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Thesis possibility after internship: YES Funding: NO

Single cell and collective phototaxis in the microalga *Chlamydomonas reinhardtii*

We propose a research internship at the physics department of ENS (LPENS, UMR 8023) aiming to understand and model the *emerging collective phototactic property* of a phase-separated suspension of the swimming unicellular micro-alga *Chlamydomonas reinhardtii.*
Thanks to a basic light detector called the eyespot, this micro-alga (Fig. 1A) is able to navigate in light fields, a property called "phototaxis" that is still poorly understood. Under strong enough lights, the cells flee the lights to protect themselves from potential damages. We discovered that a suspension of such micro-algae illuminated with multiple intense light sources can develop density instabilities, leading to the growth of very dense regions which can coarsen e.g. into dynamical branch patterns (Fig. 1B-C). In the steady-state we observe a single dense phase whose shape respects the geometry of the light arrangements. Interestingly on long time scales this dense phase composed of millions of cells is able to "sense" smooth light gradients and move towards the less intense regions of our setup (Fig. 1D), displaying therefore an *emerging collective phototactic property*. Our understanding of the system tells us that such motion originates from interfacial dynamics. Therefore we first aim at deeply understanding the statistical properties of the interface (e.g. Fig. 1E) as a function of the control parameters of the system (e.g. light intensity and wavelength, viscosity of the medium). The ultimate goal of the project (for a PhD) being the development of a statistical model able to explain the emerging collective phototaxis. This will also require to better understand how single cell phototaxis works via specific tracking experiments.
In this research project, the intern will use optics, video-microscopy, image analysis, basic microalgal culturing techniques and statistical analysis of the experimental data as well as apply theoretical concepts from Statistical Physics. The internship can lead to a PhD (not yet funded). On the long term (PhD) we will most probably use microfluidic techniques, from the design of microchips to their development and use.

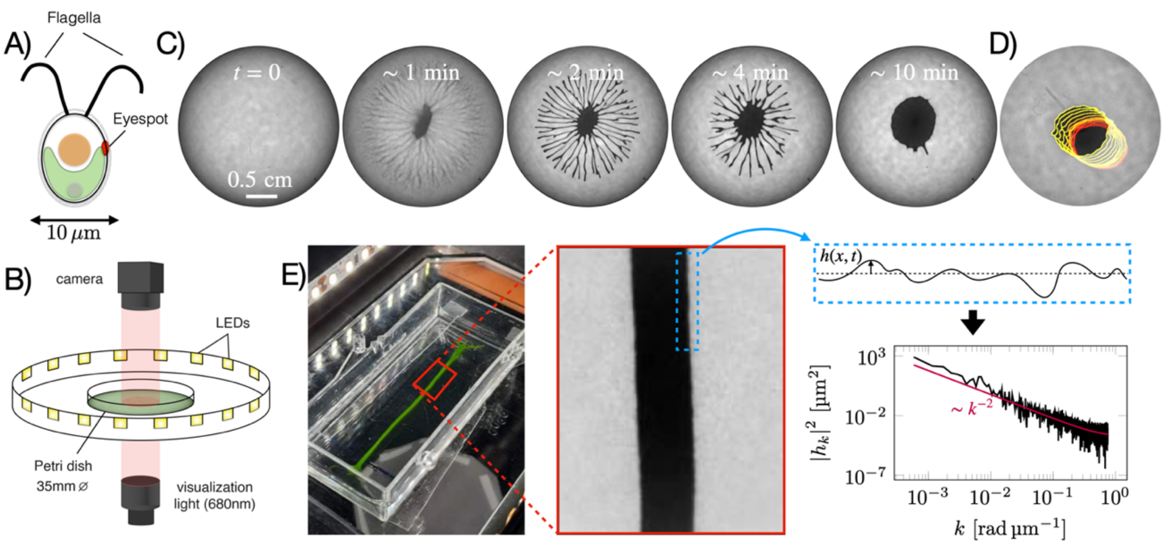

Fig.1. A) Schematics of a *Chlamydomonas reinhardtii* cell, which swims using its two front-mounted flagella and sense light with its eyespot. B) Schematics of the setup where branch patterns emerge as cells flee the light sources (LEDs). C) Destabilization of the migrating suspension into branched patterns, that retract until obtaining a final circular "drop" at the center. D) This dense drop displays emerging collective phototaxis and migrates in a region of the setup where light is slightly dimmer (time-scale of migration ~ 20min). E) Preliminary experiments where a band of dense phase is produced thanks to two linear arrays of LEDs. Digital extraction of the interface profile allows to study its statistical properties. Preliminary results show that the spatial spectrum of amplitude fluctuations decays as $\sim k^{-2}$, similar to what is observed in thermo-capillary waves for classic liquid/vapor interfaces, suggesting that the system could be described with an interfacial tension γ_{active} and an active noise $(k_B T)_{active}$.