Evolution of the brightest galaxies: what controls the turnover of the luminosity function?

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Community astrophysics with WFIRST
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• Questions

• Measurements

• Considerations for WFIRST
UV LF measurements to z~8

Finkelstein+15

Bouwens+15
LF parameter evolution

Primarily density evolution at $z>4$

Steepening faint-end slope?

WFIRST limits:

HLS: $L\sim L^* \ @ \ z=3$

SN deep:
$L\sim L^* \ @ \ z=9.8$

Finkelstein+15

Bouwens+15
The conversion of gas into stars is inefficient for high-mass and low-mass dark-matter halos.
Basic picture

SFR regulated by gas accretion rate on the main sequence

Quenching:
Above some halo or stellar mass \((M^* \sim 5 \times 10^{10})\), galaxies stop forming new stars

Mechanisms:
Mergers
AGN heating
Compaction
Ratio of \(t_{\text{cool}}/t_{\text{ff}}\)
Dust

Davé+11, Lilly+13, Dekel+14, Birrer+14

Croton+06, Hopkins+08, Tacchella+16, Voit+15, Bekki 15
Compaction (earliest quenching mechanism?)

Compaction:
Triggered by an intense gas inflow event, involving minor mergers or counter-rotating streams, and is commonly associated with violent disc instability. The inflow rate is more efficient than the SFR.

Blue Nugget Phase:
Associated with a compact, massive core of gas and star-formation rate, short depletion time and high gas fraction. The downturn at the upper bound is due to the peak in SFR and outflow and the suppression of inflow. Onset of quenching inside-out due to central gas depletion.

Quenching Attempt:
Central gas depletion gives rise to inside-out quenching. In low-mass haloes at high redshift, when $t_{\text{rep}} < t_{\text{dep}}$, inflow of gas resumes, leading to the prerequisite for another compaction.

Quenching:
Inflow rate cannot recover in hot haloes and at late times ($t_{\text{rep}} > t_{\text{dep}}$), leading to gas depletion and full quenching.

Tacchella+16
Are galaxies quenching at $z \gg 3$?
Abundance-matched by SFR

Abundance-match log(SFR)>1.5 at $z_0$ to same number density at $z_1$. Take SFR$^*dt^*(1-M_{\text{lost}}) + M_0$ to predict $M_1$. Masses exceed observed masses at $z_1$.

<table>
<thead>
<tr>
<th>$z_0$</th>
<th>$z_1$</th>
<th>$M_0$</th>
<th>$M_1$</th>
<th>SFR0</th>
<th>dt</th>
<th>Mass Ratio predicted/observed</th>
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</thead>
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<tr>
<td>6</td>
<td>5</td>
<td>9.68</td>
<td>10.2</td>
<td>41</td>
<td>0.24</td>
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<td>5</td>
<td>4</td>
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<tr>
<td>4</td>
<td>3</td>
<td>10.1</td>
<td>10.5</td>
<td>47</td>
<td>0.61</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Somerville+12 simulation does not have this issue; massive galaxies not disappearing from SFR-selected samples at $z>3$ (perhaps because quenching in the models doesn’t start until lower redshifts.)
Significant populations of red galaxies at $z \sim 3-5$

Examples of passive red galaxies at $z \sim 3-4$ that would miss LBG detection.

Grazian+14
ZFOURGE finds a substantial population of massive red galaxies at $z \sim 4$, many of them passive.
The most massive 25% of galaxies at $z \sim 3.5$ are more strongly clustered than the brightest 25%.
High-z luminosity- and mass-function predictions

• Phenomenological models
• Semi-analytical models
• N-body + hydrodynamical models
Mass function shows strong evolution, but shape of the bright end is poorly constrained at $z>3$. 

Song+15
At $z<3$ peak efficiency at $M_{\text{halo}} \sim 10^{12}$

$M_{\text{halo}}$ of peak efficiency shifts at $z>3$?
Differential evolution of quenched and star-forming sequences

Boxes:
Bottoms n=100
Left: limiting mass

CANDELS
SN Deep
HLS

Birrer+15
At the high-mass end, matches halo mass function scaled down to 20% of baryon mass (light grey)
Phenomenological approach

Assume redshift independent (but mass-dependent) efficiency; calibrate at $z \sim 5$

Predict LF with empirically-calibrated redshift-dependent dust law

Trenti+11, Mason+15, Behroozi & Silk 15
WFIRST is capable of exploring the bright end of the LF to redshifts $z \sim 13$
Somerville+12 models with and without dust attenuation.

Empirical evolution: \( \tau_{\text{dust}} \sim e^{-0.5z} \)

The effect of dust?
The effect of mergers (no dust)

SAM Regulated by gas accretion, mergers and SN feedback

Without mergers

With mergers

Constant SFE

Observed fit

Dayal+14

SAM Regulated by gas accretion, mergers and SN feedback
UVLF & Dust: second opinion

No sublimation

No dust

With dust

Dusty Radiative transfer

Dust creation & destruction
Time-dependent dust effects

z=0 isolated disk

z=3 merger

Safarzadeh+16 in prep
Photometric Redshifts
Comparison of photz estimates

GOODS-N 4.5 < z < 5.5

Finkelstein: 48%
Wuyts: 27%
Wilkind: 21%
Fontana: 16%
Pforr: 16%
Panella: 16%
Barro: 16%
3DHST: 16%
Comparison of photz estimates
High-z photometric redshifts need to improve

• WFIRST offers
  • Wide-field grism
    • Hα, [OII], [OIII] 0.7<z<4 (longer λ👍)
    • Lyα 8<z<14 (shorter λ👍)
  • Ability to calibrate via clustering vs JWST spectroscopic samples
  • Longer wavelengths than HST
  • Synergy with LSST for shorter wavelength photometry
Considerations for WFIRST

- Investigation of quenching at early times requires large-area near-IR surveys.
- Ideally in time for followup with JWST
  - Longer-wavelength observations important for constraining dust
- This topic favors extending to longer $\lambda$
  - Better constraints on Balmer break
- Need to improve photo-z estimation at high redshift
- Magnification bias likely to be important