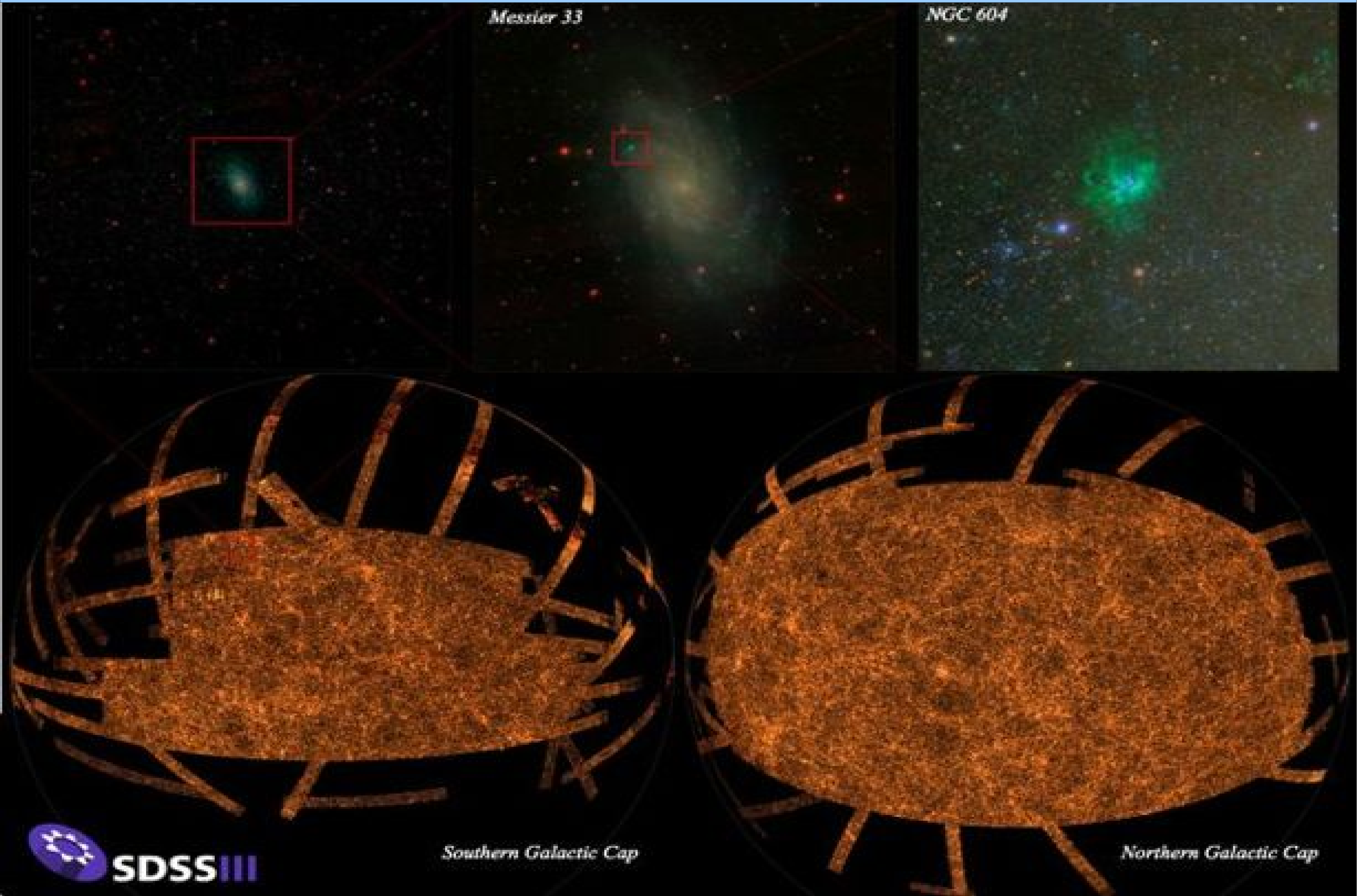
WHAT CAN WE DEDUCE FROM STUDIES OF NEARBY GALAXY POPULATIONS?



1) This talk focuses on large statistical samples, SDSS in particular

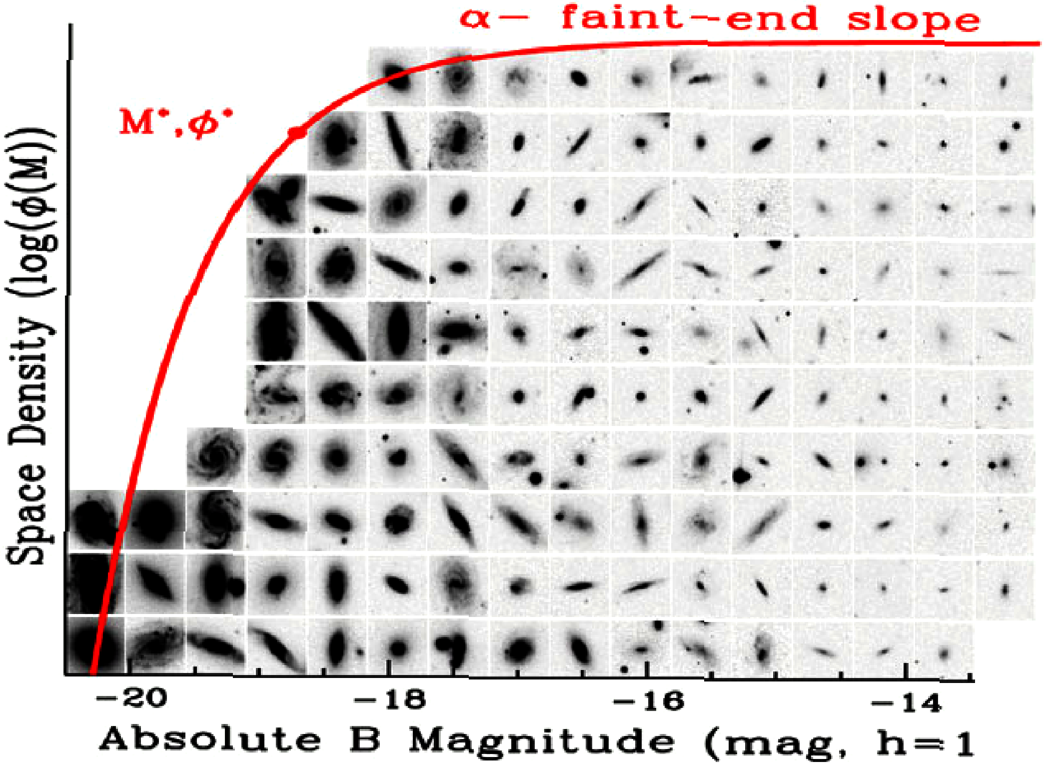
2) Spatially resolved imaging, but only single fibre spectroscopy

3) Focus is on OPTICAL imaging and spectroscopy: this provides information about stellar populations, but not gas.

TWO PARALLEL APPROACHES:

“Ab initio” approach to understanding galaxy formation: now that we know the initial conditions, let us appeal to **physical intuition** and calculate forward to the best of our abilities.

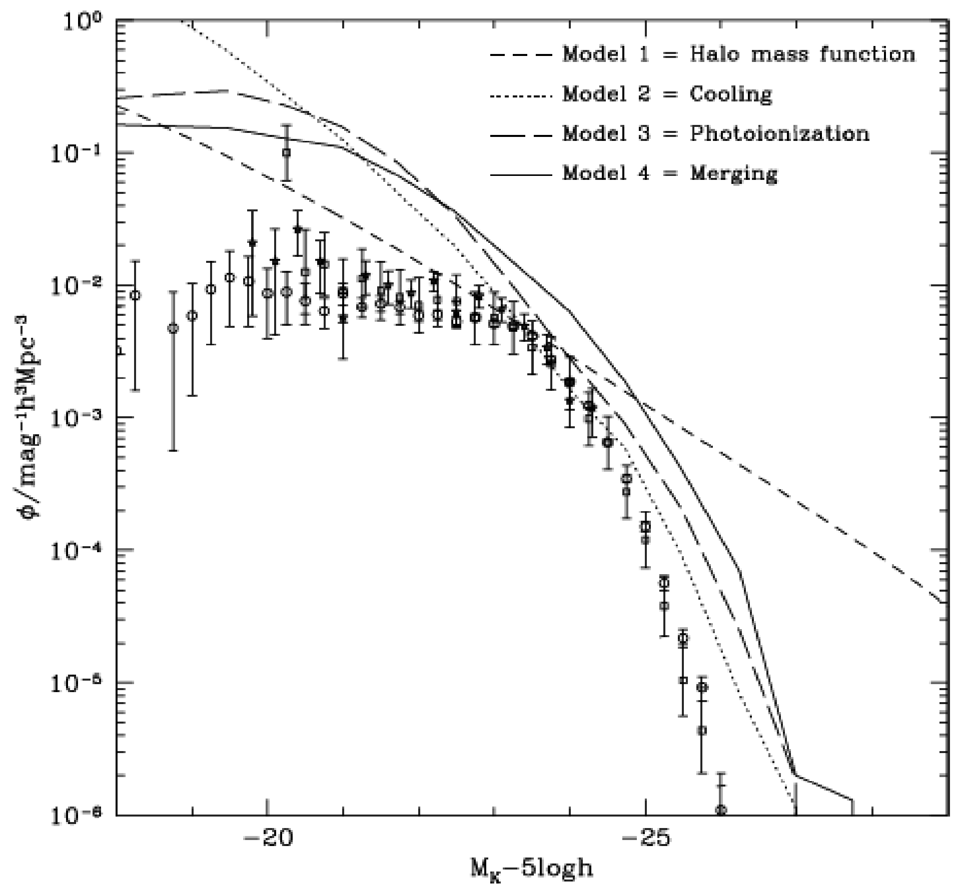
“Darwinian” approach to understanding galaxy formation: collect the pigeons and the butterflies, dissect and study them, try to ascertain whether **physical intuition** was correct.



COUNTING GALAXIES

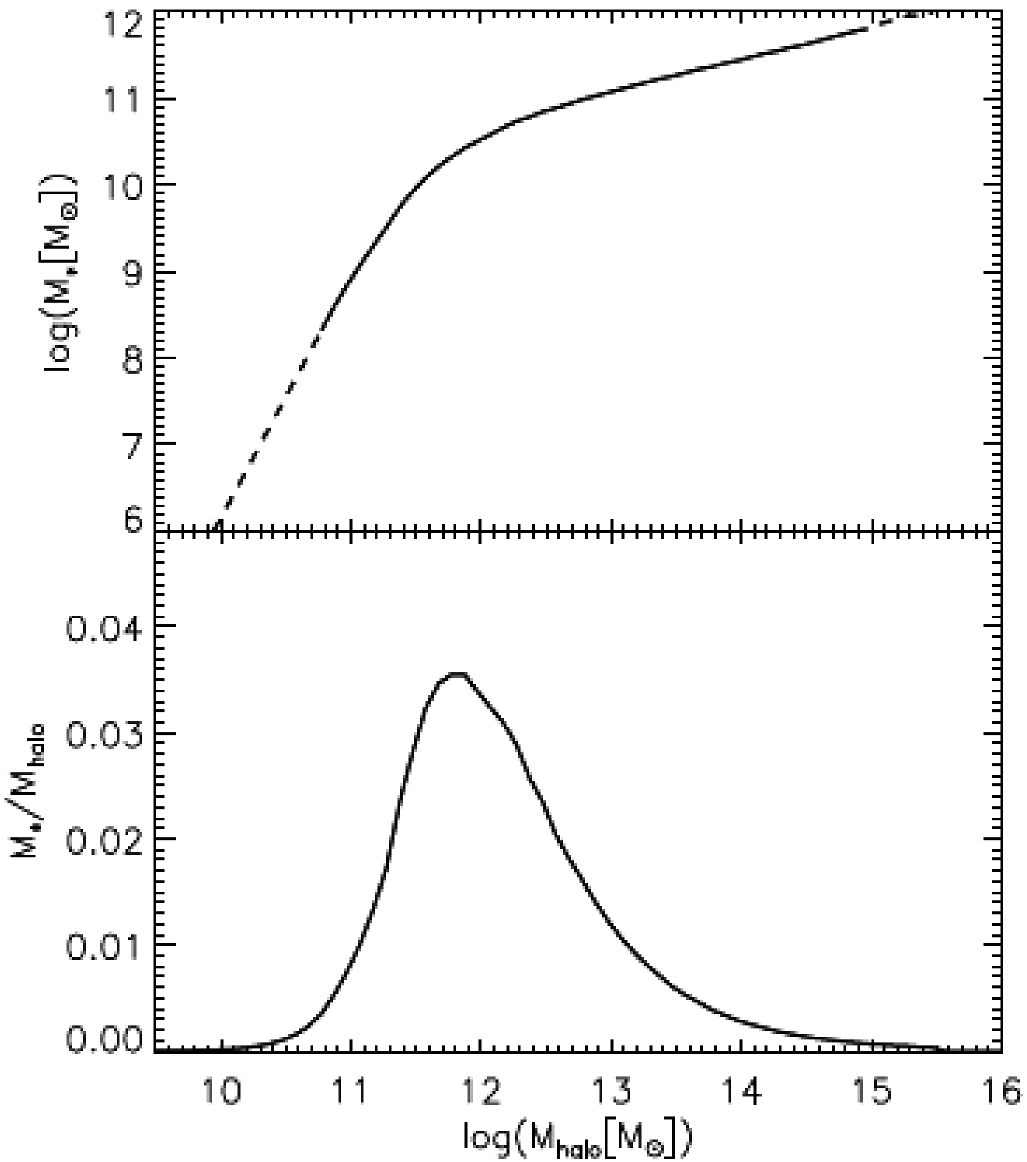
Problem: Too much degeneracy. Many different physical processes shape the luminosity function

Benson et al (2003)



BIG ADVANCE thanks to large surveys:

Use of galaxy/galaxy lensing and/or clustering to derive the relation between dark matter halo mass and galaxy mass/luminosity

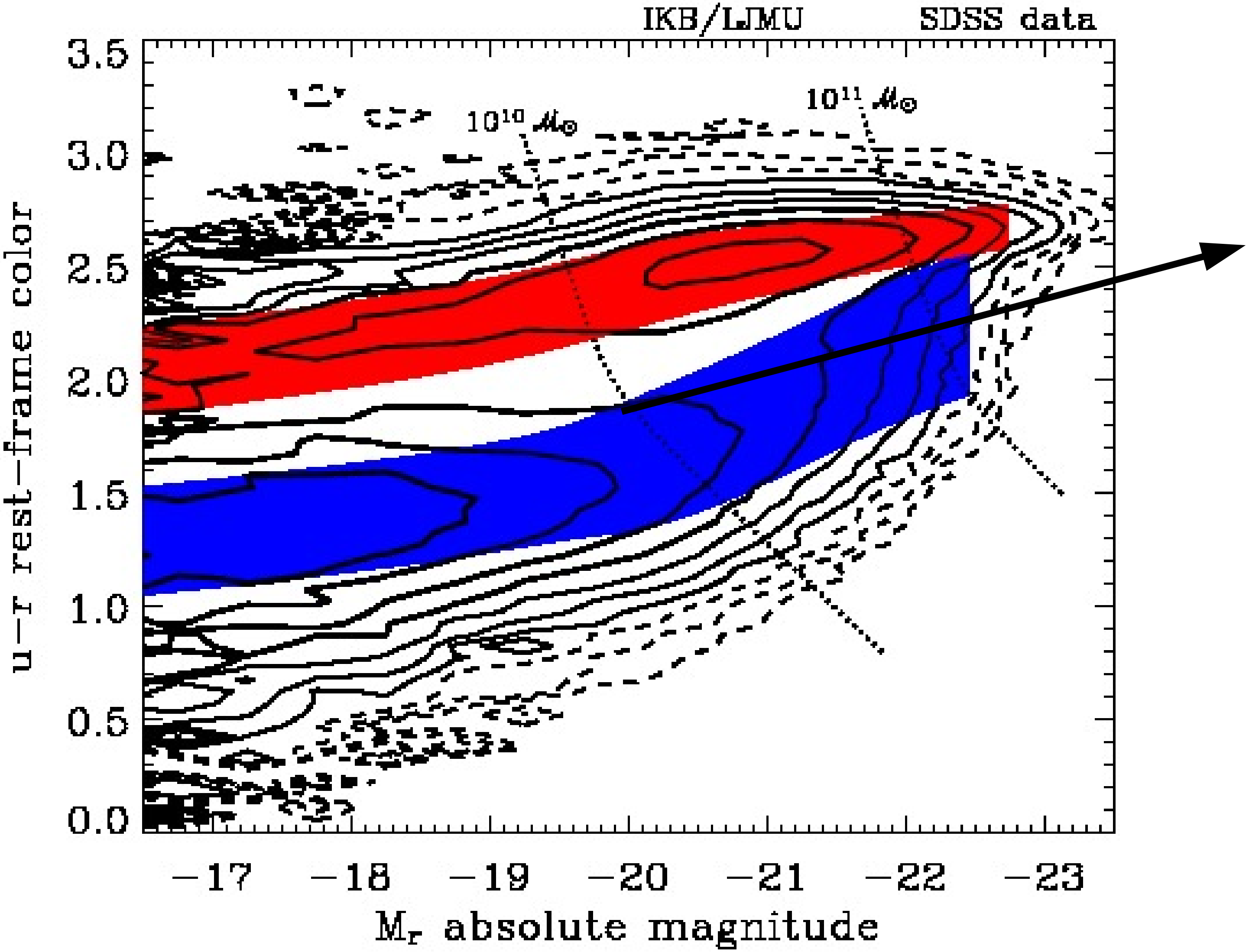


Consensus view:

Efficiency of conversion of baryons into stars peaks at a halo mass of a few x 10^11 Msun

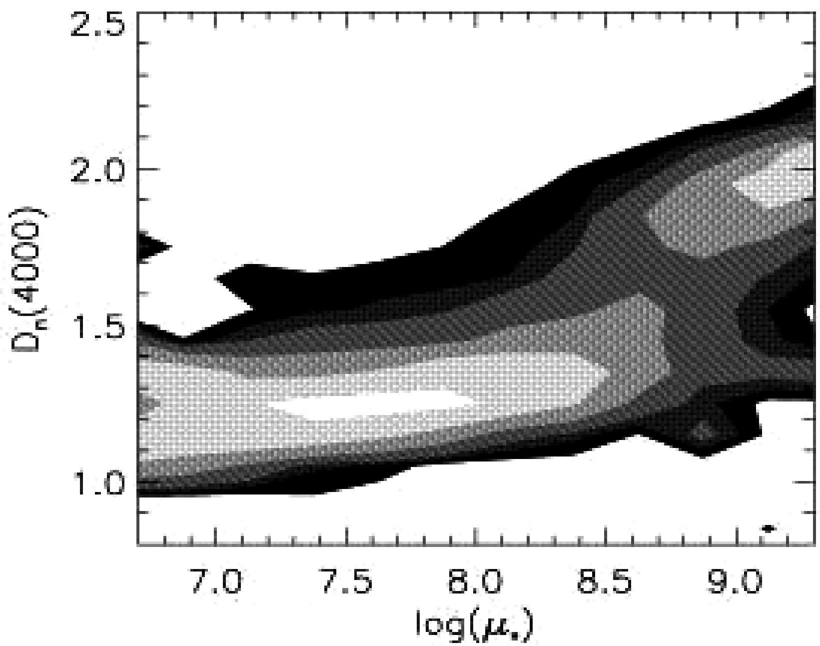
Note that the typical galaxy in such a halo has a stellar mass of
a few times 10^10 Msun

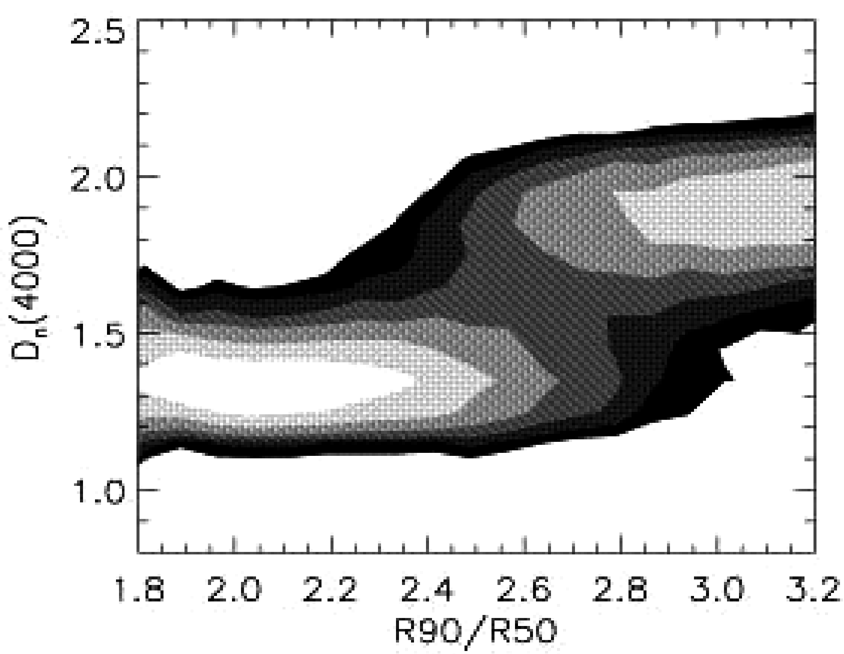
Guo & White 2010



The galaxy population undergoes an abrupt transition from "actively star-forming" to "passive" at a stellar mass of a few x 10^10 Msun

Baldry et al 2004





Is the transition from **"actively star-forming"** to **"passive"** driven by processes that connect to the dark matter **halo,** or is the transition caused by **internal** processes?

Bimodality is seen not only in stellar mass, but also in galaxy structural parameters Kauffmann et al (2003)

HALO-BASED PROCESSES

1) Quenching of star formation in massive groups and clusters

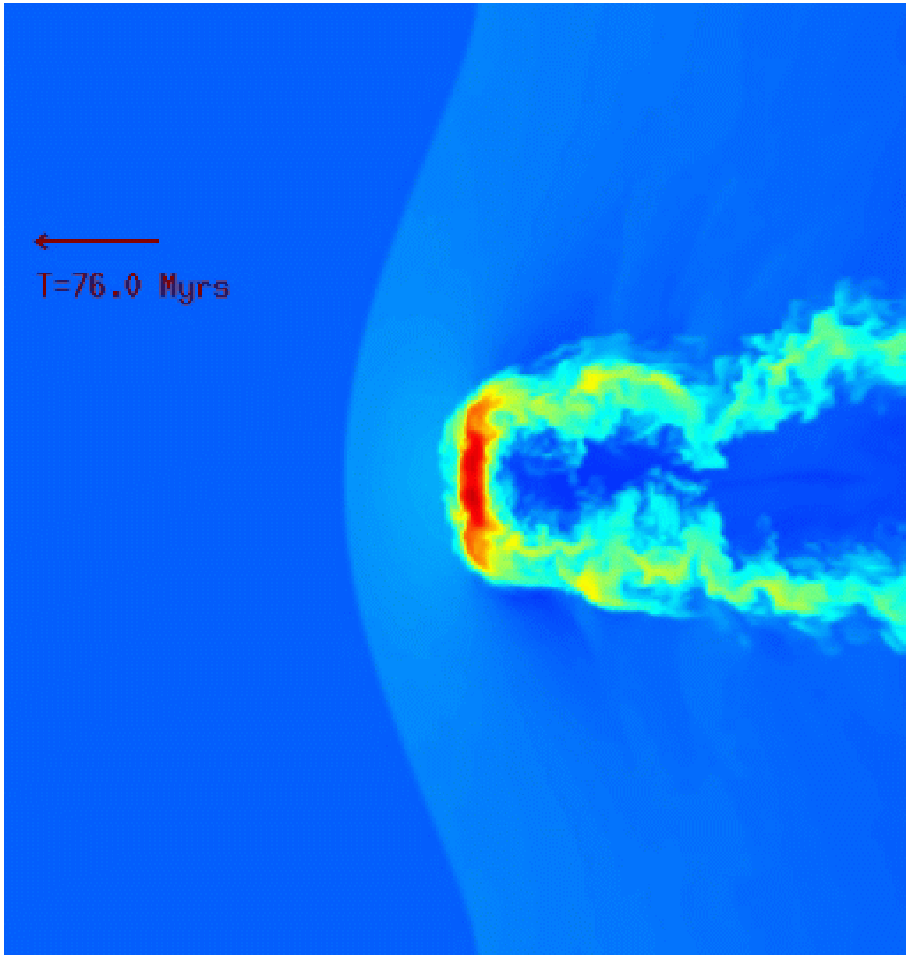
2) Radio mode feedback

INTERNAL PROCESSES

1) Ejection of metals by supernovae

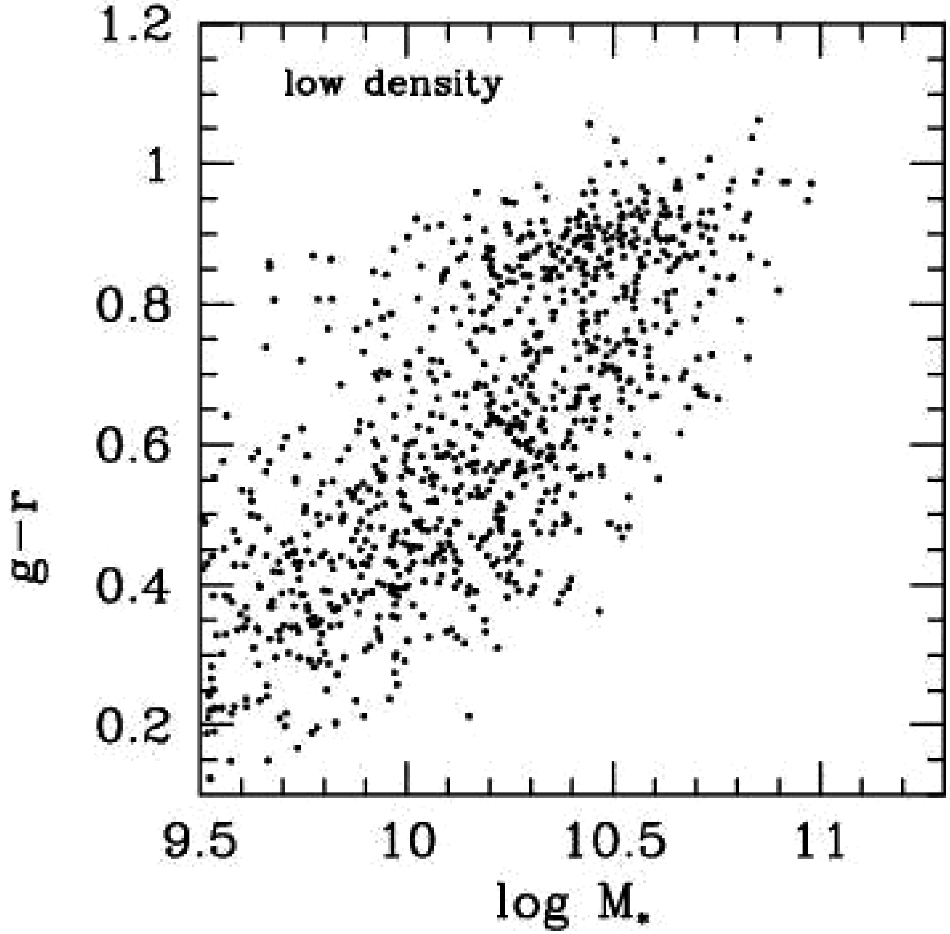
2) Regulation of star formation by interactions and internal instabilities

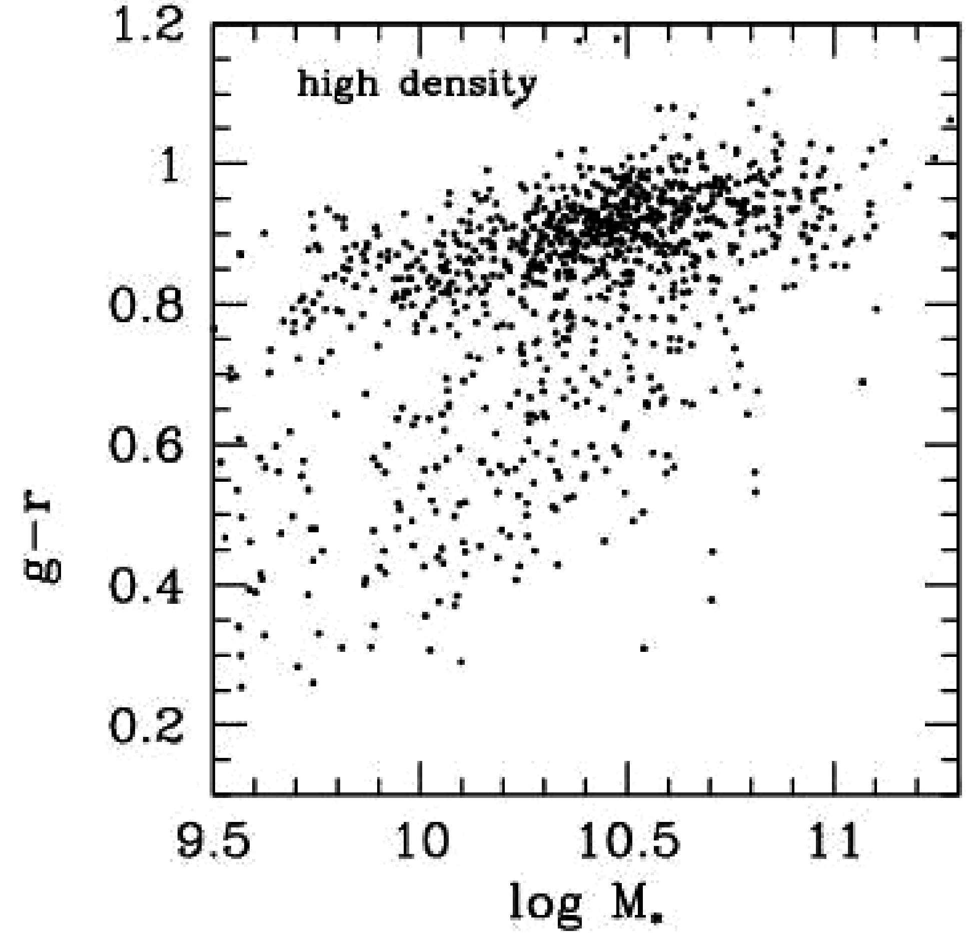
HALO-BASED PROCESS 1: quenching of star formation in massive groups and clusters through ram-pressure stripping.



Removal of INTERNAL gas reservoirs
==> rapid shutdown of SF

Removal of EXTERNAL gas reservoirs
==> slow shutdown of SF

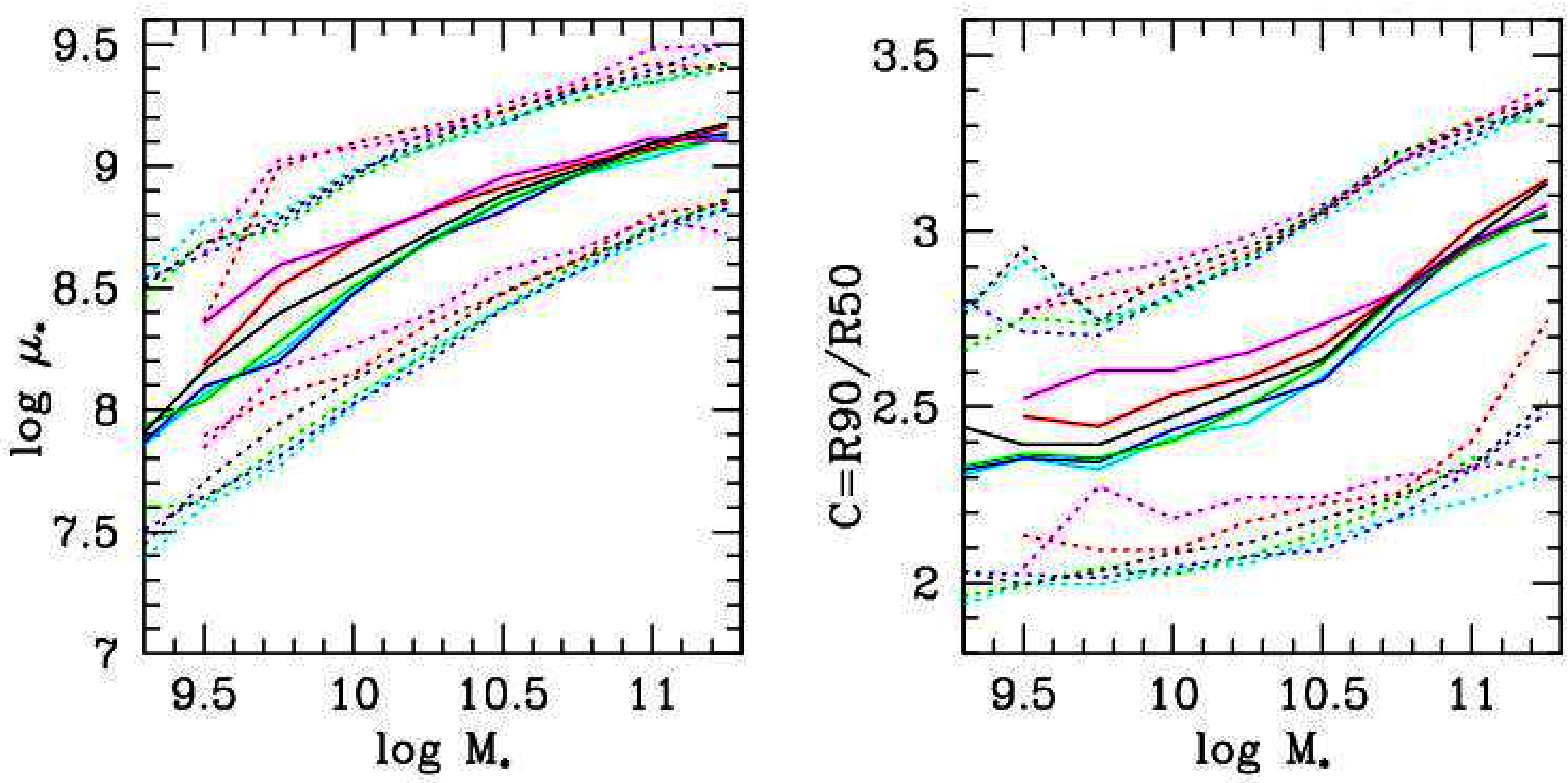




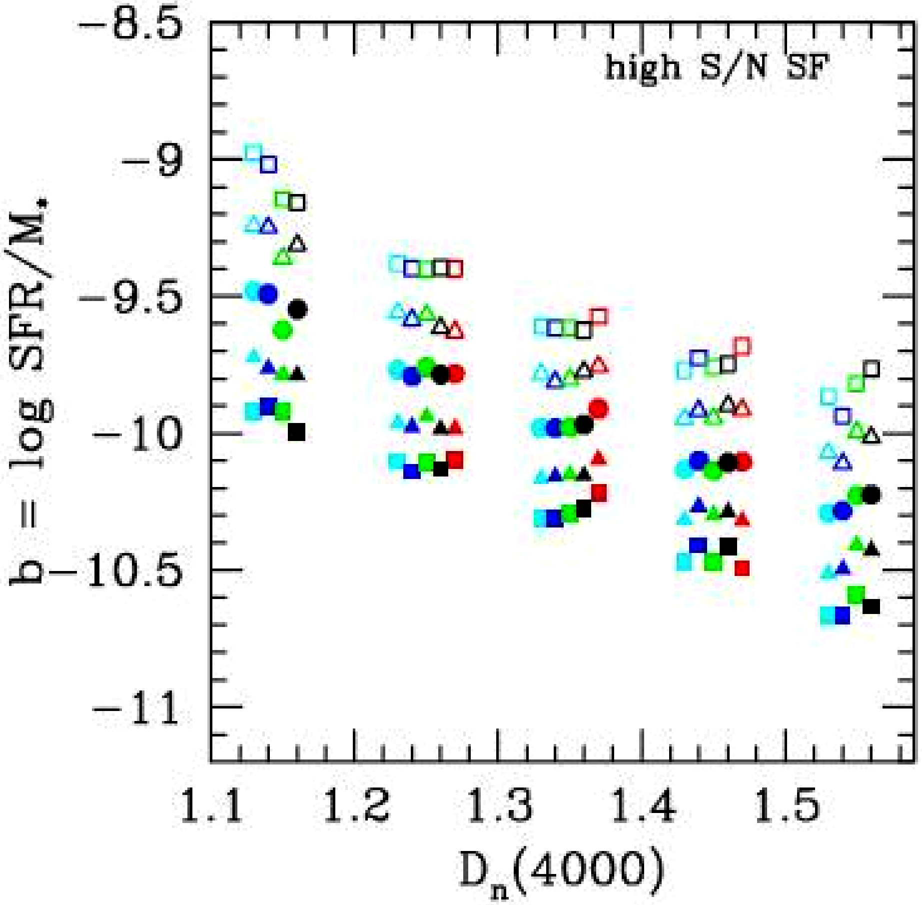
Kauffmann et al 2004

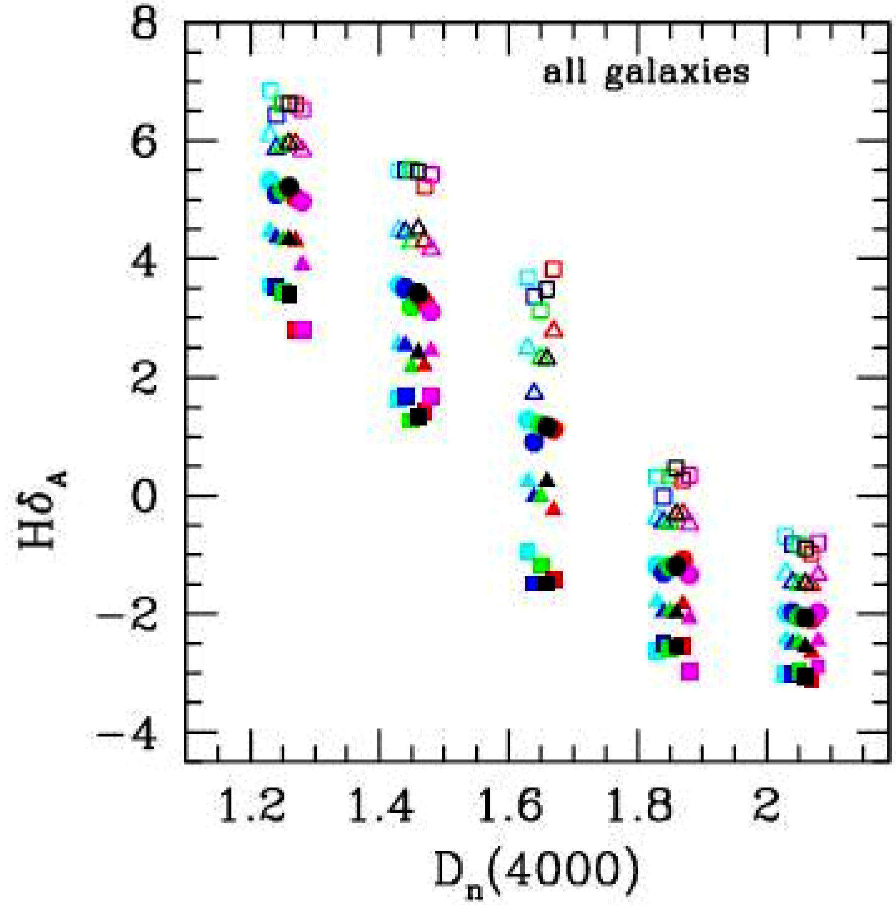
This process is NOT responsible for establishing the bimodal red and blue populations, only for shifting the relative fraction of galaxies located in the two.

•**ENVIRONMENTAL EFFECTS ON GALAXY STRUCTURE ARE VERY WEAK** (this disfavours “harassment” from playing a role in the evolution of the massive galaxy population)



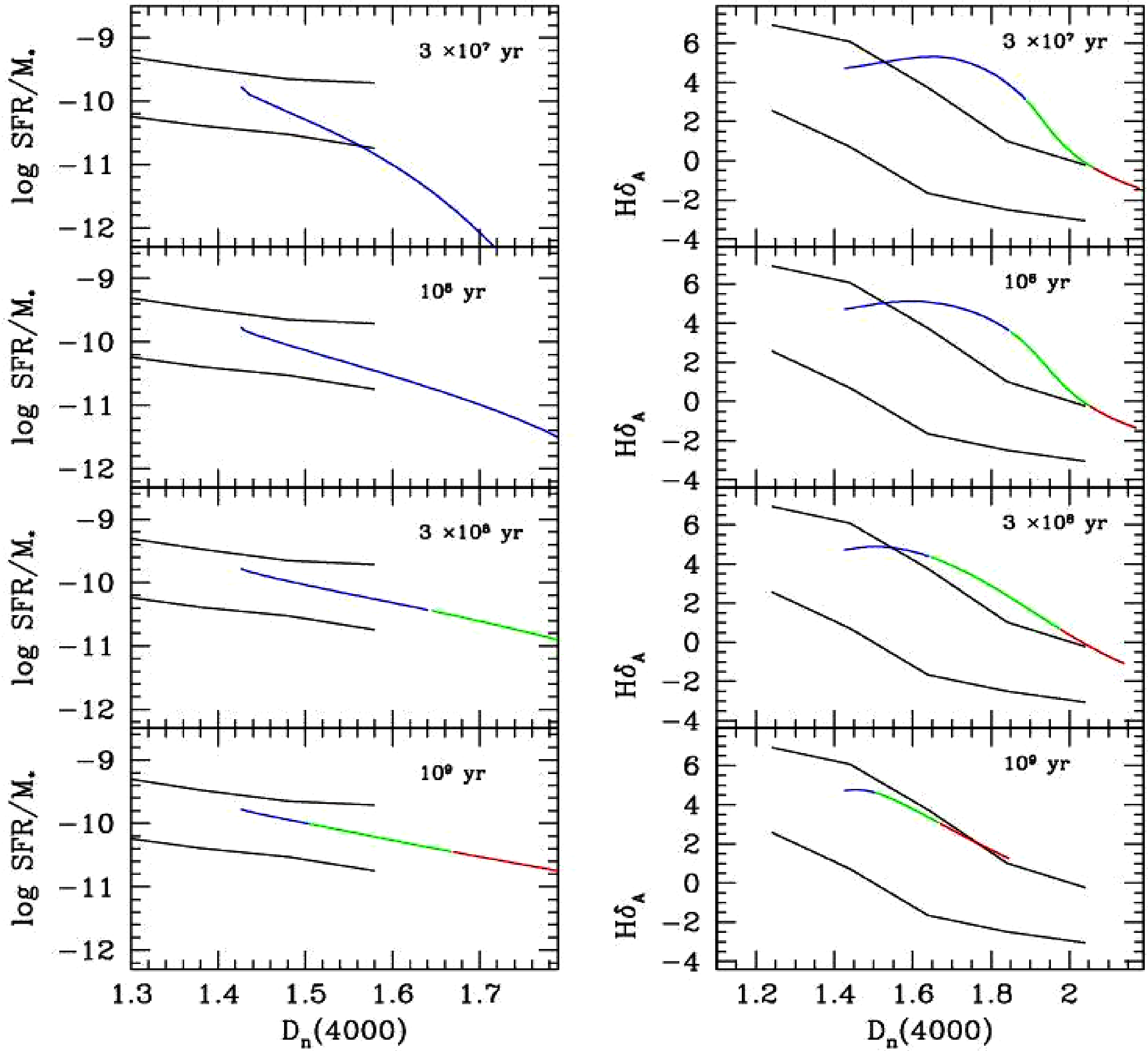
Kauffmann et al 2004

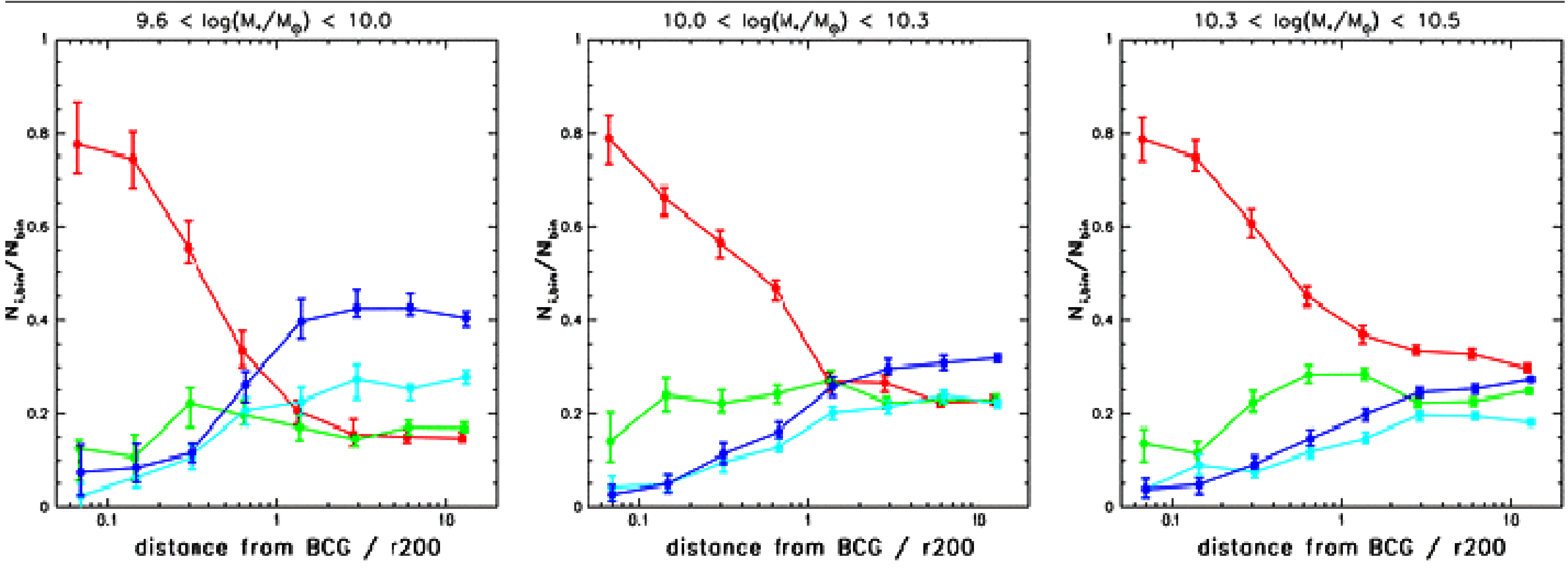


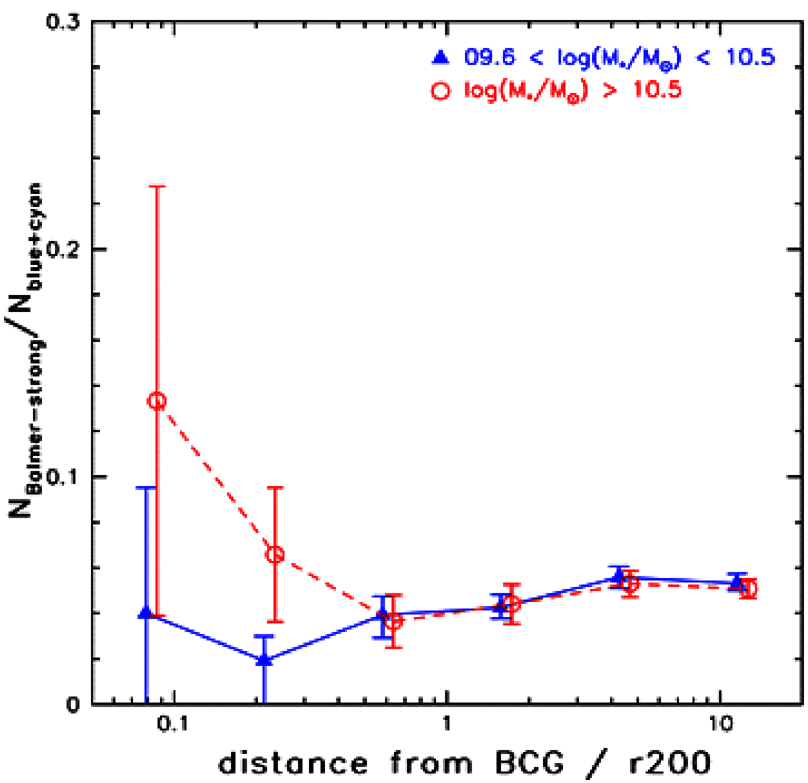


By looking at correlations between different star formation indicators that probe star formation over different **TIMESCALES** as a function of environment, we deduce that the quenching timescales were **longer than 1 Gyr** (at least in the centers of galaxies).

CONSTRAINING QUENCHING TIMESCALES



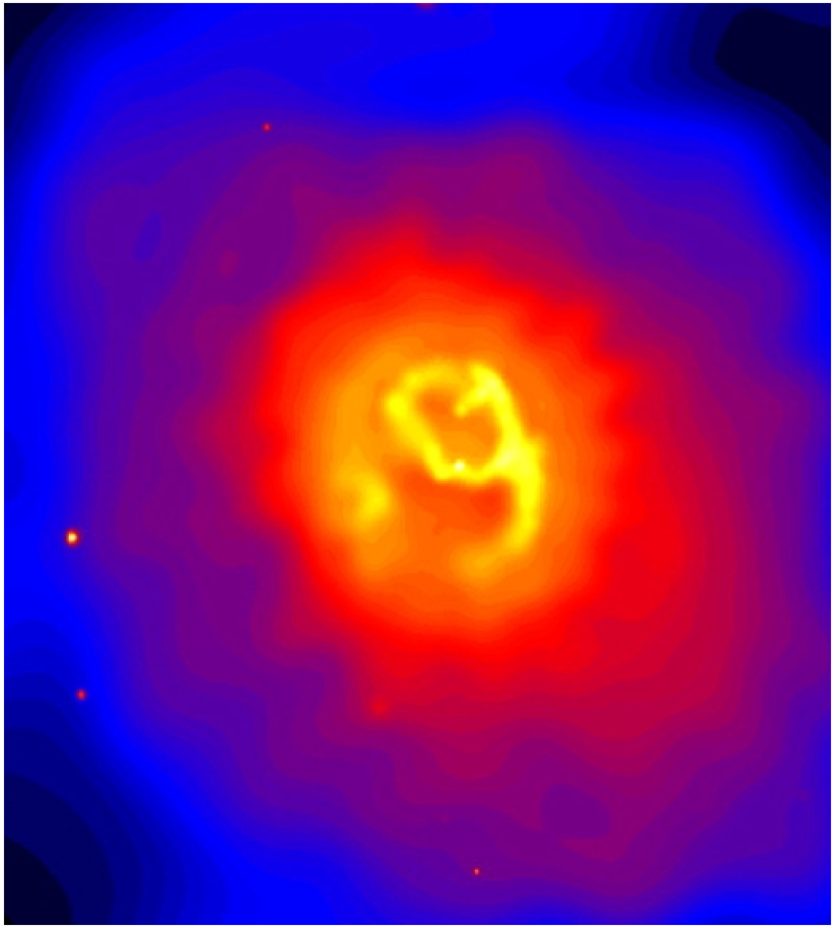




In rich clusters, a sharp increase in the number of red galaxies is seen at the virial radius. However, there is still no definitive evidence of a corresponding change in the number of strong Balmer line systems, which would indicate a sudden truncation of star formation. Note, however , that this applied to 3 arcsec diameter fiber spectra!

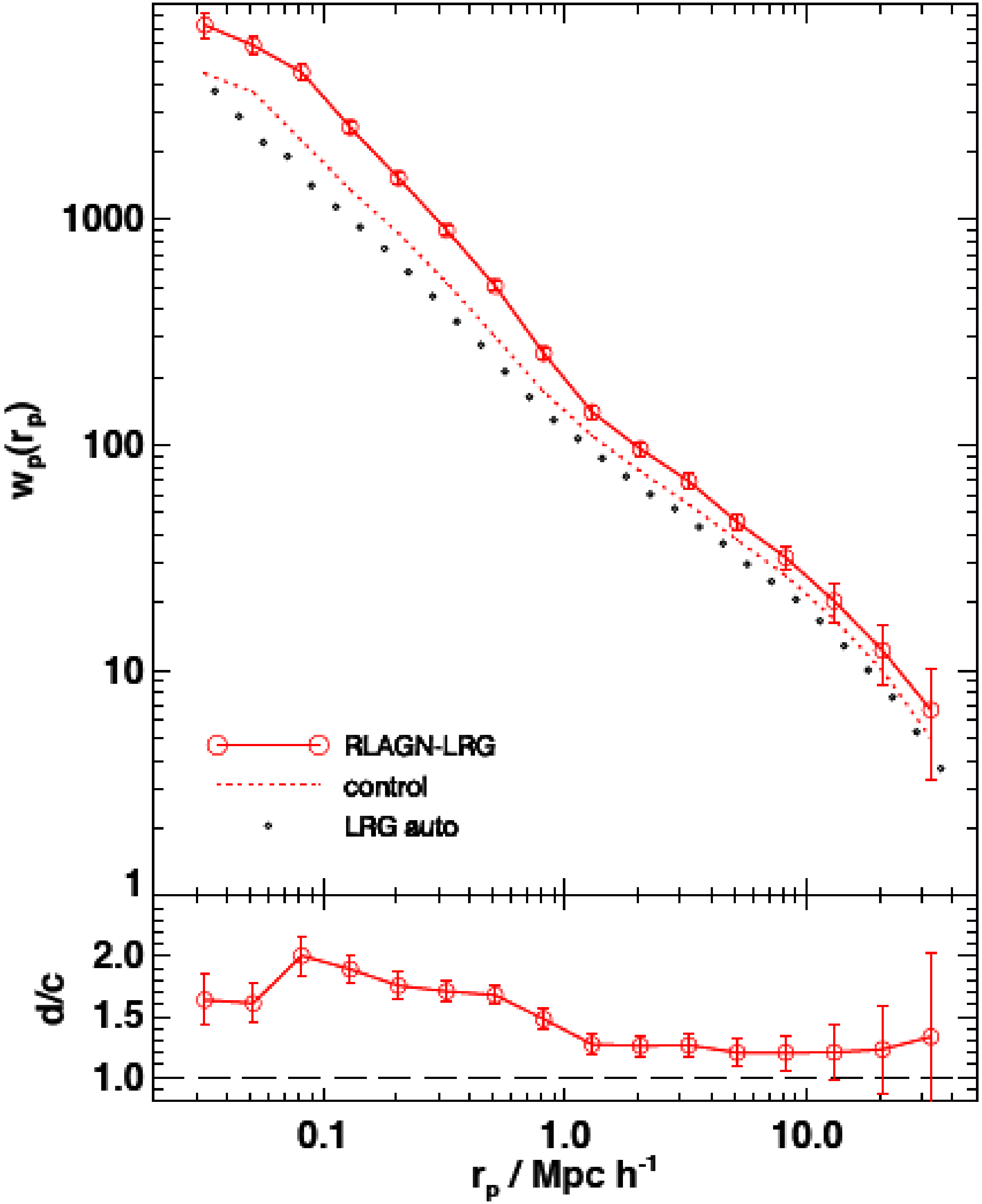
Von der Linden et al (2010)

HALO-BASED PROCESS 2: radio AGN feedback

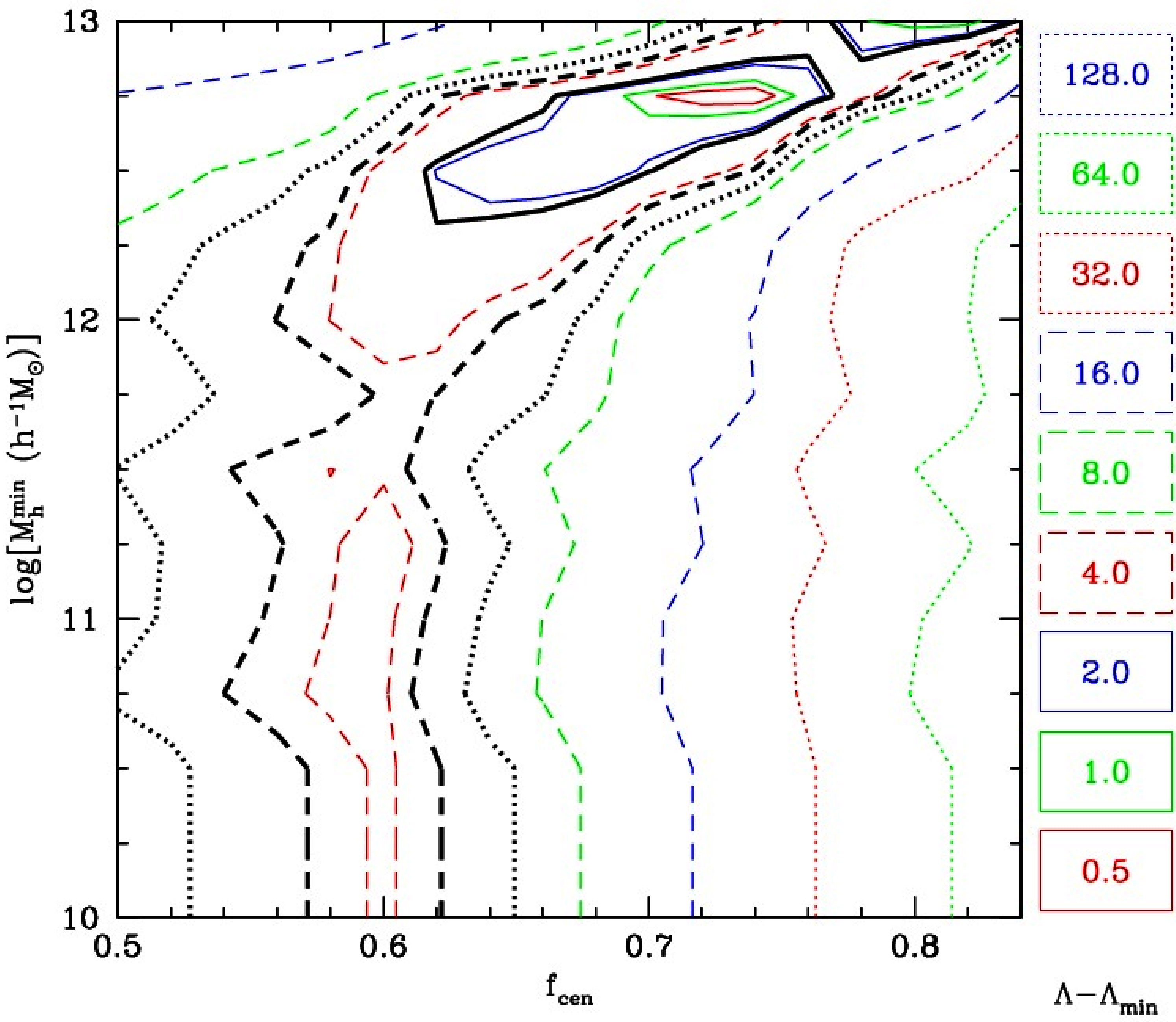


Donoso et al (2010)

SDSS has provided clear evidence that this process is halo-driven.

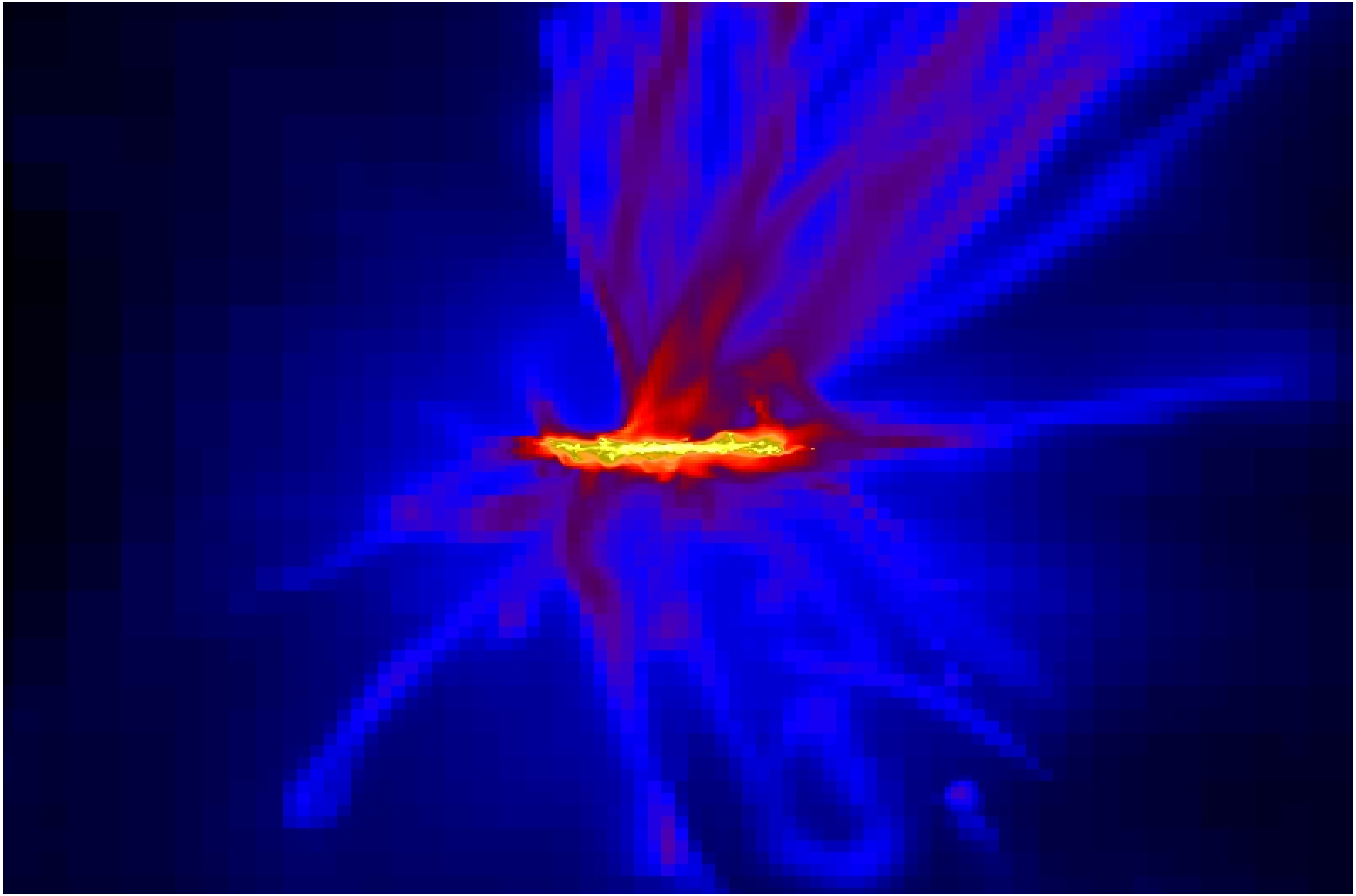


Halo-Occupation Distribution (HOD) models of the radio AGN population places them into somewhat more massive halos than required to explain the bimodality, but error bars still large (Mandelbaum et al 2009)

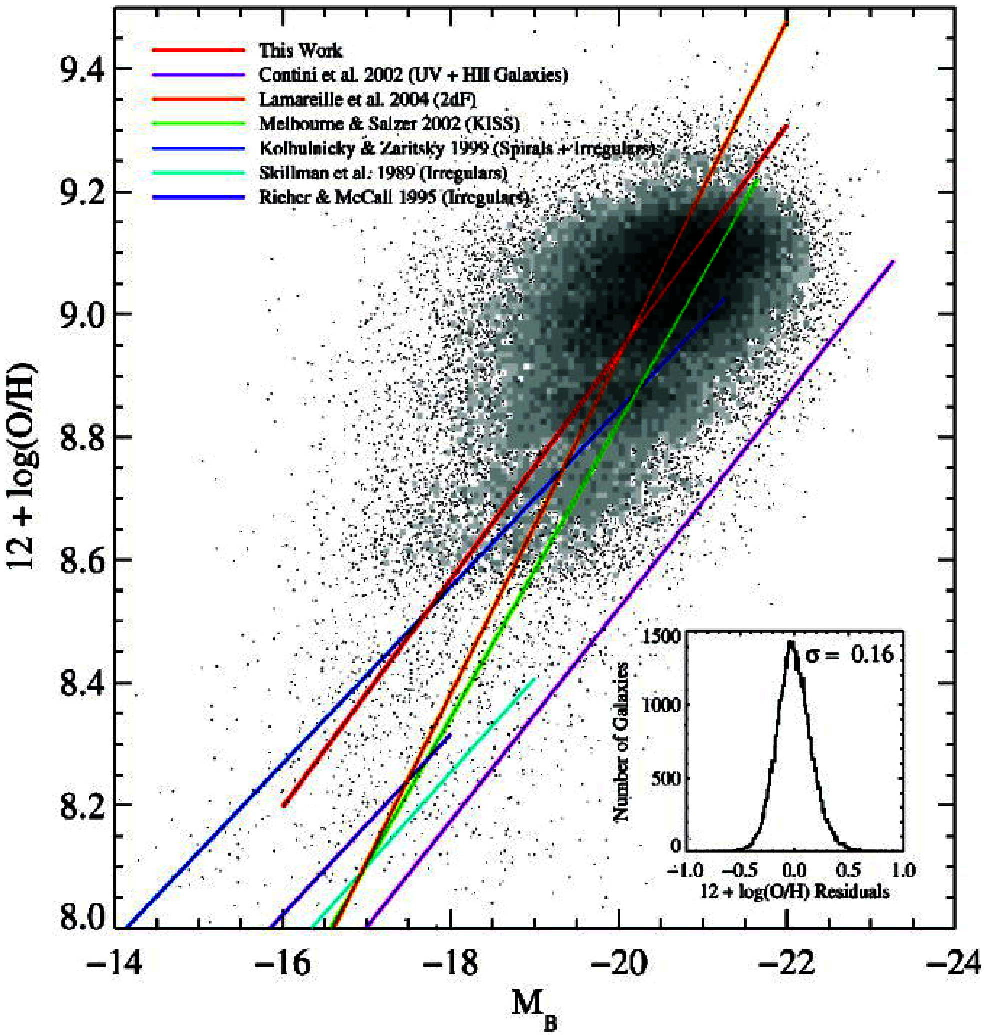


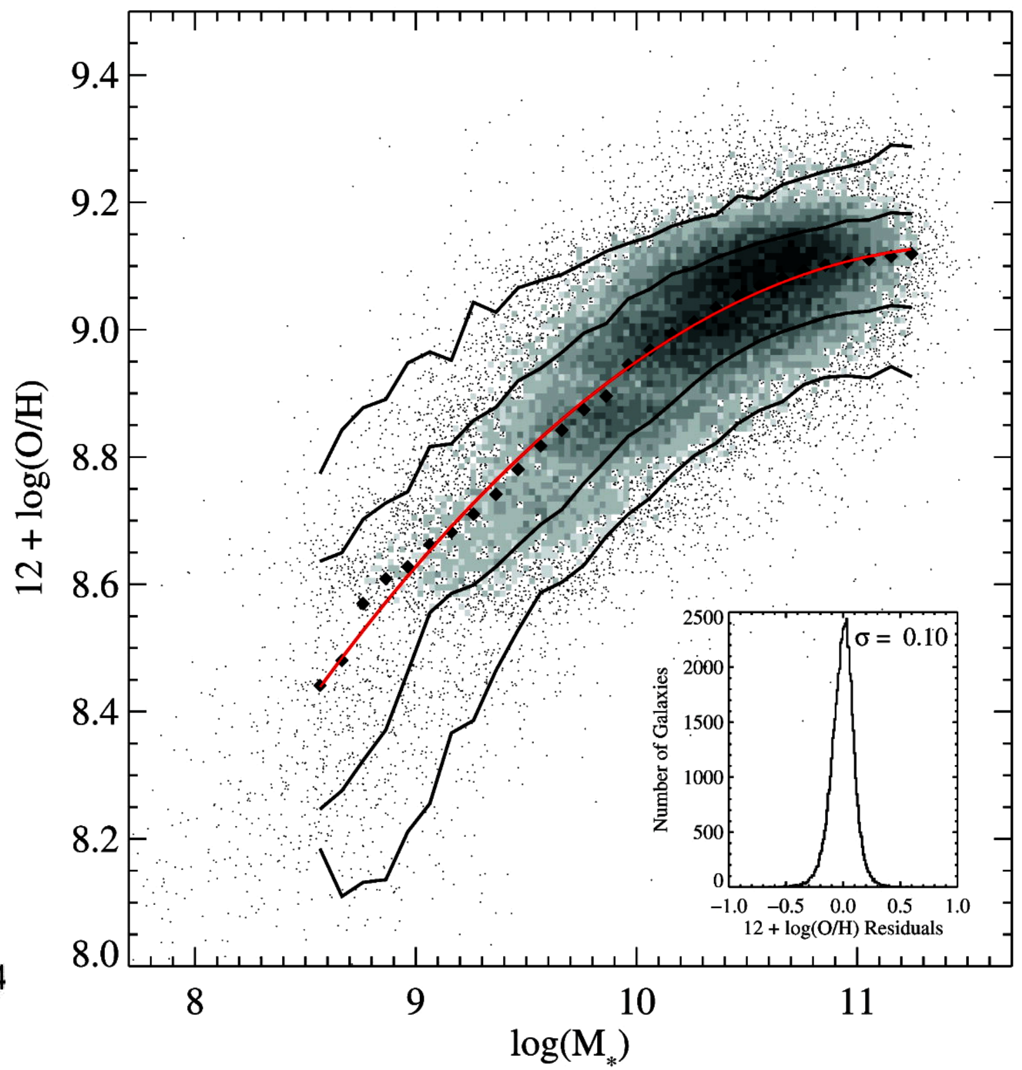
HALO-BASED PROCESS 3: gas accretion

NO DIRECT CONSTRAINTS AVAILABLE FROM OPTICAL SURVEYS

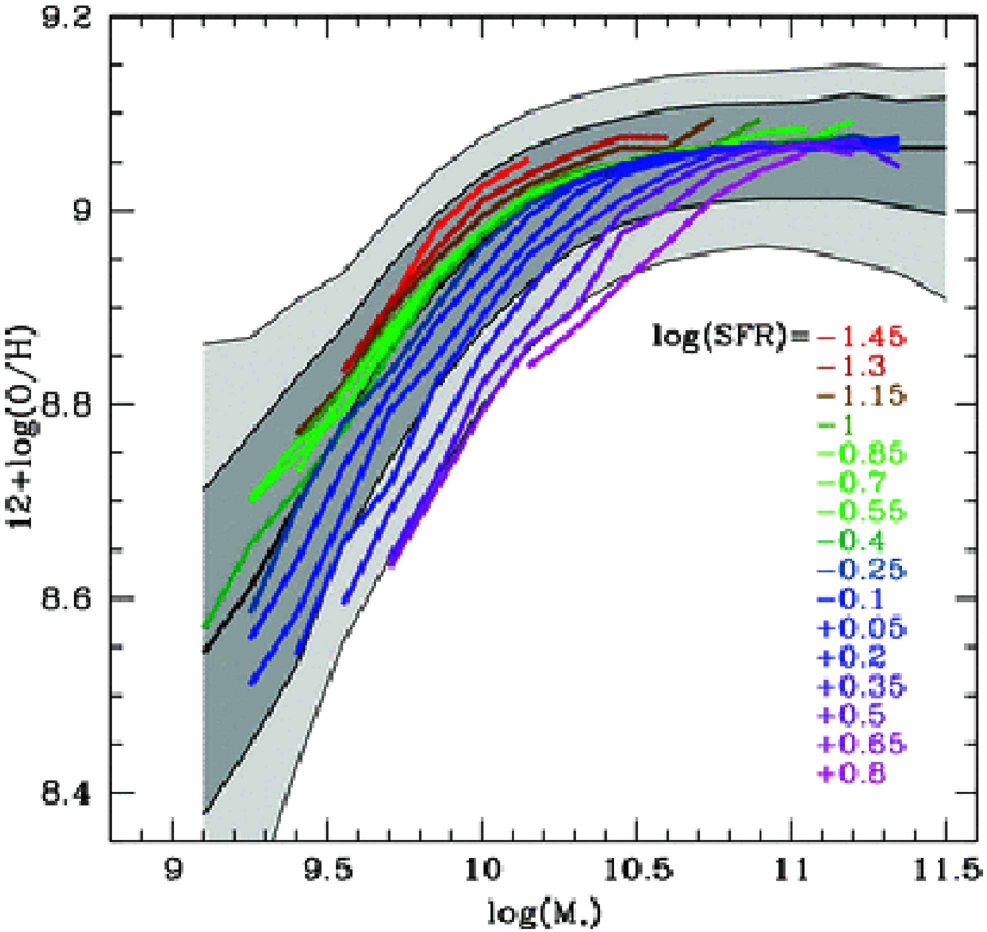


INTERNAL PROCESS 1: supernova feedback as traced by metals

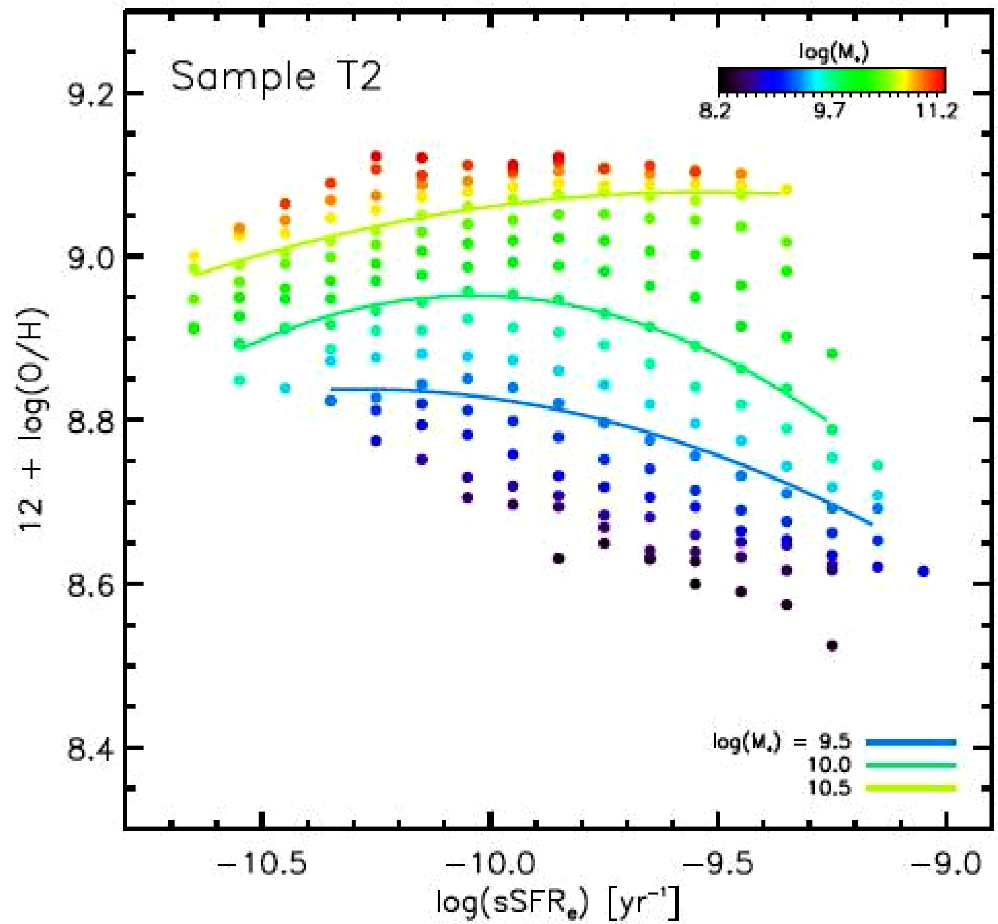




Metallicity of a galaxy is most fundamentally relates to MASS ,i.e potential well depth is regulating the fraction that escape in winds
Tremonti et al 2004

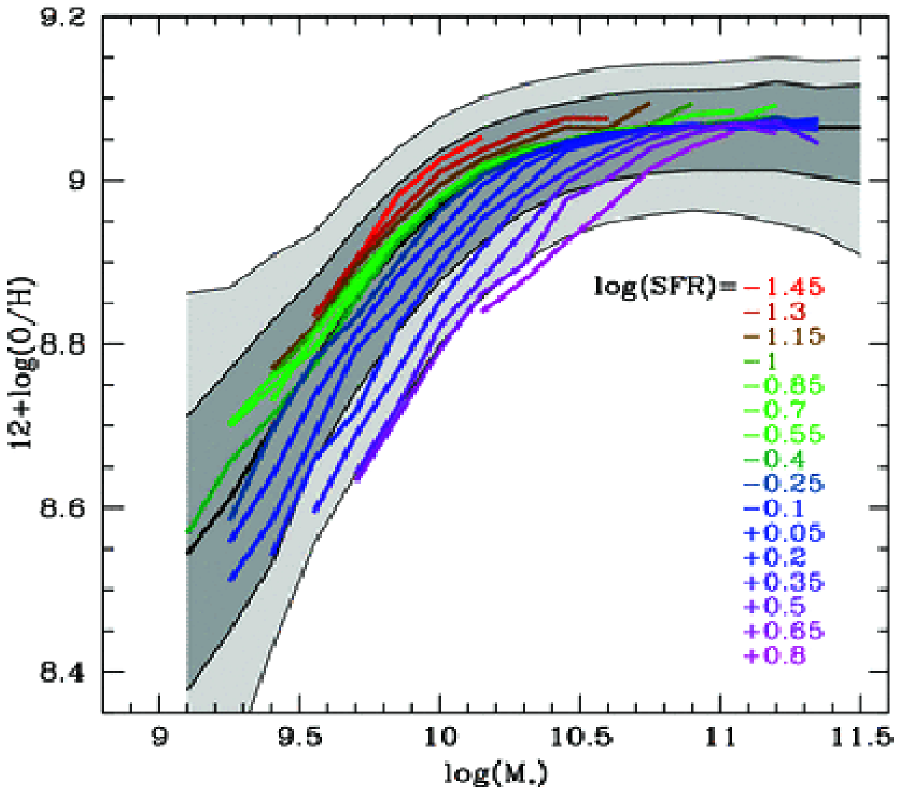


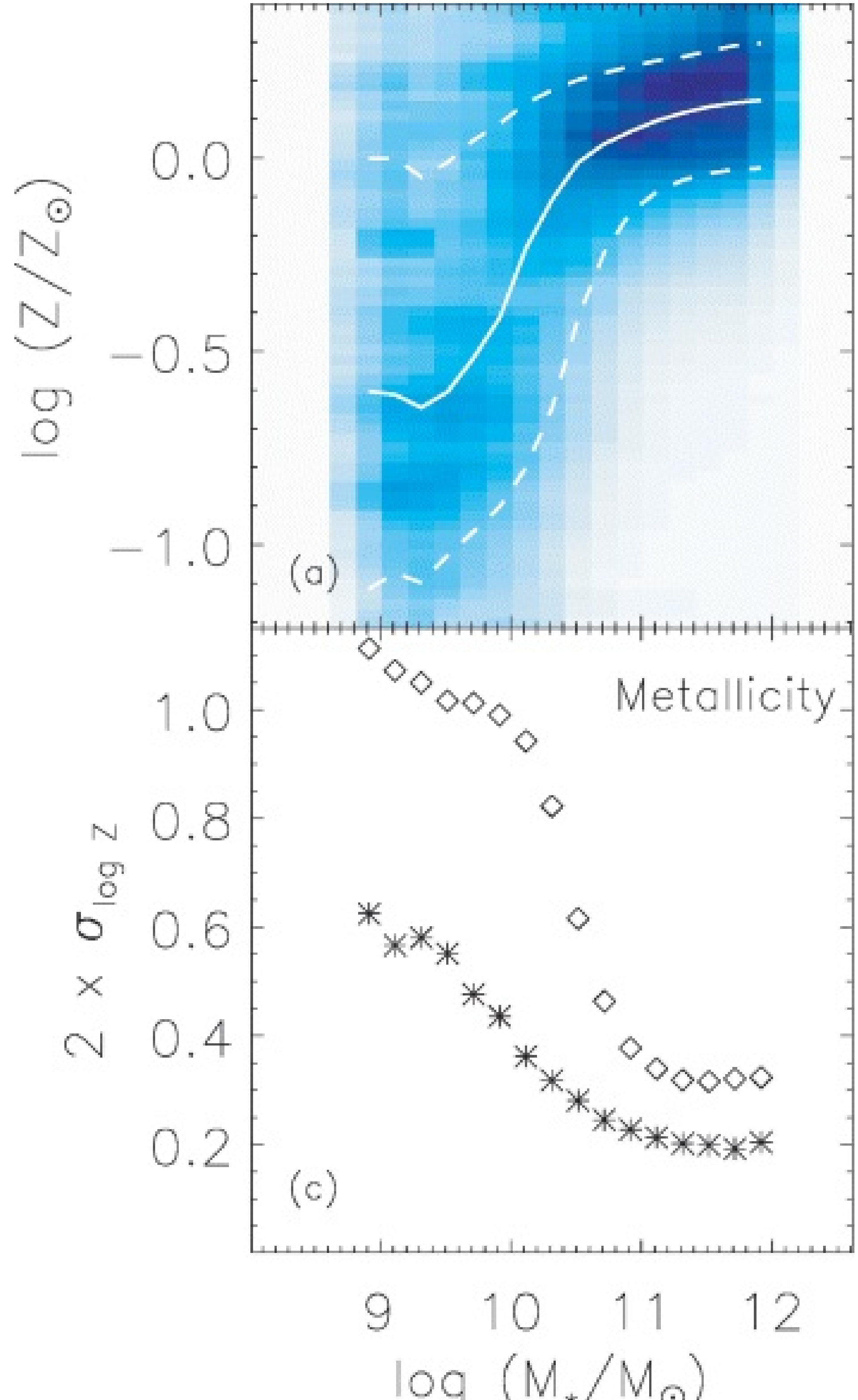
Mannucci et al 2011



Yates et al 2011, submitted

There are additional dependencies on specific star formation rate. SSFR is likely to correlate with gas fraction – a reflection of the amount of recent accretion onto the galaxy?



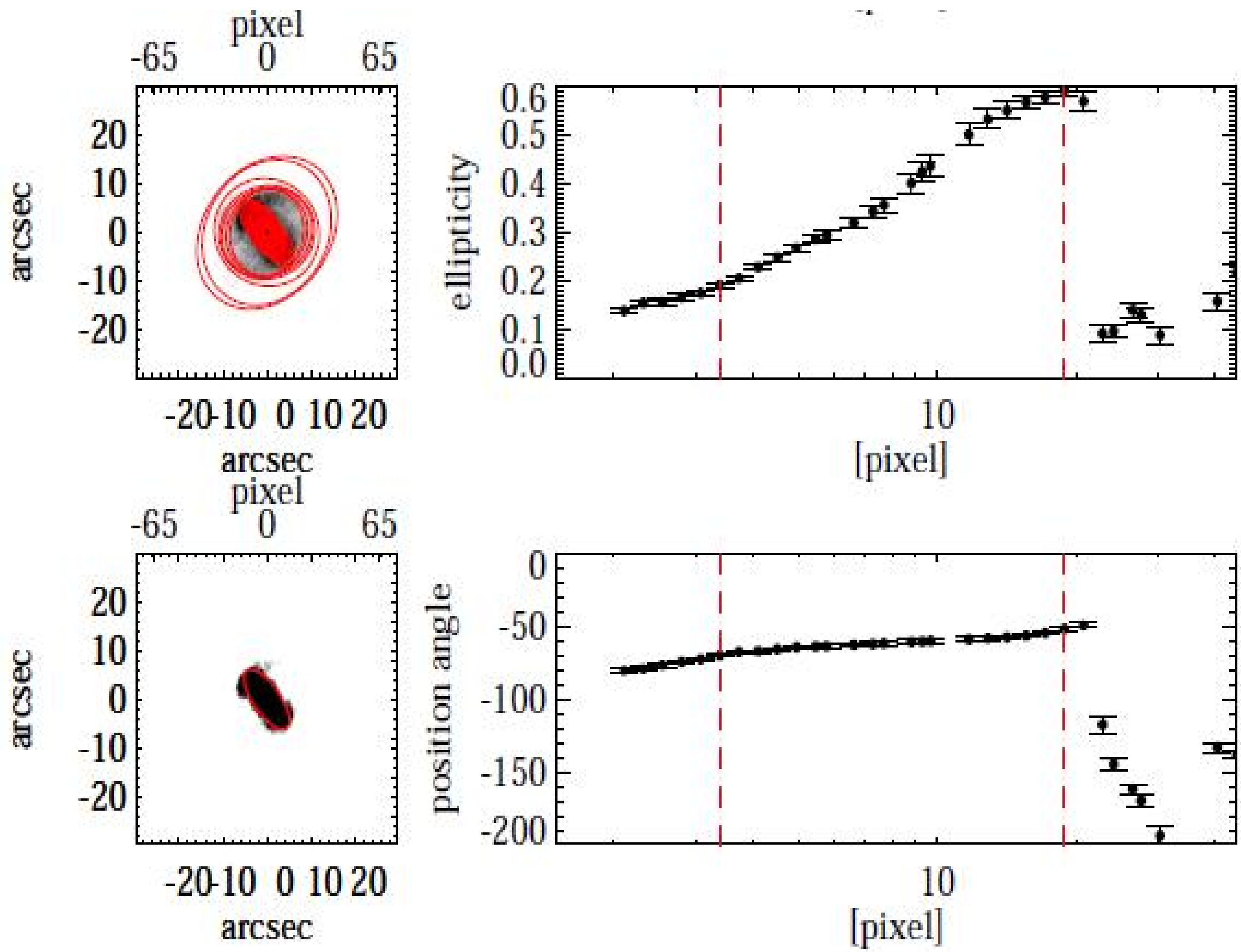


Note that although the scatter in the gas-phase M*-Z relation remains quite low down to low M*, the same is NOT true for the stellar M*-Z relation (Gallazzi et al 2005)

Why? Stochasticity in accretion history?

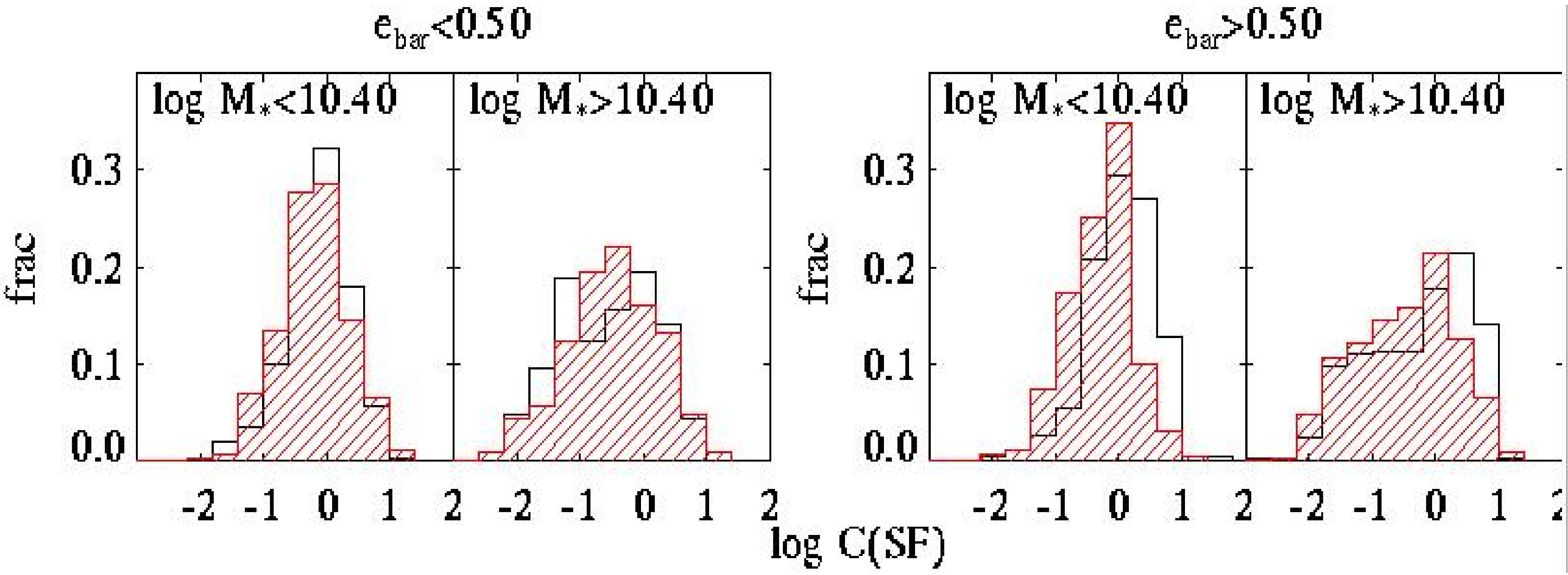
INTERNAL PROCESS 2: regulation of star formation by bar-driven inflows and interactions

Jing Wang 2011, to be submitted



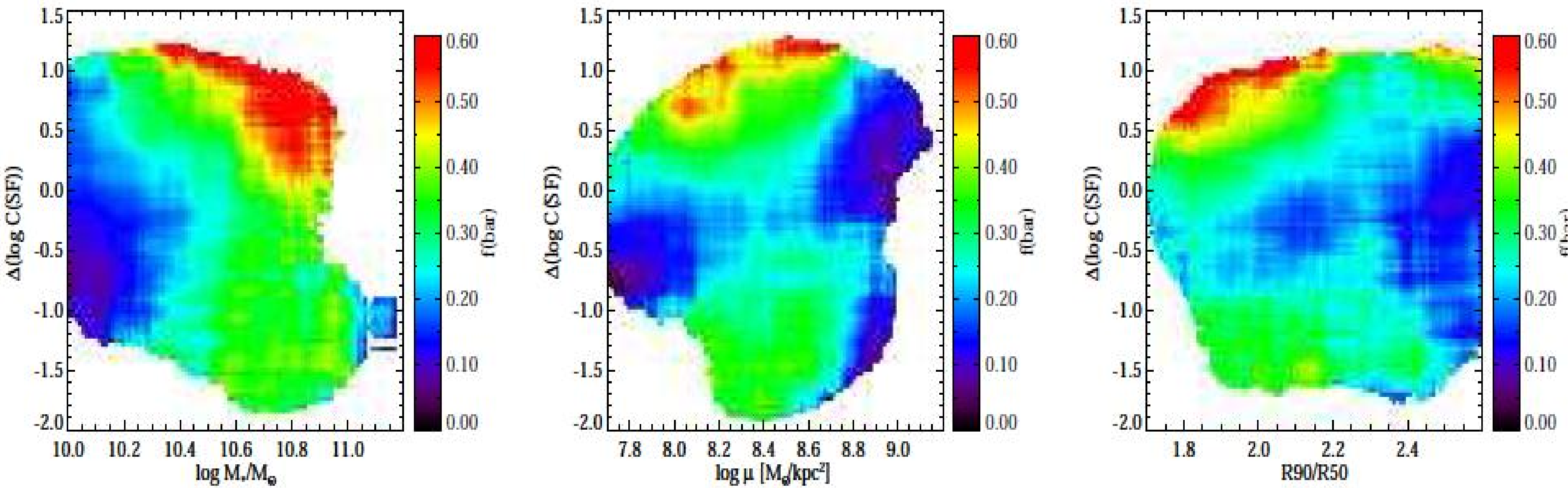
(see also recent work by Sara Ellison)

As expected, galaxies with strong bars, have more centrally concentrated star formation, when compared to controls samples matched in M*, R90/R50 and colour



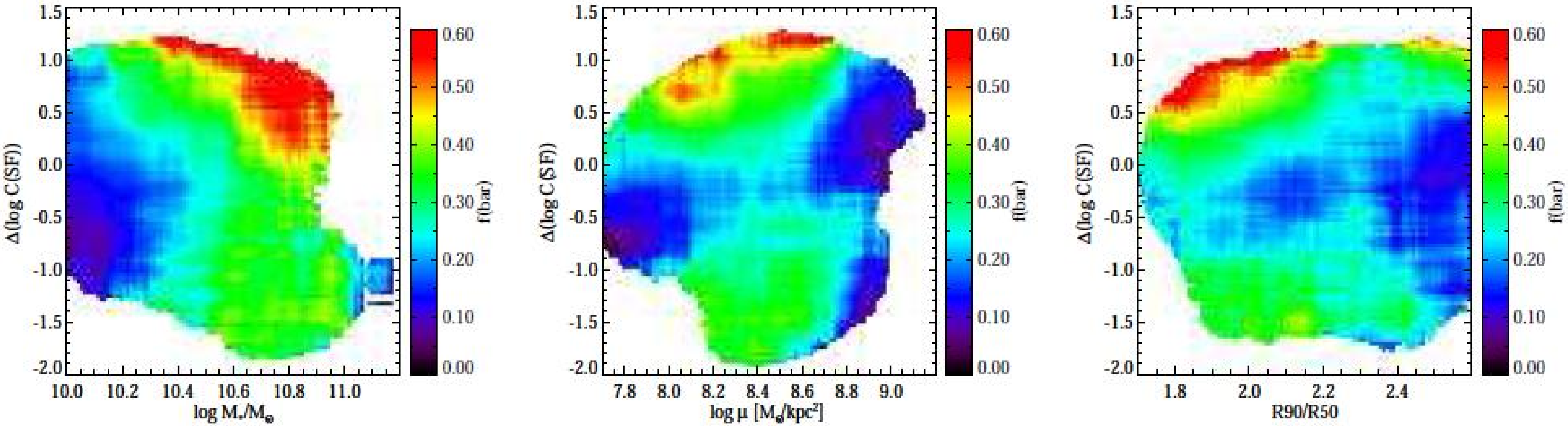
C(SF) = sSFR(in fiber)/sSFR(total)

The fraction of strong bars reaches values greater than 50% in galaxies with centrally concentrated star formation, with log M*> 10.5, with log μ* < 8.6 and low bulge-to-disk ratios (C < 2.3)

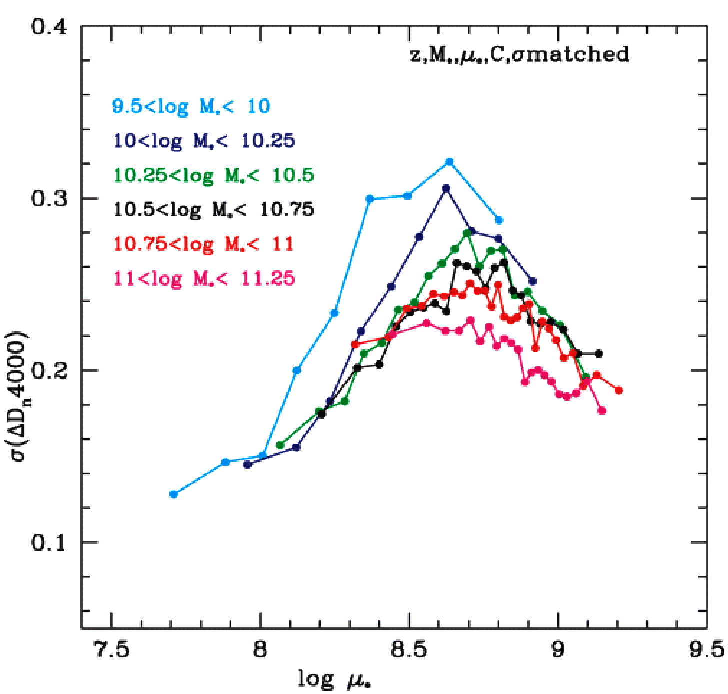


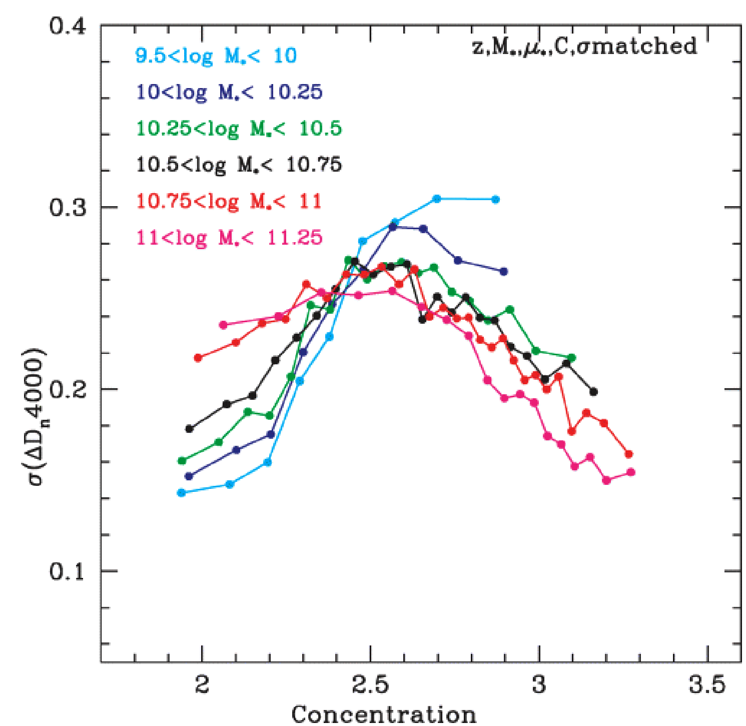
Results at odds with the Efstathiou et al (1982) formular for disk stability that is implemented in SAMs? (Note that the effect of gas is NOT taken into account)

$$\frac{V_{\rm max}}{(GM_{\rm disk}/R_d)^{1/2}} < \epsilon \sim 0.5 - 1.$$



There is a **SECONDARY** peak in strong bar fraction at low values of C(SF).
This ties in with earlier results by Kauffmann et al (2006), showing clar regions of galaxy structure parameter space where SFHs were most **STOCHASTIC.**
It now appears the at least some of this stochasticity is cased by bar-driven inflows.





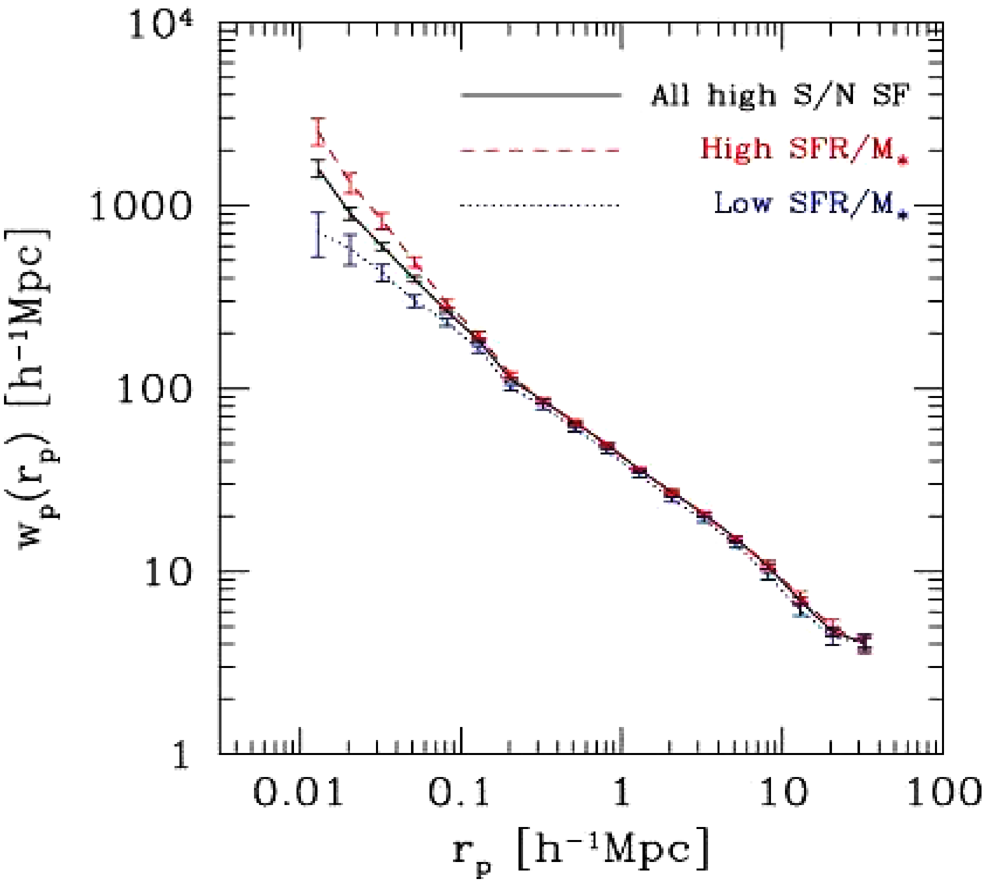
•**Galaxy-Galaxy Interactions** are another INDEPENDENT channel for triggering enhanced levelsof star formation in galaxies .

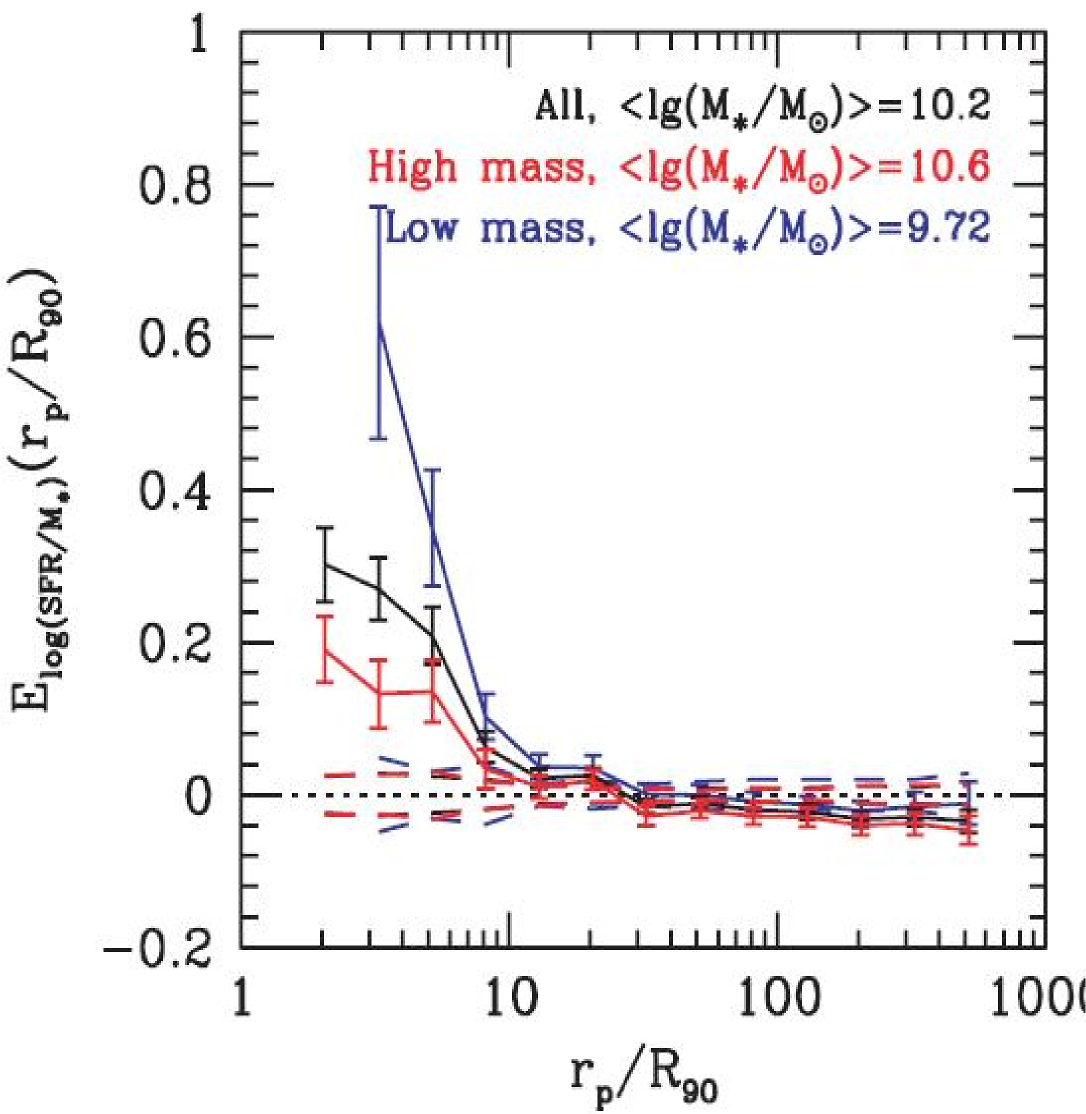
•Strongly barred galaxies exhibit no excess in close neighbours

•At fixed separation, the enhancement is larger for low mass galaxies.

•A rough estimate shows that bars + interactions together can account for all galaxies in the local Universe whose star formation is enhanced above the average level.

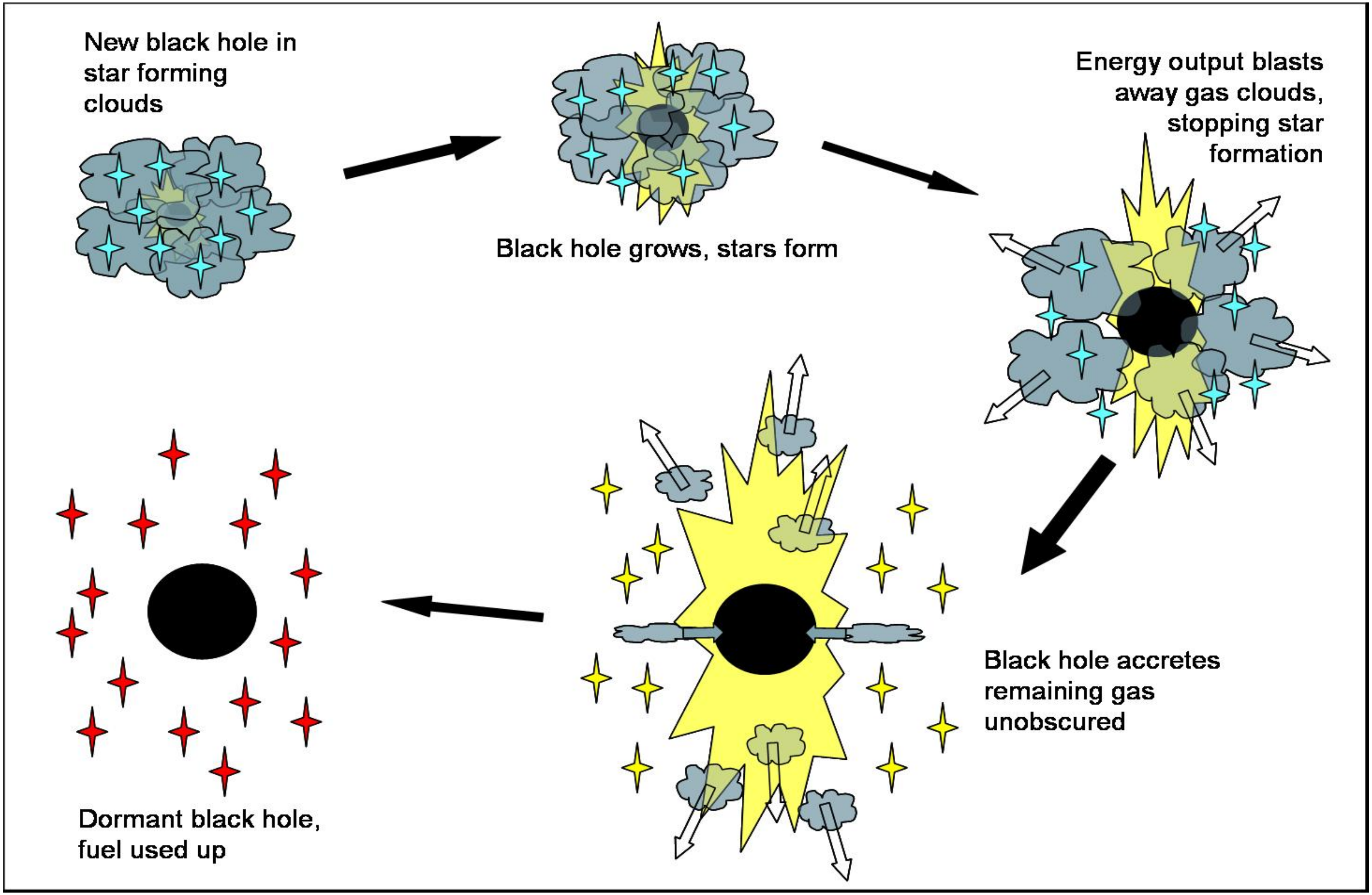
Li et al 2008,2009





INTERNAL PROCESS 3: gas expulsion by AGN, or radiation pressure from young stars

NO DIRECT CONSTRAINTS AVAILABLE FROM OPTICAL SURVEYS



SUMMARY: Recent large optical spectroscopic surveys have taught us a lot about galaxy formation, including

How galaxies trace dark matter halos (as a function of stellar mass and other properties)

That there are clear "scales" in galaxy formation – the conversion of baryons into stars peaks at M(halo) ~ 10^12 Msun. Galaxies transition from blue to red at log M* ~10.5, log mu*=8.5 and C~2.6.

These scales were likely imprinted at early epochs. They do not vary with environoment. In dense environments, star formation in galaxies shuts down over timescales of 1-2 Gyr; structural parameters remain largely fixed.

The Mass-metallicity relation , its scatter and the variation of galaxy properties perpendicular to the relation constrain gas accretion/starformation/ SN feedback in galaxies

Star formation rates may be regulated by a combination of galaxy-galaxy interactions and bar driven inflows.

WHAT THESE SURVEYS HAVE NOT CONSTRAINED VERY WELL:

1) Mechanisms and rates of accretion onto galaxies
2) Outflows of gas from galaxies (apart from some work on ionized gas outflows)
3) The influence of the black hole on galaxy evolution