A search for distant ly-alpha galaxies with multi-slit windows

Conference Poster

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Publication date:
2003

Permanent link:
https://doi.org/10.3929/ethz-a-004582381

A Search for Emission Line Galaxies at 9200A

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ABSTRACT

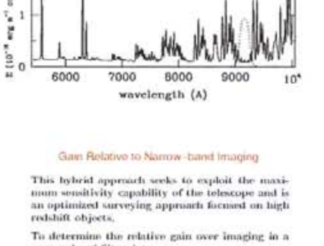
We present results from a search for Lyman–alpha emitters at z~6.5 in the 9150A window. Utilizing a novel technique that combines multiple long slit spectroscopy with a narrow band filter, we survey with the Canada France Hawaii Telescope (CFHT) 3.6m an effective area of 8 square arcminutes to a 5 sigma flux limit of 2.5e–17 erg/s/cm^2. From this initial survey, we isolate 11 emission line objects that are all confirmed to be lower redshift interlopers with photometric redshifts from deep UBVRIZ imaging and additional spectroscopy.

We also describe a program we have recently begun using this this method at the VLT to survey Ly–alpha galaxies at 3<z<4 and z~6.5 over a cumulative area of 130 and 20 square arcmins respectively. Mapping the distribution of Ly–alpha galaxies at these redshifts will provide better estimates of the auto–correlation clustering of galaxies, the Ly–alpha luminosity function, the epoch and nature of reionization, and the properties of the very first galaxies.

MULTI–SLIT TECHNIQUE

1. Long–slit dispersed spectra gives sensitivity gain of dispersed background over narrow–band imaging (see below).
2. Band–width limiting filter limits length of spectrum, allowing use of multiple parallel slits and targetting of specific redshifts and/or regions of reduced sky emission.
3. Deep imaging blueward of spectra required to establish absence of continuum for Ly–alpha candidates.

Fig. 1: Spectrum of the night sky; the OH window at 9200A is visible (dotted curve is filter response). By limiting the wavelength coverage to a specific OH window, we can minimize the noise introduced by sky lines and use multiple parallel slits.



Gain Relative to Narrow–band Imaging

This hybrid approach seeks to exploit the maximum sensitivity capability of the telescope and is an optimized surveying approach focused on high redshift objects.

To determine the relative gain over imaging in a narrow band filter, let

κ = sensitivity gain
$\delta\lambda$ = spectral resolution
$\Delta\lambda_{im}$ = filter width for imaging
$\Delta\lambda_{sp}$ = filter width for spectroscopy
η = grating efficiency = 0.85 for FORS2 600z grism
d = slit-width compared to seeing limited aperture

We see then that

$$\kappa = \left(\frac{\Delta\lambda_{im}}{\delta\lambda}\right)^{0.5}\left(\frac{\eta}{d}\right)^{0.5} \quad (1)$$

There is a reduction in survey area of $(\delta\lambda/\Delta\lambda_{sp})d$ but that may be compensated by an increase in the redshift interval of $(\Delta\lambda_{sp}/\Delta\lambda_{im})$, giving a net reduction in survey volume of $(\delta\lambda/\Delta\lambda_{im})d$.

Apart from the small η factor, which for VPH gratings can be as high as ~ 0.85, this is equal to κ^{-2}, indicating that *there is no free lunch*, only a *powerful optimization* in the trade-off between depth and area.

RESULTS FROM CFHT

(Proof of Concept Data)

CFHT Characteristics

Wavelength Range 8990–9250 A
Resolution ~25A
29 slits, each 2"x500"
Total Area ~8 sq. arcmin
5 sigma Flux Limit 2.5e–17 erg/s/cm^2
--> 11 Emission line objects

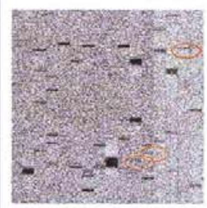


Fig 2a: Sky–subtracted spectra from the CFHT for 16 of the 29 long parallel slits. One pointing covers ~8 sq. arcmin. Emission line objects are circled.

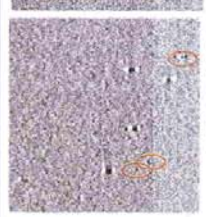


Fig. 2b: Gaussian smoothed image of the continuum subtracted spectra. An Hbeta/[OIII] triplet is visible in the upper right corner. Bright continuum objects leave residua that are easily identified.

CFHT Emission Line Galaxies

Line	z	#Objs	W(obs)
Halpha	0.40	4	10–200A
Hbeta/[OIII]	0.64	4	30–50A
[OII]3727	1.45	3	85–200A
Ly–alpha	6.5	0	----

The Case of LTBC–4

One object in the CFHT data was a good candidate for a z=6.5 galaxy. A faint, very high equivalent width line [W(obs)~200A] appeared to be associated with an extremely faint Z–band object and a string of very red galaxies in (I–Z). Subsequently we have shown that the line emission is actually associated with a nearby galaxy that has a very high equivalent width Halpha line. This galaxy is located off of the nominal slit but there was some small light leakage due to seeing. The lessons for this technique are:

1. High equivalent widths around 200A can be associated with Halpha (and also [OII]3727).
2. Building up contiguous areas by stepping perpendicular to the slits is preferable to isolated single pointings. Doing so enables information on adjacent regions of the sky to be obtained.

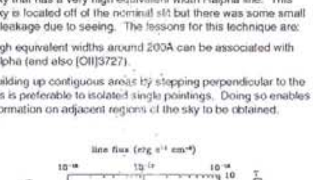


Fig. 3: Comparison of the nominal limiting depths and areal coverages of recent surveys at z>5.7. The three confirmed z~6.5 galaxies (Hu et al., Kodaira et al.) are shown as solid circles. If these objects are typical of the population at z~6.5 we expect to find between 2–40 in our current FORS2 data.

GOALS

1. Build a sample of Lyman–alpha emitters at z~6.5 and 3<z<4 to study their number density, luminosity function, and spatial clustering.
2. Enable a direct comparison of Ly–alpha emitters at z~3.5 to the population at z~6.5, and to Steidel's Lyman break galaxies.
3. Constrain the epoch and nature of reionization (z>6).
4. Use the lower redshift "interlopers" to study metallicity evolution and star formation to z~2.

VLT PROGRAM

(Started in Summer 2003; data being processed)

VIMOS Characteristics

Wavelength Range 5100–5900A
Ly–alpha Redshift Range 3.1<z<3.9
Resolution ~10A
28 slits, each 2"x420"
Area/pointing is ~6.5 sq. arcmin
5 sigma Flux Limit 1e–17erg/s/cm^2
Pending Survey Area 130 sq. arcmin

FORS2 Characteristics

Wavelength Range 9050–9250A
Ly–alpha Redshift Range 6.4<z<6.6
Resolution ~5A
9 slits, each 2"x420"
Area/pointing is ~2 sq. arcmin
Estimated 5 sigma Flux Limit 4e–18 erg/s/cm^2
Current Survey Area 20 sq. arcmin (Aug 03)

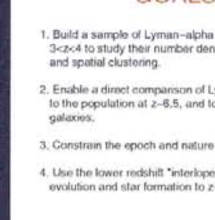


Fig. 4a: Example of the FORS2 field with 7 of the 9 long slits overlaid. Each pointing covers ~2 sq. arcmin to an estimated 5 sigma flux limit of ~4e–18 erg/s/cm^2. By stepping perpendicular to the slits, the entire field can be covered.

Fig. 4b: The 2D spectra corresponding to 5 of the 9 long slits on a FORS2 mask. The dark vertical lines are night sky lines. Spectra of individual galaxies are visible as shorter horizontal strips.

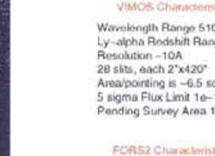


Fig. 4c: Same as Fig. 3b but with the night sky lines removed. Circled is an emission line galaxy.

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