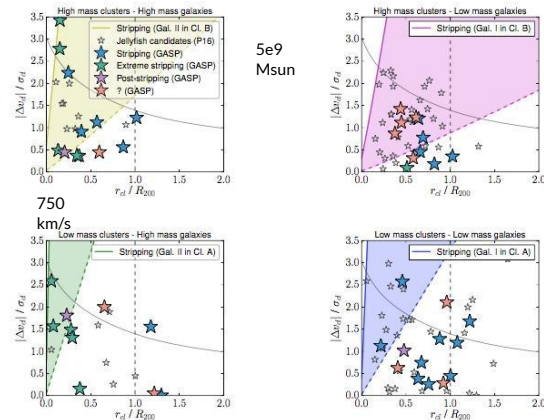
- RPS is the main mechanism responsible for the JF features
- RPS incremental, and peak stripping occurs as galaxies approach the pericenter

→ Inside R_{200} JF avoid the virialized part of the clusters (confirmed by 2d KS test)

→ Extreme JF all within $0.5 \times R_{200}$, and most have $|\Delta v| / \sigma > 1$ i.e. where RPS is expected to be more efficient

→ Both extreme and mild stripping galaxies are recent infallers (but with different distributions)

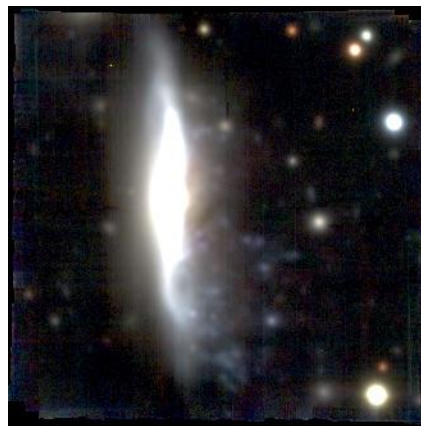
→ Post-stripping galaxies closer to the center (deceleration post pericentric passage?)



The GASP survey: Work in progress

GA**s** Stripping Phenomena in galaxies with MUSE

- Estimate the contribution of new stars born in the tails to the ICM
- Quantify the fraction of JF among spirals and the statistical relations (once the survey is completed)
- Understand if RPS is efficient also in groups
- Characterize the (unexpected) high fraction of AGN in JF galaxies
- Characterize the star formation in the tails
- Analyze the different gas phases and their interplay in the galaxies
- Derive the metallicity gradients in JF (and control sample)
- [+ more individual cases]



The GASP survey: complementary observations

GAs Stripping Phenomena in galaxies with MUSE

Molecular gas

→ CO gas with **APEX** (33+44 hrs) for 5 galaxies to detect molecular hydrogen in the galaxies and in the tails: is the molecular gas stripped as well or is it formed in situ? How much molecular gas is present in the tails and left in the main body? [molecular gas is present both in the disk and in the tails, with different velocities, Moretti et al., in prep.]

→ **ALMA** observations [4 targets, 22 hrs allocated, all with AGN, in different clusters. 1 kpc resolution would allow to resolve the knots as in GASP. CO21 and CO10]

Cold gas

→ Deep HI observations of 15 JF in 5 clusters with **JVLA** (100 hrs, 15 kpc resolution)[mainly to study the interplay of the different gas phases, but also to correlate HI deficiency to the JF appearance and to discover interactions, if any.]

Ongoing star formation

→ Ultraviolet view of RPS in action with **UVIT/Astrosat** (24.4 ks)

→ **Chandra** observations [14 galaxies with masses $>2e10$ and $JClass \geq 3$, 10-60 ks each, 560 ks in total, 11 already show X-ray emission Nicastro et al., in preparation. To detect AGN signatures, shock fronts, ULXs]

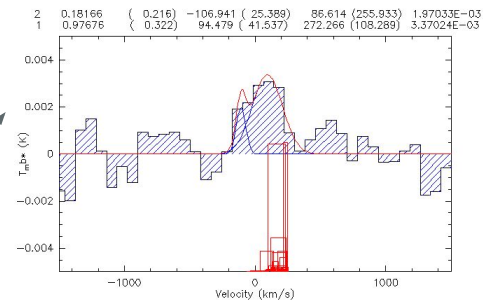
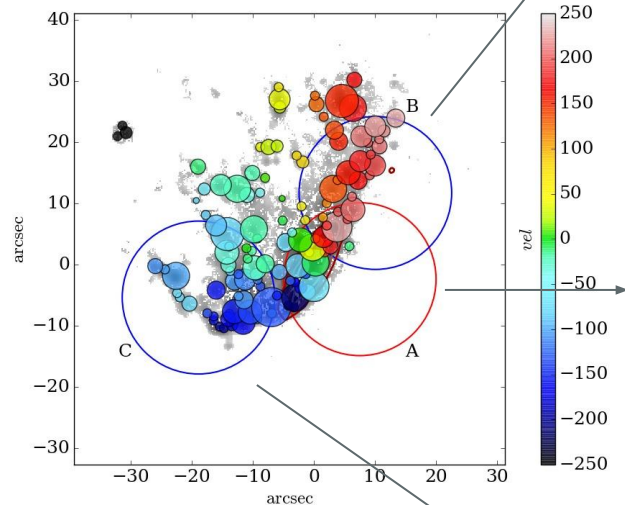
H2

HI

UV

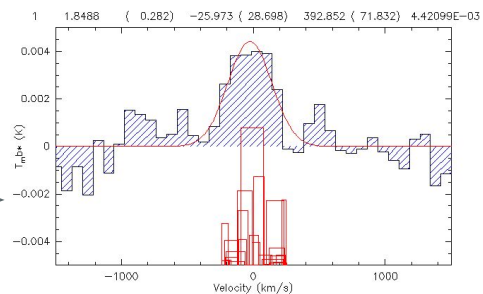
X

Molecular gas in JO204 with APEX



$M_{\text{H}_2} = 5.9e9$
 M_{\odot}

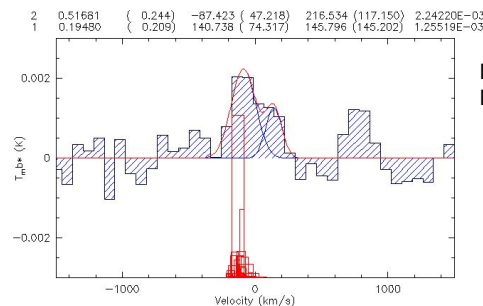
Double peak emission



$M_{\text{H}_2} = 9.4e9$
 M_{\odot}

CO follows H α but to some degree is dragged behind

Very low SFE



$M_{\text{H}_2} = 3.7e9$
 M_{\odot}

