Monte Carlo Markov Chain Parameter Estimation in Semi-Analytic Models

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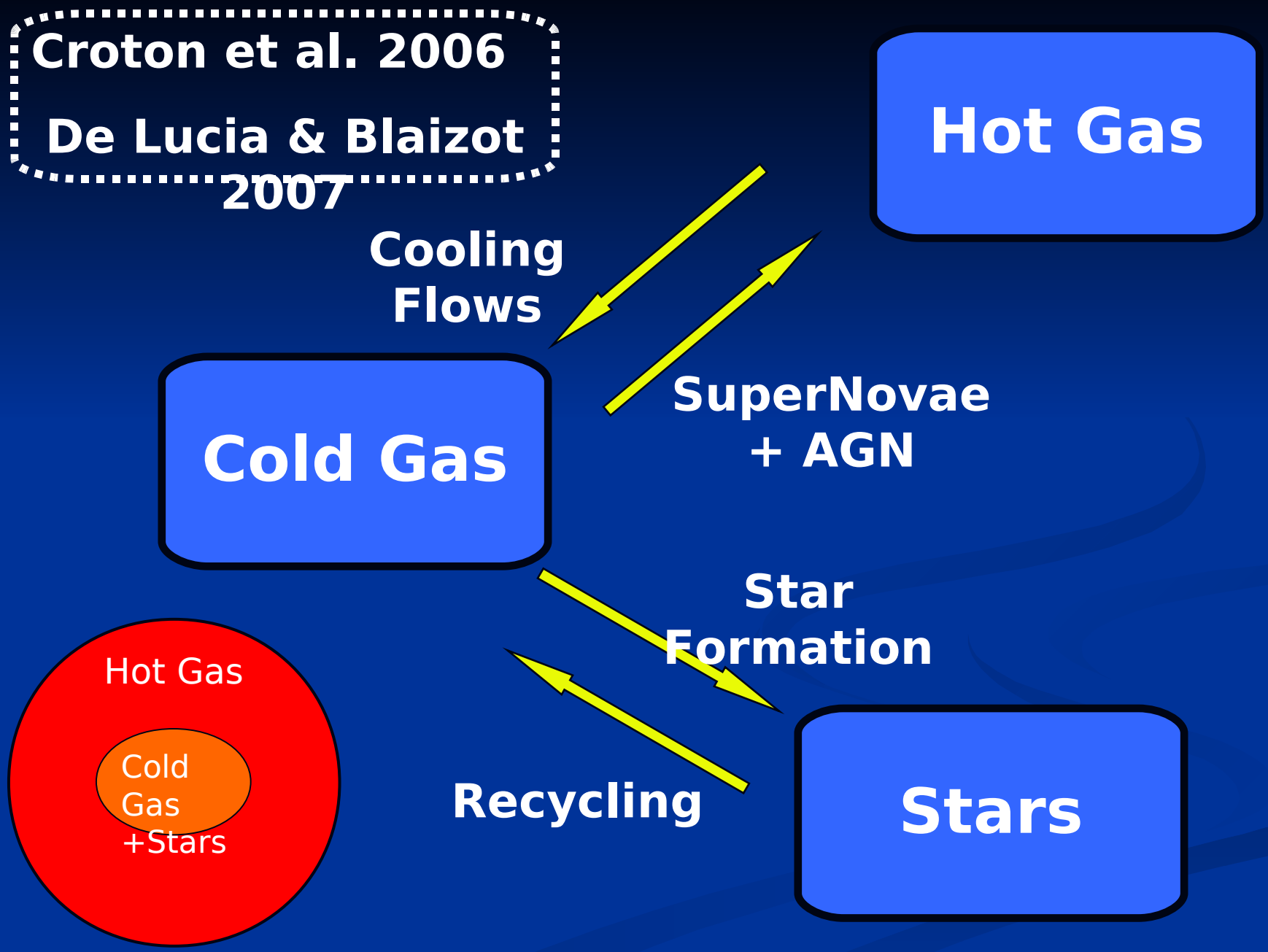
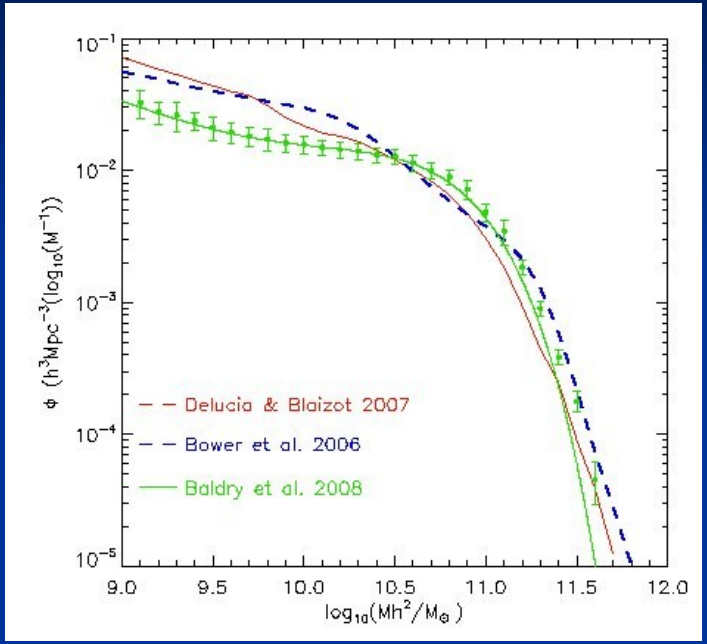
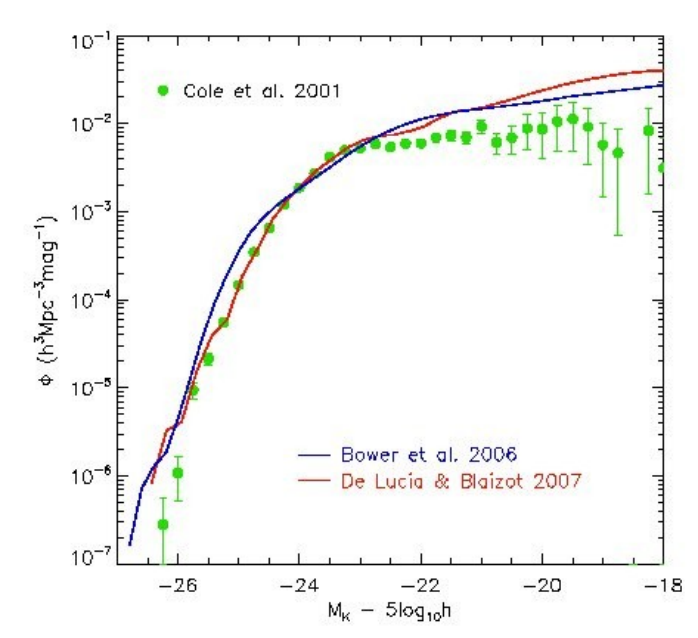
Croton et al. 2006

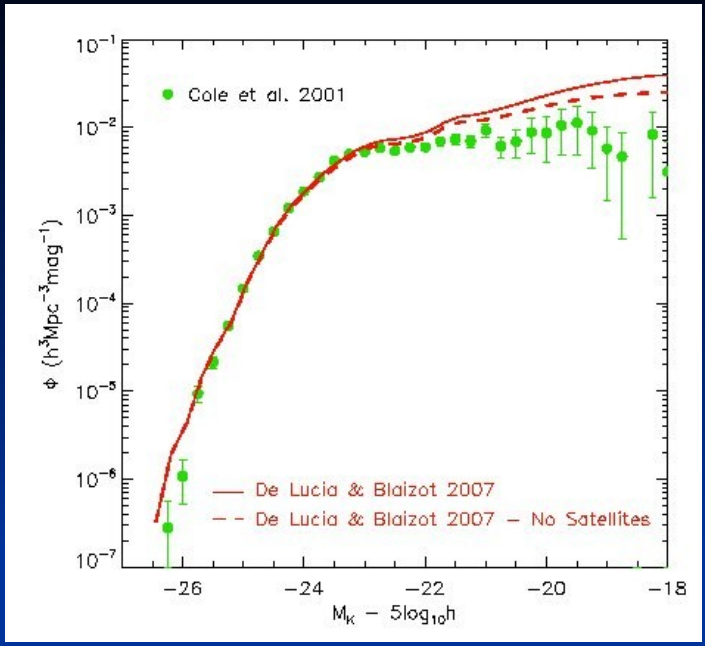
De Lucia & Blaizot 2007

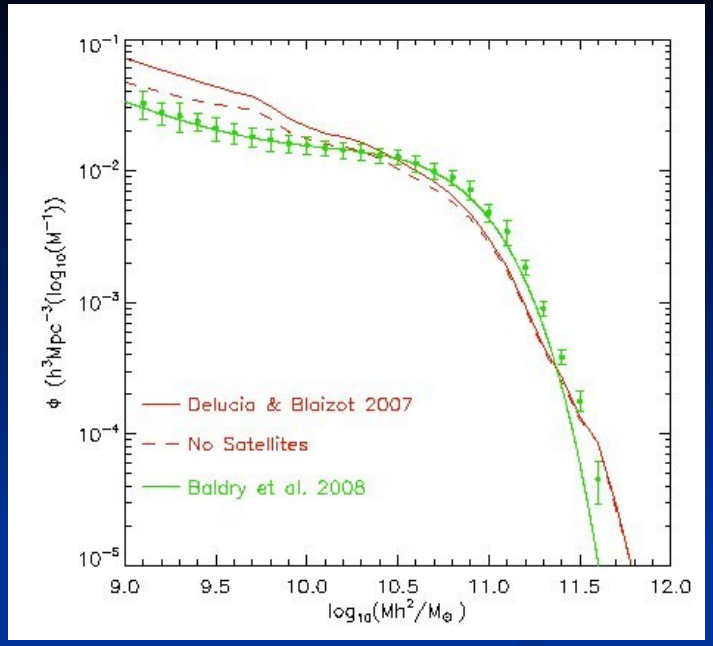


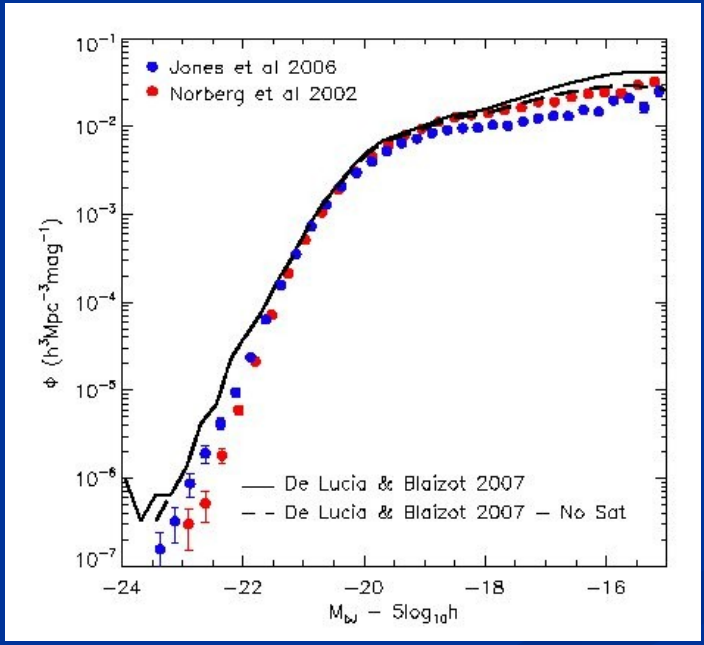




Both luminosities and stellar masses show an excess of dwarf galaxies in semi-analytic models built upon the millennium run – De Lucia & Blaizot 2007 and Bower et al. 2006.



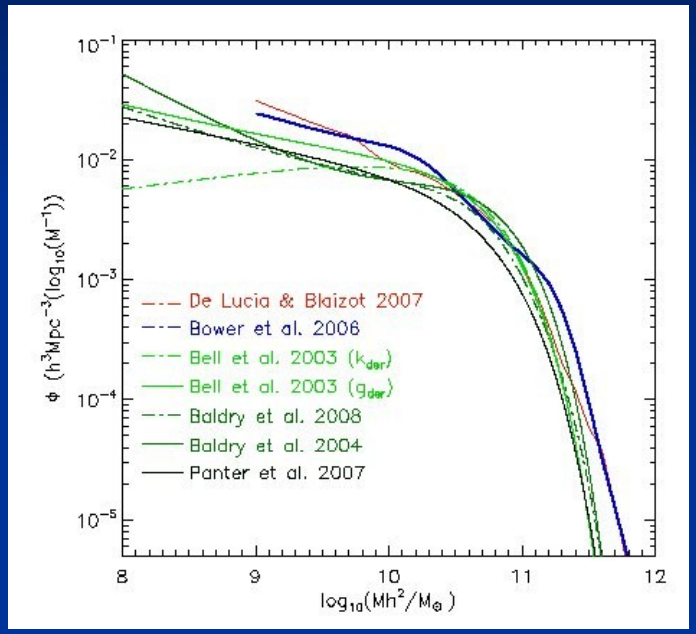


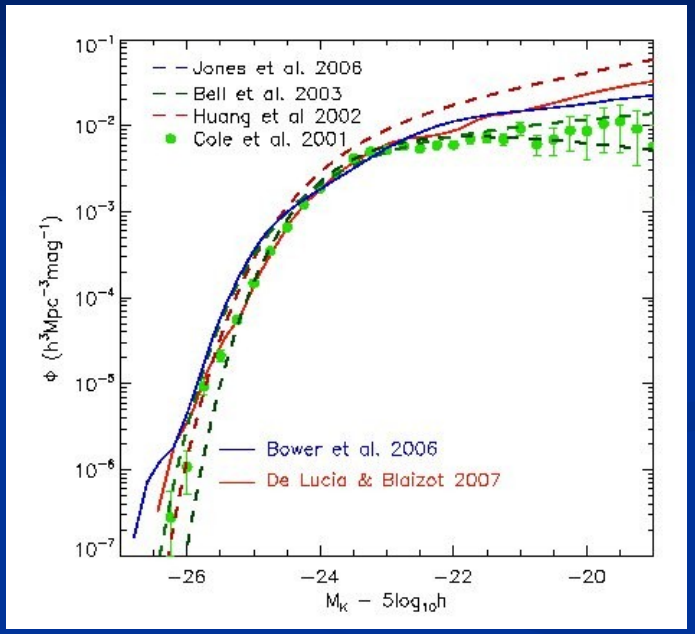


The disruption of satellite galaxies that already lost their dark matter halos is one possible way do decrease the excess of dwarf galaxies in semi-analytic models.

How significant is this excess? Can we improve the models by correctly tuning the free parameters?

Observations – Are we kidding ourselves?





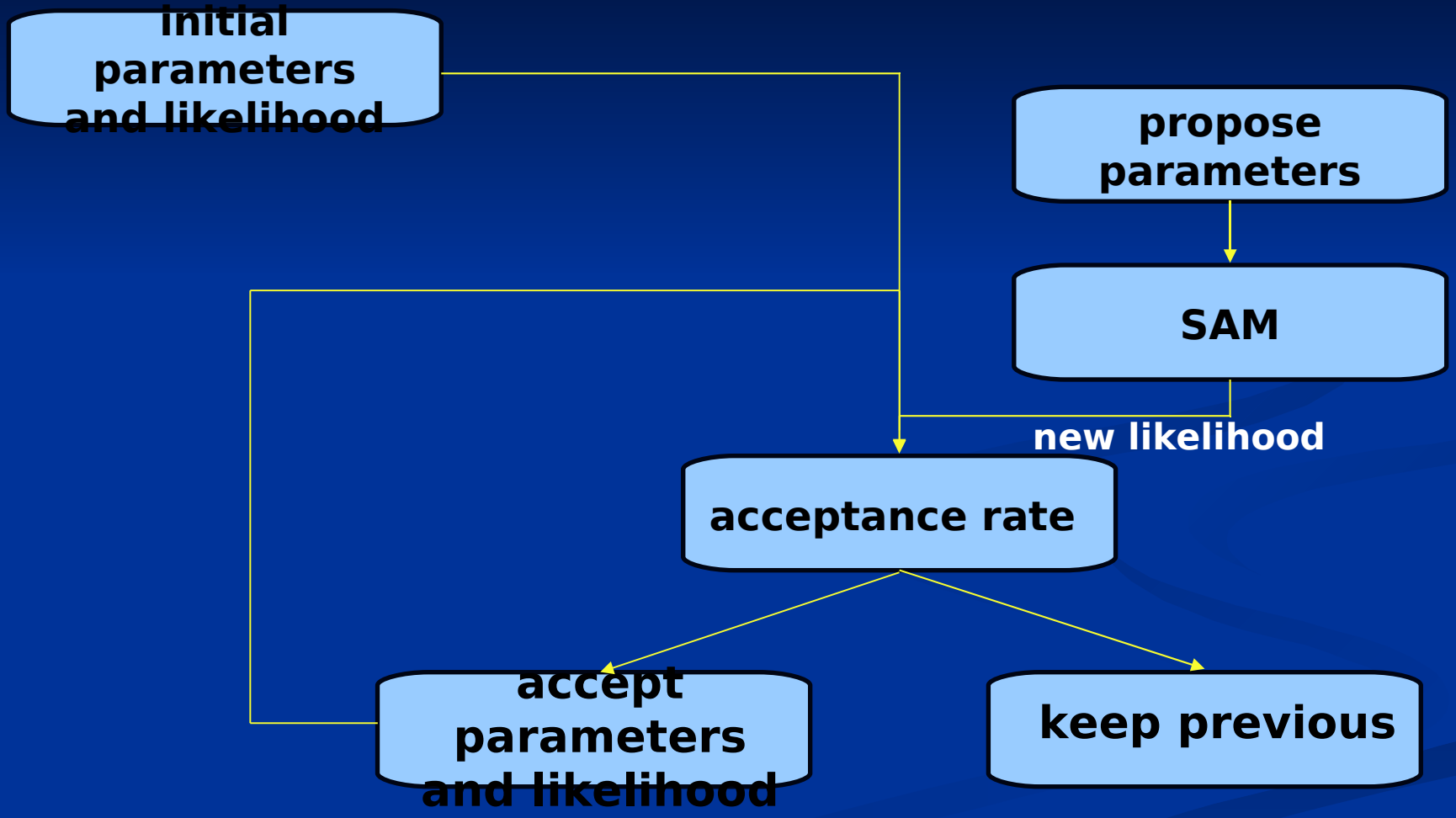
Different large galaxy surveys and different methods to determine galaxy masses produce stellar mass and luminosity functions incompatible with each other.

What is the real difference between models and observations? What level of agreement should we require?

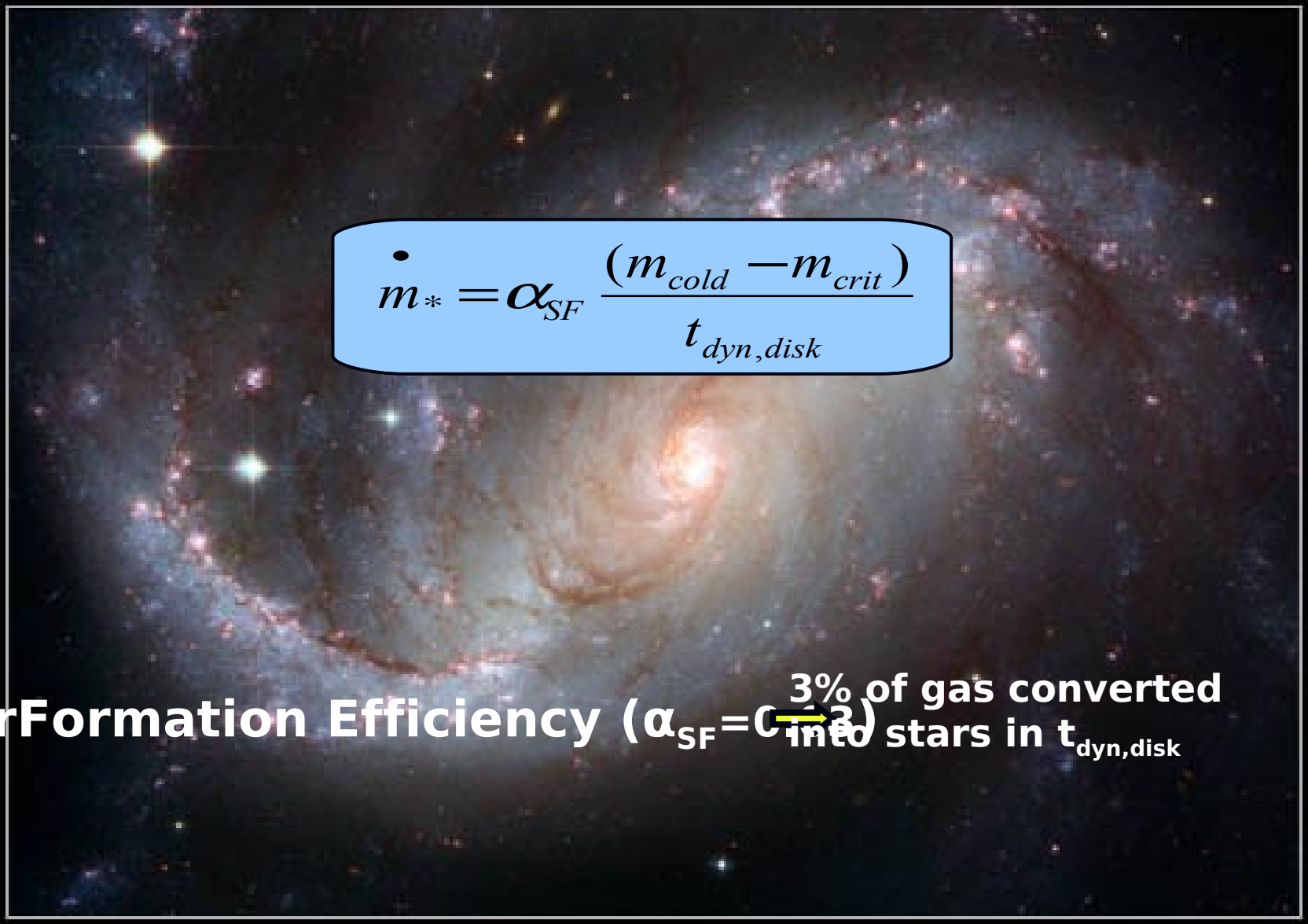
Monte Carlo Markov Chain Methods

- Model with parameters that can be changed
  - Semi-Analytic Model of Galaxy formation – De Lucia & Blaizot 2007
- A distribution of properties that the model should reproduce
  - Galaxy Stellar Mass Function
- Compare the output of the model for different sets of parameters with the expected distribution
  - Chi-Square Test (χ^2)

Monte Carlo Markov Chain Methods



Star Formation



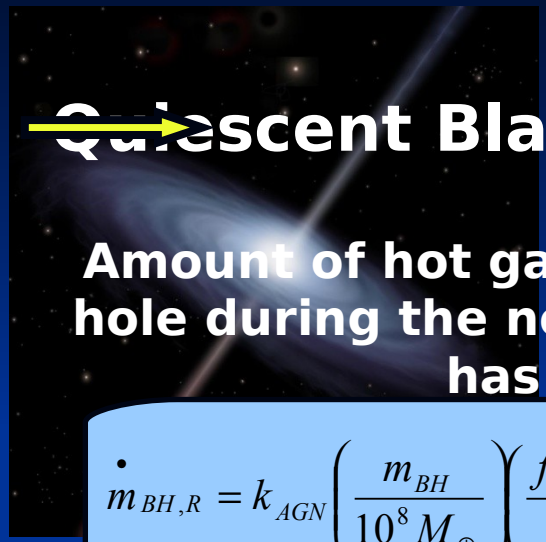
$$\dot{m}_* = \alpha_{SF} \frac{(m_{cold} - m_{crit})}{t_{dyn,disk}}$$

StarFormation Efficiency (α_{SF}=C$\Rightarrow$3)

3% of gas converted into stars in $t_{dyn,disk}$

Hubble Heritage

AGN FeedBack



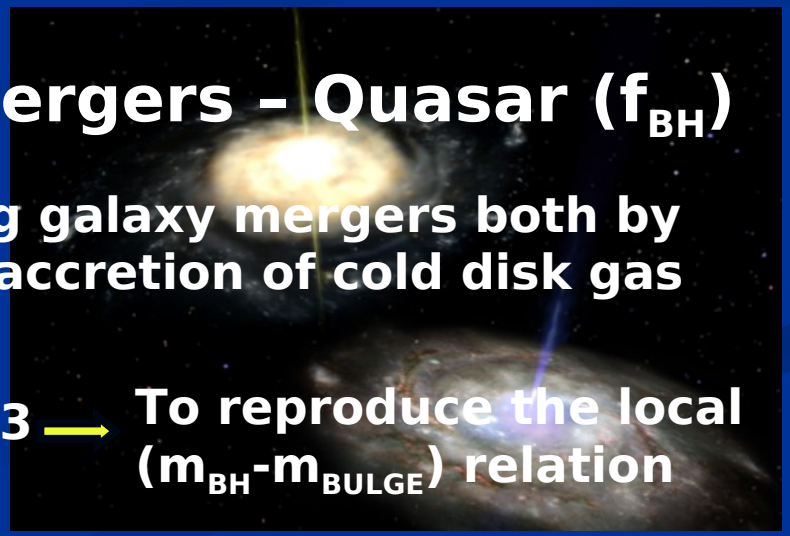
Quiescent Black Hole Accretion Rate – Radio (k_{AGN})

Amount of hot gas accreted by the central supermassive black hole during the normal life of the galaxy (once a static hot halo has formed around the host galaxy)

$$\dot{m}_{BH,R} = k_{AGN}\left(\frac{m_{BH}}{10^8 M_\oplus}\right)\left(\frac{f_{HOT}}{0.1}\right)\left(\frac{V_{vir}}{200 kms^{-1}}\right)^3$$

k_{AGN}=7.5x10^{-6} → **To reproduce the turn ov at the bright end side of**

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



Growth of black hole mass during galaxy mergers both by merging with each other and by accretion of cold disk gas

$$\dot{m}_{BH,Q} = f_{BH}\frac{(m_{sat}/m_{central})m_{cold}}{1+(280 kms^{-1}/V_{vir})^2}$$

f_{BH}=0.03 → **To reproduce the local (m_{BH}-m_{BULGE}) relation**

Supernovae Feedback

- Cold Gas Reheating

$$\Delta m_{reheated} = \varepsilon_{disk} \Delta m_*$$

$\varepsilon_{DISK}=3.5$

- Energy Released by a Supernova

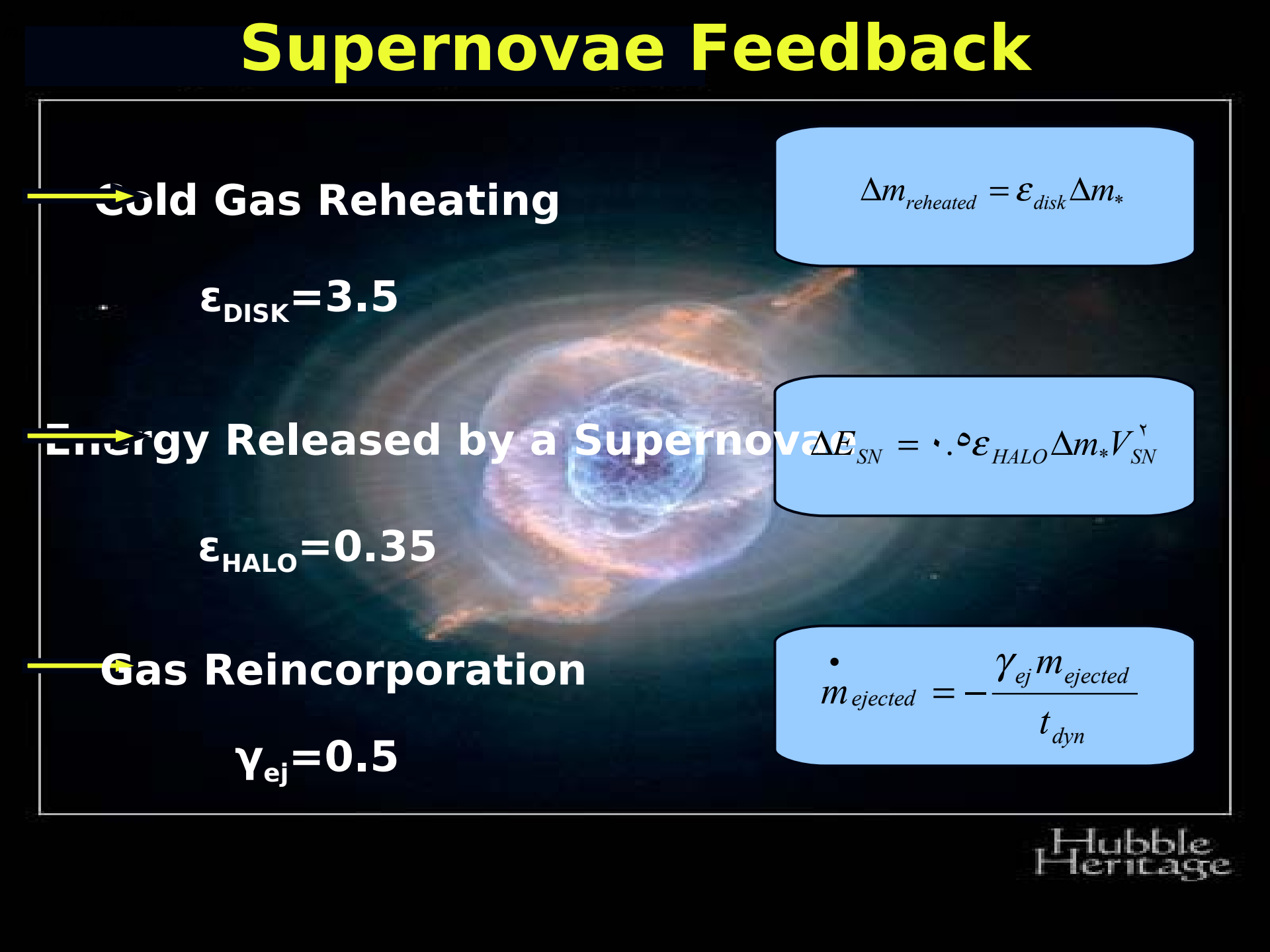
$$\Delta E_{SN} = ۰.۵ \varepsilon_{HALO} \Delta m_* V_{SN}^{۲}$$

$\varepsilon_{HALO}=0.35$

- Gas Reincorporation

$$\dot{m}_{ejected} = -\frac{\gamma_{ej} m_{ejected}}{t_{dyn}}$$

$\gamma_{ej}=0.5$



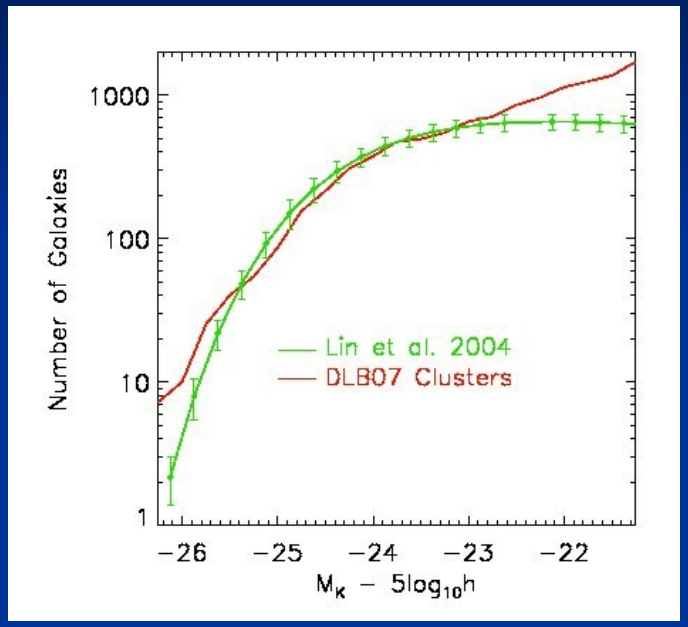
Comparison with Observational Clusters

Only requires to run the SA in a few trees (relatively fast)

Clusters are free of dust (avoid “weak” assumptions on dust corrections)

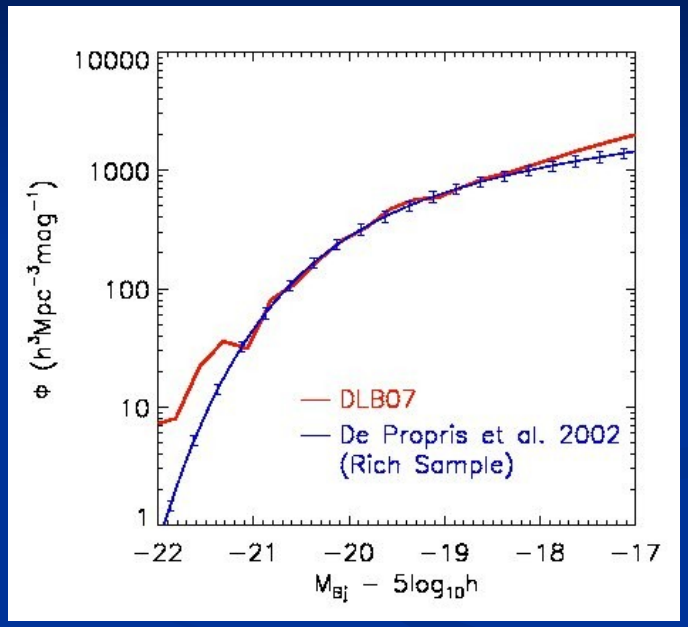
It is not affected by volume corrections

Lin et al. (2004) – 25 Clusters



derived using 2-MASS, with X-ray identified clusters

De Propris et al. (2003) – 22 Clusters



cross-matched galaxies from the 2dFGRS with published clusters catalogues (Abell, APM and EDCC).

Star Formation Efficiency

- Very well constrained at a value corresponding to 3% of cold gas being converted into stars in a dynamical time.

SN Feedback

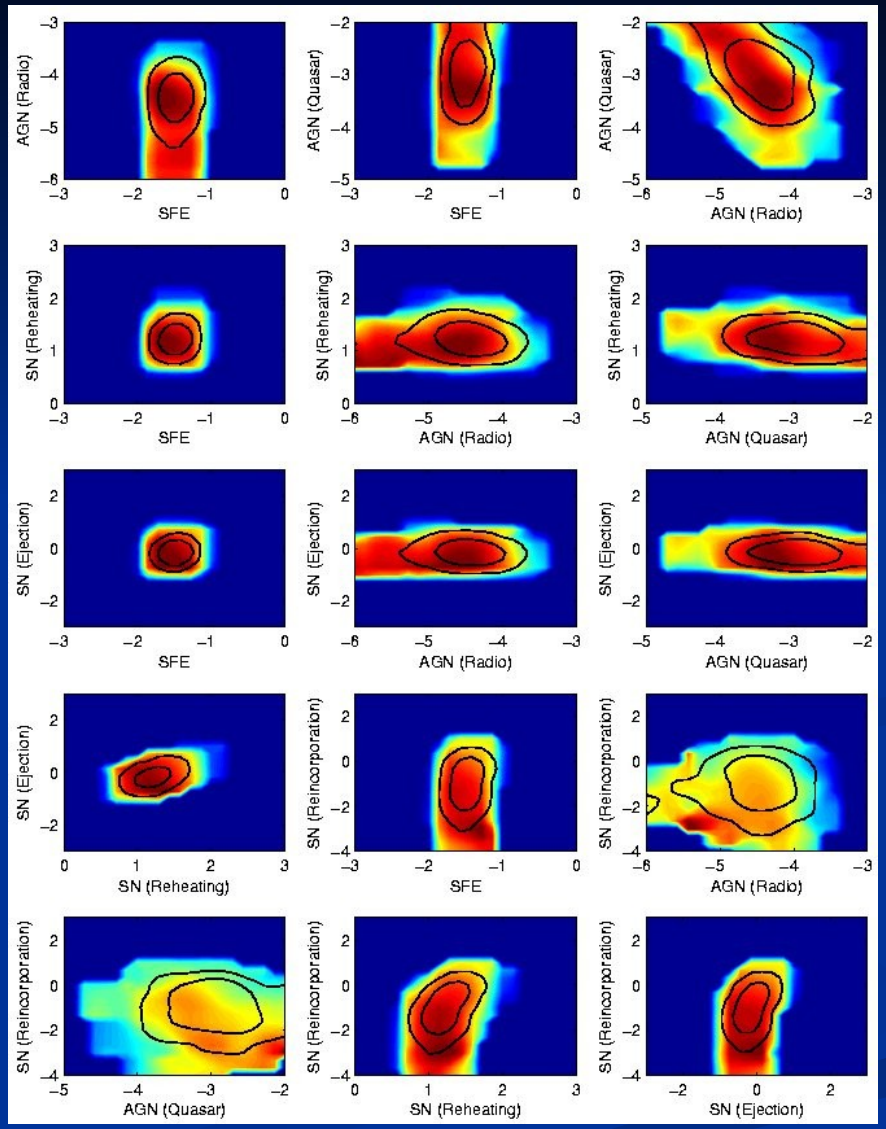
- Very well constrained at a value higher that DLB07 to reduce the number of faint galaxies.

AGN Feedback

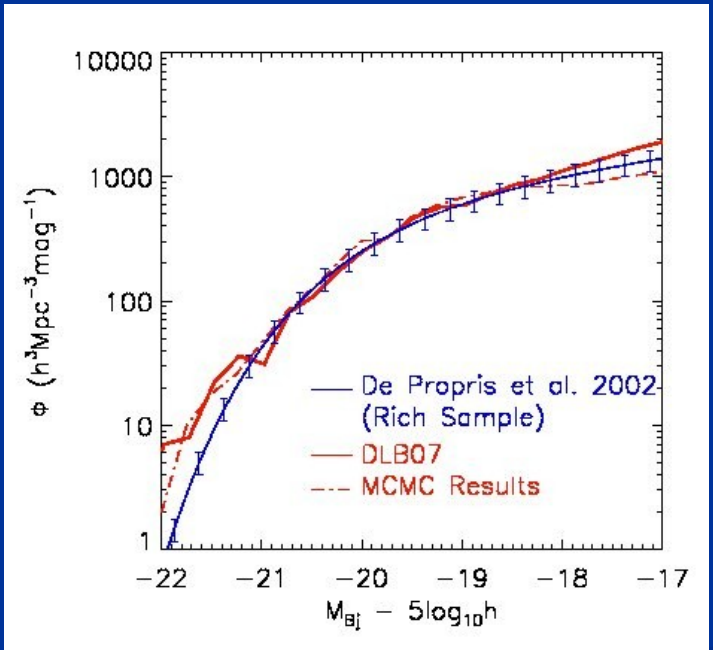
- Strong correlation between two modes.

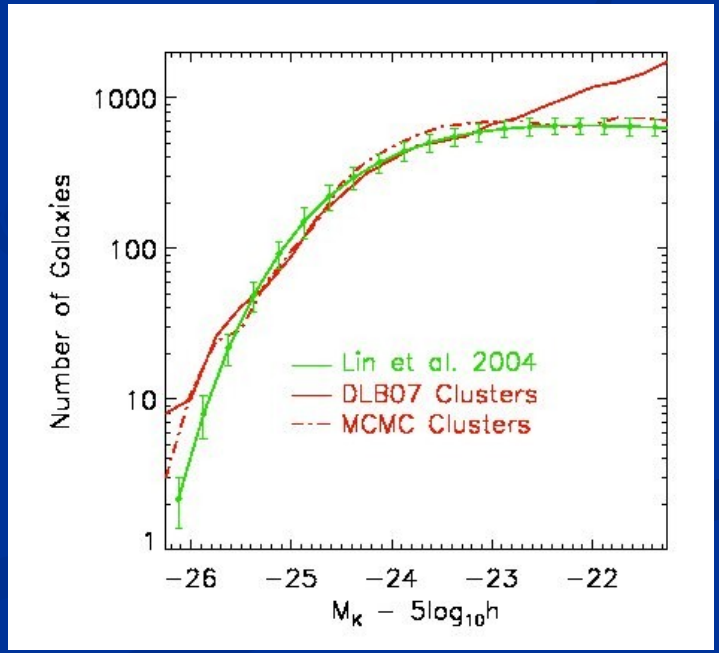
Gas Reincorporation

- Strong correlation with AGN feedback parameters.



Parameters	DLB07	Best Fit
SFE	0.03	0.033
AGN (radio)	7.5×10^{-6}	3.0×10^{-5}
AGN (quasar)	3.0×10^{-2}	1.3×10^{-3}
SN (reheating)	3.5	16.70
SN (ejection)	0.35	0.70
Reincorporation	0.5	0.018





MCMC With a Full Galaxy Catalogue

→ Chose a file with mean density the similar to that of the full millennium volume.

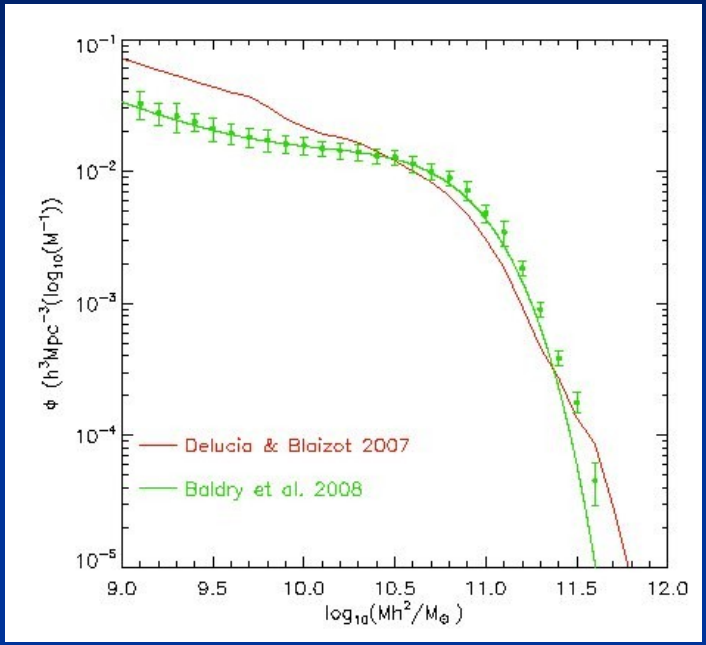
→ The luminosity function for the galaxies in this file should agree with the total LF.

Full semi-analytic model in one day

(1/512 of the Millennium volume)

30 000 steps in 100 processors

Observational Stellar Mass Function



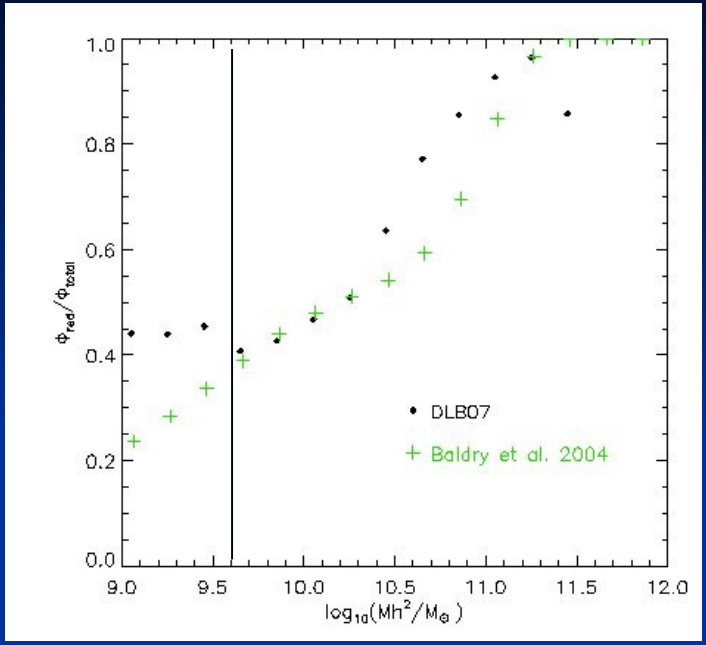
Choose a set of observables that uniquely define all galaxy properties

⇒ **Stellar Mass**

⇒ **Star Formation Rate**

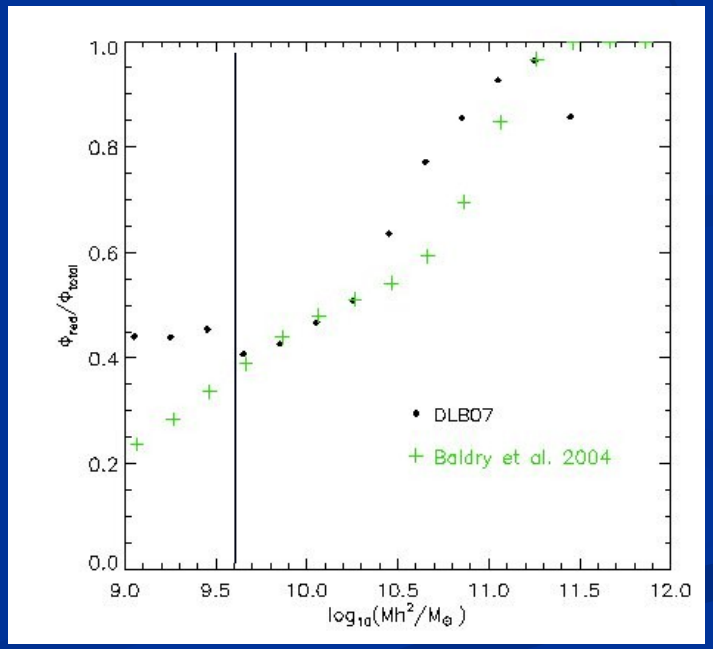
Observational stellar mass from the NYU-VAGC low redshift galaxy sample.

Colour



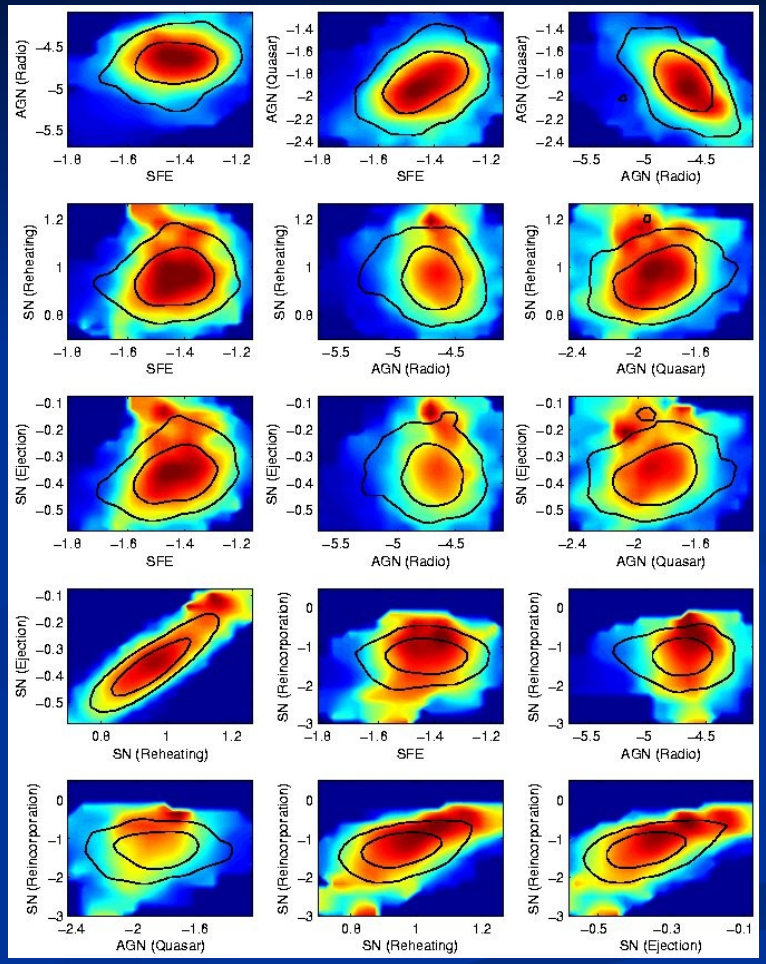
use galaxy colours to constrain the star formation history of model galaxies

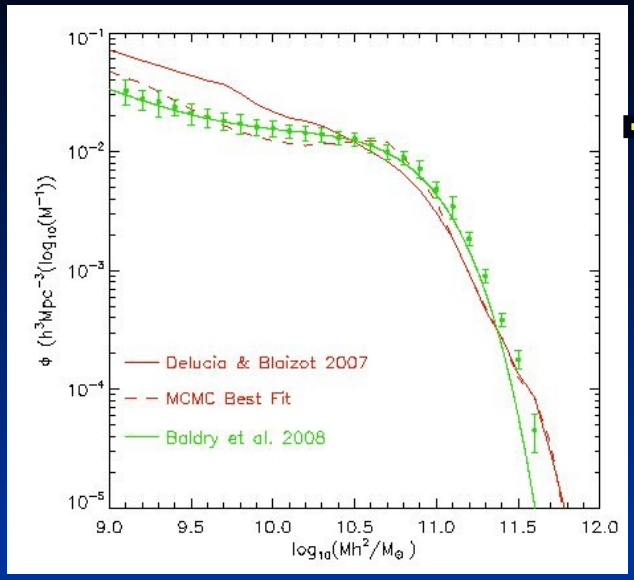
Bulge – Black Hole Mass



use bulge – black hole mass relation to constrain the AGN feedback

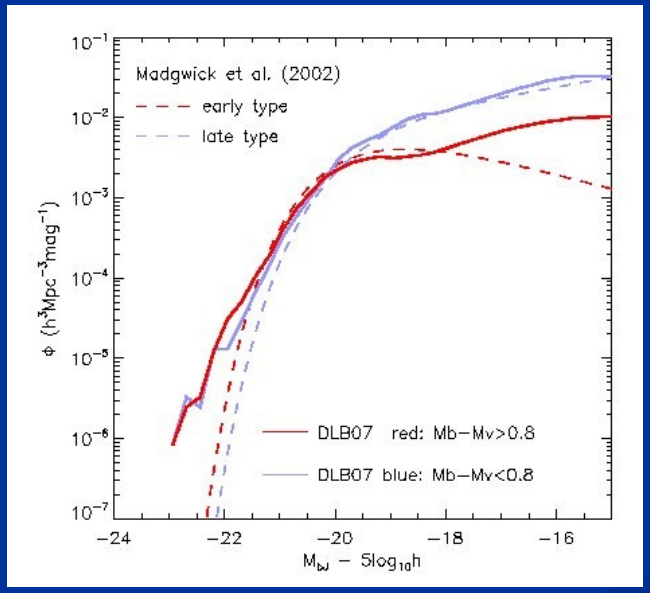
Parameters	DLB07	Best Fit Clusters	Best Fit Field
SFE	0.03	0.033	0.037
AGN (radio)	7.5×10^{-6}	3.0×10^{-5}	2.3×10^{-5}
AGN (quasar)	3.0×10^{-2}	1.3×10^{-3}	1.2×10^{-2}
SN (reheating)	3.5	16.70	8.55
SN (ejection)	0.35	0.70	0.42
Reincorporation	0.5	0.018	0.07



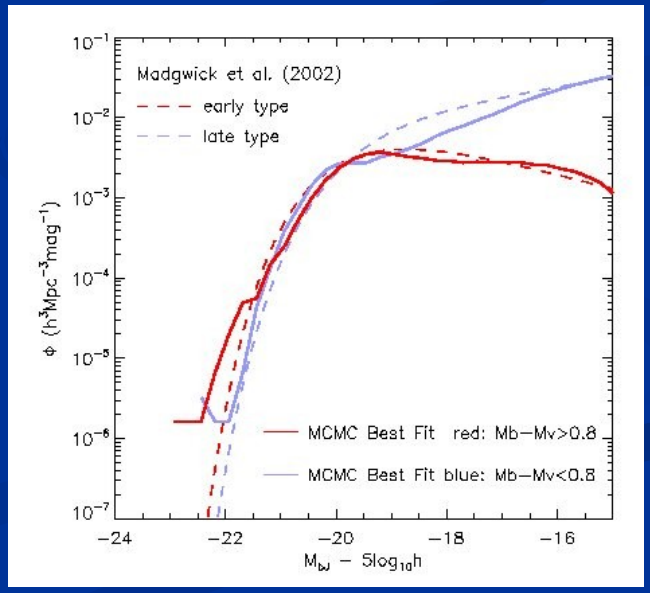


Stellar Mass Function

Original Colours



Best Fit Colours

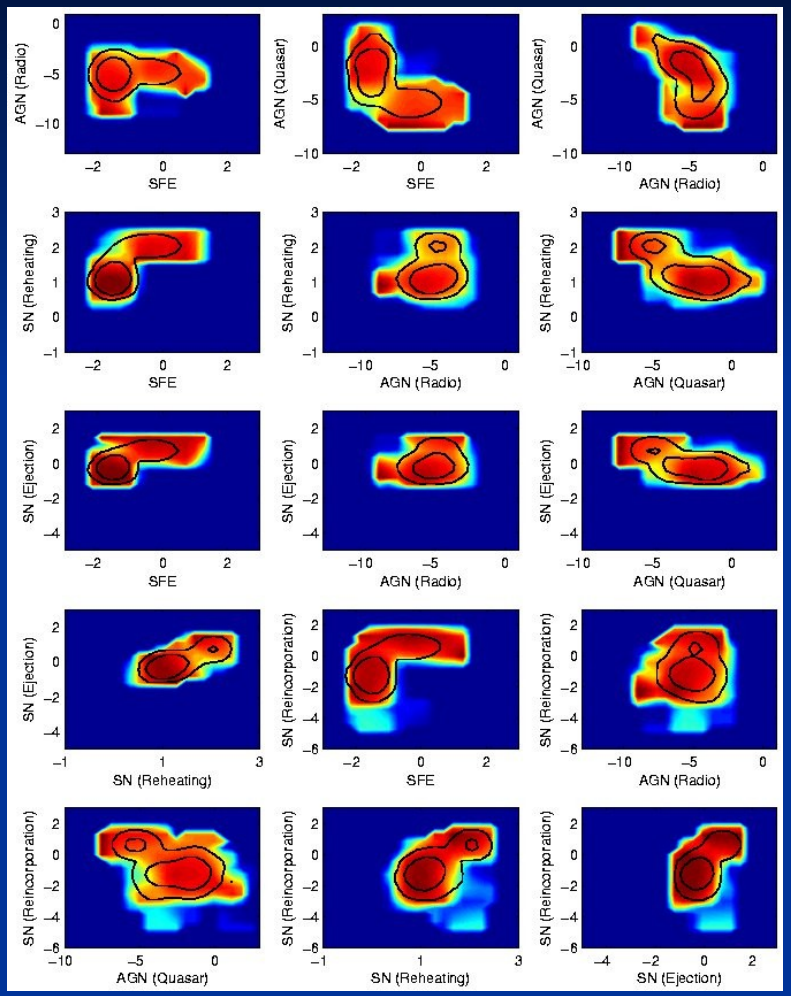


Future Work

- Increase the number of observational constrains.
- Use best fits to predict high redshift observations.
- Use a similar approach to chose between different SA models, with different parameters and physics.

Kampakoglou et al. 2007

The End



A model with instantaneous star formation is not ruled out.

At each time step all the available gas is converted into stars.

Considering the high star formation efficiency this model requires strong SN feedback, so that for most of the time steps the available gas is bellow the critical limit .

Ruled out by star formation time scales observations.