What turns galaxies off?
The evolution of the old, red and dead galaxy population in a $\Lambda$ CDM Universe

Eric F. Bell
University of Michigan

van der Wel, Papovich, Kocevski, Lotz, McIntosh, Kartaltepe, Faber, Ferguson, Koekemoer, Grogin, Wuyts, Cheung, Conselice, Dekel, Dunlop, Giavalisco, Herrington, Koo, McGrath, de Mello, Rix, Robaina, Williams
Premise

• Non-star forming galaxies are counterintuitive
  – ~90% of normal matter in diffuse gas, expected to cool and condense.
• Why do some galaxies fail to form stars?
Themes

• Under which circumstances do galaxies lose their cold gas & fail to replenish?
  – Which galaxies fail to form stars?
  – What are their properties?
  – When do they stop forming stars?
Explore themes using HST/CANDELS Survey (PIs Faber/Ferguson)

IR/optical/UV WFC3 and ACS 5 fields
- 0.2 sq. degree wide
- 0.04 sq. degrees deep

Grogin et al. 2011
Koekemoer et al. 2011

candels.ucolick.org
Optical/near IR fluxes

Fit stellar population models

- Photometric redshifts
  \[ \frac{dz}{1+z} \sim 0.05 \]
  \[ (\text{Williams et al. 2009}) \]

- Stellar mass estimates
  Quiescent vs. star-forming UVJ
  \[ d(\log M^*) \sim 0.15 \text{ dex} \]
  \[ (\text{Bell et al. 2012}) \]

Focus on galaxies \( M^* > 3 \times 10^{10} M_{\odot} \)
Halos \( > 10^{12} M_{\odot} \)
Fit Sersic (generalized exponential) profiles to galaxy images in F160W ~ rest-frame optical

n>2.5 ; prominent bulge
n<2.5 ; dominant disk

van der Wel, in prep.
Filled – \(n>2.5\)
Prominent bulge

Non-SF

Open - \(n<2.5\); disk-dominated

Axis ratio = axis ratio of galaxy

\(10^5 \text{ Mpc}^3\)

\(1.8 < z < 2.2\)

\(\log_{10} \frac{M_{\text{stellar}}}{M_\odot}\)
$10^5 \text{ Mpc}^3$

$1.8 < z < 2.2$

$U-V$ (rest-frame)

$\log_{10} M_{\text{stellar}}/M_\odot$
$1.5 < z < 1.8$
$1.3 < z < 1.5$
See also:
Brammer et al. 2011
Van Dokkum et al. 2011
Franx et al. 2008
Kauffmann et al. 2003
Bell 2008
- Dramatic emergence of massive galaxy population
  - x5-10 increase in number of massive, non star-forming galaxies
- In a variety of environments (only ~few % of galaxies >3e10 Msun are in clusters)
Most non-star forming galaxies have high $n$
  - Prominent bulge
• Stellar mass is a poor predictor of quiescence

• Sersic index / velocity dispersion / central density correlate better with quiescence
  – Having a bulge appears to be important for turning off star formation
    • Some star-forming bulge-dominated galaxies
    • Very small fraction of disk only quiescent galaxies, @ z~0 most satellites
Discussion

- Dramatic emergence of massive galaxy population
  - x5-10 increase in number of massive, non star-forming galaxies
  - The epoch of the bulk of quiescent galaxy formation is 0<z<2 (~half at z>1, ~half at z<1)

- Quenching mechanisms
  - Correlates well with galaxy structure (~bulge)
    - Very poor correlation with stellar mass
    - Stellar mass – dark halo mass correlation strong; quiescence is not only driven by dark halo mass
  - Bulge formation
    - Merging, disk instabilities
    - Gas removal?
    - Black hole mass-bulge mass (or sigma) correlation
      - Consistent with zeroth order prediction from AGN feedback paradigm