SCALING OF REACTIVE TRANSPORT IN FRACTURE NETWORKS: A FERMIONIC NETWORK APPROACH

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The study of networks as complex systems has revolutionized many disciplines in physics and the social and natural sciences. Recently, the focus of network science has shifted from the analysis of the network topology to the study of the dynamics of processes that take place on them.
Here, we adopt a fermionic network approach to characterize transport and reaction on fracture networks. In a fermionic network models, nodes may undertake contact processes within them by exchanging particles. Particles move between connected nodes along links, which reflects the traffic patterns through the network.
We assume simple lattice fracture networks with heterogeneous conductivity distribution and solve potential flow for simple flow configurations. It is well known that the transport of passive particles with complete mixing at the nodes on a fracture network or a scale-free network is anomalous [1,2,3]. Here, we extend this analysis to account for reaction at the nodes by considering two types of nodes, A and B, which come in contact if they exchange particles to produce two type-B nodes: $A+B \rightarrow 2B$. Further, type-B nodes decay into again the type-A nodes: $B \rightarrow A$. As a result, we capture the interplay among the transport and reaction time scales on a fracture network. Our analysis demonstrates the strong dependence of global mixing and spreading on the heterogeneity of the conductivity field, and allows us to obtain robust scalings for the spatio-temporal growth of the reaction process.
References:
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