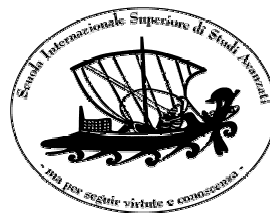


The Epoch of Reionization

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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 $z \sim 6-15$ these gradually photo-ionize the hydrogen in the IGM (“**Reionization**”).

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

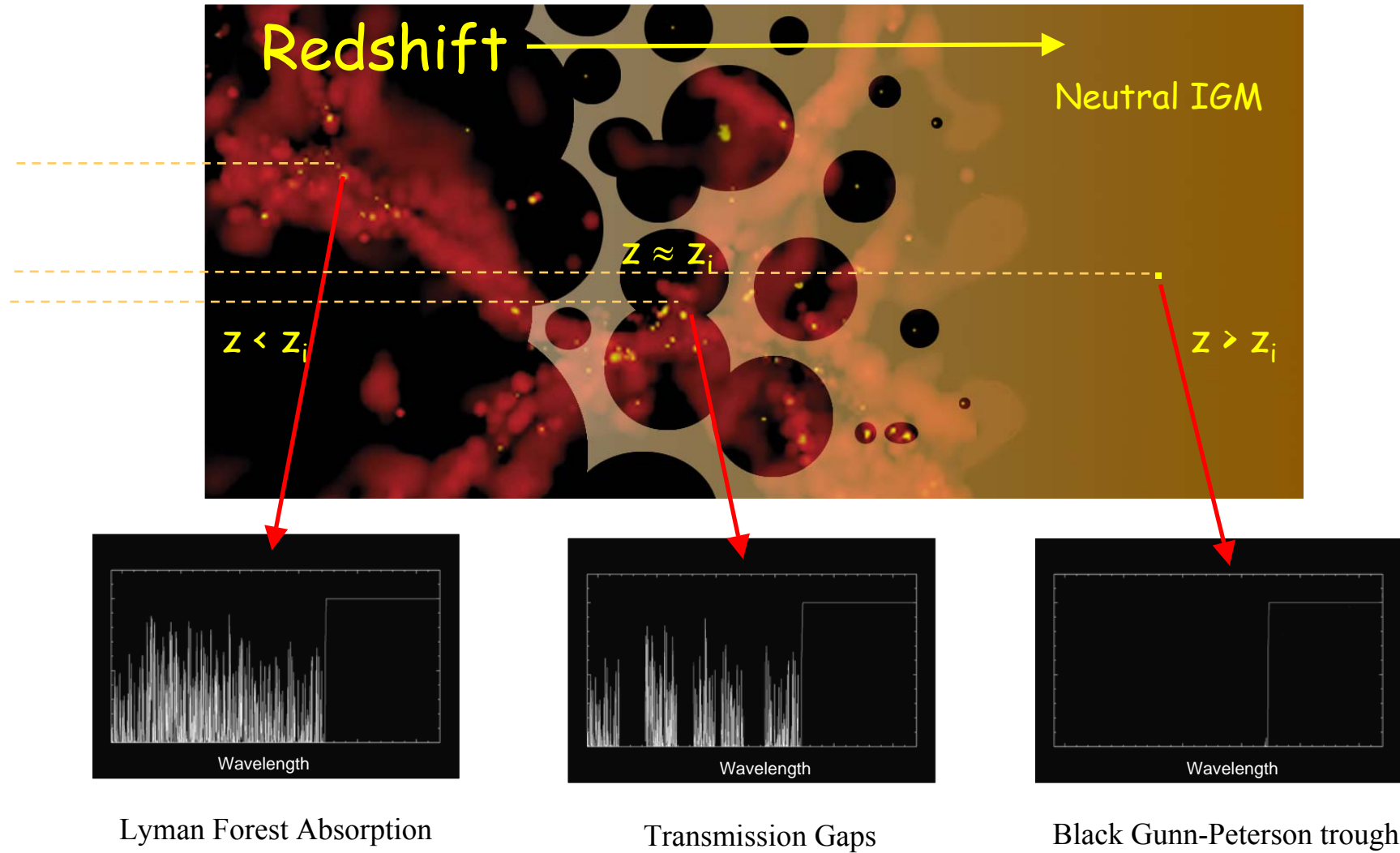
At $z < 1$ massive galaxy **clusters** are assembled.

Cosmic Dawn

Time

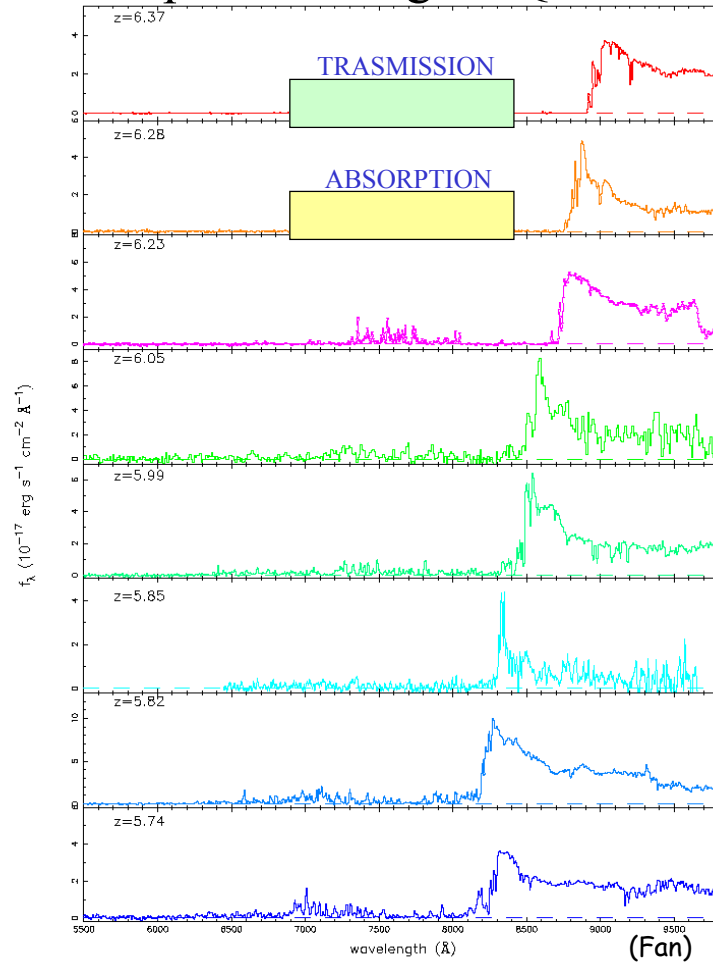


CLASSICAL REIONIZATION TESTS

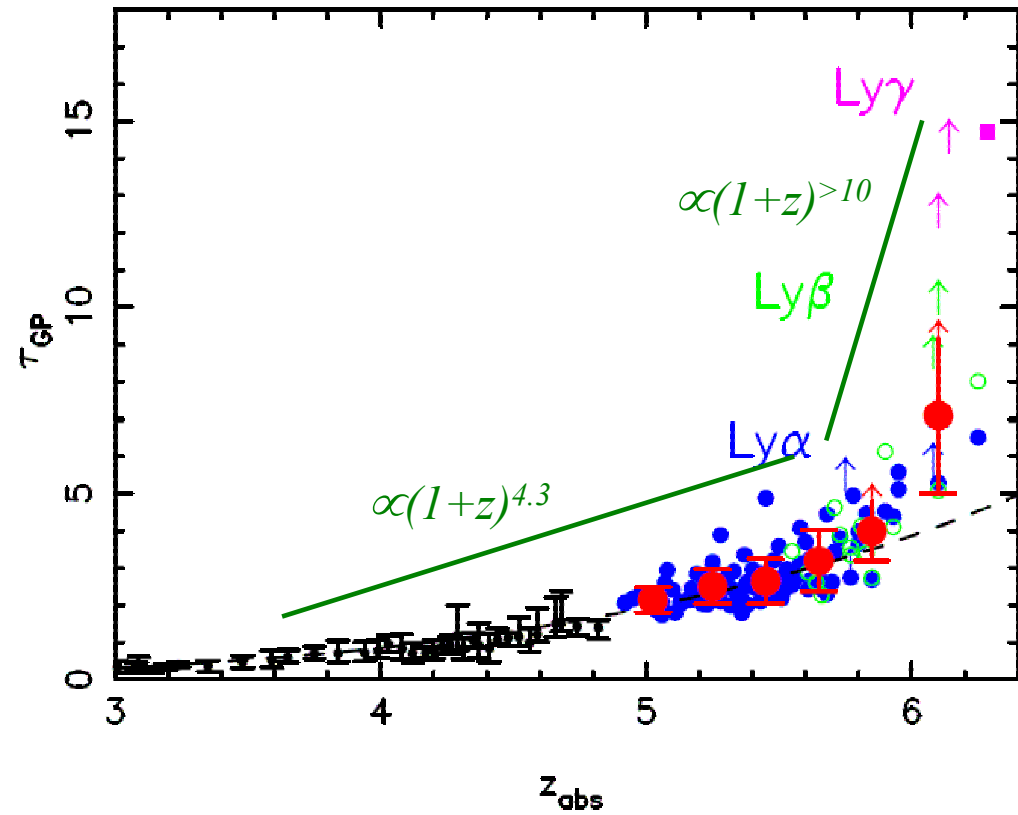


GUNN-PETERSON EFFECT

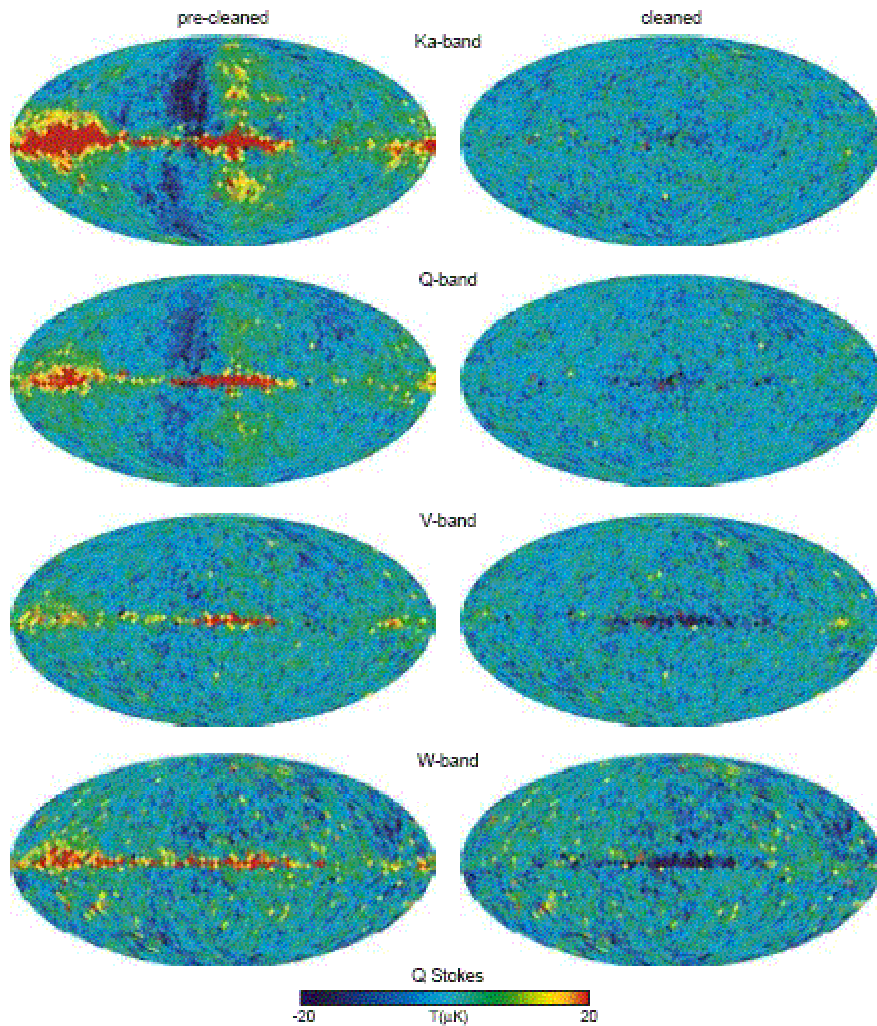
Spectra of high-z QSOs



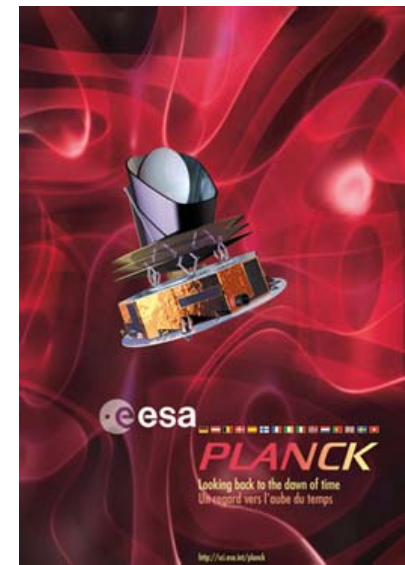
$Ly\alpha$ optical depth



WMAP3 RESULTS



Polarization Maps
Q Stokes Parameter

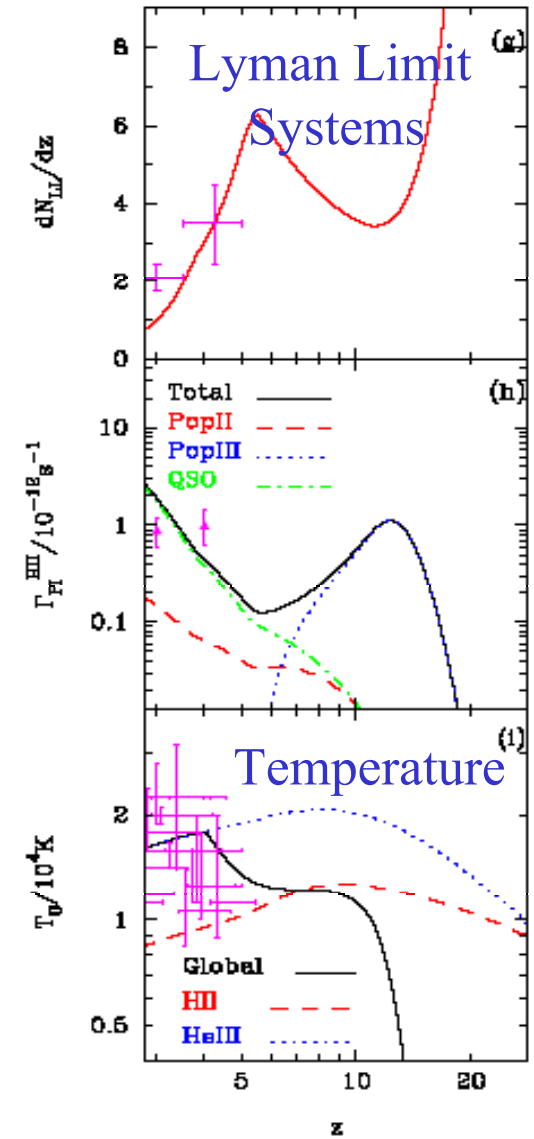
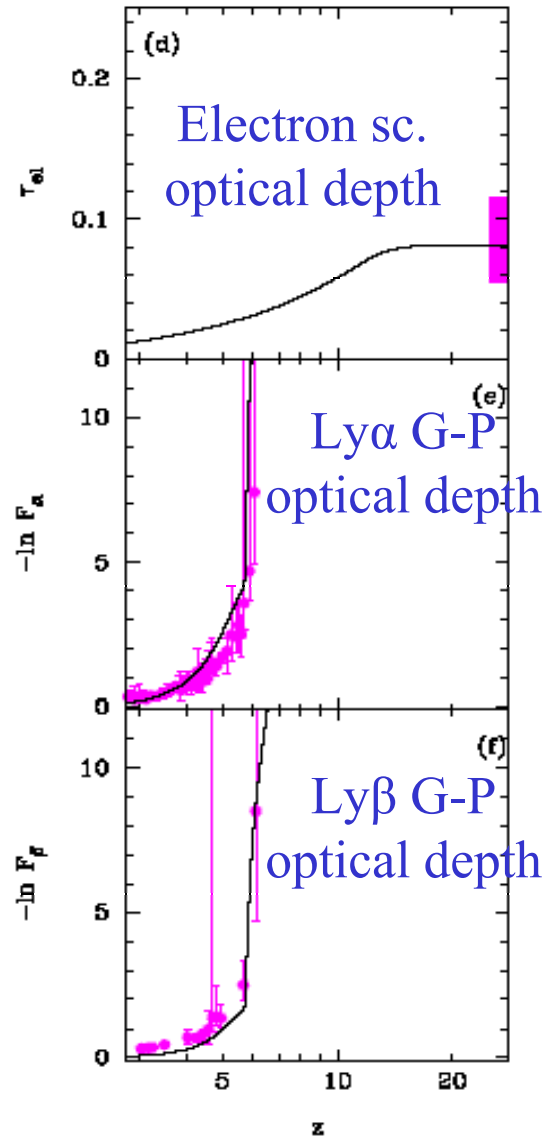
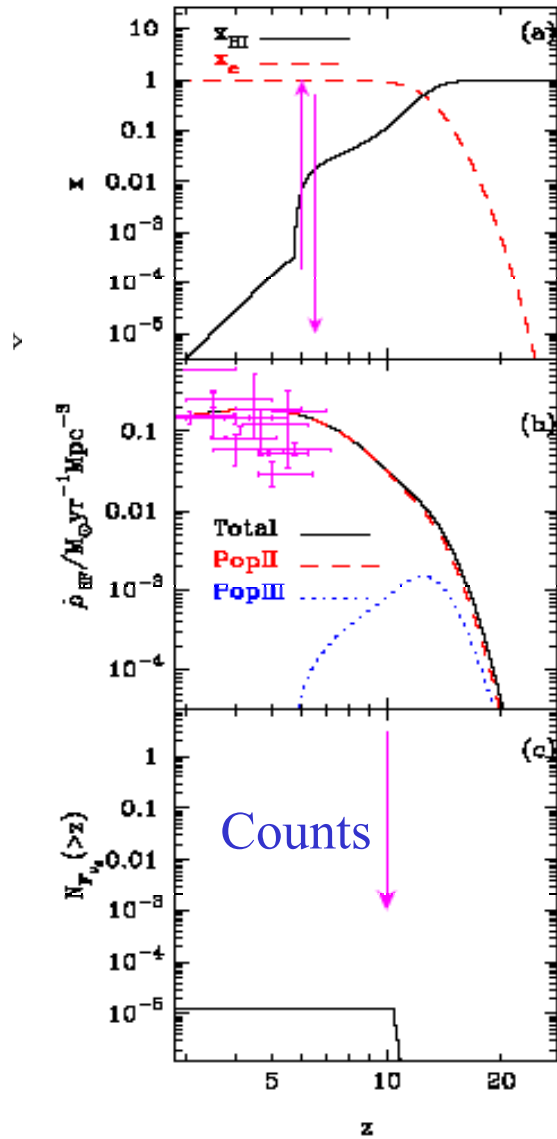


$$\tau_e = 0.09 \pm 0.03$$

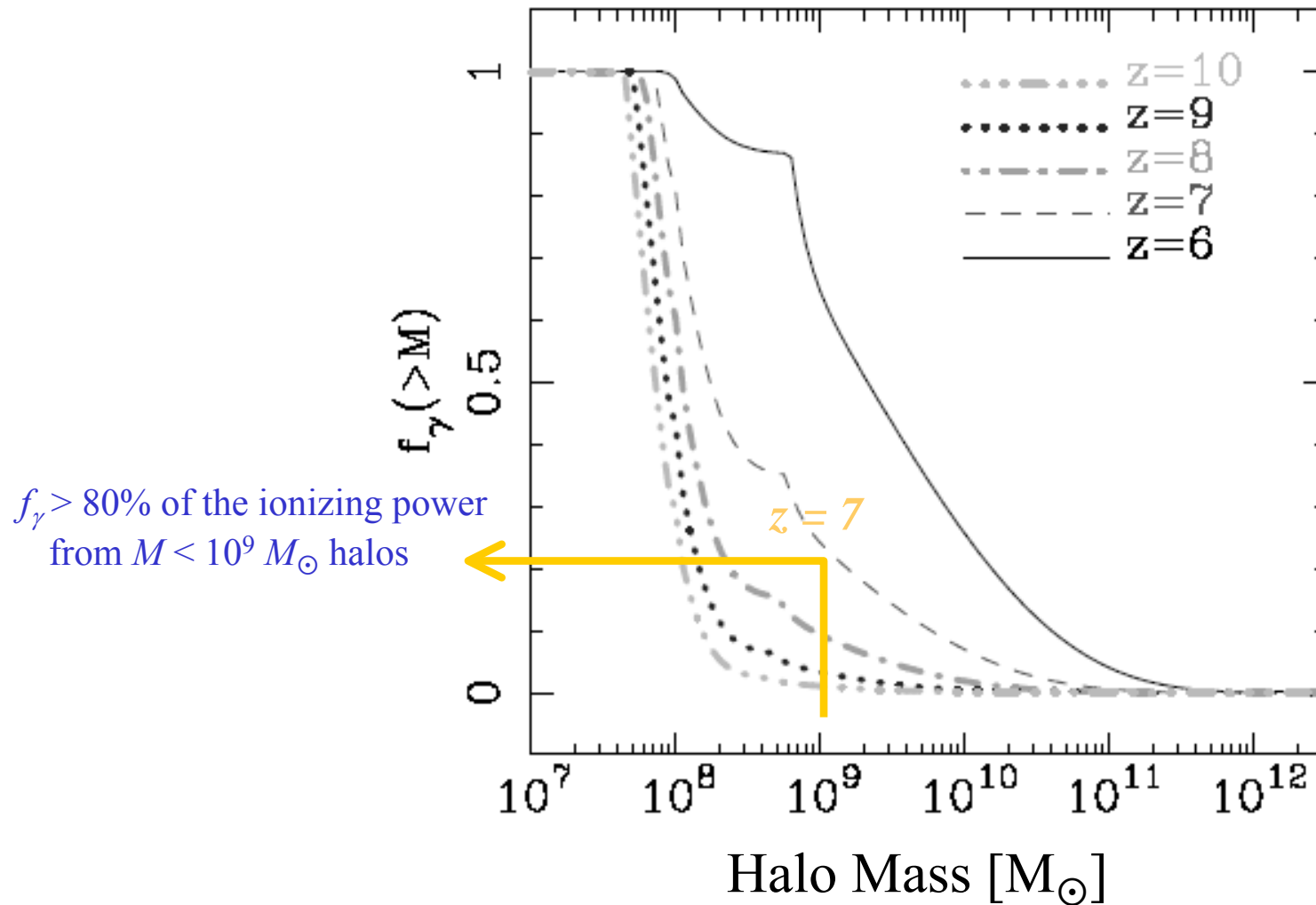
- ✓ Self-consistent treatment of the evolution of ionized regions and thermal history
- ✓ Follow evolution of neutral, HII and HeIII regions
- ✓ Three sources of ionizing radiation:
 - **PopIII stars**: early redshifts, *Salpeter IMF*, zero metallicity
 - **PopII stars**: Salpeter IMF, sub-grid PopIII-PopII 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

GLOBAL REIONIZATION MODELS

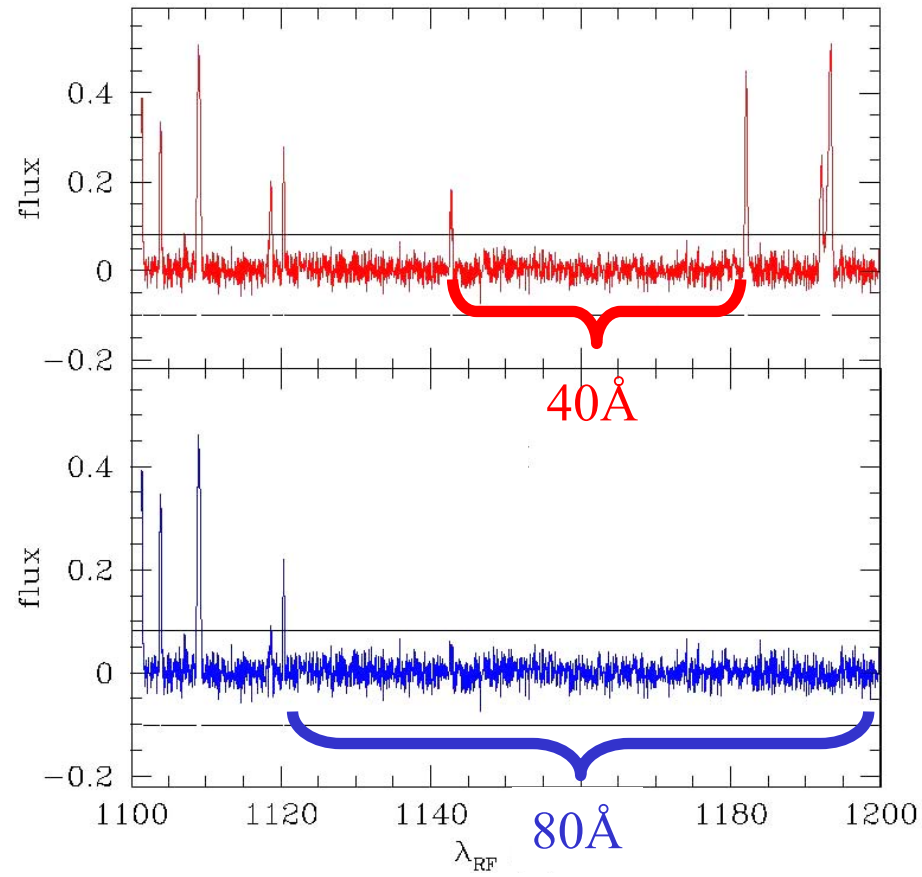
Choudhury & AF 2005, 2006



IONIZING PHOTON BUDGET



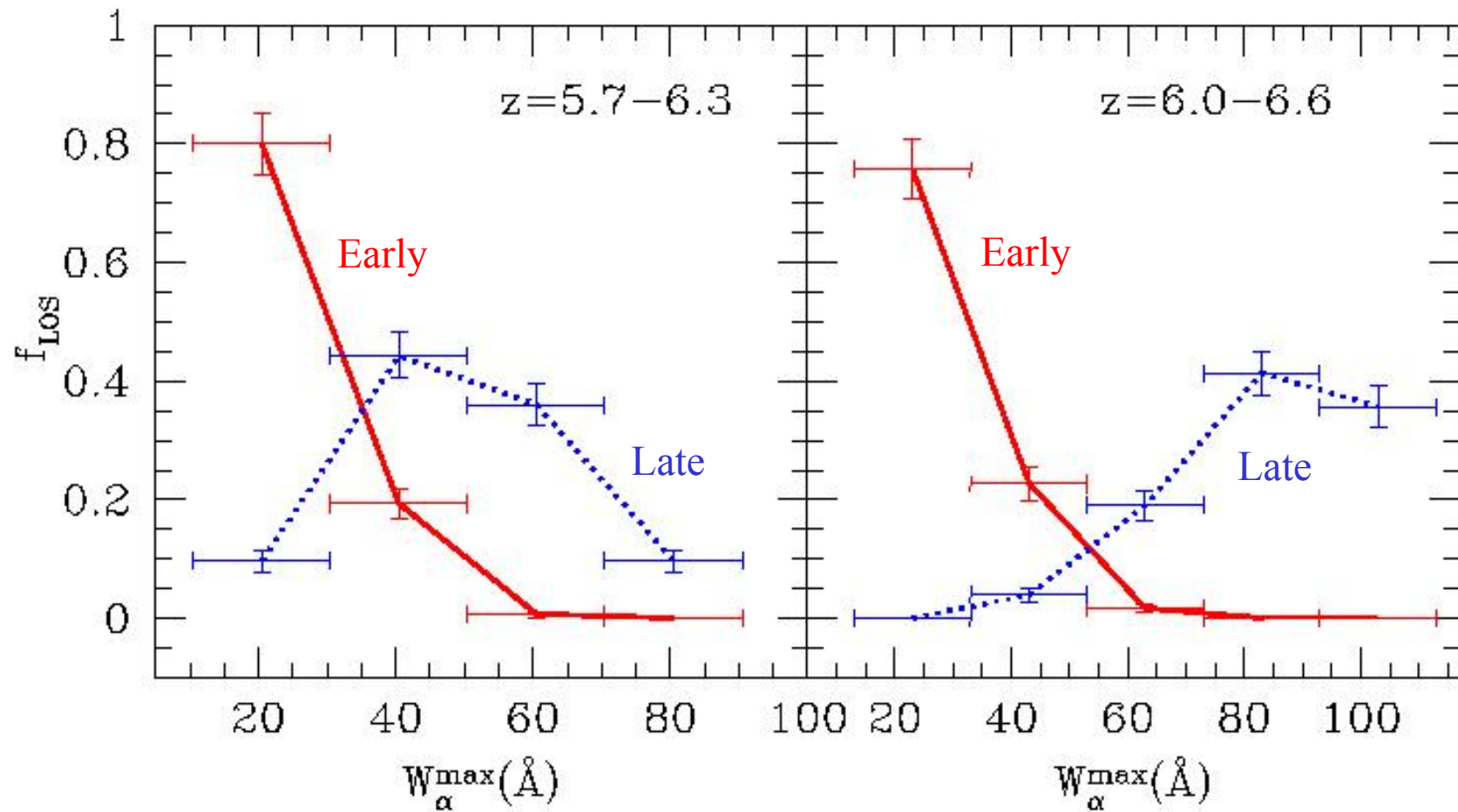
GAP STATISTICS



Early reionization

Late reionization

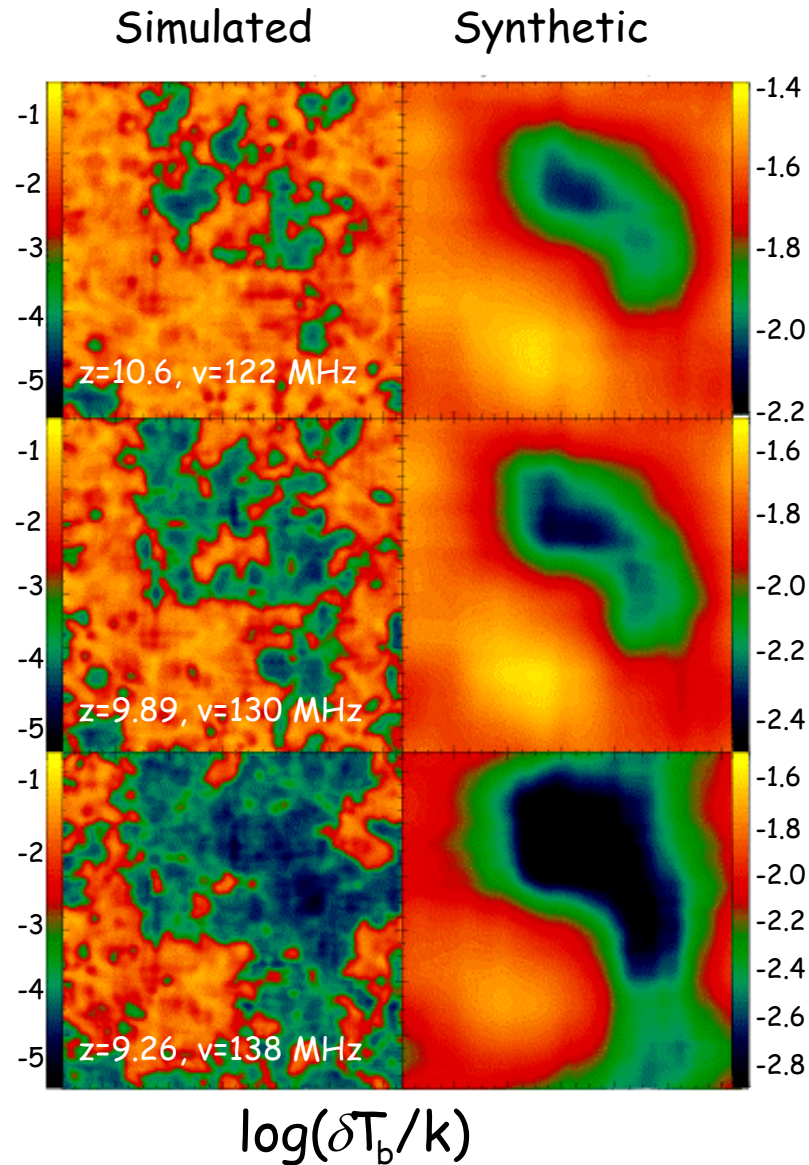
GAP STATISTICS



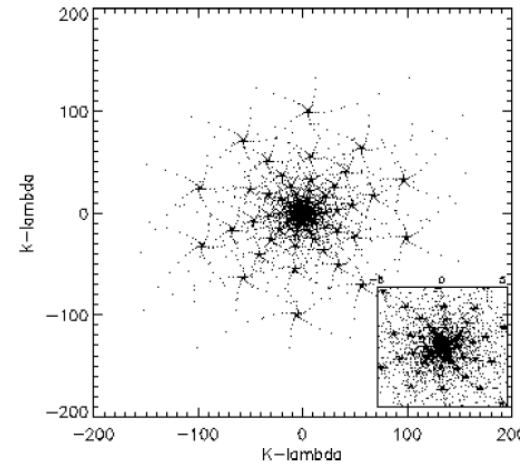
THE (NOT SO LOFAR) FUTURE

LOFAR DETECTION OF REIONIZATION

Valdes+ 2006



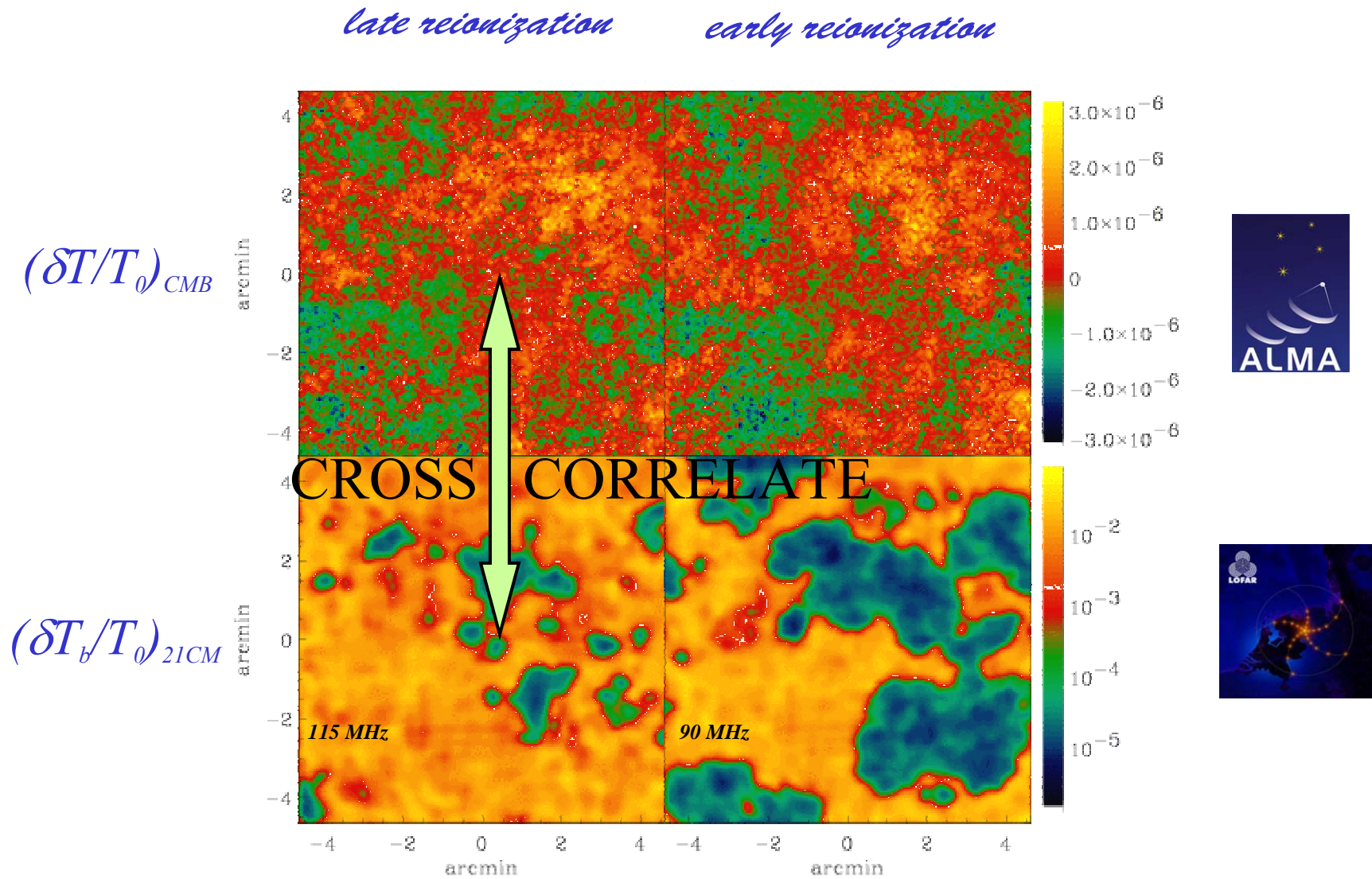
- Instrument sampling
100 stations, 360 km baseline
Instantaneous u - v coverage, $\delta_0 = \pi/2$



- Instrument sensitivity
 $\Delta\nu=128 \text{ kHz}, \Delta t=1000h$
- Gaussian beam convolution
 $\sigma = 3 \text{ arcmin}$

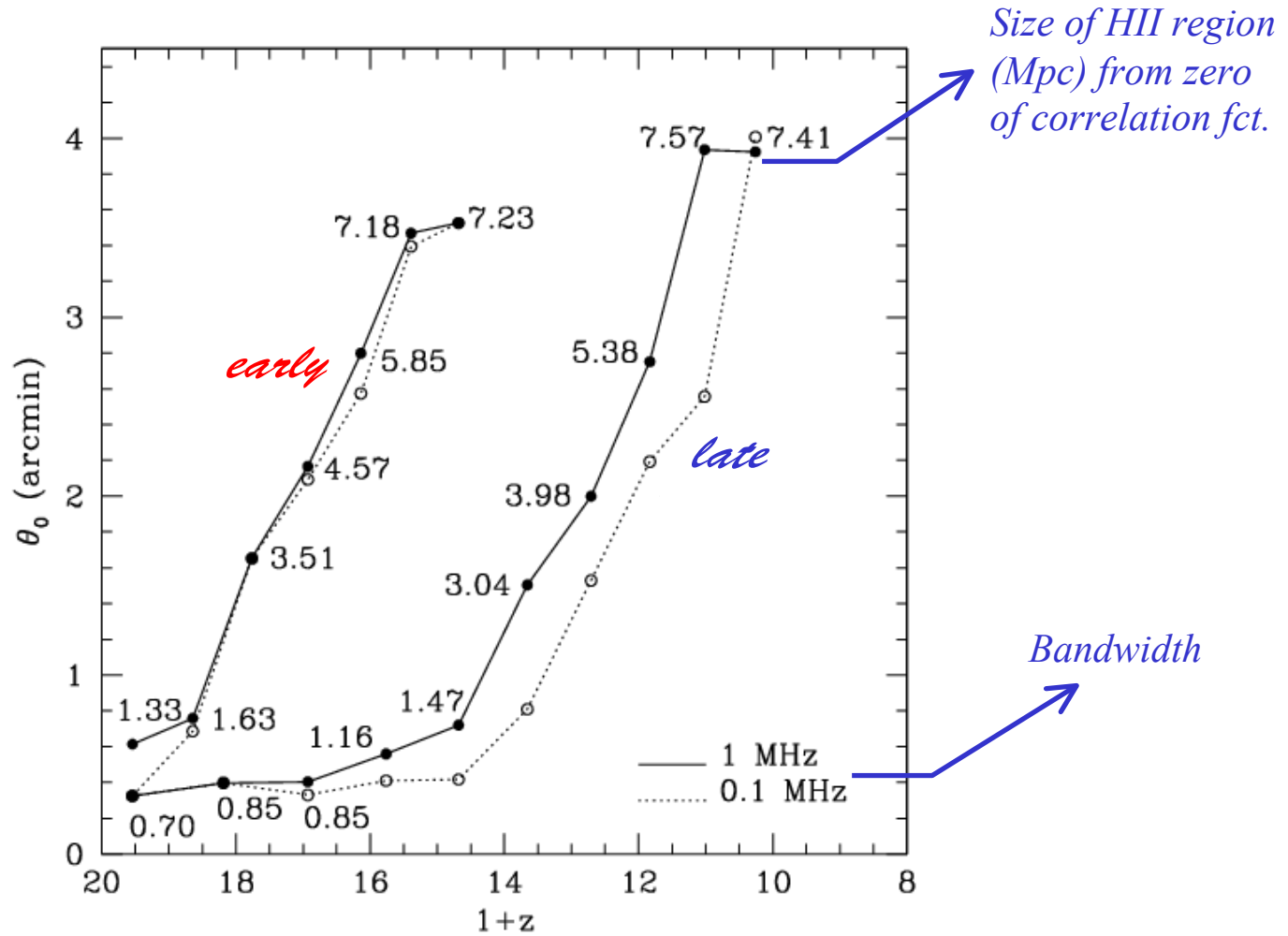
HINTS FROM COUPLED 21CM/CMB OBSERVATIONS

Salvaterra, Ciardi, AF & Baccigalupi 2005

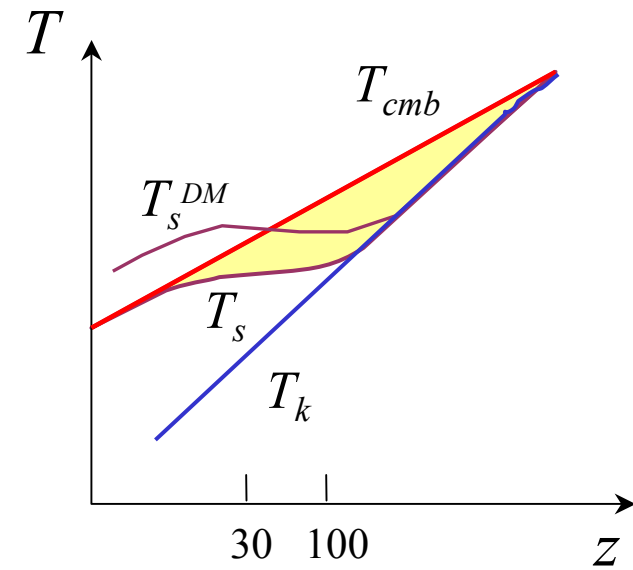
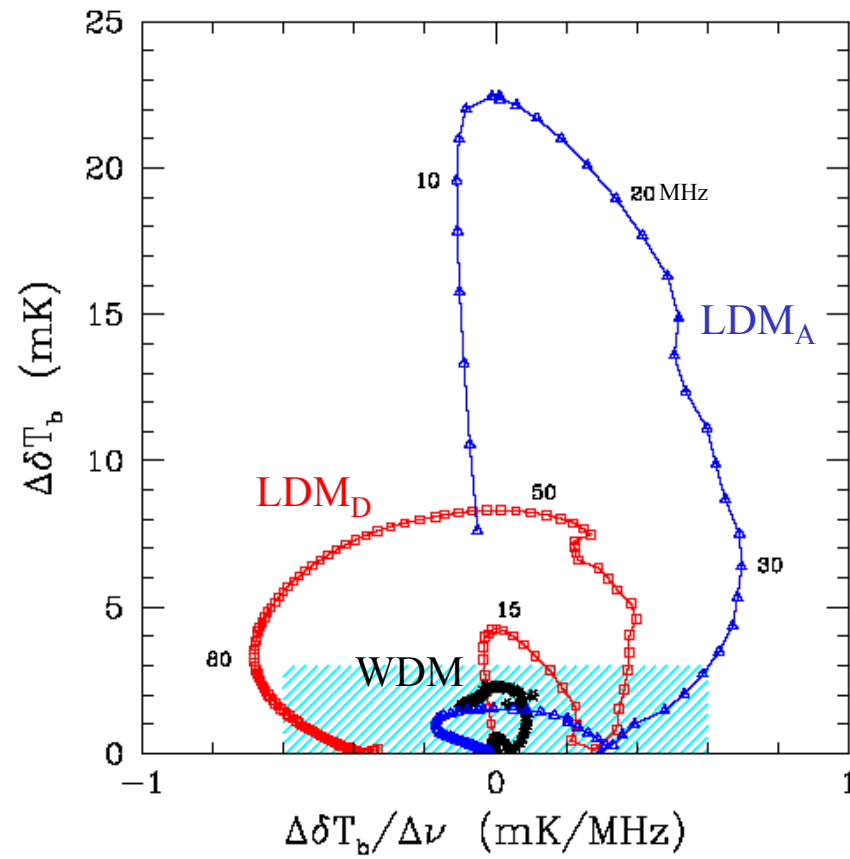


HINTS FROM COUPLED 21CM/CMB OBSERVATIONS

HII REGION SIZE EVOLUTION



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