

Morphological transformations and AGN feedback

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Collaborators:

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Horizon-AGN simulation

<http://horizon-simulation.org>

25 Mpc/h

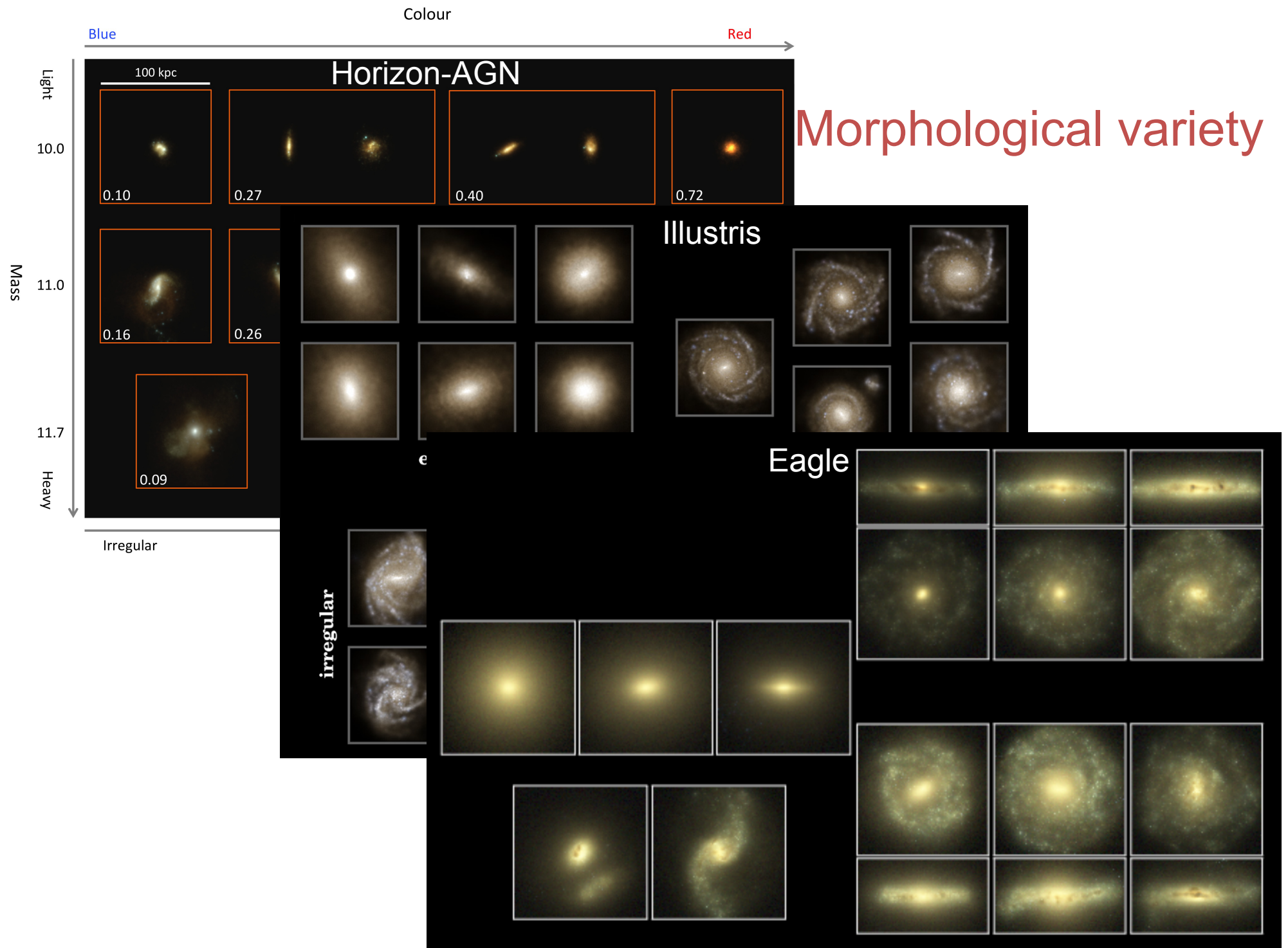
$z=0$

Morphological transformations and AGN feedback

- 1) What SMBHs do for morphology
- 2) What morphology does for SMBHs



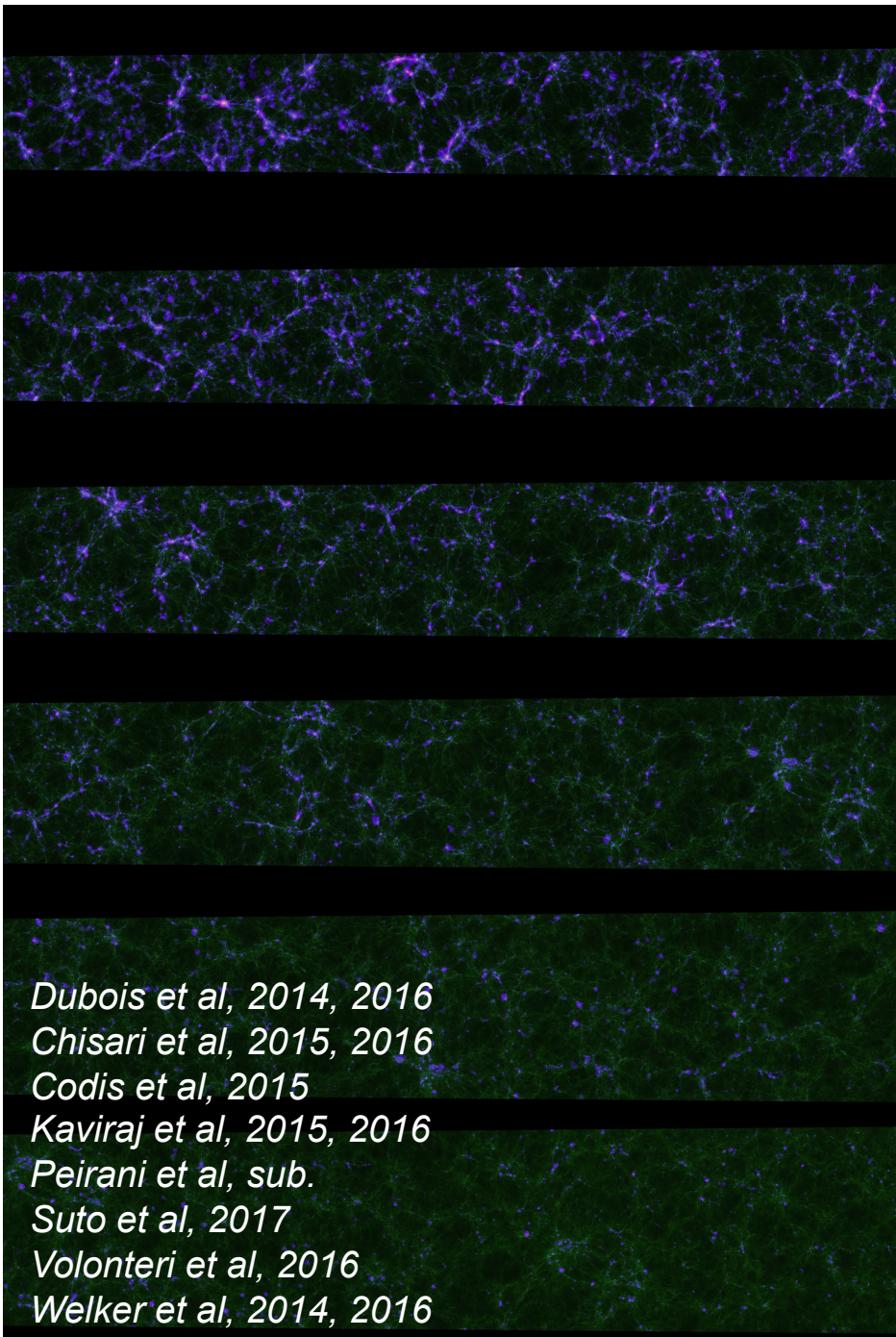
Without AGN: massive blue spirals are everywhere!



The Horizon-AGN simulation

- Simulation content
 - Run with Ramses (AMR) *Teyssier (2002)*
 - $L_{\text{box}}=100 \text{ Mpc}/h$
 - **1024³** DM particles $M_{\text{DM,res}}=8 \times 10^7 M_{\text{sun}}$
 - Finest cell resolution $dx=1 \text{ kpc}$
 - Gas cooling & UV background heating
 - Low efficiency star formation
 - Stellar winds + SNII + SNIa
 - O, Fe, C, N, Si, Mg, H
 - AGN feedback radio/quasar mode
- Outputs
 - Standard outputs $\sim 200 \text{ Myrs}$
 - Star particles are backed up every 10-20 Myr
 - Lightcones ($1^\circ \times 1^\circ$) performed on-the-fly
 - Dark Matter (position, velocity)
 - Gas (position, density, velocity, pressure, chemistry)
 - Stars (position, mass, velocity, age, chemistry)
 - Black holes (position, mass, velocity, accretion rate)
- $z=0$ using 10 Mhours on 4096 cores
- 150 000 galaxies per snapshot ($> 50 \text{ part.}$)
- $7 \cdot 10^9$ leaf cells (more than Illustris or Eagle)

<http://horizon-simulation.org/>



Dubois et al, 2014, 2016
Chisari et al, 2015, 2016
Codis et al, 2015
Kaviraj et al, 2015, 2016
Peirani et al, sub.
Suto et al, 2017
Volonteri et al, 2016
Welker et al, 2014, 2016

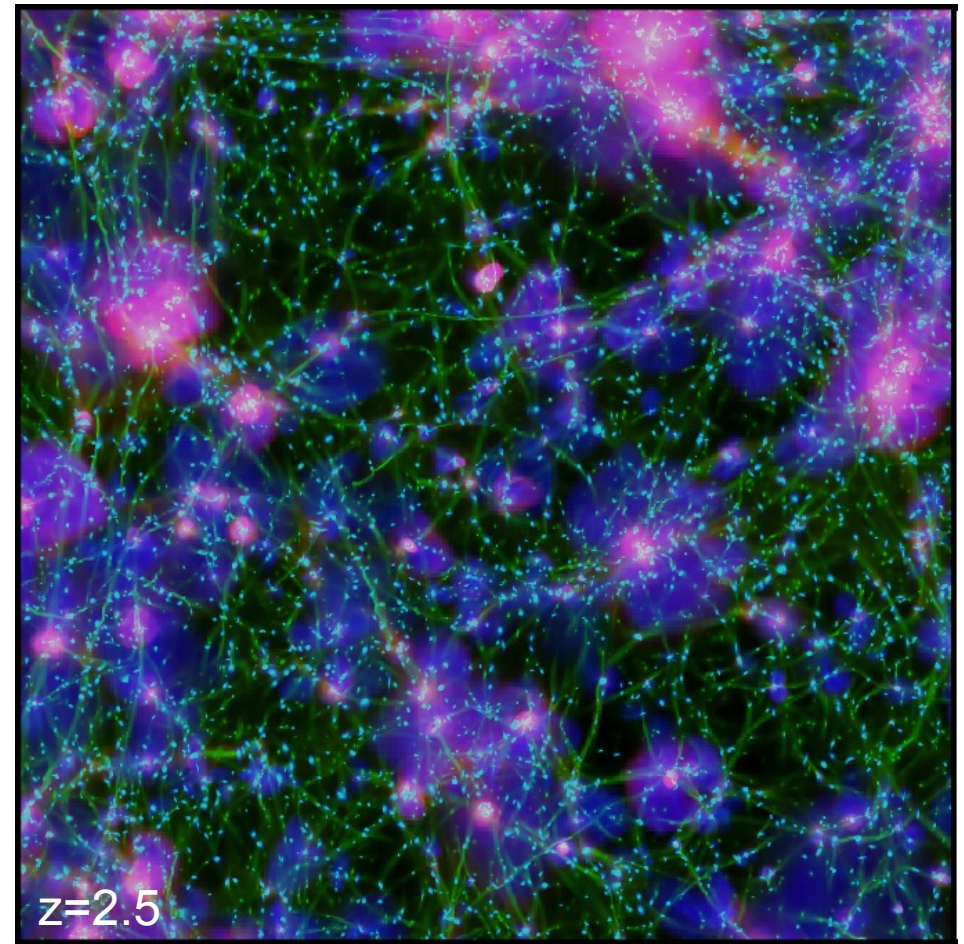
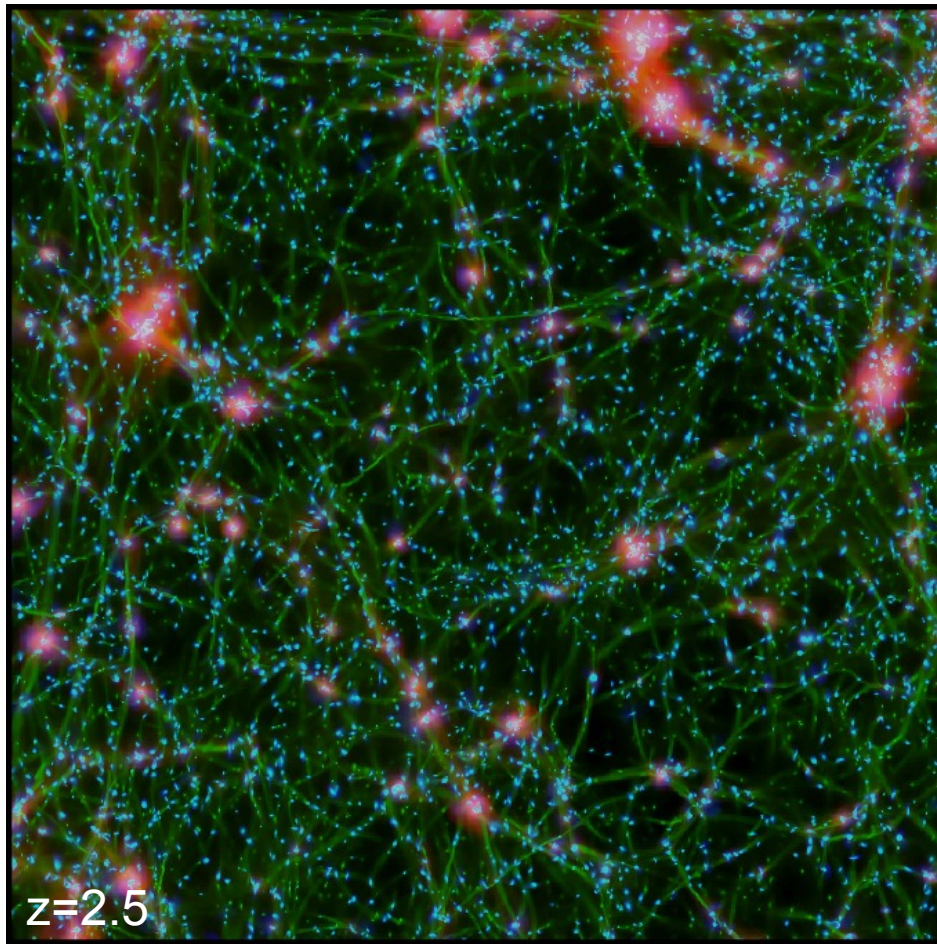
You can find me on Youtube

A visual inspection of the impact of AGN feedback on large-scale structures

Green: gas density / Red: temperature / Blue: metallicity

Horizon-noAGN

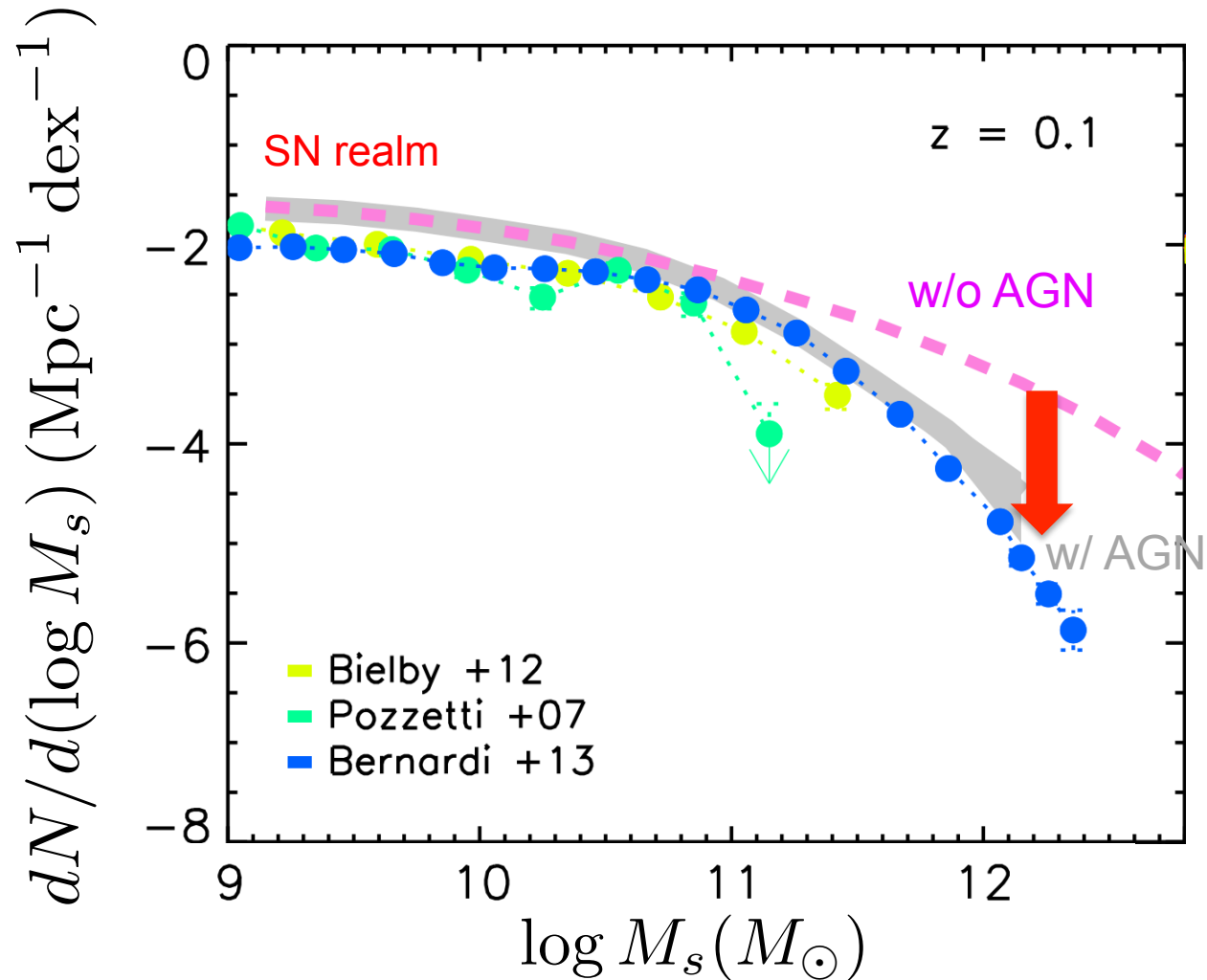
Horizon-AGN

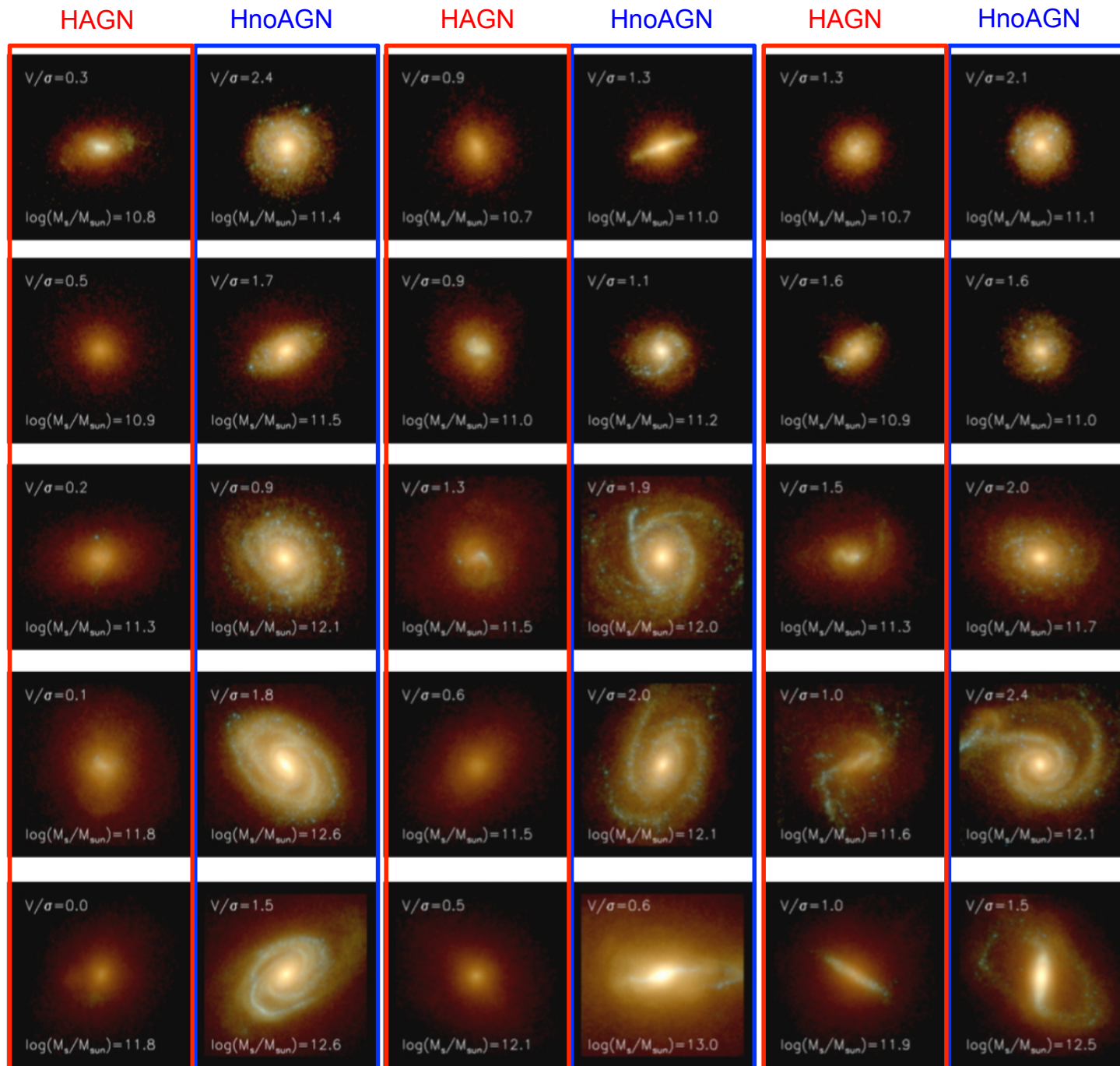


+ one DM-only simulation

Motivation for AGN feedback

Galaxy mass functions in the Horizon-AGN project

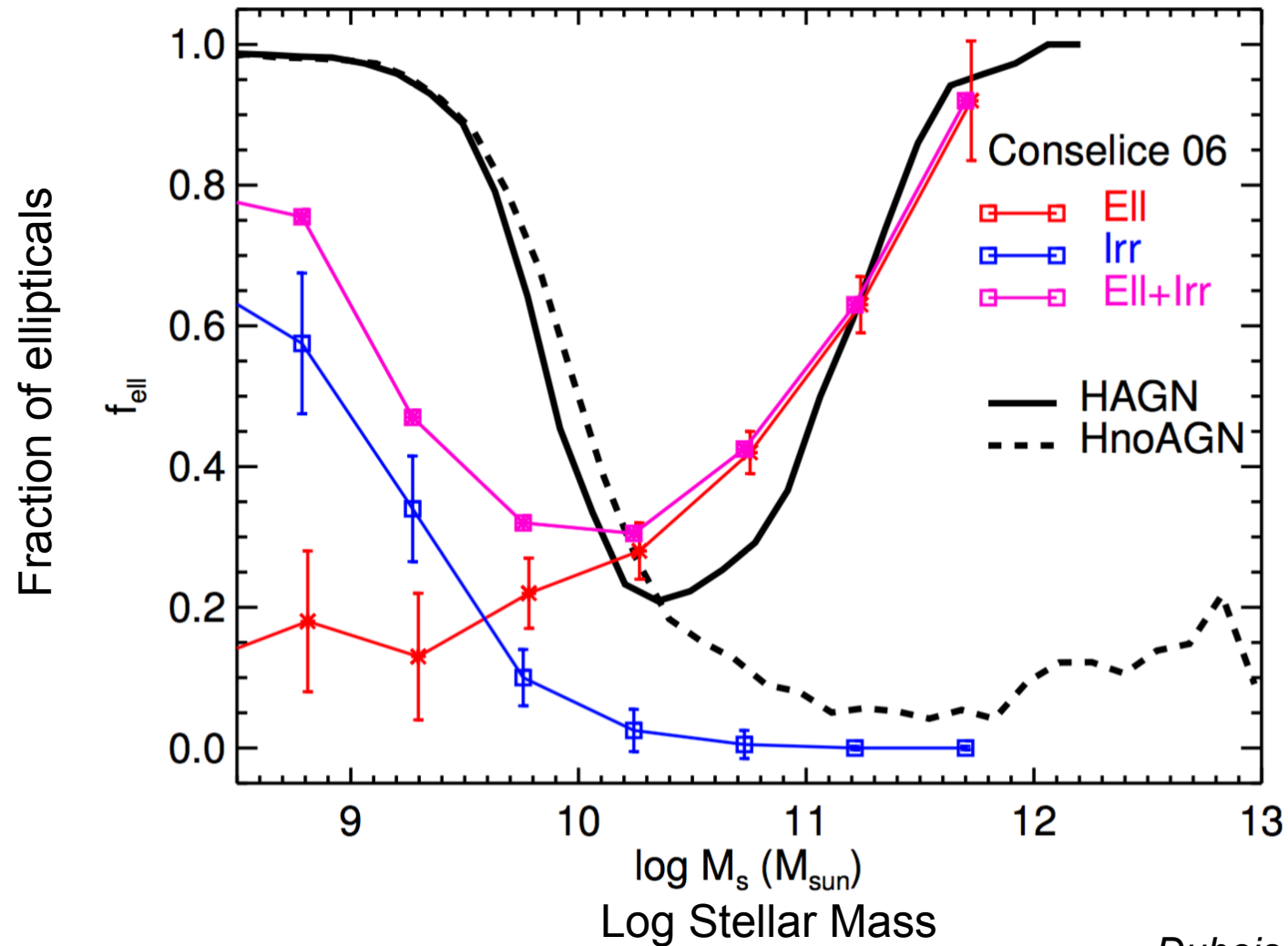




Dubois et al, 2016

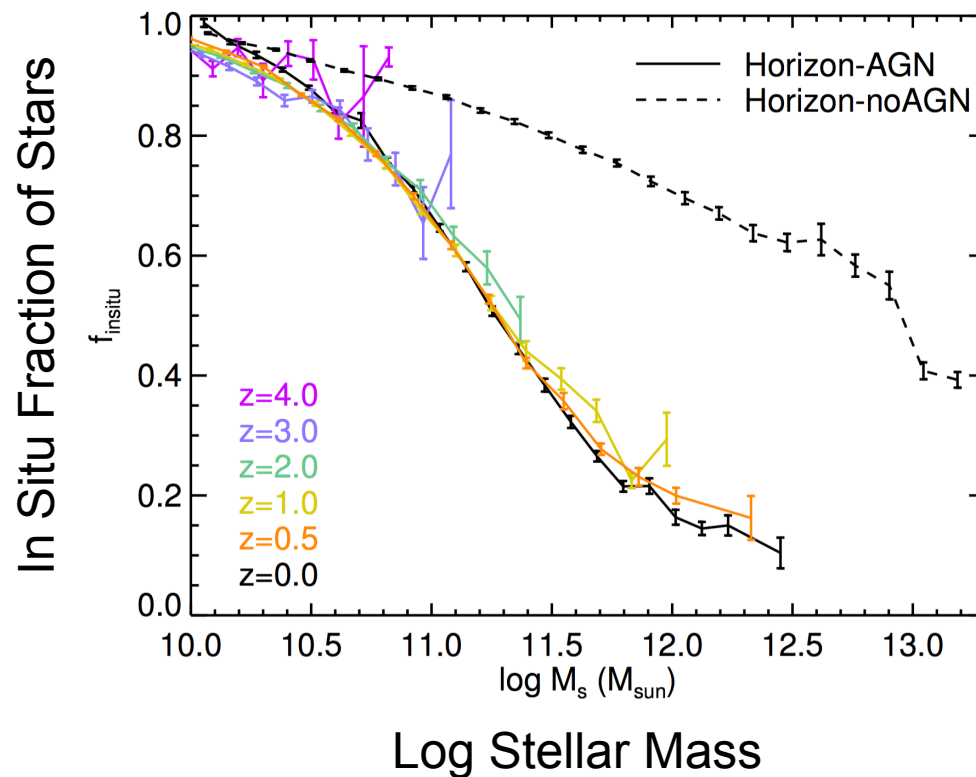
Fraction of Ellipticals

Elliptical galaxy if $V_{\text{rot}}/\sigma < 1$



Dubois et al, 2016

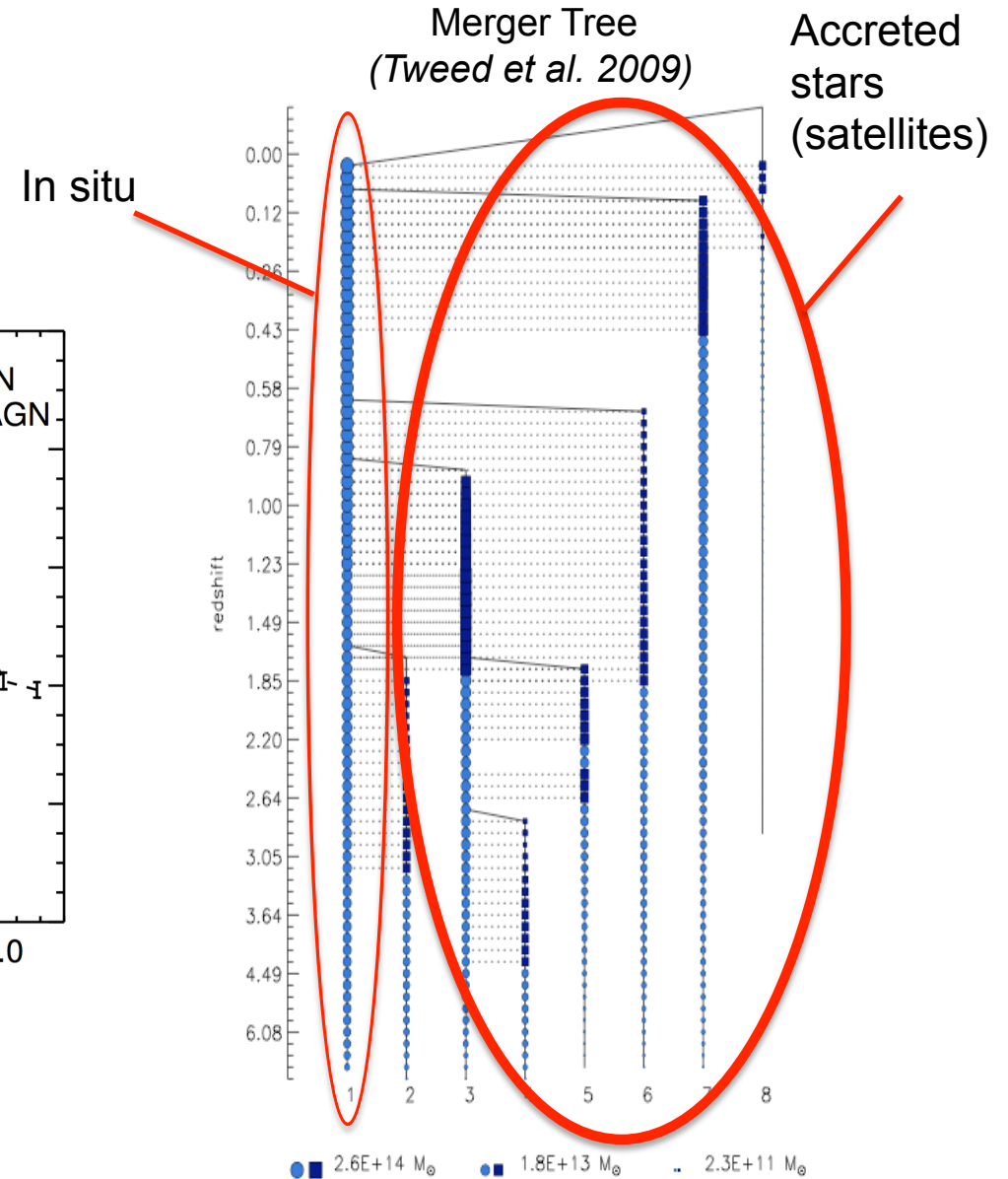
The origin of the stars



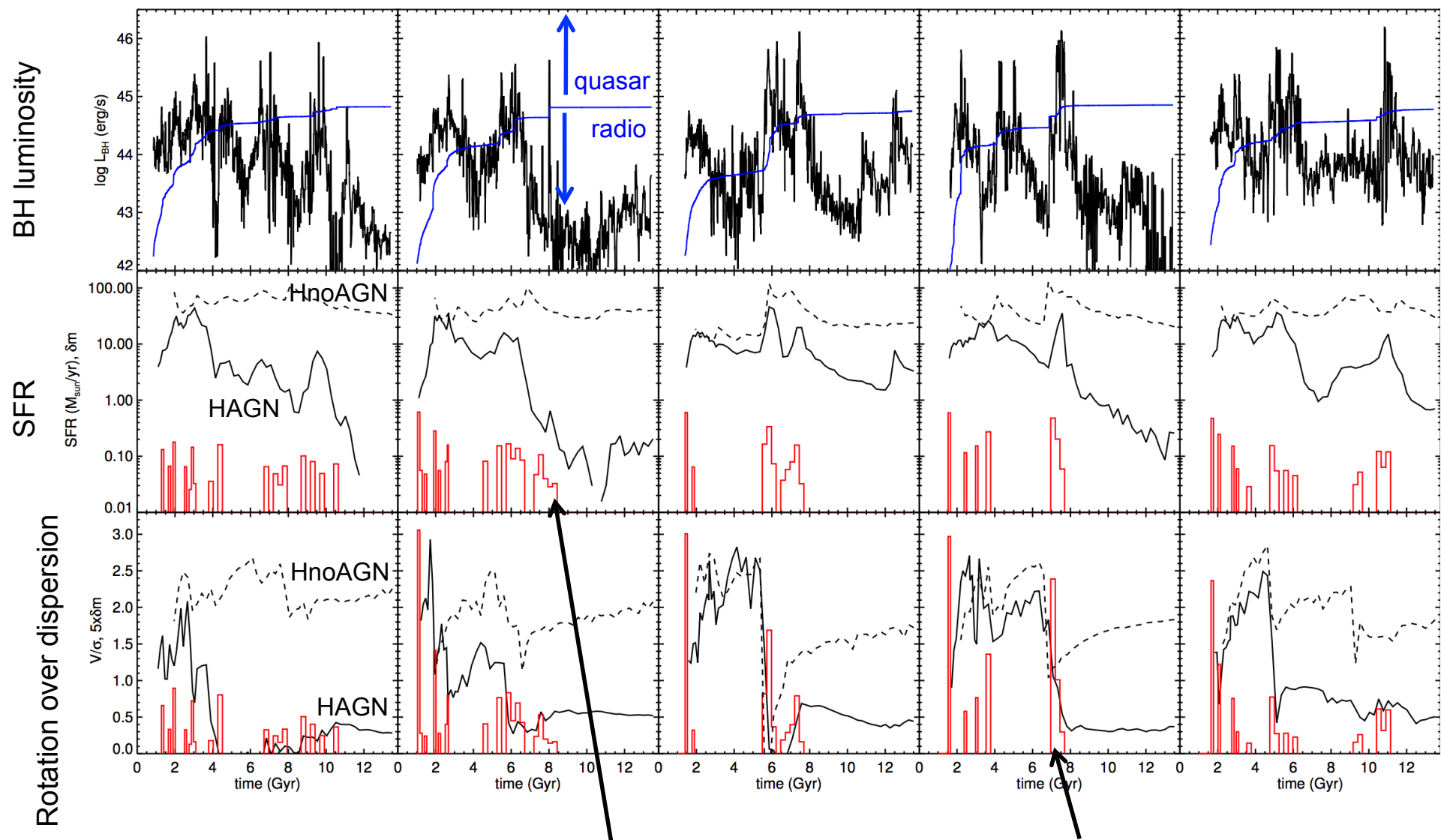
Dubois et al, 2016

See also Dubois, Gavazzi, Peirani, Silk, 2013

Lee & Yi, 2013 (SAM)



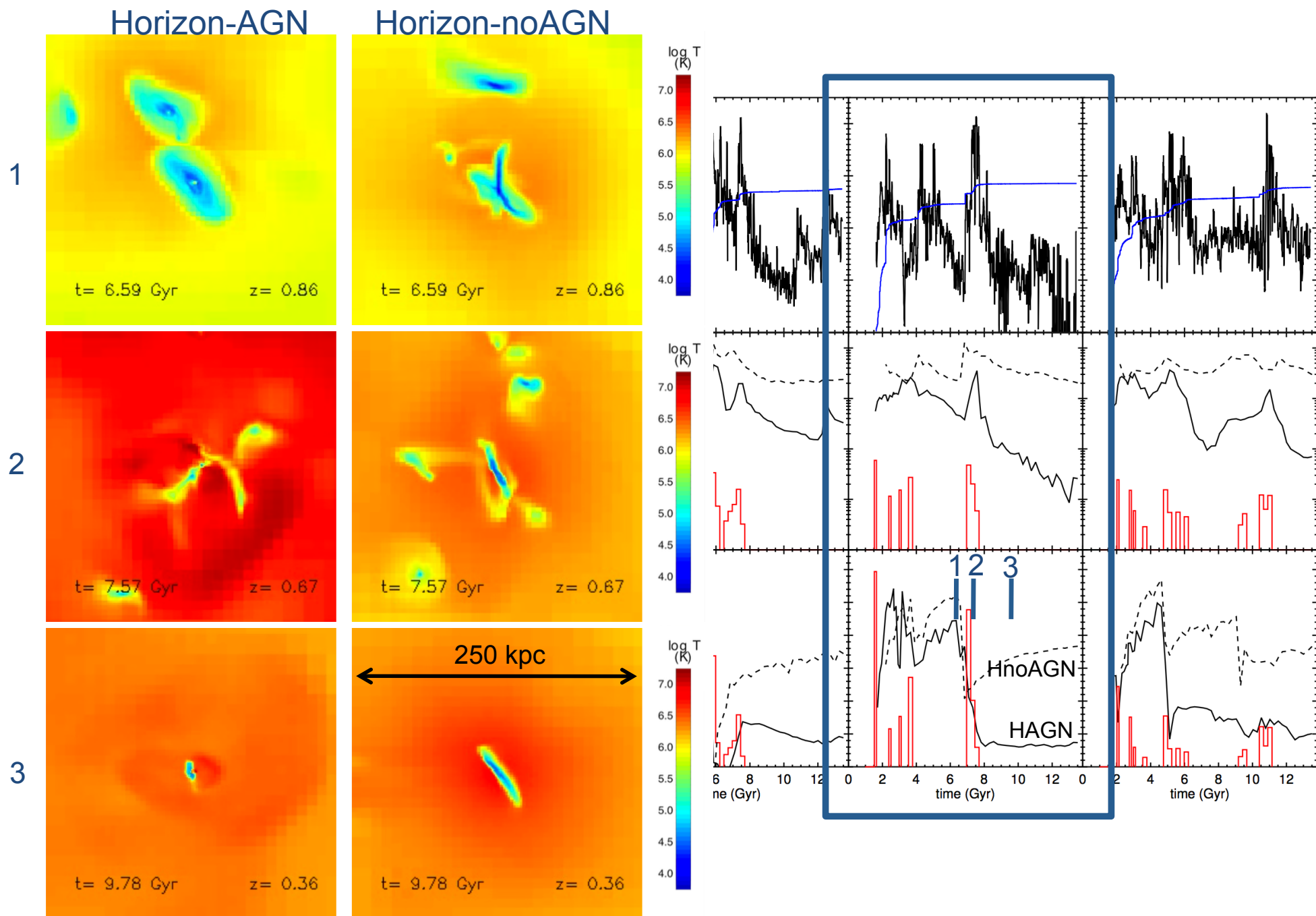
A few examples of $2 \times 10^{11} M_{\text{sun}}$ galaxies

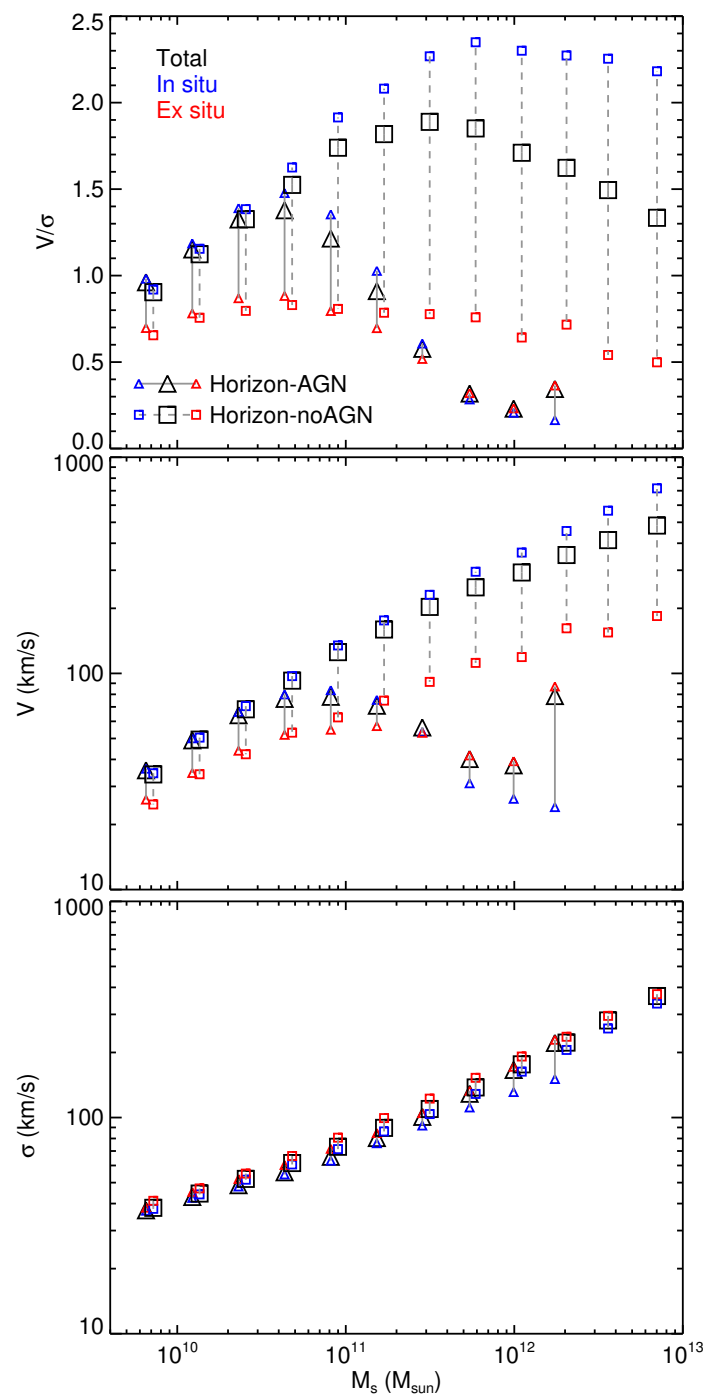
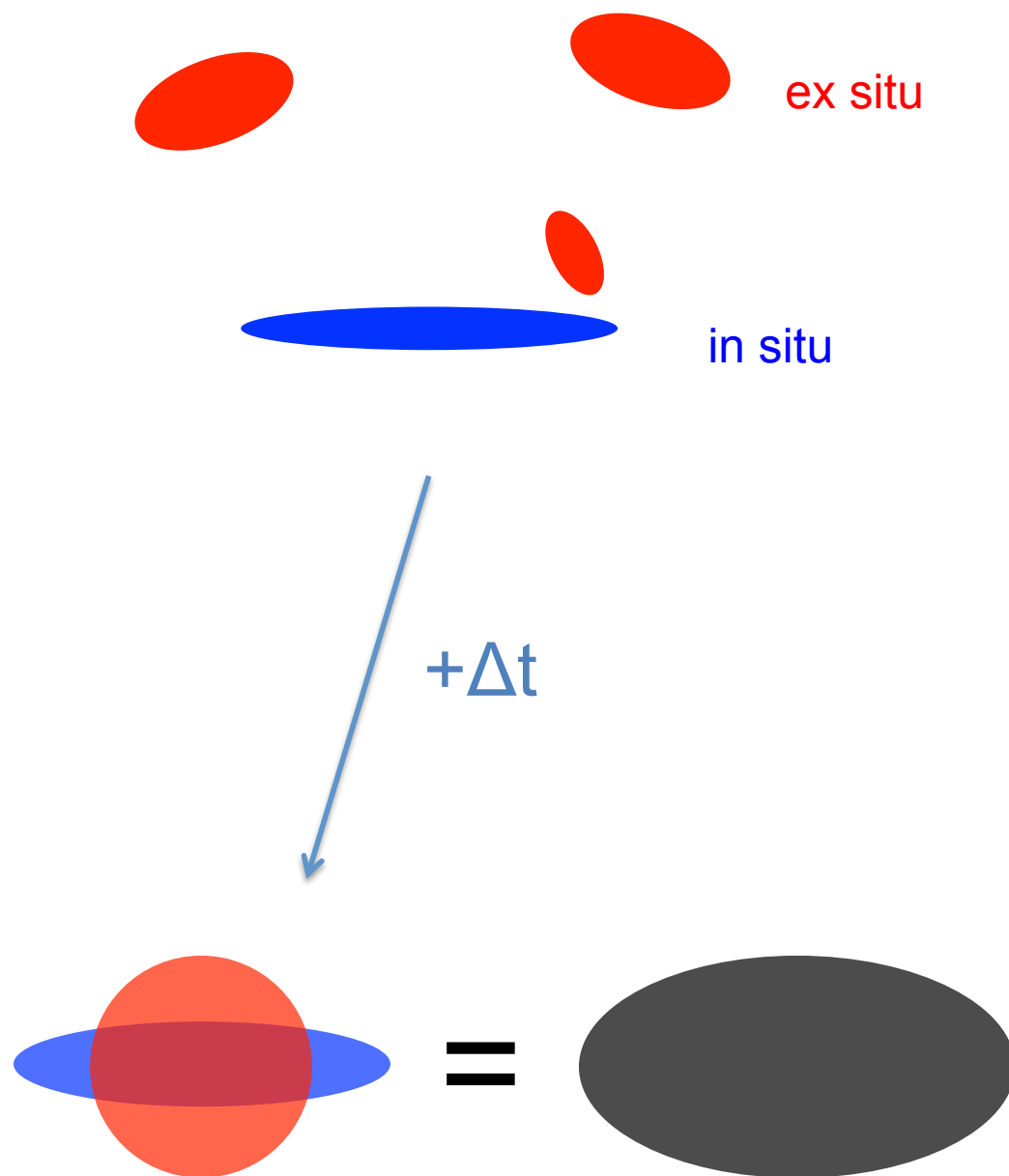


Merger Mass Ratio

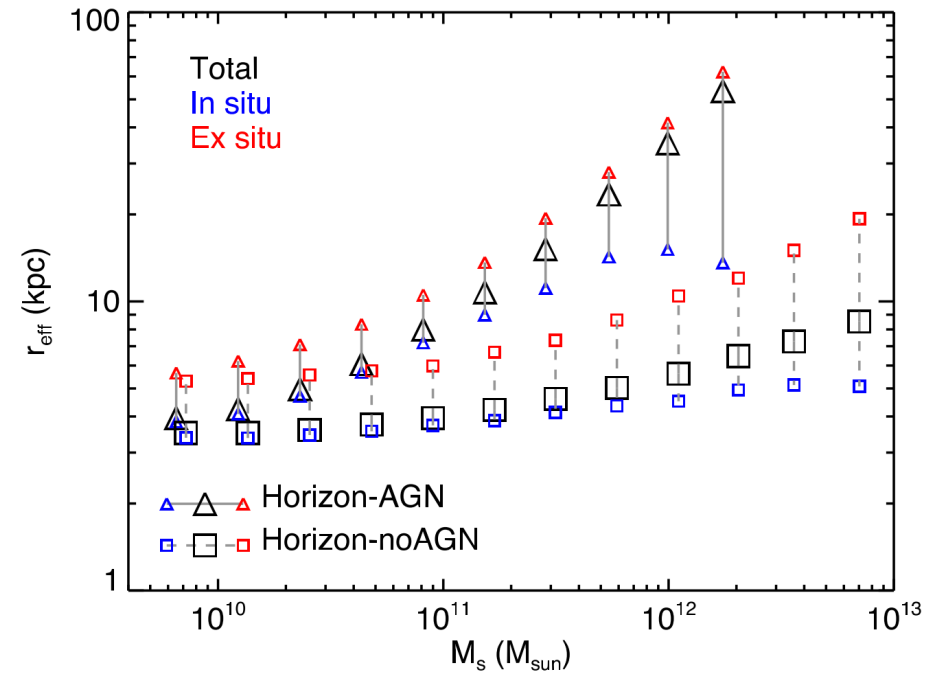
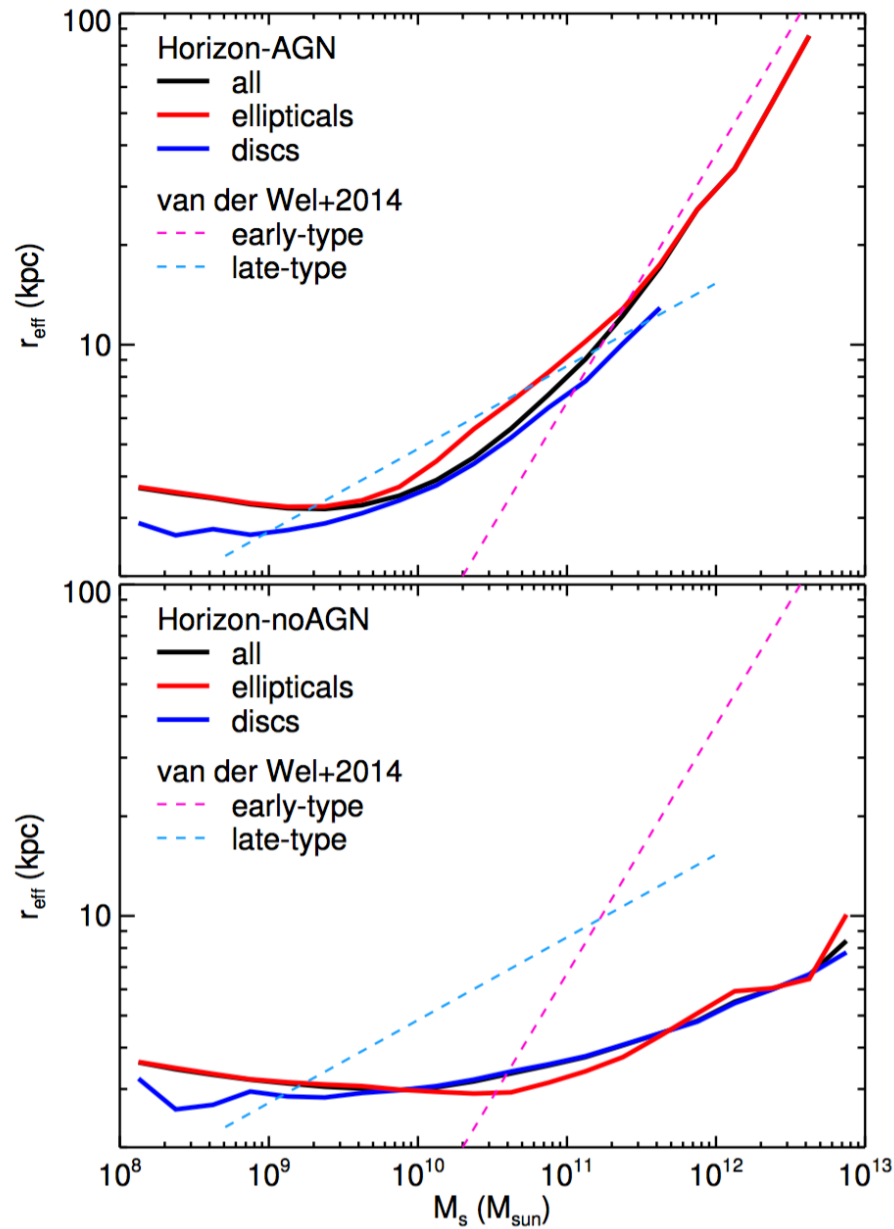
Merger Mass Ratio x5

A few examples of $2 \times 10^{11} M_{\text{sun}}$ galaxies

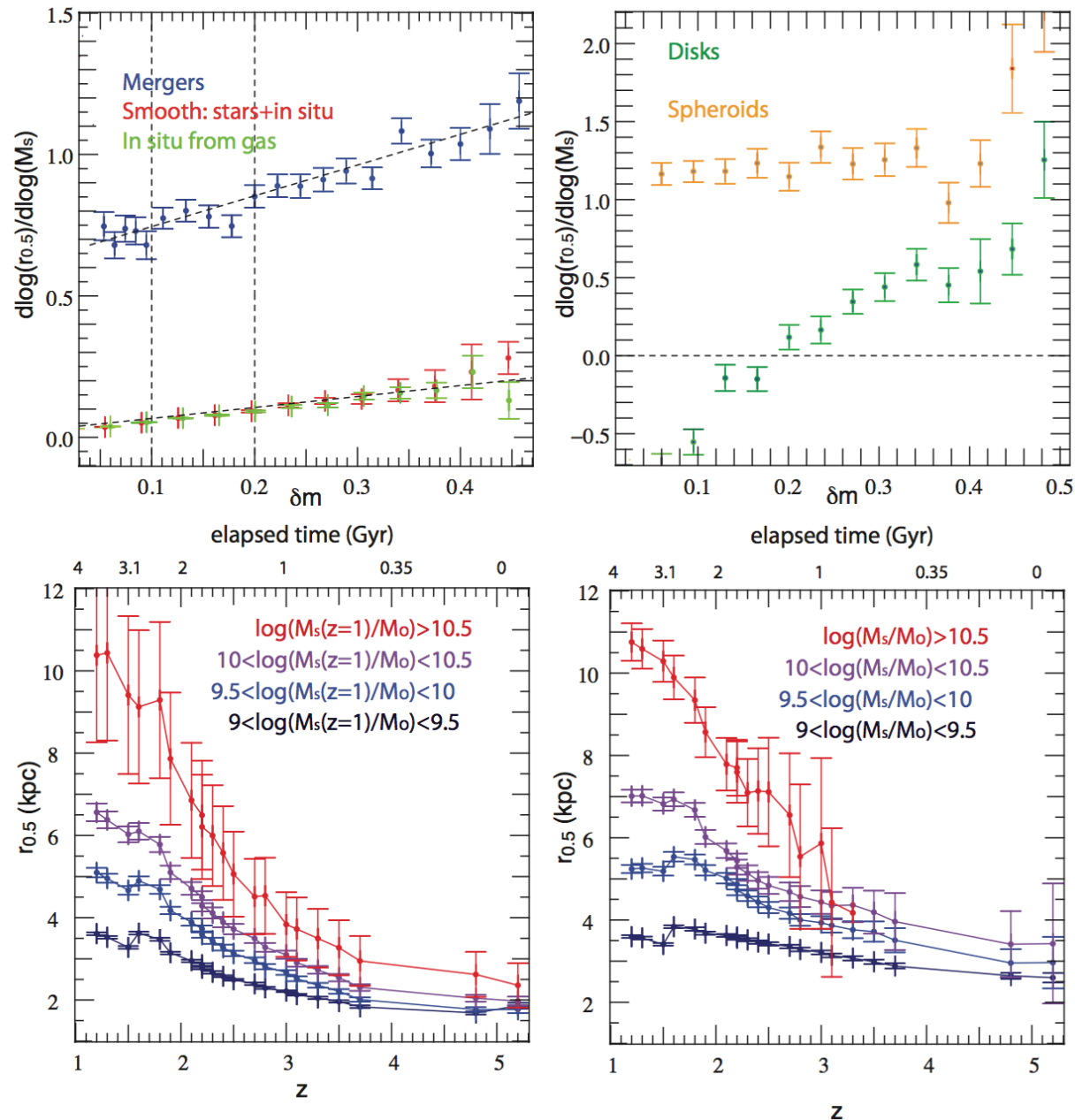




Size-Mass relation

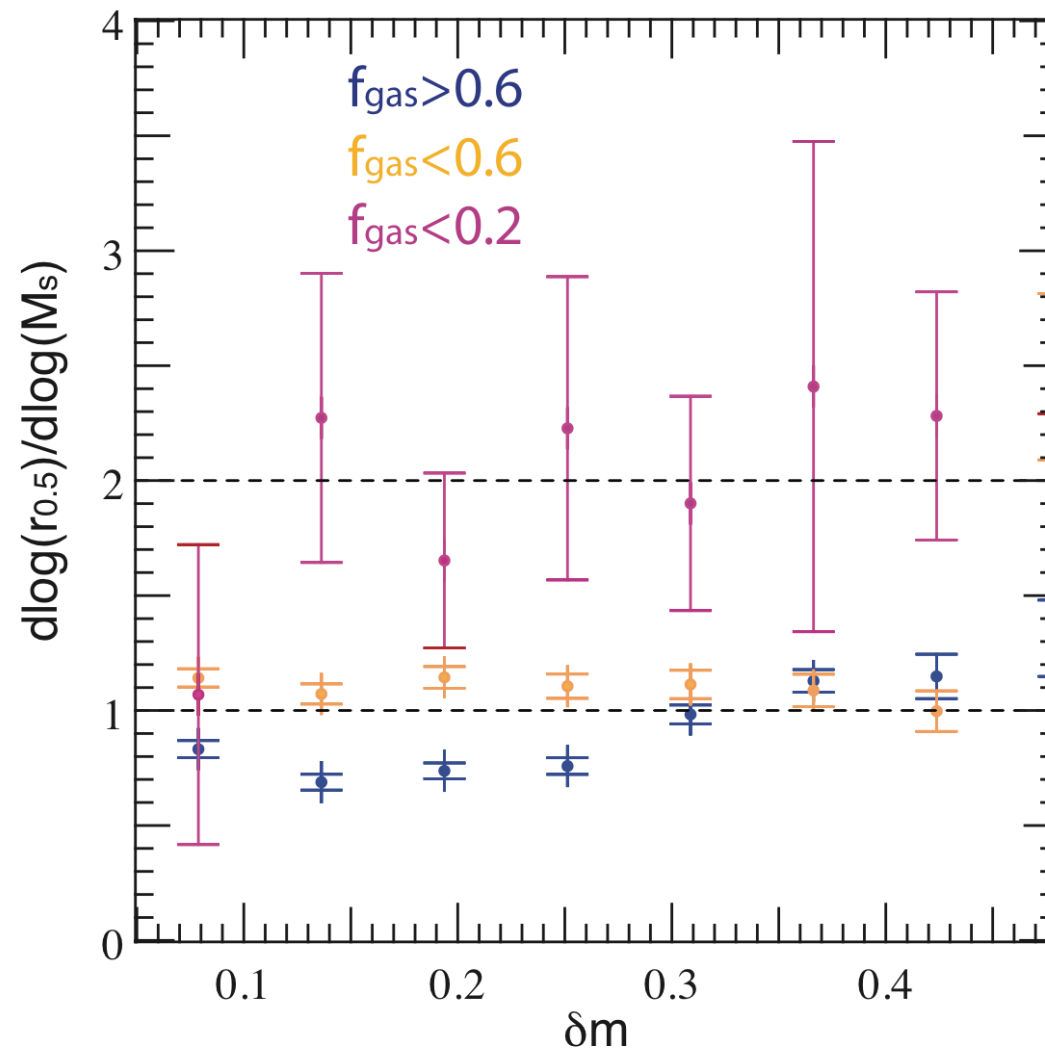


Galaxies increasing size



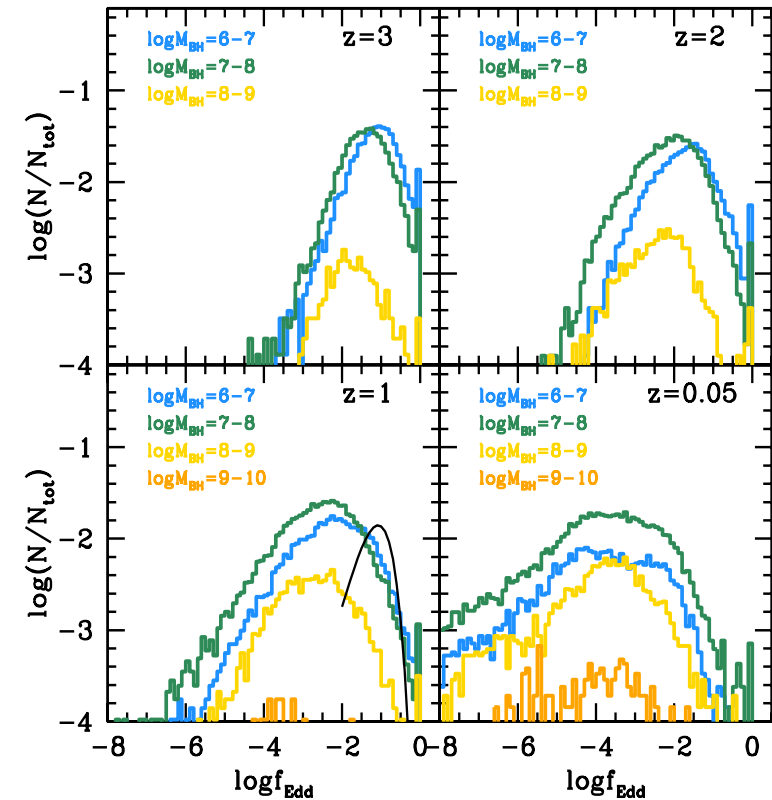
Welker et al, 2016

Dry mergers increase the galaxy size faster than wet mergers

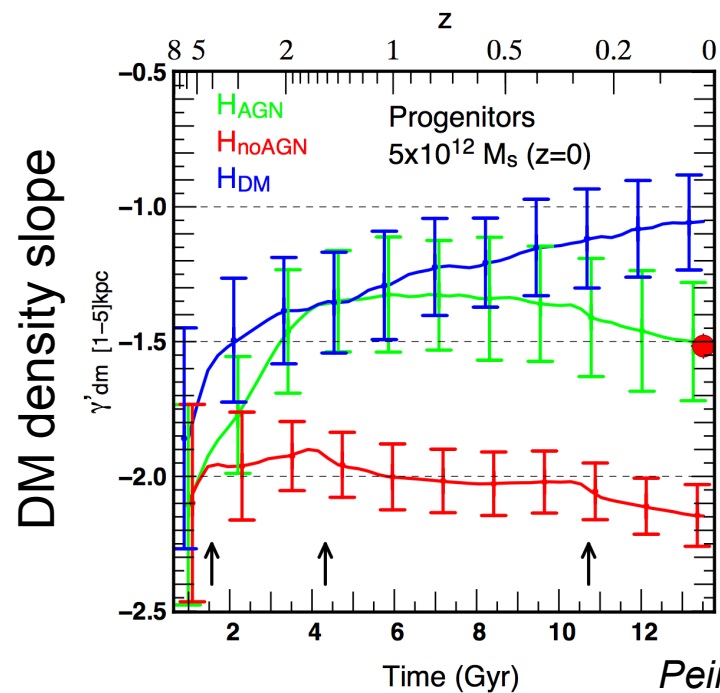
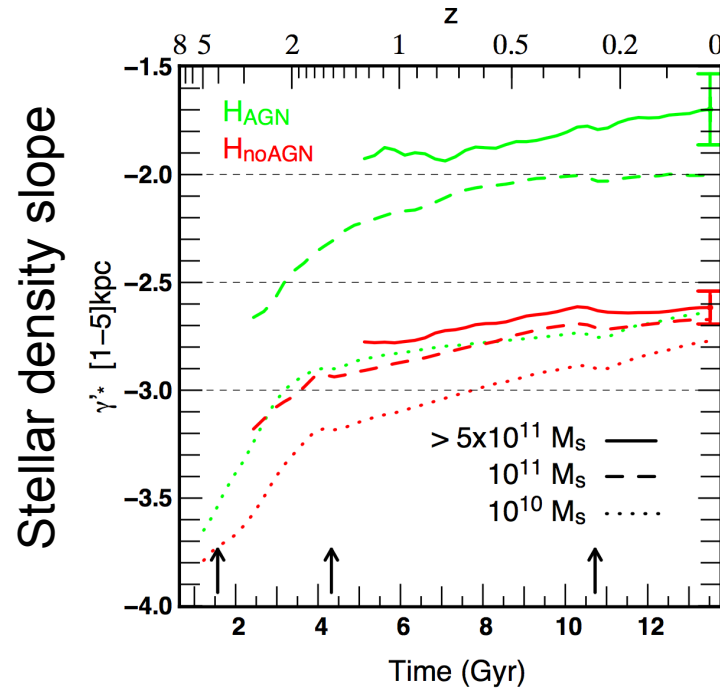


Flattening of density profiles by AGN heating

Volonteri et al., 2016



$$f_{\text{Edd}} = \frac{\dot{M}_{\text{BH}}}{\dot{M}_{\text{Edd}}}$$



Peirani et al, sub.
Peirani, Kay, Silk, 2008

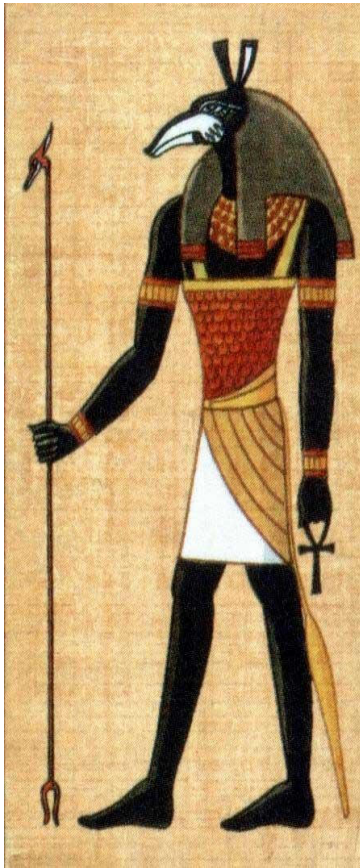
Morphological transformations and AGN feedback

1) What SMBHs do for morphology

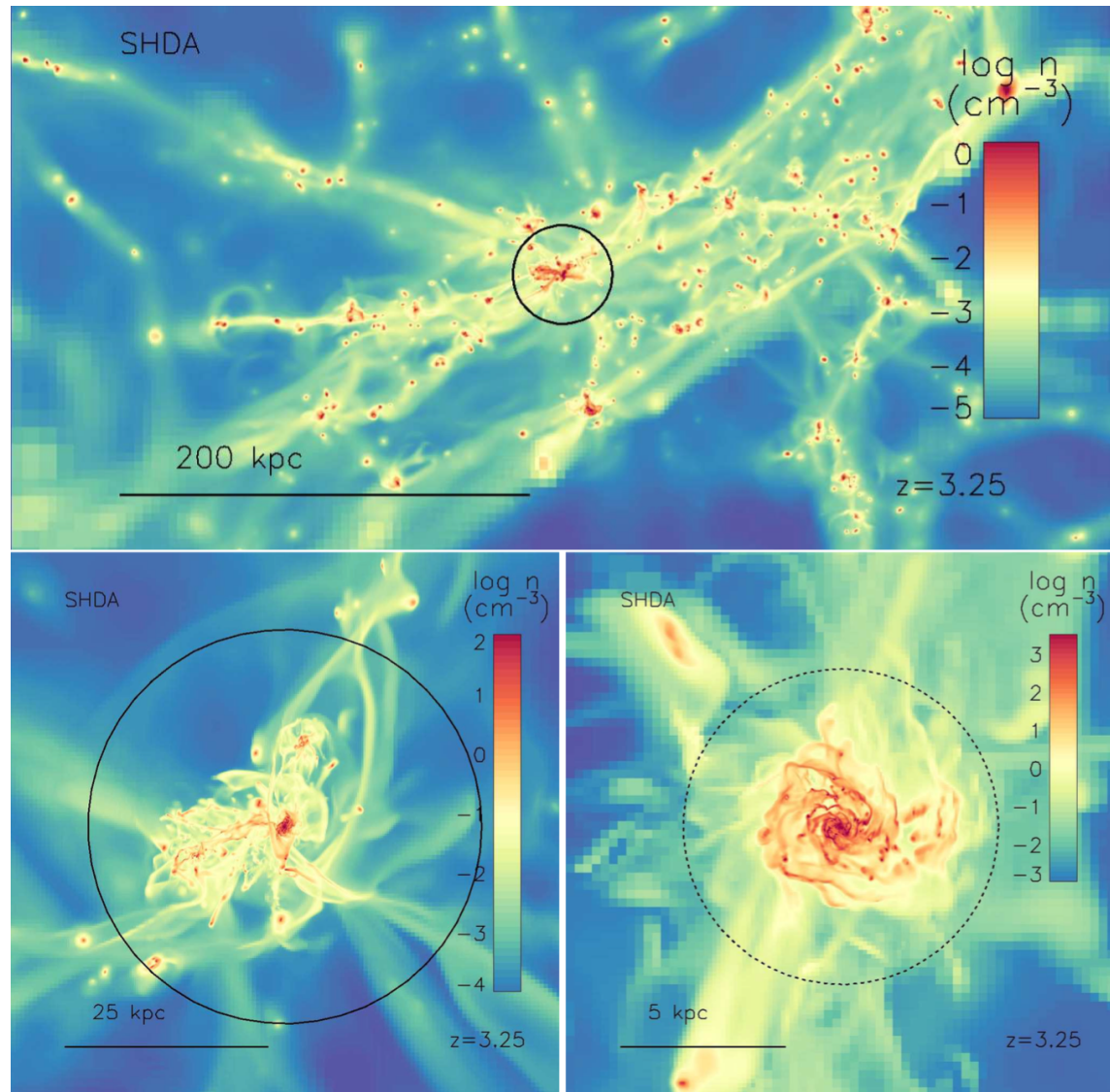
2) What morphology (and SN feedback)
does for SMBHs

Seth simulation

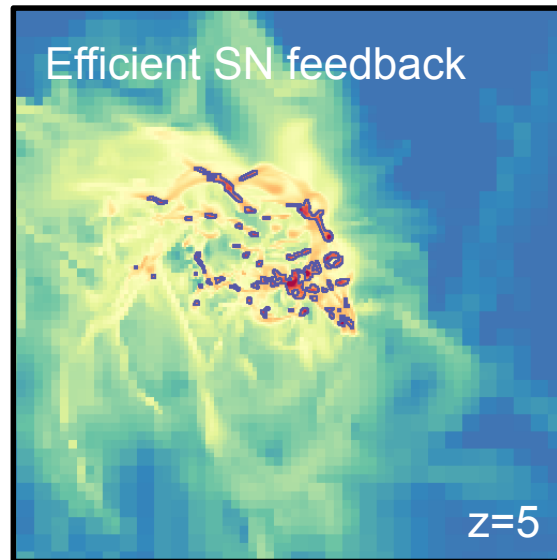
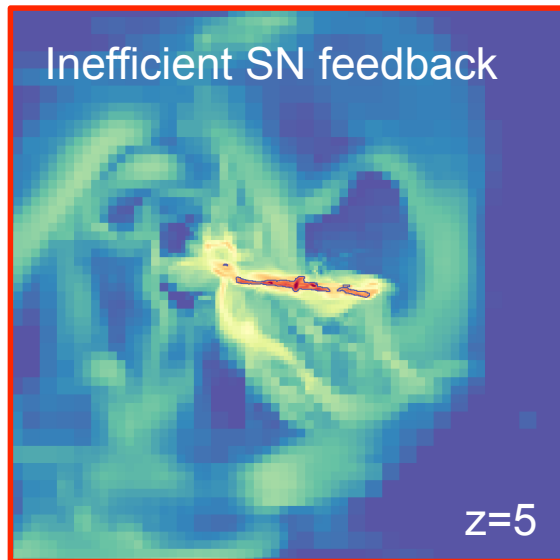
$$M_h = 10^{12} M_{\text{sun}} @ z=2$$
$$M_{\text{DM,res}} = 10^5 M_{\text{sun}}$$
$$dx = 10 \text{ pc}$$



God of death, conflict, storms



BH growth delayed by efficient SN feedback



Bondi-capped-at-Eddington accretion rate

- AGN quasar heating $f_{\text{Edd}} > 0.01$

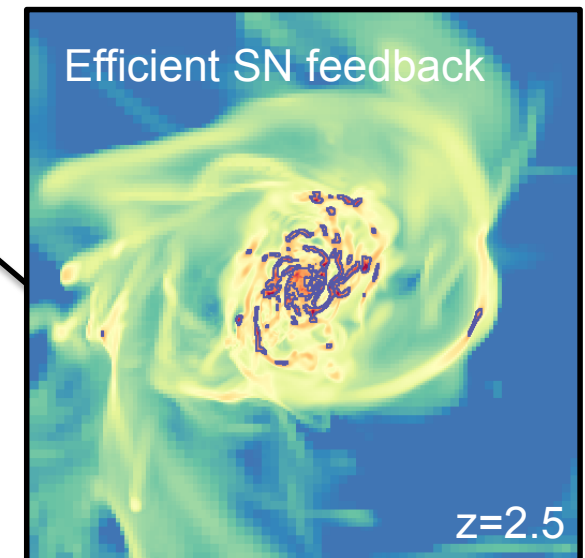
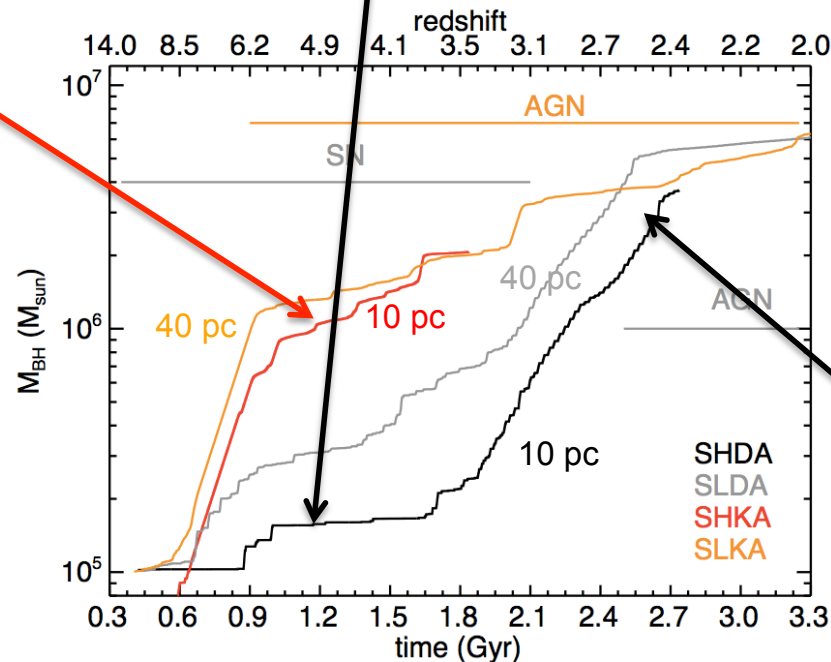
- AGN radio jets $f_{\text{Edd}} < 0.01$

(Dubois et al, 2012)

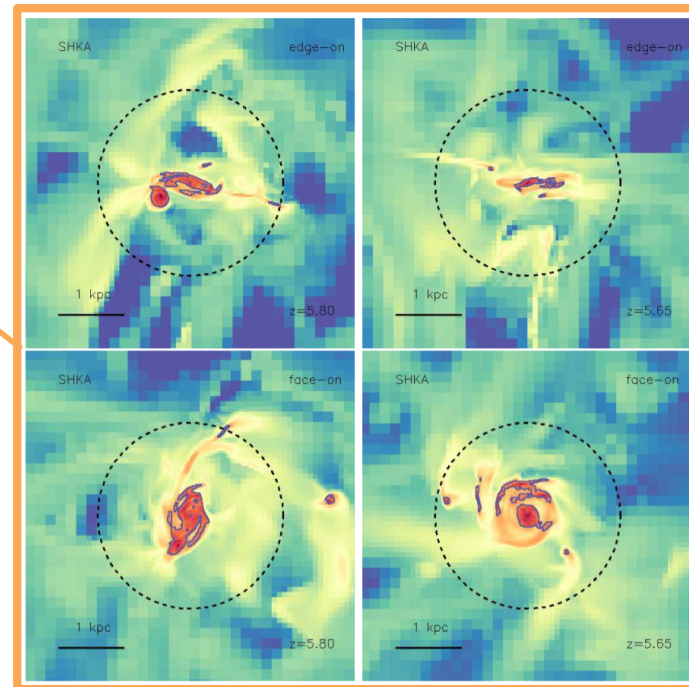
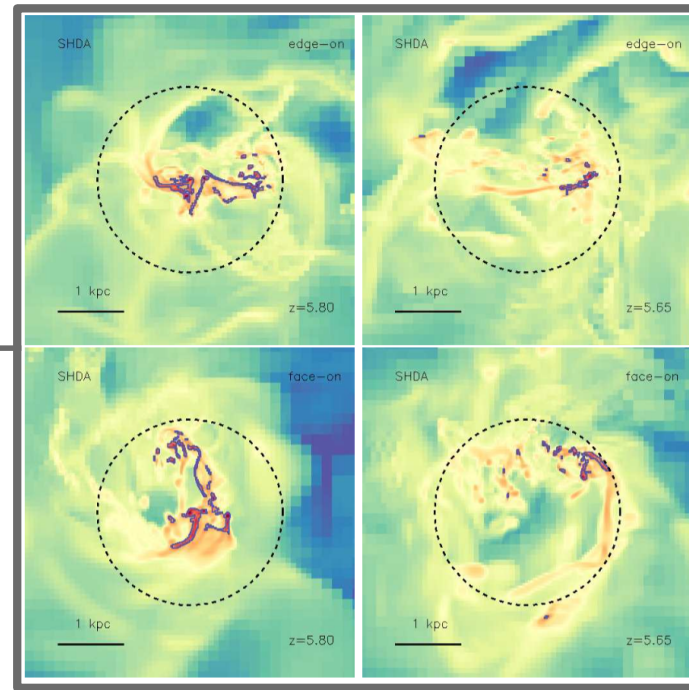
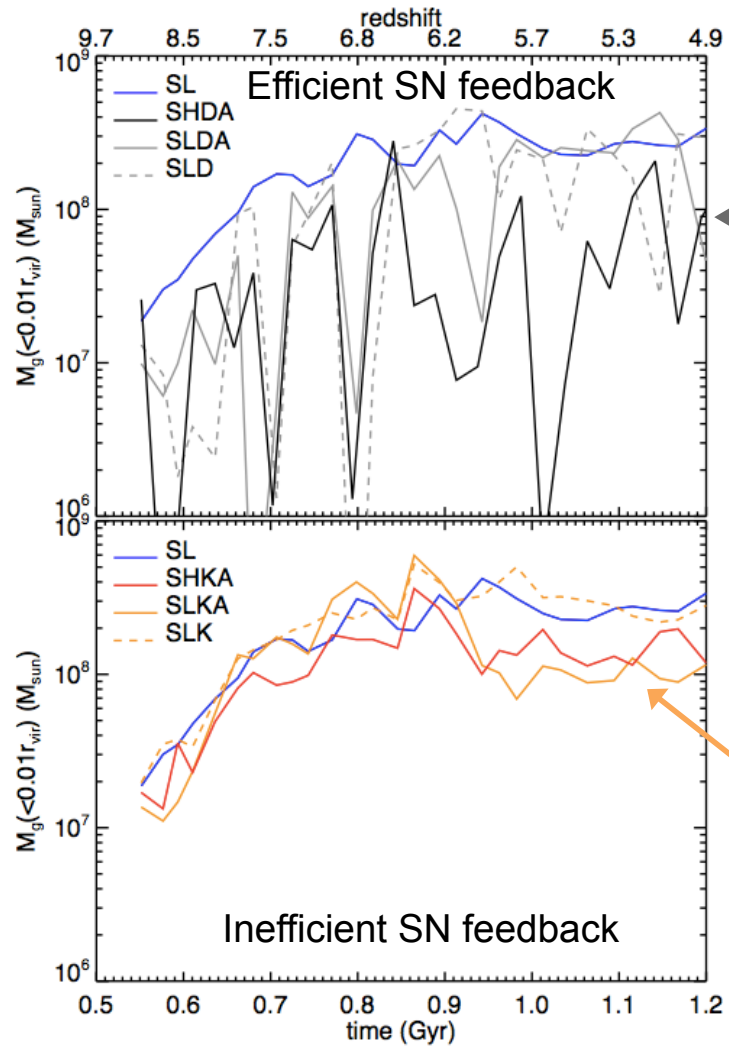
& BH spin evolution with spin-dependent radiative efficiency (and Eddington accretion rate)
(Dubois et al, 2014)

“Inefficient”: kinetic blast wave model
(Dubois & Teyssier, 2008)

“Efficient”: non-thermal component (CR, turbulence, magnetic fields) that delays gas cooling
(Teyssier, Pontzen, YD, Read, 2013)

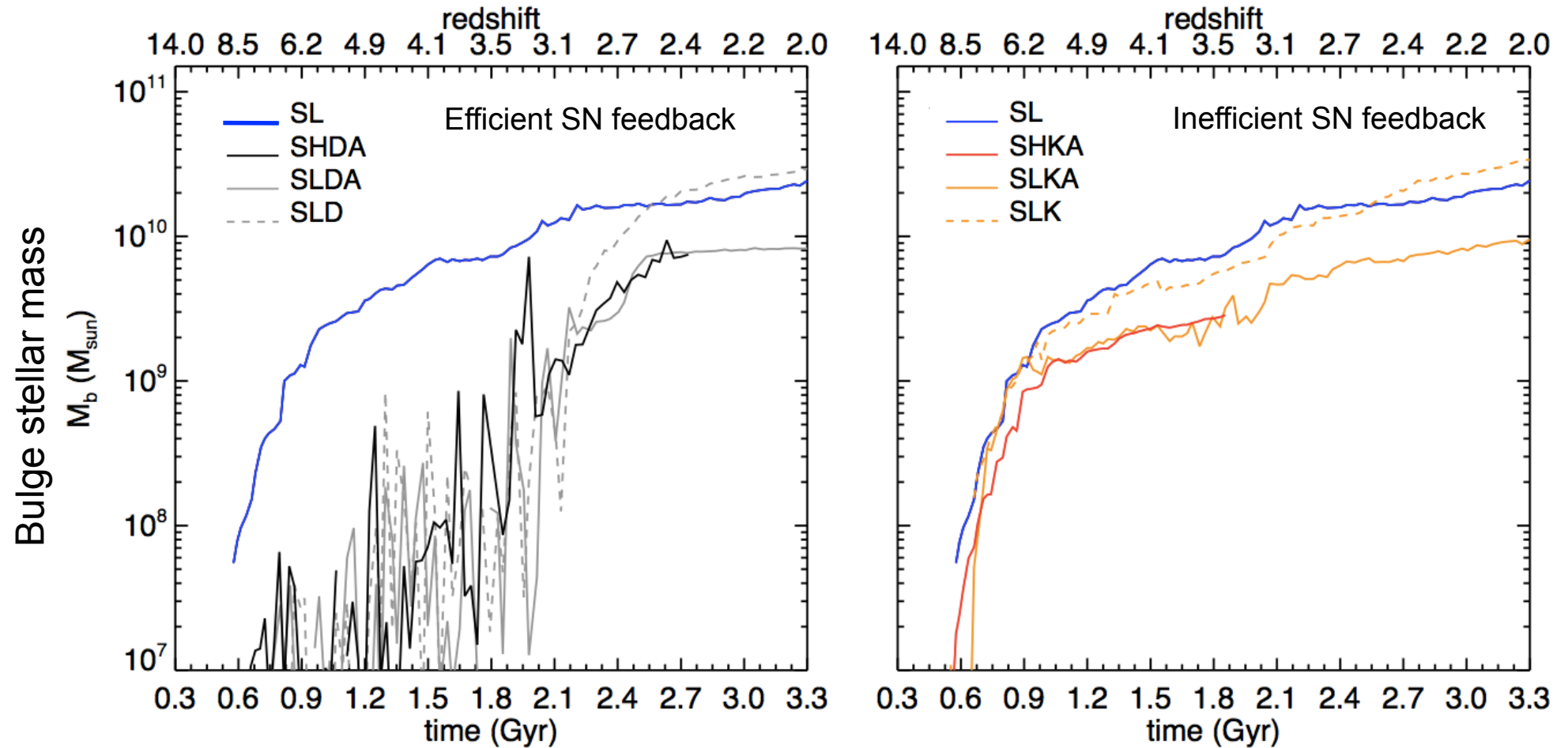


Gas mass in the bulge



Dubois, Volonteri et al, 2015

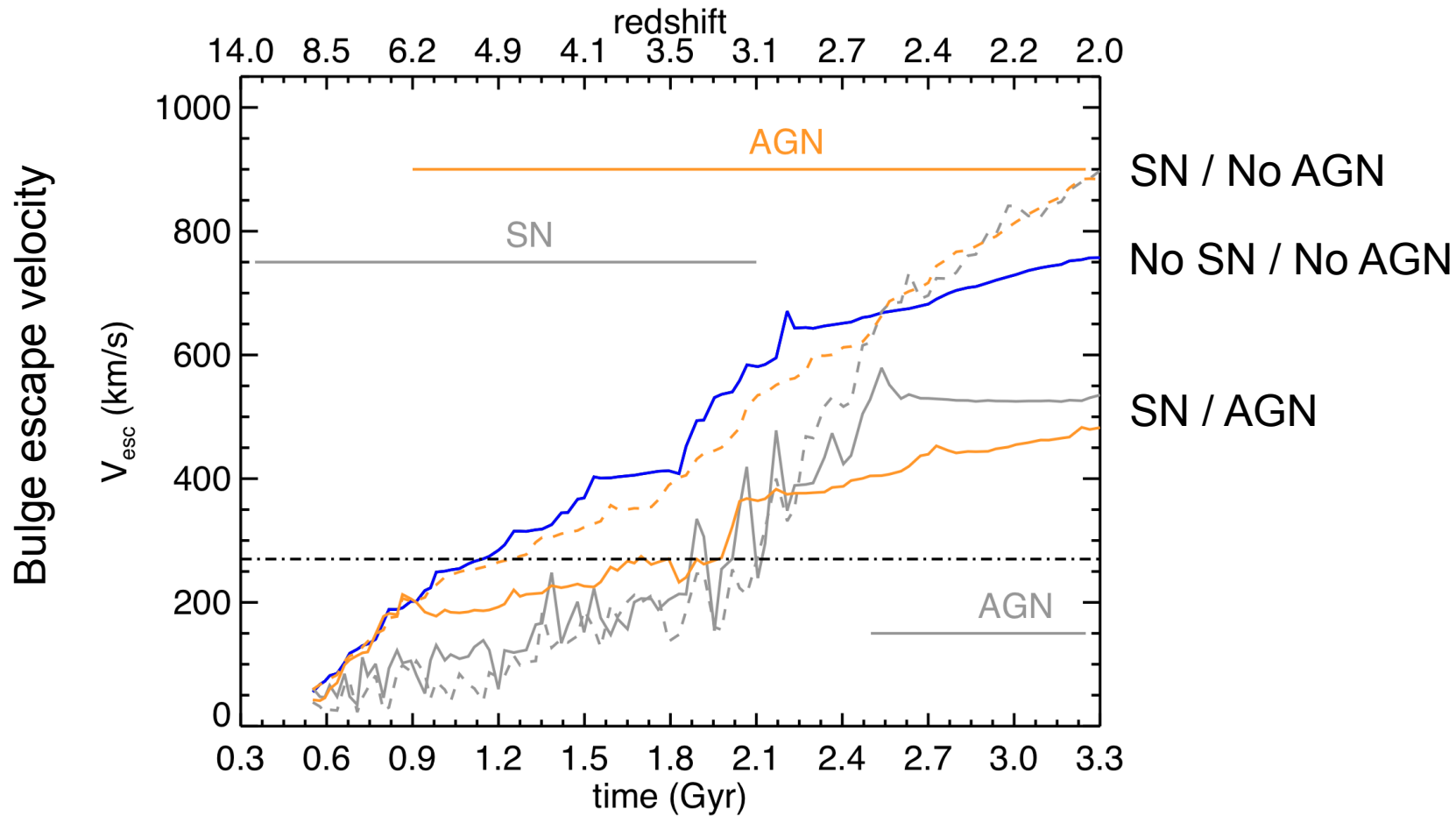
Efficient SN feedback delays bulge formation



Dubois, Volonteri et al, 2015

$$u_{\text{SN}} = 1.2 \sqrt{\frac{m_{\text{new,s}} \eta_{\text{SN}} e_{\text{SN}}}{m_{\text{g}}}} \quad u_{\text{esc}} = \sqrt{\frac{2Gm_{\text{cl}}}{r_{\text{cl}}}} \sim 300 \text{ km s}^{-1}$$

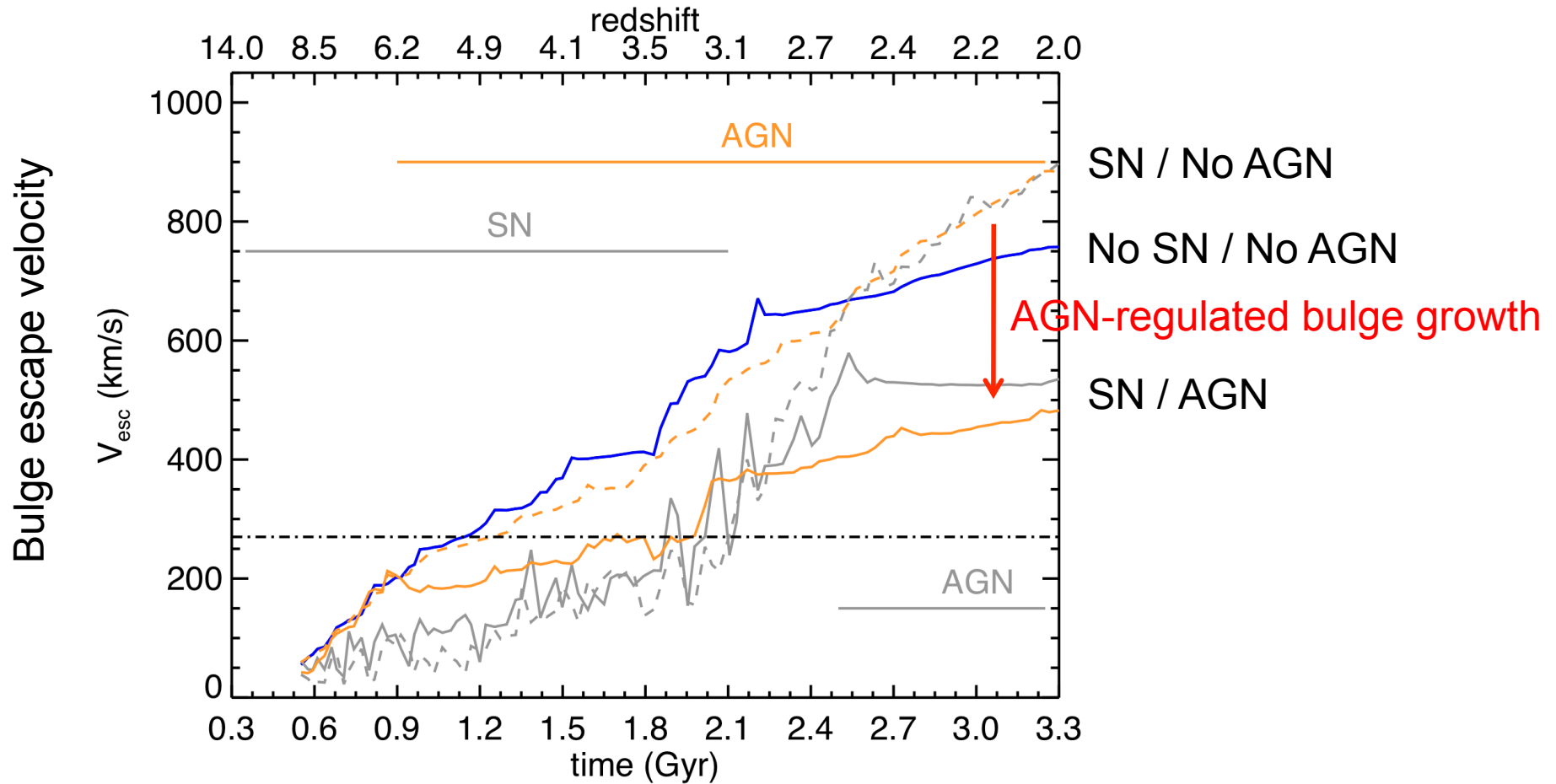
$$\simeq 270 \sqrt{\frac{\eta_{\text{SN}}}{0.1}} \sqrt{\frac{(m_{\text{new,s}}/m_{\text{g}})}{0.1}} \text{ km s}^{-1} \quad \text{For } m_{\text{cl}}=10^9 M_{\text{sun}} \text{ and } r_{\text{cl}}=100 \text{ pc}$$



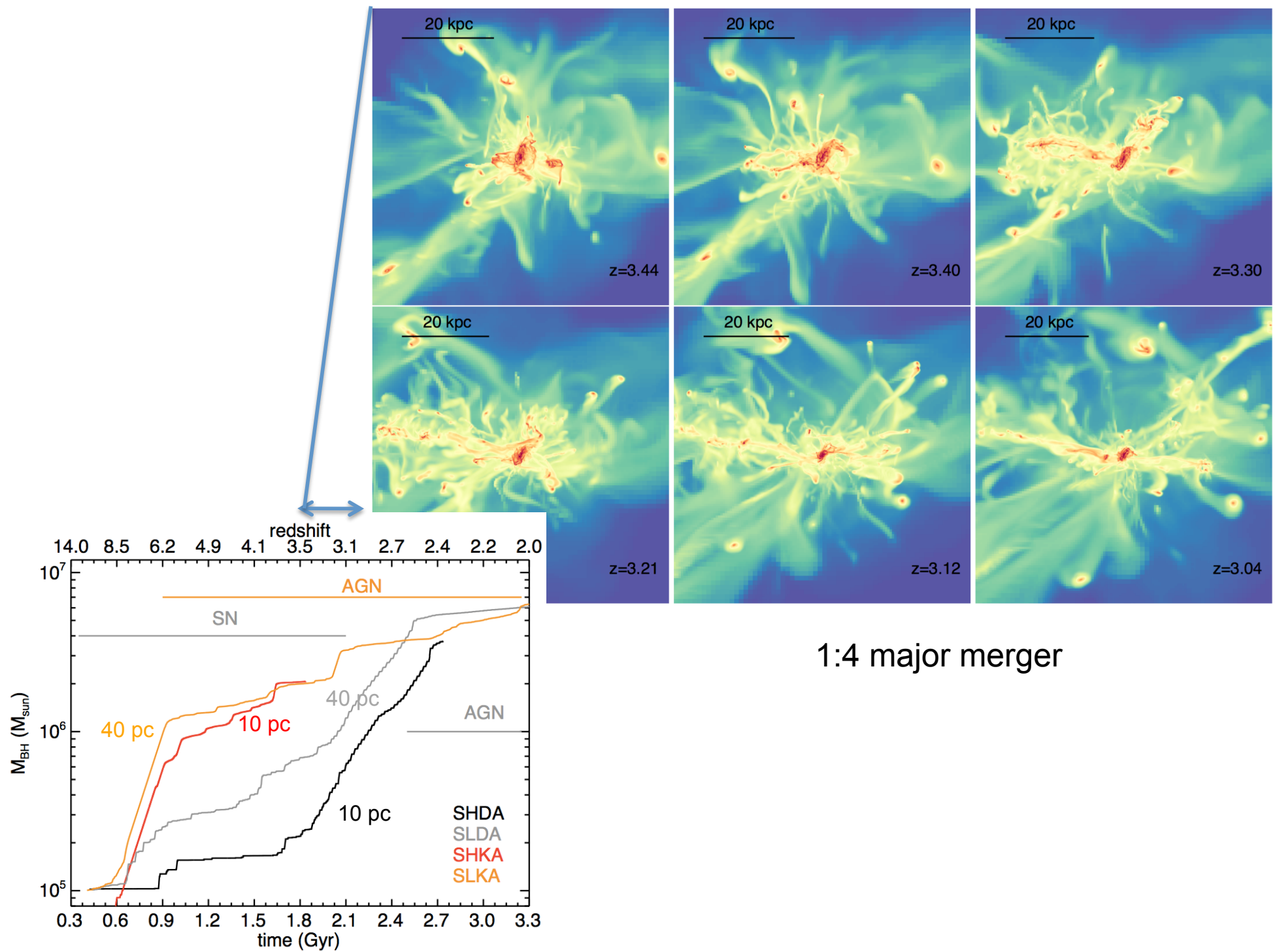
Dubois, Volonteri et al, 2015

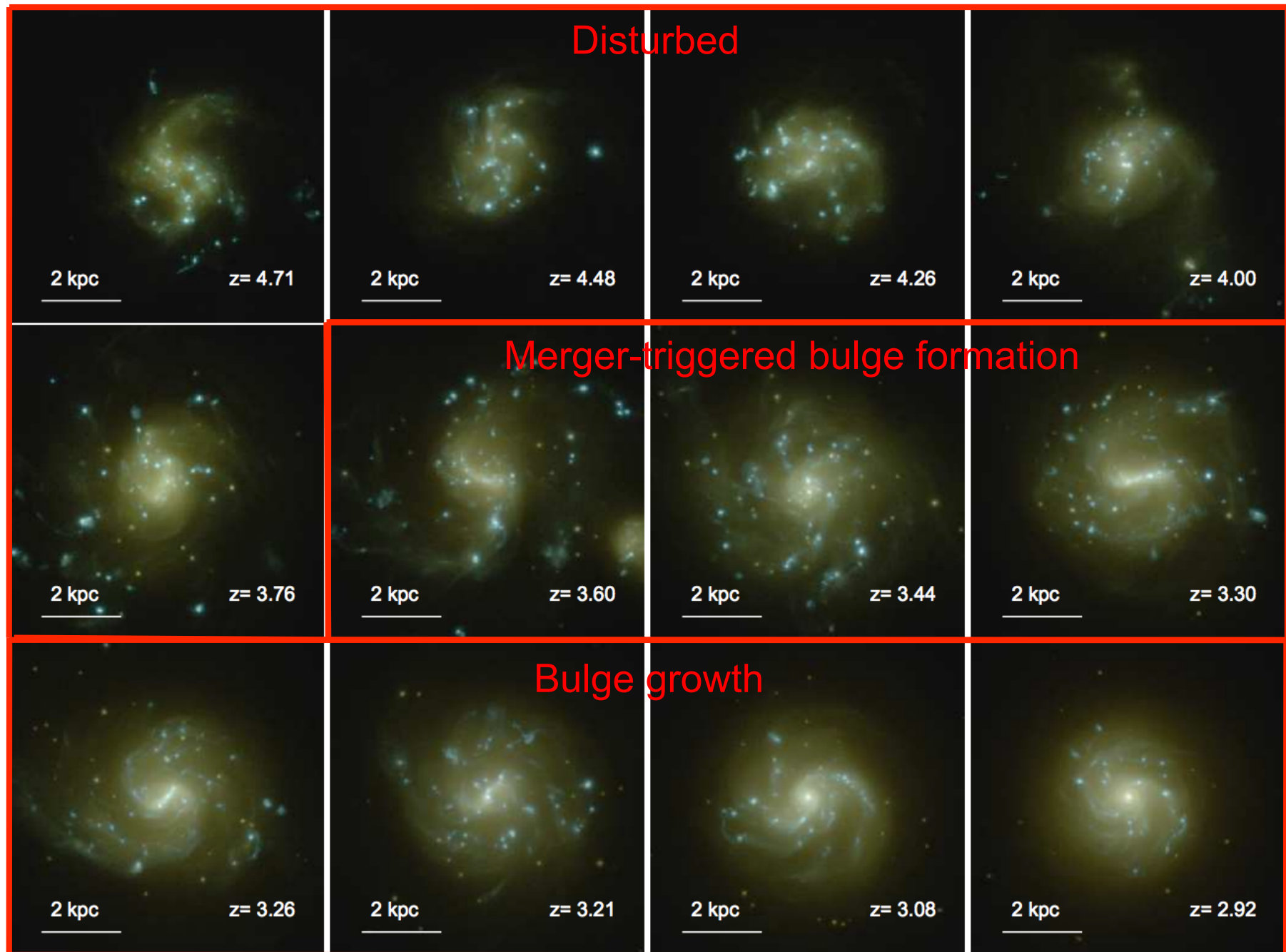
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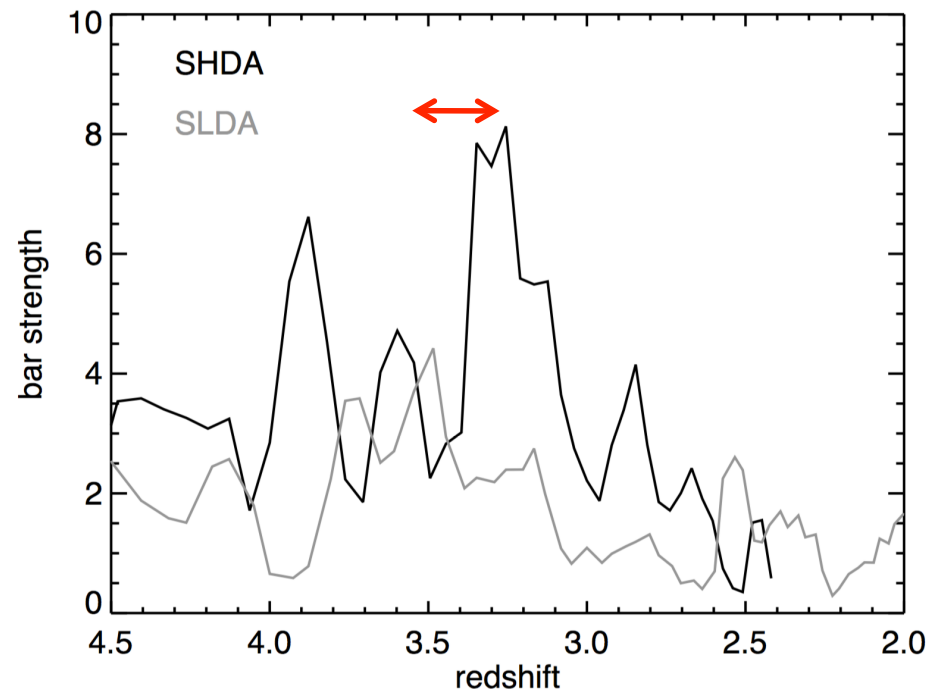
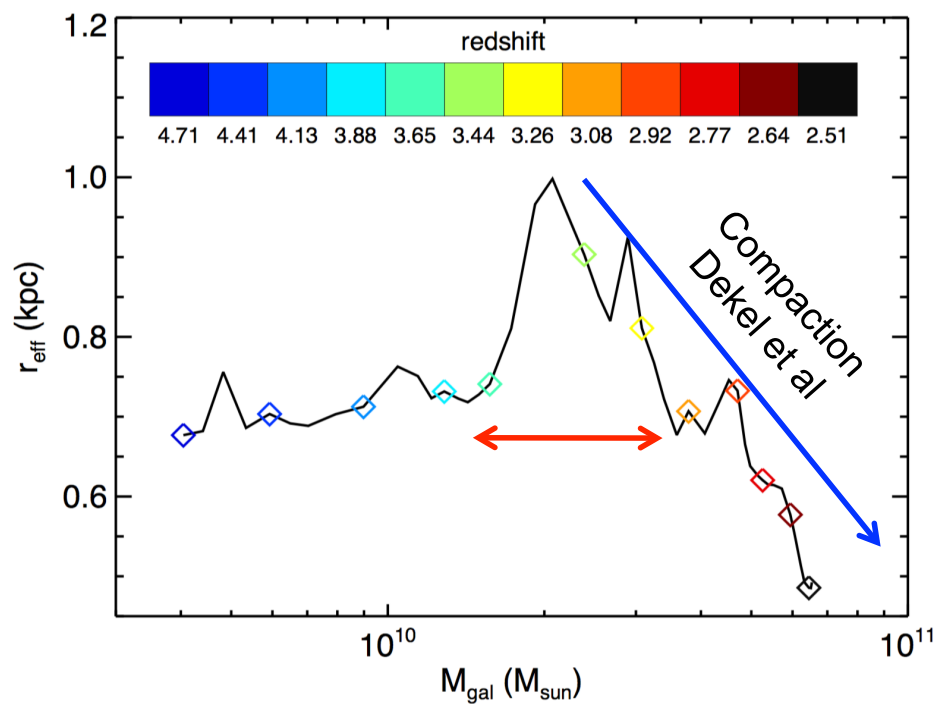
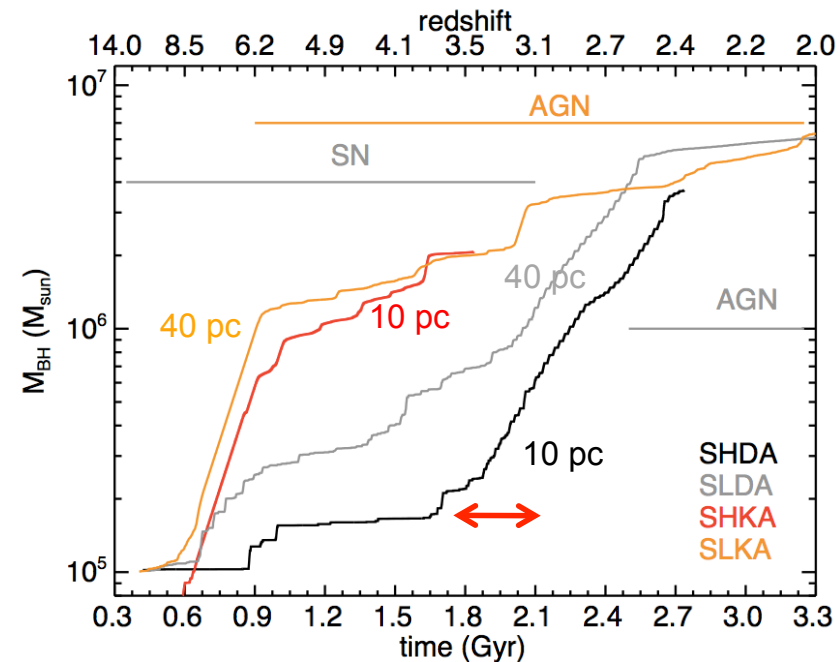
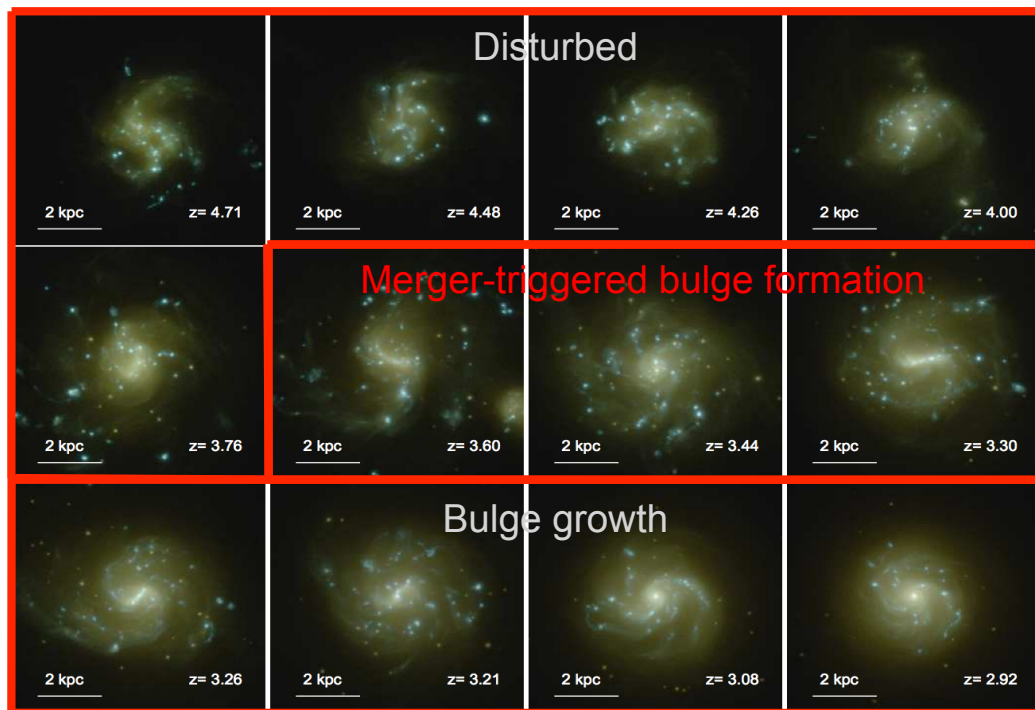
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Dubois, Volonteri et al, 2015



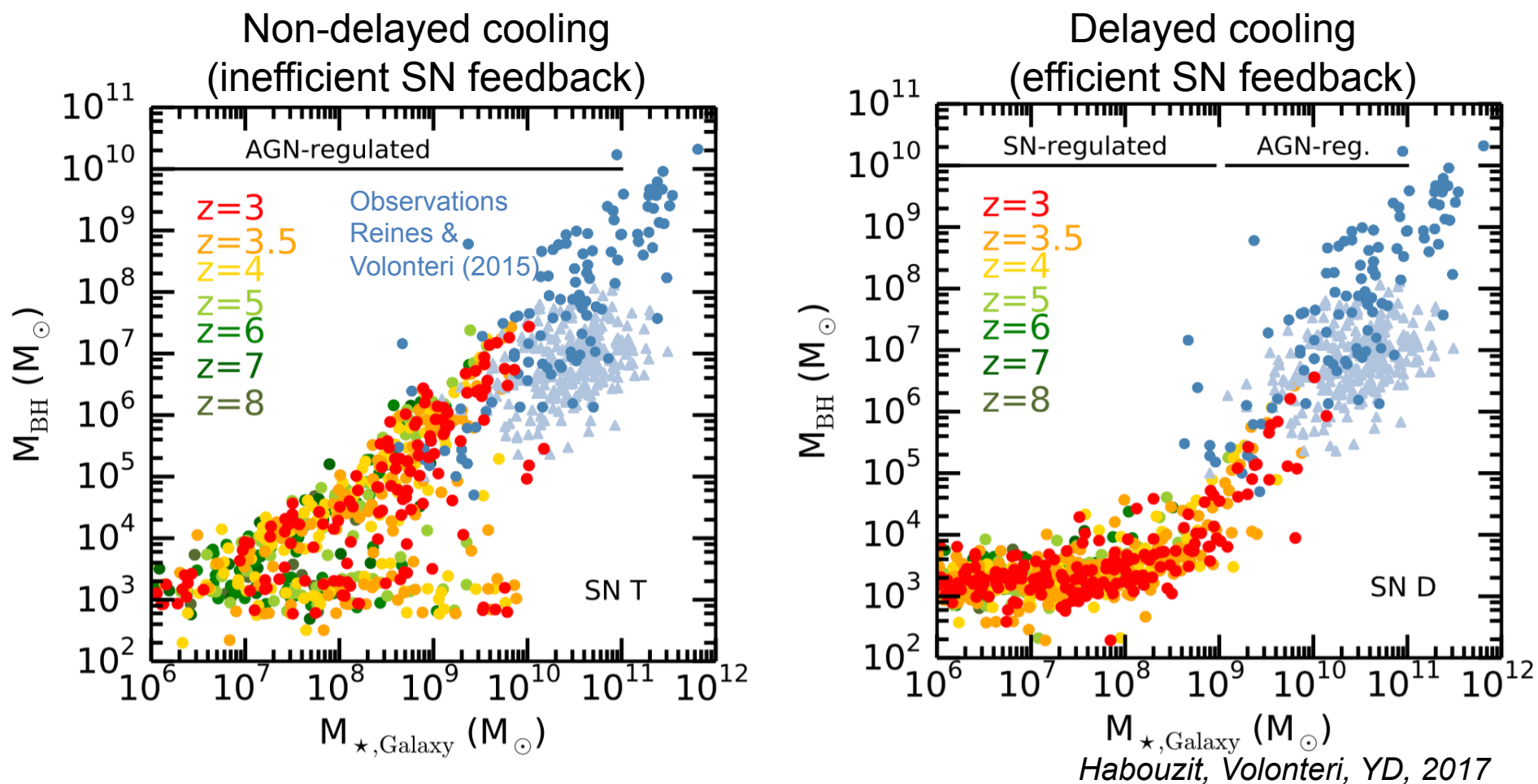




Confirmed in a statistical sense

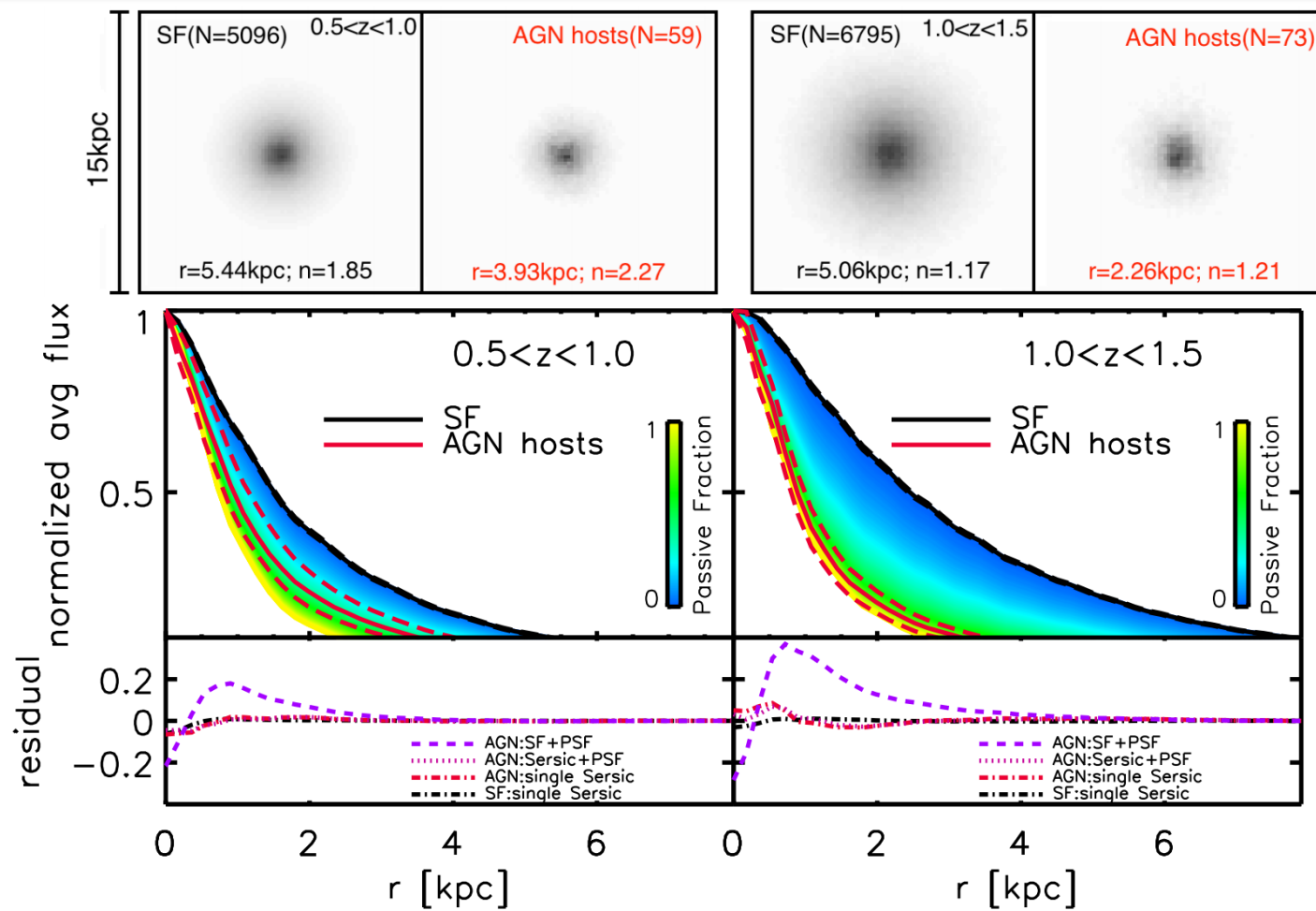
10 Mpc volume with 80 pc spatial resolution

Using pop III BH seeding



See also Park, Ricotti, et al, 2016; Bower et al, 2017; Prieto et al., 2017

AGN and compaction confirmed in COSMOS data



Chang et al, 2017

Take home message

1) What SMBHs do for morphology

- AGN feedback is a key player in shaping properties of massive galaxies: SFR, color, mass, size and morphology
- AGN feedback controls the kinematics because it prevents the rebuilding of discs after mergers that increase the ellipticity of galaxies

2) What morphology do for SMBHs

- SN feedback can delay the growth of SMBHs by destroying star forming clouds
- SMBHs fully grow once the bulge has been built, synchronised with a merger and a compaction event