Chair: Physics of Fluids group

Bachelor/master projects on droplet microswimmers

Description

Microswimmers are an emerging research discipline at the boundary of chemical engineering, physics of living and intelligent systems and chemical engineering. Artificial swimmer models are here important to understand the physical principles that drive characteristic phenomena of living systems like self-assembly, pattern formation and directed motion; and such models can be used to inspire smart materials.

The swimmer model we work with is entirely fluid based [1,2]: oil droplets dissolving in a concentrated surfactant solution - so reduced in idea and construction that you wonder how anything so simple is capable to move autonomously! They can be easily mass produced and quantified, have highly reproducible dynamics and still show a wealth of biomimetic and often counterintuitive phenomena like helical [3] or unsteady motion [4], playing 'Snake' [4,5], or self-assembled 'hovercrafts' and 'helicopters'[6,7].

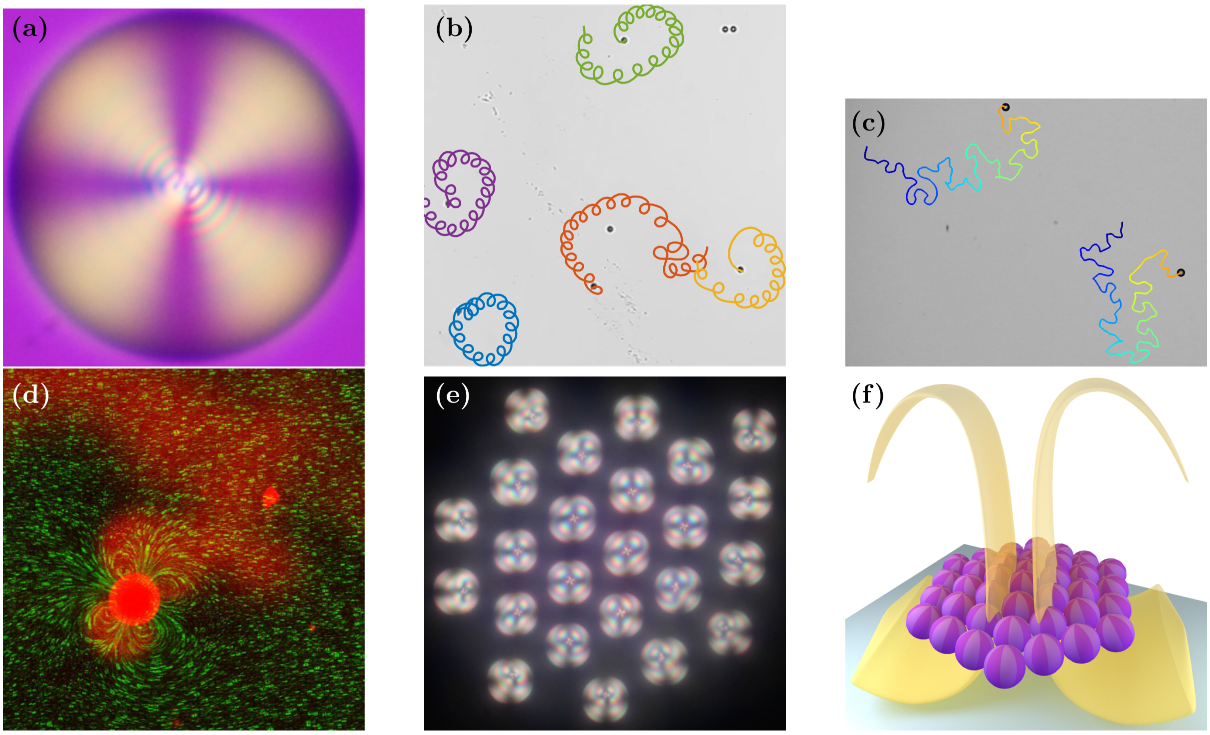

Figure 1: (a) a liquid crystal droplet under polarised microscopy. If the internal symmetry of the liquid crystal is broken, it follows (b) a curling path [3] (tracking data from bright field microscopy). In viscous media, this motion (c) becomes unsteady [4], due to higher modes (d) in the chemical and flow fields around the droplet. Multi-droplet ensembles show complex emergent behaviours, e.g. floating 'hovercraft' clusters (e,f) [6,7]

Assignments

We have projects suitable for either bachelor or master projects in 3 categories:

1. In liquid crystal swimmers, how does the internal structure of the droplet affect its motion [3]?
2. A detailed look at the forces between interacting swimmers [4,7] with a quantitative comparison of flow and chemical fields in comparison to state of the art theory models.
3. The dynamics of many-droplet systems, e.g. flocking and self-assembly [6,7].

What will you learn?

- You will learn how to mass produce monodisperse droplet swimmers in flow focusing devices and investigate them in custom high precision microfluidic geometries.
- You will analyse their collective dynamics using and adapting microscopy and digital video and image processing tools, mapping flow fields, chemical fields and droplet structure using e.g. PIV, quantitative fluorescent and polarized microscopy. Liking Python is a plus.
- You will learn fundamental microswimmer concepts like Active Brownian Motion, low Reynolds number hydrodynamics and nonlinear advection-diffusion instabilities.
- Complementary numerical projects might be arranged within PoF.

For more information and detailed thesis proposals, feel free to email Corinna and check out our research page on asm.ds.mpg.de or @activedroplets on Twitter.

Supervision	**E-mail**	**Tel.**	**Office**	**Project room**
Corinna Maass	c.c.maass@utwente.nl	+31 628522289	Meander 214c	Meander 113f
Prashanth Ramesh	p.ramesh@utwente.nl	-	Meander 212	Meander 113f

Literature

1. Maass, C. C., Krüger, C., Herminghaus, S. & Bahr, C. Swimming Droplets. *Annu. Rev. Condens. Matter Phys.* **7**, 171–193 (2016).

2. Michelin, S. Self-propulsion of chemically-active droplets. *Annu. Rev. Fluid Mech.*, in press (2023), arXiv:2204.08953

3. Krüger, C., Klös, G., Bahr, C. & Maass, C. C. Curling Liquid Crystal Microswimmers: A Cascade of Spontaneous Symmetry Breaking. *Phys. Rev. Lett.* **117**, 048003 (2016), arXiv:1605.03396.

4. Hokmabad, B. V. et al. Emergence of Bimodal Motility in Active Droplets. *Phys. Rev. X* **11**, 011043 (2021), arXiv:2005.12721.

5. Hokmabad, B. V., Agudo-Canalejo, J., Saha, S., Golestanian, R. & Maass, C. C. Chemotactic self-caging in active emulsions. *PNAS* 119, e2122269119 (2022), arXiv:2012.05170.

6. Krüger, C., Bahr, C., Herminghaus, S. & Maass, C. C. Dimensionality matters in the collective behaviour of active emulsions. *Eur. Phys. J. E* **39**, 64 (2016).

7. Hokmabad, B. V., Nishide, A., Ramesh, P., Krüger, C. & Maass, C. C. Spontaneously rotating clusters of active droplets. *Soft Matter* **18**, 2731–2741 (2022), arXiv:2112.11801.