

Baryon content of galaxy clusters: a multi-wavelength view

Optical spectroscopy: galaxies (v_g , M_g , SFR, ...)

Far-UV spectroscopy: cool ($T < 10^6$ K) ICM/CGM
(Ly- α , - β , OVI if $z=0.1-0.4$, ...)

X-ray imaging: hot ICM ($T(r)$, $n_e(r)$, M_{HICM} , M_t , ...)

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Abell 2246 field

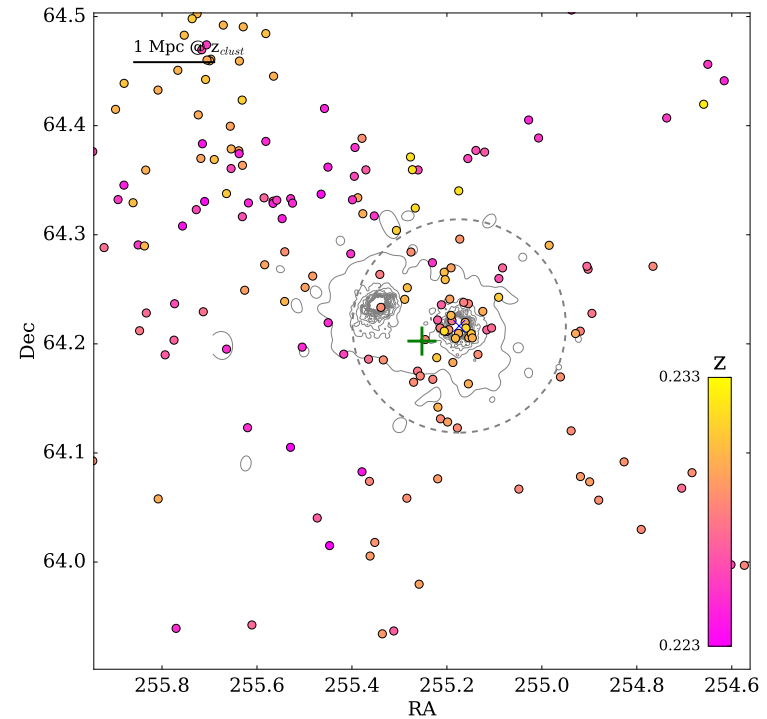
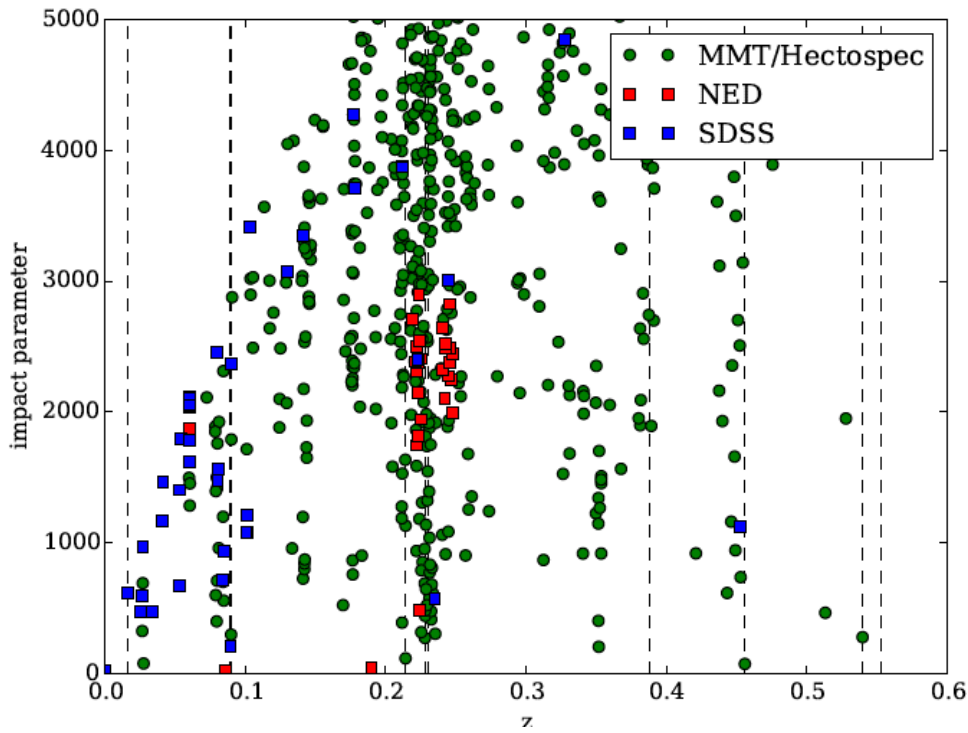
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HS1700+6416 ($z=2.74$)

GMBCG J255.34805+64.23661 ($z=0.45$)

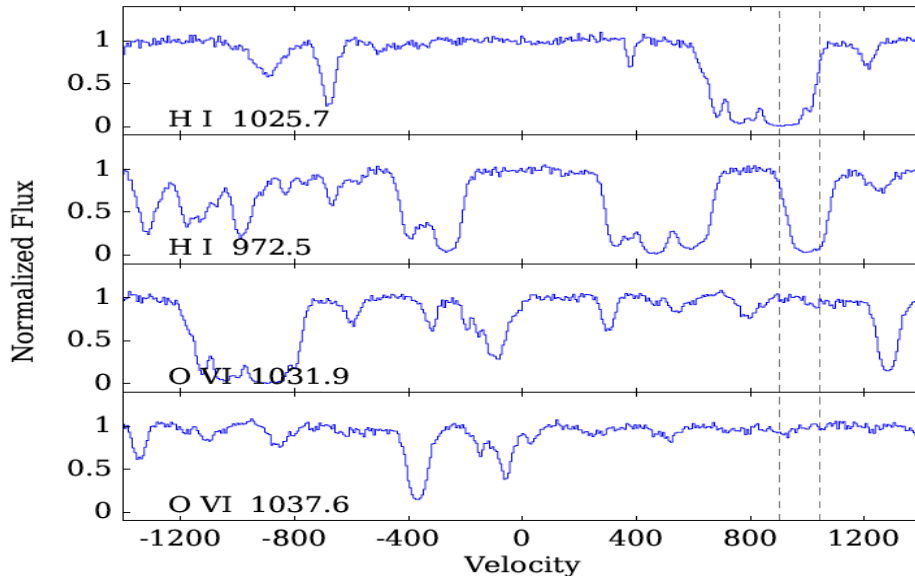
Abell 2246 ($z=0.225$)

Wang & Walker (2014)



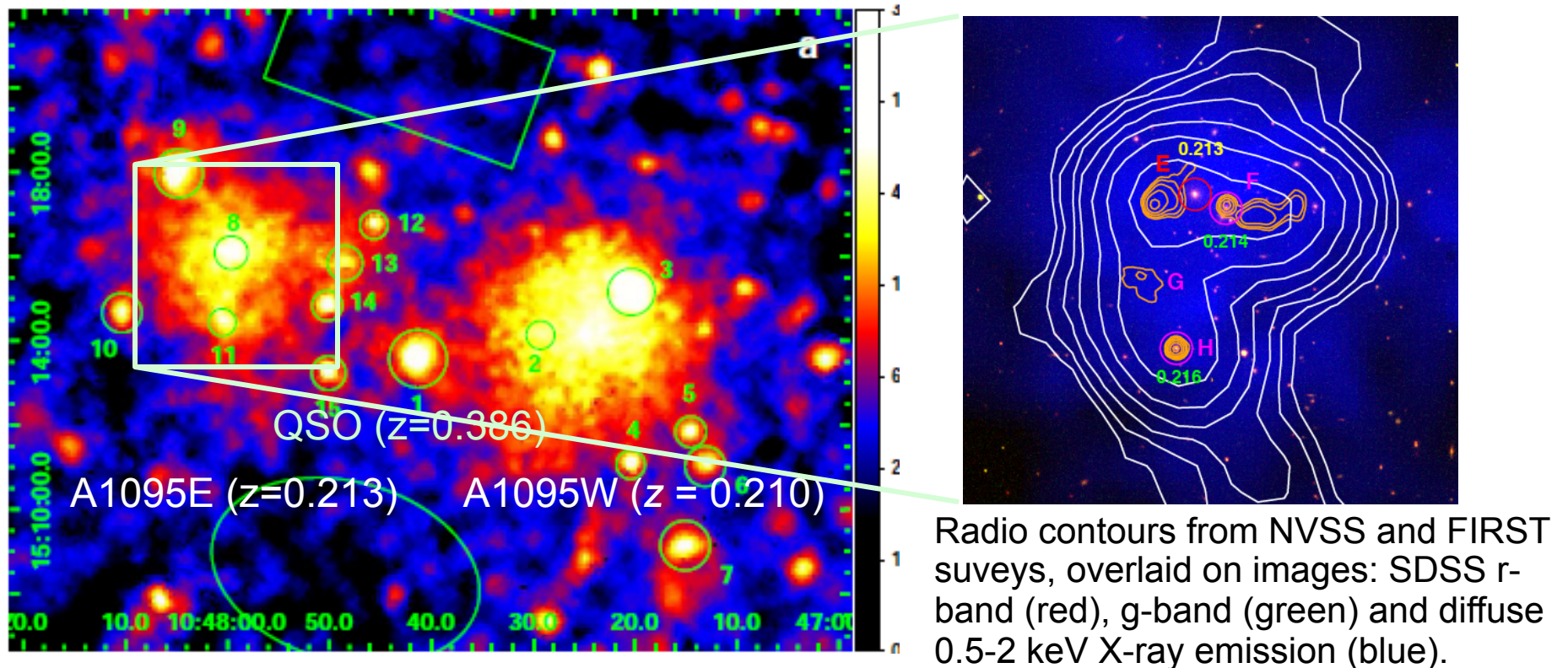
Galaxies at the Abell 2246 redshift $z = 0.214$ ($|v| < 10^3$ km/s).

- No conspicuous detections of cool ($< 10^6$ K) gas in the ICM: $N(\text{HI}) < 10^{12.9}$ cm $^{-2}$ or $N(\text{OVI}) < 10^{13.2}$ cm $^{-2}$ (at 3σ and assuming $b=100$ km/s).
- No detection of HI or OVI associated with the two individual galaxies.

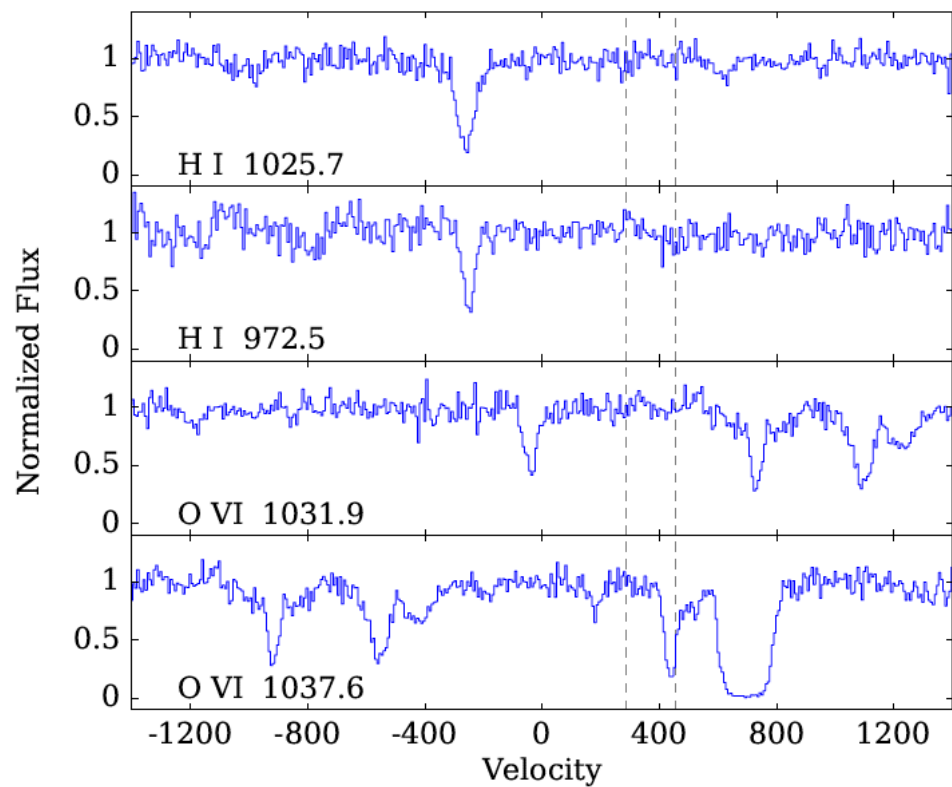
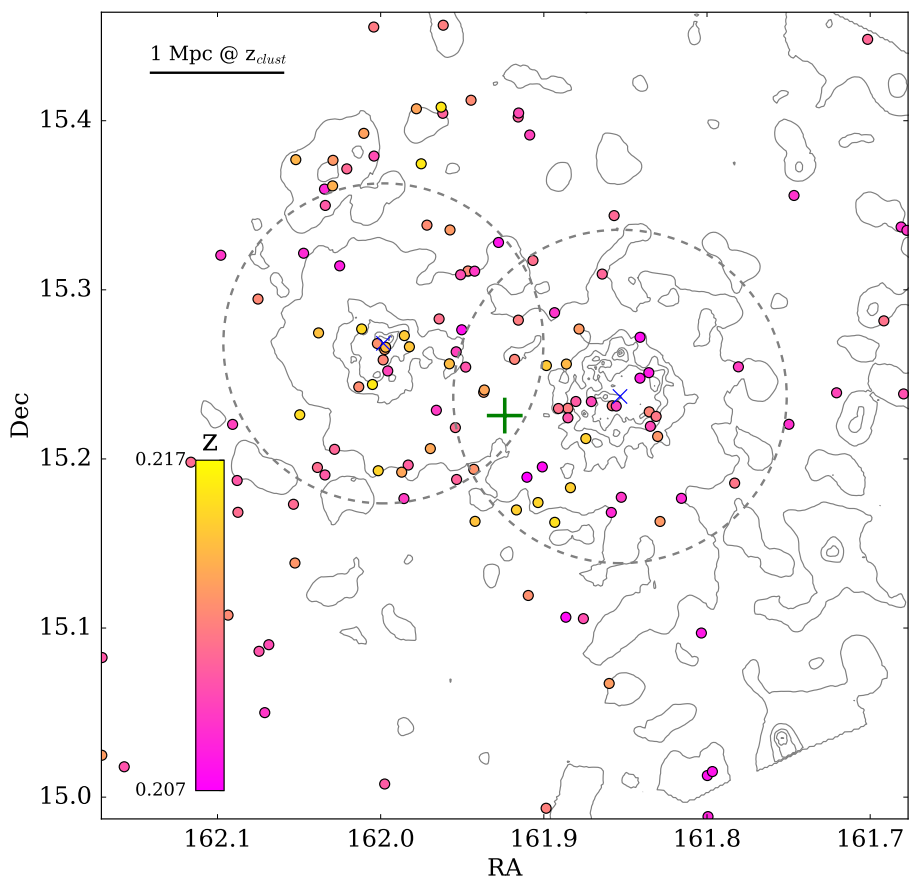


HST/COS spectra at the cluster $z = 0.214$; 2 cluster galaxies with $\rho < 300$ kpc marked by dashed lines)

Abell 1095 field

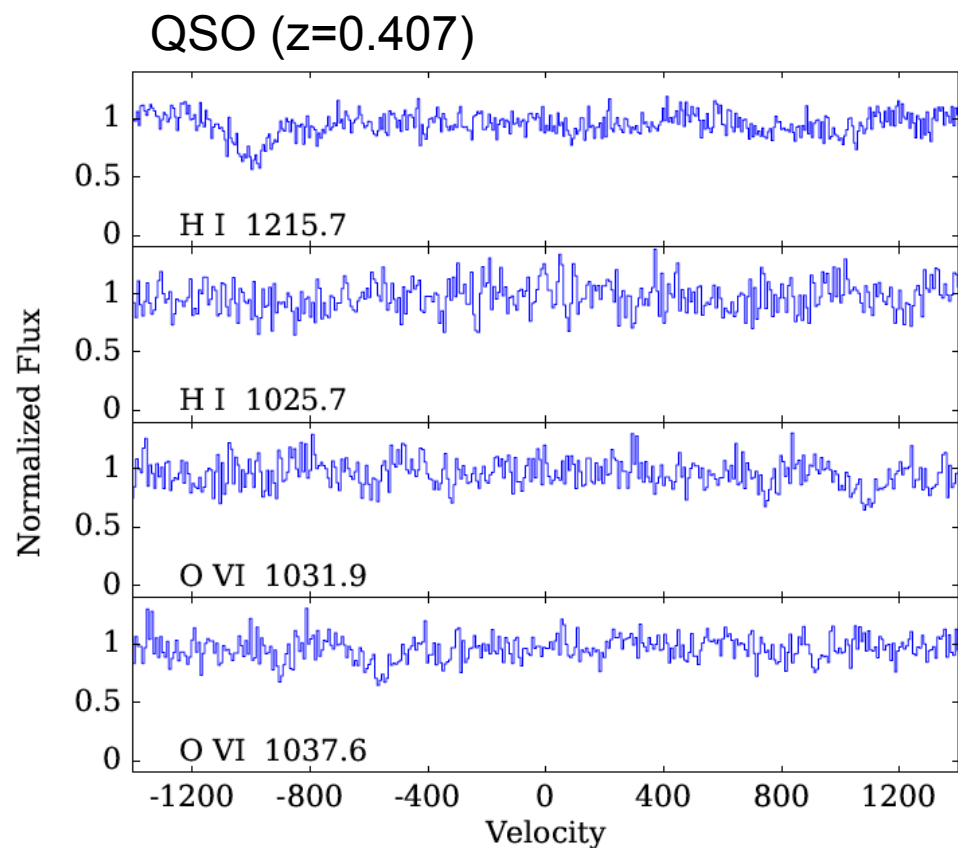
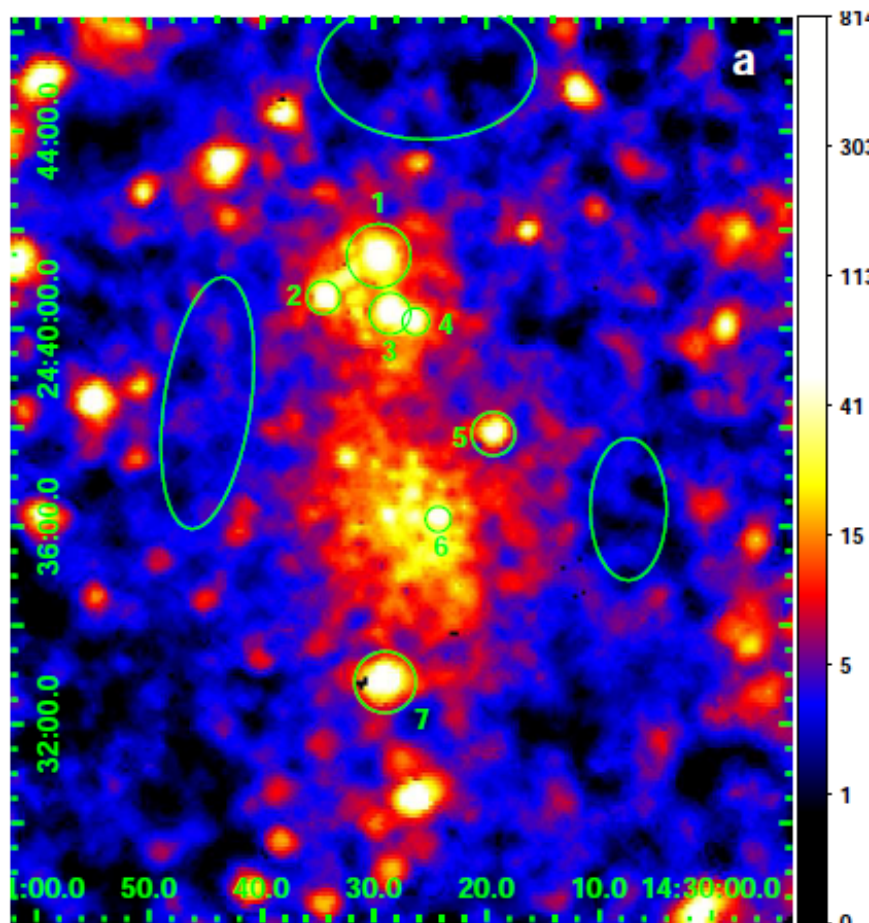


- The two clusters are most likely bound and will eventually merge into a massive cluster:
 - morphologically mutually perturbed and at about same redshift.
- Individual clusters themselves are probably the results of recent subcluster mergers or still in early formation stage:
 - large offsets of the BCGs from the diffuse X-ray emission centroids
 - significant radio emission on various scales.



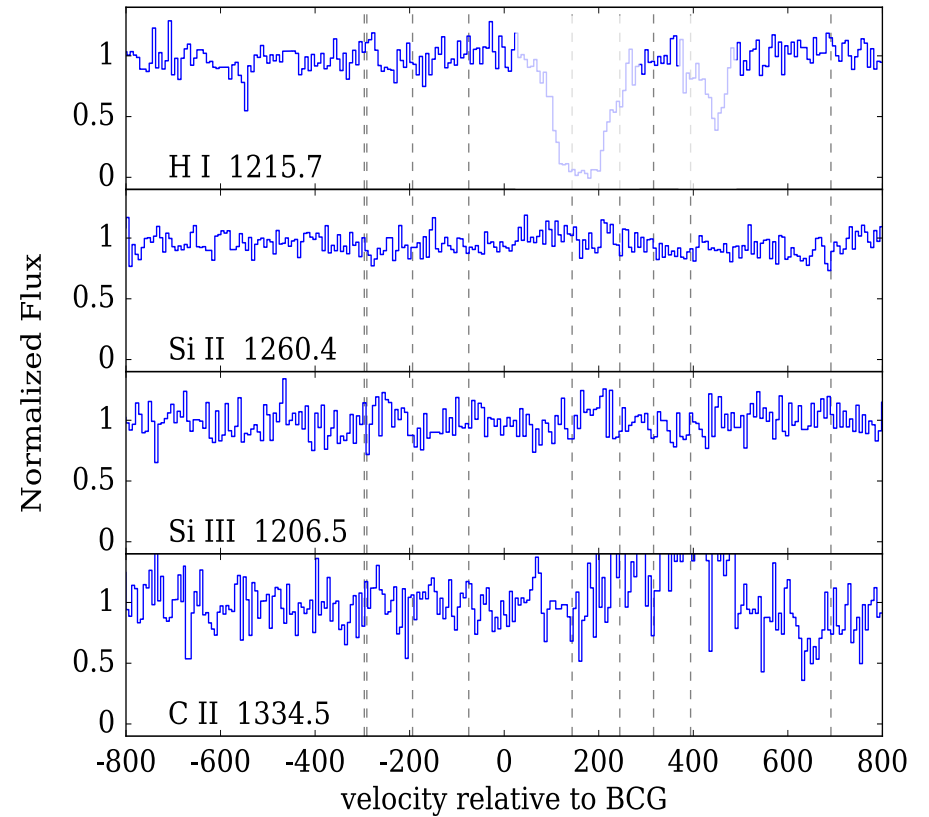
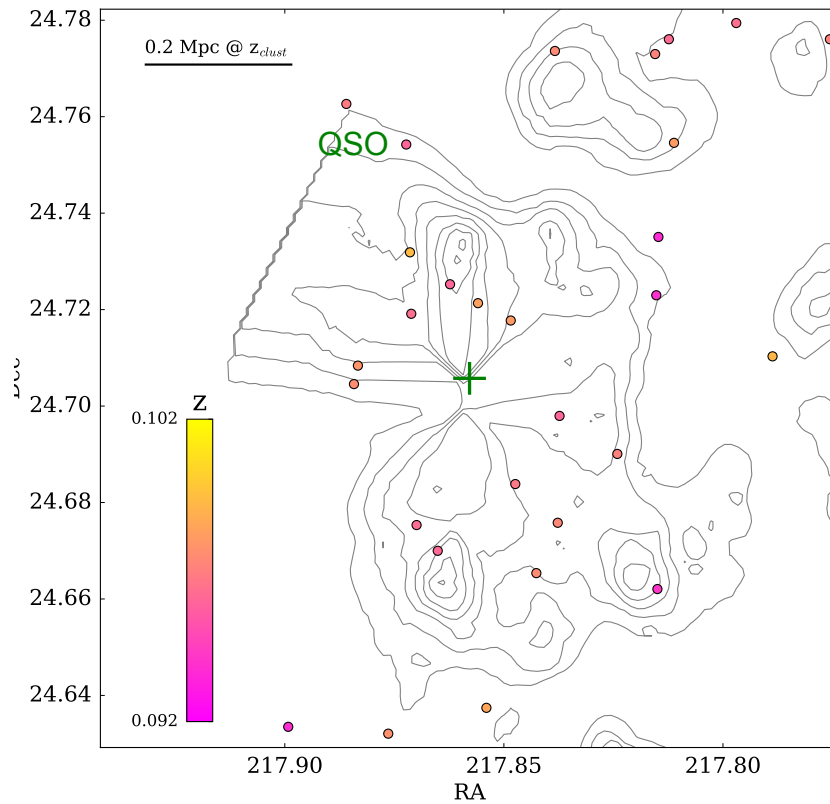
HST/COS spectra of the QSO ($z=0.386$)
 at the clusters' redshift $z = 0.211$: $\rho=0.69 r_{200}$ for
 A1095W and $\rho=0.85 r_{200}$ for A1095E

Abell 1926 field



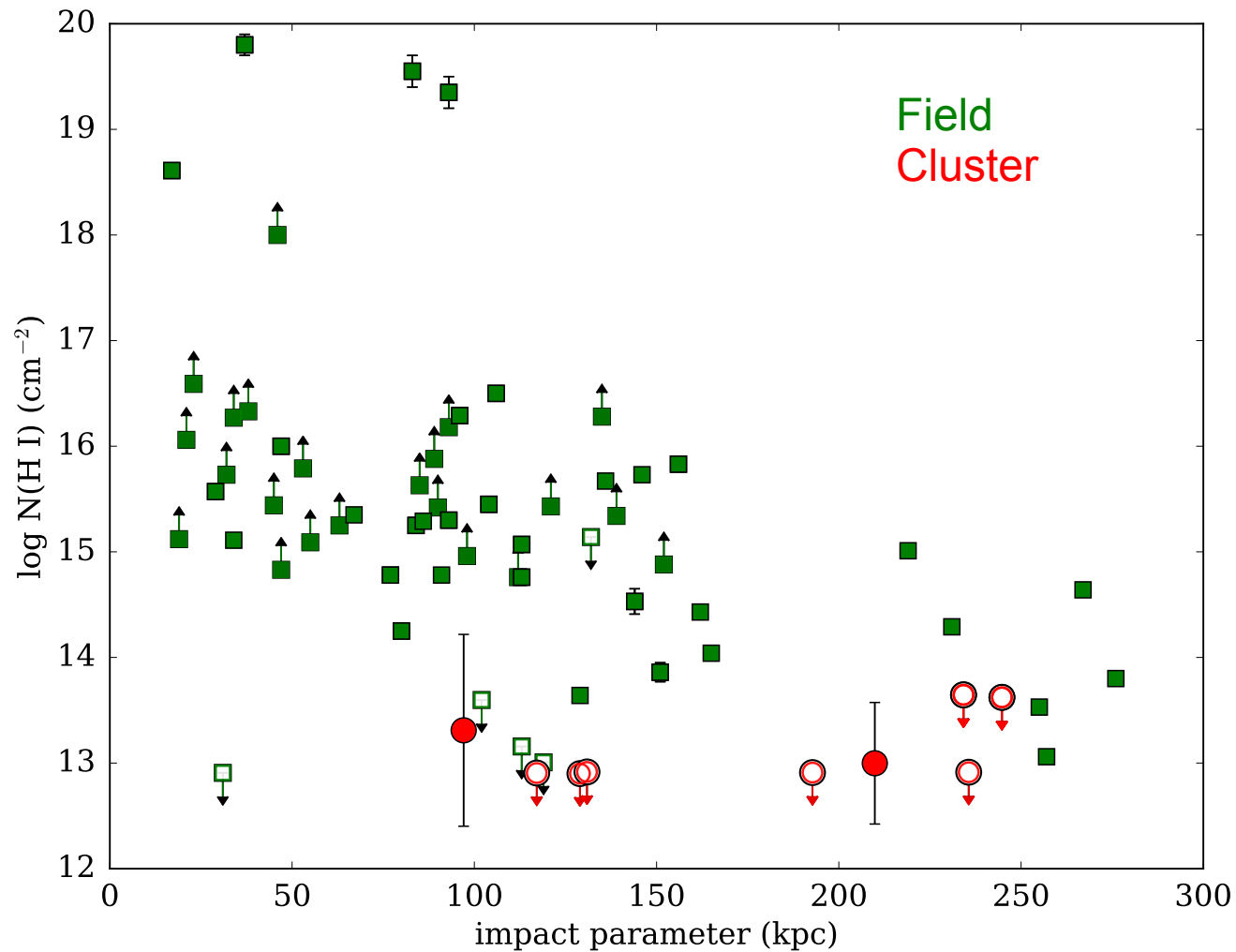
At the clusters' redshift $z = 0.136$:
 $\rho = 2.2 r_{200}$ for A1926S
 $\rho = 2.0 r_{200}$ for A1926N

MAX BCG J217.84740+24.68382 ($z=0.097$)

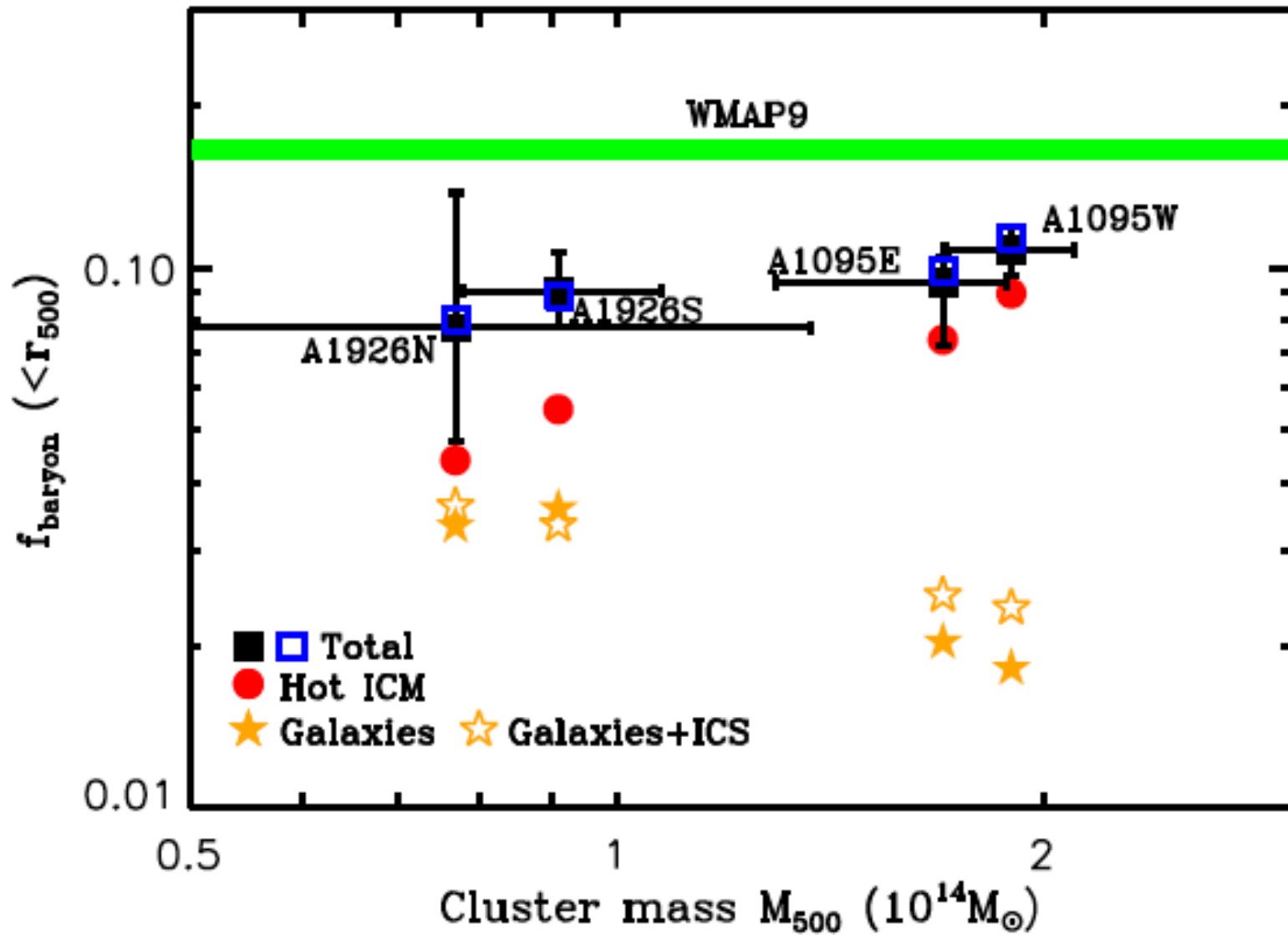


9 galaxies with $\rho < 300$ kpc, although too low redshifts for the COS to cover OVI

Galaxies have anomalously low H I column densities in X-ray-bright clusters than in fields!



Where is the missing baryon mass in clusters?



Probably not in cool gas!

Summary

- X-ray, optical, and radio observations show that most of the optically-selected clusters are dynamically young.
- No conspicuous broad HI and OVI lines are detected.
- Cool CGM is substantially reduced in cluster environments, compared in fields.
- There is indication that the cool baryon content decreases with increasing richness of a cluster.
- Such observations should be extended to poor clusters, groups, or cosmic webs in the redshift range of 0.1-0.4.