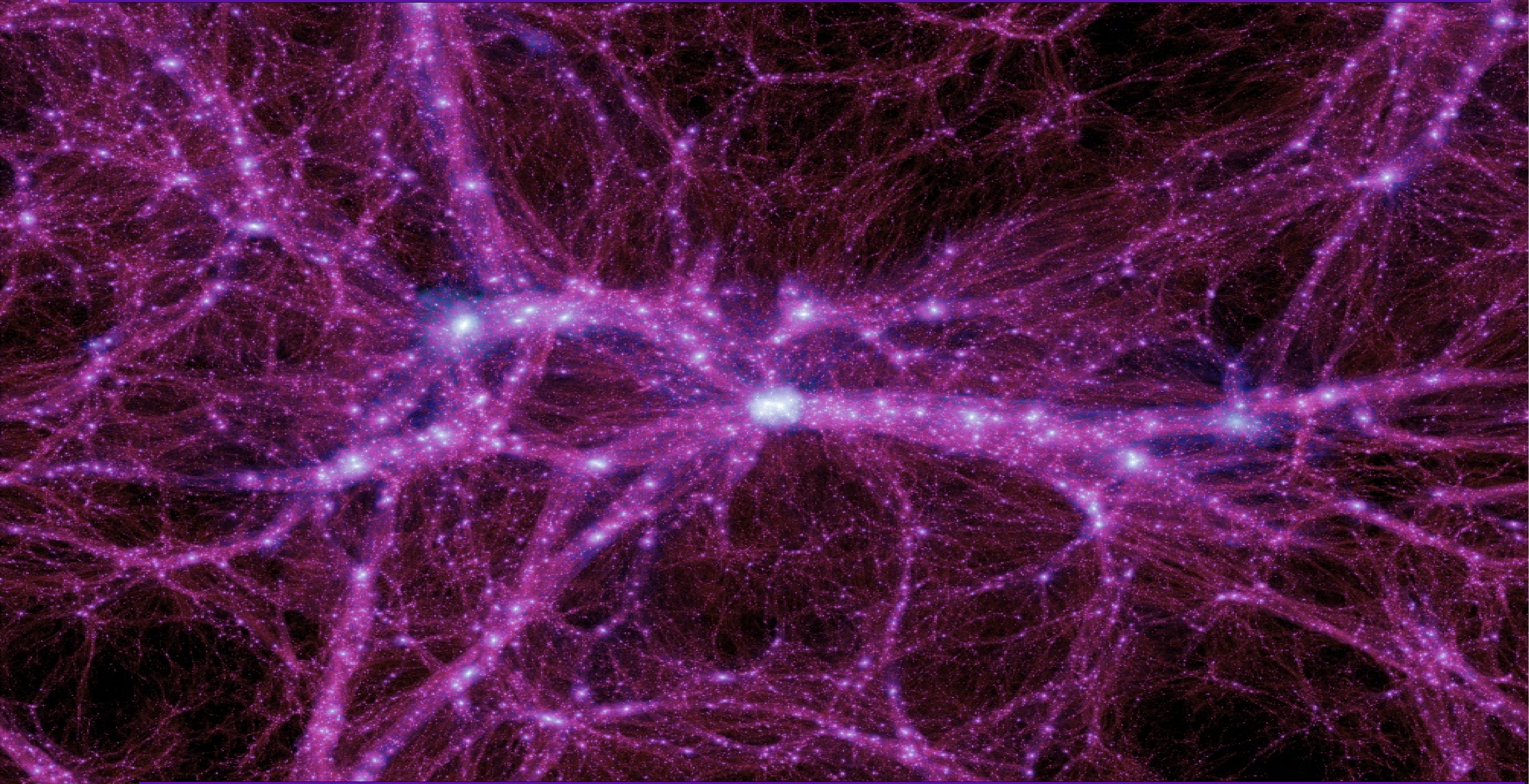
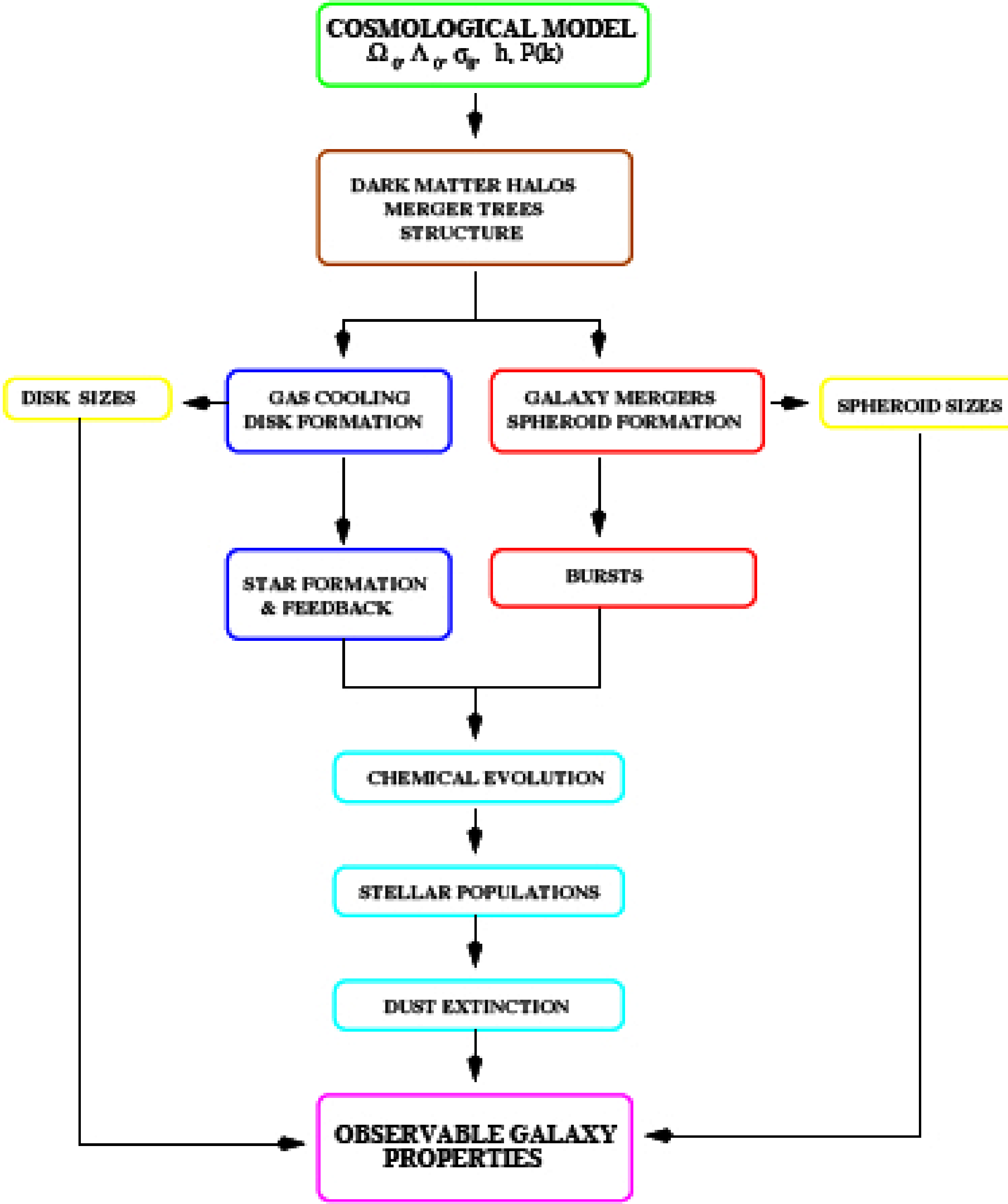
GAS IN GALAXIES: PREDICTIONS FROM SEMI-ANALYTIC MODELS VERSUS OBSERVATIONS

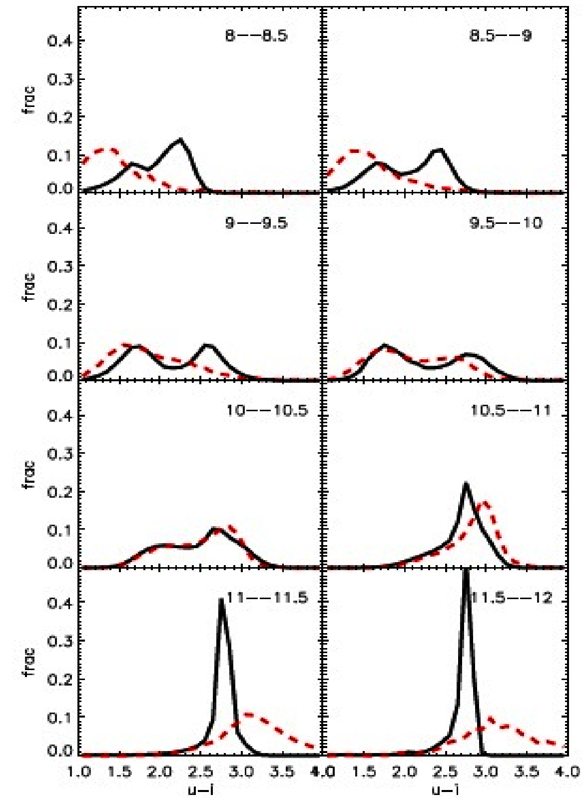


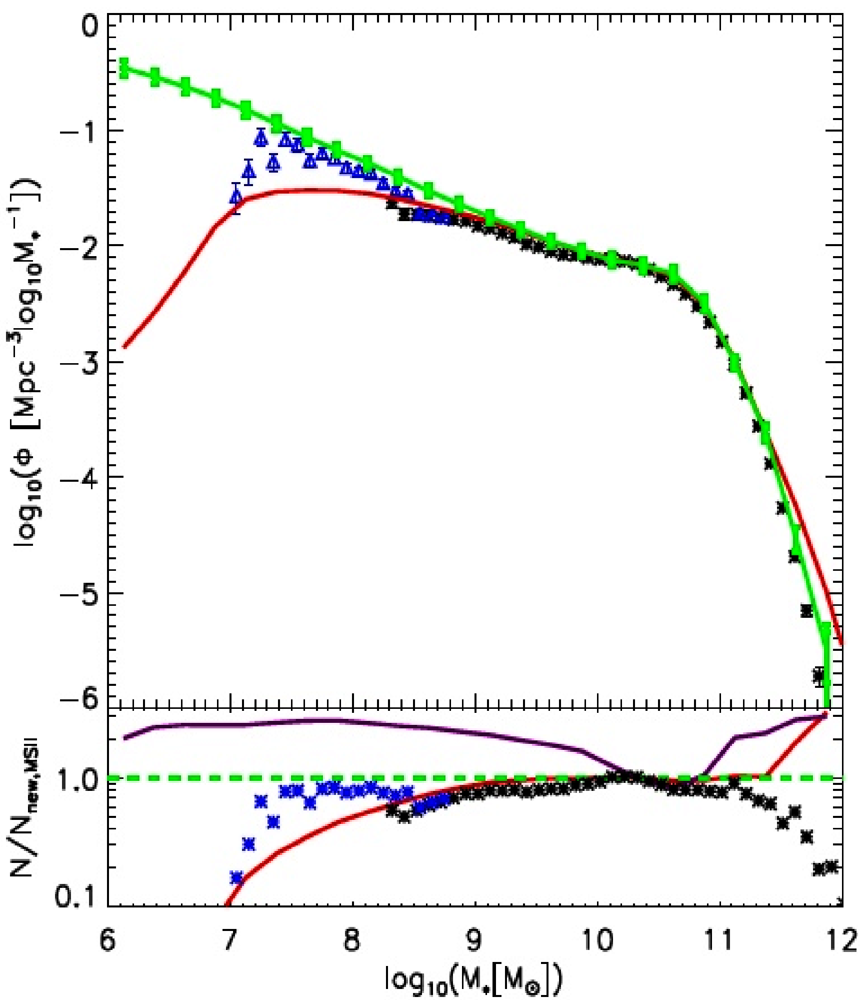
With Jian Fu, Qi Guo , Amelie Saintonge, Cheng Li ,Mark Krumholz
and the COLD GASS and GASS team.

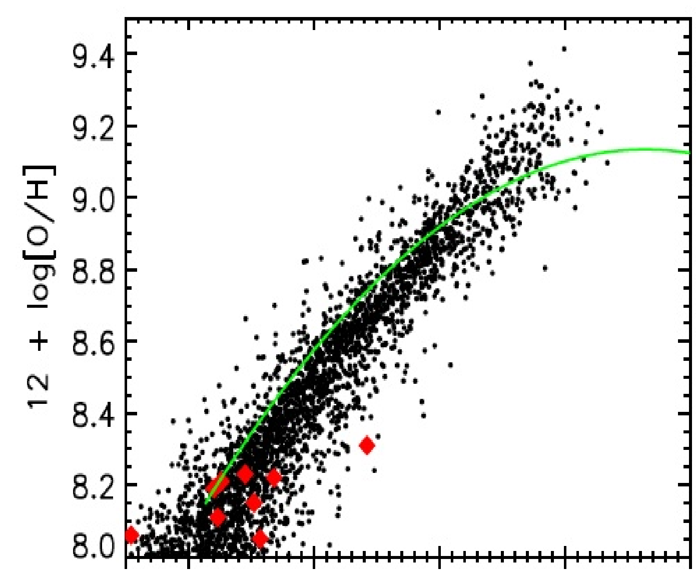

COSMOLOGICAL MODEL
$\Omega_0, \Lambda_0, \sigma_8, h, P(k)$
DARK MATTER HALOS
MERGER TREES
STRUCTURE
DISK SIZES
GAS COOLING
DISK FORMATION
GALAXY MERGERS
SPHEROID FORMATION
SPHEROID SIZES
STAR FORMATION
& FEEDBACK
BURSTS
CHEMICAL EVOLUTION
STELLAR POPULATIONS
DUST EXTINCTION
OBSERVABLE GALAXY
PROPERTIES

"Free parameters" of model tuned to reproduce certain key observations:

a) Normalization of stellar mass function sets effiiency with which gas in conveted to stars,
b) Slope of mass-metallicity relation constraints SN feedback efficiency,
c) Bimodal colour distribution constrains "quenching" processes in massive galaxies.



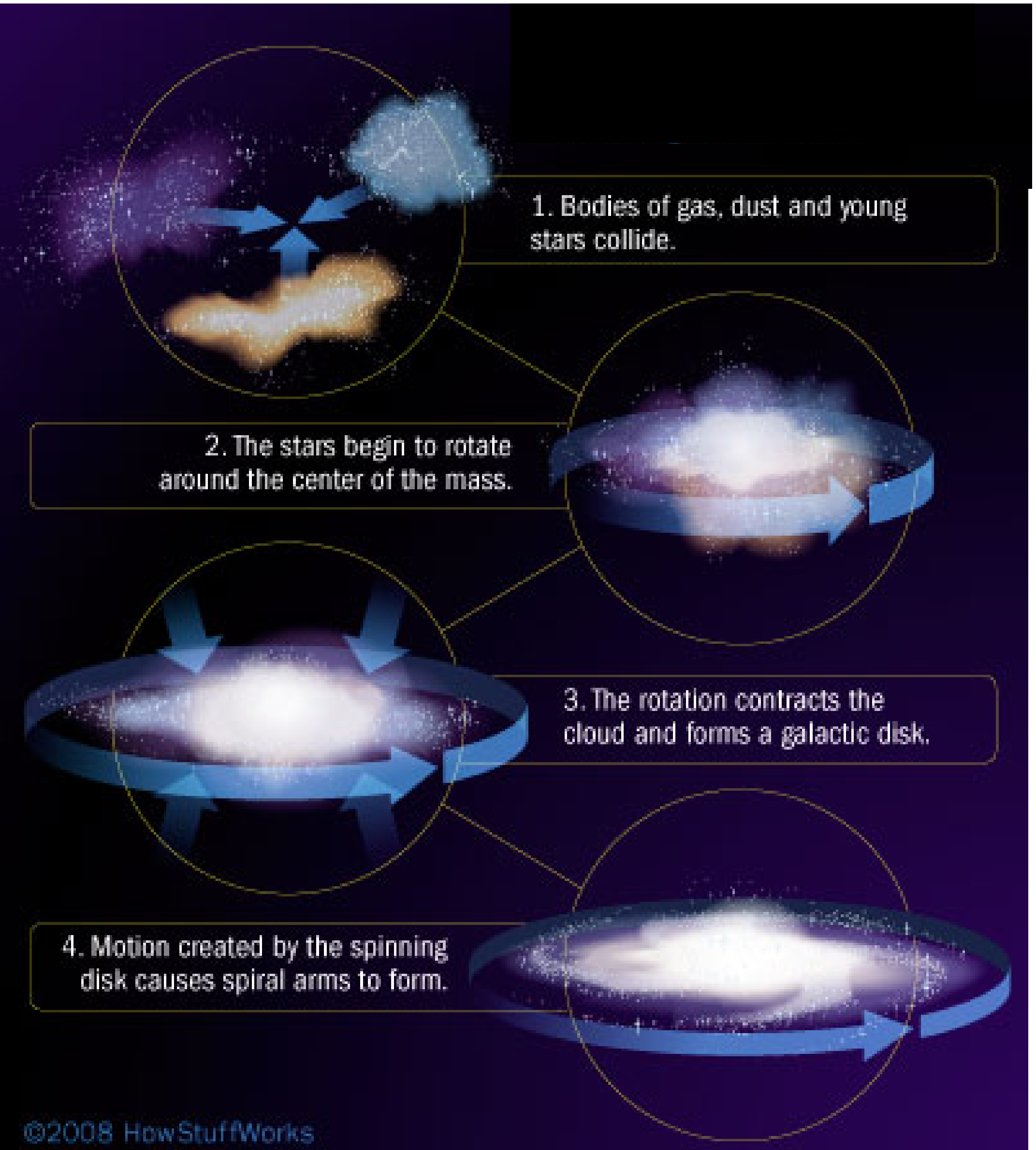




Guo et al 2010

DISK GALAXY FORMATION

Halos with mass $M_{halo} < 10^{11}$ Msun



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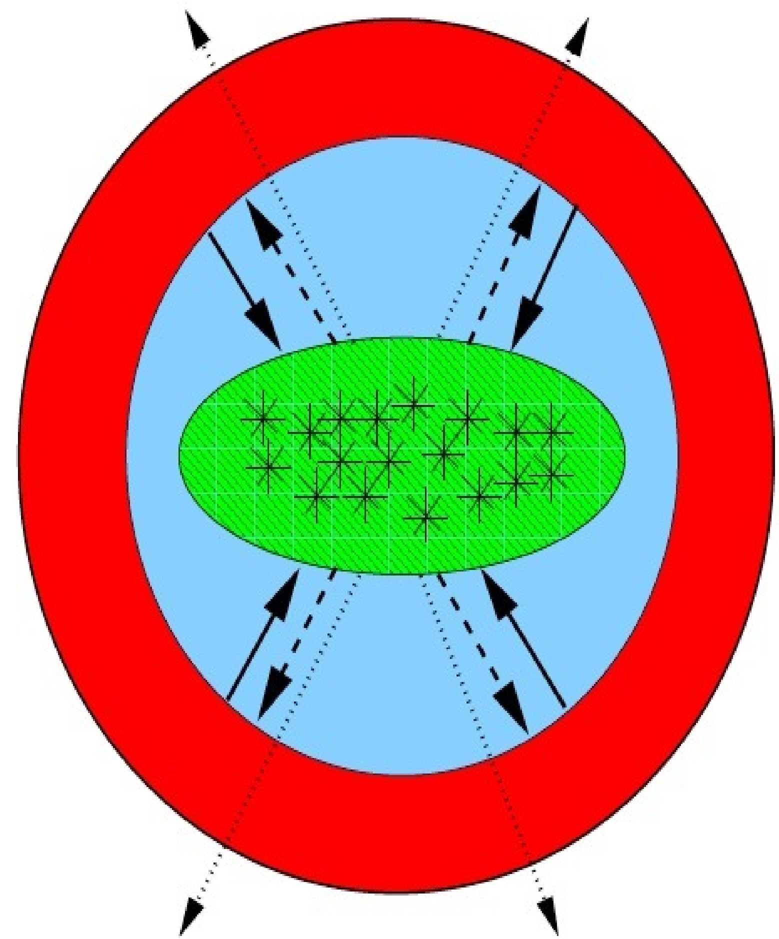
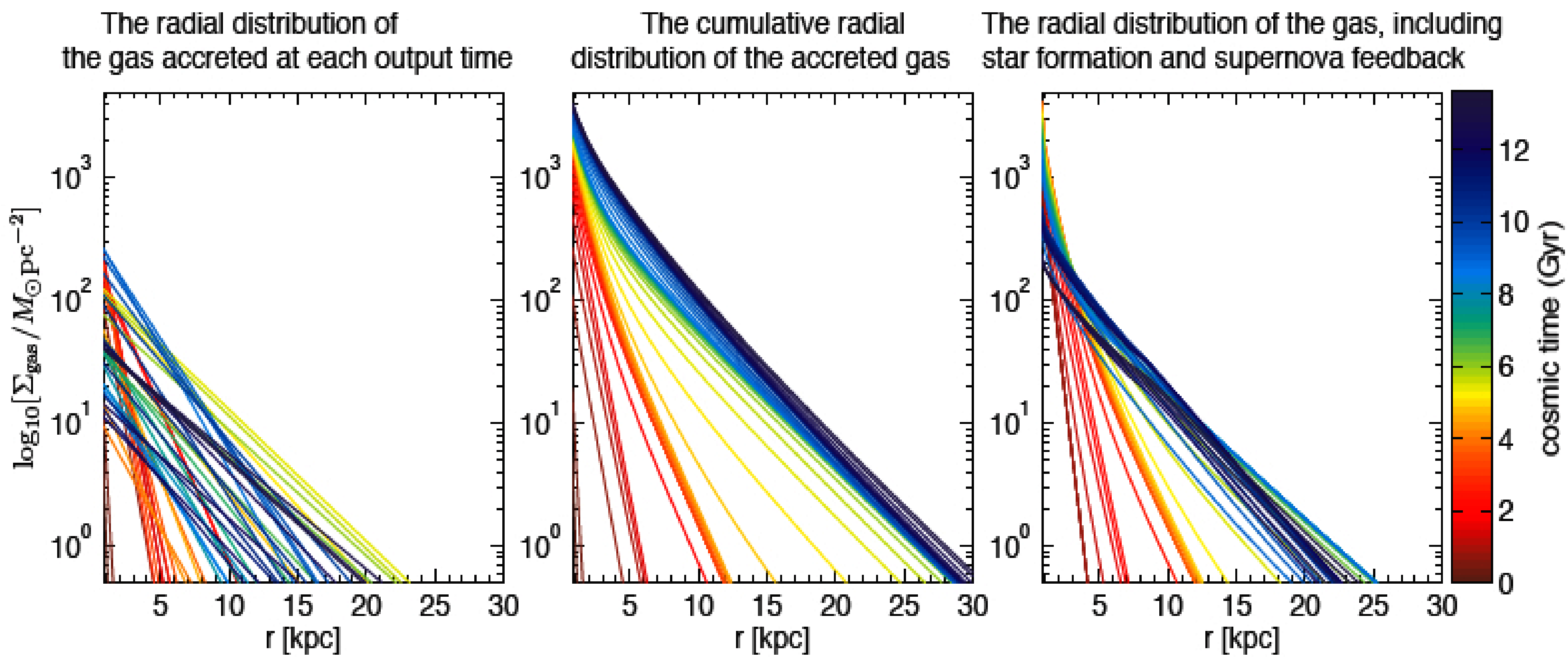


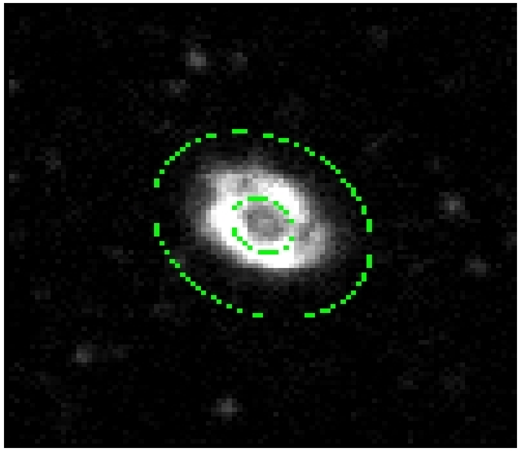
ASUME INFALLING GAS CONSERVES ANGULAR MOMENTUM:

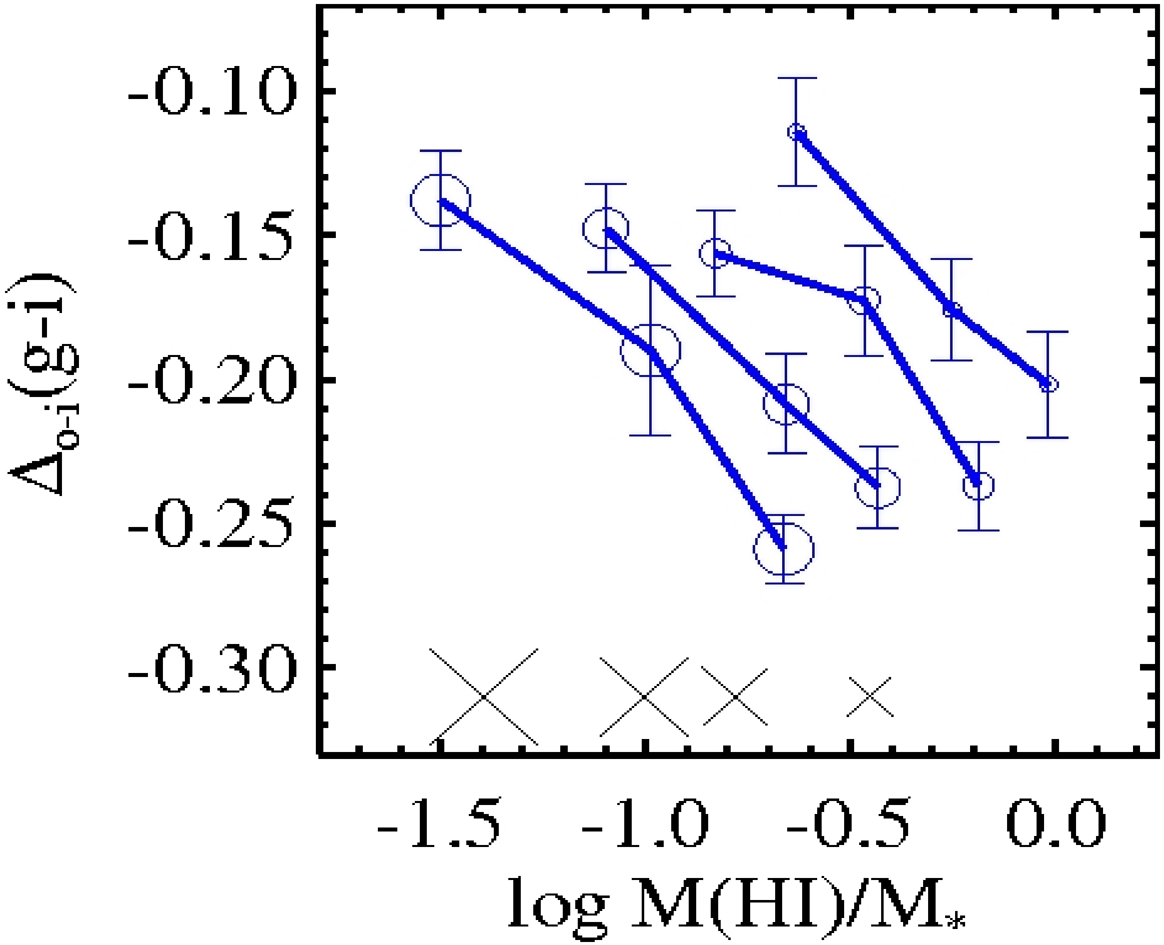
disk grows from the "inside out" over time

$$r_{\mathrm{d}} = \frac{\lambda}{\sqrt{2}} r_{\mathrm{vir}}$$

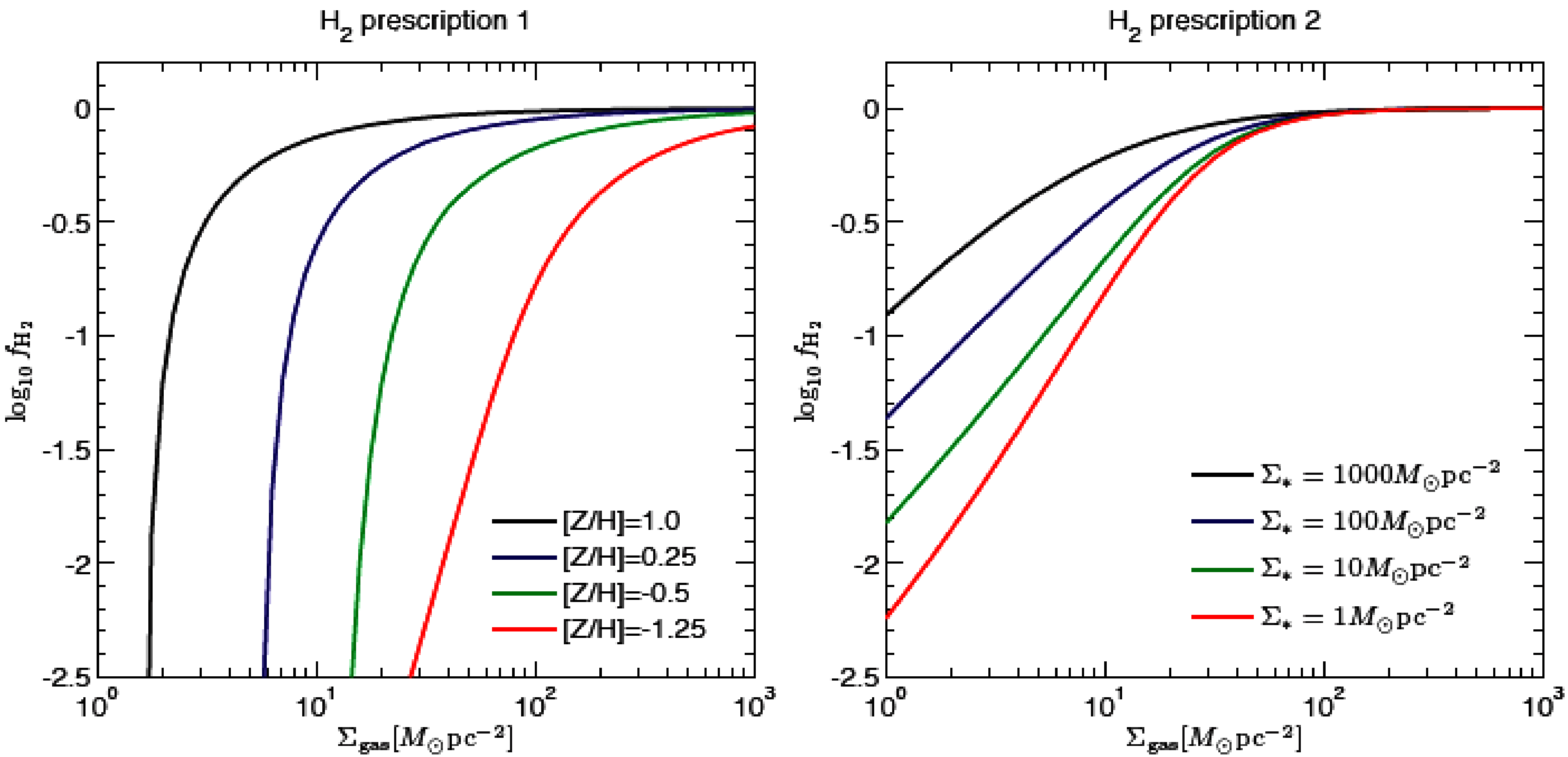


Wang, J. et al 2010：clear observational evidence for this picture



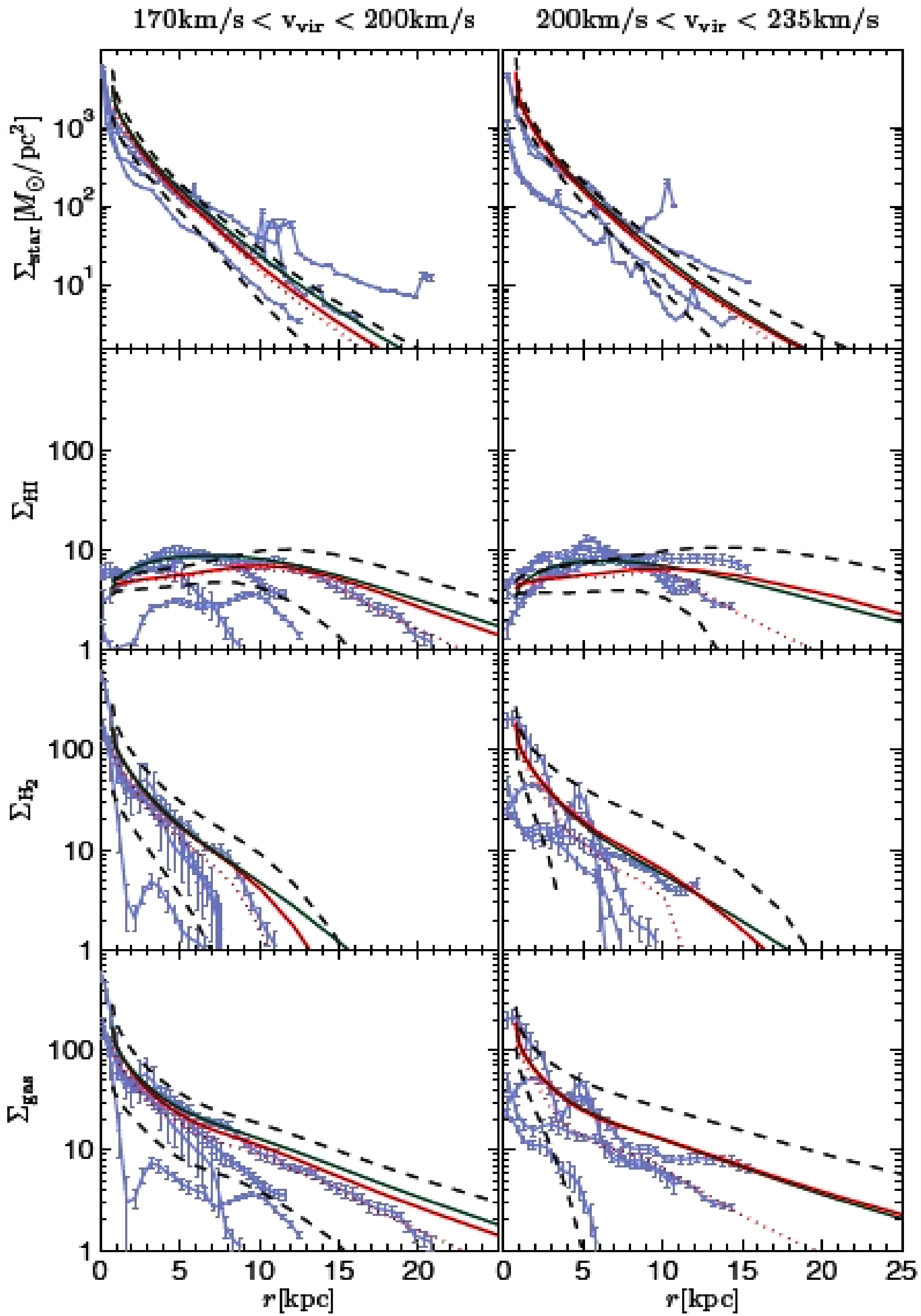


QUESTION: What does the model predict for the gas properties of galaxies?



$$\Sigma_{\mathrm{SFR}} = \alpha \Sigma_{\mathrm{H_2}}$$

$$\alpha = 4.9 \times 10^{-10} \mathrm{yr}^{-1}$$

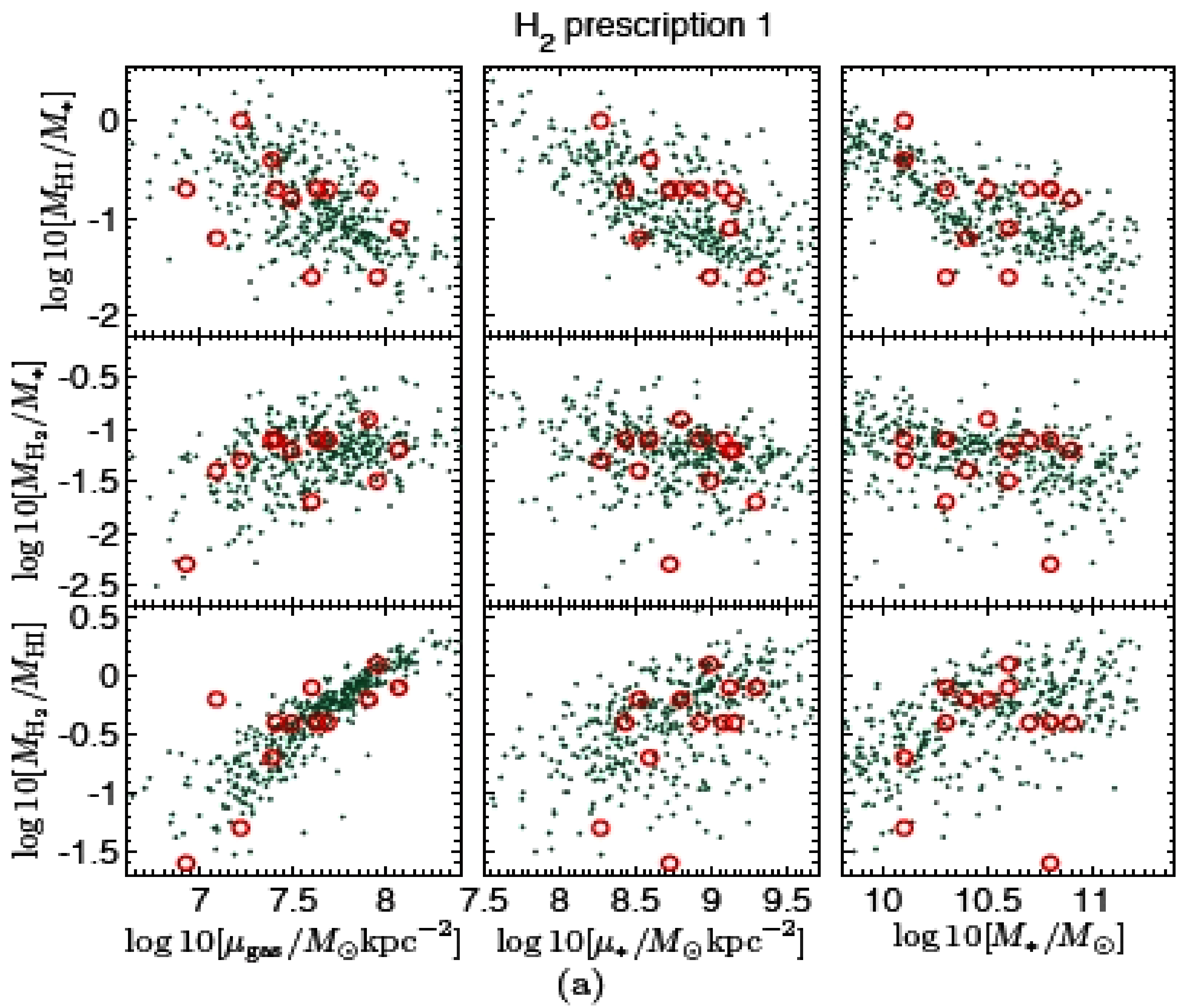


Additional free parameters in models are adjusted to reproduce mean gas and SFR profiles of galaxies from the THINGS/HERACLES survey.

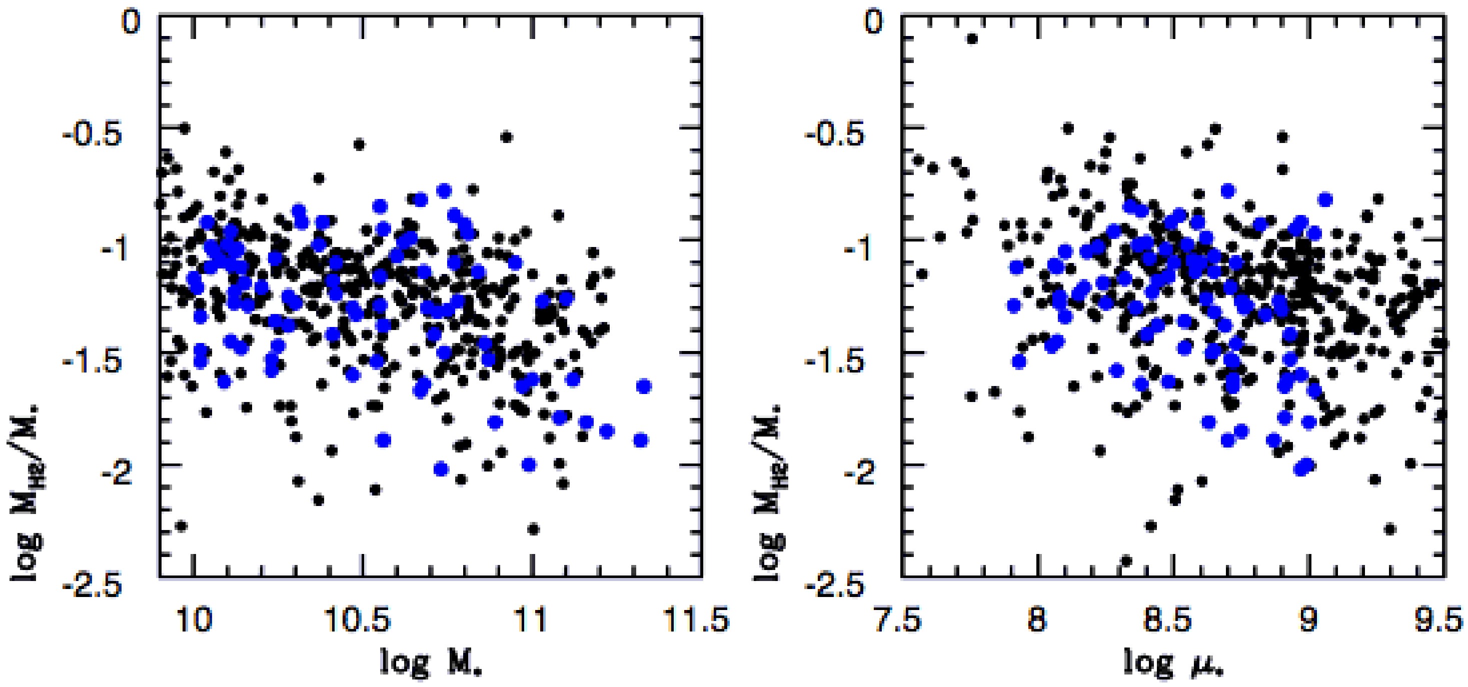
QUESTION:

Do we now reproduce gas properties for the general galaxy population?

Our models are tuned to reproduce gas density profiles of galaxies from THINGS, so the fact that they also roughly reproduce the global scaling relations for this same sample is a consistency check rather than a strong test of the models



What can we learn from comparing the models with the “UNBIASED” COLD GASS sample?



Blue points: disk-dominated COLD GASS galaxies with C<2.6

Black points: disk-dominated model galaxies

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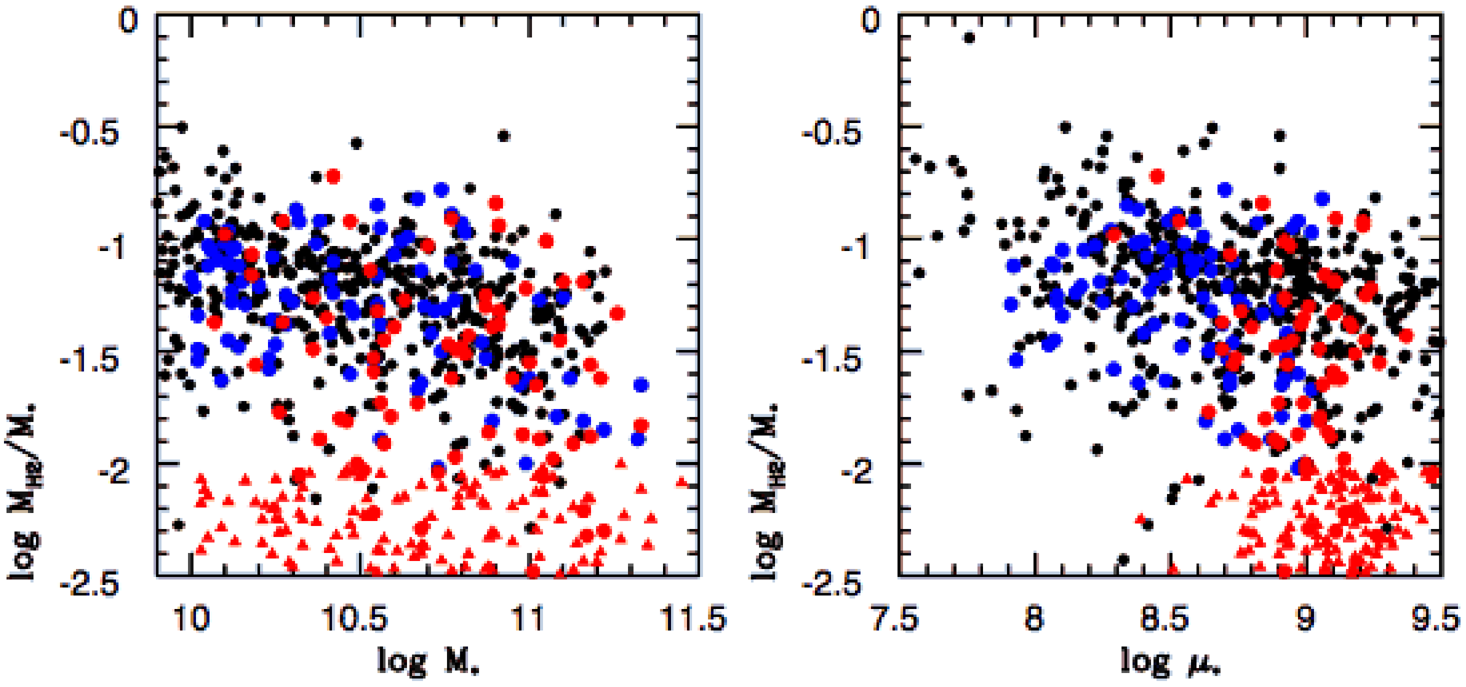
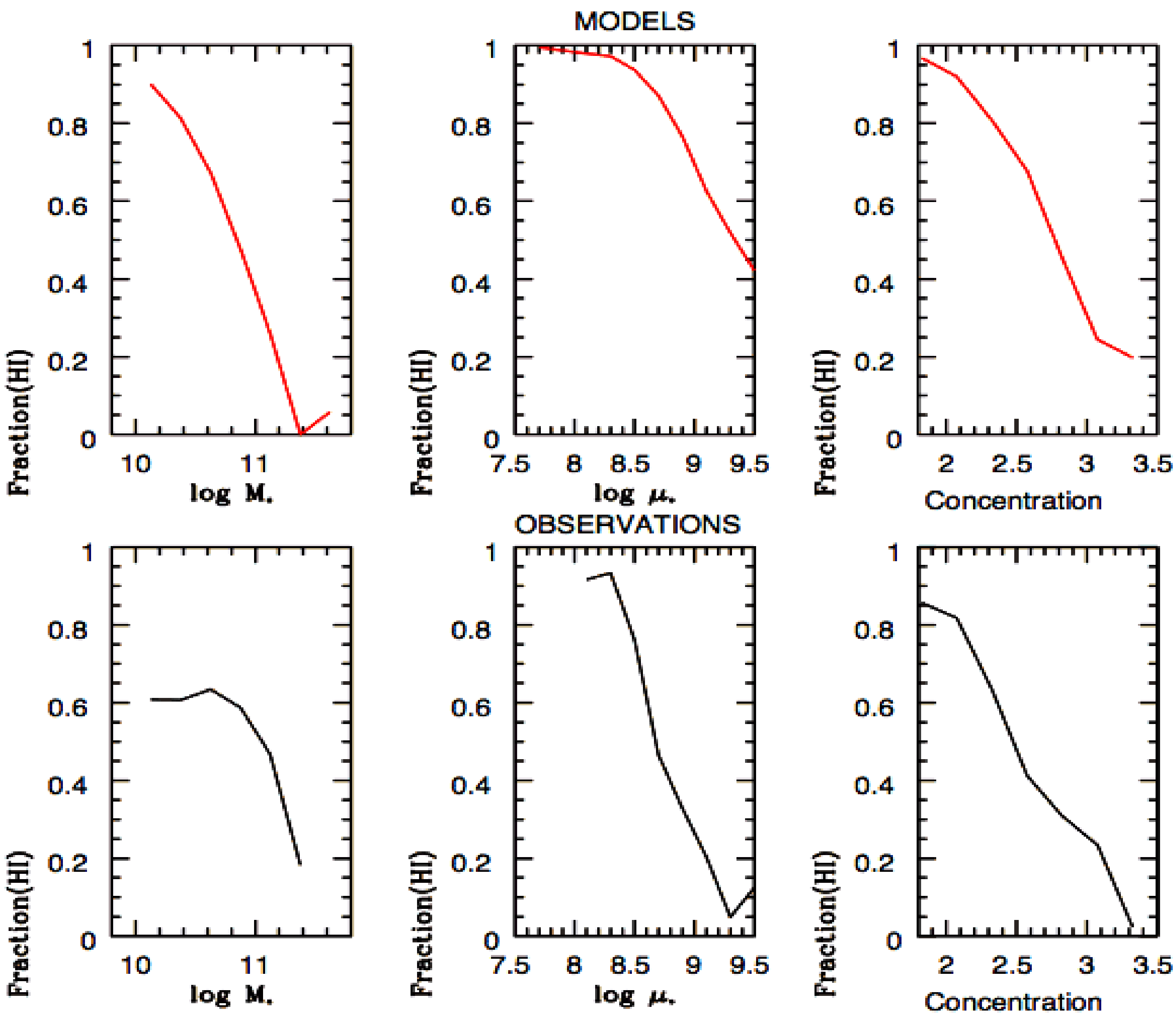


Blue points: disk-dominated COLD GASS galaxies with C<2.6
Red points: bulge-dominated COLD GASS galaxies with C>2.6
Black points: disk-dominated model galaxies

In models, “quenched fraction” is a strong function of 1) stellar mass, 2) bulge/disk ratio

In the data “quenched fraction” is a strong function of 1) **stellar density**, 2) bulge/disk ratio



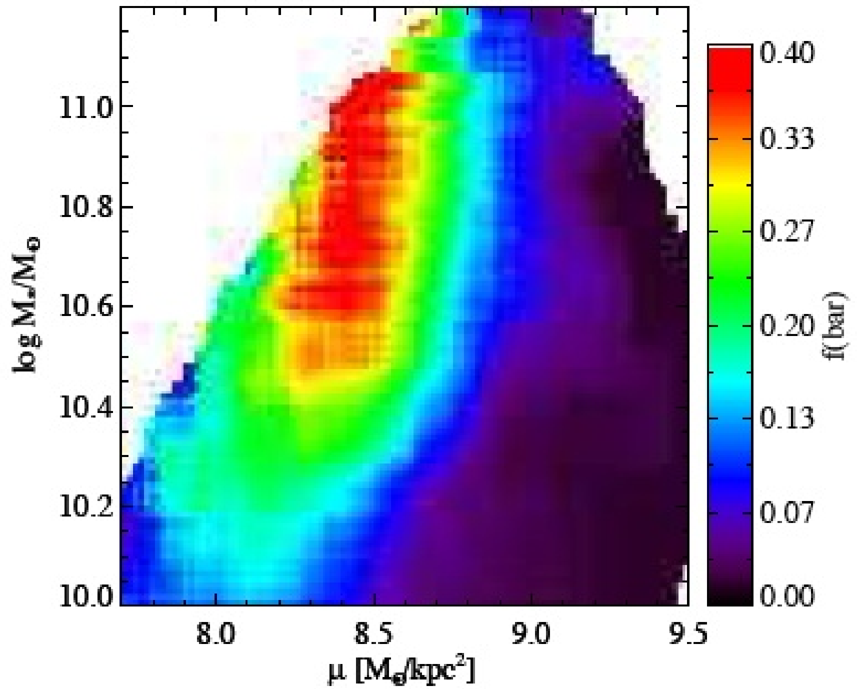
WHY is the quenched fraction scaling most strongly with M* and B/T in models?

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

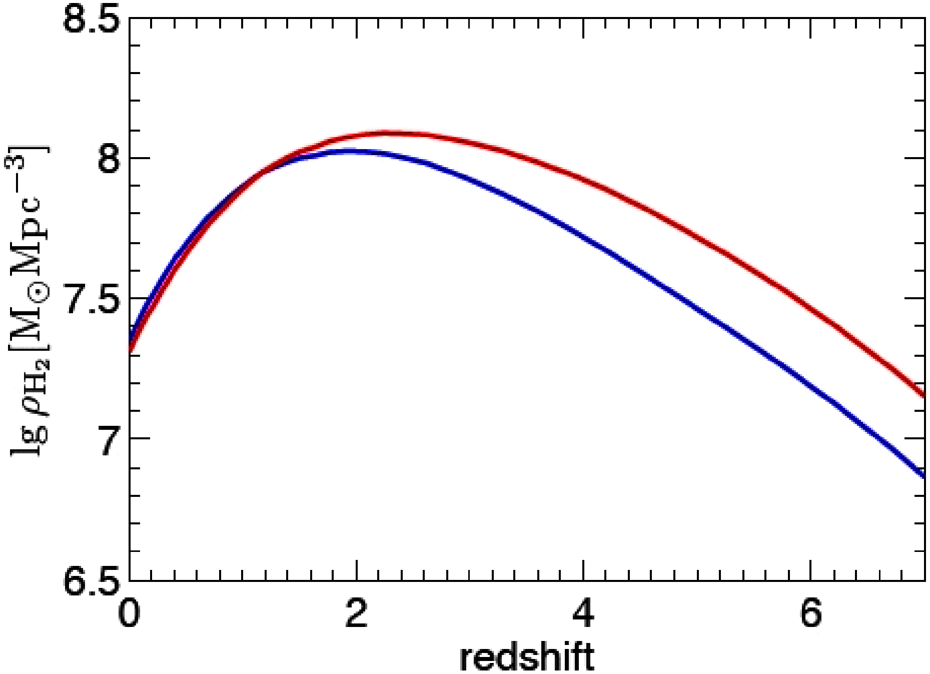
The equation for "radio mode" feedback in Croton et al (2006)

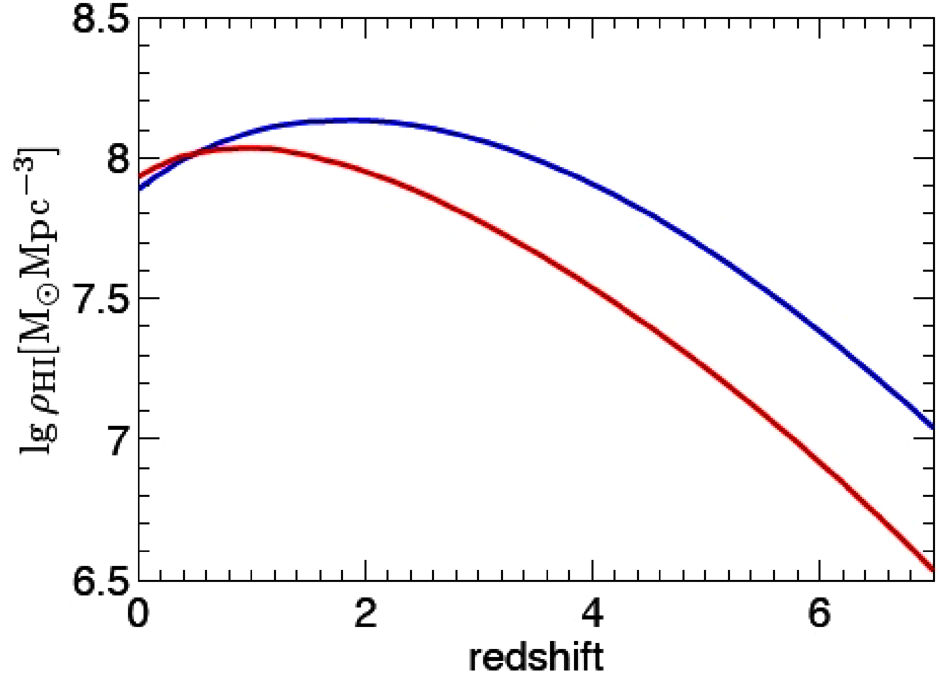
WHY is there such a strong dependence on density in the real data?

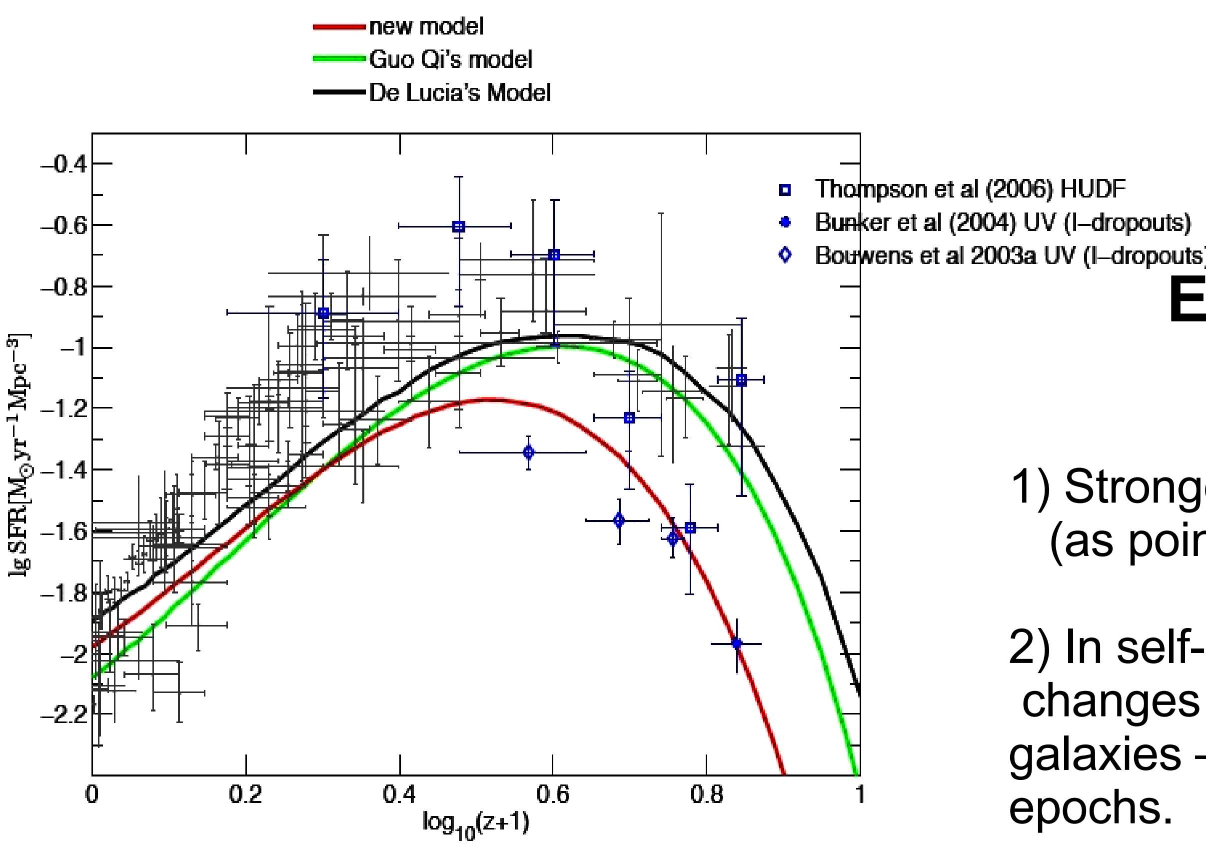
Current speculation: Disk instabilities play a role in the determining when galaxies are quenched.



Wang et al 2011, in prep







EVOLUTION TO HIGH REDSHIFT

1) Stronger evolution in H2 than in HI
(as pointed out by Obreschkow)

2) In self-consistent model , there are also changes to the star formation HISTORIES of galaxies – in general SF shifted to later epochs.

SUMMARY I

1) We have built semi-analytic models that track the inside-out formation of galactic disks from the cooling of gas within a merging hierarchy of halos.

2) We have incorporated the physically-motivated prescription of Kumholz, McKee & Tumlinson, as well as the empirically-motivated prescription of Blitz & Rosolowsky to determine the balance between atomic and molecular gas as a function of radius in these disks.

3) With a reasonable choice of parameters, the models match the gas and stellar radial profiles of disks from the THINGs/HERACLES surveys.

4) The model also reproduces global gas scaling relations for galaxies with stellar surface densities less than $10^{8.5}$ M_{sun} kpc $^{-2}$.

SUMMARY II

5) At higher densities, a large fraction of galaxies are bulge-dominated and are largely devoid of gas. This is **NOT** well reproduced in the models, which predict that gas fractions vary most strongly with halo mas (and by extension stellar mass).

6) The models predict that the comoving volume density of H2 becomes comparable to that of HI by redshifts 1-2. Properly accounting for the atomic-to-molecular transition in semi-analytic models moves star formation in galaxies to later times.