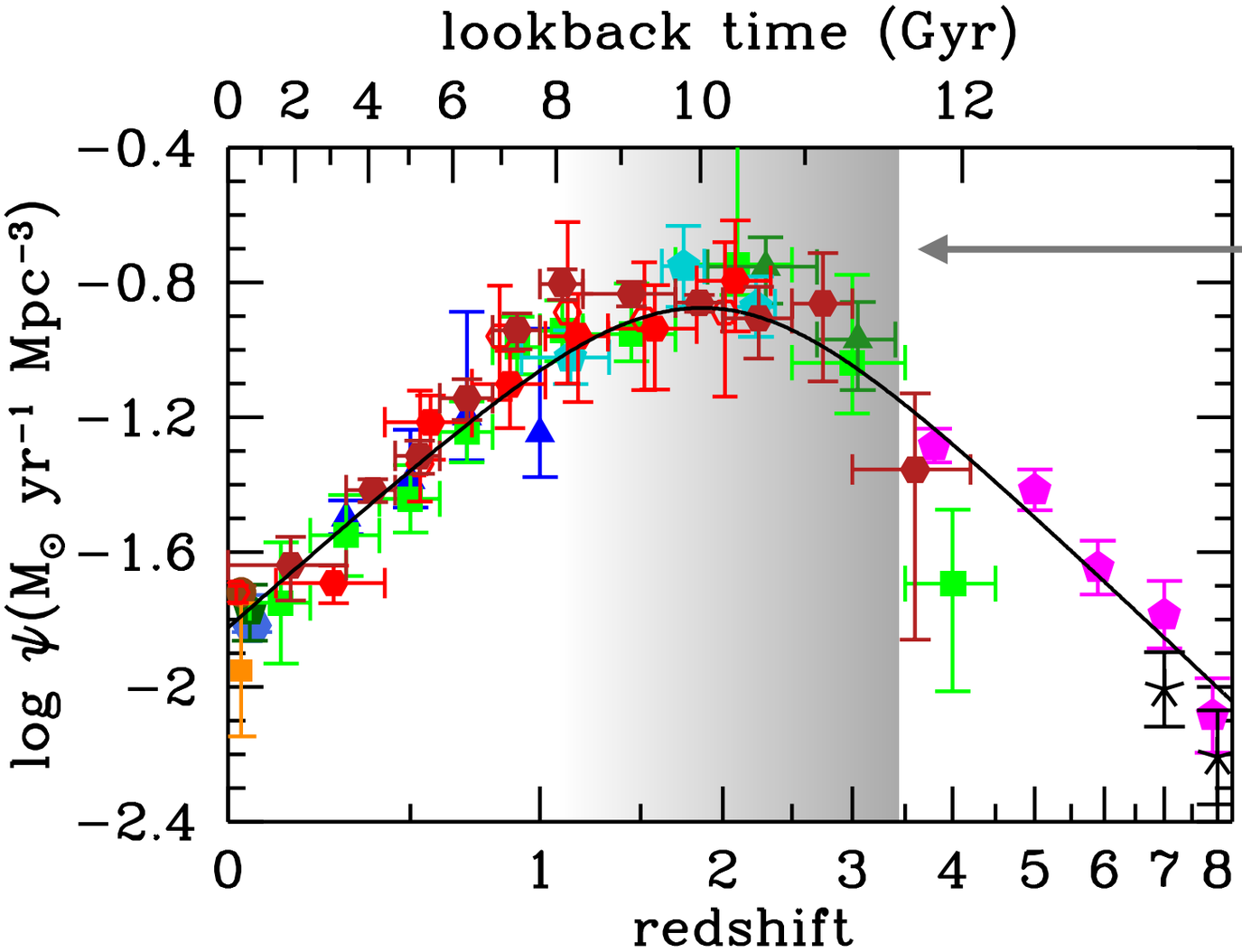
Star formation in z > 1.4 early-type galaxies

R. Gobat (KIAS)

+ E. Daddi, V. Strazzullo, S. Jin, G. Magdis, M. Sargent, F. Bournaud, M. Martig & others

6th Survey Science Group Meeting,
Ulleungdo, June 29 2017

Introduction



passive galaxies start here

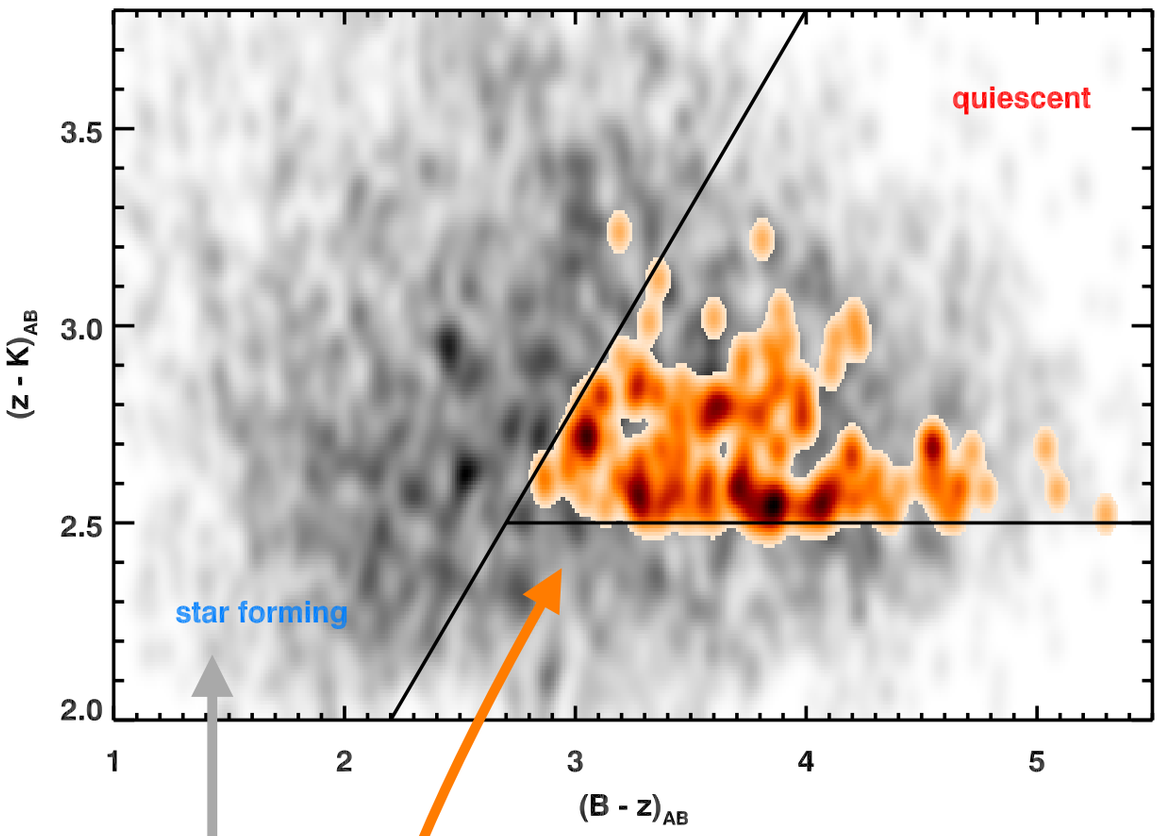
Madau et al. 2014

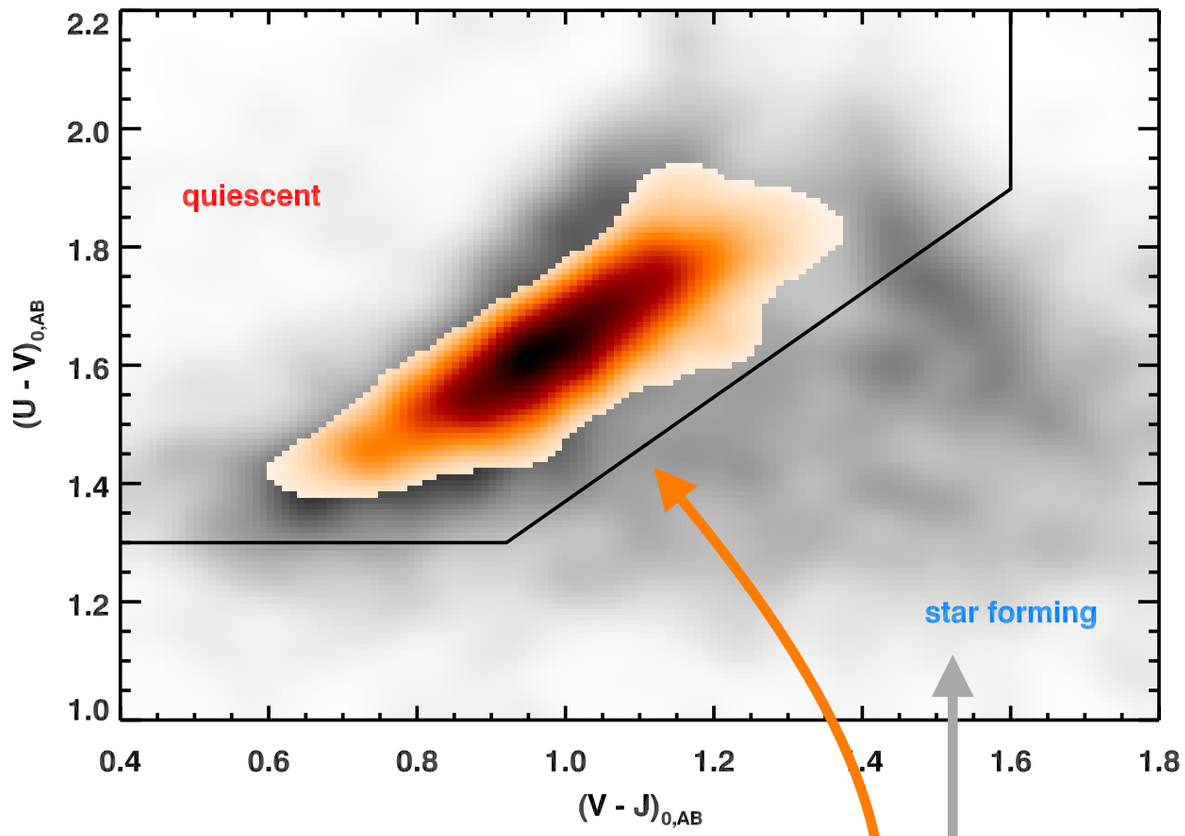
- what processes quench galaxies during the cosmic noon?

  → indices from abundances, **stellar population structure**, **residual gas**

- how do quenched galaxies stay quiescent for ~9 Gyr ?

COSMOS pBzK + UVJp sample





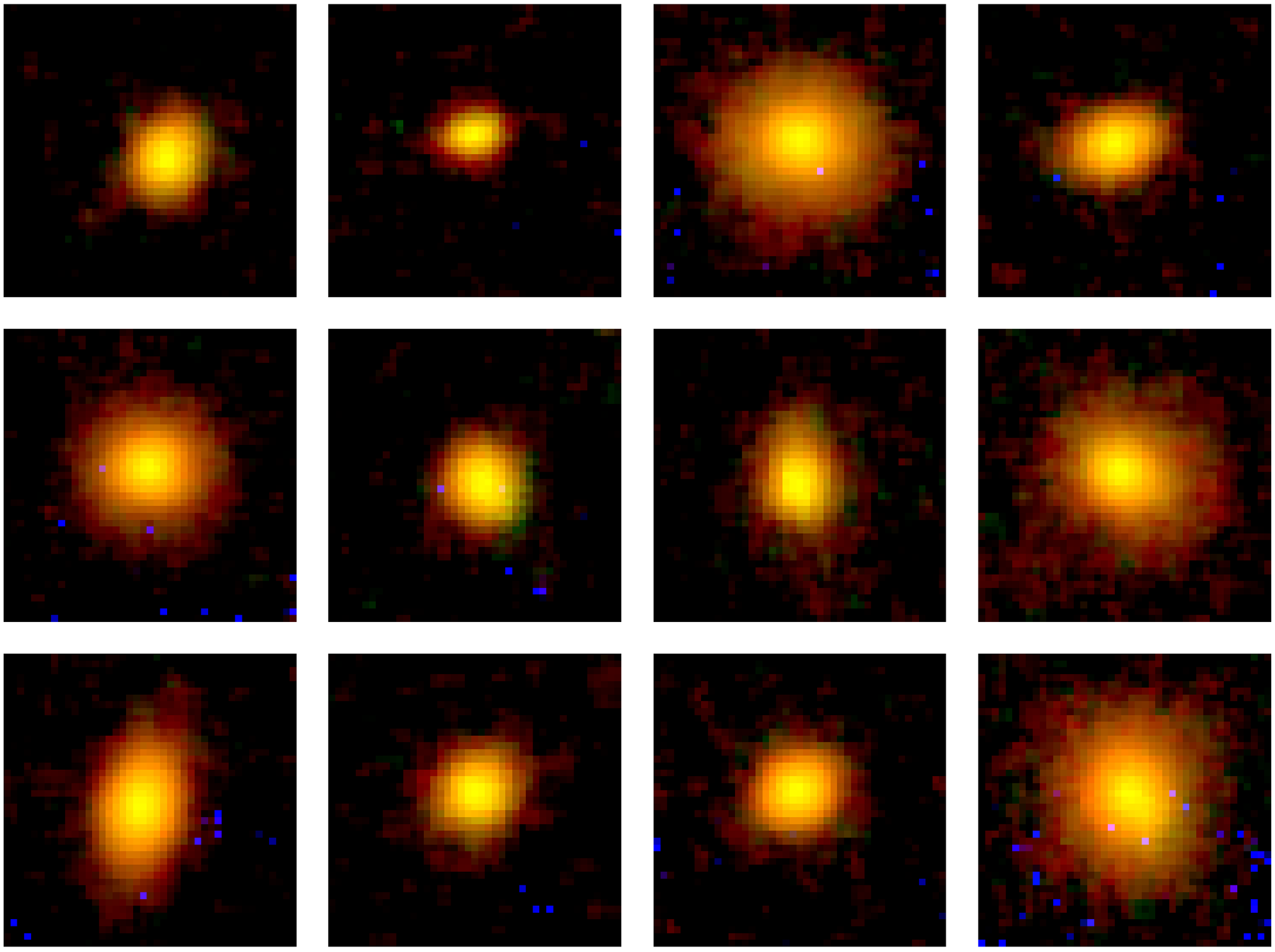
UVJ selected

BzK selected

977 quiescent galaxies in COSMOS with:

- joint BzK & UVJ selection
- no 24 μm detection at 3σ (r.m.s. ~8 μJy)
- $\log M_* > 10.8$, $\langle M_* \rangle = 1.2 \times 10^{11}\, M_\odot$

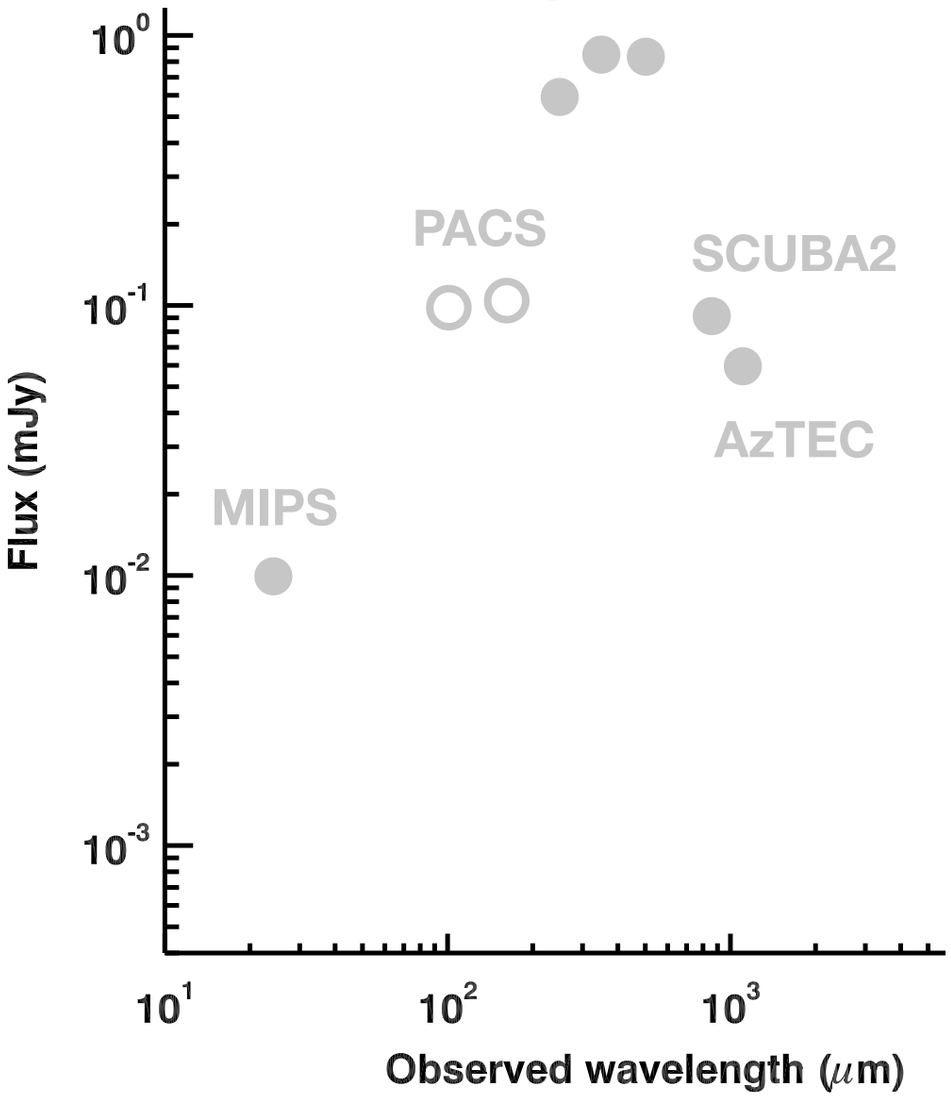
Mass-matched pBzK + UVJp sample

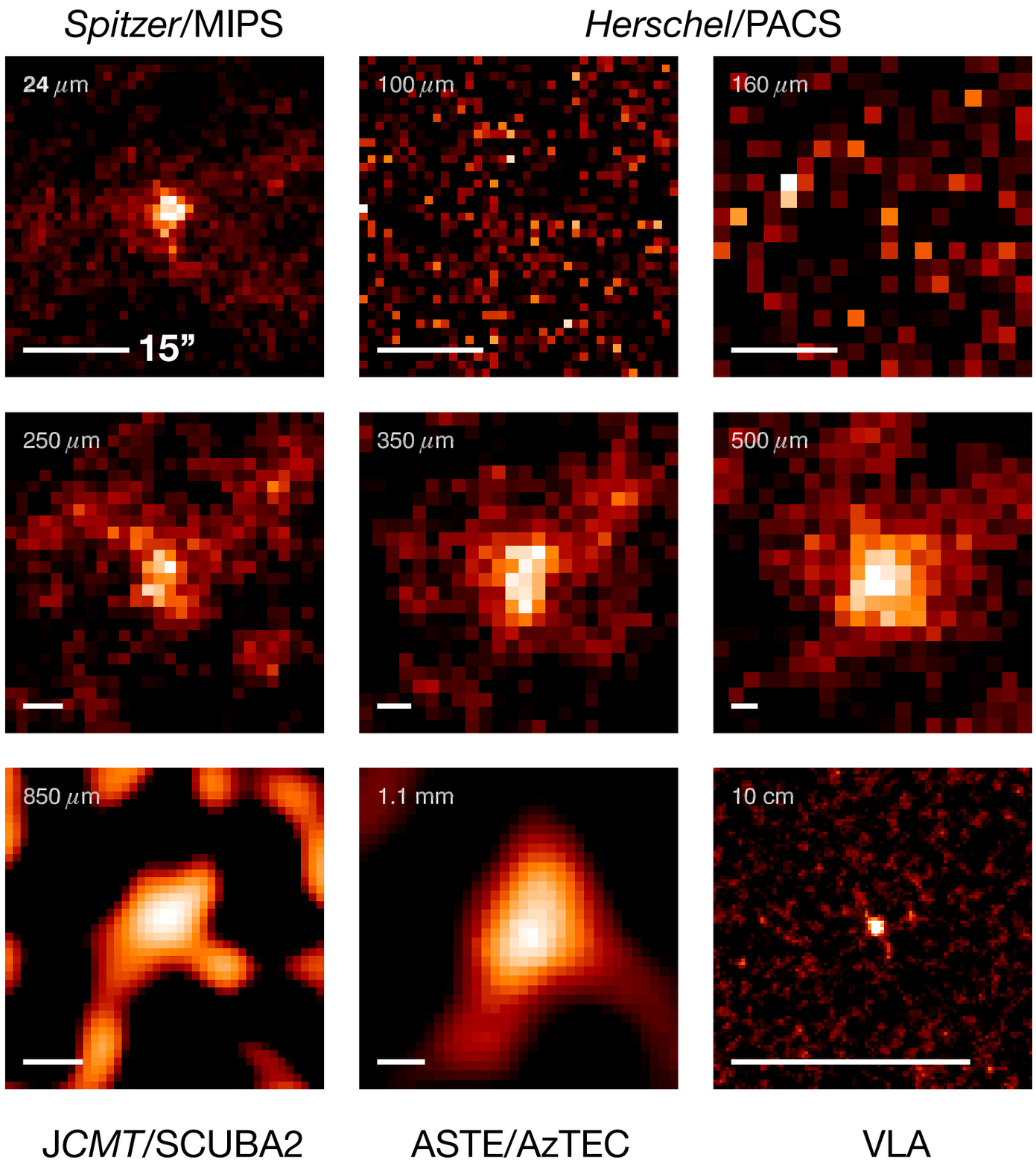


F606W, F125W, F160W (CANDELS-COSMOS; Koekemoer et al. 2011)

early-type morphologies: n ~ 3, r_{eff} ~ 1.5 kpc

Far-infrared stacks (2D)

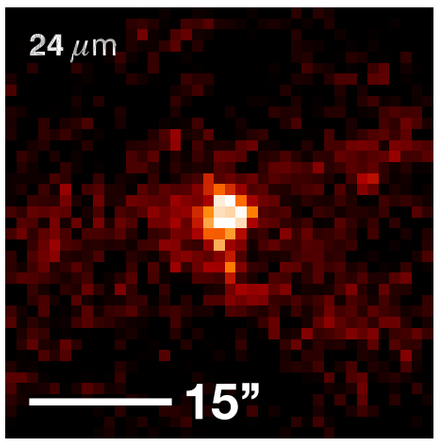


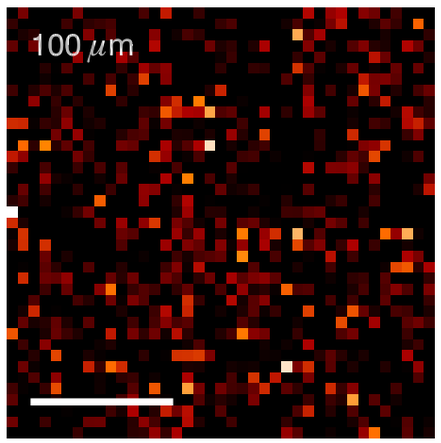


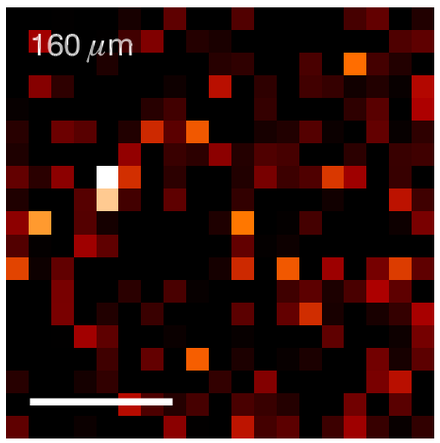
Far-infrared stacks (2D)

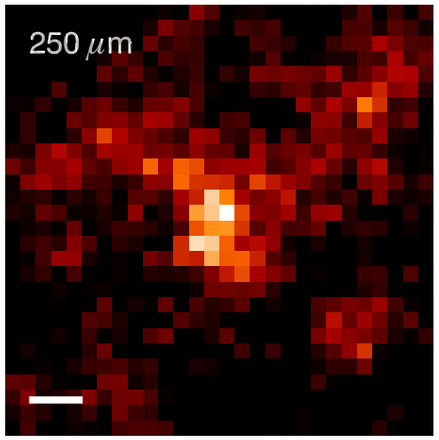
Spitzer/MIPS

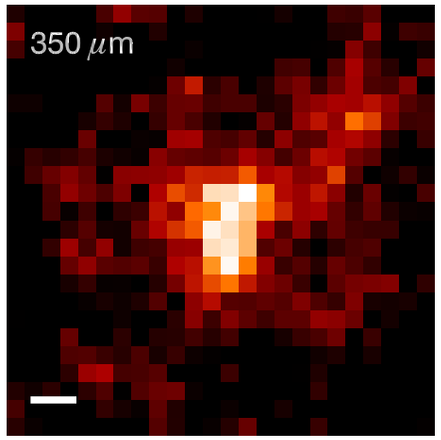
Herschel/PACS

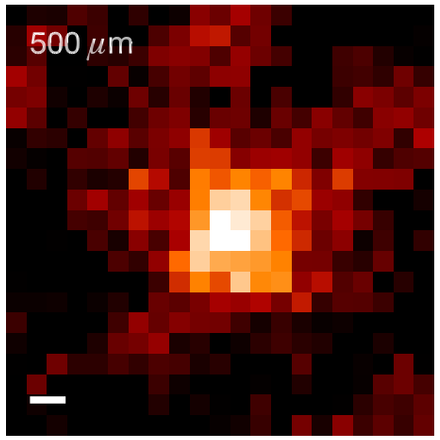




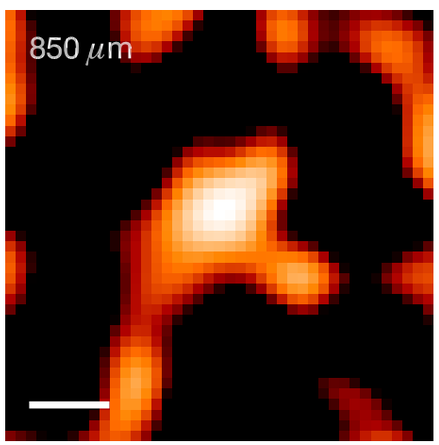


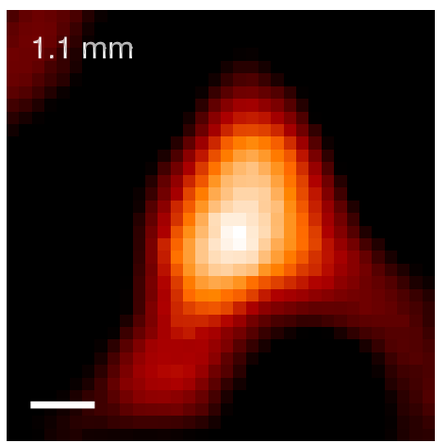


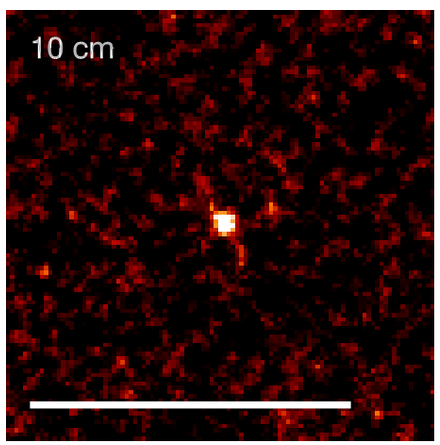




Herschel/SPIRE



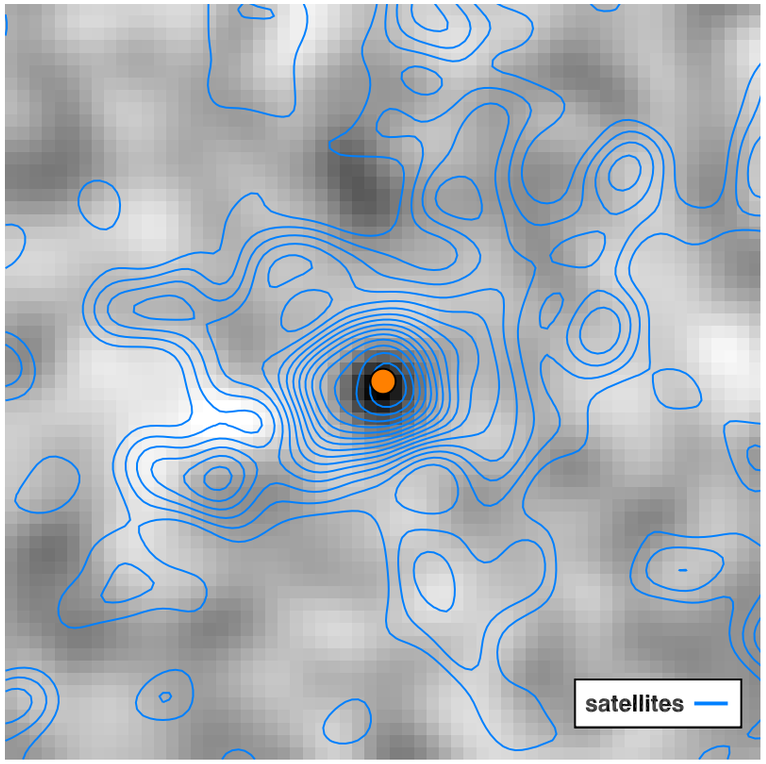




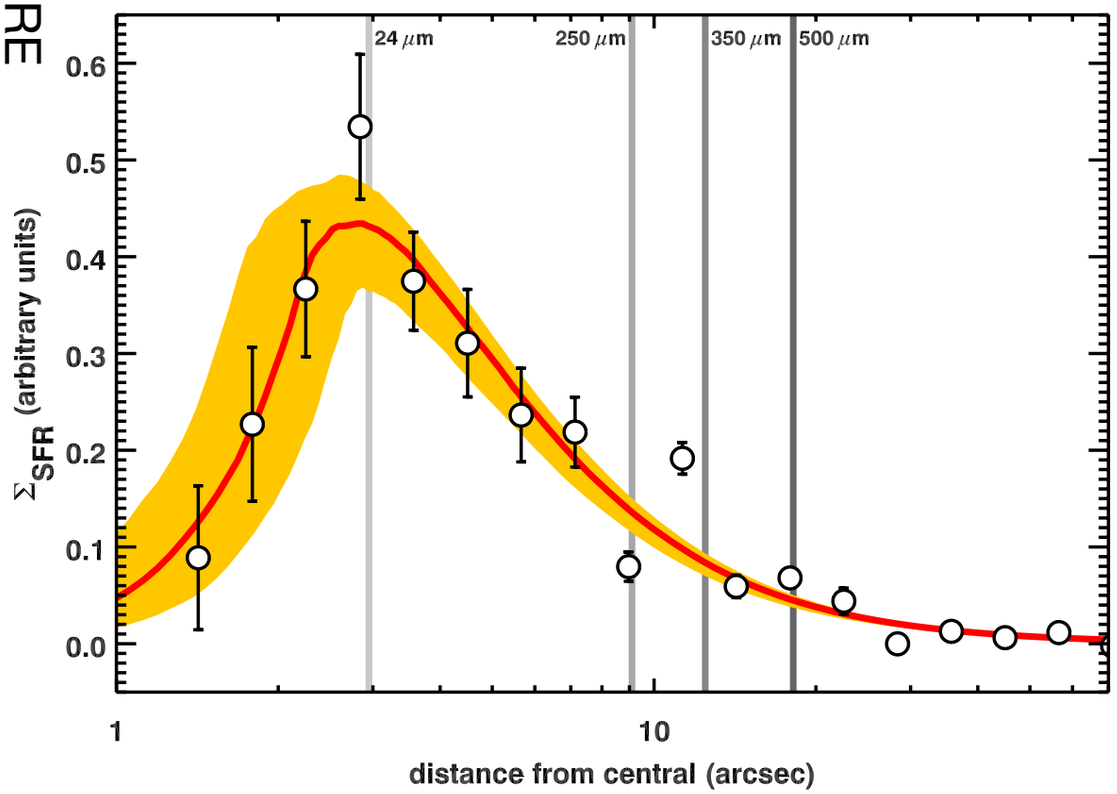
JCMT/SCUBA2

ASTE/AzTEC

VLA



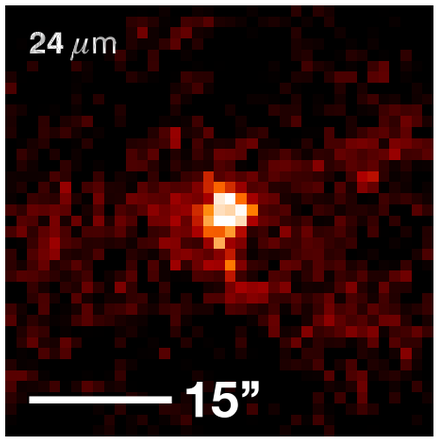
Correction for satellite contamination based on UV-corrected SFR profile

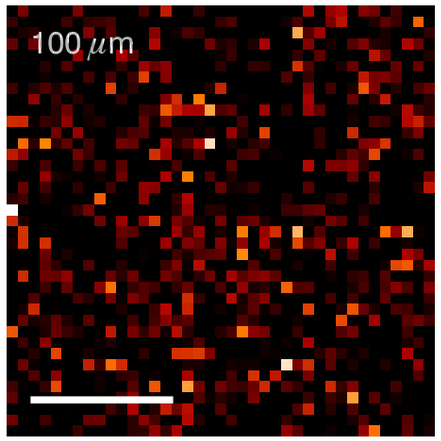


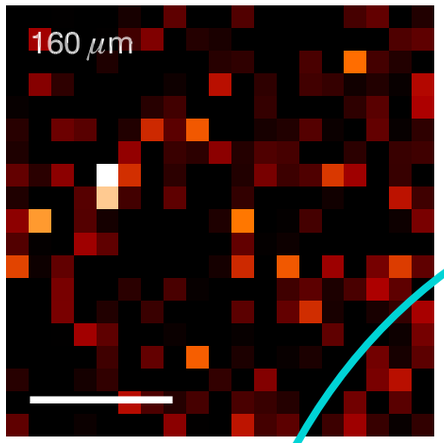
Far-infrared stacks (2D)

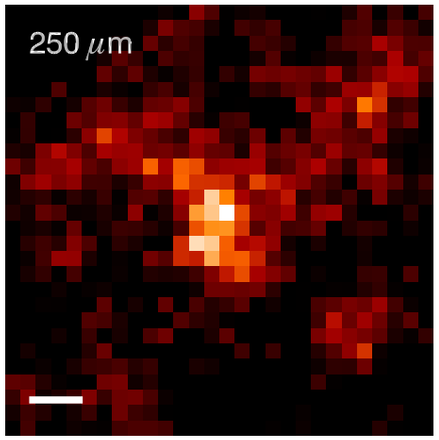
Spitzer/MIPS

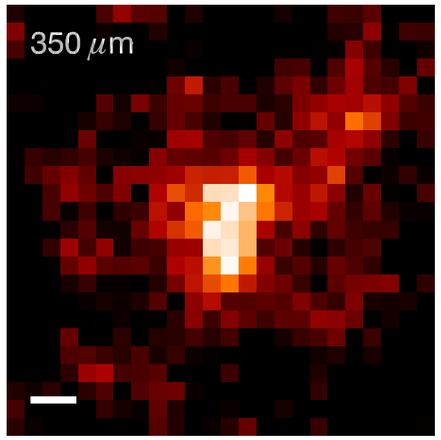
Herschel/PACS

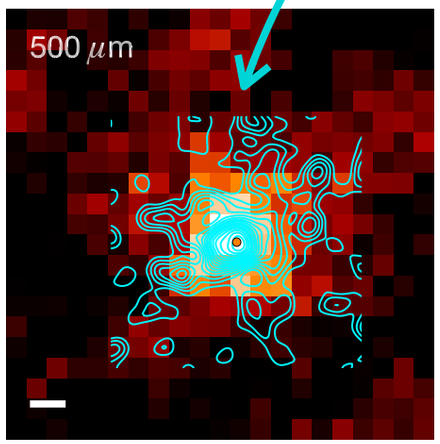




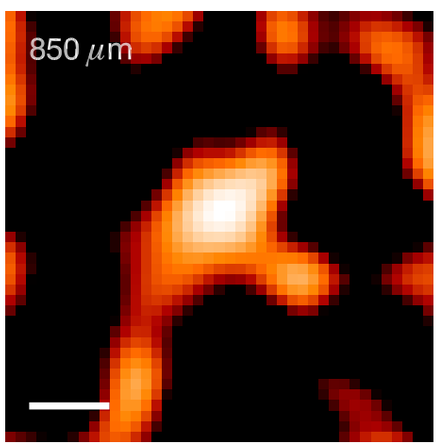


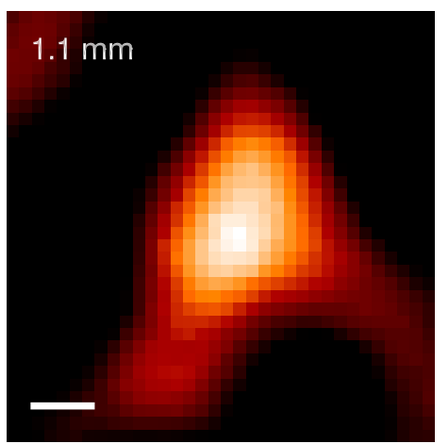


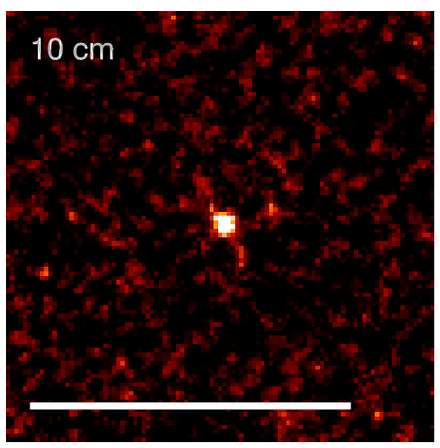




Herschel/SPIRE



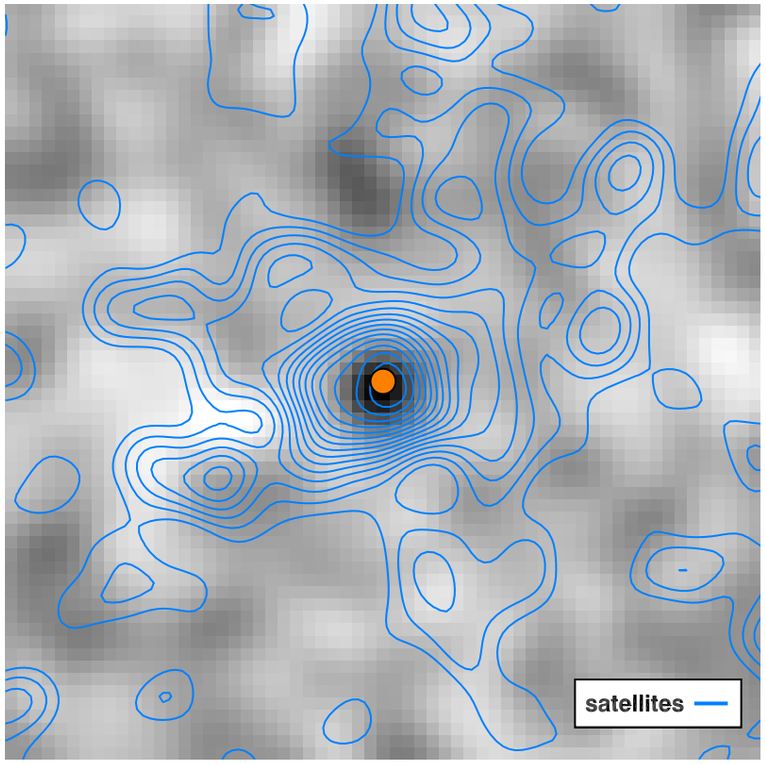




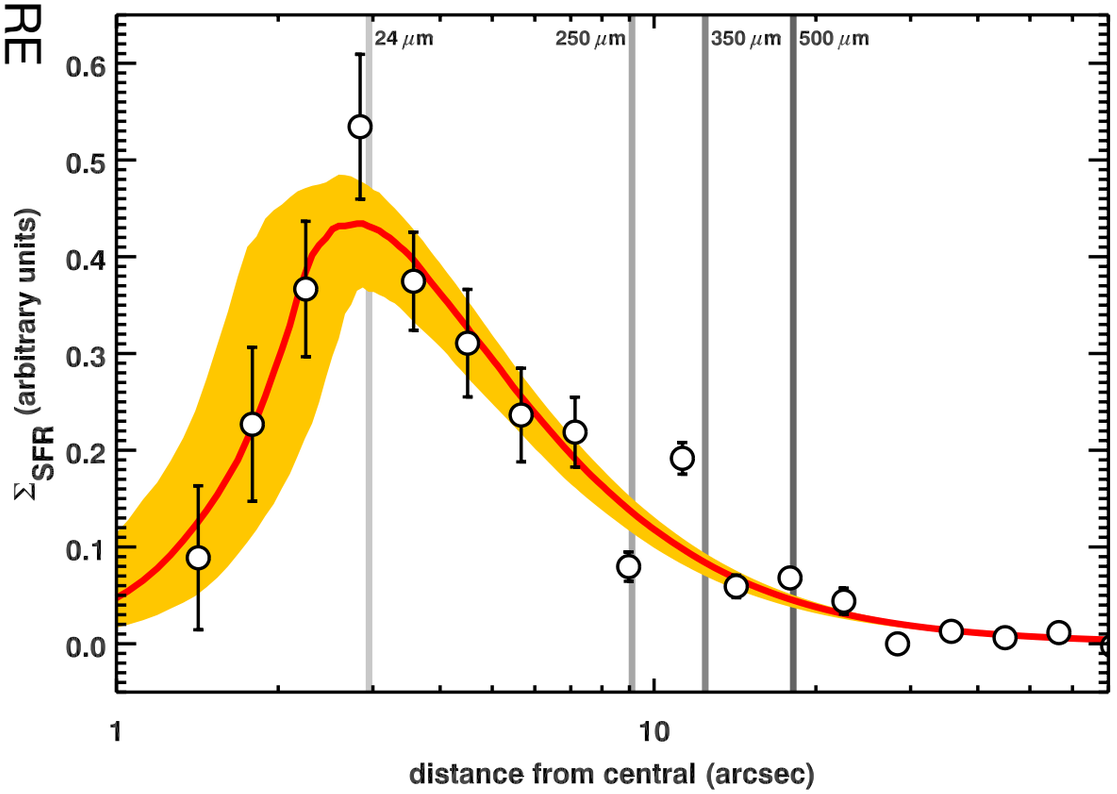
JCMT/SCUBA2

ASTE/AzTEC

VLA

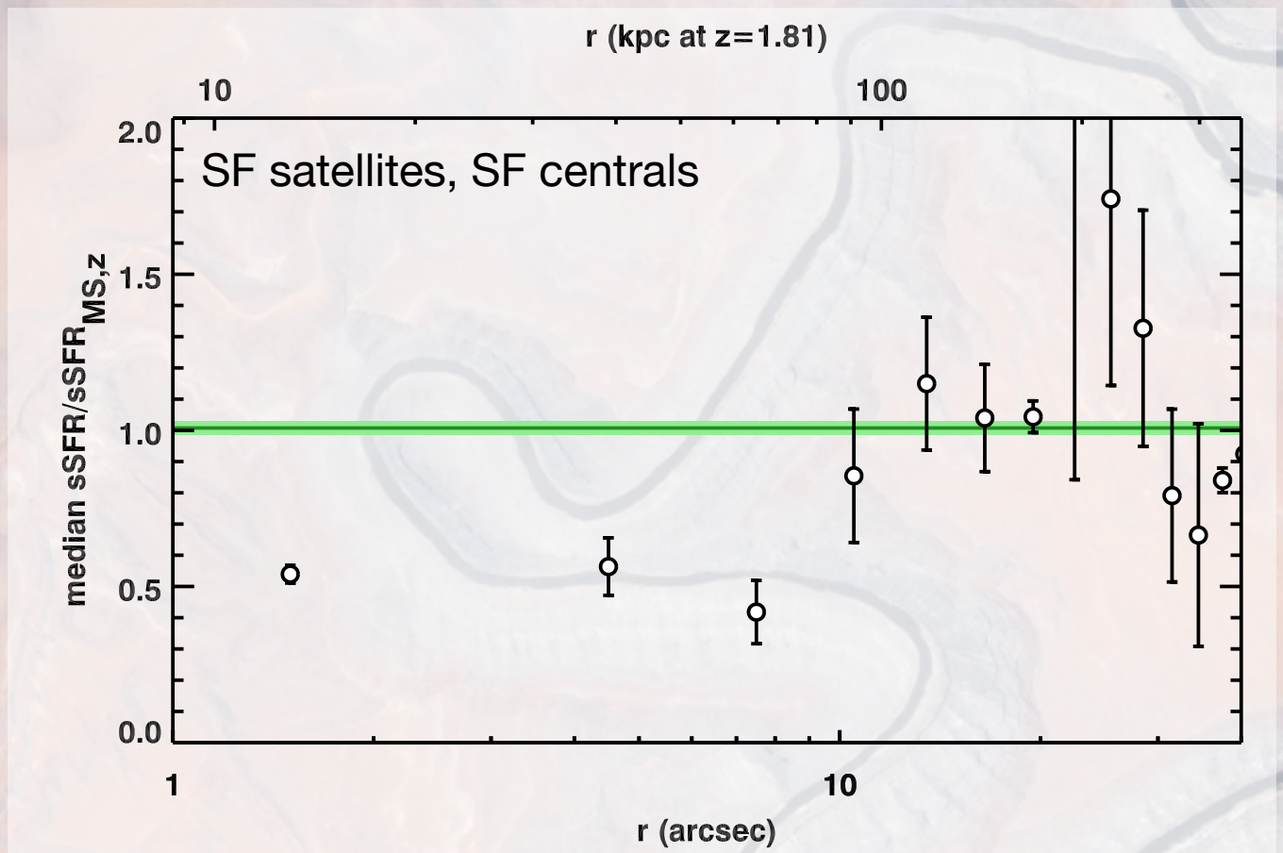


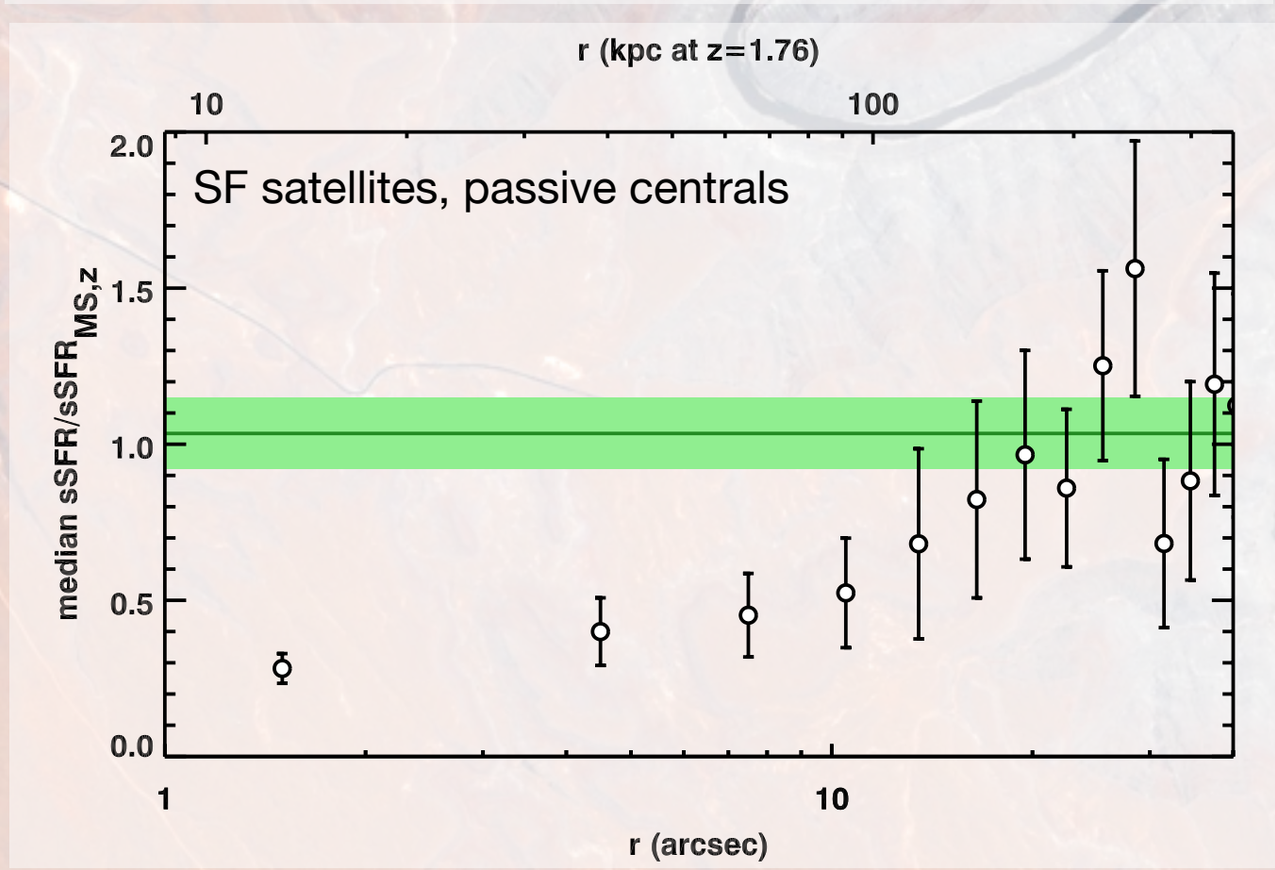
Correction for satellite contamination based on UV-corrected SFR profile

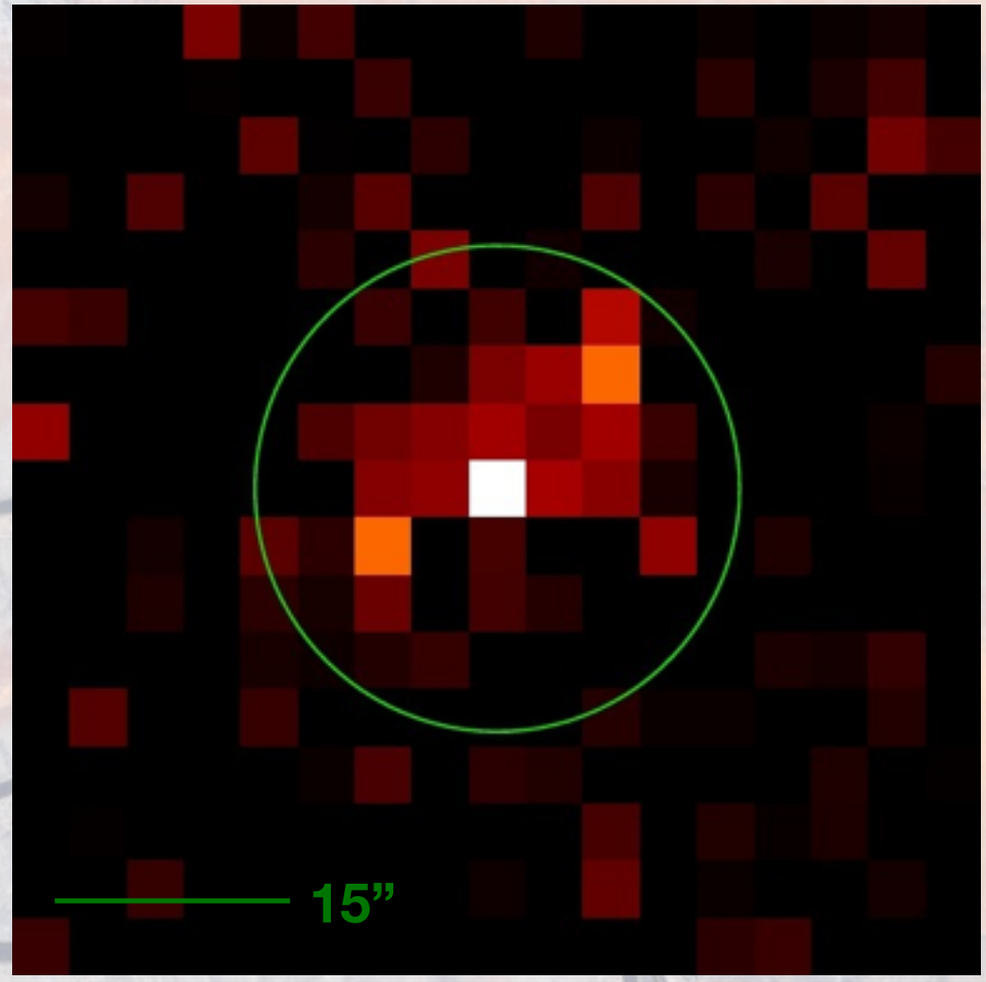


Satellite halos

Gobat et al. 2015, A&A 581, 56







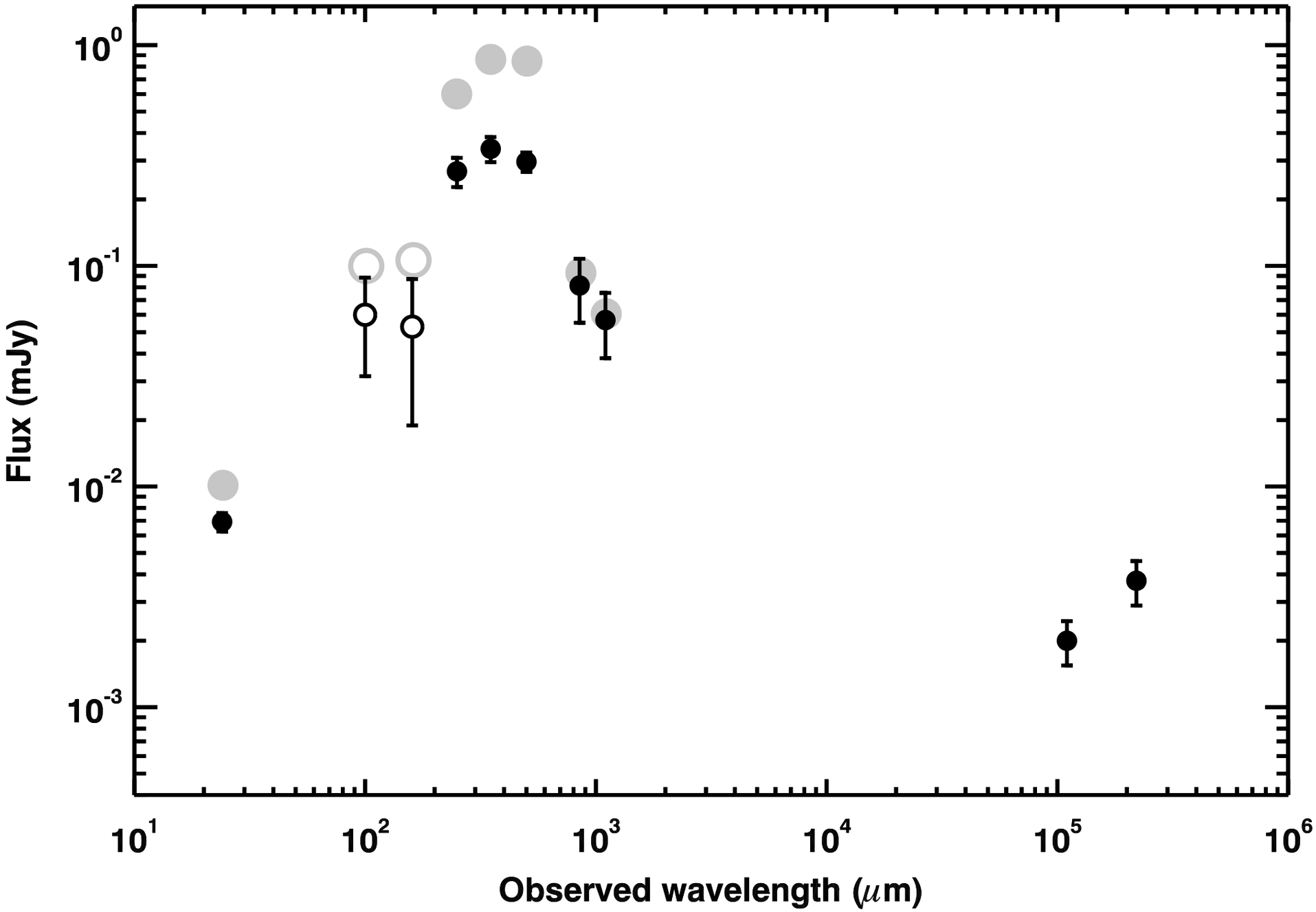
Diffuse X-ray emission:

$M_{200} = 1\text{-}3\times10^{13}\,M_{\odot}$

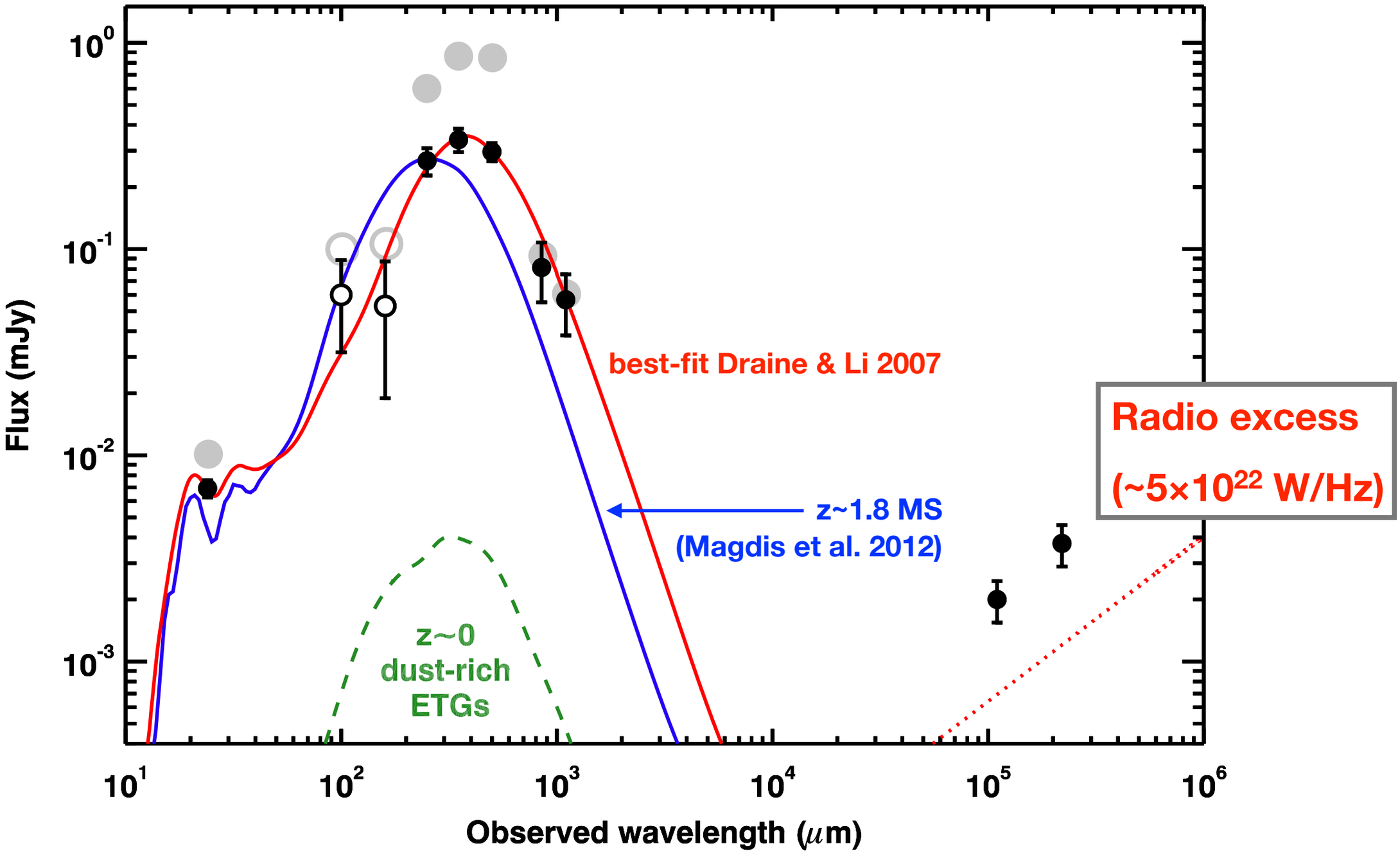
Depressed sSFR closer to the central

SFR density does not follow SF satellite number density

Far-infrared stacks (SED)



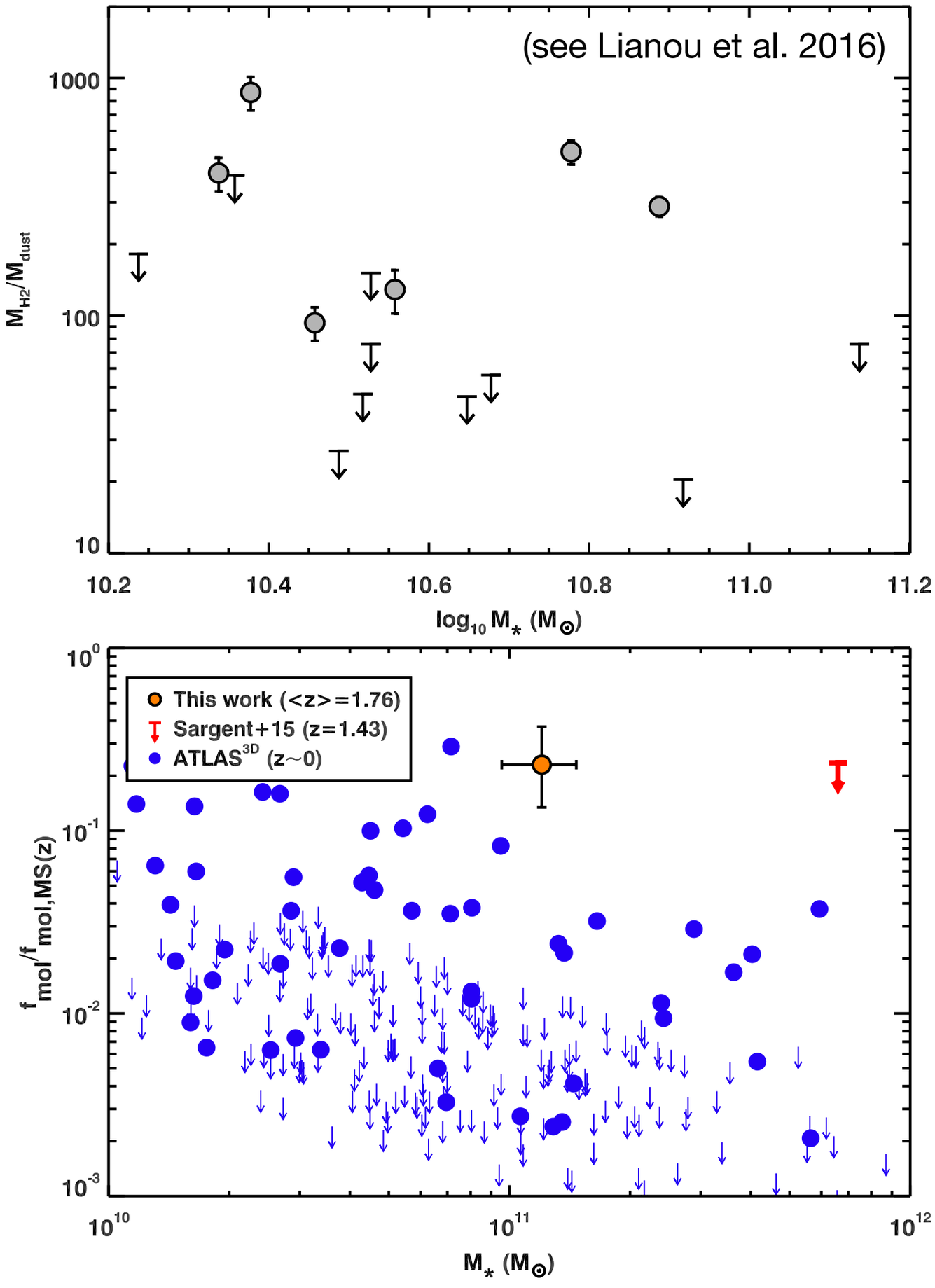
Far-infrared stacks (SED)



$\log_{10}L_{IR} = 10.46 \pm 0.14 \implies$ $SFR_{IR} = 4.8^{+1.8}_{-1.3}\ M_\odot\ yr^{-1}$

$\log_{10}M_{dust} = 8.00 \pm 0.2$ ~2-3 dex above z~0 ETGs

$T_{dust} = 23.8 \pm 1.8$ K ~10 K colder than MS



Gas mass

$\log_{10}M_{dust} = 8.00 \pm 0.20$

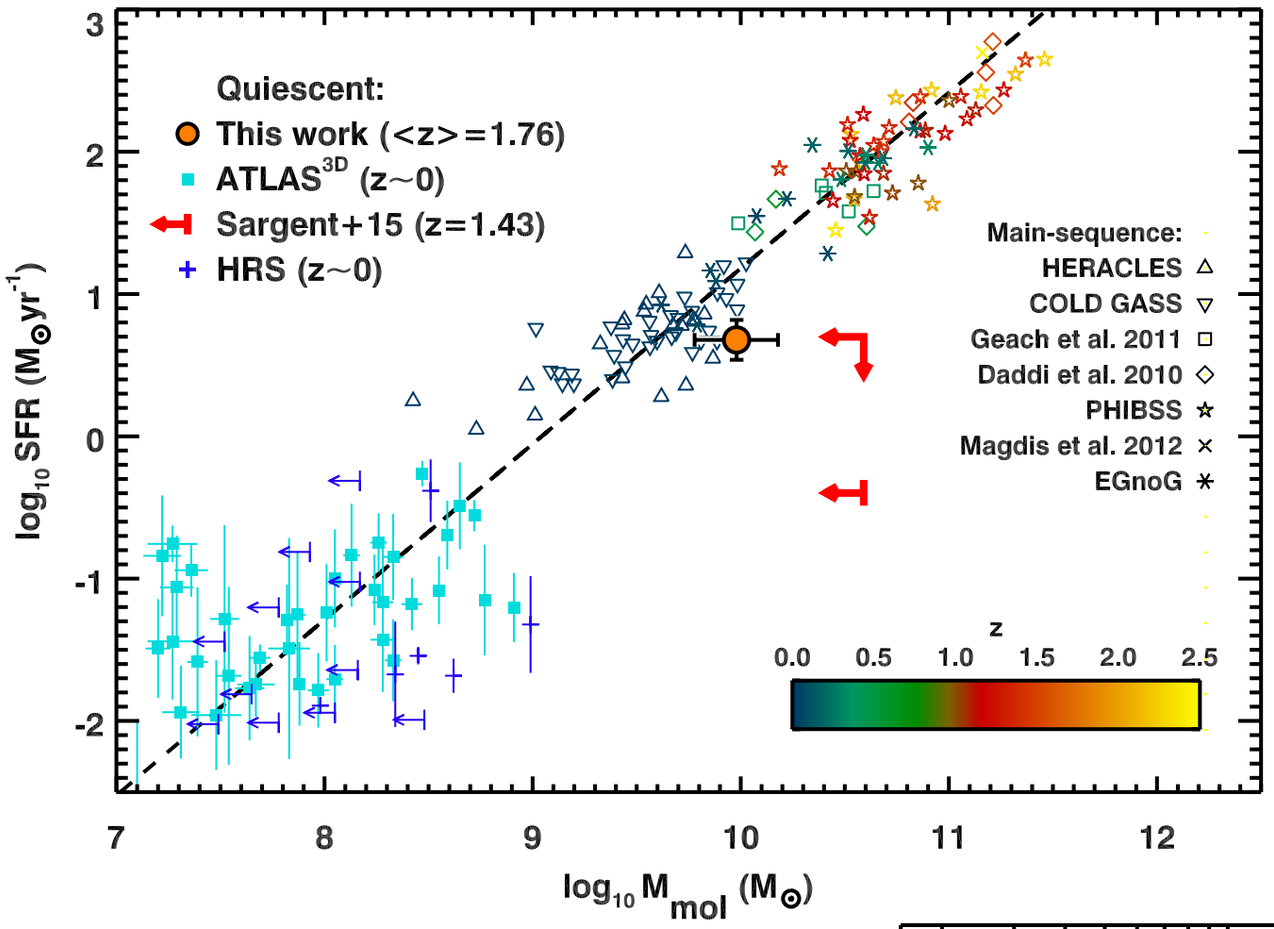
G/D ~ 100

(z~0 ETGs, ~$Z_\odot$ MS galaxies)
(UV-rest-frame stellar Z~$Z_\odot$ in z~1.4 ETGs)

$\log_{10}M_{gas} = 9.98 \pm 0.20$

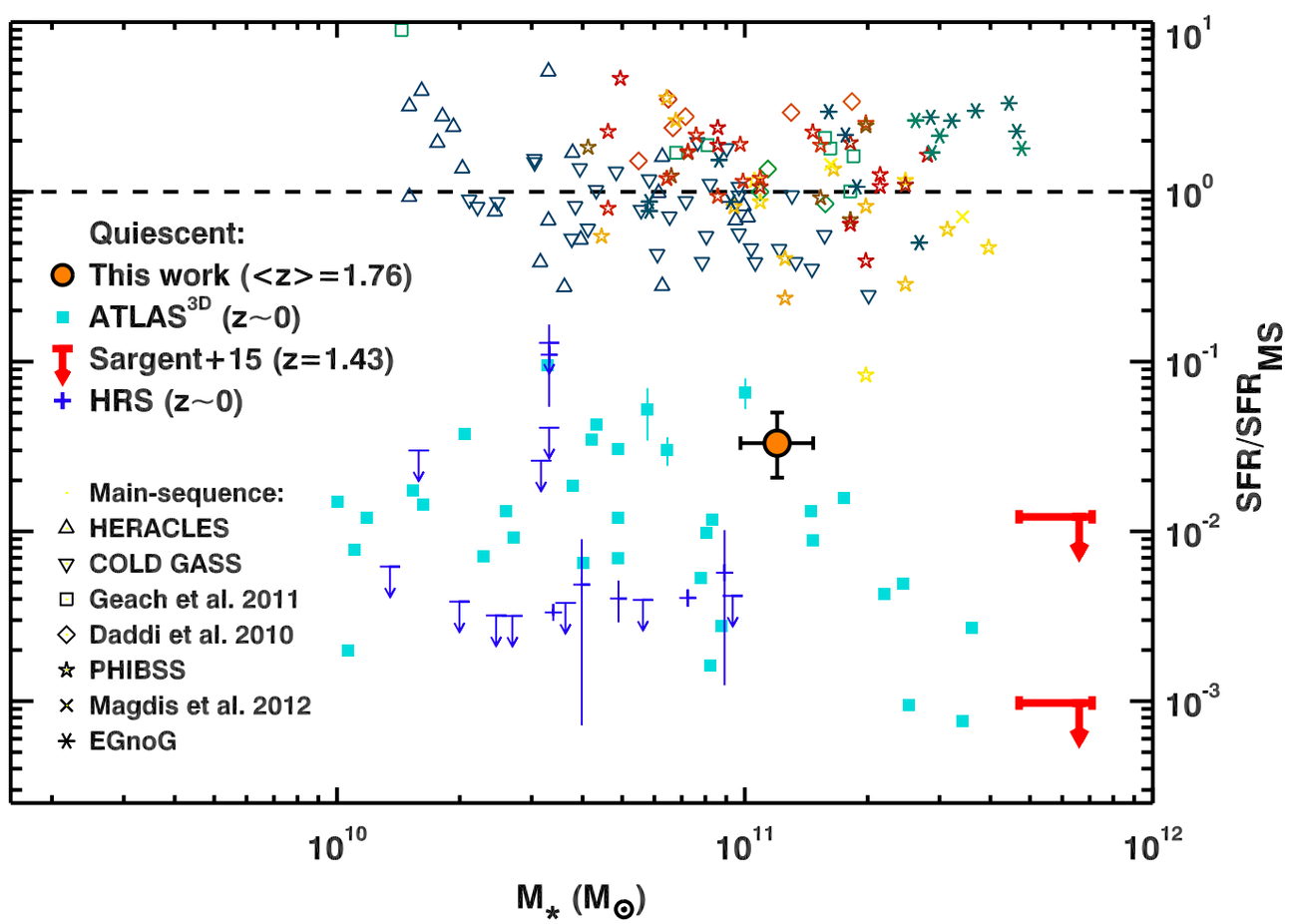
$\Longrightarrow$ **~1-2 dex above z~0**

gas-rich ETGs

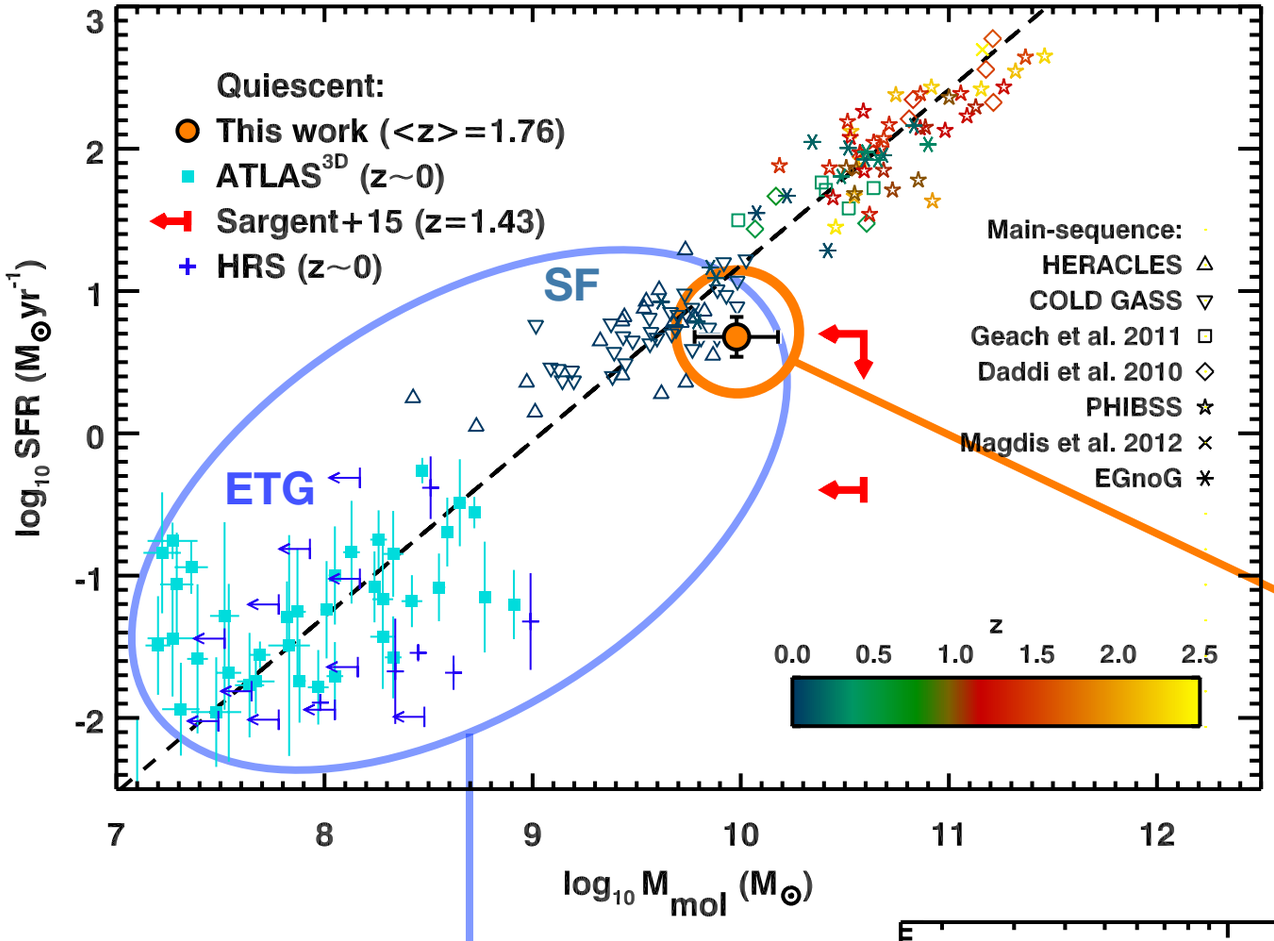


Star formation efficiency (SFE) lower by a factor ~3

Star formation rate below the main sequence by ~1.5 dex



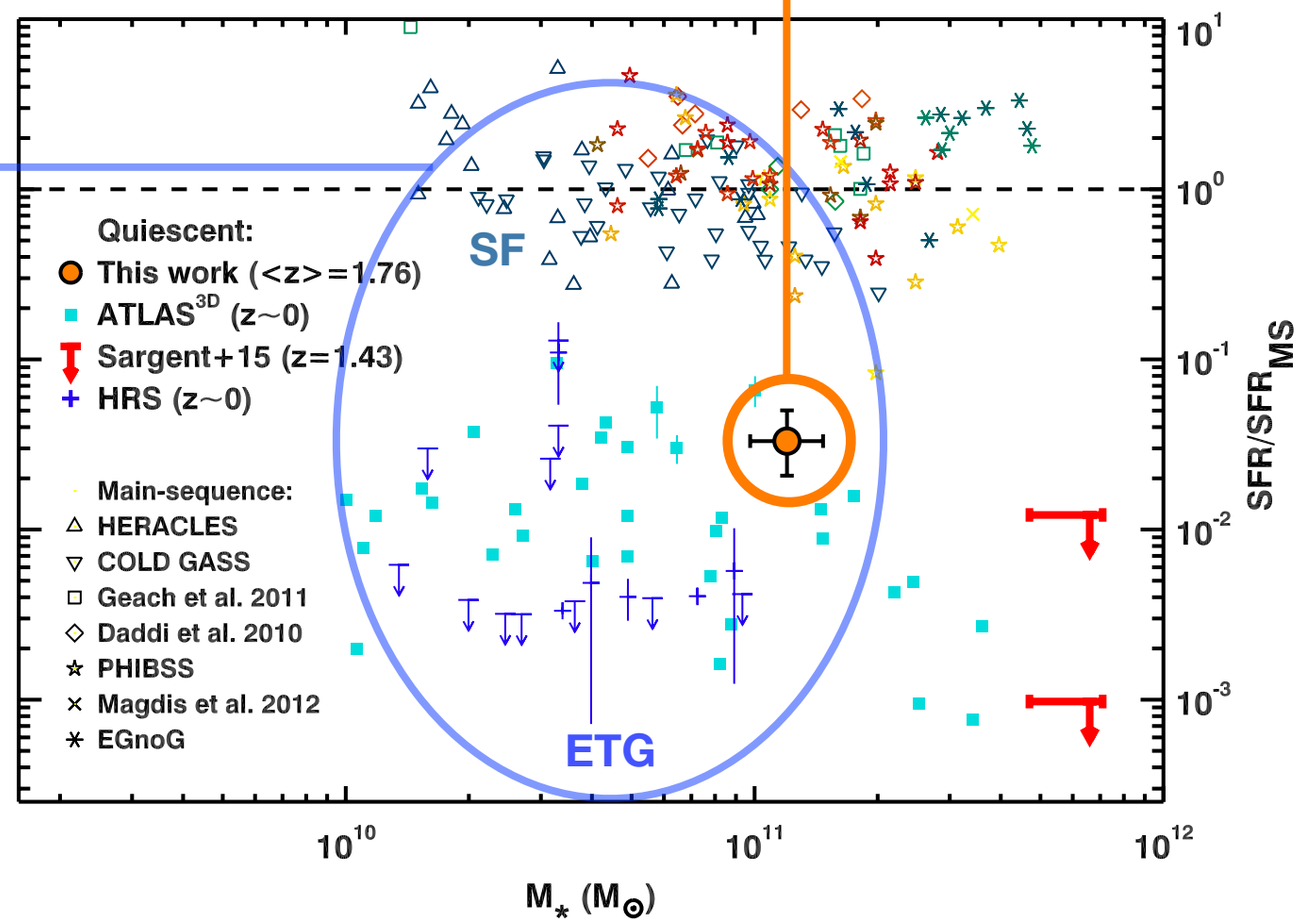
Star formation efficiency (SFE) lower by a factor ~3



z > 1.5 ETGs

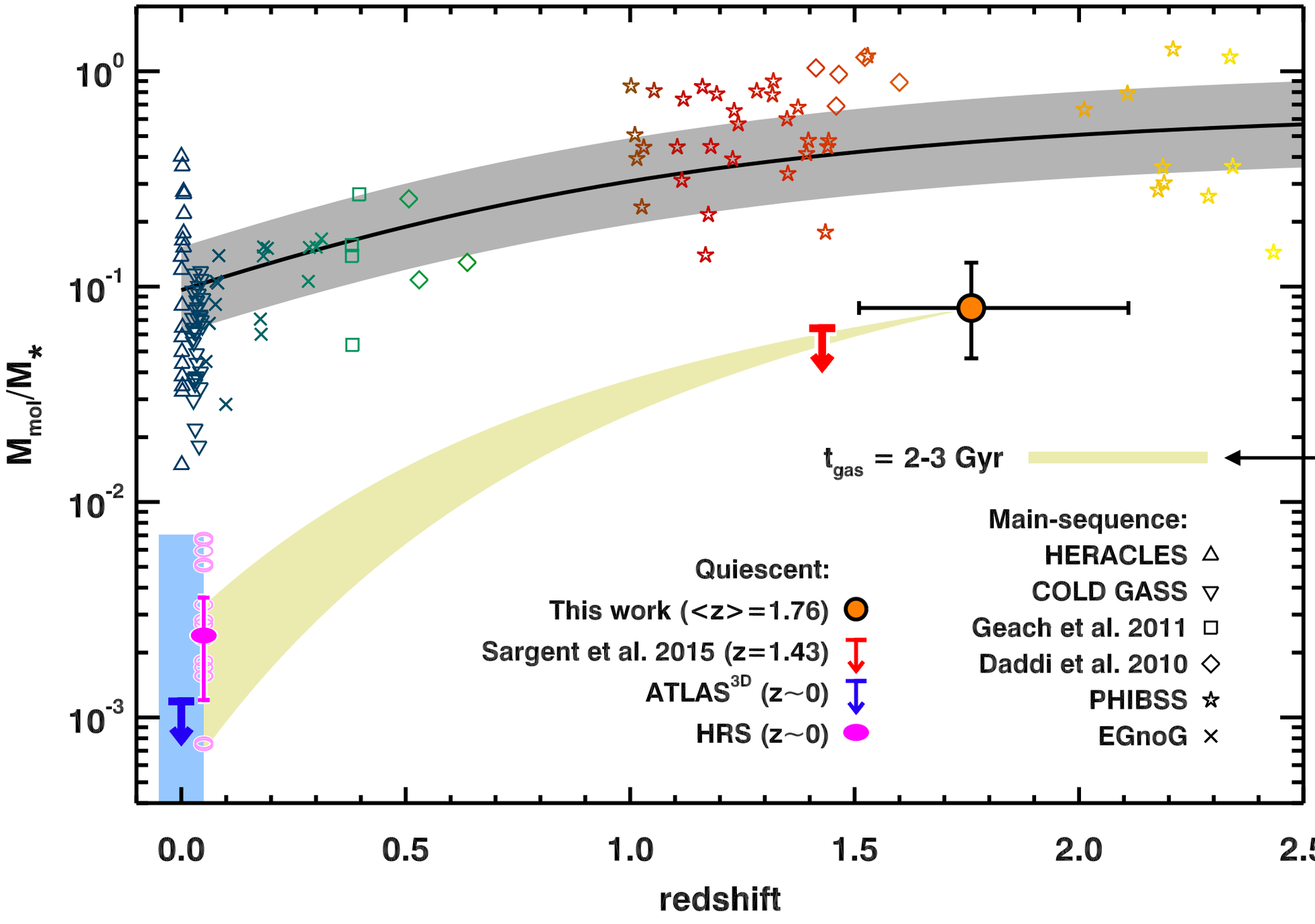
z ~ 0 galaxies

Star formation rate below the main sequence by ~1.5 dex



High dust & gas fractions in z > 1.5 quiescent galaxies

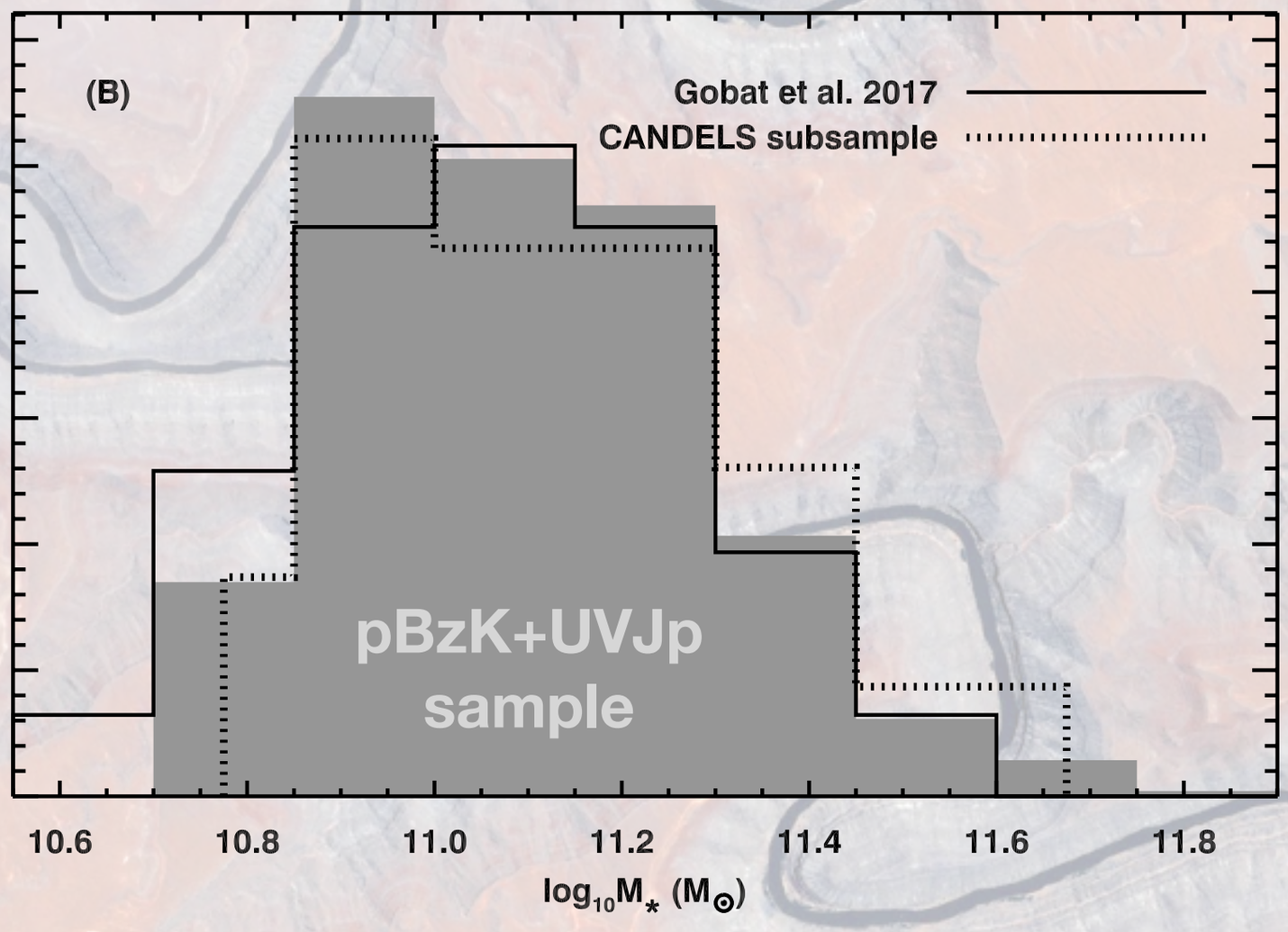
(Gobat et al., arXiv:1703.02207)



consumption without replenishment

$f_{gas} = M_{gas}/(M_{gas}+M_*) = 7.4^{+4.6}_{-3.0}$ % (1/4 of the MS)

Mass-matched spectroscopic ETG subsample



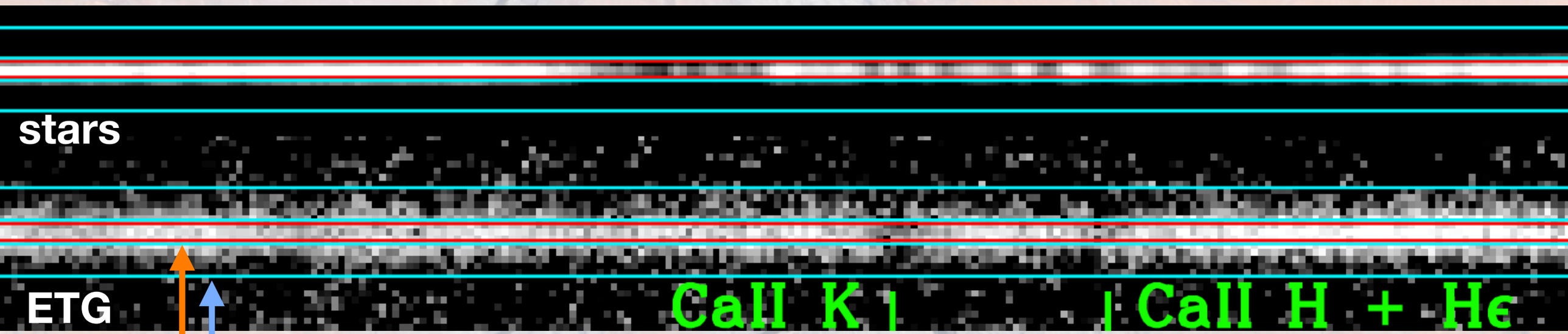
VLT/VIMOS observations of 31 *BzK*-selected quiescent galaxies in COSMOS

$\langle z \rangle = 1.51$, $\langle M_* \rangle = 1.2 \times 10^{11}\ M_\odot$ (Salpeter IMF), $\langle E(B\text{-}V) \rangle = 0.12$

Stellar metallicity from rest-frame UV spectroscopy ~ 1 $Z_\odot$

Spectroscopic ETG subsample: stacked 2D spectrum

Median stacked 2D spectra (same relative scale)



The VIMOS spectra are spatially (semi-)resolved

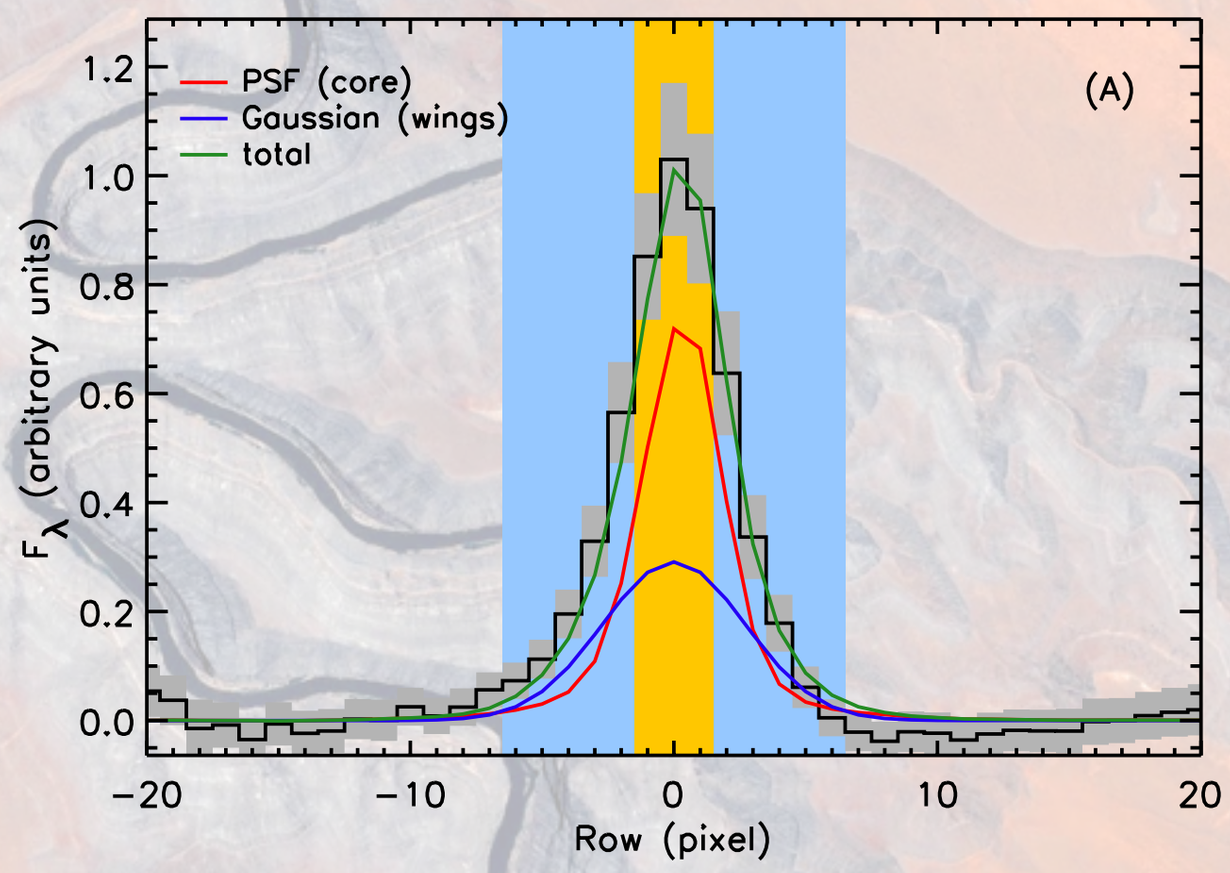
outer aperture

inner aperture (~PSF FWHM)

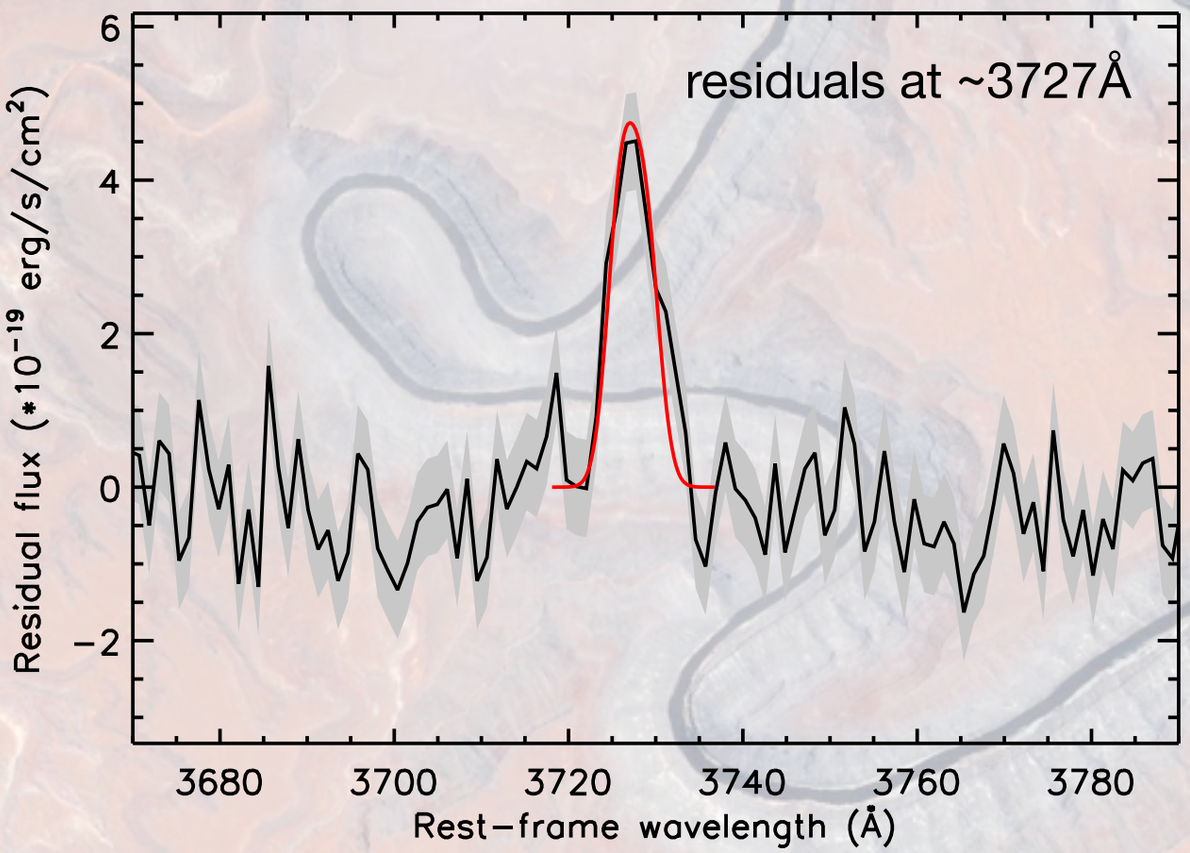
Decomposition in core and wings components:

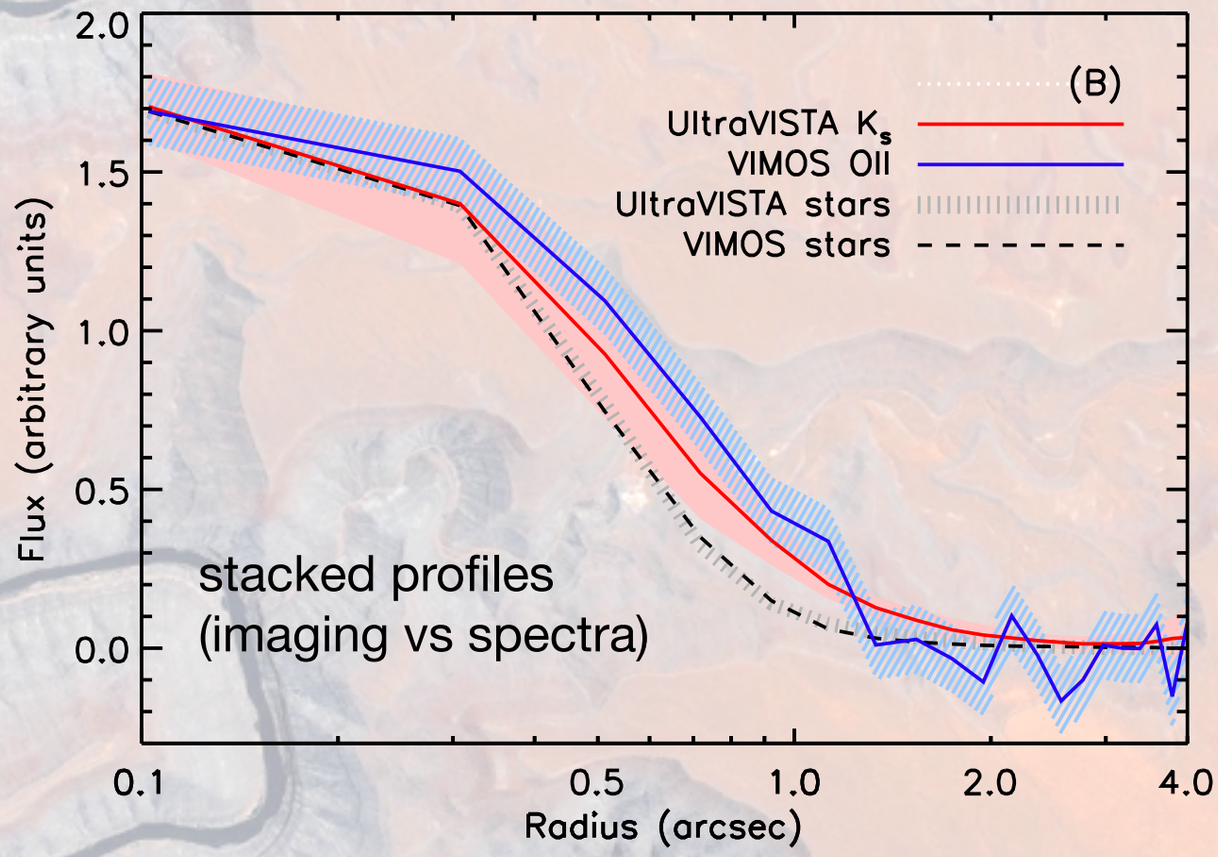
$$\begin{pmatrix} \text{in} \\ \text{out} \end{pmatrix} = \begin{pmatrix} w_{ic} & w_{iw} \\ w_{oc} & w_{ow} \end{pmatrix} \begin{pmatrix} \text{core} \\ \text{wings} \end{pmatrix} + \begin{pmatrix} \delta_{\text{in}} \\ \delta_{\text{out}} \end{pmatrix}$$

First detection of **spectroscopic gradients** at high redshift (Gobat et al. 2017, A&A 599, 95)



Spectroscopic ETG subsample: resolved [OII] emission





extended [OII]3727Å flux: (3.4±0.3)×10^{-18} erg s^{-1} cm^{-2}

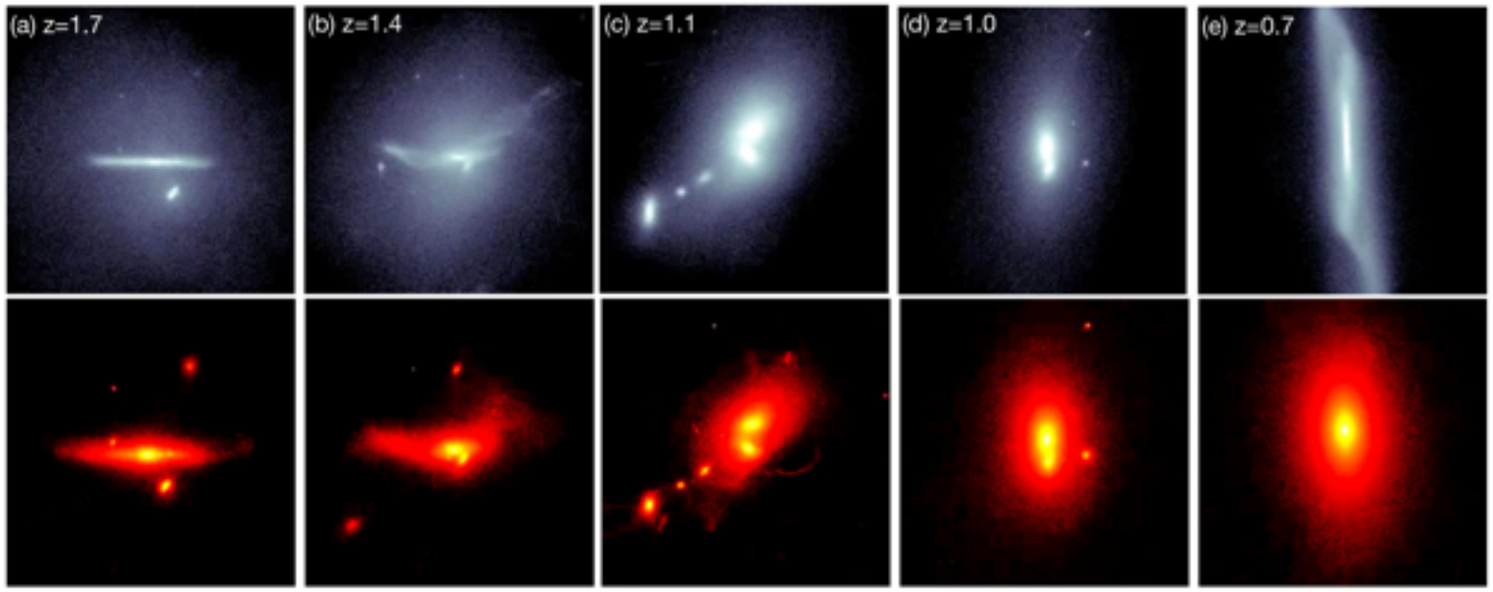
↓

flux calibration + dust & aperture corrections

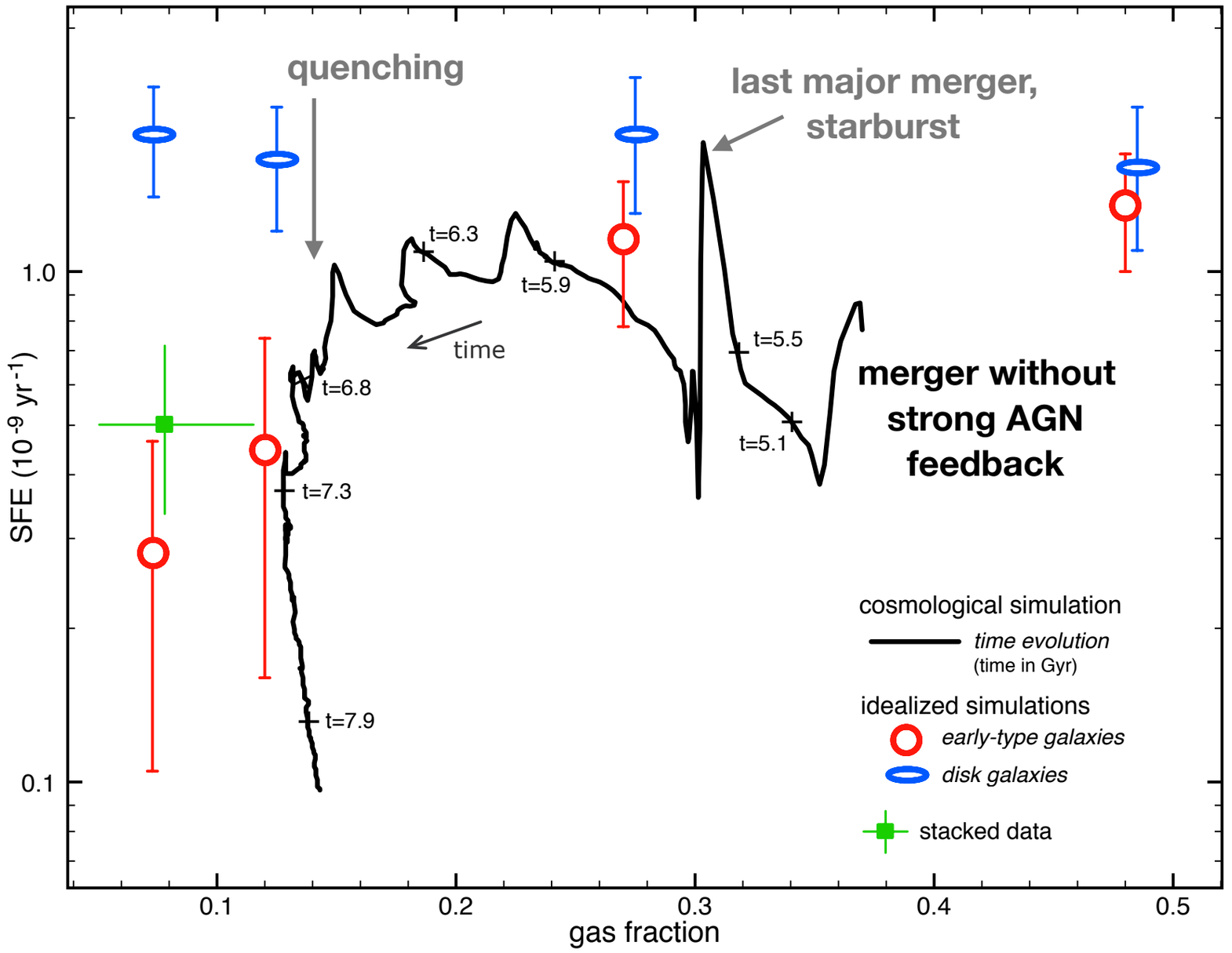
↓

if star formation, **SFR_{OII} = 4.5 ± 1 $M_\odot$ yr^{-1}**

close to the FIR value **SFR_{IR} ≅ 4.8 $M_\odot$ yr^{-1}**



Hydrodynamical simulations



1. non-expulsive quenching process leaves significant amounts of gas

2. **transition to low SFE mode when $f_{gas} \approx 15\%$**

3. **bulge stabilisation keeps SFE low**, even after later re-accretion of gas

Summary

low residual star formation in z >1.4 ETGs from both emission-line and far-infrared diagnostics.
~1.5 dex below the MS

high dust and gas fractions (10%)
~1-2 dex above the MS

low T_{dust} (~10 K)
low SFE (×1/3)

non-exhaustive quenching process

stabilization by bulge and halo

Thank you