Unravelling galaxies: where do the stars form?

GASP: **GA**s **S**tripping **P**henomena in galaxies with MUSE

Daniela Bettoni on behalf of:
Bianca M. Poggianti and the GASP team

GASP: GAs Stripping Phenomena in galaxies with MUSE

ESO Large Program with MUSE:

120 hr of MUSE over four semesters started in Period 96 (October 2015)

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Stephanie Tonnesen (simulations)
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WIde-field Nearby Galaxy-cluster Survey

(WINGS) and its extension (OMEGAWINGS)

A wide-field survey of 76 X-ray selected clusters at z=0.04-0.07

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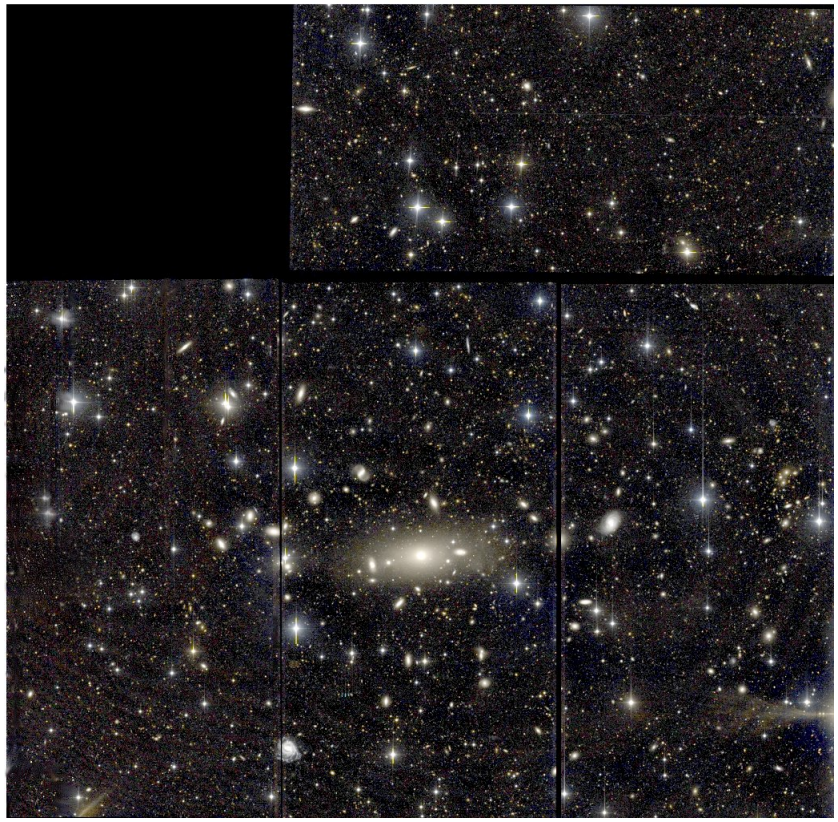


OMEGAWINGS: VST

u (1hr), V and B (25min each) on a 1deg sq. with Omegacam/ VST: 60hrs + 50hrs GTO Omegacam and VST

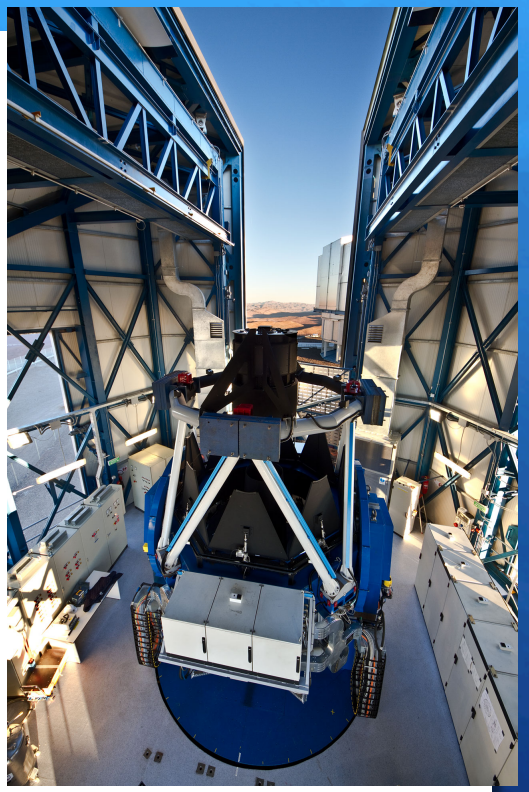


Table 1. Observation log. Columns 3 and 5 are seeing in *B* and *V* measured as the average FWHM of stars in *B*- and *V*-band final stacked images. The last column lists the reference astrometric catalogue.

cluster	DATEOBS$_B$	σ_B	DATEOBS$_V$	σ_V	src
A1069	2013-04-13	1.31	2013-05-07	0.87	2MASS
A119	2011-12-17	1.03	2011-10-23	0.74	SDSS
A147	2013-07-15	0.78	2013-08-05	0.83	SDSS
A151	2012-11-17	0.85	2012-11-04	0.75	2MASS
A160	2011-10-21	0.79	2011-10-21	0.99	SDSS
A1631a	2013-03-22	1.16	2013-02-10	0.98	2MASS
A168	2013-07-18	1.17	2013-08-03	1.23	SDSS
A193	2011-10-21	0.78	2011-10-21	1.01	SDSS
A1983	2012-05-18	1.05	2012-03-31	1.23	SDSS
A1991	2013-04-15	0.86	2013-04-14	0.84	SDSS
A2107	2013-04-08	1.03	2013-04-10	1.01	SDSS
A2382	2012-07-20	1.03	2012-06-26	2.12	2MASS
A2399	2012-06-16	0.84	2012-05-29	1.24	SDSS
A2415	2012-07-26	1.49	2012-07-22	0.82	SDSS
A2457	2012-06-16	1.08	2012-07-15	1.13	SDSS
A2589	2013-07-16	1.22	2013-07-13	0.96	SDSS
A2593	2012-10-08	1.41	2012-10-08	1.01	SDSS
A2657	2013-07-17	0.78	2013-07-11	0.77	SDSS
A2665	2013-07-12	0.96	2013-07-12	0.96	SDSS
A2717	2013-08-01	1.57	2013-06-11	1.22	2MASS
A2734	2013-06-20	1.13	2013-07-07	1.06	2MASS
A3128	2011-12-20	1.03	2011-12-18	0.77	2MASS
A3158	2011-12-18	0.95	2011-12-20	0.93	2MASS
A3266	2012-10-15	1.53	2012-10-15	1.10	2MASS
A3395	2013-03-05	0.89	2013-03-02	1.11	2MASS
A3528	2013-06-02	1.43	2013-06-05	1.11	2MASS
A3530	2013-06-03	0.95	2013-06-06	0.86	2MASS
A3532	2013-06-03	0.91	2013-06-07	0.77	2MASS
A3556	2012-06-17	1.21	2012-05-24	1.44	2MASS
A3558	2013-06-11	0.85	2013-06-28	0.76	2MASS
A3560	2012-06-18	0.89	2012-05-24	1.68	2MASS
A3667	2013-04-13	1.38	2013-05-14	0.95	2MASS
A3716	2013-05-20	1.13	2013-05-20	0.93	2MASS
A3809	2012-07-22	1.12	2012-04-18	0.99	2MASS
A3880	2013-06-11	1.31	2013-06-20	0.92	2MASS
A4059	2013-08-04	1.05	2013-07-03	0.91	2MASS
A500	2011-11-28	1.26	2011-12-02	1.28	2MASS
A754	2011-11-30	0.76	2011-11-22	0.95	2MASS
A85	2013-09-03	0.97	2013-08-03	1.00	SDSS
A957x	2012-03-26	1.05	2011-11-23	1.02	SDSS
A970	2011-12-23	1.64	2011-11-24	1.25	2MASS
IIZW108	2013-06-06	1.04	2013-06-06	0.86	SDSS
MKW3s	2012-04-20	1.14	2012-04-19	0.83	SDSS
Z8852	2012-11-10	1.02	2012-10-12	0.83	SDSS

B and V completed: 46 clusters

u-band ongoing

Great asset: out to 2.5 virial radii

Photometry, but also detailed morphologies, structural parameters, color maps etc

Gullieuszik+ 2015

Padova-Millennium Galaxy and Group Catalogue (PM2GC)

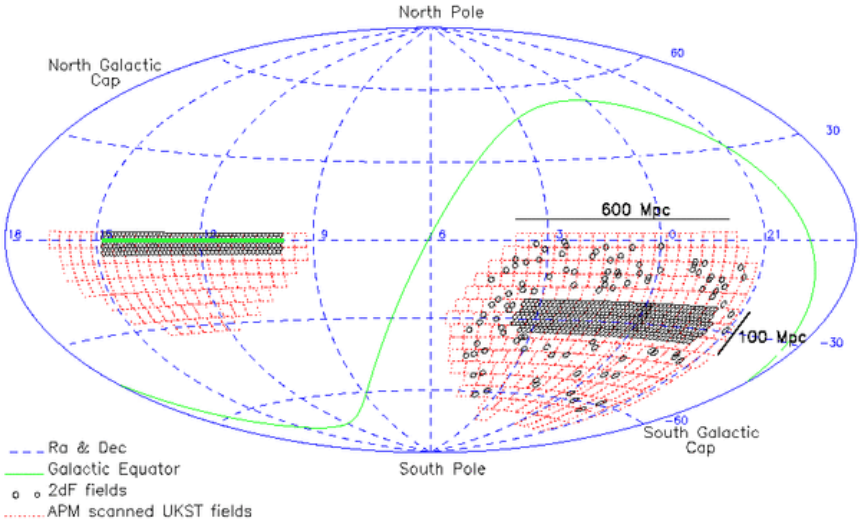
Rosa Calvi, BP + WINGS collaborators

A general field galaxy sample at z=0.04-0.1

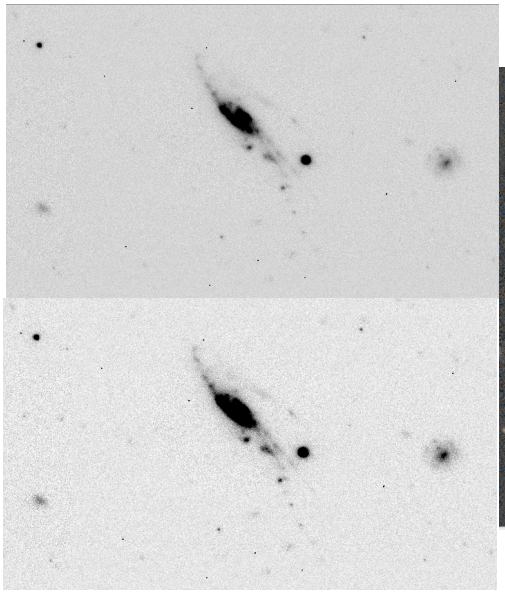
Based on the Millennium Galaxy Catalogue (PI Simon Driver, Liske et al. 2003), a 38 deg^2 equatorial survey

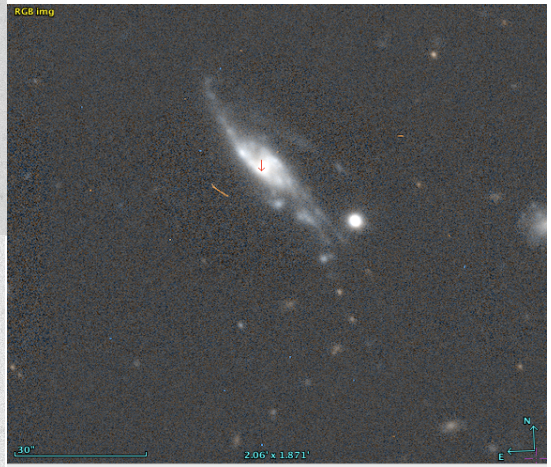
B-band imaging with WFC/INT

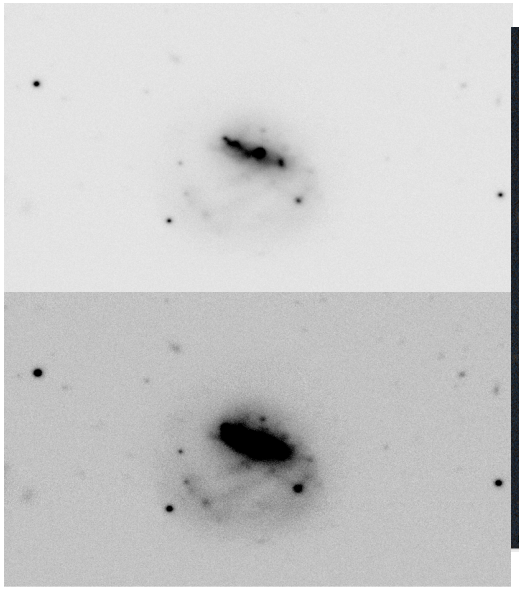
AAT/2dF redshift survey combined with 2dFGRS and SDSS: spectroscopic completeness in the area 96% to B=20

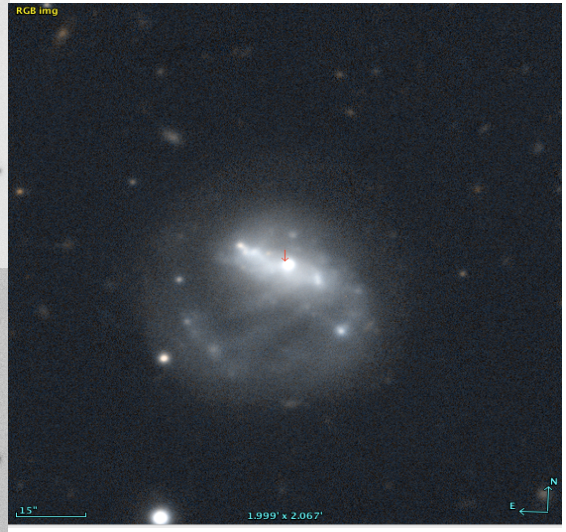


CATALOGUE OF JELLYFISH CANDIDATES









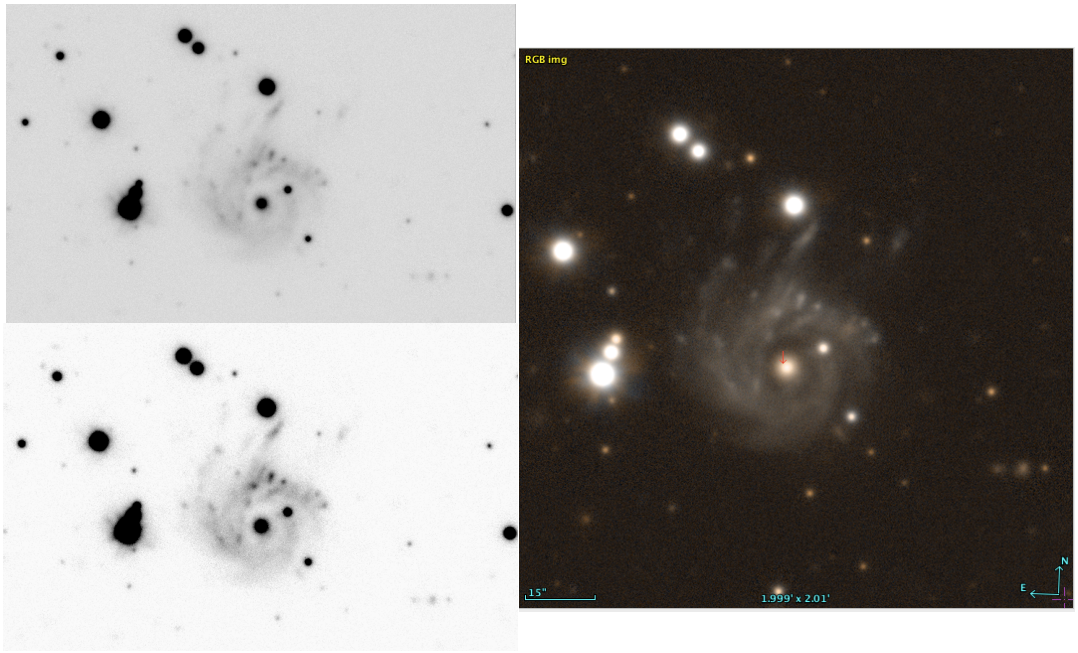
We visually searched for "stripping candidates" in deep images of clusters (OMEGAWINGS+WINGS) and field (PM2GC)

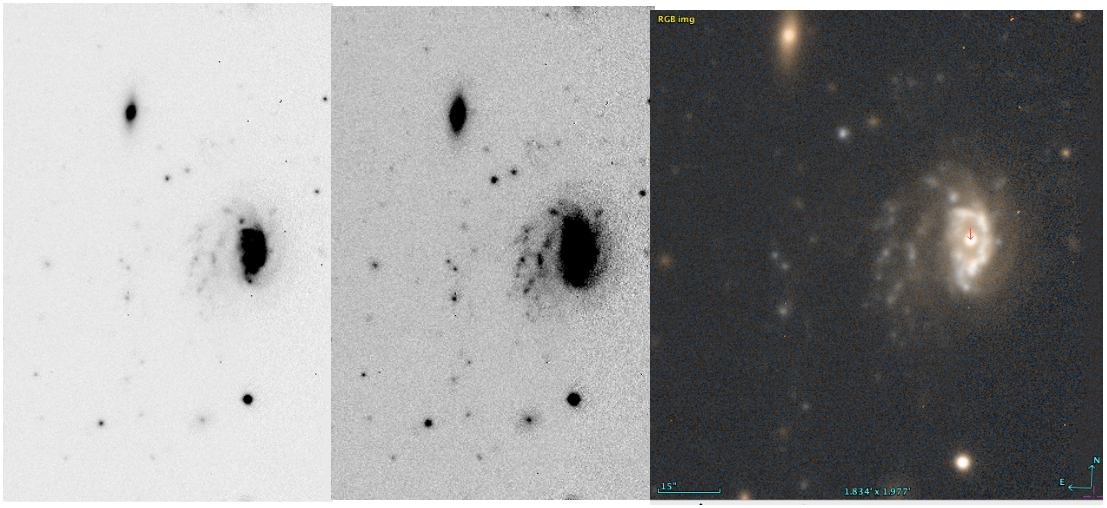
Atlas of 419 stripping candidates at z=0.04-0.1, of which 344 in clusters and 75 in "the field"

Not all are classical "jellyfishes", but all show unilaterally disturbed morphologies.

Poggianti et al. 2016, AJ

CATALOGUE OF JELLYFISH CANDIDATES





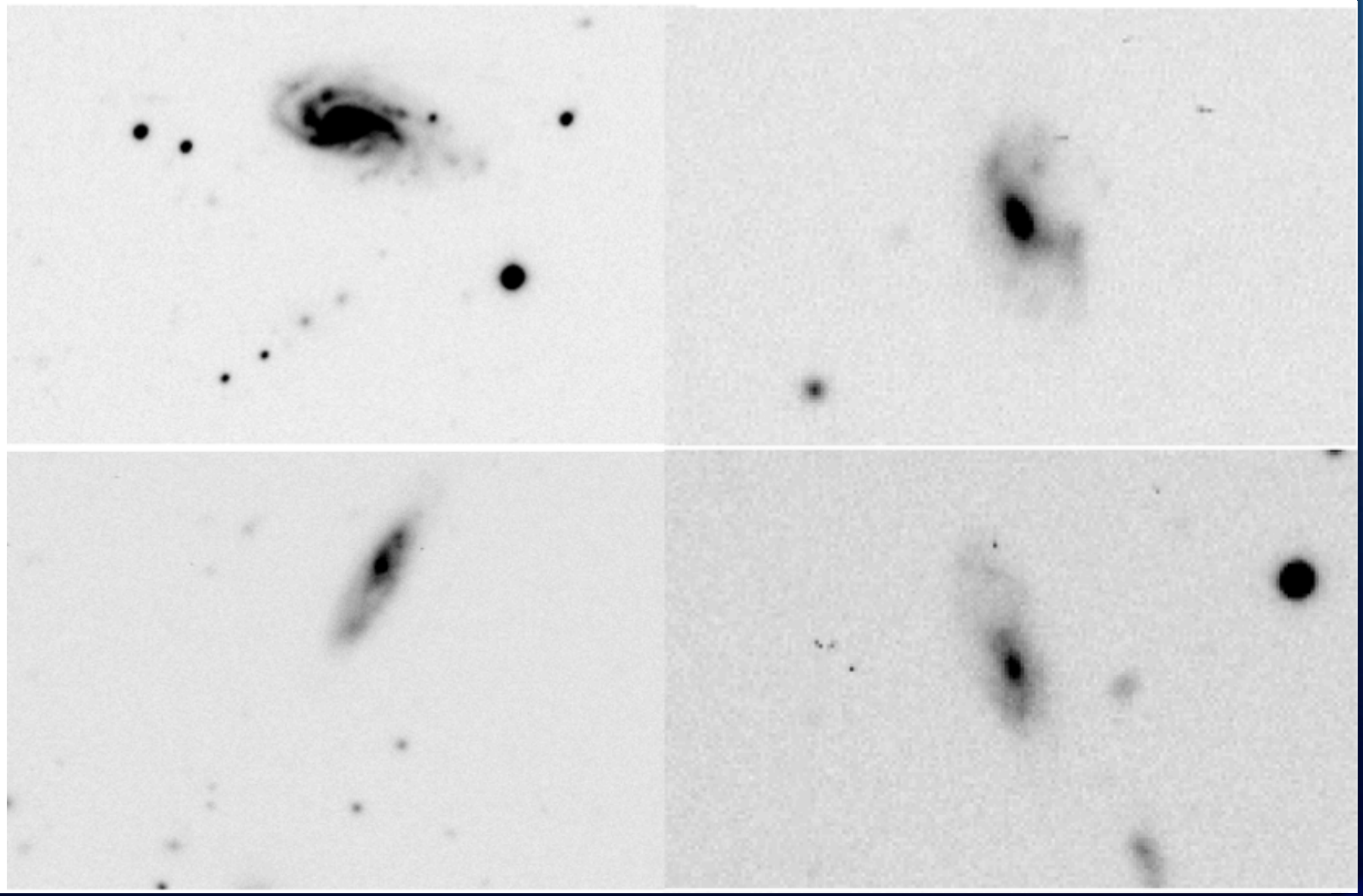
Images, positions, first analysis of galaxy environment and properties (SFR, morphology, mass, color)

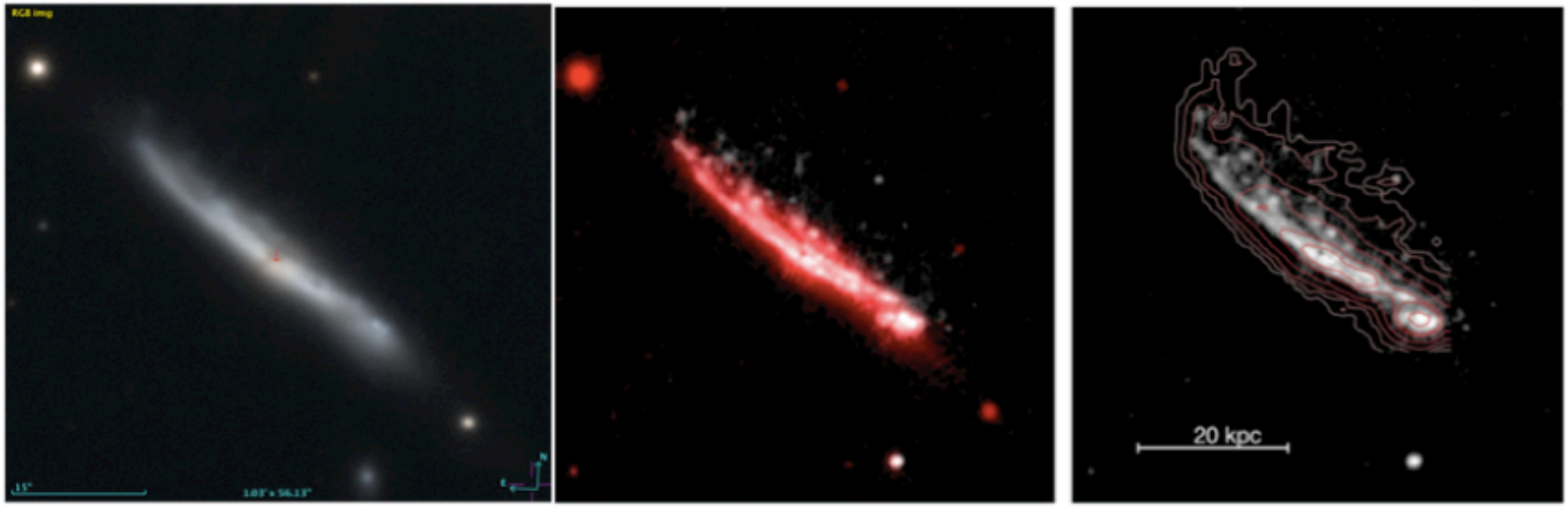
Broad range of galaxy stellar masses (logM=9-12)

SFR enhanced by a factor of ~2

Poggianti et al. 2016

“STRIPPING CANDIDATES” IN GROUPS AND LOW-MASS HALOES





Poggianti et al. 2016

Merluzzi et al. 2013

Spatially resolved gas-sensitive studies show that the optical signature is just the tip of the iceberg

That is why we decided to include in our atlas also weaker cases

Optical morphology alone is not able to identify the physical cause beyond doubt (tidal, minor and major mergers, harassment): follow-up gas IFU studies are needed

GASP's motivation

- The gas supply regulates the histories of galaxies

- Several factors can affect the gas content:
  -- galactic winds due to star formation or an active galactic nucleus
  -- affecting only gas: ram pressure stripping and strangulation
  -- affecting gas and stars: tidal effects, mergers
  and more

- Gas removal processes can lead to interruption of the star formation activity (quenching)

Observe **how** (physics), **where** (environment) and **why** (physical processes) gas gets removed from galaxies

Measure timescale and efficiency of gas removal **as a function of galaxy mass and environment**

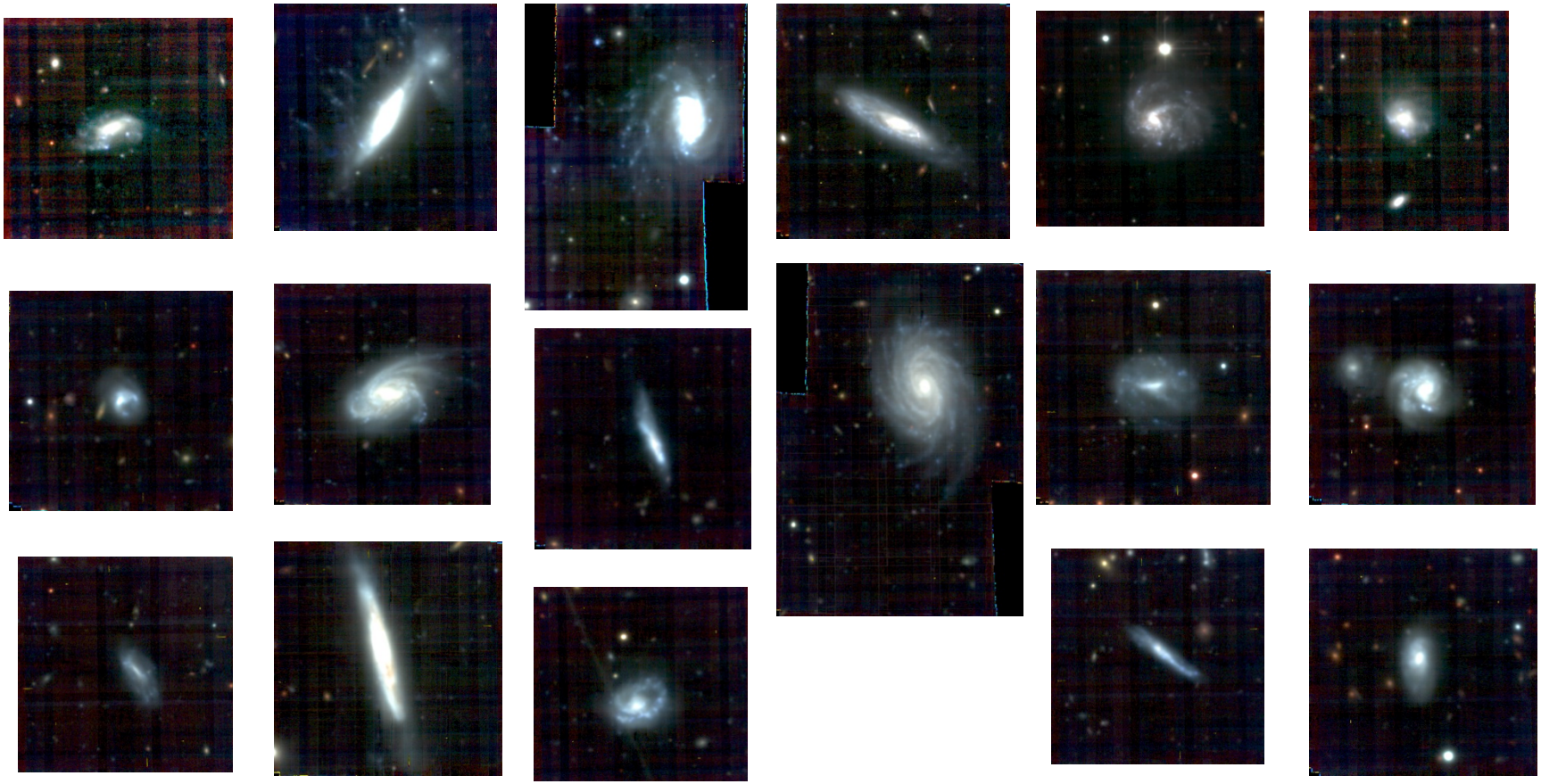
Quantify the amount of **star formation** involved and understand the effects on **galaxy quenching and evolution** in general

GASP's science questions

- Is gas being removed from galaxy?
- By what physical process (RPS, tidal, harassment, AGN, SF…)
- Amount of gas removed – amount of stars formed in the stripped gas
- SF and SFH within the galaxy and outside of the galaxy – enhanced/suppressed?
- Timescales involved
- What is the cause of gas ionization?
- Metallicity of gas and stars

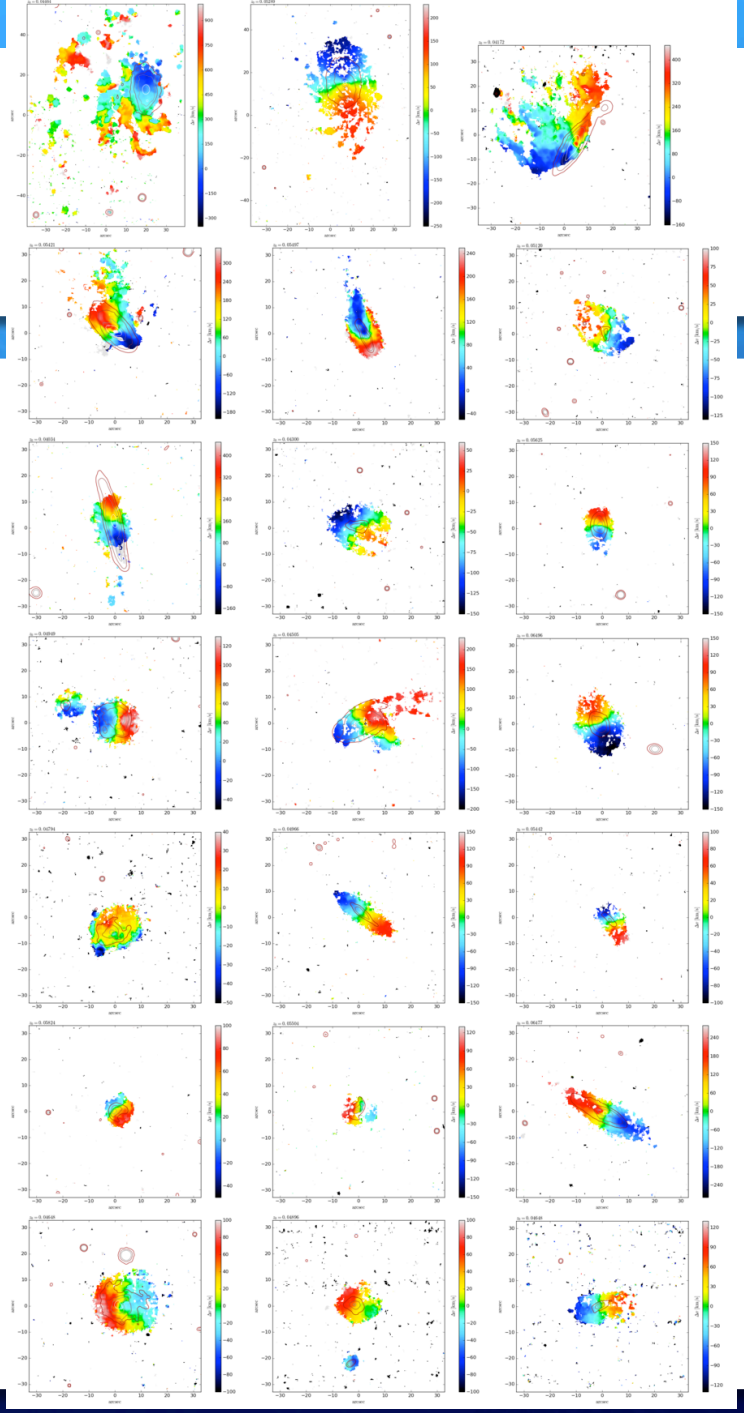
- Where does gas removal occur (environment)? Where in clusters? Depends on cluster mergers? In groups/low-mass haloes?
- What galaxy masses are affected by gas removal?
- What is the role of gas stripping/removal on galaxy transformations (quenching and morphologies)

GASP gallery (MUSE RGB images)

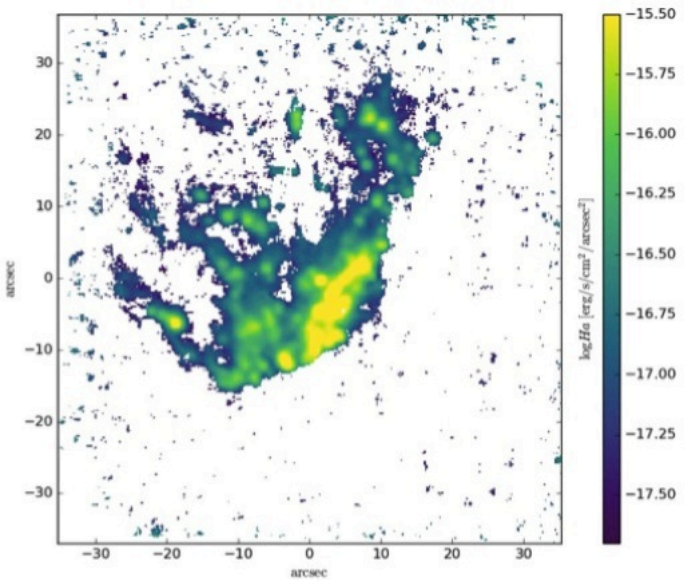


GASP status

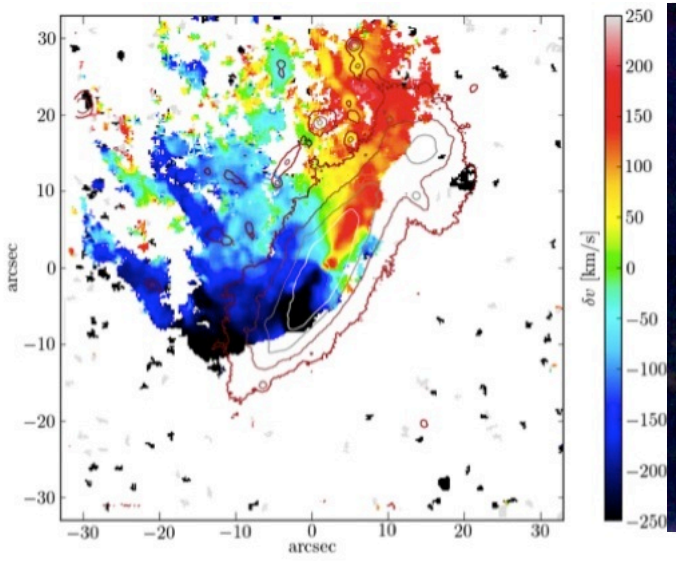
A variety of gas morphologies…



JO204



Hα map (SN>5)



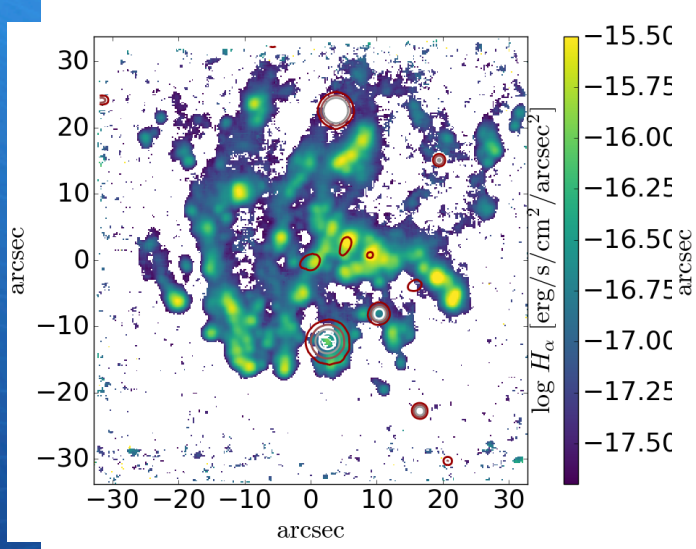
Hα velocity map

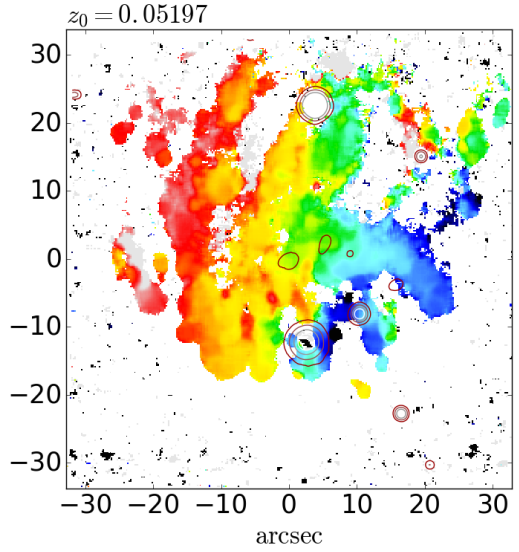
MUSE white image (RGB image)

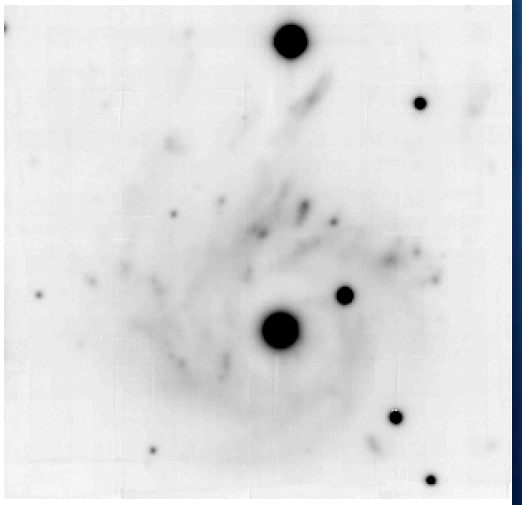
Stellar mass = 8 X 10^10 Msun - Mass similar to JO201, but cluster very different: 600 km/s, Lx=10^43.9 erg/s

Poggianti et al. in prep.

JO171: a stripped Hoag's object?







Hα map (SN>5)

Hα velocity map

MUSE white image (RGB image)

3 X 10^11 Msun, in 1000 km/s cluster undergoing a massive merger, at a radius ~0.5 R200

Moretti et al. in prep.

GASP SUMMARY

- First systematic search yielded an atlas of 400+ "stripping candidates" in low-z clusters, groups and field (Poggianti et al. 2016)
- GASP is an ongoing MUSE Large Program to study in great detail ionized gas and stars, in and out of 100 galaxies (stripping candidates + control sample)
- It is revealing:
  - the physical process responsible for the observed morphologies
  - the physics of that process
  - where and on what galaxies it happens