21cm views of the high-z universe

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Outline

- IGM heating by Lya and x-ray photons
- Simulations of reionization and 21cm emission line
- CMB/21cm line cross-correlation
- Extra-galactic foreground contamination

Simulations of reionization

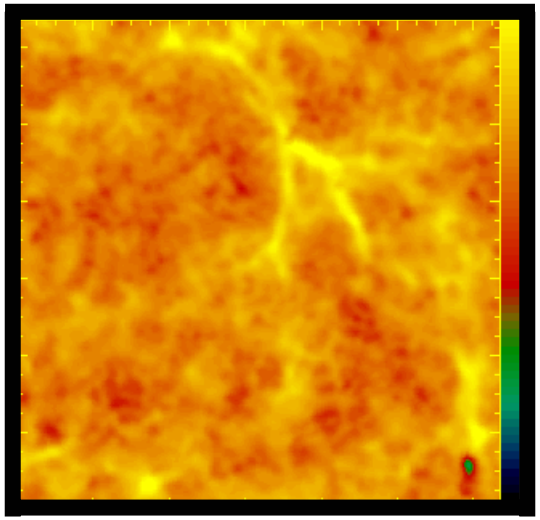
- Simulations of galaxy formation → gas & galaxy properties

  (Springel et al. 2000; Stoehr 2004)

- Stellar type sources → emission properties

- CRASH → propagation of ionizing photons

  (BC et al. 2001; Maselli, Ferrara & BC 2003)



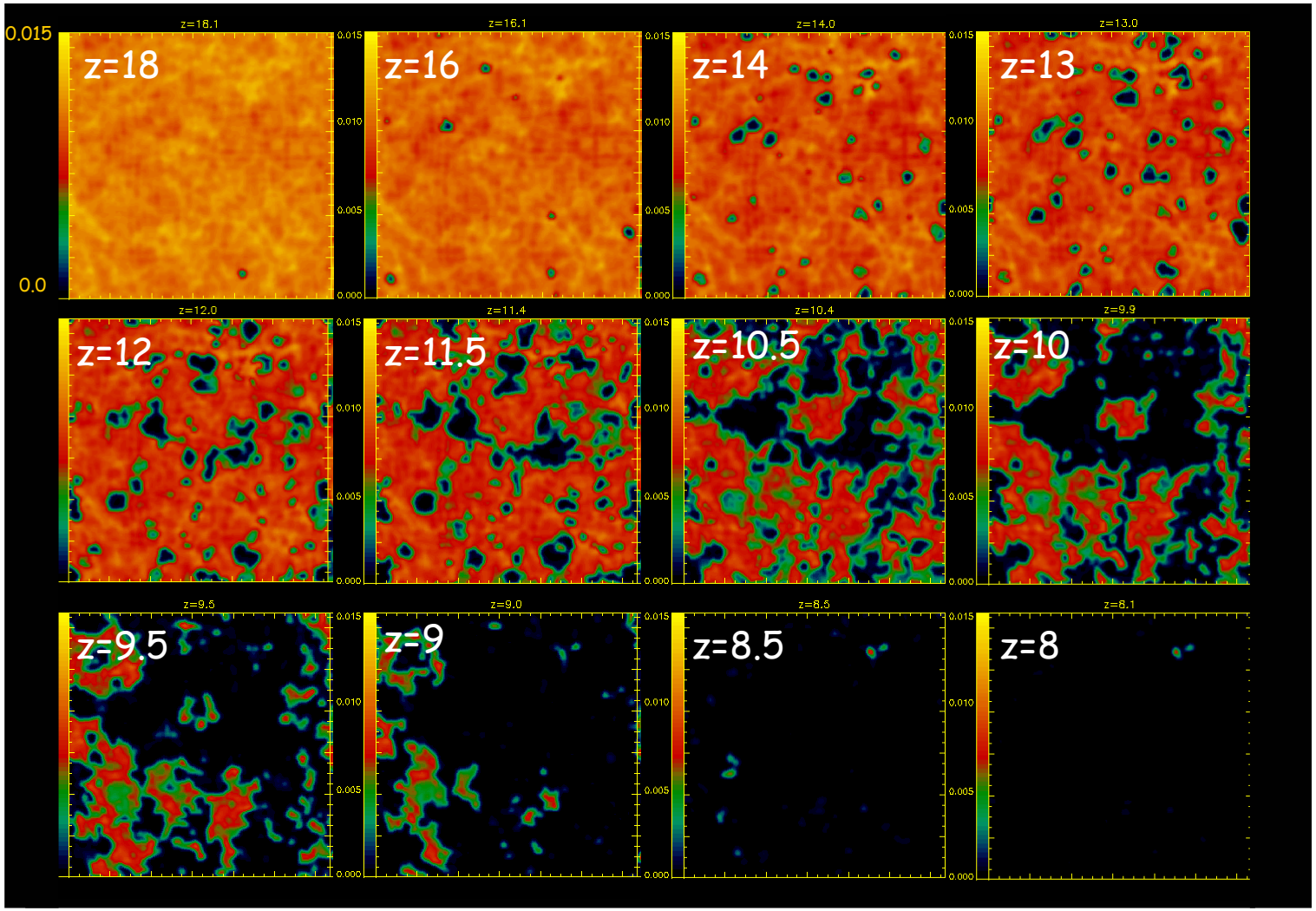
Simulation properties

- $M \sim 10^9 M_o$
- L=10-20/h Mpc com.

Source properties

- metal-free stars
- Salpeter/Larson IMF
- Fesc=5-20%

Redshift Evolution of HI density



(BC, Stoehr & White 2003)

Early/Late Reionization

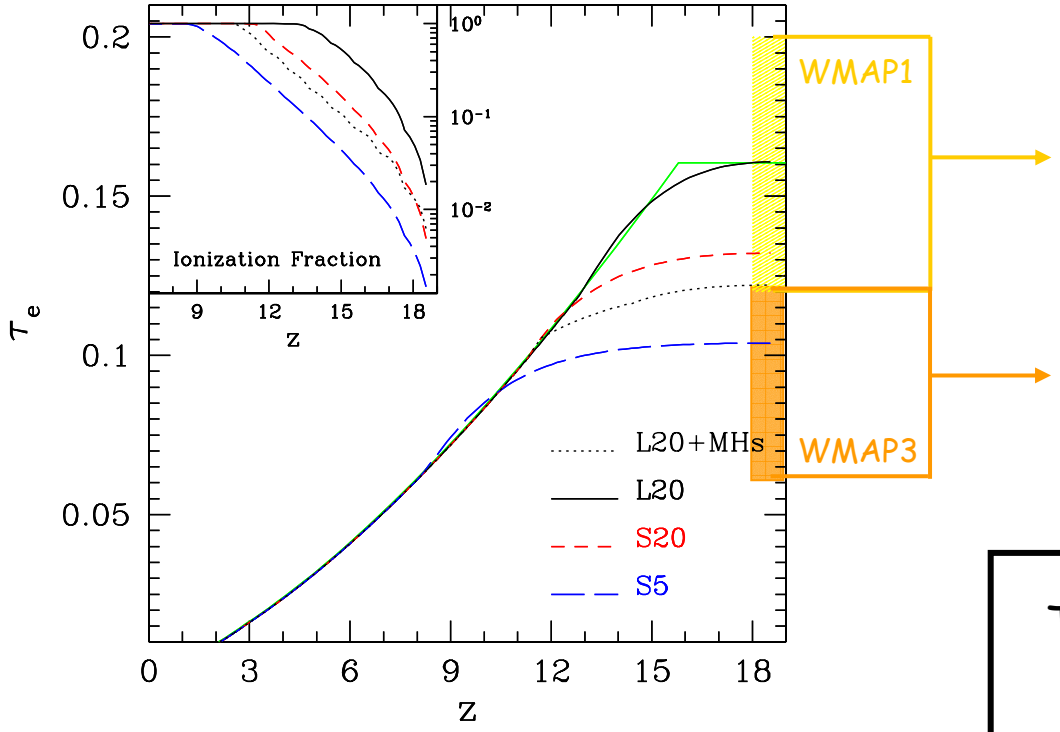
Source properties (metal-free stars):

S5: Salpeter IMF+fesc=5% (late reion. case)

S20: Salpeter IMF+fesc=20%

L20: Larson IMF+fesc=20% (early reion. case)

L20 + MHs: addition of sub-grid physics to include MHs absorption



$$\tau_e = 0.16 \pm 0.04$$

(Kogut et al. 2003)

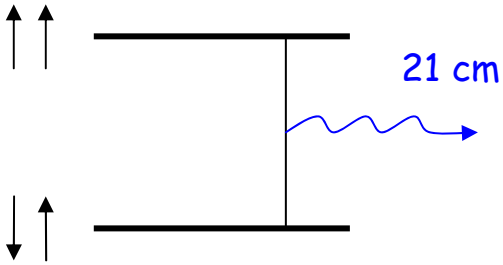
$$\tau_e = 0.09 \pm 0.03$$

(Spergel et al. 2006)

The simulations are consistent with the WMAP results

BC, Stoehr & White 2003; BC, Ferrara & White 2003; BC et al 2006

21cm line diagnostic



✓ Ideal probe of neutral H at high-z
different observed frqs. → different z

Differential brightness temperature:

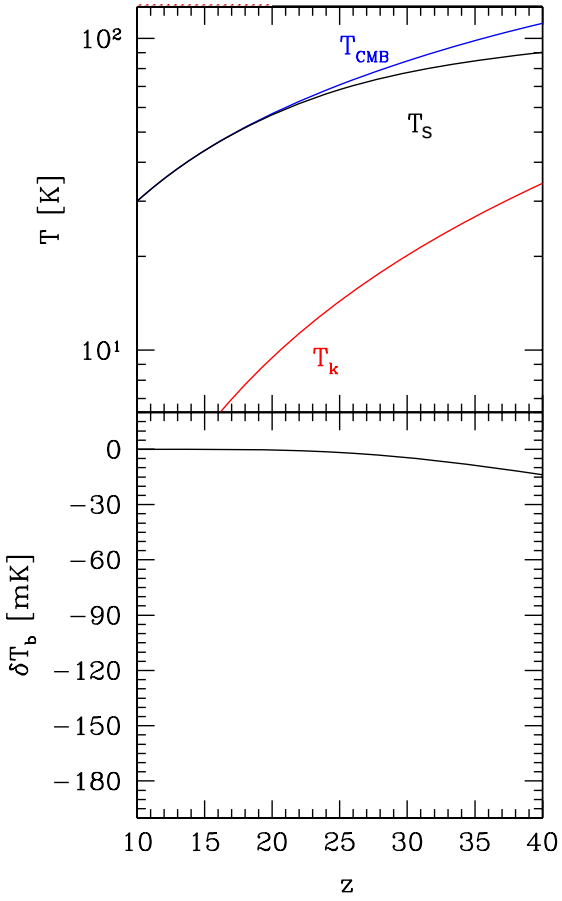
spin temperature

$$\delta T_b \approx \frac{T_s - T_{CMB}}{1+z}\tau \propto (1 - T_{CMB}/T_s)$$

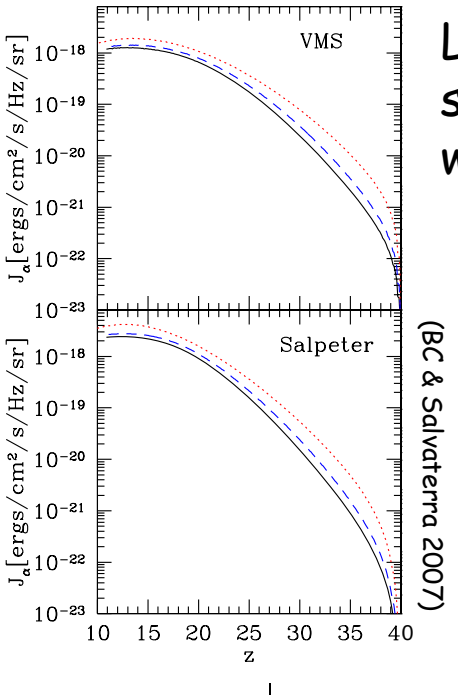
$T_{CMB} >> T_s \Rightarrow$ absorption

$T_s >> T_{CMB} \Rightarrow$ emission

Lya scattering & heating



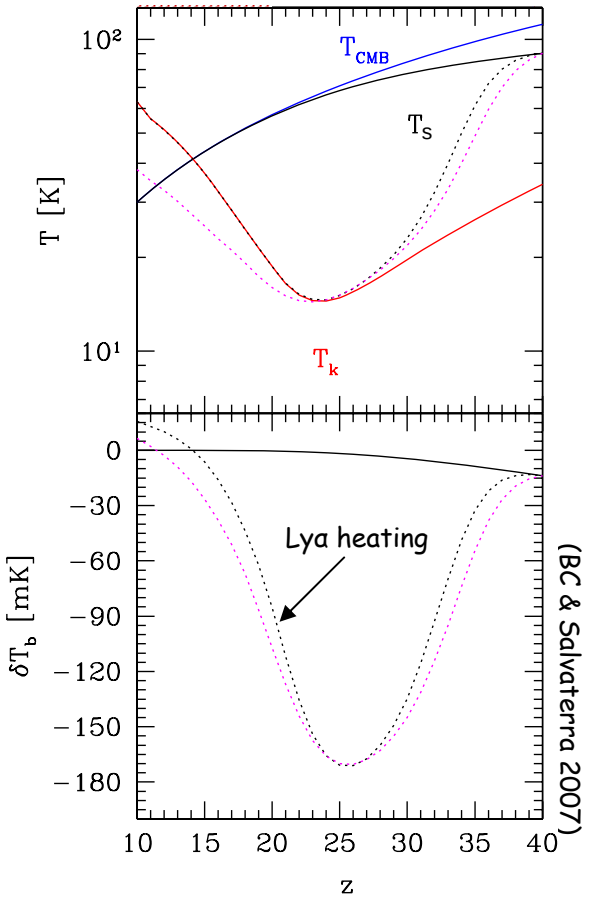
- In the absence of other decoupling mechanisms 21cm line will not be visible at z<20



Lya background from metal-free stars with Salpeter IMF or VMS with M=300Msun

(BC & Salvaterra 2007)

Lya scattering & heating



- In the absence of other decoupling mechanisms 21cm line will not be visible at z<20

- Lya photon scattering decouples T_S from T_{CMB} → 21cm line can be observed

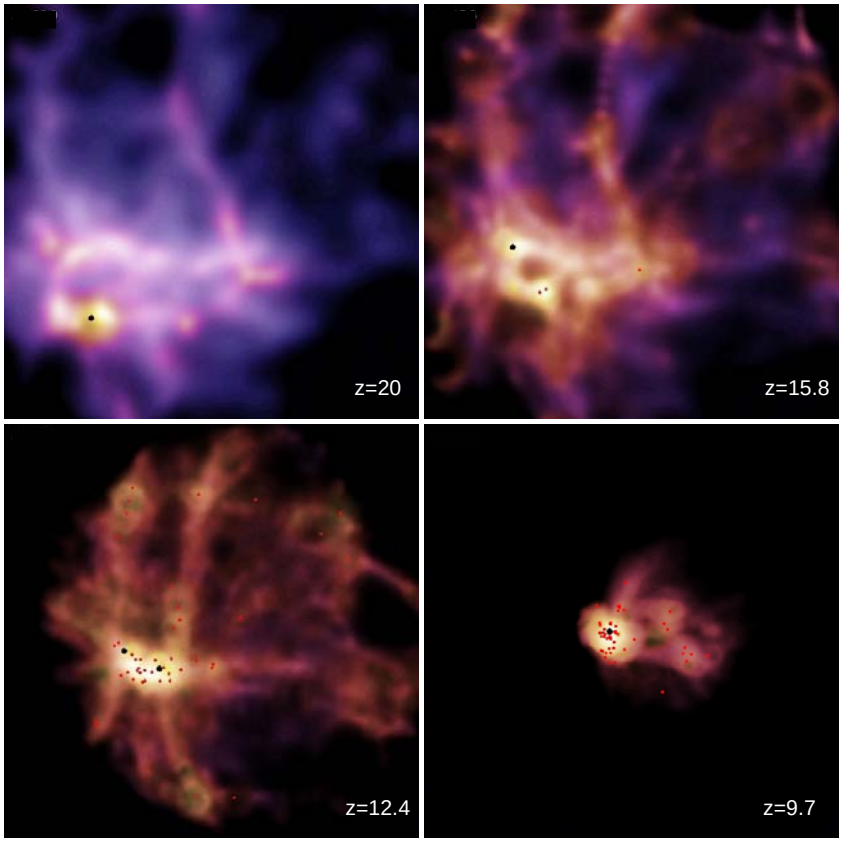
- Lya photon scattering heats the gas → 21cm line can be observed in emission

Lya heating is effective for $z \leq 15$

Metal-free stars, Salpeter IMF

Very massive metal-free stars

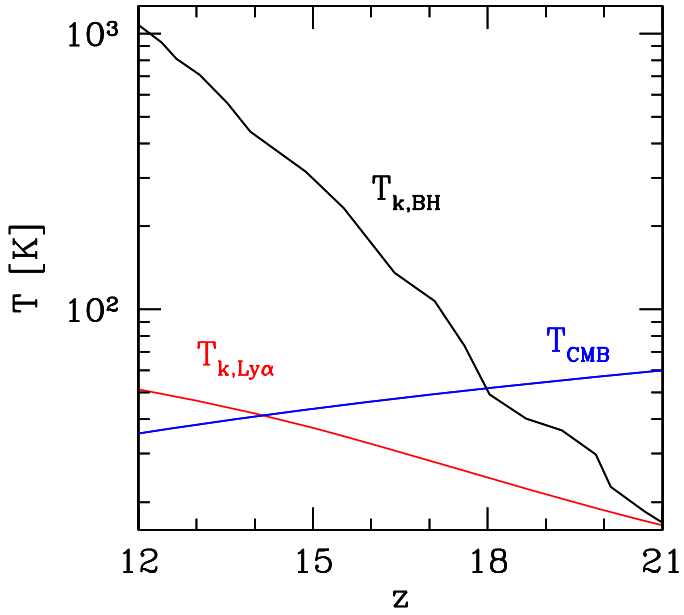
X-ray heating



200 kpc com.

(Pelupessy, Di Matteo, BC 2007)

- SPH simulations to study the formation of z~6 QSOs
- Merger of BHs hosted by parent halos and accretion onto them are followed

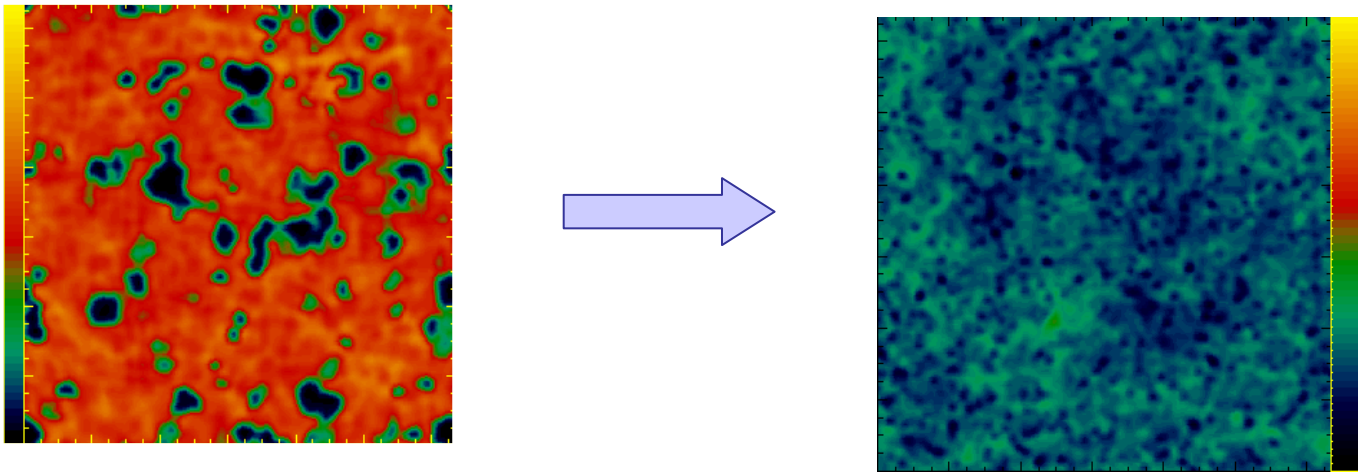


Accretion onto the BHs → X-ray emission → heating

21cm line diagnostic

The 21cm line is observed in emission if:

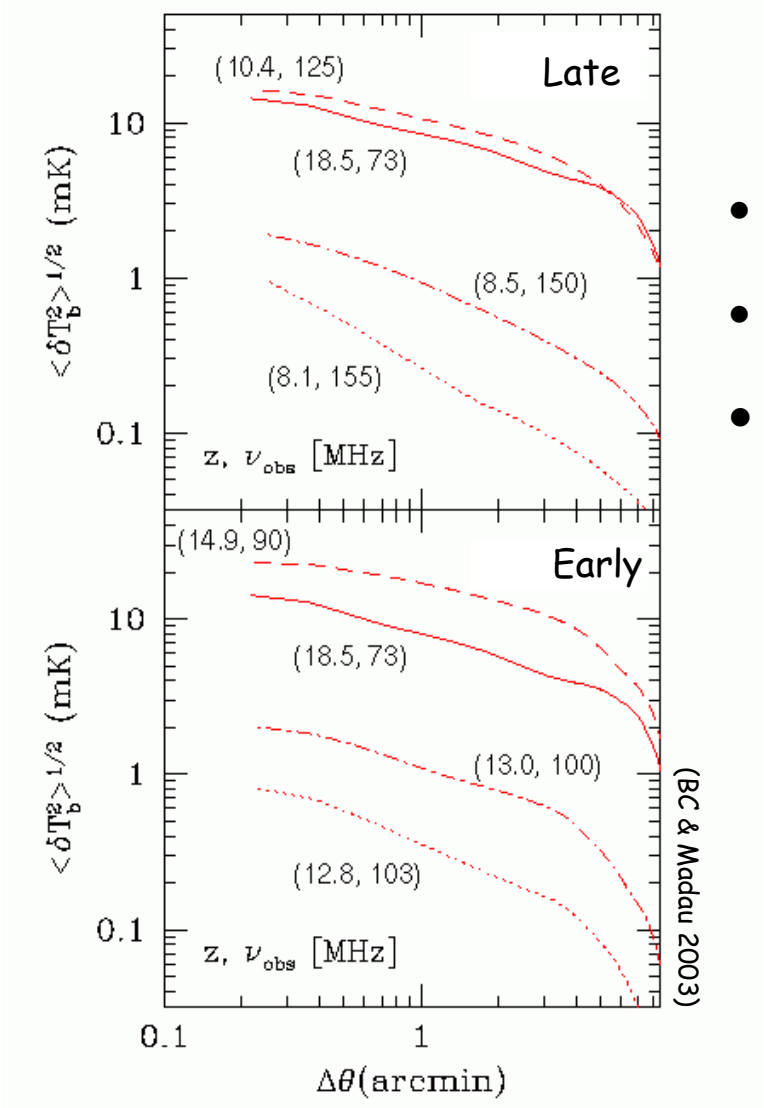
$$T_s >> T_{CMB} \Rightarrow \quad \delta T_b \propto n_{HI}$$



(BC & Madau 2003)

Fluctuations of brightness temp.

The fluctuations are due to variations in HI distribution
(density distrib. + ionized regions)



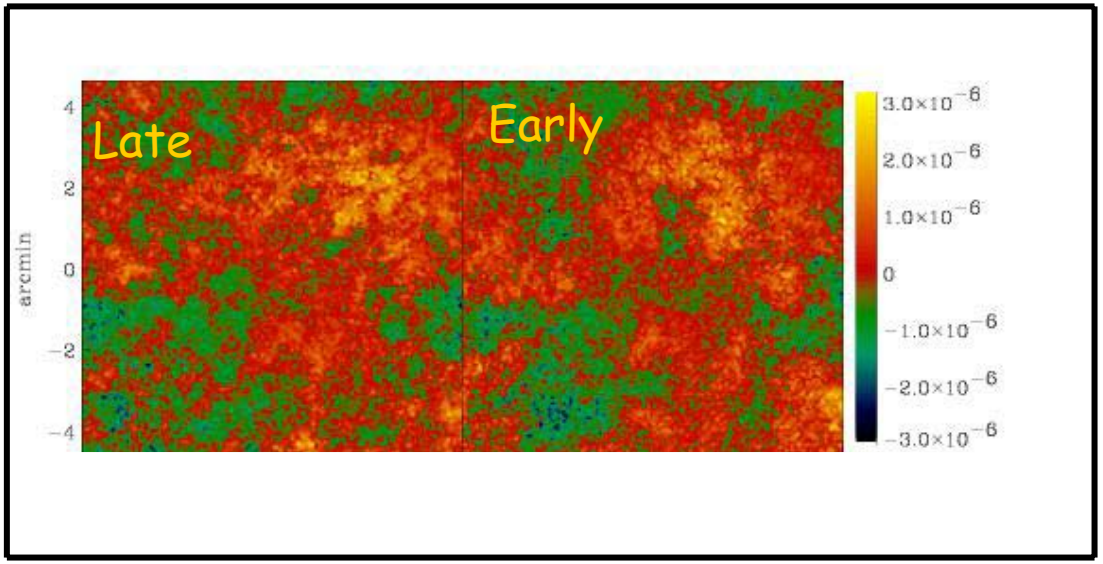
- Late/Early reionization show similar behaviour
- The peak of the emission is ~10 mK
- Early reion. peaks @ 90MHz,
  late reion. peaks @ 115MHz

Future radio telescopes should
be able to detect such signal

CMB/21cm line correlation

(Salvaterra, BC, Ferrara & Baccigalupi 2005)

$$\left(\frac{\delta T}{T}\right)_{CMB}(\hat{\gamma}) = \tau_0 \int_0^1 \frac{d\eta}{\eta^4} \chi_{HII}(\vec{x},\eta)\hat{\gamma}\cdot\vec{v}(\vec{x},\eta)$$



(δT/T)

- CMB anisotropies are produced by free electrons
- 21cm line is emitted by neutral hydrogen

CMB/21cm line correlation

(Salvaterra, BC, Ferrara & Baccigalupi 2005)

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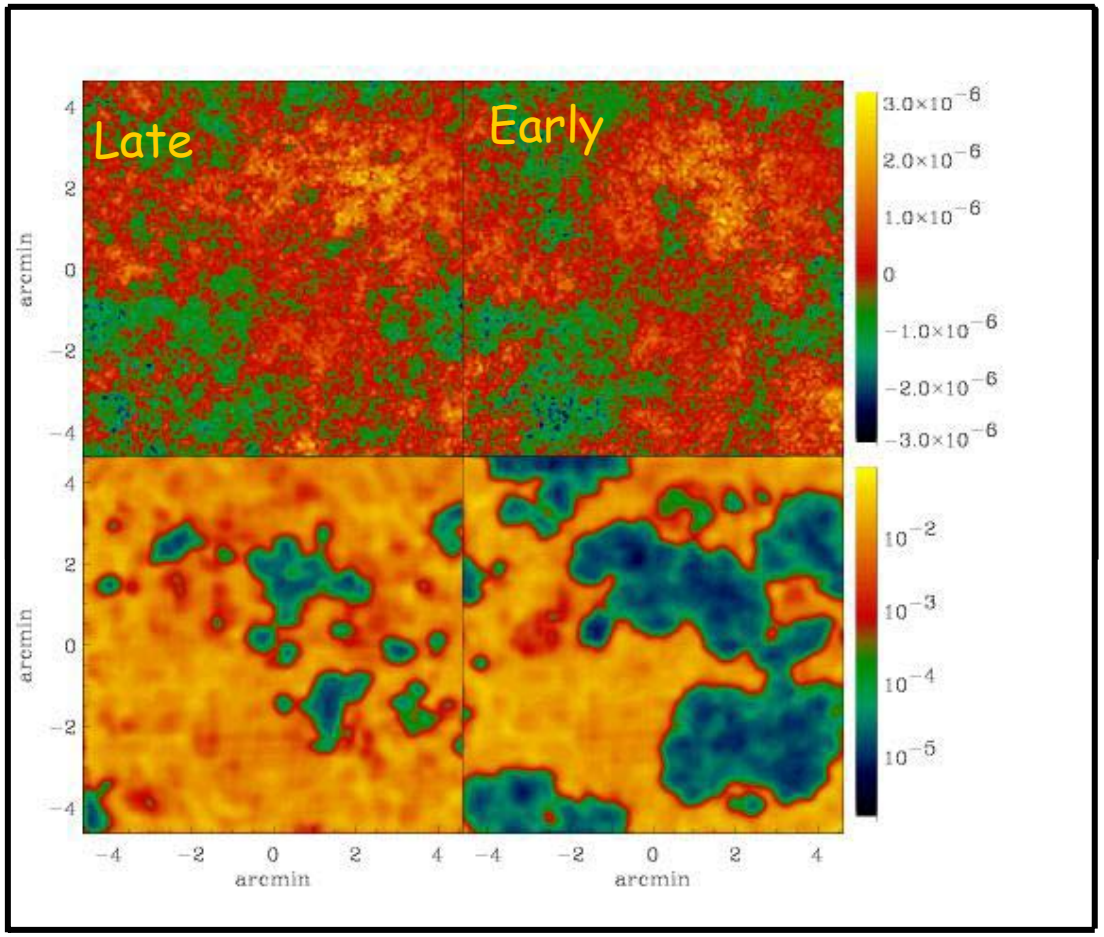
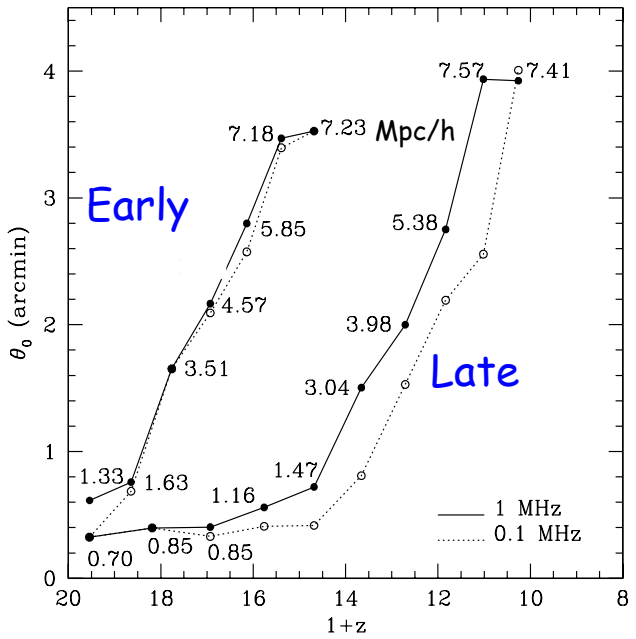


(δT/T)

CMB/21cm line correlation

We find an anti-correlation below a characteristic angular scale, θ_0, when the correlation function becomes < 0.

Characteristic angular scale of the cross-correlation function



The characteristic angular scale of the cross-correlation function gives an estimate of the typical dimension of the HII regions at redshift of the 21cm emission line.

(Salvaterra, BC, Ferrara & Baccigalupi 2005)

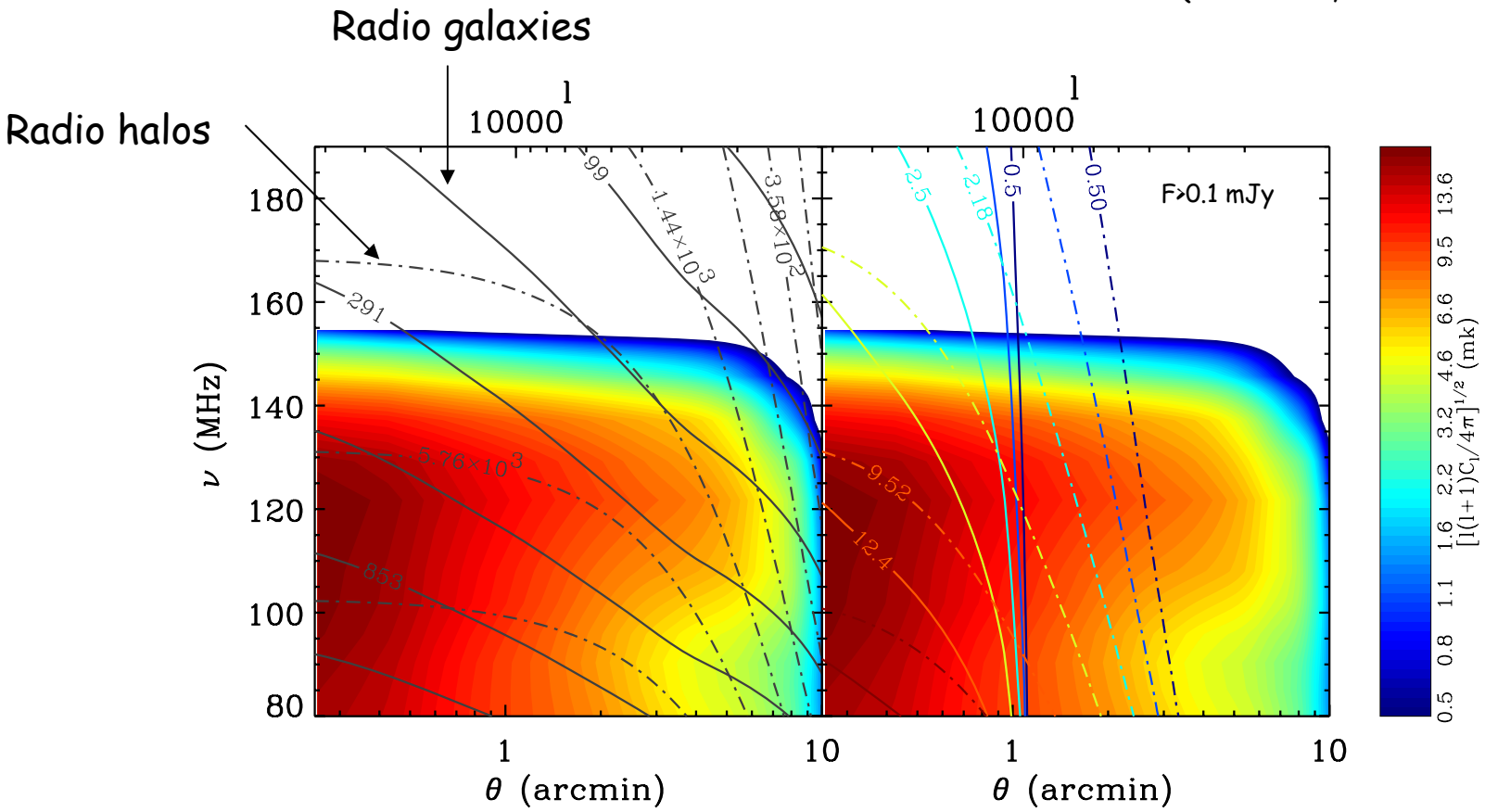
Extra-galactic foreground contamination

(Di Matteo, BC & Miniati 2004)

- Point Sources:
  - Free-free emission from IS HII regions
  - Low-z radio galaxies
- Extended Sources:
  - Free-free emission from IG HII regions
  - Syncrotron emission from cluster radio halos & relics

Extra-galactic foreground contamination

(Di Matteo, BC & Miniati 2004)



After removal of bright sources (F>0.1 mJy), at scales >1 arcmin 21cm emission line is free from extra-galactic foreground contamination

LOFAR at MPA