The early coevolution of galaxies with their black holes

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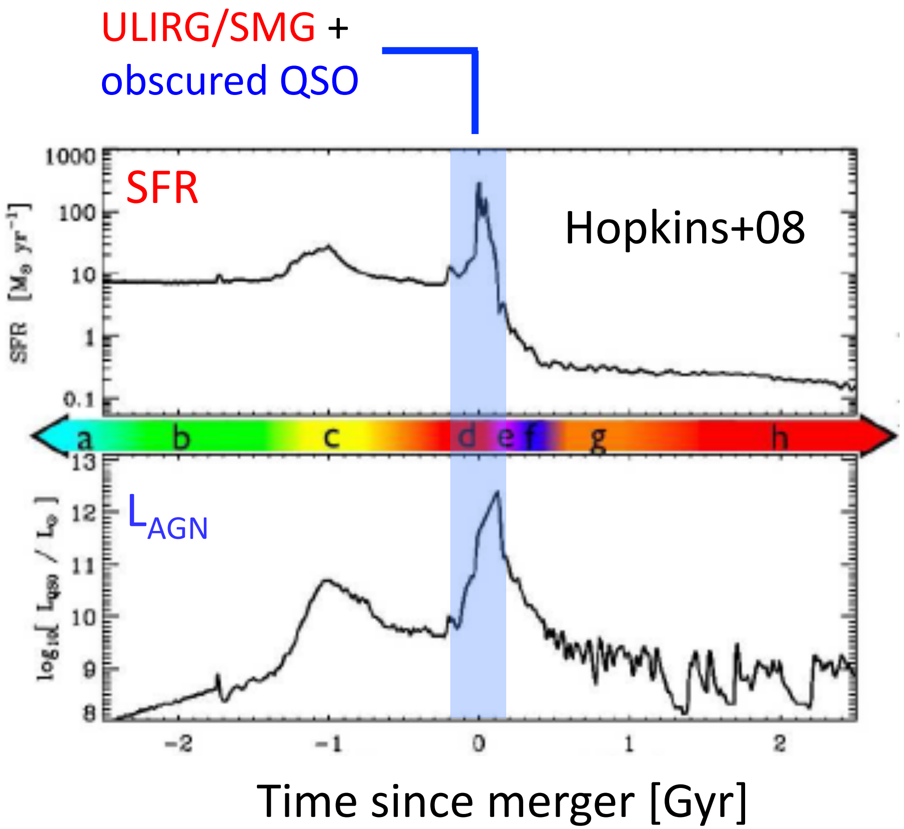
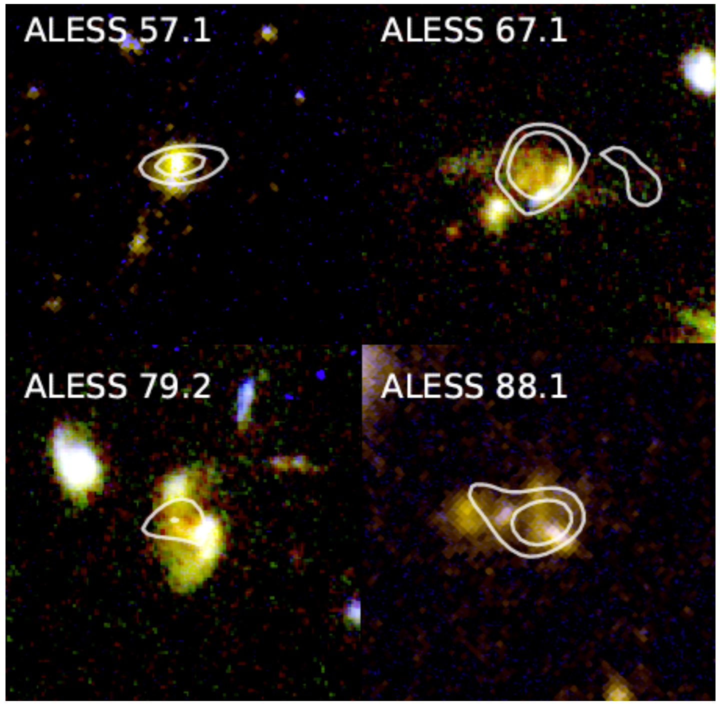
SMGs as laboratories to study BH/galaxy coevolution

Major mergers of gas-rich galaxies are one of the main channels to build massive BH/galaxy systems (Menci+08, Hopkins+08)



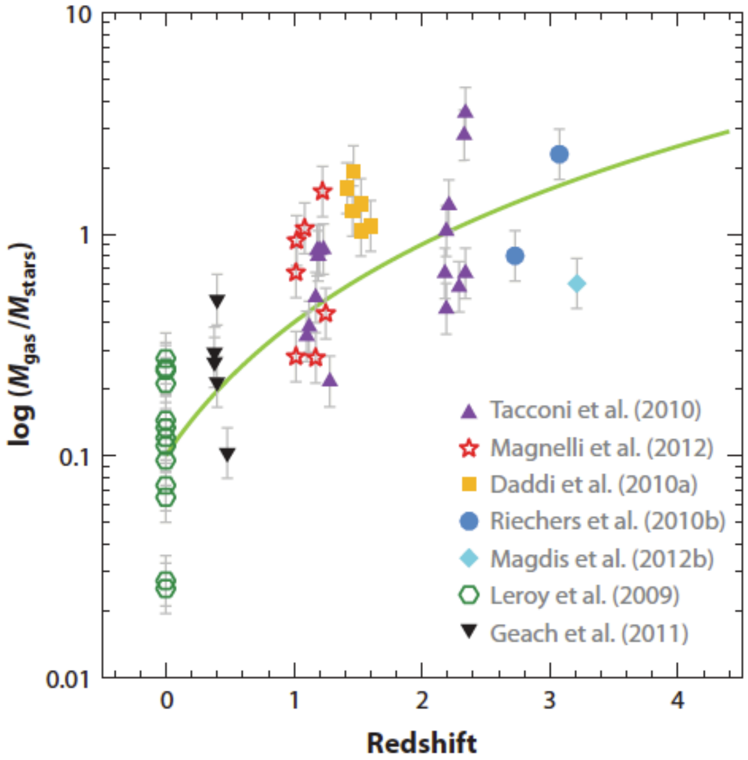
~80% of SMGs at z~2-3 are irregular or interacting systems (Chen+14)



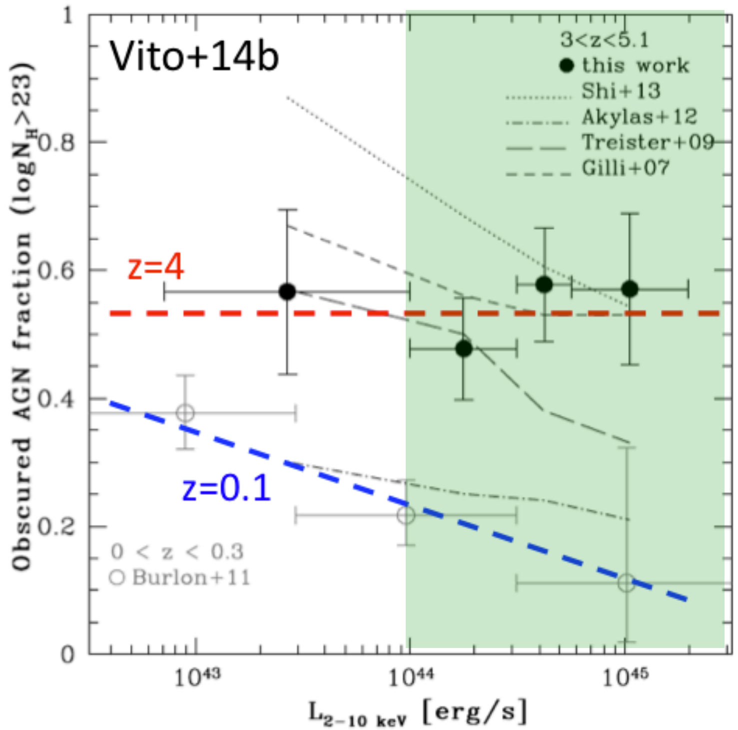
Gas in the ISM: fuel for SF and AGN accretion
(and perhaps obscuration)

AGN at z~1 preferentially reside in gas rich, SF galaxies (Vito+14a)

Average gas fraction increases with redshift (Carilli&Walter13)



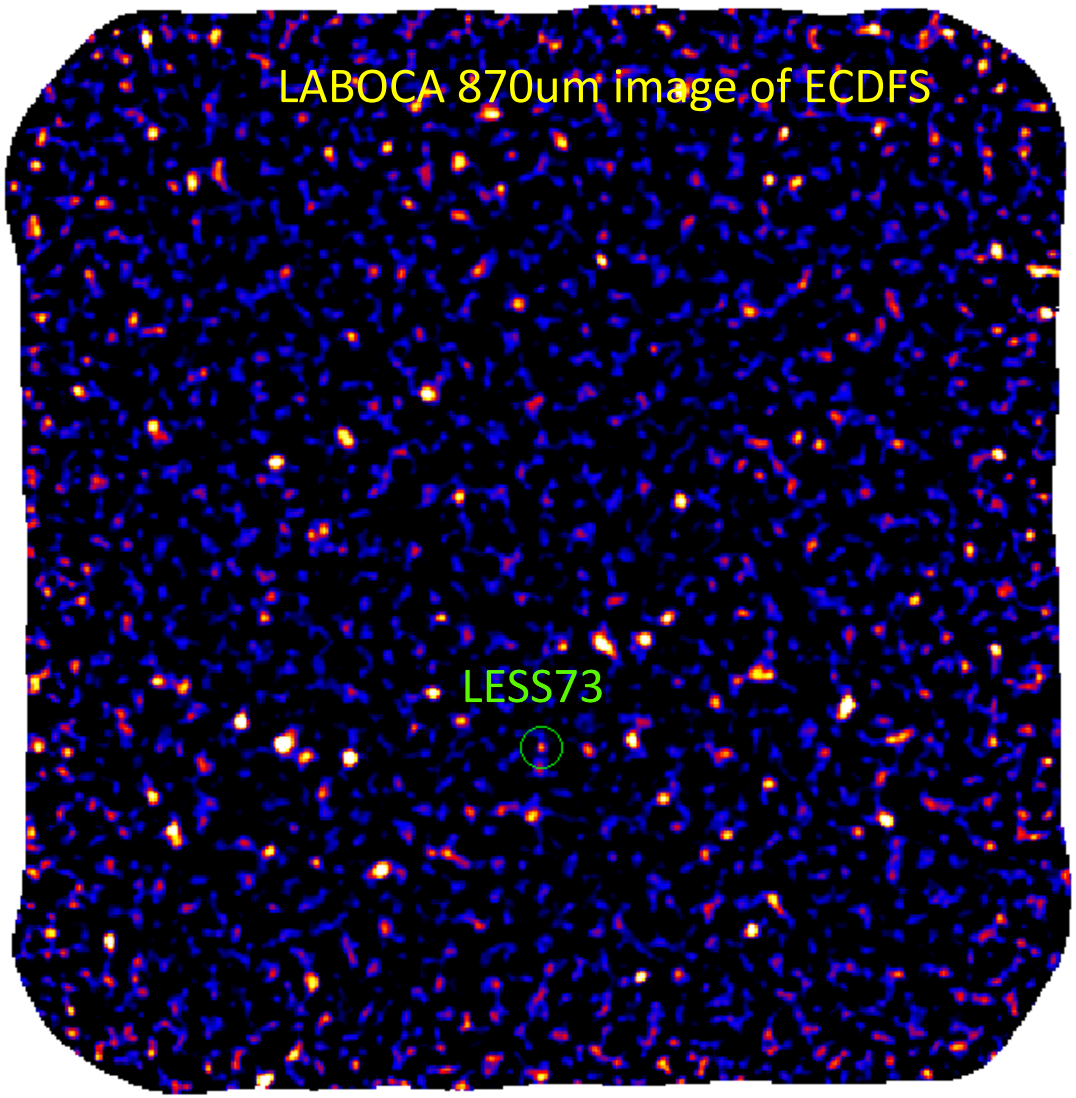
Fraction of obscured QSOs increases with redshift (La Franca+05, Treister+06, Ueda+14, ...)



Possibly connected with the higher gas fraction and merger rate at high-z (Menci+08, Lamastra+10)

LESS 73 = ALESS 73.1 = XID403 @ z=4.75 in the CDFS

Weiss+09 Hodge+13 Xue+11



F_{870}=5.0 ± 1.4 mJy
L_{IR}~$6x10^{12}$ L_{sun}
SFR ~ 1000 M_{sun}/yr
(Coppin+09)
ULIRG at z~5

LESS 73 = ALESS 73.1 = XID403 @ z=4.75 in the CDFS

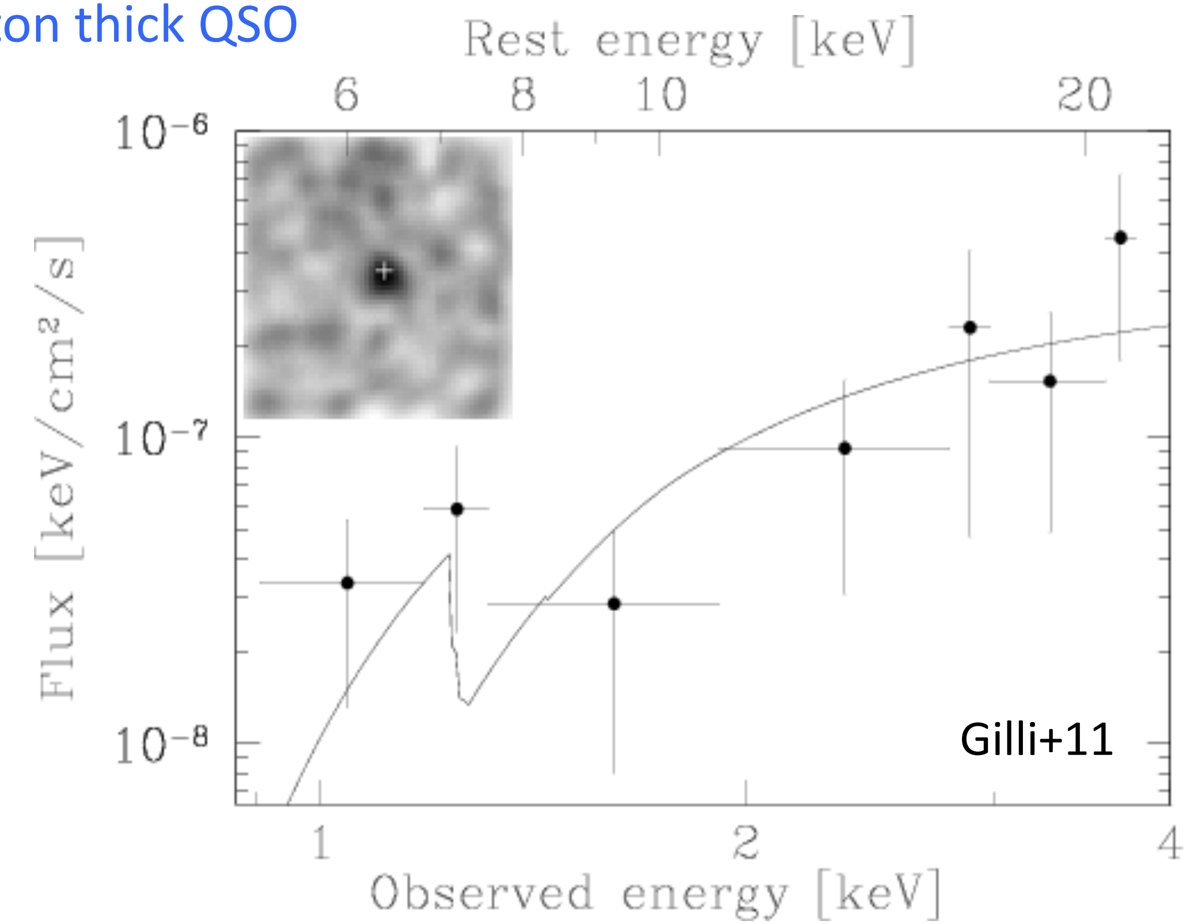
Weiss+09 Hodge+13 Xue+11

4Ms Chandra

$N_H = 1.4^{+0.9}_{-0.5} \times 10^{24}$ cm^{-2}

$L_x \sim 2 \times 10^{44}$ erg/s

→Compton thick QSO



>2Ms Chandra needed to get detection

LESS 73 = ALESS 73.1 = XID403 @ z=4.75 in the CDFS

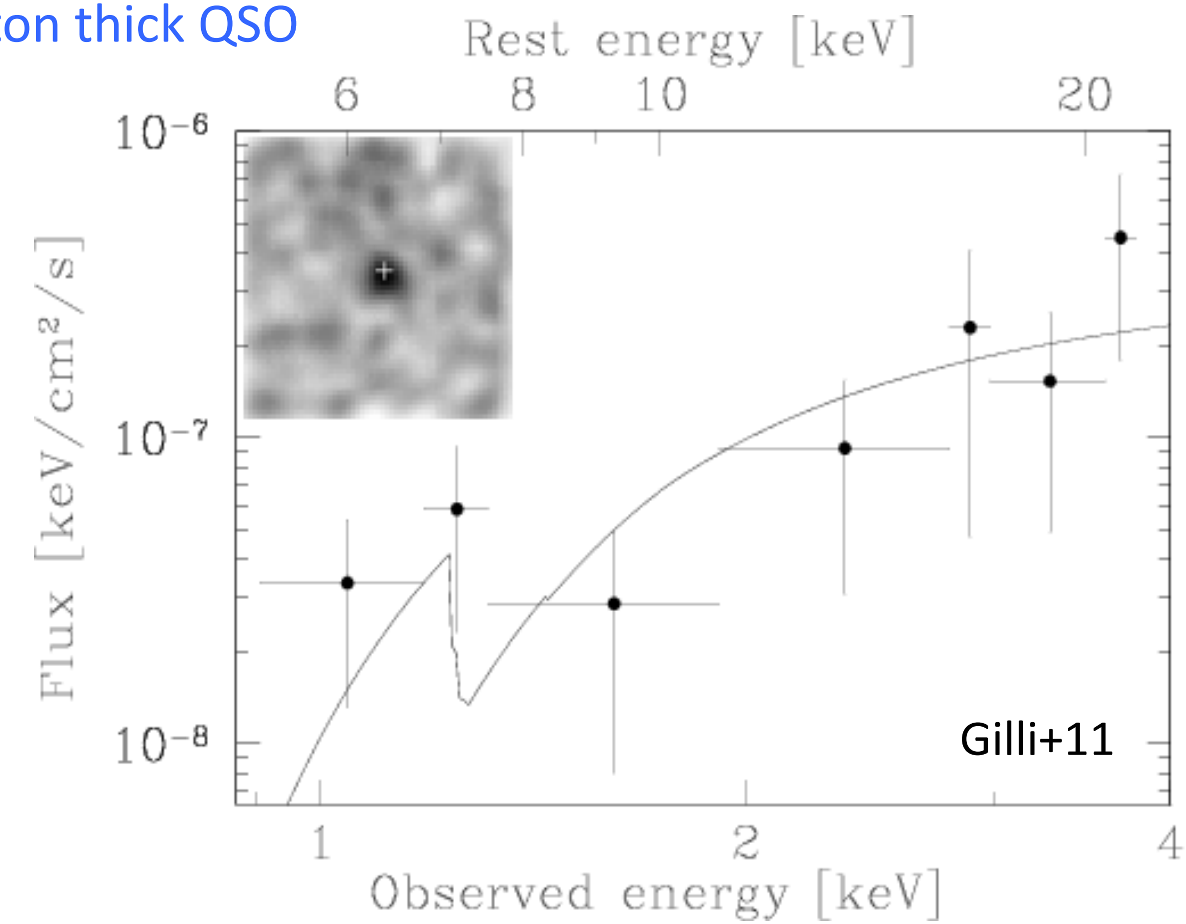
Weiss+09 Hodge+13 Xue+11

4Ms Chandra
$N_H = 1.4^{+0.9}_{-0.5} \times 10^{24}$ cm^{-2}
$L_x \sim 2 \times 10^{44}$ erg/s

5.7Ms (preliminary)
$N_H = 1.5^{+0.6}_{-0.3} \times 10^{24}$ cm^{-2}
$L_x \sim 3 \times 10^{44}$ erg/s

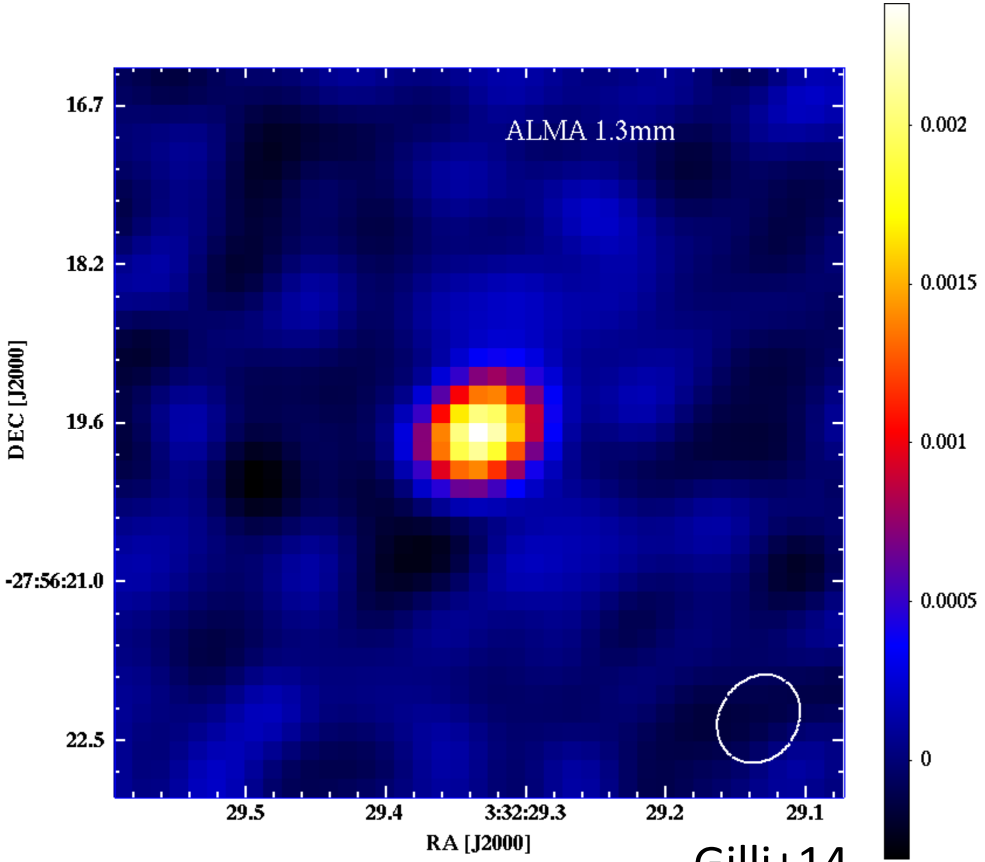
7.0Ms
by mid 2015

→Compton thick QSO



>2Ms Chandra needed to get detection

ALMA Cycle 0 detection at 1.3mm (band 6)



Gilli+14

beamsize = 0.84 x 0.71 arcsec FWHM

"filler" target

S/N ~ 35 in 3 min on-source

$F_{1.3}$ = 2.47 ± 0.07 mJy

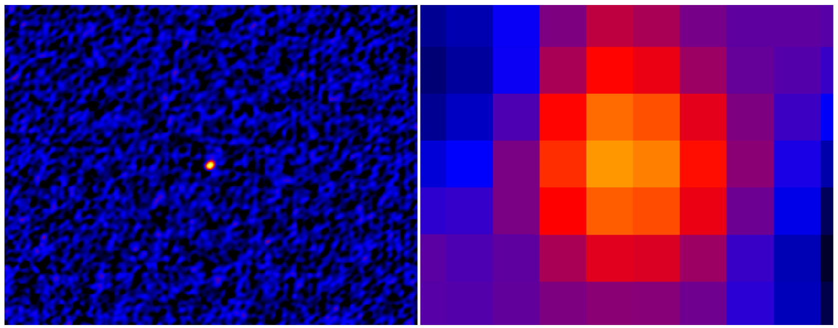
Source marginally resolved (3σ)

Gaussian FWHM = 0.27 ± 0.08 arcsec

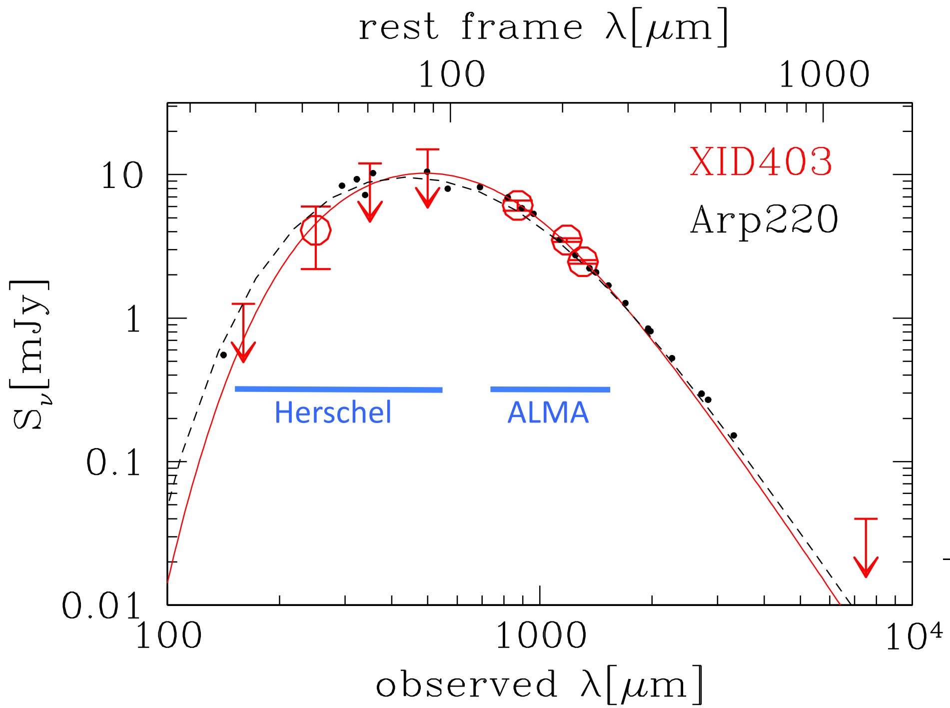
➔ r_{half} ~ 0.9 ± 0.3 kpc

ALMA constrains size of dust/SF

ALMA vs LABOCA

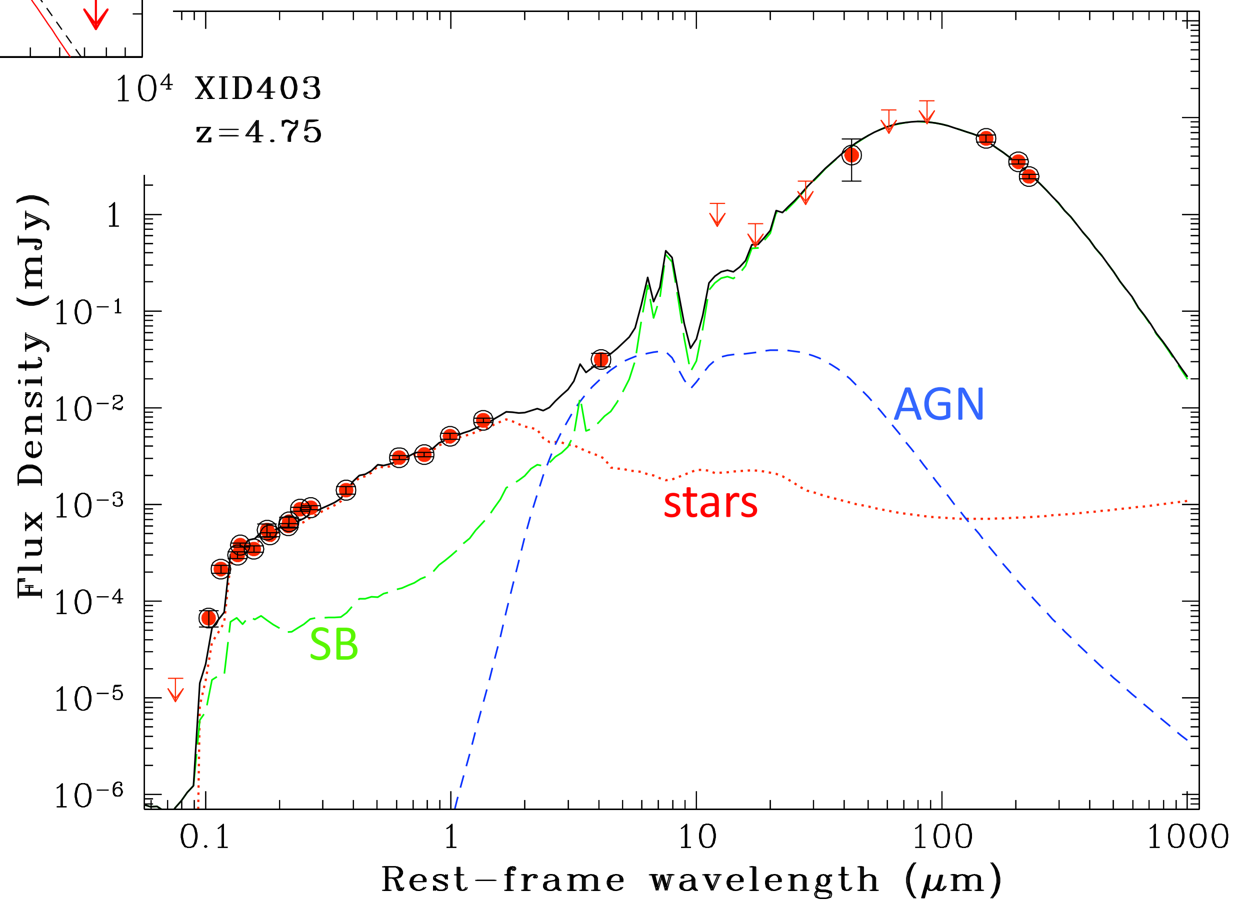


FIR and broad band SED

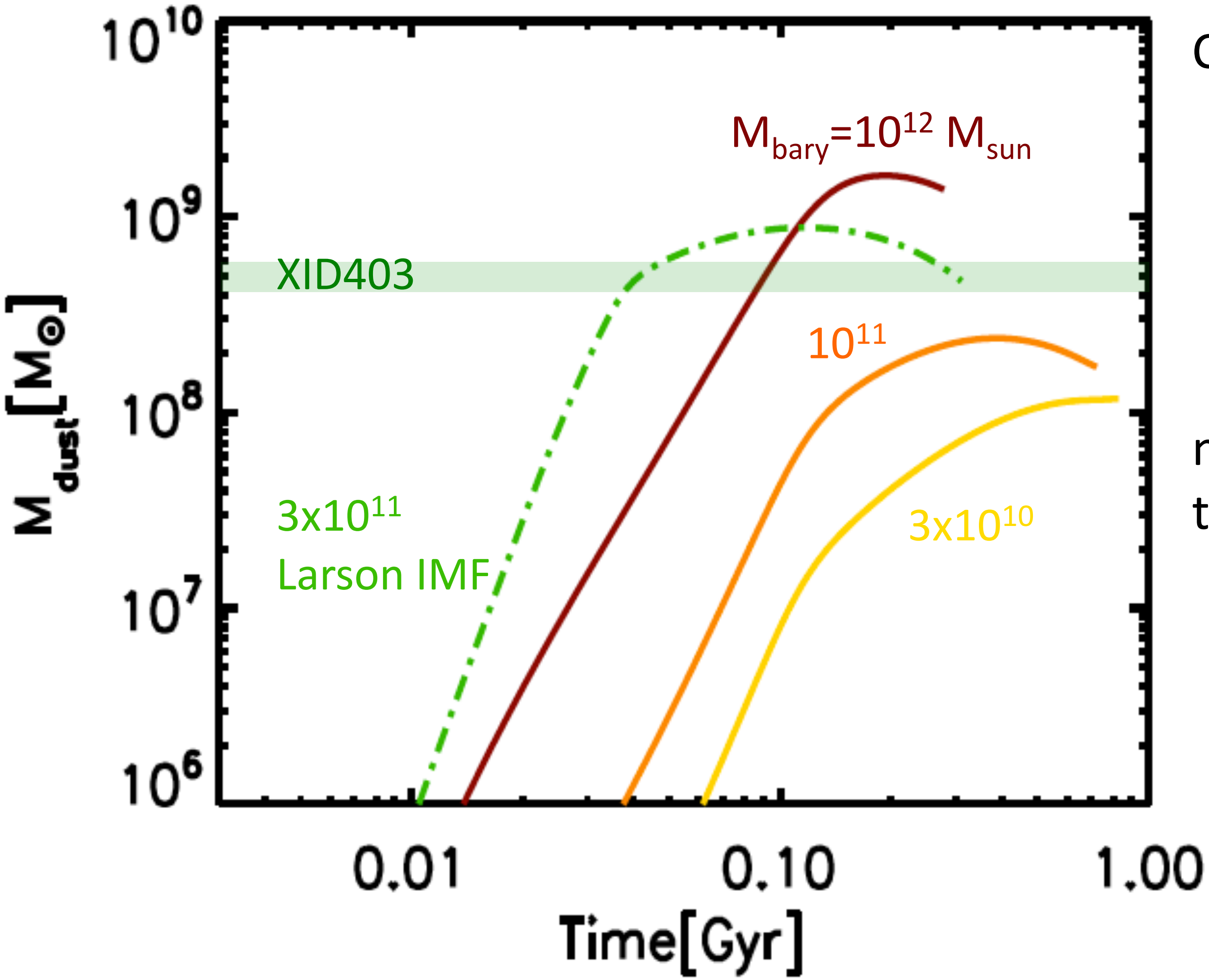


M_{star} = 1.1 x 10^{11} M_{sun}
L_{AGN} ~ $L_{SF}/2$
M_{BH} > 10^8 M_{sun}

T_{dust} = 58.5 (± 5.3) K
M_{dust} = 4.9 (± 0.7) x 10^8 M_{sun}
L_{IR} = 5.9 (± 0.9) x 10^{12} L_{sun}



Dust and stellar mass

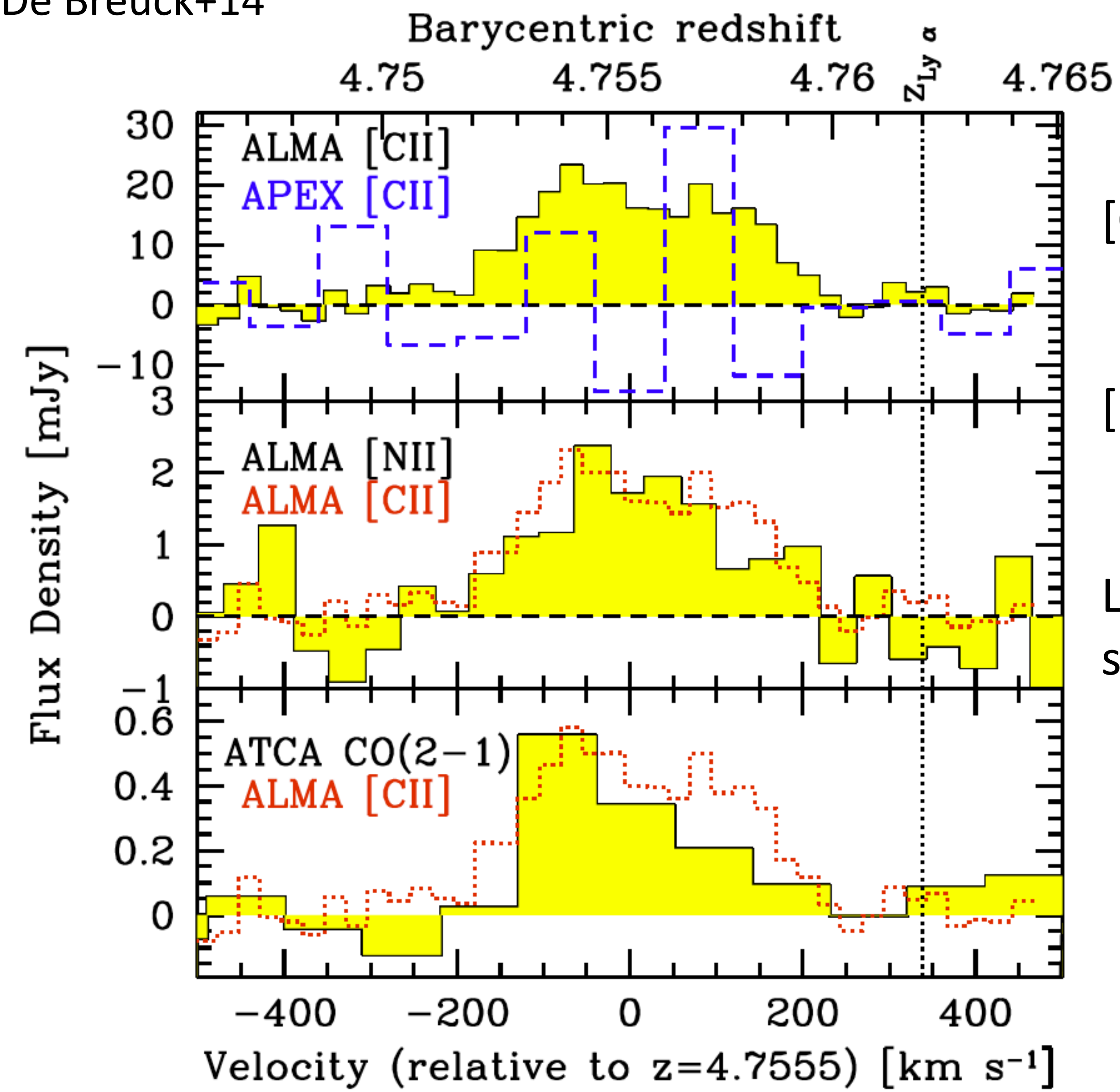


Calura+14

need $M_*>10^{11}$ M_{sun}
to get the observed M_{dust}

Gas content

De Breuck+14



[CII] ➔ M_{HI} = 4.7 x 10^9 M_{sun}

CO ➔ M_{H2} = 1.6 x 10^{10} M_{sun}

[NII/CII] ➔ Z solar

Lyα ~350km/s shift➔ outflow?
similar to LBGs (Steidel+10)

see also
Coppin+10
Nagao+12

Source compactness: gas and SFR density

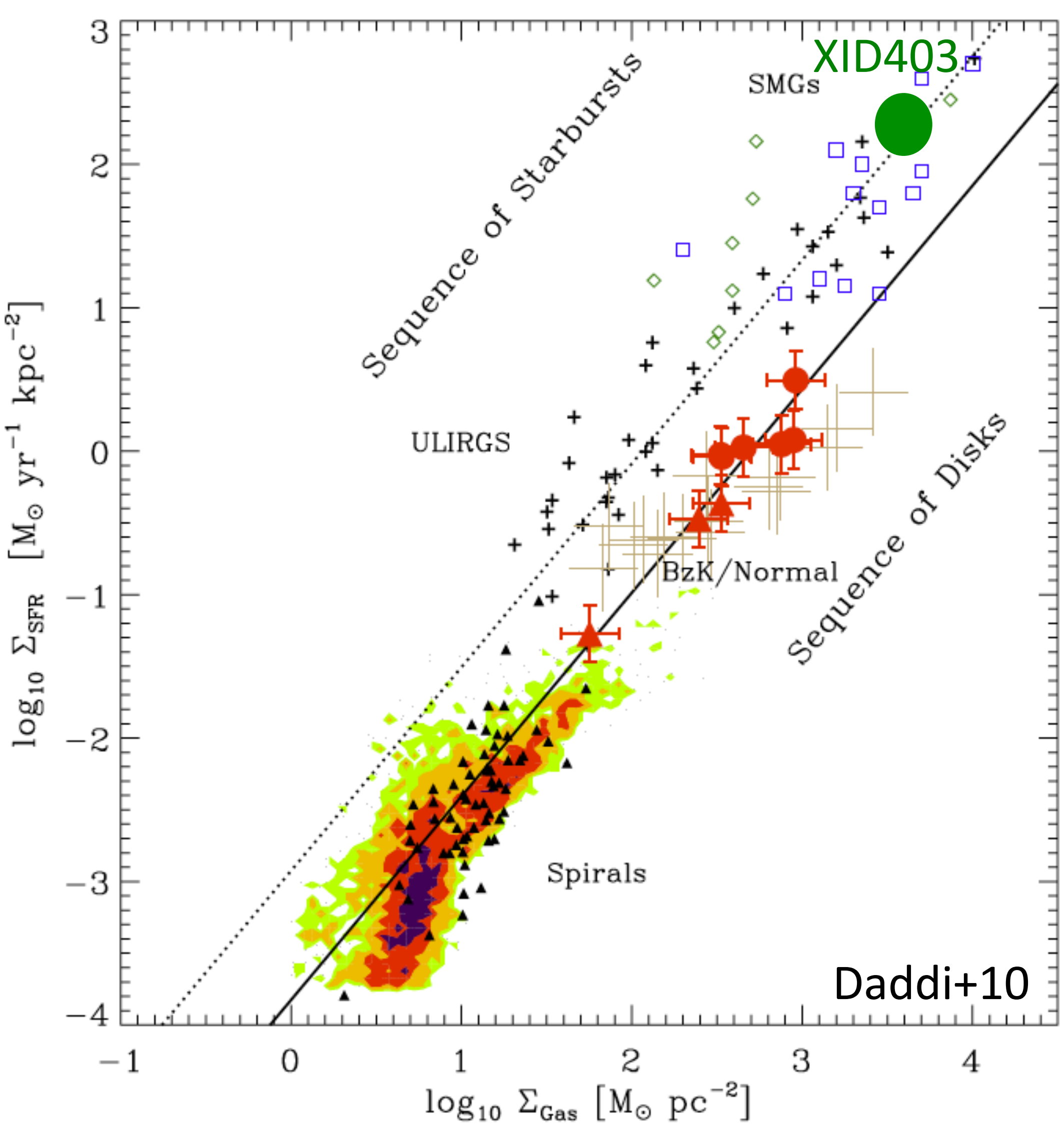
SFR surface density:

Σ_{SFR}~200 M_{sun}/yr/kpc^2
similar to distant ULIRGs (Genzel+10)
Outflowing gas very likely,
strong function of Σ_{SFR} (Bordoloi+13)

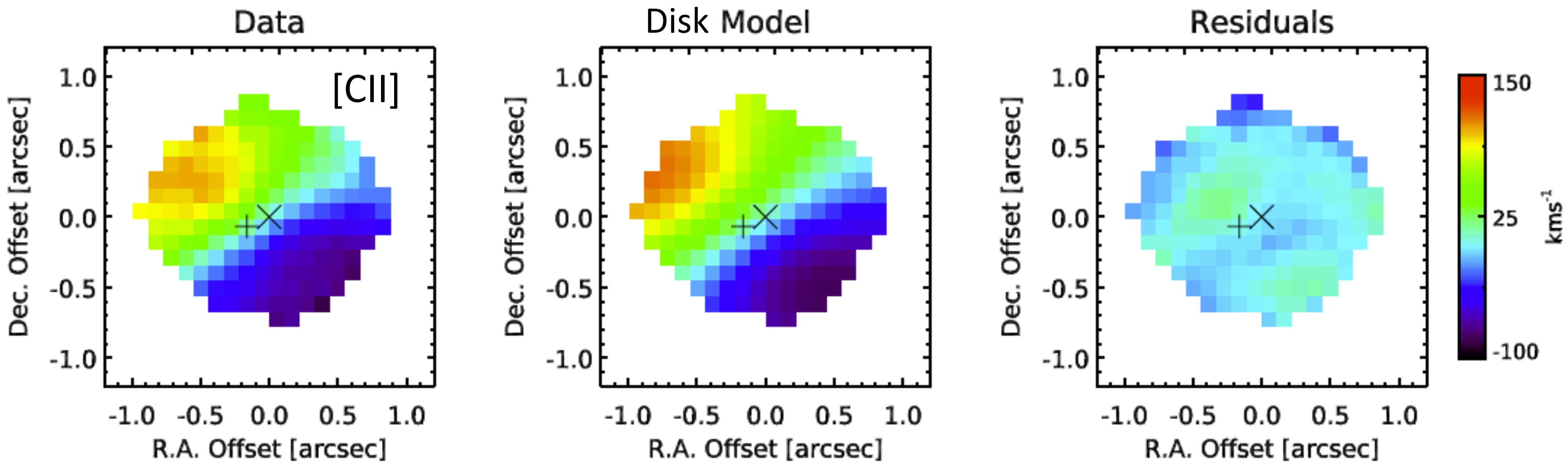
Gas surface density:
Σ_{gas}~5x10^9 M_{sun}/kpc^2

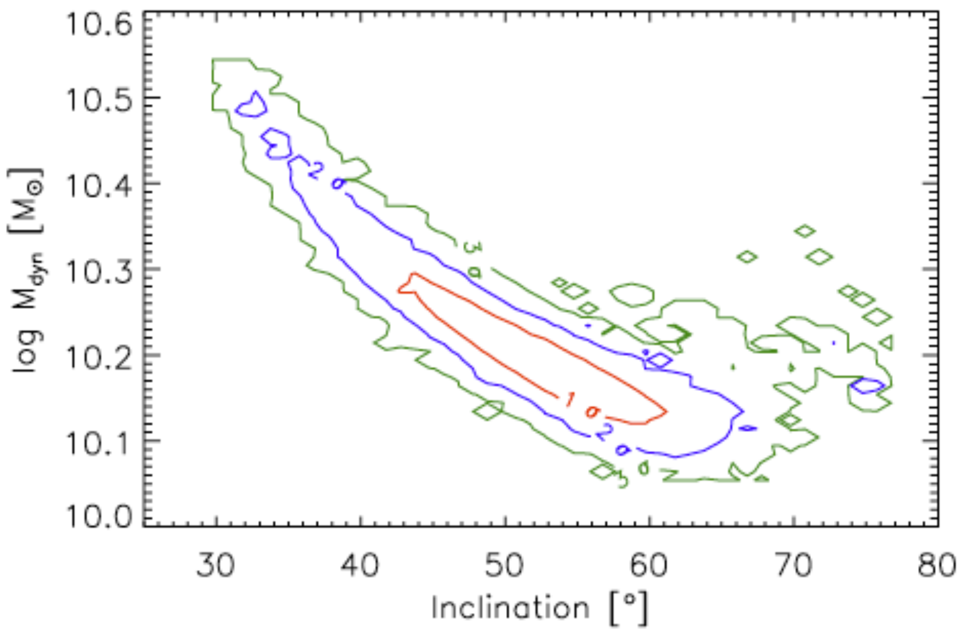
Total gas column density:
0.3-1.1 x 10^{24} cm^2
comparable with X-ray column

➔ significant obscuration produced in the host ISM? (Z is solar)
no pc-scale absorber (torus) needed?



Dynamical mass





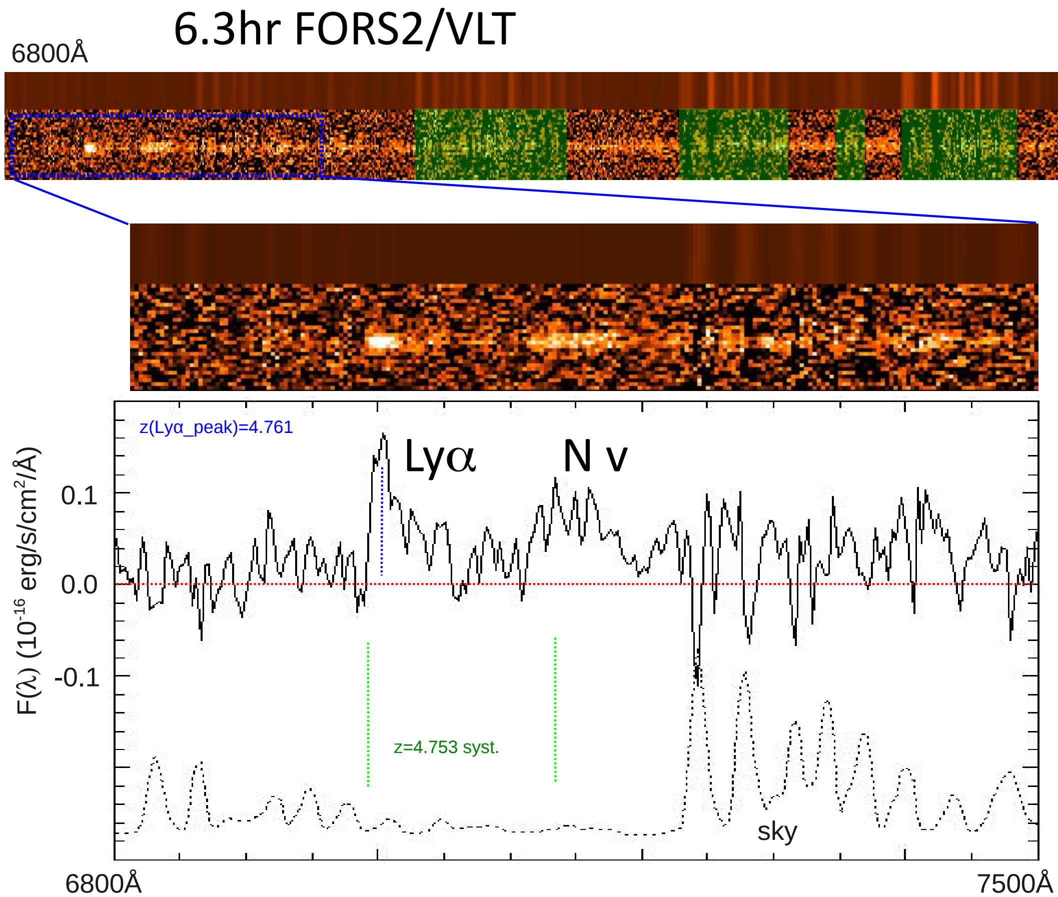
De Breuck+14
(1.6hr ALMA Cycle 0, band 7, compact. conf.)

M_{dyn} = 3x10^{10} M_{sun}

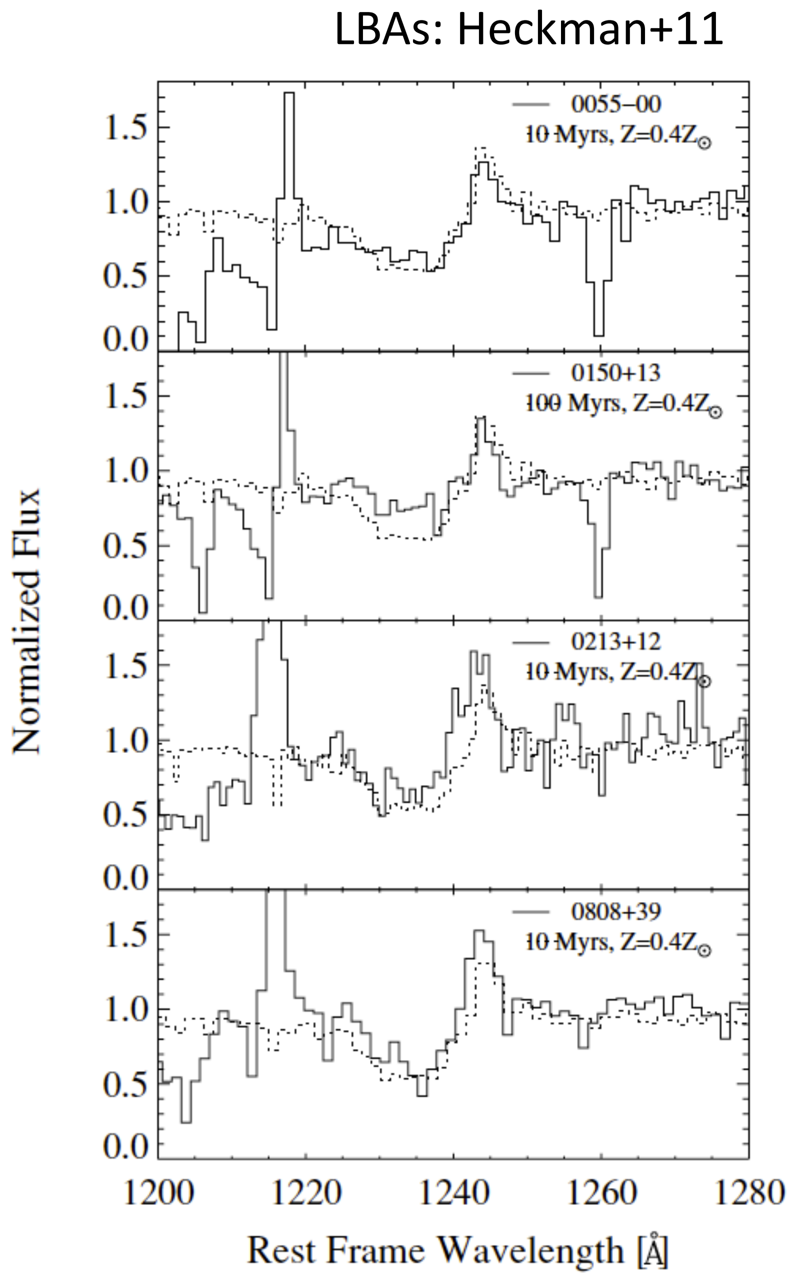
$M_* = M_{dyn} - M_{gas}$ = 1x10^{10} M_{sun}

1 dex smaller than from SED fitting
➔ tension to understand

M* from SED wrong because of AGN contamination?

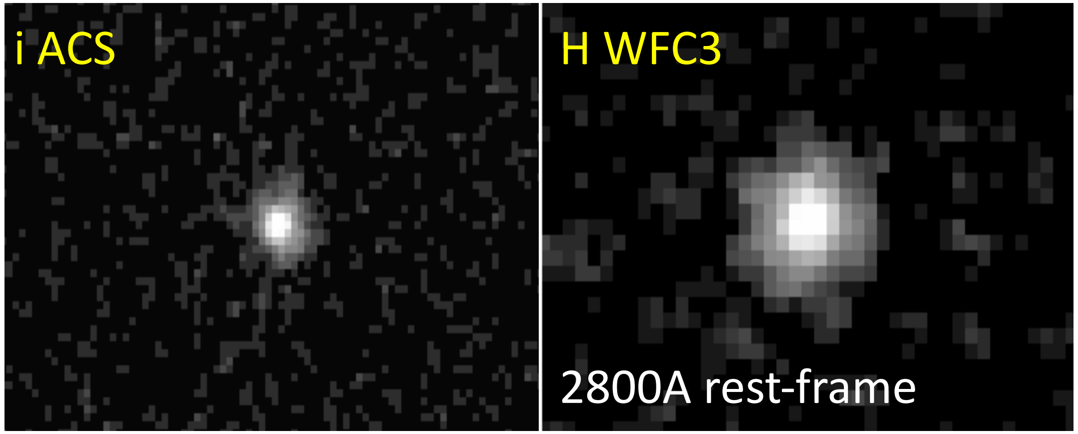


N v 1240A with line P-Cygni profile in local Lyman Break Analogs (LBAs; Heckman+11): winds from O-type stars.



Source compactness in UV/optical rest-frame

Unresolved in GOODS-S (ACS) and CANDELS (WFC3) data
Vanzella+09 Guo+13, Wiklind+14, Chen+14



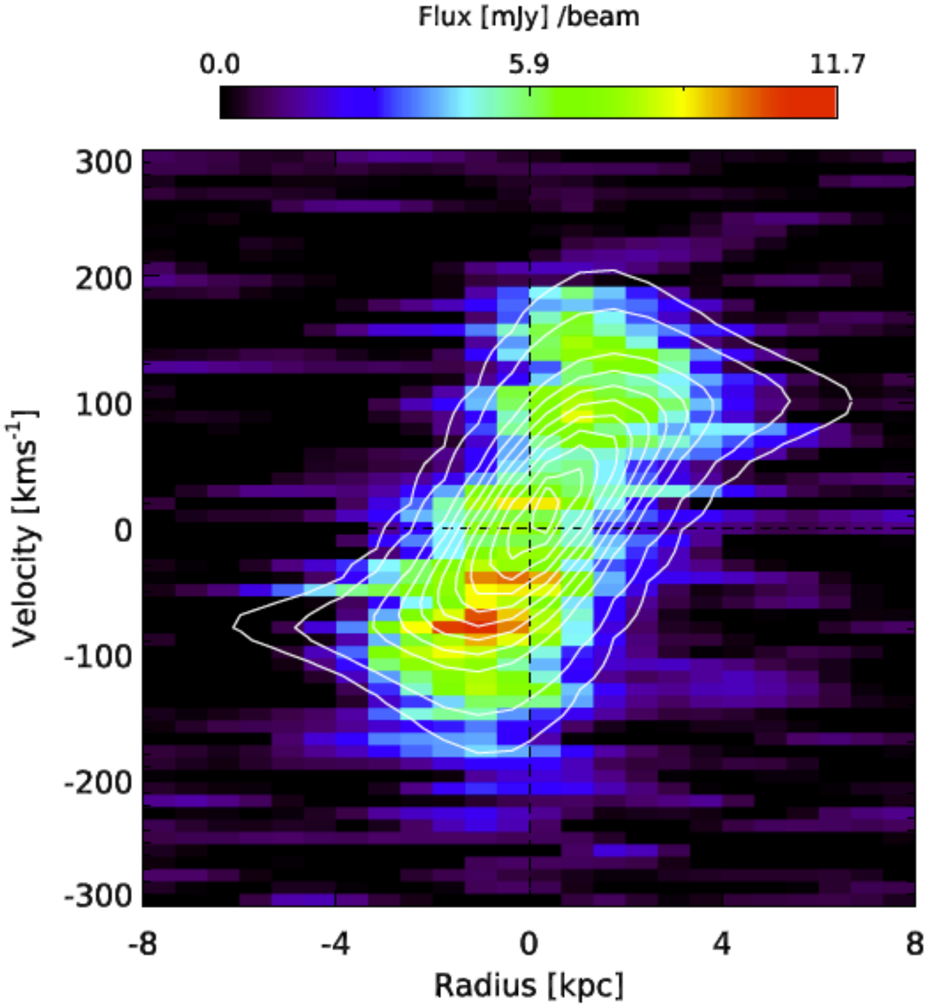
ACS: FWHM<0.1" ; r_e<0.3 kpc
WFC3: FWHM<0.3" ; r_e<0.9 kpc

perhaps resolved in deep K-band imaging with HAWK-I@VLT (Fontana+14) (r_e~0.9 kpc; under investigation)

Dominant Compact Object in 40% of LBAs with r_e~0.1 kpc i.e. 0.03" at z=4.75: cannot be resolved by HST

➔UV/optical source properties compatible with pure SF emission

Problems with the disk dynamical model?



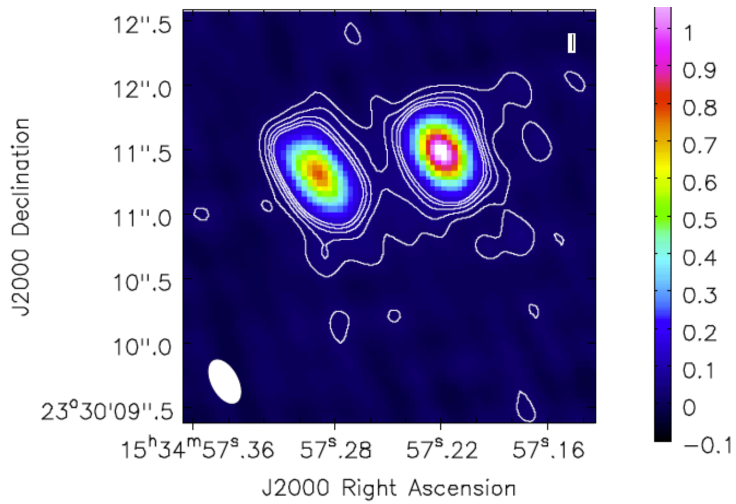
De Breuck+14

Offset between observed and expected [CII] emission

Two-clump model provides an excellent fit to the data (N. Bouche' priv. comm.)

clump sep. ~0.4", can be resolved in Cycle 3

Arp 220 band 9
(Wilson+14, Scoville+15)



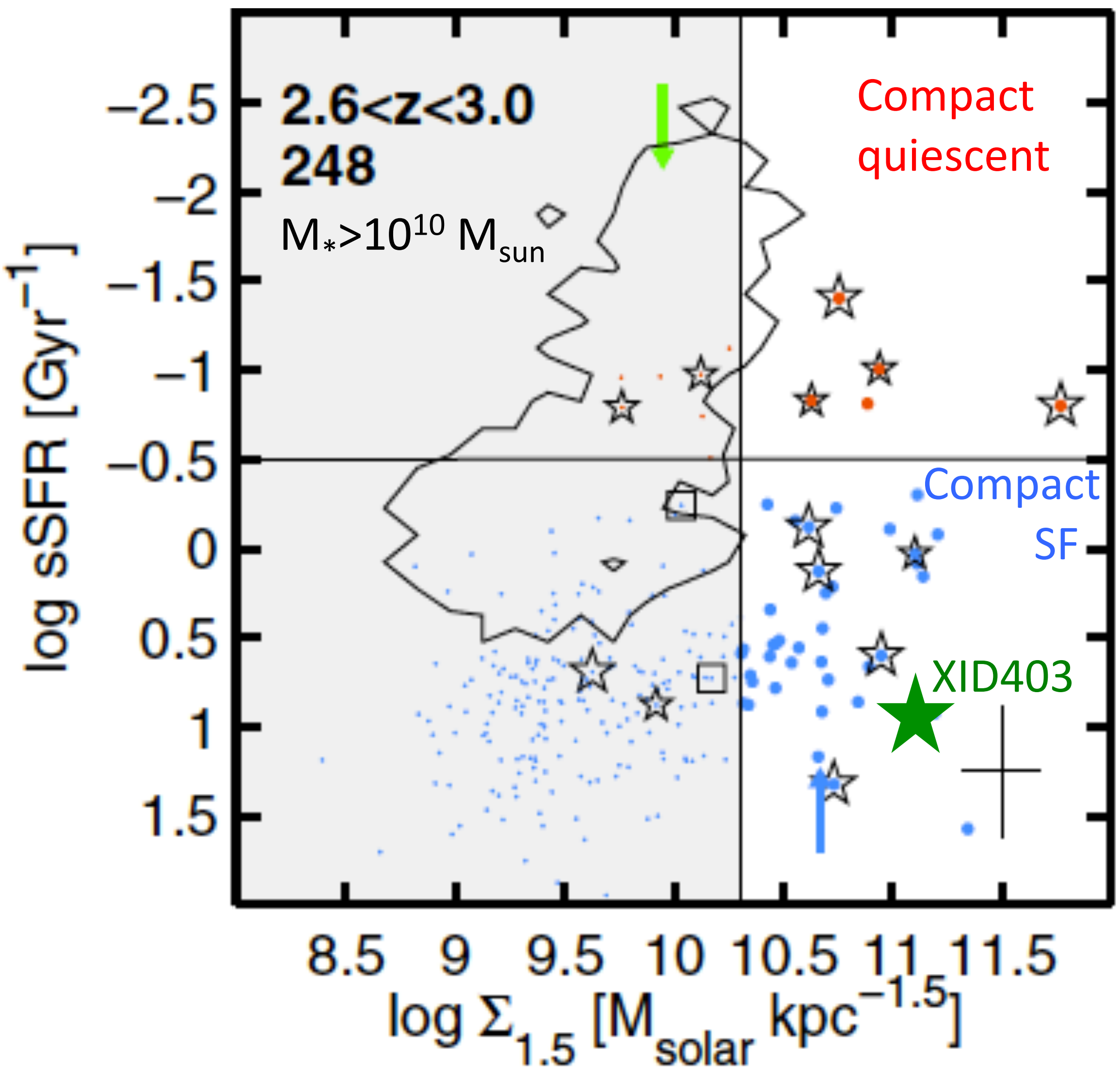
XID403 as a progenitor of a compact QG at z~3

Stellar density:
$\Sigma_* = 1.8 \times 10^{10}\ M_{sun}/kpc^2$
➔ultracompact system
(Cassata+11)

M* built in a few $\times 10^8$ yr.
SF will end in 10^7 yr and leave a compact QG by z~3

SF that builds M* **is** occurring on the same scales (< 1 kpc)

Barro+13



Compactness: $\Sigma_{1.5} = M_*/r_e^{1.5}$

Conclusions on XID403

- XID403 hosts a compact and warm starburst around a heavily obscured supermassive black hole at z=4.75 ➔ ideal laboratory to study coevolution of galaxies and black holes in the early universe.

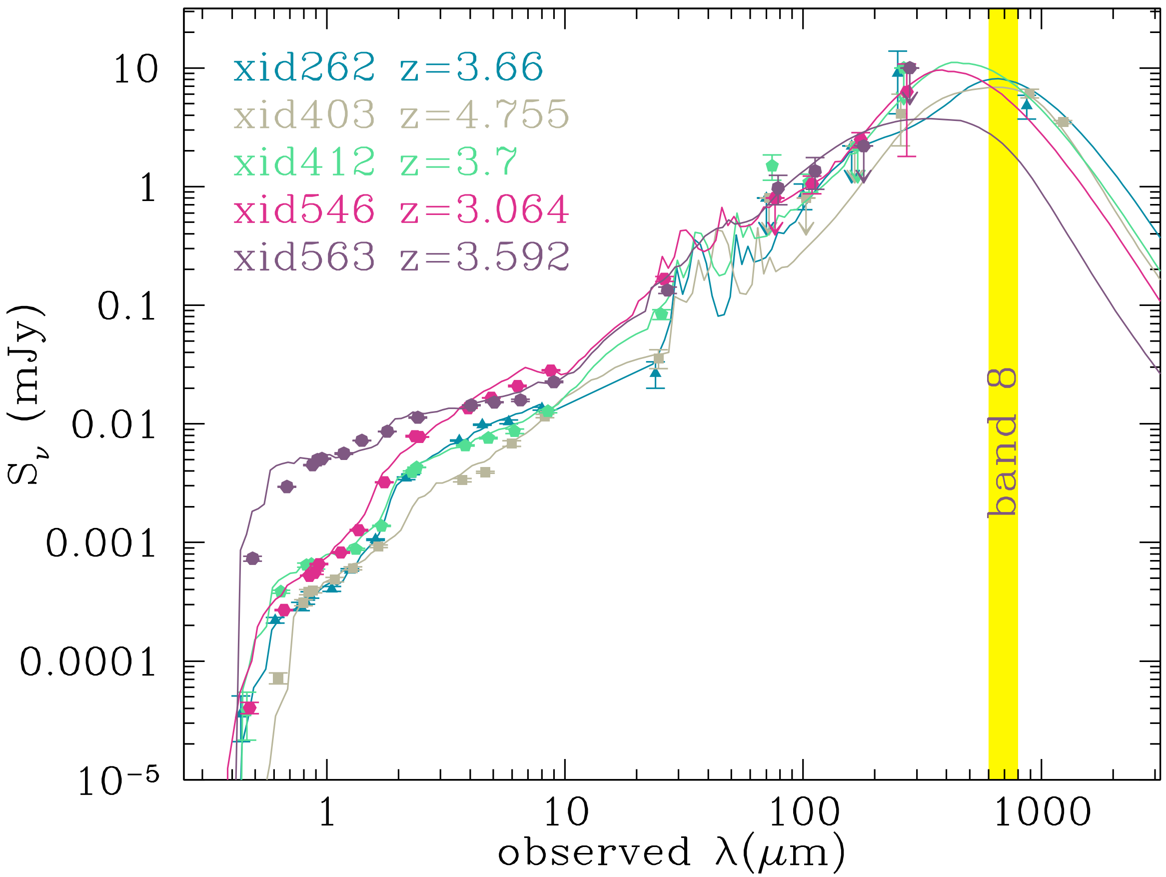
-Dust and SF confined within r_{half} ~ 0.9 kpc. ISM density and metallicity enough to produce the absorption measured in the X-rays. No pc-scale obscurer needed?

-Tension between SED-based M_{dust} and M_* vs M_{dyn} to solve

- UV/optical light likely produced by stars. Evidence from stellar winds from hot and young (O) stars associated to the strong, 1000 M_{sun}/yr , starburst

- Sub-kpc, dense stellar core in place. ALMA shows that SF is indeed happening on those scales. Besides the mass, SFR, gas depletion timescale, XID403 has also the right size to be the progenitor of a compact and massive QG at z~3.

Future prospects



5 AGN at z>3 in the CDFS accepted as fillers in Cycle 2 (but will not be observed)

Goals: measure continuum and [CII] line at 0.1" resolution to get:

1) morphology and compactness of SF (z>3 SMGs/QSO2s as progenitors of z~2 compact QGs)

2) mass and density of atomic gas (nuclear absorption caused by host ISM)