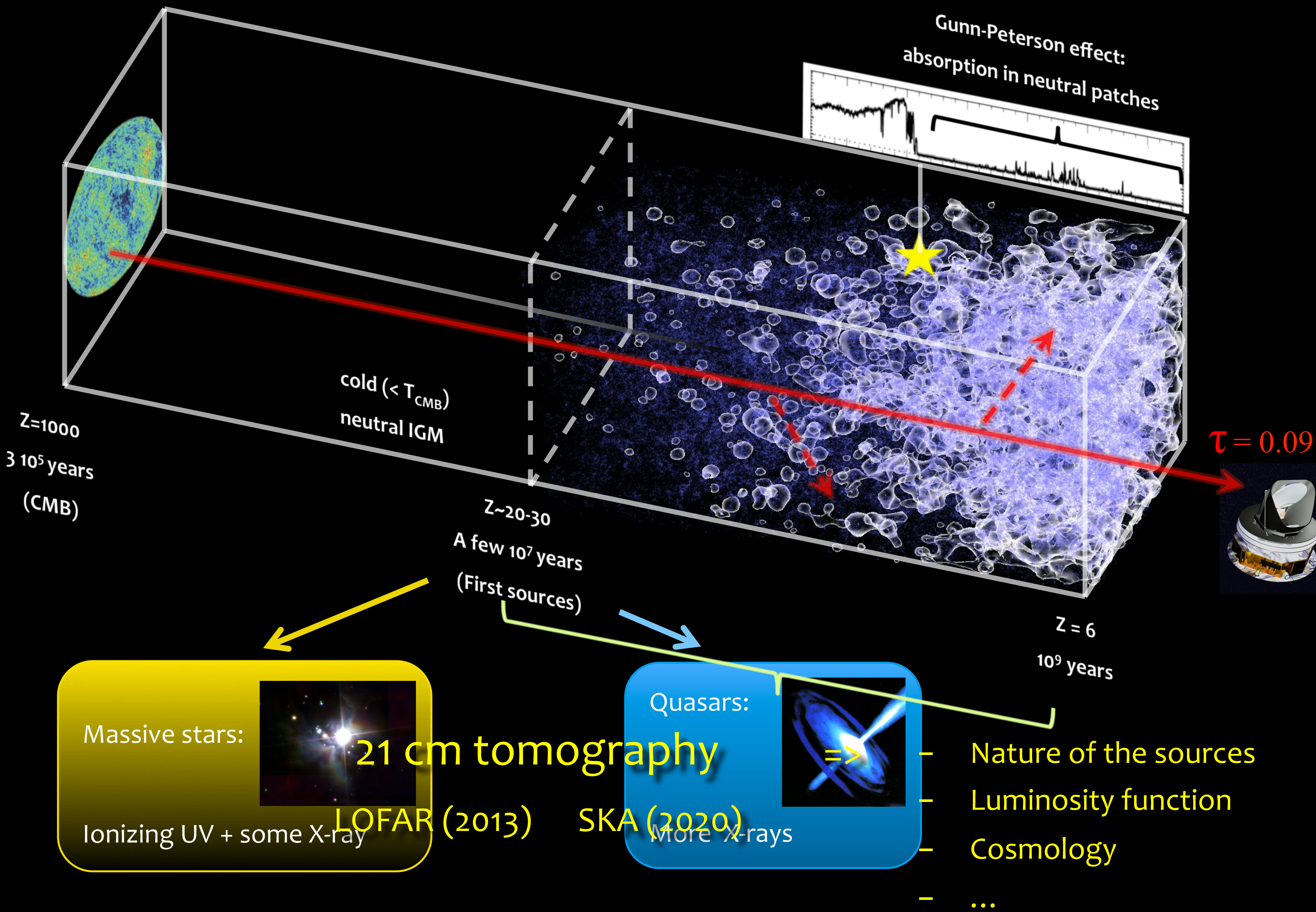
21 cm signal from the Epoch of Reionization: from models to observations

Benoît Semelin
LERMA – Observatoire de Paris

Journées SKA-LOFAR - 11-13 Fev, 2014

The epoch of reionization



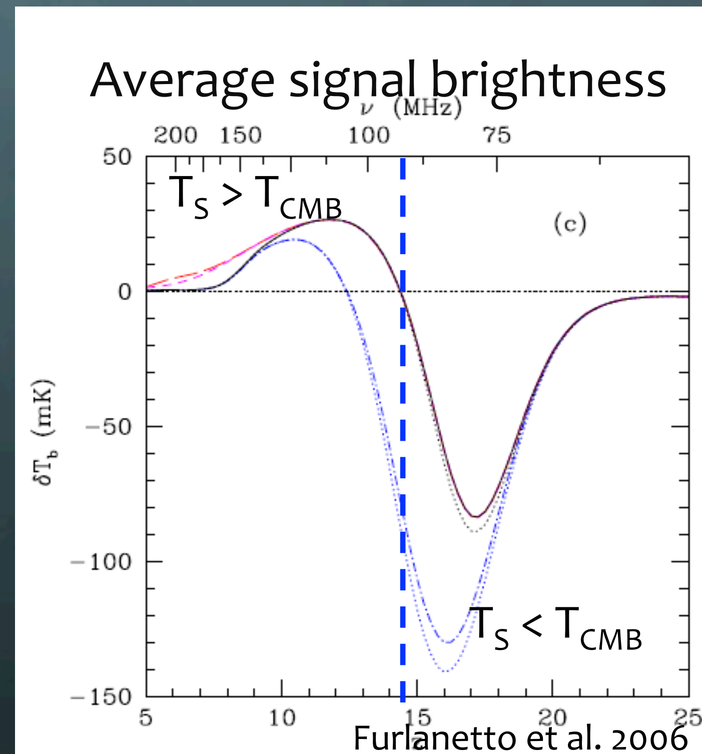
Physics of the 21 cm signal

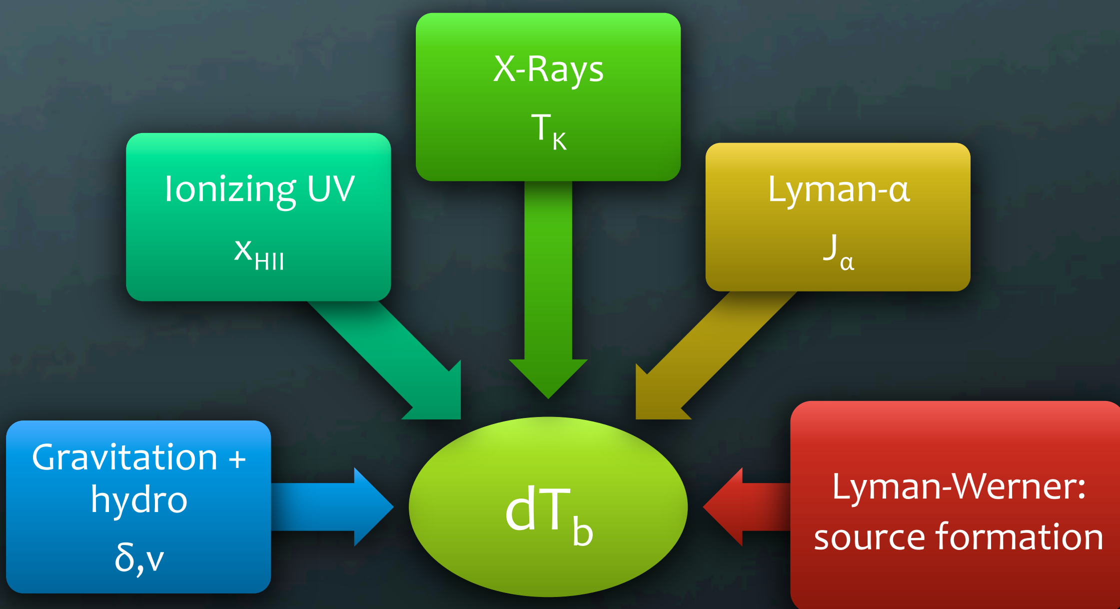
$$\delta T_B \propto 28\,\mathrm{mK}\ (1+\delta)(1+x_i)\left(\frac{T_S - T_{CMB}}{T_S}\right)\left(1+\frac{1}{H}\frac{dv}{dr}\right)^{-1}$$

Isotropic astro: $(1+x_i)\left(\frac{T_S - T_{CMB}}{T_S}\right)$

Anisotropic Cosmo: $\left(1+\frac{1}{H}\frac{dv}{dr}\right)$

$$T_S = f(J_\alpha, T_K, \delta, x_i)$$

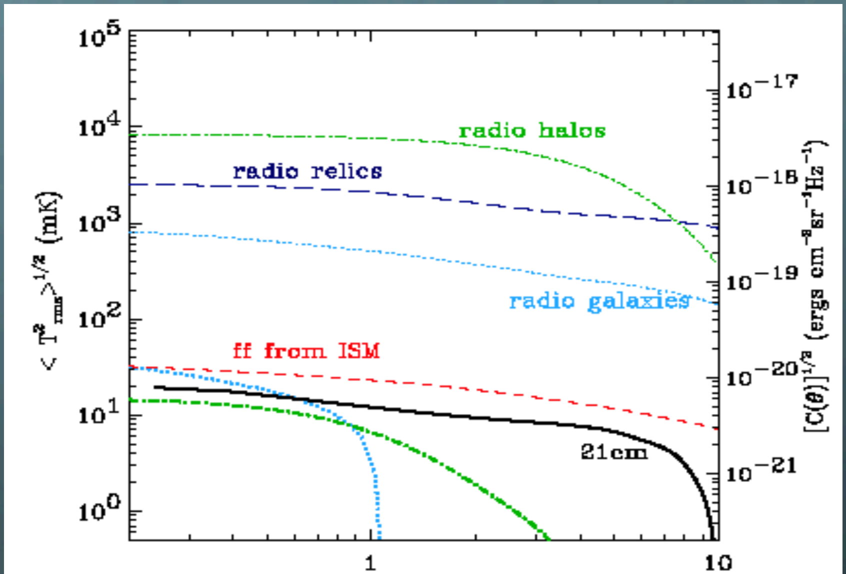




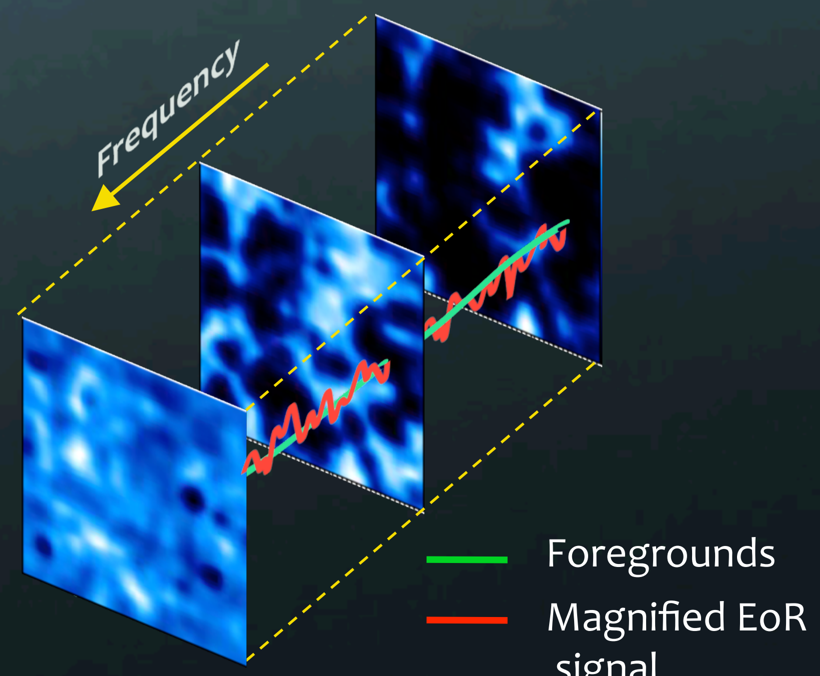
The issue of the foregrounds

Foregrounds 100 to 10^4 brighter than the 21 cm signal:

- Galactic synchrotron
- Radio-halos
- Radio-relics
- Radio-galaxies
- ISM free-free emission.



Di matteo *et al.*, 2004



Upper limits by SKA pathfinders

GMRT (India)

$(248\ \mathrm{mK})^2$

$k = 0.5\ \mathrm{h.Mpc^{-1}}$ and $z = 8.6$

(Paciga et al. 2013)

MWA (Australia)

$(300\ \mathrm{mK})^2$

$k = 0.5\ \mathrm{Mpc^{-1}}$ and $z = 9.5$

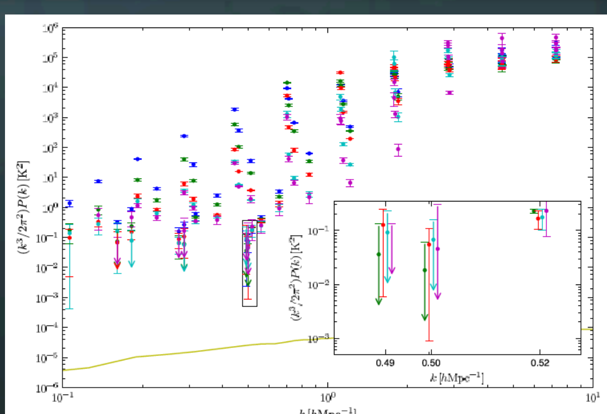
(Dillon et al. 2013)

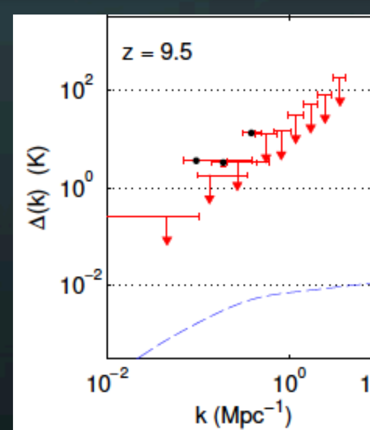
PAPER (S. Africa)

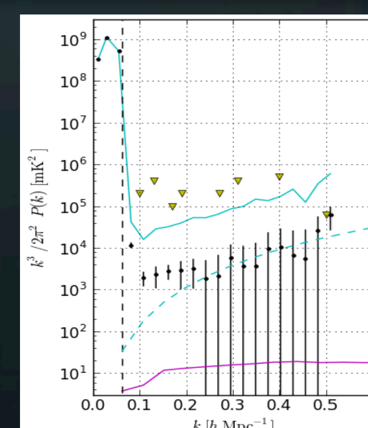
$(52\ \mathrm{mK})^2$

$k = 0.11\ \mathrm{h.Mpc^{-1}}$ and $z = 7.7$

(Parsons et al. 2013)







EoR with LOFAR and the SKA

	Justification	SKA-Low Phase 1 (~ 2020)	LOFAR (ongoing survey)	Nenufar (See A. Fialkov talk)
Bandwidth	EoR from z~30 to z~6	50-200 MHz (z = 27-6)	115-190 MHz (z = 11 – 6.5)	10-80 MHz (z > 17)
Sensitivity	rms amplitude 10 mK at z ~ 8 50 mK at z~15 ???	1 mK on 5' scale (imaging)	S/N ~ 1 on 10' scale (powerspectrum)	S/N > 1 on scales > 30' (powerspectrum)
Survey size	Largest structures + statistical relevance	> 5° x 5°	Several 5°x 5°	?

March 2013: first meeting of the new SKA EoR science team

June 2014: Renewed SKA science case.

Oct 2014: Design is frozen

Modeling the 21 signal with LICORICE:

The LICORICE code:

-Dynamics: δ

- Ionizing UV transfer: x_{HII}

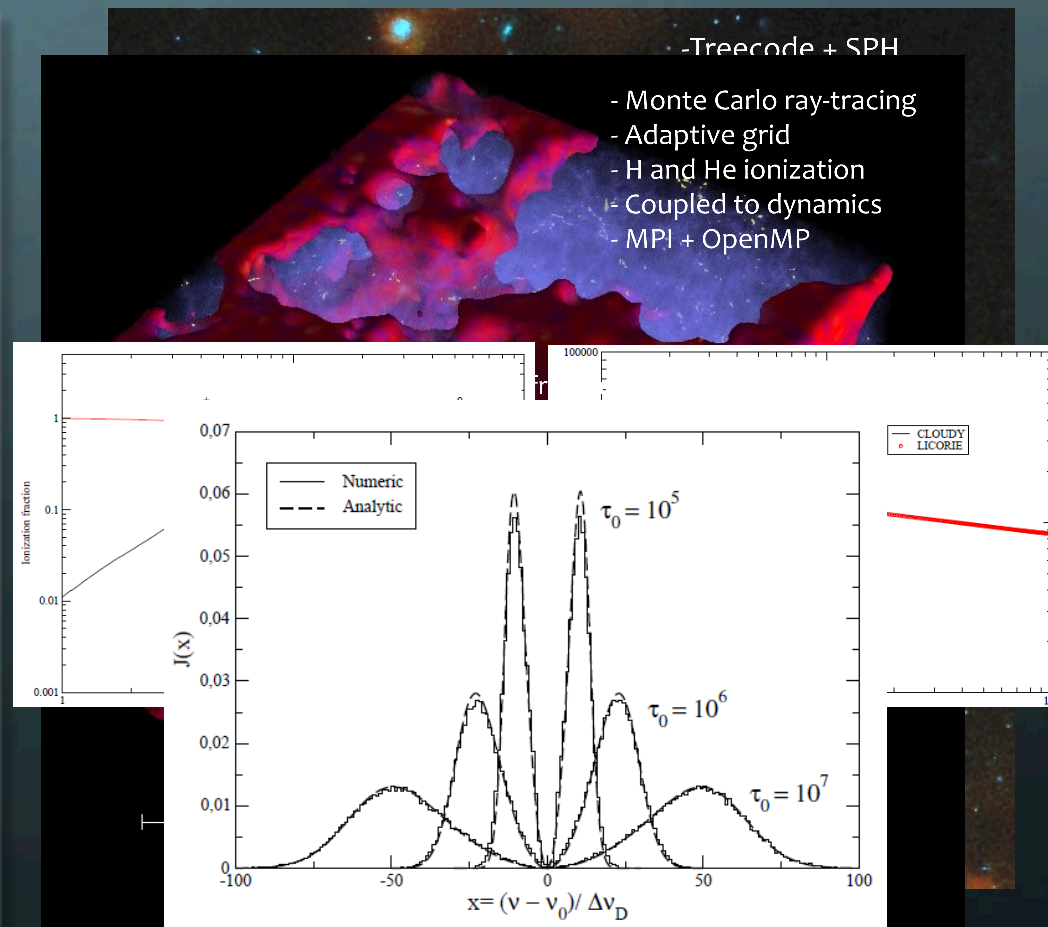
- X-ray transfer: T_K

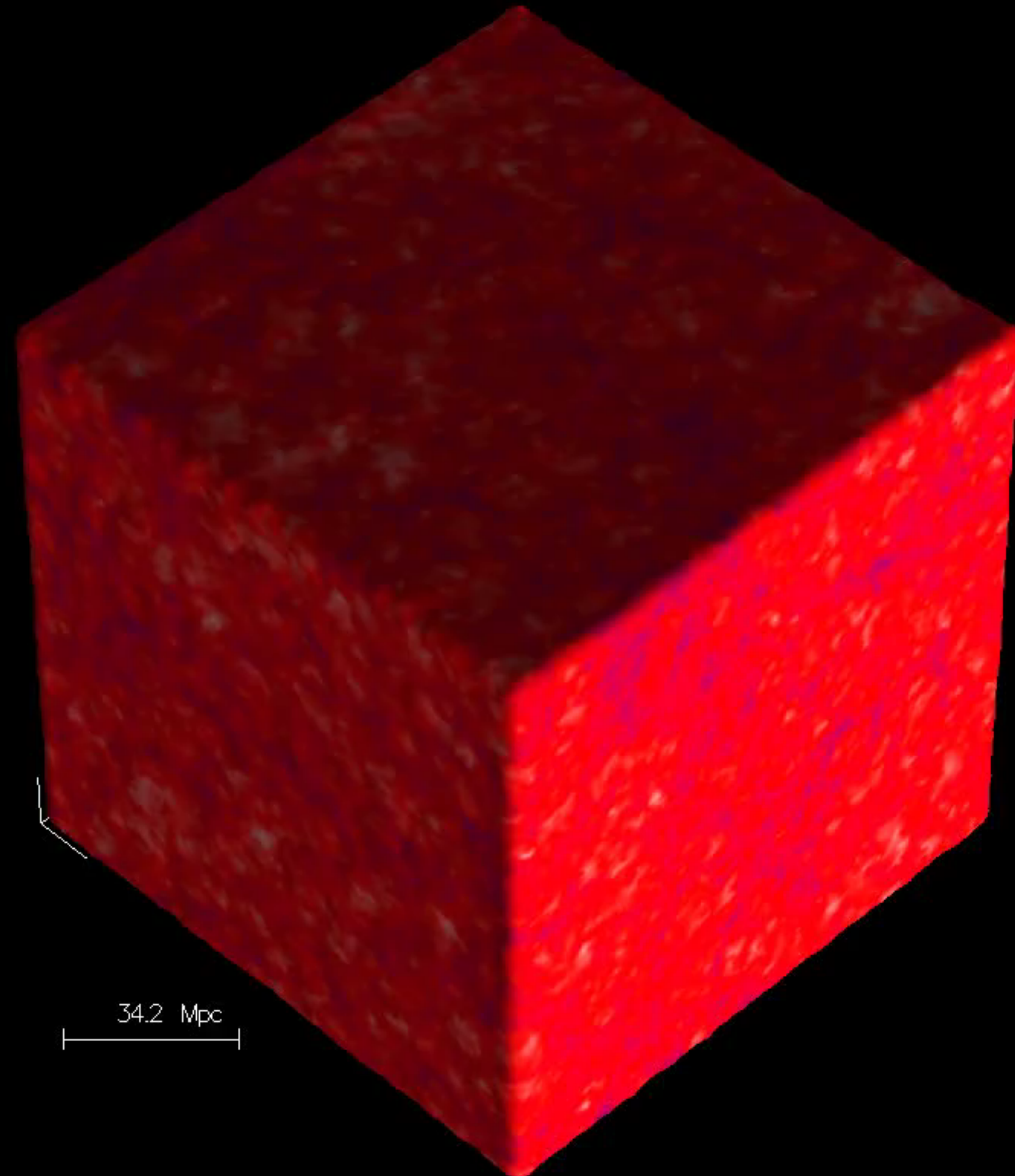
- Lyman-α transfer: J_α

- No LW transfer yet.

Current typical run:

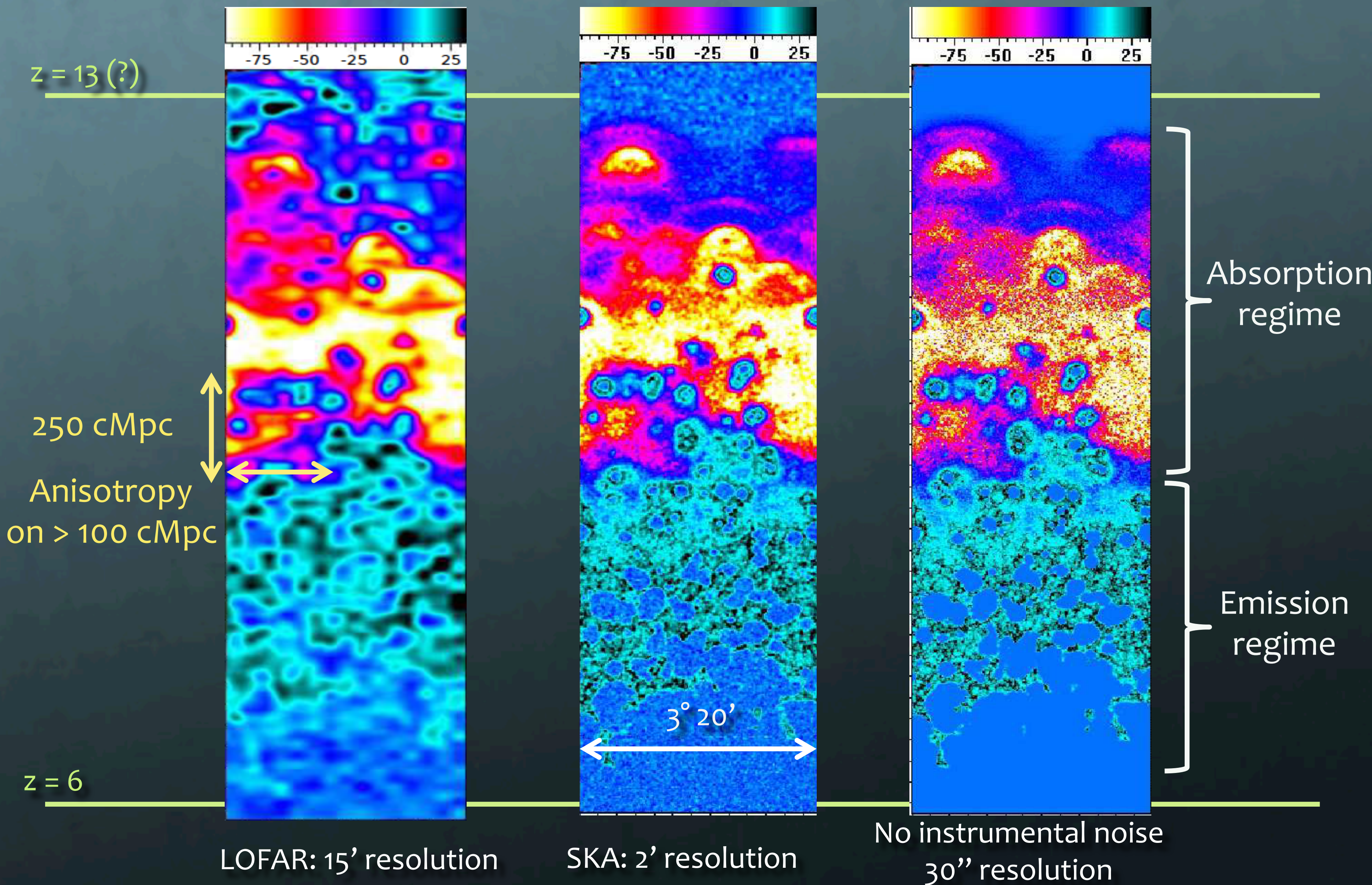
- 1024^3 particles
- 200 Mpc/h (10^8 $M_\odot$ per part)
- 10^5 CPU hours
- 4096 cores x 1 day




34.2 Mpc

Simulated 21cm signal along the light-cone

(Zawada et al. 2014)



Some open question about the 21 cm signal

What can we expect at z > 15 ? It depends on

- Intensity of X-ray heating
- Efficiency of star formation trough H_2 cooling
- Quenching of star formation by drift velocities (see A. Fialkov talk)

How should we estimate sample variance on large scales?

- How much fluctuation is there?
- On what scale mode along the LOS stop contributing?
- What survey size is enough?

What information can we extract from imaging, and how to do it?