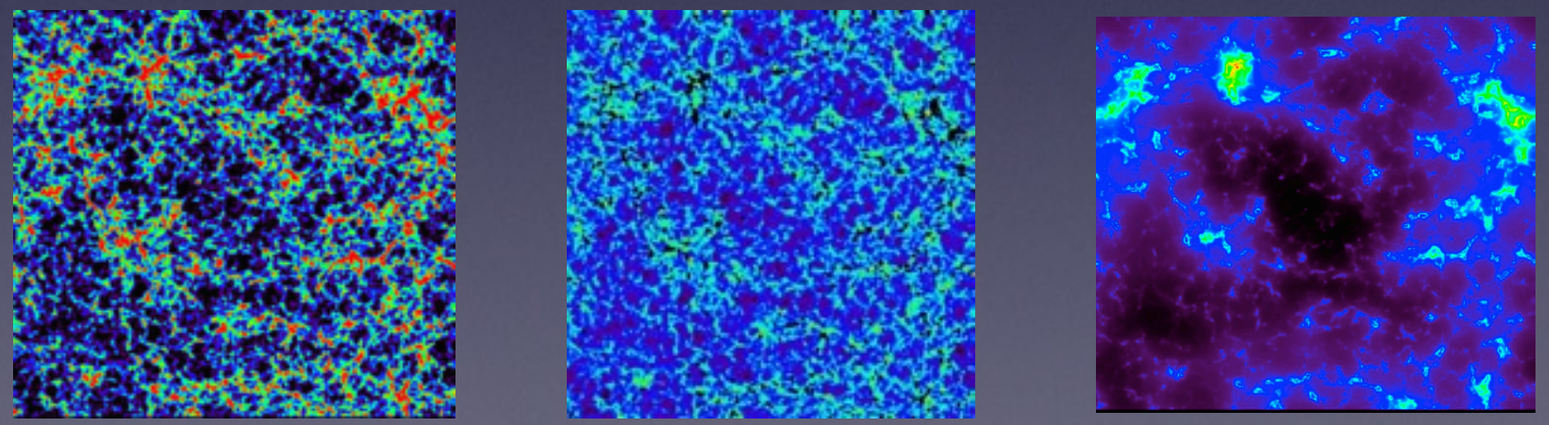
Ly-alpha and 21-cm fluctuations Cross-correlation

Caroline Heneka

Dark Cosmology Centre, NBI, Copenhagen
UC Irvine

The Reionization Epoch: New Insights and Future Prospects
Aspen Center for Physics, March 9 2016



Dark Cosmology Centre

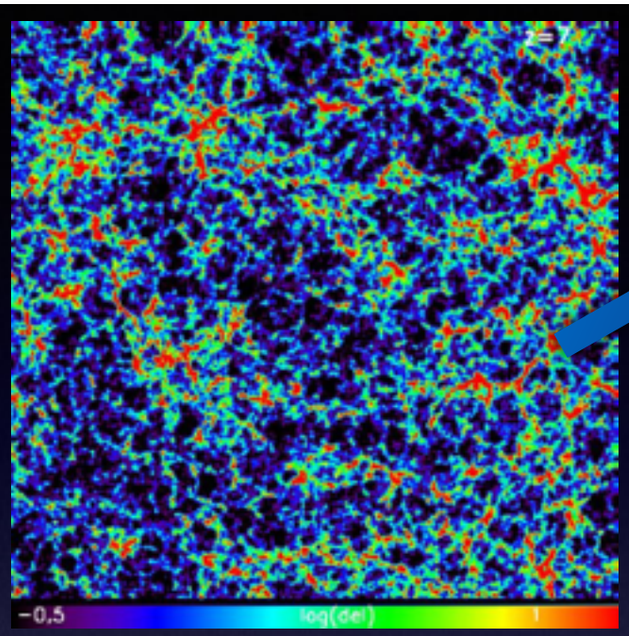
Outline

- Epoch of reionization:
  21-cm, Ly-alpha fluctuations
- Cross-correlation
- Foregrounds, 2D power spectra
- 3D intensity mapping with SPHEREx

21-cm fluctuations

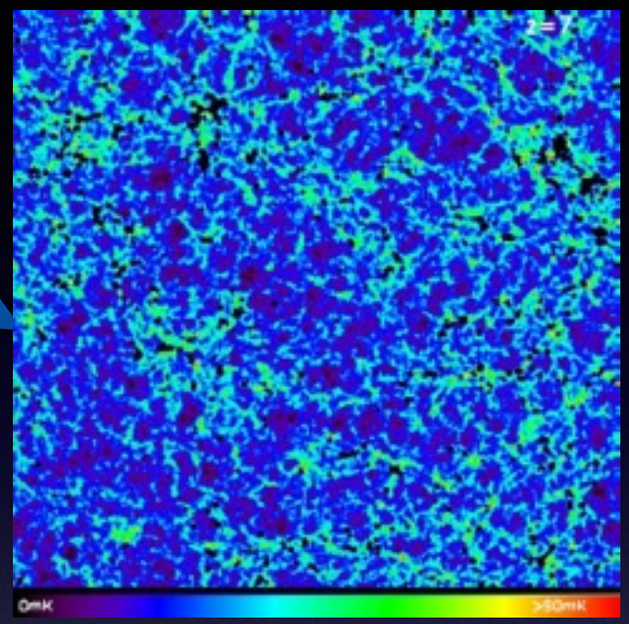
Simulation:

21cm FAST
semi-numerical
[Mesinger et al. 10]



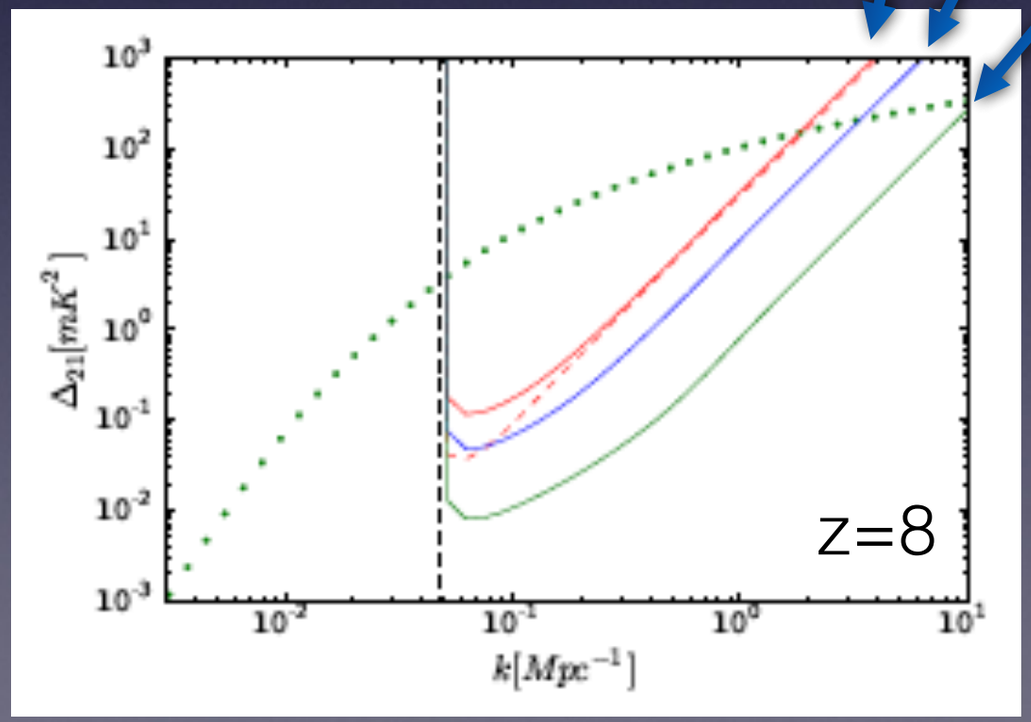
density (+ velocity) field

ionization field



offset 21-cm brightness temperature

Prediction:

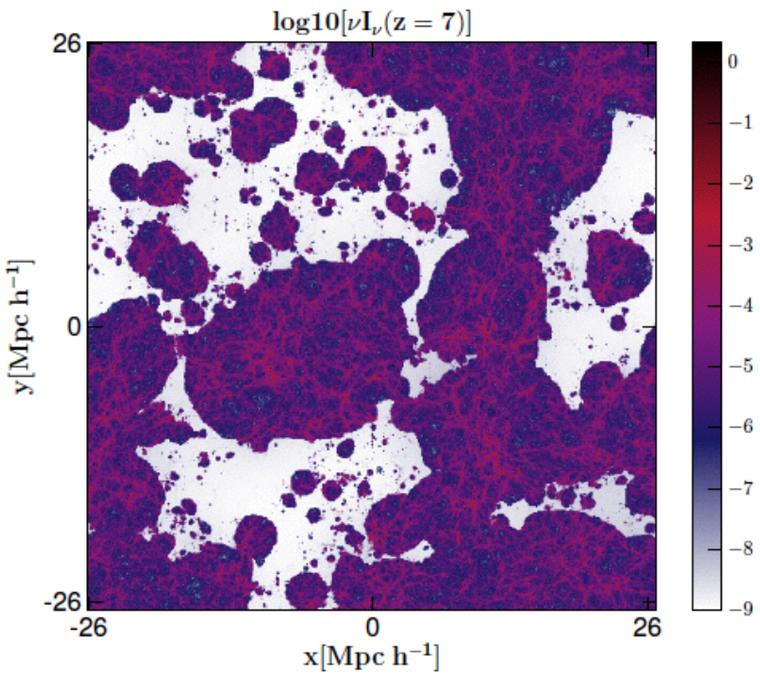


SKA sensitivities:
Pritchard et al. 2015

Ly-alpha fluctuations

Simulation:

Numerical simulation predictions:
Silva et al. 2014



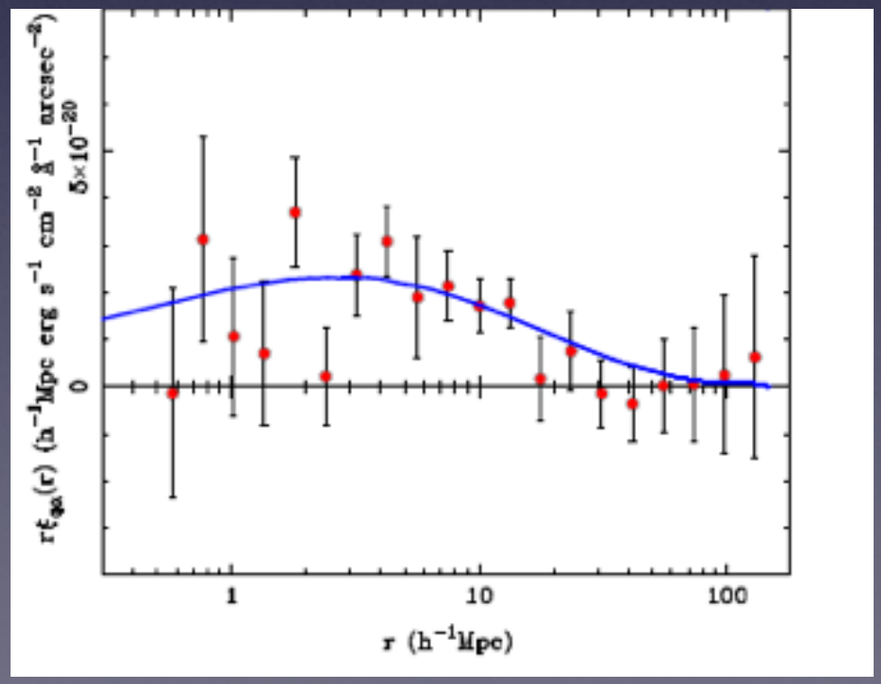
Total Ly-α intensity from galaxies and the IGM in erg s^{-1} cm^{-2} sr^{-1} at redshift 7

- Galaxy contributions:
  - Recombinations f_{rec}, f_{esc}
  - Excitations/decays E_{exc} f_{lya}
  - gas cooling (gravitational collapse)
  - Ly-α emission from stars $Q_{lya}^{stellar}$
- IGM contributions:
  - Recombinations $f_{rec}\,(T_K)$
  - Excitations/decays x_i, q_{lya}
  - Scattering of Ly-n photons from galaxies Q_{lya}^{IGM}

α SFR

T_K, x_i

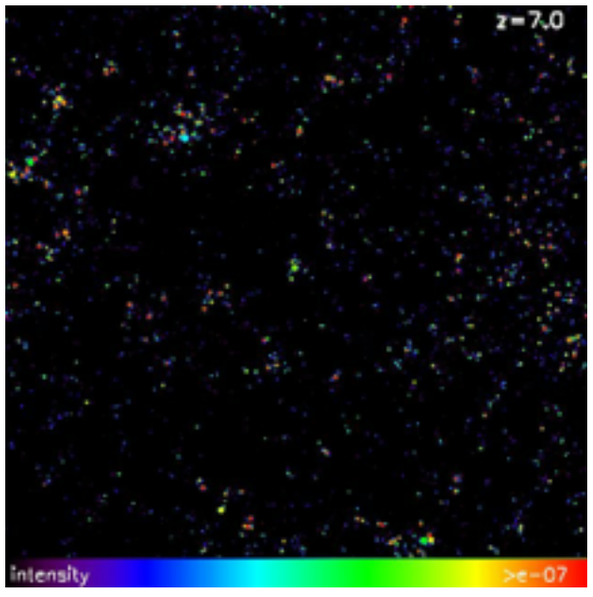
SDSS 2<z<3.5:



Ly-alpha intensity mapping with SDSS (Croft et al. 2015) quasar, Ly-alpha cross-correlation

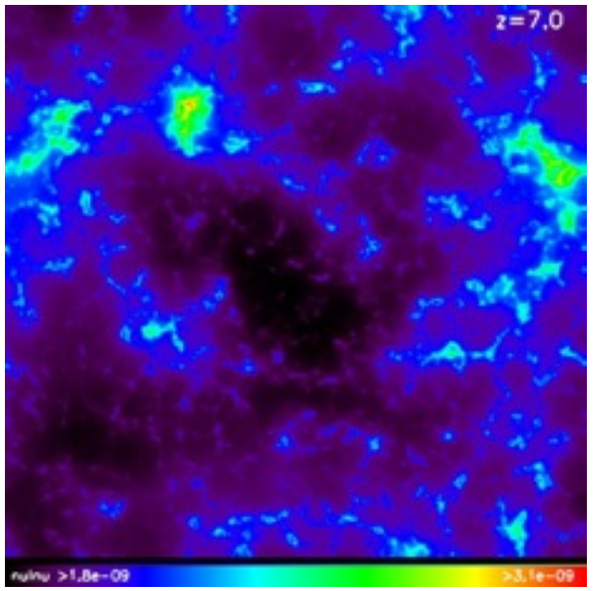
Ly-alpha fluctuations

Simulation:

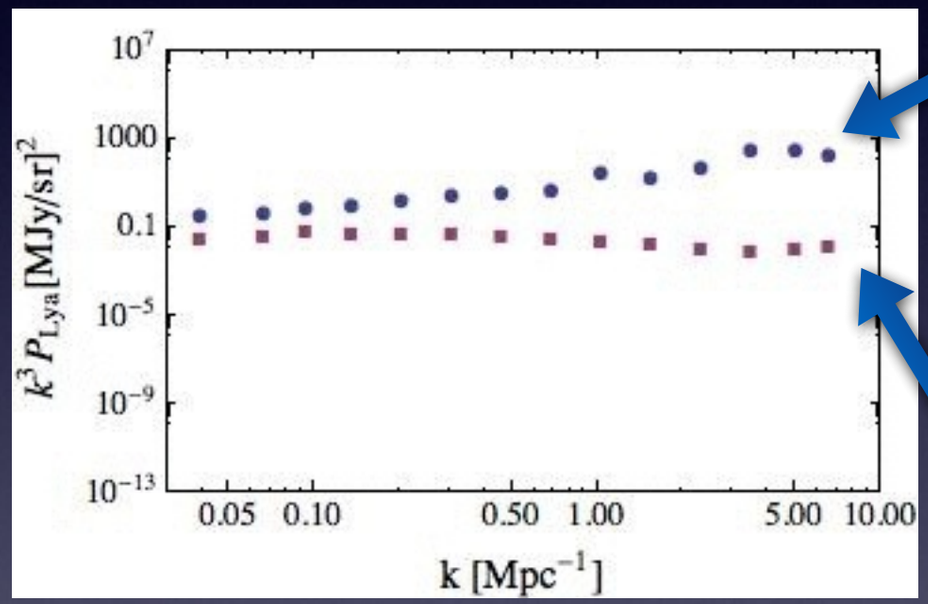


gal

z=7



IGM

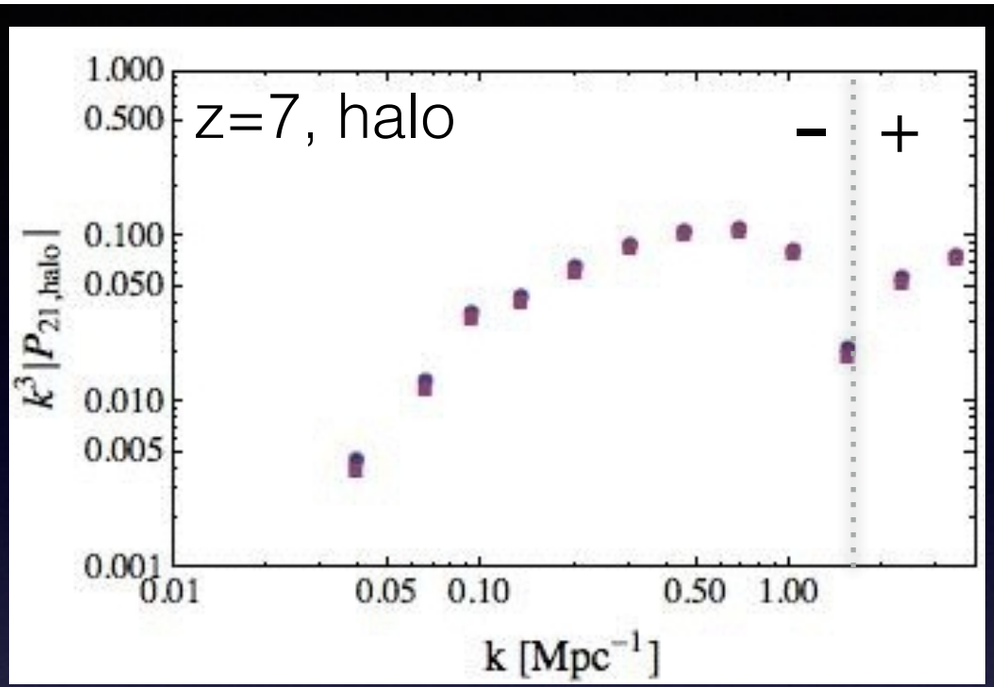


gal

IGM

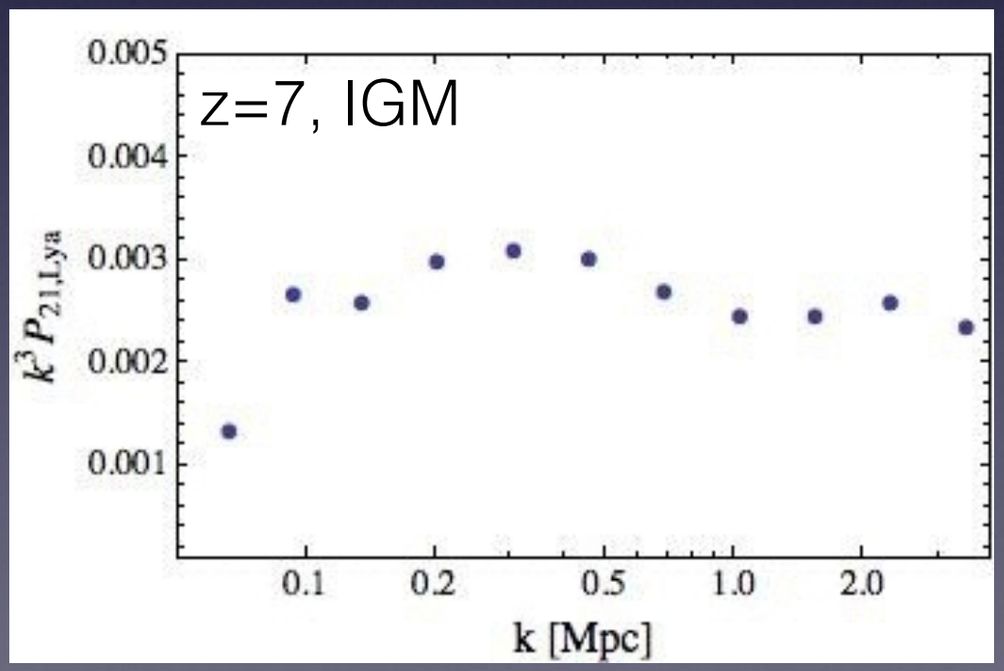
z=7

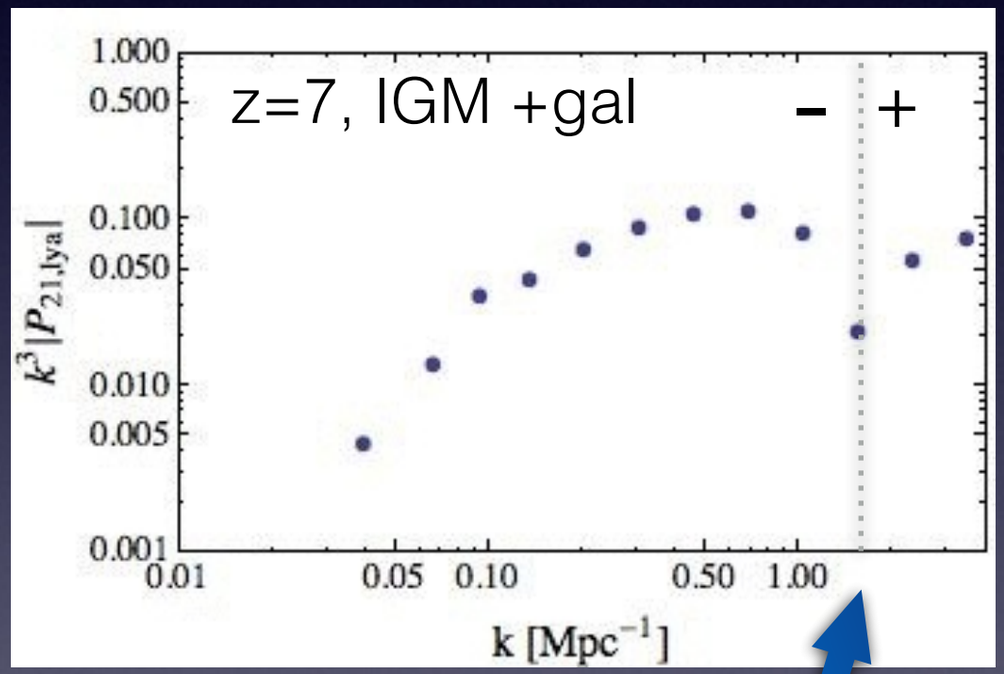
Cross-correlation



+ LAE model

+

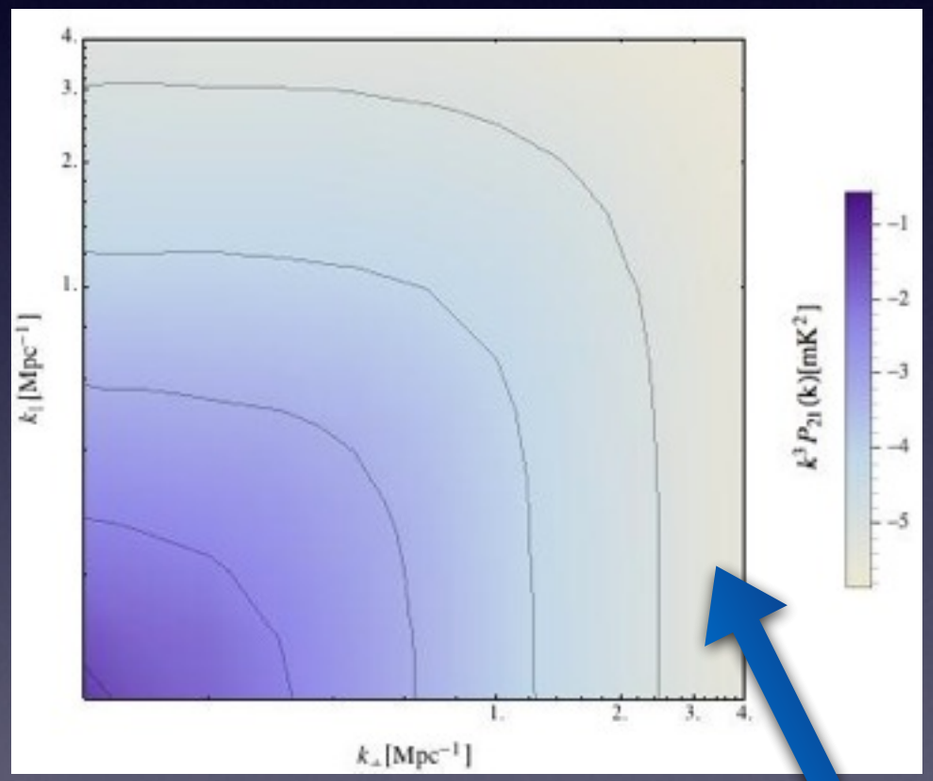


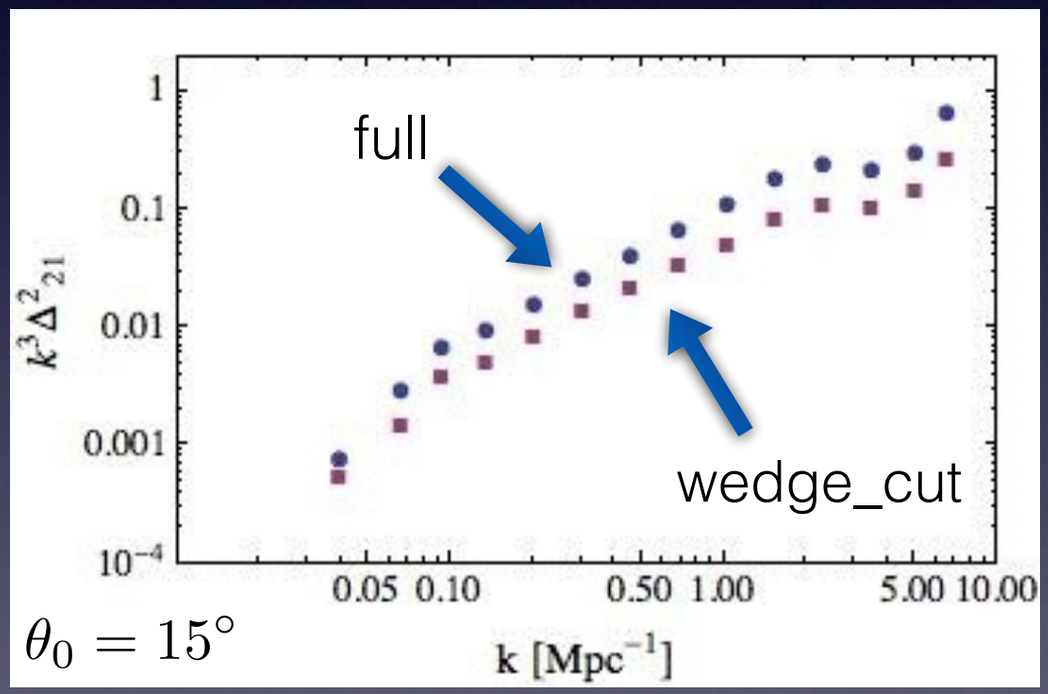


correlation change of sign shifts with z
depends on bubble size

Some words on foregrounds

- Cross-correlation of multiple lines to reduce foreground contamination
- Foreground wedge: perpendicular and parallel Fourier modes for 21cm, combination foregrounds and systematics
  BUT for Ly-alpha don't have to worry about wedge



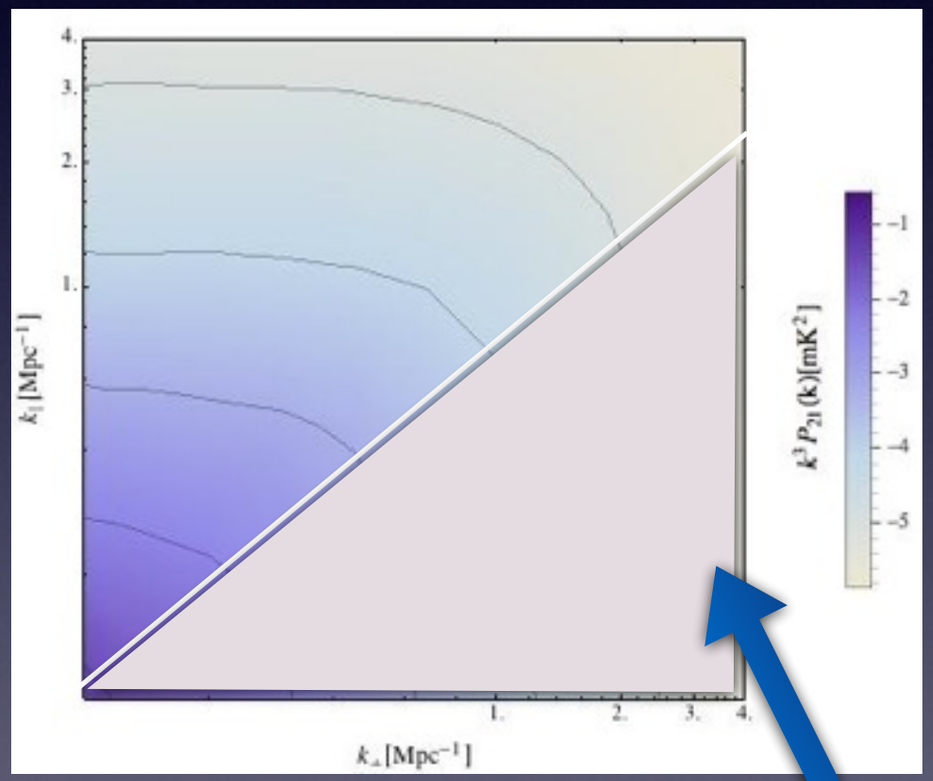


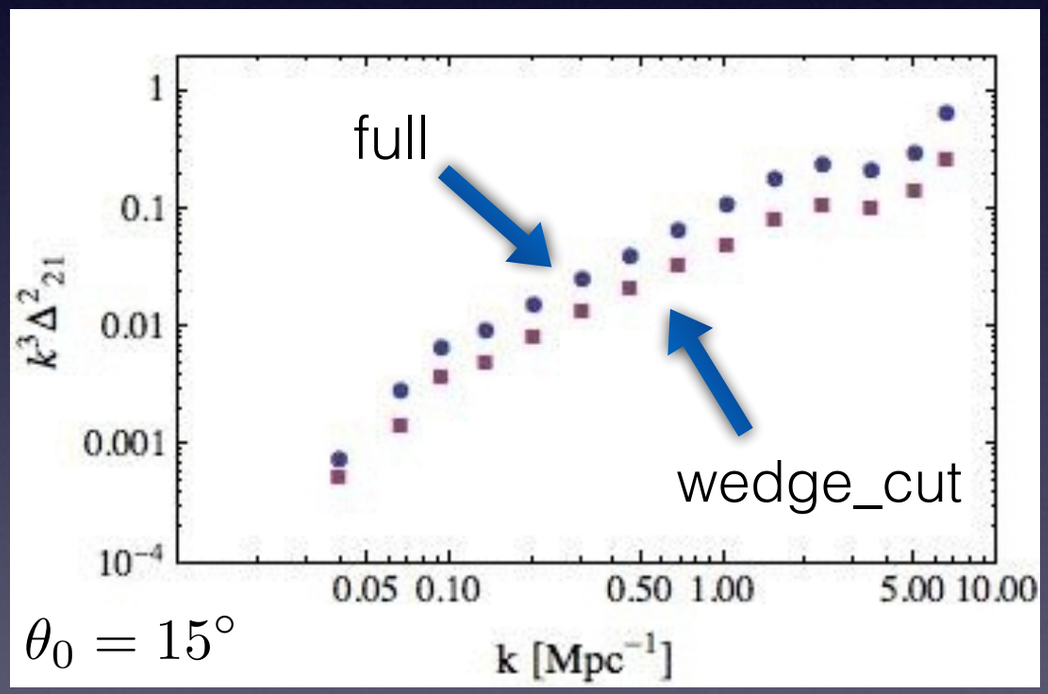
z=7

wedge: $$k_\parallel \leq \frac{d_c E(z)\theta_0}{d_H\,(1+z)} k_\perp$$

Some words on foregrounds

- Cross-correlation of multiple lines to reduce foreground contamination
- Foreground wedge: perpendicular and parallel Fourier modes for 21cm, combination foregrounds and systematics
  BUT for Ly-alpha don't have to worry about wedge



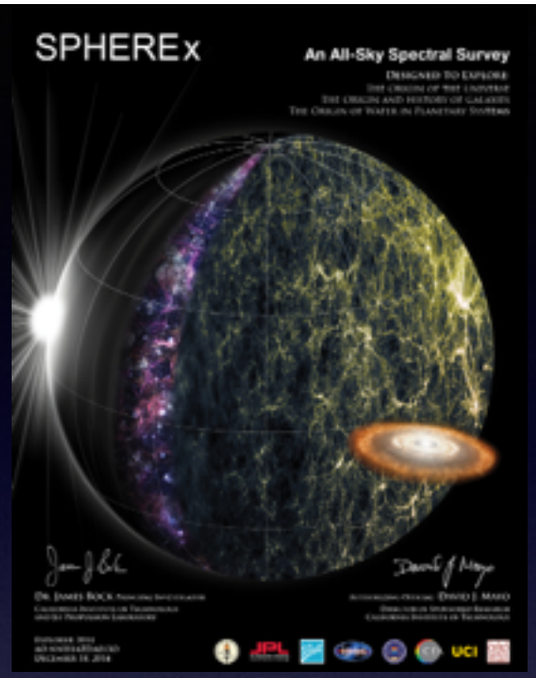


z=7

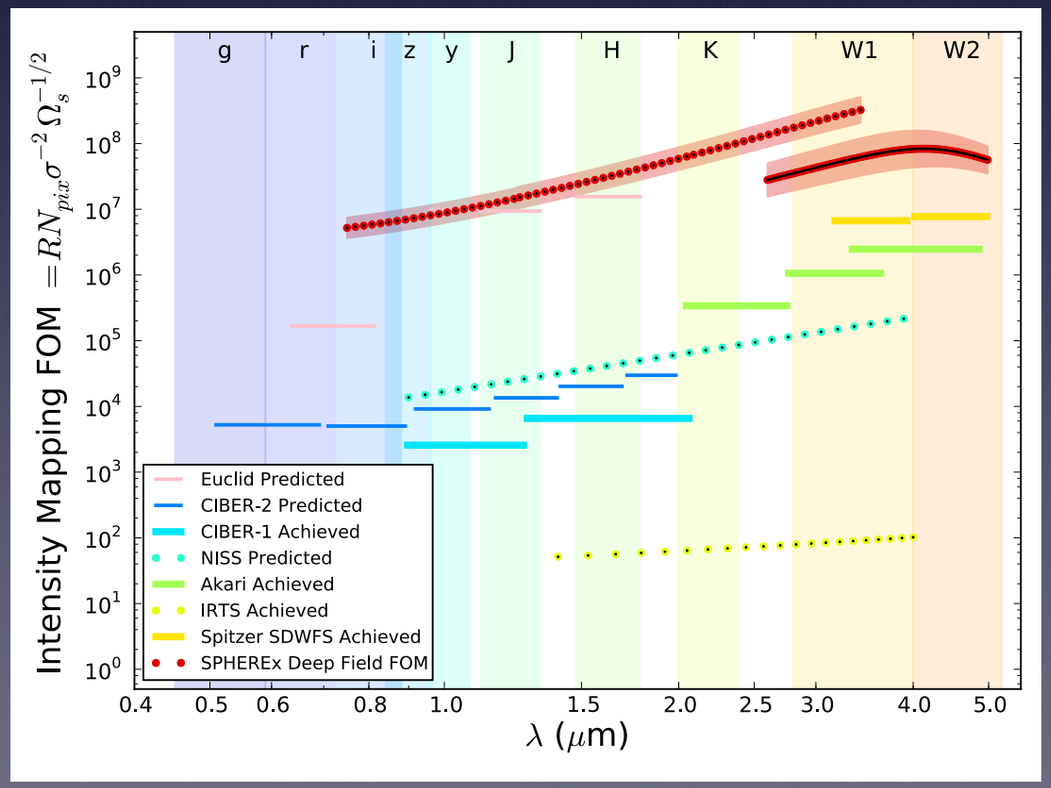
wedge: $k_\parallel \leq \frac{d_c E(z)\theta_0}{d_H\,(1+z)} k_\perp$

[simulate to include systematics, see PRISim]

The SPHEREx satellite, intro



Part of SPHEREx slides: Courtesy of Asantha Cooray



Summary paper: Doré *et al*. arXiv 1412.4872

NASA Small Explorer in Phase-A Study

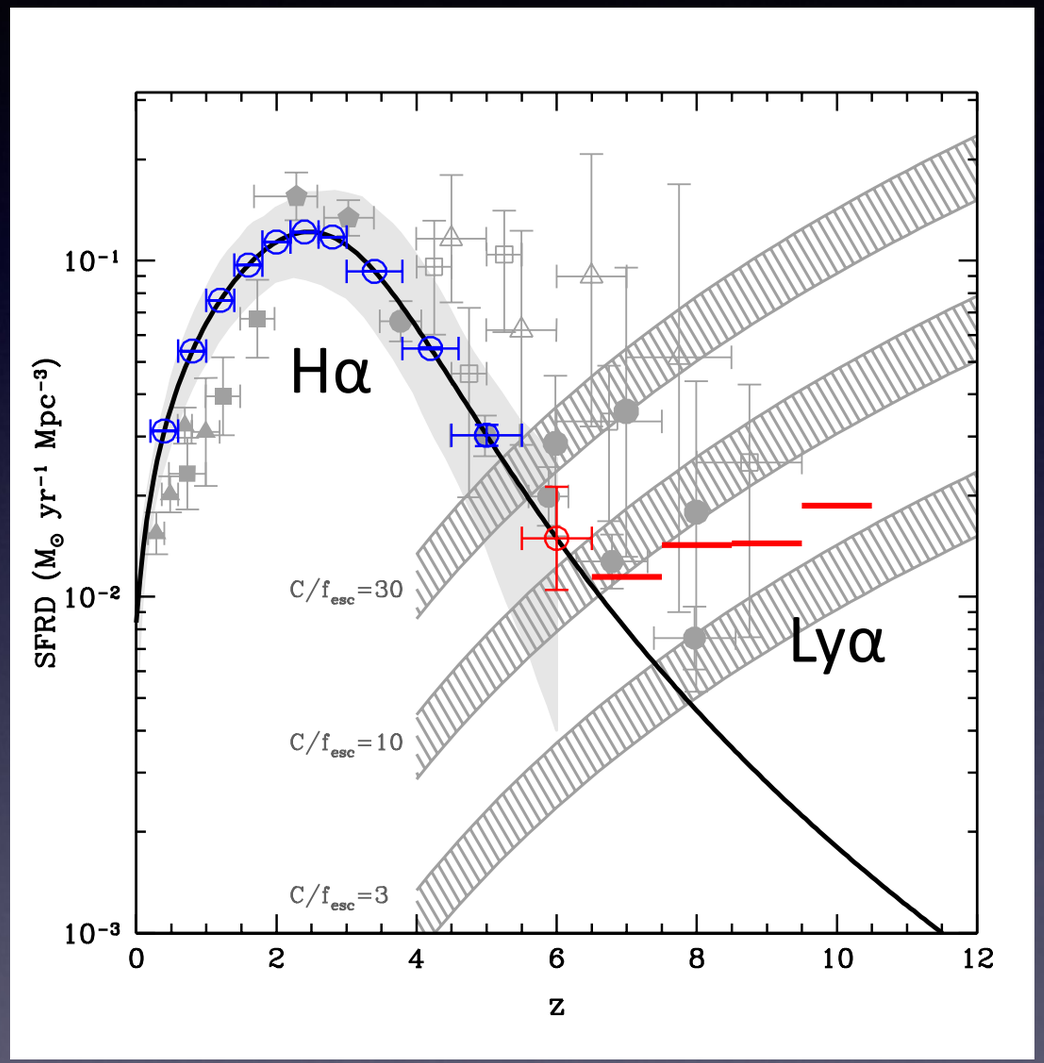
<u>All-sky near-IR spectral survey</u>

- Probing galaxy formation through precise measurements of extragalactic background light anisotropy
- Rich spectral catalog for the astronomy community
- Science enhancement option involving 3D spectral line intensity mapping (for SFRD and reionization)
- Legacy applications with 21-cm background
- SPHEREx has ideal wavelength coverage and high sensitivity to detect the EoR integrated galaxy intensity signal
- Multiple bands enable correlation tests sensitive to redshift history

Resolving Power and Wavelength Coverage :
λ= 0.75- 4.1 μm; R=41.5
λ= 4.1- 4.8 μm; R=150

Field of View: 3.5° x 7.0°

Intensity mapping with SPHEREx

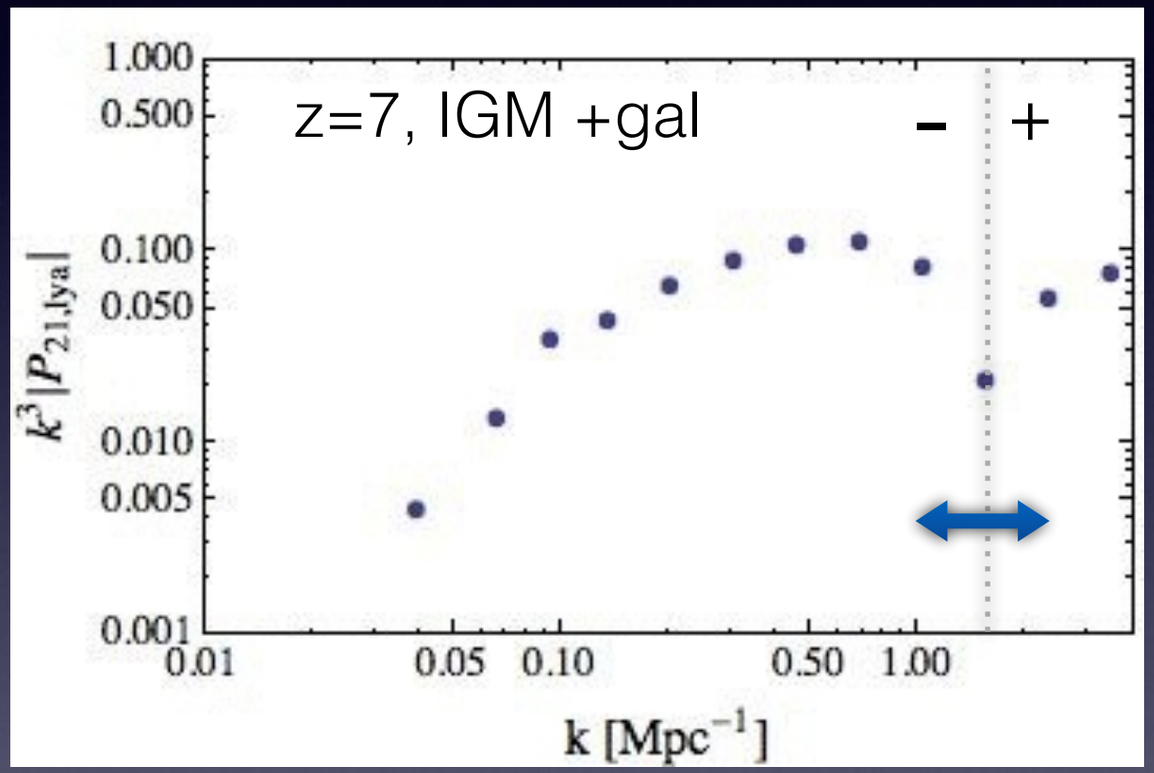


SPHEREx will map Ly-alpha emission during reionization.

We may see z~6 Lyα fluctuations

At z > 6 SPHEREx alone will not have sensitivity for a detection of the power spectrum [for Hopkins & Beacom SFRD].

Intensity mapping with SPHEREx



(a) SPHEREx Lyα intensity maps ideal for cross-correlation with 21-cm fluctuations (from SKA-low/HERA)

(b) Correlation negative at large scales to positive at small scales

(c) Statistical measure of average reionization bubble size

[S/N calculation work in progress]

Summary

- Study of Reionization:
  3D intensity mapping of spectral lines (SPHEREx)
- Power spectra, correlate -> bubble size
- Foregrounds to deal with (see 2D power spectra)