Looking High and Low – Unifying studies of Lyman alpha galaxies at high and low redshifts

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Introduction

- Motivation: study the properties of galaxies using rest-frame UV selection with spectroscopic follow-ups to compare properties of galaxy populations with the high-*z* samples of Lyα and Lyman break galaxies
- Use the GALEX sample to specify selection in the local universe; obtain optical spectra of selections
- Aim of unifying studies at both high and low redshifts
- Collaborators: Len Cowie, Amy Barger, Yuko Kakazu

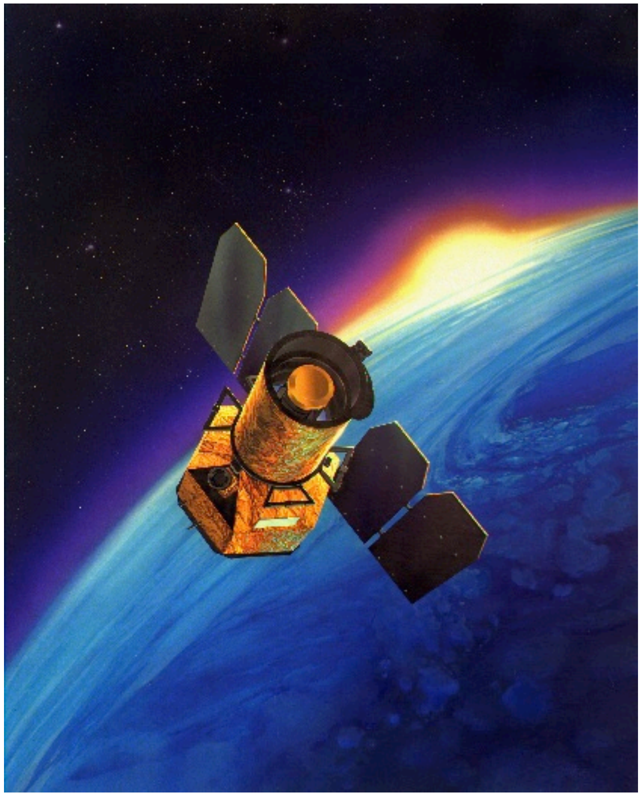
OVERVIEW

Two topics:

1) How much ionizing radiation is released by galaxies versus AGN? This uses the GALEX broad band imaging. (skip for this talk)

2) What are the properties of low redshift ($z \sim 0.3$) Lyman alpha emitters (LAEs) and what can they tell us about high redshift LAEs and LBGs? This uses the GALEX grism spectroscopy

GALEX



Lessons from nearby starbursts

- W(Lyα) and Lyα/Hβ < case B prediction !
- No clear correlation of Lyα with metallicity, dust, other parameters found.
- Strong variation of Lyα observed within a galaxy
- Lyα scattering halo observed
- Starbursts show complex structure (super star clusters + diffuse ISM); outflows ubiquitous

Lyα affected by:

- **ISM kinematics**
- **ISM (HI) geometry**
- **Dust**

Precise order of importance unclear!

Schaerer 2008 (previous workshop) & many speakers in this morning's sessions

So…..

Most galaxies are optically thick to ionizing photons… getting some photons out requires odd geometry

The escape of Lyα is also dependent on the geometry, the kinematics, the internal micro-structure and the dust content

We need to empirically calibrate the escape of the ionizing continuum and the Lyα photons

This is all most easily done with low redshift observations where we have lots of other information

This is where GALEX comes in…

- GALEX: Galaxy Evolution Explorer
- Small explorer NASA mission, led by Caltech
- LAUNCH: April 28th, 2003

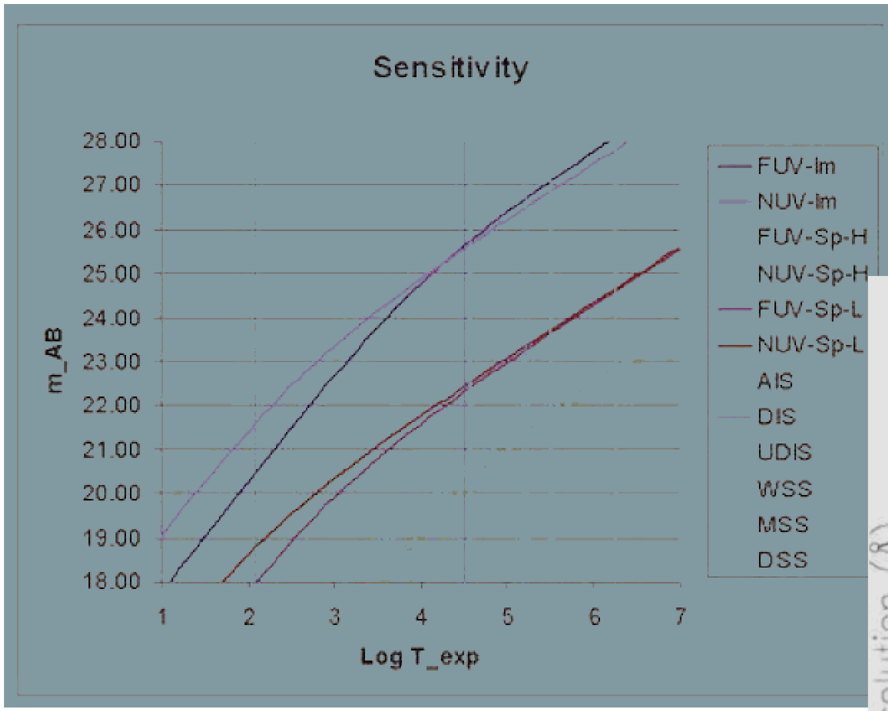
- The first all-sky imaging and spectroscopic surveys in the space ultraviolet
- Wavelength: 1350-2750 A

Instrument

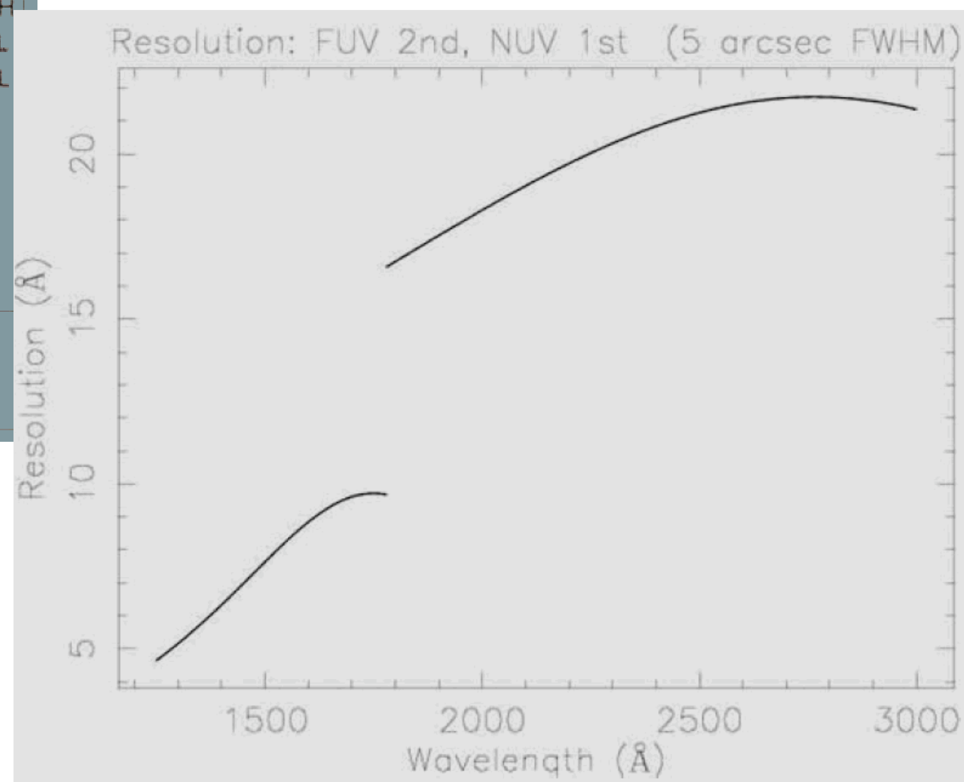
Telescope Aperture	50 cm
Optical Design	Modified Ritchey-Chrétien with 4 channels: FUV & NUV Imaging, FUV & NUV Spectroscopy. FUV & NUV obtained simultaneously using dichroic beam splitter also acting as a field aberration corrector.
Field of View	~1.25 degrees, circular
Focal Length	3 m
Telescope coatings	Al+MgF_2
Imaging/Grism Modes	Optics wheel with (1) CaF_2 Imaging window, (2) CaF_2 transmission grism; (3) Opaque position.
Grism Rotation	Grism position angle may be selected with a resolution of 0.4 degrees, independent of S/C roll
Dichroic/Corrector	Aspheric astigmatism corrector Ion-etched fused silica (aspheric surfaces on both sides) Dichroic beam splitter with dielectric multilayer coating on input side

Martin et al. 2005

Performance



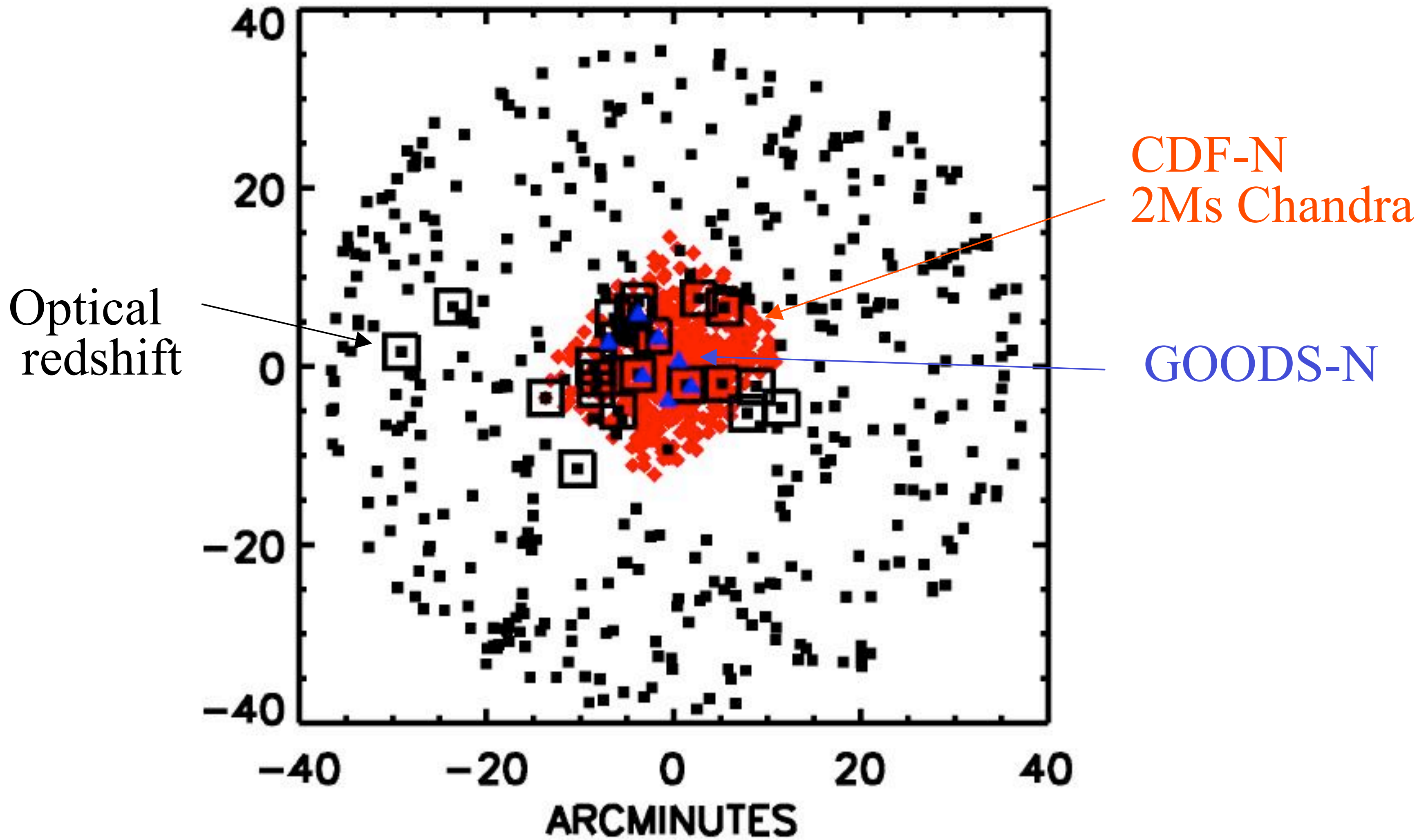
Deepest imaging observations about 25-25.5 (AB) in FUV and NUV



Deepest spectroscopic observations to about NUV=21-22 (AB)

But GALEX FOV is Large:

GALEX HDF-N: Sources with UV spectra



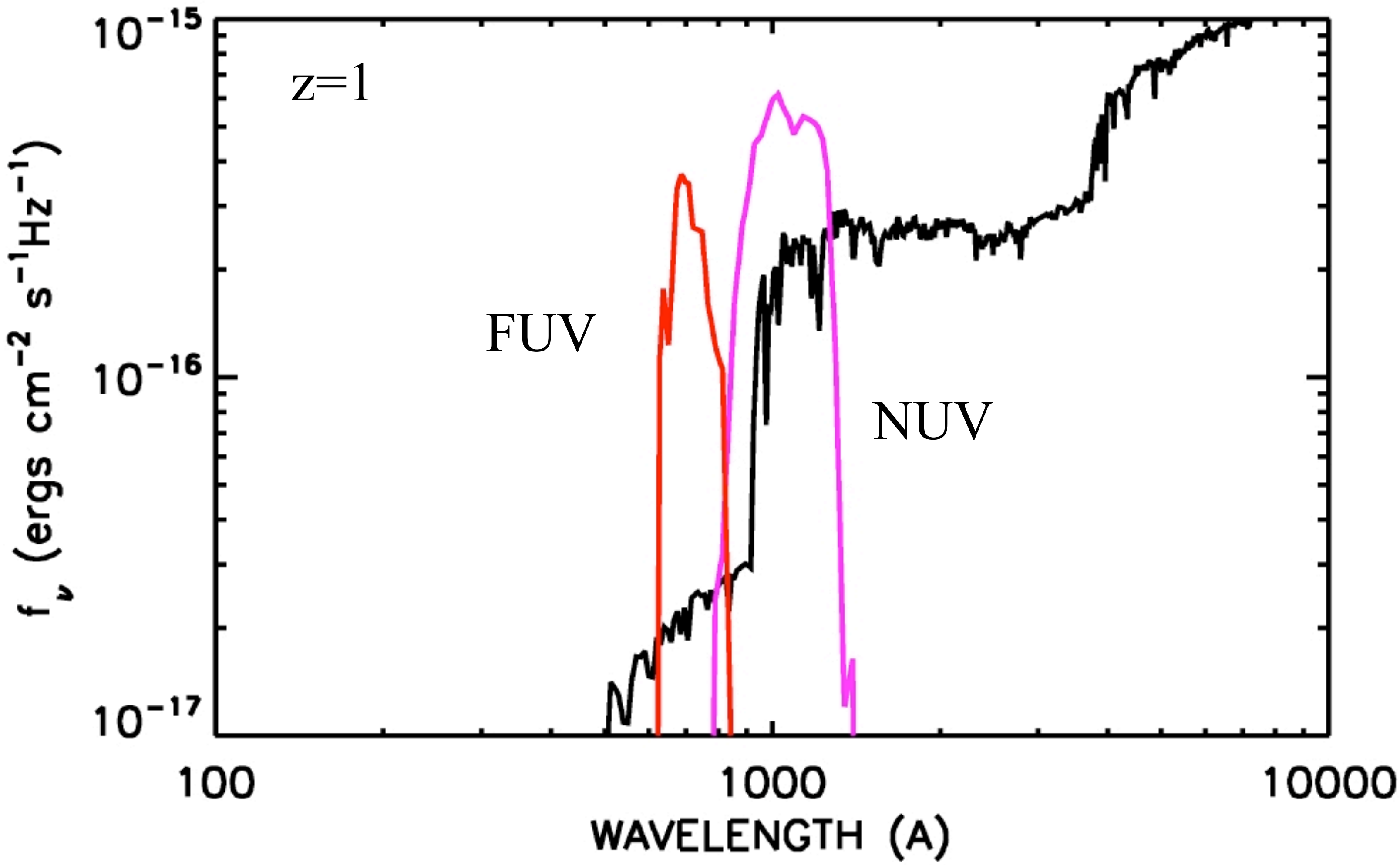
Survey Comparison Fields

- GOODS-N 145 sq arcmin (complete coverage to NUV AB~25)
- GALEX fields with deep coverage (9 regions, 8 square degrees (NUV AB~21-22) includes regions like Groth Field, CDF South, COSMOS, ELAIS, Bootes, etc.

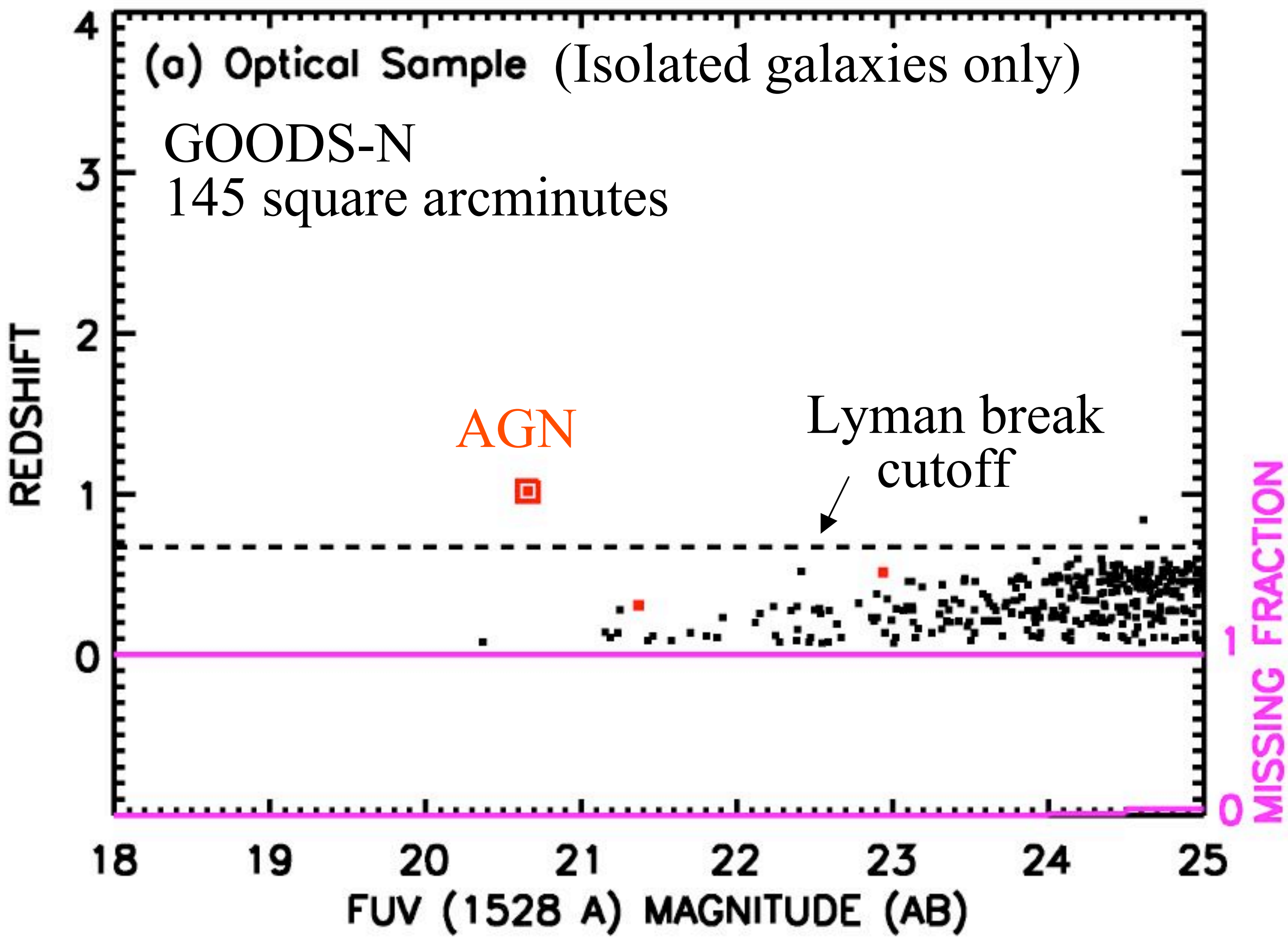
Also can be used to study the ionizing background:

- We can use the GALEX broad band measurements to determine the ionizing photon escape from galaxies and AGN
- Take pre-existing spectroscopically identified sample and determine FUV magnitudes in redshift range (z~1) where this samples the ionizing continuum
- Here we use a complete spectroscopic sample from the GOODS-N and a nearly complete X-ray selected AGN sample from the CLANS and CLASXS fields in the Lockman hole.
- One problem is poor resolution of GALEX which results in blending and confusion: need to deal with this statistically (spatial resolution ~5 arcseconds).

Lyman break in the GALEX filters

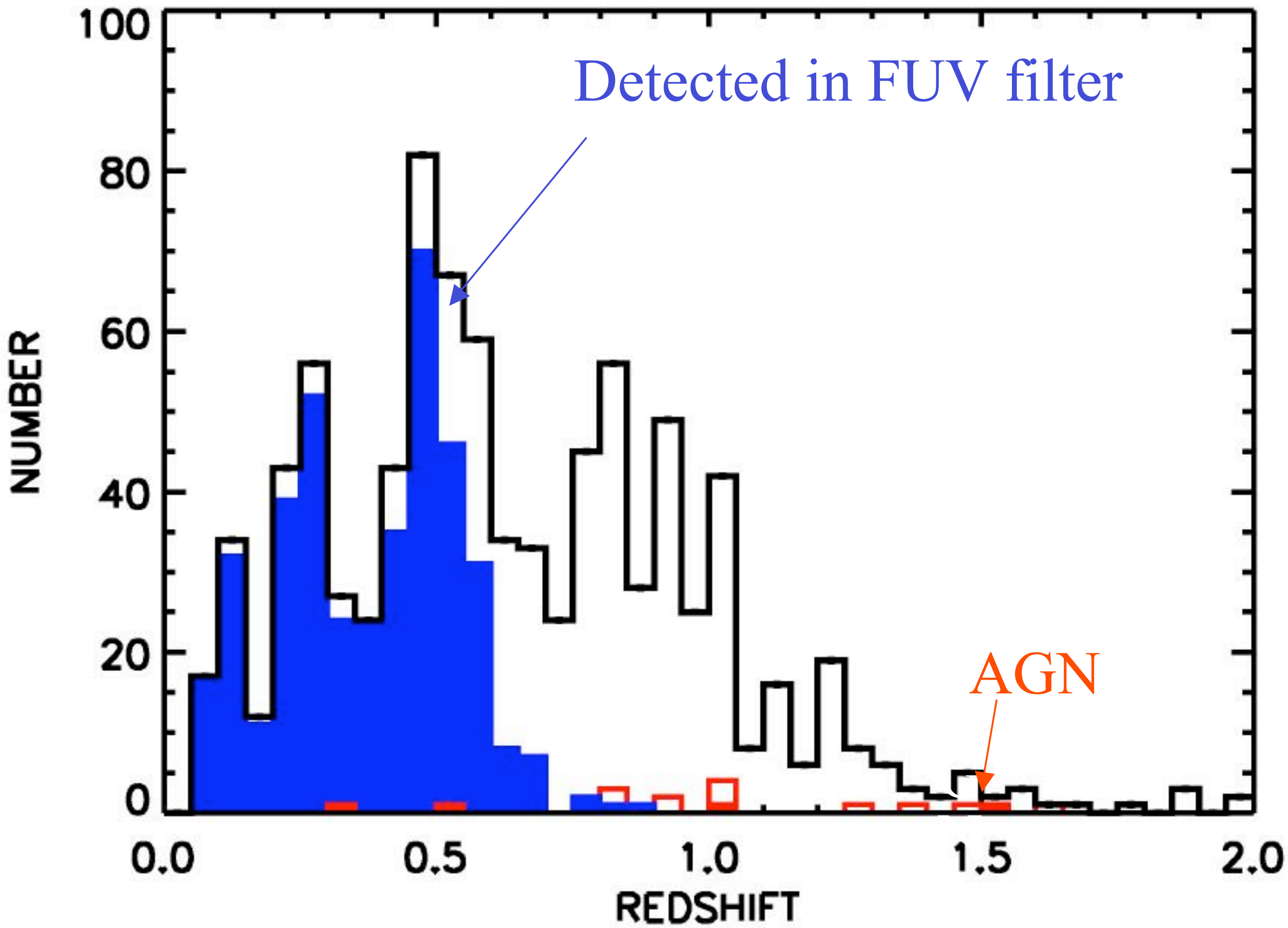


Redshift versus FUV magnitude



Barger and Cowie 2008

GOODS-N B band sample



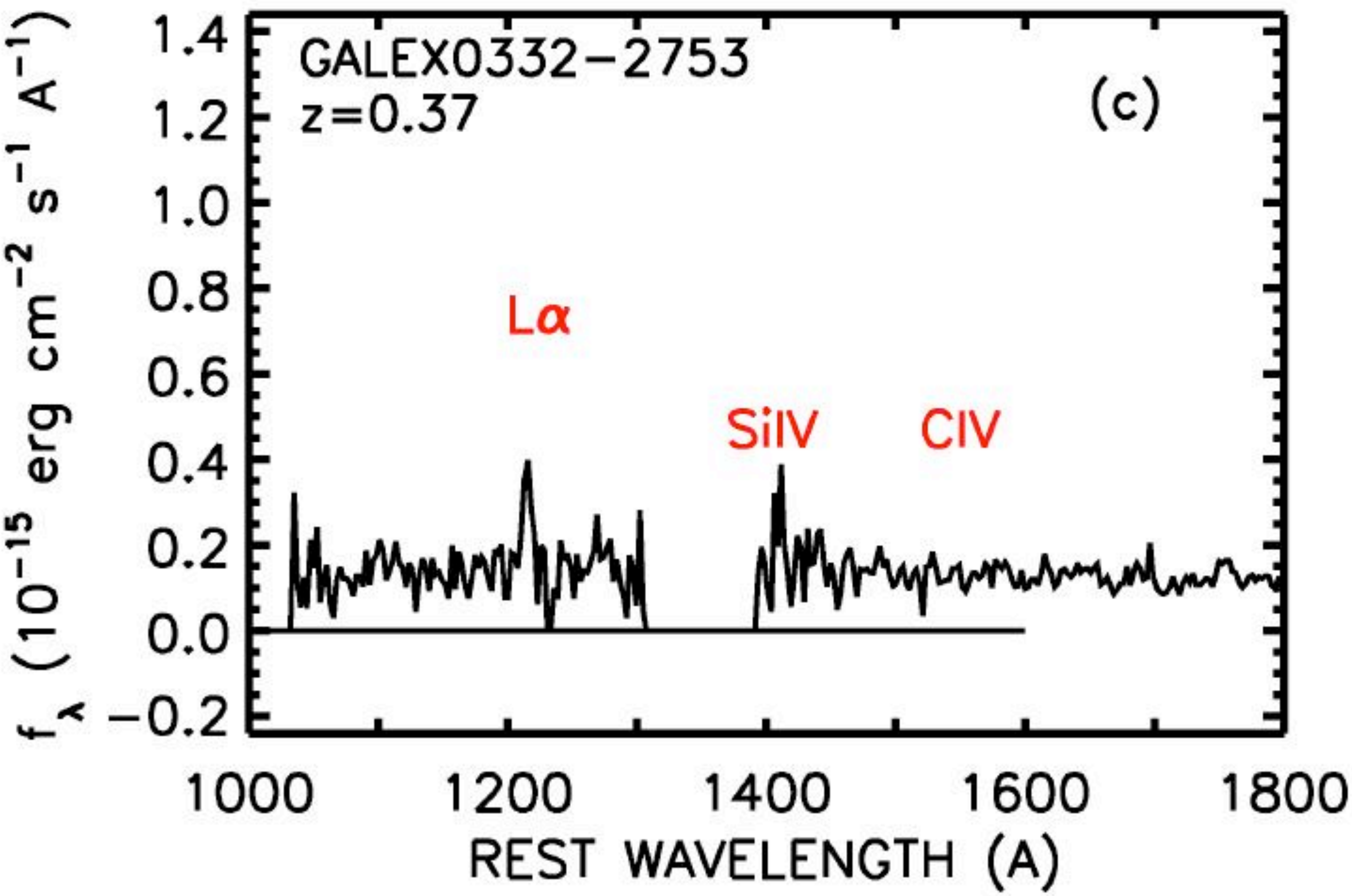
What about Lyα emission?

- We can find low redshift (z=0.2-0.4) LAEs using the GALEX grism spectroscopy (Deharveng et al. 2008)
- We can then combine this with optical spectroscopy (and other data like X-ray) to determine the properties of the LAEs: particularly what fraction of Lyα photons are escaping
- And we can compare the population with the high-redshift LAE and LBG samples to see how things are changing with redshift.

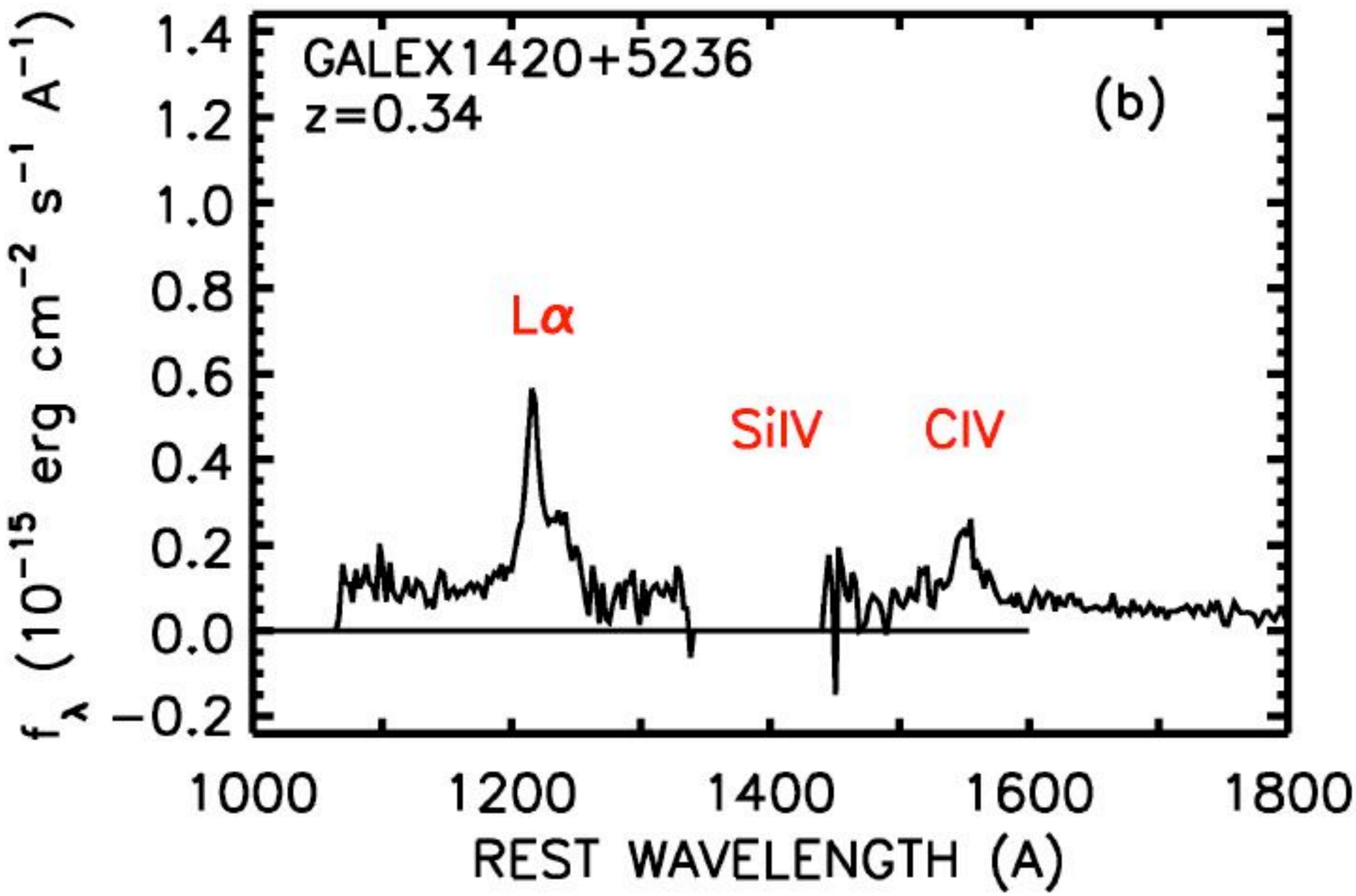
GALEX Lyα emitters

- A few percent of the GALEX spectra have emission lines in the FUV band and can be identified as Lyα emitters. (The precise fraction depends on the field depth.)
- These are divided between objects which only show a single line (assumed to be Lyα) and those which show high excitation lines and which are clearly AGN.

GALEX spectra: Lyman emitter

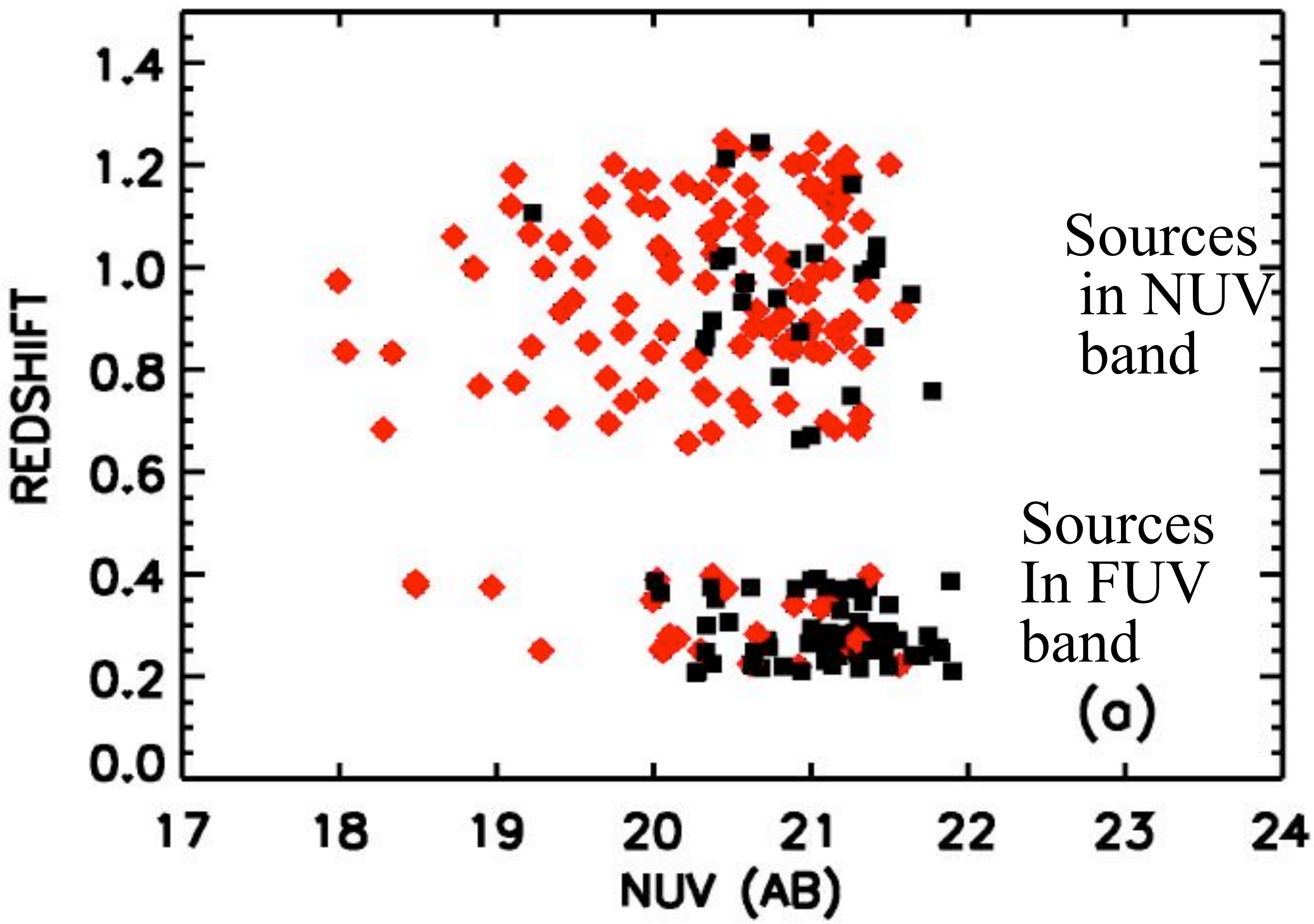


GALEX Spectra: AGN



Relative fractions of AGN and LAEs

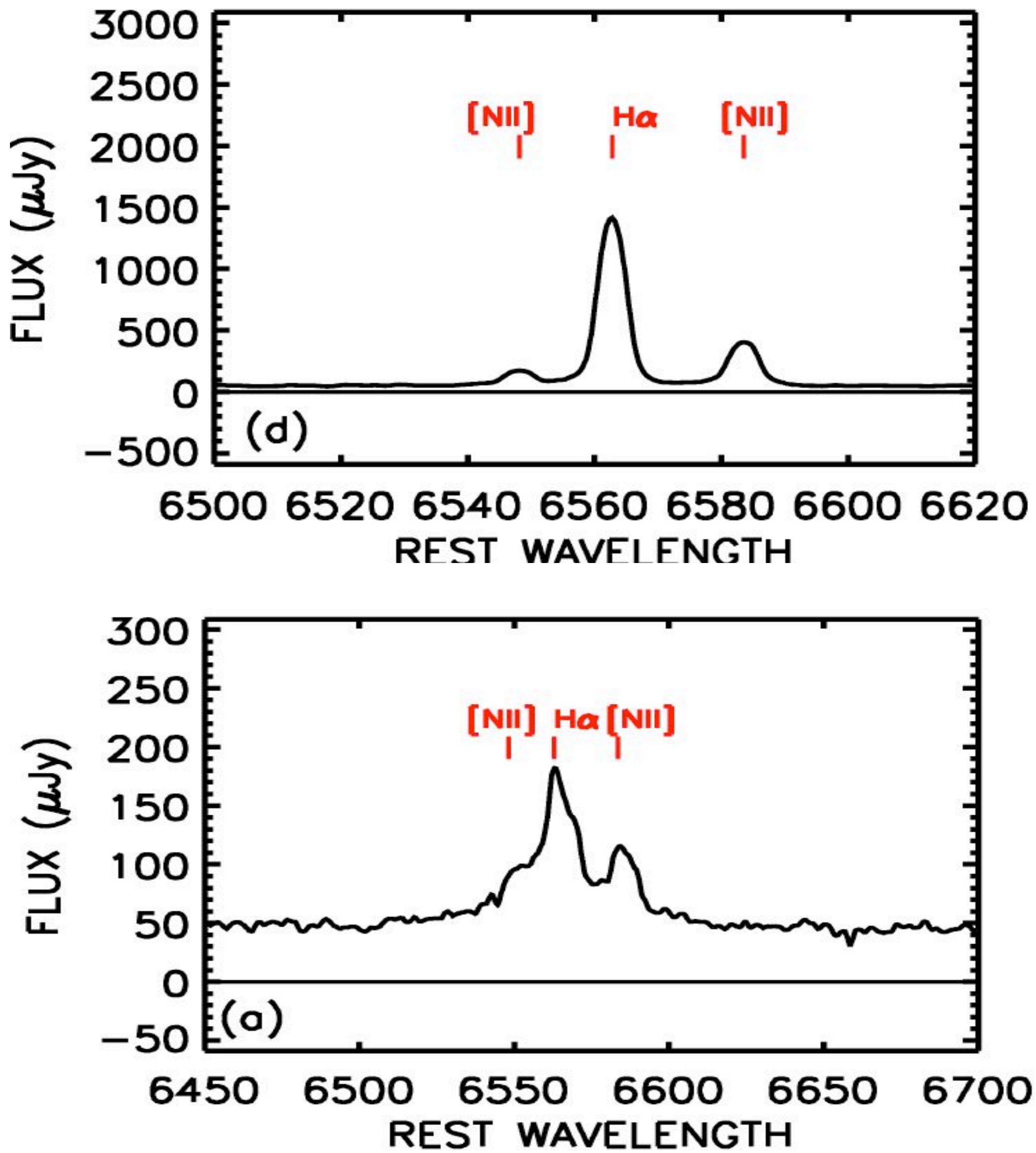
(red diamonds=AGN, black squares=LAE)



Testing the GALEX IDs

- We can test the GALEX L alpha identifications with optical spectra
- AND
- We can test the division between AGN and galaxies with X-ray data and optical spectra
- We particularly want to check if a large fraction of the potential LAEs are really AGN.

What do the optical spectra look like?
(invariably the redshifts are confirmed)



Most are modest (not extremely low) metallicity star formers

Very roughly 10% are Seyferts like this type 1.8

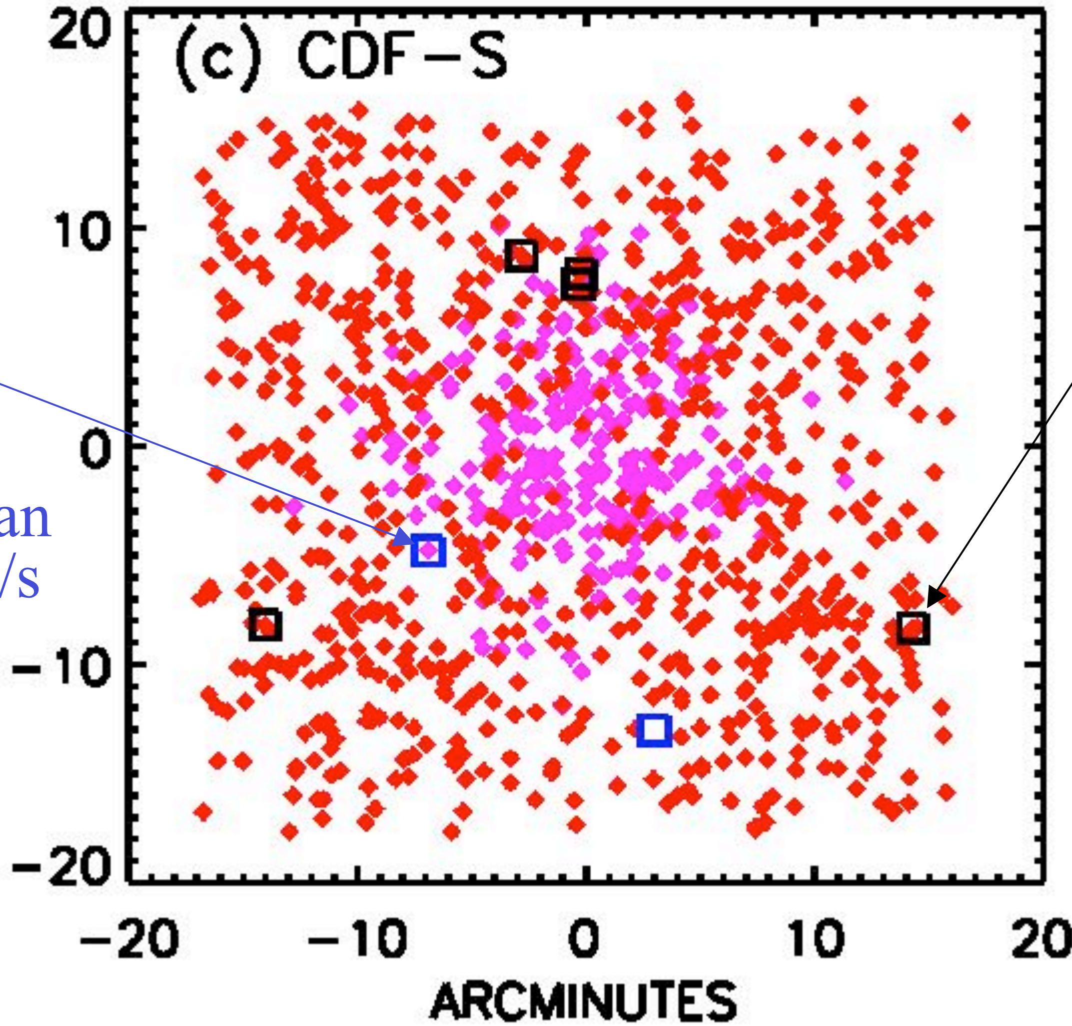
GALEX objects versus CDF-S X-ray sources

(purple=2Ms image, red=extended CDF-S)

(X-ray data from Luo et al. (2008), Lehmer et al 2005 and Virani et al. 2006)

The galaxies are low X-ray luminosity objects consistent with star formation. The AGN are luminous X-ray sources.

GALEX
Galaxies
Lx less than
10^41 erg/s



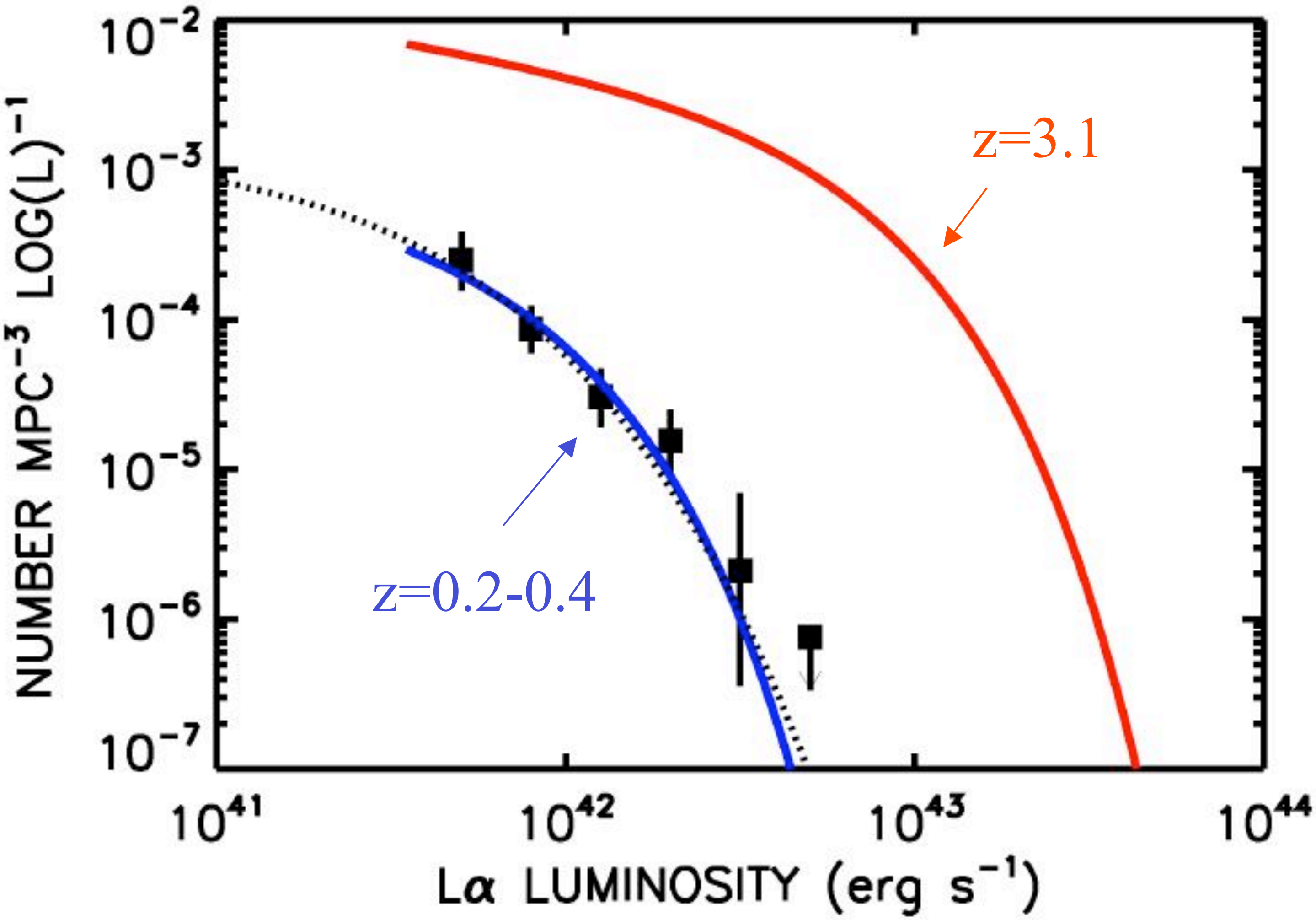
GALEX
AGN
Lx=5^43-
5^44 erg/s

What are the properties of the z=0.2-0.4 redshift LAEs?

- Firstly they are much rarer than LAEs at high redshift and pick out only about 5% of the UV continuum selected objects versus roughly 20% at z=3

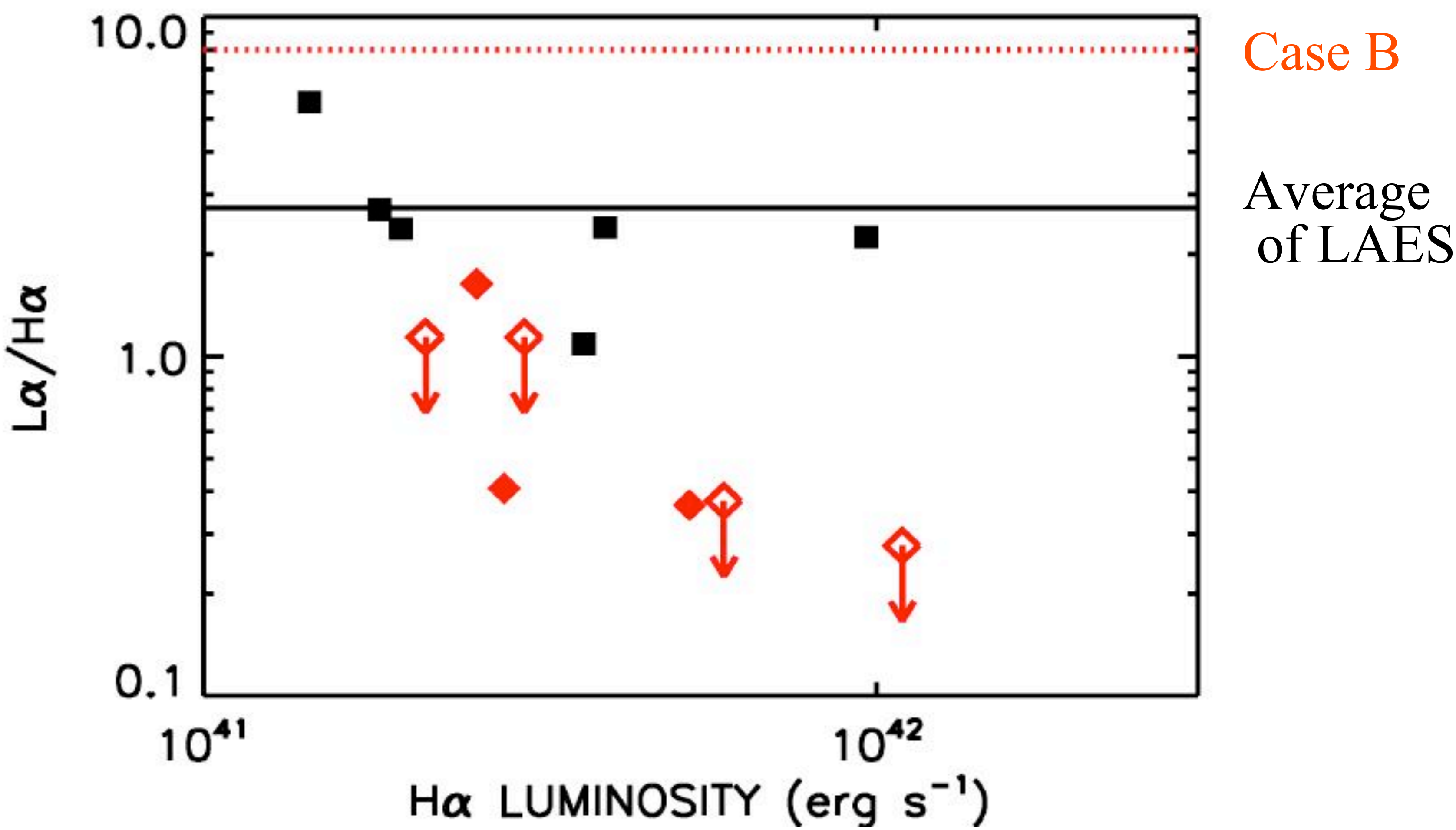
z=0.2-0.4 LAE LF compared with *z*=3.1 LAE LF of Gronwall et al. 2007

Drop in luminosity density by factor 50-60

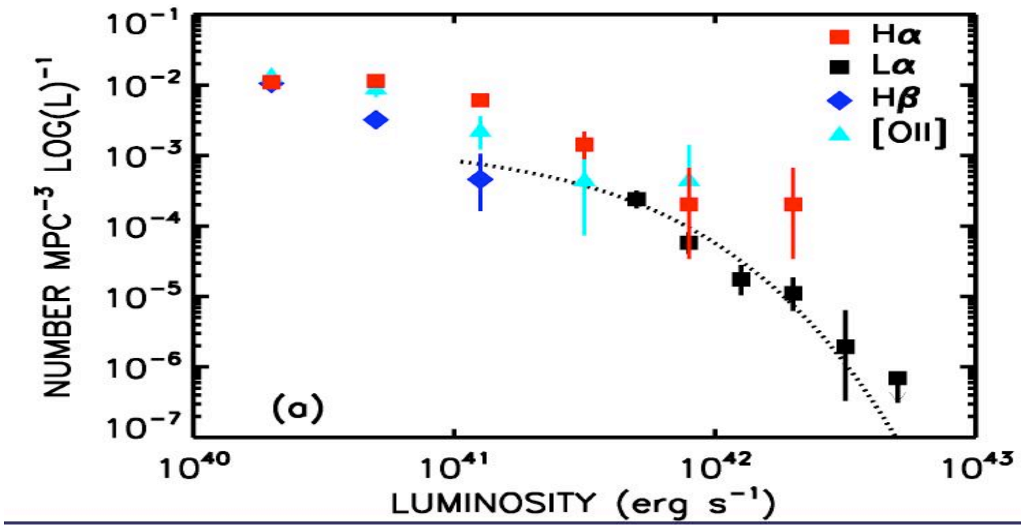


Average Lyα/Hα is about a third of case B

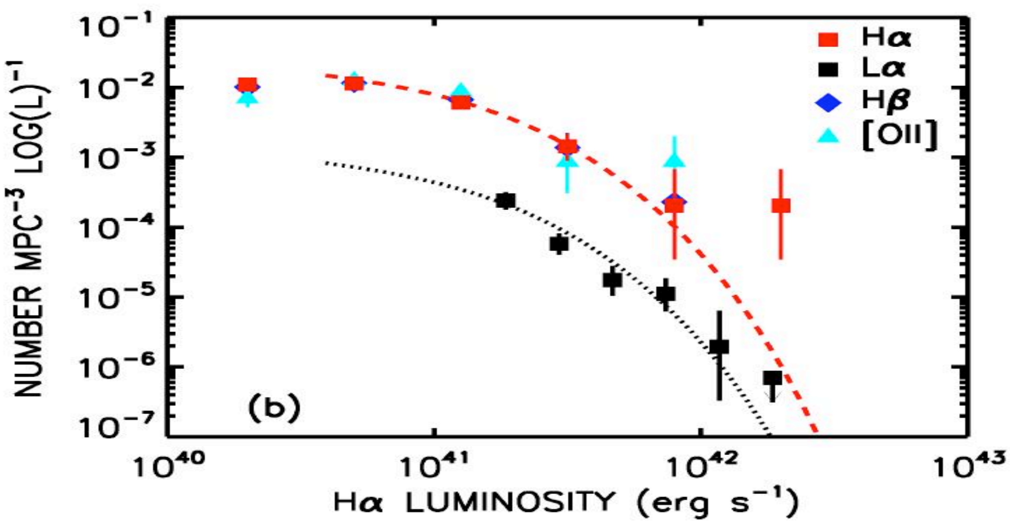
(This is a selection effect! Black squares show the LAEs: red diamonds the ratio for Hα selected objects)



Comparison with z=0.2-0.4 Optical line LFs



Without cross calibration

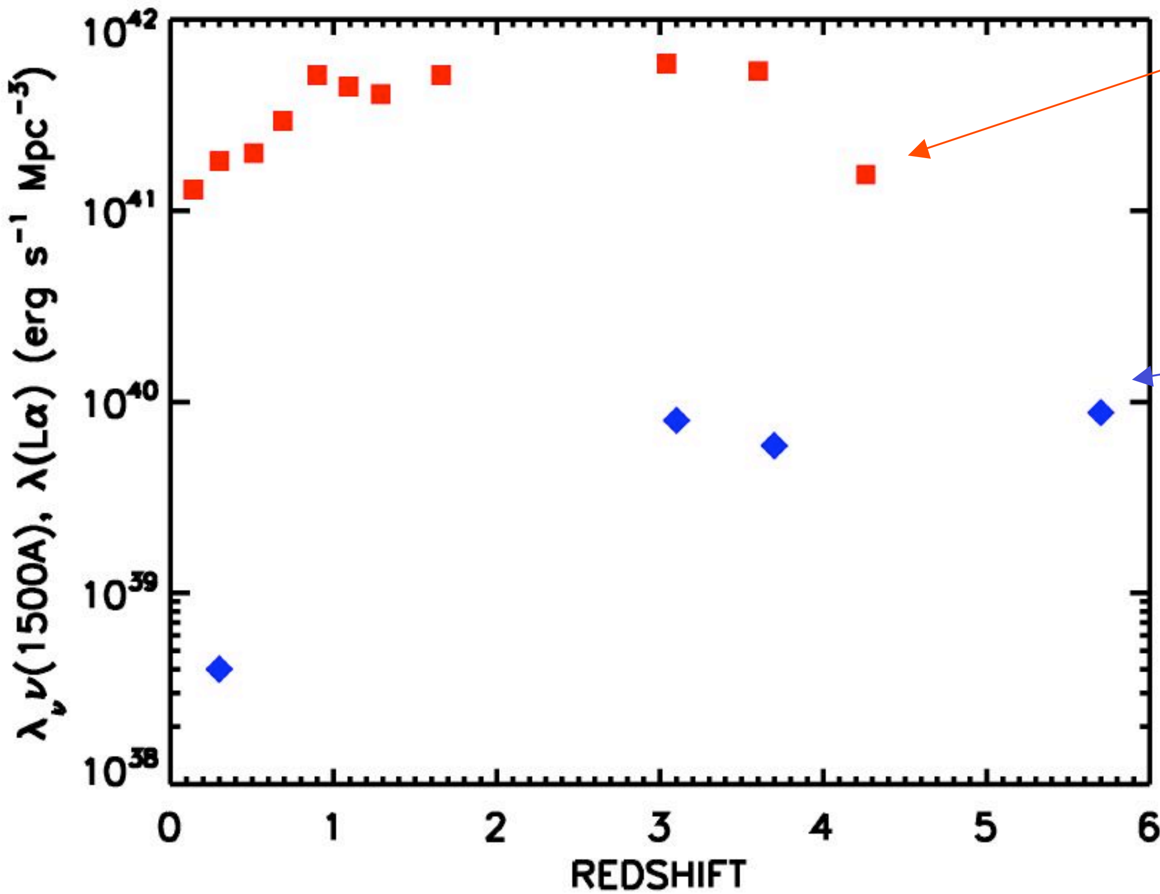


With individual cross calibration to Hα luminosities

LAEs only find about 5% of the star formation at this redshift!

Cowie, Hu and Barger 2009

LAEs were much more common at high redshifts

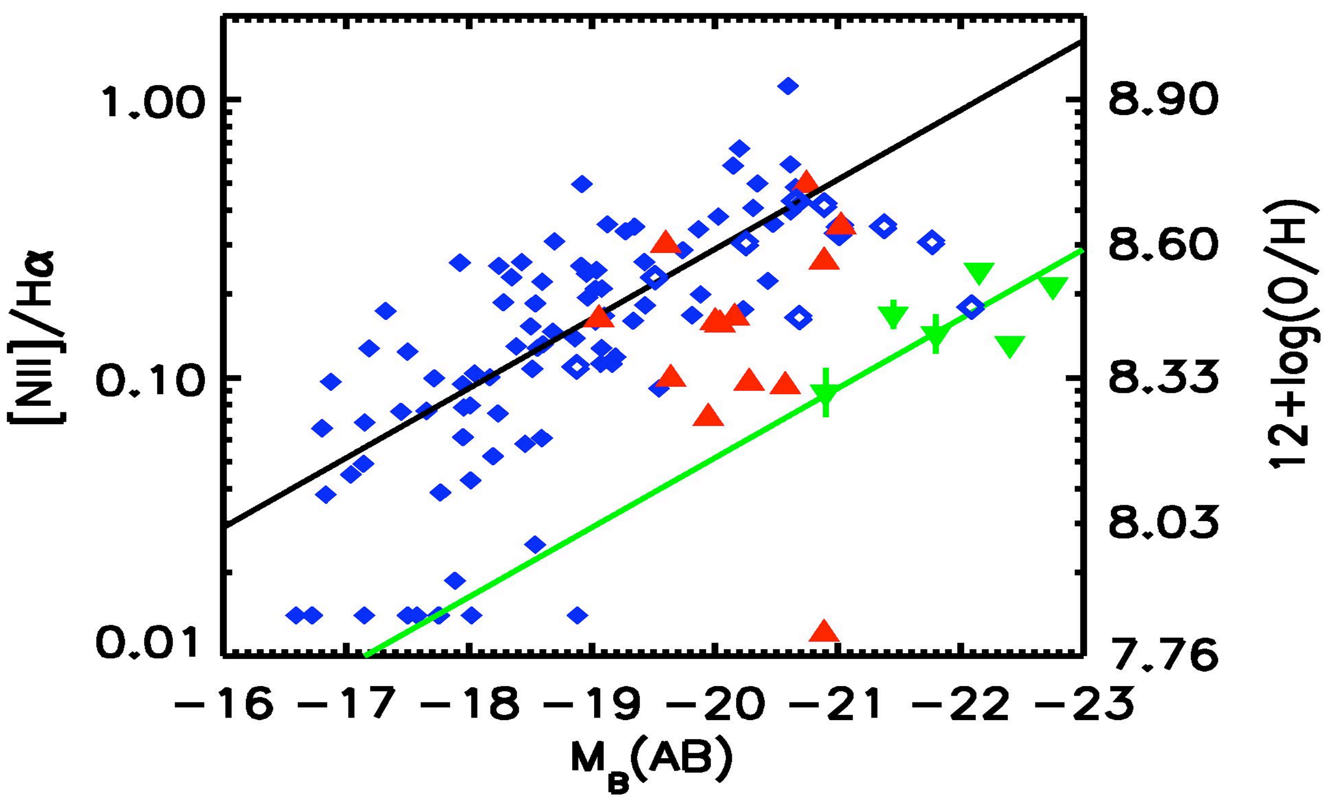


Continuum luminosity density (Tresse et al. 2007)

Lyman alpha luminsosity density: present work, Gronwall et al. 2007 Ouchi et al.2008

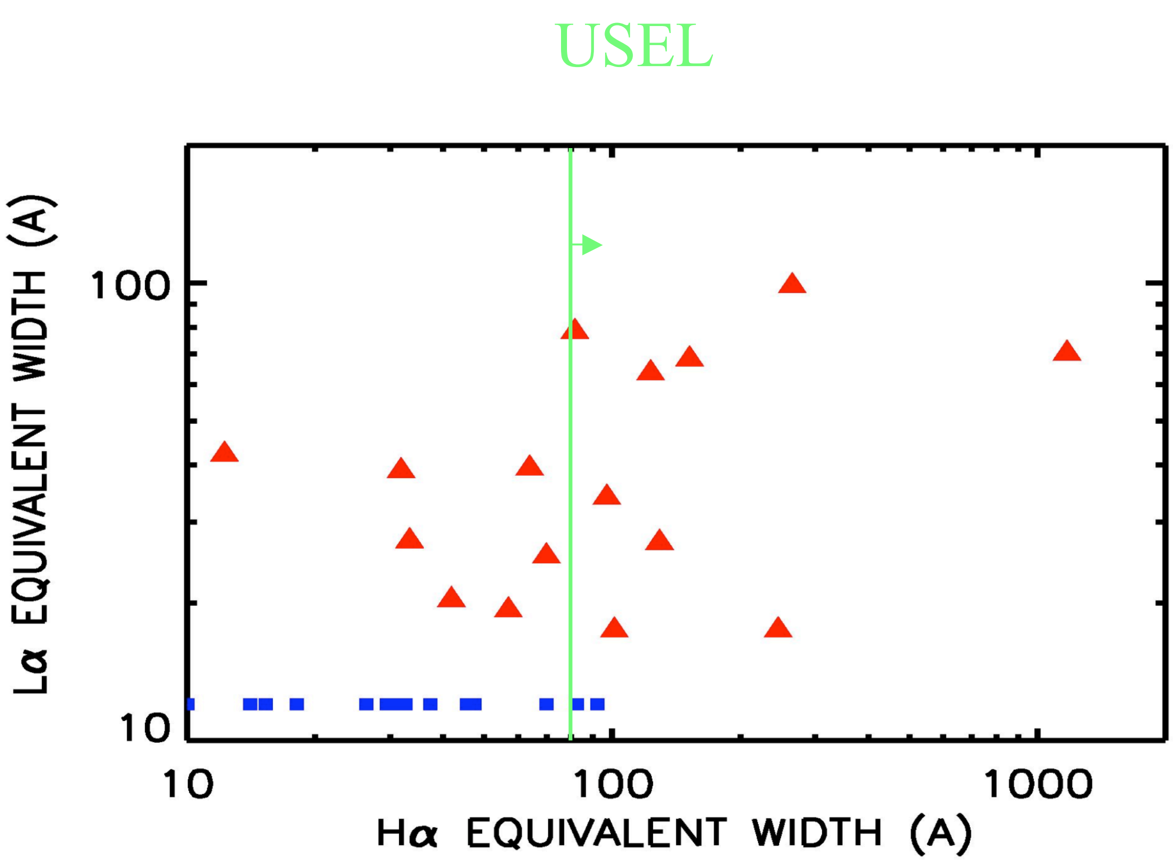
There seems to be a metal dependence

Blue diamonds are UV continuum selected objects, red triangles LAE selected all in z=0.2-0.4 redshift range green triangles are averages of z=2 LBGs from Erb et al. 2005



There is a strong dependence on Hα equivalent width

Blue squares are UV continuum selected objects, red triangles LAE selected all in z=0.2-0.4 redshift range. Optical USELs are nearly all LAEs



The LAE population corresponds to a high Hα equivalent width selection

- LAEs at z=0.2-0.4 <EW(Hα)> =54Å

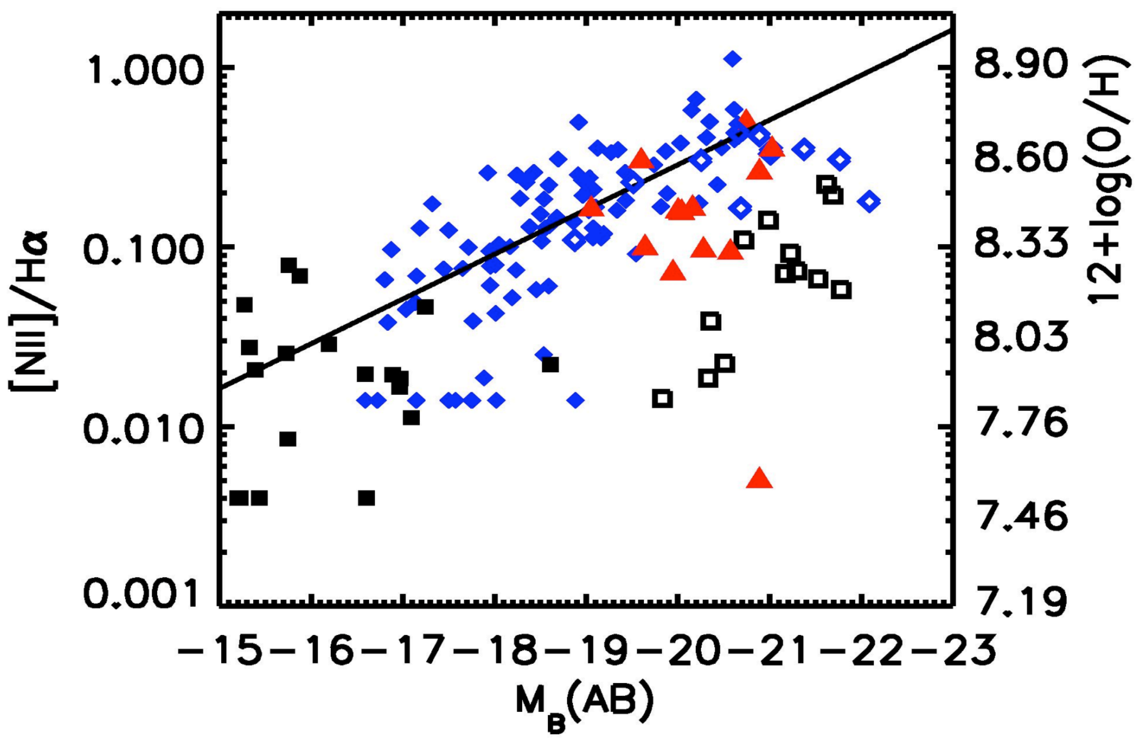
  non LAES z=0.2-0.4 <EW(Hα)>24Å

Highest Hα equivalent width for a GALEX LAE is 1200Å!!!

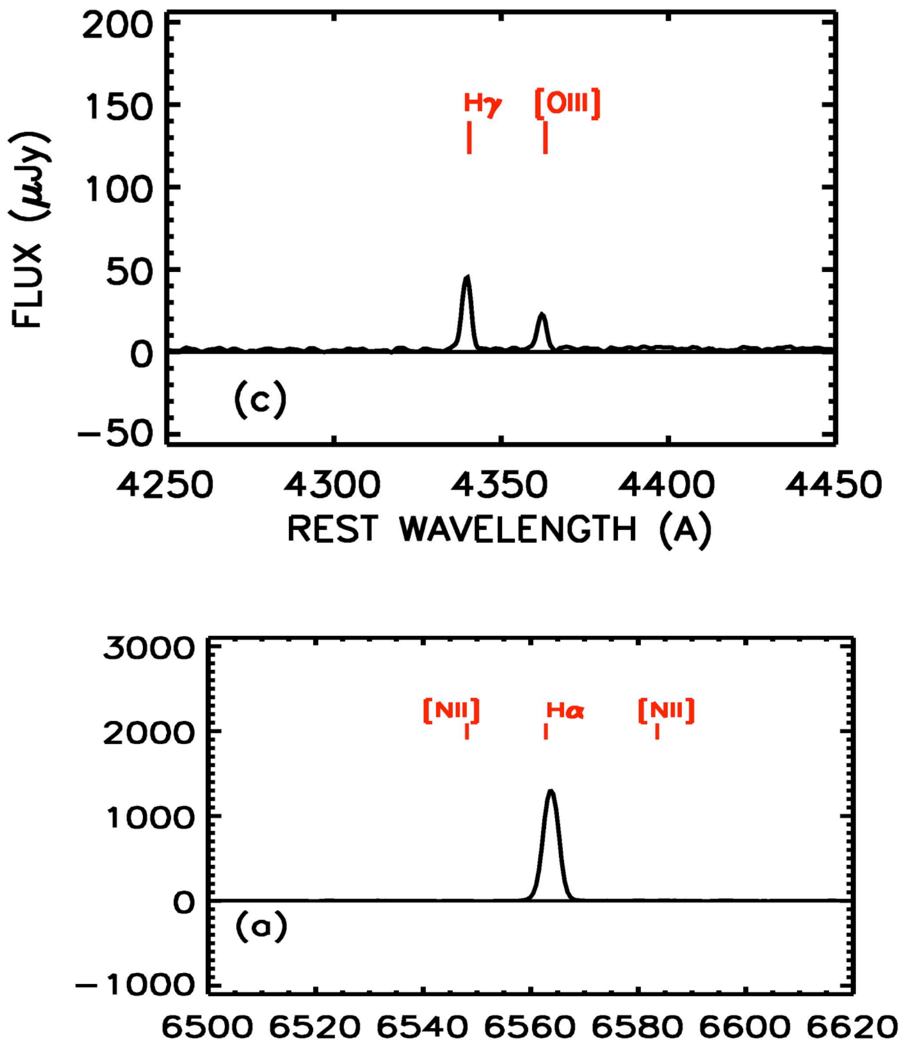
LAEs have little measurable extinction and are bluer than UV selected (i.e. LBG like galaxies)

The LAE metallicity may be closer to optical USEL selected galaxies

Blue diamonds are UV continuum selected objects, red triangles LAE selected all in z=0.2-0.4 redshift range. Black squares are Optically selected extreme emitters in the same range from Kakazu et al 2008 & Hu et al 2009 (closed squares) and Salzer et al. 2009 (



GALEX1417+5228: a very unusual galaxy



Continuum absolute
B mag approx -20

12+log(O/H)=7.5+/-0.05

EW(Hα) = 1200Å

not detected in [NII]6584

z=0.2065 (at levels of 1 in

a few hundred); strong

[OIII] 4363

SUMMARY

LAEs at z=0.3 show many similar properties to their high z counterparts but are much less common and their galaxies contain less of the light. The conversion factor from Lyα luminosity is three times lower than the case B ratio often used.

There is some metallicity dependence in whether a galaxy is an LAE. The LAEs appear to have a strong overlap with high equivalent width optical samples at the same redshift and there metal properties may be closer to these galaxies than to UV continuum selected sample

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