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Multifractal predictability and a dynamical space-time cascade model: analytical results

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We aim to bridge up a gap between statistical/stochastic insights on the predictability of the Navier-Stokes equations and the structure of these space-time equations that are apparently deterministic. Scalar valued multifractal cascades have been quite helpful to understand the fundamental role of both the space extension and the associated space-time intermittency by underpinning a full hierarchy of eddy turn-over times instead of unique one as earlier hypothesised by either statistical theories of turbulence or quasi-normal closures. However, they could not go beyond hypothesising that these eddy turn-over times are inversely proportional to the Lyapunov exponents, nevertheless pointing out their anomalous scaling and a resulting small scale divergence. This divergence was considered as a breakdown of the Multiplicative Ergodic Theorem due to a large number of spatial degrees of freedom and therefore a rather definitive divorce between two approaches of predictability of nonlinear systems.

In this communication, we show on the contrary a rather unsuspected convergence with the help of a particular expression of the Multiplicative Ergodic Theorem applied to a dynamical space-time cascade called the Scaling Gyroscope Cascade (SGC). This model is obtained by a series of precise simplifications of the Navier-Stokes equation that preserves most its fundamental structure and properties (e.g. detailed conservation of energy by the nonlinear transfer). It also yields universal multifractal exponents very close to empirical estimates. In this framework, we define a volume error of the velocity components at a given scale and obtain analytical expressions of its temporal growth.