The environment of multi-spin galaxies and its role in their formation and evolution

Daniela Bettoni

INAF – Osservatorio Astronomico di Padova

INAF ISTITUTO NAZIONALE DI ASTROFISICA
OSSERVATORIO ASTRONOMICO DI PADOVA

How to study the environment of a particular class of objects?

Neighbour Finding

a) study of the concentration and diameters of all the objects surrounding the TARGET, within a search field X times the TARGET diameter.

Fixed Aperture

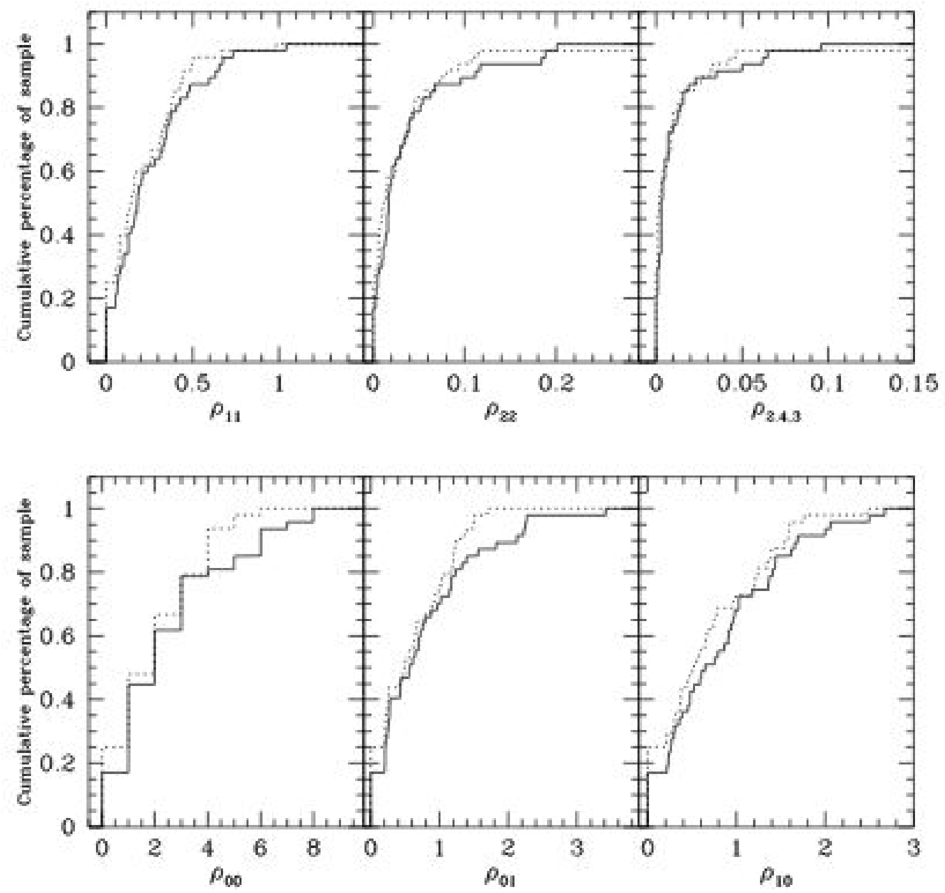
b) a search, in a wider field, in general a fixed area or volume around each galaxy, for objects that may have encountered the TARGET galaxy in a time of the order of at least X Gyr.

What we know:Polar Rings

Whitmore et al. (1990) 185 PR

Brocca et al. (1997)
Define a density parameter for each field:
ρ_{00} represents the number of neighboring galaxies, ρ_{01} is the number weighted by the relative size, ρ_{10} is weighted by proximity and ρ_{11} is weighted by size and proximity.

The environment of PRs does not appear statistically different from that of normal galaxies

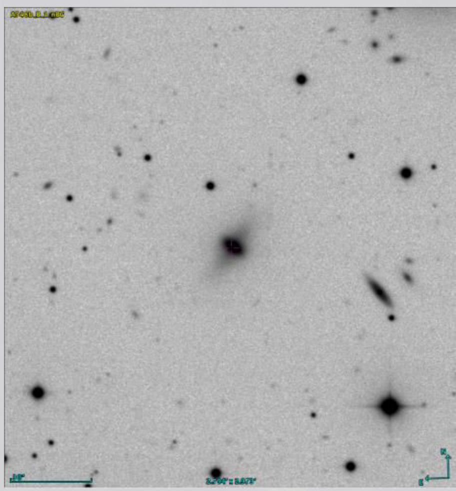


Cumulative frequency of ρ_{ij} parameters for the fields of polar ring galaxies (full lines) and the control fields of normal galaxies (dotted lines)

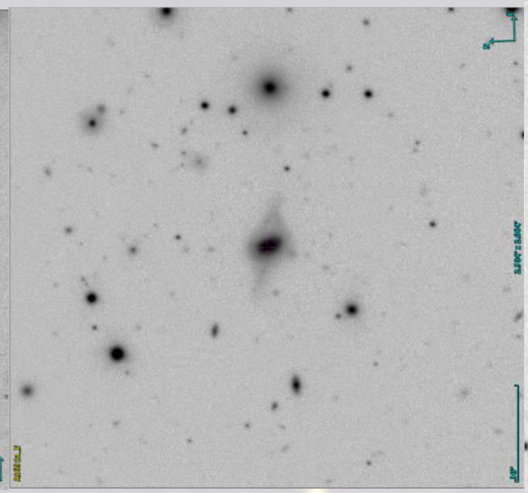
What we know: Polar Rings

Whitmore et al. (1990) indicate only 5 galaxies in very rich environments.

A548



A1631a



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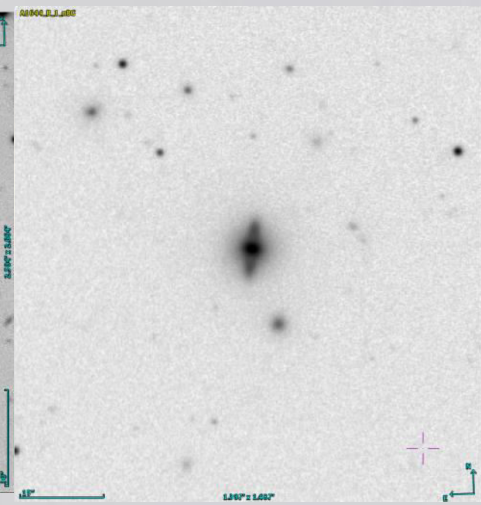
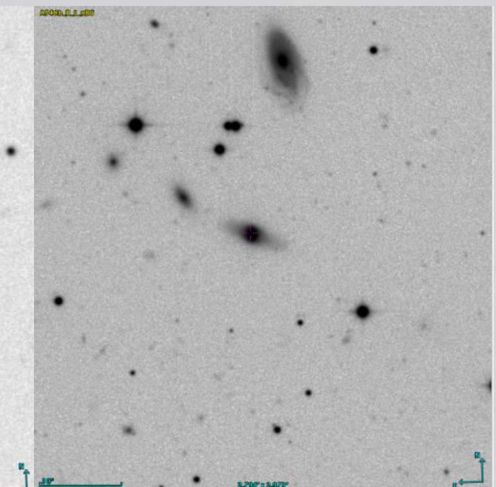


A548



30”

What we know:Polar Rings

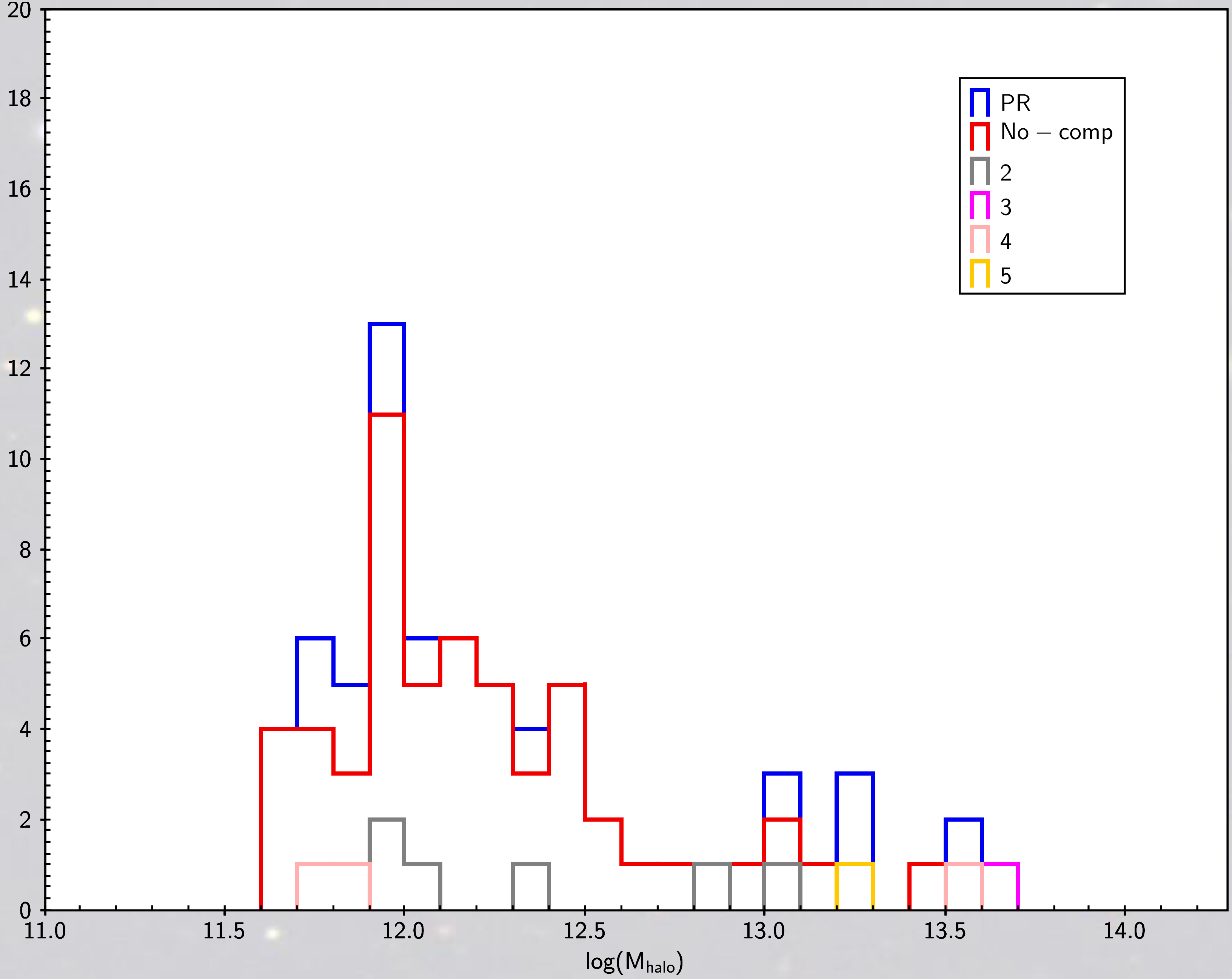
Finkelman et al. (2012)

PR Preferentially inhabit low-density environments compared to other ETG samples

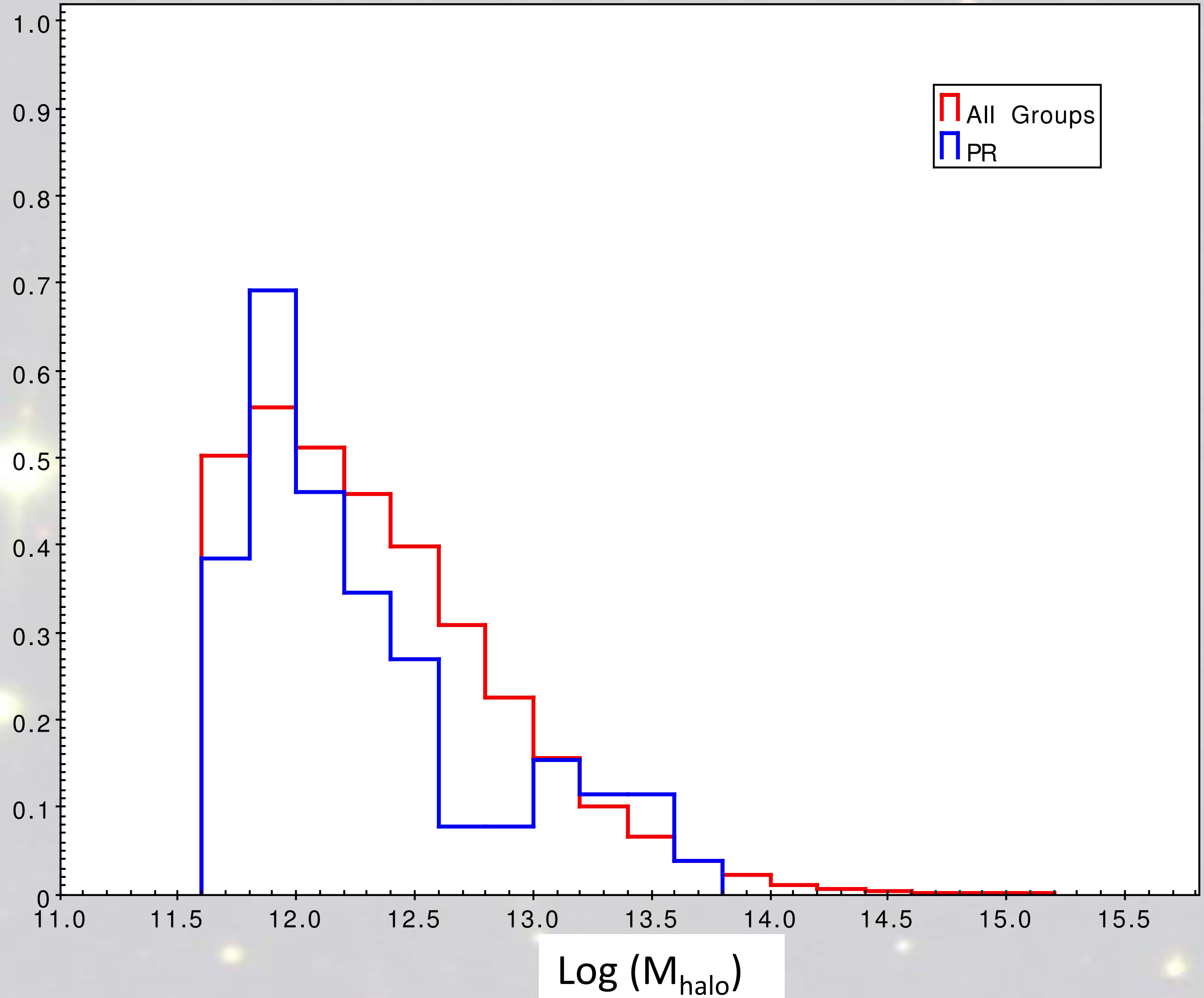
Whether or not the occurrence of PR in galaxy mergers and interactions depends on group halo mass or central/satellite designation.

Moiseev et al. (2011): 275 PR correlated with the group catalogue for SDSS-DR7 of Yang et al .(2007)

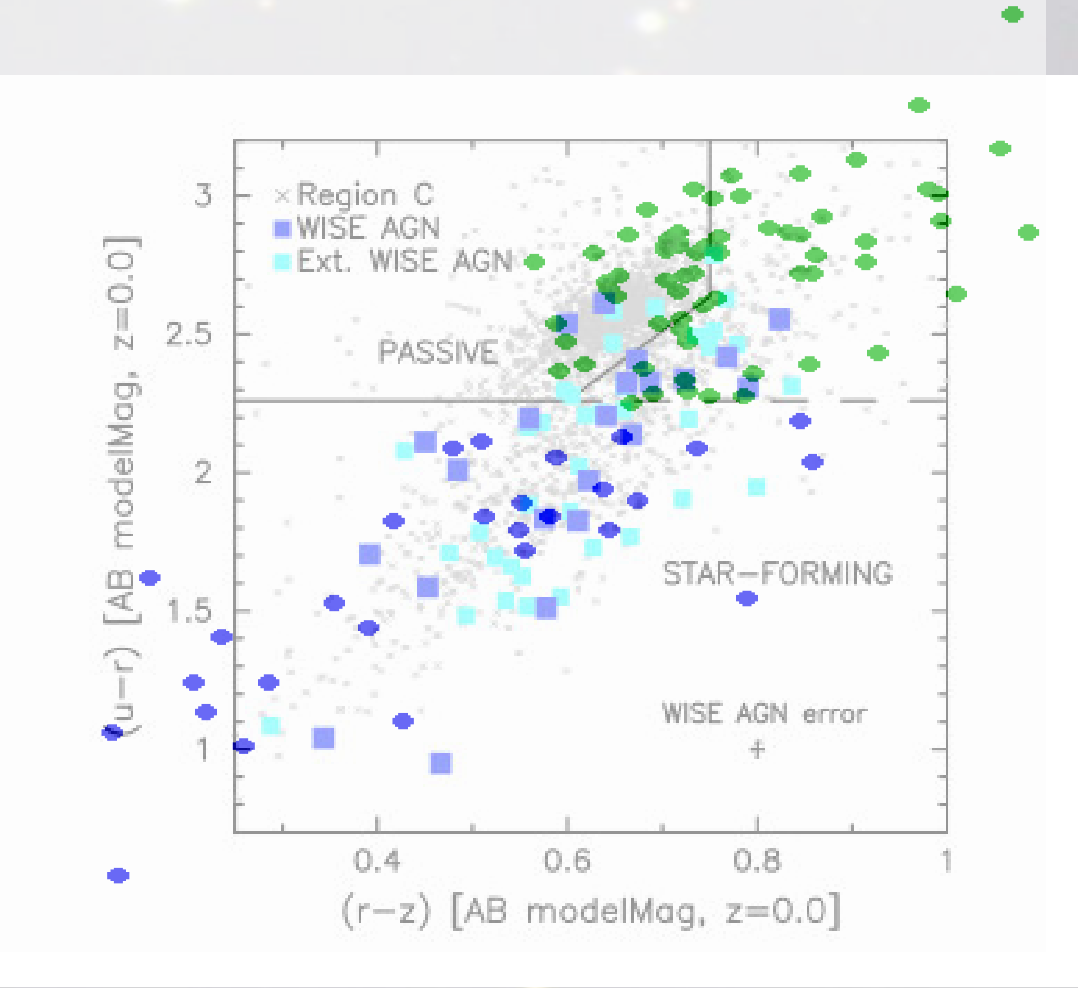
97 object matched with the group catalogue
Almost 80% are from categories B and G
85% are without apparent companions

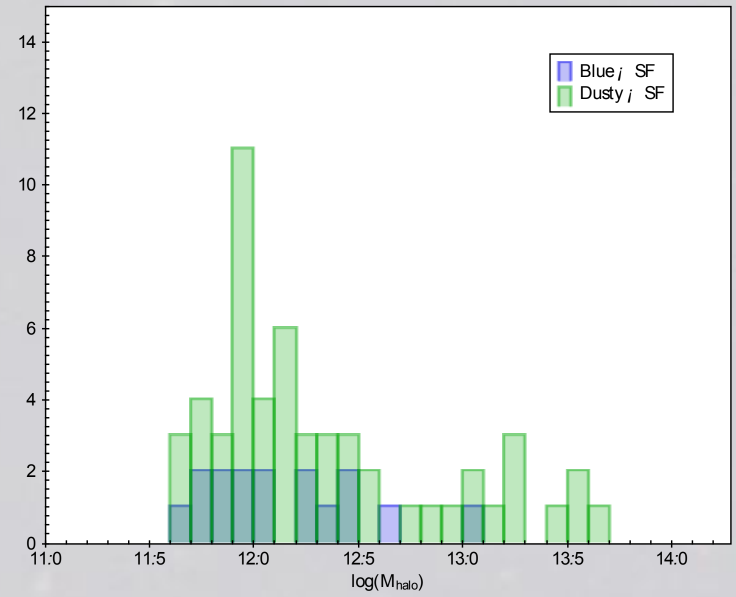

PR
No − comp
2
3
4
5
20
18
16
14
12
10
8
6
4
2
0
11.0
11.5
12.0
12.5
13.0
13.5
14.0
log(M_halo)

Halo masses from: Yang et al. 2007



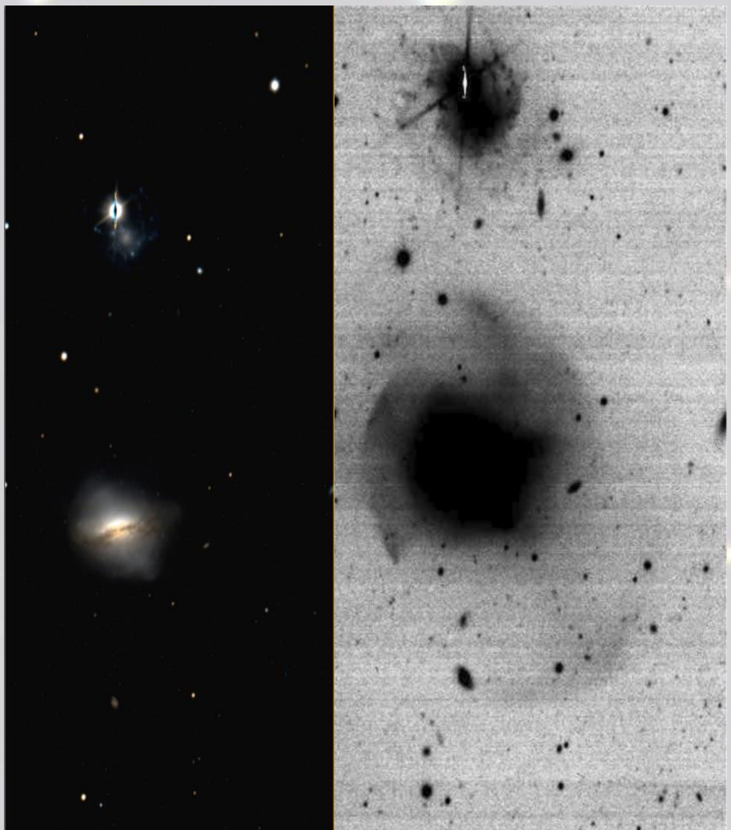
What we know: Polar Rings

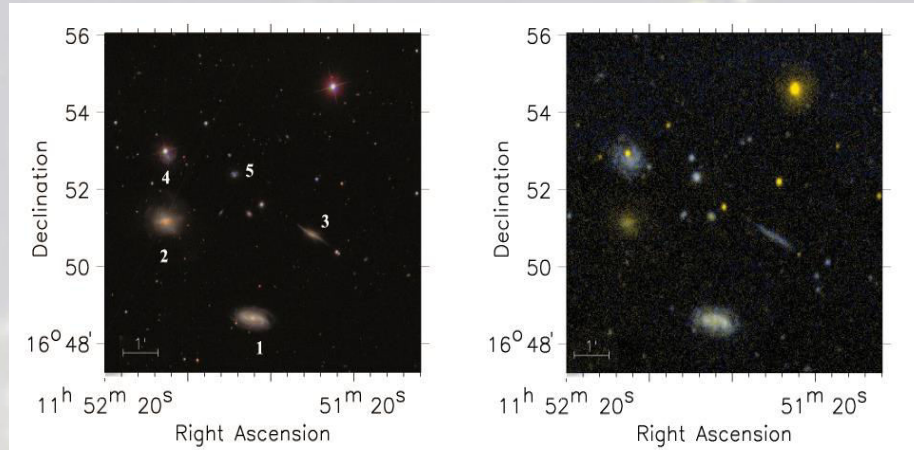


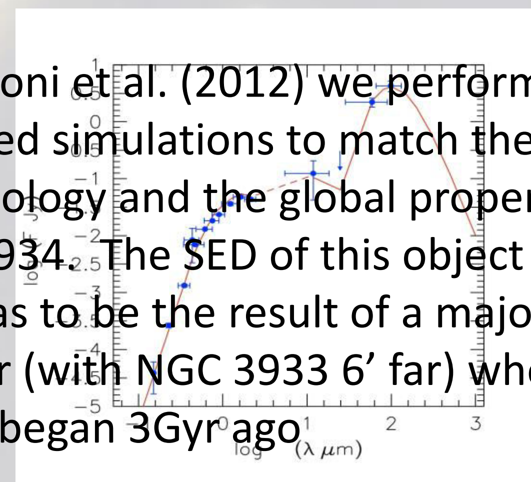


What we know: Polar Rings

NGC 3934







In Bettoni et al. (2012) we performed and analyzed simulations to match the morphology and the global properties of NGC 3934. The SED of this object is well fitted as to be the result of a major merger (with NGC 3933 6’ far) whose final phase began 3Gyr ago

What we know: Polar Rings

- Statistical studies indicate no differences with samples of normal galaxies
- However studies on smaller samples indicates preferences to low density environments
- SDSS data tend to favor the low density environment
- However rich environment are not fully excluded

What we know: Decoupled comp.

Searching the literature to collect all possible cases of Decoupled kinematics:

- Counter-rotation (Stars-Gas, Stars-Stars)
- Misaligned spin (Stars-Gas)
- Counter-rotating cores
- Decoupled nuclei

75 galaxies
In the very local volume

Galletta !1986;, Corsini & Bertola (1998); Sil'chenko et al. 2009; Katkov et al.2013a,b; Kannappan and Fabricant 2001; (SAURON) de Zeeuw et al. 2002; Emsellem et al. 2007; (ATLAS-3D)Cappellari et al. 2011; Krajnović et al. 2011

What we know: Decoupled comp.

This serendipity selected sample is composed by

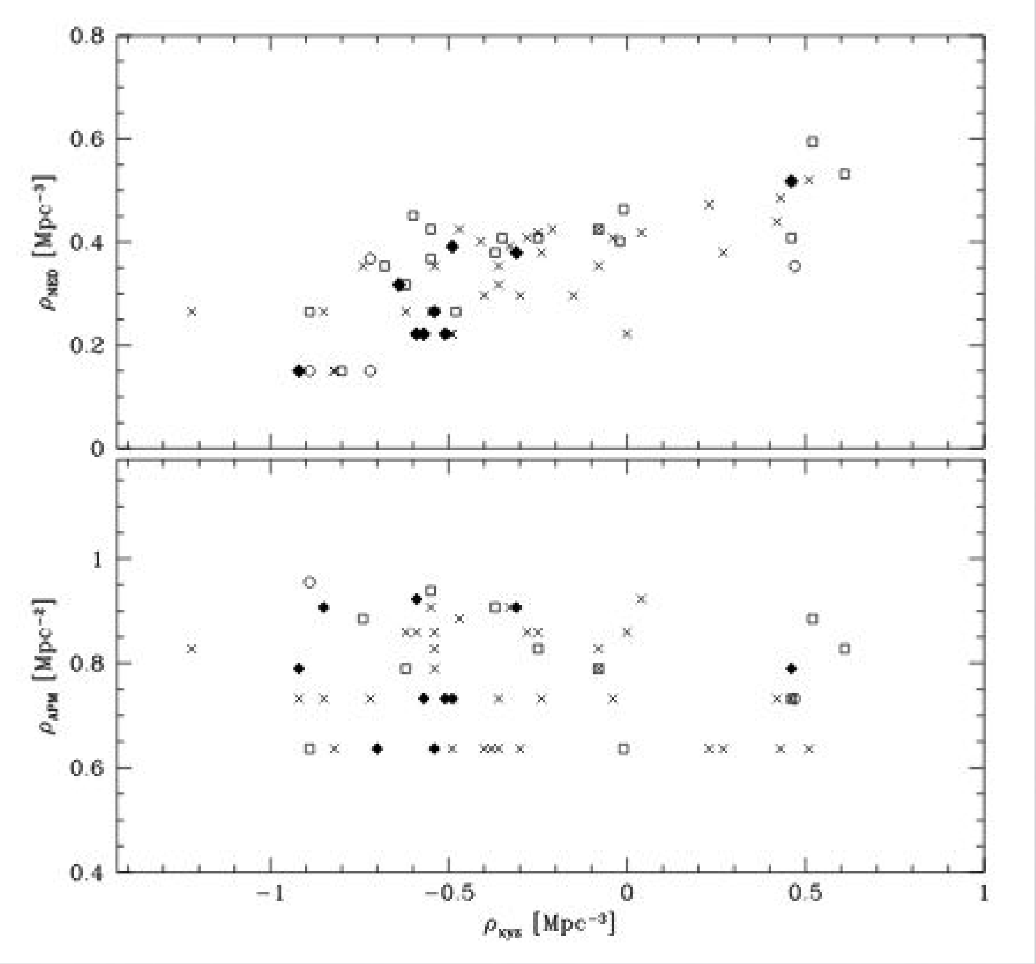
- 80 % of ETGs (morphological type T ≤0)
- 20 % of late type galaxies.

The sample spans a range of about five magnitudes in M_B , from −22.4 to −17.2 mag, with $<M_B>= -20.04 \pm 1.21$ mag

What we know: Decoupled comp.

Bettoni et al. (2001)

We deduce that in general the surrounding regions of galaxies with counterrotation do not appear statistically different from those of normal galaxies.



Plot of(ρ_{NED}) the density of galaxies/Mpc^3 present in NED database with a crossing time lower than 1 Gyr versus (ρ_{xyz}), the density of galaxies computed within 40 Mpc from Tully (1988). Bottom panel: plot of(ρ_{APM}), the density of galaxies extrapolated to a square of 1 Mpc side on the sky, versus (ρ_{xyz})

What we know: Decoupled comp.

SAMI survey

Fogarty et al. 2014
79 ETG in 3 Abell clusters (A85, A168, A2399) found some kinematics misalignment and one case of star-star counterotation

Oh et al. 2016: (arXiv:1609.03595)
investigate 63 bright ($M_r < -19.3$) spectroscopically-selected galaxies in Abell 119

suggest that galaxy interactions, including mergers and perhaps fly-bys, play an important role in determining the orientation and magnitude of galaxy's angular momentum.

What we know: Decoupled comp.

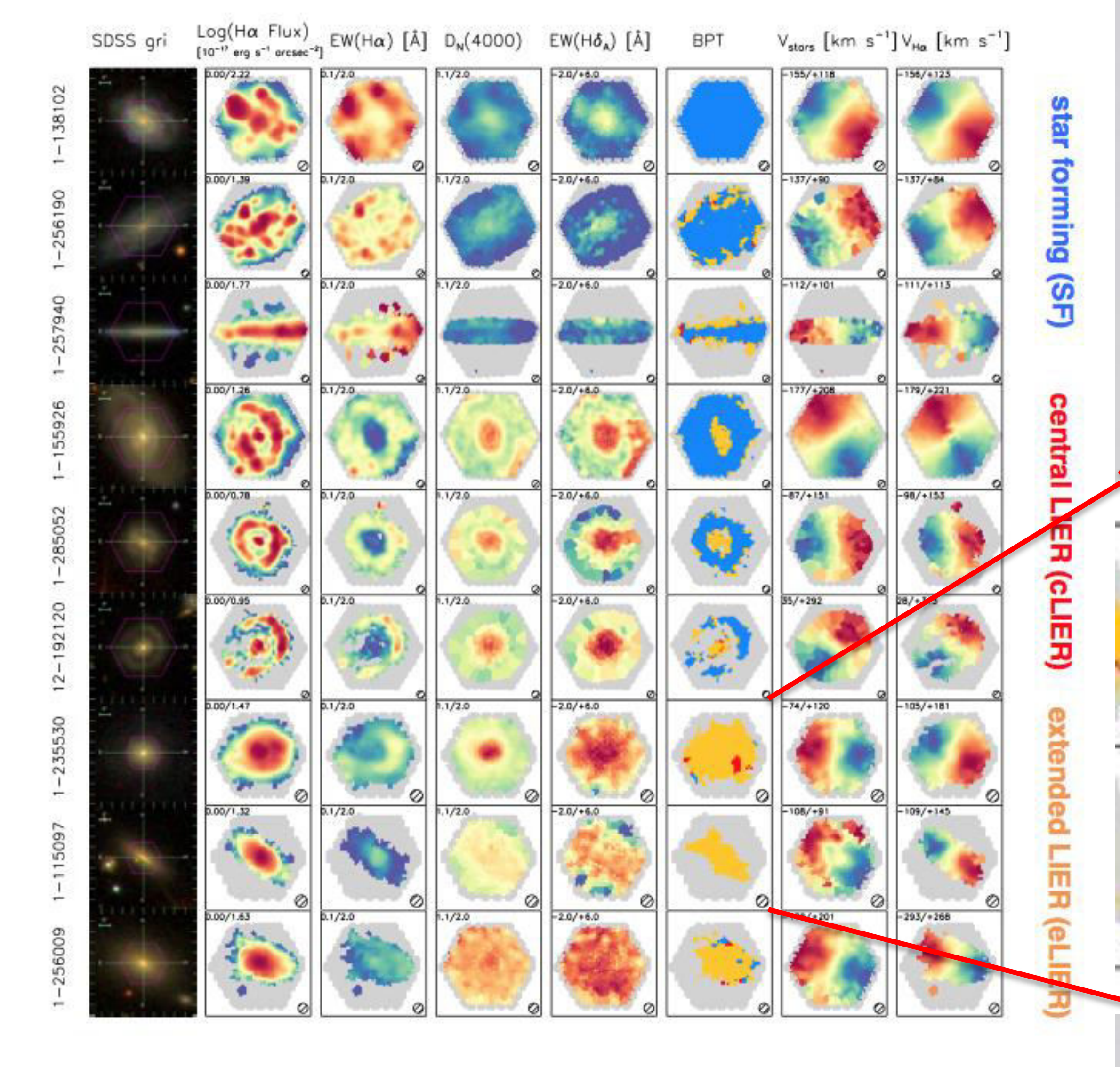
MANGA Survey

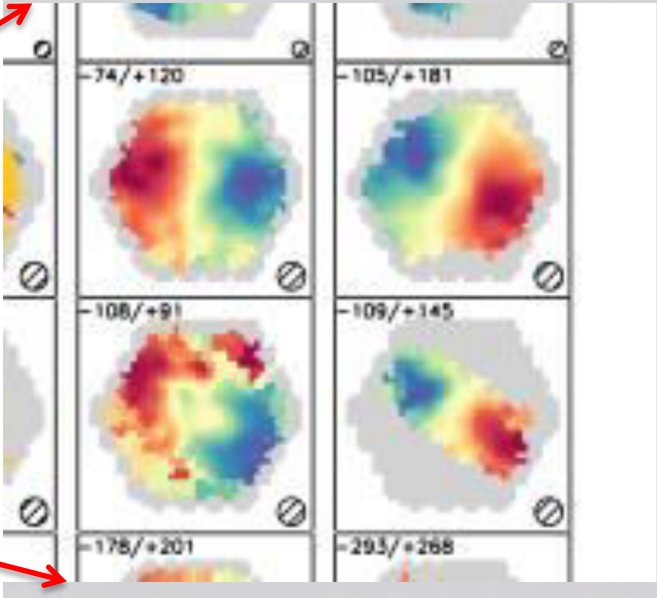
Penny et al. 2016 (arXiv:1609.01299)
This sample includes 39 quenched low-mass galaxies. $M_r > -19.1$, stellar masses 10^9 $M_\odot < M_\star < 5 \times 10^9$ $M_\odot$, $EWH_\alpha < 2$ Å, and all have red colours $(u - r) > 1.9$.
Two galaxies with Counter-rotating cores

Belfiore et al 2016 (arXiv1609.01737)
~600 galaxies from the whole SDSSIV MANGA sample.

30 out of 49 galaxies with extended (eLIER) emission have misalignments larger than 30°
This ->> 65 ± 7% of eLIERs are misaligned with $|\phi_{stars} - \phi_{gas}| > 30^\circ$.

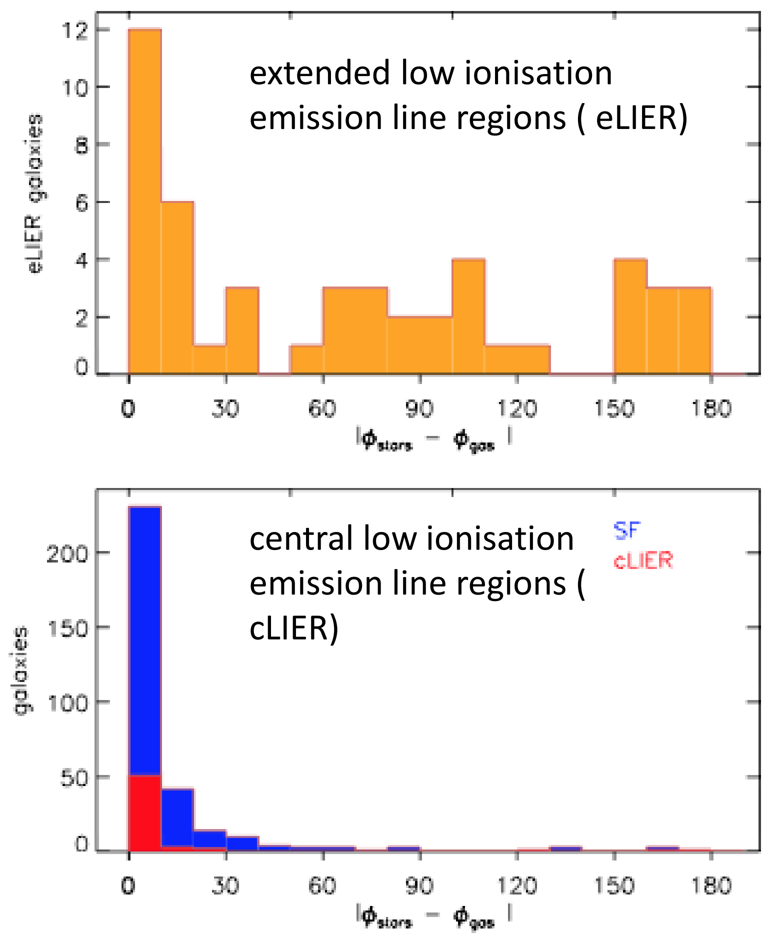
What we know: Decoupled comp.





Belfiore et al. 2016 arXix1609.01737

What we know: Decoupled comp.



Belfiore et al. 2016

The misalignments for eLIERs peaked at 0,90 and 180° confirm the theoretical prediction for the case of external accretion (Davis & Bureau 2016, MNRAS, 457, 272).

The peak at zero implies that internal processes play a minor role in shaping the observed misalignment distribution.

What we know: Decoupled comp.

- Decoupled kinematical components are visible in all environments but the small numbers of objects prevented a clear statistical study
- SAMI survey indicate that also rich environments can host galaxies with disturbed kinematics
- SDSS-IV MANGA indicate that galaxies with extended emission line regions have an high probability to present decoupled gas/stars components.
- In this case these galaxies have the tendency to live in less dense environments.

PR and CR in dense environments
a personal view

- 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)

GASP Stratey

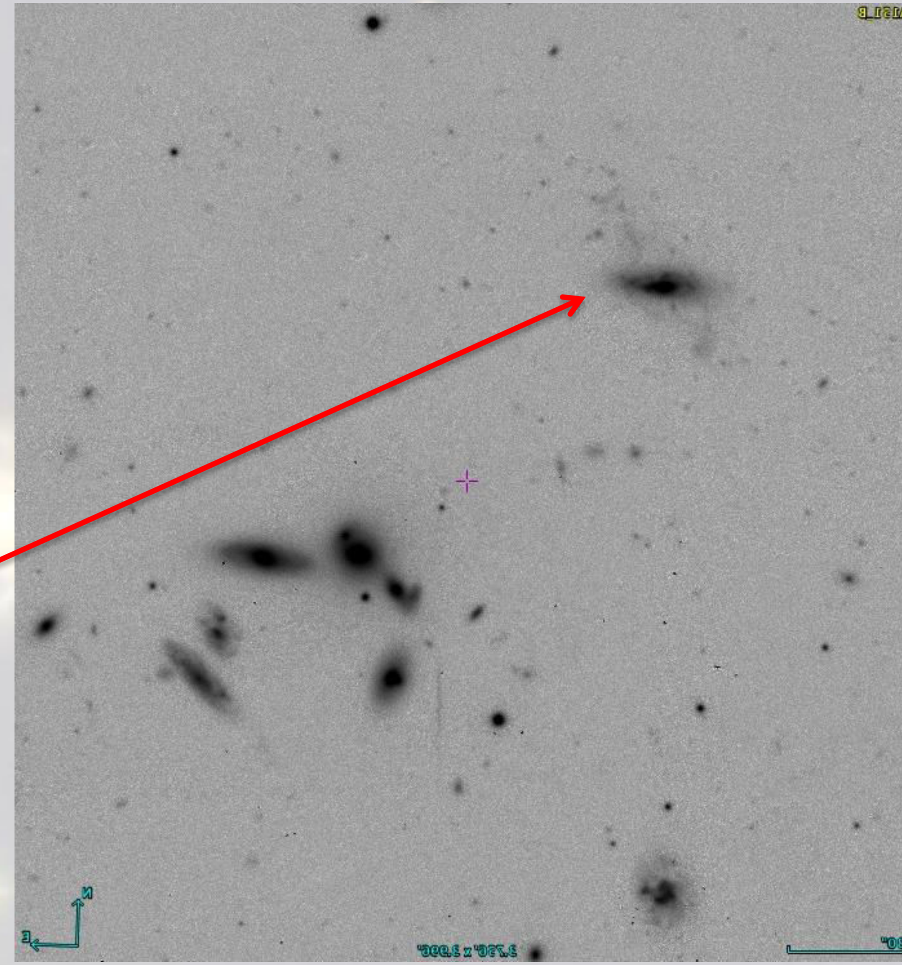
- First systematic search yielded an atlas of 400+ “stripping candidates” in low-z clusters, groups and field (Poggianti et al. 2016)

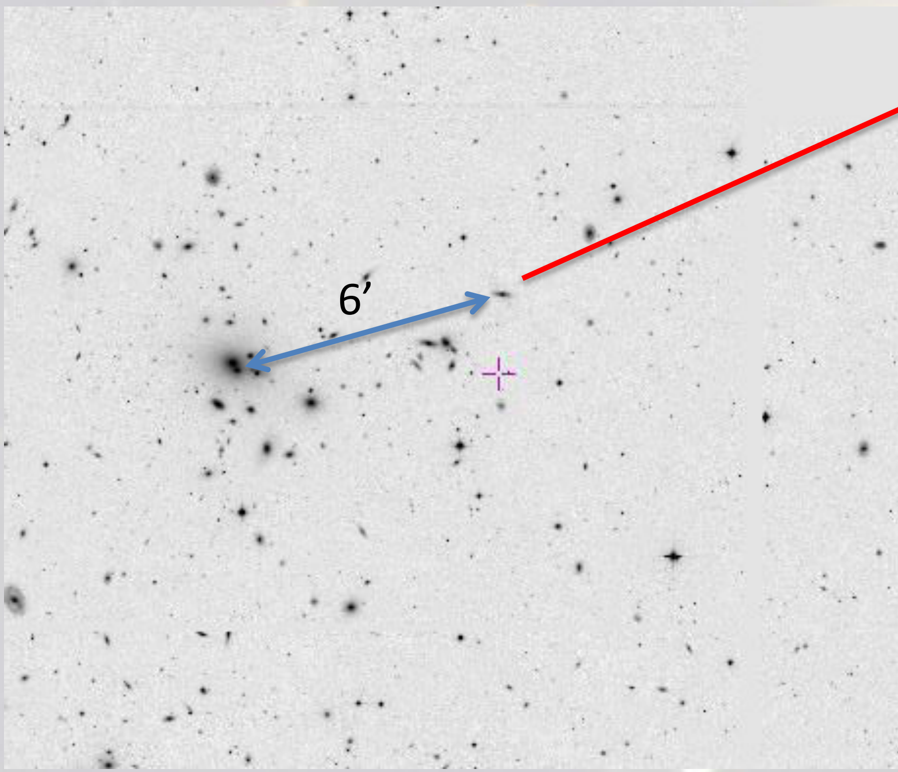
- GASP is an ongoing MUSE Large Program to study in great detail ionized gas and stars, in and out of 100 galaxies (stripping candidates + control sample)

- It is revealing:
  - the physical process responsible for the observed morphologies
  - the physics of that process
  - where and on what galaxies it happens

A151
z=0.0536
σ= 762 km/sec
Custer with 4 substructures
(Ramella et al. 2007)

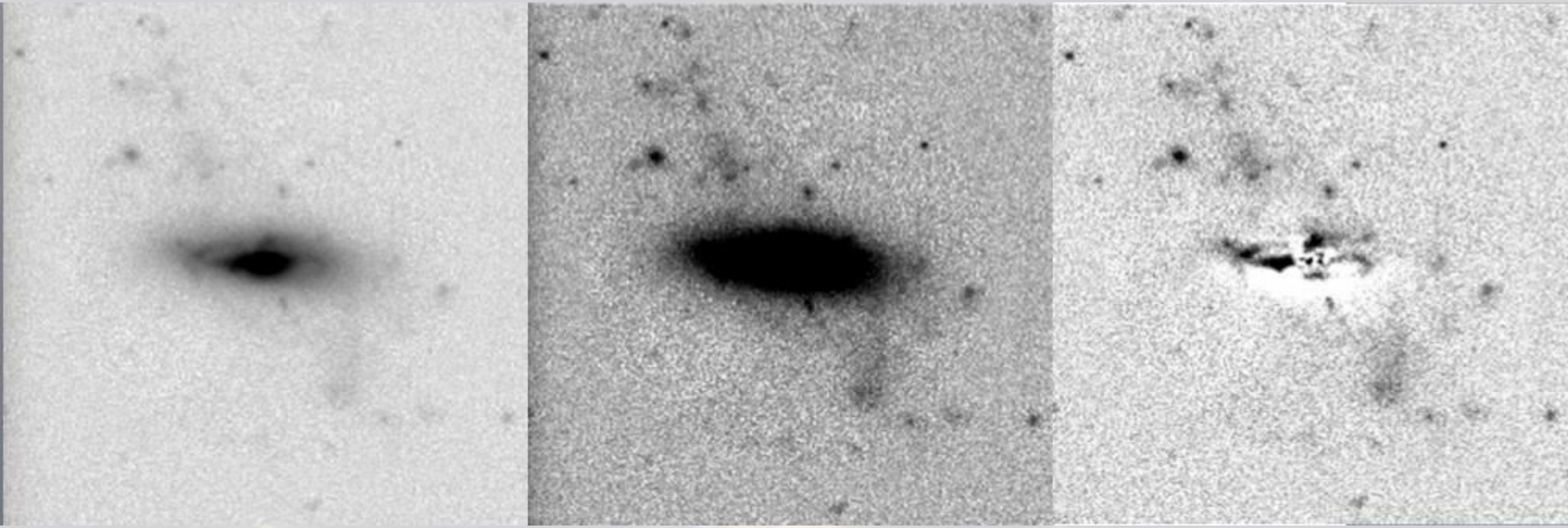
WINGSJ10825.94-152245.7





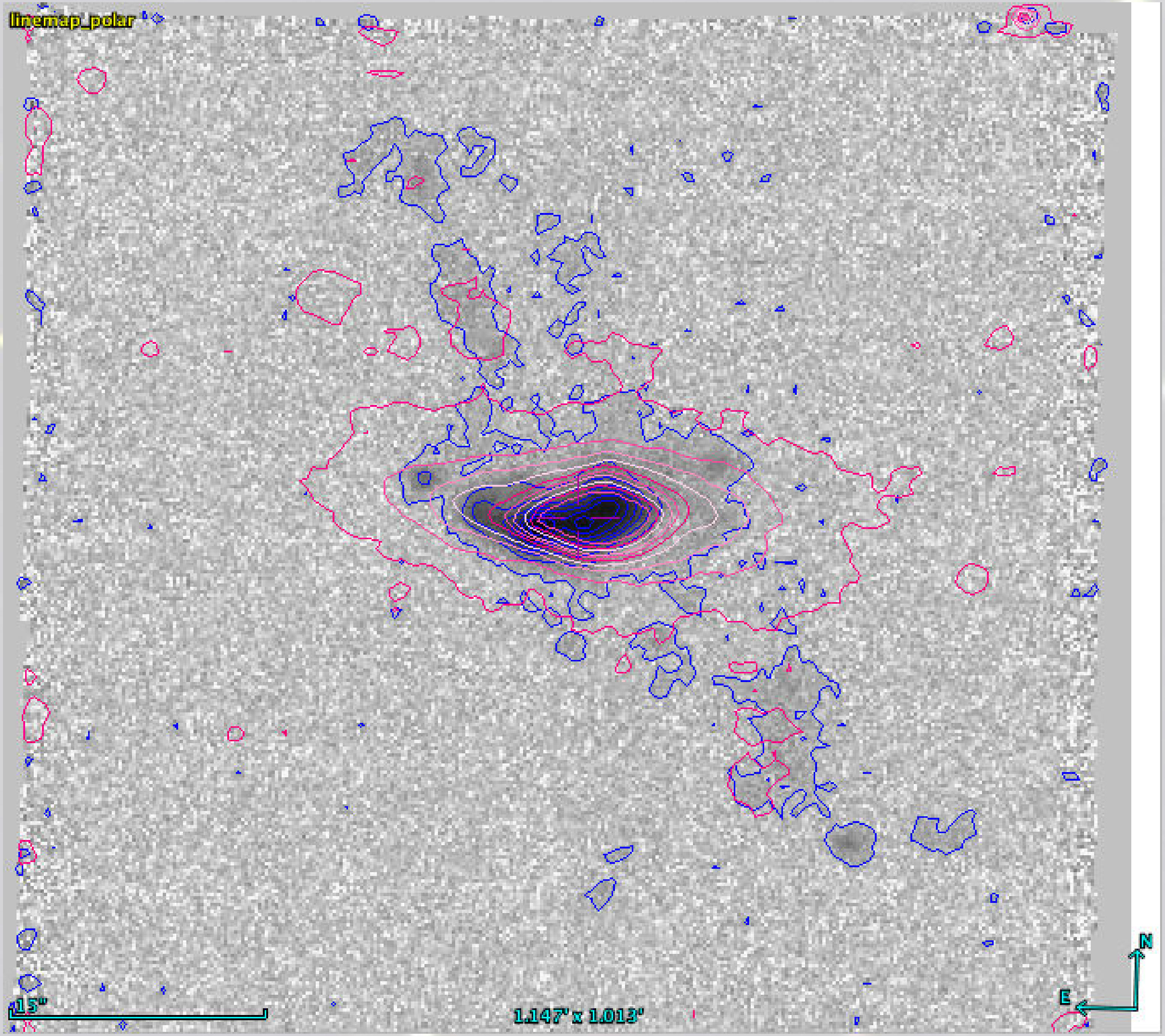
VST+OMEGACAM V-band image, from
OMEGAWINGS Survey (Gullieuszik et al. 2015)

WINGSJ10825.94-152245.7

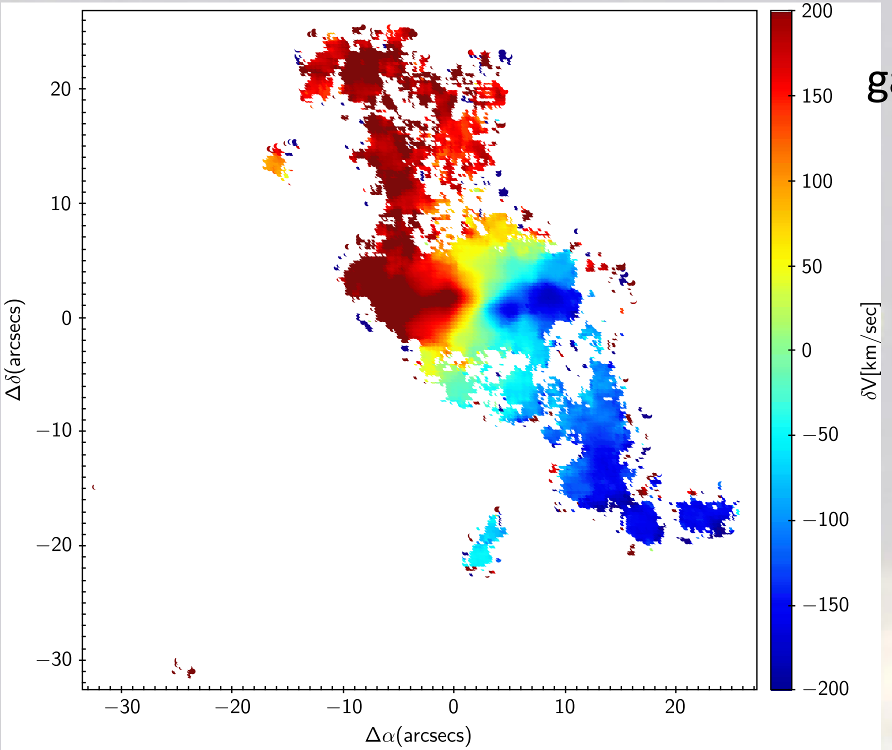


Comp	V(mag)	R_e(arcsecs)	n	b/a	PA (deg)
Sersic	16.87	4.92	3.01	0.35	-87.53
Disc	19.35	4.57	1.00	0.27	-89.-7

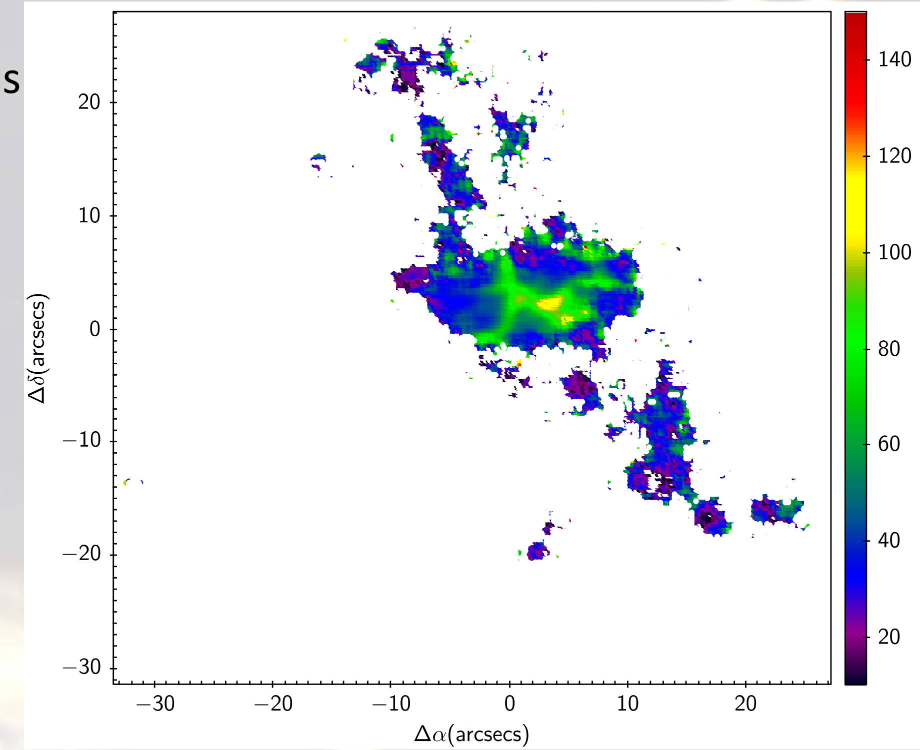
VST+OMEGACAM V-band image, from OMEGAWINGS Survey (seeing 0.8”)

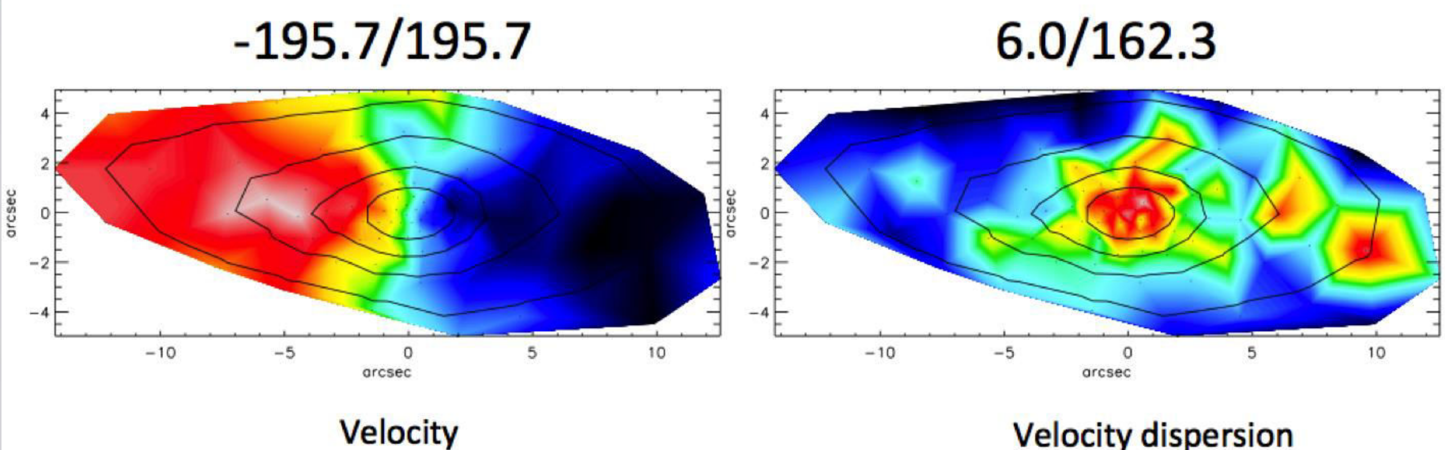


linemap_polar
15"
1.147' x 1.013'
N
E

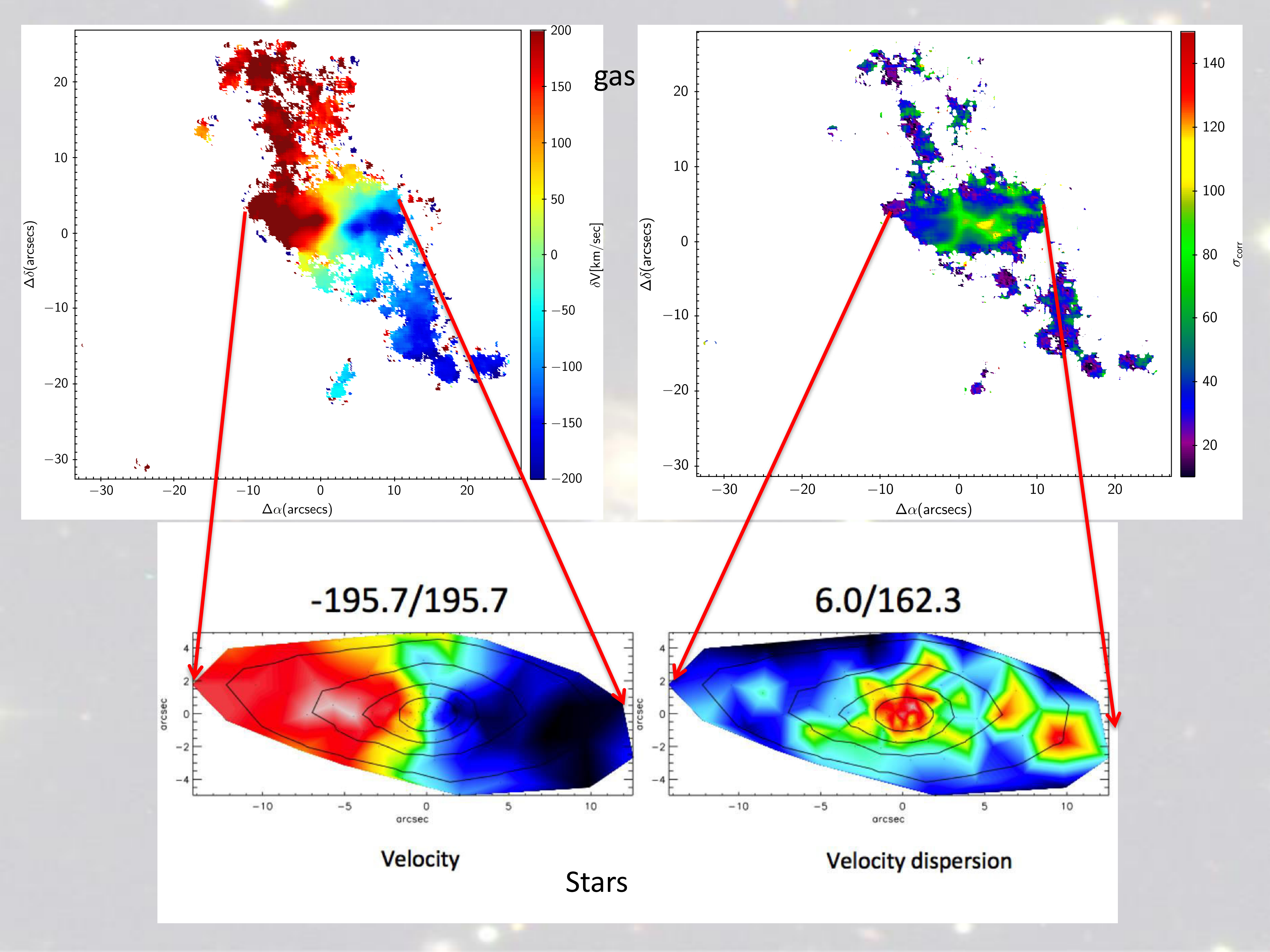

Δδ(arcsecs)
Δα(arcsecs)
δV[km/sec]

gas

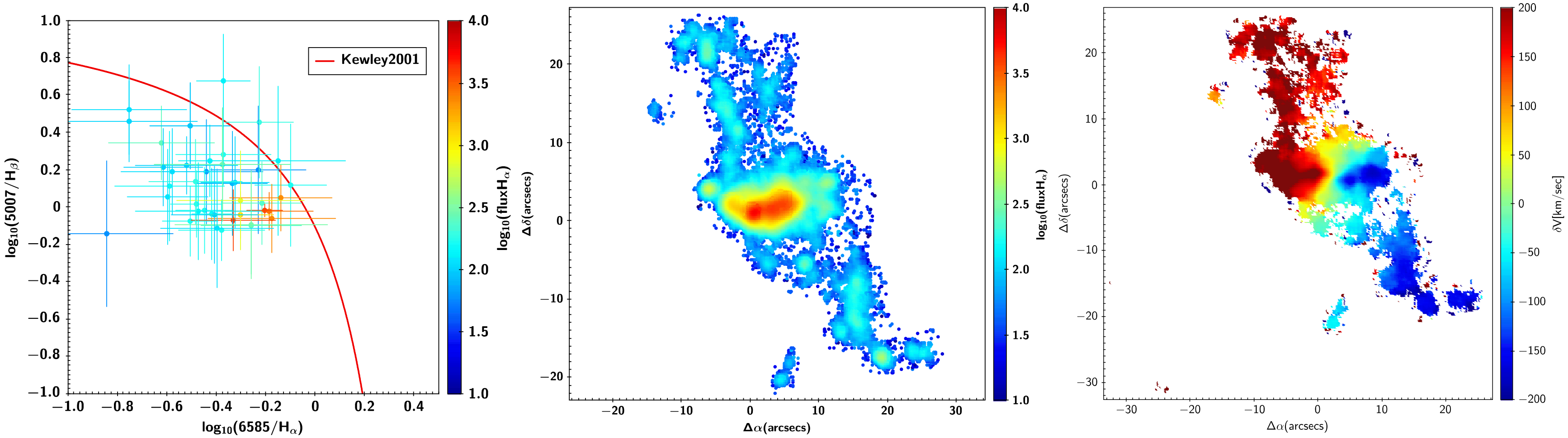

Δδ(arcsecs)
Δα(arcsecs)
σcorr


-195.7/195.7
6.0/162.3
arcsec
arcsec
arcsec
arcsec
Velocity
Velocity dispersion

Stars


gas
Δδ(arcsecs)
Δα(arcsecs)
δV[km/sec]
σ_{corr}
-195.7/195.7
6.0/162.3
arcsec
Velocity
Velocity dispersion
Stars

WINGSJ10825.94-152245.7

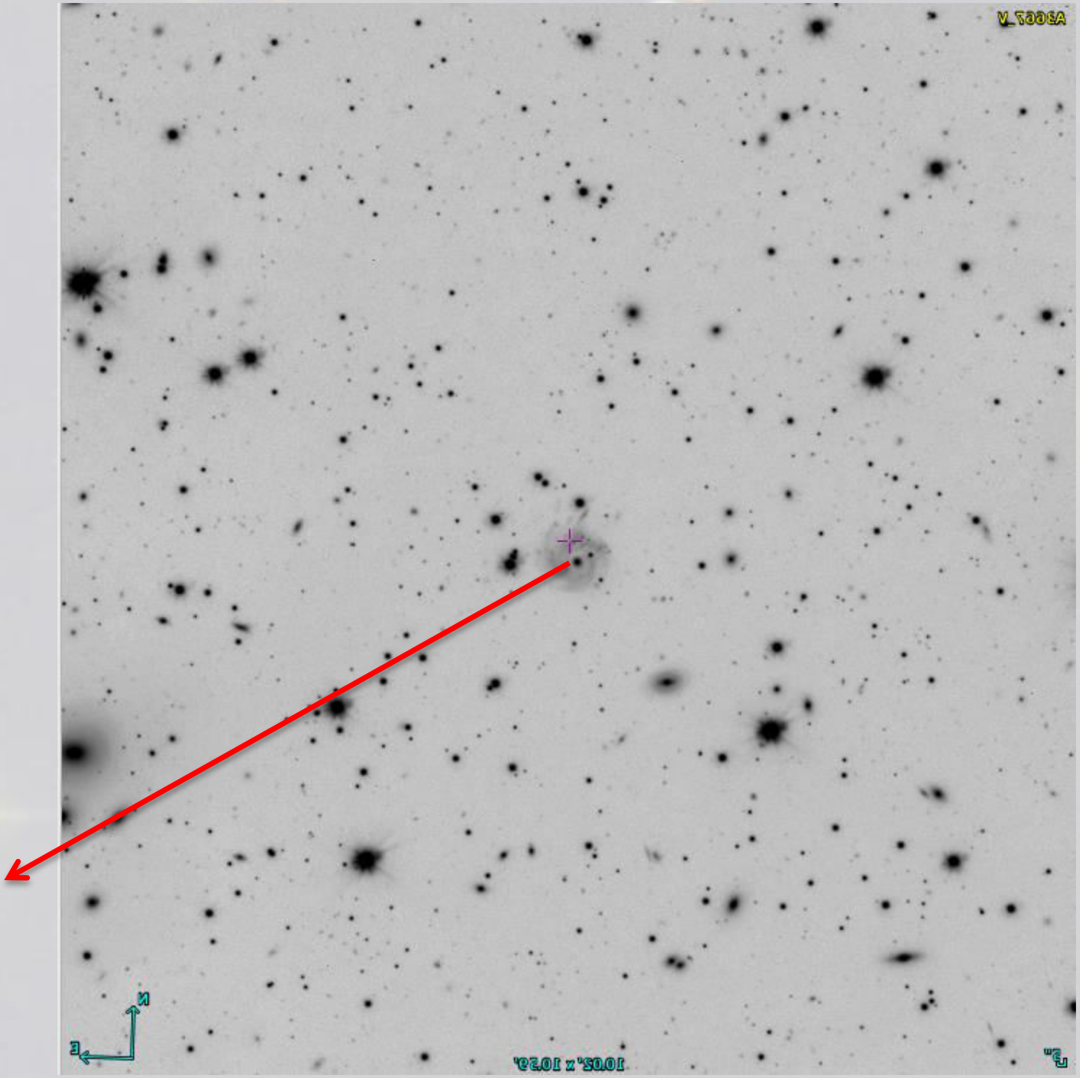


BPT plot typical of HII regions, no AGN

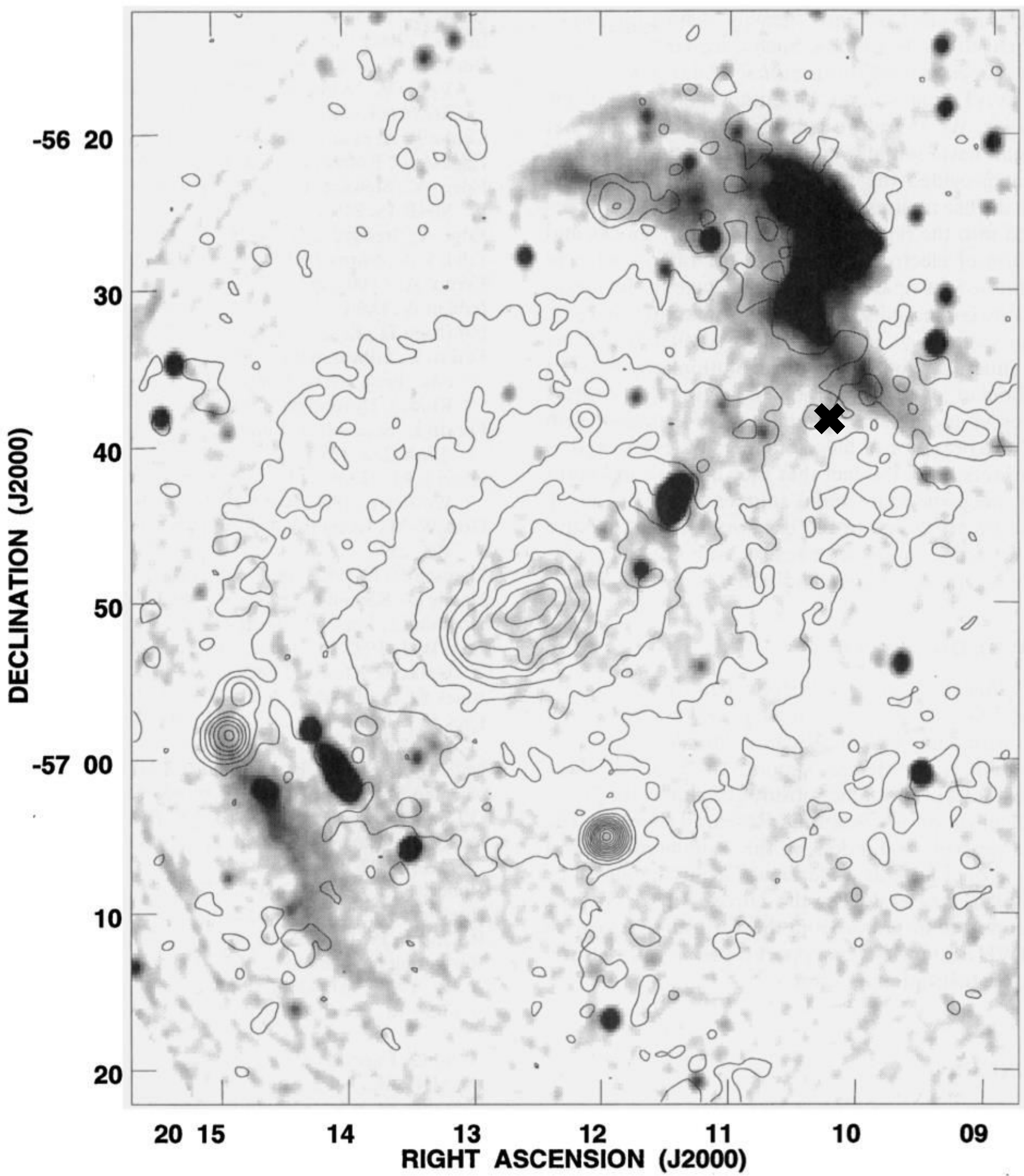
PR in Abell 151

- The galaxy is a member of the cluster: z=0.0548
- In projection is very close to the central CD galaxy: 6’
- Gas and stars in the central stellar body are corotating with V_{max}~ 200 km/sec
- The gas velocity dispersion show a very filamentary structure that is visible also in the stellar velocity dispersion map
- The BPT plot indicate that the gas properties are typical of a star-forming galaxy

JO171 Counter rotating Galaxy in A3667

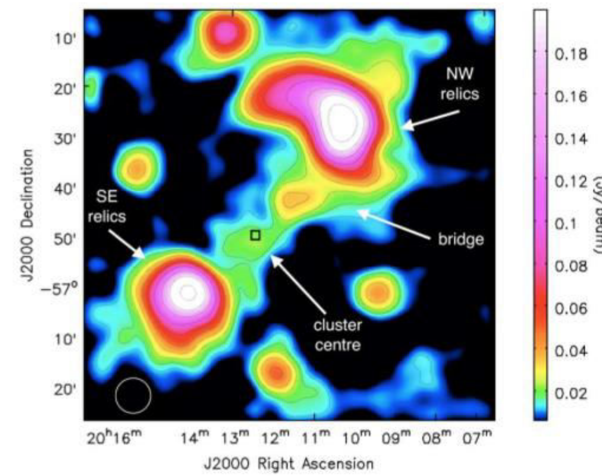


A3667
z=0.053
σ=1059 km/sec
4 substructures



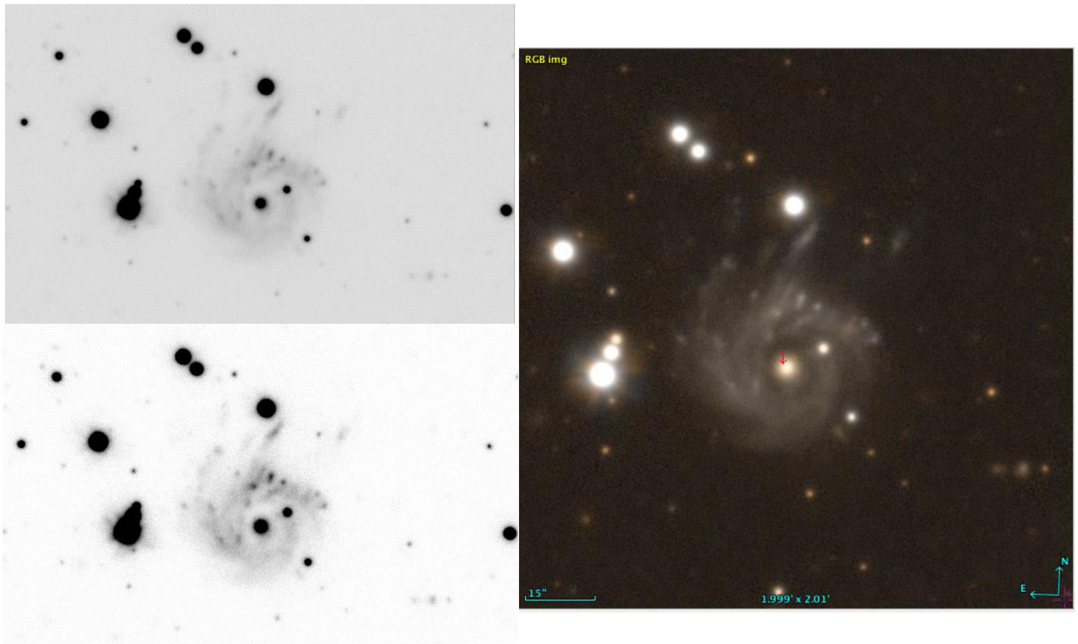
Contours: ROSAT
Grey-scale image:
radio relic

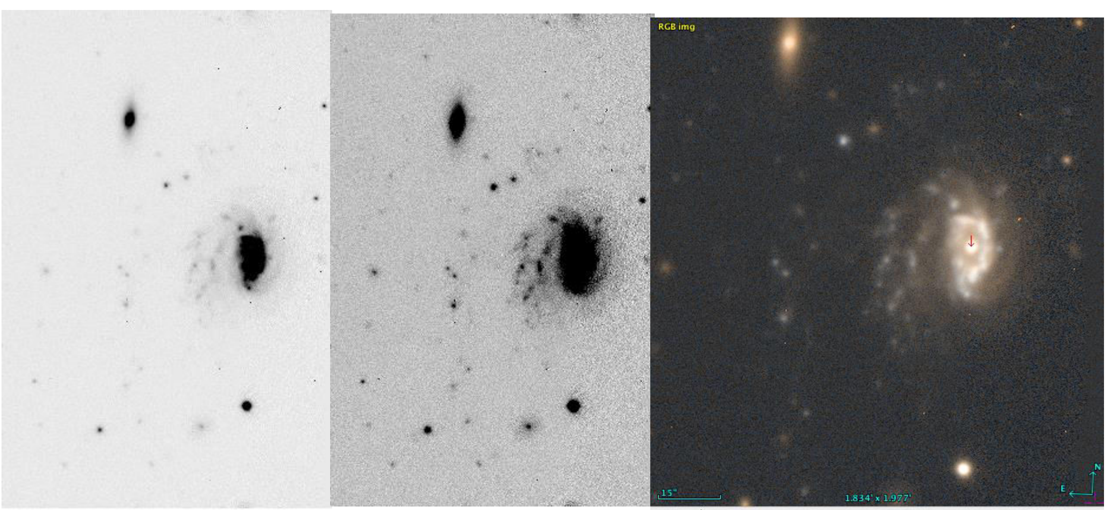
Rottgering et al.
1997



Radio bridge
Carretti et al.2013

CATALOGUE OF JELLYFISH CANDIDATES





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

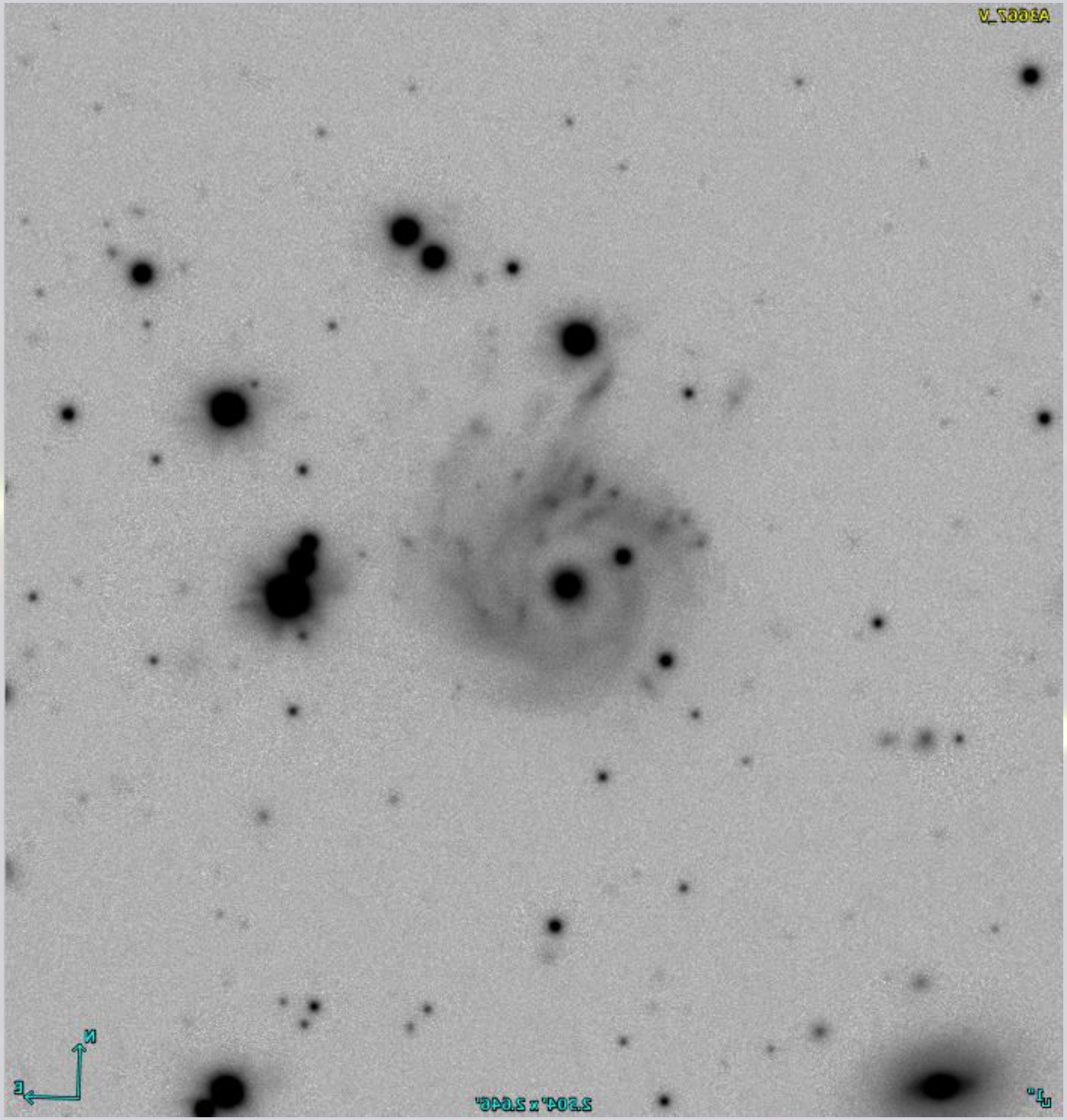
Broad range of galaxy stellar masses (logM=9-12)

SFR enhanced by a factor of ~2

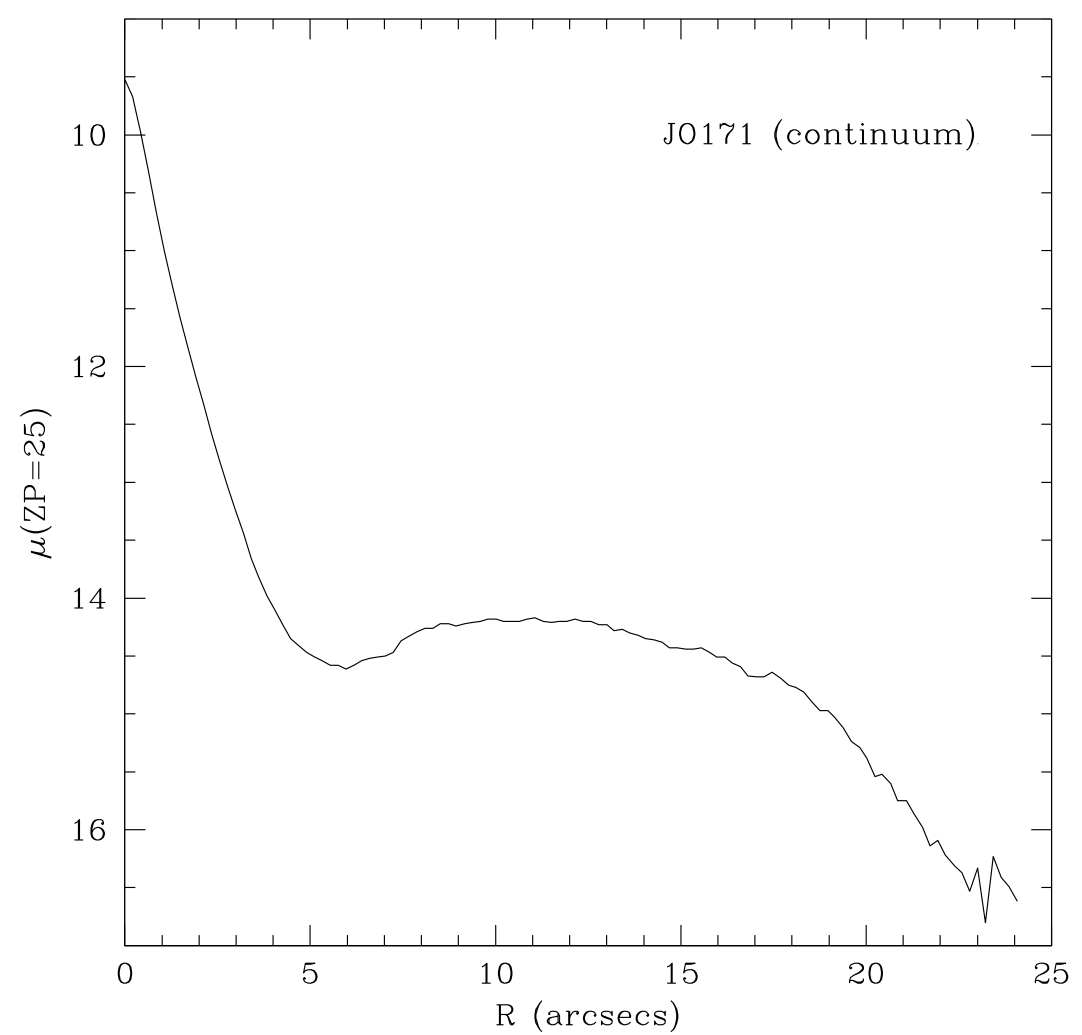
Poggianti et al. 2016

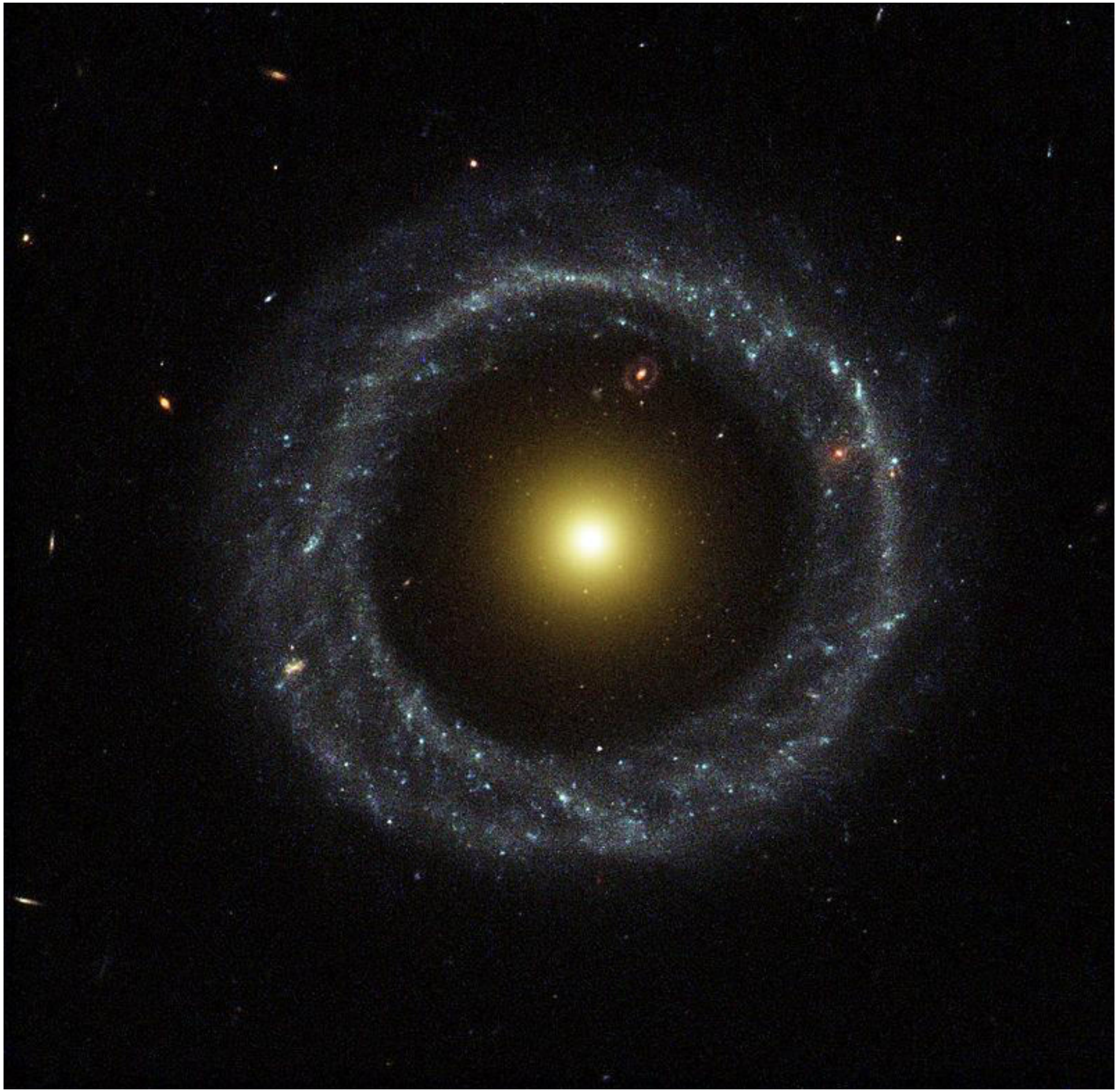
JO171 Counter rotating Galaxy in A3667

35’ from center of A3667



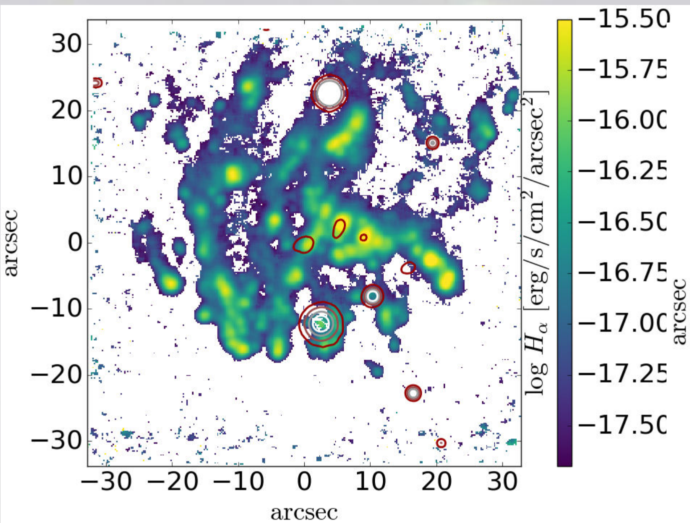
JO171 Counter rotating Galaxy in A3667



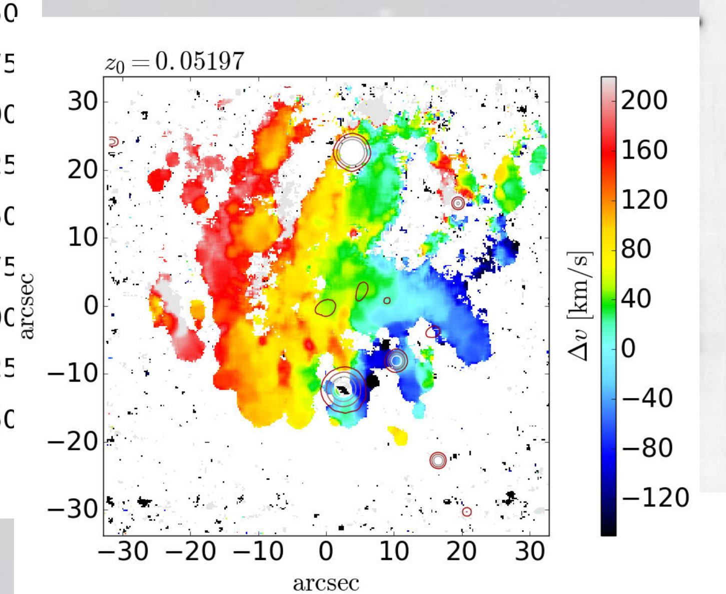


Hoag object (PRC D-51)

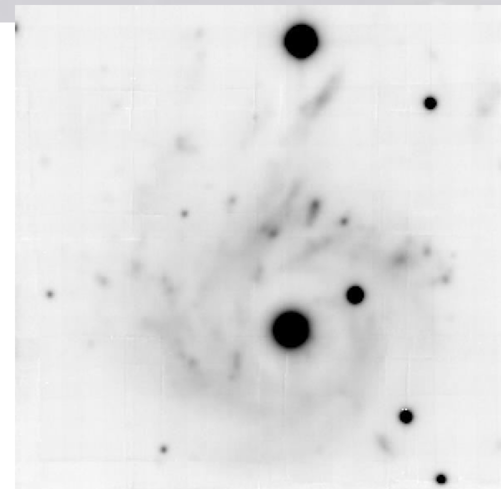
JO171: a stripped Hoag's object?



Hα map (SN>5)



Hα velocity map

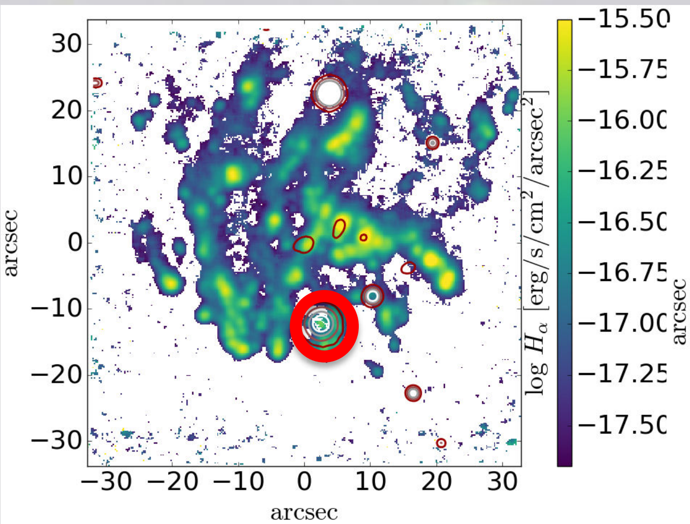


MUSE white image (RGB image)

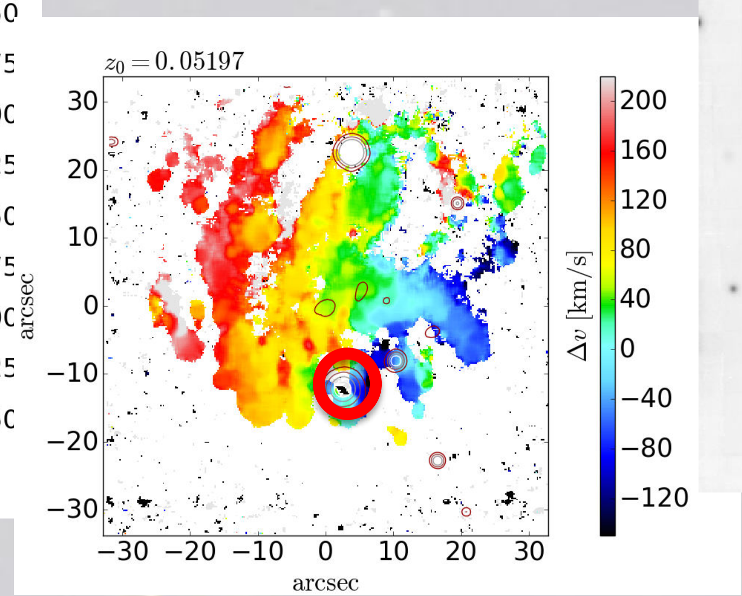
3 X 10^{11} $M_\odot$, in 1000 km/s cluster undergoing a massive merger, at a radius ~0.5 R200

Moretti et al. in prep.

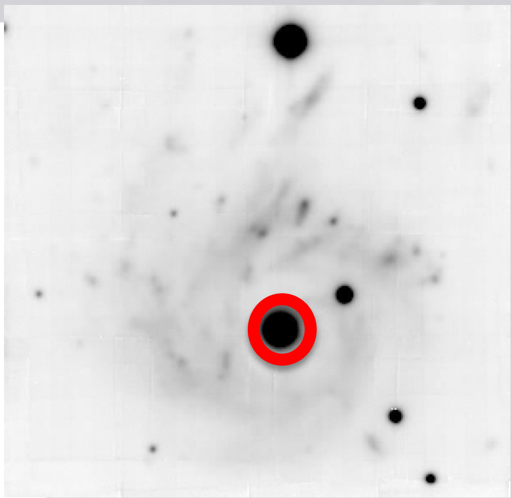
JO171: a stripped Hoag's object?



Hα map (SN>5)



Hα velocity map



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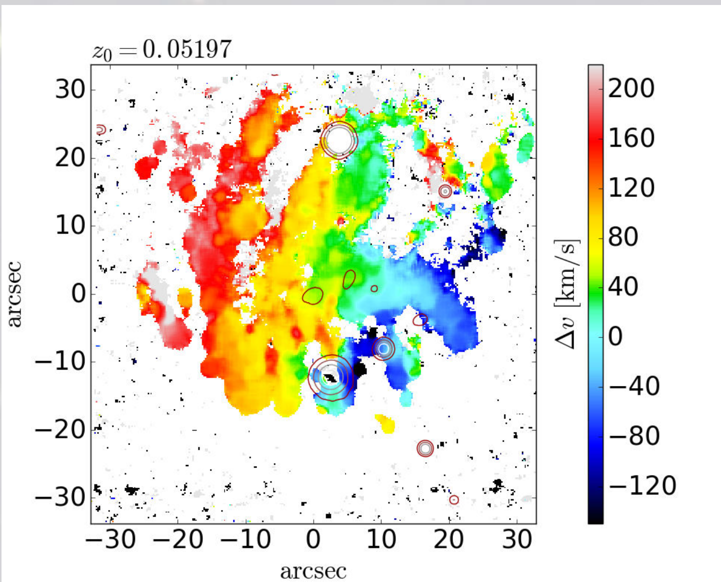
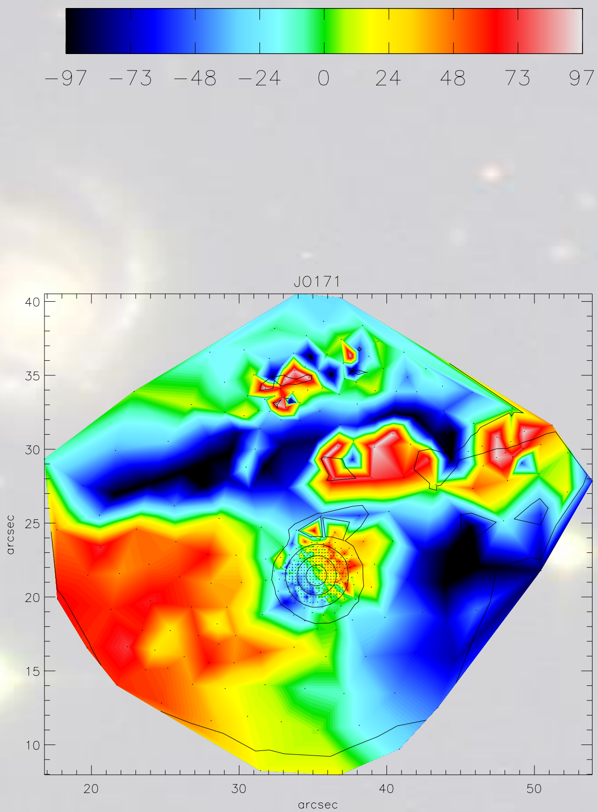
JO171: counter-rotation



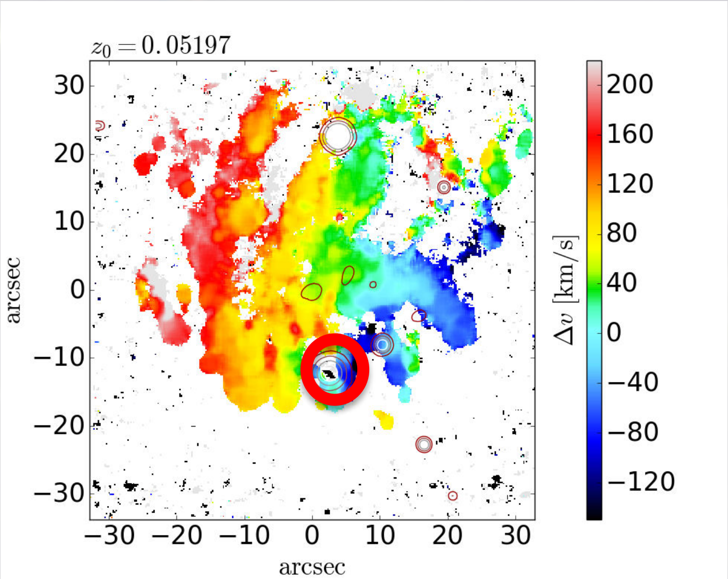
Hα velocity map



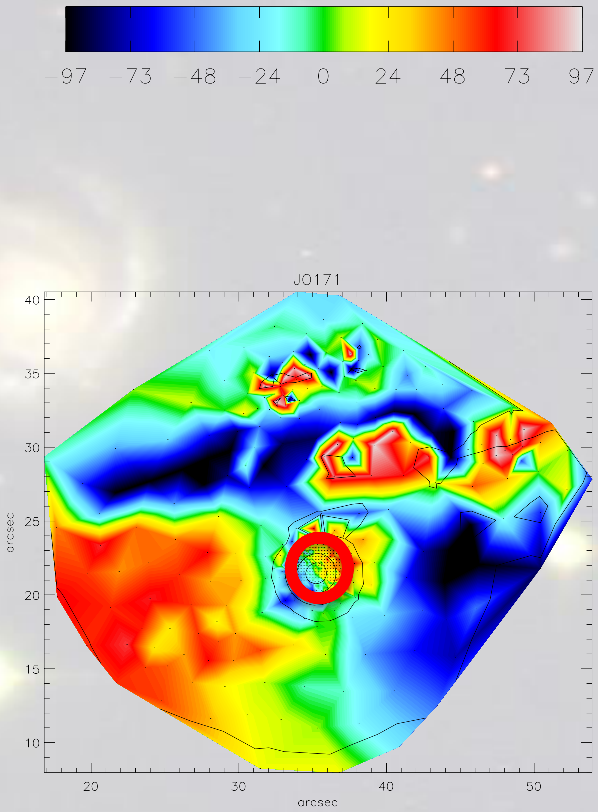
Stellar velocity map

Moretti et al. in prep.

JO171: counter-rotation



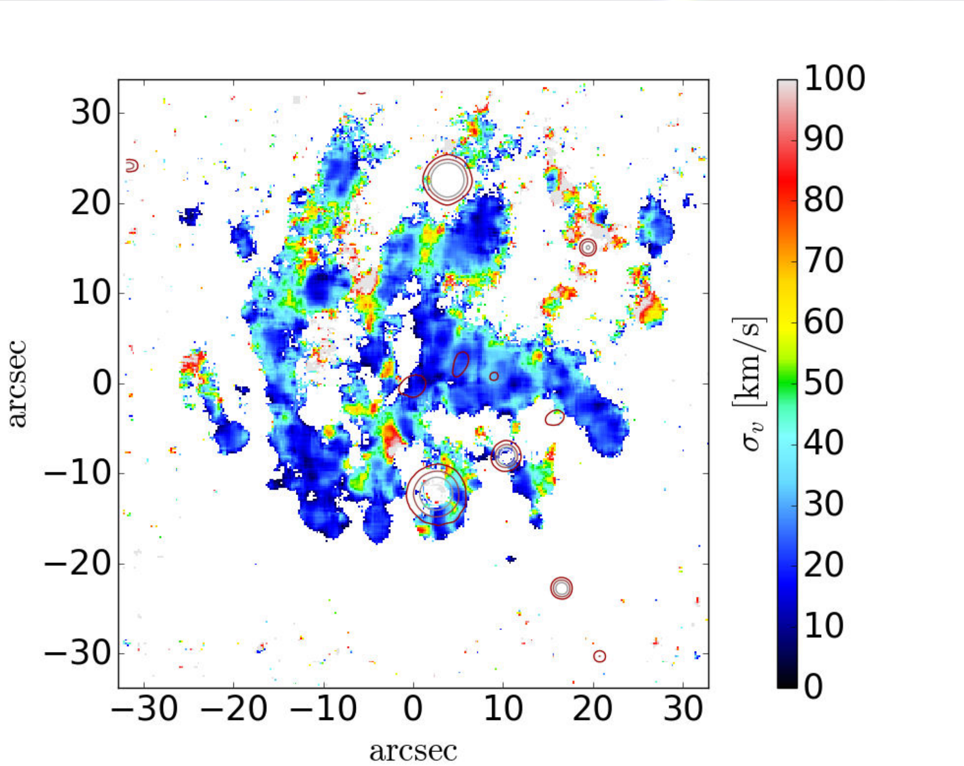
Hα velocity map



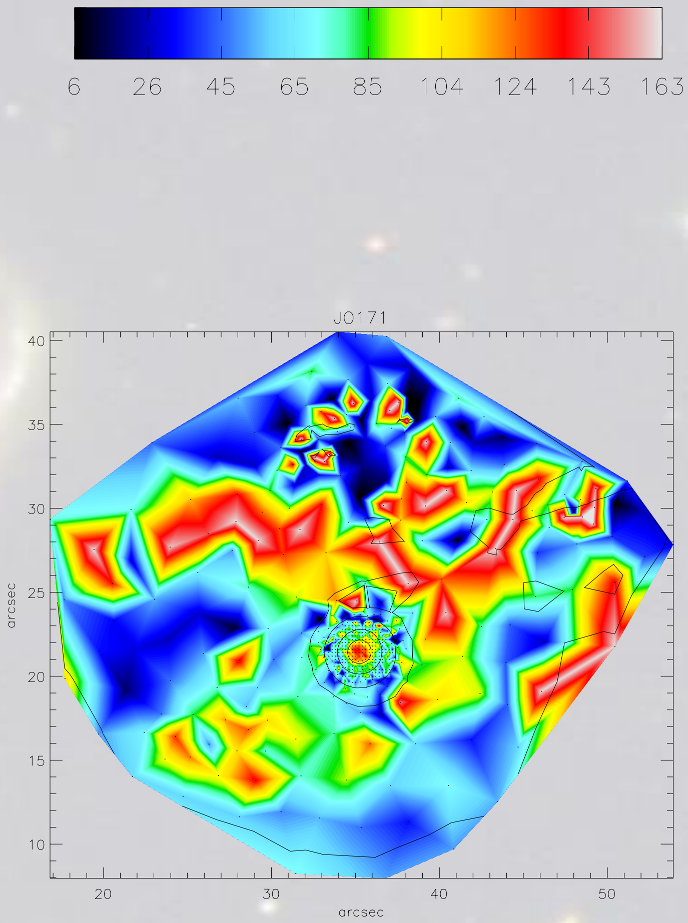
Stellar velocity map

Moretti et al. in prep.

JO171: counter-rotation



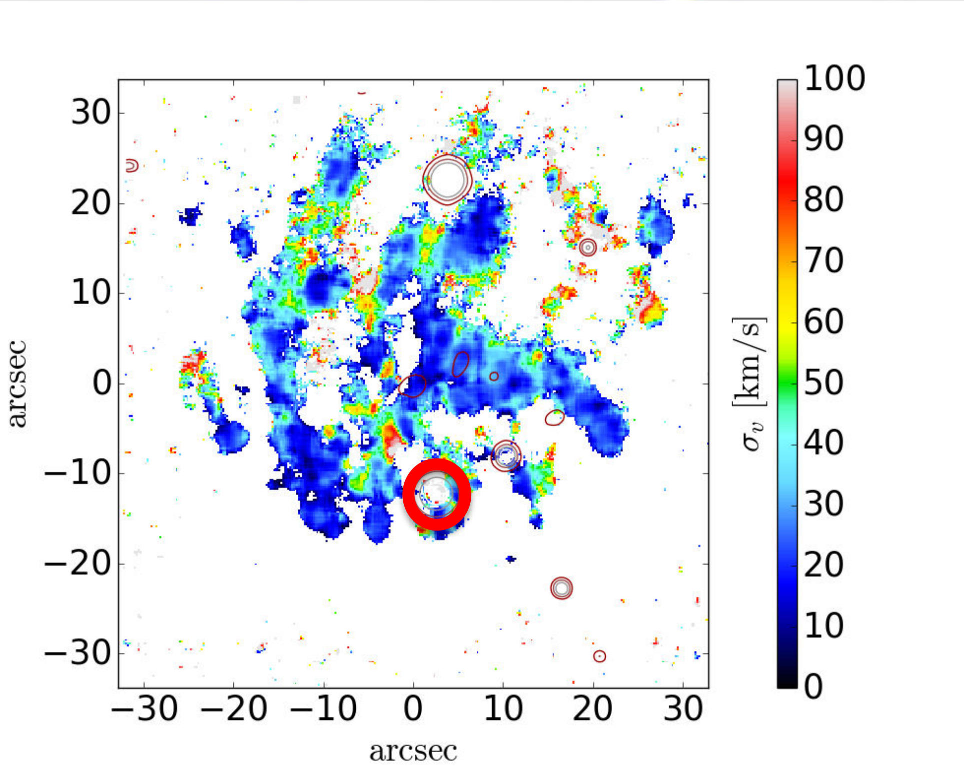
Hα velocity dispersion map



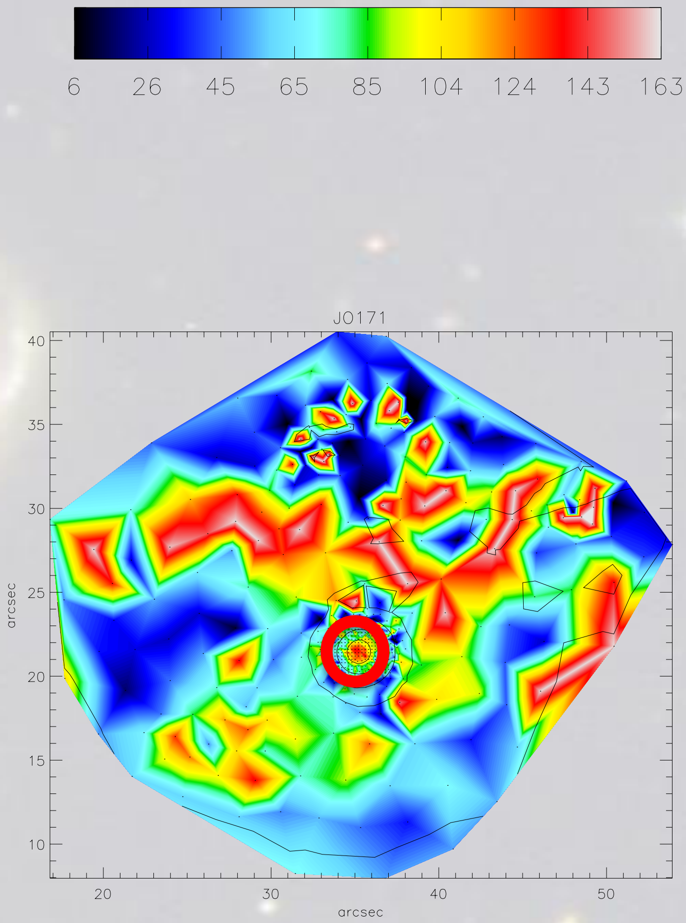
Stellar velocity dispersion map

Moretti et al. in prep.

JO171: counter-rotation



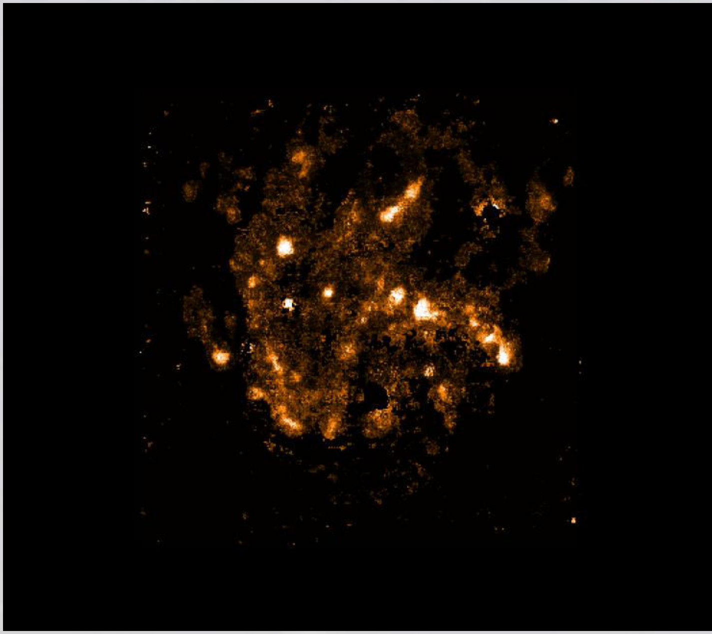
Hα velocity dispersion map

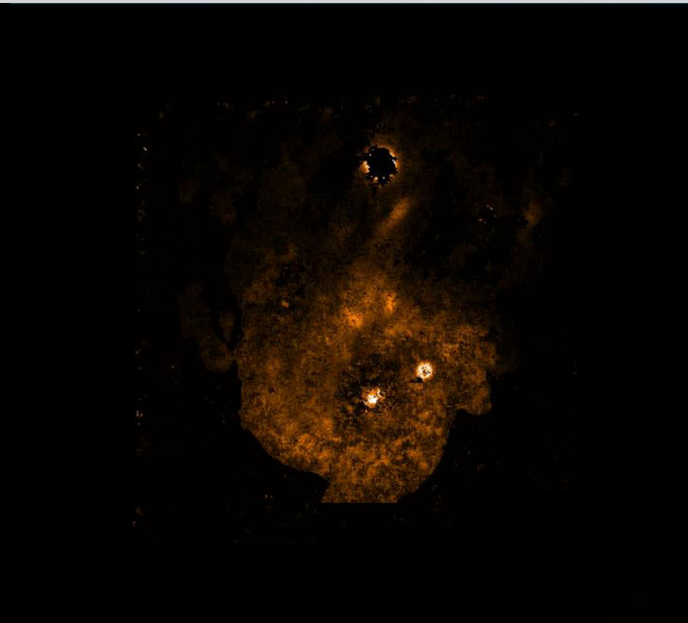


Stellar velocity dispersion map

Moretti et al. in prep.

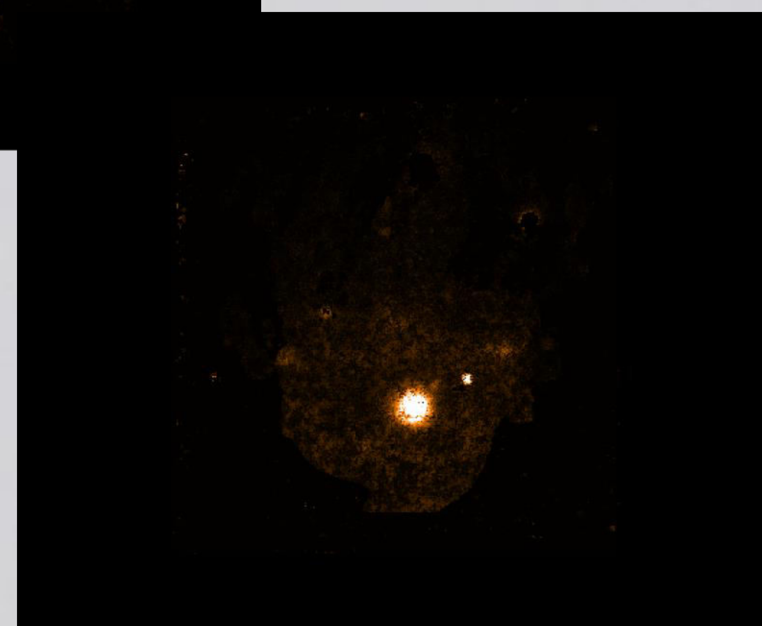
JO171: stellar ages





2 X 10^7 - 6 X 10-^8 yr

< 2 X 10^7 yr



SINOPSIS (Fritz et al. 2007, 2011)

> 6 X 10-^9 yr

JO171 Counter rotating Galaxy in A3667

- The galaxy is a member of the cluster: z=0.0525
- In projection is in the outer regions of the cluster: ~35’ from the center
- The galaxy is in projection at the edge of a radio bridge
- Gas and stars in the central stellar body are counterrotating with V_{max}(stars)~ 50 km/sec
- The gas velocity dispersion show a peak in the central stellar body with a maximum σ~150 km/sec
- The stellar ages indicate that the nuclear body is dominated by an old stellar population with age >$2x10^9$yr
- The H_α outer regions are dominated by very a population of young stars with age <$2x10^7$yr

Are GASP stripping-candidates in transition?

They are caught during initial stages of gas stripping, still star-forming when observed, in a "pre-transition" phase (SFR excess X2)

The most extreme cases (e.g. jellyfishes) will be soon fully stripped and passive – for weaker cases, harder to say, but we observe "local transitions" whenever gas is being stripped

More questions to finish

Do galaxies with PR prefer a particular environment? *Yes (may be) – but not always easy to discriminate them from normal galaxies*

Are all PR related (cause-effect) to external factors? *For the known cases, yes, but might be a bias*

Is my case-list of CR exhaustive? *Certanly not. As far as observables are concerned, pretty much. New survey are posing new questions*

What fraction of all passive galaxies today have experienced a "transition"? *How relevant is the transition phenomenon for galaxy evolution in general? Clusters-groups-loose environments how to link all these?*