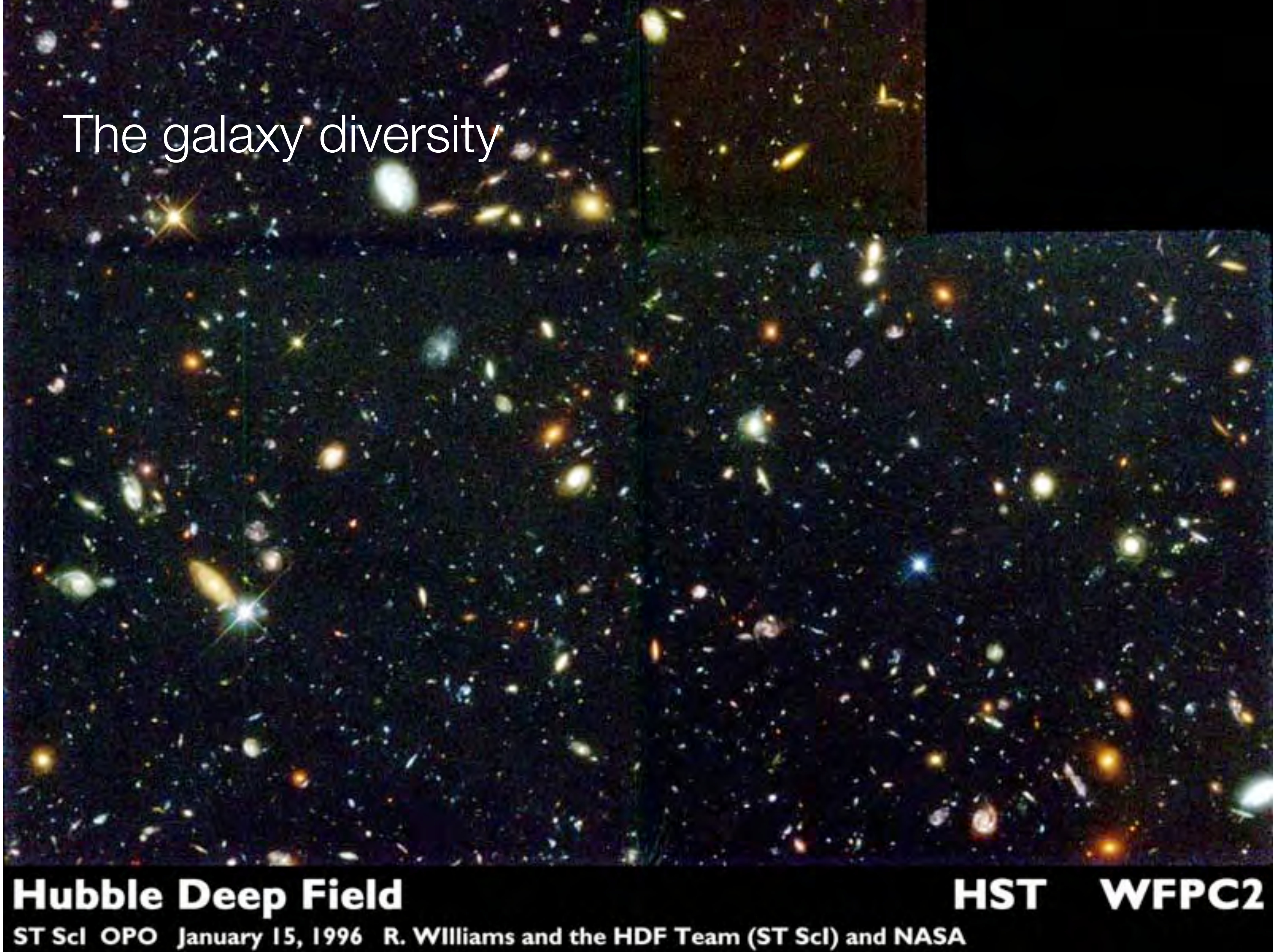
UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES
Département d'astronomie

The gas-galaxy-halo connection

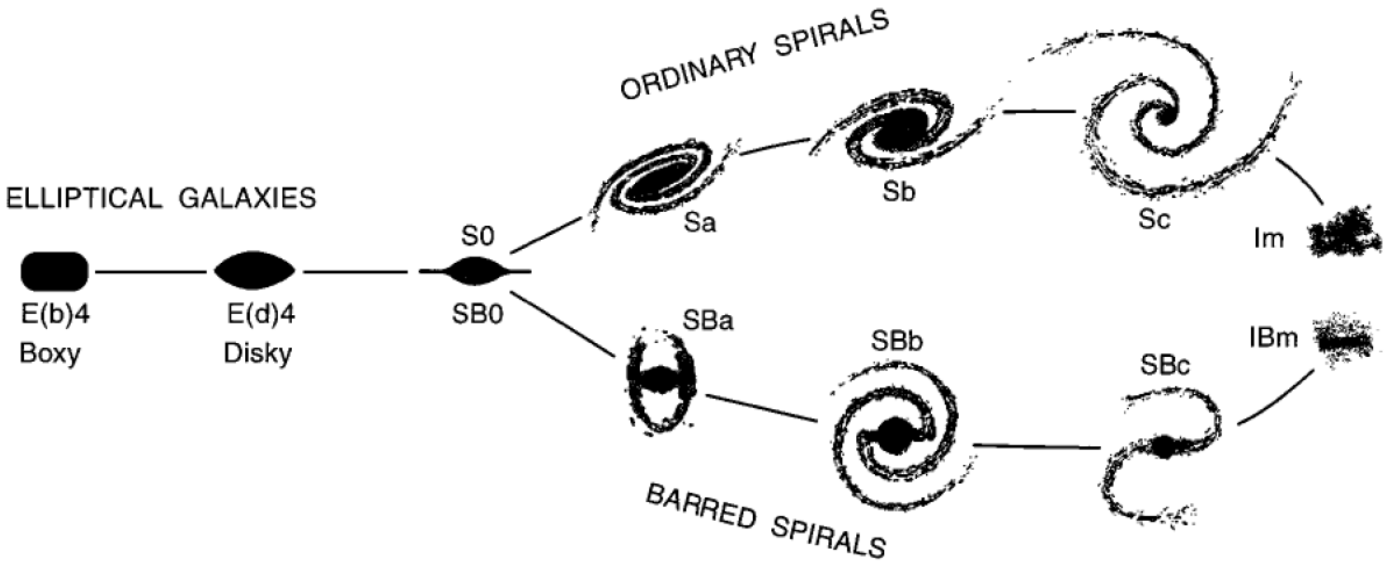
Jean Coupon (University of Geneva)
Collaborators: **Miriam Ramos**, **Dominique Eckert**, Stefano Ettori, Mauro Sereno, Keiichi Umetsu, Sotiria Fotopoulou, Stéphane Paltani, and the XXL collaboration

IPMU - 2016, Thursday April 28th

The galaxy diversity



The galaxy zoology: the Hubble sequence



dwarf, irregular,
+ peculiar galaxies and
active galactic nuclei

Kormendy & Bender (1996)

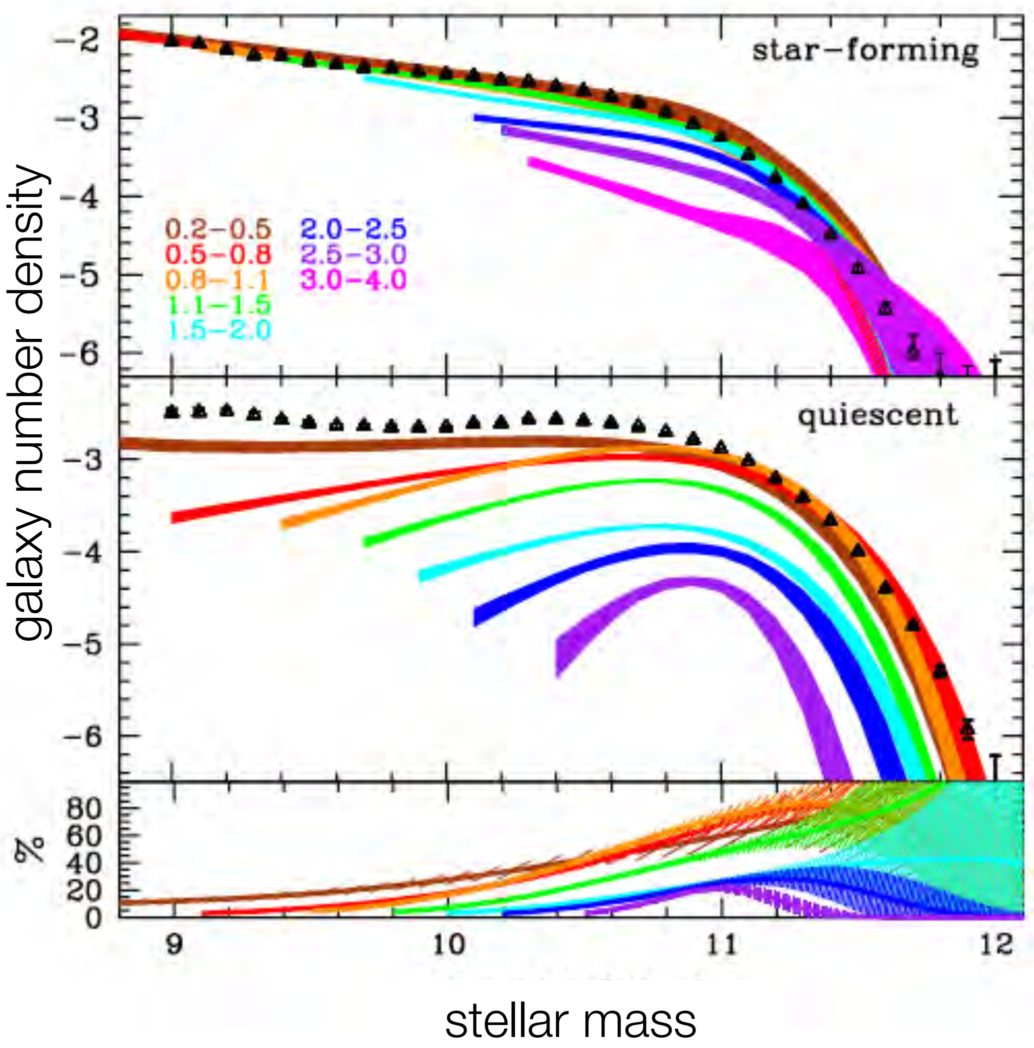
Elliptical galaxies
or early-type galaxies
or “red” galaxies

Spiral (disk) galaxies
or late-type galaxies
or “blue” galaxies

rare objects but carry
some precious information
about galaxy evolution

How did galaxies form and evolve from the initial baryon density field to the galaxy diversity as seen today?

The galaxy statistics (e.g. the stellar mass function)



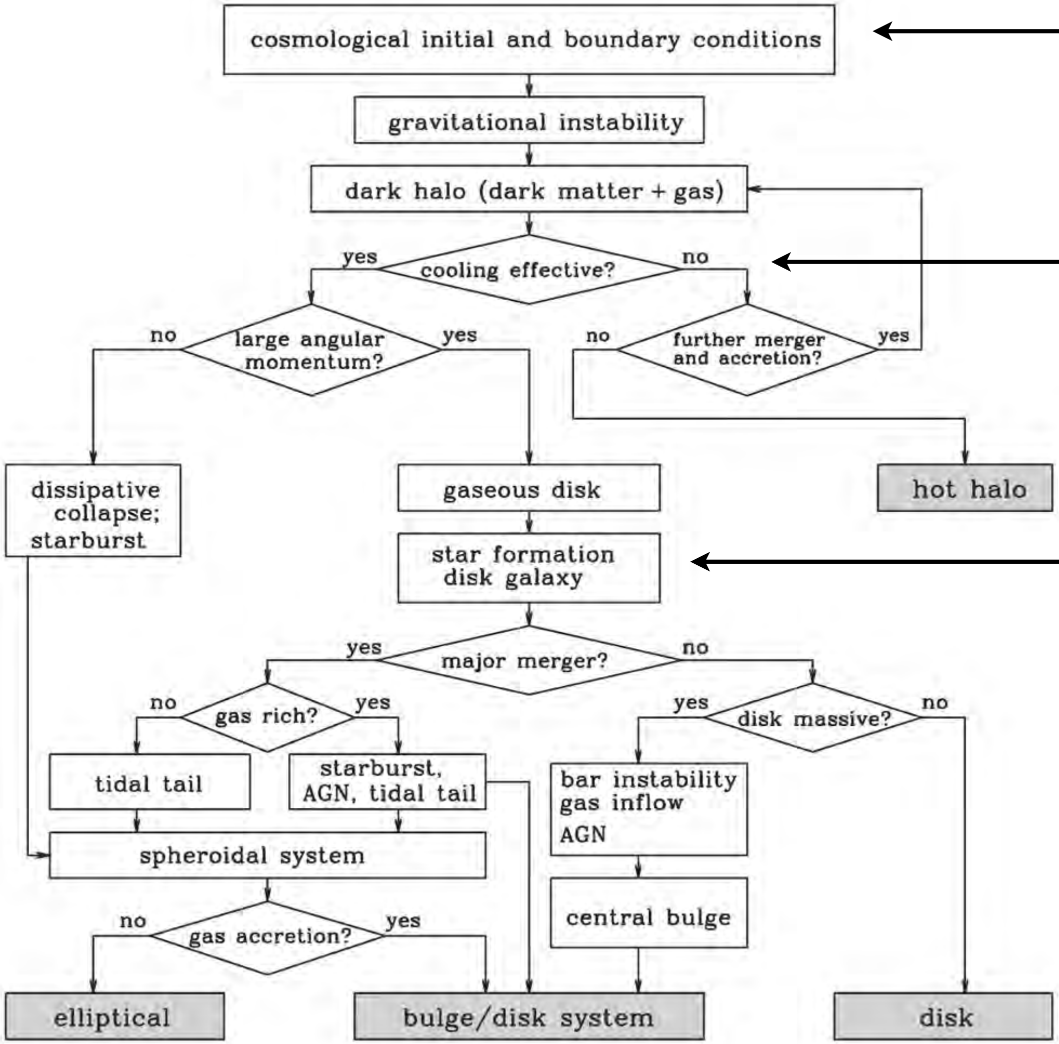
Ilbert et al. (2013)

- all galaxies. redshift evolution
- sf galaxies. Dominate at faint luminosity/low z
- passive galaxies. Dominate at bright luminosity

WHY?

What is the interplay between physical processes?

Mo et al. (2011)



ΛCDM cosmology

No cooling, no star

Star formation stops

Star formation goes on

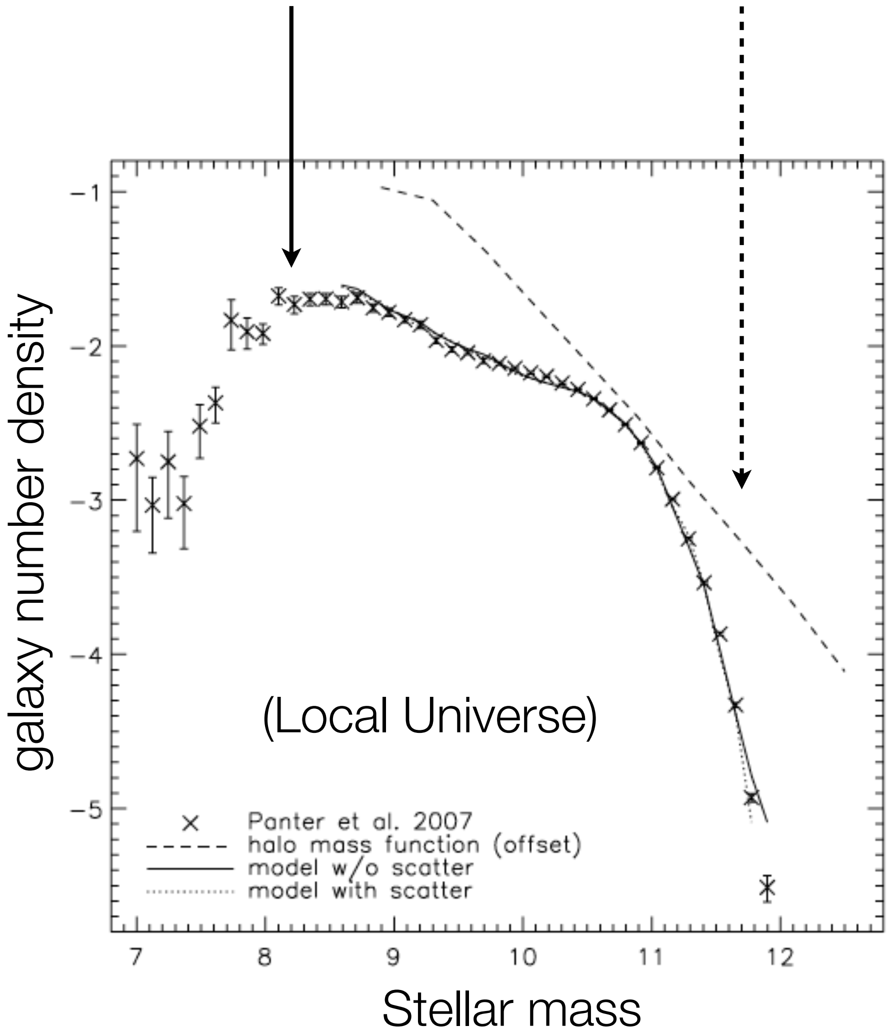
Galaxy evolution: depends on halo mass, environment and redshift

Hubble sequence observed today

SDSS, Blanton & Hogg

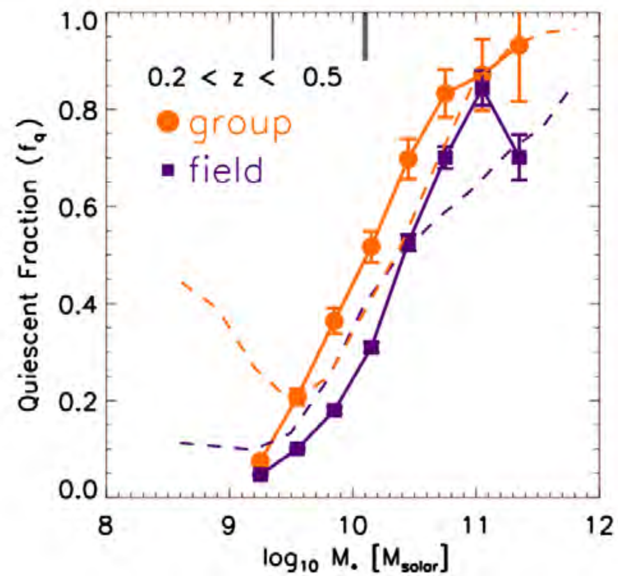
Star formation (in)efficiency in dark matter haloes

Stellar mass function halo mass function scaled to baryon fraction



Moster et al. (2010)

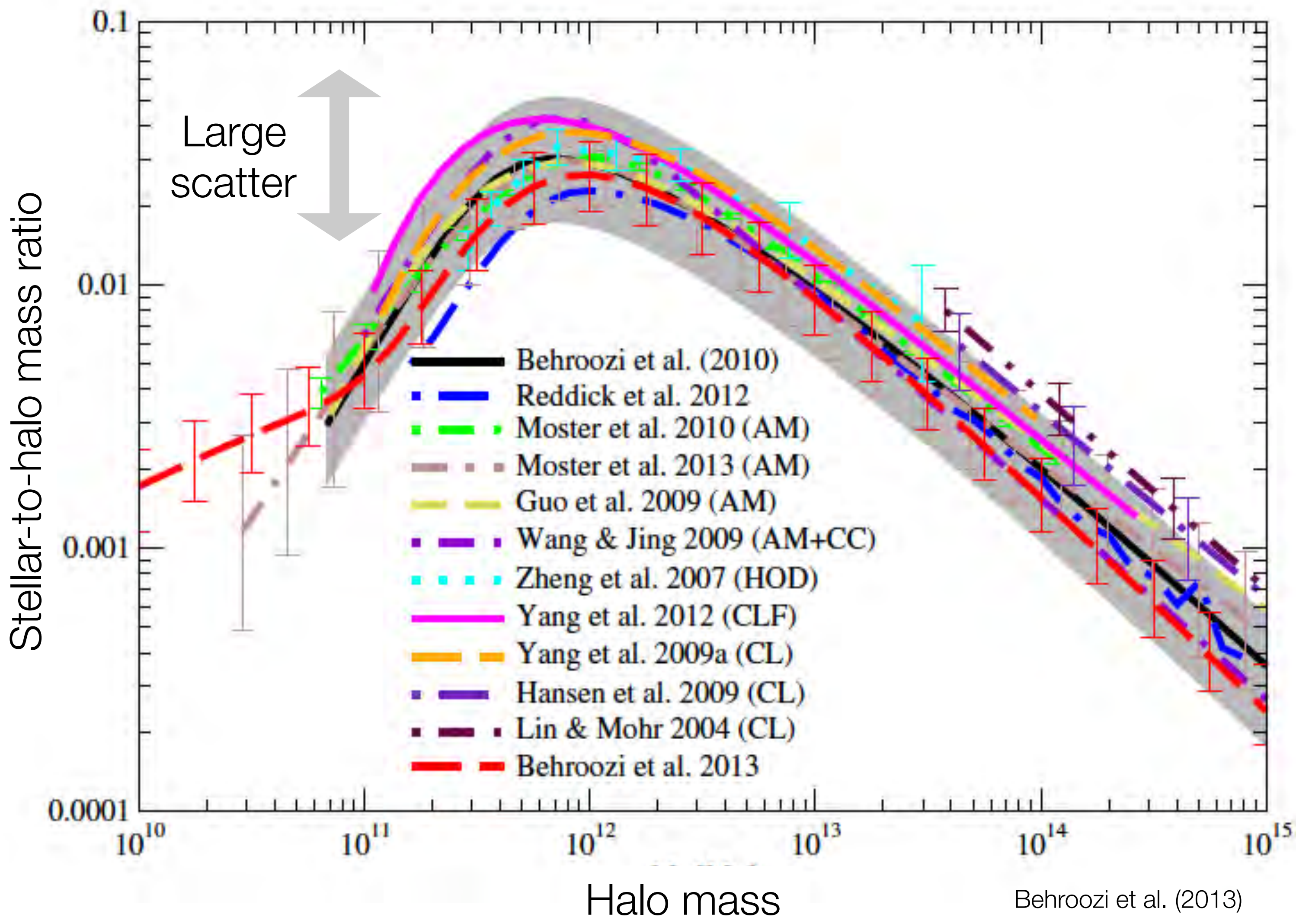
star formation efficiency depends on halo mass (environment)



Lin et al. (2014)

At z=0, from low- to high-mass haloes

Observations in the local Universe (mostly: SDSS)

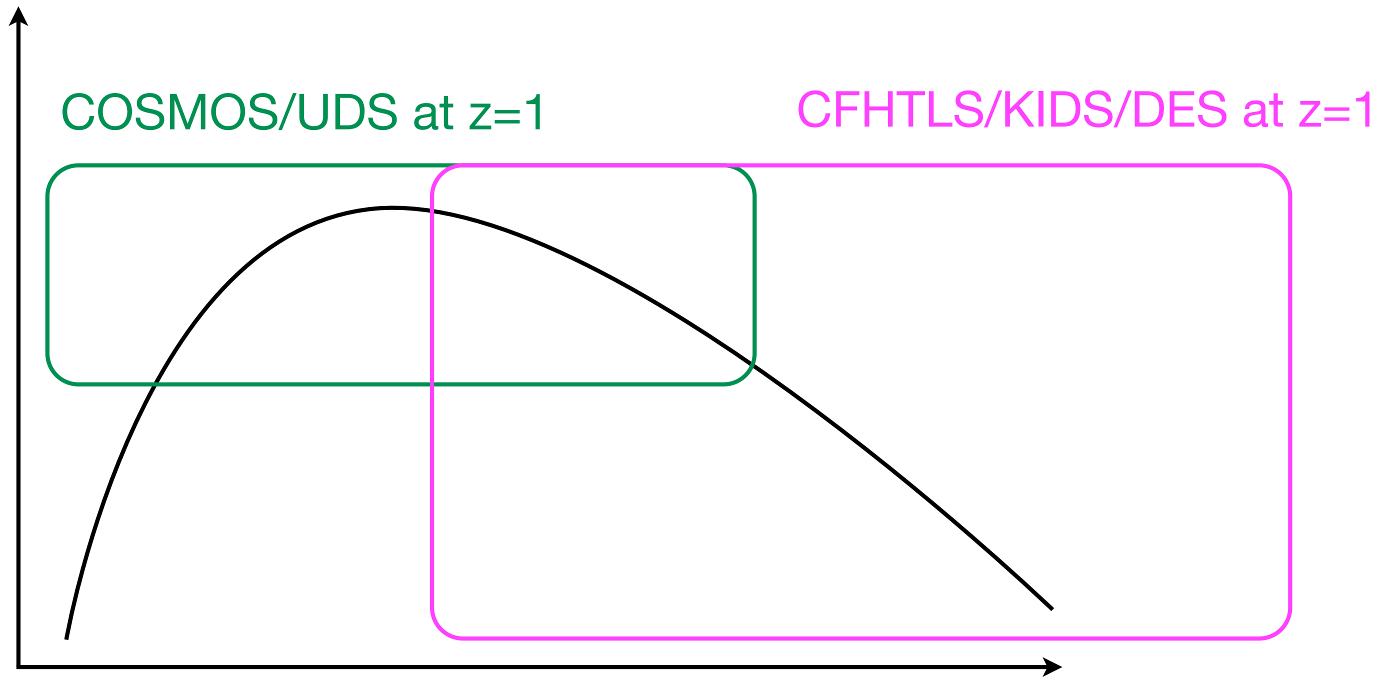


Behroozi et al. (2013)

Where do we stand at z=1?

Ideally one wants to probe both the low- and high-mass regime

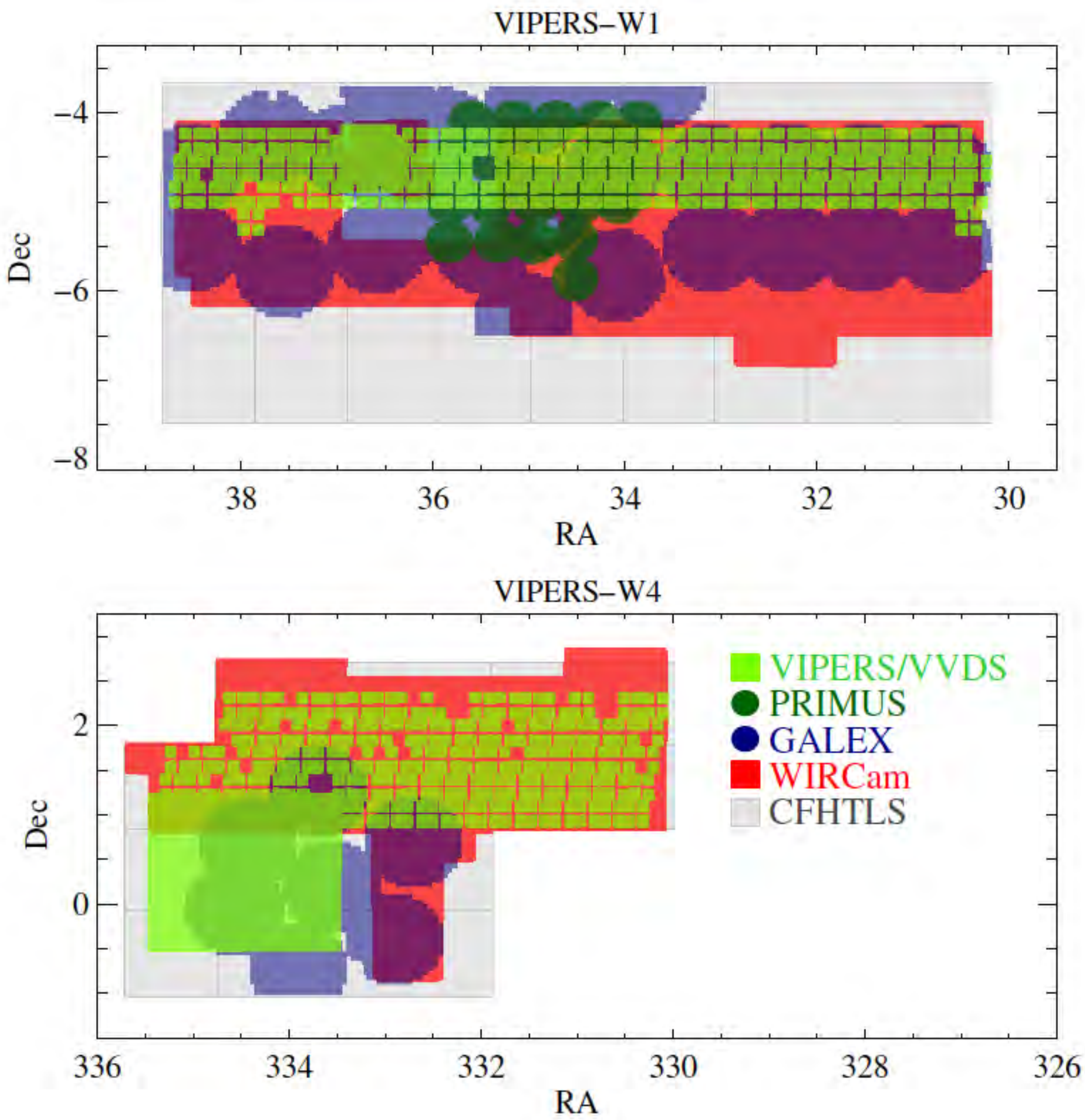
M_{star}/M_h



low mass galaxies =
requires deep data

M_h

clusters = requires volume



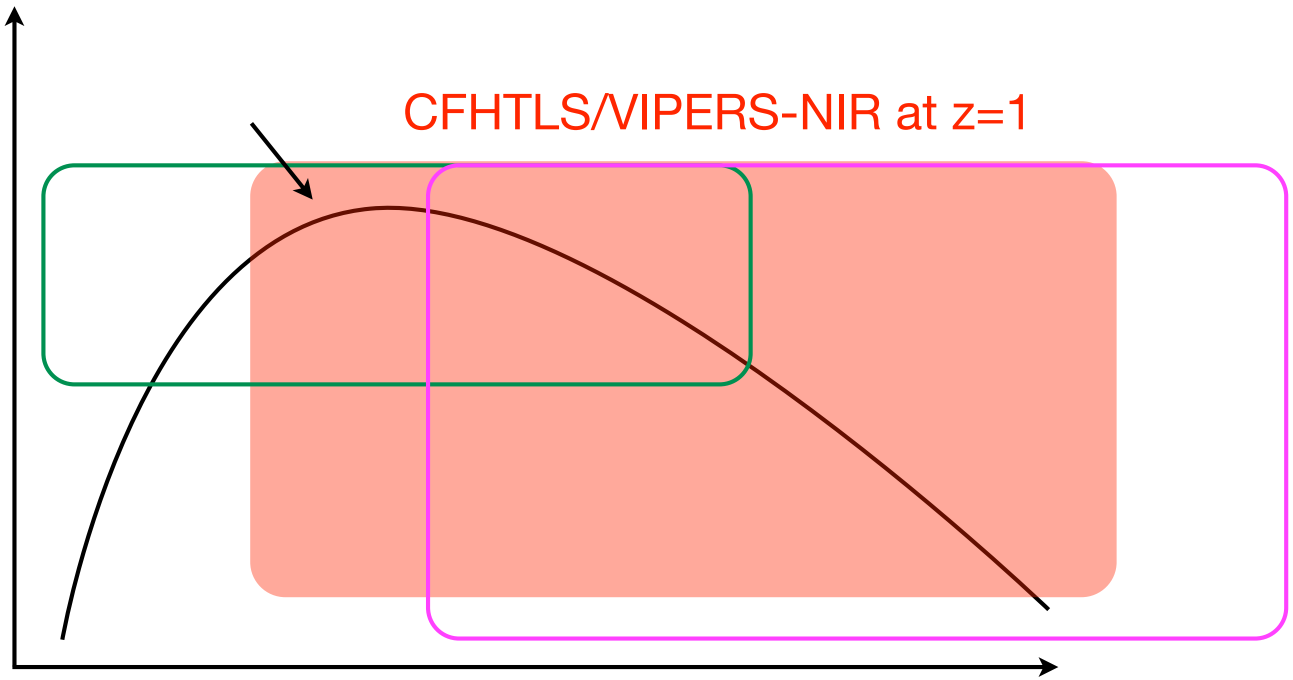
NUV < 24.5, ugriz < 25, K < 22, ~ 0.1 Gpc^3 in 0.5 < z < 1.0


03h00m
02h30m
02h00m
01h30m
01h00m
00h30m
23h30m
23h00m
22h30m
22h00m
21h30m
VIPERS W1
VIPERS W4
SDSS LRG
SDSS Main
Redshift
Distance Mpc/h
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
0
500
1000
1500
2000
2500

Where do we stand at z=1?

M_{star}/M_h

Unique depth/volume combination at z=1!

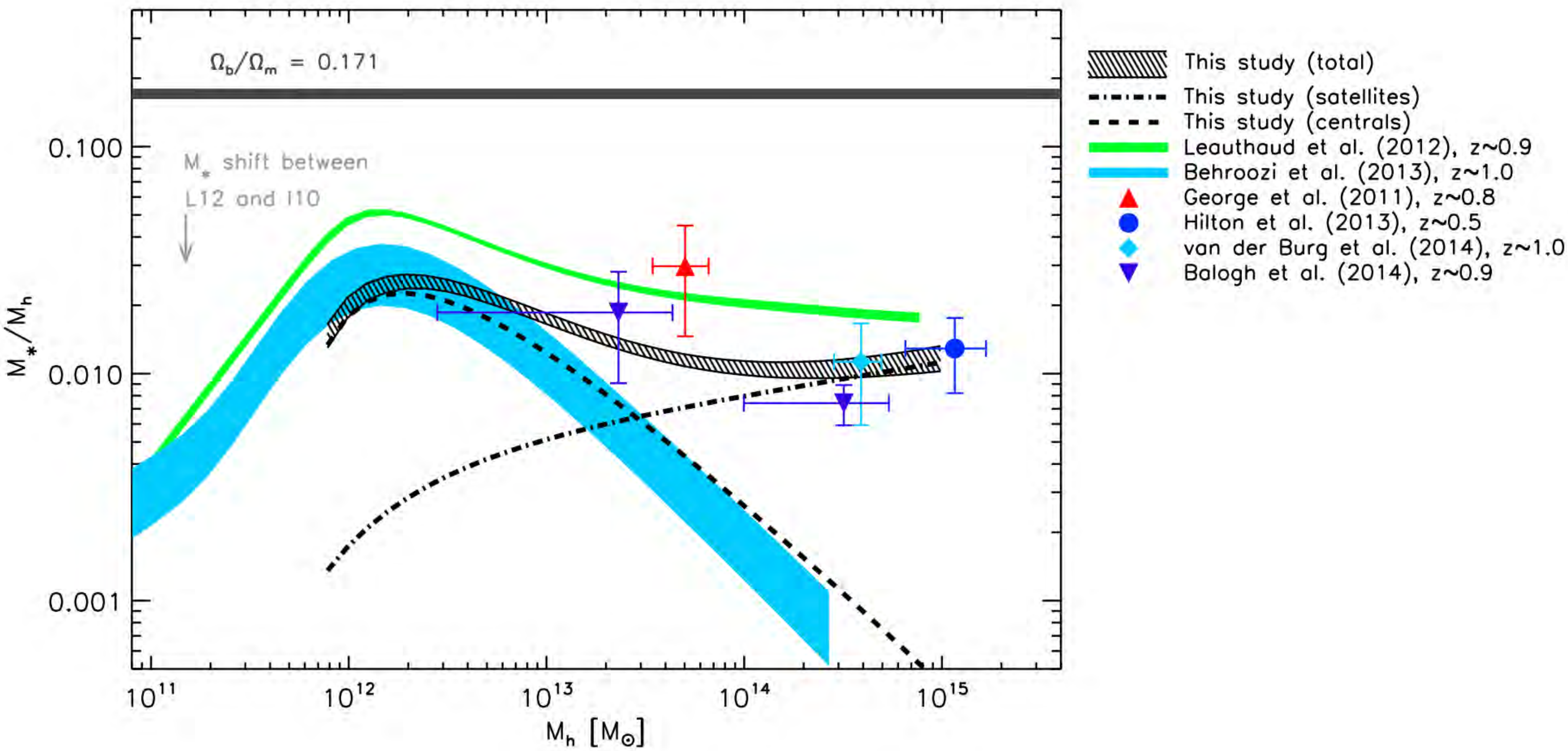


M_h

M* gals ~ 10^{10} $M_\odot$

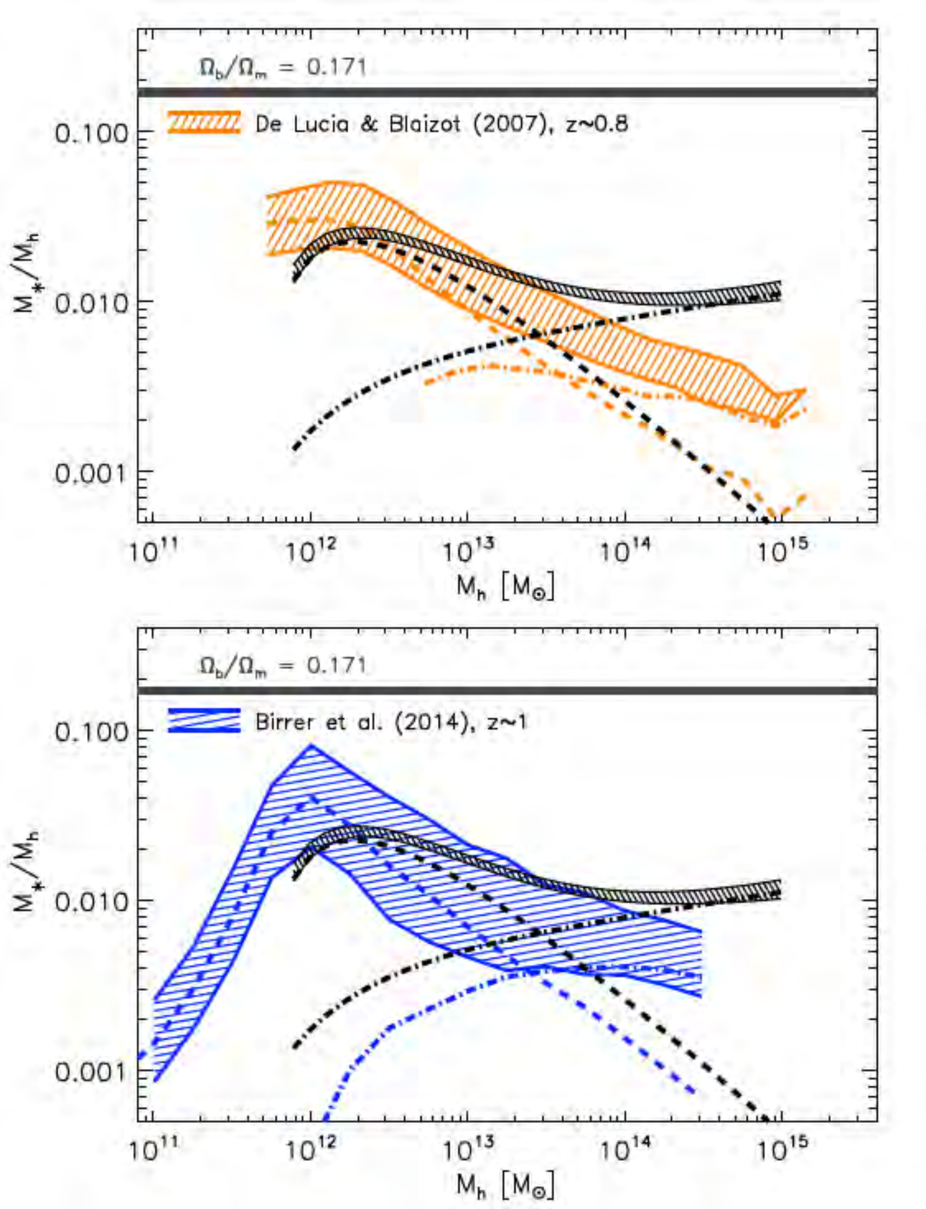
clusters ~ a few 5.10^{14} $M_\odot$

Stellar to halo mass relationship



JC et al. (2015)

Comparison with simulations



Deficit of star formation in medium mass (10^10) satellites

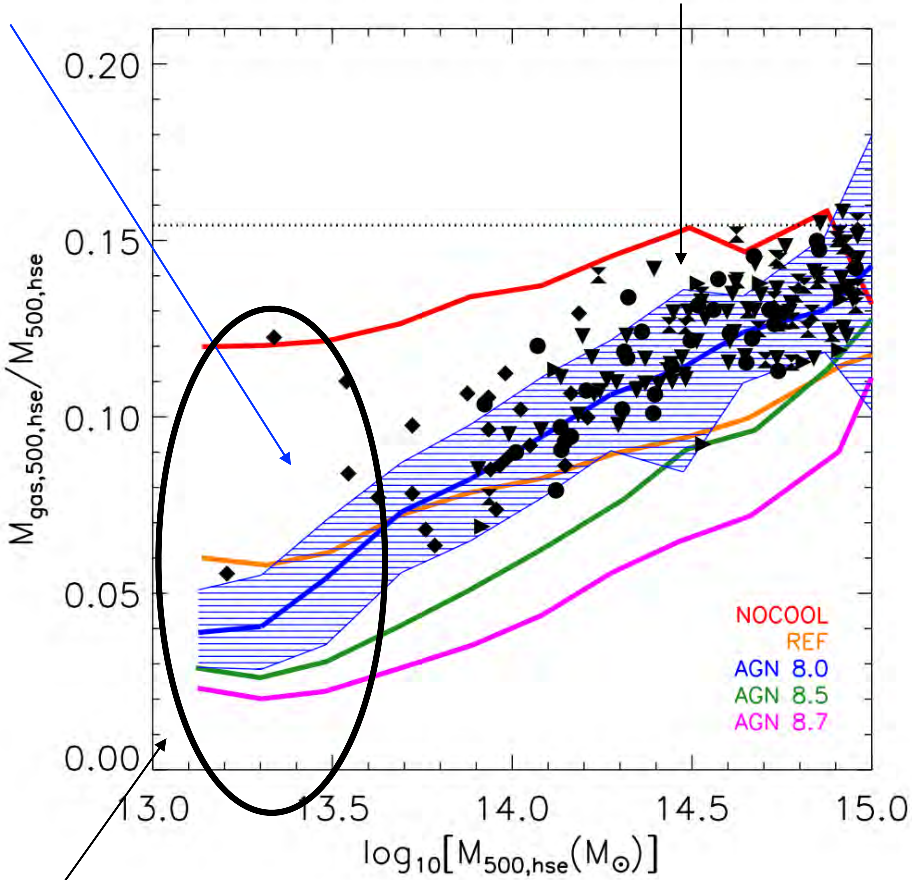
The *gas*-galaxy-halo connection

- gas “temperature cycle” and AGN feedback are the drivers of star formation
- f_{gas} is a key observable to understand galaxy evolution
- galaxy group regime is the new frontier for X-ray probes
- we measured stacked X-ray, lensing and star fraction profiles for groups up to z=1 in CFHTLenS/XXL field
- we obtained constraints on baryon fraction down to 10^{12} M_{sun} halos up to z=1

I. The gas-halo connection as a tracer of feedback

- AGN feedback
  - expulses the gas to outer regions (>r500)
  - flattens out profile (decreases Lx)
- gas fraction is a sensitive probe of AGN feedback strength

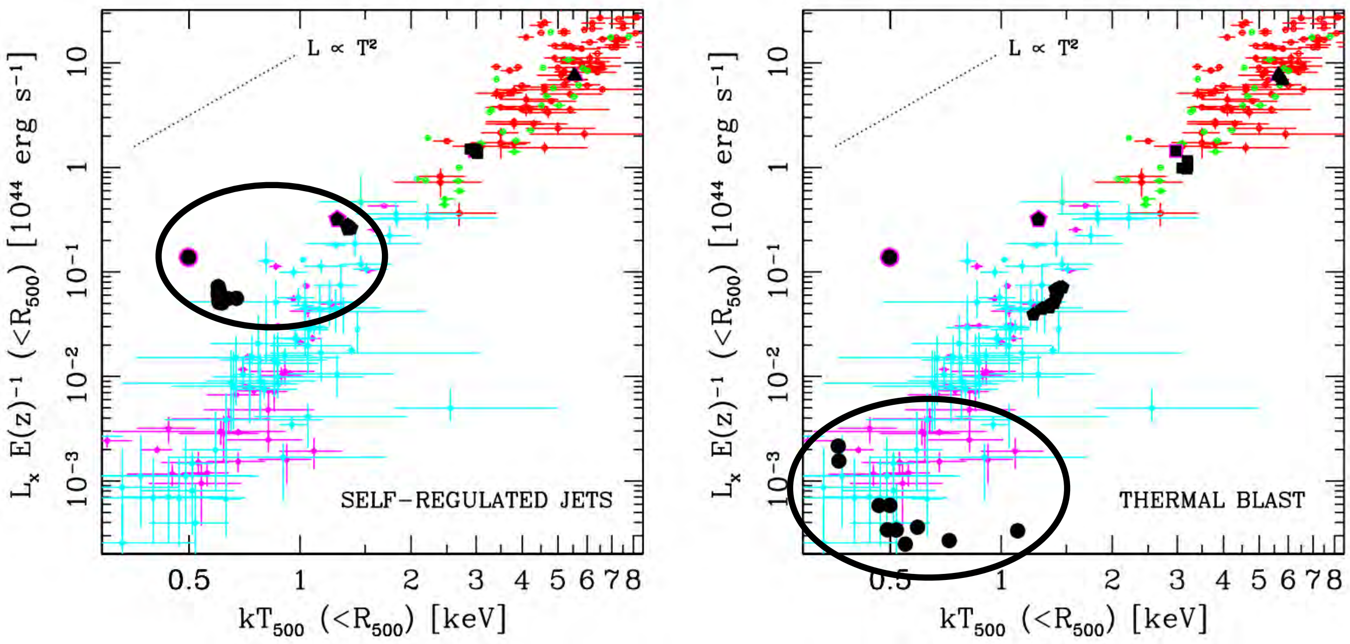
Hydro simulations   measured fractions (z=0)



"halo-mass desert"   Le Brun et al. (2014)

I. The gas-halo connection as a tracer of feedback

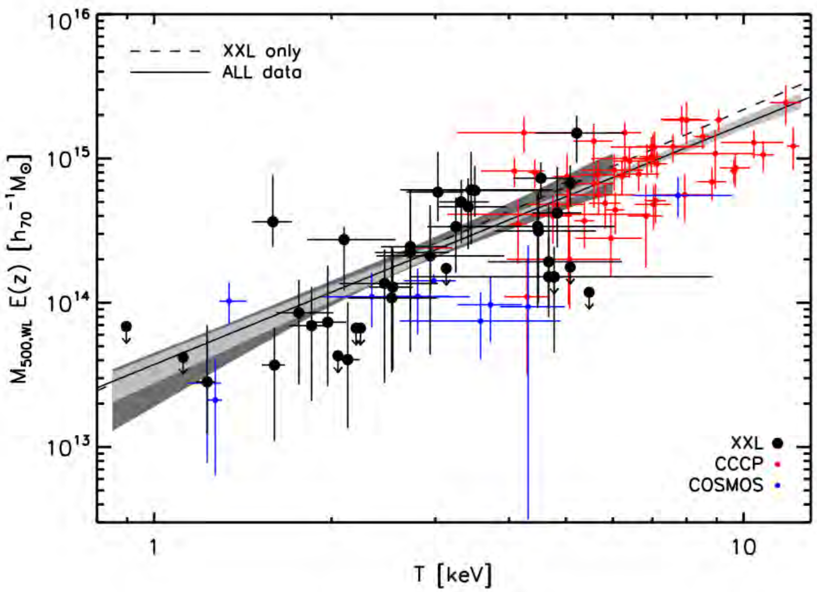
- several models: self-regulated jets, QSO thermal blast
- low-mass regime is most sensitive to feedback modes



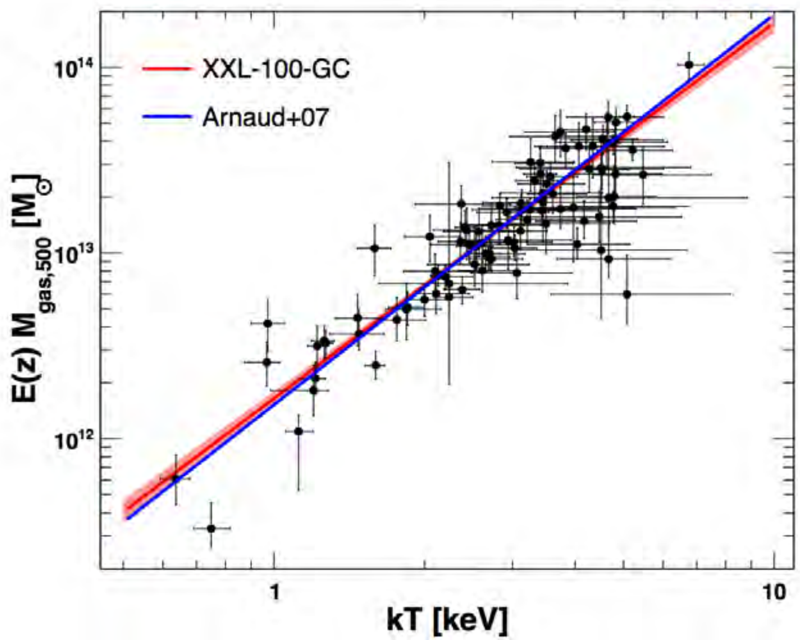
Gaspari et al. (2014)

II. The gas-halo connection as a tool for cosmology

- Mgas as primary proxy for halo mass?
- XXL clusters reveal tighter for Mgas-Tx



Lieu et al. (2016)



Eckert, Ettori, JC et al. (2016)

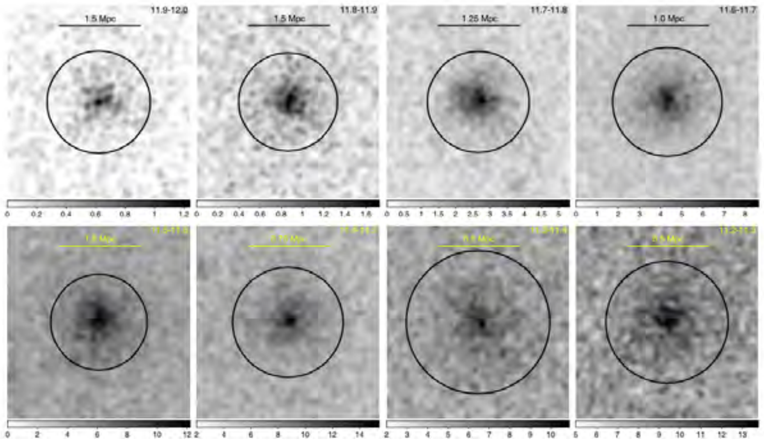
Probing the gas in groups is very challenging

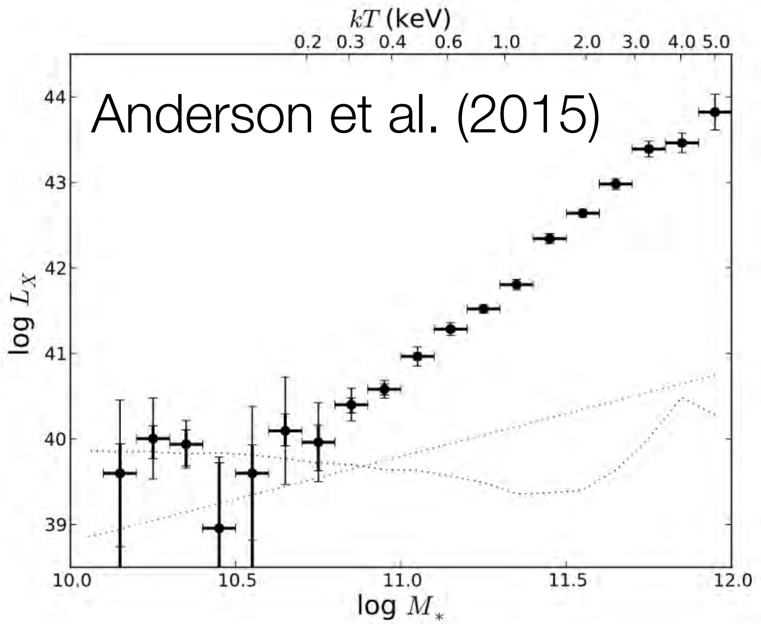
- X-ray brightness is proportional to gas density
- hot gas in groups is thousand times dimmer than in massive clusters
- star binaries become as bright as hot gas at low-mass
- is AGN contamination an issue?
- so far hot gas profiles were only measured at low-z or for a handful of very deep observations

Probing the gas in groups is very challenging

- but we can “stack” X-ray photons from optically detected BCGs
- requirements:
    - contiguous X-ray survey
    - a sample of central galaxies (although a gas-profile parametric model including satellites is feasible)
- main drawback of stacking analysis is that we can’t easily measure the scatter -> need to assume one
- biased results if scatter is off

Stacking L_X in the local Universe



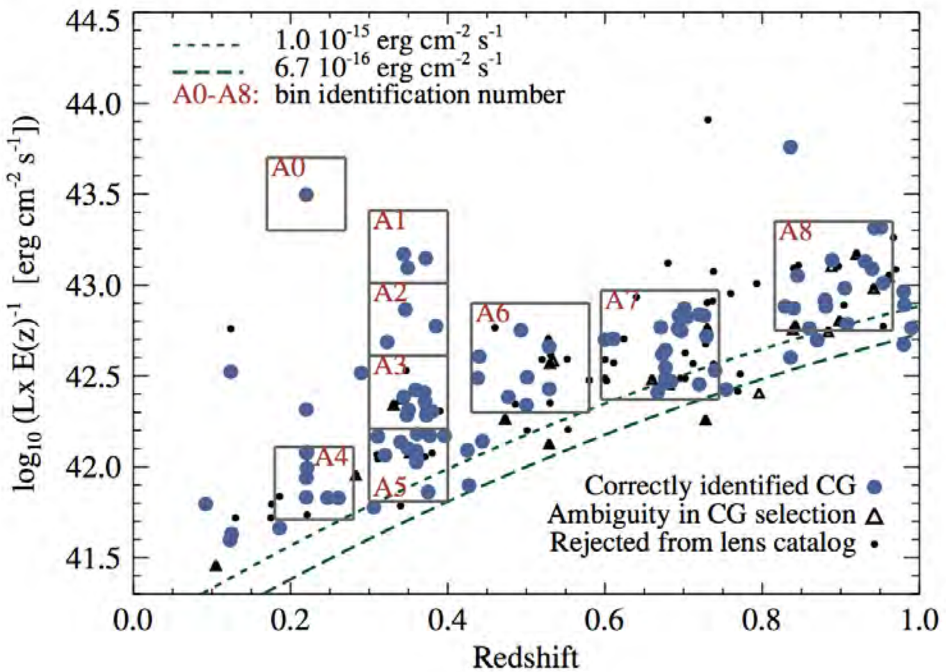


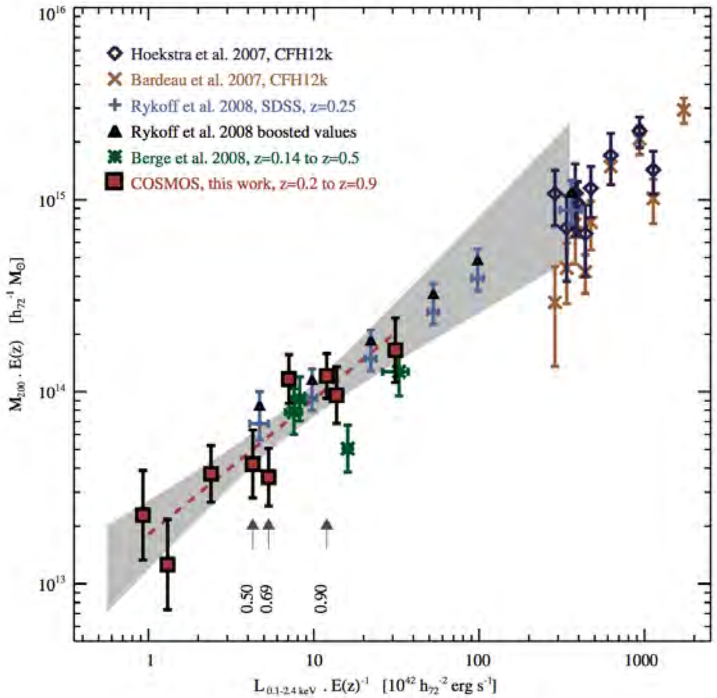
(a) Total

- Anderson et al. (2014) stacked X-ray luminosities of local BCGs
- followed-up with lensing masses by Wang et al. (2015)
- impressive detection of hot gas signal down to group-scale systems
- but large PSF, no density profile -> no gas mass
- restricted to the local Universe

Stacking L_X at higher redshift

- Leauthaud et al. (2010) stacked X-ray detected groups in deep XMM/Chandra data
- measurements up to z=1
- group/cluster regime at mid-z, massive cluster regime at high-z, no gas masses

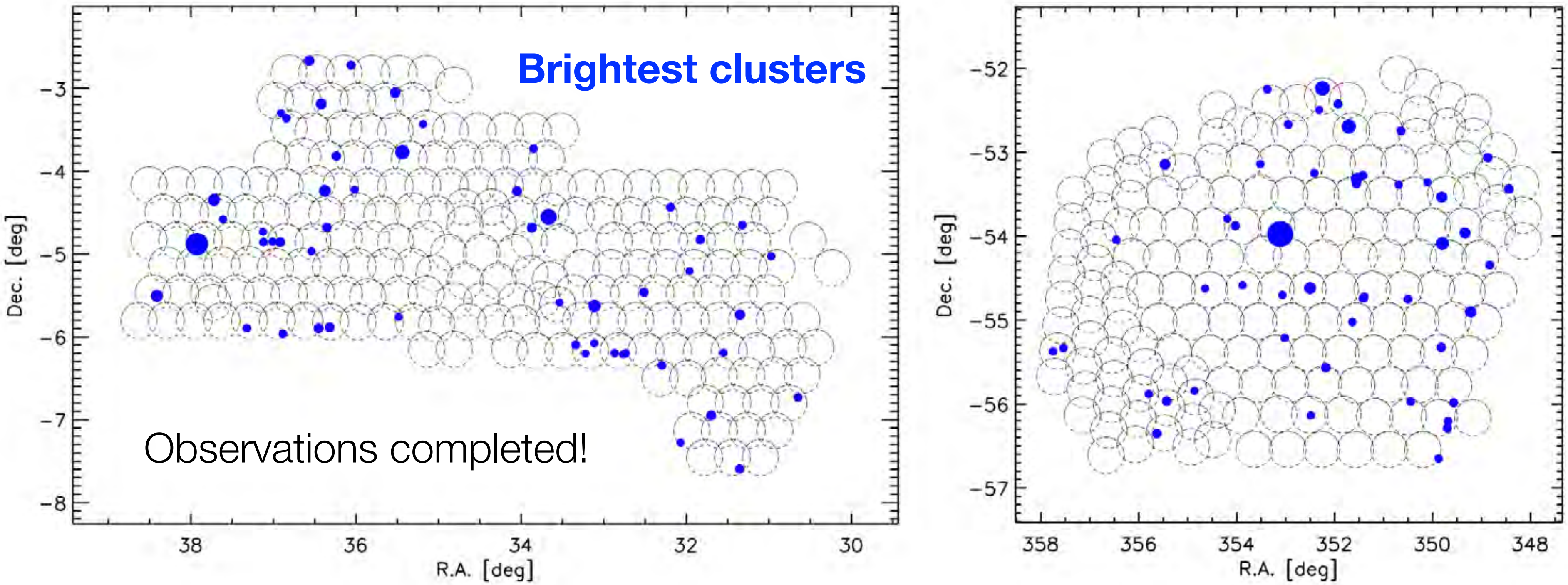




Leauthaud et al. (2010)

The XXL survey

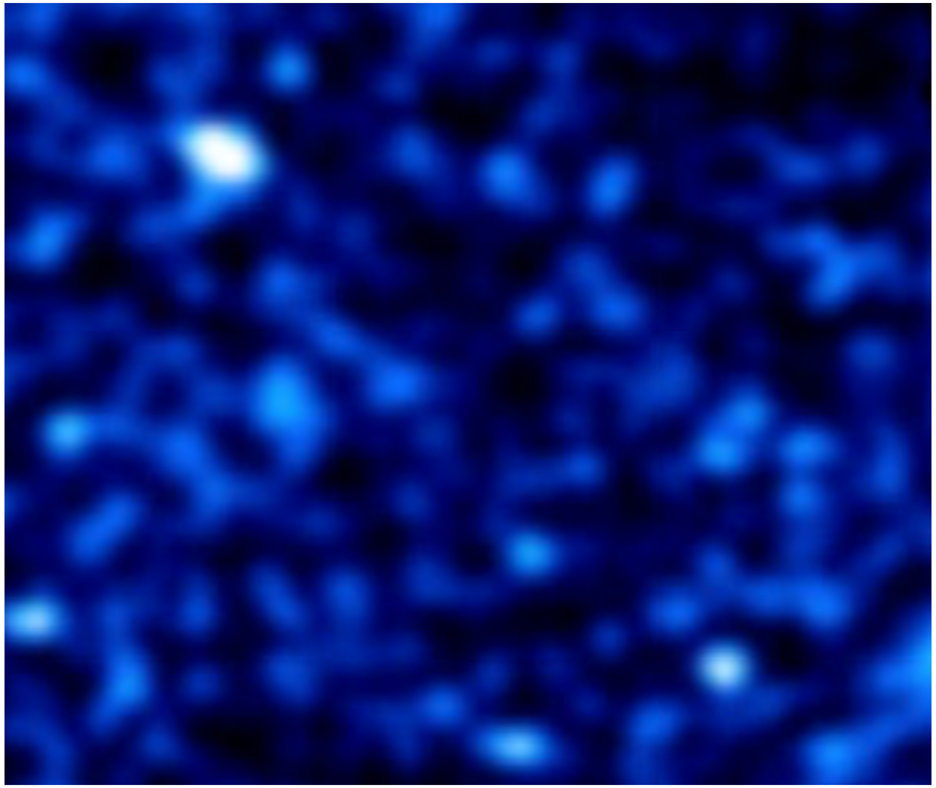
- X-ray survey over 50 deg^2 (2 fields) with XMM-Newton
- contiguous 10 ks observations (largest program ever allocated with XMM)
- resolution four times better than ROSAT



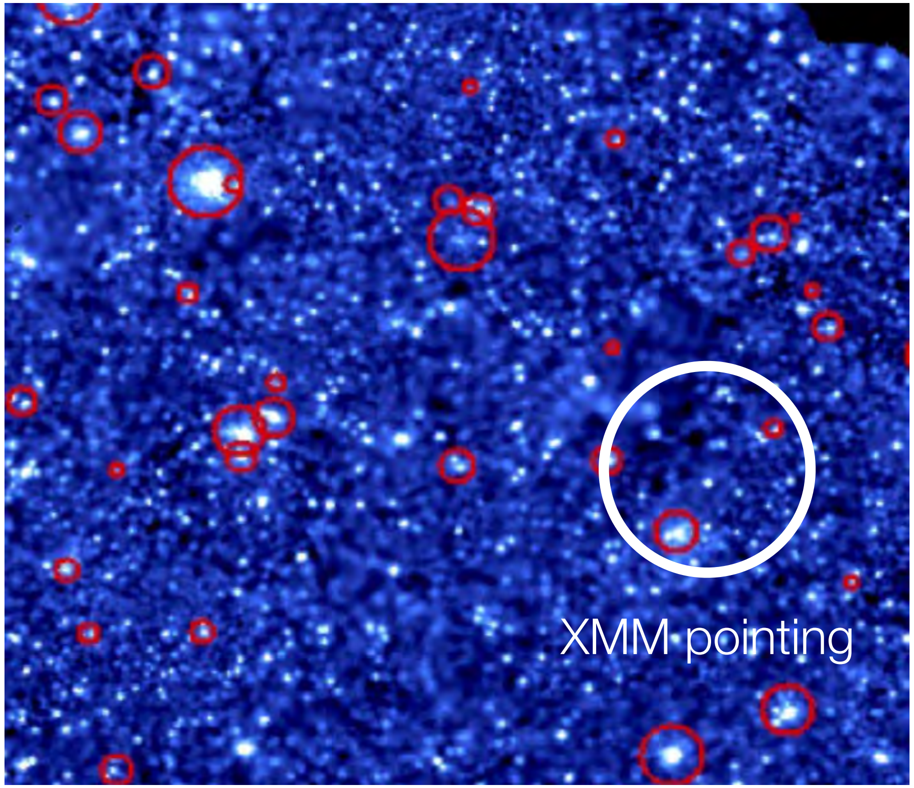
Pacaud et al. (2016)

The XXL survey

ROSAT all sky survey

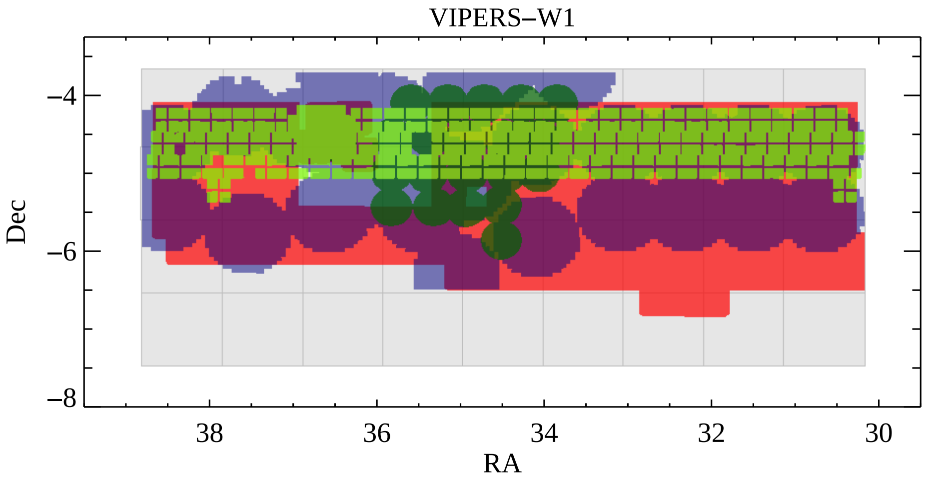


XXL

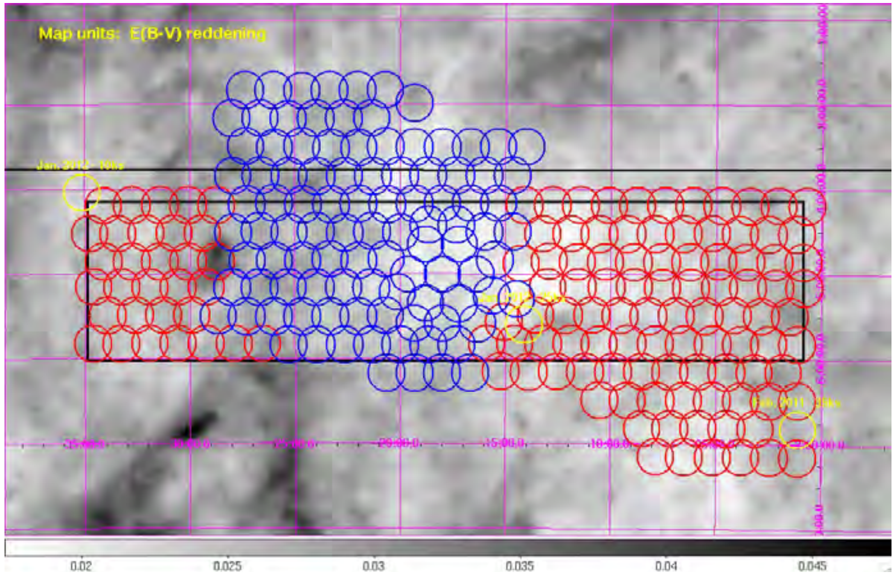


A unique combination of data

- near-IR from WIRCam follow-up
- 20-40% complete spectroscopy for bright galaxies (VIPERS/SDSS)
- lensing data from CFHTLenS
- secure BCG sample

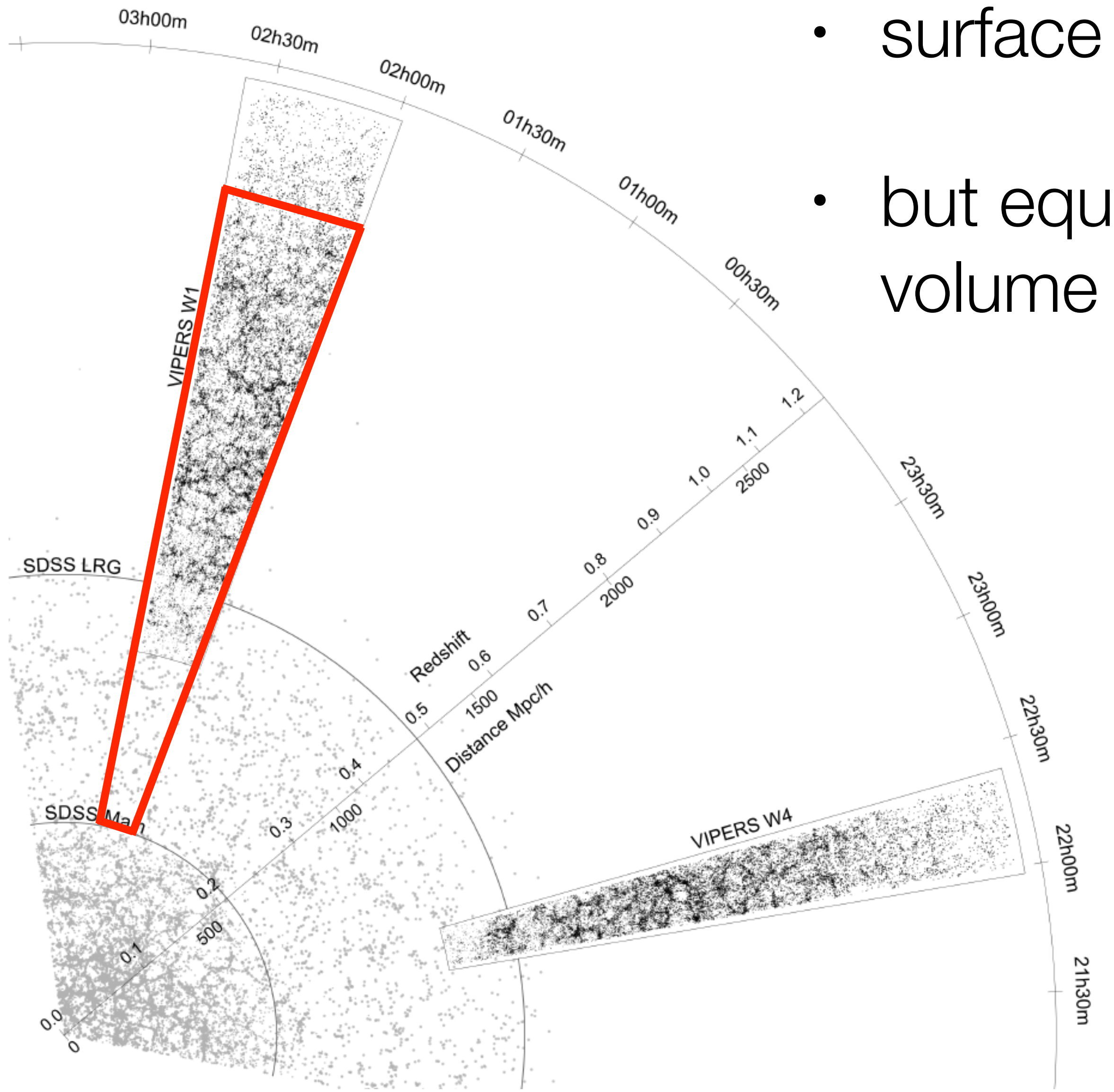


Optical+NIR



X-ray data

A large volume up to z=1



- surface of a few 10's of deg2
- but equivalent to large volume at $z > 0.2$

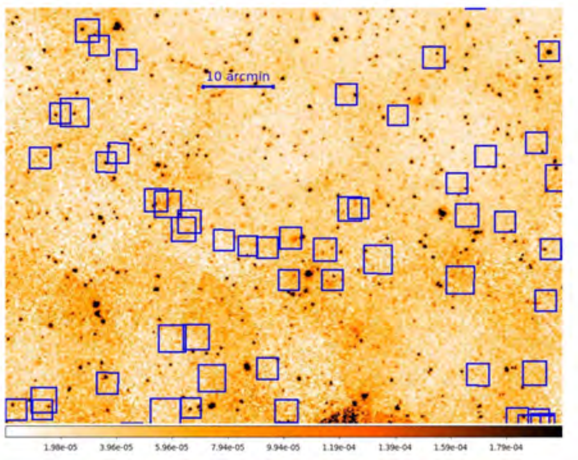
Stacking X-ray photons

- we selected a sample of ~20,000 central galaxies from spectroscopy and deep optical/near-IR data

- binned in 3 redshift bins ($0.2 < z < 1.0$) and 6 stellar mass bins ($10.5 < \log M_{star} < 12.0$)

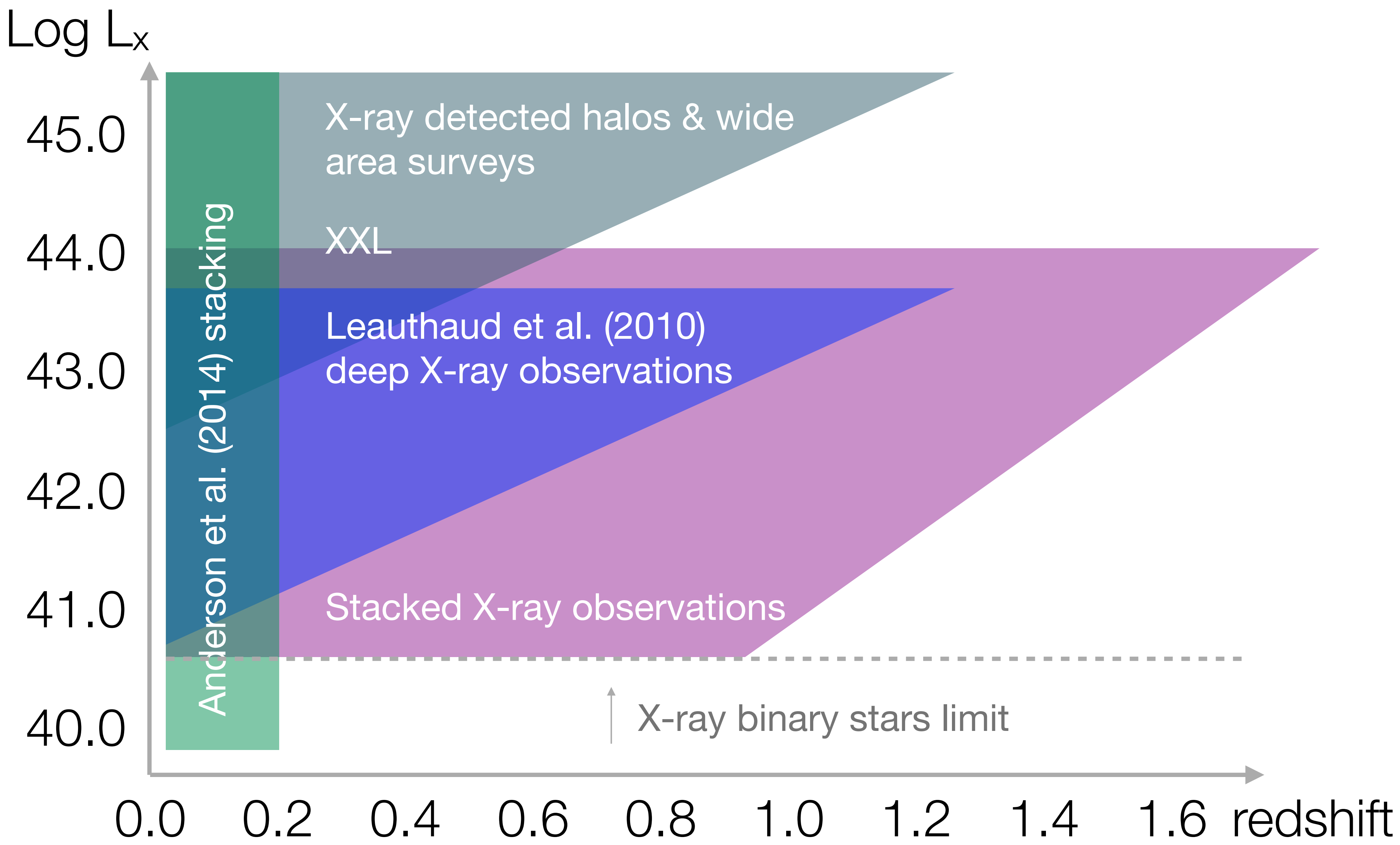
- low-mass bins contains ~3,000 gals -> 30 Ms (!) of X-ray observations per bin (1 year of XMM data)

- point sources detected in soft and hard bands masked



(from M. Ramos)

Where do we stand in the L_X/redshift plane?



Stacked X-ray profiles (0.2 < z < 0.35)

Preliminary results

Stacked X-ray profiles ($0.2 < z < 0.35$)

Preliminary results

Galaxy-galaxy lensing profiles ($0.2 < z < 0.35$)

Preliminary results

X-ray luminosity versus halo mass

Preliminary results

Gas fraction (z~0.29)

Preliminary results

Extreme AGN feedback is ruled out

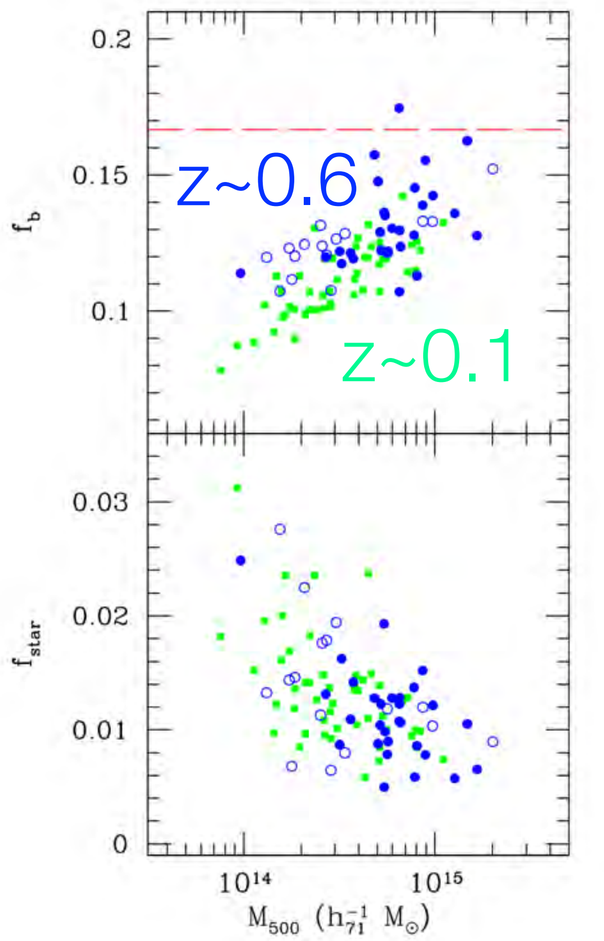
Preliminary results

Gas fraction at high-z

Preliminary results

Gas fraction at high-z

- gas fraction evolution?



- Vikhlinin et al. (2009), Lin et al. (2012)
- increased gas fraction between z~0.1 and 0.6
- evolution due background critical density evolution (hence M_{500})?

Measurement systematics?

Preliminary results

AGN contamination?

Preliminary results

The baryon fraction

Preliminary results

Conclusions

- measured the halo-galaxy connection up to z=1 in the CFHTLS
- measured X-ray and lensing profiles up to z=1 in galaxy groups
- rules out extreme AGN feedback
- self-regulated feedback seems to be favoured (TBC)
- baryon fraction increasing with redshift?
- very low-mass regime still exploratory, systematics not under full control
- -> needs better photo-z's and lensing large area (Subaru HSC)
- -> and deeper X-ray observations (Athena, STAR-X?)