Search for Spatially Extended Star Formation around Lyman Break Galaxies in the Hubble Ultra Deep Field

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Wolfe & Chen 2006 Result

- The cumulative comoving star formation rate density of DLAs is lower than expected from the Kennicutt-Schmidt Law, suggesting reduced star formation efficiency in DLAs at z~3

A few possible explanations:

- At high z, critical surface density for disk instability is increased, therefore DLAs are stable against star formation
- Low molecular fraction in DLAs could contribute to lower SFR
- Lots of other possibilities, like the one you may be thinking of right now

Wolfe & Chen 2006

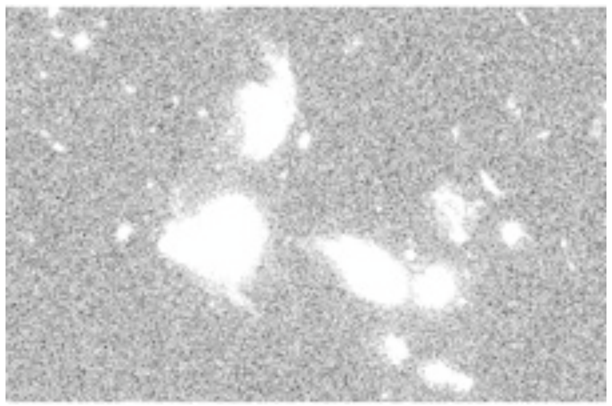
Difficulties with explanations for DLAs

- Upper limits on the SFR density limits the rate of metal production in DLAs
- Cooling rates measured for DLAs are higher than heating rates due to the background
(expect thermal balance: heating=cooling)
- Turbulence level of the DLA gas is to high

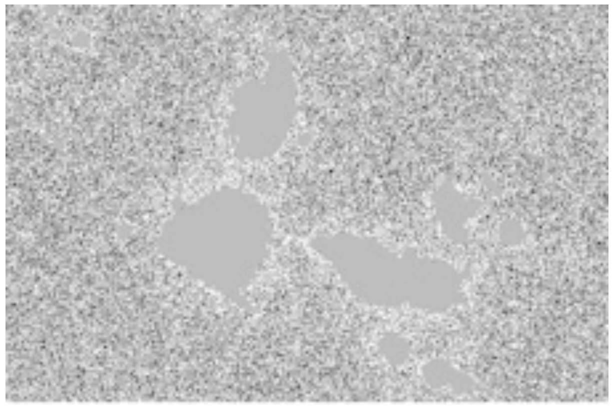
Wolfe & Chen 2006

Caveat to the Wolfe & Chen 2006 Result

- High surface brightness objects excluded from their search



image



masked image

smoothed & masked

- It is possible that in-situ star formation occurs in DLAs associated with high surface brightness objects
- Such star formation was not previously constrained

Wolfe & Chen 2006

Another limit on the comoving star formation rate density of DLAs

- The aim of this work is to put a limit on the cumulative comoving star formation rate density around high surface brightness objects at a redshift of z~3

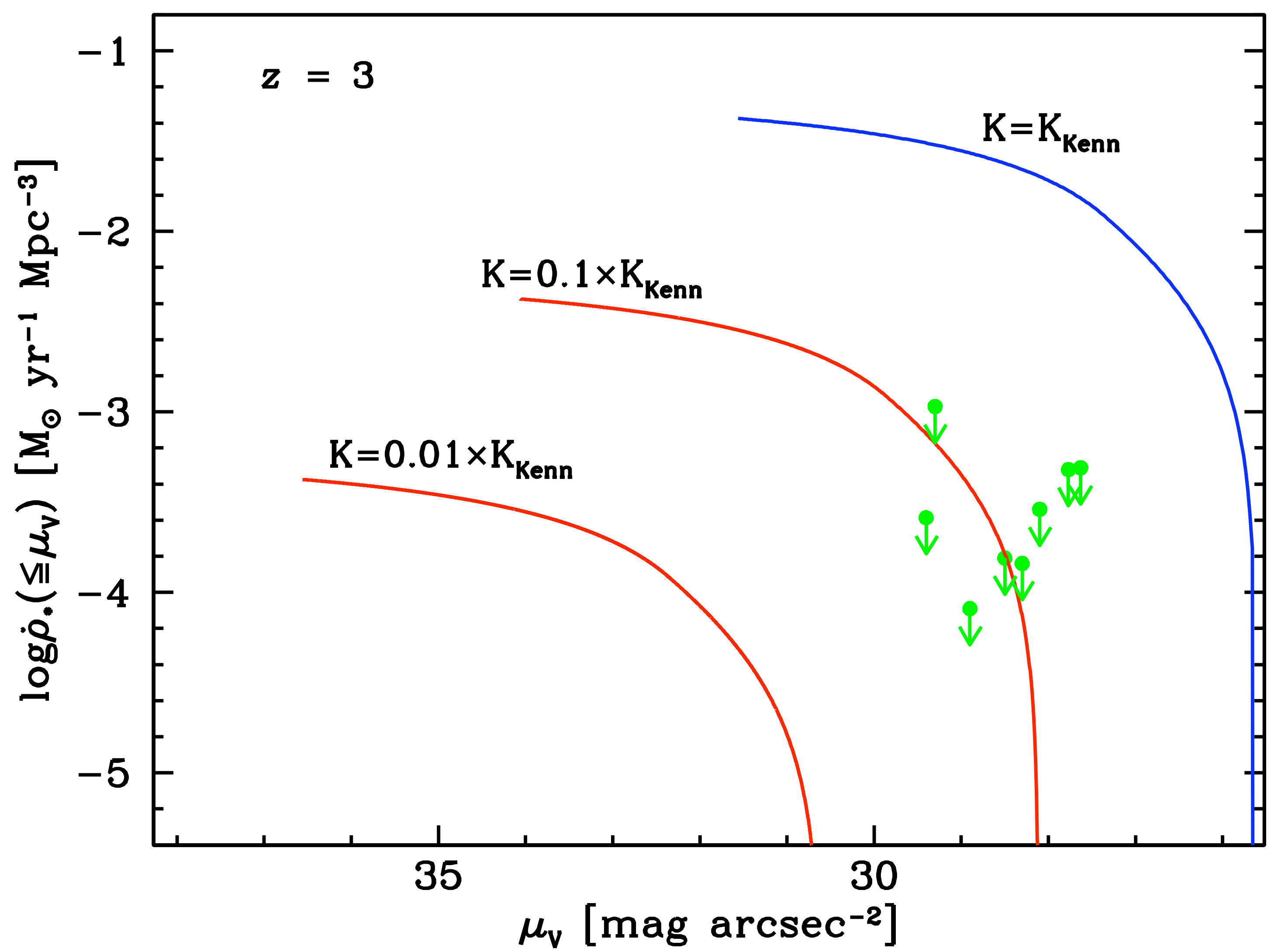


Figure by Wolfe & Chen 2006

Another limit on the comoving star formation rate density of DLAs

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High Surface Brightness Objects at z~3 are LBGs

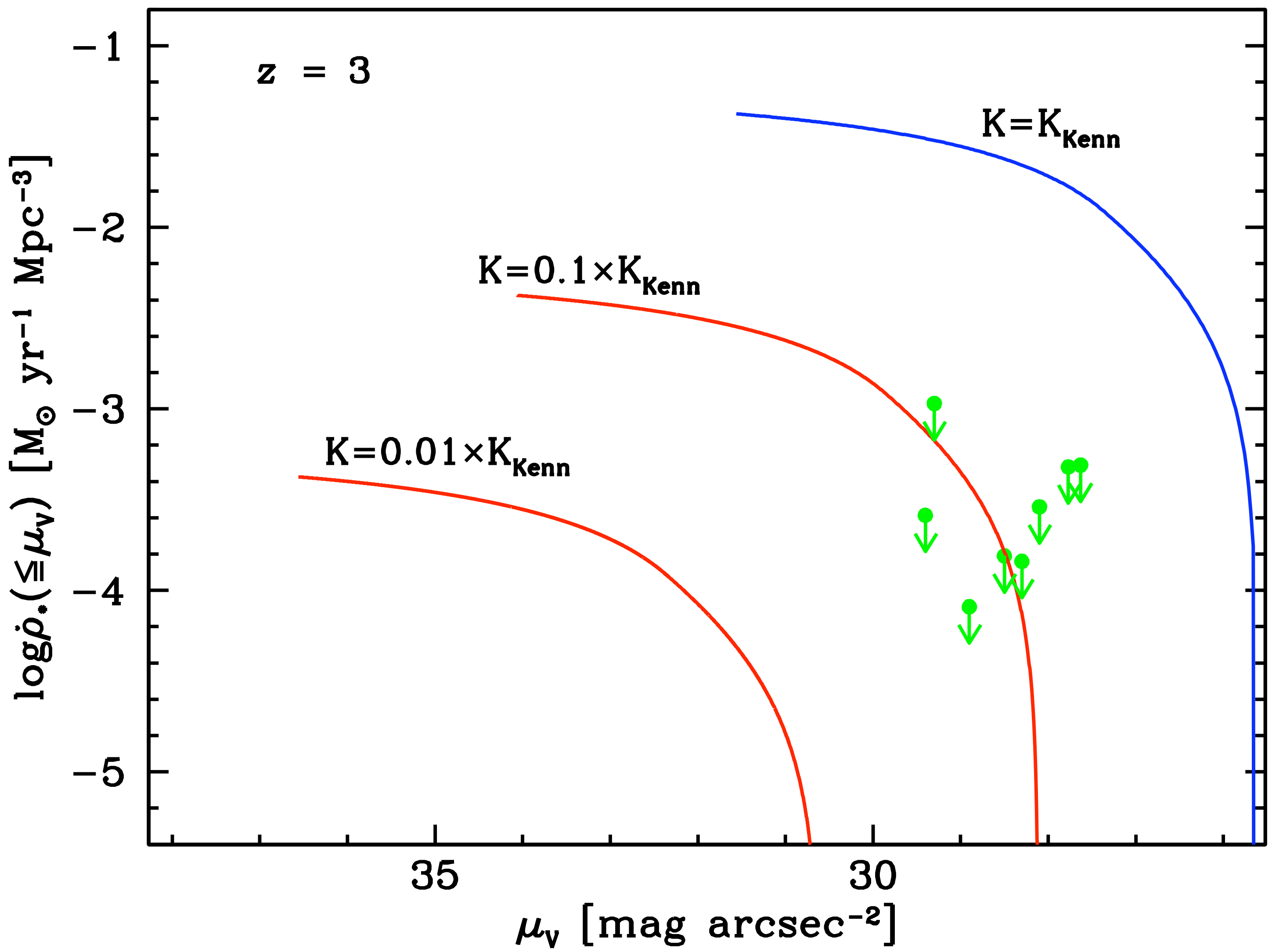

Figure by Wolfe & Chen 2006

Properties of Lyman Break Galaxies (LBGs)

- Compact Morphology

  ($D_{half\text{-}light}$ ~2-3 kpc)

- Dust corrected Star Formation Rate (SFR) ~ 40 M_{sun}/yr

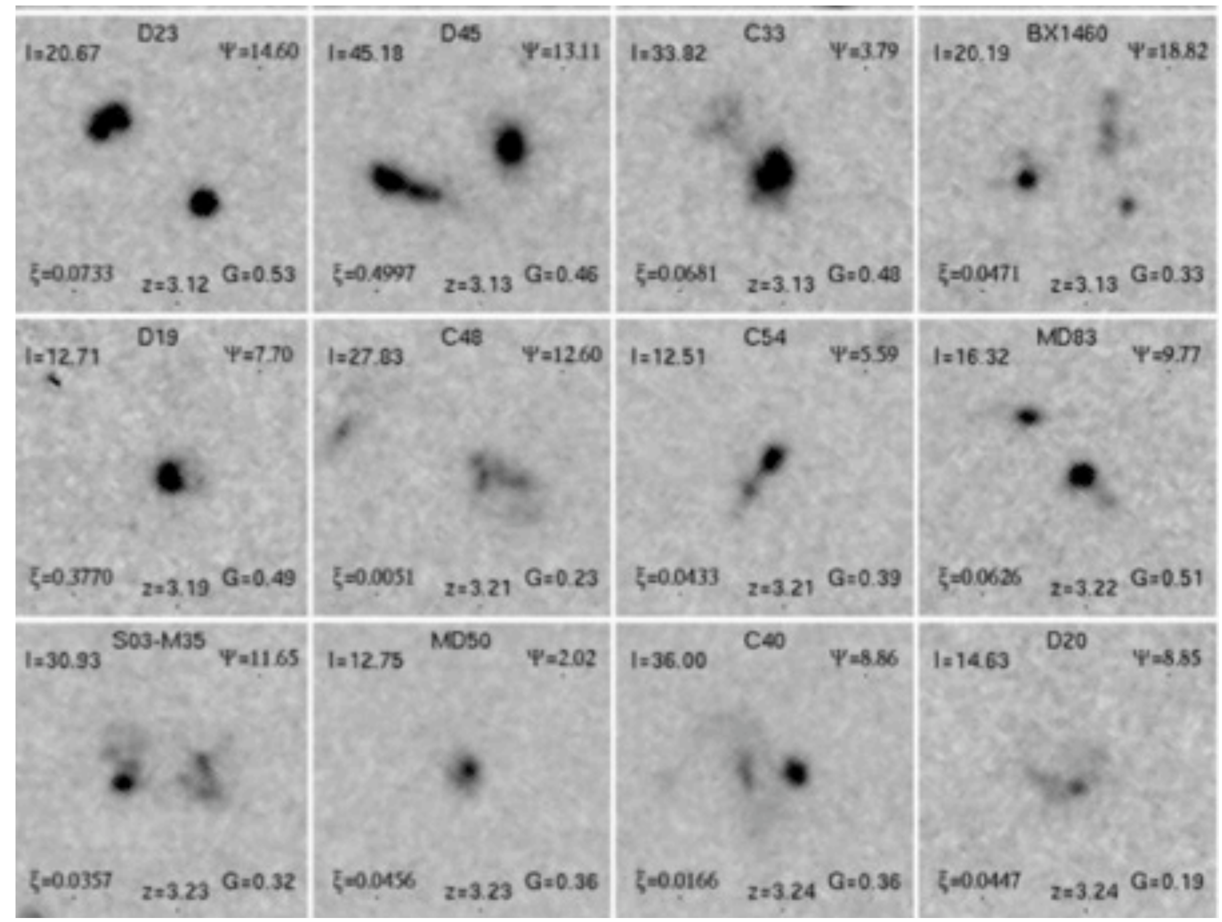

Image from Law et al. 2007

- Models predict that accretion rate = gas consumption rate

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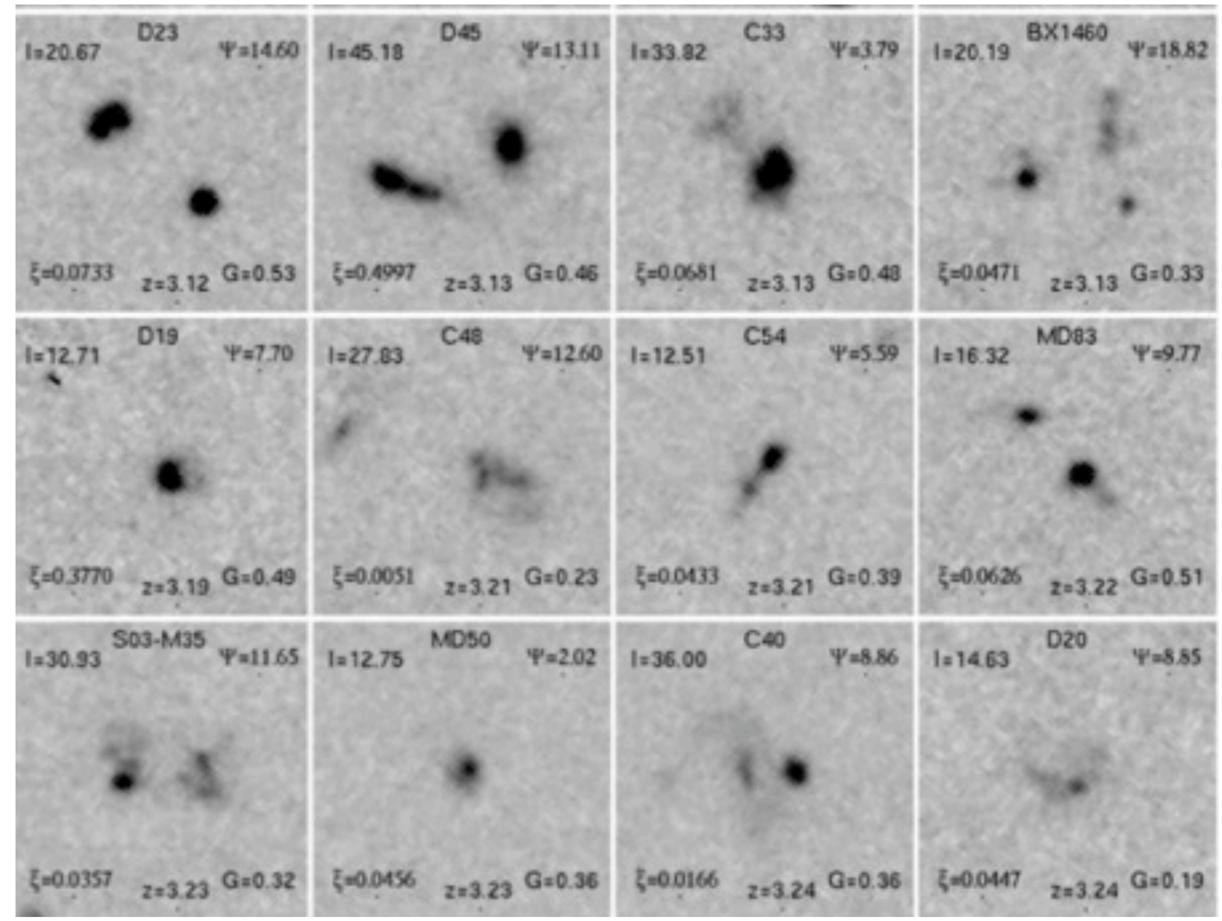


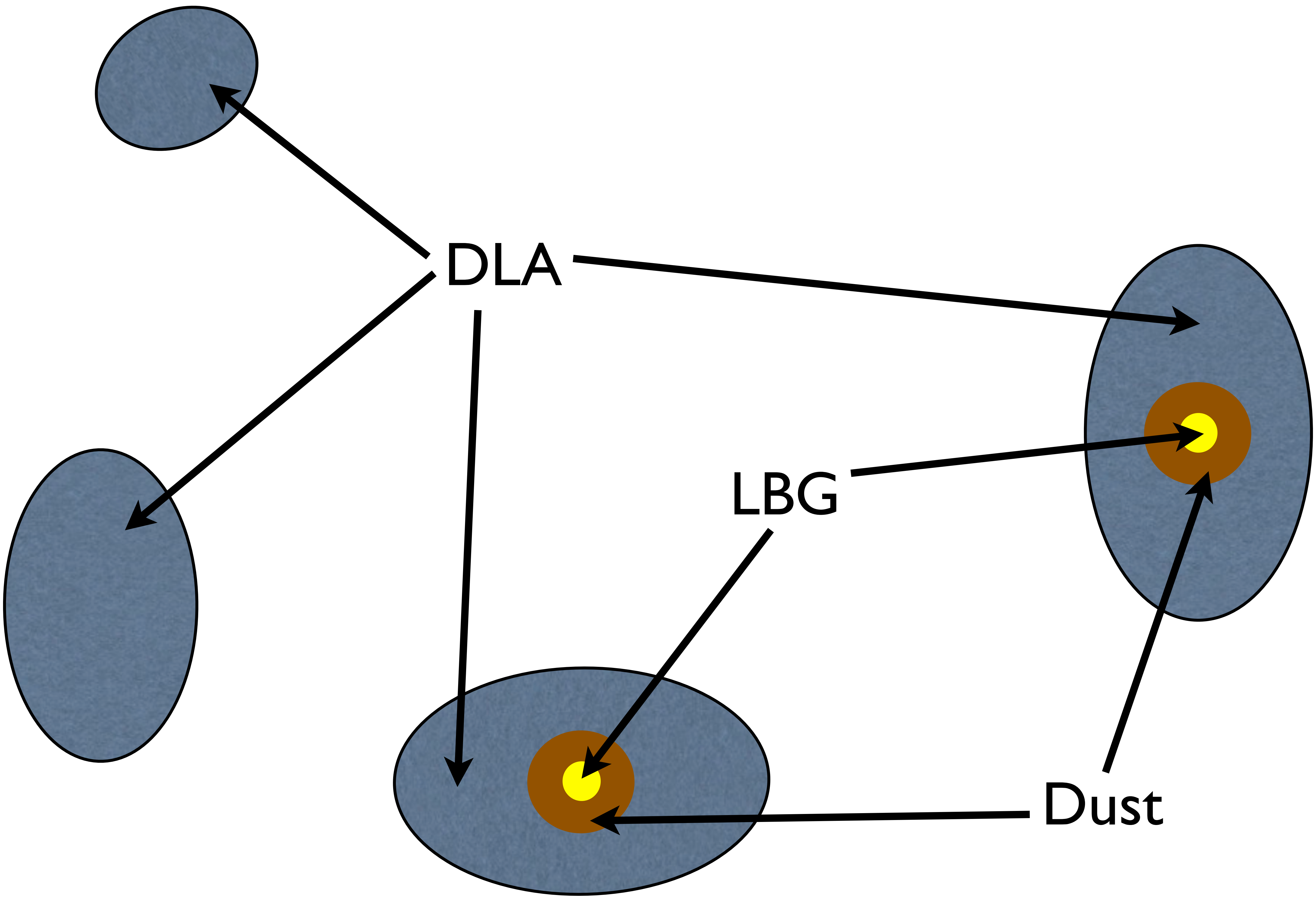
Image from Law et al. 2007

- Models predict that accretion rate = gas consumption rate

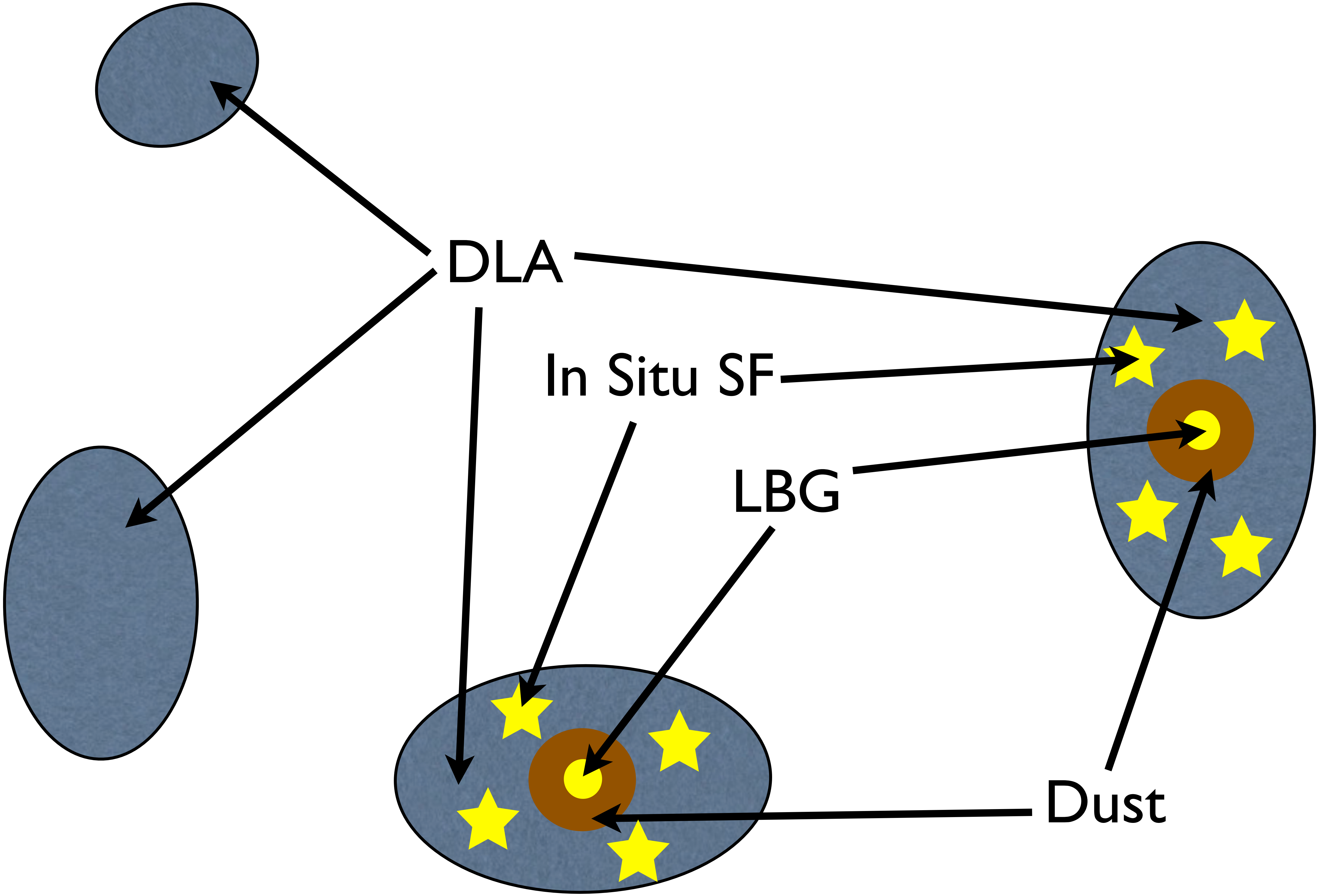
Where does all this gas to form stars come from?

- One possibility is Damped Lyman Alpha Systems (DLAs) (although stars generally form in molecular clouds)

A Potential Solution: LBGs in DLAs



Another possibility:
In situ star formation in DLAs associated with LBGs



We need a sample of z~3 LBGs in the HUDF

- Very few z~3 spectroscopic redshifts as most are faint
- Photometric Redshifts exist, although without the u-band they don't sample the Lyman break at z~3, so their reliability is unclear

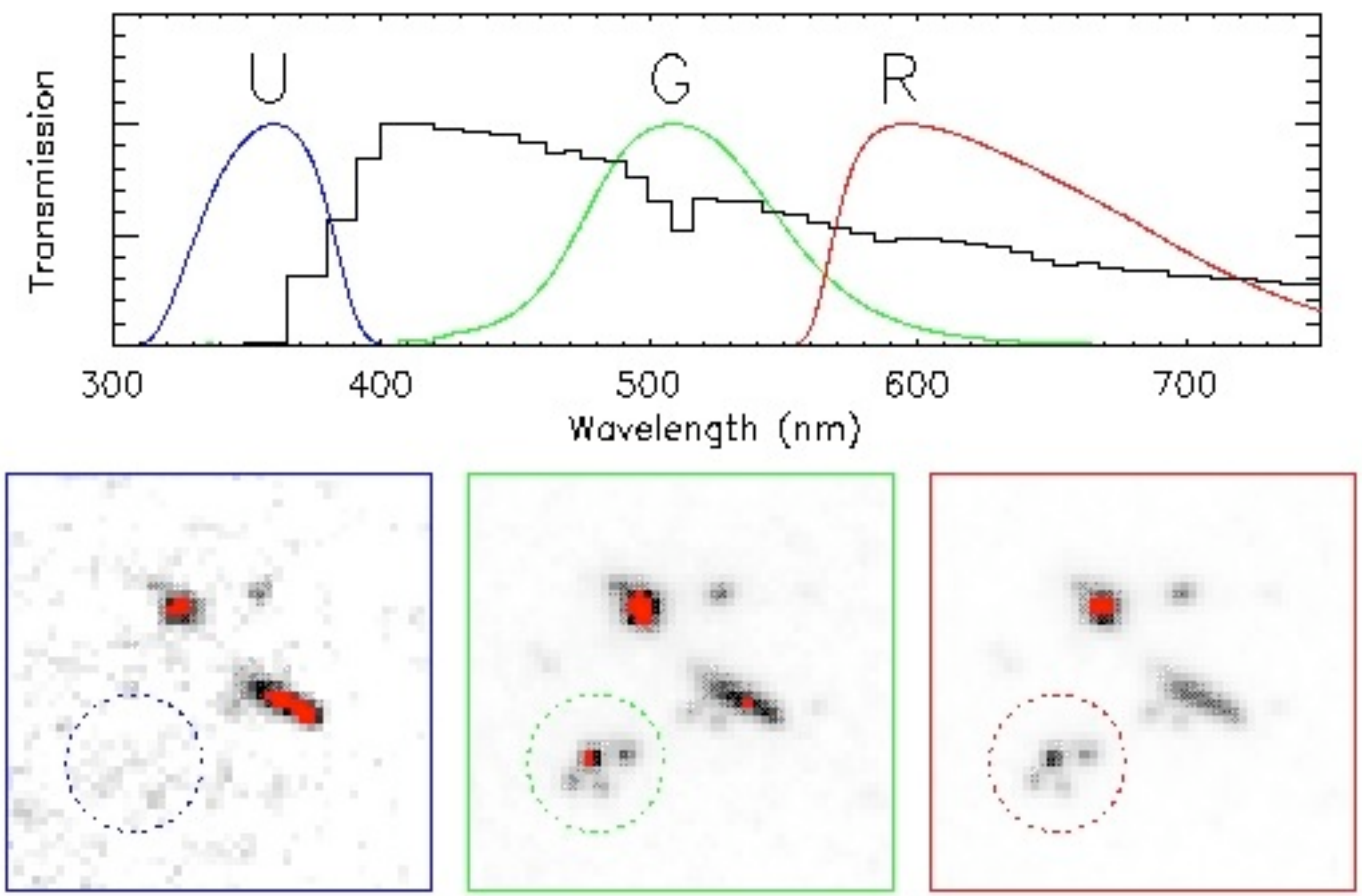
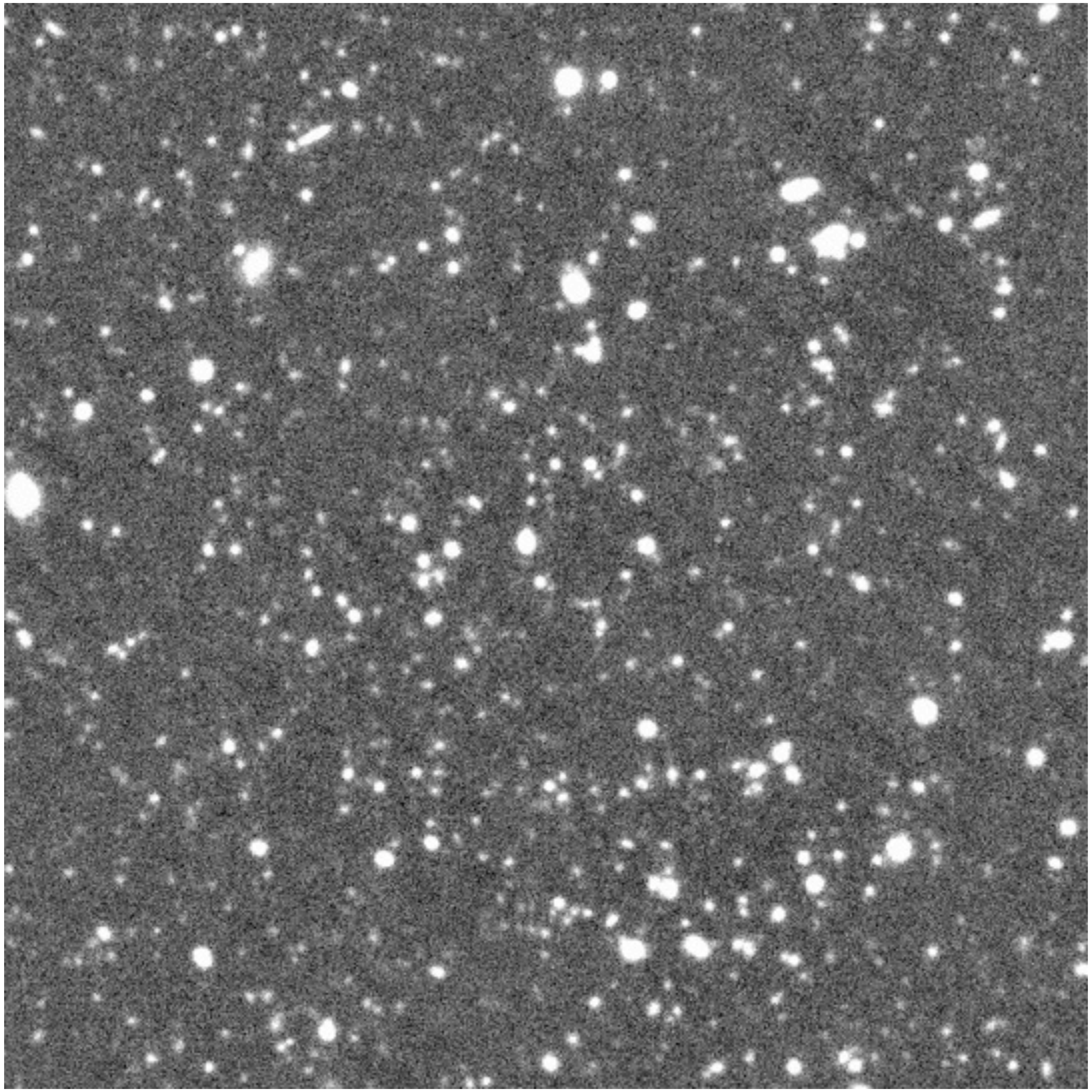


Image: Johan Fynbo

Solution: Ultra Deep u'-band image of UDF with Keck

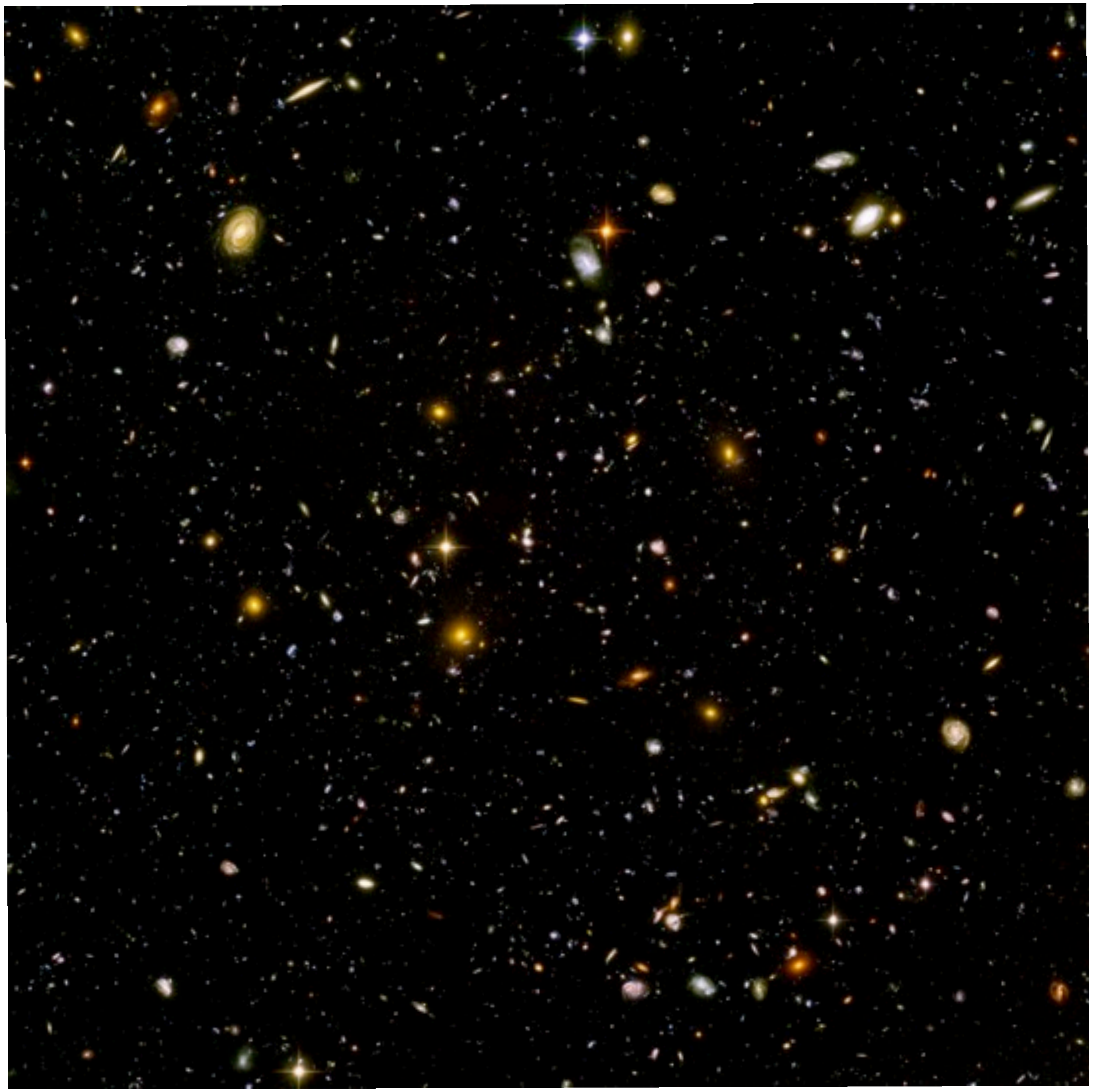


Rafelski et al. submitted May 2009

The Keck Telescopes in Hawaii

1 σ depth = 30.7 mag/arcsec^2
Detection limit =27.6 mag/arcsec^2
FWHM = 1.3 arcsec

The Hubble Ultra Deep Field

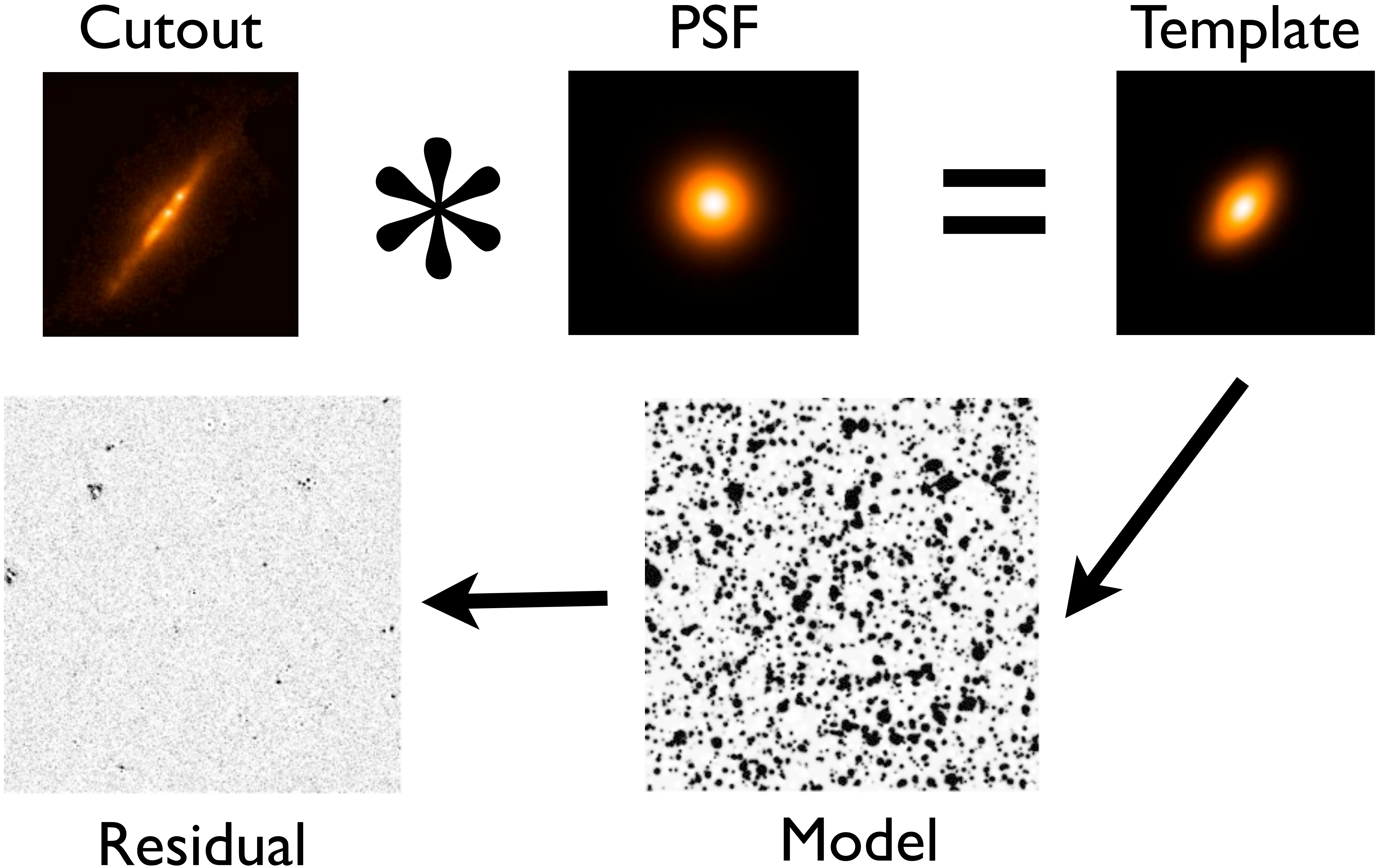


Beckwith et al. 2006

The Hubble Space Telescope

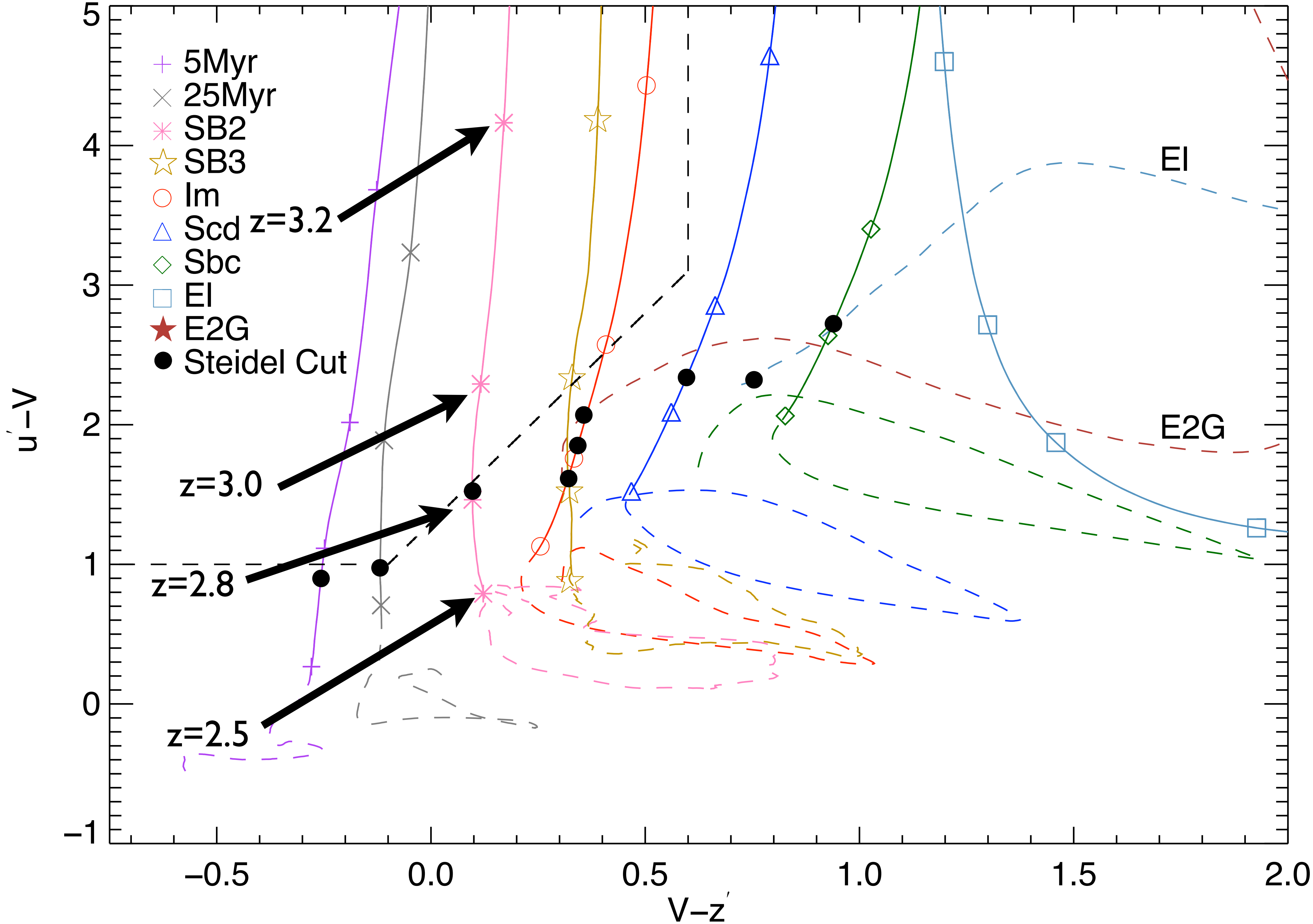
1 σ V-band depth
 = 30.2 mag/arcsec^2
FWHM = 0.09 arcsec
10σ Point Source: ~29 mag
Notice the much higher resolution
UDF has a few different filters

Photometry through Template Fitting (TFIT)



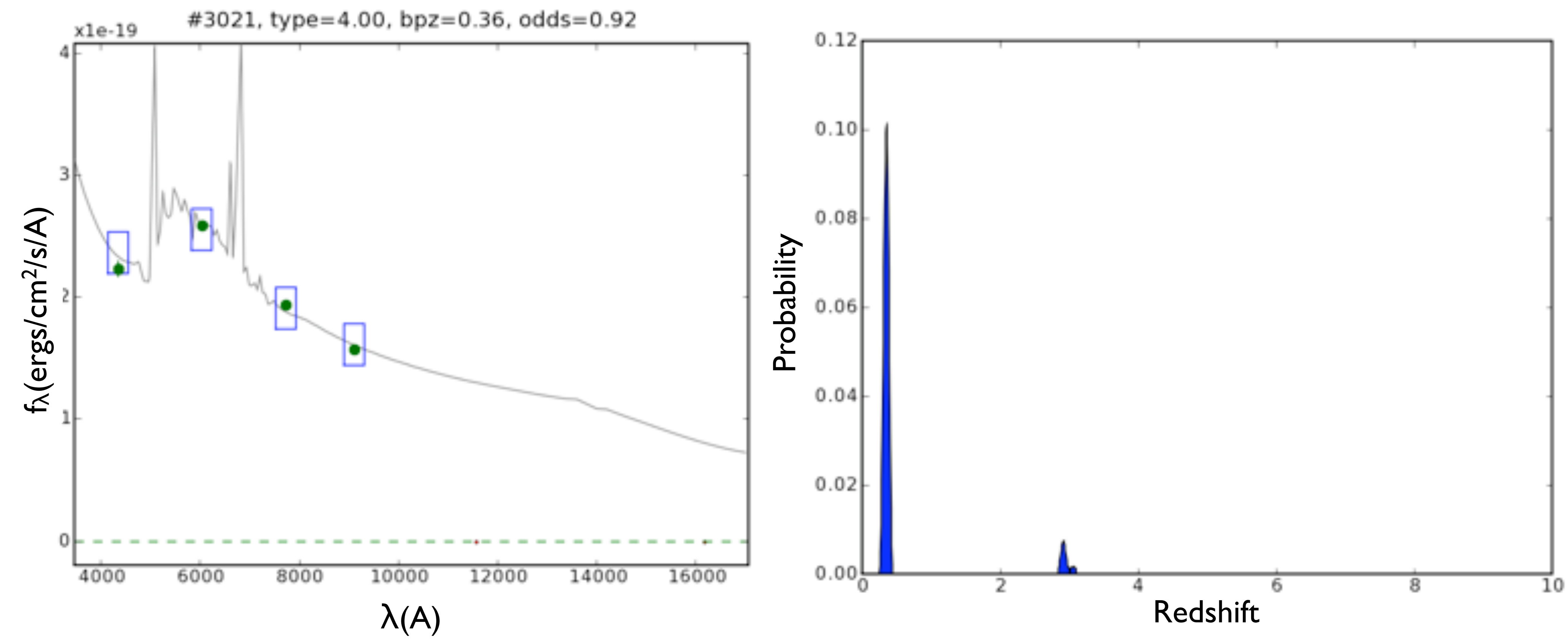
Method by Laidler et al. 2007

Color Selection to find z~3 LBGs

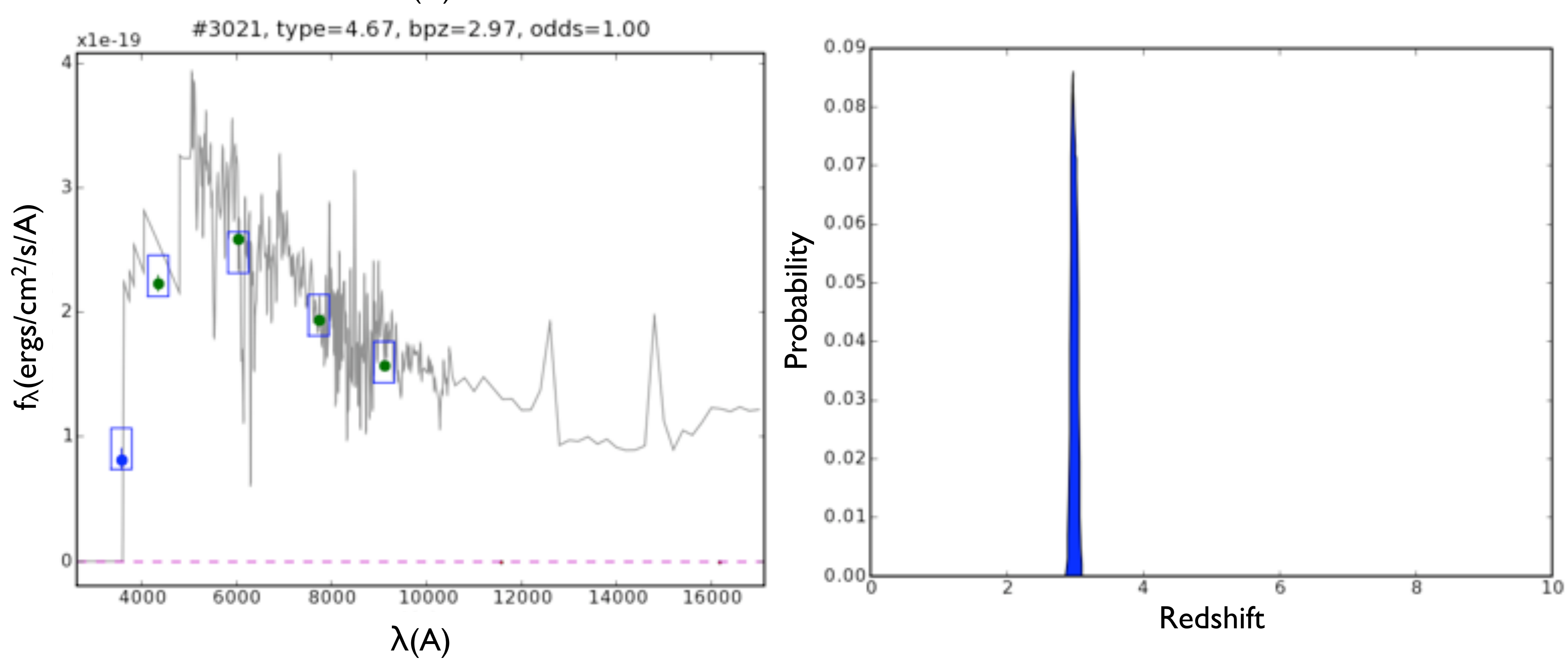


Photometric Redshifts reliable with u-band

Without u-band

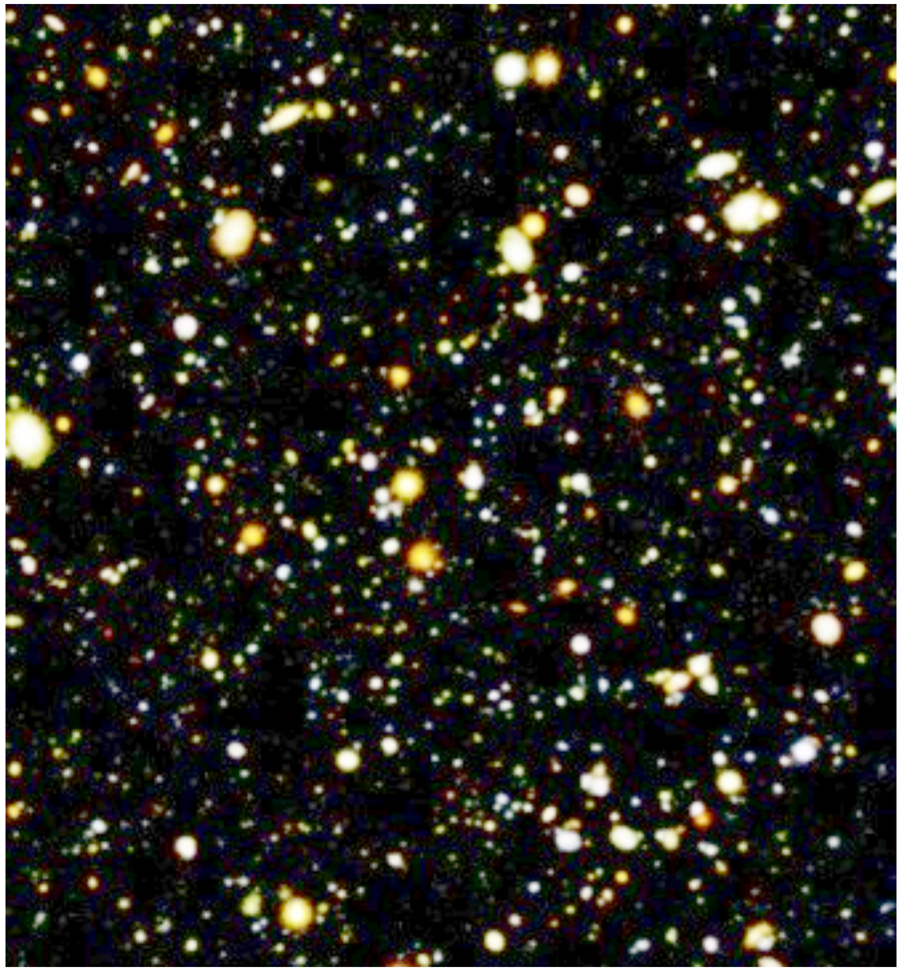


With u-band



Results from u-band data

- 413 LBGs identified in redshift interval $2.5 \lesssim z \lesssim 3.5$
- u-band affected photometric redshifts for about 50%
- Complete to V~27th magnitude
- Results agree well with available spectroscopic data



More details soon on astro-ph:
Deep Keck u′ -band imaging of the Hubble Ultra Deep Field: A catalog of z ~ 3 Lyman Break Galaxies
Rafelski et al. submitted May 2009

Spatially extended low surface brightness emission and a limit on the comoving star formation rate density

- We have a sample of LBGs at $2.5 \lesssim z \lesssim 3.5$
- We go back to the V-band image in UDF
- Measure spatially extended low surface brightness emission around LBGs
- Determine comoving star formation rate density

Spatially extended Low Surface Brightness (LSB) Emission around LBGs

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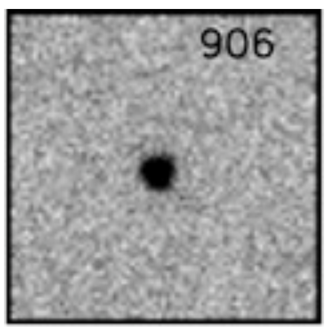
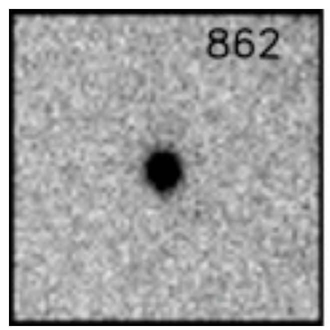
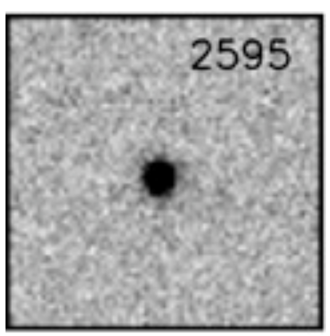
- Isolated, compact, and symmetric objects







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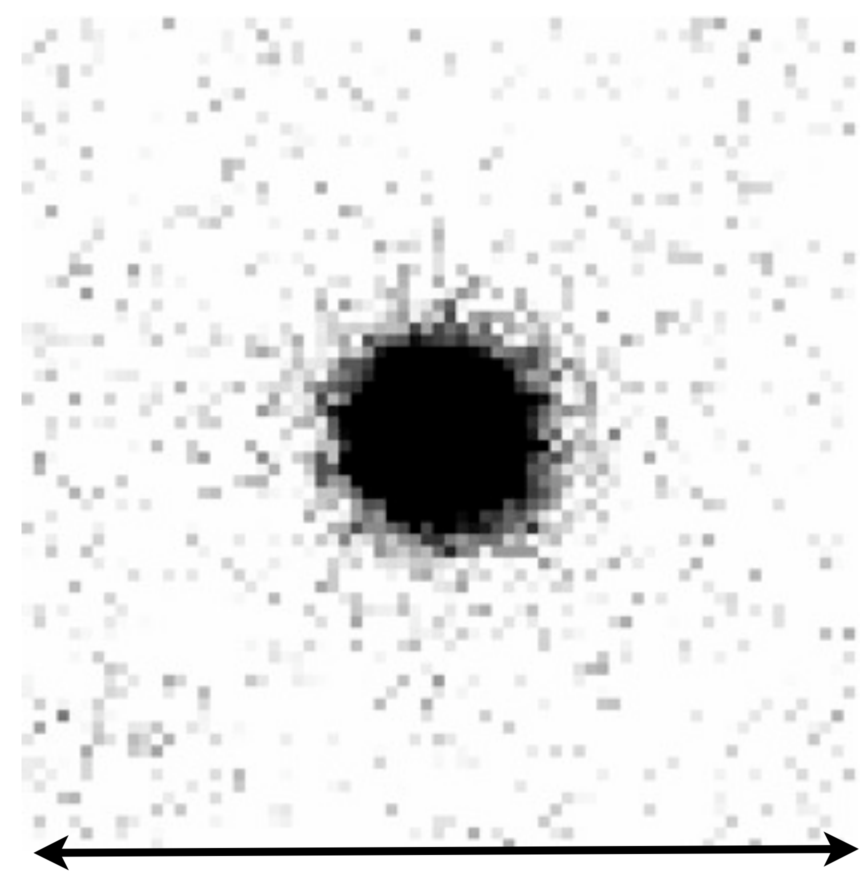
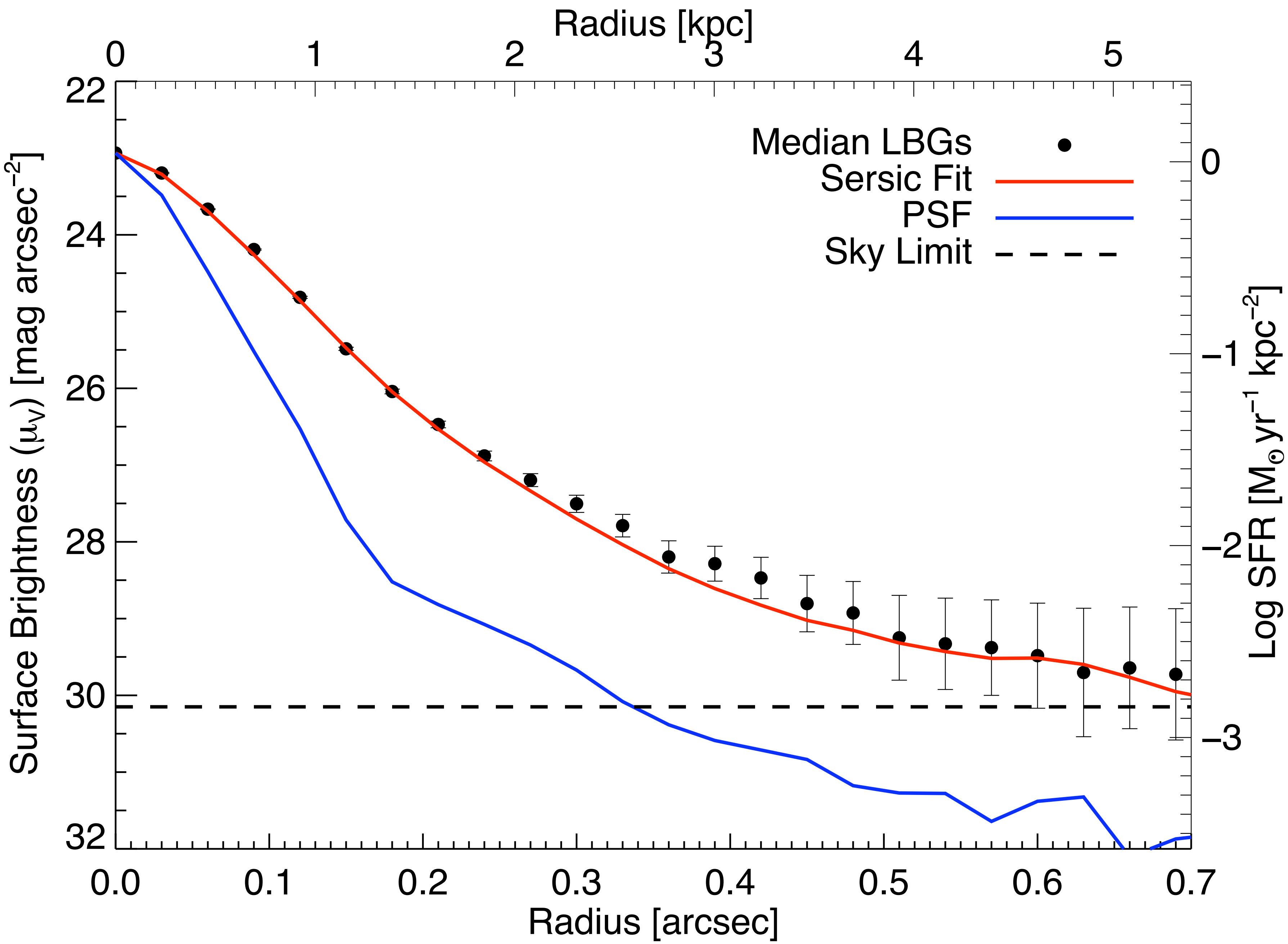


Stack of 60 isolated, compact, symmetric z~3 LBGs in the V-band

Surface Brightness Profile of Stacked LBGs



$$I = I_o e^{-\left(\frac{R}{R_e}\right)^{\frac{1}{n}}}$$

$$n \sim 1.4$$

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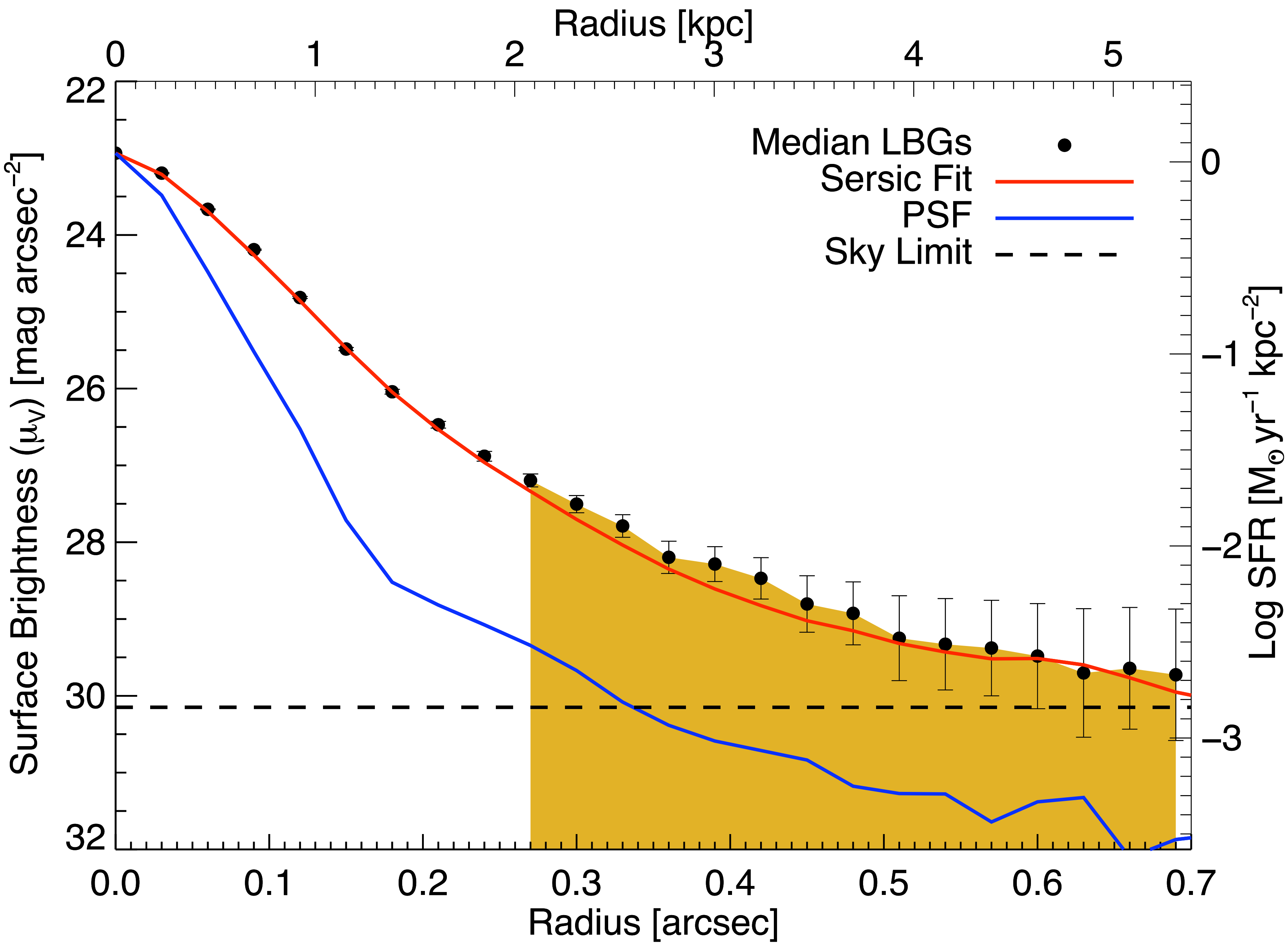

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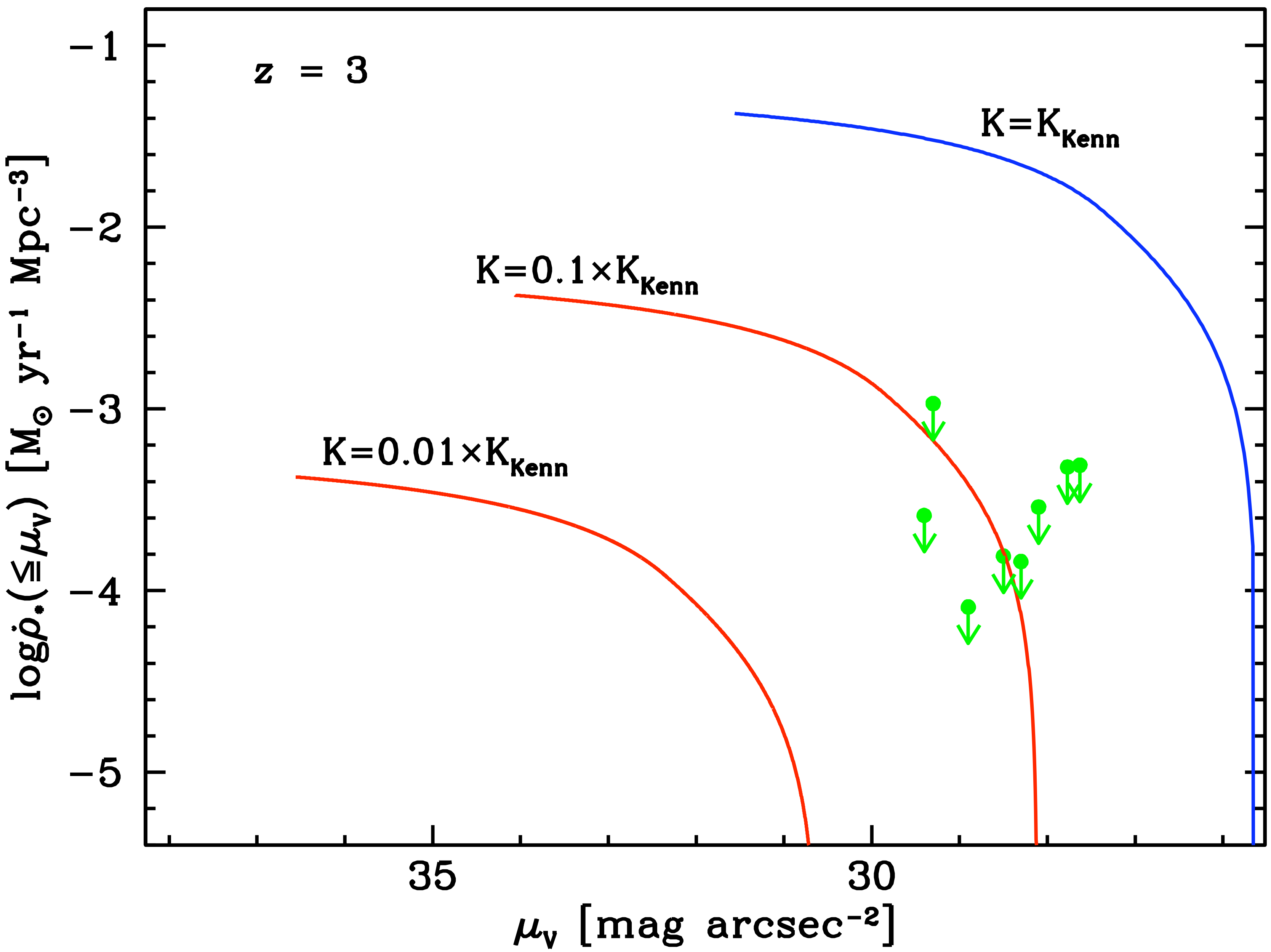
Detection of in-situ star formation around high surface brightness objects



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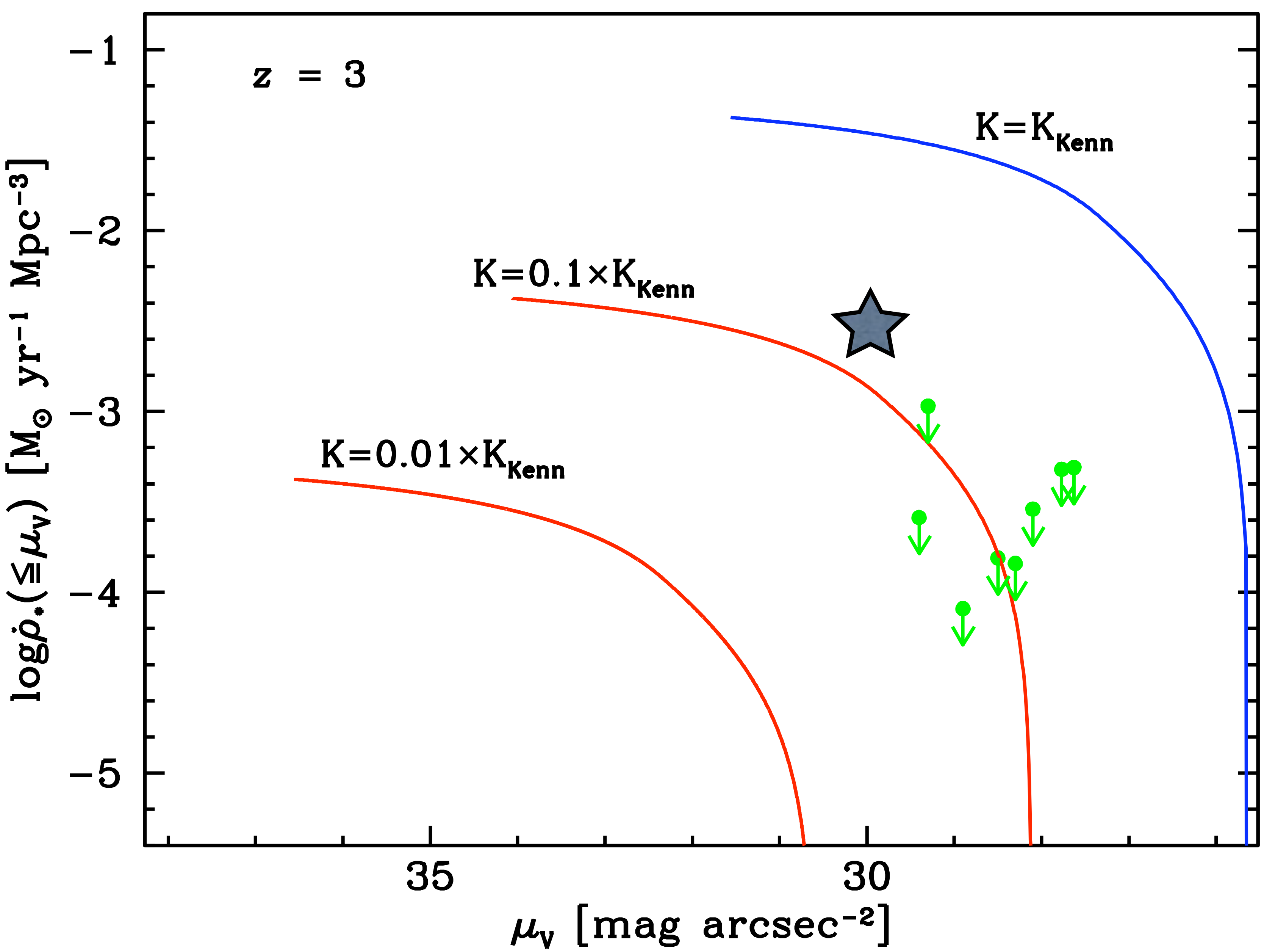
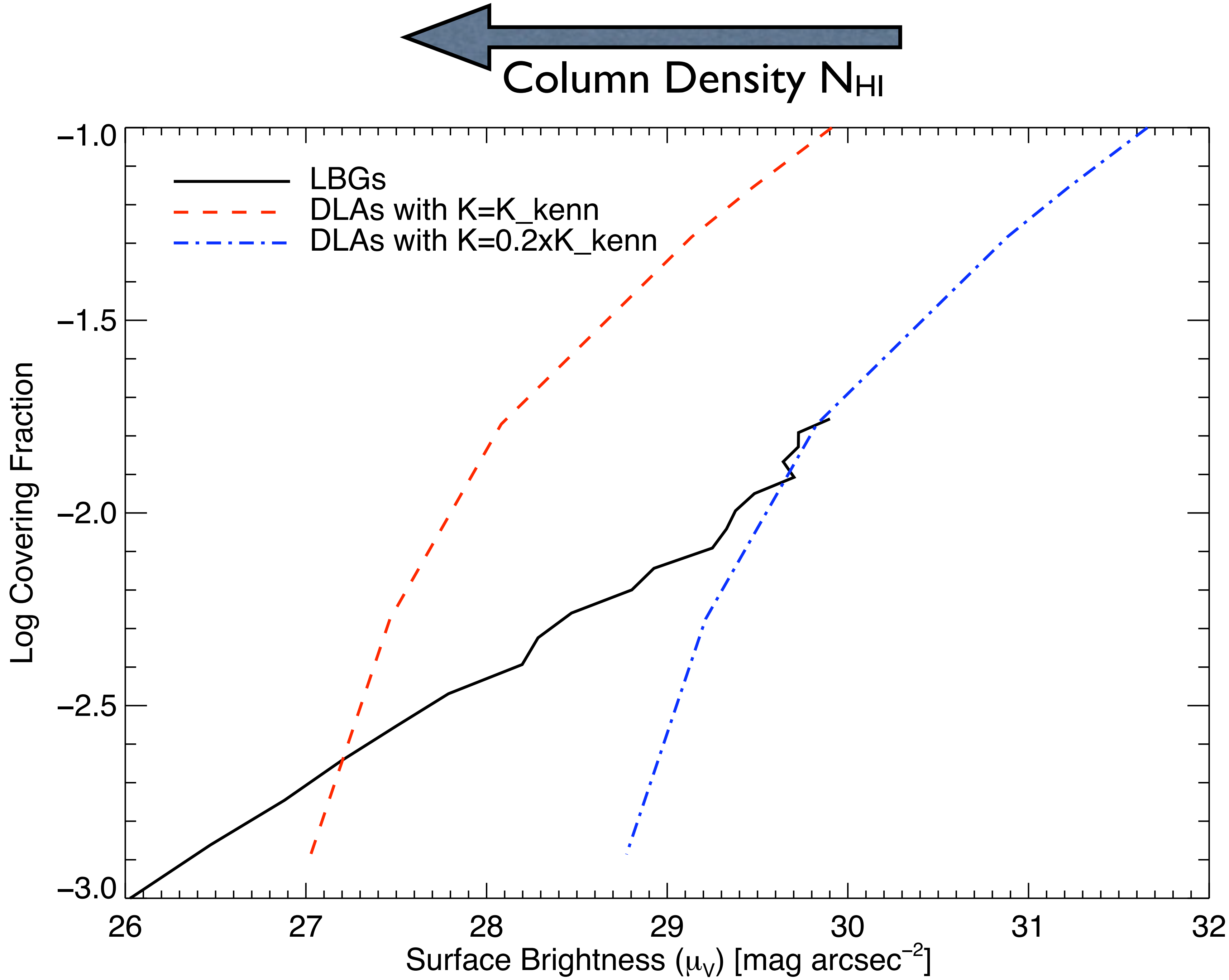


Covering Fraction



Summary

- Aim was to test the caveat of in situ star formation in DLAs around high surface brightness objects
- Used new very deep u-band image to create first reliable sample of $2.5 \lesssim z \lesssim 3.5$ LBGs in the Hubble Ultra Deep Field
- Detected spatially extended low surface brightness emission around LBGs
- Constrained the cumalative comoving star formation rate density of DLAs, if the gas around LBGs is DLA gas.
- The covering fraction of the low surface brightness emission is consistent with the reduced star formation efficiency measured in DLAs