ID: P2.21

Title: Anomalous scaling of moments and multifractality in two-phase flow in porous media

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Multiphase flow in porous media plays a pivotal role in a vast range of applications in different fields like oil recovery, soil mechanics and hydrology. A wide range of experimental, numerical and theoretical studies have been performed in order to understand the complex flow characteristics. Here, we address this problem by analyzing the scaling behavior of the moments [1,2] of local two-phase flow distribution in a disordered system. A two dimensional transport network of cylindrical tubes with disordered radii is considered as a model for the porous medium [3]. The network is filled with two immiscible fluids, one is less wetting and the other is more wetting with respect to the pores that flow inside the tubes. The fluids are separated by menisci associated with capillary pressure. The local flow rate q_i in each tube i follows Washburn equation of capillary flow. The distribution of the two-phase flow rates is calculated using conjugate gradient method. In the steady state, we compute the n-th moment $M(n)$ of the flow distribution as a function of the system size L keeping the capillary number constant. Depending on the Capillary number and the saturation of the fluids, we find the moments show anomalous scaling with the system size, characterized by a series of exponents $x(n)$ defined as $M(n) \sim L^{x(n)}$. This again leads to multifractal scaling [4] via Legendre transformation of the anomalous scaling exponents. This analysis provides a way to characterize the richness of structures that observed in the two-phase flow patterns by an infinite hierarchy of critical exponents. REFERENCES [1] G. G. Batrouni, A. Hansen and M. Nelkin, J. Physique 48, 771 (1987). [2] L. de Arcangelis and A. Coniglio, J. Stat. Phys. 48, 935 (1987). [3] T. Ramstad and A. Hansen, Phys. Rev. E 73, 026306 (2006). [4] H. E. Stanley and P. Meakin, Nature 335, 29 (1988).