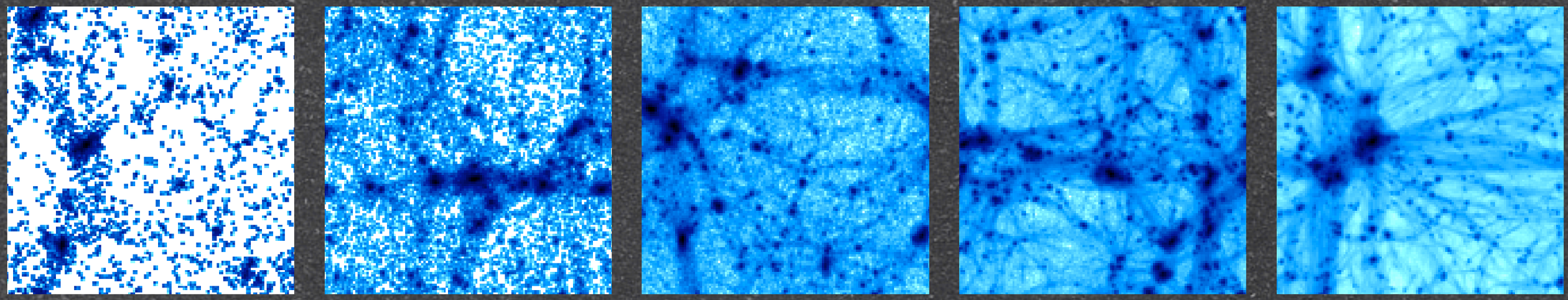

Discreteness Effects in ΛCDM Simulations

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See our ApJ paper (arXiv:0804.0294)

WHY ?

The effects of particle discreteness in *N*-body simulations are a fundamental point that needs careful thought and analysis, since all such simulations suffer from numerical noise arising from the use of finite-mass particles.

WHAT IS NEW ?

1. We assess the actual significance of discreteness effects against statistical scatter.

2. We offer a deeper and wider view of such effects through a thorough wavelet-statistical analysis.

3. We probe particular aspects of the problem, such as the range of scales affected by discreteness and a variety of statistical effects arising from the initial conditions.

OUR FIRST CONCLUSION

Dynamical evolution does not propagate discreteness noise up from the small scales at which it is introduced.

- This is one important aspect of the robustness of cosmological *N*-body simulations, which we can prove rigorously thanks to new and powerful wavelet statistics.

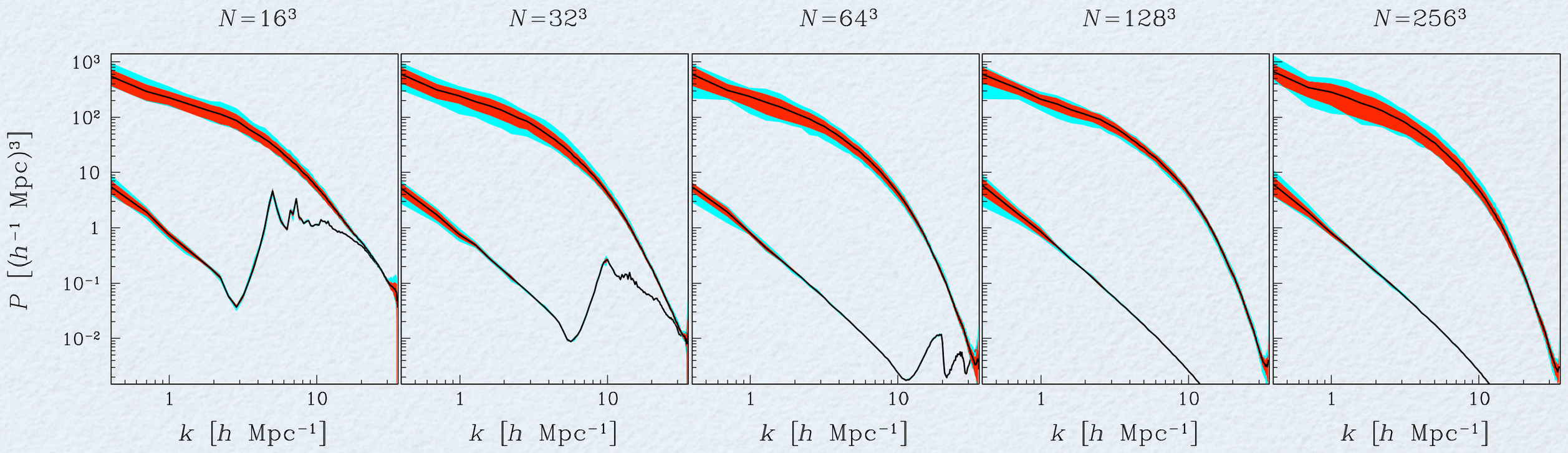
- The point is that the final power spectra, correlation functions and mass variances only show marginal differences, if any, once their scatter is taken into account (see **Fig. 1**).

OUR FIRST CONCLUSION (continues)

- This is also true for diagnostics that are sensitive to the phase of the density fluctuations (see **Fig. 2**).

- One needs minimum-scatter phase-sensitive statistics, such as our wavelet set, to show that discreteness noise is not propagated upwards (see **Fig. 3**).

FIGURE 1



The final correlation functions and mass variances are not shown here, but they look the same.

FIGURE 2

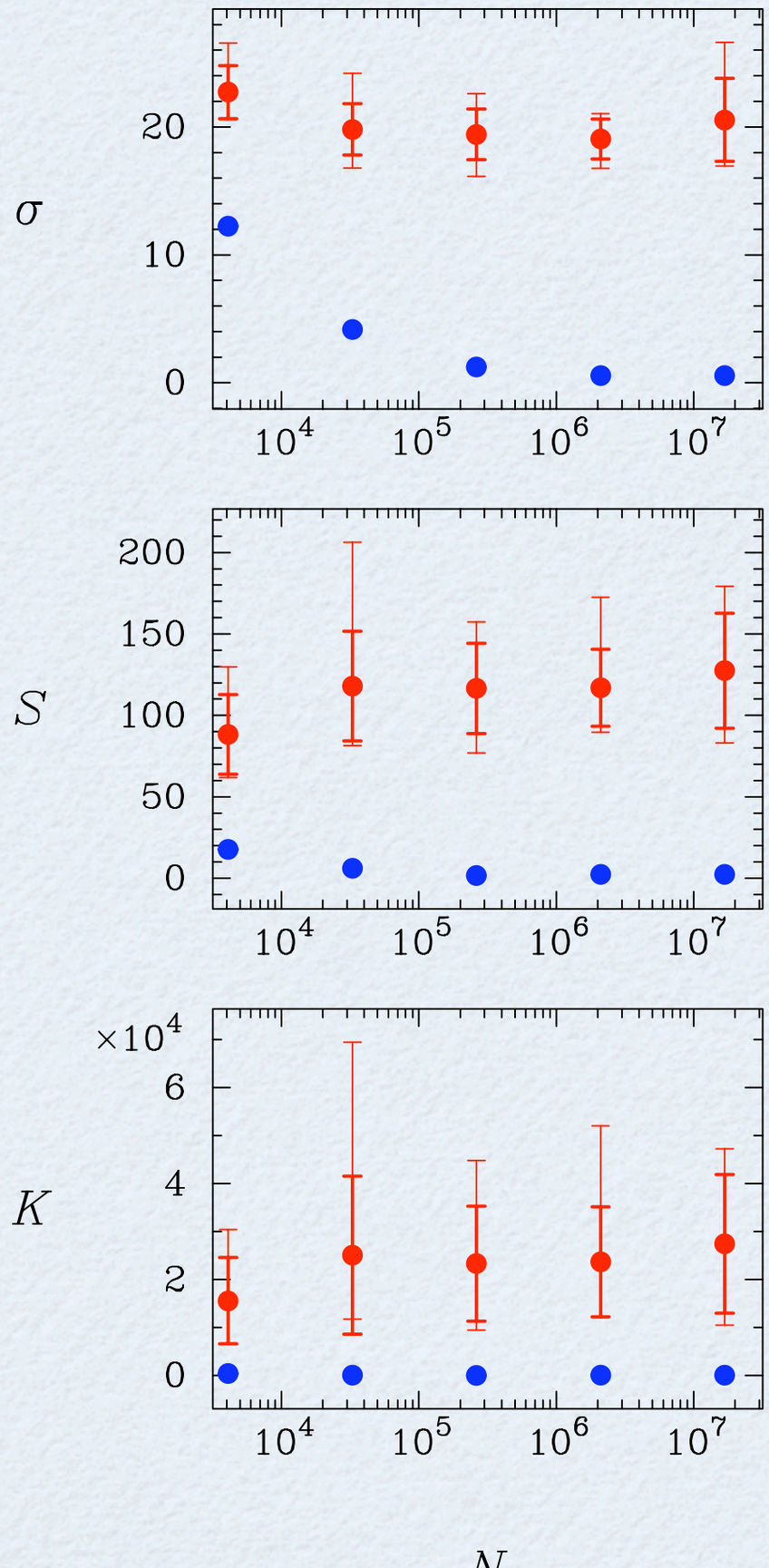
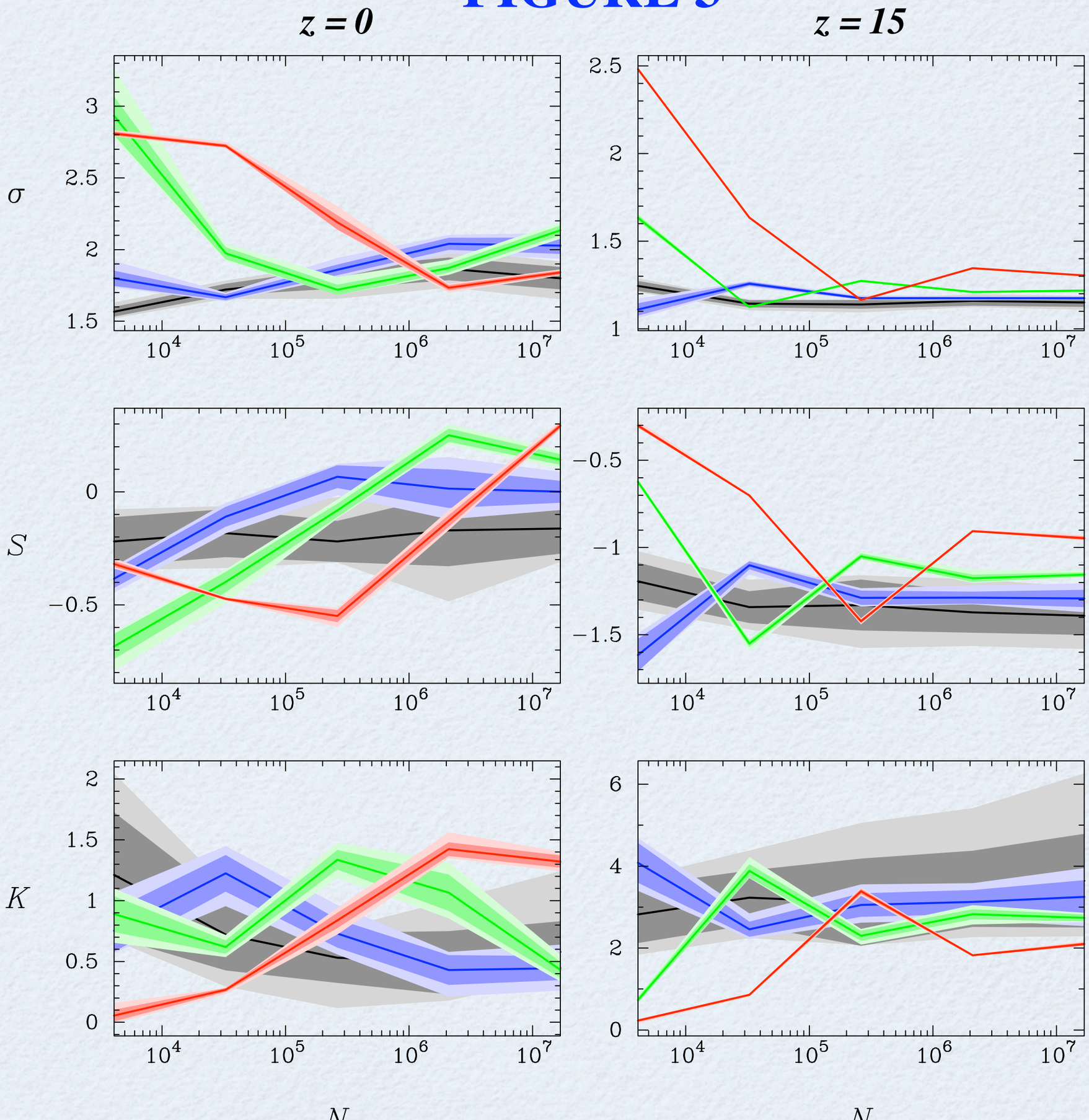


FIGURE 3



OUR SECOND CONCLUSION

One should aim to satisfy the condition $\varepsilon \sim 2d$, where ε is the force resolution and d is the interparticle distance.

- This condition involves several aspects of discreteness, which appear if there is unbalance between force and mass resolution: initial non-Gaussianity from Gaussian initial conditions (see **Figs 4 and 5**), departure from lognormality and rise of further complexity at low redshifts (see **Fig. 6**).

- This is a fresh view of the problem, which we discuss together with its implications.

OUR SECOND CONCLUSION (continues)

- Concerning the range of scales affected by discreteness, approximately $\varepsilon < s < 2d$, this is a result that again we can prove rigorously thanks to our wavelet statistics.

- Previous attempts to quantify this point neglected the statistical scatter of the diagnostics, which generally dominates over the systematic effects of discreteness, as pointed out above (see first conclusion).

FIGURE 4

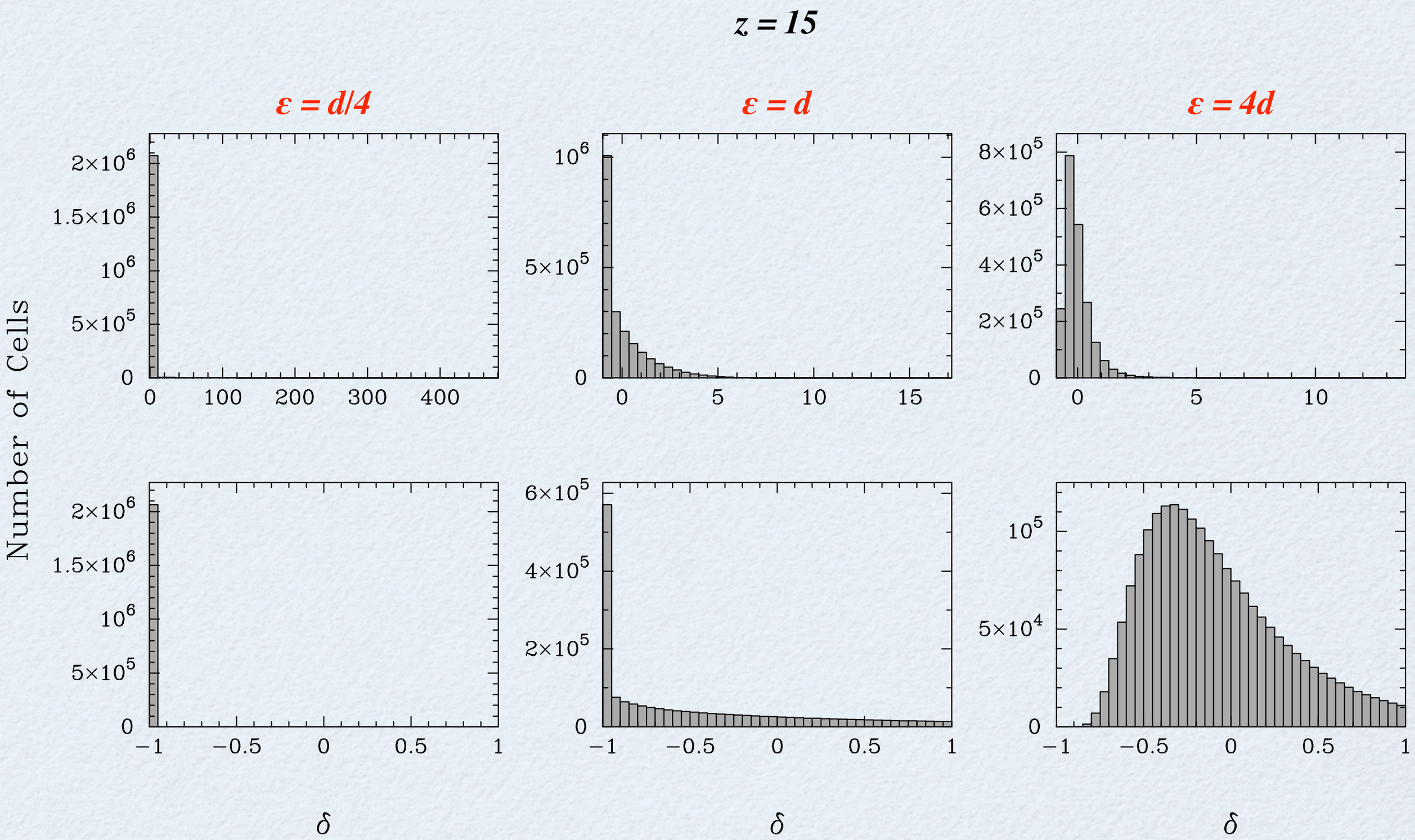


FIGURE 5

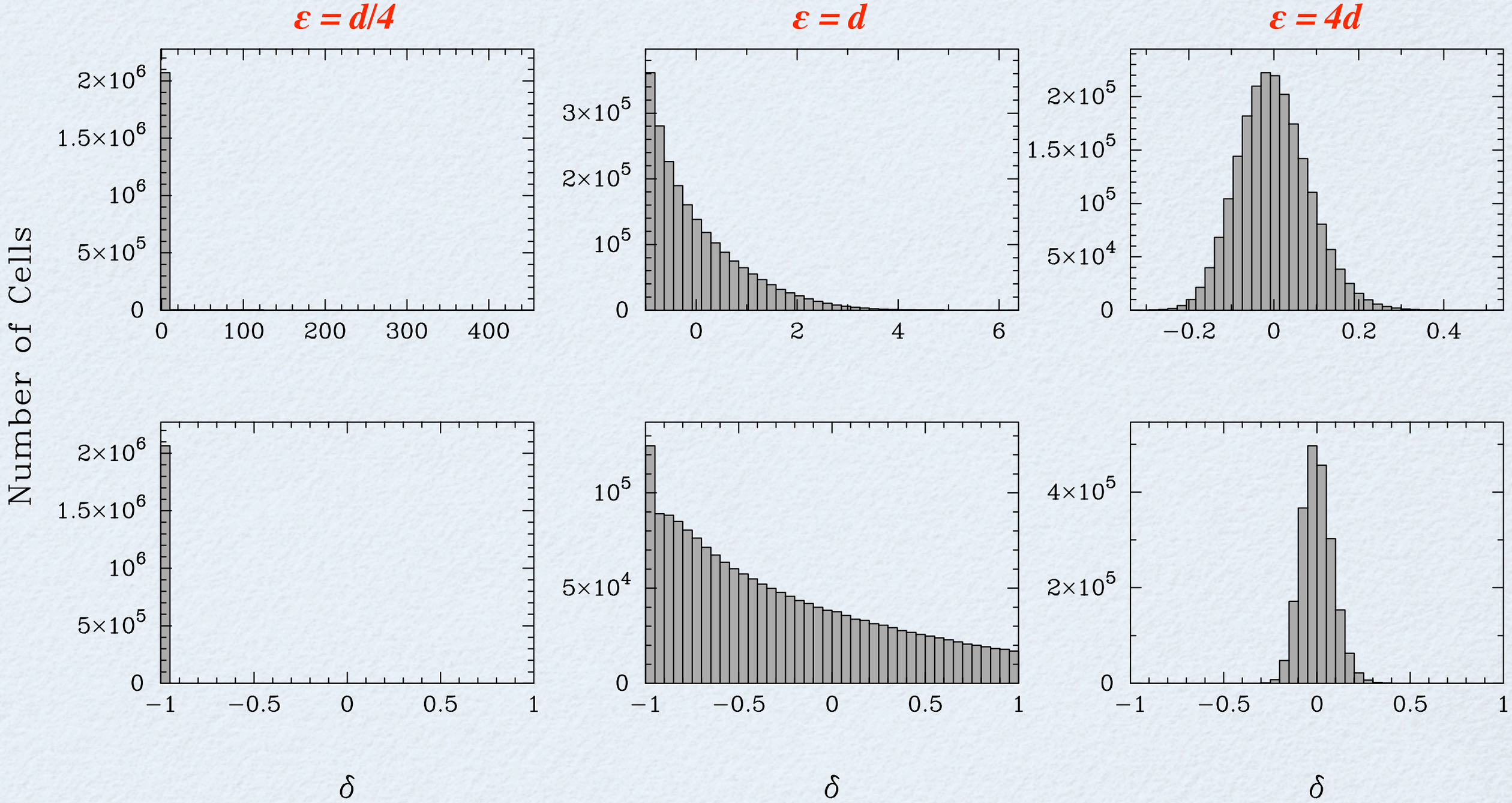
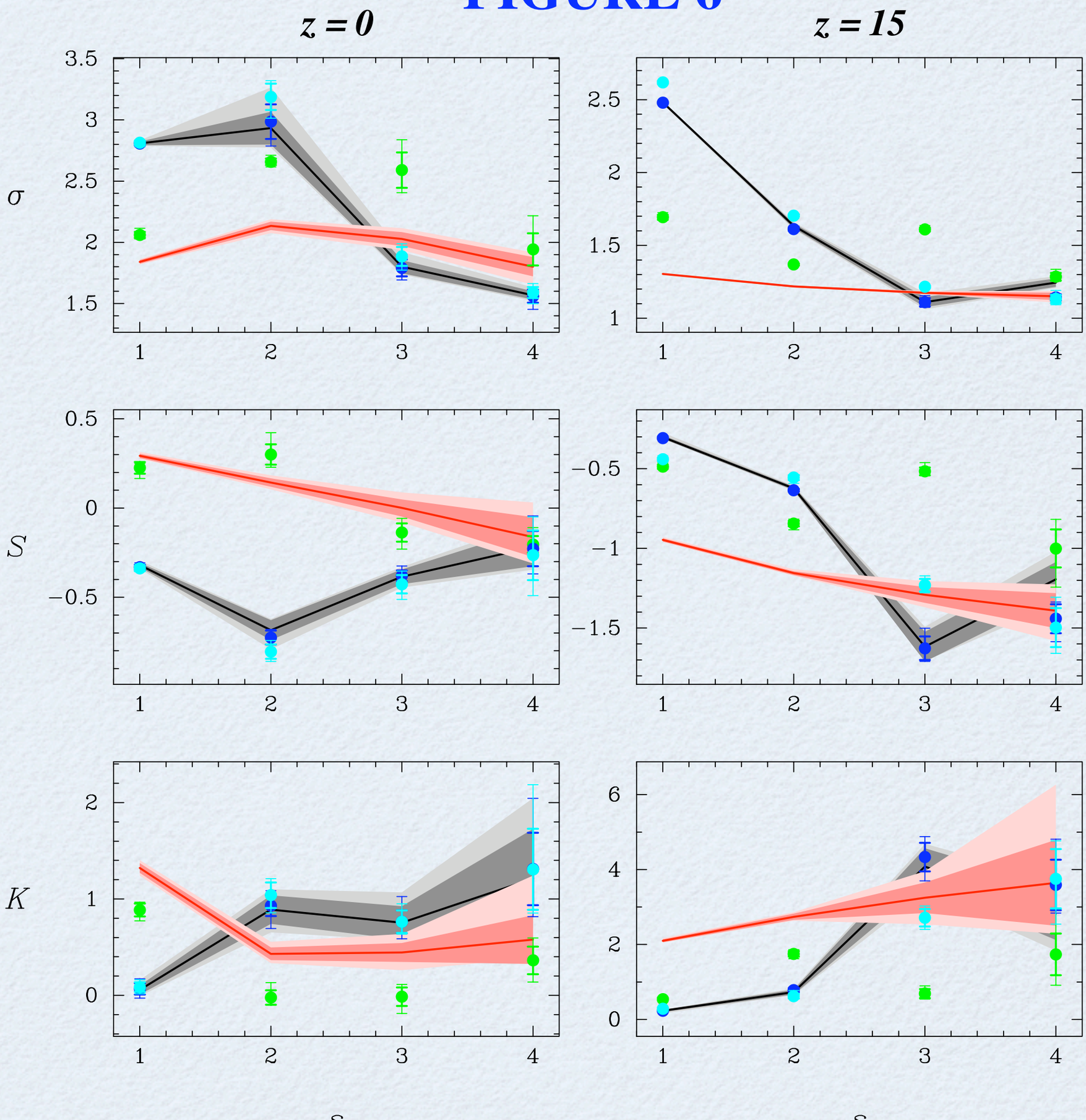

z = 100
ε = d/4
ε = d
ε = 4d
Number of Cells
Number
δ
δ
δ
2×10^6
1.5×10^6
10^6
5×10^5
0
100
200
300
400
3×10^5
2×10^5
10^5
2
4
6
1.5×10^5
5×10^4
−0.2
0.2
0.4
−1
−0.5
0.5
1
4×10^5

FIGURE 6



IMPLICATIONS

We conclude that discreteness effects can be kept under control by implementing our condition $\varepsilon \sim 2d$ adaptively, not only in AMR codes but also in tree-based codes, and clarify how [**See our ApJ paper (arXiv:0804.0294)**].