Chair: Physics of Fluids group

Playing ping-pong with liquid droplets

Description

Recently, during one of his trips to the International Space Station, astronaut Scott Kelly demonstrated that one could play ping-pong in space using water drops (link here). This demonstration follows from a long history of research on bouncing drops on superhydrophobic surfaces (see the discussions related to bouncing off superhydrophobic surfaces in Josserand and Thoroddsen (2016) and Sanjay (2022d)).

In this study, we would like to further our understanding of this process of bouncing droplets (Sanjay et al., 2022a,b; Zhang et al., 2022). A typical sequence of events is shown in Figure 1. In our simulation, we will use an in-house developed read-to-use code to solve the problem of the liquid drop impact on dry substrate. We will focus on the hydrodynamics of the process.

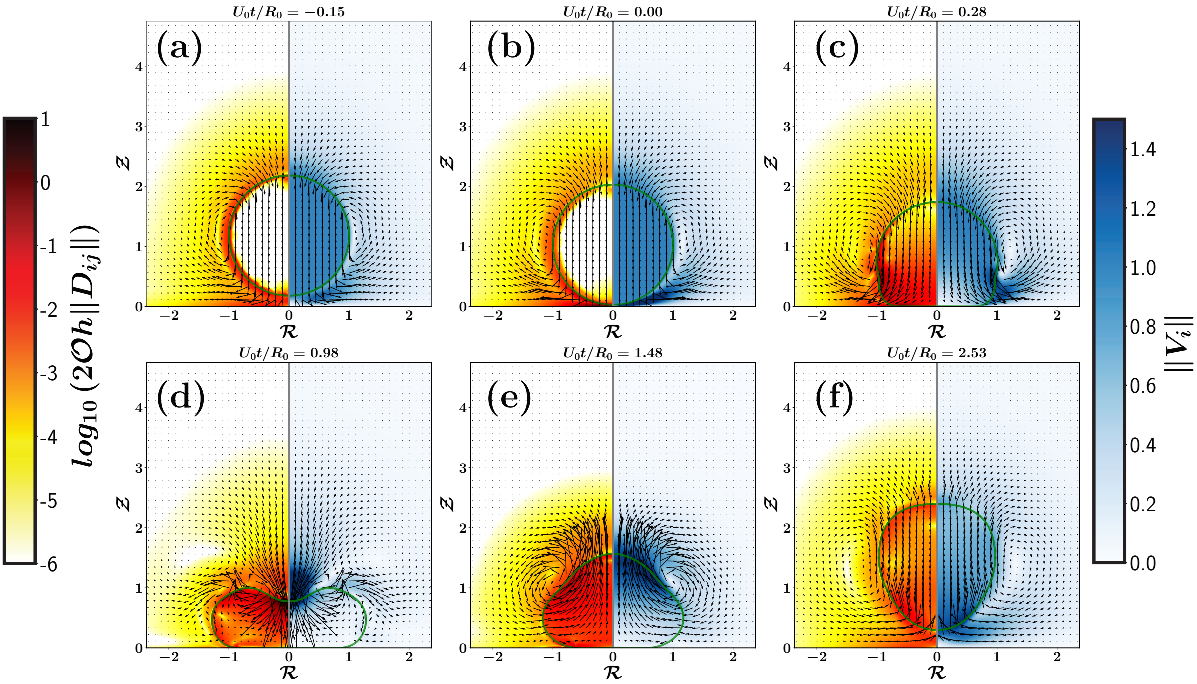

Figure 1: A typical simulation of a drop bouncing off a superhydrophobic substrate: (a) The drop approaches the substrate, (b) Air is squeezed out of the thin gap between the drop and the substrate, leading to lubrication flow in the gap, (c) The drop spreads on the substrate (see Wildeman et al. (2016)), (d) - (e) The drop changes the direction of motion because of the substrate, and (f) The drop bounces back.

What you will do and what you will learn?

In the Physics of Fluids group, we are looking for enthusiastic students to work on this topic.

1. You will learn about fundamental fluid dynamics.
2. You will get hands-on experience with Computational Fluid Dynamics (CFD).
3. You will learn how to do basic and advance data analysis.
4. You will learn how to document and publish ready to use codes and share it with the community, similar to Sanjay (2022a,b,c).

As a part of your bachelor's/master's assignment, we would like you to explore the field and come up with exciting avenues. To get you started, here is a list of open questions:

1. How does the normal contact force between the drop and the substrate vary with the drop's viscosity and velocity?
2. Drop impact dynamics (including normal contact force and coefficient of restitution) in the limit of zero impact velocity.
3. Dissipate anomaly in the limit of zero drop viscosity.
4. Hydrodynamic singularities in drop impact and how are they regularized? See: Mandre and Brenner (2012) for impact time singularity and Bartolo et al. (2006), Sanjay et al. (2021), and Zhang et al. (2022) for singular jets.

If you have any questions, fell free to contact Vatsal (details below).

Supervision	E-mail	Office
Dr. Vatsal Sanjay	contact@vatsalsanjay.com	Meander 246B
Dr. Pierre Chantelot	p.r.a.chantelot@utwente.nl	Meander 246B
Prof. Detlef Lohse	d.lohse@utwente.nl	Meander 261

References

Bartolo, D., Josserand, C., and Bonn, D. (2006). "Singular jets and bubbles in drop impact". *Phys. Rev. Lett.* 96.12, p. 124501.

Josserand, C. and Thoroddsen, S. T. (2016). "Drop impact on a solid surface". *Annu. Rev. Fluid Mech.* 48, pp. 365–391.

Mandre, S. and Brenner, M. P. (2012). "The mechanism of a splash on a dry solid surface". *J. Fluid Mech.* 690, pp. 148–172.

Sanjay, V. (2022a). *Code repository: Drop impact on viscous liquid films.* https://github.com/VatsalSy/Drop-impact-on-viscous-liquid-films (Last accessed: April 1, 2022).

Sanjay, V. (2022b). *Code repository: Impact forces of water drops falling on superhydrophobic surfaces.* https://github.com/VatsalSy/Impact-forces-of-water-drops-falling-on-superhydrophobic-surfaces.git (Last accessed: February 4, 2022).

Sanjay, V. (2022c). *Code repository: When does a drop stop bouncing?* https://github.com/VatsalSy/When-does-a-drop-stop-bouncing (Last accessed: April 20, 2022).

Sanjay, V. (2022d). "Viscous Free-Surface Flows". English. PhD thesis. Netherlands: University of Twente. ISBN: 978-90-365-5407-7. DOI: 10.3990/1.9789036554077.

Sanjay, V., Chantelot, P., and Lohse, D. (2022a). "When does an impacting drop stop bouncing?" *arXiv preprint arXiv:2208.05935.*

Sanjay, V., Lakshman, S., Chantelot, P., Snoeijer, J. H., and Lohse, D. (2022b). "Drop impact on viscous liquid films". *arXiv preprint arXiv:2206.06298.*

Sanjay, V., Lohse, D., and Jalaal, M. (2021). "Bursting bubble in a viscoplastic medium". *J. Fluid Mech.* 922, A2.

Wildeman, S., Visser, C. W., Sun, C., and Lohse, D. (2016). "On the spreading of impacting drops". *J. Fluid Mech.* 805, pp. 636–655.

Zhang, B., Sanjay, V., Shi, S., Zhao, Y., Lv, C., and Lohse, D. (2022). "Impact forces of water drops falling on superhydrophobic surfaces". *Phys. Rev. Lett.* 129.10, p. 104501.