Extreme Anomalous Particle Transport in the Random Linear Amplification Model of the Edge Plasma Turbulence.

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The anomalous, or strange character of the particle transport in random environment is characterised by the algebraic asymptotic behaviour of the mean values of powers of particle displacement \( r(t) \) versus time. In the most general case, the anomalous or strange character is encoded in the dependence on \( p \) of the exponents \( \zeta_p = \lim_{t \to \infty} \log \left( \langle |r(t)|^p \rangle \right)/\log(t) \). In the normal case: \( \zeta_p = p/2 \) [1]. The extreme anomalous particle transport studied in this work is characterised by an exponential divergence, in the limit of large times \( t \), of the higher moments of the particle displacement. For \( p > \beta \geq 0 \), the asymptotic formula hold: \( p - \beta = \lim_{t \to \infty} \log \left( \langle |r(t)|^p \rangle \right)/t \), in other words for \( p > \beta \) and large time \( t \), we have: \( \langle |r(t)|^p \rangle \propto \exp((p - \beta)t) \). We remark the contrast with usual anomalous case [1], where for large time \( t \) we have \( \langle |r(t)|^p \rangle \propto t^{\zeta_p} \).

This new result is demonstrated in the framework of the random linear amplification model described in [2], which was developed to explain the experimental results on the edge turbulence on DIII-D tokamak, from refs. [3-4]. The constant \( \beta \) is the power law decay exponent of the heavy tail of the cumulative probability distribution function of the intensity of electrostatic field fluctuations in the plasma edge [2].

From empirical approximate [4] or exact self-similarity arguments, it follows [2], that \( 0 < \beta << 1 \), which is confirmed by tokamak edge plasma measurements [3] as well as by three fundamental self-organized criticality models [5]. It follows that all the integer moments of the particle displacement diverge exponentially, justifying the “extreme anomalous” terminology. We proved that the extreme anomalous particle transport qualitatively give rise to the correct, experimentally verified, isotope effect.

References.