Semi-analytic modeling of galaxy formation: the local Universe

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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

$V_c(r_{\text{vir}}) \sim$ size of Halo
Prescribe for Each Halo

- Cooling of gas
- Disc formation
- Reheating – SN feedback
- Star formation
- Galaxy distribution, evolution (stripping etc)
- Galaxy morphologies
- Stellar population synthesis models
- Dust absorption
- Chemical evolution
- Mergers
Gas Cooling

\[ \rho_{\text{cool}} = \frac{3}{2} \frac{\mu m_p}{(n_e/n_{\text{tot}})^2} \frac{k_B T}{\tau_{\text{cool}} \Lambda(T)} \rightarrow r_{\text{cool}} \]

\[ \text{d}m_{\text{cool}} = 4\pi r_{\text{cool}}^2 \rho_g (r_{\text{cool}}) \Delta r \]

Through a merger

Static Cooling:
* Merger Independent
* \( \tau_{\text{cool}} = t_{\text{universe}} \)

Dynamic Cooling:
* Merger Halo Mass Dependent

If \( m_2/m_1 < f_{\text{reheat}} \)
all gas reheated

If \( m_2/m_1 > f_{\text{reheat}} \)

\[ \tau_{\text{cool}} = \tau_{\text{cool}, m_2} \]
\[ r_{\text{cool}} = r_{\text{cool}, m_2} \]

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

\[ \dot{m}_* = \frac{m_{\text{cold}}}{\tau_*} \]

SFR-C

\[ \tau_* = \tau_*^0 \]

SFR-D

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

SFR-M

\[ \tau_* = \tau_*^0 \tau_{\text{dyn}} \quad \tau_{\text{dyn}} \sim \frac{r_{\text{disc}}}{V_c} \]
Supernova Feedback
Disc-Halo Model

\[ \dot{m}_{\text{rh,disc}} \propto \frac{\dot{\epsilon}_{\text{SN}}}{\left\langle v_{\text{esc,disc/halo}}^2 \right\rangle} \]

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 center (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 $f_{\text{reheat}}$, or $\tau^0_*$

1. $\tau^0_* (2.5)$: the star formation time-scale;
2. $\epsilon^0_{\text{SN}} (2.6)$: the supernova reheating efficiency;
3. $y (2.7)$: the chemical evolution yield (mass of metals produced per unit mass of stars);
4. $f^*_{\text{lum}} (2.9)$: the fraction of the total stellar mass in luminous stars;
5. $f_{\text{mrg}} (2.8.1)$: the initial distance of satellite haloes from the central galaxy after a halo merger, in units of the (post-merger) virial radius, and
6. $f_{\text{bulge}} (2.8.4)$: 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

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

<table>
<thead>
<tr>
<th>model</th>
<th>$\tau_*^0$</th>
<th>$\epsilon_{SN}^0$</th>
<th>$y$</th>
<th>$f_{lum}^*$</th>
<th>$f_{bar}$</th>
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<tbody>
<tr>
<td>Munich</td>
<td>100</td>
<td>0.2</td>
<td>1.3</td>
<td>1.0</td>
<td>0.1</td>
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<tr>
<td>Durham</td>
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<td>1.0</td>
<td>0.125</td>
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<tr>
<td>Santa Cruz (fiducial)</td>
<td>100</td>
<td>0.1</td>
<td>1.8</td>
<td>1.0</td>
<td>0.125</td>
</tr>
<tr>
<td>Santa Cruz (high fb)</td>
<td>100</td>
<td>0.5</td>
<td>4.0</td>
<td>1.0</td>
<td>0.125</td>
</tr>
<tr>
<td>Santa Cruz (C)</td>
<td>8.0</td>
<td>0.125</td>
<td>1.8</td>
<td>1.0</td>
<td>0.125</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>model</th>
<th>$\tau_*^0$</th>
<th>$\epsilon_{SN}^0$</th>
<th>$y$</th>
<th>$f_{lum}^*$</th>
<th>$f_{bar}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCDM</td>
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<td>0.1</td>
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<tr>
<td>$\tau$CDM</td>
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<td>$\Lambda$CDM.5</td>
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<td>0.125</td>
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<td>1.0</td>
<td>0.11</td>
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<tr>
<td>OCDM.5</td>
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<td>0.125</td>
<td>3.5</td>
<td>1.0</td>
<td>0.11</td>
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<td>$\Lambda$CDM.3</td>
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<tr>
<td>OCDM.3</td>
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<td>0.125</td>
<td>3.7</td>
<td>0.9</td>
<td>0.13</td>
</tr>
</tbody>
</table>
RESULTS : Gass Mass, and $M_I$ for Average $L^*$ Galaxies
Gas Fits Well
SFR/SN Prescription Effects
Problem
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