Properties and evolution of Active Galactic Nuclei in clusters

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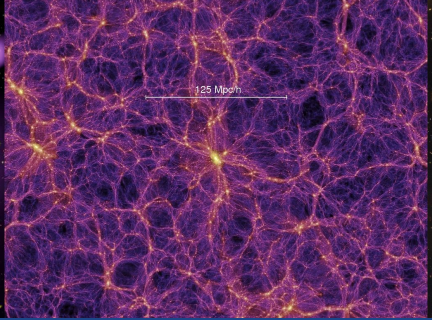
E. Koulouridis, A. Gkini + the XXL survey + the Hyper Suprime Cam (HSC) collaboration

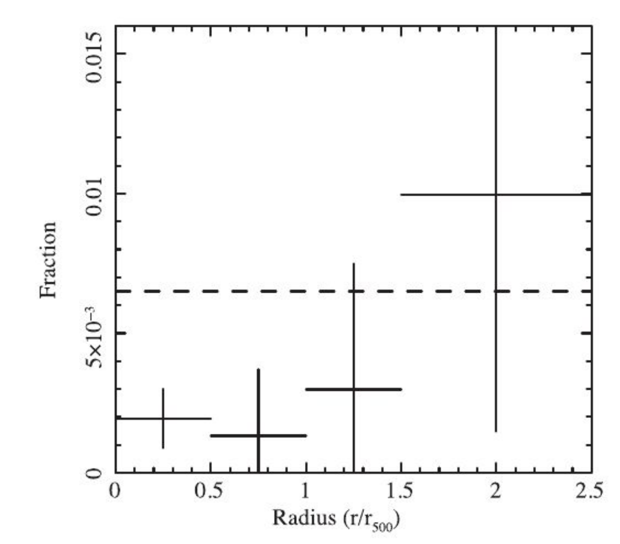
XMM-Newton survey legacy for Athena and beyond, 26-29 Feb 2024, Toulouse, France



Motivation

- Studying the evolution of AGN provides insights into the coevolution of supermassive black holes and the galaxies they inhabit.
- As a consequence of hierarchical structure formation, the majority of galaxies eventually fall in clusters. Therefore, clusters are the principal environment of galaxies and they can play a very important role in galaxy evolution.
- Inclusion of AGNs in cosmological simulations is crucial for constructing more realistic models of the universe. However, AGNs are modelled in simulations following only field demographics.

AGN & ram pressure in massive galaxy clusters



- Ehlert et al. (2013, 2014): the X-ray AGN fraction in the central regions of 42 of the most massive known clusters is about three times lower than the field value.

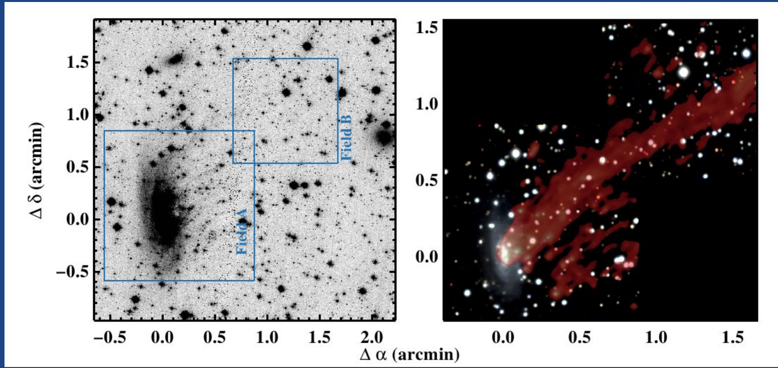
Several studies have shown that massive clusters can effectively suppress the fraction of AGN in cluster galaxies:

- Kauffmann+2004
- Martini+2007: 40% lower
- Koulouridis & Plionis+2010: ~3x lower
- Haines+2012: 40% lower
- Mishra+2020
- Beyoro+2021

Important note: AGN in cluster galaxies are more numerous than in the field. But the fraction of AGN in cluster galaxies is lower than in the field.

Ram pressure stripping by the hot ICM

★ In massive clusters we find less AGN in the centre
★ In the central region of galaxy clusters the hot ICM causes the stripping of the gas of cluster galaxies. The result is the quenching of star formation and possibly of the BH accretion, leading to a reduced fraction of AGNs in clusters.

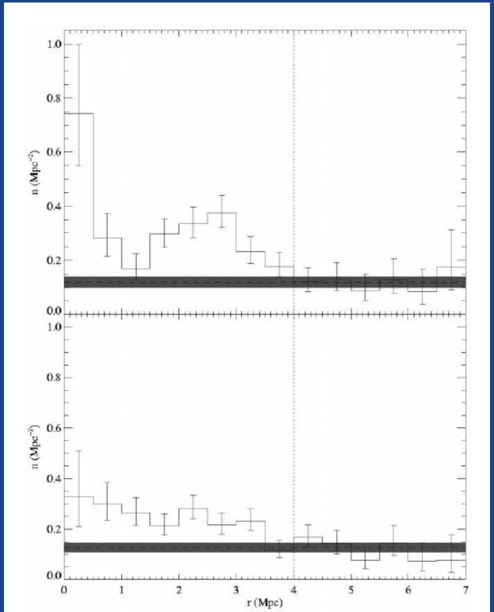


Jellyfish galaxies, Fumagalli+14

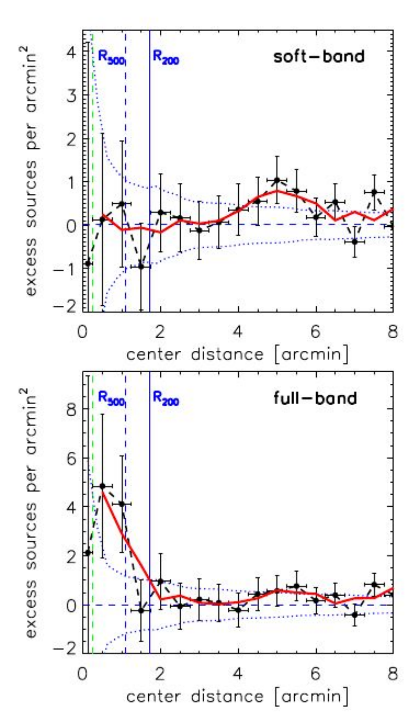
★ Poggianti+2017 suggested that ram pressure stripping may act as a triggering mechanism for AGN activity in cluster members
★ Peluso+2022 confirmed that "jellyfish" galaxies host a significantly higher number of AGN than similar galaxies in the field.

jellyfish galaxies probably represent a small fraction of the total population of RPS galaxies

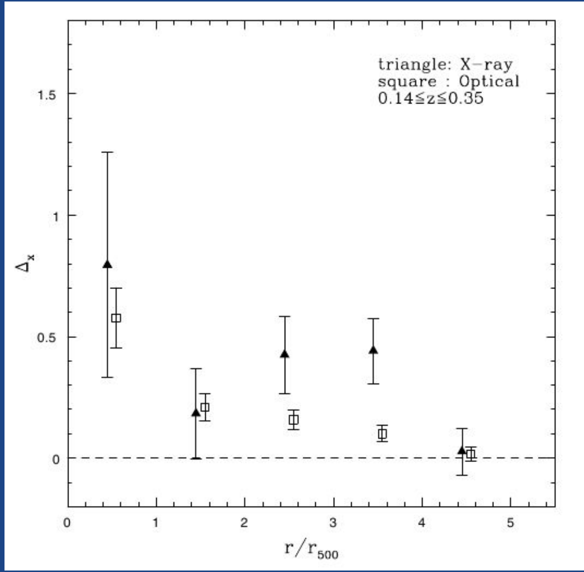
Excess of X-ray point sources in the outskirts of clusters



Ruderman & Ebeling (2005)
z=0.3-0.7



Fassbender et al. (2012)
z=0.9-1.6

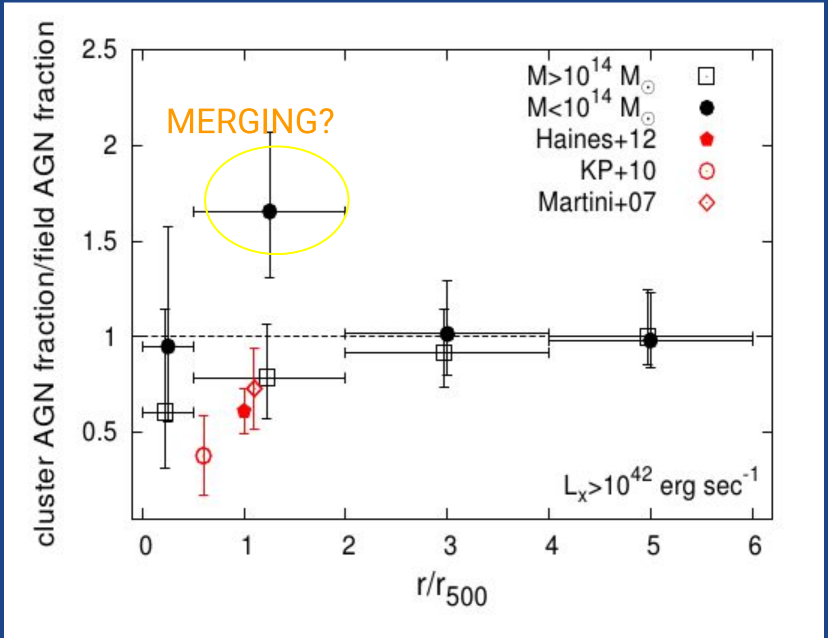


Koulouridis et al. (2014)
z=0.14-1.0

The role of cluster mass in AGN activity

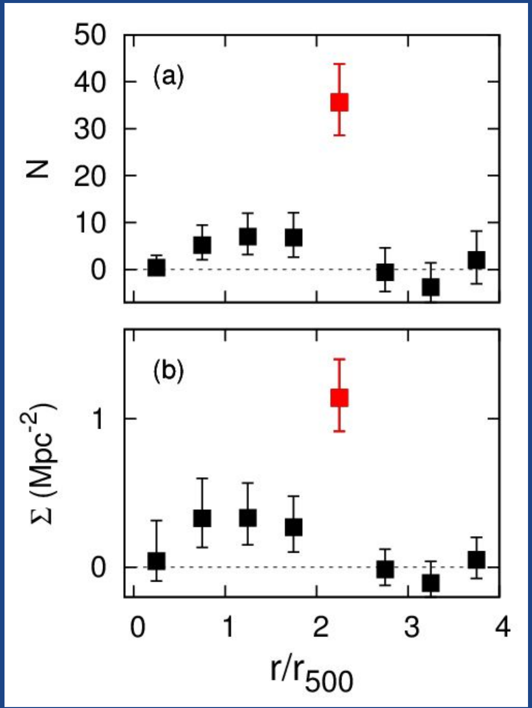
The XXL survey XXXV

Koulouridis et al. (2018b)

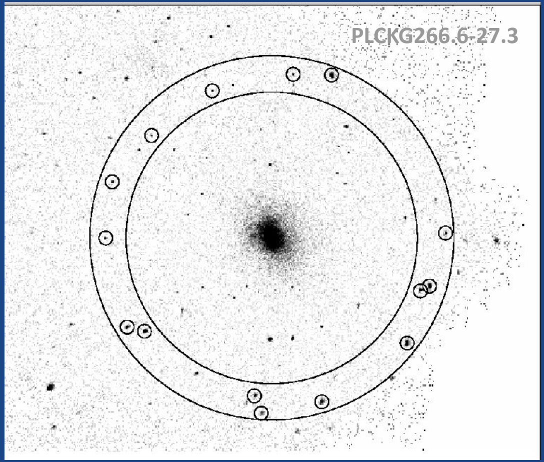


- Evidence for AGN triggering in the cluster outskirts (1-2 r_{500}, 95% confidence)
- Ram pressure stripping towards the cluster centre but less efficient than in massive clusters

High density of accreting super massive black holes in the outskirts of distant galaxy clusters



Top panel: distribution of X-ray point sources in galaxy clusters as a function of radius. **Bottom panel:** total surface density of X-ray point sources divided by the optical galaxy profile.

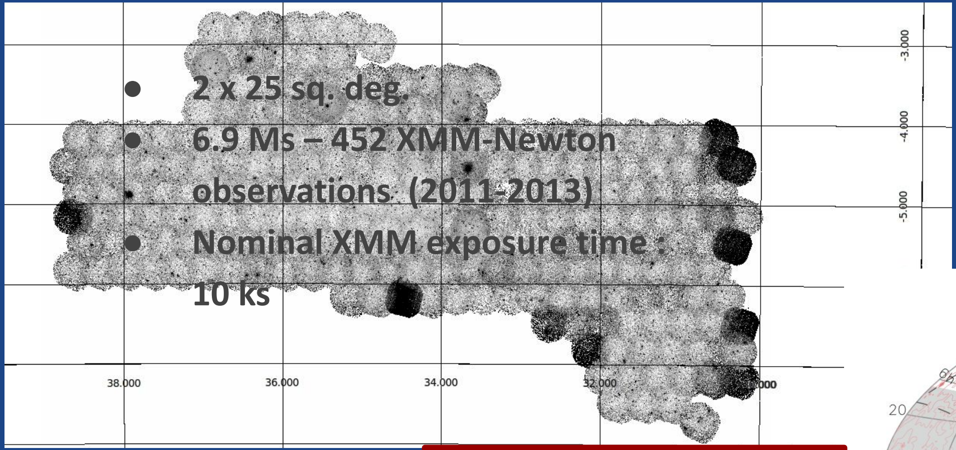


Example of an excess of X-ray point-sources in the outskirts of a massive clusters at z~1

A significant excess of X-ray point-sources is found in the outskirts of clusters. This can be due to the high density of galaxies that leads to a higher merging rate and thus AGNs, or to the presence of in-falling small groups from fillaments where galaxies have already been pre-processed.

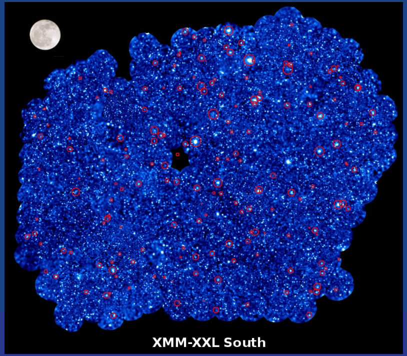
E. Koulouridis & I. Bartalucci, A&A, 2019

XXL-Hyper Suprime Cam (HSC-Subaru Telescope) joint project



- 2 x 25 sq. deg.
- 6.9 Ms – 452 XMM-Newton observations (2011-2013)
- Nominal XMM exposure time : 10 ks

XXL North



- ➔ Morphology?
- ➔ Merging fraction?
- ➔ AGN type/ Obscuration?

- ➔ XXL+HSC North → deep photometry
- ➔ properties+morphology of Xray AGN in clusters

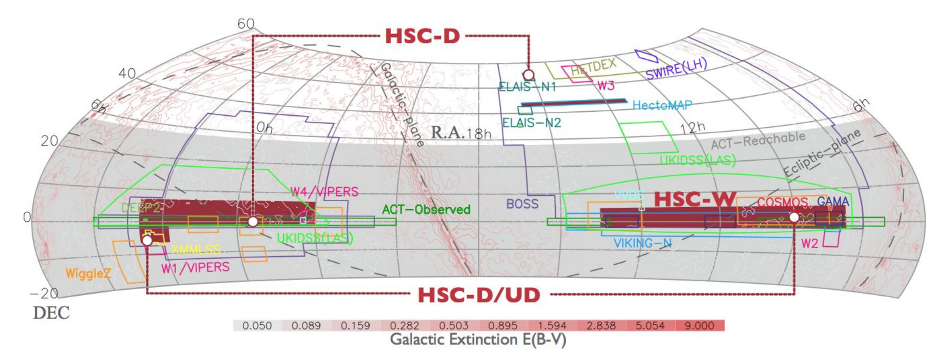
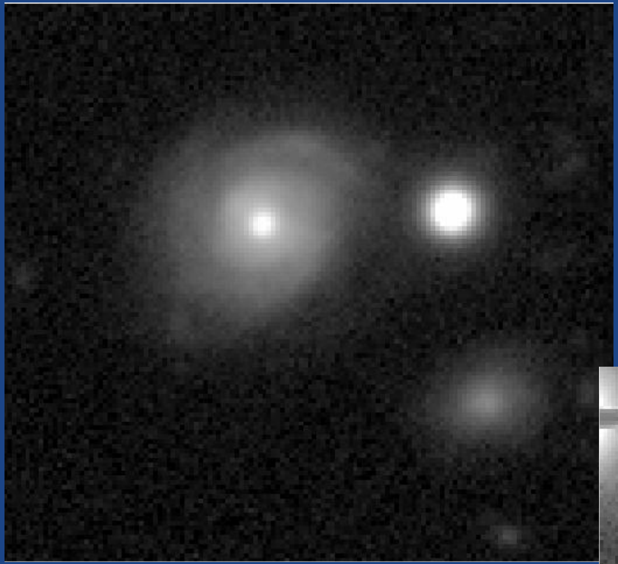
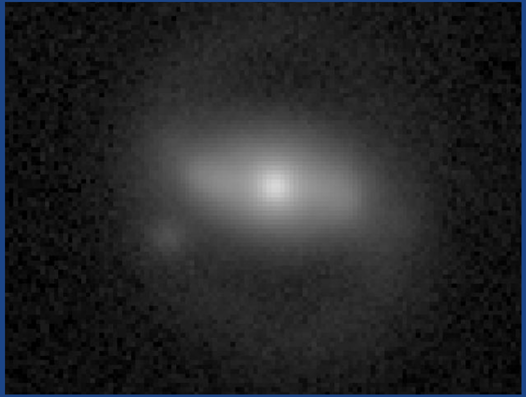
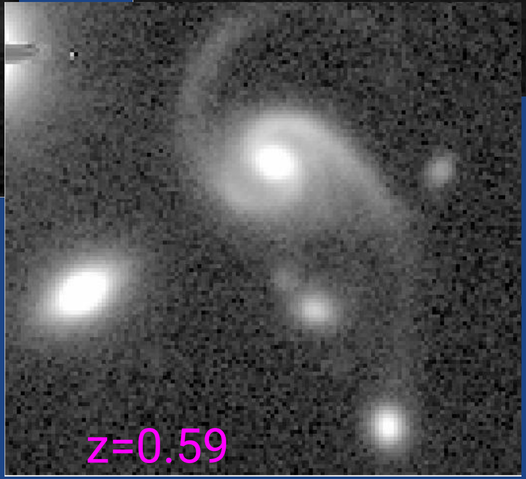


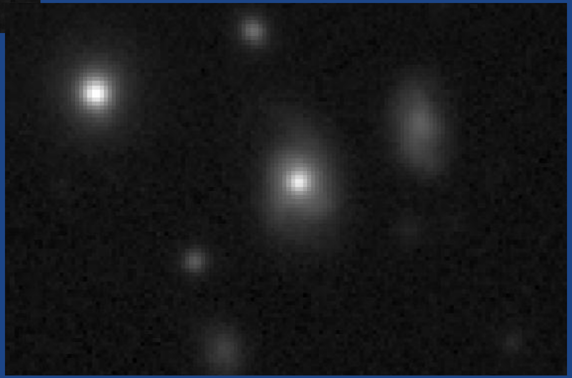
Figure 11: The location of the HSC-Wide, Deep (D) and Ultradeep (UD) fields on the sky in equatorial coordinates. A variety of external data sets and the Galactic dust extinction are also shown. The shaded region is the region accessible from the CMB polarization experiment, ACTPol, in Chile.

AGN host morphology with HSC in XXL north









HSC i-band

Morphology of the host: Merging fraction

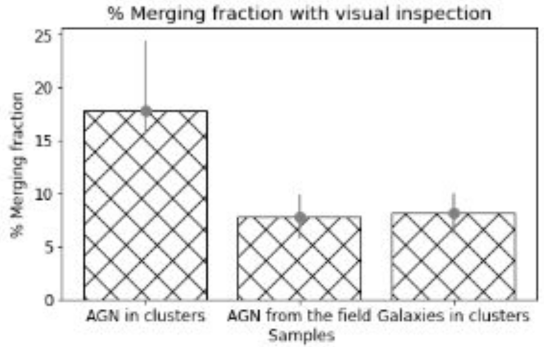
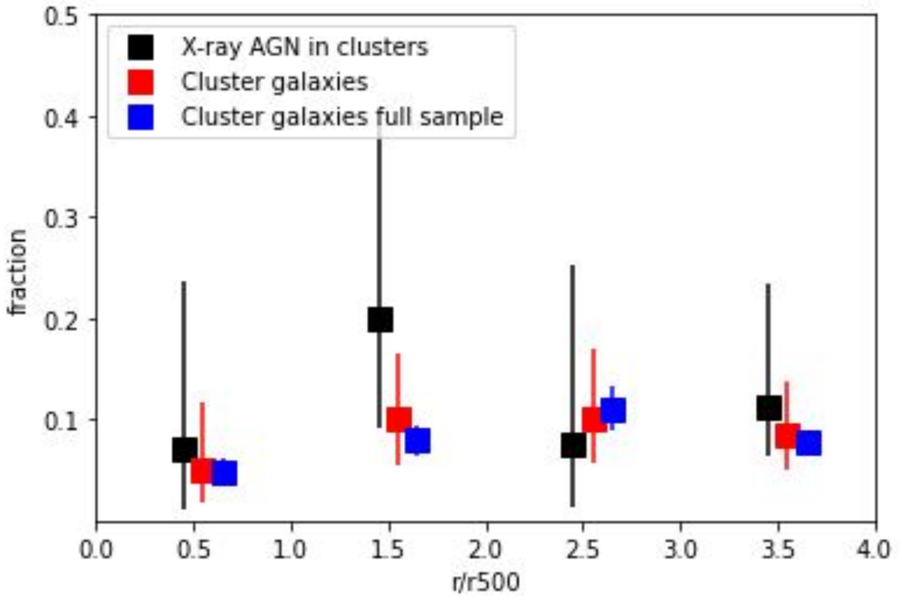
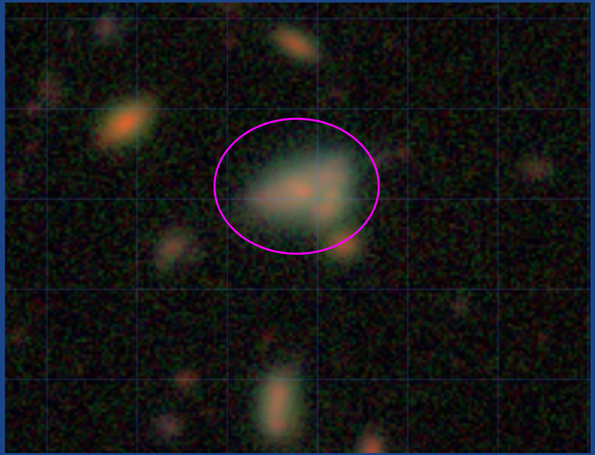
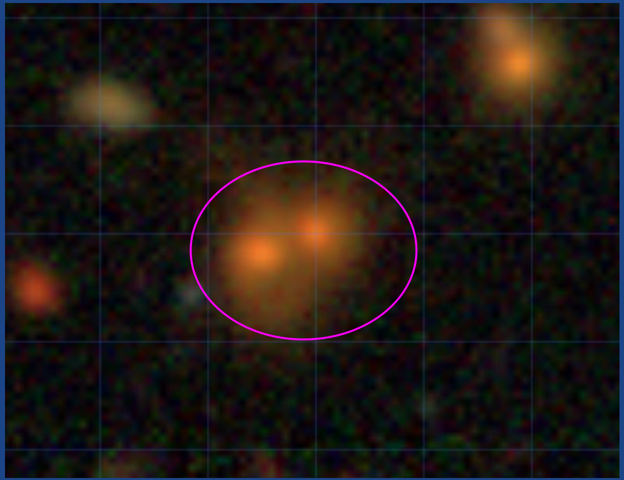


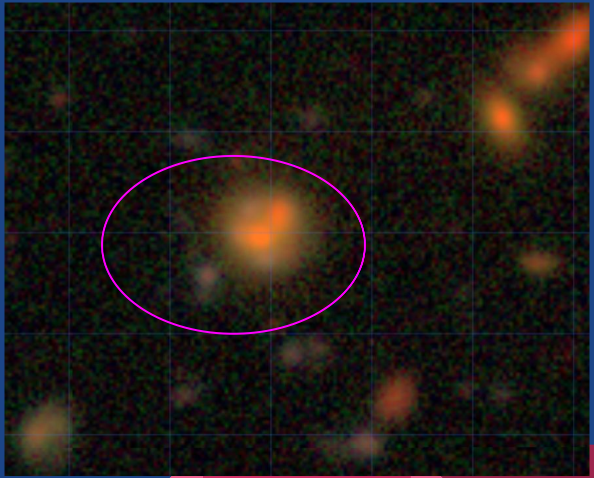
Fig. 3: Fraction of merging X-ray AGN in clusters (main sample) in comparison with the fraction of merging cases detected in control samples (iii) and (iv). Error bars indicate the 1σ confidence limits for small numbers of events (Gehrels 1986). A significant excess in the merging fraction is found at the 95% confidence level only in the sample of the X-ray AGN in clusters.



Xray AGN in clusters: Merging examples







the role of infalling groups, ram pressure stripping, cluster mass and dynamical state

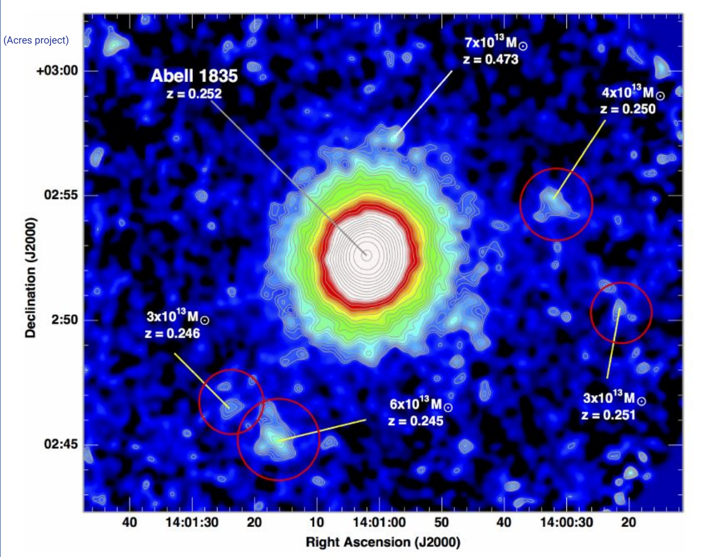
E. Koulouridis, A. Gkini, E. Drigga 2024

Name	RA(J2000)	Dec(J2000)	Redshift $\langle z \rangle$	$M_{200,m}$ $10^{14} h^{-1} M_\odot$	Infalling groups?	Low entropy core?
Abell 68	00:37:06.84	+09:09:24.28	0.251	$8.39^{+2.00}_{-1.64}$	Y	N
ZwCl 0104.4+0048	01:06:49.50	+01:03:22.10	0.253	$2.98^{+2.21}_{-1.26}$	N	Y
Abell 209	01:31:53.45	−13:36:47.84	0.209	$17.01^{+3.70}_{-2.93}$	Y	N
Abell 383	02:48:03.42	−03:31:45.05	0.189	$6.90^{+2.18}_{-1.64}$	N	Y
Abell 586	07:32:20.22	+31:37:55.88	0.171	$8.32^{+3.54}_{-2.32}$	N	N
Abell 611	08:00:56.81	+36:03:23.40	0.286	$11.77^{+2.77}_{-2.35}$	Y	N
Abell 697	08:42:57.58	+36:21:59.54	0.282	$14.22^{+6.14}_{-3.73}$	Y	N
ZwCl 0857.9+2107	09:00:36.86	+20:53:39.84	0.234	$3.52^{+1.97}_{-1.39}$	N	Y
Abell 963	10:17:03.65	+39:02:49.63	0.204	$9.46^{+2.20}_{-1.79}$	Y	Y
Abell 1689	13:11:29.45	−01:20:28.32	0.185	$13.15^{+2.32}_{-1.97}$	N	N
Abell 1758	13:32:33.50	+50:30:31.61	0.279	$7.22^{+2.42}_{-1.83}$	Y	N
Abell 1763	13:35:18.07	+40:59:57.16	0.232	$22.89^{+5.94}_{-4.32}$	Y	N
Abell 1835	14:00:52.50	+02:52:42.64	0.252	$12.27^{+2.75}_{-2.28}$	Y	Y
Abell 1914	14:25:59.70	+37:49:41.63	0.167	$12.51^{+3.55}_{-2.65}$	Y	N
ZwCl 1454.8+2233	14:57:15.11	+22:20:34.26	0.257	$6.28^{+6.10}_{-2.69}$	Y	Y
Abell 2219	16:40:22.56	+46:42:21.60	0.226	$15.17^{+4.53}_{-3.16}$	Y	N
RXJ 1720.1+2638	17:20:10.14	+26:37:30.90	0.160	$7.23^{+3.46}_{-2.26}$	Y	Y
RXJ 2129.6+0005	21:29:39.88	+00:05:20.54	0.234	$7.35^{+4.11}_{-2.48}$	N	Y
Abell 2390	21:53:36.85	+17:41:43.66	0.229	$13.75^{+2.91}_{-2.42}$	Y	Y
Abell 2485	22:48:31.13	−16:06:25.60	0.247	$7.56^{+2.27}_{-1.74}$	N	N

Bianconi et al. 2021

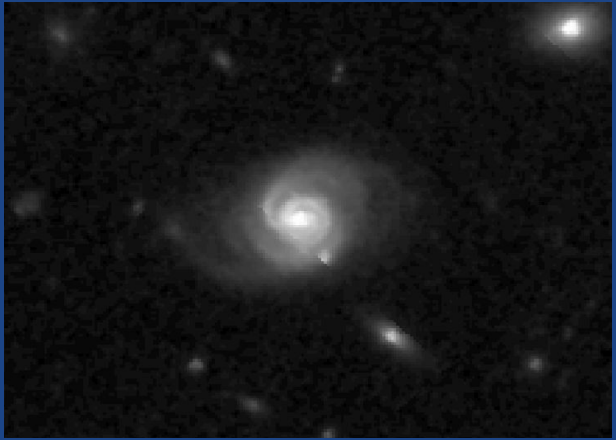
90% complete spectroscopy of cluster galaxies out to 3xR200 with Hectospec Arizona Cluster Redshift Survey (ACReS)

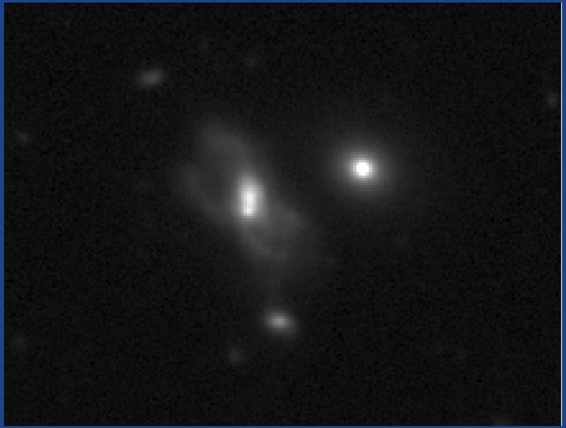
X-ray AGNs with Lx>10e42 from 4XMM-DR10 catalogue out to ~R200 with spectroscopic redshifts

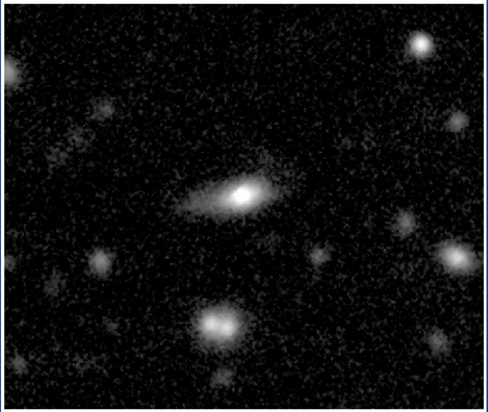
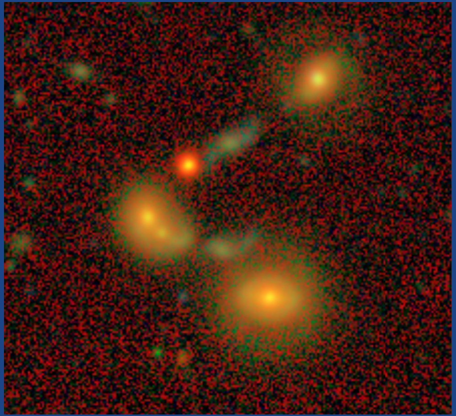


Haines et al. 2018

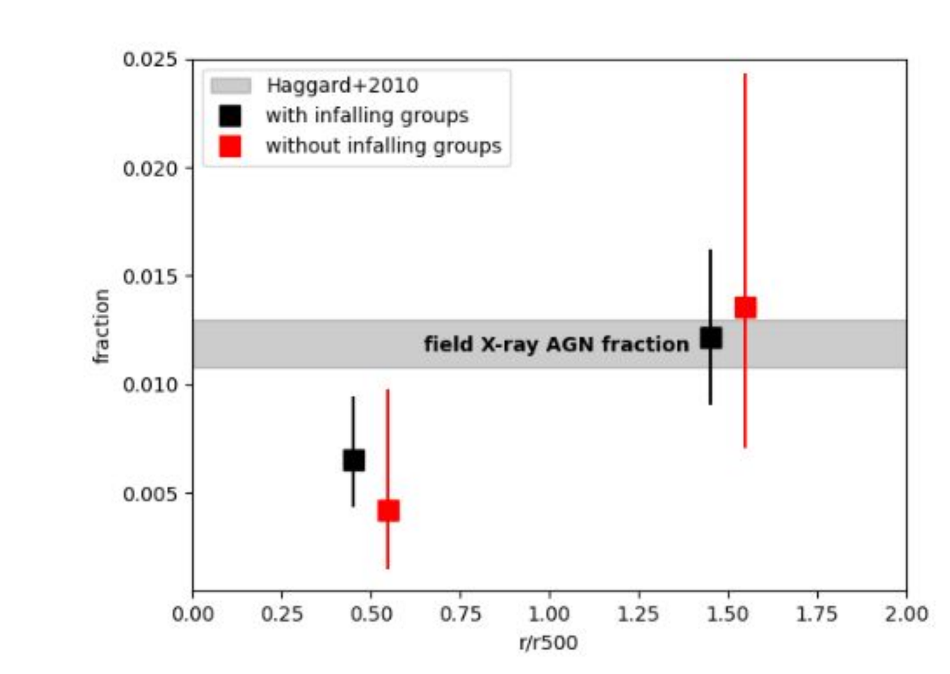
Morphological classification

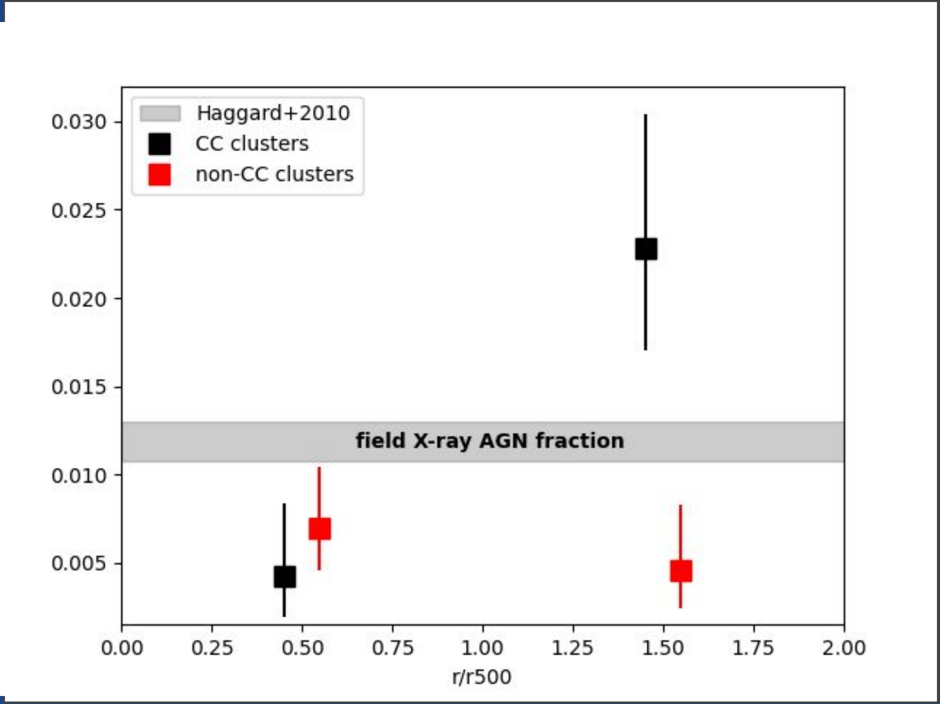




The role of infalling groups & cluster dynamical state

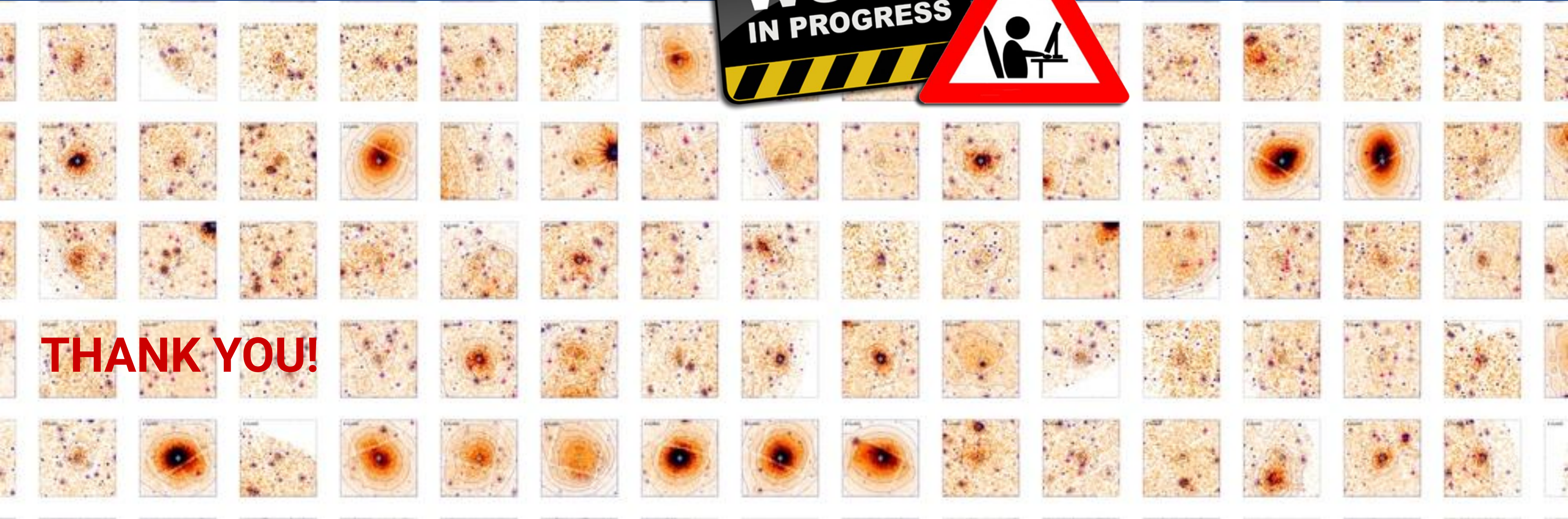




A significant excess of X-ray AGN is found in the outskirts of relaxed clusters, compared both to non-relaxed clusters and to the field

The X-CLASS survey: A catalogue of 1646 X-ray-selected galaxy clusters up to z~1.5

E. Koulouridis, N. Clerc, T. Sadibekova + the XCLASS collaboration (2021)



THANK YOU!