A stochastic approach to the filling dynamics of a porous medium: full/empty pores duality symmetry and the emergence of Darcy’s law

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Abstract

A stochastic approach to the filling dynamics of an open topology porous structure permeated with a perfectly wetting fluid is presented. From the discrete structure of the disordered voids network with only nearest neighbors links, we derive the “microscopic” (at the pores scale) dynamical equations governing the filling dynamics of the coupled pores and the fluid pressure dynamics. The model yields two fundamental consequences. The first consequence regards the emergence of Darcy’s law and the dependence of the predicted permeability with the voids network topology. The second one is the prediction of a diffusive dynamics for the degrees of freedom of the pores filling. These equations exhibit a new type of symmetry manifested by their invariance under the full/empty pores duality transformation jointly with the velocity reversal. Non-trivial steady non-equilibrium pores filling states are also obtained and found to follow a Fermi-Dirac type law. The analogy with the single occupation of lattice sites by fermions
is highlighted together with the corresponding hole-particle symmetry.

**Keywords**: porous; Darcy’s law; duality symmetry