On the analogy between gravitationally driven turbulence and classical turbulence

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Abstract

Power spectra of simulated density fluctuations generated by gravitational fragmentation are compared to corresponding expressions from classical turbulence.

1. Introduction

A recent paper [1] includes power spectra of simulated density fluctuations generated by gravitational fragmentation. We have used [2] to extract the power spectrum for the scale factor $a = 200$, so there are inaccuracies in our postprocessing.

Previously, we have studied large-scale cosmological power spectra and attempted to place them in the context of classical turbulence using the example of turbulence measured in fusion plasmas [3, 4].

2. Power spectra

We treat power spectra P as a function of wavenumber ratio $k_{ratio} \equiv k/k_{horizon}$. For classical turbulence, the 3D Kolmogorov scaling is:

$$P(k_{ratio})_{3D} \propto \frac{E(k_{ratio})_{3D}}{k_{ratio}^2} \propto k_{ratio}^{-11/3}, \tag{1}$$

where E is energy.

For large wavenumbers, energy is dissipated and becomes an exponential function:

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$$P(k_{ratio})_{dissipation} \propto \exp(-n \times k_{ratio}), \tag{2}$$

where n is a constant.

Results are summarized in Fig. 1:

- The Kolmogorov scaling agrees with the simulated power spectrum over roughly an order of magnitude of intermediate wavenumber ratios.
- The exponential fit is applied for wavenumber ratios larger than 10; here, $n = 1.14$.

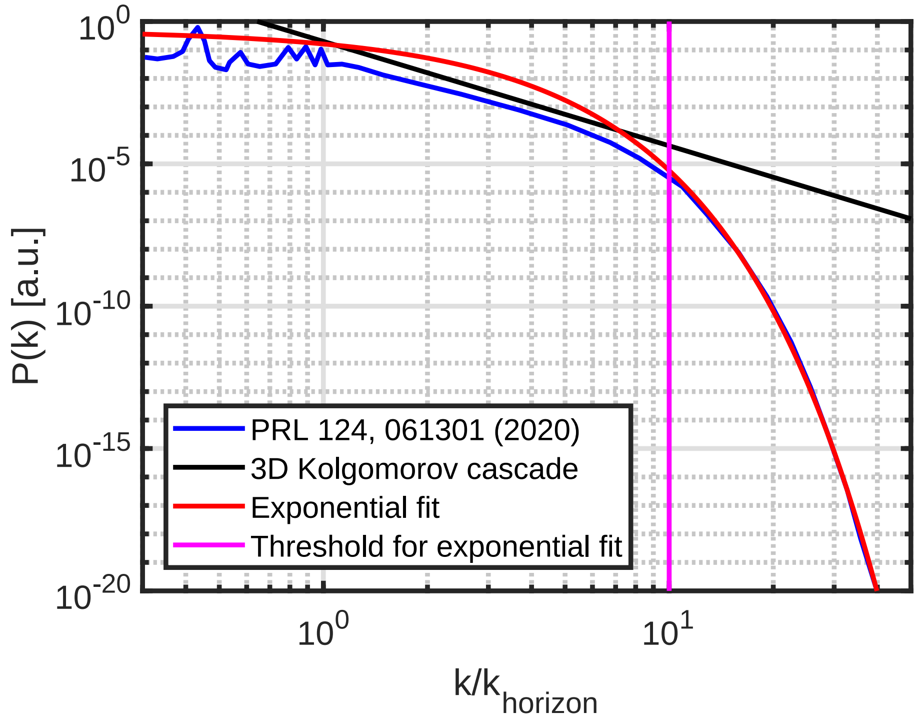

Figure 1: Simulated power spectrum (blue) with Kolmogorov scaling (black) and exponential fit (red) versus wavenumber ratio. The vertical magenta line indicates the wavenumber ratio used for the exponential fit: Only wavenumber ratios larger than the threshold value are used.

3. Dimensionality of cosmological turbulence

Findings in this work indicate that density fluctuations based on gravitational fragmentation appear to be 3D. However, our previous work has shown that large-scale cosmological power spectra are most likely closer related to 2D.

Thus, we speculate that early cosmological turbulence was 3D and during expansion transitioned to 2D [5]. This departure from isotropy might be related to the anisotropy of cosmic acceleration [6].

4. Conclusions

We have shown that the simulations of density fluctuations based on gravitational fragmentation can be analysed as classical turbulence. Based on this, we argue that an analogy exists between fluctuations observed in cosmology and classical turbulence.

References

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