Other Conference Item

Reionization and high-z galaxies

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Publication Date:
2003

Permanent Link:
https://doi.org/10.3929/ethz-a-004585080

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Reionization and high-z galaxies

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What causes the reionization?

What is the origin of the UV photons that reionize the universe, stars or quasars?

If stars, then what is the nature of the galaxies they are found in?
How do you find out what reionized the universe?

- Universe was reionized by about $z=6$ by either QSOs or UV starlight from star forming galaxies.
- So image an area of sky deeply in order to find galaxies and QSOs at $z>5$, they will all "drop out" in the R-band.
- $Z=5$ and $z=6$ are only 300 Million years apart, so there should be no real change in populations over this time.
- Add up the UV luminosity from the QSOs and galaxies that you find at $z>5$, compare it to what is needed to keep the universe ionized at $z=5-6$.
- Does it add up?
Reionization of the Universe

How do you find out what reionized the universe?

• Image a 40 arcmin$^2$ field with FORS2 on the VLT to limit of $R_{AB}=27.8$, $I_{AB}=26.5$, $Z_{AB}=26$.

• Select objects with $I_{AB}<26.25$ and $R_{AB}>27.8$

• Take spectra of these objects.

• Between $4.8<z<5.8$ the volume probed by this field is $\sim 10^5$ Mpc$^3$.

• Scaling from the mass density of the universe at $z=0$, require about $5 \times 10^{56}$ ionizing photons per sec to keep this volume ionized (one SLOAN QSO, typically with $I=22$ish at $z=5.5$).
Reionization of the Universe

Identifying the source of the ionizing photons: R-band dropouts

Any source at z > 5, whether a star forming galaxy or an AGN, will have little or no R-band flux as this is absorbed by intervening hydrogen in the IGM. It will therefore have a very red $R - I$ colour.

Spectrum of $z = 5.5$ galaxy Overlayed with R,I,Z filters

Reionization of the Universe
High redshift sources reddened by H opacity

Model galaxy at $z=6.6$
Dashed line shows photons absorbed by hydrogen at rest wavelengths shorter than 121.6nm
Elliptical galaxy formed in exponential burst starting $z=9$
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Results


- $\text{Lum (Ly alpha)} \sim 10^{42} \text{ erg/s} \ (\text{flux } 10^{-17} \text{ erg/s/cm}^2)$
  Rest Eq Width 30-50 Angstrom.

- Brighter sources with $R-I>1.5$ proved not to be at high redshift.

- Other sources in “spare” slits included galaxy pair at $z=4.4$ and serendipitous line emitter. If Ly alpha then at $z=6.59$
Some spectra

- SDSS J110 z=5.744
- SDSS J11 z=4.822
- SDSS J18 z=5.018
- SDSS J19 z=5.870

Reionization of the Universe
Some spectra

Reionization of the Universe
Galaxies: Some spectra

$Z=4.9$ and $5.0$ Lyman break galaxy candidates with Ly$\alpha$

$R_{AB}>27.8, I_{AB}\sim 26, Z_{AB}>25.8$
Reionization of the Universe

Some spectra

$Z=5.6$ and 5.7 Lyman break galaxy candidates with Ly$\alpha$

$$R_{AB} > 27.8, \ I_{AB} \sim 26, \ Z_{AB} \sim 25.3$$

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Interpretation

• In the following assume all 13 of the faint R-breaks are between $4.8<z<5.8$, not just the six with confirmed redshifts.

• Need to work out detectability as fn of redshift and magnitude:- Number counts and monte-carlo

• Fold through $z=3-4$ results into detectability to determine expected number of sources given no evolution between $z=3$ and 6.
Interpretation: Source detectability
Number of detected sources relative to number of sources expected for no evolution
Constraints on AGN lum fn

Reionization of the Universe
Summary of results

• No QSOs or AGN selected/spectroscopically confirmed at $z>5$. Lum fn does not steepen enough to give enough AGN to reionize universe.

• Star formation/UV density several times lower at $z>5$ than at $z=3$.

• UV emission from all detected objects that could be at $z>5$ is not enough to ionize the volume.

• So universe is reionized by objects fainter than $I_{AB}=26$, or $M_{1450}>-20.5$. 
What do the high redshift galaxies look like in detail?

GOODS ACS data

Half-light radii typically 2kpc or less

Sources undetected in 1Msec Chandra: $L < 2 \times 10^{43}$ erg/s
Are high redshift galaxies uniformly distributed?
Conclusions

• Using the Lyman dropout technique is a reliable way of finding star-forming galaxies at z>5. Gets hard at z>5.8.

• Star formation reionized the universe. Star formation in less luminous (less massive?) galaxies dominates.

• Star formation/UV density decreases by factor 3-10 from z=3 to z>5 at the bright end of the luminosity function (LF).

• Individual sources small, r_h~2kpc. No X-ray emission brighter than that expected from strong starbursts.

• The sources cluster, this will eventually help determine their nature and let us better understand early galaxy formation. Need a lot more area to do this properly.
What do the high redshift galaxies look like in detail?
What causes the Reionisation
or
How do quasars and galaxies evolve at z>5?

(1) Quasars:
What causes the Reionisation

or

How do quasars and galaxies evolve at $z>5$?

(1) Quasars:
What causes the Reionisation
or
How do quasars and galaxies evolve at z>5?

(2) Galaxies: