Observational constraints on reionization from high-z galaxy studies

Author(s):
Hu, Esther

Publication Date:
2003

Permanent Link:
https://doi.org/10.3929/ethz-a-004582580

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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 x 30 ′)
- Wide deep fields with Suprime (3 x 600 ′)
- 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 $1.3 \times 10^{-17}$ ergs/cm$^2$/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
HST F814W vs Suprime 8160 narrow band
Equivalent width

Continuum break

Red stars

Time variable

O II

O III

I-N (AB)

R-z (AB)

SSA17 LRIS

25.50
Suprime Narrow Band to $f=1.3 \times 10^{-17}$ ergs/cm$^2$/s

Known $Z = 5.7$
Composite of Deimos Spectra  Hu et al. (2003)

Instrument profile
$Z=3.4 \ L \ alpha \ LF$

$Z=5.7 \ L \ alpha \ LF$

(Approx 1 solar mass per year: no extinction case B)
Incompleteness corrected
Z=5.7

Steidel et al, Z=3
Z=4

Raw L alpha selected
STAR FORMATION HISTORY

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

Graph showing star formation rate density (SFRD) vs. redshift

- OPTICAL, 20cm DATA
- ALL SCUBA
- $(1+z)^2$
- $(1+z)^{0.8}$
- SCUBA ABOVE 6 mJy
A370 R, N, Z Band

9190 emitter
Z=6.56 Galaxy comp'd in narrowband vs. R

z=6.56 Galaxy Behind A370

NARROW BAND (strong Ly $\alpha$ emission)  R BAND (no galaxy detected)
Keck LRIS spectrum

1% Night Sky

Filter profile

FLUX (10^{-30} erg cm^{-2} s^{-1} Hz^{-1})

OBSERVED WAVELENGTH (Å)
Keck LRIS spectrum

Keck LRIS spectrum of z~6.56 galaxy
Z=6.56 Galaxy comp’d in narrowband vs. R

z=6.56 Galaxy Behind A370

NARROW BAND (strong Ly α emission)  R BAND (no galaxy detected)
Keck LRIS spectrum of z=6.56 galaxy

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

Haiman 2002, Madau 2002
Deimos Spectrum Hu et al. 2003

Pre scattering spectrum (schematic).

Sharp edge
SHARP EDGE

Spatially resolved about 4 independent positions

No sharp cutoff
• H REIONIZATION at z~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.