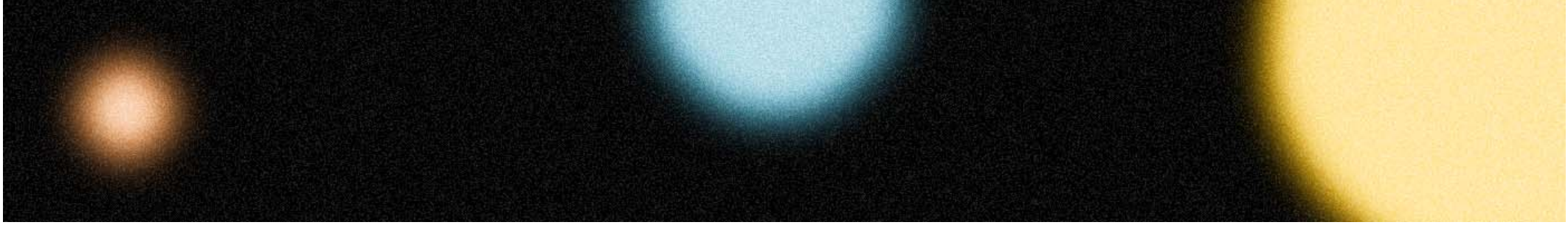
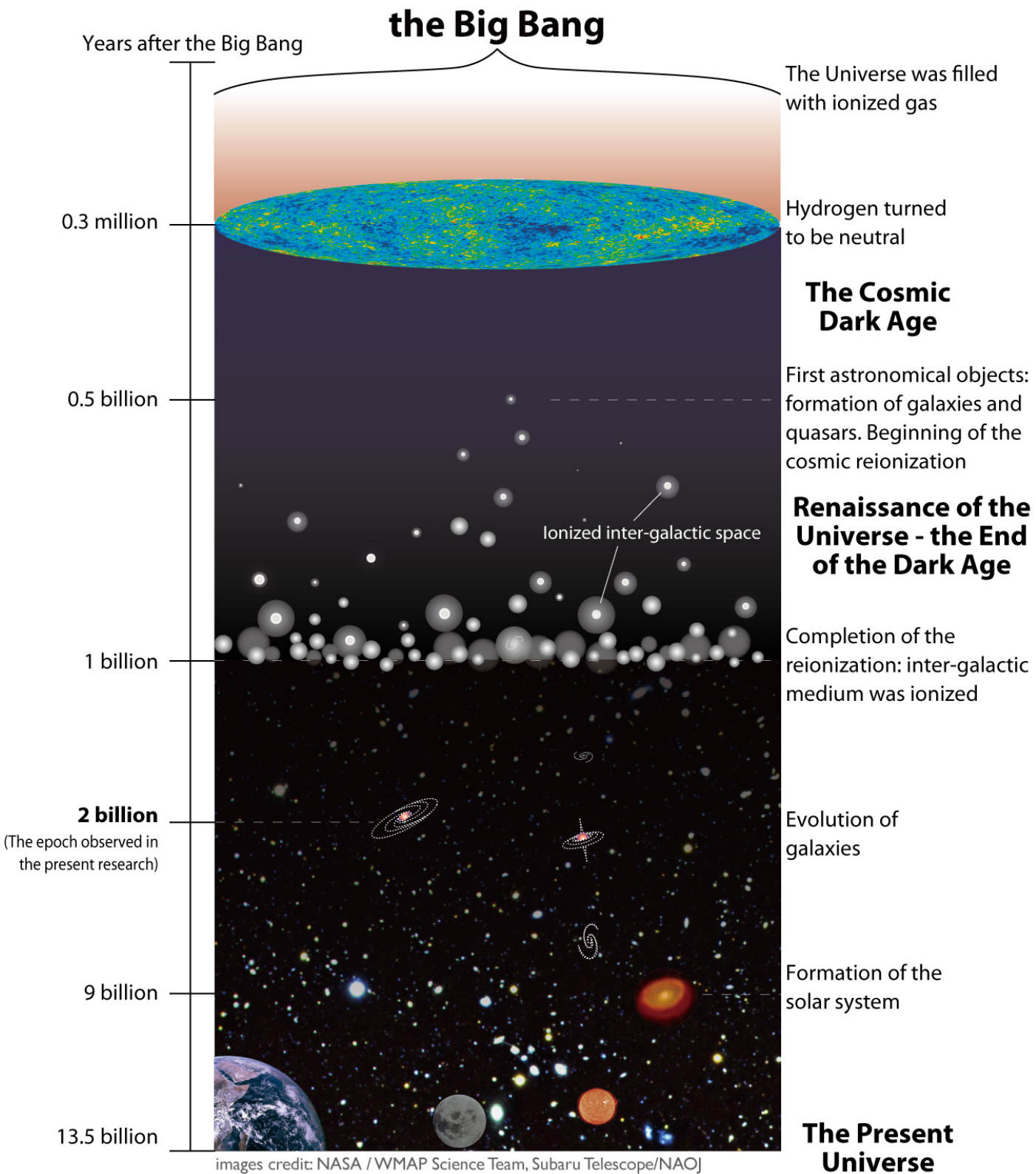


2D genus topology of 21cm differential brightness temperature during cosmic reionization

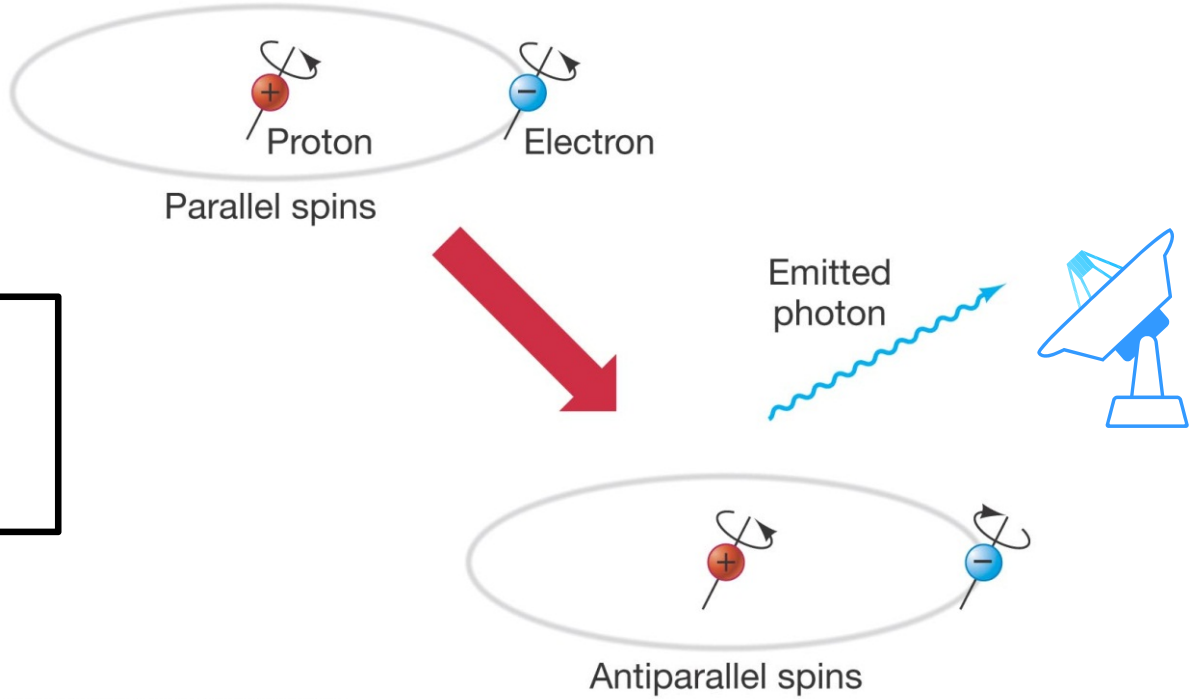
Kyungjin Ahn (Chosun), **SEH** (CNU/KAIST), Changbom Park, Juhan Kim (KIAS),
Ilian T. Iliev (Sussex) and Garrelt Mellema (Stockholm)
arXiv:1008.3914

Sungwook E. Hong
KNAG meeting, 2011/09/23


the Big Bang
Years after the Big Bang
The Universe was filled with ionized gas
0.3 million
Hydrogen turned to be neutral
The Cosmic Dark Age
0.5 billion
First astronomical objects: formation of galaxies and quasars. Beginning of the cosmic reionization
Ionized inter-galactic space
Renaissance of the Universe - the End of the Dark Age
1 billion
Completion of the reionization: inter-galactic medium was ionized
2 billion
(The epoch observed in the present research)
Evolution of galaxies
9 billion
Formation of the solar system
13.5 billion
The Present Universe
images credit: NASA / WMAP Science Team, Subaru Telescope/NAOJ

Redshifted 21cm signal

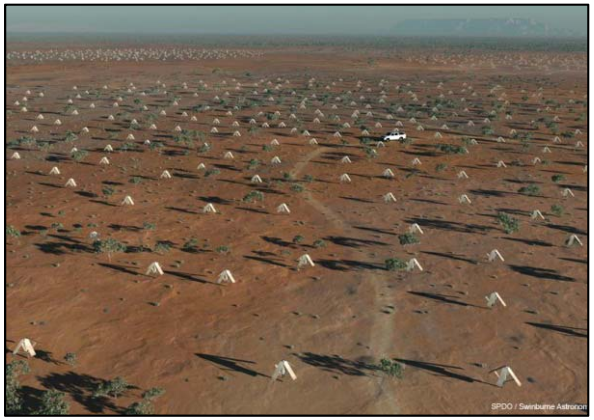
Most promising method for the direct detection of cosmic reionization!



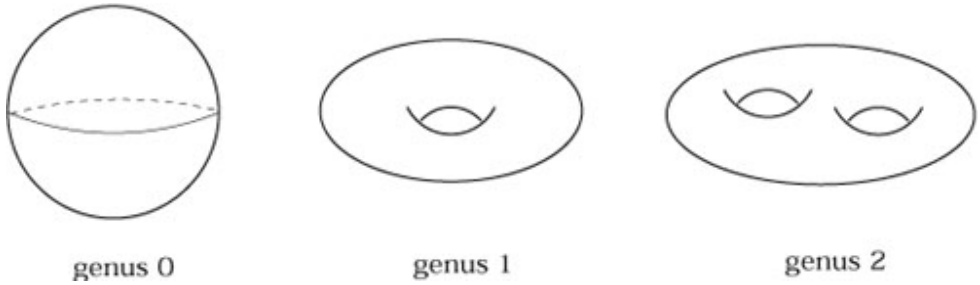
LOFAR

MWA

SKA



2D genus?

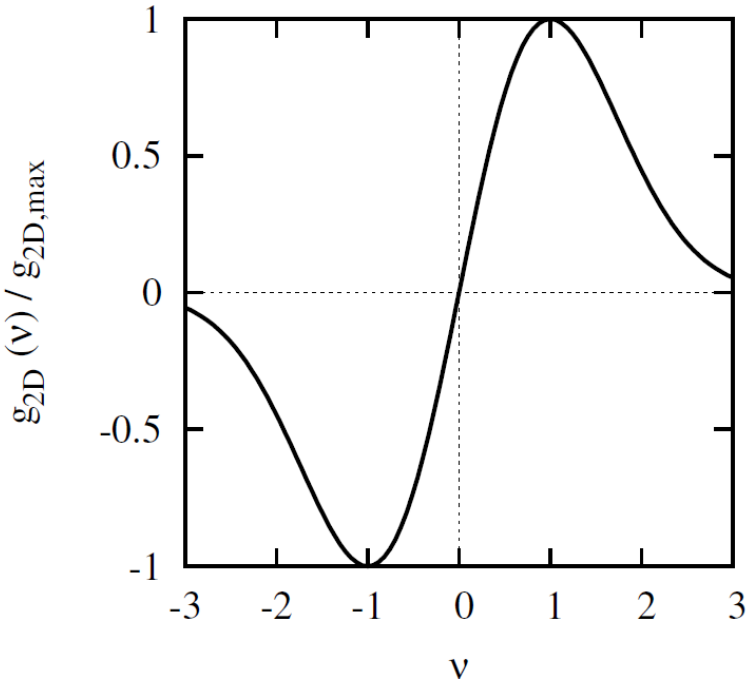


- $g_{2D}(T_{th})$ = (# of hot spots) – (# of cold spots)
  Melott et al. 1989; Gott et al. 1990; Colley & Gott 2003; Gott et al. 2007

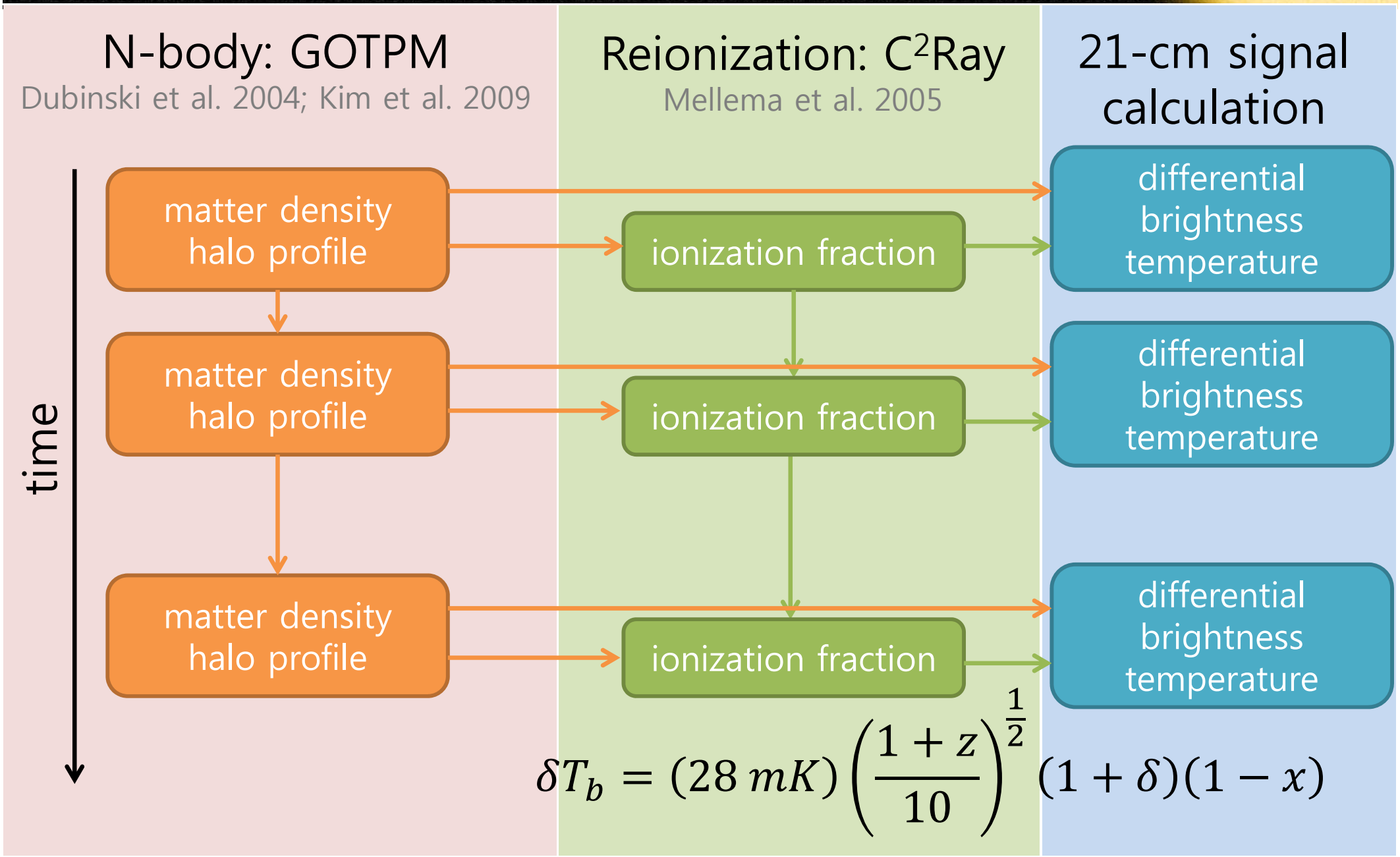
- Gaussian random field

$$g_{2D} \propto \nu \exp(-$$

(ν: deviation from average)



Simulations



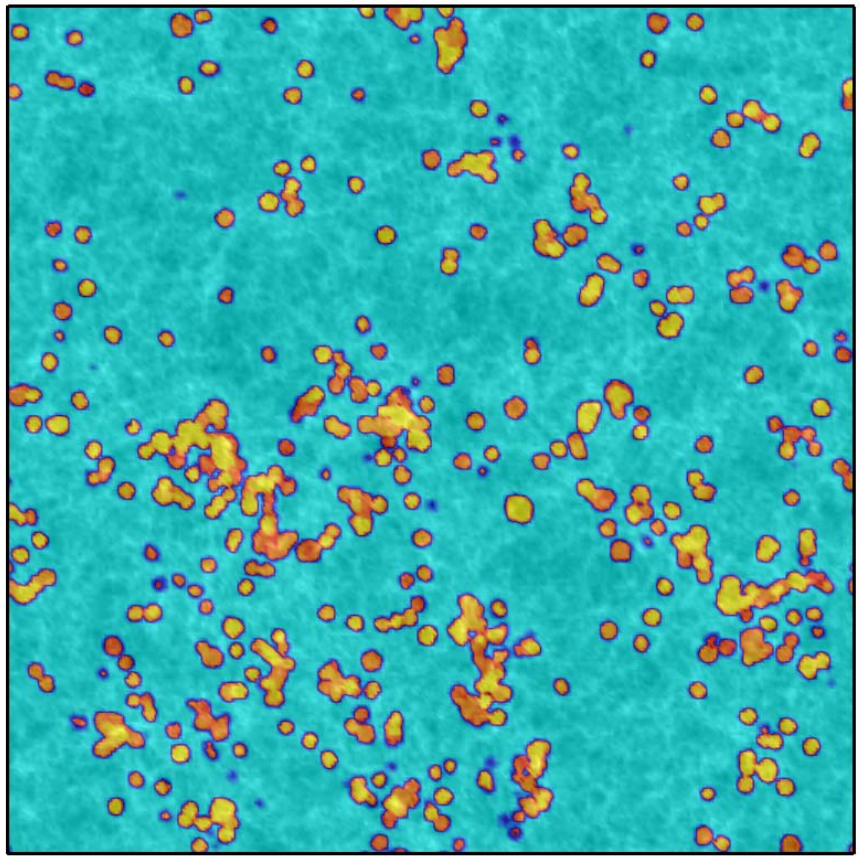
$$\delta T_b = (28\,mK)\left(\frac{1+z}{10}\right)^{\frac{1}{2}}(1+\delta)(1-x)$$

Simulations

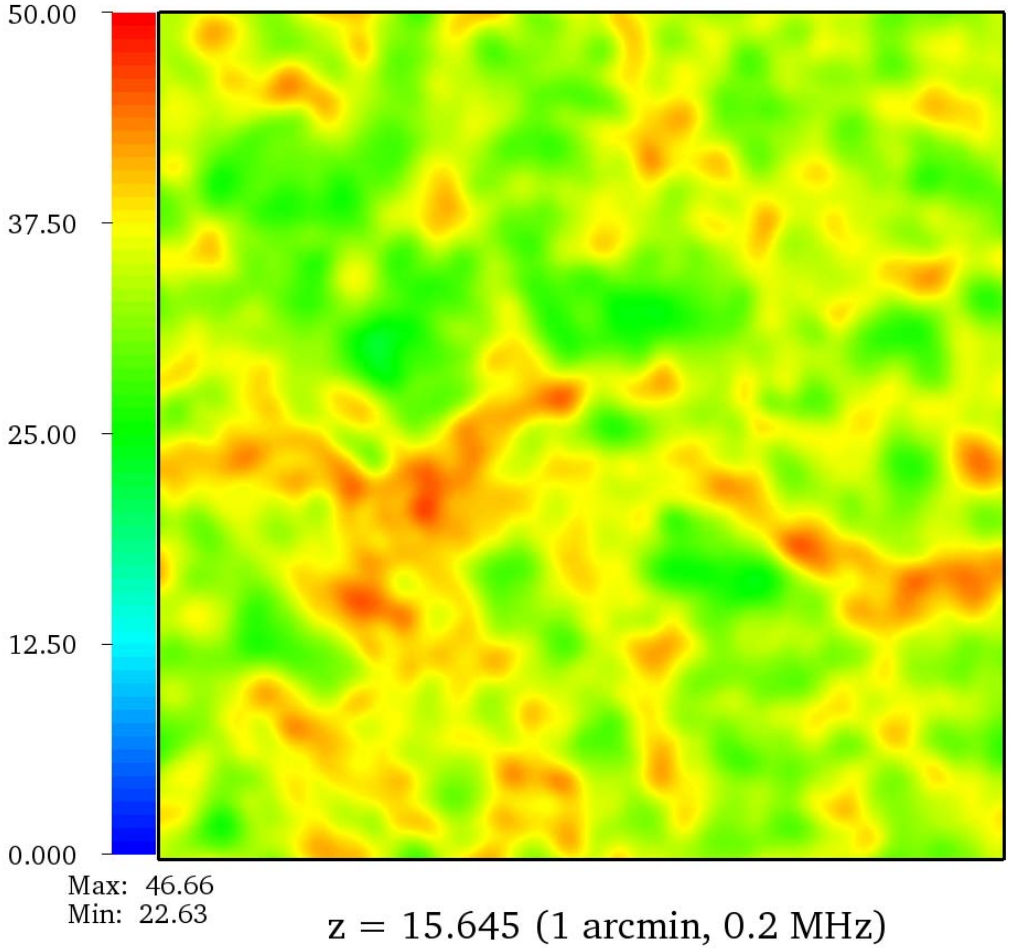
- N-body simulation
  - ΛCDM model with WMAP 5yr parameters
  - 2048^3 particles
  - 66 Mpc/h box (~30′ at z = 14)

- Reionization simulation
  - 256^3 mesh
  - 4 source property models
    - 2 for high-mass halos only ($M > 10^9\ M_{sun}$)
    - 2 for high-mass and low-mass halos ($10^8 < M/M_{sun} < 10^9$)

Mock 21-cm sky map

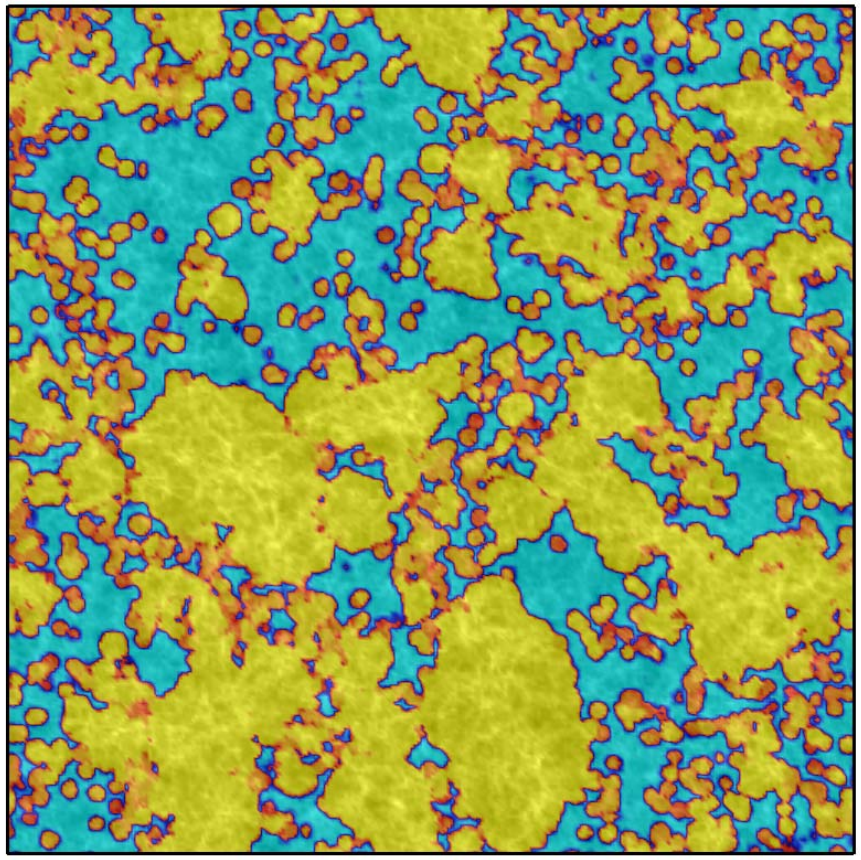


z = 15.645 (x_v = 0.04)

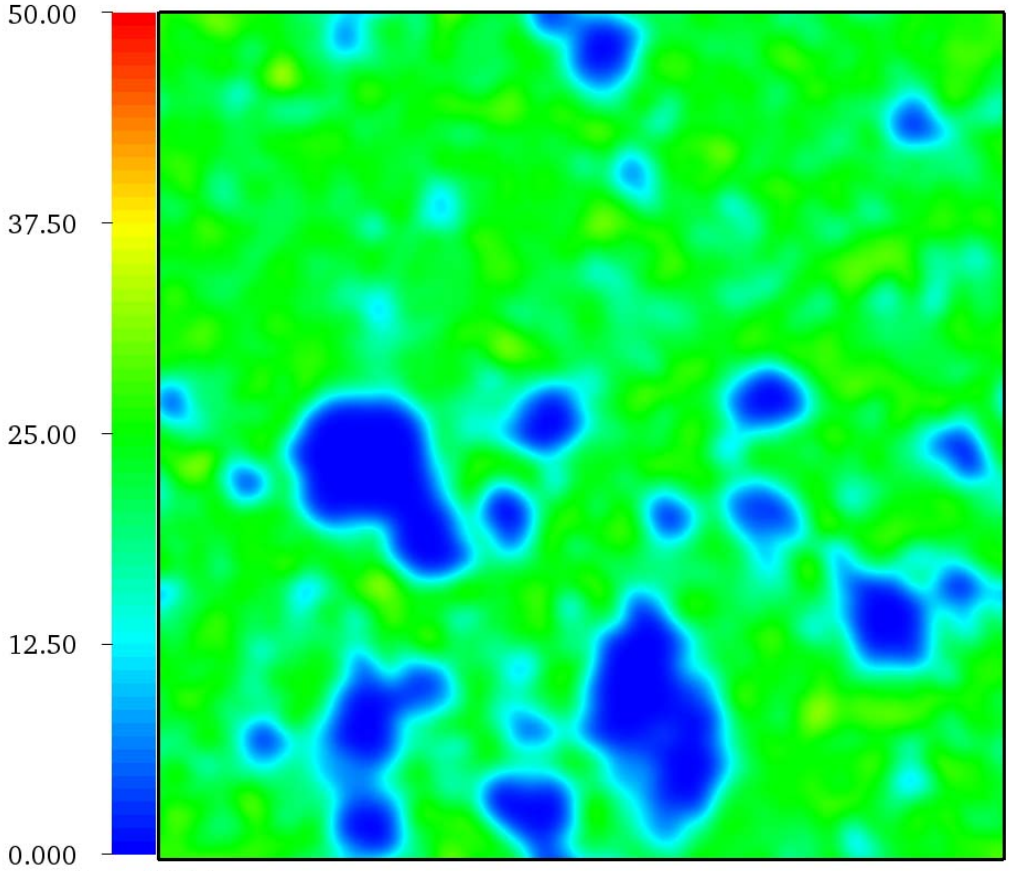


z = 15.645 (1 arcmin, 0.2 MHz)

Mock 21-cm sky map

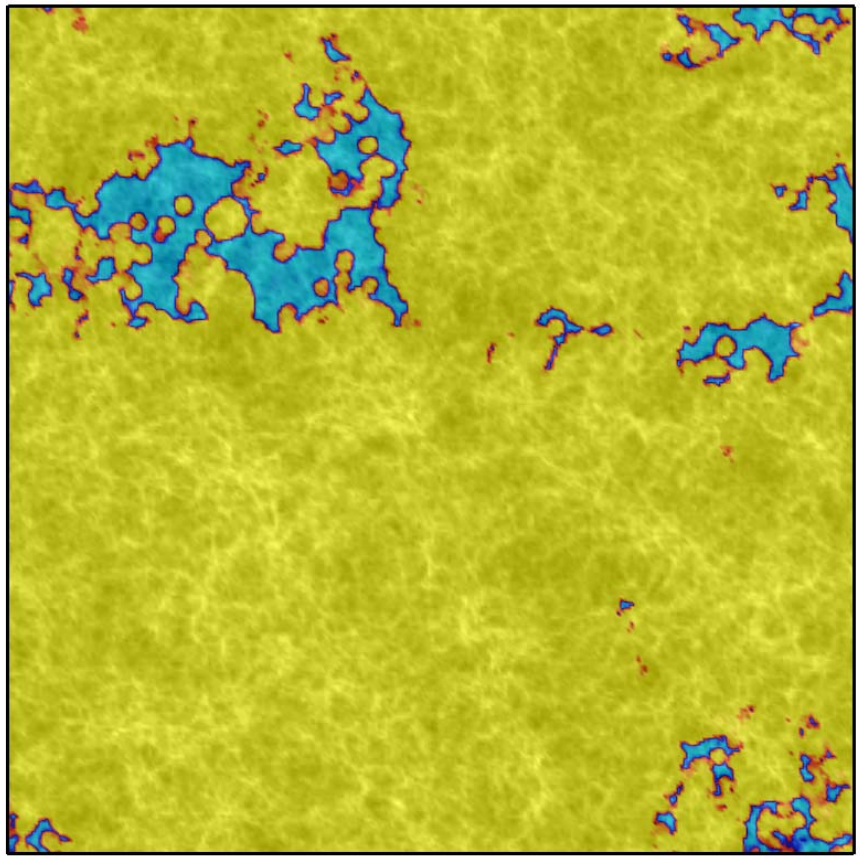


z = 12.184 (x_v = 0.4)

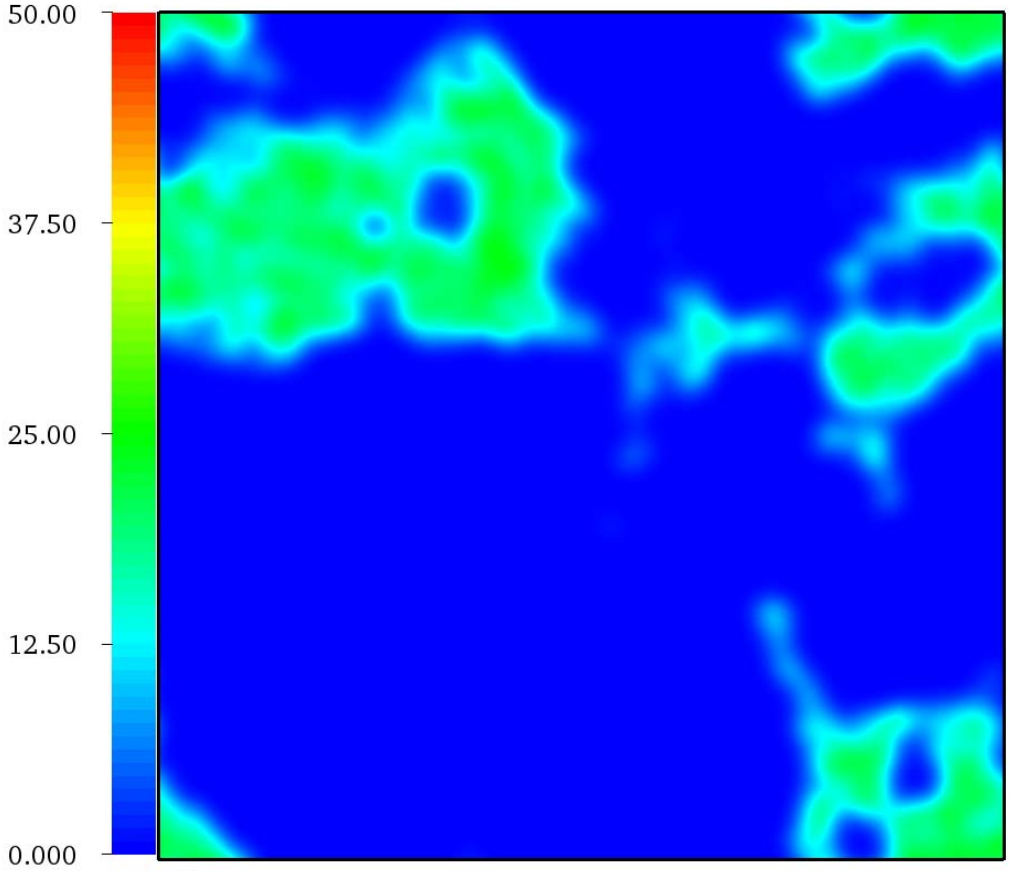


z = 12.184 (1 arcmin, 0.2 MHz)

Mock 21-cm sky map

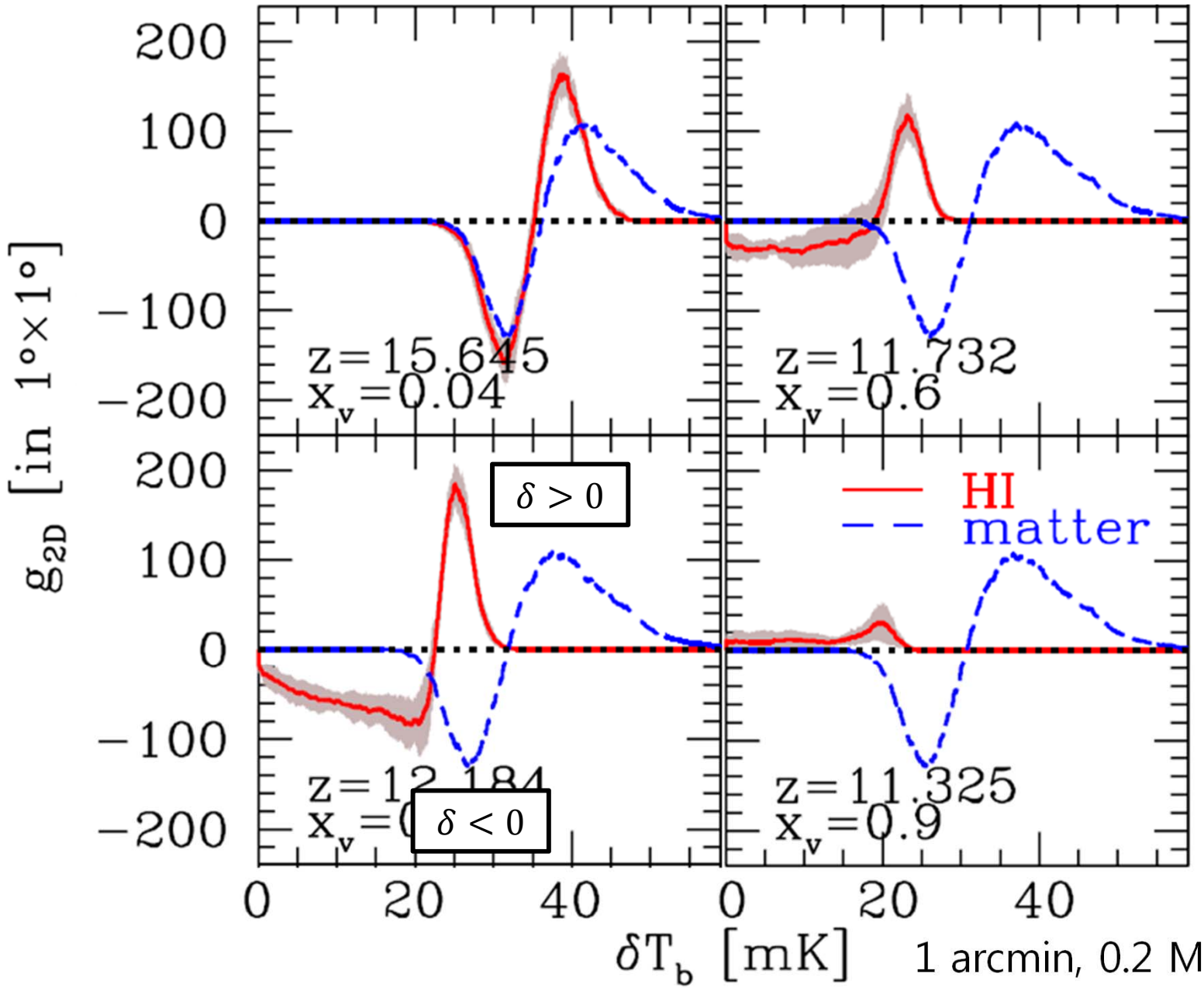


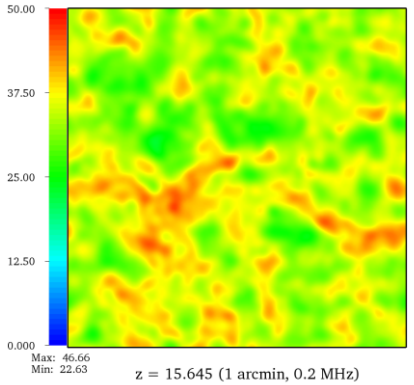
z = 11.325 (x_v = 0.9)

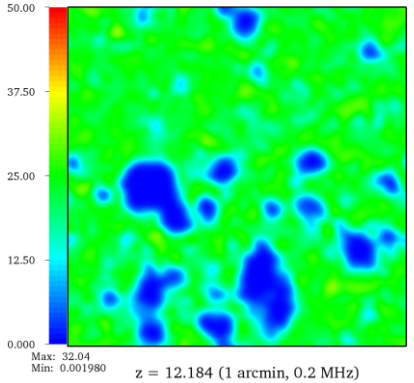


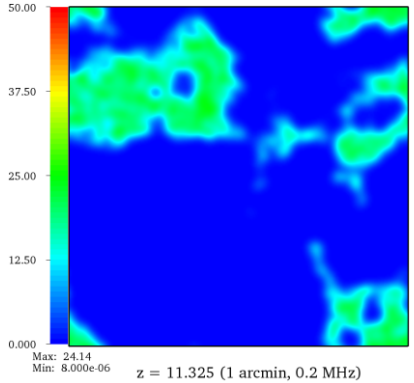
z = 11.325 (1 arcmin, 0.2 MHz)

2D genus: evolution process



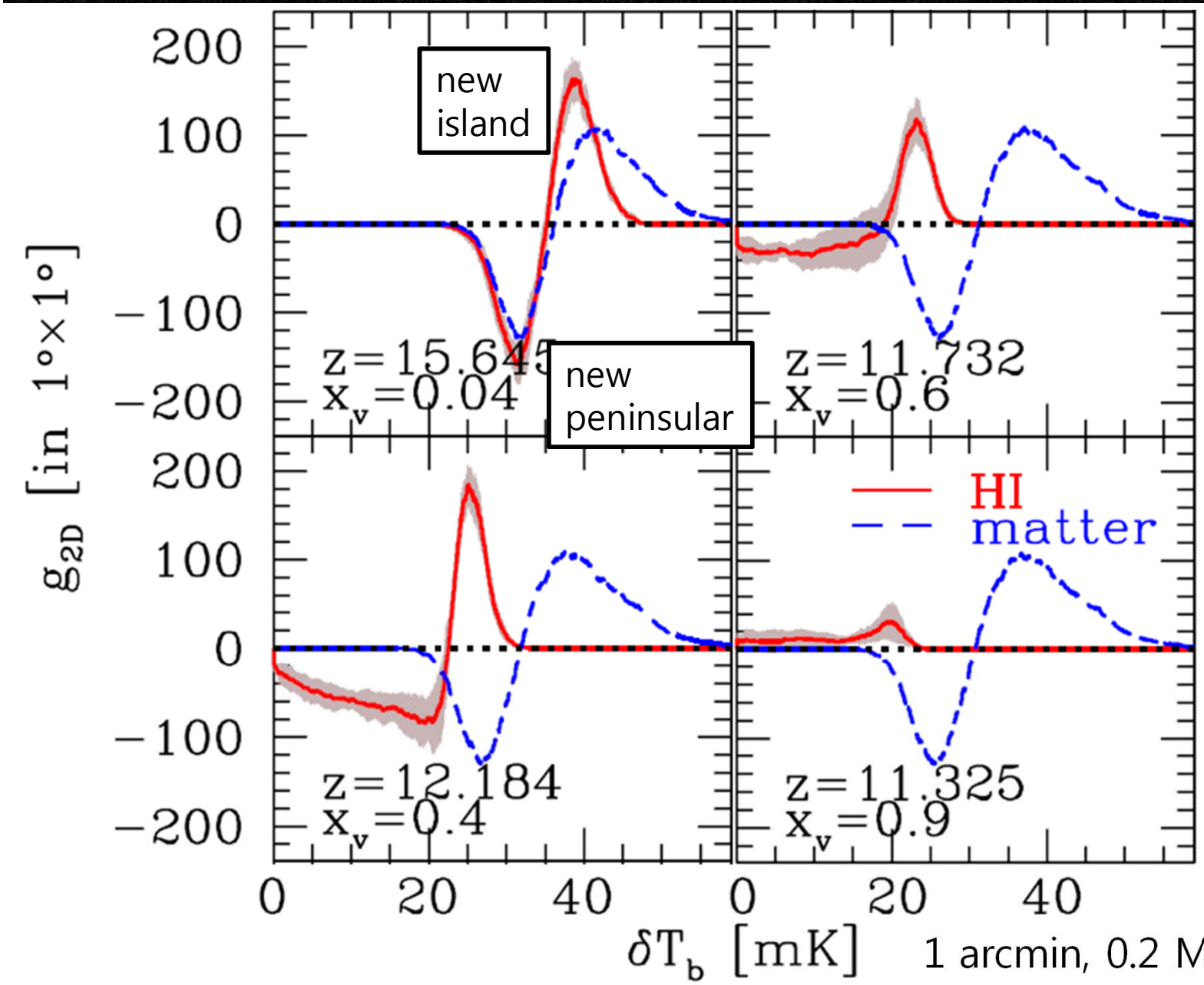


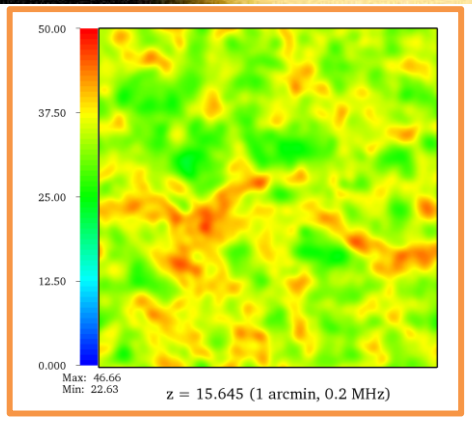


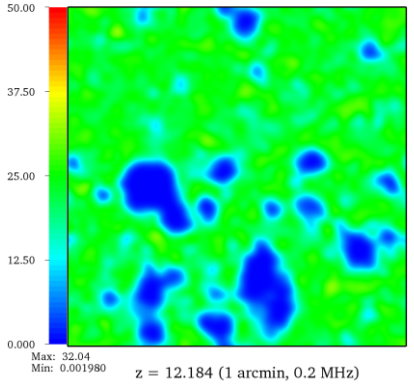


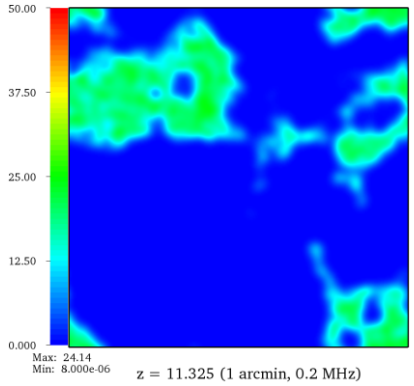
1 arcmin, 0.2 MHz

2D genus: evolution process



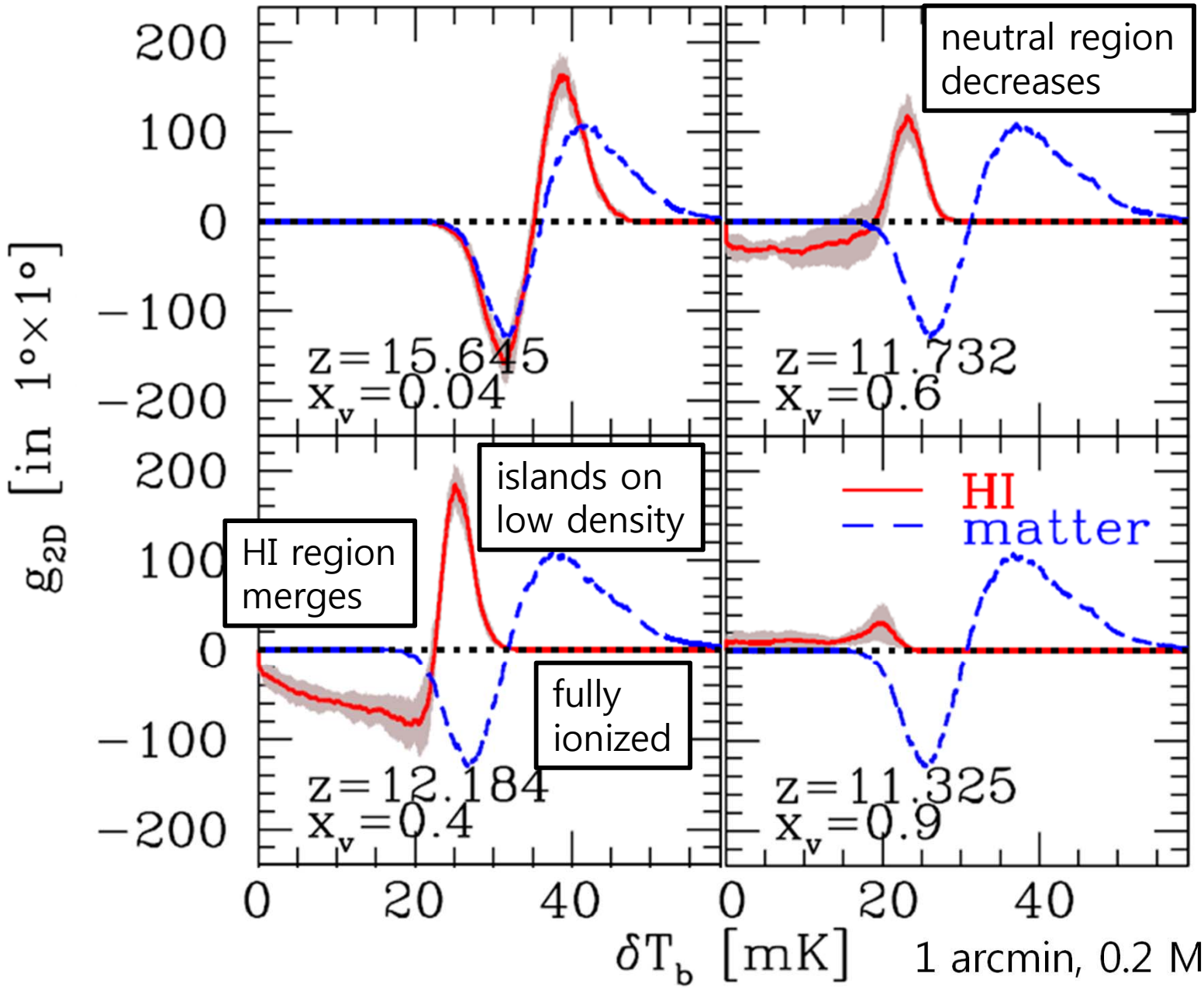


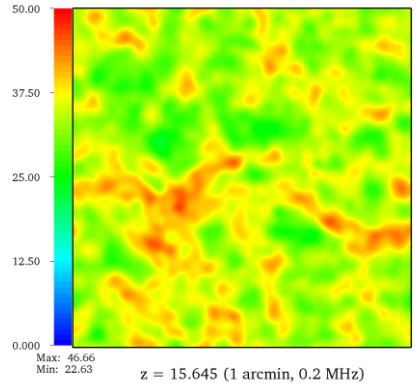


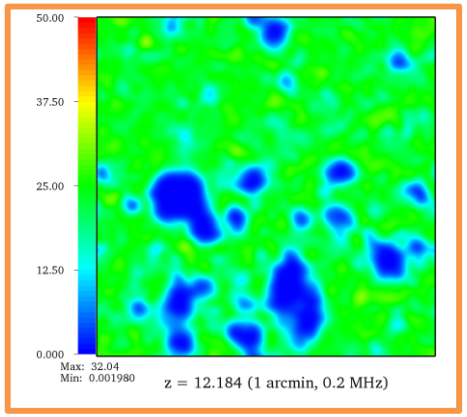


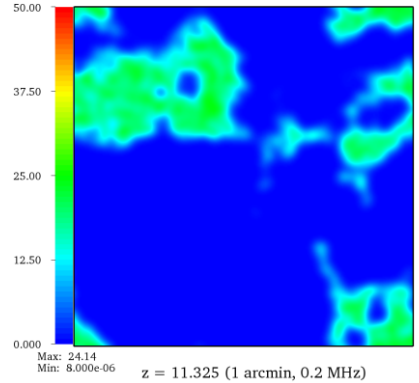
1 arcmin, 0.2 MHz

2D genus: evolution process



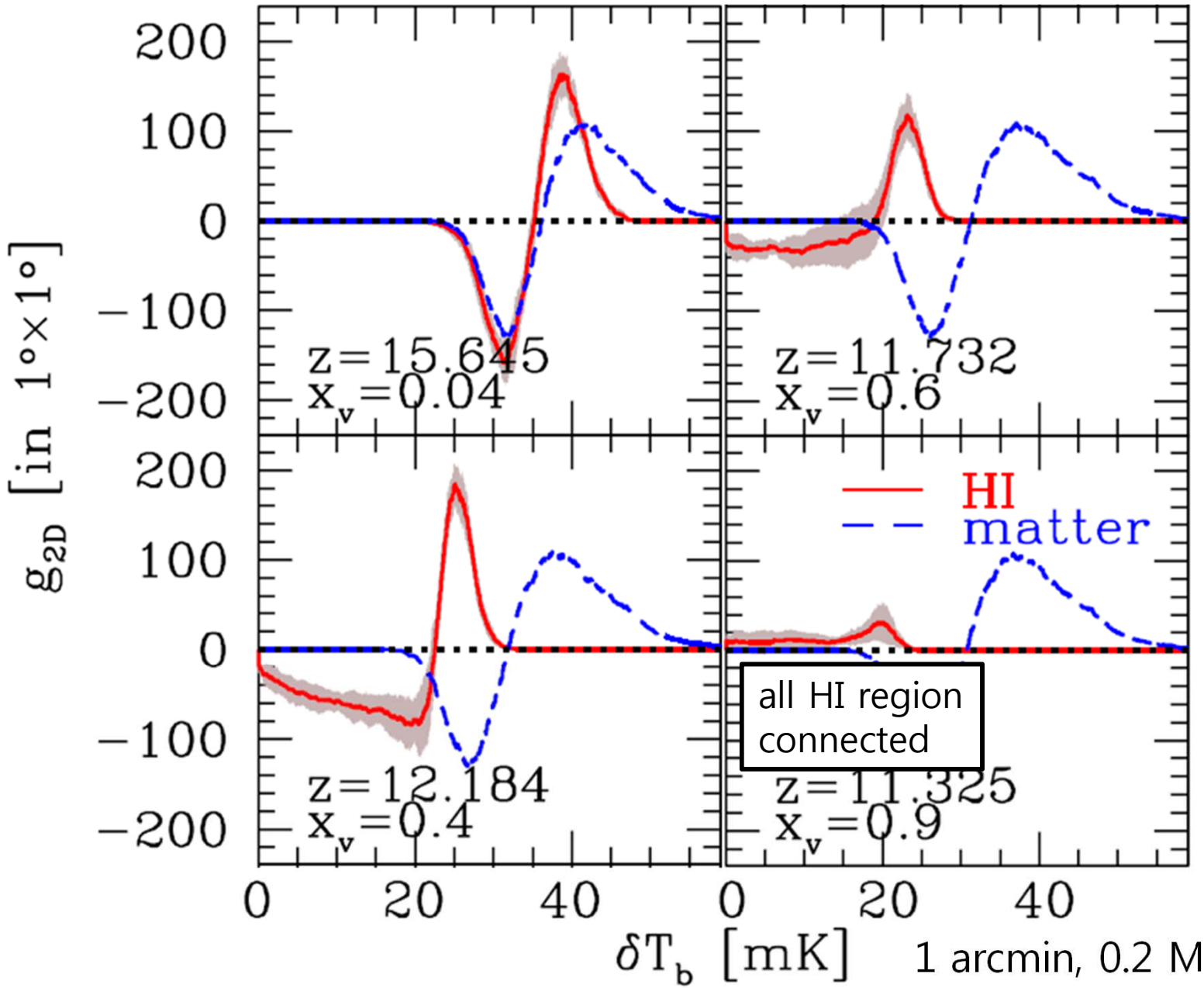


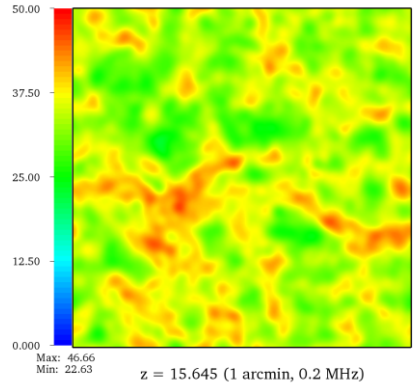


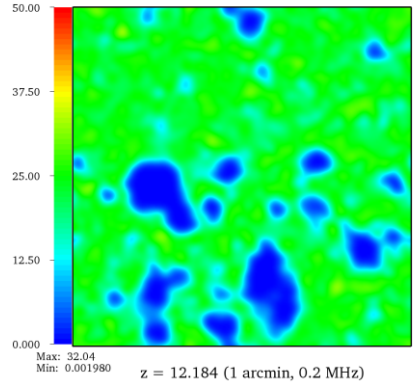


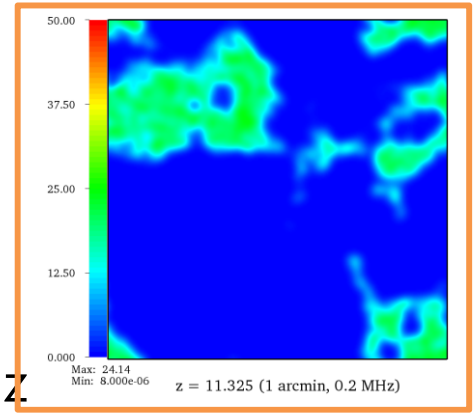
1 arcmin, 0.2 MHz

2D genus: evolution process



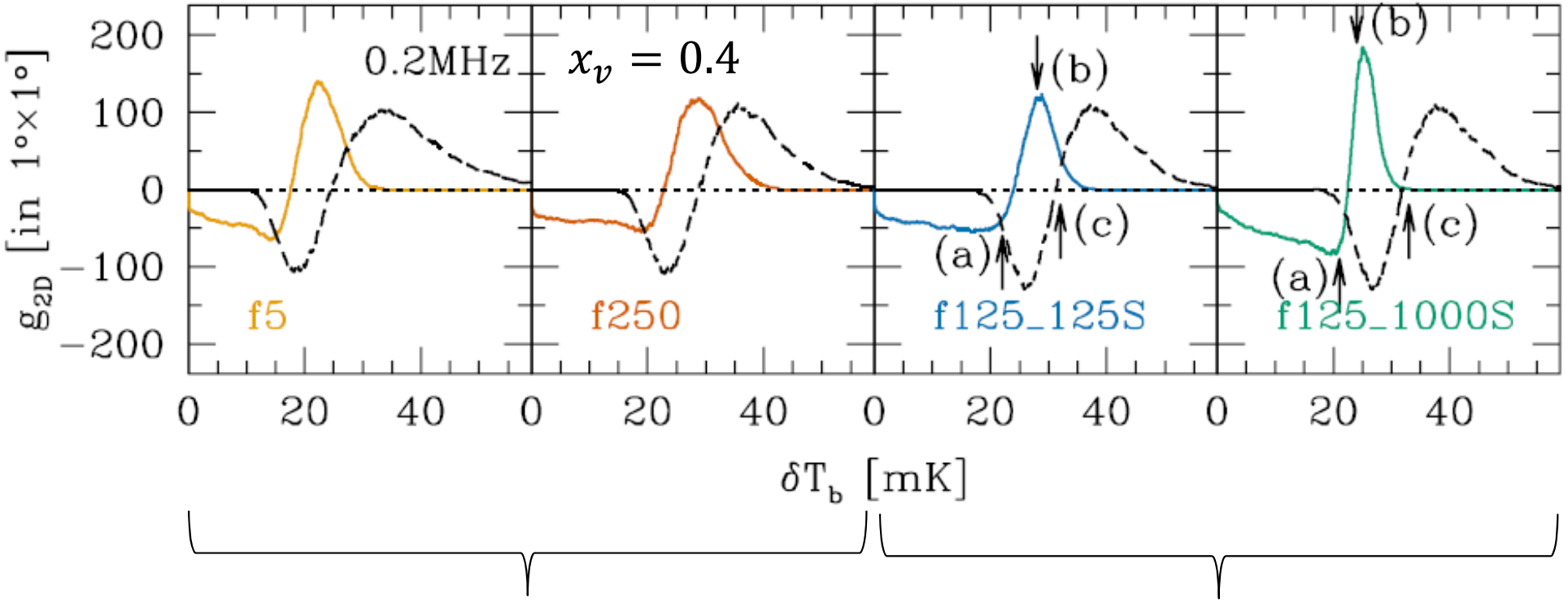






1 arcmin, 0.2 MHz

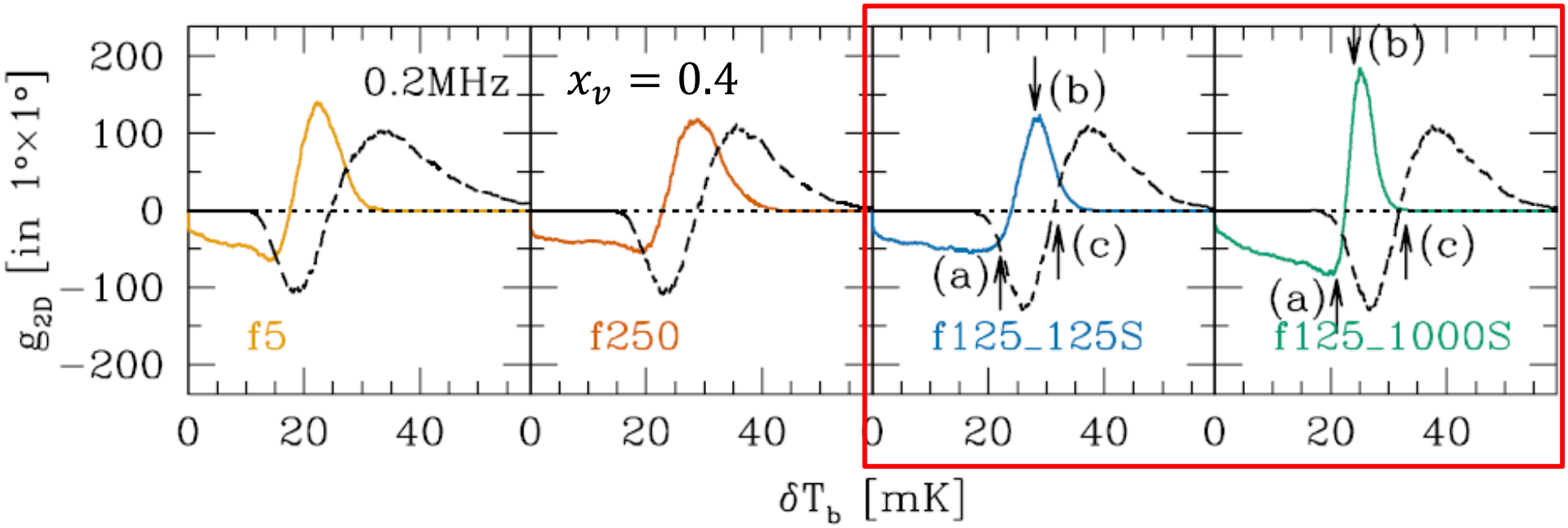
Model dependency



High-mass source only

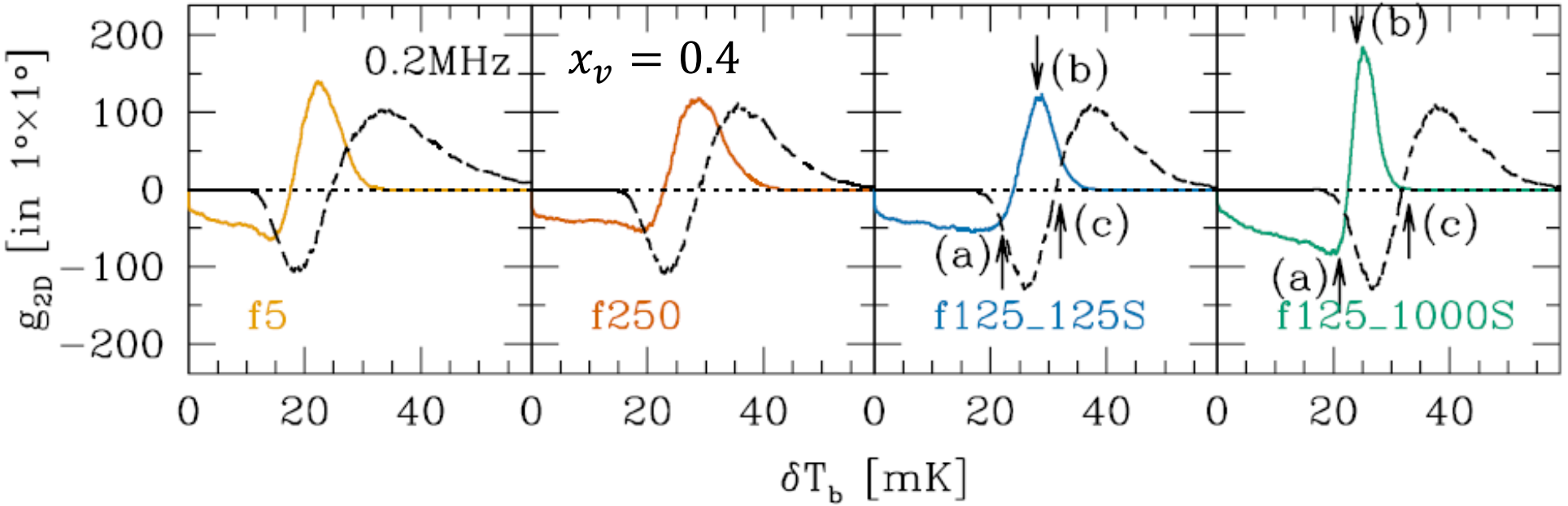
High-mass source + Low-mass source

Model dependency

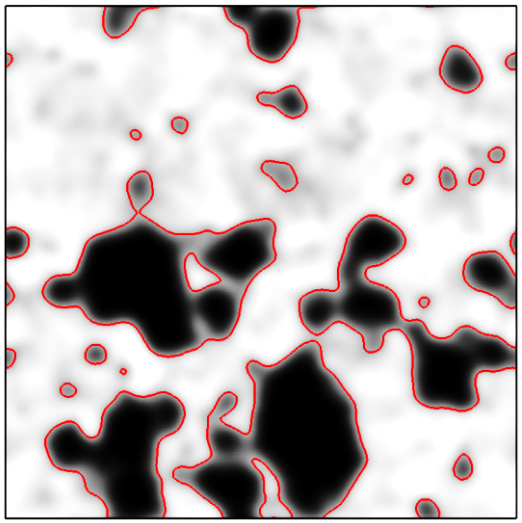


- High-mass ($M \geq 10^9 M_\odot$) source emissivity: **same**
- Low-mass ($10^8 \leq \frac{M}{M_\odot} \leq 10^9$) source emissivity:
  - f125_125S: low
  - f125_1000S: high

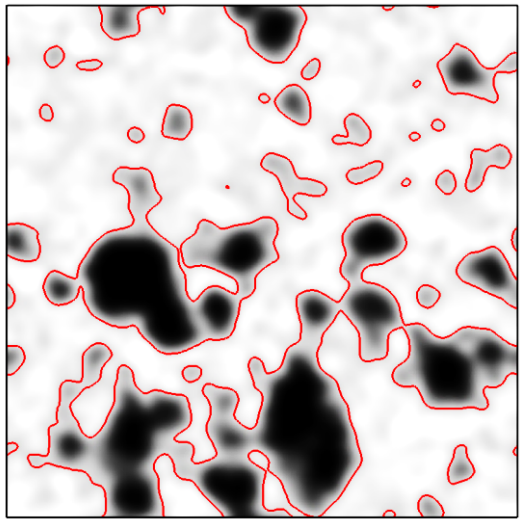
Model dependency



(a)



f125_125S



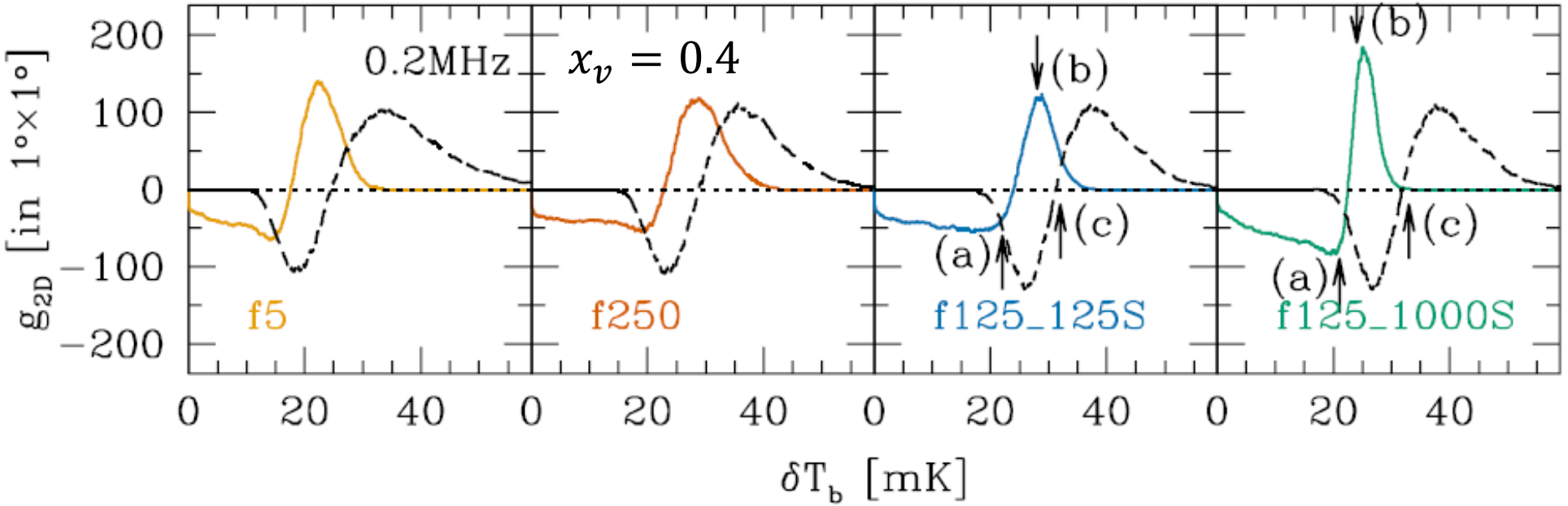
f125_1000S

high low-mass efficiency

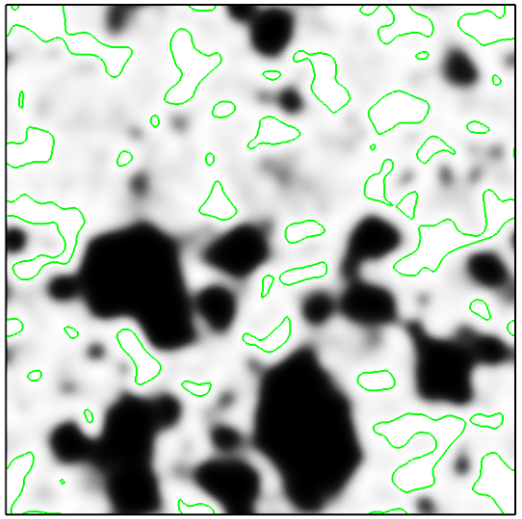
more detailed bubbles

amplitude increases

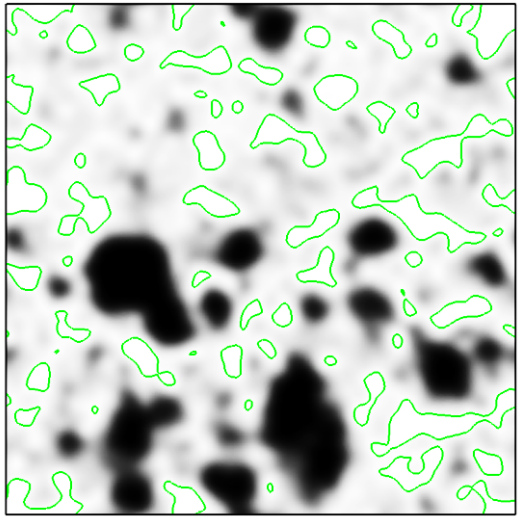
Model dependency



(b)



f125_125S



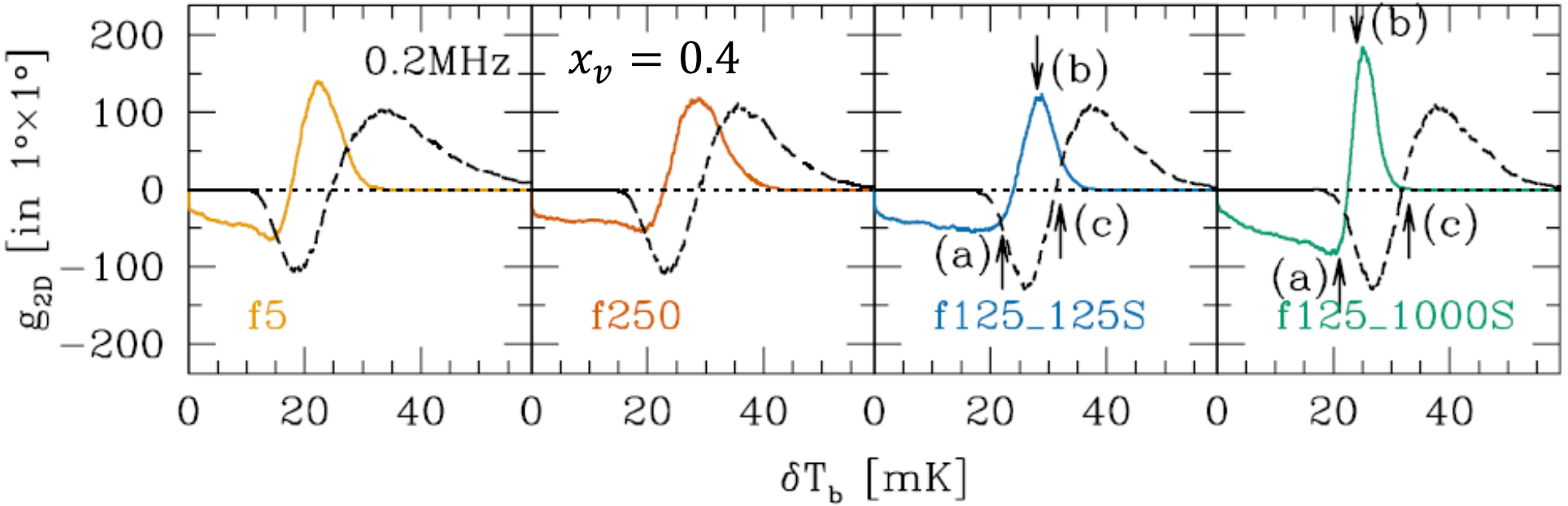
f125_1000S

high low-mass efficiency

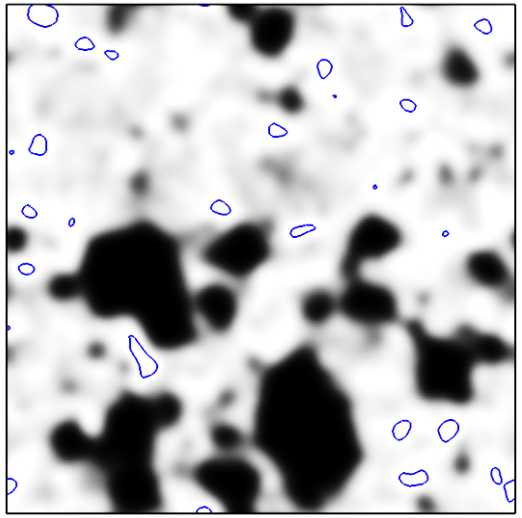
more detailed bubbles

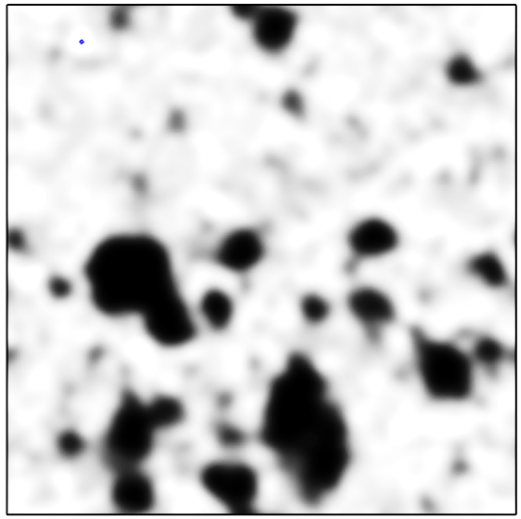
amplitude increases

Model dependency



(c)





f125_125S

f125_1000S

high low-mass efficiency

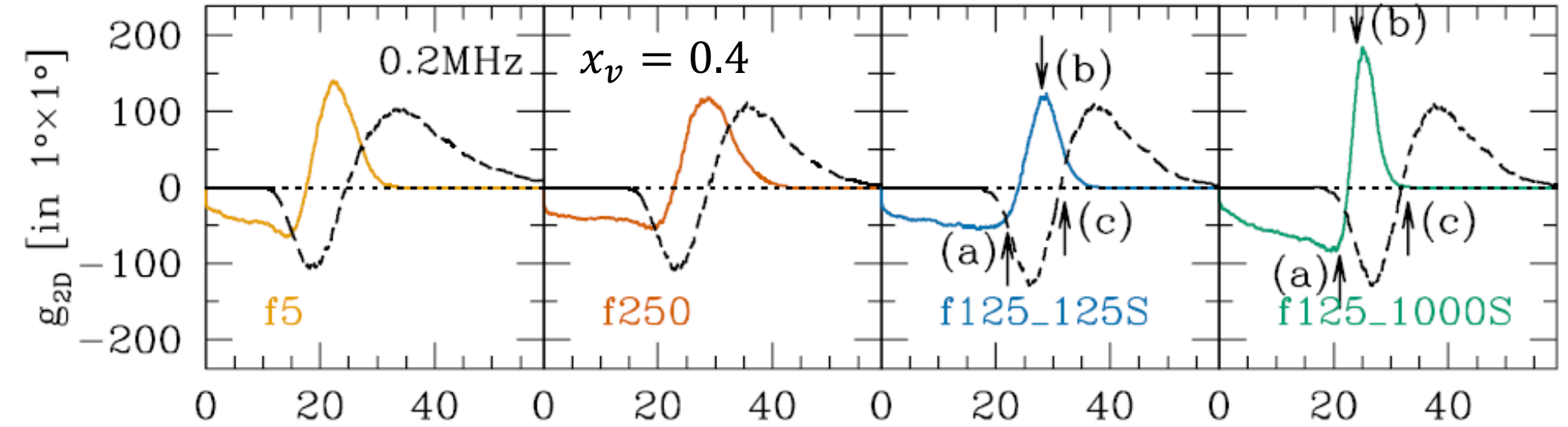
↓

all overdense region ionized

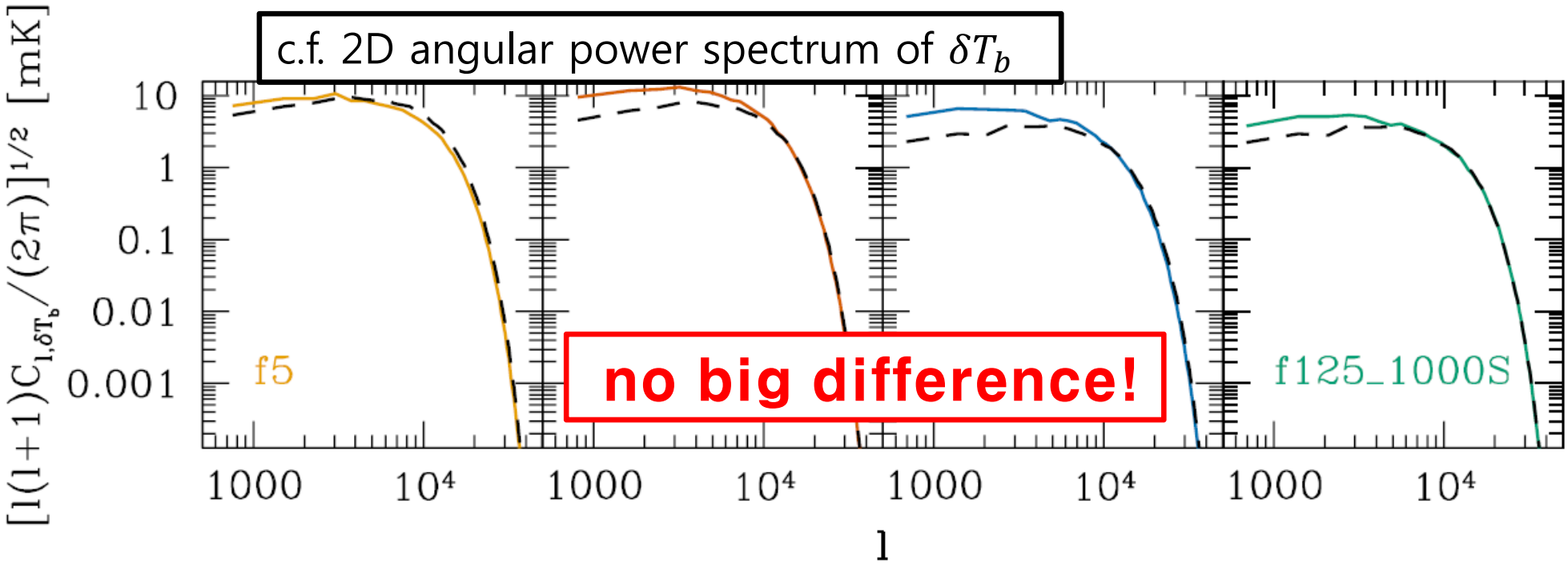
↓

genus = 0

Model dependency

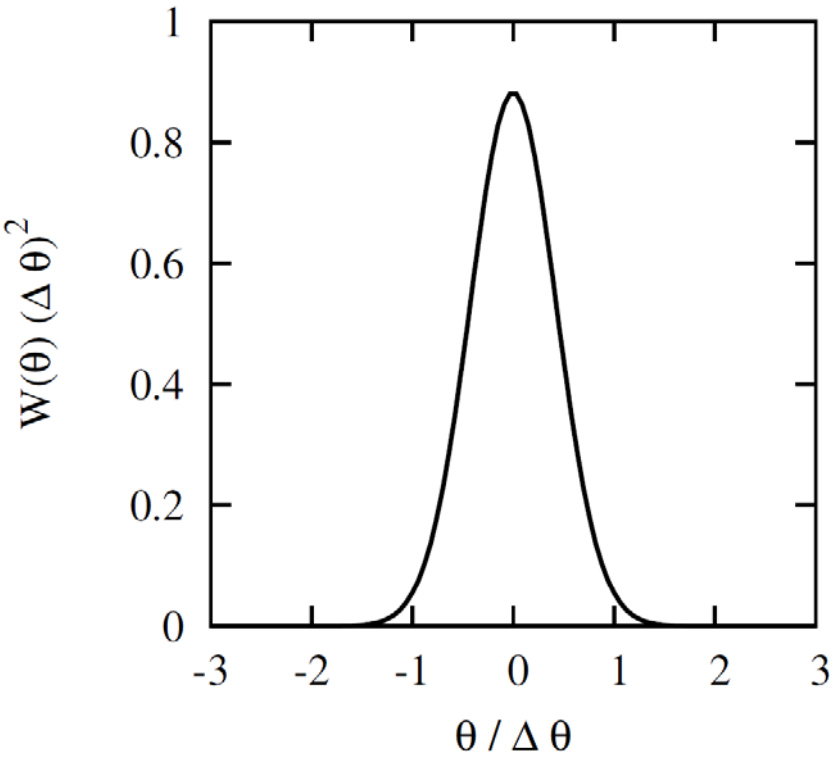


c.f. 2D angular power spectrum of δT_b



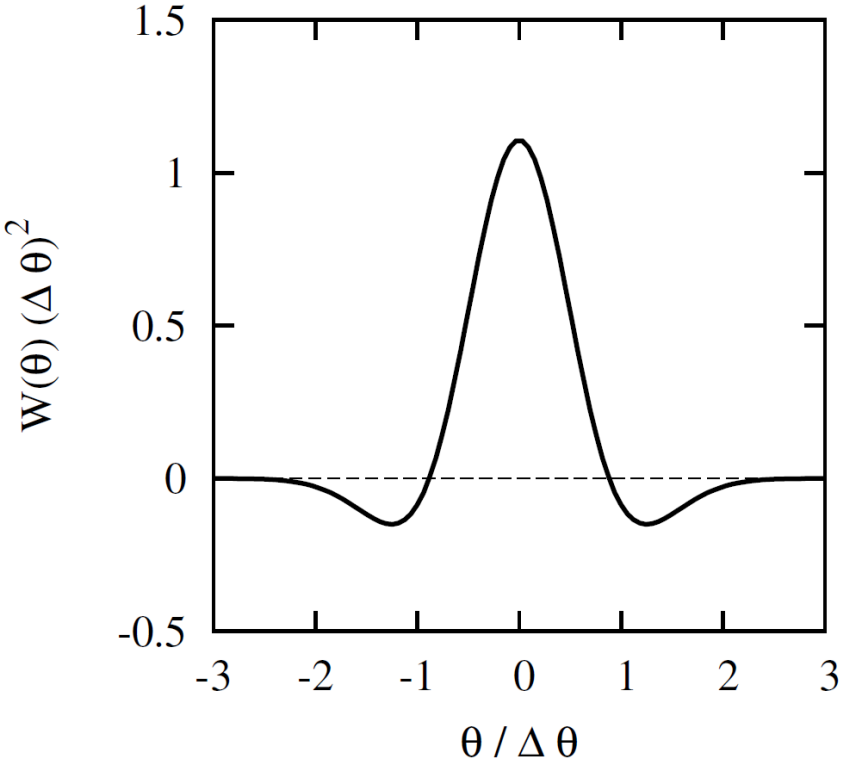
Beam shape dependency

Gaussian

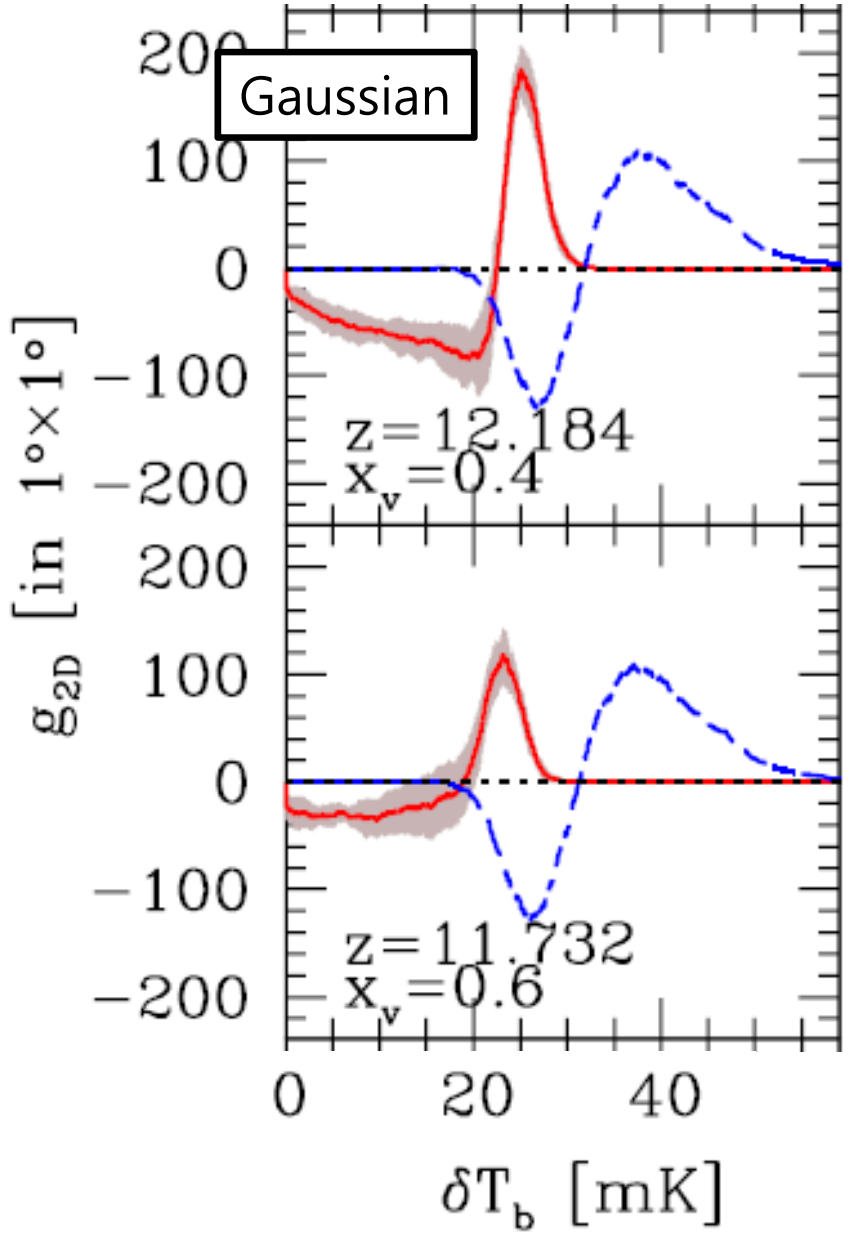


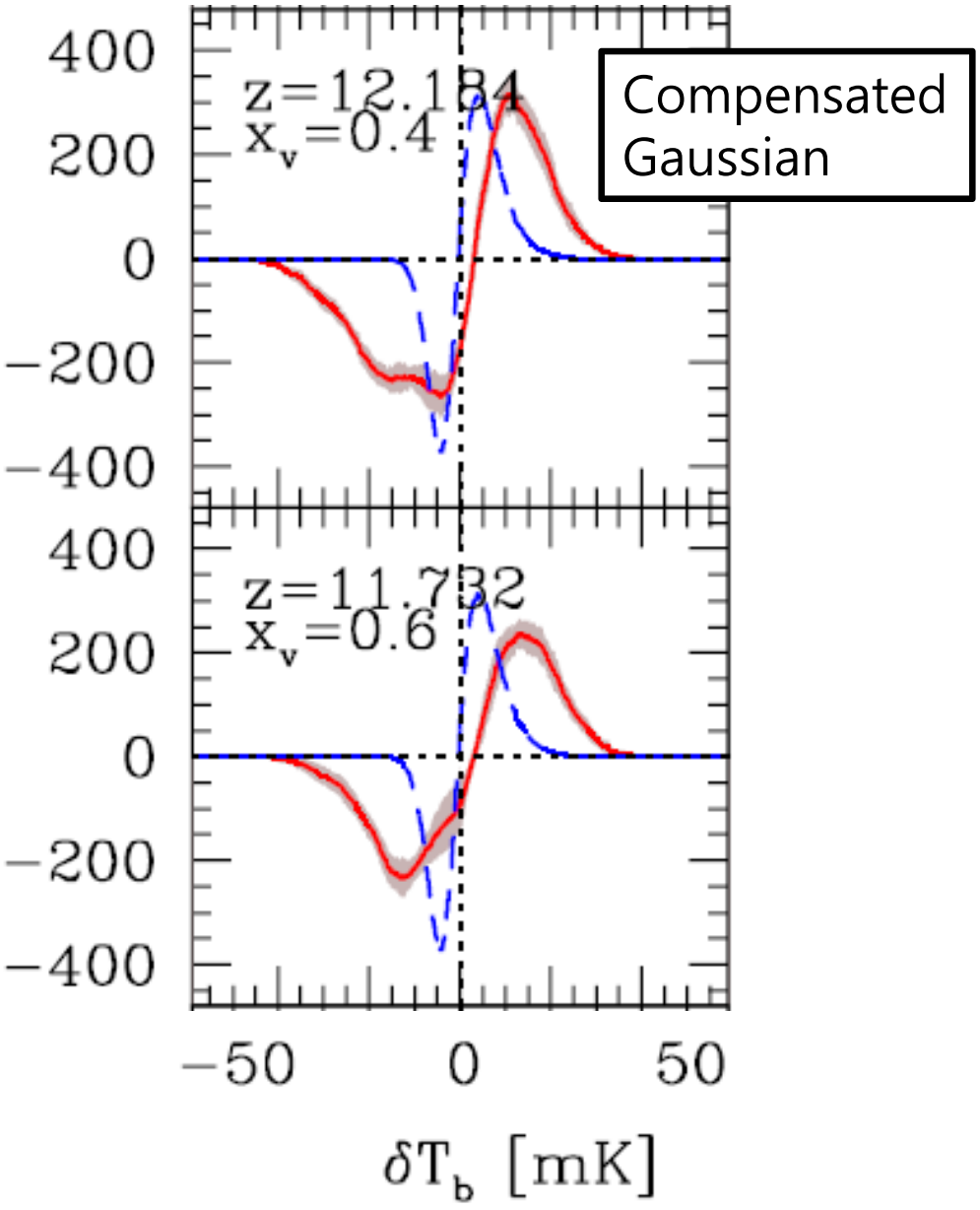
Compensated Gaussian

Crude approximation of actual beam with lack of large scale signal

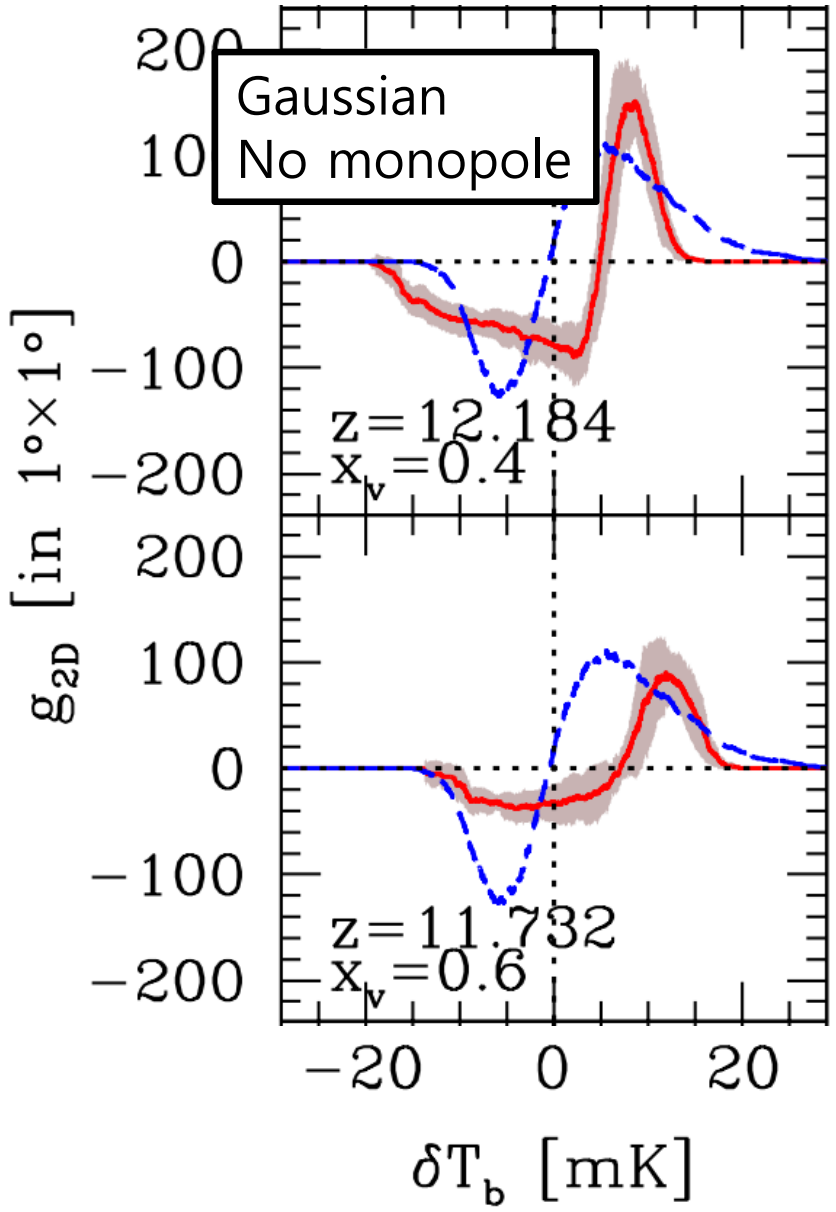


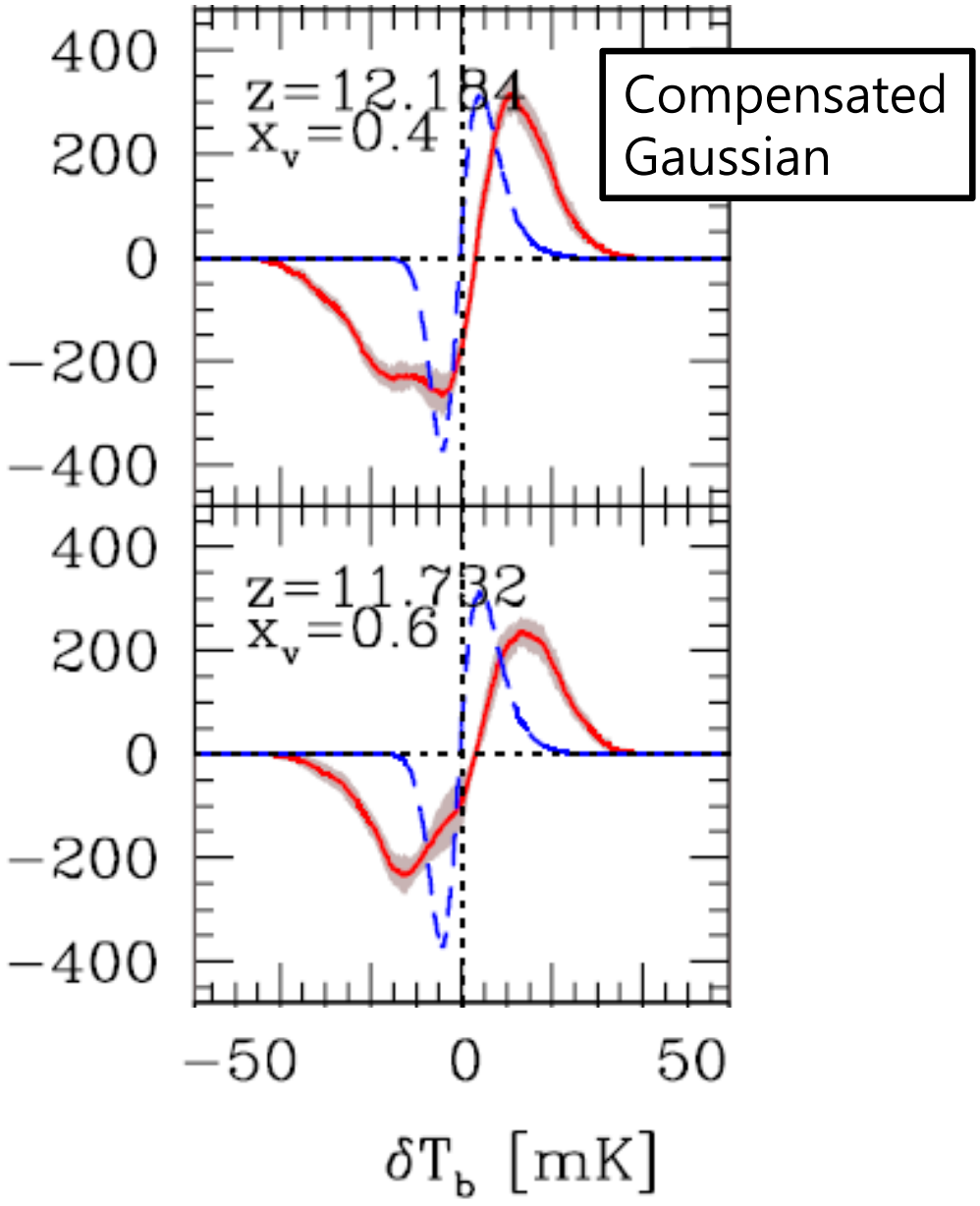
Beam shape dependency



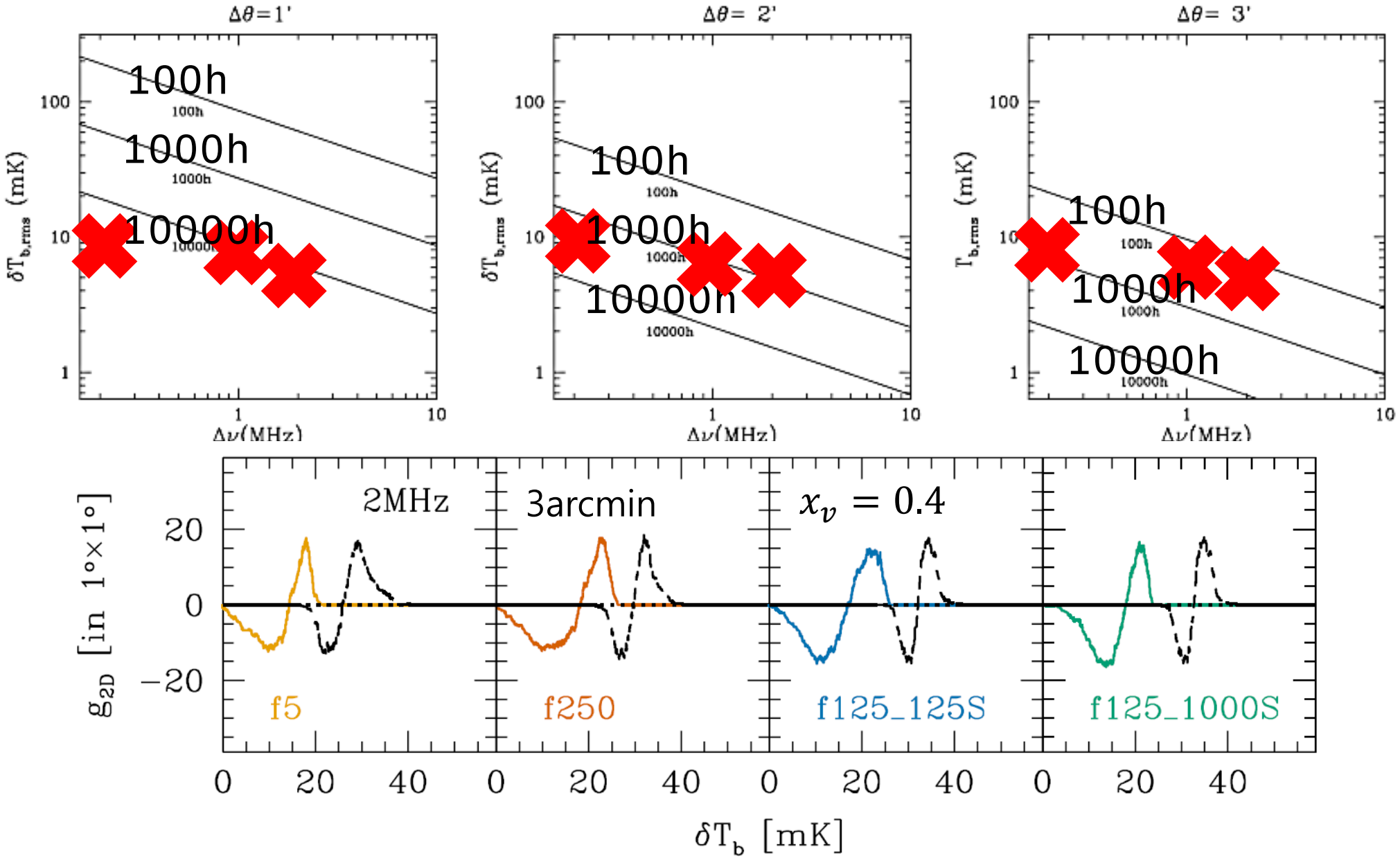


Beam shape dependency



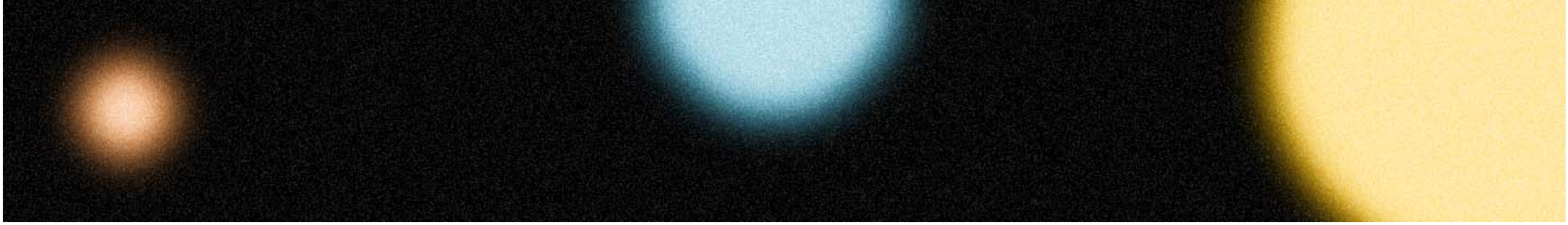


Sensitivities in SKA



Summary

- 2D genus curve clearly shows the evolution of the reionization process.
- 2D genus method can be used to discriminate between various scenarios.
- SKA will be able to produce data suitable for the 2D genus analysis, with
  - Integration: 100 ~ 1000 hours
  - Beam size: 2 ~ 3 arcminutes
  - Bandwidth: 1 ~ 2 MHz



Thank you!

Model dependency