Multi-wavelength study of the environment of AGNs using XMM-Newton and Gaia data

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Gaia Workshop, Athens, September 2022

AGN selection

- **Optical** selection is biased against obscured AGNs
- **Mid-IR and optical** identification can be hampered by the host galaxy’s emission, and this is a known bias against AGNs accreting at low fractions of the Eddington limit
- **X-ray** selection is more robust against obscuration
- **Mid-IR and X-ray** observations are usually space based because of the Earth’s atmosphere, though the latter require significantly longer exposure time

- + The WISE mission imaged the entire sky in four mid-IR bands, centred at 3.4, 4.6, 12, and 22 μm, referred to as W1, W2, W3, and W4, respectively.
- + It was shown (e.g. Lacy et al. 2004; Stern et al. 2005, 2012; Nikutta et al. 2014) that AGNs tend to have redder W1 − W2 colours relative to stars and inactive, low-redshift galaxies.
- − Generally poor imaging resolution of mid-IR data (~6"in WISE W1 and W2 bands).
- − Some non-AGNs have similarly red W1 − W2 colours as AGNs, which are difficult to distinguish with mid-IR data alone.

AGN triggering in the outskirts of galaxy clusters

Elias Koulouridis

Iacopo Bartalucci, Anamaria Gkini

XXL collaboration

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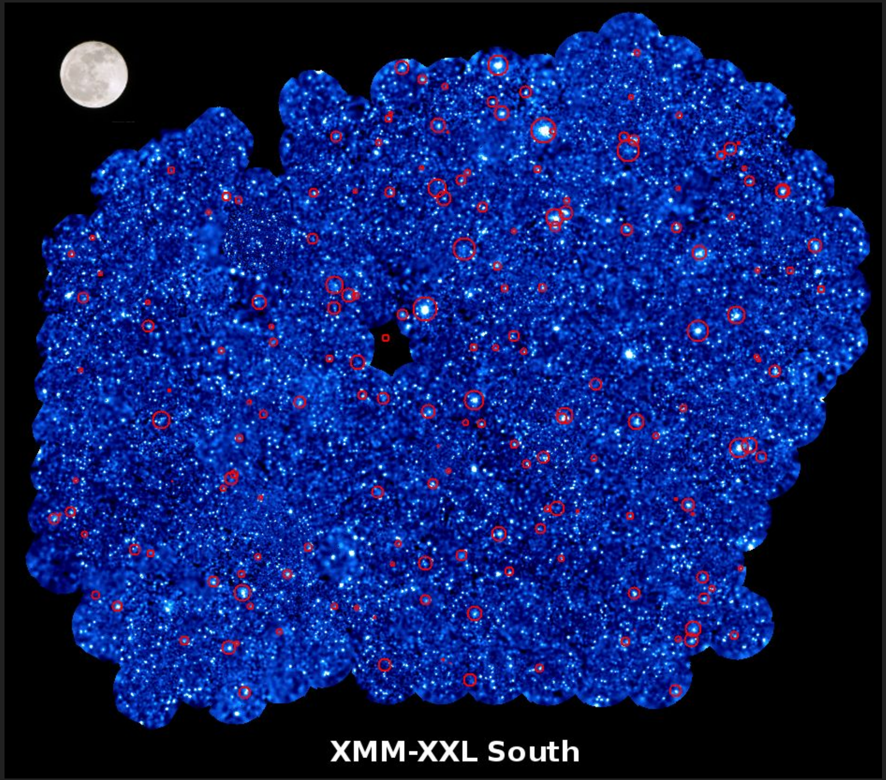
Studying AGNs in galaxy clusters using X-rays

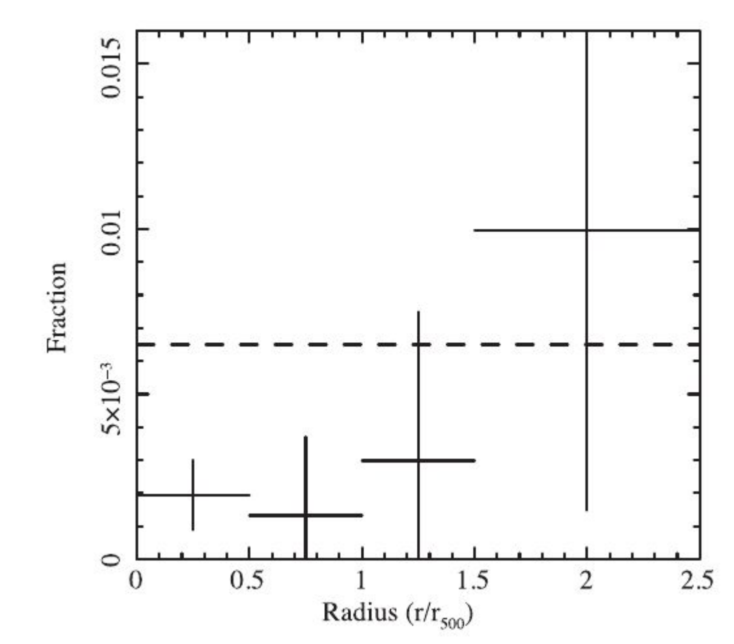
The XXL survey

XMM-Newton VLP

- 2 x 25 sq. deg.
- 6.9 Ms – 452 XMM observations (2011-2013)
- Nominal XMM exposure time : 10 ks
- ESO LP and numerous associated surveys from UV to 74 MHz



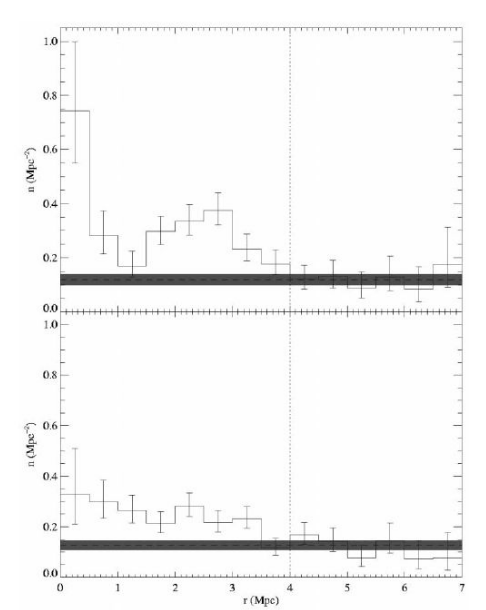
AGN & ram pressure in massive galaxy clusters



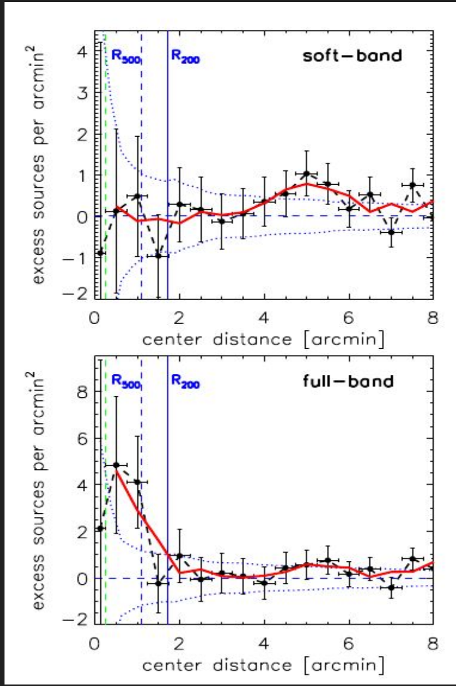
- Ehlert et al. (2013, 2014): the X-ray AGN fraction in the central regions of 42 of the most massive known clusters is about three times lower than the field value.

- Martini et al. (2007): 40% lower
- Koulouridis & Plionis (2010): ~3x lower
- Haines et al. (2012): 40% lower

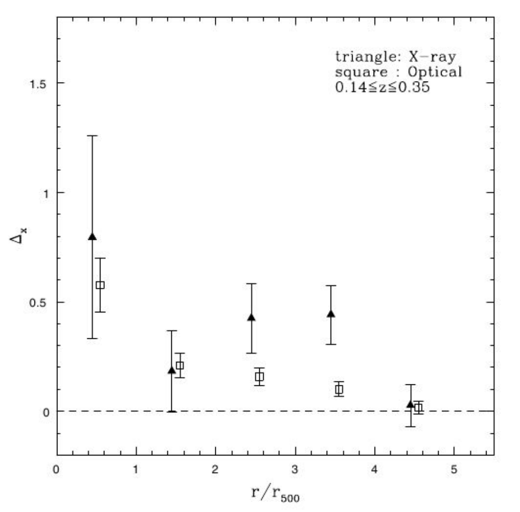
X-ray AGN in the outskirts of clusters



Ruderman & Ebeling (2005)
z=0.3-0.7



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

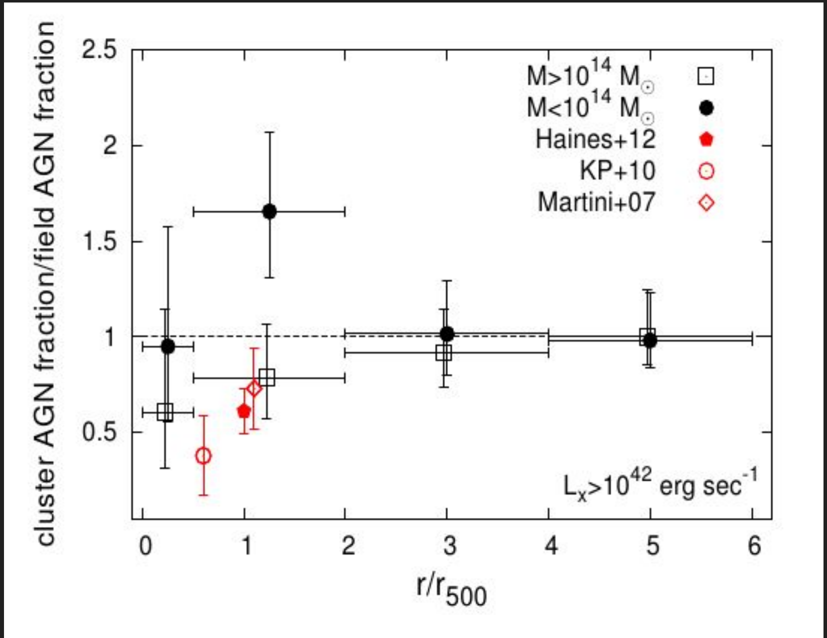


Koulouridis et al. (2014)
z=0.14-1.0

The role of cluster mass in AGN activity

The XXL survey XXXV

Koulouridis et al. (2018)

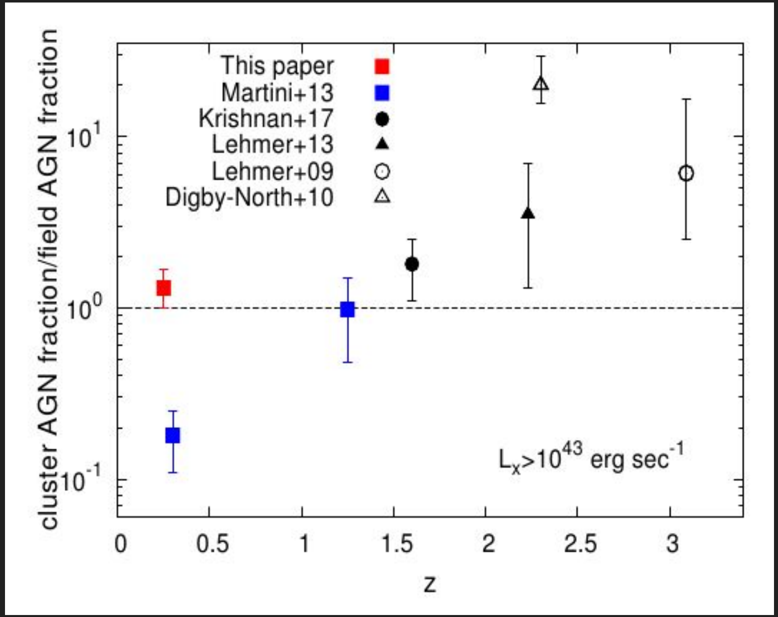


- Evidence for AGN triggering in the cluster outskirts (1-2 r_{500}, 95% confidence)
- Ram pressure stripping towards the cluster centre but less efficient than in massive clusters

The role of cluster mass in AGN activity

The XXL survey XXXV

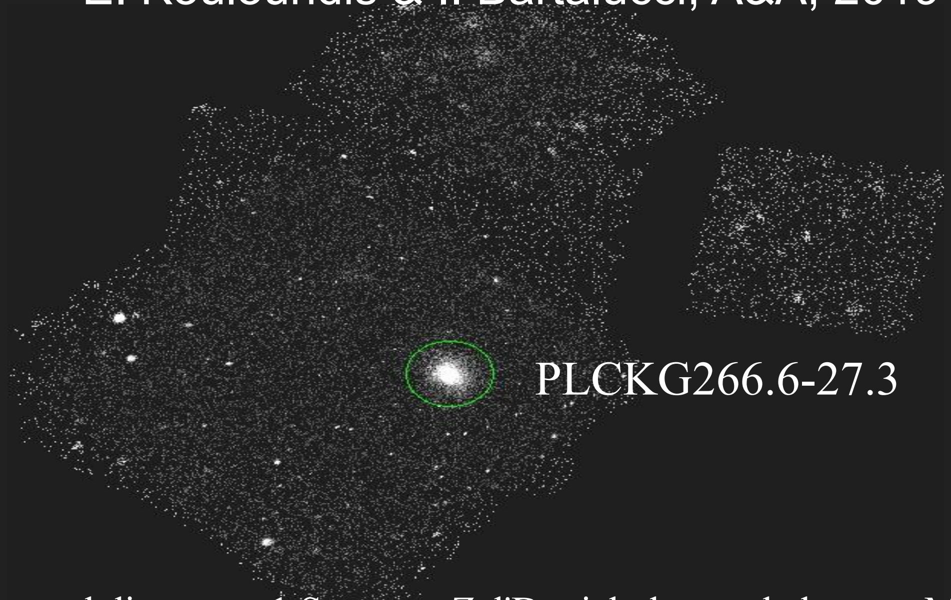
Koulouridis et al. (2018)



- AGN density consistent with clusters and proto-clusters above z=1.
- Probable AGN dependance on the cluster mass

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

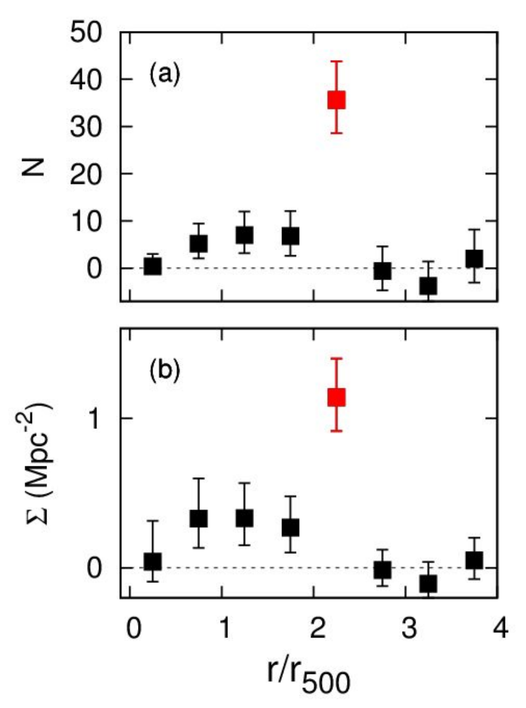
E. Koulouridis & I. Bartalucci, A&A, 2019

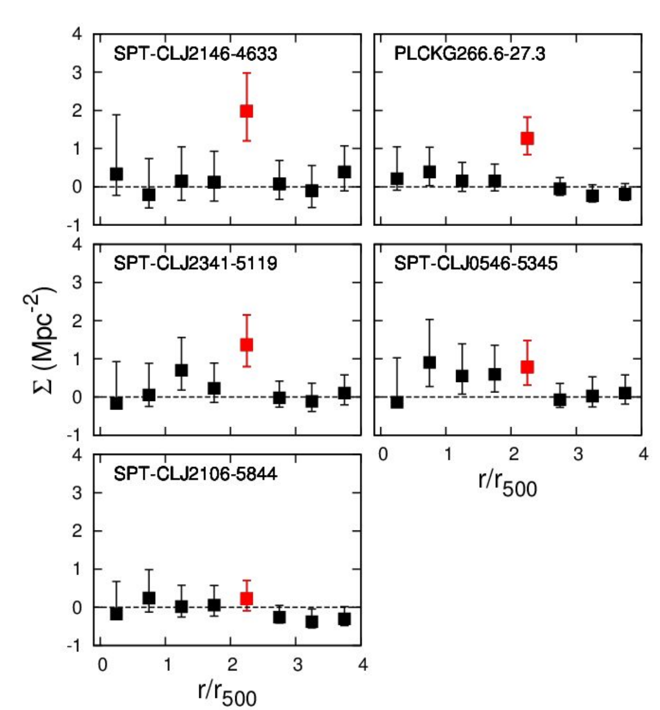


- The five most massive and distant, z~1 Sunyaev-Zel'Dovich detected clusters, M_{500}> $5x10^{14}$ Mo, in the *Planck* and *SPT* surveys.
- They are covered by deep X-ray observations that have yielded accurate cluster masses and the r_{500} radii (bartalucci18)

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

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





X-ray AGNs in clusters with/out infalling groups

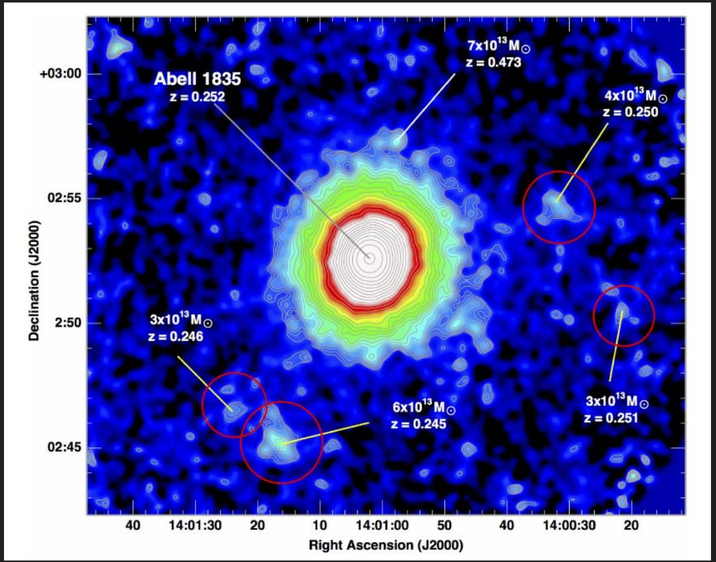
A. Gkini & E. Koulouridis (in prep.)

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

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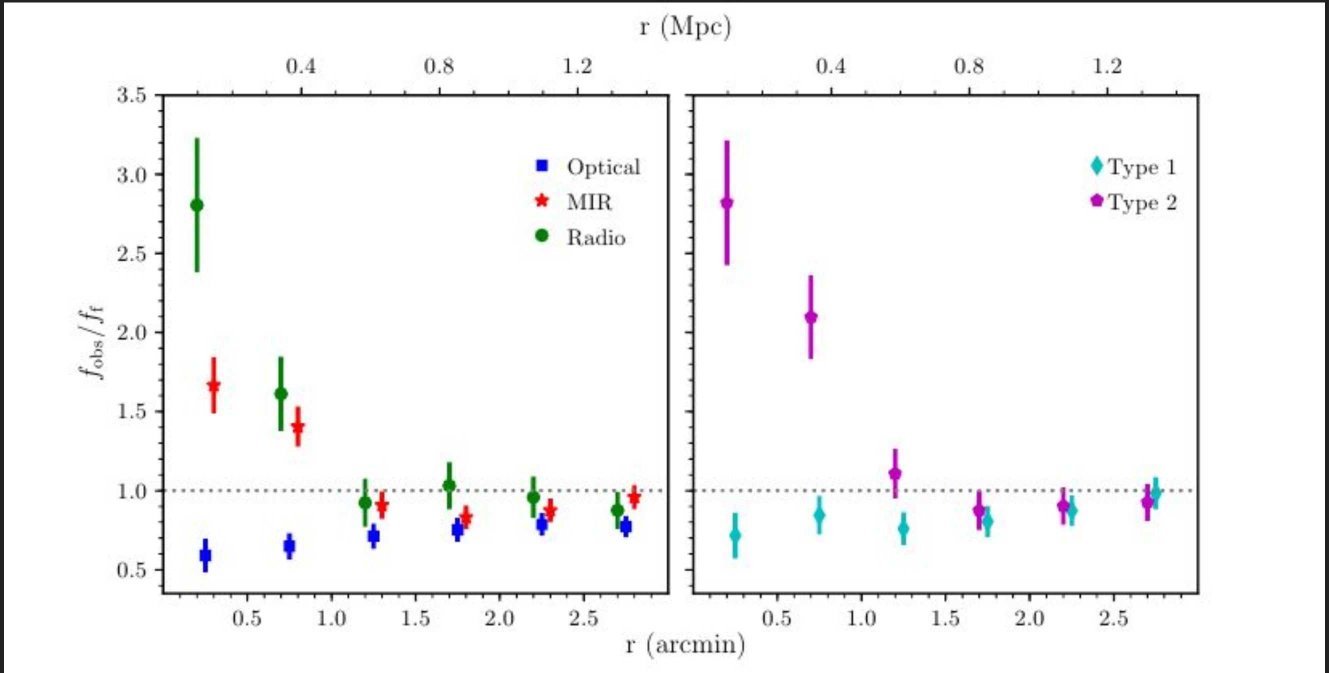
Optical, MIR, Radio AGN in the outskirts of clusters



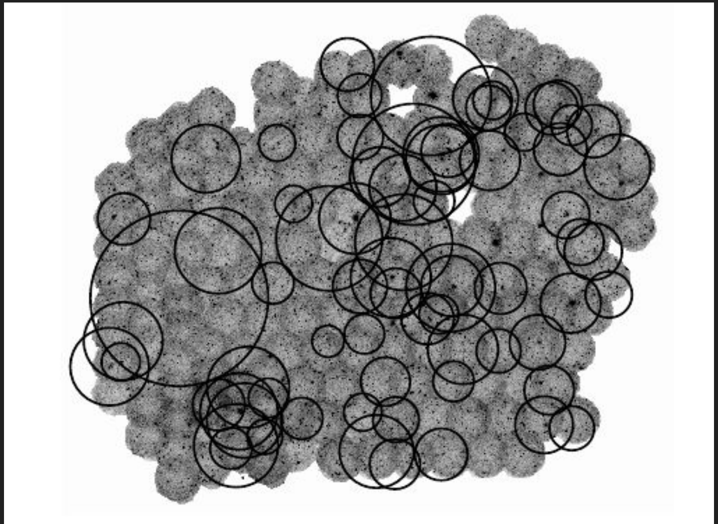
Mo et al. (2019)

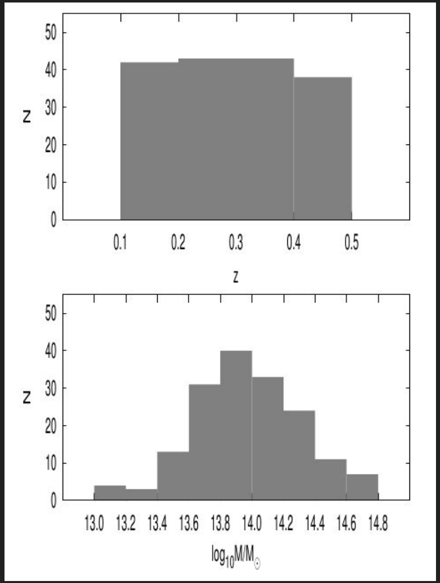
X-ray AGN in XXL galaxy clusters

The XXL survey XXXV

“The role of cluster mass in AGN activity”

Koulouridis et al. (2018b)



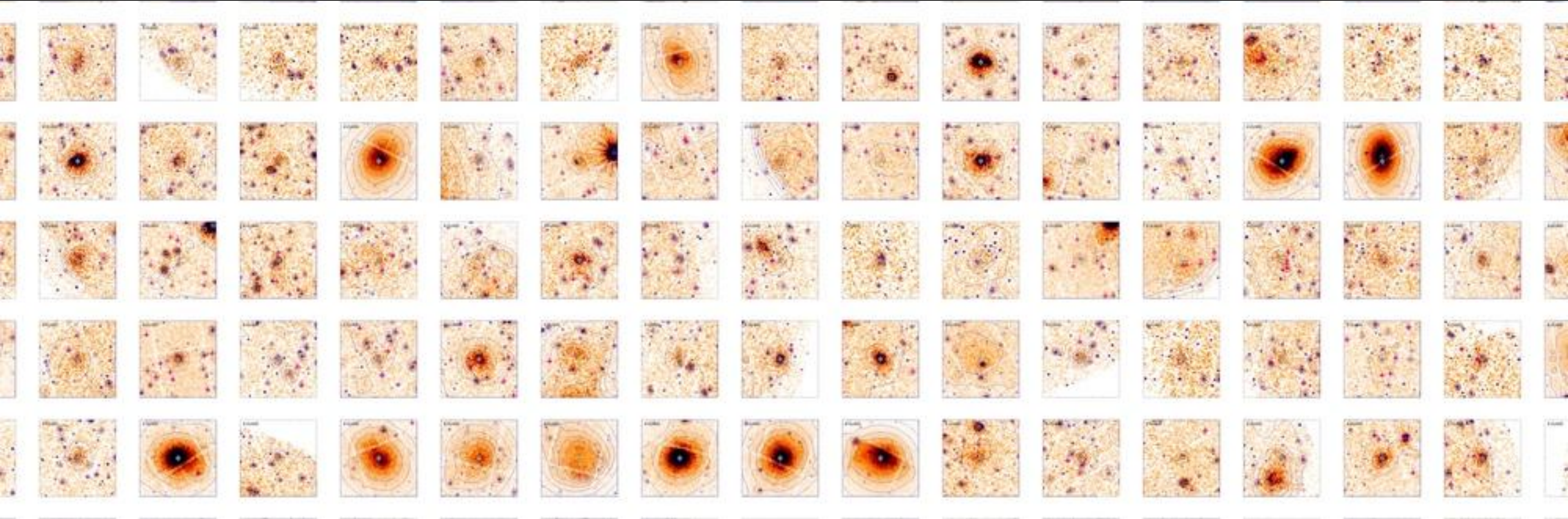


167 clusters with measured properties (Tx –> mass – r_{500} radius)

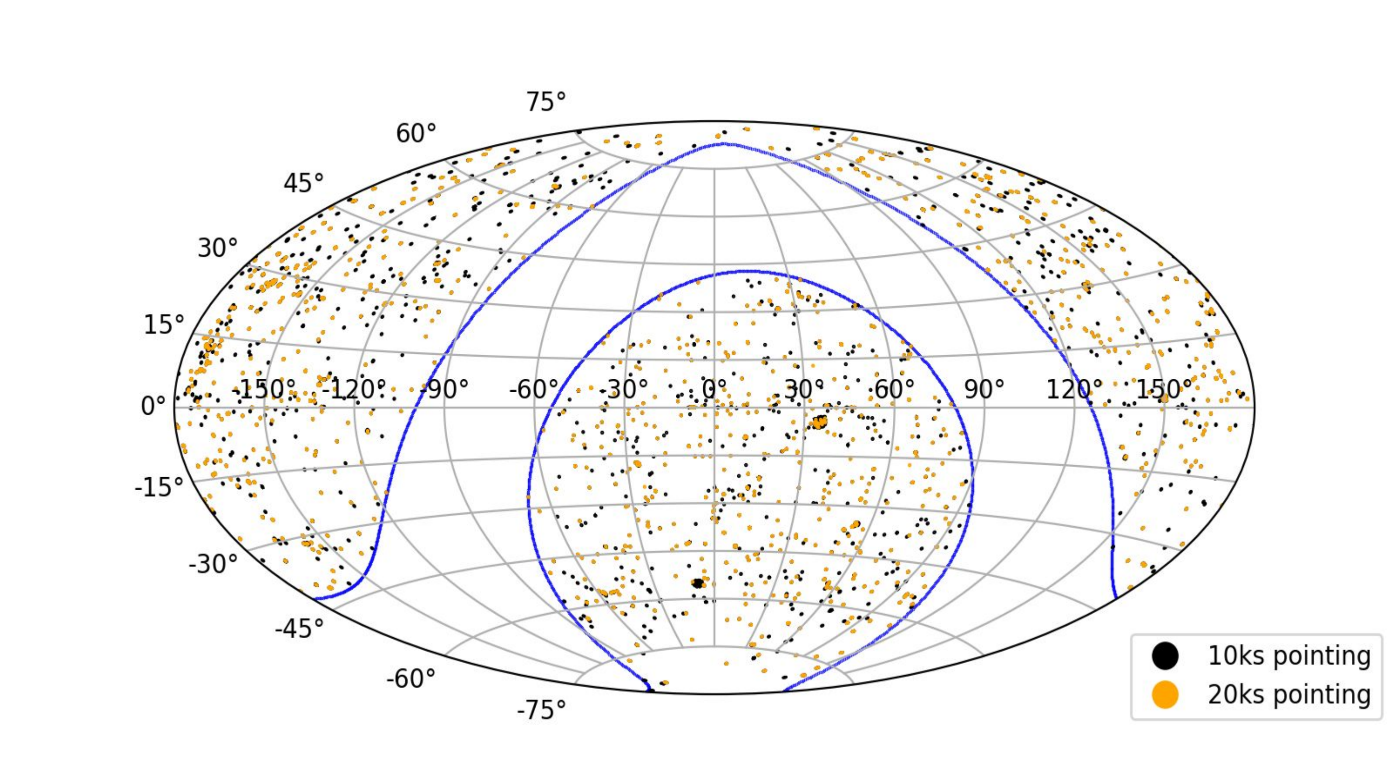
- X-ray AGNs with spectroscopically confirmed optical counterparts and Lx>10^{42} erg/s.
- High spectroscopic completeness. ~70% in the north, ~90% in the southern field.
- Largely unexplored mass range of poor and moderately rich clusters. The XXL sample is

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)



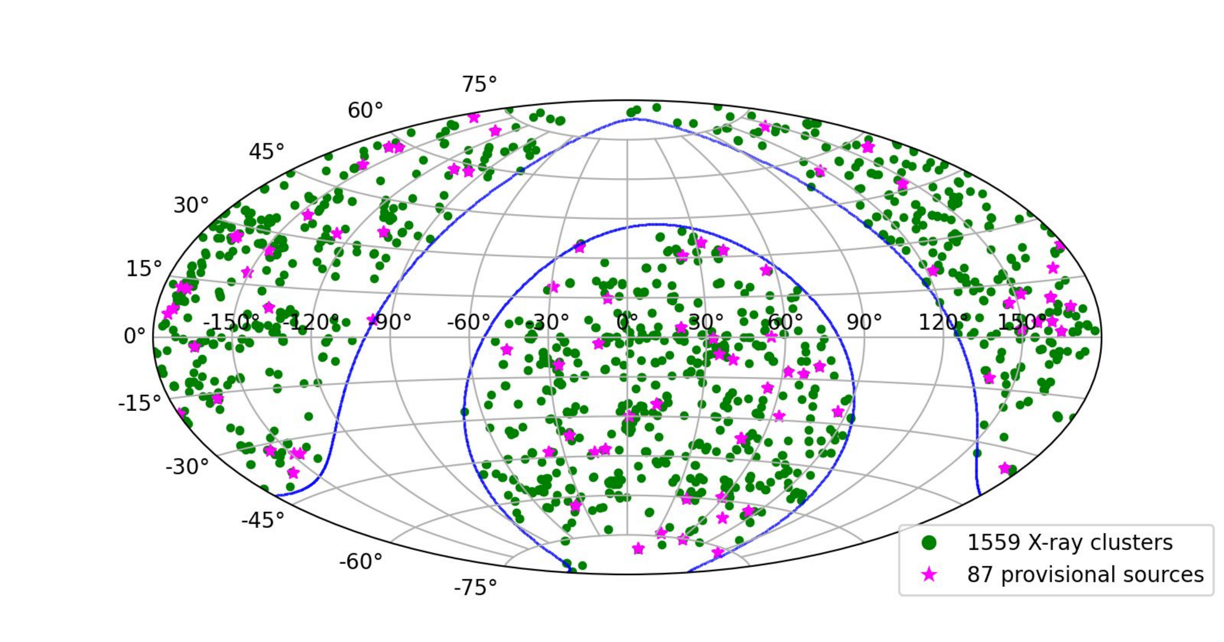
9333 XMM-Newton observations



2461 observations after a cut at 10 or 20 ks in order to facilitate the computation of the selection function

total area of 269 sq. degrees

The X-Class survey of X-ray detected galaxy clusters



Multiwavelength AGN selection + spectroscopic data is needed to disentangle the various effects of the dense environment on AGN activity

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Gaia DR2 + Wise selection (Shu+2019)

Shu+2019: AGN/non-AGN classification of more than 641 million sources in the Gaia–unWISE sample across the entire sky using astrometric and photometric data from Gaia and WISE.

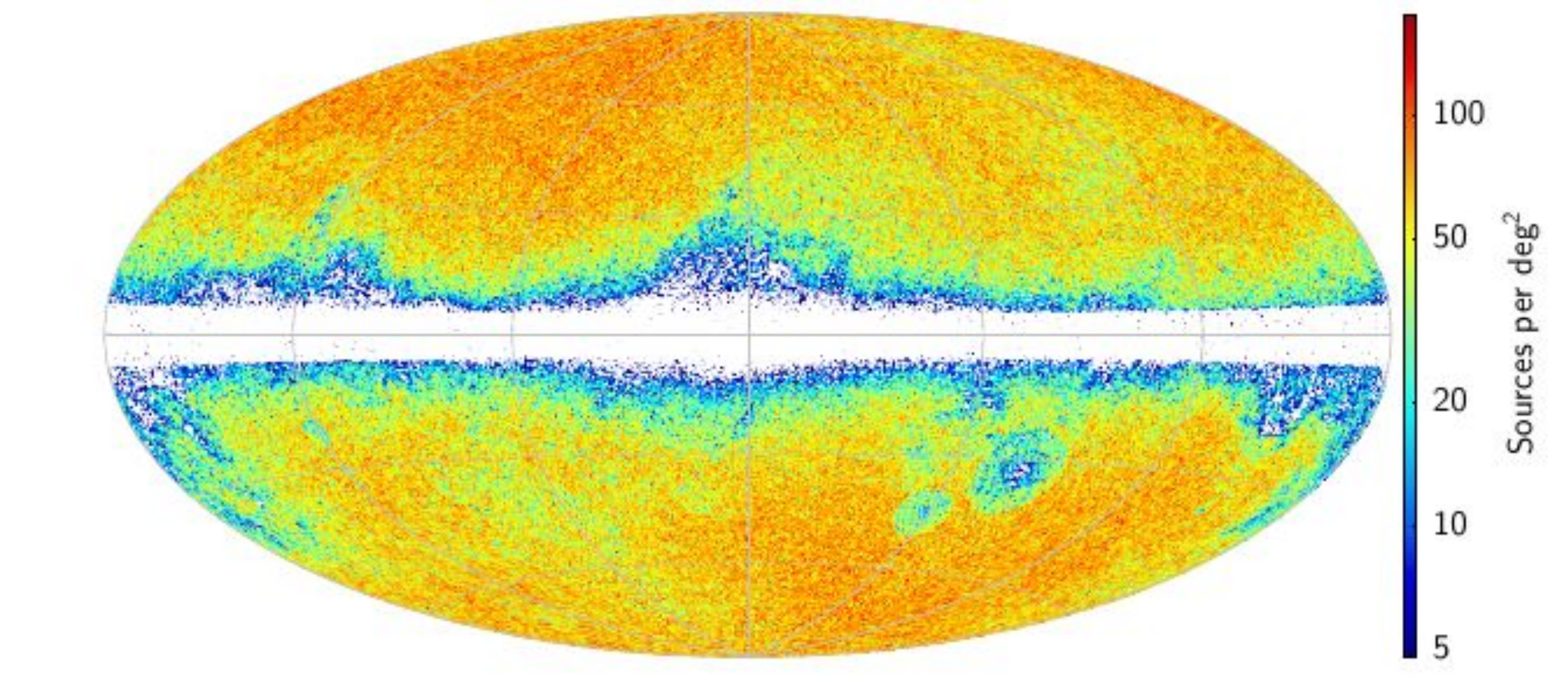
Result: ~2.2M high probability AGN candidates

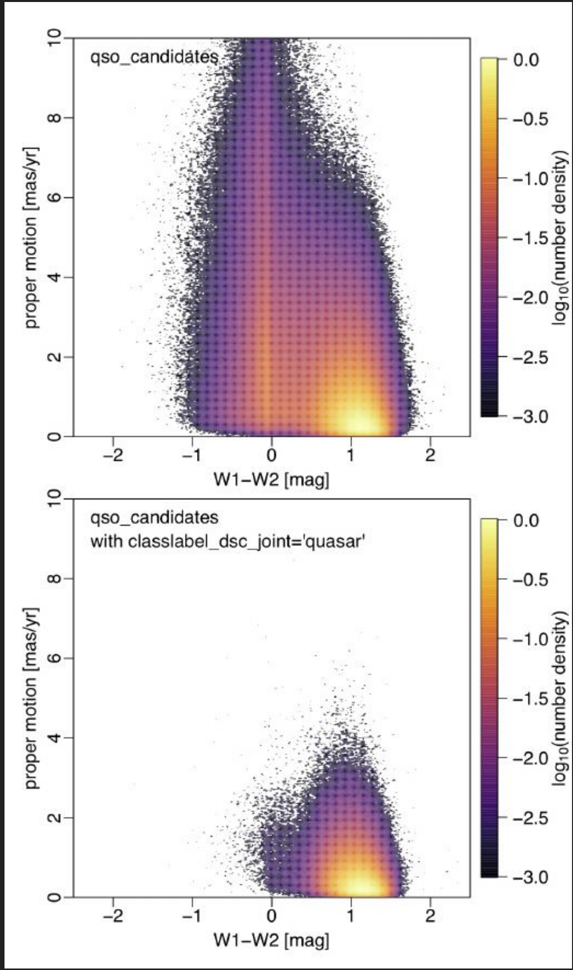
Cross-matching against a known AGN compilation including almost 29 million AGNs and AGN candidates with a matching radius of 5 arcsec at least ≈0.91 (0.52) million AGN candidates were new discoveries.

Comparing to WISE-only AGN selection techniques used in Stern et al. (2012) and Assef et al. (2018), the RF classifier achieves significantly better TPR and FPR when applied to the Gaia–unWISE sample.

	TPR	FPR
This work, $P_{RF} \geq 0.69$	98.10%	0.15%
This work, $P_{RF} \geq 0.94$	92.73%	0.08%
Stern et al. (2012)	84.03%	0.34%
Assef et al. (2018), C75	90.63%	0.58%
Assef et al. (2018), R90	60.67%	0.17%

DR3 catalogue of QSOs (~1.9M)





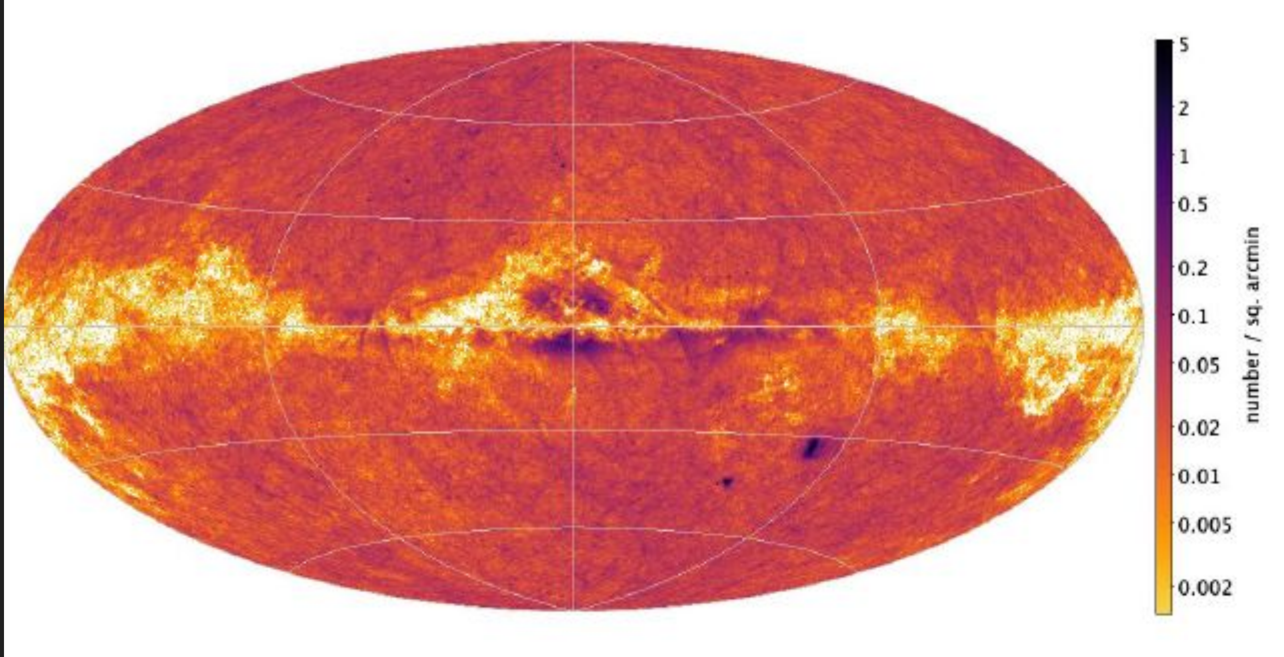
Gaia DR3 selection

- **TOP:** Gaia proper motion vs catWISE W1−W2 colour for all sources in the qso_candidates table
- **BOTTOM:** The subset with classlabel_dsc_joint = quasar.

The colour scale shows the density of sources on a log scale relative to the peak density.

Result: 0.5M QSOs

DR3 catalogue of galaxies

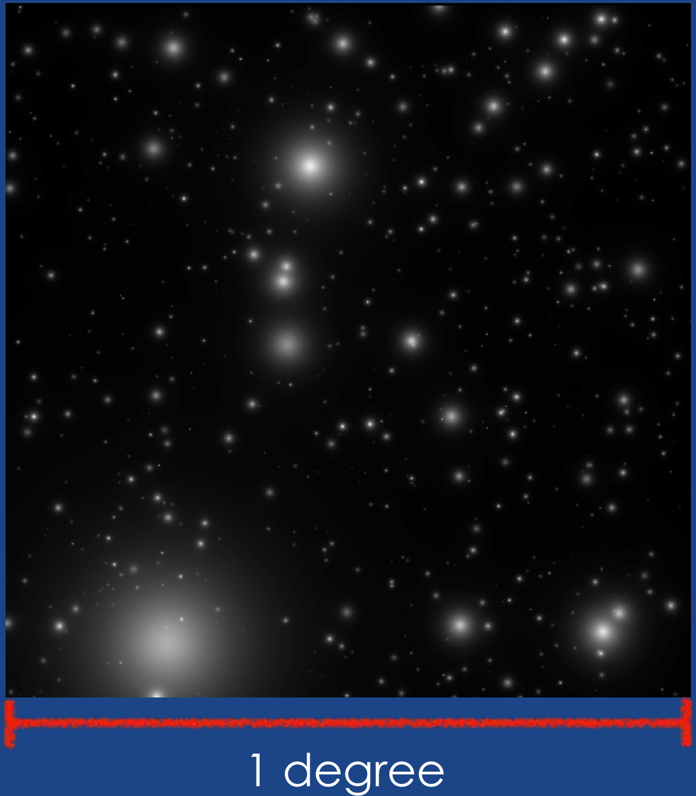


Galactic sky distribution of all the sources in the galaxy_candidates table

Simulating X-ray galaxy clusters and QSOs for cosmological applications

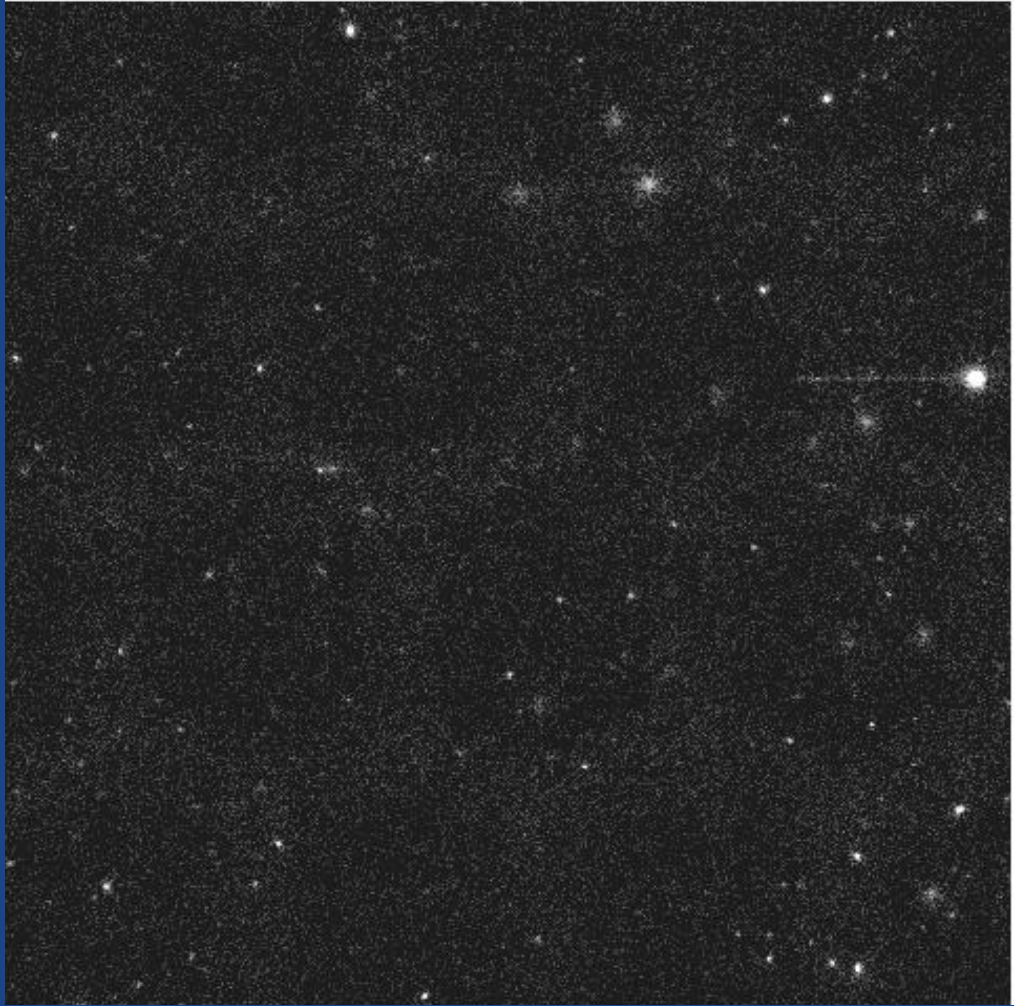
ICM emissivity map in the soft X-ray band [0.5-2] keV

- 1 square degree
- DMH > 1e+13 Mo (466 sources)
- z < 2.1



- 1 square degree
- DMH > 1e+13 Mo (466 sources)
- z < 2.1

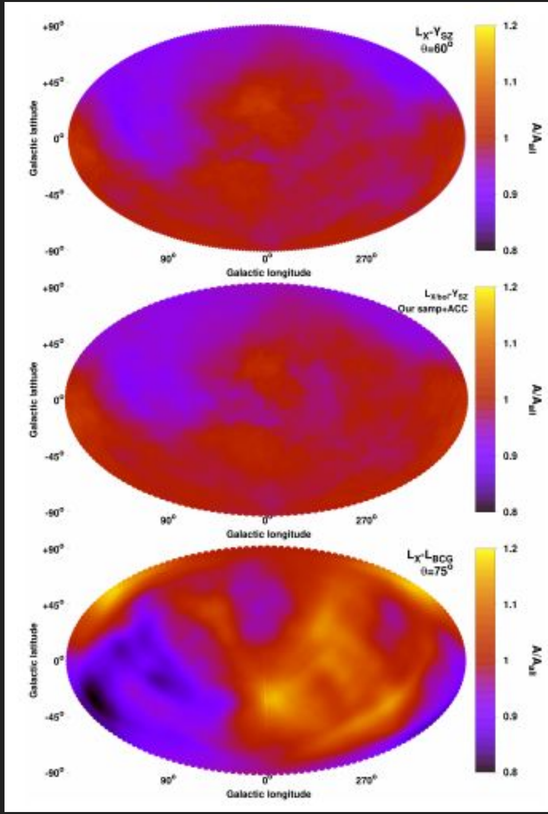
40 ks including AGNs



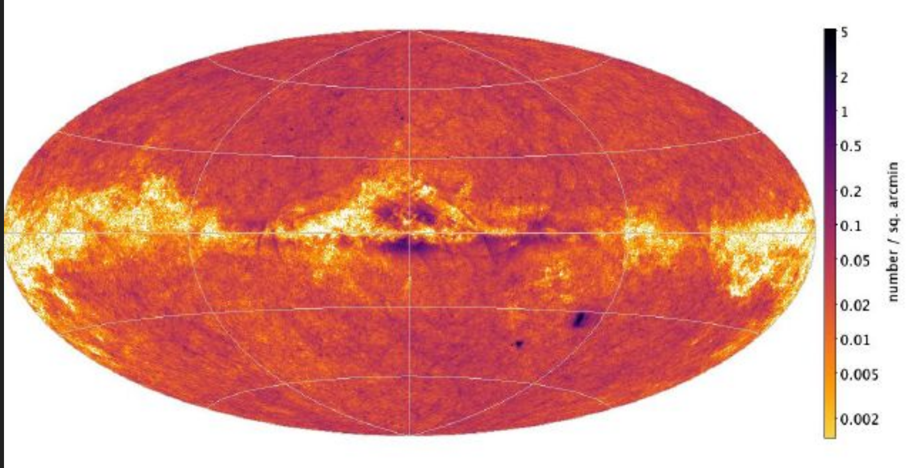
Testing cosmic isotropy with XCLASS scaling relations

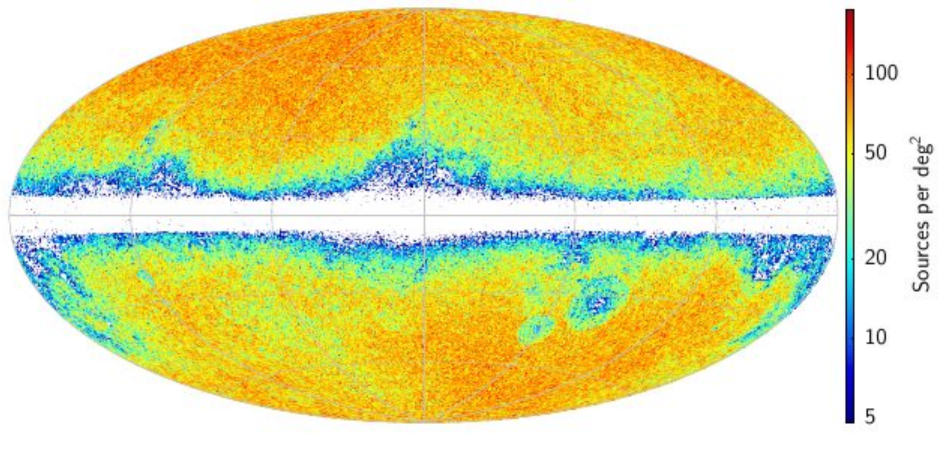
We will study the isotropy of Ho and the existence of bulk flows in the local Universe using the Lx-T and Ysz-T scaling relations for the XCLASS clusters. These two effects are imprinted in the directional behavior of these two scaling relations and one can put very tight constraints on the spatial variation of Ho.

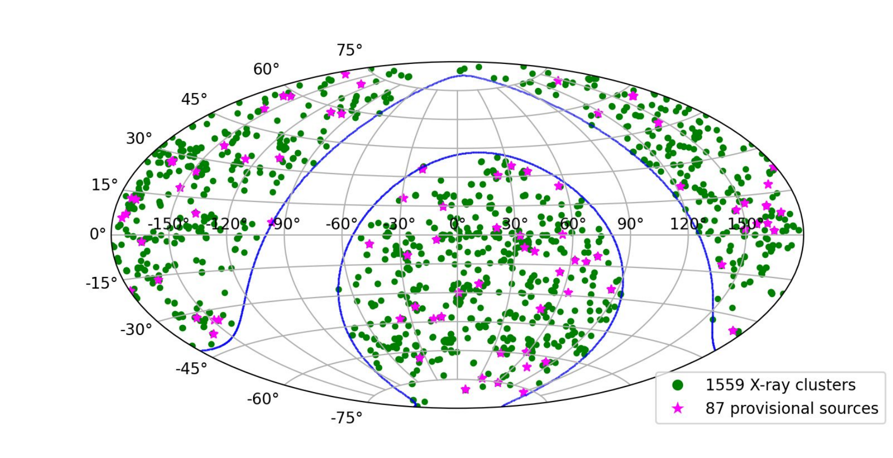
XCLASS will make a difference due to the **large number of clusters and the wide redshift range** it covers to help us understand better the previously detected anisotropies. **We will need reliable spectroscopic Tx measurements** for as many clusters as possible. As a complementary test, possible X-ray absorption effects beyond the well-known ones will be studied using the Lx-Ysz relation, as in Migkas+21.



Migkas+21







Thank you!!

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