B-MODE SIGNAL FROM PATCHY REIONIZATION

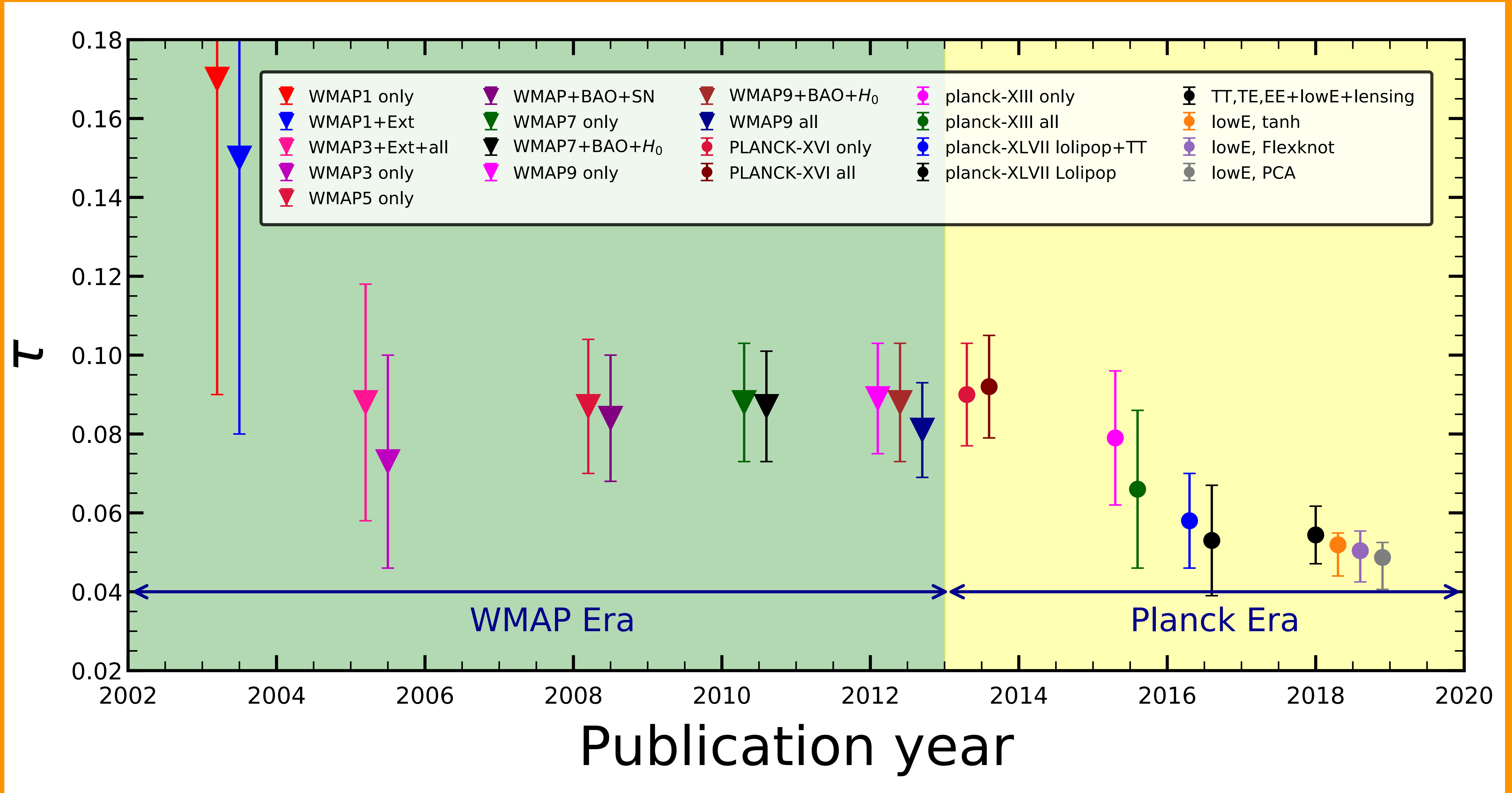
ANIRBAN ROY

PHD STUDENT

SISSA, TRIESTE

With Girish Kulkarni (TIFR), Daan Meerburg (Cambridge/Groningen), Anthony Challinor (Cambridge), Martin Haehnelt (Cambridge)

Constraints from CMB



$$\tau(z) = c\sigma_T n_{p0} \int_0^{z_s} \frac{dz(1+z)^2}{H(z)} \bar{x}_e(z)$$

How patchy is reionization?

What are the secondary anisotropies generated due to the patchy reionization?

How patchy is reionization?

Probing tau fluctuations

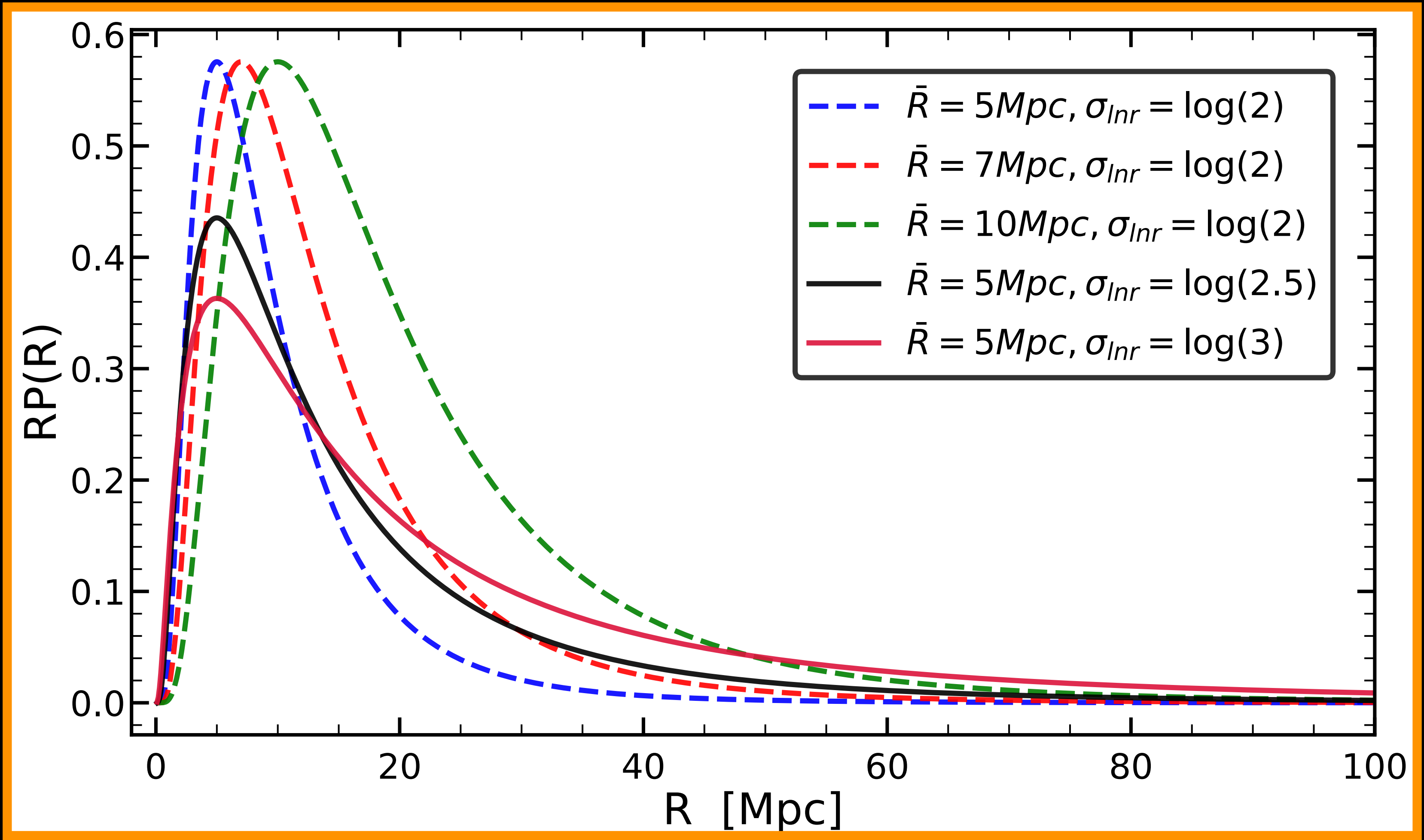
(Roy et al. 2018, Dvorkin & Smith 2009)

What are the secondary anisotropies generated due to the patchy reionization?

Secondary B-mode signal, Patchy KSZ+TSZ

(Roy et al. 2018, Smith & Ferraro 2017, Alvarez 2016, Zahn et. Al 2005, Hu 2000, Lliev 2007, McQuinn et. al. 2003)

Patchy Reionization



Fluctuations in tau

$$\tau(\hat{n}) = \bar{\tau} + \Delta\tau(\hat{n})$$

Patchy KSZ Signal

Patchy screening by a factor $e^{-\tau(\bar{n})}$

$$P(R) = \frac{1}{R}\frac{1}{\sqrt{2\pi\sigma_{lnr}^2}}\exp\left[-\frac{\{\ln(R/\bar{R})\}^2}{2\sigma_{lnr}^2}\right].$$

Wang & Hu 2006, Furlanetto et al. 2004

Imprints on CMB

Tau and B-mode power spectra can be written as:

$$C_\ell^{\tau\tau} = \sigma_T^2 n_{p0}^2 \int \frac{d\chi}{a^4\chi^2} P_{\delta x_e \delta x_e}\left(\chi, k = \frac{\ell}{\chi}\right).$$

$$C_\ell^{BB-patchy} = \frac{3\sigma_T^2 n_{p0}^2}{100} \int \frac{d\chi}{a^4\chi^2} e^{-2\tau(\chi)} Q_{rms}^2 P_{\delta x_e \delta x_e}\left(\chi, k = \frac{\ell}{\chi}\right)$$

Imprints on CMB

Tau and B-mode power spectra can be written as:

$$\boxed{C_\ell^{\tau\tau}} = \sigma_T^2 n_{p0}^2 \int \frac{d\chi}{a^4\chi^2} \boxed{P_{\delta x_e \delta x_e}} \left(\chi, k = \frac{\ell}{\chi}\right).$$

Reconstructed signal

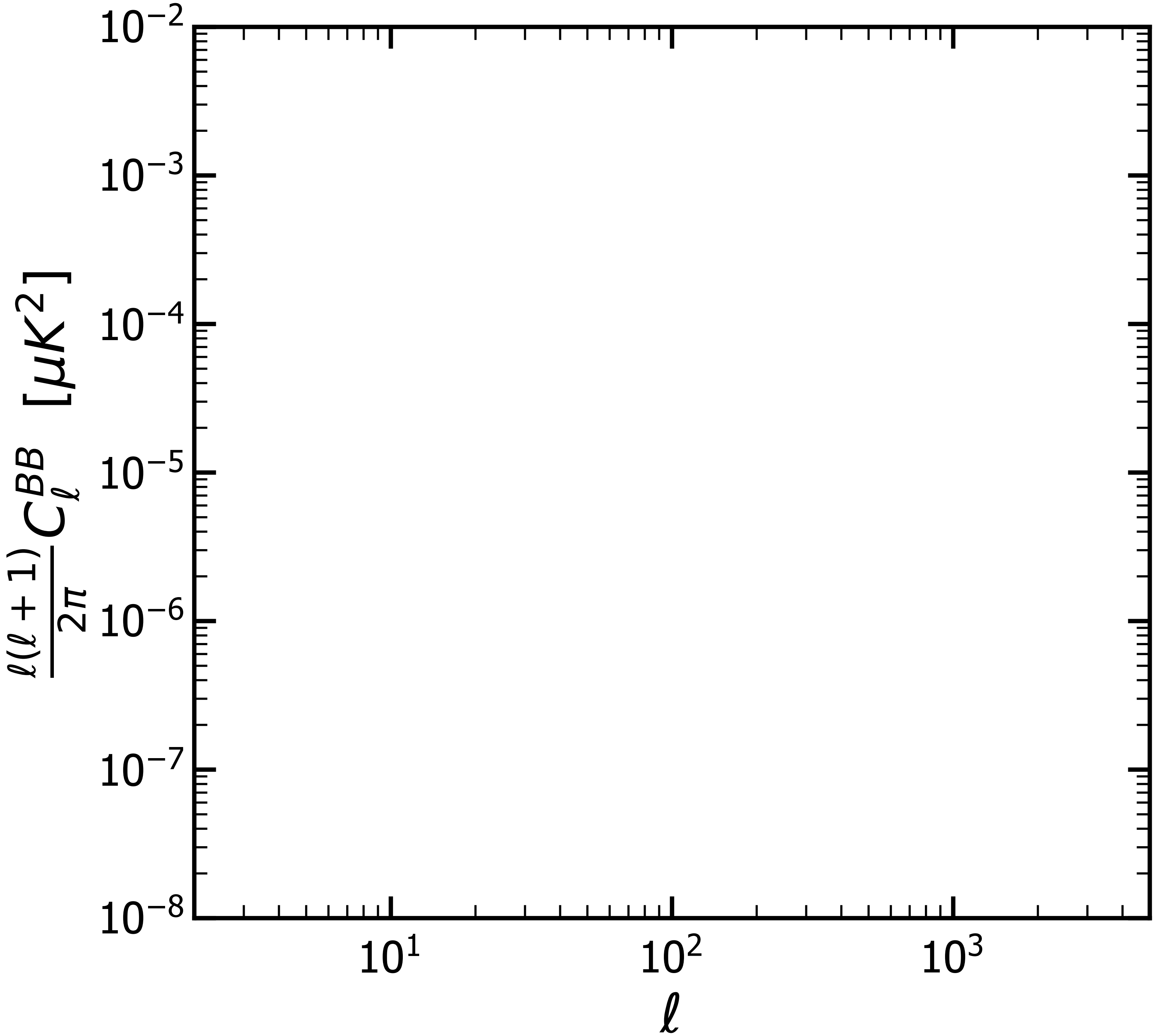
Astrophysical aspects of Reionization

$$\boxed{C_\ell^{BB-patchy}} = \frac{3\sigma_T^2 n_{p0}^2}{100} \int \frac{d\chi}{a^4\chi^2} e^{-2\tau(\chi)} Q_{rms}^2 \boxed{P_{\delta x_e \delta x_e}} \left(\chi, k = \frac{\ell}{\chi}\right)$$

Cosmological Signal

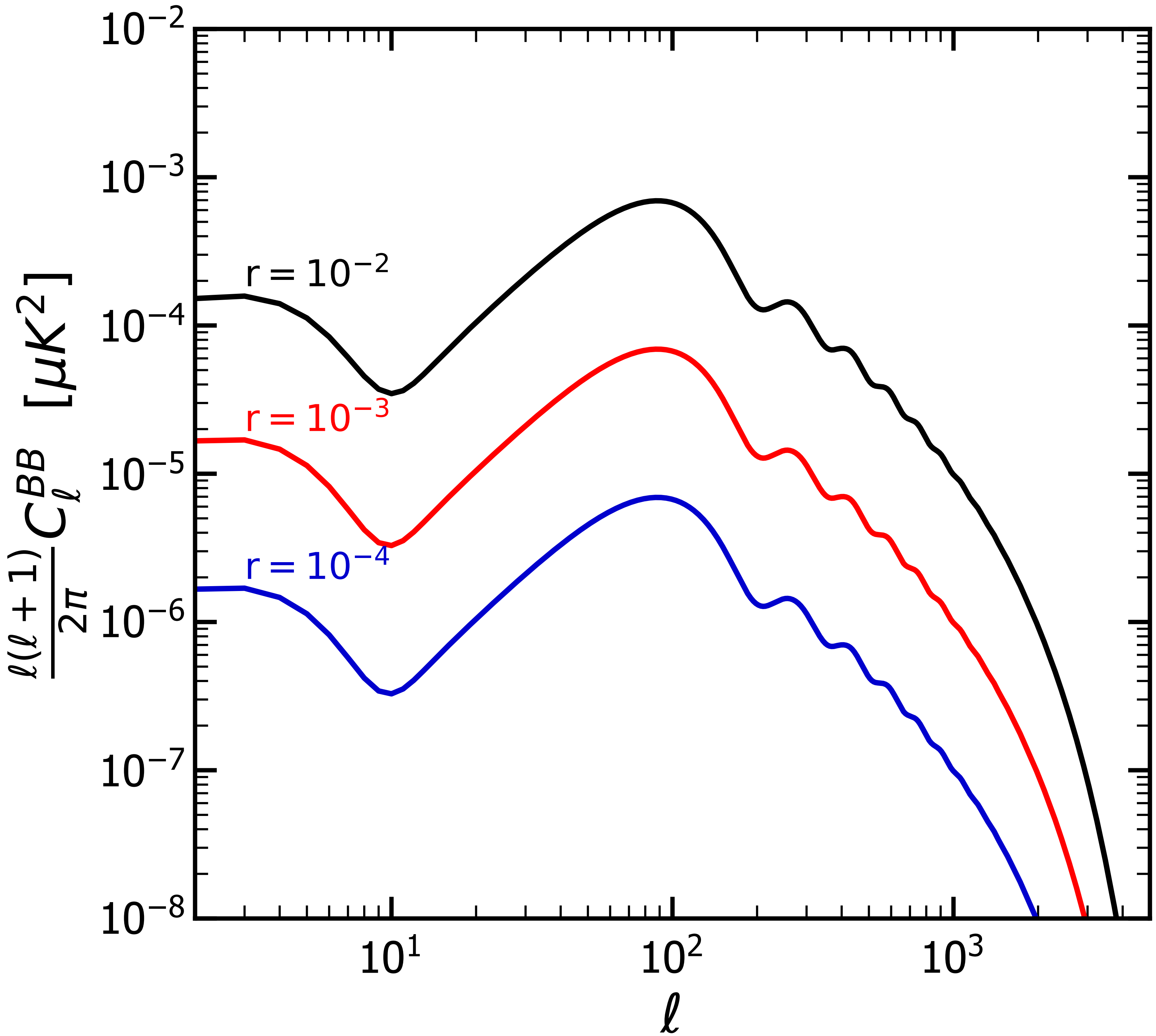
Hu 2000, Dvorkin & Smith 2009

Patchy B-mode Signal



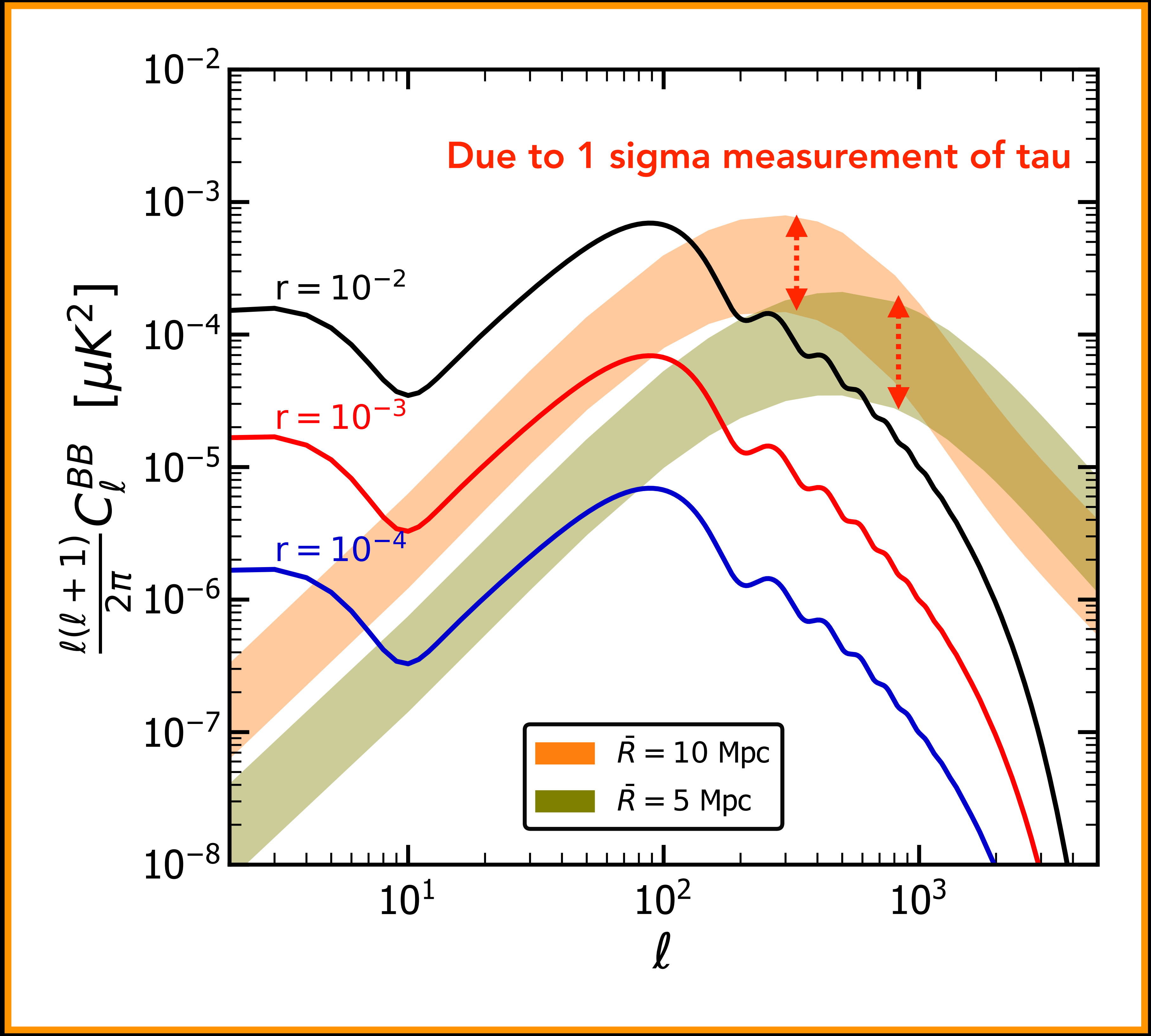
Roy et. al 2018

Patchy B-mode Signal



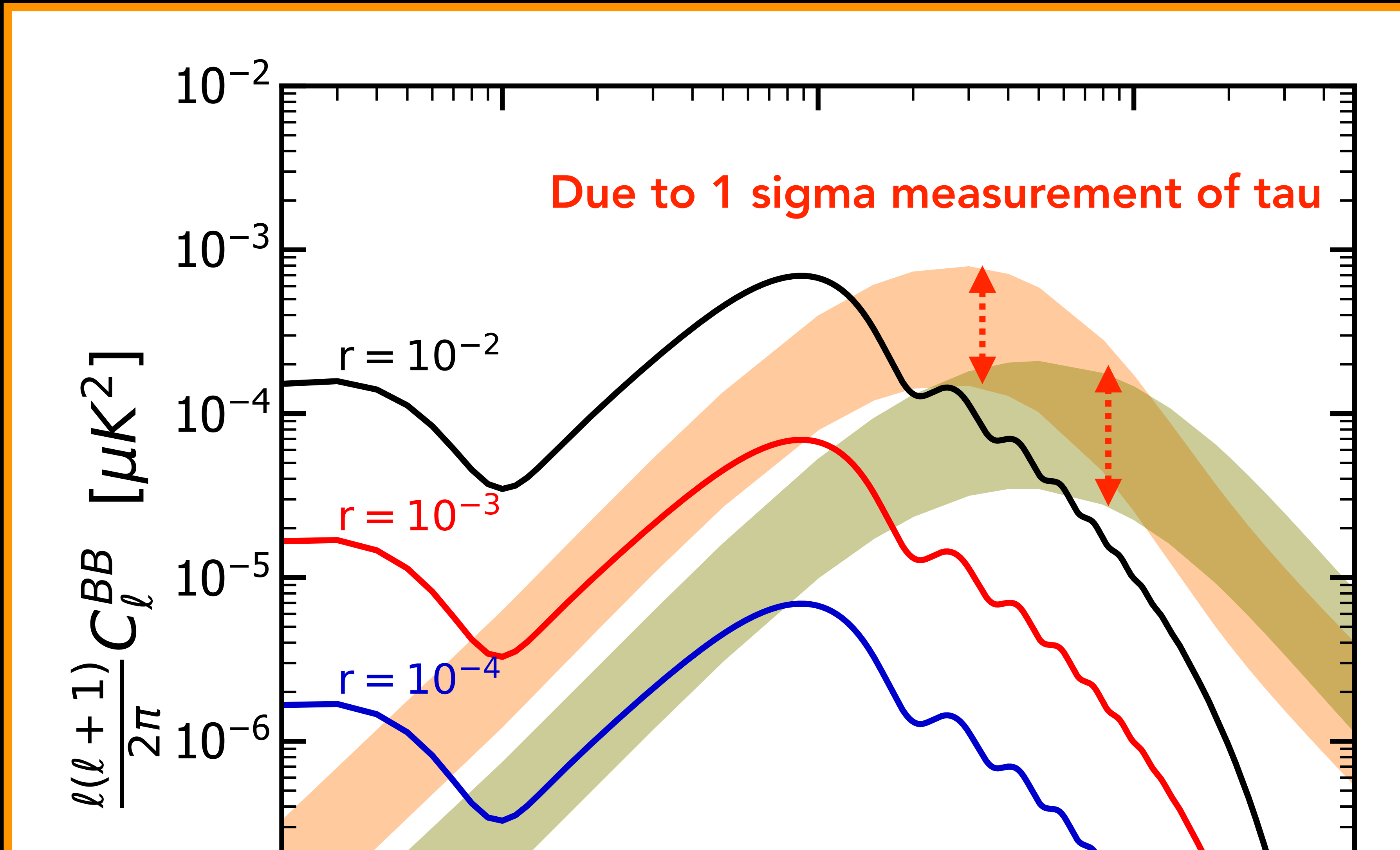
Roy et. al 2018

Patchy B-mode Signal



Roy et. al 2018

Patchy B-mode Signal

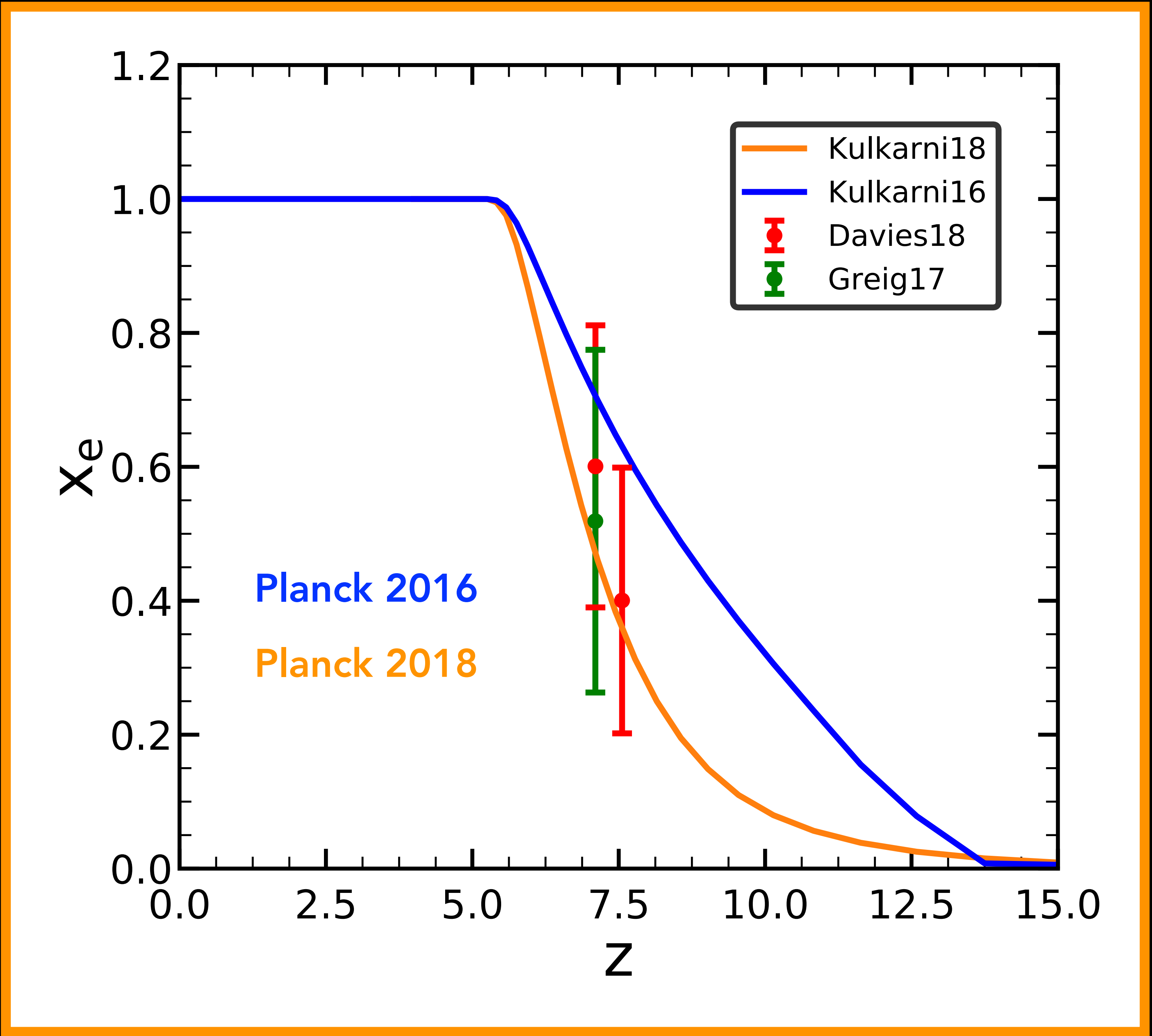


Can we trust this reionization model ? NO!

We need realistic simulations to calculate the amplitude of patchy B-mode signal.

Roy et. al 2018

Radiative Transfer Simulations



Lyman Alpha opacity

constraints on Tau from CMB

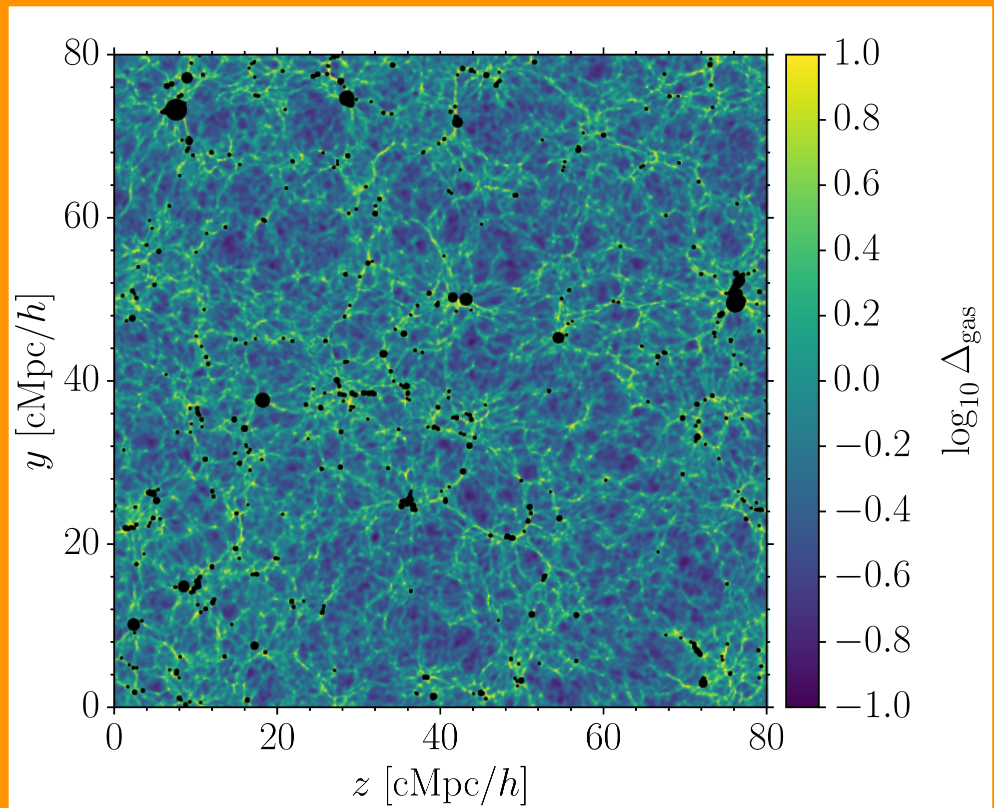
Dynamic Range (320 Mpc, 2048)

Observation of QSO near-zones

In details: Girish's talk tomorrow!

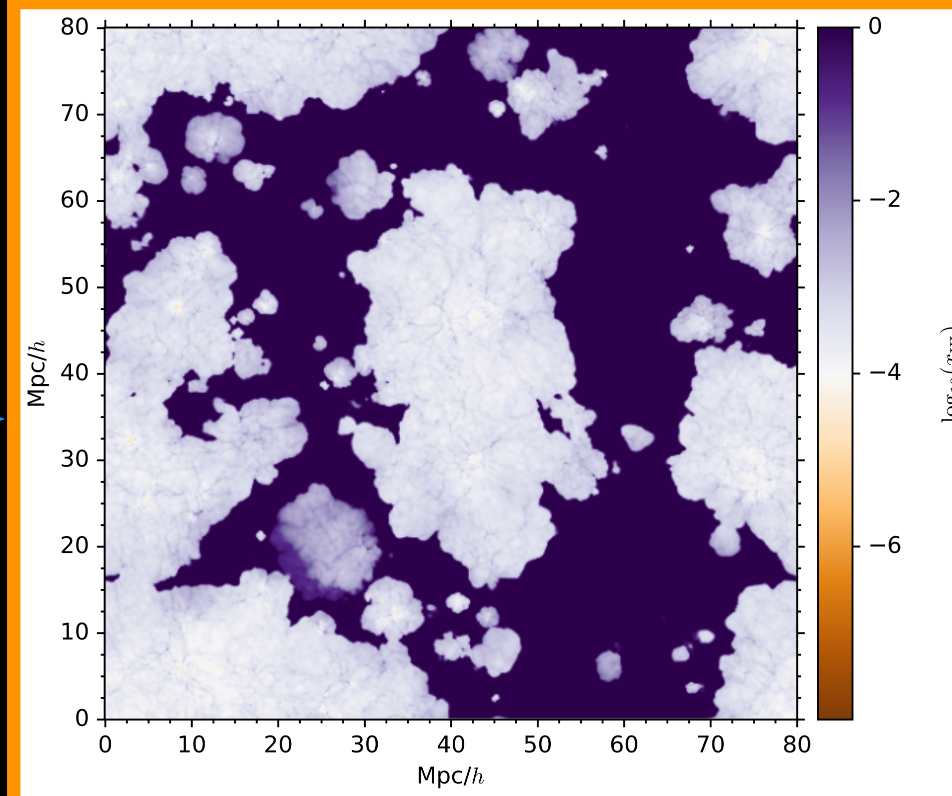
Kulkarni et. al 2018/ 2016, Bolton et al. 2016

Excursion Set Approach

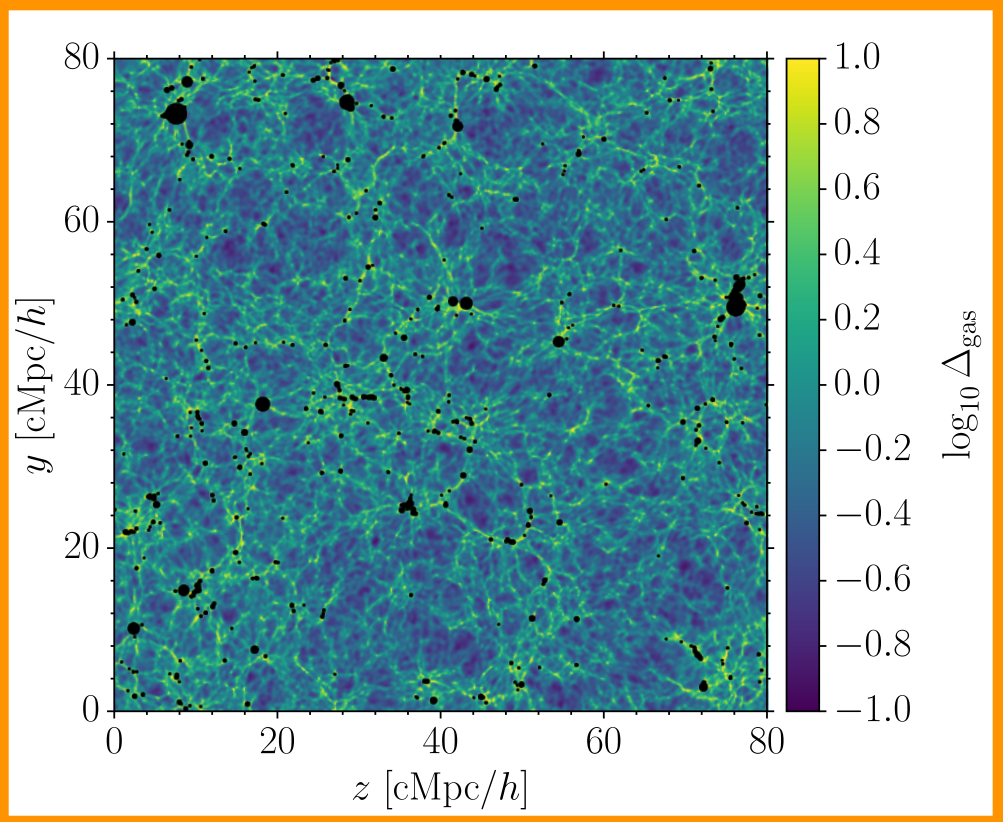


Radiative Transfer algorithm

Realistic Ionization History

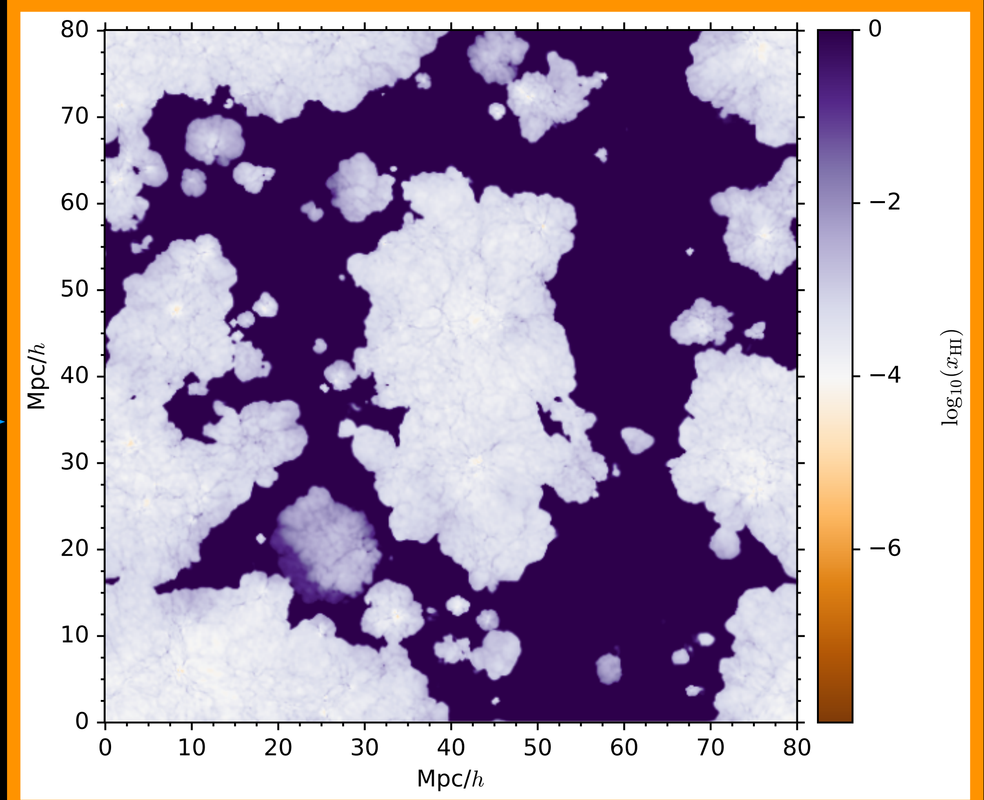


Excursion Set Approach



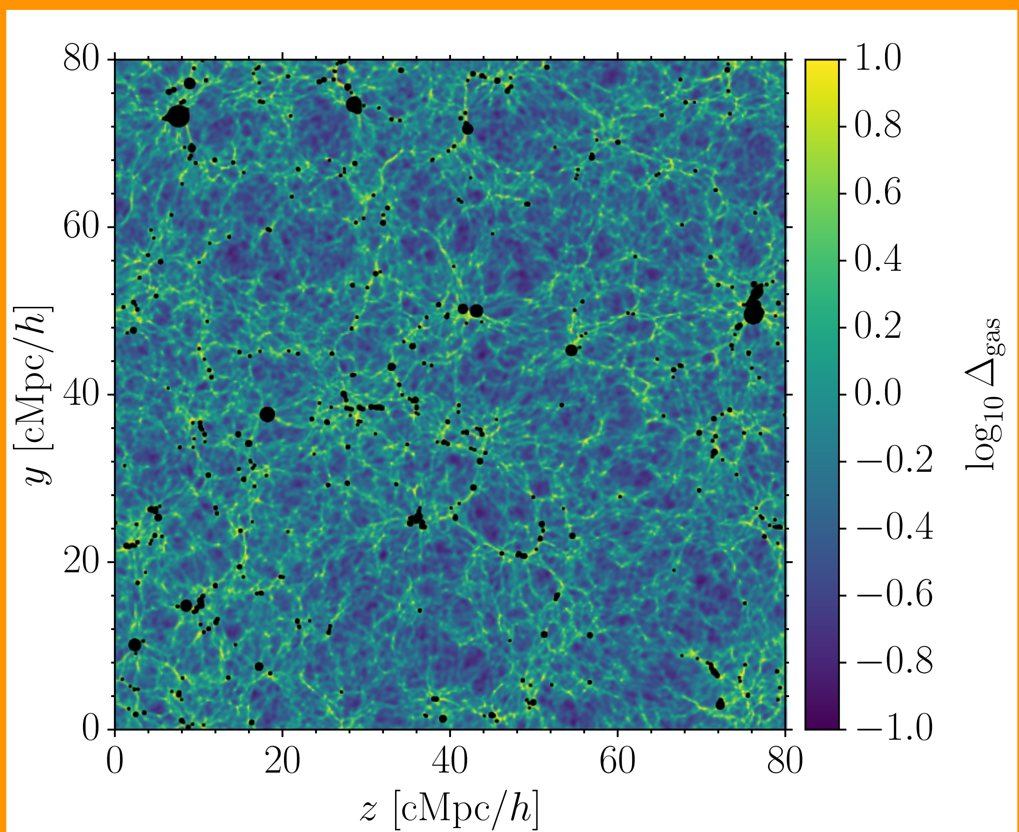
Radiative Transfer algorithm

Realistic Ionization History



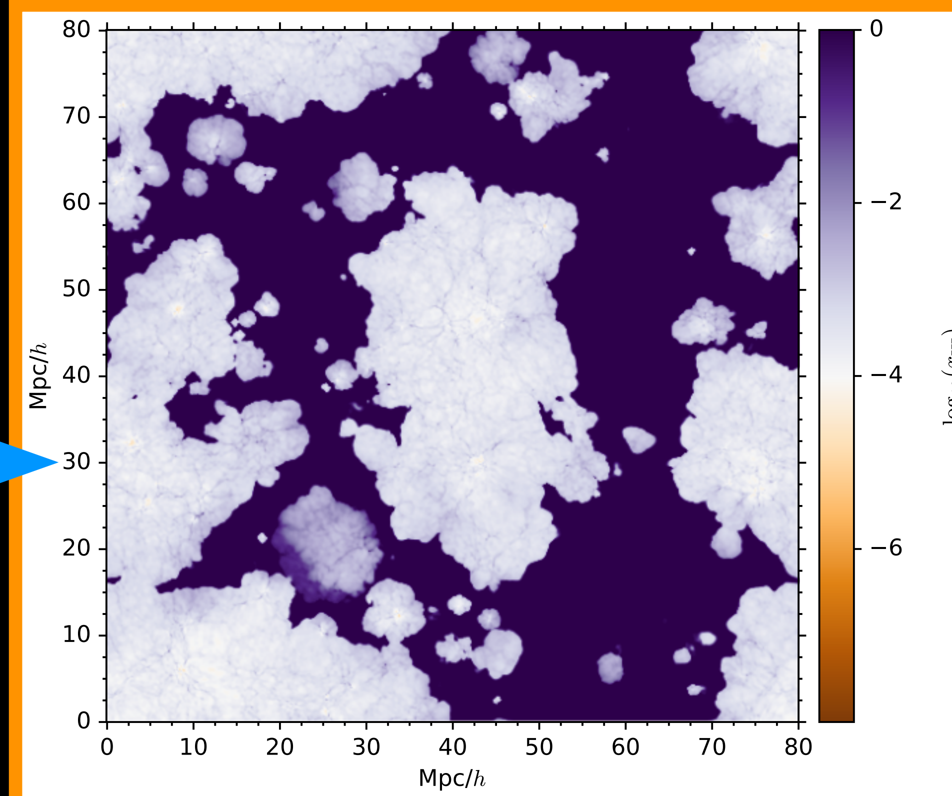
Radiative transfer simulations can generate ionization field ~ 320 Mpc with ngrid=2048 (lmin~220).

Excursion Set Approach



Radiative Transfer algorithm

Realistic Ionization History



Identical density in RT simulation.
320 Mpc
lmin~220

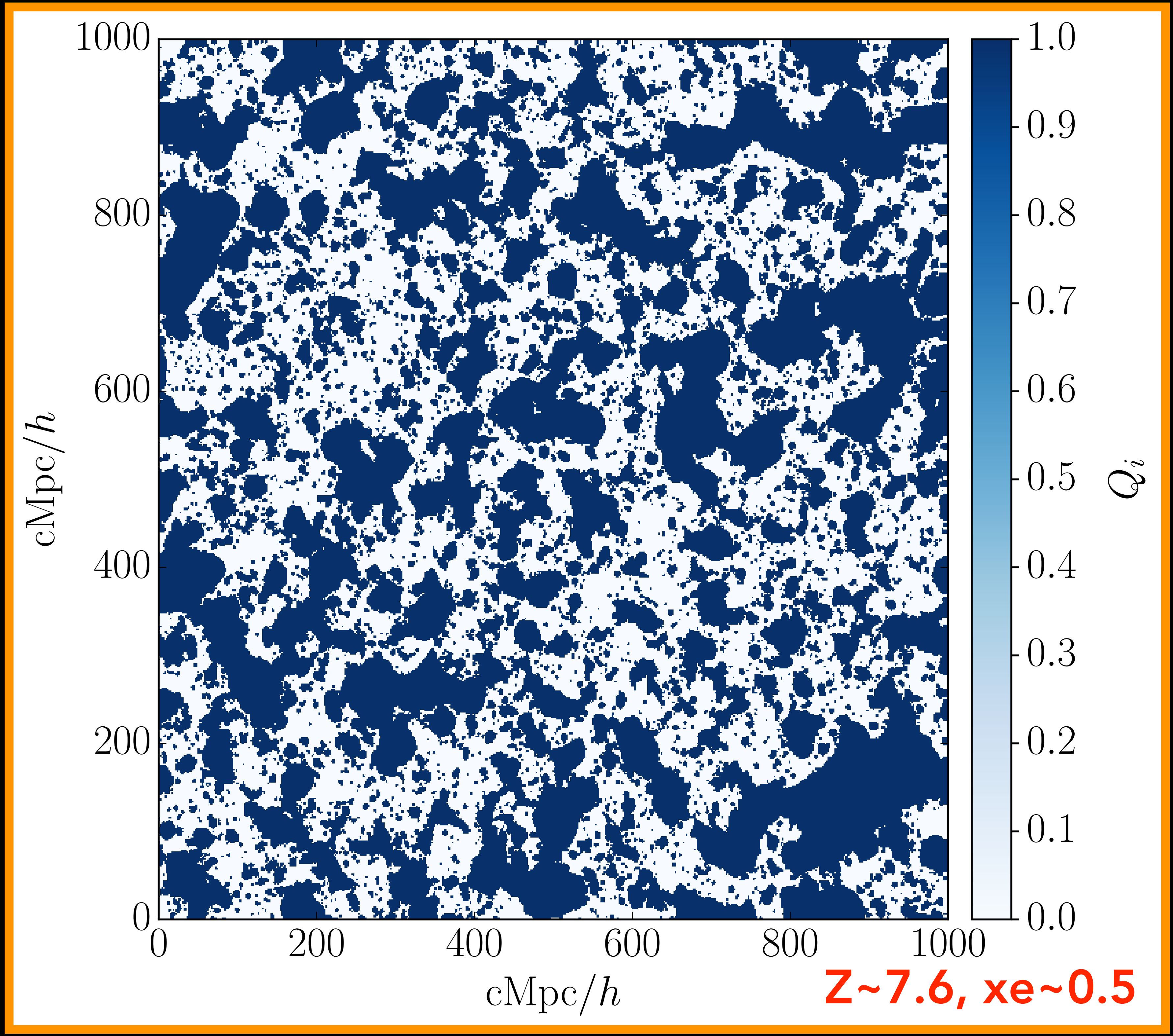
density field and halos from 21cmFAST.
1000 Mpc
lmin~50

Excursion set code

Same Ionization History

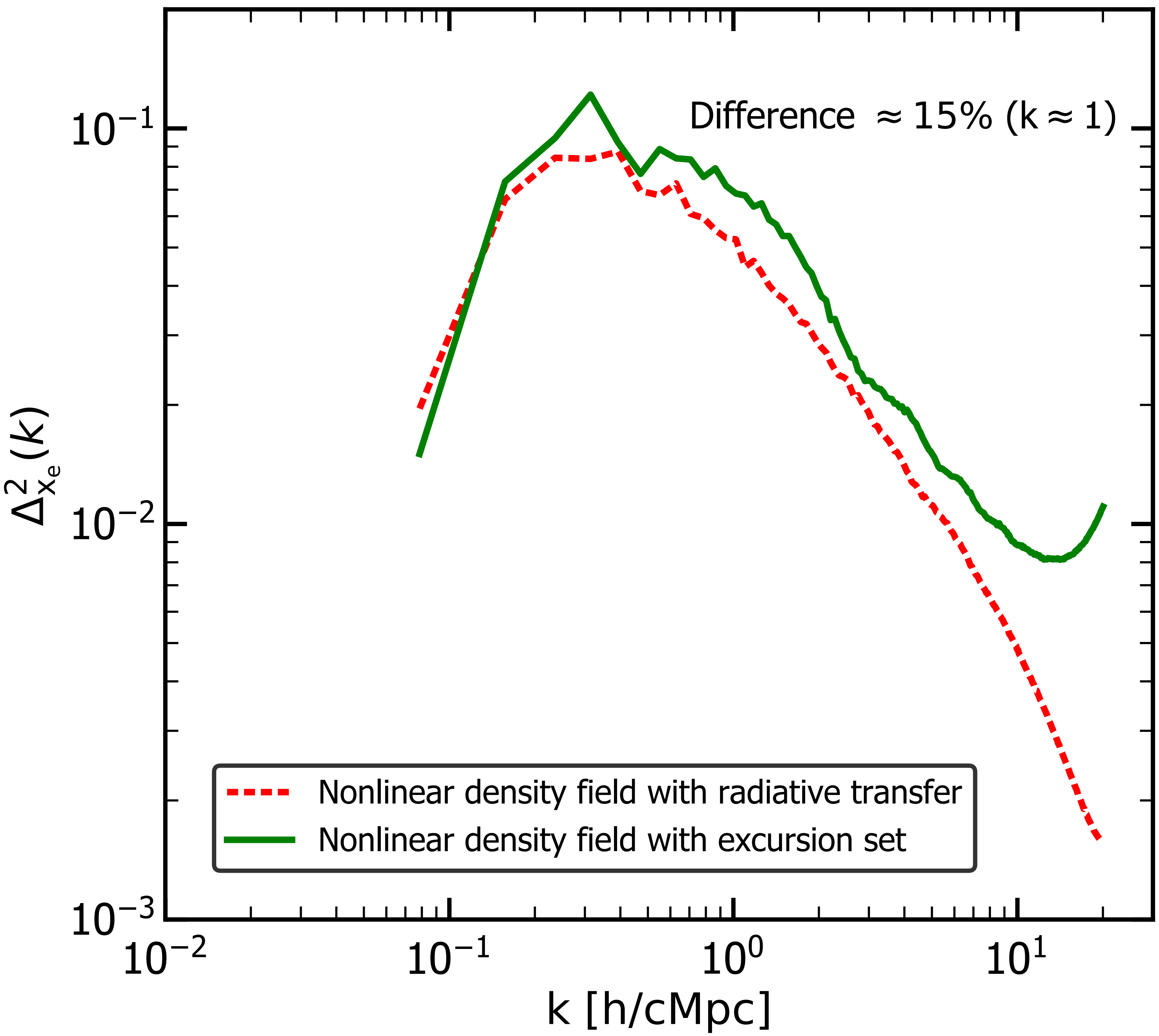
LARGE SCALE IONIZATION FIELD

Large Scale Ionization Field



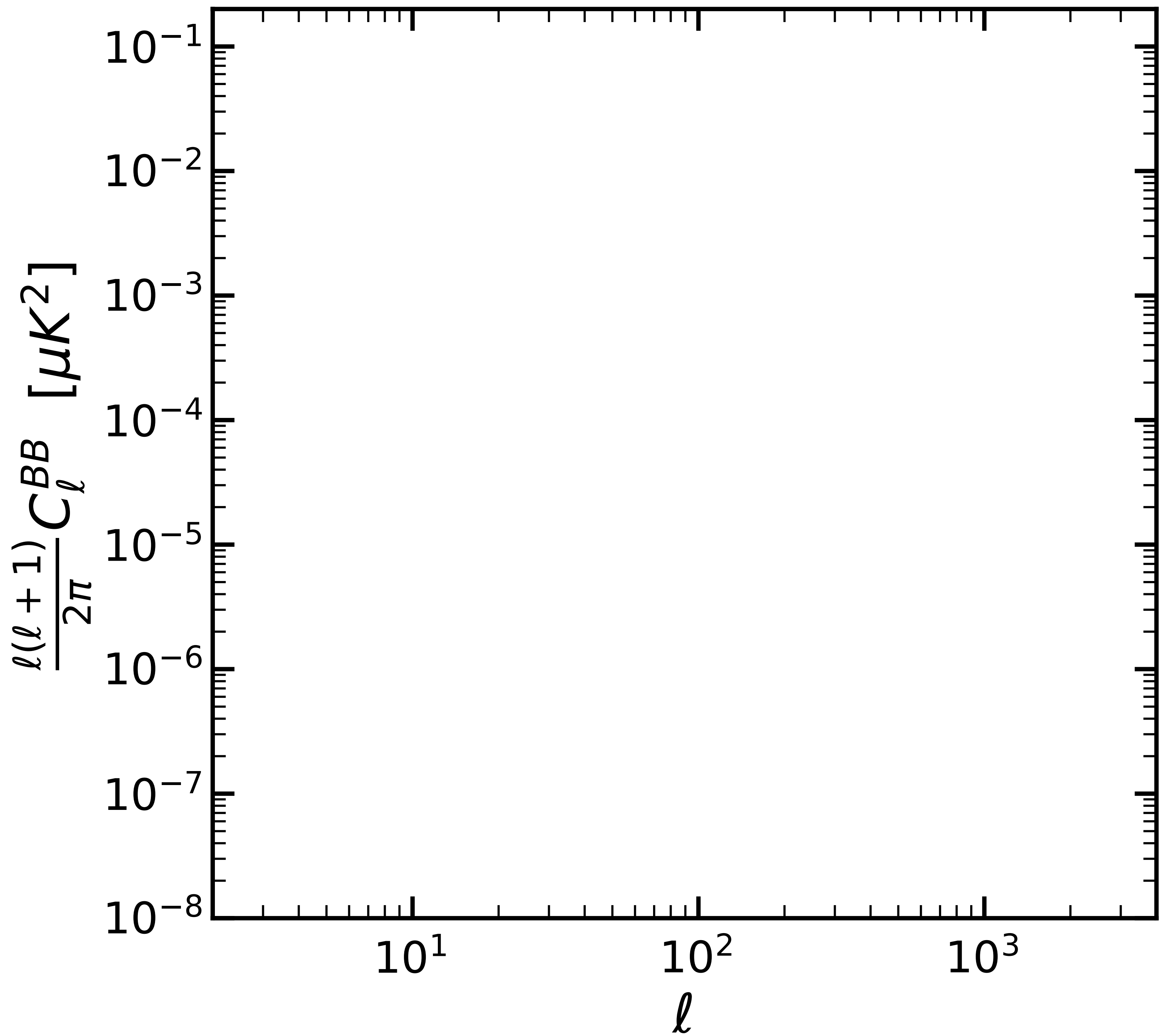
Roy, Kulkarni, Meerburg, Challinor, Haehnelt (In Preparation)

Ionization Power Spectra



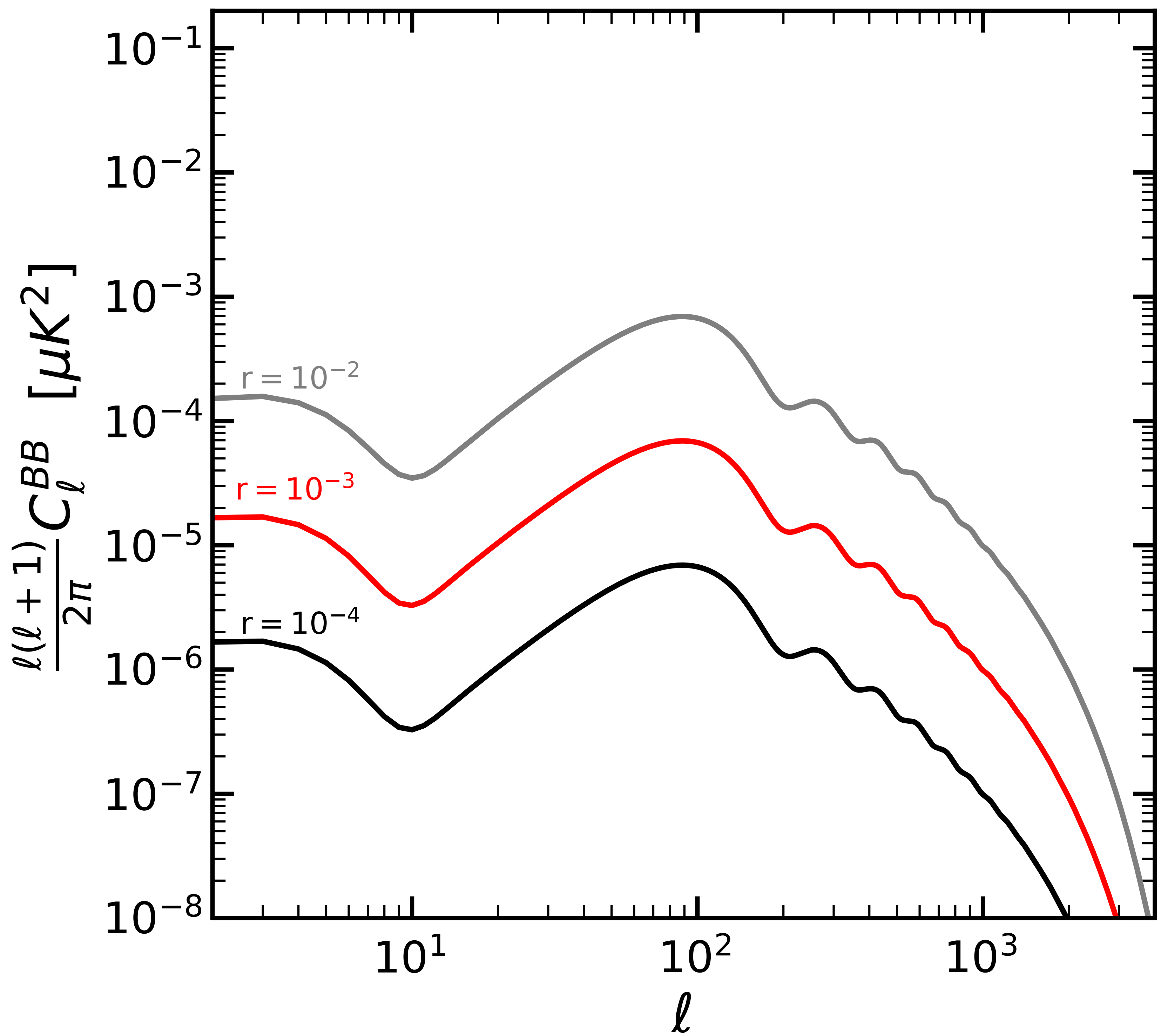
Roy, Kulkarni, Meerburg, Challinor,Haehnelt (In Preparation)

Patchy B-mode Signal



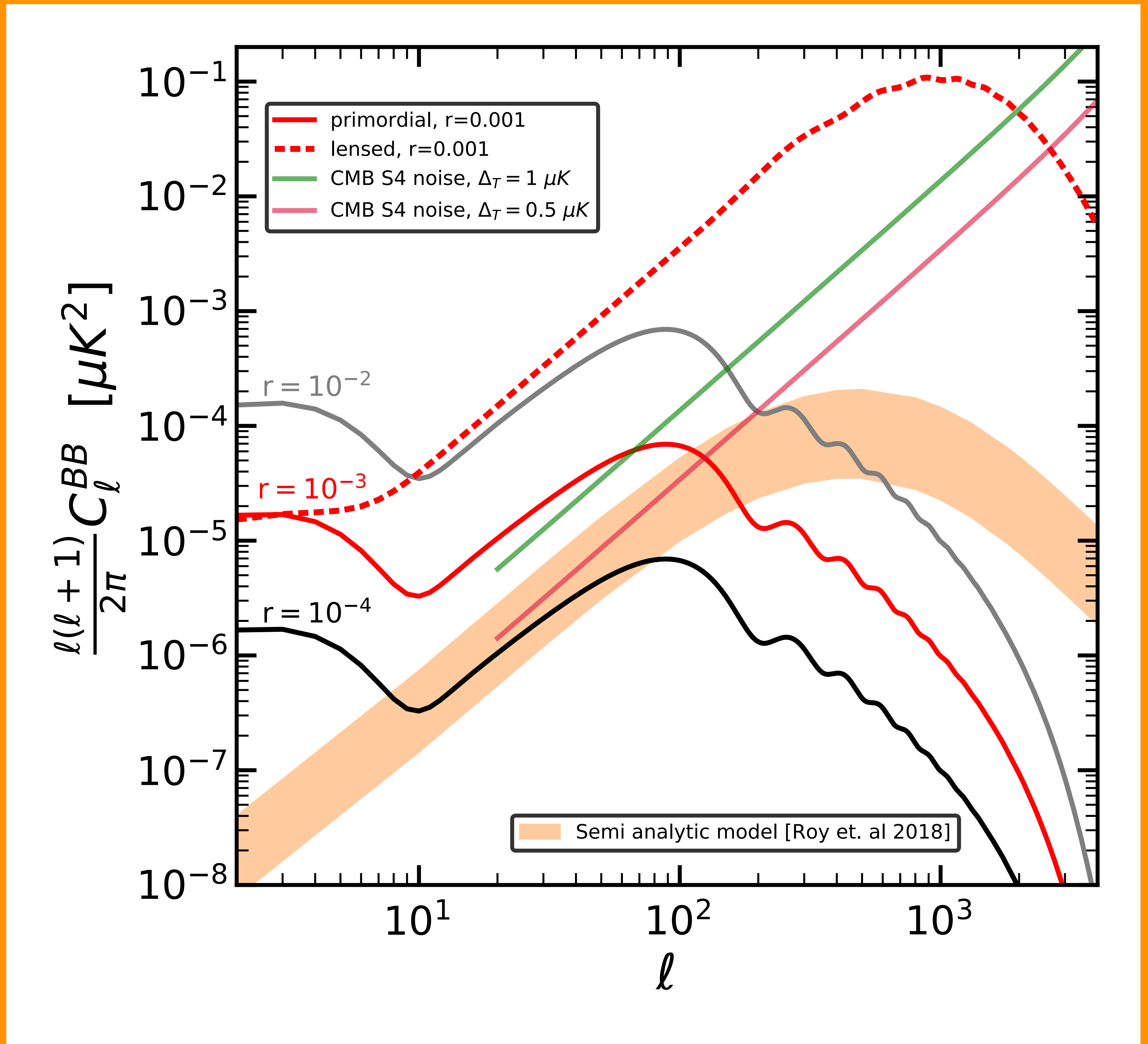
Roy, Kulkarni, Meerburg, Challinor,Haehnelt (In Preparation)

Patchy B-mode Signal



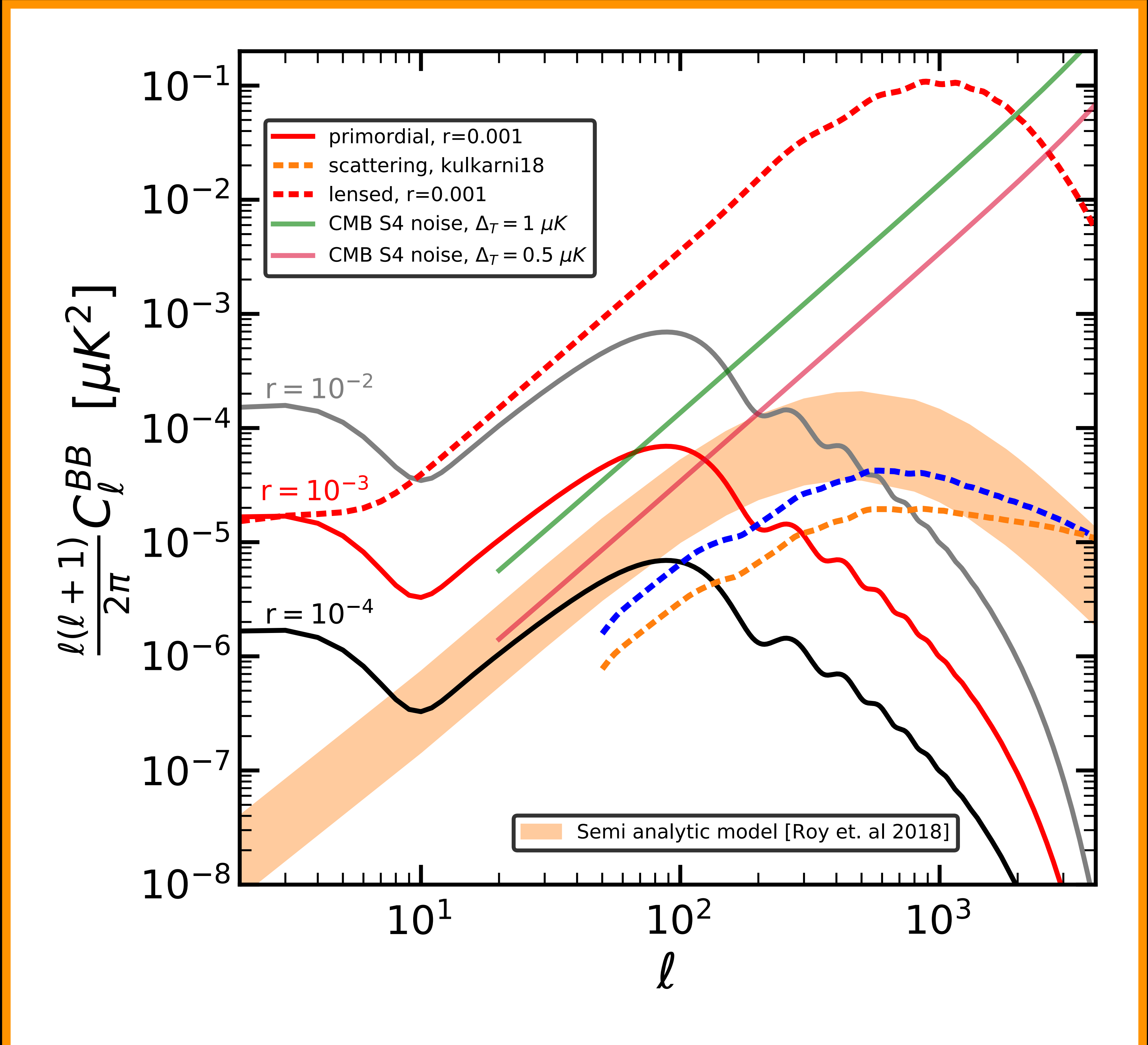
Roy, Kulkarni, Meerburg, Challinor,Haehnelt (In Preparation)

Patchy B-mode Signal



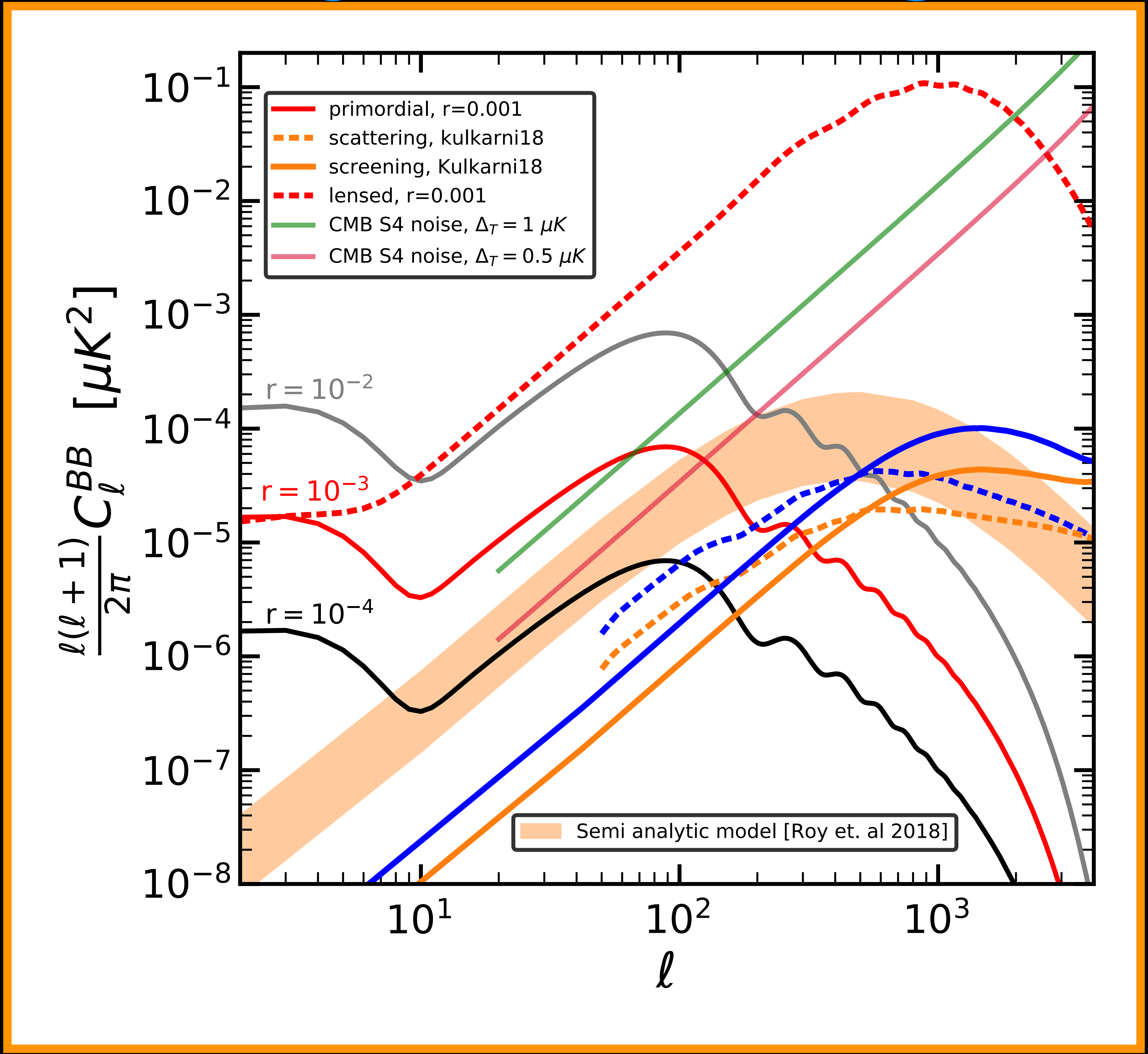
Roy, Kulkarni, Meerburg, Challinor,Haehnelt (In Preparation)

Patchy B-mode Signal



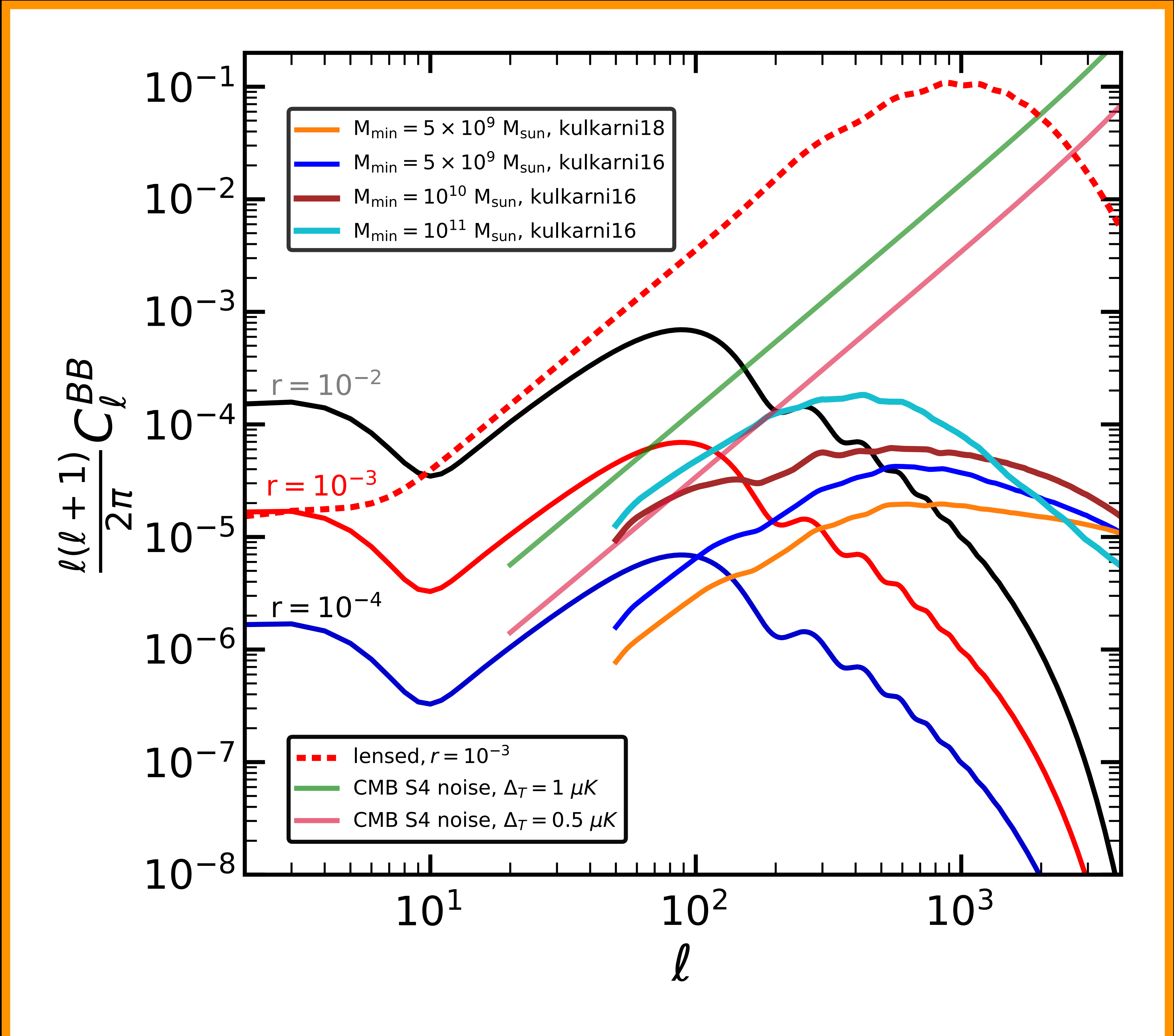
Roy, Kulkarni, Meerburg, Challinor,Haehnelt (In Preparation)

Patchy B-mode Signal



Roy, Kulkarni, Meerburg, Challinor,Haehnelt (In Preparation)

Patchy B-mode Signal



Roy, Kulkarni, Meerburg, Challinor,Haehnelt (In Preparation)

Summary

- We used radiative transfer simulations which agrees well with the available data.
- Patchy BB signal is **Small.** It is lower than the primordial B-mode signal with r=0.001 at l~100.
- Increase of minimum mass of the halo can increase B-mode signal significantly.

Thanks!

Comments / Questions?