Lagrangian curvature statistics from Gaussian sub-ensembles in von Kármán flow and Rayleigh-Bénard convection

Y. Hengster*and M. Linkmann*

A salient feature of fully turbulent flows far from onset is the intermittent occurrence of extreme fluctuations at small spatial and temporal scales. Here, we derive an expression for the curvature probability density function (pdf) for the ensemble of tracer particle trajectories in turbulence including spatio-temporal intermittency. We obtain a master curve for the pdf for near-Gaussian sub-ensembles, obtained by conditioning on the squared acceleration coarse-grained over a few viscous time units[1], where an analytic form of the pdf is known[2], from which we obtain the pdf for the full ensemble. The derived expression is compared against curvature pdfs calculated using tracer particle data obtained by Shake-The-Box processing[3] from two datasets, von-Kármán flow at $Re_\lambda = 270$ and Rayleigh-Bénard convection (RBC)[4] at moderate Rayleigh number $Ra = 1.53 \times 10^9$. For the RBC data we only consider events in the bulk. The theoretical curve agrees qualitatively and quantitatively with the data for all cases, see fig. 1 for the von-Kármán data.

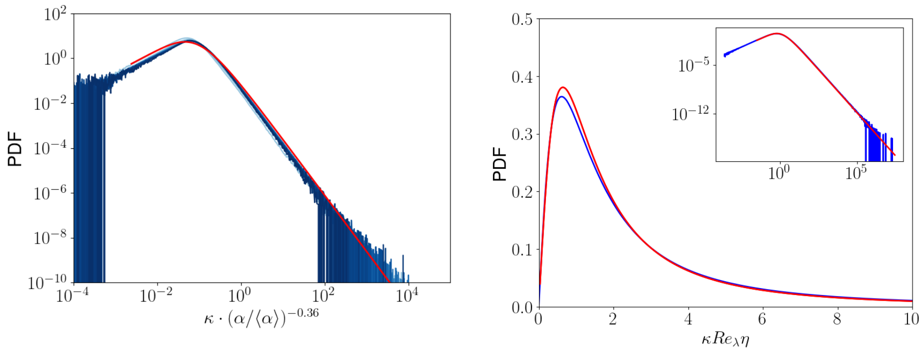

Figure 1: Curvature pdf for von-Kármán flow. Left: Master curve for curvature pdfs pertaining to Gaussian sub-ensembles obtained by conditioning on the persistent acceleration, α. The colour gradient indicates different values of α, the red curve is the analytical expression for the curvature pdf in a Gaussian ensemble. Right: Comparison between the derived expression for the full data (red) and the curvature pdf calculated from the data (blue).

*School of Mathematics and Maxwell Institute for Mathematical Sciences, University of Edinburgh, UK.

[1] L. Bentkamp, et al., *Nat. Comm.* **10**, 3550 (2019).

[2] H. Xu, N. Ouellette, E. Bodenschatz, *Phys. Rev. Lett.*, **98**, 050201 (2007)

[3] D. Schanz, S. Gesemann, A. Schröder, *Exp. Fluids* **57**, 70 (2016)

[4] P. Godbersen, J. Bosbach, D. Schanz, A. Schröder. *Phys. Rev. Fluids*, **6**, 110509 (2021)