Using Lyman-α Emitters to Study Reionization

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Size of HII region has to be $\sim 1$ proper Mpc for emitter to be observed.

Miralda-Escude (1998)
Goal: To use LAEs to detect and study reionization

• Reasons why this might be possible:
  – The width of the IGM damping wing is $\sim 1000$ km s$^{-1}$
    \[ \tau_\alpha(\Delta \nu, R_b, \bar{x}_H) \approx 900 \text{ km s}^{-1} \bar{x}_H \left( \frac{1+z}{8} \right)^{3/2} \left( H(z) R_b + c \frac{\Delta \nu}{\nu} \right)^{-1} \]  
    \[ (1) \]
  – Hard for astrophysics to shift line by 1000 km s$^{-1}$
    • Kinematics: The circular velocity of $10^{11}$ M$_{\text{sun}}$ halo at $z=6.6$ is 100 km s$^{-1}$ (and $n(M>10^{11}) = 4\times10^{-4}$ cMpc$^{-3}$)
    • Winds: Can several hundred km s$^{-1}$ winds be driven out of these dwarf galaxies like from massive galaxies at lower $z$?
    • Radiative transfer: Line center shifted by 160 $(N_{\text{HI}}/10^{21})^{1/3}$ km/s
      – need columns of $10^{17}$ cm$^{-2}$ for ionizing photons to escape to ionize IGM
      – Ly$\alpha$ photons take path of least resistance
  – Large-scale clustering could be robust to internal processes that shape Lya emission
Presently Favored Picture of Reionization

Each panel is 100 cMpc comoving and subtends the same solid angle as the moon.
Lyman-α Emitters in Reionization Simulations

McQuinn et al (2007)  (also see Iliev et al 2008)

These calculations do not treat scattering in host halo and just the damping wing suppression from a large intergalactic neutral column. Zheng’s clustering effect is not included.
From McQuinn et al (2007) for one model of reionization where $L_{\text{Ly} \alpha}$ is proportional to halo mass (and ionizing luminosity).

Furlanetto, Zaldarriaga and Hernquist (2005)
Ratio of Luminosity function during reionization to case with $x_i = 1$ at $z=6.6$ calculated from simulations

Models in left panel assume Lyα flux is proportional to ionizing emissivity in simulations, where the proportionality constant is a free parameter related to $f_{\text{esc}}$. 
EFFECT ON CLUSTERING
Effect on Correlation Function/Power Spectrum

Inner error is just shot noise and outer includes cosmic variance. Bottom two panels are for same depth as SDF.
How can this be distinguished from LCDM?

The points on each curve are for $x_H = 0, 0.2, 0.5$, and 0.7 in the simulation.
What is causing large clustering increase?

Clustering during reionization ($x_f = 0.5$) for intrinsically unclustered population
More about clustering

• Can detect clustering signature with comparable number density and FoV to SDF
• If line-center is shifted redward by 400 km/s, not a large effect on clustering in our models.
• If an increase in clustering is seen, can do the following to test reionization explanation (with sensitive future telescope): select galaxies with other technique aside from Lyα emission, then observe them in Lyα. LAE subsample will be much more clustered.
Many Telescopes are aiming to detect redshifted 21cm emission.

Sensitivity forecast for Murchison Widefield Array to 21cm 3-D power spectrum:

Lidz et al (2007)

What would we need to be convinced that these arrays are actually detecting reionization?
Cross Correlation with a LAE Emitter Survey

- If IGM is $>\sim 20\%$ neutral at $z\sim 6.6$, cross spectrum detectable with mild extension to Subaru survey! (Need $\sim 1 \text{deg}^2$ w/ 2x present depth of spectroscopic sample).

- LOFAR has more collecting area, but smaller field of view than MWA. Comparable sensitivity for 21cm auto spectrum, but slightly better sensitivity for cross spectrum.

Lidz et al (2009)

S/N of detection as a function of LAE narrowband survey area with $n = 1.6 \times 10^{-4} \text{ Mpc}^{-3}$ and 1% $z$-determinations
Conclusions

• IGM damping wing is very broad. >400 km/s internal line shifts would be required to significantly change how reionization affects LAE clustering and LF.

• Reionization caused the normalization of LF to decrease. Predictions are that it had a smaller effect on its shape.

• Astrophysics of individual emitters cannot induce large-scale correlations, whereas reionization can. Could increase clustering more than is possible otherwise (although, see Zheng’s talk).

• Redshifted 21cm is potentially detectable in cross correlation with a LAE survey. This could verify a claimed detection of high-z 21cm emission.