Microswimmers in Flow

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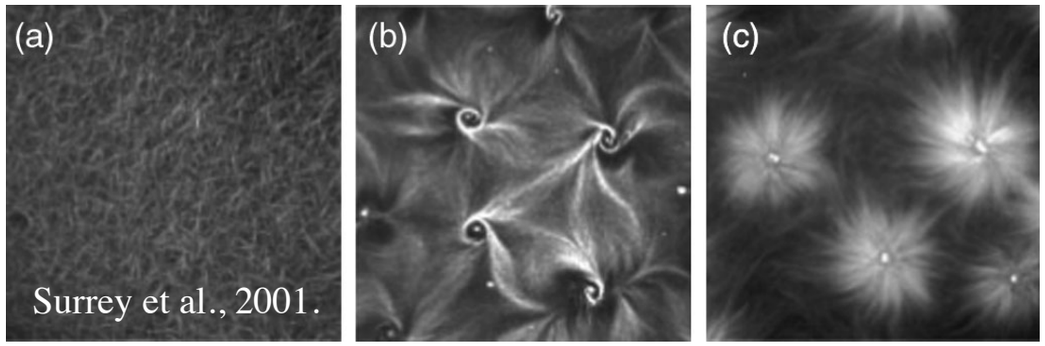
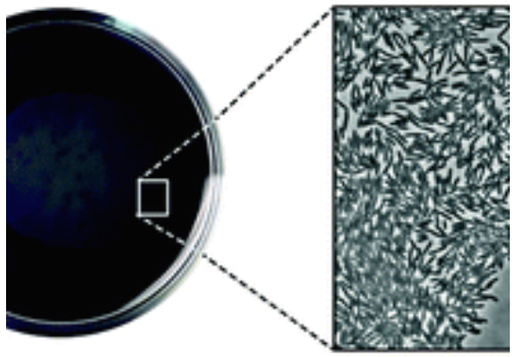
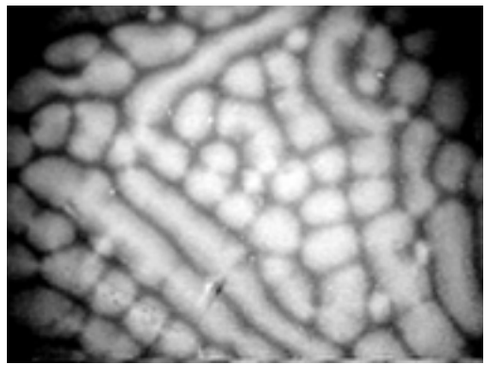
Active Matter



Motor proteins



Bacterial biofilm



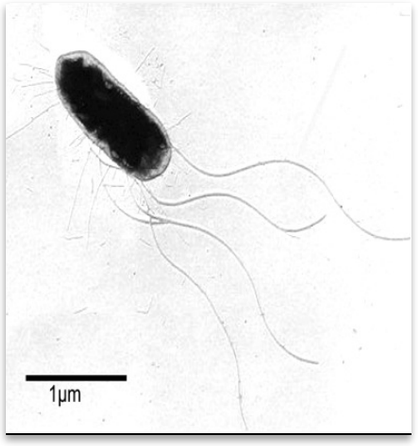
Bioconvection

Fish school

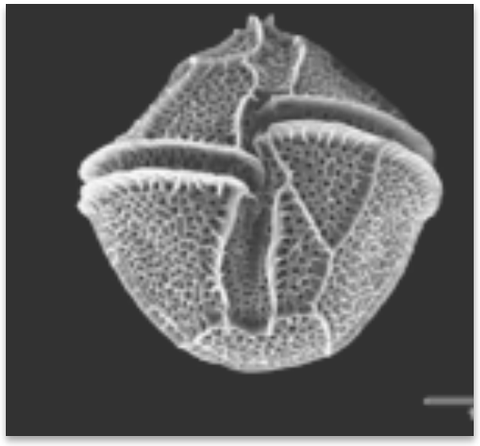
Plankton bloom

Starling flock

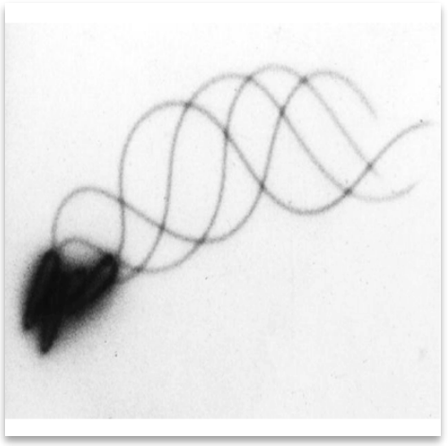
Living microswimmers



E. Coli



Gonyaulax

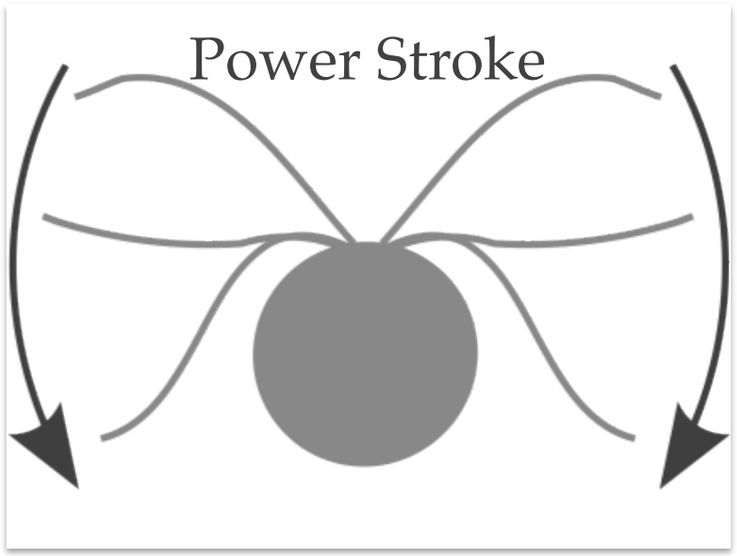


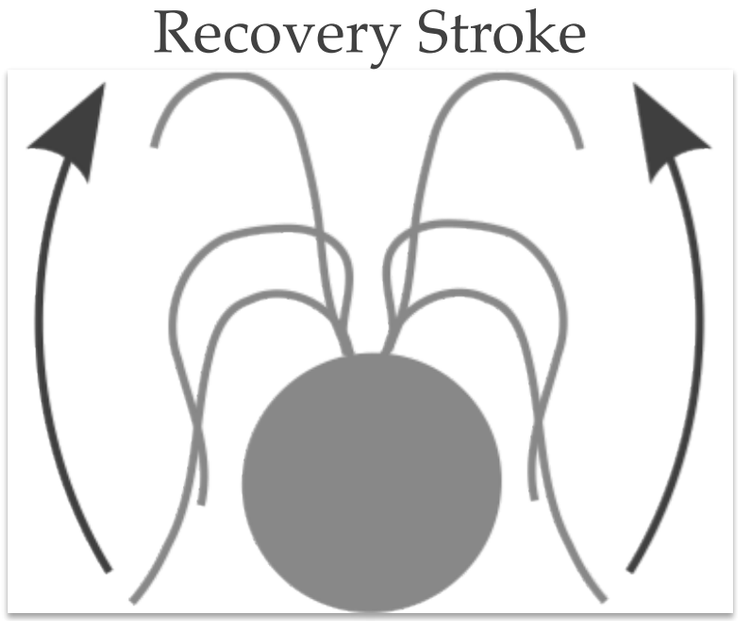
Sperm cell

Paramecia

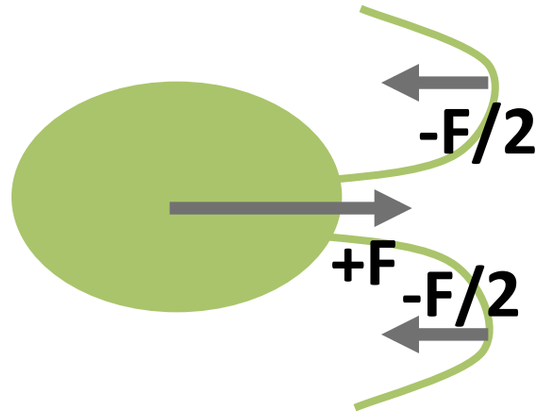
- Full name: *Chlamydomonas Reinhardtii*
- *Microalga*
- Size: 10 μm
- Shape : Quasi-spherical
- Gender : Puller-type
- Velocity ~100μm/s
- favorite drinking: freshwater + nutrients

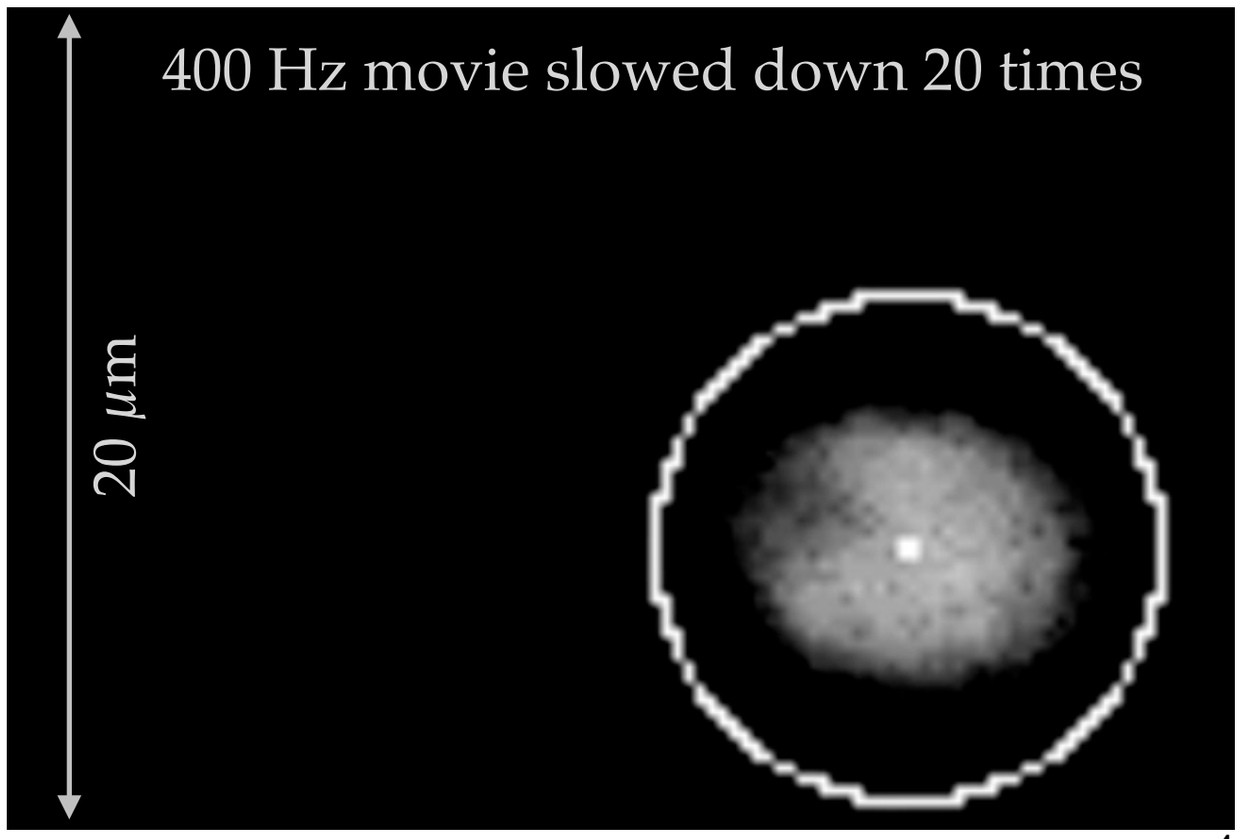
The complex random walk of Chlamy

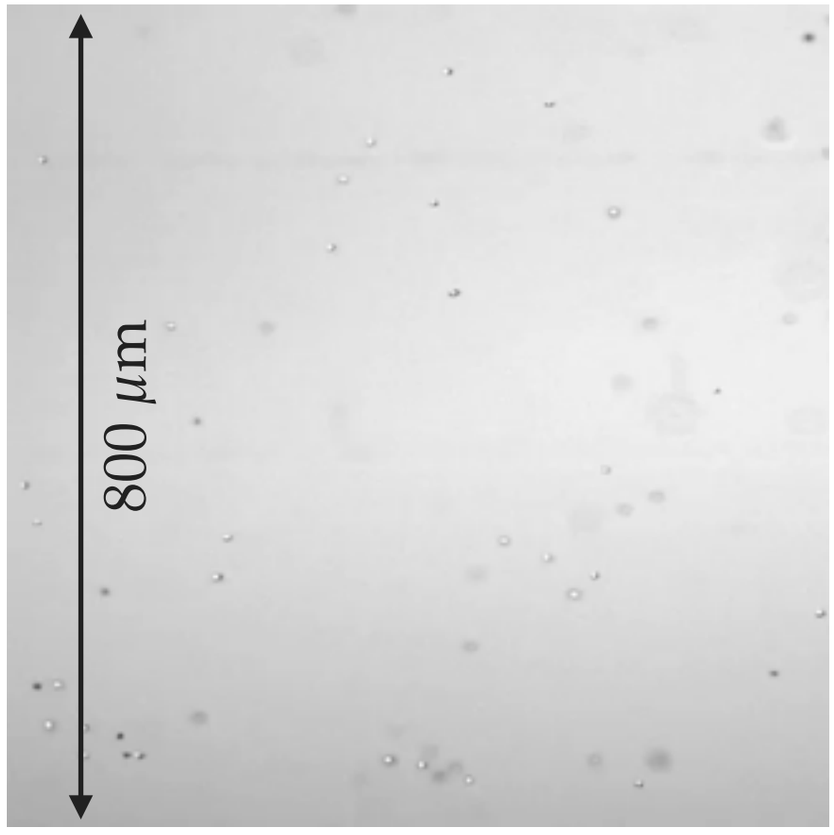




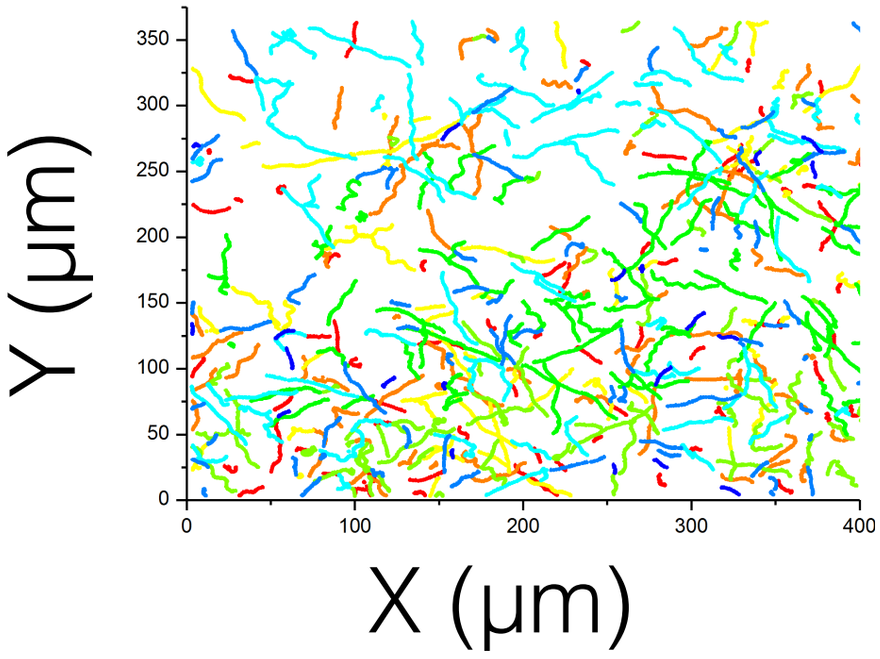
Re = 10^{-4}



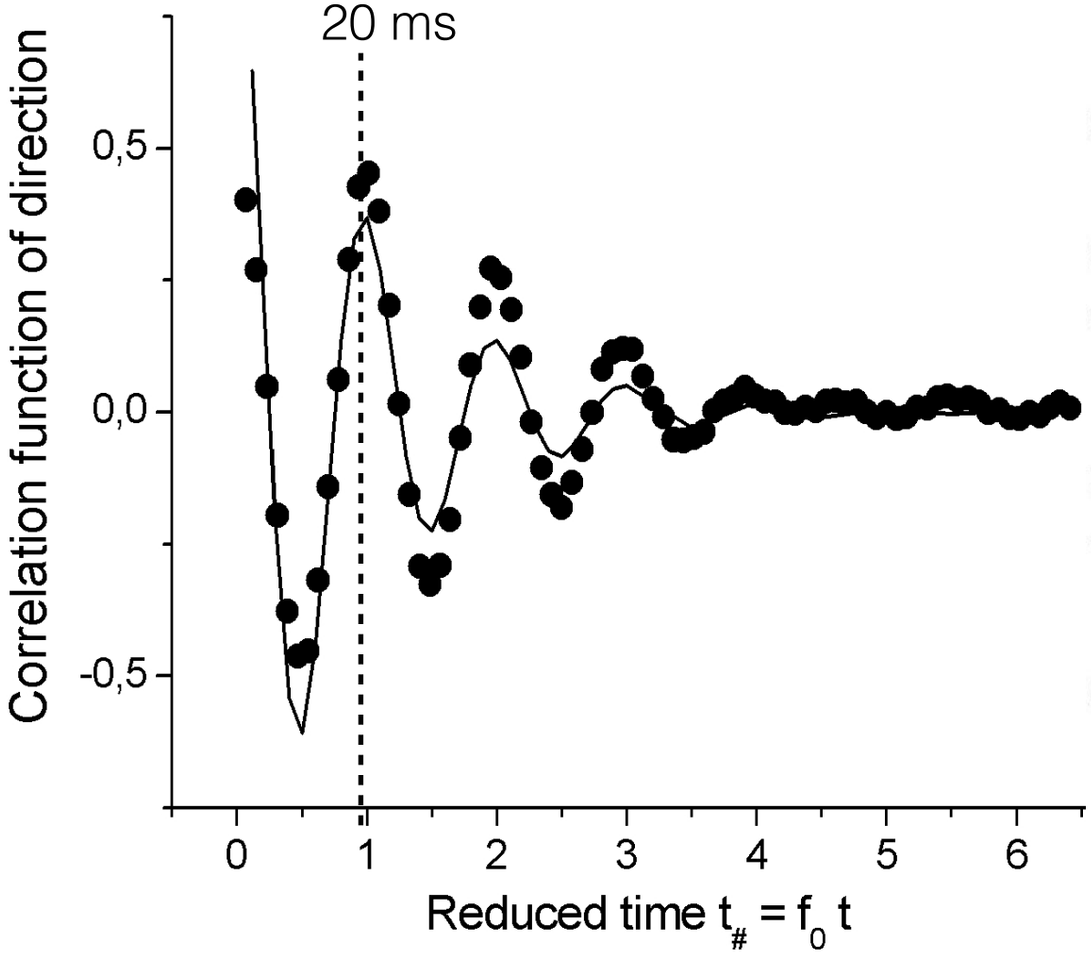


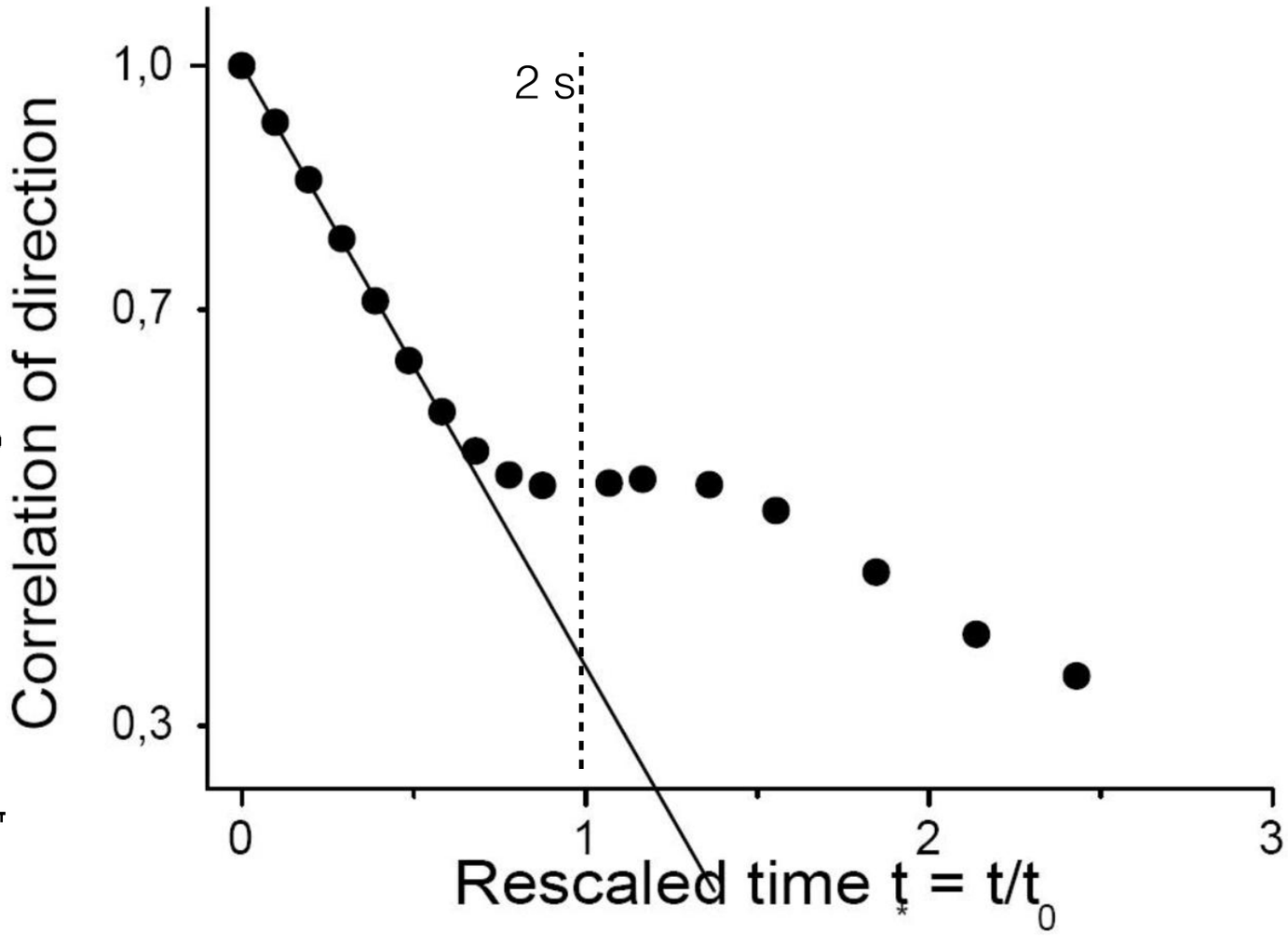


Particle tracking and classical analysis



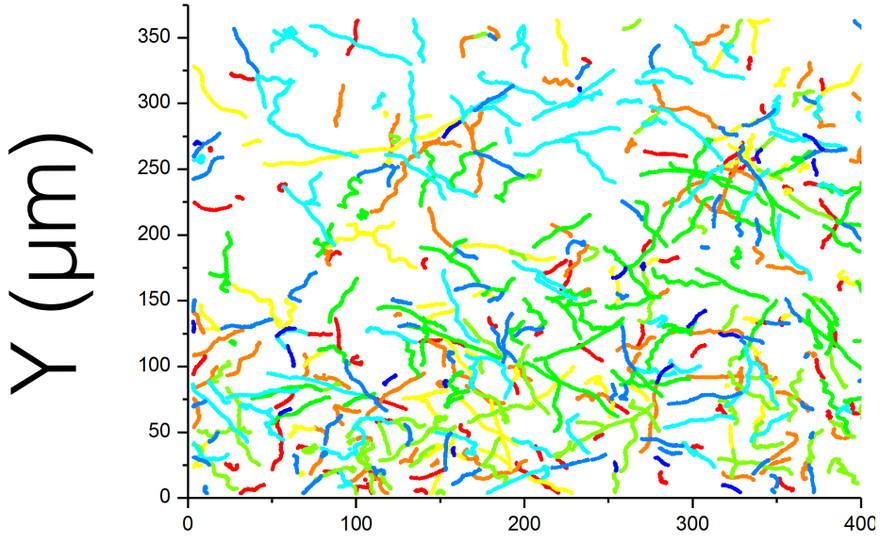
A persistent random walk

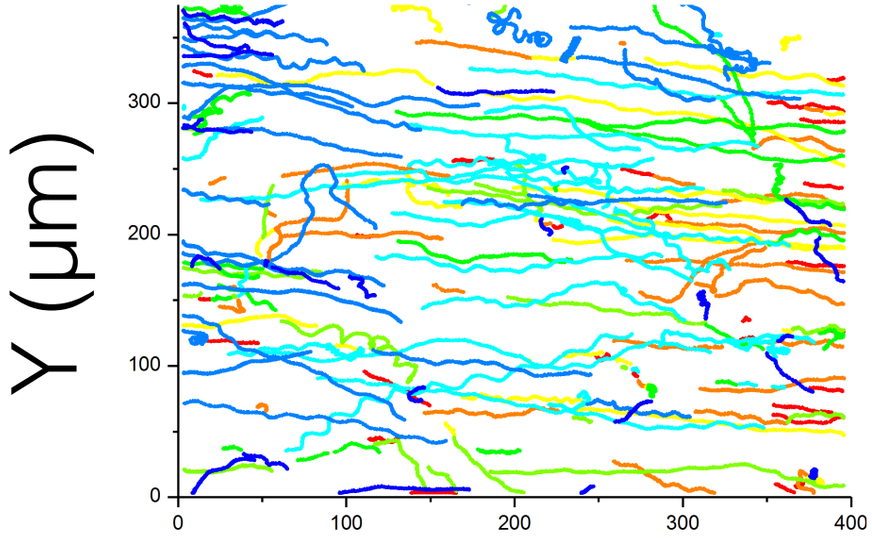


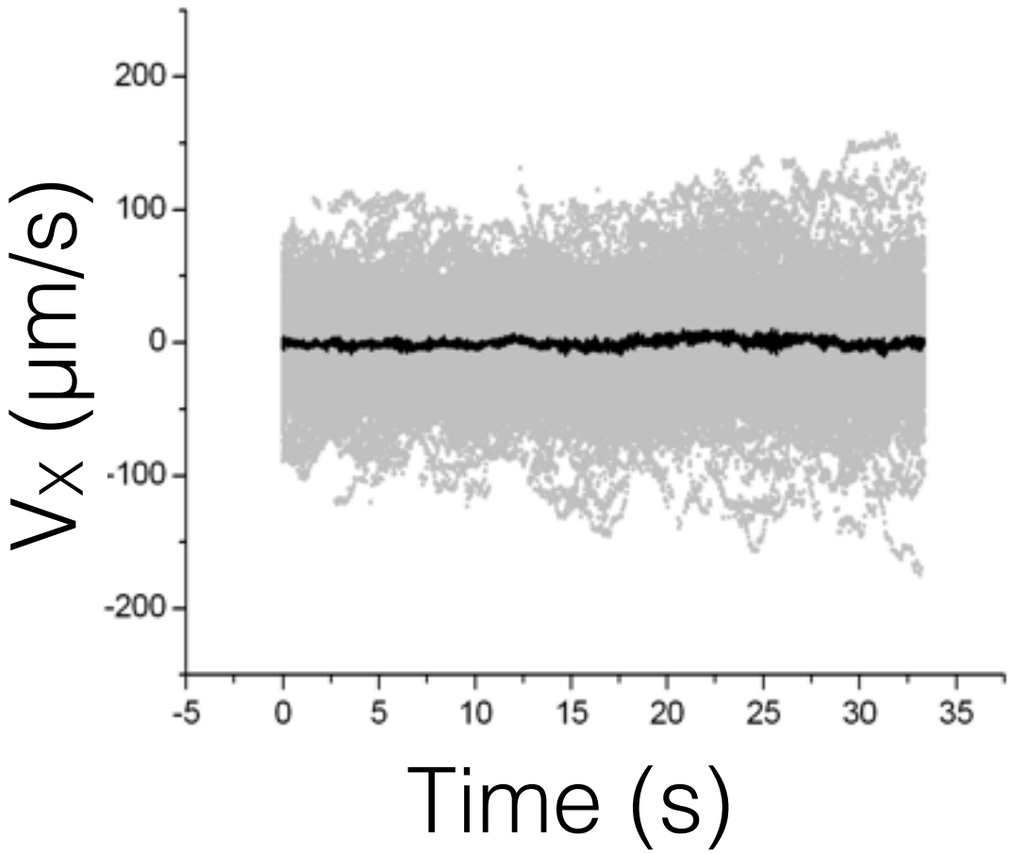


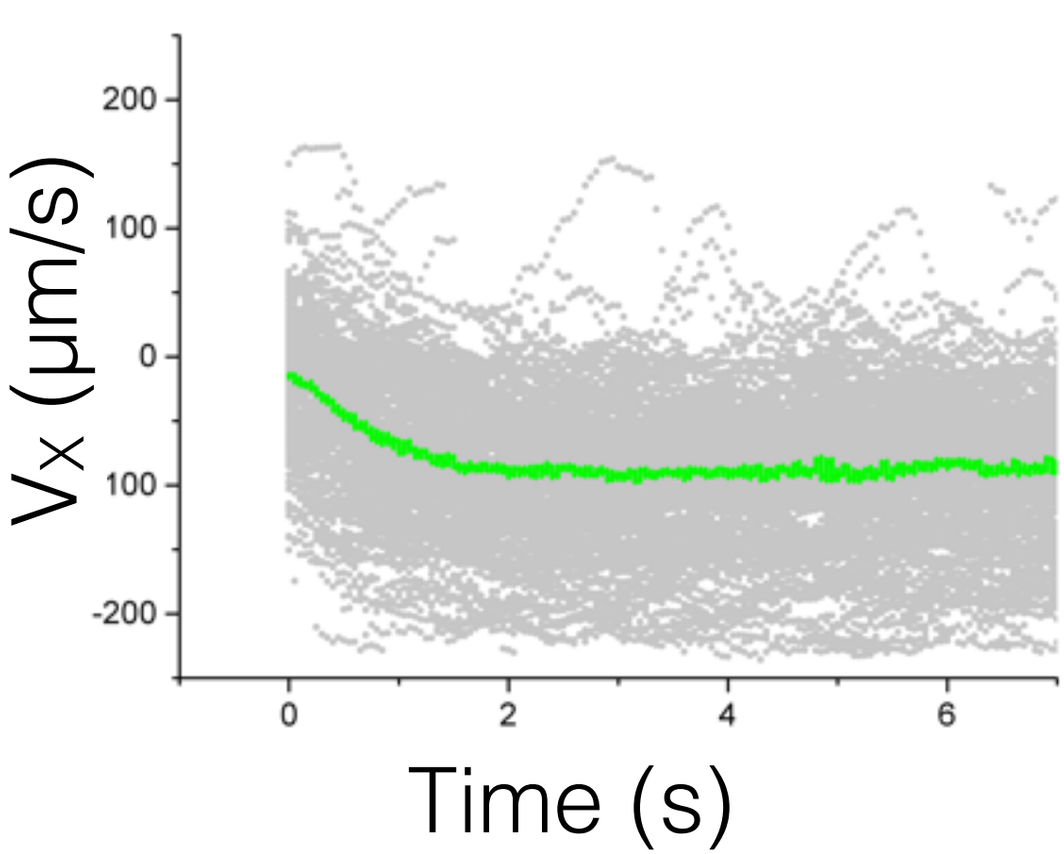
M. Garcia, S. Berti, P.Peyla & S.Rafaï
Phys. Rev. E (R) (2011)

Chlamy & phototaxis

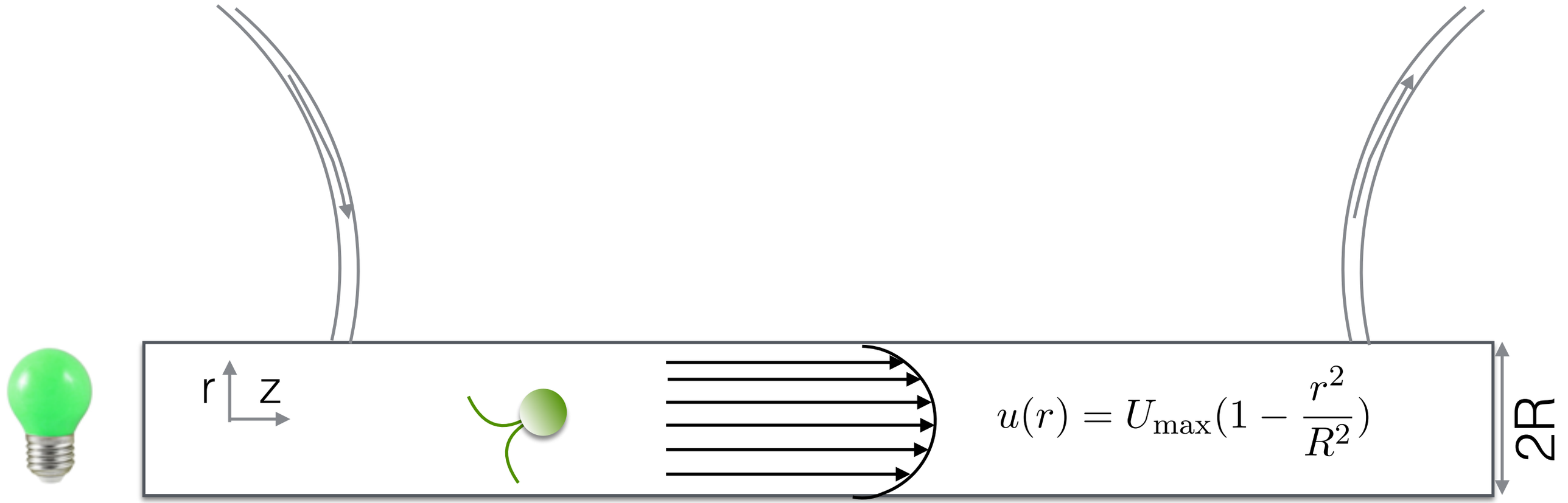




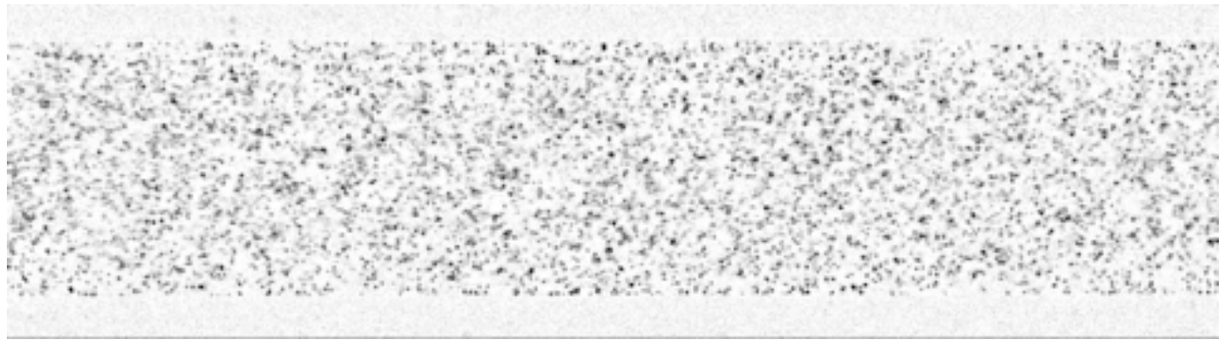




Phototaxis & Poiseuille flow

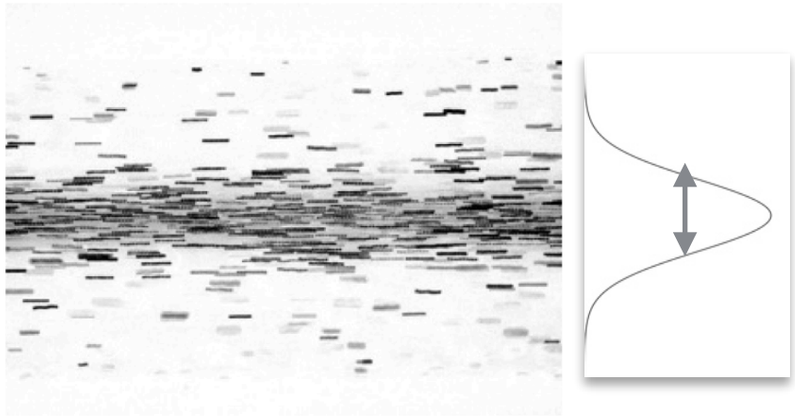


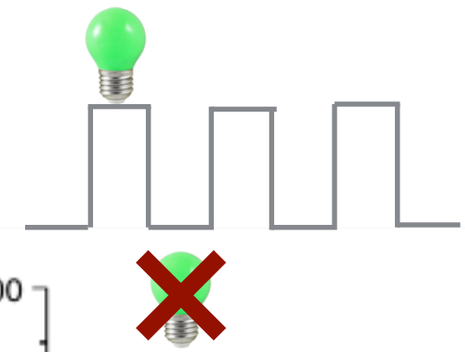
Phototaxis & Poiseuille flow: Photofocusing

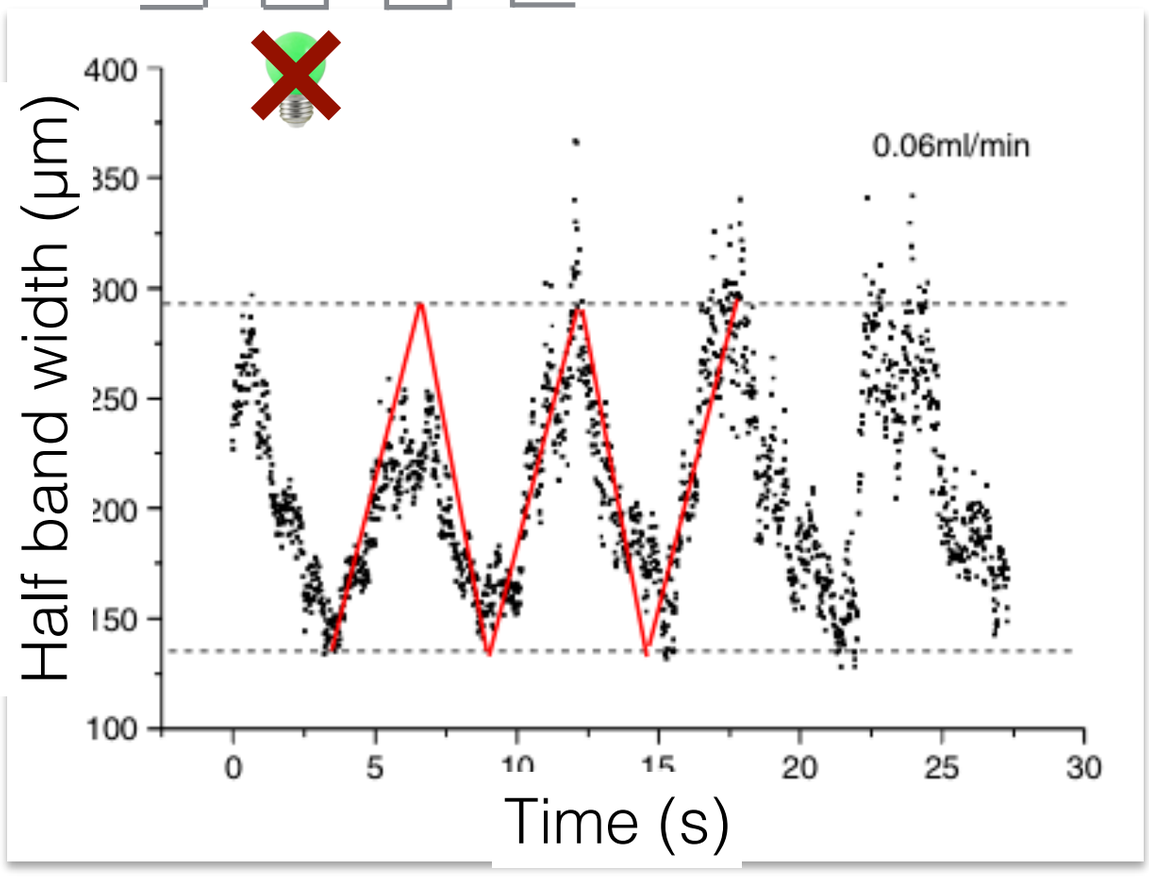


Light Control of the Flow of Phototactic Microswimmer Suspensions
X. Garcia, S.Rafaï & P.Peyla (Z013) Phys. Rev. Lett. 110 , 138106

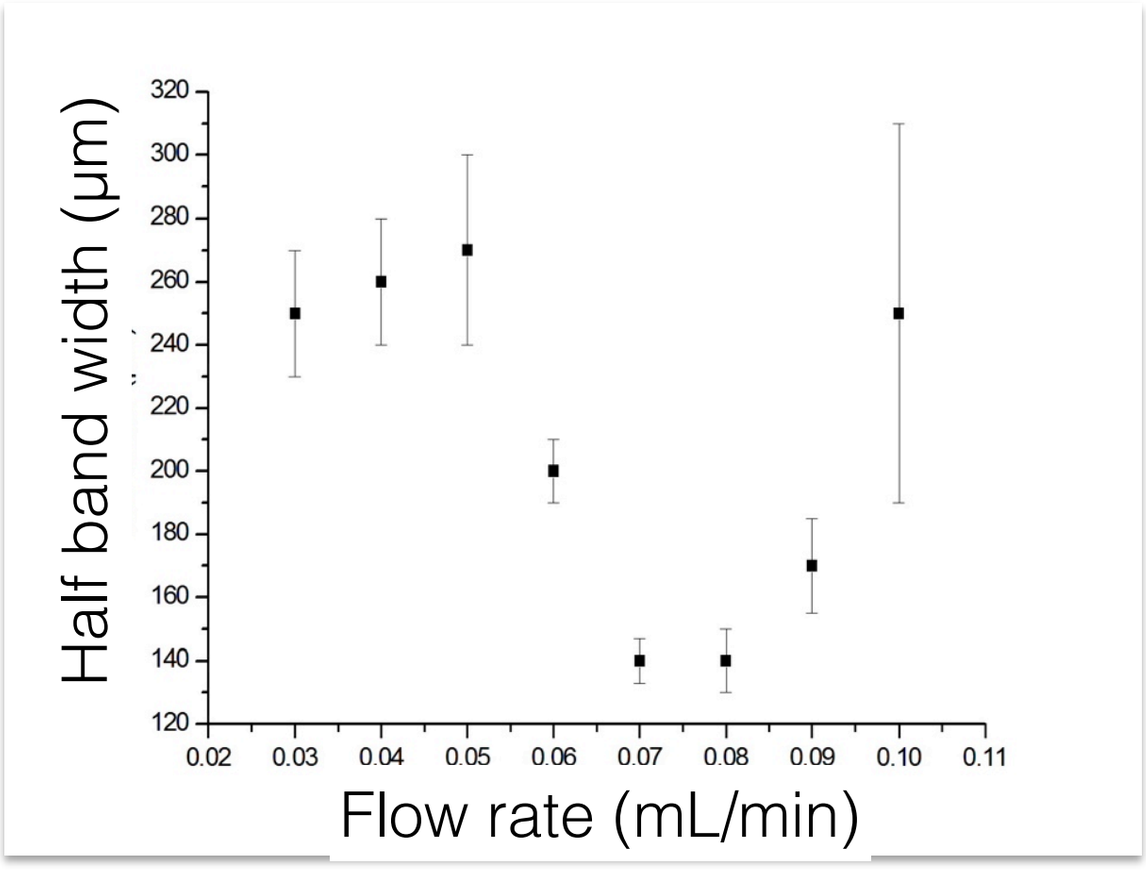
Photofocusing: a reversible effect







Microswimmer velocity controls the dynamics

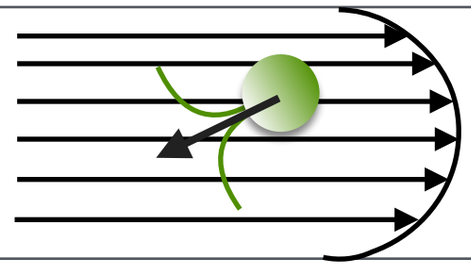


A range of flow rate where focusing occurs

Swimming in the flow

A non linear model: swimming speed Vswim+ flow speed u

$$\begin{cases} \dfrac{dr}{dt} = V_{\text{swim}} \sin\theta(r) \\ \dfrac{dz}{dt} = V_{\text{swim}} \cos\theta(r) + u(r) \end{cases}$$

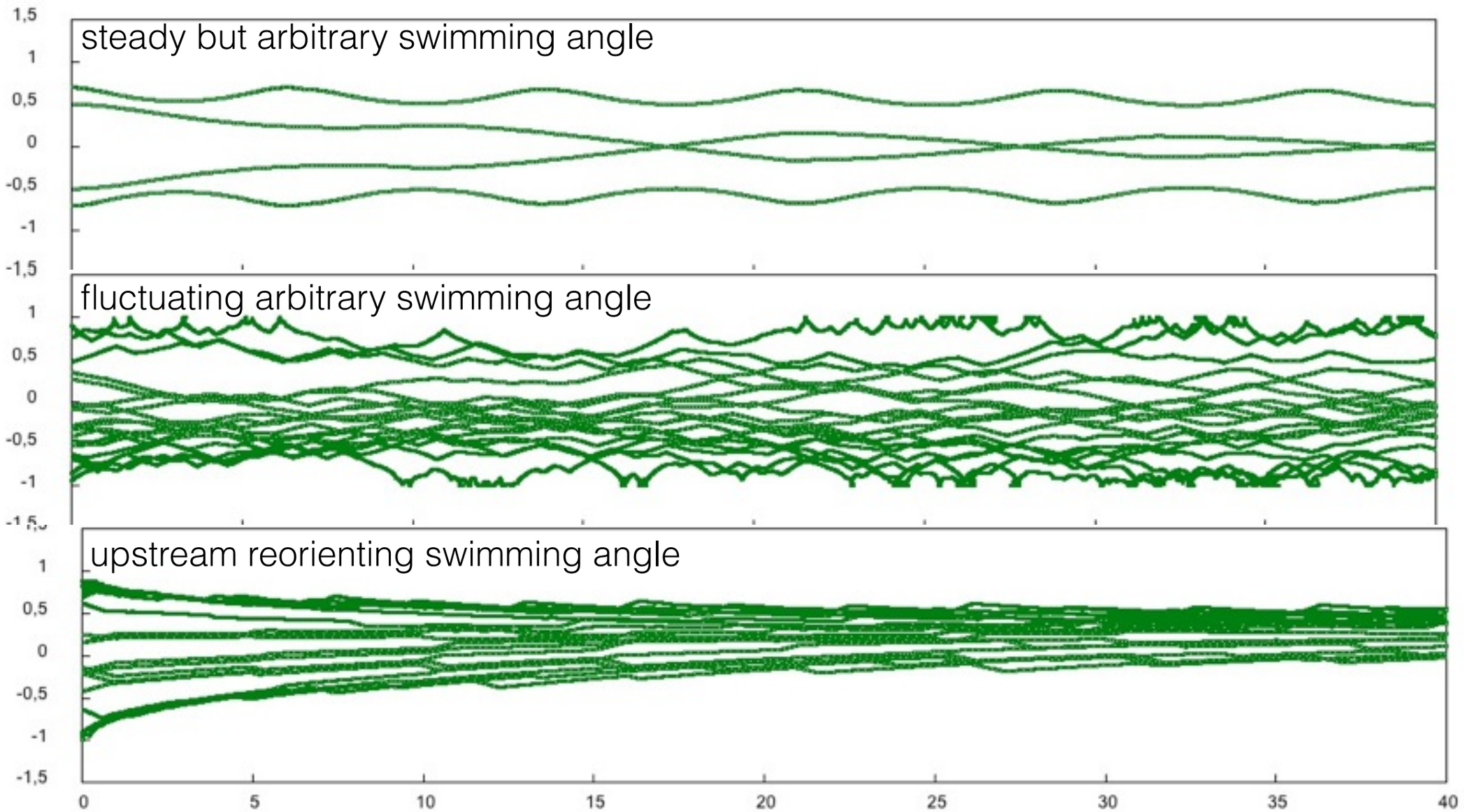


$$u(r) = U_{\max}(1 - \frac{r^2}{R^2})$$

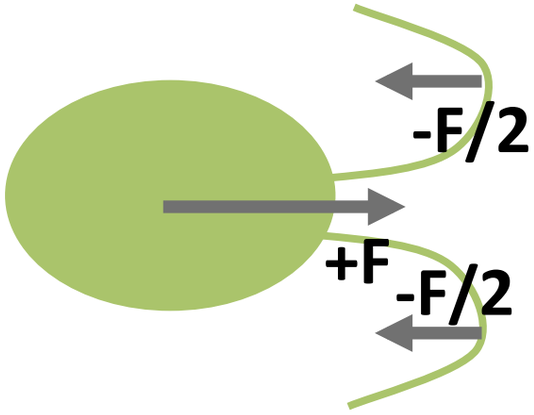
$$\theta(\mathbf{r}) = \int_0^t \omega(\mathbf{r})dt'$$

r z

2R



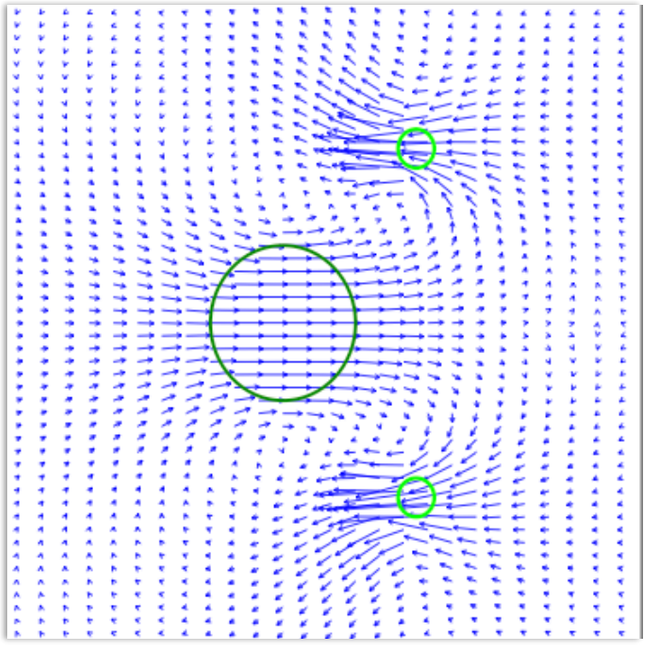
Modeling with full hydrodynamics



Phantom flagella model

Mehandia & Nott

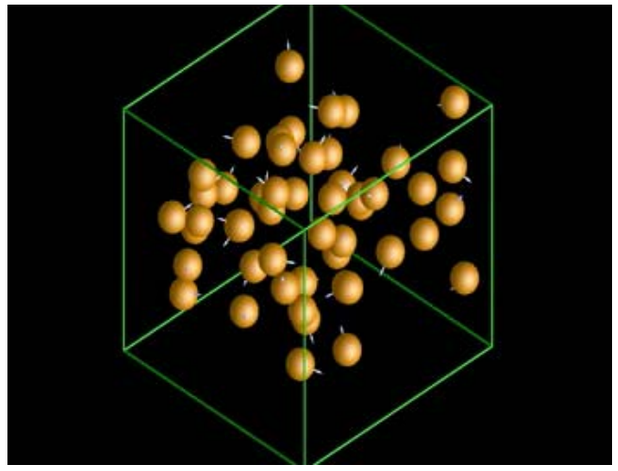
J. of Fluid Mech. 2008



consistent with

Experimental hydrodynamic field

Drescher et al. Phys Rev Lett 2010



3D Fluid Particle Dynamics

Peyla et al. J. Fluid Mech. 2012

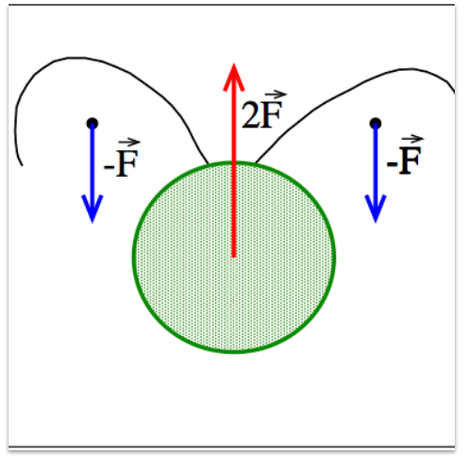
Penalization method

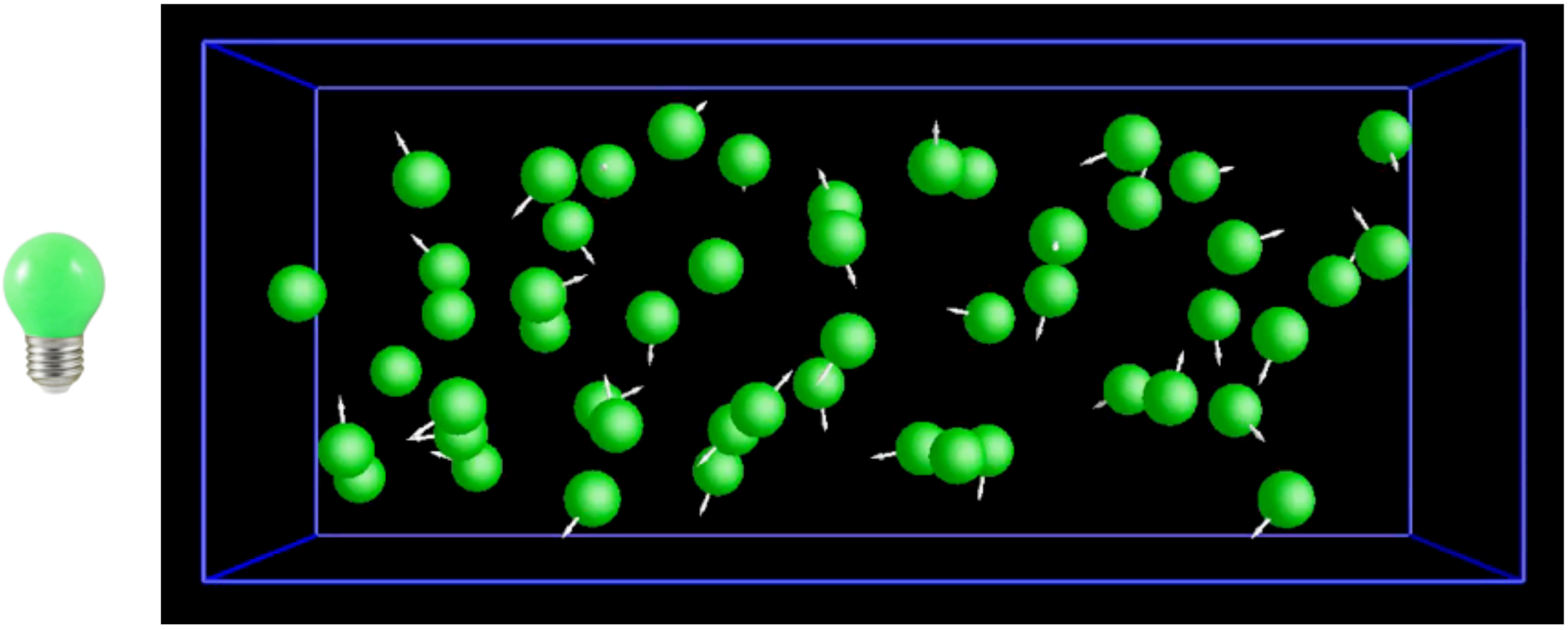
Tanaka 2D (PRL 2000),
Peyla 3D (EPL 2007)

$$\rho\frac{D\mathbf{v}}{Dt} = -\boldsymbol{\nabla}P + \boldsymbol{\nabla}.[\eta(\mathbf{r})(\boldsymbol{\nabla}\mathbf{v} + \boldsymbol{\nabla}\mathbf{v}^t)] + \mathbf{f}$$

Navier Stokes + Active forces

Clustering





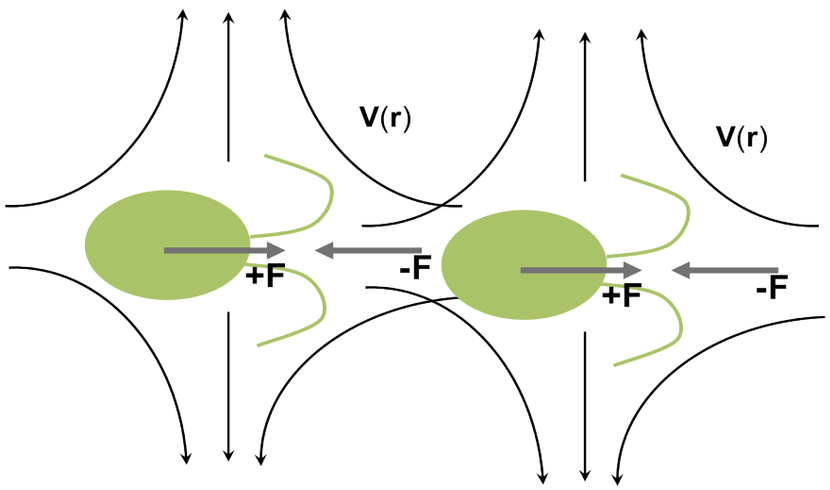
Full hydrodynamics numerical simulations (FPD method)

Self-focusing and jet instability of a microswimmer suspension
L. Jibuti et al. (2014) Phys. Rev. E, ***90****, 063019*

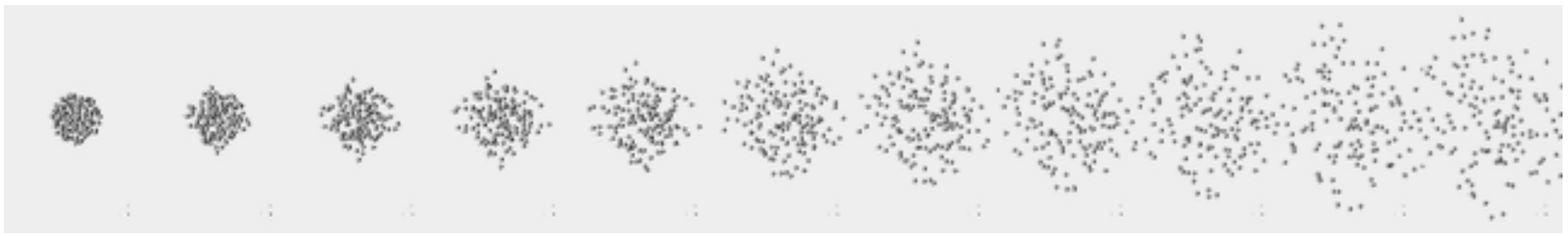
Perspectives

together with Philippe Peyla (Prof. UJF)

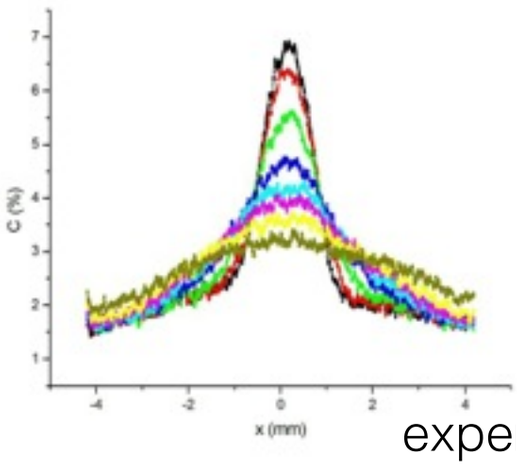
Experimental evidence of clustering?



Effect of hydrodynamic interactions on the dispersion of μswimmers



numerics



experiments

Johannes Greber PhD
(Bayreuth)

Matthieu Martin PhD

Thank you

People:

Philippe Peyla, Prof.

Michaël Garcia, PhD (2009-2013)
Levan Jibuti, PhD (2008 – 2011)
Stefano Berti, Post-Doc 2008
Xabel Garcia, Master 2011
Matthieu Martin, PhD (2014-)

Prof. W. Zimmermmann Bayreuth
Johannes Greber, PhD

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