Semi-analytic modeling of galaxy formation: the local Universe

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OUTLINE

Advantages

How?

* Components
* Implementation

RESULTS from SAM

Discussion/Conclusions

Advantages

Follows complicated baryonic physics through simple (averaged) prescriptions

Computationally cheap

Cosmological scale simulation

HOW ?

Monte Carlo technique to calculate merger tree (i.e. allow mass loss, and merger event z chosen randomly).

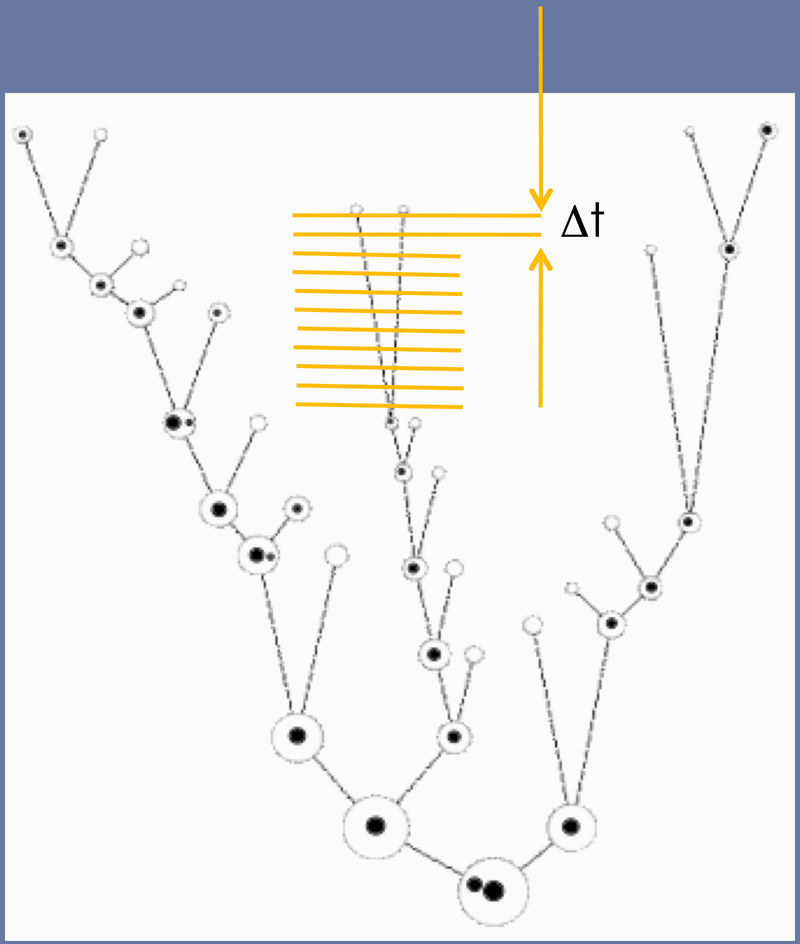
Normalized to Sheth-Tormen

Choice of 6 cosmologies

Grid of 50 halos

Halo = Singular Isothermal Sphere (sets density profile), virialized

$V_c(r_{VIR})$ ~ size of Halo



Prescribe for Each Halo

Cooling of gas

Disc formation

Reheating – SN feedback

Star formation

Stellar population synthesis models

Dust absorption

Chemical evolution

Galaxy morphologies

Galaxy distribution, evolution (stripping etc)

Mergers

Gas Cooling

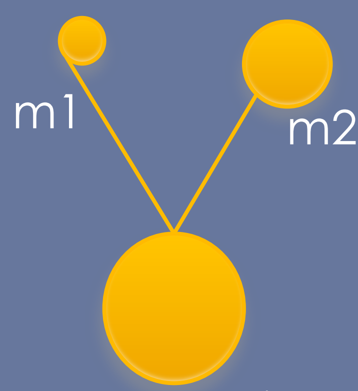
$$\rho_{\rm cool} = \frac{3}{2}\frac{\mu m_p}{\left(n_e/n_{\rm tot}\right)^2}\frac{k_B T}{\tau_{\rm cool}\Lambda\left(T\right)} \longrightarrow r_{\rm cool}$$

$$\mathrm{d}m_{\rm cool} = 4\pi r_{\rm cool}^2 \rho_g\left(r_{\rm cool}\right)\Delta r$$

Through a merger

Static Cooling:

* Merger Independent
* $\tau_{\rm cool} = t_{\rm universe}$



Dynamic Cooling:

* Merger Halo Mass Dependent

If $m_2/m_1 < f_{reheat}$

all gas reheated

If $m_2/m_1 > f_{reheat}$

$$\tau_{\rm cool} = \tau_{{\rm cool},m_2}$$

$$r_{\rm cool} = r_{{\rm cool},m_2}$$

All newly accreted gas falls onto exponential disk.
Accretion rate is constant between mergers

Star Formation

$$\dot{m}_* = \frac{m_{\rm cold}}{\tau_*}$$

SFR-C

$$\tau_* = \tau_*^0$$

SFR-D

$$\tau_* = \tau_*(V_c) = \tau_*^0 \left(\frac{V_c}{V_0}\right)^{\alpha_*}$$

SFR-M

$$\tau_* = \tau_*^0 \tau_{\rm dyn} \qquad \tau_{\rm dyn} \sim \frac{r_{\rm disc}}{V_c}$$

Supernova Feedback
Disc-Halo Model

$$\dot{m}_{\mathrm{rh,disc}} \propto \frac{\dot{\epsilon}_{\mathrm{SN}}}{\langle v^2_{\mathrm{esc,disc/halo}} \rangle}$$

Mass that can escape disc, but not halo, is added back to halo

Mass that escapes halo is lost forever

Mergers: Life in a Cluster

Dynamical friction helps move subhalos/galaxies closer to the parent halo cetner (facilitates stripping)

Stripping changes morphology, mass, and luminosity. Morphology determined by disc/bulge ratio

Satellite halo mergers (new)

* Disc may get destroyed
* Always mass added to bulge

Normalization

- Choose reference halo with V_c = 220 km/s to be Milky Way like halo. Ensure its properties are on the I-band Tully Fisher Relation.

- This fixes free parameters like f_{reheat}, or τ^0_*

(1) τ_*^0 (2.5): the star formation time-scale;
(2) ϵ_{SN}^0 (2.6): the supernova reheating efficiency;
(3) y (2.7): the chemical evolution yield (mass of metals produced per unit mass of stars);
(4) f_{lum}^* (2.9): the fraction of the total stellar mass in luminous stars;
(5) f_{mrg} (2.8.1): the initial distance of satellite haloes from the central galaxy after a halo merger, in units of the (post-merger) virial radius, and
(6) f_{bulge} (2.8.4): the mass ratio that divides major mergers from minor mergers; it determines whether a bulge component is formed.

Comparisons With Observations

From SFR recipe, get rough stellar ages.

Assume IMF, with ages allows prediction of stellar luminosities, and develop SEDs

Convolve predicted SED with instrument filter response (I – band, B – band, etc…) to get observed luminosities in bands, and magnitudes to compare with observations!

Models

"Classic":
- Static cooling
- dynamic friction

Table 4. Galaxy formation parameters for the 'Classic' models (SCDM).

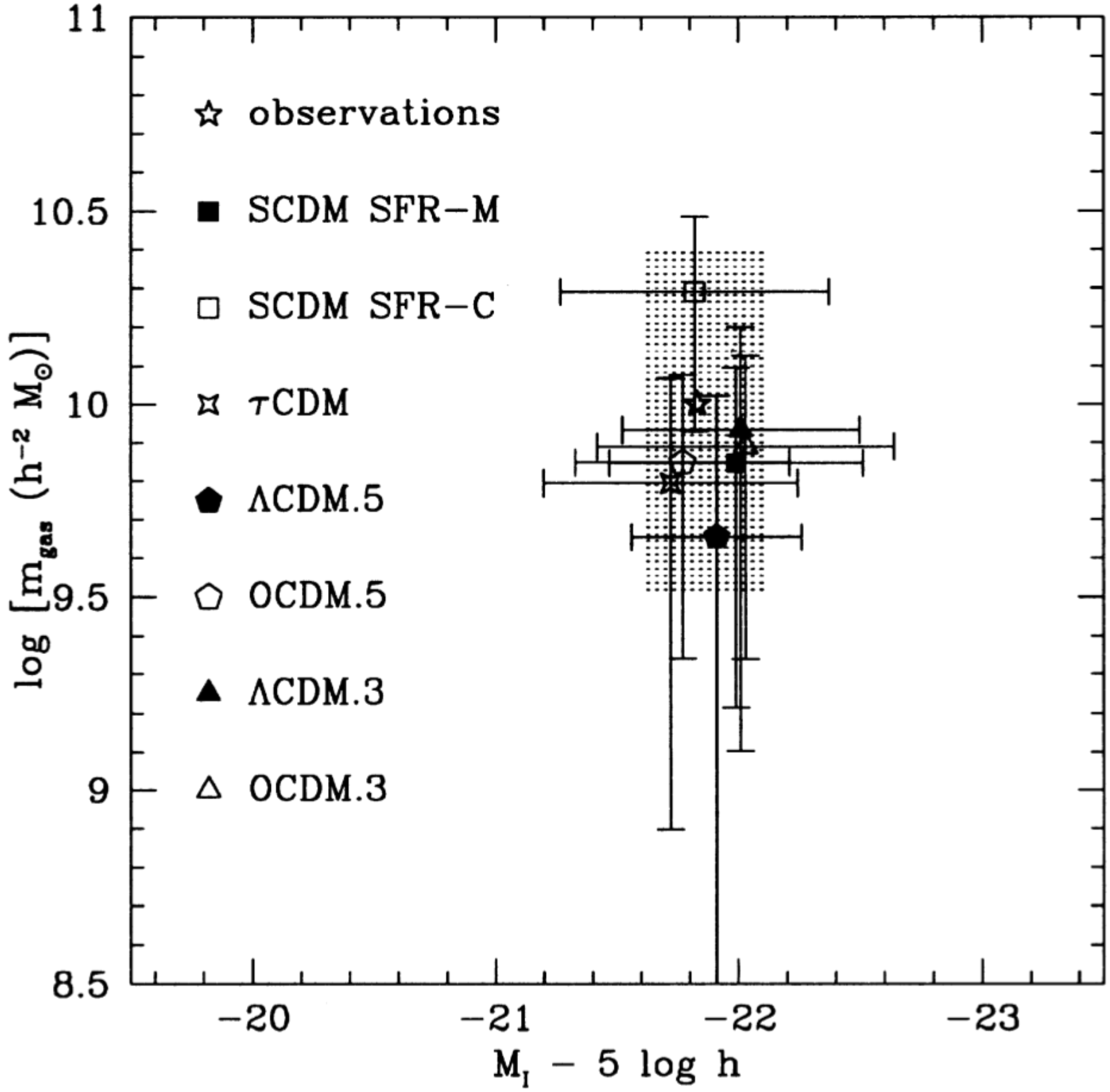
model	τ_*^0	ϵ_{SN}^0	y	f_{lum}^*	f_{bar}
Munich	100	0.2	1.3	1.0	0.1
Durham	4.0	N/A	1.8	1.0	0.125
Santa Cruz (fiducial)	100	0.1	1.8	1.0	0.125
Santa Cruz (high fb)	100	0.5	4.0	1.0	0.125
Santa Cruz (C)	8.0	0.125	1.8	1.0	0.125

"NEW":
-Dynamic cooling
- dyn. Friction + satellite mergers

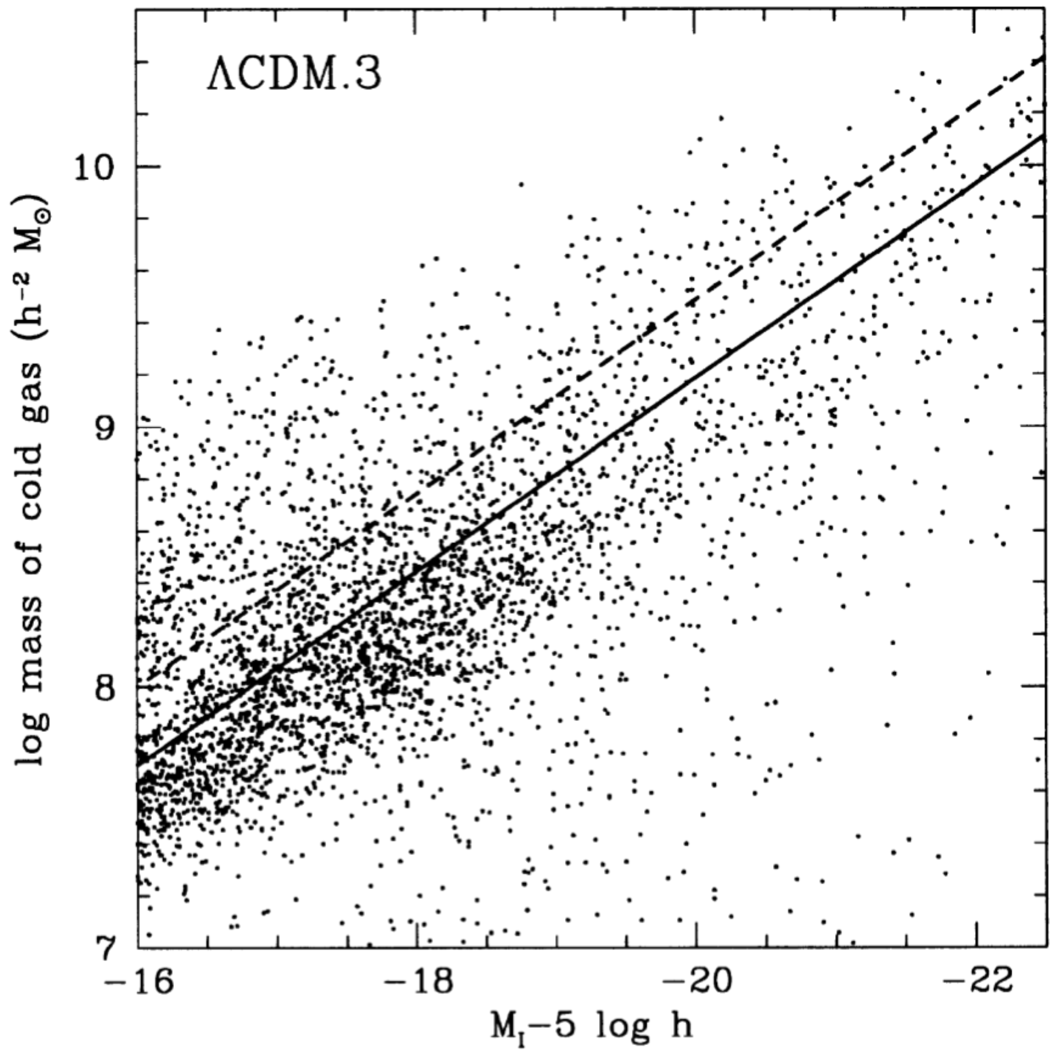
Table 5. Galaxy formation parameters for the 'New' (Santa Cruz fiducial) models.

model	τ_*^0	ϵ_{SN}^0	y	f_{lum}^*	f_{bar}
SCDM	100	0.1	1.7	1.0	0.125
τCDM	100	0.05	1.8	1.0	0.11
ΛCDM.5	100	0.125	3.5	1.0	0.11
OCDM.5	100	0.125	3.5	1.0	0.11
ΛCDM.3	50	0.125	2.2	0.80	0.13
OCDM.3	80	0.125	3.7	0.9	0.13

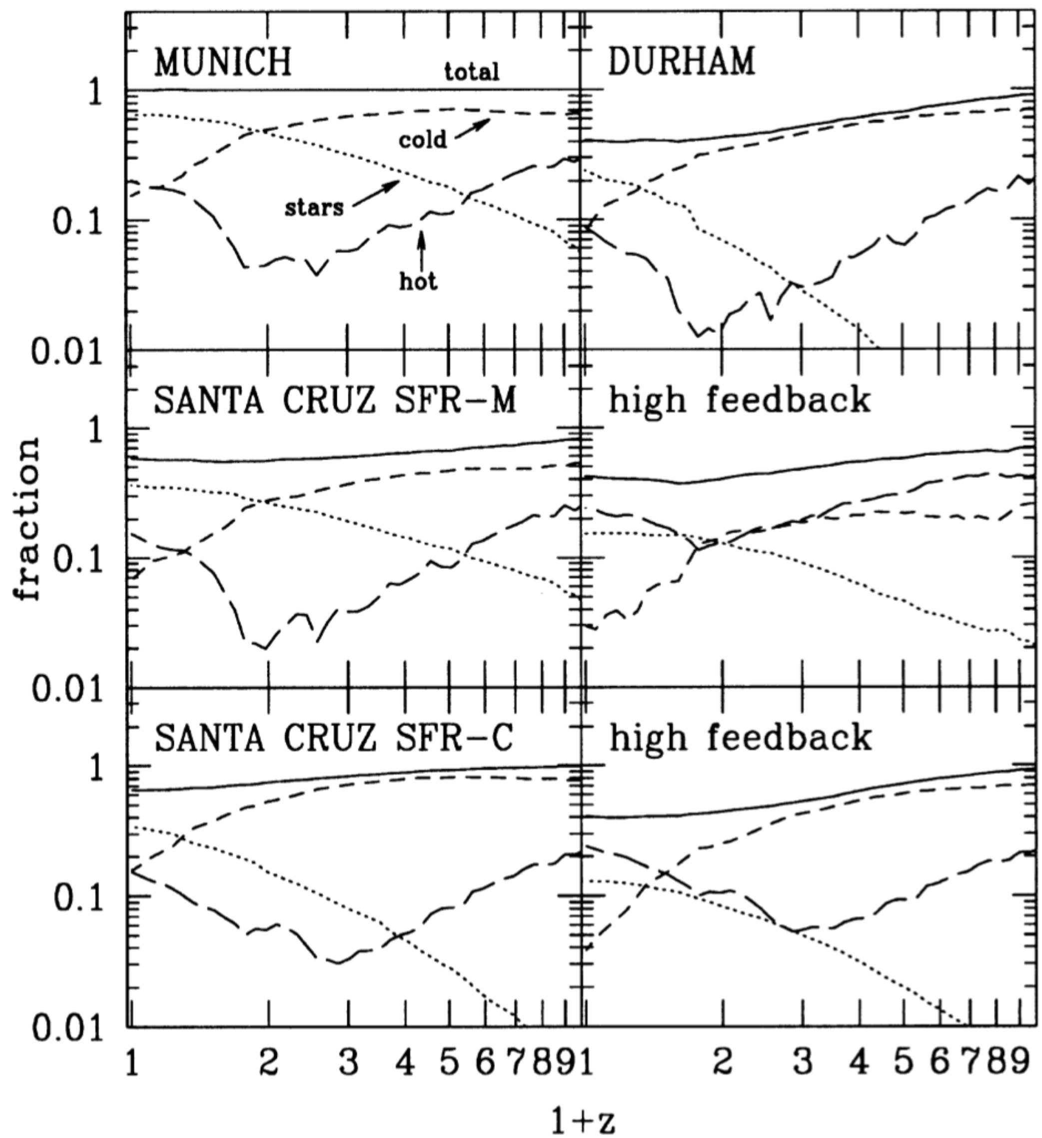
RESULTS : Gass Mass, and M_I for Average L* Galaxies



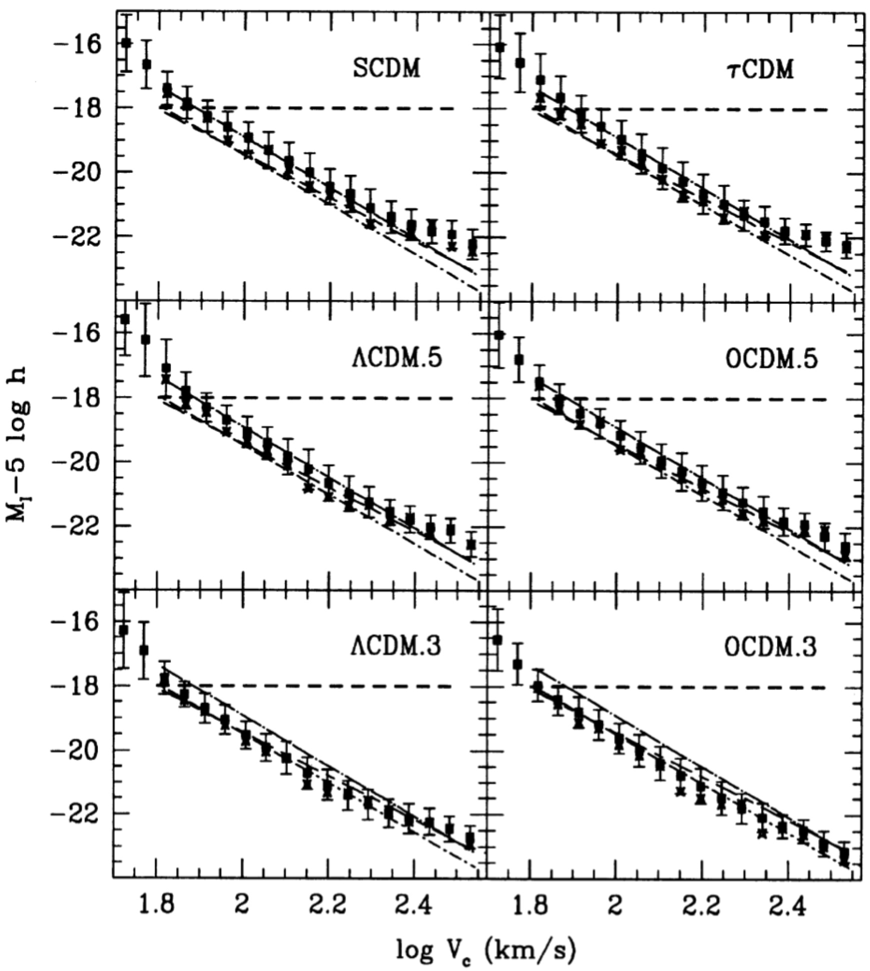
Gas Fits Well

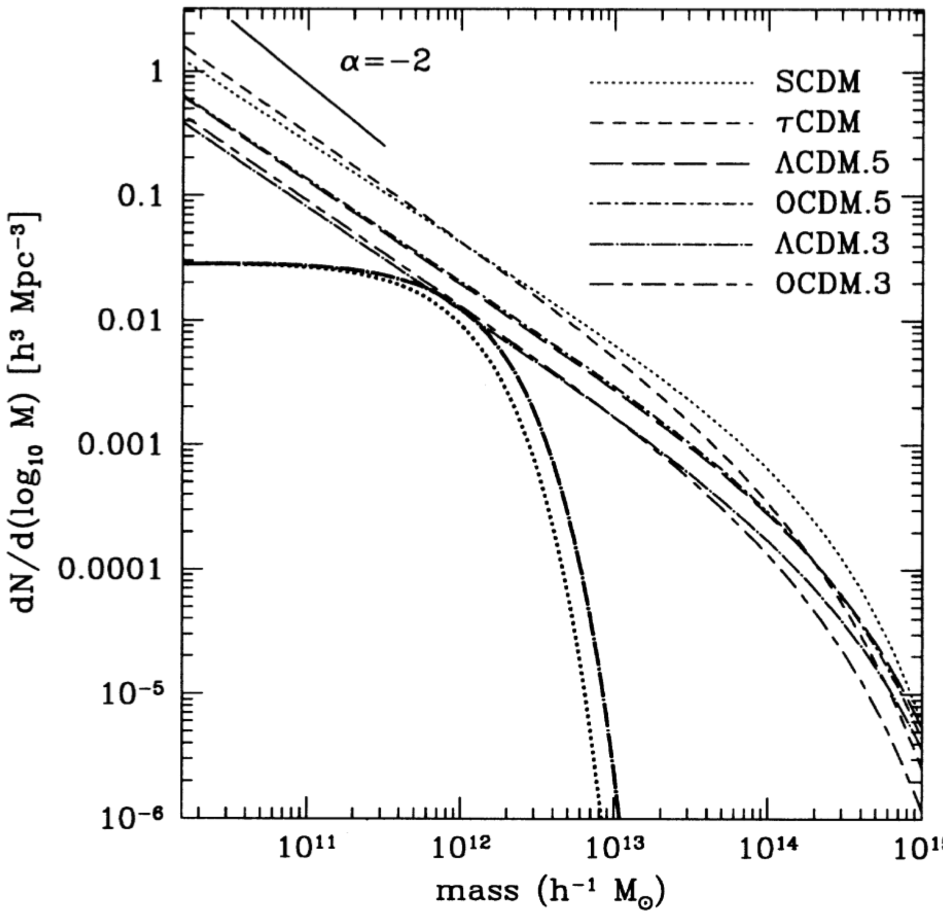


SFR/SN Prescription Effects



Problem


SCDM
τCDM
ΛCDM.5
OCDM.5
ΛCDM.3
OCDM.3
M_I−5 log h
log V_c (km/s)


α=−2
SCDM
τCDM
ΛCDM.5
OCDM.5
ΛCDM.3
OCDM.3
dN/d(log10 M) [h3 Mpc−3]
mass (h−1 M⊙)

Conclusions

Luminosity function and Tully Fisher Relation simultaneously produced to fit well (improvement over past SAMs)

Definitely unable to convert luminosity function to dark matter mass function without introducing systematics that will skew above result

Lot more room to play