Follow the guide

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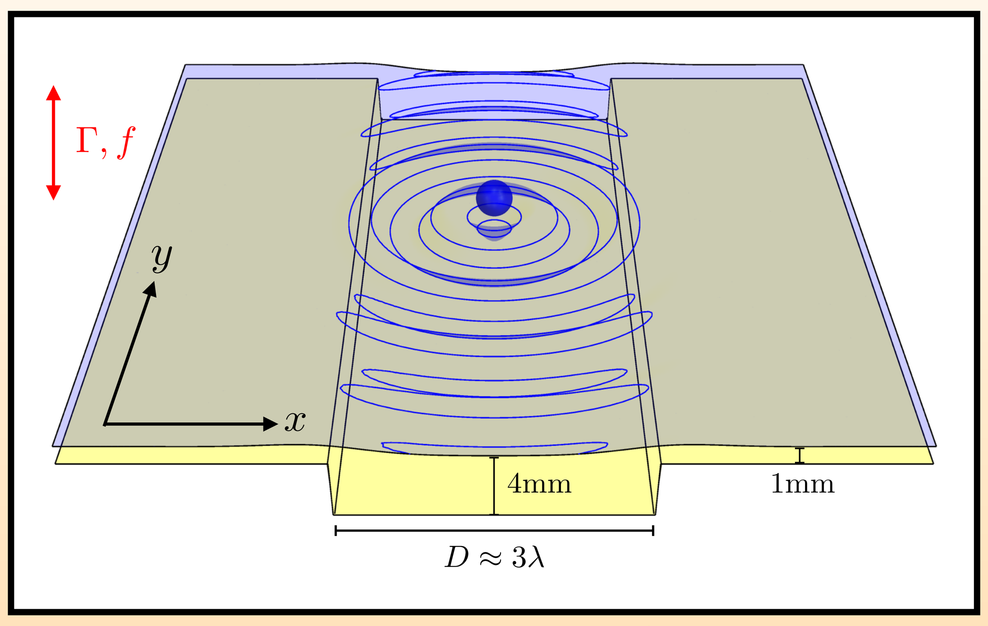
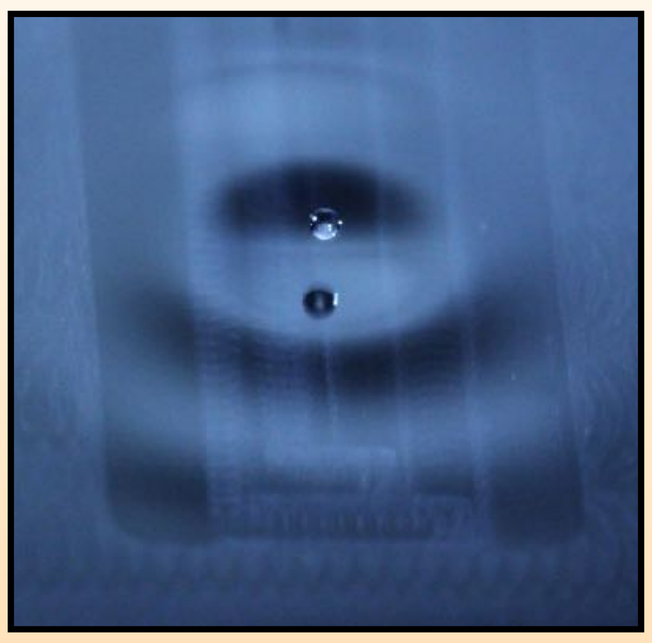
Abstract: *Since the pioneering works of Couder and coworkers [1], a growing interest has emerged about bouncing and walking droplets. Various experimental works have been performed in 2d systems. Recent studies focused on droplet confinement. In particular, it was shown that, by using a magnetic force it is possible to trap a drop in a harmonic potential [2,3]. For the very first time, we present the possibility to control droplet trajectories so that droplets are confined along 1d paths, thanks to linear submerged cavities used as waveguide for the drop. Thus, we work with an annular cavity and we evidence differences between 2d behaviors [4].*

Walk the line

We study the motion of a droplet in submerged linear cavities, of different widths *D*.
The drop remains in the deep water region, and can not walk in the shallow water region





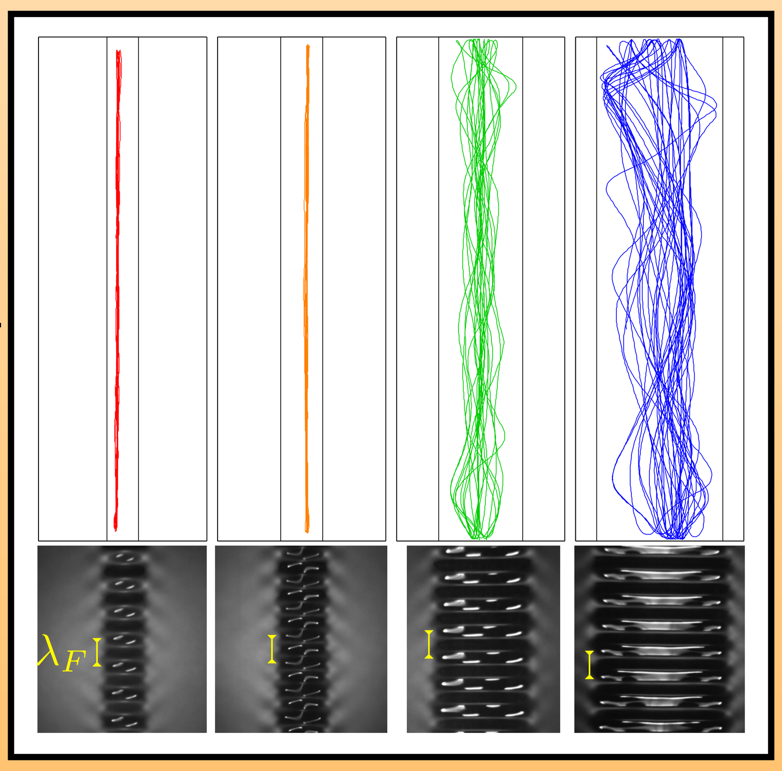
A walker and its wavefield in a channel of 2λ width.

Forcing frequency : $f = 70\mathrm{Hz}$
Forcing acceleration : $\Gamma = 4.0$
Memory parameter : $\mathrm{Me} = 20$
Faraday wavelength : $\lambda = 5\mathrm{mm}$

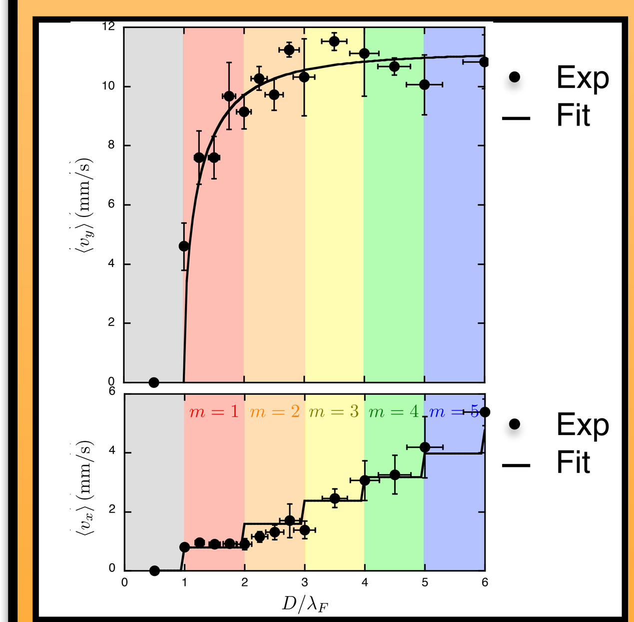
2d and 1d trajectories

Trajectories of a drop within four channels, of width D/λ = {1.5,2,4,6}.
The path followed by the walker is linear in the two first channels.
In contrast the walker wobbles in the two last ones.

Below each trajectory: pictures of the Faraday pattern within each cavity.
Along the *y* axis, one can observe the **Faraday periodic pattern**.
Along the *x* axis, it corresponds to a **bump**.
In addition we evidence a substructure along the *x* axis.



Faraday propagation / waveguide analogy



A waveguide separates the wave characteristics into a **transport component** and a **stationary one**. The stationary component corresponds to the transverse lines. The transport component can be seen as the propulsive component along the channel.

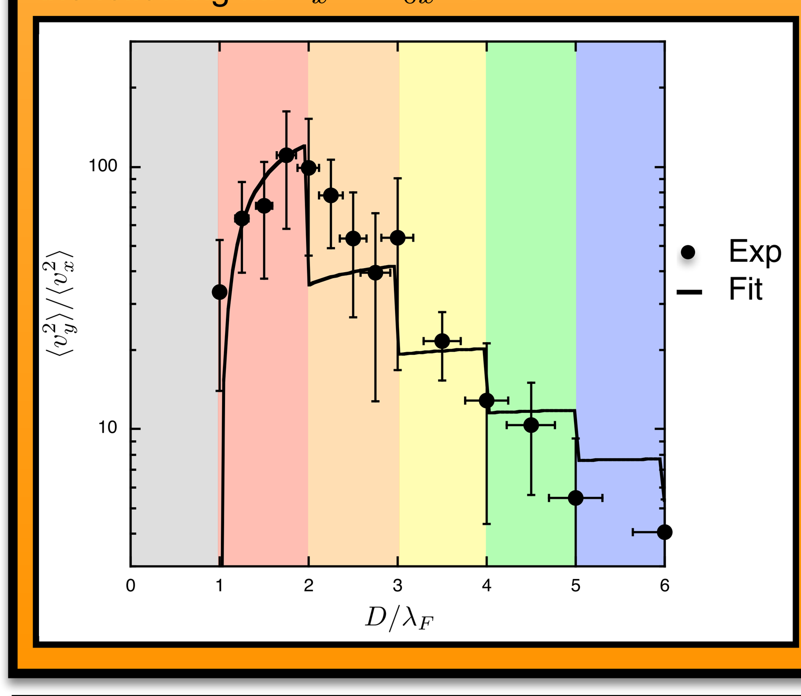
We assume the wave propagation is **similar to a waveguide or a quantum wire system.**
This leads to the relationship: $k_x^2 + k_y^2 = \frac{\omega^2}{c^2} = \left(\frac{2\pi}{\lambda_F}\right)^2$.

$k_x = \frac{2\pi}{D}$ is set as the Faraday bump excited in the transverse direction.

In the longitudinal direction, upon estimating $v_y \propto k_y$,

we obtain: $v_y = v_{0y}\sqrt{1-\left(\frac{\lambda_F}{D}\right)^2}$.

Considering the transversal energy proportional to $(am)^2$, where a is the amplitude of undulations of size λ_F, and $m = [D/\lambda_F]$ corresponds to an integer number of undulations along the transverse direction, one obtains the following fit: $v_x = v_{0x}m$.

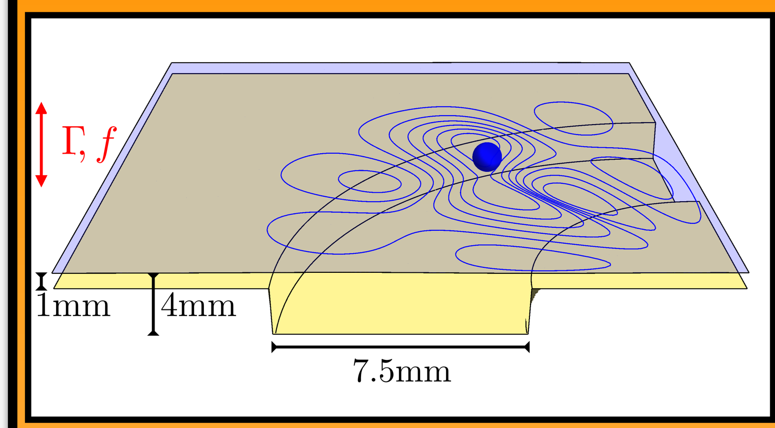


Ratios of the kinetic energies along the *y* and *x* axis.
What is the optimal width *D* to **limit speed fluctuations** along the *x* axis?
One can observe a peak around $1.5 \leq D/\lambda \leq 2.25$.
Here, the trajectory of the drop is **quasi mono-dimensional**.

The experiment is fitted with $\frac{\langle v_y^2\rangle}{\langle v_x^2\rangle} = \frac{\sigma^2 + \langle v_y\rangle^2}{\sigma^2 + \langle v_x\rangle^2}$,

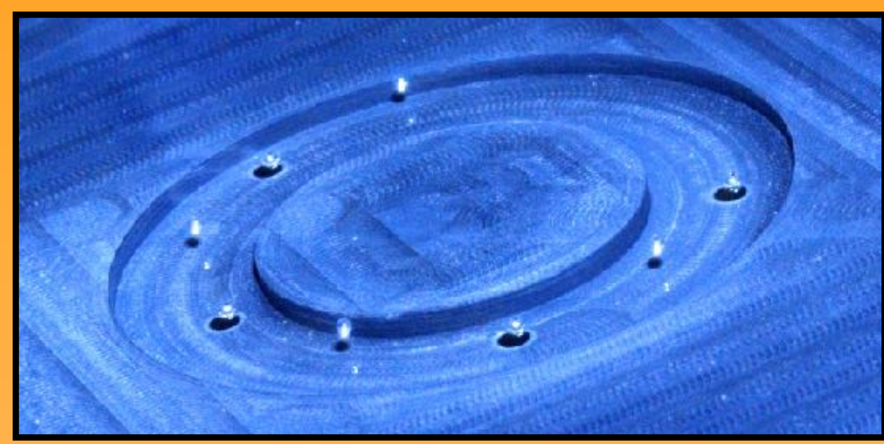
where σ corresponding to the magnitude of speed fluctuations in our system in both directions.

One ring to rule them all

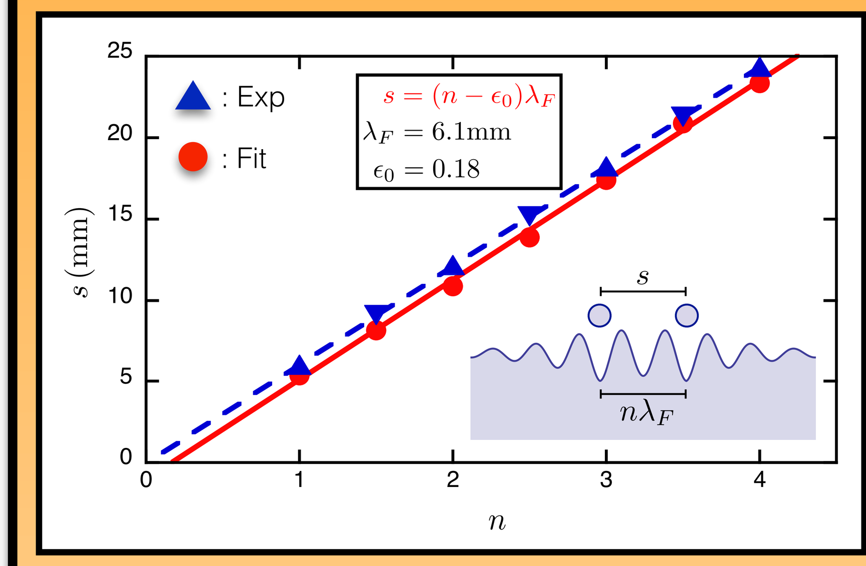


We investigate the case of a droplet confined in a submerged annular cavity.
The experimental parameters remain the same.
The width is adjusted to ensure a 1d motion to the drop.

A string of 8 identical droplets in an annular cavity.
One can notice the antisynchronous bounces for the successive drops, but also the quantized interdistances.



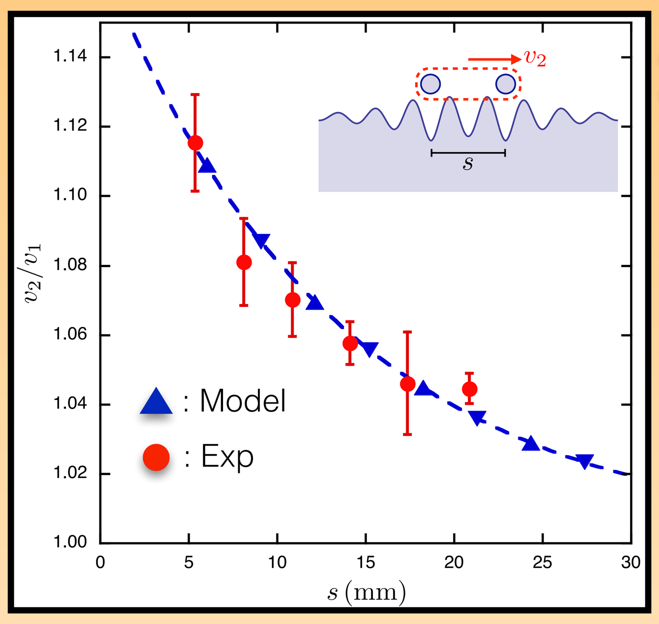
Quantization of the distance between two drops



Two identical walkers move at the **same speed**.
The distance s between them is **constant**, and proportional to λ_F.

▲ : synchronous bounce
▼ : anti-synchronous bounce

Influence of the distance between droplets on the speed



▲ : synchronous bounce
▼ : anti-synchronous bounce

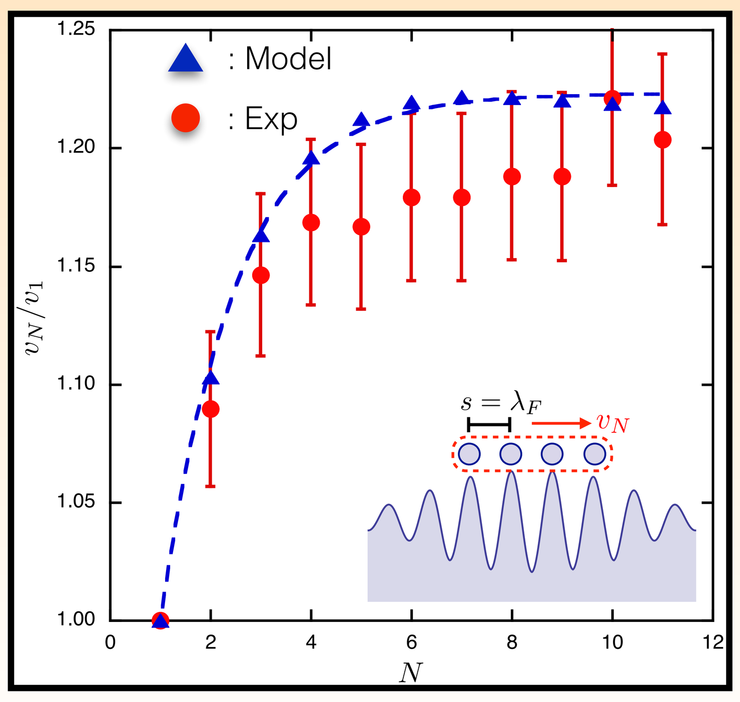
v_1 : speed of a single walker
v_2 : speed of a pair of walkers

v_2/v_1 **decreases exponentially** with the interdistance.
We developed a model which is in good agreement with the experiment (see [5] for further details).

The closer a pair of walkers are, the faster they move.

Influence of the number of droplets on the speed

We study the speed of a string of droplets.
The drops are regularly spaced, and are $\lambda_F \simeq 5.3\mathrm{mm}$ apart.



v_1 : speed of a single walker
v_N : speed of a string of N walkers

The speed of a string rises exponentially with the number of walkers, until it saturates.
A model [5] is in good agreement with the experiment.

The trend is similar by increasing the interdistance, but with lower velocities, regarding the last result.

Finally, all the drops are interacting and sharing a coherent wave.

Conclusions

- It is possible to **confine** a drop in a 1d geometry.
- The channels are **waveguides** for Faraday waves.
- A **single mode** dominates the longitudinal motion.
- A **fine structure** of *m* modes is observed in the transversal direction.
- Fits in good agreement with our experimental datas.
- **Optimal width** limiting speed fluctuations along the *x* axis.
- Channels between $\{\lambda_F, 2\lambda_F\}$ are considered as **linear droplet guides**.

- The results **differ** from the 2d case.
- **Quantization**, influence of the **distance** between droplets.
- Influence of the **number of drops** on the speed of a string.
- A model developed, in good agreement with the experiment.
- A chain of drops share the same **coherent wave**.
- **Constructive interferences** cause an increase of the speed.

[1] Couder *et al.*, Nature **437**, 208 (2005).
[2] Perrard *et al.*, Nat. Commun. **5**, 3219 (2014).
[3] Labousse *et al.*, Phys. Rev. E **90**, 022913 (2014).
[4] Borghesi *et al.*, Phys. Rev. E **90**, 063017 (2014).
[5] Filoux *et al.*, arXiv:1504.00484 (2015).