

# Observational Constraints on Reionization from High Redshift Galaxy Studies

- Did the intergalactic hydrogen reionize at  $z$  just beyond 6 ?
- Can we find galaxies and faint AGN at these redshifts ?
  - What can their properties tell us about reionization?
  - Are these observations self-consistent ?

# How can we find galaxies at these redshifts?

Hard to get the sensitivity for color searches to very faint limits. (May be possible with GOODS ACS survey)

Alternative route is to search for Lyman alpha with narrow band filters

# Narrow-Band/Color Survey

## Hu, Cowie, McMahon, Capak + SuprimeCam Team

- Ultradeep 8160 and 9150 narrow band images
- Smaller deeper fields with Keck+LRIS ( $5 \times 30 \text{ } \square'$ )
- Wide deep fields with Suprime ( $3 \times 600 \text{ } \square'$ )
- 4-5 hour exposures per field
- Ultradeep continuum images in (B), V, R, I and z'
- Several hour exposures in each of continuum bands
- Well studied field targets (HDF, SSA22 and SSA17)
- And lensing cluster fields (A370, A2390)

# Narrow band results

- Emission line searches can effectively probe the dark ages
- Substantial star formation rates from these objects
- (Comparable to lower redshifts)
- Very steeply rising luminosity function at  $z=5.7$
- Less than 30 objects per square degree to  $1.3e-17$  ergs/cm<sup>2</sup>/s
- Have found a  $z=6.56$  object, and other galaxies in this redshift range (Kodaira et al. 2003)
- THIS OBJECT IS PROBABLY NOT CONSISTENT WITH  $z=6.2$  REIONIZATION; larger samples may be used to test whether reionization is at  $z=6.2$  by comparing LFs

HDF

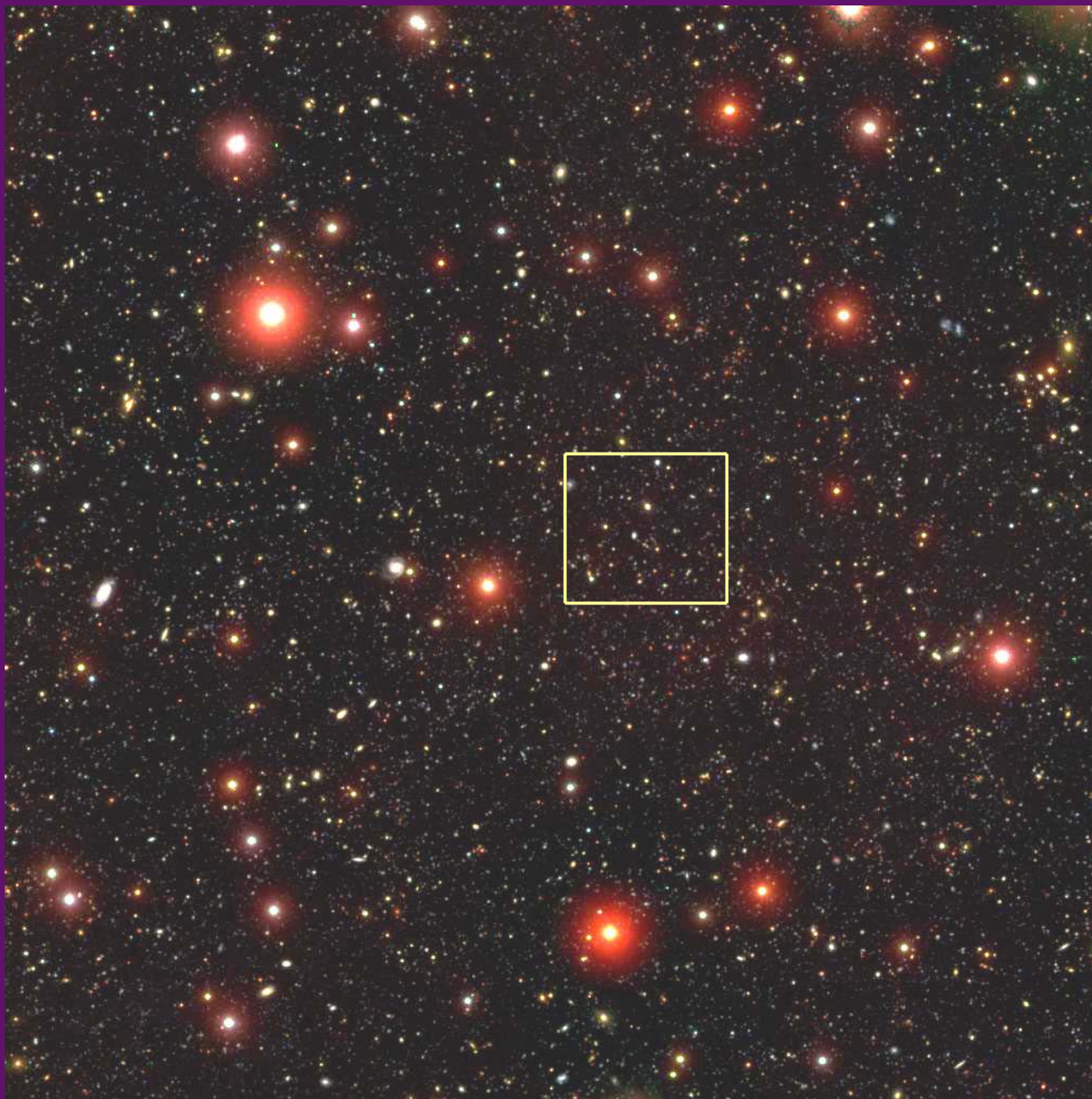
B,R,Z

SUPRIME

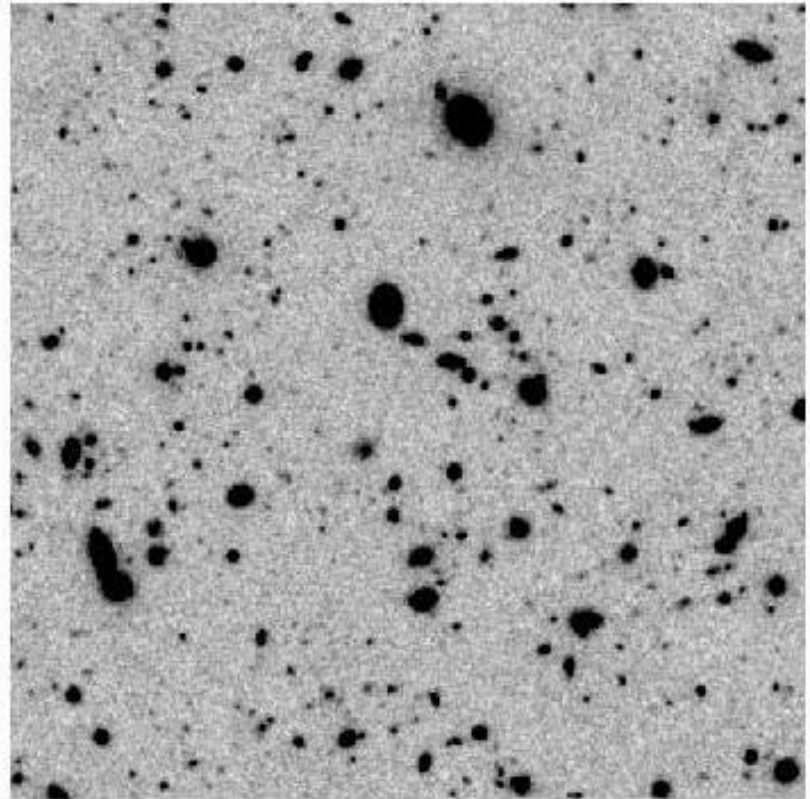
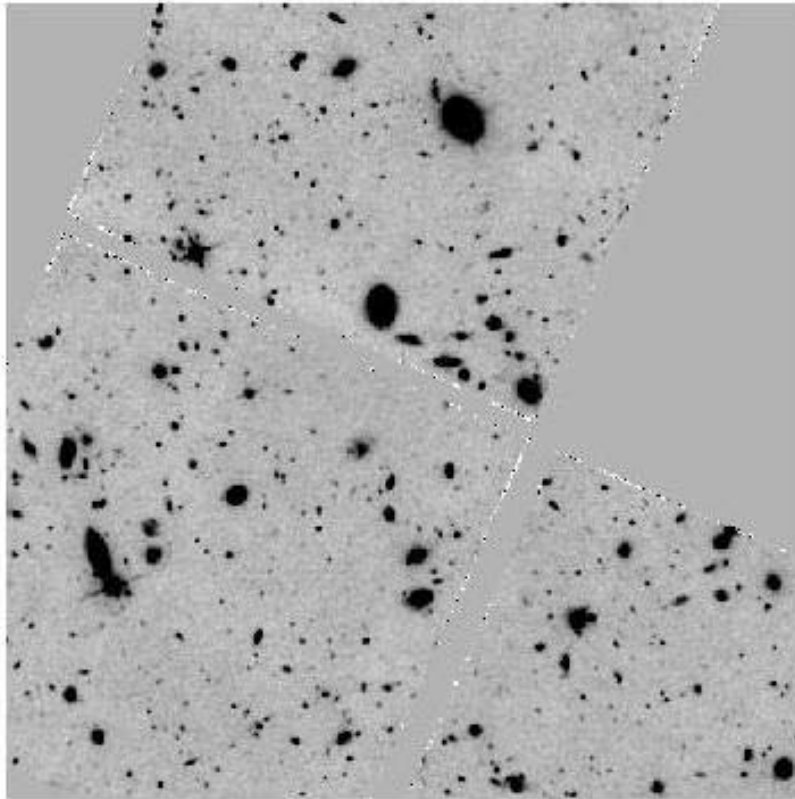
15' X 15'

Capak

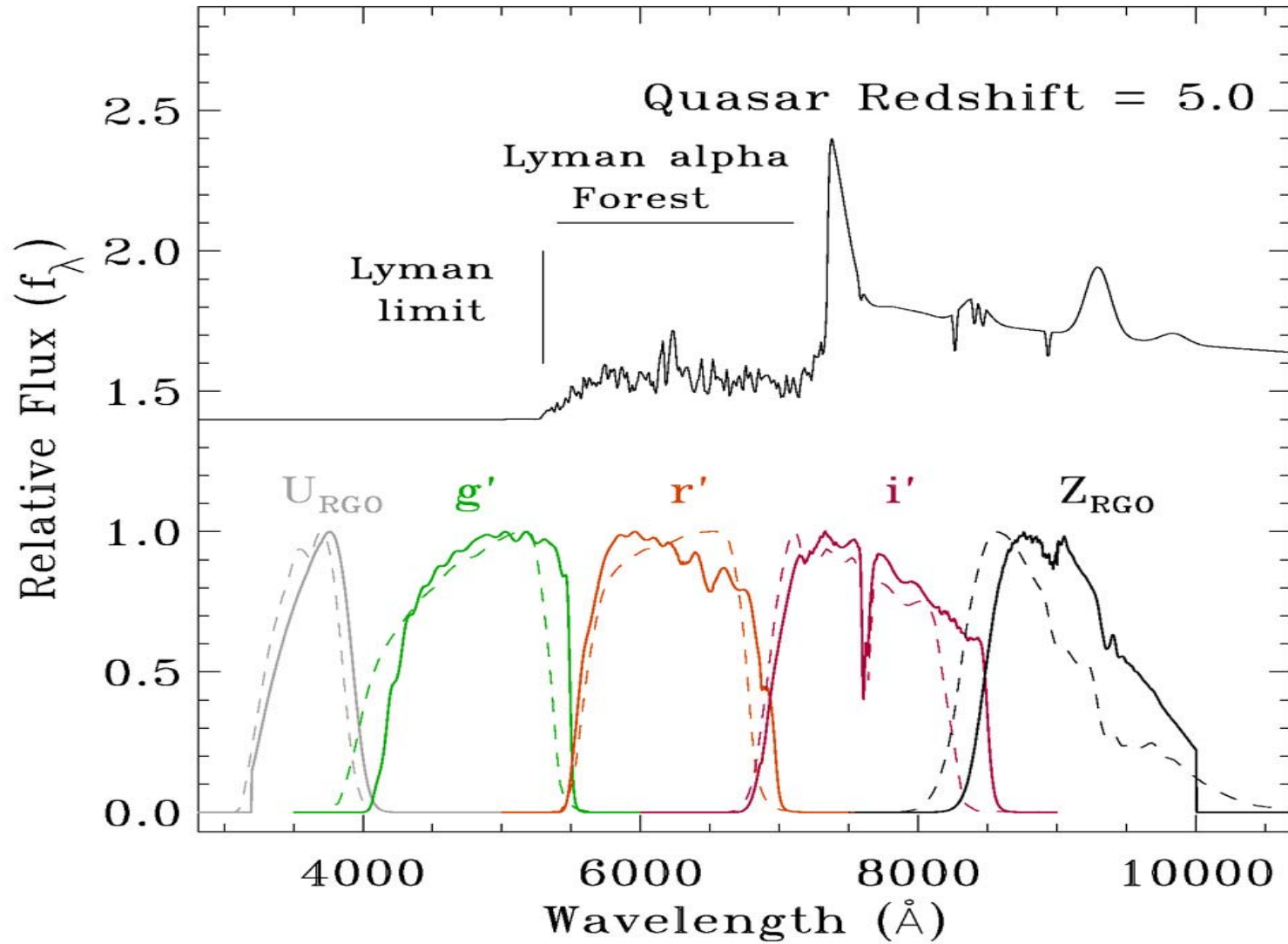
et al. 2003



# HST F814W vs Suprime 8160 narrow band

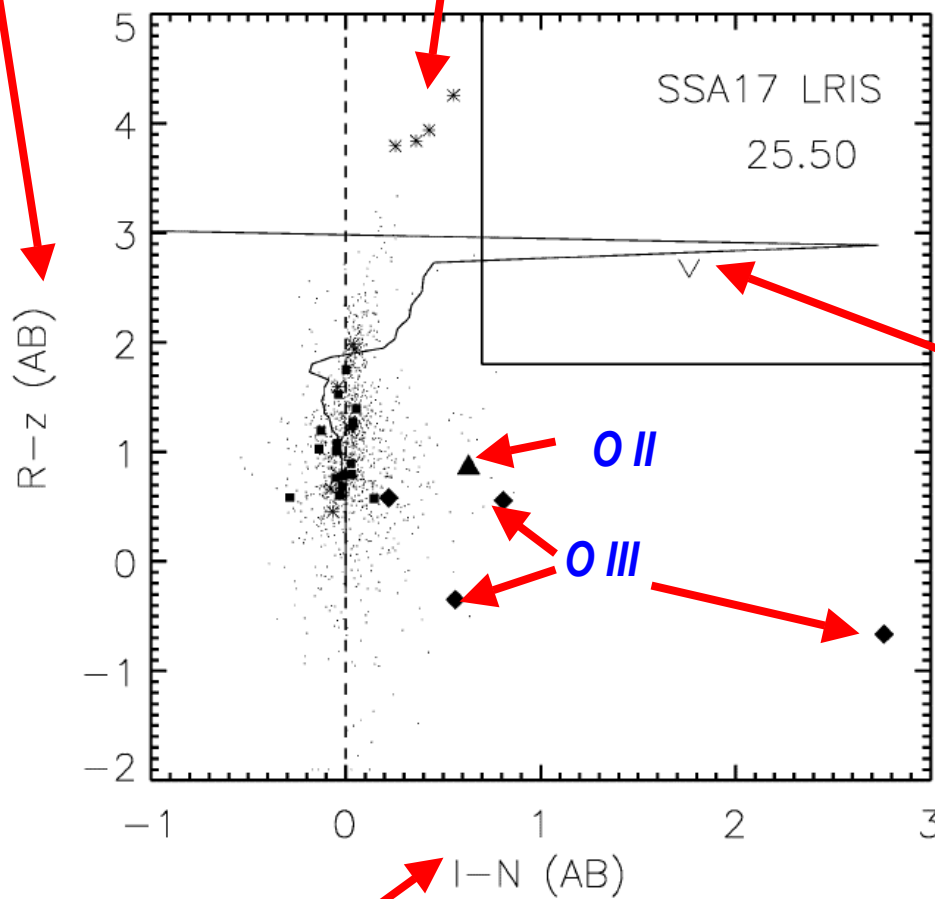


McMahon



*Continuum break*

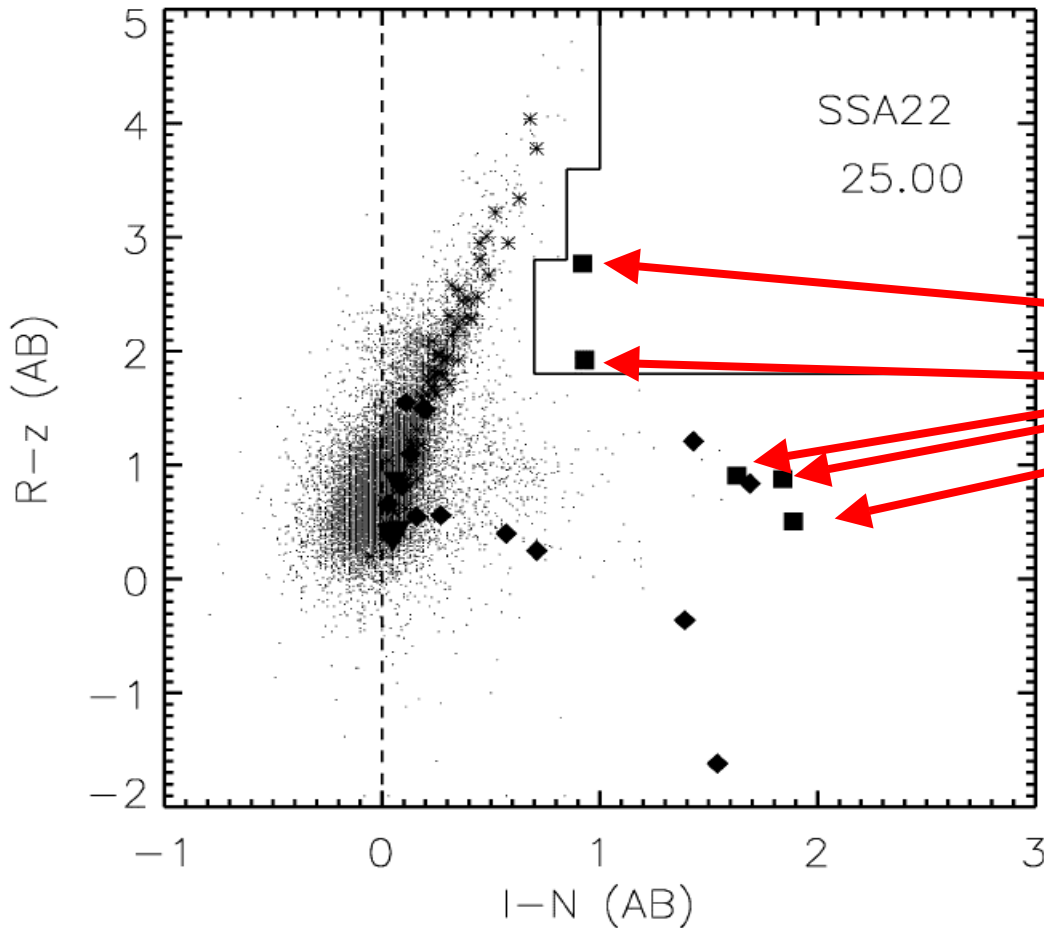
*Red stars*



*Time variable*

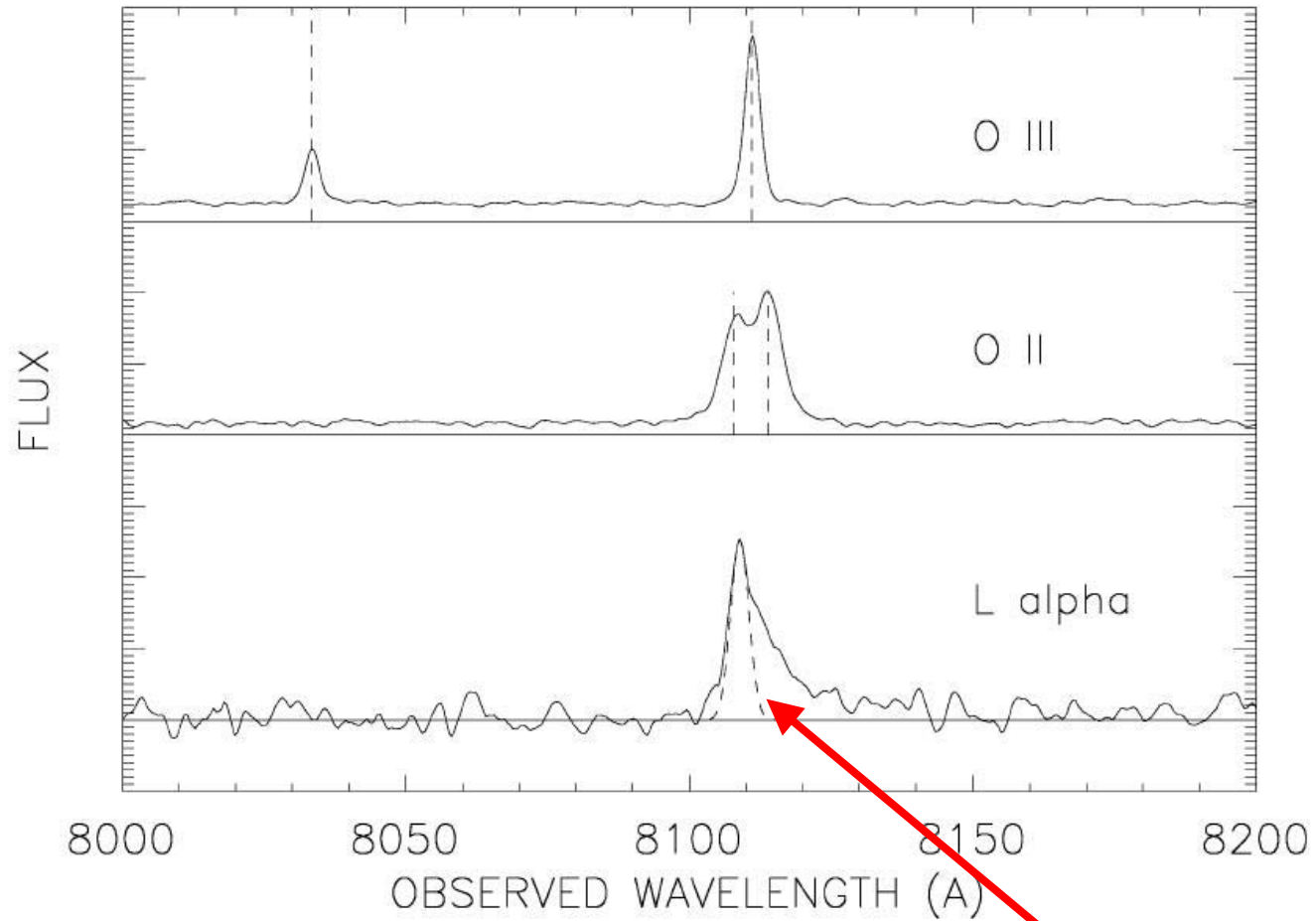
*Equivalent width*

# Suprime Narrow Band to $f=1.3 \times 10^{-17}$ ergs/cm<sup>2</sup>/s

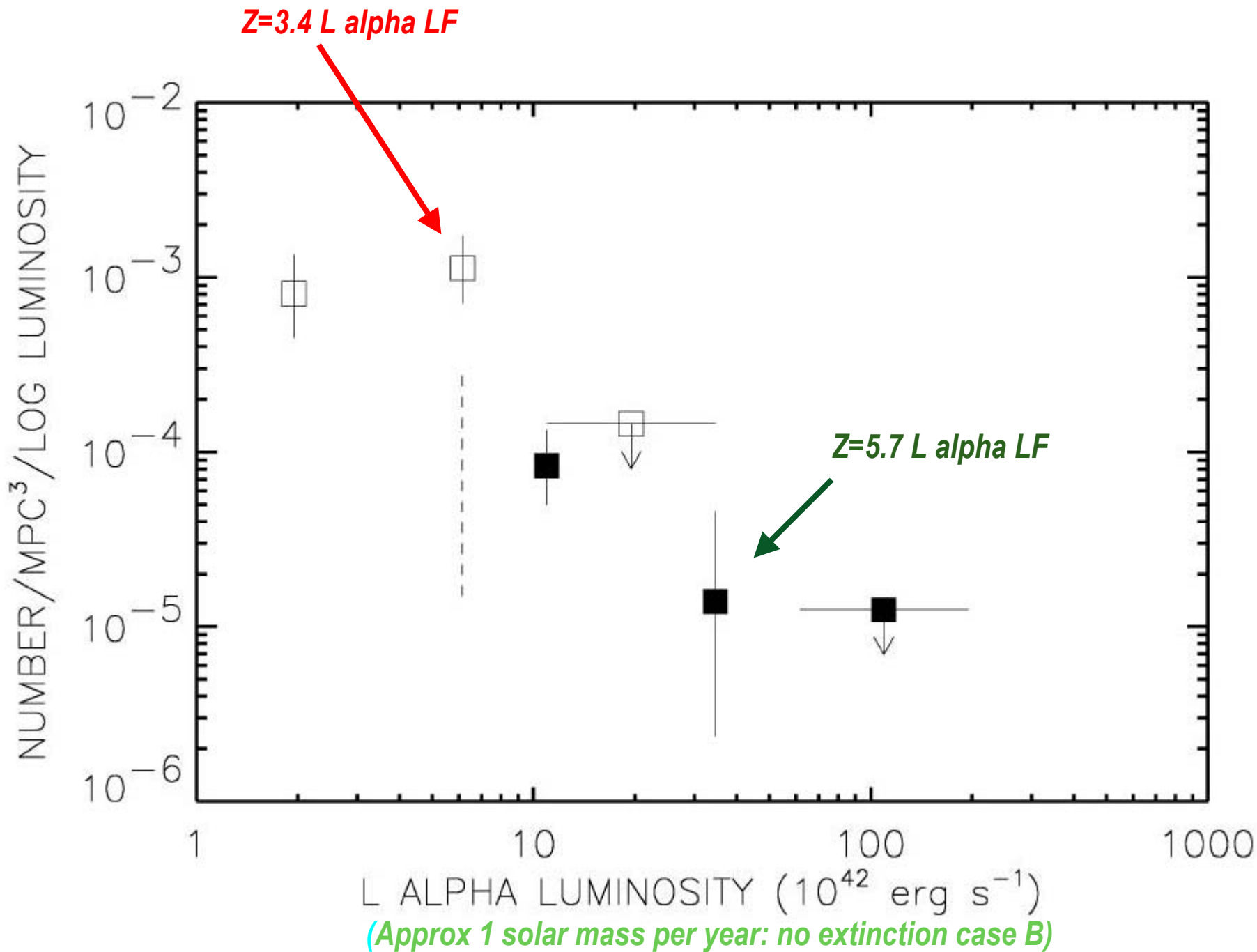


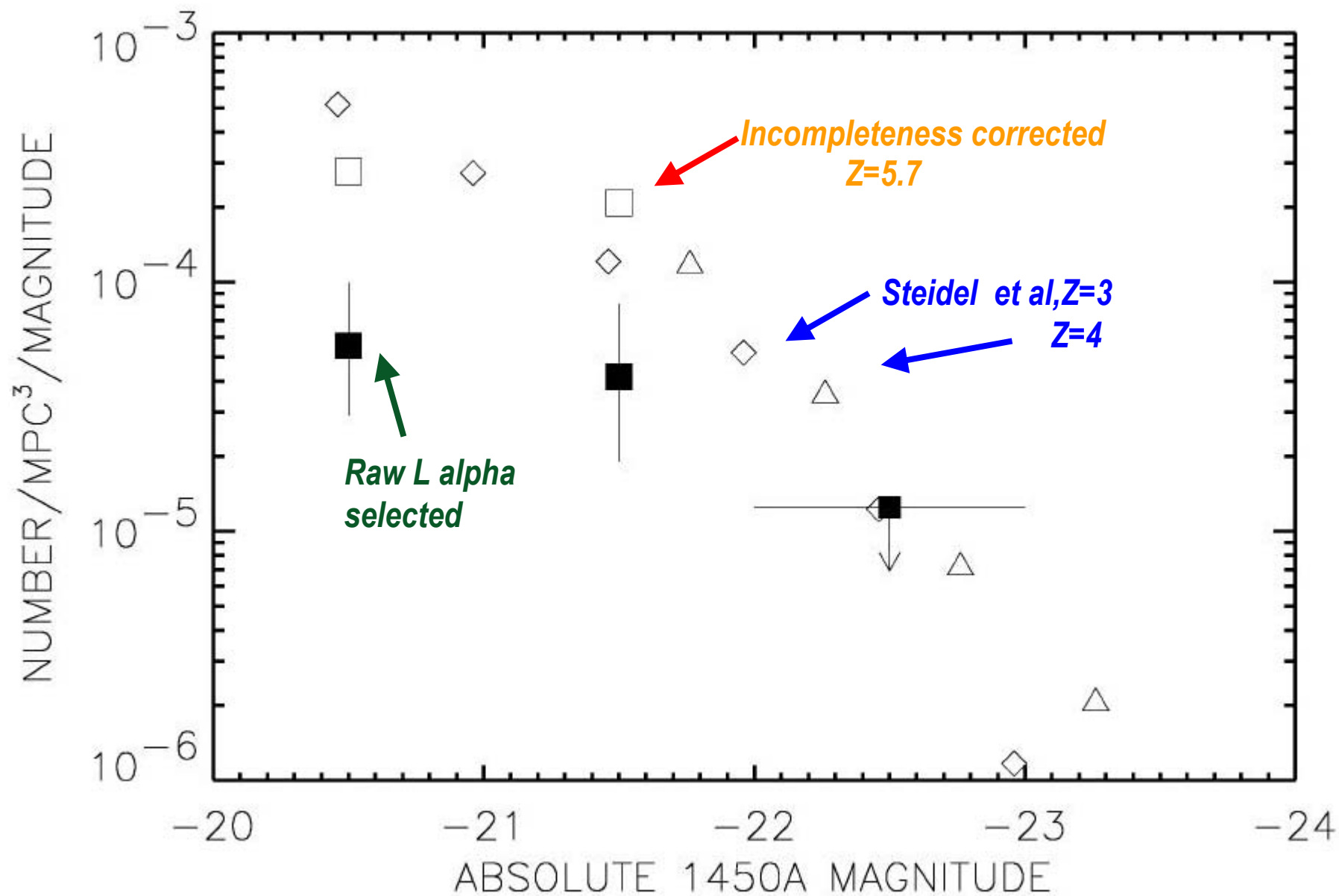
*Known*  
 $Z = 5.7$

**Composite of Deimos Spectra Hu et al. (2003)**



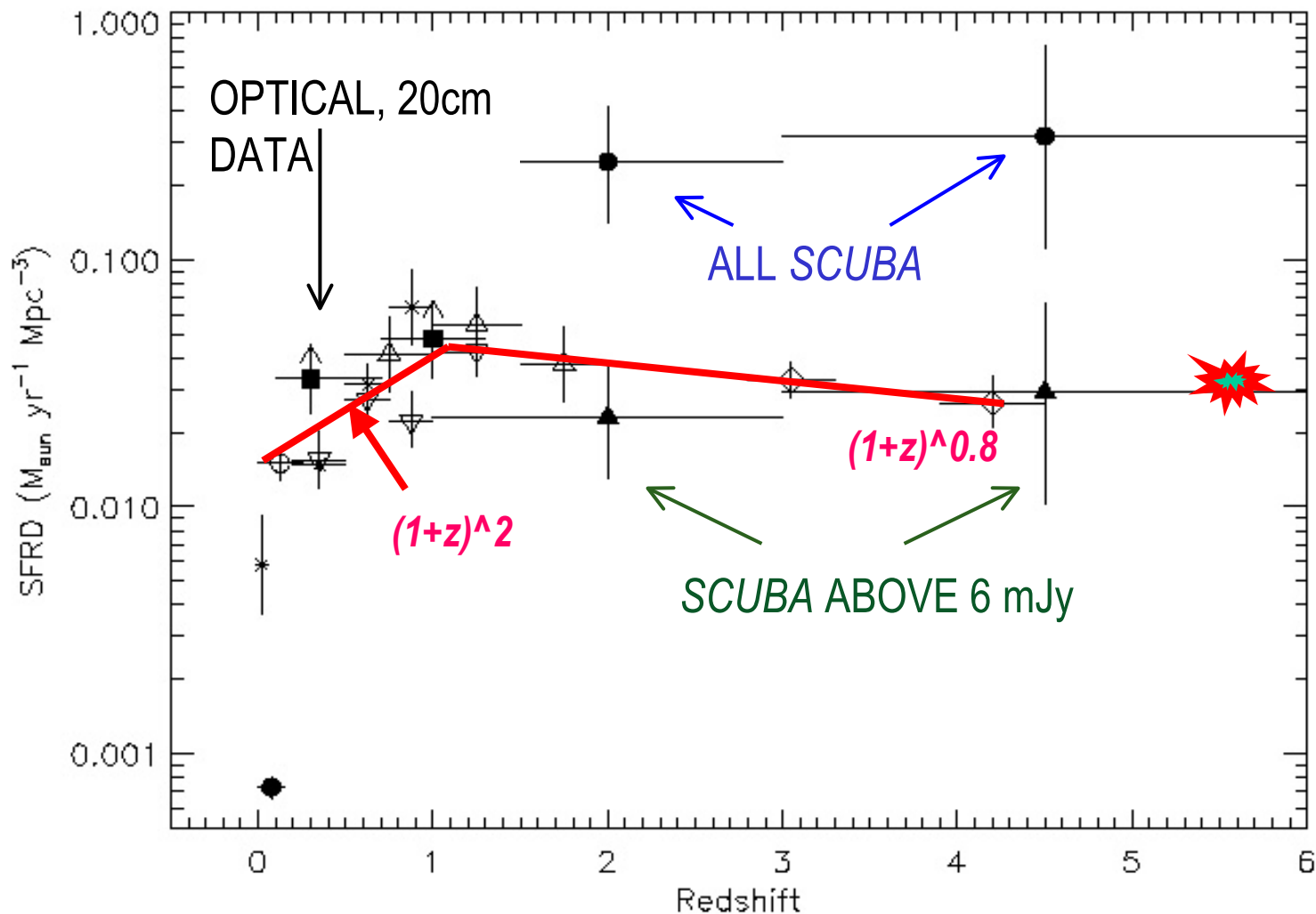
**Instrument  
profile**





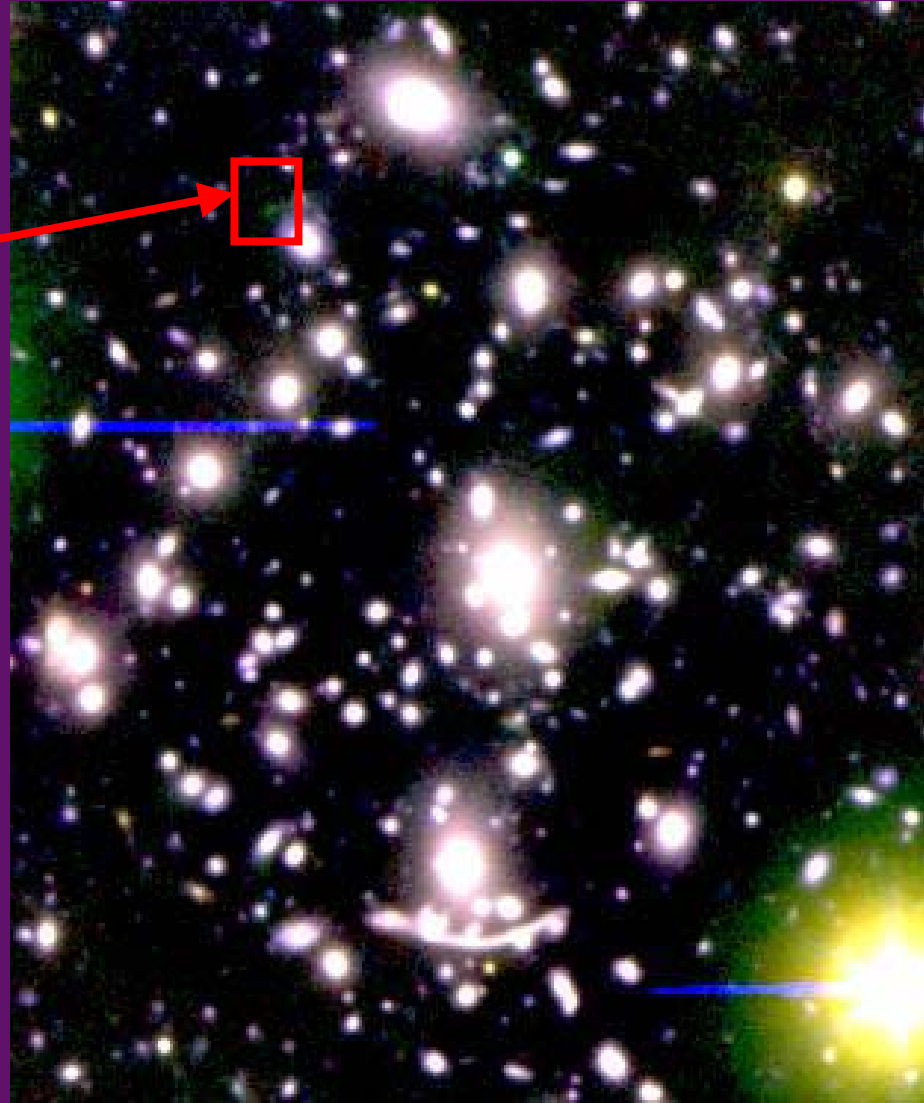
# STAR FORMATION HISTORY

Wilson et al. 2002 and Barger, Cowie and Richards 2000

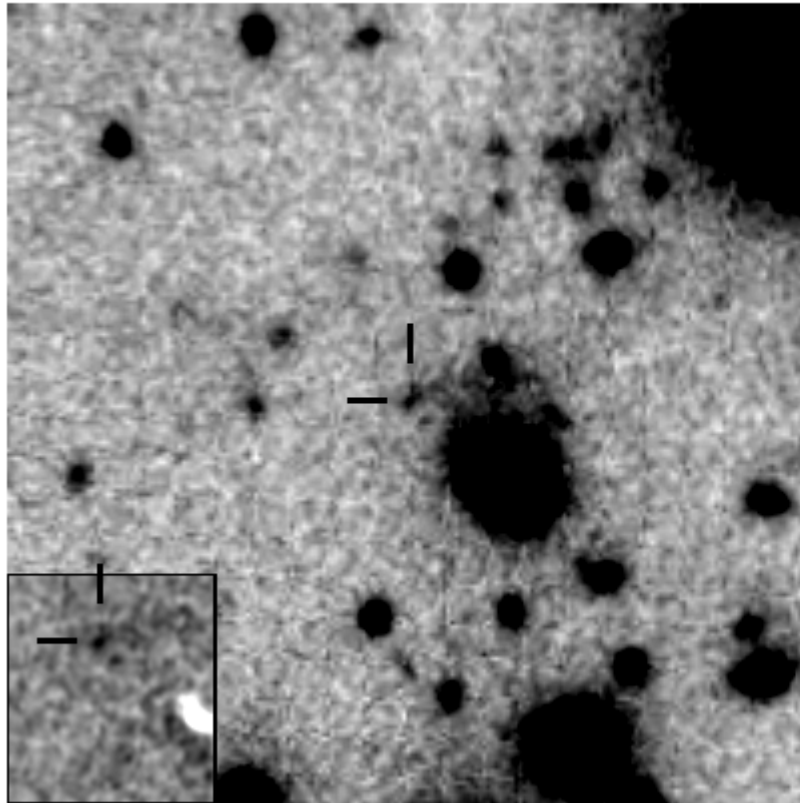


# A370 R, N, Z Band

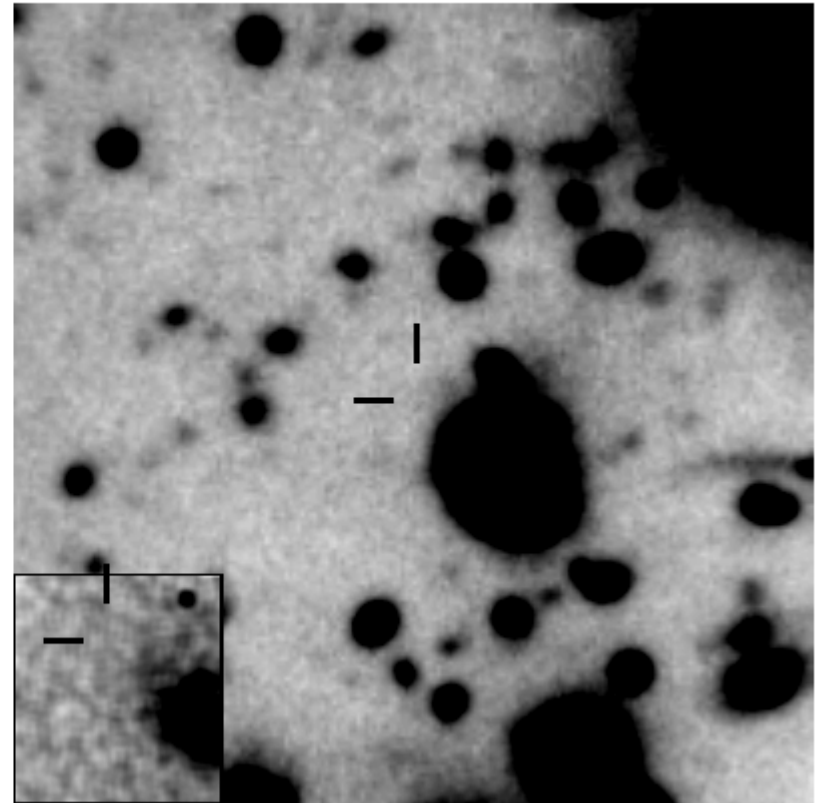
9190 emitter



# ***z=6.56 Galaxy Behind A370***

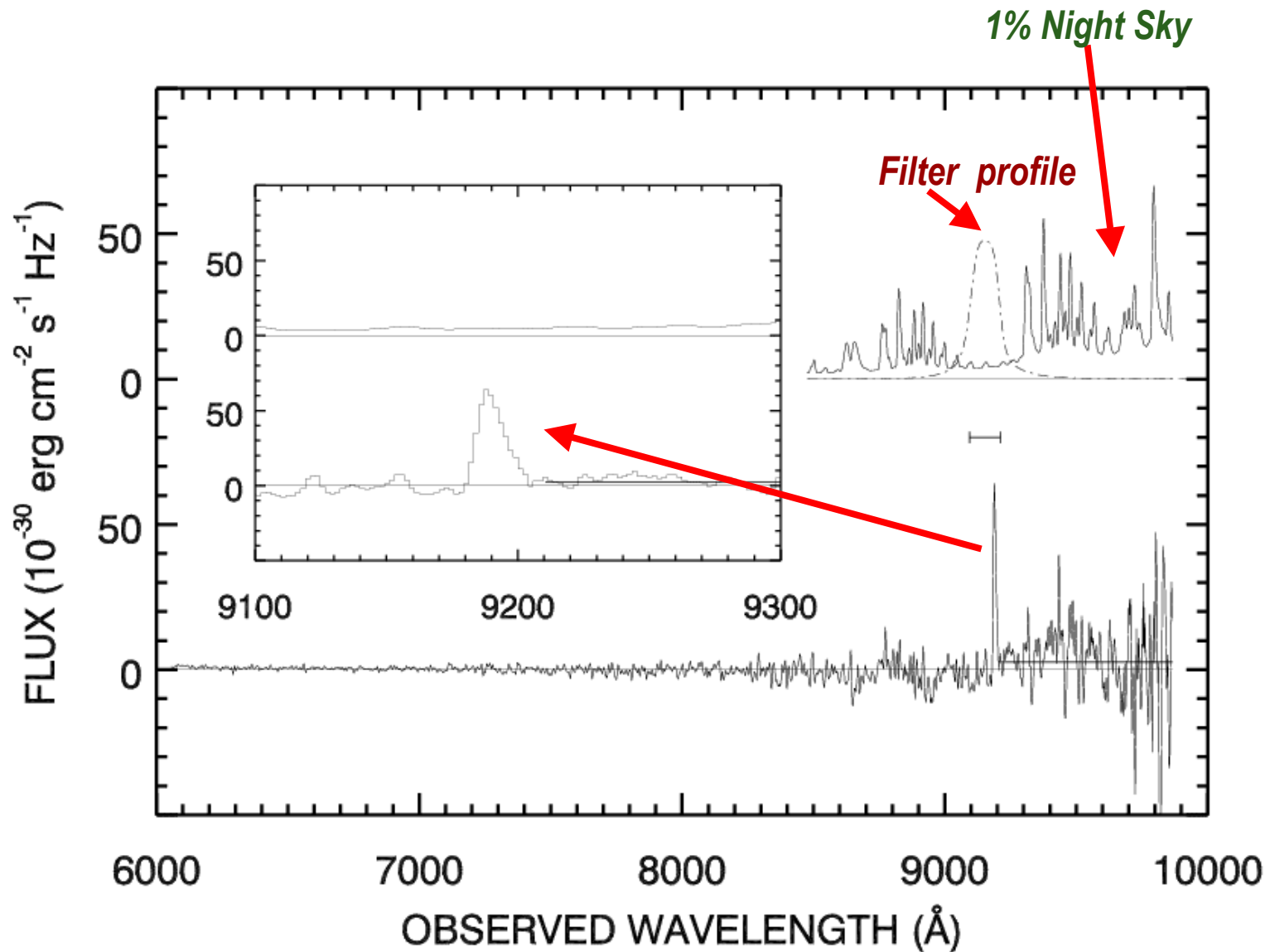


***NARROW BAND (strong Ly  $\alpha$  emission)***

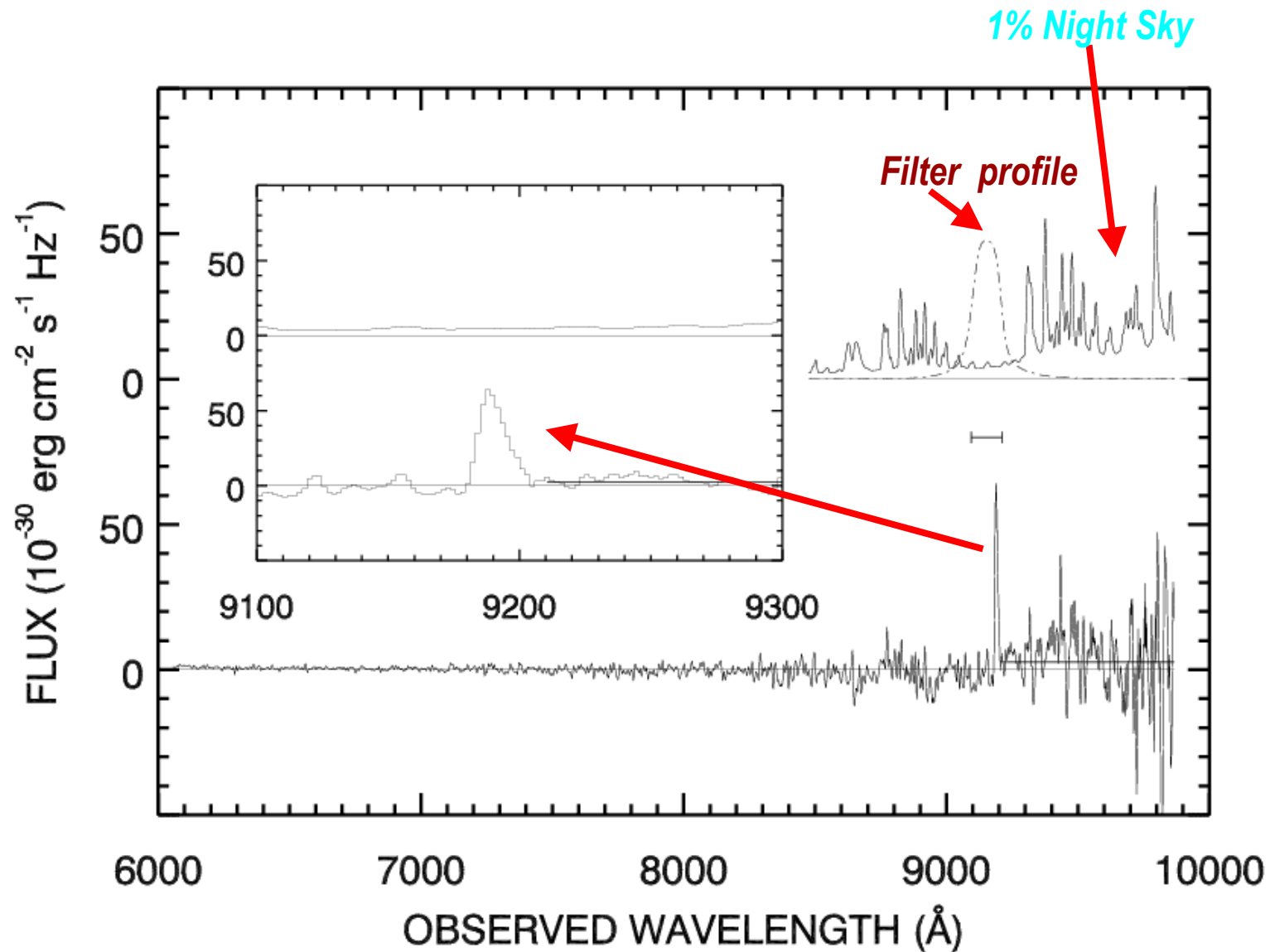


***R BAND (no galaxy detected)***

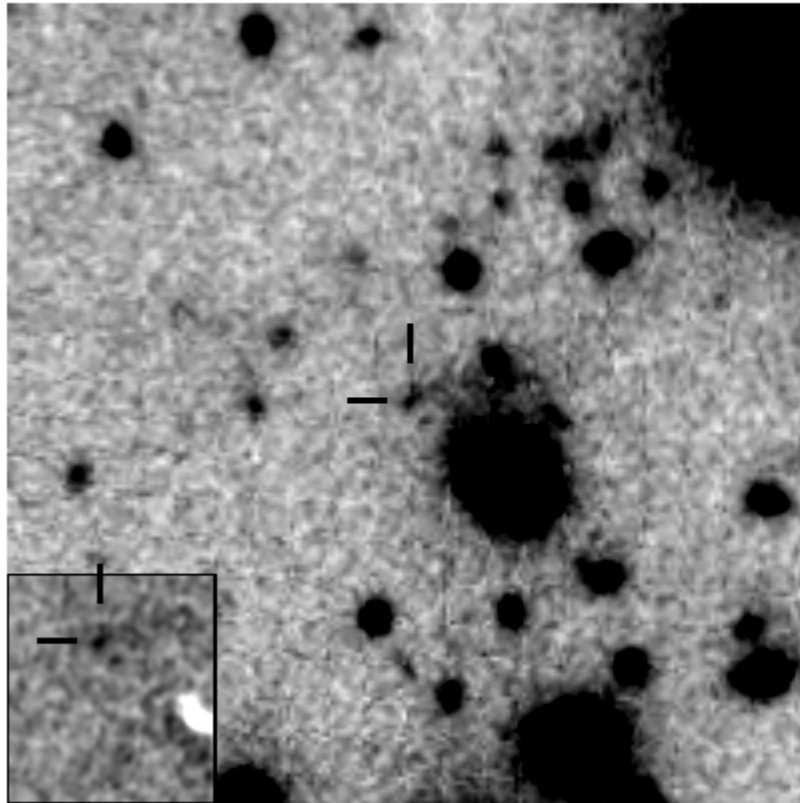
# Keck LRIS spectrum



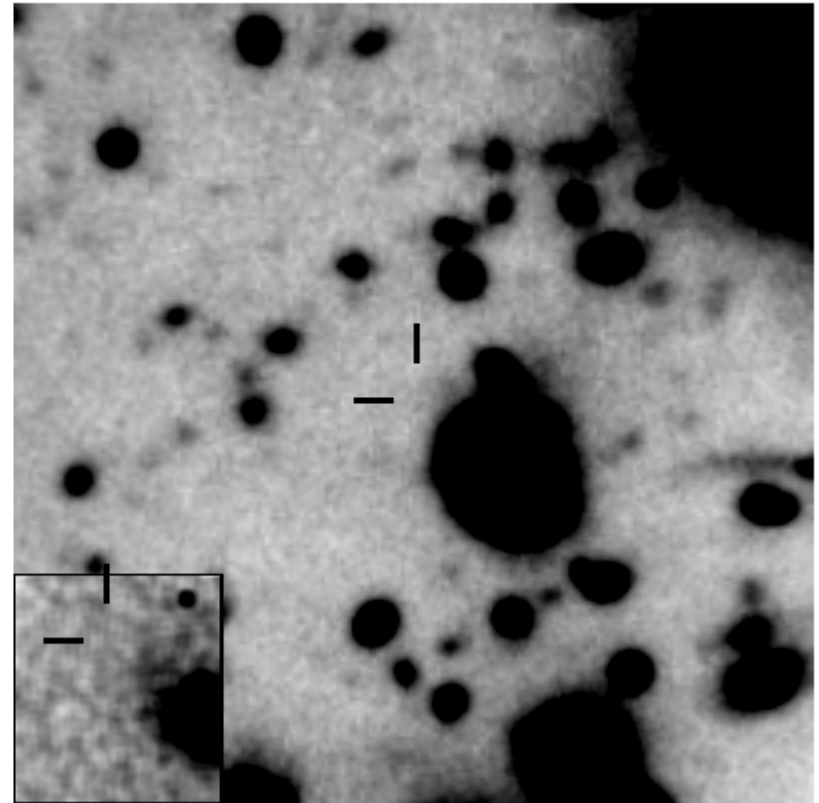
# Keck LRIS spectrum



# $z=6.56$ Galaxy Behind A370

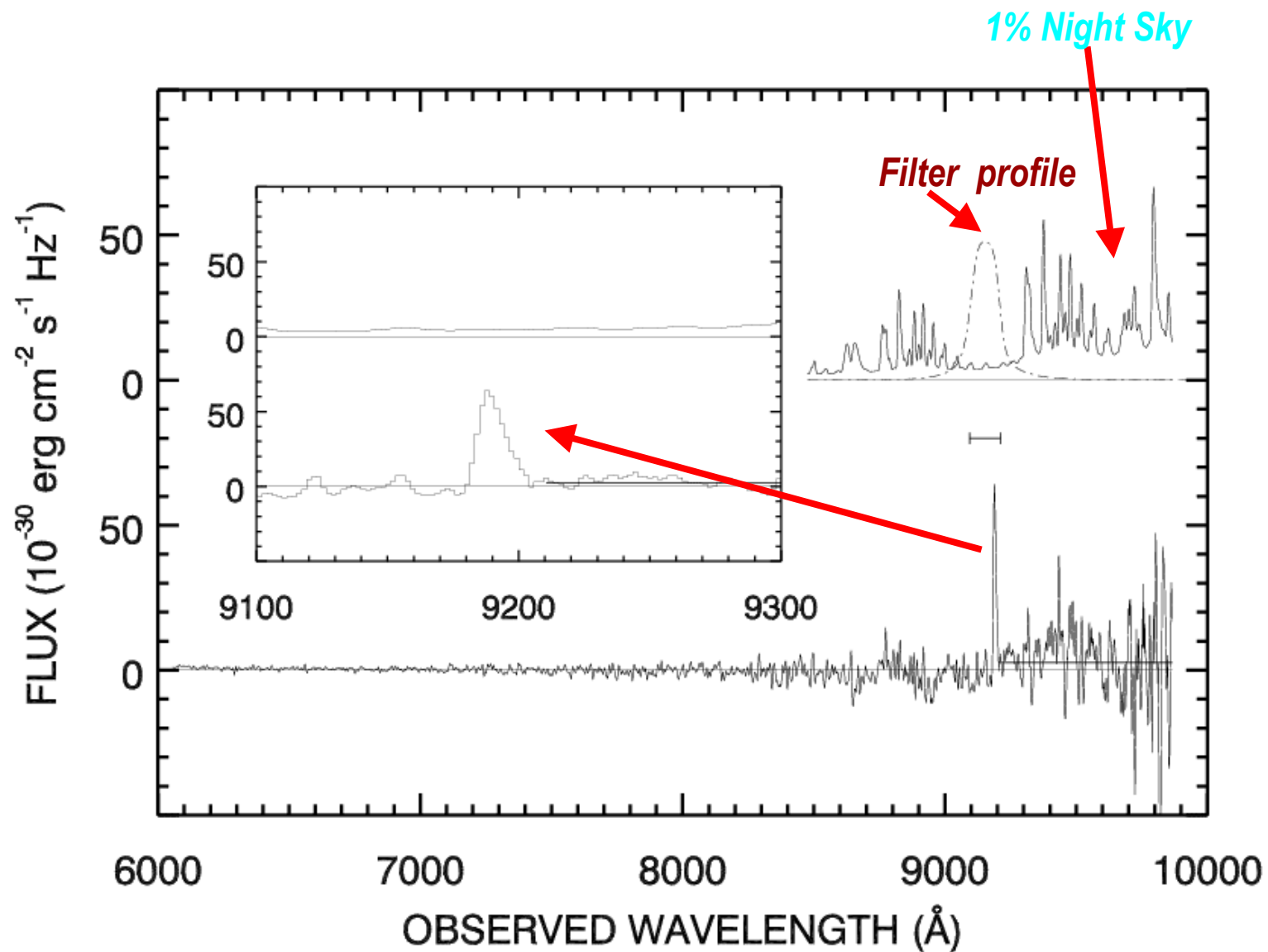


**NARROW BAND** (strong  $Ly\ \alpha$  emission)



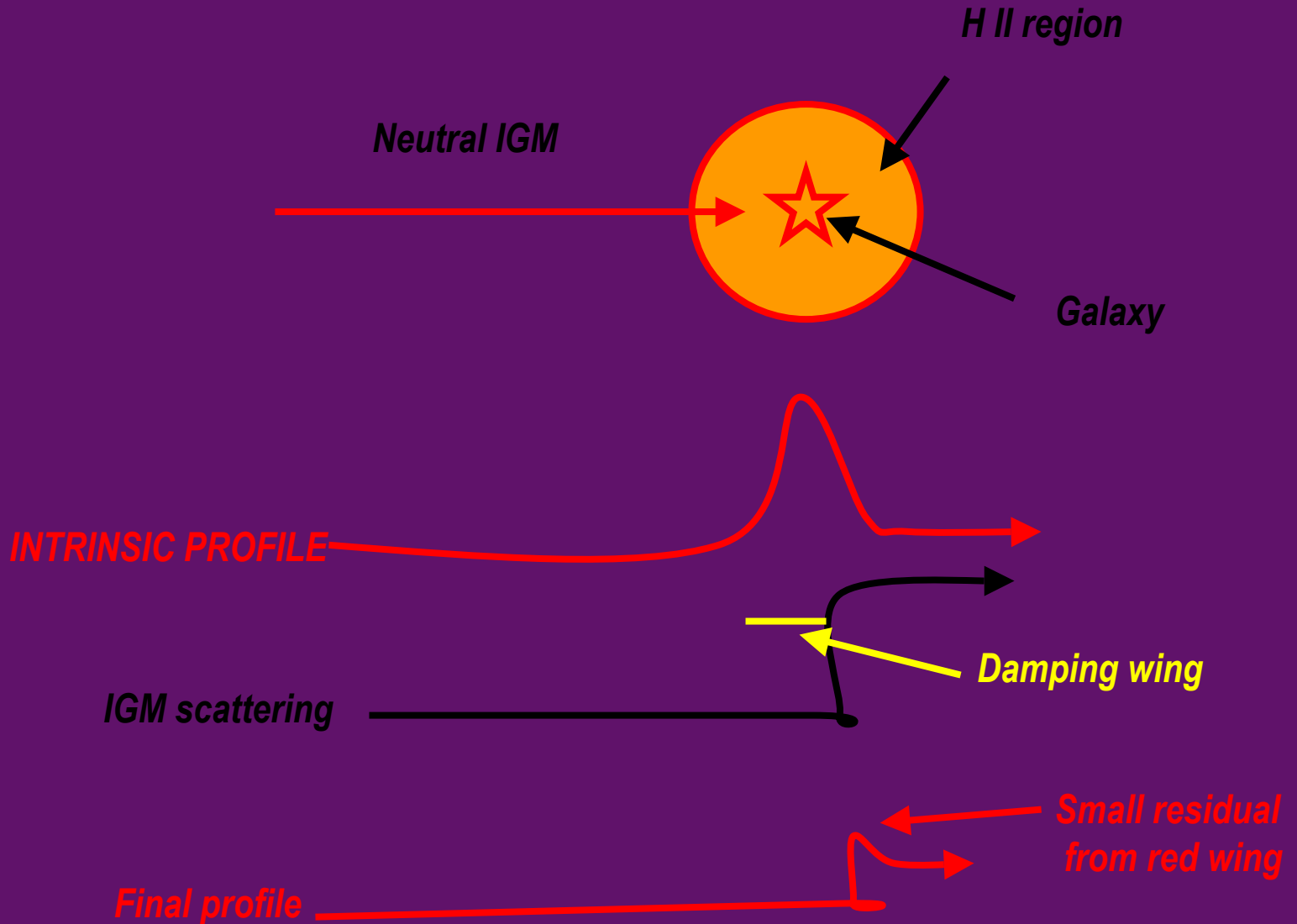
**R BAND** (no galaxy detected)

# Keck LRIS spectrum

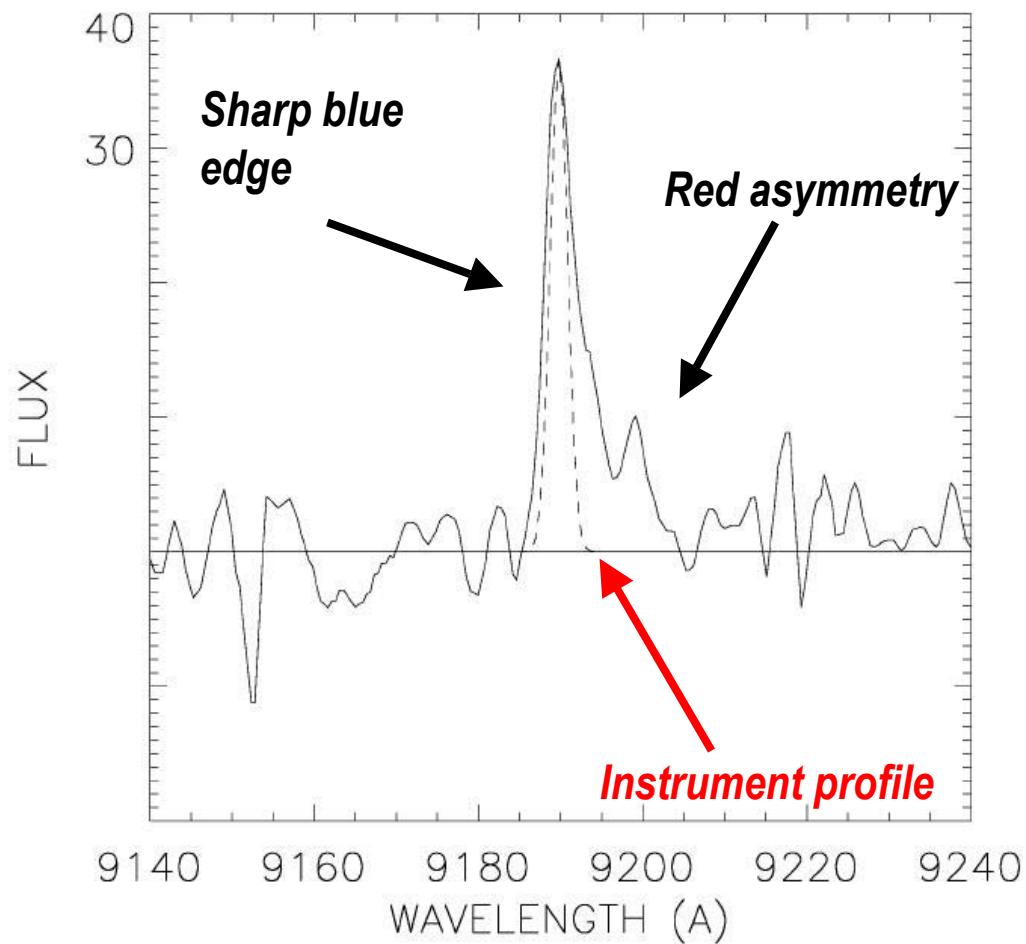


Can we see see such an emitter prior to reionization?  
Maybe? If the galaxy is luminous enough.....

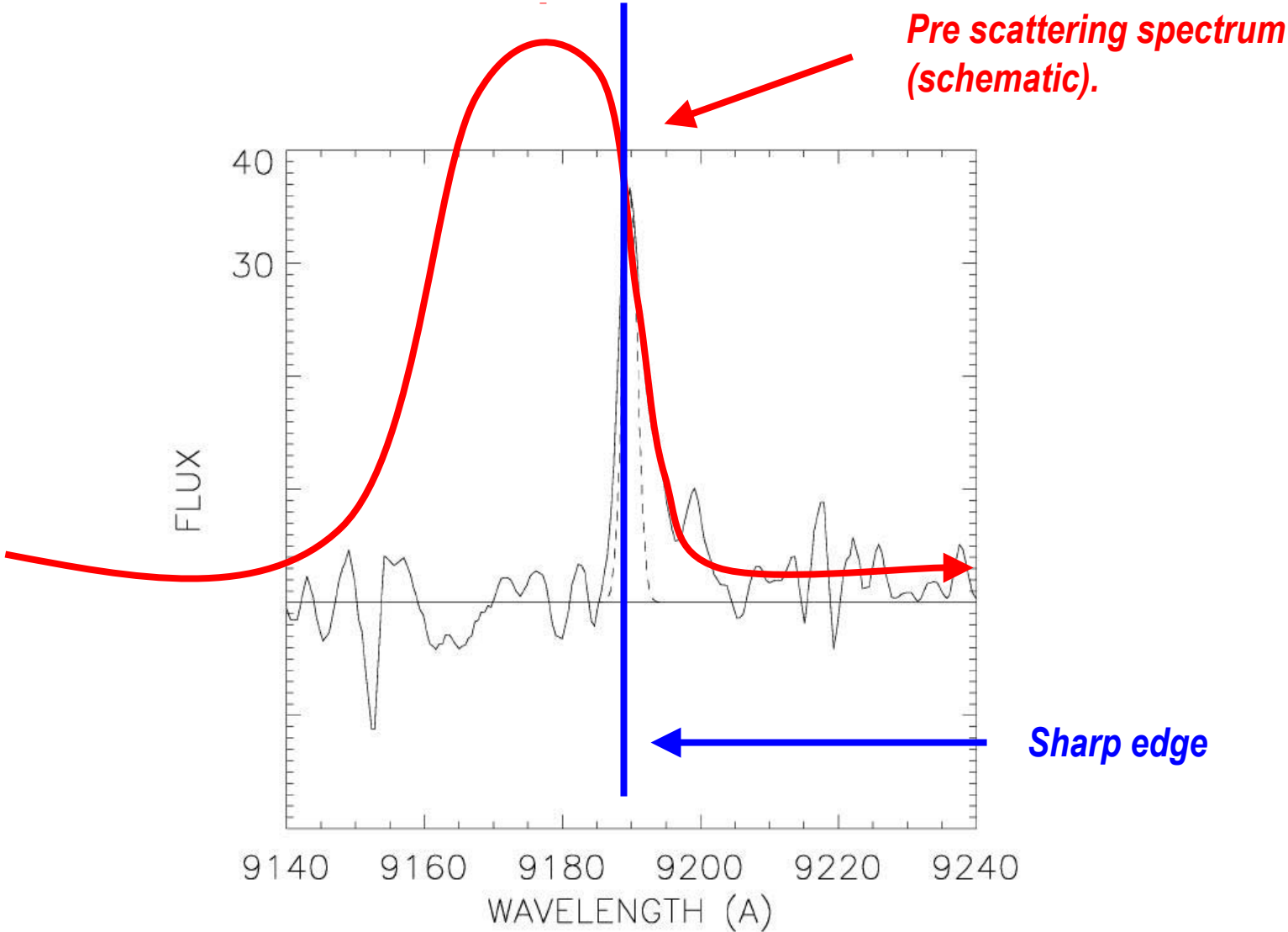
Haiman 2002, Madau 2002



**Deimos Spectrum Hu et al. 2002**

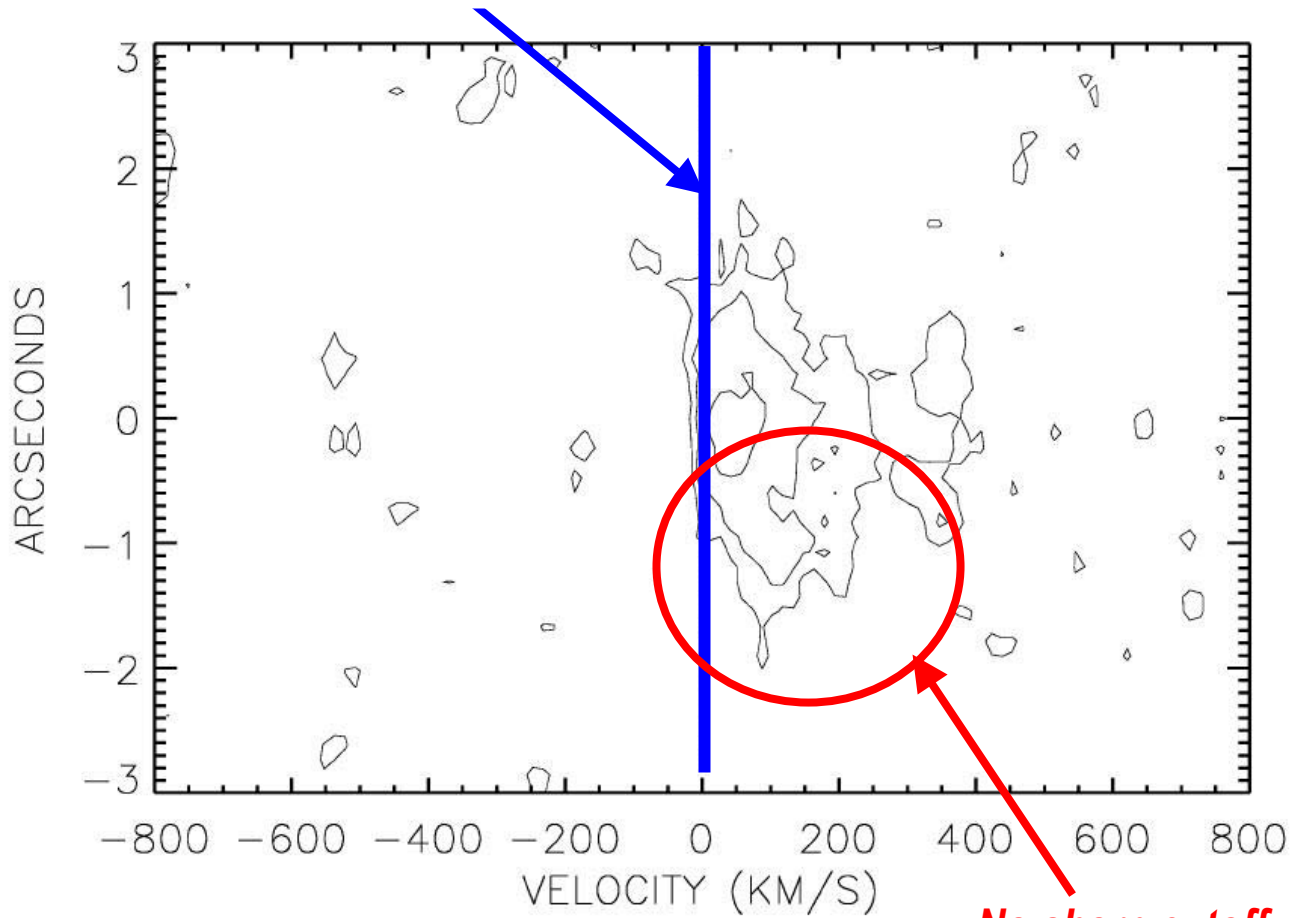


*Deimos Spectrum Hu et al. 2003*



*Spatially resolved about  
4 independent positions*

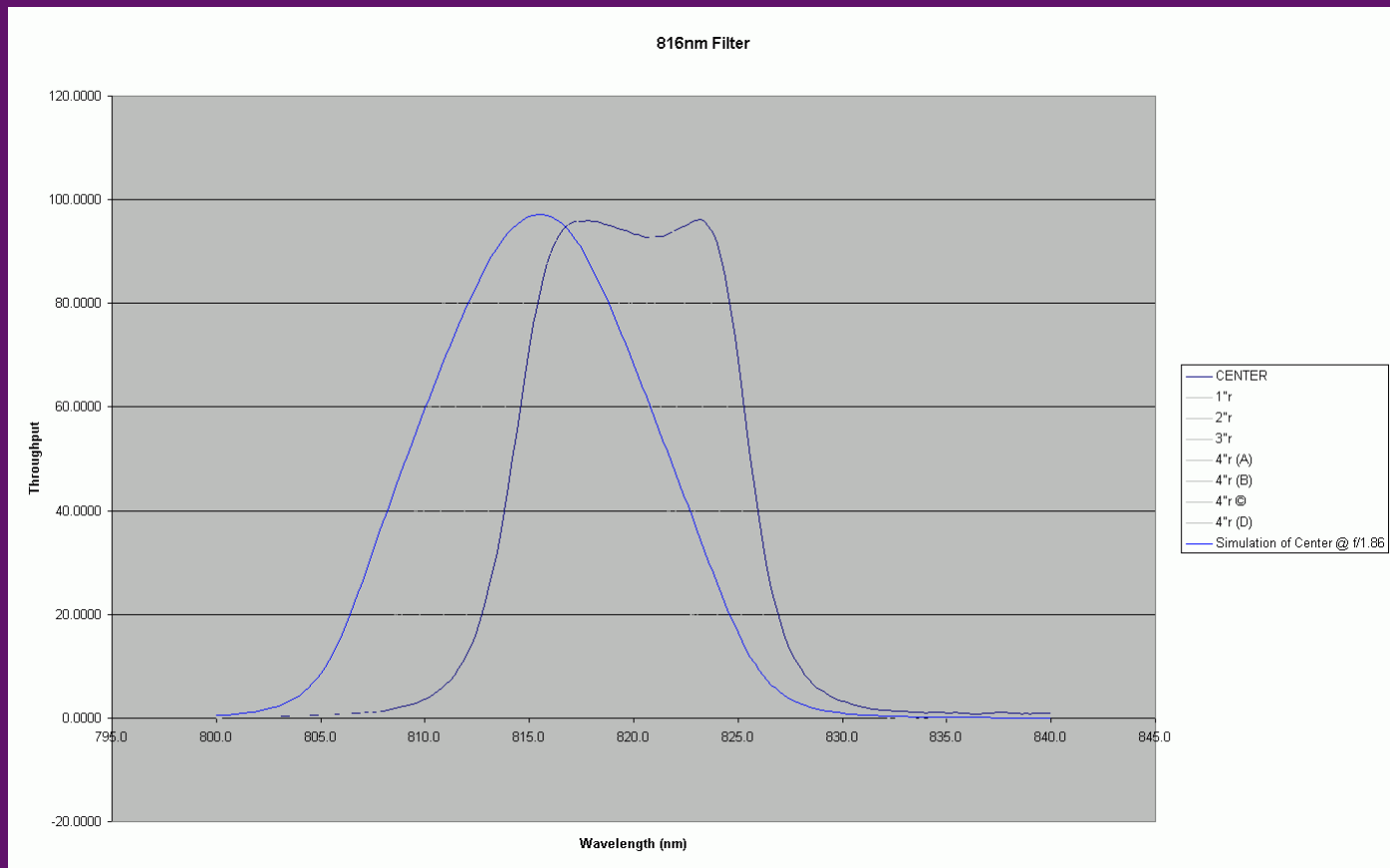
**SHARP EDGE**



*No sharp cutoff*

- H REIONIZATION at  $z \sim 6.2$  ? Maybe ???
- Dark gaps may be a genuine Gunn-Peterson effect but could be just line blanketing of the increasing neutral hydrogen density
- $Z=6.5$  emitter probably only consistent if it lies in a highly ionized hole produced by a neighbor object.

# Effects of f/1.86 Beam on Narrow-band Filter



Broader filter and triangular profile at f/1.86 (vs. parallel beam) decrease sensitivity to emission, increase possible contribution of nightsky lines.