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Visions of fluid dynamics

Dancing marbles in a soap film

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ABSTRACT

Two millimeter-sized particles deposited in a large horizontal soap film are attracted towards each other. Due to the very low friction at the surface of the soap film, the particles can exhibit a complex trajectory, and appear to dance together for about ten seconds before colliding. We give here a short overview of the topic and its perspectives. Refers to: https://www.sciencedirect.com/journal/european-journal-of-mechanics-b-fluids/about/news/visions-of-fluid-dynamics-video-competition.

Small particles deposited at the surface of a bath deform it by a combination of gravity and capillarity. This induces an attractive force between identical particles [1], known as the "Cheerios Effect" [2], from the well-known cereal which cluster at the surface of the milk. Beyond this everyday-life observation, the Cheerios Effect is responsible for the self-assembly of colloids or millimeter-sized particles [3]. The particles form a "raft" [4] which properties are controlled by the shape and contact angle of the particles [5,6]. With some rare exceptions [7], the floating objects experience a substantial drag due to the friction with the underlying bath, which generally limits the observable dynamics to straight-lines approach [8].

We focus here on an analogous situation, where the interface supporting the particles is now the surface of a soap film. As with the Cheerios effect at the surface of a bath, the deformation of the film generates an attractive force. In contrast with the previous case, the attractive force acts at much longer distances on a soap film – as discussed later – and friction is drastically reduced. The particle motion is slowed down only by viscous friction within the surrounding air (50 times less viscous than water) and in the micrometer-sized film [9]. When two particles are deposited simultaneously, the combination of attractive forces and low friction gives rise to complex trajectories, where the marbles seem to swirl around one another.

The experiment presented in the video is the following. An horizontal soap film (Fig. 1a) is generated by dipping an octagonal frame (with size L = 8,9 cm) in a soap solution made of 5.6 g/L of sodium dodecyl sulfate (SDS) and 50 mg/L of dodecanol in a water–glycerol solution (with 15% glycerol in volume). A first particle (with diameter D = 626 μm and mass m = 1,0 mg) is gently deposited in the film using tweezers. Due to the deformation of the film under its own weight [9], the particle spontaneously moves towards the center of the film, where it stabilizes. A second particle is then deposited ∼2 cm from the edge of the film, and gently pushed so that its initial velocity is in the orthoradial direction. The second particle starts sliding into the film, while simultaneously, the first particle — attracted by the newcomer — leaves the center and joins the dance. The two particles then follow a complex trajectory, as they are attracted at the same time towards the center of the film and towards each other. This mesmerizing ballet is filmed from the top, using a high-speed camera at 1200 fps. The particles trajectories are tracked as a function of time using Python, from which the interaction force can be deduced. Fig. 1b shows the successive positions (separated by 58 ms) of the two particles as they circle each other. The color code indicates their velocity: it is of the order of a few centimeters per second, more than one order of magnitude higher than what is usually observed when particles aggregate at the surface of a bath [2,8].

In contrast with Fig. 1a, which is shot in reflection, Fig. 1b uses fluorescence imaging. A fluorescent dye (fluorescein at 0.8 g/L) is added to the soap solution. Once formed, the film is lit at the absorption wavelength of fluorescein (470 nm) using a blue LED. The high-speed camera is equipped with a band-pass filter centered around 520 nm, so that only the light emitted by the soap film is visible. This setup is used to evidence variations in the thickness of the soap film, with the thickest areas appearing lighter. Particles appear here as black dots at the center of a white circle, which evidences a liquid meniscus surrounding them. The meniscus is present as soon as the bead (wetting and pre-wetted) is deposited in the film, and it slowly grows over time by sucking liquid from the thin soap film [9–11]. On the timescale of an experiment (typically 10 s), its size remains nearly constant. When the particles are far from each other, as in Fig. 1b and 2a, the liquid menisci move as a bulk with the particles and follow them in their

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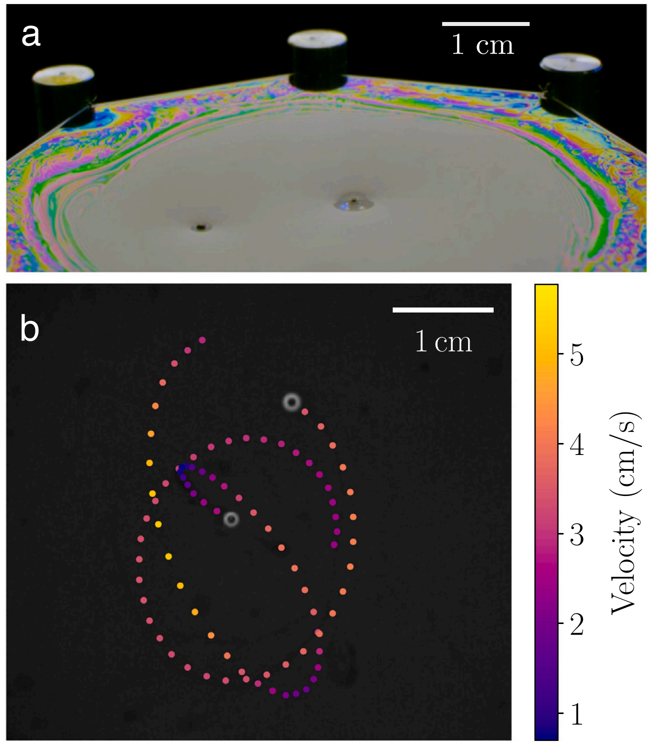

Fig. 1. a. Experiment: two millimeter-sized particles are deposited in an horizontal soap film. They are attracted towards each other, and, due to the low friction, exhibit intricate trajectories. **b.** Successive positions (separated by 58 ms) of two marbles of identical mass m = 1,0 mg moving in a soap film, filmed using fluorescence imaging. The color code indicates the particle velocity. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

motion. At large distance, the menisci only marginally influence the particle dynamics, by increasing the effective diameter of the moving objects (by a factor ~ 3) and their mass (by typically 10%) [9], which has to be taken into account in the interaction force.

The long-distance attractive force between two marbles in a soap film results from a film-scale deformation due to the weight of the beads [12]. More precisely, each particle is sensitive to the vertical deformation of the soap film surface caused by the presence of the other bead. Noting h the film deformation induced by a first isolated particle, and d the distance between the two particles, the deformation $h(d)$ felt by the second particle (with mass m) is associated with an interaction potential $E = mgh(d)$, with g gravity.

The film deformation h induced by the mass of a particle is catenoid-like so that, in the limit of small deflections, h varies logarithmically with the distance to the particle [9]. The interaction force $F = -\partial E/\partial d$ is thus expected to vary proportionally to $1/d$, a prediction that matches well the observed trajectories [12].

This model is valid as long as the particles remain far enough. Indeed, at short distances, the menisci play a central role on the interaction force. As evidenced in Fig. 2, the two menisci, initially axisymmetrical and centered on each particle (Fig. 2a) merge when the marbles are close enough (Fig. 2b); eventually forming a unique, ellipsoidal meniscus. Experimentally, menisci coalescence is associated with a sudden drop of the distance d between the particles, which evidences the apparition of a larger attractive force. This force is typically one order of magnitude higher than the film-mediated force.

To conclude, it is interesting to emphasize the fundamental differences between capillary attraction at the surface of a soap film and that at the surface of a liquid bath. On a bath, the interface deformation h_{bath} decays exponentially with the distance r to the particle, over a few millimeters. More precisely, it follows $h_{\mathrm{bath}} \propto K_0(r/l_c)$ [2], with l_c the capillary length and K_0 a modified Bessel function of the first kind. On a soap film, however, the interface remains deformed far from the particle: the deflection h evolves logarithmically with r, over a characteristic length scale set by the film size L, as $h \propto \ln(r/L)$ [9]. As a result, the attractive force in a soap film can act over much larger distances than at the surface of a bath. Combined with the extremely low friction inside a soap bubble, this gives rise to complex trajectories that cannot be observed on a bath. Another original feature of this system is the transition between a long-range interaction mediated by the film and a short-range interaction mediated by the menisci. This particularly rich behavior is currently the object of further investigation.

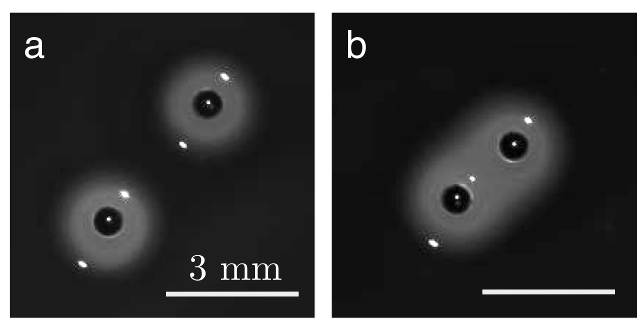

Fig. 2. a. Zoomed-in view of two particles in a soap film using fluorescence imaging. Each particle is surrounded by a liquid meniscus, which moves along with it. **b.** When the particles are close enough, the two menisci merge. The scale bar indicates 3 mm in both panels **a** and **b**.

CRediT authorship contribution statement

Youna Louyer: Investigation, Software, Visualization, Writing – review & editing. **Benjamin Dollet:** Investigation, Writing – review & editing. **Isabelle Cantat:** Conceptualization, Supervision, Investigation, Writing – review & editing. **Anaïs Gauthier:** Conceptualization, Supervision, Investigation, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.euromechflu.2025.204423.

Data availability

Data will be made available on request.

References

[1] M.M. Nicolson, The interaction between floating particles, in: Mathematical Proceedings of the Cambridge Philosophical Society, vol. 45, (2) Cambridge University Press, 1949, pp. 288–295.
[2] D. Vella, L. Mahadevan, The Cheerios effect, Am. J. Phys. 73 (9) (2005) 817–825.
[3] G.M. Whitesides, B. Grzybowski, Self-assembly at all scales, Science 295 (5564) (2002) 2418–2421.
[4] S. Protière, Particle rafts and armored droplets, Annu. Rev. Fluid Mech. 55 (1) (2023) 459–480.
[5] L. Botto, E.P. Lewandowski, M. Cavallaro, K.J. Stebe, Capillary interactions between anisotropic particles, Soft Matter 8 (39) (2012) 9957–9971.
[6] D. Ershov, J. Sprakel, J. Appel, M.A. Cohen Stuart, J. van der Gucht, Capillarity-induced ordering of spherical colloids on an interface with anisotropic curvature, Proc. Natl. Acad. Sci. 110 (23) (2013) 9220–9224.
[7] A. Gauthier, D. van Der Meer, J.H. Snoeijer, G. Lajoinie, Capillary orbits, Nat. Commun. 10 (1) (2019) 3947.
[8] M.-J. Dalbe, D. Cosic, M. Berhanu, A. Kudrolli, Aggregation of frictional particles due to capillary attraction, Phys. Rev. E 83 (5) (2011) 051403.
[9] Y. Louyer, B. Dollet, I. Cantat, A. Gauthier, Sliding dynamics of a particle in a soap film, J. Fluid Mech. 1007 (2025) R8.
[10] A. Aradian, E. Raphael, P.-G. De Gennes, ‘‘Marginal pinching’’ in soap films, Europhys. Lett. 55 (6) (2001) 834.
[11] S. Guo, X. Xu, T. Qian, Y. Di, M. Doi, P. Tong, Onset of thin film meniscus along a fibre, J. Fluid Mech. 865 (2019) 650–680.
[12] J.-P. Martischang, B. Reichert, G. Rousseaux, A. Duchesne, M. Baudoin, Orbiting, colliding and merging droplets on a soap film: toward gravitational analogues, 2025, arXiv preprint arXiv:2503.08331.