CHANCES

CHileAN Cluster galaxy Evolution Survey

Christopher Haines
Yara Jaffé
Patricia Arévalo
Maria Argudo-Fernández
Arianna Cortesi
Ricardo Demarco
Alexis Finoguenov
Raphael Gobat
Eduardo Ibar
Iván Lacerna
Sebastian Lopez
Claudia Mendes de Oliveira
Antonela Monachesi
Lorenzo Morelli
Veronica Motta
Julie Nantais
Emanuela Pompei
Thomas Puzia
Cristóbal Sifón
Nicolas Tejos
Sergio Torres Flores
Alfredo Zenteno

CHANCES CHileAN Cluster galaxy Evolution Survey

Summary

- Cluster galaxy evolution survey targeting ~500,000 galaxies around 150 of the most massive clusters over $0<z<0.4$, extending out to $5r_{200}$ and down to r_{AB}~21. All using LRS.

- Aims to provide legacy spectroscopic support for the eROSITA X-ray mission, complementing the 4MOST Consortium eROSITA Cluster Redshift Survey (S5). Target rare massive clusters across the ~10,000deg^2 4MOST-eROSITA footprint

- **Low-z CHANCES:** Survey 50 $z<0.07$ clusters ($M>10^{14}M_{\odot}$), two superclusters, and our nearest systems (20-40 Mpc) including the Fornax, Hydra and Centaurus clusters, targeting galaxies out to $5r_{200}$ and down to low stellar masses ($10^{8\text{-}9}M_{\odot}$). SNR>15/Å to get stellar population indices, σ_v.

- **CHANCES evolution:** Target the 50 most massive clusters over $0.07<z<0.4$ to track evolution of cluster galaxies over last 4Gyr. High target density (4000deg^2), so aim is to simply get redshifts.

- **CHANGES CGM:** Observe 24K background QSOs within $3r_{200}$ of all $z>0.35$ eROSITA clusters, to search for MgII absorption systems within their spectra.

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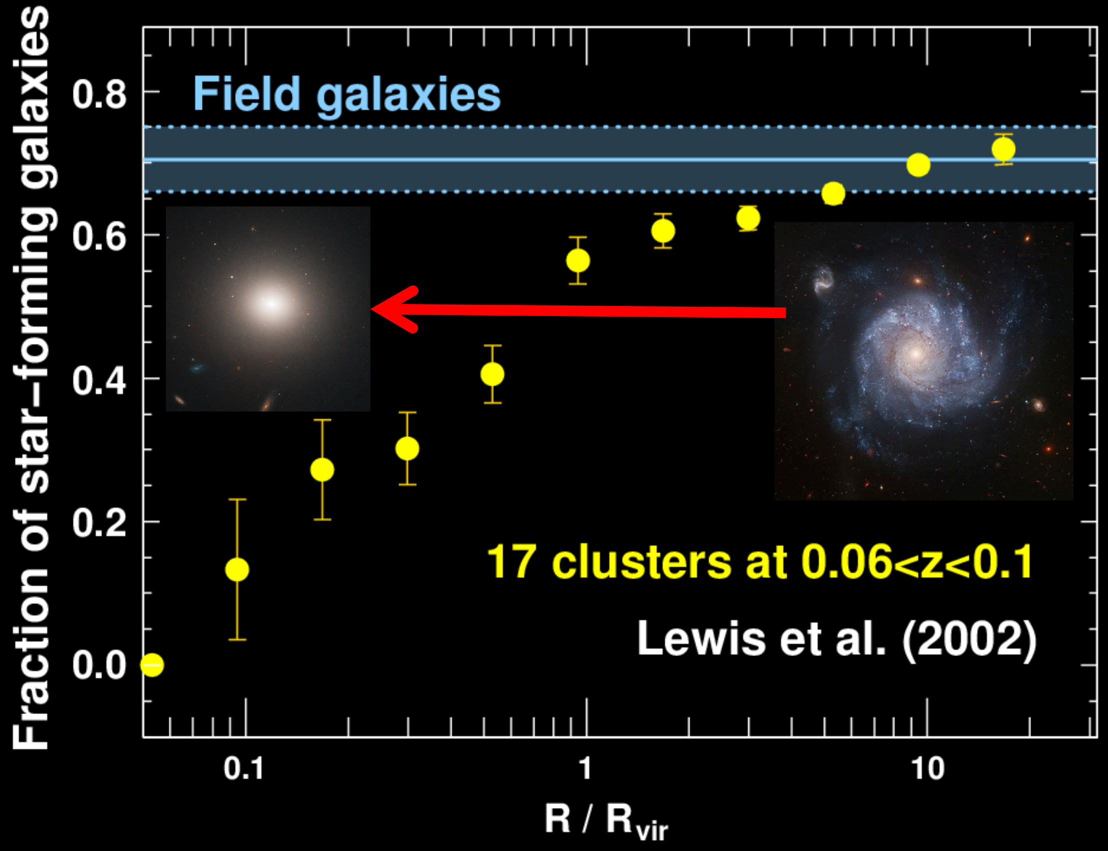
Key science goals

- Quantify **when, where** and **how** star-forming spirals are transformed in and around massive clusters to build up the present-day population of quiescent early-type cluster galaxies, as a function of M*
- Track the ongoing assembly of massive clusters at late-epochs, identifying the filaments and infalling galaxy groups through which each cluster accretes its mass and galaxy populations
- Quantify importance of pre-processing in groups for assembling the quiescent galaxy populations that dominate present-day clusters
- Probe the formation and evolution of the cluster dwarf galaxy population
- Track the continuous evolution of cluster galaxies over the last 4 billion years
- Use background QSO sightlines to probe the effect of cluster environments on the gaseous contents of galaxies at $z>0.35$

Introduction: The SF-density relation



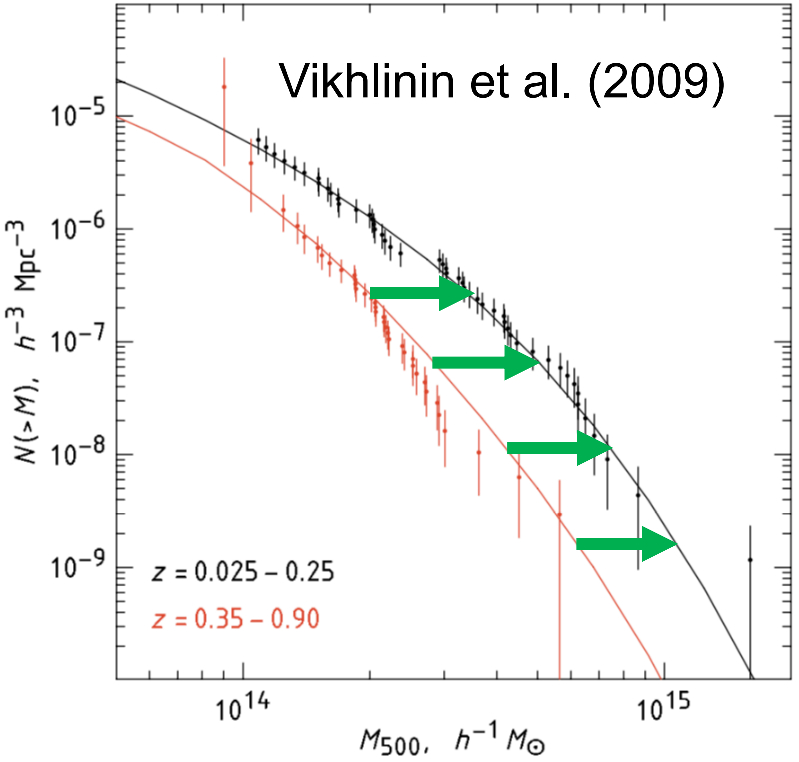
The ability of galaxies to continue forming stars is well known to strongly depend on their local environment

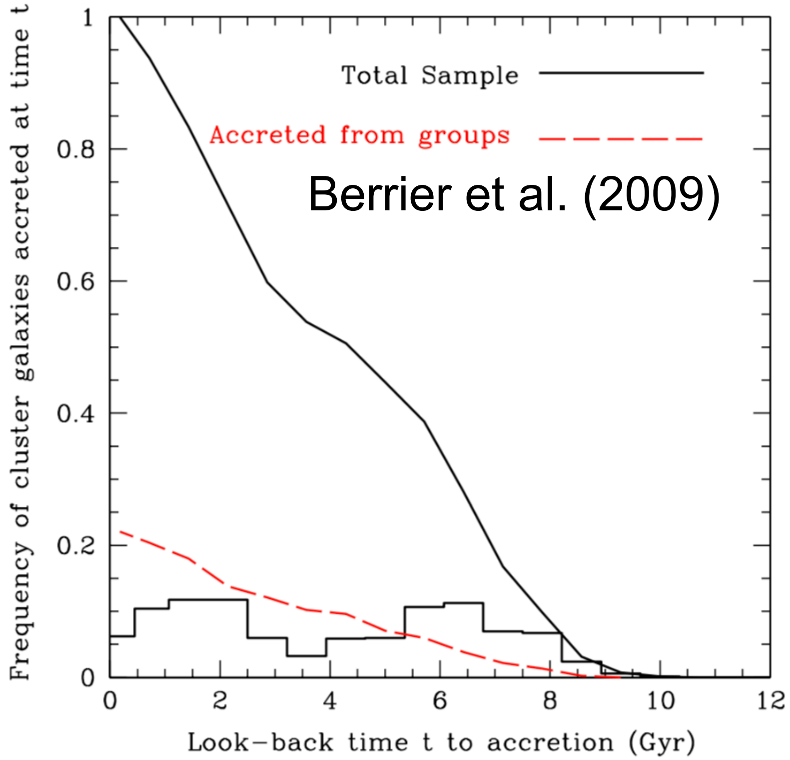
While isolated field galaxies are mostly star-forming, almost all galaxies in the cores of rich clusters are now passively-evolving

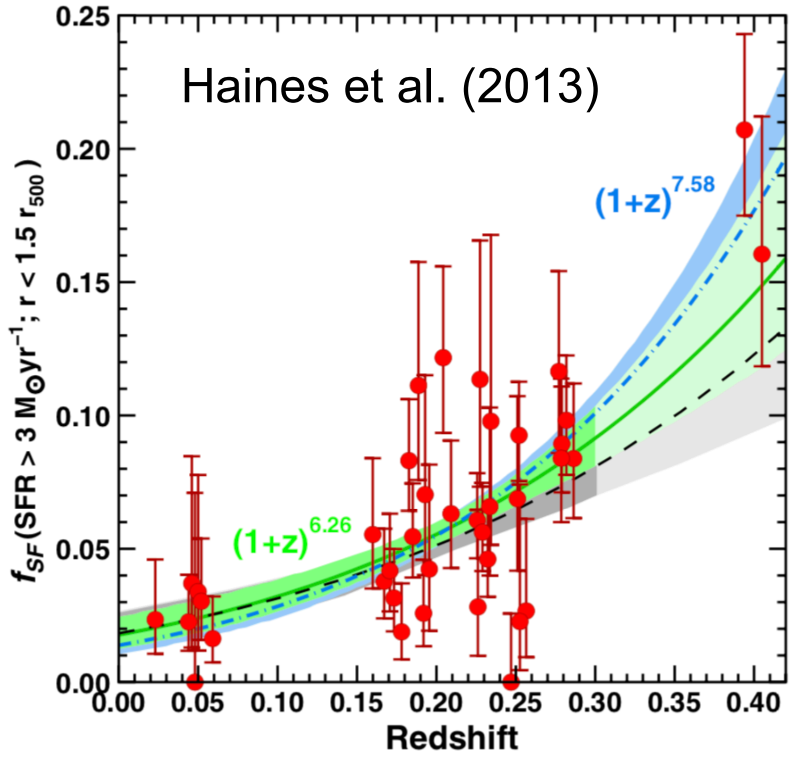
Mechanisms such as ram-pressure stripping, starvation, harassment, tidal interactions, pre-processing have been proposed to remove gas and quench star formation in cluster galaxies (e.g. Boselli & Gavazzi 2006)

The rapid late evolution of clusters and their galaxies

- Galaxy clusters are assembled late, empirically doubling their masses on average since z~0.5 (Vikhlinin et al. 2009). Similarly, they accrete half of their present-day member galaxies at z<0.5 (Berrier et al. 2009)
- The fraction of star-forming cluster galaxies has evolved rapidly since z~0.4 (Butcher-Oemler effect), but this evolution has been mostly measured using heterogeneous data, with few clusters at z>0.3
- Motivates a single homogeneous survey that can track the rapid evolution of cluster galaxies over the last 4 billion years, and that extends well into the infall regions of z~0.4 clusters to track future member galaxies

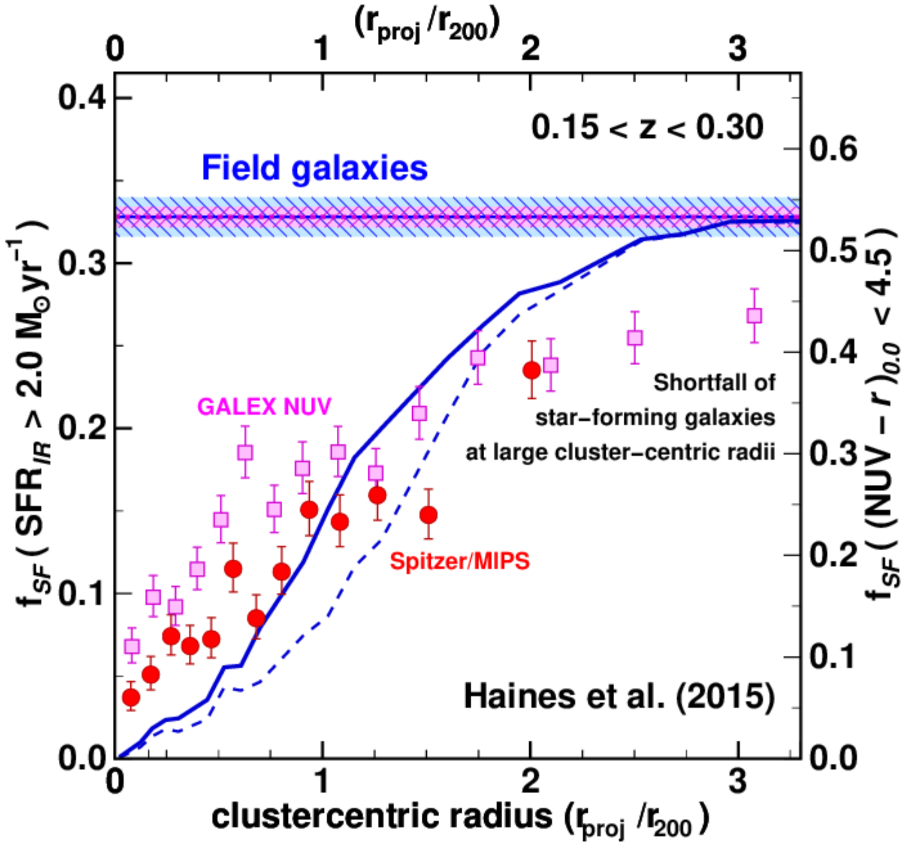


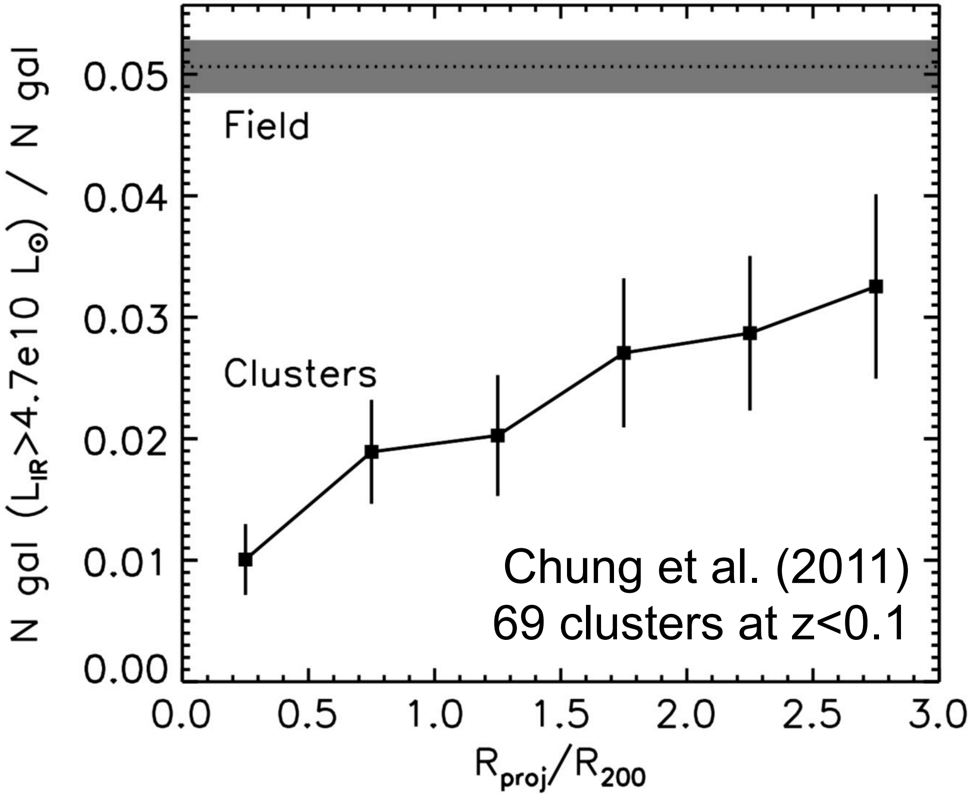




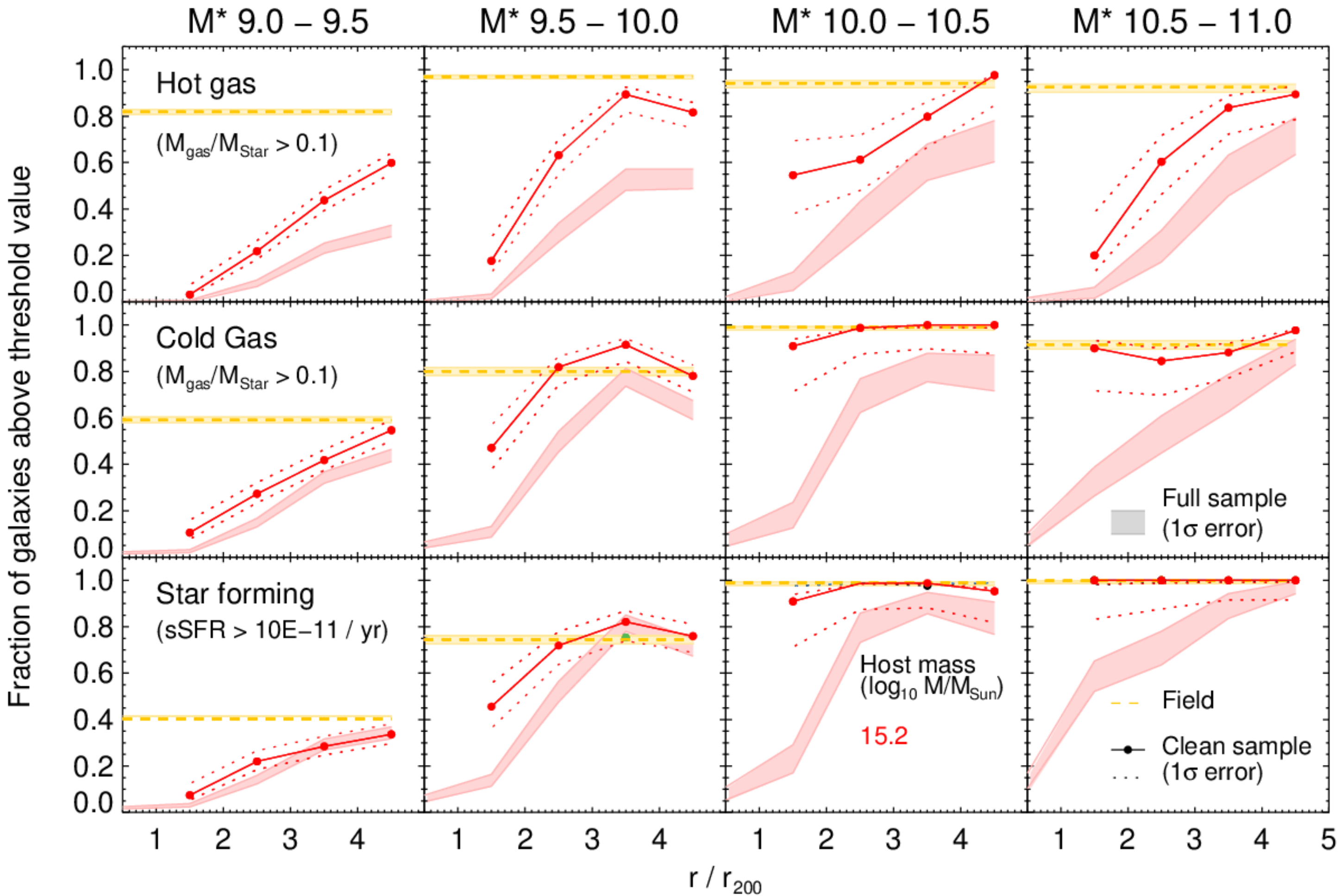
The need for pre-processing

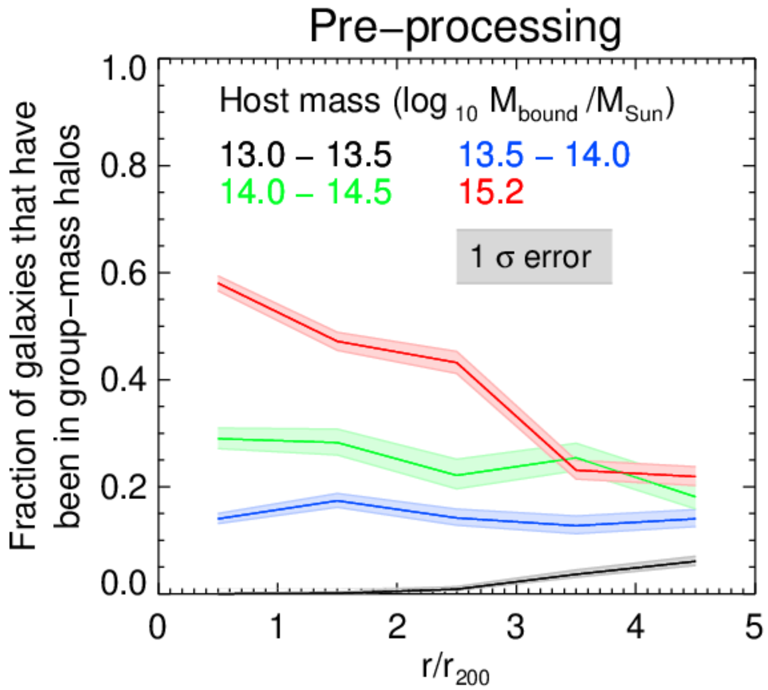
- Galaxies in the vicinity of clusters are more likely to be quiescent than counterparts in typical field regions, at fixed stellar mass and redshift, even at large distances from the cluster (~$3r_{200}$)
- Need a physical mechanism that can transform these galaxies prior to their arrival into the cluster.
- Galaxies may be pre-processed within galaxy groups that are later accreted onto the cluster

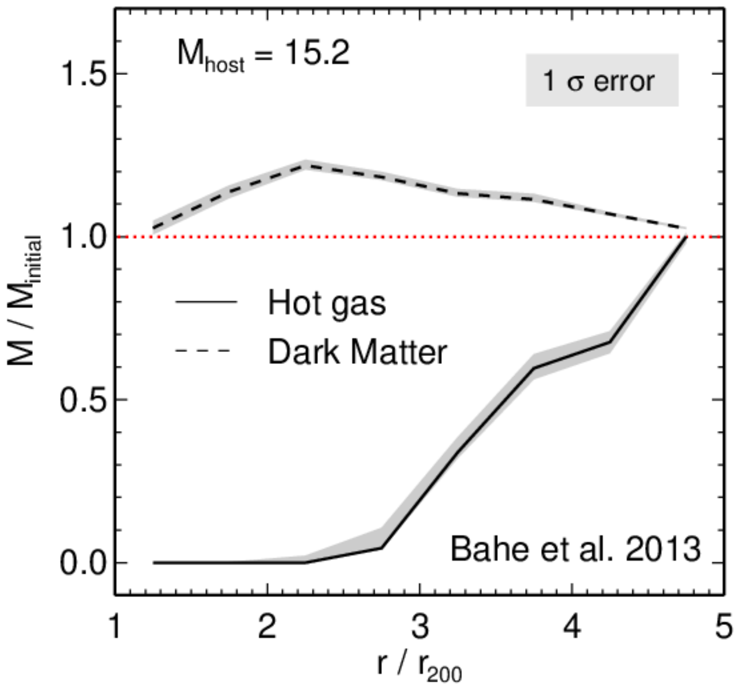




Hydrodynamical simulations suggest that galaxies falling into massive clusters can start to be affected by ram-pressure stripping, starvation or pre-processing in groups as far out as $5r_{200}$, long before they are accreted into the cluster (Bahé et al. 2013)



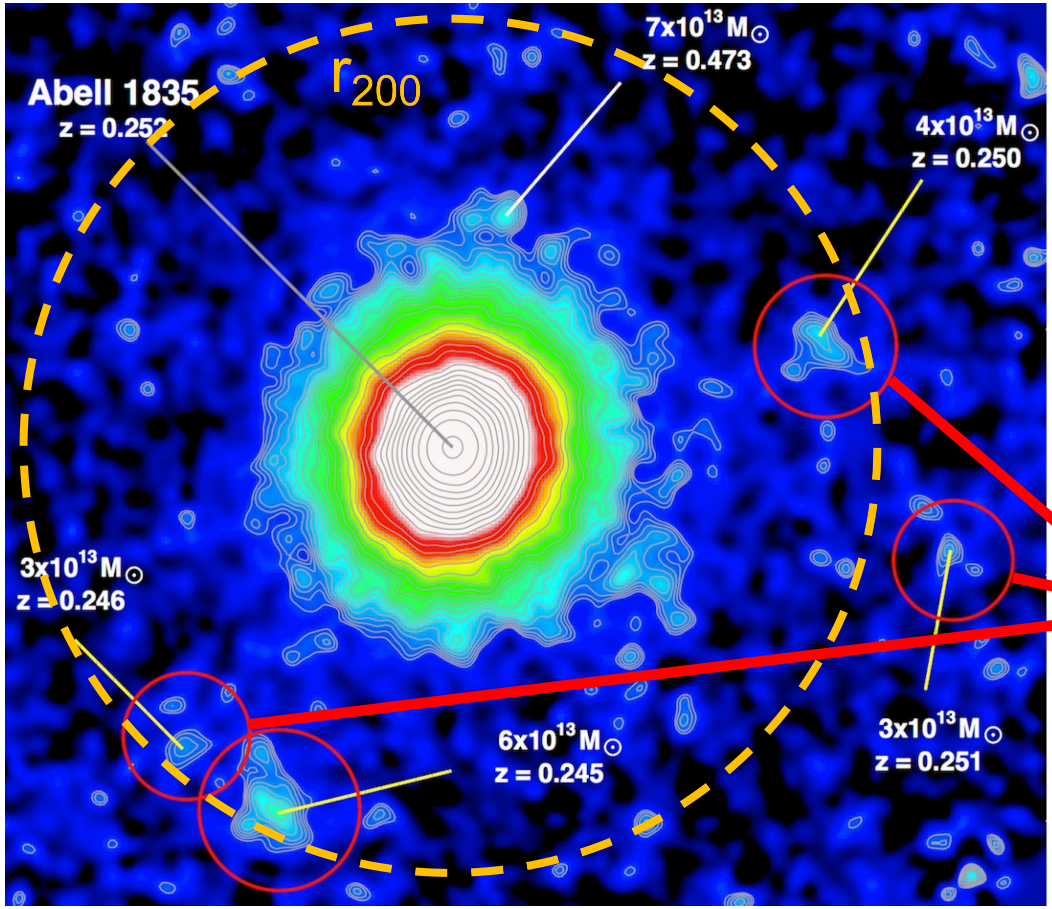




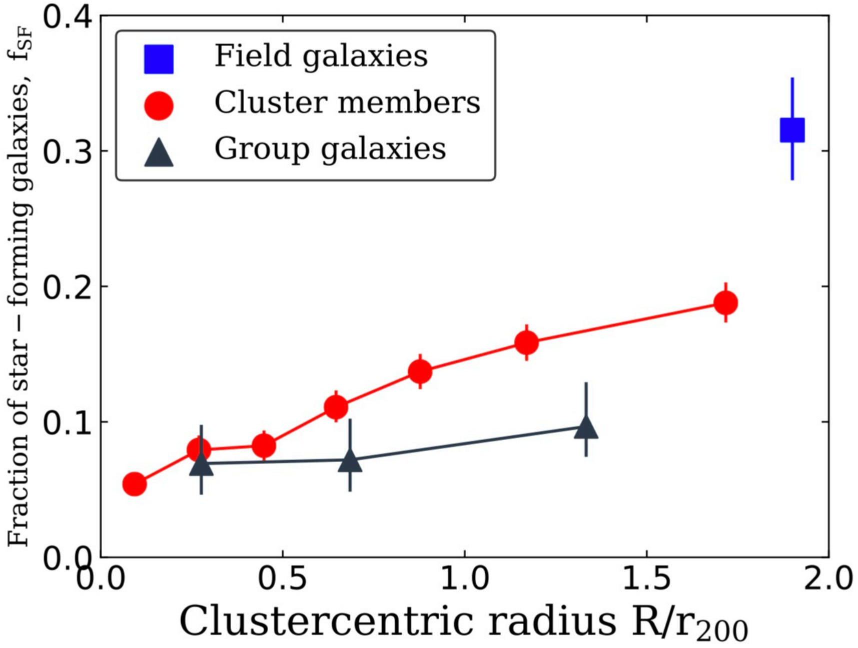
XMM survey of groups around massive clusters

Haines et al. (2018)

- Search XMM images of 23 massive clusters at z~0.2 for extended X-ray emission from groups falling into the clusters
- 39 infalling X-ray groups with spec-z at cluster redshift
- Typically 7+ confirmed group members, σ_v~300km/s
- Mass of infalling groups ~20% of cluster mass, contributing ~half of expected mass growth rate of clusters at late times.
- Limited XMM field-of-view means that can only find groups out to ~r_{200}. Can't map the whole cluster infall regions.
- Member galaxies of these infalling groups have same low f_{SF} as the host clusters. => pre-processing

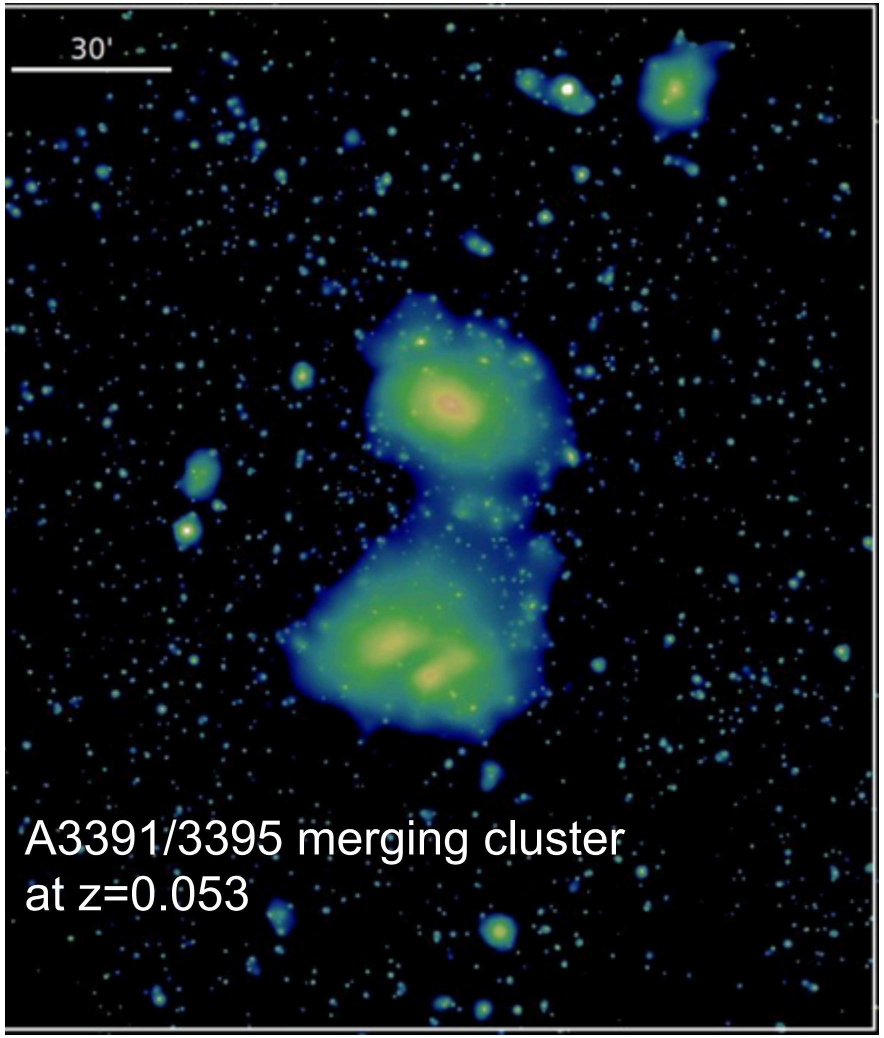


Sites for pre-processing galaxies in groups prior to their accretion into the clusters

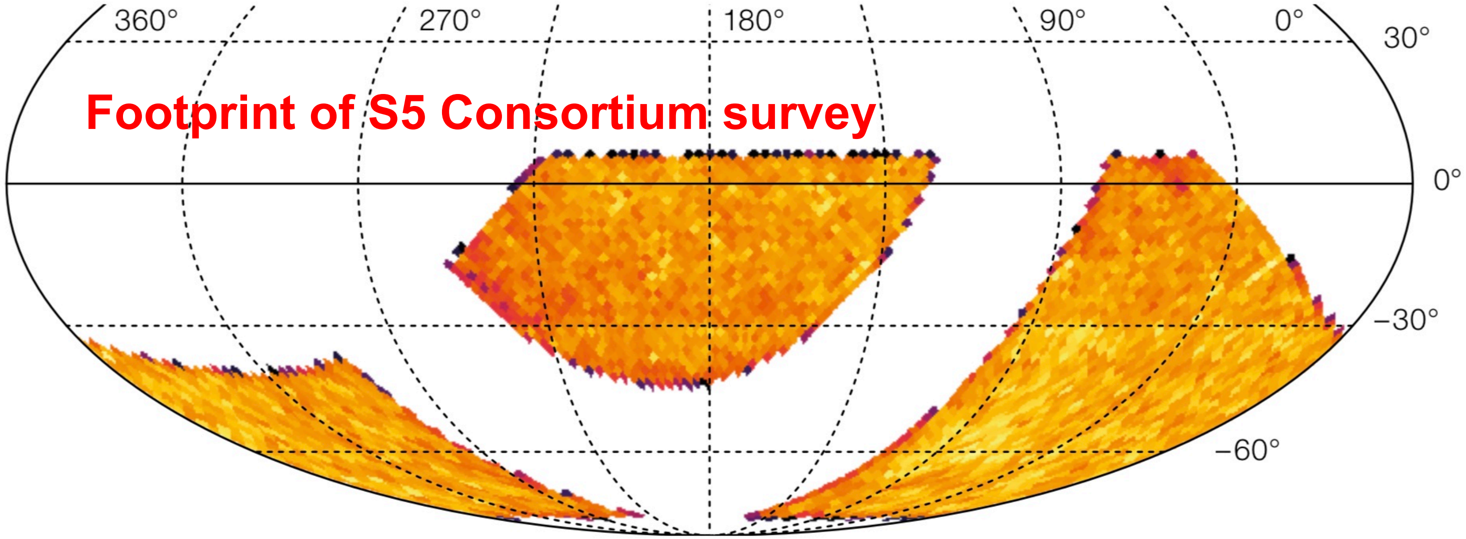


Synergy with the eROSITA all-sky X-ray survey

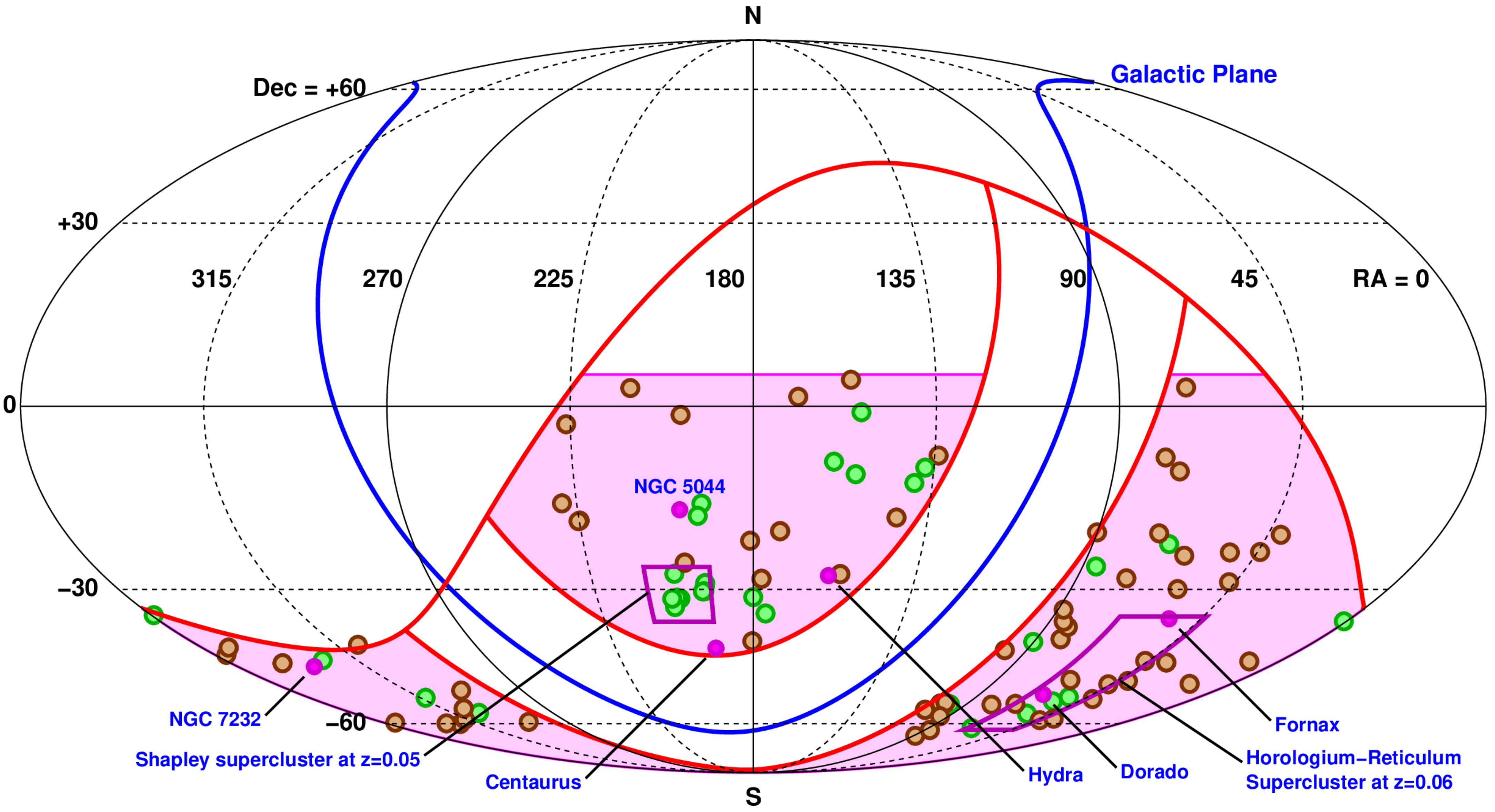
No field-of-view limitations!



- eROSITA will detect all massive clusters in the observable Universe
- For z<0.2 clusters, eROSITA will detect infalling groups ($M>10^{13}\,M_{\odot}$) over the entire cluster infall regions, and the connecting filaments
- Define environment using halos detected by their X-ray emission rather than clustering of member galaxies, permitting us to separate effects of ICM-halo processes from galaxy density (interactions)
- CHANCES will target clusters from the German half of eROSITA sky, that mostly lies in the Southern hemisphere => 4MOST
- Complementary to S5 eROSITA Galaxy Cluster Redshift Survey

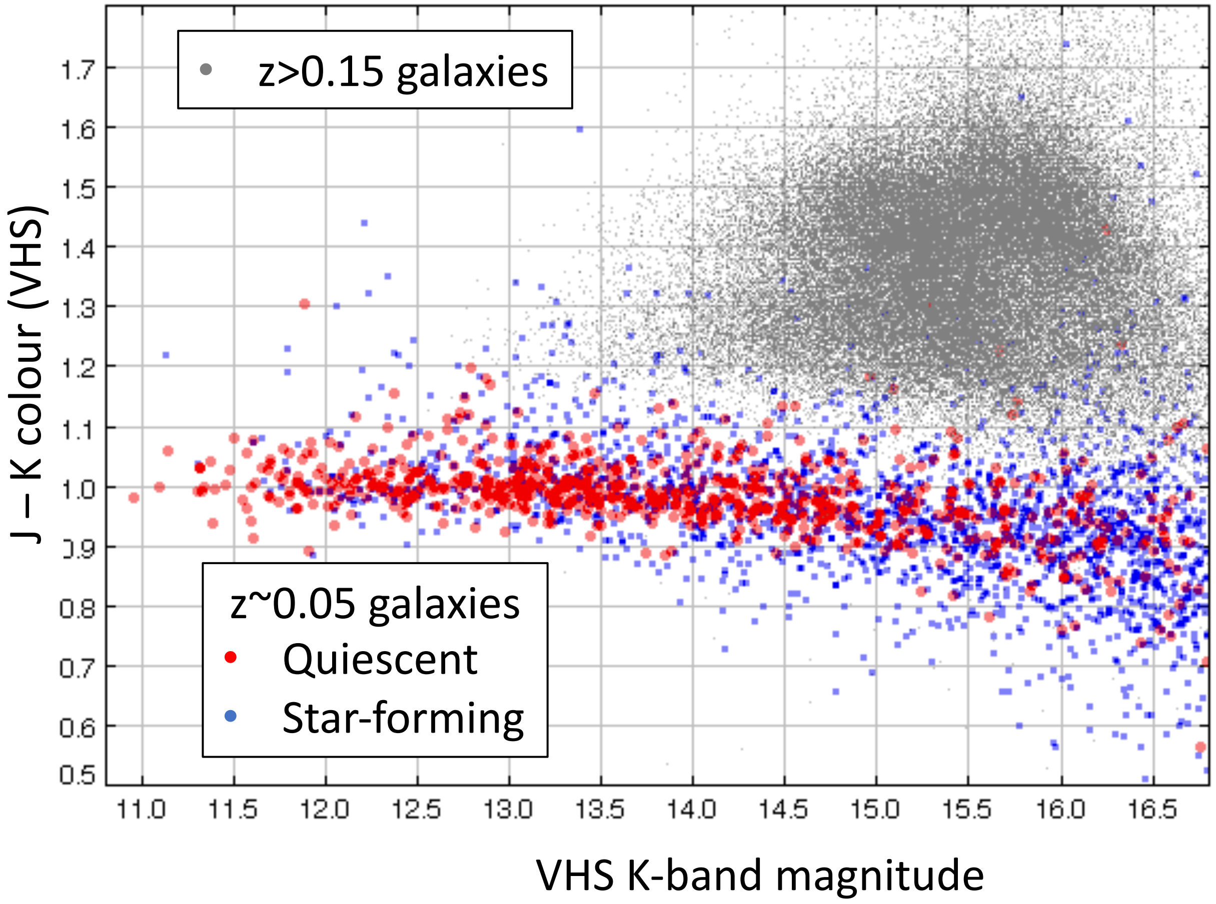


Distribution of CHANCES target clusters



Near-infrared selection of target galaxies

- The near-infrared SED of galaxies is largely independent of star formation history, so that star-forming and quiescent galaxies lie along the same linear sequence in J-K versus K.

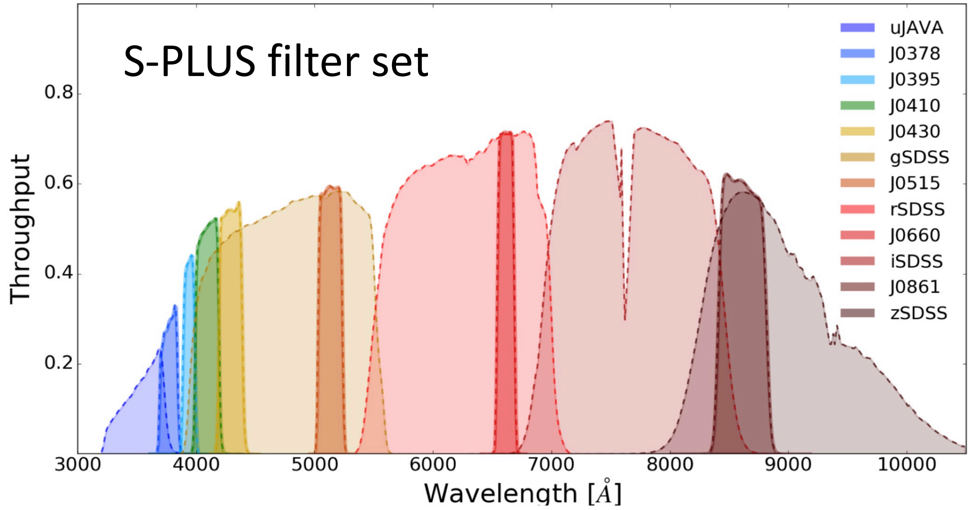


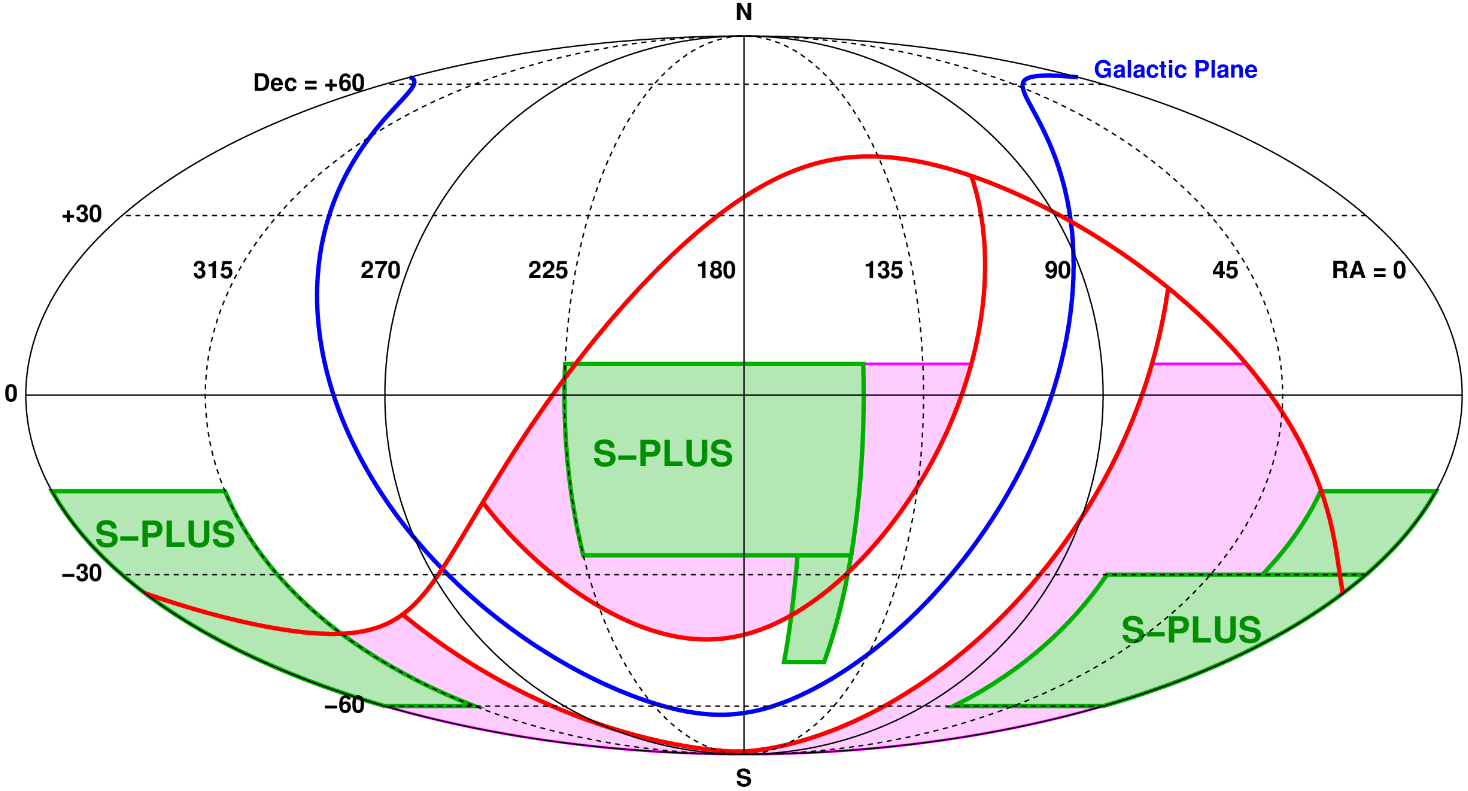
- The J-K colour of galaxies increases steadily with redshift over 0<z<0.5, enabling us to use it as a cheap redshift proxy
- The VISTA Hemisphere Survey (VHS) provides sufficiently deep JK photometry for all our target cluster fields
- Select targets for 4MOST spectroscopy as those galaxies lying on the J-K versus K-band sequence for galaxies at the cluster redshift
- Very efficient at removing most background contaminants for our z~0.05 clusters

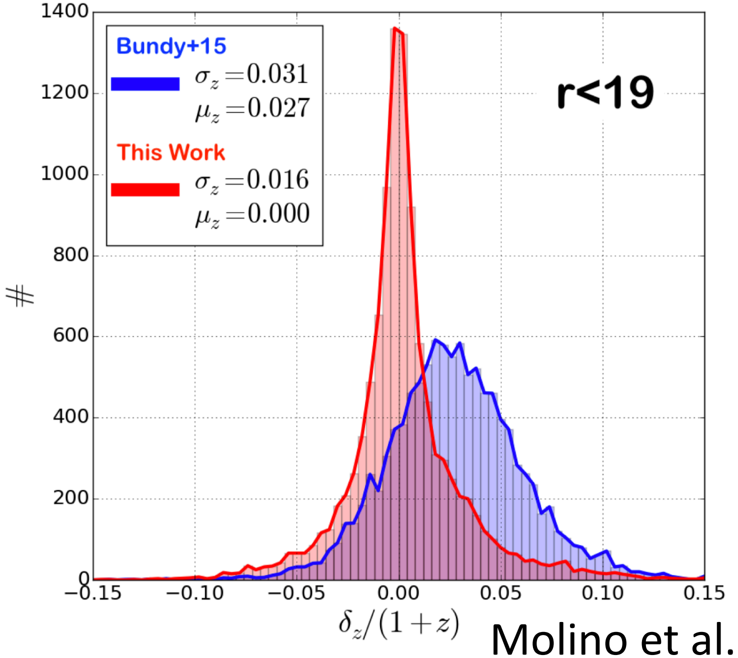
Southern Photometric Local Universe Survey

PI: Claudia Mendes de Oliveira (São Paolo)

- Observing 8000 deg^2 of Southern Sky in 12 optical filters.
- Dedicated 0.8m robotic telescope at Cerro Tololo
- SDSS *ugriz* filters plus 7 narrow-band filters, to r=21
- Greatly improved photometric redshift estimates relative to SDSS
- Use S-PLUS survey to select 4MOST targets as having photometric redshifts consistent with being cluster members
- Expand S-PLUS to cover our other target low-redshift clusters





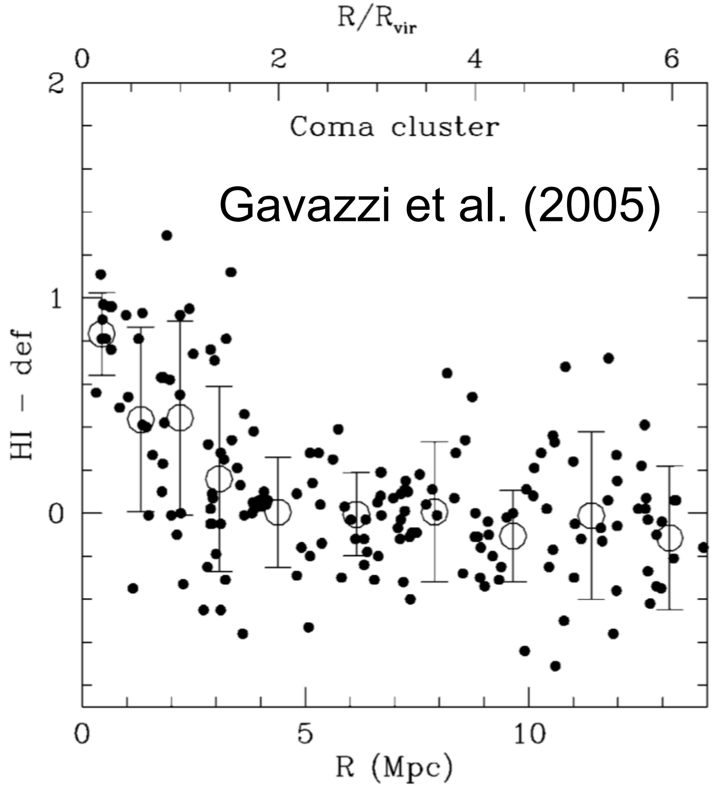


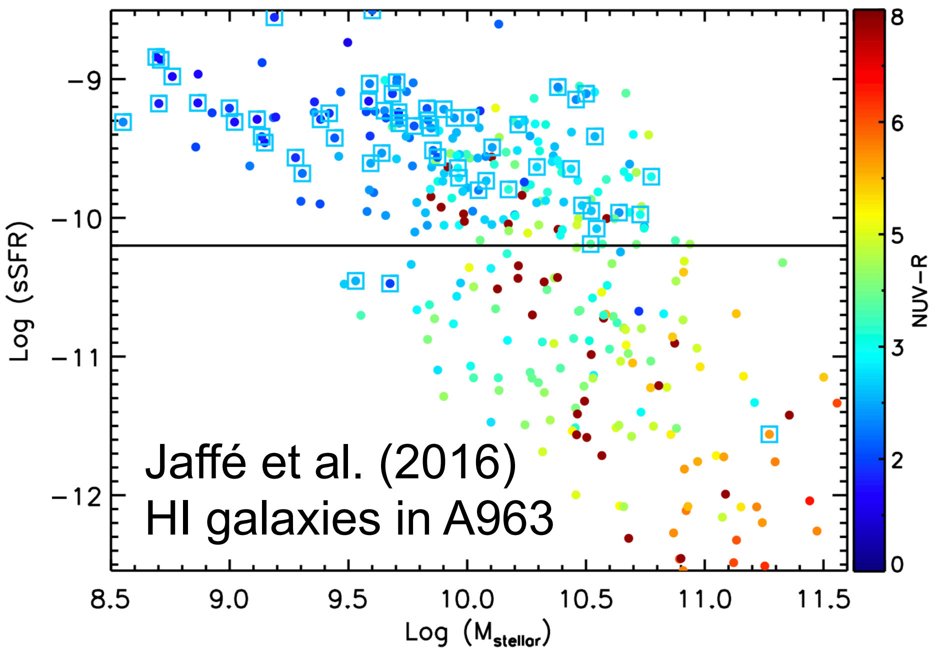
Molino et al. 2019

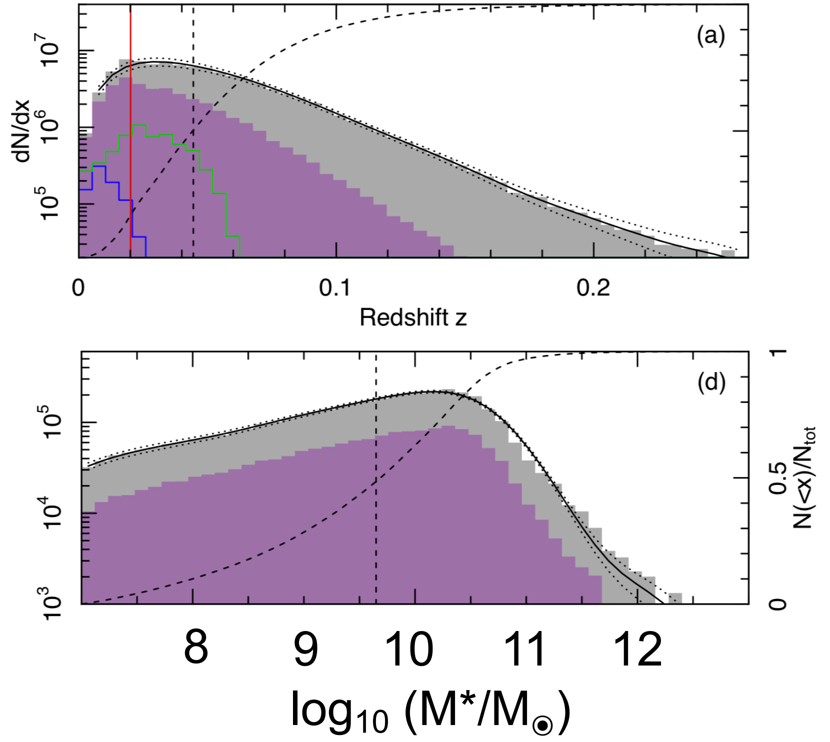
Synergy with Wallaby/ASKAP Survey

- The large HI gas disks of galaxies are very susceptible to ram-pressure stripping in clusters, making HI a sensitive tracer of environmental effects
- Most HI-detections are in low-mass galaxies, due to their high gas fractions
- CHANCES-Wallaby synergy to track impacts of cluster environment on the HI gas contents of dwarf galaxy population in nearby (z<0.07) clusters, and how this feeds through to their ability to continue forming stars

Expected mass and redshift distribution of galaxies detected by the Wallaby HI survey

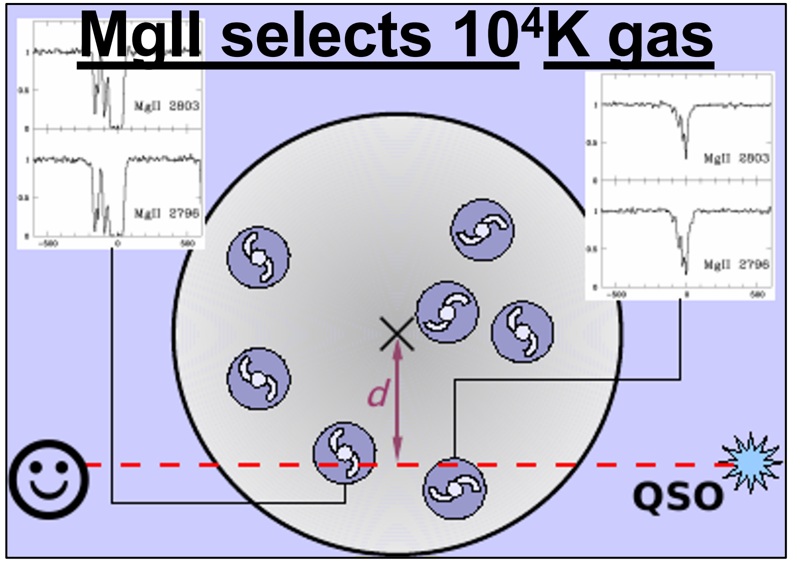


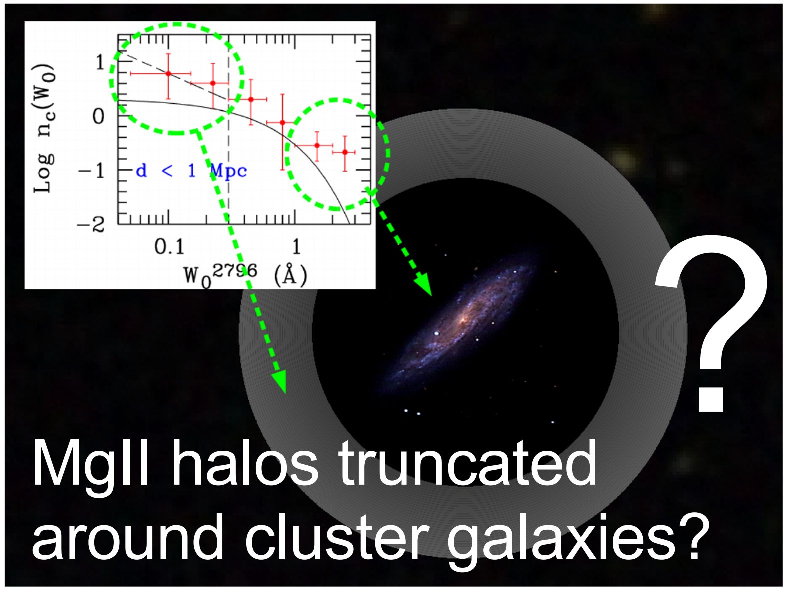




Koribalski et al. (2020)

CHANCES CGM: Cool gas in clusters





Lopez+2008

Use X-ray selected bkg AGN to detect intervening MgII (rest-EW>0.3 Å) at $z_{cluster}$>0.35

Expect ~24,000 confirmed AGN in CHANCES footprint - increase MgII statistics **50x** - get cluster-centric distance cuts of **dN/dW/dz.**

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Summary

Sub-survey	Redshift range	No. of clusters	Area (deg^2)	LRS/ HRS	Target density (deg^{-2})	T_{exp} (min)	SNR	Number of targets
Low-z	0<z<0.07	100	~900	LRS	100-1000	20-120	>15	300K
Evolution	0.07<z<0.4	50	~100	LRS	800-5000	20	2-3	100K
QSO	Z>0.35	10^4	10^4	LRS	3	10	10	24K

Key requirement will be to achieve high-completeness for each cluster observed with 4MOST

Can be flexible about the selection of clusters, to minimize issues with global 4MOST observing strategy

The anticipated X-ray data returns from eROSITA motives a cluster galaxy evolution legacy survey across the Southern hemisphere matched to the German half of the eROSITA sky, tracking the late assembly of massive clusters, and the continual accretion and transformation of cluster galaxies since z~0.4. Synergies with Wallaby/ASKAP and LSST further motivate a Southern 4MOST cluster survey.