Dynamics of a fluid interface in imbibition experiments. Part 1: Local waiting time fluctuations along the interface

R. Planet*, S. Santucci, K.J. Måløy and J. Ortín
Departament d'Estructura i Constituents de la Matèria
Universitat de Barcelona
Martí i Franquès 1, 08028 Barcelona

The dynamics of immiscible fluid-fluid displacements in porous media has been a subject of much interest in last years[1], both from a fundamental point of view, as a dynamical nonequilibrium process, and from a technological point of view. The process is called forced-flow imbibition when an invading fluid that wets preferentially the medium displaces a resident fluid at a constant injection rate.

While the scaling properties of the interfacial morphology in imbibition experiments have been studied extensively (see Alava et al.[1] and references therein), the spatiotemporal dynamics of the process has not received the same attention[2].

In this work we use a high resolution camera with a high acquisition rate to track the dynamics of the interface in a model porous medium that consists on a Hele-Shaw cell with two different values of gap spacing, randomly distributed in space[4].

We show that the fluid interface dynamics is governed by local and irregular avalanches with very large size and velocity fluctuations. In order to characterize the scaling features of this local intermittent dynamics -the local pinnings and depinnings of the front- we adopt the analysis procedure recently proposed by Måløy et al.[3], and compute the local waiting time fluctuations along the front during its propagation: we measure at each point (x, y) of the recorded region the time spent by the front as it passes through this position. A typical gray-scale image of this so-called waiting time map is shown in Fig.1. The diversity of regions of different gray levels reflects the intermittent character of the local dynamics.

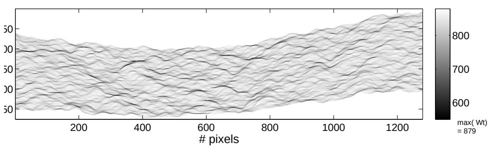

Figura 1. Gray-scale image of the waiting time matrix obtained from 12000 front positions, recorded with a 1280 × 276 pixels resolution at 100 fps. The darker parts correspond to the longer waiting times.

Avalanches are defined as clusters of velocities v larger than a given threshold v_c. Our results (see Fig.2) show that the avalanche size distribution follows a power law (with an exponential cut-off at large sizes). The analysis allows studying also the anisotropic shape of the avalanches and the statistical distribution of their durations.

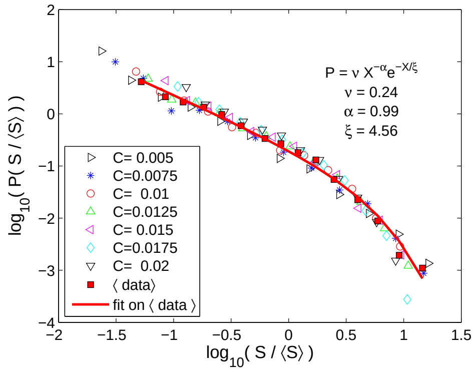

Figura 2. Statistical distributions of avalanche sizes for a given set of experimental parameters. The different distributions are obtained by keeping the velocities larger than a given threshold v_c, defined by $v_c = \langle v \rangle + C(\max(v) - \langle v \rangle)$, where C is the clip level.

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* rplanet@ecm.ub.es

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