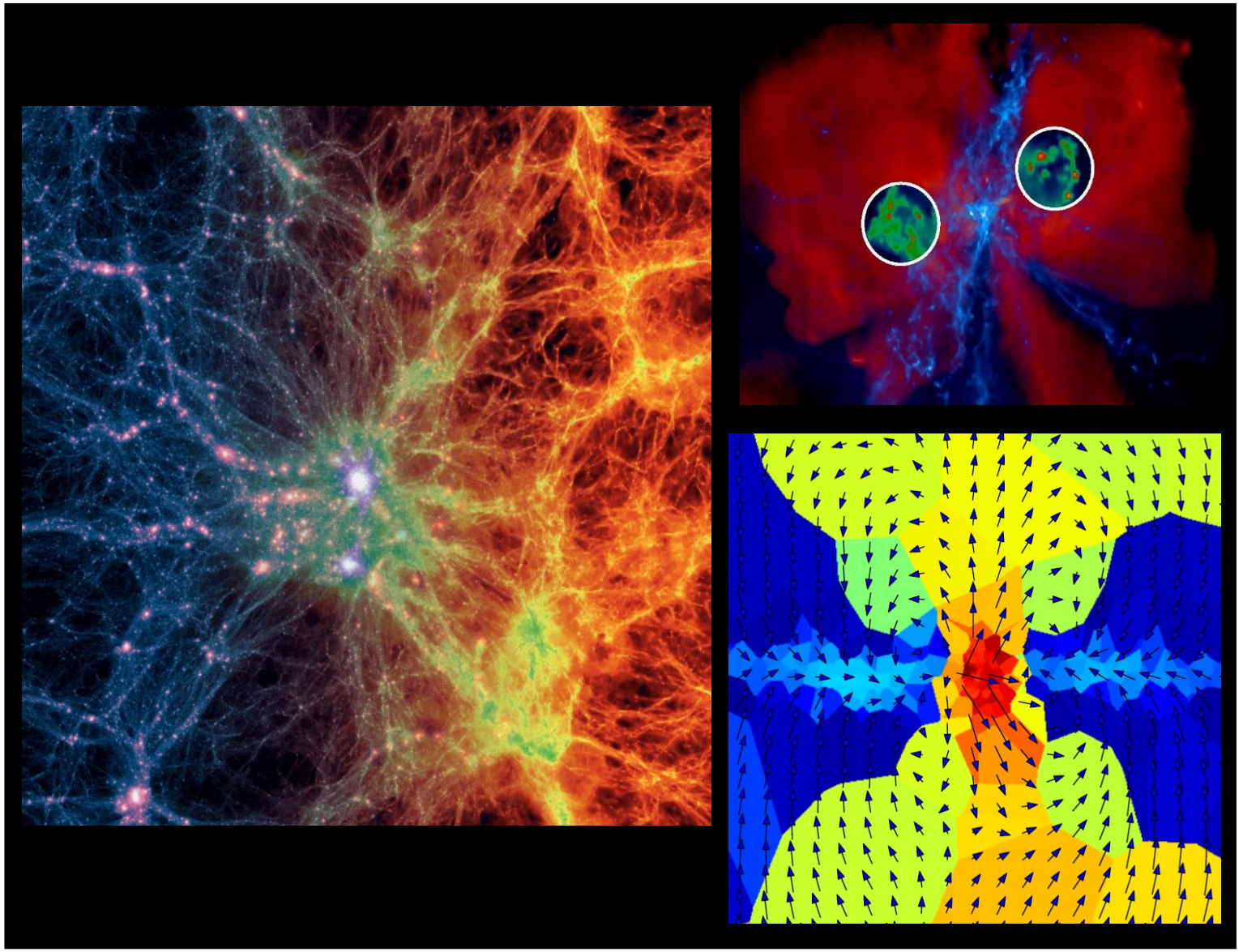
The Illustris simulation: a new look galaxy – black hole co-evolution

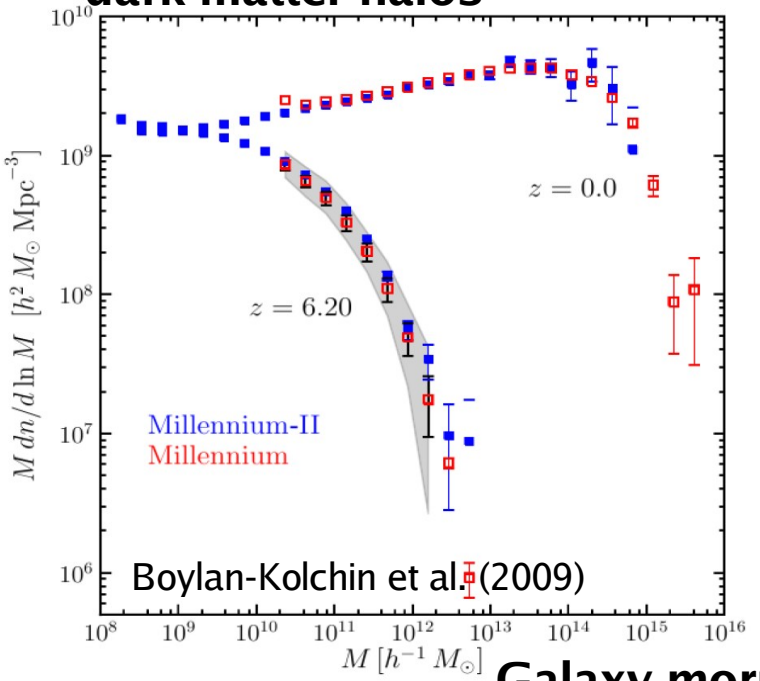


Debora Sijacki
IoA & KICC
Cambridge

LSS conference
July 23 2015

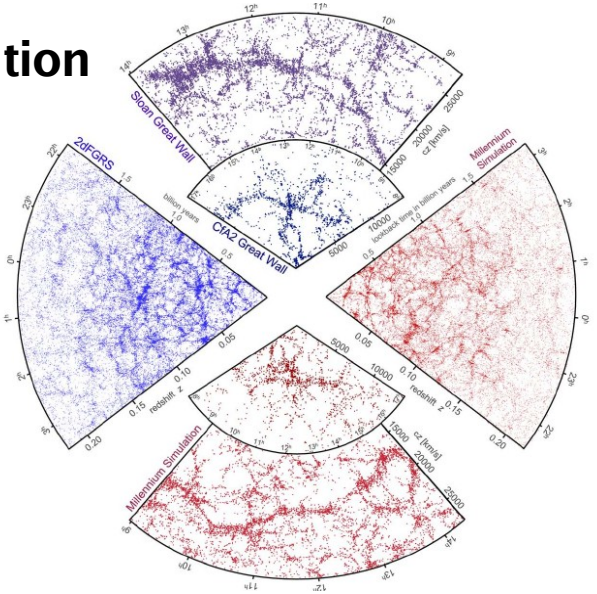
Cosmological simulations of galaxy and structure formation

Hierarchical growth of dark matter halos



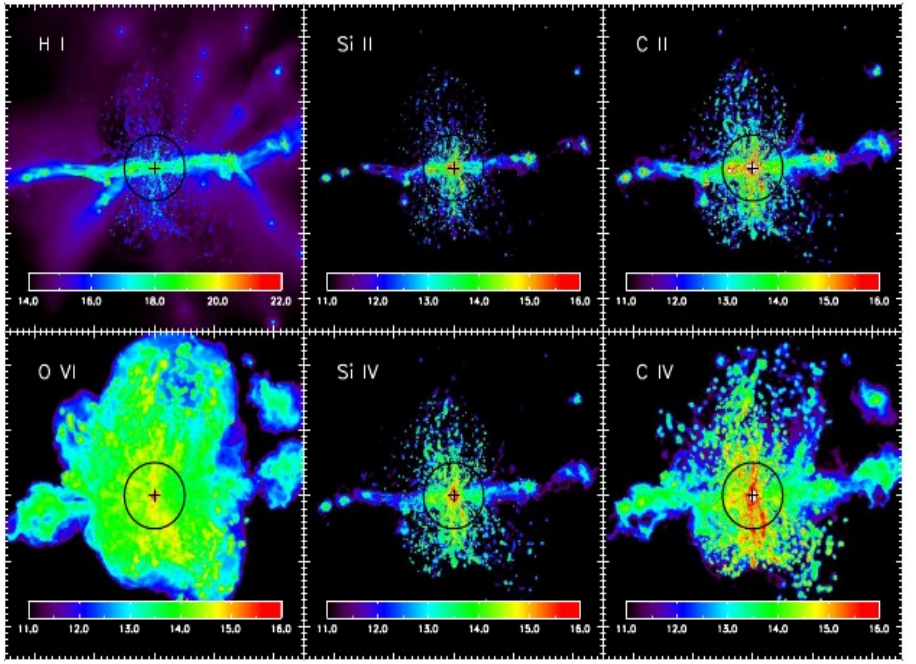
Boylan-Kolchin et al. (2009)

Large scale distribution of galaxies



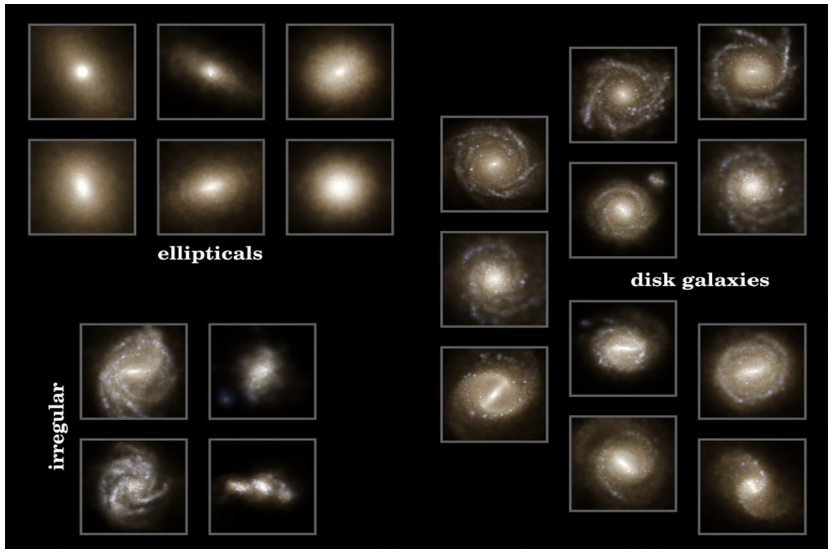
Springel et al. 2006

Large scale environments of galaxies: inflows and outflows

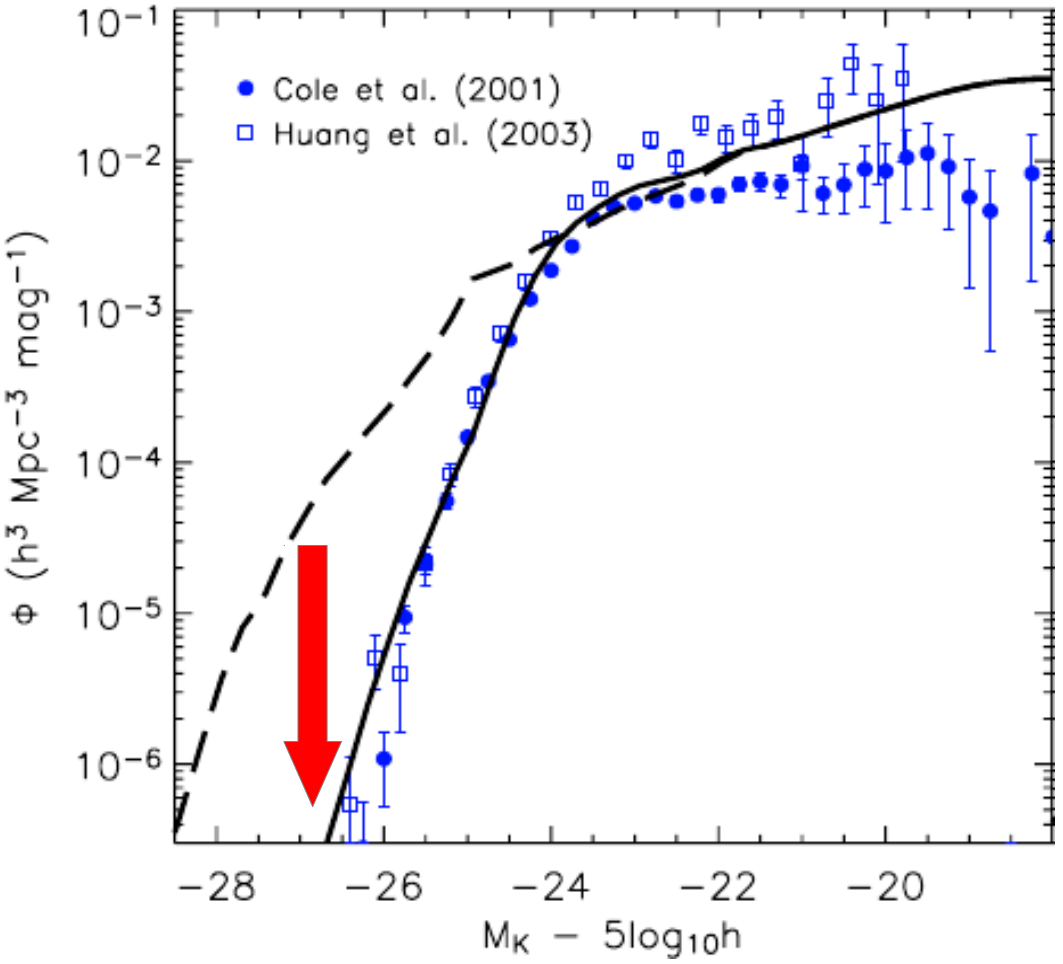


Shen et al. 2013

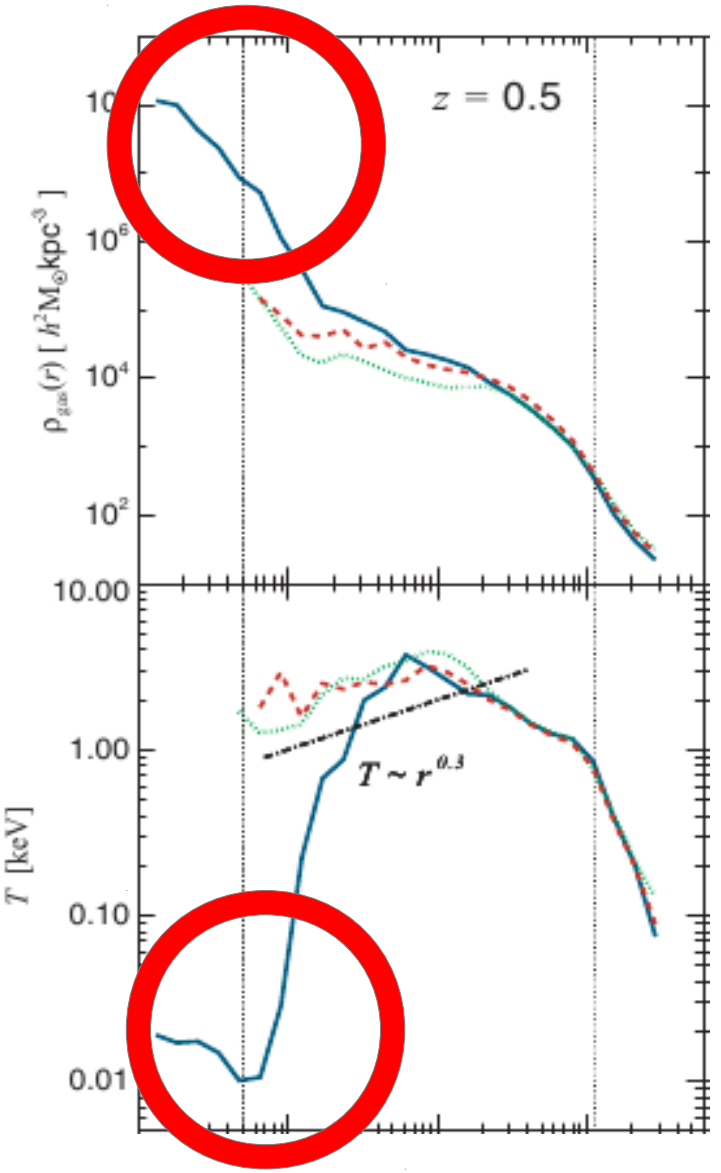
Galaxy morphologies Illustris project



One of the main issues:
Gas overcooling in massive galaxies

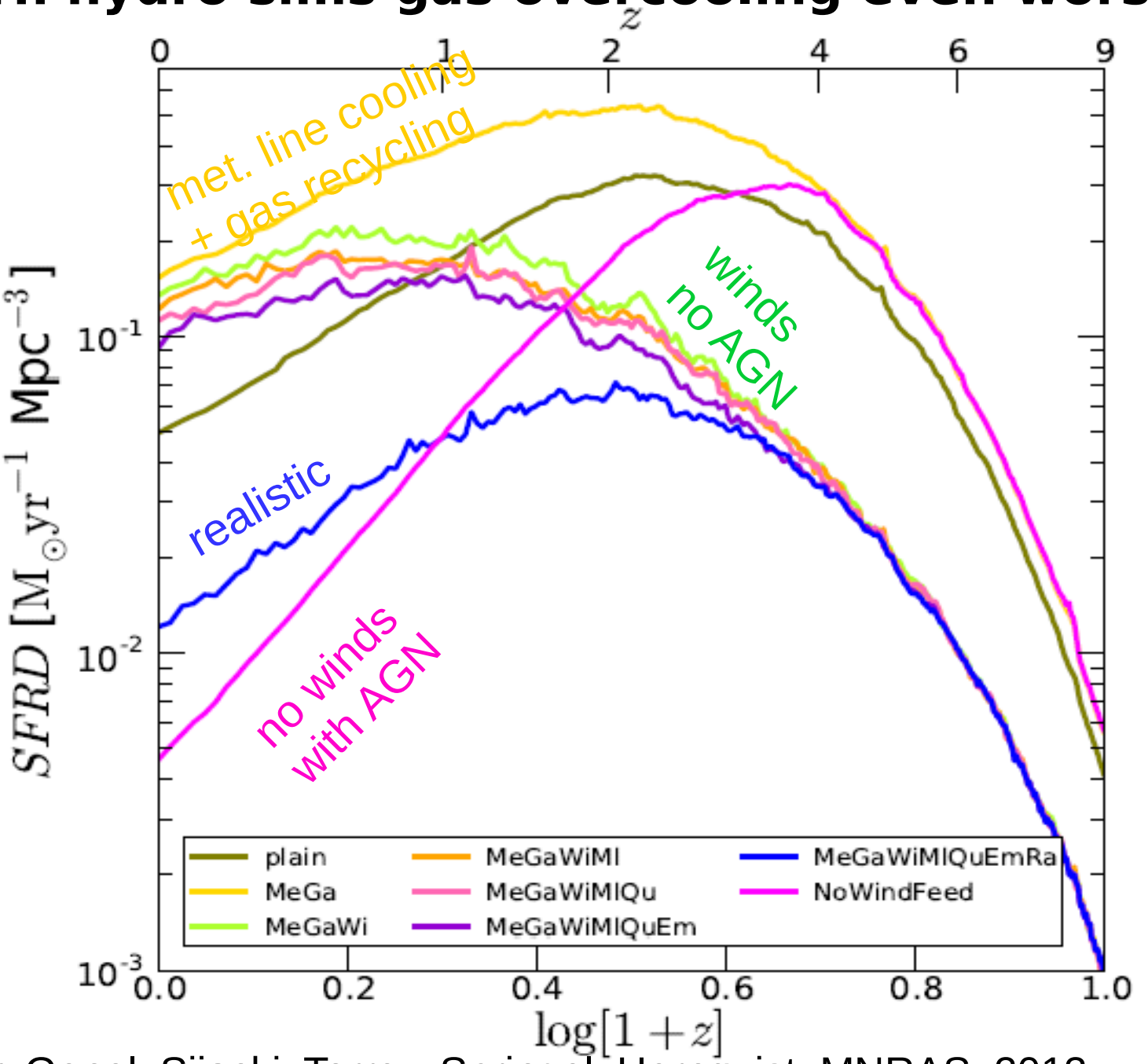


Croton et al. 2006



Sijacki et al. 2007

In modern hydro sims gas overcooling even worse!



Vogelsberger, Genel, Sijacki, Torrey, Springel, Hernquist, MNRAS, 2013

Observational evidence for the feedback from supermassive black holes: high z QSOs

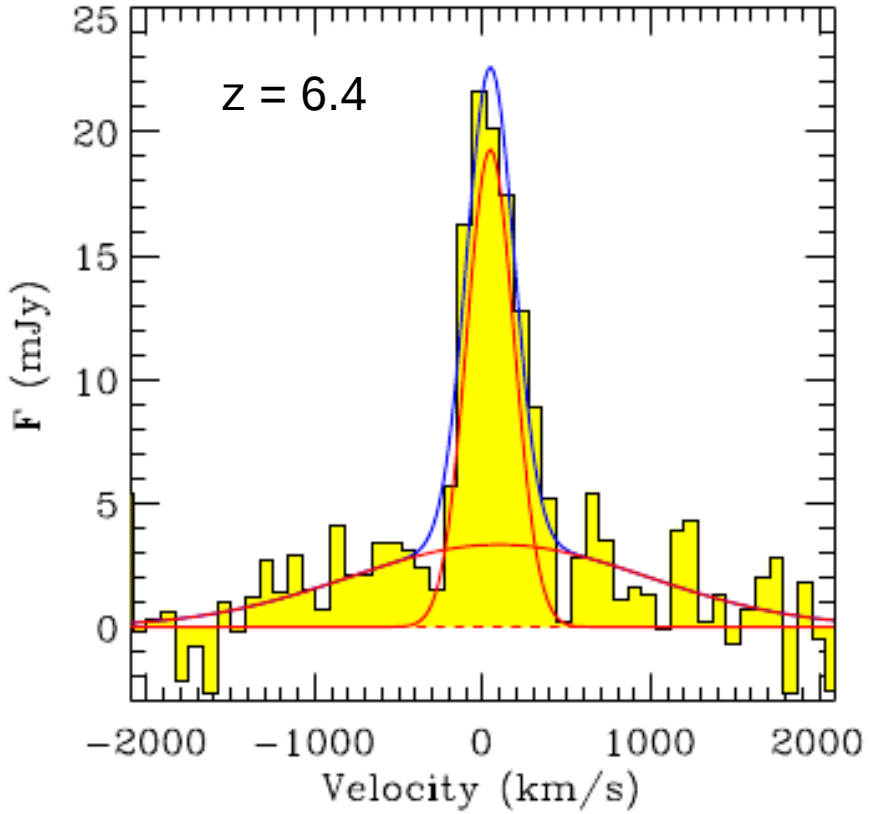
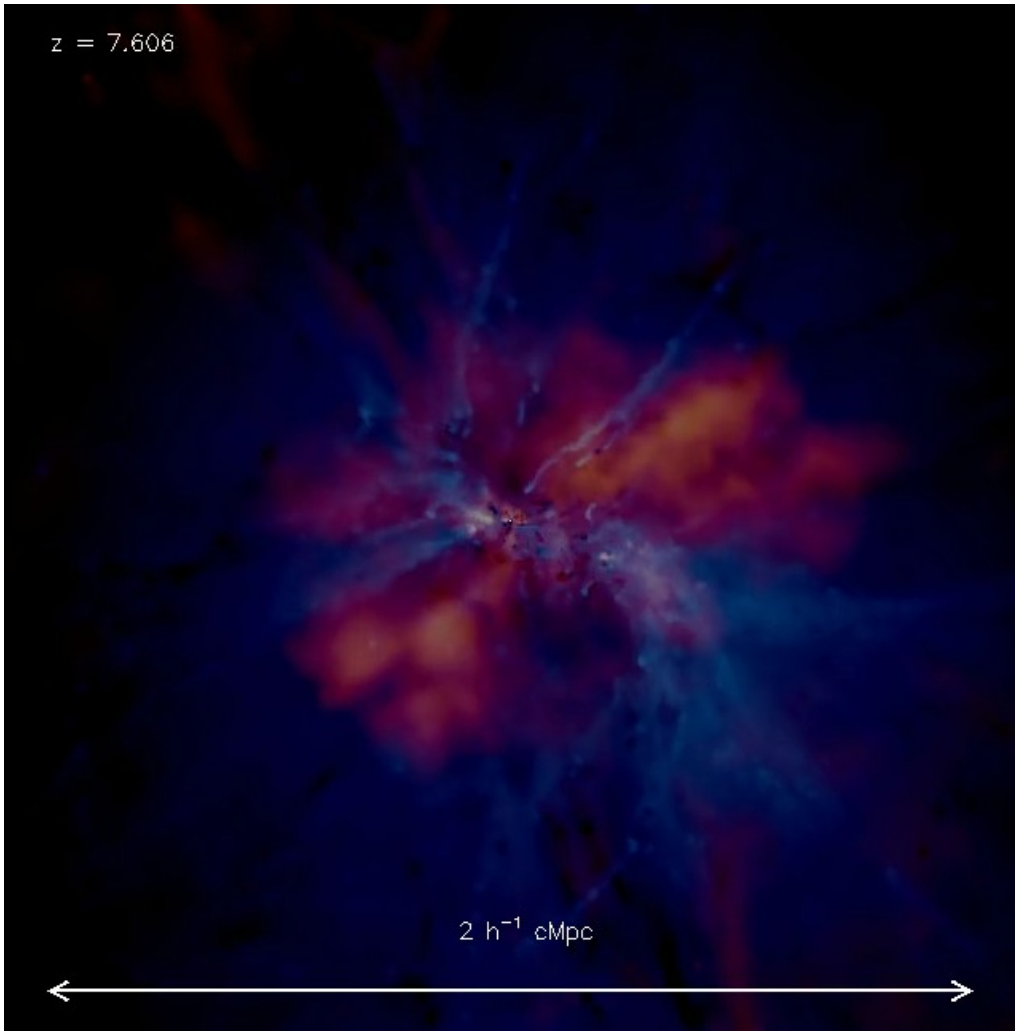


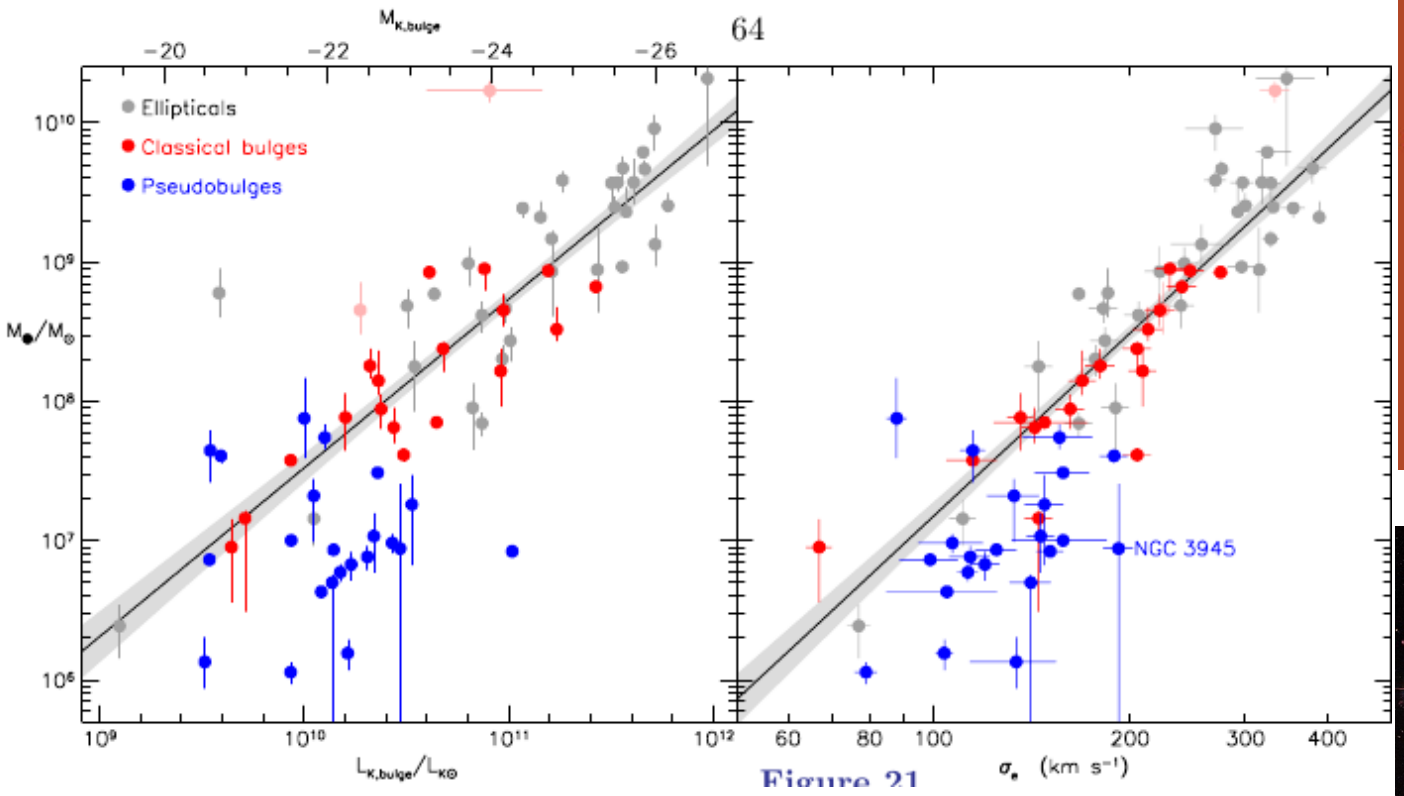
Figure 1. IRAM PdBI continuum-subtracted spectrum of the [CII]158μm line, redshifted to 256.172 GHz, in the host galaxy of the quasar J1148+5152 extracted from an aperture with a diameter of 4″, top, and 6″, bottom. The spectrum has been resampled to a bin size of 85 km s^{-1}. The red lines show a double Gaussian fit (FWHM=345 km s^{-1} and FWHM=2030 km s^{-1}) to the line profile, while the blue line shows the sum of the two Gaussian components.

Maiolino et al. 2012

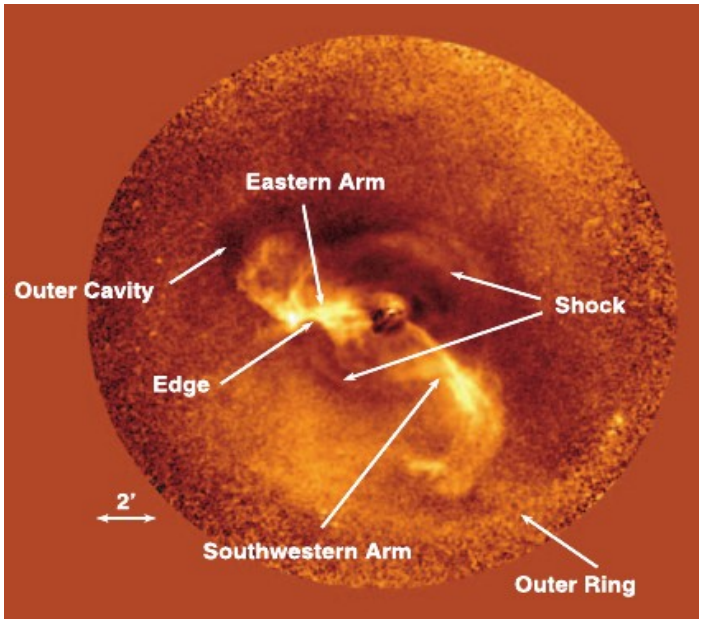


Costa, Sijacki, Trenti, Haehnelt 2012

Observational evidence for the feedback from supermassive black holes: low z Universe



Kormendy & Ho 2013



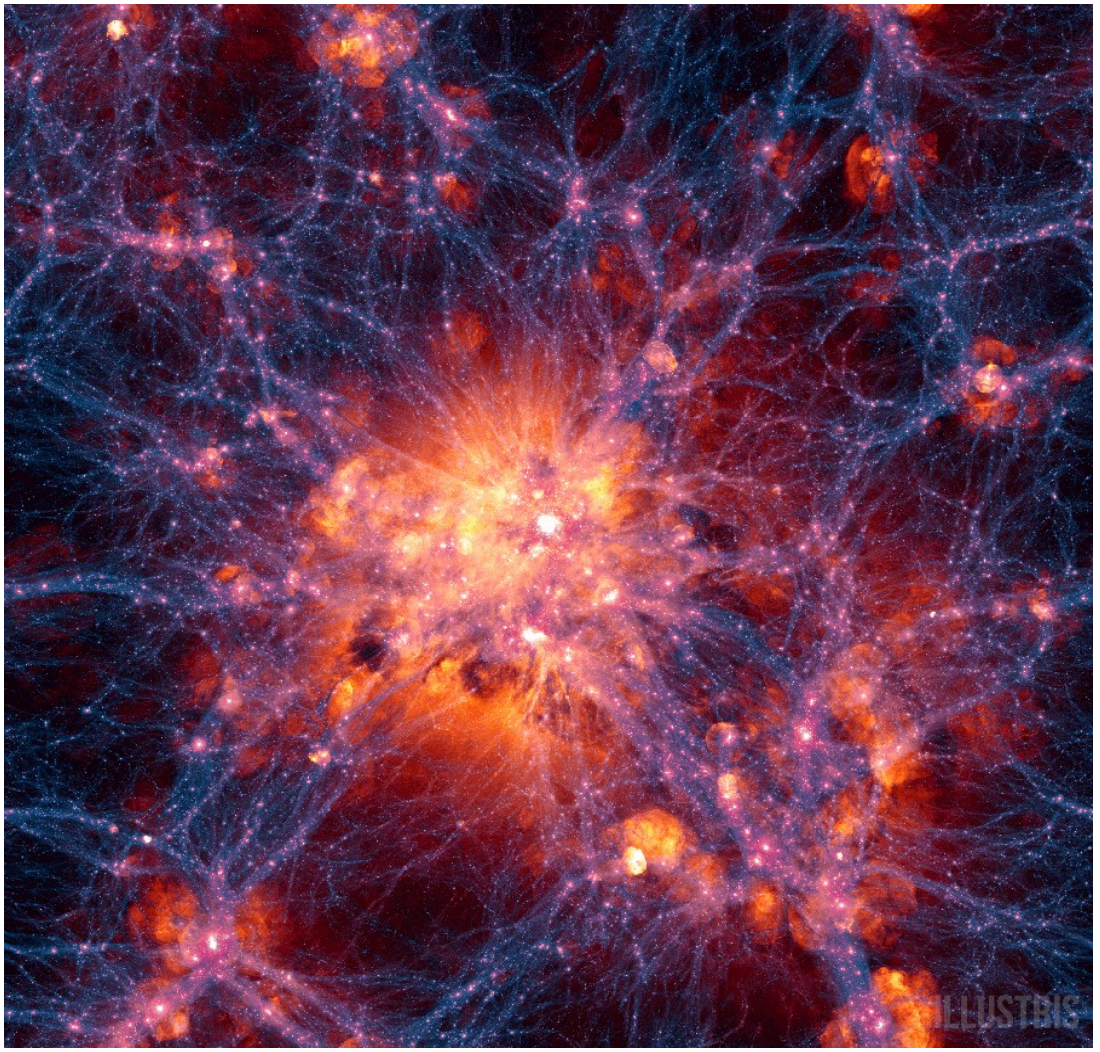
M87, Forman et al.

Perseus cluster, Fabian et al.

see also McConnell & Ma, 2013

The Illustris project

DM DENSITY with overlaid GAS VELOCITY



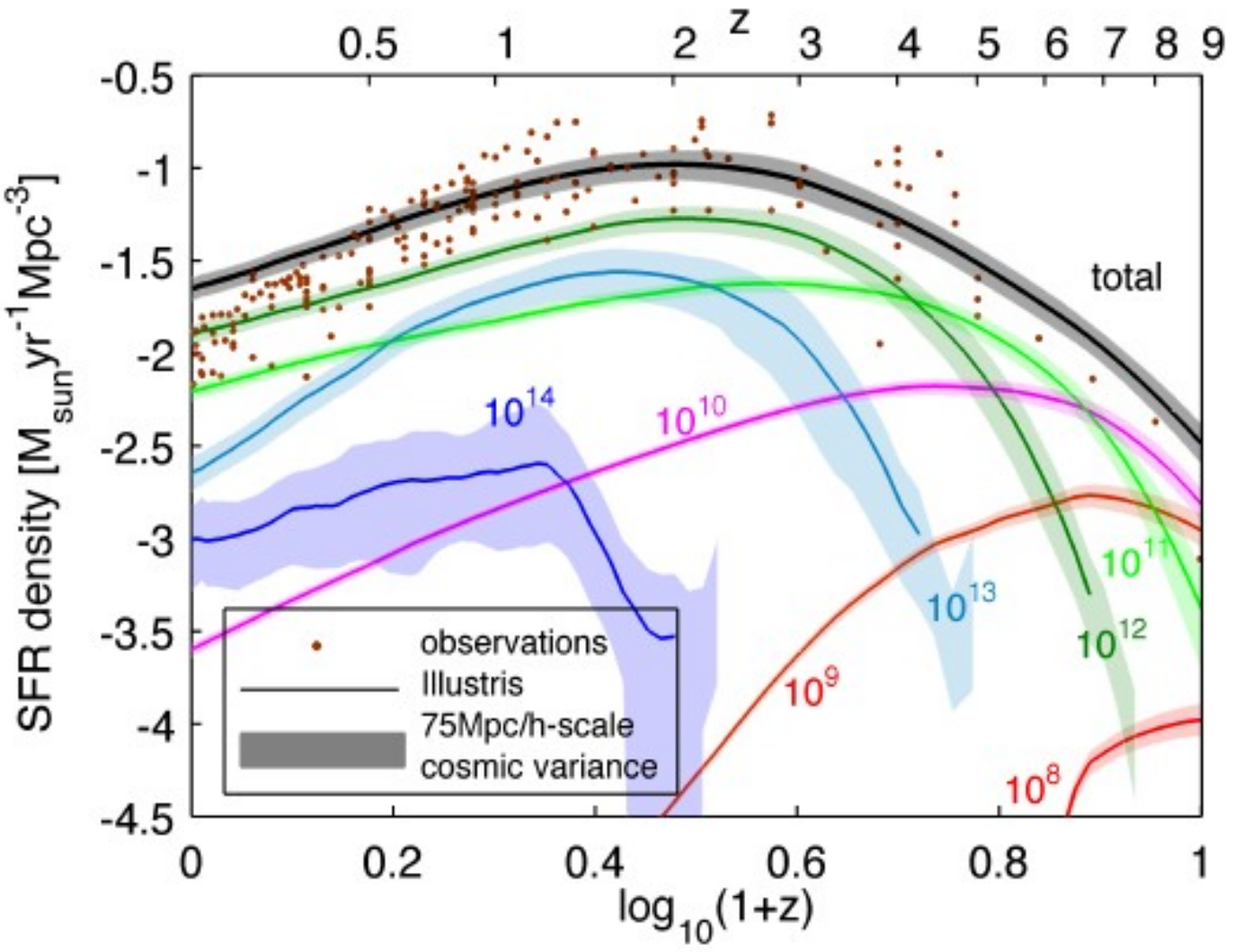
Box size = 106.5Mpc
Min cell size = 48pc
3 x 1820^3
dark matter particles
gas cells
passive tracers -> 18 billion
8192 cores, 19 MCPUh

Physics:

primordial & metal line cooling
+ self-shielding
stellar evolution
stellar feedback
gas recycling
chemical enrichment
black hole growth
black hole feedback:
quasar, radiative and radio bubbles
(see Springel et al. 2005
Sijacki et al. 2007,
Vogelsberger et al. 2013)

The Illustris project

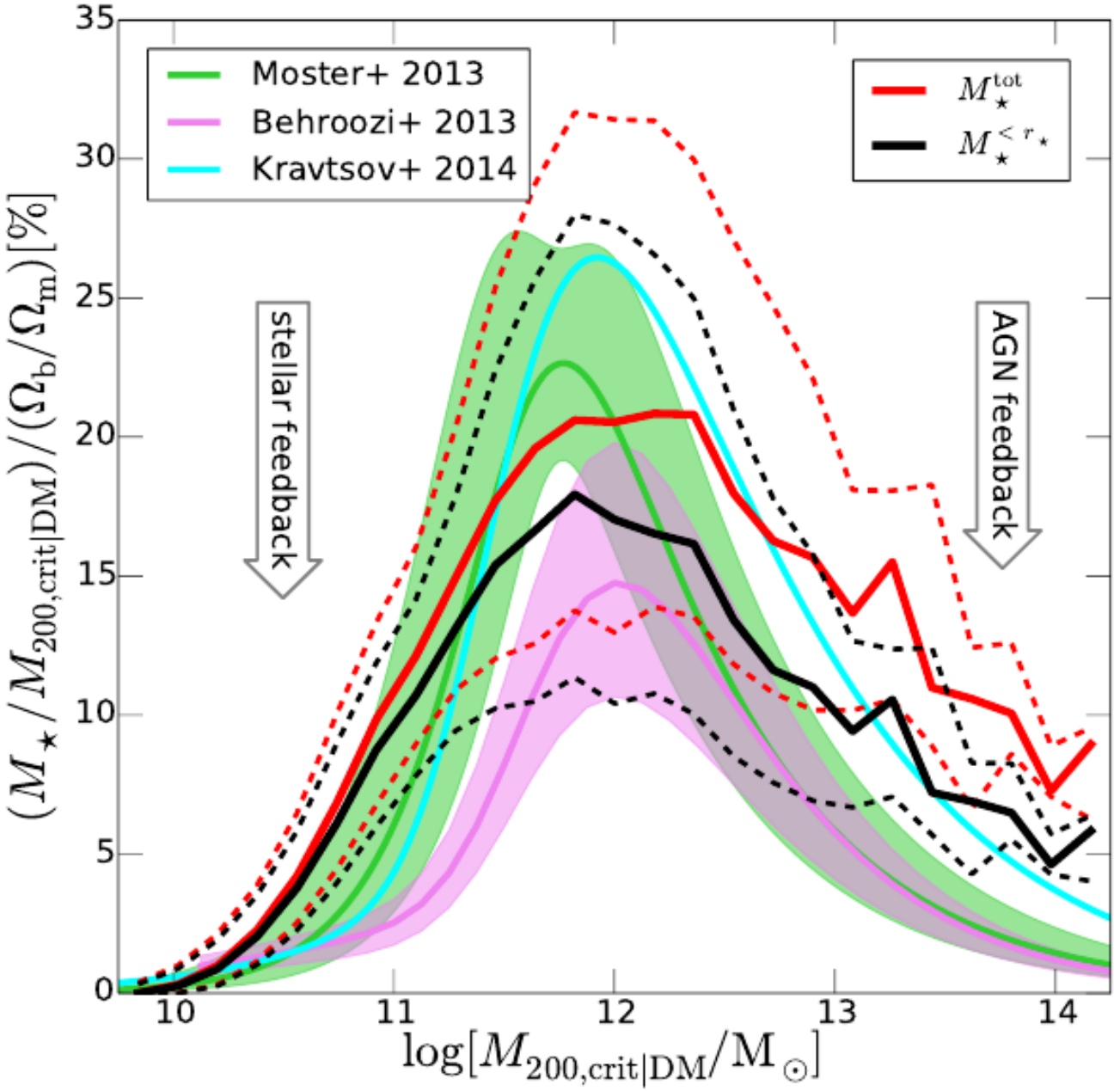
COSMIC STAR FORMATION RATE DENSITY



Genel, Vogelsberger, Springel, Sijacki, et al., MNRAS, 2014

The Illustris project

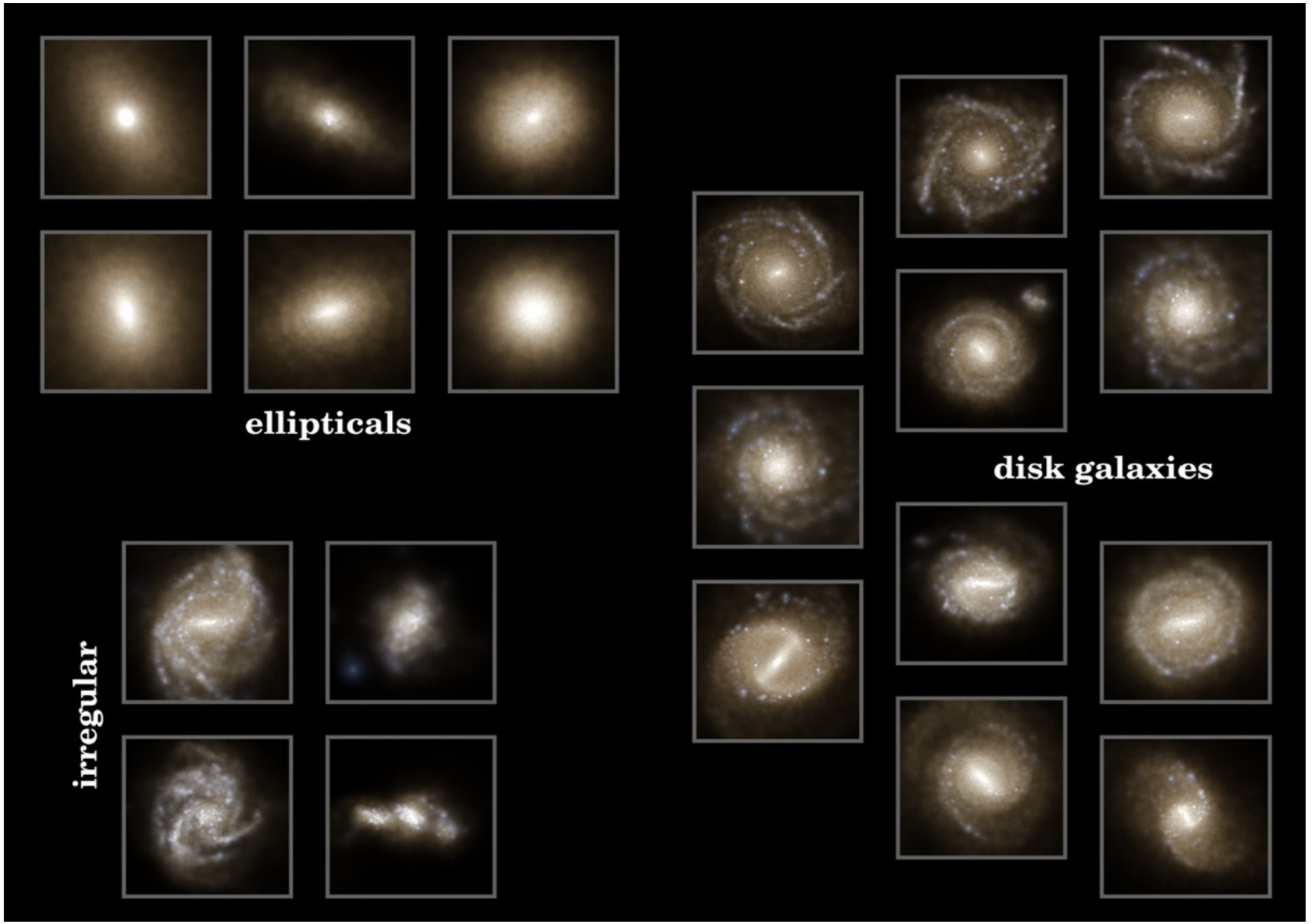
STELLAR VS. HALO MASS



Vogelsberger, Genel, Springel, Torrey, Sijacki, et al., MNRAS, 2014

The Illustris project

GALAXY MORPHOLOGIES

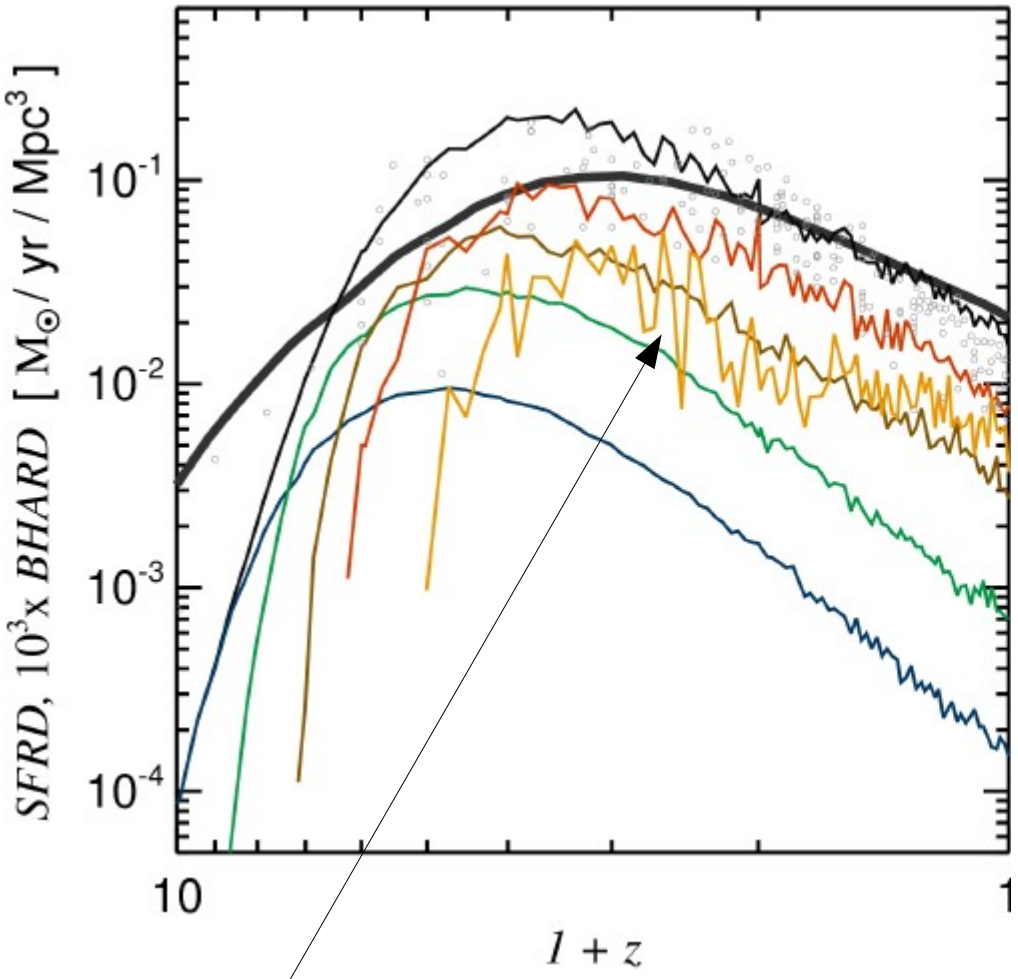


Vogelsberger et al., MNRAS, 2014
Genel et al., MNRAS, 2014

see also e.g. EAGLE, HORIZON AGN, MASSIVE BLACK and MAGNETICUM projects

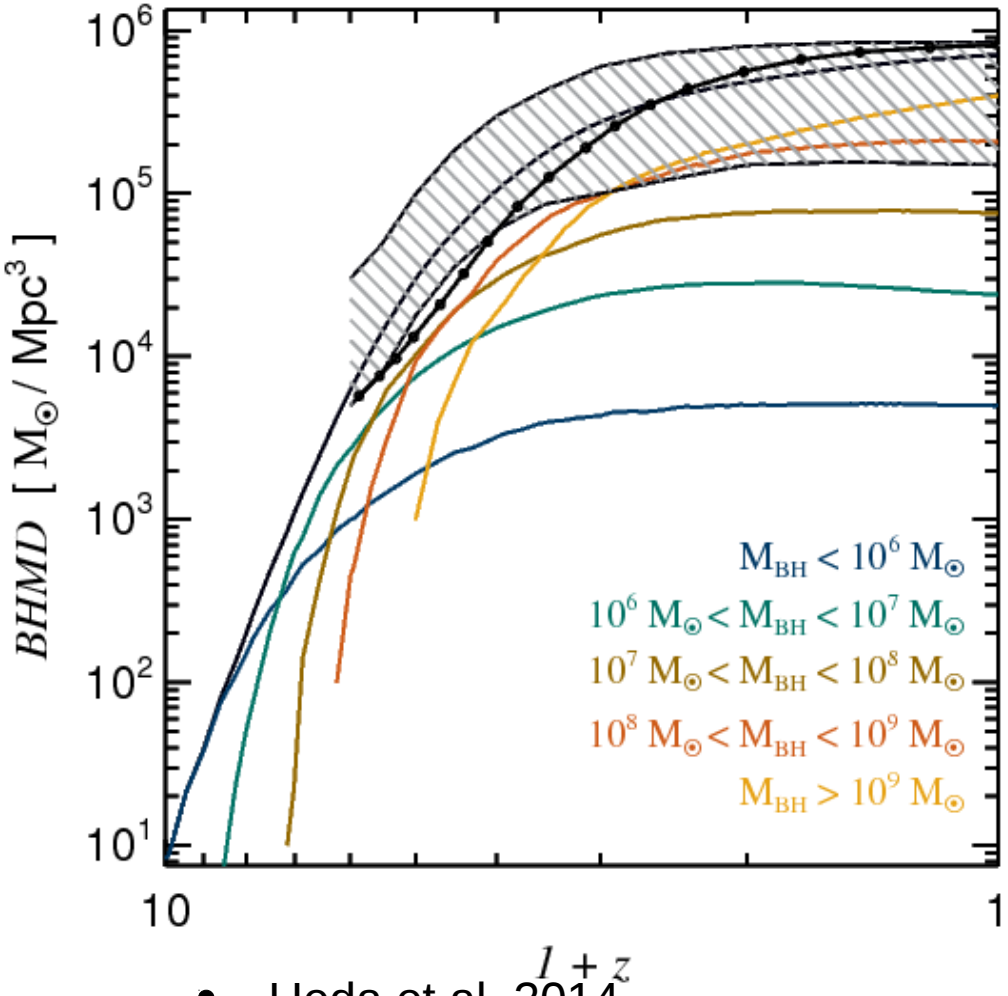
BHs in Illustris

SFR DENSITY &
BH ACCRETION RATE DENSITY



DUTY CYCLE DUE TO THE RADIO MODE

BH MASS DENSITY

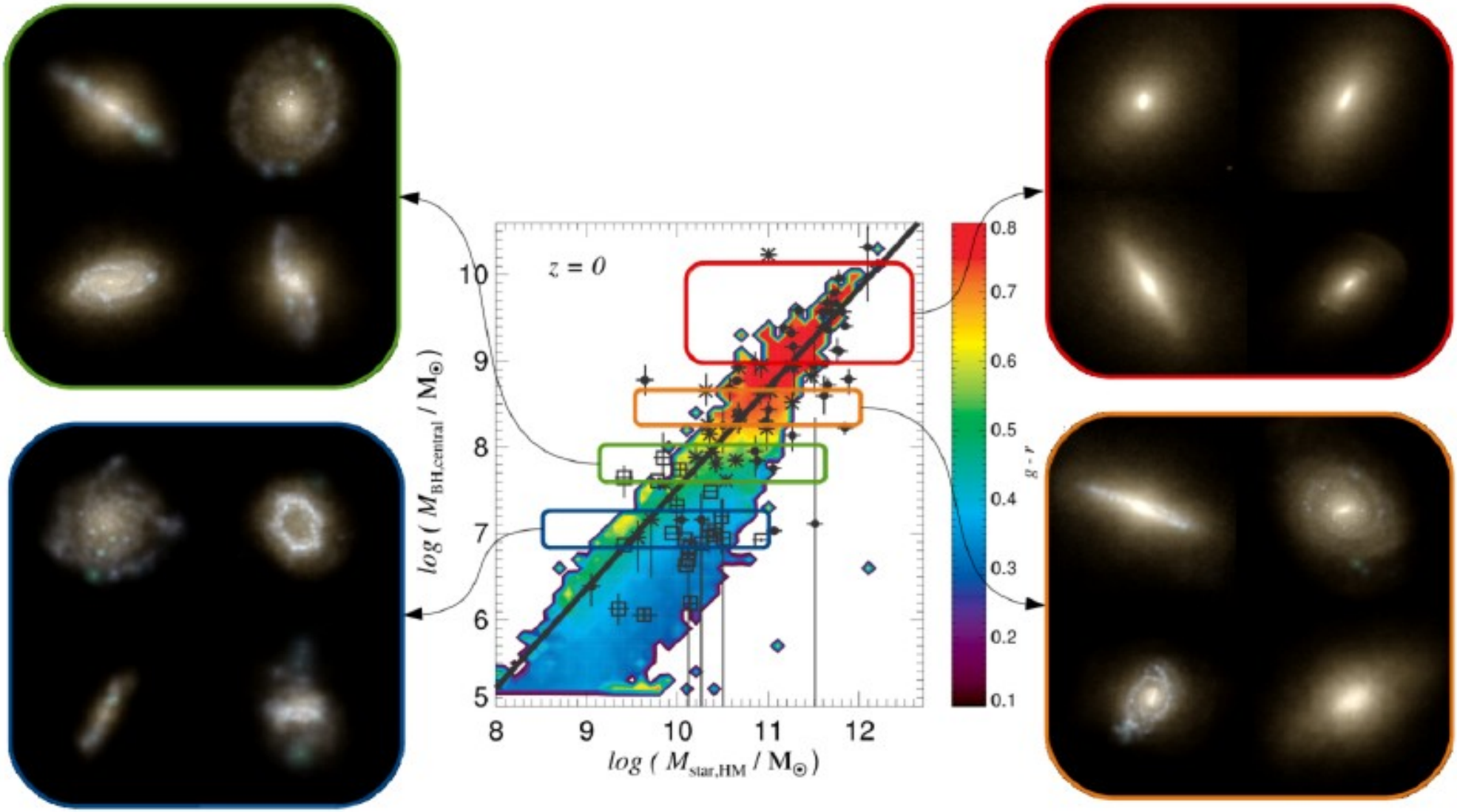


- Ueda et al. 2014
- Volonteri et al. 2013

Sijacki et al., MNRAS, 2015

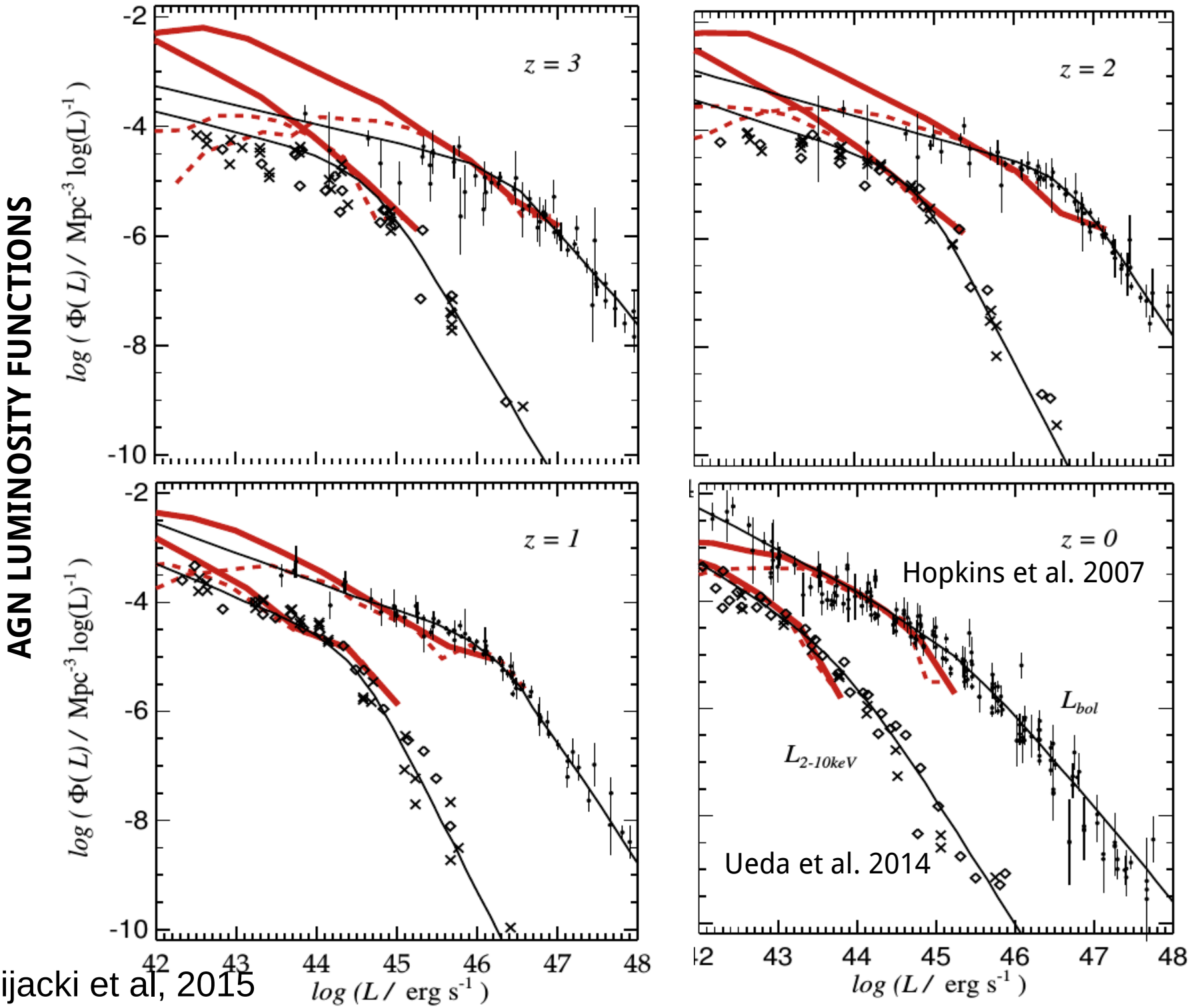
BHs in Illustris

BH MASS – BULGE MASS RELATION



Kormendy & Ho, 2013: best fit
circles: ellipticals; stars: spirals with bulges; squares: pseudo bulges

Sijacki et al., MNRAS, 2015

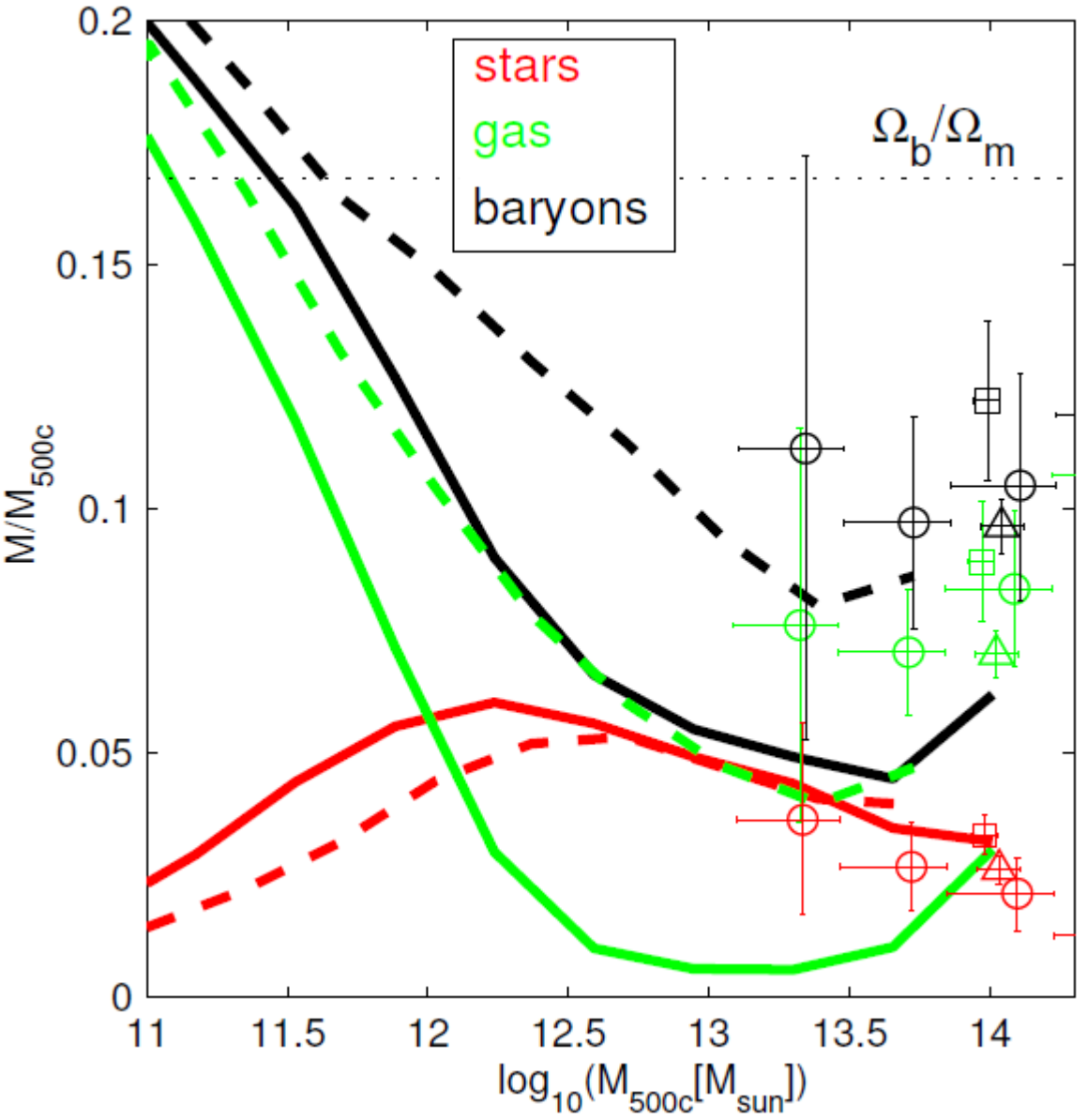


Sijacki et al, 2015

Some of the problems in Illustris...

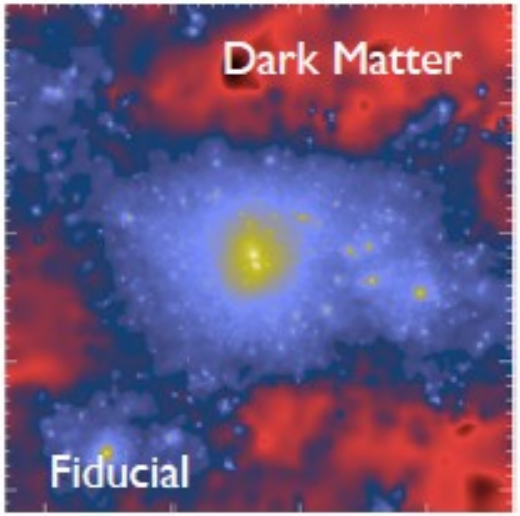
TOO LOW GAS FRACTIONS IN MASSIVE GALAXIES

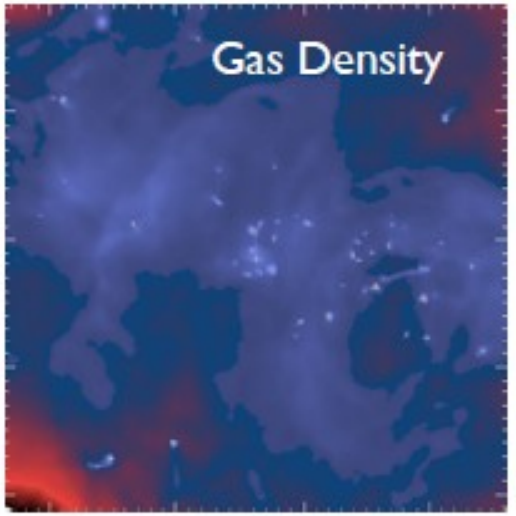
Ewald Puchwein's talk:
effect on the matter power spectrum

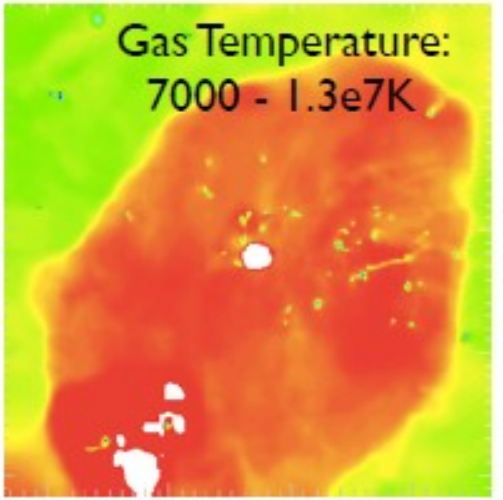


Genel et al., 2014

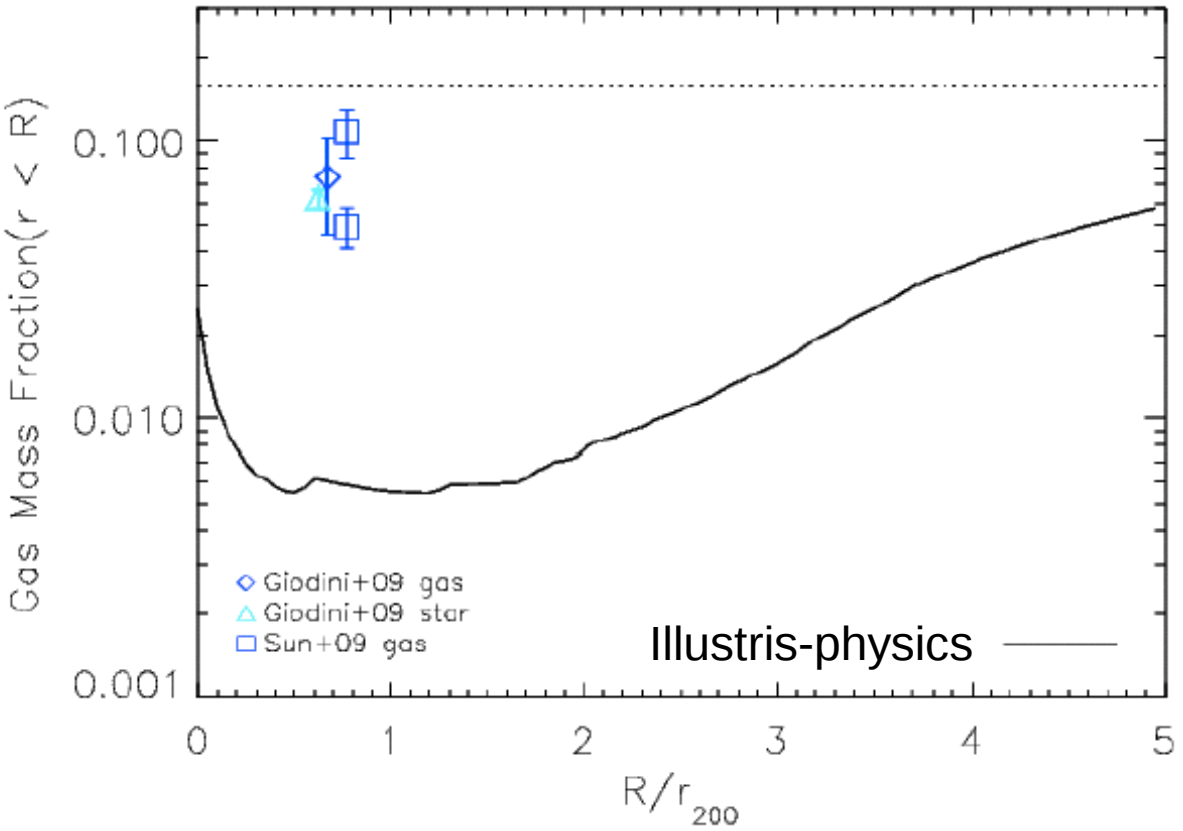
Some of the problems in Illustris...





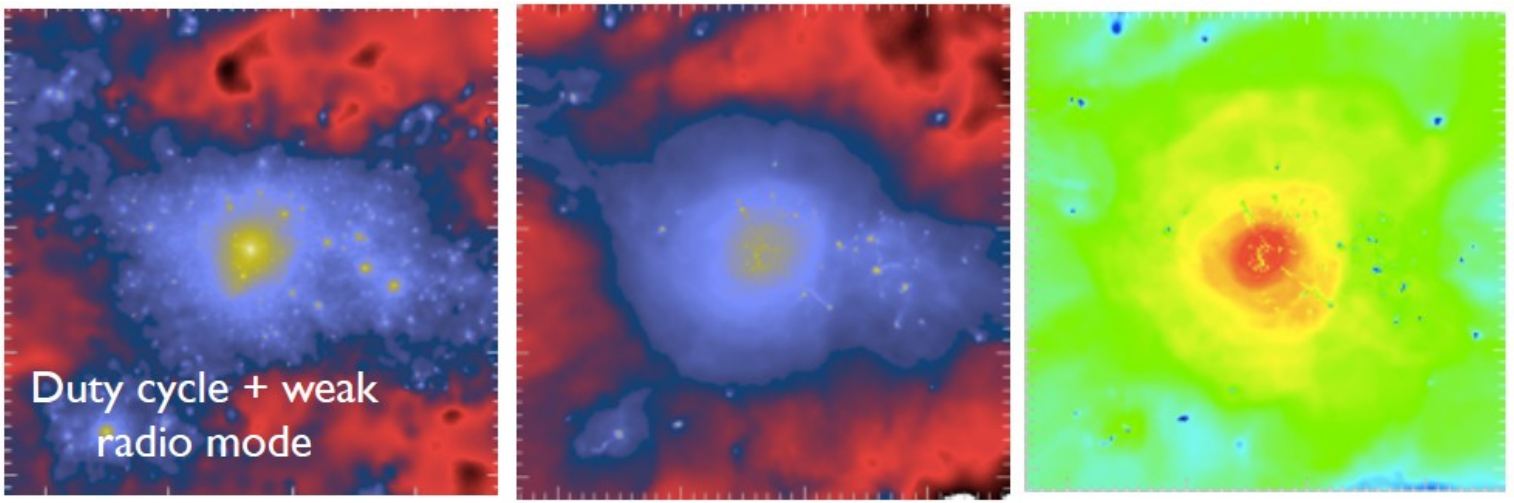


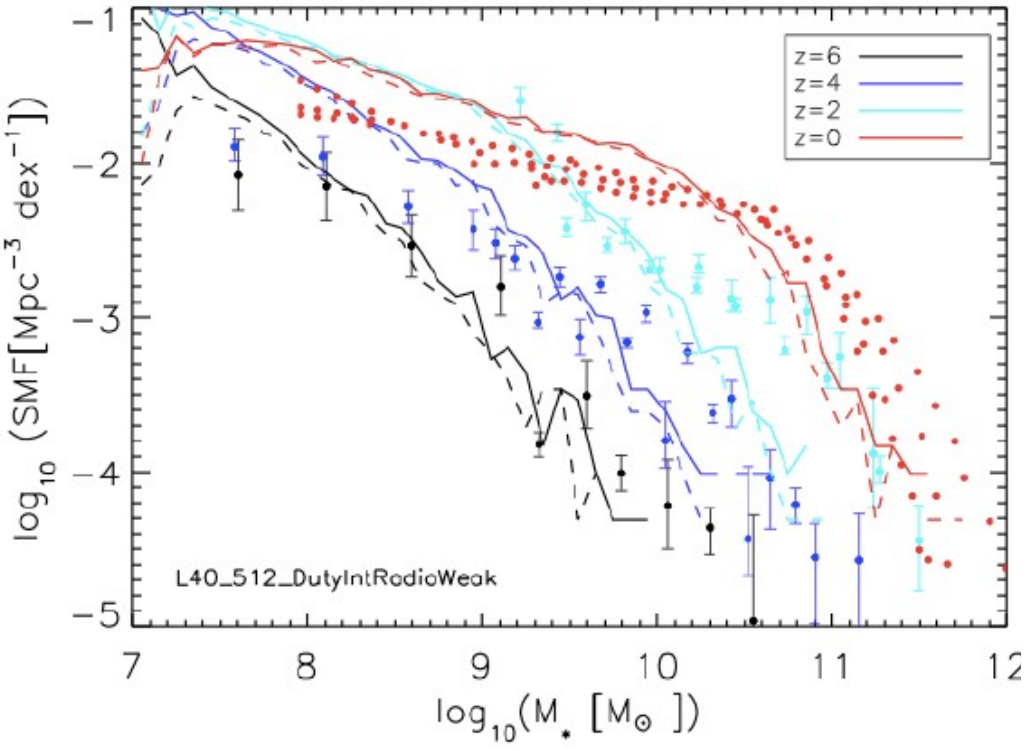
TOO LOW GAS FRACTIONS IN MASSIVE GALAXIES:
ZOOMS OF ELLIPTICALS

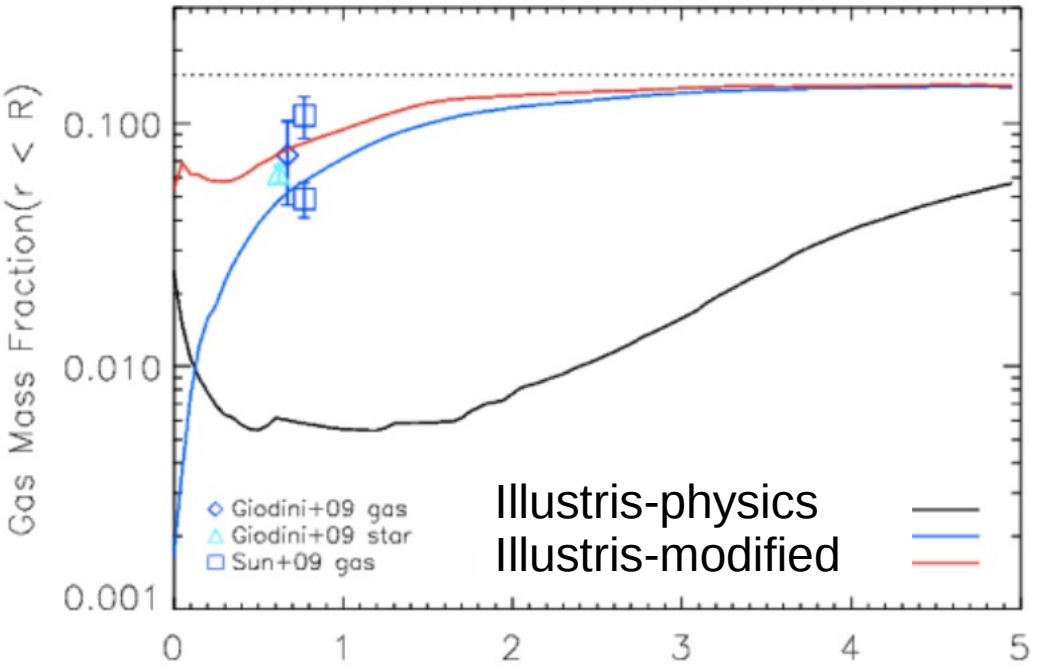


Shen, Sijacki et al, in prep.

Some of the problems in Illustris...



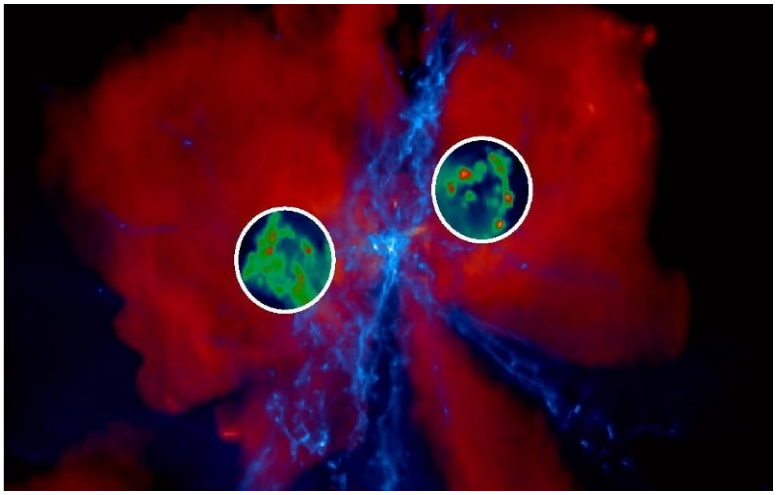


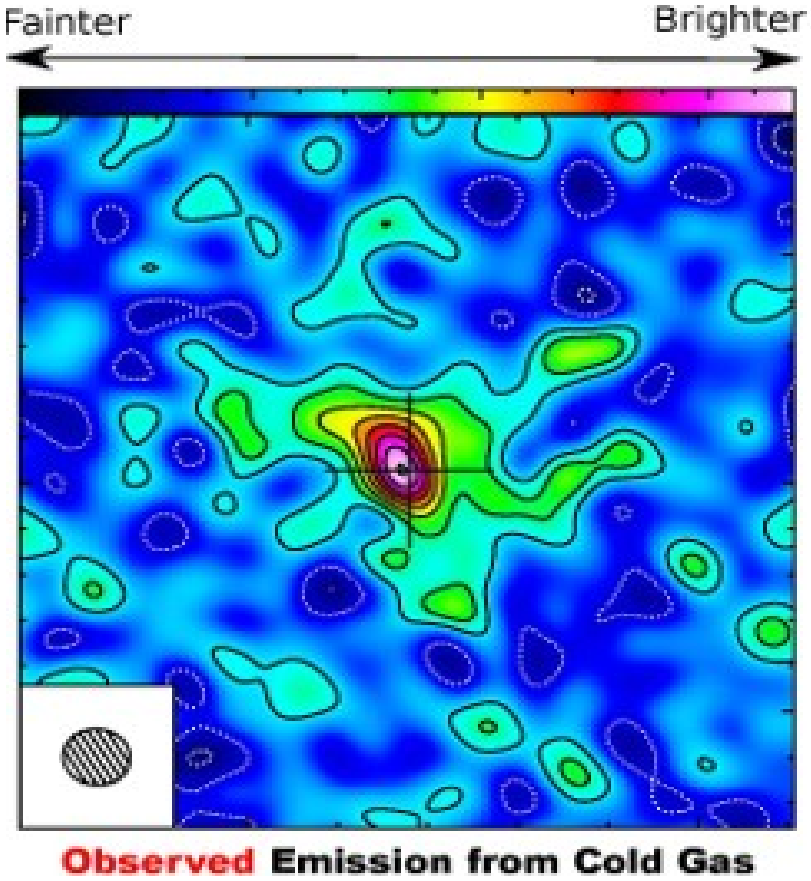


Shen, Sijacki et al, in prep.

Fast cold gas in hot AGN outflow

PR “A galactic hailstorm in the early Universe”





Cicone et al., A&A, 2015

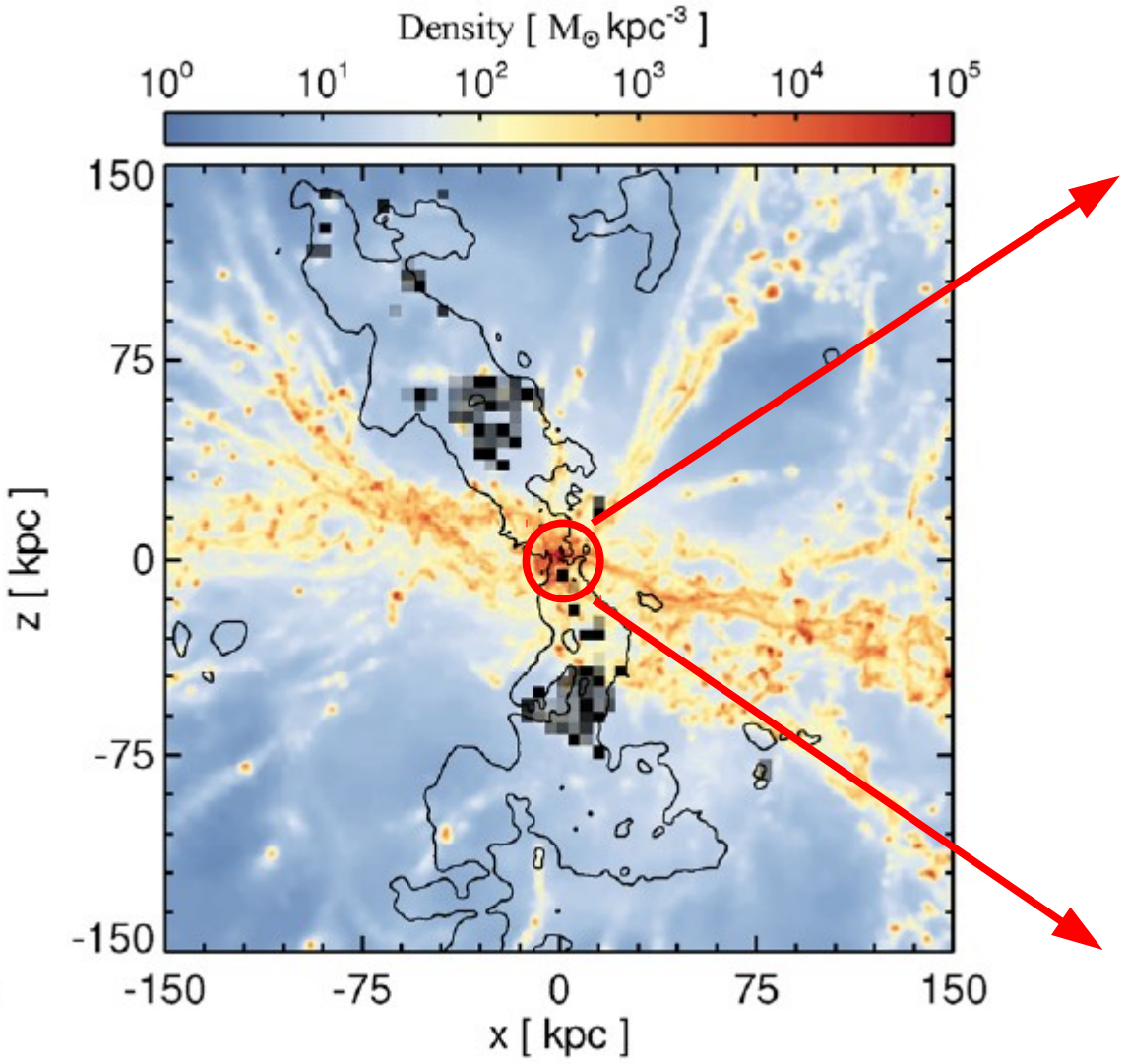
IRAM Plateau de Bure Interferometer

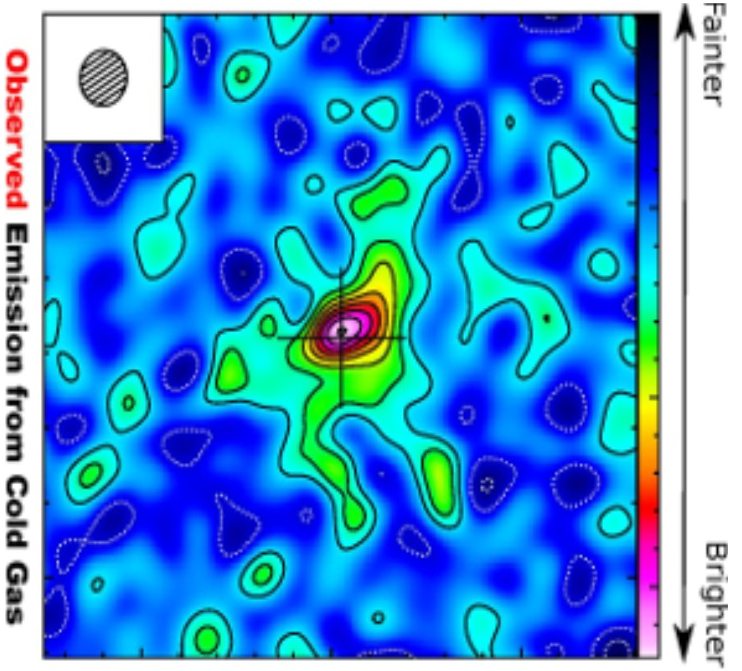
[C II] 158 um emission line

SDSS J1148+5251 QSO z = 6.4189

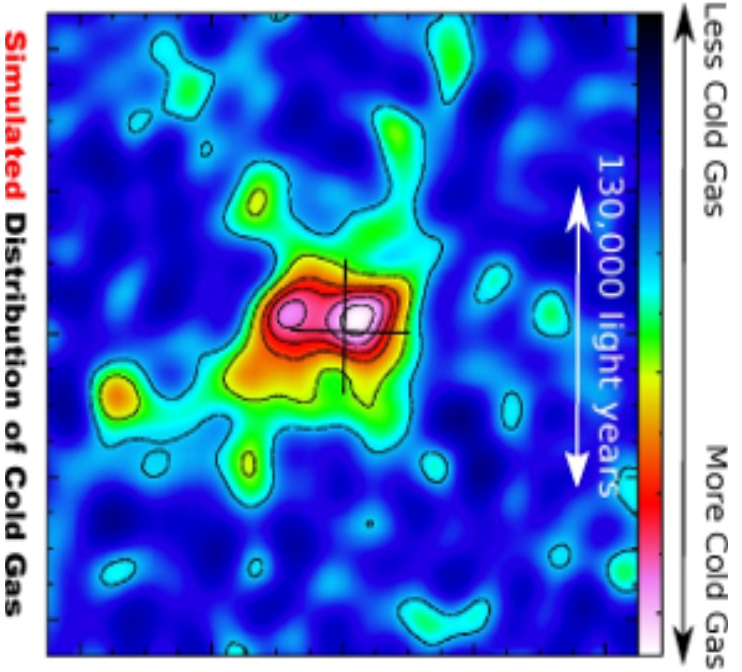
very extended (30kpc projected) cold gas with large velocities up to ~1400km/s

Fast cold gas in hot AGN outflow





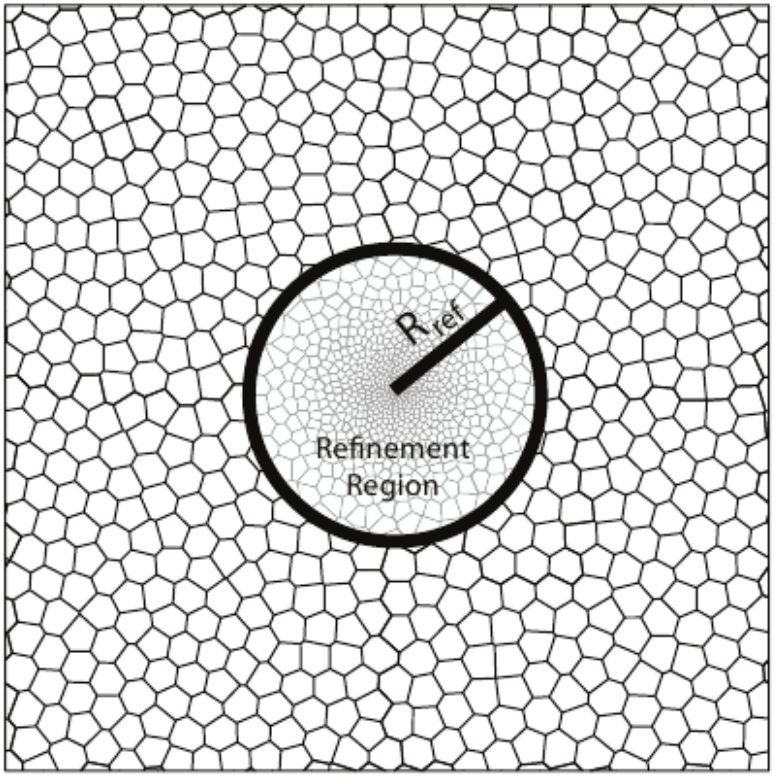
Cicone, Maiolino et al., A&A, 2015

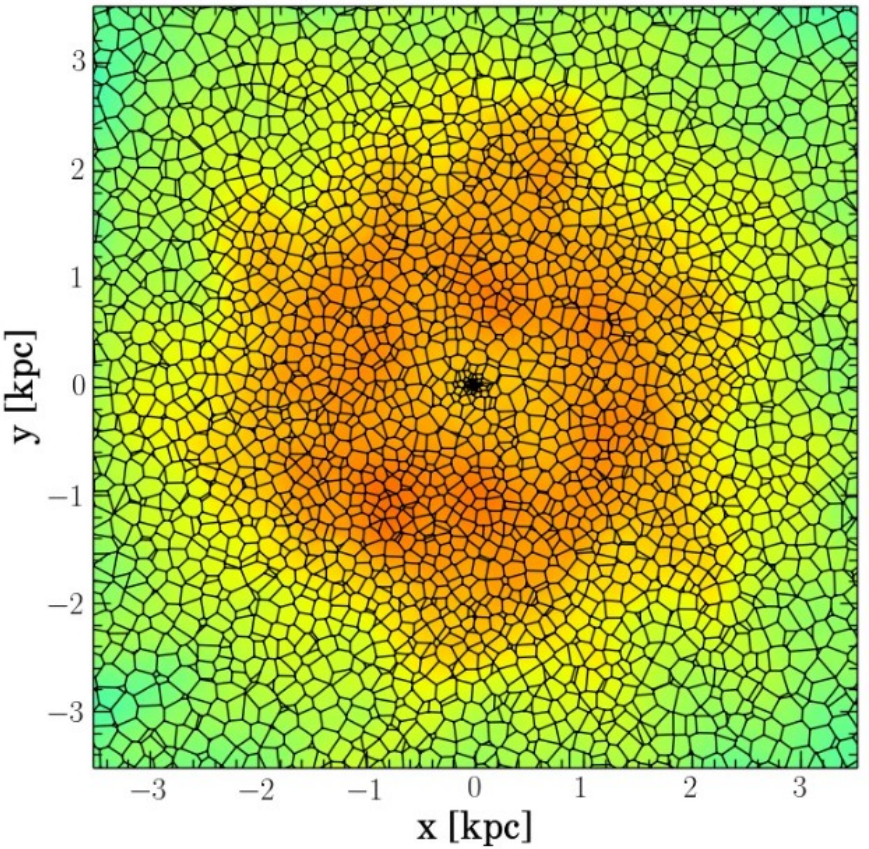


Costa, Sijacki, Haehnelt, MNRAS, 2015

Resolving flows around BHs

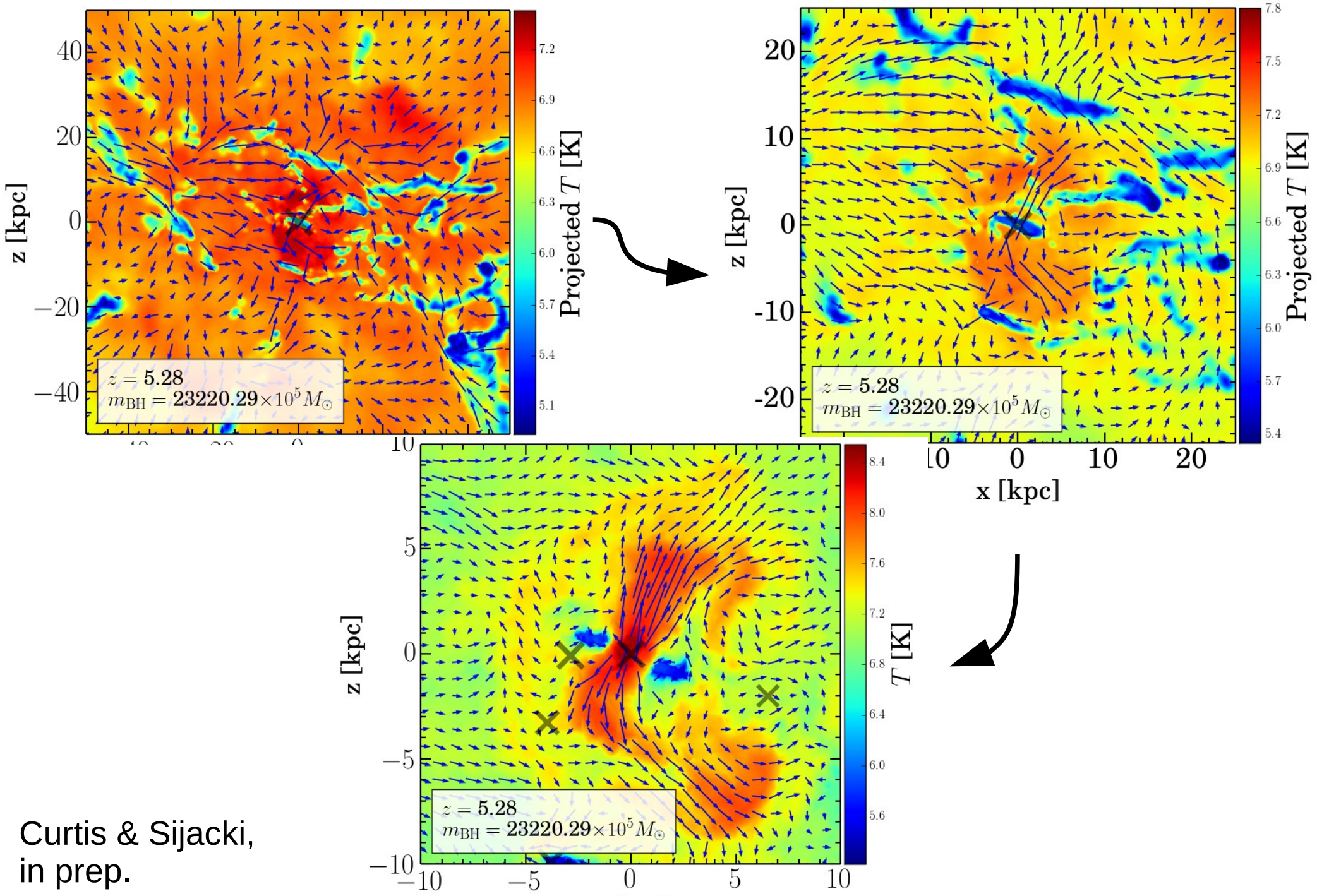
super-Lagrangian refinement





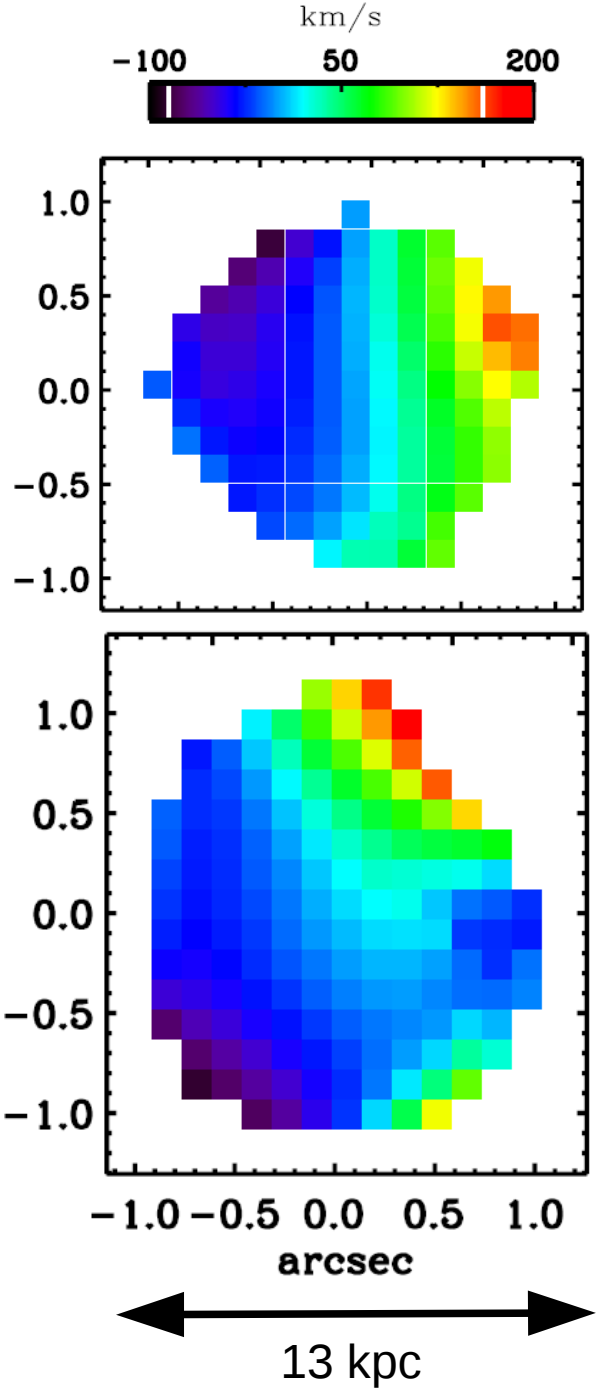
Curtis & Sijacki, MNRAS, 2015

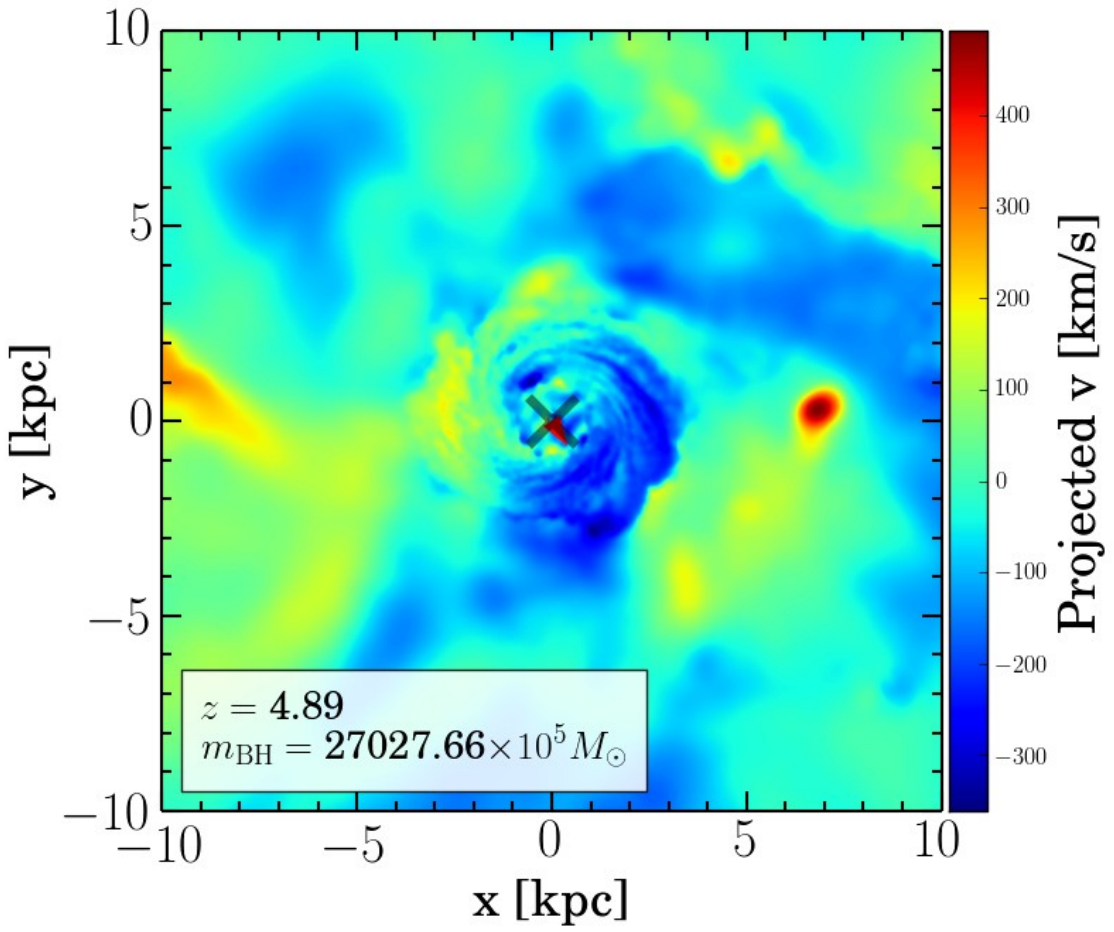
Resolving flows around high z QSOs



Curtis & Sijacki,
in prep.

Resolving flows around high z QSOs





Carniani et al. 2013
ALMA data of a QSO/SMG
At z = 4.7

Curtis & Sijacki, in prep.

Conclusions

→ Calibrating galaxy formation physics in simulations requires careful study of numerics and unbiased comparison with large observational datasets

→ Black hole – host galaxy scaling relation in very good agreement with observations:

1. steepeing at the massive end
2. no strong correlation for low mass, blue star-forming galaxies

→ Future: detailed properties of outflows and galaxy kinematics