Galaxies populate different environments with a large range of densities

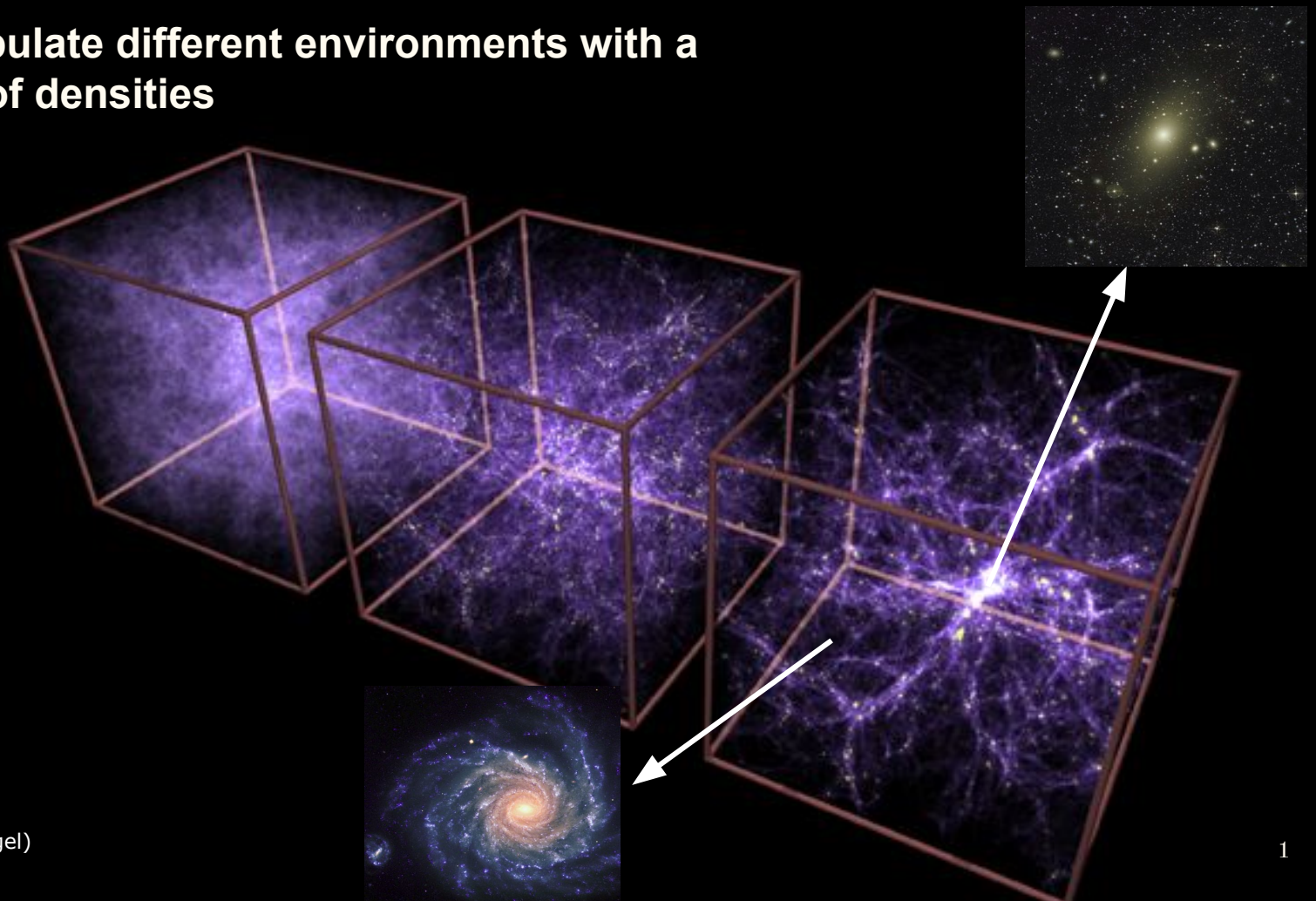
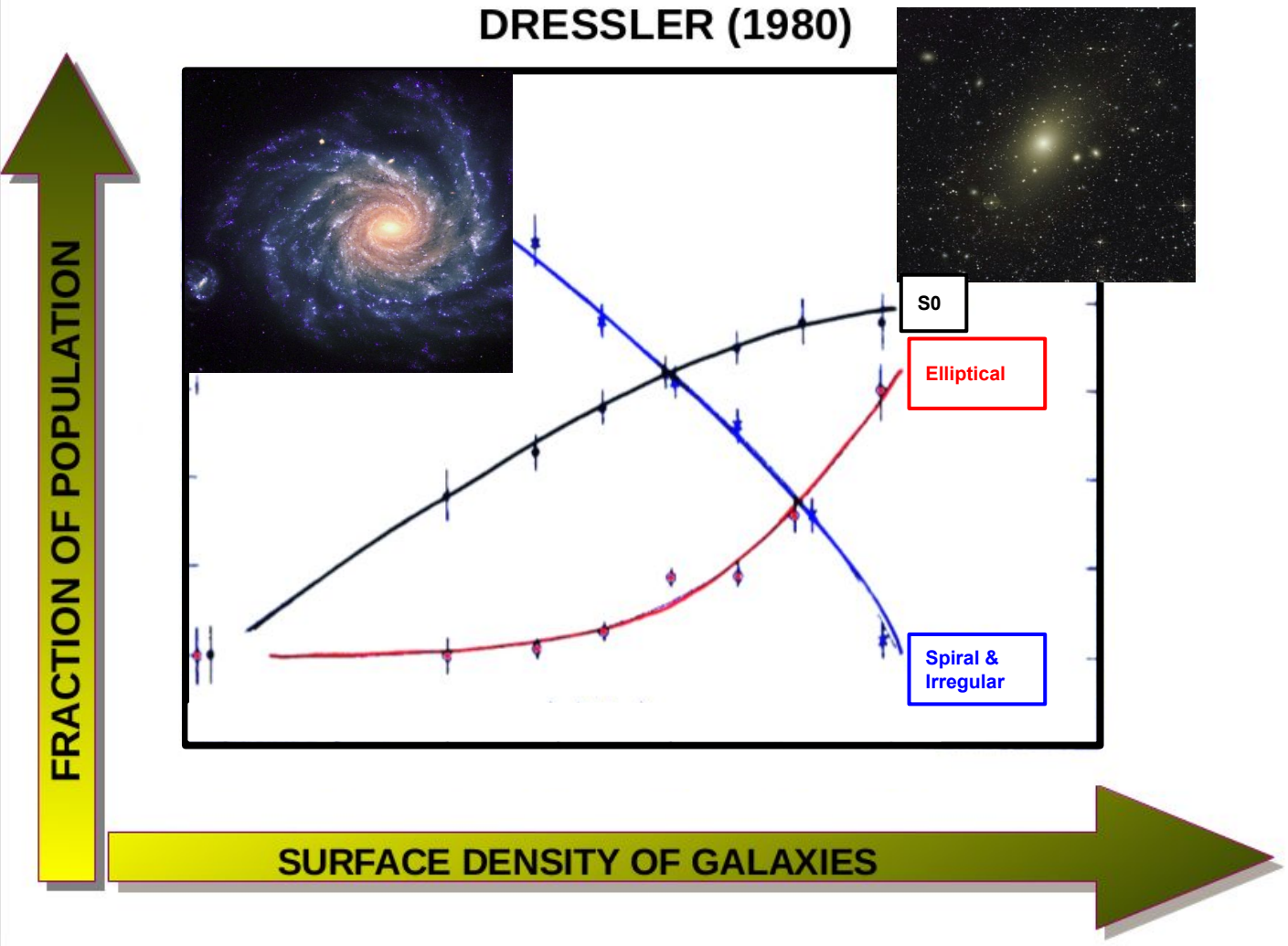


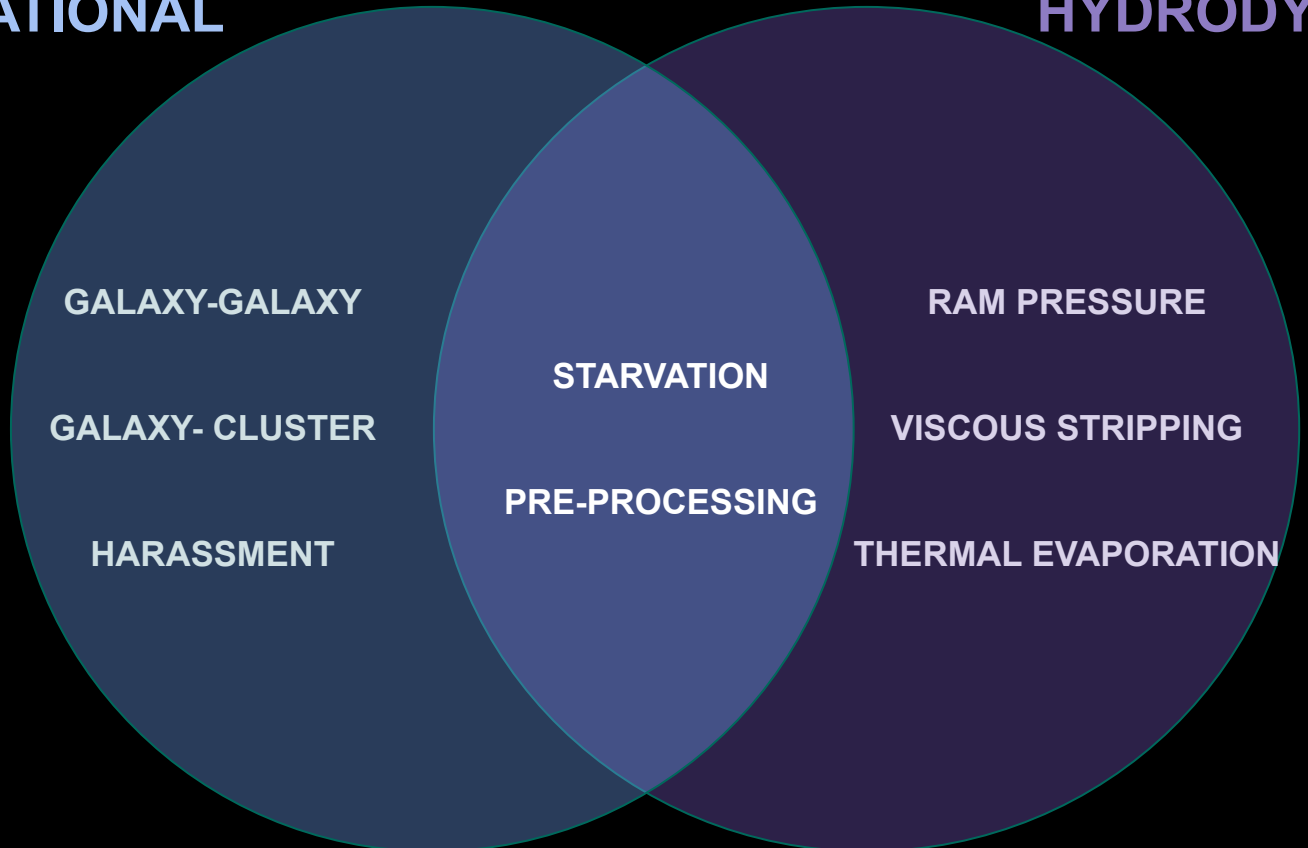
Illustration (MPE/V.Springel)



MORPHOLOGY-DENSITY

(Dressler+80. See also Lokas & Mamon+03;. Guzzo+97; Goto+03; Bamford+09; Skibba+09; Fasano+15; Lokas+20)

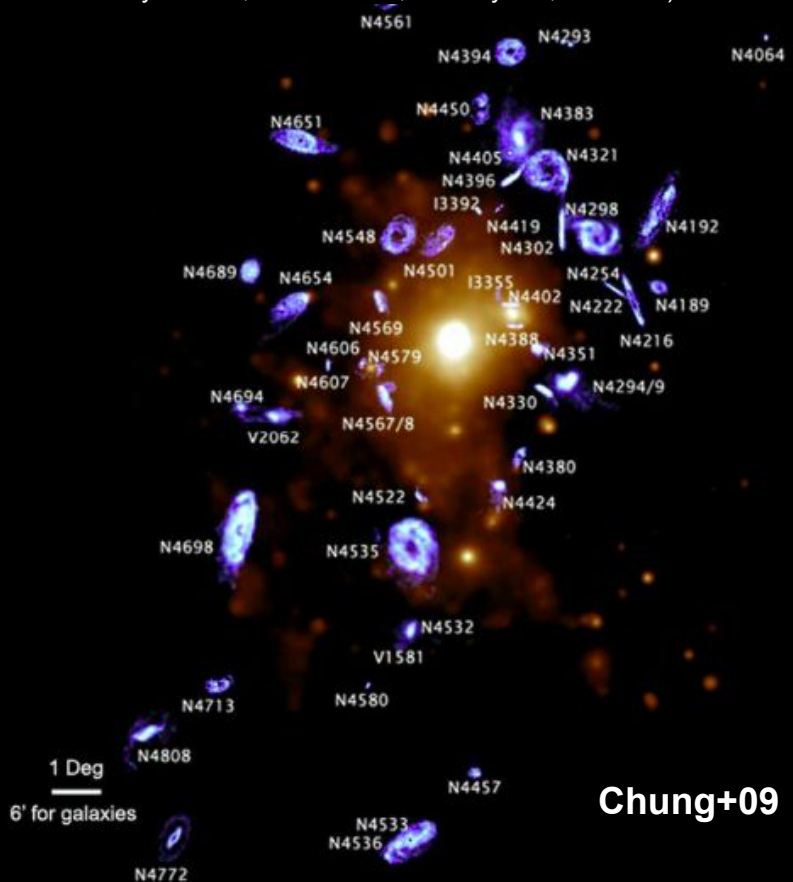
ENVIRONMENTAL PROCESSES



For a review see
Boselli & Gavazzi 2006

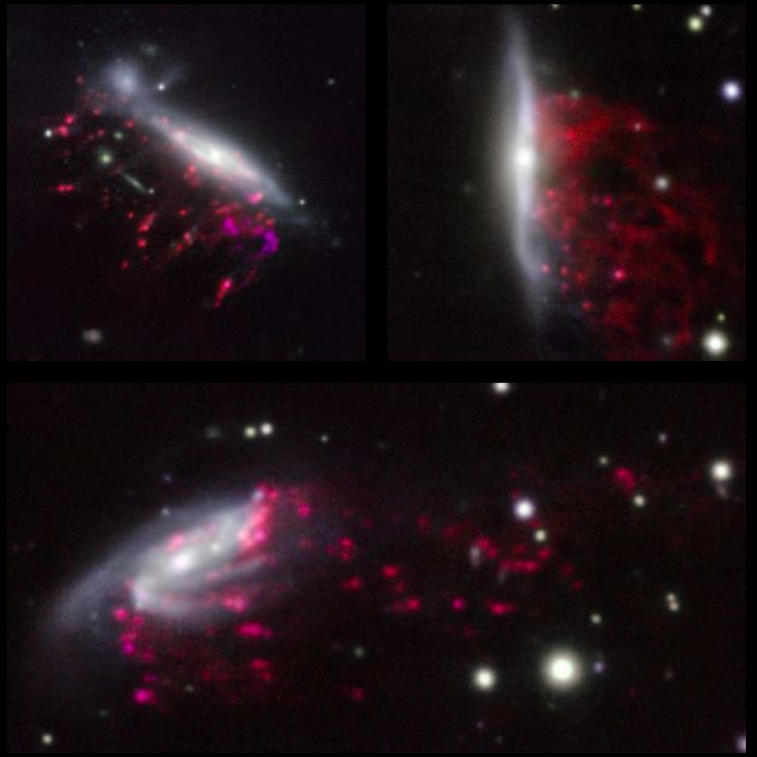
Ram Pressure Stripping (RPS, Gunn & Gott+72) **is one of the most efficient mechanism at removing gas in clusters**

(Giovanelli & Haynes+85; Gavazzi+89; Kenney+04; Jaffé+15)

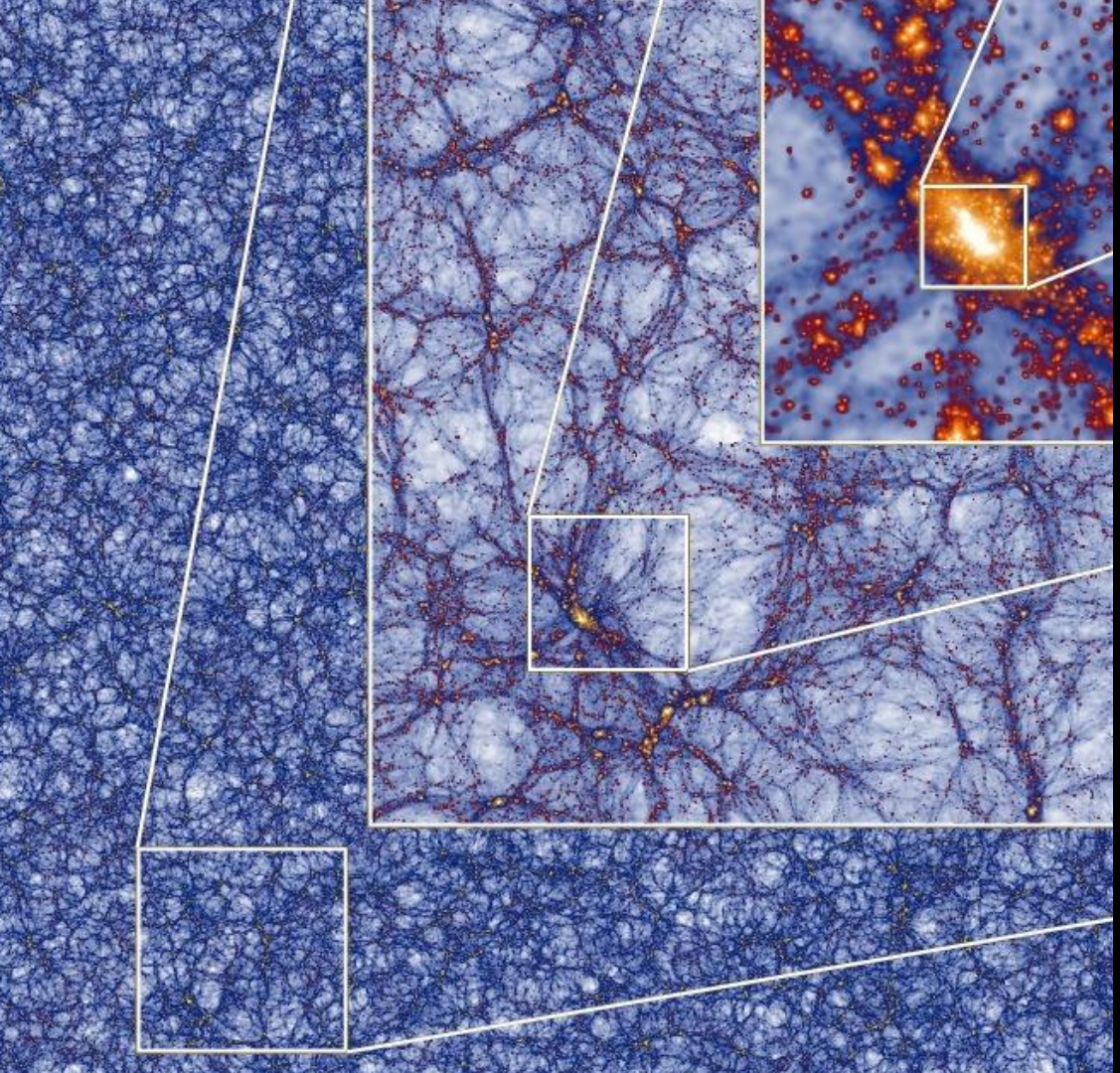


Chung+09

Jellyfishes - the most spectacular cases of ram pressure stripping



(GASP: Gas Stripping Phenomena with MUSE; Poggianti+17. See also Bellhouse+17; Gullieuszik+17, Poggianti+17b)

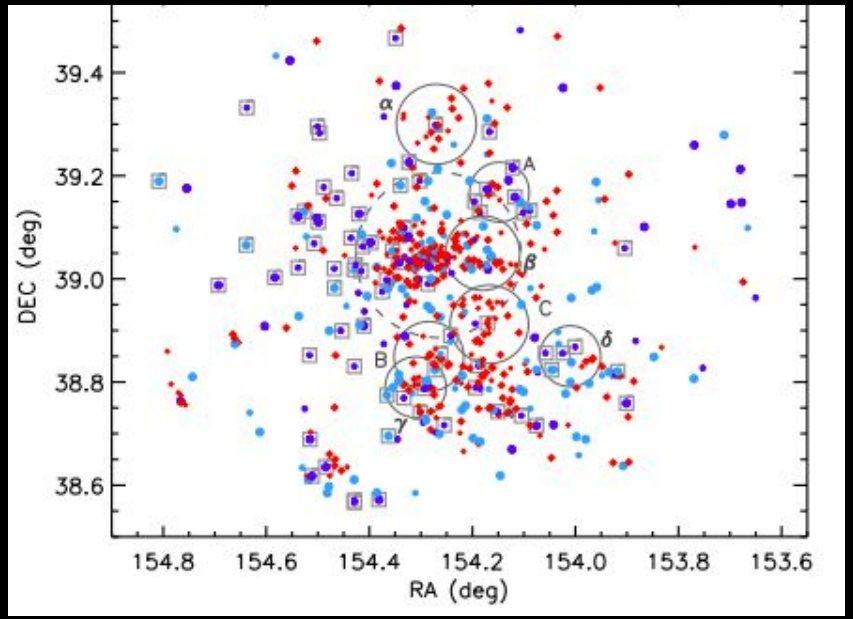


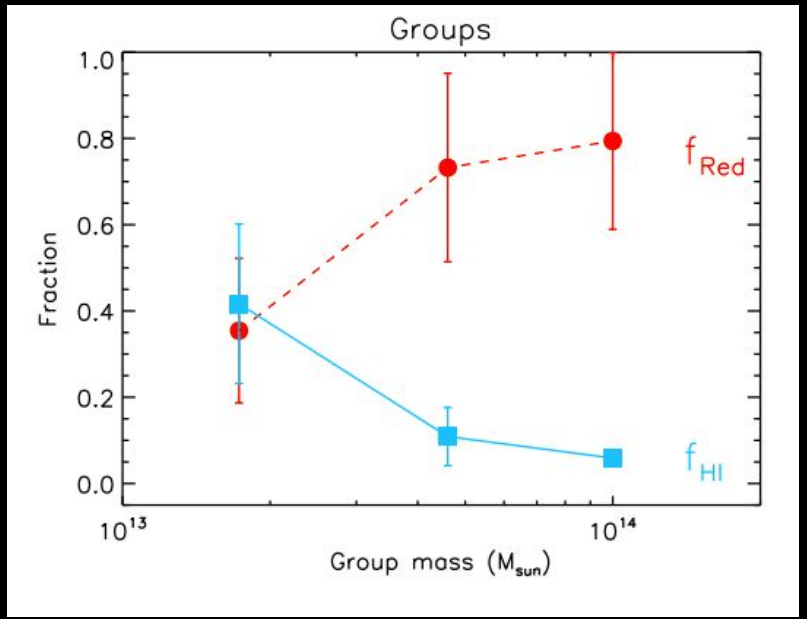
COSMOLOGICAL SIMULATIONS suggest that massive Clusters at z=0 have accreted ~40% of their galaxies from groups of mass greater than 10^{13} $M_{\odot}$
(McGee et al. 2009)

OBSERVATIONS suggest that 10 − 20% of clusters at z < 0.3 are undergoing mergers with other clusters
(e.g., Katayama et al. 2003; Sanderson, Edge & Smith 2009; Hudson et al. 2010)

It is known that cluster growth can affect galaxy evolution through two main ways:

1. **Group pre-processing** (e.g. Gómez+03; Lu+12; Rasmussen+12; Jaffé+16; Dzudzar+19)

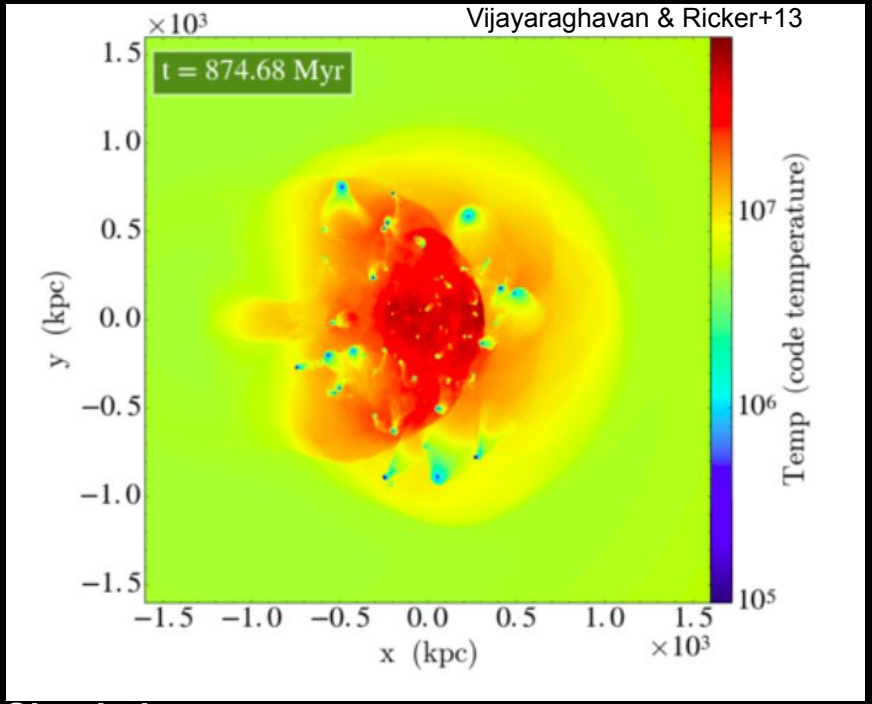




Jaffé+16

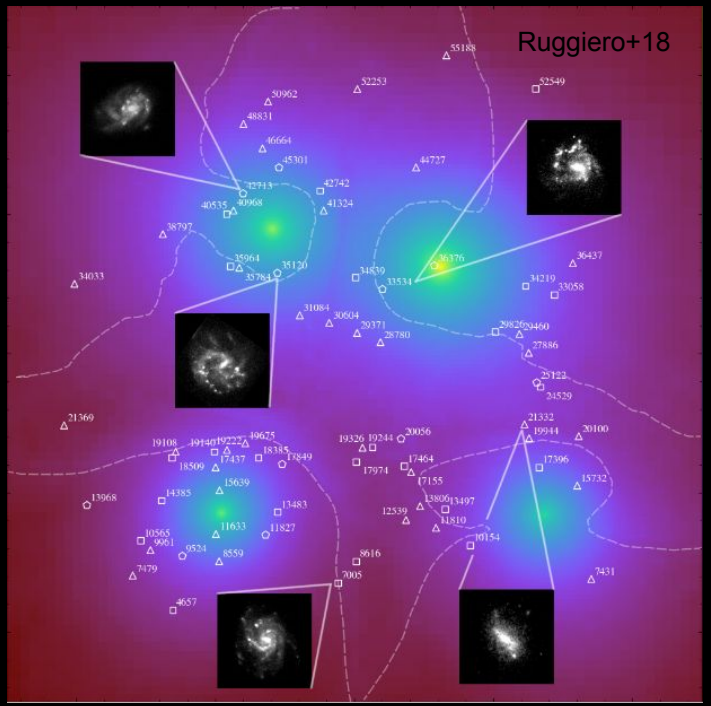
2. Post-processing due to major mergers

(Bekki+99; Domainko+06; Stroe+14,17; Mansheim+17a,b; Kelkar+20)



Simulations

(See also Machado+15;Monteiro-Oliveira+17; Mansheim+17)



A few focused observational studies

(see also, Owers+12; Stroe+15; McPartland+16; Deshev+17;Ebeling+19;Roman-Oliveira+19;+20)

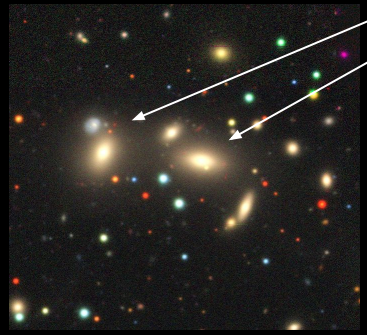
The impact of clusters mergers on the formation of jellyfishes

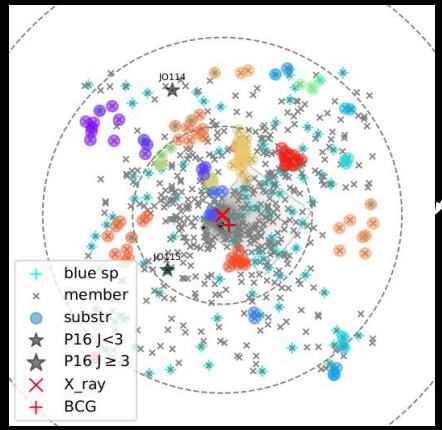
Robust classification of dynamical state of a large homogeneous sample of galaxy clusters using different metrics from optical, x-ray, and radio.

Optical proxies for dynamical state

Relaxed

Disturbed





SEVERAL CENTRAL BRIGHT GALAXIES (Magnitude Gap)
(e.g. Dariush+07;Ramela+07;Gozalias+14;Raouf+19)

DRESSLER-SHECTMAN
(e.g. Dressler-Shectman+88; Sodre+89; Bird & Beers+93;Oegerle & Hill+01;Einasto+12; Jaffé+16)

VELOCITY MULTIMODALITY
(e.g. Yahil & Vidal+77; Hou et al. 2009; Ribeiro et al. 2010, 2011, 2013)

PROJECTED OVER-DENSITIES
(e.g. Flin & Krywult+06; Ramella+07)

GAUSSIAN MIXTURE MODELS
(e.g. Einasto+12a,b; Ribeiro+13; Monteiro-Oliveira+20; Lourenço+20)

DS+ technique
(eg. Biviano+17)

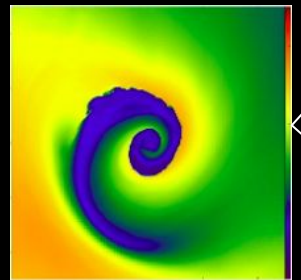
X-ray proxies for dynamical state

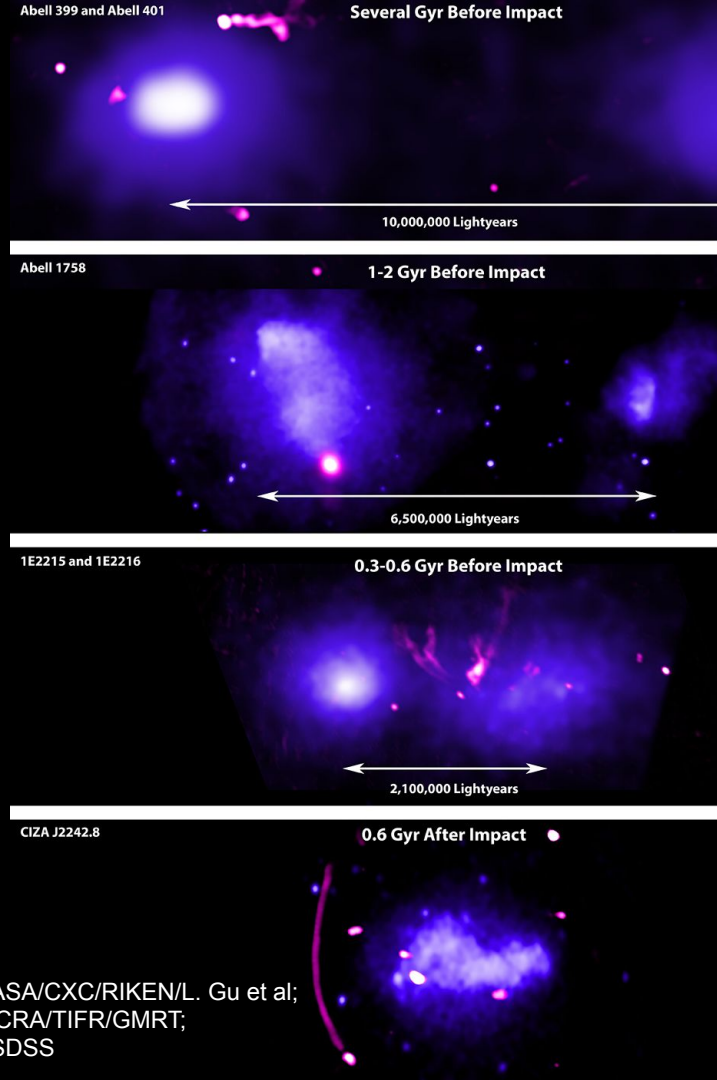
SHOCK FRONTS
(e.g. Markevitch+02, 05; Simionescu+09; Russell+10; Owers+11;14; Eckert+16; Thölken+18; Botteon+18)

COLD FRONTS
(e.g Ghizzardi+10; Birnboim+10; Hallman+10)

SLOSHING (SPIRAL PATTERNS)
(e.g. Churazov+03;Fabian+06; Laganá+10;Simionescu+10;Roediger+12b;Gastaldello+13; Rossetti+13)

CONCENTRATION, CENTROID SHIFT, ASYMMETRY & POWER RATIO
(eg. Rasia+13; Yuan+20)



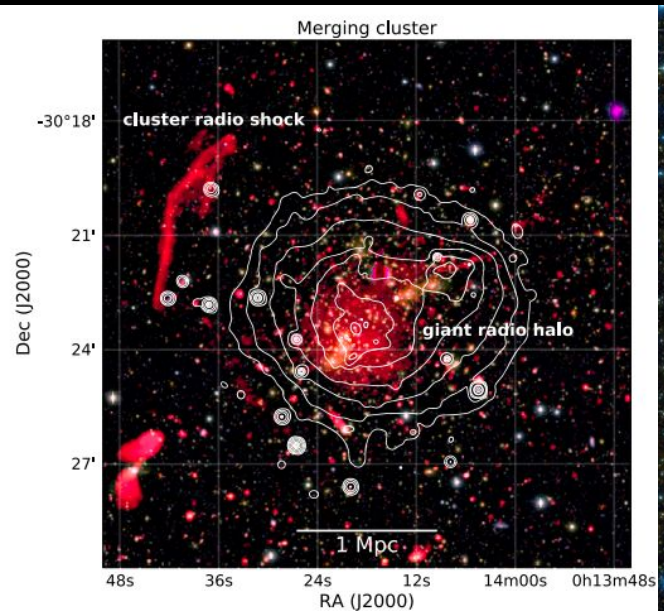


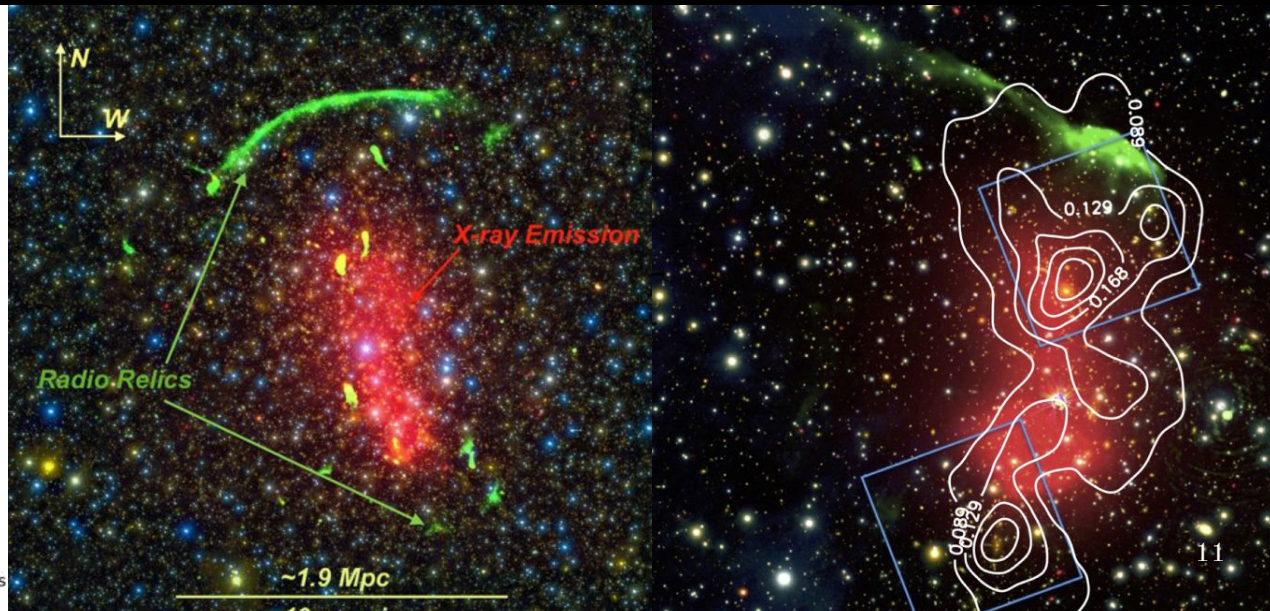
X-ray: NASA/CXC/RIKEN/L. Gu et al;
Radio: NCRA/TIFR/GMRT;
Optical: SDSS

Radio proxies for dynamical state (see Van Heeren+19 for a review)

Relics (Feretti+12;Stroe+13)

Haloes (Feretti+01; Eckert et al. 2017; Brunetti & Lazarian+07,11)





Sample

WINGS (0.04 < z < 0.07 ; Brightest ROSAT sample (Ebeling+96,+98,+00))

~ 5 × 10^{14} to >10^{15} $M_\odot$; M_V ~ -14 (dwarf galaxies) ; FOV: 34'x34' ~ 1.6-2.7 Mpc

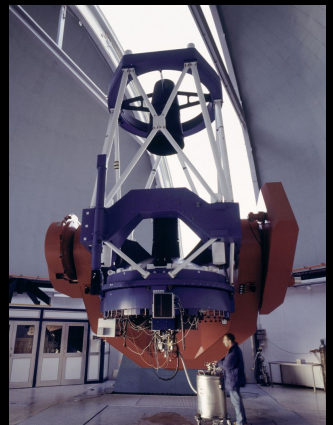
- **photometry** (Fasano+06) ⟶ **WFC@INT & WFI@MPG** ⟶ **(77 Clusters)**
- **spectroscopy** (Cava+09) ⟶ **WYFFOS@WHT & 2dF@AAT** ⟶ **(48 Clusters)**

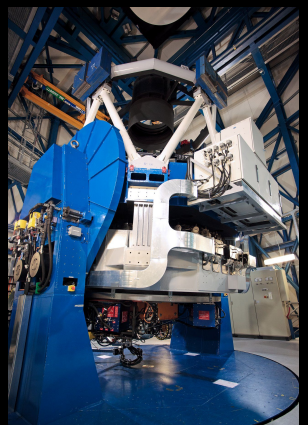
OmegaWINGS (46 Clusters) ; FOV: 2×2 deg^2

- **photometry (Gullieuszik+15)** ⟶ **OmegaCAM** ⟶ **(46 Clusters)**
- **spectroscopy (Moretti+17)** ⟶ **AAOmega** ⟶ **(33 Clusters)**

Archival X-ray for available WINGS Clusters

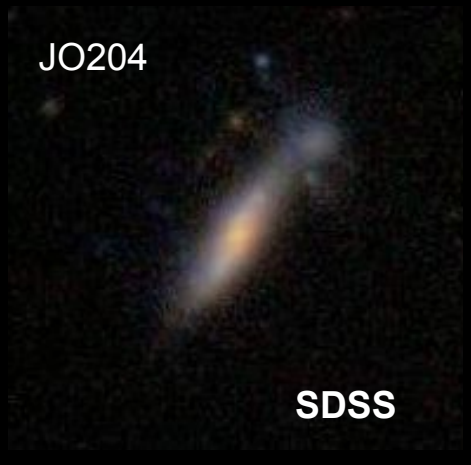
- **48 Chandra**

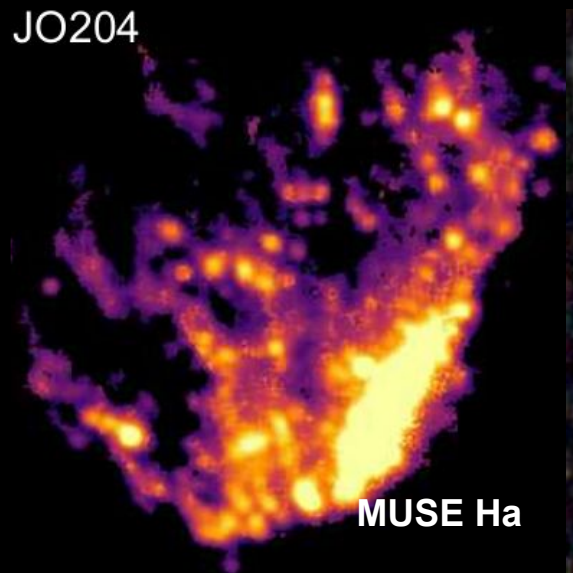


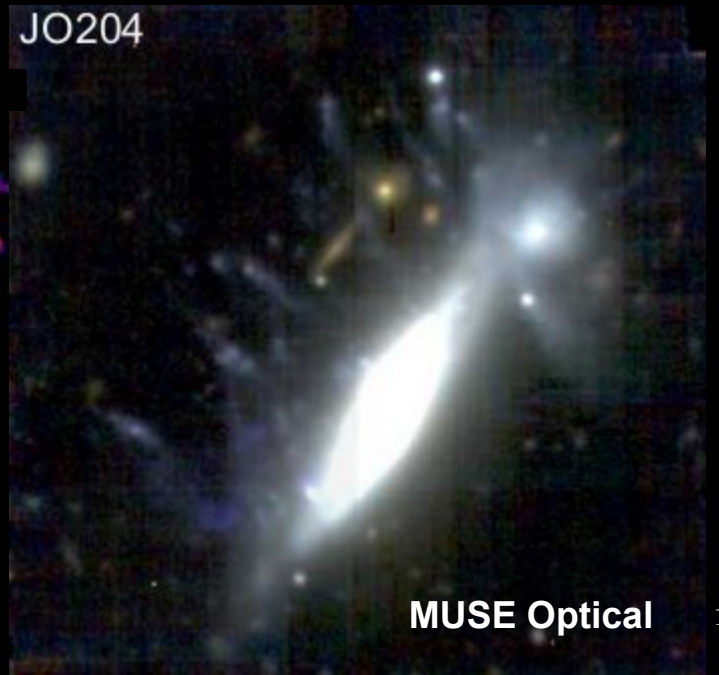


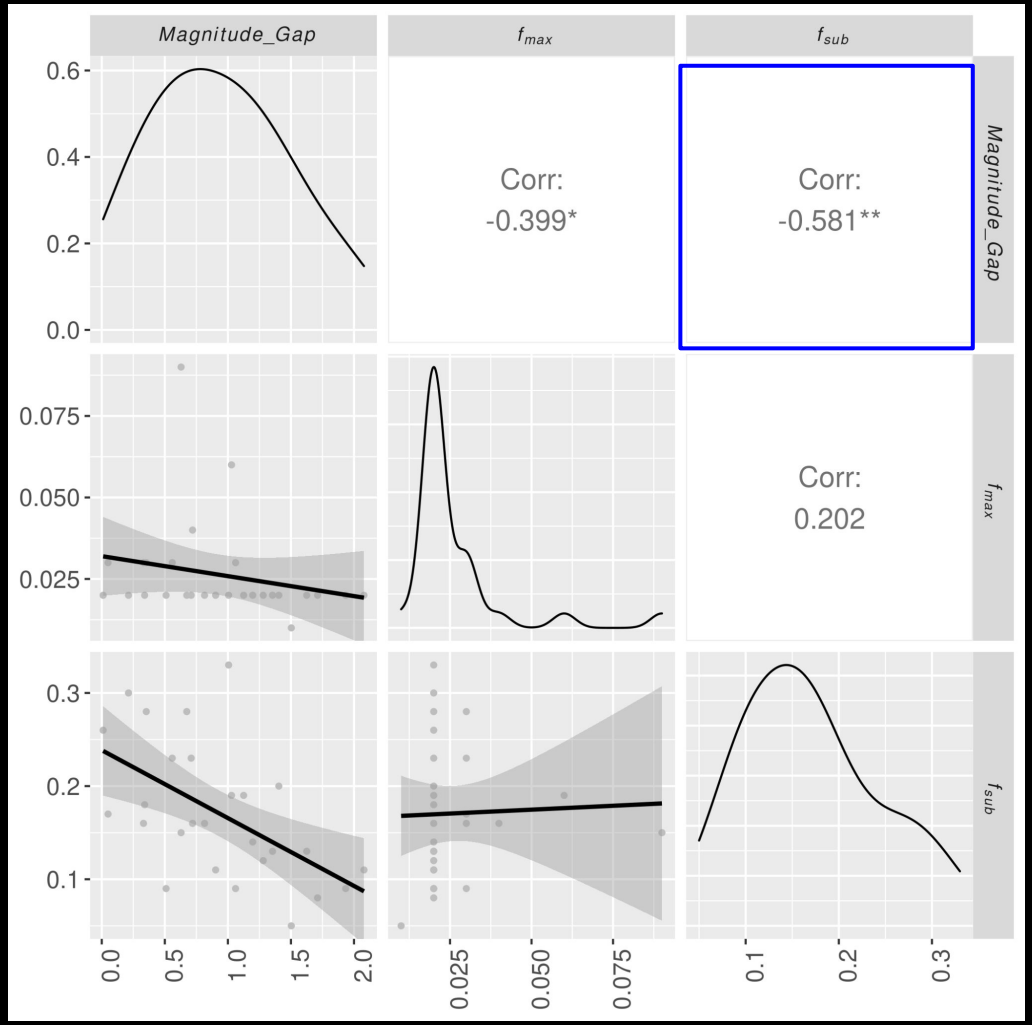
Sample

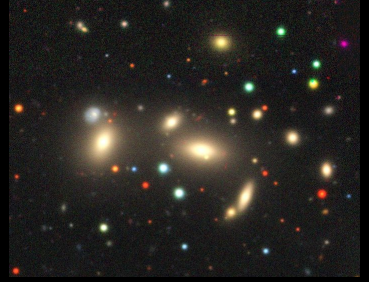
- **Homogeneous sample that has multi-wavelength coverage**
- **Largest sample of 344 RPS candidates known to date** (Poggianti+16)
- **MUSE follow-up for 114 galaxies** (GASP; Poggianti+17)







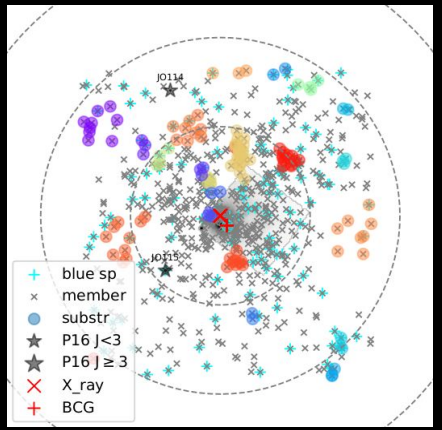


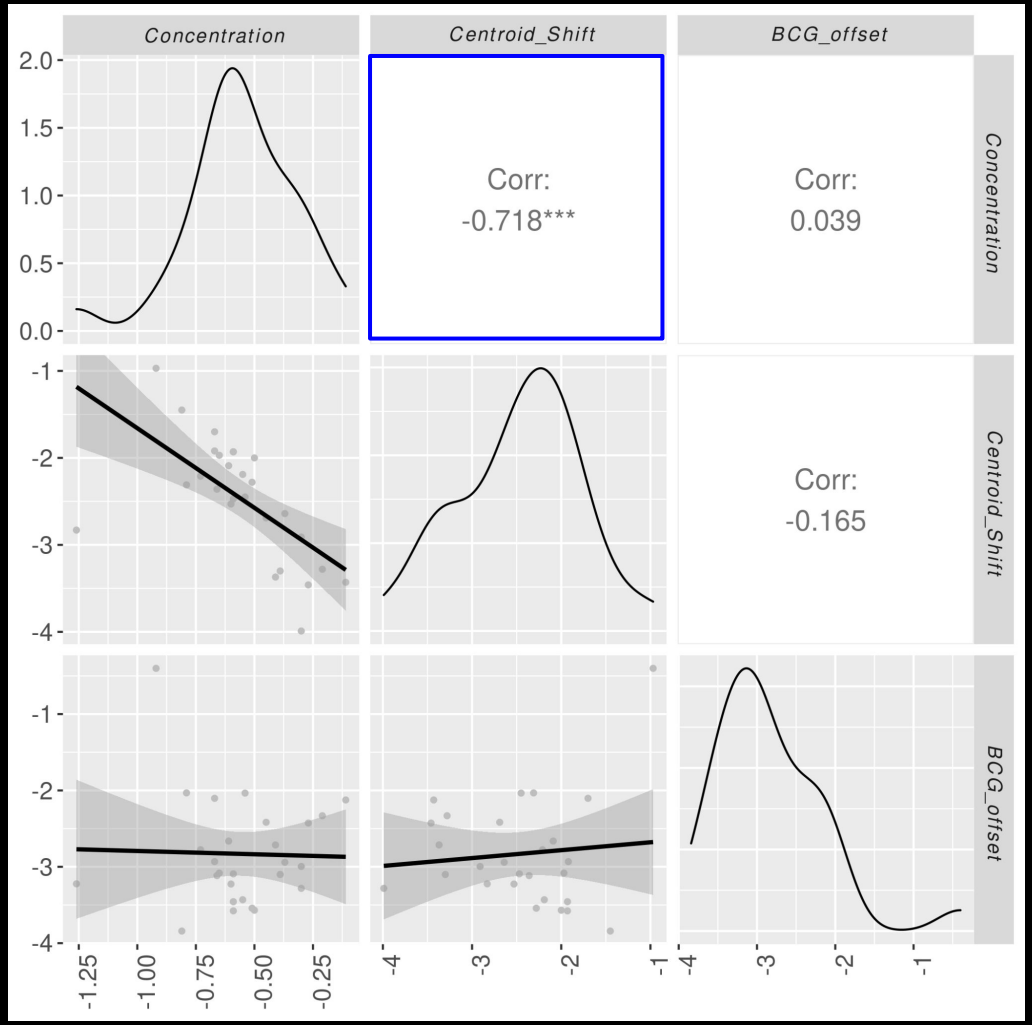


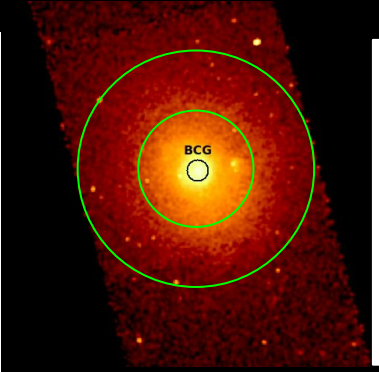
Magnitude Gap = $AbsV_1$- $AbsV_2$

Fmax = # members in the richest substructure / # members

Fsub = # members in substructures / # of members

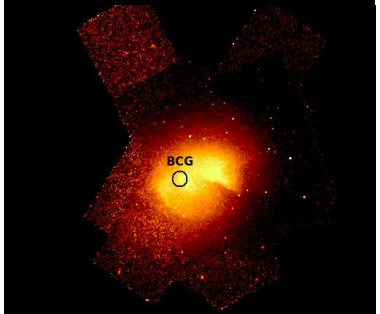






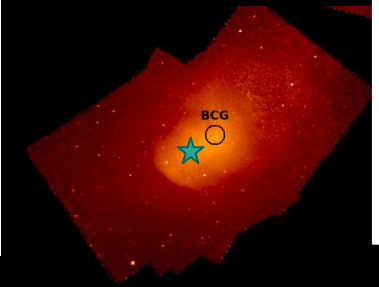
Concentration =
flux (100 kpc) / flux (500 kpc)

Yuan+20



Centroid Shift ~ Centroid measured in different apertures and see how much it varies

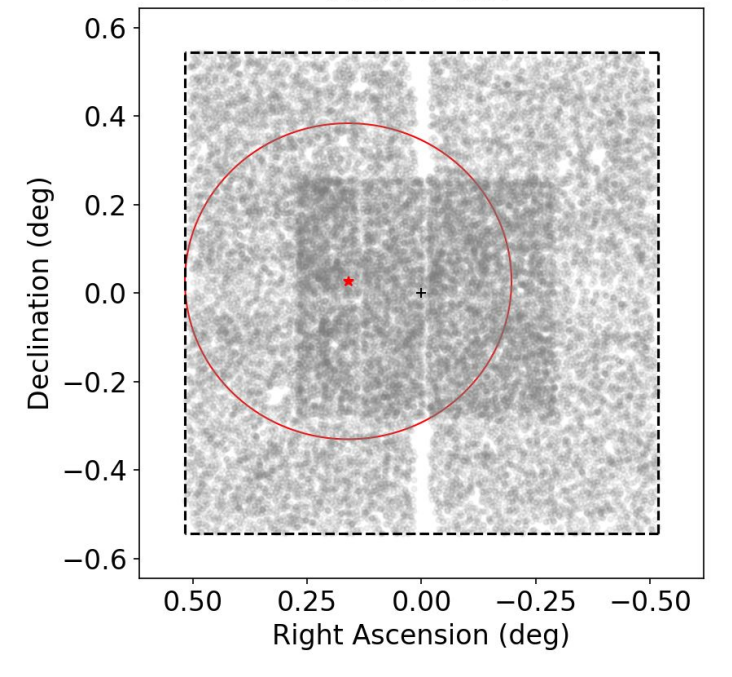
Yuan+20



BCG offset =
BCG (x,y) - X-ray Peak (x,y)

Computing Jellyfish fractions

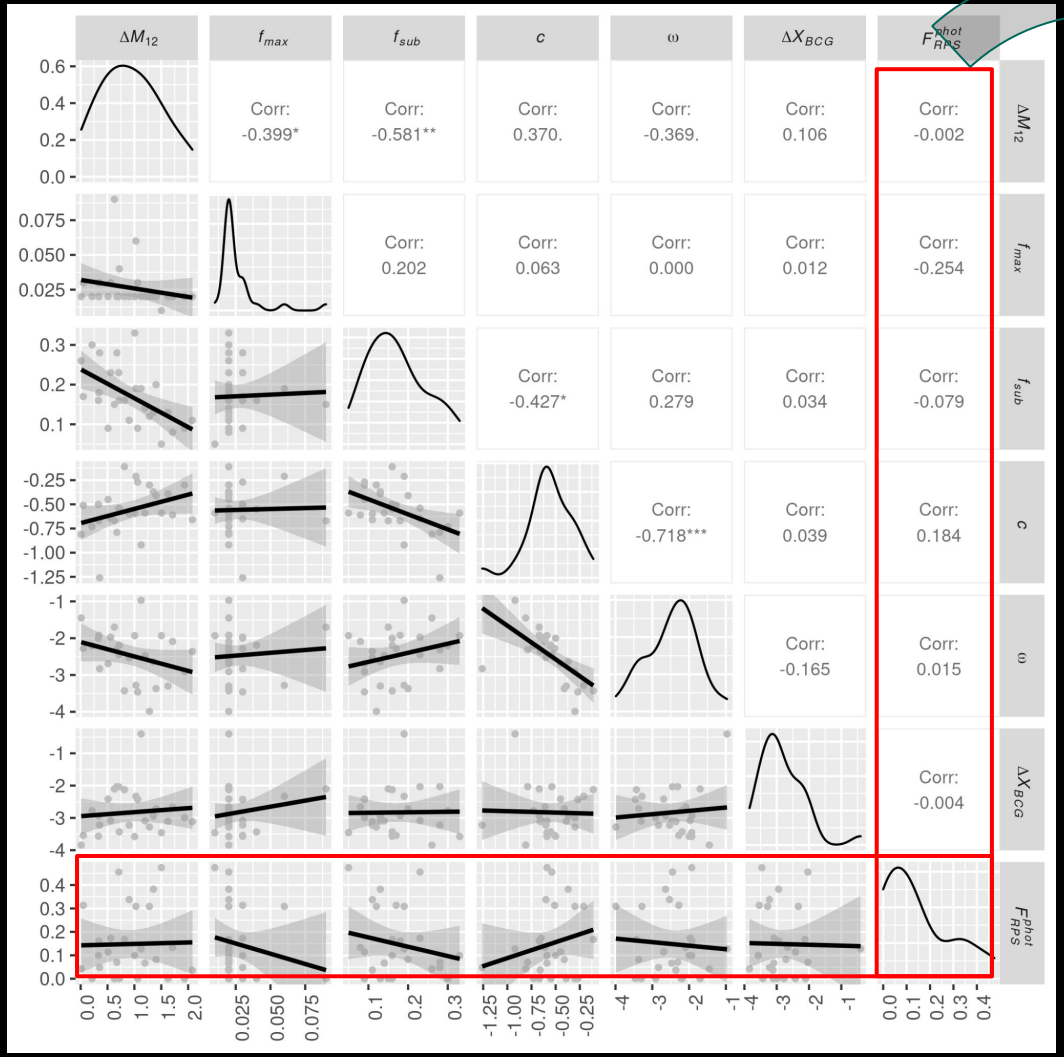
Centers and coverage issue



Merging clusters can have several bright galaxies in the center and be multi peaked in the X-rays

Post mergers we chose the center to be the mid point between the brightest galaxies associated with the X-ray peaks.

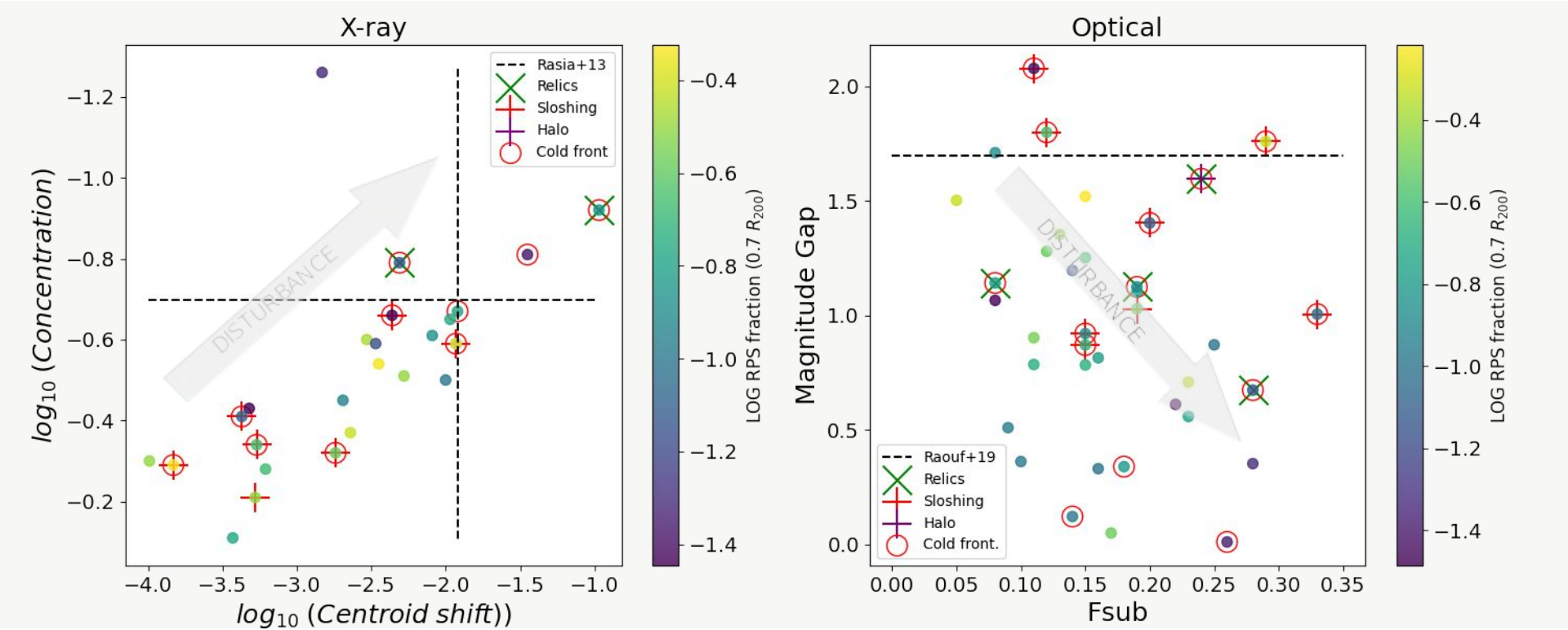
We tested coverage of WINGS/Omega photometric data and found that 0.7 R200 was the radius that maximized our sample



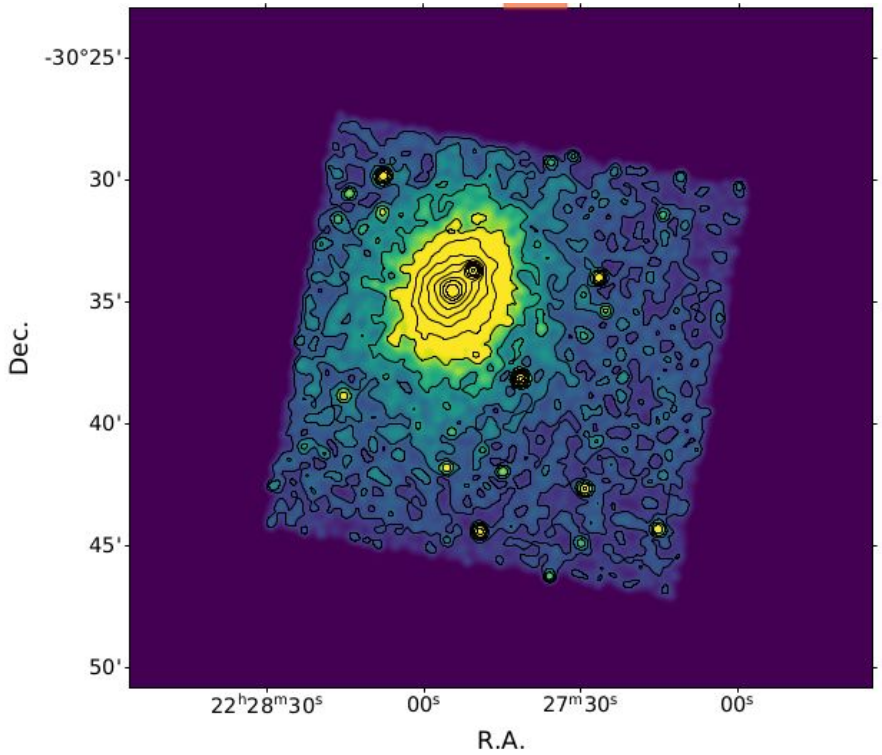
$$Jellyfish\ fraction = \frac{n^o\ of\ jellyfishes}{n^o\ of\ spirals - n^o\ of\ field\ spirals}$$

Lourenço et al in prep.

We tried to adds extra info (cold fronts, sloshing, relics & halos)



Relaxed (1) - The simplest case



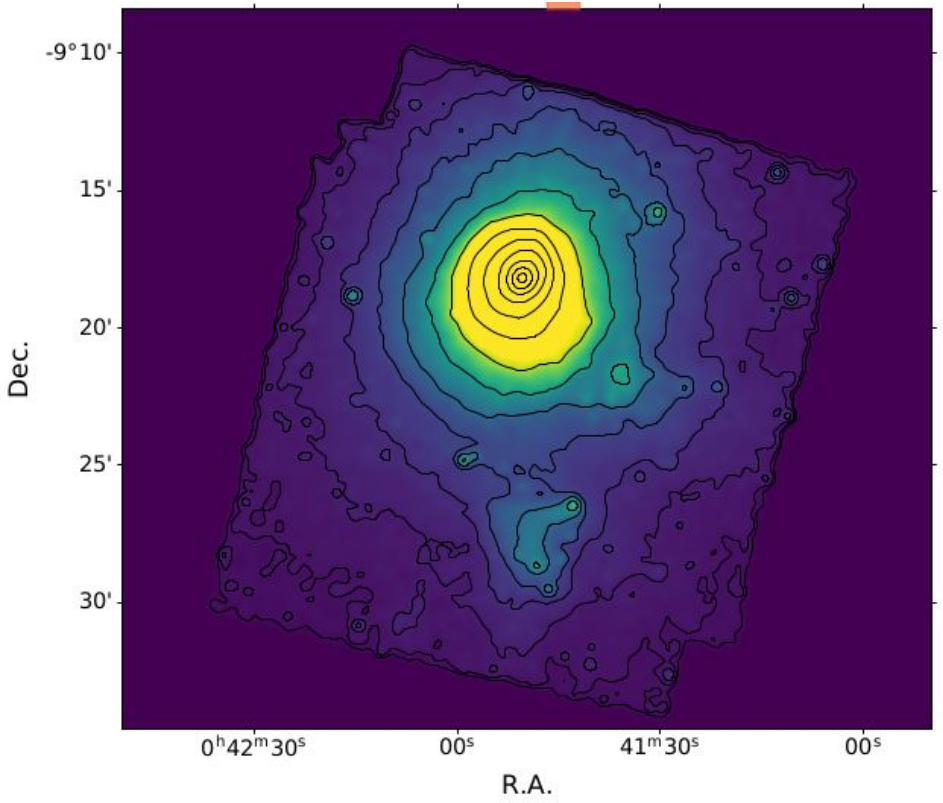
Symmetrical

Concentrated

BCG coincides with X-ray peak

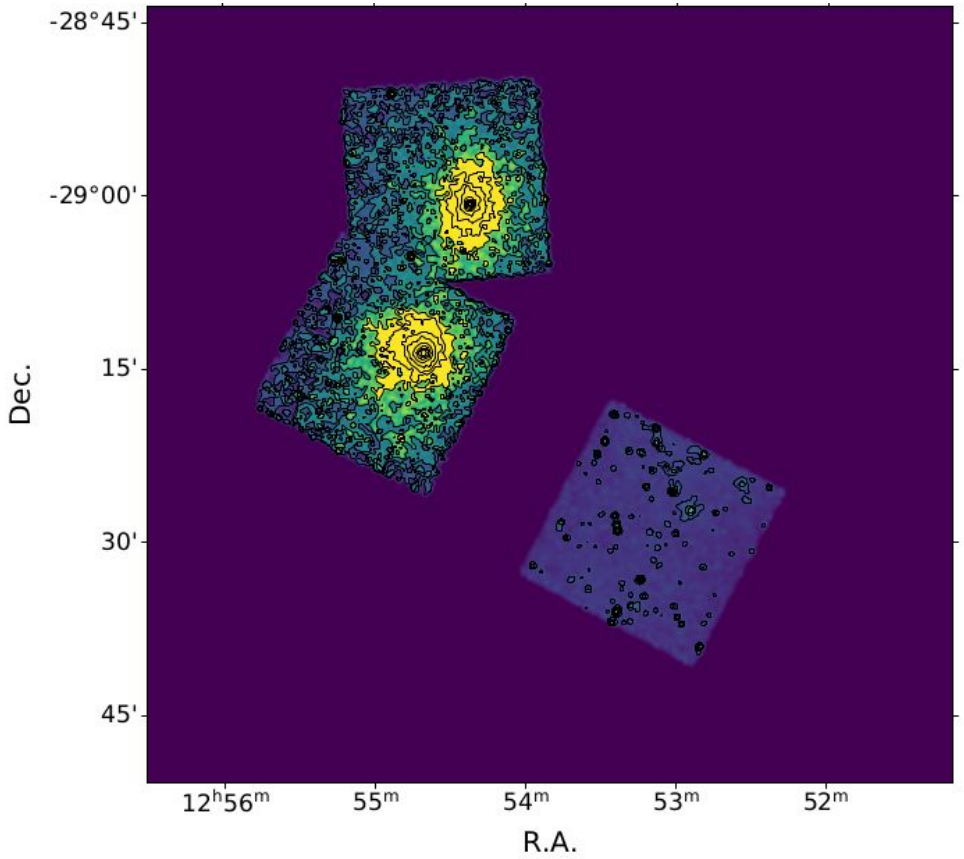
Mildly Interacting (2)

Small substructures
Sloshing

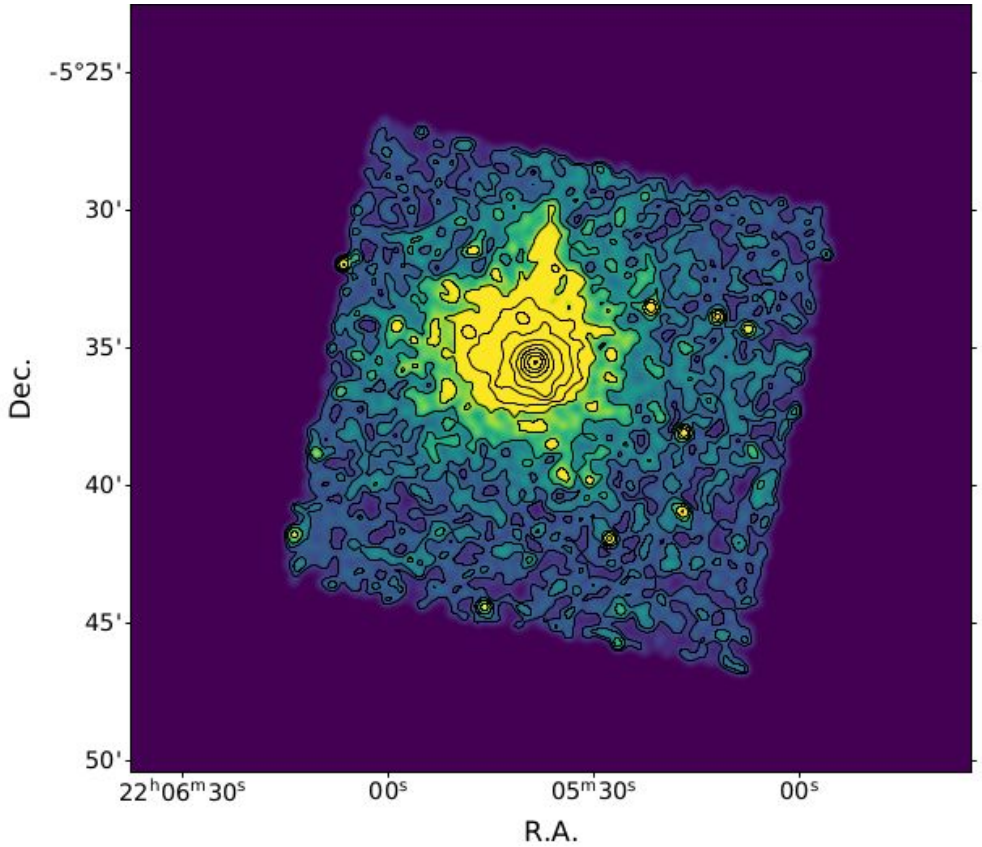


Pre Mergers (3)

Two or more structures of comparable sizes close in projection and velocity



Interacting (4)



Asymmetrical

Not concentrated

BCG often does not match with X-ray peak

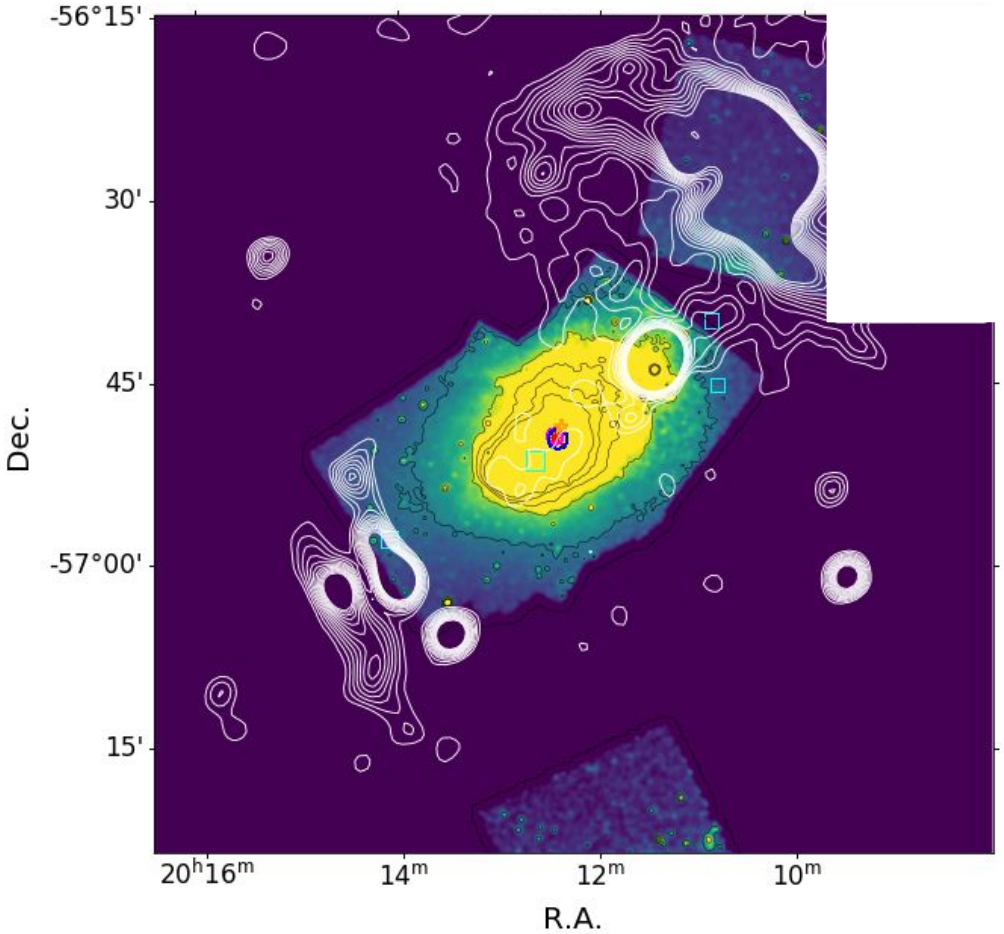
Post-merger (5)

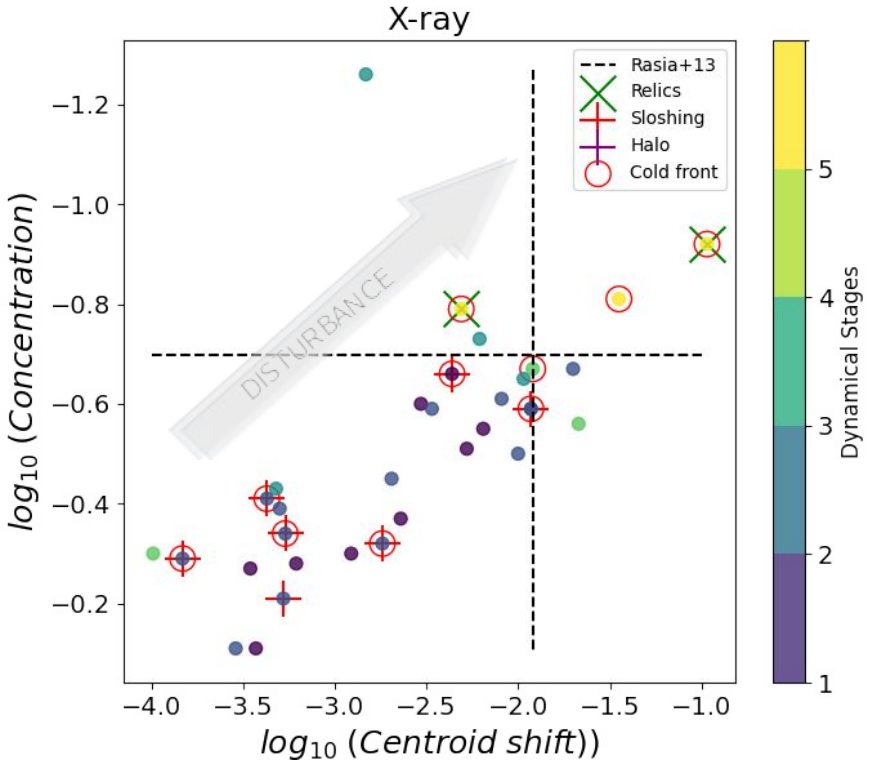
Asymmetrical

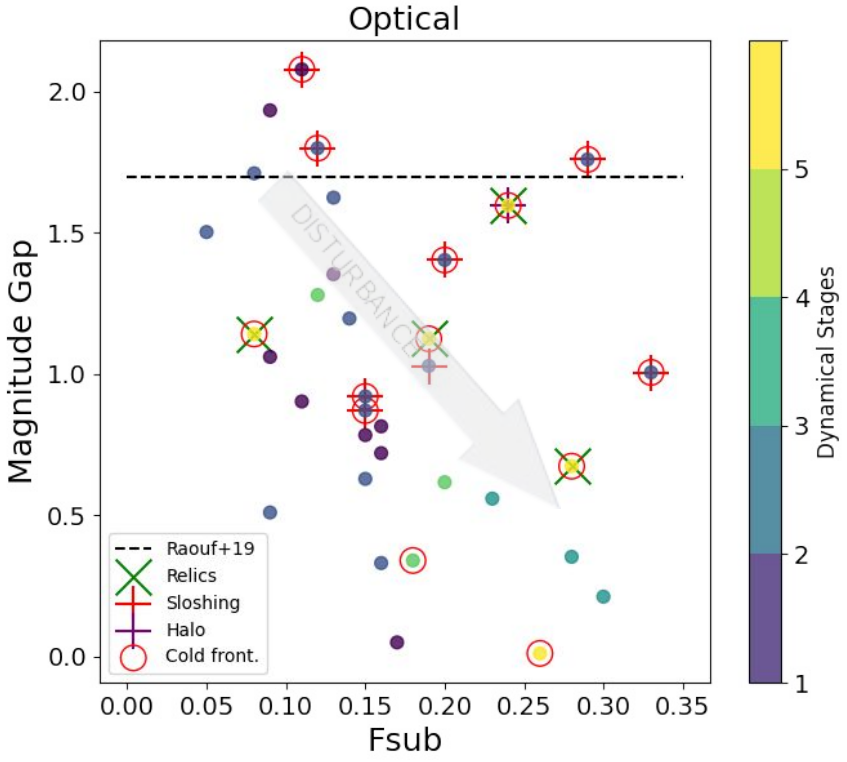
Not concentrated

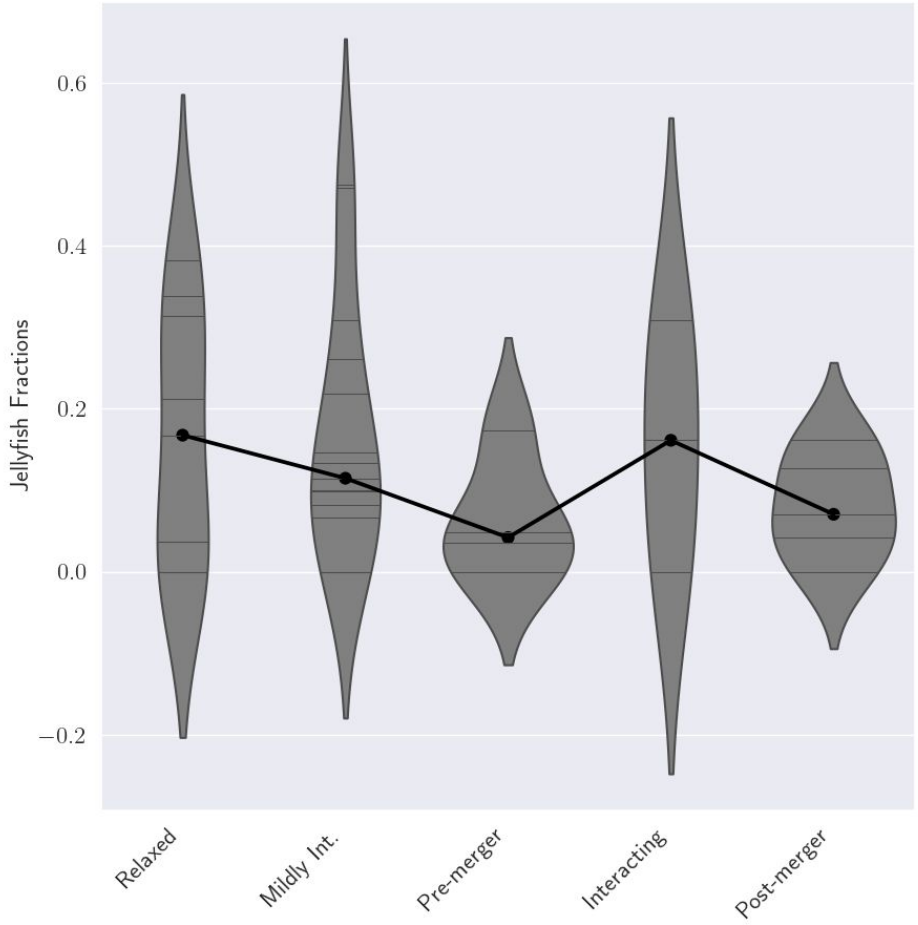
BCG often does not match with X-ray peak

Extended radio emission




X-ray
Rasia+13
Relics
Sloshing
Halo
Cold front
DISTURBANCE
log_{10} (Concentration)
log_{10} (Centroid shift))
Dynamical Stages

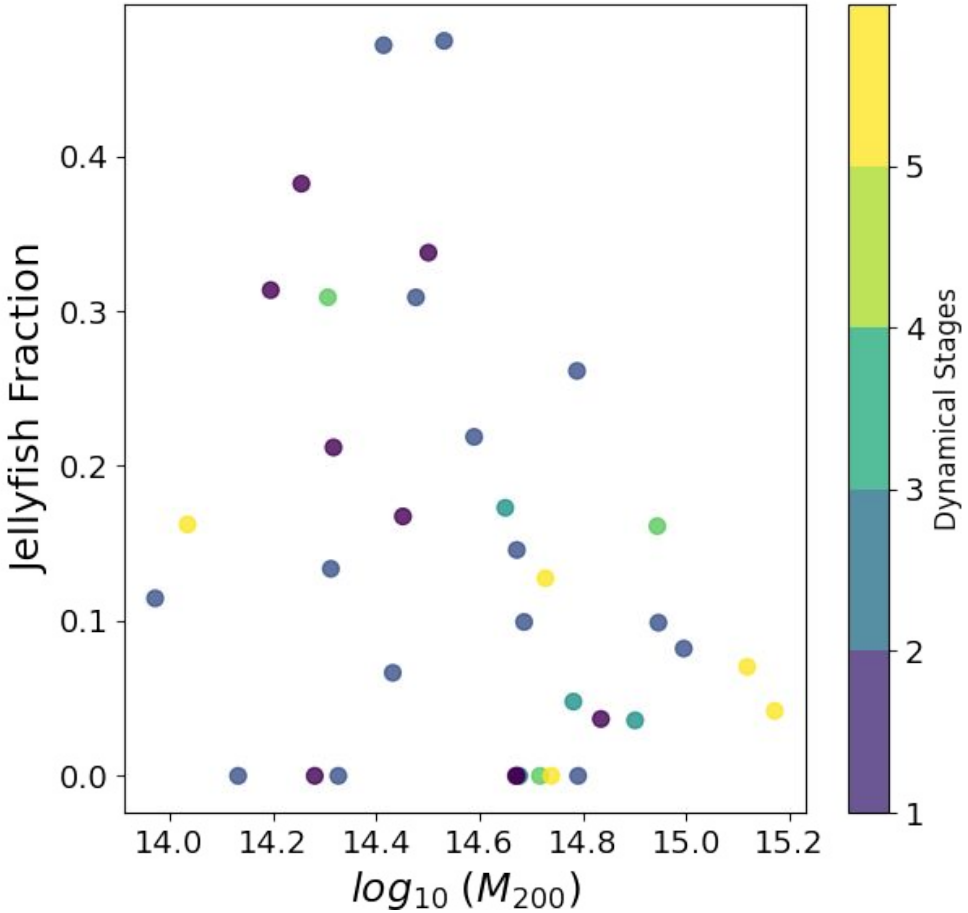

Optical
Raouf+19
Relics
Sloshing
Halo
Cold front.
DISTURBANCE
Magnitude Gap
Fsub
Dynamical Stages



Again we found no trend between jellyfish fractions and dynamical states

Are we at the odds with other studies?

Poggianti 2016 - Jclass >=3 - 2% of galaxies with SFR > 0.1 in both wings and PM2GC
Roberts 2020 - 41 JFS from 296 star forming galaxies (with sSFR > 10^11) which is 15% (390 other galaxies in Coma)
Roman-Oliveira 2019 - 73 from 439 Ha emitters (17%)
Roberts 2021a - 95 from 1968 galaxies (with sSFR > 10^11). 2%
Roberts 2021b - 60 from 3493 star forming galaxies (with sSFR > 10^11). 2%
Durret 2021 - 178 from 1868 total. There is an average of 9% in clusters with at least 10 spectroscopic members, and 13% in the large and complete cluster.
Vulcani 2022 - 35% of blue late-type are ongoing ram pressure stripping
Lourenço in prep - 13% late type are ongoing ram pressure stripping (photometric fractions within 0.7 R200)



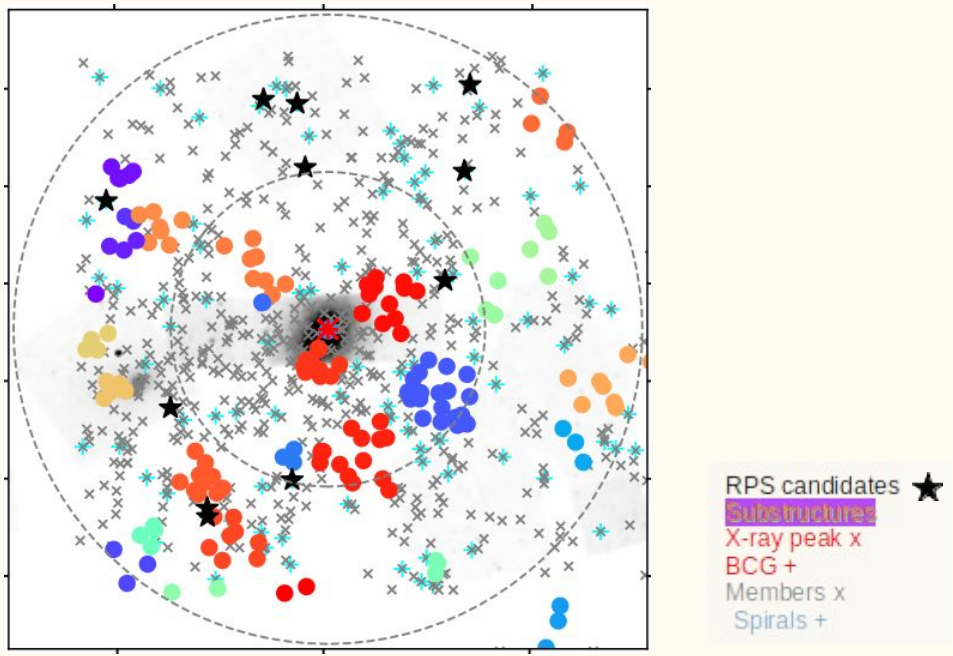
Against expectations, massive clusters don't hold the highest fractions of jellies

Take home messages:

- We found no correlation between jellyfish fractions and dynamical state indicators.
- After classifying the sample into five different dynamical state, we found no hints of a possible jellyfish fraction enhancement in specific dynamical classes.
- We found no apparent correlation between RPS fractions and the cluster masses.

Next step:

- To extend the radius of this analysis



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Instituto de Física y Astronomía

Agencia Nacional de Investigación y Desarrollo
Ministerio de Ciencia, Tecnología, Conocimiento e Innovación
Gobierno de Chile

Are there more jellyfish galaxies in merging clusters?

Ana Lourenço (Universidad de Valparaíso)

Yara Jaffé (Supervisor) & Collaborators