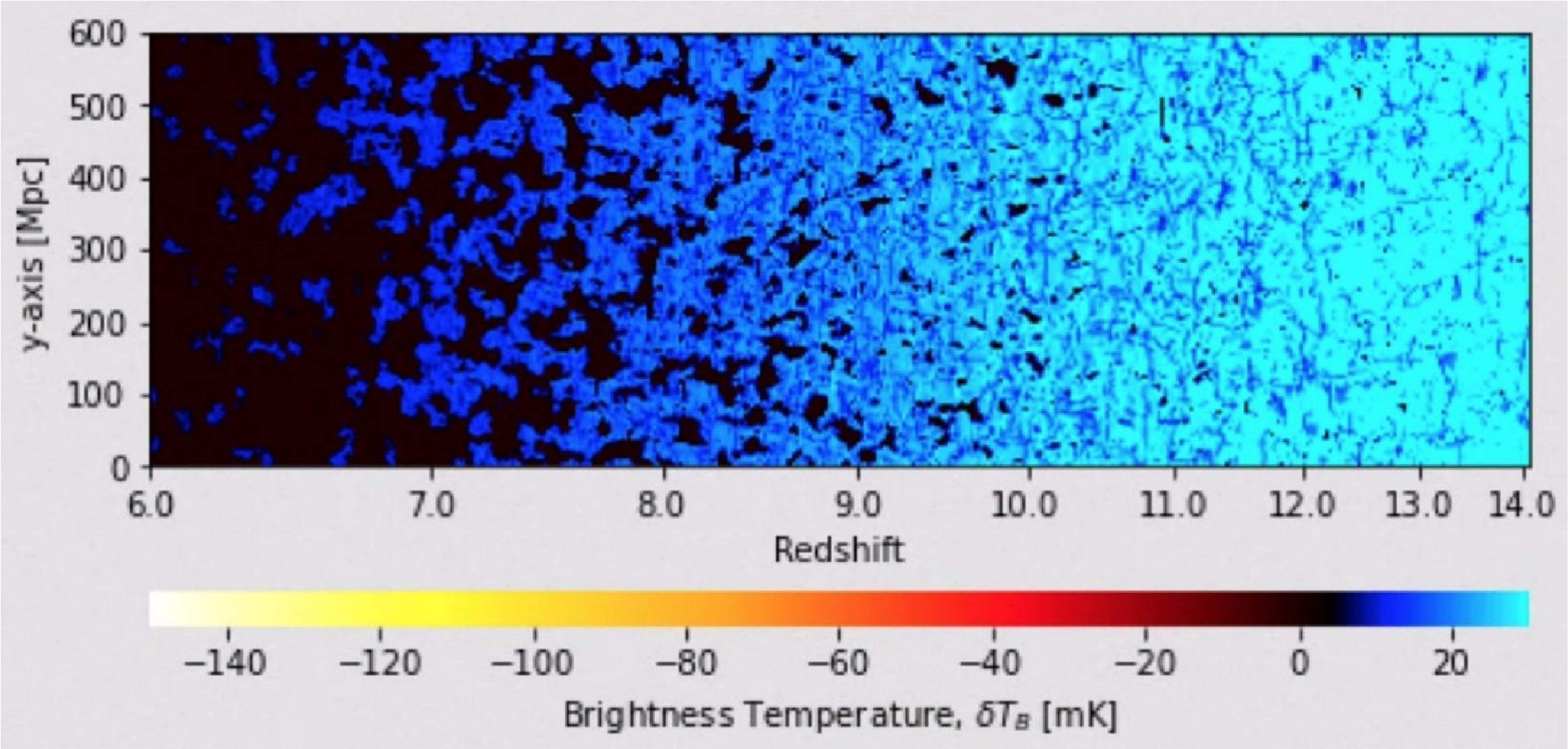
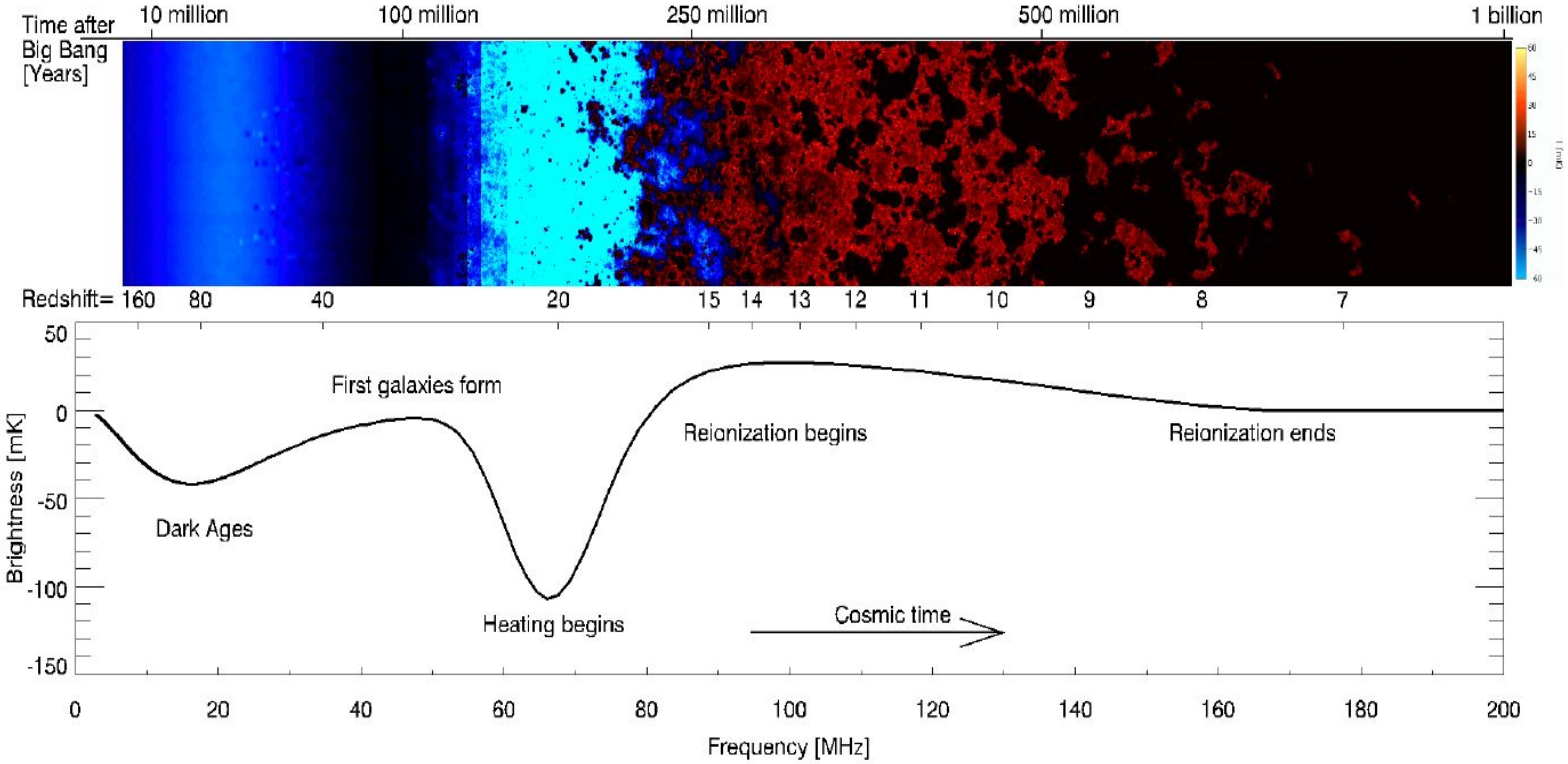
Experimenting with 21cmFAST for future radio observations

Cristiano Sabiu



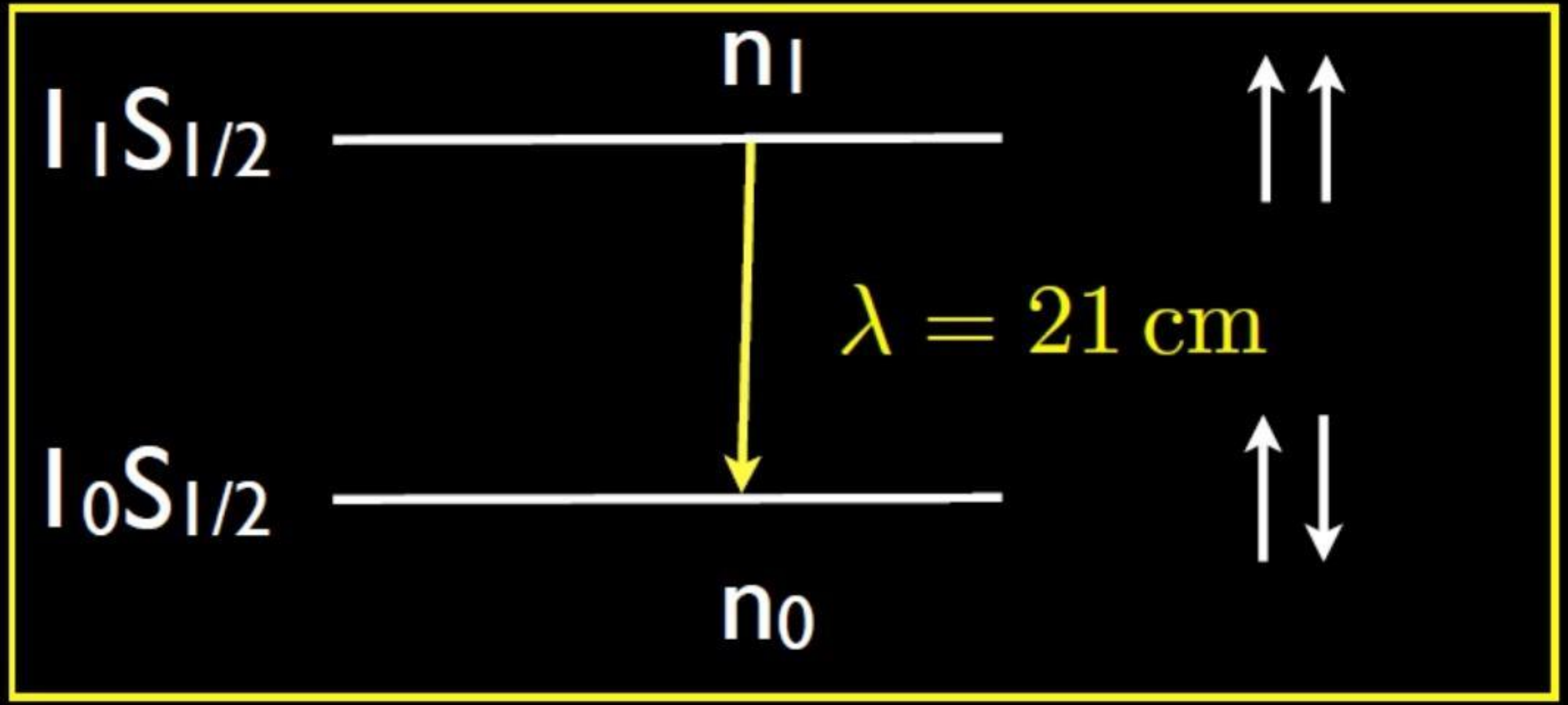
CPLUOS Group Meeting
26/2/2021

Cosmic Reionization History



$$\nu_{21cm} = 1,420,405,751.768 \pm 0.001\,\mathrm{Hz}$$

Hyperfine transition of neutral hydrogen



Spin temperature describes relative occupation of levels

$$n_1/n_0 = 3\exp(-h\nu_{21\mathrm{cm}}/kT_s)$$

Useful numbers:

$200\,\mathrm{MHz} \to z = 6$

$100\,\mathrm{MHz} \to z = 13$

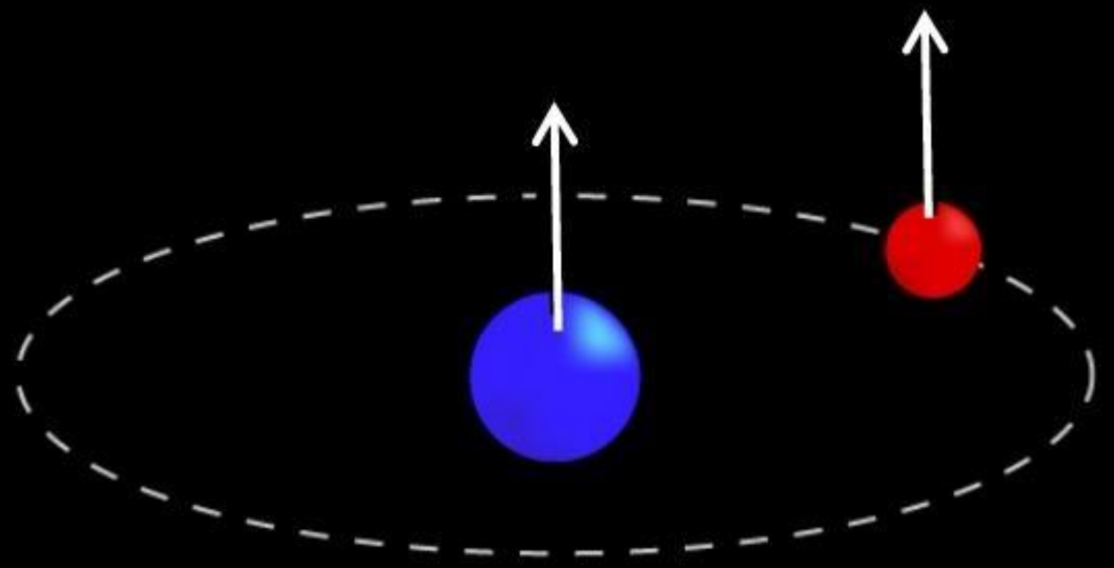
$70\,\mathrm{MHz} \to z \approx 20$

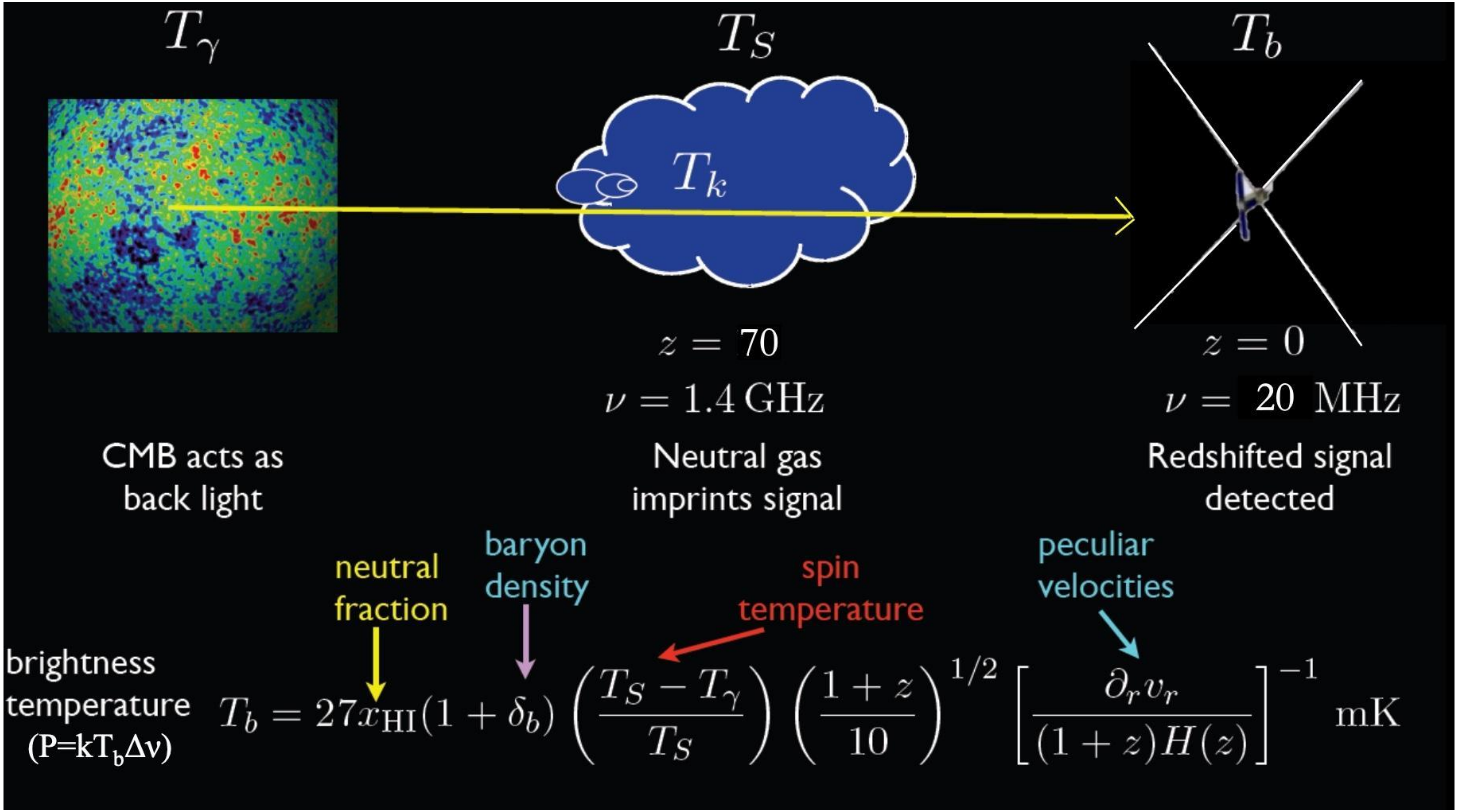
$40\,\mathrm{MHz} \longrightarrow z \approx 35$

$t_{\mathrm{Age}}(z=6) \approx 1\,\mathrm{Gyr}$

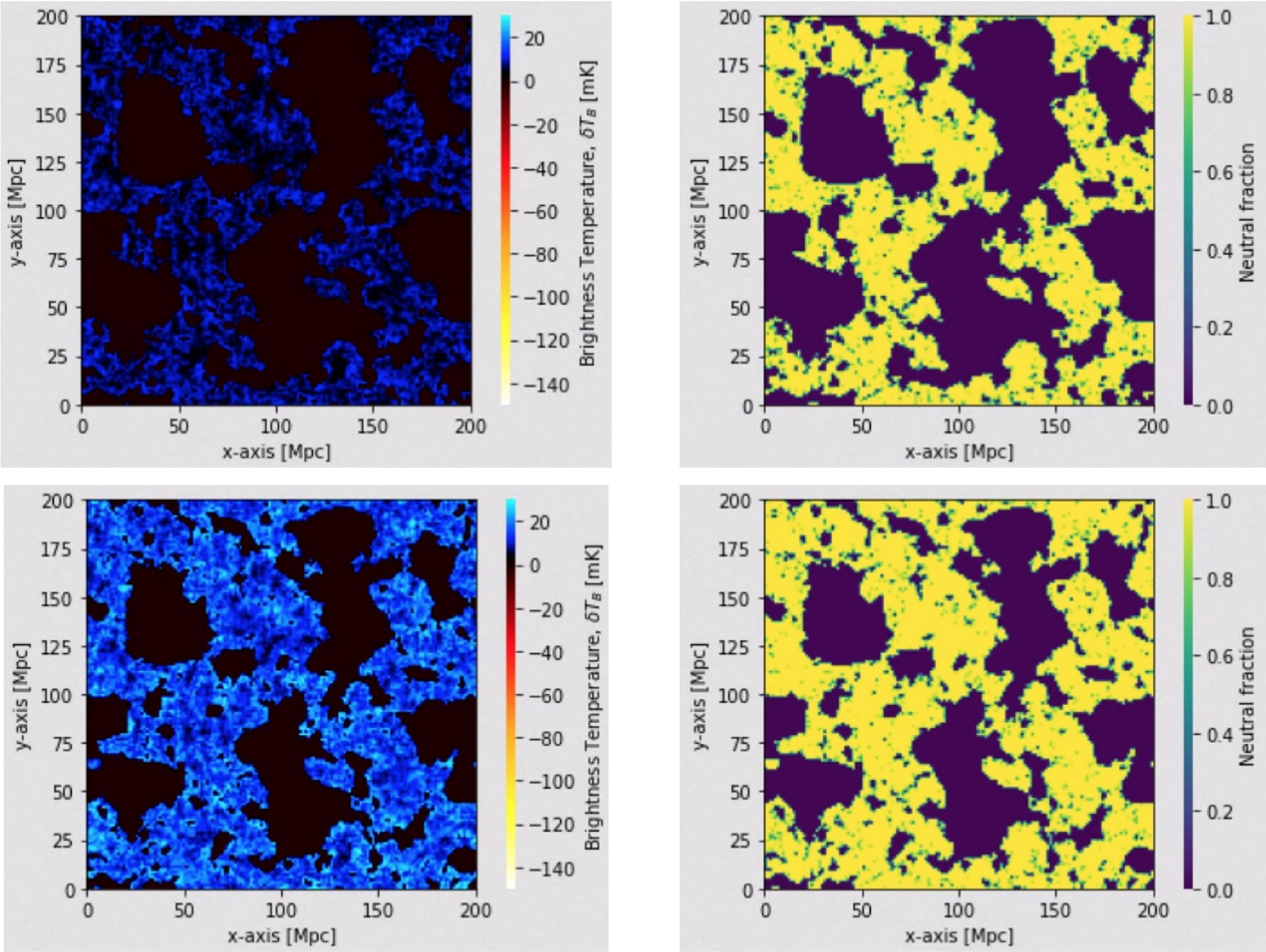
$t_{\mathrm{Age}}(z=10) \approx 500\,\mathrm{Myr}$

$t_{\mathrm{Age}}(z=20) \approx 150\,\mathrm{Myr}$





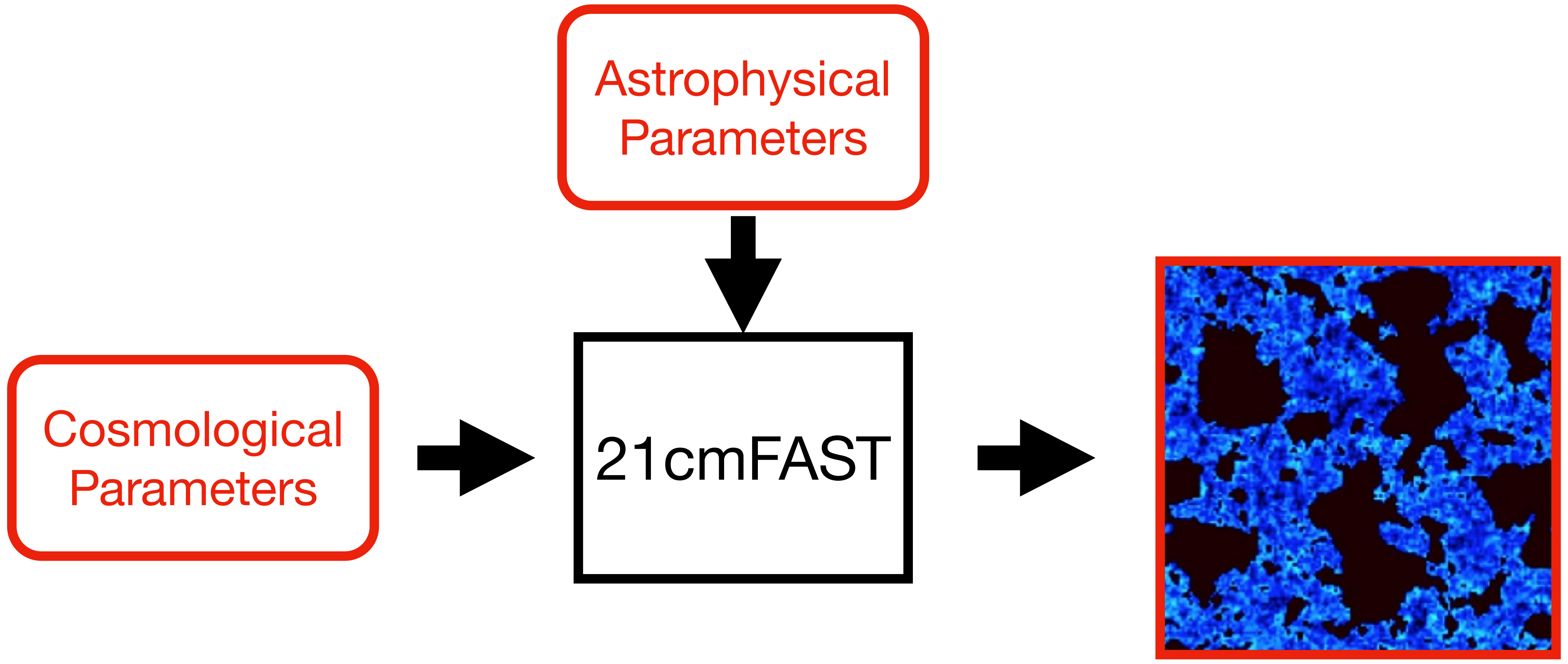
T_γ
T_S
T_b
T_k
$z = 70$
$\nu = 1.4\,\mathrm{GHz}$
$z = 0$
$\nu = 20\ \mathrm{MHz}$
CMB acts as back light
Neutral gas imprints signal
Redshifted signal detected
neutral fraction
baryon density
spin temperature
peculiar velocities
brightness temperature
($P=kT_b\Delta\nu$)
$T_b = 27 x_{\mathrm{HI}}(1+\delta_b)\left(\frac{T_S - T_\gamma}{T_S}\right)\left(\frac{1+z}{10}\right)^{1/2}\left[\frac{\partial_r v_r}{(1+z)H(z)}\right]^{-1}\ \mathrm{mK}$



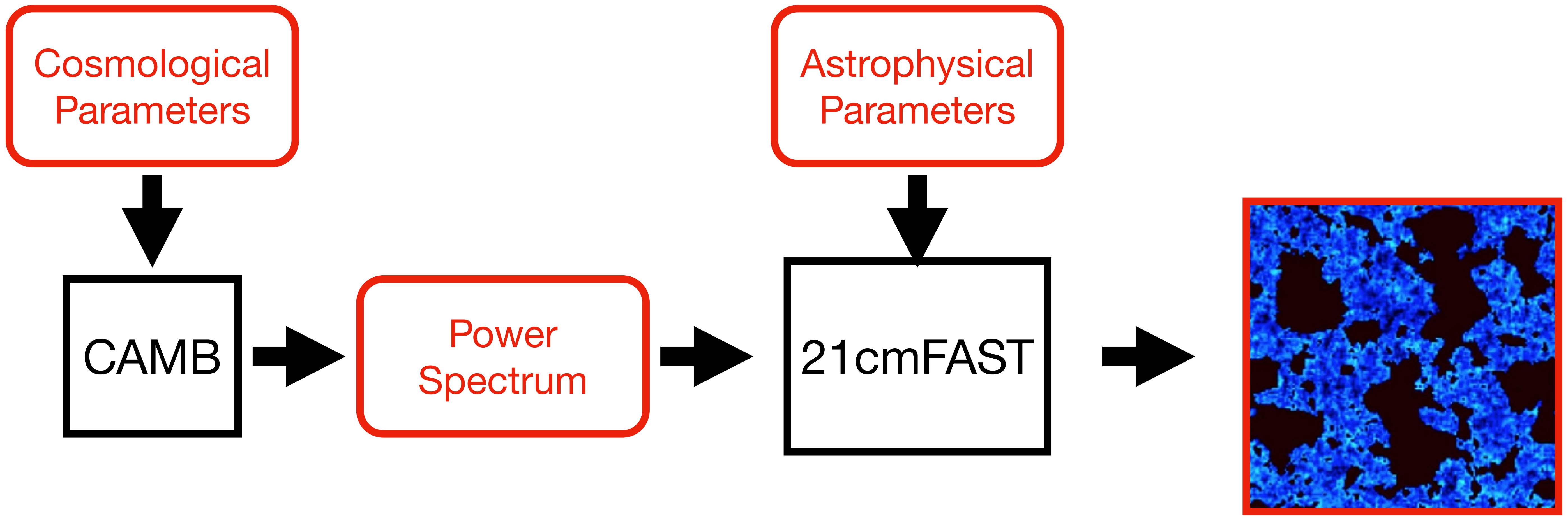
Low baryon fraction

High baryon fraction

Pipeline

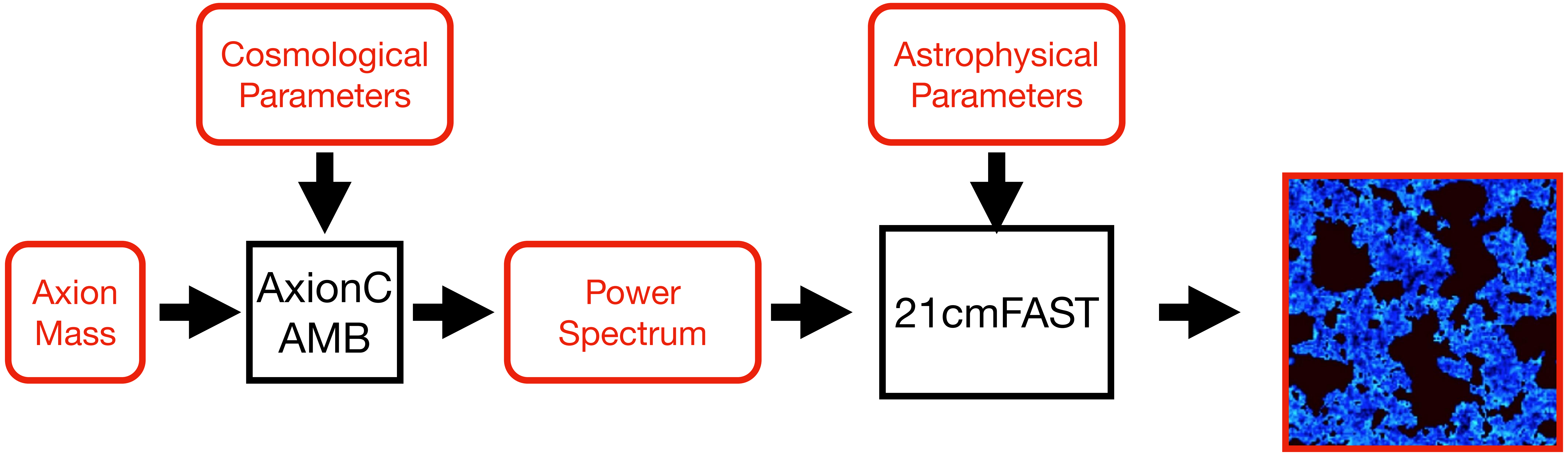

Astrophysical Parameters
Cosmological Parameters
21cmFAST

Pipeline



Thanks to Jaehong Park (KIAS), I can now run 21cmFAST with a custom Power Spectrum

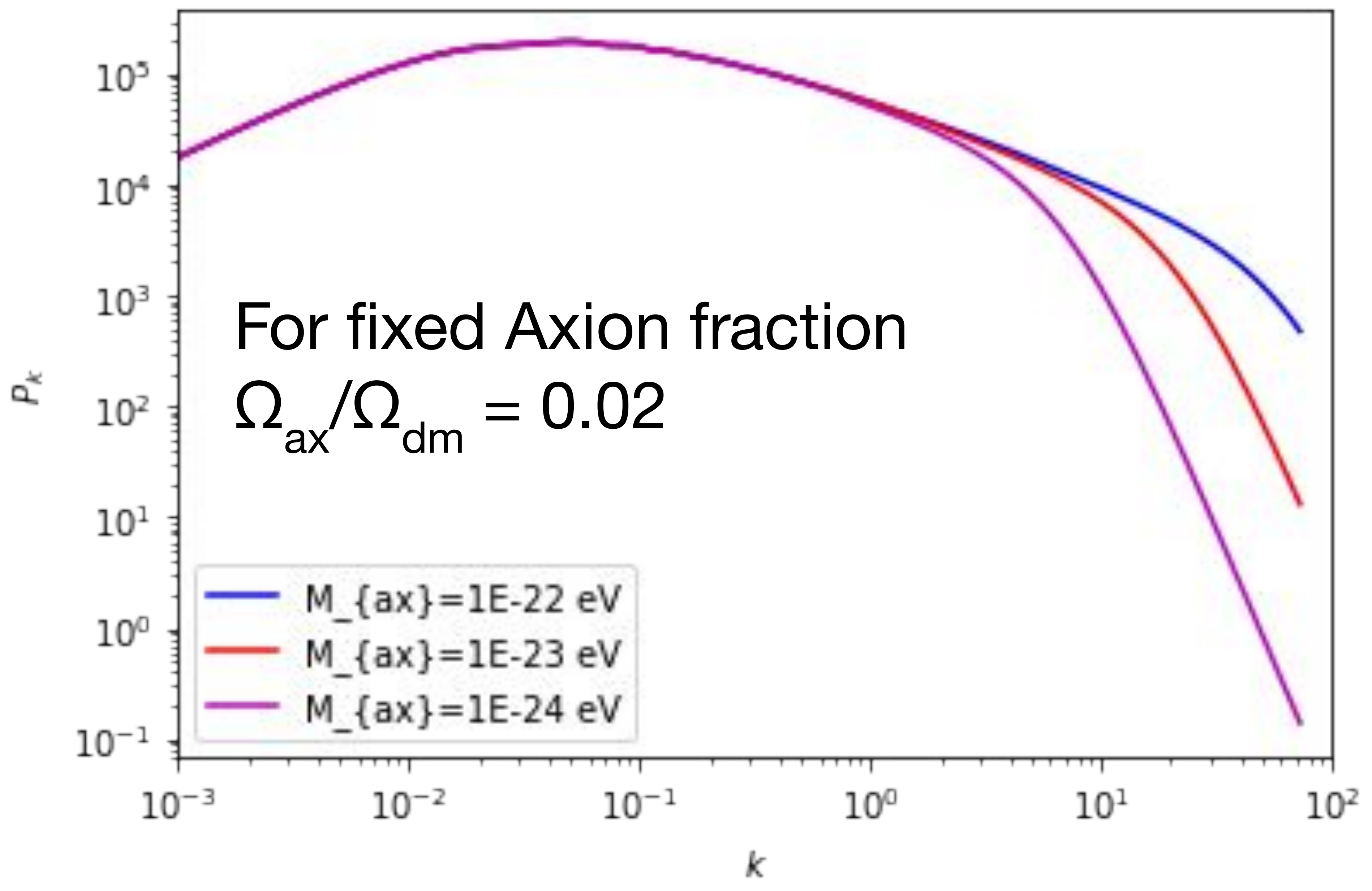
Pipeline

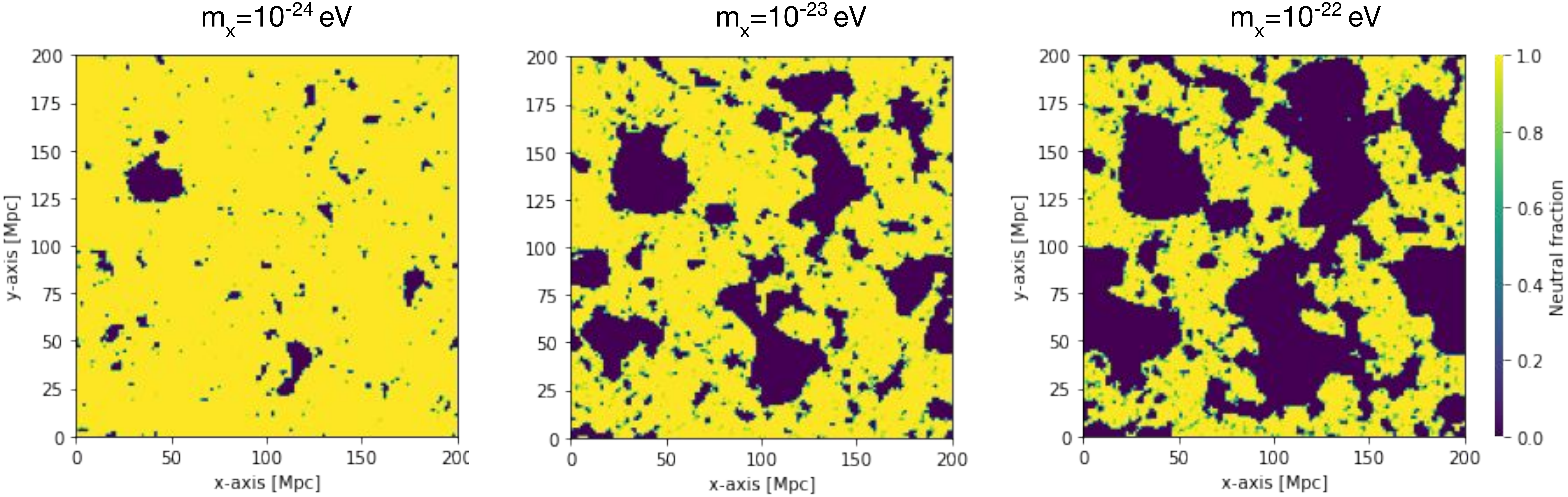


With Kenji Kadota (IBS, Daejeon) we want to see the effect of Axion particles on early structure formation

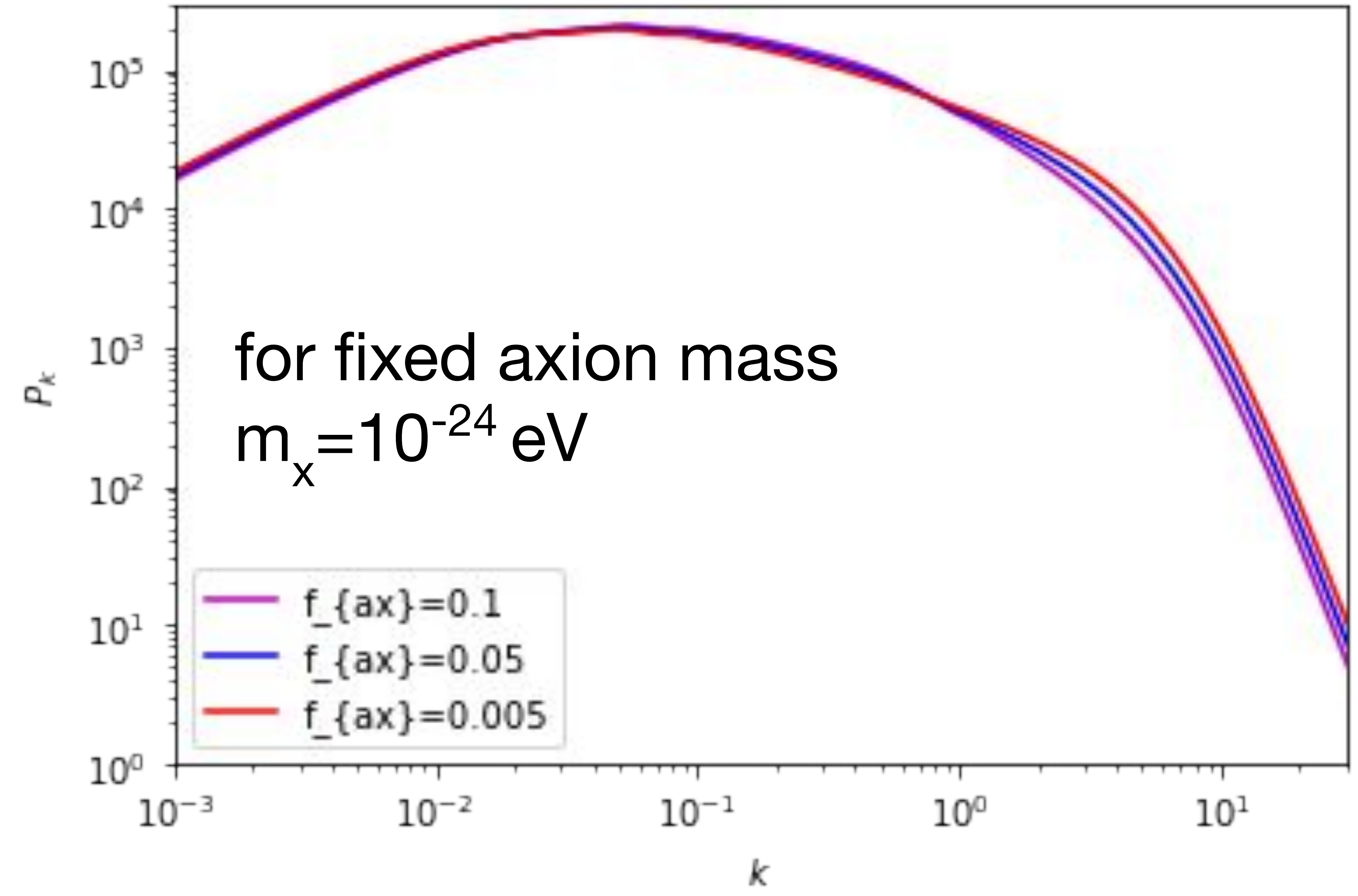
Varying Axion Mass

for $m_x<10^{-24}$ eV neutral hydrgen intact at z=8.0

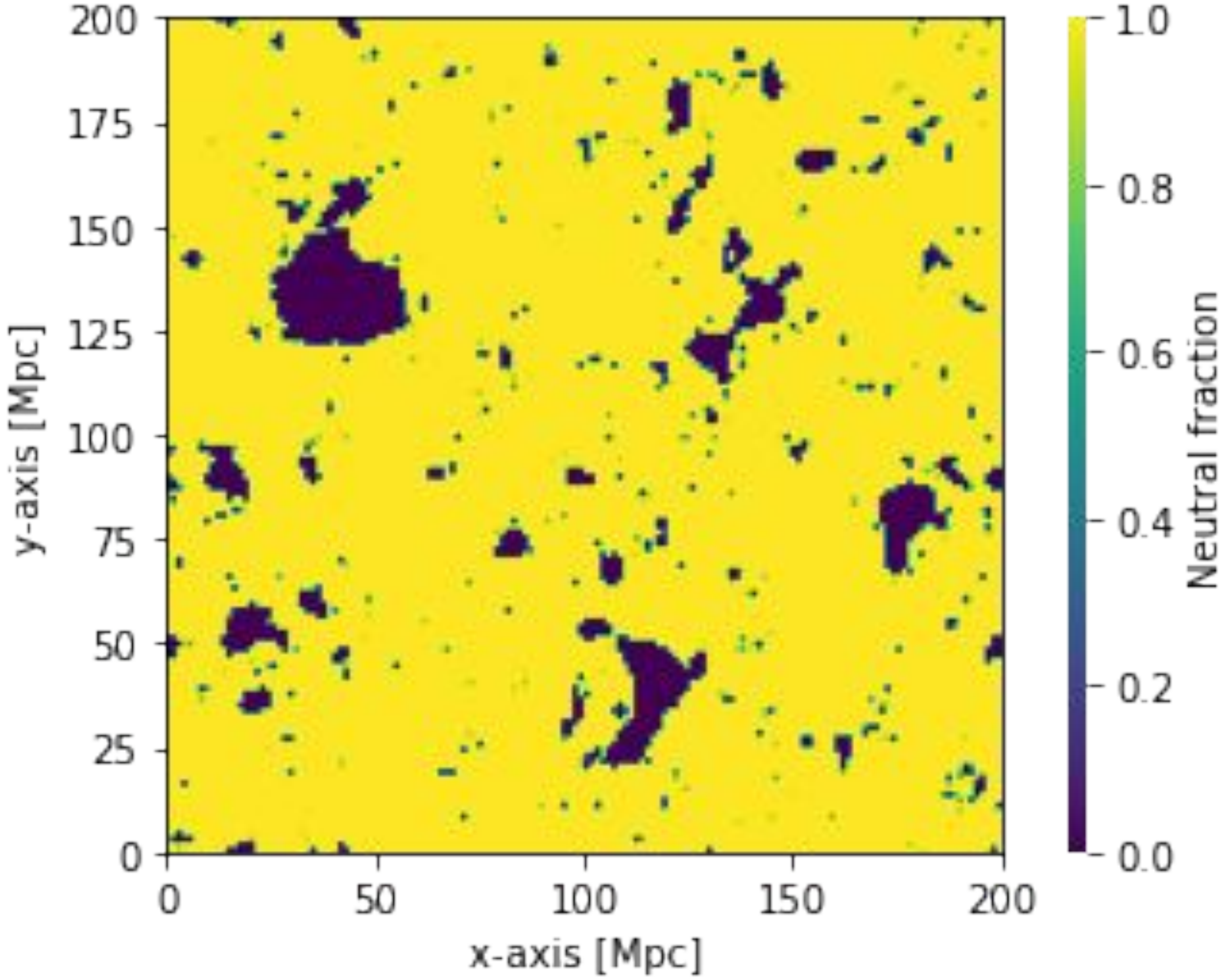




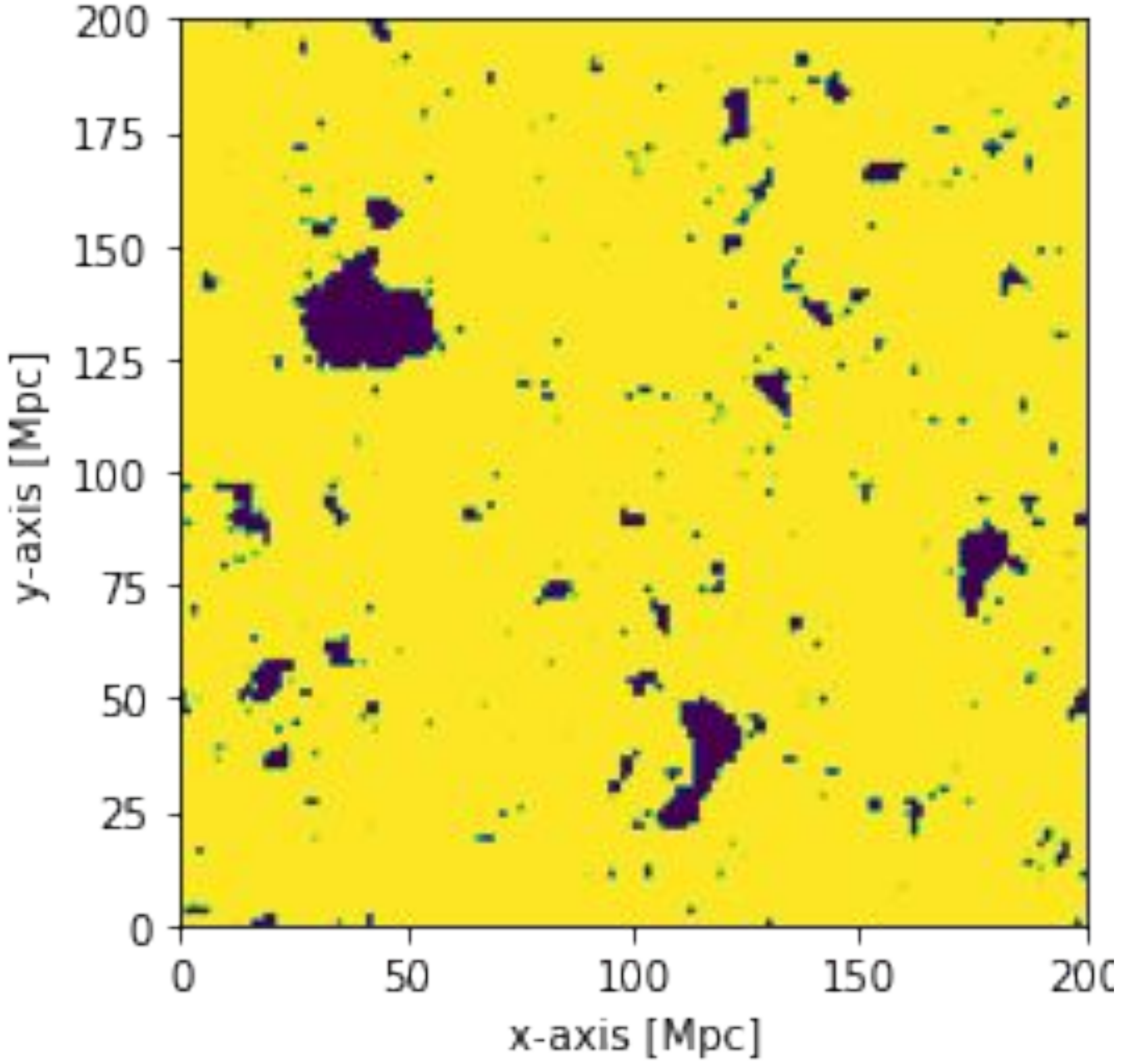
Varying Axion Fraction



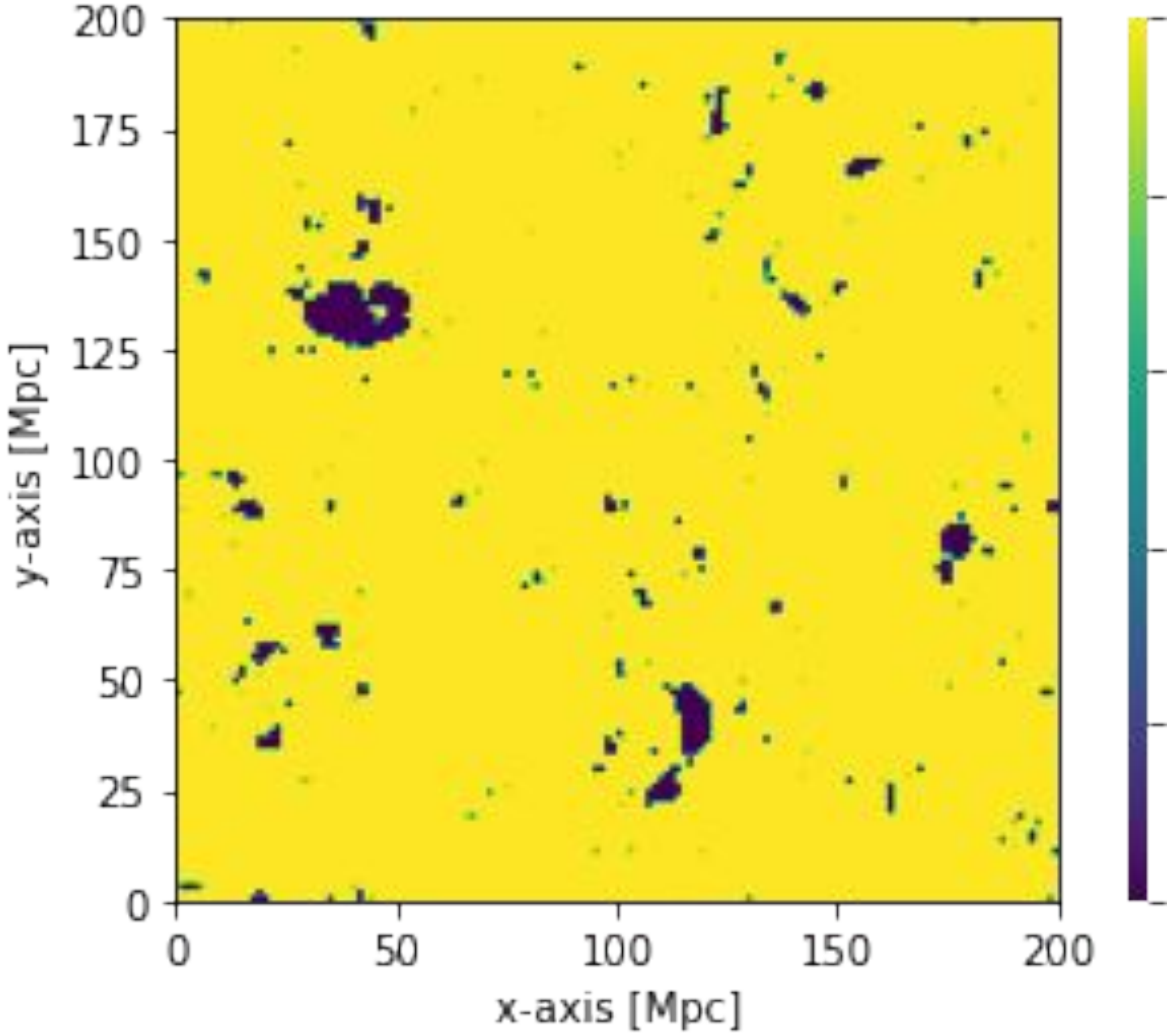
Ω_{ax}/Ω_{dm} = 0.005



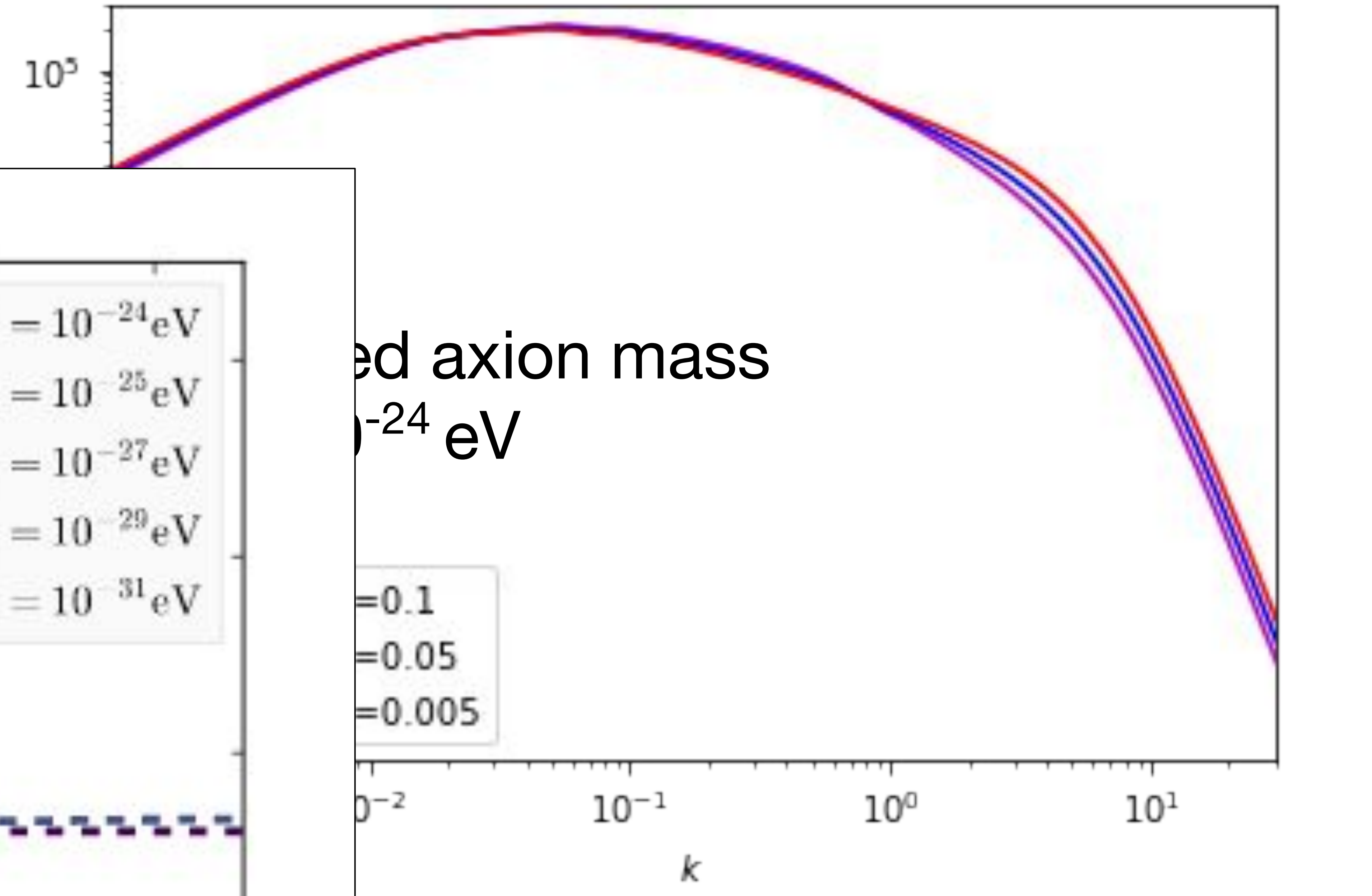
Ω_{ax}/Ω_{dm} = 0.02

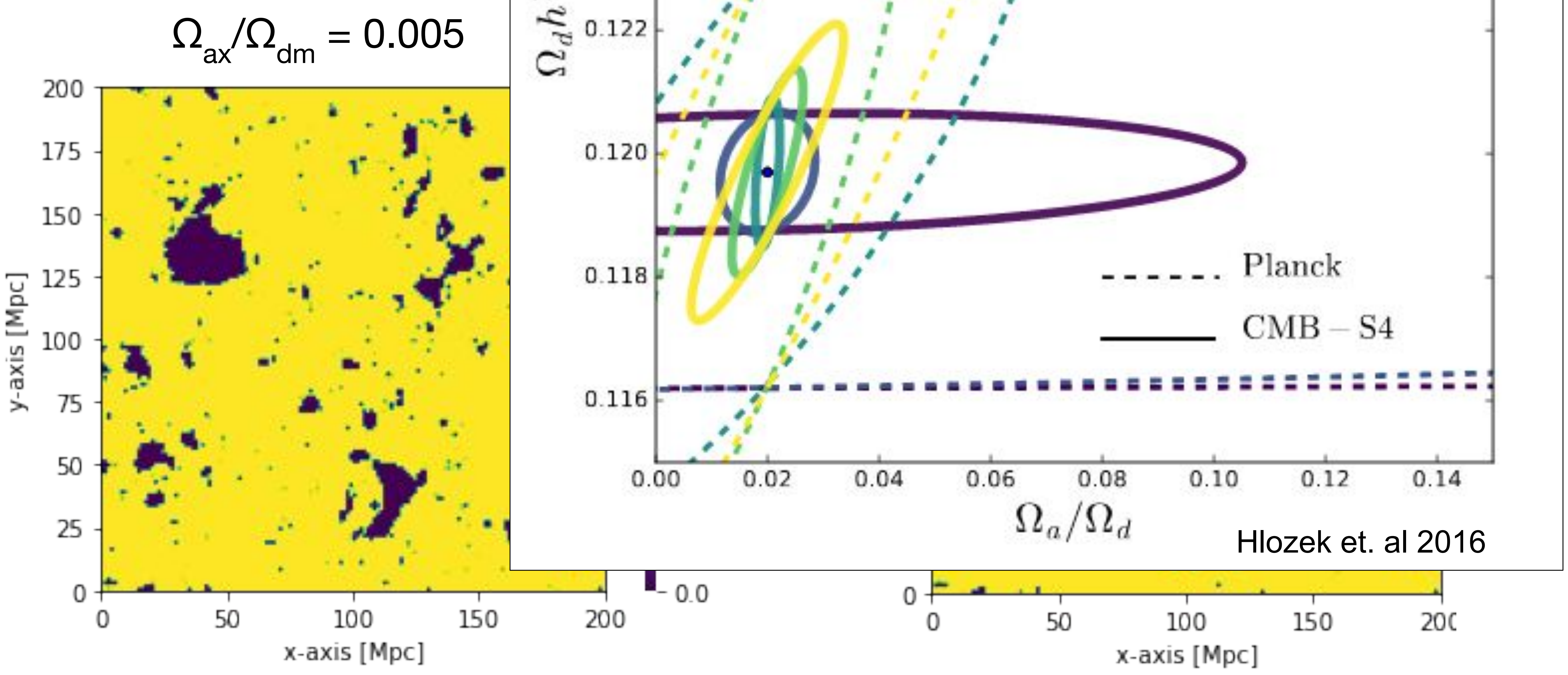


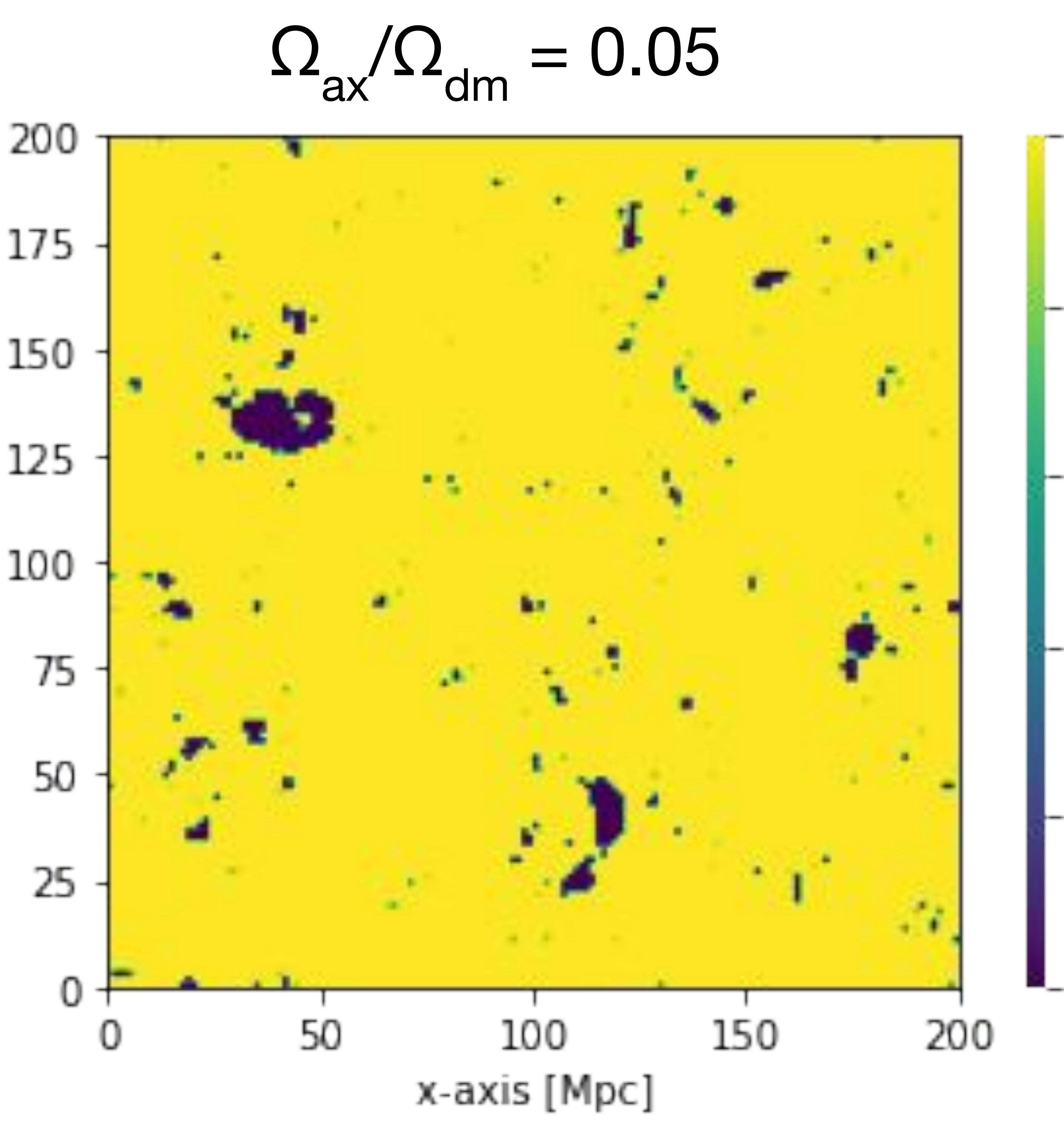
Ω_{ax}/Ω_{dm} = 0.05



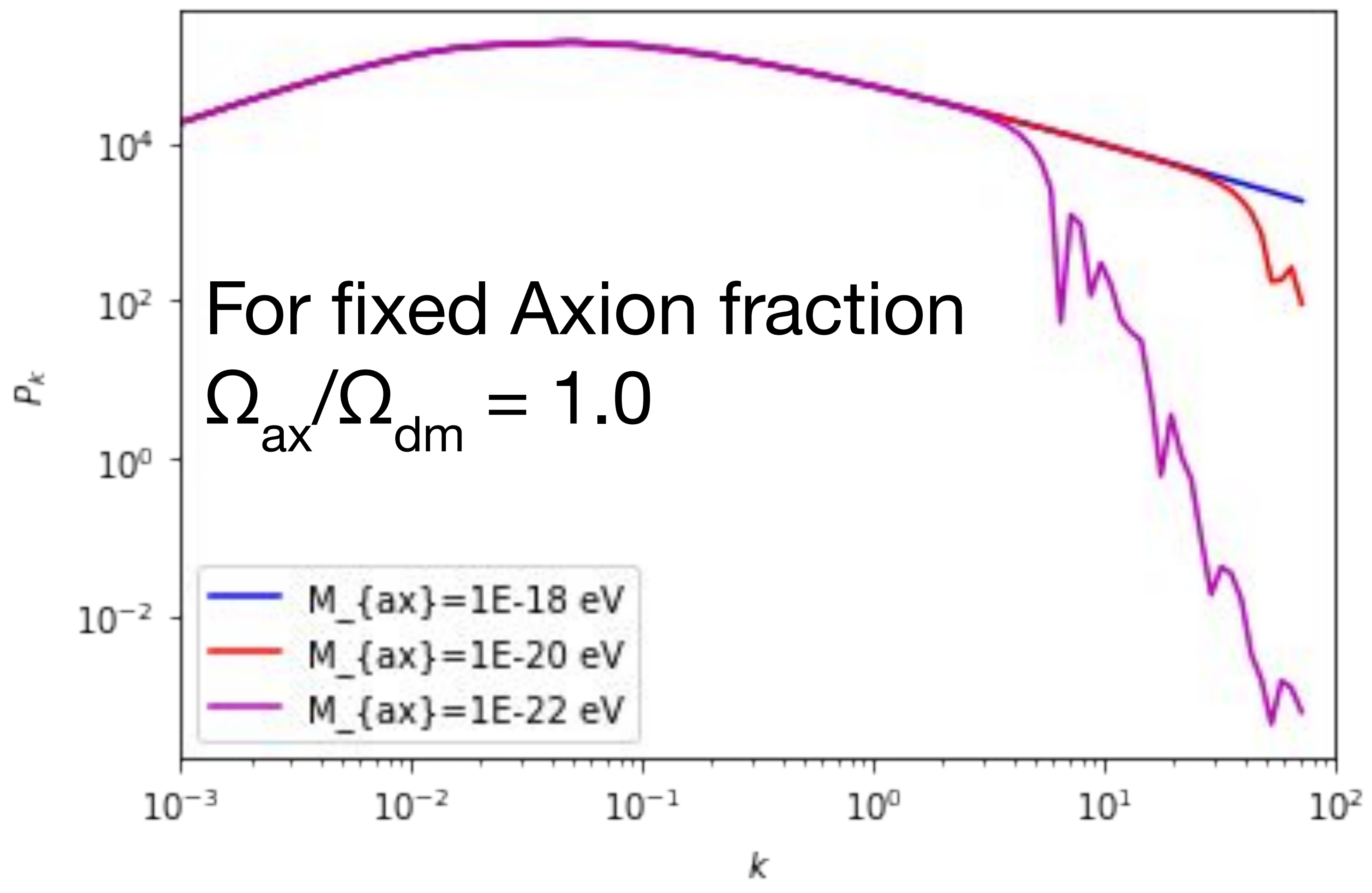
Varying Axion Fraction

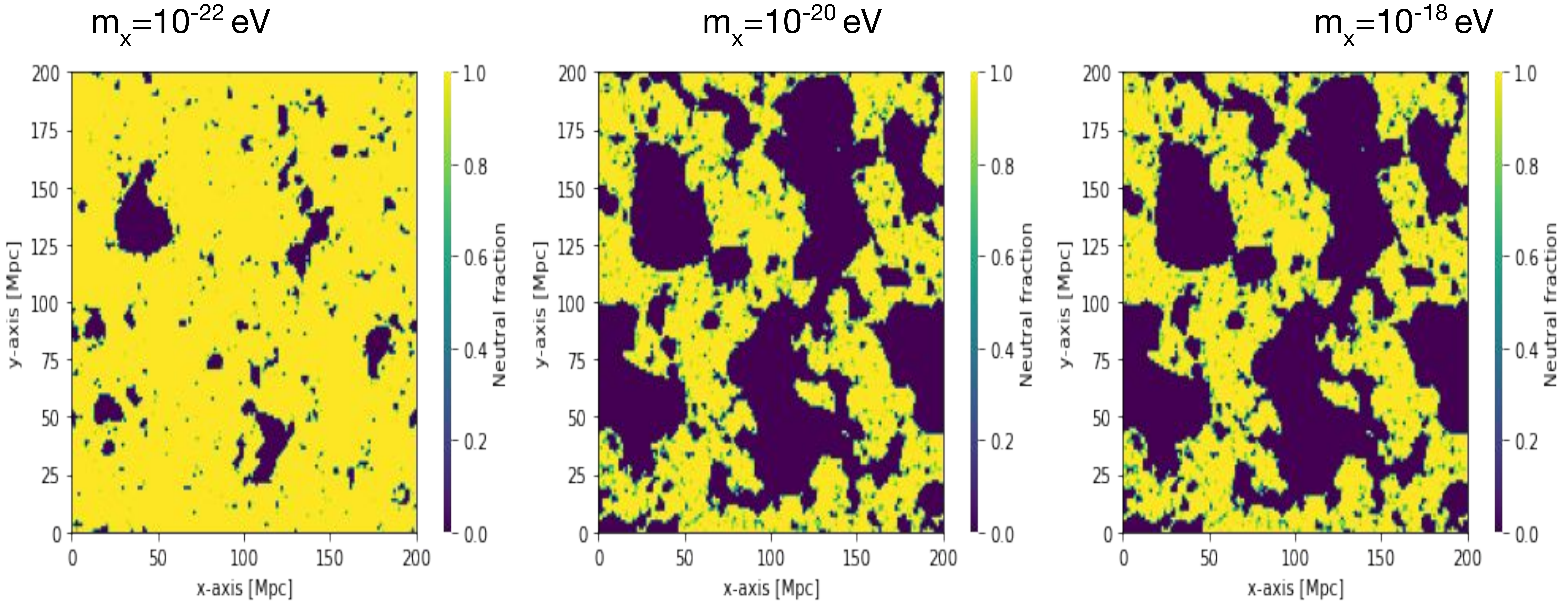






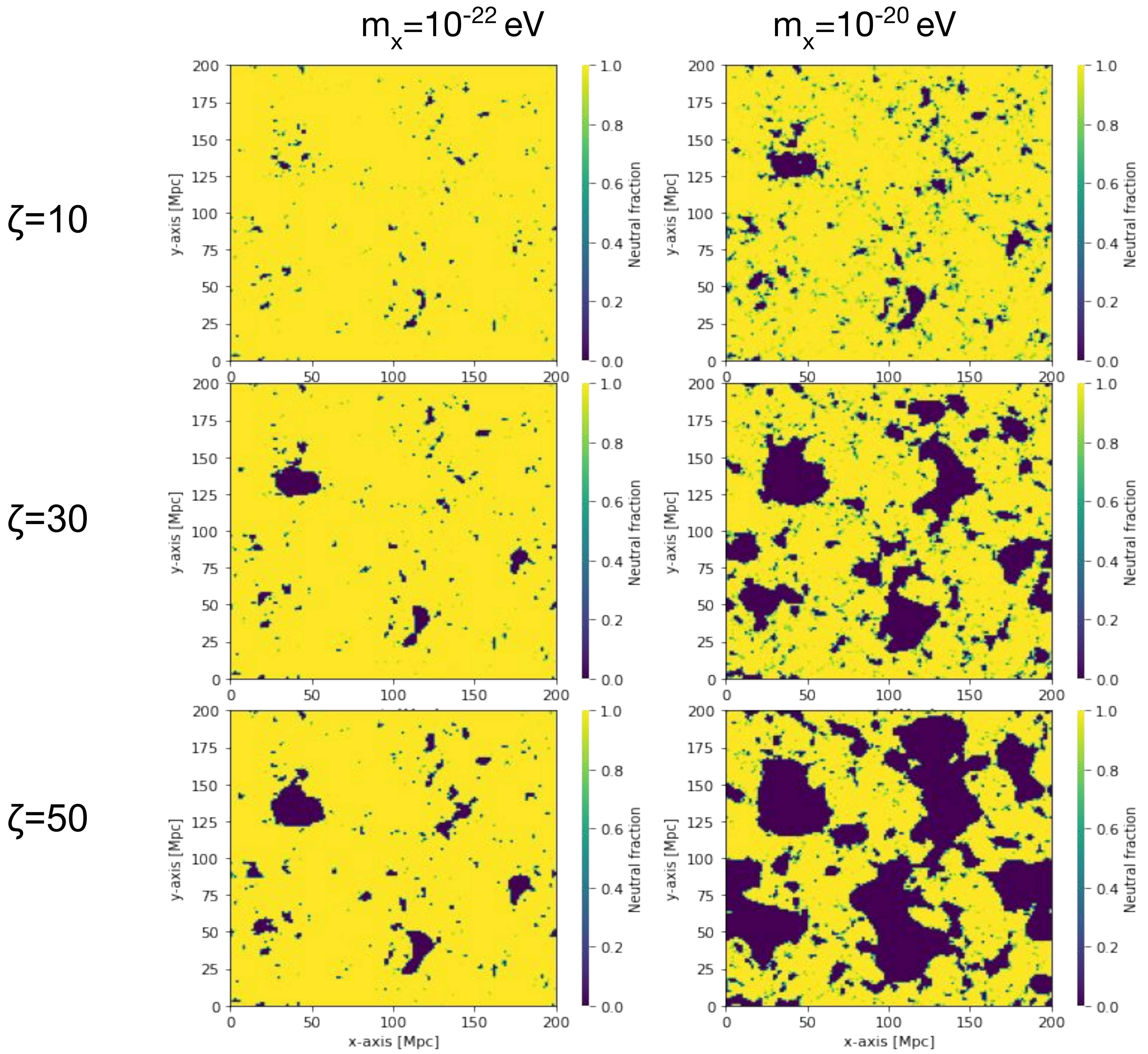
Varying Axion Mass (Axion only DM component)





Varying Nuisance Parameters: Ionization Efficiency

ζ,the ionizing efficiency: ζ is the combination of several parameters related to ionizing photons escaping from high redshift galaxies and is defined as $\zeta = fesc f_* N\gamma/(1+nrec)$. Here, fesc is the fraction of ionizing photons escaping from galaxies into the IGM and f_* is the fraction of baryons locked into stars. These parameters are extremely uncertainat high redshift. Nγ is the number of ionizing photons produced per baryon in stars and nrecis the mean recombination rate per baryon.In our calculation, we explore a range of $10 \leq \zeta \leq 60$ following the work of Shimabukuro & Semelin (2017)



Varying Nuisance Parameters: T_{vir}

T_{vir},the minimum virial temperature of haloes producing ionizing photons: T_{vir} parameterizes the minimum mass of haloes producing ionizing photons during the EoR. Typically, T_{vir} is chosen to be 10^4K, corresponding to the temperature above which atomic cooling becomes effective. T_{vir} parameterizes the physics of star formation in high redshift galaxies. In haloes with virial temperature>10^4K atomic cooling is sufficient to trigger gravothermal instability and thus star formation.