The effect of the error on the visibility mask on 2-point and 4-point statistics of clustering

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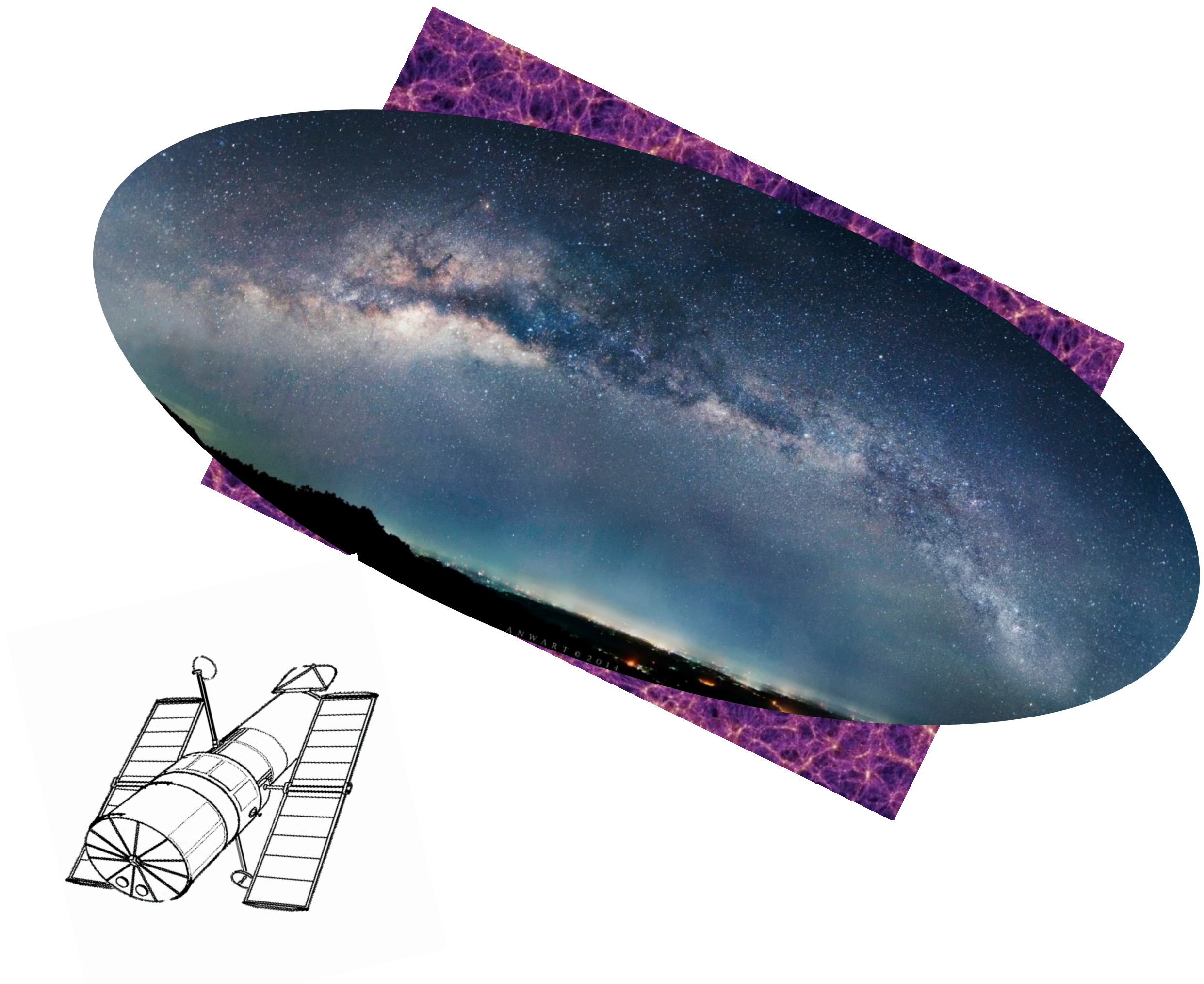
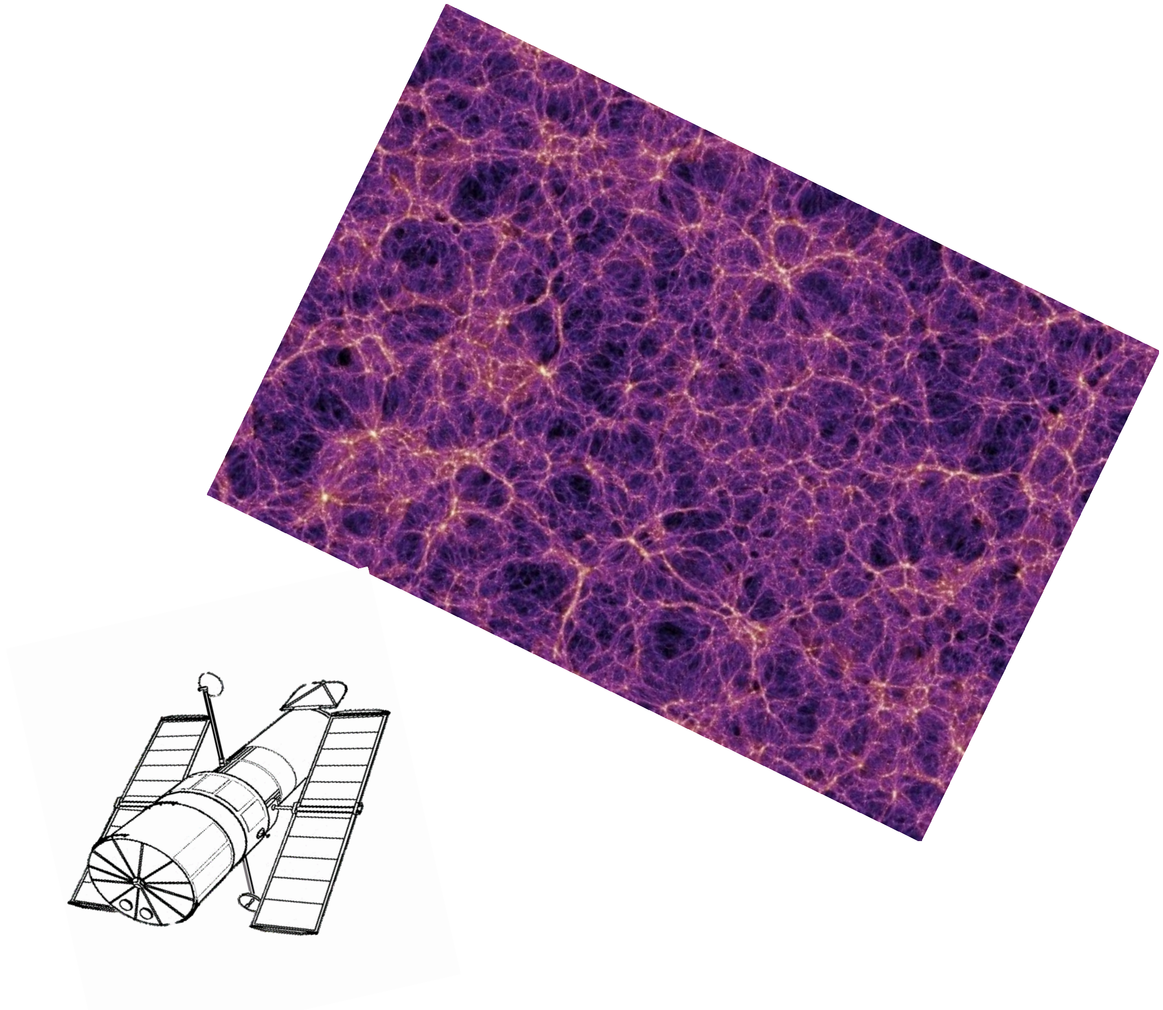
The Big Picture

- The limiting magnitude of a galaxy sample is modulated by foregrounds



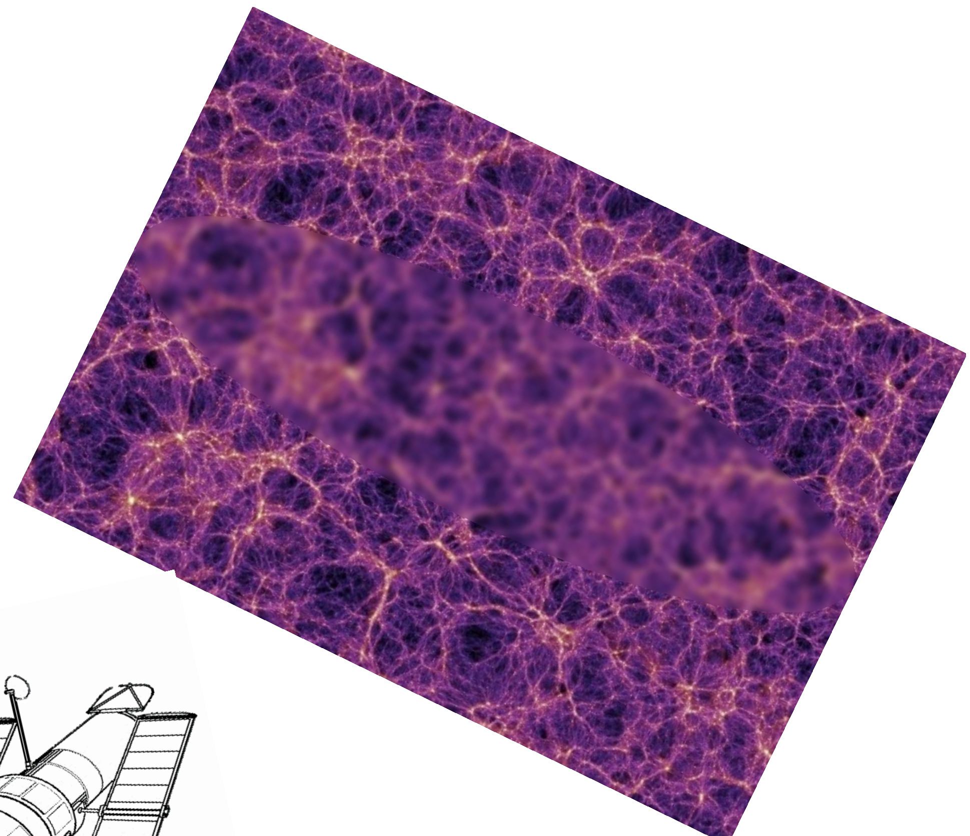
The Big Picture

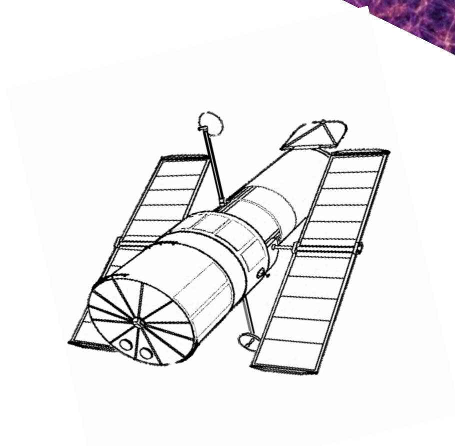
- Cosmological measurement is obtained subtracting the foreground



The Big Picture

- This subtraction is subject to an uncertainty and the residual foreground will be correlated on the sky and will create structure on large scales





Why is it important ?

For next future surveys the precision requirements will be very high and the effects to study very faint:

- Non-Gaussianity induced by gravity
- Relativistic Effects
- Departures from the standard cosmological model
- . . .

Taking under control the error on these effects will require a strong control on foreground

➢ Foreground residual can mimic some of these effects

Purpose of the talk

- Give an idea of the analytic model to predict the effects of foreground on 2pt and 4pt statistics

- Description of a simple model for a generic mask

- Understanding the effect of the uncertainty of foreground subtraction on power spectrum covariance matrix using a simple model

Luminosity function and galaxy number density

$$n(\vec{x}, L) = n(\vec{x}) \cdot \phi(L)$$

Number density of galaxies with luminosity within [L,L+dL]

$$n(\vec{x}) = \bar{n}[1 + \delta(\vec{x})]$$

Simplified assumption:
Removes the mass-bias dependence

Assumptions:

$$< n(\vec{x}) > \longleftrightarrow \frac{1}{V} \int_V d^3\vec{x} \; n(\vec{x})$$

$$< \delta(\vec{x}) > = \frac{1}{V} \int_V d^3\vec{x} \; \delta(\vec{x}) = 0.$$

$$n_{obs}(\vec{x}) = \int_{L_0}^{+\infty} n(\vec{x}, L) dL = n(\vec{x})$$

$$\int_{L_0}^{+\infty} \phi(L) dL = 1$$

The limiting luminosity(L_0) of the galaxy sample changes because of:

- Zodiacal light
- Extinction due to our Galaxy

$$n_{obs}(\vec{x}) = \int_{L_0 + \delta L(\theta)}^{+\infty} n(\vec{x}, L)\, dL = n(\vec{x}) \int_{L_0+\delta L(\theta)}^{+\infty} dL\ \phi(L)$$

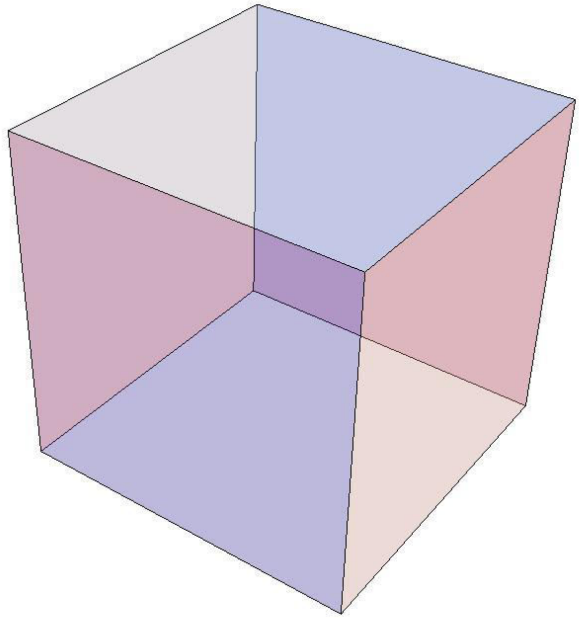
$$n_{obs}(\vec{x}) = n(\vec{x})[1 - A(\theta)]$$

$$\delta_{obs}(\vec{x}) = [1 - A(\theta)]\delta(\vec{x}) - A(\theta)$$

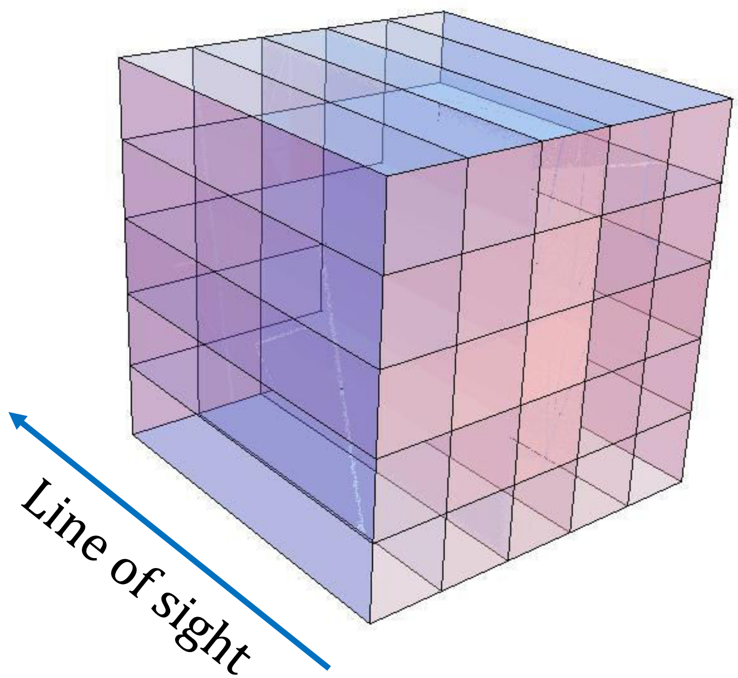
$$A(\theta) = \phi(L_0)\delta L(\theta)$$

→ For the theory part, $A(\theta)$ is a generic function acts like a generic mask

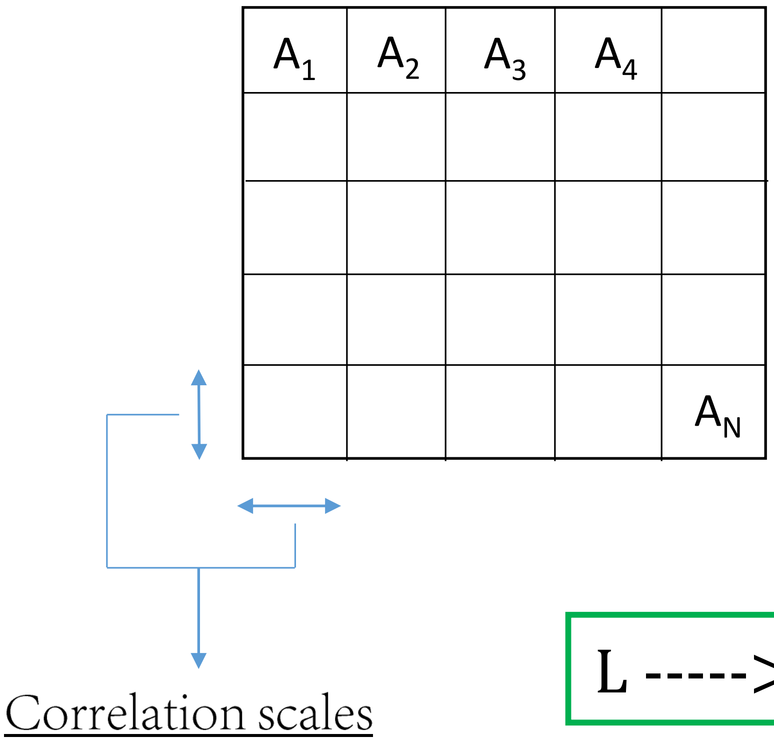
A simple model for the Mask



A simple model for the Mask



A simple model for the Mask

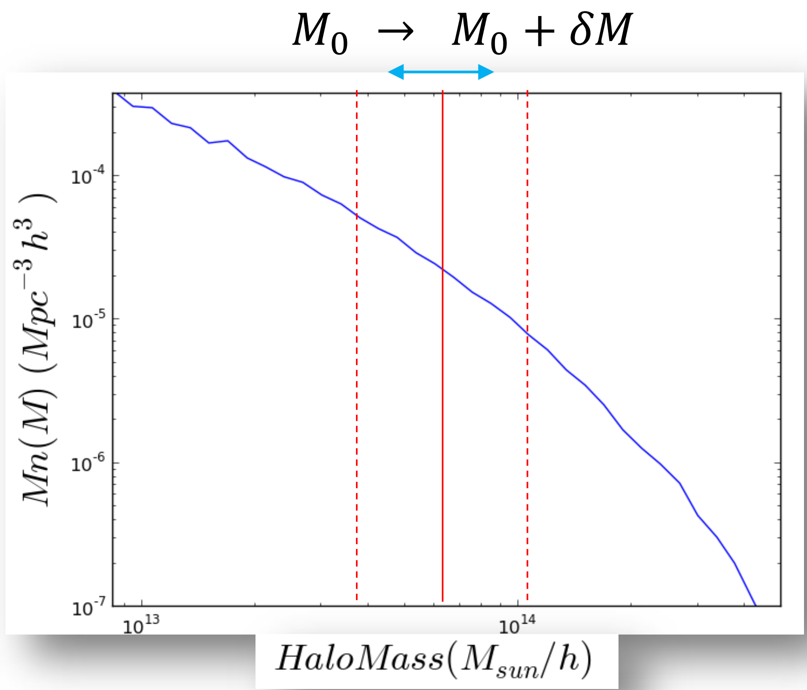


$$< A > = \frac{1}{N}\sum_{i=1}^{N} A_i = 0$$

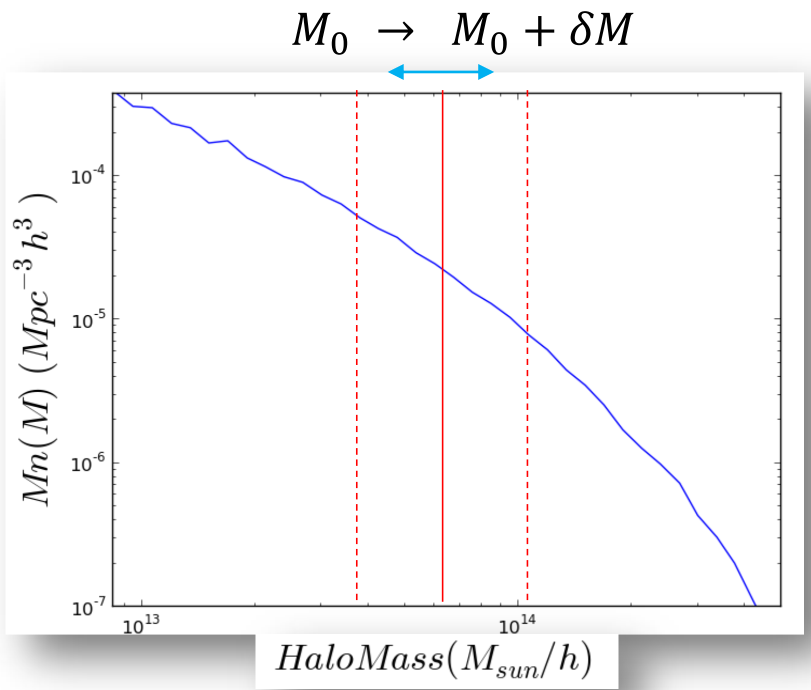
$$< A^2 > = 0.01, 0.05, 0.1, 0.2$$

L -----> Halo Mass M

$$A = \delta L \phi(L) \; \rightarrow \delta M \phi(M)$$



The presence of the mask will change the number of halos in the cosmological catalogue



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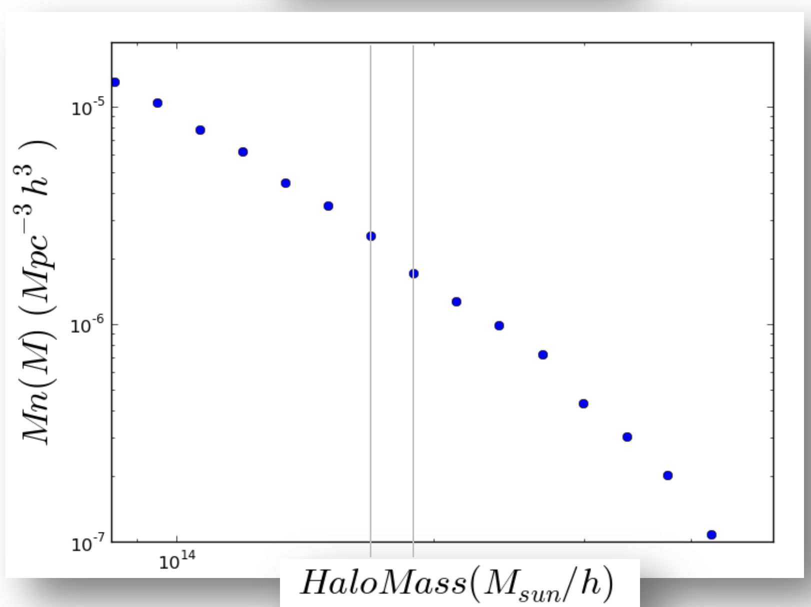
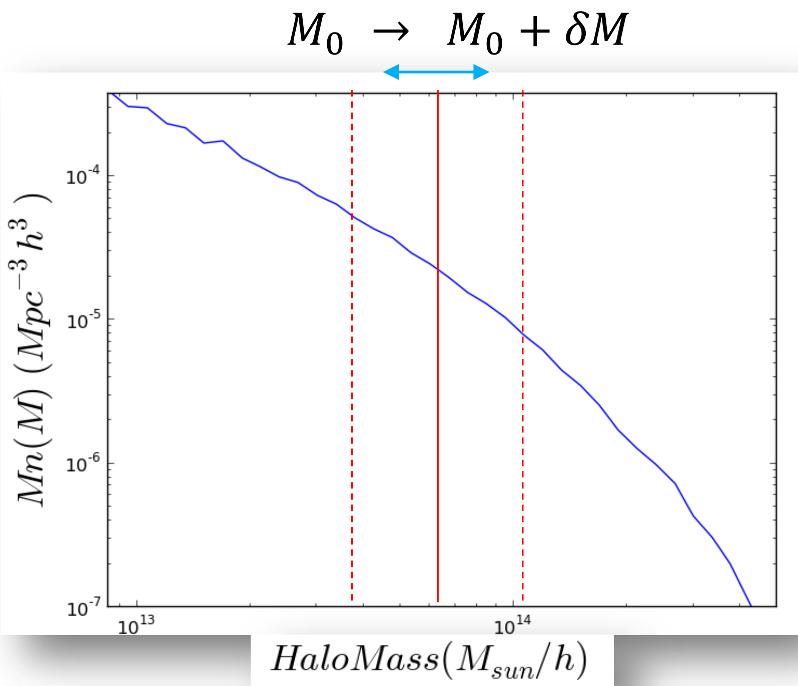
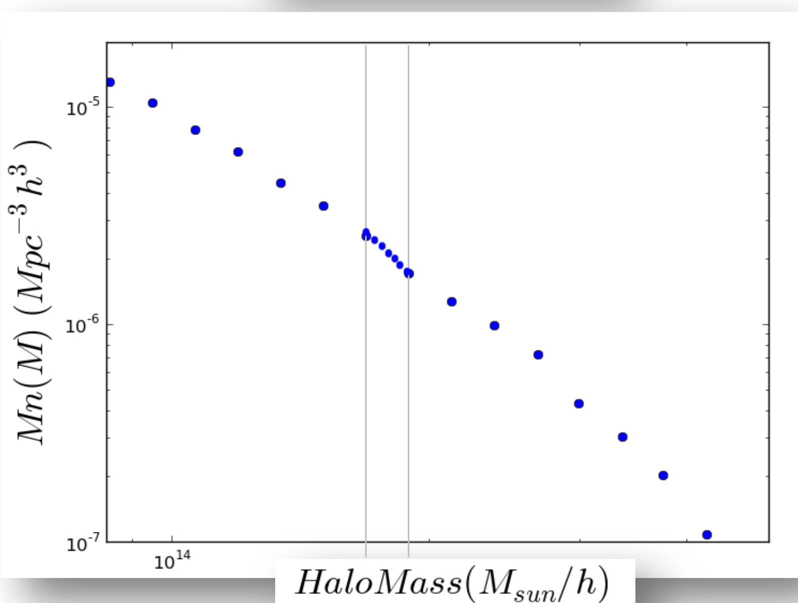


We need a criterion to decide which halos will be part of the new catalogue



The presence of the mask will change the number of halos in the cosmological catalogue

From discrete to continuous



- Construction of a mass distribution function to mimic the mass function

$$M_{new} = M_0 \left(1 + r\left(\left(\frac{N(M)+1}{N(M)}\right)^{\alpha} - 1\right)\right)^{1/\alpha}$$

- The Choice

$$If\ M_{new} > M_0 + \delta M(A)$$ ✔

Two-Point Statistics

-> Power Spectrum (PS)

$$\delta^{obs}(\vec{x}) = \delta(\vec{x}) - A(\vec{x}) - \delta(\vec{x})A(\vec{x})$$

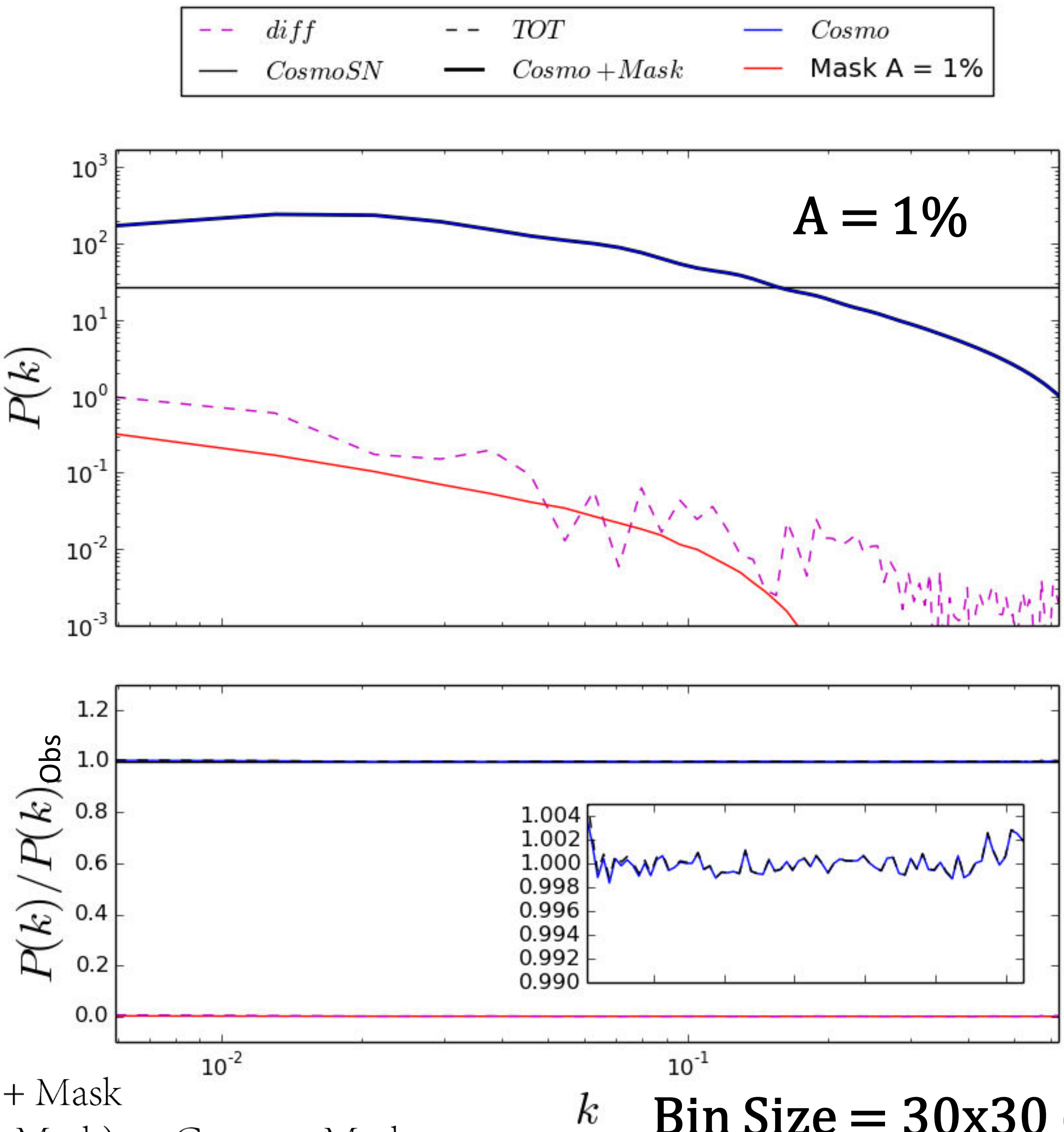
$$\delta^{obs}(\vec{k}) = \delta(\vec{k}) - A(\vec{k}) - \delta(\vec{k}) \otimes A(\vec{k})$$

Convolution product

$$< \delta^{obs}(\vec{k}_1)\delta^{obs}(\vec{k}_2) >= \delta_D(k_{12})P^{obs}(\vec{k}) =$$

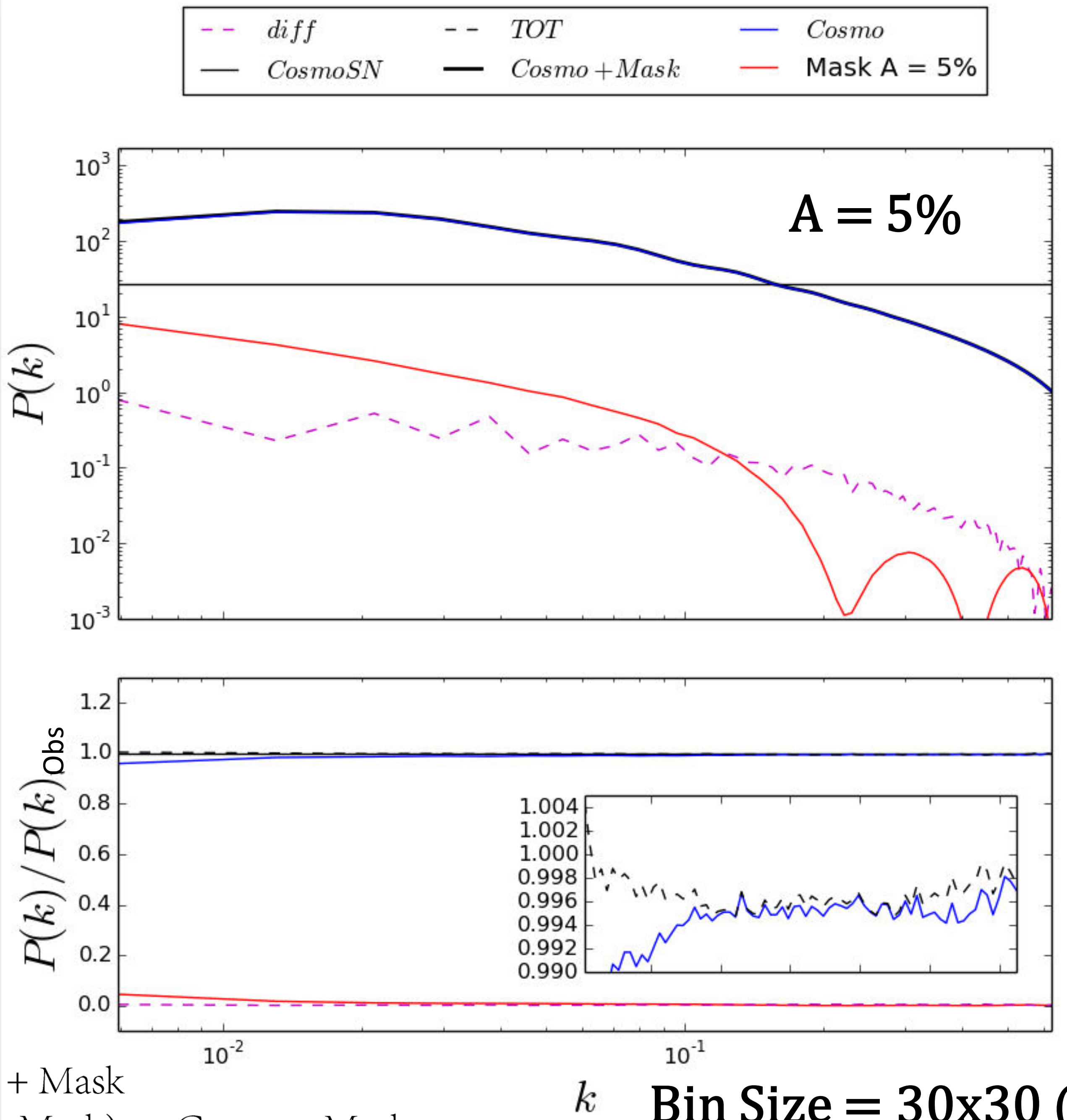
$$\delta_D(k_{12})\boldsymbol{P}(\boldsymbol{k_1}) + \delta_D(k_{12})\boldsymbol{P_A}(\vec{\boldsymbol{k}}_1) + \delta_D(\vec{k}_{12})\boldsymbol{P}(\boldsymbol{k_1}) \otimes \boldsymbol{P_A}(\vec{\boldsymbol{k}}_1)$$

$$P^{obs}(\vec{k}) = P(k) + P_A(\vec{k}) + P(k) \otimes P_A(\vec{k})$$



Bin Size = 30x30 (Mpc/h)²

TOT = Cosmo + Mask
Diff = (Cosmo+Mask) − Cosmo - Mask



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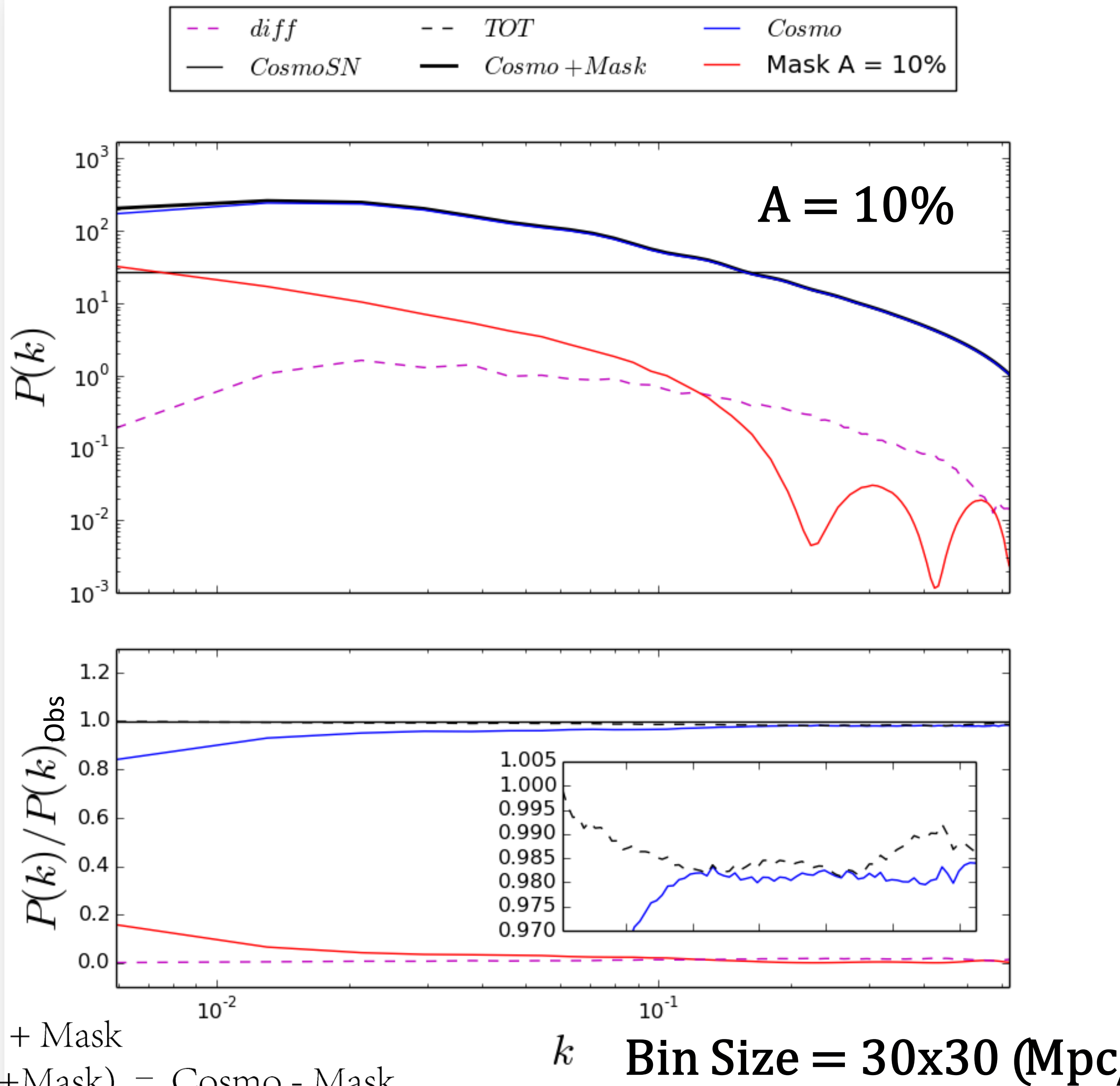

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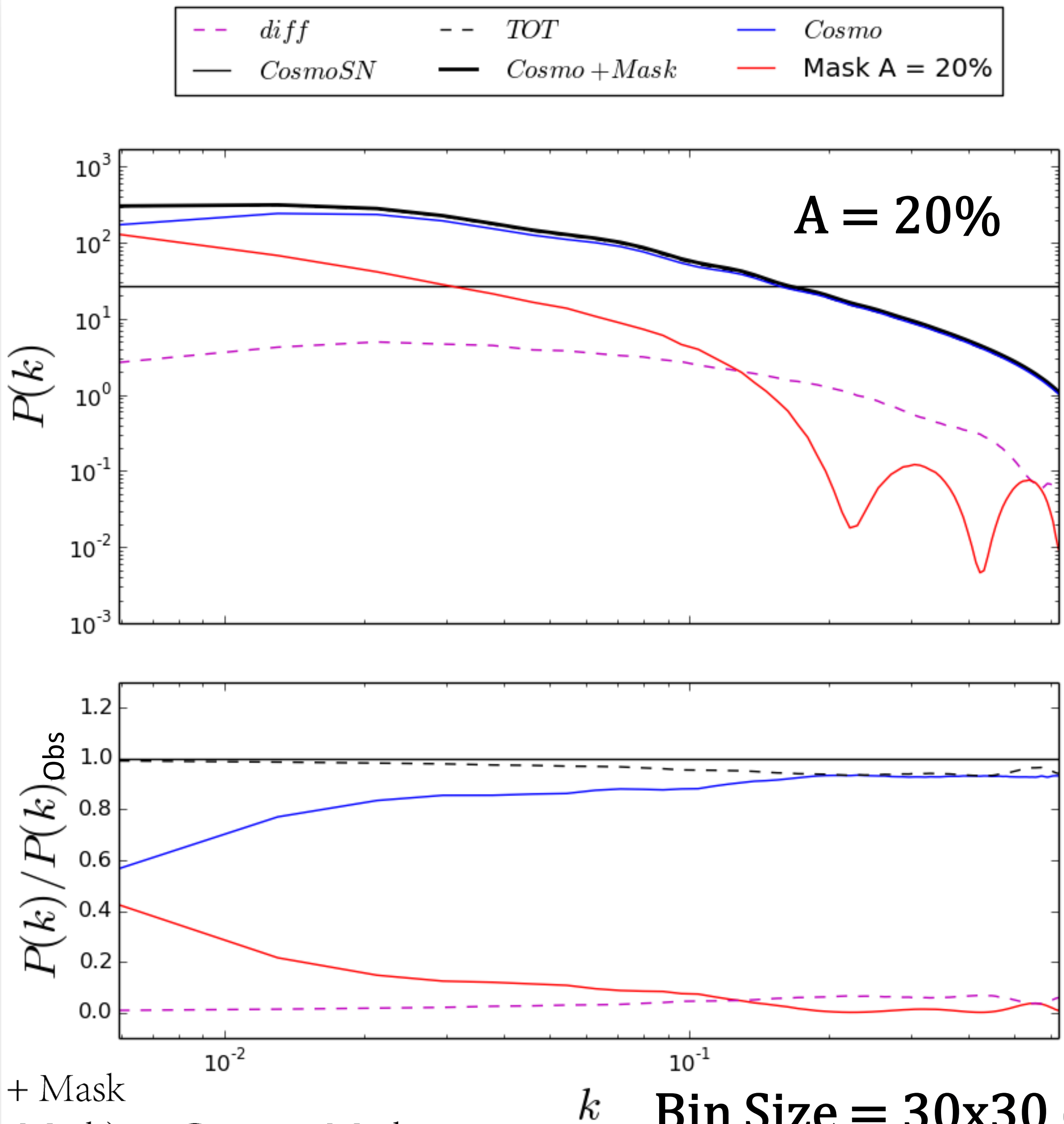
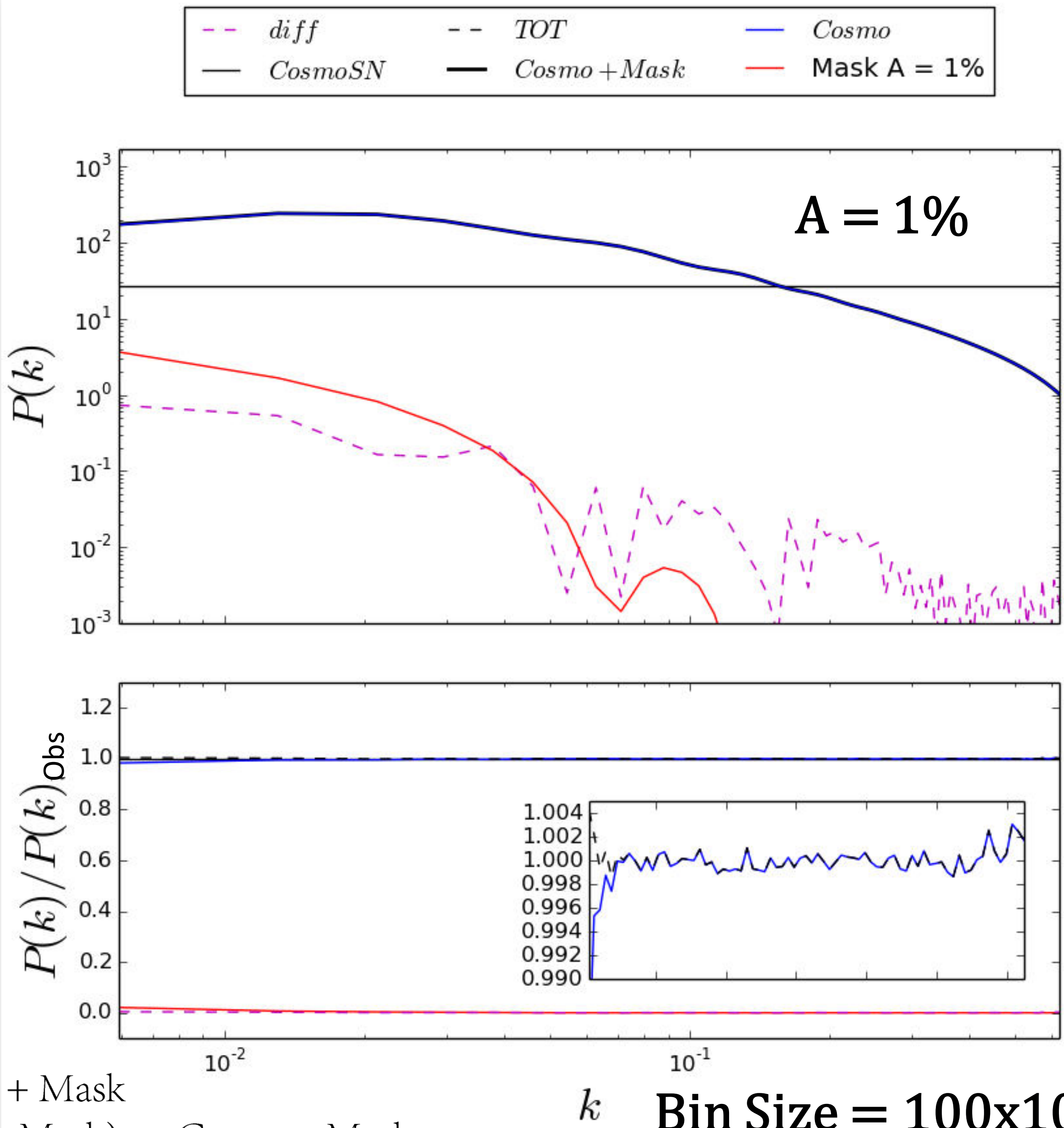
Bin Size = 30x30 (Mpc/h)^2



TOT = Cosmo + Mask

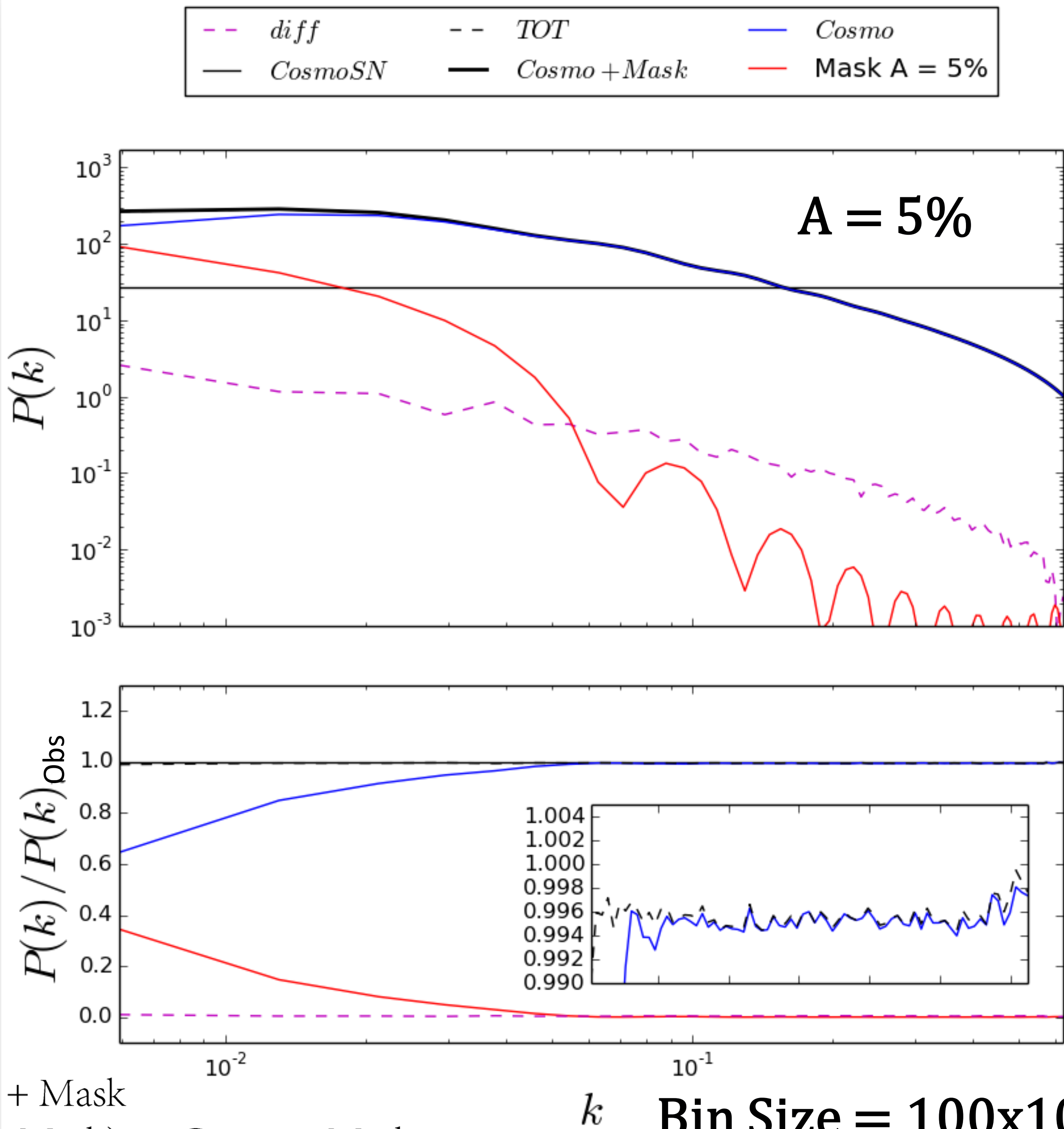
Diff = (Cosmo+Mask) − Cosmo - Mask

Bin Size = 30x30 $(\mathrm{Mpc/h})^2$



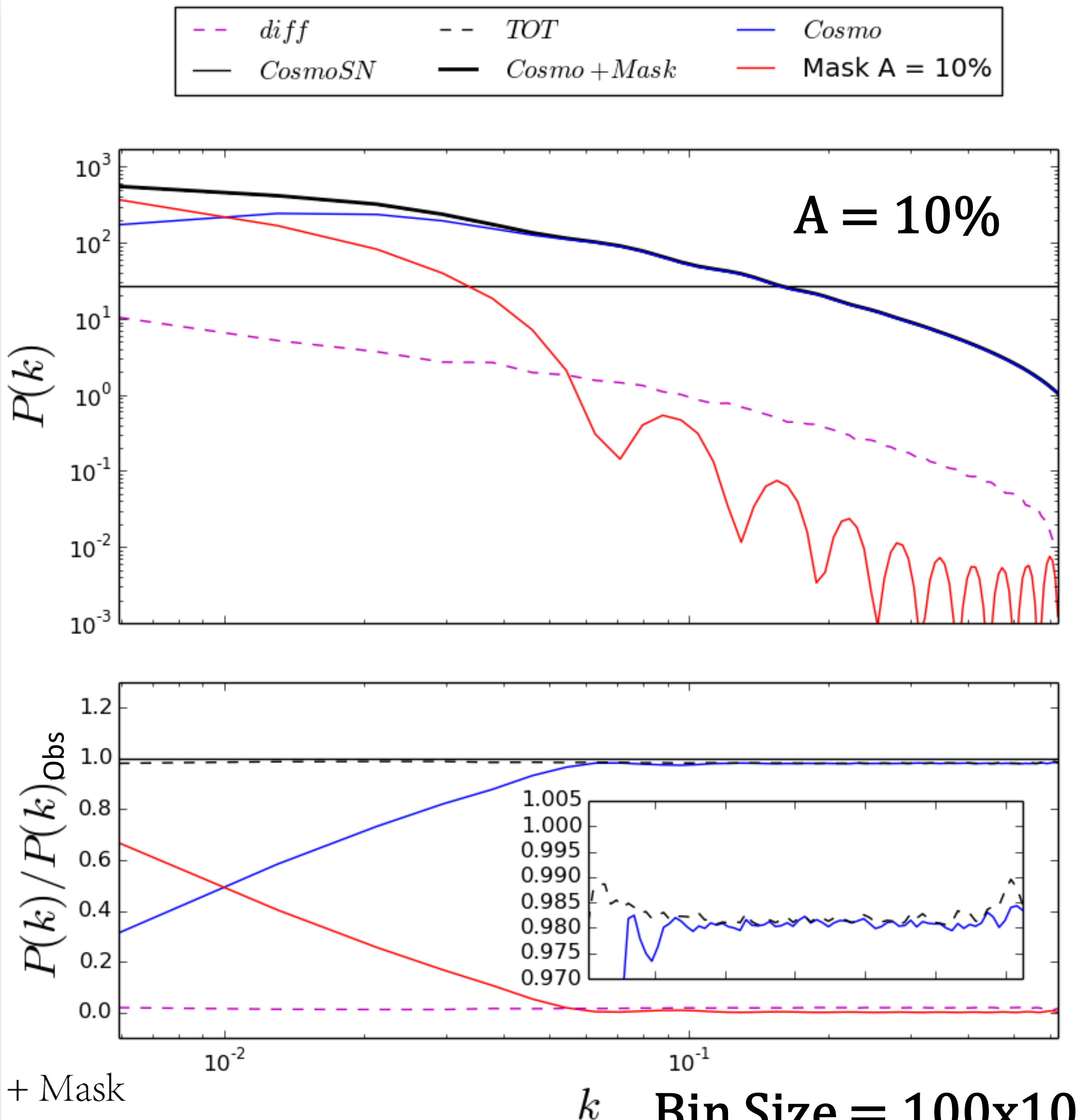
TOT = Cosmo + Mask
Diff = (Cosmo+Mask) − Cosmo - Mask

Bin Size = 100x100 (Mpc/h)²



TOT = Cosmo + Mask
Diff = (Cosmo+Mask) − Cosmo - Mask

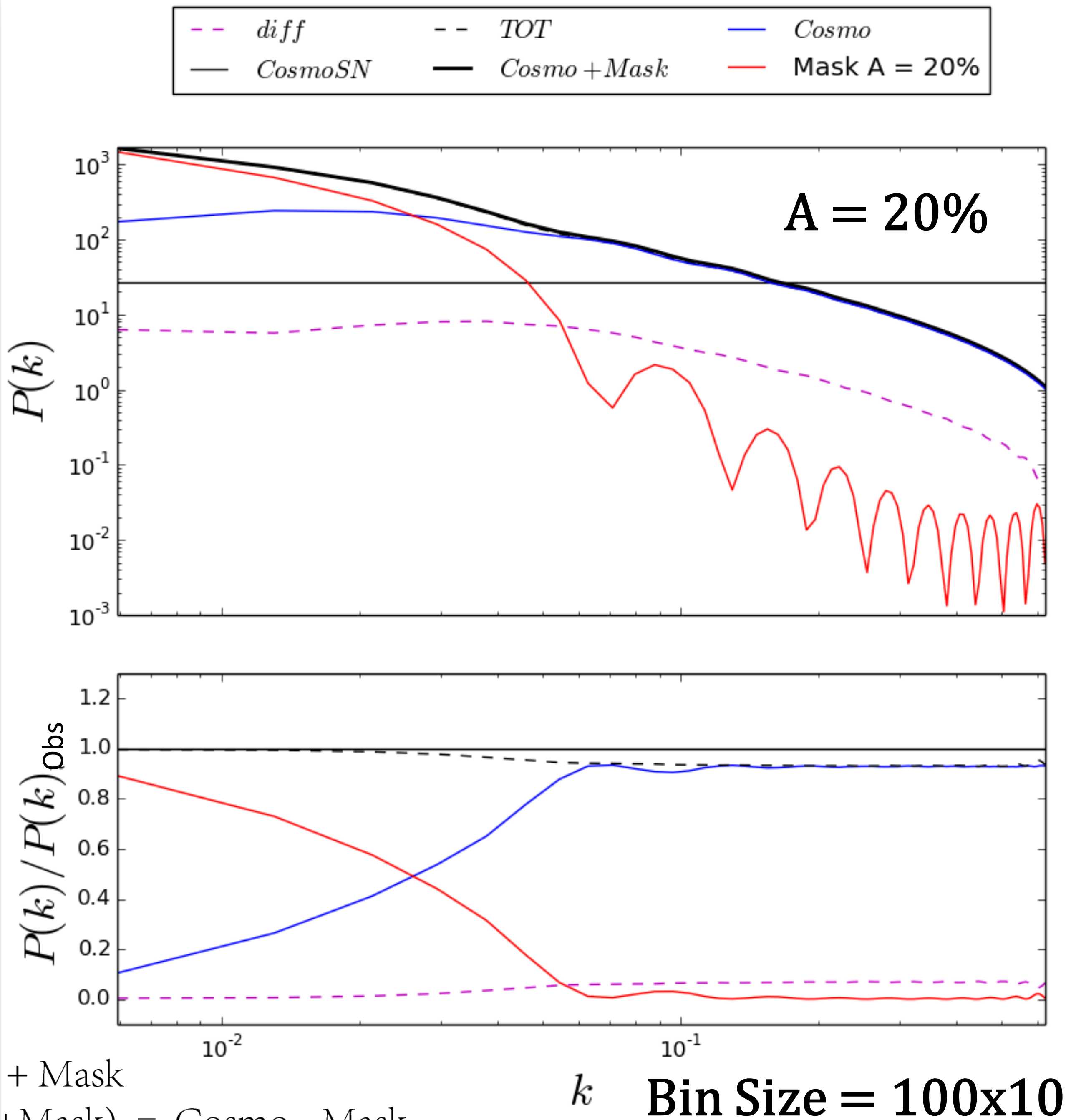
Bin Size = 100x100 (Mpc/h)^2



TOT = Cosmo + Mask

Diff = (Cosmo+Mask) − Cosmo - Mask

Bin Size = 100x100 (Mpc/h)²



TOT = Cosmo + Mask
Diff = (Cosmo+Mask) − Cosmo - Mask

Bin Size = 100x100 (Mpc/h)^2

Four-Points Statistics

-> PS Covariance

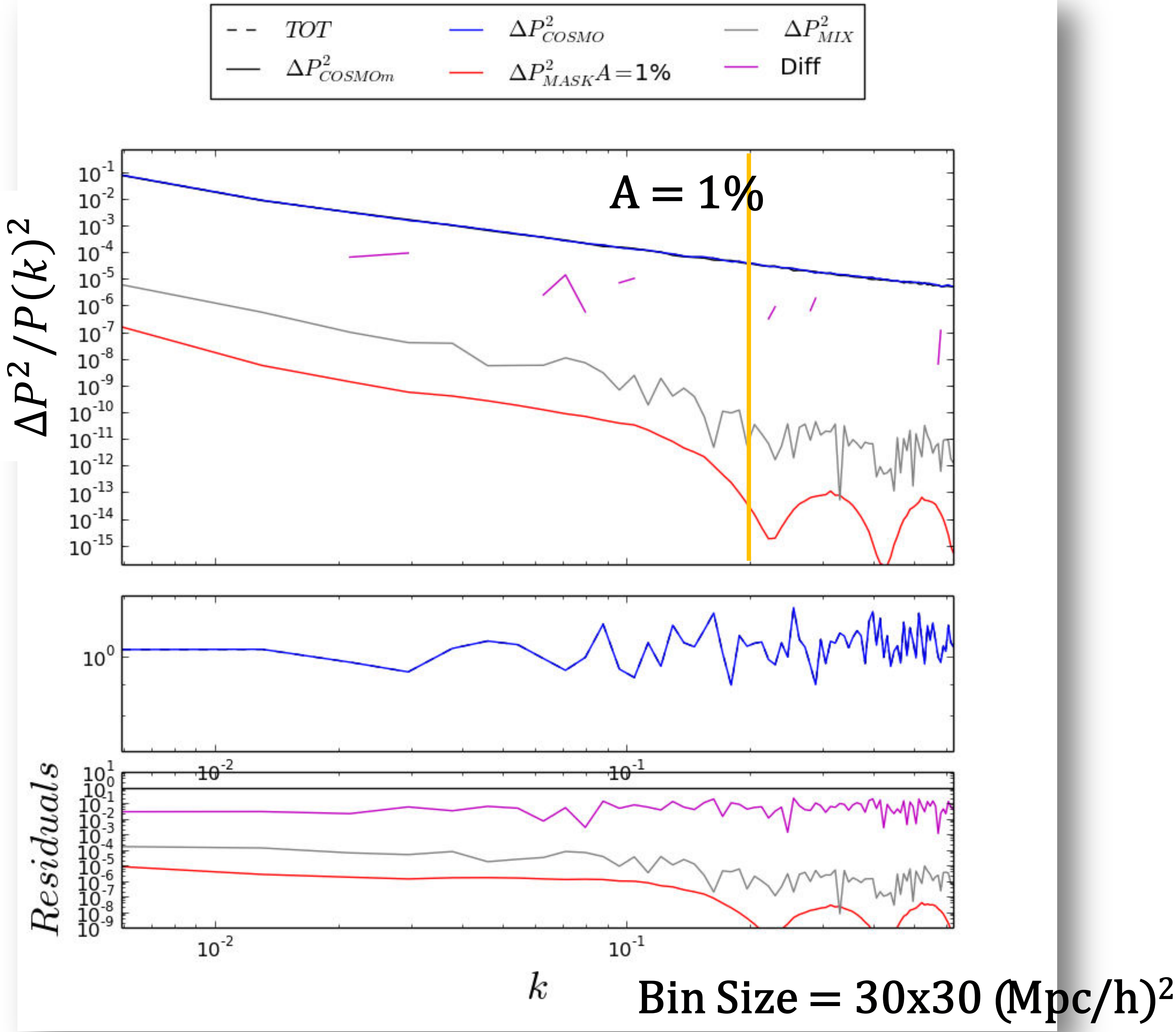
$$C\left(P^{obs}(\vec{k}_i), P^{obs}(\vec{k}_j)\right) = < P^{obs}(\vec{k}_i)P^{obs}(\vec{k}_j) > \; - < P^{obs}(\vec{k}_i) >< P^{obs}(\vec{k}_j) >$$

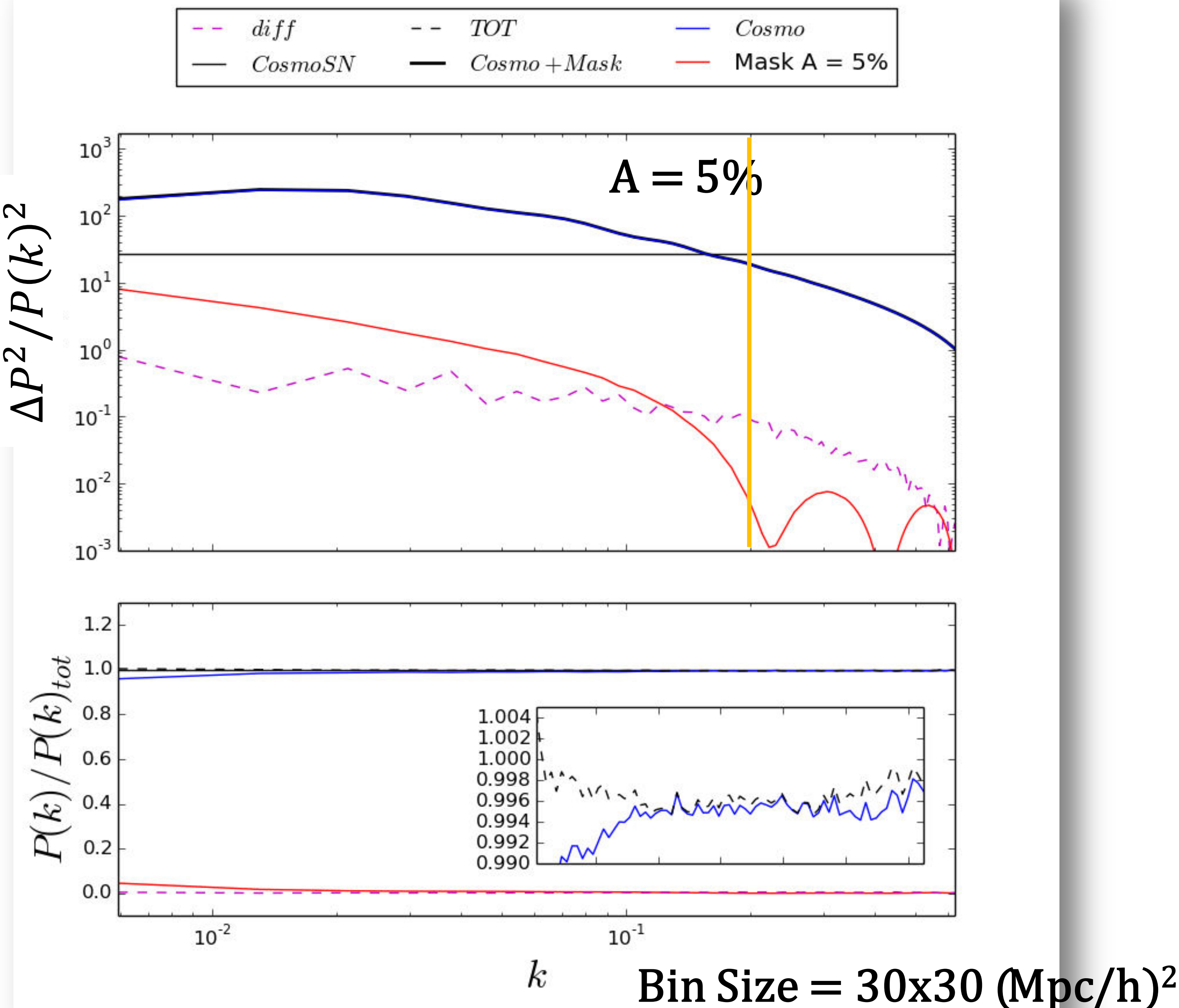
$$= C\left(P(\vec{k}_i)P(\vec{k}j)\right) + C\left(P_A(\vec{k}_i)P_A(\vec{k}_j)\right) + 2C\left(P(\vec{k}_i)P_A(\vec{k}_j)\right) + \textit{mix convolution terms}$$

Cosmology covariance

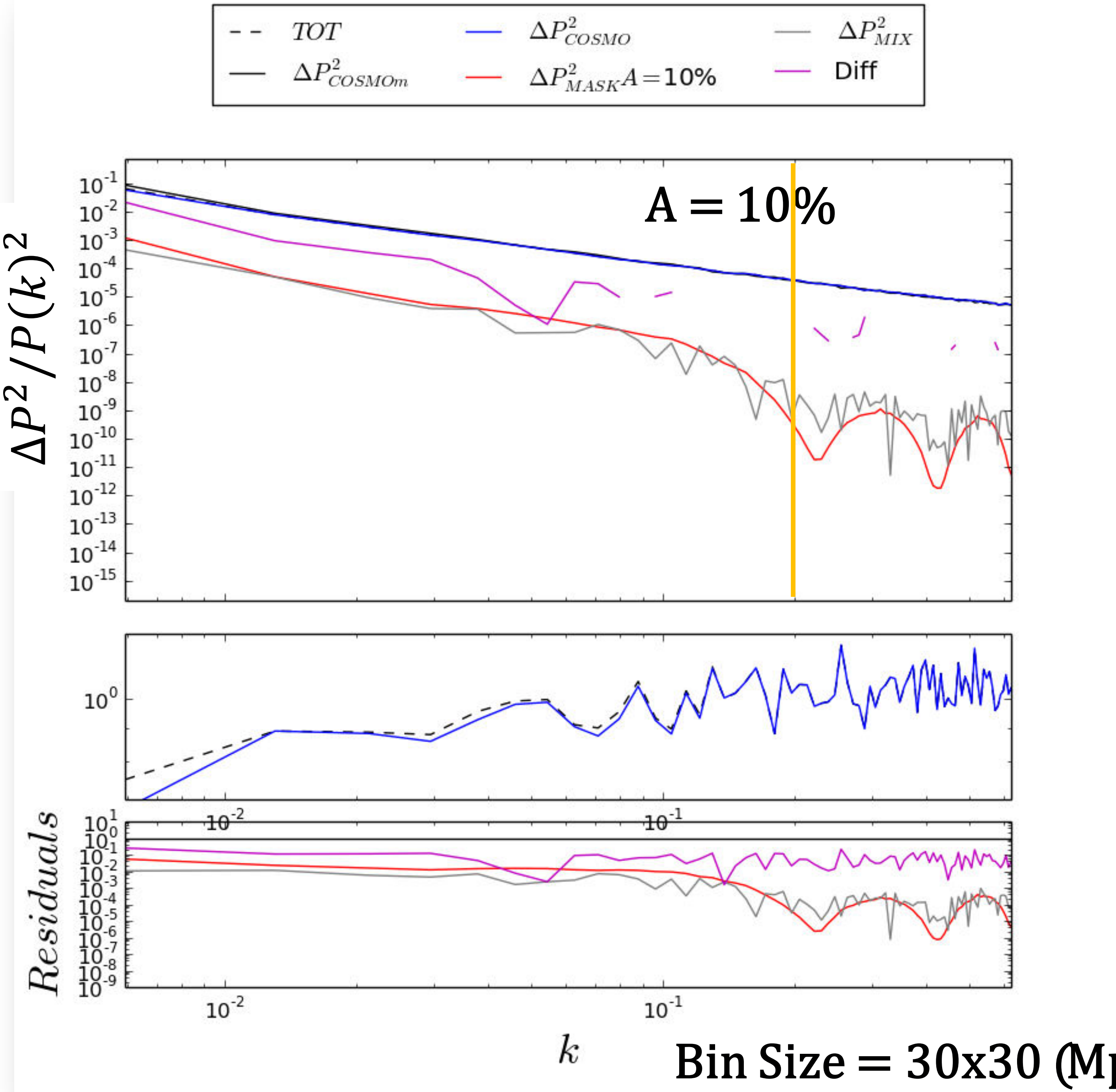
Pure Mask Covariance

Coupling Cosmology-Mask

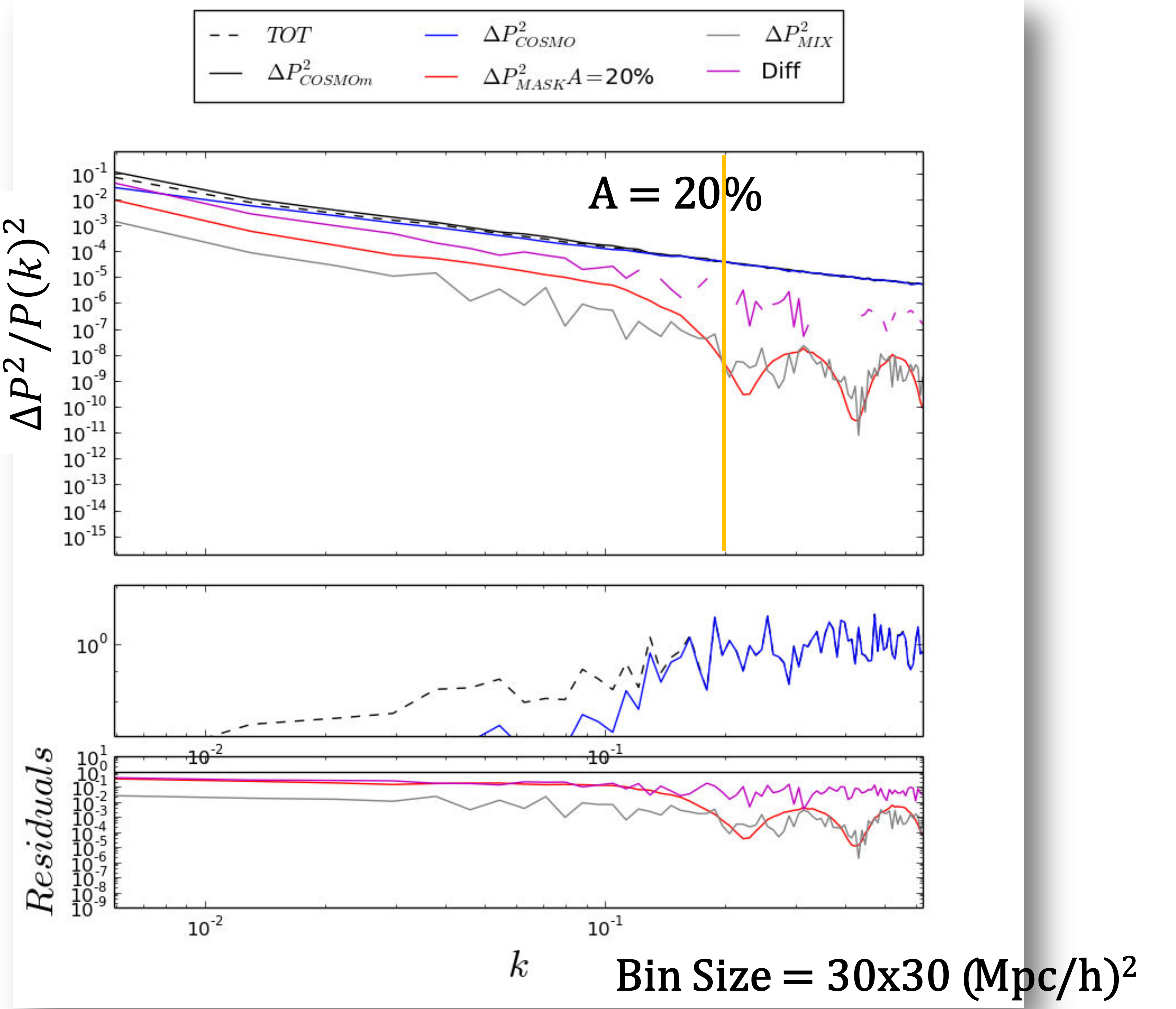

TOT
ΔP^2_{COSMO}
ΔP^2_{MIX}
ΔP^2_{COSMOm}
$\Delta P^2_{MASK} A = 1\%$
Diff
A = 1%
$\Delta P^2 / P(k)^2$
Residuals
k
Bin Size = 30x30 (Mpc/h)^2

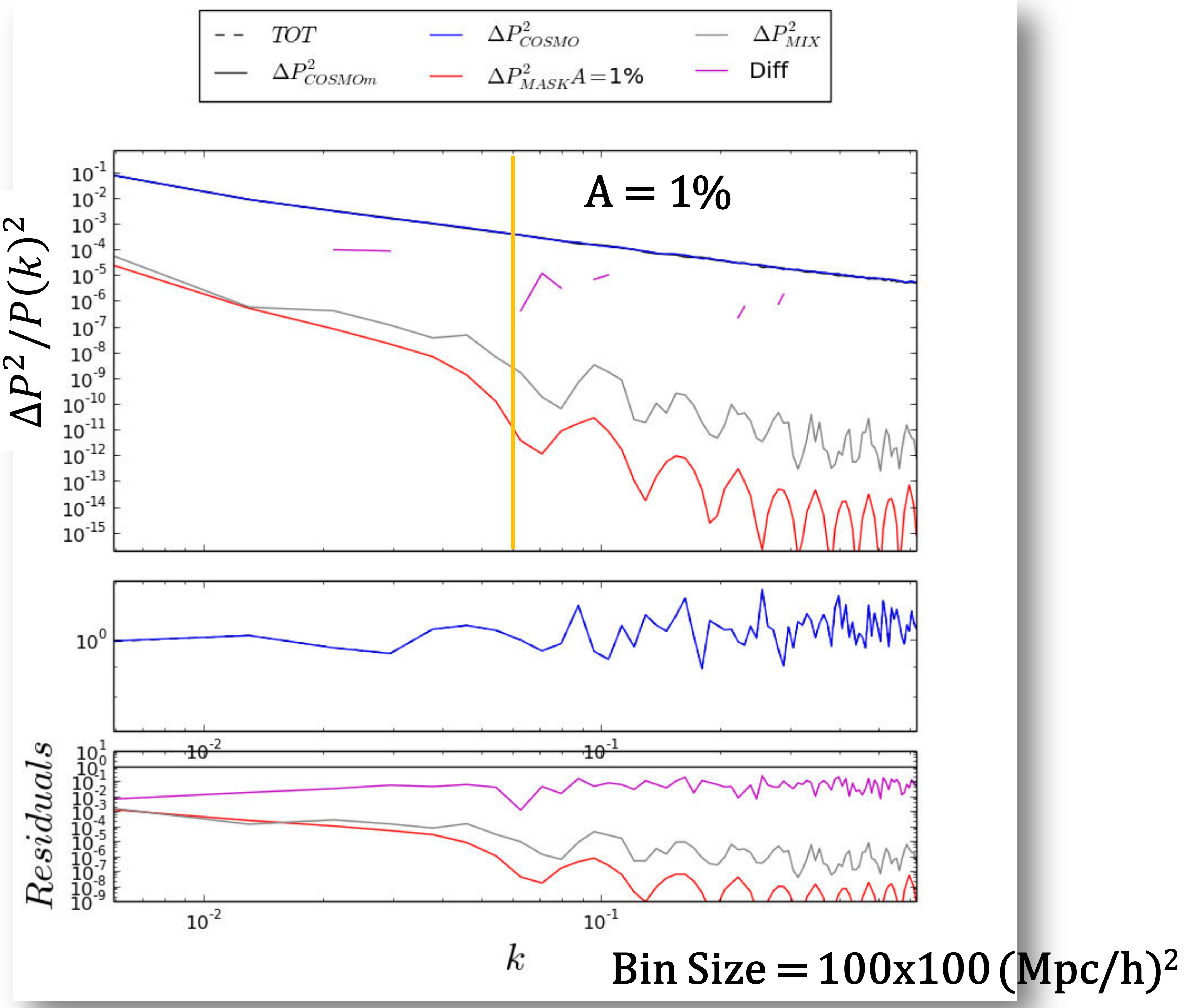


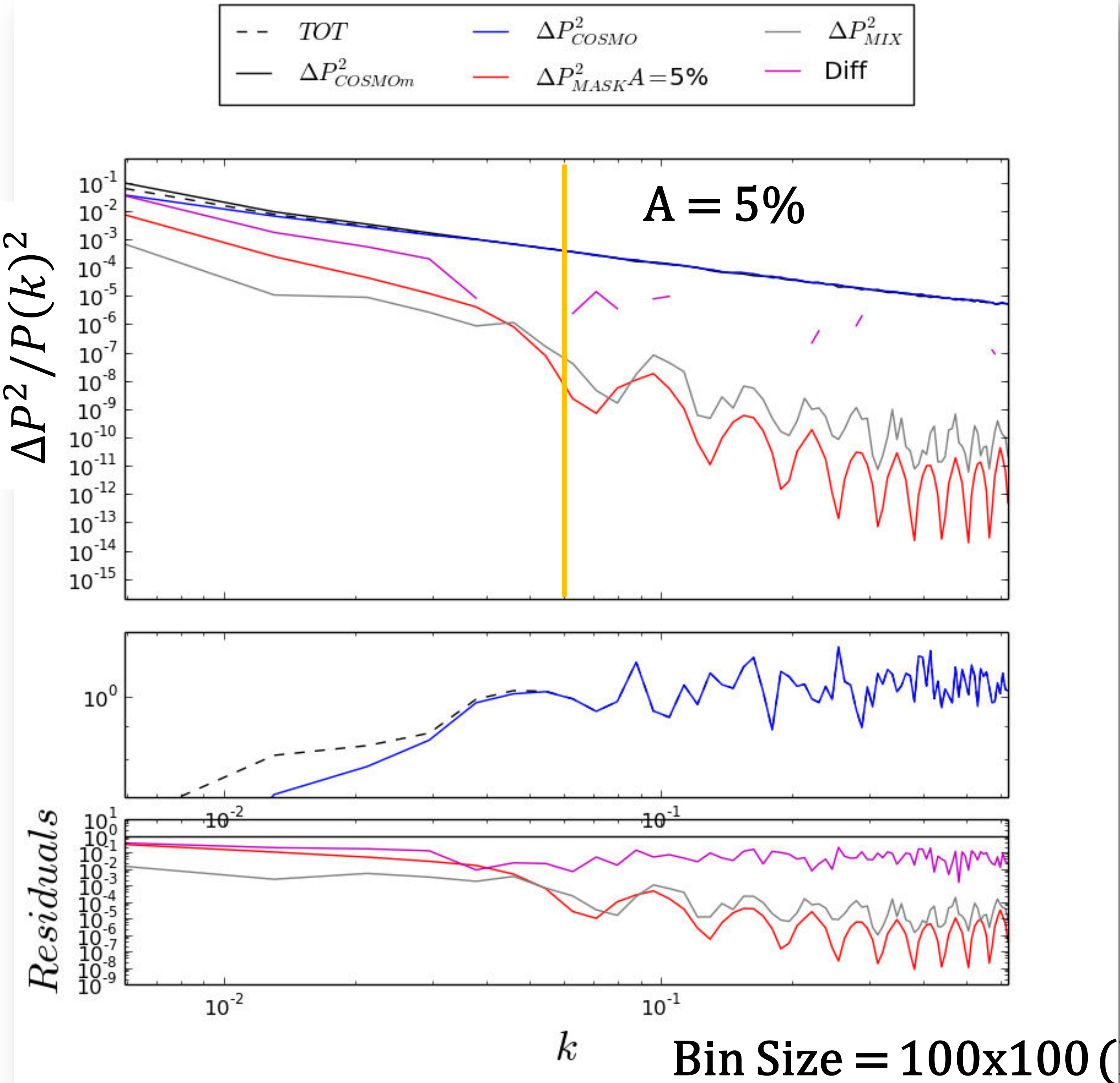
diff
TOT
Cosmo
CosmoSN
Cosmo+Mask
Mask A = 5%
A = 5%
$\Delta P^2/P(k)^2$
$P(k)/P(k)_{tot}$
k
Bin Size = 30x30 (Mpc/h)^2



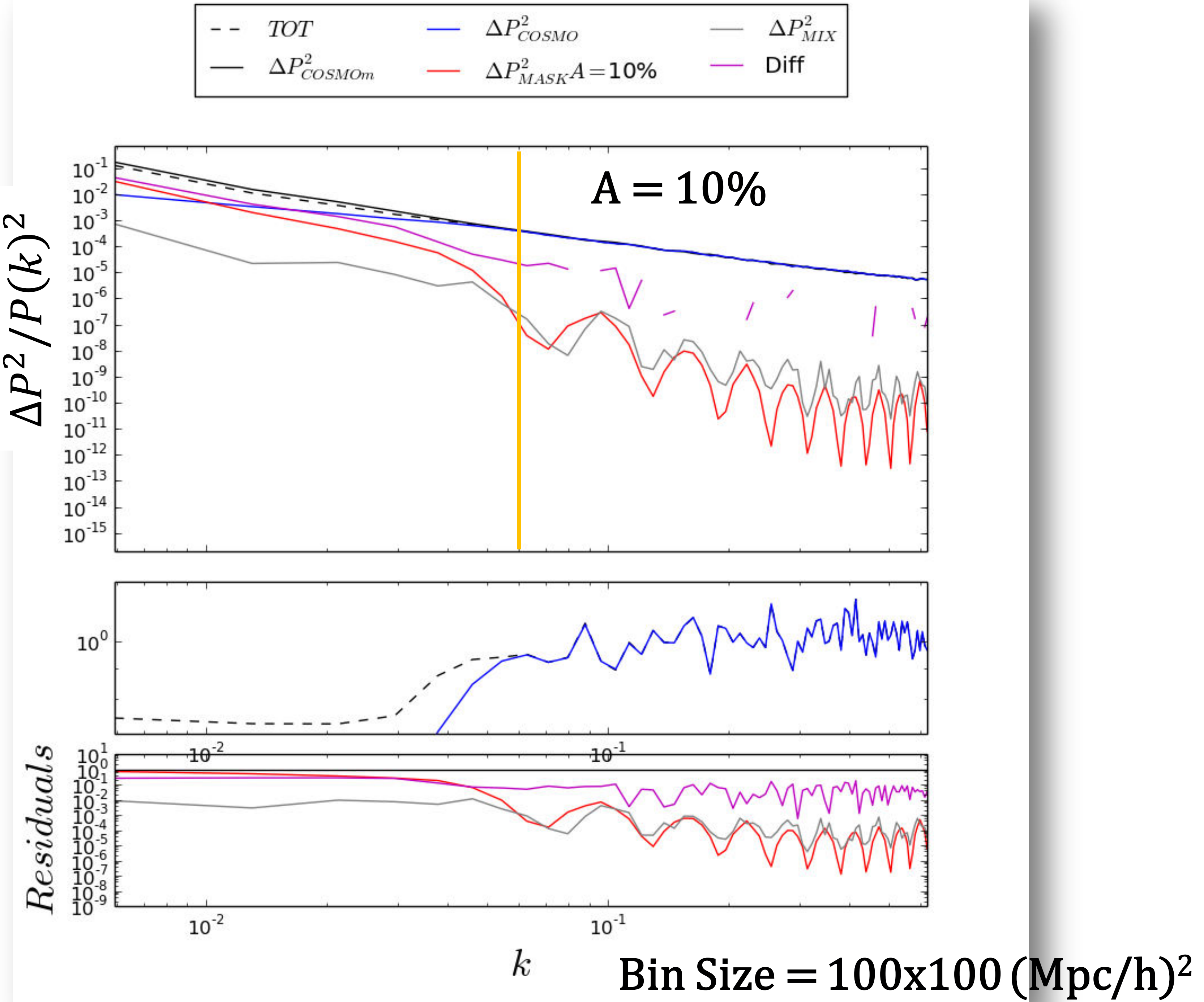
Bin Size = 30x30 $(\mathrm{Mpc}/h)^2$

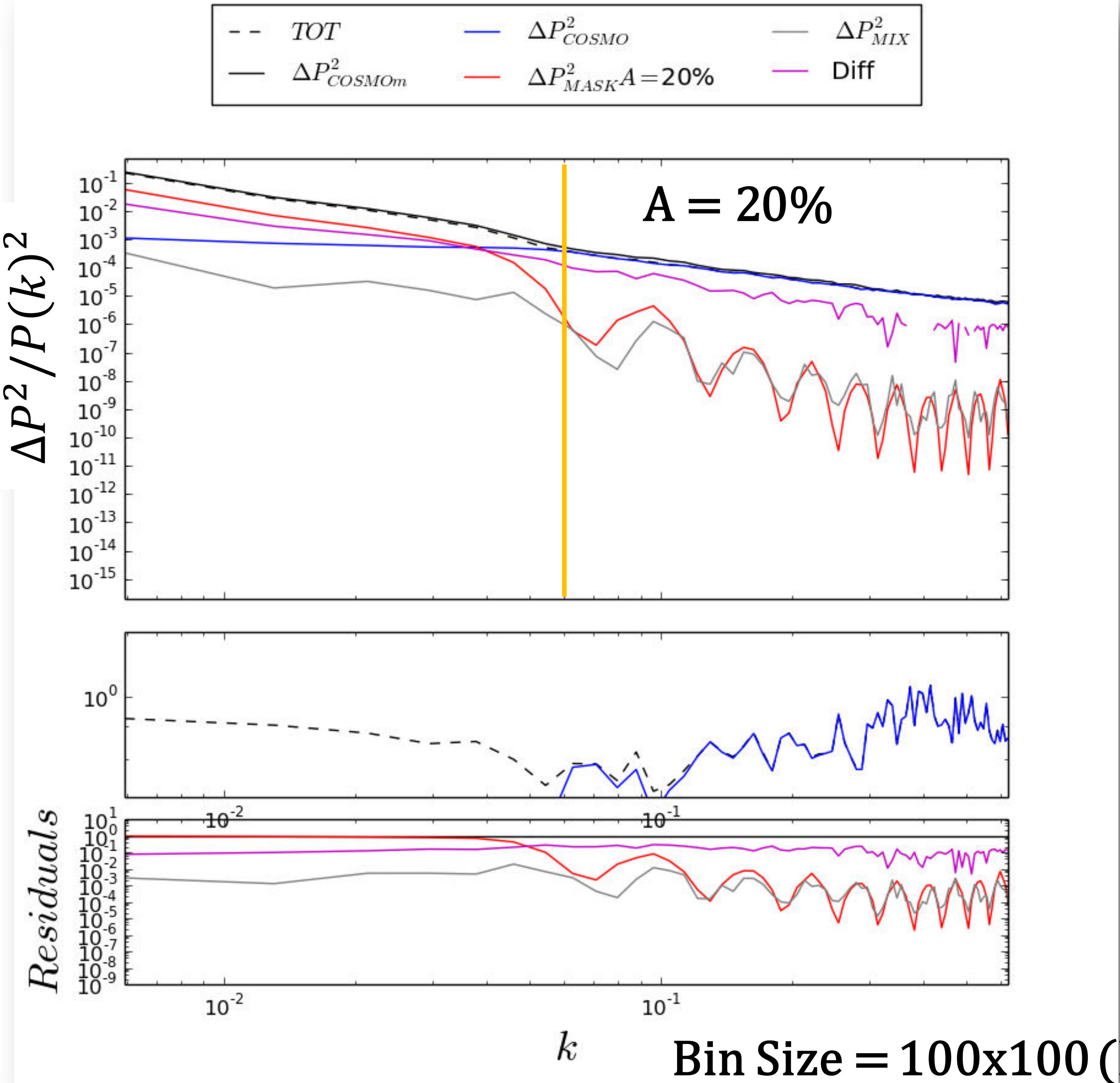

TOT
ΔP^2_{COSMO}
ΔP^2_{MIX}
ΔP^2_{COSMOm}
$\Delta P^2_{MASK} A=20\%$
Diff
A = 20%
$\Delta P^2/P(k)^2$
Residuals
k
Bin Size = 30x30 (Mpc/h)^2


TOT
ΔP^2_{COSMOm}
ΔP^2_{COSMO}
$\Delta P^2_{MASK} A=1\%$
ΔP^2_{MIX}
Diff
A = 1%
$\Delta P^2/P(k)^2$
Residuals
k
Bin Size = 100x100 (Mpc/h)^2



Bin Size = 100x100 $(\mathrm{Mpc/h})^2$


TOT
ΔP^2_{COSMOm}
ΔP^2_{COSMO}
$\Delta P^2_{MASK} A = 10\%$
ΔP^2_{MIX}
Diff
A = 10%
$\Delta P^2 / P(k)^2$
Residuals
k
Bin Size = 100x100 (Mpc/h)^2



Bin Size = 100x100 $(\mathrm{Mpc/h})^2$

Conclusion

- ✓ The foreground noise is relevant both for the 2pt and 4pt statistics at percent level and high order corrections can not be neglect for stringent precision requirements

- ✓ The mixed terms due to the convolution between the mask and cosmological power spectrum are not always negligible and should be considered to have the complete control of the CM

- ✓ Beside the mix terms the foreground analysis requires the knowledge of the mask four point statistics

$$C\left(P(\vec{k}_i)P(\vec{k}j)\right) + C\left(P_A(\vec{k}_i)P_A(\vec{k}_j)\right) + 2C\left(P(\vec{k}_i)P_A(\vec{k}_j)\right) + mix\ convolution\ terms$$

Improvements: more then 1000 mocks to have a good prediction of the mix terms