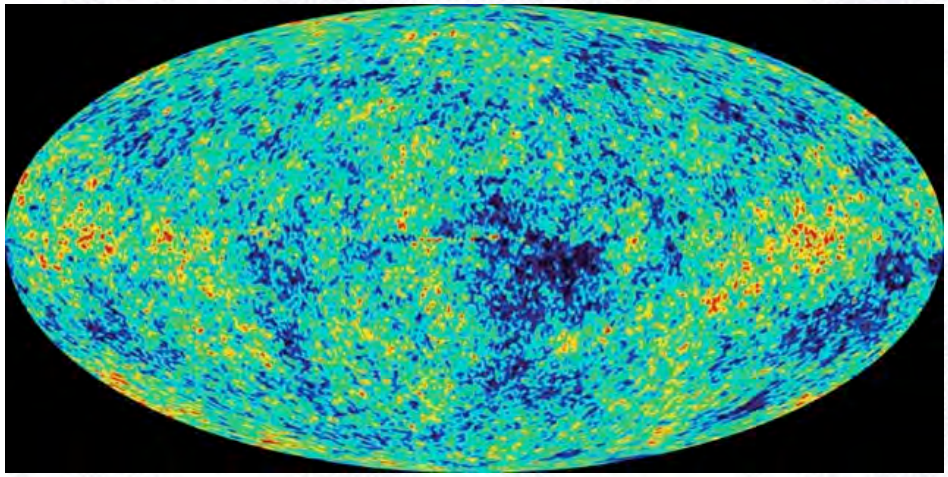
Reionisation: how, what for?

Nabila Aghanim

Institut d'Astrophysique Spatiale, Orsay

Cosmic evolution : formation and growth of structures



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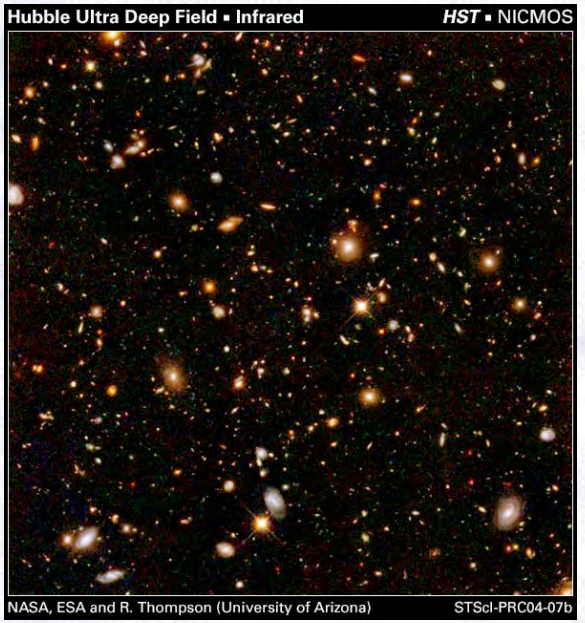
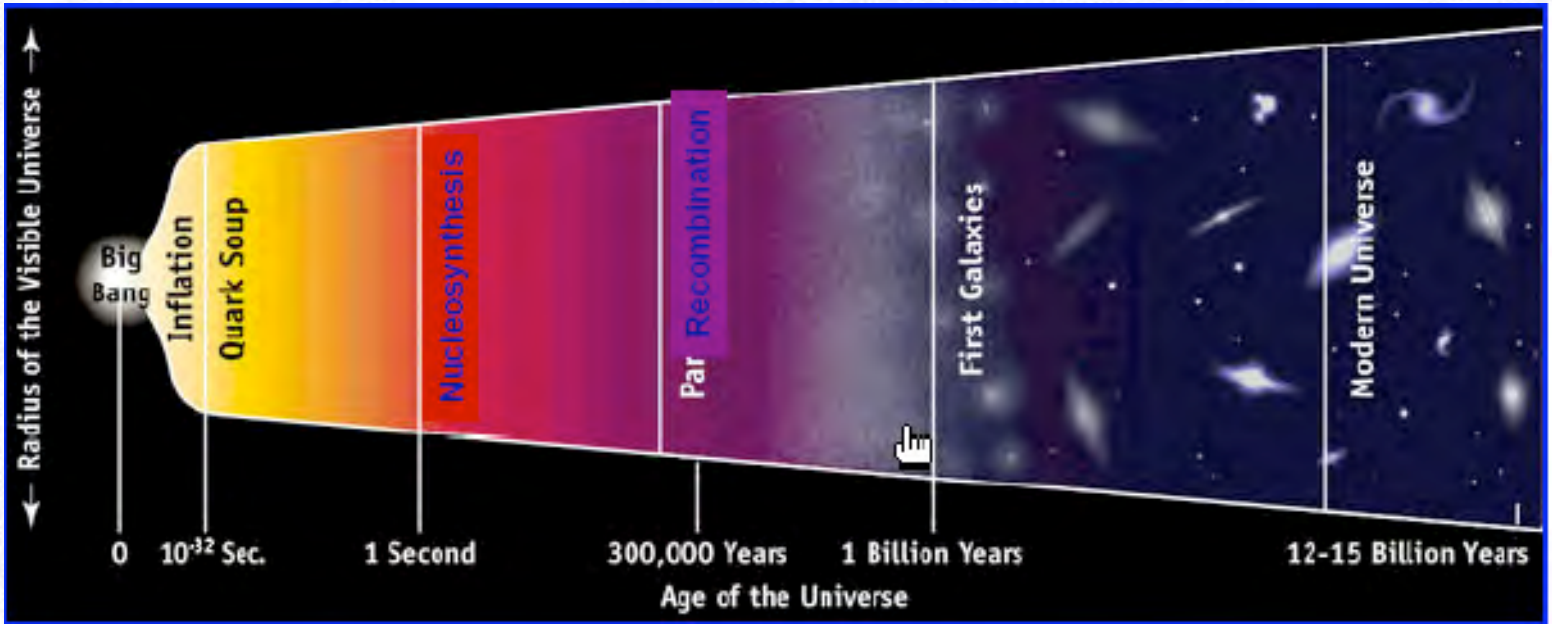
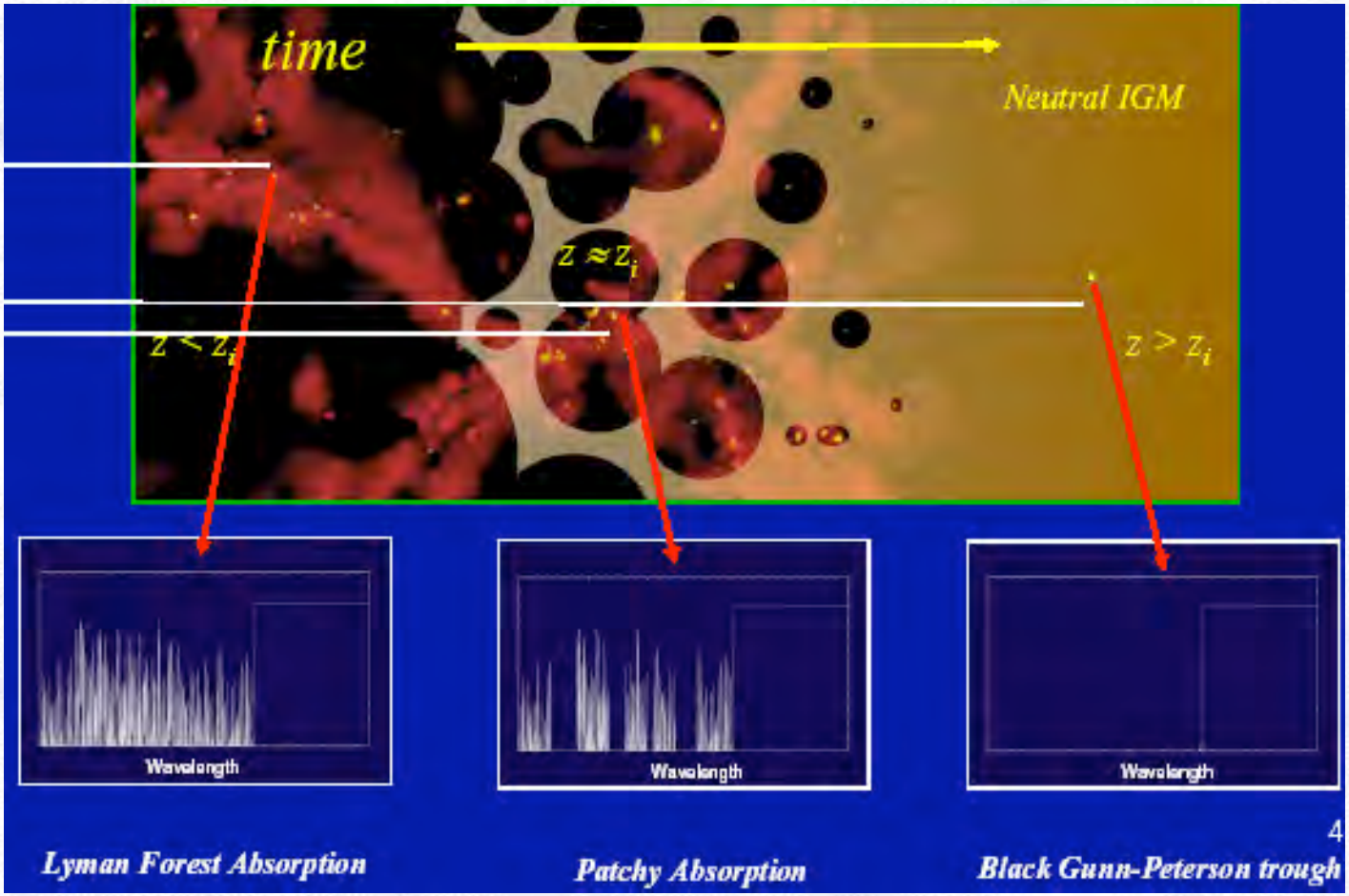




Reionisation = transition of universe from neutral state (after decoupling) @z~1000 to ionised state @z~20 to 6

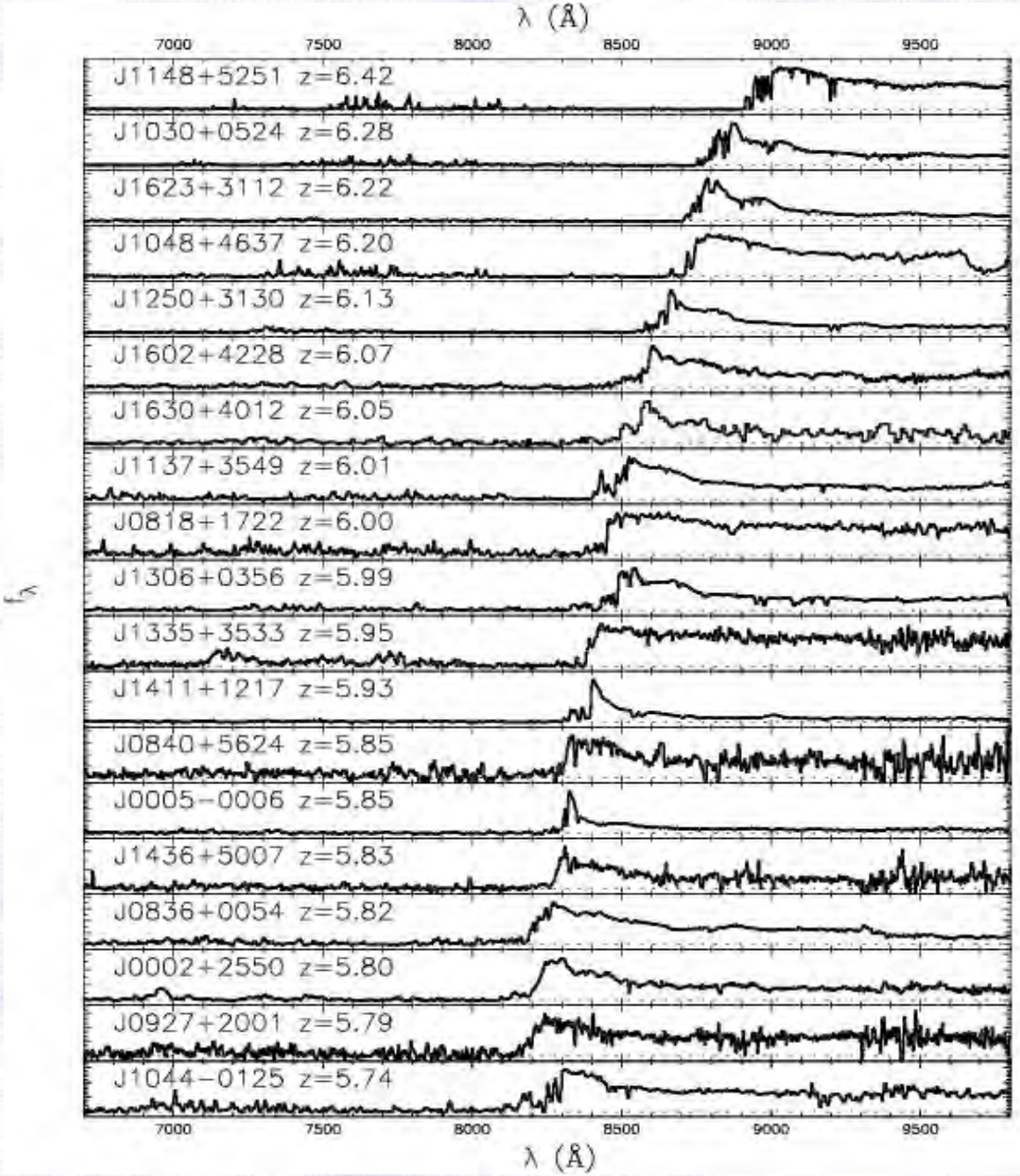


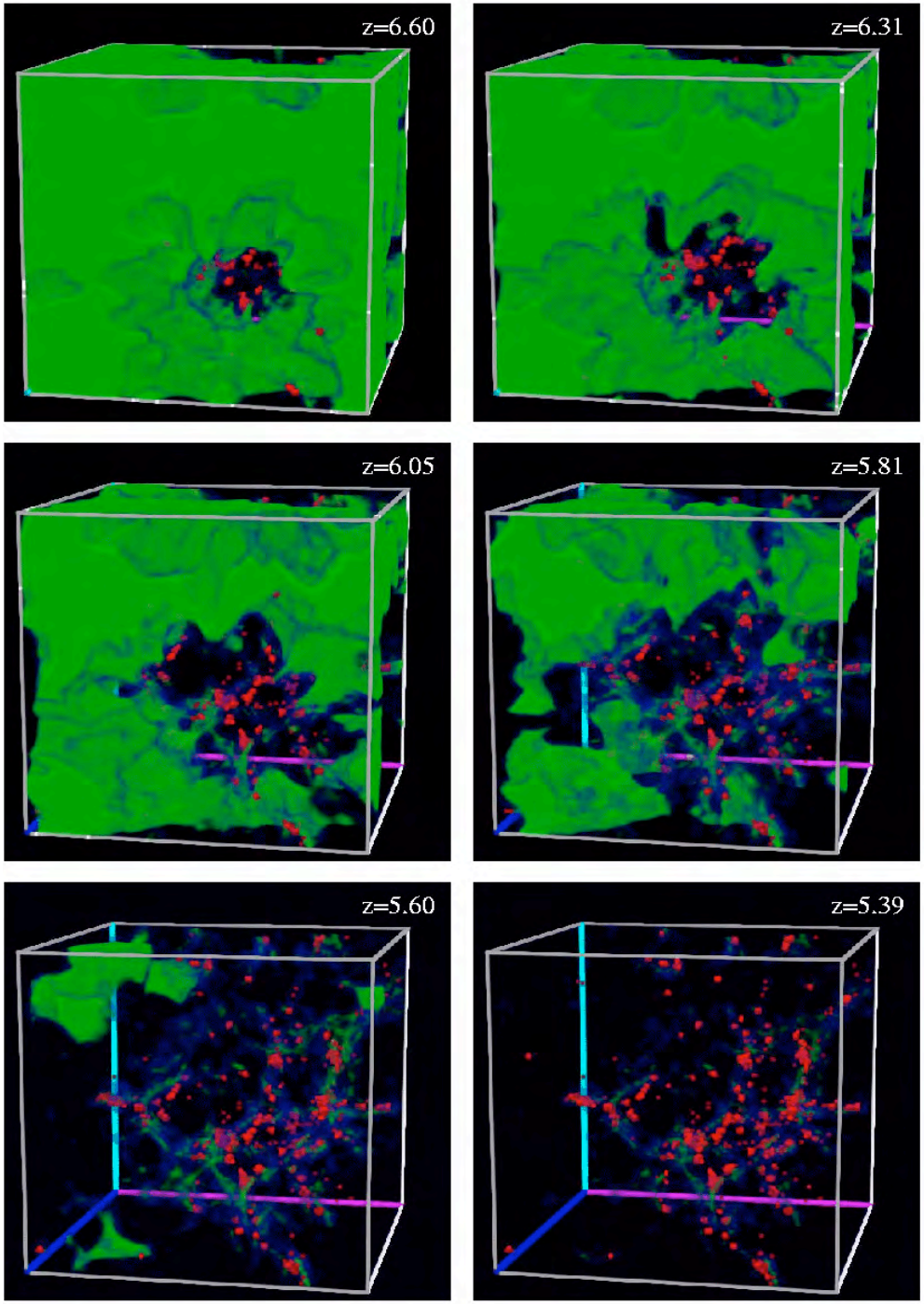
Ly-alpha photons absorbed

Back in time, universe

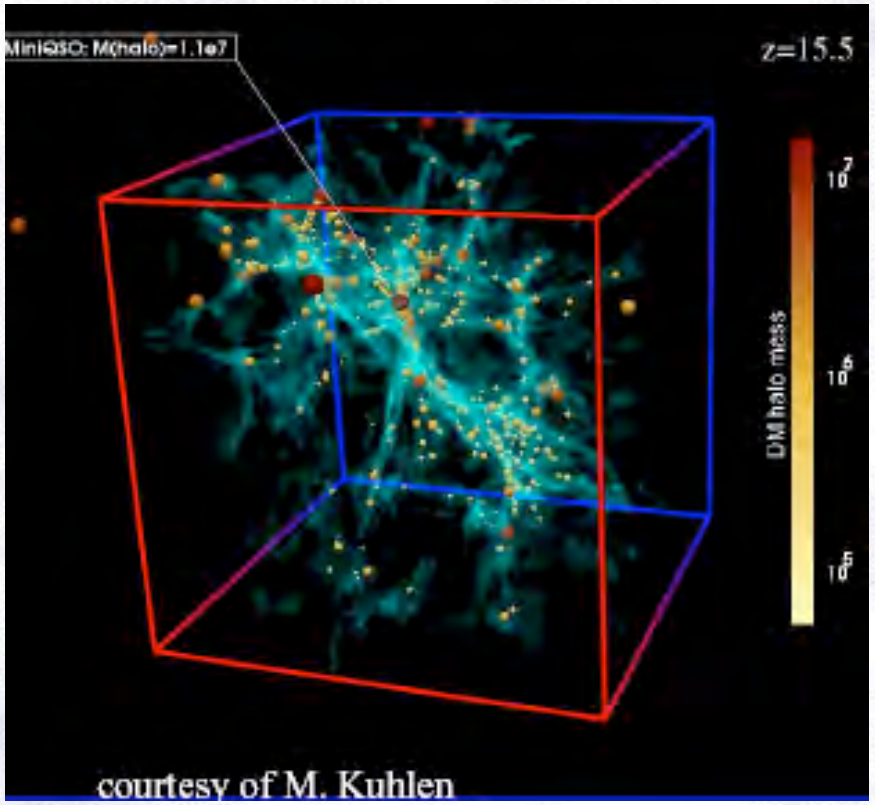
is more and more

neutral

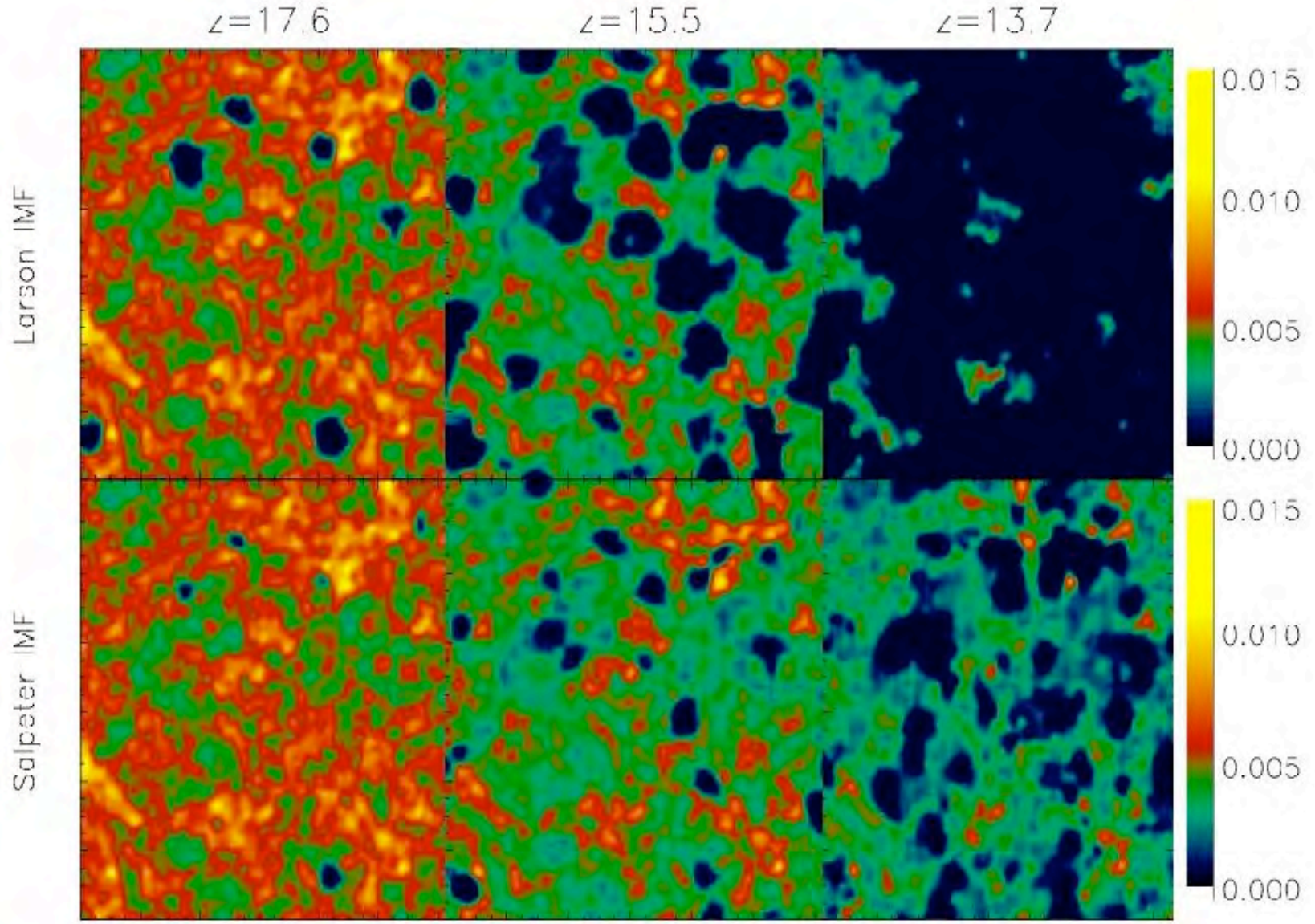




What are the first emitting objects formed?
Mini-BH, metal free massive stars (pop III), star-burts galaxies?
What are their observational effects?
How long? When? Can we test for reionisation models?



The evolution and distribution of sources induce different reionisation scenarii -> Here 2 different IMF

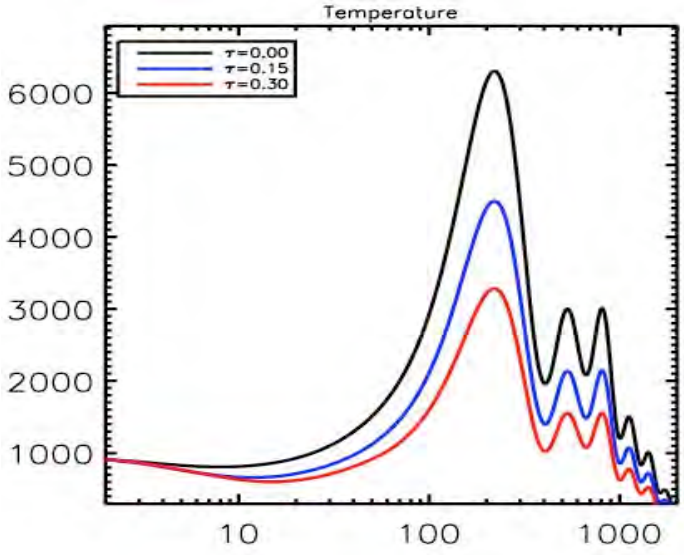


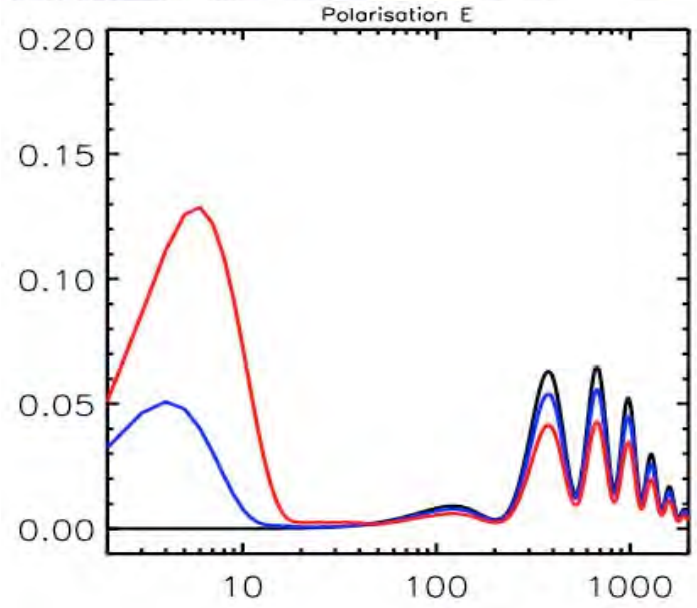
Ciardi et al.

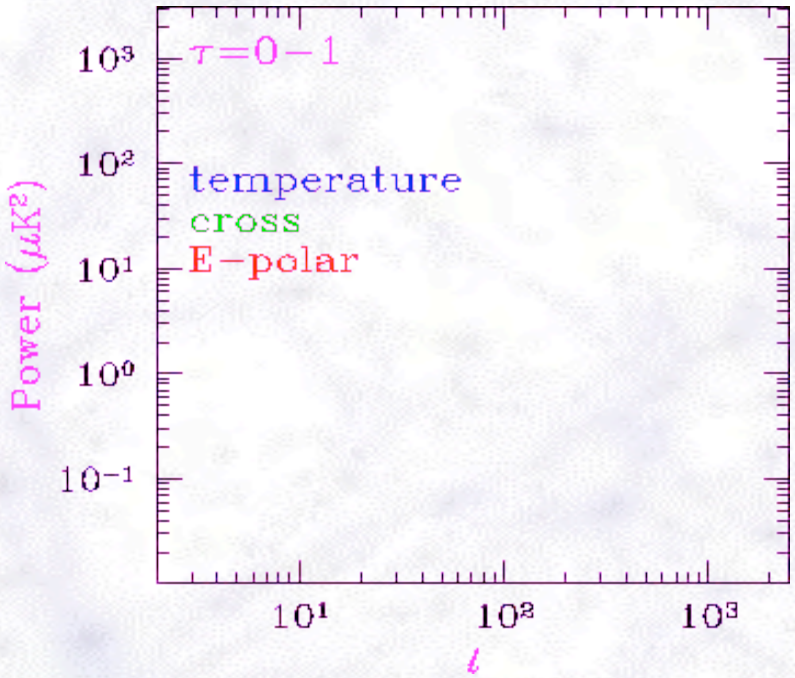
CMB polarisation and temperature

E modes (scattering) probe ionised phases: decoupling and reionisation

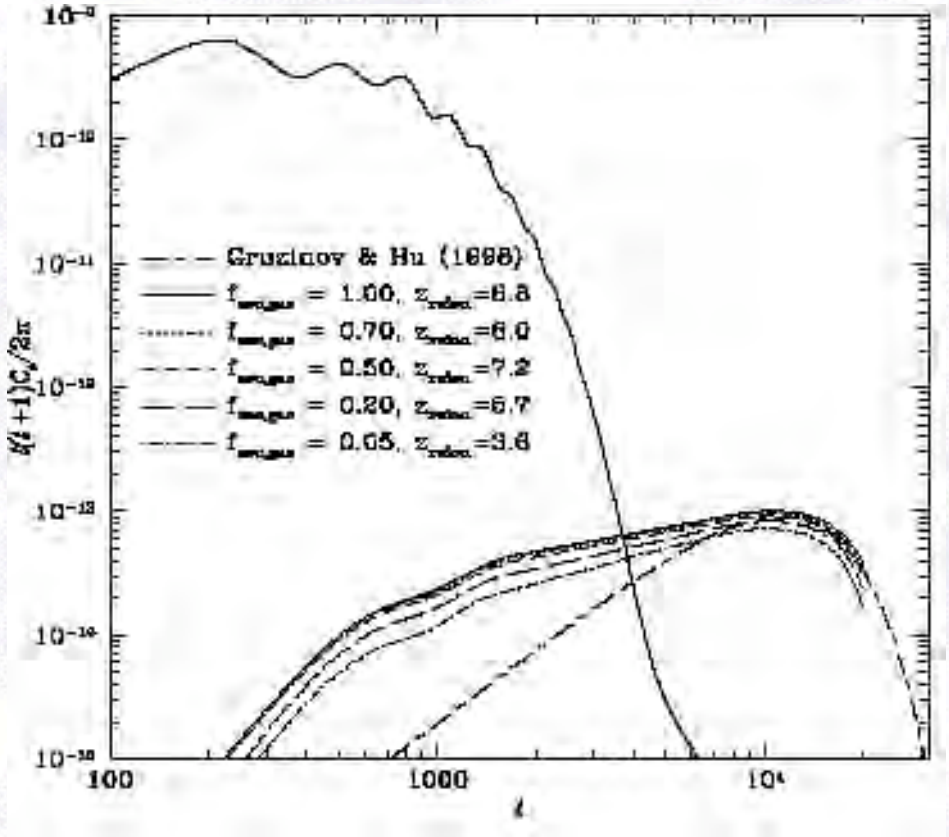
Reionisation -> large scales & peaks -> Optical depth, duration of reio



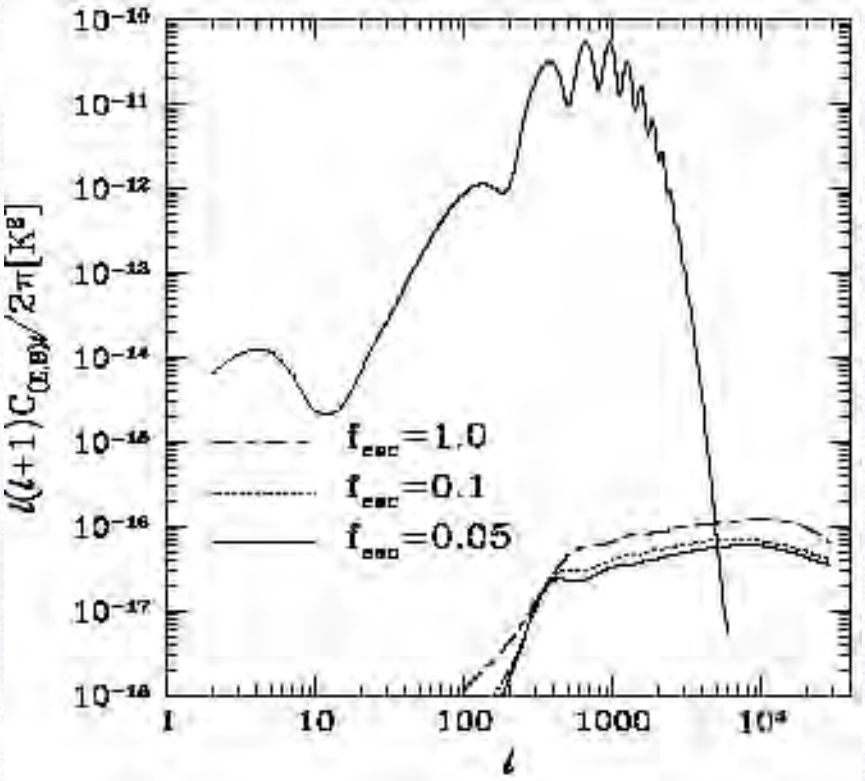




Effects at small angular scales



Benson et al. 01

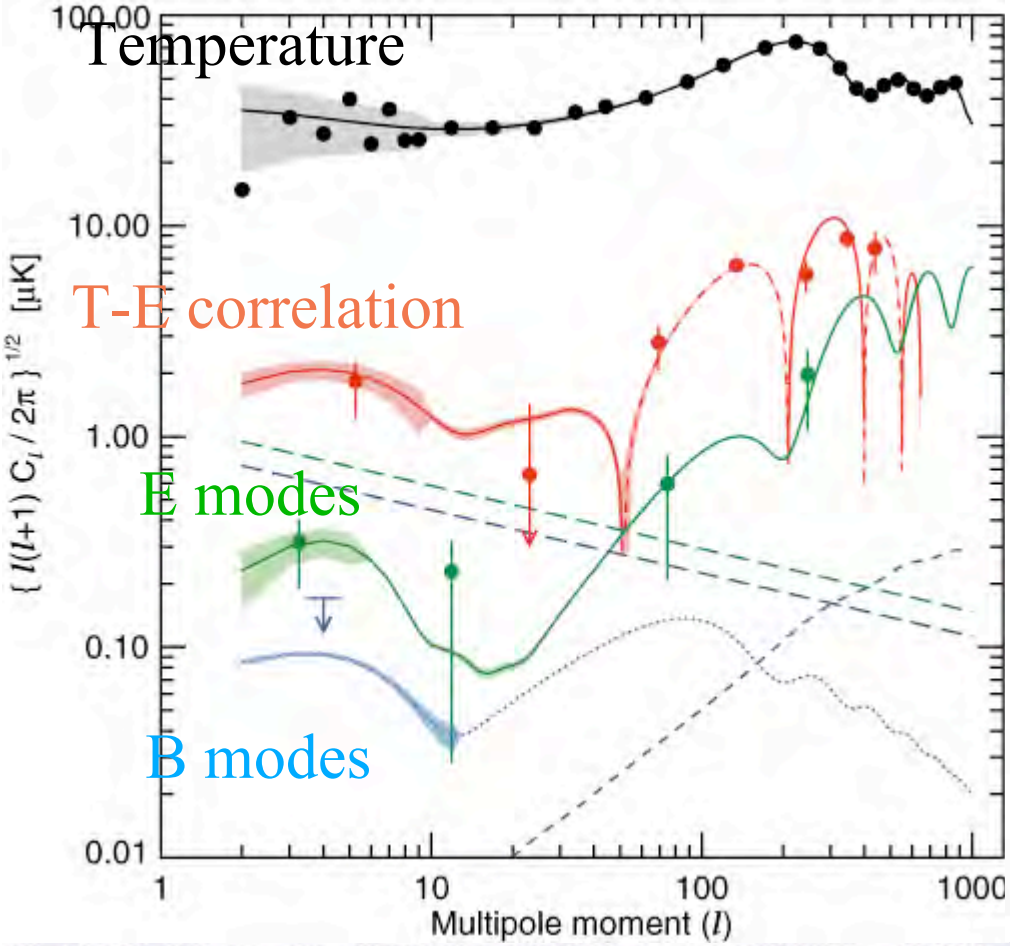


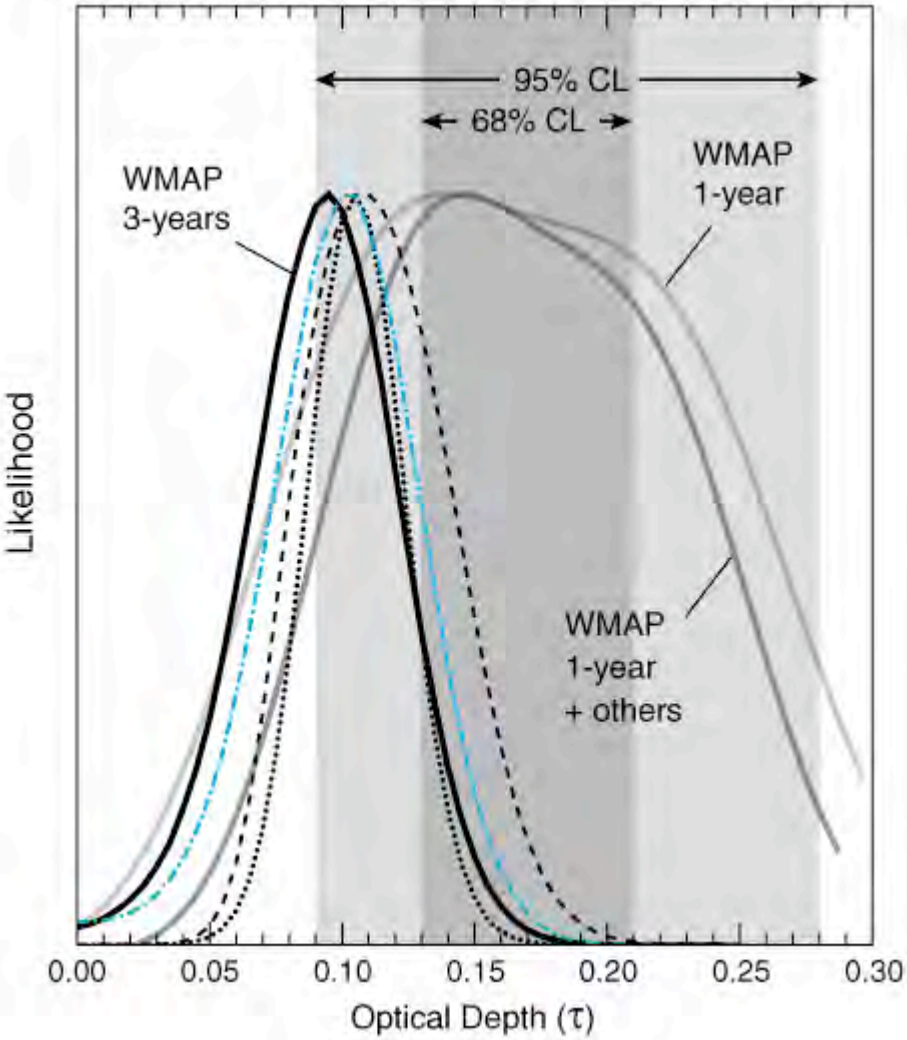
Liu et al. 01

WMAP-3yrs results

Optical depth ~0.09

Reionisation redshift ~ 10

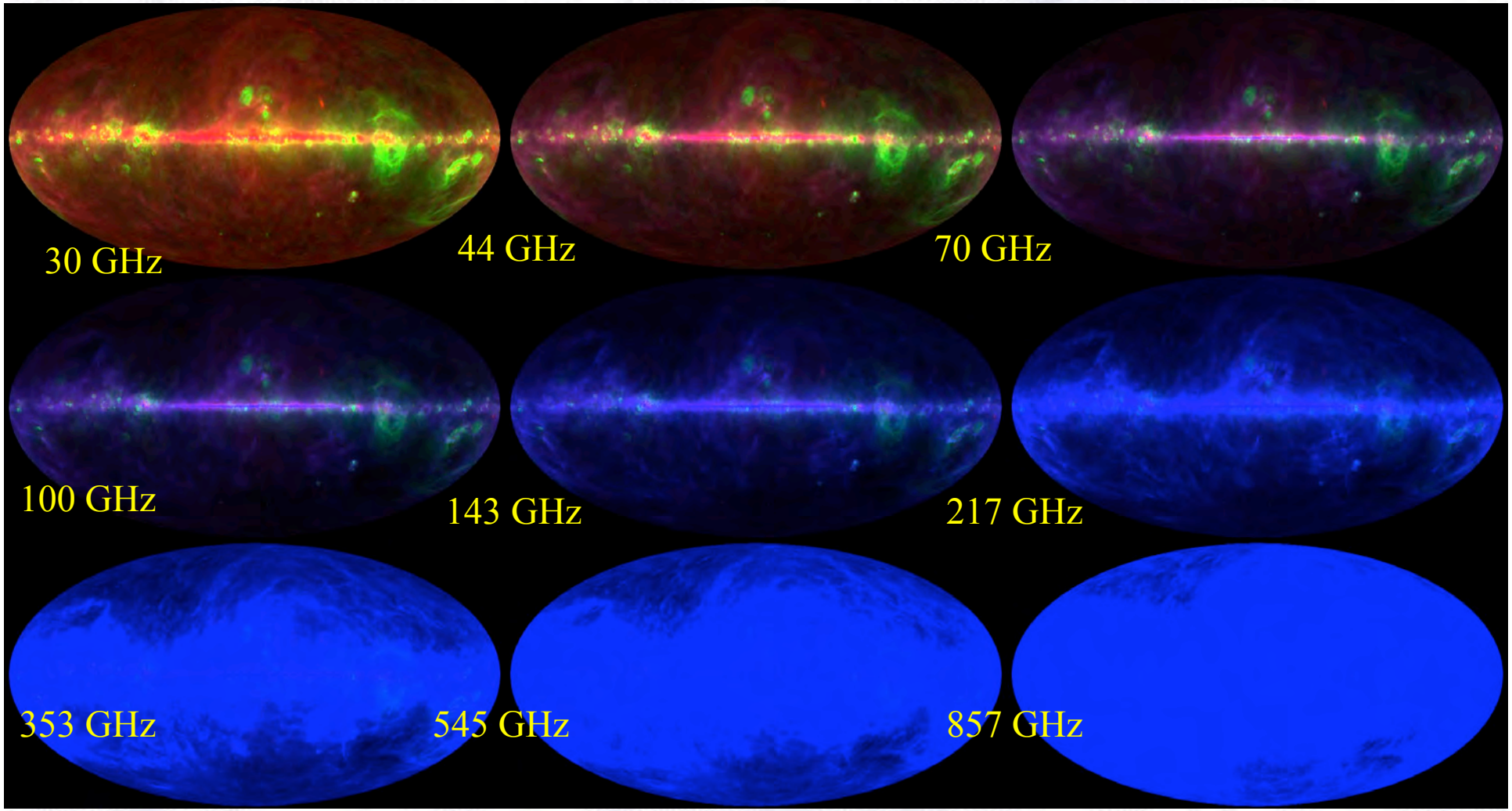


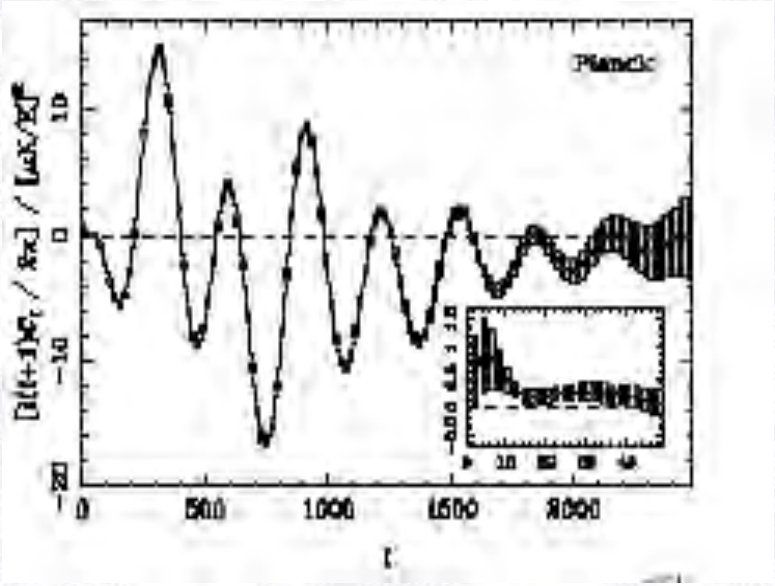


Courtesy WMAP team

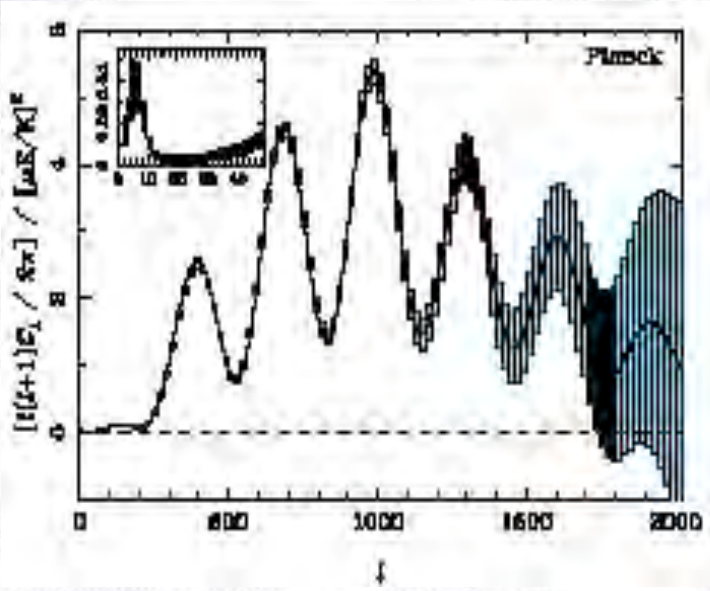
Planck Sky Model

Synchrotron
Bremsstrahlung (Free-Free)
Emission from dust



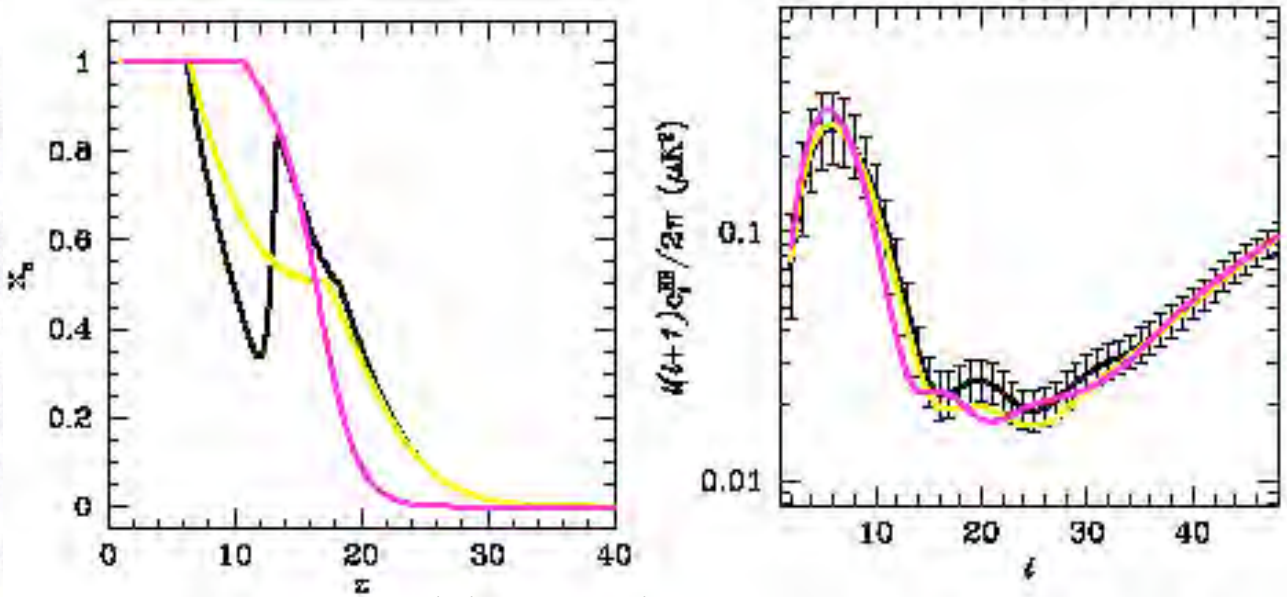


TE power spectrum



EE power spectrum

Constraining different reionisation scenarii with CMB?



Holder et al. '03

21cm for reionisation: Neutral H absorption

Optical depth to 21cm line $\tau = \frac{3c^3 h A_{10} n_{HI}}{16 k_B \nu_{21}^2 T_S H(z)} \sim 0.0074 \frac{x_{HI}}{T_S}(1+\delta)(1+z)^{3/2}[H(z)/(\frac{dv}{dr})]$

In RJ : $T_B \simeq \frac{T_S - T_{CMB}}{1+z}\tau \simeq 7(1+\delta)x_{HI}(1-\frac{T_{CMB}}{T_S})(1+z)^{1/2}$ mK

Ts ~ Tcmb -> no signal, Ts >> Tcmb -> Tb independent of Ts
Ts << Tcmb -> absorption against CMB

Collisions and resonnant scattering can couple Ts and Tk

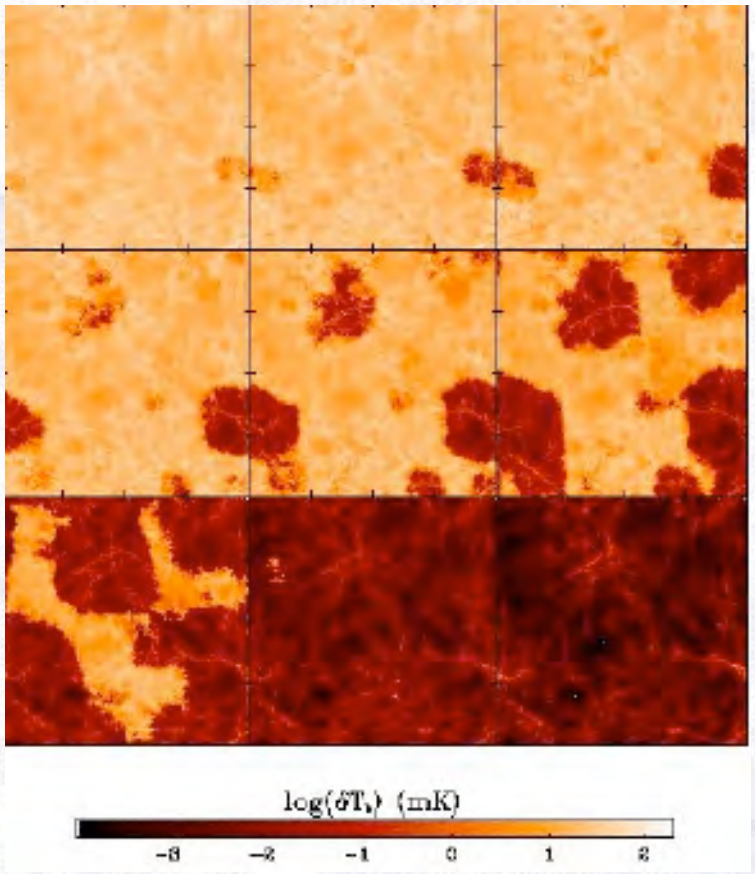
z>200 -> Ts, Tk, Tcmb in equil. -> no 21cm signal

z~ 200-30 -> gas cools Ts, Tk coupled -> 21cm absorption

z~30-20 -> mixture of absorption, emission and no signal

z~20-6 -> IGM heated, Ts > Tcmb 21cm signal

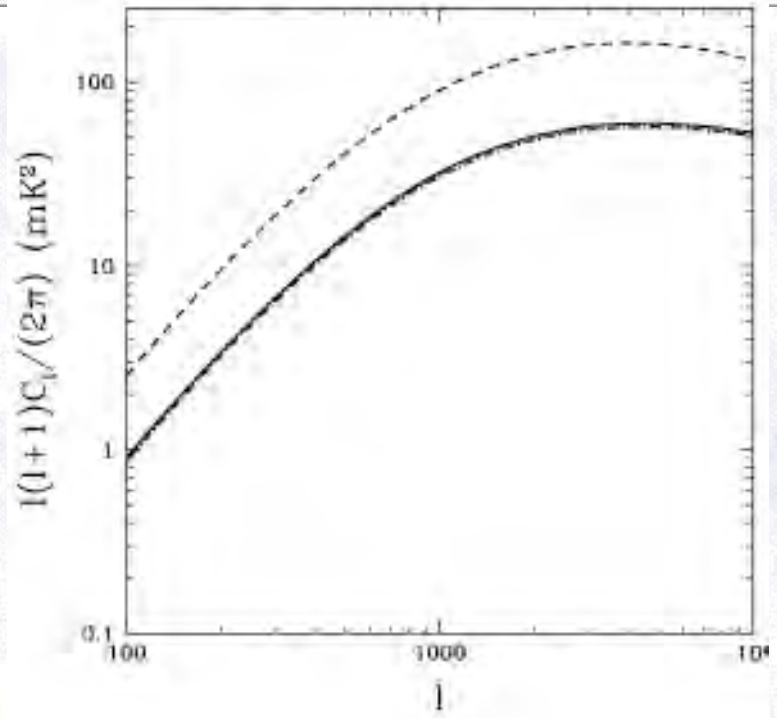
21cm in emission
Furlanetto et al. 04



Need for very high sensitivities! -> Global quantities

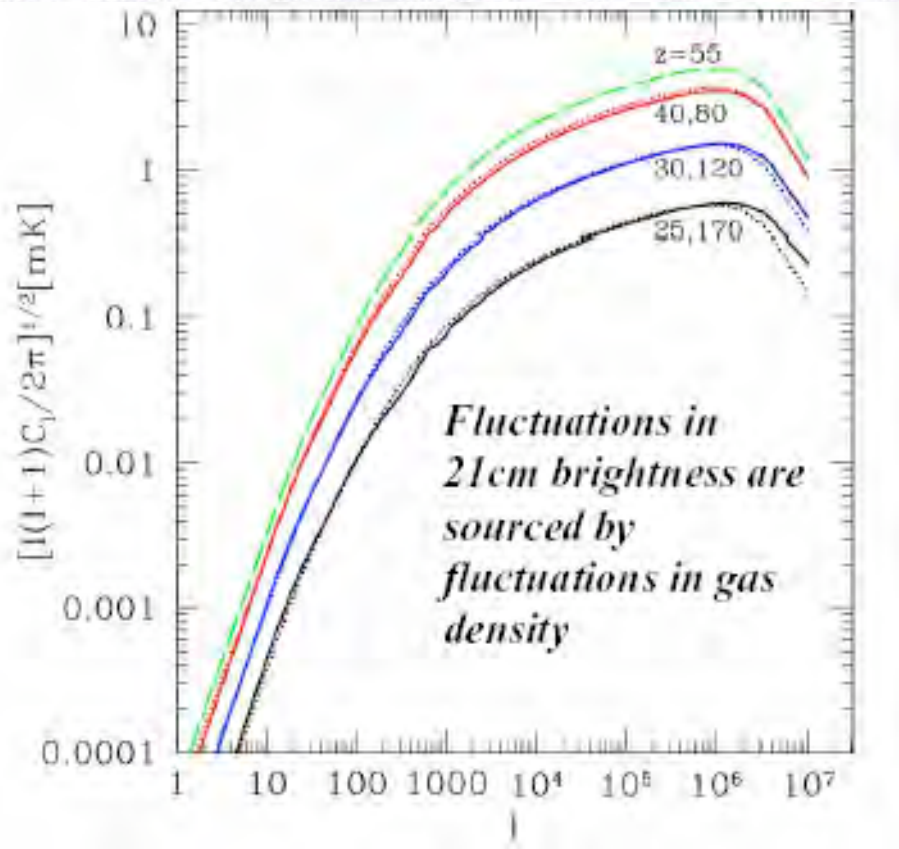
21cm power spectrum

$$P_{21}(k,z) = c^2 \left[(1-\bar{x}_e)^2 P_{\delta\delta}(k,z) + \bar{x}_e^2 P_{\delta_x\delta_x}(k,z) - 2P_{\delta\delta_x}(k,z)\bar{x}_e(1-\bar{x}_e) \right]$$

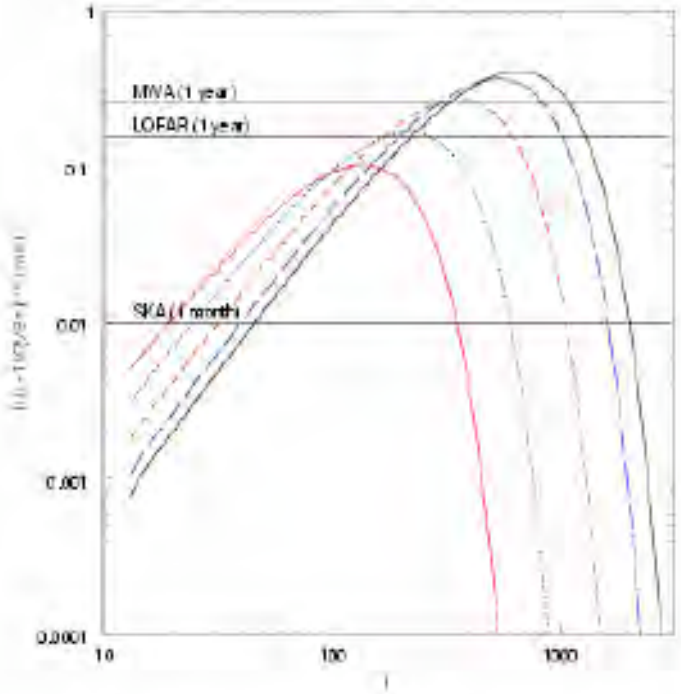


Santos et al. 05

Loeb & Zaldarriaga 04



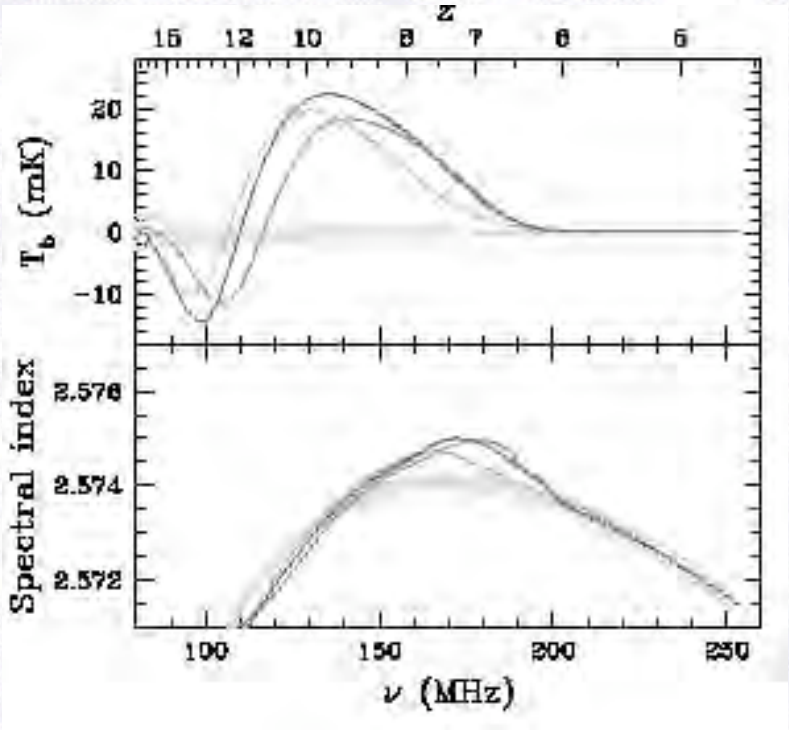
Some limits in the future



The temperature-polarization cross-correlation spectra sourced by Poisson fluctuations of II $\bar{\text{II}}$ regions for an emission and reionization redshift $z_E = z_R = 30$ (black, solid), $z_E = z_R = 25$ (blue, long dashed), $z_E = z_R = 17$ (red, dashed), $z_E = z_R = 10$ (black, dotted) and $z_E = z_R = 6$ (red, solid). The theoretical detection threshold of SKA is also shown for a 1 month integration time, LOFAR – 1 year and MWA – 1 year.

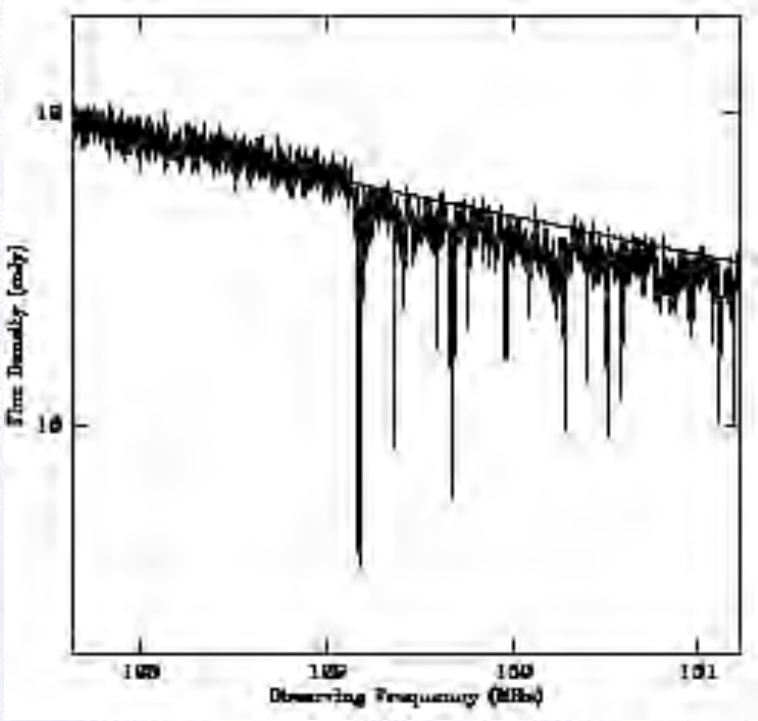
Babich & Loeb 05

Overall signal Tb



Gnedin & Shaver 03

Absorption towards radio sources (z=10)

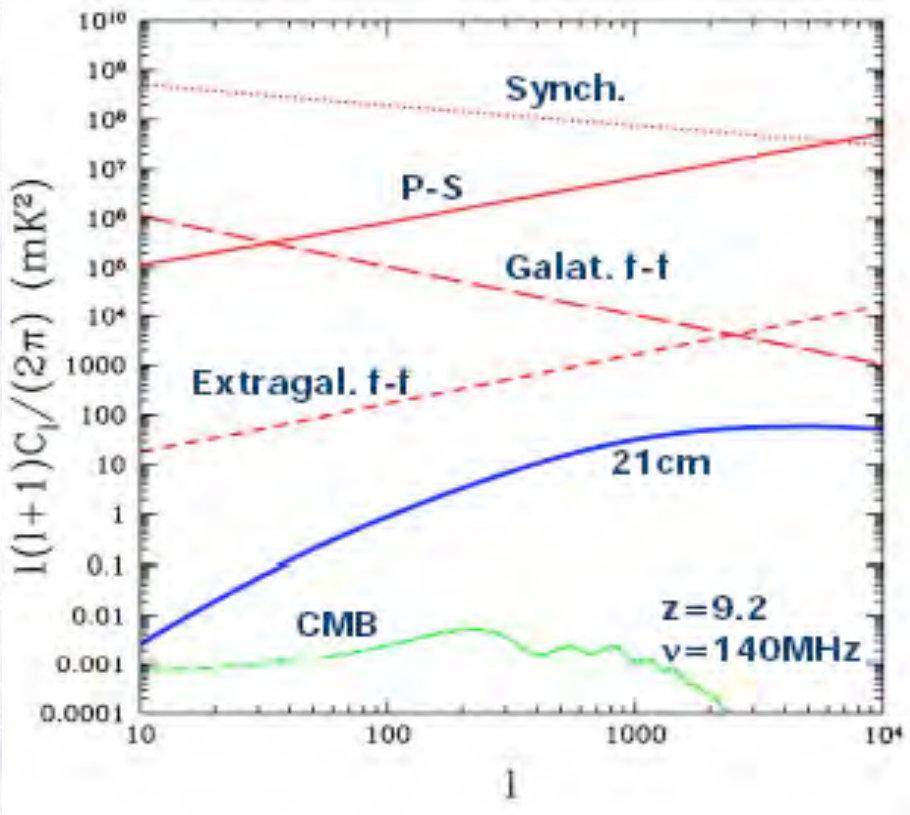


Carilli et al. 02

Big challenge: foreground emissions (including polarisation)

Need for complementary data, use of spatial templates

Component separation techniques (-> similarity with CMB)



Santos et al. 05

Reionisation ->

Different observational probes: CMB temperature + polarisation (ionised gas), 21cm (neutral), GRB, high-z galaxies, Lyman alpha forest -> Correlations

Formation and evolution of structures: different emitting sources

How can we discriminate between them?

- Study the sources (simulations, observations)
- Study the detailed structure of ionised and neutral gas

Effects of reionisation: generation of extra-galactic magnetic field, metal enrichement...

Possible additional confusion.