Magnetocapillary self-assemblies: Swimming and micromanipulation

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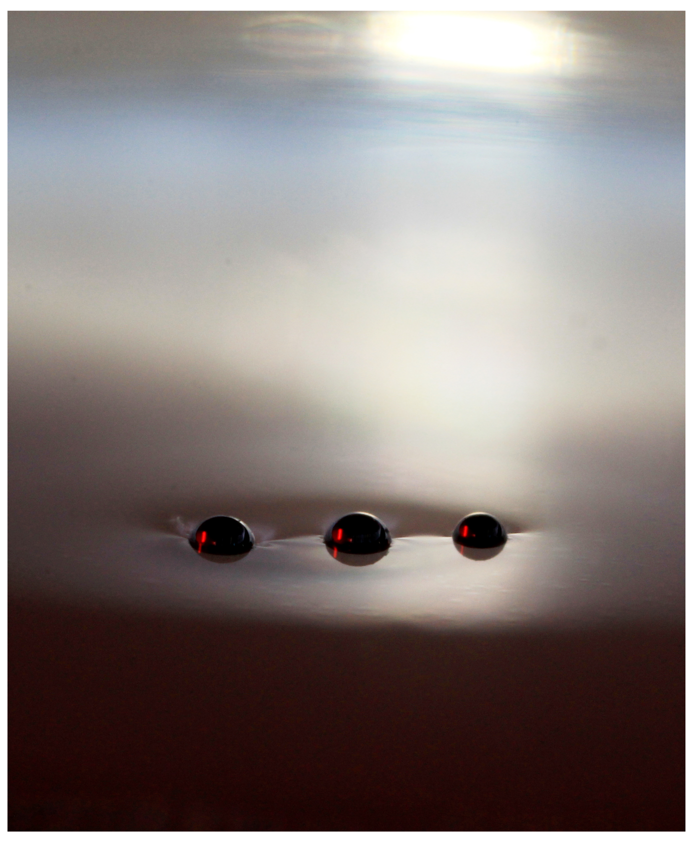
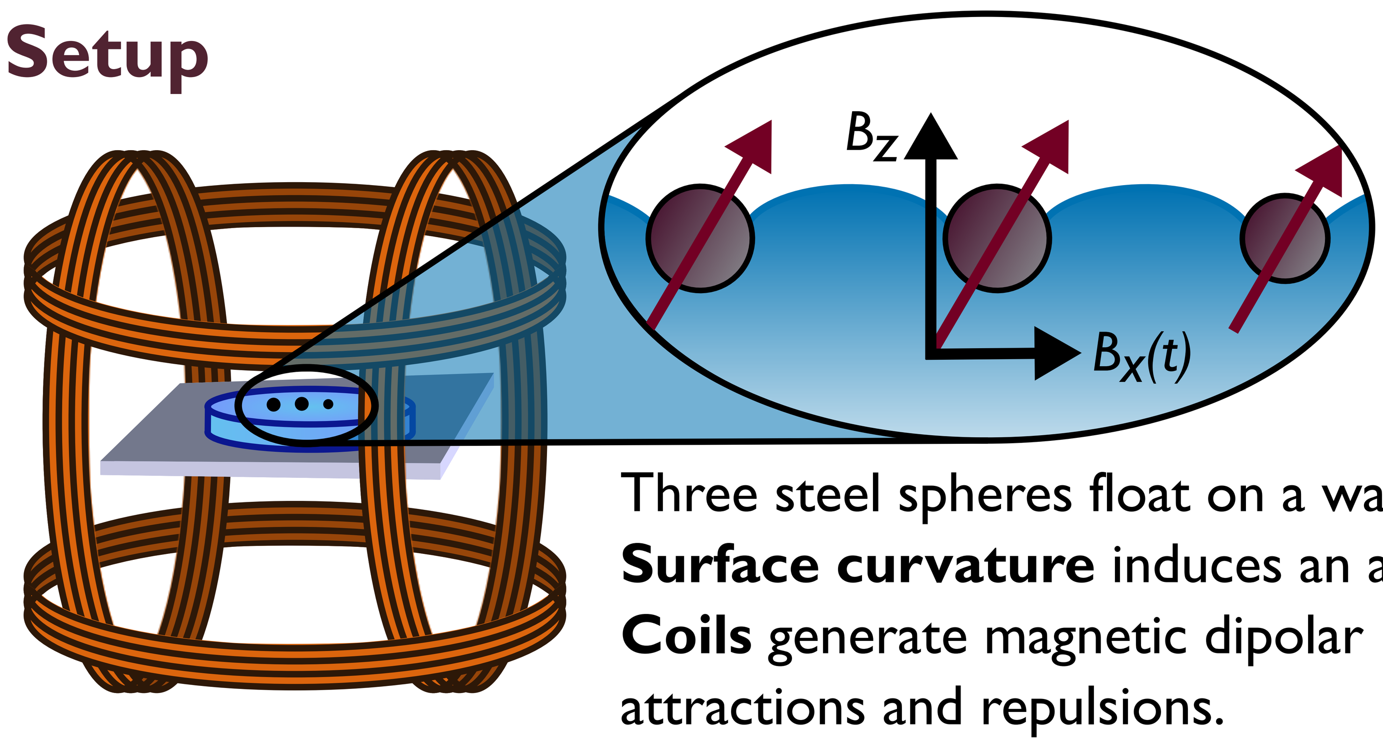
Microswimmer

Simple microswimmers are created using floating **steel spheres**. **Magnetic** and **capillary** interactions cause the particles to **self-assemble**. Magnetic oscillations generate **motion**. Three in-line spheres behave like the **Najafi-Golestanian** swimmer [1]. **Speed** is proportional to the **cycle** described by the two elongations. A **spring model** gives predictions.



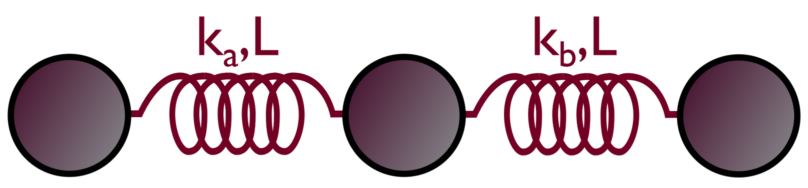
Setup

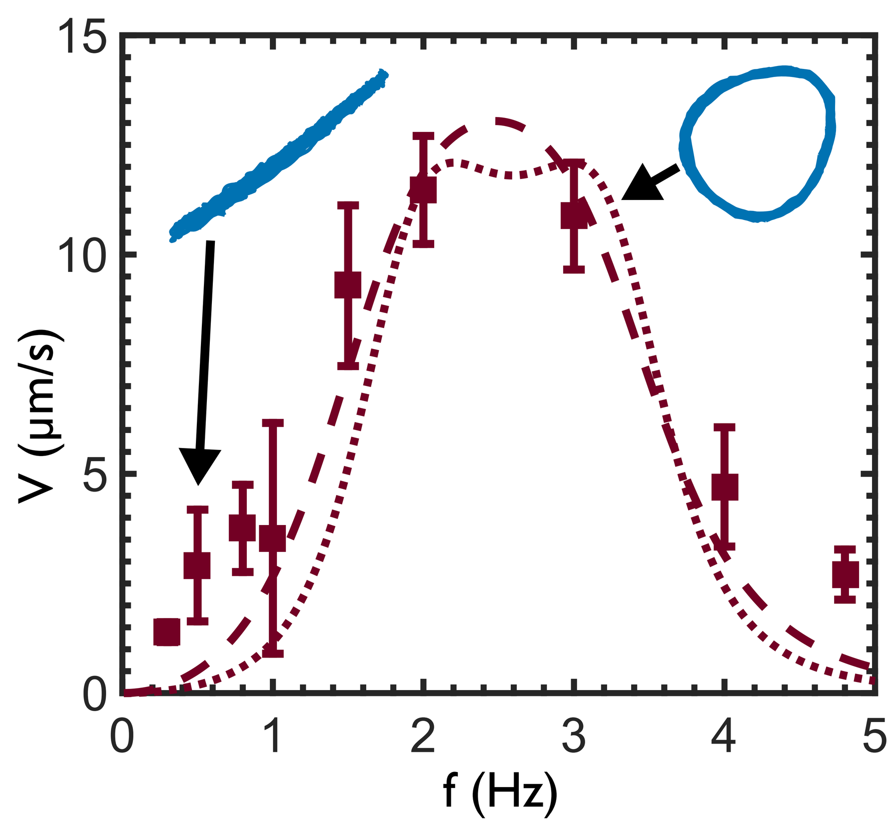


Three steel spheres float on a water bath. **Surface curvature** induces an attraction. **Coils** generate magnetic dipolar attractions and repulsions.

Results and model

A **sinusoidal field** $B_x(t)$ generates **deformations** and motion. The magnetocapillary interaction acts as a **spring force** [2]. Using spheres of different sizes allows to have **different spring constants**.



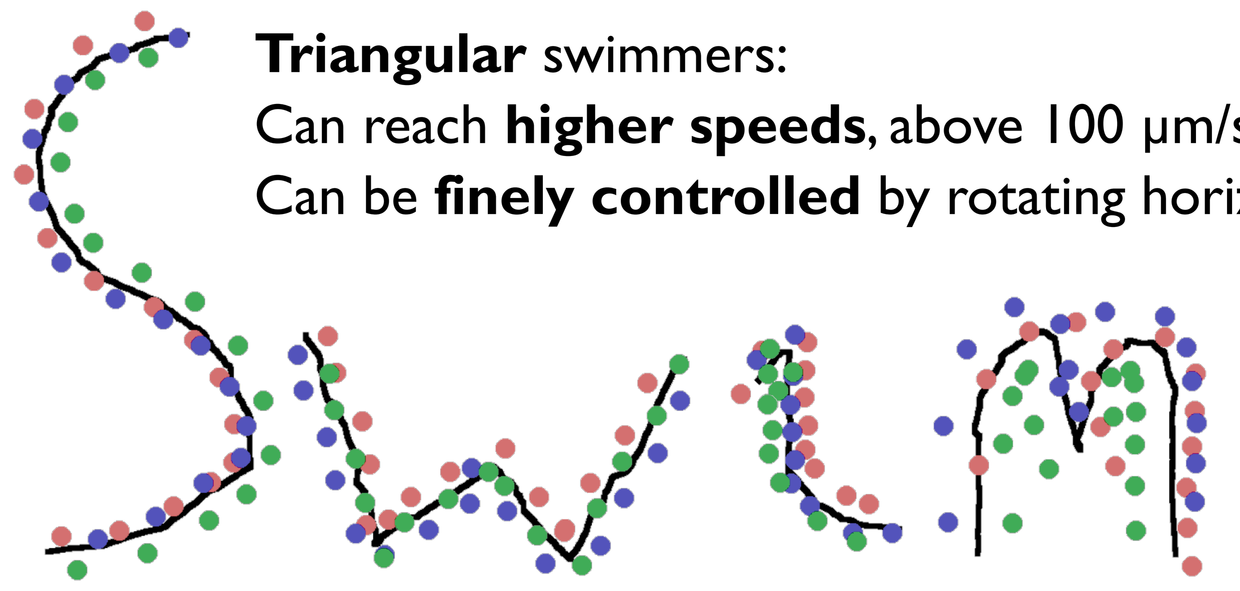


Speed is maximal close to the spring's **resonance**. It is proportional to the **area** enclosed in the trajectory described by the elongations. A linear spring model predicts the **speed profile** accurately, analytically, and with no adjustable parameter [1].

Micromanipulator

Different kinds of structures can be built for **different purposes**.
Triangular swimmers are **faster** (~100 µm/s) and **controllable** [3].
Larger swimmers can **transport cargo**.
Rotating swimmers generate local **mixing** at low Reynolds number.

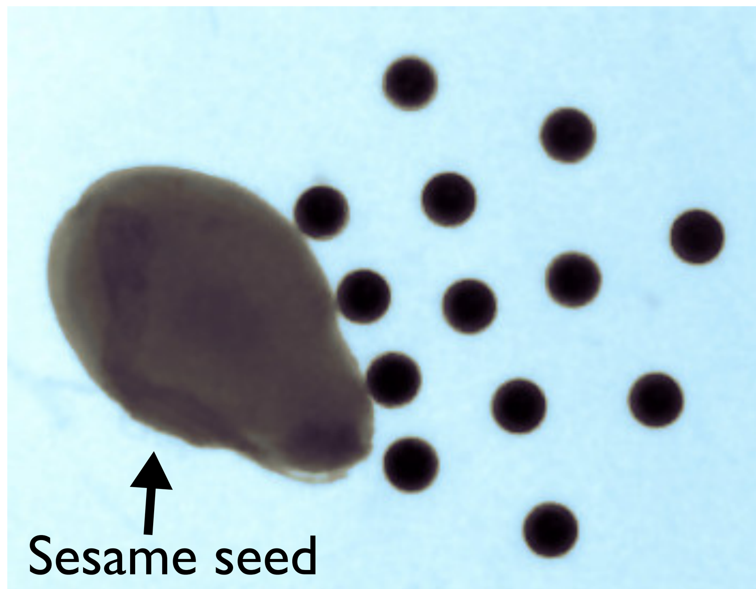
Remote-control



Triangular swimmers:
Can reach **higher speeds**, above 100 µm/s.
Can be **finely controlled** by rotating horizontal field $B_x(t)$.

Cargo transport

Floating objects are **captured** through **capillary interaction**. **Transport** can be achieved. The cargo can be **released** using a **magnetic field** gradient.



Mixing

Micromixing relies on **diffusion** instead of convection.
The goal is to **maximize** the contact **area** between the fluids.
In a rotating field, we can **swirl** fluids **together**, enhancing diffusion.

Acknowledgements

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References

Contact: ga.grosjean@ulg.ac.be

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[2] G. Lagubeau *et al.*, Phys. Rev. E **93**, 053117 (2016).
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