Gaussianizing Away the Universe's Age Wrinkles

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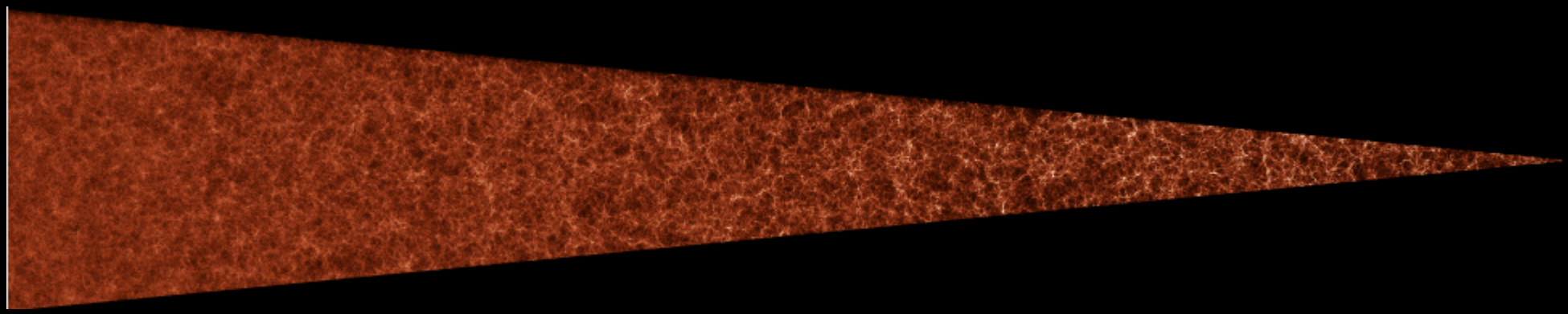
Scales and Statistics

- Large, linear scales: power spectrum
- Slightly nonlinear scales: power spectrum + higher-order statistics? → Gaussianized power spectrum
- Highly nonlinear scales: ¿Halo, void statistics?

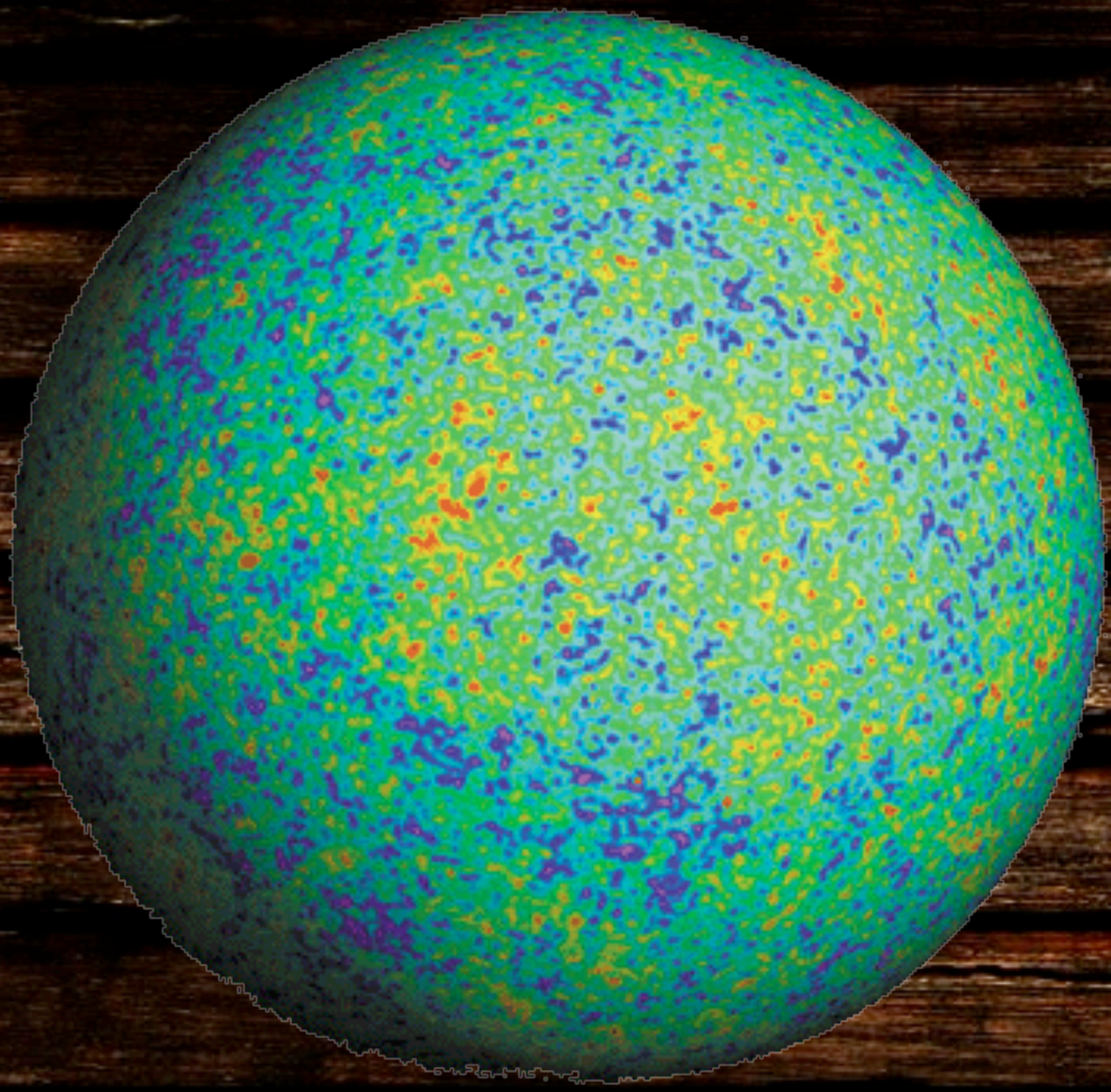


Gaussian random field: e.g. CMB

The initial power spectrum $P(k) = |\delta(k)|^2$ of spatial fluctuations depends on cosmological parameters.

Fourier amplitudes drawn from a distribution about the mean power spectrum

Fourier phases entirely random, uncorrelated

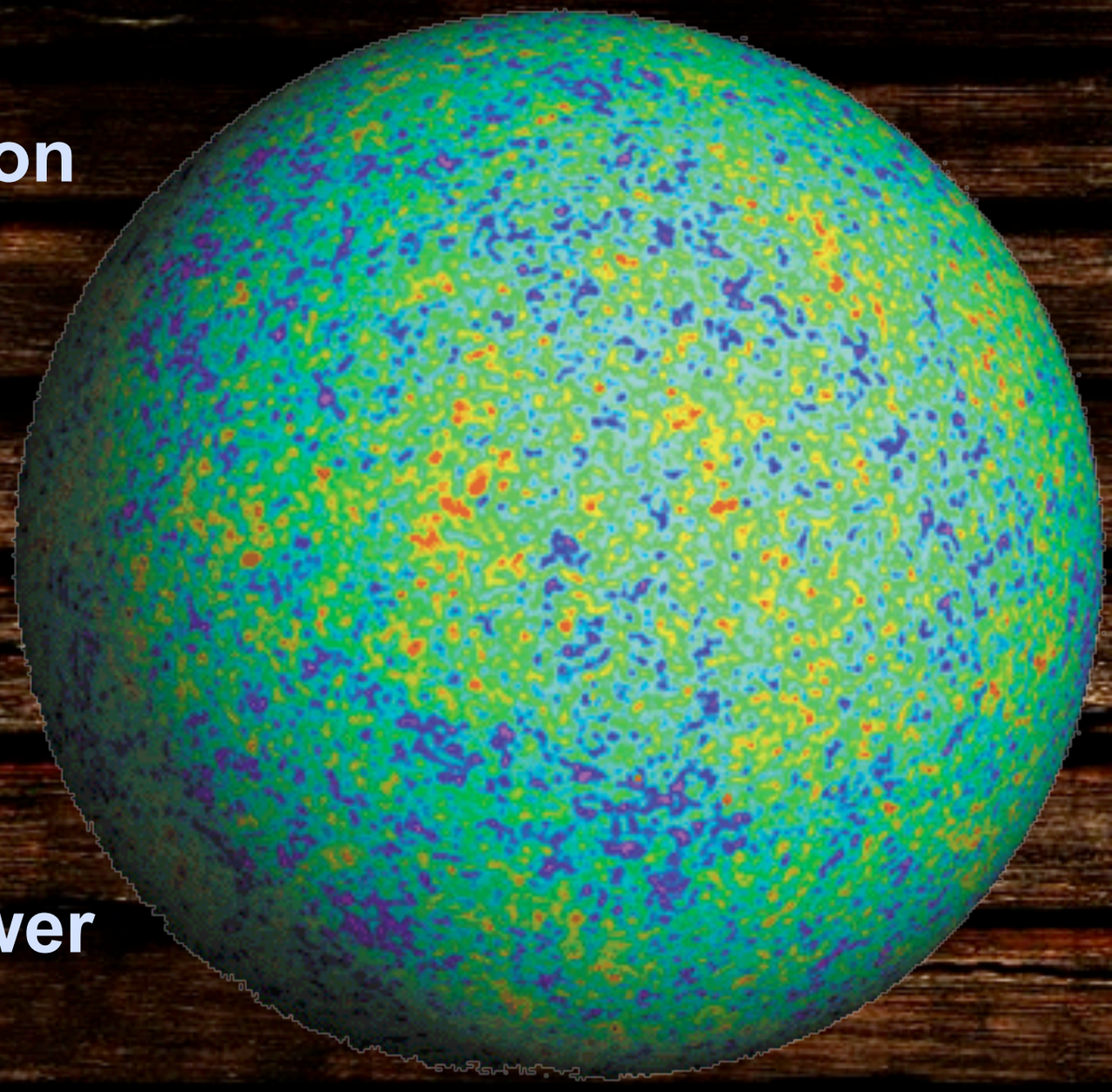


Why use the power spectrum?

In linear theory, simple evolution of Fourier modes:
$\delta(z,k)/\delta(z_0,k)$ independent of k

If $\delta(z,k) \gtrsim 1$: use higher-order perturbation theory, N-body simulations

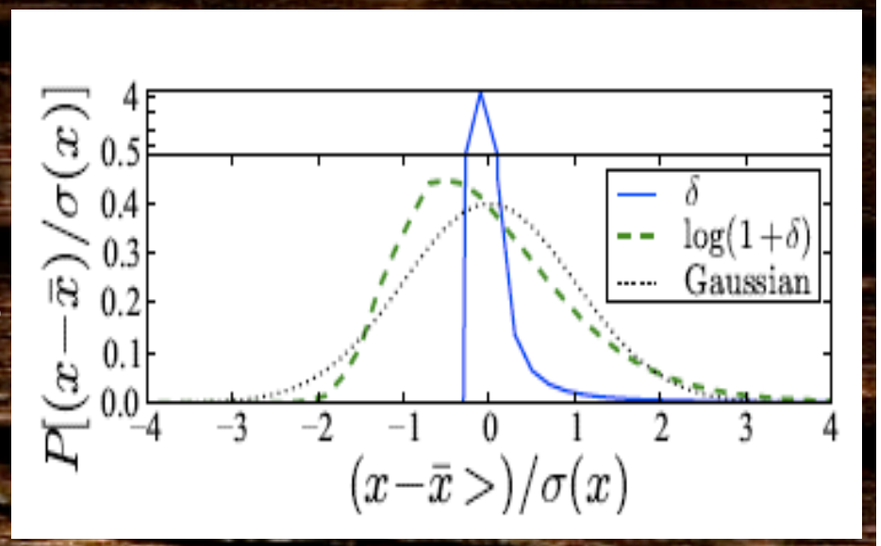
Not the only problem: information leaks from the power spectrum



GAUSSIANIZING THE PDF OF δ.

- Power spectrum well-suited to translational, rotational symmetry of initial conditions, final conditions

- Add'l symmetry of Gaussian PDF shattered at late times; does it restore info to restore a Gaussian PDF?



- Motivations for Gaussianization:
  - Reduce small-scale ~white noise from high peaks
  - Mass conservation eqn simpler using A=log(1+δ) (Poisson's eqn more complicated, though)

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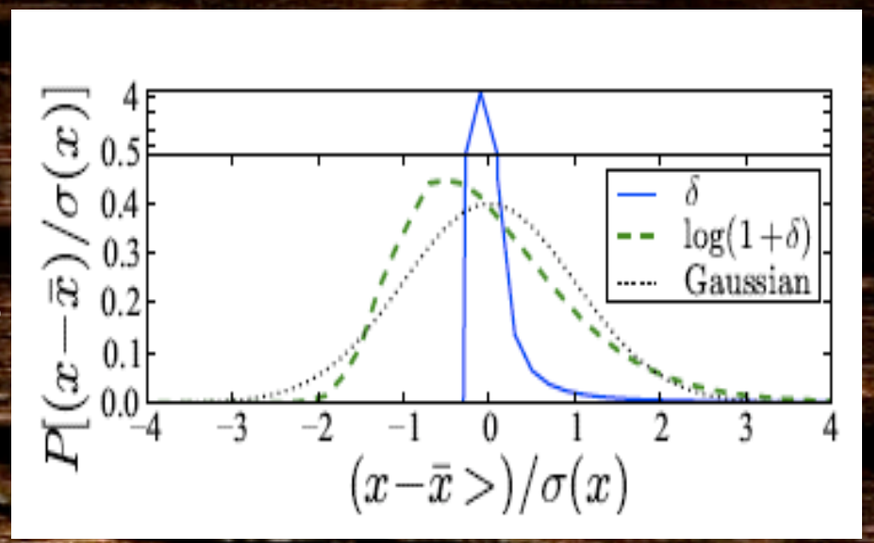

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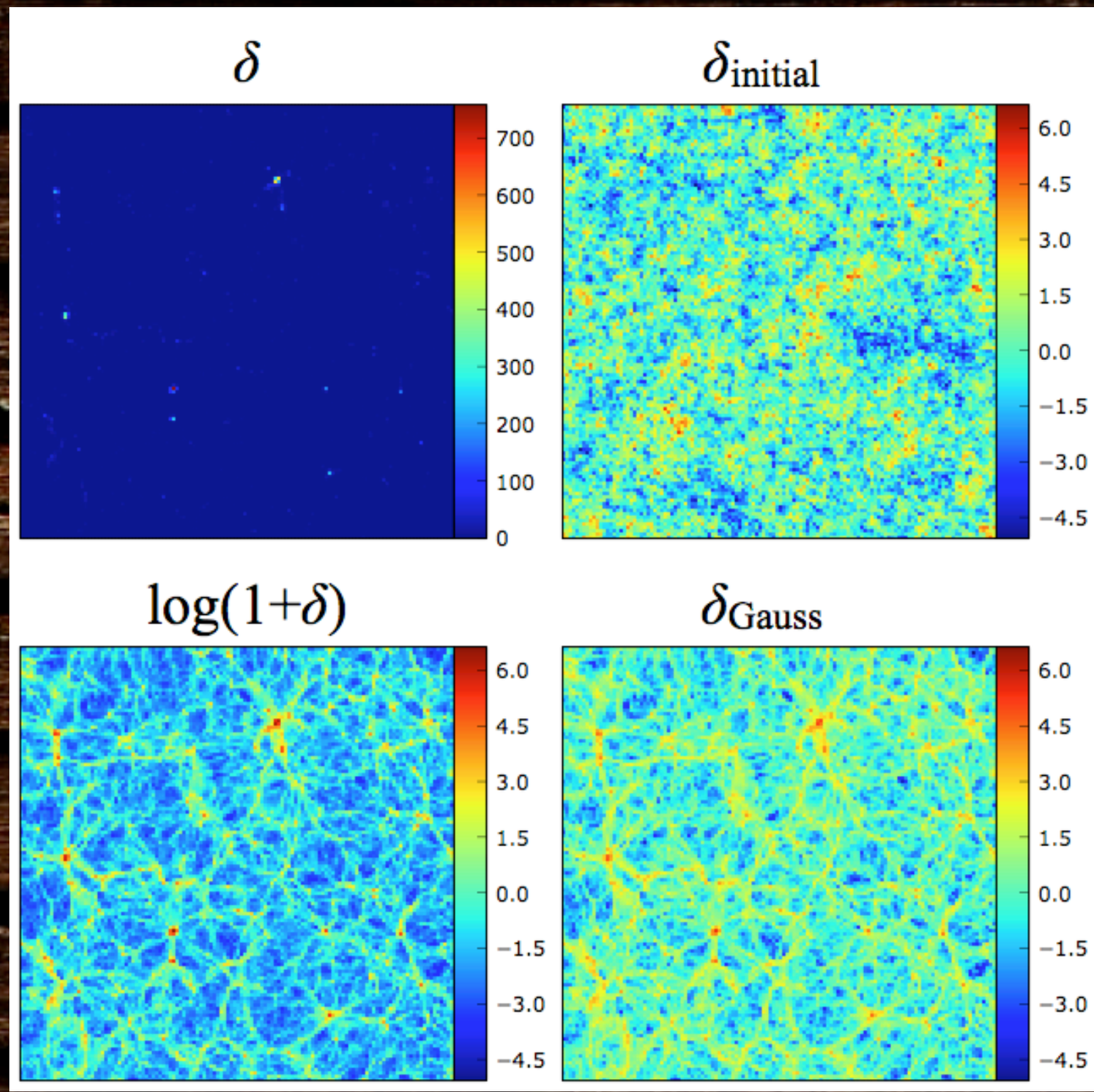
GAUSSIANIZING THE PDF OF δ.

Millennium Sim. (Springel et al. 2005)

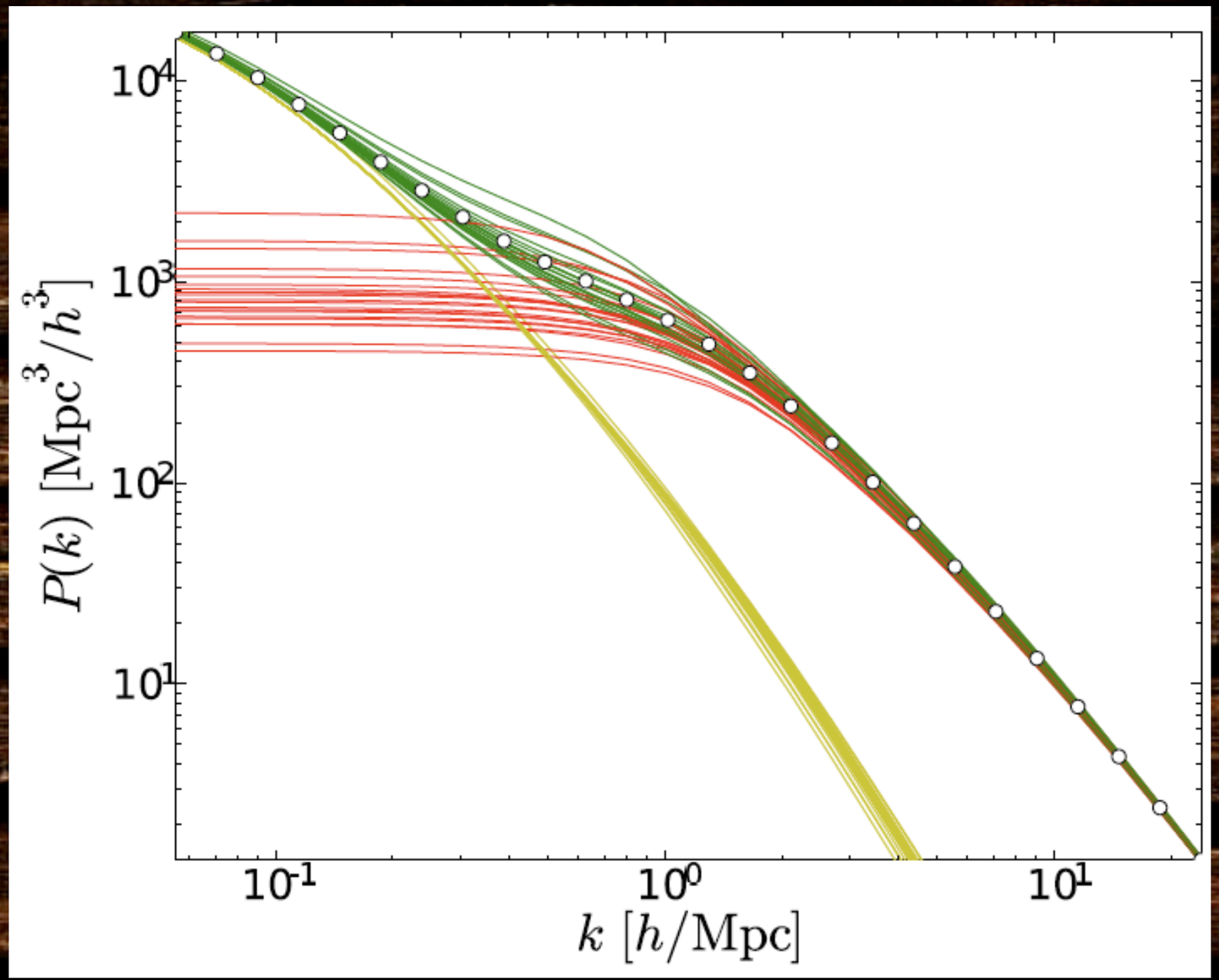
- More structure revealed

- Only a few peaks (halos) visible in normal δ -- explains why power spectrum is so sensitive to halo population



Fourier amplitudes become correlated

large, linear scales

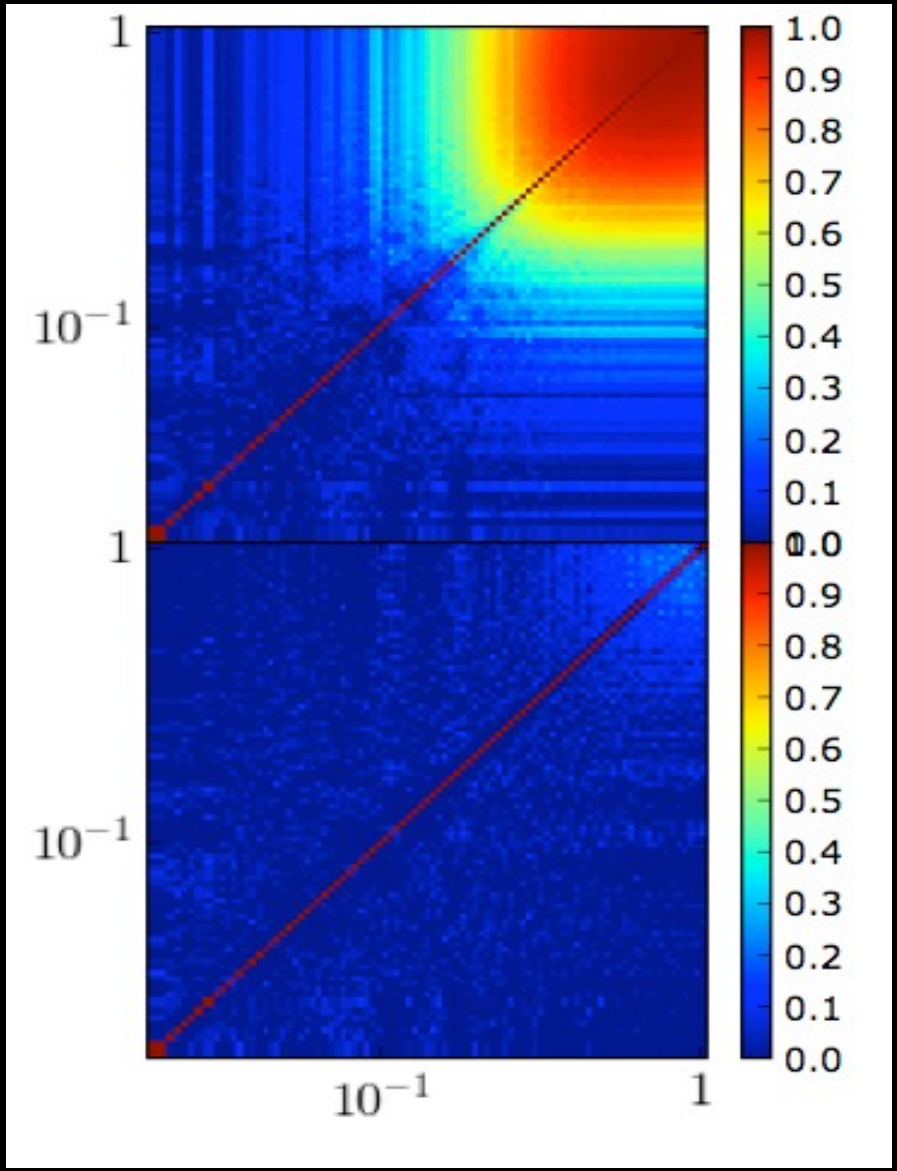


small, halo scales

MN, Szapudi & Rimes 2006

Power-spectrum correllation matrices

$k\ [h/\mathrm{Mpc}]$



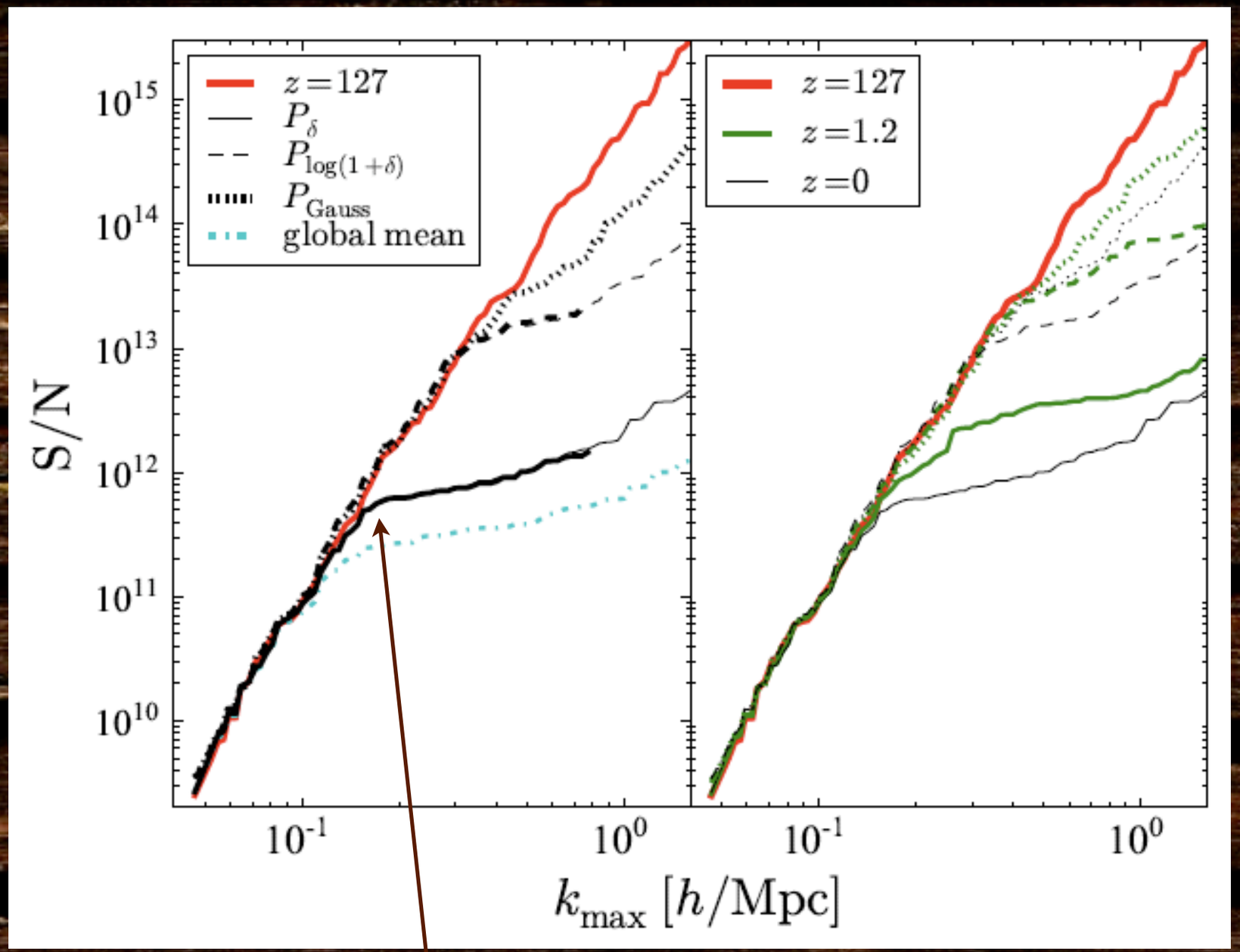
Gaussianized

$k\ [h/\mathrm{Mpc}]$

A log transform reduces nonlinearities in $P(k)$'s covariance ~ Fisher information ~ S/N

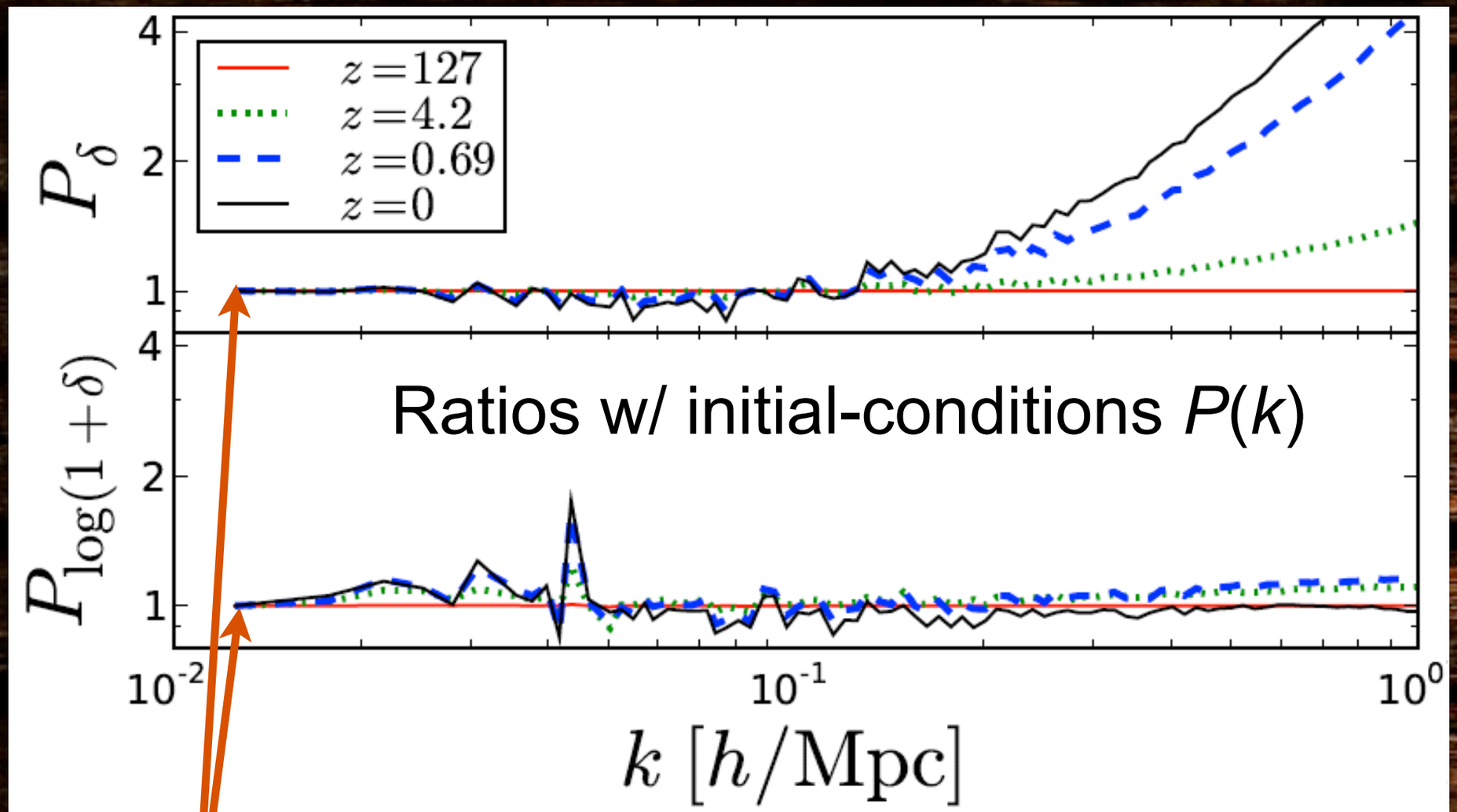
small, halo scales

large, linear scales



"translinear plateau"
(Rimes & Hamilton 2006)

A log transform reduces nonlinearities in $P(k)$'s mean

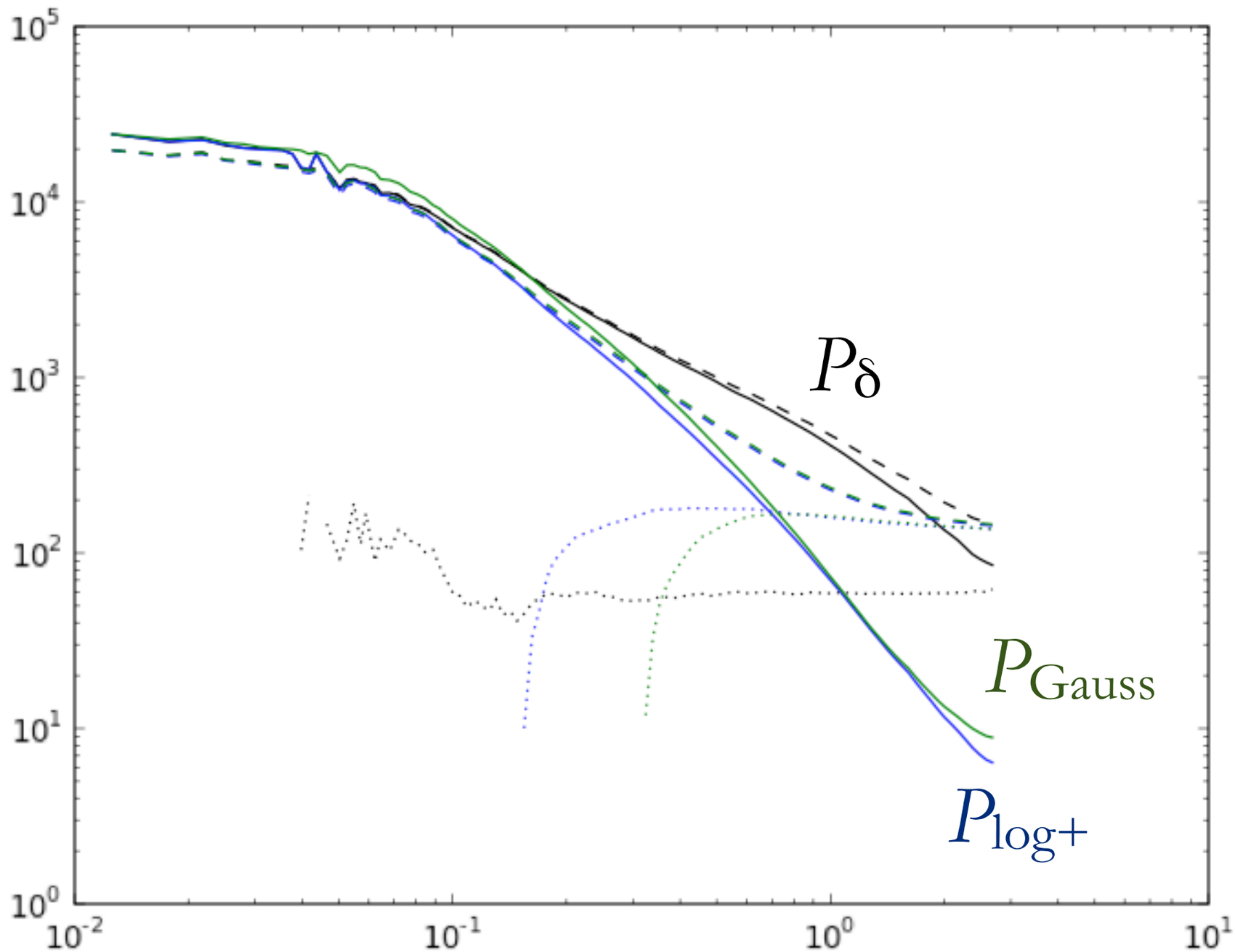


Aligned in lowest-k bin

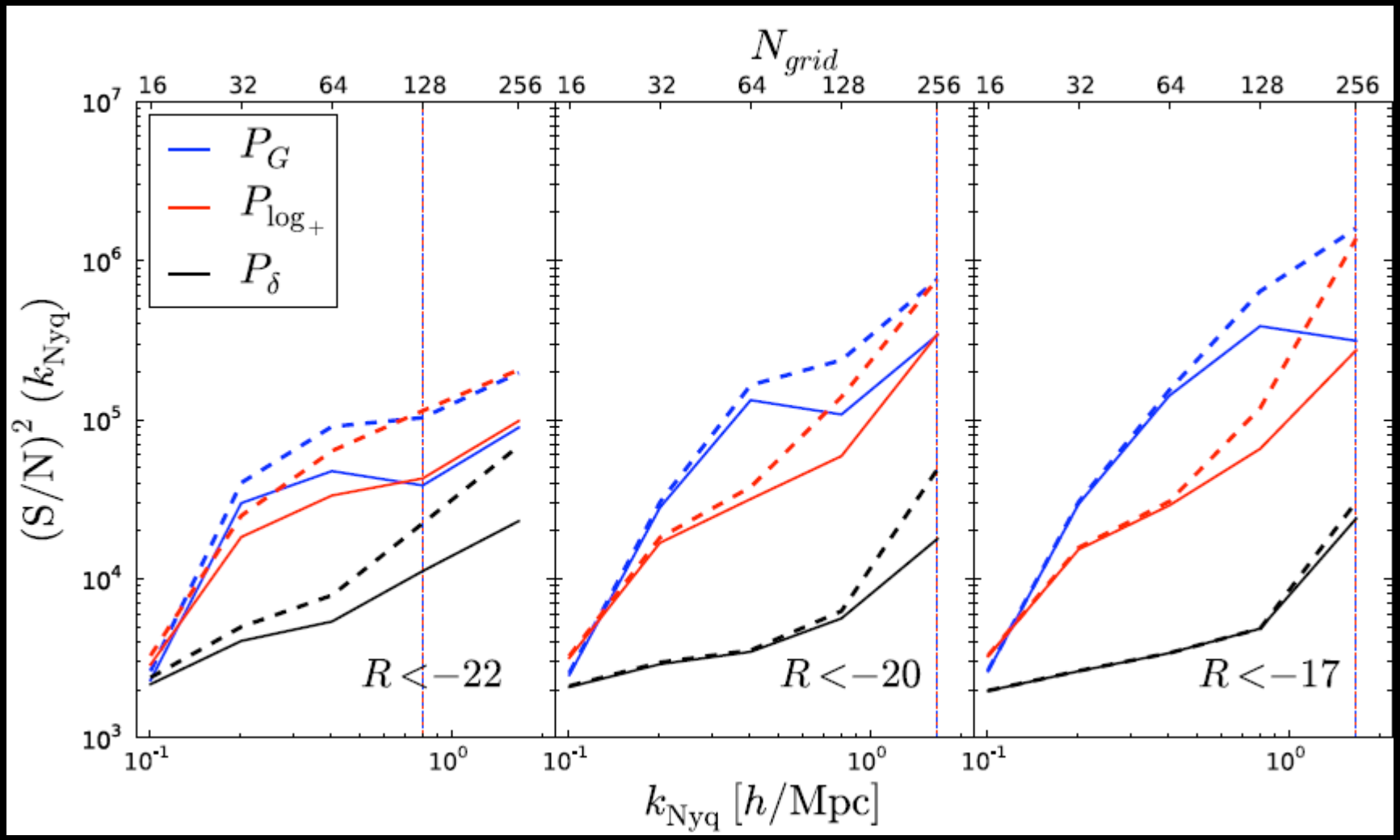
What about galaxy power spectra?

- Redshift distortions, galaxy bias (just as with P_δ)
- Extra compliation with galaxy discreteness: how to assign $\log(1+\delta)$ if δ=-1?
- One solution: explicit Gaussianization still works

How does particle discreteness affect the shape of P_{Gauss}? Increased shot noise ...



Info in the presence of shot noise

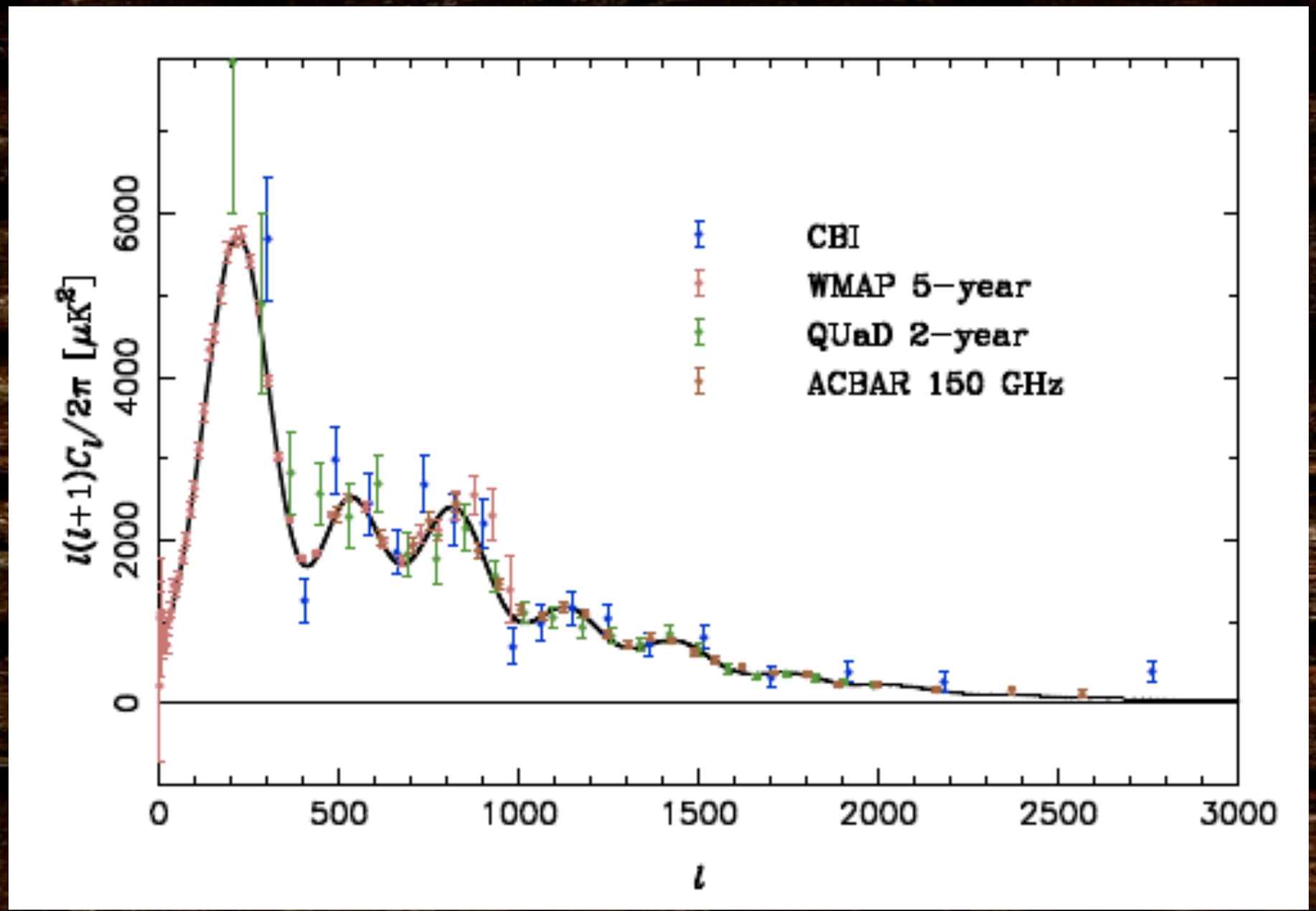


Conclusions

- $A=\ln(1+\delta)$ is in many ways a better variable than δan. e.g. can exceed -1!

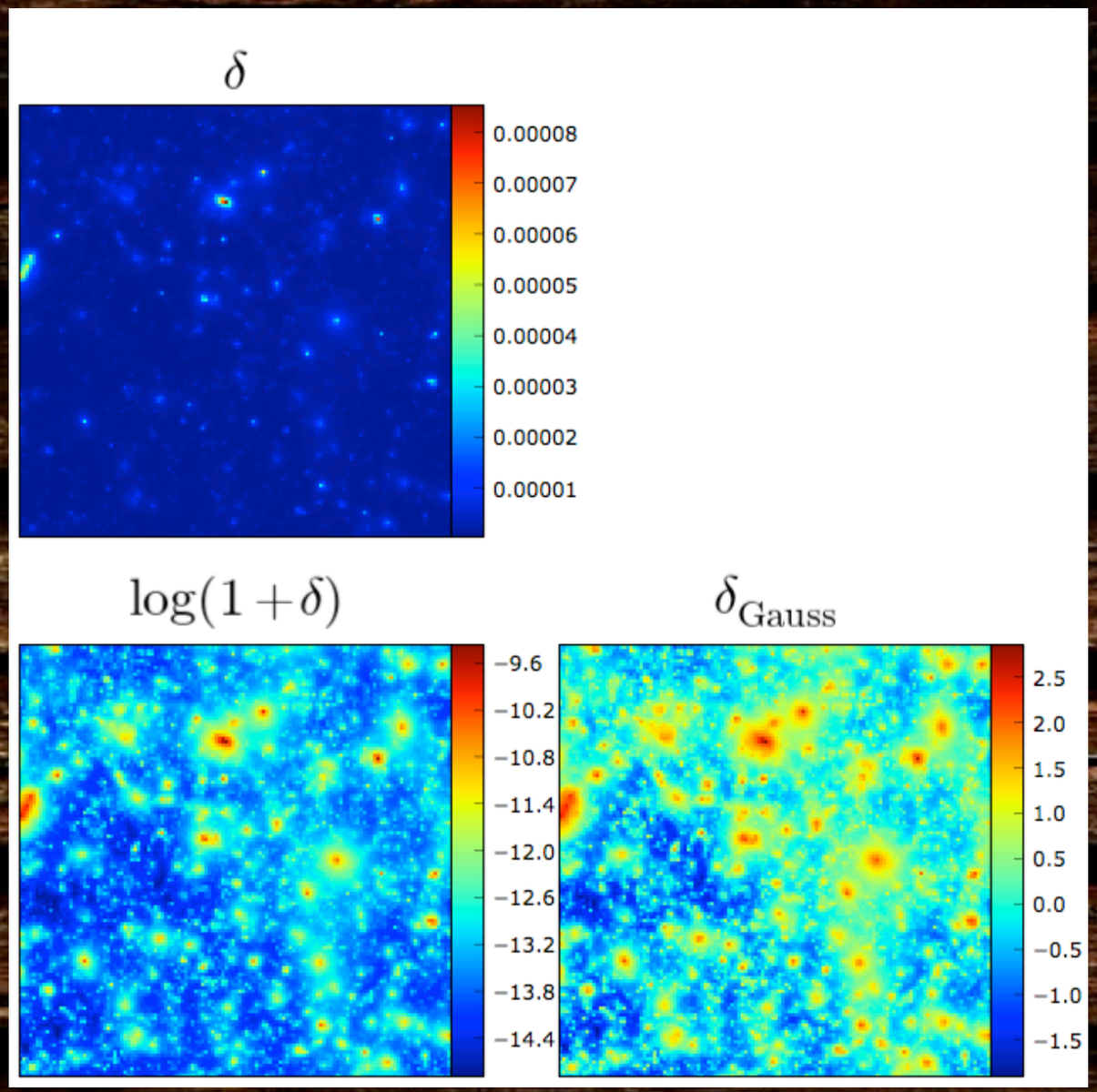
- Transformations done for visual ease can be useful quantitatively, too.

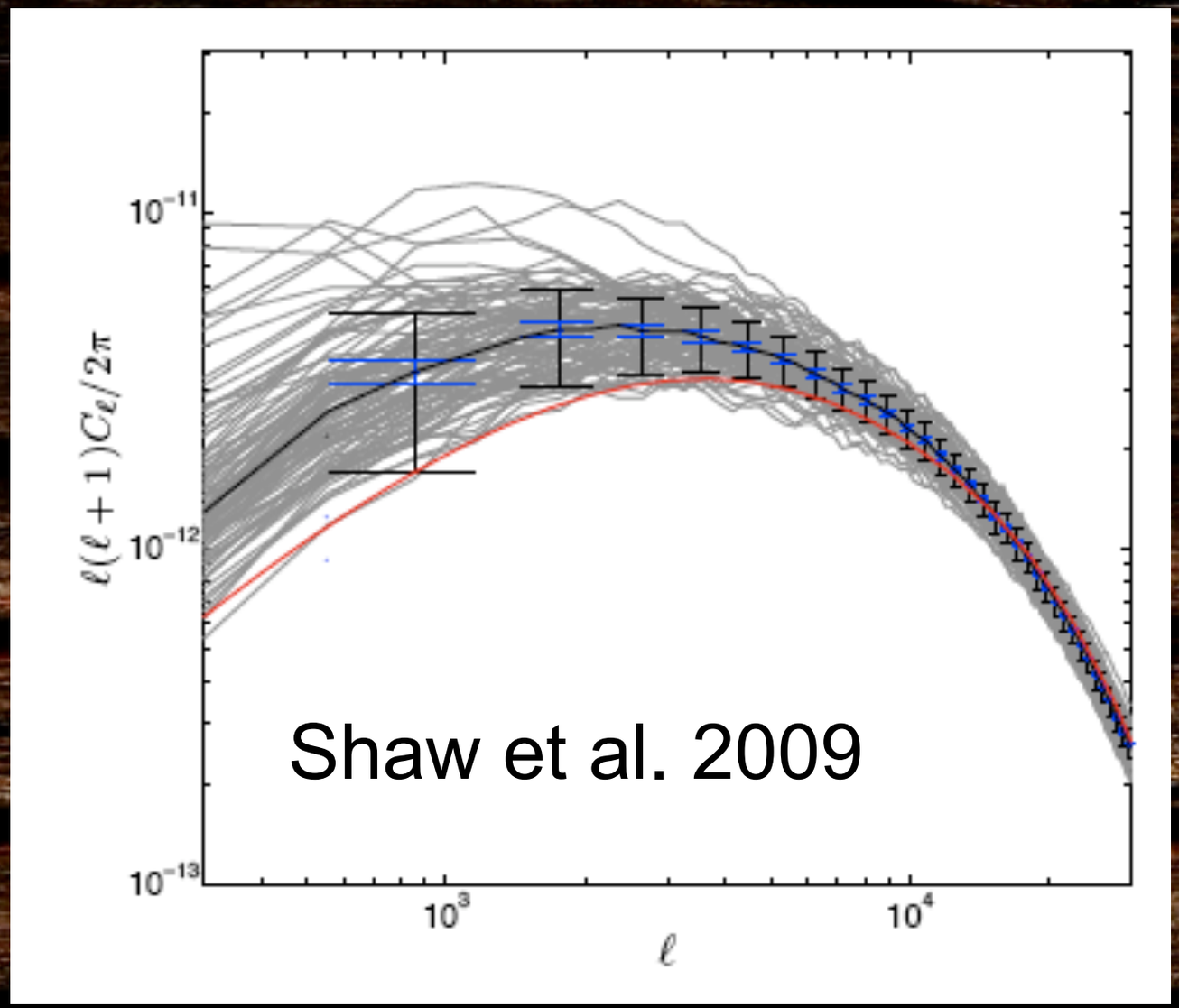
SZ power spectrum (small-scale CMB)



SZ small-scale power spectrum $\propto \sigma_8^7$!

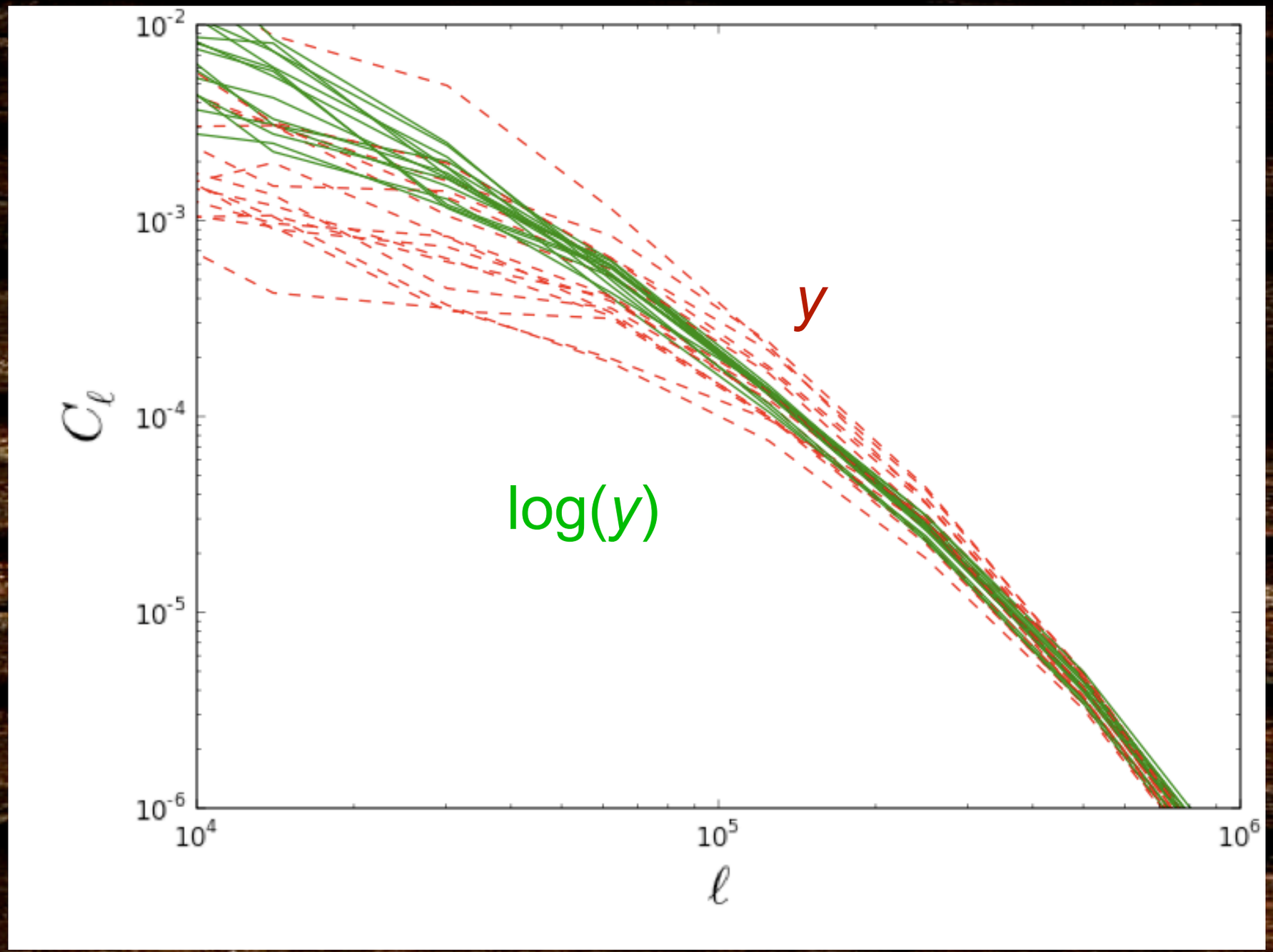
SZ power spectrum (small-scale CMB)





(simulation from White, Hernquist and Springel 2002)

SZ power spectra (small-scale CMB)



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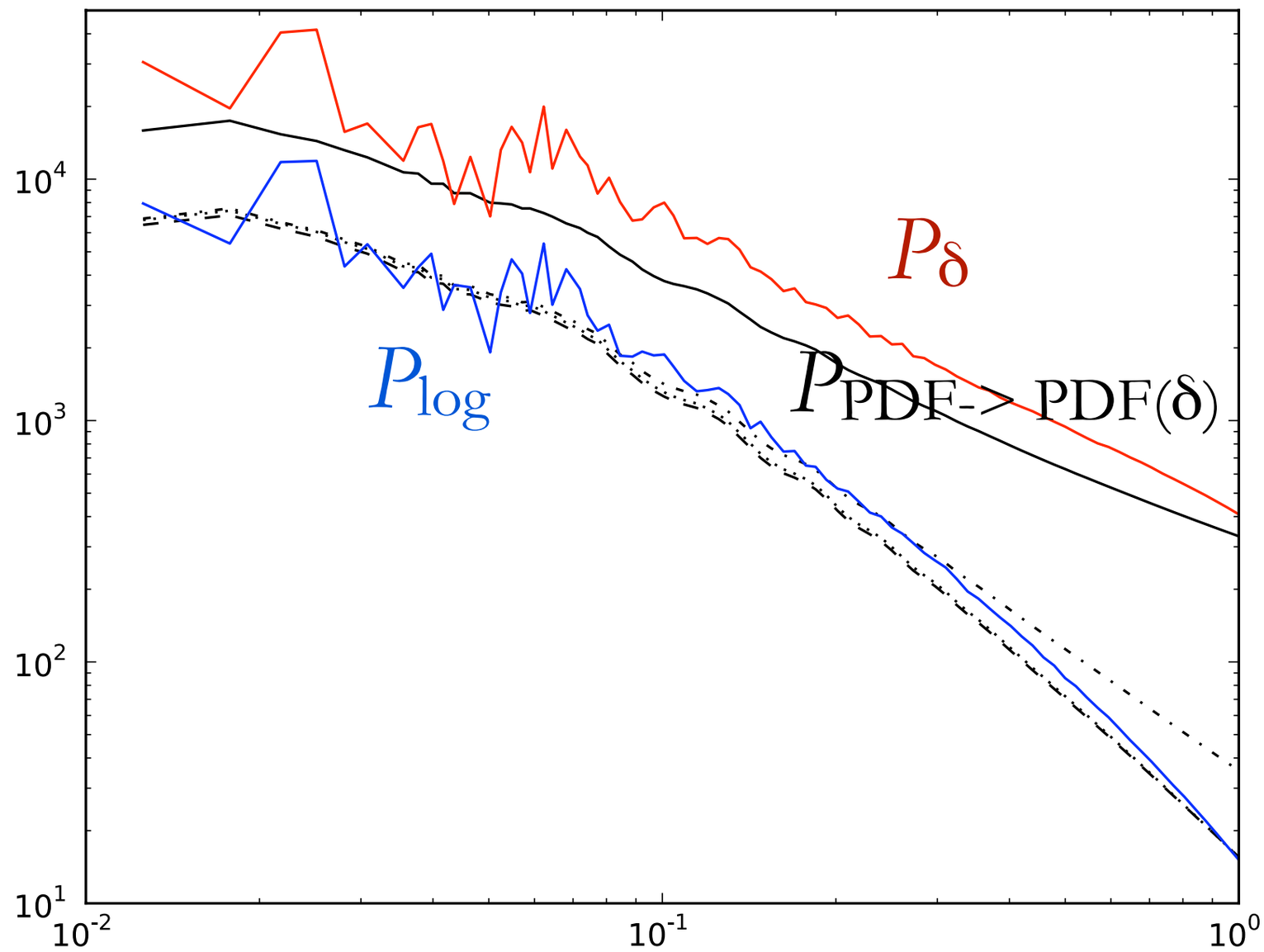
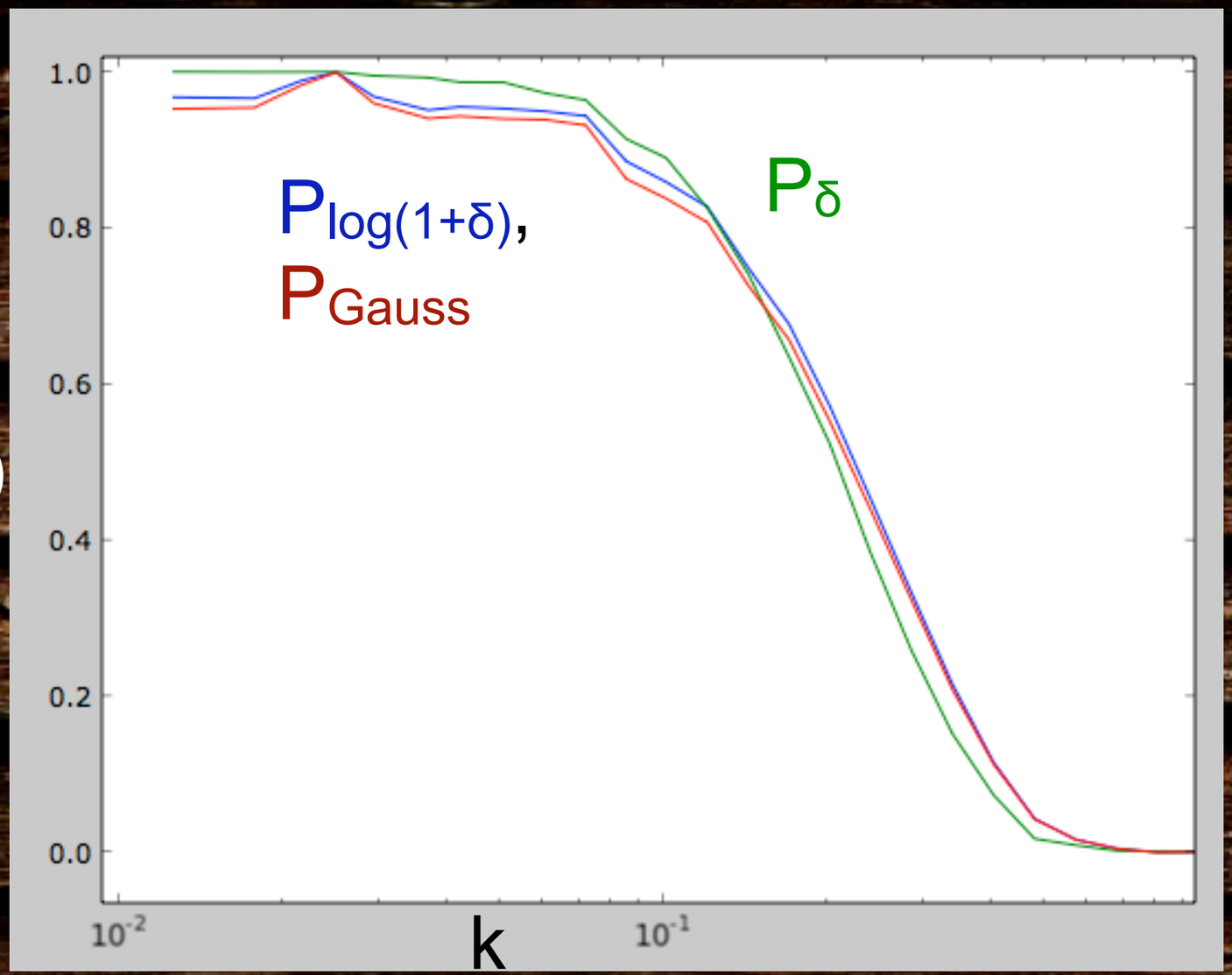
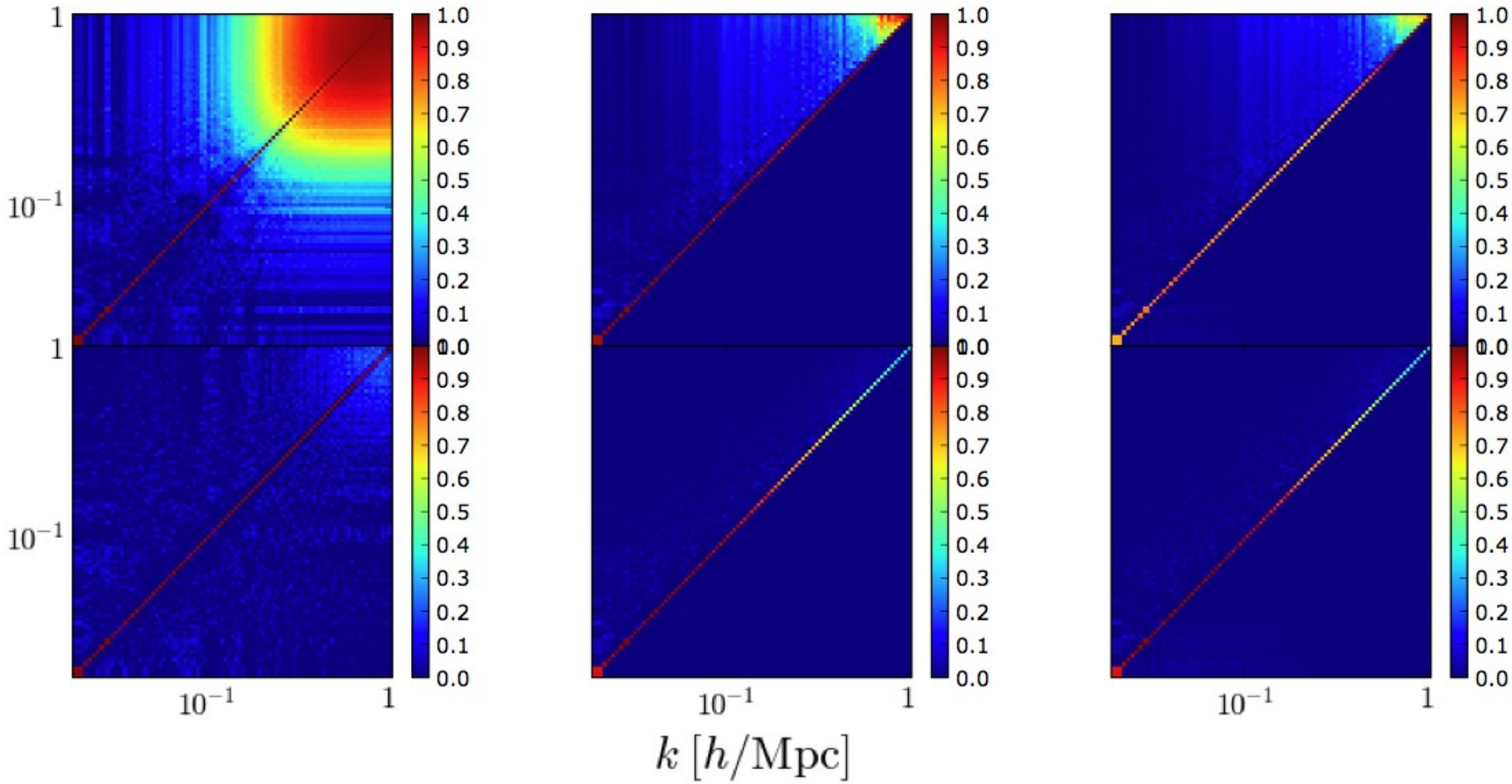
Another view:



Memory of Initial Conditions:
Cross-correlation coefficient (e.g. Crocce & Scoccimarro 2006)

$$R(k) = \frac{P_{init\times final}(k)}{\sqrt{P_{init}(k)P_{final}(k)}}$$



Somewhat disappointing for P_{log} enthusiasts.
However, this really just measures the fidelity of the phases to the initial conditions.

Model $P^{nl}_{i} = T_{ij} P^{lin}_{j}$