Predictions for High-z CO (Diffuse) Measurements

Steve Furlanetto for the COnsortium

Adam Lidz, Chris Carilli, Tzu-Ching Chang,
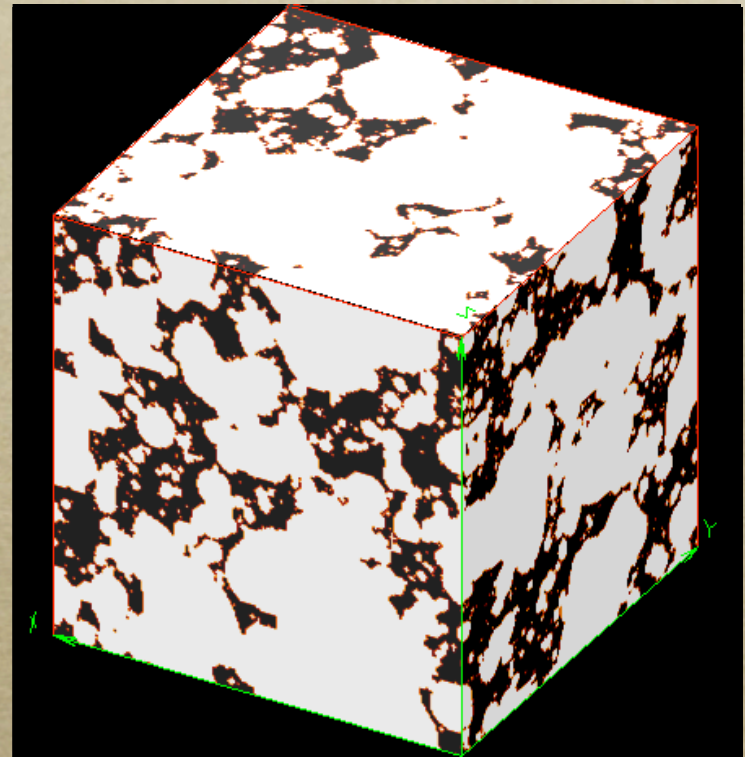*Olivier Dore, Peng Oh, Jonathan Pritchard*
November 18, 2010

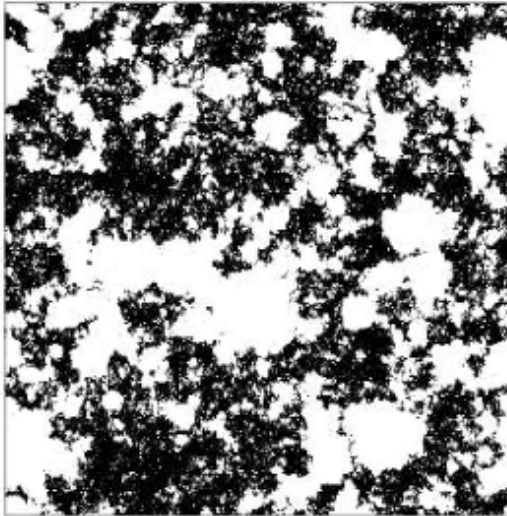*Independent calculation by Asantha Cooray in the works

Reionization

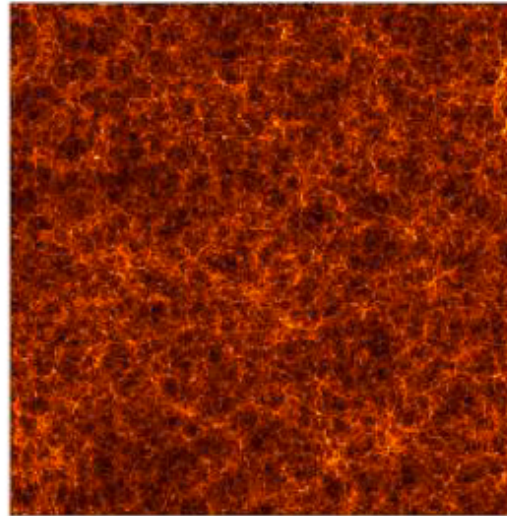○ *Key question: where are the bubbles, and what galaxies drive them?*
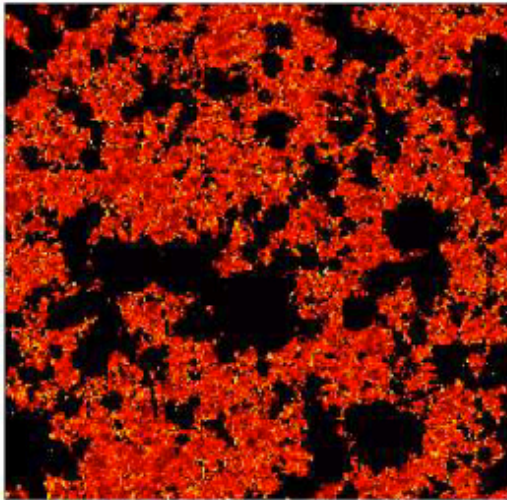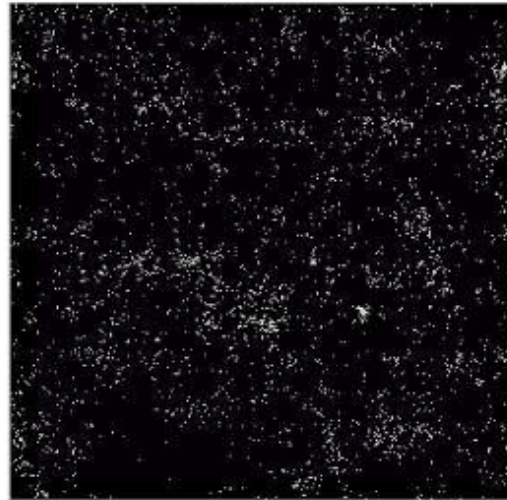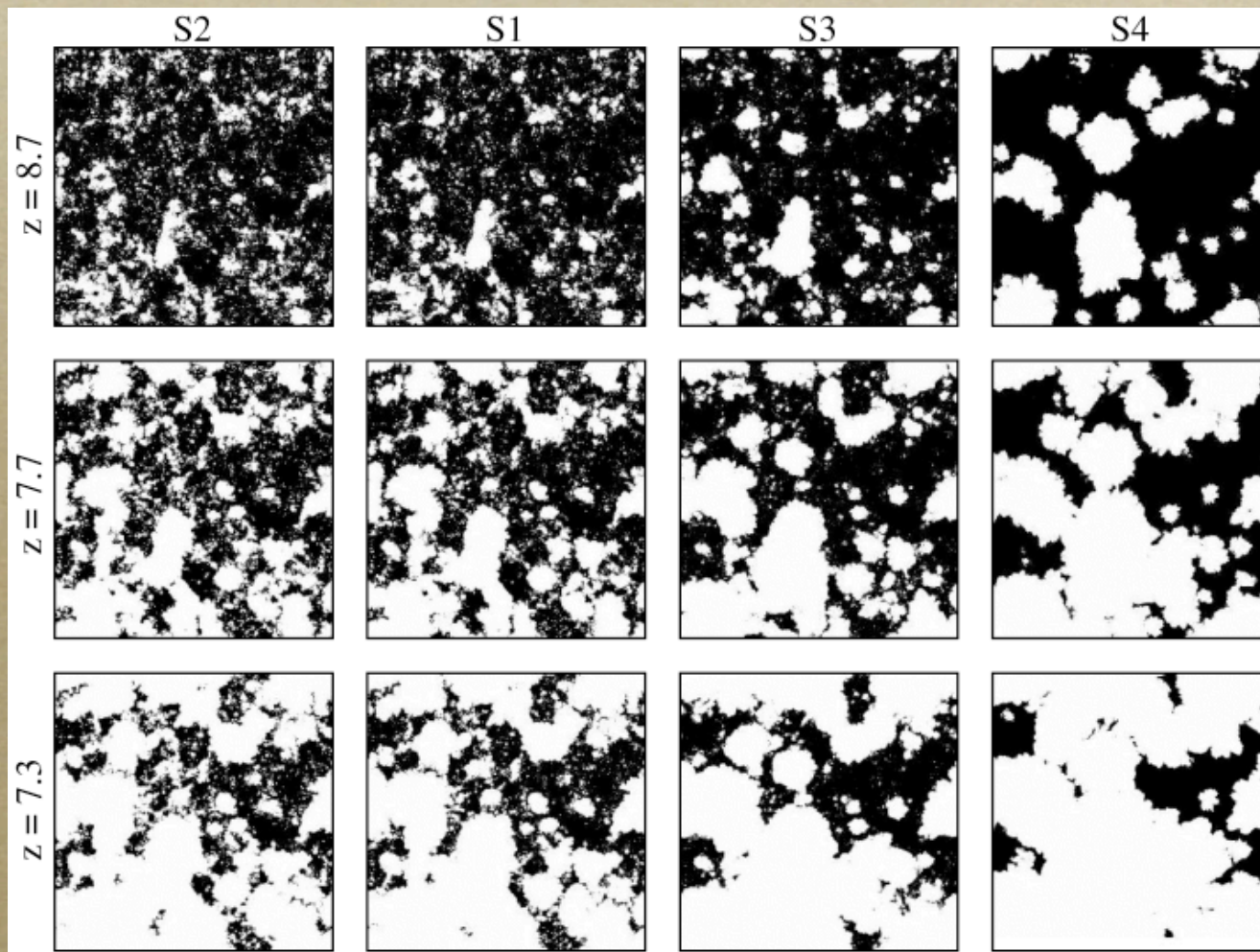
The Big Picture

Reionization: Galaxy Populations

McQuinn et al. (2007); Furlanetto et al. (2004)

Estimating CO: The Carilli Algorithm

- *Assumptions*

  - *Universe is reionized at z=7 (using "standard" relation between SFR and ionization state)*

    - *Depends on UV escape fraction, IMF, and IGM clumping factor*

  - *Local relation between IR luminosity and SFR applies*

  - *Local relation between IR luminosity and CO luminosity applies*

$$S_{2-1} = 58 f_{\text{esc}}^{-1} \left(\frac{C}{5} \right) \, \mu\text{Jy} \quad \textit{(for 15' pixels [40 cMpc])}$$

For comparison: 25 m antenna, 100 hrs, 1% spectral resolution: noise = 78 μJy

CO Fluctuations

- *Fluctuations will trace dark matter power spectrum*

- *Only additional input is mean bias of galaxies (b~2-4; take M=10^10 Msun here)*
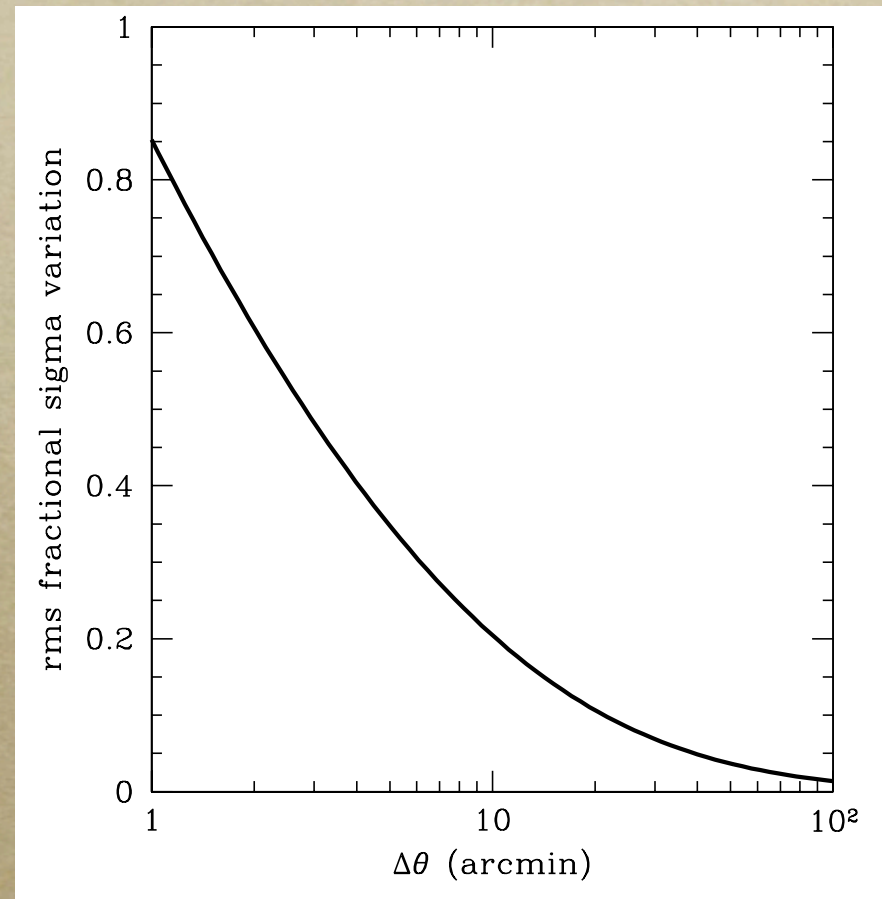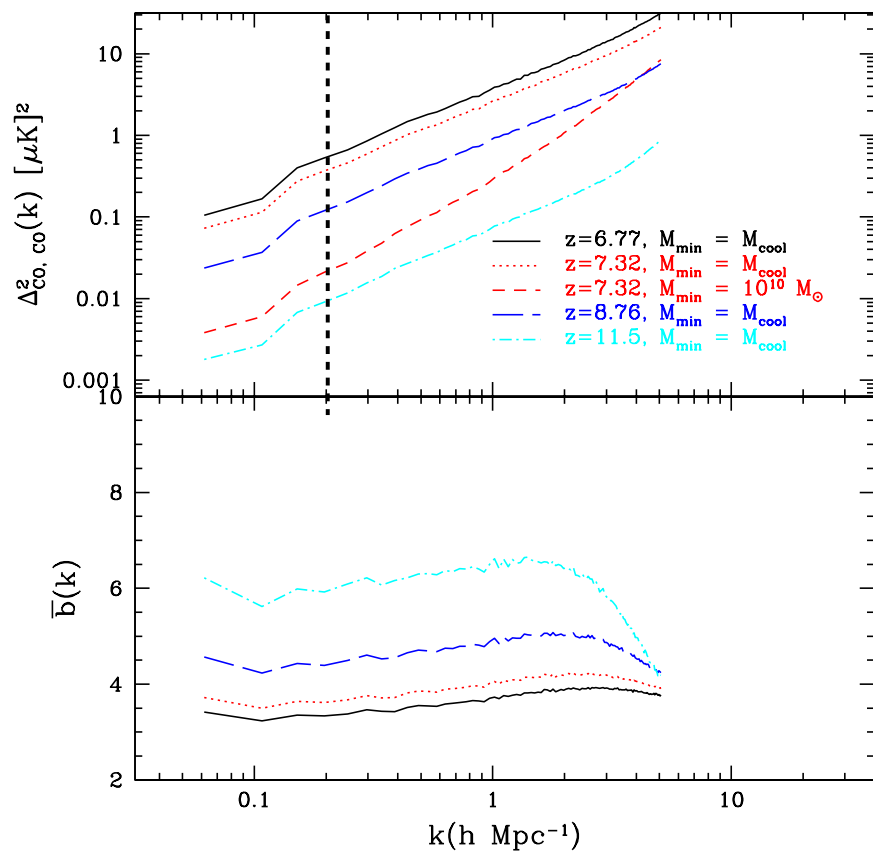
Underlying Assumptions

- *One-to-one relation between halo mass and SFR:* $\mathrm{SFR} = 0.2(M/10^9\,\mathrm{M_\odot})\,\mathrm{M_\odot\,yr^{-1}}$

- *All halos above some threshold mass form stars (10^4 K or 10^{10} Msun)*

- *Use Righi et al. conversion from SFR to CO luminosity:* $L_{CO} = 10^4(\mathrm{SFR/M_\odot\,yr^{-1}})\,\mathrm{L_\odot}$

- *Mean brightness:* $T_b(\nu_{\mathrm{obs}}) = 1.5(f_{\mathrm{coll}}/0.1)\mu\mathrm{K}$

Carilli estimate (I hope!): $T_b \approx 0.15 f_{\mathrm{esc}}^{-1}(C/5)\mu\mathrm{K}$
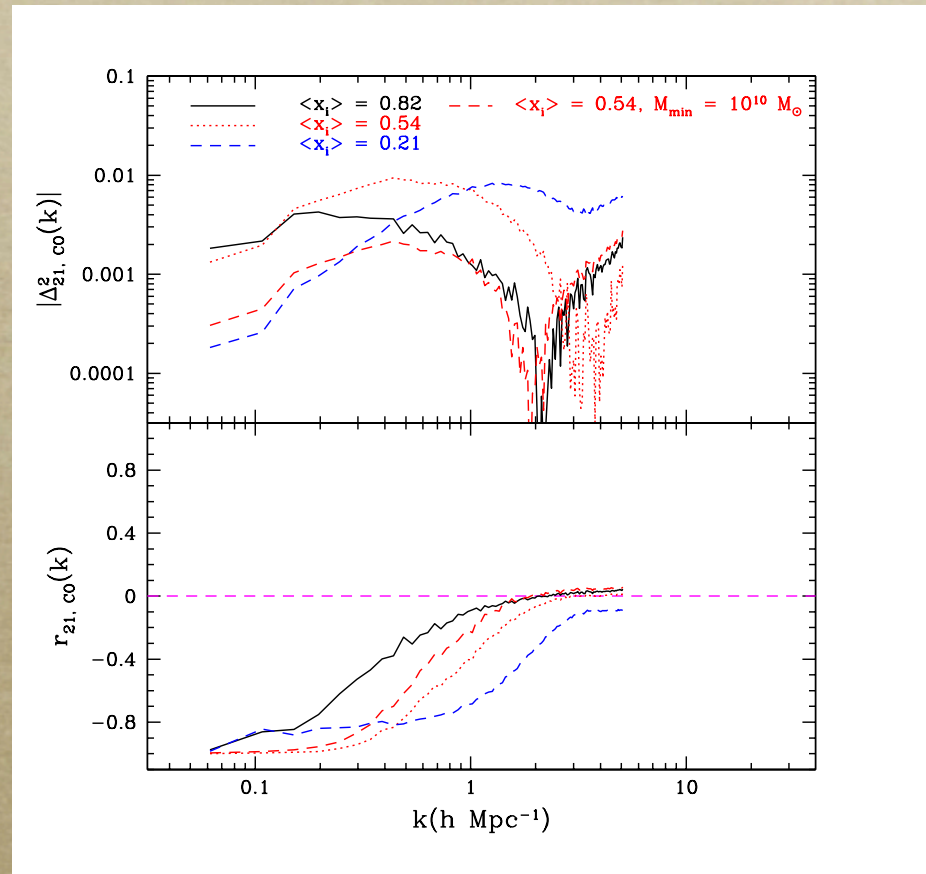
Simulation Estimates: CO power spectrum

40 cMpc

- *Auto-power spectrum over variety of redshifts*

- *Optimistic case: small galaxies (total higher SFR)*
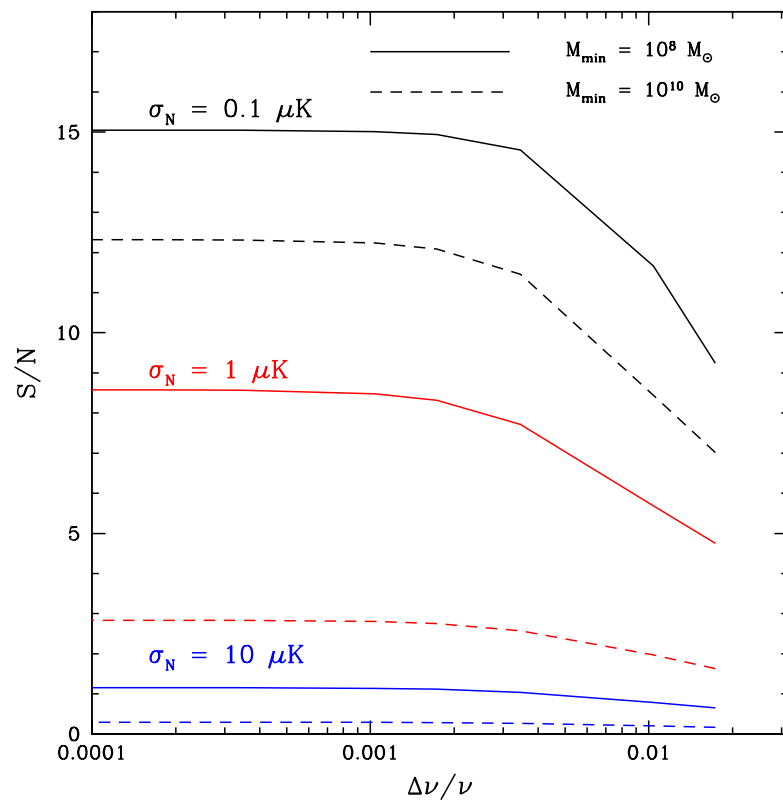
- *On ~10' scales, ~0.1-1 μK*

21 cm-CO cross-power spectrum

○ *Cross-power between 21 cm signal and CO luminosity*

○ *Cross-correlation coefficient is*

$$r = P_{21-CO}/\sqrt{P_{21}P_{CO}}$$

S/N Estimates

- *Assume: MWA-like survey (LOFAR likely a couple times better)*
  - *$\Delta\nu/\nu \sim 0.03$ bandwidth*
- *Assume 25 sq. degrees for CO survey*
- *Prescribe thermal noise per channel (listed for 10' pixels)*
  - *Assume "white noise" power spectrum*

Pitfalls: The L_{CO}-SFR Relation

- *Theoretically, depends on…*

  - *Excitation temperature of the gas (local radiation field: bursty galaxies?; thermalization at low J? IMF?)*

  - *CMB radiative transfer ($T_{ex} >> T_{CMB}$?)*

  - *Metallicity*

  - *Optical depth of molecular clouds*

  - *Geometry of star-forming gas (discrete clouds or smooth medium?)*

- *Empirically...*

  - *What kinds of galaxies are they - "normal" or starbursts?*

To-Do List

- *Check results*

- *Look at range of "properly-normalized" models*

- *Need reasonable estimates for noise (T_{sys}) and noise power spectrum*

- *Foregrounds!*