Bouncing droplets and liquid time crystals

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Droplets on the surface of a fluid bath subjected to periodic forcing below the Faraday threshold can be made to bounce indefinitely [1]. The capillary surface waves periodically added onto the fluid surface by the droplet's impacts coupled to the dynamics of the localised droplet of fluid gives rise to exceptionally rich non-equilibrium dynamics, which has lead to the emergence of a nascent research field coined hydrodynamic quantum analogs [2].

Building upon our discovery of superwalking droplets [3, 4], we have now established a new Australian research laboratory dedicated for studies of such gravitationally bouncing droplets of fluid [5]. Our system incorporates a droplet printer that enables an on-demand computer controlled deposition of droplets on the fluid surface. We demonstrate the operation of this instrument by creating and observing long-lived and interacting time crystals whose evolution we have witnessed for more than one hundred thousand oscillation periods. Our observations provide points of comparison for experiments that differentiate between quantum and classical time crystal behaviours in driven non-equilibrium systems.

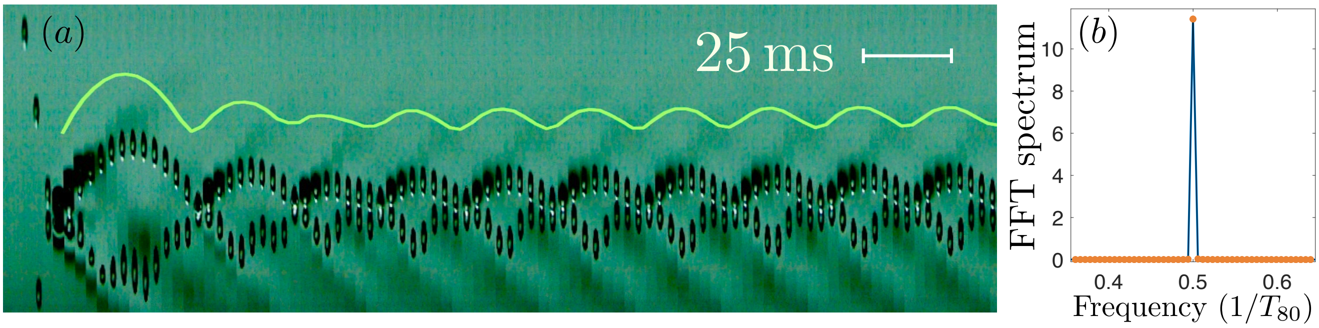

Figure 1: Liquid time crystal behaviour of a gravitationally bouncing droplet. Visualization of the first ten bounces (a) of a droplet bouncing off the surface of a liquid which is periodically driven at the frequency $f = 80$ Hz. The solid curve is the droplet height function $h(t)$ extracted by tracking the brightest pixel in the high-speed video frames. The Fourier power spectrum $|\mathscr{F}(h)|^2$ with $T_{80} = 1/f$ of the next one hundred bounces is shown in (b).

[1] Y. Couder, S. Protière, E. Fort and A. Boudaoud, *Nature* **437** 208 (2005).

[2] J.W.M. Bush and A.U. Oza, *Reports on Progress in Physics*, **84** 017001 (2020).

[3] R.N. Valani, A. Slim and T. Simula, *Physical Review Letters*, **123** 024503 (2019).

[4] R.N. Valani, J. Dring, T.P. Simula and A. Slim *Journal of Fluid Mechanics*, **906** A3 (2021).

[5] T. Simula, *arXiv:2202.05407* (2022) PREPRINT OR EQUIVALENT.