Prospects for cosmic dawn observations with NenuFAR

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NenuFAR: The science NenuFAR
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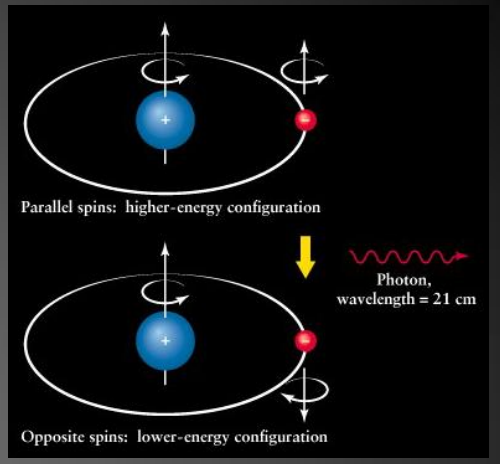
Cosmic Dawn with NenuFAR (z ~ 17 - 50)

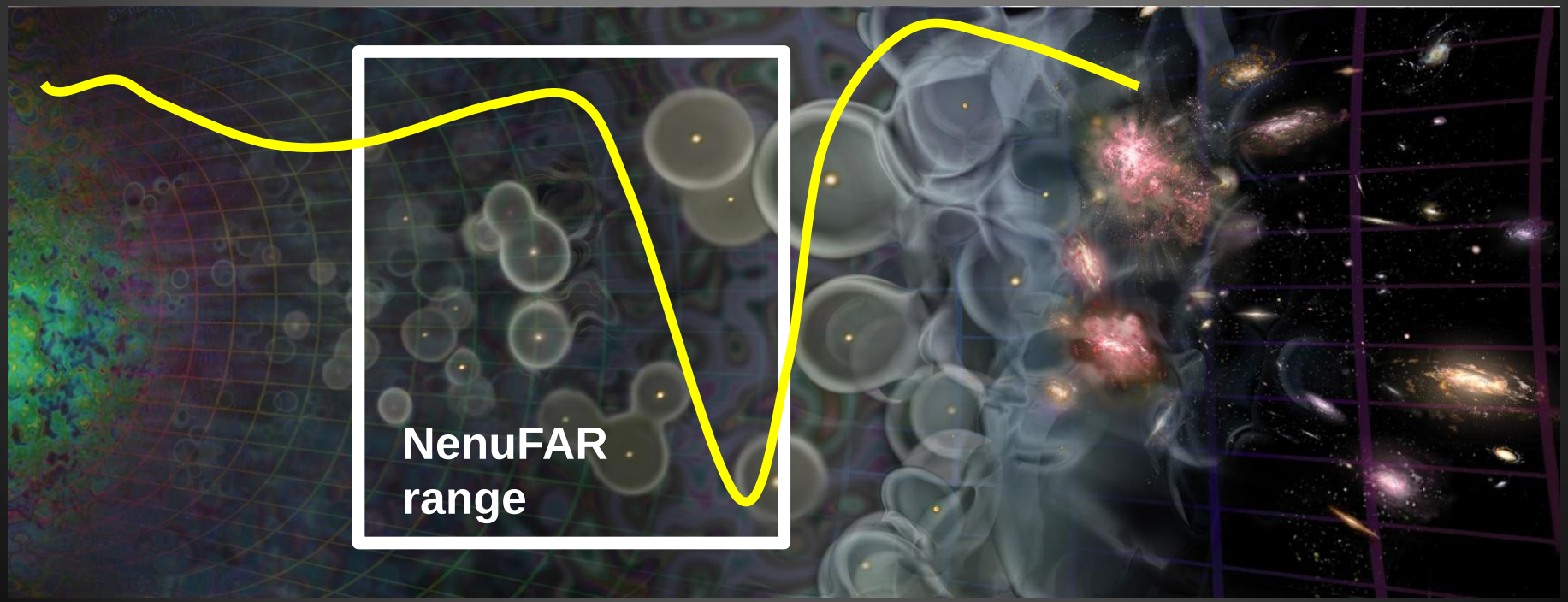


The true dark ages

First stars

The early stages reionization

Image: Loeb, Scientific American 2006



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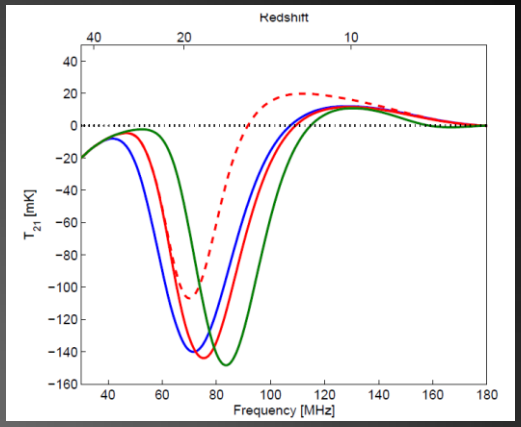
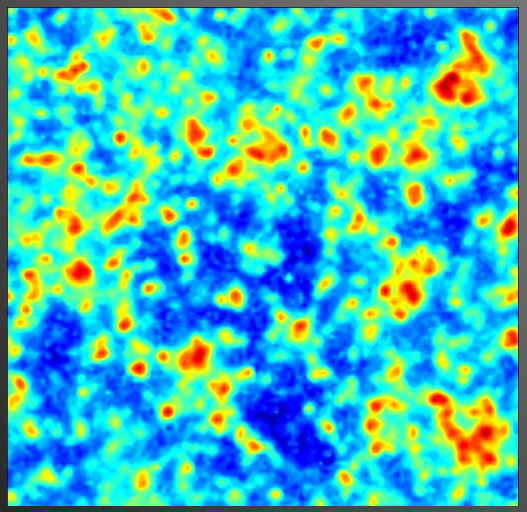
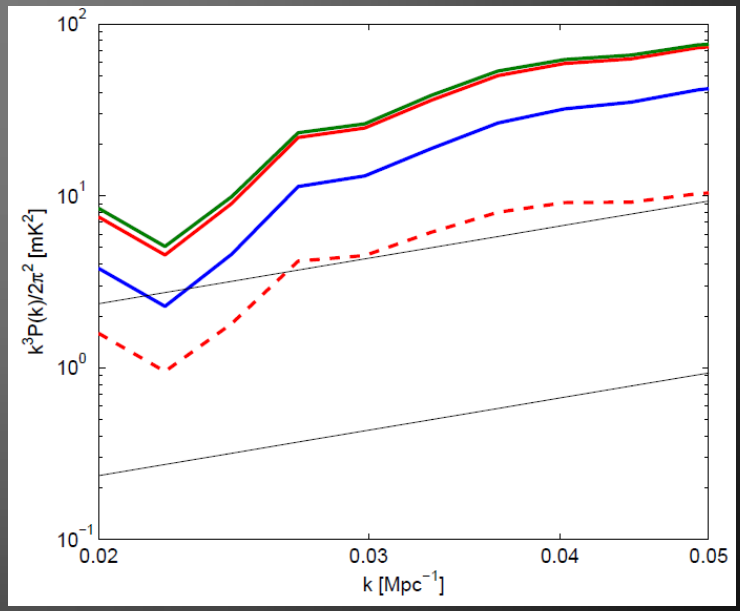


- Global spectrum (best candidate, a lot of physics)
- Power spectrum at each redshifts (only large scales>BAO)
- Imaging (low resolution)





Prospects for global observations with NenuFAR

Cosmic dawn + dark ages

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Cosmic dawn + dark ages

Sensitivity at z = 20 (Koopmans)

$$t_{\rm int} = 17\ {\rm hr} \times f_{\rm rec}^{-2} \left(\frac{\nu}{70\ {\rm MHz}}\right)^{-5.1} \left(\frac{\Delta\nu}{1\ {\rm MHz}}\right)^{-1} \left(\frac{\delta T}{10\ {\rm mK}}\right)^{-2}$$

- t_{int} integration time
- f_{rec} = filling factor
- $\Delta\nu$ = bandwidth
- δT = brightness temperature

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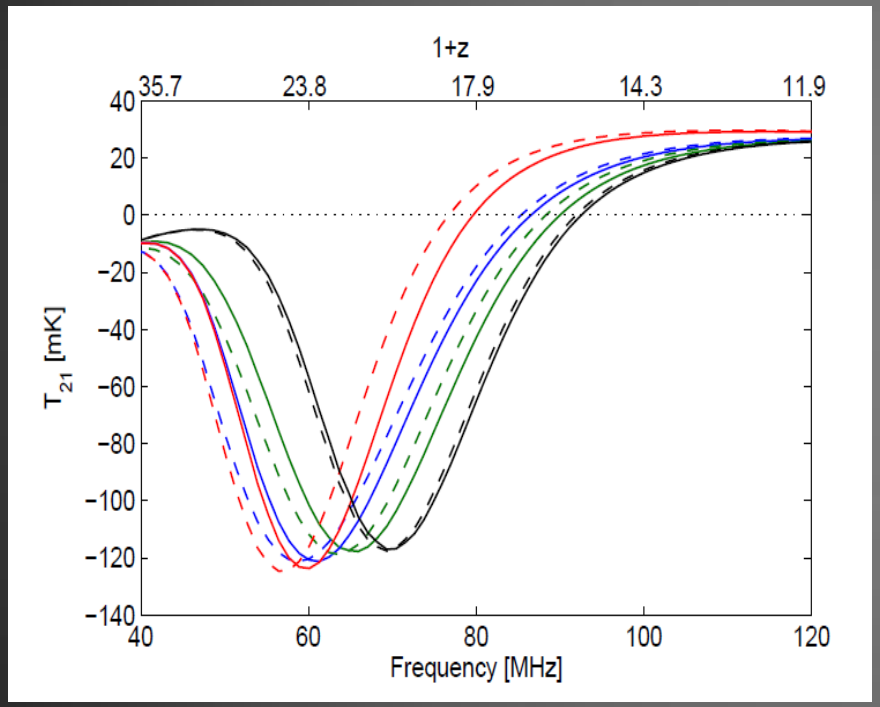
In principle the global signal can be observed within 1 day!

Difficulty: calibration to 10^{-6}.

Expected global signal

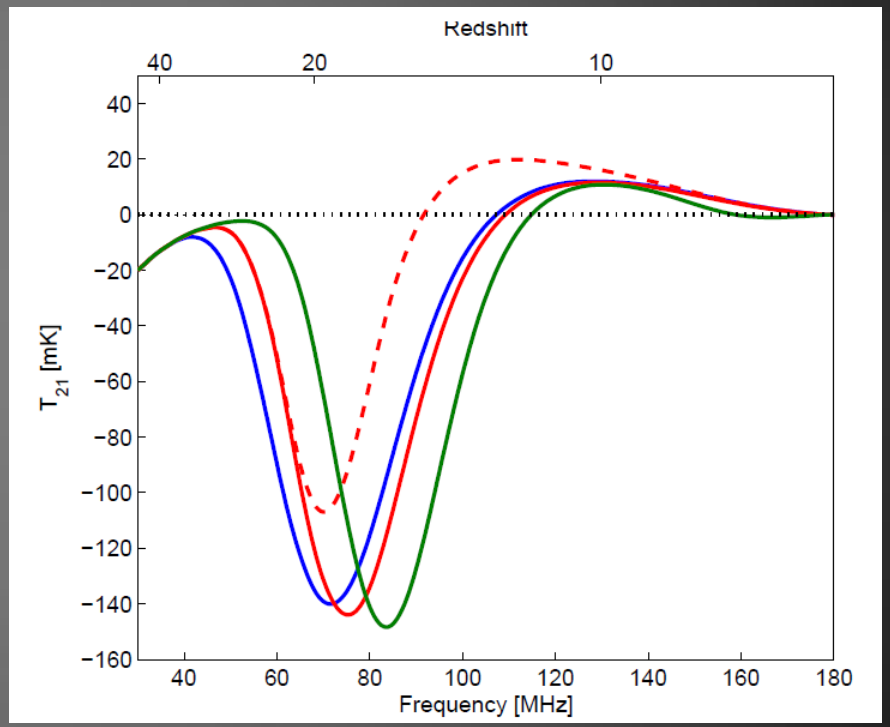
(original idea for global measurements with NenuFAR: L. Koopmans)

Effect of feedback and bulk flows



Fialkov, Barkana, Visbal, Tseliakhovich, Hirata (2013)

Effect of minima masses of halos and heating spectrum



Fialkov, Barkana, in preparation

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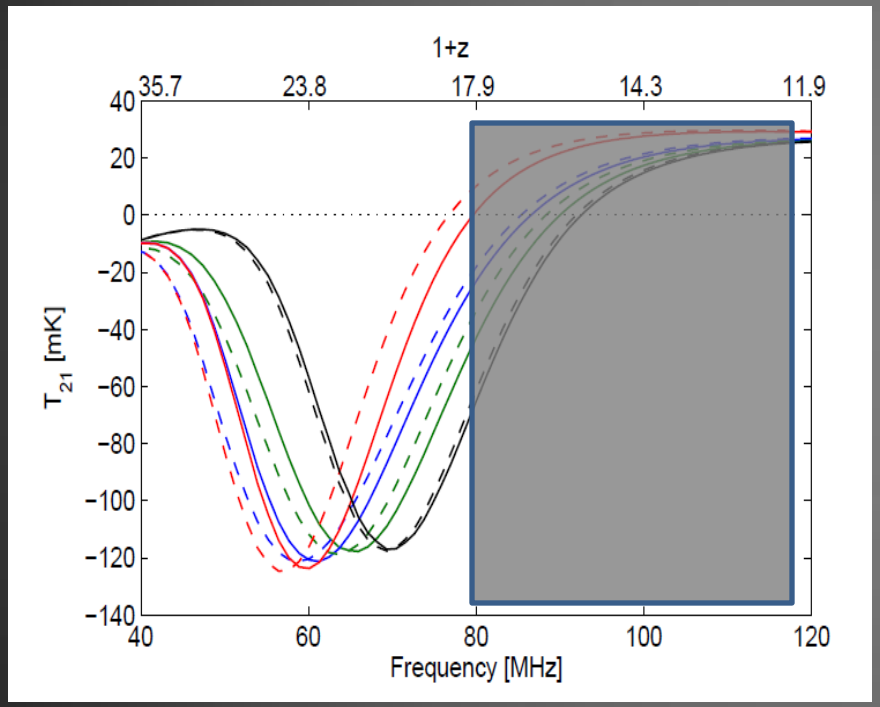

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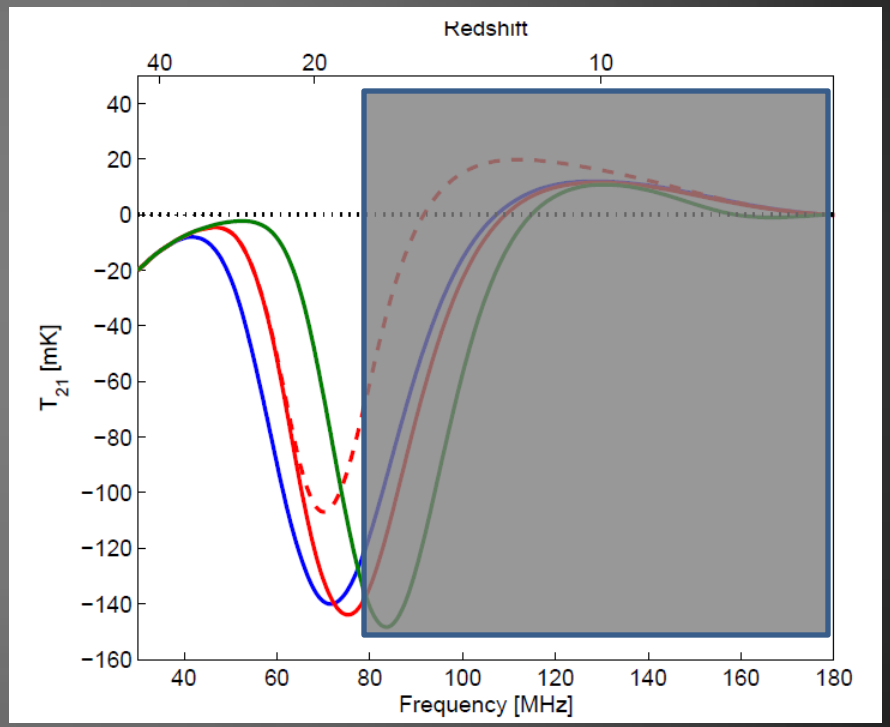

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Prospects for power spectrum observations with NenuFAR

NenuFAR should be able to measure power spectrum at very large scales (> BAO)

$k \sim 0.001 – 0.05\ \mathrm{Mpc}^{-1}$

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$k \sim 0.001 - 0.05$ Mpc^{-1}

Sensitivity model (Mellema et al 2013), uniform uv coverage

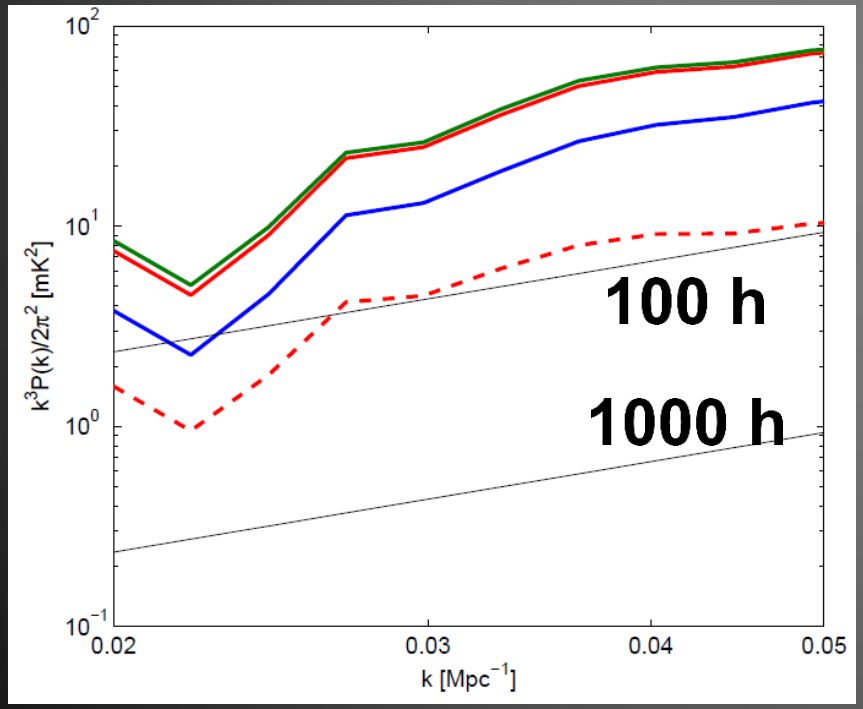
$$\Delta^2_{\mathrm{Noise}} = \left(\frac{2}{\pi}\right) k^{3/2} \left[D_c^2 \Delta D_c \times \Omega_{\mathrm{FoV}}\right]^{1/2} \left(\frac{T_{\mathrm{sys}}}{\sqrt{B t_{\mathrm{int}}}}\right)^2 \left(\frac{A_{\mathrm{core}} A_{\mathrm{eff}}}{A^2_{\mathrm{coll}}}\right)$$

- $T_{sys} = 180(\nu/180\ \mathrm{MHz})^{-2.6}$
- B = 1 MHz
- $A_{core} = 15400\ m^2$
- $A_{eff} = 62000/96\ m^2$
- $A_{coll} = 62000\ m^2$
- FoV= $0.21^2\ (1+z)^2 / A_{eff}$ is smallest beam-formed receiver element
- t_{int} integration time

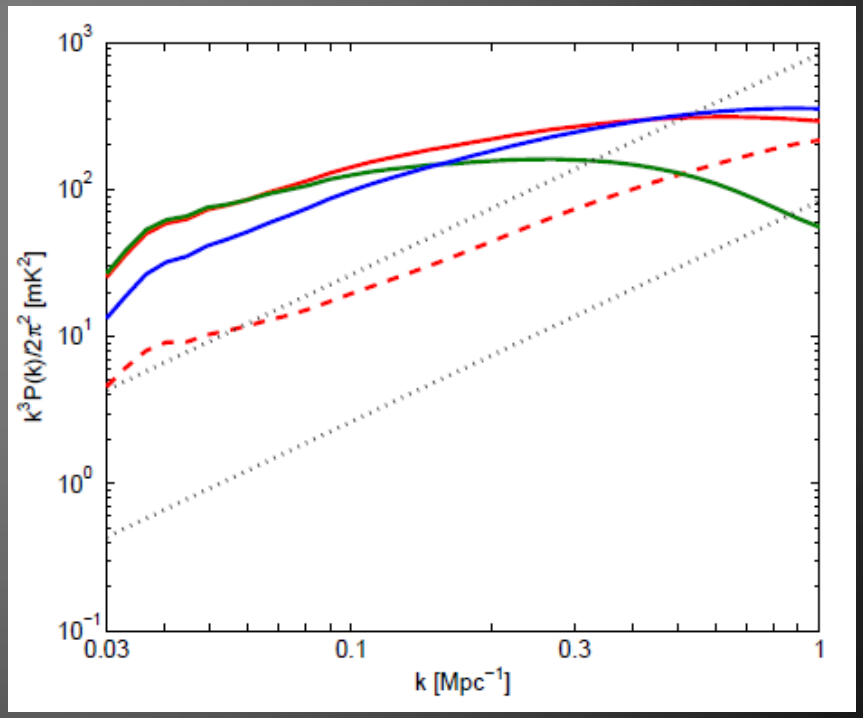
Expected power spectrum

100-1000 hours of observations needed at z ~ 20.

~ NenuFAR resolution



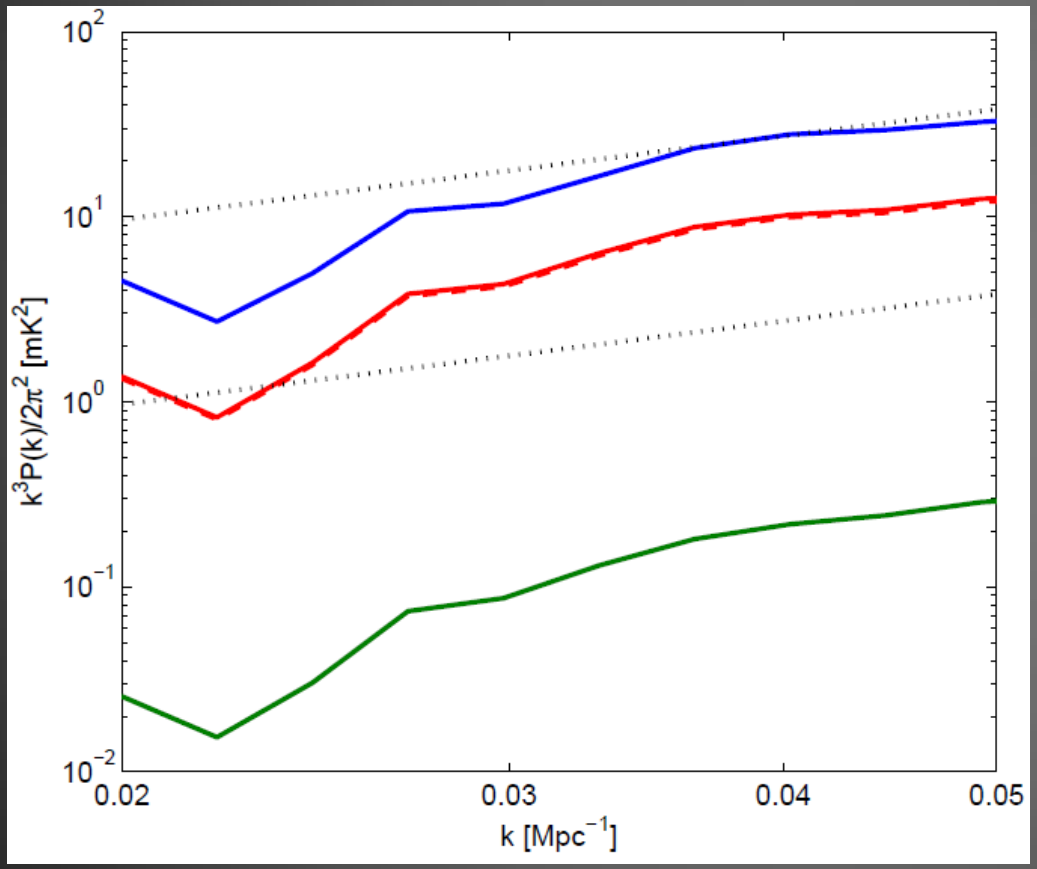
Beyond NenuFAR resolution (SKA)



Signal from **Fialkov**, Barkana, in preparation
Noise - ~ NenuFAR

Expected power spectrum

>1000 hours of observations needed at z ~ 25.

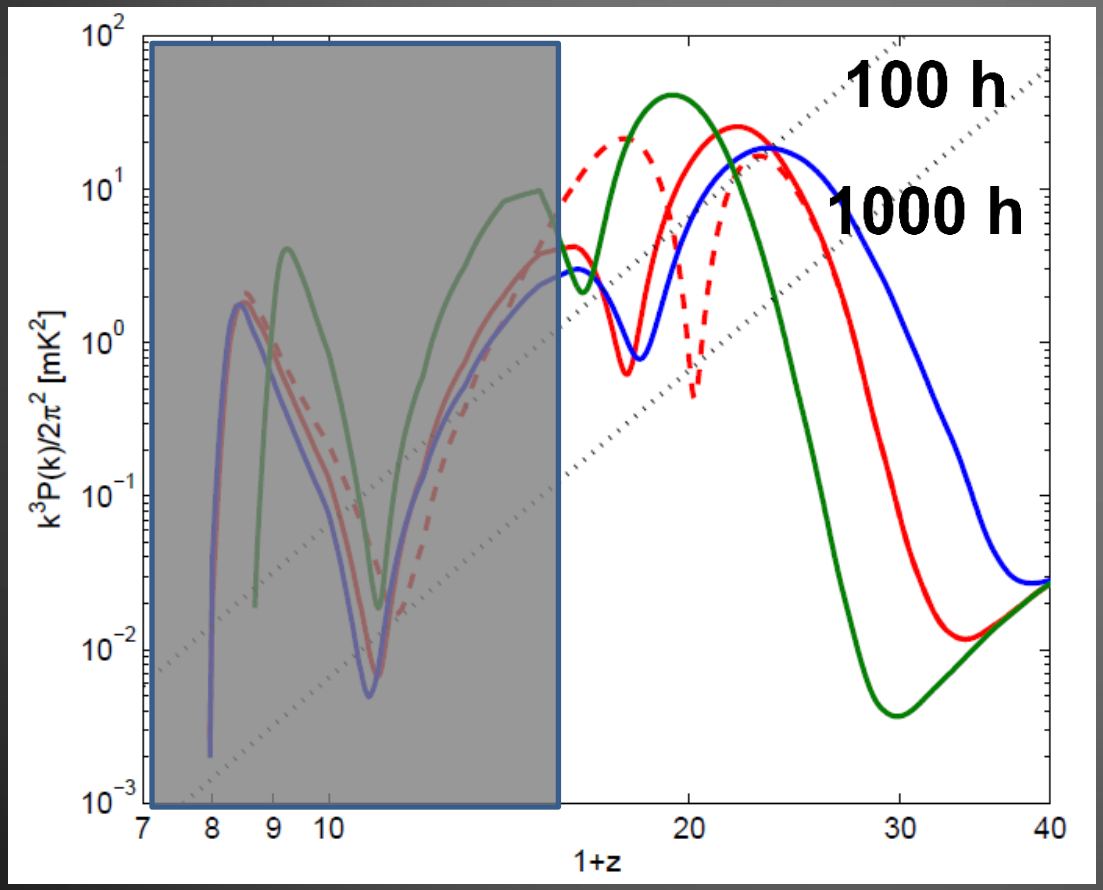


100 h

1000 h

Signal from **Fialkov**, Barkana, in preparation
Noise - ~ NenuFAR

Another example:
Power ($k^3P(k)/2\pi^2$) at k = 0.03 Mpc^{-1}

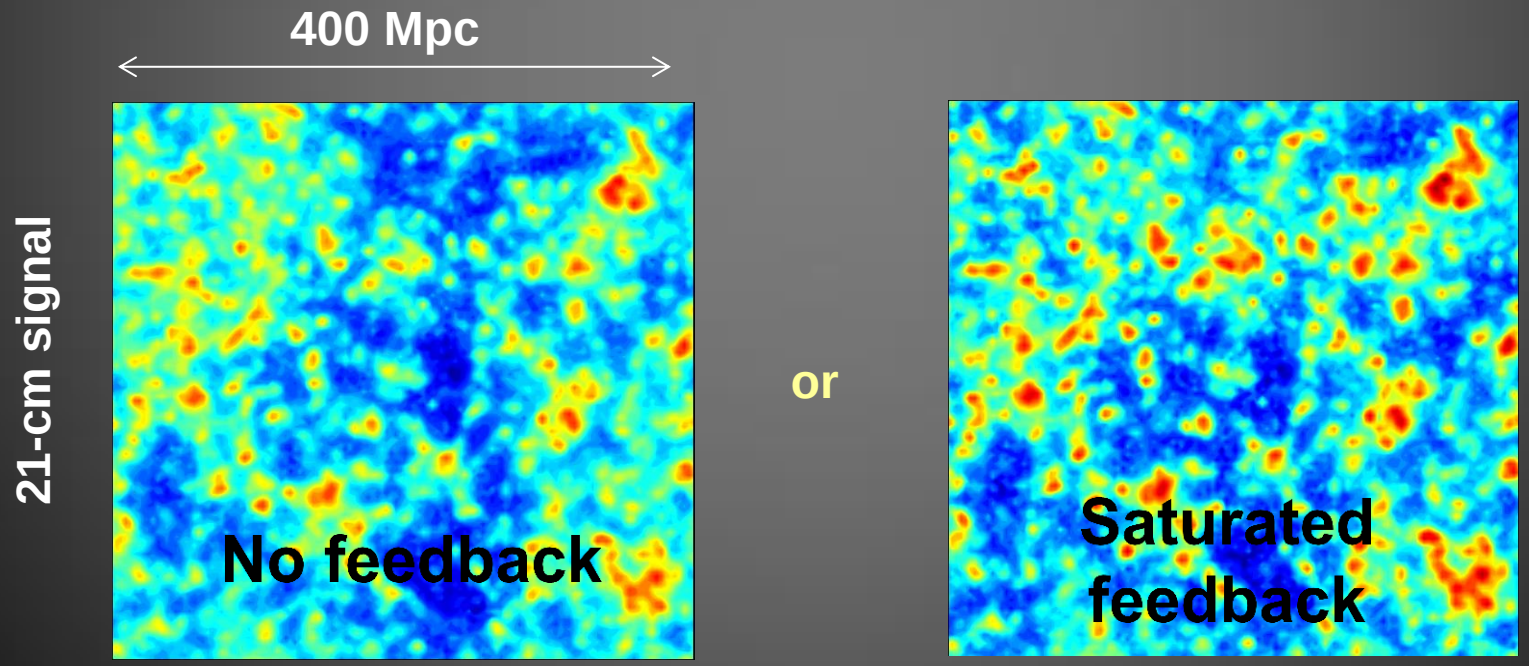


Signal from **Fialkov**, Barkana, in preparation
Noise - NenuFAR

Imaging
(NenuFAR resolution ~200 Mpc at z = 20)

- Resolution ~ 1 degree (~ 200 Mpc at z = 20)
- Field of view ~ 34 – 9 degrees at 20 – 80 MHz (~ several Gpc)

Can we see high and low supersonic flow regions?



Constraining the Early Universe with NenuFAR

For the first time detect the global signal

- Timing of cosmic milestones during cosmic dawn
- Probe the halos in which PopIII stars formed. Feedbacks
- Constrain heating mechanisms at high z
- Dark ages. Cosmology and exotic physics (dark matter annihilation, warm dark matter, primordial magnetic field etc.…)

Power spectrum at large scales, coarse imaging

Almost SKA science before SKA (but at ~1 degree resolution)

Cosmic Milestones