High redshift quasars host galaxies: is there a stellar mass crisis?

Rosa Valiante

INAF-Osservatorio Astronomico di Roma

In collaboration with:

Raffaella Schneider, Stefania Salvadori, Simona Gallerani

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FIRST
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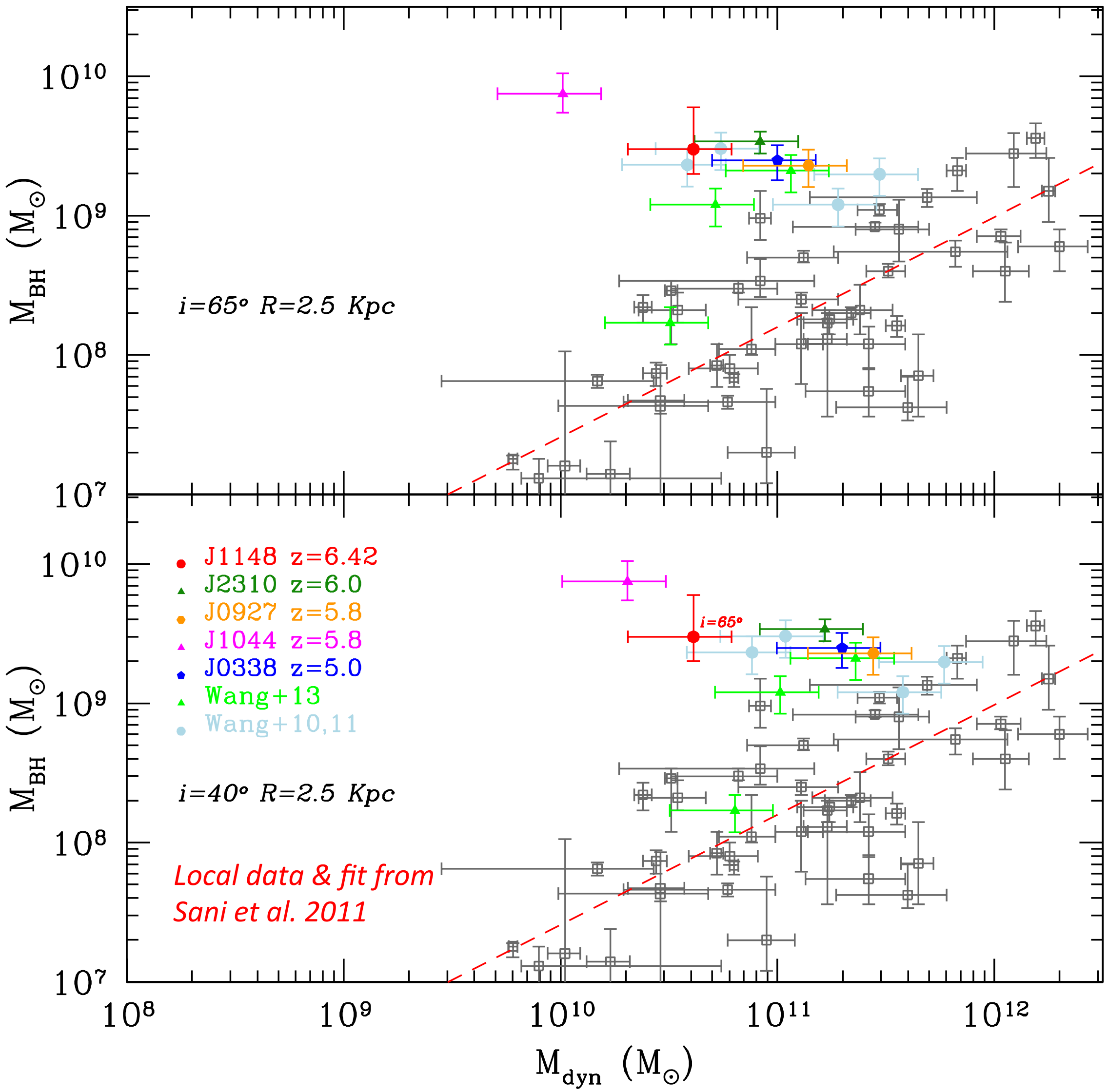
Physical properties of the first QSOs:
the black hole-dynamical mass relation

Valiante et al. 2014



BH masses:

from L_{bol} assuming Eddington accretion
from virial estimators using MgII and/or CIV

$M_{bh} \approx [0.2 – 7.5]\ 10^9\ M_{sun}$

Dynamical masses:

from CO observations assuming an inclined disk geometry

$M_{dyn} = R\, v_{circ}^2/G \qquad v_{circ} = (3/4)\ FWHMco/\sin i$

$M_{dyn} \sin^2 i \approx [0.84 – 15.3]\ 10^{10}\ M_{sun}$

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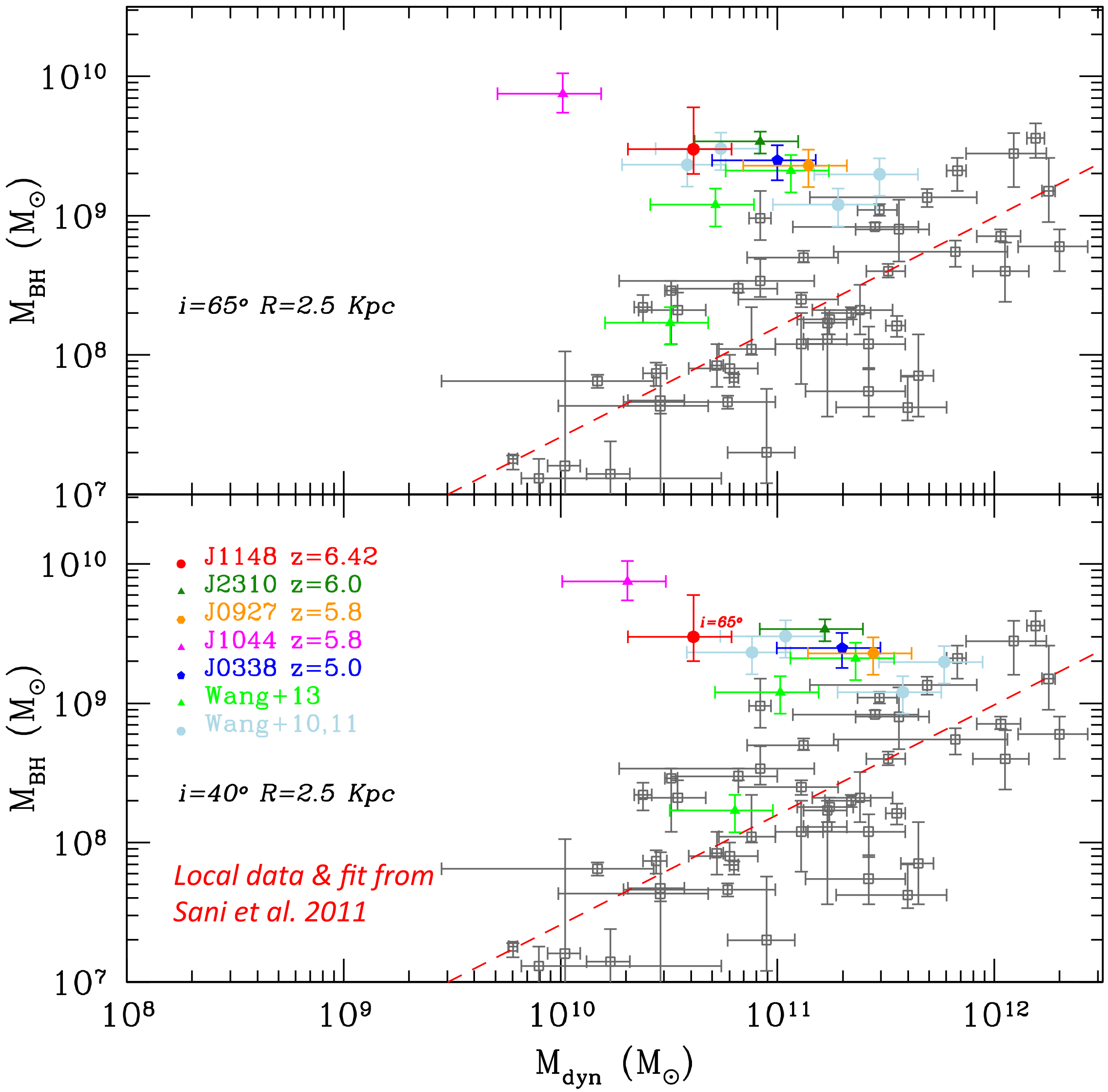

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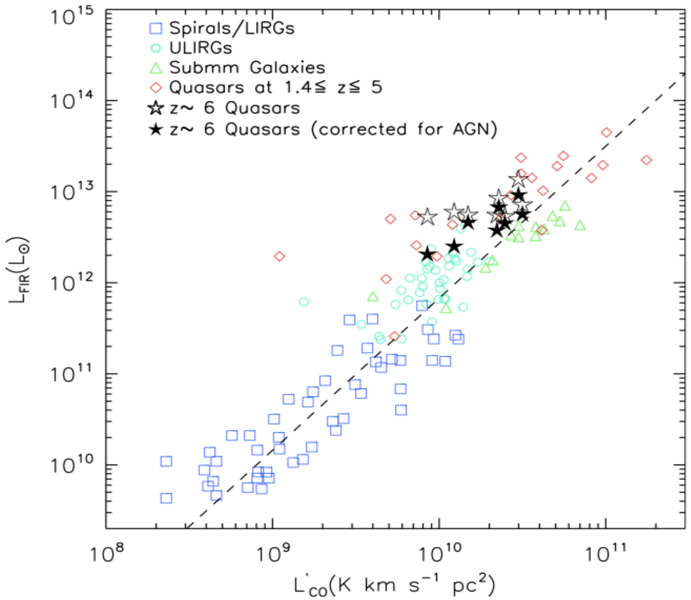
is the observed off-set real?

selection biases and observational uncertainties are important

(Lauer et al.2007; Ho et al. 2007; Merloni et al. 2010; Schulze & Wisotzki 2011; Volonteri & Stark 2011)

Physical properties of the first QSOs:
star formation and outflow rate

Wang et al. 2008, 2010, 2013



SFR:

from the AGN-corrected L_{FIR} assuming the Kennicutt (1998) correction

SFR ≈ [2 – 6.9] 10^3 M_{sun}/yr

Outflow rate:

from the broad wings of the CII line:

$R_{outflow}$ ~ 8 kpc

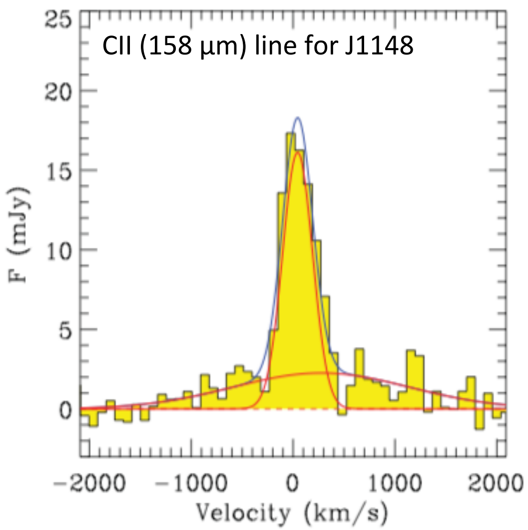
$dM_{outflow}/dt >$ 3500 M_{sun}/yr

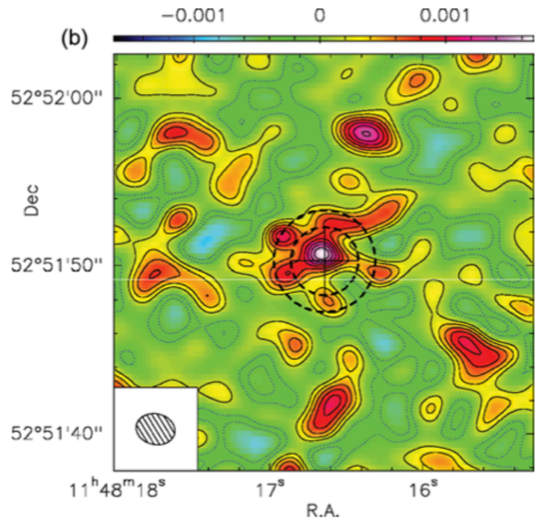
Maiolino et al. 2012

$R_{outflow}$ ~ 30 kpc

$dM_{outflow}/dt >$ 1400 M_{sun}/yr

Cicone et al. 2014





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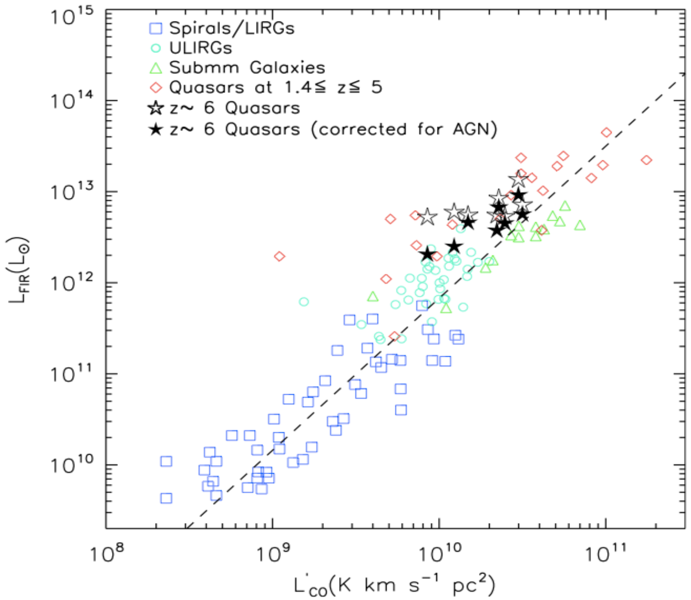

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What is the powering mechanism for this outflow?

how can we simultaneously power strong starbursts?

(Valiante et al. 2012, 2014)

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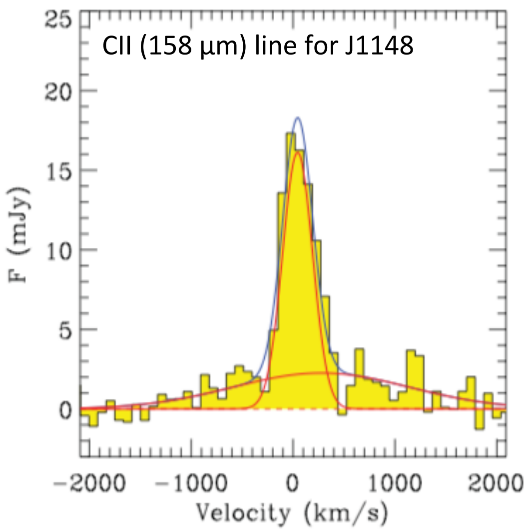
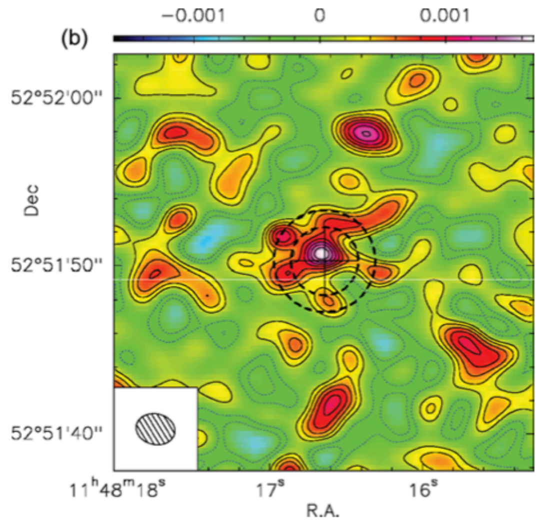




Physical properties of the first QSOs: molecular, stellar and dust masses

Molecular masses:

from CO observations

$M_{H2} = \alpha_{CO}\ L'_{CO(1\text{-}0)}$

$\alpha_{CO} = 0.8 \pm 0.5\ M_{sun}/(K\ km/s/pc^2)$

$M_{H2} \approx [0.9 - 4.8]\ 10^{10}\ M_{sun}$

Stellar masses:

$M_{star} = M_{dyn} - M_{H2}$

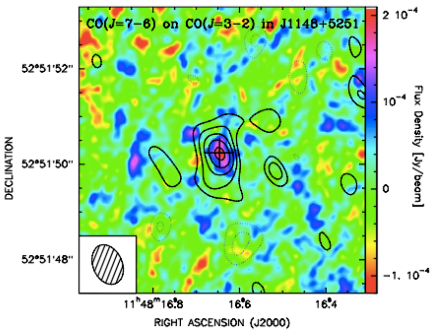
$M_{star} = [0.1 - 4]\ 10^{11}\ M_{sun}$

Dust masses:

from L_{FIR} assuming optically thin grey-body emission

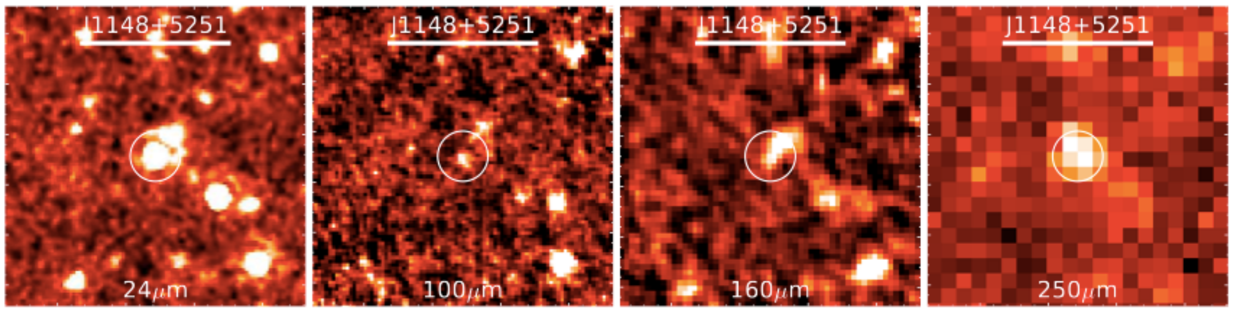
$M_{dust} \approx [1.8 - 9]\ 10^{8}\ M_{sun}$

CO (7-6) line in J1148



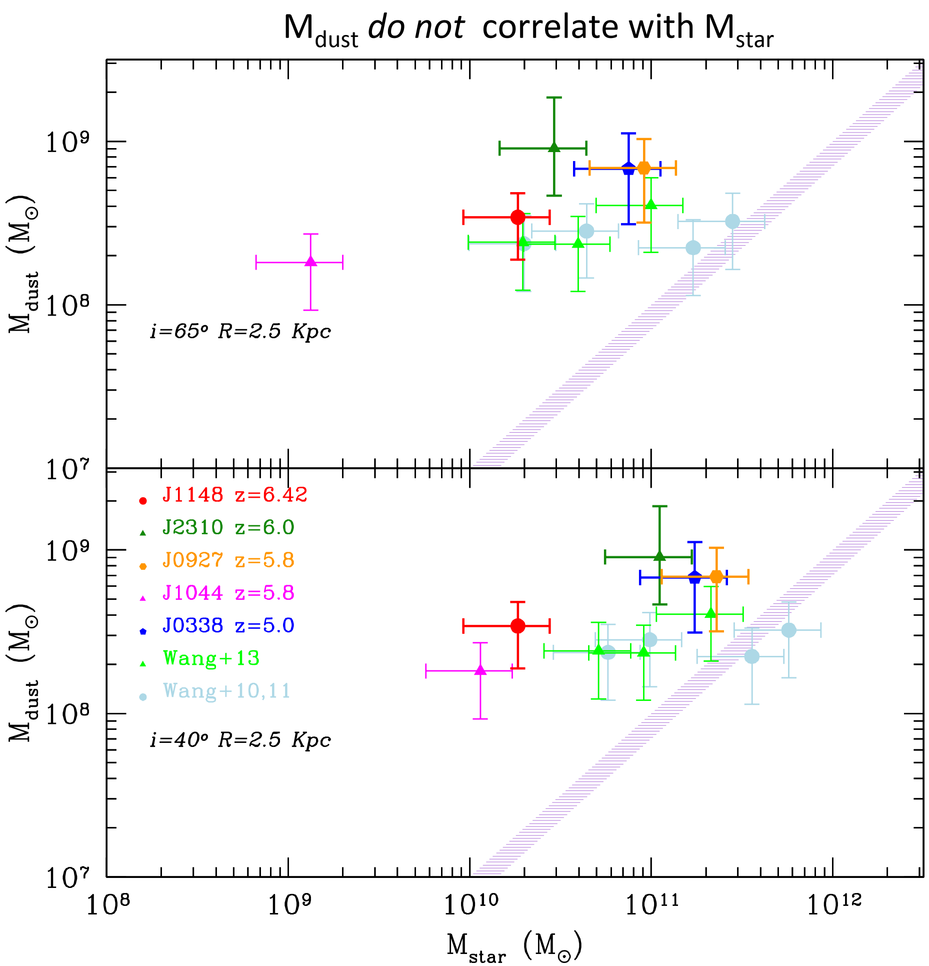
Riechers+09

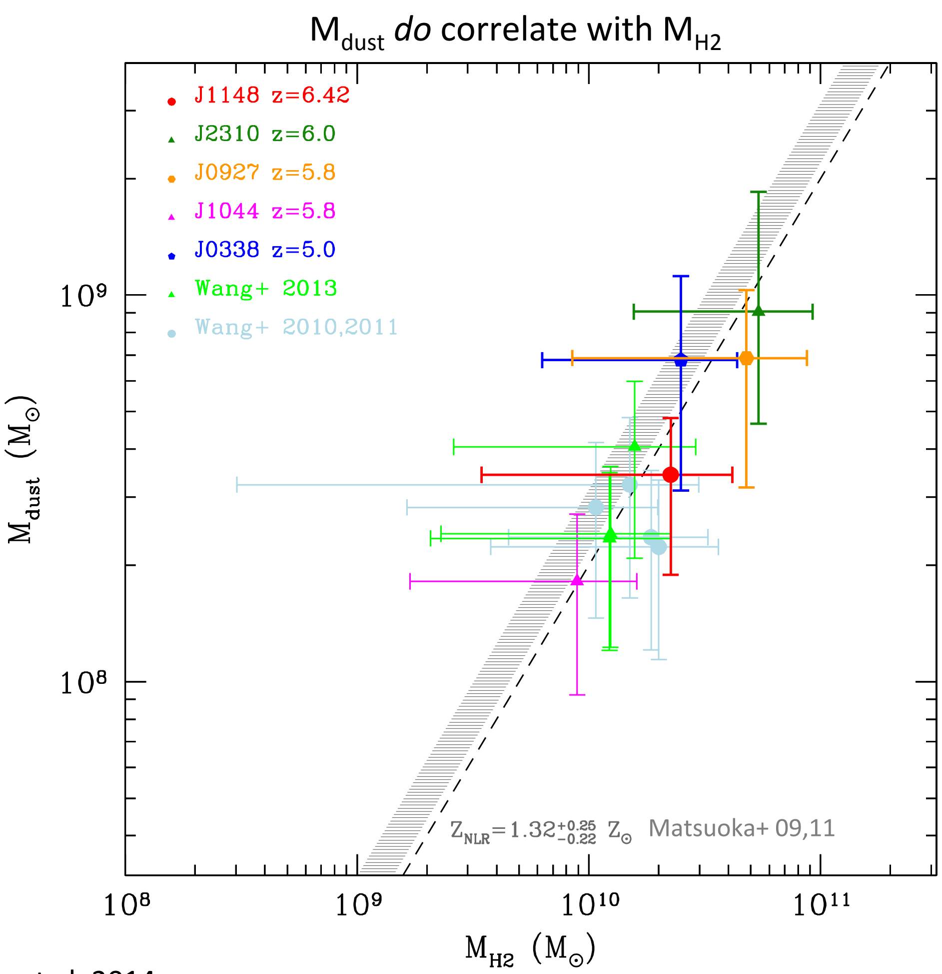
Herschel maps of J1148 @ 24, 199, 169, 259 μm



Leipski+13

Physical properties of the first QSOs: molecular, stellar and dust masses

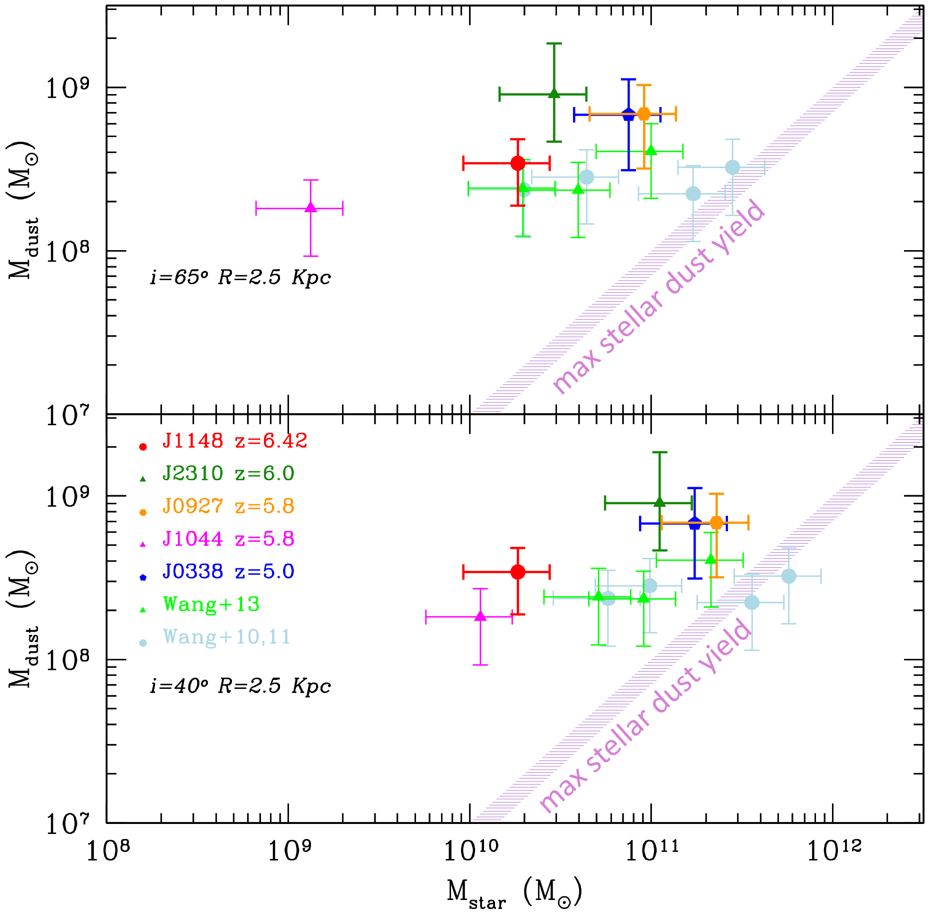




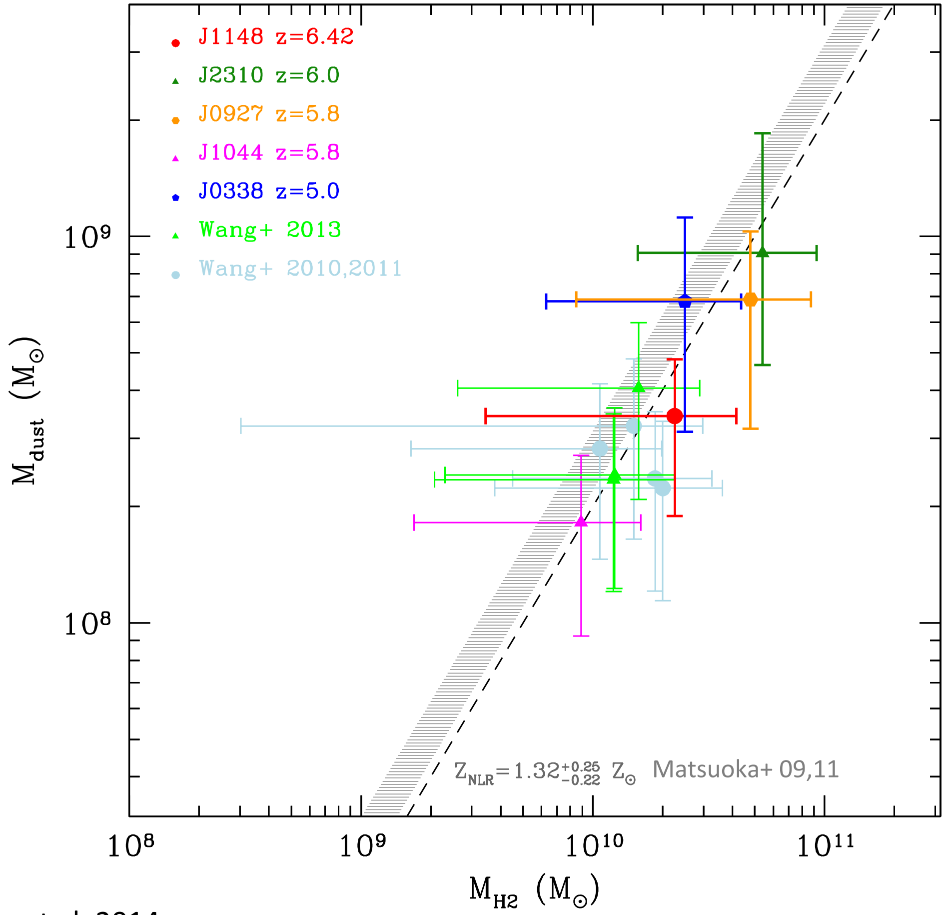
Valiante et al. 2014

Physical properties of the first QSOs: molecular, stellar and dust masses

M_{dust} *do not* correlate with M_{star}



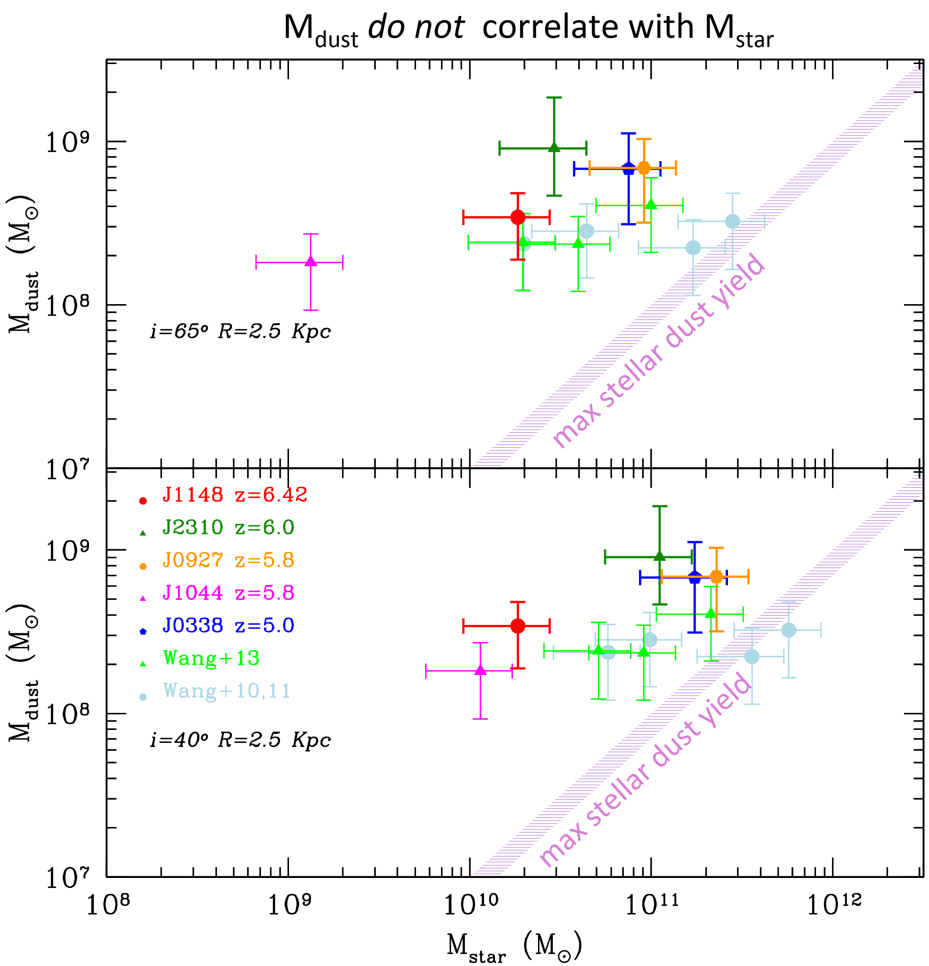
M_{dust} *do* correlate with M_{H2}

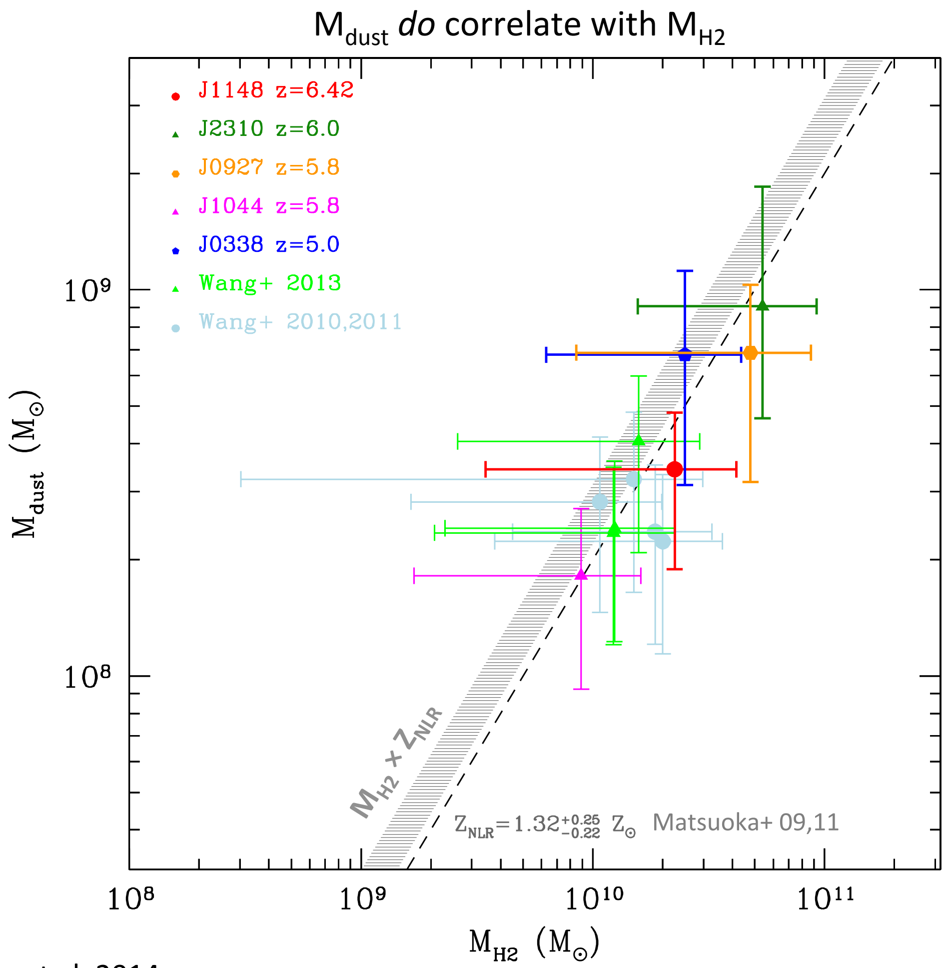


Valiante et al. 2014

stellar dust is not enough to reproduce the observed M_{dust}

Physical properties of the first QSOs: molecular, stellar and dust masses





Valiante et al. 2014

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the observed M_{dust} require very efficient grain growth in dense gas

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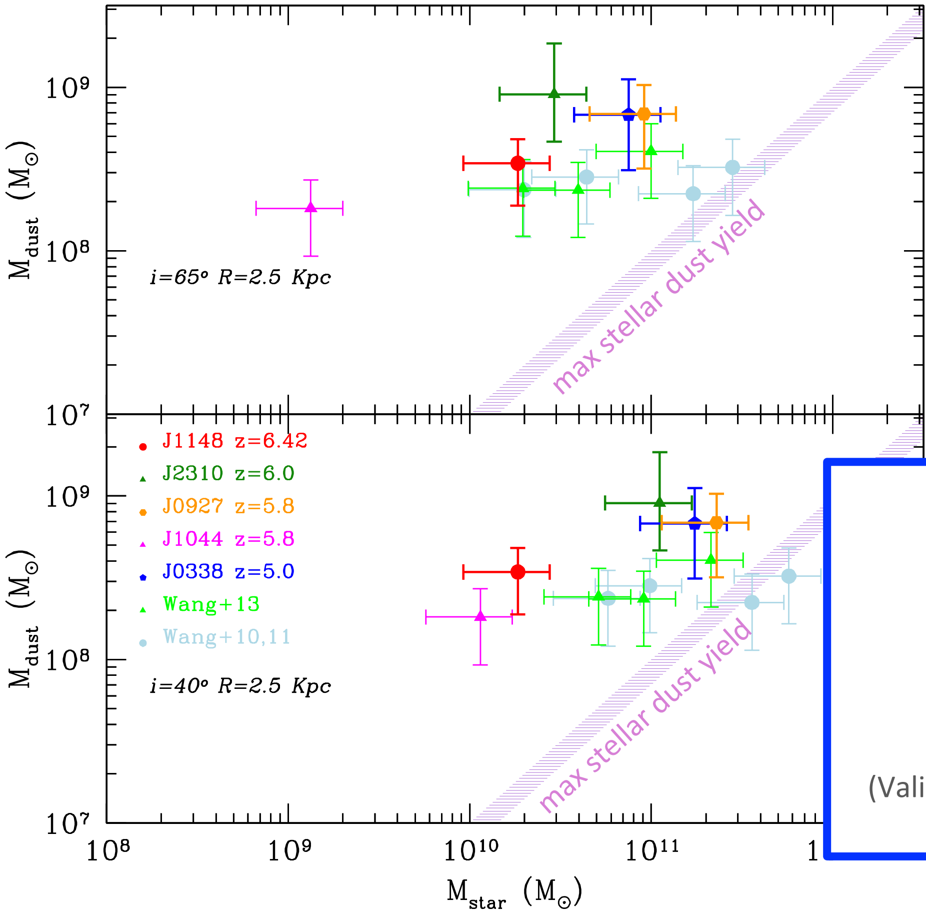

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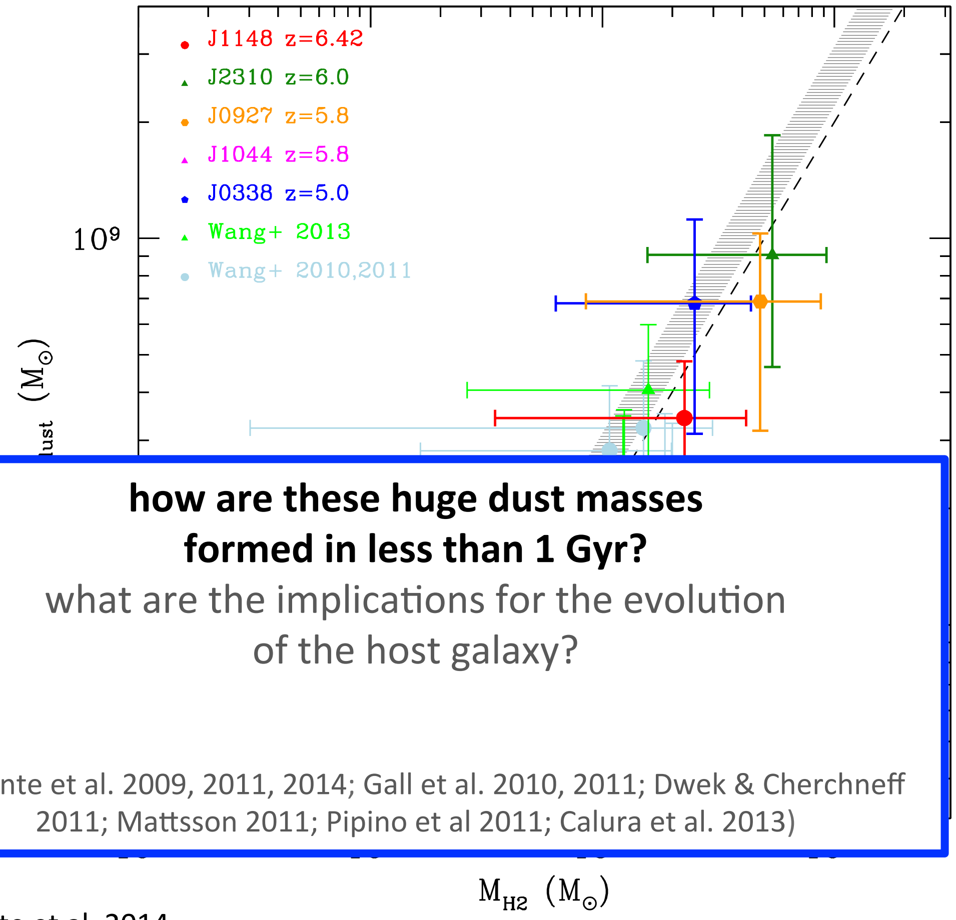

how are these huge dust masses formed in less than 1 Gyr?

what are the implications for the evolution of the host galaxy?

(Valiante et al. 2009, 2011, 2014; Gall et al. 2010, 2011; Dwek & Cherchneff 2011; Mattsson 2011; Pipino et al 2011; Calura et al. 2013)

Valiante et al. 2014

stellar dust is not enough to reproduce the observed M_{dust}

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GAlaxyMErgerTree&Evolution

GAMETE QSOdust

Salvadori, Schneider, Ferrara (2007)

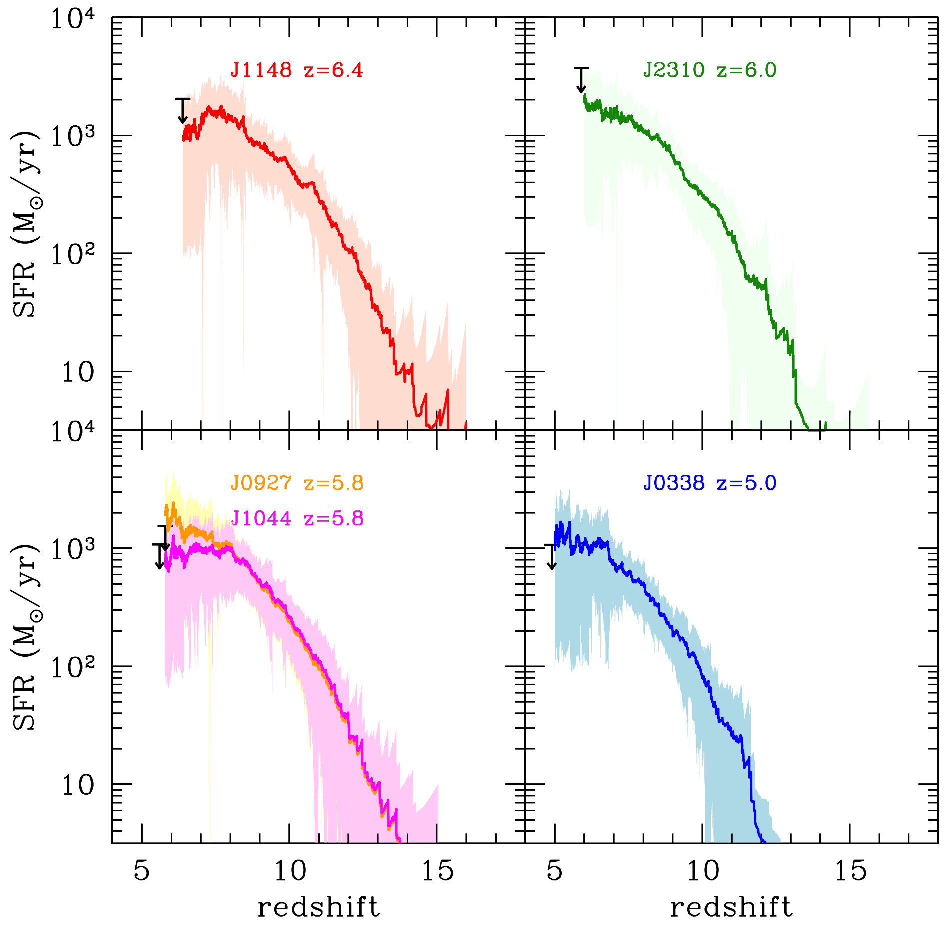
with BH evolution/feedback and dust formation/processing in the ISM

Valiante et al. (2011, 2012, 2014)

- **merger histories of 10^{12} - 10^{13} M_{sun} DM halos @ z = 5 – 6.4**
- **star formation in quiescent and/or merger-driven bursts**
- **BH growth via gas accretion and mergers**
- **BH feedback**
- **chemical enrichment (metals and dust) on the stellar characteristic timescales**
- **dust cycling in the ISM: grain destruction by interstellar shocks and grain growth in molecular clouds**

High-z QSOs evolution: star formation & BH accretion

Valiante et al 2011, 2012, 2014

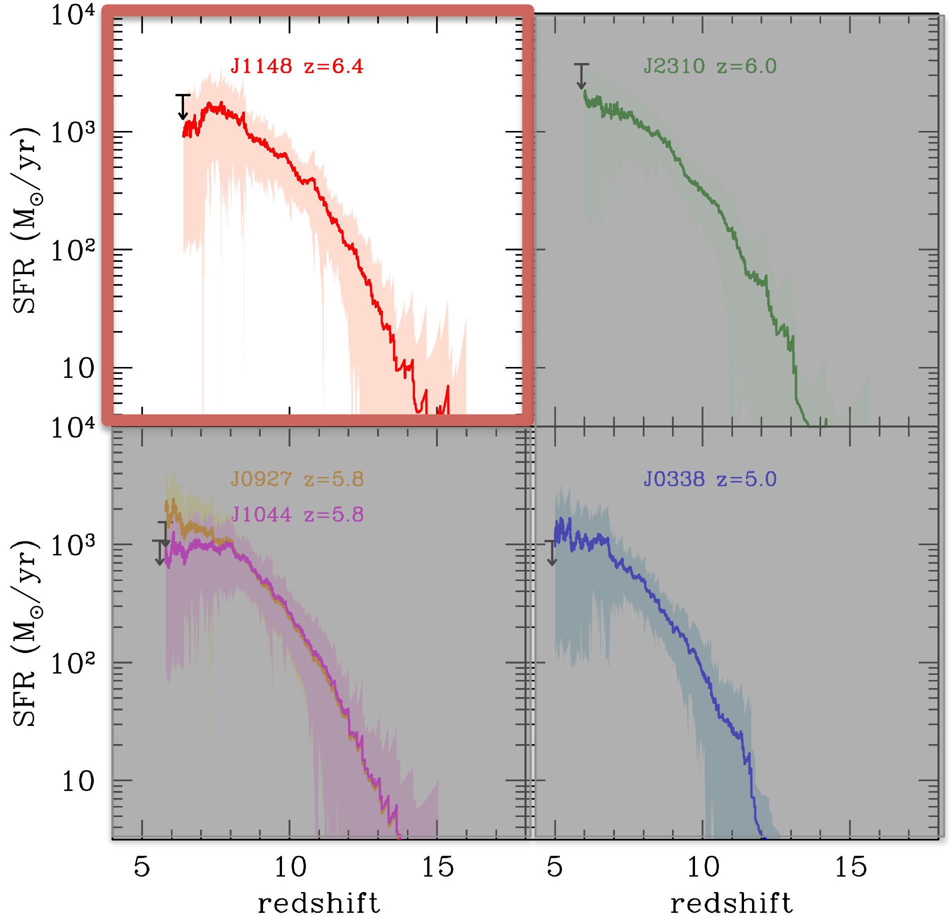


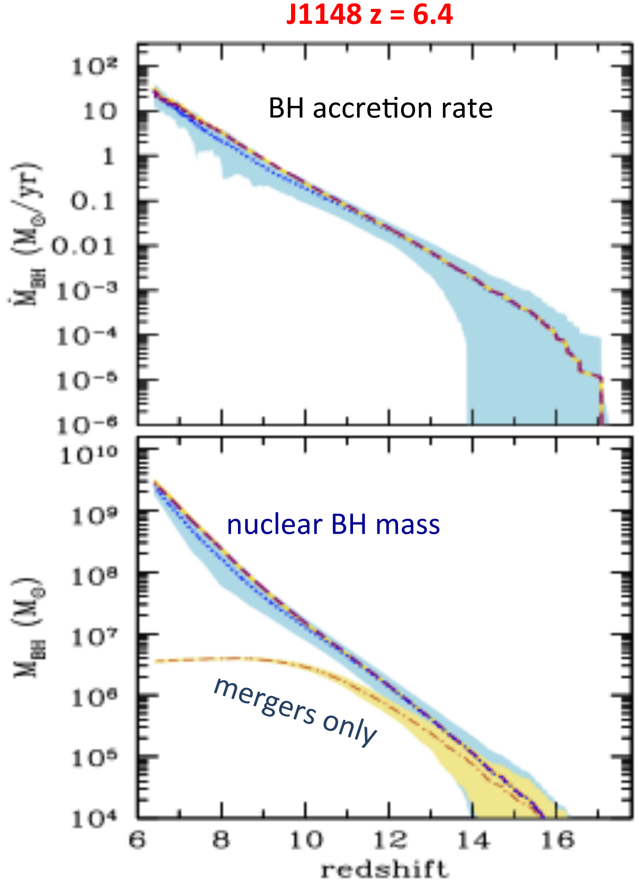
SFR occurs in a quiescent mode and in starbursts activated during major mergers:

$$\mathrm{SFR} = M_{\mathrm{gas}}(\epsilon_{\mathrm{quies}} + \epsilon_{\mathrm{burst}})/t_{\mathrm{dyn}}(z)$$

High-z QSOs evolution: star formation & BH accretion

Valiante et al 2011





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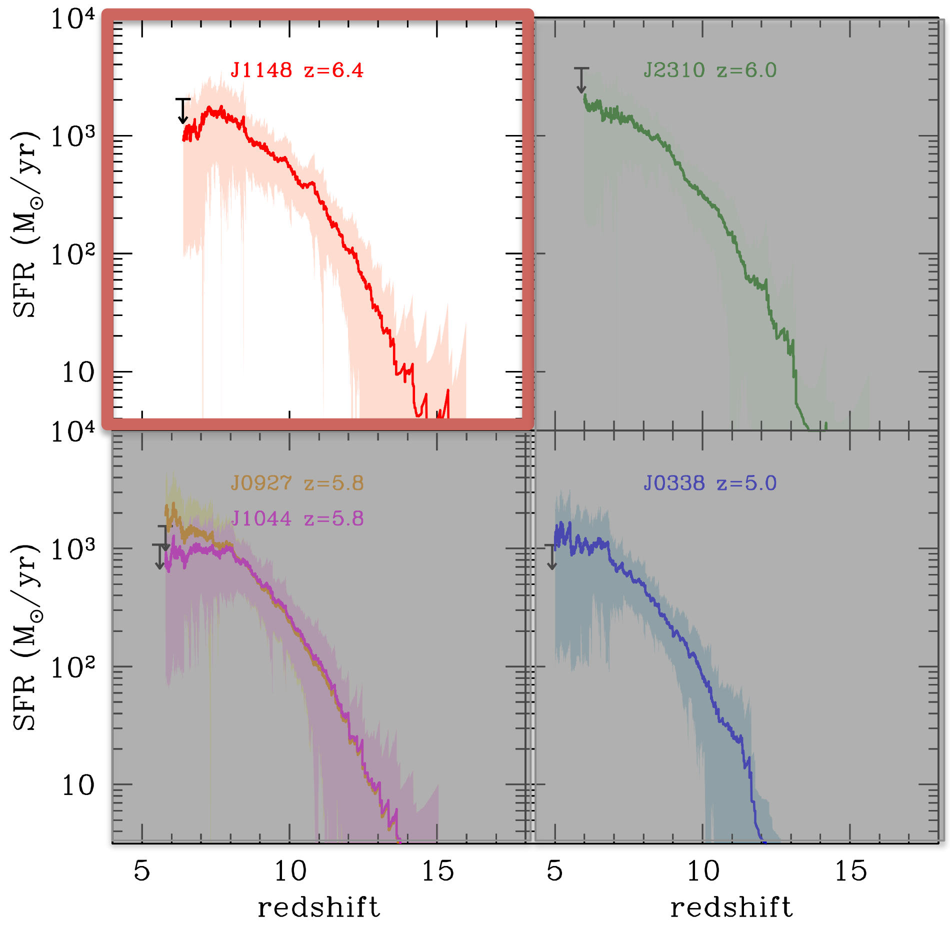
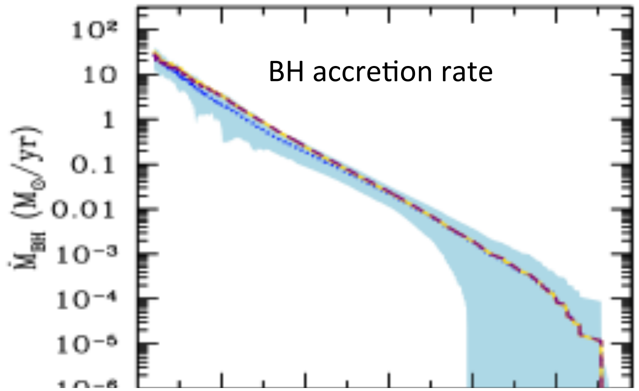
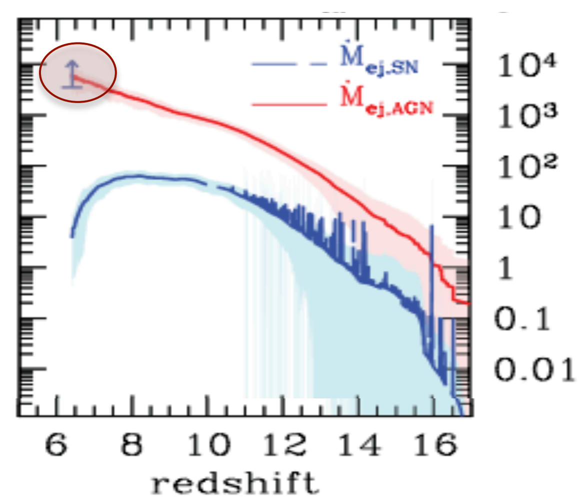


J1148 z = 6.4



Gas outflow rate (Valiante et al 2012)



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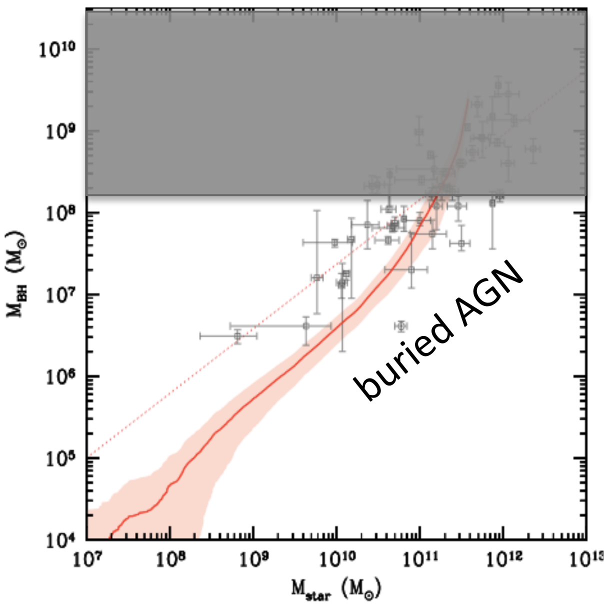
$$\mathrm{SFR} = M_{gas}(\epsilon_{quies} + \epsilon_{burst})/t_{dyn}(z)$$

$$\frac{dM_{ej,AGN}}{dt} = 2\epsilon_{w,AGN}\epsilon_r\left(\frac{c}{v_e}\right)^2 \dot{M}_{accr}$$

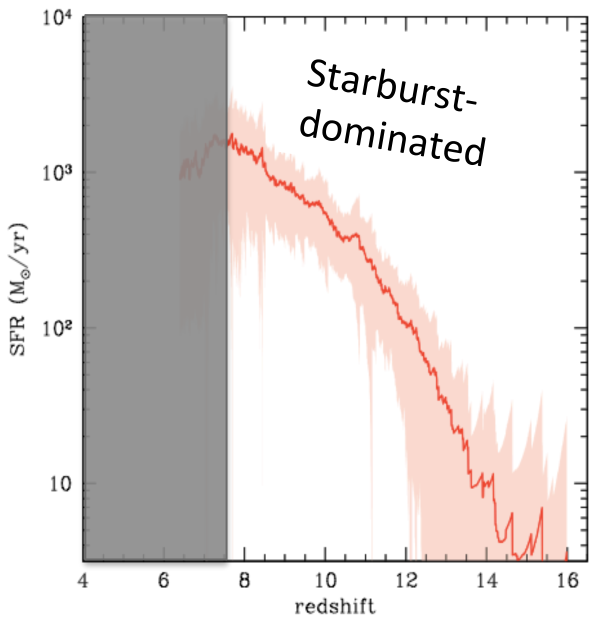
$$\frac{dM_{ej,SN}}{dt} = \frac{2\epsilon_w E_{SN}}{v_e^2} R_{SN}(t),$$

high-z QSO evolution: the cosmic cycle

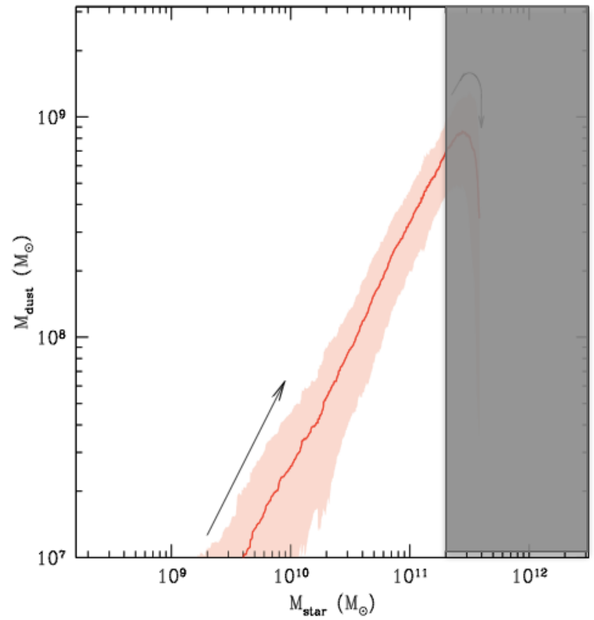
BH-stellar mass



SFH



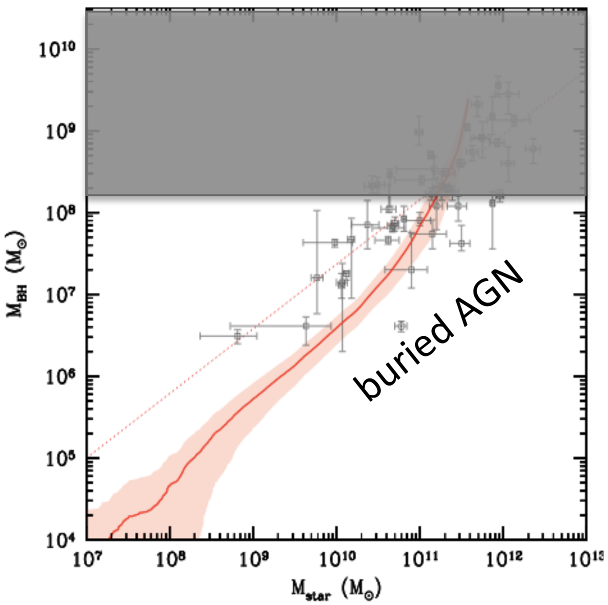
dust-stellar mass

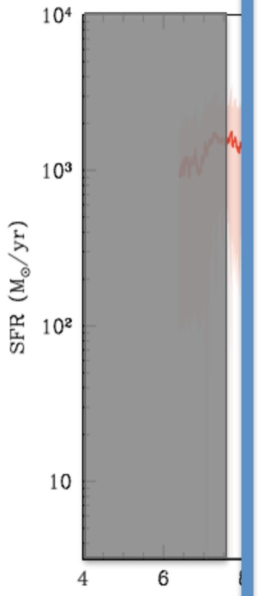


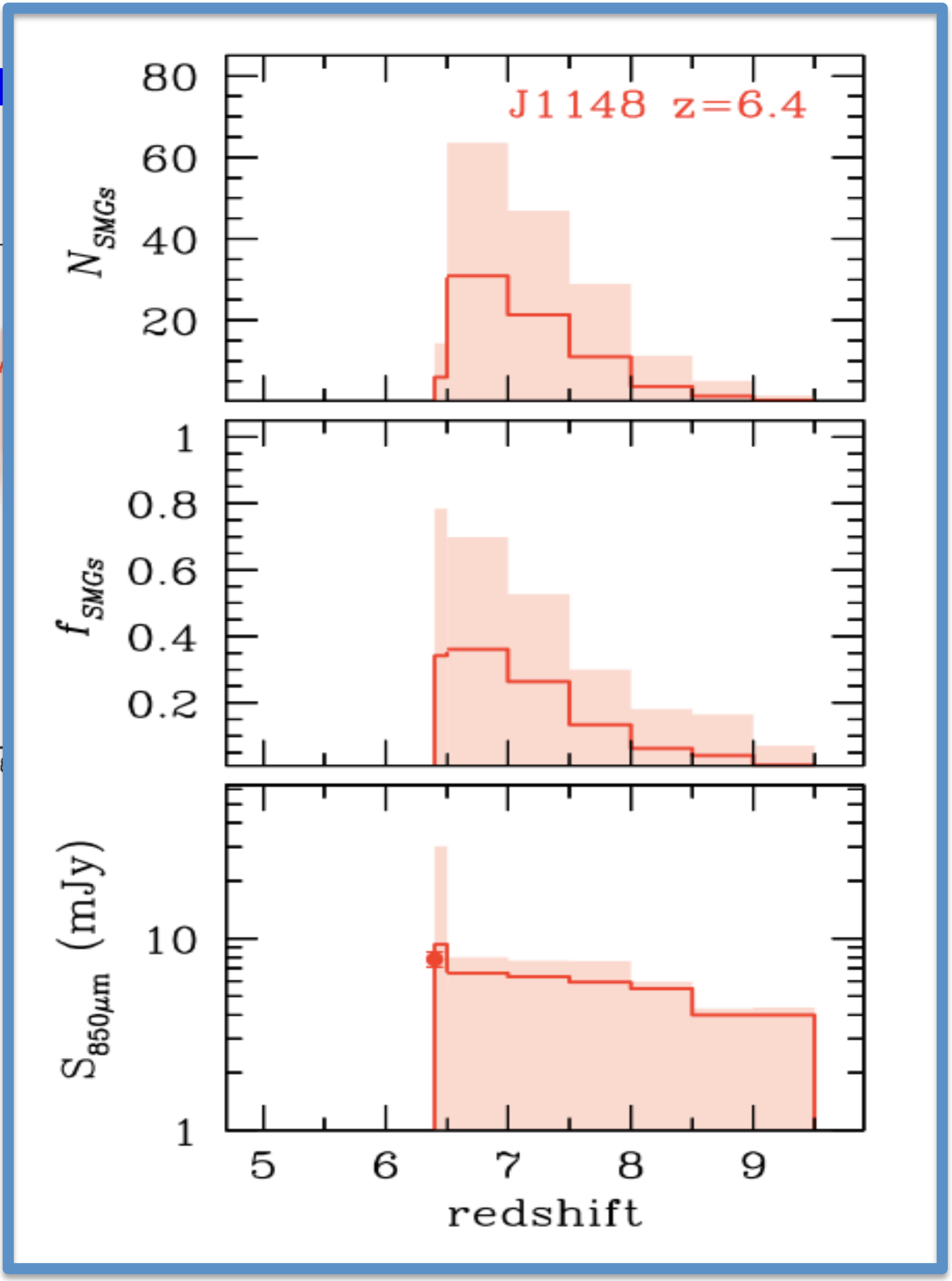
Valiante et al. 2011, 2014

high-z QSO evolu

BH-stellar mass



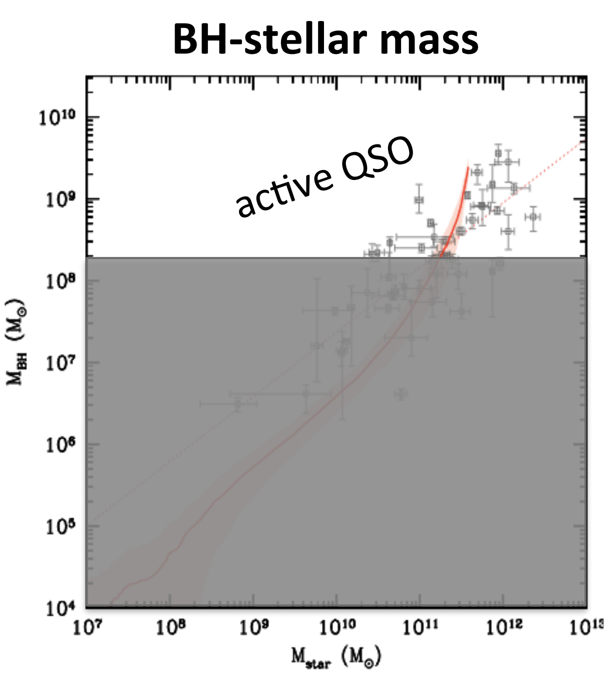


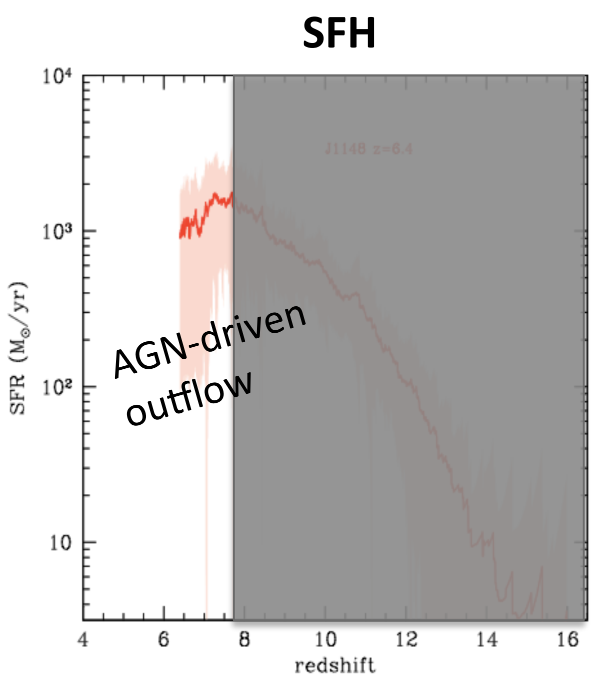


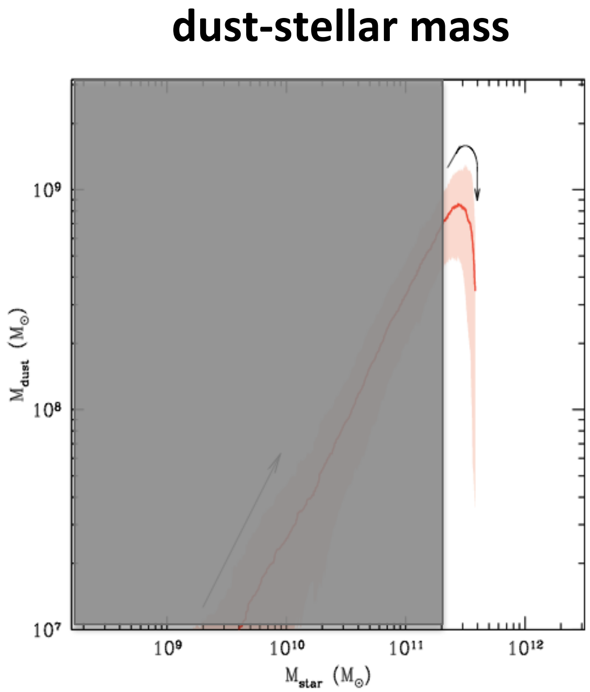
20-40% of J1148 progenitors at
at 6.5 < z < 8 are sub-mm galaxies
with $S_{850\mu m}$ > 3 mJy

Valiante et al. 2014

high-z QSO evolution: the cosmic cycle

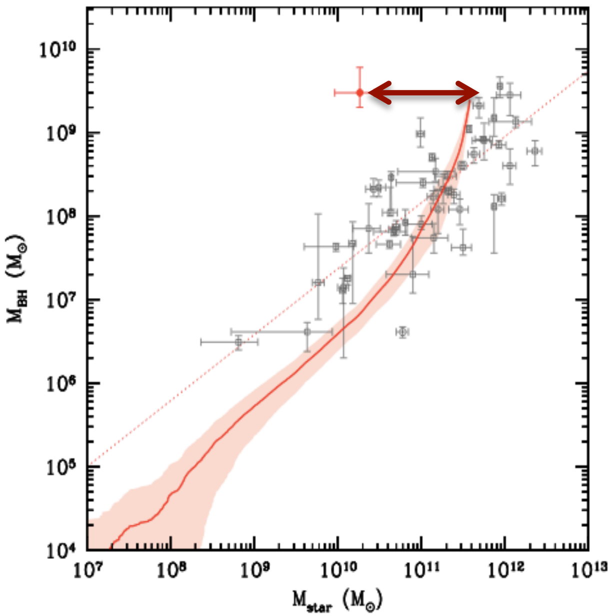


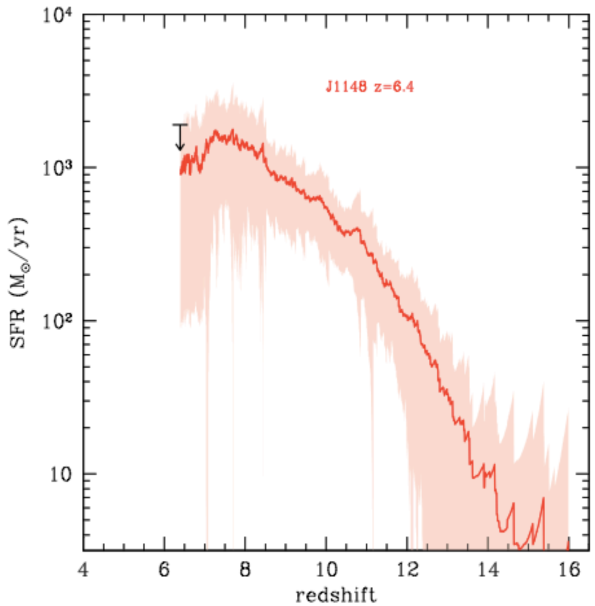


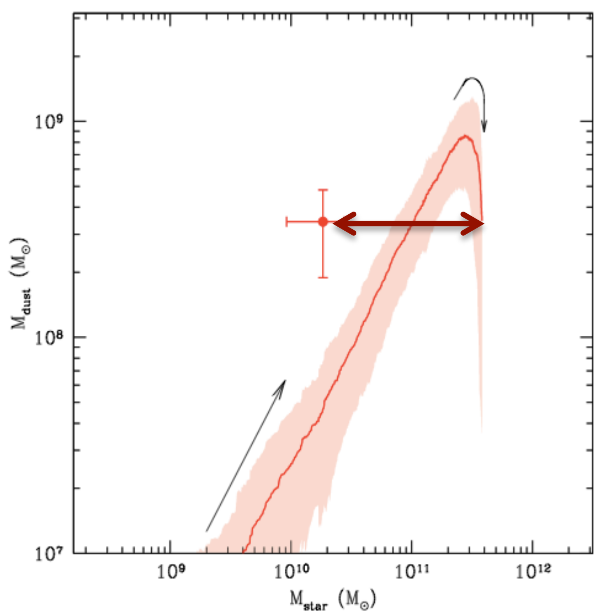


Valiante et al. 2011, 2014

high-z QSO evolution: the cosmic cycle







The best fit scenario reproduces the properties of J1148: M_{BH}, M_{dust}, M_{H2}, L_{FIR}, SFR

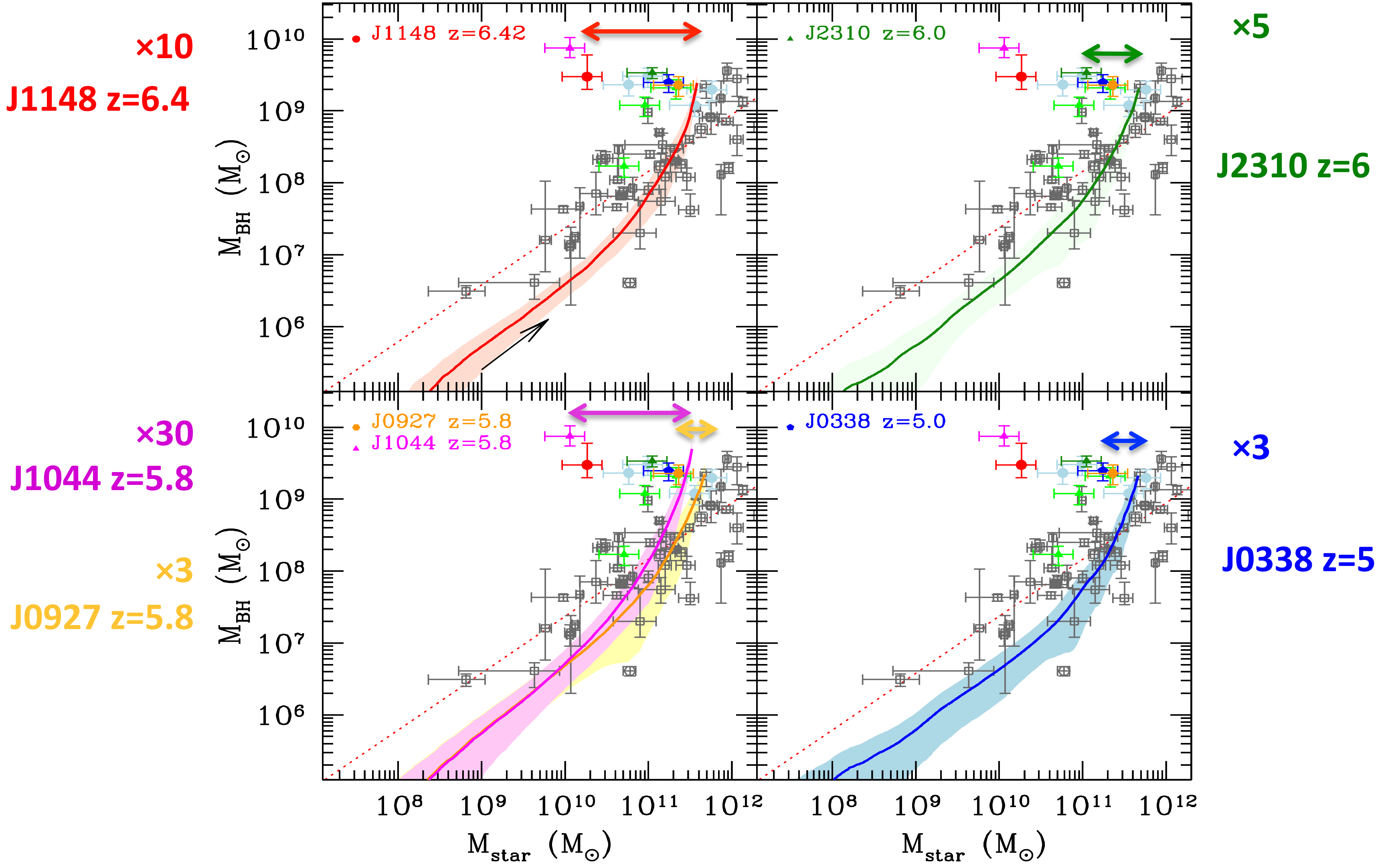
but

predicts a factor of 10 higher stellar mass than derived from $M_{dyn} - M_{H2}$

Valiante et al. 2011, 2014

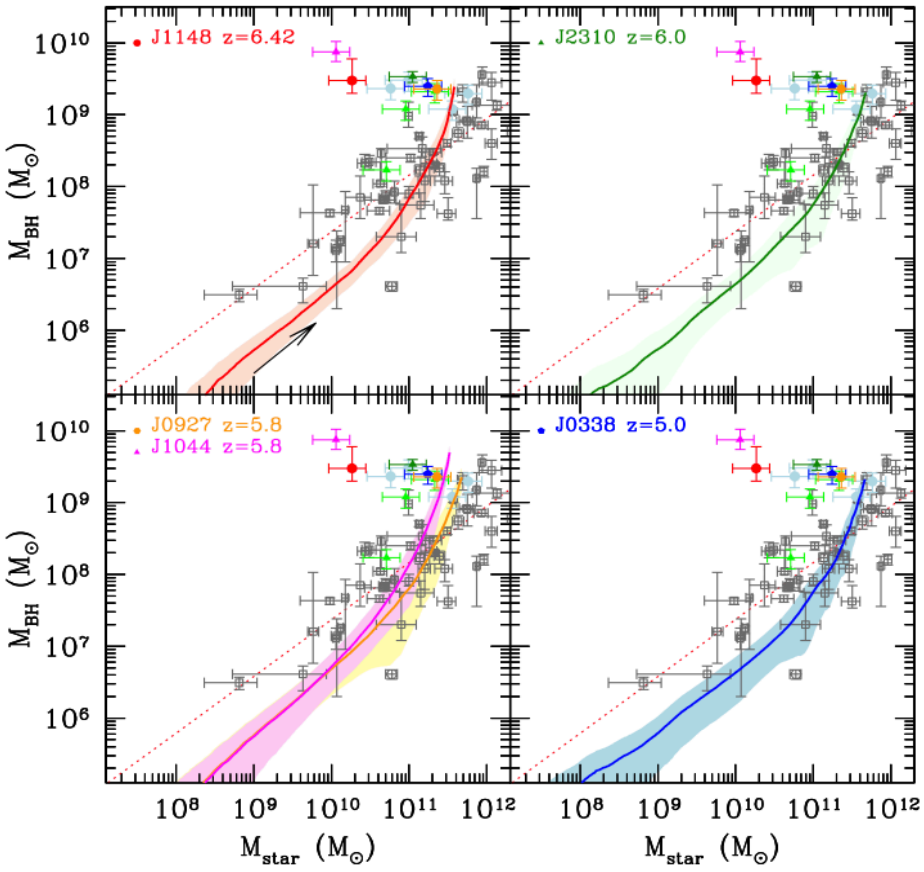
Is there a stellar mass crisis?

For all the QSOs we predict the same behavior:
final stellar masses > $M_{dyn} - M_{H2}$

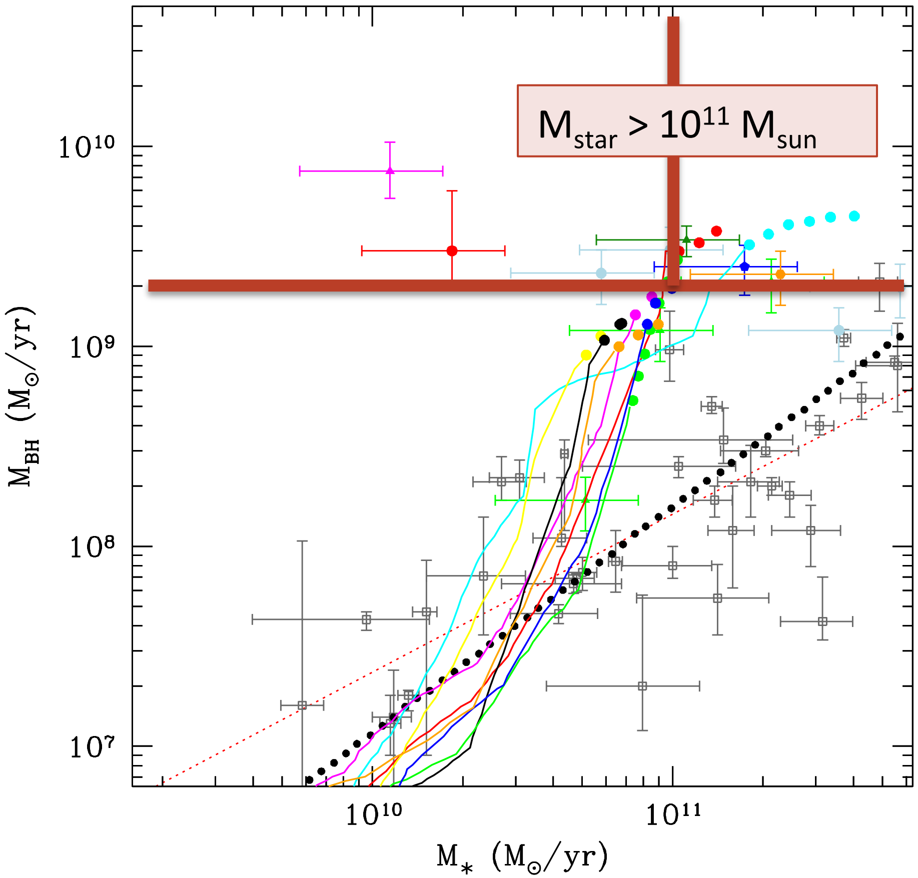


Comparison with MASSIVE-BLACK evolutionary tracks

Valiante et al. 2014



Khandai et al. 2012

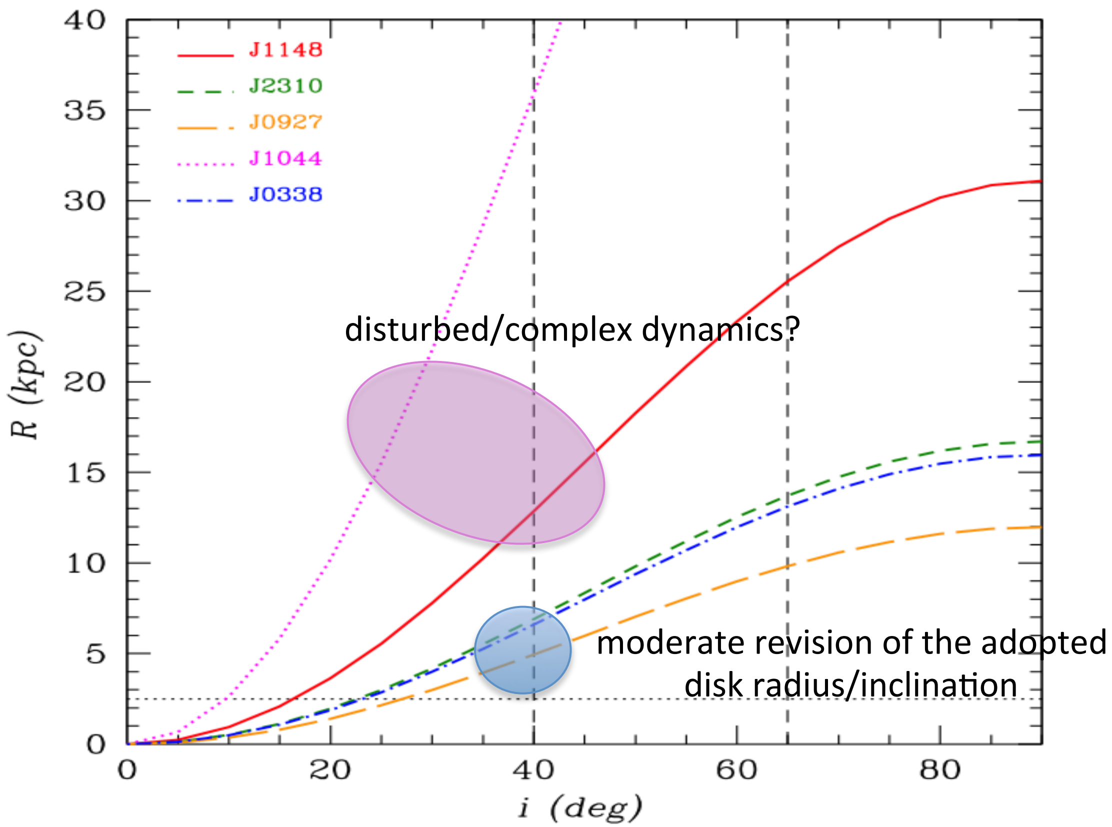


theoretical models predict the first ~ 10^9 M_{sun} SMBHs to live in 10^{11} M_{sun} galaxies, more massive than observed

Uncertainties in the dynamical mass estimates:

what kind of disk geometries would reconcile theory and observations?

observational assumptions:
i = **65°** (J1148) or **40° (other quasars) and R = 2.5 Kpc**

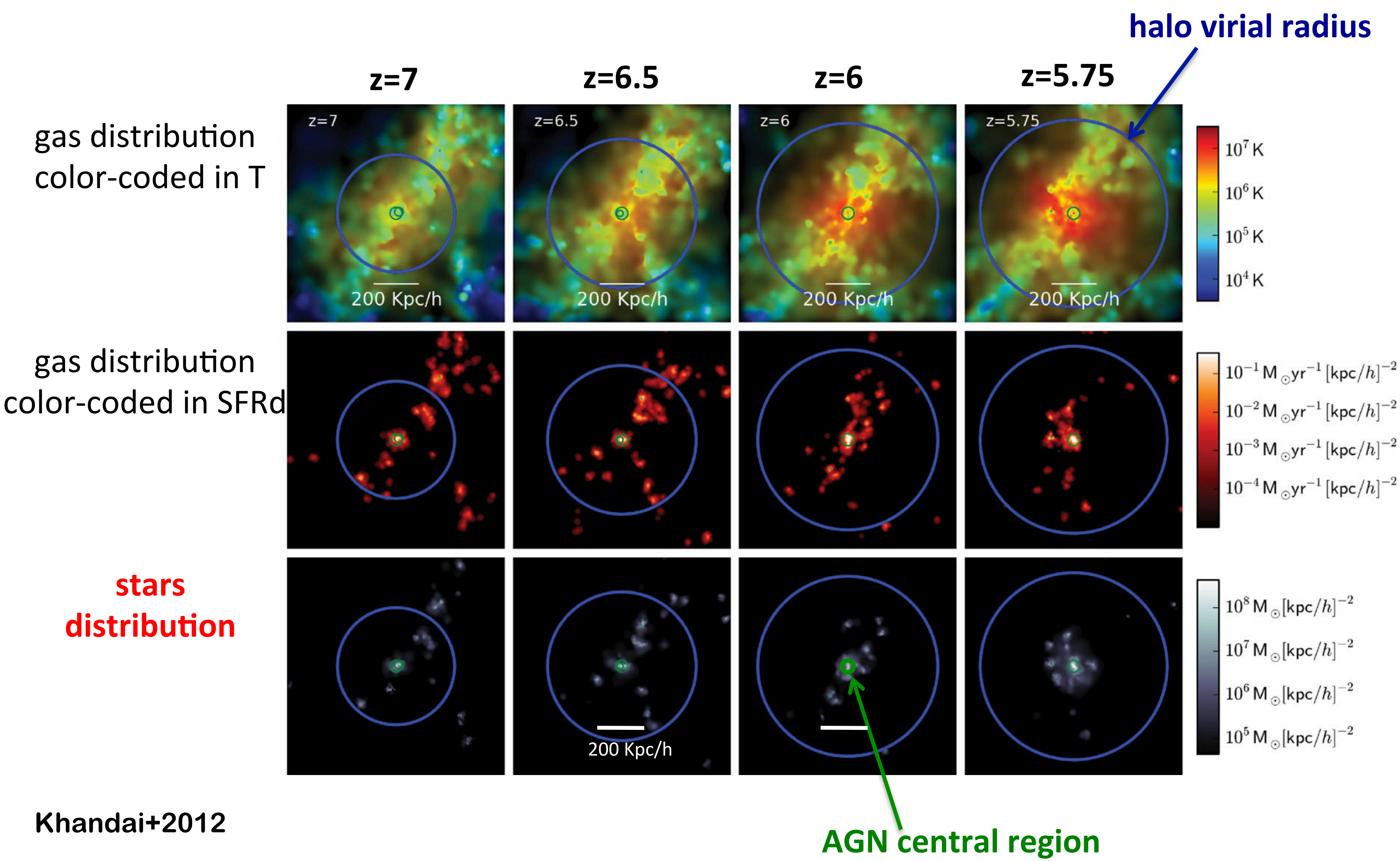


Valiante et al. 2014

R > 25 kpc or i < 15°
for J1148 and J1044

R ≈ 5 – 8 kpc or i ≈ 20° – 30°
for J2310, J0927 and J0338

Are there stars beyond the CO-emitting region?



Khandai+2012

Are there stars beyond the CO-emitting region?

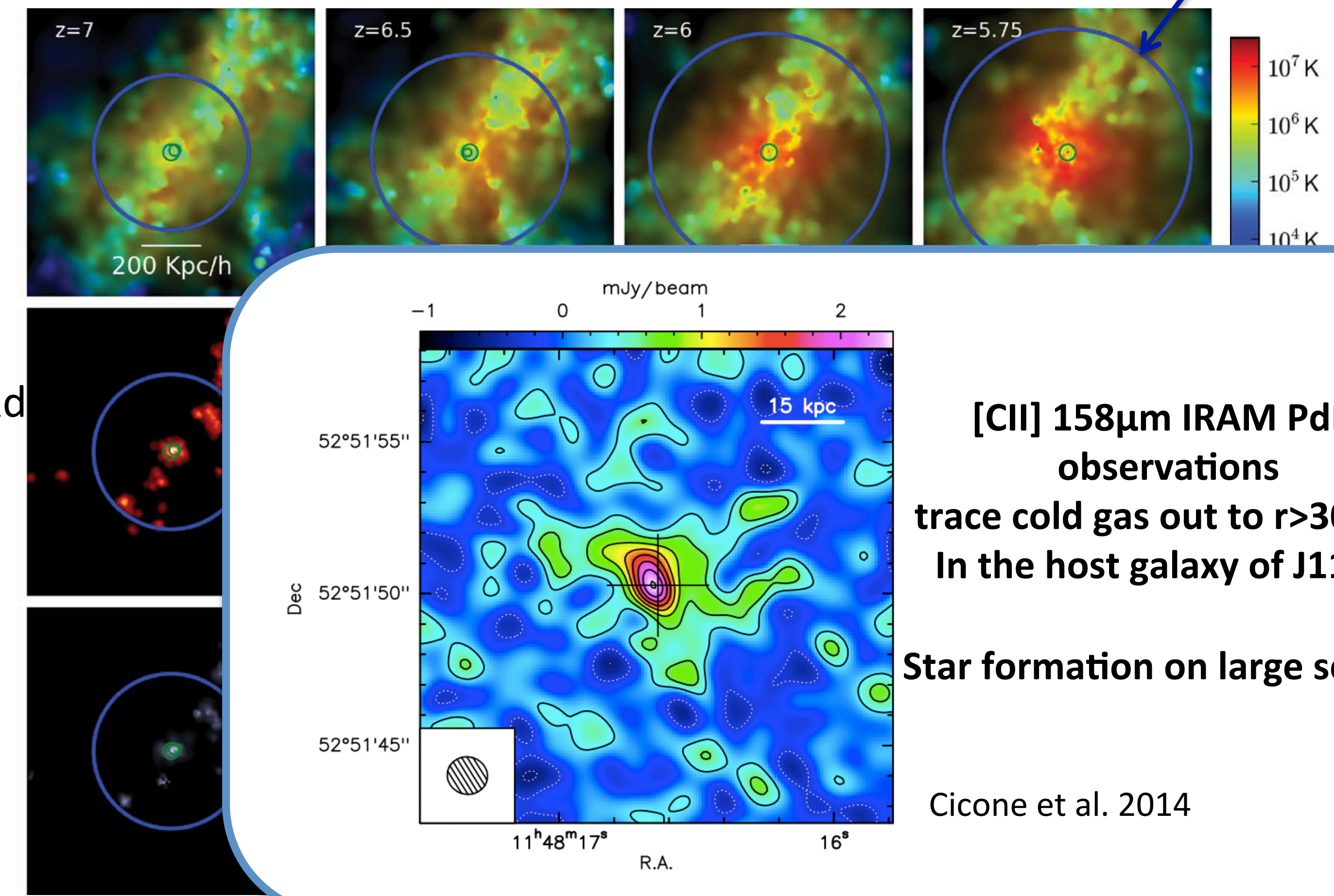
halo virial radius

	z=7	z=6.5	z=6	z=5.75

gas distribution color-coded in T

gas distribution color-coded in SFRd

stars distribution



Khandai+2012

[CII] 158μm IRAM PdBI observations trace cold gas out to r>30 Kpc In the host galaxy of J1148.

Star formation on large scales?

Cicone et al. 2014

AGN central region

Conclusions

- theoretical models suggest that the first 10^9 M_{sun} SMBHs live in M_{star} > 10^{11} M_{sun} galaxies → M_{bh}/M_{star} is within the scatter of the local relation

- at z < 10, when > 10^8 M_{sun} of dust mass has been produced by means of efficient grain growth in dense molecular clouds, the progenitors of high-z QSOs may be observable as SMGs

- For most of the QSOs the apparent tension could be resolved assuming different disk properties, with 5 kpc < R < 8 kpc or 20 < i < 30

- some of the stars may be distributed outside the observed CO-emitting region, as suggested by numerical simulations…

THANK YOU!