The Gravitational Lensing of Pregalactic 21 cm Radiation

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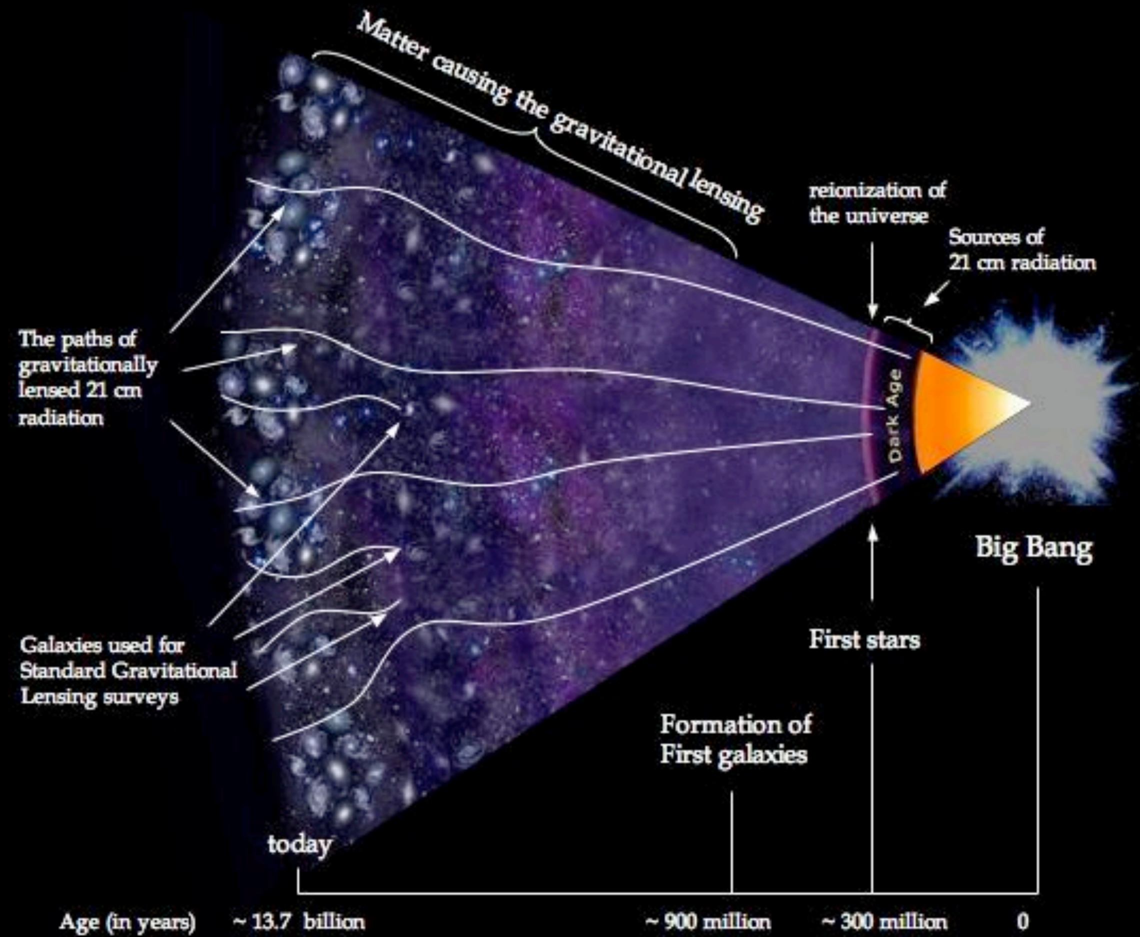
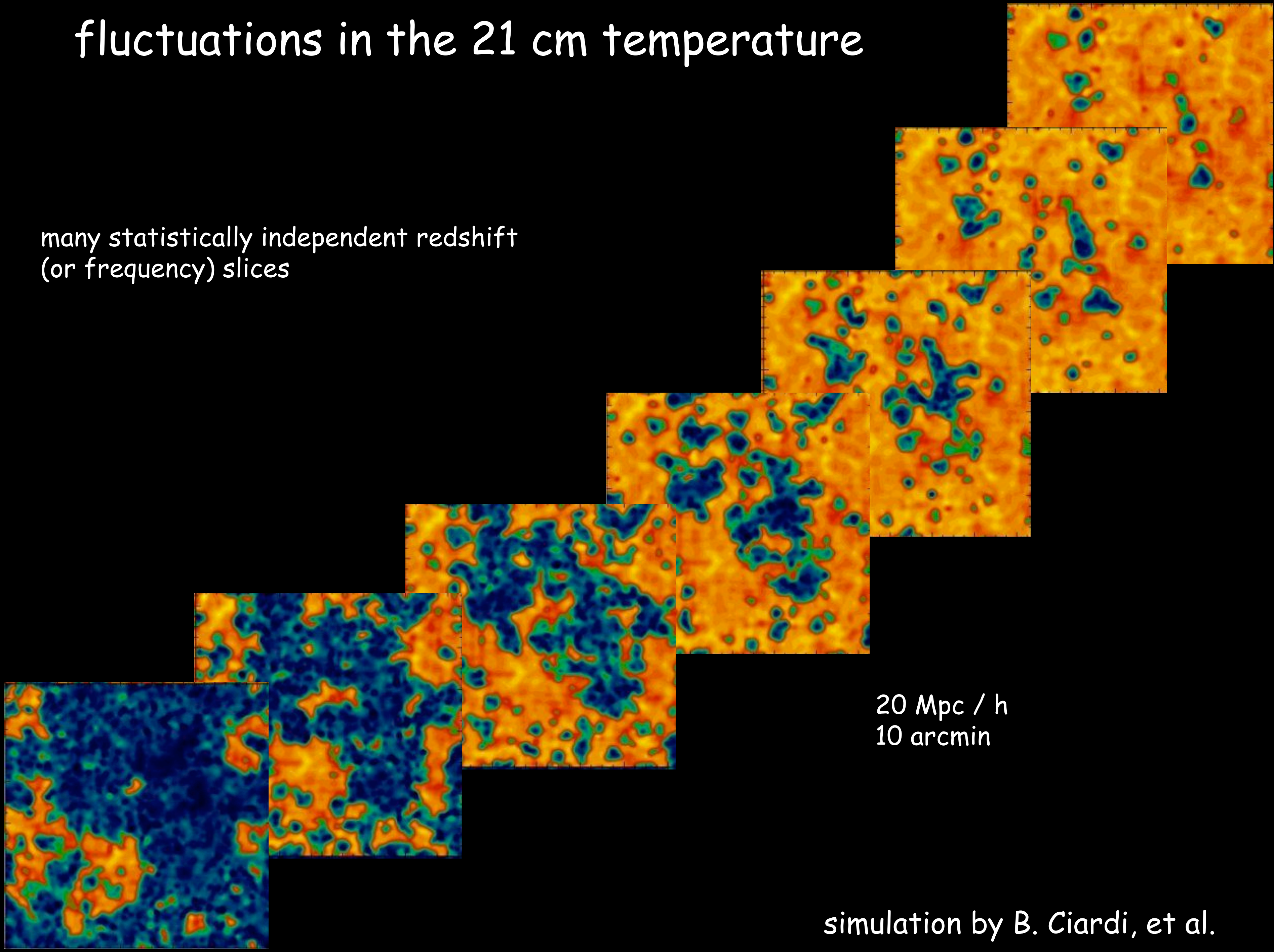
(Venice August 30, 2007)



Matter causing the gravitational lensing
reionization of the universe
Sources of 21 cm radiation
The paths of gravitationally lensed 21 cm radiation
Dark Age
Big Bang
Galaxies used for Standard Gravitational Lensing surveys
First stars
Formation of First galaxies
today
Age (in years)
~ 13.7 billion
~ 900 million
~ 300 million
0

fluctuations in the 21 cm temperature

many statistically independent redshift
(or frequency) slices



20 Mpc / h
10 arcmin

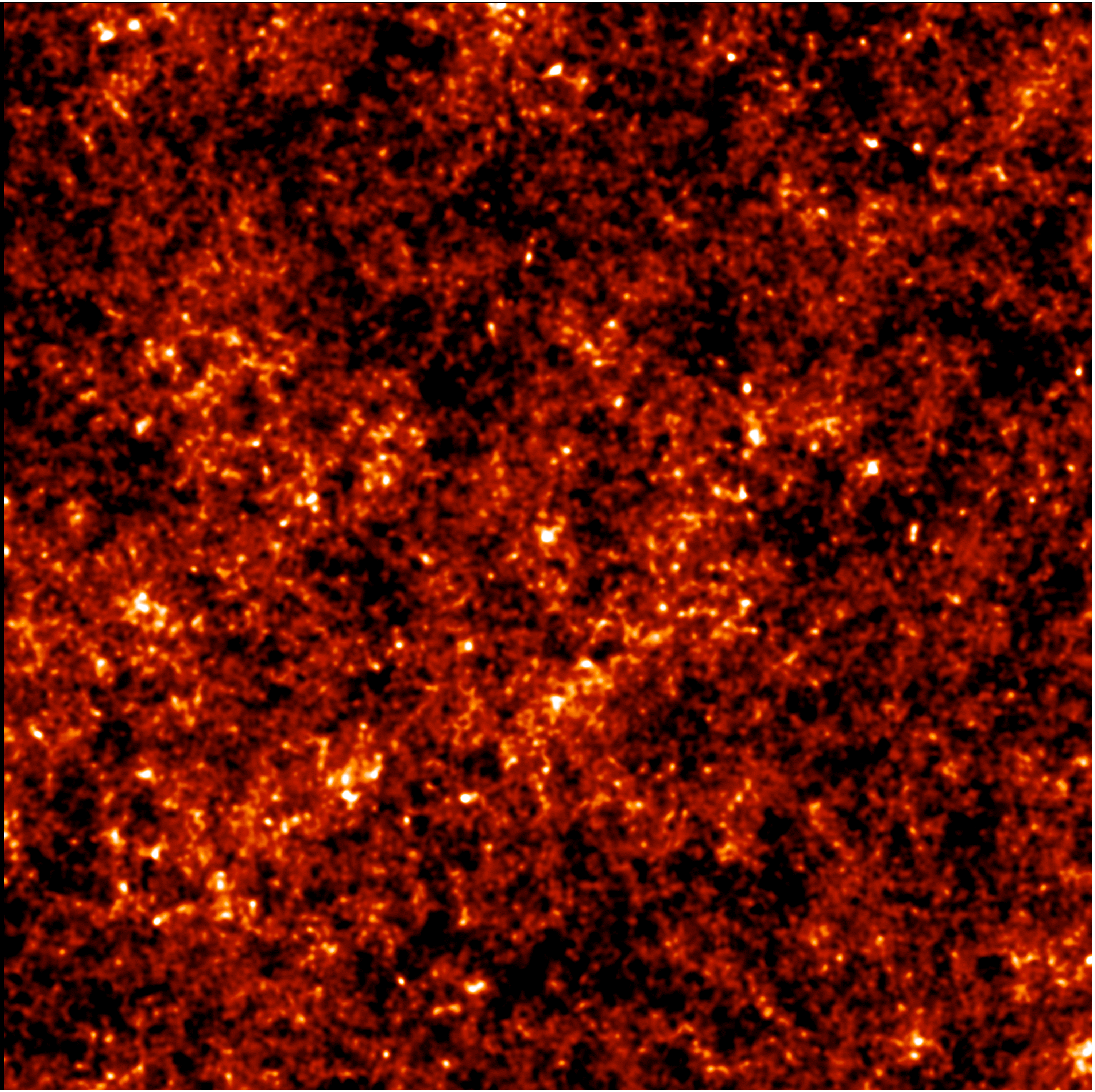
simulation by B. Ciardi, et al.

4 X 4 deg

Lensing through
The Millennium Simulation

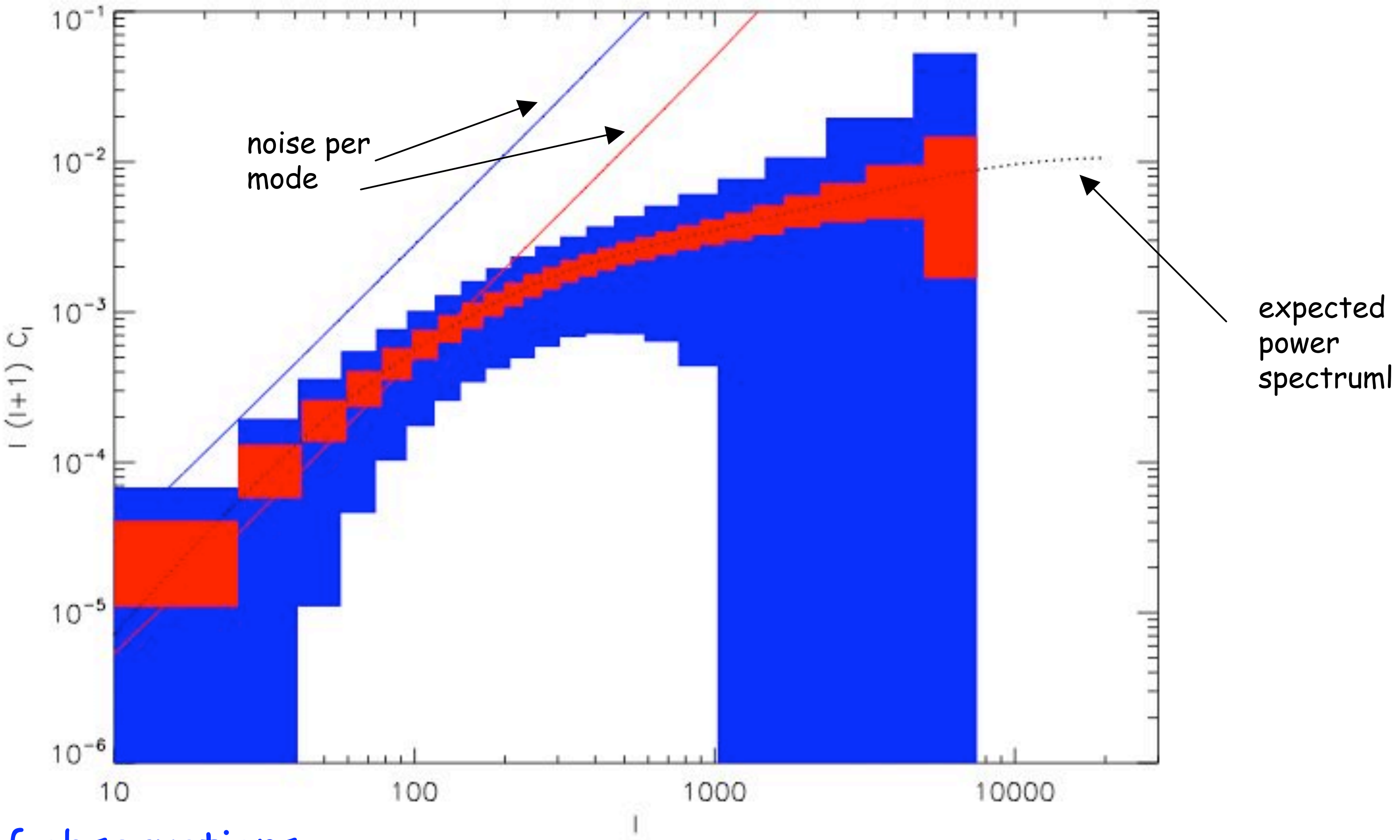
21 cm Sources at z = 12
1′ pixels

Hilbert, Metcalf
& White (2007)



Convergence Power Spectrum Estimation

telescope like the core array of LOFAR



30 days of observations

90 days of observations

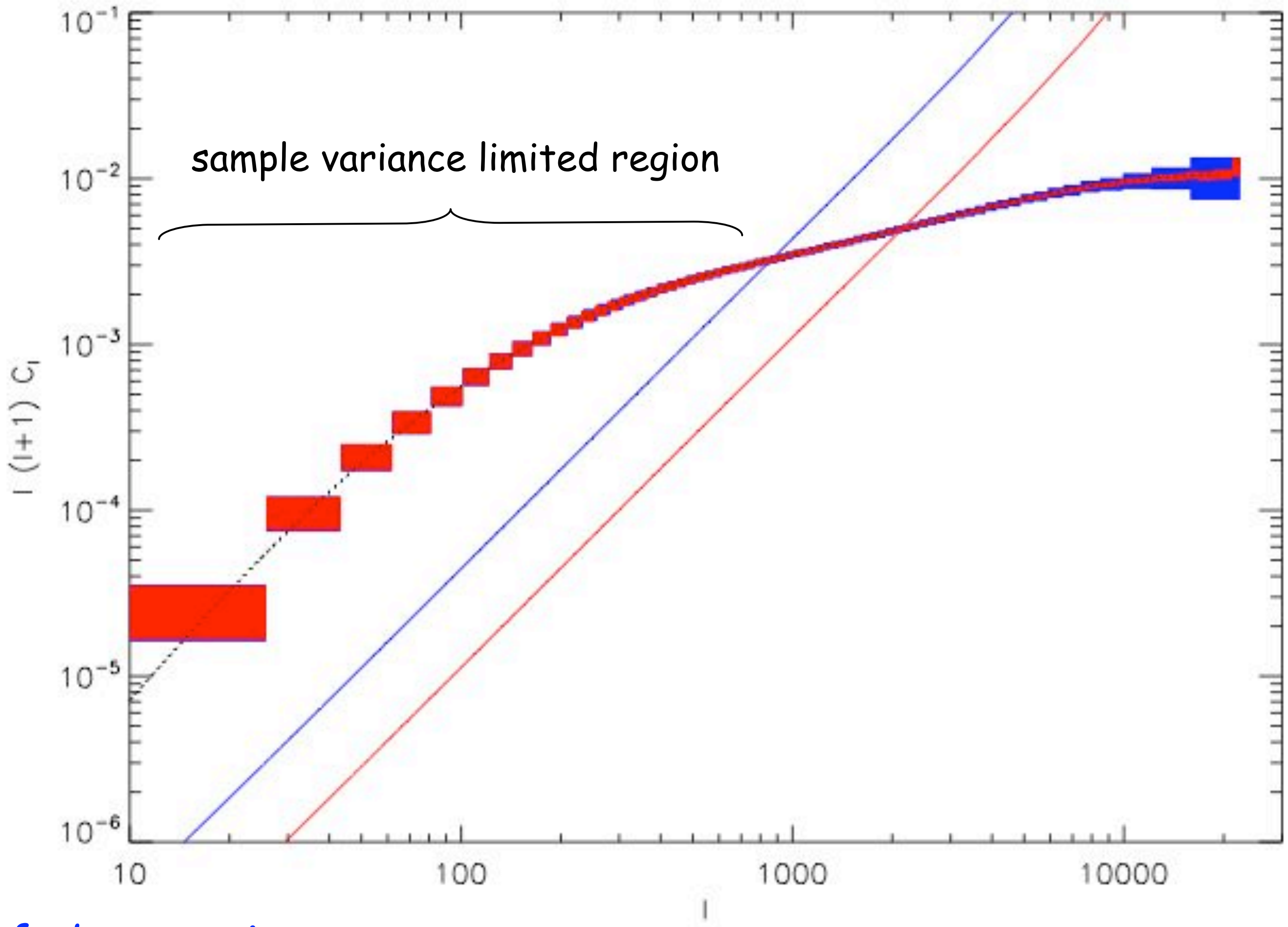
10% of the sky surveyed

D = 2 km with covering fraction of 1.6% ν_{min} = 110 Mhz

reionization at z=7

Convergence Power Spectrum Estimation

telescope like the core array of SKA



30 days of observations
90 days of observations

10% of the sky surveyed

D = 6 km with covering fraction of 2% ν_{min} = 100 Mhz
reionization at z=7

Cosmological parameter estimation

Ω_m	matter density	Ω_Λ	dark energy density	$w = \frac{p}{\rho}$	dark energy equation of state
Ω_b	baryon density	n_s	slope of the primordial density powers spectrum		

A normalization of the primordial power spectrum

$$w_a = \left.\frac{dw}{da}\right|_{a=2/3}$$ evolution of dark energy equation of state

SKA-like + GLS	LOFAR-like + GLS
$\sigma_{\Omega_m} \simeq 6 \times 10^{-4}$	$\sigma_{\Omega_m} \simeq 0.002$
$\sigma_{\Omega_\Lambda} \simeq 0.001$	$\sigma_{\Omega_\Lambda} \simeq 0.01$
$\sigma_{\Omega_b} = 0.002$	$\sigma_{\Omega_b} = 0.003$
$\sigma_w \simeq 0.006(0.001)$	$\sigma_w \simeq 0.03(0.005)$
$\sigma_{w_a} \simeq 0.03$	$\sigma_{w_a} \simeq 0.2$
$\sigma_A \simeq 0.025A$	$\sigma_A \simeq 0.04A$
$\sigma_n \simeq 0.004$	$\sigma_n \simeq 0.006$

all scale by $f_{sky}^{-1/2}$

Conclusions:

- Gravitational lensing can be measured in the low frequency radio data by stacking up the signal from many statistically independent redshift slices

- Many cosmological parameters could be measured with more precision than with any other proposed method
  - need sky coverage
  - need wide frequency, or redshift, range before the completion of reionization

- A telescope like the core of LOFAR should be able to measure gravitational lensing

- An SKA-like telescope should be able to map dark matter on arcminute scales if the reionization history of the universe is favorable.

References:

Poster

Metcalf, R.B. & White, S.D.M., 2006, to appear in MNRAS, astro-ph//0611862

Hilbert, S., Metcalf, R.B. & White, S.D.M., 2007, astro-ph/0703337

Metcalf, R.B. & White, S.D.M., 2007, in preparation.

The Comoving Volume of the Universe