WFIRST and Reionization

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Cosmic Reionization



- Third (and last)
 global phase
 transition
- Landmark event of first generations of galaxies
- Affects fuel for future generations of galaxies

Alvarez, Kahler, & Abel

Constraints on Reionization

- *Reionization must end by z~6 (McGreer et al. 2015)*
- CMB Polarization from Planck Collaboration (2015): τ=0.066 +- 0.012 (corresponds to instantaneous reionization at z~7-11)
- Lots of other model-dependent astrophysical constraints
- Can model reionization history from galaxy observations, with many assumptions, especially:
 - Higher redshifts
 - Fainter galaxies
 - Escape fraction of ionizing photons



Robertson et al. (2015)

(Some) Open Questions About Reionization

- When did it occur?
- What did it look like?
- What sources drove it?
- *How did reionization end?*

When did reionization occur?



Mesinger, Furlanetto, & Cen (2011)

When did reionization occur?



Hydrogen Epoch of Reionization Array (PI: A. Parsons, UC Berkeley)



Pre-WFIRST Goal: solve using 21-cm line





What did it look like?

- "Simple" models of reionization are now commonplace and based on simple physical principles (photon counting) -"seminumeric" codes
- But they create complex structures whose origins are NOT fully understood!

1 arcmin ~ 2 comoving Mpc



Furlanetto & Oh (2016)

What did it look like?



Lidz et al. (2008)

- Cross-correlation with galaxy field **directly** reveals bubble scale!
- Requires...
 - Large volume (10s of square degrees)
 - "Tracer" population of galaxies
 - Accurate redshifts $(\Delta z < 0.1 ish)$

What sources drove it?

• Bubble scale also reveals mass of galaxies driving reionization (through clustering)



McQuinn et al. (2007); Furlanetto et al. (2005)

What sources drove it?

- Relative importance of bright and faint galaxies is key question
- "Intensity mapping"
 - Radio lines (CO, CII)
 - Lyman-α
 (SPHEREx)
- Cross-correlation also makes signal extraction easier!





Lidz et al. (2011)

How did reionization end?

- Bright quasars allow us to measure relic neutral gas after reionization along the line of sight
- Recent observations show substantial fluctuations on very large scales
- NOT consistent with standard models just after reionization!



Becker et al. (2015)

How did reionization end?

- End of reionization is regulated by absorbers in Lyman-α forest - poorly understood past z~5!
- Recently Becker et al. (2015) found very large fluctuations on very large scales (50/h Mpc) in the forest at z>5.5
 - Explanation #1: stronglyvarying ionizing background (Davies & Furlanetto 2016)
 - Explanation #2: variations in heating from reionization (D'Aloisio et al. 2016)
- These two models make OPPOSITE predictions for high-τ environments!



Davies & Furlanetto (2016)

D'Aloisio, McQuinn, & Trac (2015)

How did reionization end?



- *Requires large-field observations to detect environments*
- Probably many lines of sight to overcome cosmic variance

Conclusions

- WFIRST will be a key contributor to reionization studies because of its large survey volume
 - (Some) Key Strategies:
 - Cross-correlation with 21-cm (feature size)
 - Cross-correlation with intensity mapping (properties of faint galaxies)
 - Environments of IGM structures (properties of cosmic web)
 - Implications for WFIRST
 - Most applications need redshifts
 - Richest information from comparisons with other data
 - Need filter coverage!