Phototaxis of *Chlamydomonas reinhardtii* in absorptive environment

Advisor: Sofia Böling

Supervisor: Prof. Jaakko Timonen

Chlamydomonas reinhardtii is a green unicellular alga that can swim with the help of its two flagella (Fig. 1a). As a photosynthetic organism, it is crucial for *C. reinhardtii* to swim towards weak light and away from strong light that can damage the organism [1]. *C. reinhardtii* has an eyespot with which it can sense light, leading to the reorientation of the cell towards or away from light (positive and negative phototaxis) [1]. Phototaxis of individual cells can lead to a suspension of cells forming patterns collectively [2-5]. For instance, it was shown that when a suspension of *C. reinhardtii* cells is illuminated with strong light, cells escape from the light in collective structures that form because cells self-shade (Fig. 1b) [5].

In this project, the motility and patterns of a dilute suspension of *C. reinhardtii* cells to light in a medium that absorbs light is studied, so that medium rather than other cells shade cells. *C. reinhardtii* cells are grown in the laboratory according to a standardized protocol [6].

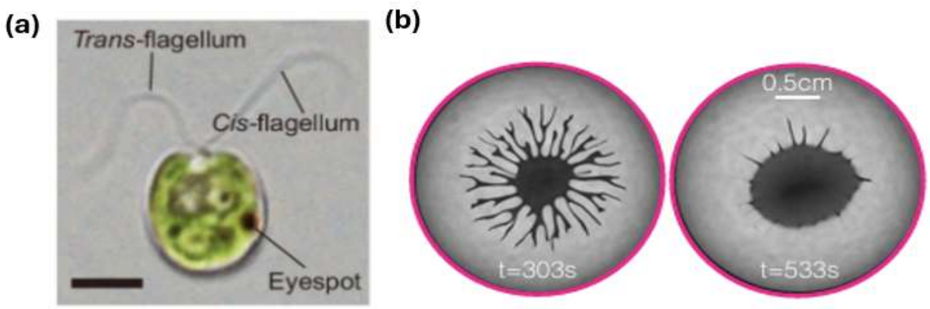

Figure 1. (a) Microscopy image of an individual *C. reinhardtii* cell showing the eyespot [2]. The size of the scale bar is 5 µm. (b) Collective patterns formed in a suspension of *C. reinhardtii* swimming away from strong light intensity [5].

The tasks of the research assistant:

- Literature review on phototaxis and other light-induced responses on *C. reinhardtii*
- Maintaining *C. reinhardtii* cultures
- Improving experimental setups and procedures
- Performing experiments on *C. reinhardtii* culture in an absorbing medium
- Analyzing the data using image processing tools, such as ImageJ

When selecting the candidate, interest and good study records in optics and fluid dynamics are emphasized. Knowledge and experience in cell biology and optical microscopy are considered a bonus.

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Call for Summer Student 2026: Modelling flagella of E. coli

Supervisor: Prof. Jaakko Timonen[1] and Advisor: Dr. Dom Corbett[1]

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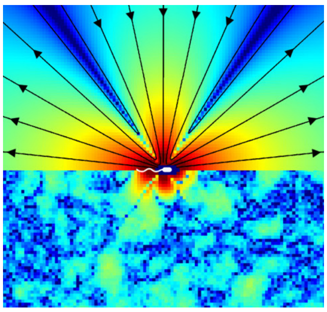
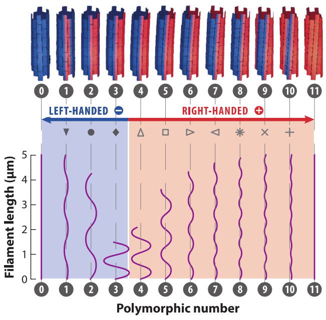
The Active Matter group studies the macroscopic dynamics of systems driven away from equilibrium by microscopic interactions [1–7]. Some of these active systems are also studied by biologists, and these living systems naturally lend themselves to interdisciplinary research with broad implications for potential impact [8–11]. Bacterial suspensions are amongst the living systems that we study in the group [12].

Swimming bacteria, such as E. coli, excite Stokes flows in the fluid around them by rotating helical filaments called flagella [13–16] (see fig. 1d). Sufficiently far from the cell, the excited flow is well-approximated by a dipolar field such as that shown in the upper panel of fig. 1a. These flows advect and rotate neighbouring bacteria, giving rise to complex and nonlinear collective flow phenomena such as bacterial turbulence [12]. The dipolar approximation has been crucial in modelling and understanding many of these phenomena [16, 17]. In a cell's immediate vicinity, however, complex and time-dependent near-field flows diverge from this dipolar approximation, as illustrated in the lower panel of fig. 1a. A key technique in our lab is negative magnetic tweezing using ferrofluids, which affords us a minimally-invasive way to apply forces and torques to non-magnetic colloidal objects, such as bacteria. Using this technique, we have produced collective states with bacteria held in such mutual proximity that these near-field flows become relevant.

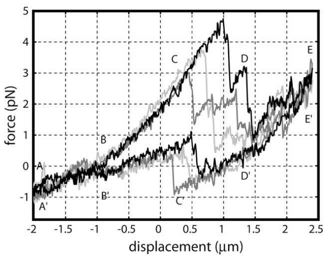
In this project, you will review the literature on flagellar propulsion and model these hydrodynamic flows, the resulting stresses, and the interactions they mediate between cells. The scope of the project will be scaled according to your prior experience with hydrodynamic simulations. A hook anchors each flagellum to a motor complex embedded in the cell's surface. Under typical conditions, hydrodynamic interactions cause the flagella to spontaneously gather into a relatively rigid bundle akin to a corkscrew propeller for propulsion. However, during swimming the flagella themselves can also undergo discontinuous shape transitions in response to stresses (see fig. 1c), giving rise to 12 distinct metastable polymorphisms (see fig. 1b). Despite the complications these transitions bring to the analysis, recently published simulations [18, 19] (see snapshot in fig. 1d) using the open source package LAMMPS [20] have successfully reproduced normal run-and-tumble swimming observed experimentally. With the support of your advisor, you will run and analyse similar simulations adapted to the experimental conditions in our lab. Candidate selection will focus on good study records and an understanding of low Reynolds number hydrodynamics. Experience with the Triton cluster, coarse grained molecular dynamics, and scripting in bash and python are considered a bonus.



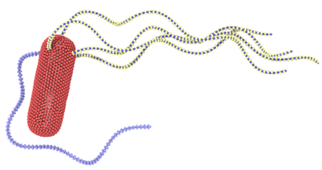
(a) Flow field created by a single freely swimming bacterium [21]. Upper: best-fit force dipole flow. Lower: difference with measured field.



(b) Illustration of the 12 polymorphic shapes of bacterial flagellar filaments [22].



(c) Force-extension curves showing discontinuous polymorphic transitions in a flagellum stretched with optical tweezers [23].



(d) Recent bead-and-spring model of E. coli. Flagellum in blue has undergone polymorphic transition. DPD solvent not shown [19].

Figure 1

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Call for Summer Student - Active Matter Group

Investigations around the Onsager-Wien effect

Department of applied physics - Etienne Niemiec

Plan proposal for summer 2026

1 Topic description

The Active Matter group investigates systems set out of equilibrium where particles or agents are individually spending energy to displace themselves. This results in rich and diverse collective motions showing interesting structures and features [1]. Examples include flocks of birds and fish schools [2] but also in the motion of bacteria, algae or cells. It is possible to reproduce artificially active matter by the means of electrohydrodynamics (EHD), where fluid media are carefully chosen and put out of equilibrium [1], [3], [4]. Electric and magnetic fields are examples of external sources of energy used to set these systems out of equilibrium although other ways also exist (gravity, light, acoustics, etc).

One of the most popular fluid phases used in our laboratory is a system composed of n-dodecane containing a surfactant called AOT [4]. This surfactant creates reverse micelles around water traces in the dodecane medium, and these micelles can contain charges [5], [6]. This fluid is quite interesting because its conductivity or charge carriers load can be tuned by the concentration of surfactant. However, when put under intense electric fields, some complex conduction phenomena take place, and one of them is the Onsager-Wien effect [7], [8]. A result of this physical effect taking place is a non-constant and non-linear conductivity as a function of the electric field. In order to progress on other projects, a better understanding of this phenomenon would be very useful and constitutes a good topic for a summer internship and possibly a bachelor thesis.

The plan of the internship is to test n-dodecane / AOT fluid systems by the means of diverse methods and techniques in order to understand how to better choose sample preparation conditions and features. These would include for instance electrochemical measurements (electro-impedance spectroscopy [9], I-V measurements), observation (optical microscopy) and basic chemistry knowledge (sample preparation). The overall project would divide in 3 overlapping phases: experimental work, conduction phenomena literature review and data processing / analysis (ImageJ, MATLAB or Python). Knowledge of scripting language such as MATLAB or Python can be useful but not mandatory.

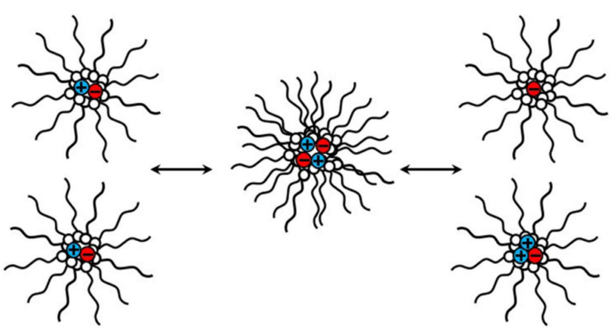

Figure 1: Example of charge creation by disproportionation among reverse AOT surfactant micelles in n-dodecane (figure from [5])

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Call for Summer Student – Active Matter Group
Understanding and Optimizing Hanging Drops

Department of Applied Physics
Advisor: Senna Luntama — Supervisor: Prof. Jaakko Timonen

Plan proposal for Summer 2026

Hanging drops, liquid sessile drops deposited on inverted substrates, are used widely in various applications in experimental sciences, including in studies of liquid evaporation in colloidal liquid drops [1], photonic crystal self-assembly [2, 3], and bacterial motility [4]. In addition, hanging drops are used in mammalian cell culturing as a method for producing three-dimensional cell cultures, namely cellular aggregates [5–7]. The advantage of using the hanging drop method for creating cellular aggregates is that it is a simple and effective way of producing consistent 3D cell cultures without external scaffolding.

In cell culturing, the hanging drop method is based on gravity: when a cell-culture medium drop is placed on an inverted substrate, the suspended cells ideally descend according to Stokes' law, slide along the air-liquid interface as if on a slip boundary, and adhere together due to attractive cell-cell adhesion mechanics (Figure 1). The same principle applies when using hanging drops for crystalline self-assembly with sedimenting particles. However, experiments with both living cells and inert microparticles have shown that, depending on the experimental conditions and liquid composition, the air-liquid interface can act as a no-slip boundary where sedimenting particles adhere to, preventing ideal cellular aggregate or crystal formation [8]. Possible reasons for these non-ideal hanging drop mechanics and particle pinning include protein aggregation at the air-liquid interface, but the exact phenomenon and the contributing factors are still unknown. To further enhance and develop the use of the hanging drop method for various applications, more research is needed.

In this summer internship project, the goal is to develop further practical and/or theoretical understanding of the behavior of cells and microparticles in hanging drops, as well as of the possible anomalies in the air-liquid interface. The focus and methodology of the project can be adjusted depending on the interest of the applicant. Experience in cell culturing is not required, and previous knowledge of data analysis using ImageJ and MATLAB or other similar scripting languages can be beneficial but is not mandatory. This project is suitable for a Bachelor's thesis or a special assignment.

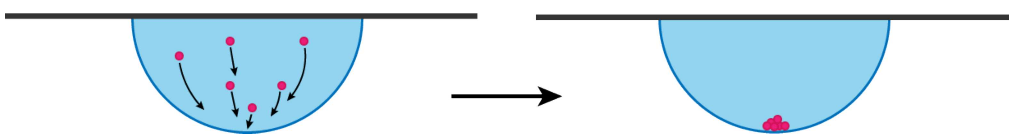

Figure 1: Illustration of the hanging drop method. Particles or cells (red) suspended in liquid (blue) in an ideal hanging drop descend to the bottom of the drop due to gravity.

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Call for Summer Student - Active Matter Group

Scaling down electrohydrodynamically controlled liquid-liquid systems for switchable optical scatterers

Department of applied physics
Advisor: Johannes Haataja - Supervisor: Prof. Jaakko Timonen

Plan proposal for summer 2026

Topic description

Spontaneous emergence of patterns in planar confinement of two liquid systems using electrohydrodynamic (EHD) shear is a novel research topic that is being vigorously investigated in the Active Matter group [1–3]. At low voltages these systems exhibit vortex flows (i.e. Taylor cones) that upon increasing the voltage assemble into reptating chains, networks and lattices. As the voltage increases, the characteristic length scale of the system decreases. The current interest is to investigate the systems above an upper voltage threshold levels where the bicontinuous fluid phase is broken down to densely packed collections of small droplets that exhibit multiple light scattering [4, 5] resulting in highly reflective material with application for tunable display materials.

We are looking for enthusiastic students for this experimental summer project involving high speed imaging, visible-light microscopic, and spectroscopic experiments. Experience in batch processing of data and images in either Matlab or Python is considered as an advantage, but not mandatory. The project is suitable for a Bachelor's thesis or for a special assignment.

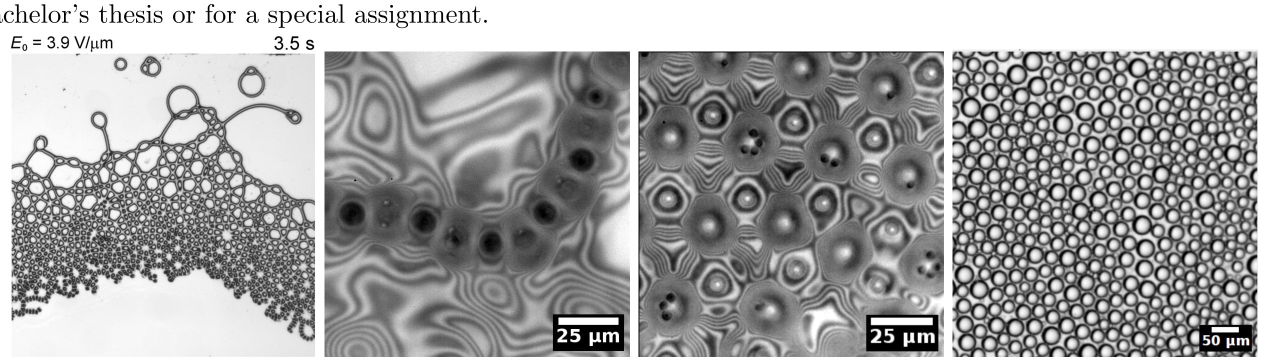

Figure 1: Examples of EHD shear driven systems exhibiting complex behaviour. From left to right: 1) Quincke filament formation at the interface of two liquids (reproduced from [1]). 2) Assembly of vortices into reptating chains. 3) Lattice formation 4). Dispersion of fluid to glassy state.

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