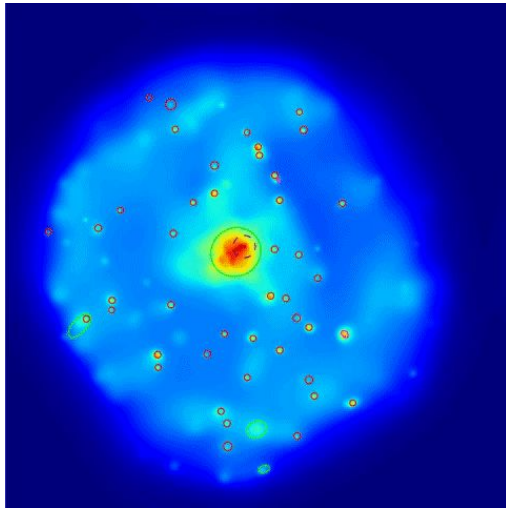


Cosmology with galaxy clusters, XCS and the Dark Energy Survey



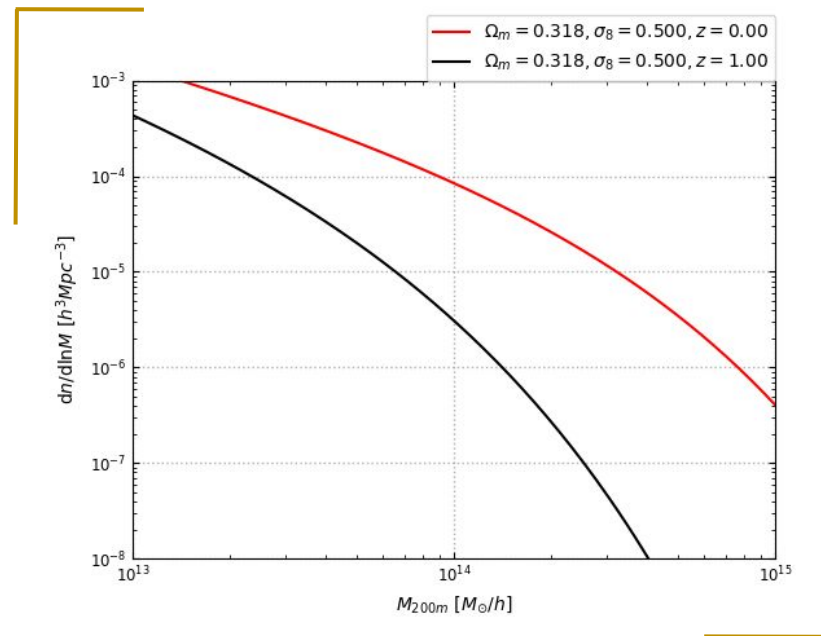
P. Giles* on behalf of XCS
and the DES Cluster
working group

Outline

- ❖ Light introduction to galaxy clusters
- ❖ XMM Cluster Survey (XCS) and the Dark Energy Survey (DES)
- ❖ XCS (no DES), XCS - DESY1, XCS - DESY3, DES cosmology
- ❖ The future
- ❖ Fireworks

Cosmology with galaxy clusters

- ❖ The halo mass function is sensitive to changes in cosmology.
- ❖ Derived analytically by Press and Schechter in 1974.
- ❖ Tinker et al. produced a simulation-calibrated mass function in 2008.
- ❖ By **finding galaxy clusters**, measuring **masses**, and finding the number of clusters per mass interval, we can infer cosmology.
- ❖ DES finds clusters with **redMaPPer**, and measures masses with weak lensing.
- ❖ **XCS' MOR** will provide an independent alternative to the DES MOR, and can act as a prior in our analysis.

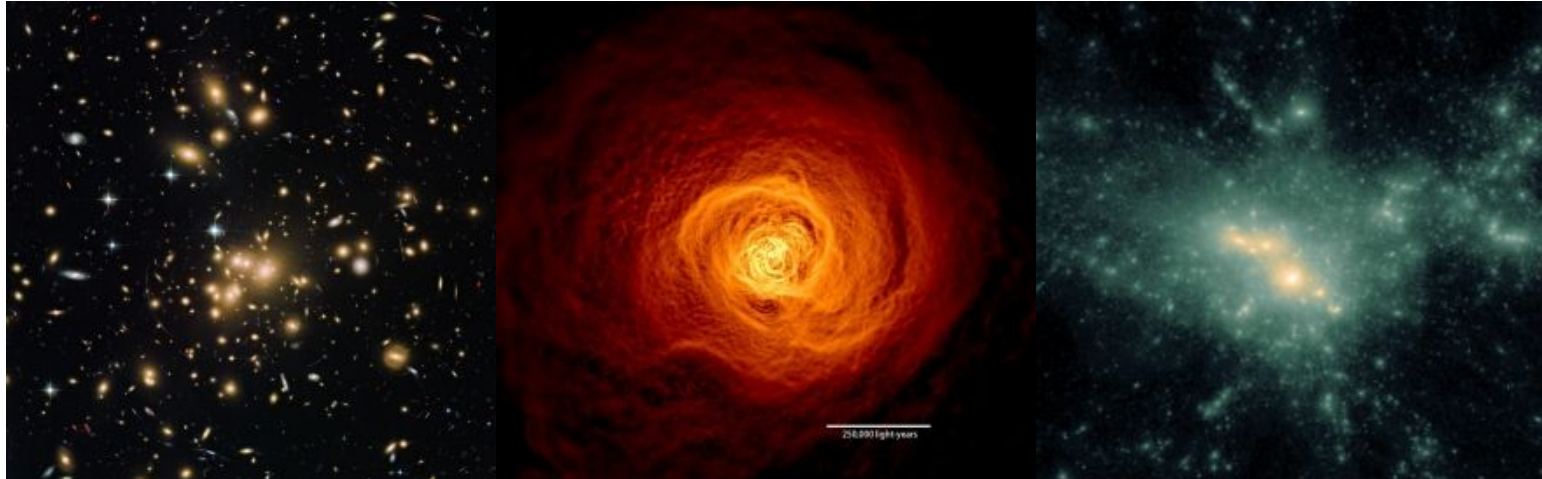


Galaxy clusters

Galaxies and Stars (~3%)

ICM (~12%)

DM Halo (~85%)

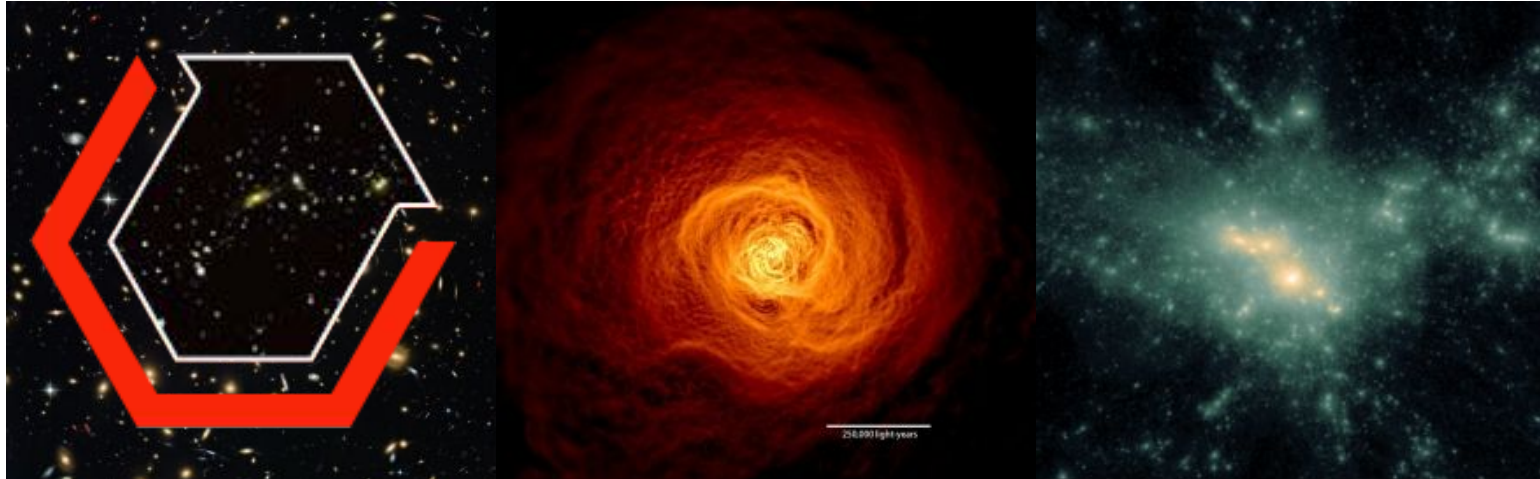


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Galaxy clusters

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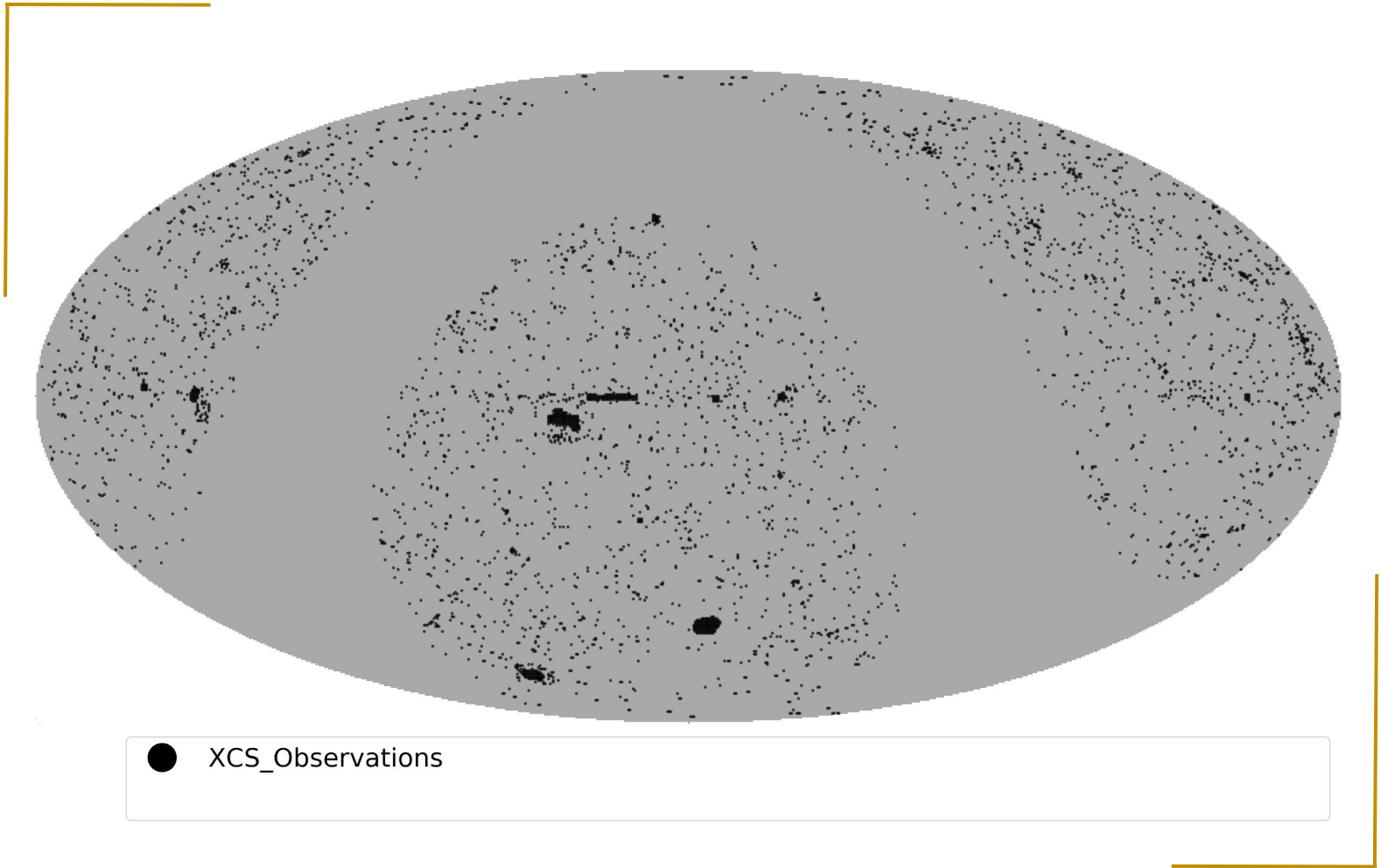
DM Halo (~85%)



The XMM Cluster Survey

- ❖ 1000 sq.deg (non contiguous) single band (soft X-ray) imaging survey
 - ~330,000 detected sources, ~13000 XMM observations
 - Periodically updated, another data release soon
- ❖ Clusters found using in-house developed XAPA code
- ❖ Primary goal of XCS is the measurement of cosmological parameters, but has many more applications
- ❖ Small collaboration, ~10s of people

The XCS footprint

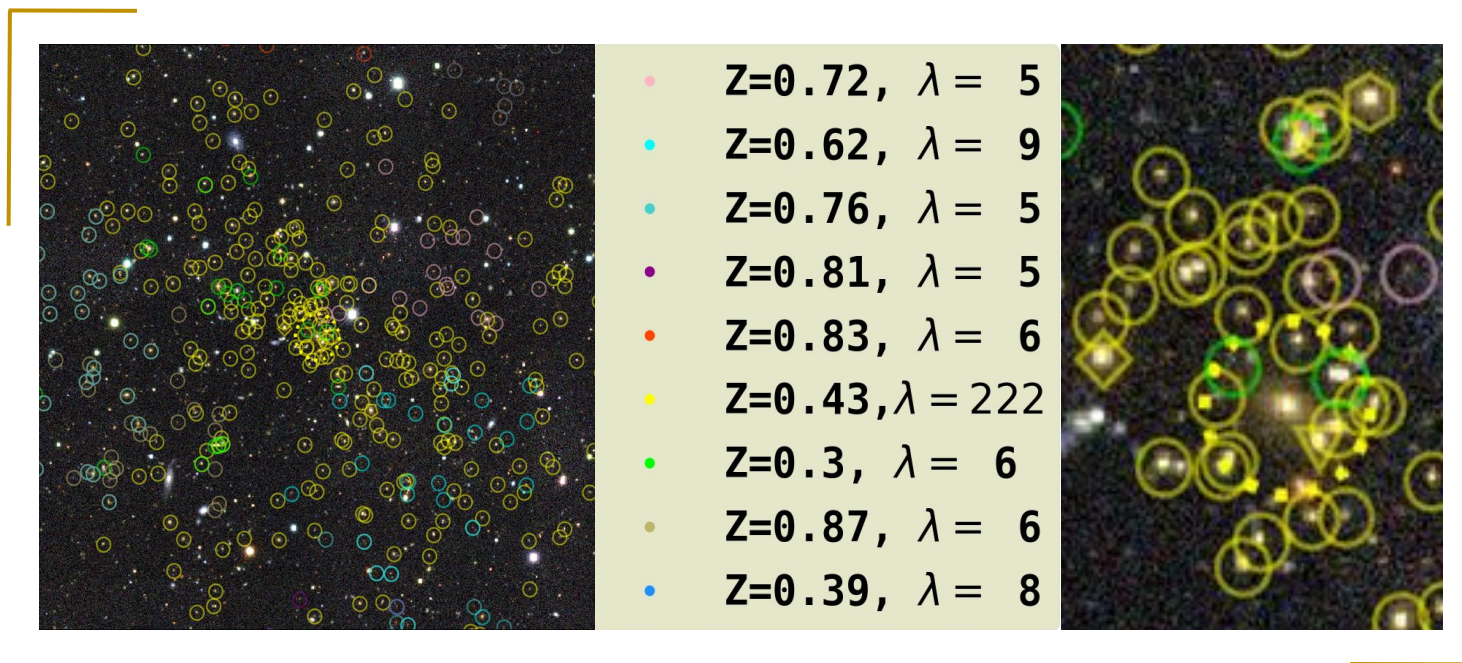


The Dark Energy Survey

- ❖ 5000 sq.deg (contiguous) multi-band (optical/IR) imaging survey taken with 4m Blanco telescope
 - DR1 released Jan 18
 - Some optical/IR spectroscopy (from AAomega etc..)
- ❖ Clusters found using redMaPPer (Rykoff+ 14,16)
- ❖ Primary goal of DES is the measurement of cosmological parameters, but has many more applications
- ❖ Large collaboration, ~100s of people

redMaPPer

- ❖ **red**-sequence **Ma**tched-filter **P**robabilistic **Per**colation cluster finding algorithm. (Rykoff+14)
- ❖ Provides (among other things):
 - Photo-z, richness, galaxy members, 5 most likely centrals

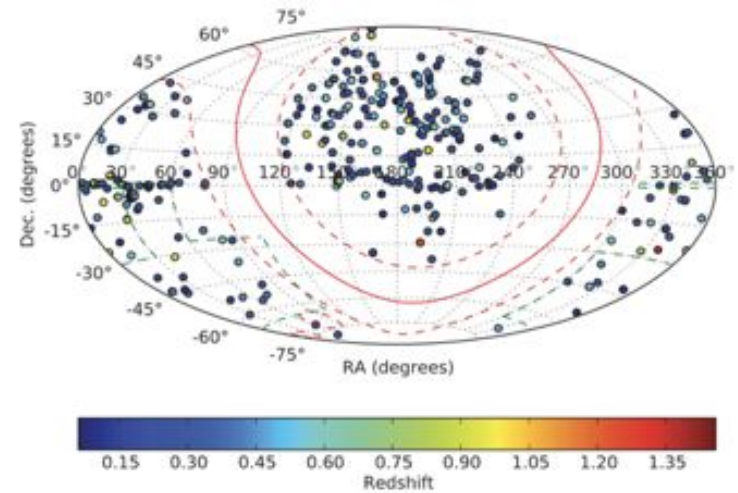




XCS (excl. DES)
- previous
work

XCS DR1 (2012)

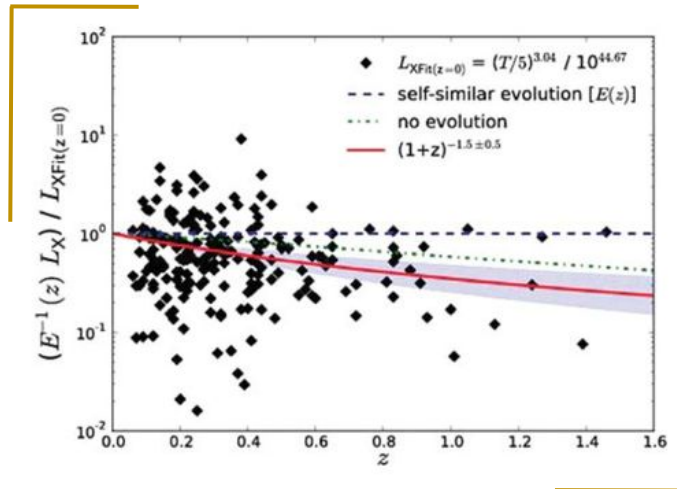
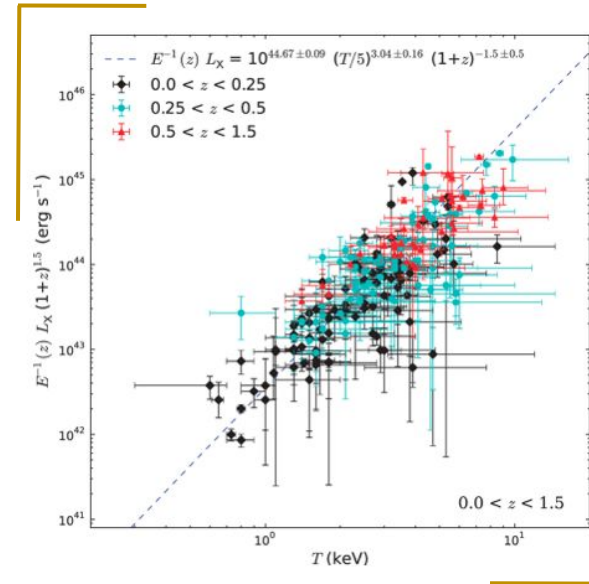
- ❖ 503 serendipitously detected clusters
- ❖ 256 new cluster to lit
- ❖ $0.06 < z < 1.46$ (for 463 clusters)
- ❖ $0.4 < T_x < 14.7$ (for 401 clusters)



Distribution on the sky of the 463 clusters with measured redshifts in XCS-DR1. The colours of the dots represent the redshift of the clusters

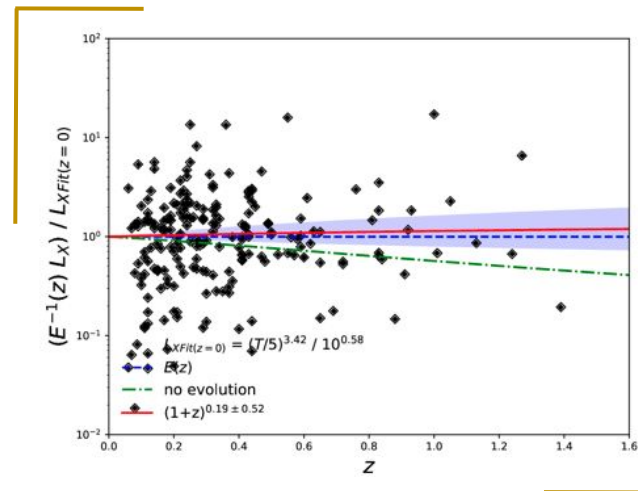
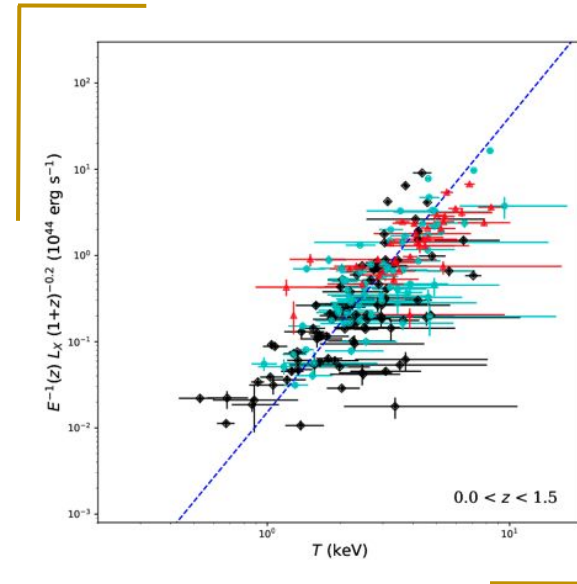
THE LT relation (Hilton+12 / XCS DR2 update)

- ❖ Study of the LT relation using 211 XCS clusters
- ❖ Updated analysis with DR2 analysis shows slightly +ve evolution (consistent with SS), differs from Hilton+12 -ve evolution
- ❖ Many differences in XCS analysis from Hilton+12 to current analysis (Giles+ In Prep.)



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XCS science in the literature

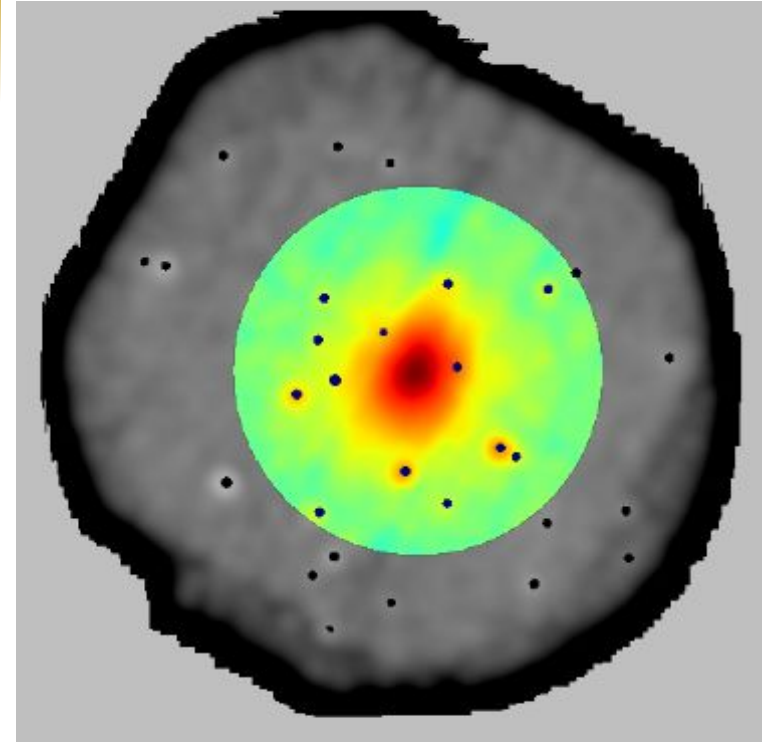
- ❖ **First data release:** Lloyd-Davies+ 11 & Mehrrens+ 12
- ❖ Stott+ 12 – Interaction between the BCG, supermassive black hole and the intra-cluster medium
- ❖ Viana+ 13 – Review and status of XCS data until 2013
- ❖ Wilcox+ 15 – Tests of chameleon modified gravity on X-ray and lensing stacked cluster profiles
- ❖ Mehrrens+ 16 – Direct measurement of the mean halo occupation distribution of cluster galaxies
- ❖ **Scaling relations:** X-ray luminosity – temperature (Hilton+ 12, Ebrahimpour+ subm), velocity dispersion – temperature (Wilson+ 16)
- ❖ XCS – SDSS catalogue (Giles+ In prep)
- ❖ Modified gravity (Tamosiunas+ In prep)
- ❖ The 3.5keV line (Bhargava+ in prep)



XCS DR2 - SDSS (current work)

Creating the sample (matching between SDSS and XCS)

- ❖ Take the SDSS DR8 RM catalogue
- ❖ Match to all XCS observations with cuts
- ❖ Match to all XCS extended sources within 2Mpc of RM cluster
- ❖ Eyeball matched RM clusters for association

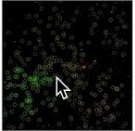
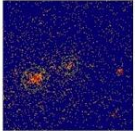
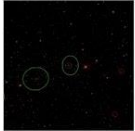
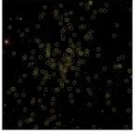
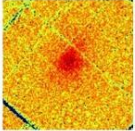

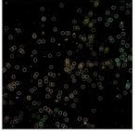
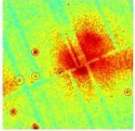
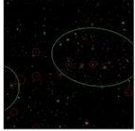


Creating the sample (eat, sleep, eyeball, repeat)

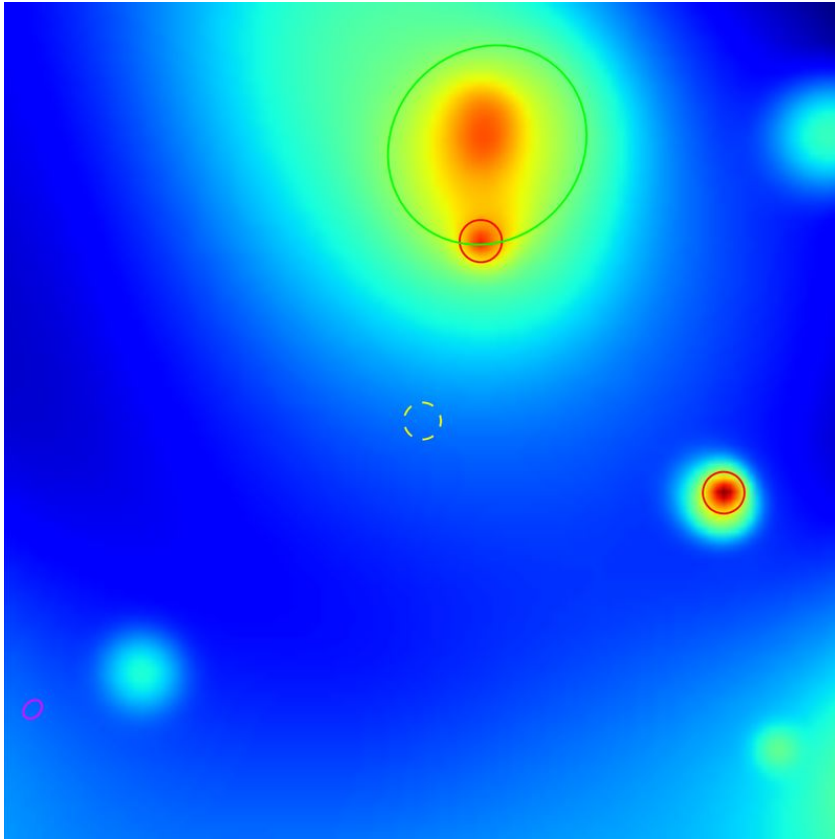
Load Images | Header Info

Show 100 entries

Search:

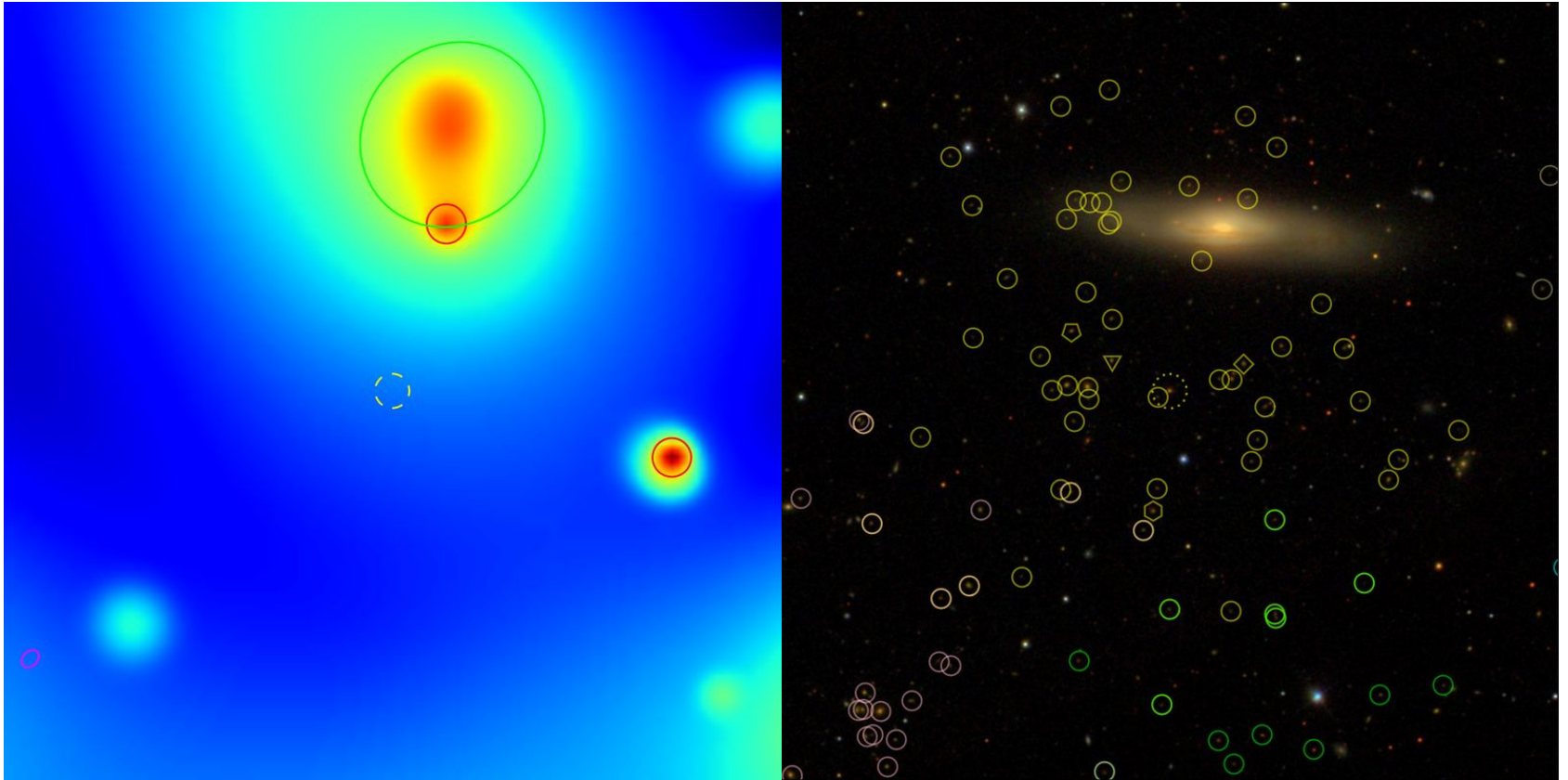
#	ID	XCS_NAMES	OBSID	Z	RM_LAM	R_LAMBDA	RM_OFFAX	EXP	MEDIAN_EXP	COUNTS	RM_X_DIS	RA_rm	DEC_rm	Mark	Comments_inc_initials	Size	SDSS with Members	XMM with Regions	SDSS with Regions
0	9	XMMXCS J100213.9+203222.7	0761590101	0.32	151	1.086437	5.03	5852	6724	365.0	32.3	150.56	20.54	XCS2RM_DefCorrect XCS2RM_MayBCorrect XCS2RM_ambiguous XCS2RM_MayBWrong XCS2RM_DefWrong Xreg_Support Xreg_OutOfTime Xreg_HiBk Xreg_Other XAPA_wrong_rerun XCS_2nd XCS_3rd Interesting inc_in_stack	<input type="text"/> SEND	12x12			
1	16	XMMXCS J131505.6+514912.1	0653530101	0.28	153	1.088118	1.88	20434	21331	4167.0	43.1	198.77	51.82	XCS2RM_DefCorrect XCS2RM_MayBCorrect XCS2RM_ambiguous XCS2RM_MayBWrong XCS2RM_DefWrong Xreg_Support Xreg_OutOfTime Xreg_HiBk Xreg_Other XAPA_wrong_rerun XCS_2nd XCS_3rd Interesting inc_in_stack	<input type="text"/> SEND	1x1			
2	21	XMMXCS J092021.2+303014.5	0401170101	0.30	39	0.827031	3.38	96549	101882	44509.0	513.6	140.13	30.50	XCS2RM_DefCorrect XCS2RM_MayBCorrect XCS2RM_ambiguous XCS2RM_MayBWrong XCS2RM_DefWrong Xreg_Support Xreg_OutOfTime Xreg_HiBk Xreg_Other XAPA_wrong_rerun XCS_2nd XCS_3rd Interesting inc_in_stack	<input type="text"/> SEND	1x1			

Creating the sample (why we eyeball)



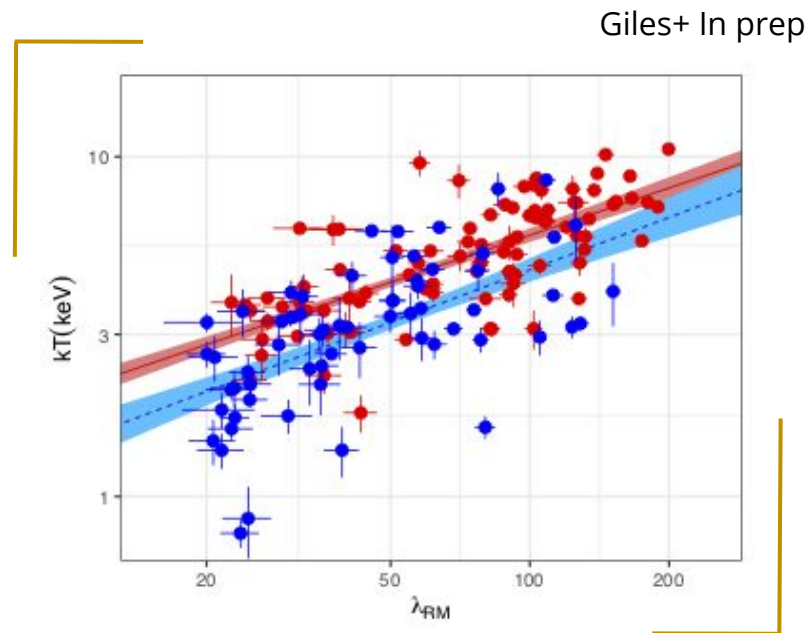
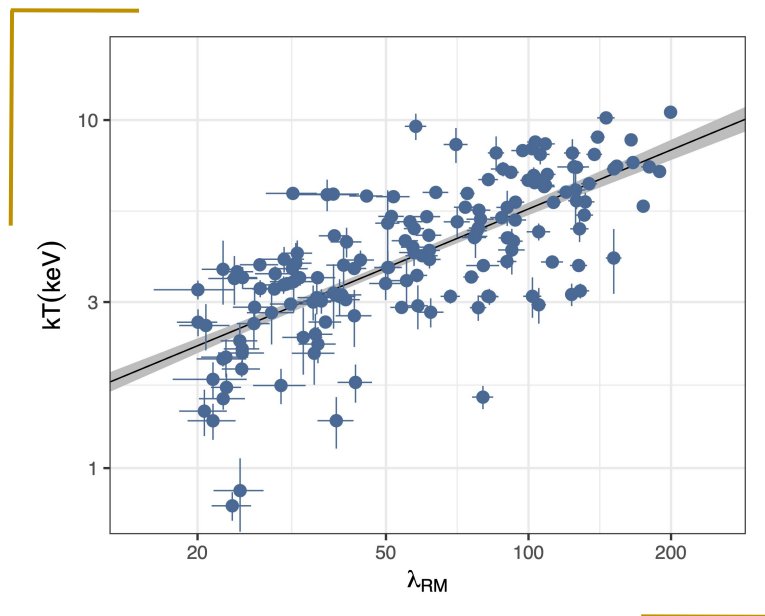
- ❖ RM cluster at $z=0.39$ with richness 26

Creating the sample (why we eyeball)



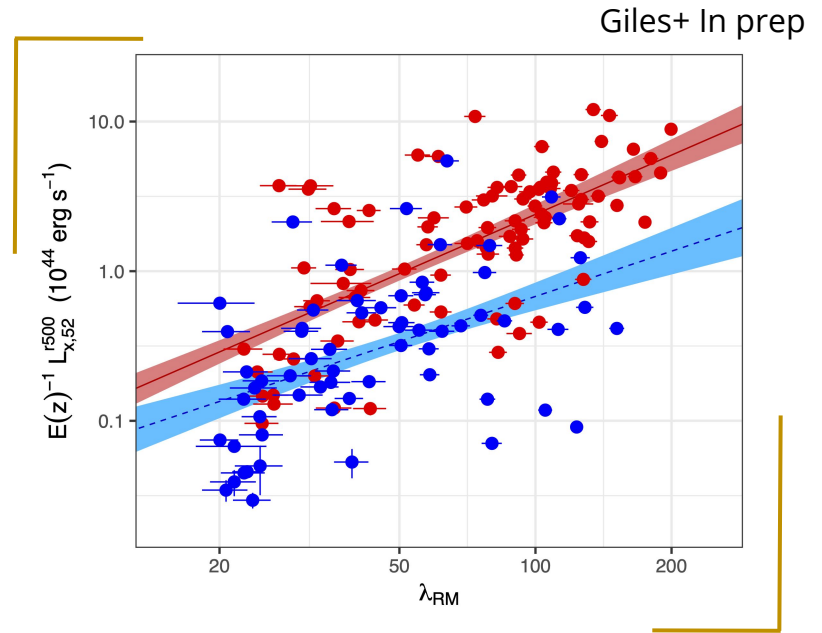
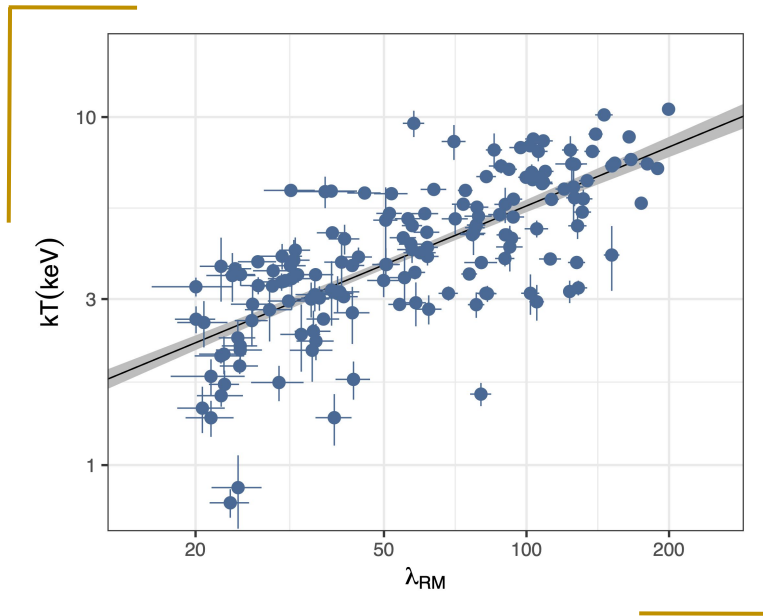
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Some simple relations



- ❖ Cross-match of the SDSS DR8 redMaPPer sample with XCS source catalogue
- ❖ Sample contains 1317 SDSS clusters, 489 with a corresponding extended X-ray source
- ❖ 298 clusters with a robust T_x measurement

Some simple relations



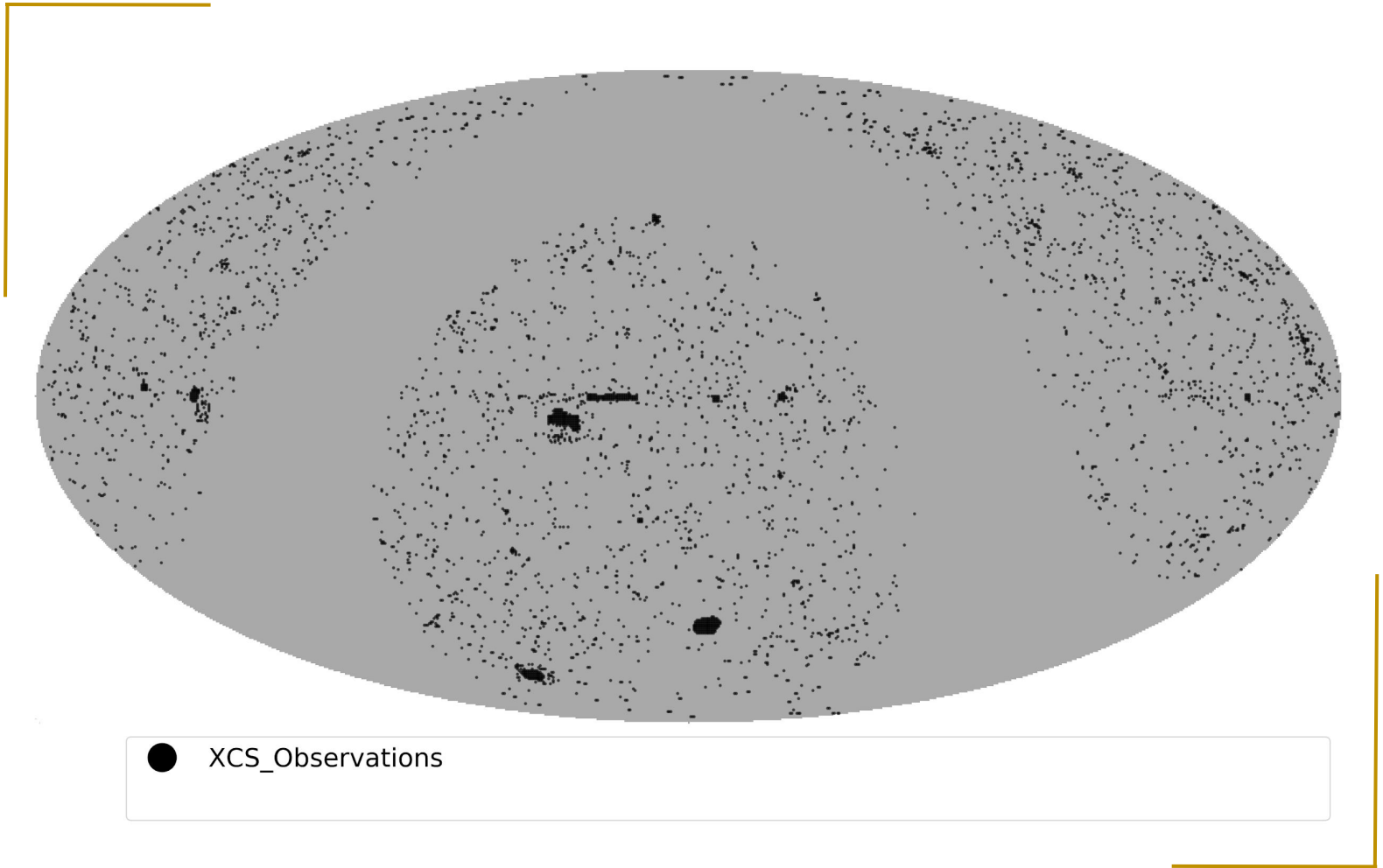
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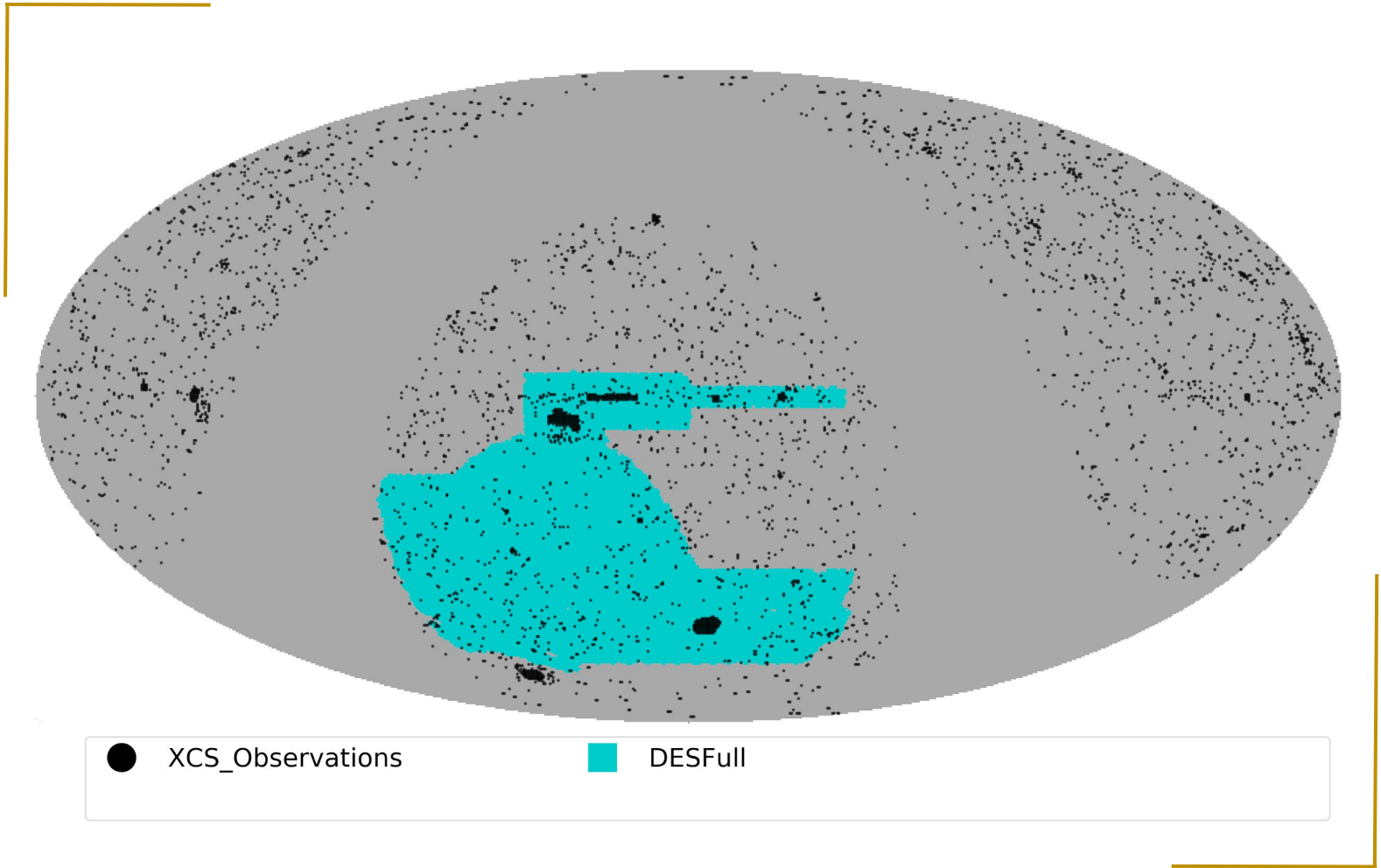
XCS - DES (Y1)



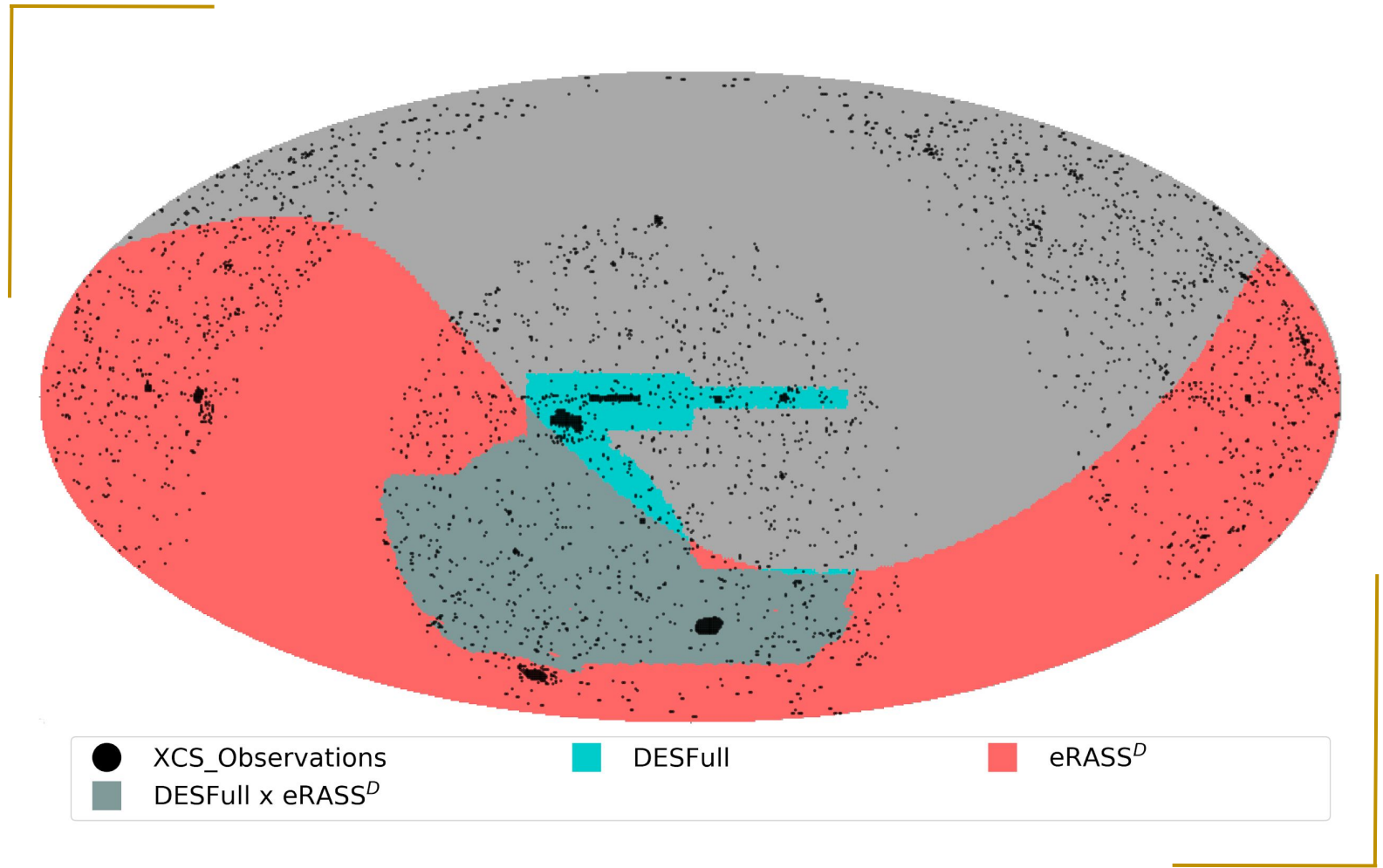
The XCS and DES footprint (and others)



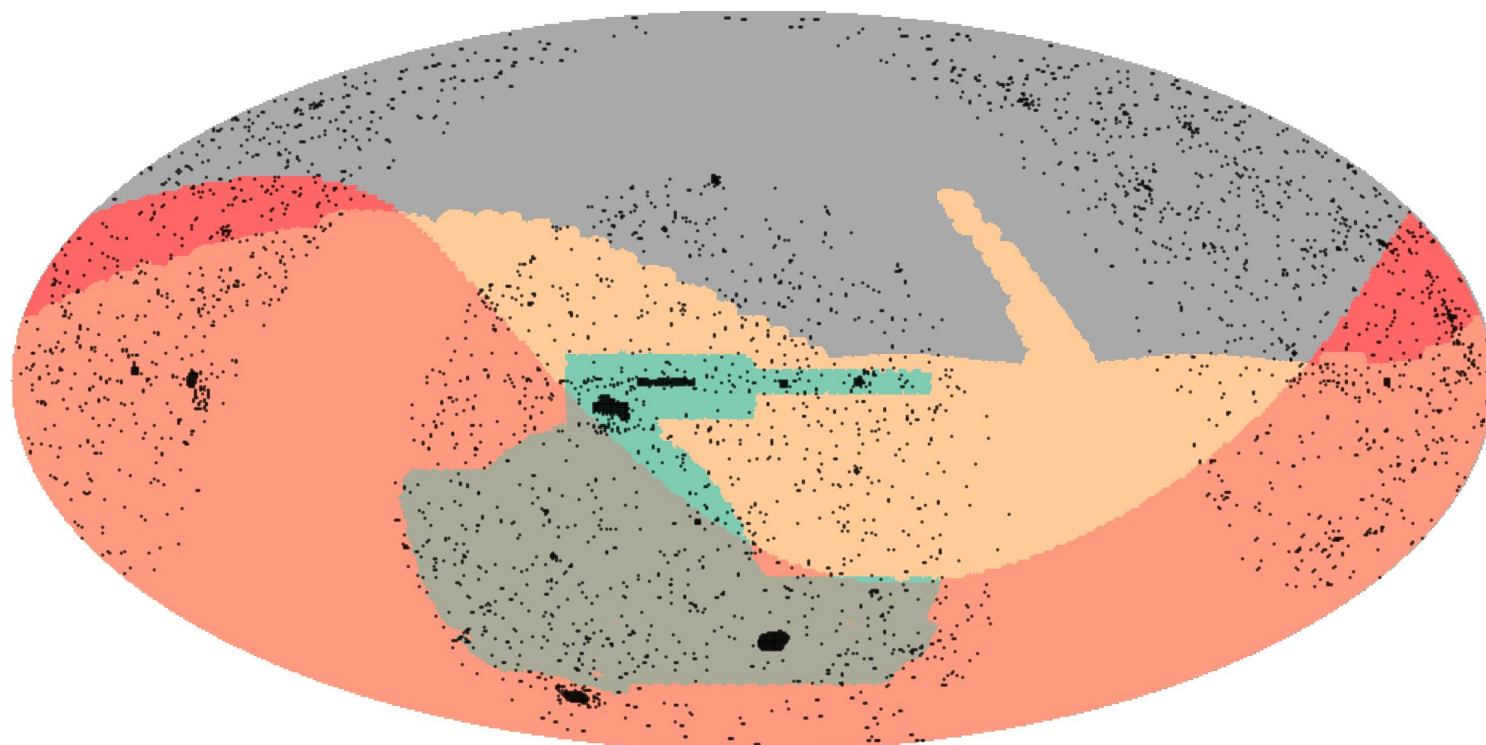
The XCS and DES footprint (and others)



The XCS and DES footprint (and others)



The XCS and DES footprint (and others)



● XCS_Observations

■ DESFull x eRASS^D

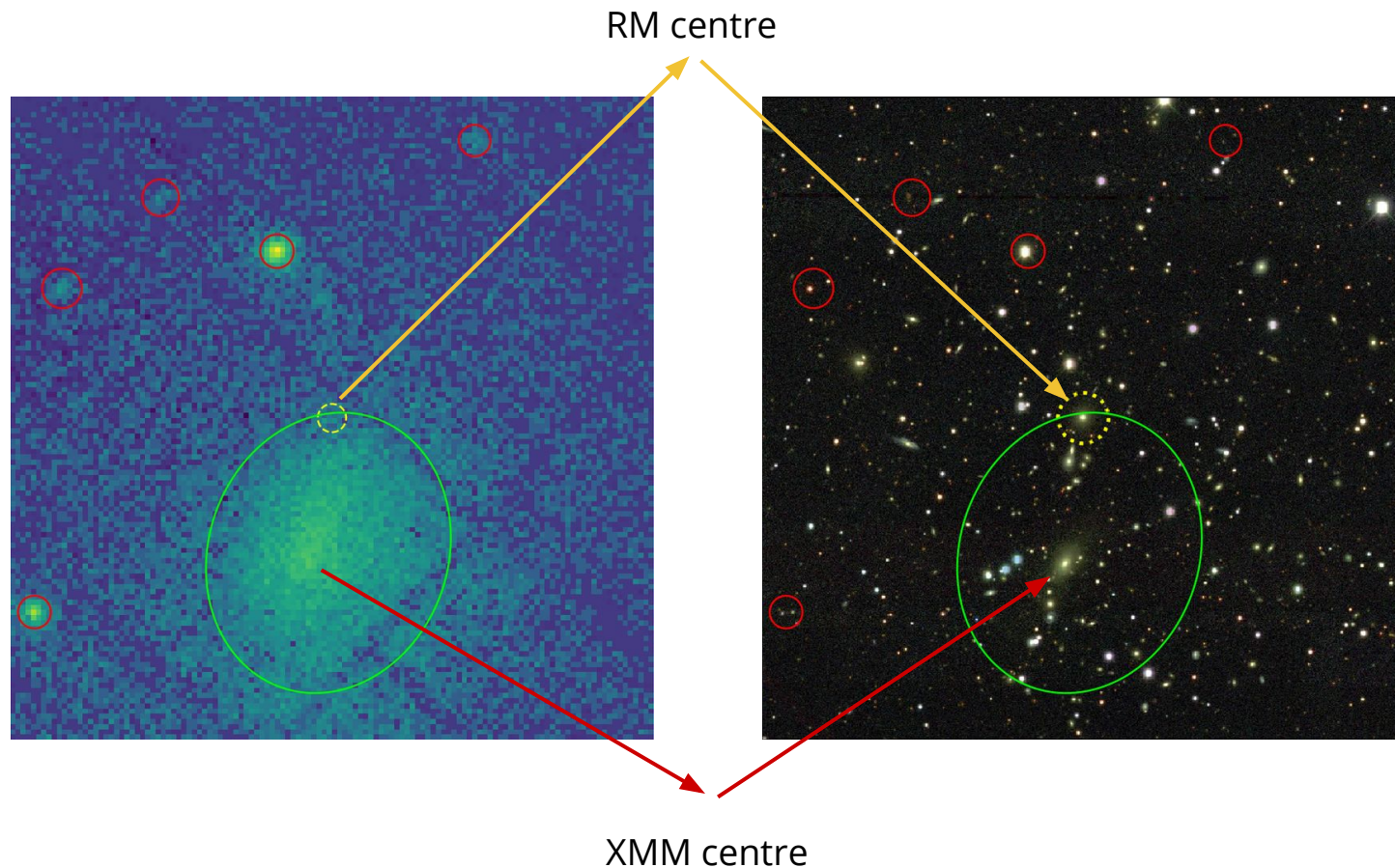
■ DESFull x LSST

■ LSST

■ eRASS^D

■ DESFull x LSST x eRASS^D

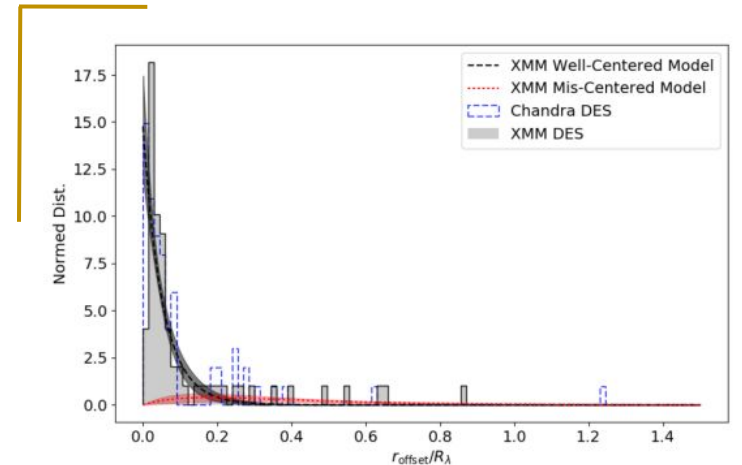
Mis-centering in XCS and DES



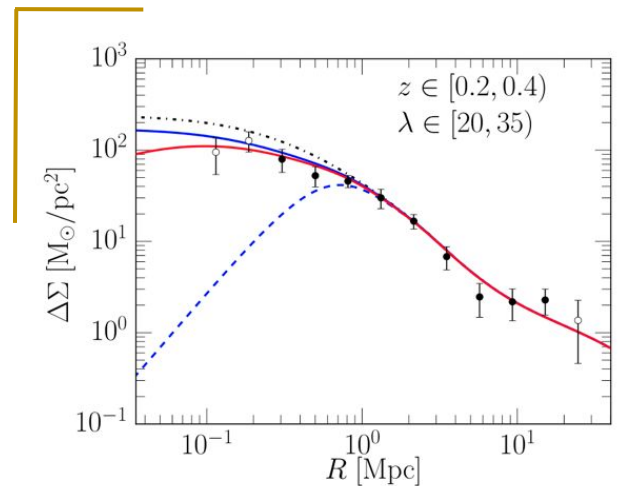
- ❖ RM can mis-identify the central galaxy for a number of reasons (e.g. masking, poor fit on red-sequence)

Mis-centering in XCS and DES

- ❖ Correctly identifying the centre of the cluster of great importance for WL mass estimation
- ❖ Fraction of miscentered clusters can be used as a prior in WL analysis (e.g. Melchior+ 17)
- ❖ Fraction has been studied using Chandra (Hollowood+ 19) and XCS samples

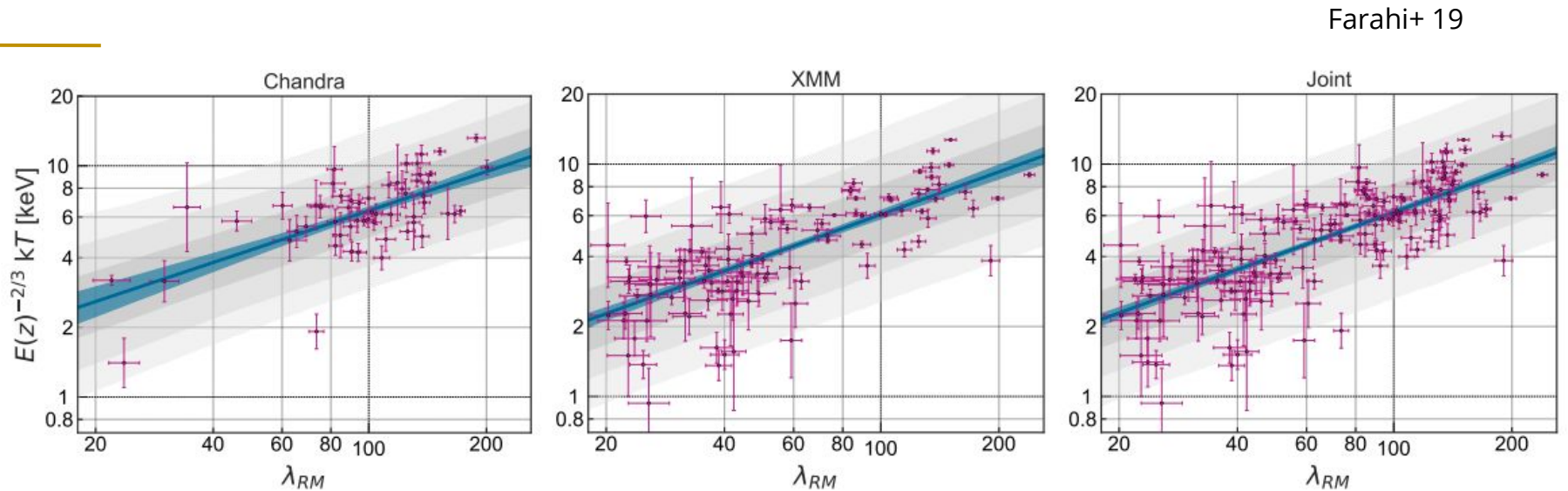


Zhang+ 19



Melchoir+ 17

The Tx-richness relation (DESY1)

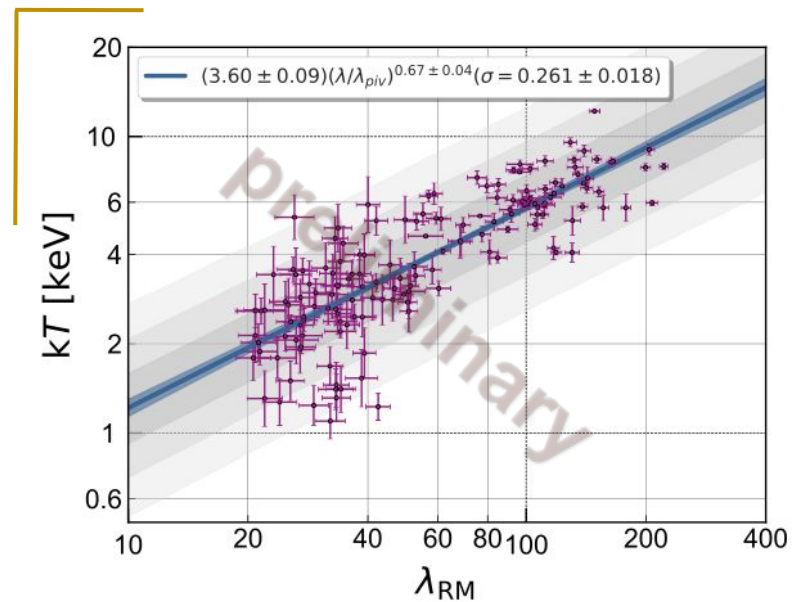
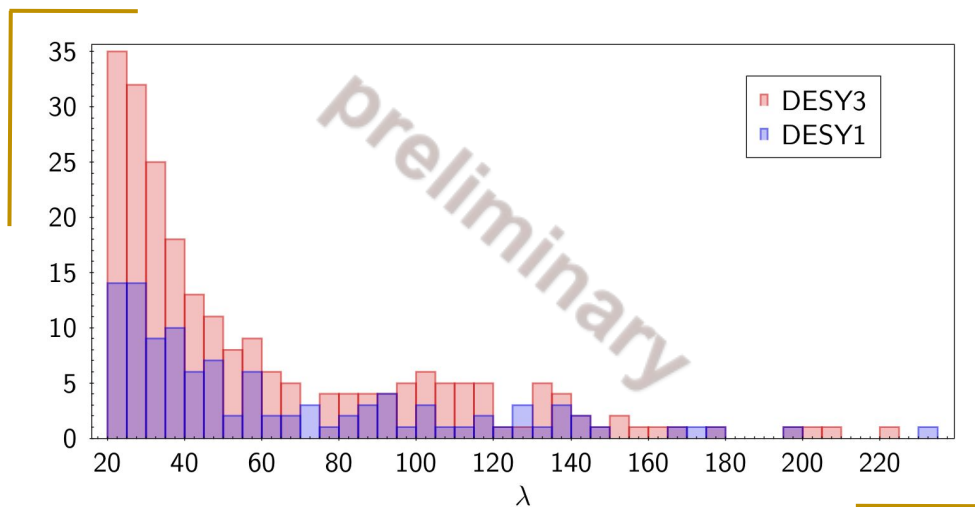


- ❖ Study of Tx-richness relation using DESY1 clusters
- ❖ Joint study using both Chandra and XMM data
- ❖ Can give information of the scatter in mass with richness



XCS - DES (Y3)

Doing it again for DESY3



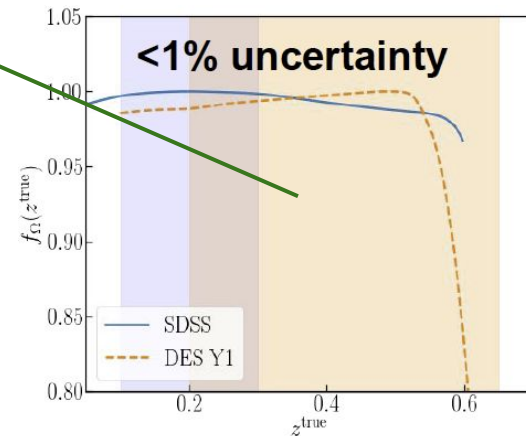
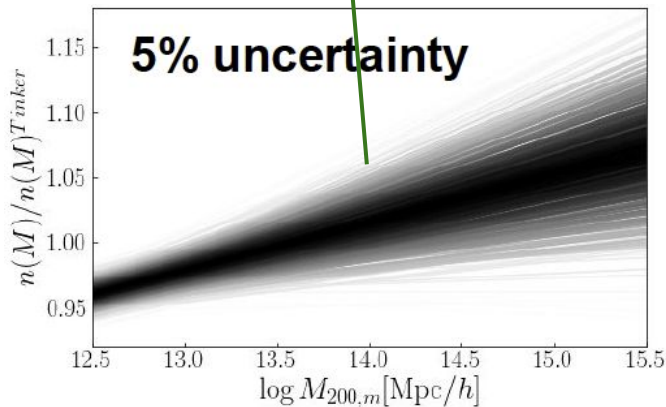
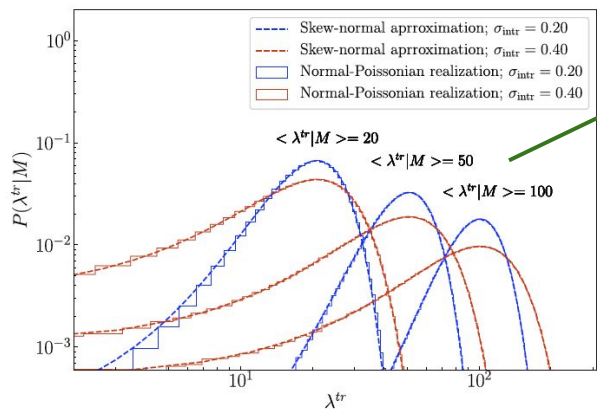
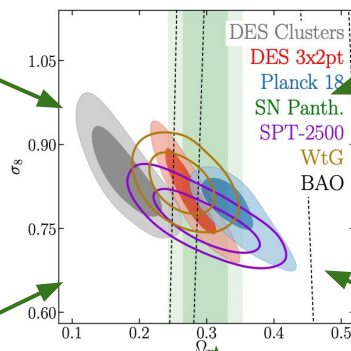
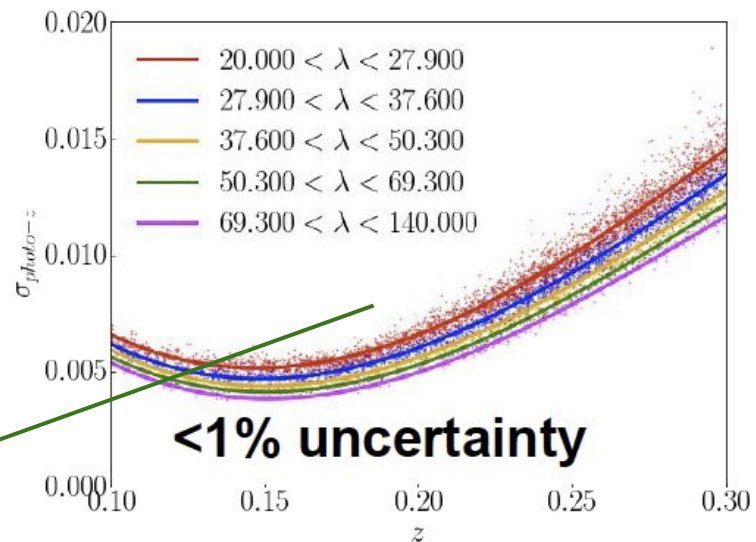
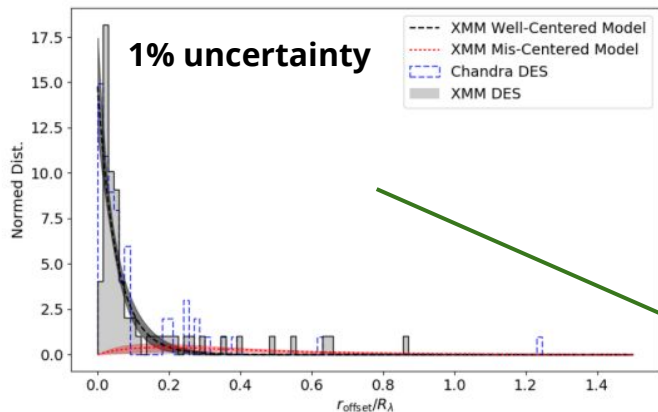
- ❖ 333 clusters matched between DESY3 and XCS (228 within $0.2 < z < 0.7$)
- ❖ ~200 clusters with Tx
- ❖ Factor ~2 times increase over DESY1 (expecting more??)



DES Cosmology

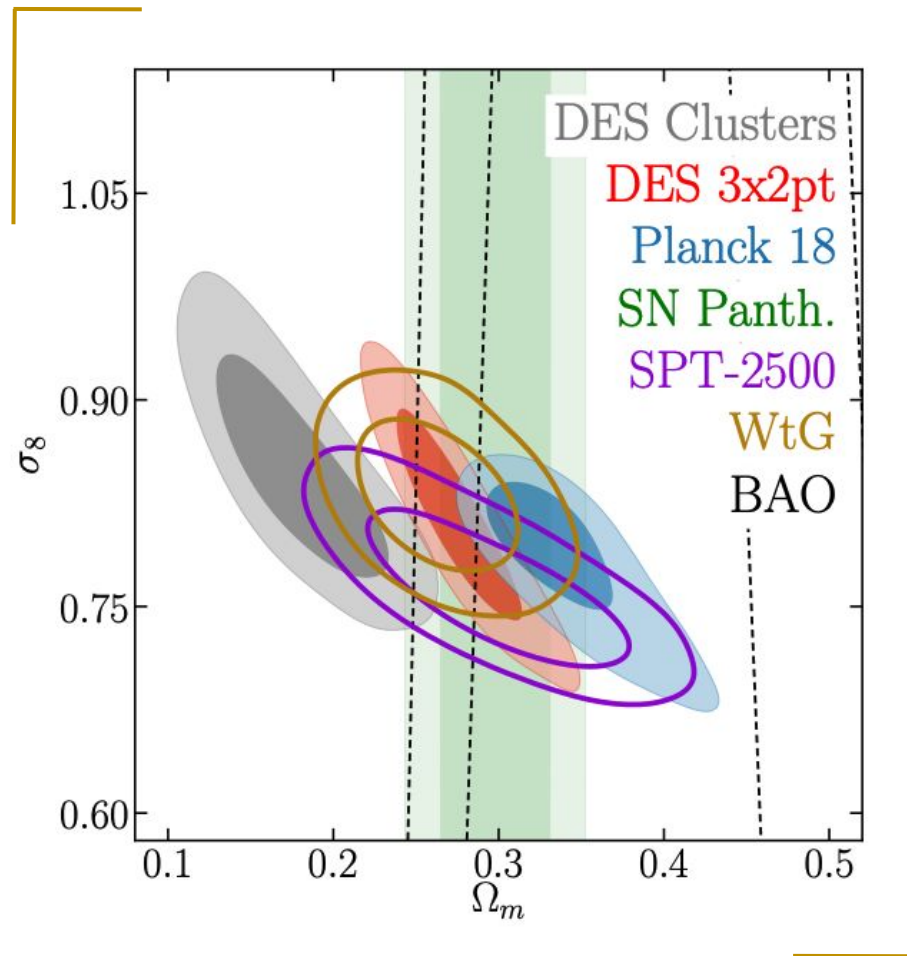


All roads lead to cosmology



DES Collaboration+ 20

All roads lead to cosmology



DES Collaboration+ 20

For some light reading

Modeling of the Selection Function: Costanzi+ 18a (arXiv:1807.07072)

Methodology paper - SDSS Cluster Cosmology: Costanzi+ 18b (arXiv:1810.09456)

DESY1 WL mass calibration: McClintock+18 (arXiv:1805.00039)

Modeling of Membership Dilution: Verga+ 18 (arXiv:1812.05116)

Modeling of Miscentering Effects: Zhang+ 19 (arXiv:1901.07119)

Prior on observable-mass relation scatter: Farahi+ 19 (arXiv:1903.08042)

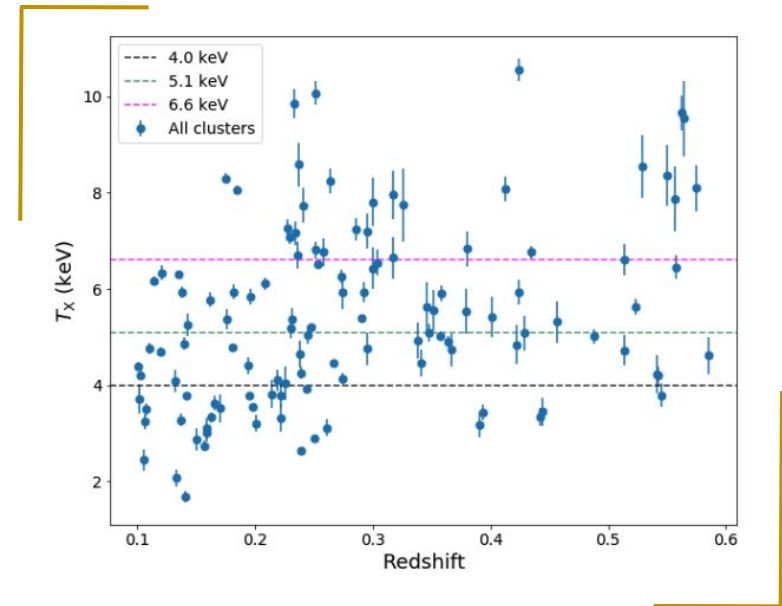
DES Y1 Cluster Cosmology: DES Collaboraton 20 (accepted, arXiv:2002.11124)



XCS Science - optional extras

Searching for dark matter in XCS

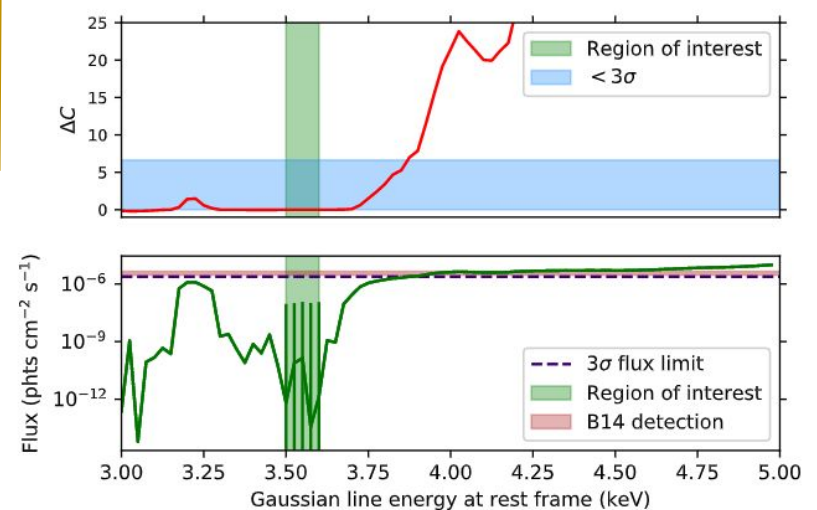
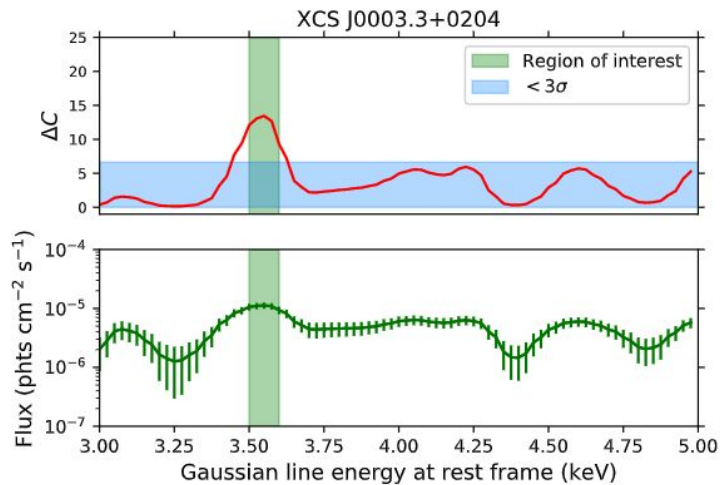
- ❖ X-ray observations of galaxy clusters can be used to constrain models of dark matter
- ❖ A decaying dark matter signal from ~ 7.1 keV sterile neutrinos can be observed as a detectable excess in X-ray spectra in the 3.5 keV range
- ❖ Various studies have searched for this unidentified emission in clusters, dwarf spheroidals, individual galaxies, and blank sky observations
- ❖ XCS are repeating the search for a 3.5 keV signal using the largest sample of X-ray selected galaxy clusters so far (~ 114 clusters)



Bhargava+, accepted

Searching for dark matter in XCS

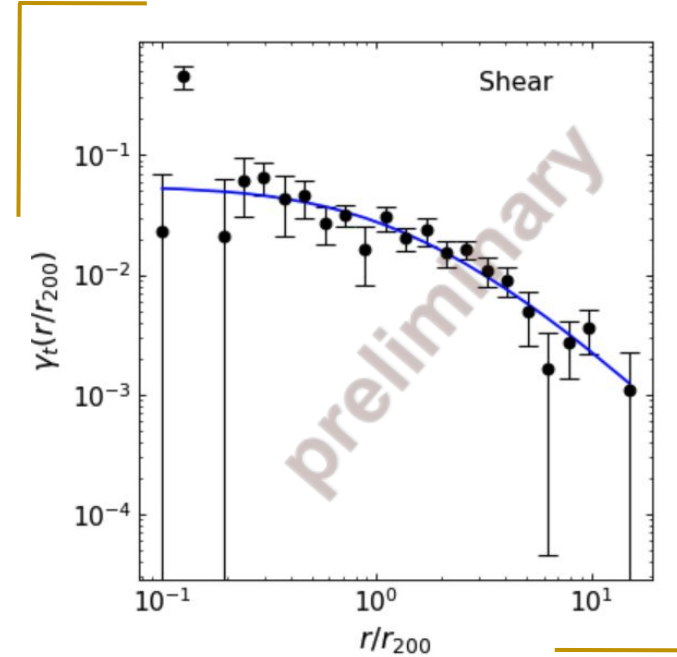
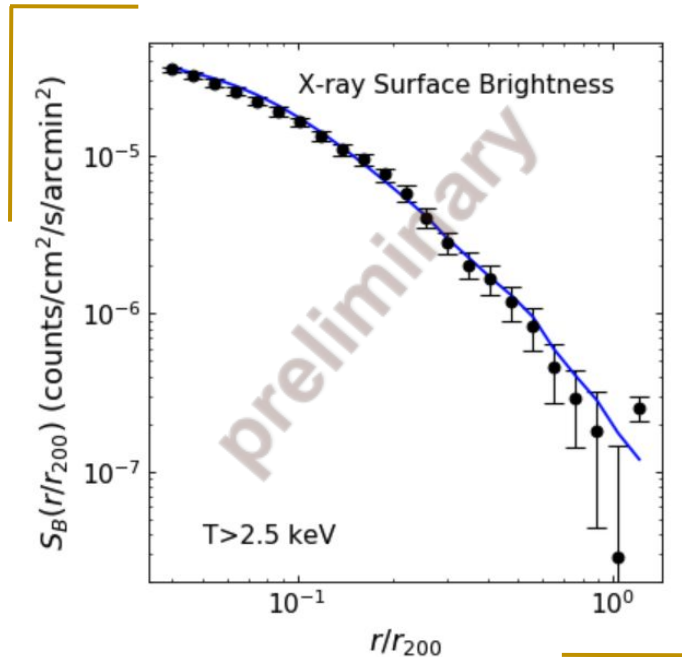
- ❖ We detect a 3.5 keV line at $>3\sigma$ in three individual clusters, but not evidence for DM
- ❖ We don't find any evidence of a 3.5 keV excess in a simultaneous fit of all our clusters
- ❖ Individual clusters can have an impact on your joint/stacked fit



Bhargava+, accepted

Alternative gravity models

Tamosiunas+, in prep



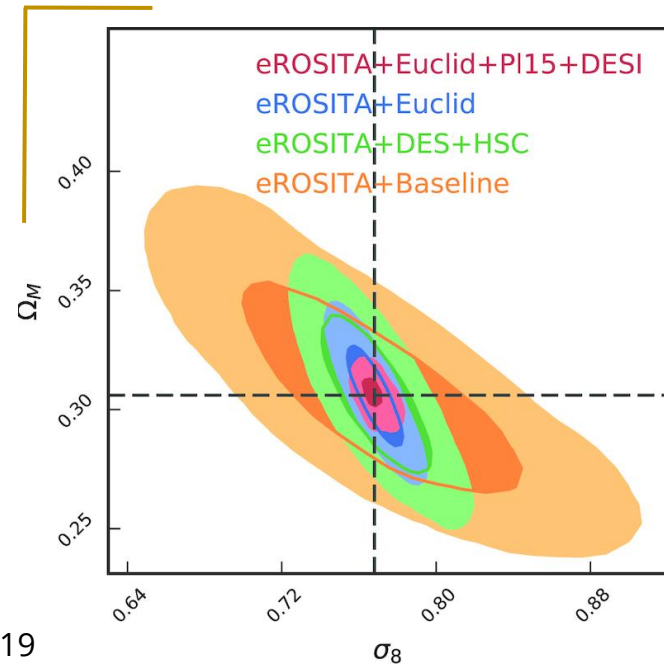
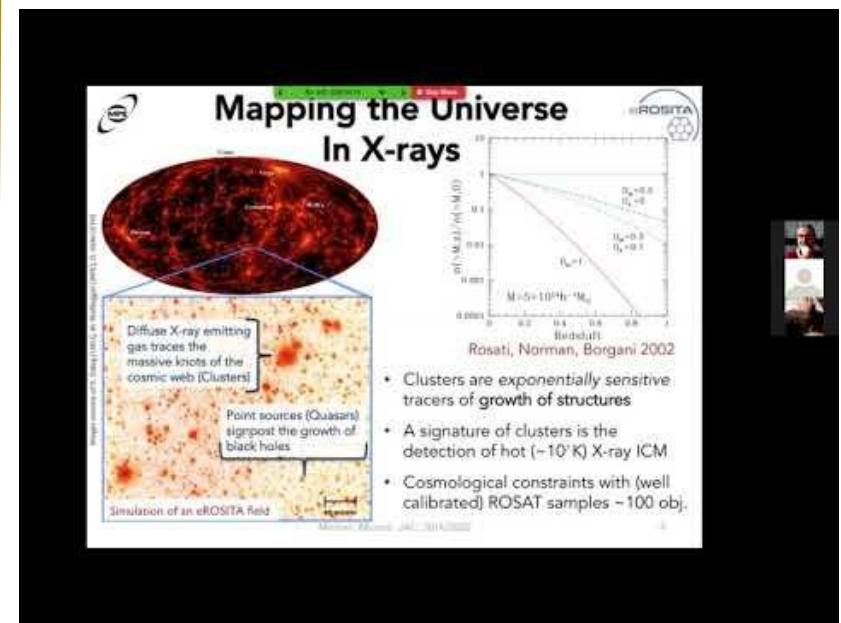
- ❖ Search for evidence of fifth force (chameleon gravity) by comparing X-ray surface brightness profiles and WL profiles
- ❖ Similar to analysis carried out in Wilcox+ 15, but applied to larger CFHTLS and DES samples



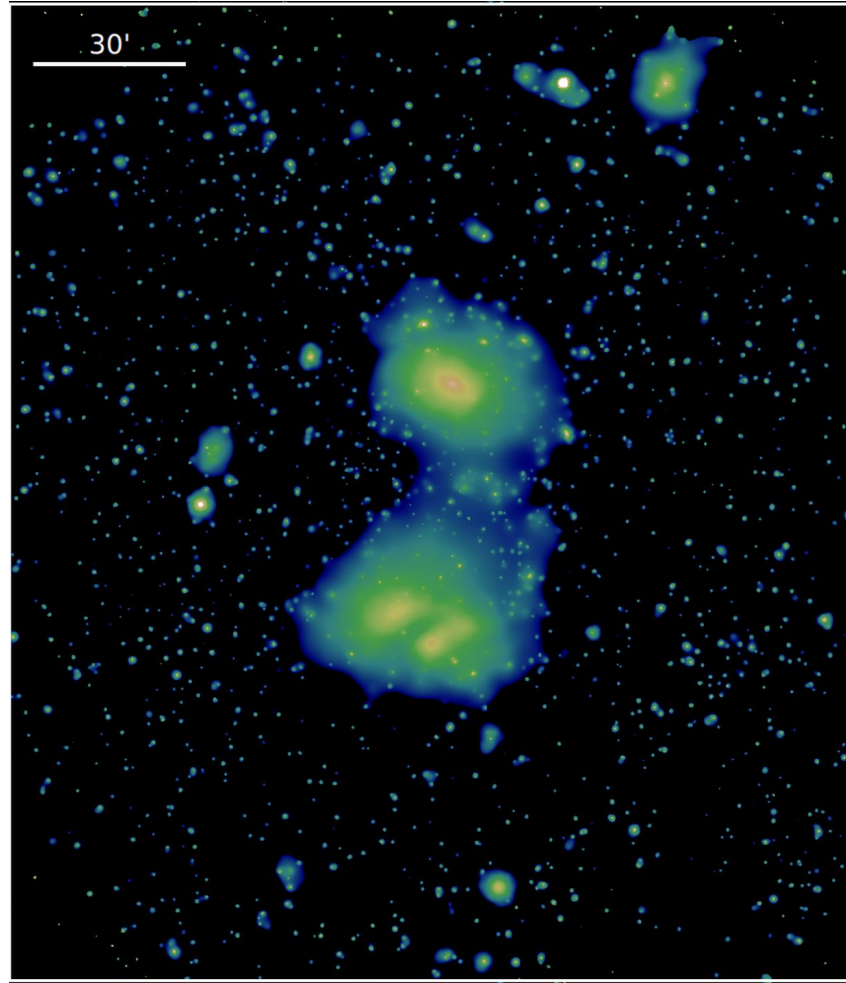
Looking forward to the future

eROSITA (present really)

- ❖ eROSITA will detect ~100000 clusters over the whole sky
- ❖ Launched in July 2019
- ❖ Perform 8 passes of the sky
- ❖ Will then move to a guest observer mode

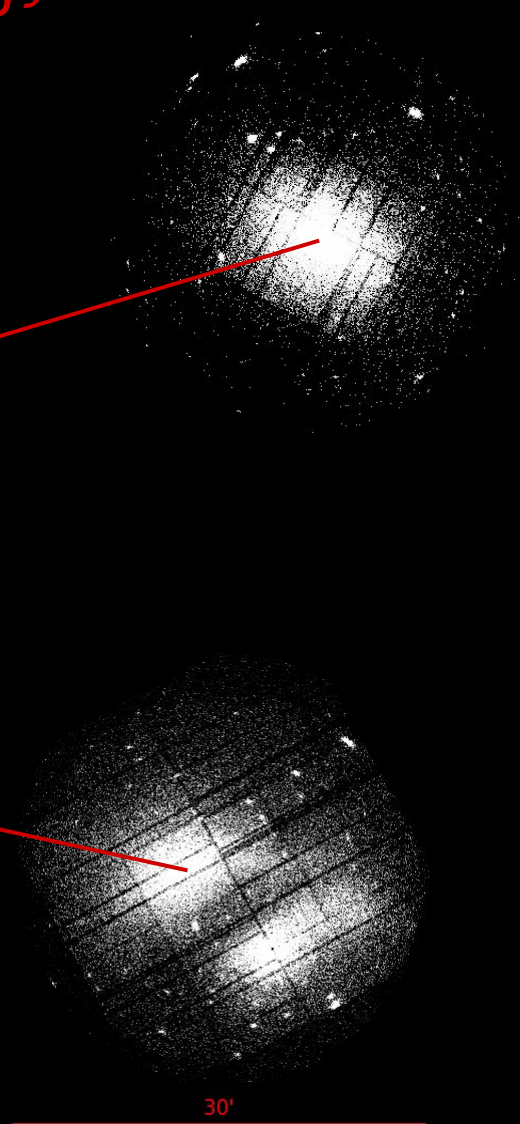
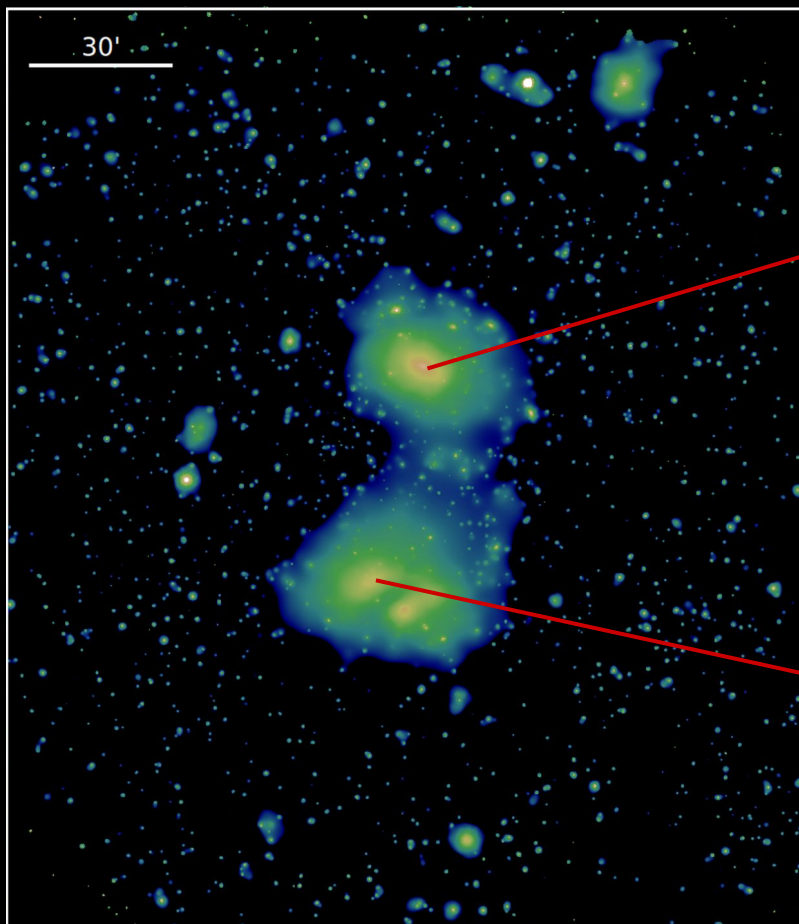


eROSITA (present really - Tuesday)

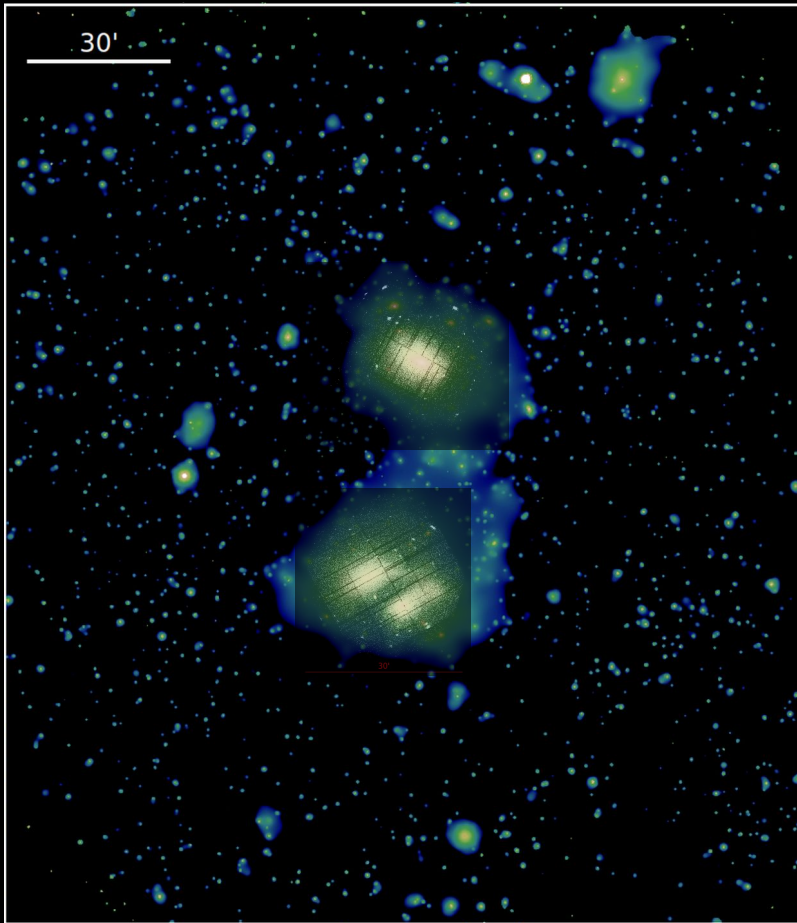


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eROSITA (present really - Tuesday)

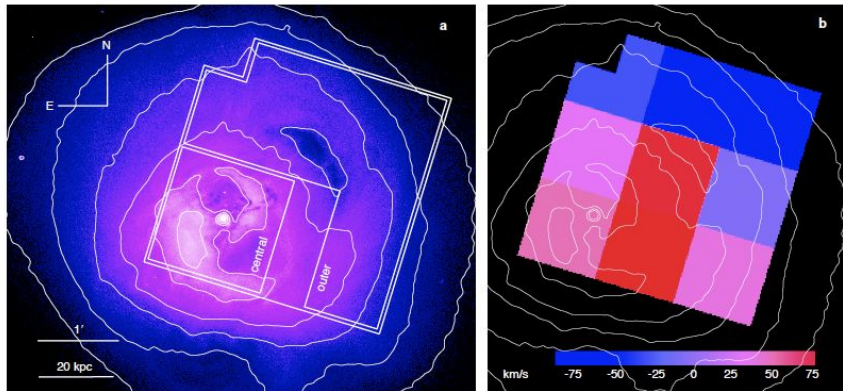


eROSITA (present really - Tuesday)



XRISM (rising like a Phoenix)

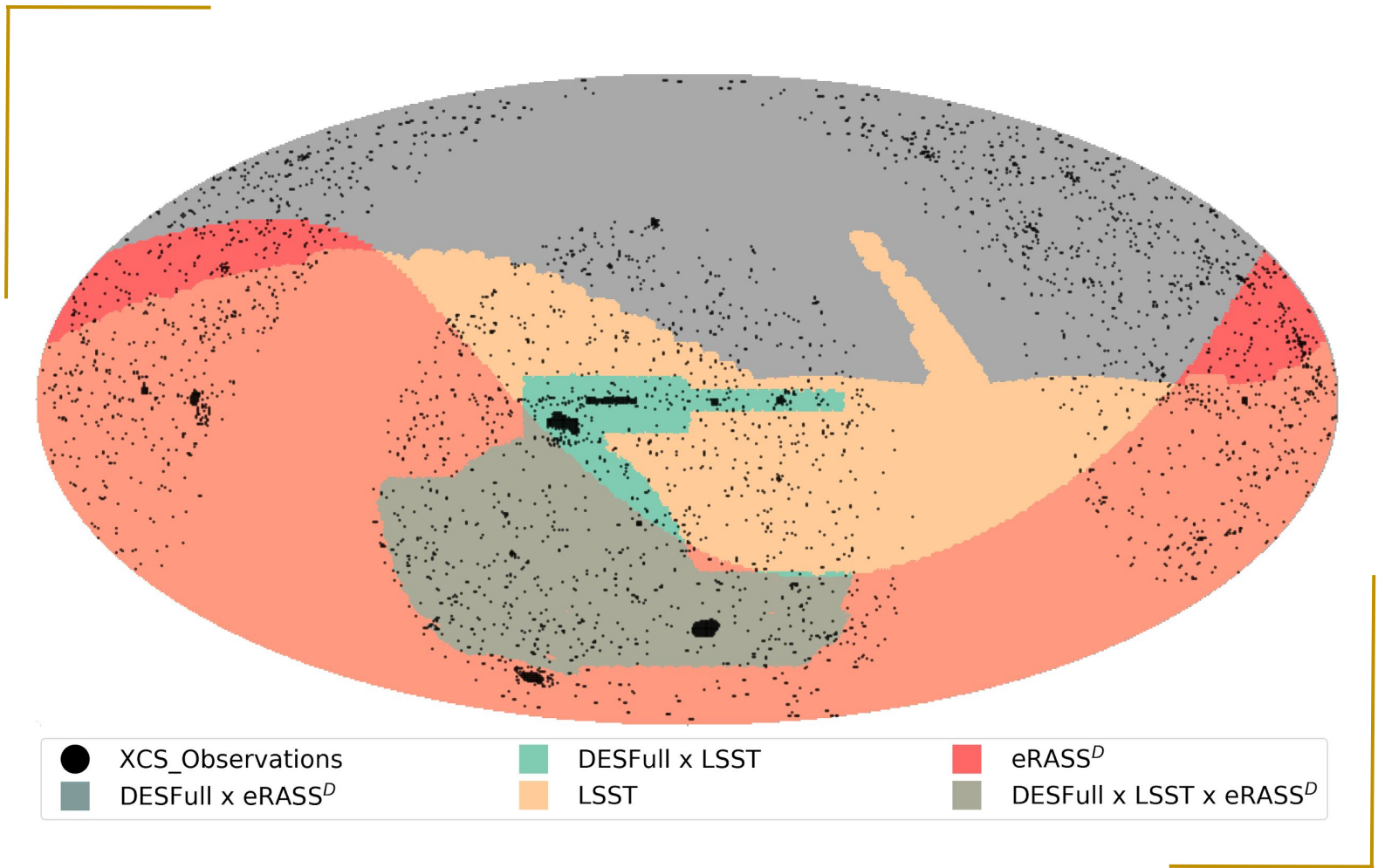
- ❖ Aiming to launch 2021
- ❖ Retain most of the science capabilities of Hitomi
- ❖ Soft X-ray spectrometer - 5-7 keV resolution



- ❖ Soft X-ray imager - 38 arcmin FOV
- ❖ Removing high energy component

Hitomi Collaboration+ 19

The XCS and DES footprint (and others)



The End

