Meandering of liquid rivulets on partially wetting inclines

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This fluid dynamics video illustrates recent advances in the understanding of the mechanism which causes the sinuous path formed by liquid rivulets on partially wetting inclines. The images themselves show how a simple lighting set-up using a large Fresnel lens can be used to obtain high contrast images of large transparent objects.

Video links[1]: 640×360 version, 6MB 1280×720 version, 34MB

The meandering of liquid rivulets is an ubiquitous phenomenon whose mechanism has however remained subject to debate[1]. While the main intervening forces are quickly listed, the wetting hysteresis found on most partial wetting substrates causes contact line pinning, which makes modelling difficult. The recent description of a system exhibiting meandering in total wetting conditions[2] has led us to measure and calculate the dynamics of the rivulet and to identify an inertial linear instability, with good agreement between theory and experiment[3].

We revisit meandering in partial wetting conditions with an experimental set-up that delivers high contrast images of the rivulet for quantitative analysis at both local and large scales. This is achieved by lighting the rivulet from below through a Fresnel lens (lateral dimenions 1.2 m by 0.8 m, focal length $f = 1$ m) and a transparent substrate, and placing a camera at the point where the light rays emanating from a light emitting diode are focussed by the lens. The minimal distance of camera and light source is $4f$ if the conjugated positions are chosen symmetrically, at equal distance to the lens. In the absence of any obstacle, the substrate appears evenly illuminated, as light rays through every point of the lens enter the camera's entrance pupil. The set-up is very sensitive to the quality of the optical components in play, as there is now essentially only one light ray through any point in the substrate, at least in the limit where the size of the light source and the objective diaphragm (both about 1 mm in diameter) are negligible compared to the length of the light path ($\sim 4f = 4$ m). In practice we see mainly chromatic aberrations and diffraction on the rings of the Fresnel lens.

The rivulets shown in the video are distilled water running down a vertical polyethylene or glass substrate at flow rates of a few cm^3/s.

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[1]Alternate video links — arXiv: `http://arxiv.org/src/1210.3902/anc`
Youtube: `https://www.youtube.com/watch?v=vMygH-gOWKU`

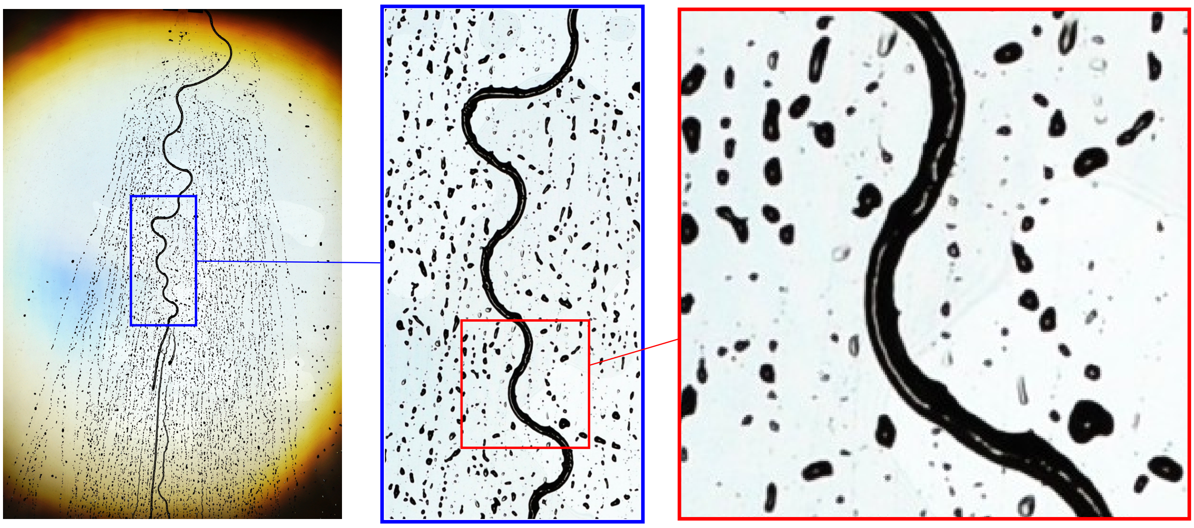

Figure 1: Photograph of the meander, with magnified details in the middle and to the right. Note how the white line in the rivulet, visible in the most zoomed detail to the right, indicates the locus of maximum rivulet thickness.

With a 12 Megapixel digital camera, the resolution is sufficiently good to measure the curvature of the meander down to the scale of the rivulet width (see Fig. 1). We have used this recently to find a relation between the mean roughness of the initial straight rivulet, and the threshold flow rate at which that rivulet starts forming meanders[4].

The meander dynamics shows a surprising range of time scales. While the liquid takes only about one second to run down the incline, the lateral motion of the rivulet is typically two orders of magnitude smaller ($\sim$1 cm/s). Stationary shapes of meanders are sometimes reached only after about 10^4 s. In principle our highly contrasted images, compatible with automatic detection and image processing, should allow for detailed analysis of this long dynamics.

References

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