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Energy diffusion in the long-range interacting spin systems

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We investigate energy diffusion in long-range interacting spin systems, where the interaction decays algebraically as $V(r) \propto r^{-\alpha}$ with the distance r between the sites. We consider prototypical spin systems, the transverse Ising model, and the XYZ model in the D-dimensional lattice with a finite exponent $\alpha > D$ which guarantees the thermodynamic extensivity. In one dimension, both normal and anomalous diffusion are observed, where the anomalous diffusion is attributed to anomalous enhancement of the amplitude of the equilibrium current correlation. We prove the power-law clustering property of arbitrary orders of joint cumulants in general dimensions. Applying this theorem to equal-time current correlations, we further prove several theorems leading to the statement that the sufficient condition for normal diffusion in one dimension is $\alpha > 3/2$ regardless of the models. The fluctuating hydrodynamics approach consistently explains L\'{e}vy diffusion for $\alpha < 3/2$, which implies the condition is optimal. In higher dimensions of $D \geq 2$, normal diffusion is indicated as long as $\alpha > D$. [1] [1] HN and K.Saito, arXiv:2502:10139

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