

FIG. 1. Falling drop and resulting splash sequence: (a) 0 ms; (b) 2 ms; (c) 7 ms; (d) 19 ms; (e) 33 ms; (f) 45 ms.

### Elastic splash of two Newtonian liquids

Torben Grumstrup and Andrew Belmonte

*W. G. Pritchard Laboratories, Pennsylvania State University,  
University Park, Pennsylvania 16802, USA*

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When a falling drop impacts a thin liquid surface, the resultant splash involves the competition of inertia, viscosity, and surface tension, and in certain limits the familiar crown results.<sup>1,2</sup> For viscoelastic fluids (either polymeric or micellar), there is typically much less of a splash due to the high extensional viscosity of these fluids.<sup>2</sup> Here we present a novel cross between these two cases: the splash of two Newtonian liquids that only become viscoelastic during the splash.

At the instant depicted in Fig. 1(a), both the falling droplet (0.2 ml) and the thin quiescent layer (2 mm deep) are still Newtonian fluids. The droplet is an aqueous solution of organic salt (350 mM sodium salicylate), and the thin layer is an aqueous surfactant solution (350 mM cetyltrimethylammonium bromide). When mixed homogeneously, these solutions are known to produce a highly elastic wormlike micellar fluid; when brought into contact slowly in a Hele-Shaw cell, a thin viscoelastic skin forms.<sup>3</sup> For an impact speed of 7.5 m/s, the sequence of images in Fig. 1 (with times indicated) provides evidence of increasing viscoelasticity throughout the growth and collapse of the splash. The fingers on the elastic crown stretch out like tentacles, showing a stability to pinch-off typical of elastic fluid filaments [Figs. 1(b)–1(f)]. Furthermore, the rising fluid curtain develops a texture indicative of the growing structures in the fluid [Figs. 1(c)–1(e) and Fig. 2]. The onset of these effects allows us to estimate a reaction rate for the two components at about  $500 \text{ s}^{-1}$ . The elastic crown can extend up to several cm above the surface, whereas the splash is much reduced for

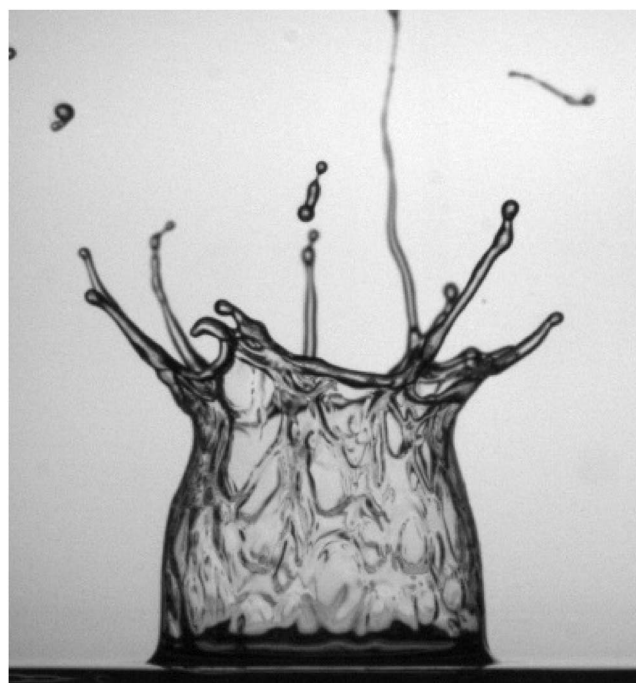


FIG. 2. Closeup of the elastic splash from the same sequence shown in Fig. 1 (at 27 ms); image is about 7 cm across.

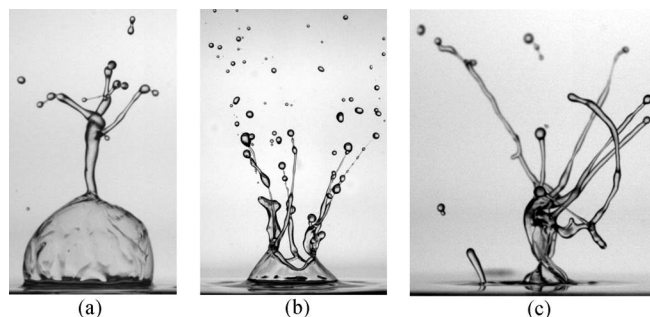


FIG. 3. Variety of forms observed during the collapse of the elastic splash. drop impact when both fluids are comprised of the constituents premixed.

In some cases, the fluid curtain closes and forms an elastic bubble, with a jet often poised at its apex [Fig. 3(a)]. If the dome fails to close, the curtain rapidly collapses, often pulling the beaded filaments back down into the fluid [Figs. 1(f) and 3(b)]. The resulting tangle often produces interesting forms [Fig. 3(c)]. Such effects would not have occurred in a viscoelastic splash, in which elastic effects present from the beginning limit the formation of structure. By combining these two reactive (wormlike micelle forming) fluids *during* the splash, the elastic effects are delayed—with spectacular results.

<sup>1</sup>H. E. Edgerton and J. R. Killian, *Moments of Vision* (MIT Press, Cambridge, MA, 1979).

<sup>2</sup>A. L. Yarin, “Drop impact dynamics: Splashing, spreading, receding, bouncing,” *Annu. Rev. Fluid Mech.* **38**, 159 (2006).

<sup>3</sup>T. Podgorski, M. Sostarecz, S. Zorman, and A. Belmonte, “Fingering instabilities of a reactive micellar interface,” *Phys. Rev. E* **76**, 016202 (2007).