Result from Herschel-PACS

"Deep Herschel far-infrared extragalactic surveys"

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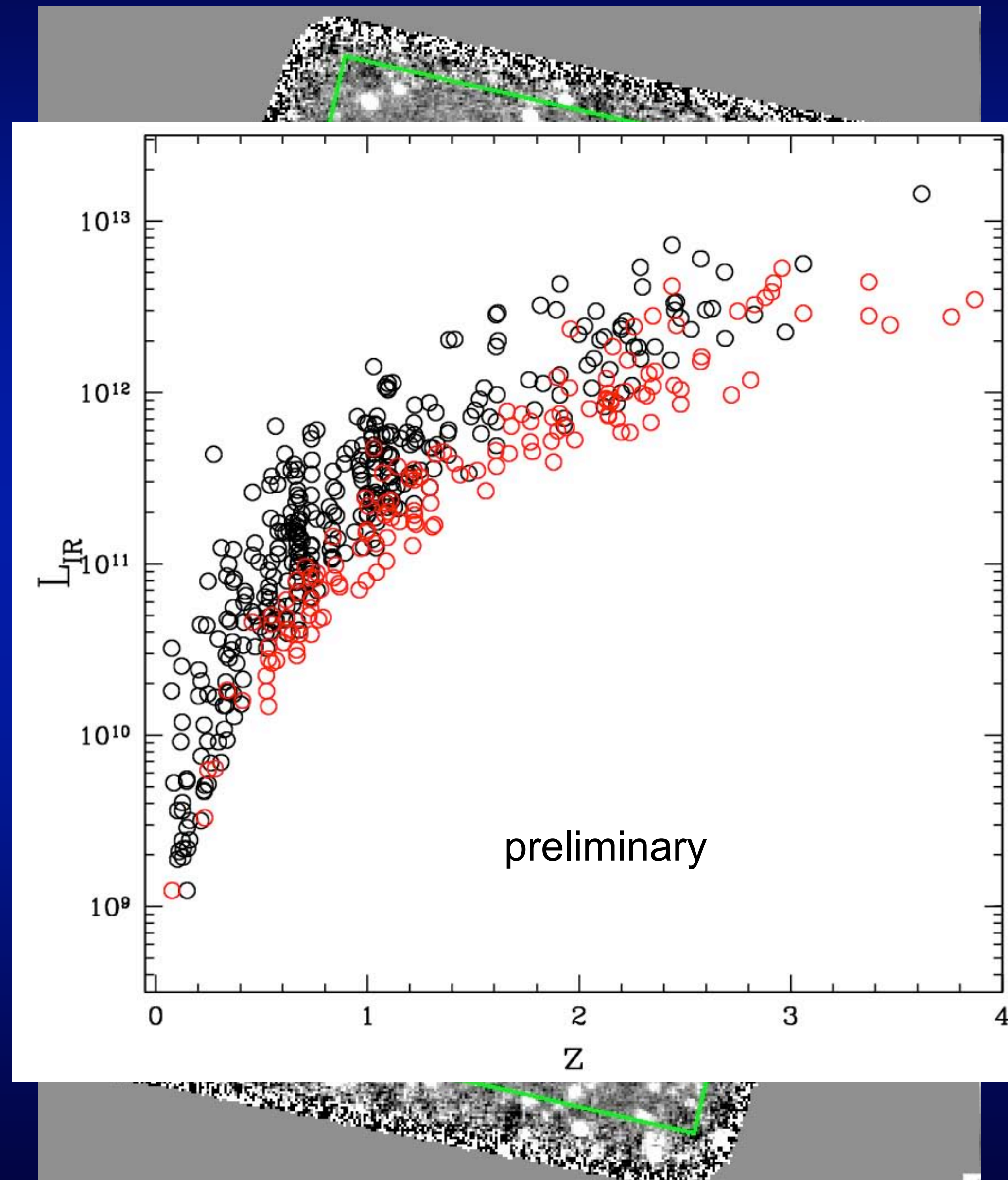
+ PEP Herschel GTO survey team

The Submillimeter Universe: The CCAT view

Ithaca, November 12, 2010

From MIPS to PACS



GOODS-S MIPS 160μm
GOODS-S PACS 160μm
FIDEL team
PEP team

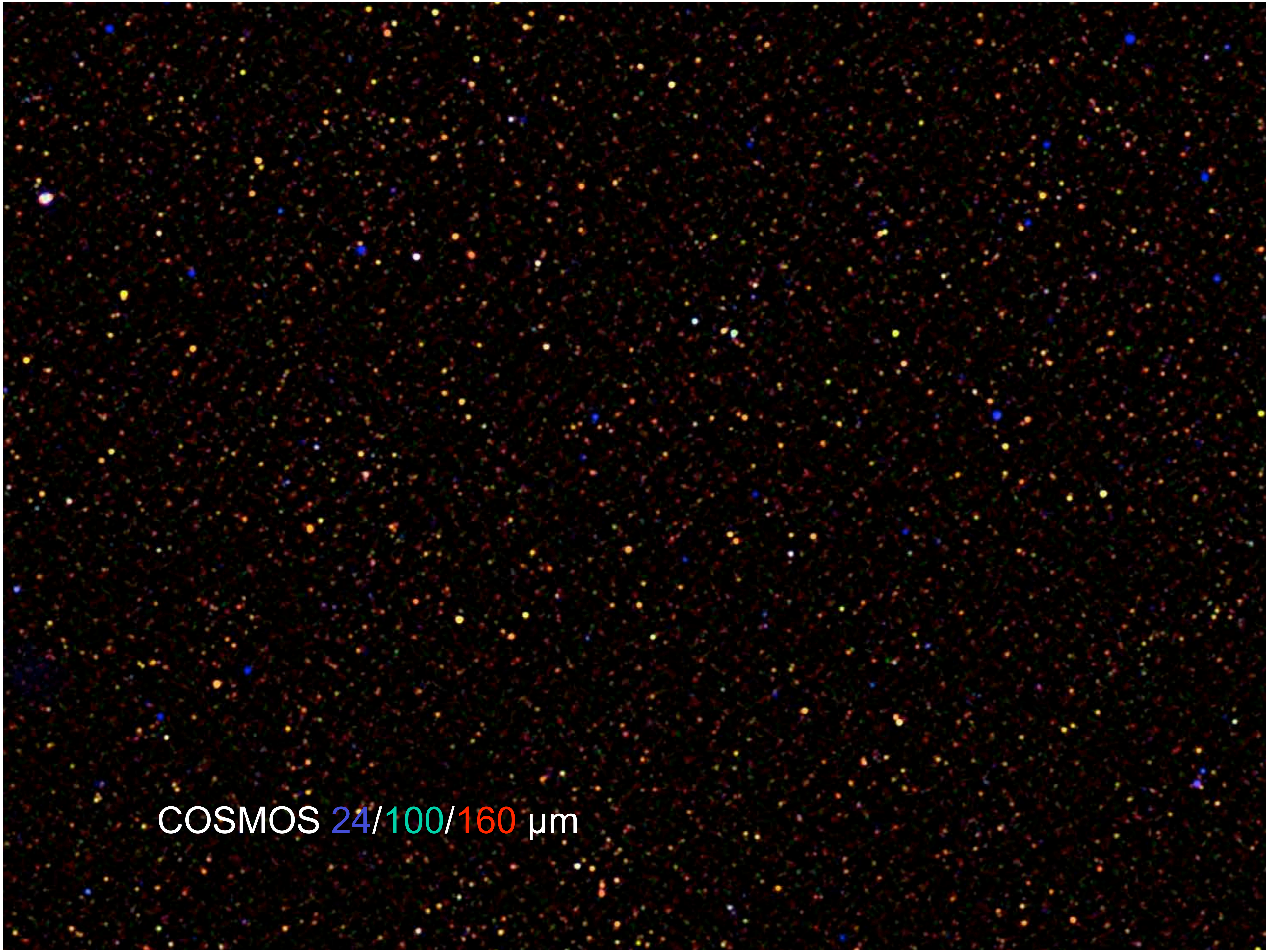
PACS Evolutionary Probe (PEP) - Fields

- PEP is the major Herschel 100/160μm extragalactic survey of key multiwavelength fields

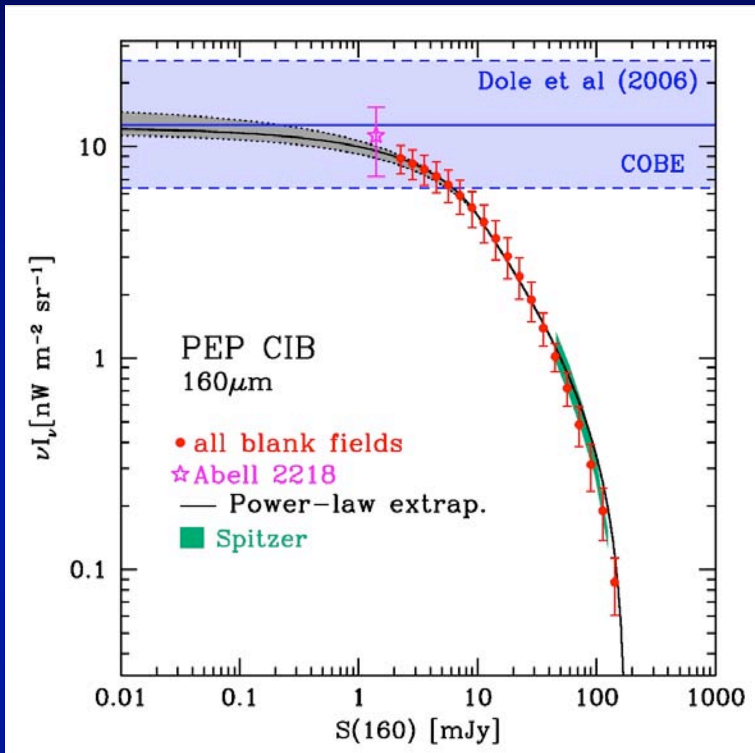
Field	Area	Total Exp. [hours]
COSMOS	85'x85'	213
Lockman Hole	24'x24'	35
E-CDFS	30'x30'	35
Groth Strip	67'x10'	35
GOODS-S	10'x15'	113 113
GOODS-N	10'x15'	30

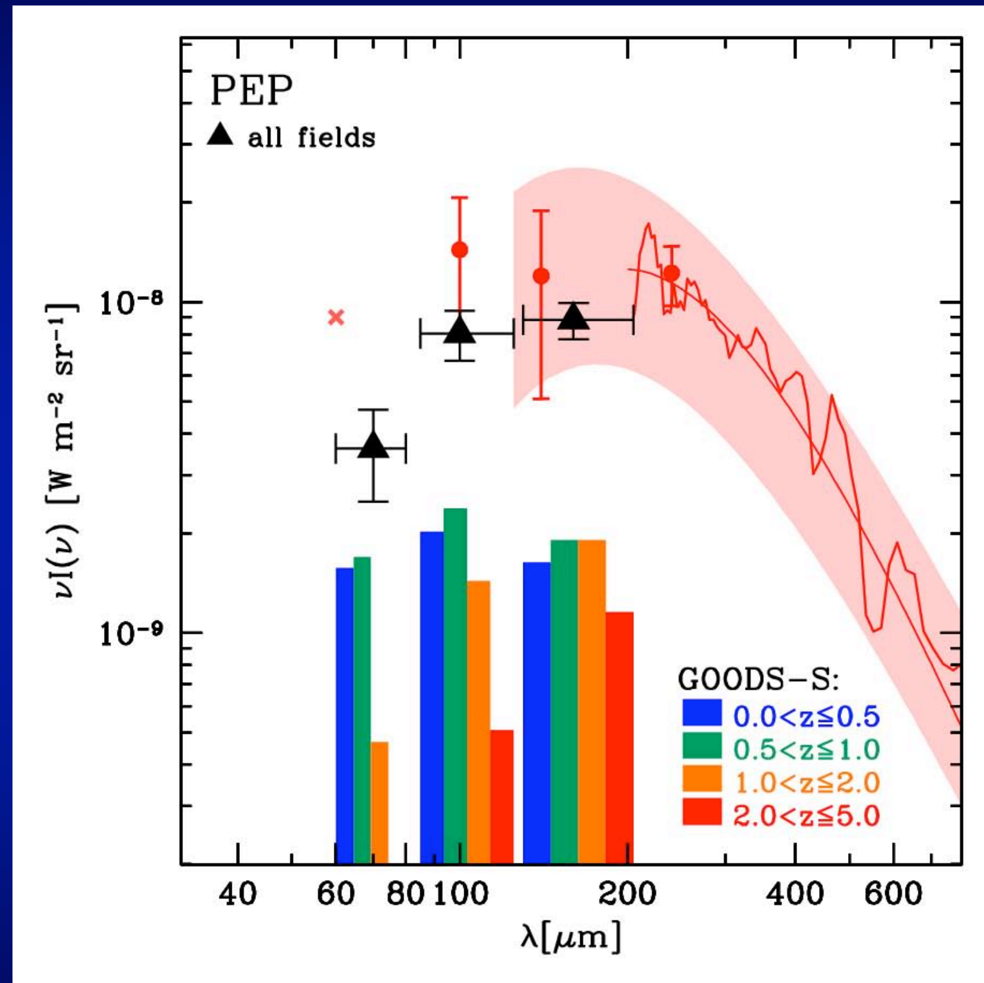
- +10 lensing galaxy clusters

- Coordinated with Hermes for SPIRE 250, 350, 500 μm coverage
- Hermes and Atlas extend to wider+shallower PACS coverage
- GOODS-Herschel is going deeper on (parts of) GOODS fields
- Herschel lensing survey substantially extends the number of lensing clusters


COSMOS 24/100/160 μm

Resolving and slicing the CIB





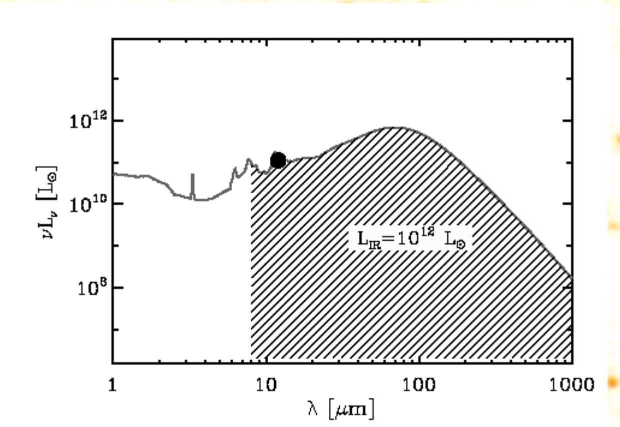
10x deeper!

Resolved into individual sources:
(~35% @ 70μm)
~55% @ 100μm
~70% @ 160μm

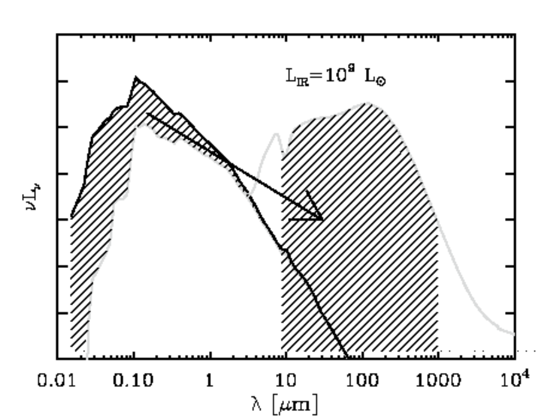
Berta+ 2010 and in prep.

Far-infrared calorimetric star formation rates

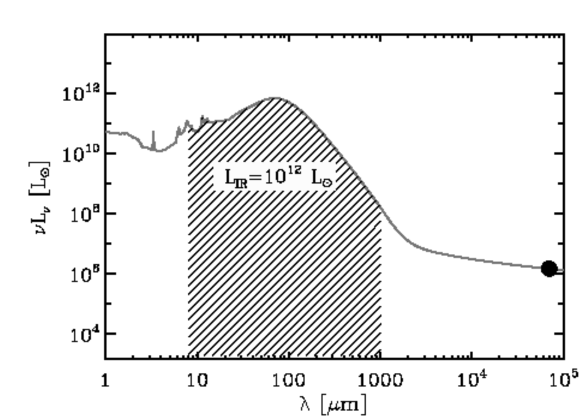
How good are the extrapolations from the mid-infrared, optical, radio that we have been using for studying galaxy evolution and star formation rates?



From 24μm



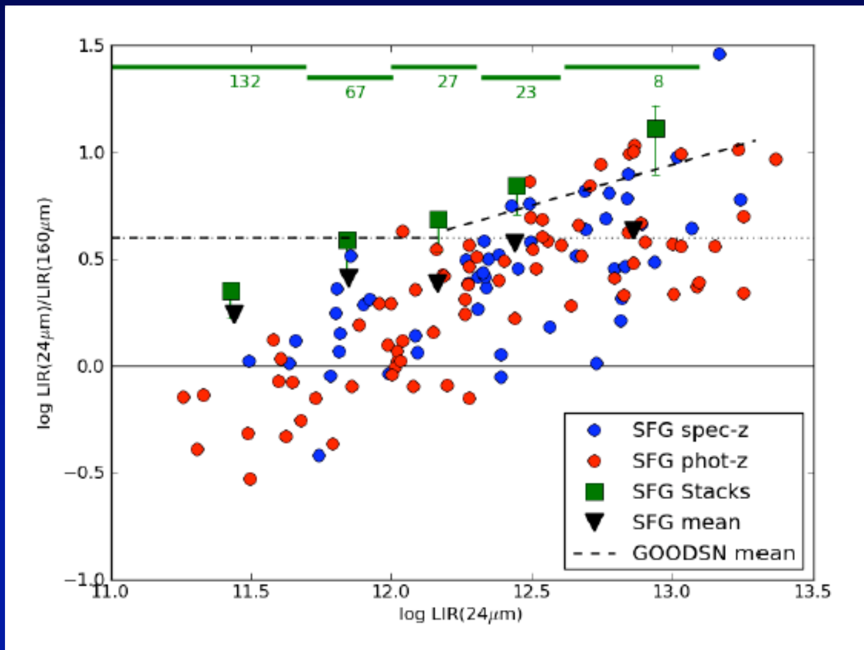
From rest frame UV



From submm/radio

COSMOS 24μm image

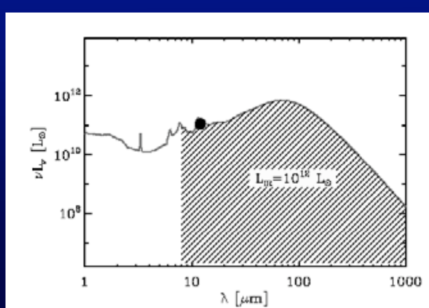
Z~2: Extrapolation from 24μm overpredicts FIR

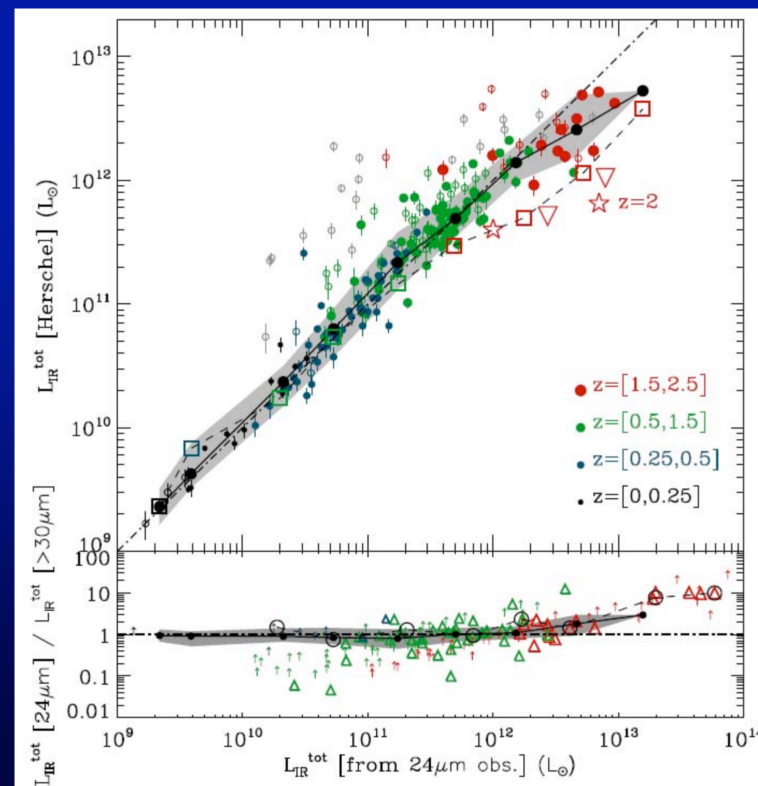


Obscured AGN and/or changing SED shape/PAH strength at given L?
See also Daddi+07, Papovich+07

Setting in of the effect at z=1.5 favours PAH

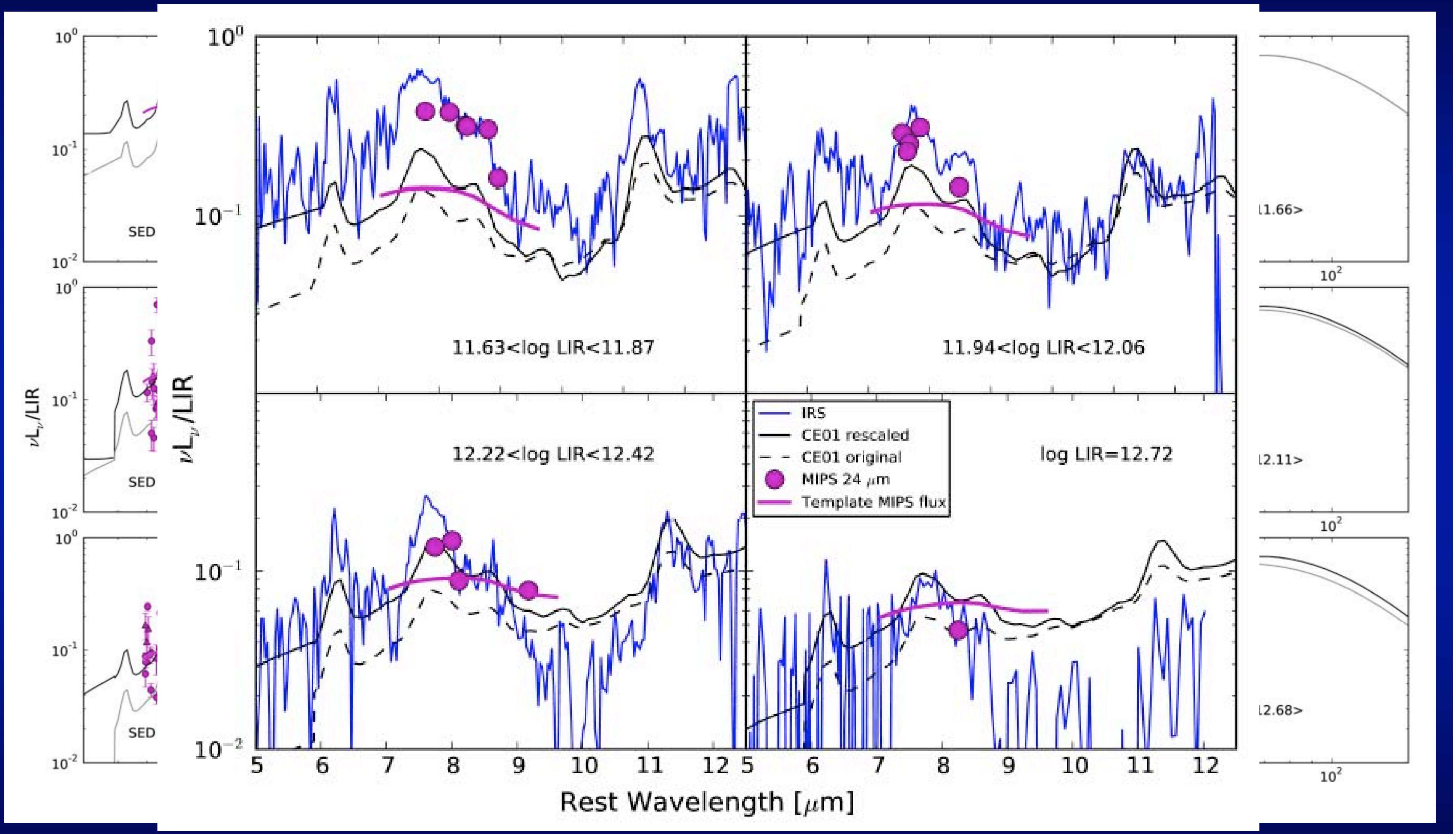
Nordon et al. 2010
Massive BzK galaxies





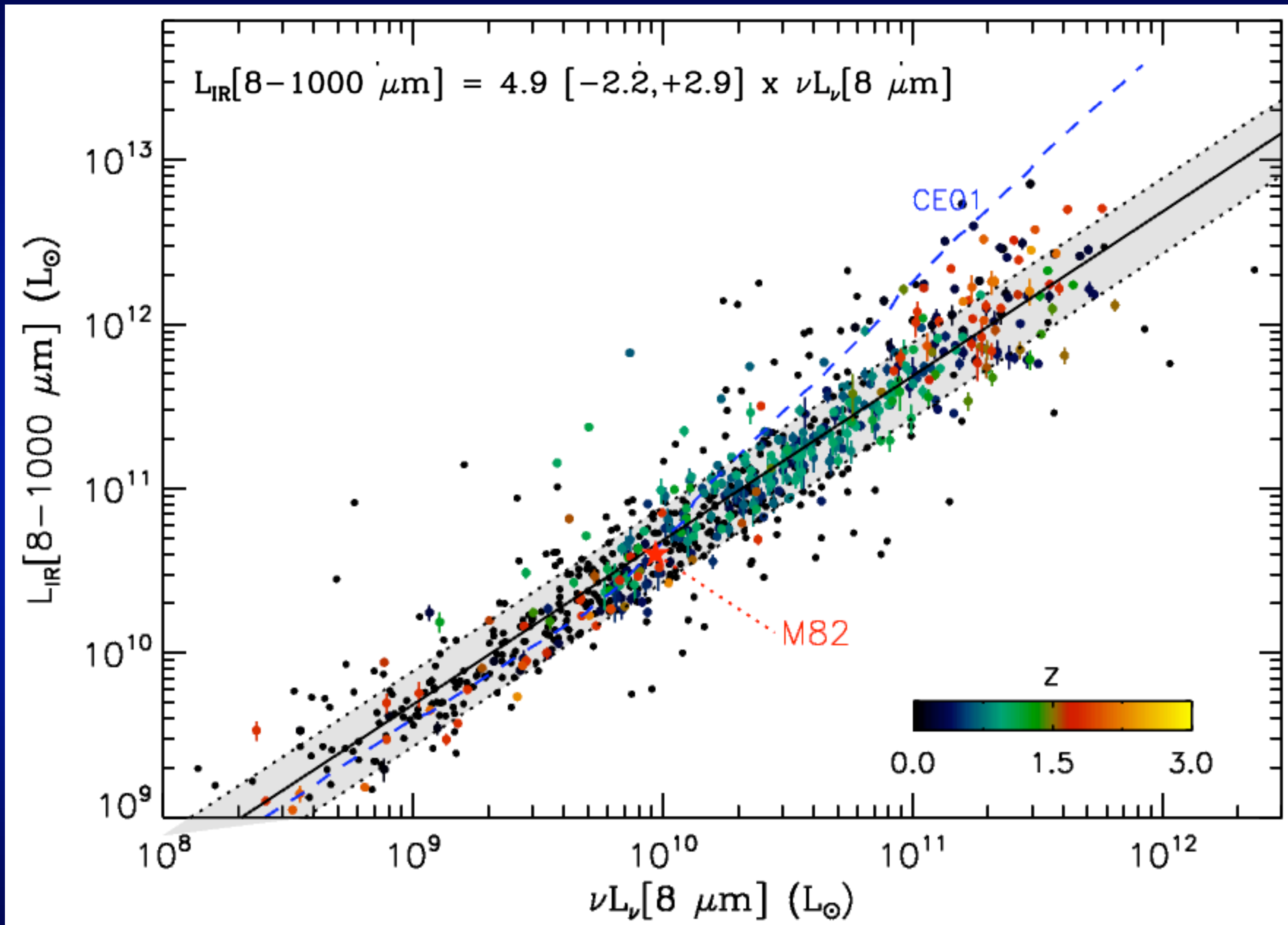
Elbaz et al. 2010
IR galaxies

AGN dilution or enhanced PAH / FIR ratio?



IRS spectra: Fadda, Yan+ 2010, see also Murphy+ 2009

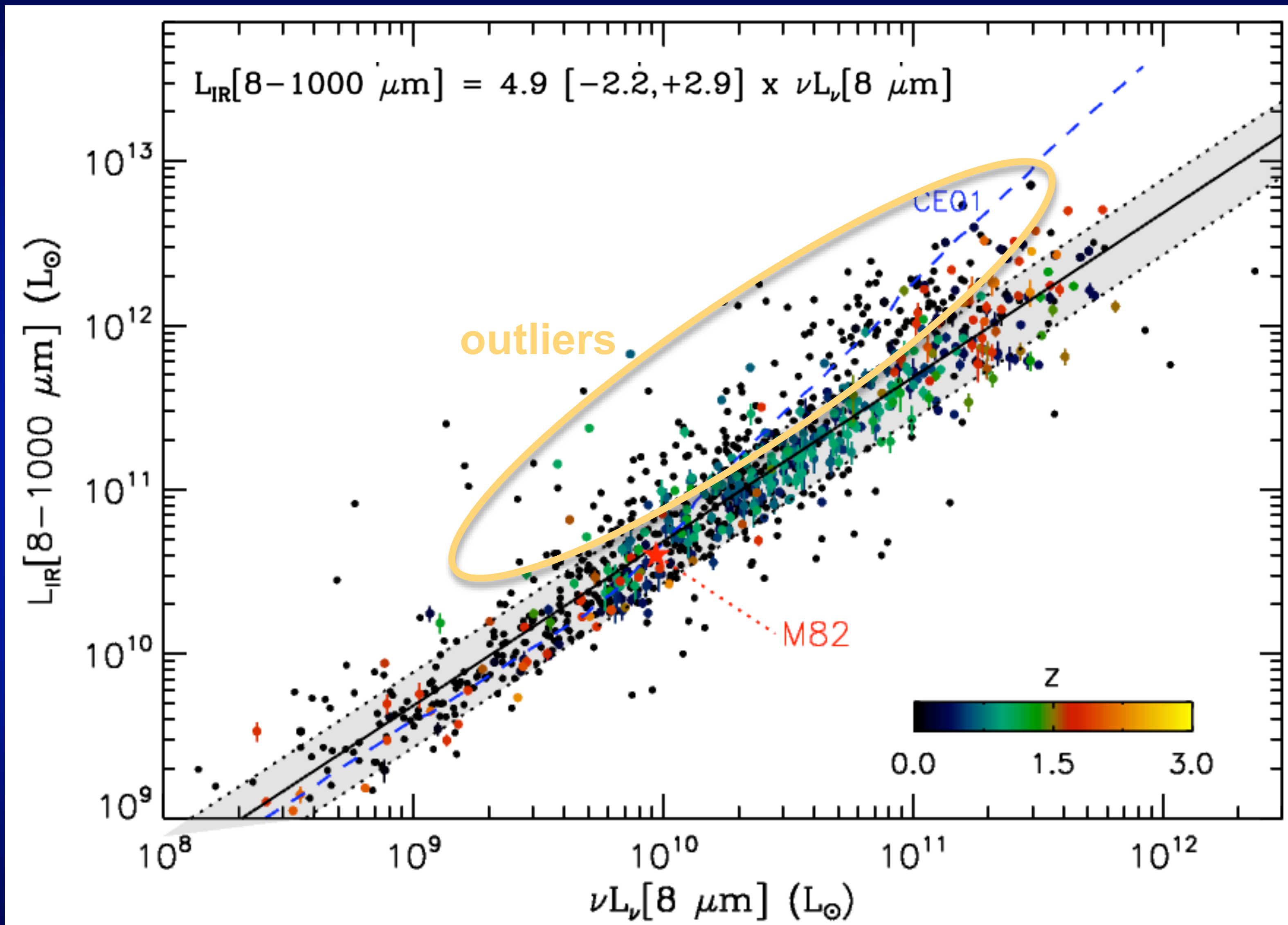
Local galaxies & distant galaxies



ISO + AKARI + GOODS-H + PEP/GOODS-S

Elbaz+ in prep

Local galaxies & distant galaxies



Elbaz+ in prep

ISO + AKARI + GOODS-H + PEP/GOODS-S + GOALS

Implications for SEDs of z~2 galaxies

- Far-Infrared SED shape changes little between 10^11 and 10^13 L_{Sun}, always 'LIRG-like'

- Mid-Infrared:
  - Systematically higher compared to FIR than previous local templates
  - Less trend of MIR/FIR with L_{IR} than local
  - Significant scatter of MIR/FIR ~0.4dex –This is what will remain as limitation to 24um based studies!
  - The mid-IR excess is PAH, even for many X-ray AGN

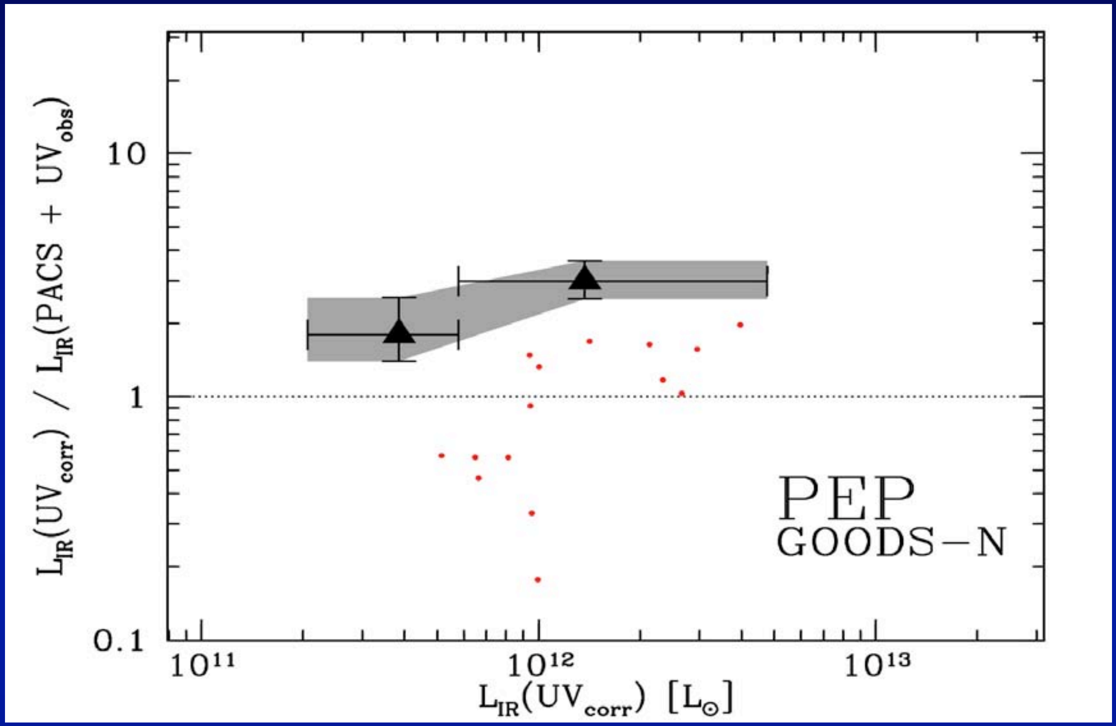
- The term 'ULIRG' has conotations on properties besides the luminosity threshold that apply at z~0 but not necessarily at z~2

A galaxy forming stars at 100Msun/year:

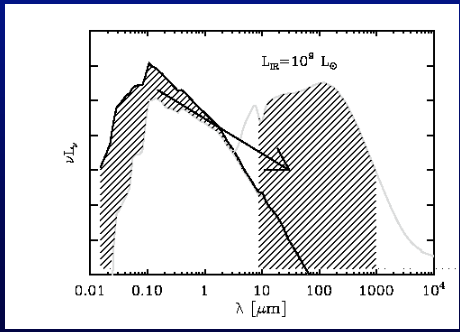
- z~0: A peculiar interacting/merging galaxy with a compact obscured circumnuclear star forming region
- z~2: A galaxy on the mass / star formation `main sequence', extended and less obscured disk star formation

Nordon+10 and in prep, Elbaz+ 10 and in prep, Hwang+ 10, Rex+ 10

Z~2: Extrapolation from rest frame UV slightly overpredicts FIR

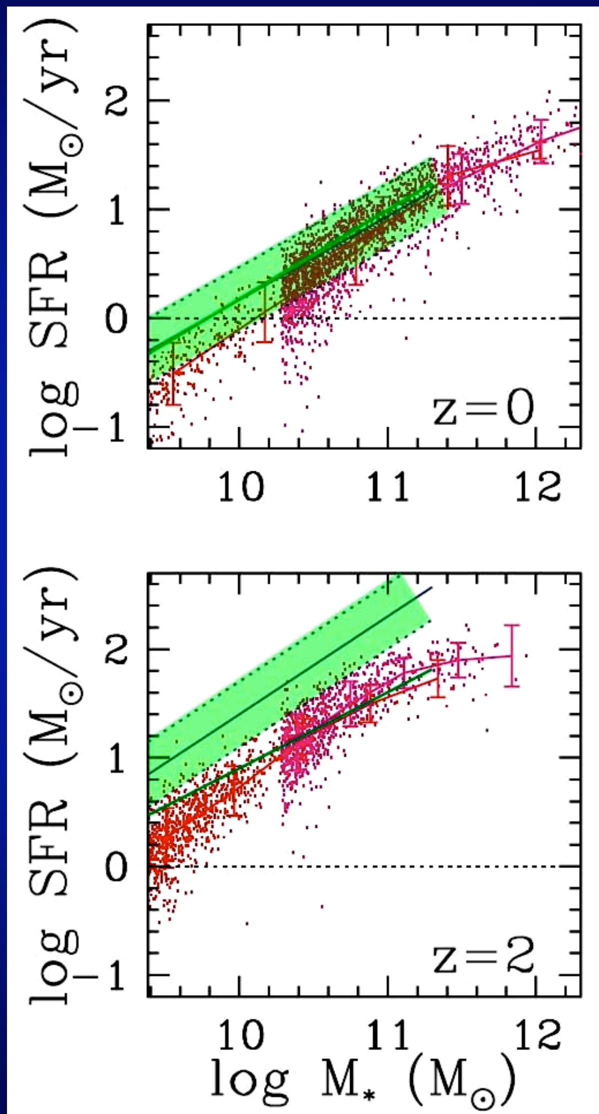


Modest modification to extinction law needed?

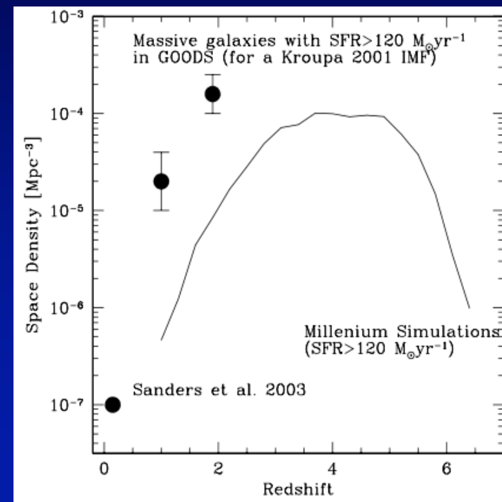


Nordon+ 2010

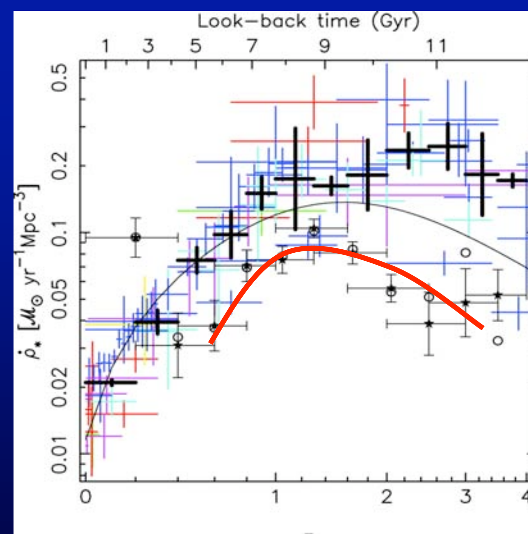
Towards reconciling observed and theoretical star formation rates



Dave 08

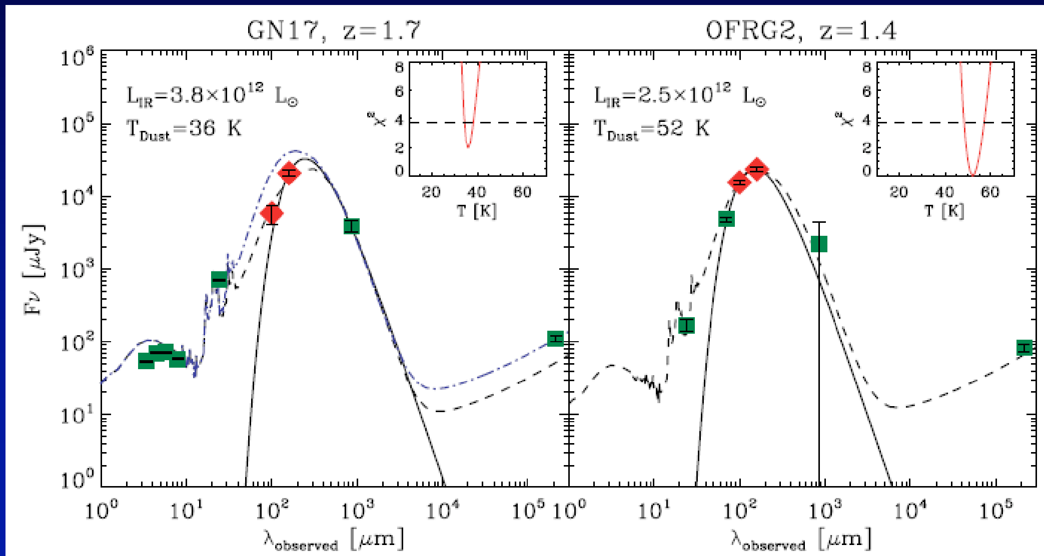


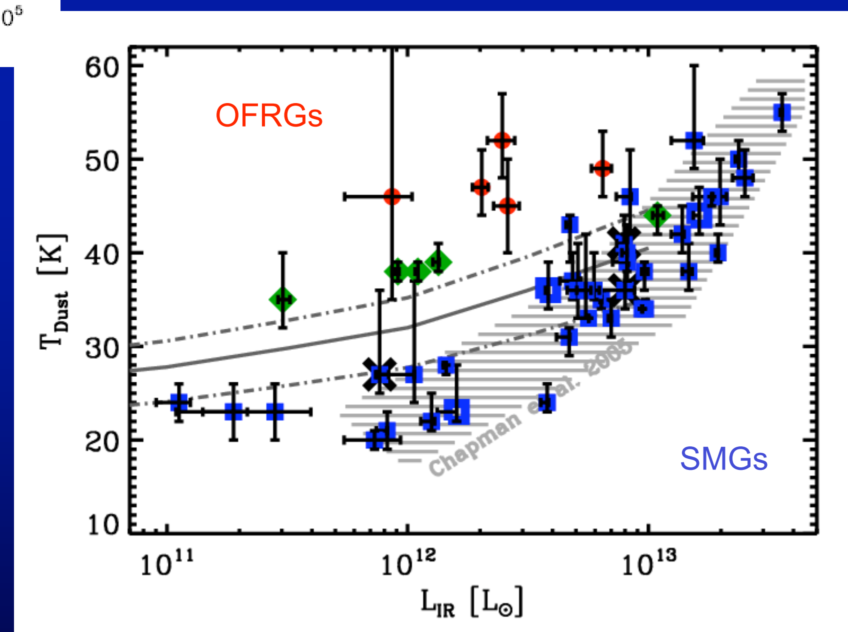
Daddi+ 07



Perez-Gonzalez+08

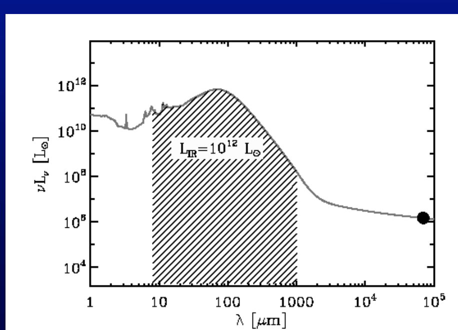
The most luminous star forming galaxies





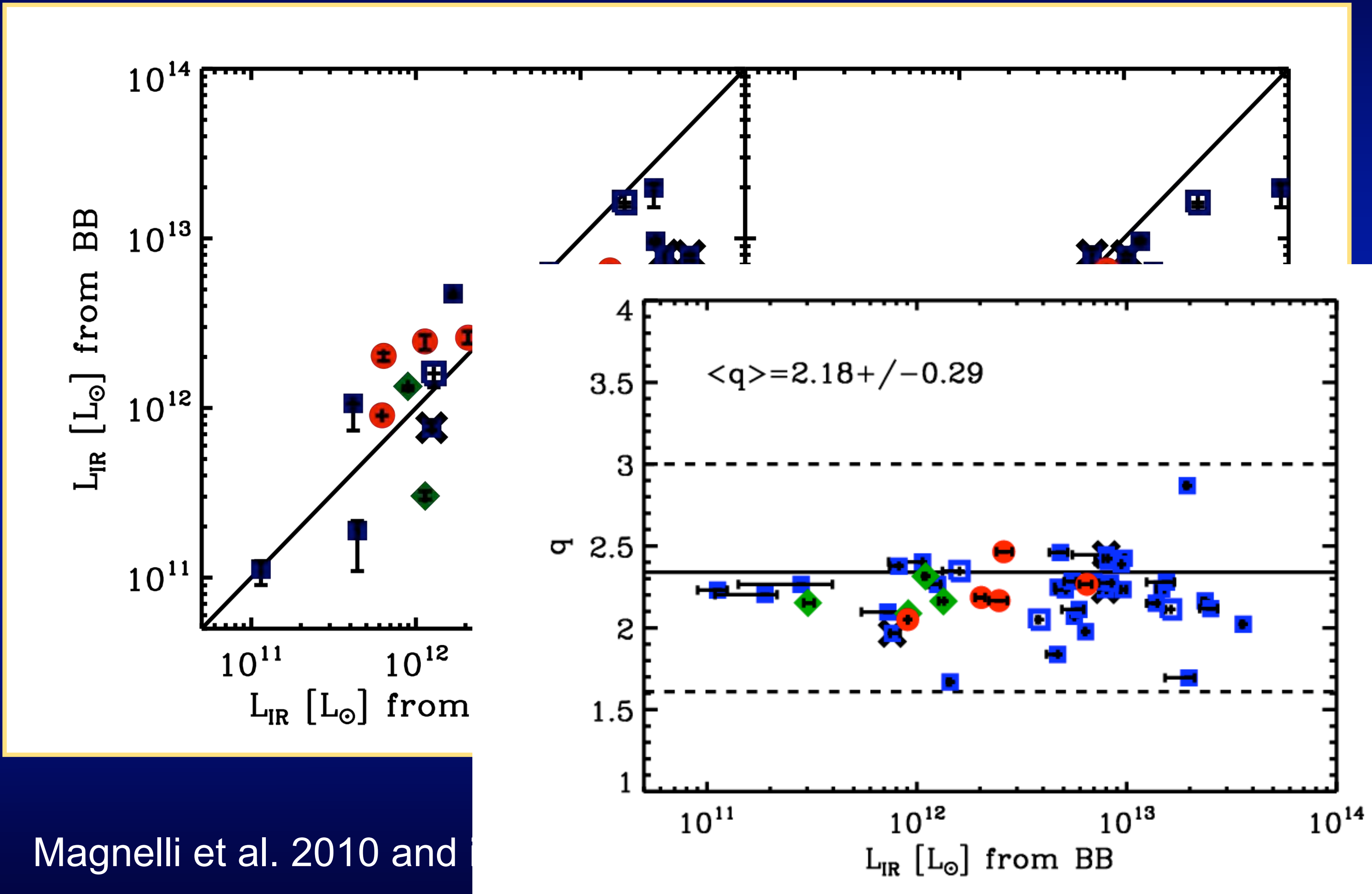
Star formation rates ~1000M_{Sun}/yr!

.. Note previous selection effects



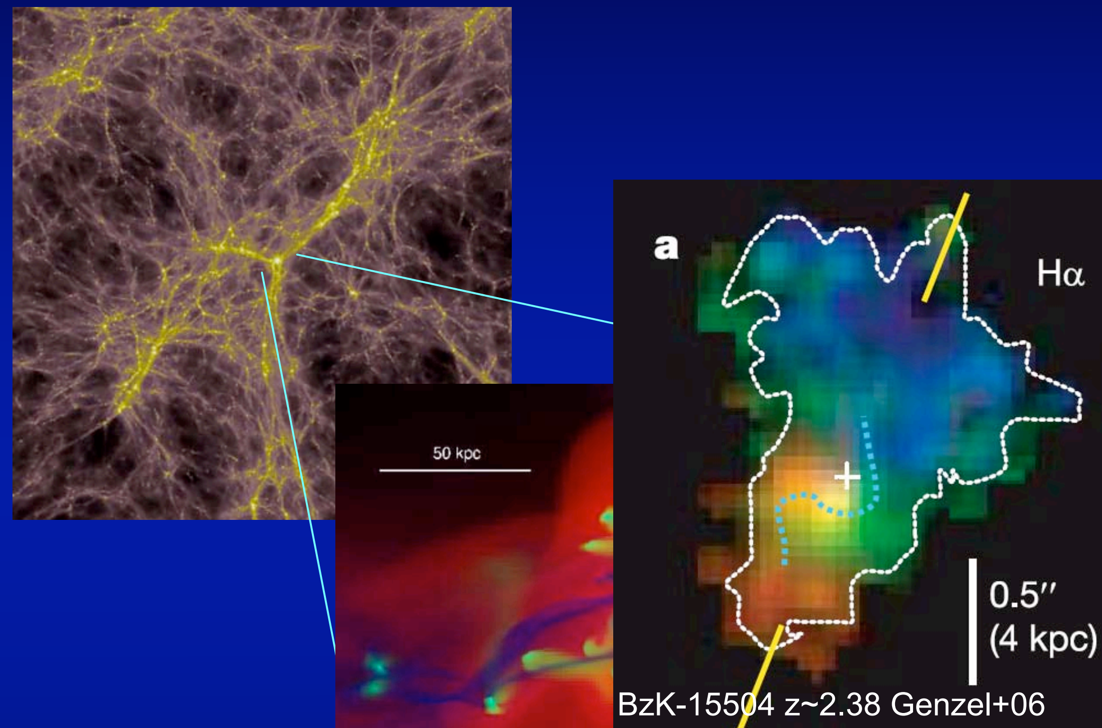
Magnelli et al. 2010 and in prep.
see also Chapman et al. 2010

24µm and radio-based star formation rates vs. Herschel



Magnelli et al. 2010 and

Drivers of galaxy and star formation at high-z



Major mergers
Hernquist, Springel, di Matteo, Hopkins et al

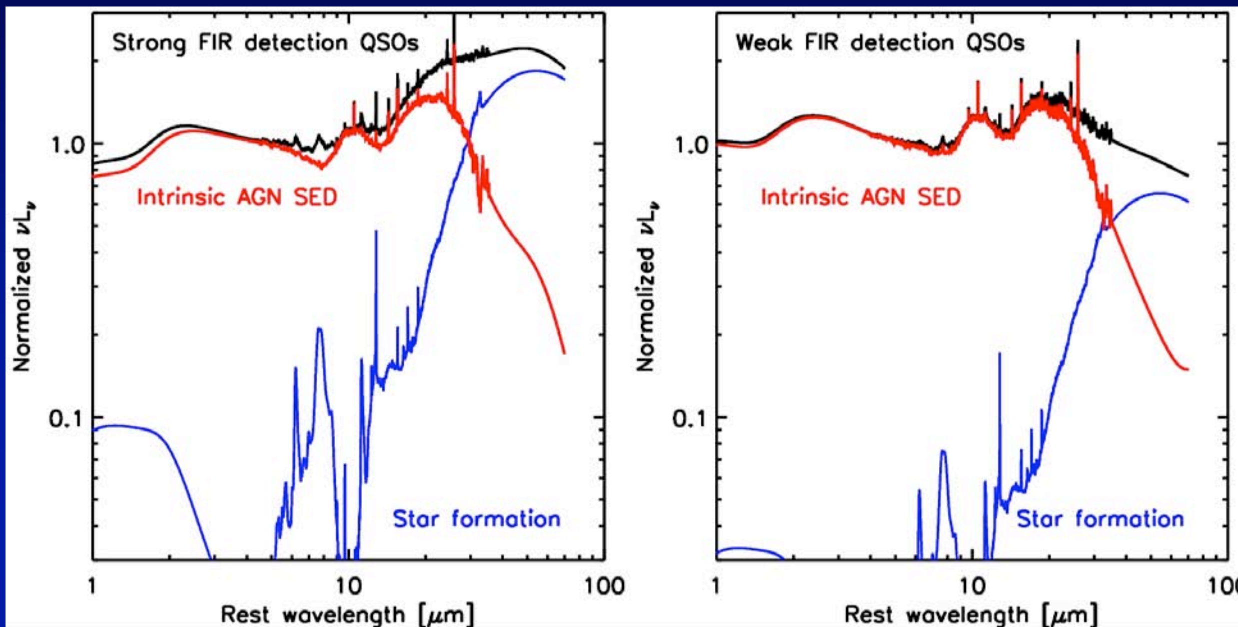
Minor mergers and steady accretion
White, Rees. Dekel, et al.

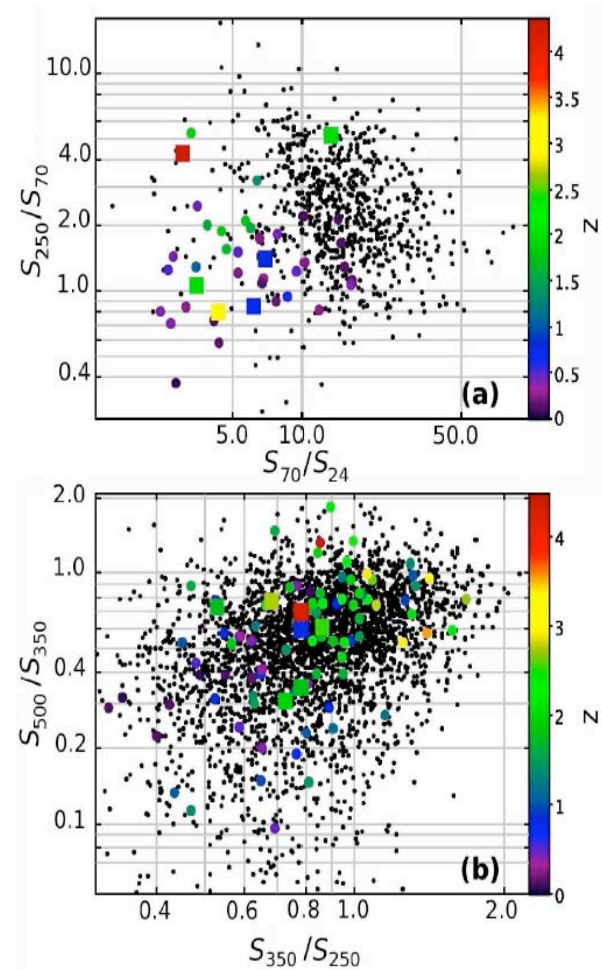
Sanders ’88 merger scenario
for local ULIRG/PG QSOs

Fairly tight star formation ‘main sequence’ SFR vs. Mass (Noeske+ Elbaz+ Daddi+)

Massive z~2 clumpy turbulent star forming disks (SINS, Genzel+, Förster Schreiber+)

Using the far-infrared continuum to measure star formation





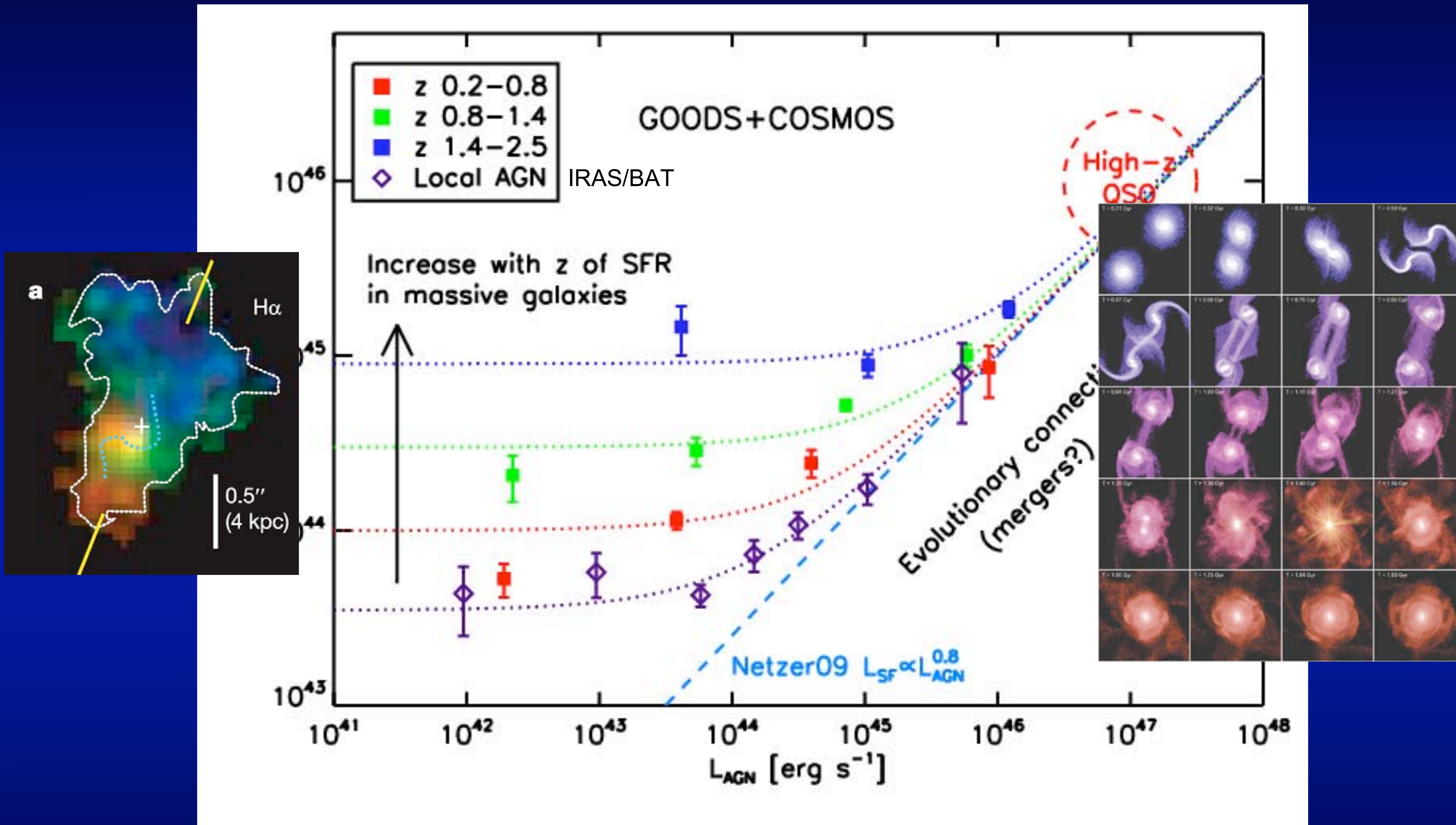
Hatziminaoglou+ 2010

QSO SEDs from Netzer+07

L(FIR)~0.1 L(BOL,AGN)

PEP far-infrared detection rates of hosts of Chandra 2Msec AGN:
~20% GOODSN
~40% GOODSS
Stack on nondetections

Two modes of AGN / host coevolution: Merger vs. secular

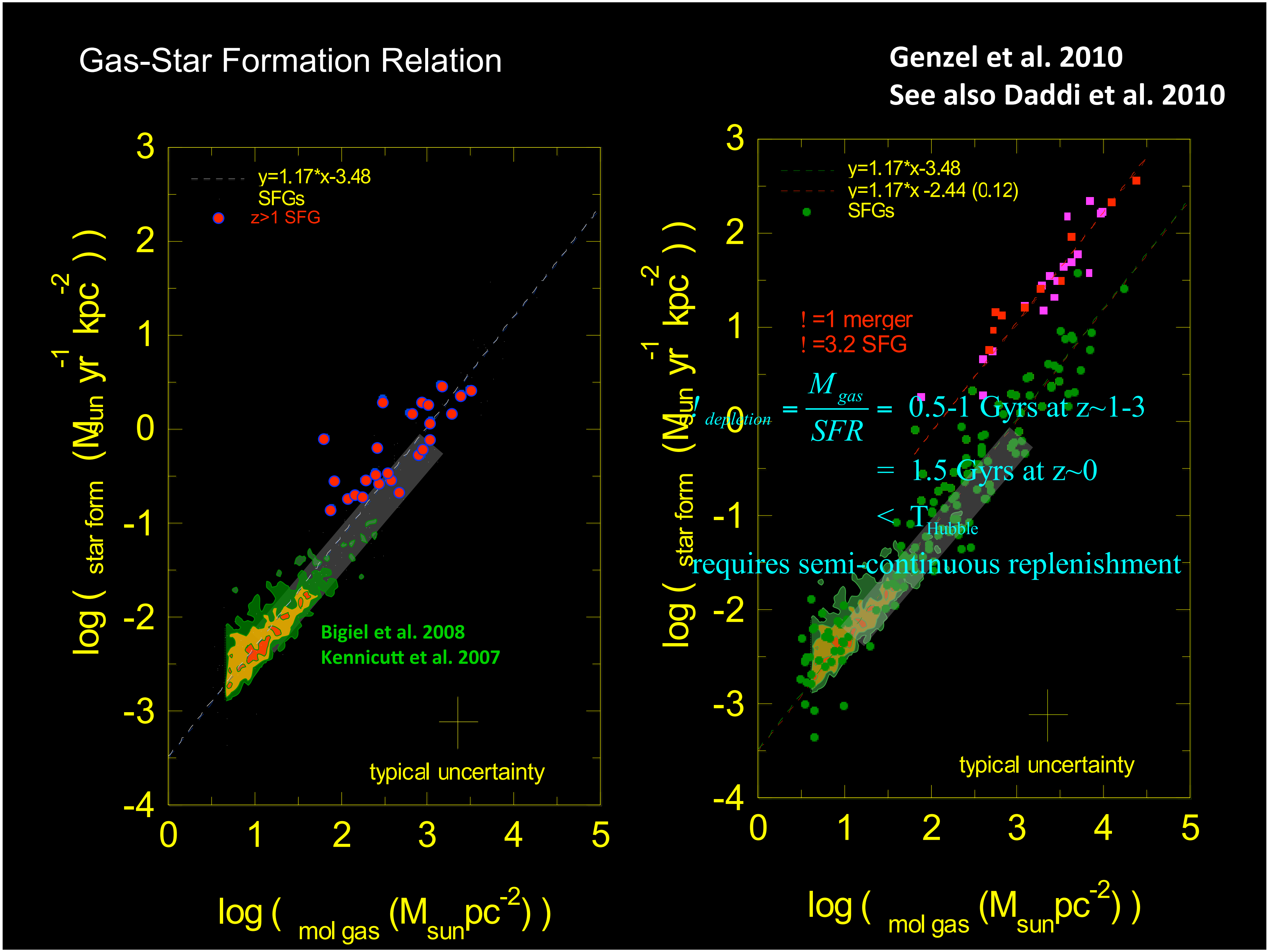


Shao et al. 2010 and in prep.

(see also Lutz et al. 2010 submm results, Mullaney et al. 2010 Spitzer)

Further support for non-merger nature of a major fraction of X-ray AGN

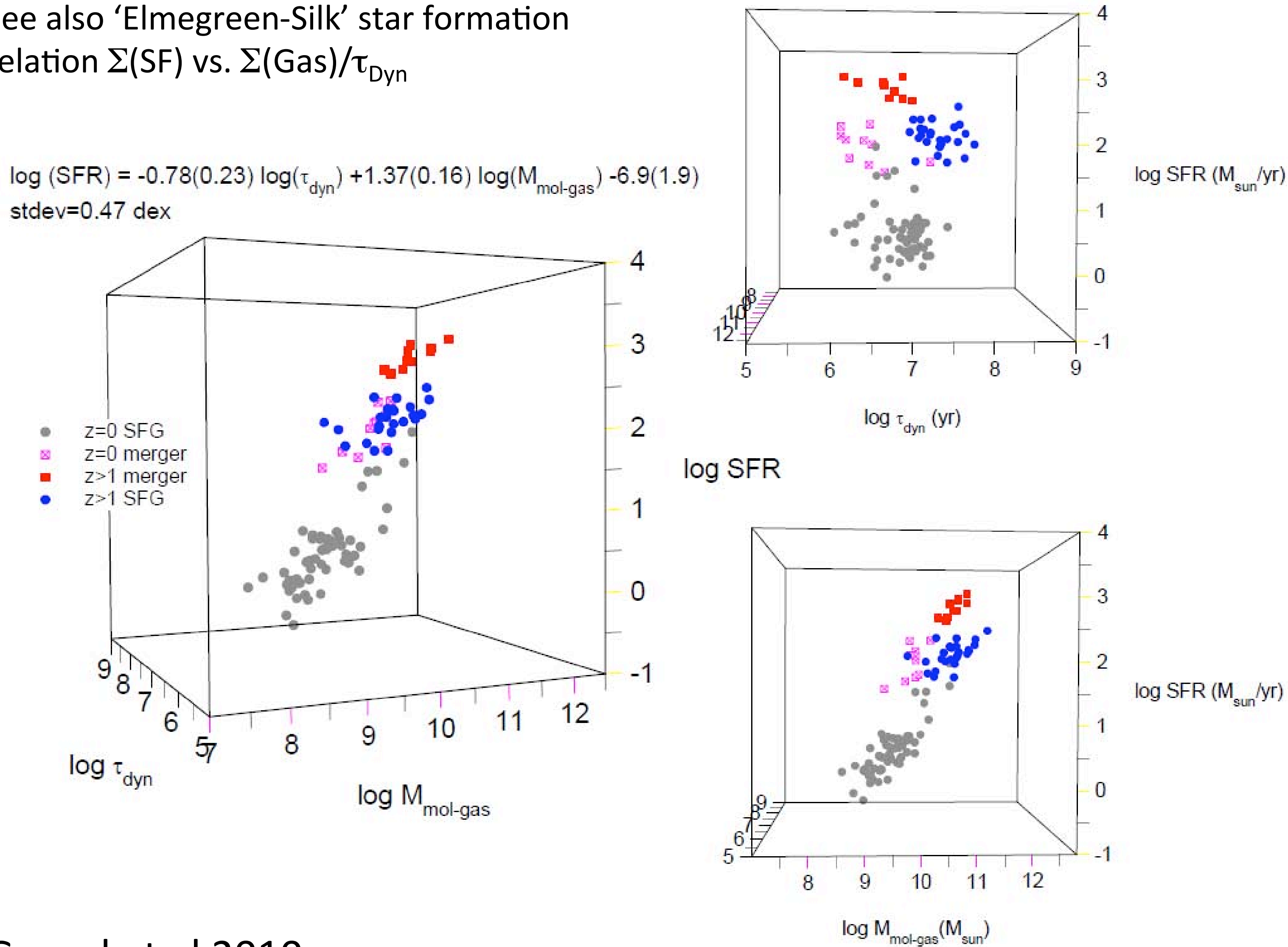
- HST morphologies typically show bulgy morphologies with few mergers (Grogin+05 Pierce+07, Gabor+09, Cisternas+10)
- Host colors are similar to *mass-matched* non active galaxies (Xue +10)
- [OII] SFRs are similar to those of inactive galaxies (Silverman+09)
- Rate of cosmic halo mergers is ok to match quasars, but not all X-ray AGN (Hasinger+08, Hopkins+09)



Gas-Star Formation Relation
Genzel et al. 2010
See also Daddi et al. 2010
y=1.17*x-3.48
SFGs
z>1 SFG
Bigiel et al. 2008
Kennicutt et al. 2007
typical uncertainty
log (star form (Msun yr-1 kpc-2))
log (mol gas (Msun pc-2))
y=1.17*x-3.48
y=1.17*x -2.44 (0.12)
SFGs
! =1 merger
! =3.2 SFG
! depletion = M gas / SFR = 0.5-1 Gyrs at z~1-3
= 1.5 Gyrs at z~0
< T Hubble
requires semi-continuous replenishment
typical uncertainty
log (star form (Msun yr-1 kpc-2))
log (mol gas (Msun pc-2))

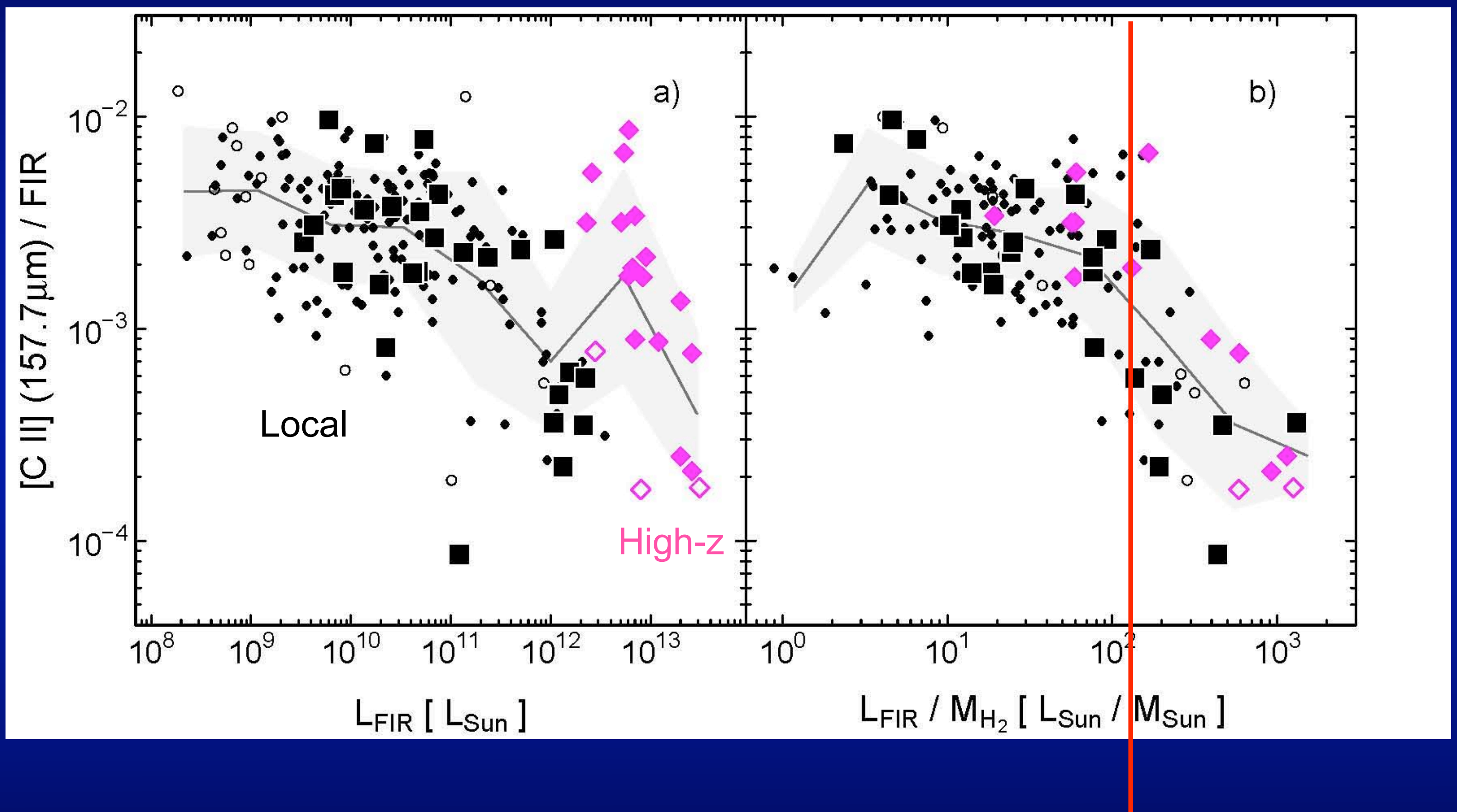
Global Galaxy Dynamical Timescale matters!

See also 'Elmegreen-Silk' star formation relation Σ(SF) vs. Σ(Gas)/τ_{Dyn}



Genzel et al 2010

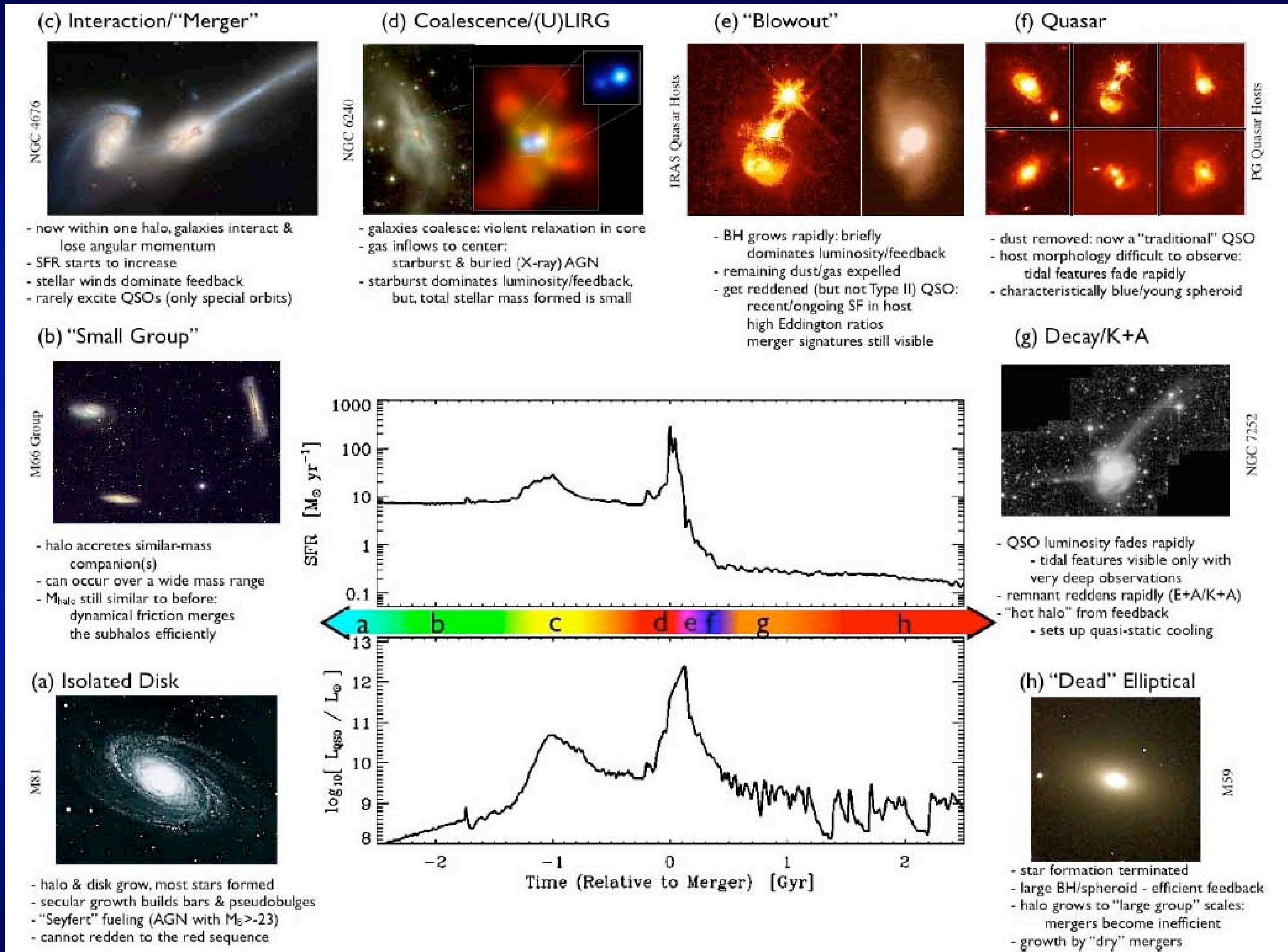
The [CII] deficit: Express in L/M_{Gas} rather than L



Border star forming / merger

Gracia-Carpio et al. submitted

Do we observe trends of star formation with AGN obscuration?

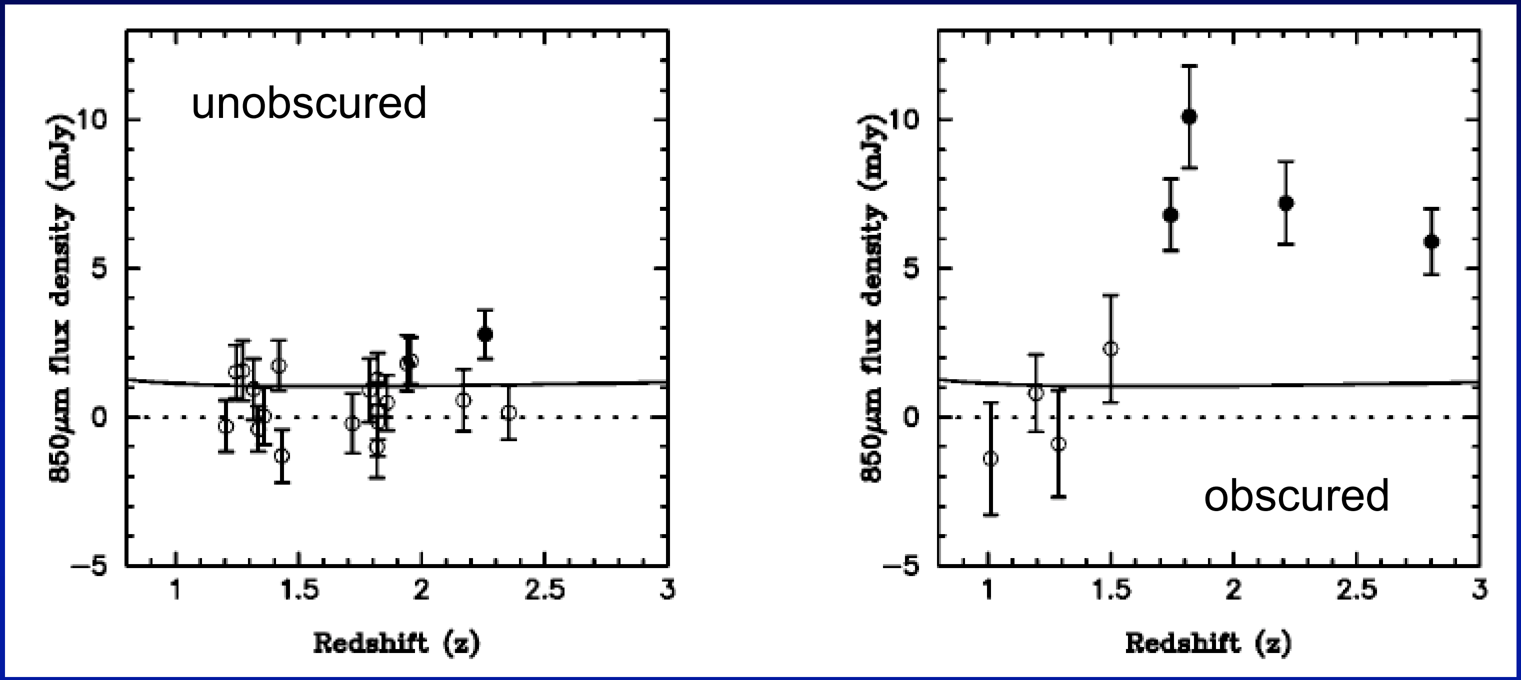


High SFR -- High SFR and obscured AGN -- Decreasing SFR and unobscured AGN

→ Expect a correlation host star formation – AGN obscuration!

Hopkins+08

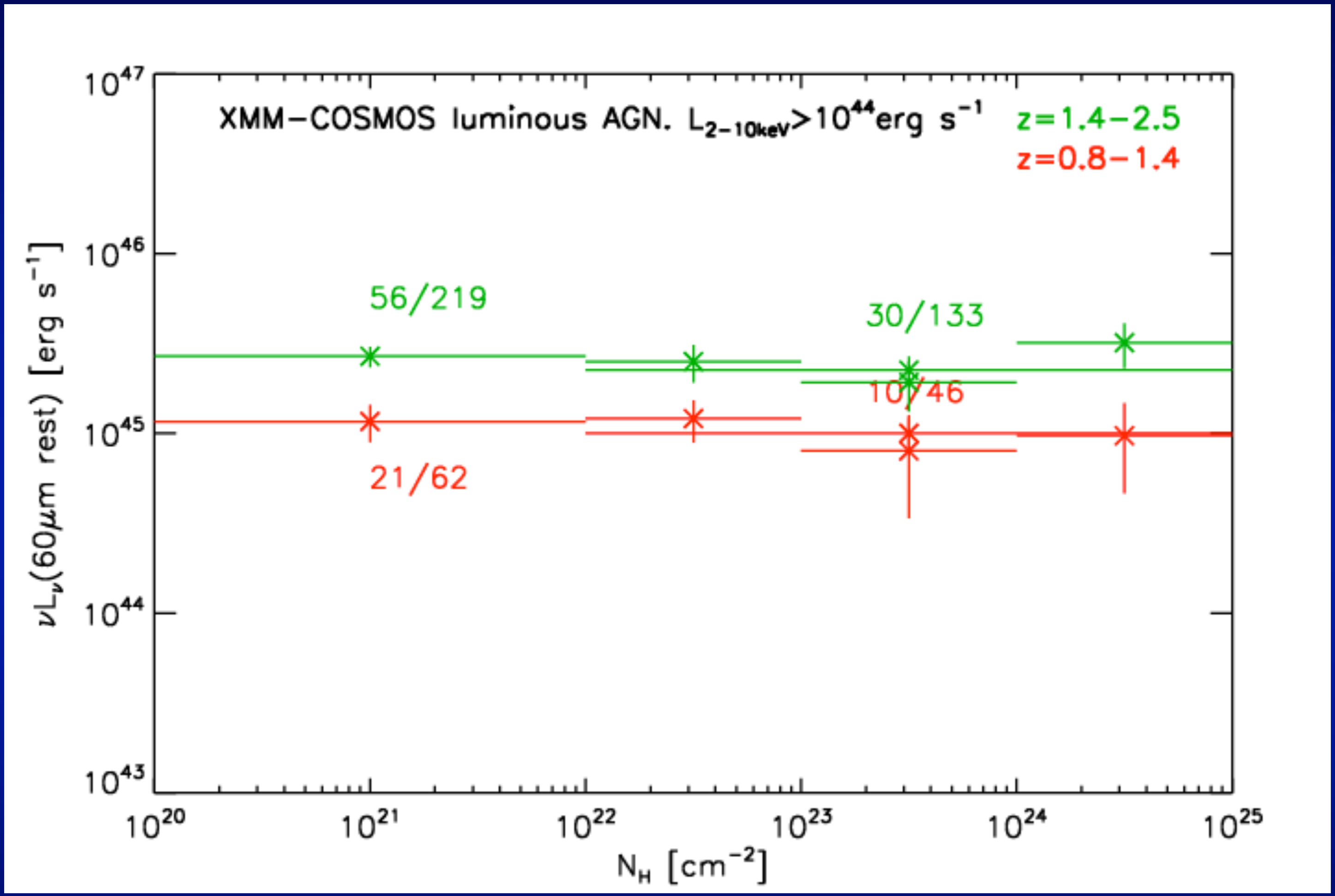
Submm indication for link host SF/ AGN obscuration:



Page, Stevens et al., 2001 etc.

Higher submm detection rate of X-ray obscured QSOs compared to unobscured
… but note special objects: Optical Type 1 but X-ray absorbed, extremely luminous

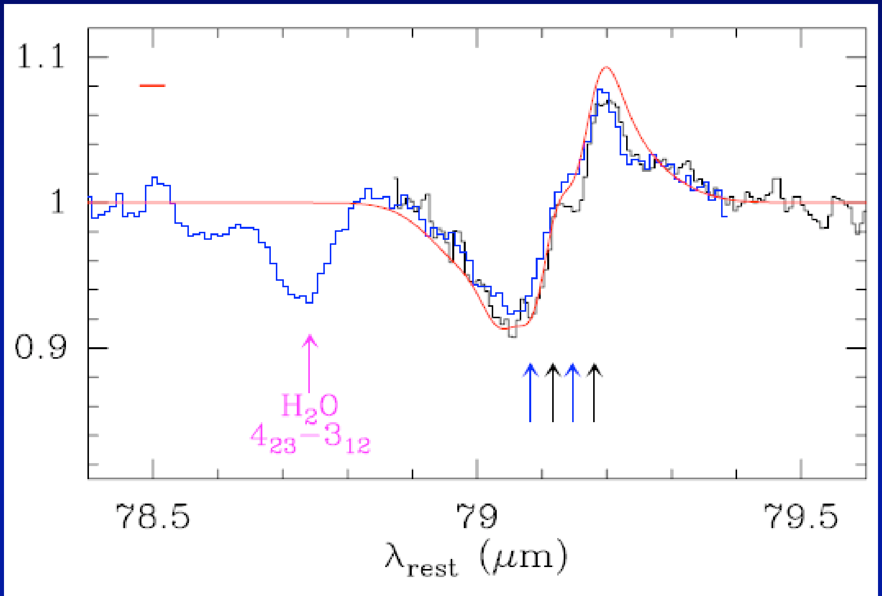
Z~1-2 L(2-10keV)>10^44 COSMOS AGN: No trend

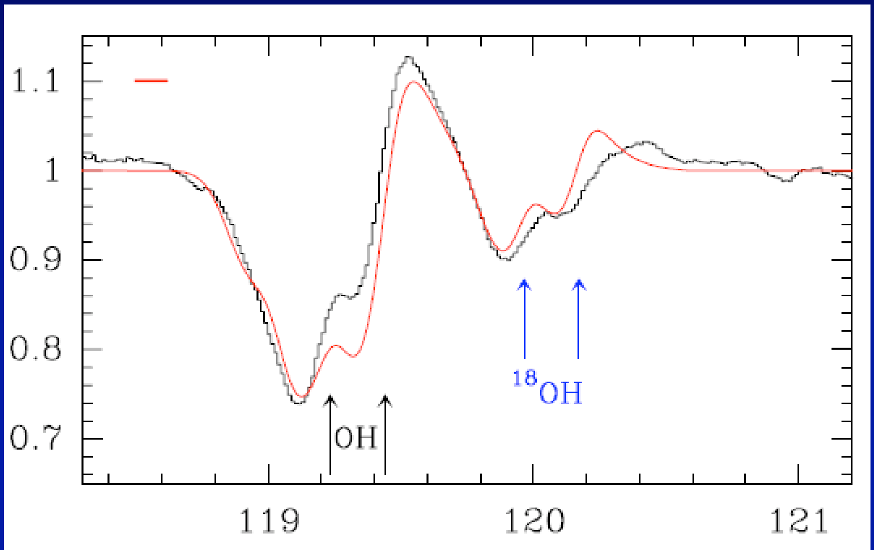


… not what is suggested by the most simple version of a merger evolutionary pattern!

AGN(?) feedback at work…

OH absorptions in the AGN ULIRG Mrk 231



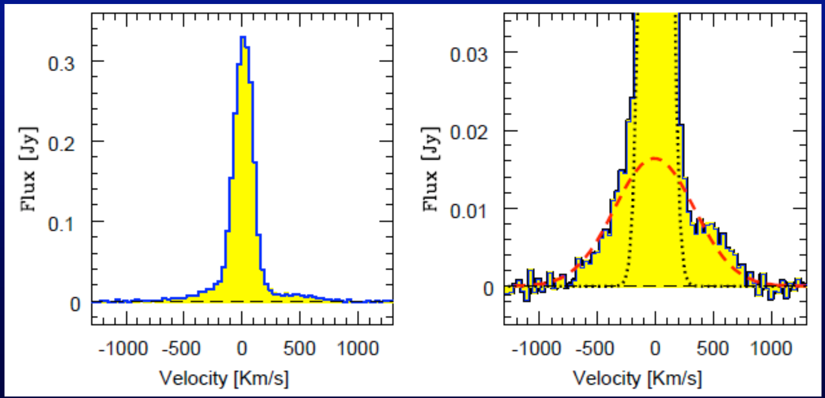


Fischer et al. 2010. First estimates:

- outflow mass of $7x10^7$ Msun
- outflow velocities of -1400 km/s
- Mechanical energy ≥ 10^{56} erg/s

See also Feruglio et al. 2010
(Mrk 231 CO IRAM PdB)

- Outflow rate ~700Msun/yr



Summary

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Michael Wetzstein
Eckhard Wieprecht

- More than half of the cosmic infrared background resolved into individually detected sources
- SED evolution with respect to z~0 affects mid-IR star formation estimates
- AGN host star formation rates suggest 2 evolutionary modes: merger vs. secular
- Star formation and AGN obscuration not clearly correlated, even for luminous AGN
- Detection of molecular AGN outflows

Lockman Hole