Preliminary

Galaxy Transformation in Galaxy Clusters - The View from Herschel

SDP Initial Results Workshop

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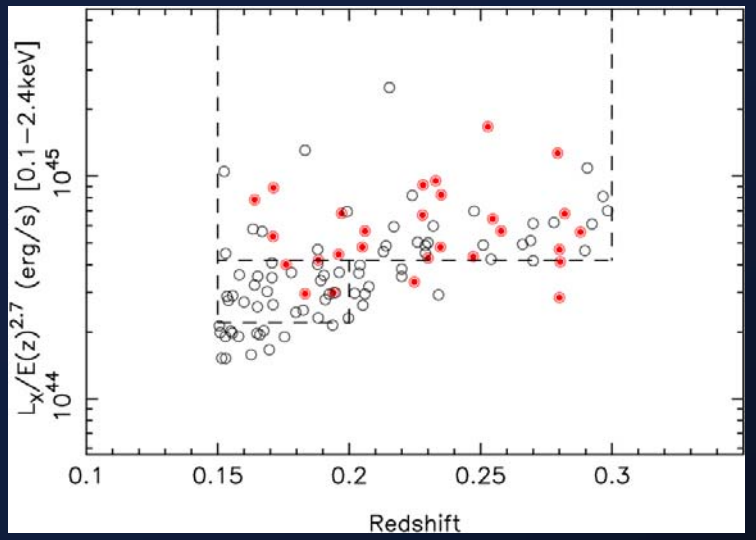
Chris Haines (Birmingham); Eiichi Egami, Maria Pereira, Marie Rex,
Tim Rawle, Emily Hardegree-Ulman (Arizona); Sean Moran (John Hopkins);
Alastair Edge (Durham); Nobuhiro Okabe (Sinica)

Local Cluster Substructure Survey

PI: Graham Smith

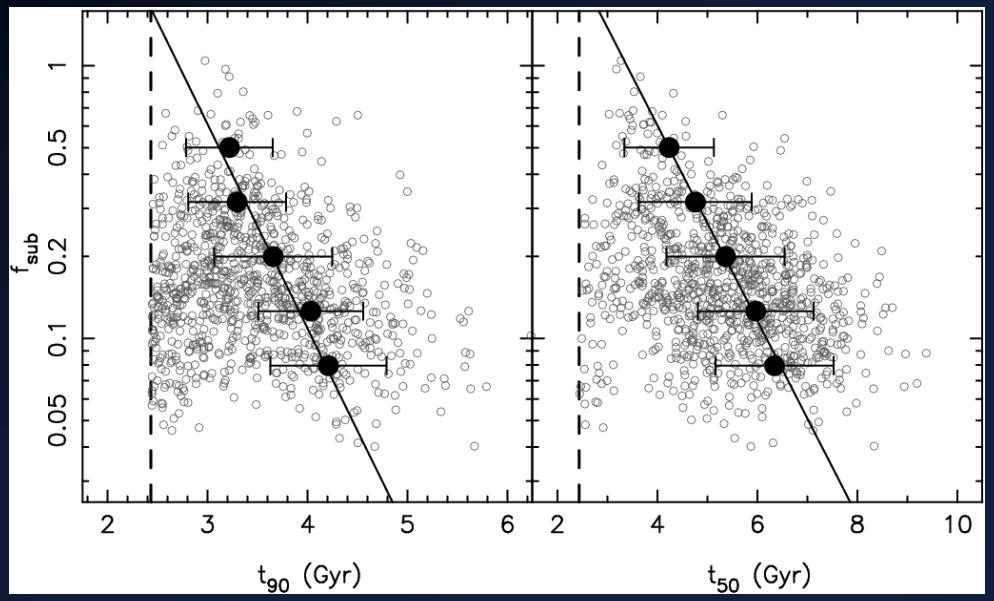
- How does the observed cluster-cluster scatter relate to the age and recent assembly history of clusters?
  - Mass-observable scaling relations
  - Galaxy transformation in clusters



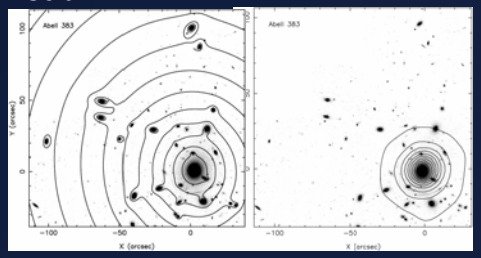
- Morphologically unbiased sample
  - 0.15<z<0.3, -70<dec<+70deg, n_H<7E-20cm^{-2}
  - ROSAT All Sky Survey catalogs: BCS, eBCS, REFLEX
  - 165 clusters with L_X>2E44erg/s

- Huge multi-wavelength effort (~30-50% complete):
  - Subaru, HST, Keck, VLT, Gemini, Chandra, XMM, SZA, Palomar
  - Subaru, Spitzer, GALEX, Herschel, MMT, KPNO, CTIO, UKIRT

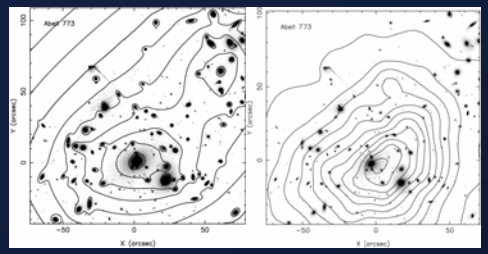
Lensing → Substructure (f_{sub}) → Assembly history



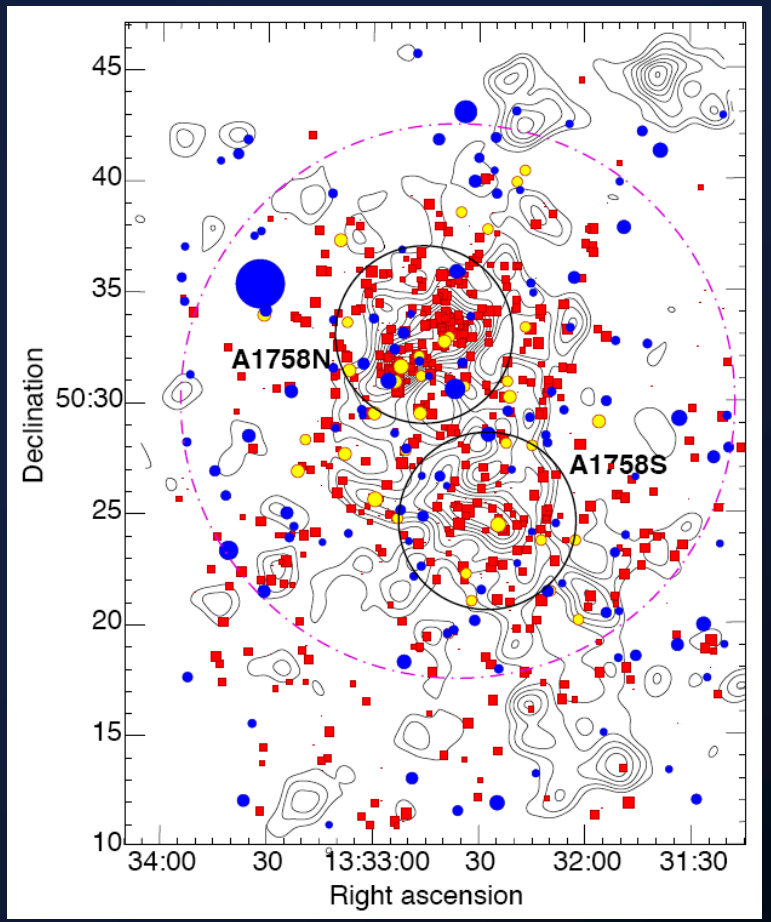
f_{sub}<0.1



f_{sub}>0.4



Smith et al., 2005, MNRAS, 359, 417
Smith & Taylor, 2008, ApJ, 682, 73

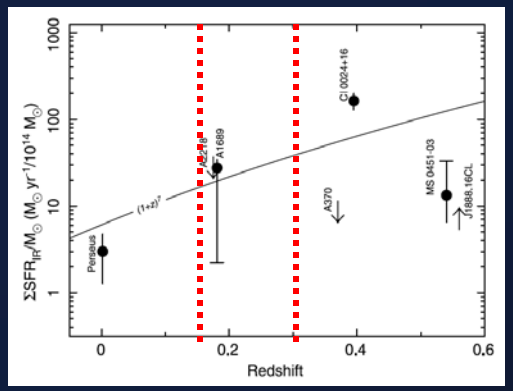


Okabe & Umetsu, 2008, PASJ,
Haines et al., 2009, MNRAS, 396, 1297

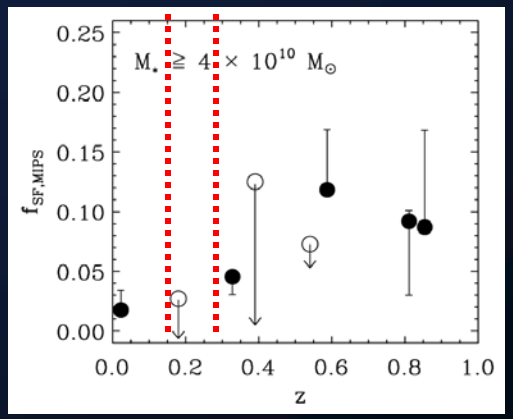
Motivation of Herschel Key Programme:

A Legacy Survey of Galaxy Clusters at z=0.2

- What is the star formation history (i.e. origin) of S0 galaxies found in local clusters?
  - Gradual fading of gas rich disk galaxies?
  - Rapid quenching of star-formation?
  - Intense (obscured) starburst?
  - Exhaustion of gas in field galaxies since z~1?
- Summary of ISO/Spitzer results:
  - ~10 clusters, heterogeneous selection, depths, fields of view
  - Connection between cluster-cluster mergers and starbursting cluster galaxies?
  - Order of magnitude variations in IR populations in clusters
- Need: a large homogeneous wide-field survey of clusters



Geach et al., 2006



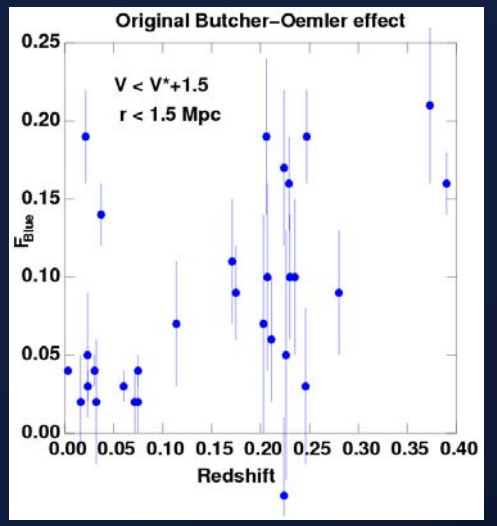
Saintonge et al., 2008

Strategy of Herschel Key Programme:
A Legacy Survey of Galaxy Clusters at z=0.2

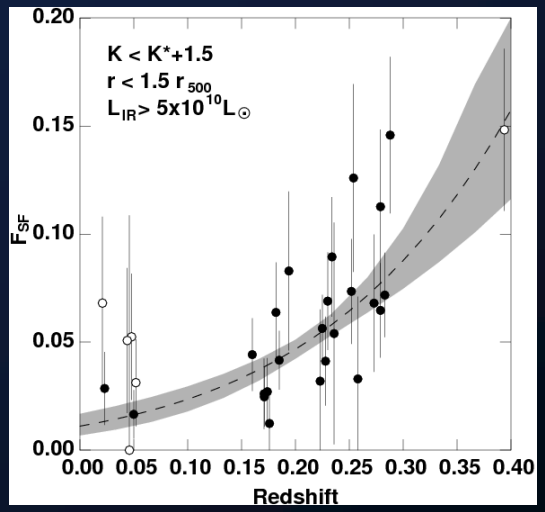
- Large sample of clusters at “low” redshift
- 100/160um observations probe SED peak
- Probe out to $\geq 1.5 r_{virial}$

- A bit more detail:
  - Optical Butcher Oemler effect is “smoking gun” of significant cluster-cluster variations at z~0.2
  - Global SFR (gas supply) is ~2-3× lower at z~0.2-0.3 than at z~1, but it is not negligible!
  - Observations at z=0.2 are 5× cheaper than at z=0.8!

- Currently a large statistical sample is only feasible at z~0.2
- 32 clusters ➔ ~600-1000 galaxies with $L_{IR}>5\times10^{10}L_{\odot}$



Butcher & Oemler 1978, 1984



Haines et al., 2009, ApJ, 704, 126

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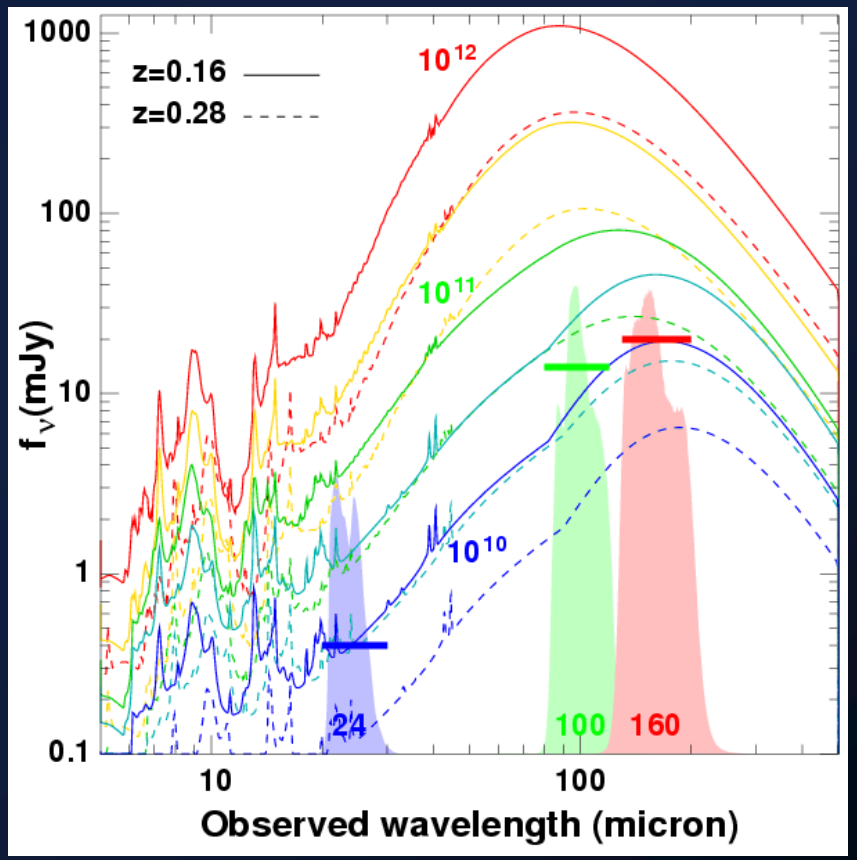
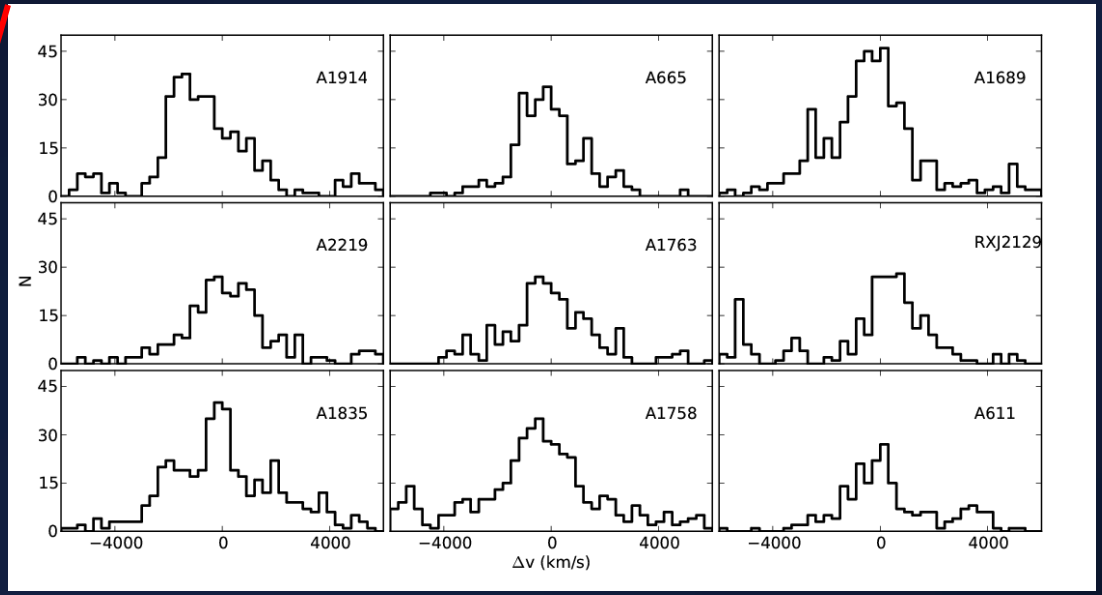
SDP Observations, Data Processing, and Sensitivity

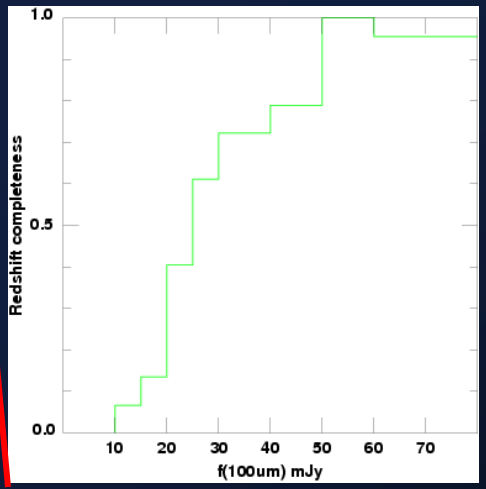
- Observations of A1758 & A2390:
  - PACS 100um and 160um
  - 25x25arcmin maps
  - 110 sec on-sky per pixel
  - Total 4.8 hours per cluster
- Data processing:
  - Standard hipe pre-processing
  - ≥2.5σ sigma sources masked using 20/25" apertures (BL/R)
  - high pass filter with a filter size of 30/35 frames (BL/R)
  - small offsets (<1") in astrometry between scans eliminated from individual frames
  - final maps created using photproject map making routine

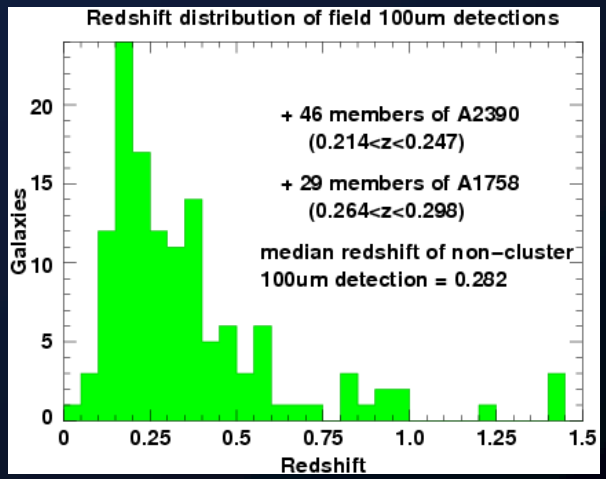


Brief Note on Supporting Data

- Spitzer MIPS 24um
  - initial selection of IR sources
- MMT Hectospec
  - optical redshifts and SF indicators
- GALEX FUV/NUV
  - recently quenched SF
- UKIRT & KPNO
  - stellar masses
- Subaru
  - weak-lensing maps
- HST WFPC2/ACS
  - strong-lensing
- XMM and Chandra
  - hot gas density, entropy, etc.







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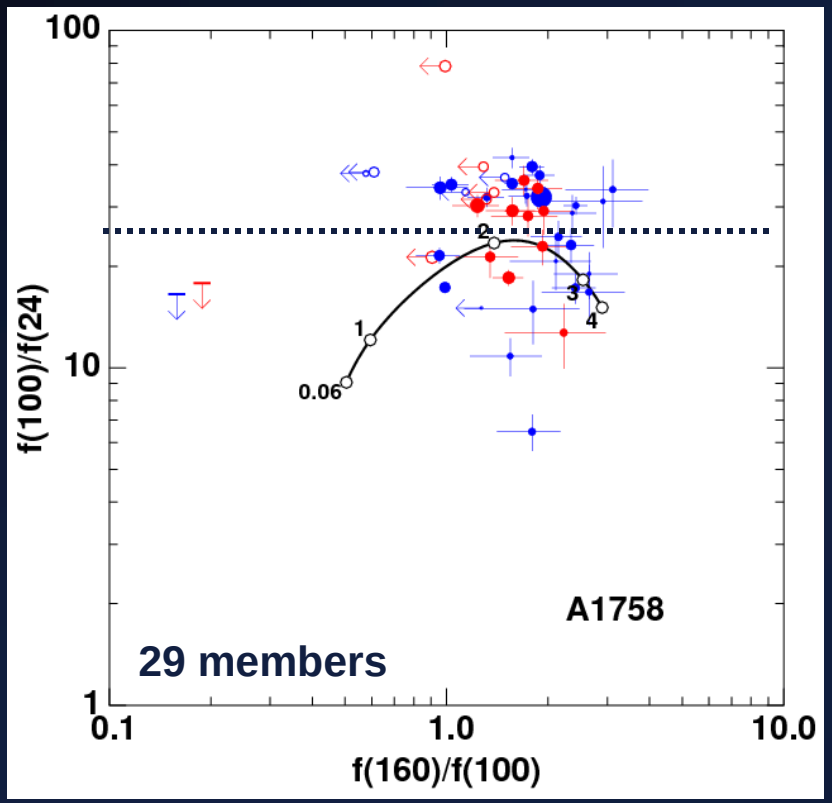
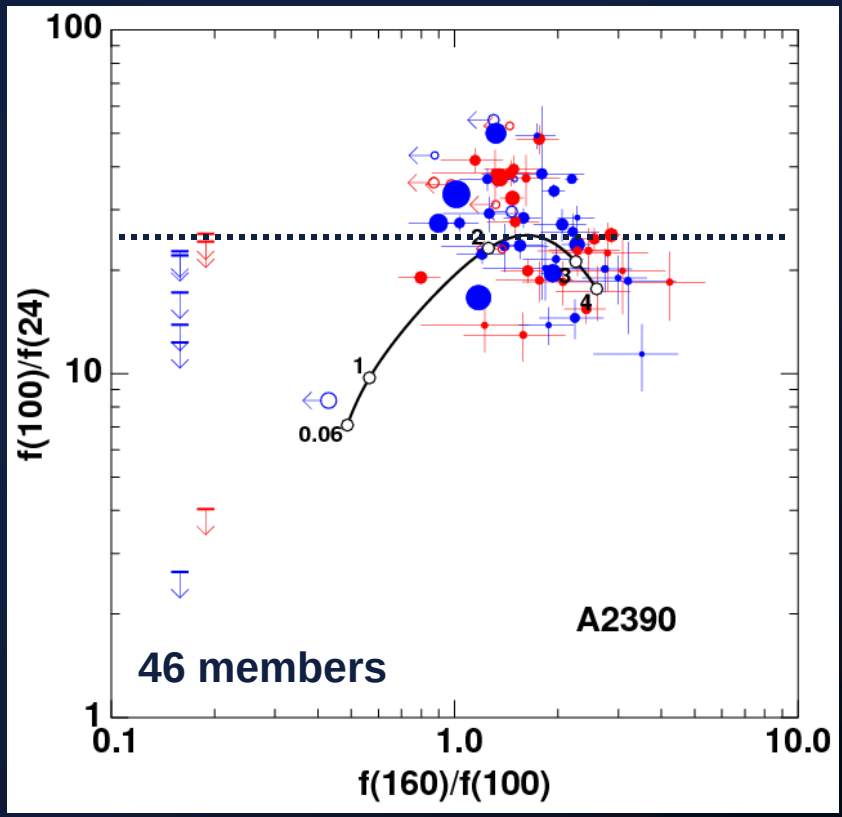
Infrared colours of cluster galaxies

L_{IR}>~5×$10^{10}L_{\odot}$

Abell 1758 - multiply-merging cluster



Abell 2390 - cool core cluster



Blue = Field galaxies 0.15<z<0.3
Red = Cluster members

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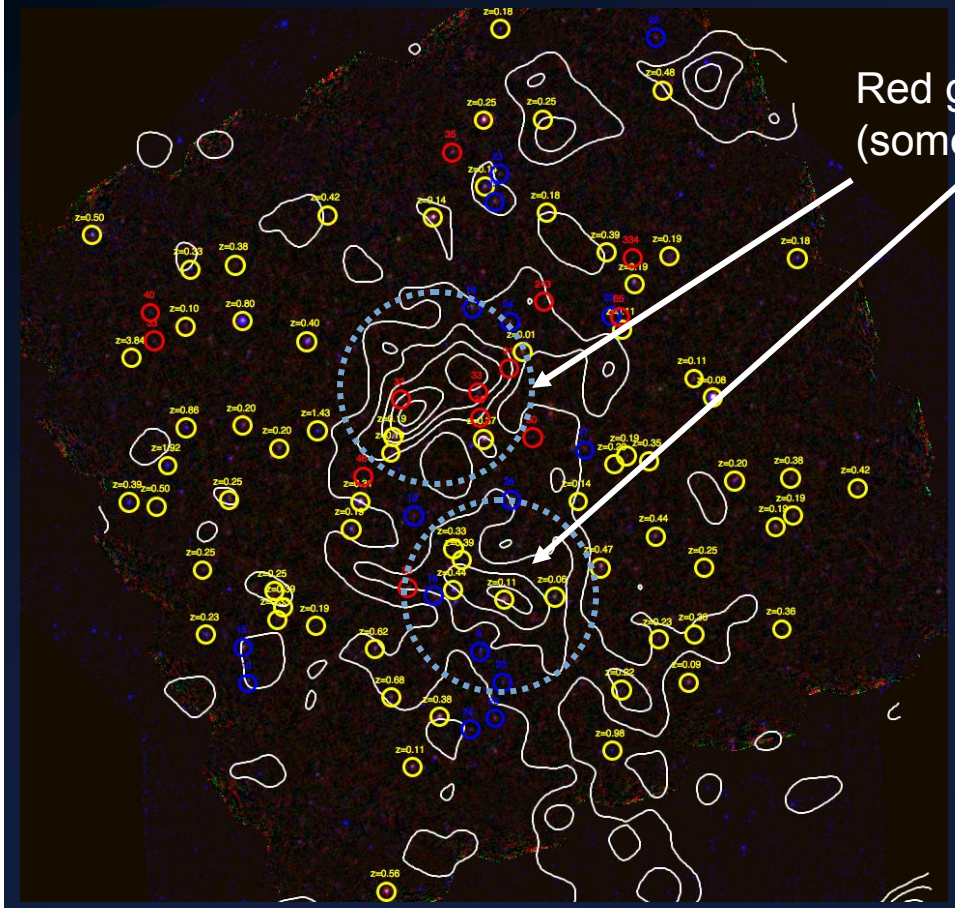
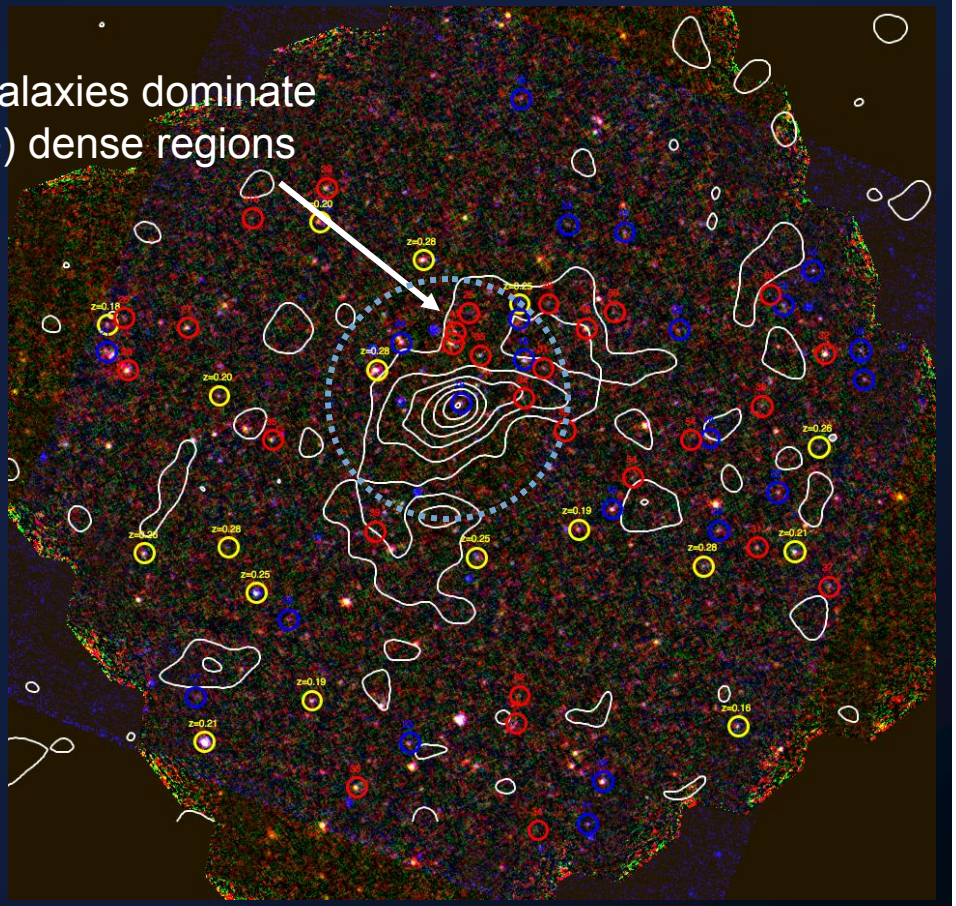
Comparison with weak lensing maps

Abell 1758 - multiply-merging cluster

Abell 2390 - cool core cluster



Red galaxies dominate
(some) dense regions



Yellow = Field galaxies 0.15<z<0.3
Red = red cluster members log[f_ν(100um)/f_ν(24um)]>25
Blue = blue cluster members log[f_ν(100um)/f_ν(24um)]<25

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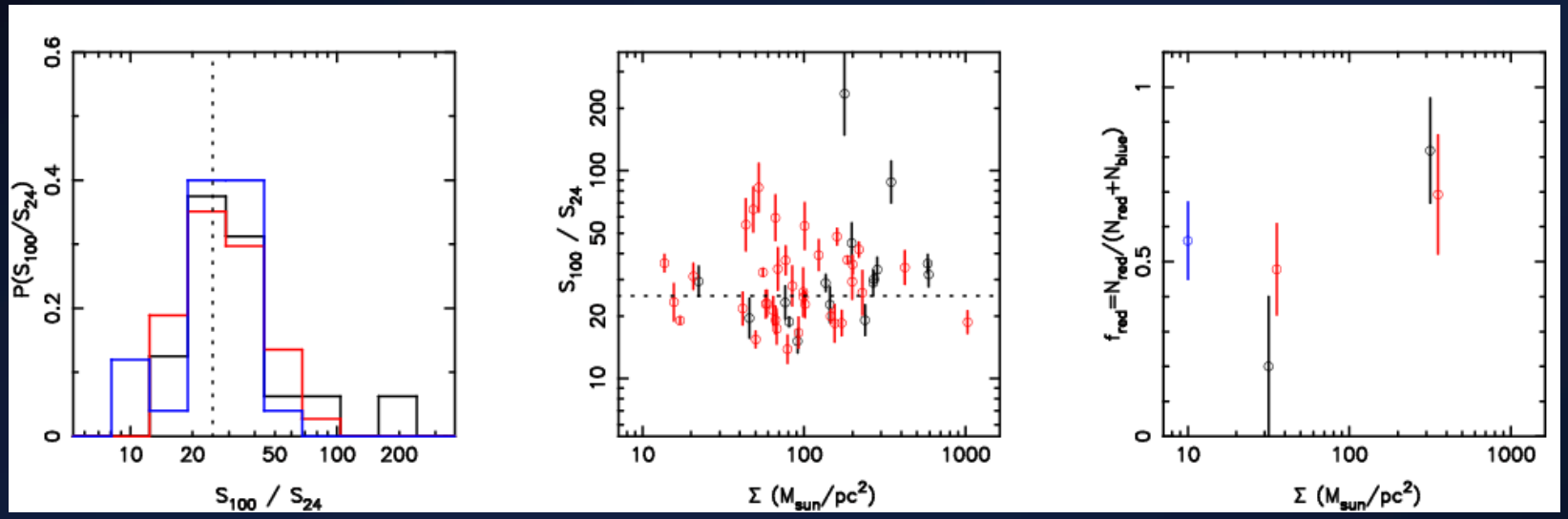
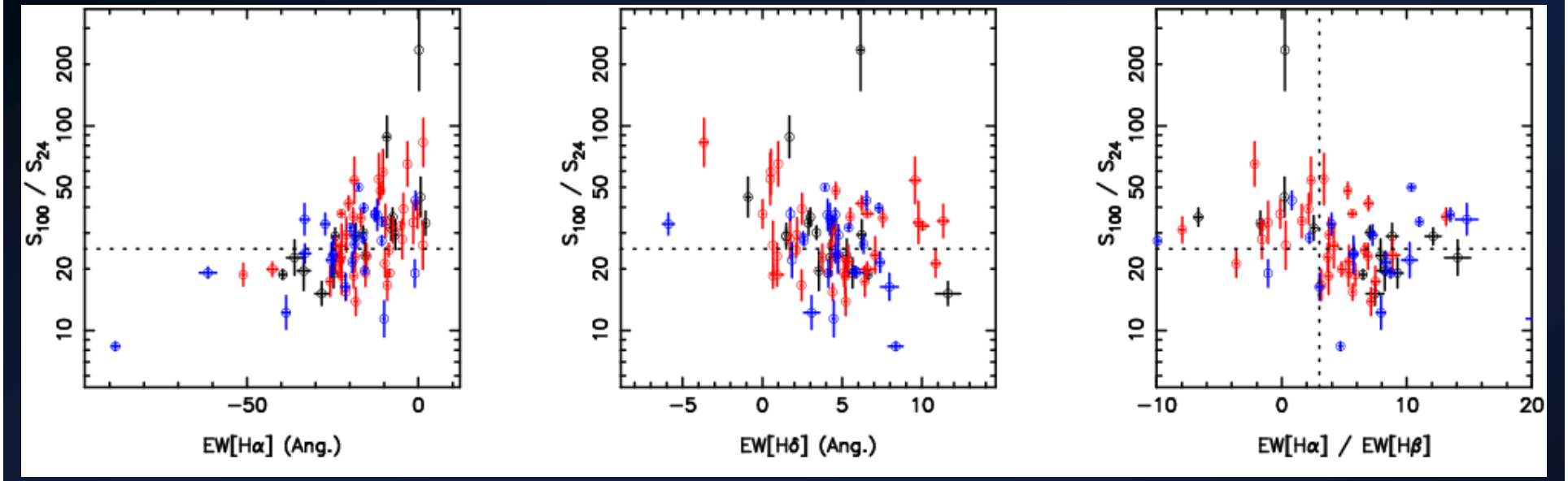
Far-IR colour / Mass density relation

Black = A1758 Red = A2390 Blue = Field galaxies 0.15<z<0.3



- Reddest galaxies ~only found in clusters?
- Red galaxies appear to dominate the densest regions
- Need a bigger sample than 2 clusters!

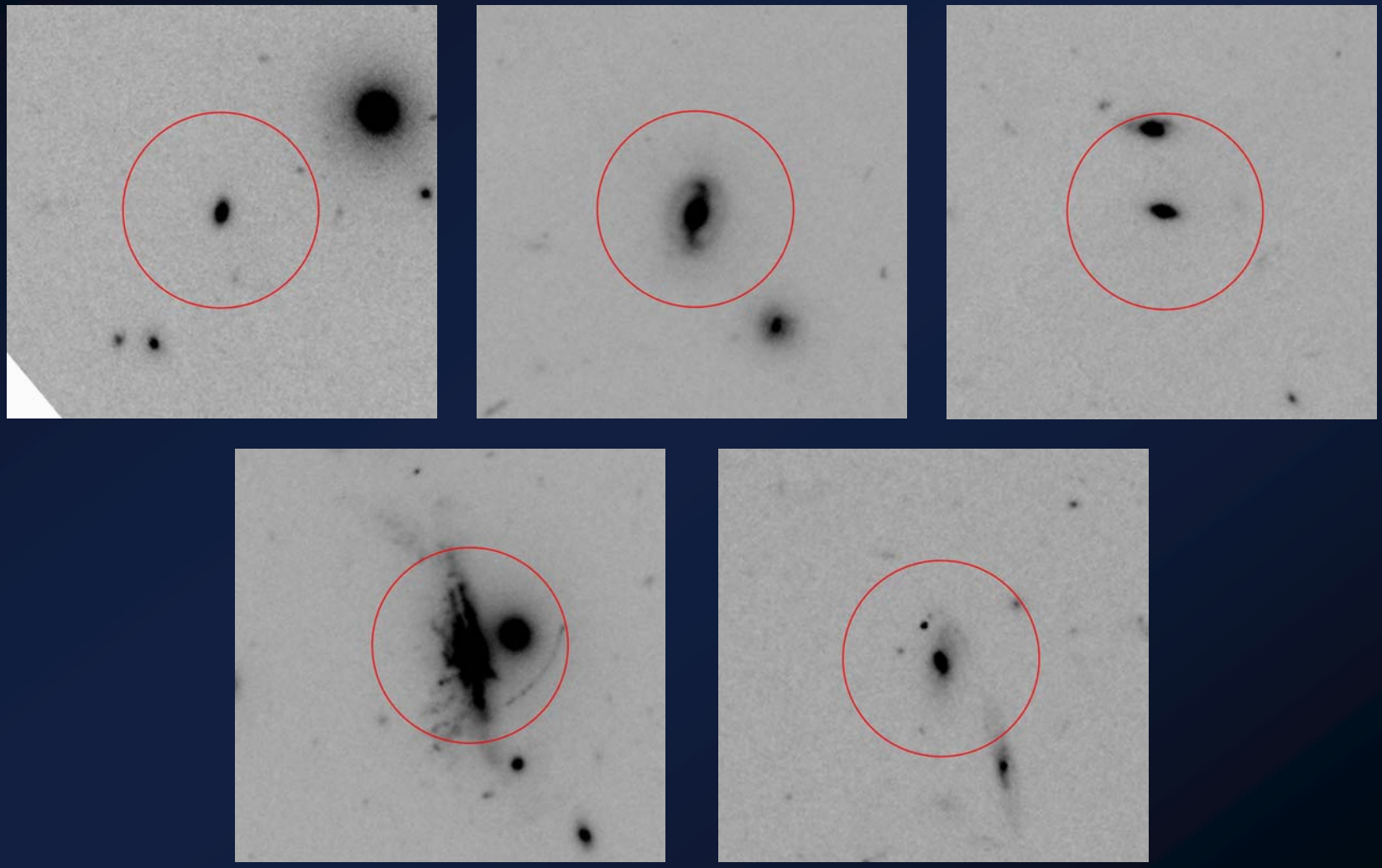
Far-IR colours versus optical lines



- As a population, red galaxies appear to …
  - have weaker Hα emission lines
  - and weaker Hδ absorption lines
  - suffer less reddening than blue galaxies
- Cooler dust? Post-starbursts? (More reddened?)

Optical morphology of red galaxies

Small HST/WFPC2 mosaic of A1758



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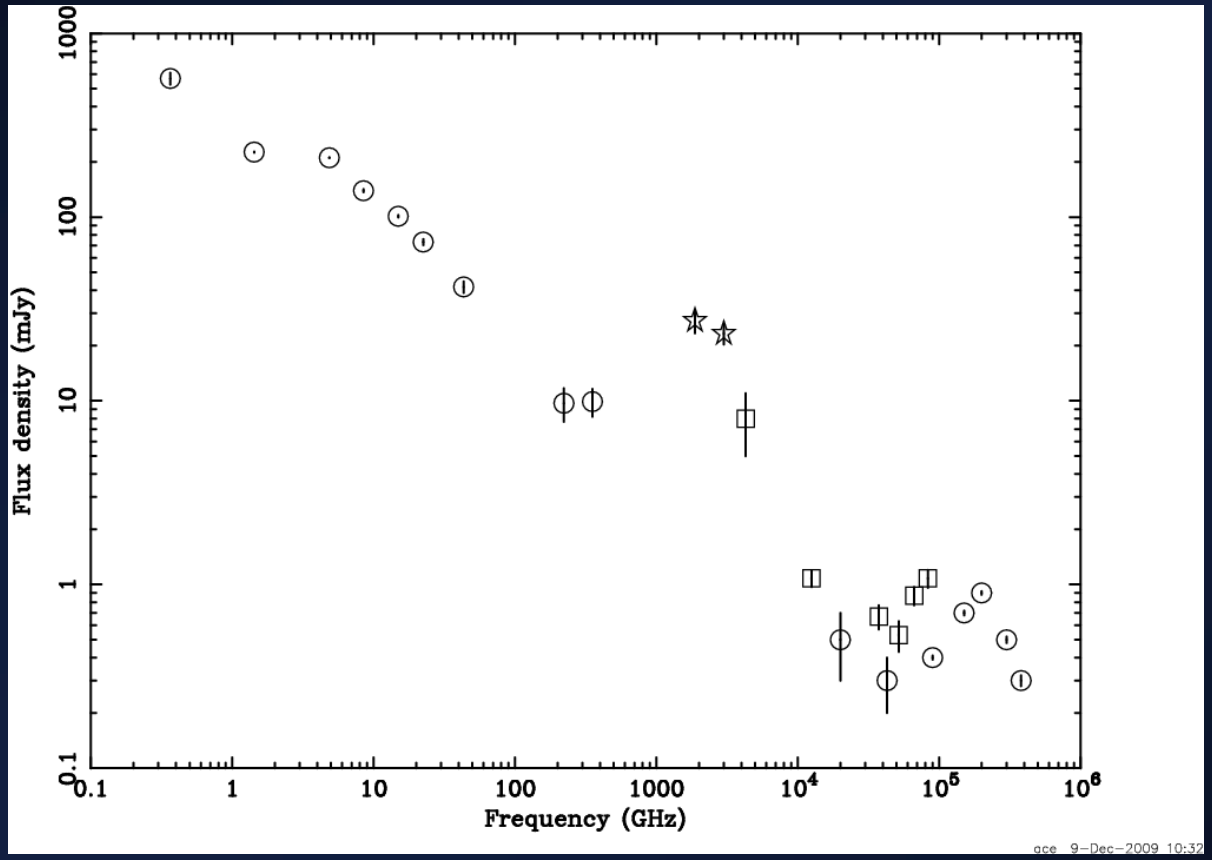
A2390 - Brightest Cluster Galaxy



- See Alastair Edge's talk

Summary

A Legacy Survey of Galaxy Clusters at z=0.2

- LoCuSS:
  - Morphologically unbiased sample of 32 massive clusters at $0.15<z<0.3$ ➔ ~600-1000 galaxies with $L_{IR}>5\times10^{10}L_{\odot}$
  - How do the amplitude of different physical pathways from Spiral to S0 correlate with the thermodynamic and assembly history of clusters?
- SDP observations of 2 clusters:
  - Confirm observing strategy (~2x worse than expected @ 160um)
  - Galaxies with red 100/24 colors live in cluster cores
    - Less active and cooler than bluer galaxies in cluster outskirts?
- Short/medium term:
  - 7 clusters scheduled December 22-24 - improved statistics
  - More detailed/careful IR/optical/UV analysis
  - Use more sophisticated SED models to interpret data
  - Additional probes of environment - X-ray, galaxy density
- Long-term?:
  - Detailed morphologies from HST/WFC3?