The Epoch of Reionization

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Sequence of events

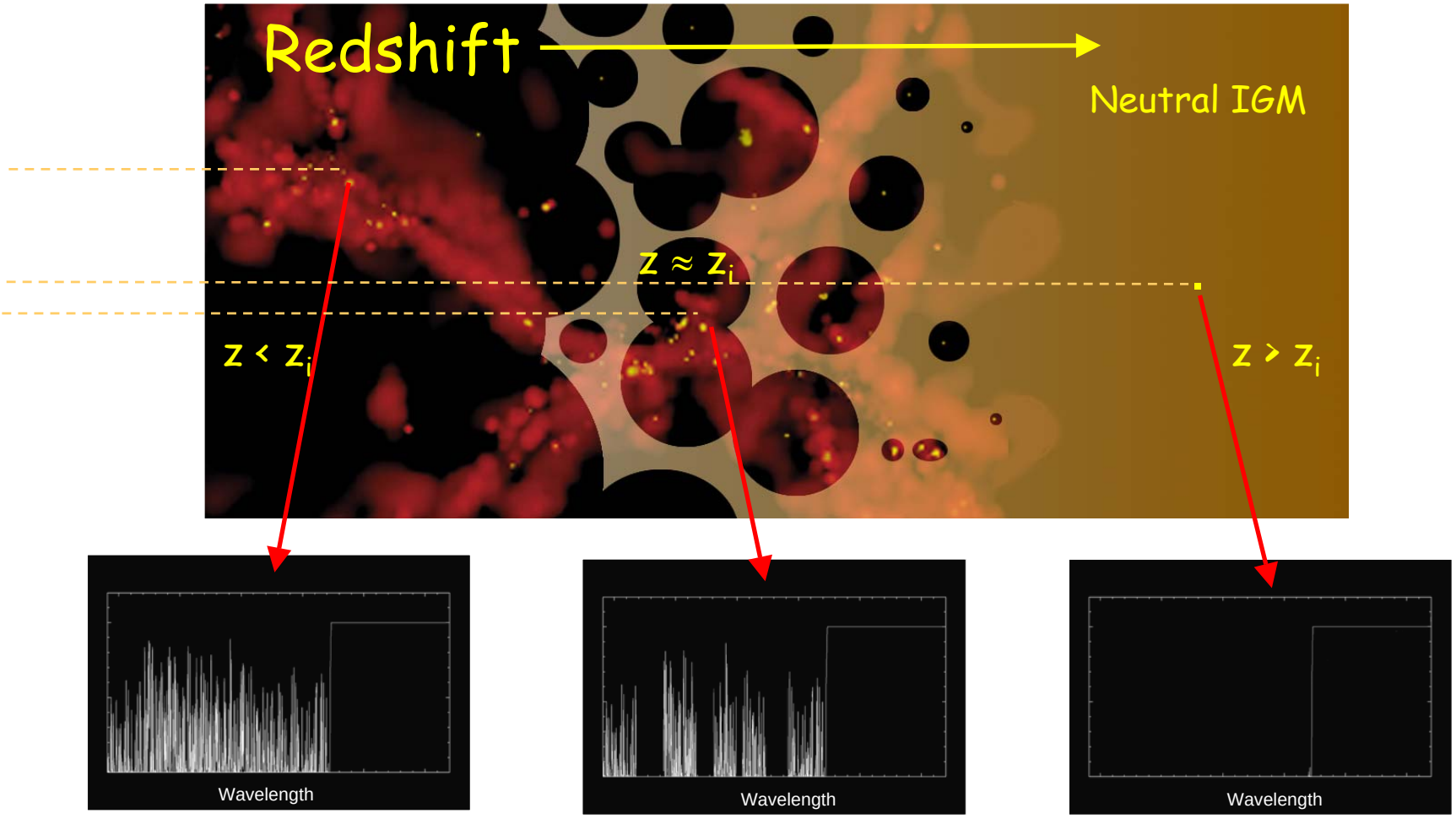
At z=1000 the Universe has cooled down to 3000 K. Hydrogen becomes neutral ("Recombination").

At z < 20 the first "PopIII" star (clusters)/small galaxies form.

At z ~ 6-15 these gradually photo-ionize the hydrogen in the IGM ("Reionization").

At z<6 galaxies form most of their stars and grow by merging.

At z<1 massive galaxy clusters are assembled.



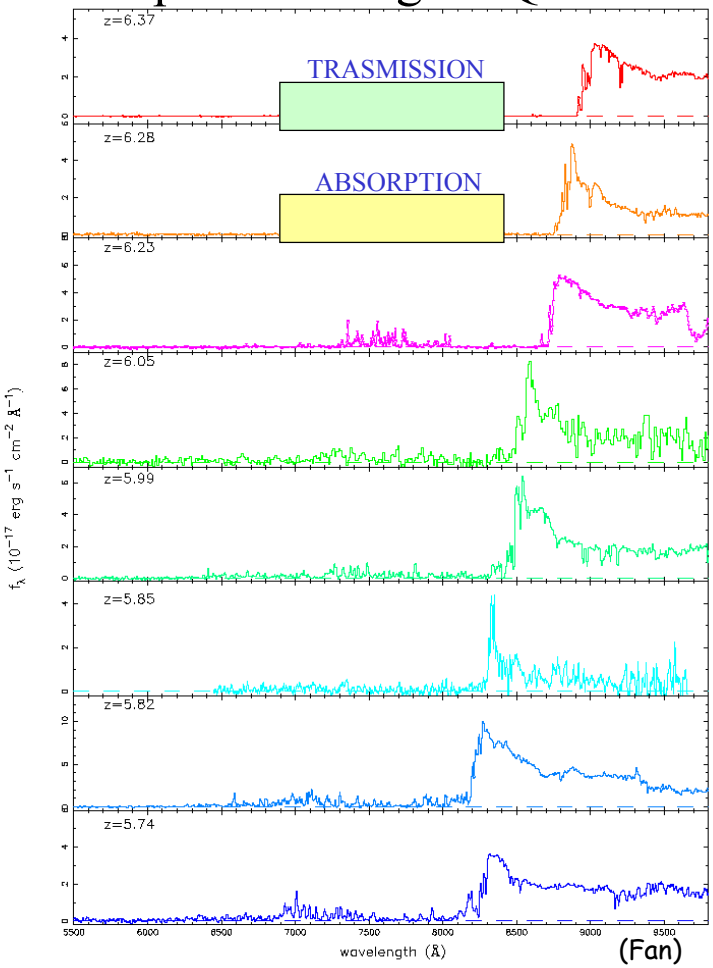
Lyman Forest Absorption

Transmission Gaps

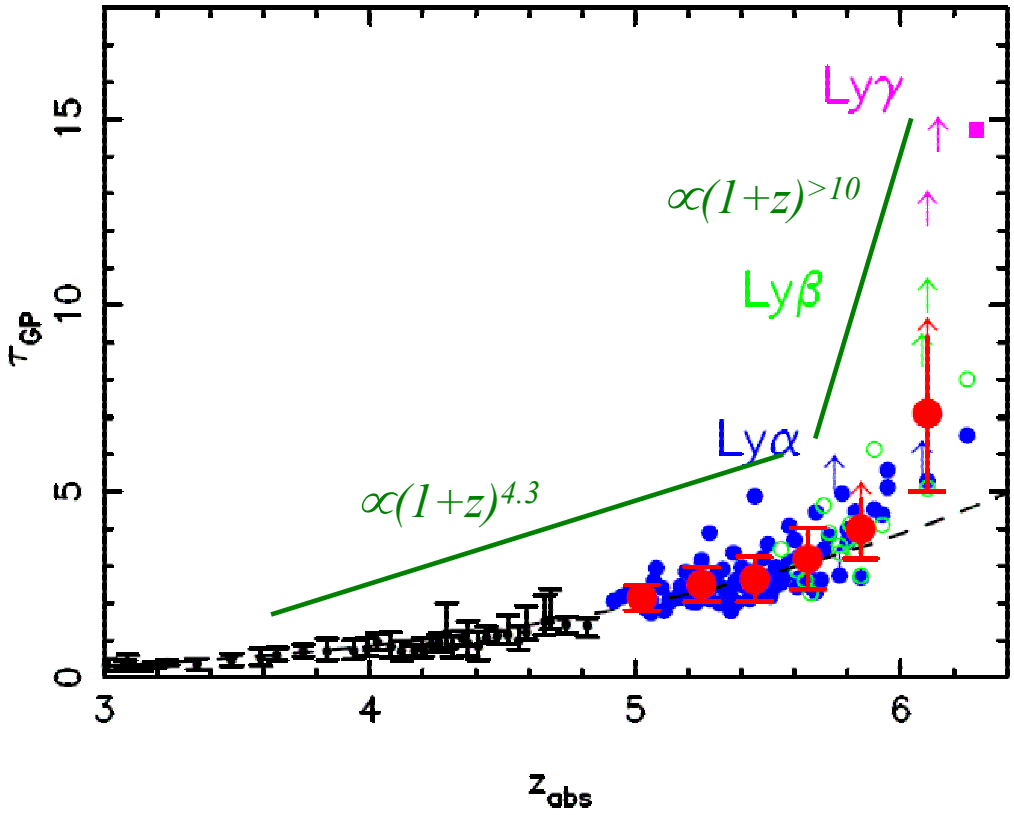
Black Gunn-Peterson trough

GUNN-PETERSON EFFECT

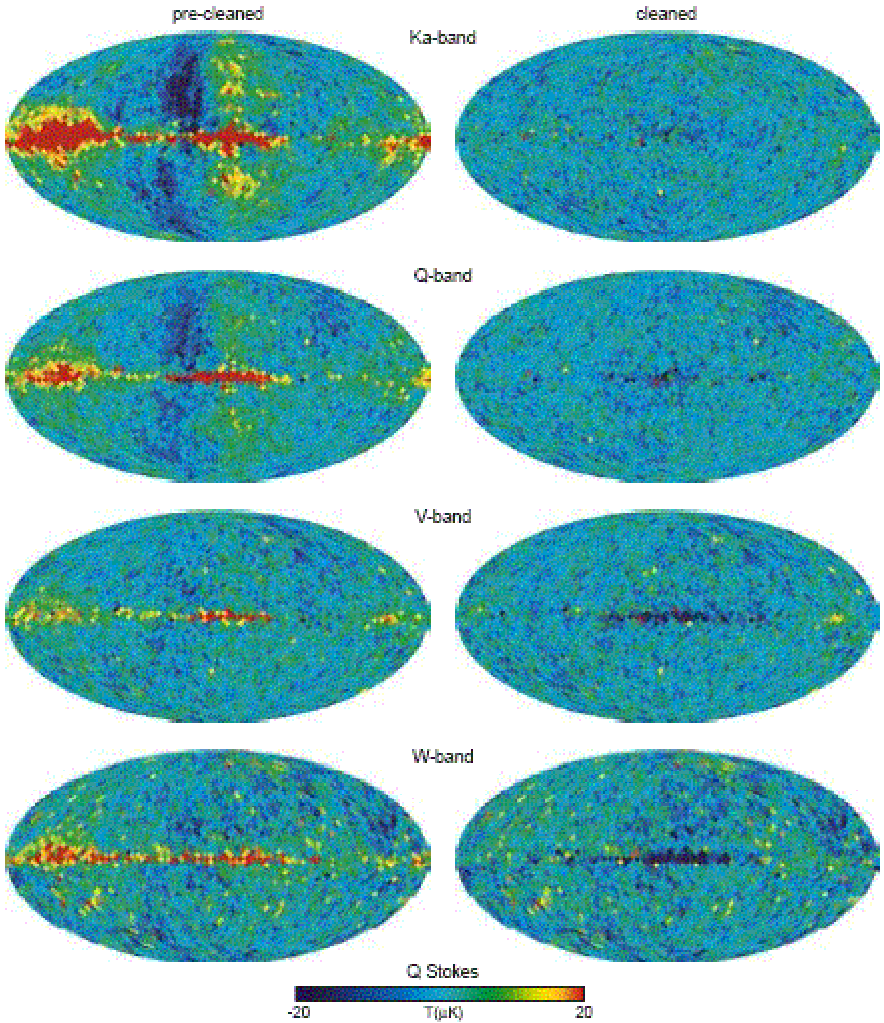
Spectra of high-z QSOs



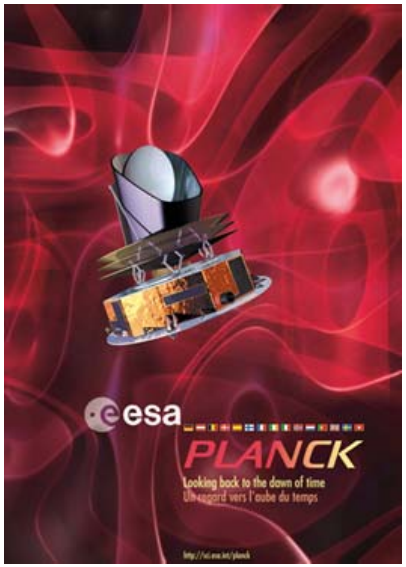
Lyα optical depth



WMAP3 RESULTS



Polarization Maps
Q Stokes Parameter



$$\tau_e = 0.09 \pm 0.03$$

Choudhury & AF 2005, 2006

✓ Self-consistent treatment of the evolution of ionized regions and thermal history

✓ Follow evolution of neutral, HII and HeIII regions

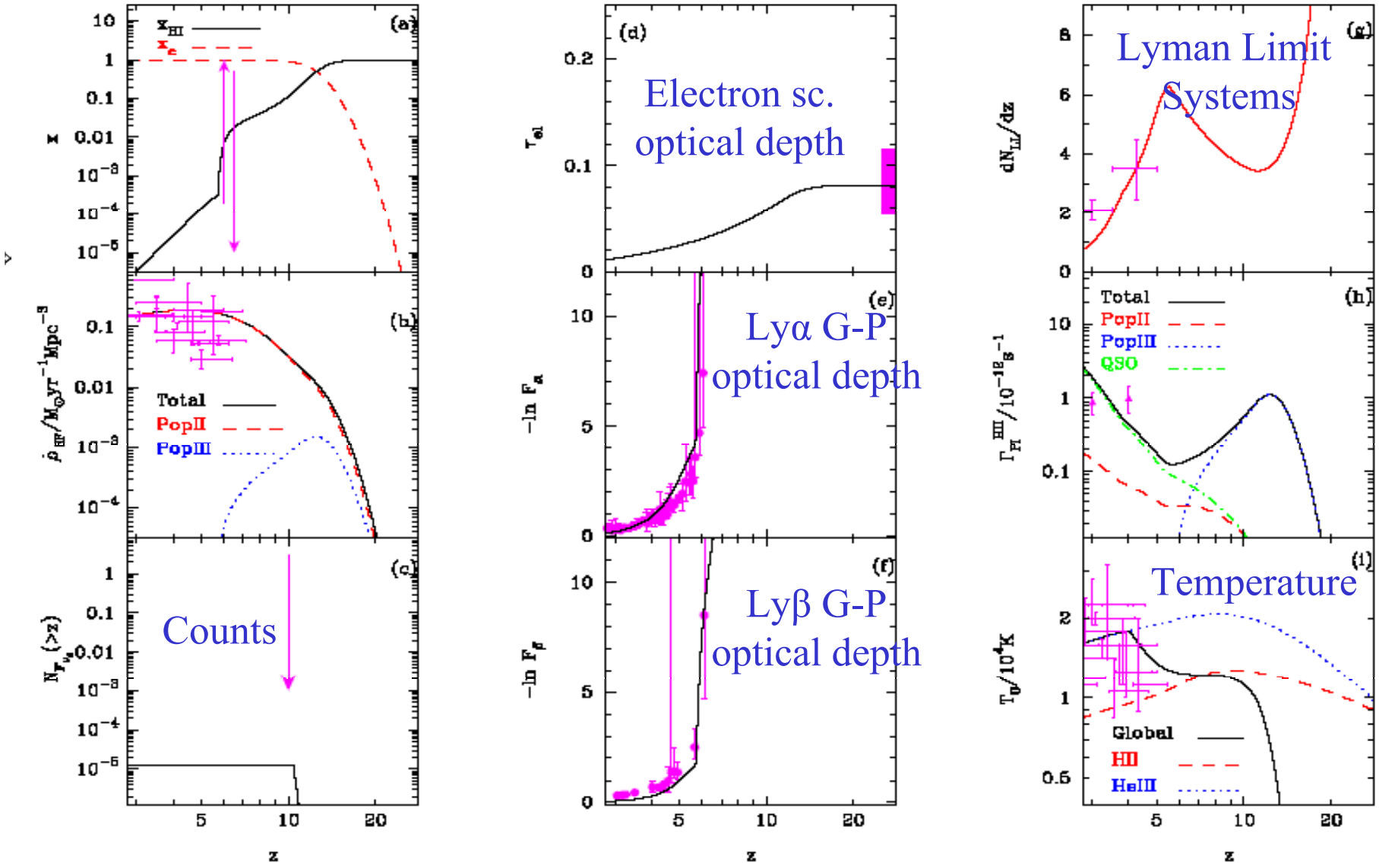
✓ Three sources of ionizing radiation:

- PopIII stars: early redshifts, *Salpeter IMF*, zero metallicity
- PopII stars: Salpeter IMF, sub-grid PopIII-PopII transition model
- Quasars: significant @ $z < 6$, using σ-M_{BH} relation

✓ Radiative feedback suppressing SF in low-mass halos, set by:

- Molecular cooling in neutral regions
- Photoionization temperature in ionized regions

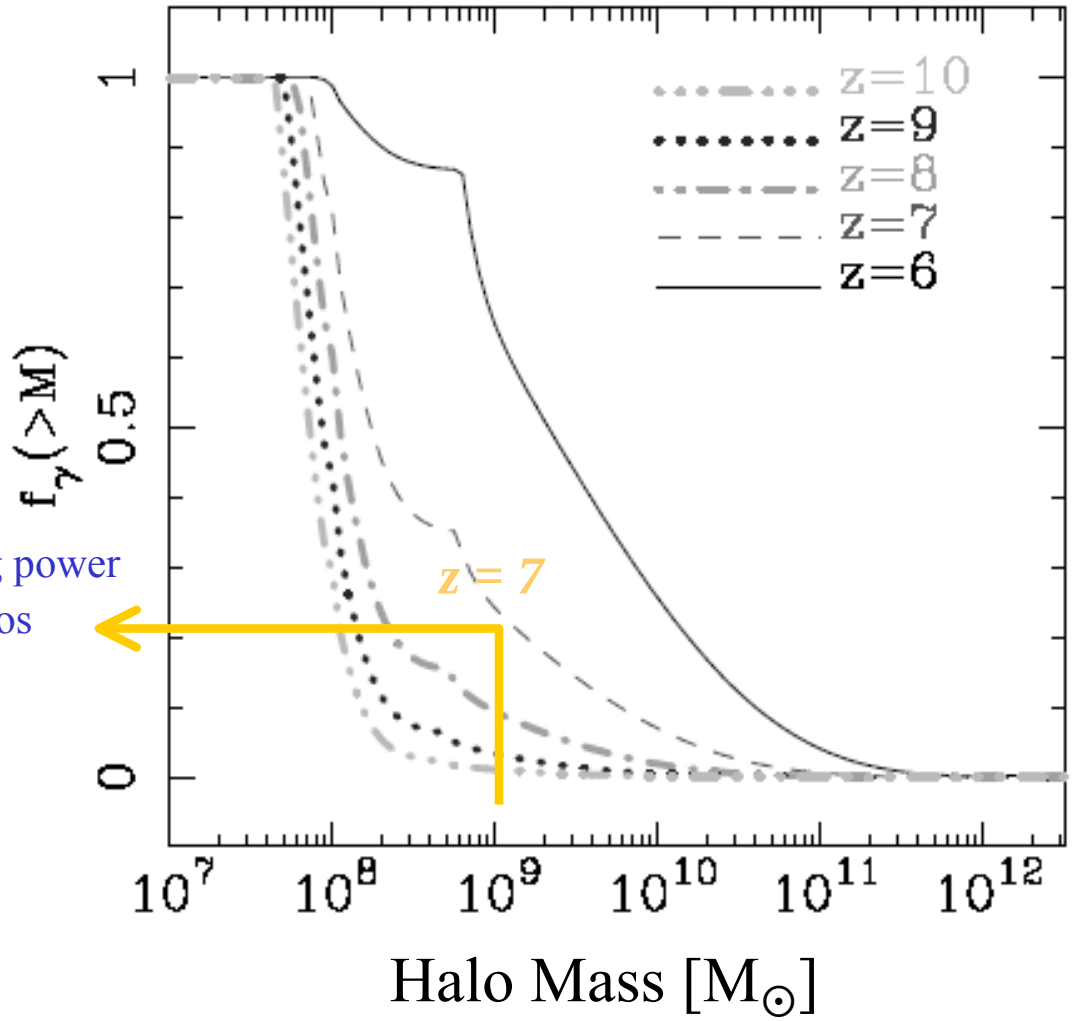
Choudhury & AF 2005, 2006



Choudhury & AF 2007

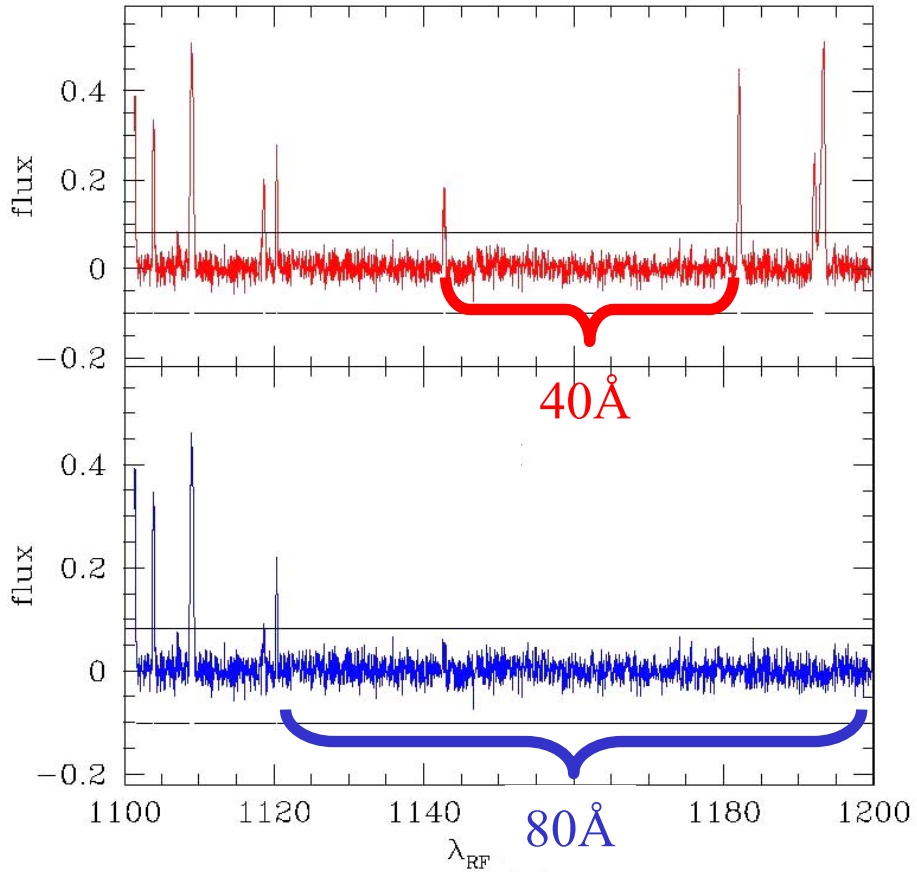
IONIZING PHOTON BUDGET

$f_\gamma > 80\%$ of the ionizing power from $M < 10^9\ M_\odot$ halos



Gallerani+ 2006

GAP STATISTICS

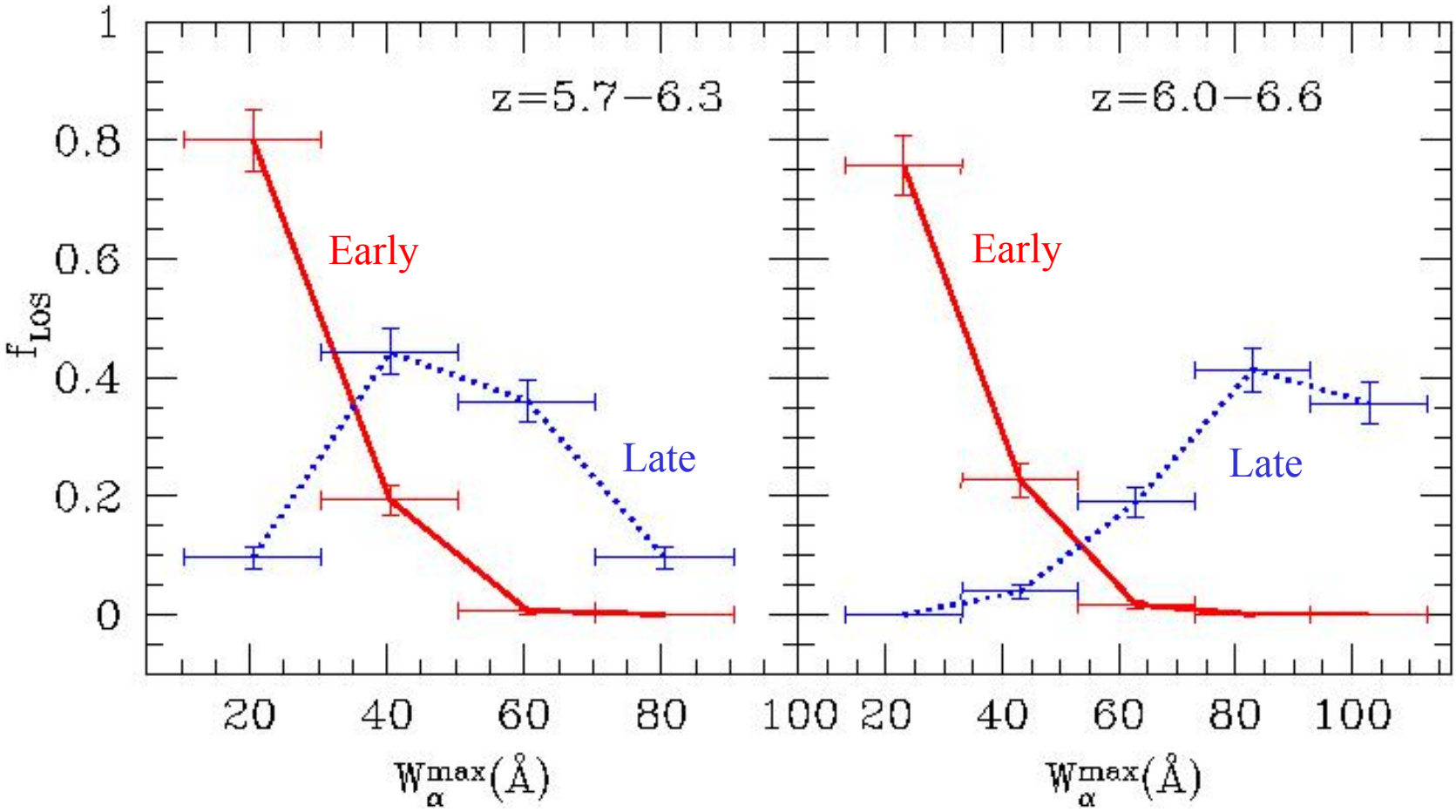


Early reionization

Late reionization

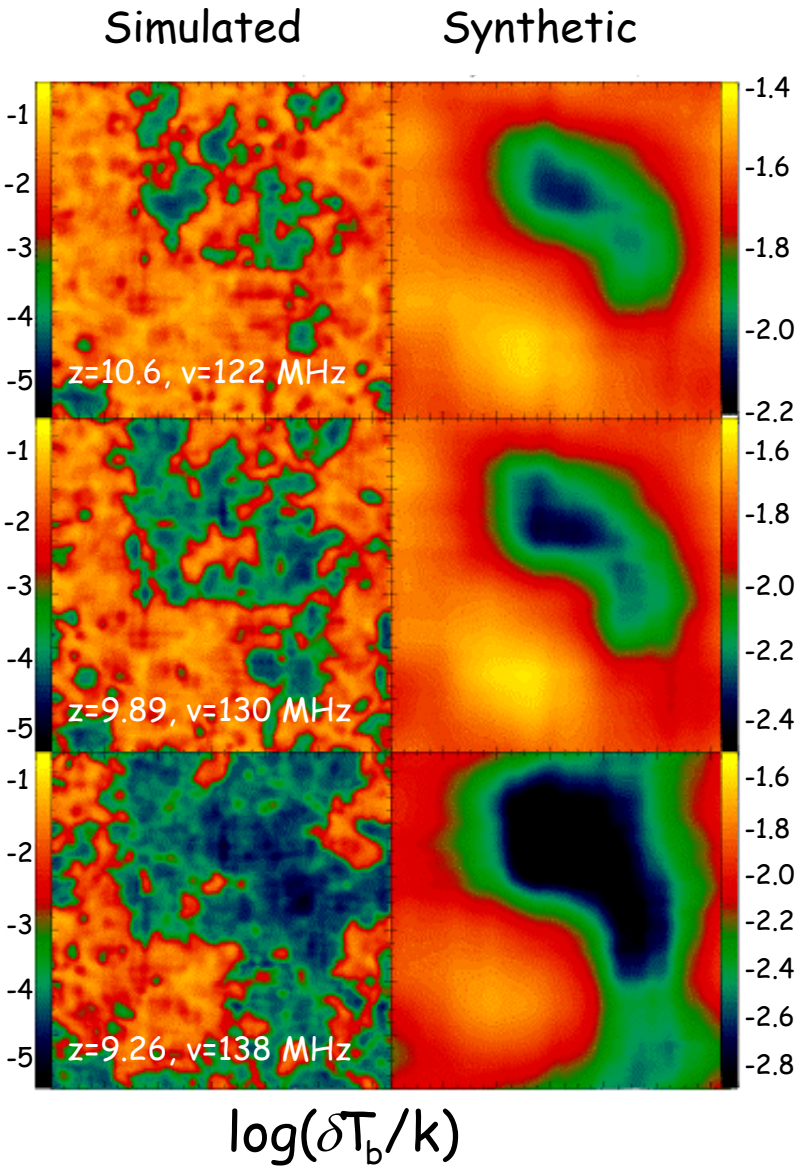
Gallerani+ 2006

GAP STATISTICS

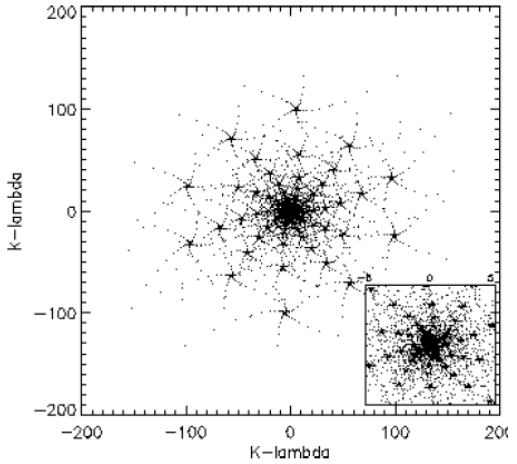


THE (NOT SO LOFAR) FUTURE

Valdes+ 2006



- Instrument sampling
  100 stations, 360 km baseline
  Instantaneous u-v coverage, $\delta_0 = \pi/2$



- Instrument sensitivity
  $\Delta\nu$=128 kHz, Δt=1000h

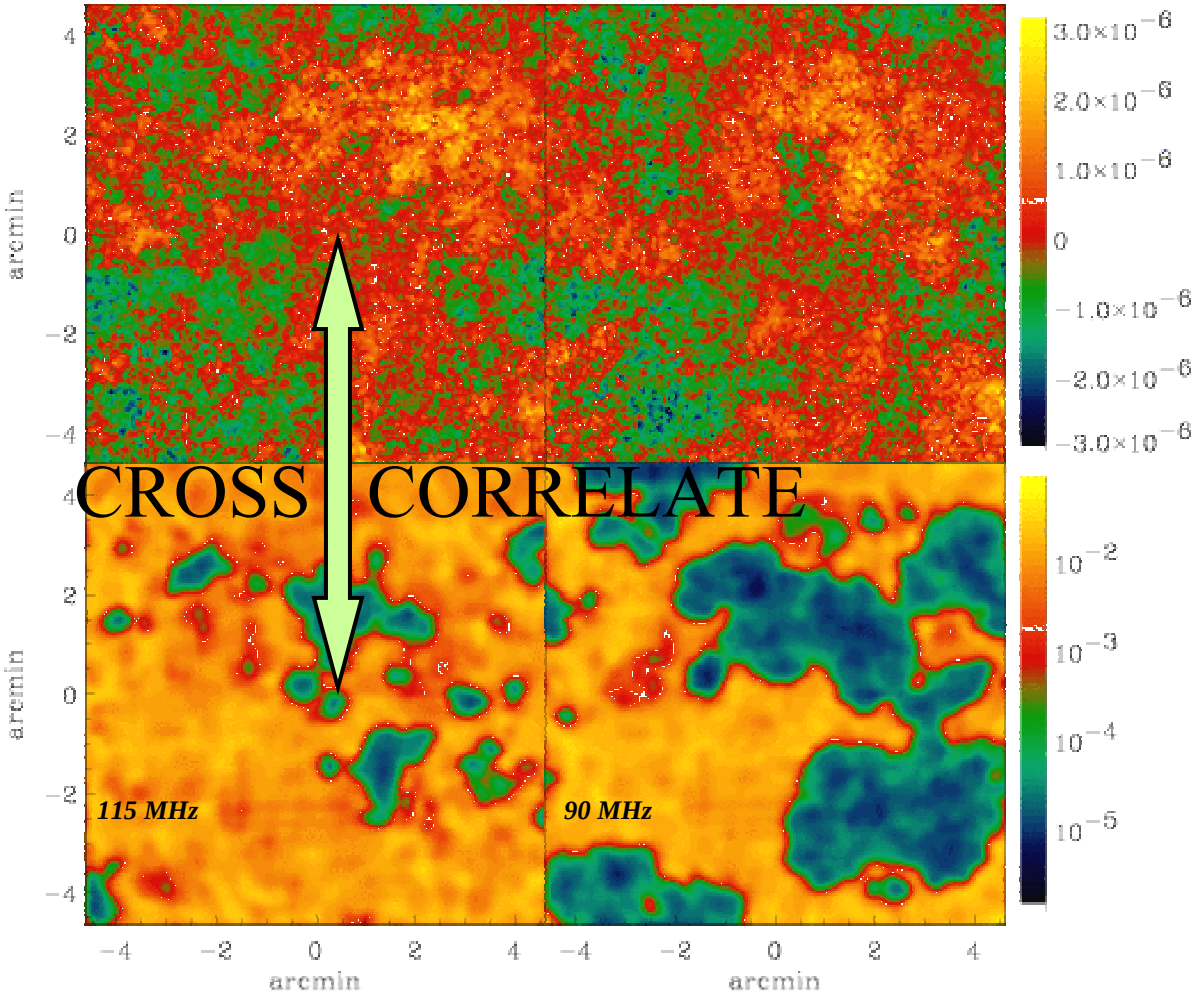
- Gaussian beam convolution
  σ = 3 arcmin

Salvaterra, Ciardi, AF & Baccigalupi 2005

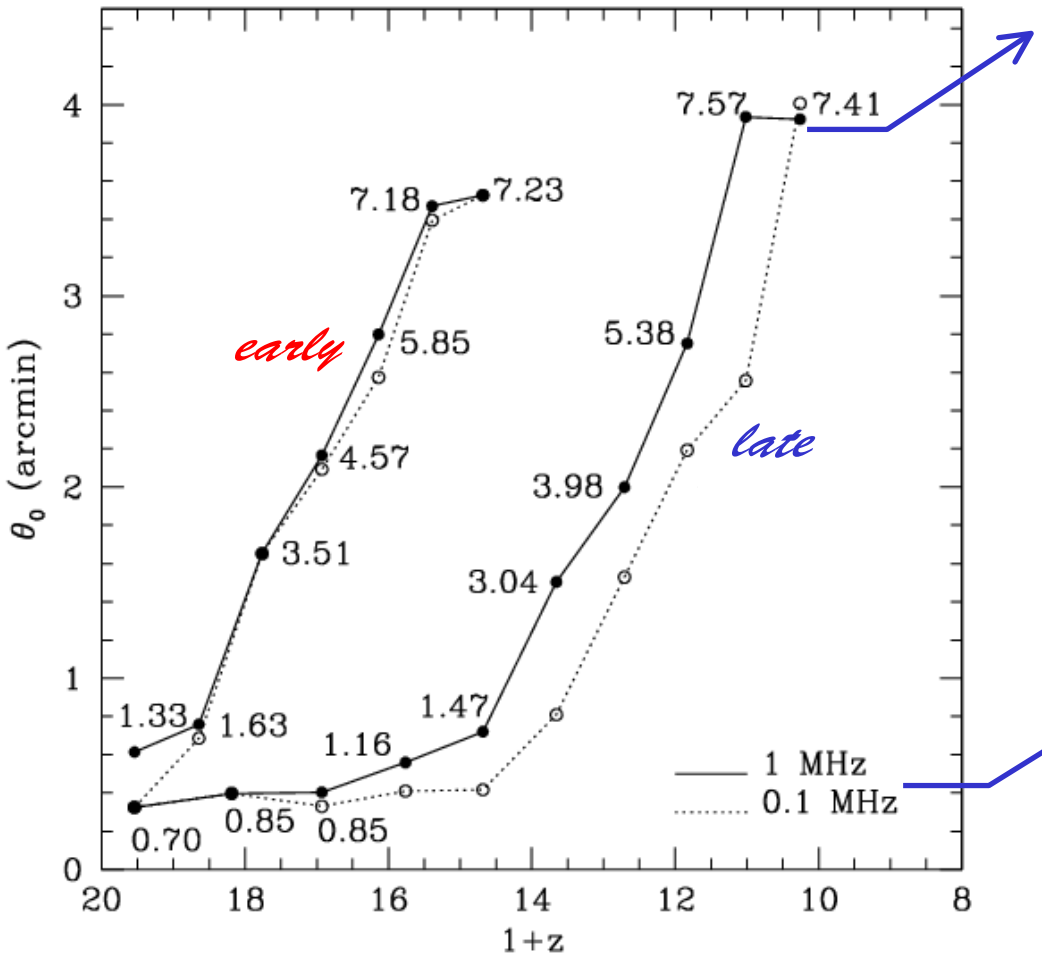
late reionization *early reionization*

$(\delta T/T_0)_{CMB}$

$(\delta T_b/T_0)_{21CM}$



HII REGION SIZE EVOLUTION

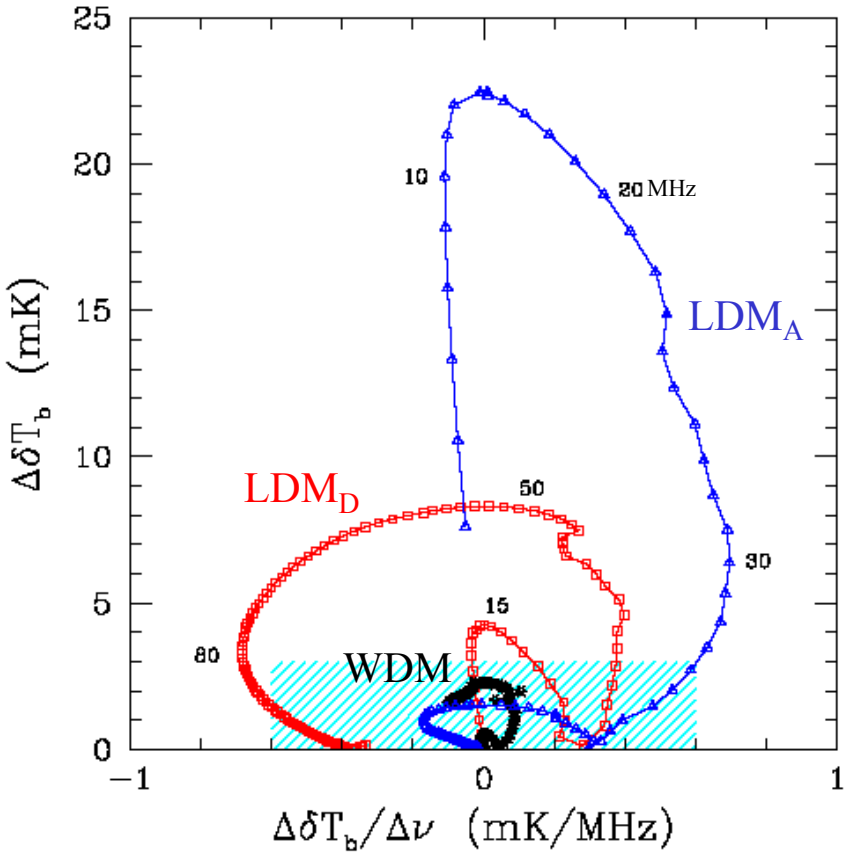


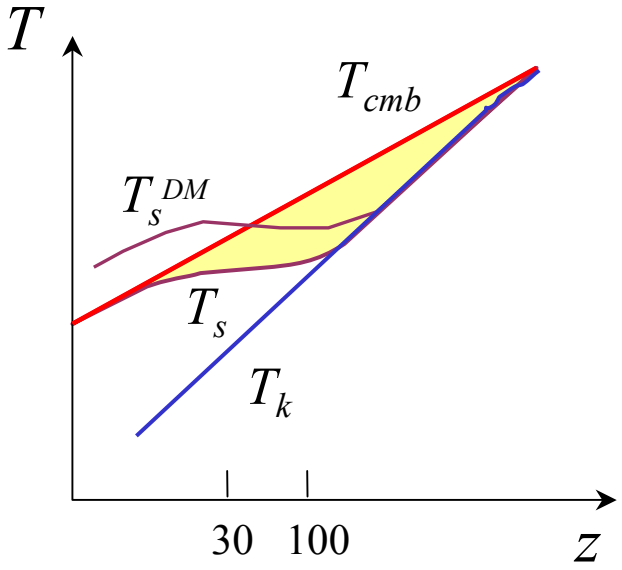
Size of HII region (Mpc) from zero of correlation fct.

Bandwidth

Valdes+ 2007

21CM SIGNAL FROM DM DECAY/ANNIHILATION





- Reionization started by metal-free stars @ z=20; 90% complete @ z=8
- Reionization @ $z > 7$ not in contrast with any constraint from QSOAL data
- $f_\gamma > 80\%$ of the ionizing power at $z \geq 7$ from halos of $M < 10^9\ M_\odot$
- Gap statistics to discriminate early/late reionization from analysis of QSOAL spectra
- Significant progress expected from HI 21cm detection from $z > 6$
- Cross-correlate of 21cm & CMB data to reconstruct reionization history
- 21 cm from pre-reionization epochs: cleanest possible DM tracer