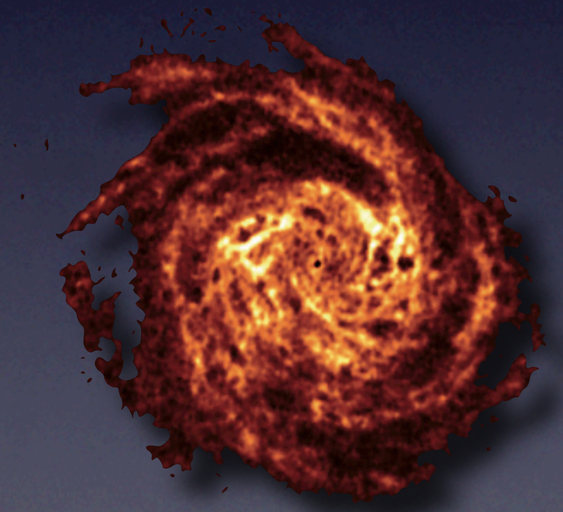
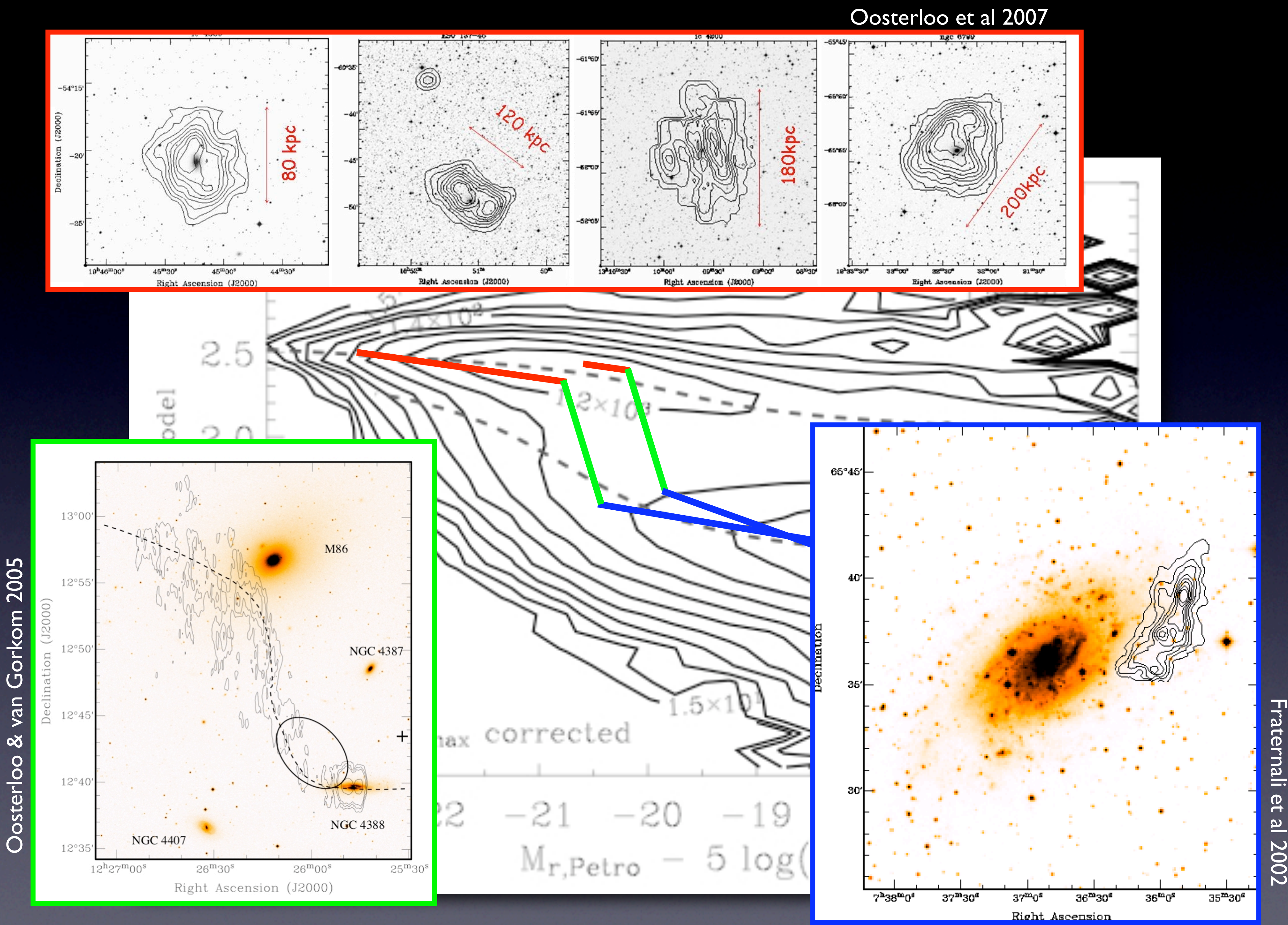
Deep HI volumes at z=0.2
and beyond


Boomsma

Marc Verheijen
Kapteyn Institute

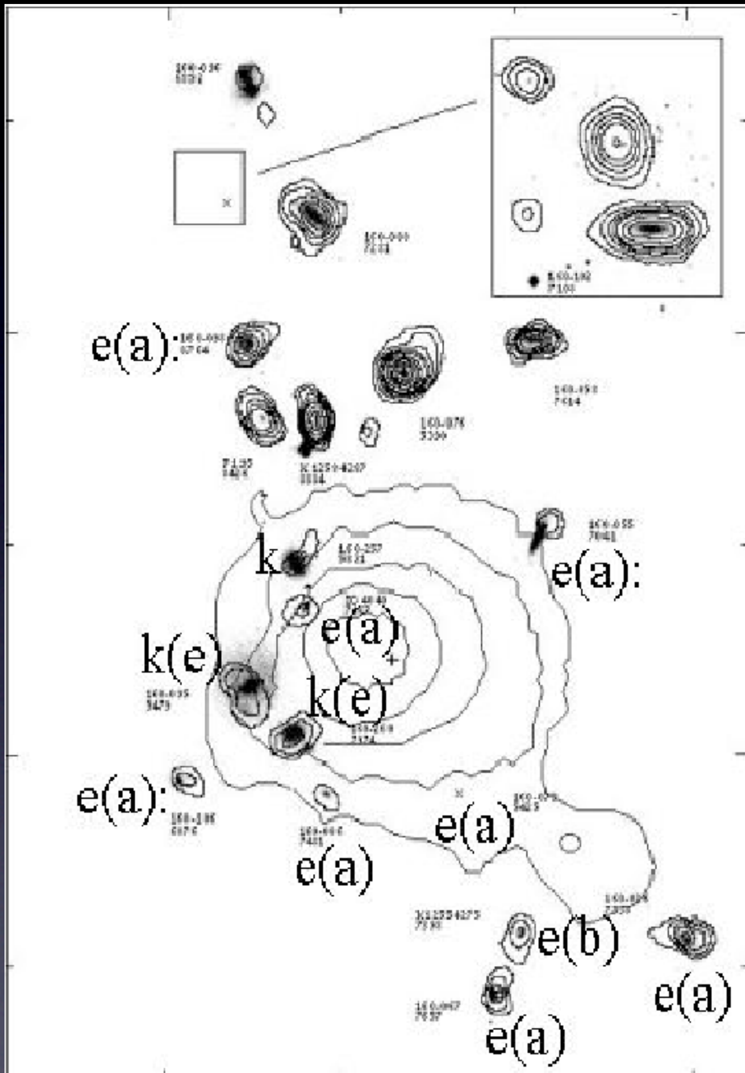
university of groningen
Kapteyn Astronomical Institute



Oosterloo et al 2007
80 kpc
120 kpc
180kpc
200kpc
Declination (J2000)
Right Ascension (J2000)
2.5
1.2×10³
1.5×10⁴
corrected
-21
-20
-19
M r,Petro − 5 log(
Oosterloo & van Gorkom 2005
M86
NGC 4387
NGC 4388
NGC 4407
Fraternali et al 2002
Declination
Right Ascension

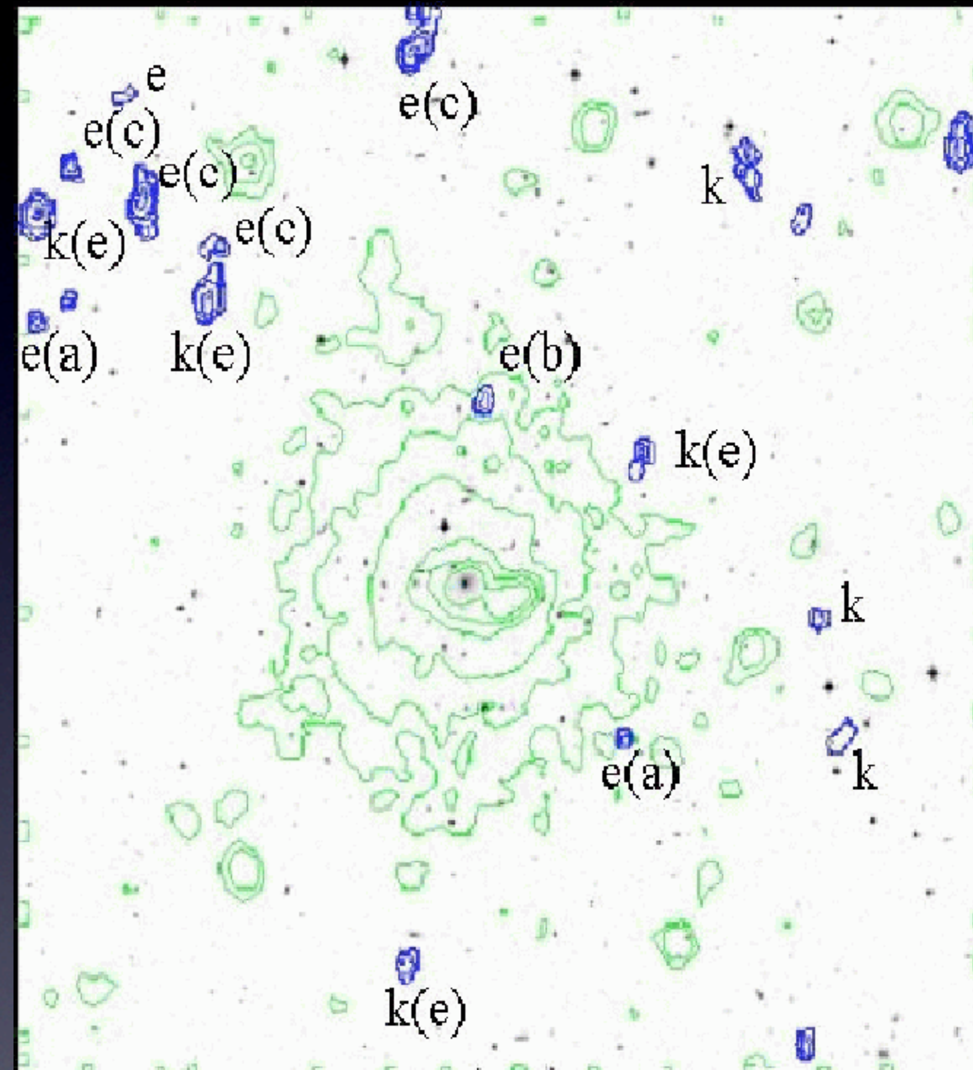
HI, ICM, SFR, SP interrelations

Coma



Bravo-Alfaro et al, 2001

Abell 2670



Poggianti & van Gorkom, 2001

Infalling galaxies are clustered in space and velocity

- ➢ relates to substructures in redshift space

Why clusters at higher redshift?

Content of galaxy clusters and the surrounding field evolves over cosmic time.

→ Exploratory steps towards understanding the role and fate of cold gas in cosmological evolution.

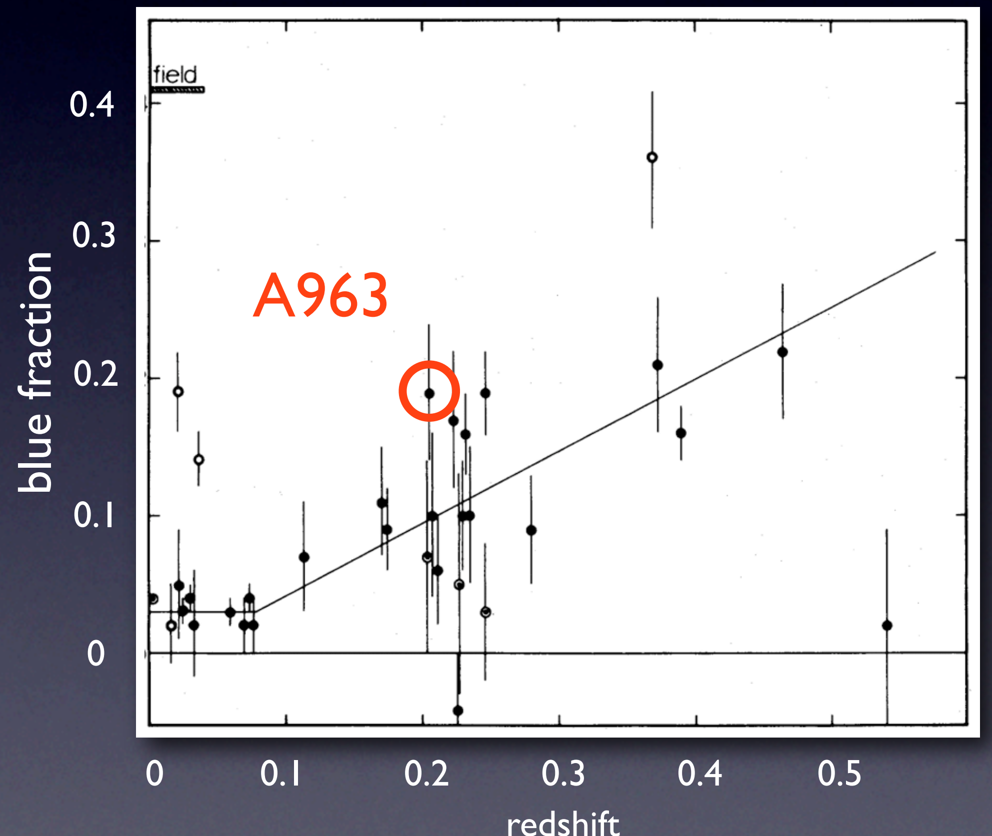
Why Z~0.2 ?

→ Highest redshift for ‘practical’ HI imaging with existing arrays

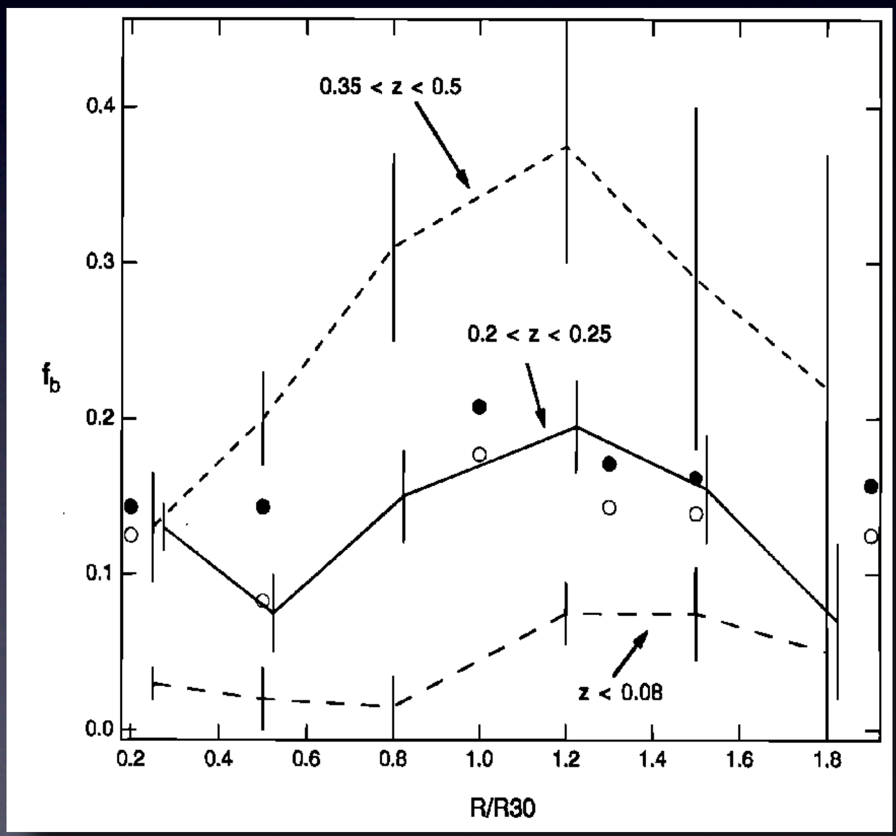
→ Lowest redshift where cosmological evolutionary effects are seen

Butcher-Oemler effect

The fraction of blue (starforming?) galaxies in clusters increases with redshift and peaks in cluster outskirts.



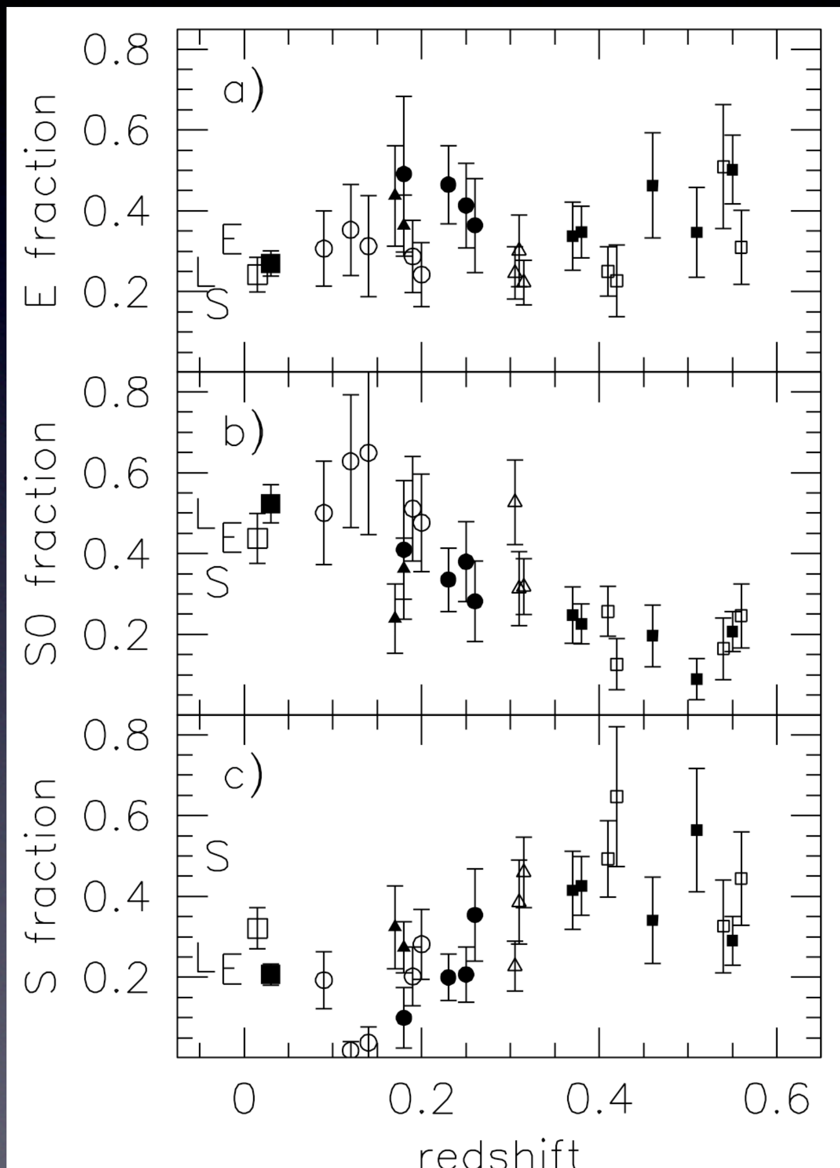
Butcher & Oemler, 1984

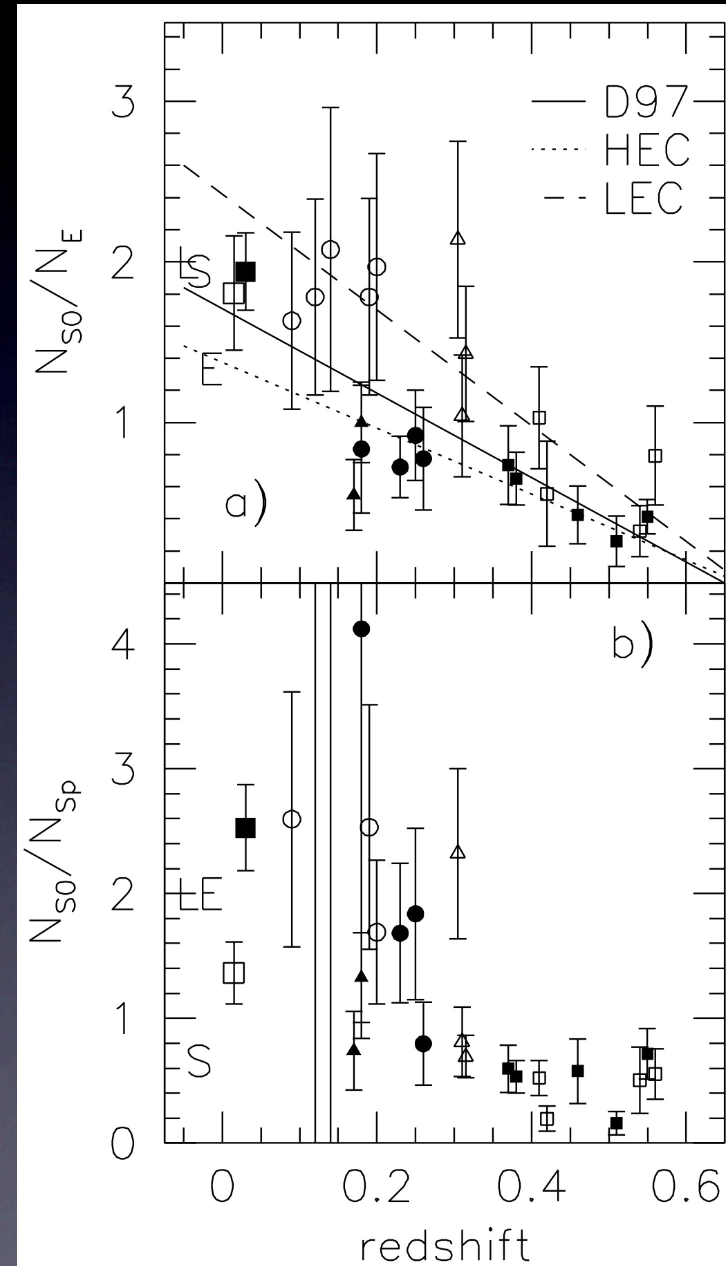


Abraham et al, 1996

Morphological mix in clusters depends on redshift and compactness

• HEC ○ LEC



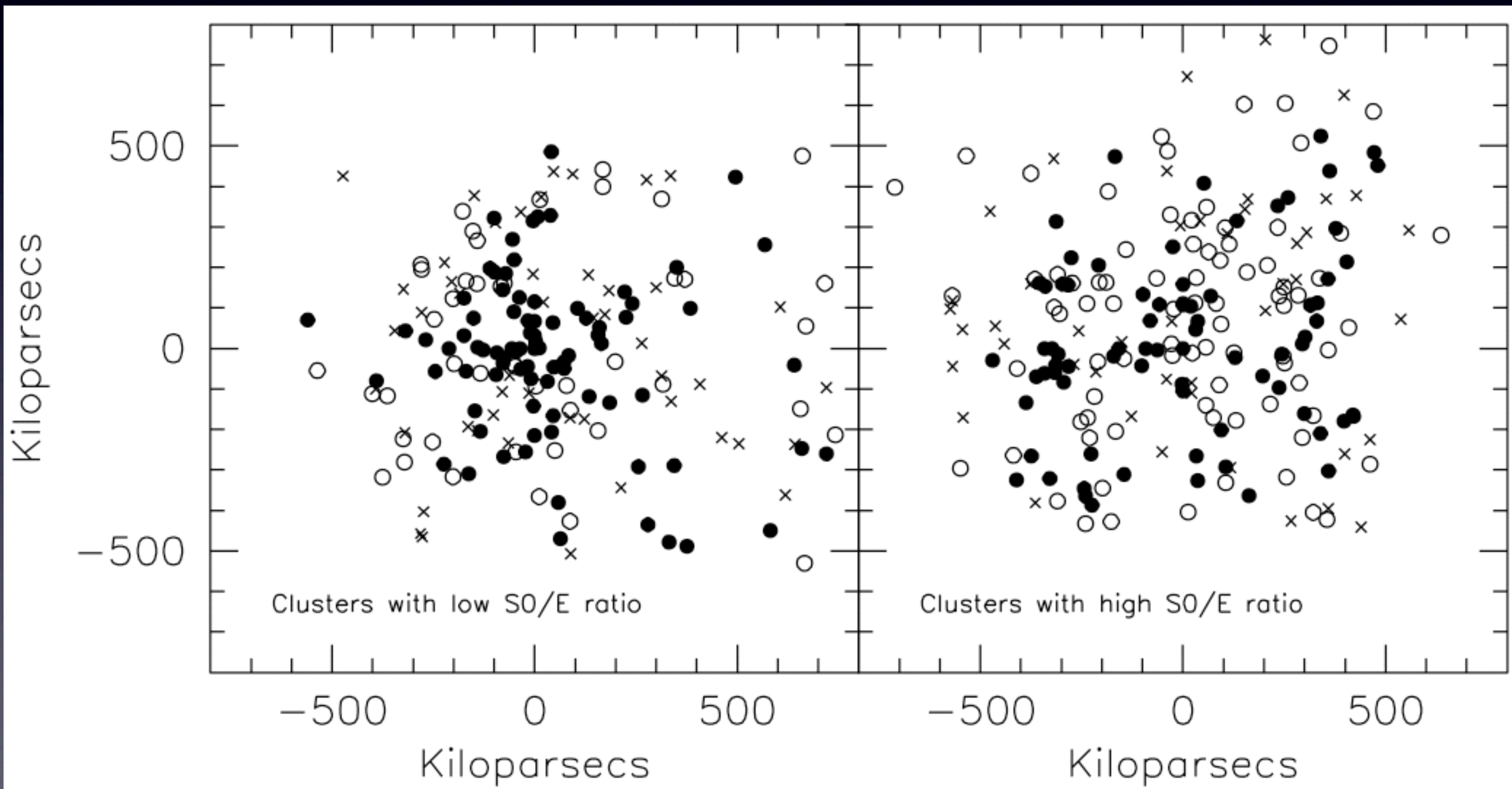


Fasano et al, 2000

Clusters of different compactness

Concentration of ellipticals:

High → S0/E low   Low → S0/E high



Fasano et al, 2000

Goals of HI observations at $z \leq 0.5$:

- Characterize nature of blue galaxy population
  ➝ gas content, SFR, stellar populations
- Witness galaxy transformation in various environments
  ➝ which physical mechanisms dominate where?
- SFR versus environment (from continuum fluxes)
- Evolving Ω^{HI} from HI 21cm emission
- Evolving HI Mass Function?
  ➝ HIMF in different environments
- HI based Tully-Fisher and rotation curve studies

A tale of two clusters

prologue

Abell 963

Abell 2192

SDSS images

z=0.206

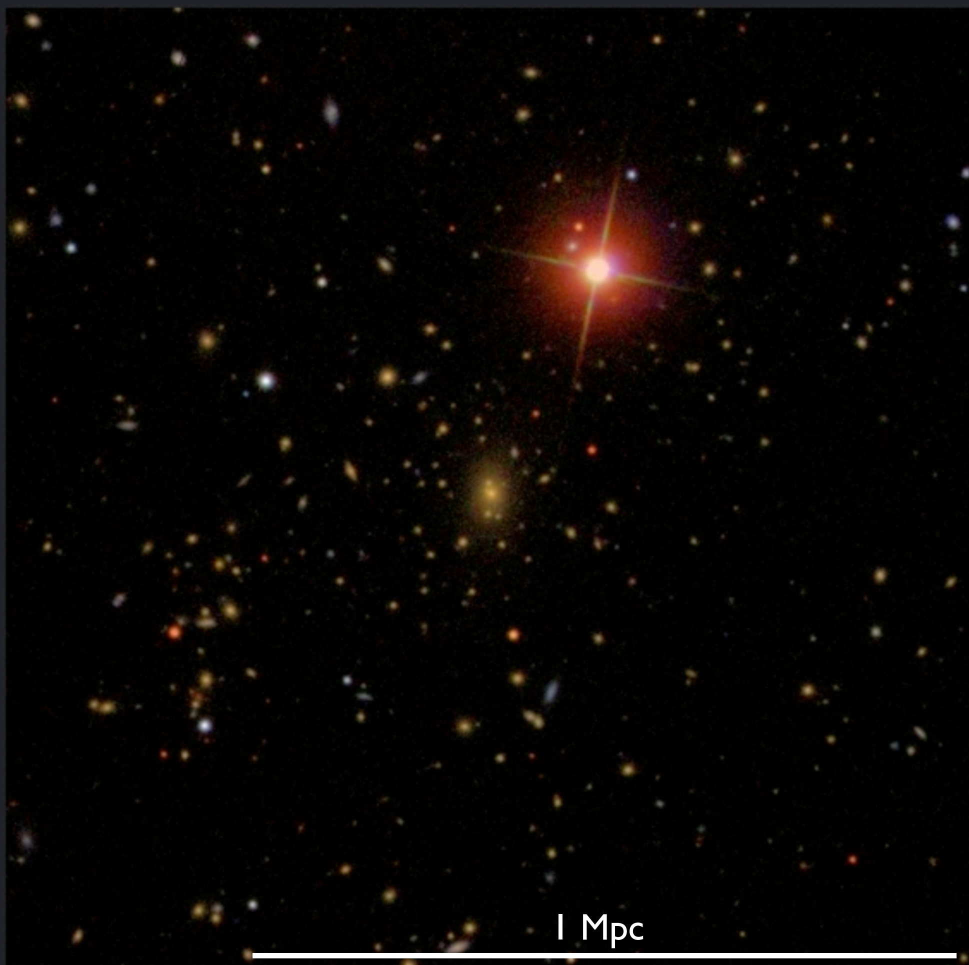
z=0.188

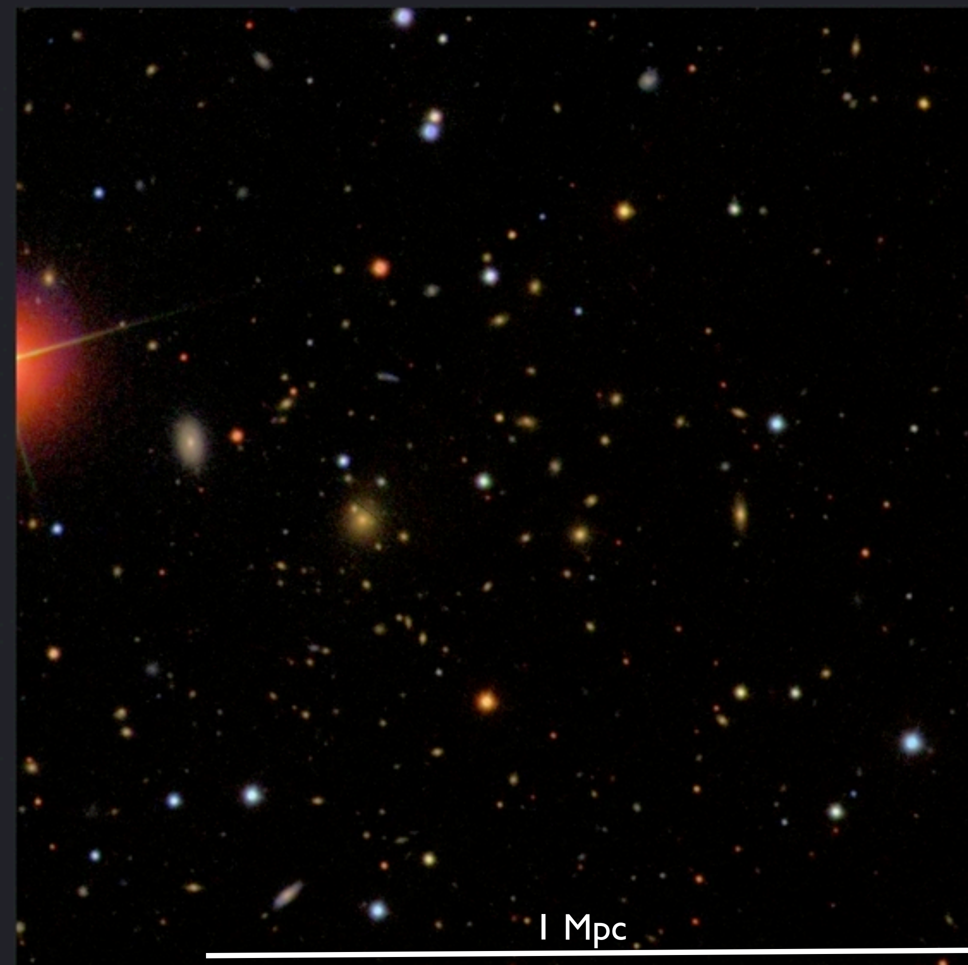
A tale of two clusters

prologue

Abell 963

Abell 2192





SDSS images

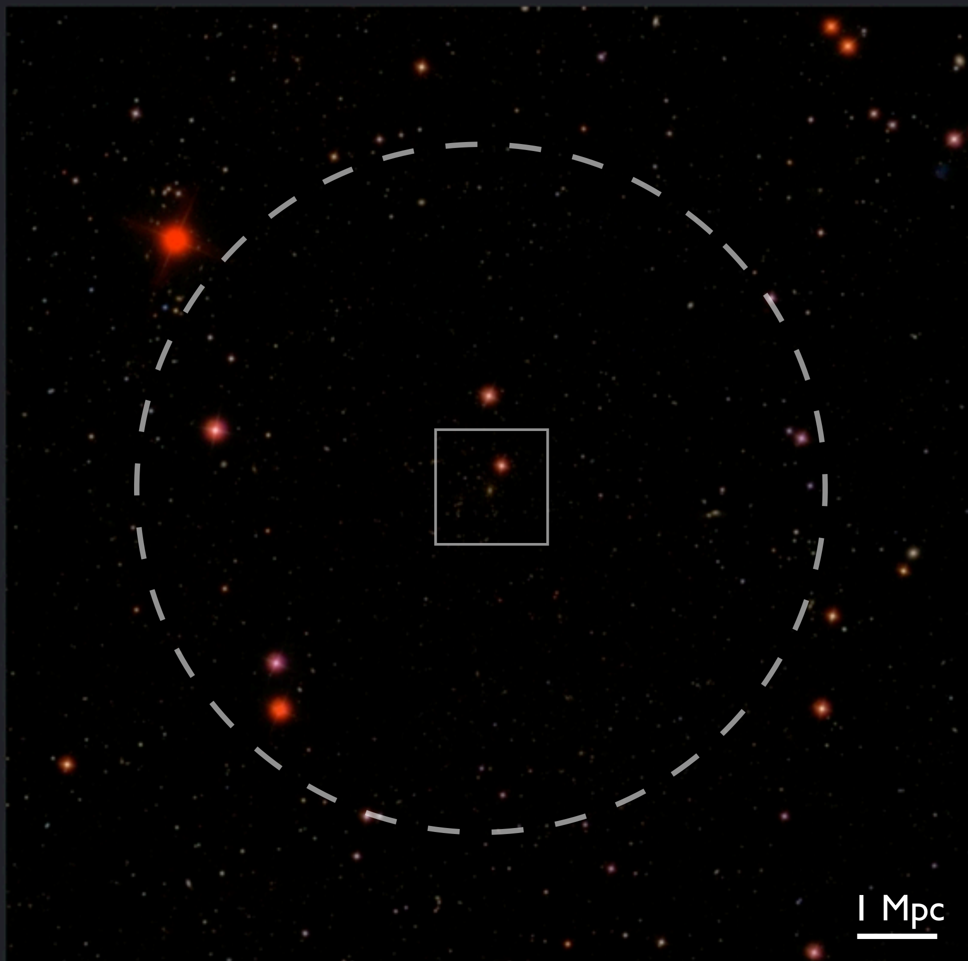
z=0.206

z=0.188

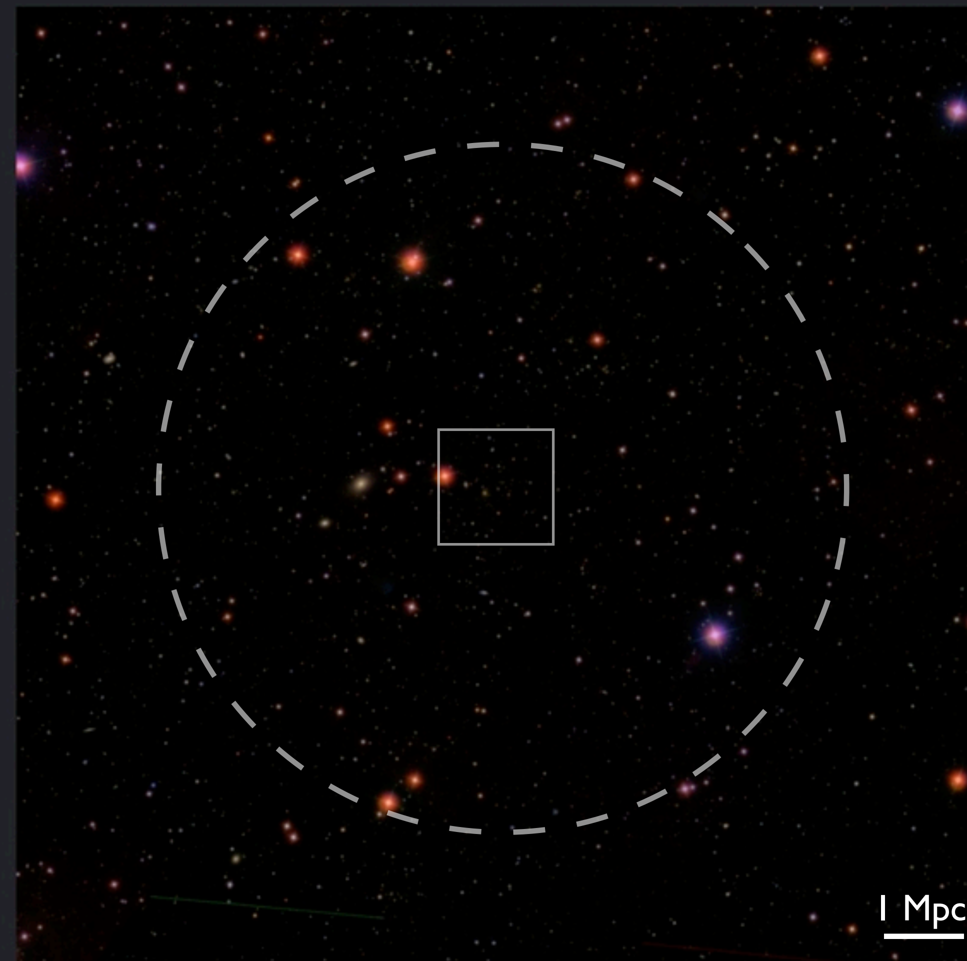
A tale of two clusters

prologue

Abell 963



Abell 2192



SDSS images

z=0.206

z=0.188

Ultra-deep WSRT observations

- Minimum detectable HI mass: $2 \times 10^9\ M_\odot$ over 150 km/s profile width, with 4σ in each of 3 resolution elements.
- Corresponding limiting column density: $3 \times 10^{19}\ (cm^{-2})$ over 75 km/s profile width at 7σ.

This requires: 73×12^{hr} for A2192 at z=0.188
117×12^{hr} for A963 at z=0.206

WSRT pilot observations

- 8x10MHz bands, overlapping to cover 1160-1220 MHz
  Z = 0.164-0.224 , surveyed volume ≈ 70,000 Mpc^3
- 8x256 channels, covering 18,000 km/s velocity range
  20 km/s velocity resolution (after Hanning smoothing)
- dual polarisation, 2-bit correlation, recirculation
- $20x12^{hr}$ on Abell 963, $15x12^{hr}$ on Abell 2192
- rms noise per channel: 68 μJy and 91 μJy
- ~5% lost to RFI

Verheijen et al, 2007, ApJ Lett, 668, 9

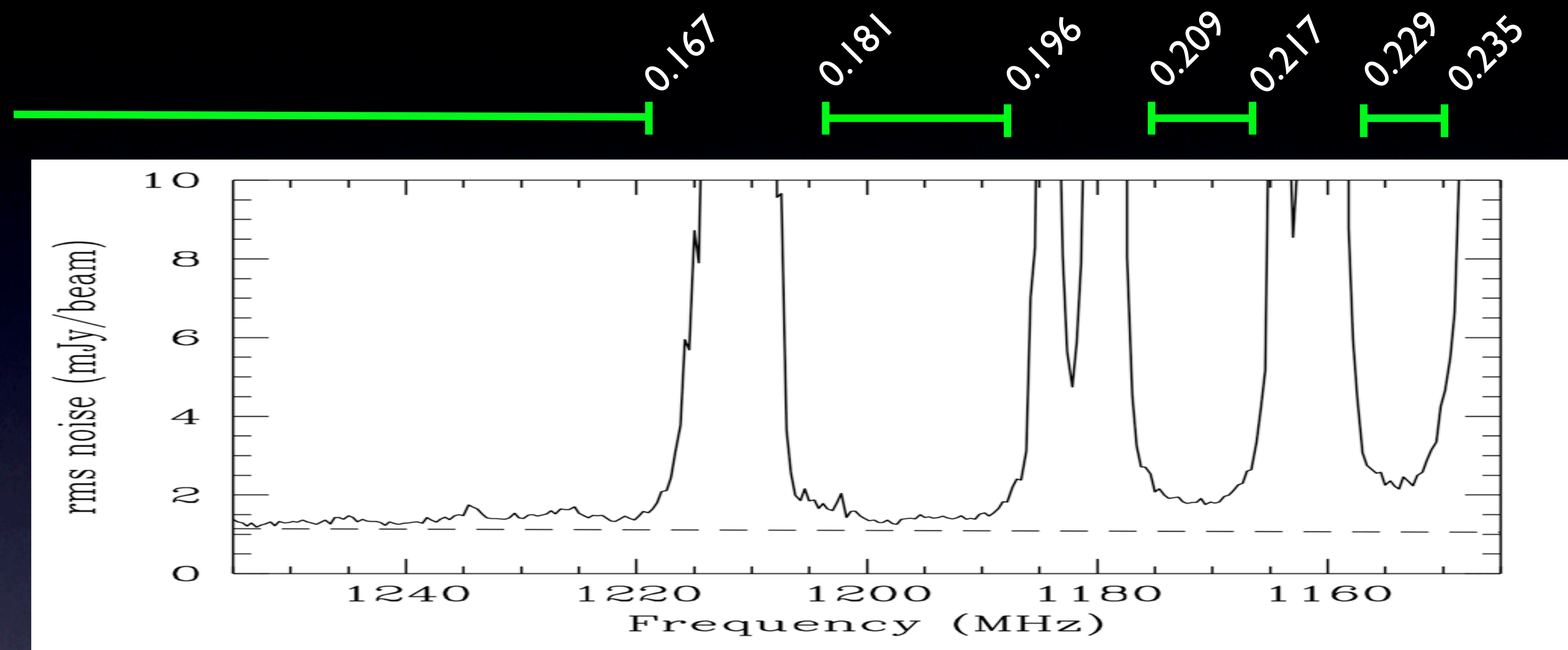
The power of a fully upgraded WSRT

<u>'old' VLA</u>

$A_{eff} / T_{sys} =$

$182\ m^2/K$

2x6.25 MHz

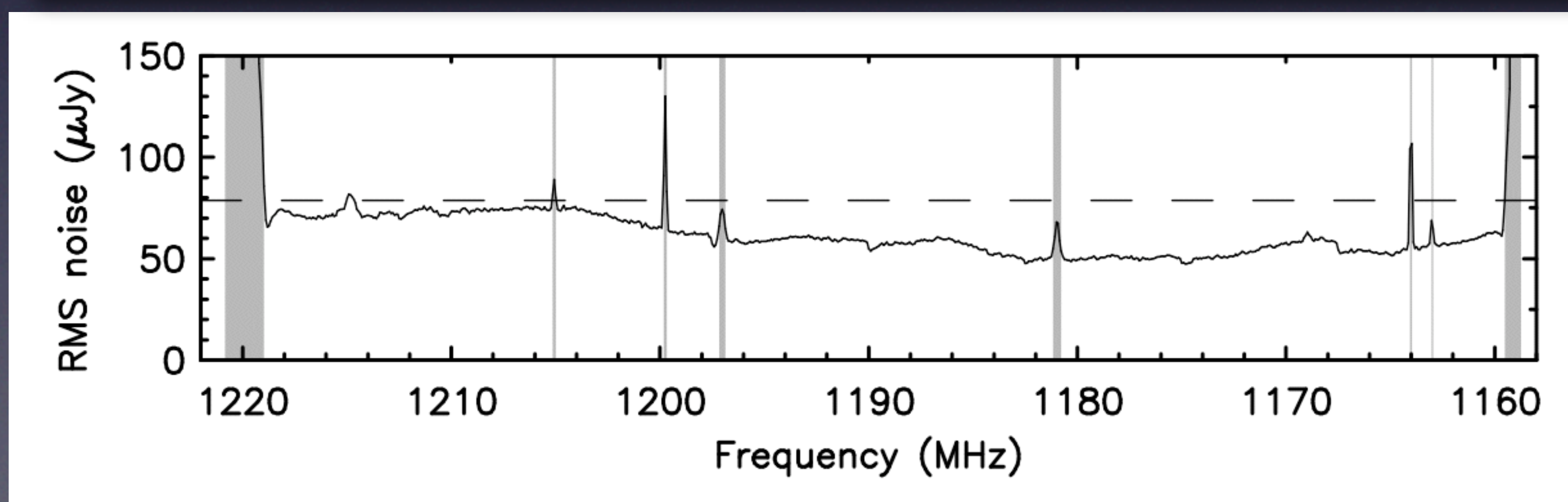


<u>new WSRT</u>

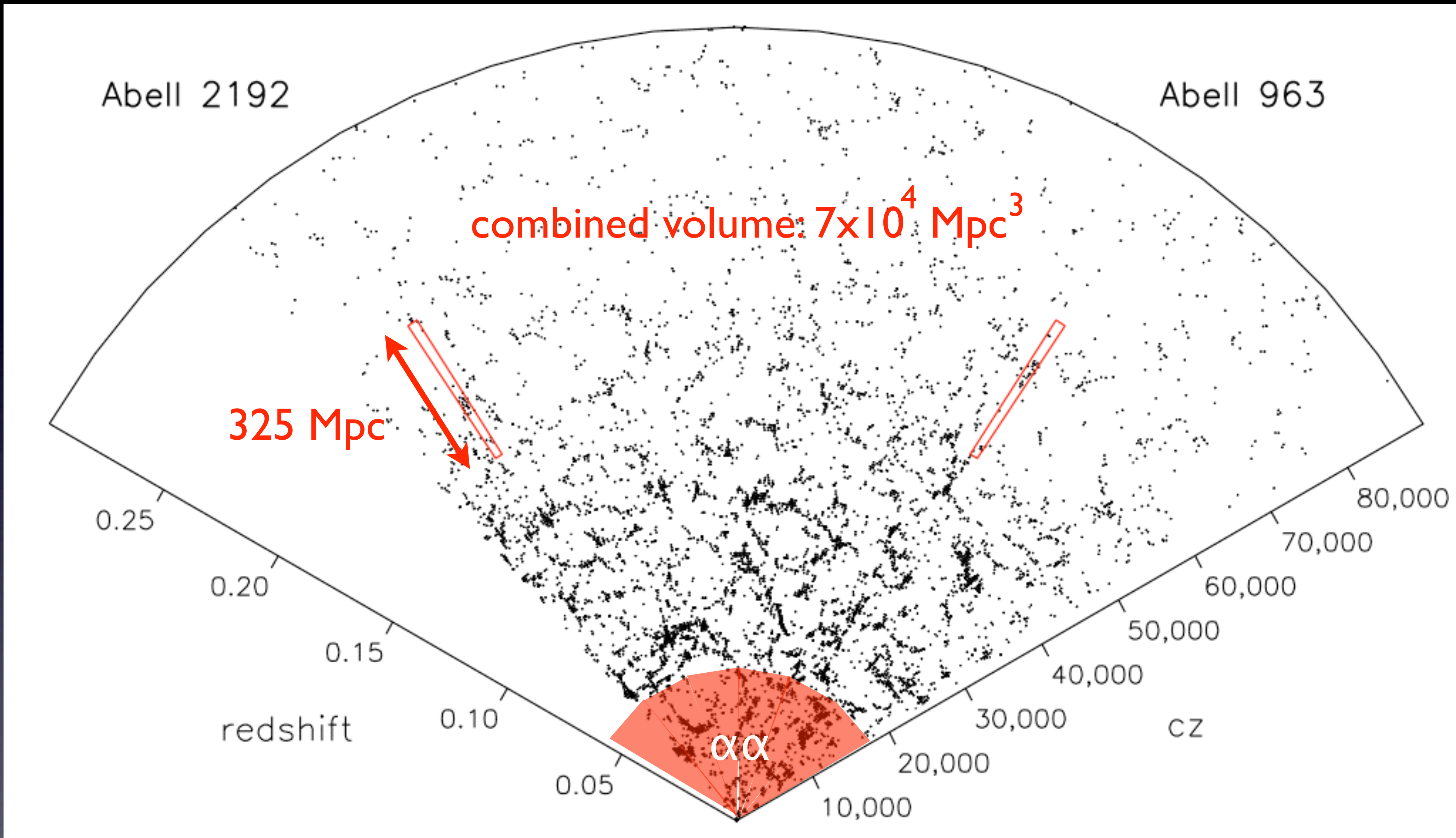
$A_{eff} / T_{sys} =$

$140\ m^2/K$

8x10 MHz



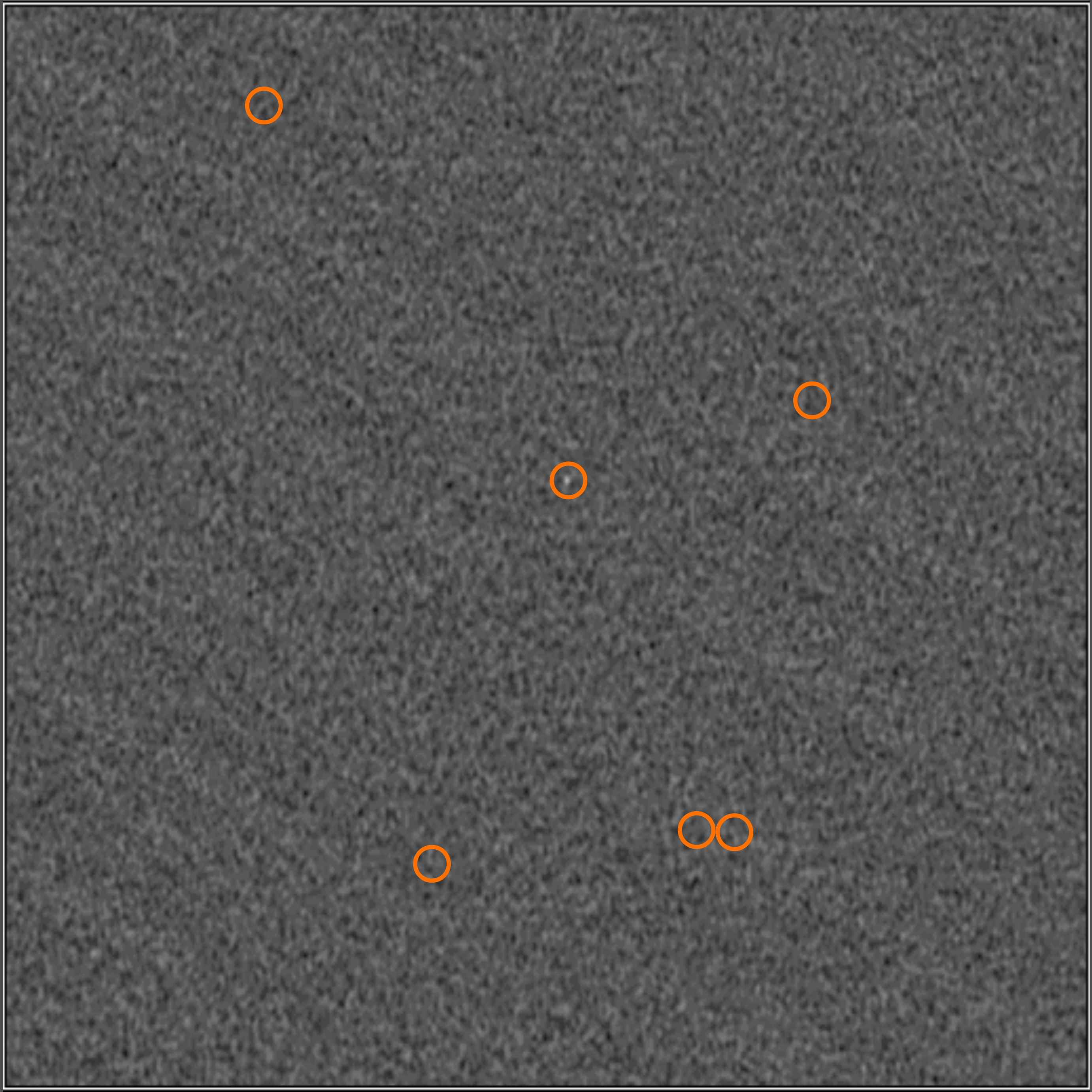
Survey Volume & Large Scale Structure



SDSS redshift slice

Abell 2192

9.7 x 9.7 Mpc



one IF , 87 channels
(ΔV=20 km/s, R=2ΔV)

ν : 1196.9 – 1190.2 MHz

Z : 0.1867 - 0.1934

cz : 55,970 - 57,980 km/s

15 x12hr
σ_{rms}= 39 μJy/beam

one IF , 91 channels
(ΔV=20 km/s, R=2ΔV)

ν : 1174.8 – 1167.8 MHz

Z : 0.2091 - 0.2163

cz : 62,687 - 64,847 km/s

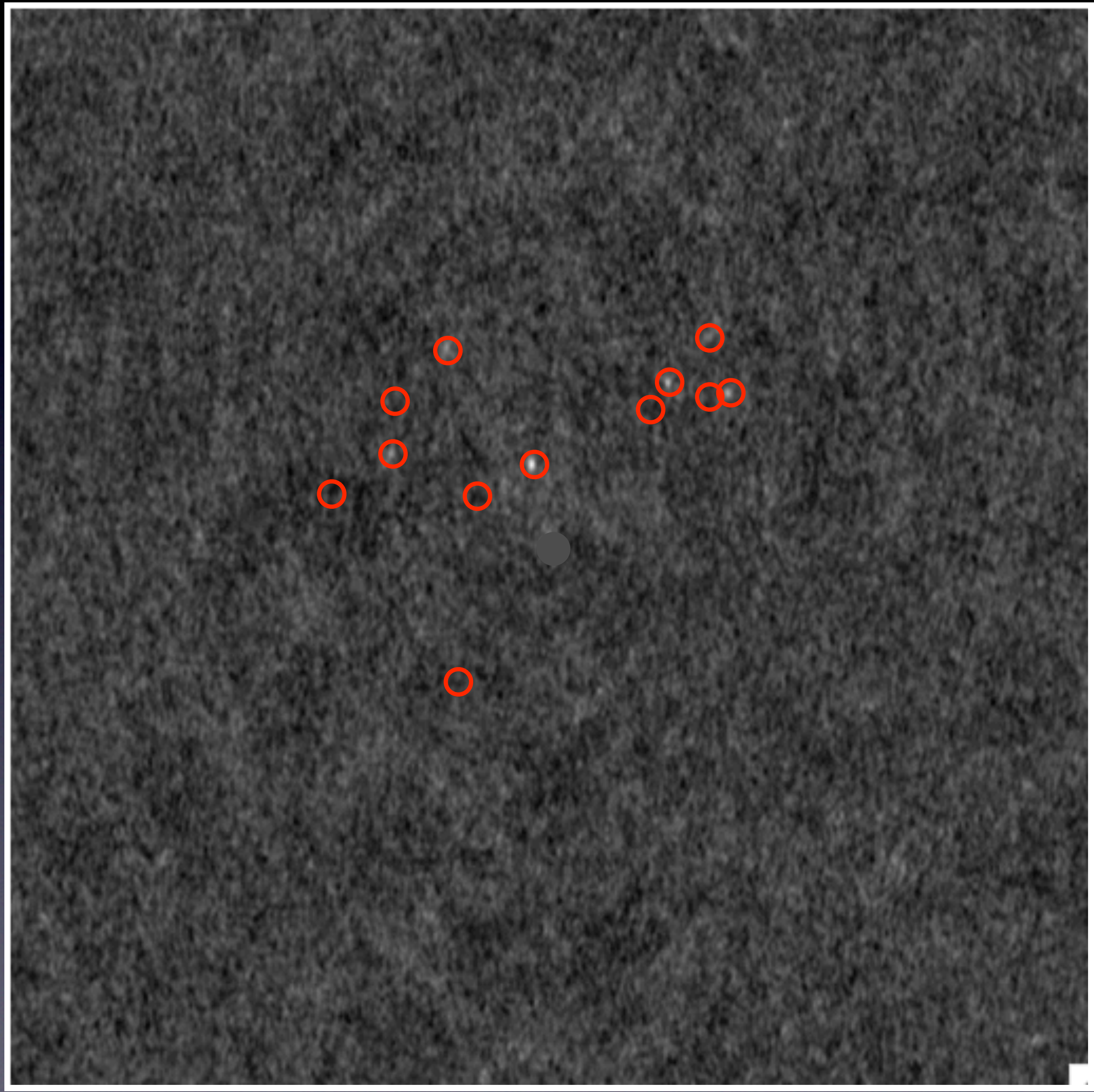
115x12hr
σ_{rms}= 18 μJy/beam

41 galaxies detected in two clusters

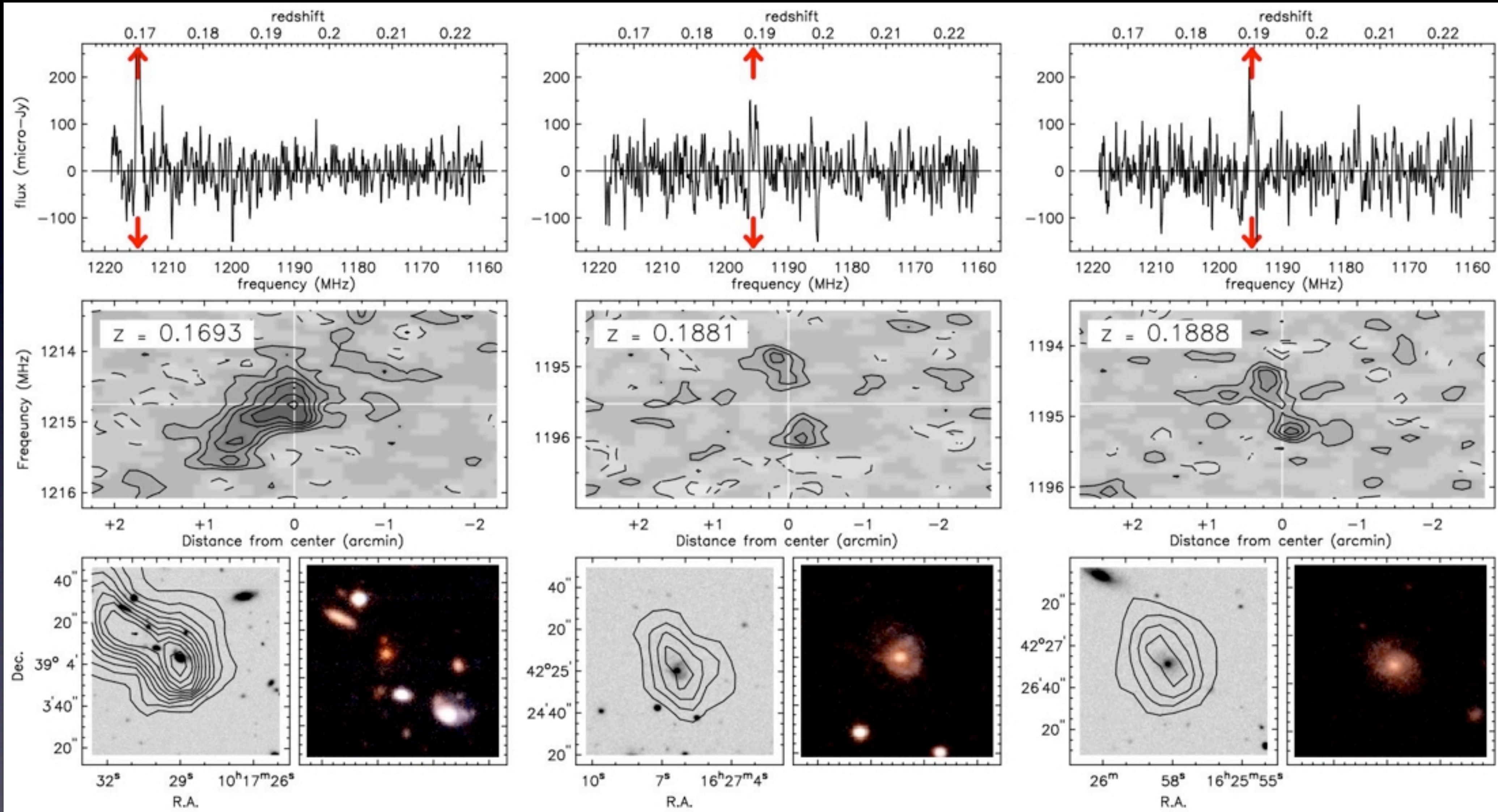
$5\times10^{9} - 4\times10^{10}\ M_{\odot}$

Abell 963

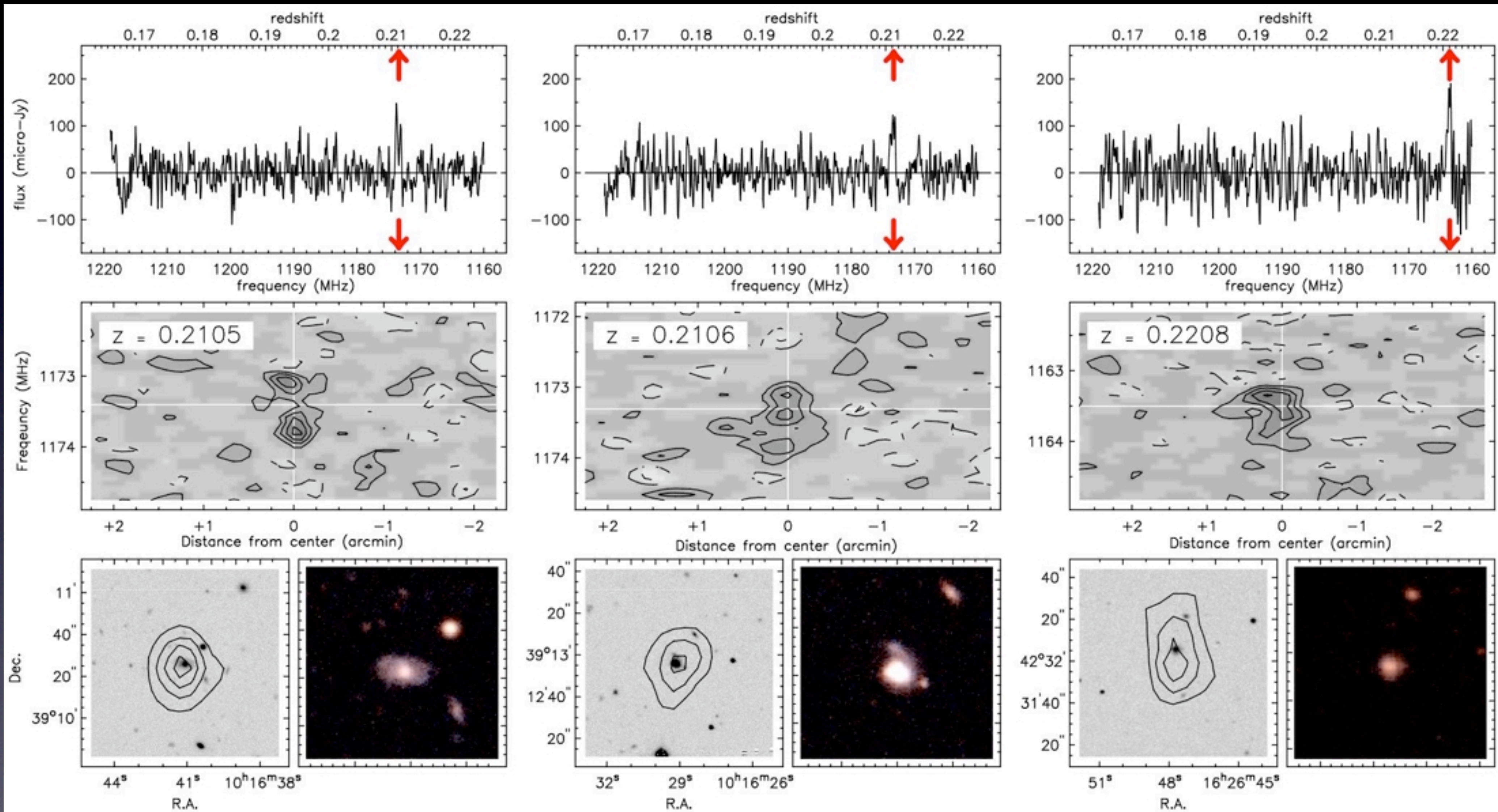
12.3 x 12.3 Mpc



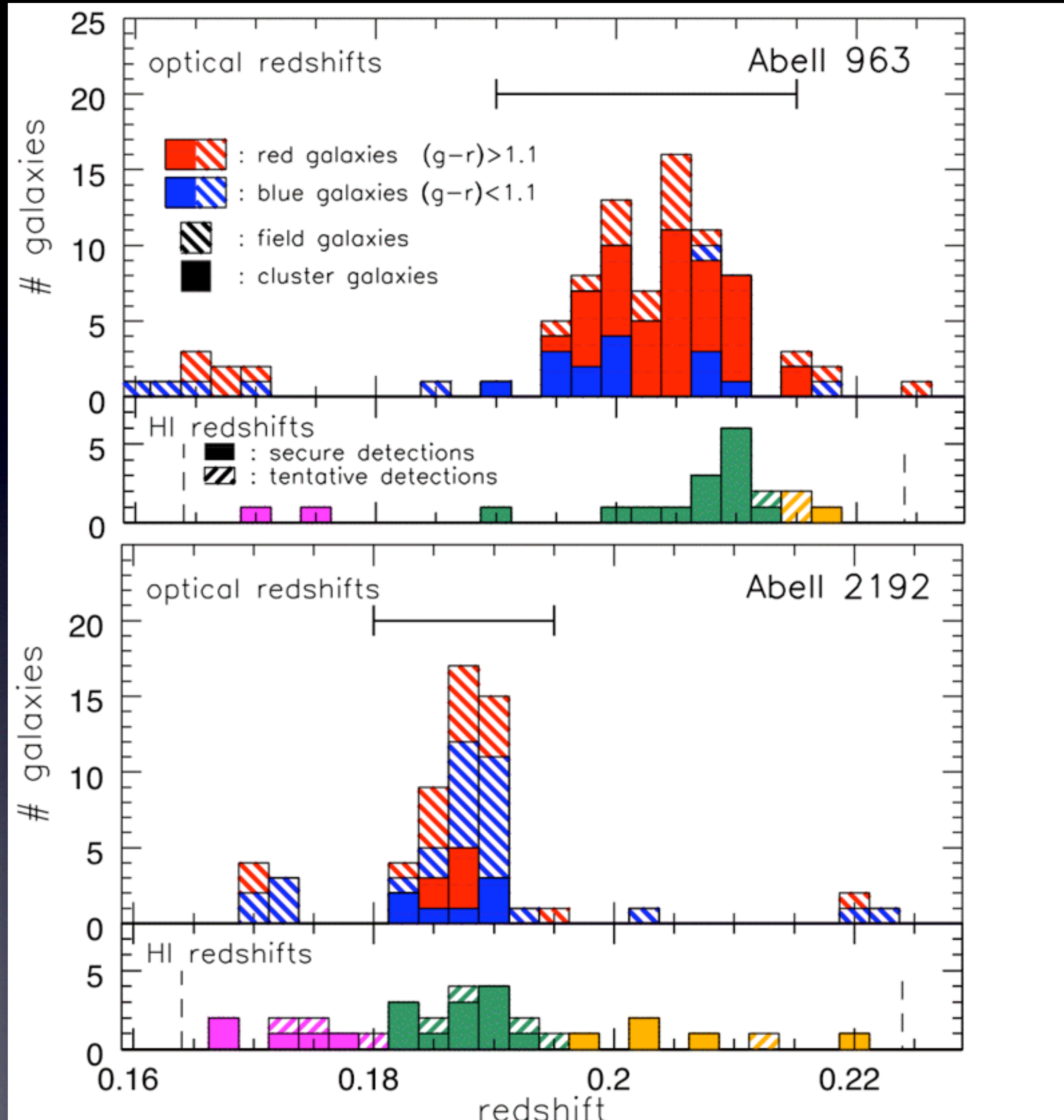
Detections in pilot observations



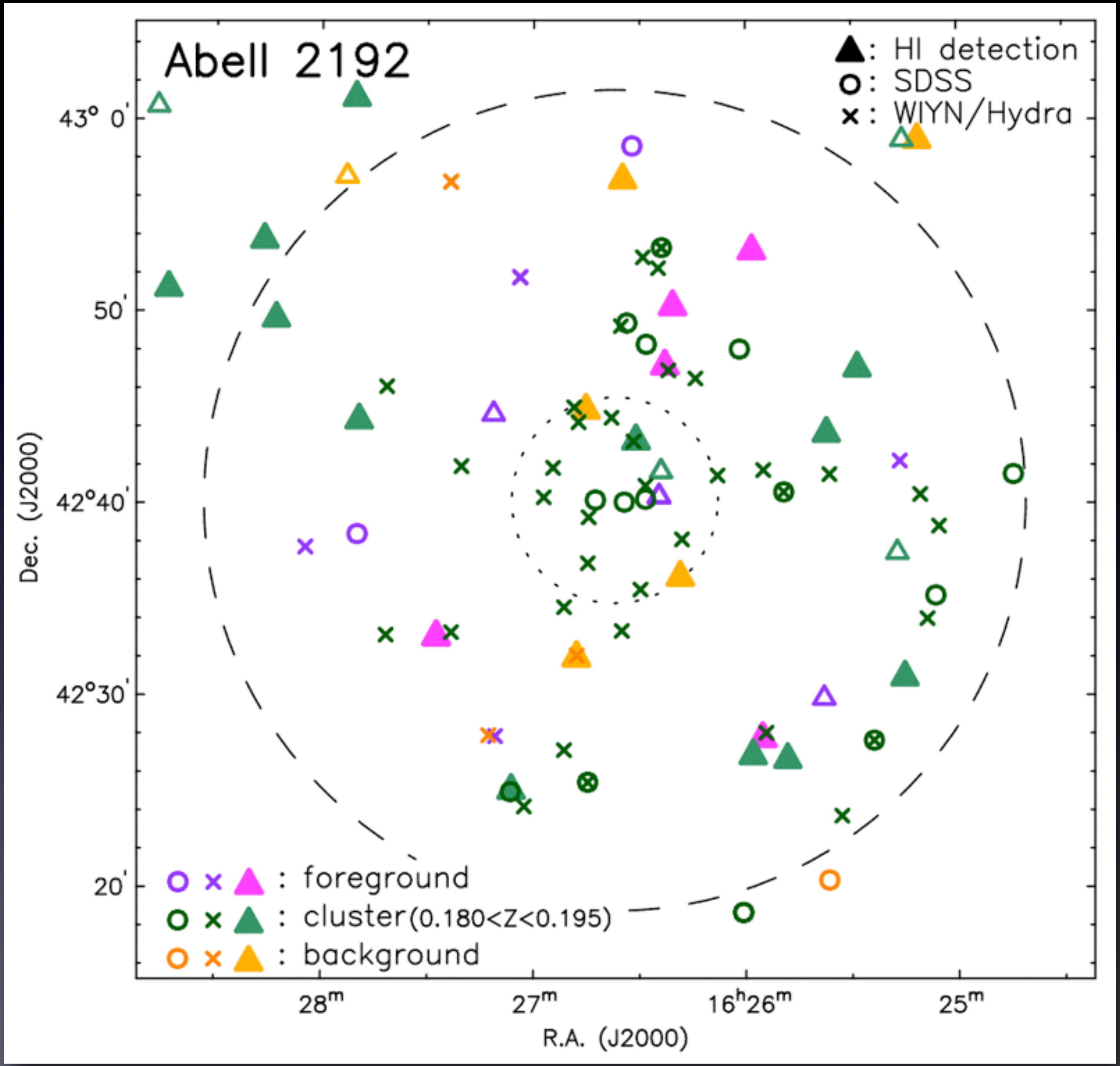
Detections in pilot observations



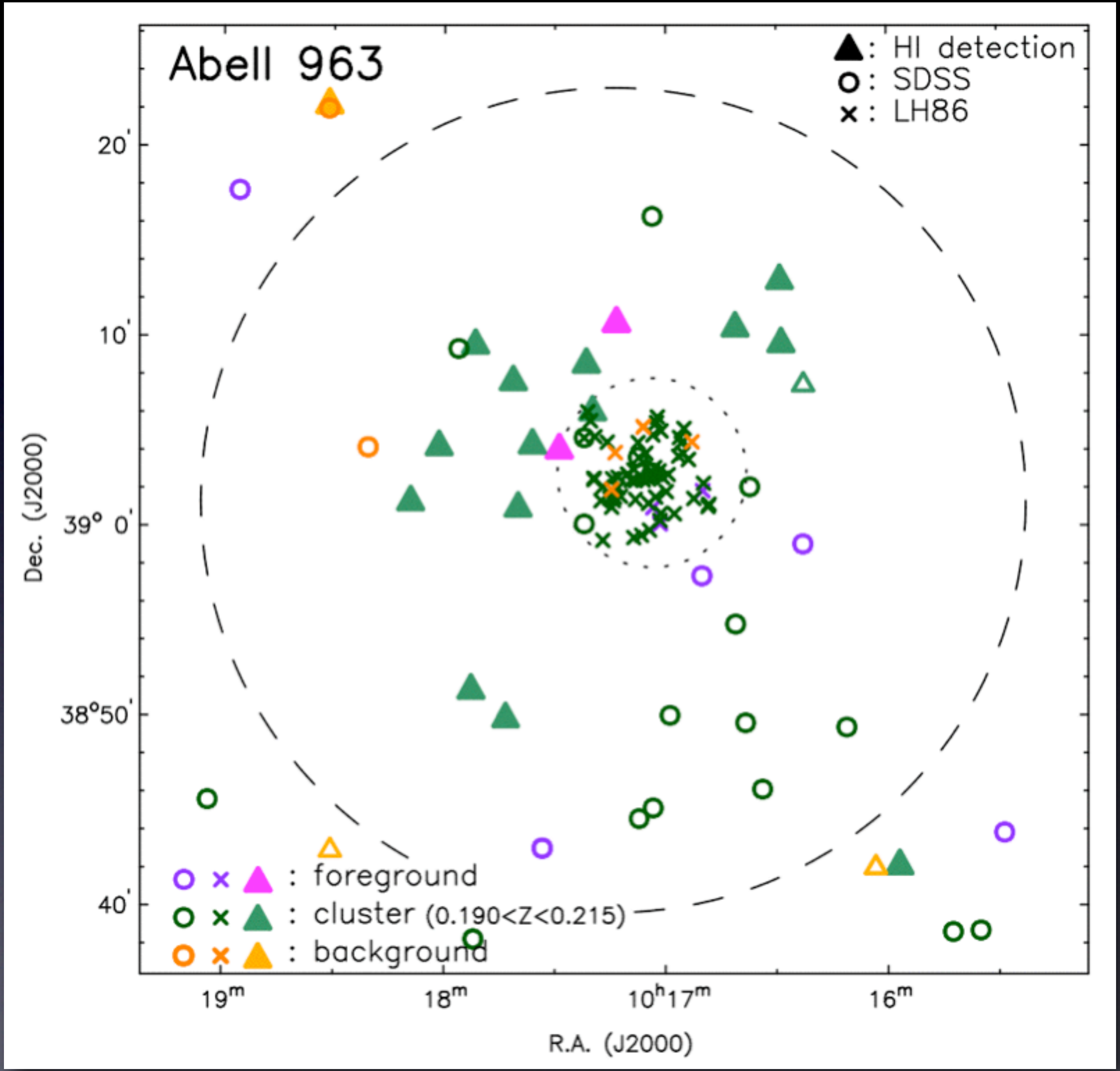
Redshift distributions



Revealing the surrounding field



Revealing the surrounding field



Colour-Magnitude diagrams

Galaxies with known redshifts only

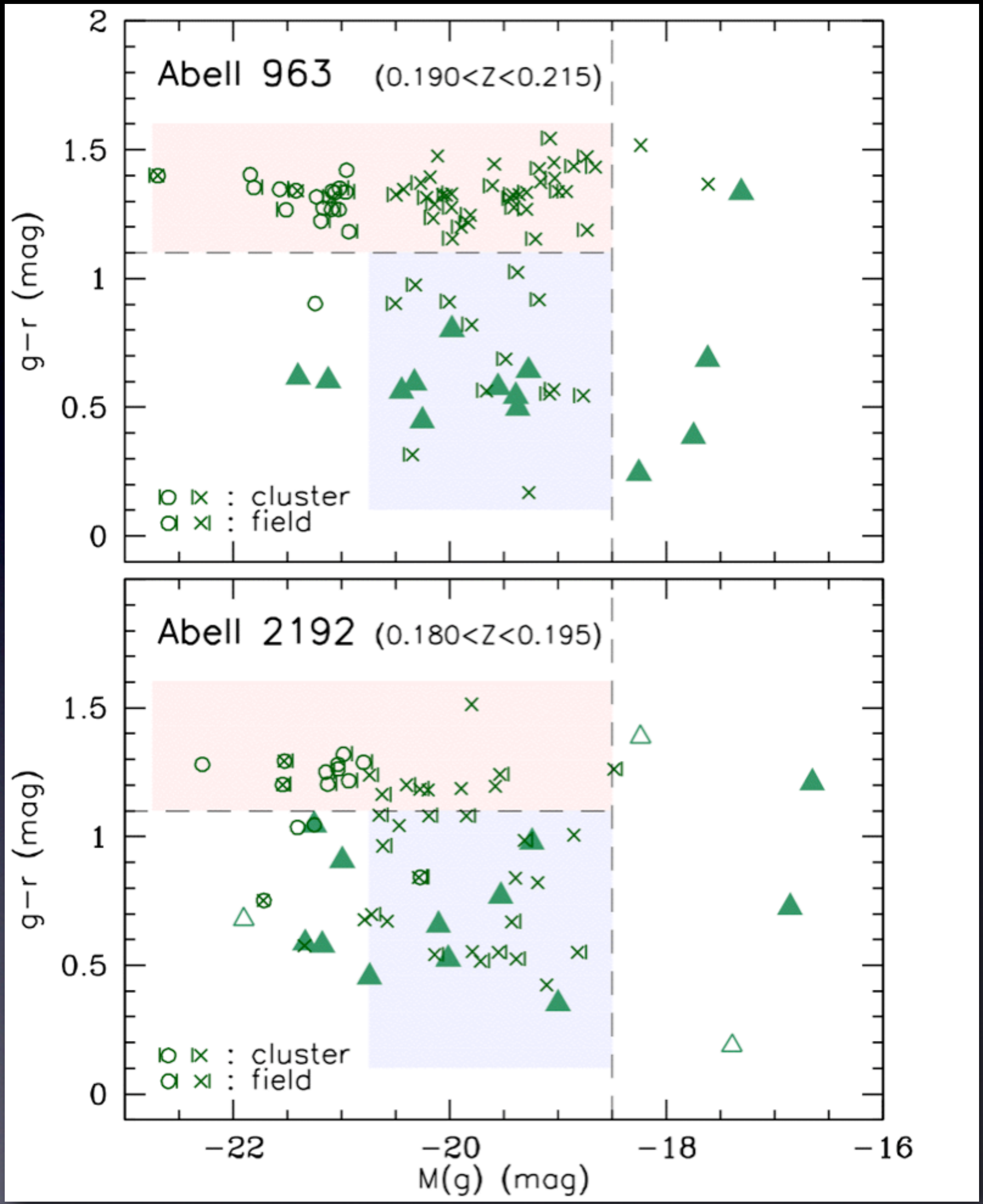
optical redshifts

○ : SDSS

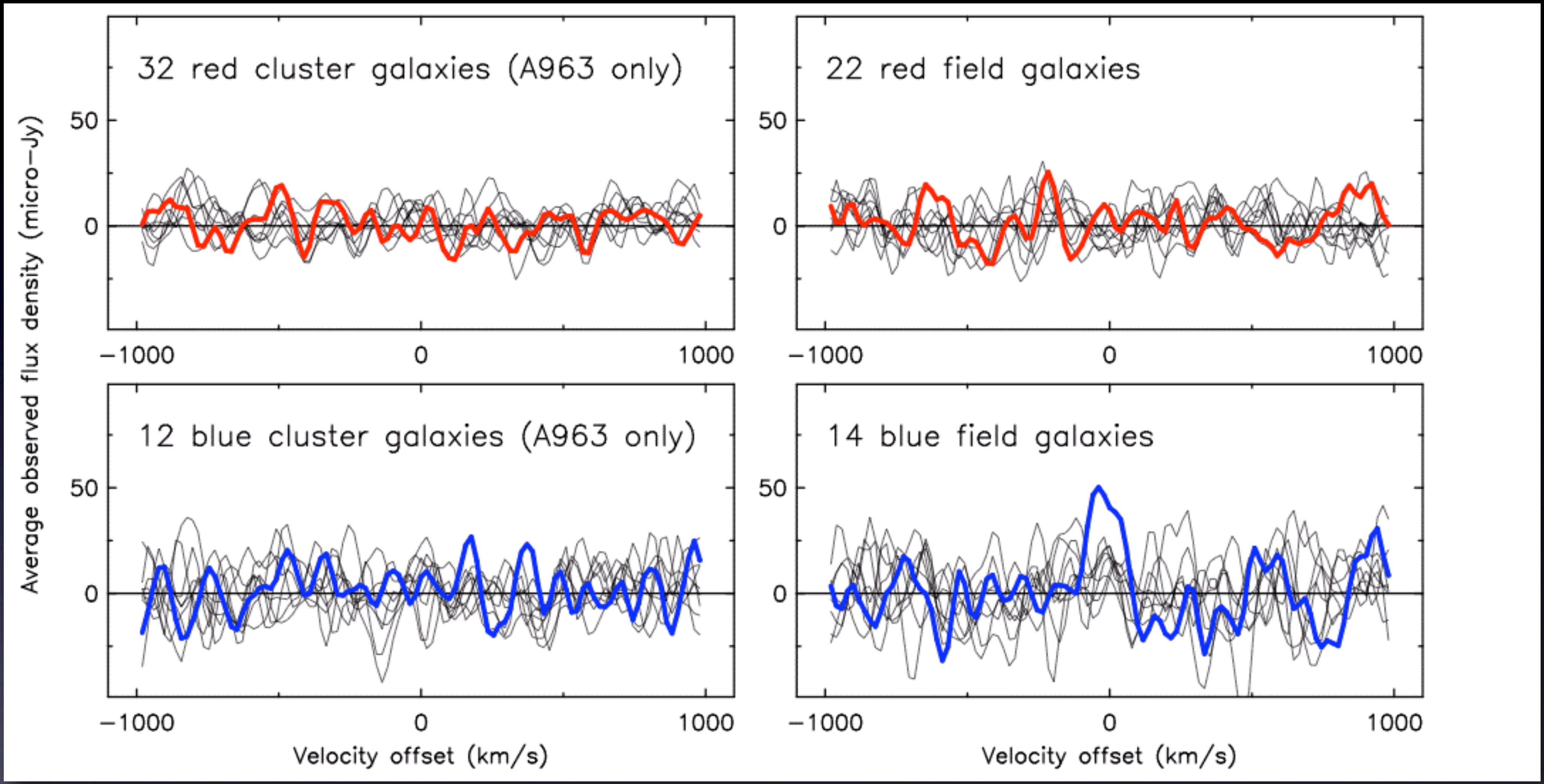
× : other

HI redshifts

▲ : WSRT



Stacking HI spectra



Average HI mass: ~ $2 \times 10^9 M_{\odot}$

Summary & Outlook

- HI reveals physical processes not seen otherwise
- HI emission from 41 galaxies at $Z \approx 0.2$
(need EVLA & ASKAP for $Z \leq 0.5$ and SKA for $Z \geq 0.5$)
- Blind HI survey uncovers LSS not seen by SDSS
- Blue 'BO-galaxies' gas-poor wrt similar field galaxies
- Long-term program on WSRT completed
(~200 detections expected in full cubes)
- ASKAP & APERTIF will enable
all-sky $0 < Z < 0.2$ surveys at 30"-15"