Does the environment play a minor role in the star formation history of galaxies ?

David Elbaz – CEA Saclay

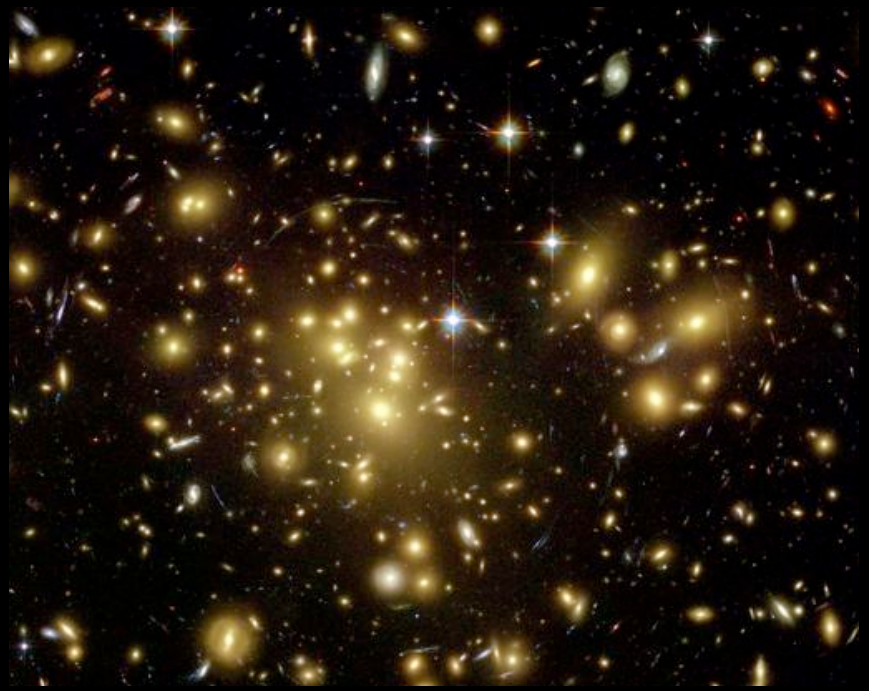
Galaxies in dense environments are redder, *deader*, fater than in the field
→ is it an effect of the environment or a selection effect ?

the fraction of ill people is larger in hospitals than outside
→ do hospitals make people sick or do diseased persons go to hospitals ?

= the H - effect

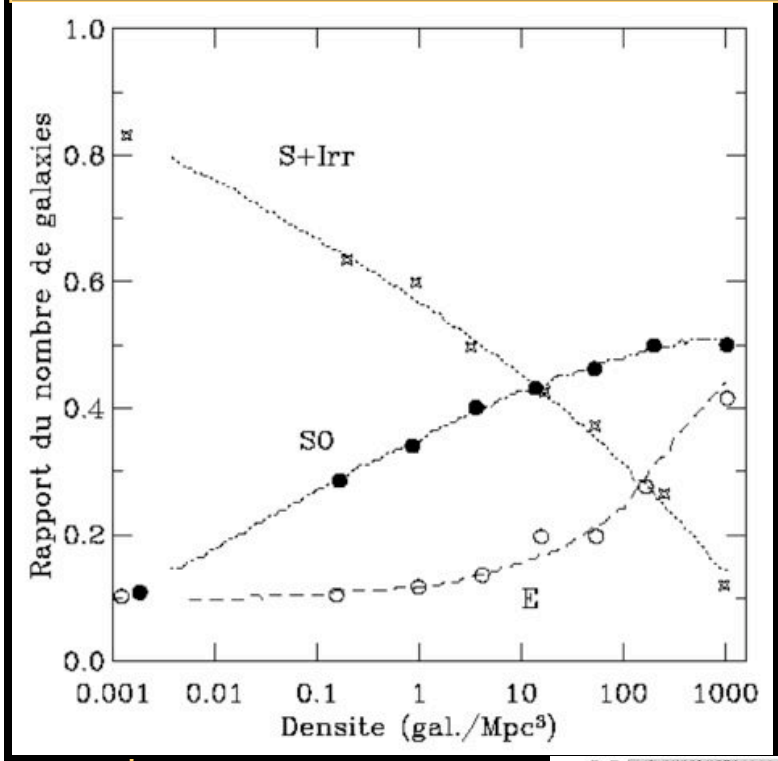


=

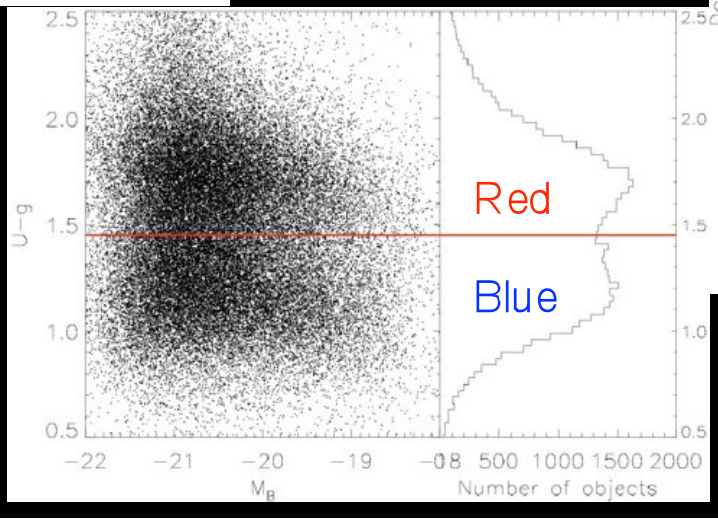


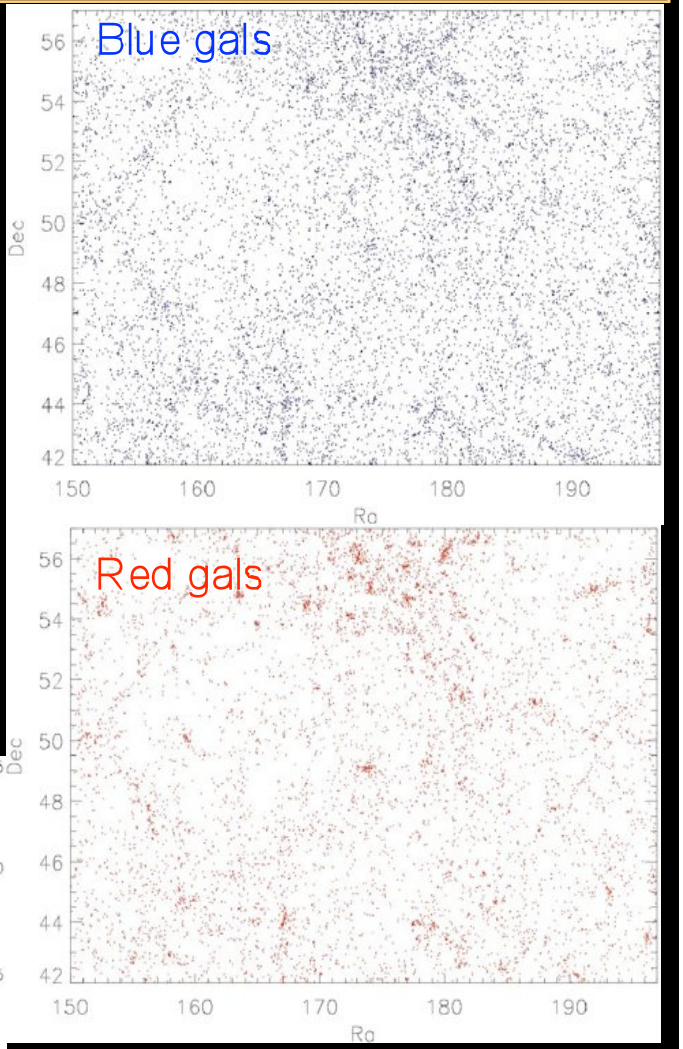
Does the environment play a minor role in the star formation history of galaxies ?

David Elbaz – CEA Saclay



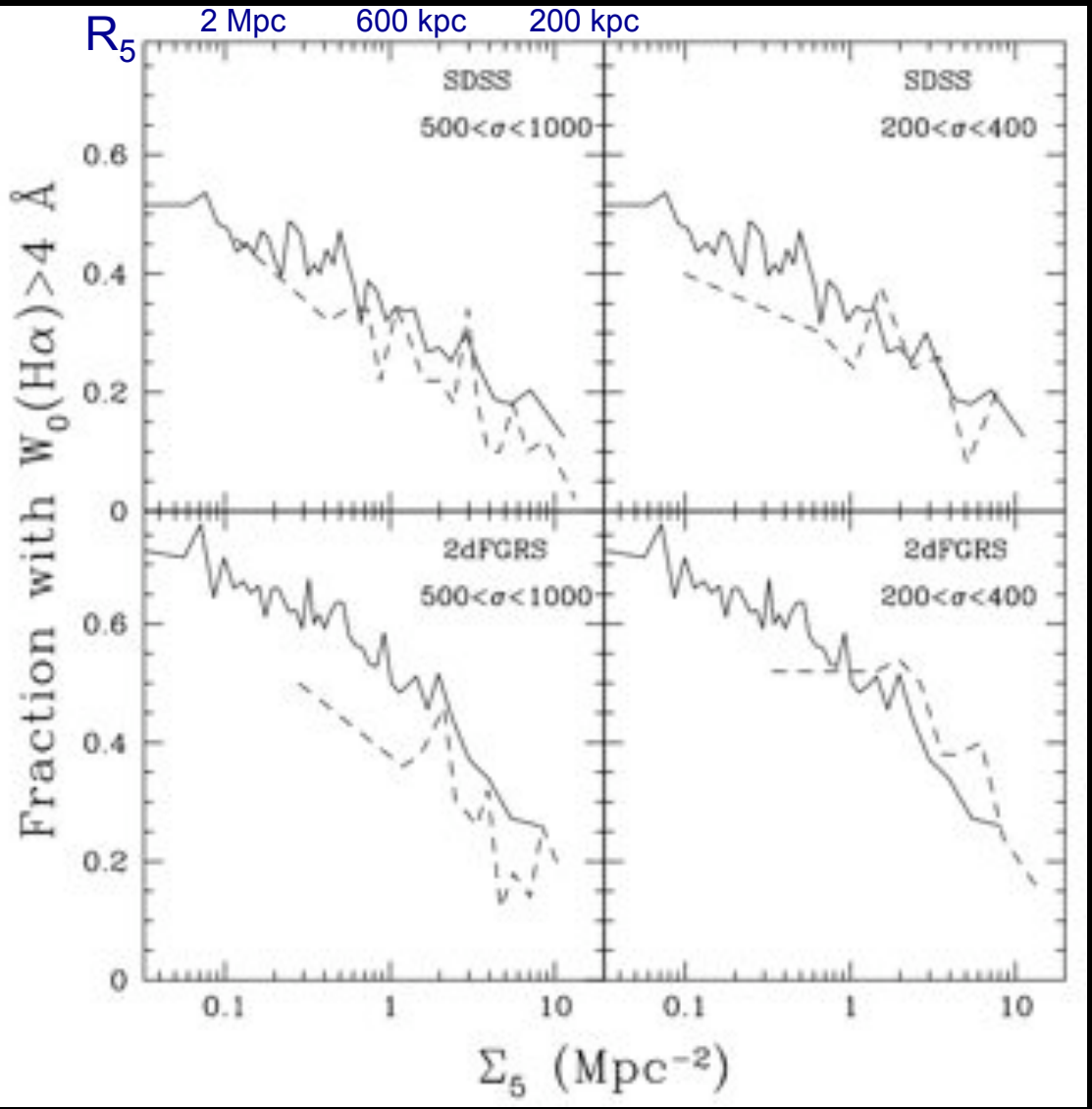
Dressler 1980
interactions: Sp → E
Ram pressure: Sp → S0





Elbaz +07

The star formation - density relation : from clusters to the field



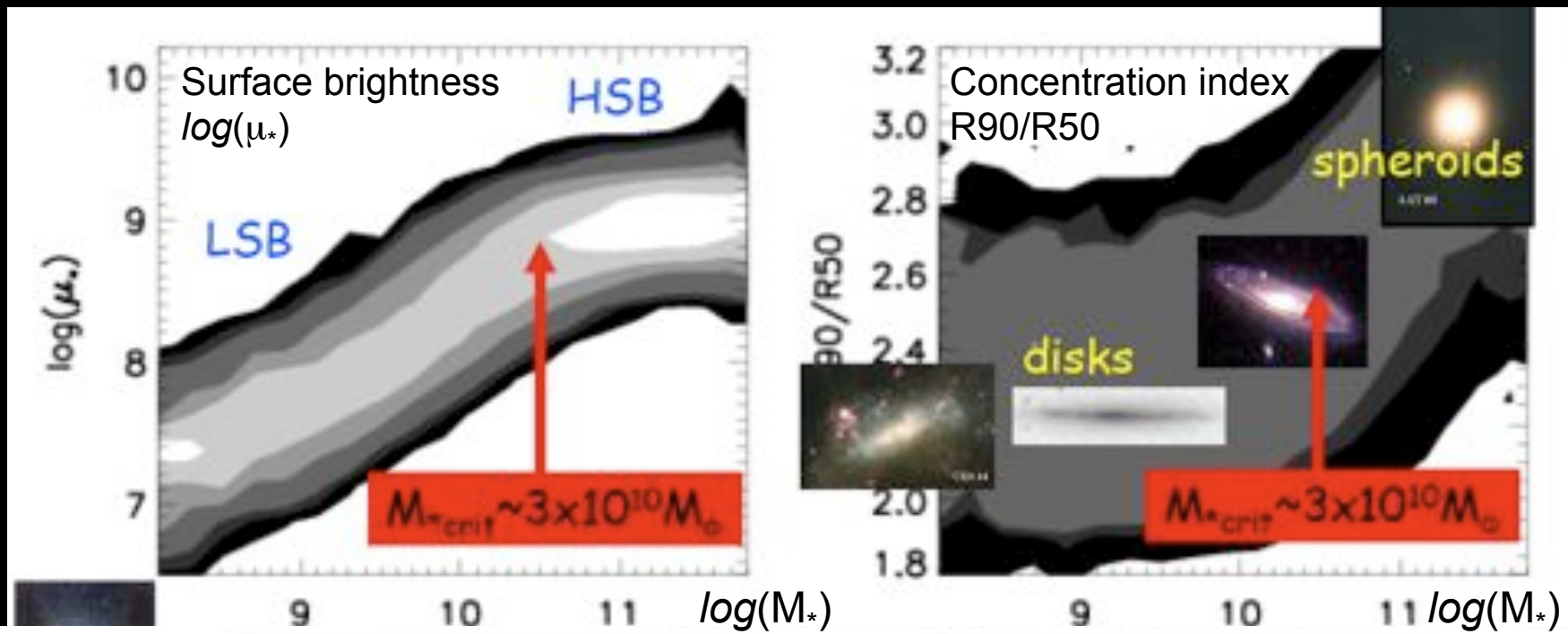
Study of clusters (Balogh +00):
"the main effect of the environment is to quench star formation by ram pressure stripping (RPS) the fuel of gas"

Local environment (5th closest galaxies; Balogh +04):
"RPS does not act at these low densities, there must therefore be an acceleration of star formation in the past by the environment"

- how does the environment act ?
→ quenching / triggering ?
- what scale matters ?
→ clusters/groups, 5 - 1 - 0.1 Mpc ?

$\Sigma_5 = 5 / (\pi R_5^2)$, R_5= distance to the 5th closest galaxy

Kauffmann et al. 05:
structural parameters independent of environment but depend on stellar mass !



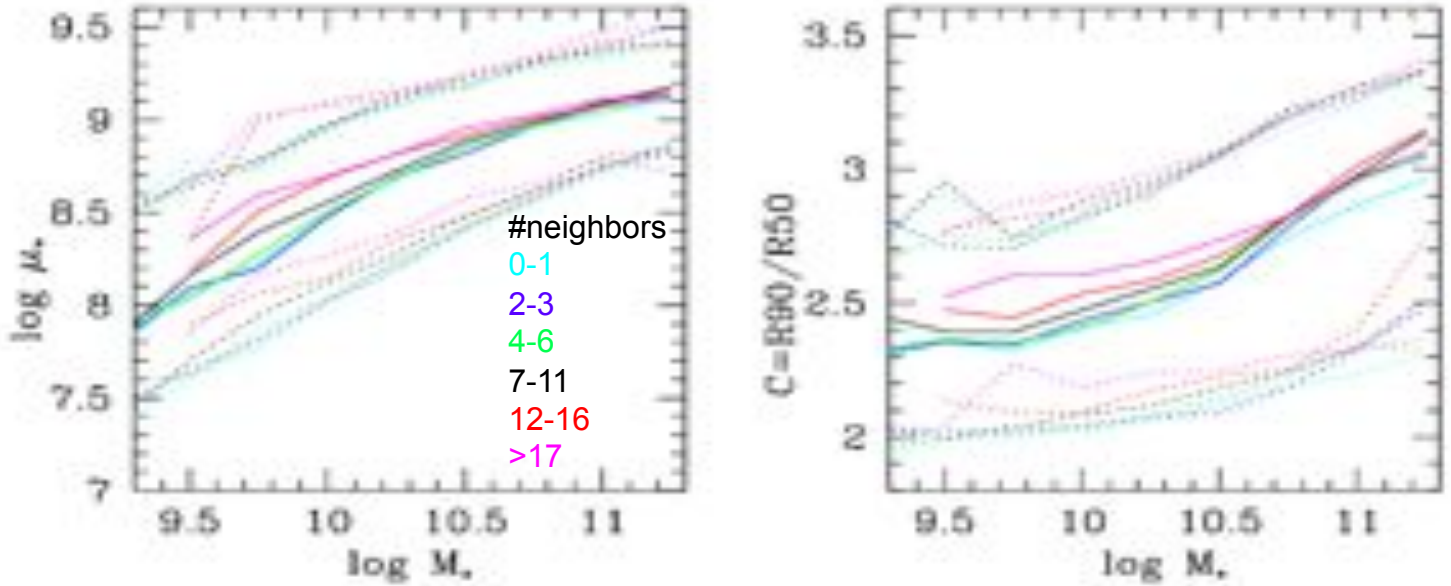


Figure 5. The relation between surface mass density and stellar mass (left) and concentration index and stellar mass (right) are plotted for galaxies in six

A rather provocative statement…

What physical processes can …

… "tell" galaxy star-formation rates about their environments

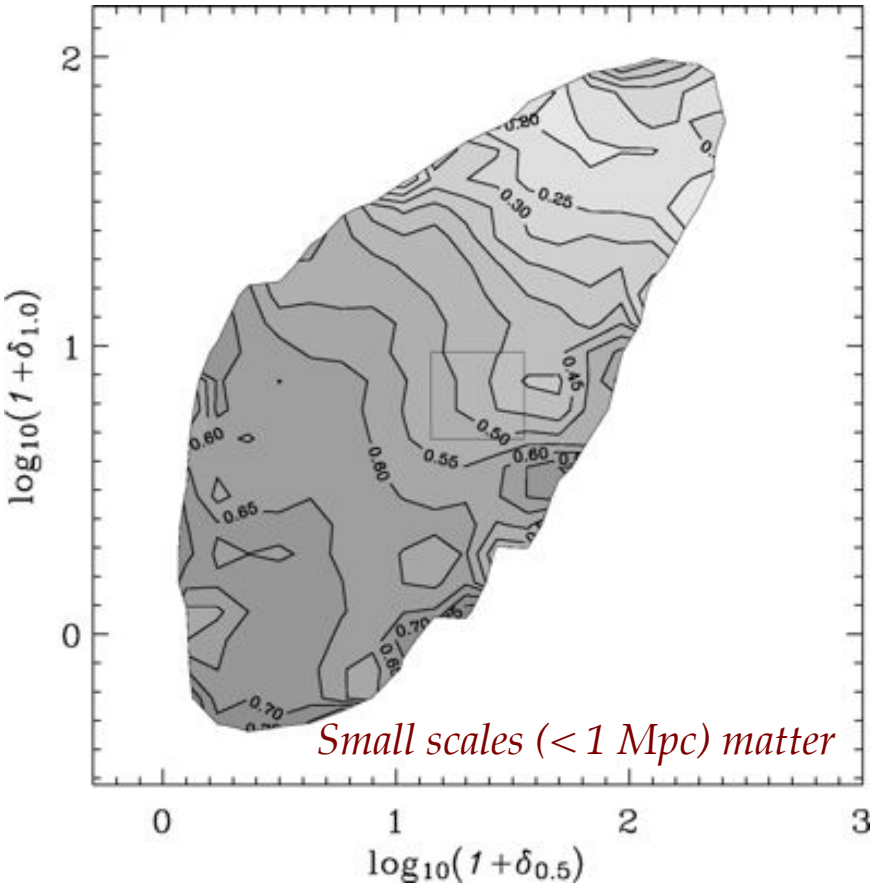
… but not do much to the morphologies independently ?

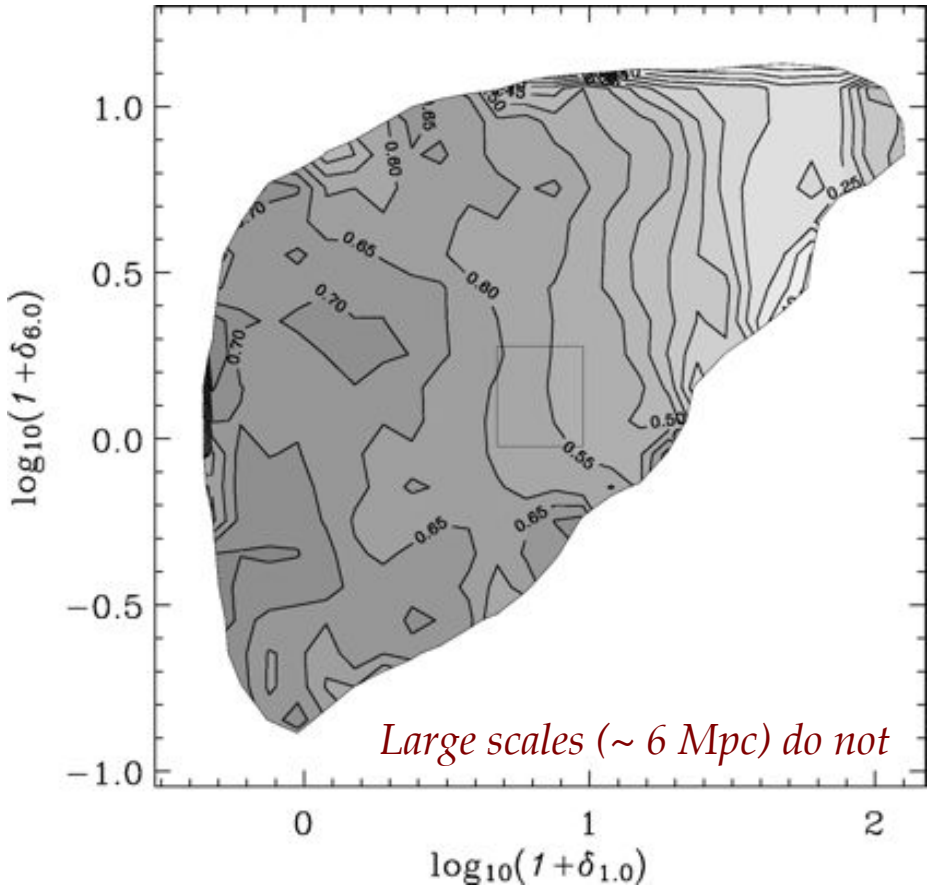
I think the conclusion has to be that the processes that set the morphology (or, really, concentration or bulge/total ratio) are somehow internal to the galaxies.

That's going to be hard to reconcile with CDM cosmogony.

Hogg 2005

What scale matters ?



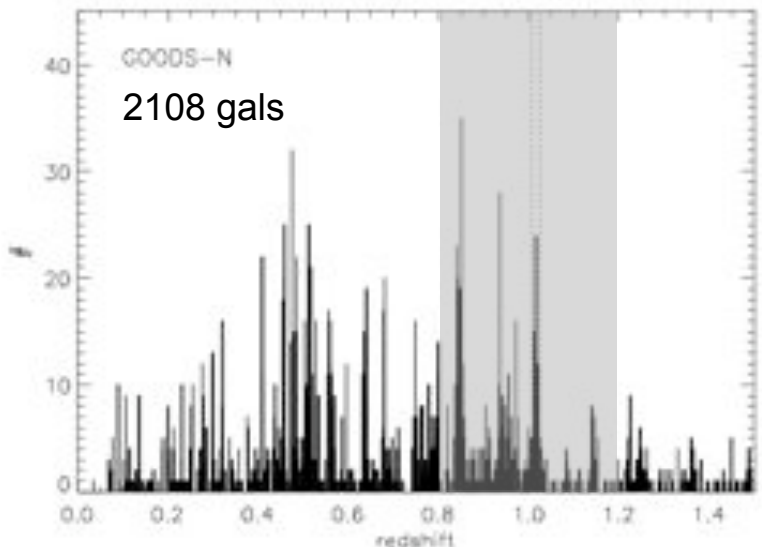


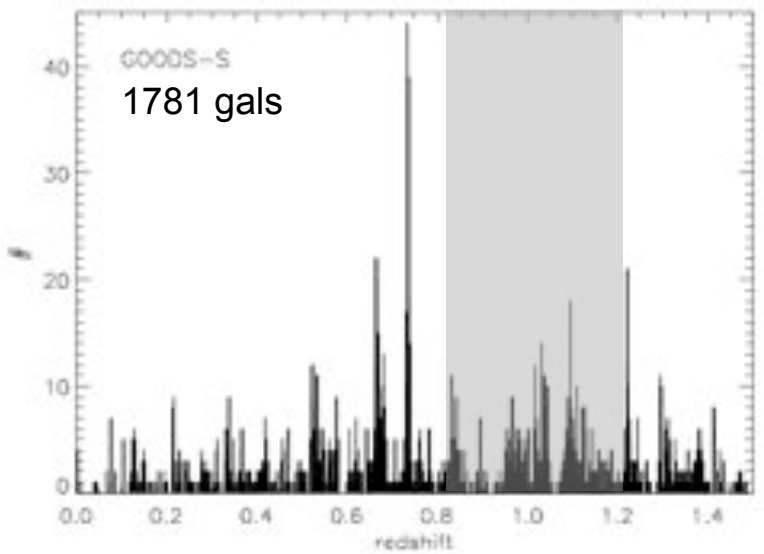
fraction with $H\alpha$ EW > 4Å

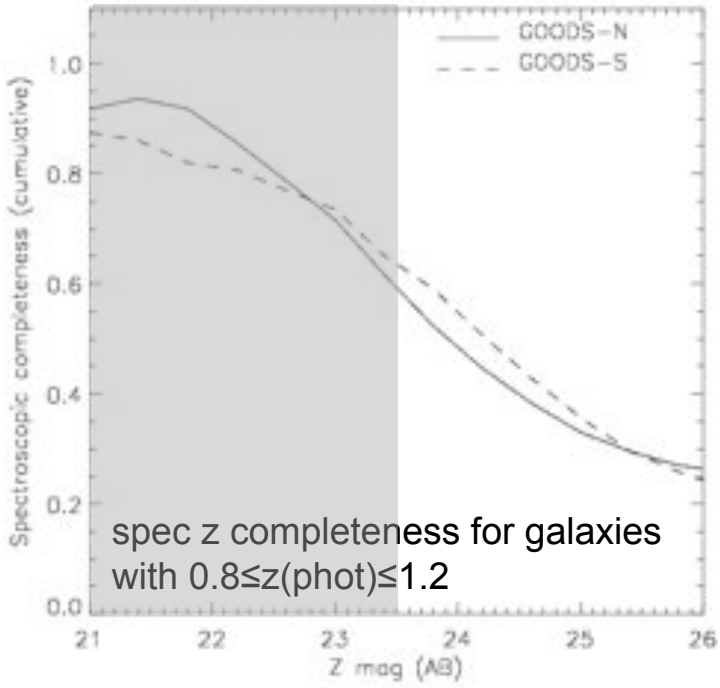
Blanton et al. 06

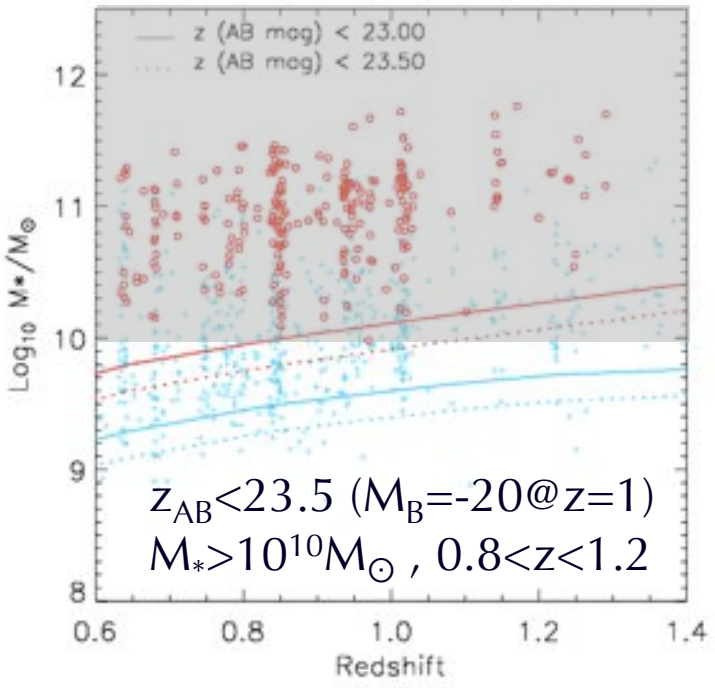
→ the dominant scale is ~1 Mpc

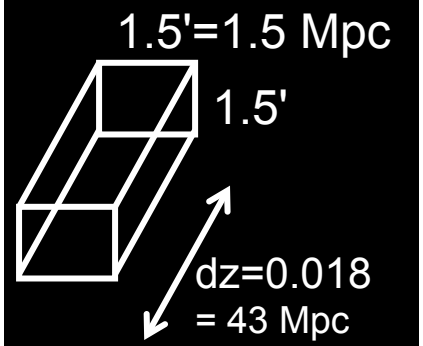
The star formation-density relation at z=1+/-0.2 in GOODS



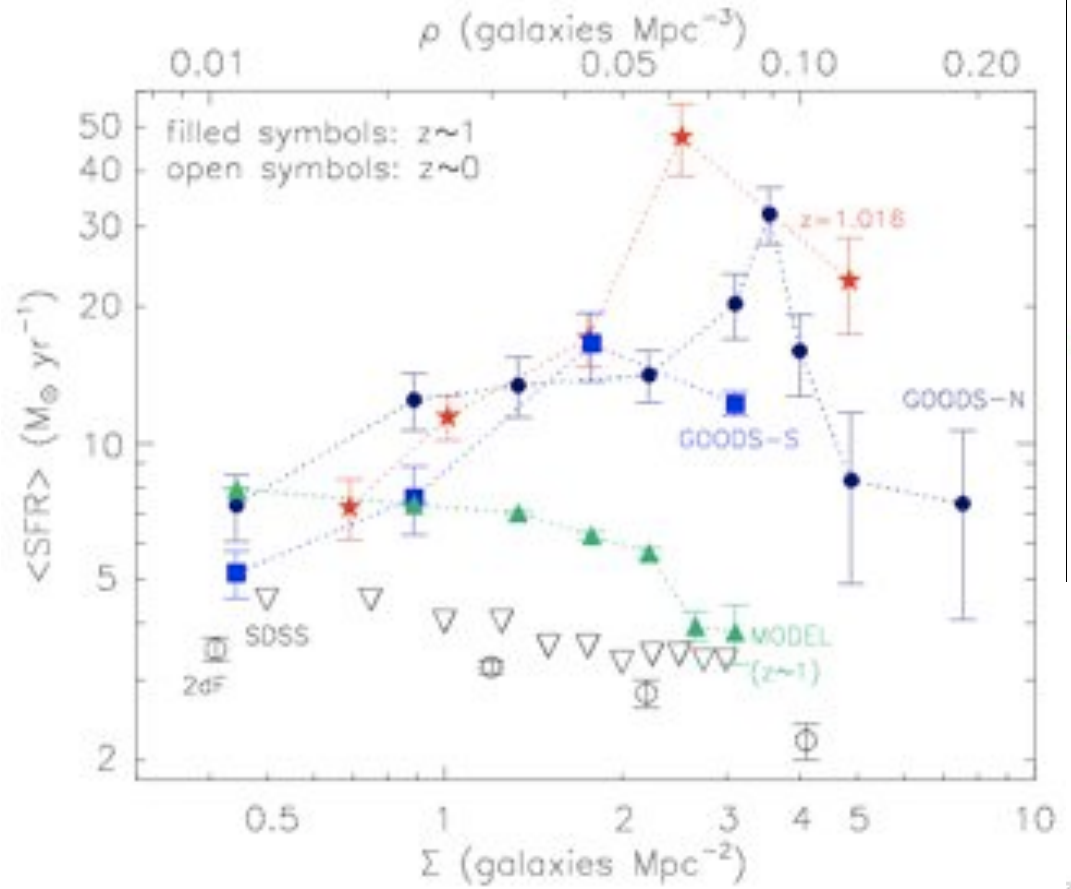


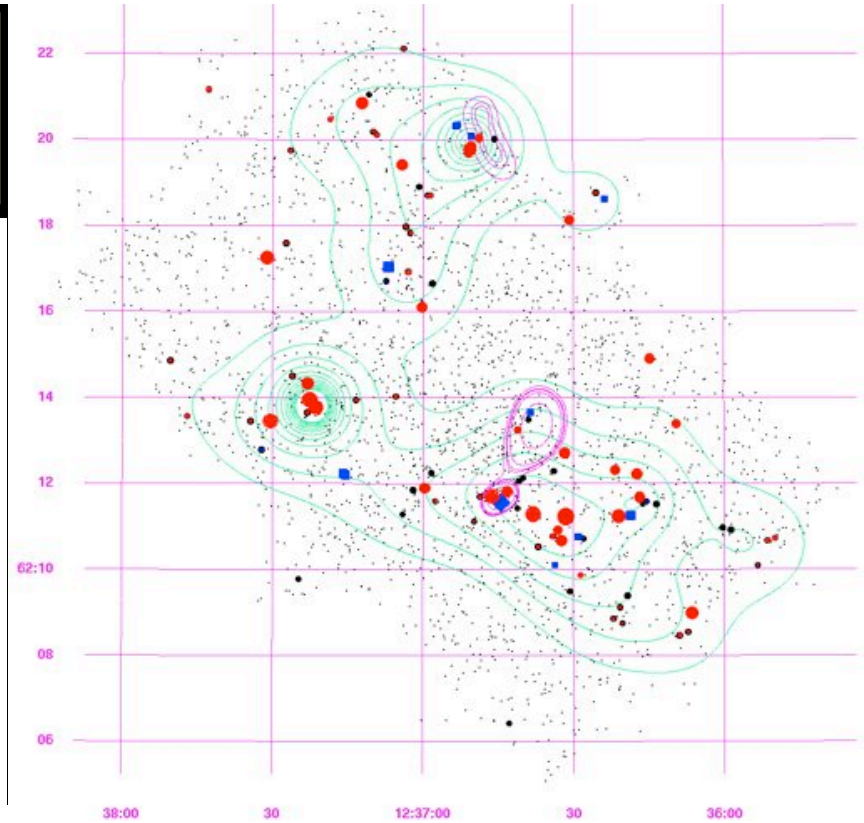


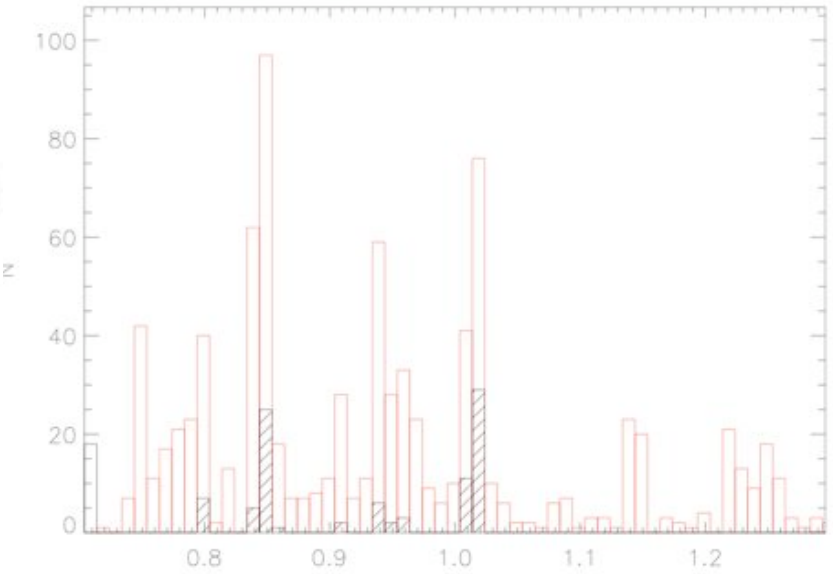




The star formation - galaxy density relation is reversed at z~1 (Elbaz et al. 2007)

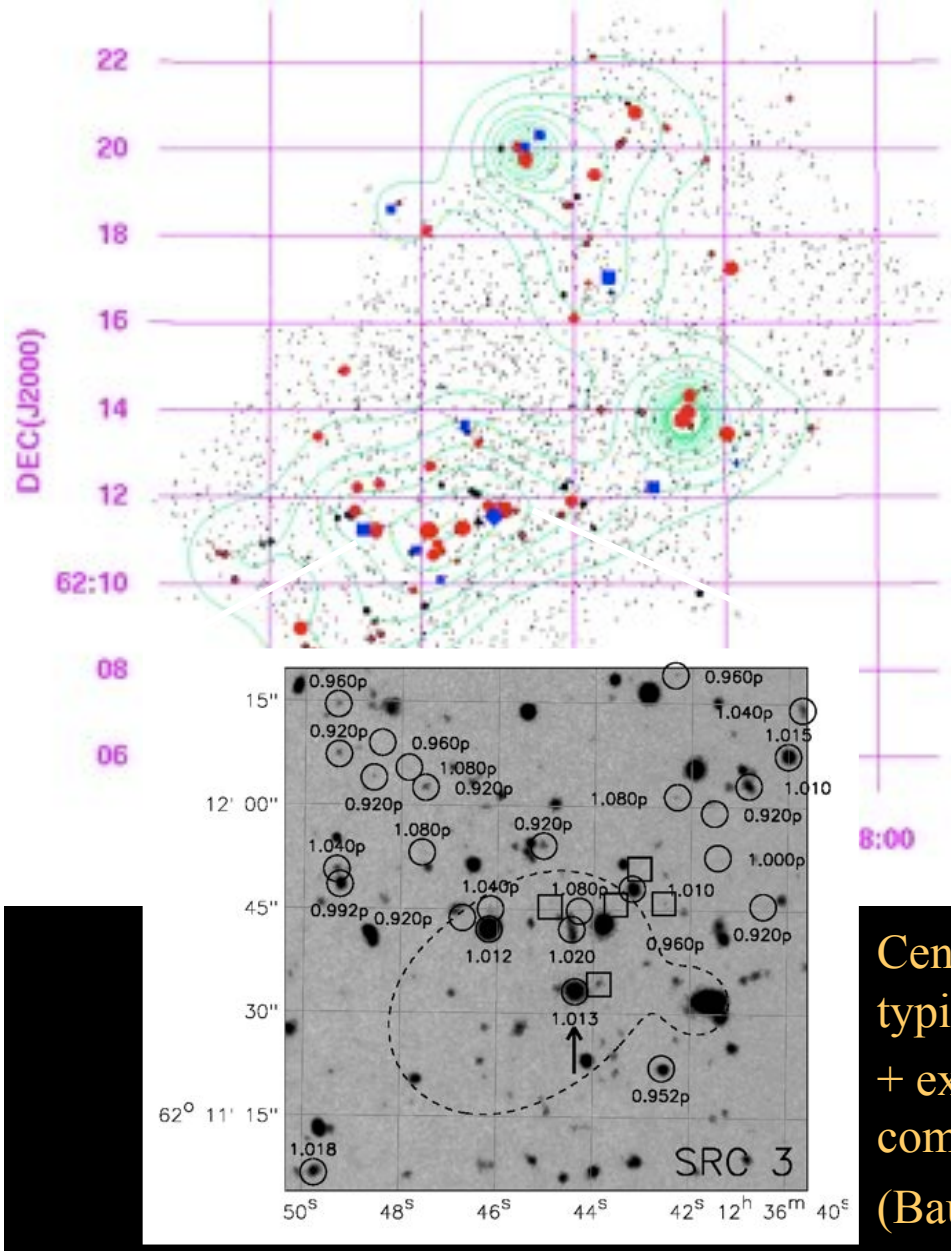






The reversal is dominantly produced in the major z-peaks

A candidate proto-Virgo cluster at z=1.016



From the X-ray cluster luminosity function (Rosati et al 02), we derive:

$$N(>L_X, 0.8 \le z \le 1.2) = 5.7 \times (L_{43})^{-1} \left[\text{cluster}/^{\circ 2}\right]$$

where: $L_{43} = L_X[0.5-2\text{keV}]/10^{43}$ erg s^{-1}.

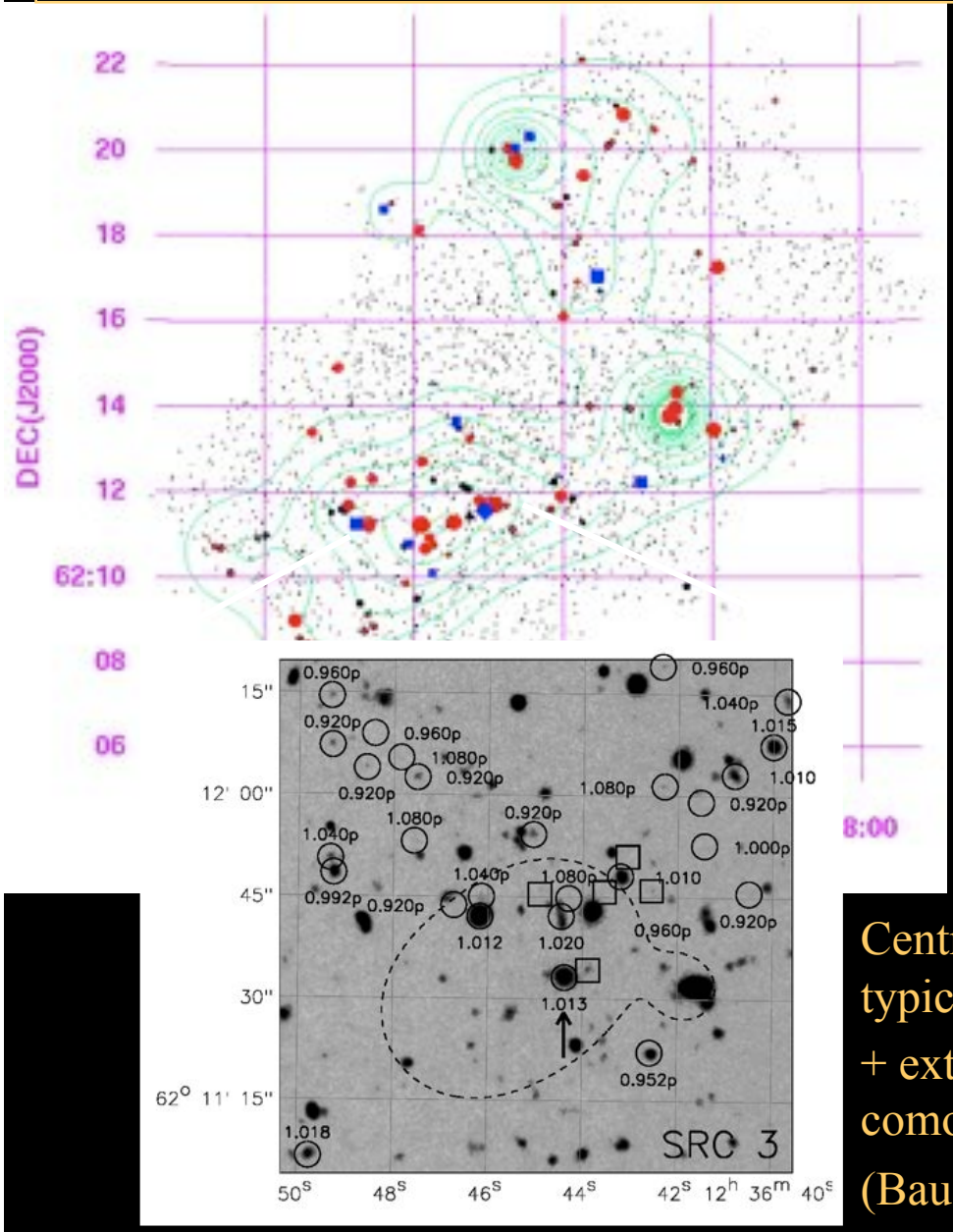
Hence, we should be able to detect 1 proto-Virgo cluster per GOODS field, i.e. with L_X [0.5-2 keV] = 2 x 10^{42} erg s^{-1}

Central Fanaroff-Riley type I (FrI) radio galaxy typical of cluster environment

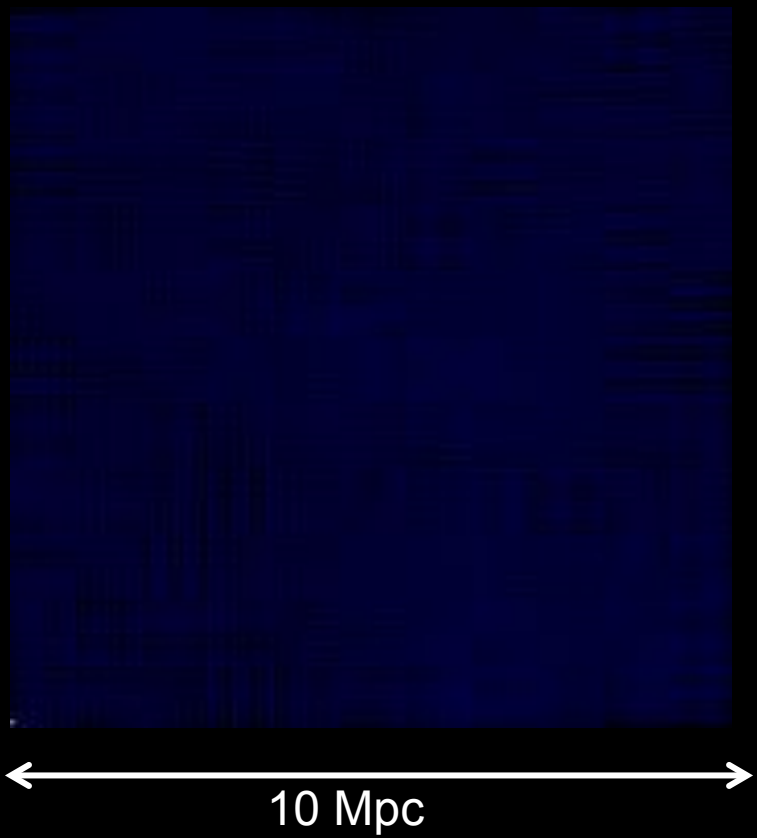
+ extended Chandra X-ray emission (0.5Mpc-comobiles) L_X(0.5-2 keV)=2x10^{42} ergs s^{-1}

(Bauer et al 02)

A candidate proto-Virgo cluster at z=1.016



Simulation Horizon (cluster 6) 10^{14} $M_{\odot}$



Central Fanaroff-Riley type I (FrI) radio galaxy typical of cluster environment

+ extended Chandra X-ray emission (0.5Mpc-comobiles) L_X(0.5-2 keV)=2x10^{42} ergs s^{-1}

(Bauer et al 02)

What is causing the reversal ? Major mergers ?

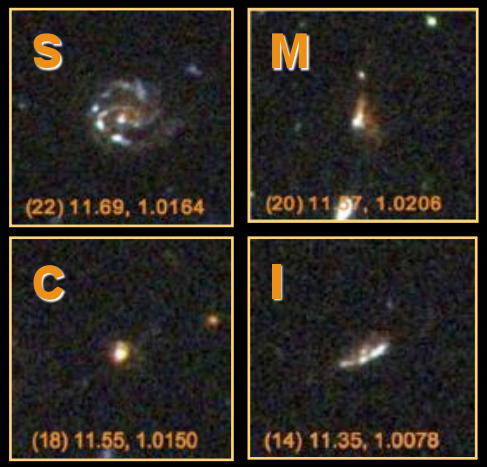
Morphology of 36 LIRGs at z=0.8±0.4 show only a minority of obvious major mergers (Zheng+04)

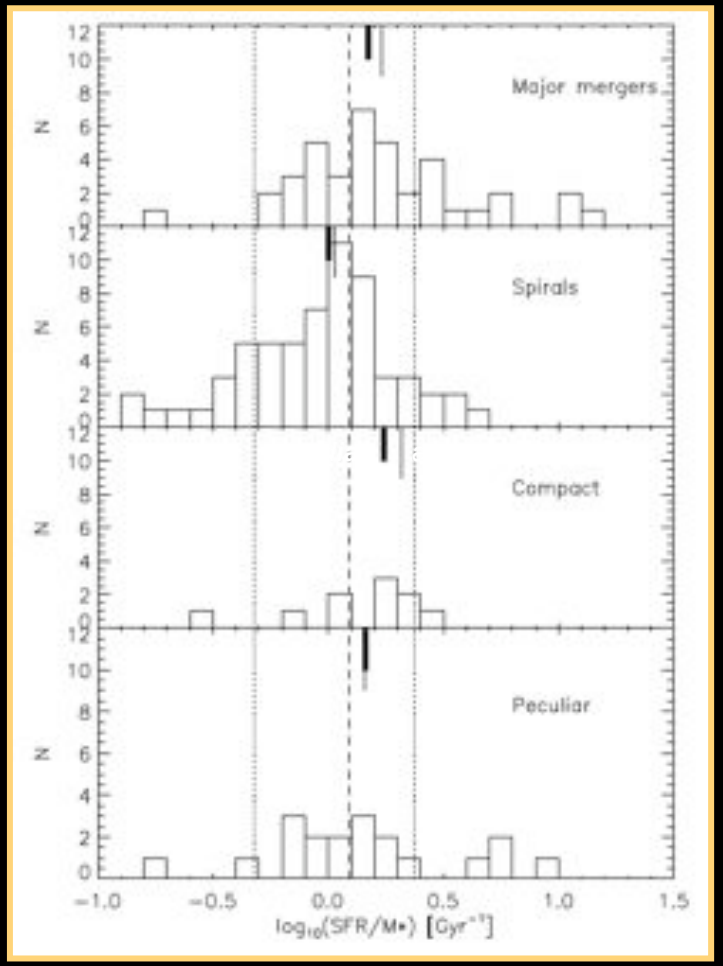
Elbaz +07: complete sample of 140 LIRGs from GOODS-N
[S_{24}>25 μJy at 24 μm]

	z~0 Ishida 04	z~0.7 Bell 05	z~1 Elbaz 07
Spiral (S)	26 %	51 %	46 %
Merger (M)	41%+33% +close pair	26 %	31 %
Compact (C)	-	10 %	9 %
Irregular (I)	-	13 %	14 %
interactions		26-39 %	30-45 %

The role of major mergers is not dominant in LIRGs @ z~1

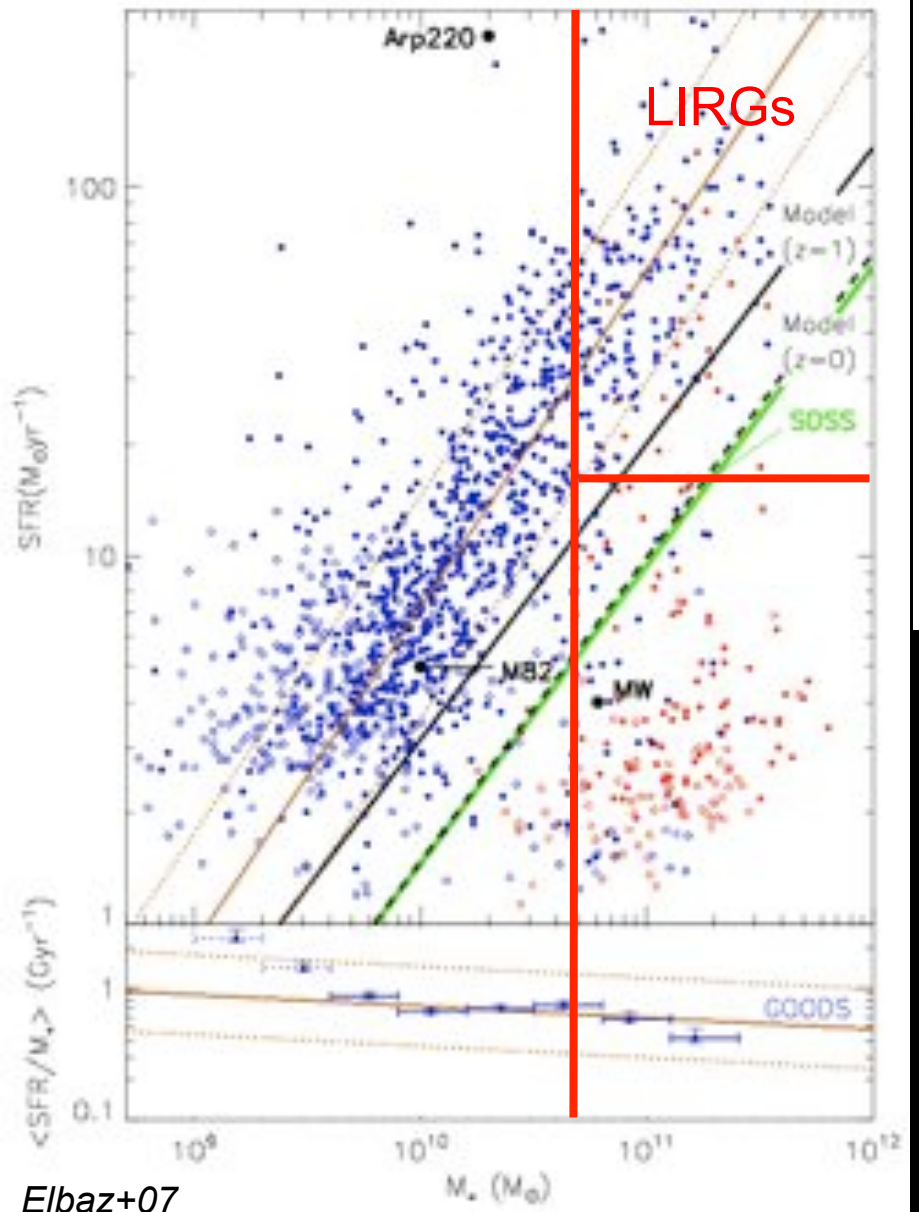
(see also Melbourne, Koo & Le Floc'h 2005)





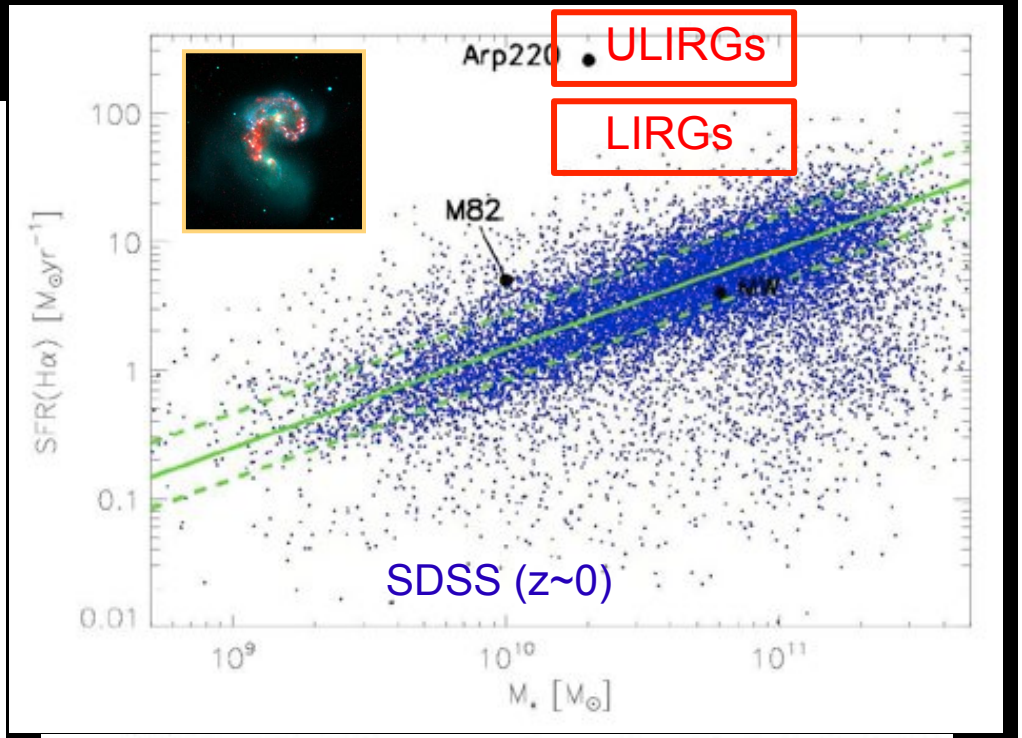
sSFR(mergers) ~ sSFR(isolated) x 1.5-1.7
consistent with Lin et al. (2007; x 1.9) DEEP2

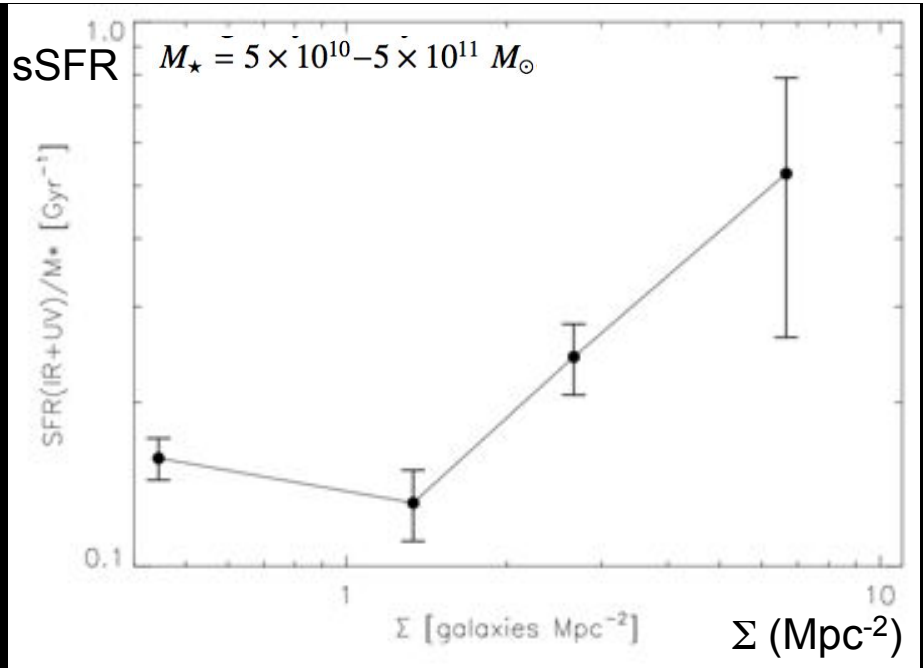
SFR – M* relation: is M* the key parameter ?

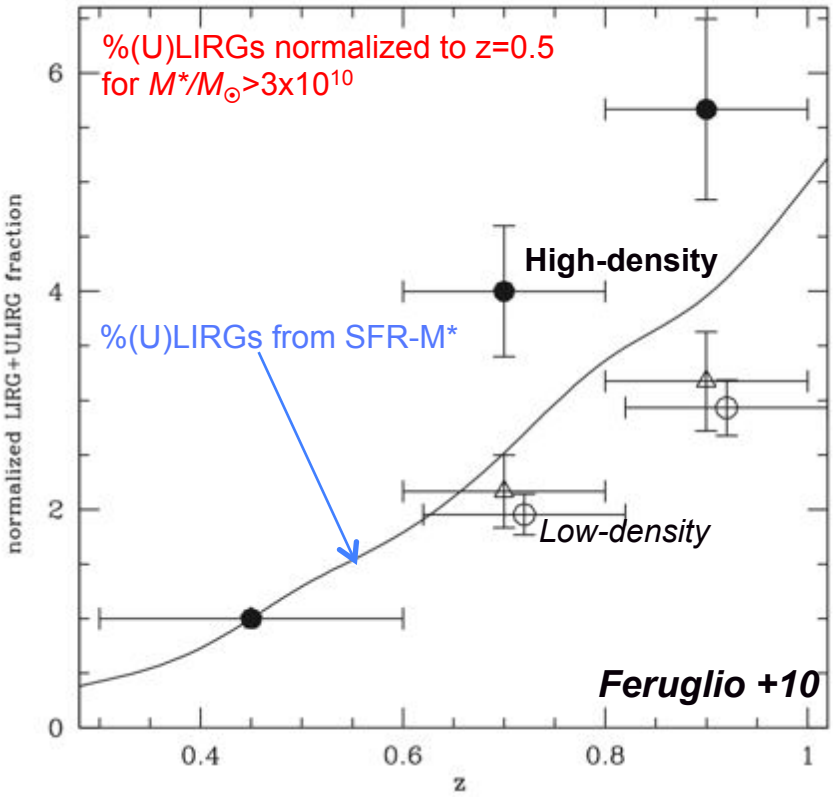


Elbaz+07

SFR=7.2 [-3.6,+7.2] x $(M_*/10^{10}M_\odot)^{0.9}$







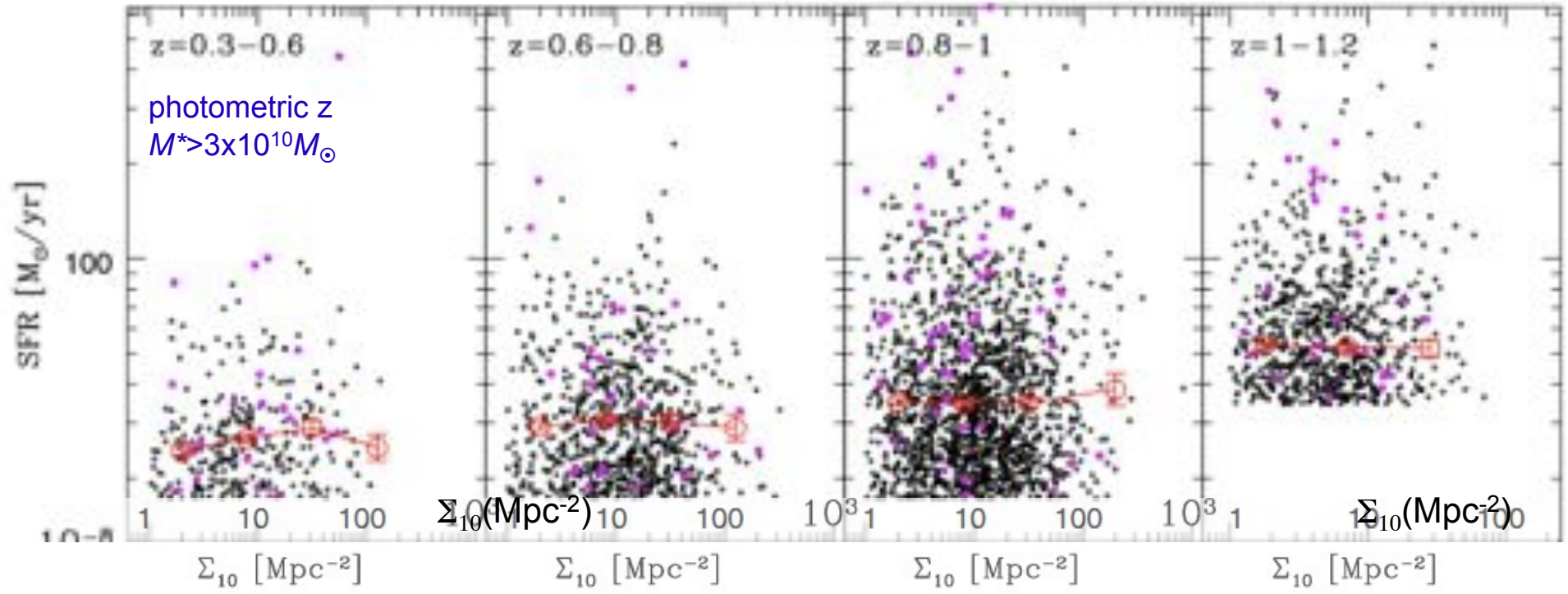
Feruglio +10 : no reversal of SFR-Σ_{10} with z_{phot}

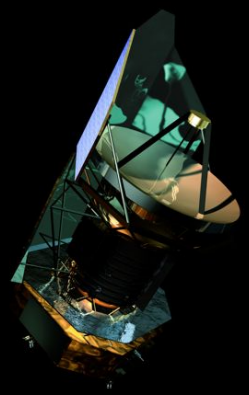
→too sparse sampling, not probing the right scale ?

But larger % of LIRGs in dense environments

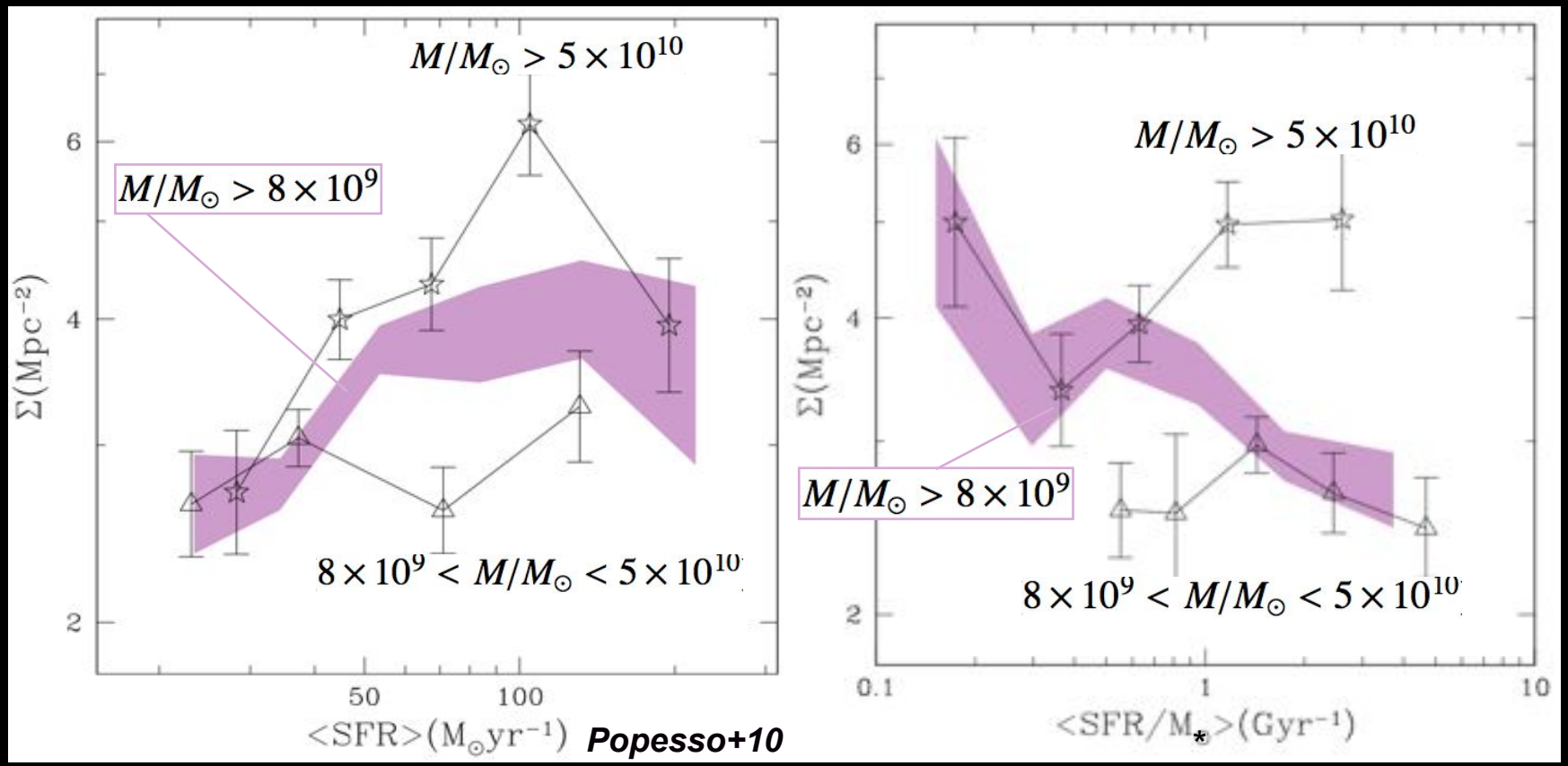
Σ_{10}= 10 / (πR_{10}^2)

R_{10}= distance to the 10th closest galaxy



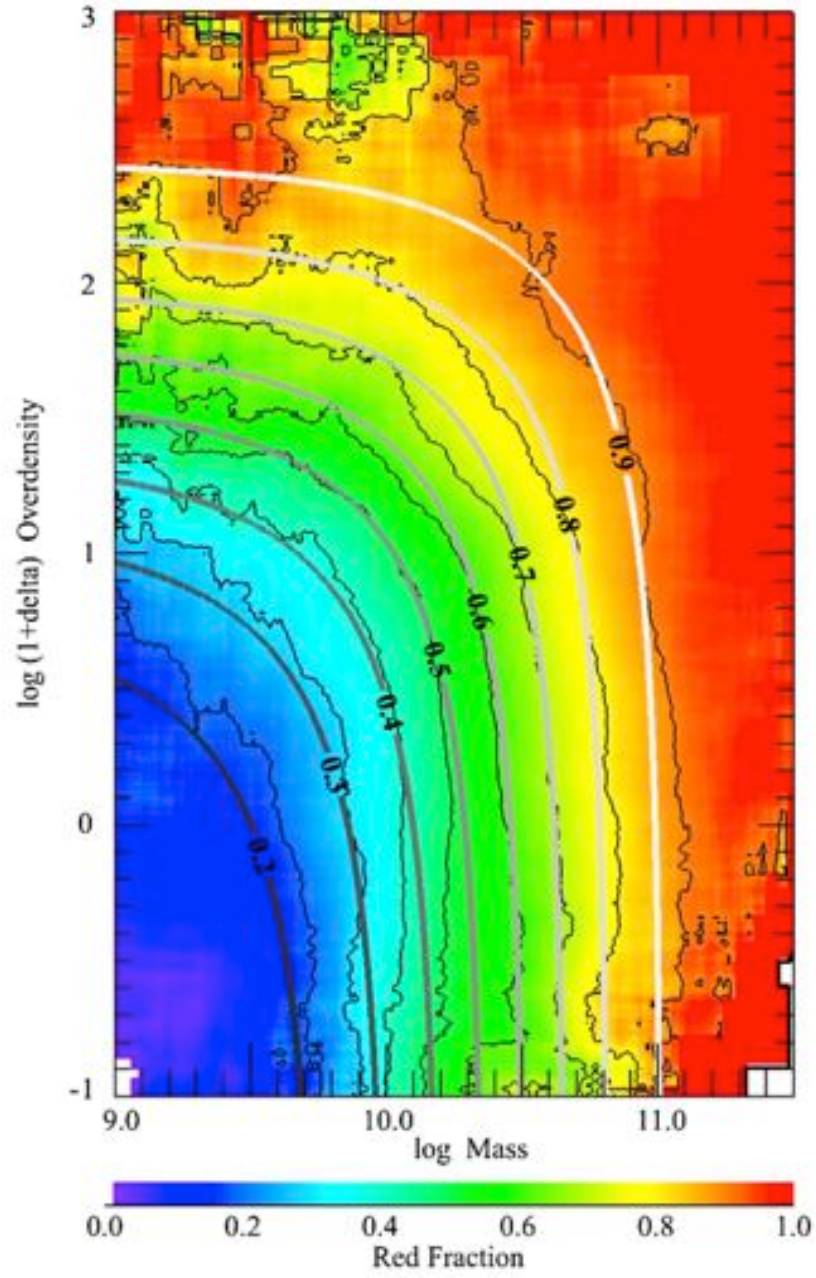


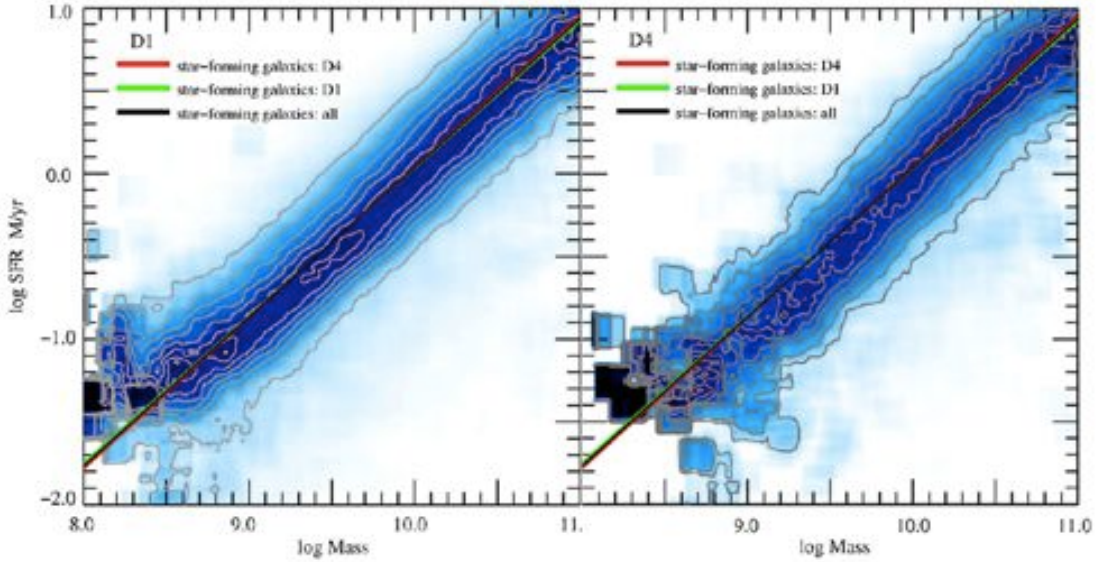
The reversal of the SFR – density relation as probed by Herschel

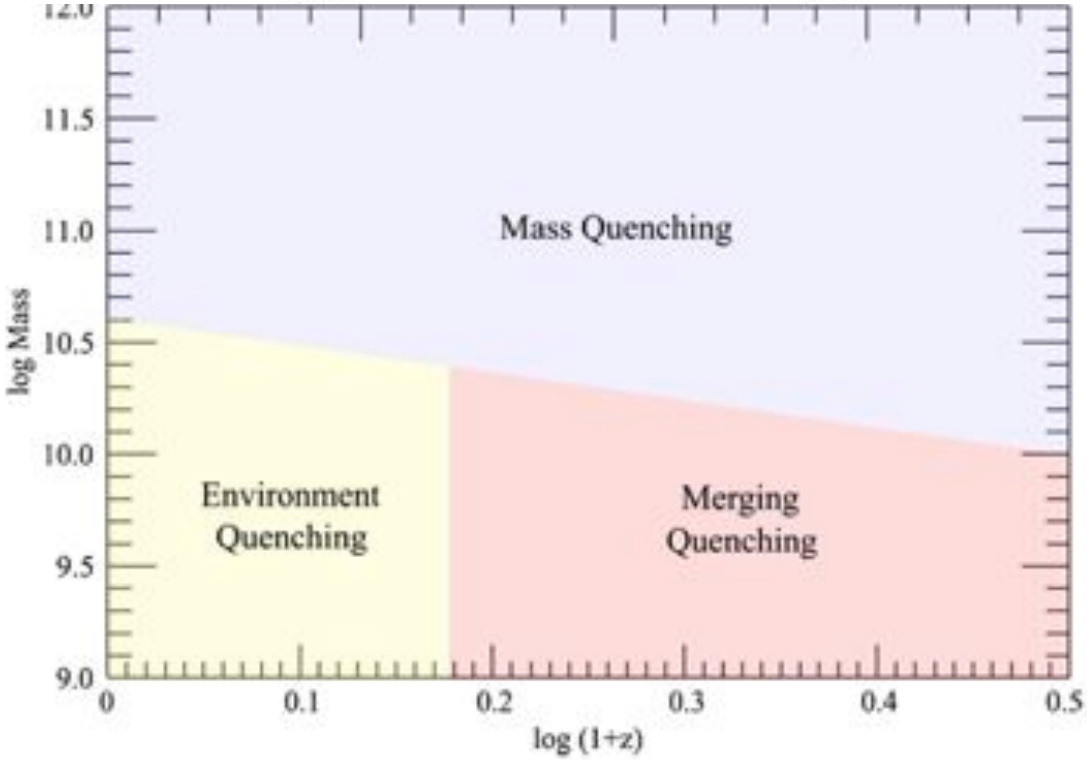


PACS 100 & 160 μm + 24 μm extrapolations using CE01 at faint fluxes

Mass & environment quenching (Peng +10)

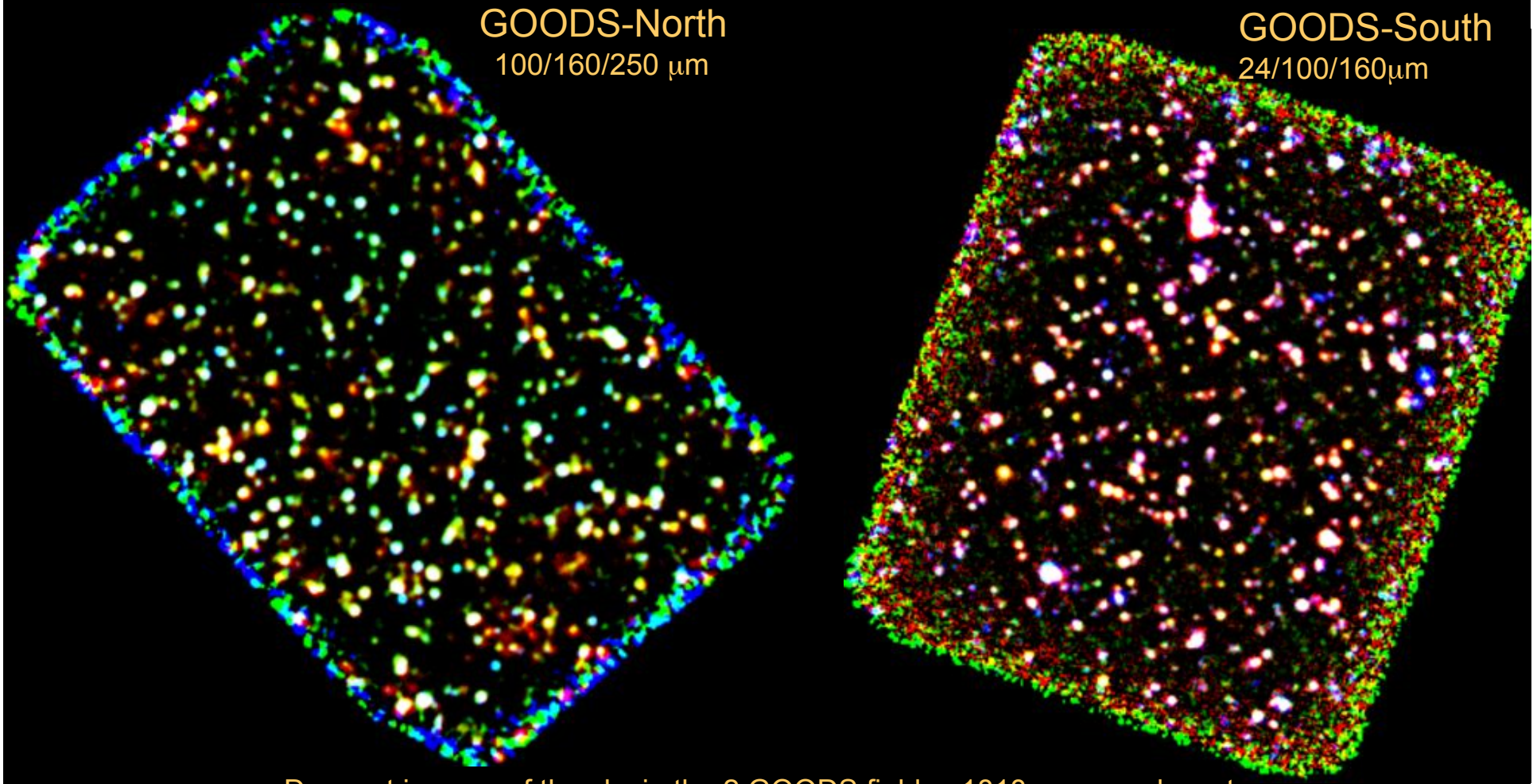






GOODS-Herschel (*Herschel Open Time Key Program*)

The Great Observatories Origins Deep Survey : far IR imaging with Herschel



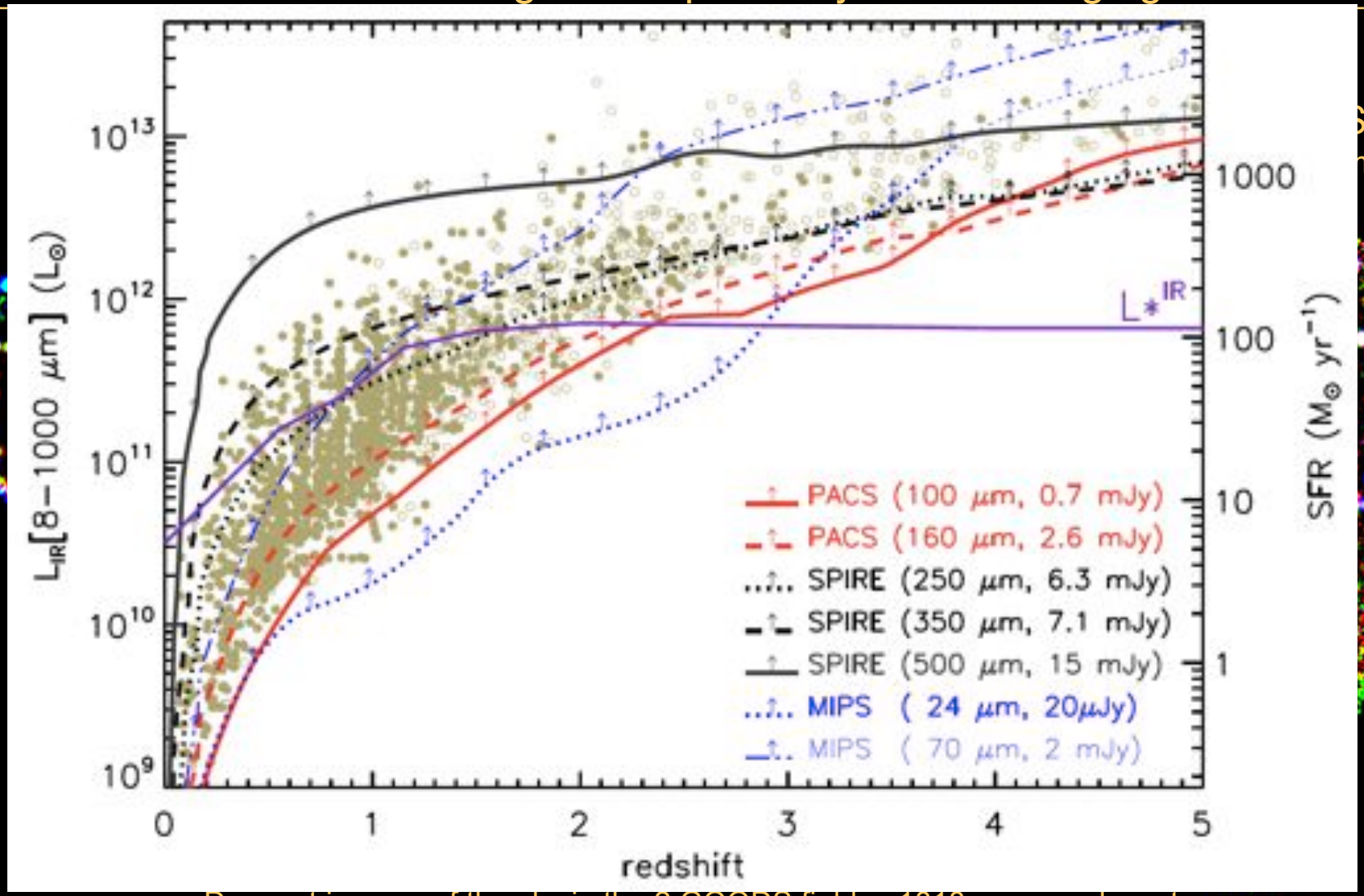
Deepest images of the sky in the 2 GOODS fields : 1818 sources down to

1 mJy at 100 μm, 2.6 mJy@160μm, 5mJy@250μm, 8mJy@350μm, 10mJy@500μm

X	UV	U	B	V	I	Z	J	H	K	3.6μm	4.5μm	5.8μm	8μm	IRS16	MIPS24	radio
$2x10^{-16}$erg/s/cm^2		~28AB		22AB			~1μJy								50μJy	20μJy	12μJy

GOODS-Herschel *(Herschel Open Time Key Program)*

The Great Observatories Origins Deep Survey : far IR imaging with Herschel

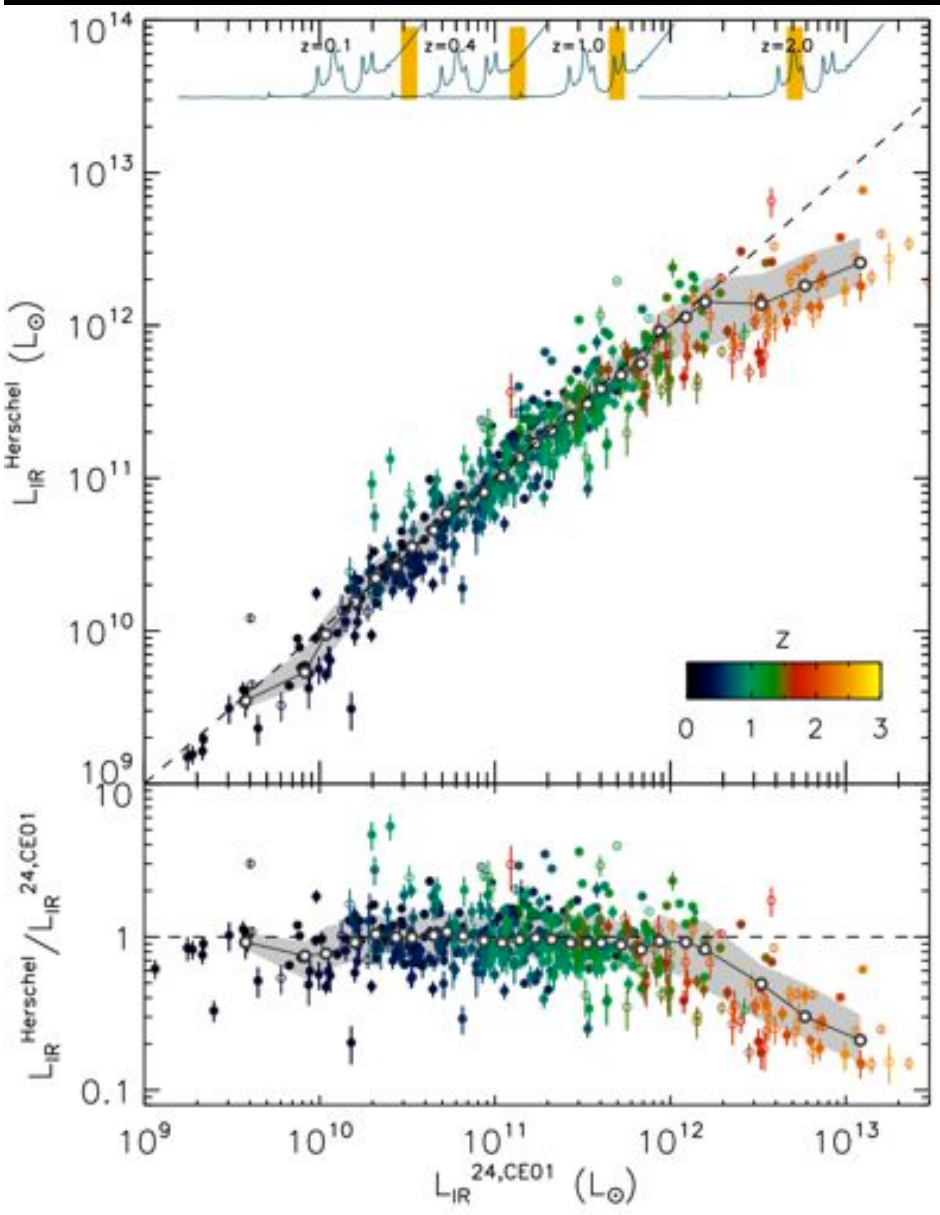


Deepest images of the sky in the 2 GOODS fields : 1818 sources down to

1 mJy at 100 μm, 2.6 mJy@160μm, 5mJy@250μm, 8mJy@350μm, 10mJy@500μm

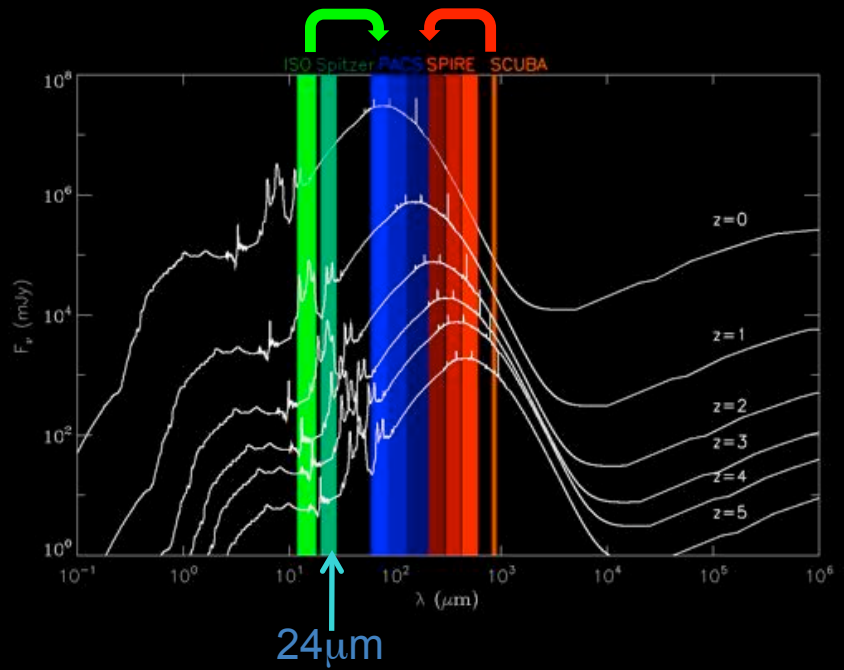
X	UV U B V I Z J H K 3.6μm 4.5μm 5.8μm 8μm IRS16 MIPS24 radio					
$2x10^{-16}$erg/s/cm²	~28AB	22AB	~1μJy		50μJy	20μJy	12μJy

The mid-IR excess problem... SED evolution/AGN/k-correction ?...



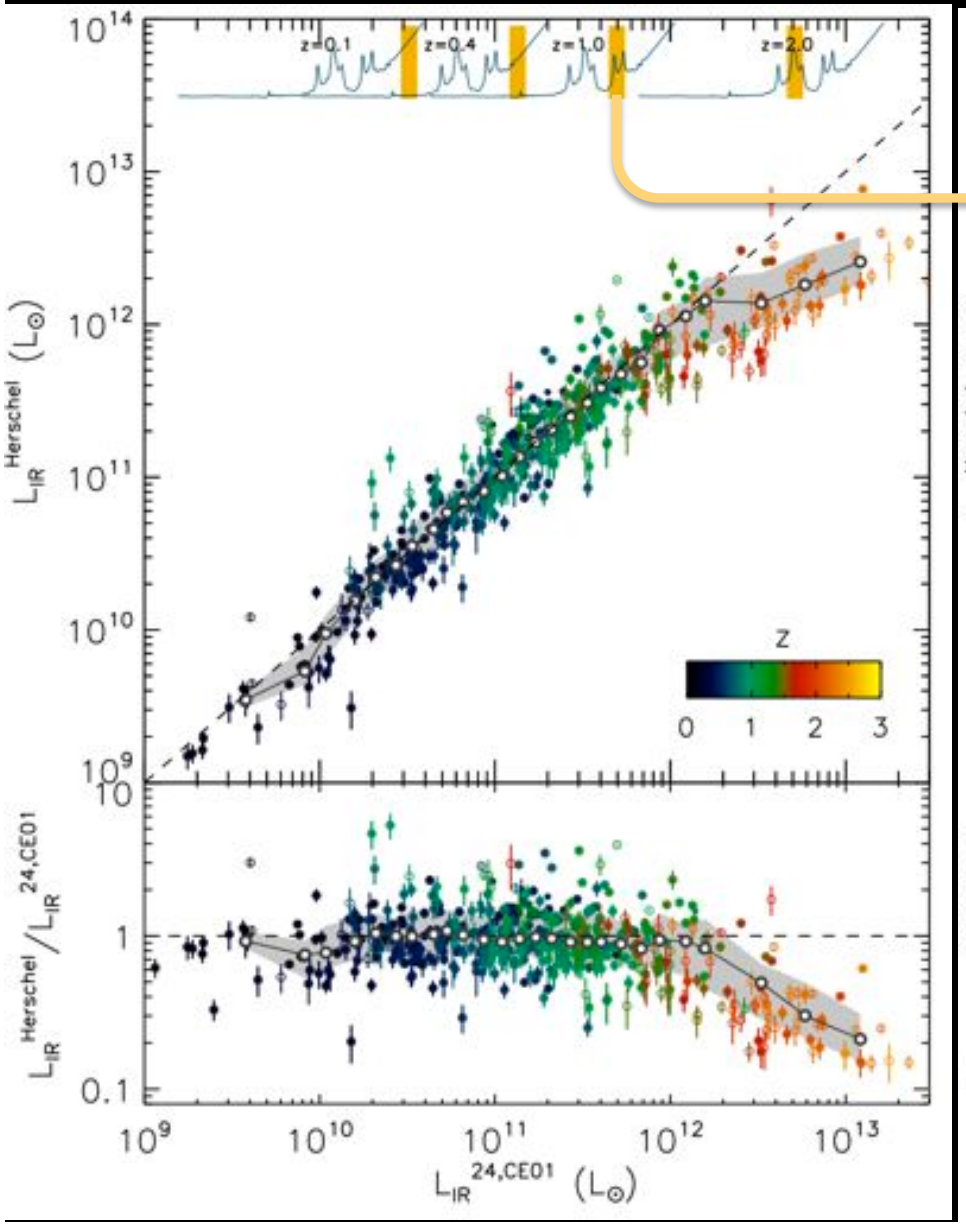
- mir and far IR consistent with local SEDs (Chary & Elbaz 01) up to z~1.5 (blue, green dots)

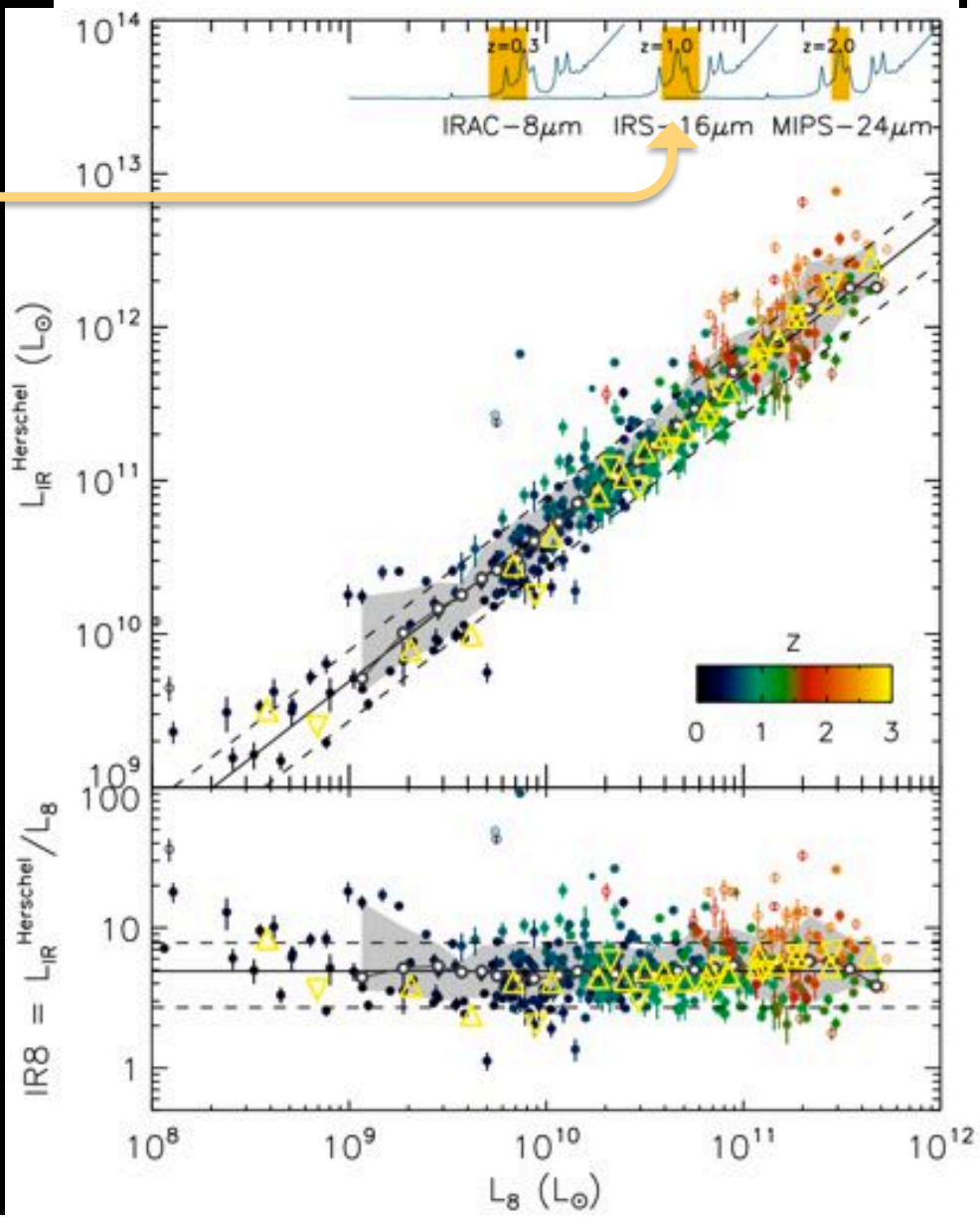
- at z>1.5: "mid-IR excess" (Daddi +07, Papovich +07) (orange, red dots)



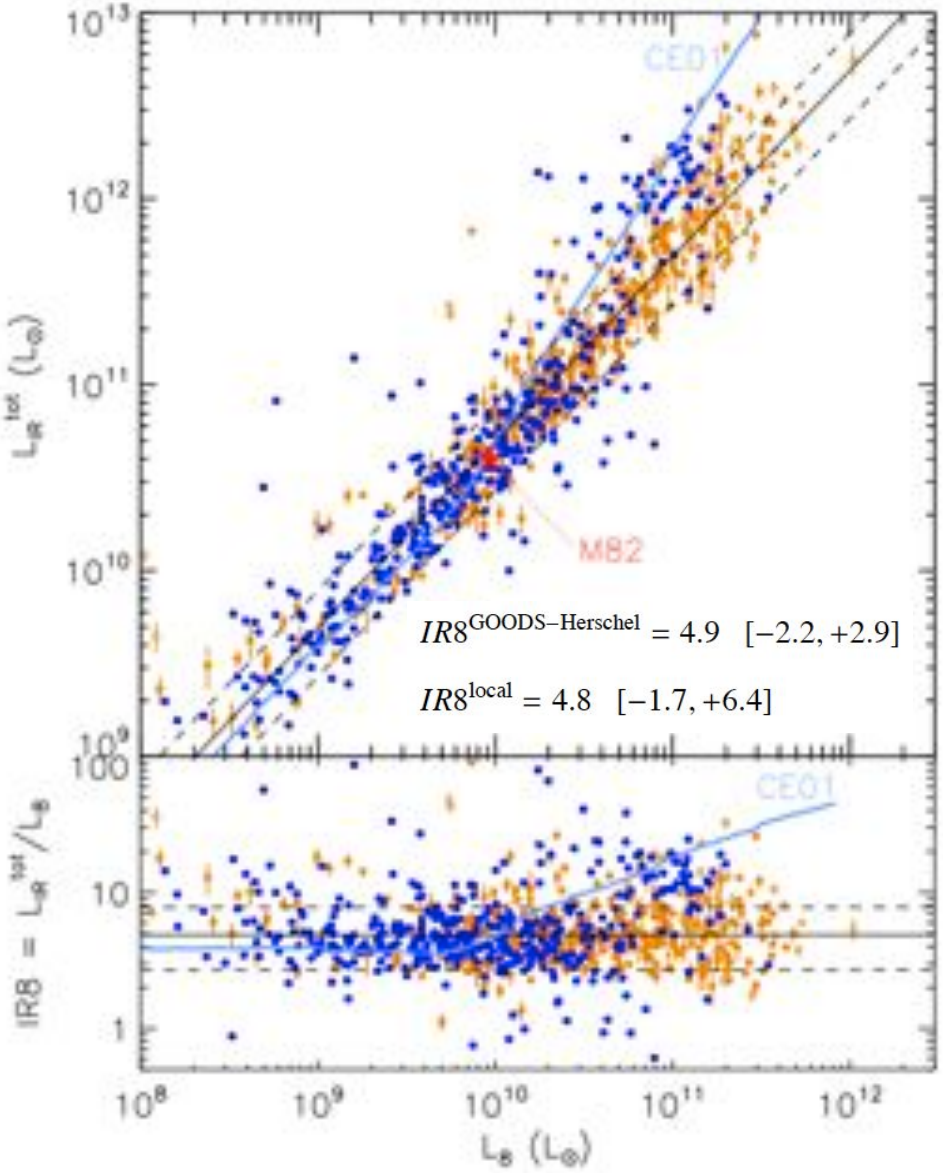
Elbaz, Hwang +10, 11
GOODS-Herschel (*Elbaz, Hwang +11*)

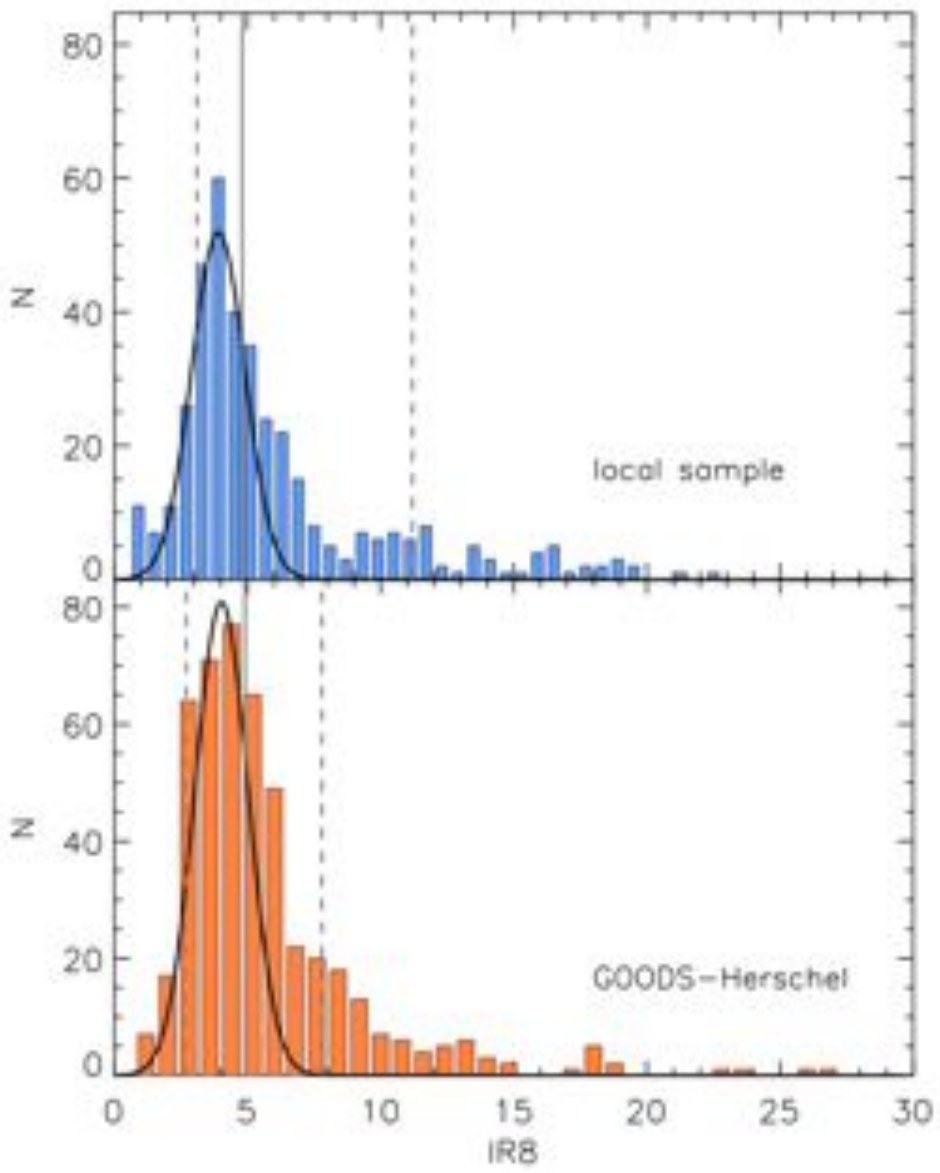
The mid-IR excess problem... SED evolution/AGN/k-correction ?...





IR main sequence : 2 modes of star formation ?

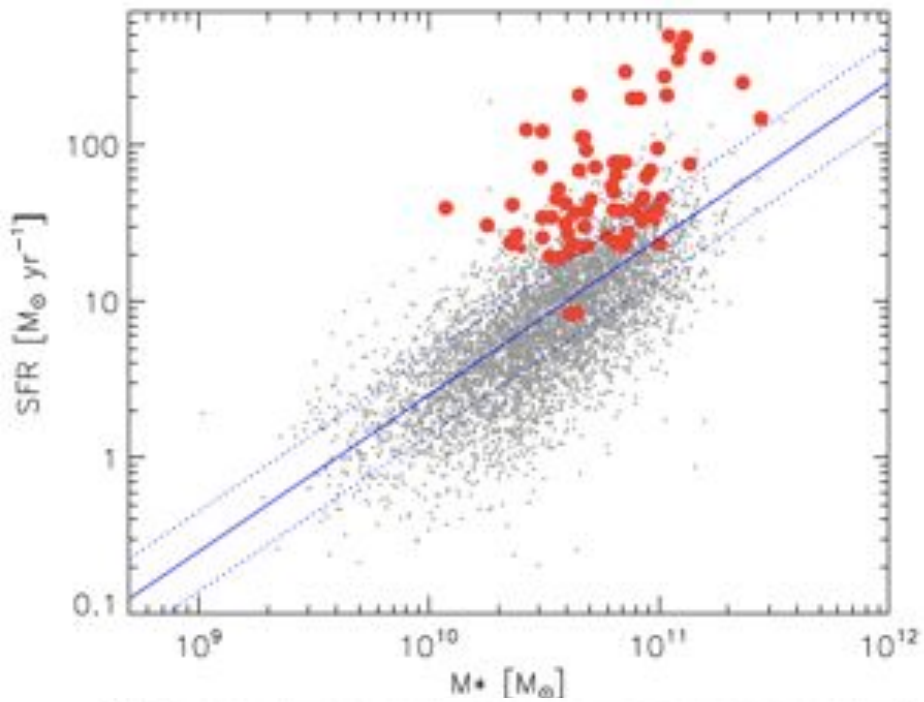


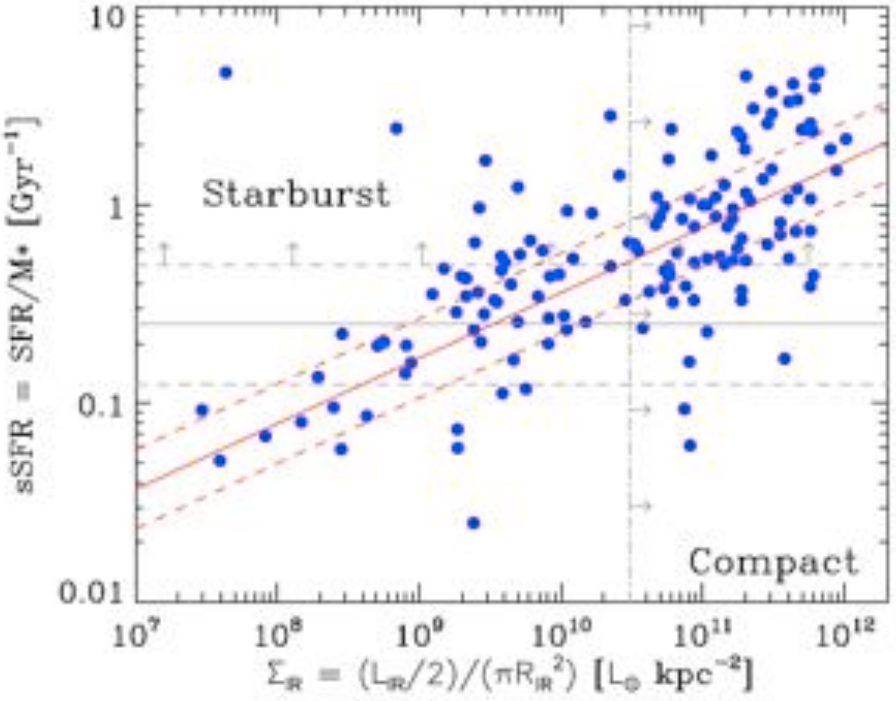


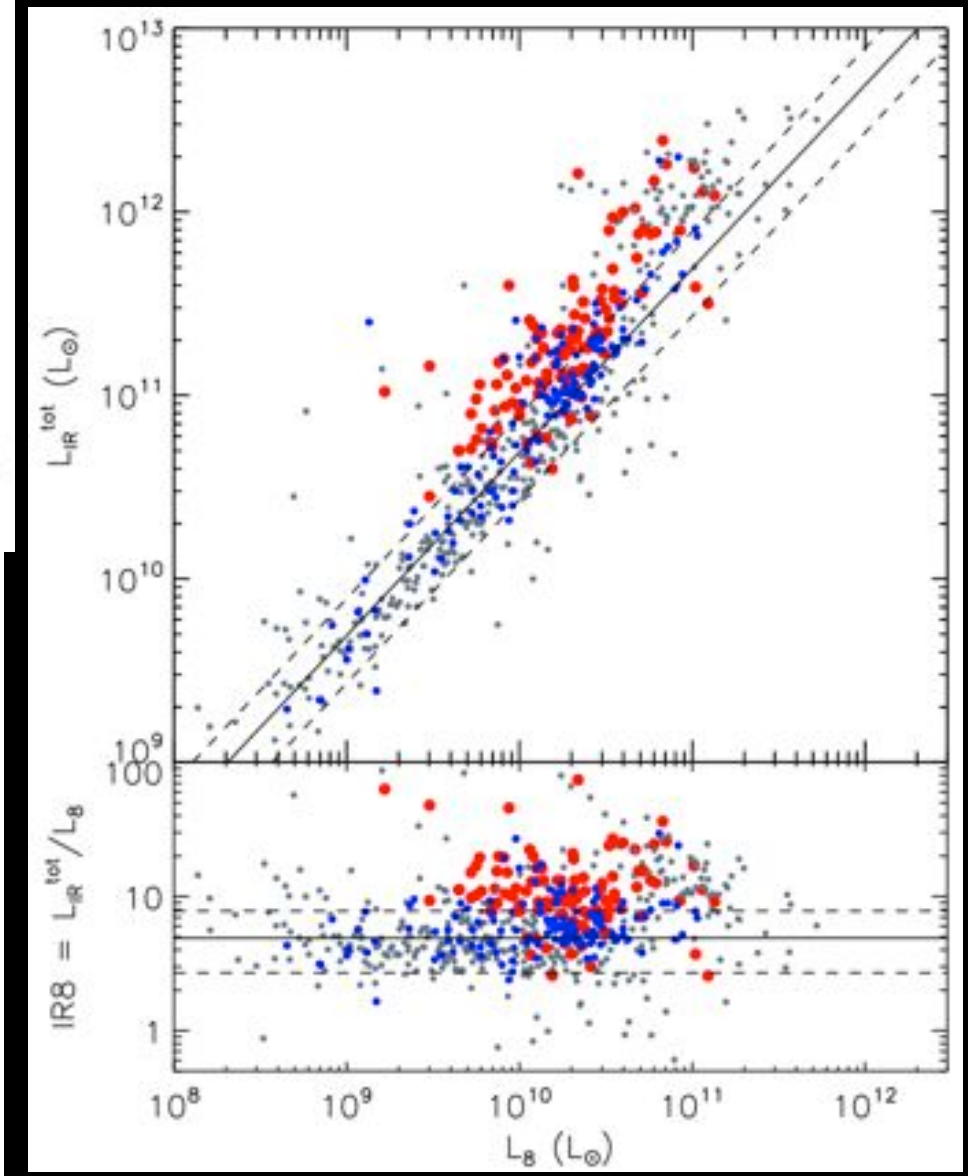
$IR8^{\mathrm{local}}$(center Gaussian) = 3.9 $[\sigma = 1.25]$

$IR8^{\mathrm{GOODS-Herschel}}$(center Gaussian) = 4.0 $[\sigma = 1.6]$

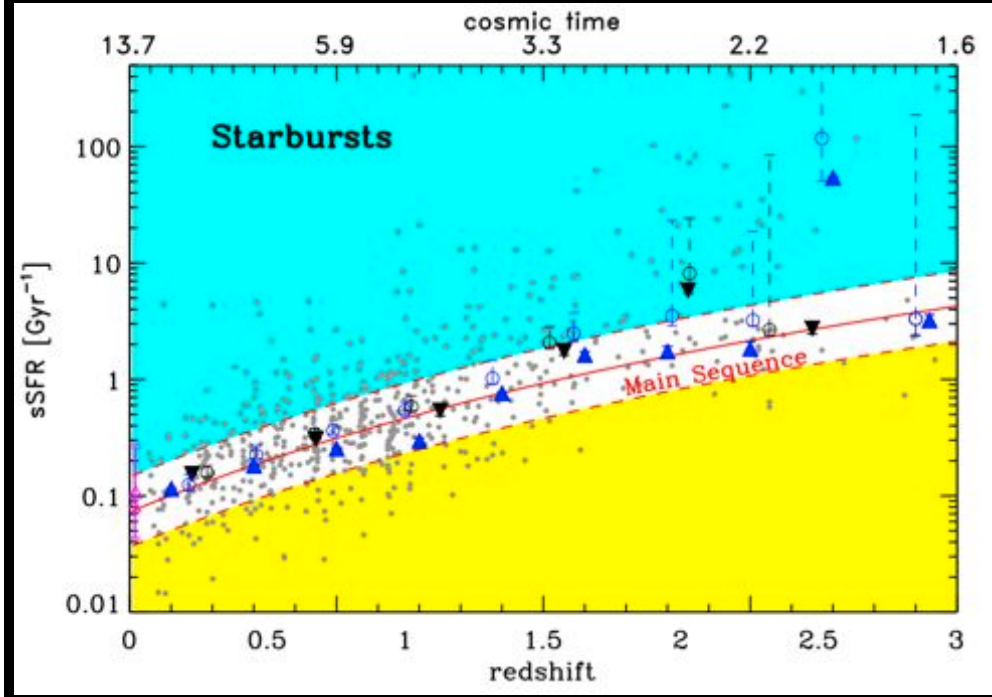
IR main sequence : role of SF compactness



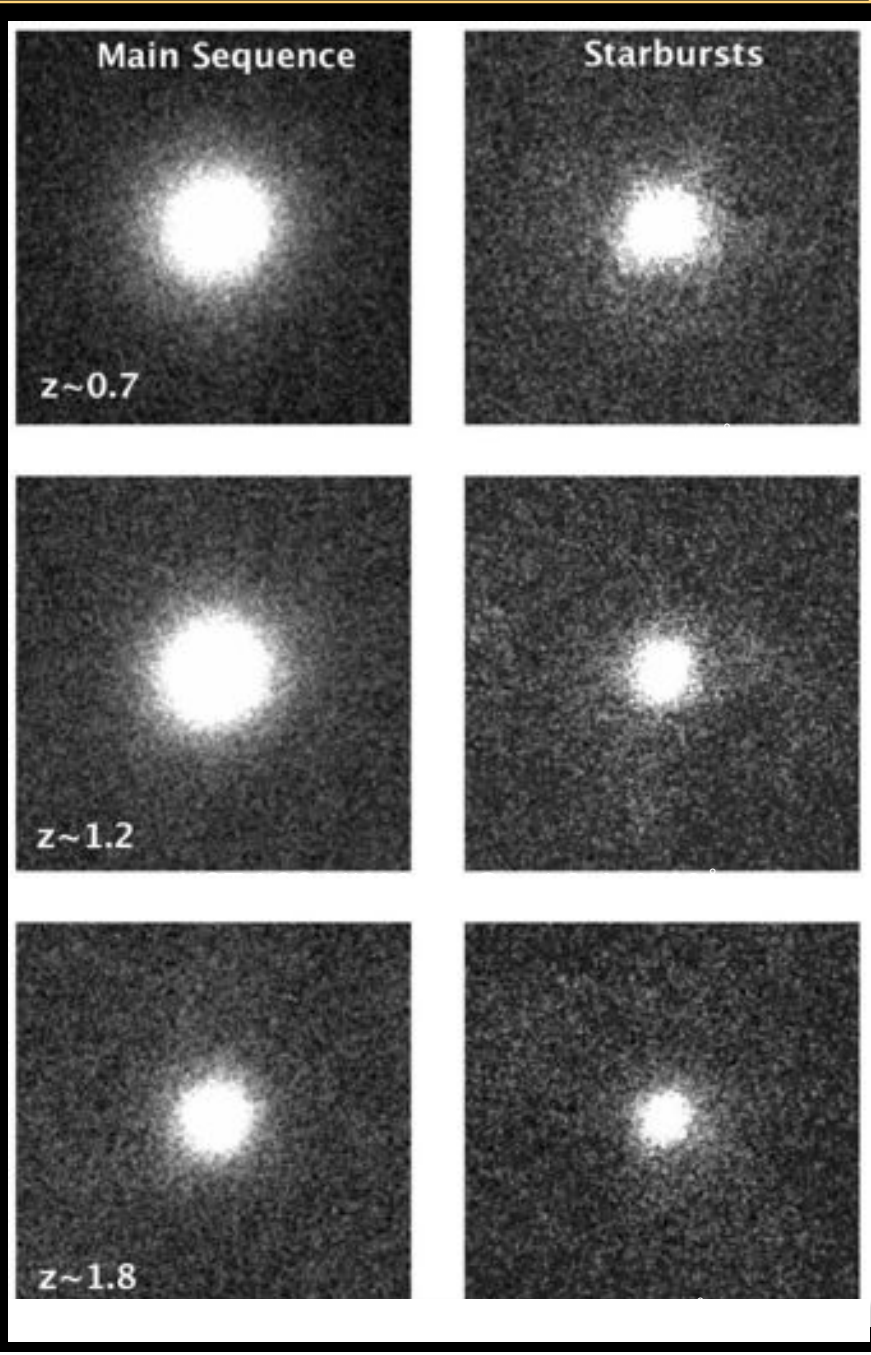




SF in distant excess IR8 galaxies is more compact in rest-frame UV

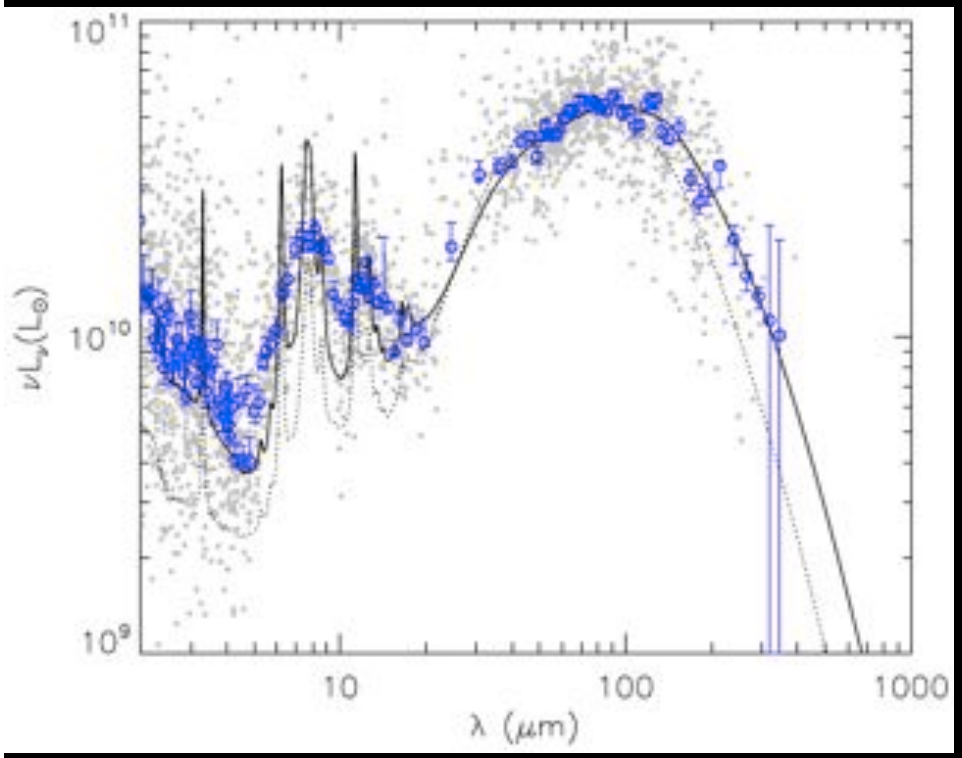


Redshift	Main Sequence	Starburst	
		R_{SB}>2	R_{SB}>3
0.7	5.2 kpc	3.9 kpc	2.5 kpc
1.2	4.4 kpc	3.3 kpc	2.5 kpc
1.8	3.0 kpc	2.5 kpc	2.0 kpc



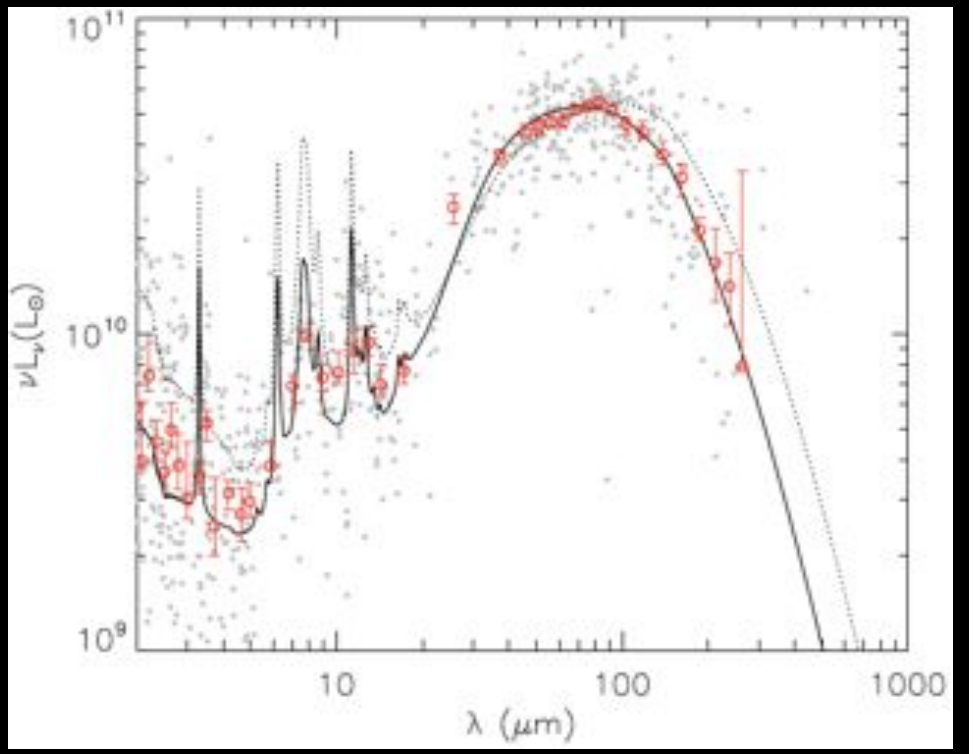
Proto-typical IR SED of Main Sequence and Starburst galaxies

Main Sequence



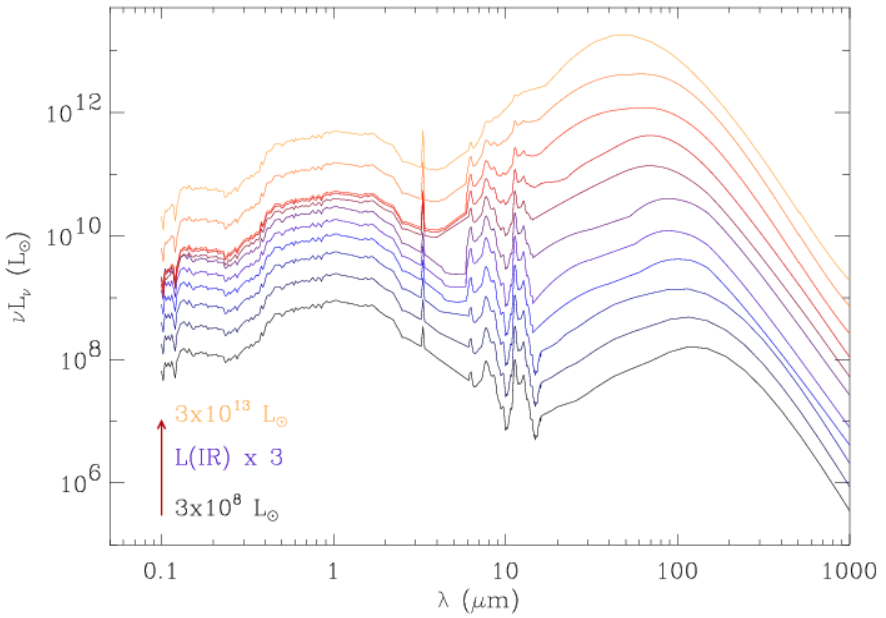
Main Sequence : broad far-IR bump 15 – 50 K, strong PAH features, ISM= 38 %, SF= 62 % SED

Starburst : IR8 > 2 x IR8(MS)

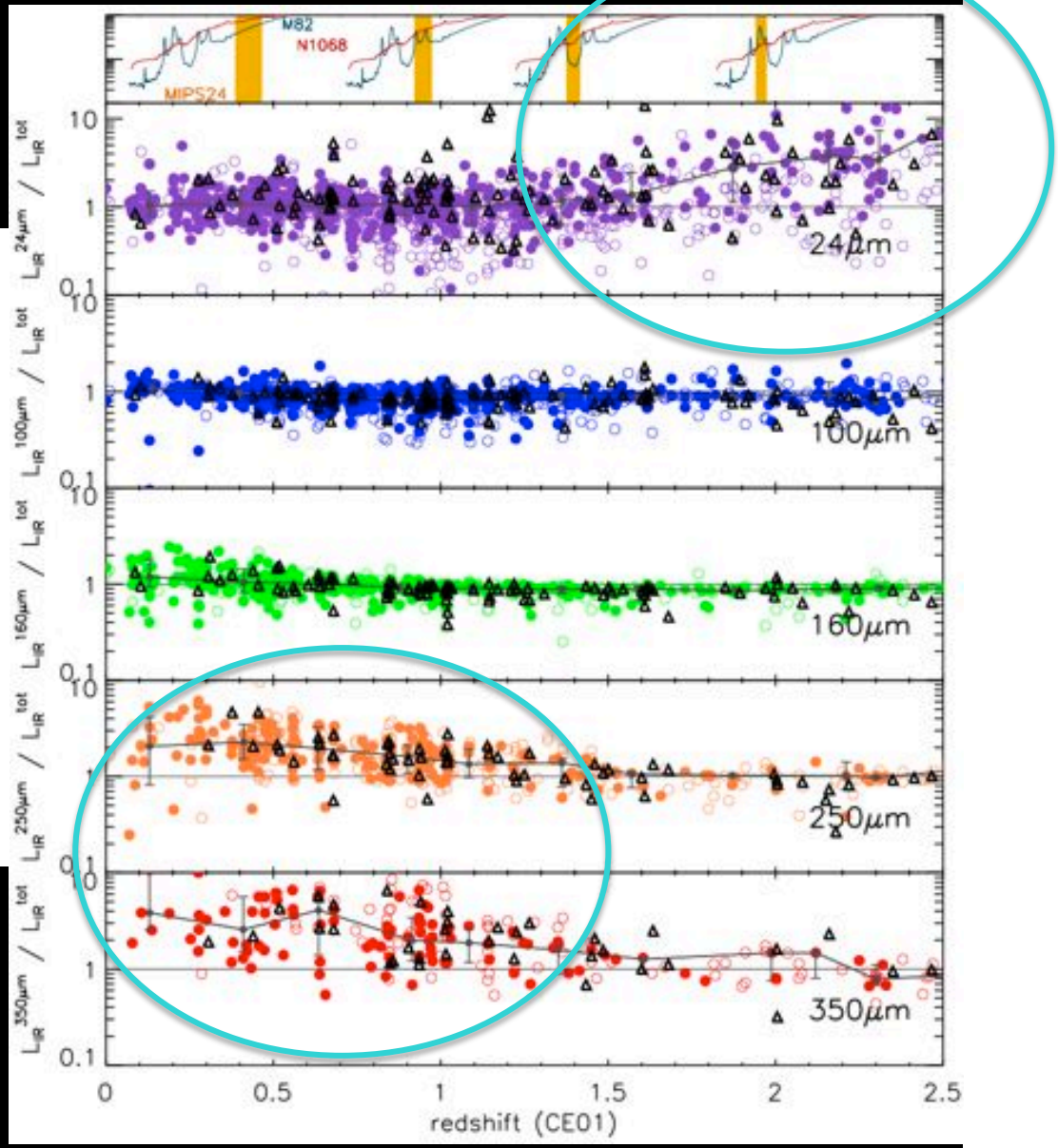


Starbursts : peaked far-IR bump 45 – 50 K, weak PAH features, ISM= 0 %, SF= 100 % SED

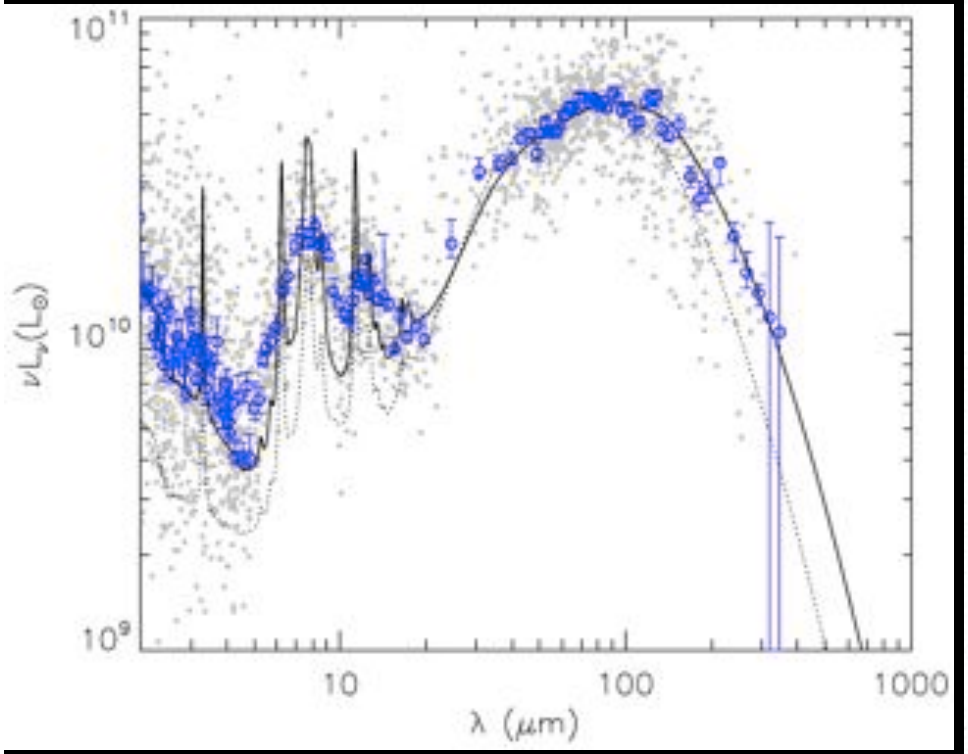
Improving the bolometric correction for SF galaxies



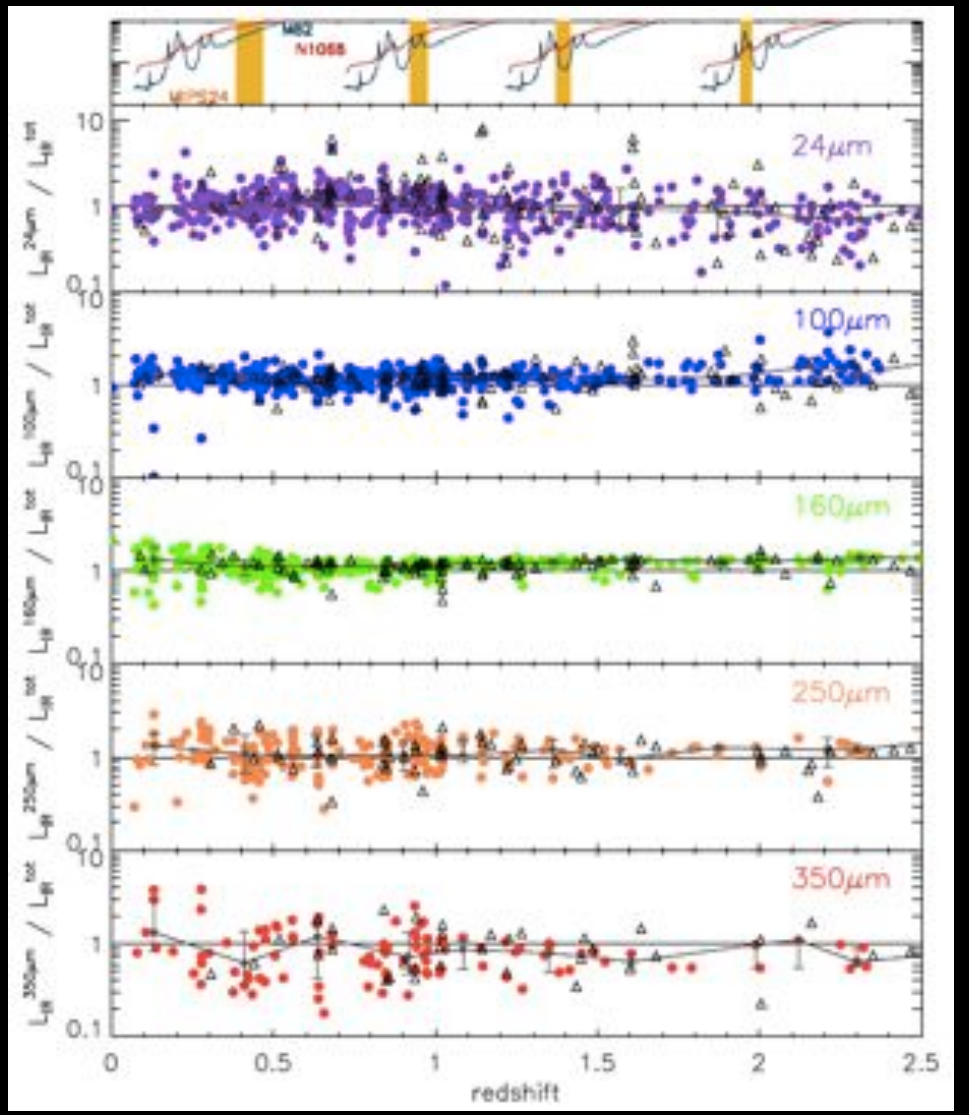
CE01 library of template IR SEDs



Improving the bolometric correction for SF galaxies



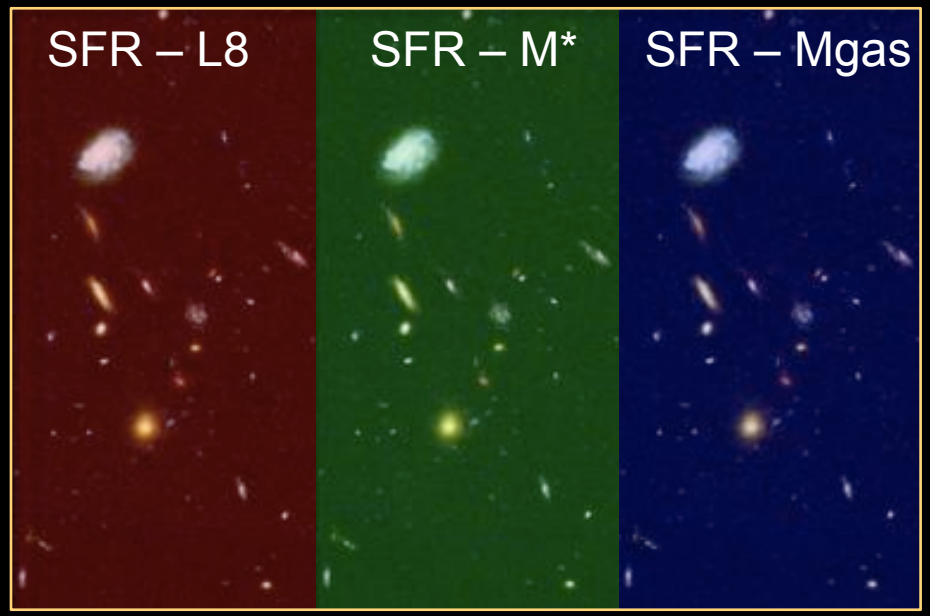
Unique IR SED for all galaxies:
main sequence



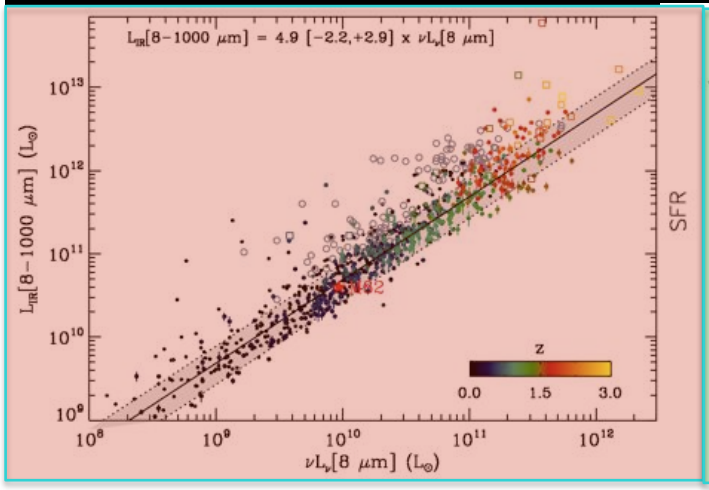
Role of IR8 = L_{IR}/L_8

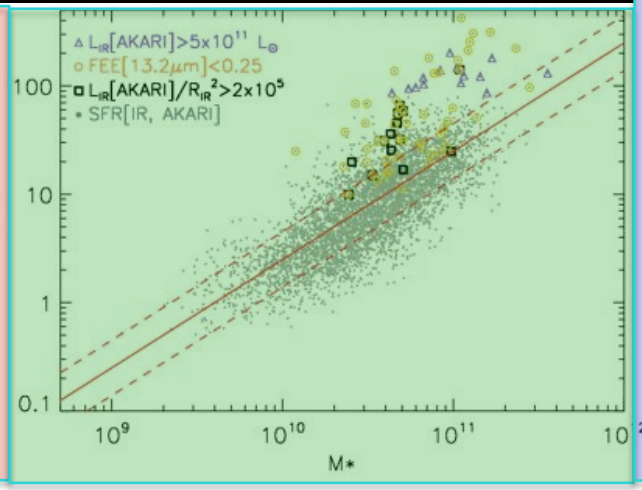
- IR8 is a tracer of the star-formation compactness (Σ_{IR}) & starburstiness (sSFR)
- it defines two main regimes of star formation (no clear dichotomy though):
- a main sequence (MS) of star-forming galaxies & starbursts
- starbursts are always a minority
- distant (U)LIRGs are mostly MS star-forming galaxies, few are SB depending on z

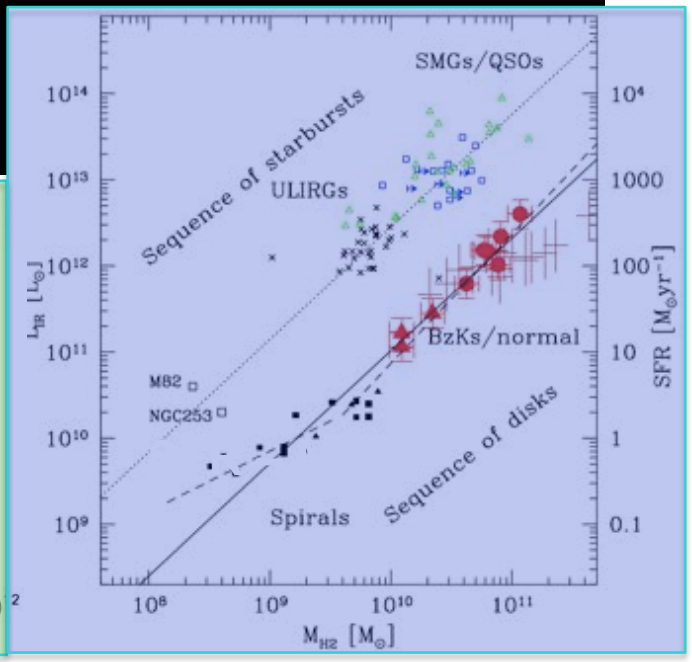
The fundamental tryptic of star forming galaxies











Conclusions

- the star formation history of galaxies depends on their local density

but due the existence of the SFR – M* correlation it is extremely difficult to determine whether the environment acts effectively or if it biases galaxies to high masses

- % of LIRGs vs density, sSFR=SFR/M* vs density => real environment effect exists

- Yet M* is the key parameter. Does this imply pure internal physics ?

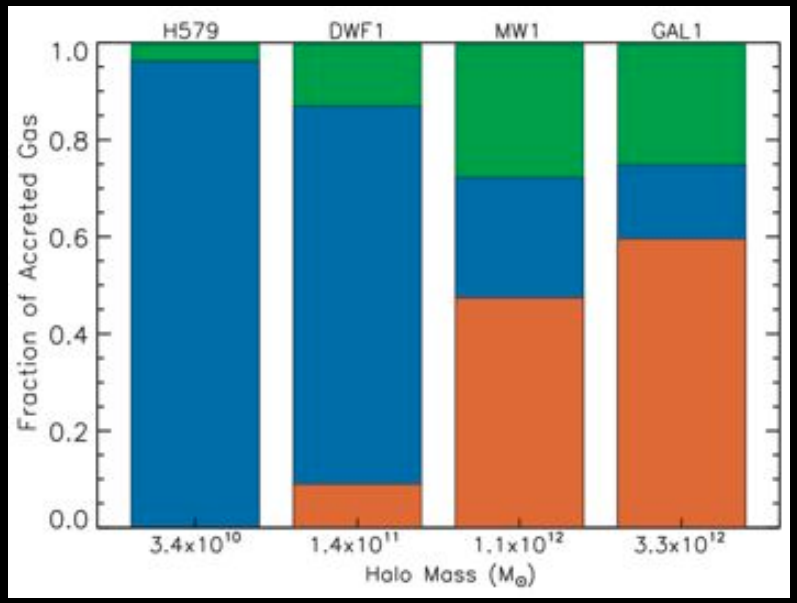
→ cold flows are evocated to explain the SFR – M* relation (Bouché+,Peng+,Dekel)

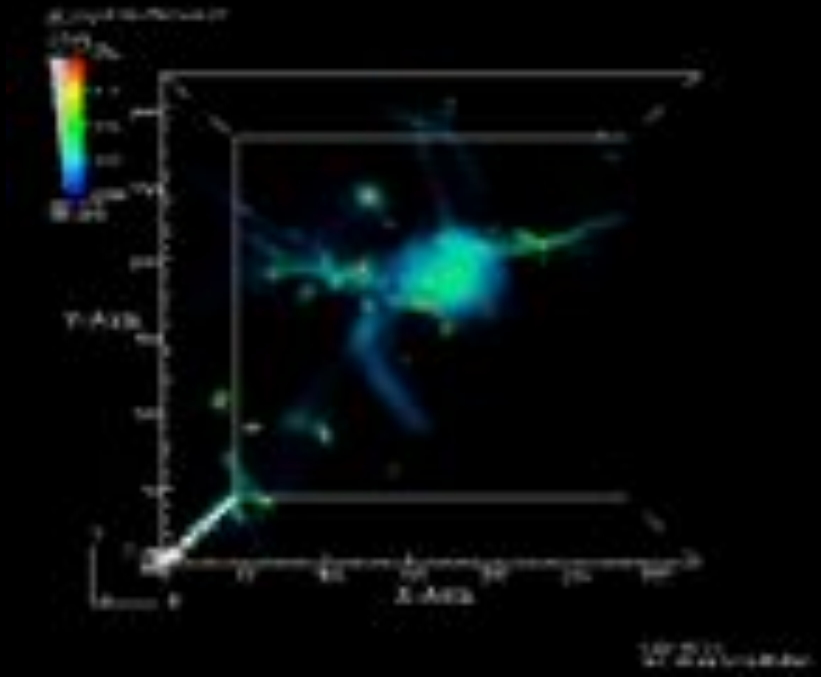
→ hence environment effect ! + ~25% minor mergers with the "clumps" of the flows

- SFR – M* relation → long duty cycle for high SF gals & 2 regimes of star formation
  - → distant (U)LIRGs are not systematically starbursts but mainly Main Sequence SF
  - → ≠ in the spatial distribution of SF
  - → starbursts always make <20% of the cosmic SFR density
  - → IR8=Lir/L8 = SF density indicator

- Today dense regions of Universe "dead": quenching/acceleration of SF ?
  - → need to study MS and SB galaxies (≠sSFR) vs M*, environment, z (Z)

Cold flows, galaxy interaction & environment





% gas accreted in virial radius since z = 6 as: "clumpy", "unshocked" & "shocked" gas
(Brooks +09)

Galaxy	f_{smooth}	f_{clumpy}	f_{shock}	$f_{unshock}$
H579	0.96	0.04	0.00	1.00
DWF1	0.87	0.13	0.10	0.90
MW1	0.73	0.27	0.65	0.35
GAL1	0.75	0.25	0.79	0.21