

Environmental effects on galaxy luminosity functions in clusters

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Effects of cluster mergers on the galaxies (and X-ray gas) in clusters

- Morphological segregation: ellipticals are in the more central regions and spirals are in the cluster outskirts (infall)
- Cluster mergers can trigger star formation (compression of gas in the galaxies by shocks) or quench it (ram pressure stripping)
- Galaxy luminosity functions (GLFs) tend to be flatter in the inner regions and steeper in the outskirts; they can be modified by cluster mergers (faint end slopes, dips, wiggles)
- Faint galaxies in clusters tend to be rather blue (global GLFs tend to be steeper in the u band, tracing star formation)
- Existence of cEs (compact Ellipticals=ram pressure stripped ellipticals)
- Presence of large scale filaments of galaxies

Effects of cluster mergers on the intracluster gas

- Mergers are not always apparent on X-ray images
- But their traces are seen on temperature and metallicity maps of the X-ray gas
- Numerical simulations can reproduce these maps
- Presence of large scale filaments of X-ray gas in a few cases (Abell 85)

Our favorite clusters

Relaxed

- Abell 496
- Abell 780 (Hydra A)

Unrelaxed

- Coma
- Abell 85
- Cluster pairs: Abell 222 / Abell 223
Abell 1758 North / South

Schechter function fit
to the GLF:

$$S(M) = 0.4 \ln 10 \Phi^* y^{(\alpha+1)} e^{-y}$$

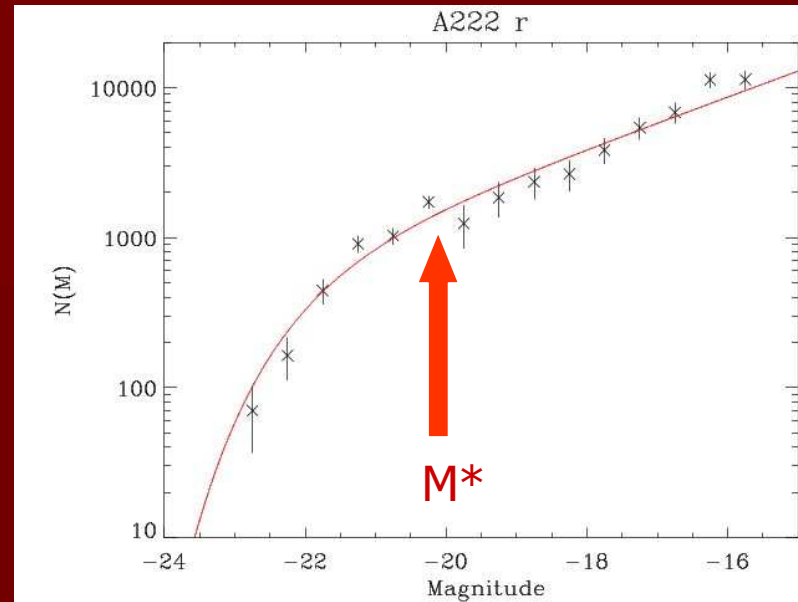
$$y = 10^{0.4(M^* - M)}$$

Φ^* = normalization

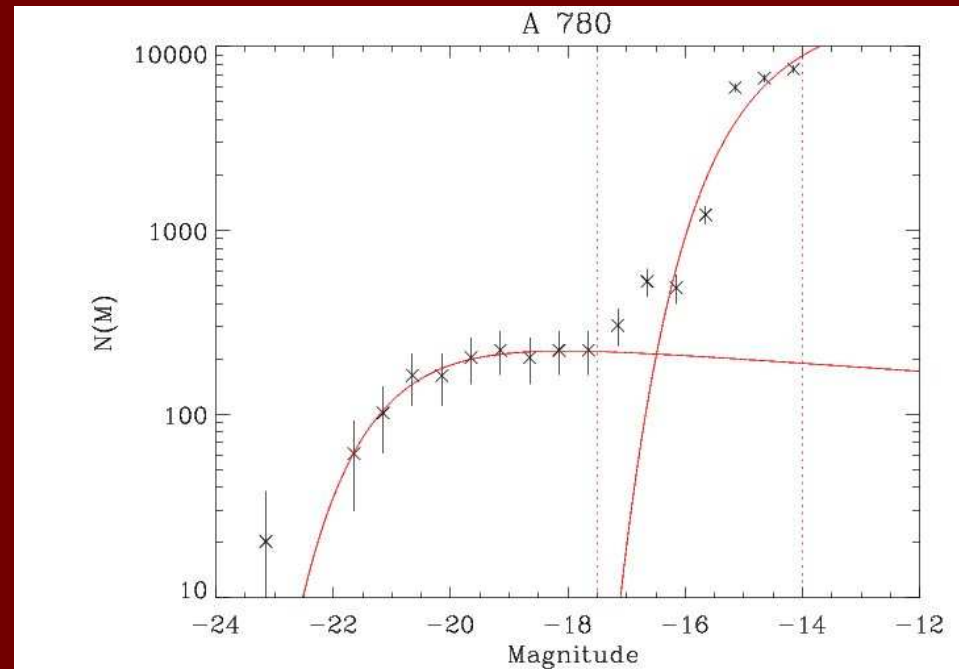
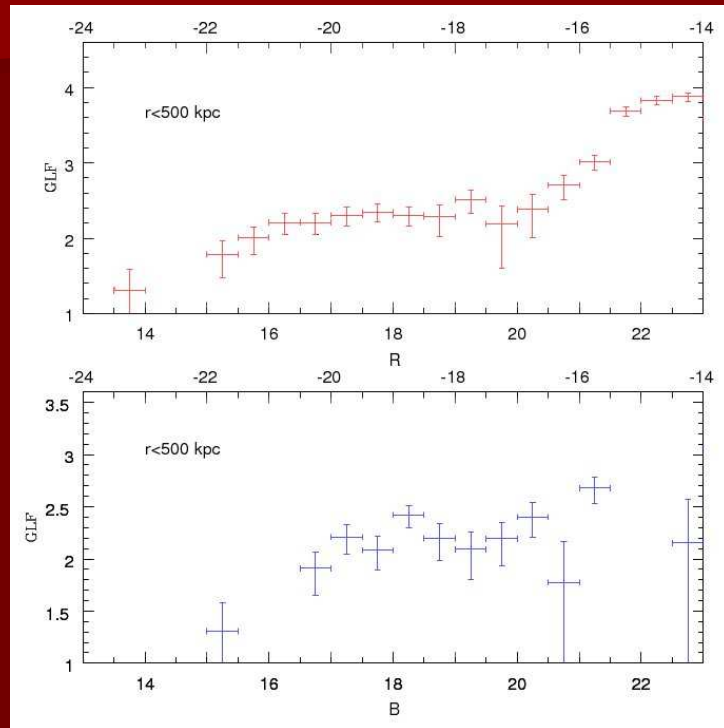
M^* = absolute magnitude of « elbow »

α = faint end slope

α found to depend on photometric band and on region of
the cluster

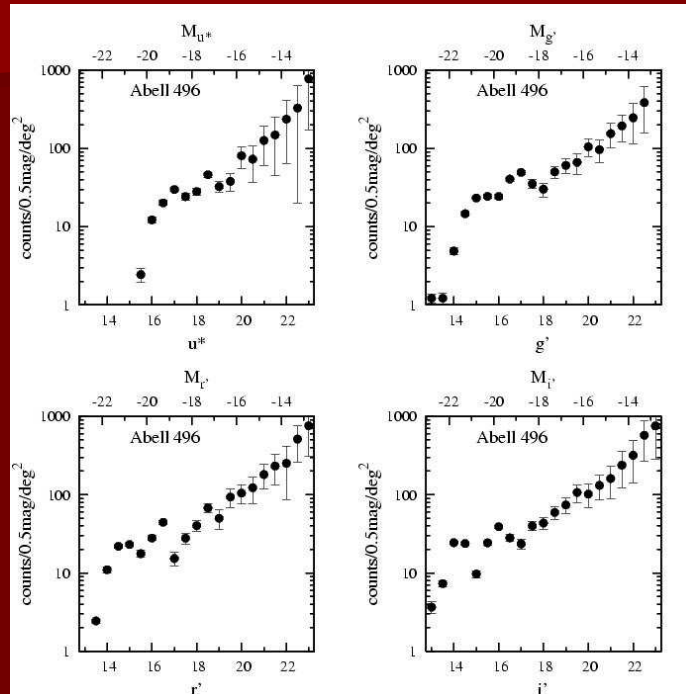


GLFs of a very relaxed cluster: Abell 780



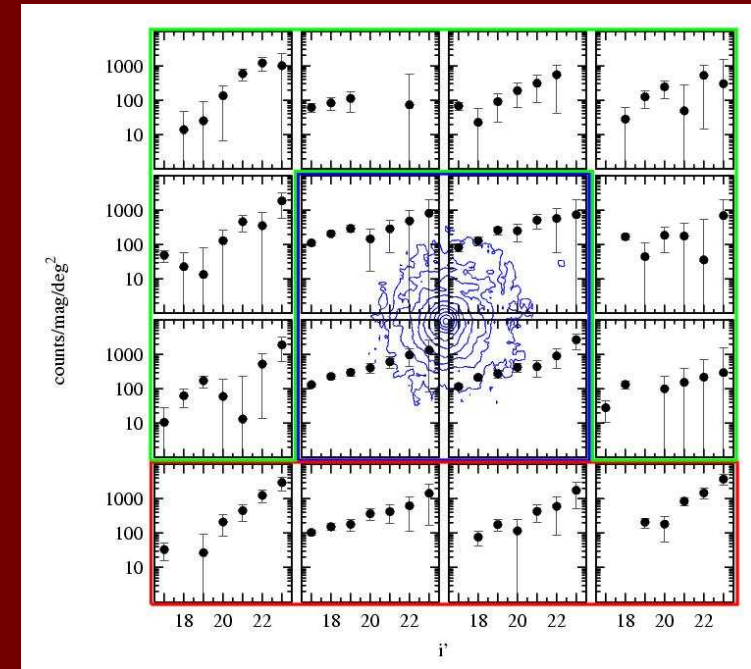
Two Schechter functions needed
Flat faint end slope
in the R band:
 $\alpha = -1.09 \pm 0.05$

GLFs of a relaxed cluster: Abell 496



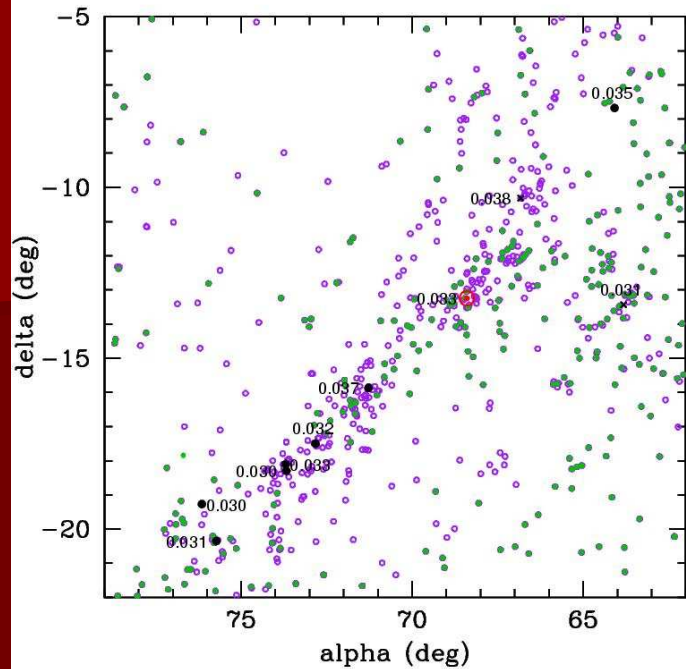
Global faint end slope:
 $\alpha = -1.68 \pm 0.35$ in u^*
 $\alpha = -1.52$ to -1.62 ± 0.05 in g', r', i'

Boué, Adami, Durret, Mamon, Cayatte,
 2008, A&A 479, 335



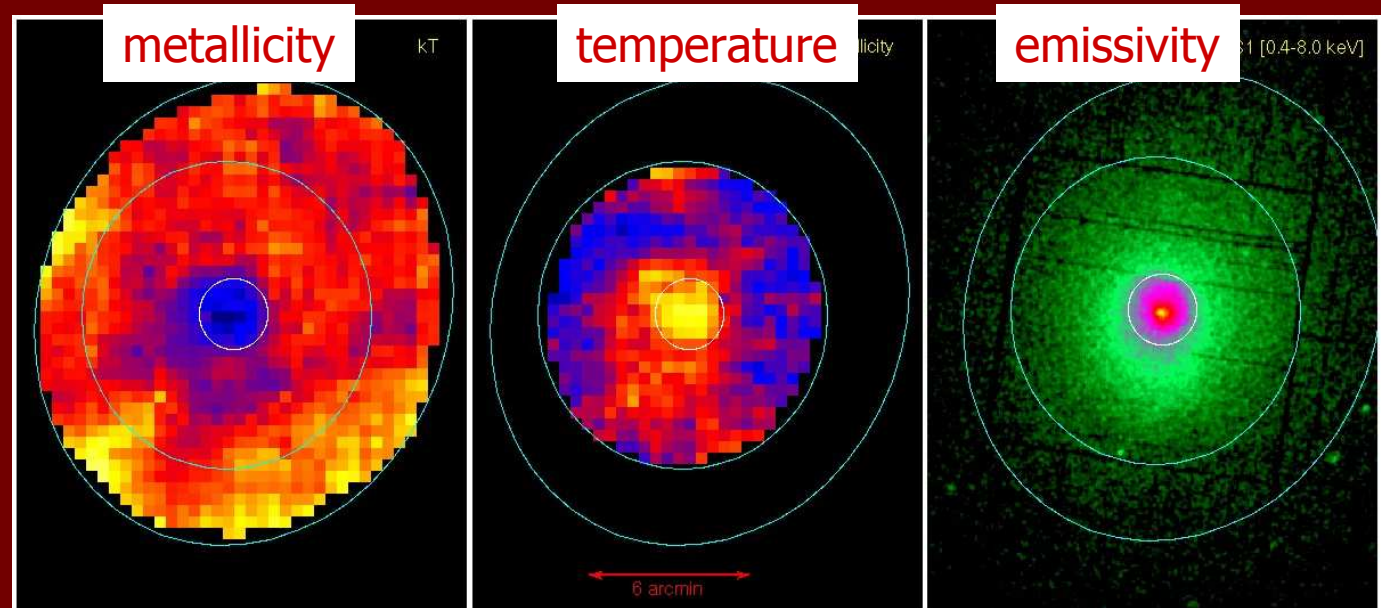
Center: $\alpha = -1.60 \pm 0.27$ in u^*
 -1.40 ± 0.08 in other bands
 South: $\alpha = -1.8$ in all bands
 East-north-west: $\alpha = -1.88$ in u^* ,
 -1.4 to -1.6 in other bands

Filament of galaxies at same z

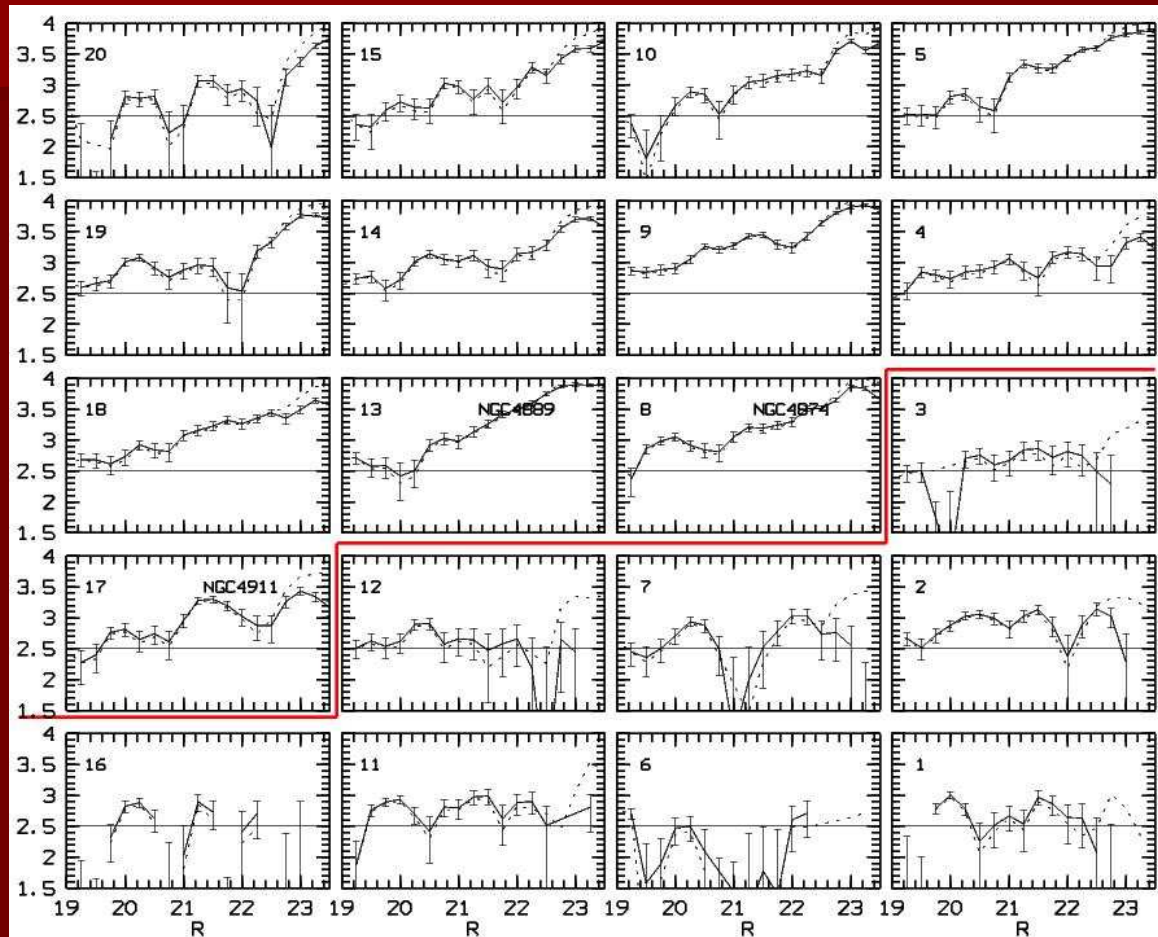


But is Abell 496 really relaxed?

X-ray maps (XMM-Newton)



Unrelaxed clusters: Coma



Faint end slope in R:

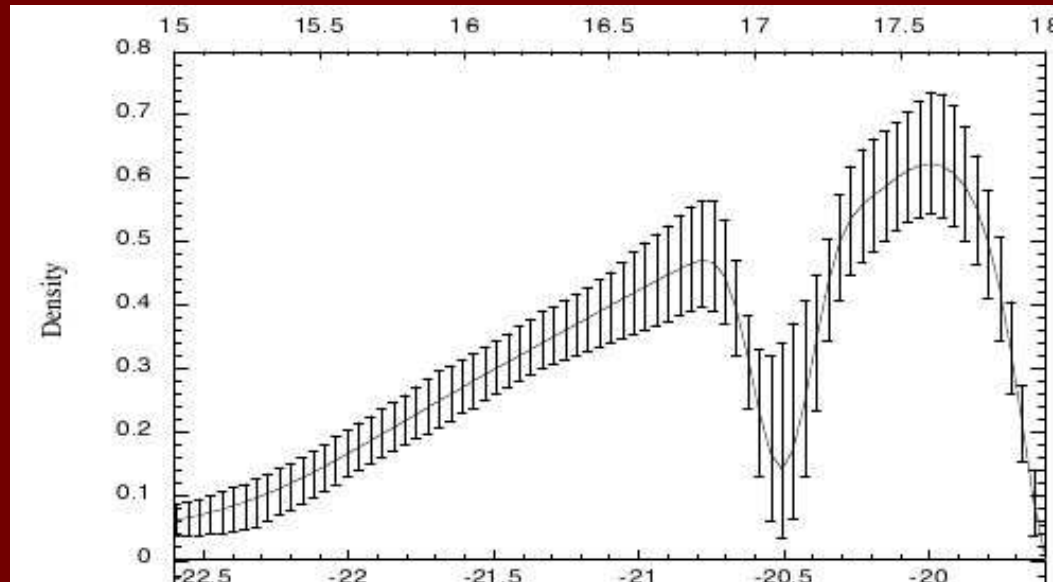
North of red line
 $\alpha = -1.74 \pm 0.02$

South of red line
 $\alpha = -1.28 \pm 0.05$

Very difficult to explain since infall comes from the south (several background subtractions give the same result)

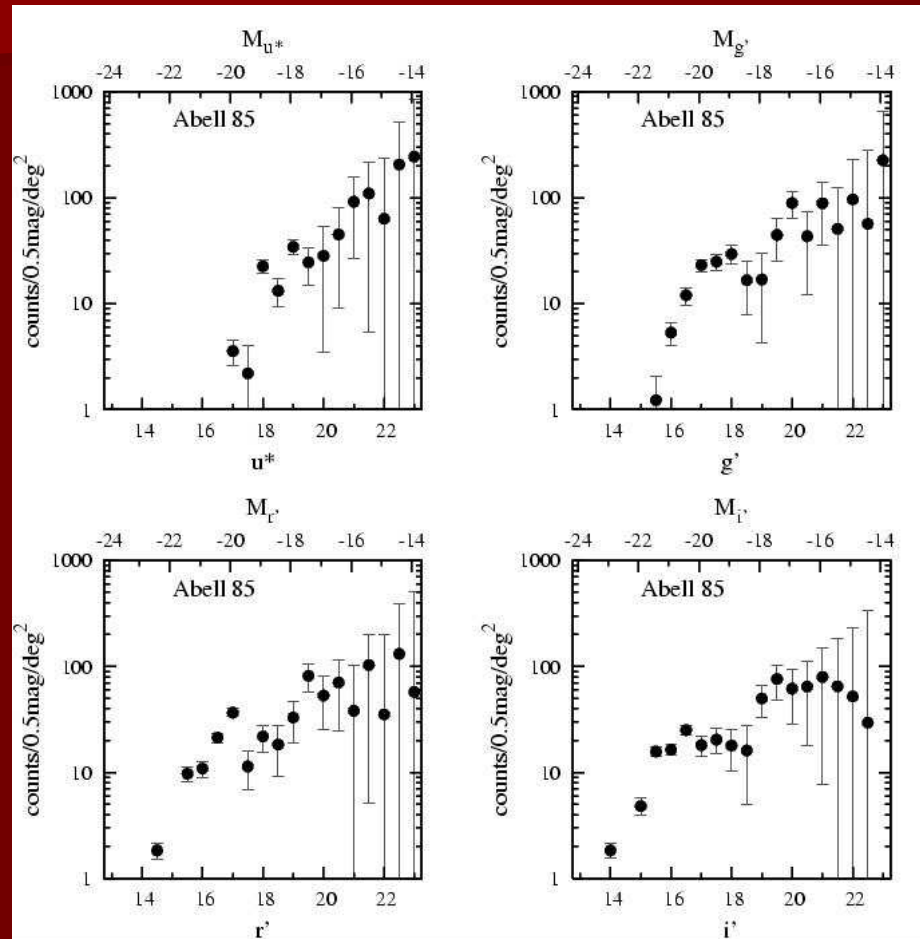
What about dips and wiggles in the GLFs?

- Coma: some dips due to galaxy mergers, others to the inhibition of star forming activity, which are probably due to environmental effects
- Abell 85: dip confirmed spectroscopically



Durret, Gerbal,
Lobo, Pichon, 1999,
A&A 343, 760

Abell 85: south half and filament

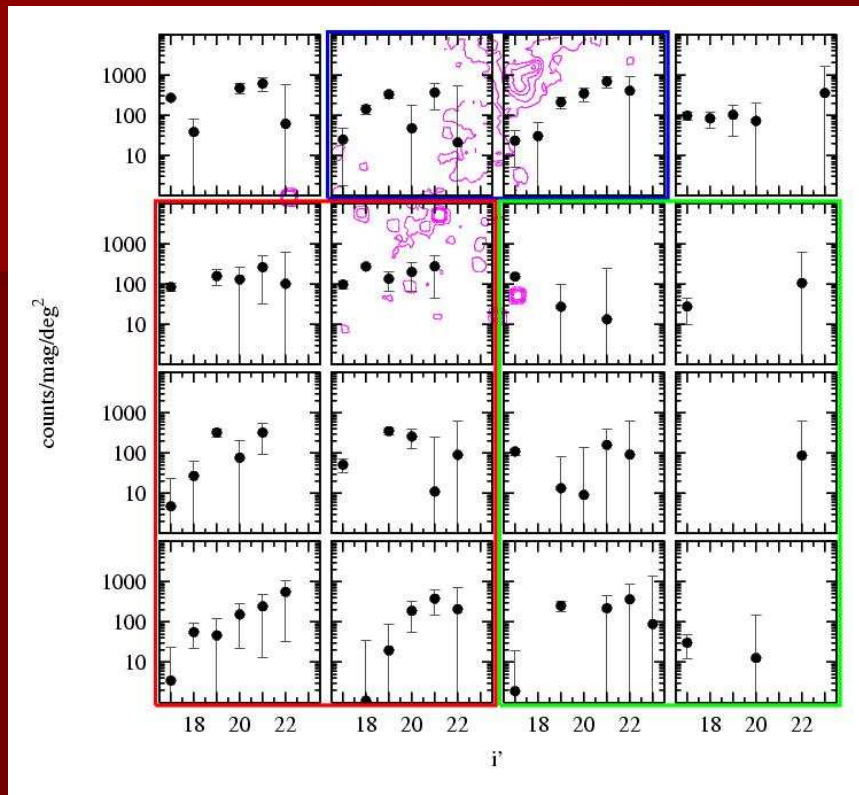


Global faint end slopes:

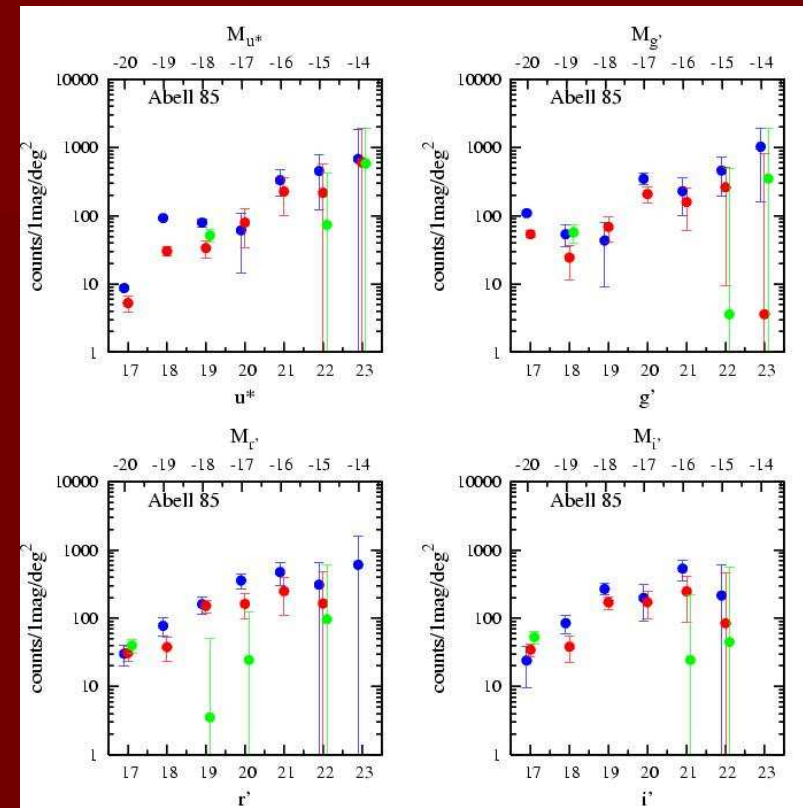
$$u^* \\ \alpha = -1.70 \pm 0.48$$

$$g' r' i' \\ \alpha = -1.5 \pm 0.1$$

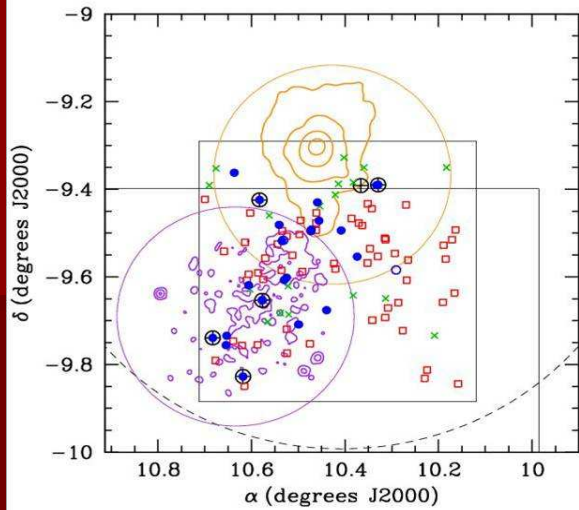
Boué, Durret, Adami, Mamon, Ilbert, Cayatte, 2008, A&A 489, 11



Blue: cluster and « impact » region
 Red: filament region
 Green: empty region



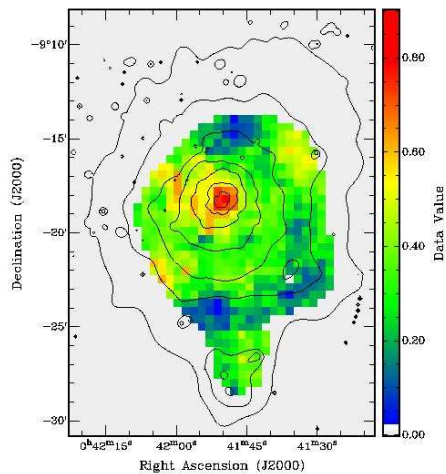
Blue and red regions have comparable GLFs



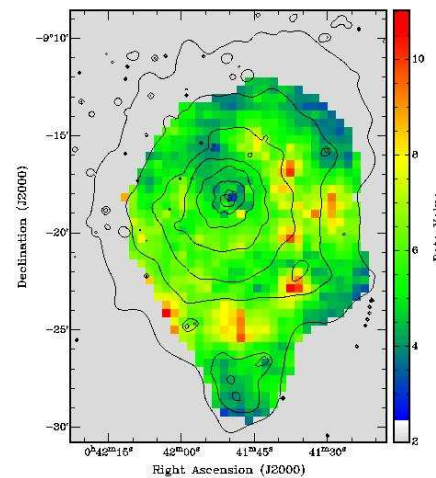
Excess of star forming galaxies in the filament region

Abell 85 is undergoing several mergers, environmental effects must be important

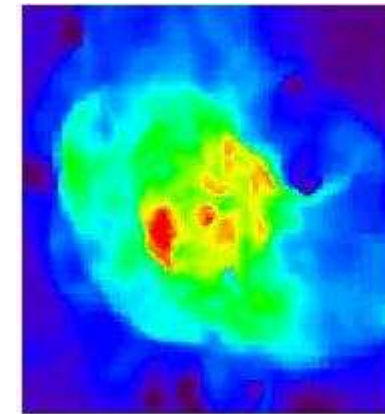
X-ray metallicity map



X-ray temperature map

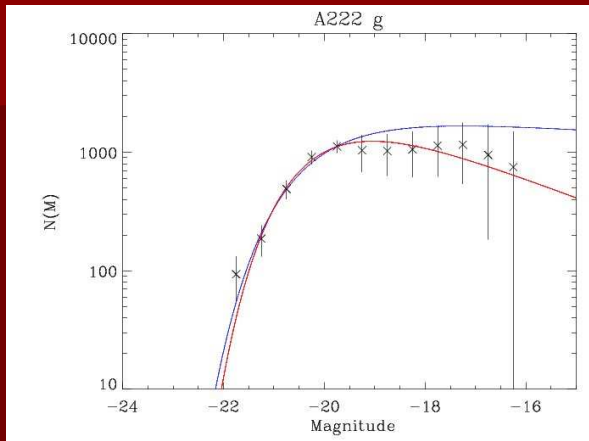


Simulated X-ray kT map (Bourdin et al. 2004, A&A 429, 443)



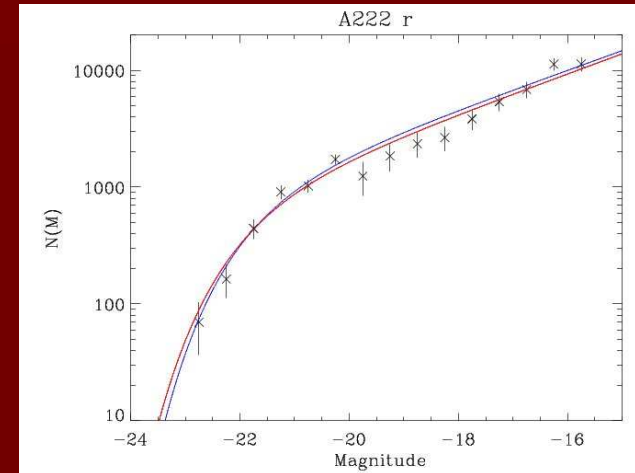
What about cluster pairs? Abell 222/223

A222

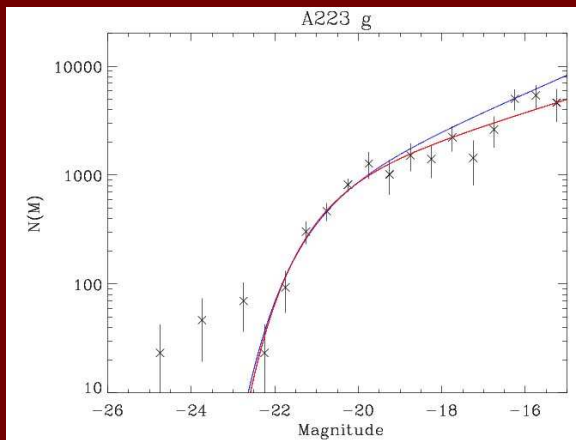


$$g' \quad \alpha = -0.60 \pm 0.05$$
$$\alpha = -0.94 \pm 0.03$$

$$r' \quad \alpha = -1.43 \pm 0.01$$
$$\alpha = -1.42 \pm 0.01$$

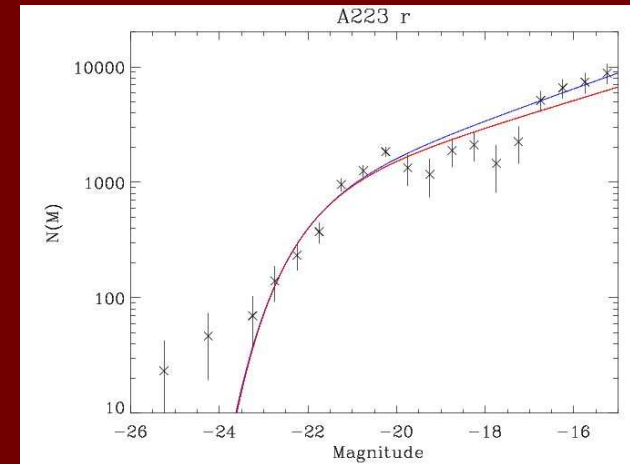


A223

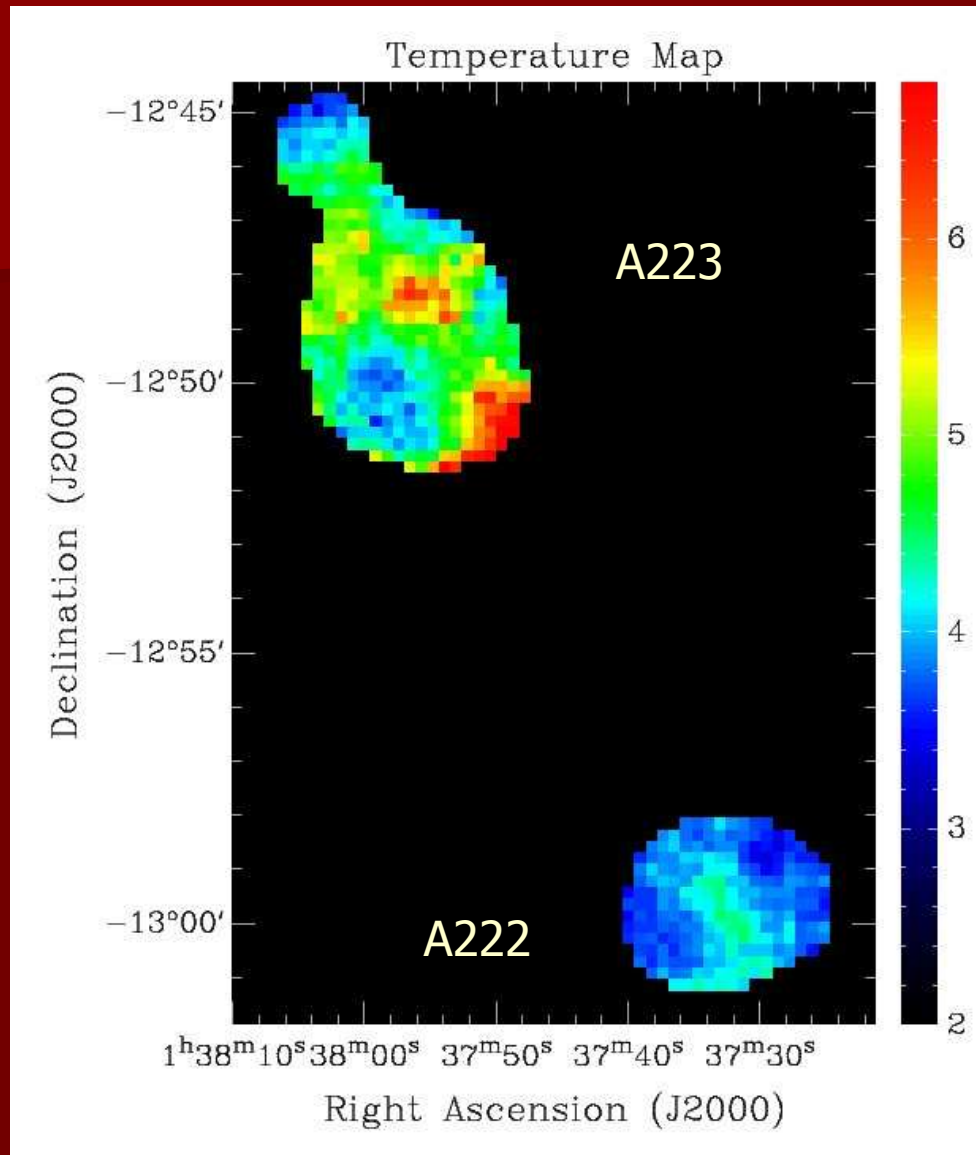


$$g' \quad \alpha = -1.30 \pm 0.02$$
$$\alpha = -1.42 \pm 0.01$$

$$r' \quad \alpha = -1.29 \pm 0.01$$
$$\alpha = -1.34 \pm 0.01$$



Global faint end slopes may depend on background subtraction!



Lack of faint blue galaxies in A222

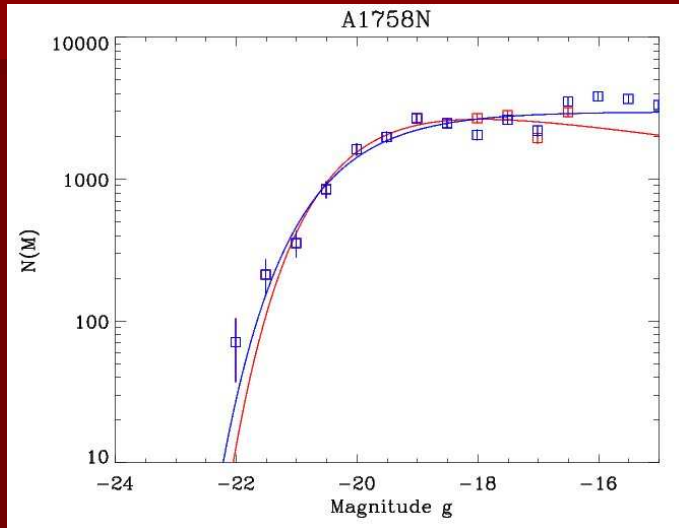
No sign of interaction between A222 and A223

A222 shows no obvious perturbation in X-rays, but its center is warmer

GLF of A223 show an excess of bright galaxies and wiggles

A223 has just been crossed by a small subcluster going northeast

Abell 1758: two double clusters!



A1758 North

$$g'$$

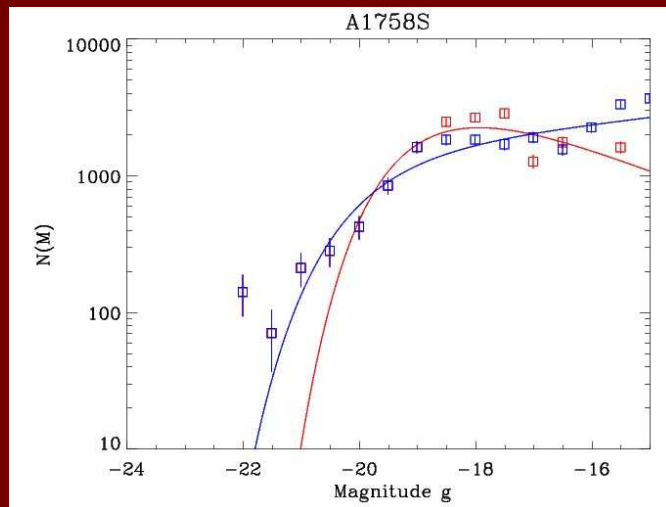
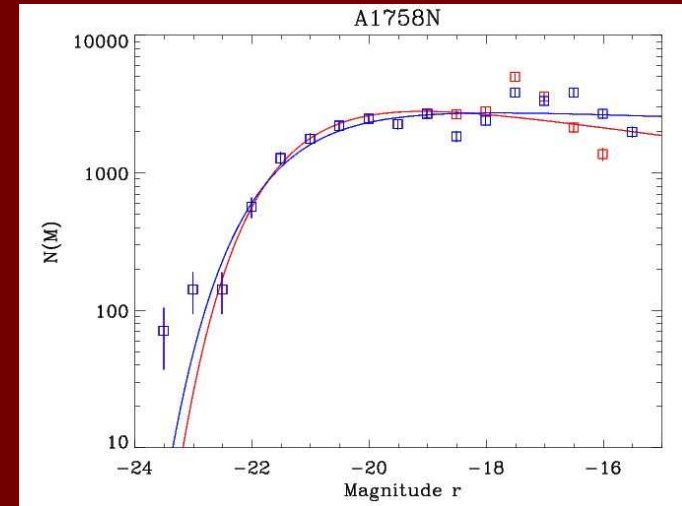
$$\alpha = -0.60 \pm 0.05$$

$$\alpha = -0.94 \pm 0.03$$

$$r'$$

$$\alpha = -1.43 \pm 0.01$$

$$\alpha = -1.42 \pm 0.01$$



A1758 South

$$g'$$

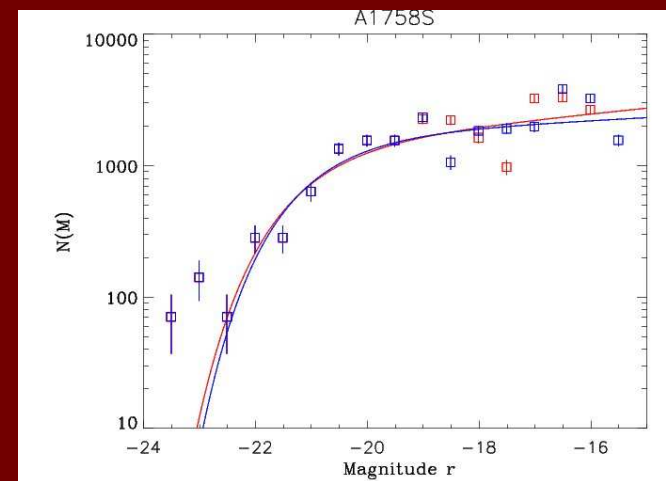
$$\alpha = -1.30 \pm 0.02$$

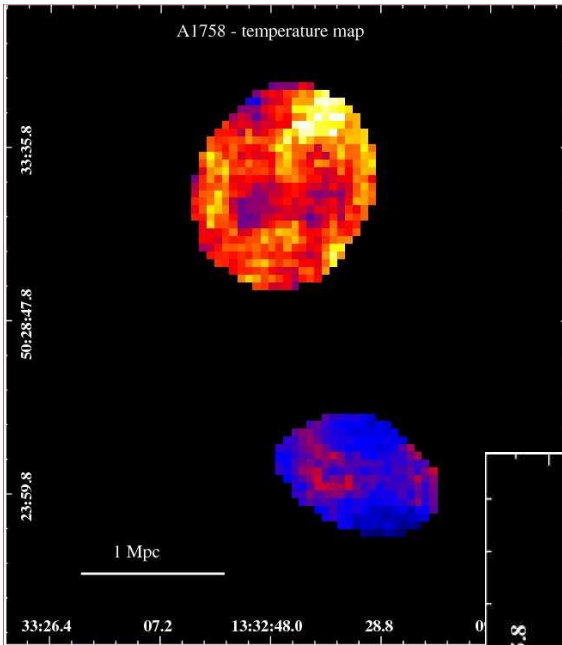
$$\alpha = -1.42 \pm 0.01$$

$$r'$$

$$\alpha = -1.29 \pm 0.01$$

$$\alpha = -1.34 \pm 0.01$$

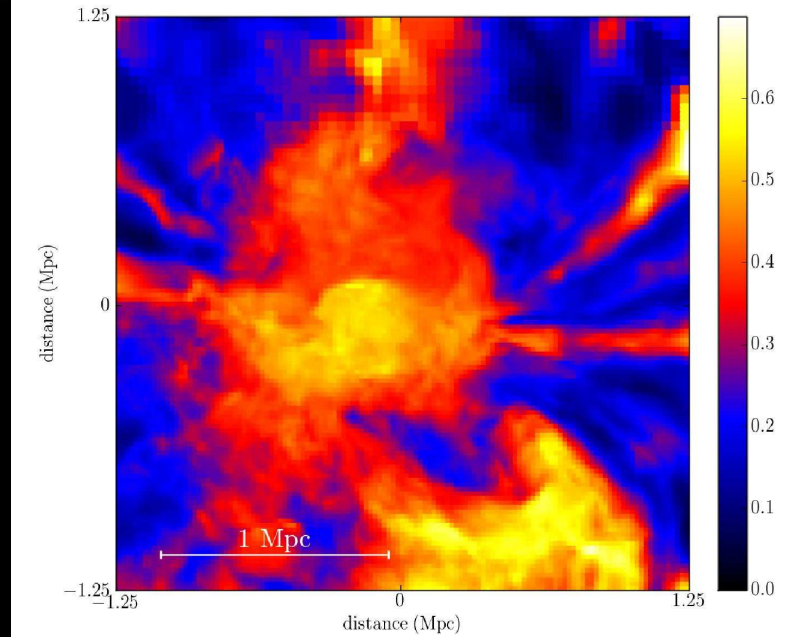
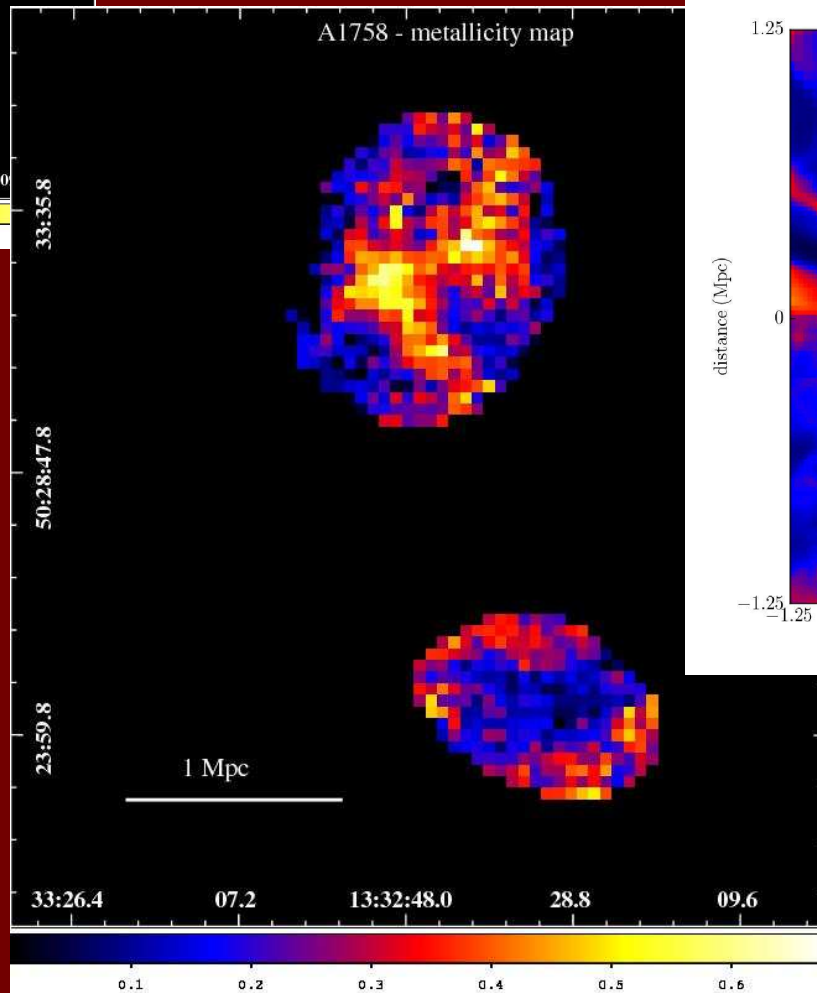




← Temperature map

Metallicity map

Simulated metallicity map



Durret, Laganá &
Haider 2011, A&A
submitted

A few conclusions

- The study of GLFs can give insight on dynamical and merging processes having occurred or still occurring in clusters – but they are tricky!
- Infall of material on to clusters is not isotropic, so avoid any hypothesis of spherical symmetry (such as GLFs in concentric rings)
- Multi-wavelength data + hydrodynamical numerical simulations are very helpful to disentangle various processes