Cosmic Dichotomy in the hosts of star-forming galaxies at low and high redshifts

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Credits for image: Hi-GAL

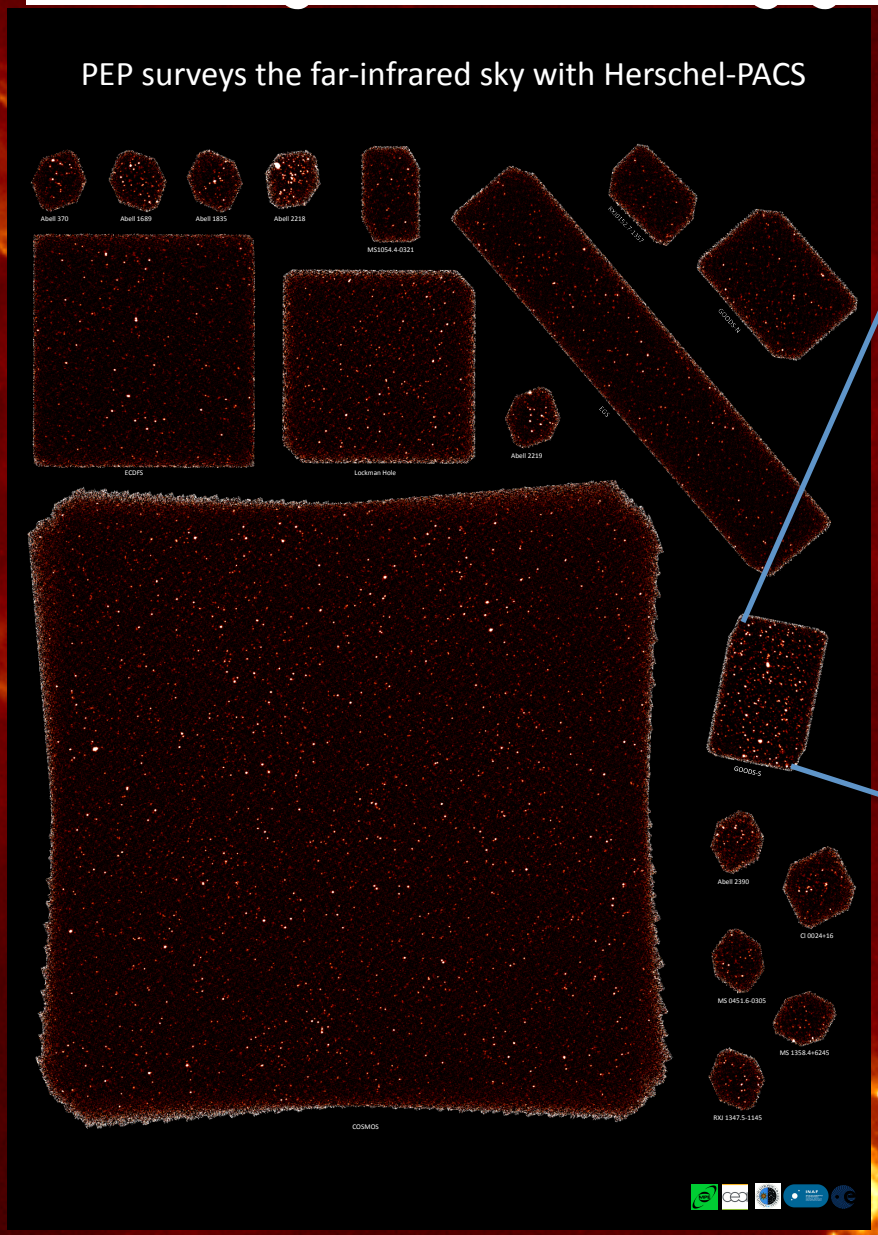
Outline

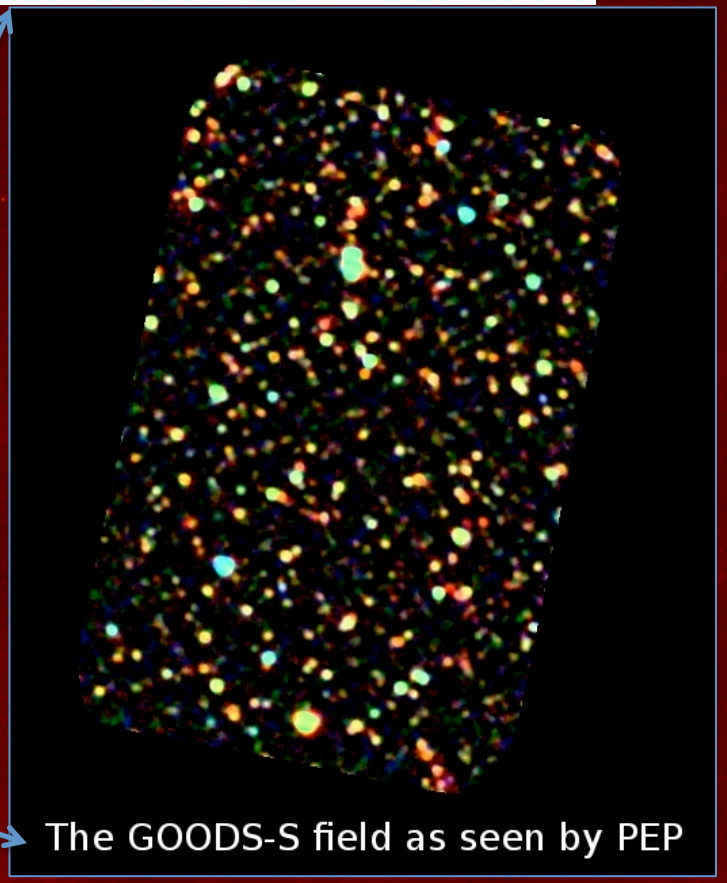
-Clustering of star-forming galaxies:
the Herschel/FIR view

-Clustering of star-forming galaxies:
the multi-wavelength view

- Possible scenarios for evolution into galaxies/AGN

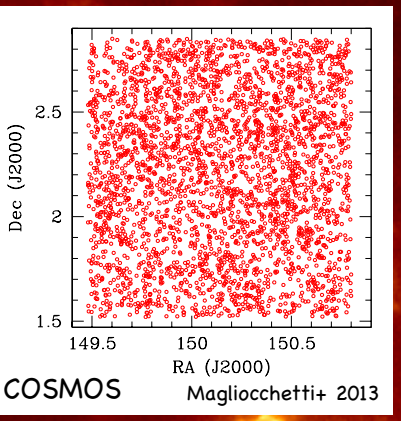
Clustering of star-forming galaxies: the Herschel view

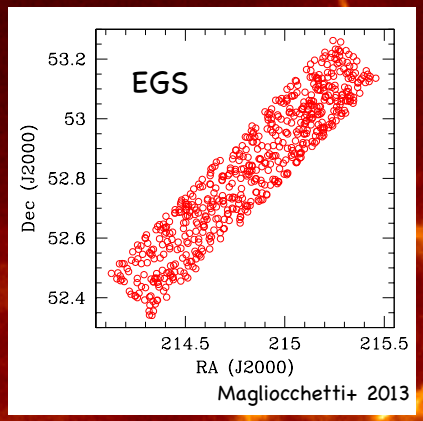




Concentrate on **COSMOS**, **EGS** and **GOODS-S** as either wide enough or deep enough to ensure statistically meaningful clustering measurements

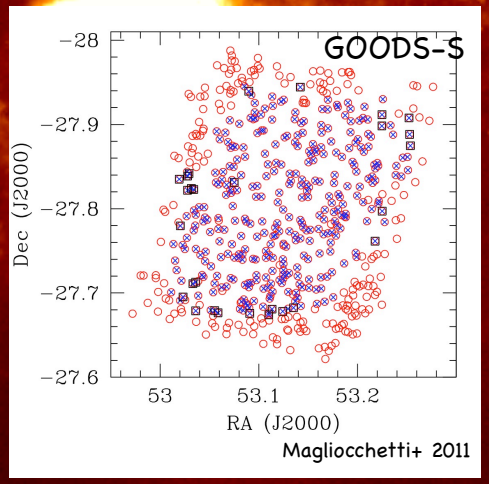
Clustering of star-forming galaxies with Herschel: characteristics of the fie

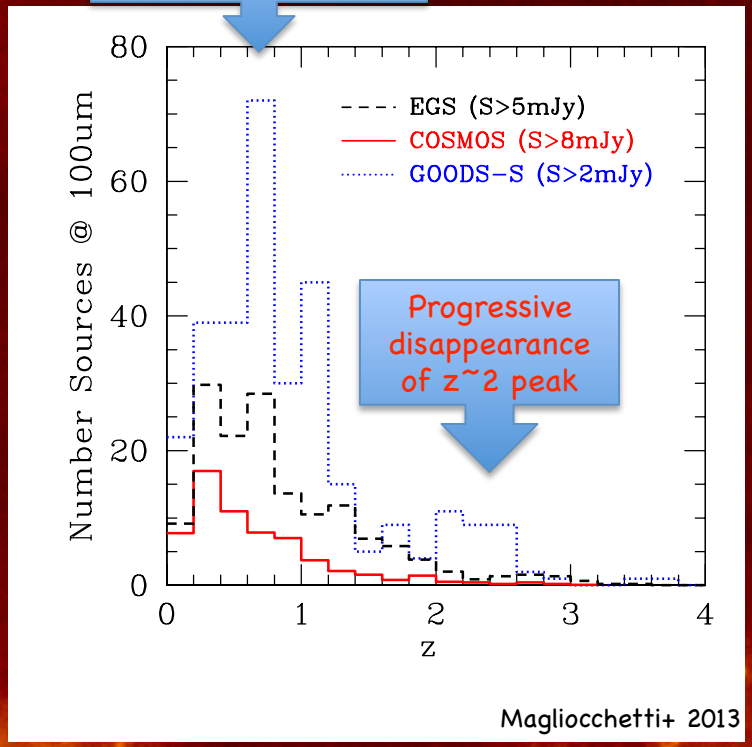




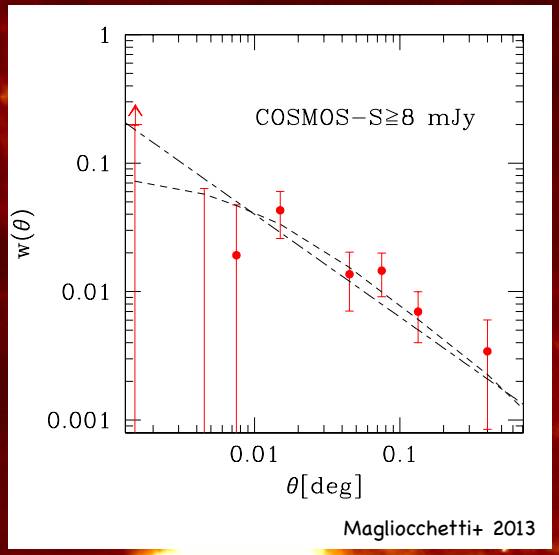
FLUX

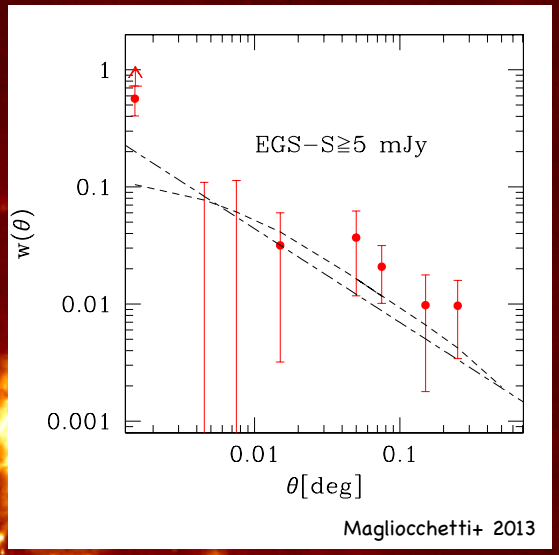
<u>COSMOS</u>: 80% completeness @100μm 8 mJy
<u>EGS</u>: 80% completeness @ 100μm 5 mJy
<u>GOODS-S</u>: 80% completeness @100μm 2 mJy

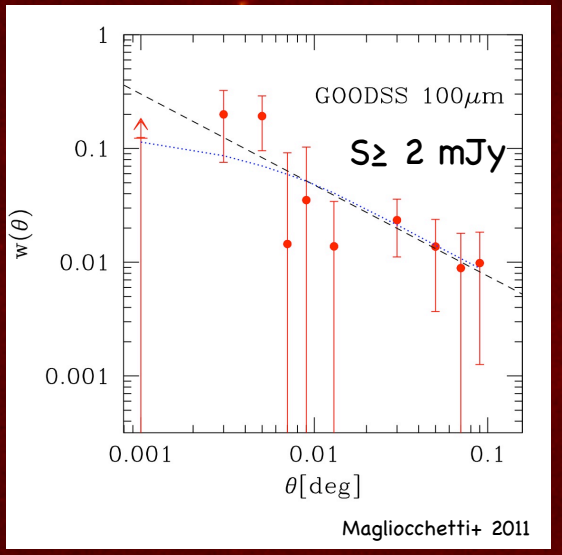




CLUSTERING PROPERTIES OF HERSCHEL-SELECTED GALAXIES I







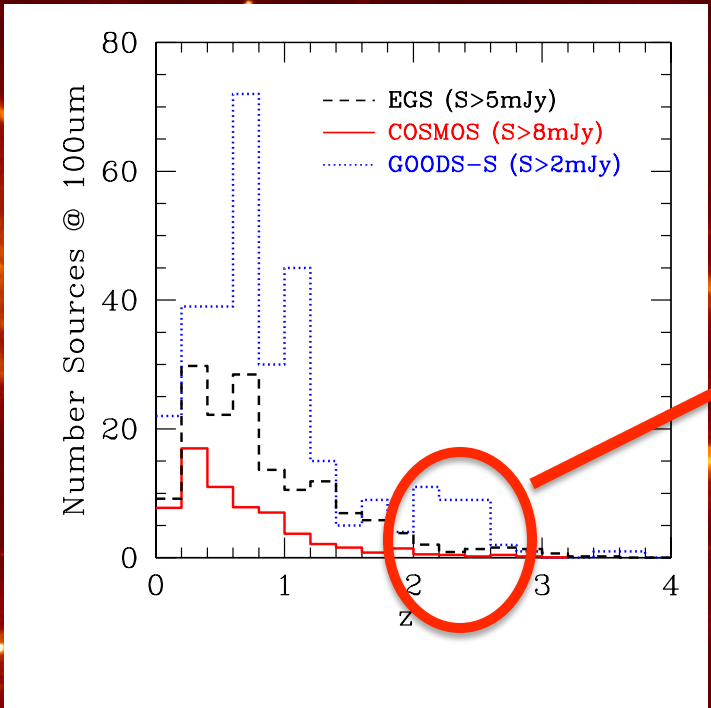
$S_{100\,\mu m}$>8 mJy
r_0~4.3 Mpc
M_{halo}>~$10^{11.6}$ M_{sun}

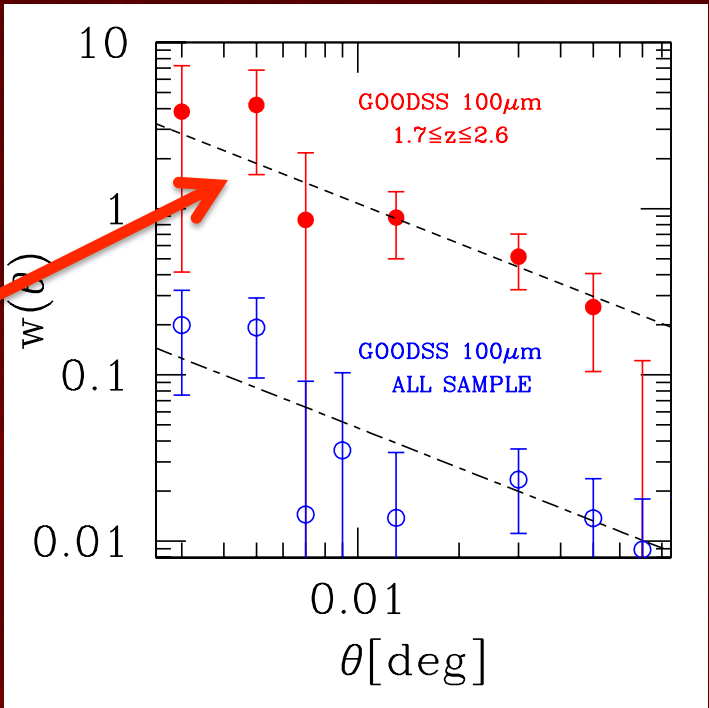
$S_{100\,\mu m}$>5 mJy
r_0~5.8 Mpc
M_{halo}>~$10^{12.4}$ M_{sun}

$S_{100\,\mu m}$>2 mJy
r_0~6.3 Mpc
M_{halo}>~$10^{12.5}$ M_{sun}

r_0 and M_{halo} increase for decreasing fluxes

THE CLUSTERING PROPERTIES OF HERSCHEL-SELECTED GALAXIES II



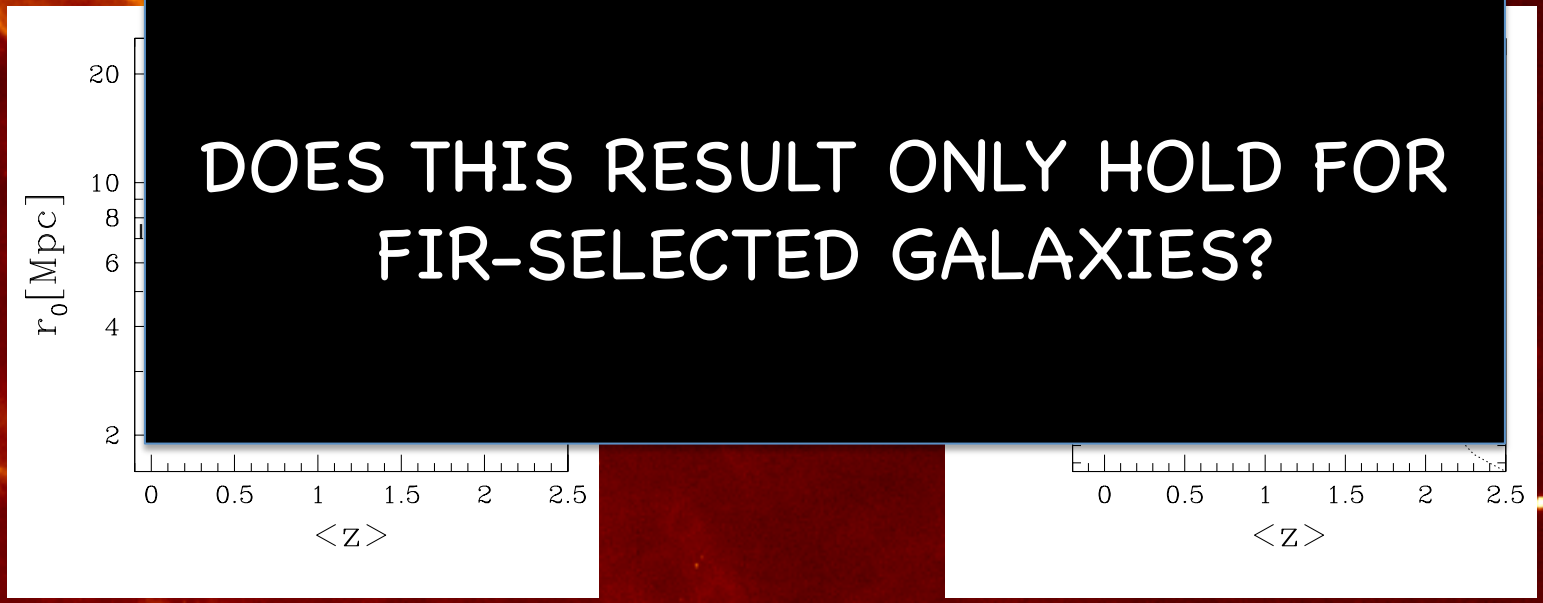


Galaxies at z~2 are 10 times more strongly clustered than the whole GOODS-S (and also COSMOS and EGS) sample

MALMQUIST BIAS (i.e. luminosity dependent) EFFECT?

THE CLUSTERING PROPERTIES OF FIR-SELECTED GALAXIES

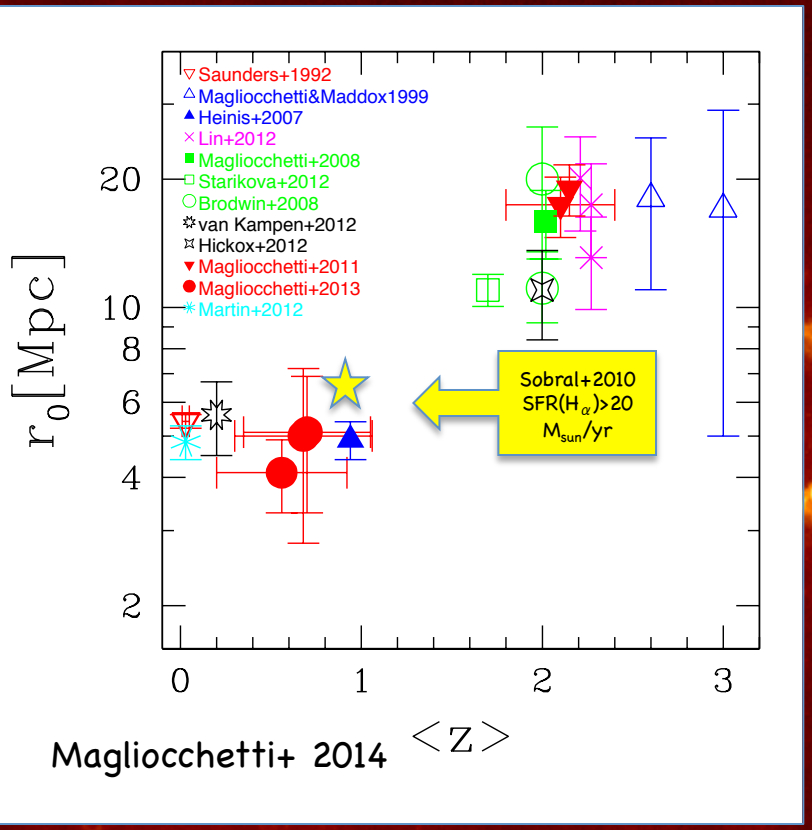
Consider clustering measurements of FIR sources ***all*** selected at 60μm rest frame
All PEP galaxies with comparable SFR≥100 M_{sun}/yr → minimization of bias effects
Relevant quantities plotted as a function of median z of survey



DOES THIS RESULT ONLY HOLD FOR FIR-SELECTED GALAXIES?

DESPITE SIMILAR SELECTION CRITERIA SOURCES @ z~2 ARE A FACTOR 3 MORE CLUSTERED THAN LOCAL, z<1 COUNTERPARTS. REFLECTED IN EVOLUTION OF HALO MASS WHICH INCREASES FACTOR ~10^2 BETWEEN z~1 AND z~2

THE CLUSTERING PROPERTIES OF RAPIDLY STAR-FORMING SYSTEMS AT LOW AND HIGH Z



CONSIDER CLUSTERING MEASUREMENTS OF **ALL** SF GALAXIES AVAILABLE IN THE LITERATURE

Galaxies selected at all z only on the basis of their bolometric luminosity/SFR.
Minimum 30 ≤SFR_{min}≤ a few 10^3 M_{sun}/yr.

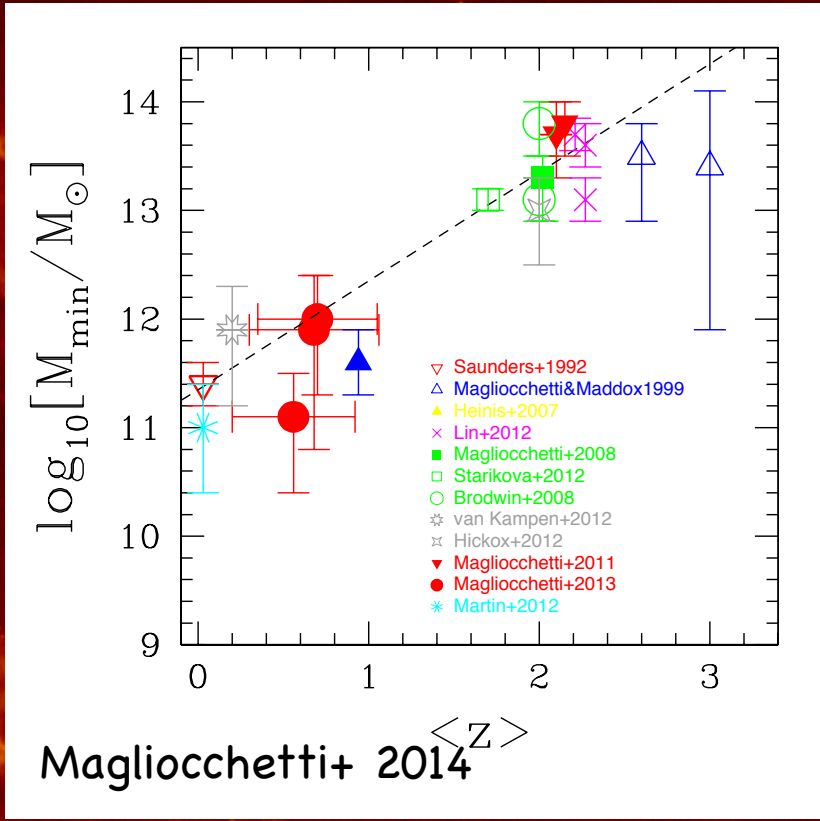
Data homogenized to correct for cosmology and γ dependence

Groups with same colour-coding selected at same rest-frame frequency

Blue: UV selection (SFR_{min} ~ a few 10^1 M_{sun}/yr)
Green: mid-IR selection (SFR_{min}~a few 10^3 M_{sun}/yr)
Magenta: BzK selection (SFR_{min}~[30-100] M_{sun}/yr)
Black: sub-mm selection (SFR_{min}~[60-900] M_{sun}/yr)

Irrespective of the selection technique and only very mildly depending on the SFR, clustering lengths of ALL very active star-forming galaxies present sharp increase from ~ 5 Mpc to ~15-20 Mpc (> factor 3) when moving from z≤1 to z≥2.

IS THAT AN EXPECTED EFFECT DUE TO INCREASE OF BIAS WITH Z AT CONSTANT MASS?



Magliocchetti+ 2014

Quick answer: NO!

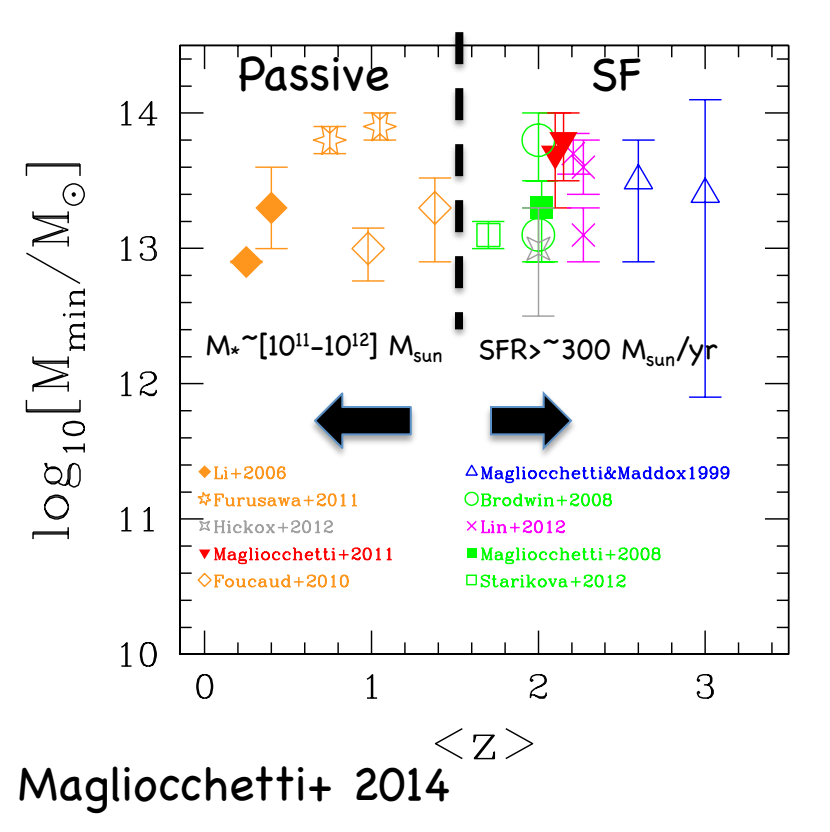
Halo masses also increase by about 2 orders of mag from ~$10^{11.5}$–10^{12} M_{sun} at $z \lesssim 1$ to $10^{13.5}$ M_{sun} and higher at $z \gtrsim 2$

As for r_0, very little spread amongst low-z group and high-z group (~independence of SFR)

GALAXIES WHICH ACTIVELY FORM STARS AT HIGH z ARE NOT THE SAME POPULATION WE OBSERVE IN THE MORE LOCAL UNIVERSE. VIGOROUS STAR FORMATION IN THE EARLY UNIVERSE IS HOSTED BY VERY MASSIVE STRUCTURES, WHILE FOR $z \lesssim 1$ A COMPARABLE ACTIVITY IS ENCOUNTERED IN MUCH SMALLER SYSTEMS → DOWNSING (M_{halo} propto z)

WHAT HAPPENS TO HIGH-z STAR-FORMING GALAXIES?

- Space densities of SF galaxies @ z~2 indicate the rapid star-forming phase is very common amongst massive galaxies (~ 1 out of 2).
- Estimate T_{SF}~1 Gyr (see also Granato+ 2004; Lapi+ 2006 model).
- Merging excluded as dominant trigger of rapid SF phase as either too low masses or too short T_{SF} (e.g. Baugh+ 2005: Narayanan+2009)



Magliocchetti+ 2014

For typical SFR~300 M_{sun}/yr at the end of phase galaxy with M_*~3 10^{11} M_{sun}
→ look for clustering properties of low-z passive galaxies with very high M_*

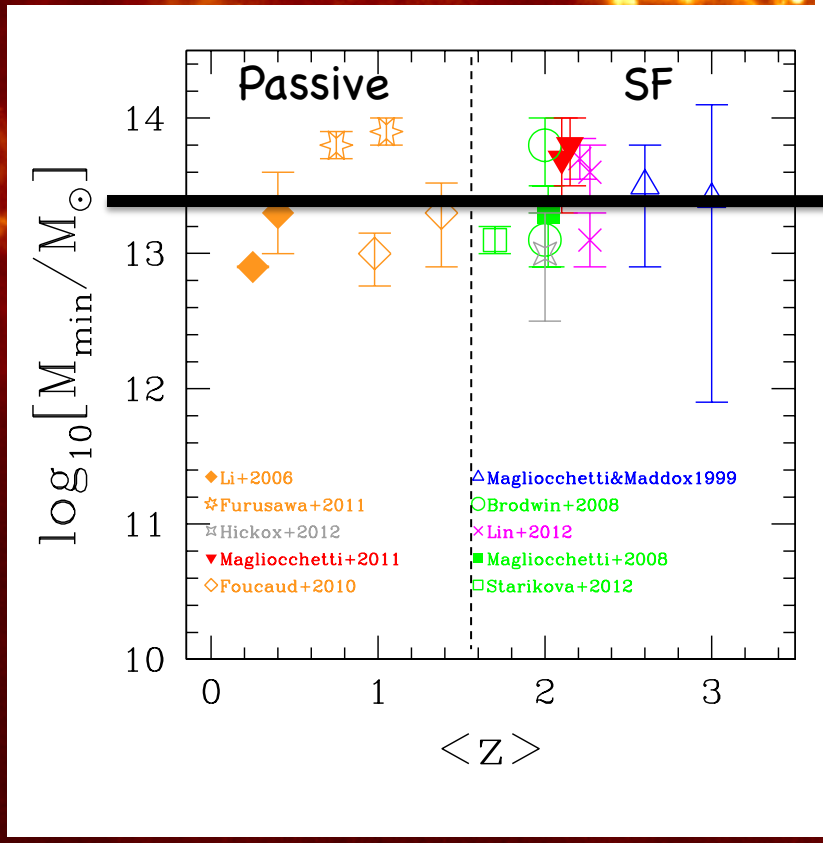
-High-z points: star-forming galaxies
-z≤1.5 points : early type galaxies with M_*~[10^{11}-10^{12}] M_{sun}

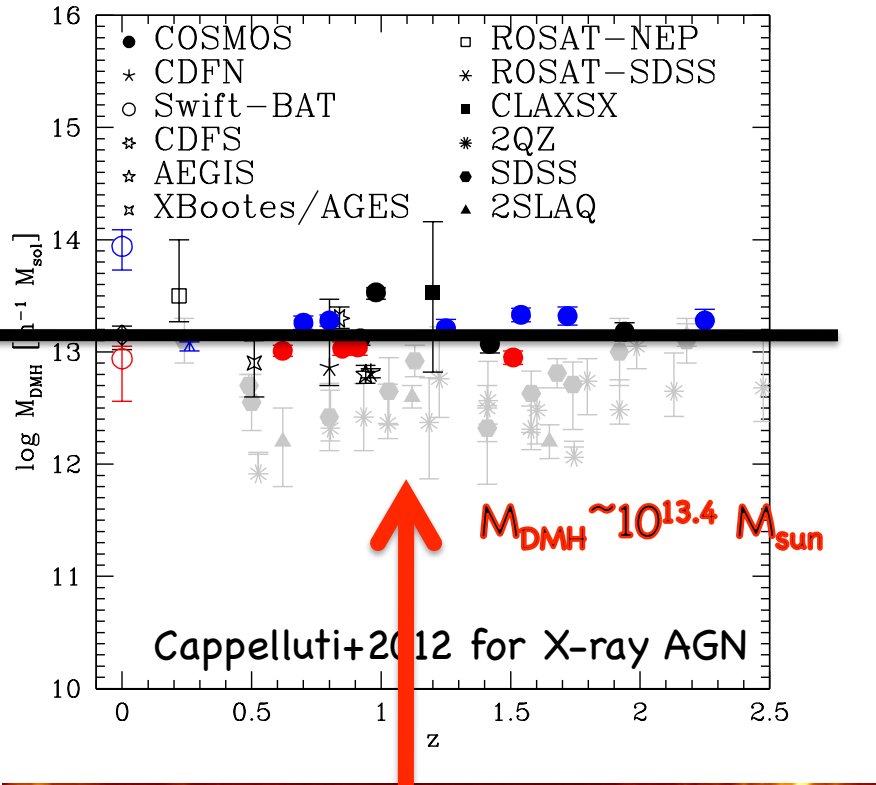
Halo masses ~[10^{13}-10^{14}] M_{sun} →
→perfect agreement with high-z values

WHERE DO AGN FIT IN THIS SCENARIO?

AGN vs Star-forming Galaxies: the X-ray band

Remarkable agreement between clustering properties of high-z SF-low-z passive galaxies and those of X-ray selected AGN.
High SFR SFG→ X-ray AGN → high M* passive?

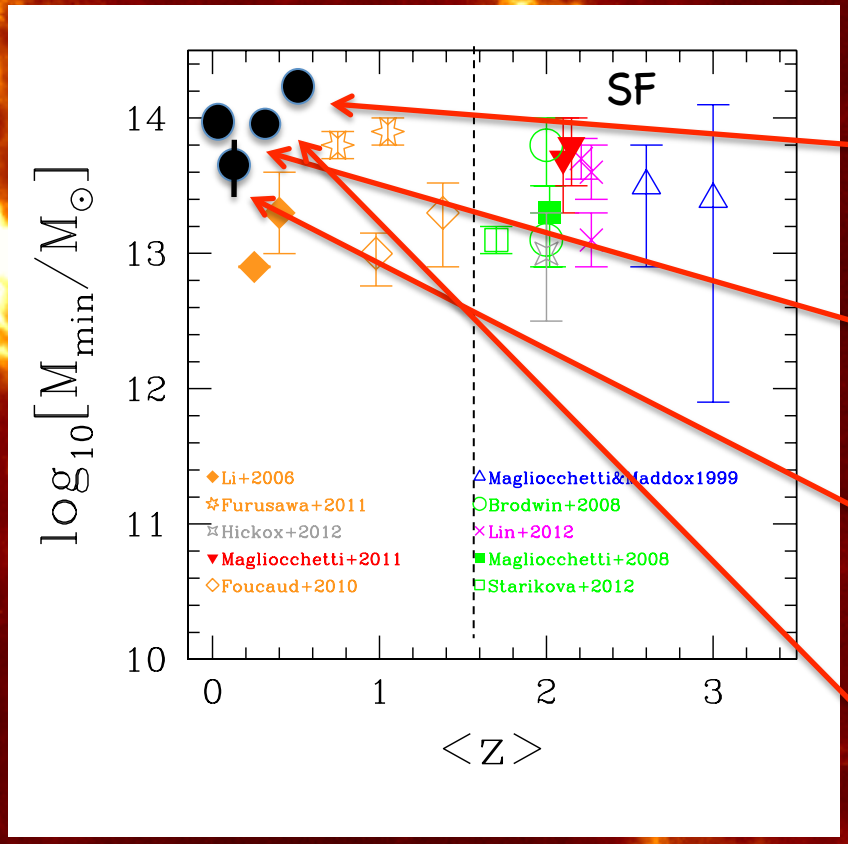




However, optically selected QSO are hosted by smaller structures…

AGN vs Star-forming Galaxies: the radio band

Clustering properties of relatively local radio galaxies still compatible (although on the high side) with those of intense SF galaxies at z>~1.5. High SFR SFG→ radio galaxies → group environment?



Wake+2008 for $L_{1.4GHz}>10^{24}$ W/Hz 2SLAQ LRG sources (possibly biased high).

Peacock & Nicholson 1991 $S_{1.4GHz}>0.5$ Jy

Magliocchetti+ 2004 For FIRST/2dF AGN $S_{1.4GHz}>1$ mJy

Lindsay+ 2014 FIRST/GAMA $S_{1.4GHz}>1$ mJy

CONCLUSIONS

Star forming galaxies at high and low redshifts are two different populations.

Low-z (z<~1) intense star formation takes place in small galaxies (M_{DMH}~$10^{11.5}$ M_{sun}) over long timescales.
Only a fraction of virialized halos will host the SF event and such a fraction decreases for decreasing redshifts

The same intense star formation activity (SFR>~ 30 M_{sun}/yr) at z>~1.5 takes place in very massive galaxies (M_{DMH}~$10^{13.5}$ M_{sun}) on relatively short timescales (T_{SF}~1 Gyr).
It is a very common event: about 1 out of 2 galaxies at z=2 is found in the rapid star forming stage.

At z<~1.5-2 high SFR sources evolve in passive galaxies with M_*~10^{11}-10^{12} M_{sun}

Tantalizing resemblance between clustering properties of intense SF galaxies at z>~1.5 and of X-ray (and also possible radio) selected AGN at all z point towards evolutionary connection between these populations.

What about optically selected QSOs?