

# Probing models of minimal swimming vehicles in vivo with microalgae phototaxis.

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## Abstract

We divert an experimental device from its artistic purpose to test the properties of minimal sensorimotor loops resulting in phototactic behaviour. The study of microalgae like *Euglena* or *Chlamydomonas* is coupled with a modeling effort to characterize the swimming behaviour.

The microalgae *Chlamydomonas Reinhardtii* has been proven to be a useful model organism for photosynthesis or cilia physiology. Based on recent studies of its swimming behaviour from Goldstein (2015), experimental measurement of phototaxis and mathematical model for the dynamics of the cell density, we propose that it also provides a framework to study sensorimotor loops. The ability of *Chlamydomonas* to move toward or to escape from a source is a minimal biological example of *vehicle* behaviour as in Braitenberg (1986).

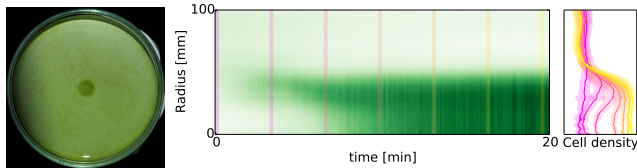


Figure 1: Phototactic behaviour: **Left** Picture of the Petri dish after 20 minutes illumination by a centered disk of light. **Middle** Time course of the cell density as selected by the pixel intensity depending on the distance from the center. **Right** Cell density as a function of the radius ( $\pm$  std) at various times marked on the time course.

## Macroscopic measures of phototaxis.

The illumination of a culture of *Chlamydomonas* in a Petri dish generates changes in the density of cells. In the example of figure 1, the moderate light stimulation at the center (5mm disk) results in accumulation of the cell at the lightened area. With the time lapse record of the Petri dish (12fps), it is possible to characterize the dynamics of phototaxis and to track the spatial profile of cell density as reflected by the

pixel intensity (not that the decrease in cell density outside of the lightened spot is barely visible).

## Microscopic mechanisms and cell density dynamics.

Intracellular fluctuations modulated by the light intensity generate reorientations of the helical swimming trajectory of the cell by desynchronization of the 2 flagella at random times with a higher rate when the cell is far from the light source. The microscopic components and simulations snapshots of the resulting biased random walk are illustrated on figure 2.

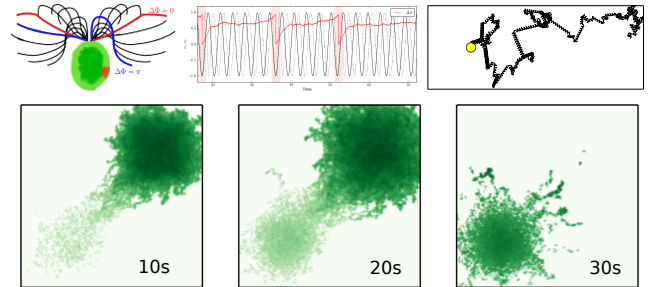


Figure 2: **Up-left** Flagella configurations for synchronized (red) and desynchronized state (blue). **Up-middle** Simulation of stochastic coupled oscillators (Adler model similar to Goldstein (2015)). **Up-right** Sample trajectory of an algae moving to the light source (yellow spot), combining run and tumble trajectory and helical motion. **Bottom** Density of a population initialized with Gaussian distribution moving toward a light source.

Interacting with a microalgae population is thus a way to characterize its sensorimotor loop.

## References

- Braitenberg, V. (1986). *Vehicles: Experiments in Synthetic Psychology*. MIT Press.
- Goldstein, R. E. (2015). Green algae as model organisms for biological fluid dynamics. *Annual Review of Fluid Mechanics*, 47(1):343–375.