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The rise of the bubbles

Path instability of an air bubble rising in water

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Recommended with a Commentary by Luca Giomi, Leiden University

Next time you will be sipping a glass of Prosecco, pay attention to the trajectory of the bubbles rising to the top of your flute: it is often zig-zagged. And no, this is not because of the other glasses of Prosecco you had before that one, but as a consequence of an elusive hydrodynamic instability that puzzled fluid dynamists since the days of Da Vinci. Small bubbles — he reported on the folio 25r of the Leicester code (see Fig 1A) — tend to rise along a straight path, whereas larger bubbles prefer to zig-zag their way to the water/air interface or move along a spiral trajectory. Some 500 years later Miguel Herrada (Universidad de Sevilla) and Jens Eggers (University of Bristol) may have found the key to unlock this mystery. An account of their research was published on the Proceeding of the National Academy of Science on January 2023 [1].

At first, this phenomenon appears like an affair between two classic actors of fluid mechanics: buoyancy, which propels bubbles towards the top, and viscous dissipation, originating from the gliding of the external fluid over their surface. A closer inspection, however, unveils the presence of two more players. First, as in the case of an airfoil slicing through a viscous fluid,

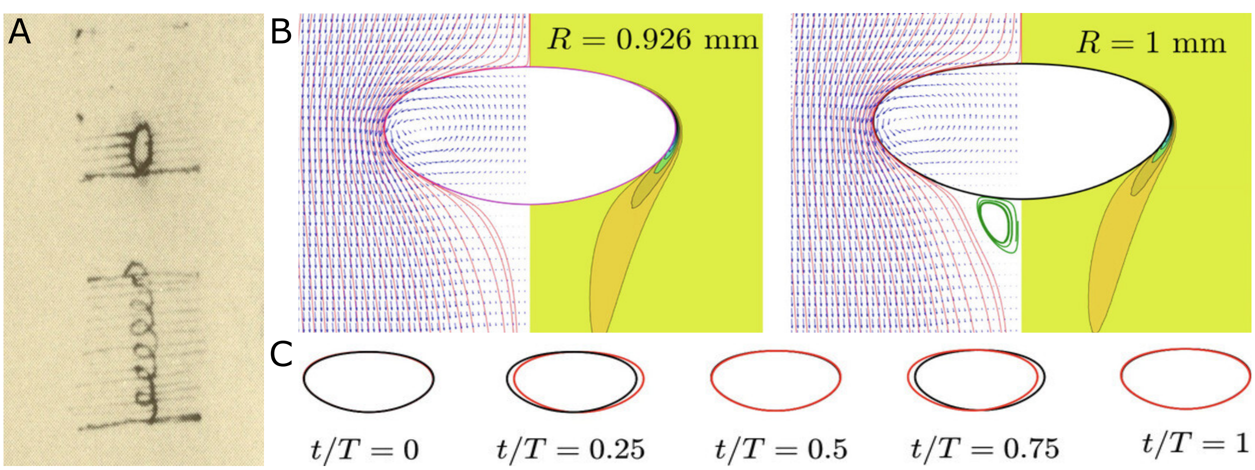

Fig.1 (A) The original drawing of Da Vinci from the Leicester code. (B) Configuration of a rising bubble and the corresponding flow field for different values of the bubble's radius (marked as R in the plot). (C) Typical cycle in the bubble's shape leading to a zig-zagged trajectory. Panel (B) and (C) are reproduced from Ref. [1].

dissipation is limited to a boundary layer in close proximity of the bubble's surface, thus making its correct resolution computationally challenging. Second, because of their relatively fast rising motion, bubbles depart from their natural spherical shape (Fig. 1B). Much of the research efforts towards deciphering the physical mechanism behind the bizarre phenomenon reported by Da Vinci, focused on overcoming the former hurdle, but neglected the latter and approximated the bubble shape as an oblate ellipsoid perpendicular to the direction of motion. Thanks to a clever coordinate transformation, which allowed mapping the free surface of the bubble to a stationary rectangular boundary, Herrada and Eggers were instead able to account for all the plotters of this conspiracy.

Their analysis revealed that, when the bubble is large enough for shear forces to generate enough torque, its axially symmetric shape becomes unstable (Fig. 1C). This causes a slight tilt of the droplet's mostly curved side, thereby altering its rising trajectory. This conformational change in the region of maximal curvature, in turn, affects the configuration of the velocity in the surrounding boundary layer, resulting in a speed up of the flow and, by virtue of Bernoulli's principle, in a drop of the local pressure. The latter, finally, pushes back the bubble to its original position and the process repeats itself again and again. Like when sipping Prosecco.

References

[1] M. Herrada and J. Eggers, Proc. Natl. Acad. Sci. USA 120, e221683012 (2023).