

Foreground mitigation strategy for measuring the 21 cm-LAE cross-correlation

Yoshiura et al 2017 (arXiv : 1709.04168)

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Collaborators :

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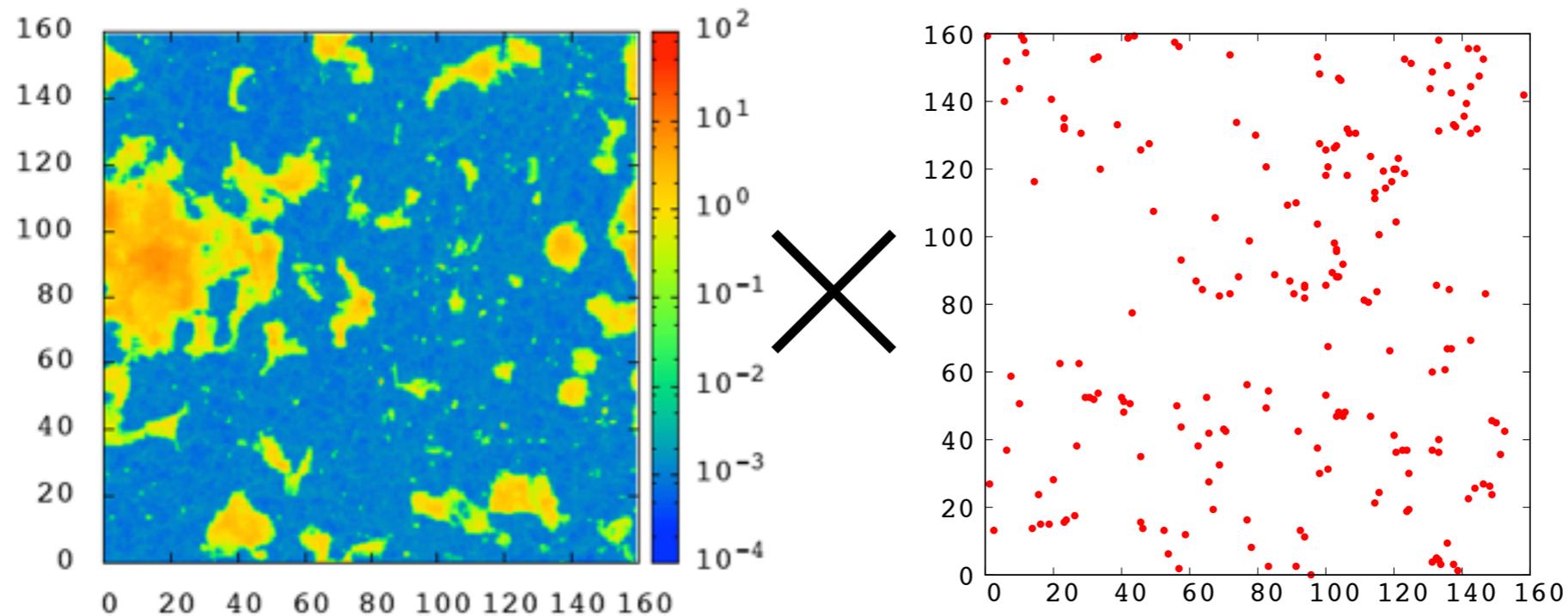


Objective

Estimate the detectability of 21 cm - LAE cross power spectrum(CPS), and the astrophysical foreground contamination.

Correlation between 21 cm signal and LAE distribution ?

- Lyman- α Emitter (LAE) : high- z galaxy, a candidate for ionizing source



Why cross correlation ?

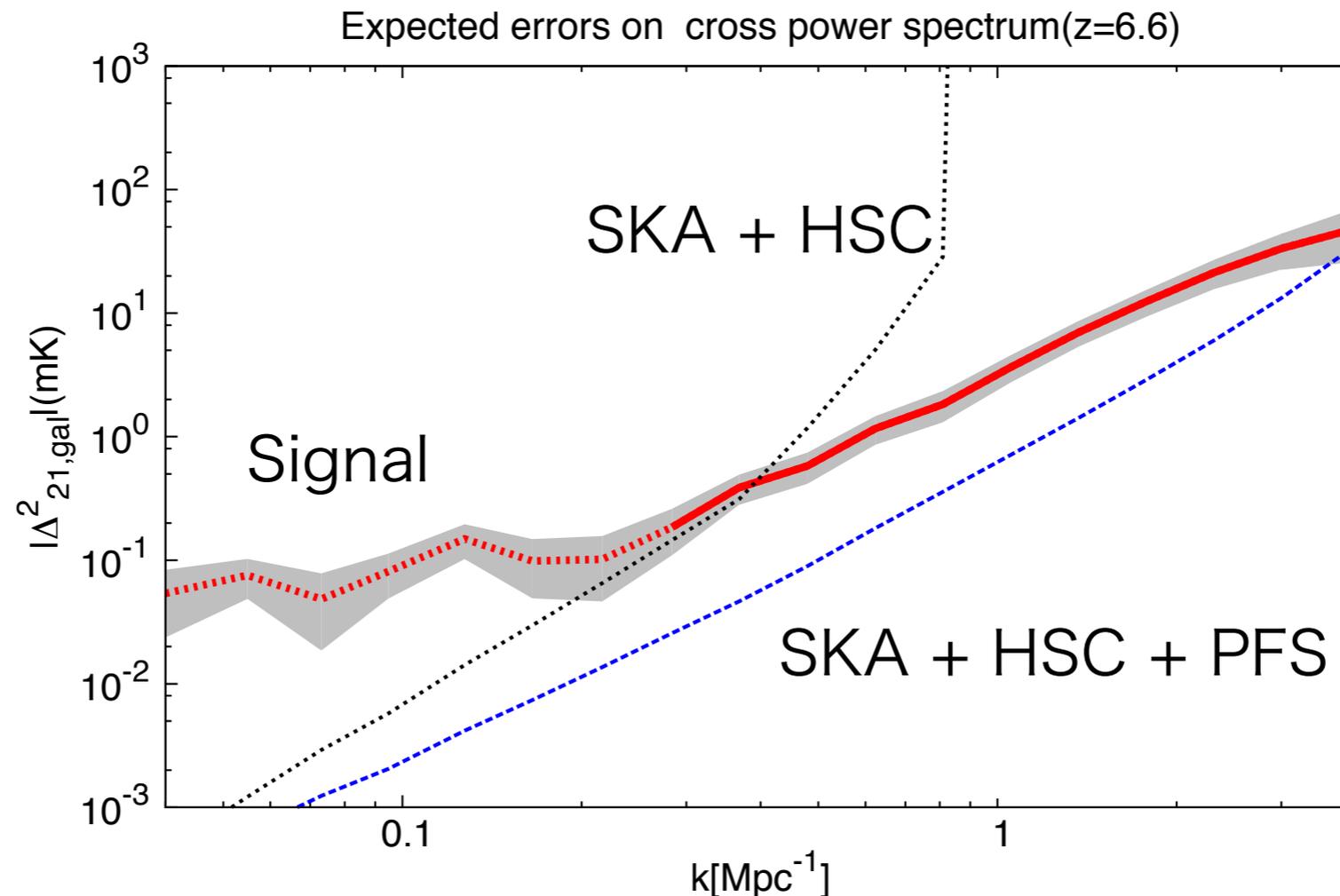
- Reduce foreground contamination
- Confirmative detection of the 21-cm signal

The error formula of CPS measurement

$$2\sigma_{21,\text{gal}}^2 = P_{21,\text{gal}}^2 + (P_{21} + N_{21} + P_{\text{FG}}) (P_{\text{gal}} + N_{\text{gal}})$$

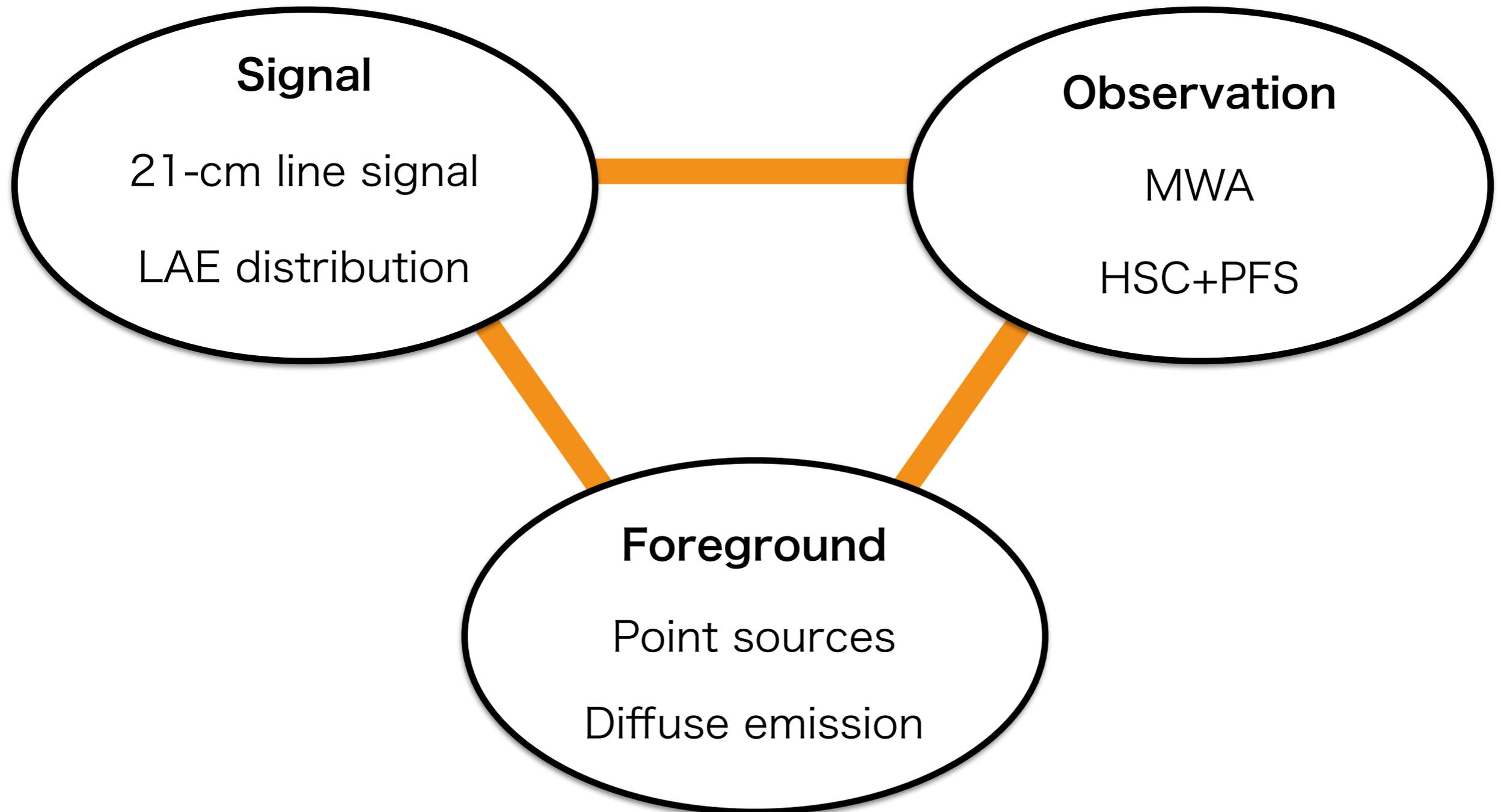
Sample variance	21cm PS	Noise	FG PS	LAE PS	Shot noise + z error
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The 21cm-LAE CPS can be observed with either MWA and SKA_LOW, in tandem with Subaru Hypersuprime Cam - Prime Focus Spectrograph

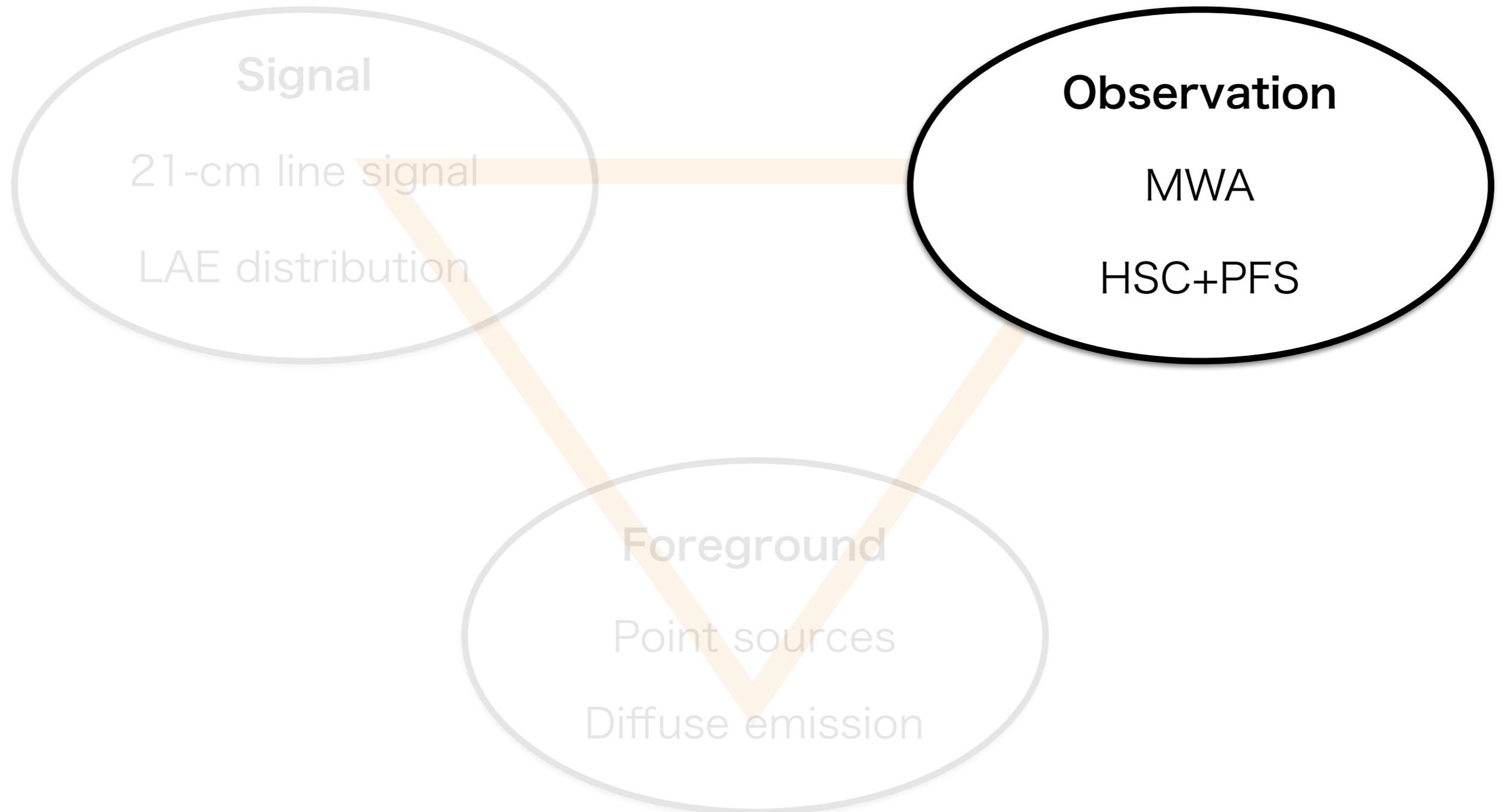


Result from
Kubota, SY + 2017
(arXiv : 1708.06291)

To estimate the detectability of 21cm-LAE CPS



To estimate the detectability of 21cm-LAE CPS



Observation

MWA

128 Tiles

1000 hours observation

Band width : 8MHz

Channel width : 80kHz

Beam model

EoR 0 field (RA, Dec) = (0,-27)

HSC

Subaru Hyper Suprime Cam

Deep field : 27deg^2

PFS

Prime Focus Spectrograph

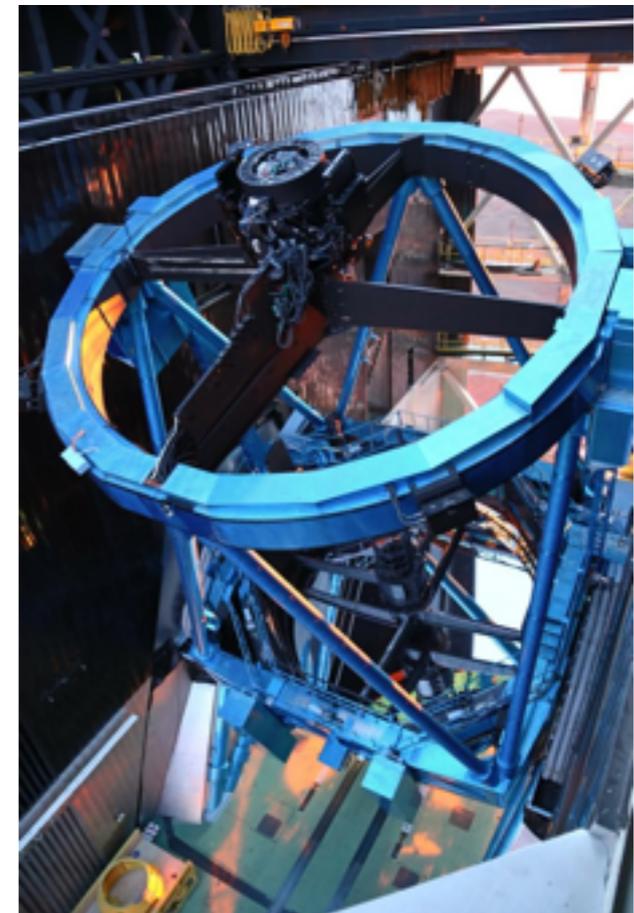
Redshift error $\Delta z = 0.0007$

(Takada et al 2014)

Observation will start in 2020

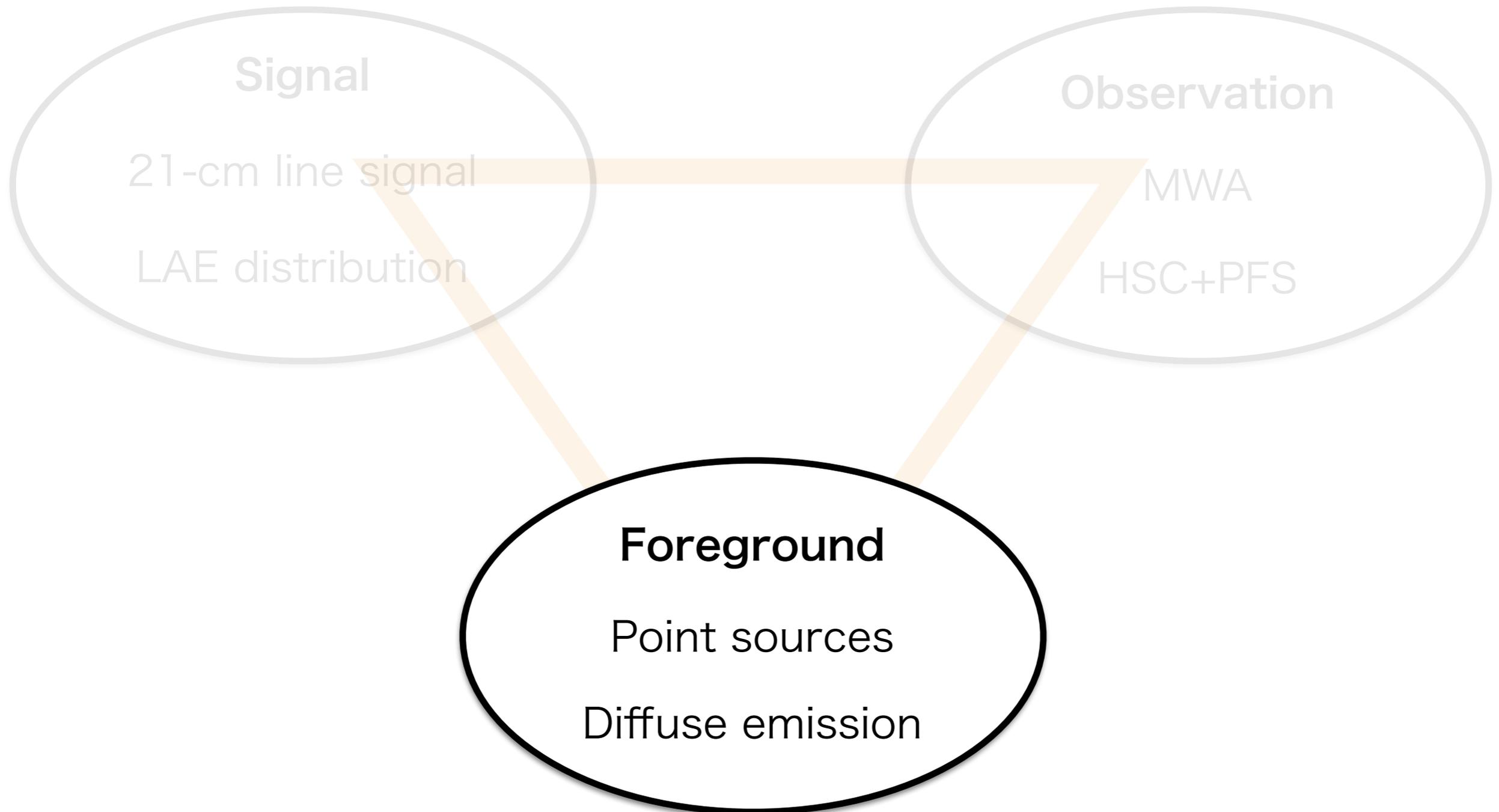


Credit: Natasha Hurley-Walker



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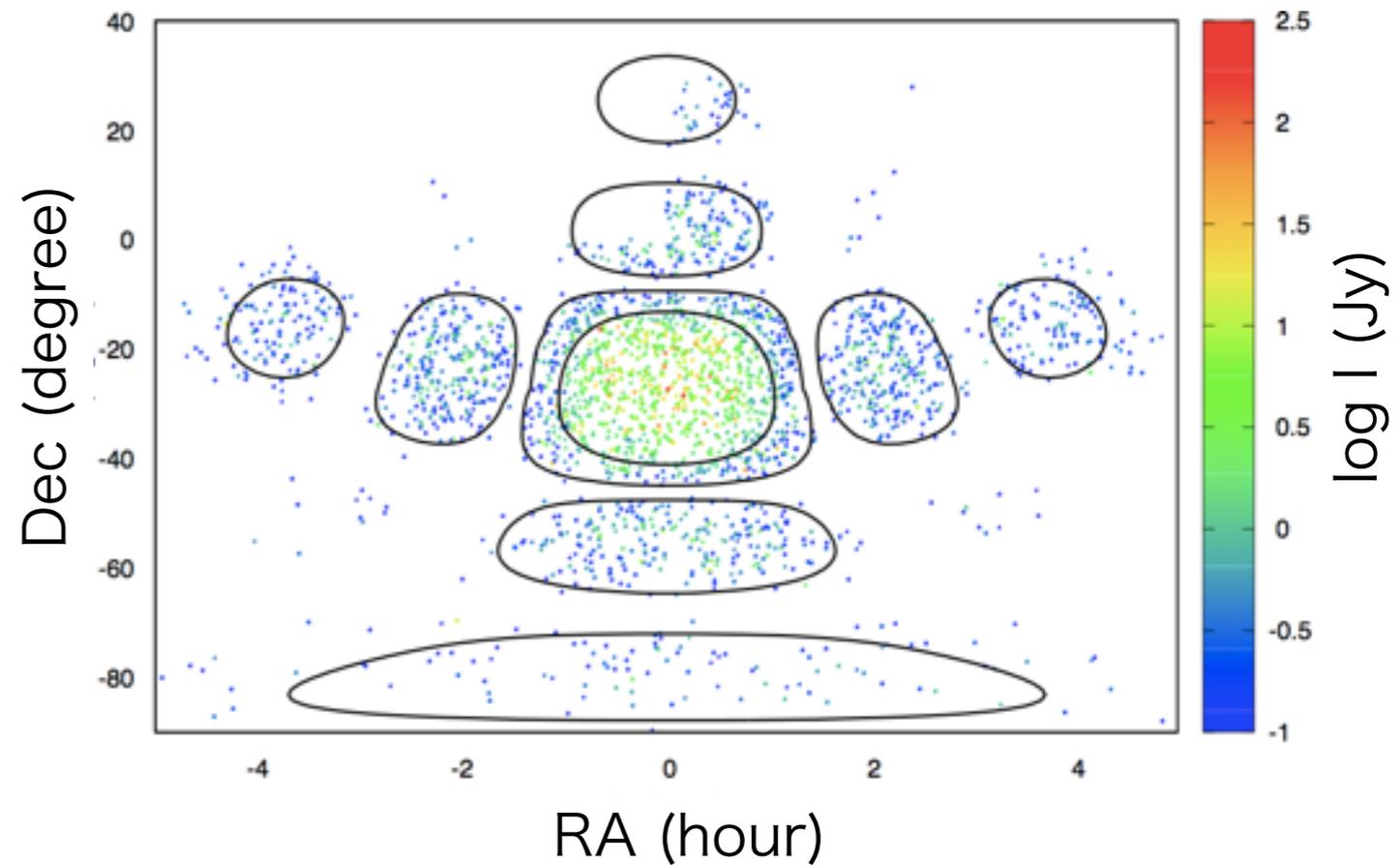
To estimate the detectability of 21cm-LAE CPS



Foreground models

Point sources

GLEAM catalogue
(Hurley-Walker+2017)
The pointing-dependent
beam shape
Simulated by J. Line

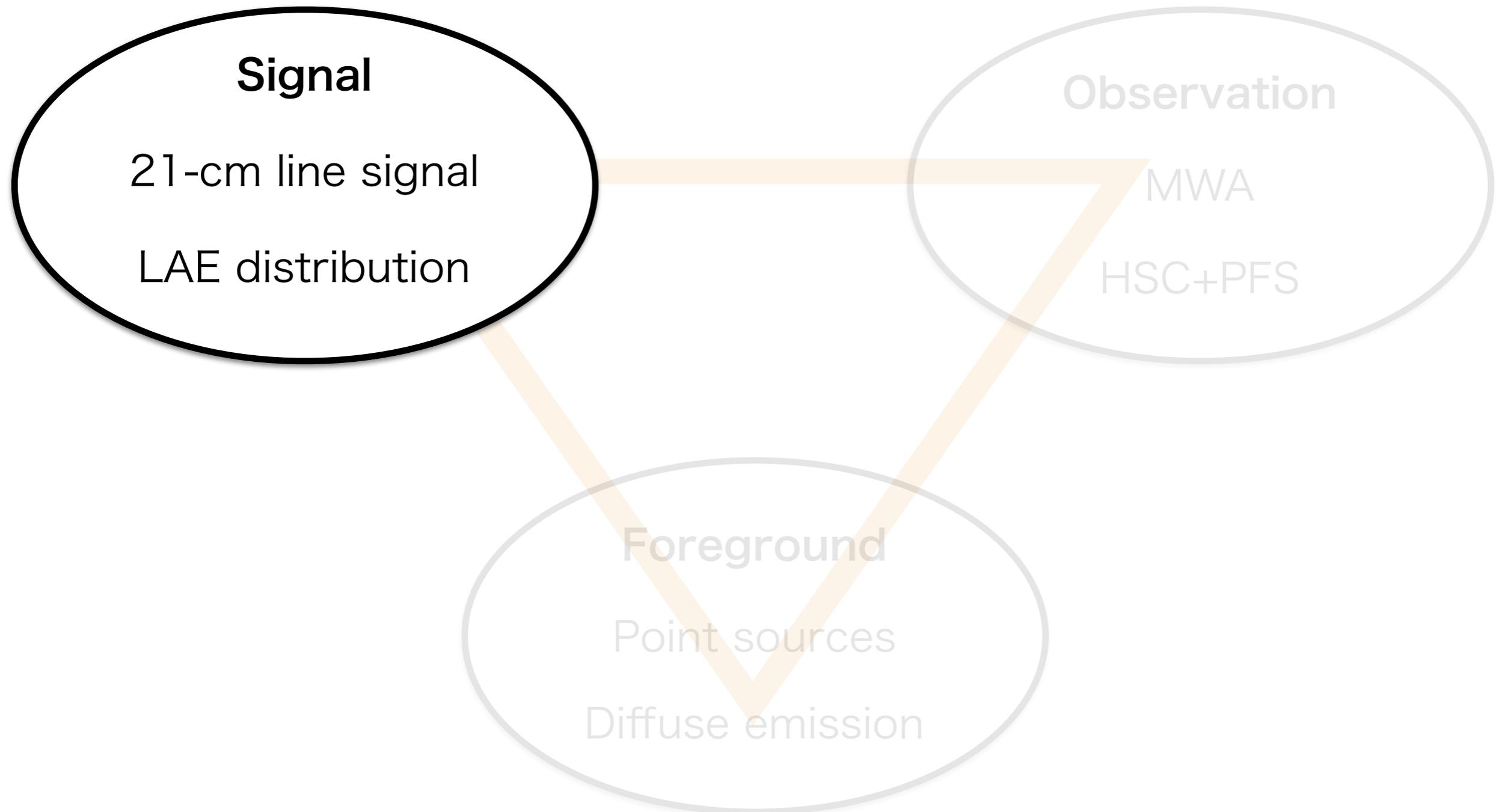


Diffuse emission

A parametric model of diffuse emission from our Galaxy
(Jelic et al 2008, Trott et al 2016)

$$P_{\text{FG,D}} = (\eta T_{\text{FG,D}})^2 \left(\frac{u}{u_0} \right)^{-2.7} \left(\frac{\nu}{\nu_0} \right)^{-2.55}$$

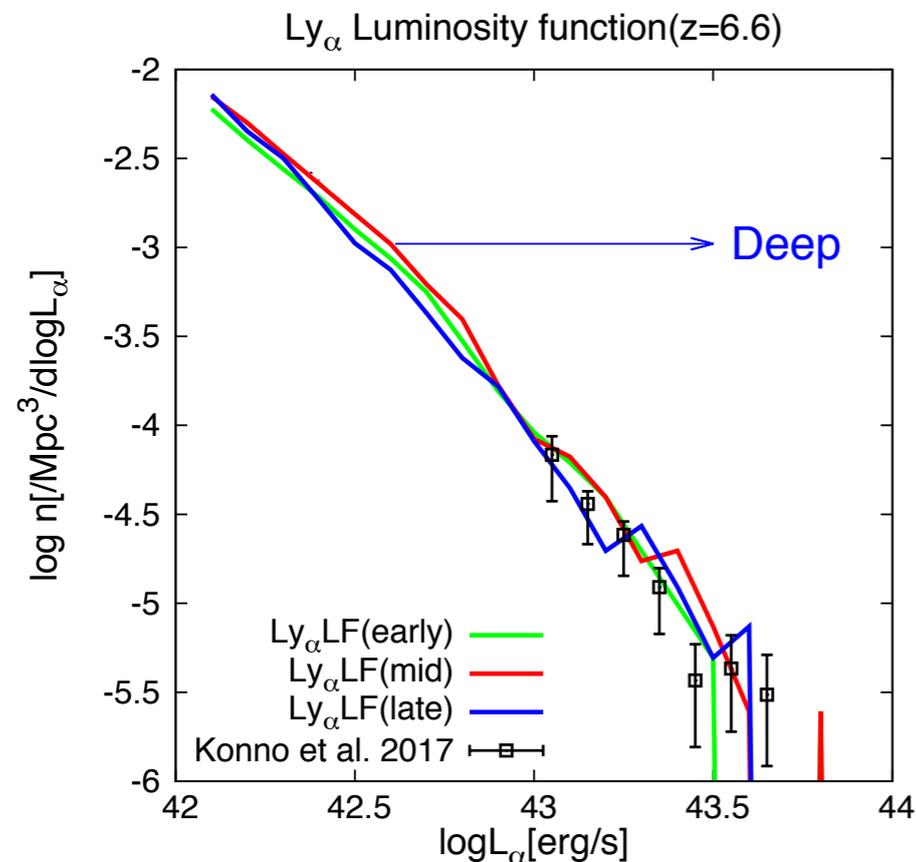
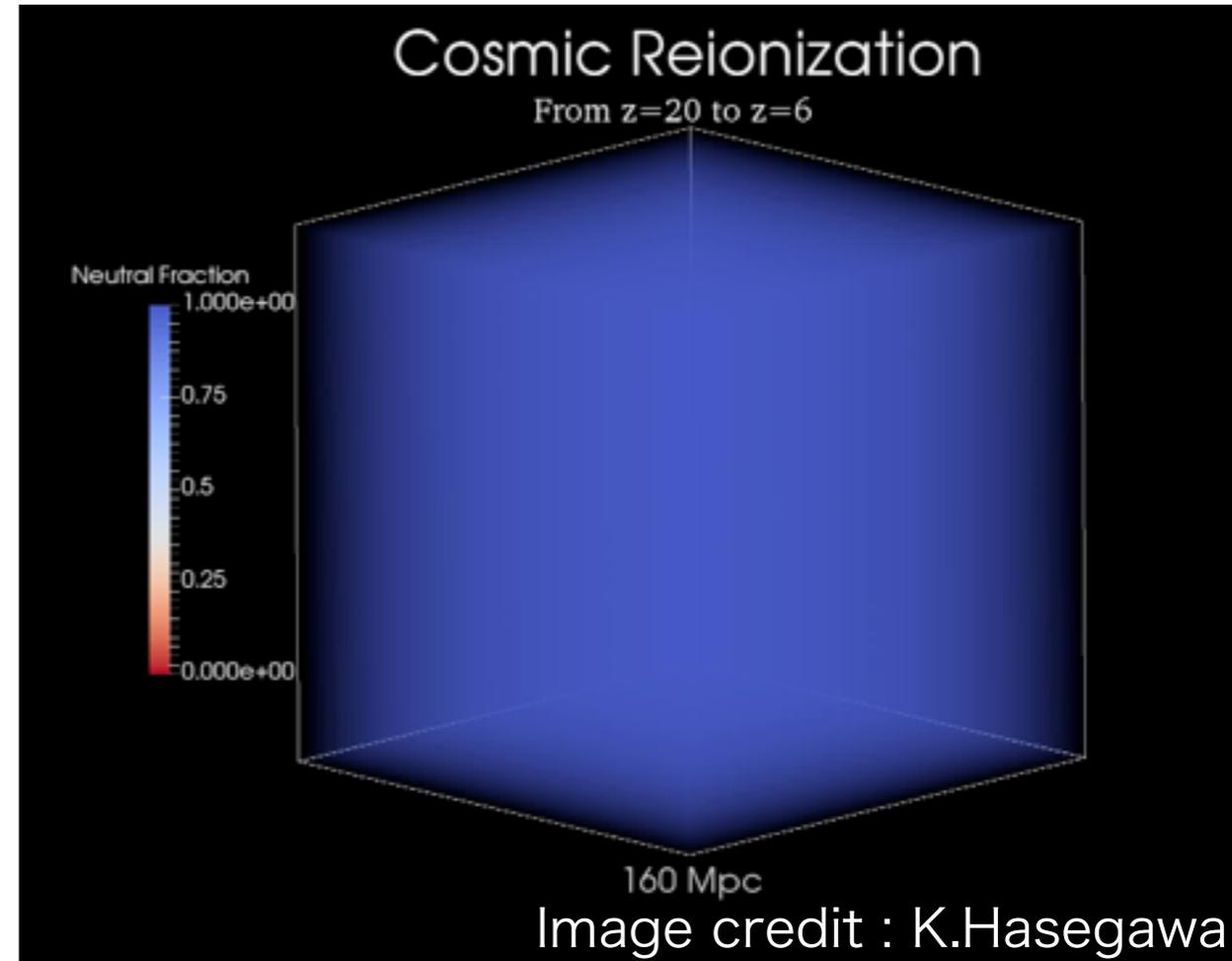
To estimate the detectability of 21cm-LAE CPS



Signal

Reionization & 21cm signal

(160Mpc)³ box, 256³ grids
N-body simulation (4096³ particles)
+
Sub-grid model based on RHD sim
+
Large scale RT simulation
Simulated by K.Hasegawa



LAE distribution

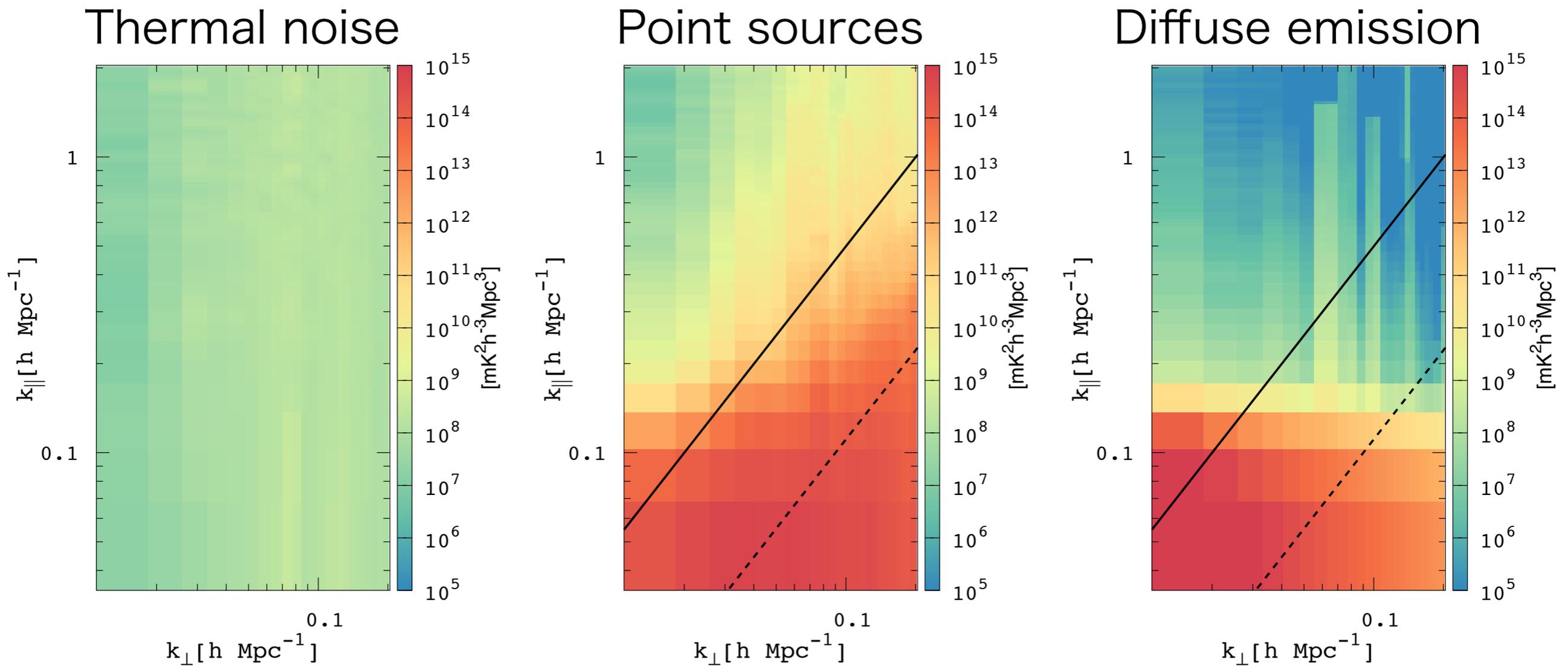
Lyman- α transmission (Yajima et al 2017)
Set parameters so that the simulated LF corresponds to observation in Konno et al 2017

Results

MWA noise, Foregrounds

The 2D power spectrum

Reduce foreground contamination in EoR window



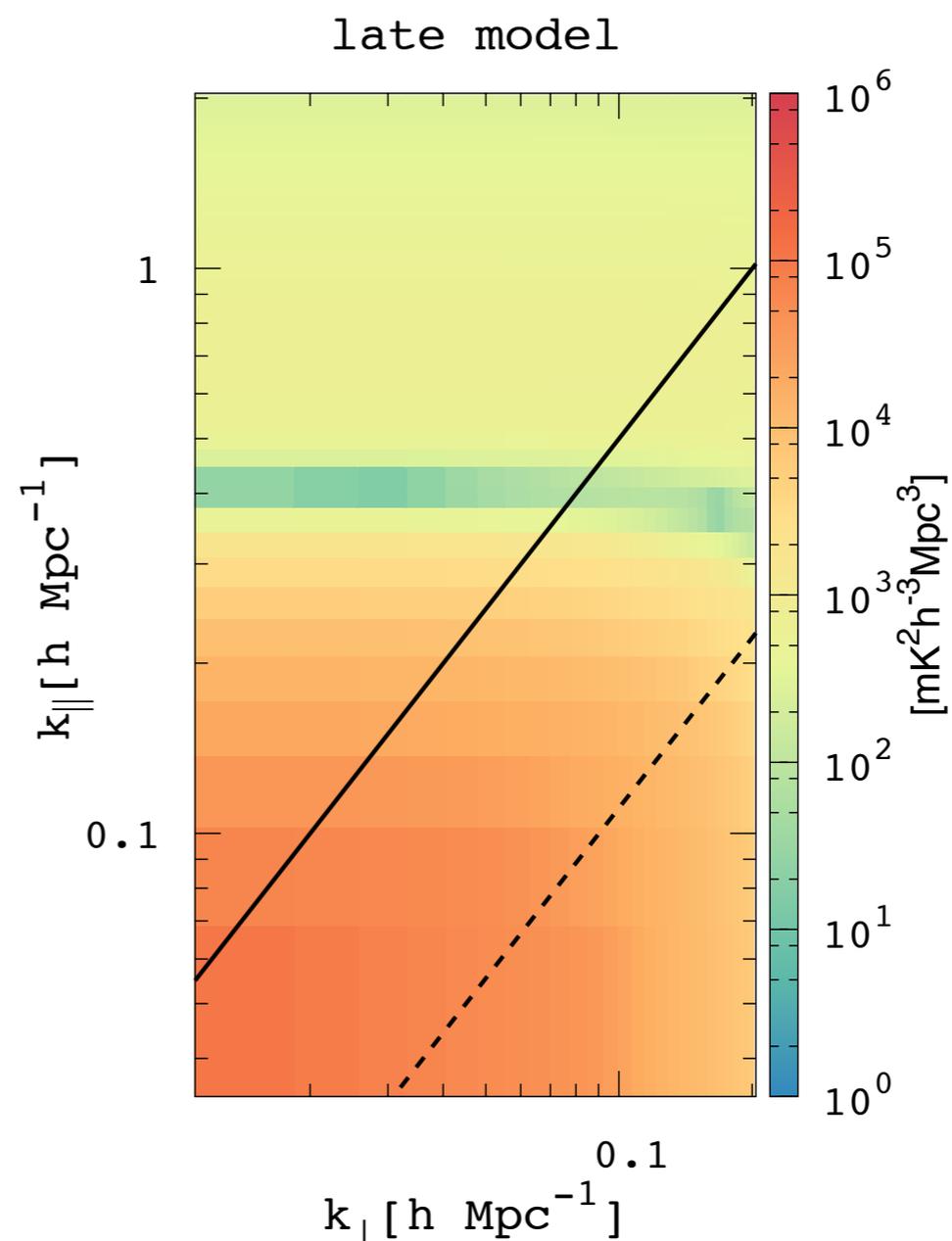
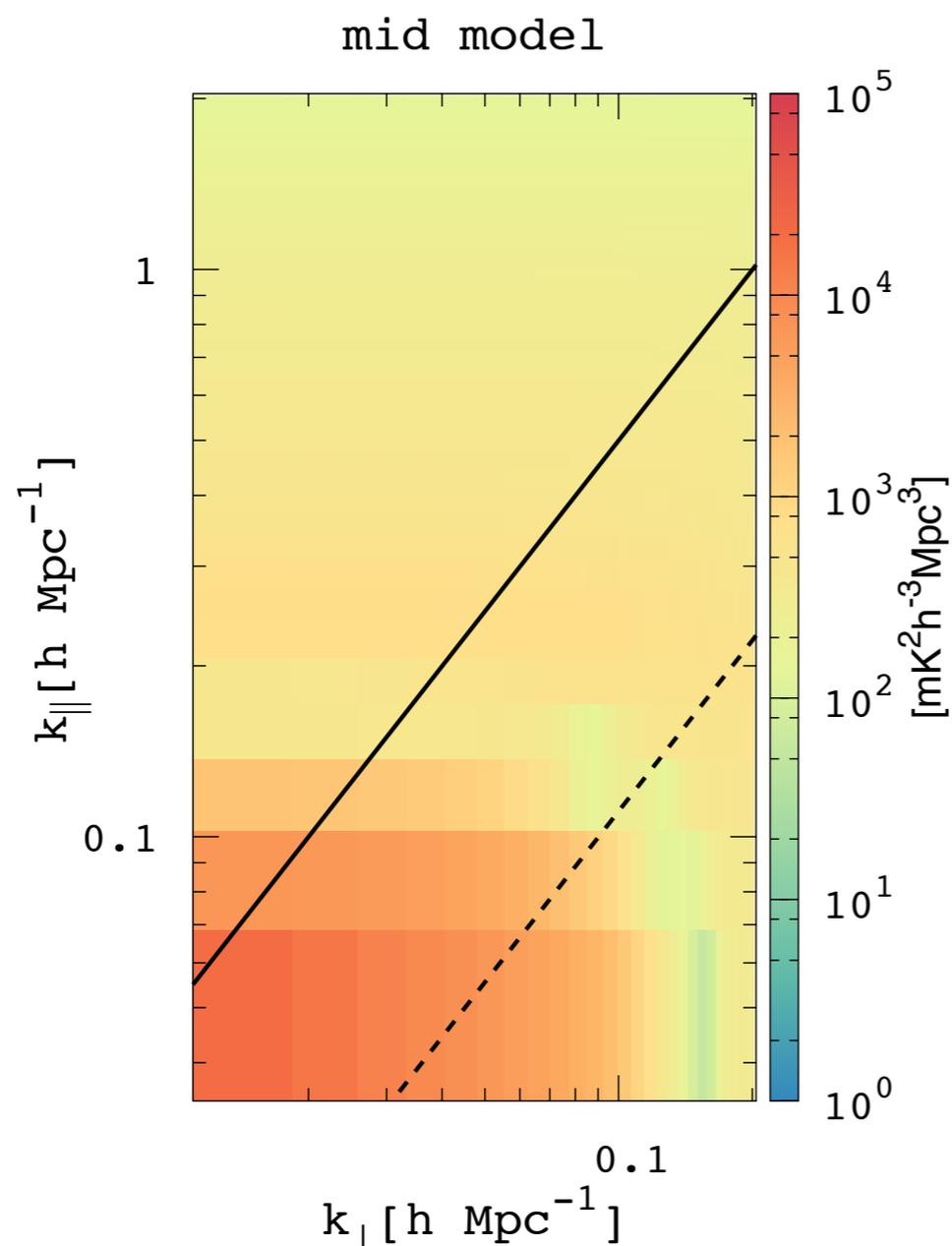
21cm-LAE cross power spectrum (CPS)

Two models ($z=6.6$)

Mid $x_{\text{HI}} = 0.017$, Late $x_{\text{HI}} = 0.44$

CPS is negative at large scales and positive at small scales.

The green lines indicate sign transition.



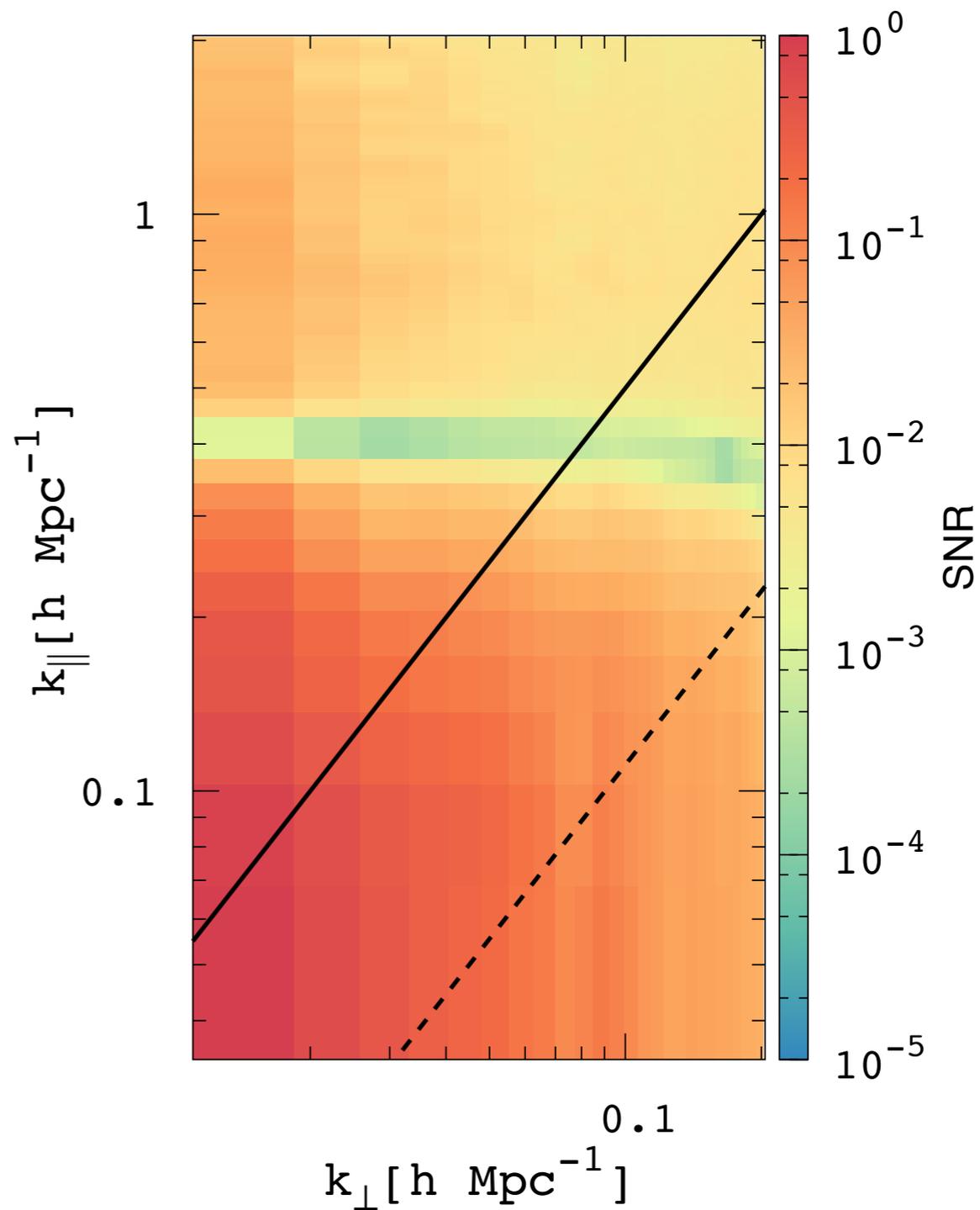
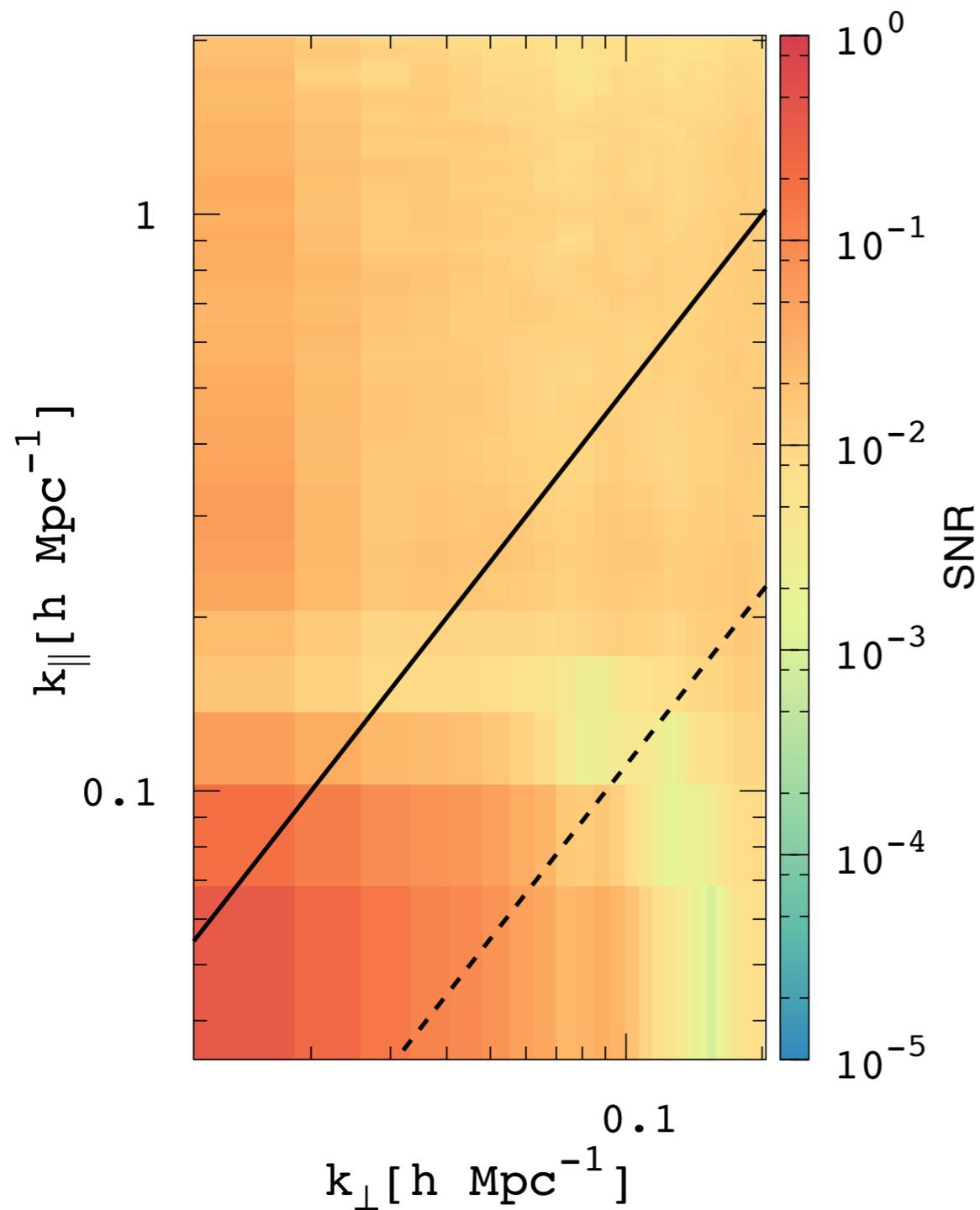
Signal to Noise Ratio without the foreground

Mid

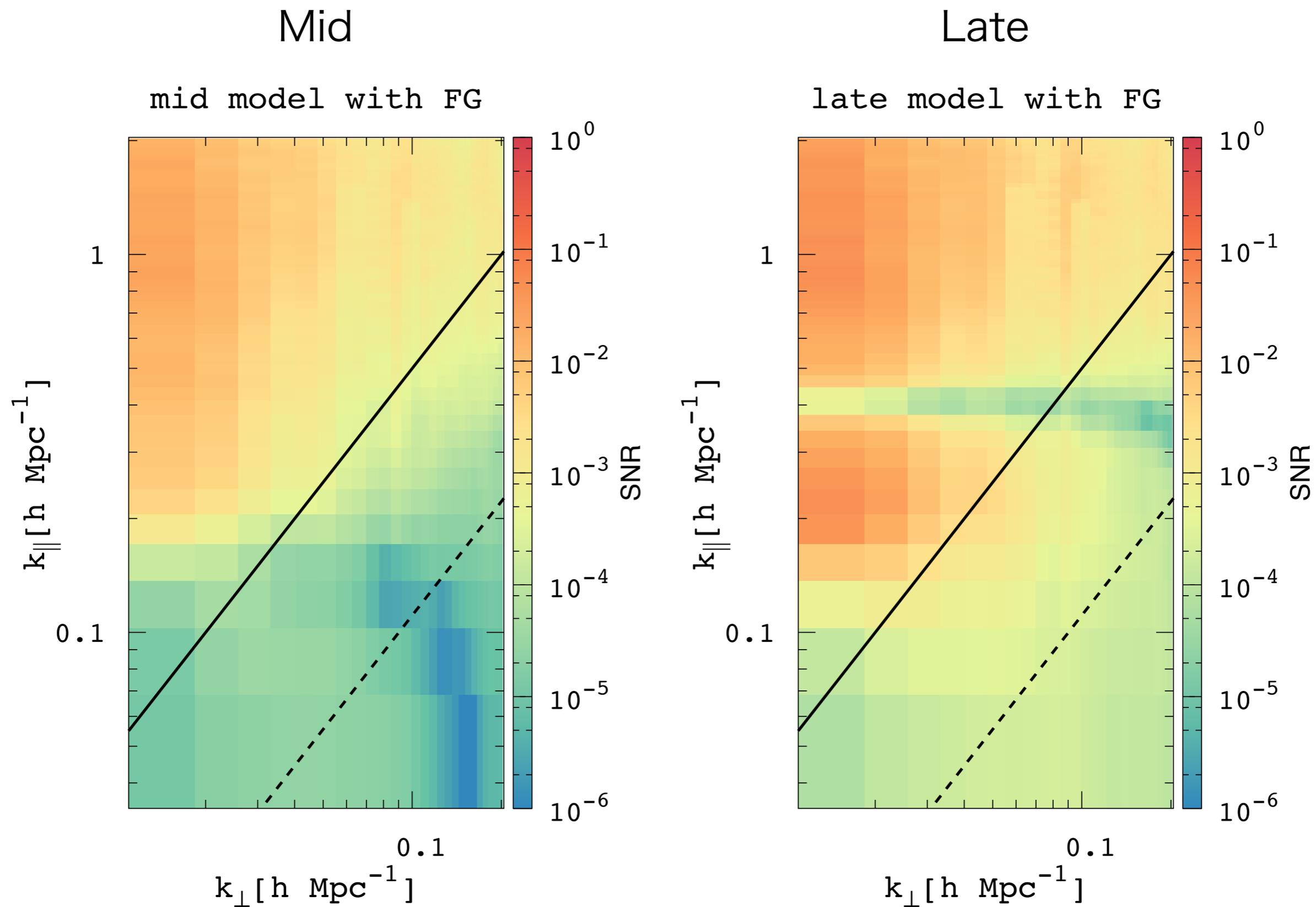
Late

mid model without FG

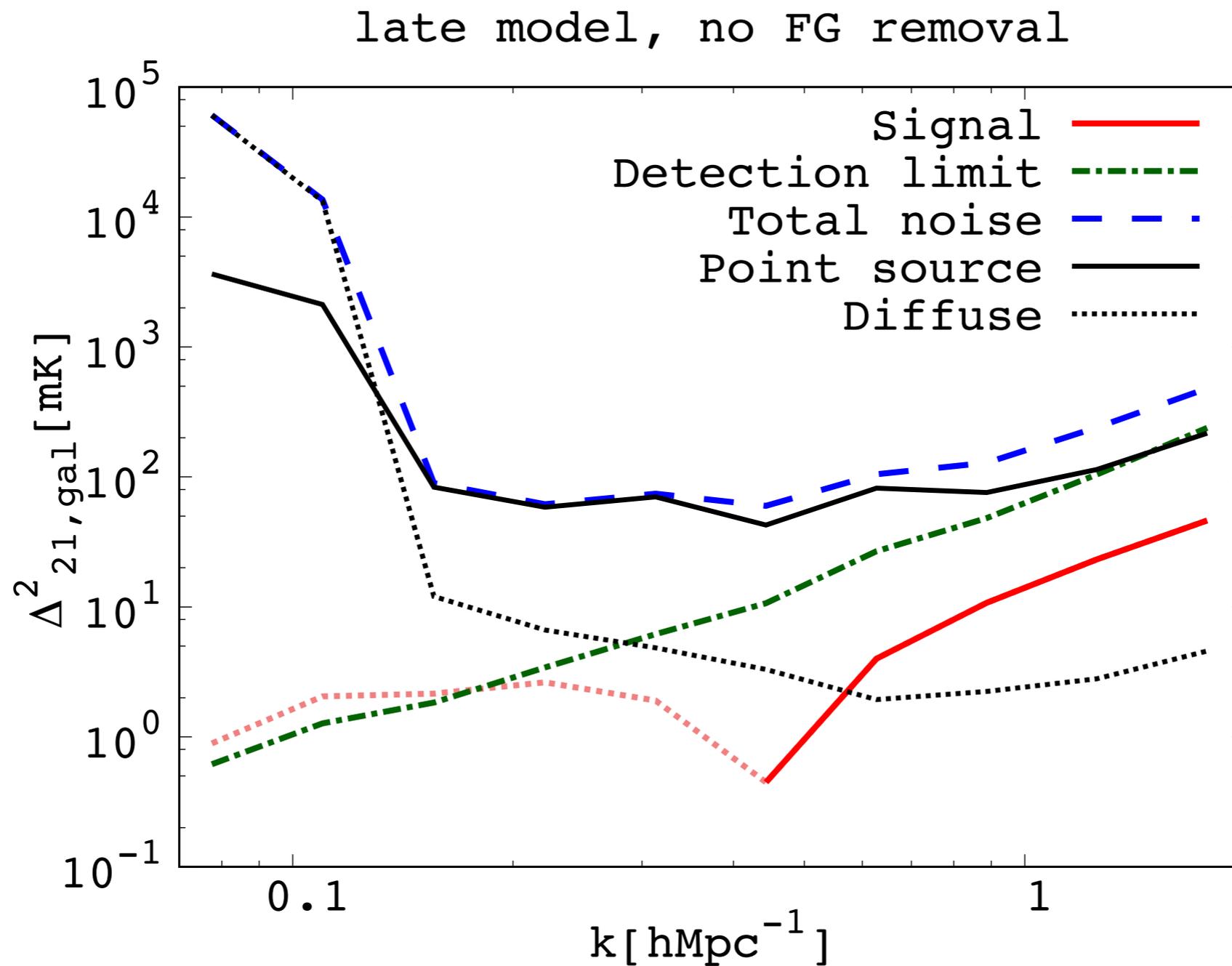
late model without FG



Signal to Noise Ratio with the foreground



1D power spectrum



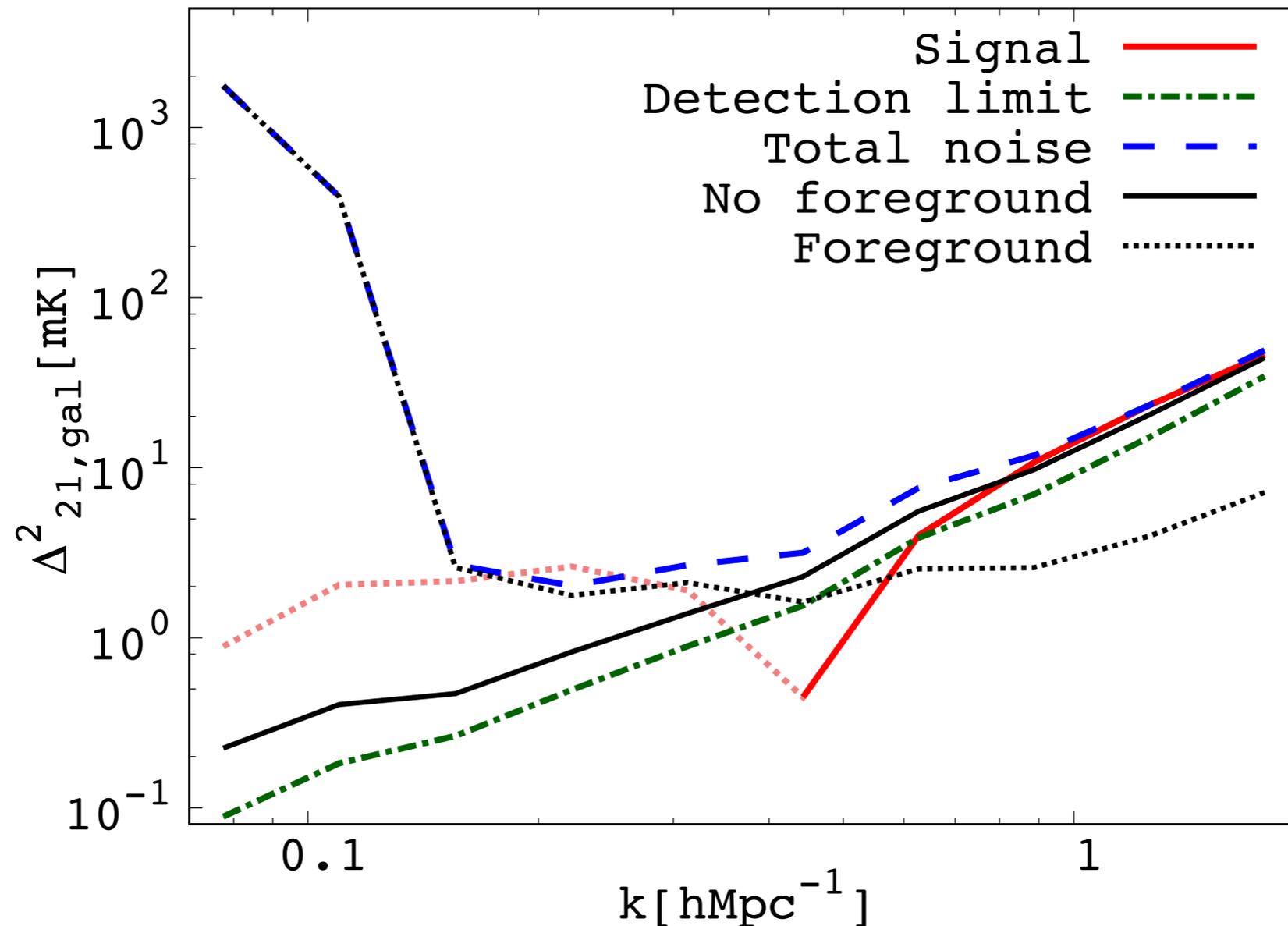
1D power spectrum

calculated from 2D power spectrum without wedge

Detection limit : thermal noise * shot noise

Requirement

late model, 95% FG removal, MWA512tile, $3V_{\text{sur}}$



Subtract astrophysical foregrounds (95%) +
16times higher sensitivity (MWA 512 tiles) +
Extending LAE survey area (3 times $\sim 81 \text{ deg}^2$)

Summary

As anticipated, foreground is dominant term of error. Even in the case of SKA-HSC+PFS, it's difficult to measure the 21cm-LAE power spectrum without FG removal.

In order to measure the 21cm-LAE power spectrum, at least,

- remove 95% of astrophysical foreground
- sensitivity of 21cm observation 16 times higher than MWA
- extent survey area as 3 times as HSC

Future work

Including systematic problems such as coarse band of MWA, calibration and instrumental error, ionosphere, and more.