The density and spectral energy distributions of red galaxies at $z \sim 3.7$


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The first 2 billion years of galaxy formation, Aspen
Red galaxies at $z>2$

Forster-Schreiber et al. (2004)

The first 2 billion years of galaxy formation (Aspen, 2008)
Red galaxies at z>2: DRGs

- Significant population of red z>2 galaxies missed by UV selection alone

Forster-Schreiber et al. (2004)

J-K>2.3 DRGs
Red galaxies at $z>2$

van Dokkum et al. (2006)
Red galaxies at $z>2$

van Dokkum et al. (2006)
Red galaxies at $z > 2$

- DRGs galaxies dominate $M > 10^{11} \, M_\odot$ sample at $2 < z < 3$

van Dokkum et al. (2006)
Red galaxies at z>2

- A significant fraction of K-bright galaxies are “red and dead” at z~2.3

Kriek et al. (2006)
Red galaxies at $z>2$

- A significant fraction of K-bright galaxies are “red and dead” at $z \sim 2.3$
Red galaxies at $z>2$

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Kriek et al. (2006)
Red galaxies at z>3

- Select red galaxies at z>3 with red H-K colors, analogous to the DRG, J-K, selection
Red galaxies at $z>3$

- Select red galaxies at $z>3$ with red $H-K$ colors, analogous to the DRG, $J-K$, selection

- Compare with narrower $z>2$ selection based on $J-H$
  - Match limiting (abs) magnitude in red band
  - Match rest-frame color selection
Results, FIRES (HDFS: Labbe et al. 2003, MS1054-03: Forster-Schreiber et al. 2006)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Count</th>
<th>Density</th>
<th>Density (Mpc$^{-3}$)</th>
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<tbody>
<tr>
<td>J-H &gt; 0.9, H &lt; 23.4</td>
<td>18</td>
<td>0.58 ± 0.18 arcmin$^{-2}$</td>
<td>1.5 ± 0.5 x 10^{-4}</td>
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<td>H-K &gt; 0.9, K &lt; 24.6</td>
<td>23</td>
<td>0.74 ± 0.19</td>
<td>1.2 ± 0.4 x 10^{-4}</td>
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![Histogram](image)
## Results, FIRES

(HDFS: Labbe et al. 2003, MS1054-03: Forster-Schreiber et al. 2006)

These galaxies are fairly common

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The first 2 billion years of galaxy formation (Aspen, 2008)
SEDs: H-K > 0.9, z~3.7
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$z_{\text{spec}} = 3.4$
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SEDs: $J-H > 0.9$, $z \sim 2.4$

$z_{\text{spec}} = 2.4$
Rest-frame SEDs

- “Red” galaxies at $z \sim 3.7$ have significantly bluer UV-optical colors than $z \sim 2.4$
"Red" galaxies at $z \approx 3.7$ have significantly bluer UV-optical colors than $z \approx 2.4$

* Peak at $\beta = -2$, similar to UV-selected galaxies (Adelberger & Steidel 2000)

* UV selection likely more complete at $z > 3.5$ than $z \approx 2.4$
Rest-frame SEDs

- “Red” galaxies at $z \sim 3.7$ have significantly bluer UV-optical colors than $z \sim 2.4$
  - Peak at $\beta = -2$, similar to UV-selected galaxies (Adelberger & Steidel 2000)
  - UV selection likely more complete at $z > 3.5$ than $z \sim 2.4$

- Color+limiting mag selection designed to select complementary samples of galaxies in two redshift bins. At higher $z$:
  - Higher specific SFR?
  - Less dust?
  - Is $z \sim 3$ an important epoch for quenching of massive galaxies??
Context: massive galaxies at $z > 3.7$

- Unlikely that there is a significant population of "old", massive galaxies at $z > 4$
- e.g. Mobasher et al. (2005)
  * problem: photo-z
Context: massive galaxies at $z>3.7$

- Unlikely that there is a significant population of "old", massive galaxies at $z>4$
  
  - e.g. Mobasher et al. (2005)

  * problem: photo-zs
Next steps

- Include IRAC photometry in more careful modeling (see earlier talk by Ivo Labbe)
- Larger samples with GOODS-CDFS, UDS
Next steps

- Improve photo-zs
  - “EAZY” – Brammer, van Dokkum, Coppi, et al.
Next steps

- Improve photo-zs, however...
Next steps

- Improve photo-zs
  
  * 5 Medium band NIR filters
  
  * ~60 nights, Kitt Peak 4m + NEWFIRM
    (PI: van Dokkum; Marchesini, Brammer, Whitaker, Rudnick, Kriek, Illingworth, Quadri, Labbe, Franx, Lee)
  
  * 4x30’x30’, K<21.5, H<22.2, J<23.0 (Vega, 10σ)
  
  * Expect Δz/(1+z) ~ 0.02 at 1.5 < z < 3.5, fewer “catastrophic” outliers