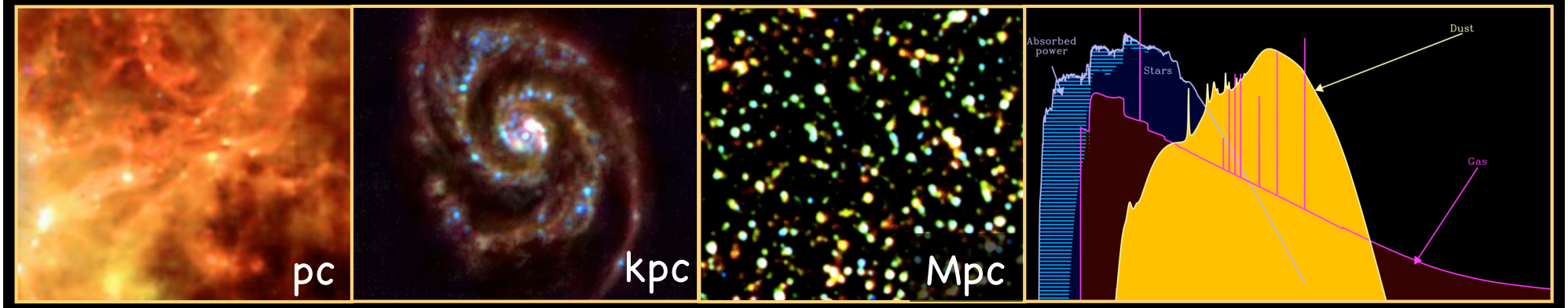
Searching for the dominant mode of galaxy growth from deepest far-IR Herschel surveys

How did galaxies acquire their mass ?

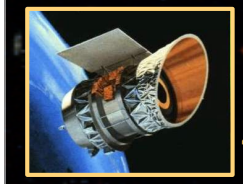
the Large Herschel telescope for Cosmology (LHC)
→ galaxies have been traveling in a field that gave them their mass



D.Elbaz (CEA Saclay)

M.Pannella, C.Schreiber (PhD), R.Leiton, M.Dickinson, H.S.Hwang, G.Magdis, B.Magnelli, P.Popesso, H.Inami, J.R.Mullaney, E.Daddi

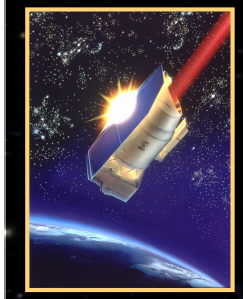
+GOODS-Herschel team: B.Altieri, I.Valtchanov, T.Díaz-Santos, D.Le Borgne, F.Galliano, P.Chanial, L.Armus, V.Charmandaris, H.Aussel, J.Kartaltepe, D.Coia, H.Dannerbauer, D.M.Alexander, V.Buat, D.Burgarella, R.-R.Chary, R.Gilli, R.J.Ivison, S.Juneau, E.Le Floc'h, D.Lutz, G.E.Morrison, E.Murphy, A.Pope, D.Scott, M.Brodwin, D.Calzetti, C.Cesarsky, S.Charlot, H.Dole, P.Eisenhardt, H.C.Ferguson, N.Förster Schreiber, D.Frayer, M.Giavalisco, M.Huynh, A.M.Koekemoer, C.Papovich, N.Reddy, C.Surace, H.Teplitz, M.S.Yun, and G.Wilson



IRAS 1985
57 cm
41" fwhm

100 μm

Discovery of luminous IR galaxies, >90% of light in IR mergers & 2% local luminosity density !



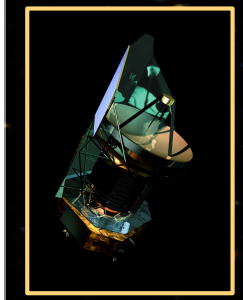
ISO 1995
60 cm

100μm

Space density of LIRGs x70 at z~1
Extrapolation to FIR → CIRB resolved

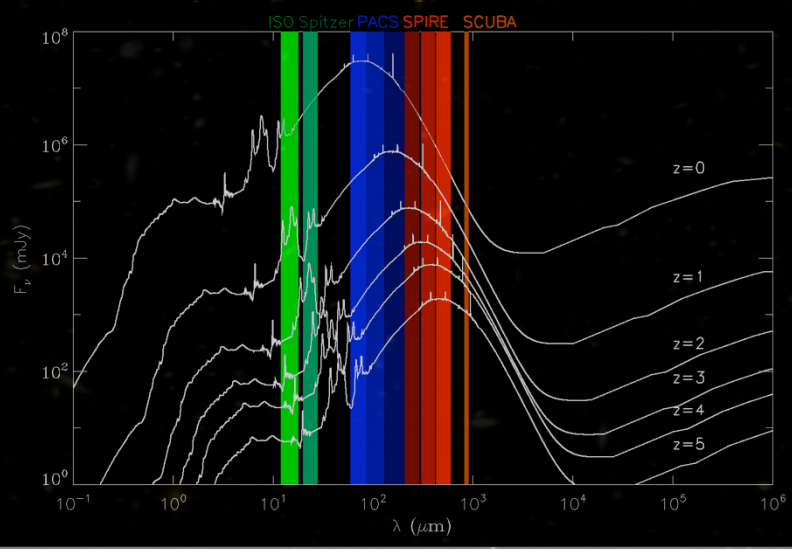
Spitzer 2003
85 cm

rise of ULIRGs up to z~2
Stacking in FIR → CIRB resolved at 70μm

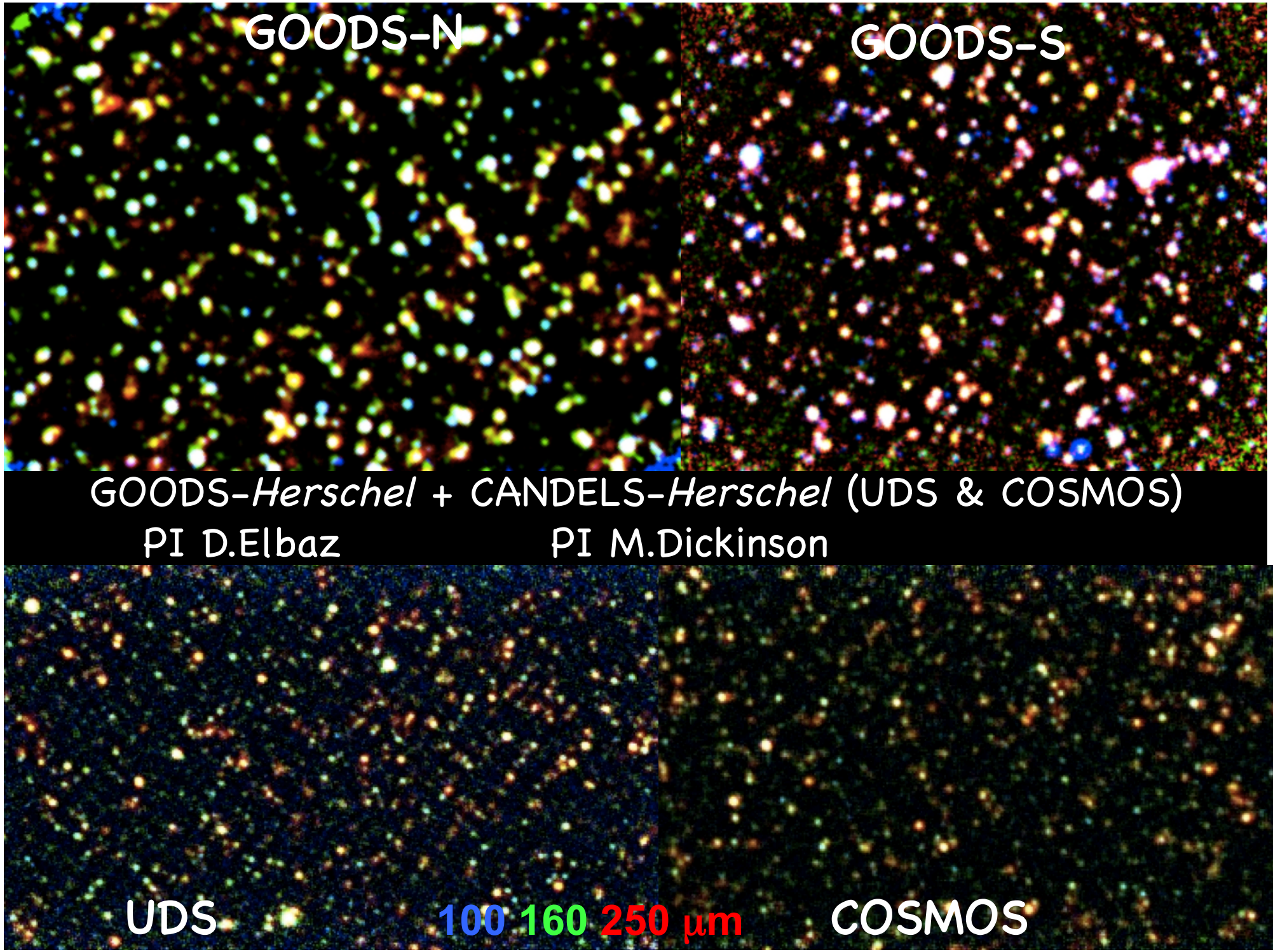


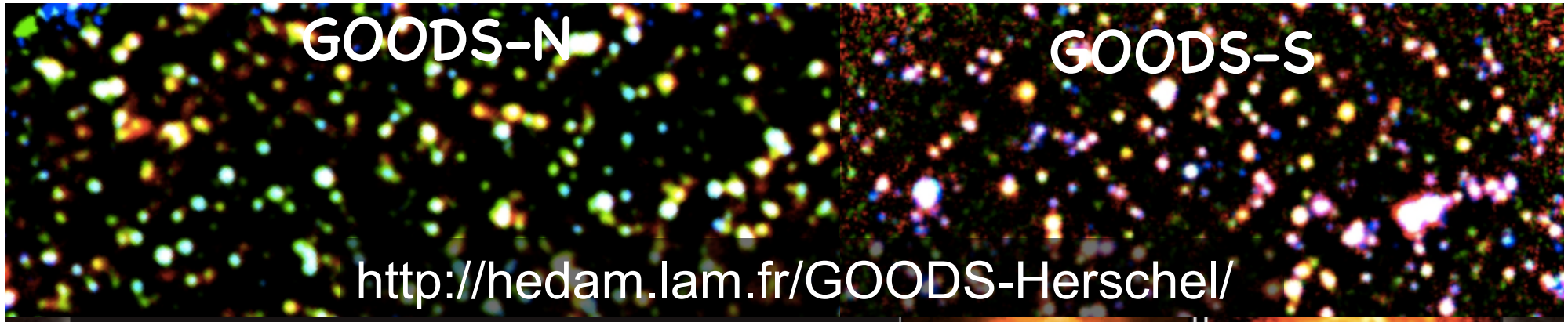
Herschel 2009
350 cm

FWHM
100μm=6.7 arcsec



Herschel:
- robust SFR
- M_{dust} → M_{gas} → SFE
- SED: Tdust, FIR/MIR
-→ signature of mergers


GOODS-N
GOODS-S
GOODS-*Herschel* + CANDELS-*Herschel* (UDS & COSMOS)
PI D.Elbaz
PI M.Dickinson
UDS
100 160 250 μm
COSMOS



http://hedam.lam.fr/GOODS-Herschel/

HeDaM Herschel Database in Marseille

Home | Survey description | Get data... | Publications | Acknowledgements | Contacts

The GOODS-Herschel Survey

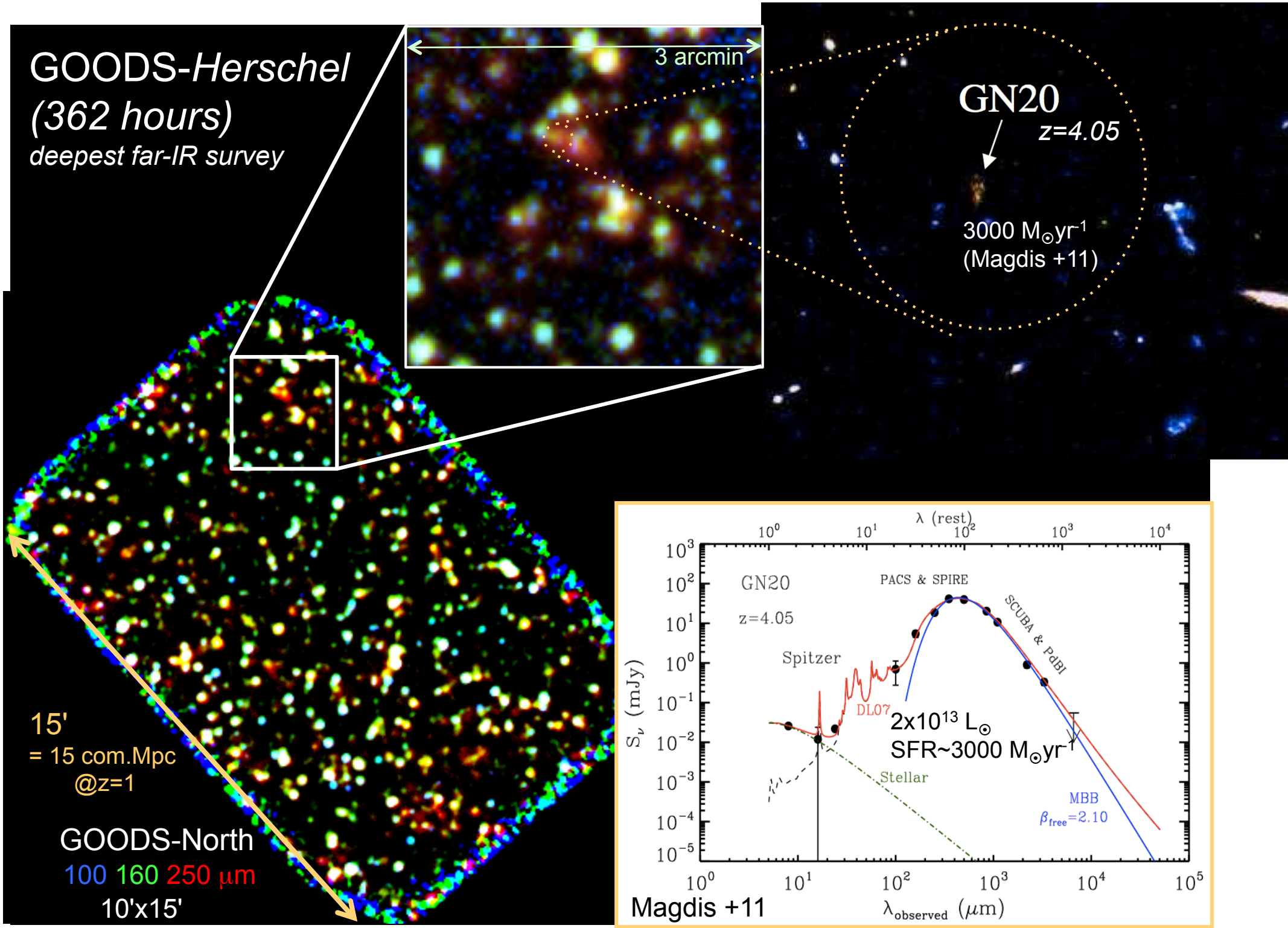
Welcome on the *Herschel Database in Marseille* section dedicated to the "*Great Observatories Origins Deep Survey*: far-infrared imaging with Herschel" (GOODS-Herschel, Elbaz *et al.*, 2011) survey.

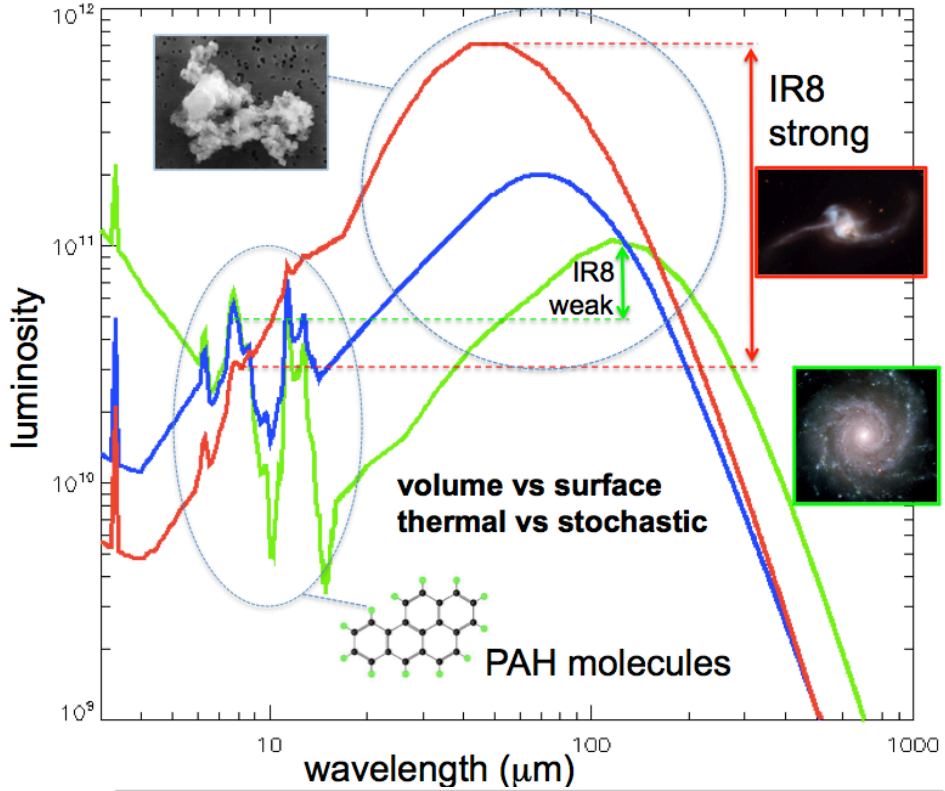
GOODS-Herschel is an open time key programme of more than 360 hours of observation with the Herschel instruments SPIRE and PACS from 100 μm to 500 μm on the two fields of the Great Observatories Origins Deep Survey (GOODS).

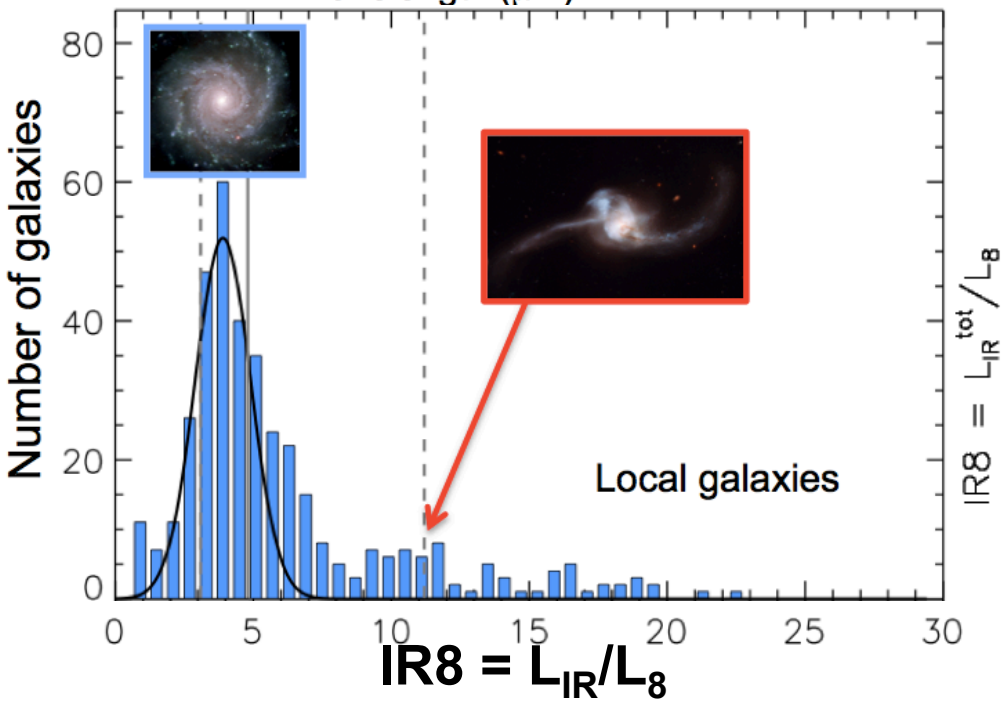
What's new?

- **September 2012**: Opening of the site and first release of GOODS-Herschel public data.

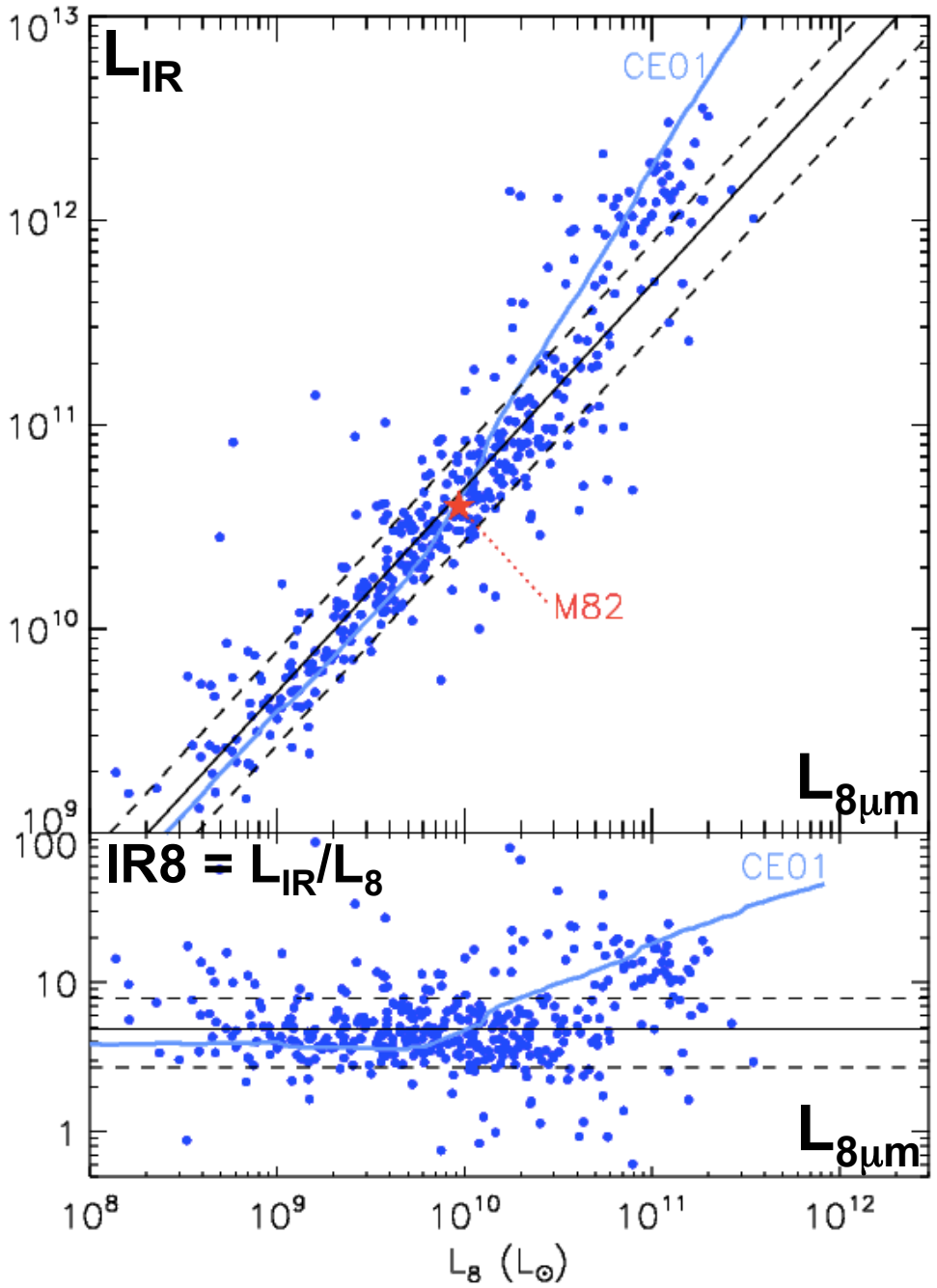
Download GOODS-North data | Download GOODS-South data


GOODS-*Herschel*
(362 hours)
deepest far-IR survey
3 arcmin
GN20
z=4.05
3000 $M_\odot yr^{-1}$
(Magdis +11)
15'
= 15 com.Mpc
@z=1
GOODS-North
100 160 250 μm
10'x15'
GN20
z=4.05
PACS & SPIRE
SCUBA & PdBI
Spitzer
DL07
2x10^{13} $L_\odot$
SFR~3000 $M_\odot yr^{-1}$
Stellar
MBB
β_{free}=2.10
S_ν (mJy)
λ (rest)
$\lambda_{observed}$ (μm)
Magdis +11

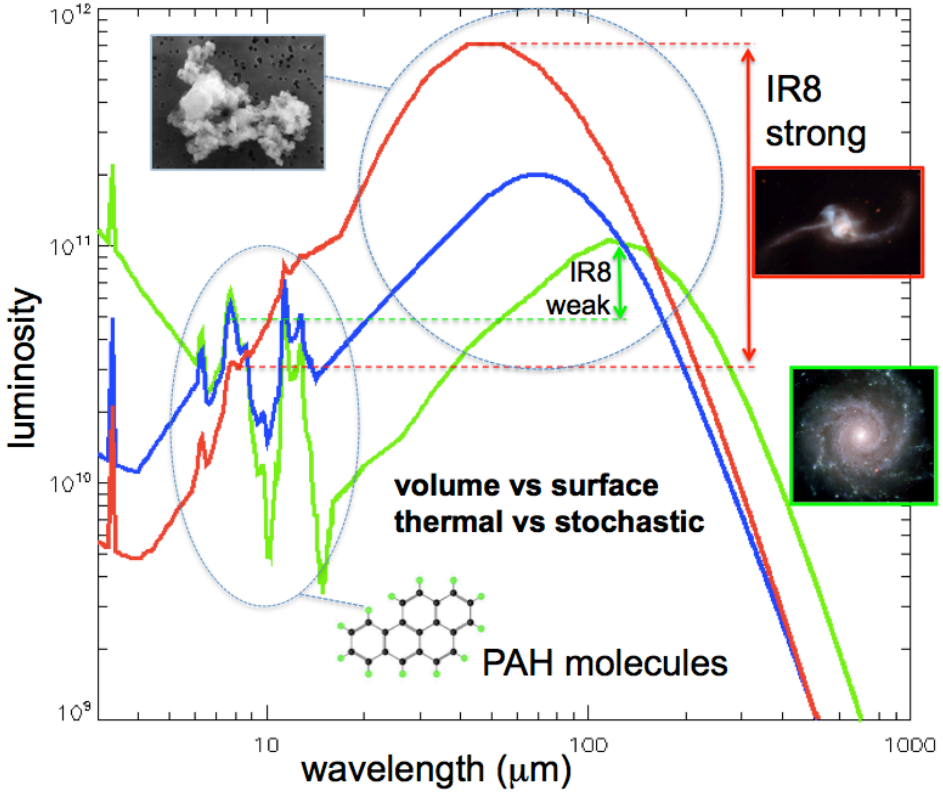


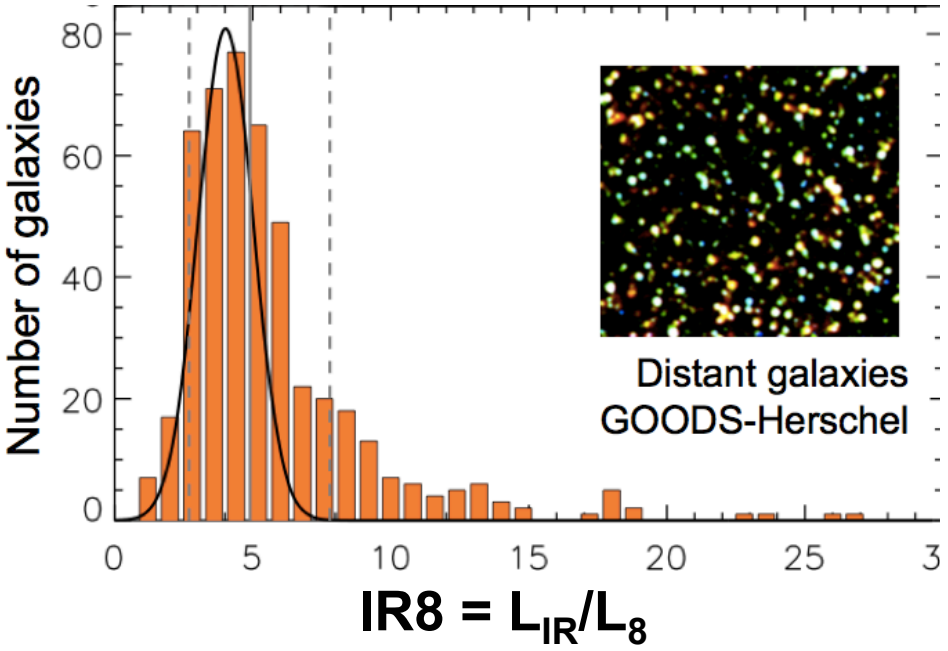


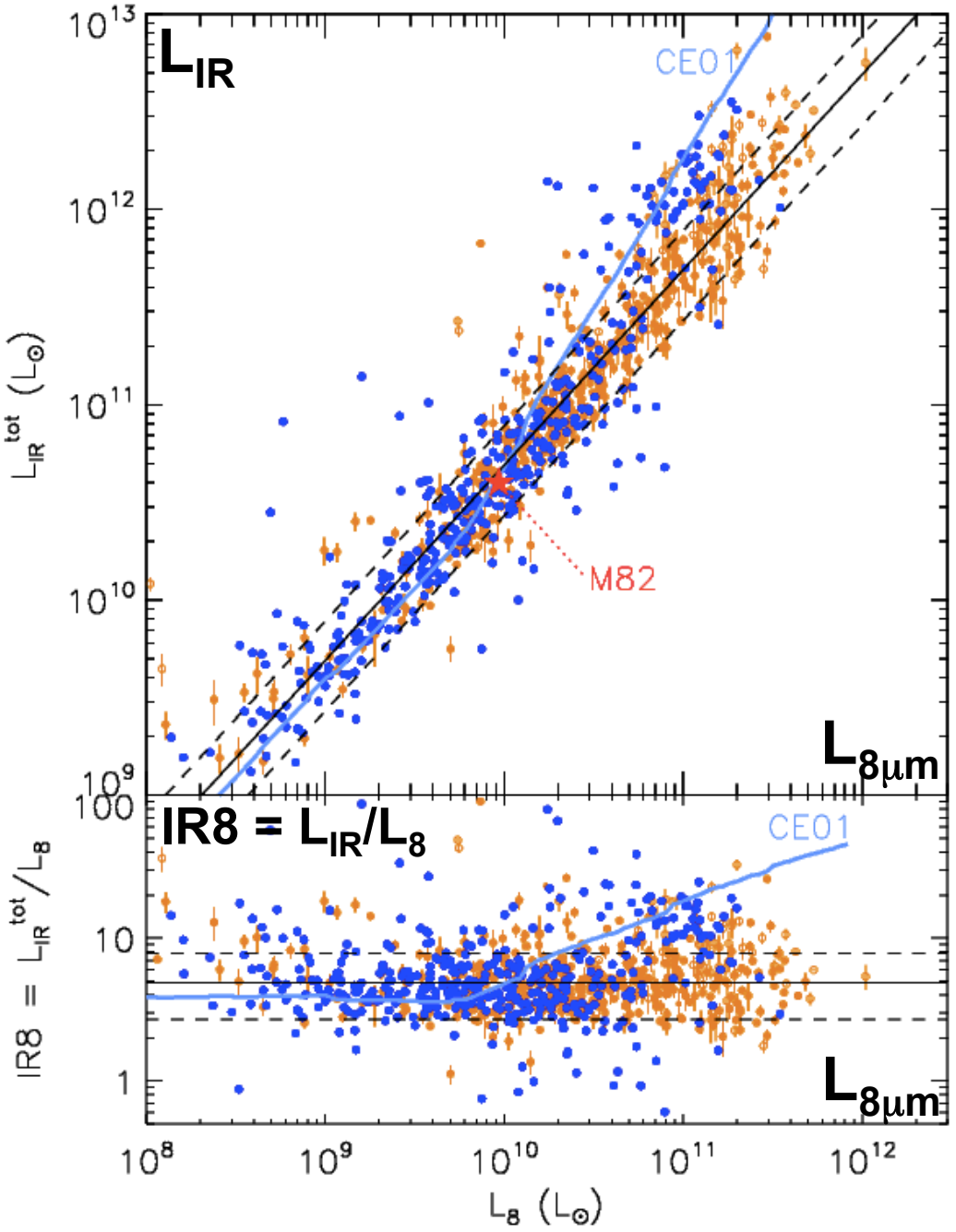
Local Universe



Local vs distant Universe

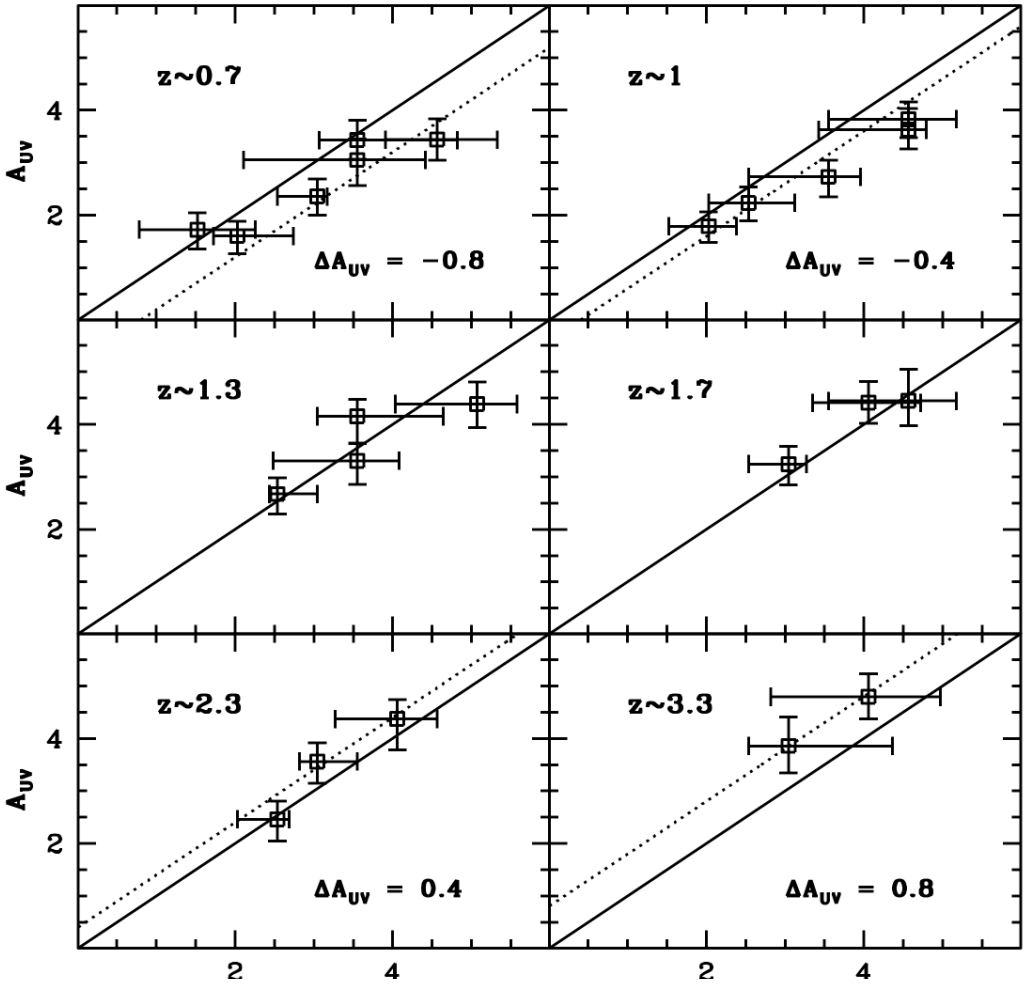




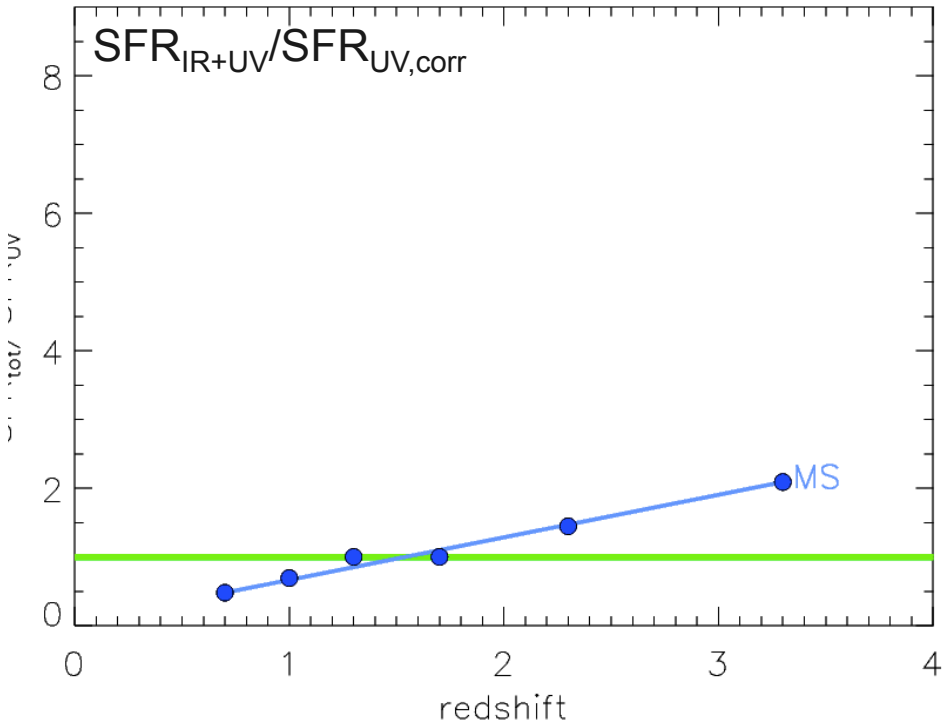


Herschel vs no Herschel
SFR(IR+UV) vs SFR(SED, UV)

$A_{UV} = 2.5 \log (SFR_{IR}/SFR_{UV} + 1)$



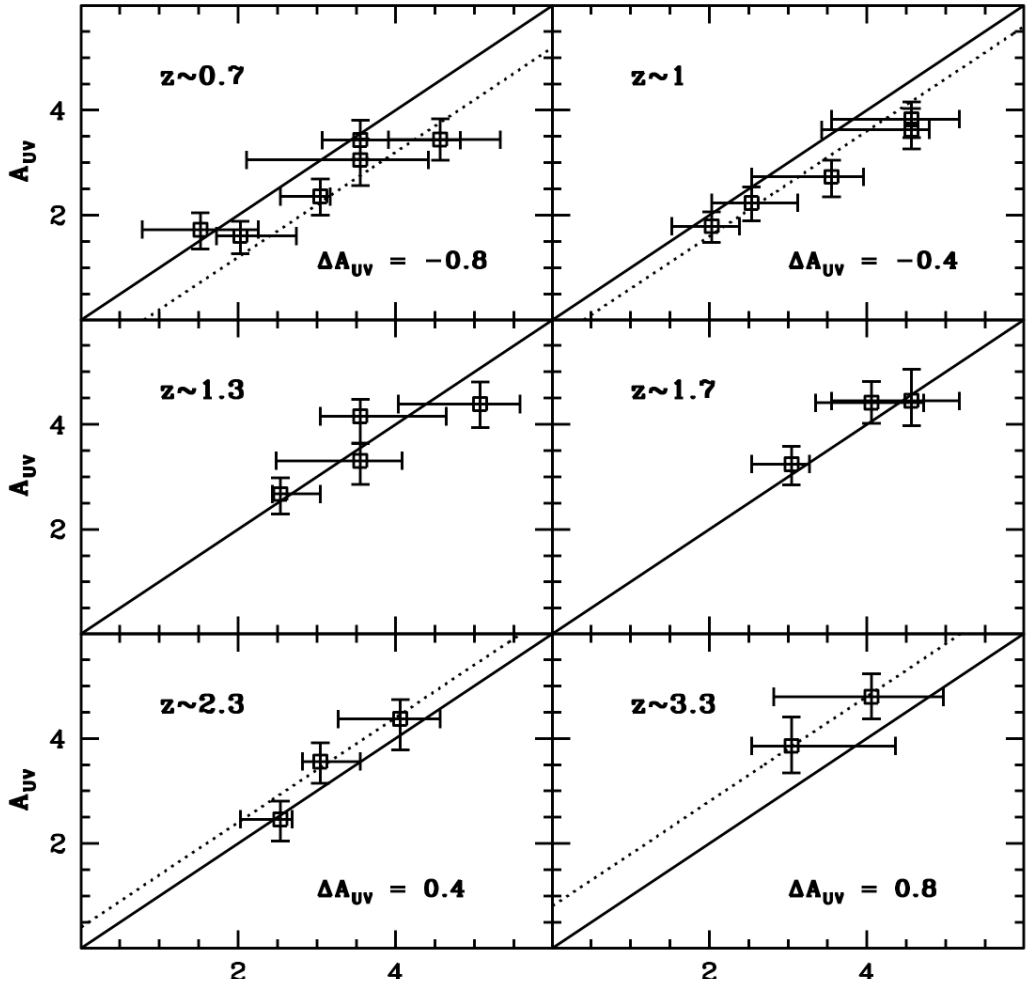
A_{UV} SED fit or β slope



Pannella +13 TBS

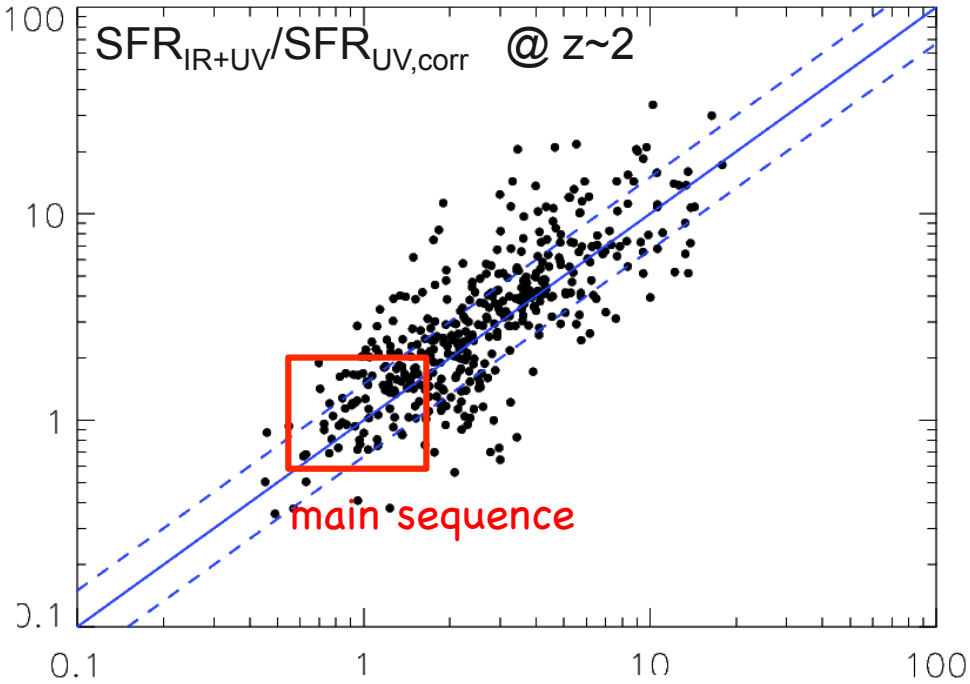
Herschel vs no Herschel
SFR(IR+UV) vs SFR(SED, UV)

$A_{UV} = 2.5\ \mathrm{Log}\ (SFR_{IR}/SFR_{UV} + 1)$

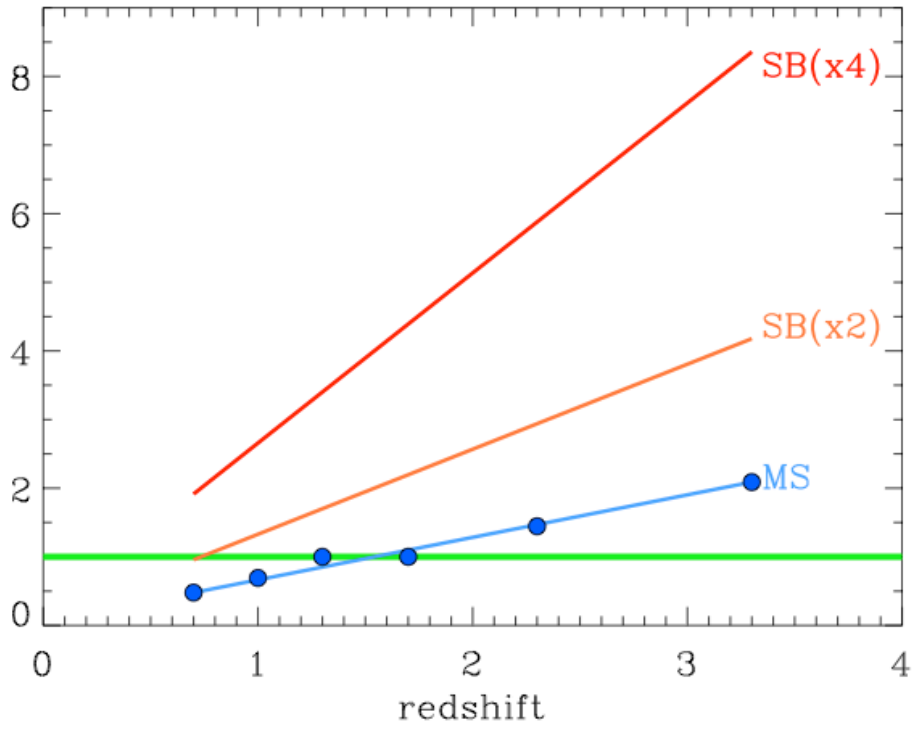


A_{UV} SED fit or β slope

Pannella +13 TBS



starburstiness= $(sSFR/sSFR_{MS})$

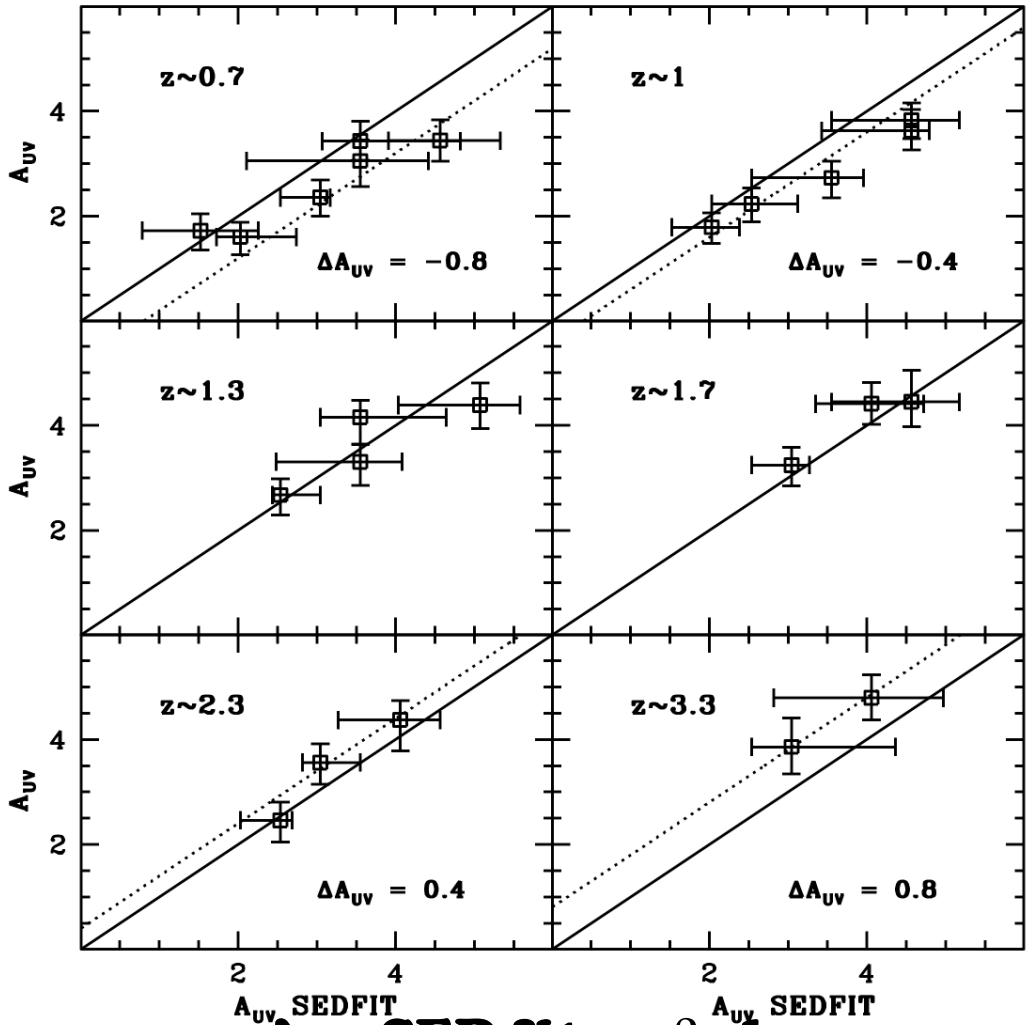


Pannella +13 TBS

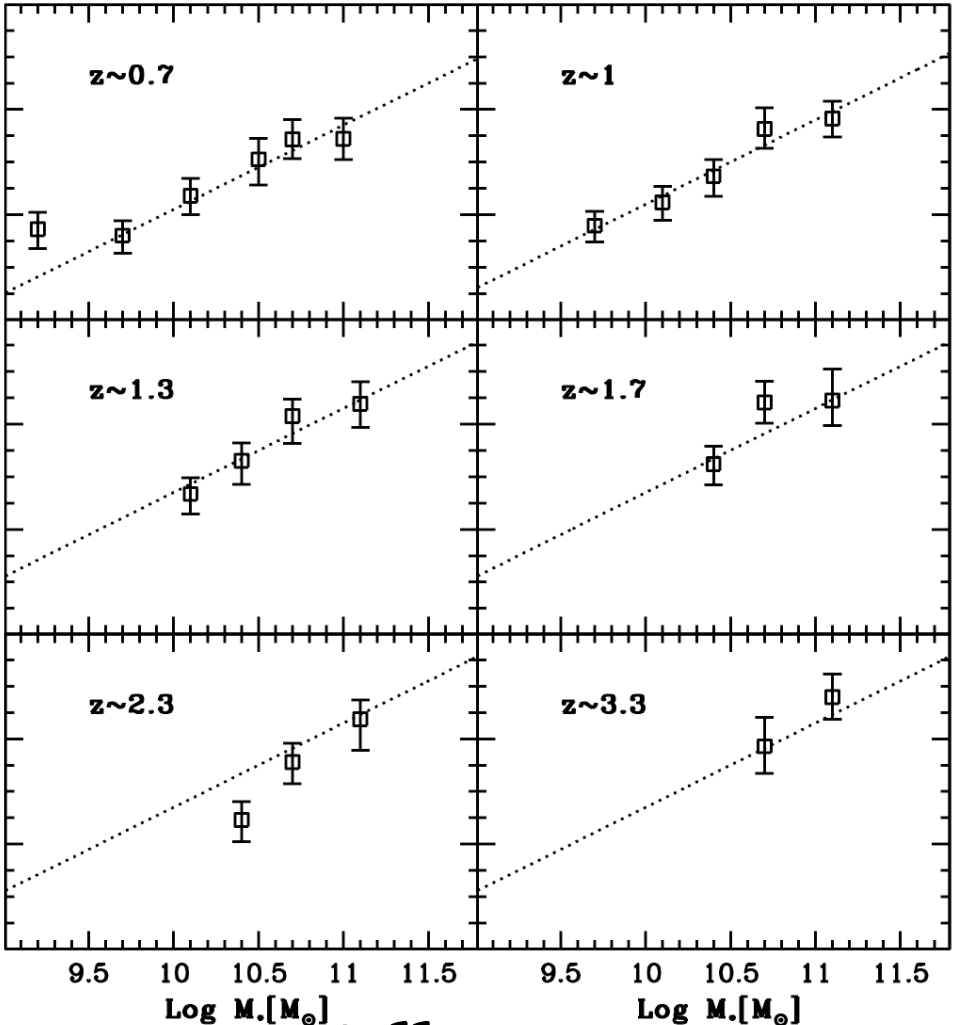
SFR overestimated at z < 1
SFR underestimated at z > 2

Mstar = best proxy for A_{UV} (for MS galaxies)

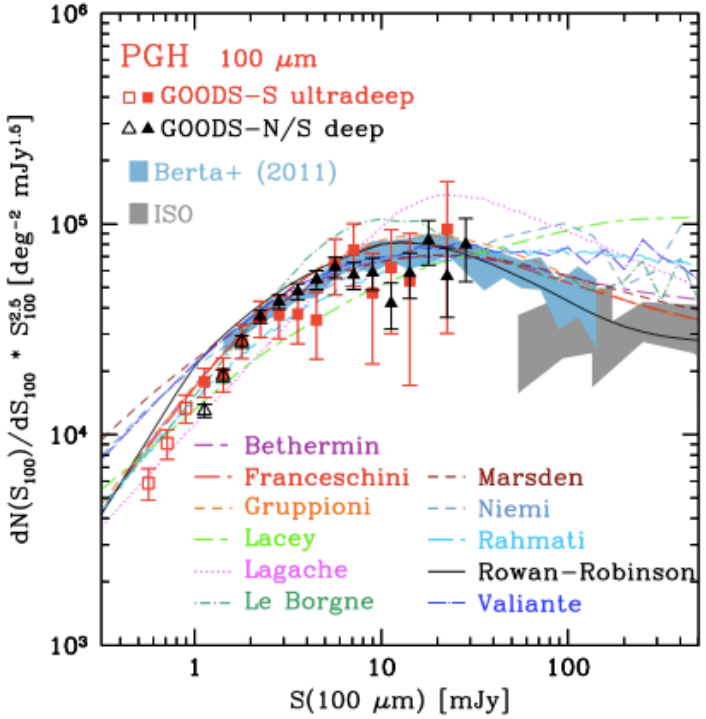
$$A_{UV} = 2.5 \text{ Log } (SFR_{IR}/SFR_{UV} + 1)$$

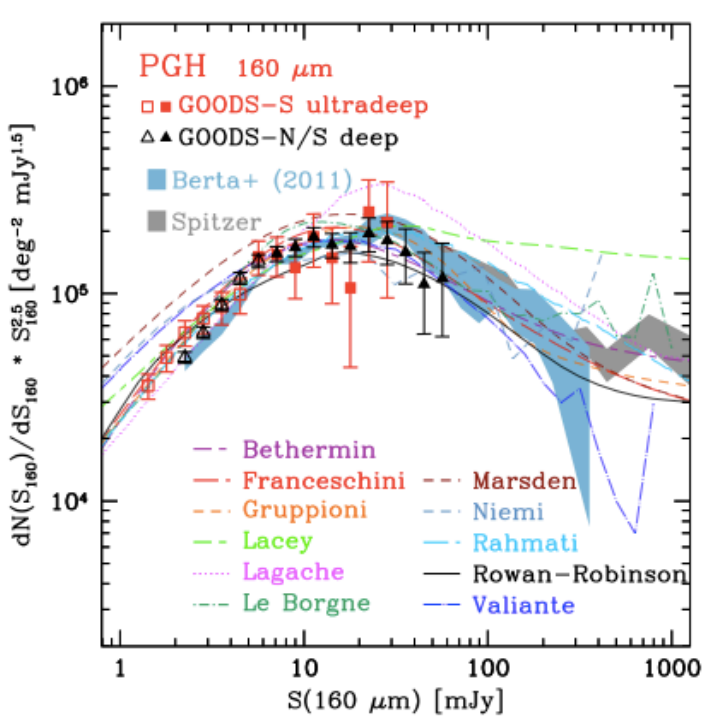


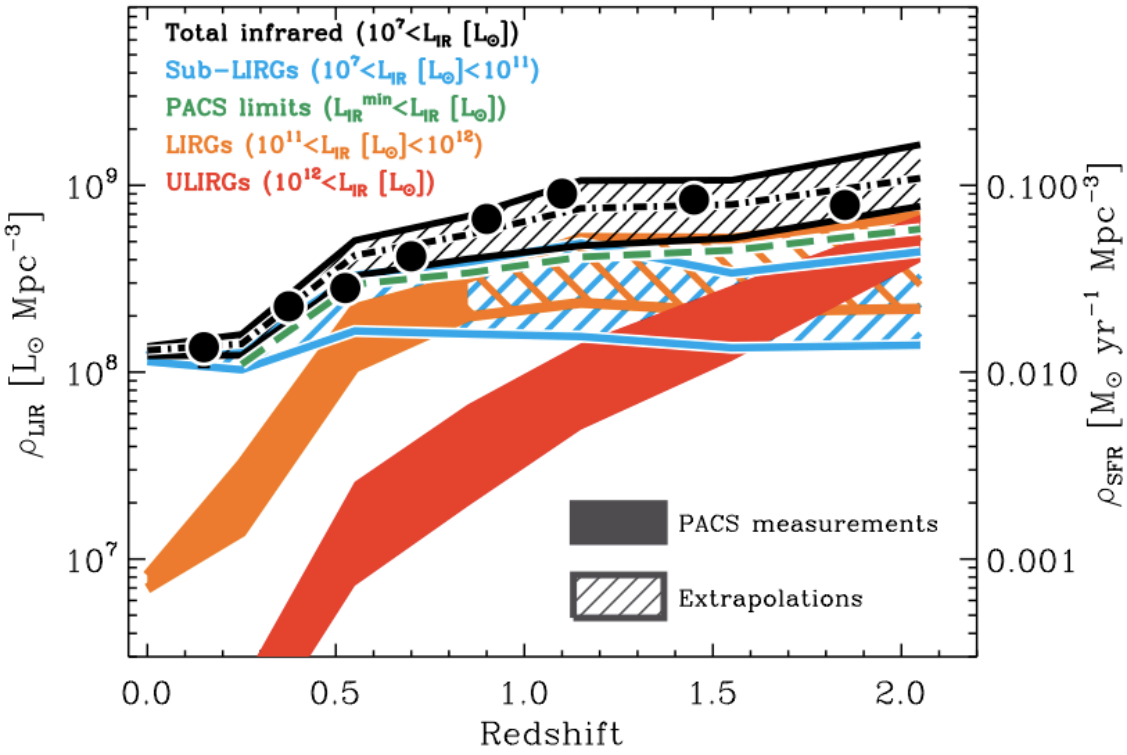
A_{UV} SED fit or β slope



stellar mass





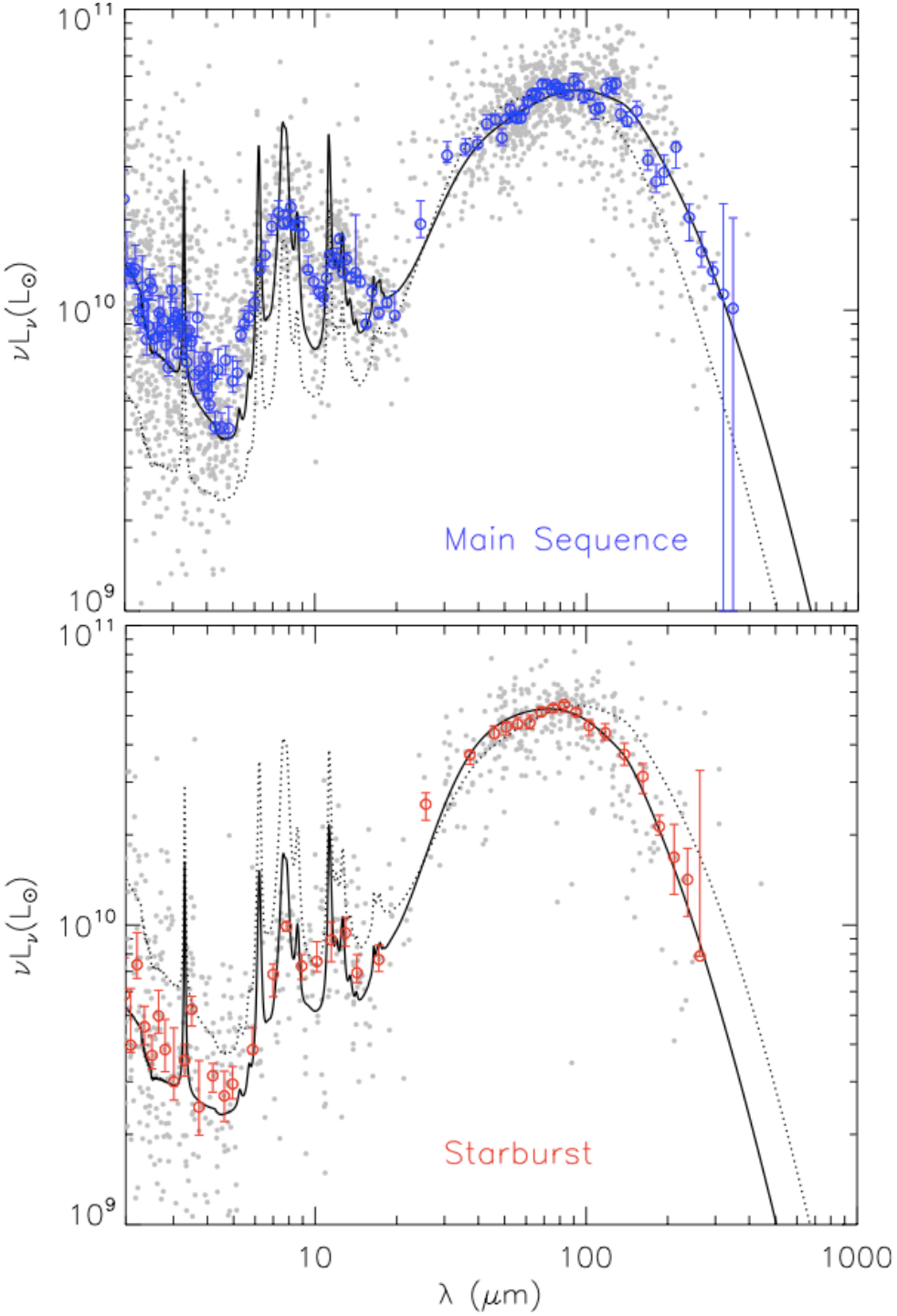


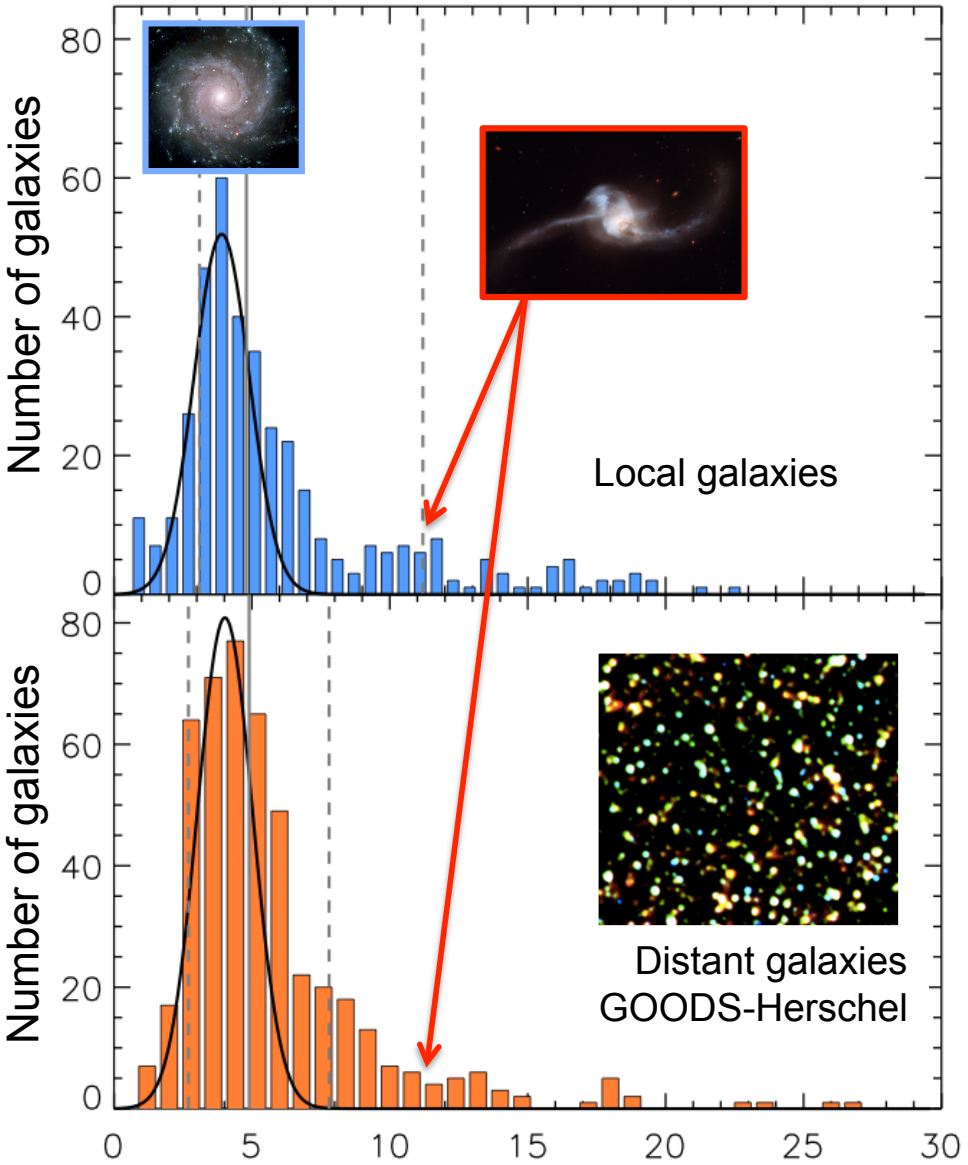
Magnelli +13 (GOODS-H+PEP)

- 100, 160μm down to 0.6 & 1.3 mJy
→rise of LIRGs & ULIRGs to z~2
→make up ~80% of SFR density

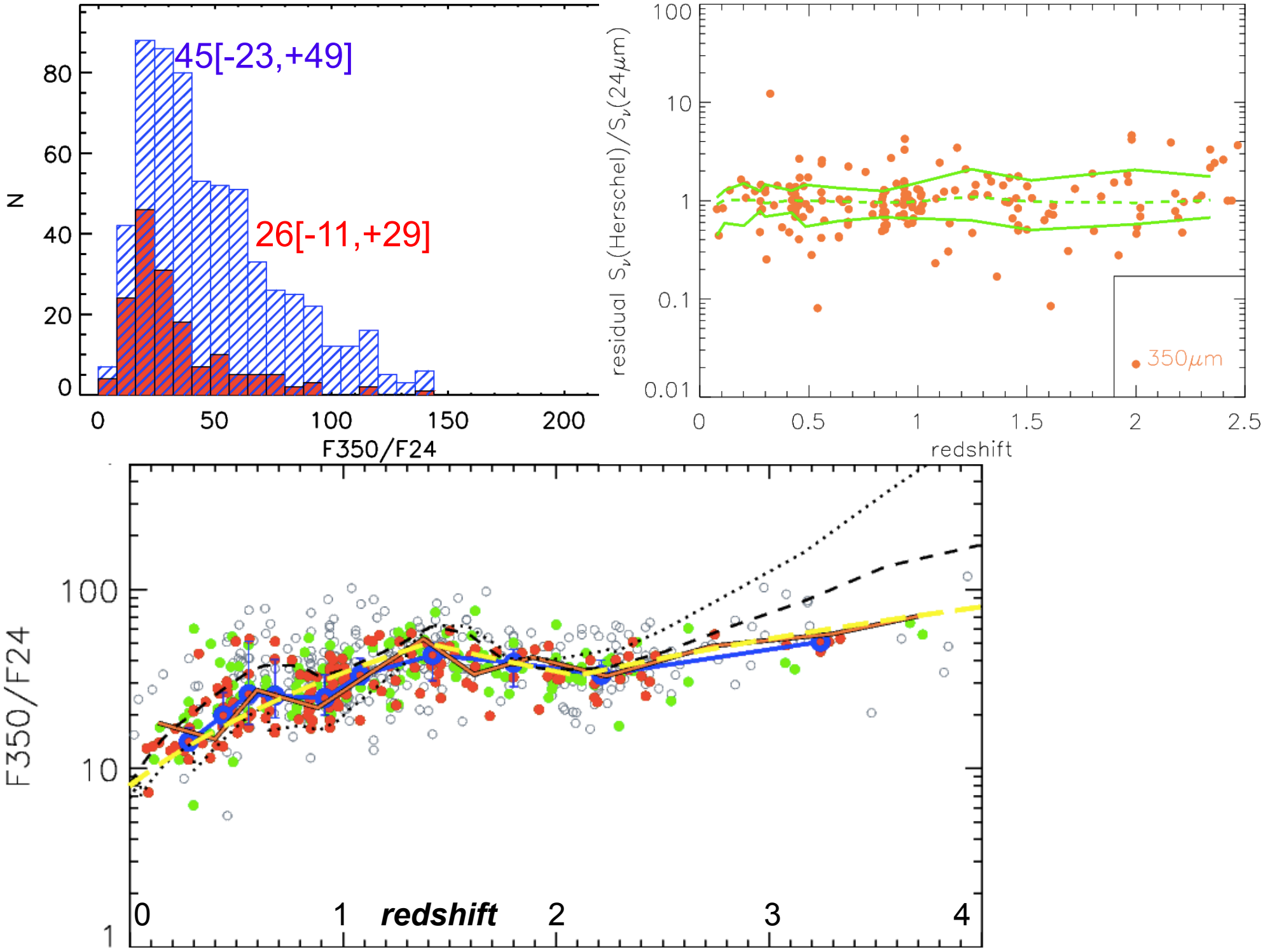
- resolve 75% of cosmic IR background due to sources z<1.5

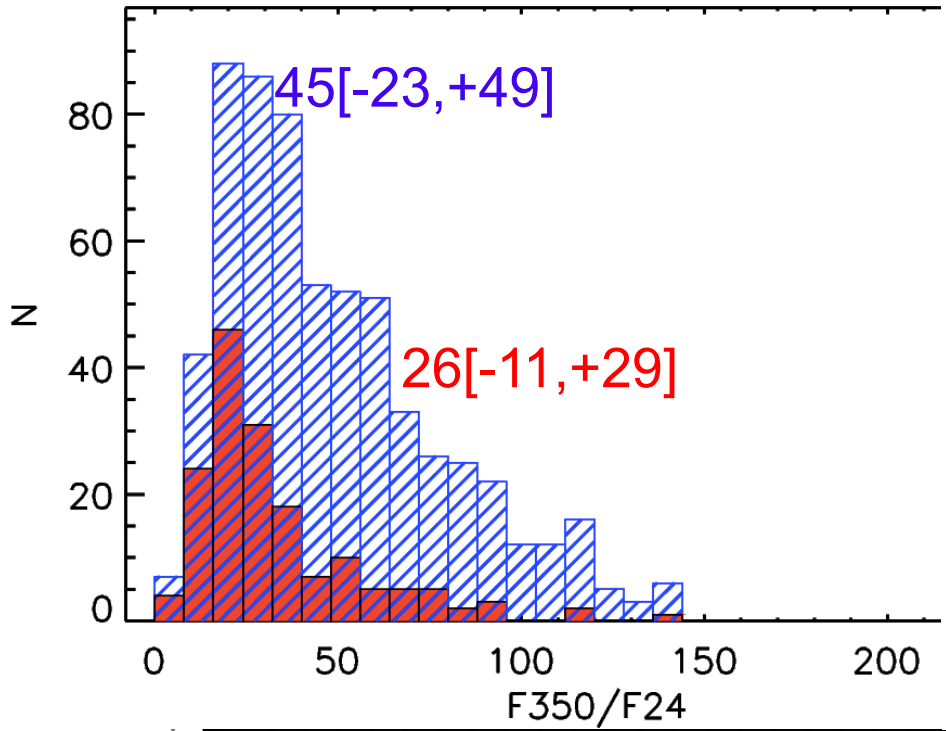
→SPIRE confusion limit 15-20 mJy, <15% resolved (Oliver +10)

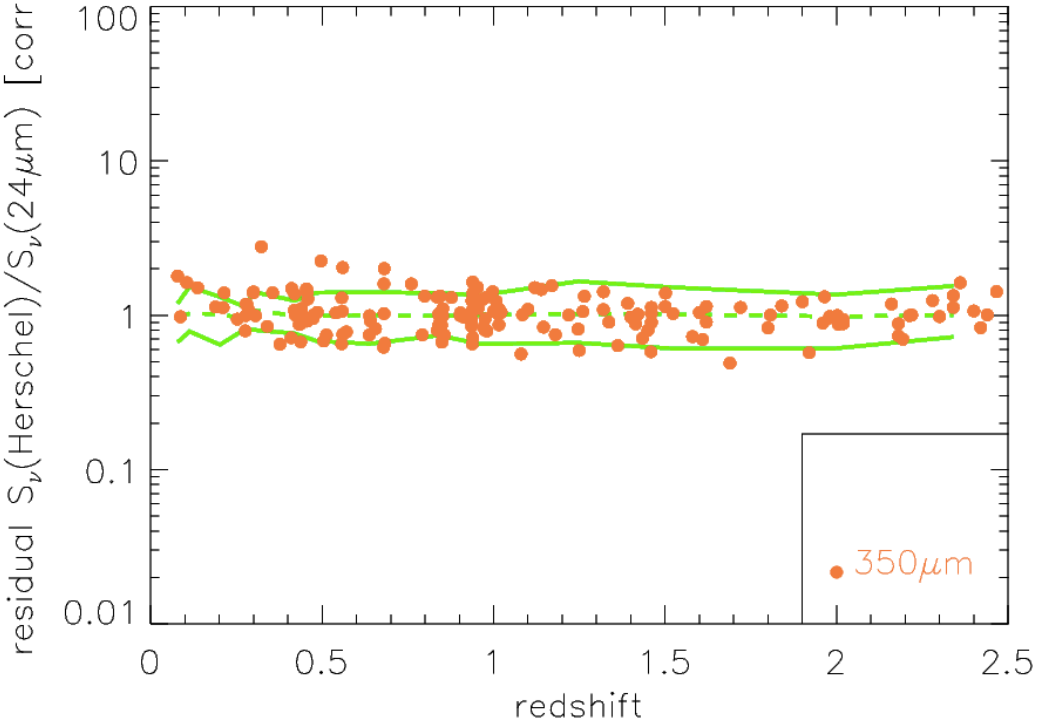


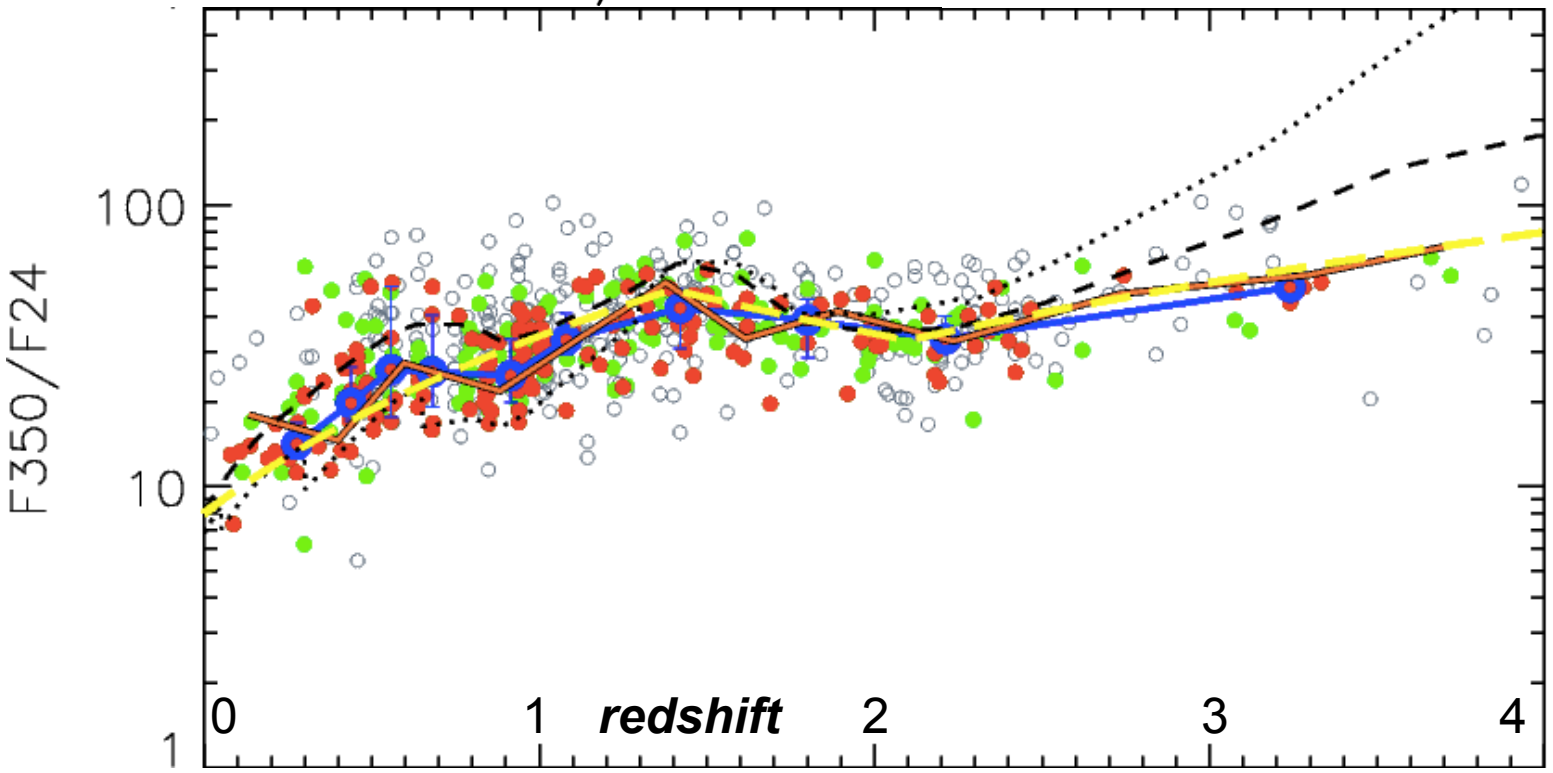


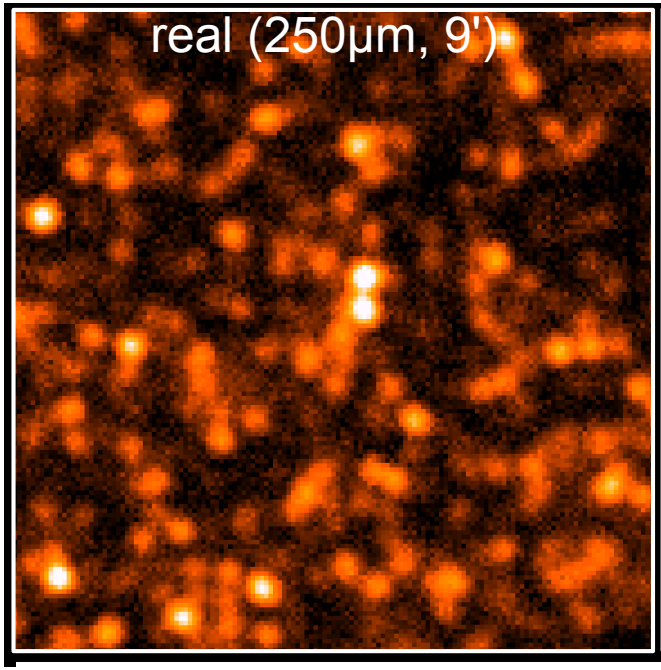
IR8= L_{IR}/L_8= robust / fragile dust emission
a signature of galaxy mergers

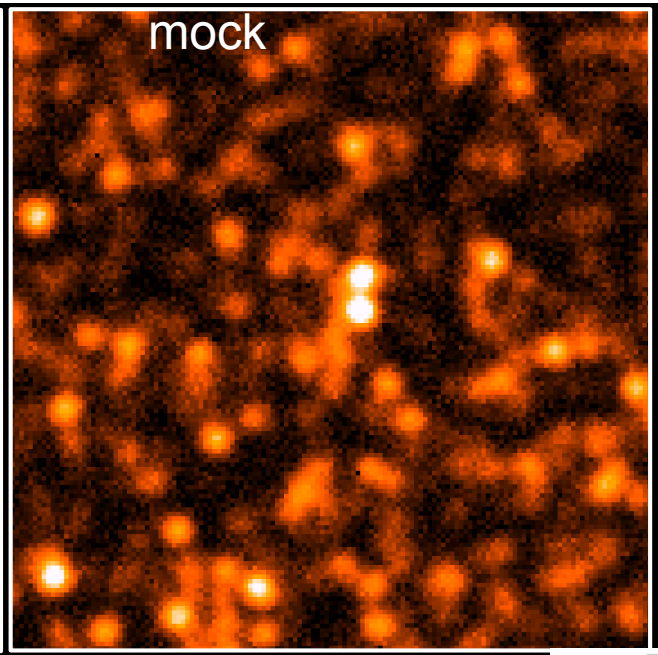

45[-23,+49]
26[-11,+29]
N
F350/F24
residual S_ν(Herschel)/S_ν(24μm)
350μm
redshift
F350/F24
redshift


45[-23,+49]
26[-11,+29]
N
F350/F24


residual S_ν(Herschel)/S_ν(24μm) [corr.]
350μm
redshift


F350/F24
redshift



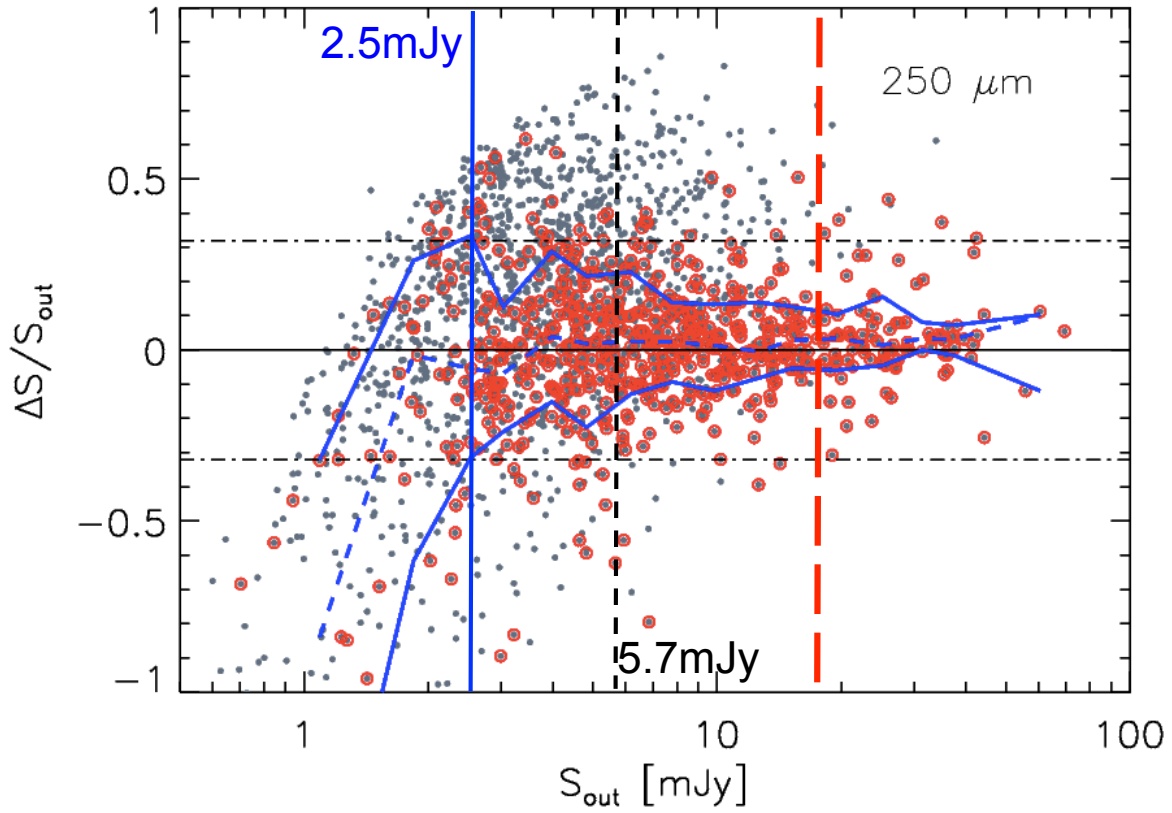


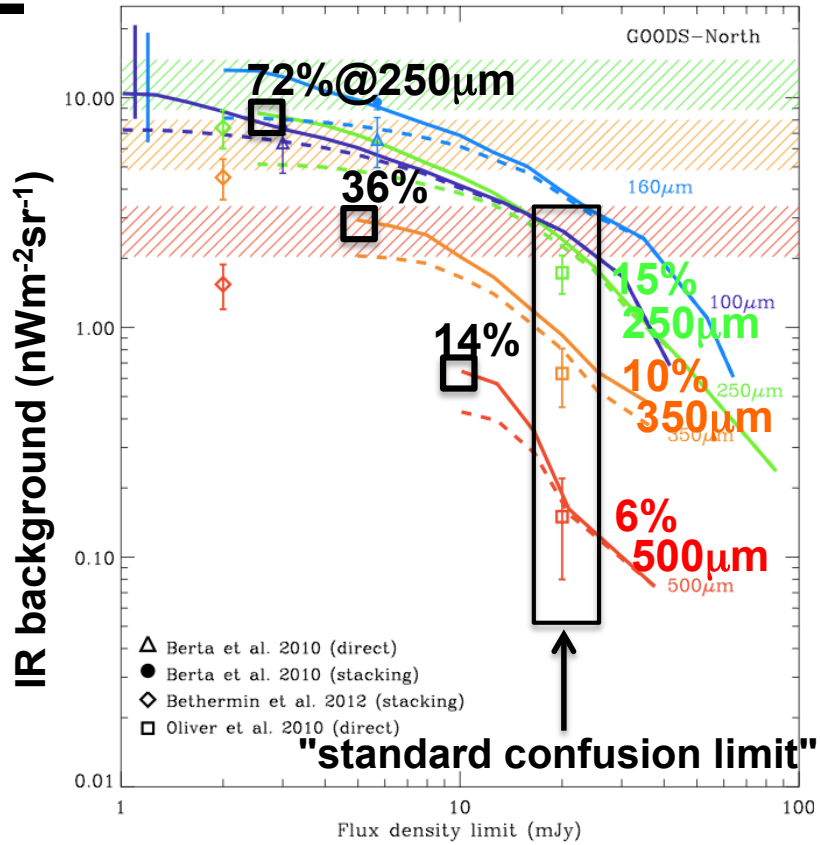
Simulating realistic Herschel images to identify faint & robust faint detections

Leiton +13 (in prep)

8x< "standard" confusion limit !
12m tel. standard confusion limit (Béthermin +11 model)

15% → 72% of 250μm resolved





Astrodeep FP7-SPACE project

Unveiling the power of the deepest images of the Universe

CANDELS fields + COSMOS + ECDFS

PI Adriano Fontana (Obs.Rome)

co-I J.Dunlop (Edinburgh) / D.Elbaz (CEA Saclay)

+ S.Derrière (CDS Strabourg)

→ objective : improve and publicly distribute multi-wavelength catalogs from SPACE experiments (HST+Spitzer+Herschel+XMM)

Saclay:

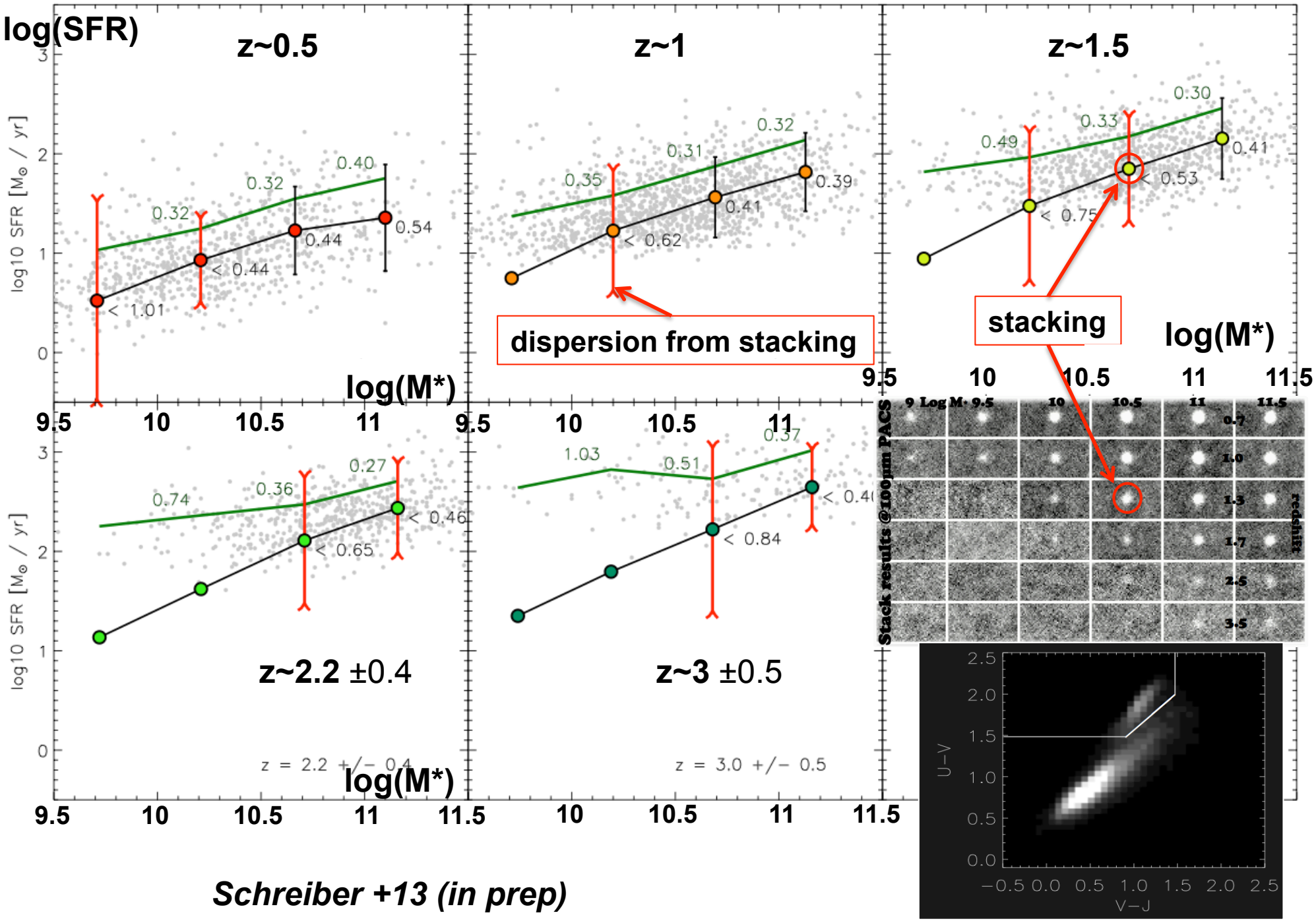
- Xinwen Xu & Tao Wang

→ test src extraction methods

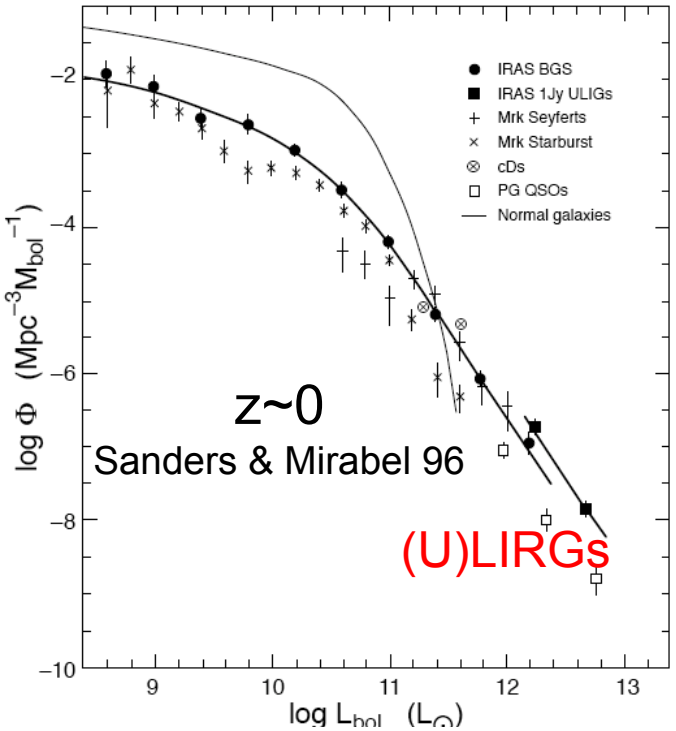
- → develop techniques for identification of z>2.5 Herschel sources ,
- Corentin Schreiber (PhD) → stacking + Main Sequence vs SB

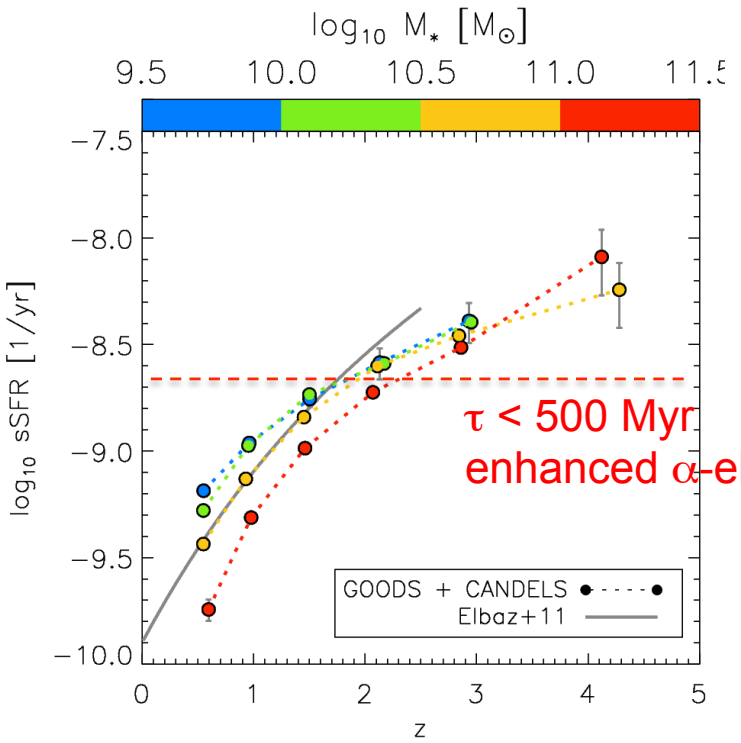
http://www.oa-roma.inaf.it/astrodeep

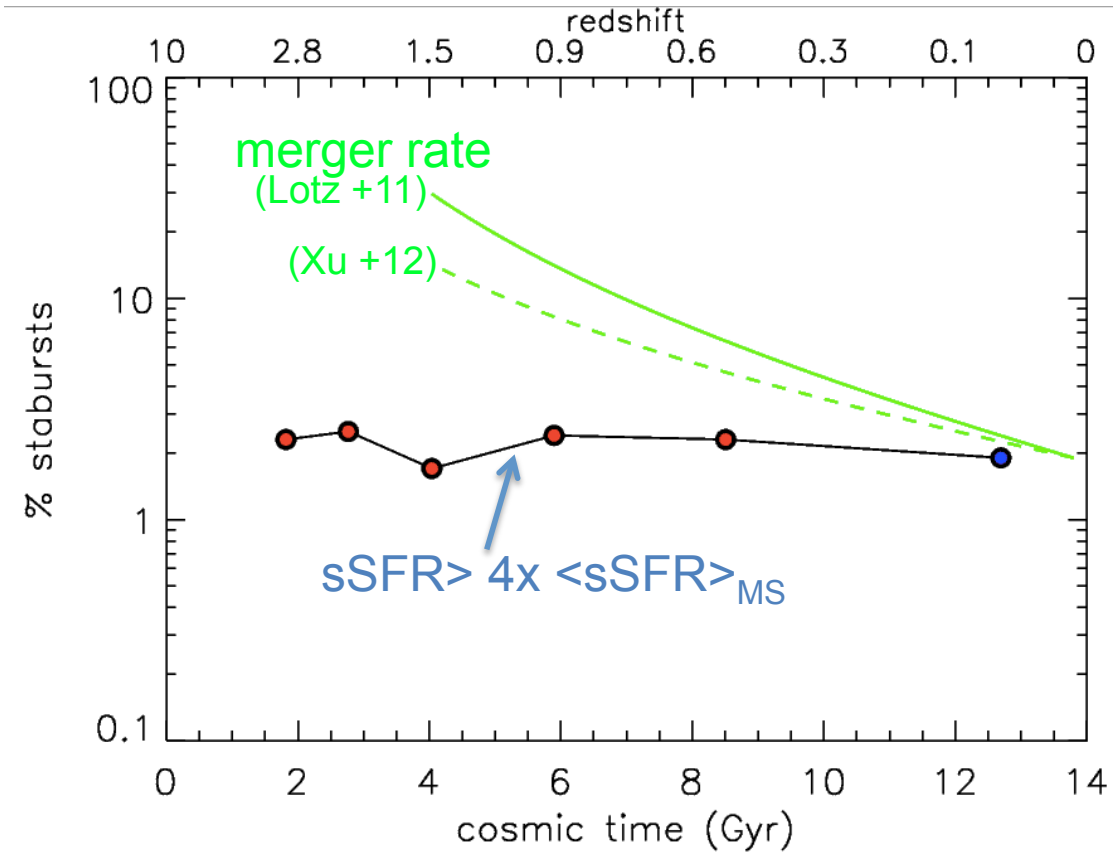
The SFR-M* main sequence as probed by Herschel up to z=2.6



Schreiber +13 (in prep)



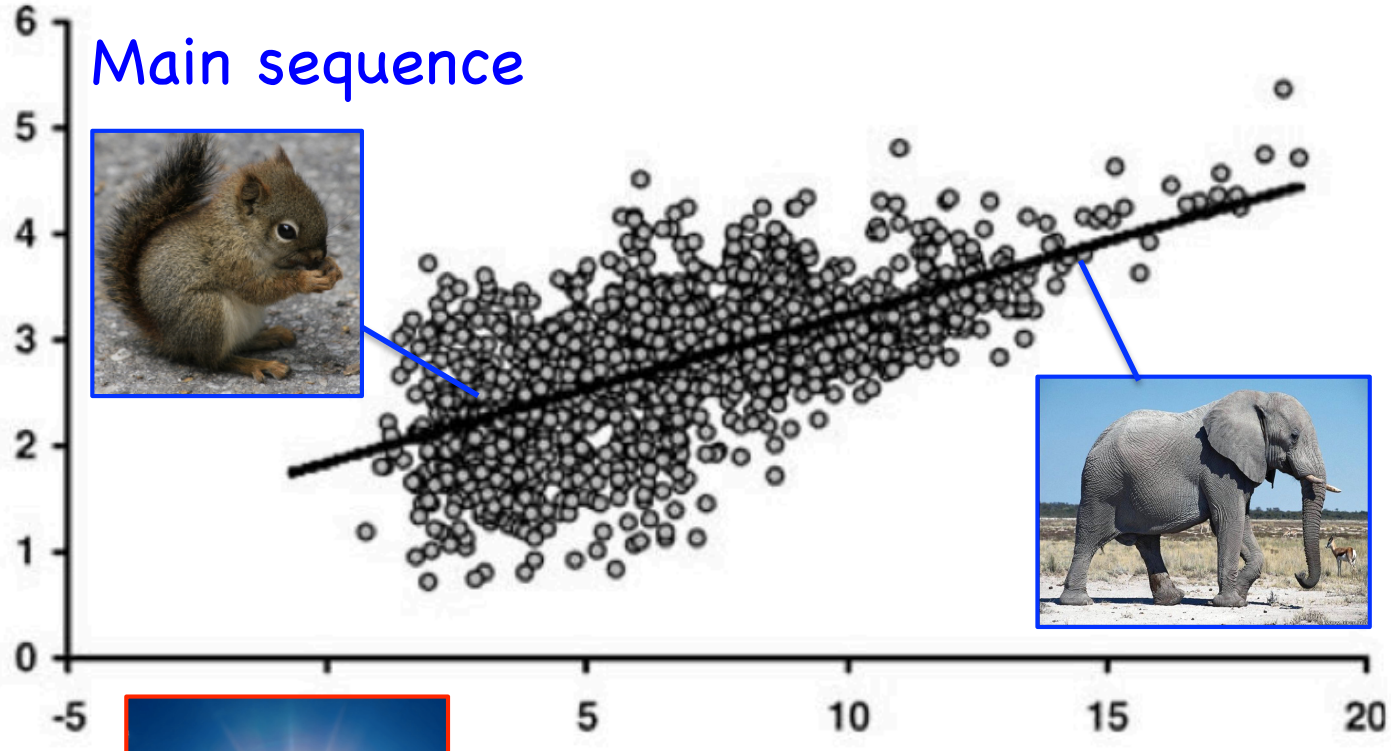


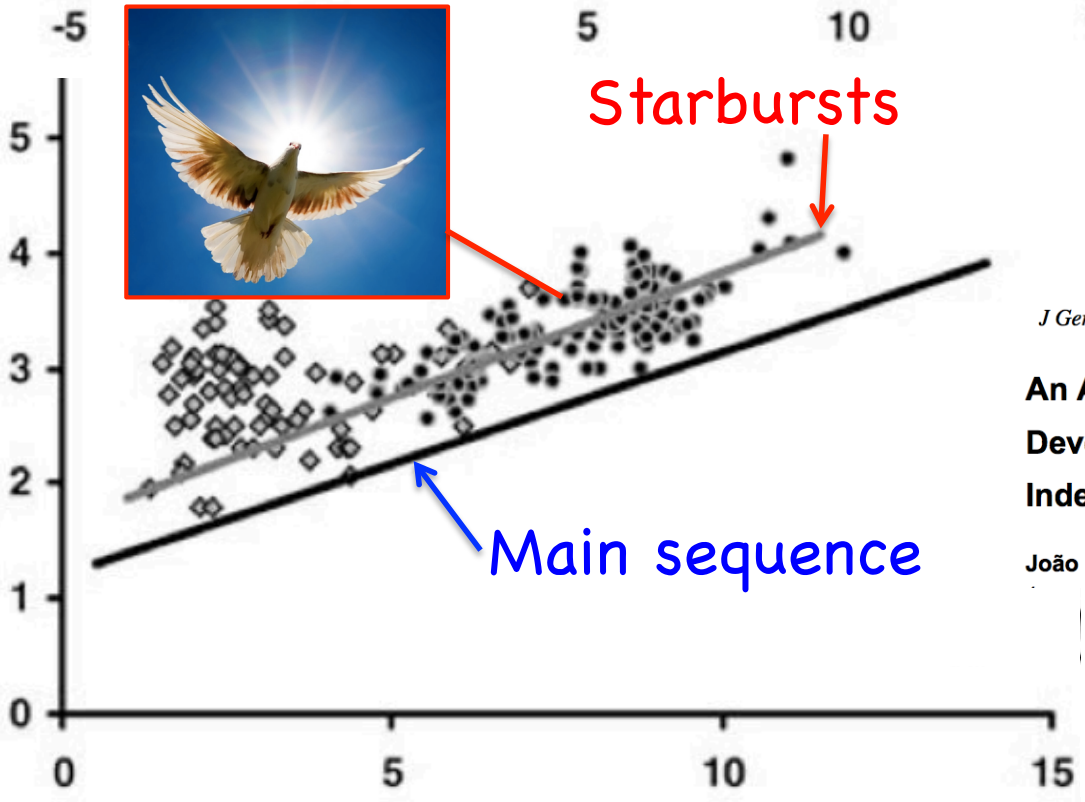


Starbursts or not starbursts ?

~70% mass of present-day stars in E's
→ formed in main sequence !

Schreiber +13 (in prep)



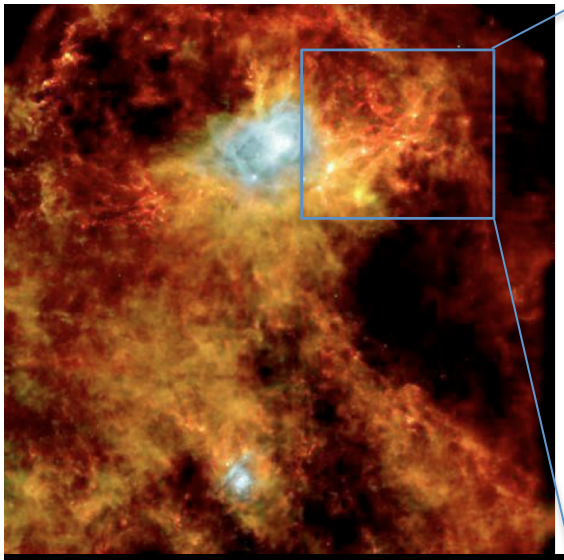


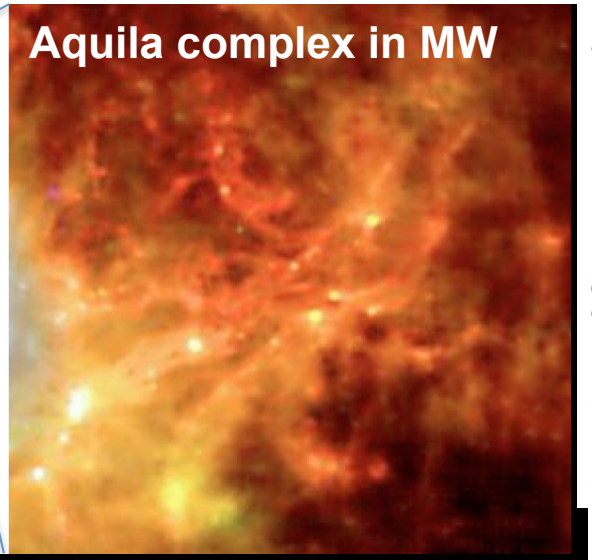
J Gerontol A Biol Sci Med Sci. 2007 February ; 62(2): 149–160.

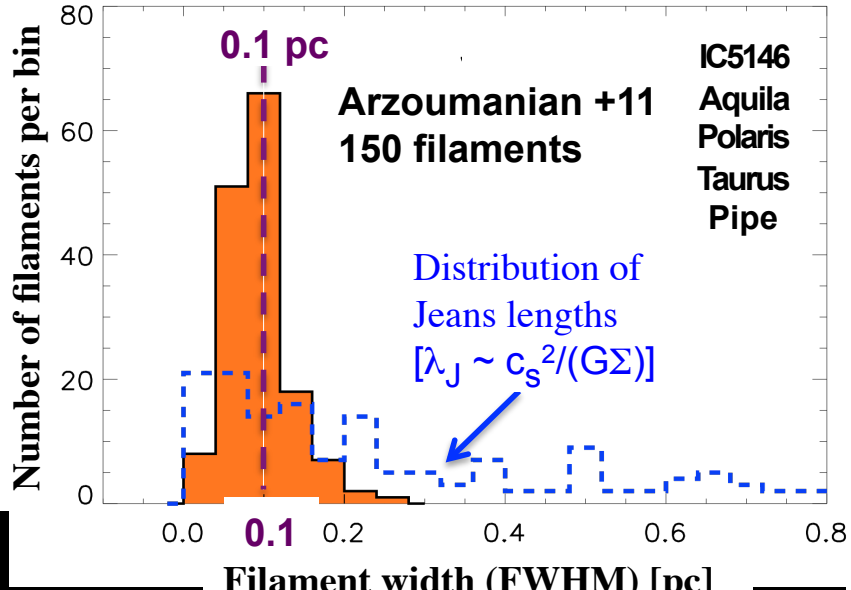
An Analysis of the Relationship Between Metabolism, Developmental Schedules, and Longevity Using Phylogenetic Independent Contrasts

João Pedro de Magalhães[1], Joana Costa[2], and George M. Church[1]

1456 mammals, birds, amphibians, reptiles

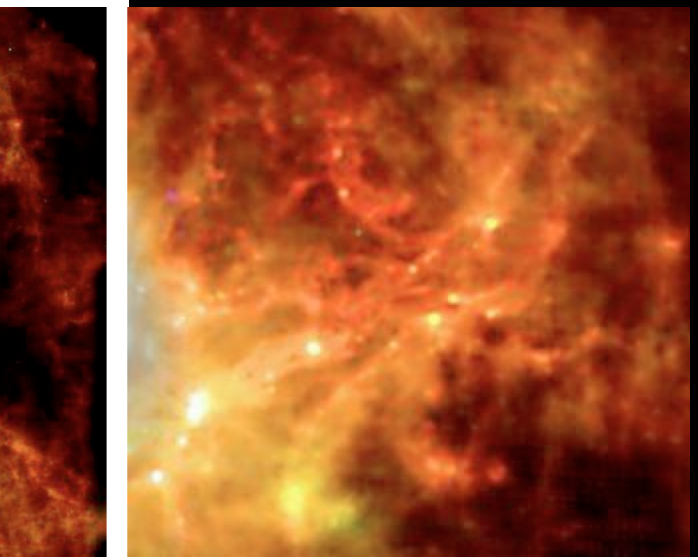




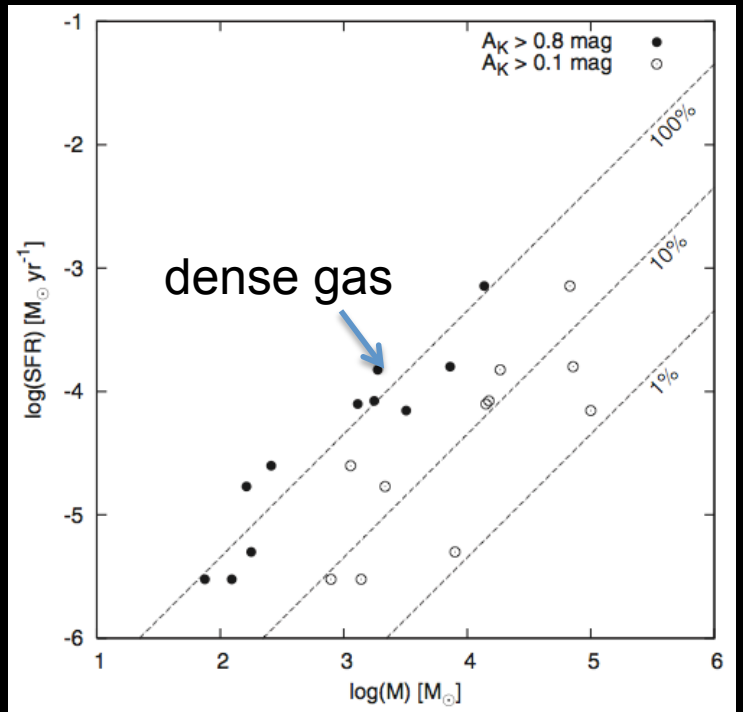


SFR ~ $4.5 \times 10^{-8}\ M_{dense}\ M_{\odot} yr^{-1}$

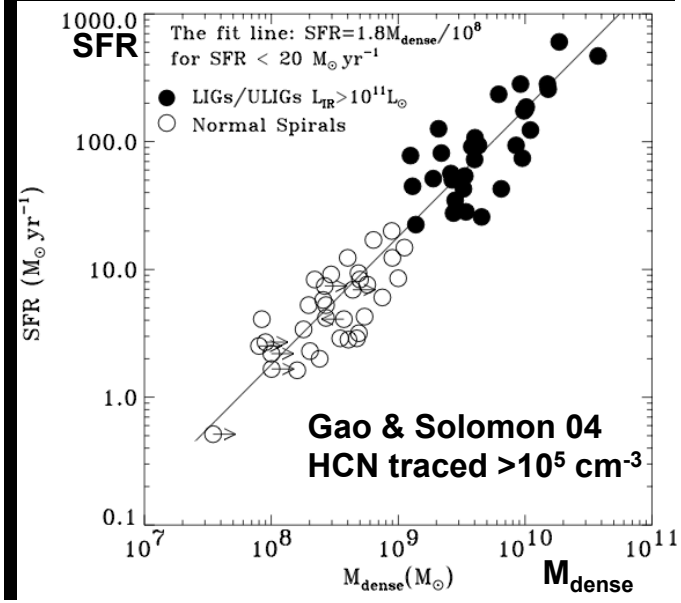
few pc scales (Andre +11)



few 100 pc scales (Lada +12)



10 kpc scales = galaxies (Gao & Solomon 04)



Implications of the main sequence

$M^*=5x10^{10}M_\odot$ galaxy at z~2 has $M_{gas}=5x10^{10}M_\odot$

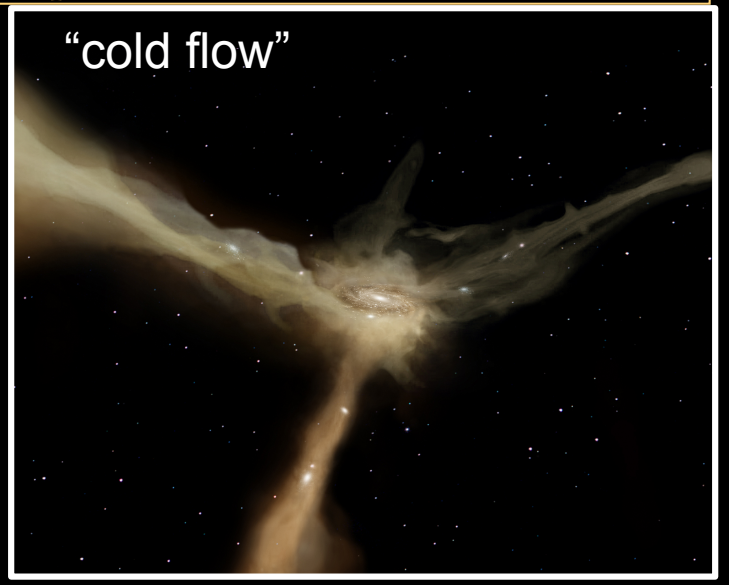
MS→ $SFR\sim90M_\odot yr^{-1}$ → gas exhausted in 570 Myr

main sequence= probably best indirect evidence that galaxies are fed continuously by extragalactic matter !

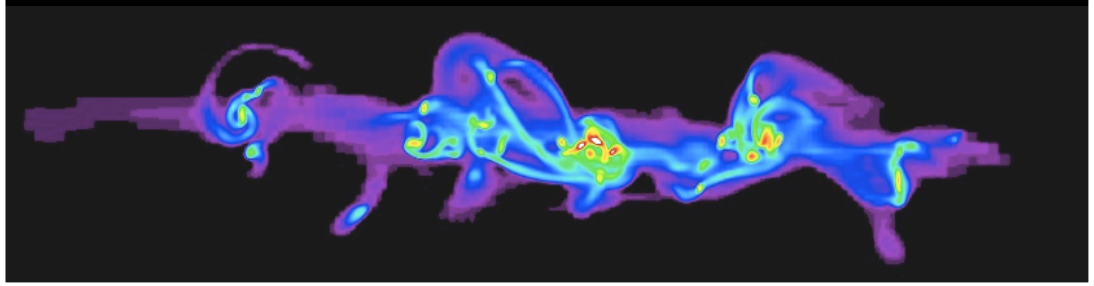
$M_{halo}=3x10^{12}M_\odot$ → infall rate 50 $M_\odot yr^{-1}$

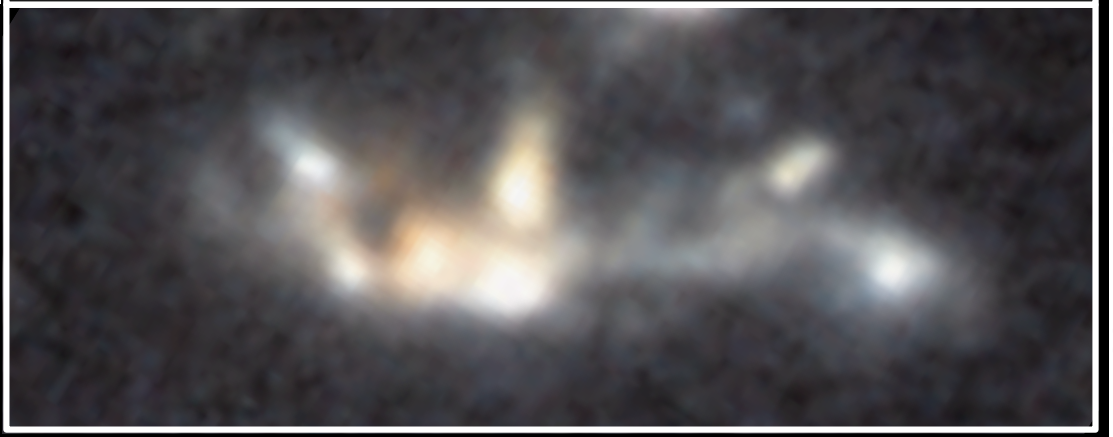
infall rate= 6.6 $f_{baryons}$ $(M_{halo}/1e12)^{1.15}$ $(1+z)^{2.25}$ (Dekel +09)

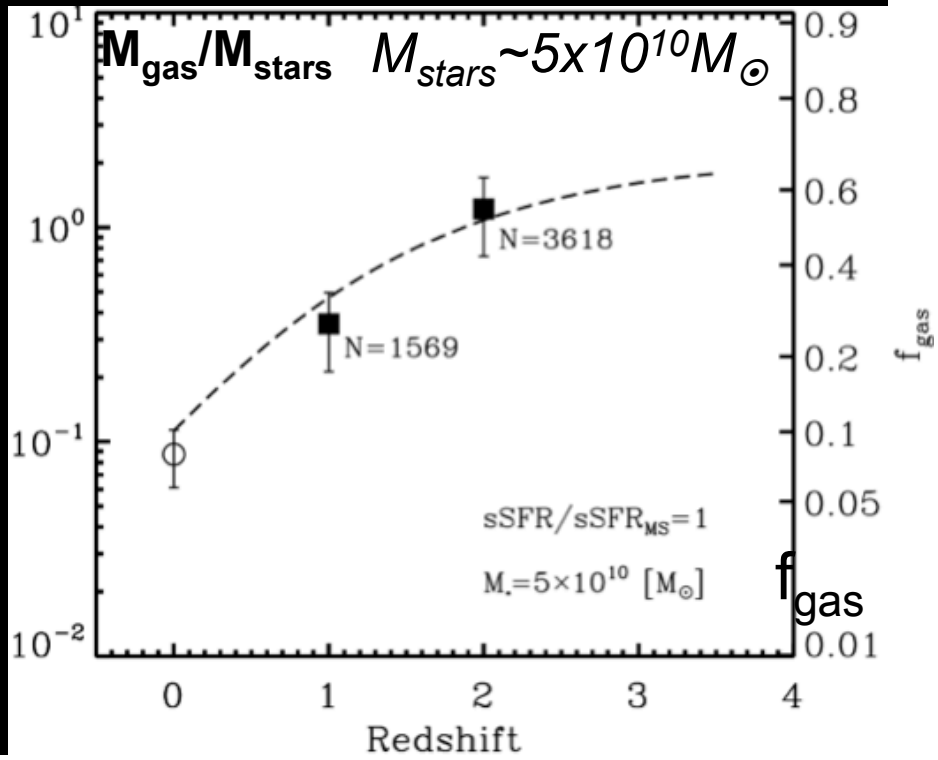
→ presence of massive reservoir (accumulated)



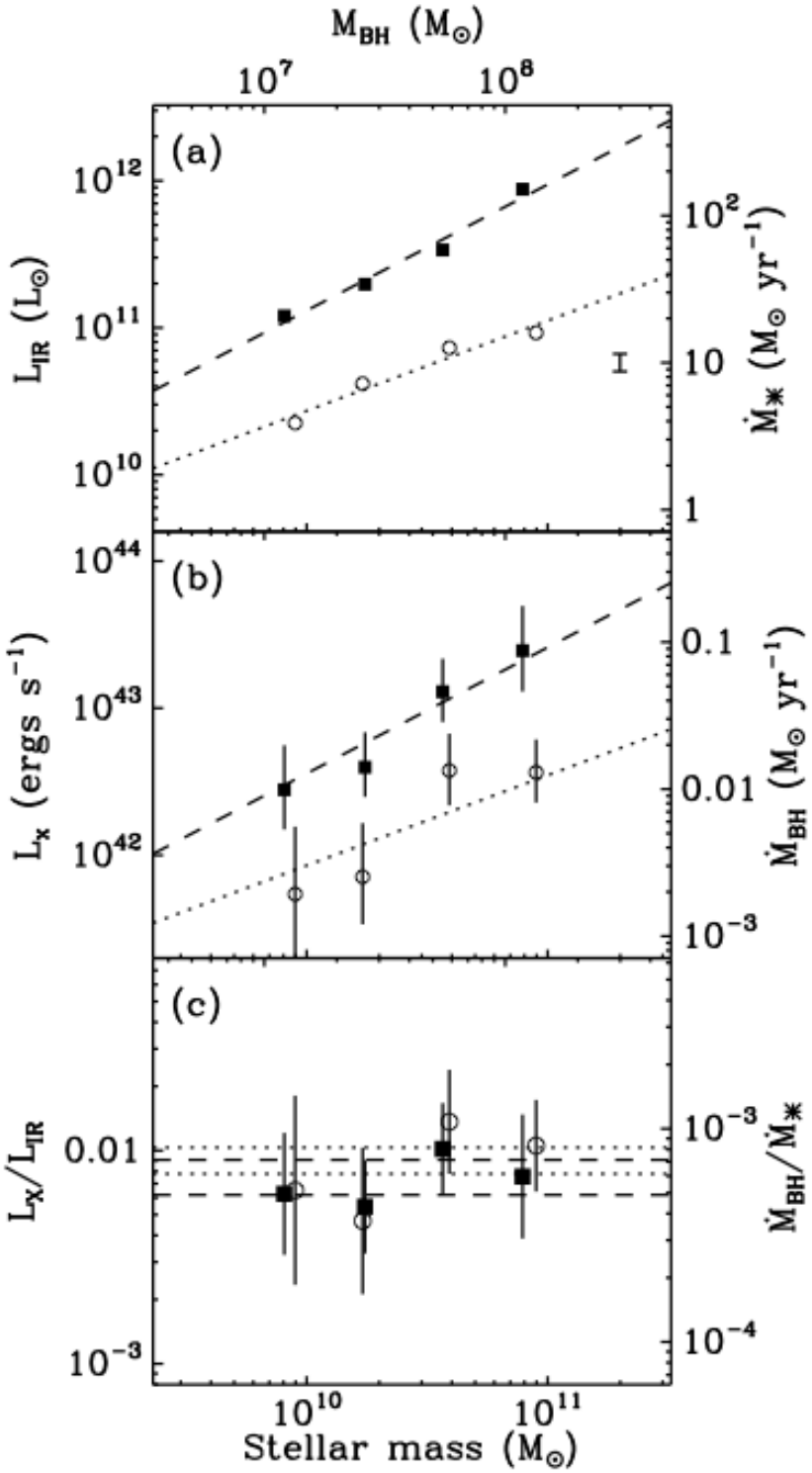
Strong dynamical instabilities induced by large infall of intergalactic matter

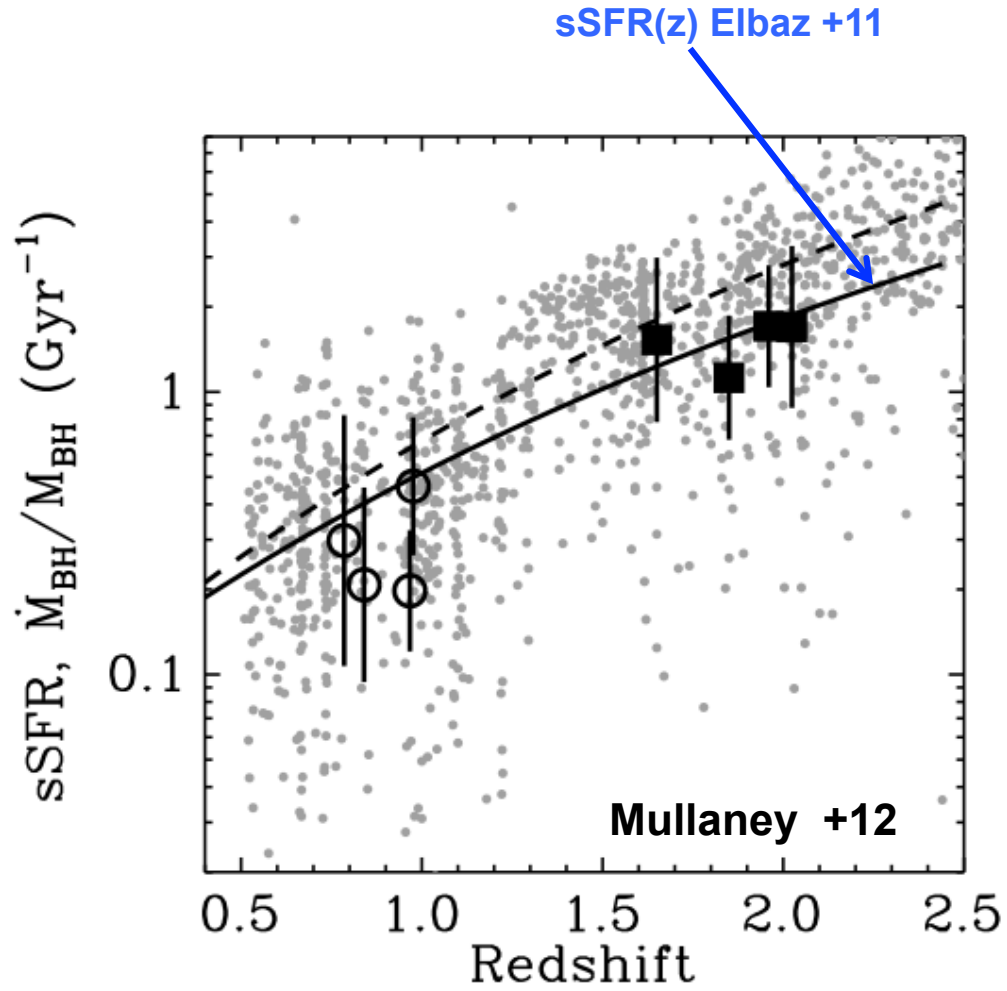






co-eval growth of BH and stars

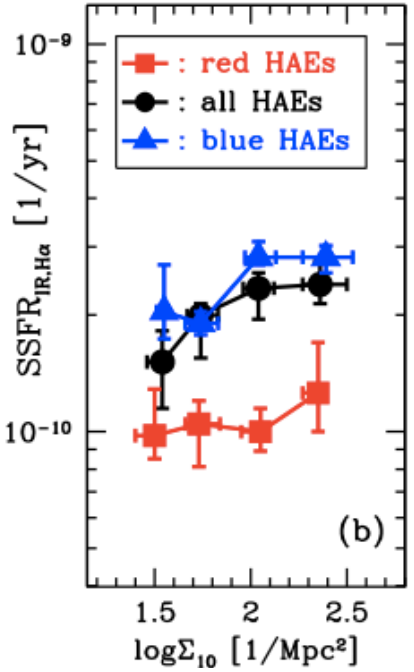


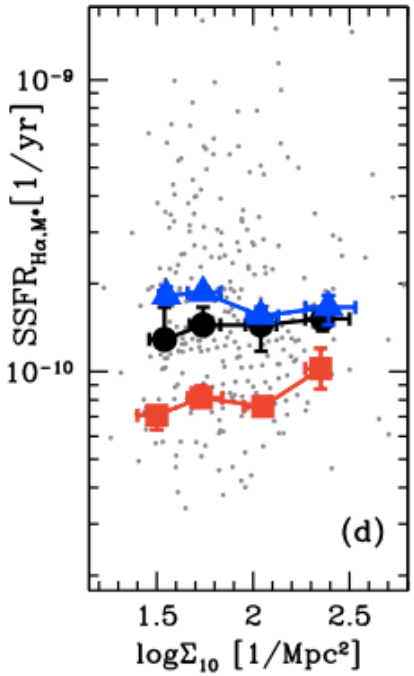


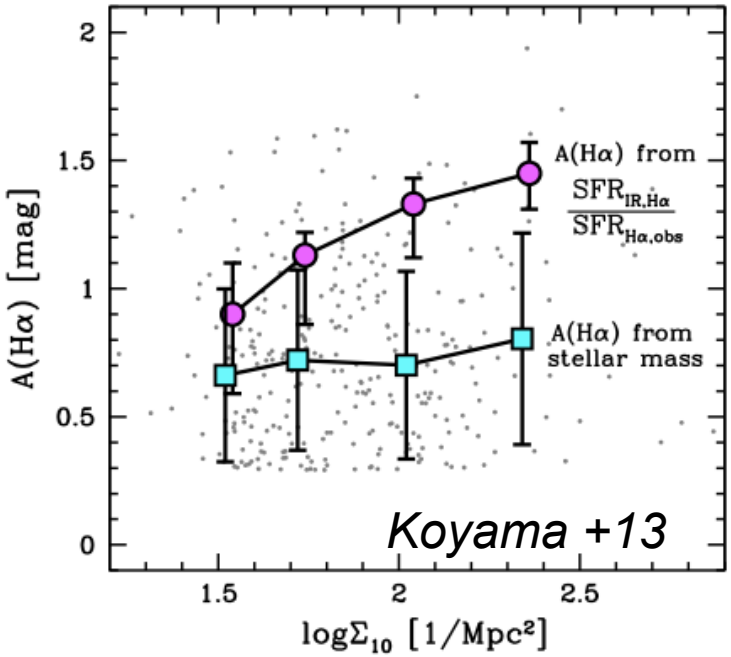
$$\dot{M}_{\rm BH}(M_{\rm gal},z) = \frac{(1-\epsilon)L_{\rm bol}(M_{\rm gal},z)}{\epsilon c^2} \qquad \epsilon = 0.1$$

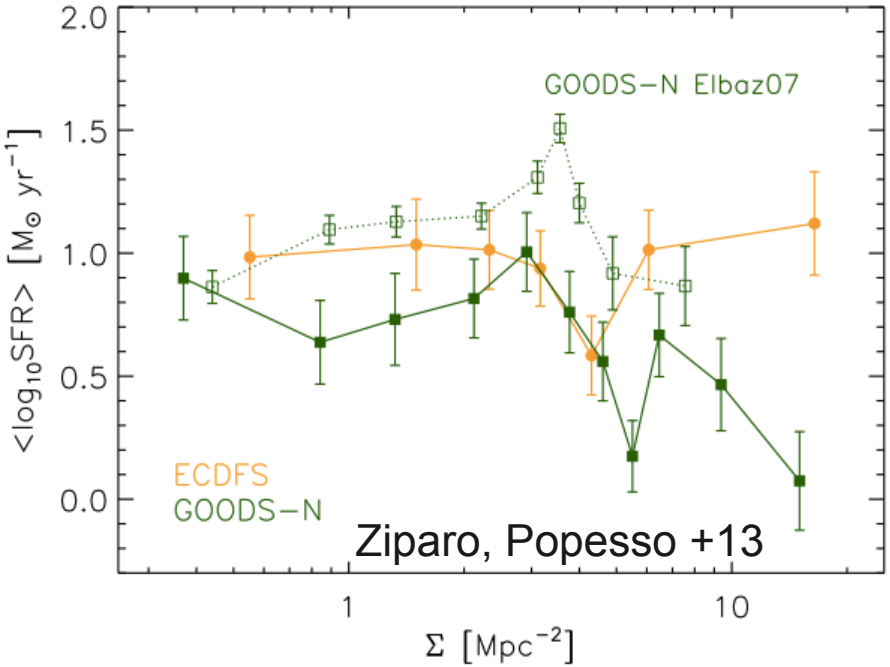
L_{bol}=L_X x 22.4 (Vasudevan & Fabian 07)

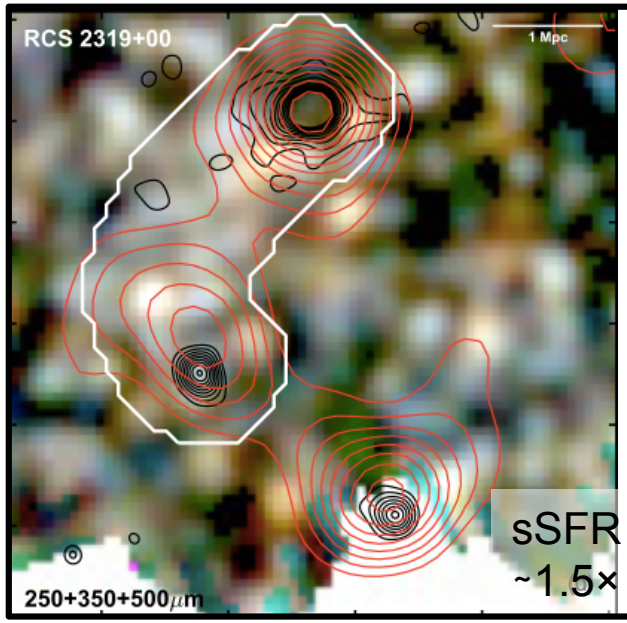
Environment or no environment effect on SFR ?
Beware of enhancement of attenuation in sub-population of starbursts...







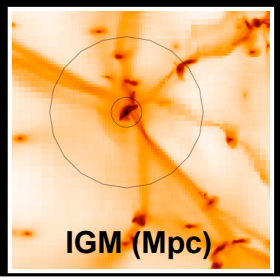




Coppin +12
z~0.9 supercluster

sSFR (central cluster gals)
~1.5× rest of supercluster

Main results from Herschel surveys on star-formation mode of galaxies

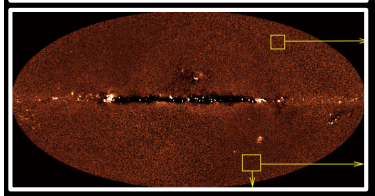


proof that star formation has been dominantly sustained by gas support external to galaxies over > 12 Gyr

→ *next step: observe infall/gas haloes (ALMA abs°/SKA)*

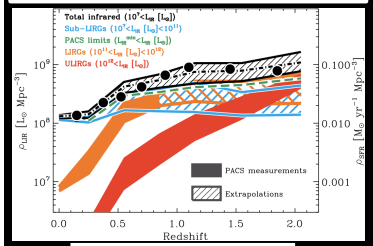
role of mergers secondary = paradox in expanding Universe !

→ *What causes the % of starbursts to remain nearly constant at the level of a few % ? Ellipticals mostly formed in main sequence !*



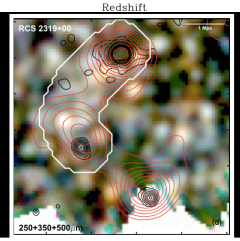
Herschel resolves >70% of 100-160-250μm CIRB

→ *global budget of star-formation*



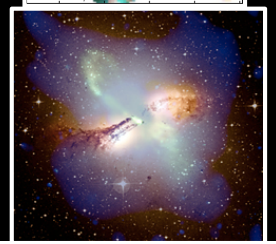
Drop of SFR density since ~8 Gyr mostly due to lack of gas rather SF efficiency !

→ *problem: what is preventing gas from infalling onto galaxies.*



role of large-scale environment secondary vs internal physics

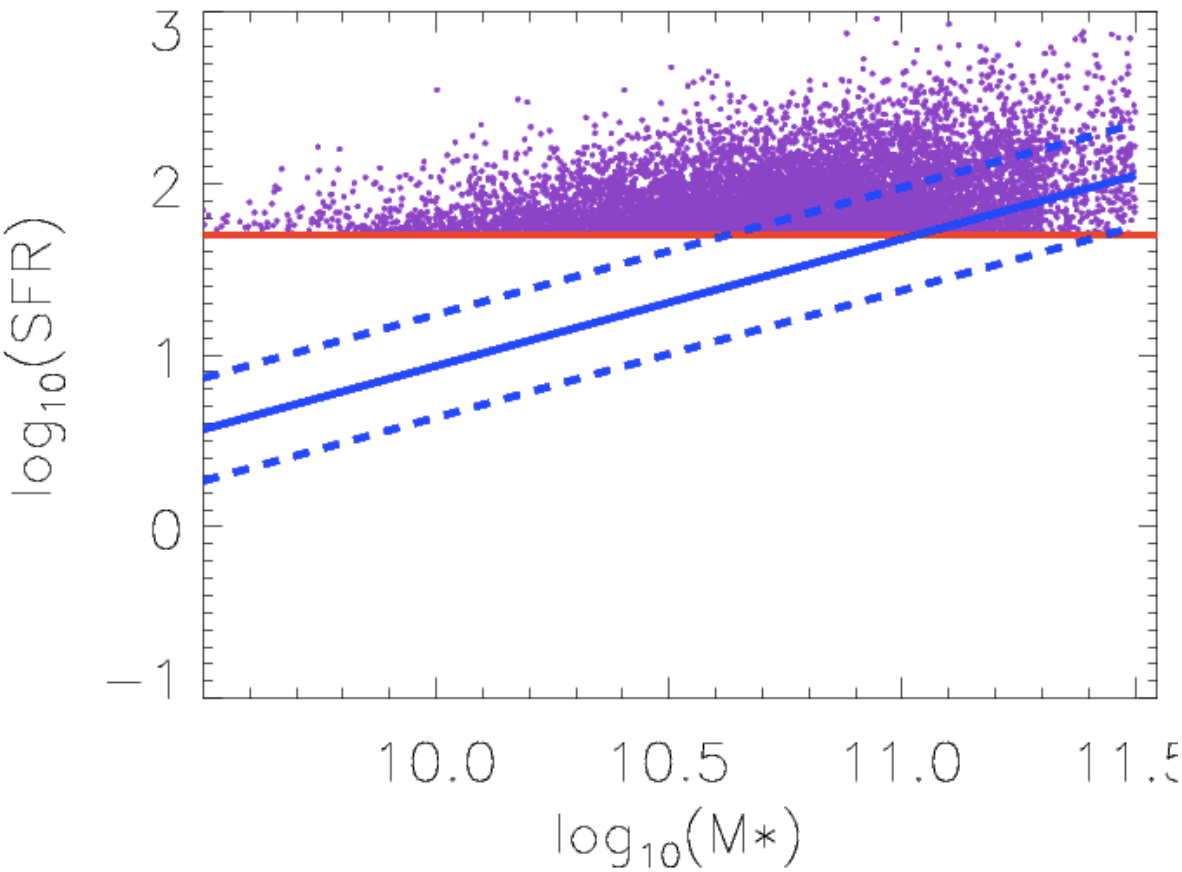
→ *hidden role of environment since infall from Mpc scales !*



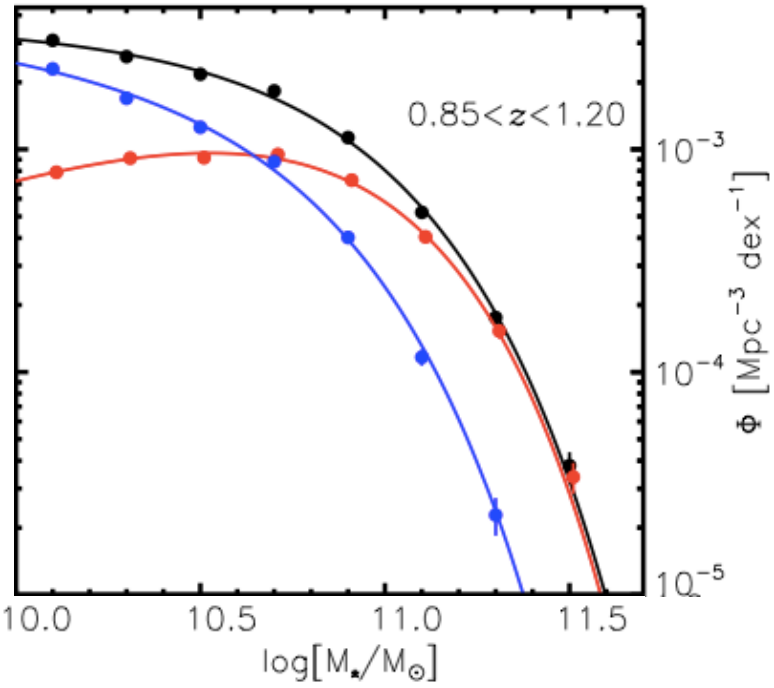
Black holes grow in parallel with stars (& mildly affect IR)

→ *what feeds the central SMBH ? Infall ?...*

Main sequence or not main sequence ?
Beware of selection effects in SFR > limit (Herschel depth)



z~0.5-1.5



68% of Herschel selected galaxies in COSMOS 2sq.deg. are >0.3 dex offset