Reionization & 21cm observations

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& the LOFAR Team

Simulations of reionization

(BC, Stoehr & White 2003; BC, Ferrara & White 2003; BC et al. 2006)

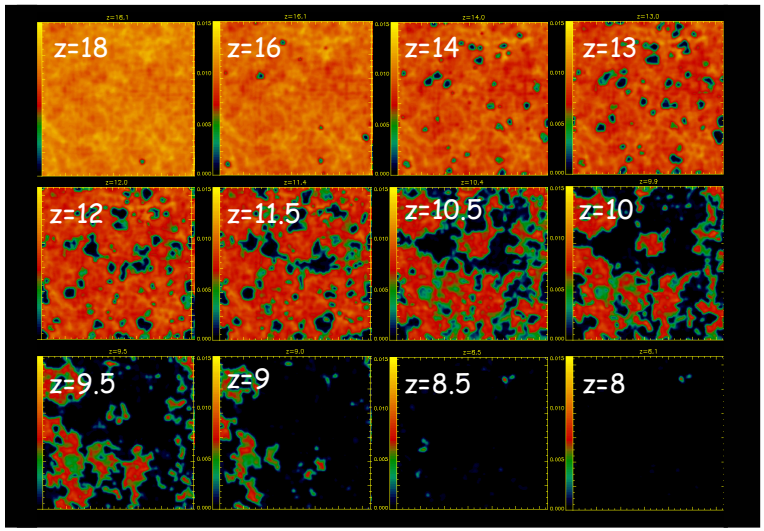
- Simulations of galaxy formation → gas & galaxy properties

  (Springel et al. 2000; Stoehr 2004)

- Stellar type sources → emission properties

- CRASH → propagation of ionizing photons

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



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%

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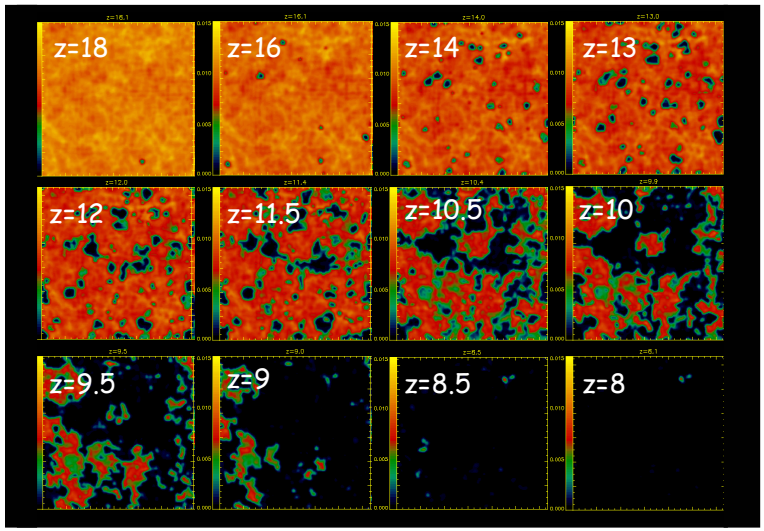
- Sub-grid physics to include MHs absorption/photoevap



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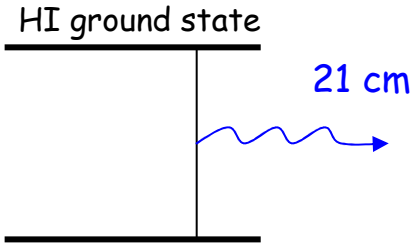
21cm line diagnostic

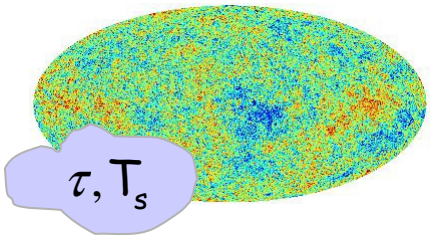


Ideal probe of neutral H at high-z
different observed frqs. → different z

Differential brightness temperature:

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

spin temperature



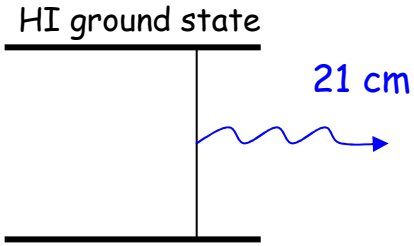
$T_{CMB} = T_s \Rightarrow$ no signal

$T_{CMB} > T_s \Rightarrow$ absorption

$T_s > T_{CMB} \Rightarrow$ emission

The value of T_s is critical

21cm line diagnostic



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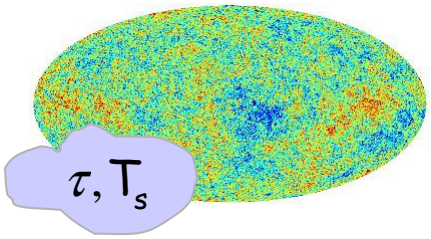

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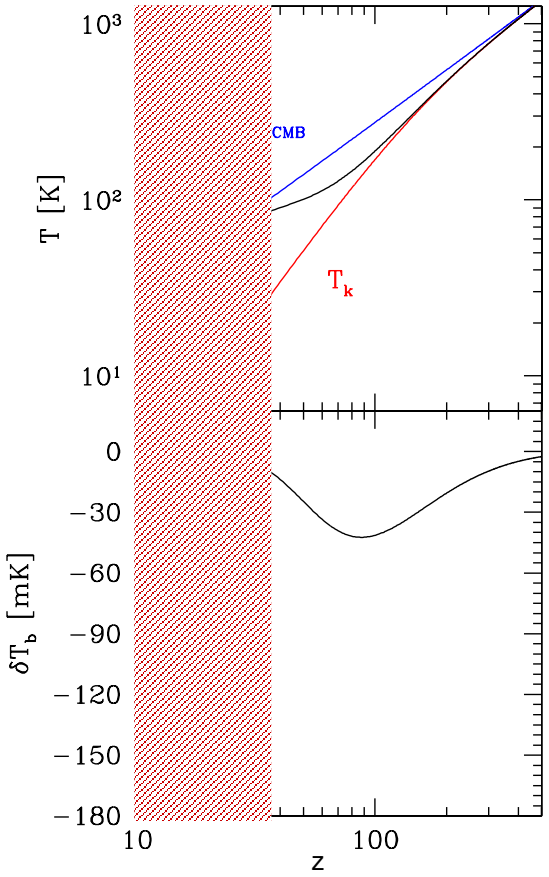
kinetic temperature of the gas

$$T_s = \frac{T_{CMB} + (y_\alpha + y_c)T_k}{1 + y_\alpha + y_c}$$

Lya scattering & heating



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

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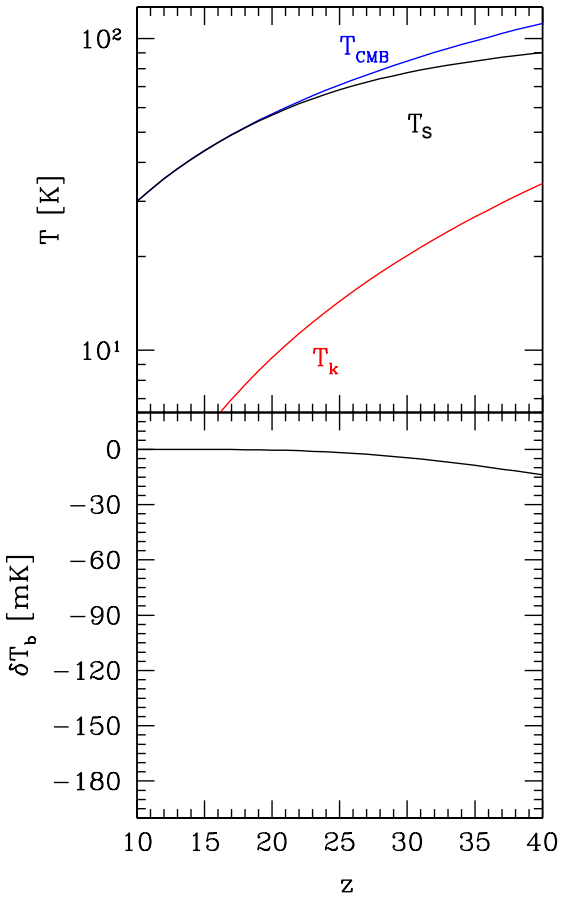

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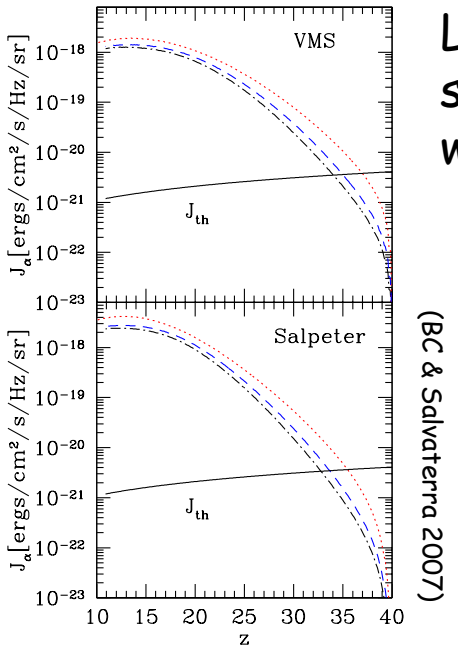
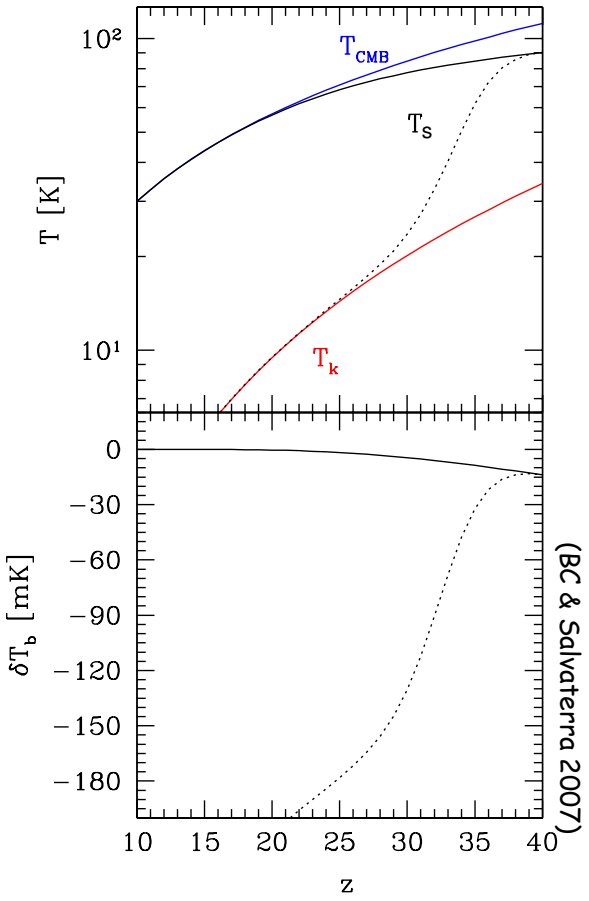


Lya background from metal-free stars with Salpeter IMF or VMS with M=300Msun

(BC & Salvaterra 2007)

Lya scattering & heating



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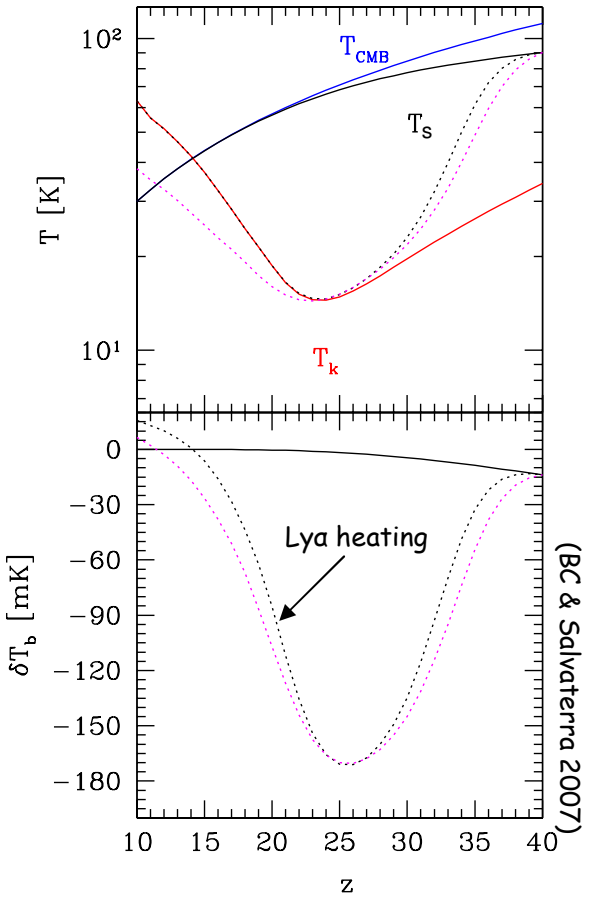
Lya scattering & heating



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

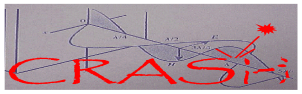
- Lya photon scattering heats the gas → 21cm line can be observed in emission

Lya heating is effective for $z \leq 15$

Metal-free stars, Salpeter IMF

Very massive metal-free stars

CRASHalpha



: continuum radiation (H, He)

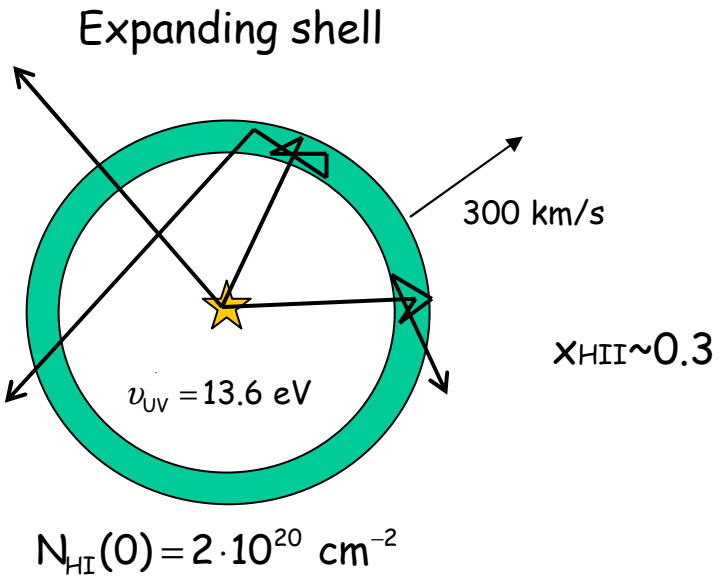
(BC et al. 2001; Maselli, Ferrara & BC 2003; Maselli, BC & Kanekar in prep.)

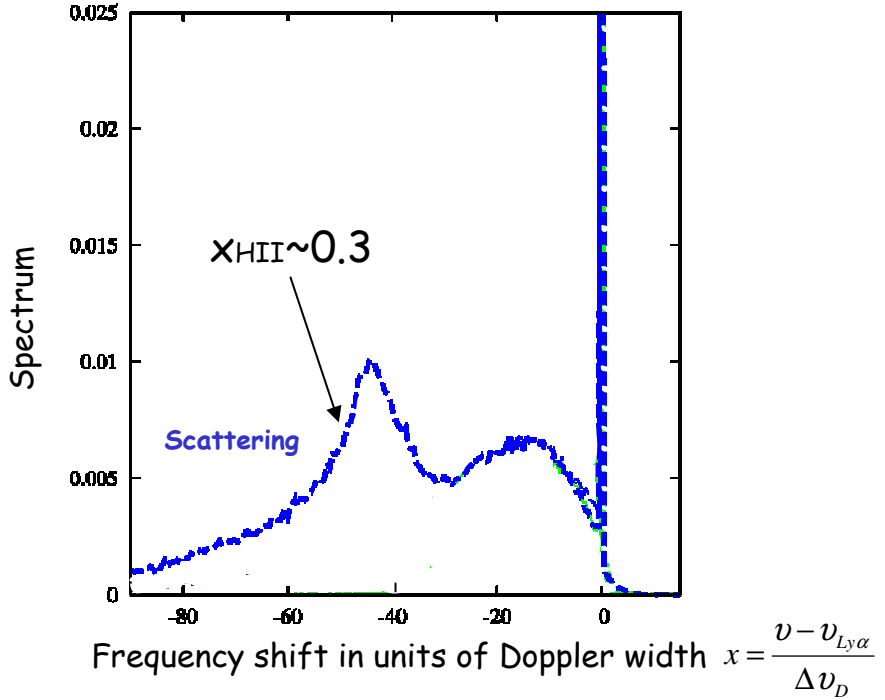
MCLyalpha: Lyalpha scattering

(Verhamme, Schaerer & Maselli 2006)

CRASHalpha: continuum radiation + scattering

(Pierleoni, Maselli & BC 2008)





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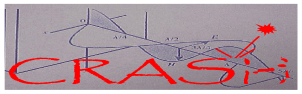

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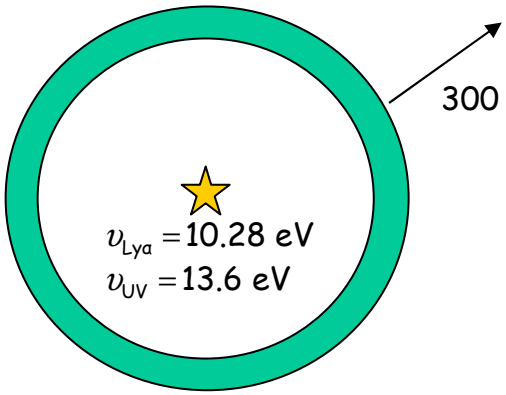
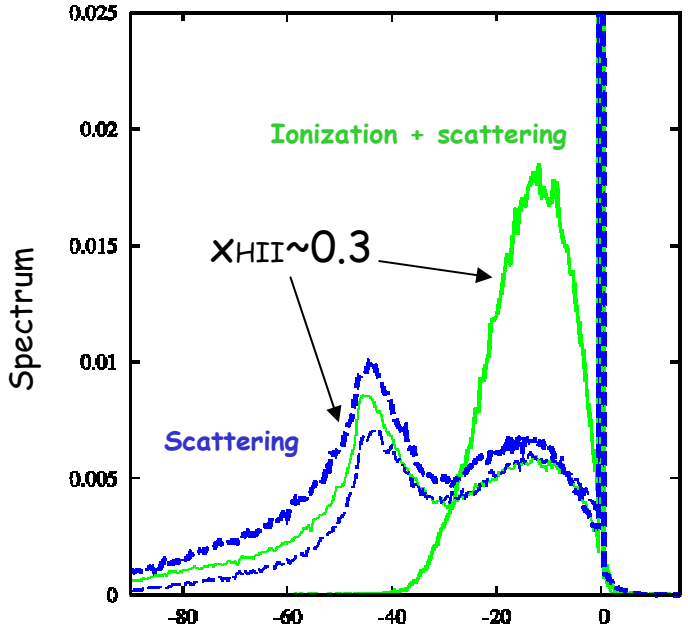
Expanding shell



$N_{HI}(0) = 2 \cdot 10^{20}$ cm^{-2}



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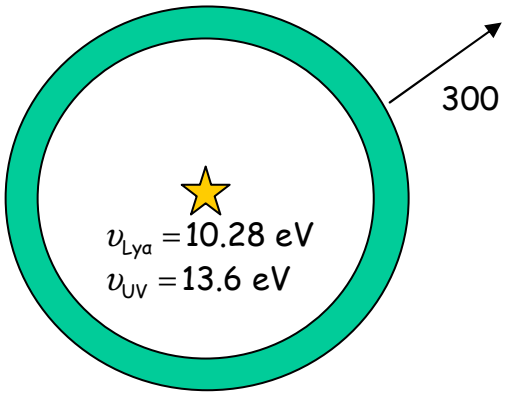

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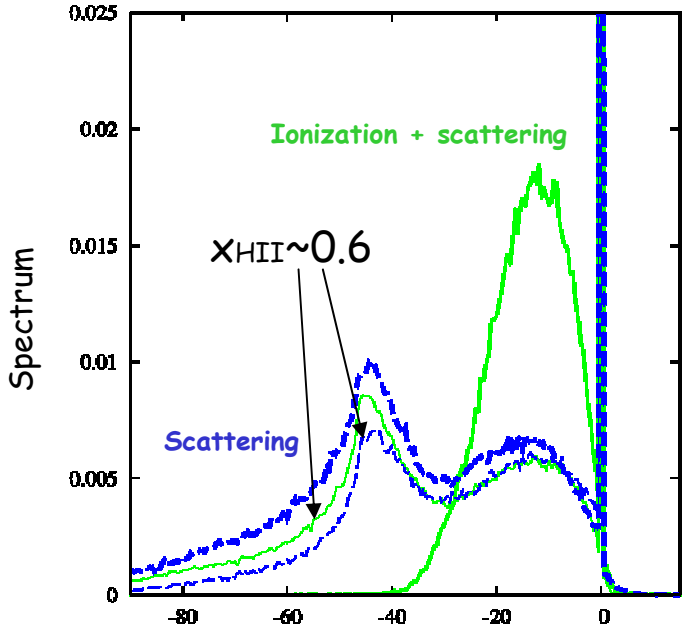
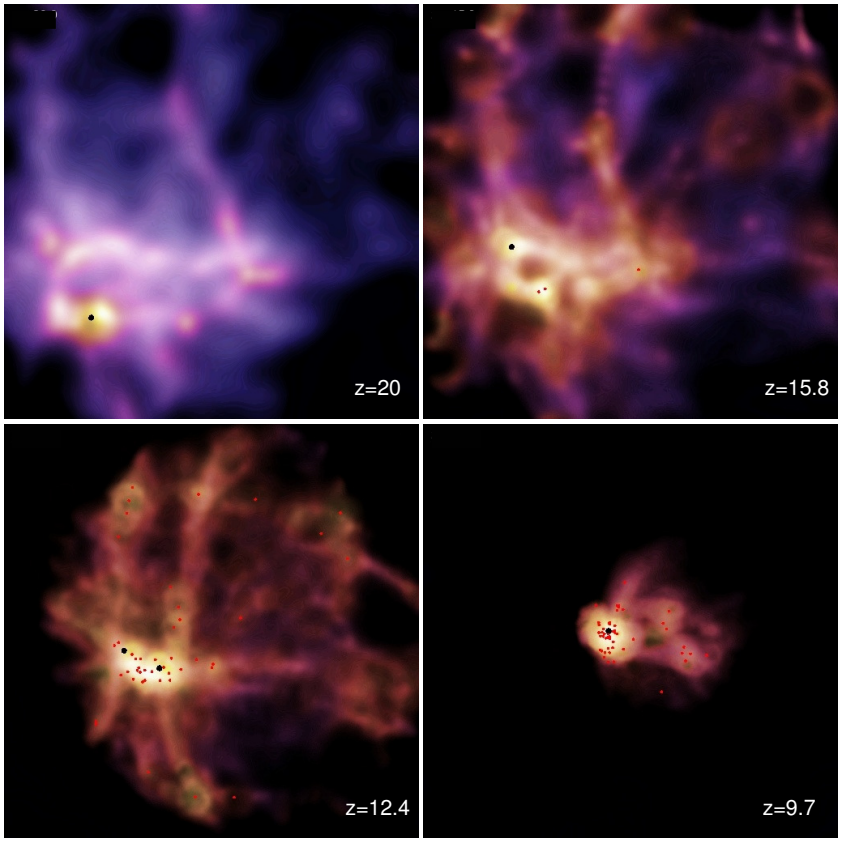


X-ray heating

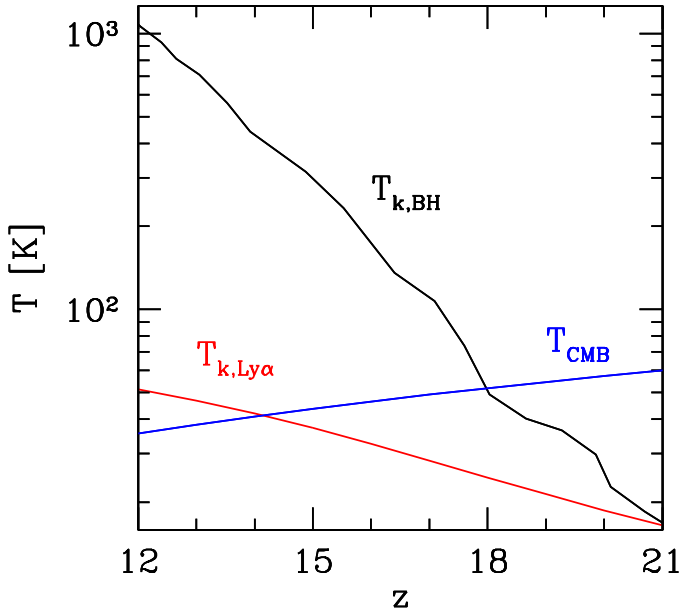


200 kpc com.

$M = 10^{10} M_{\oplus}$

(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

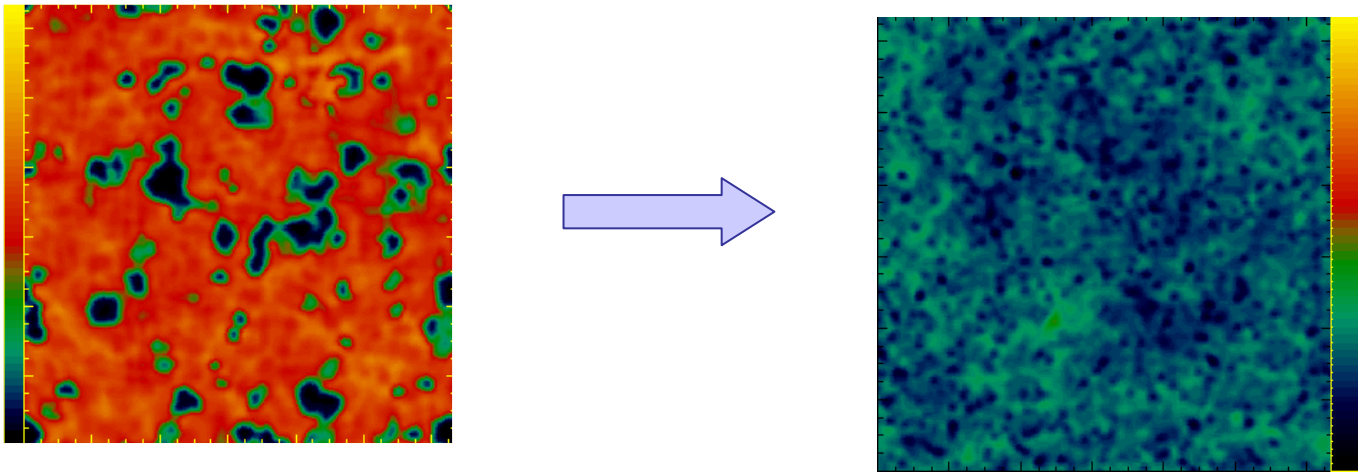


Accretion onto the BHs → X-ray emission → heating

21cm line diagnostic

The 21cm line is observed in emission if:

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

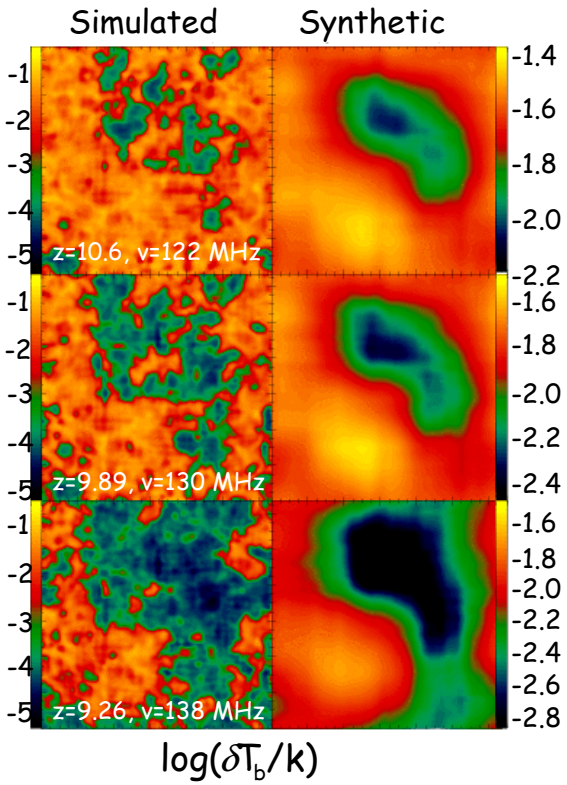


(BC & Madau 2003)

21cm line diagnostic

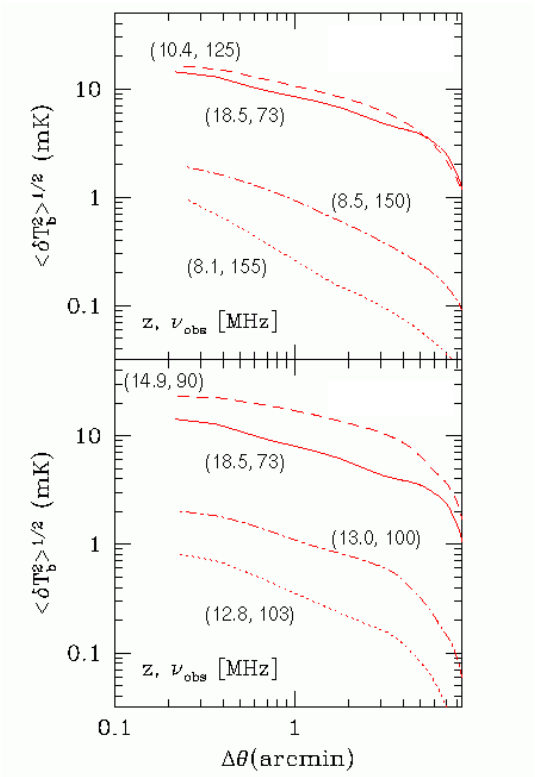
IGM Tomography

(Valdes, BC et al. 2006)



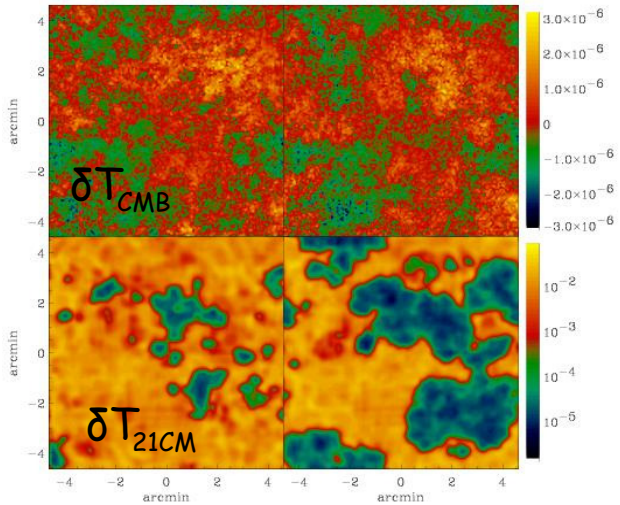
δTb Fluctuations

(BC & Madau 2003)

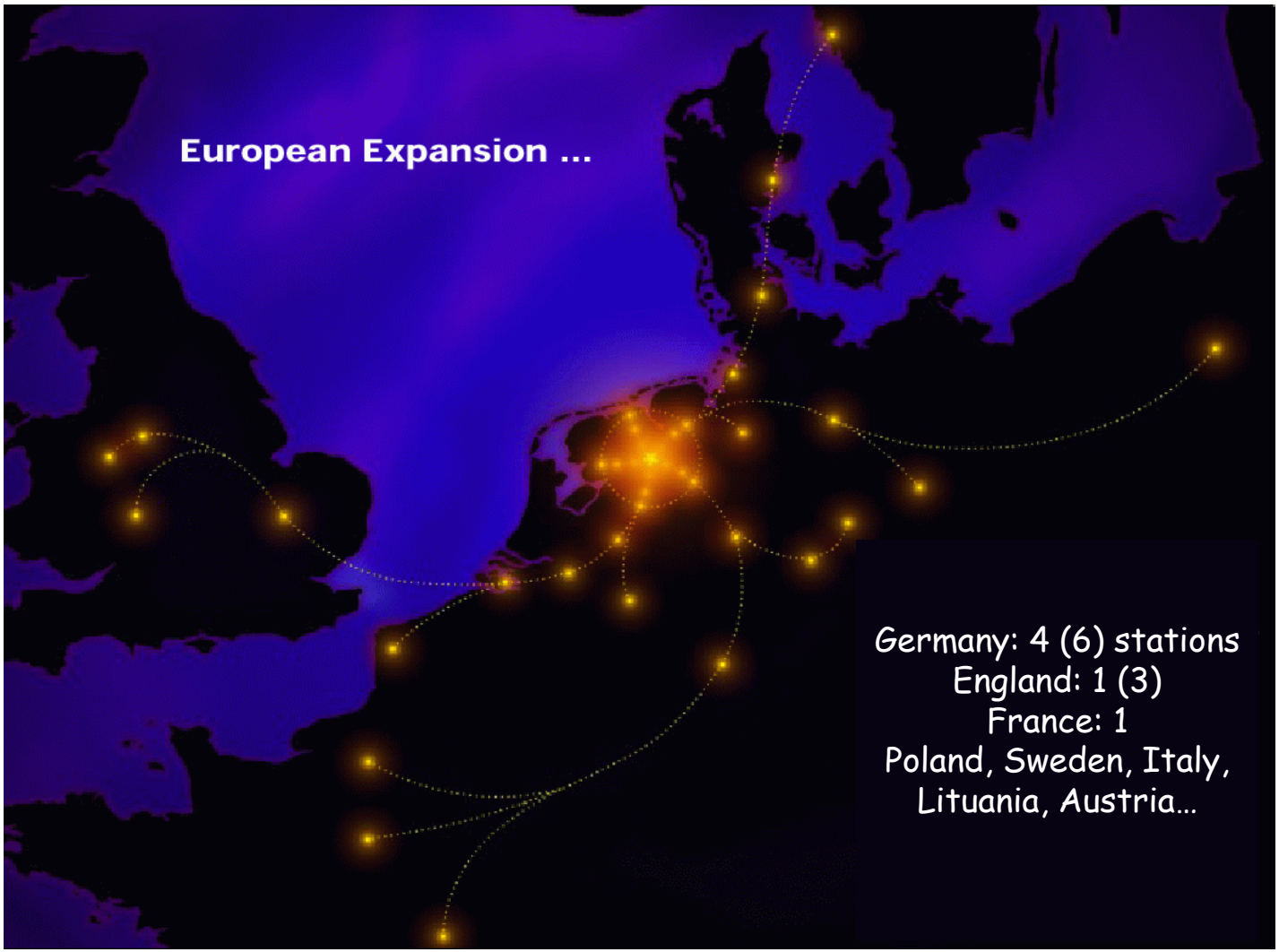


Correlation 21cm-CMB

(Salvaterra, BC et al. 2005)



LOFAR in Europe



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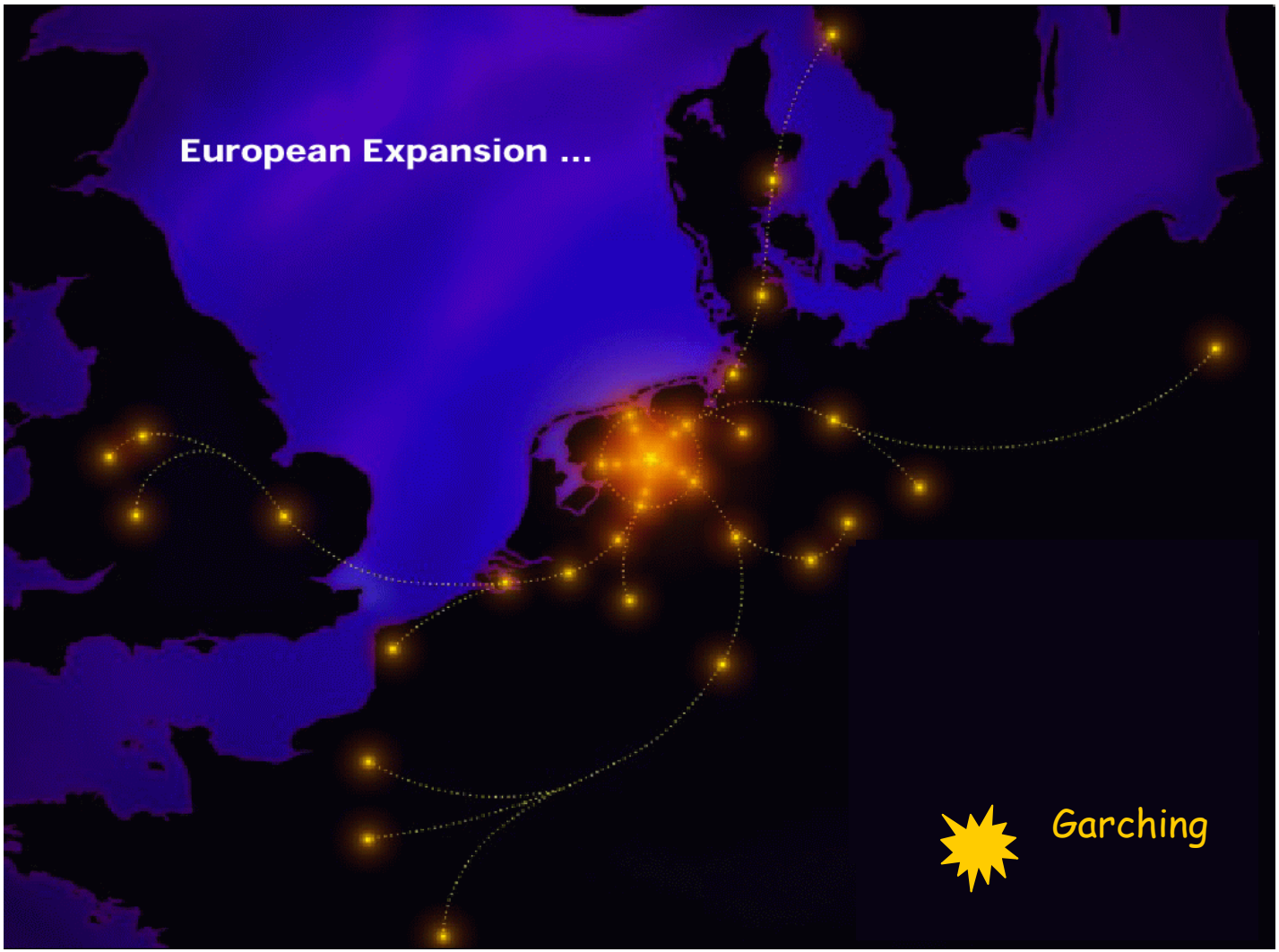
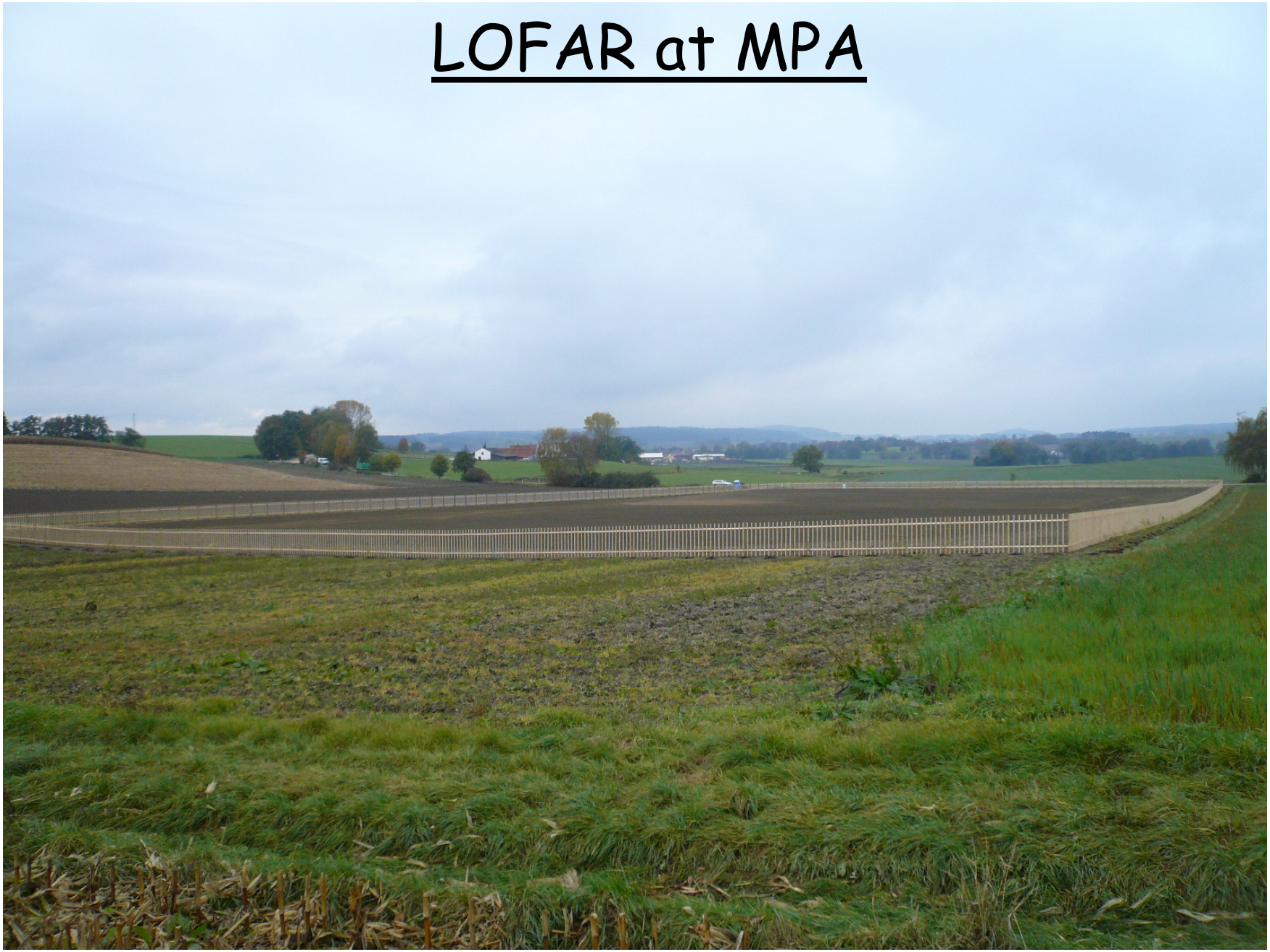


LOFAR at MPA



Conclusions

- Simulations of cosmic reionization → predictions for 21cm line
- 21cm diagnostic:
  - IGM tomography
  - Brightness temperature fluctuations
  - Combination with other observations, i.e. CMB anisotropies
- Importance of Lyalpha and x-ray photons for observability