

Galaxies and Reionization: Cross-Correlating Spectroscopic Surveys and 21-cm Surveys

Steve Furlanetto

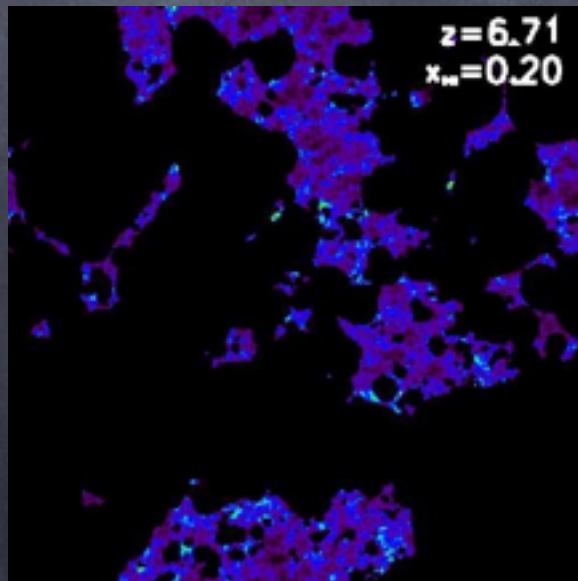
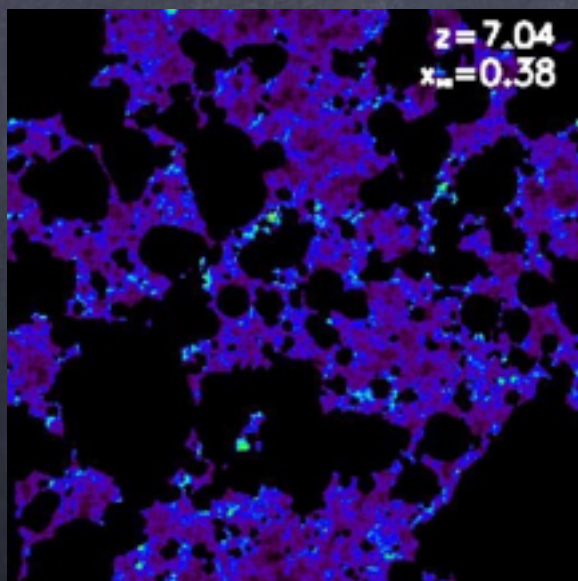
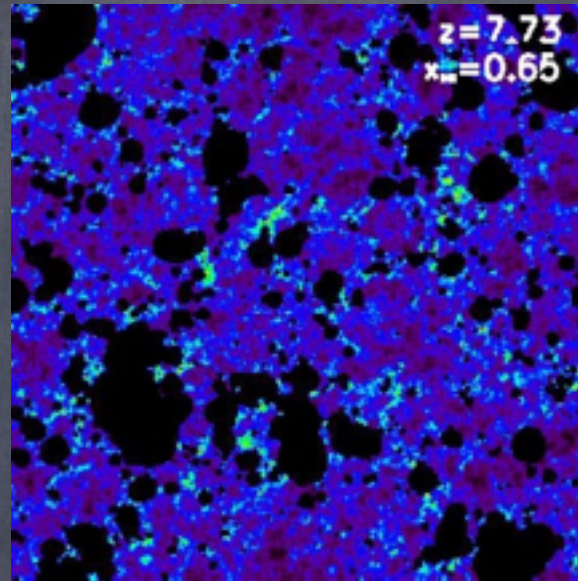
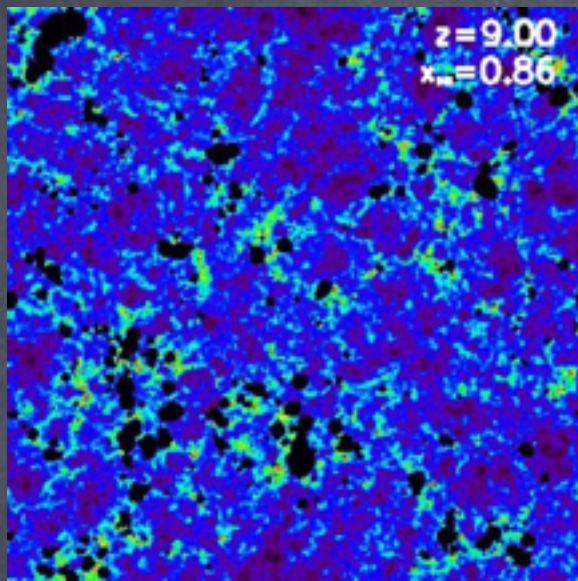
UCLA

October 19, 2018

Outline

- What is reionization?
- 21-cm Surveys
- Case Study: Cross-correlating galaxies and Ly α absorption
- How do we make it work for 21-cm surveys?

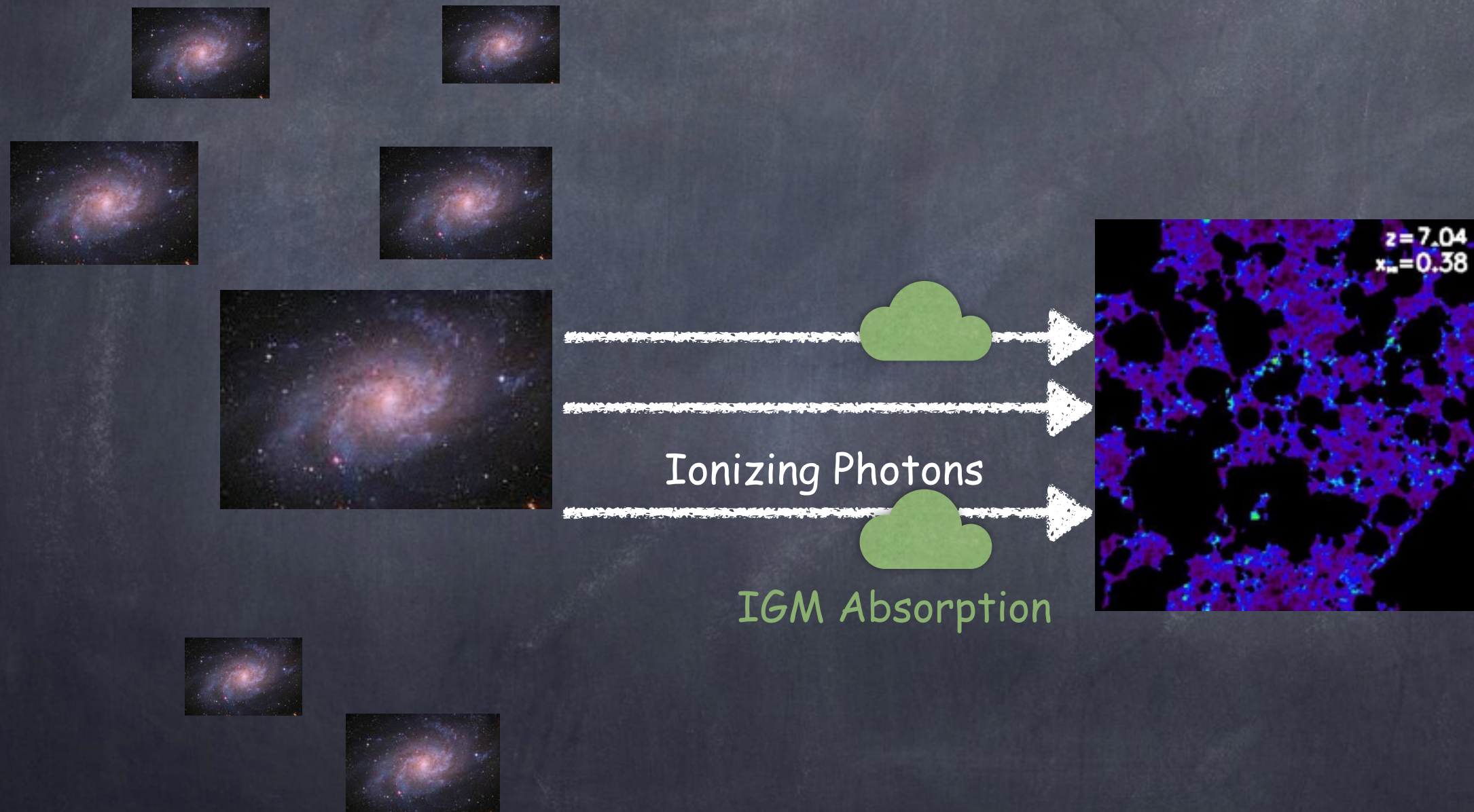
What is reionization?



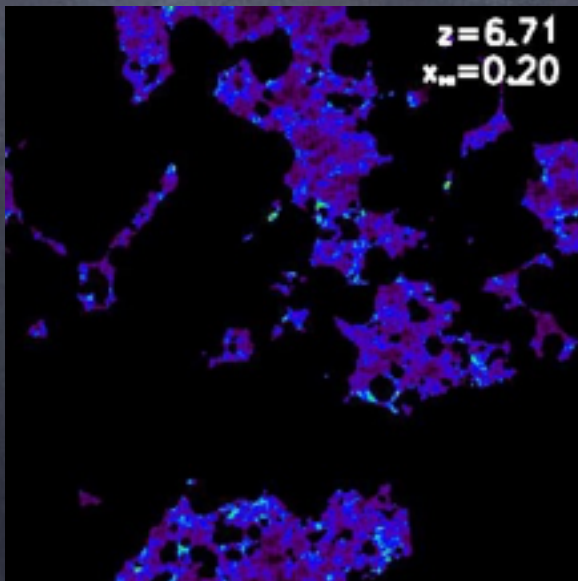
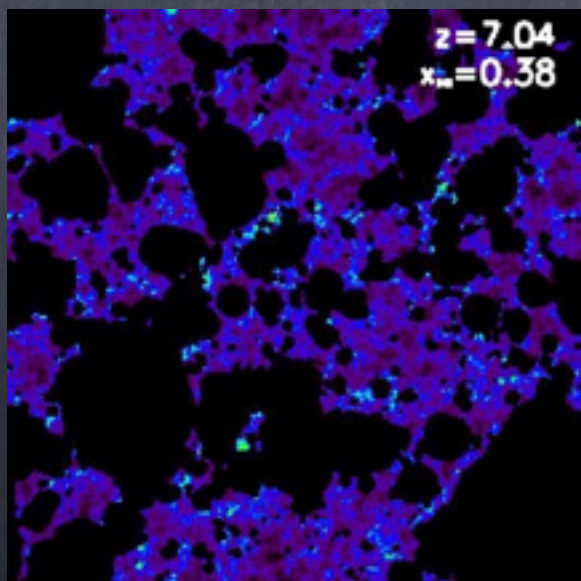
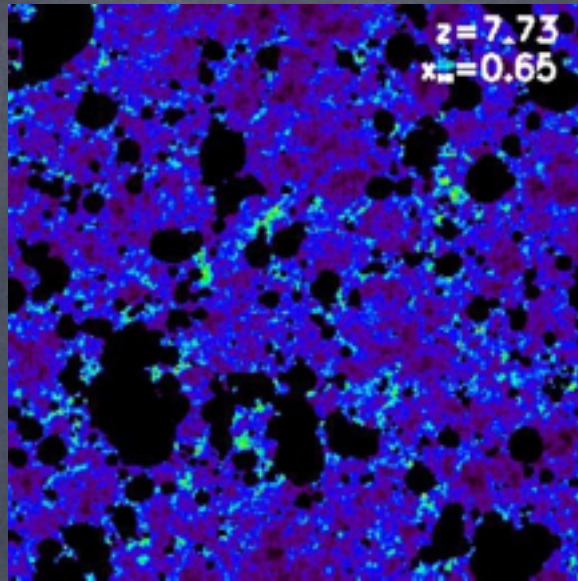
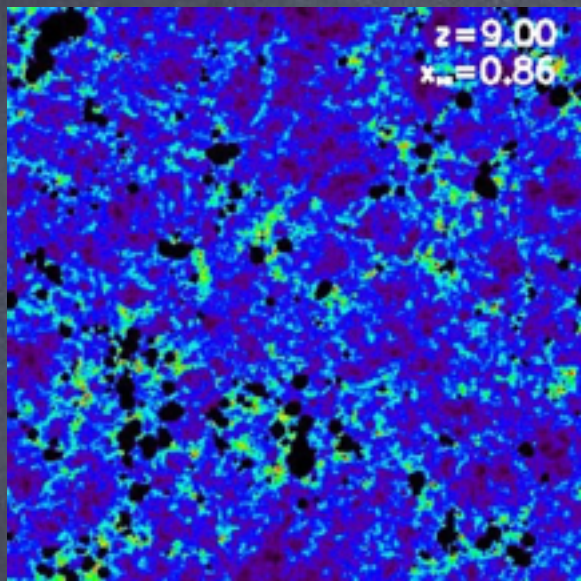
- Landmark event of first generation of galaxies
- Affects fuel for future generations of galaxies
- Powerful probe of all those galaxies you CAN'T see
- Probably occurred at $z \sim 10-6$

A. Mesinger

Galaxies and Reionization



Observing Reionization with the 21-cm Line

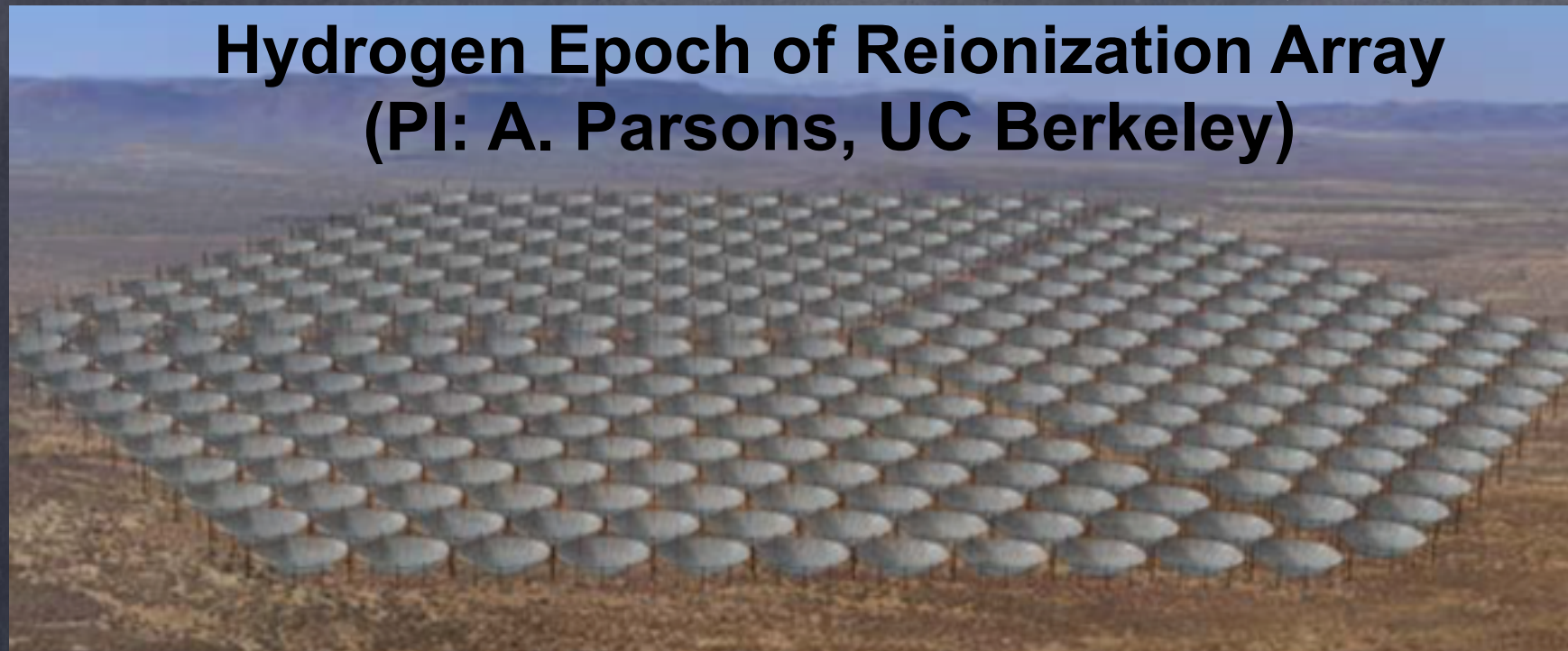


- Observe emission or absorption from neutral hydrogen via 21-cm line
 - Disappears during reionization!
- Observed frequencies ~50-200 MHz - hard!
- First detection (maybe) from EDGES; Bowman et al. 2018

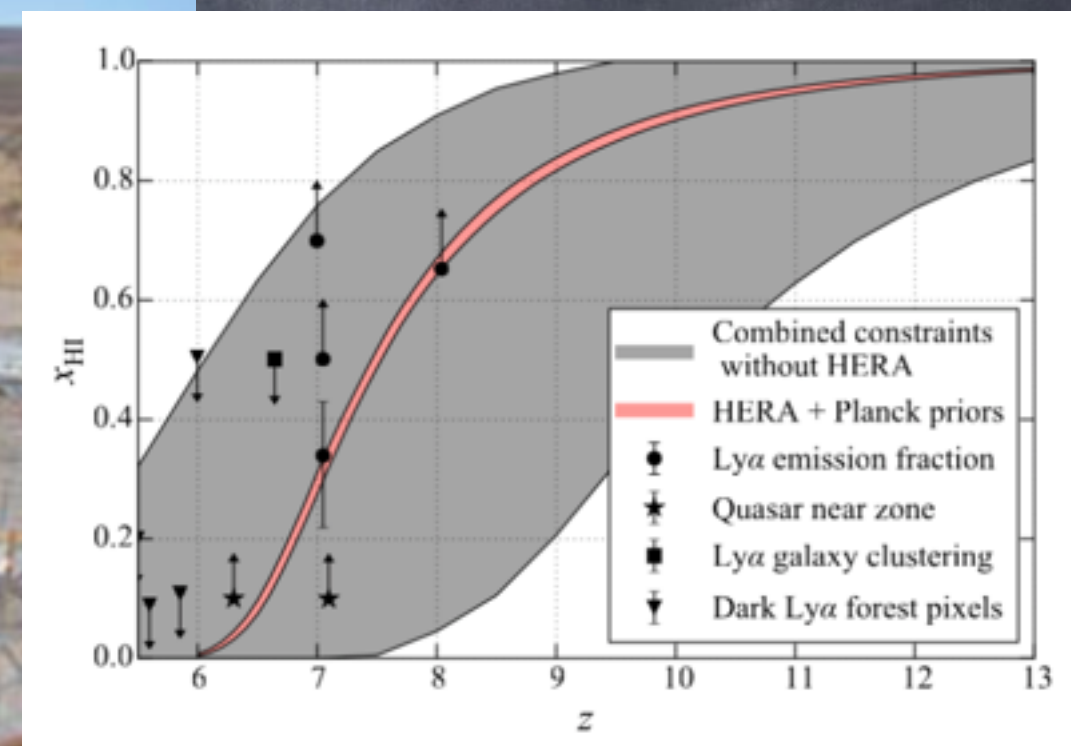
21-cm Surveys: HERA



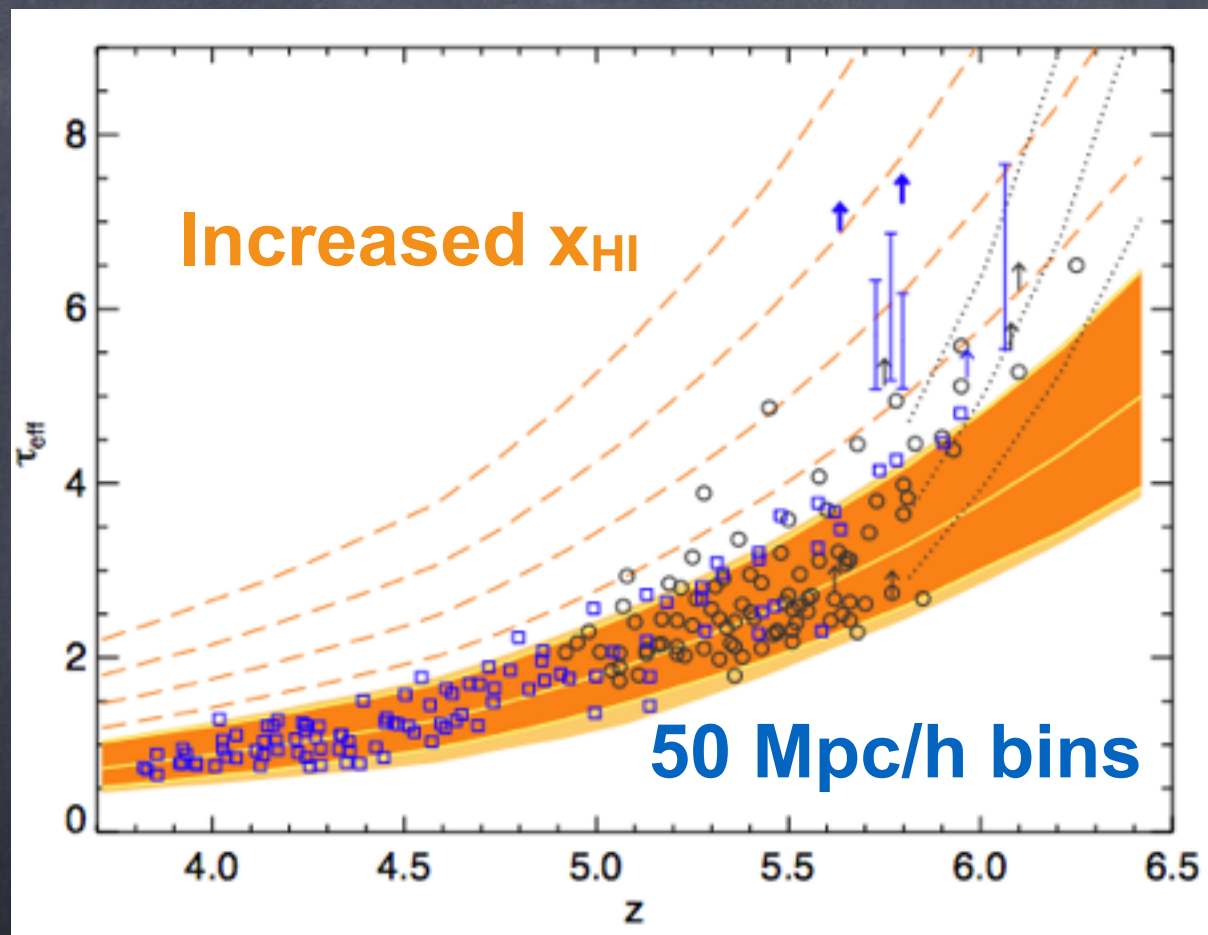
Hydrogen Epoch of Reionization Array
(PI: A. Parsons, UC Berkeley)



- Now under construction; complete in ~2020



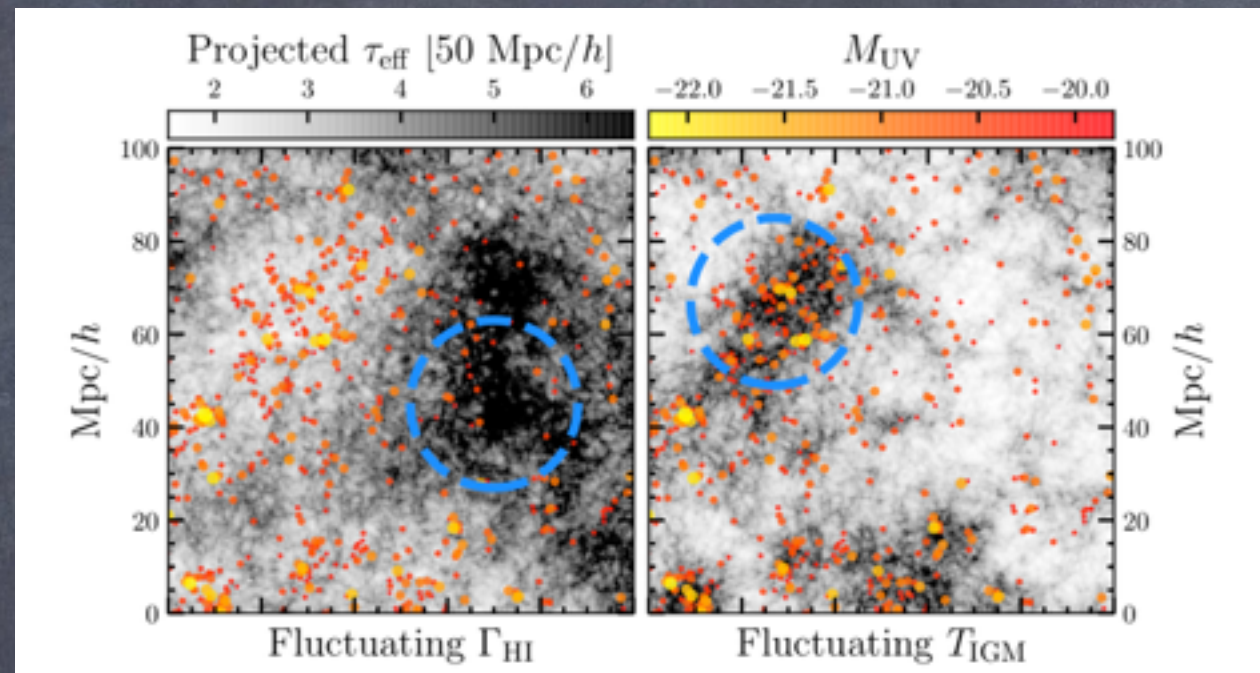
Case Study: The Post-Reionization Universe



Becker et al. (2015)

- Ly α forest fluctuates VERY strongly shortly after reionization
- Cannot be explained by a standard model of the ionizing background

Two Potential Explanations, with Opposite Predictions!

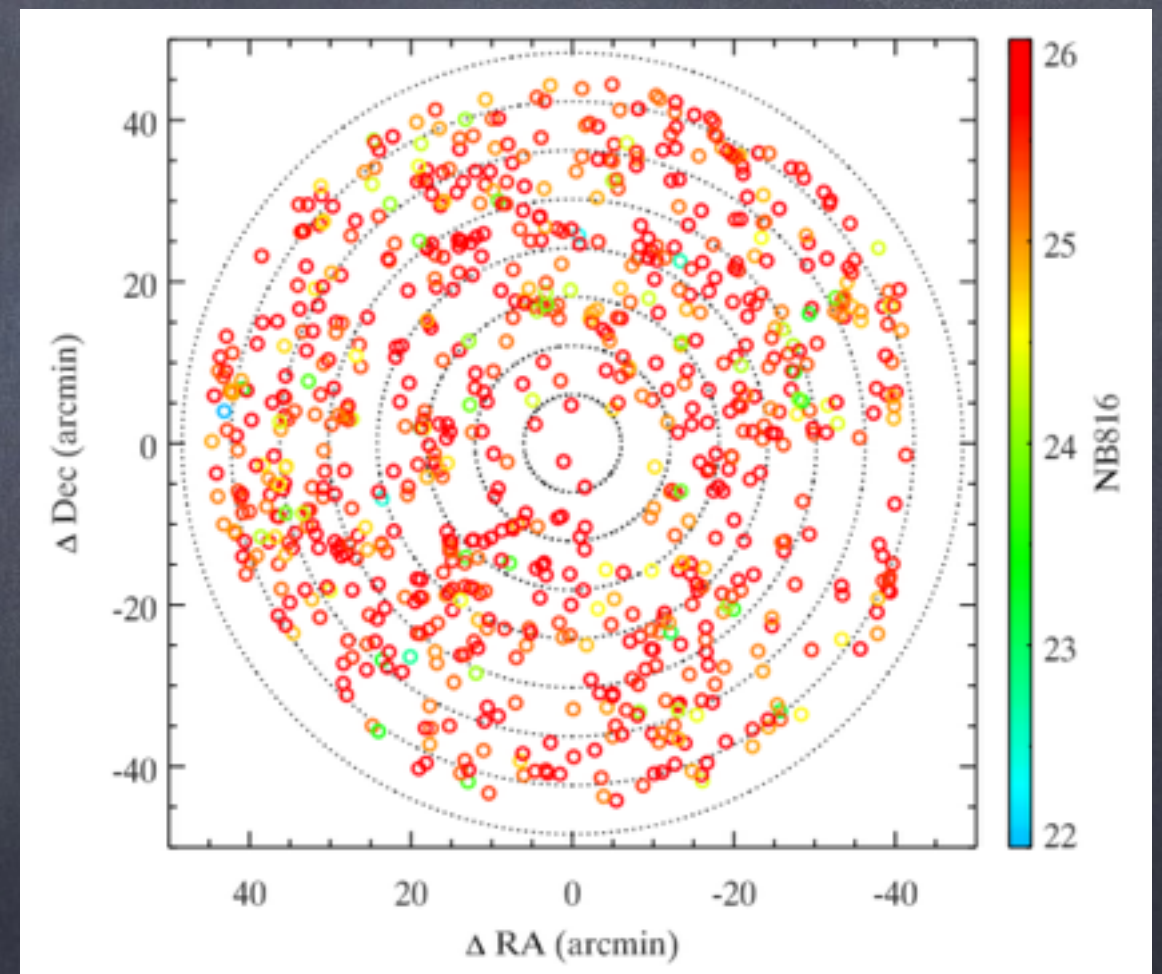
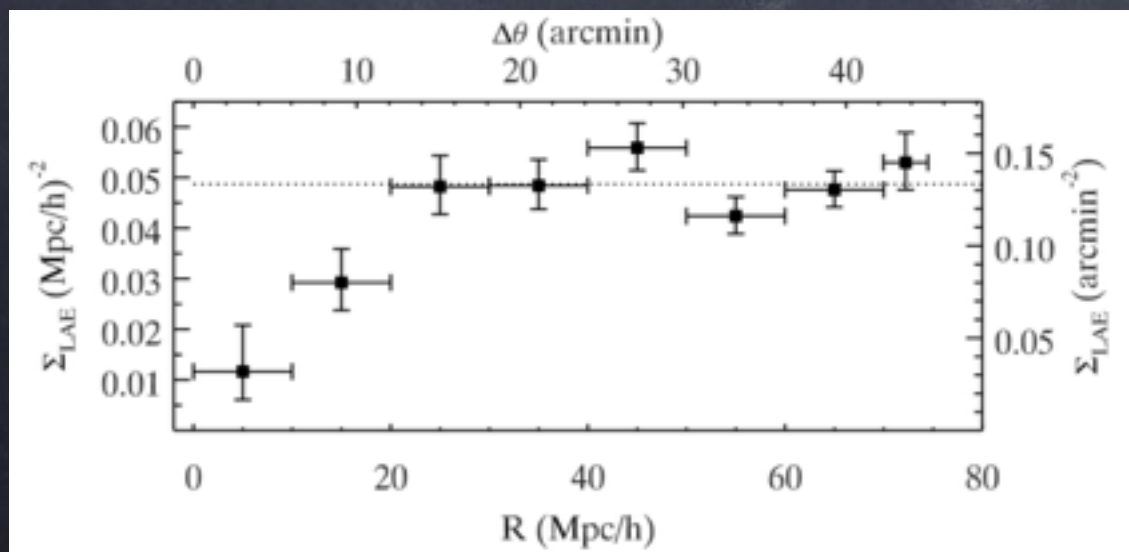


Davies et al. (2018)

- Option #1: a short mean free path triggers large fluctuations in the ionizing background (Davies & Furlanetto 2016) - possibly even ongoing reionization (Kulkarni et al. 2018)
- Option #2: relic temperature fluctuations from extended reionization (D'Aloisio et al. 2016)

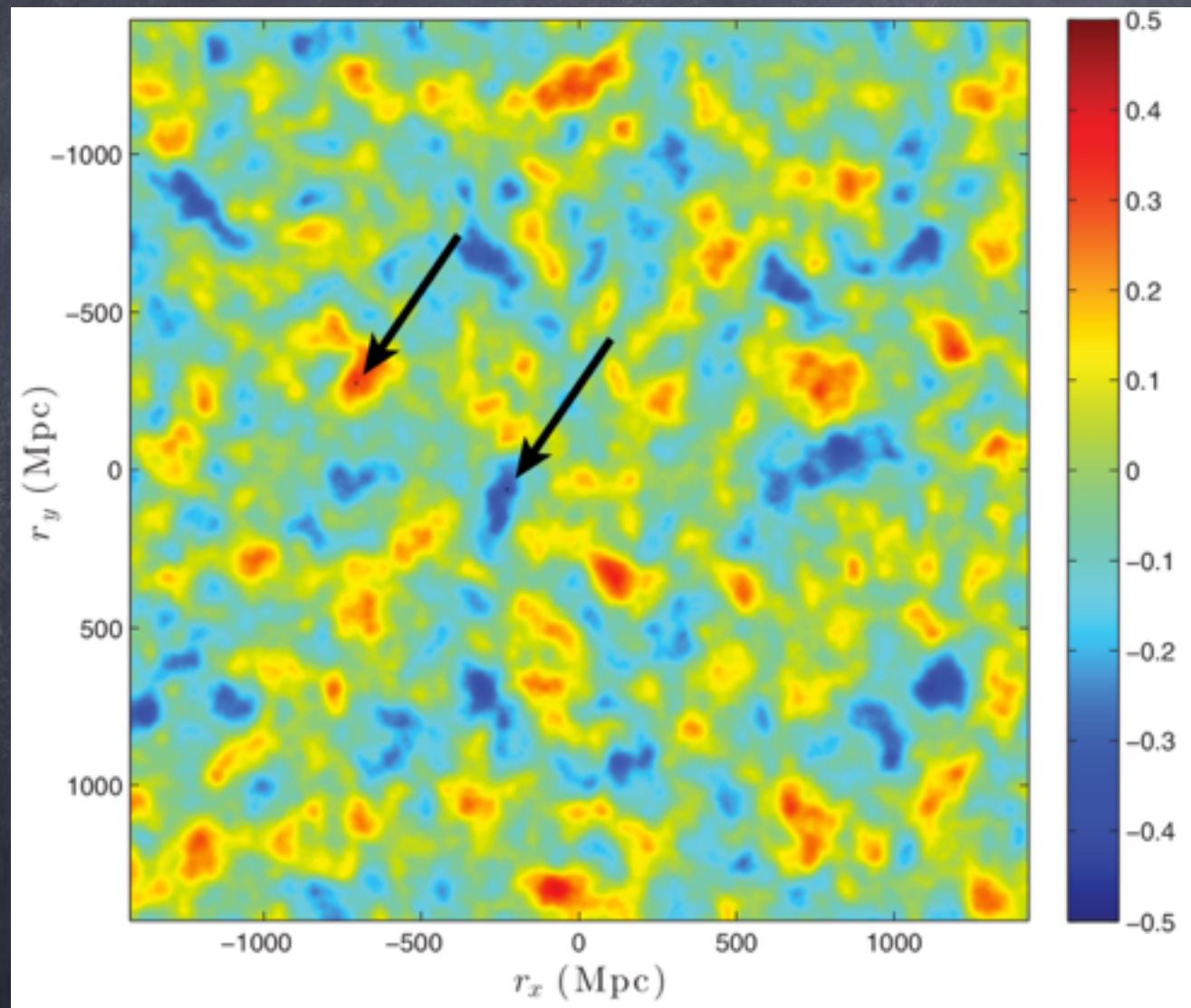
Observations!

- Used narrowband filter on HyperSuprimeCam (fortuitously matching deepest absorption trough at $z=5.7!$)
- Clear DEFICIT of LAEs in this area: points toward ionizing background explanation!
- Lessons:
 - Features in ionizing background occur on large scales (>10 Mpc)
 - Redshift information is essential!



Becker et al. (2018)

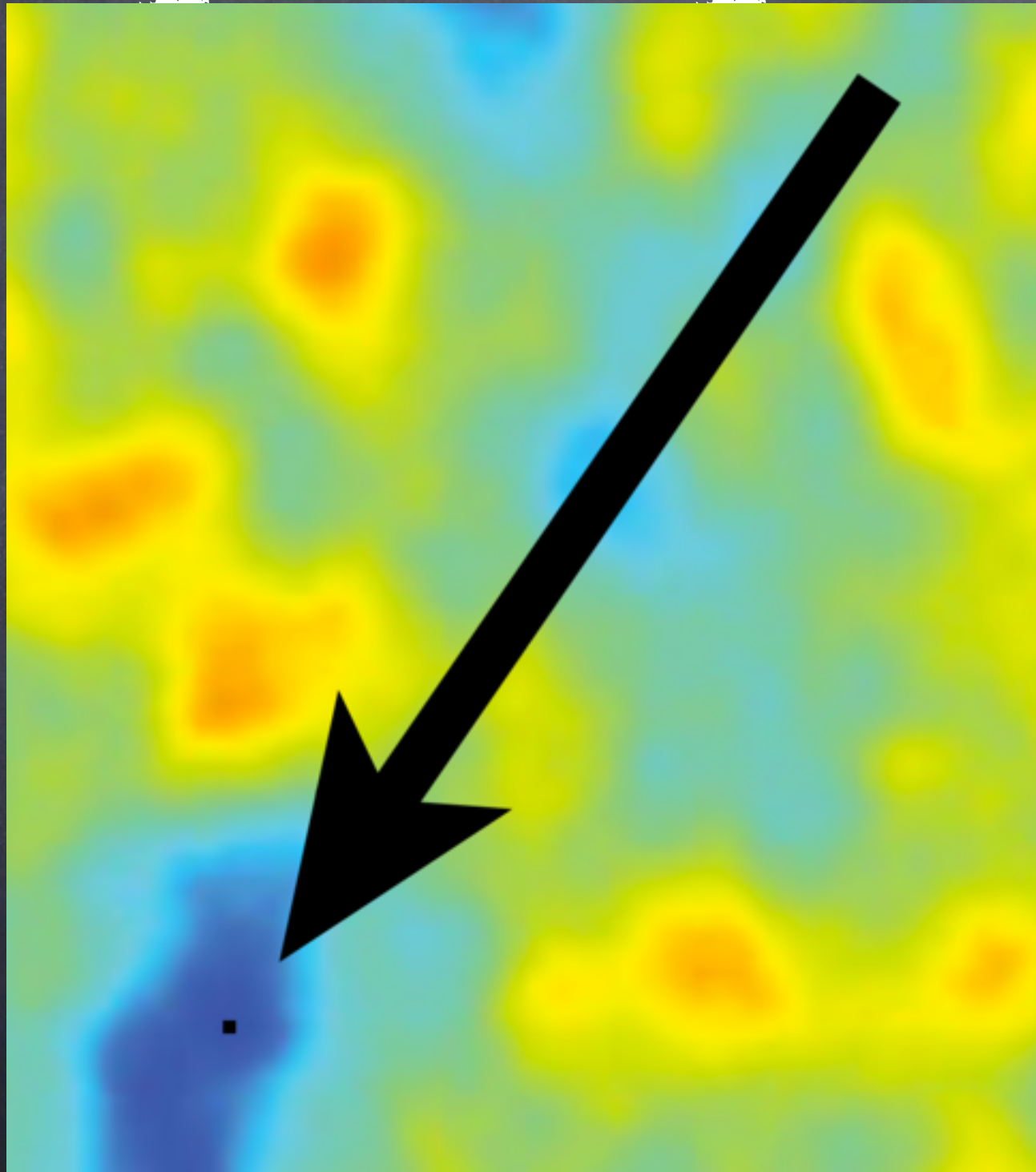
Challenges of Cross-Correlation



Beardsley et al. (2015)

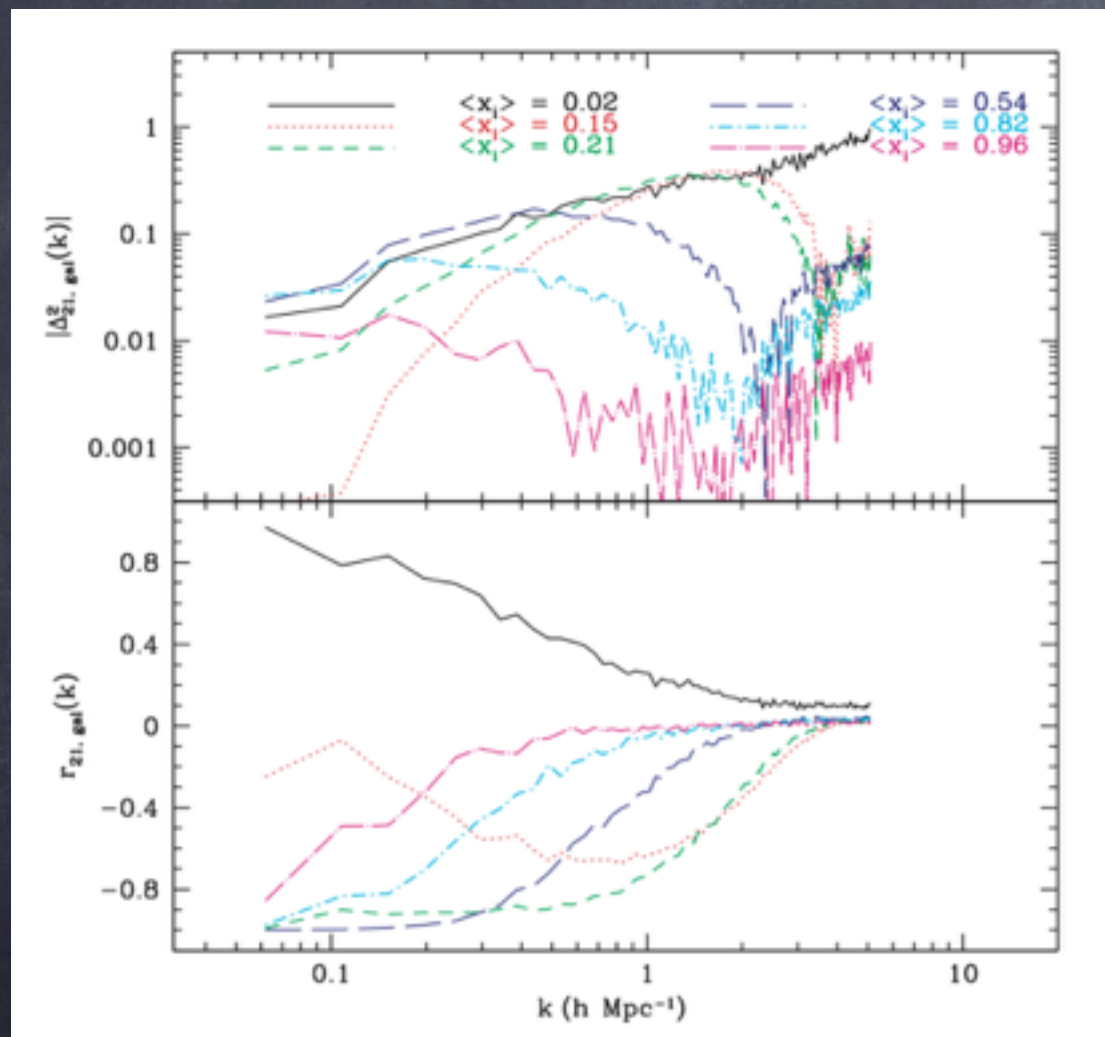
- 21-cm surveys have VERY POOR angular resolution!
 - Not SO bad because features in reionization are also large
 - Current plans call for throwing out nearly all modes with angular information
- Detailed cross-correlation⁵ requires deep observations (>10 galaxies), excellent redshifts (<3% errors), and a large areal coverage (>30 square degrees)

Challenges of Correlation



- 21-cm surveys have VERY POOR angular resolution!
 - Current plans call for throwing out nearly all modes with angular information
- Detailed cross-correlation requires deep observations ($>10^4$ galaxies), excellent redshifts ($<3\%$ errors), and a large areal coverage (>30 square degrees)

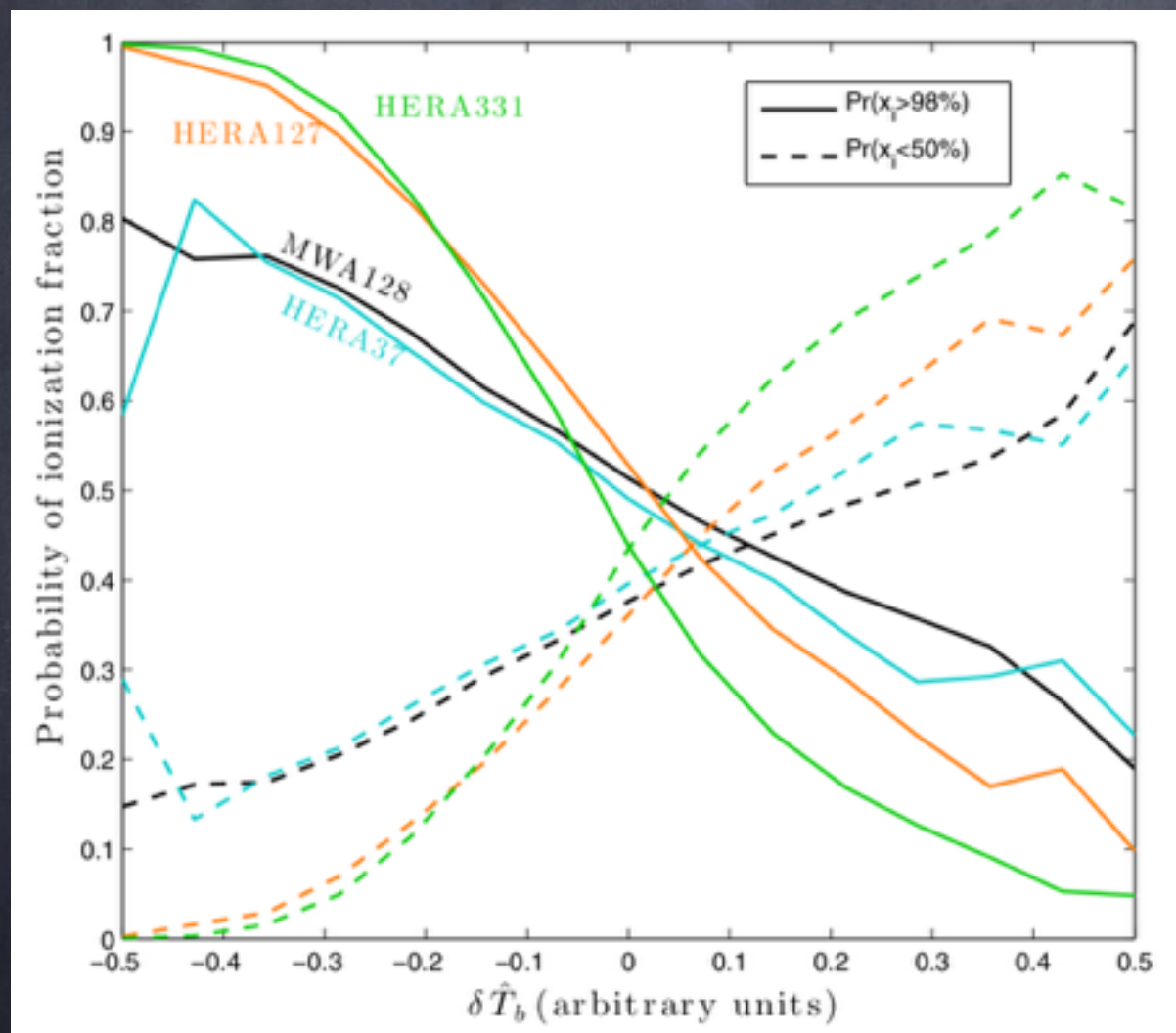
Cross-Correlation Provides Unambiguous Information on Ionized Structures



Lidz et al. (2008)

- 21-cm surveys are sensitive to the INTEGRATED emissivity, so can infer properties of faintest galaxies
- Efficient method to confirm 21-cm detection
- Offers clearer information about ionized structures

Cross-Correlation Can Provide Statistical Constraints on Galaxy Environment



Beardsley et al. (2015)

- HERA (and other near-future instruments) CAN offer statistical constraints on ionization fraction over $\sim$ arcmin scales

Conclusions

- Interpreting reionization requires overlapping studies of the ionization structures and the sources
- The post-reionization Universe already shows the power of such a connection!
- NIR surveys and 21-cm surveys are poorly matched for such an exercise...