Dynamics of a fluid interface in imbibition experiments. Part 2: Global dynamics

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In many different correlated systems global quantities have been found to display non-Gaussian fluctuations around their mean value[1]. The probability density function of the fluctuations seems to have an universal character[2].

Forced-flow imbibition is a particular case of two-phase fluid transport in porous media, in which an invading fluid that wets preferentially the medium displaces a resident fluid at constant injection rate. In this system the average velocity of the interface behaves as a global quantity. Recently, Rost et al.[3] have performed phase-field simulations of imbibition flows, and have shown indeed that the fluctuations of this average velocity follow a PDF that resembles the universal distribution mentioned above.

In this work we present an experimental study of the average velocity fluctuations in imbibition. The experiments are carried out in a model porous medium that consists on a Hele-Shaw cell with a two-valued gap spacing randomly distributed in space[4]. We use a high resolution camera with a high acquisition rate to track effectively the dynamics of the interface. The large spatial and temporal resolution of our measurements allows to carry out the analysis procedure recently proposed by Måløy et al.[5], 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. The inverse of the local waiting time gives a measure of the local velocity. The global fluid interface dynamics is then obtained by computing the average velocity $V(t) = \langle v(x,t)\rangle_x$, where $\langle\cdots\rangle_x$ is the spatial average along the front direction x.

Our results show that $V(t)$ is a jerky signal, characterized by sudden bursts, signature of an intermittent dynamics. We analyze the scaling features of this signal along the lines of Rost et al.[3]: the average velocity fluctuations follow the universal BHP distribution studied by Bramwell et al.[1,2], and the rms fluctuations of the average velocity are linearly related to its time average, in very good agreement with the theoretical predictions.

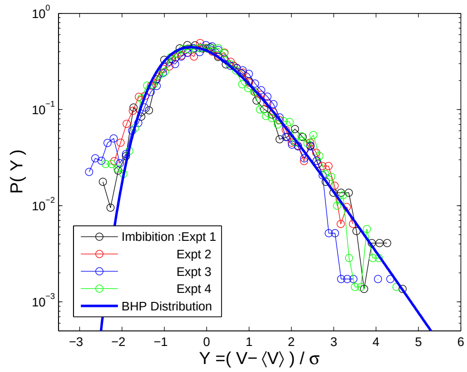

Figura 1. Probability density function of the average velocity fluctuations for forced-flow imbibition experiments at four different flow rates. The data collapse in a single curve, consistent with a BHP distribution.

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