



Lattice simulations of α -attractor inflation: numerical sensitivity and model comparisons

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<https://nickbeavis.github.io/inflation-report.pdf>



Motivation & Summary

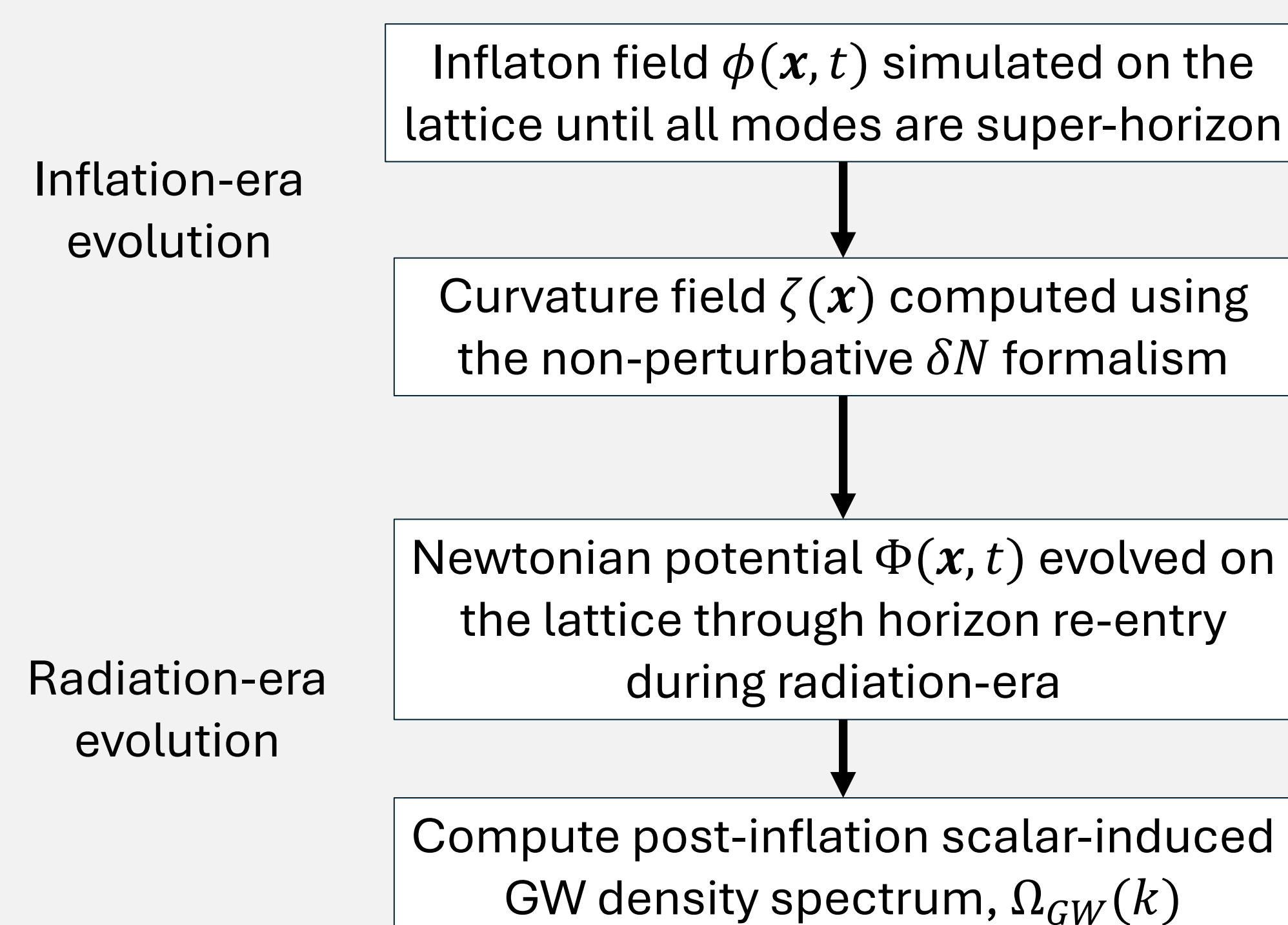
Measurements of the CMB tightly constrain observables on large scales. Many inflationary models, including the well-motivated E- and T-model α -attractors [1], have smooth plateau potentials and can reproduce n_s and r but evolve with very different dynamics away from CMB scales. Lattice simulations provide a means of investigating the nonlinear dynamics of inflation, along with potential observable consequences, however, the nonlinear corrections are expected to be small, making them difficult to resolve numerically.

Research question: How reliably can a nonlinear lattice pipeline recover the perturbative and observationally relevant predictions of smooth E/T-model α -attractor inflationary potentials, and can nonlinearity be detected once numerics are accounted for?

Conclusion: The pipeline can recover perturbative and observationally relevant predictions of the smooth E/T α -attractor models within a narrow k -range to within 1%-5%, but the nonlinear and model-to-model differences of E/T α -attractor models lie below the current numerical floor.

Numerical Method

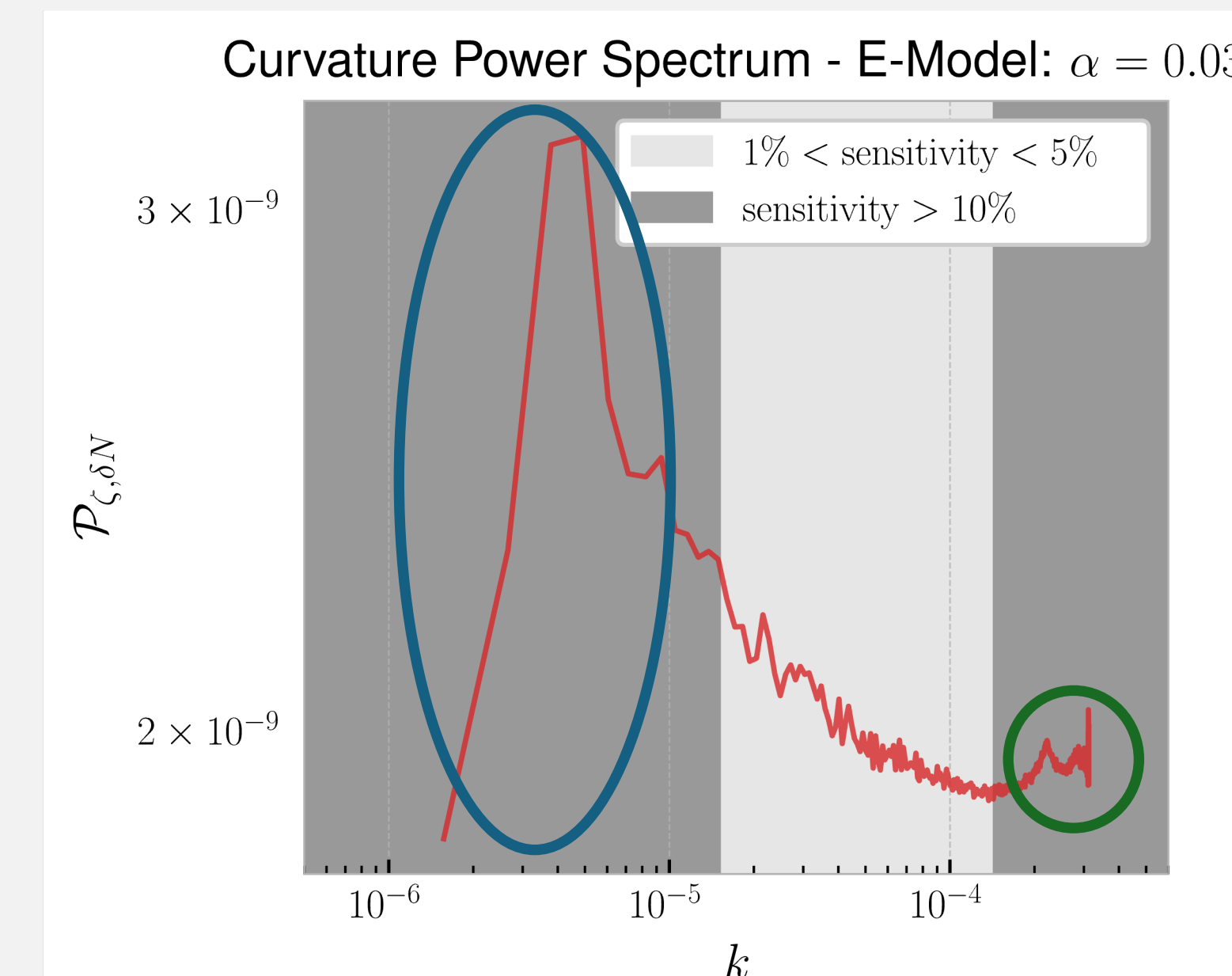
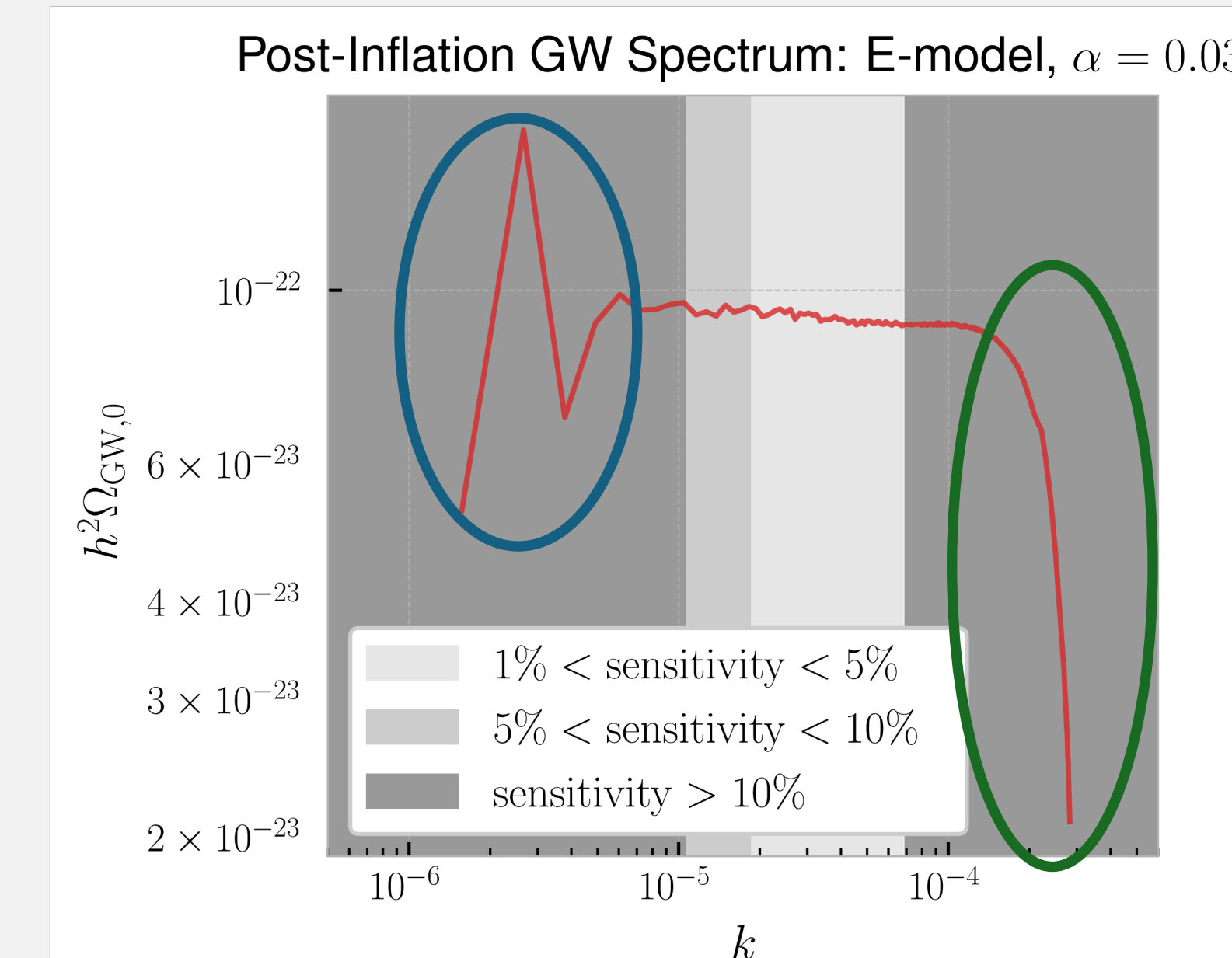
We used open-source 3D lattice code InflationEasy [2] which evolves a single-scalar field nonlinearly in an expanding FLRW spacetime across two distinct phases.



Numerical Validation & Sensitivity

The pipeline was validated using a USR benchmark [3] with curvature predictions reproduced to sub-percent level and post-inflation GW predictions <1.5%. A parameter sweep to test for numerical convergence and parameter sensitivity, found the IR (blue) and UV (green) regions sensitive input settings allowing us to trade-off computational expense and accuracy. From these results we established a percentage sensitivity in the predictions within different wavenumber (k) ranges that could be used to justify physical signal from numerics.

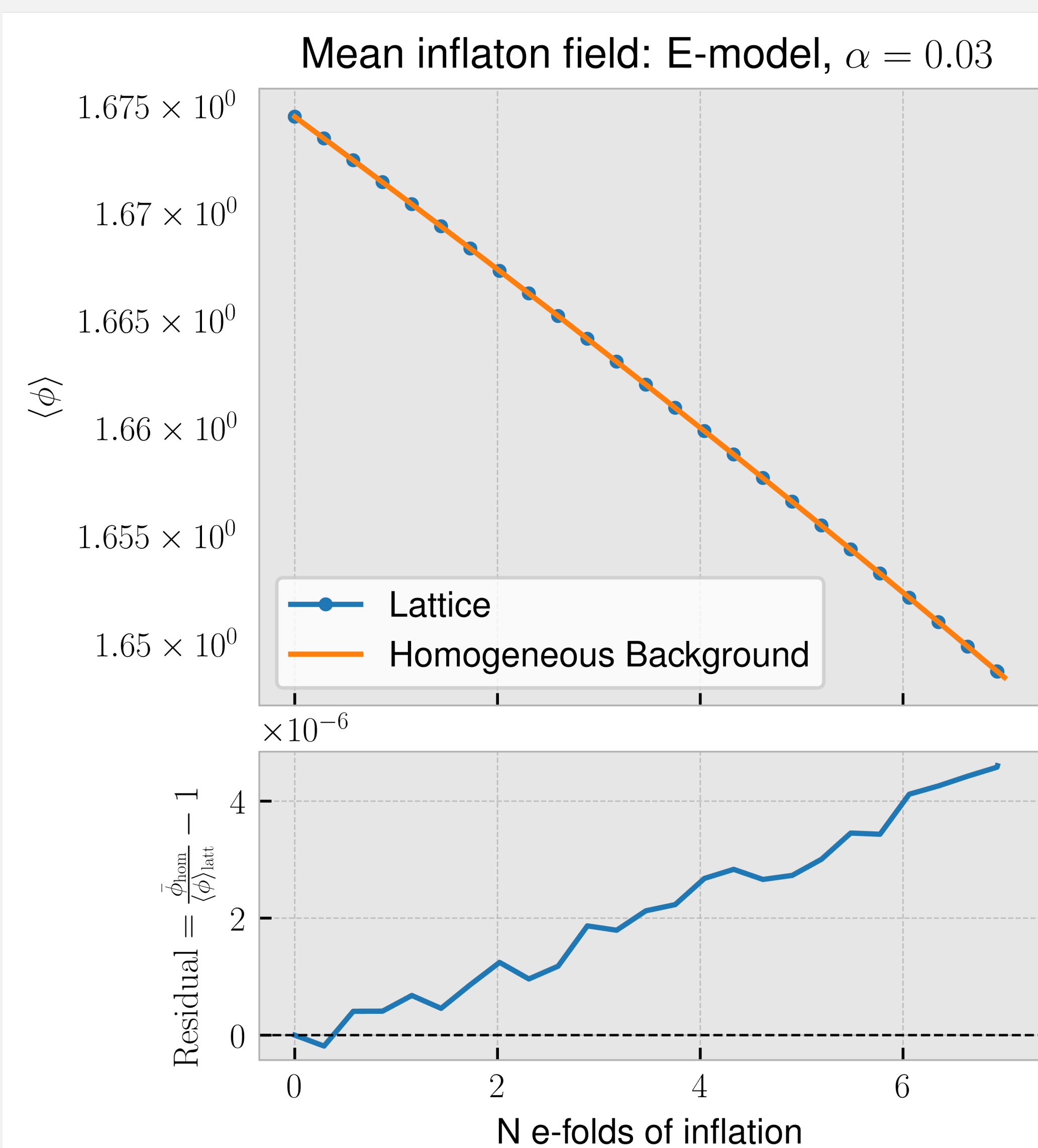
Sensitivity study established a restricted k -range with 1-5% numerical sensitivity



Results

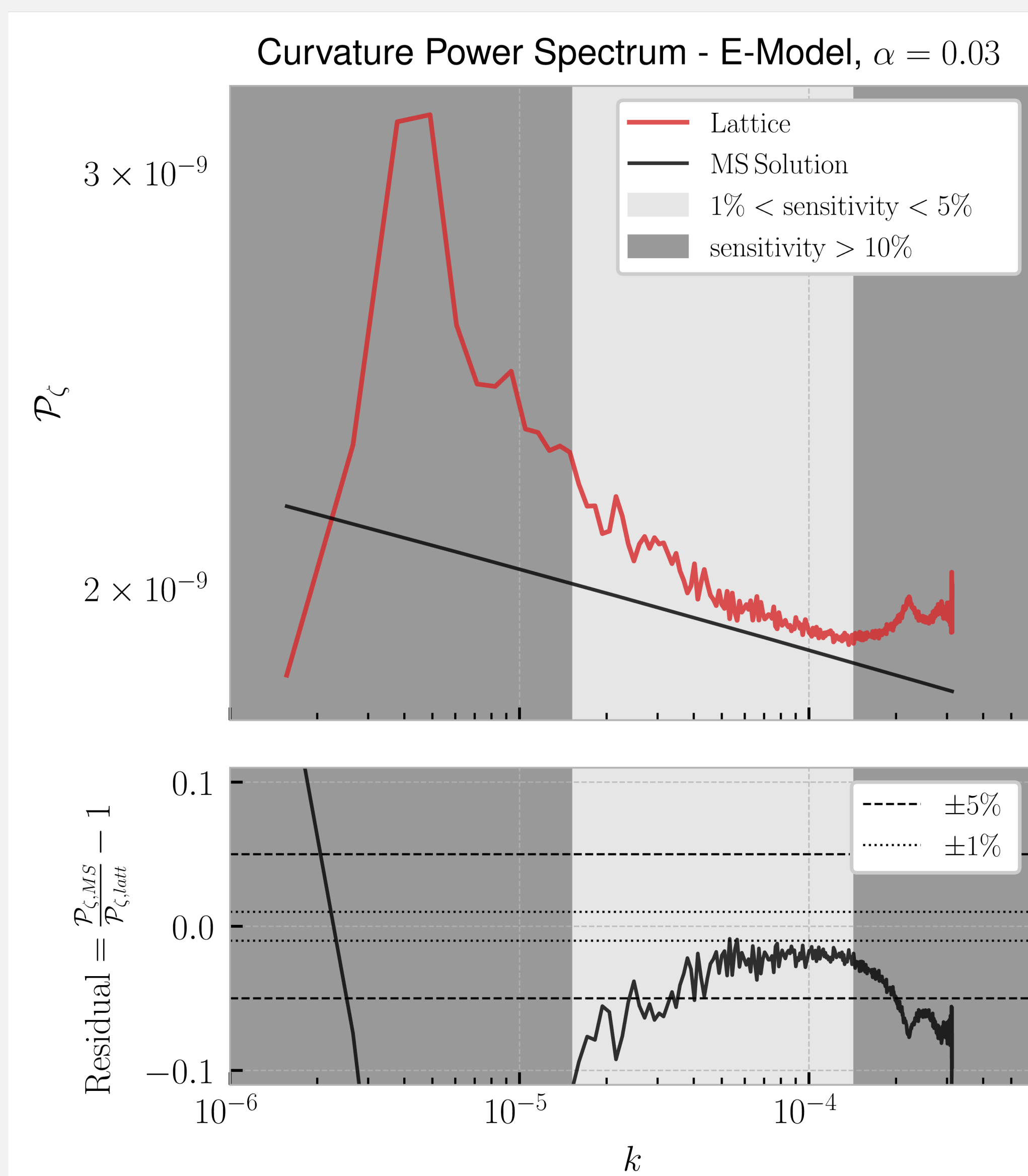
Backreaction was not resolvable within numerical precision

Backreaction is the impact of fluctuations on the evolution of the mean field. Comparing the spatially averaged field from the nonhomogeneous nonlinear lattice predictions against an evolved homogeneous field, found that the impact of backreaction with these α -attractor models below the current level of numerical precision.



Lattice predictions agreed with Mukhanov-Sasaki theory within numerical sensitivity

A comparison against the full Mukhanov-Sasaki (MS) solution, found the lattice results largely within 5% of the linear theory, and nonlinearity undetectable within established numerical sensitivity.



Model-specific normalisation reduces E/T-model differences below numerical sensitivity

Predictions using a typical leading order normalisation across both models at $\alpha = 0.3$ differed by >3% in curvature power and 7% in GW spectrum power, above the 5% numerical sensitivity. Using a model-specific normalisation reduced differences to 0.2% and 0.3% respectively, implying that for $\alpha \gtrsim 0.1$ a leading order correction is no longer appropriate and model-specific normalisation should be used.

