Starbursts at High Redshifts

Building blocks of present-day massive galaxies?

Svara Ravindranath
(Space Telescope Science Institute)

& the GOODS team

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Observed evolution of stellar masses suggests:

- > 50% stellar mass assembled by z=1
- progenitors of massive galaxies at z>2
- Likely high-z candidates: LBGs, sub-mm sources, EROs, K20

Why LBGs?

- Hierarchical galaxy formation suggests mergers & starbursts are important
- High star formation rates, smaller sizes - attractive candidates
- Strongest arguments from clustering
Goals:

• Study LBGs on individual galaxy basis rather than integrated properties

• Characterize rest-frame UV morphology: compact, extended, or mergers

• Derive luminosities & sizes

• Measure star formation rates & star formation rate density

• Compare LBGs to local starbursts
Great Observatories Origins Deep Survey (Giavalisco et al. 2004)

Hubble Ultra Deep Field (Beckwith et al. 2004)

GOODS: ~320 arcmin²
UDF: ~10 arcmin²
HST/ACS: F435w, F606w, F775w, F850lp
Star-forming galaxies at high redshift (LBGs) routinely identified by the color signature of the Lyman limit and Ly α breaks.

GOODS is sensitive to LBGs at z>2.5.

At z~3, expect to reach ~0.3-0.5 mag deeper than previous large surveys (Steidel et al. 1999).
Lyman-break galaxies

color selection

$B$-dropouts, $z \approx 4$

$V$-dropouts, $z \approx 5$

Giavalisco et al. 2004
Examples of B-dropouts:
U-dropout sample : LBGs at z=3
B - dropouts : LBGs at $z = 4$
V-dropouts : LBGs at $z = 5$
Morphological Analysis:

- Parametric approach using Sérsic function fit to light profile.

\[ \Sigma(r) = \Sigma_e \exp \left[ -\kappa \left( \left( \frac{r}{r_e} \right)^{1/n} - 1 \right) \right]. \]

- allows convolution by the point spread function
- better handle on flux in the galaxy wings where S/N drops at low surface brightness levels
- Measurement biases minimized

Exponential disks: \( n = 1 \)
R\(^{1/4}\) spheroids: \( n = 4 \)
B-dropout with $n \geq 5$
B-dropout with $n > 3.0$
B-dropout with $n \sim 0.8$
B-dropout with $n<0.5$
Profile Shapes: - measure of concentration

- Among LBGs with $L_{UV} > 0.6 L^*$ (Steidel et al. 1999)

Distribution of morphologies:

Concentrated ($n > 2.5$) : 30%

Extended disks ($2.5 < n < 0.5$) : 60%

Multiple cores/mergers ($n < 0.5$) : 10%

Morphological mix shows that disks are more common at $z > 3$
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Luminosity-Size relation at $z > 3$
Starburst intensity:

- *Panchromatic starburst intensity limit for local starbursts (Meurer et al. 1997)*

\[ S_e (L_\odot \text{kpc}^{-2}) = 2 \times 10^{11} \]

- Constraints on the feedback processes (Meurer et al. 1997)
- Bulge formation as maximum intensity starburst (Meurer et al. 1997; Elmegreen 1999)

After correction for dust extinction, converting to bolometric luminosity,

\[ S_{e,90} = 3.2 \times 10^{10} \, L_\odot \, \text{kpc}^2 \]
\[ S_{e,50} = 5.0 \times 10^9 \, L_\odot \, \text{kpc}^2 \]
Star Formation Rates in LBGs at $z > 3$
Summary

• LBGs exhibit large diversity in rest-frame UV morphologies. Profile shapes suggest that disks are dominant, and about 10% show obvious multiple cores.

• Distribution of axial ratios also suggest extended configuration for the star-forming region

• Luminosity-size relation: median size 2.1 kpc at z=3 and only mild evolution towards smaller sizes at higher redshifts

• Starburst intensity limit consistent with that seen for local starbursts. SFRs are on average = few tens of solar masses per year. SFR densities very similar in the range z = 3 to 5. (but need to check correction for dust extinction!)
Comparison of Sersic parameters: GOODS vs UDF
Comparison with HUDF NICMOS F160W images
Comparison of Sersic index in ACS & NICMOS

U - and B - dropouts in UDF