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

David Colliaux ¹, Lia Giraud ², Claude Yéprémian³, Pierre Bessière ¹ and Jacques Droulez ¹

Motivations

- Unicellular algae, like Chlamydomonas Reinhardtii, are living examples of microscopic phototactic vehicles [1,2].
- The study of their swimming behavior at single cell and population levels unravels properties of their sensorimotor system.
- Microrobots operating in a low Reynolds number regime would benefit from the understanding of their living counterparts.

Characterization

The density of cells (A) is monitored through the gray level intensities:

As a circular area is exposed to constant light, we measure:

- The sensitivity and the dynamic range of the algae from the density at the center (Ac) for various light intensities.
- The spatial resolution (s) as the slope on the border of the algae bump.
- The formation time where the bump to reach maximal resolution and its persistence time.

Other data from microscope recordings allows to get independent estimations for parameters of the model using single cell trajectories and population dynamics.

Collective behavior

At high density of cells, the interactions between individual behaviours leads to specific patterns of cell density, as shown here, which could not be explained if cell trajectories are independent. See also vortexx in https://bit.ly/1K7se2a

Models of phototaxis

Desynchronization in the beating of flagella.

The dynamics of the 2 flagella (considered as oscillators) can be reduced to their phase difference Φ:

\[ \Delta \Phi = \Delta \omega t + K \cos(\phi) dt + \sigma(I) dW. \]

With:

- \( \Delta \omega \): the difference of beating frequency.
- \( K \): the coupling constant.
- \( \sigma(I) \): fluctuations due to the stochasticity of biochemical signals.
- \( I \): Light intensity.

Population dynamics.

- In the above example, the tumbling rate depends on the distance from the light source / as well as the orientation relative to the light source \( \theta \), \( r(I, \theta) = \frac{1}{1 + e^{\alpha(I - \beta \cos(\theta))}} \).
- Macro and micro data will give us independent estimations of the diffusion coefficient as well as the dependance of the tumbling rate on the light intensity.

References