The mechanisms responsible for quenching star formation (the view from the L-Galaxies, Henriques15 model)

Bruno Henriques

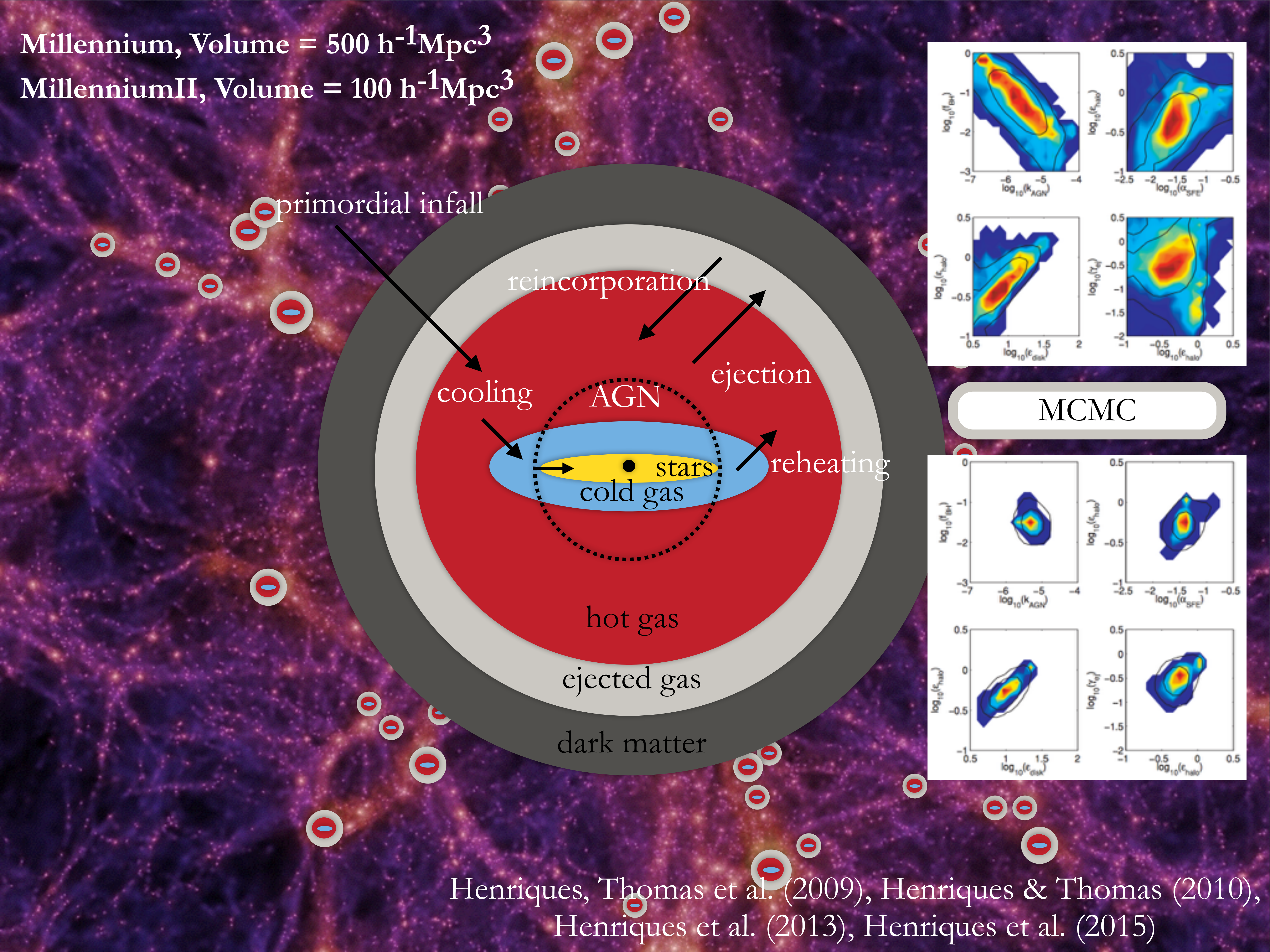
Zwicky Prize Fellow

Galaxy Formation in the PLANCK cosmology I:

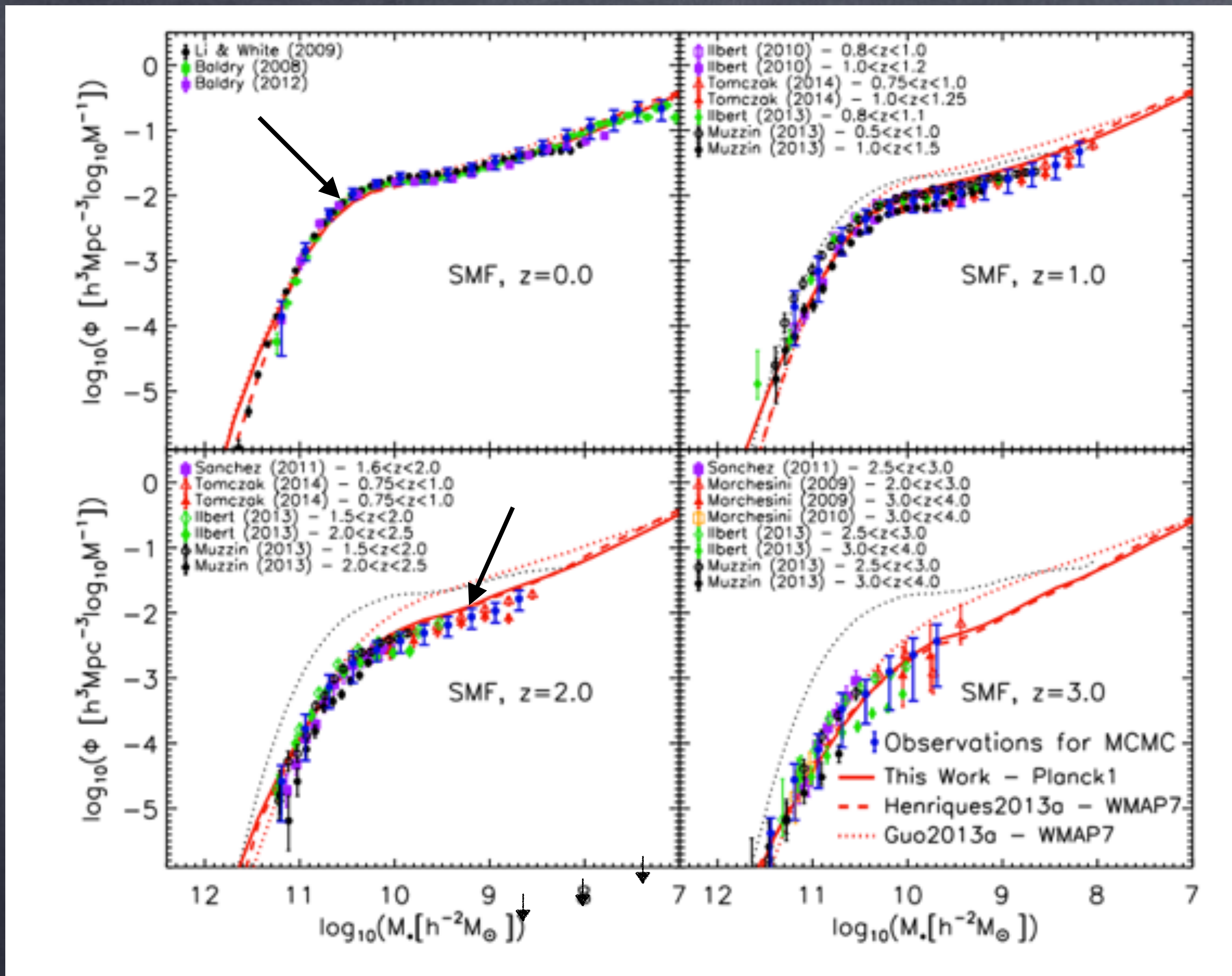
matching the observed evolution of star-formation rates, colours and stellar masses;

Bruno Henriques, Simon White, Peter Thomas, Raul Angulo,

Qi Guo, Gerard Lemson, Volker Springel, Roderik Overzier; MNRAS; 2015


Millennium, Volume = 500 h-1Mpc3
MillenniumII, Volume = 100 h-1Mpc3
primordial infall
reincorporation
ejection
cooling
AGN
stars
cold gas
reheating
hot gas
ejected gas
dark matter
MCMC
Henriques, Thomas et al. (2009), Henriques & Thomas (2010),
Henriques et al. (2013), Henriques et al. (2015)

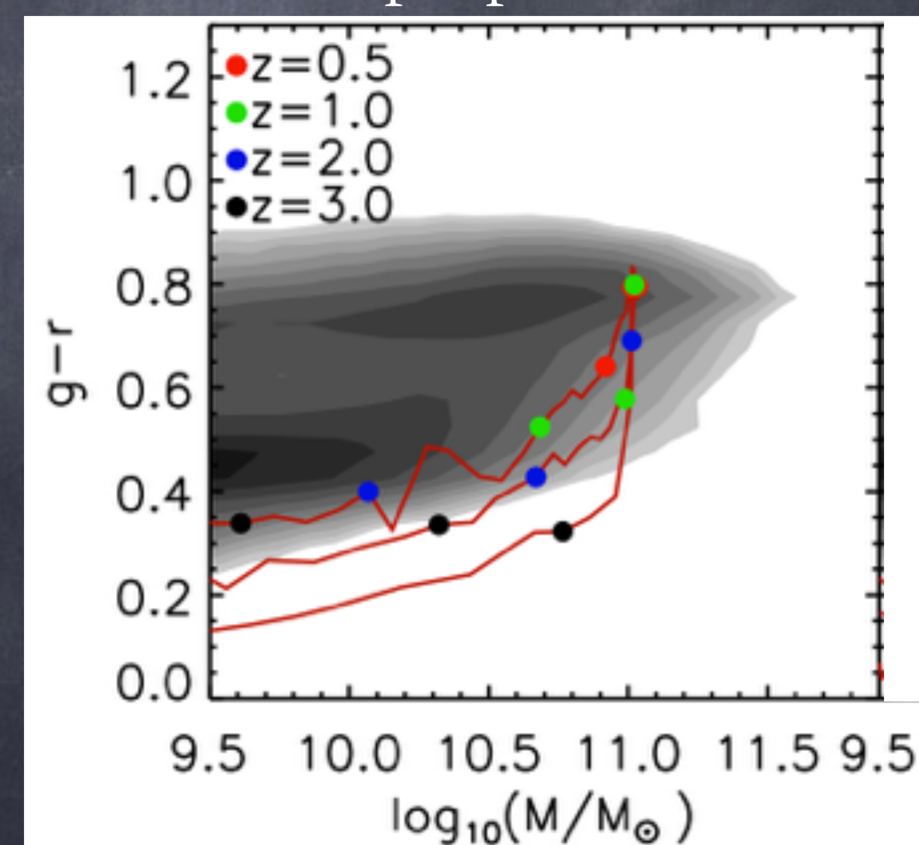
Model results



Henriques et al. 2013 in agreement with Oppenheimer & Dave 2008

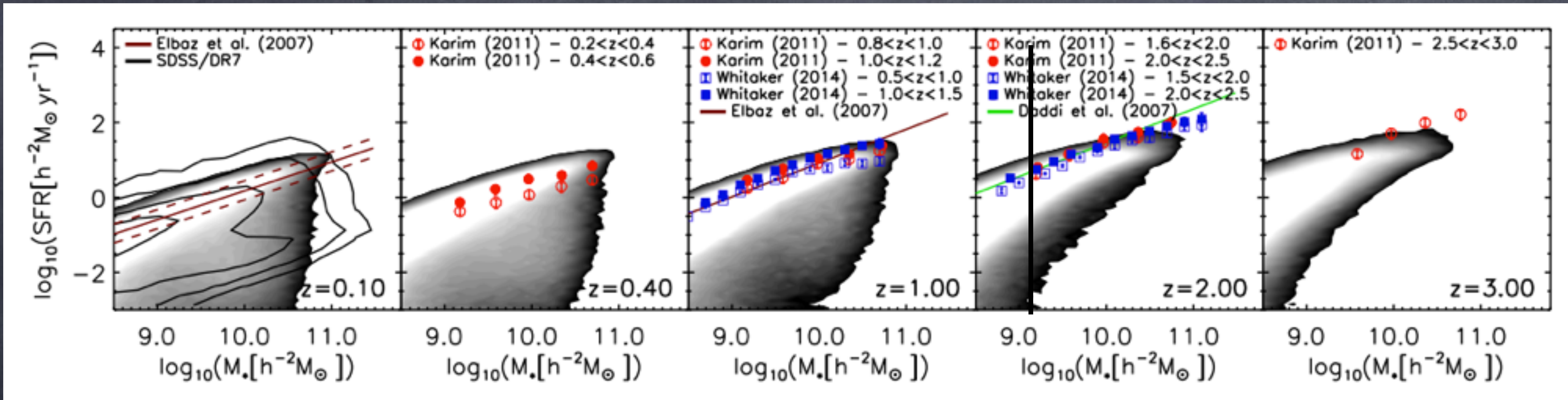
$$t_{\rm reinc} = -\gamma' \frac{10^{10}\,{\rm M}_\odot}{M_{\rm vir}},$$

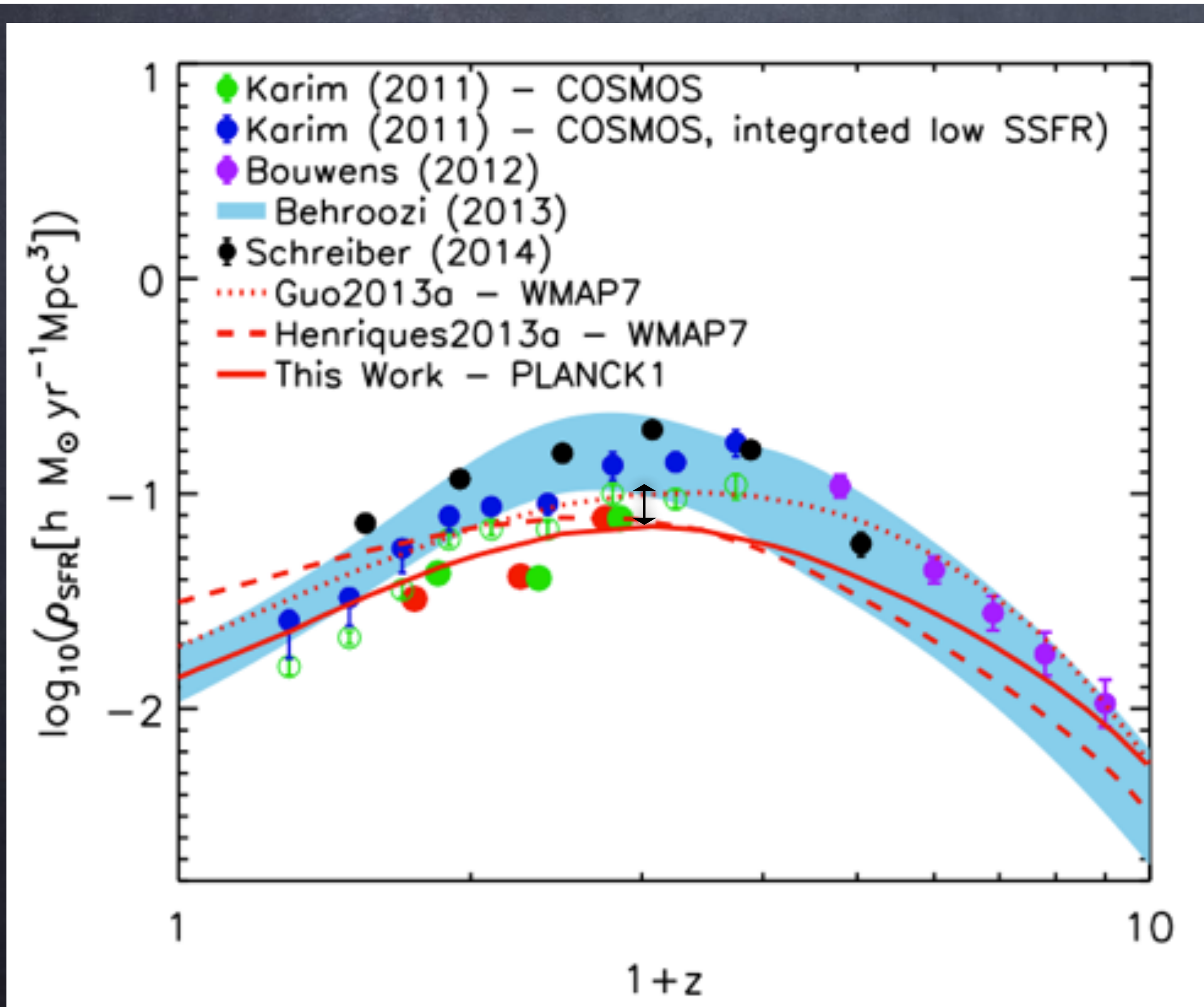
Henriques et al. 2015 changes to satellite properties



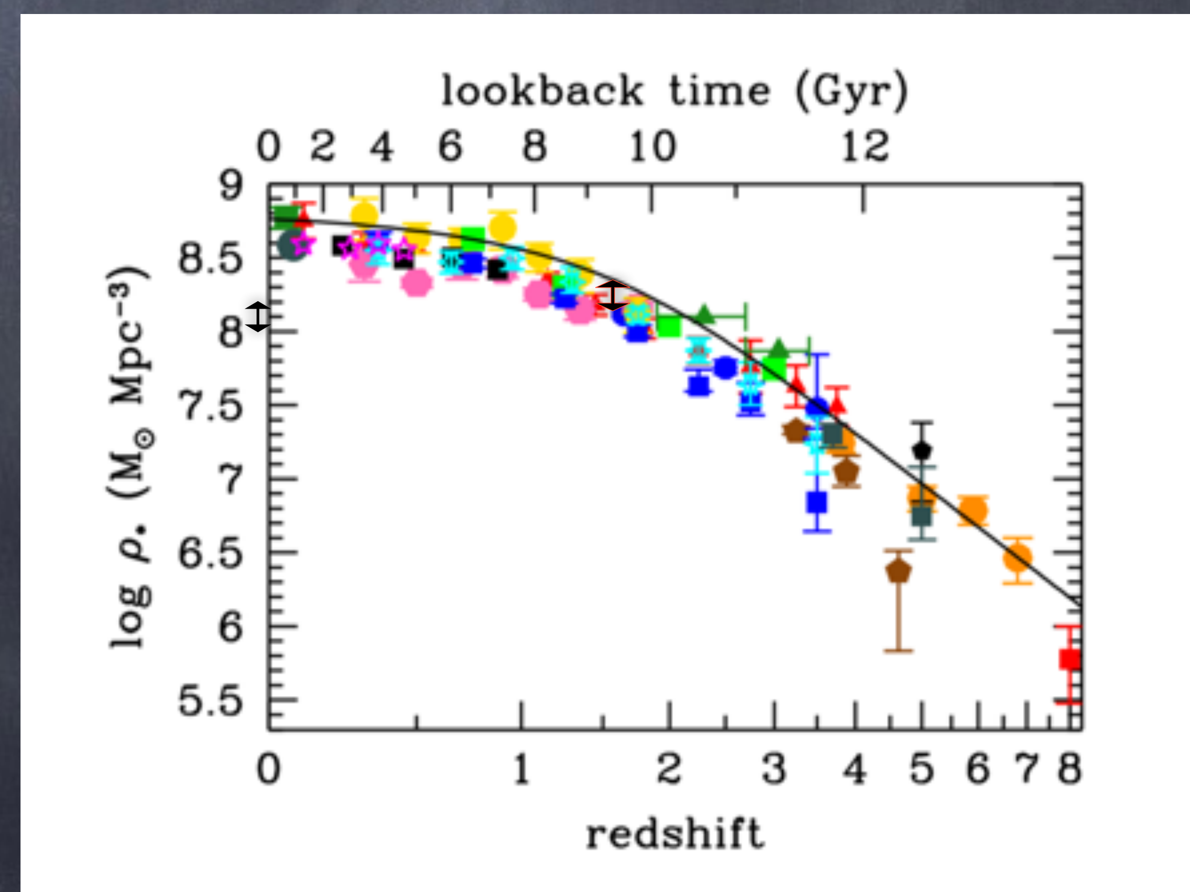
longer reincorporation time-scales for gas ejected by SN in low mass galaxies: lower number density at early times, stronger build up at later times

Model results

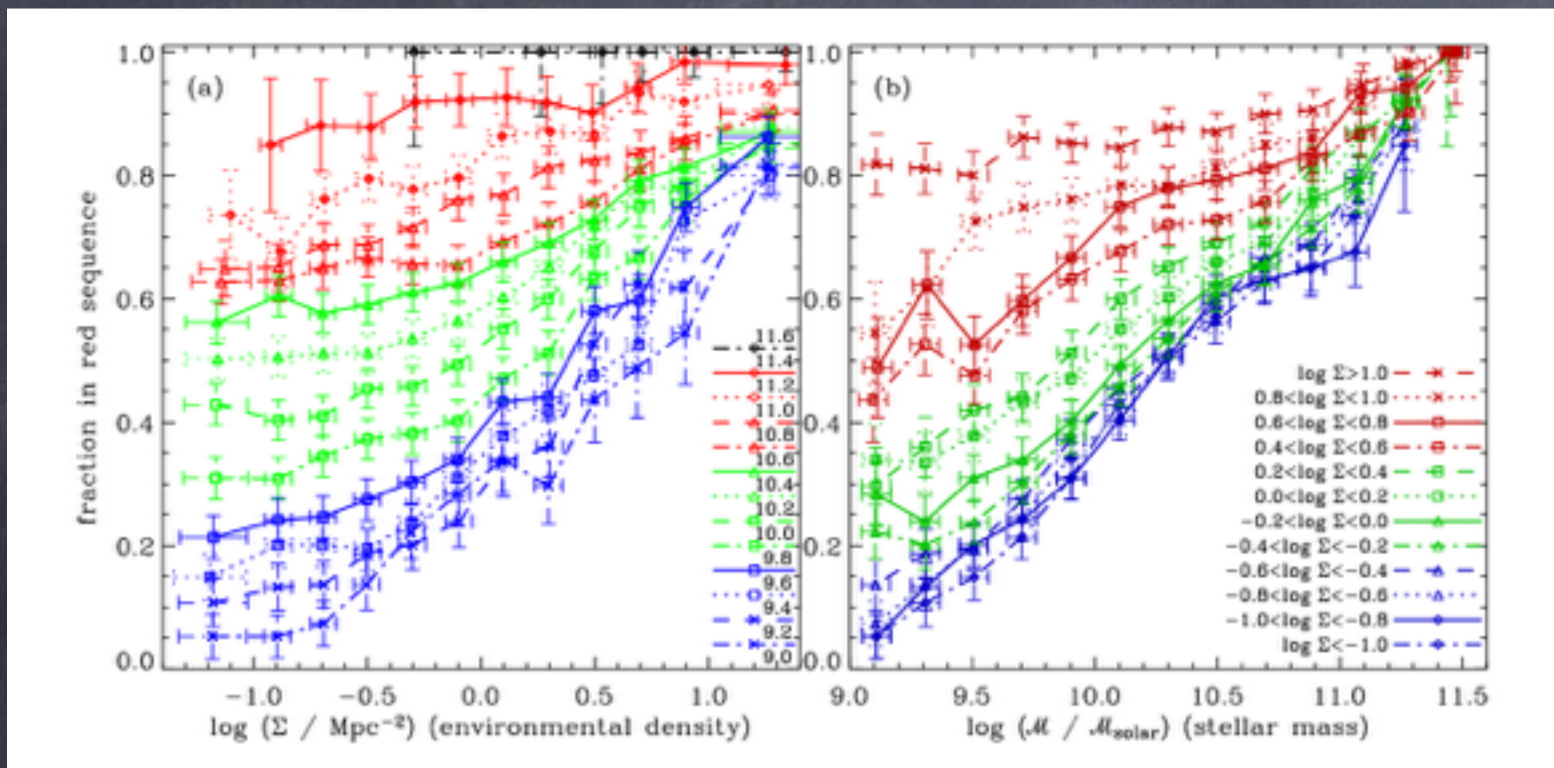




Madau & Dickinson (2014)

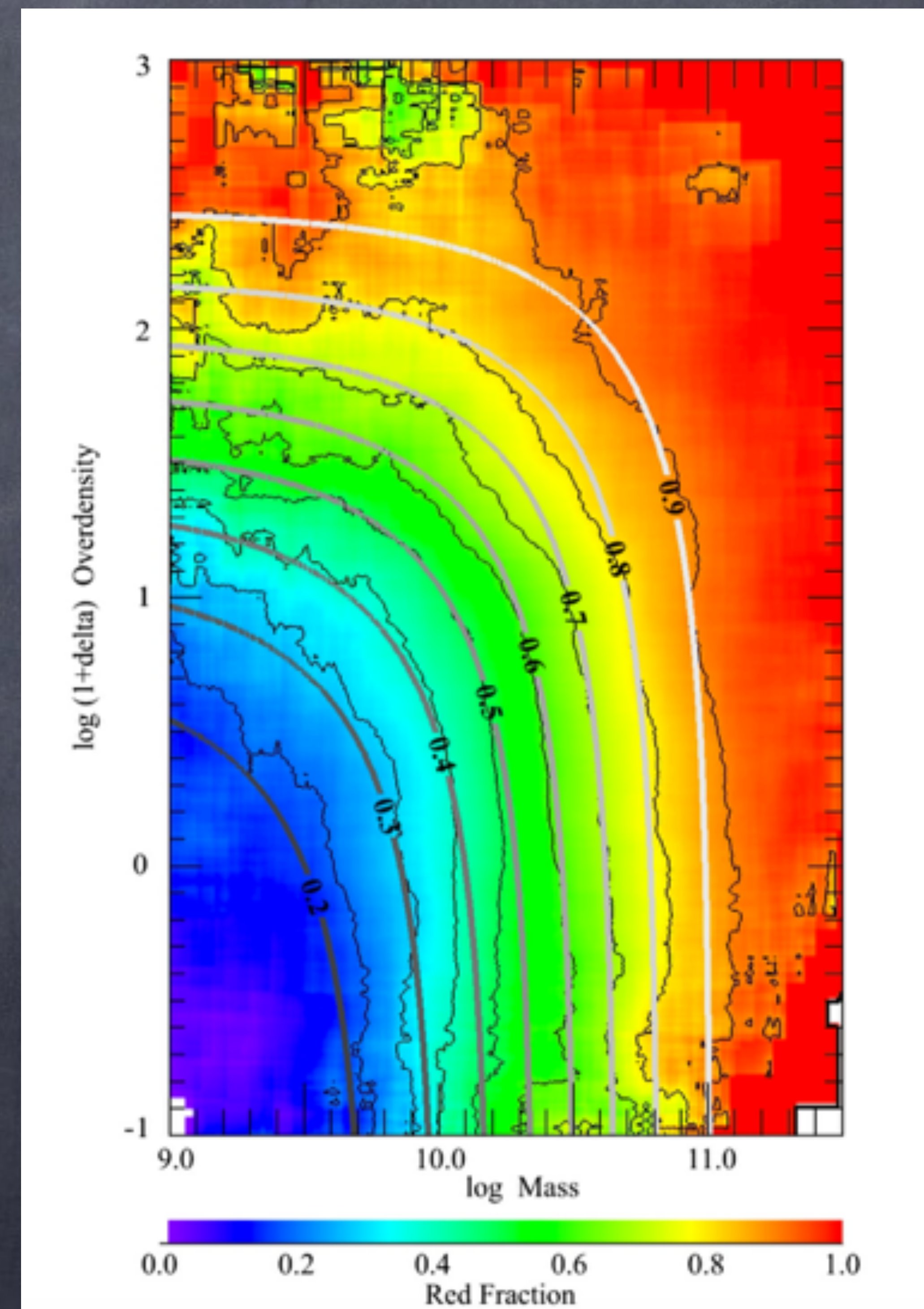


Quenching of Star Formation



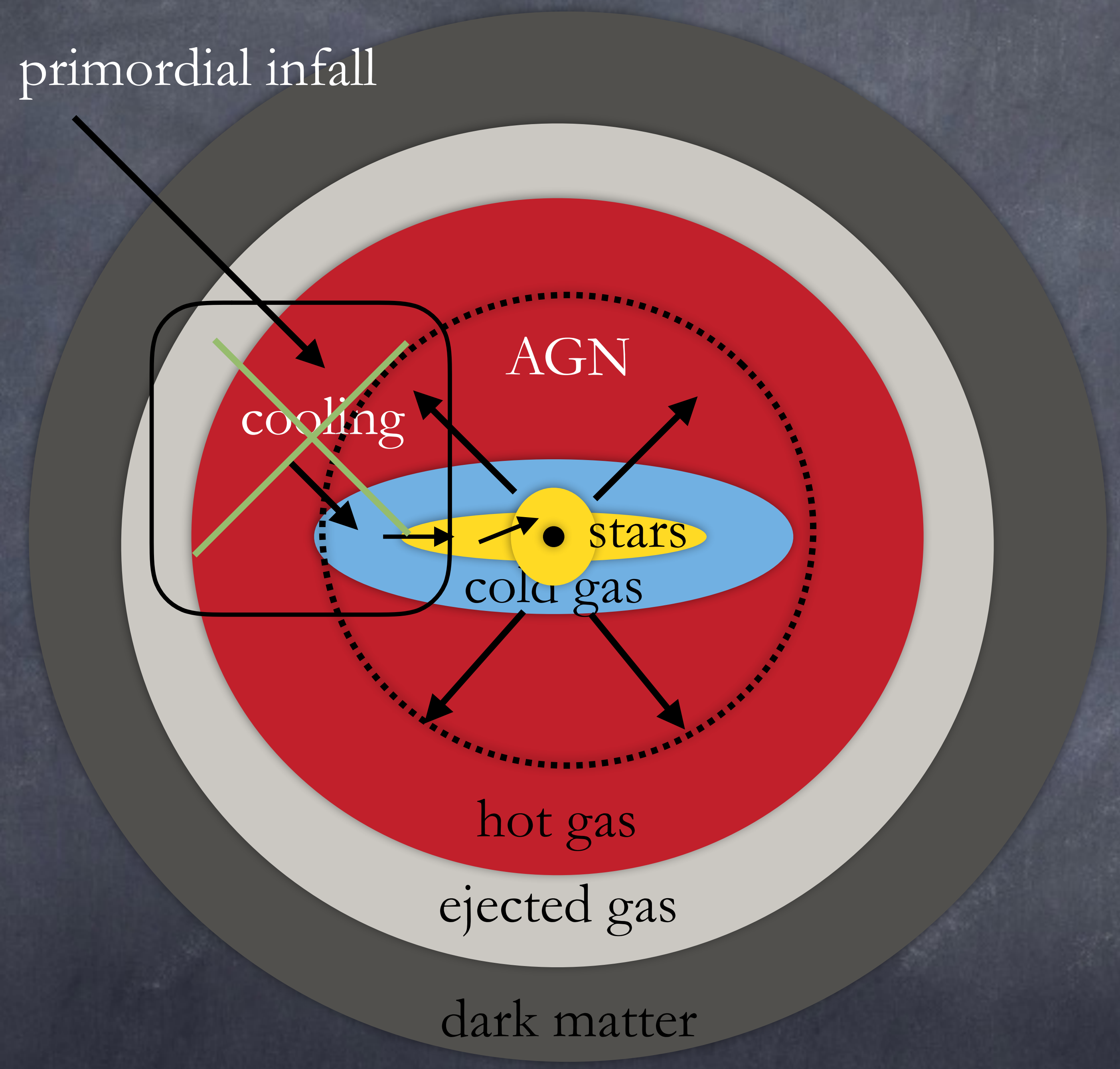
Baldry et al. 2006

Peng et al. 2010



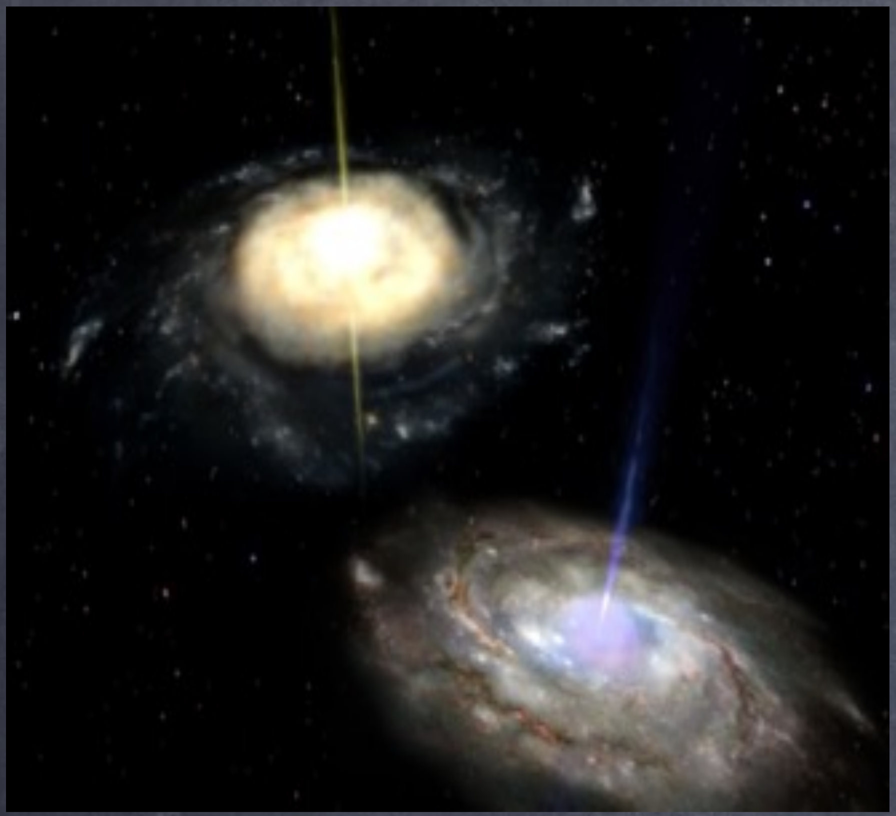
Massive galaxies and galaxies in denser environments tend to be quenched

AGN feedback



completely shuts down the cooling in massive galaxies (those with large enough black holes) leading to a quick cessation of star formation

Black Hole Growth

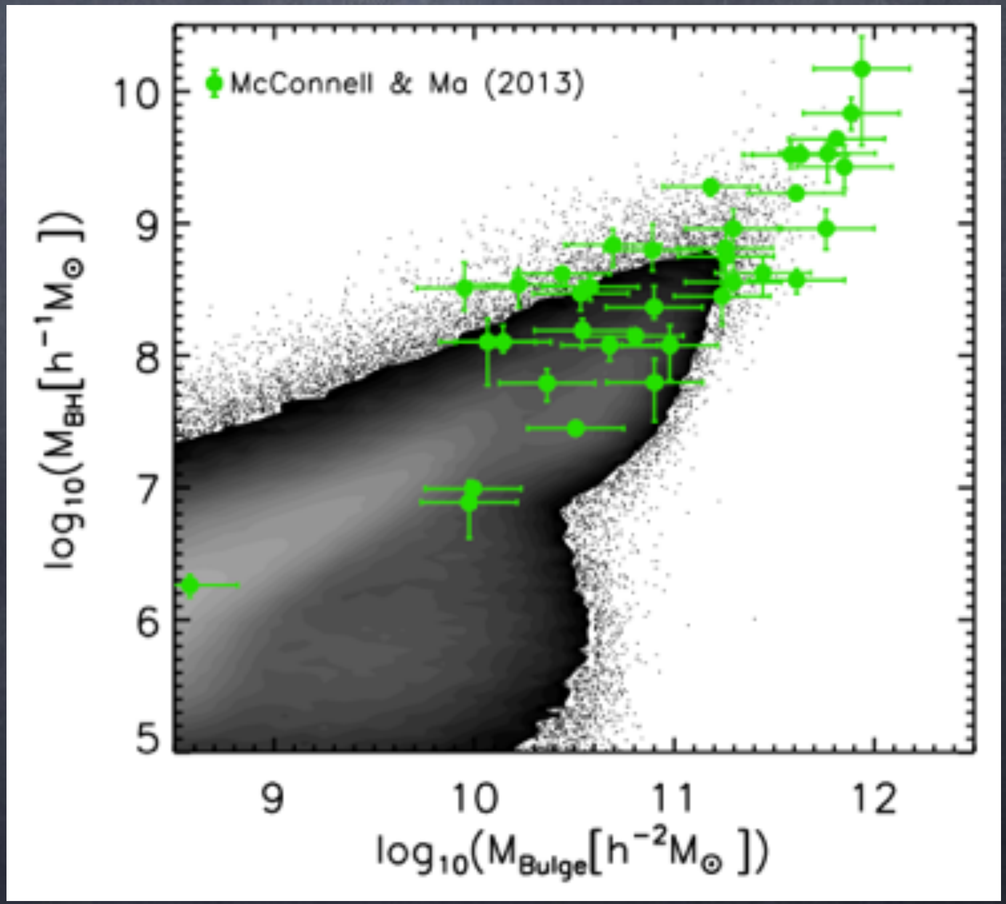


Black Hole Growth During Mergers – Quasar (f_{BH})

BH growth during galaxy mergers both by merging with each other and by accretion of cold disk gas

$$\Delta m_{\rm BH,Q} = \frac{f_{\rm BH}(m_{\rm sat}/m_{\rm central})\, m_{\rm cold}}{1 + (V_{\rm BH}{\rm km\, s^{-1}}/V_{\rm vir})^2}.$$

Kauffmann & Haehnelt 2000



Black Hole Feedback

HST+Chandra

Quiescent Black Hole Accretion Rate – Radio (k_{AGN})

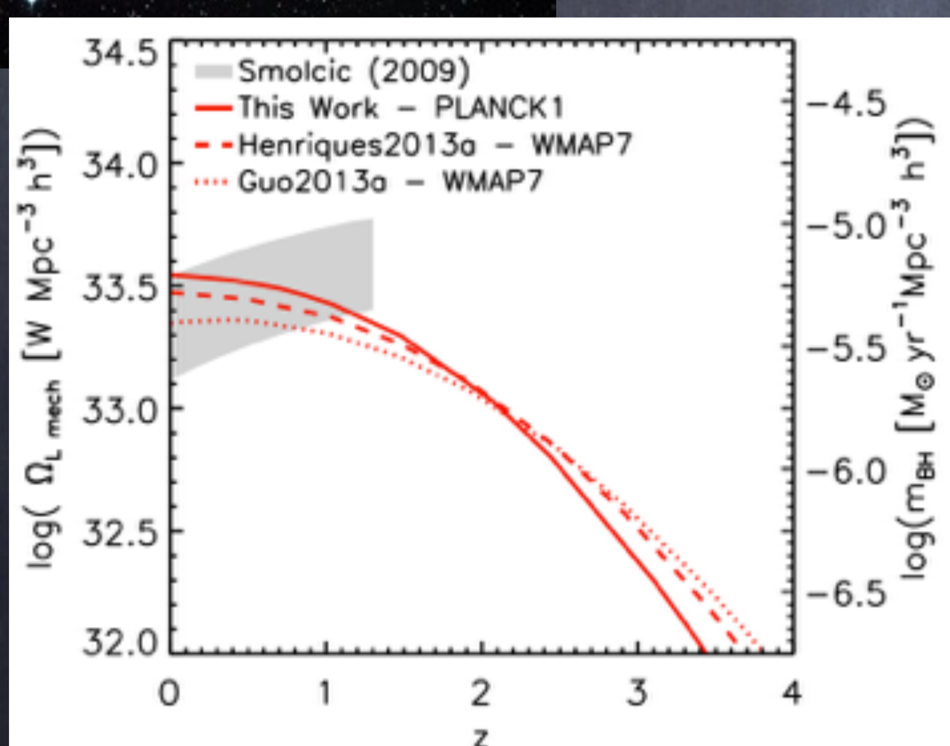
Hot gas accreted by the BH, once a static hot halo has formed around the host galaxy

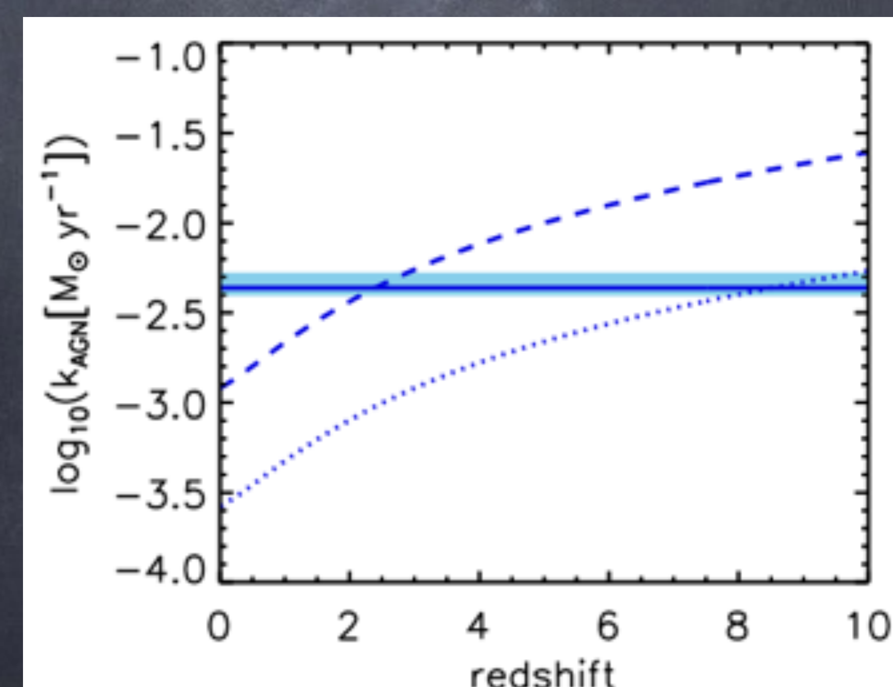
$$\dot{m}_{\rm BH,R} = k_{\rm AGN} \left(\frac{m_{\rm BH}}{10^8\ {\rm M}_\odot}\right) \left(\frac{f_{\rm hot}}{0.1}\right) \left(\frac{V_{\rm vir}}{200\,{\rm km\,s^{-1}}}\right)^3, \quad \text{(A11)}$$

Croton et al. 2006

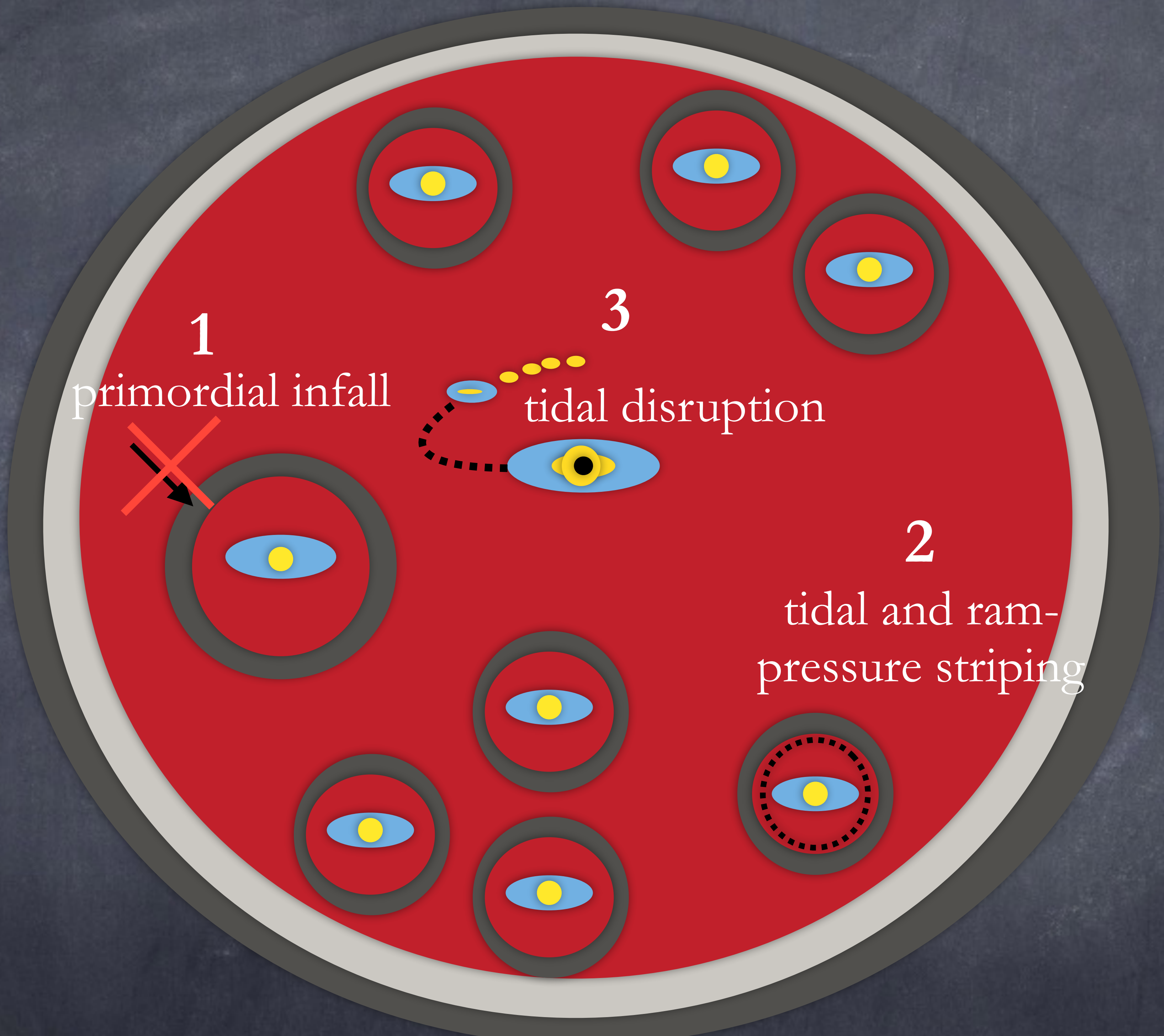
Henriques et al 2015

$$\dot{M}_{\rm BH} = k_{\rm AGN} \left(\frac{M_{\rm hot}}{10^{11}/{\rm h\,M_\odot}}\right) \left(\frac{M_{\rm BH}}{10^8/{\rm h\,M_\odot}}\right).$$





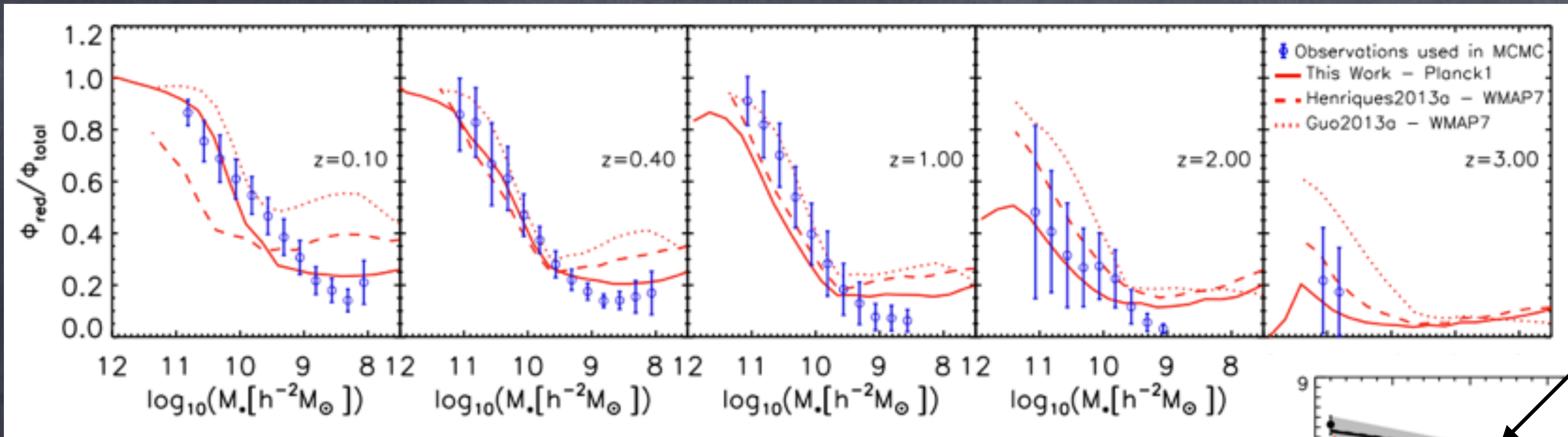
Environment

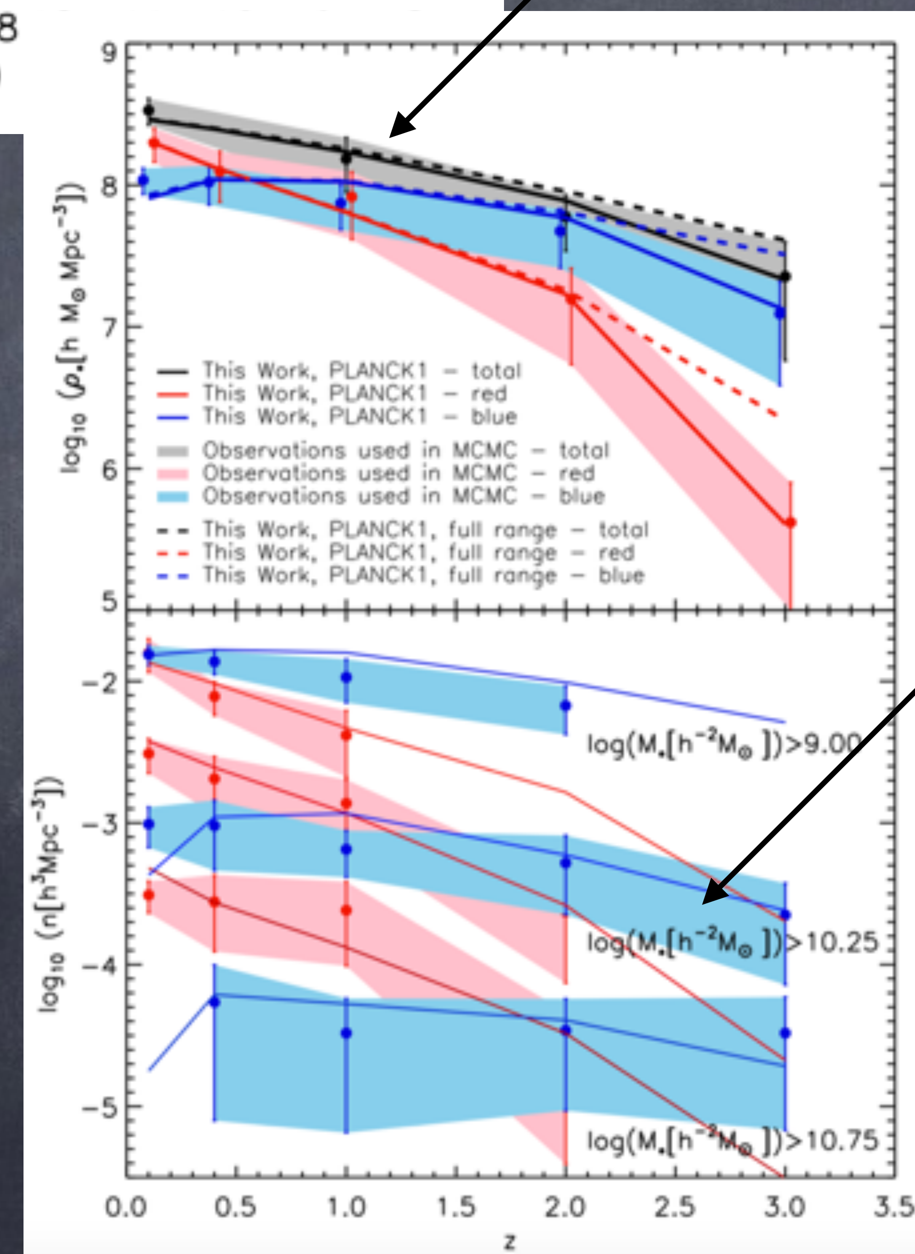


Environment removes the fuel for star formation in satellite galaxies. It is the predominant quenching mechanism in satellite galaxies

AGN Quenching

Henriques et al. 2015

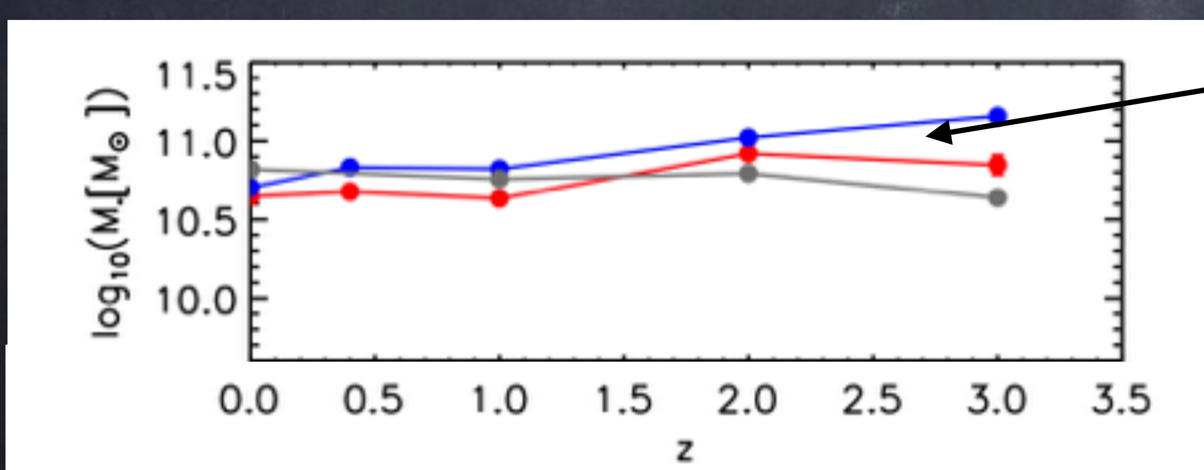




What process drives more than 50% of galaxies to become quenched and remain quenched below z=1?

Why are more massive galaxies quenched first?

(satellites never more than 40%)

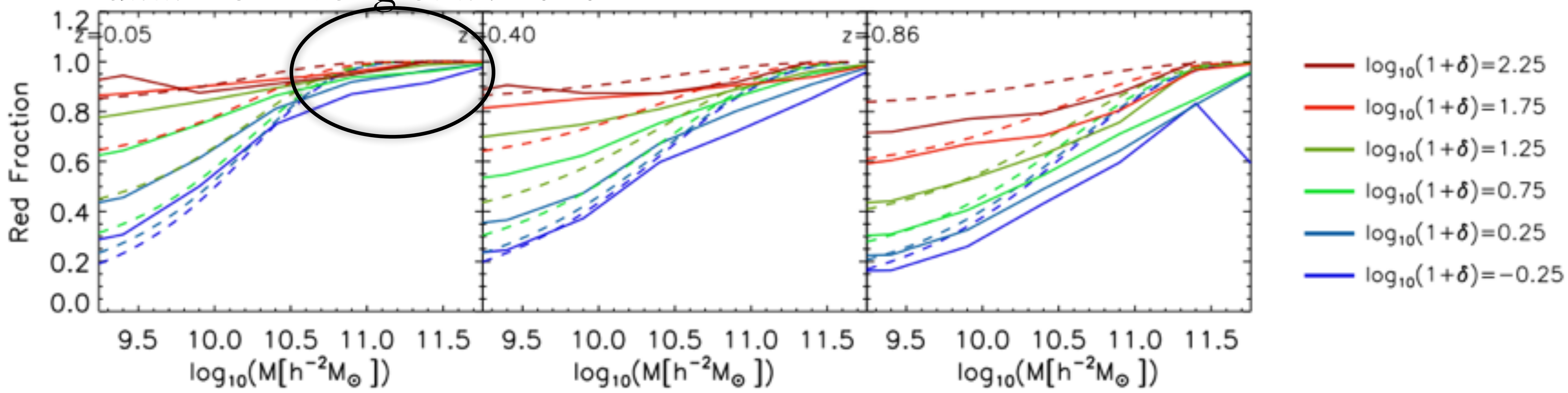


fixed mass scale

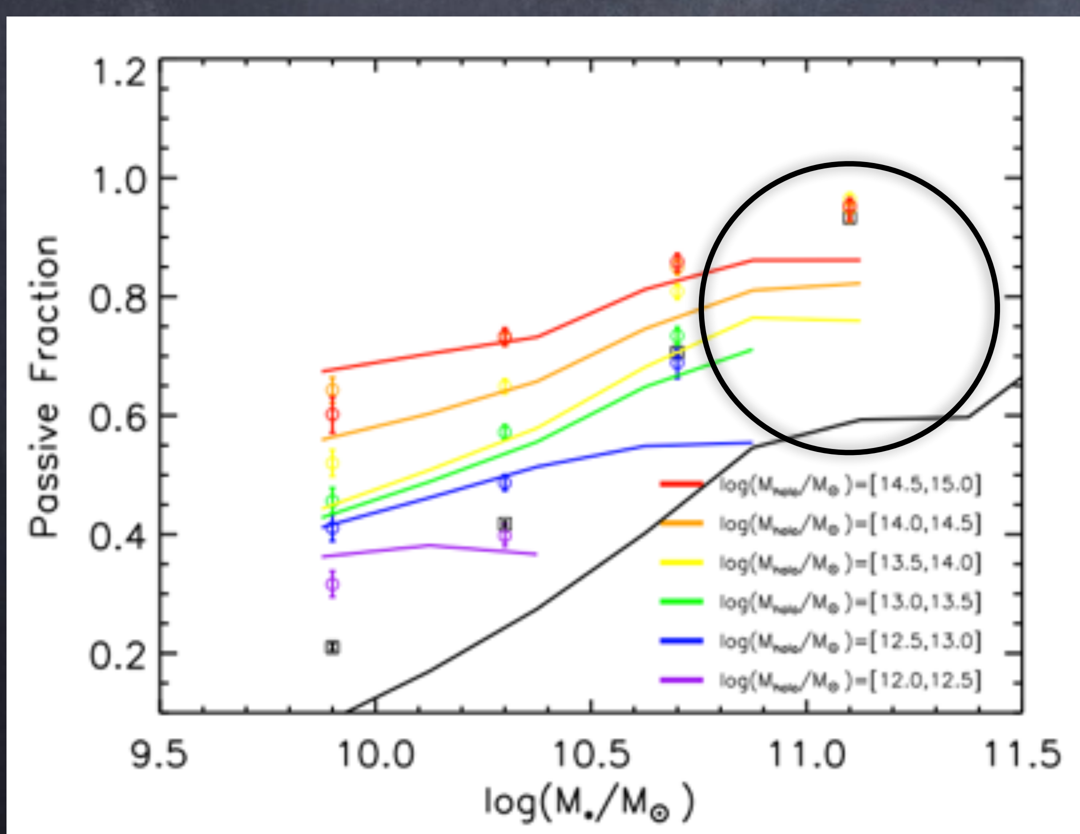
AGN Quenching

passive fraction vs stellar mass at fixed environment

data from Peng et al. 2010



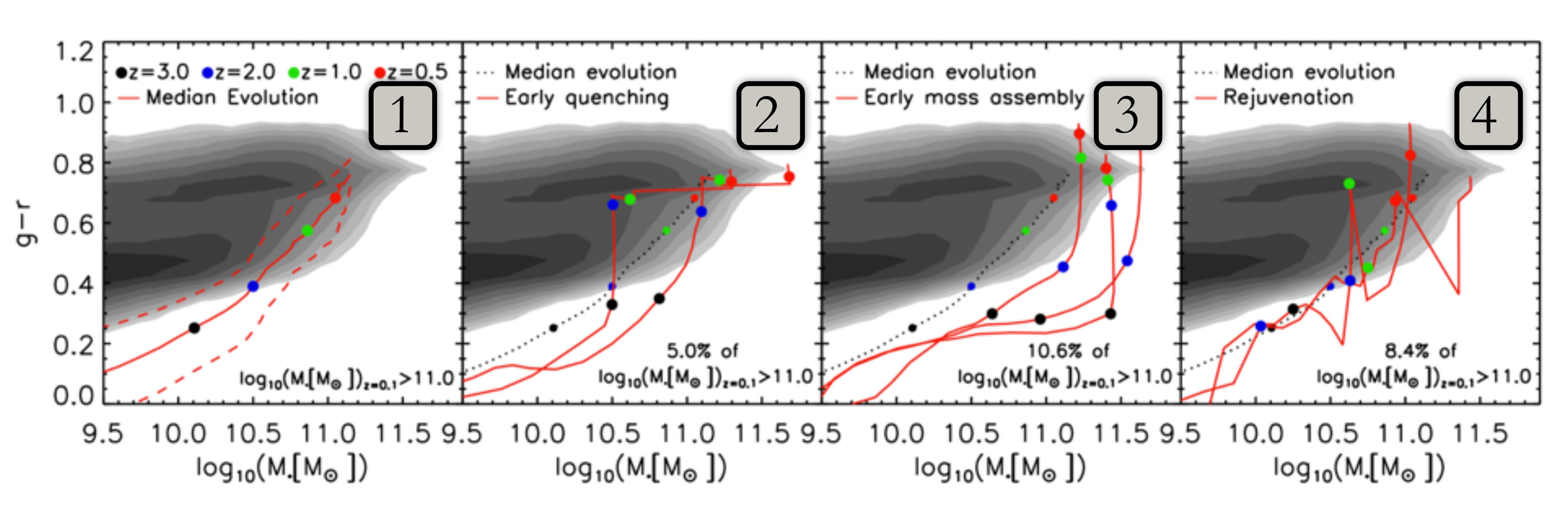
data from Wetzel et al. 2012



AGN quenches massive galaxies at the expected rates, but 30% of very massive galaxies remain SF - BH growth only in mergers

Galaxy Formation in the Planck Cosmology IV; Henriques, White, Thomas, et al.; 2016; in prep

Colour evolution of massive galaxies



1 - median evolution of massive galaxies with quenching at 0.5<z<3.0

2 - extreme age “downsizing” with quenching at z~2

3 - extreme mass-assembly “downsizing” ($10^{11}M_{sun}$ at z~3)

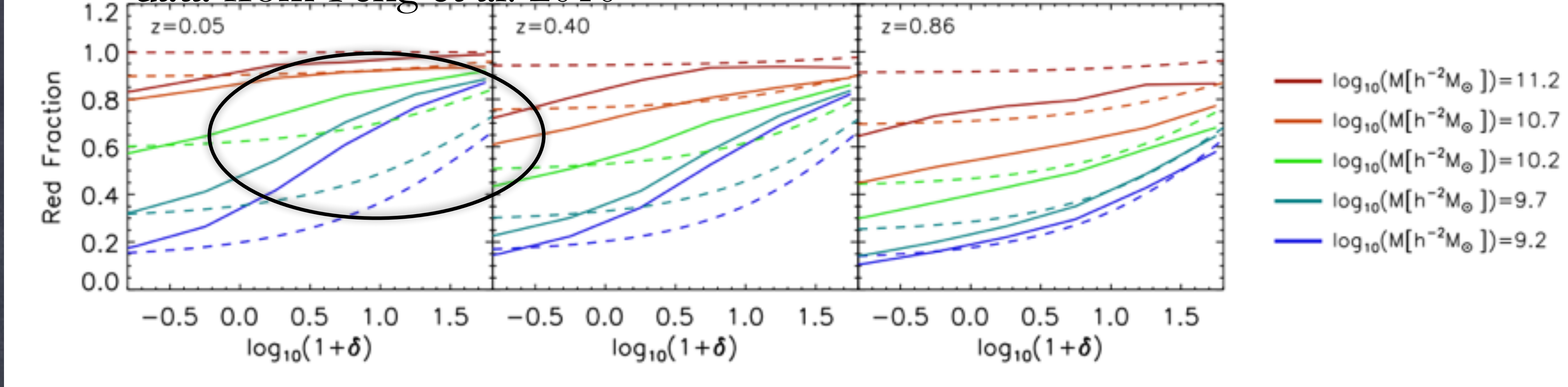
4 - return to the star-forming sequence

Galaxy Formation in the Planck Cosmology IV; Henriques, White, Thomas, et al.; 2016; in prep

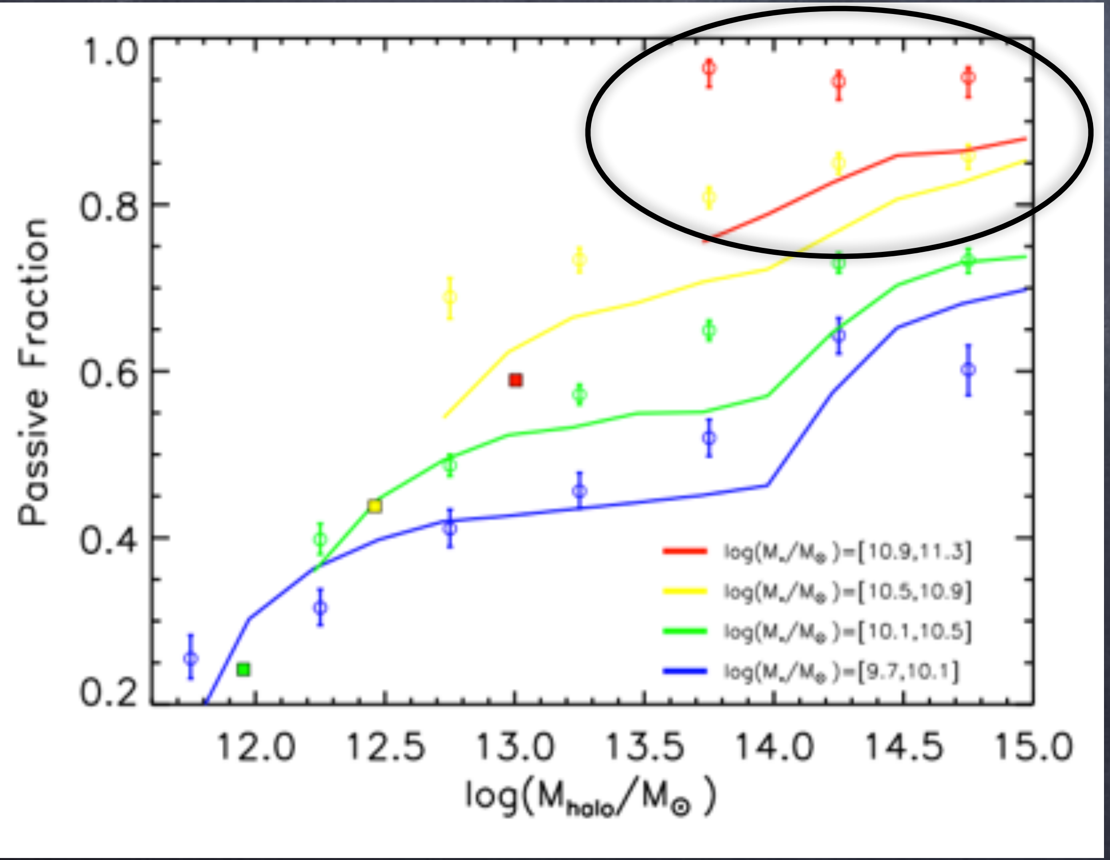
Environment Quenching

passive fraction vs environment at fixed stellar mass

data from Peng et al. 2010



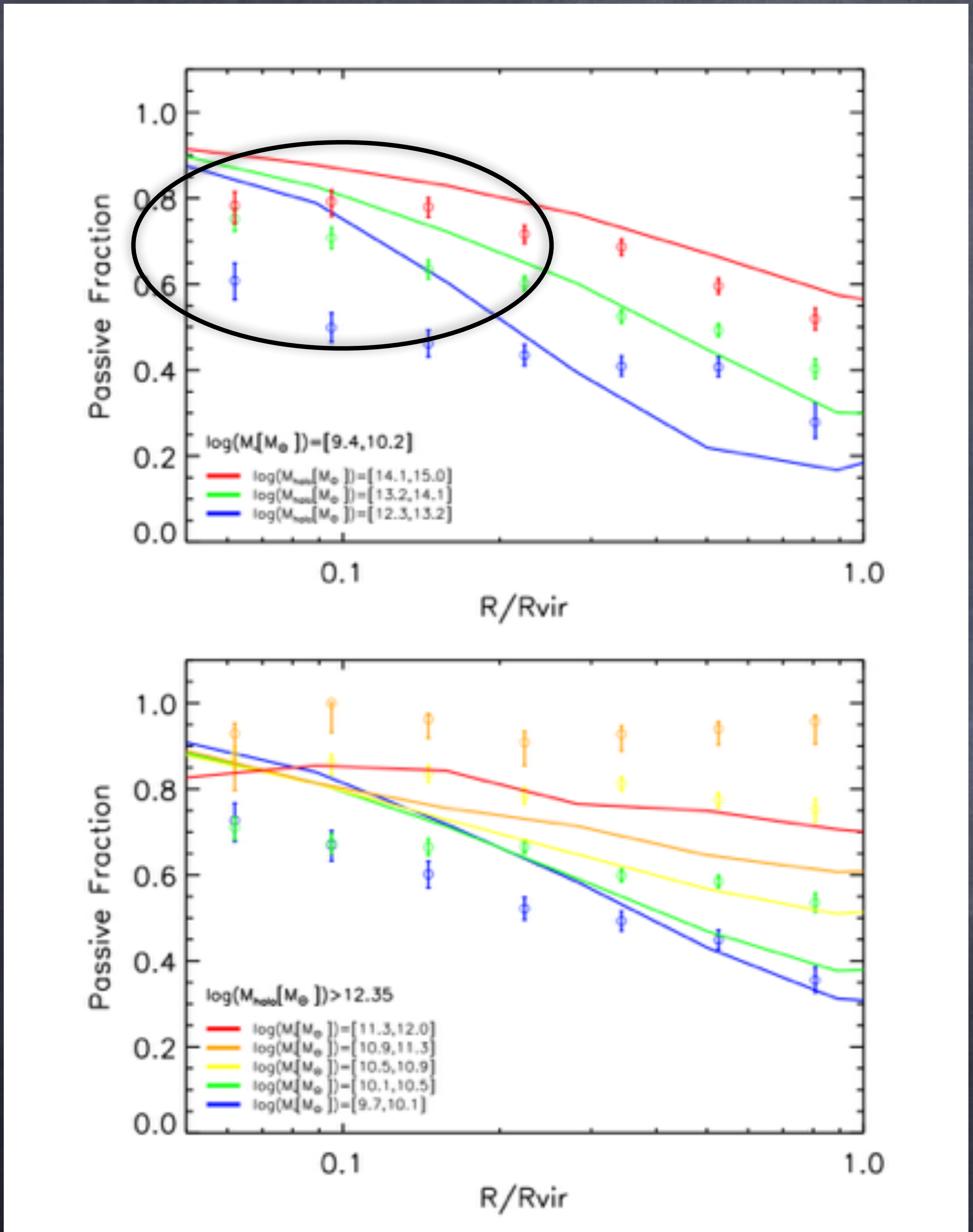
data from Wetzel et al. 2012



environmental effects quench satellites at the observed rates, except in the densest regions

Galaxy Formation in the Planck Cosmology IV; Henriques, White, Thomas, et al.; 2016; in prep

Environment Quenching

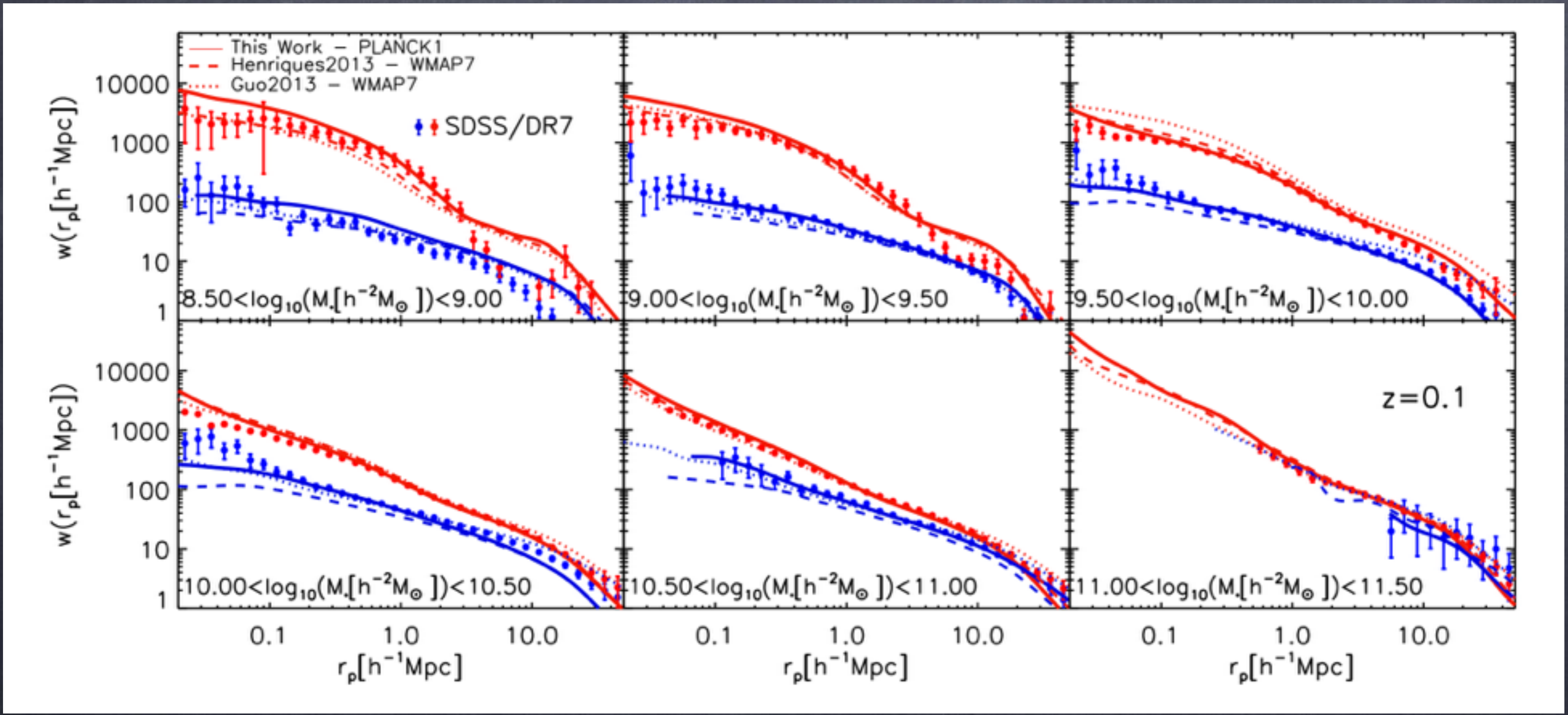


too many quenched galaxies in the inner regions of groups and clusters ($0.1R_{vir}$), less than 10% of the galaxies

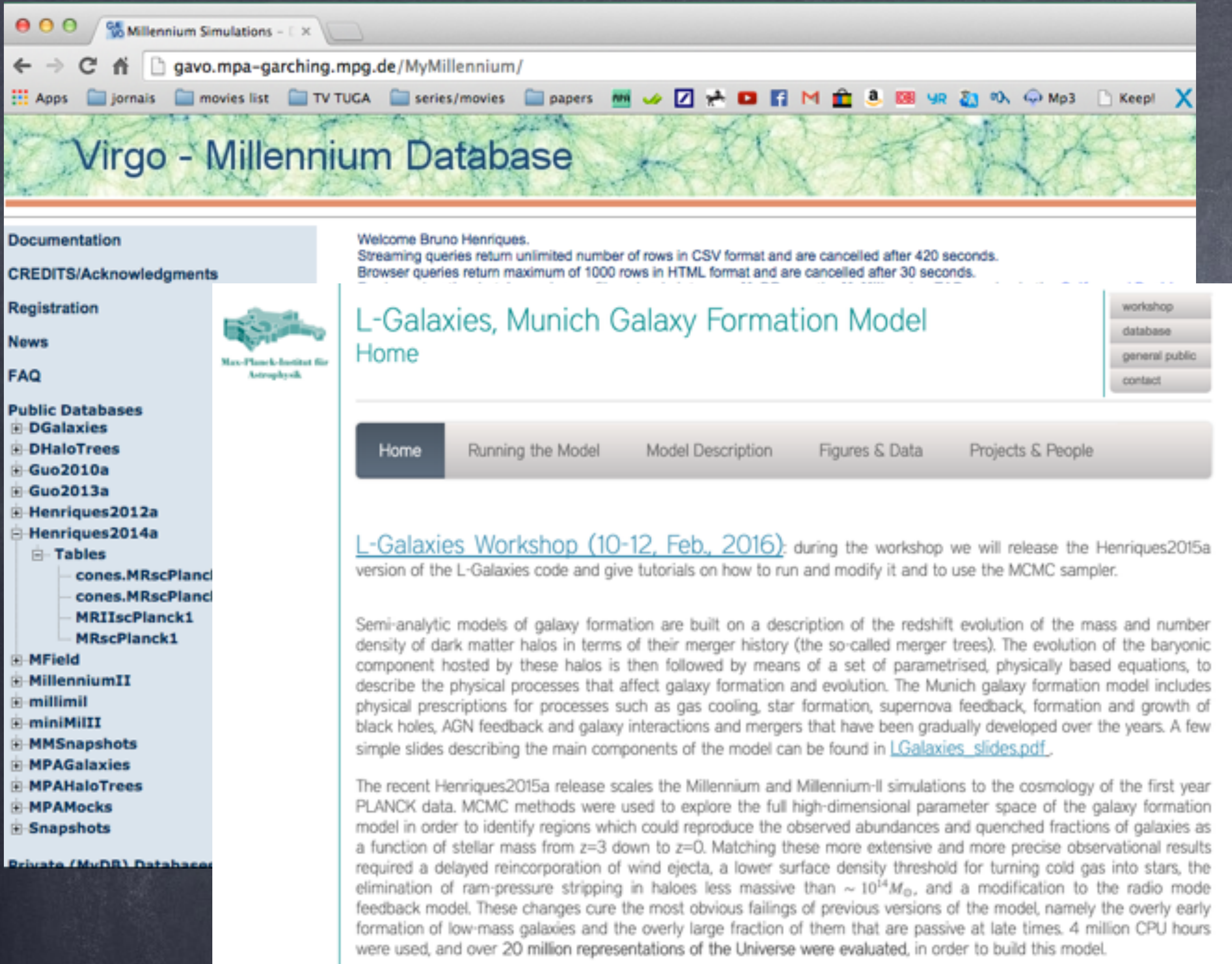
despite no ram-pressure striping in clusters the remaining environmental effects are still too strong. Do we need interaction induced star formation events?

Galaxy Formation in the Planck Cosmology IV; Henriques, White, Thomas, et al.; 2016; in prep

Environment Quenching



Galaxy Formation in the Planck Cosmology IV;
Henriques, White, Thomas, et al.; 2016; in prep


Millennium Simulations
gavo.mpa-garching.mpg.de/MyMillennium/
Apps | jornais | movies list | TV TUGA | series/movies | papers | Mp3 | Keep!

Virgo - Millennium Database

Documentation
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DGalaxies
DHaloTrees
Guo2010a
Guo2013a
Henriques2012a
Henriques2014a
Tables
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MRIIscPlanck1
MRscPlanck1
MField
MillenniumII
millimil
miniMilII
MMSnapshots
MPAGalaxies
MPAHaloTrees
MPAMocks
Snapshots
Private (MyDB) Databases

Welcome Bruno Henriques.
Streaming queries return unlimited number of rows in CSV format and are cancelled after 420 seconds.
Browser queries return maximum of 1000 rows in HTML format and are cancelled after 30 seconds.

Max-Planck-Institut für Astrophysik

L-Galaxies, Munich Galaxy Formation Model
Home

workshop | database | general public | contact

Home | Running the Model | Model Description | Figures & Data | Projects & People

L-Galaxies Workshop (10-12, Feb., 2016): during the workshop we will release the Henriques2015a version of the L-Galaxies code and give tutorials on how to run and modify it and to use the MCMC sampler.

Semi-analytic models of galaxy formation are built on a description of the redshift evolution of the mass and number density of dark matter halos in terms of their merger history (the so-called merger trees). The evolution of the baryonic component hosted by these halos is then followed by means of a set of parametrised, physically based equations, to describe the physical processes that affect galaxy formation and evolution. The Munich galaxy formation model includes physical prescriptions for processes such as gas cooling, star formation, supernova feedback, formation and growth of black holes, AGN feedback and galaxy interactions and mergers that have been gradually developed over the years. A few simple slides describing the main components of the model can be found in LGalaxies_slides.pdf.

The recent Henriques2015a release scales the Millennium and Millennium-II simulations to the cosmology of the first year PLANCK data. MCMC methods were used to explore the full high-dimensional parameter space of the galaxy formation model in order to identify regions which could reproduce the observed abundances and quenched fractions of galaxies as a function of stellar mass from z=3 down to z=0. Matching these more extensive and more precise observational results required a delayed reincorporation of wind ejecta, a lower surface density threshold for turning cold gas into stars, the elimination of ram-pressure stripping in haloes less massive than $\sim 10^{14} M_\odot$, and a modification to the radio mode feedback model. These changes cure the most obvious failings of previous versions of the model, namely the overly early formation of low-mass galaxies and the overly large fraction of them that are passive at late times. 4 million CPU hours were used, and over 20 million representations of the Universe were evaluated, in order to build this model.