An HST search for Escaping Lyman Continuum at z~1

Evidence for an Evolving Escape Fraction

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Intro

- QSOs aren't responsible for bulk of ionizing background at $z > 3$
- Star-forming galaxies must be responsible
- Lyman Continuum photons must escape

- Many non-detections in searches at z~0, 1, 3
- Only detections at z~3 by Steidel et al. (2001), Shapley et al. (2006)
  - Only 2 individual detections (out of 14)
  - Only some LBGs have high f_{esc}
  - Implies high relative escape fractions $f_{esc,rel} \sim 1.0$ => $f_{esc} \sim 0.15$

The Boring Part: Escape Fraction Definitions

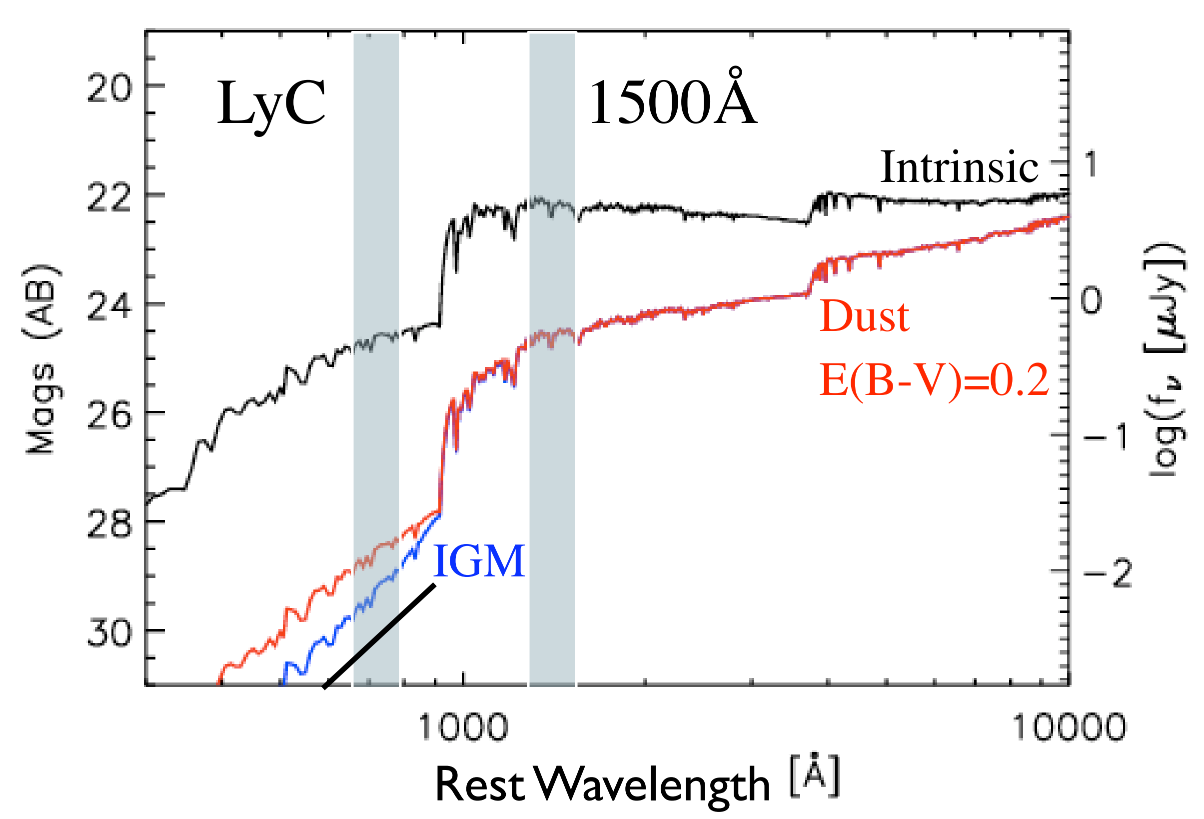
- Absolute Escape Fraction: Fraction of LC photons that escape
  - HI + Dust Attenuation
  - SFR/IMF => ionizing background

- Relative Escape Fraction: Fraction of LC photons that escape divided by fraction of 1500Å photons that escape
  - HI + Differential Dust Attenuation
  - No assumptions about dust reddening
  - UV Luminosity Functions => ionizing background

- $f_{esc} = f_{esc,rel} * 10^{-0.4*(A\_1500)}$ $\Rightarrow$ $f_{esc} \approx f_{esc,rel} / 7$

The Painful Part: Measuring f_{esc}

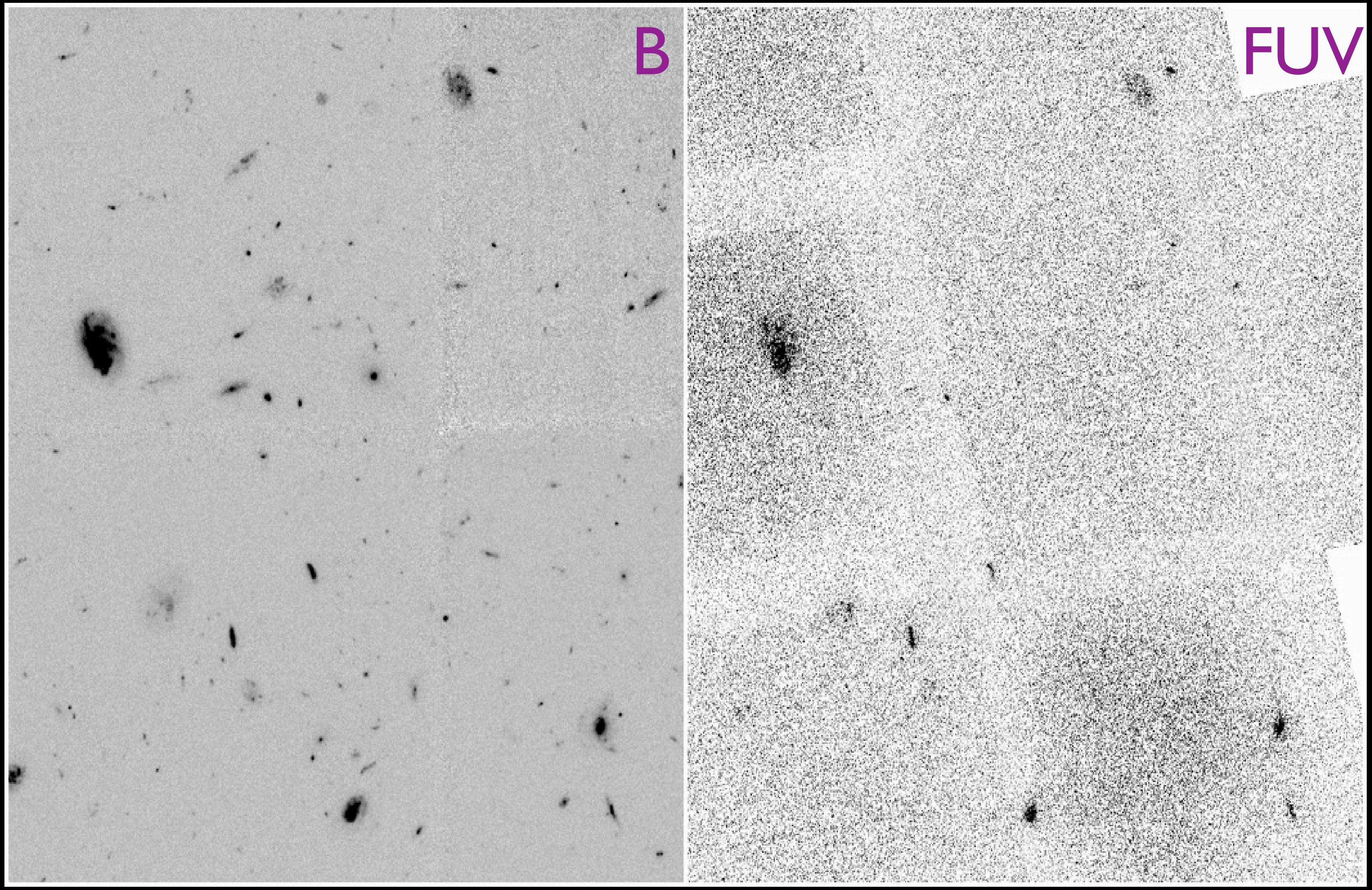
	$\Delta(f_{1500}/f_{700})$
Intrinsic	~6-10
Dust	2-10?
IGM	2-3
HI (ISM)	?
Total	>20-200



Must go a minimum of 3 mags deeper !!

The Pretty Part: The Survey

- HST ACS-Solar Blind Channel - 1600Å imaging
- 12 arcmin^2 covering HDF-N and UDF
- Blueward of Lyman Break at $z > 1.2$
- m_{AB}(1600Å) < 29.5
- 21 gals with $1.2 < z_{spec} < 1.5$
- We can triple z~1 sample size and sample low L space



Technique

- Measure $(f_{1500}/f_{LC})_{obs}$
- Correct for IGM (factor of ~2)
- Correct for intrinsic break (factor of ~10)

$$f_{esc,rel} = \frac{(f_{1500}/f_{LC})_{stel}}{(f_{1500}/f_{LC})_{obs}} \times \exp(\tau_{IGM}(LC))$$

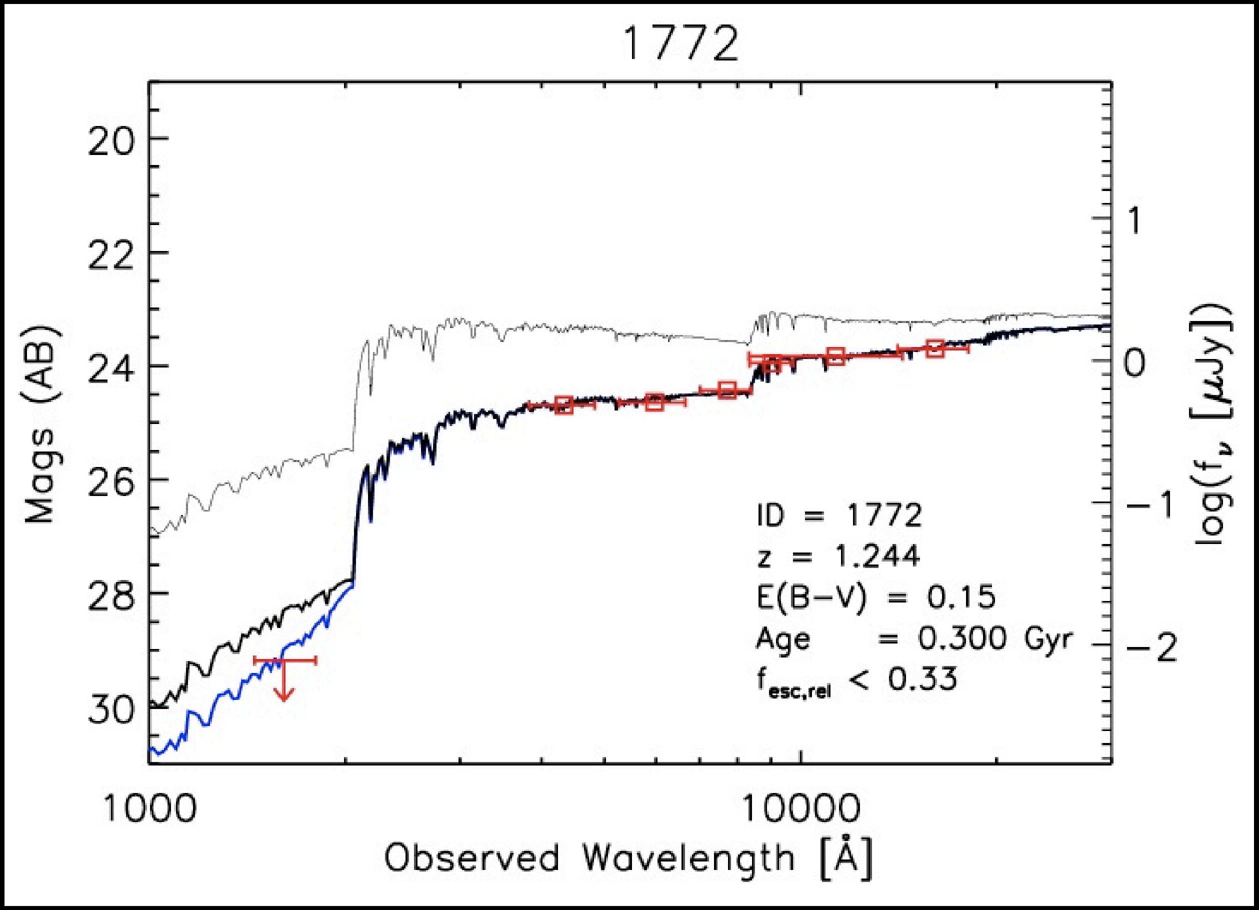
$$f_{esc,rel} = \frac{20}{(f_{1500}/f_{700})_{obs}}$$

SED Fits

SFH + Age => Intrinsic Lyman Break

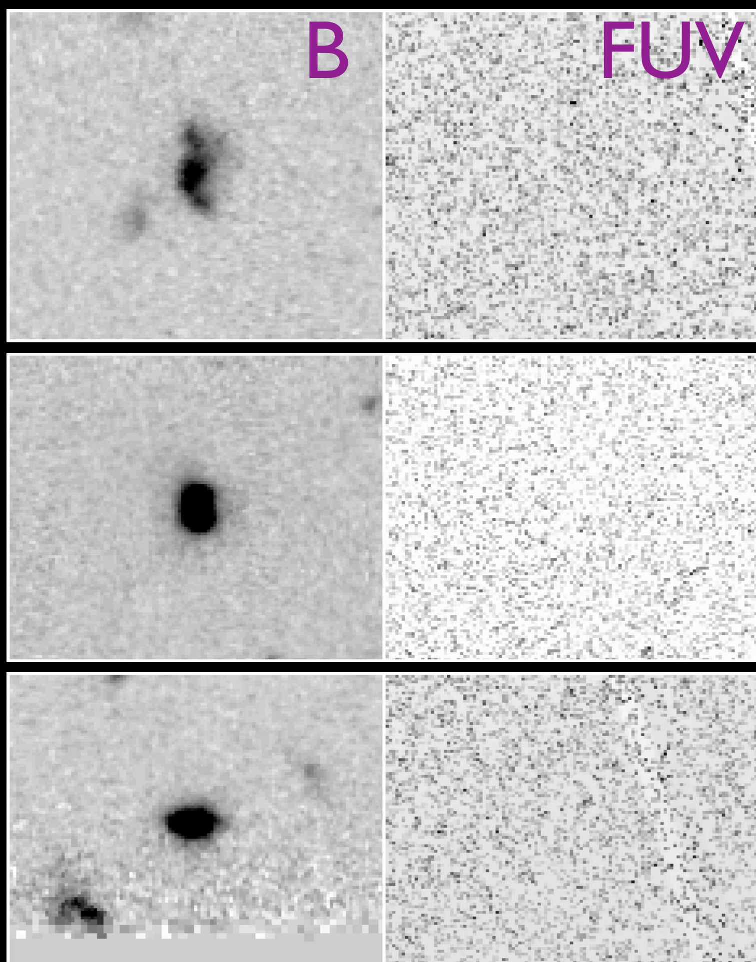
Dust Reddening => Conversion of $f_{esc,rel}$ to f_{esc}

- Salpeter IMF
- SFH
  - Constant
  - Single Burst
  - Exponential Decay
- Solar Metallicity
- Calzetti Extinction Law (Calzetti, 1997)



Results

- No detections!
- 18 Galaxies with $f_{esc,rel} < 1.0$ down to $f_{esc,rel} < 0.10$
- Stack gives $f_{esc,rel} < 0.08$
- No indication of any $f_{esc,rel} \sim 1$ as seen at $z\sim3$



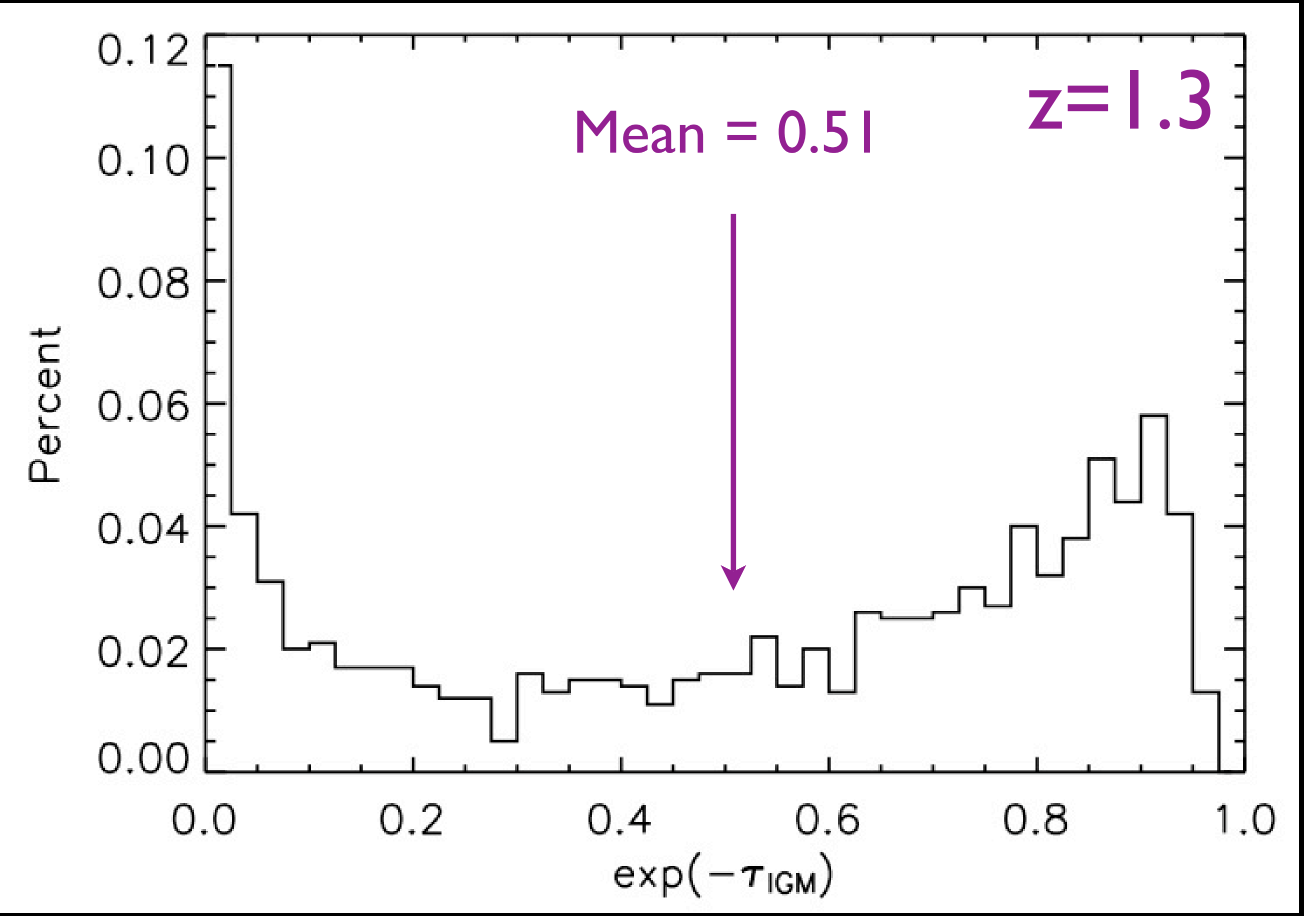
$f_{1500}/f_{700} > 27.7$ $f_{esc,rel} < 0.58$

$f_{1500}/f_{700} > 105$ $f_{esc,rel} < 0.15$

$f_{1500}/f_{700} > 87.7$ $f_{esc,rel} < 0.18$

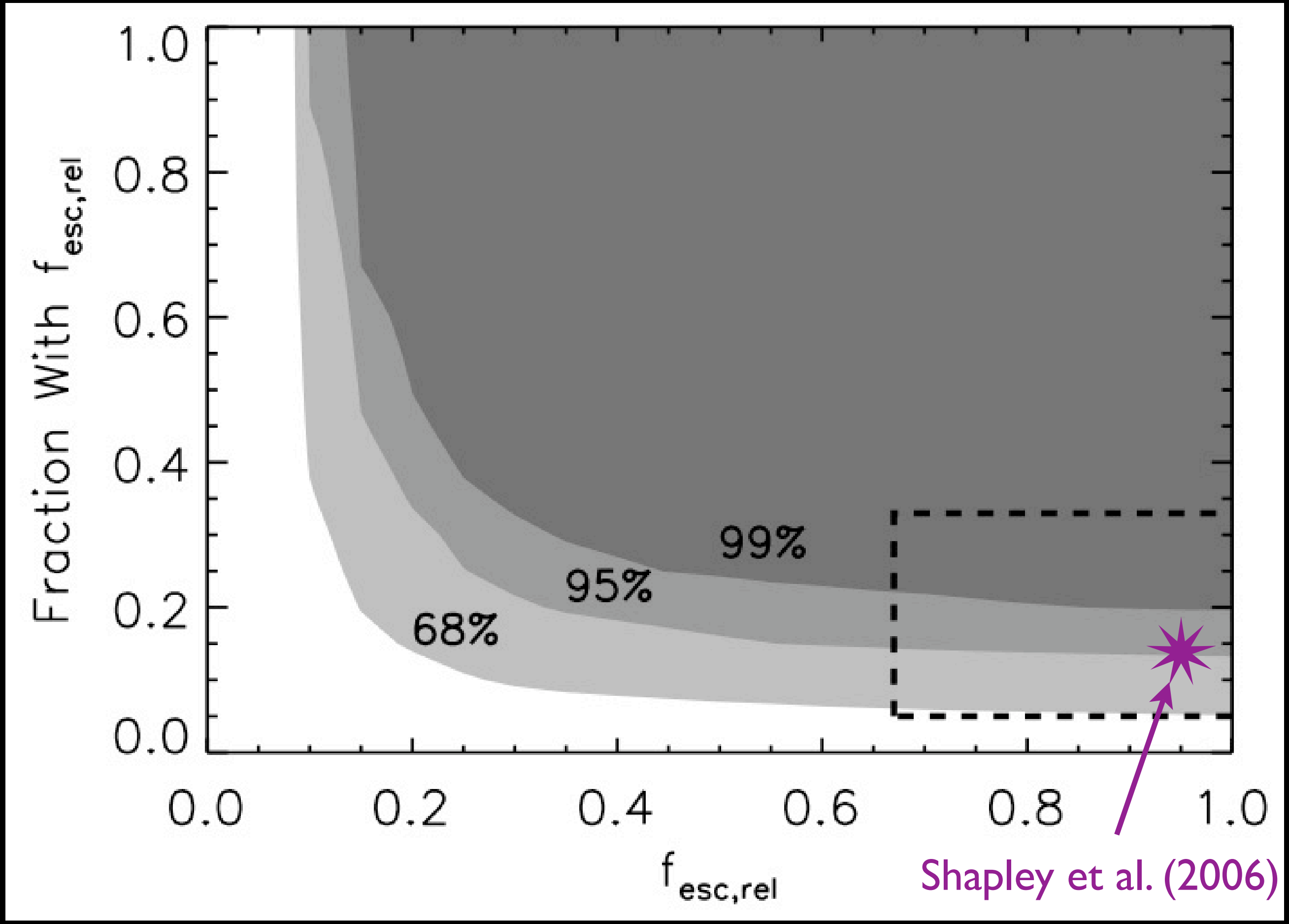
IGM Transmission

- Large dispersion in IGM transmission
- Some lines-of-sight opaque, others clear.
- Need Monte-Carlo simulations



Monte-Carlo

- Combine sample with Malkan et al. (2003)
- Perform experiment 10,000 times with same limits accounting for IGM distribution.
- Assume only a fraction X of gals have $f_{esc,rel} = Y$, else 0



Siana et al. 2007

Conclusions

- SED Fits: Ages, reddening, similar to LBGs though L = 0.1-1.0 L^*_{LBG}
- If all starbursts have same escape fraction:
  - $f_{esc,rel} < 0.14$ fesc < 0.02
- If only subset have escape fractions near unity:
  - Must be less than 20%
- Rules out Shapley et al. (2006) z~ 3 values at 1σ
- Escape Fraction likely decreasing from z~3 to z~1

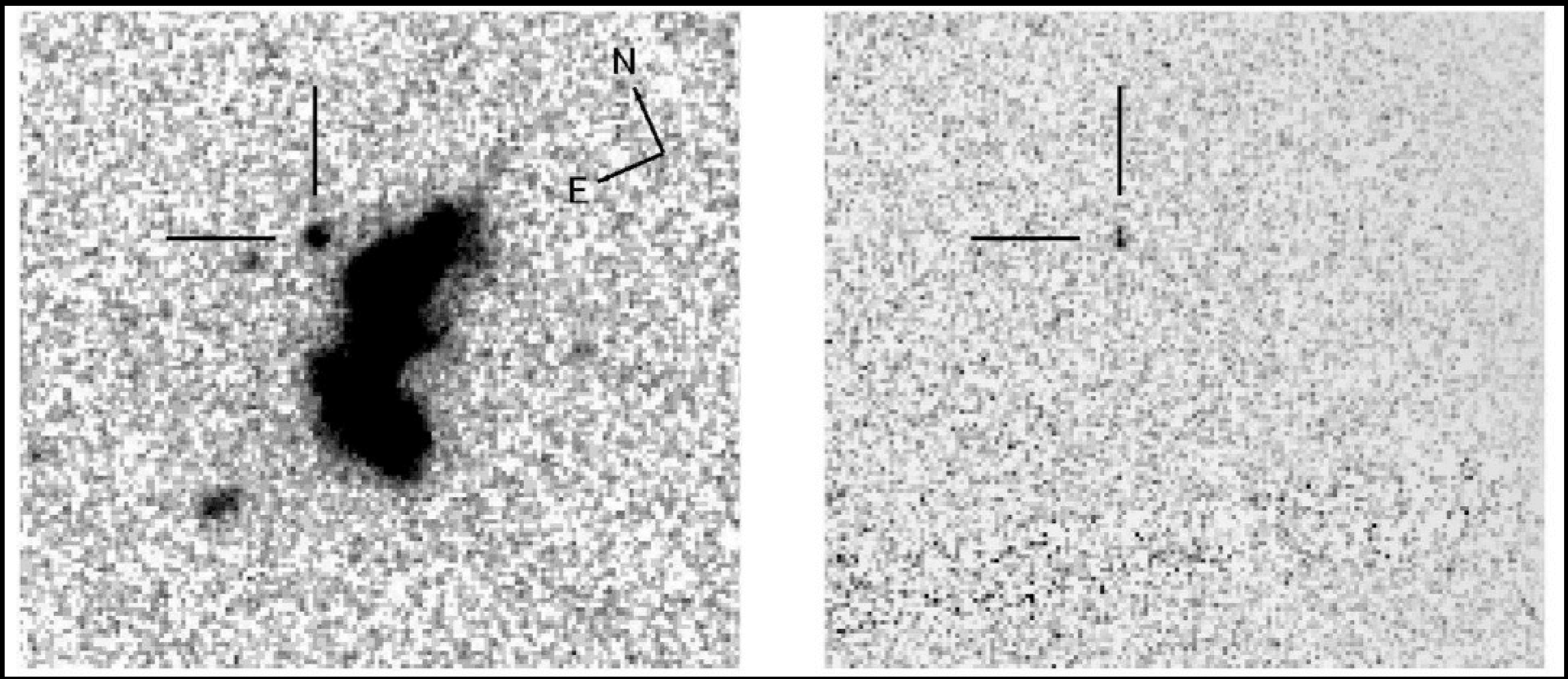
Stay tuned…

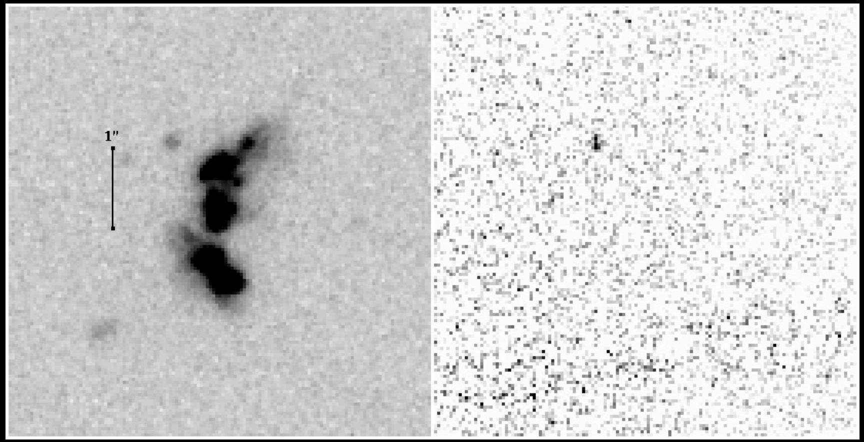
- 75 orbits of HST ACS/SBC Imaging (H. Teplitz, PI)
  - 15 gals with L ~ L^*_{LBG} in GOODS
  - > 10x more sensitive than current survey
- 121 orbits of HST ACS/SBC prism spectroscopy at z~0.75 (H. Teplitz, PI)
  - 41 galaxies => large numbers
- Conclusive determination of f_{esc} evolution between $1<z<3$
- Investigate where escape occurs if at all…
- ACS/SBC is back in business and taking our data: No detections!!

Additional Slides...

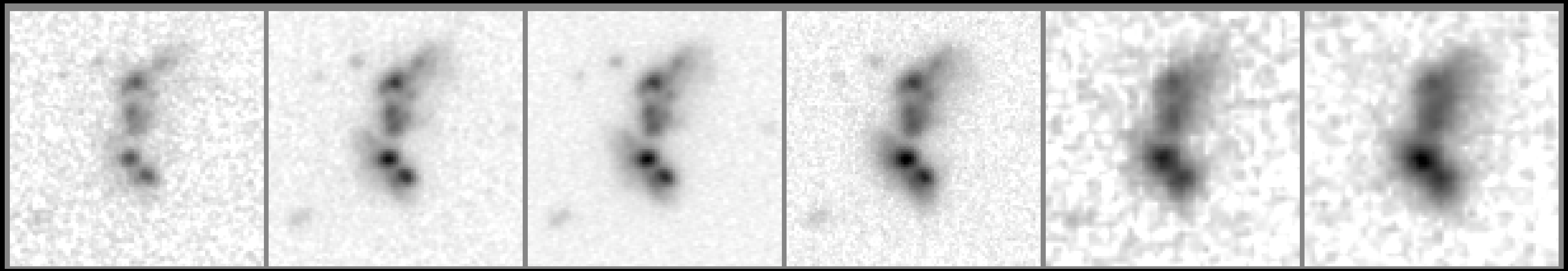
Foreground Contamination?

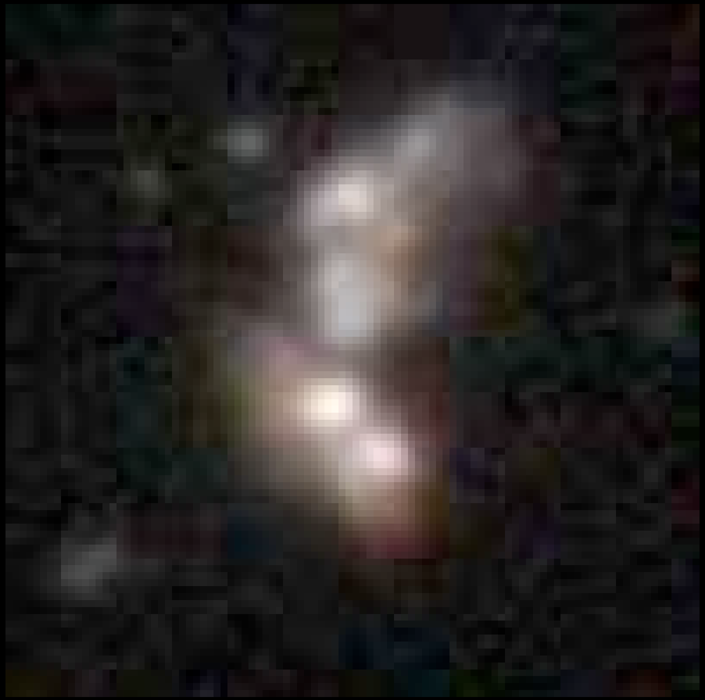
- Possibly at z~1.3 but impossible to know
- This object would have $f_{esc,rel} \sim 0.2$

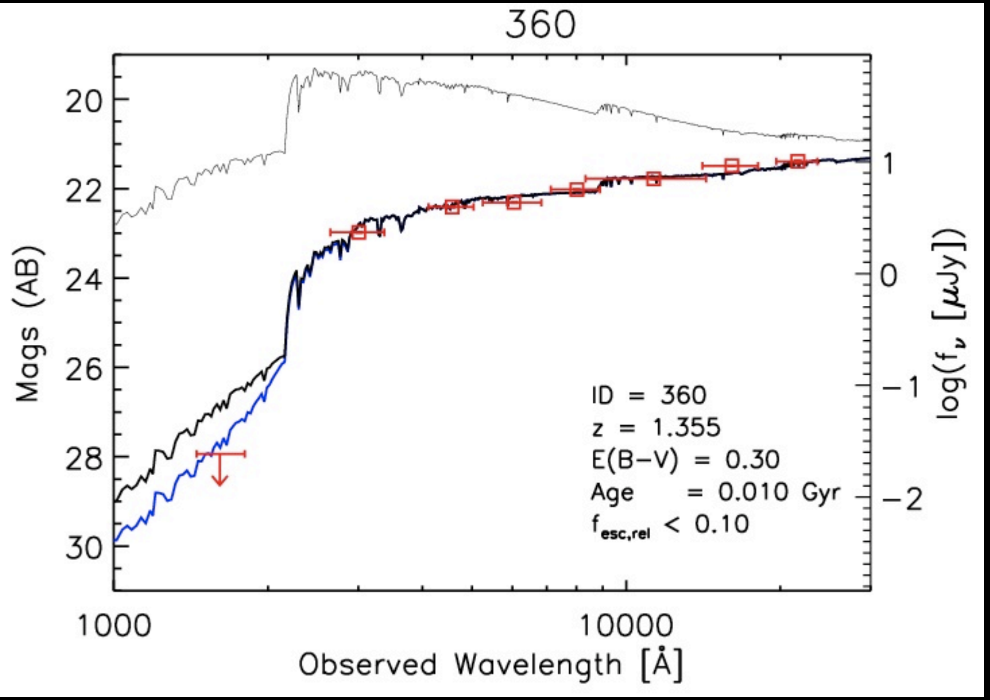




$f_{1500}/f_{700} > 132$ (3σ)
$f_{esc,rel} < 0.10$

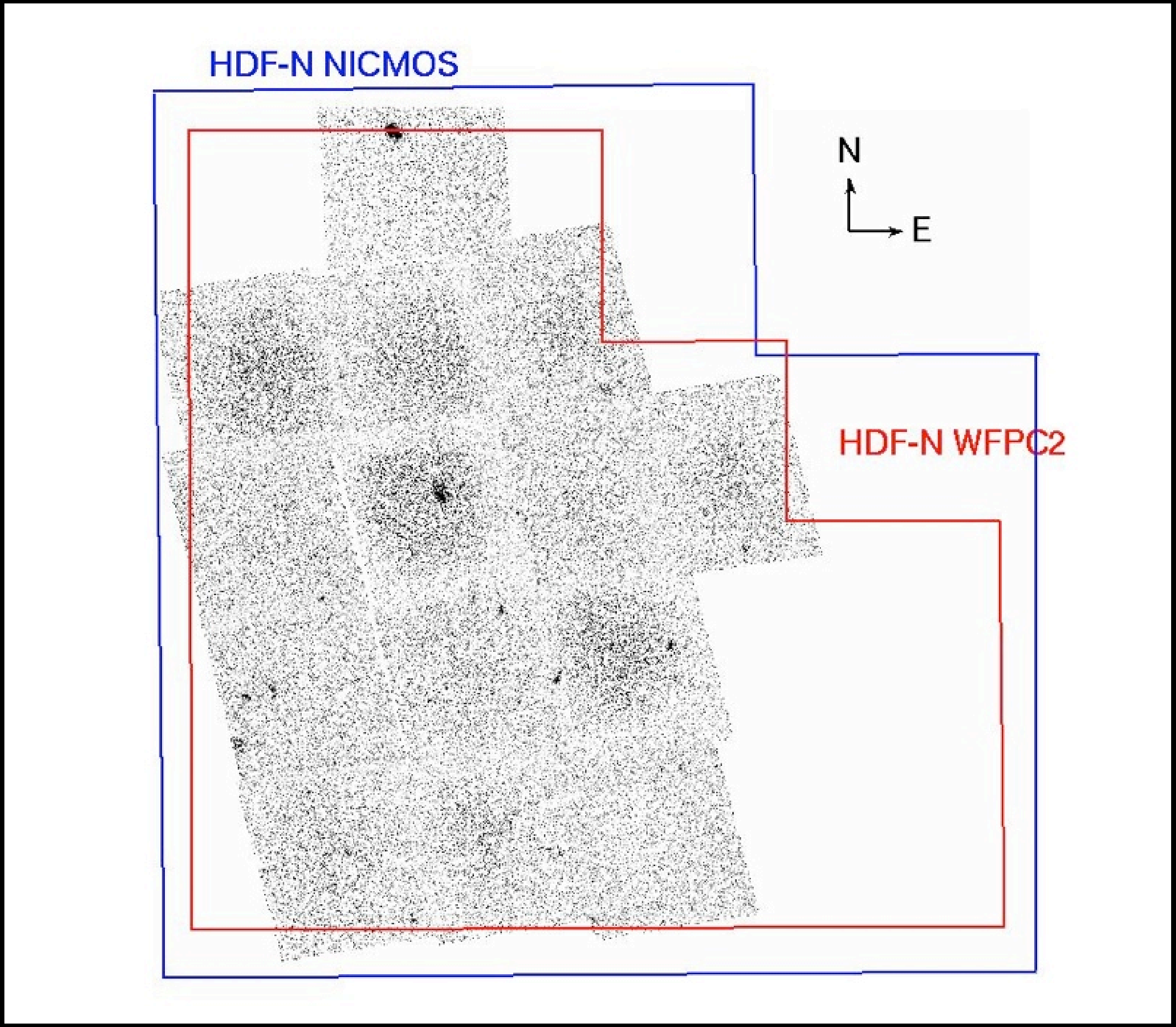






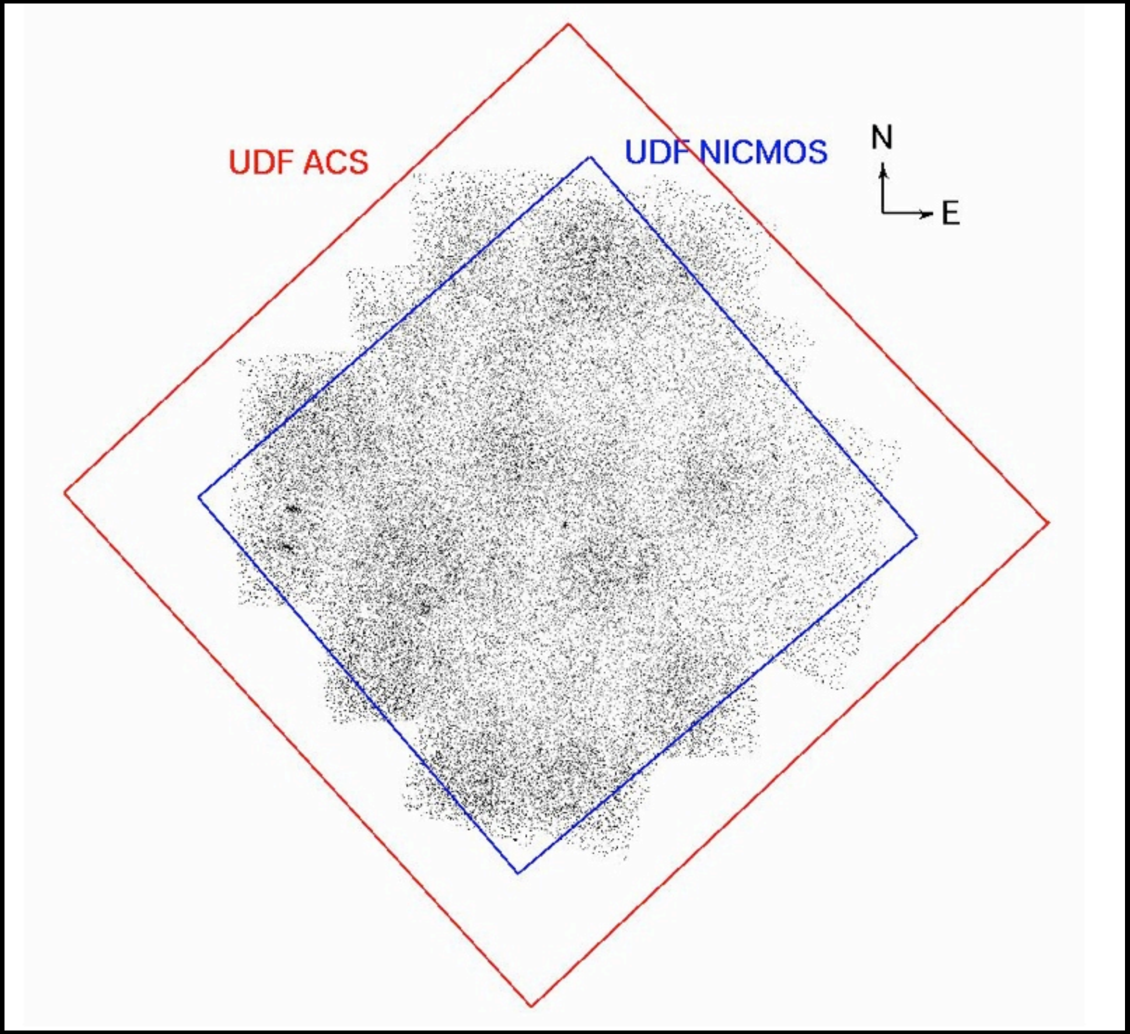
HDF-N

- ACS/SBC 1600Å
- 14 pointings x 2 orbits
- m(AB) < 29.5
- 3.77 $arcmin^2$



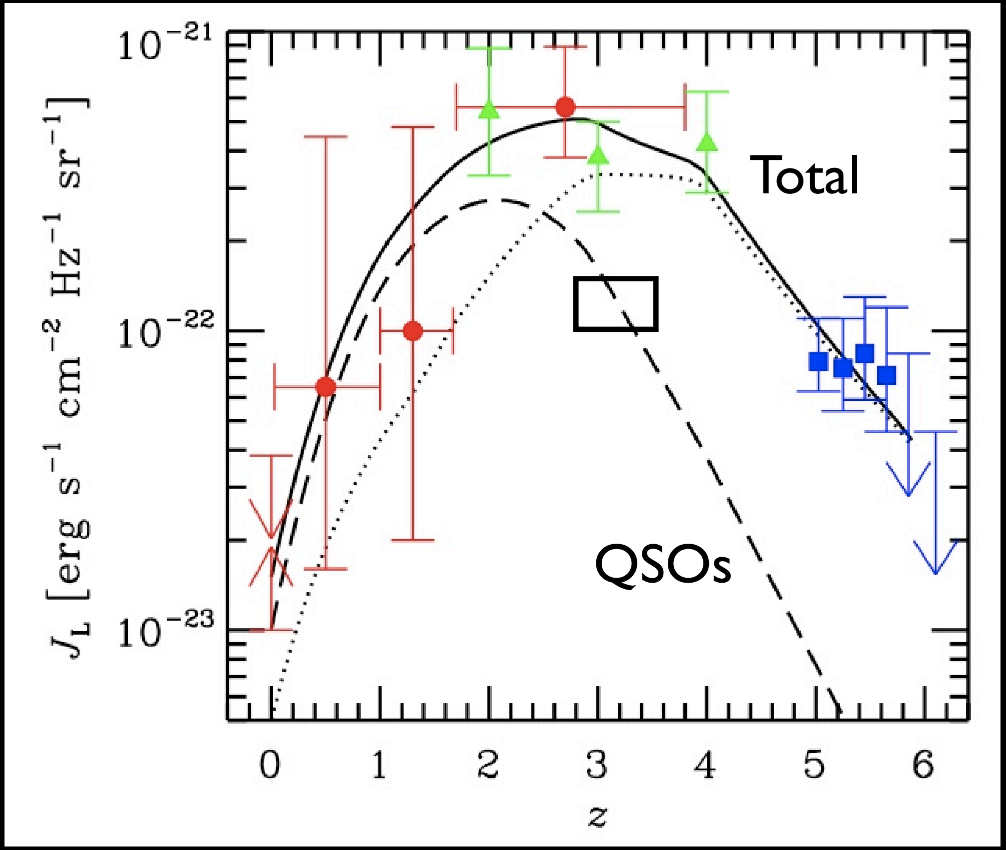
Ultra Deep Field

- ACS/SBC 1600Å
- 25 pointings x 2 orbits
- m(AB) < 29
- 7.77 arcmin^2



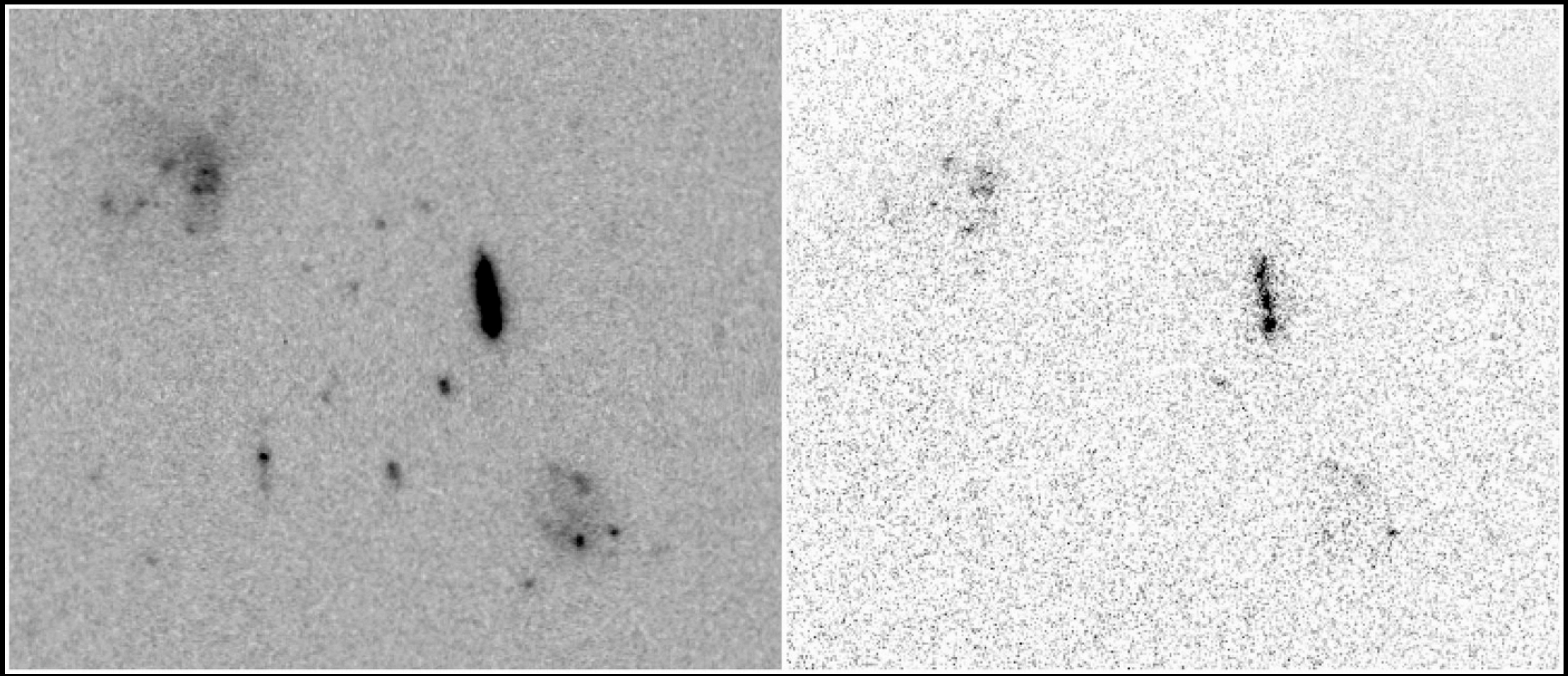
What reionized the universe?

- Rapid decline in space density of luminous QSOs at z > 3 (Fan et al. 2001; Richards et al. 2006)
- Faint end of QSO LF insufficient (Hunt et al. 2004; Fontanot et al. 2006; Siana et al. 2007; Bongiorno et al. 2007)
- Star formation must be responsible



Inoue et al. (2006)

Benefits of Ancillary Data



- Optimize extraction using optical (B band) isophotes.
- Determine where Lyman continuum is escaping.
- Great HST photometry for SED fitting.

Lots of Questions…

- What is special about the galaxies with high f_{esc}?
  - Function of morphology, luminosity, metallicity?
- Is f_{esc} anisotropic?
- Does f_{esc} evolve with redshift?
  - Pop III stars (Jimenez & Haiman, 2006)
  - Increased SF efficiency --> SNe Chimneys (Fujita et al. 2004)
  - Gas clumping/feedback (Razoumov et al. 2006)
- We have not sampled enough morphology/L/z space!

Results

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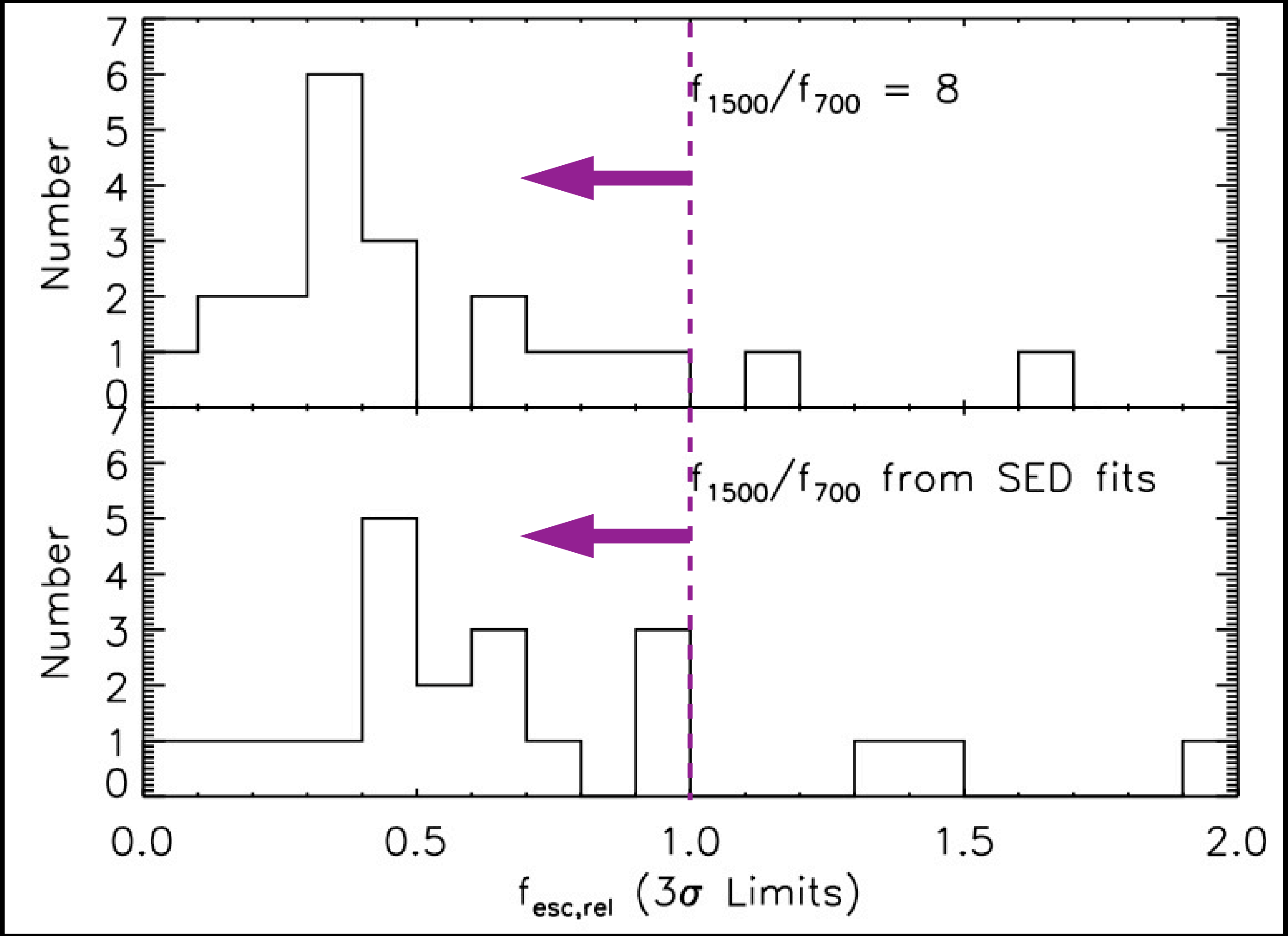

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