



東北大學
Northeastern University

21 cm Cosmology Workshop 2023 & Tianlai Collaboration Meeting

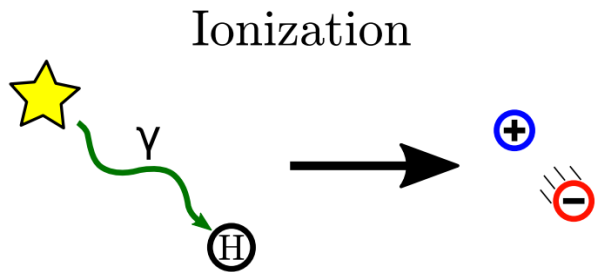
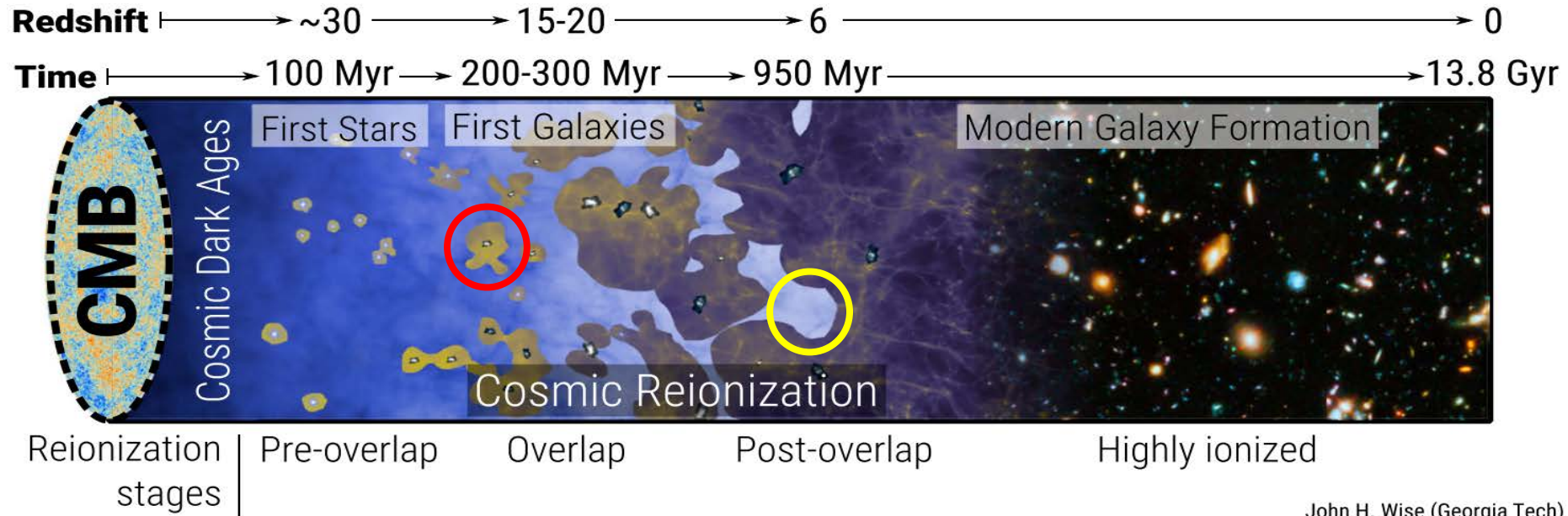
Effects of Small-Scale Absorption Systems on the Neutral Islands during the Late Epoch of Reionization

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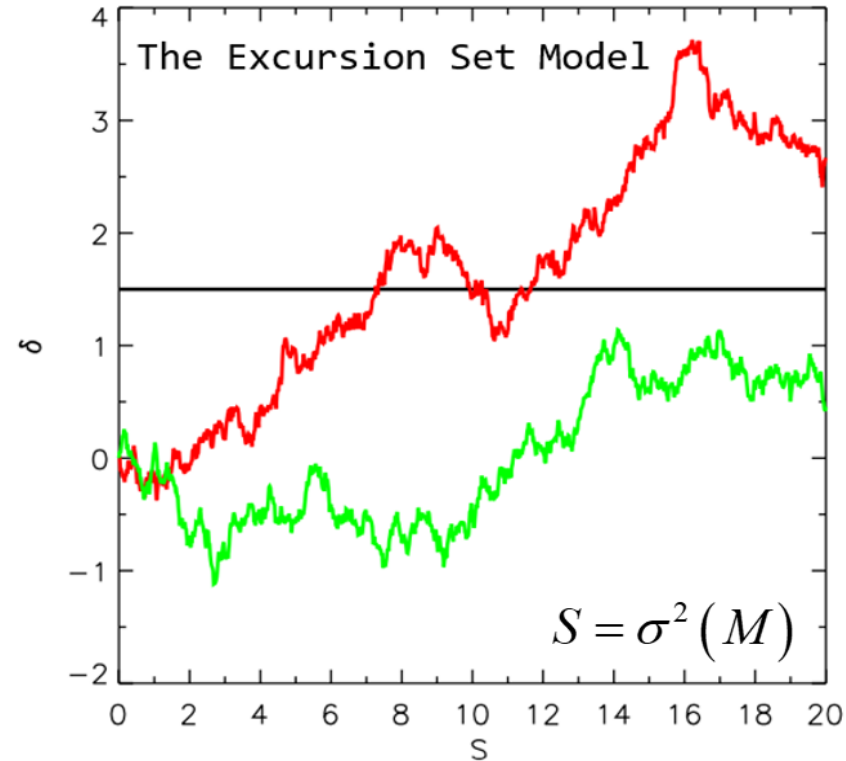
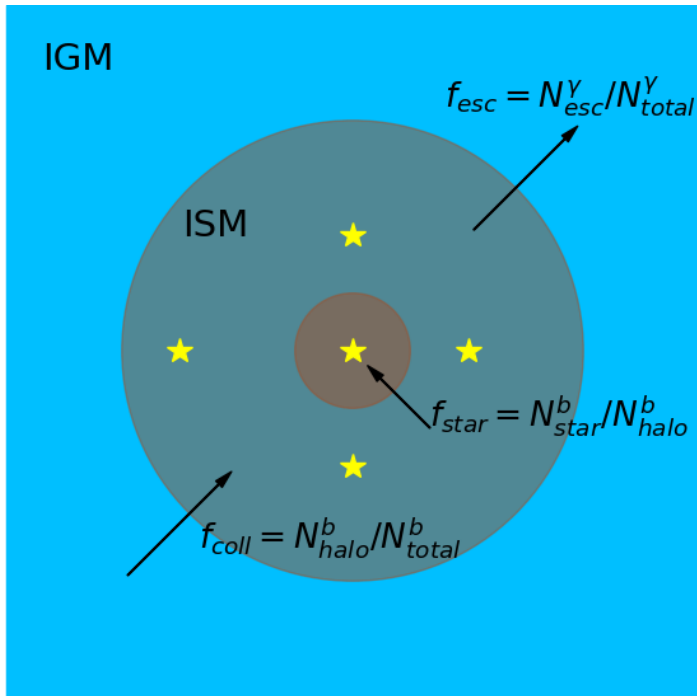
Wu et al. 2022, ApJ, 927, 5

Cosmic reionization



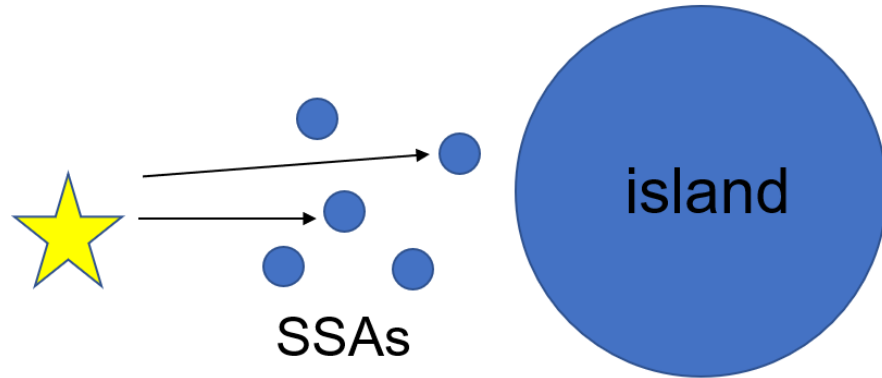
- Cosmic reionization begins in earnest at $z \sim 15$
- Cosmic reionization is nearly complete at $z \sim 6$

21cmFAST is a semi-numerical simulation of the high-redshift 21-cm signal.



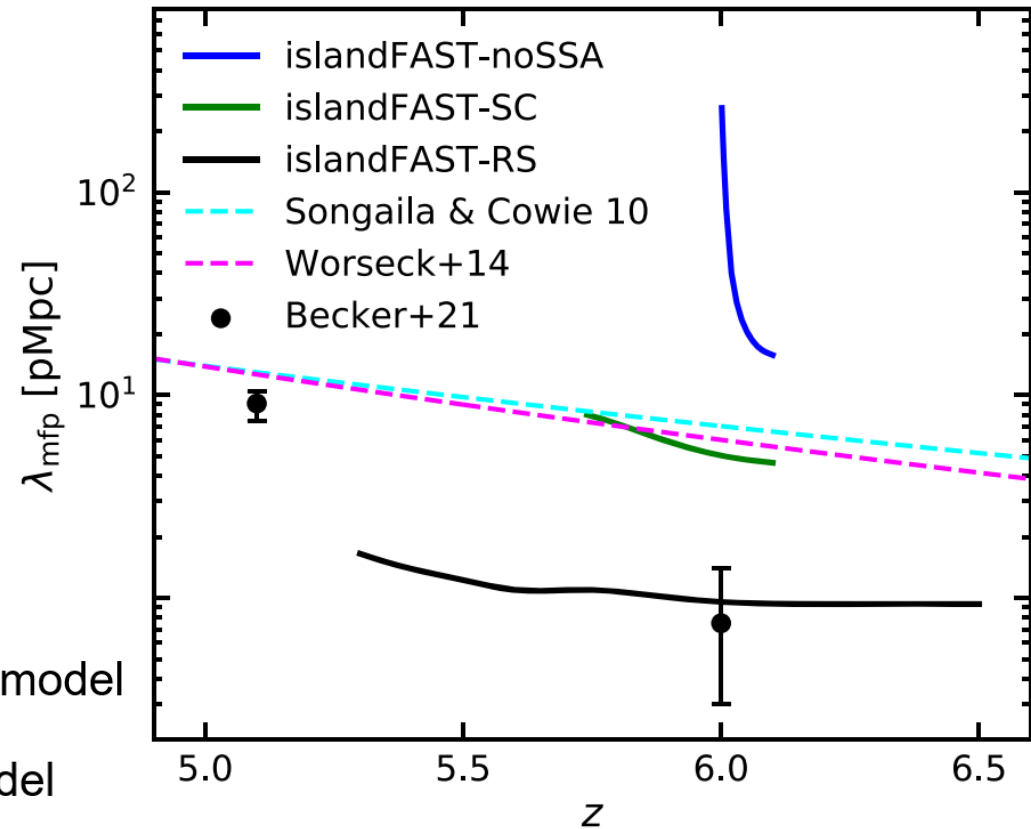
$$f_{coll} \geq \xi^{-1}, \quad \xi = f_{esc} f_{\star} N_{\gamma/H} (1 + \bar{n}_{rec})^{-1}$$

IslandFAST is a semi-numerical tool for simulating the late epoch of reionization.



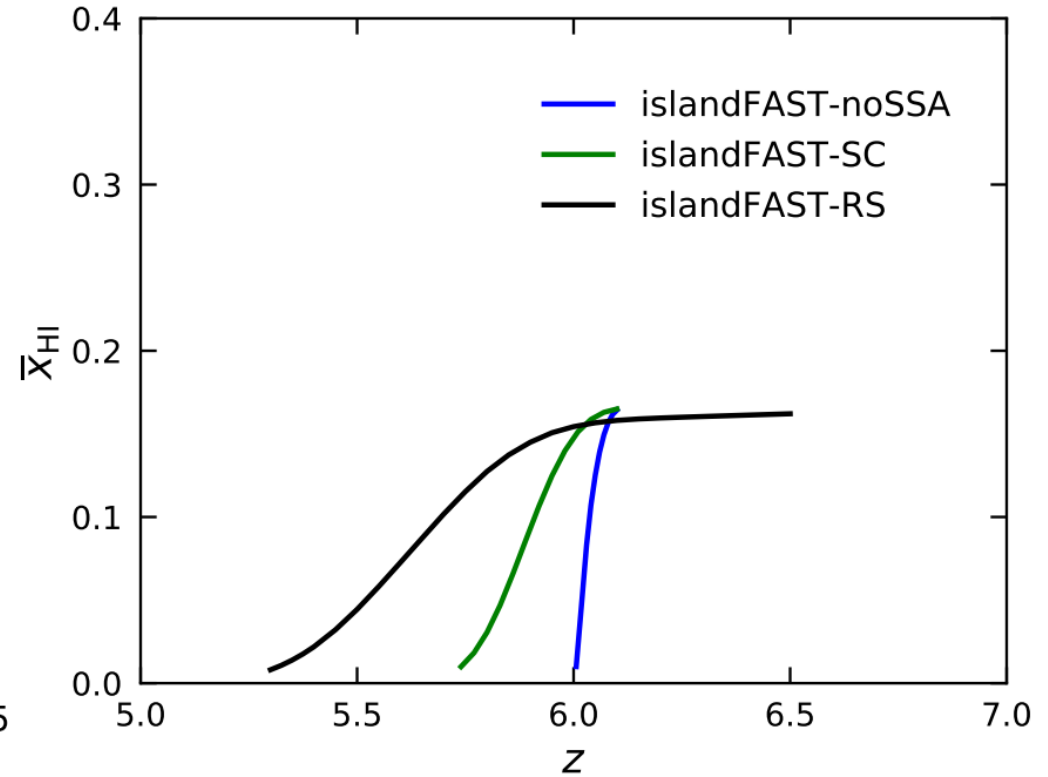
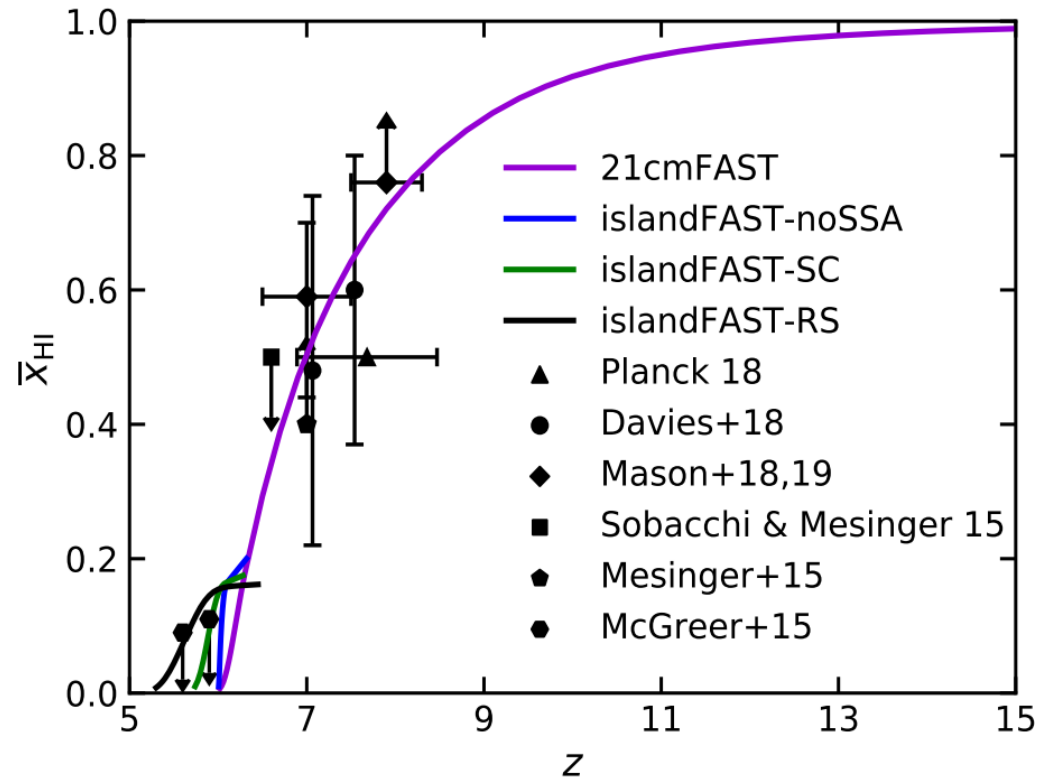
The propagation of photons is affected by small-scale absorption systems (SSAs).

- islandFAST-noSSA a no-SSA model
- islandFAST-SC a moderate-SSA model
- islandFAST-RS a dense-SSA model

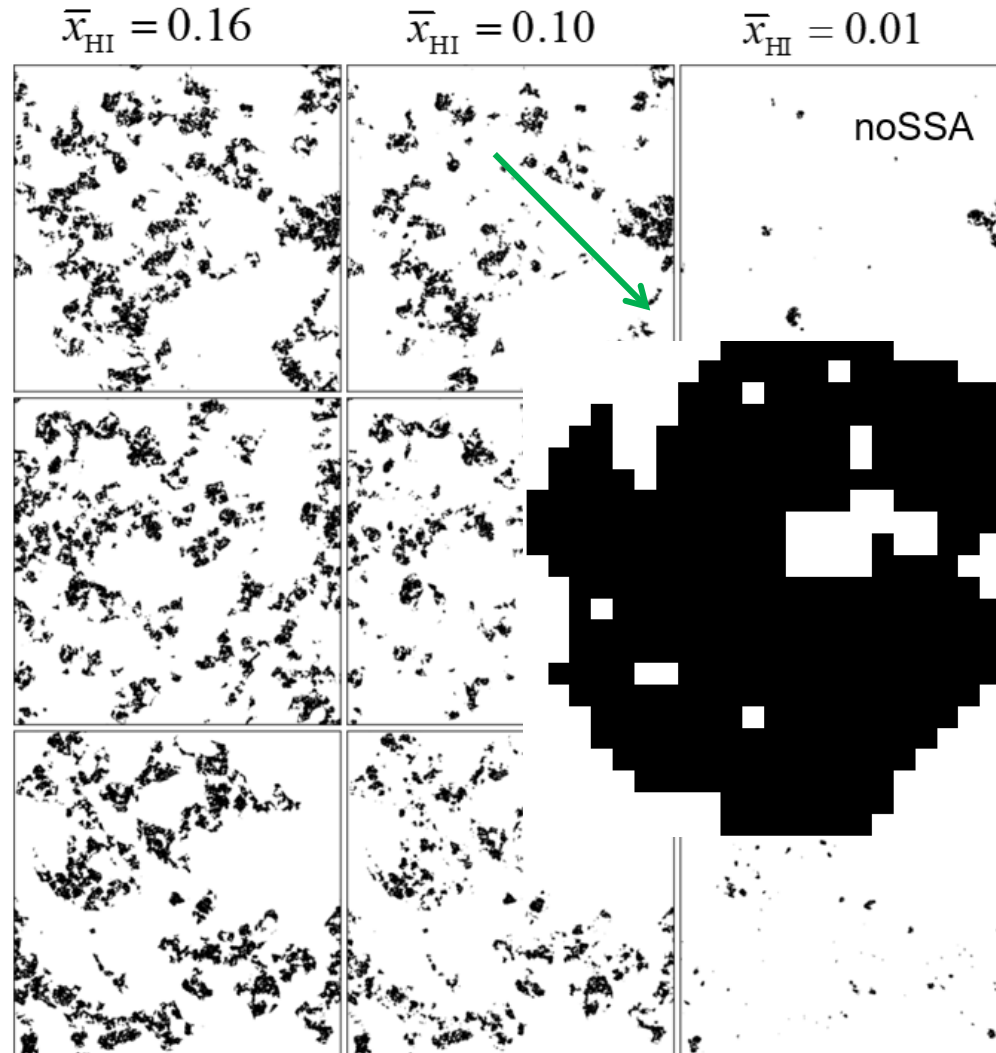


The reionization history

We confirm that the presence of SSAs prolongs the reionization process.



Ionization field slices

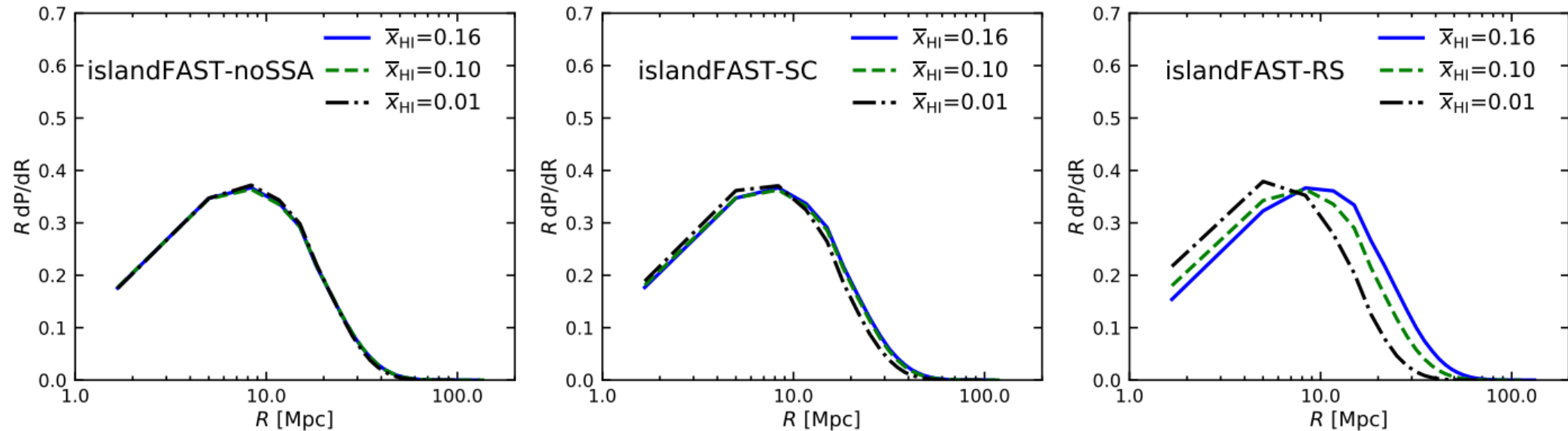


➤ The islands are “porous”, showing the “bubbles-in-island” effect.

➤ For RS model, the island scale changes significantly during the late EoR.

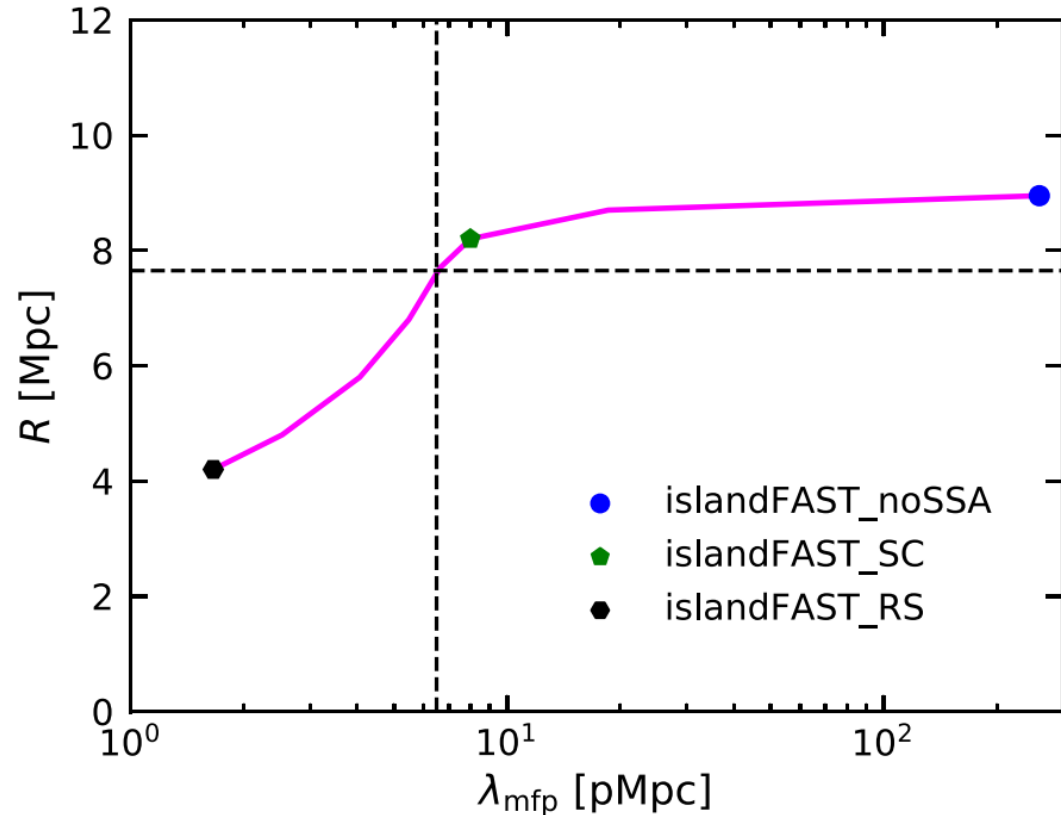
➤ For RS model, the remaining islands are small in number but large in scale.

The size distribution of islands



- The characteristic island scale stays nearly unchanged at about 10 co-moving Mpc for the no-SSA and moderate-SSA models
- In the RS model (dense SSA), the characteristic island scale shows obvious evolution.

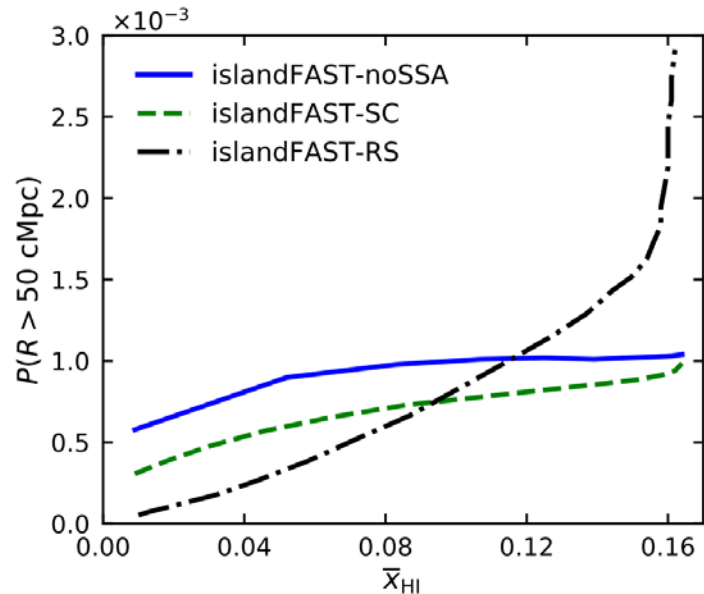
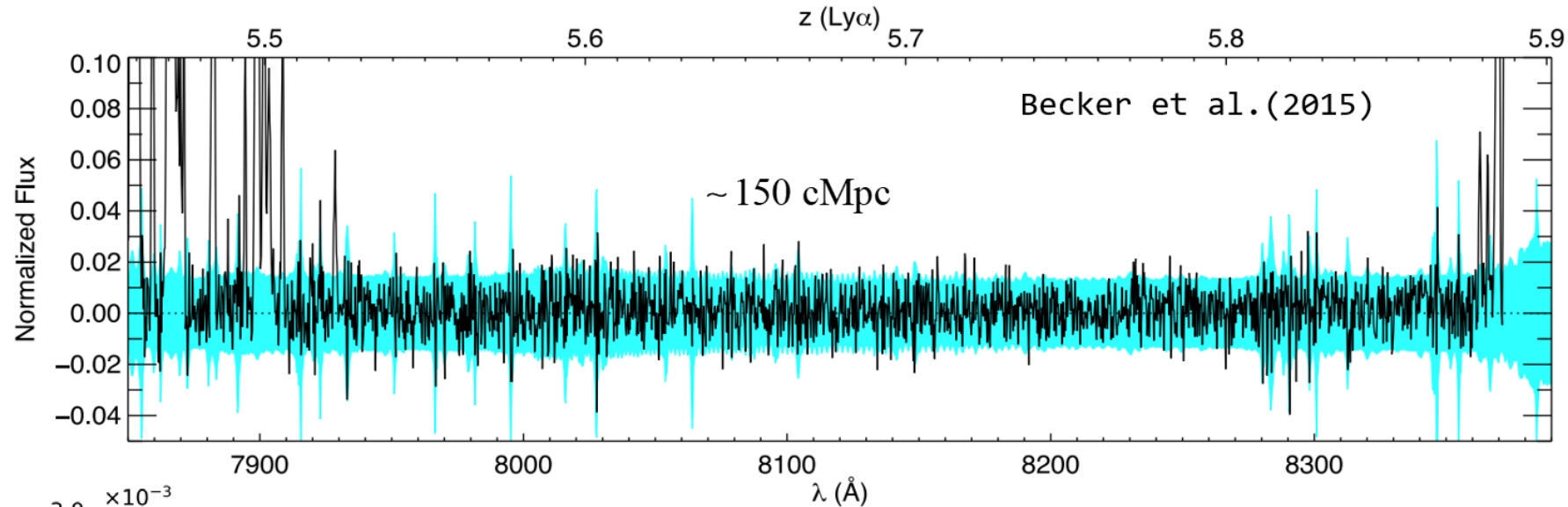
The size distribution of islands



- The island scale is not sensitive to the abundance of the SSAs, at least below a certain threshold.
- The island size provides a constraint on the SSA abundance, the MFP, and the level of the ionizing background during the late EoR.

Fig. The relation between the island scale and λ_{mfp} .

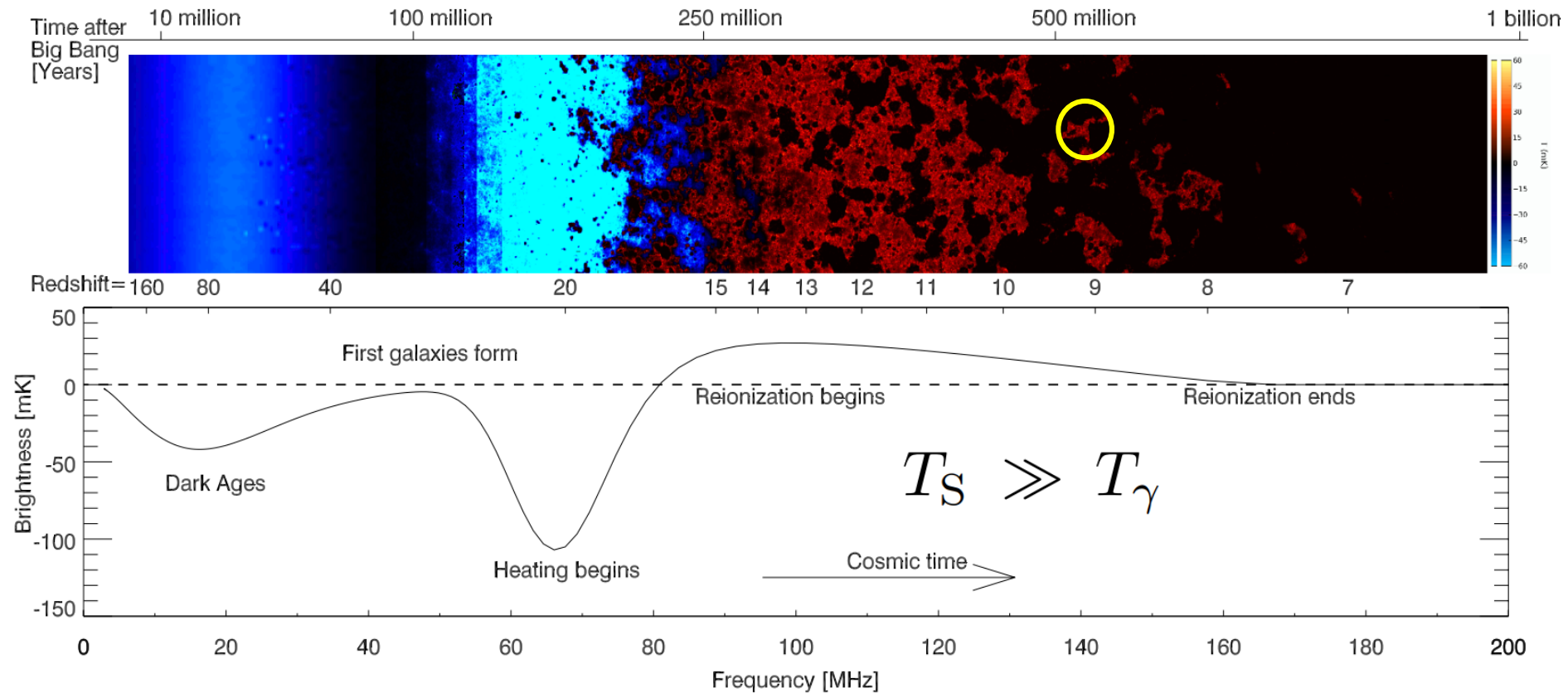
The maximum scale of neutral islands



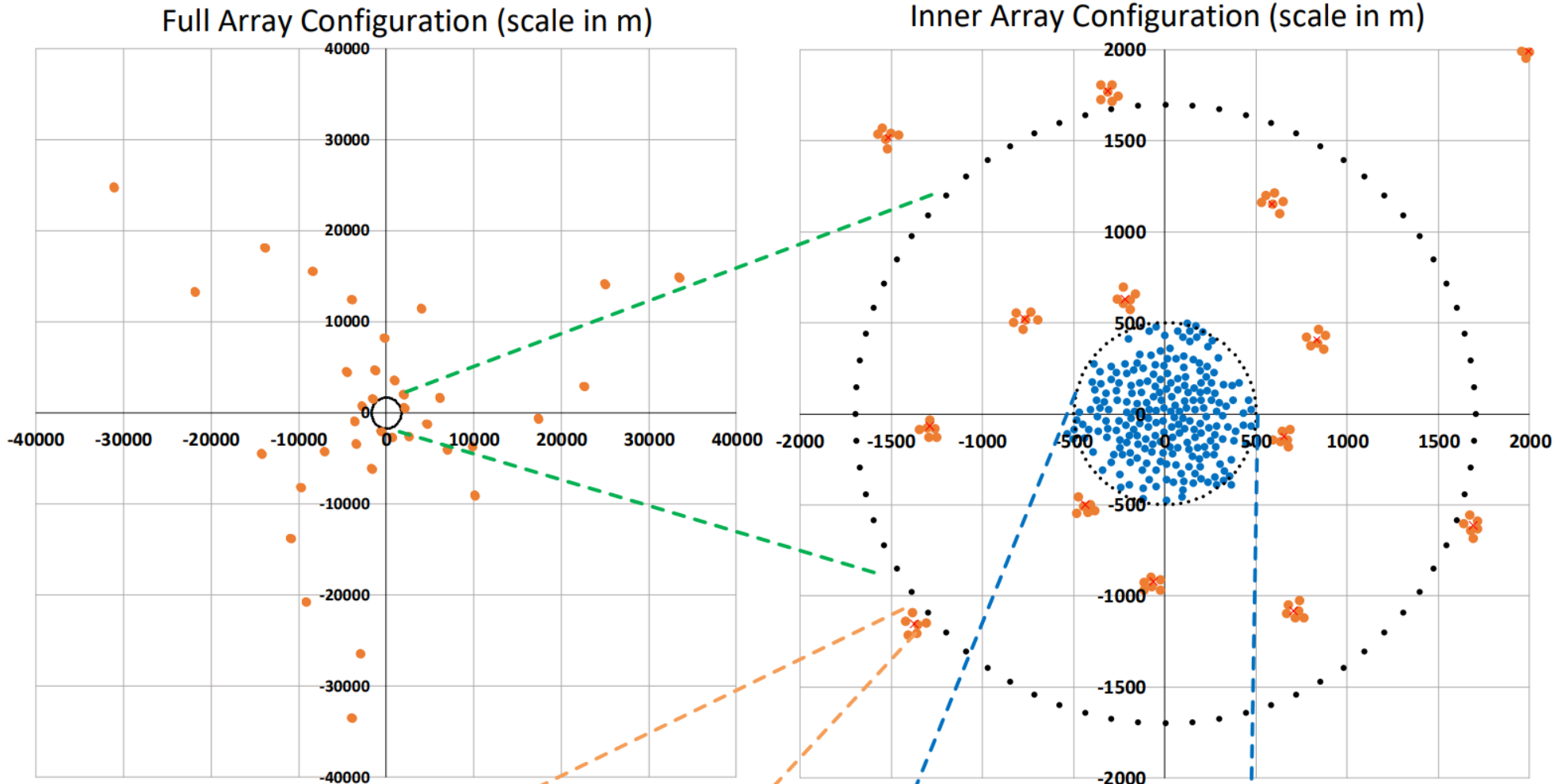
- The possibility of having an island scale larger than 50 comoving Mpc is quite low.
- Our model does not include partial ionizations.
- The bubbles in islands reduce the length of the lines passing through the islands.

The 21-cm brightness temperature

- During the late EoR, X-rays have probably heated the IGM temperature to a level much higher than the CMB temperature.



Observations with SKA1-Low

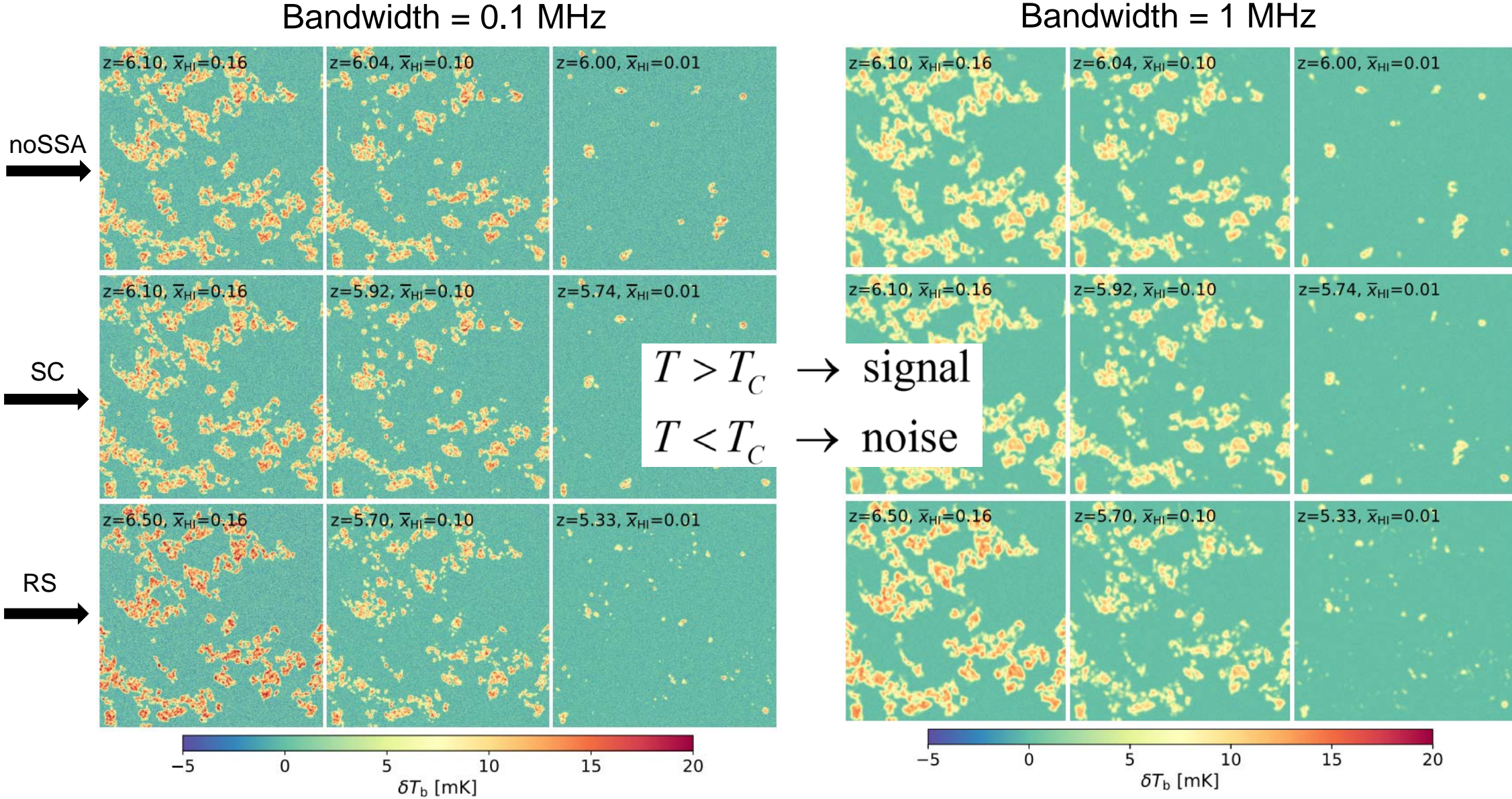


Station

Core array

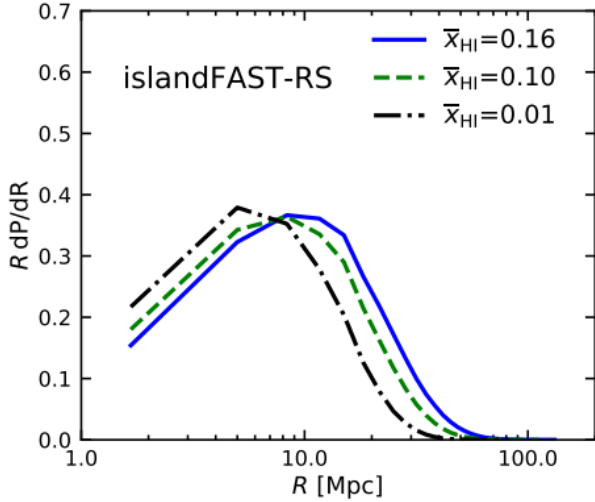
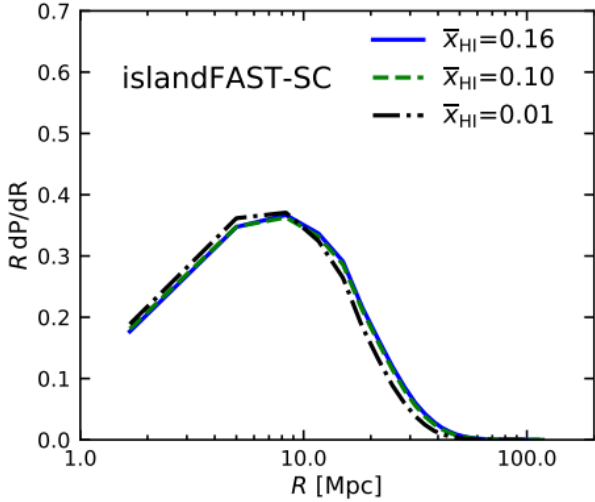
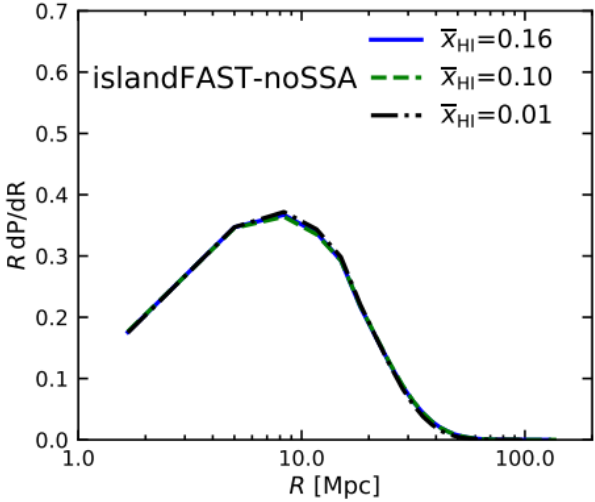
credit: SKAO

Mock images

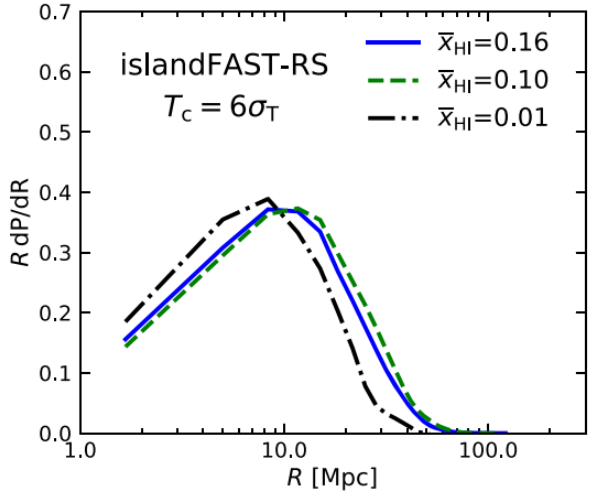
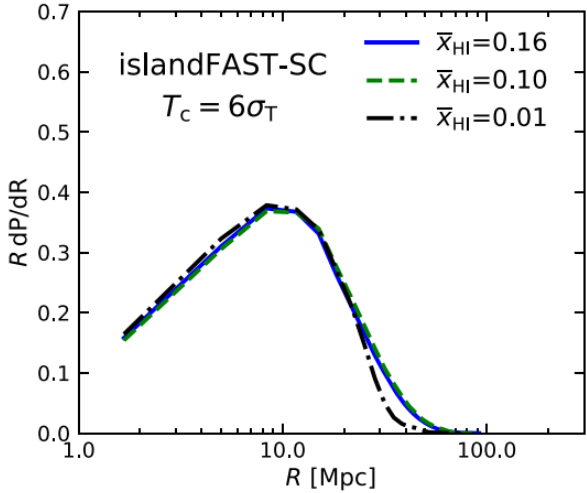
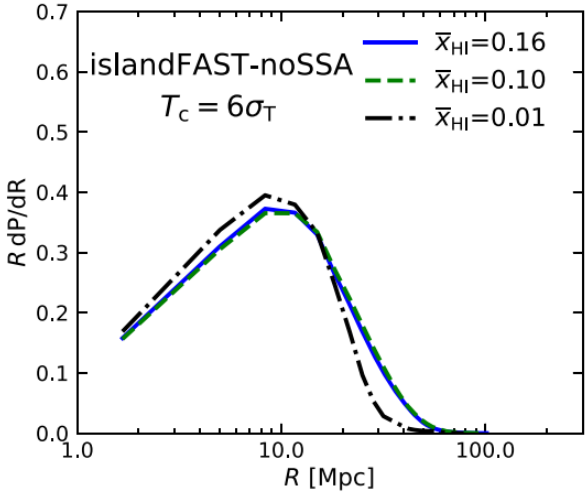


Size distributions of neutral islands

intrinsic
→

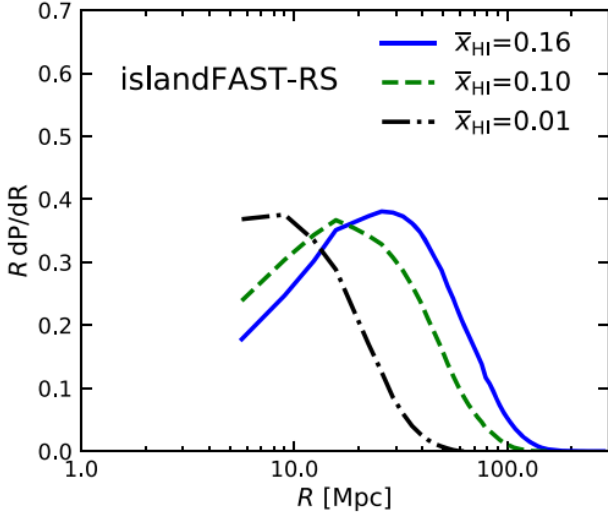
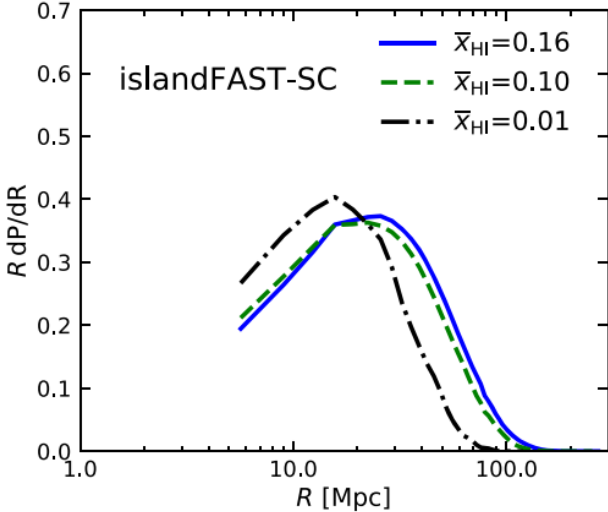
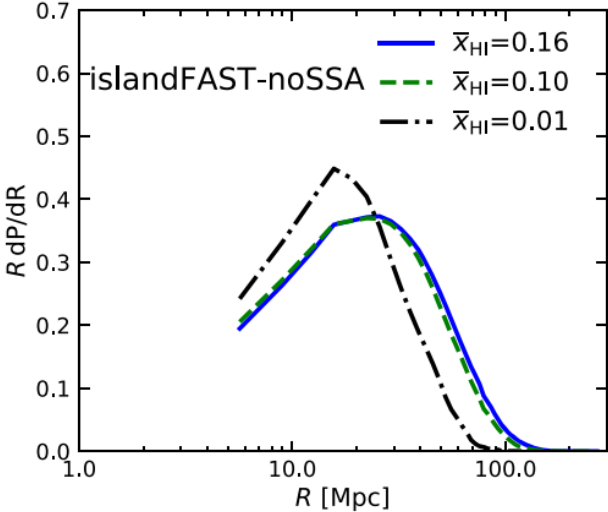


extracted
→
B=0.1 MHz

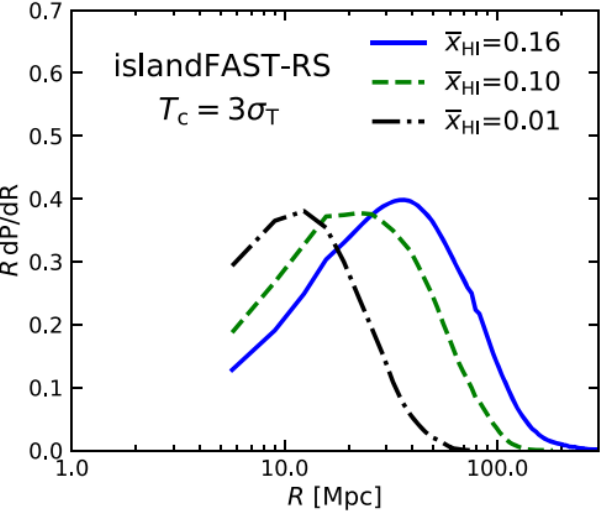
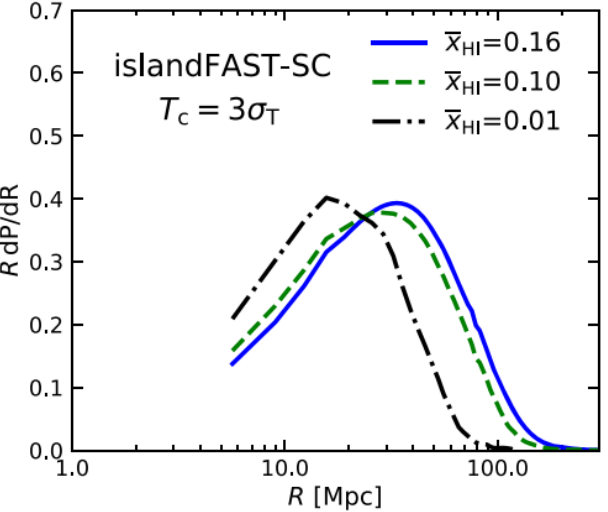
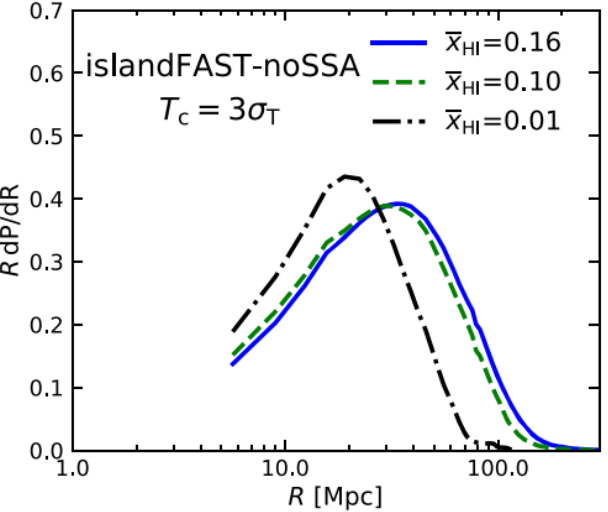


Size distributions of neutral islands

intrinsic
→

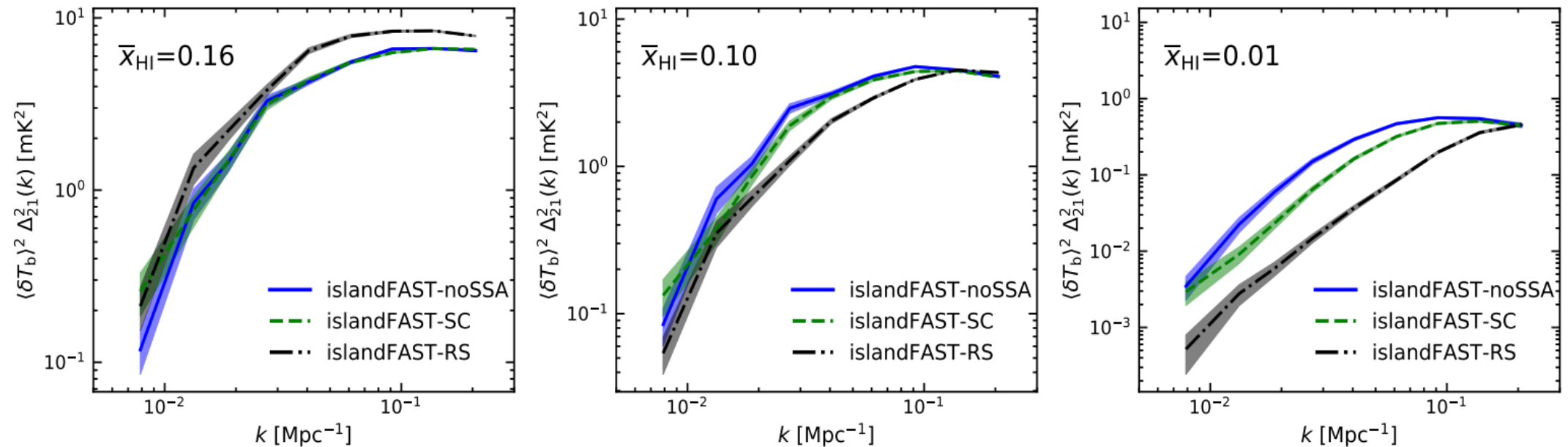


extracted
→
B=1 MHz



The 21-cm power spectrum

The SKA survey could discriminate the reionization models with the 21-cm power spectrum measurements.



Summary

- The characteristic island scale stays nearly unchanged at about 10 cMpc during the late stage for the no-SSA and moderate-SSA models.
- In the dense-SSA model, the characteristic island scale shows obvious evolution, as large islands break into many small ones.
- The evolutionary behavior of neutral islands during the late EoR provides a novel way to constrain the abundance of SSAs.
- The different models can be distinguished by the 21-cm power spectrum measurement and the imaging observation with a proper choice of the 21-cm brightness threshold.

Thank you