Program for the next two hours:

Modelling Daphnia Swarming

Bruno Eckhardt

Dynamics of a Continuum Model of Swarms

Edward Ott

Crowd Synchronisation on the London Millennium Bridge

Edward Ott and Bruno Eckhardt

Modelling Daphnia Swarming

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Experiments:

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Modelling:

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Christof Lange	
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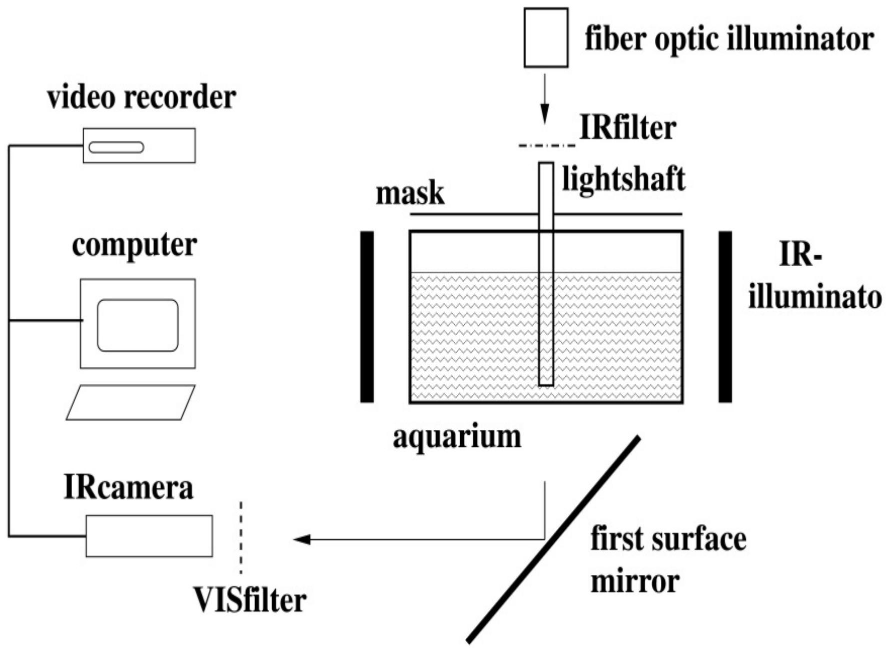
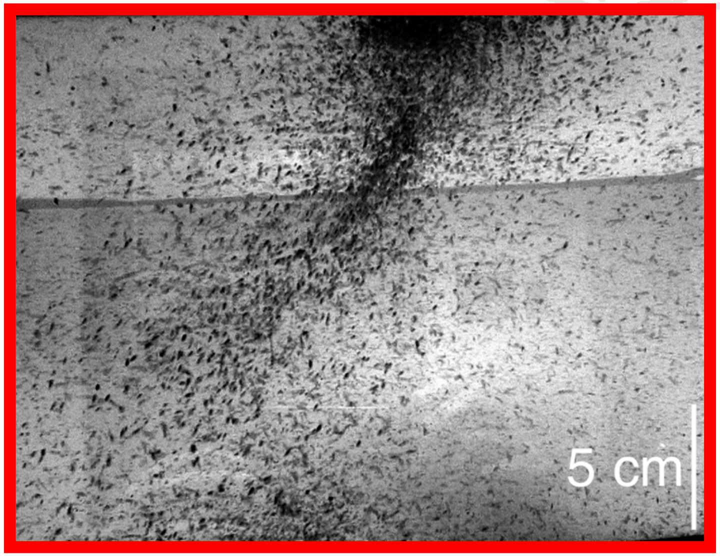
Publication: Phys. Rev. E, in revision

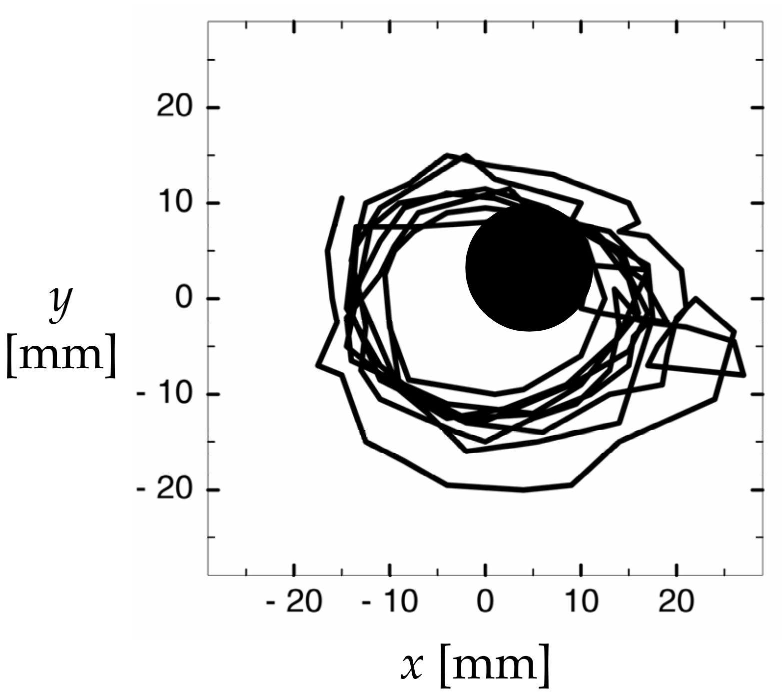
Daphnia in Moss's Lab



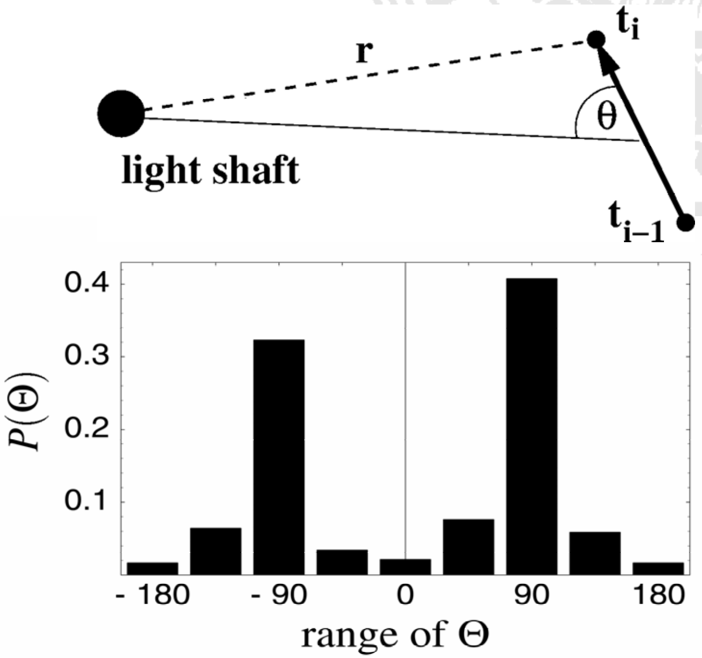


Sideview of swarm

Single Daphnia tracks



Track of one *Daphnia* individually circling horizontally around light shaft (146s).



Single *Daphnia* circle individually in both directions around light shaft, frequently changing their circling direction

Our model

- Self propulsion
- Attraction to light center
- Repulsion and avoidance
- Hydrodynamic interaction

$$\dot{\vec{x}} = \vec{v}$$

$$\dot{\vec{v}} = \gamma(1 - \vec{v}^2)\vec{v} - \nabla V(\vec{x})$$

Of course, all the interesting aspects are hidden in the potential

Single particle motion

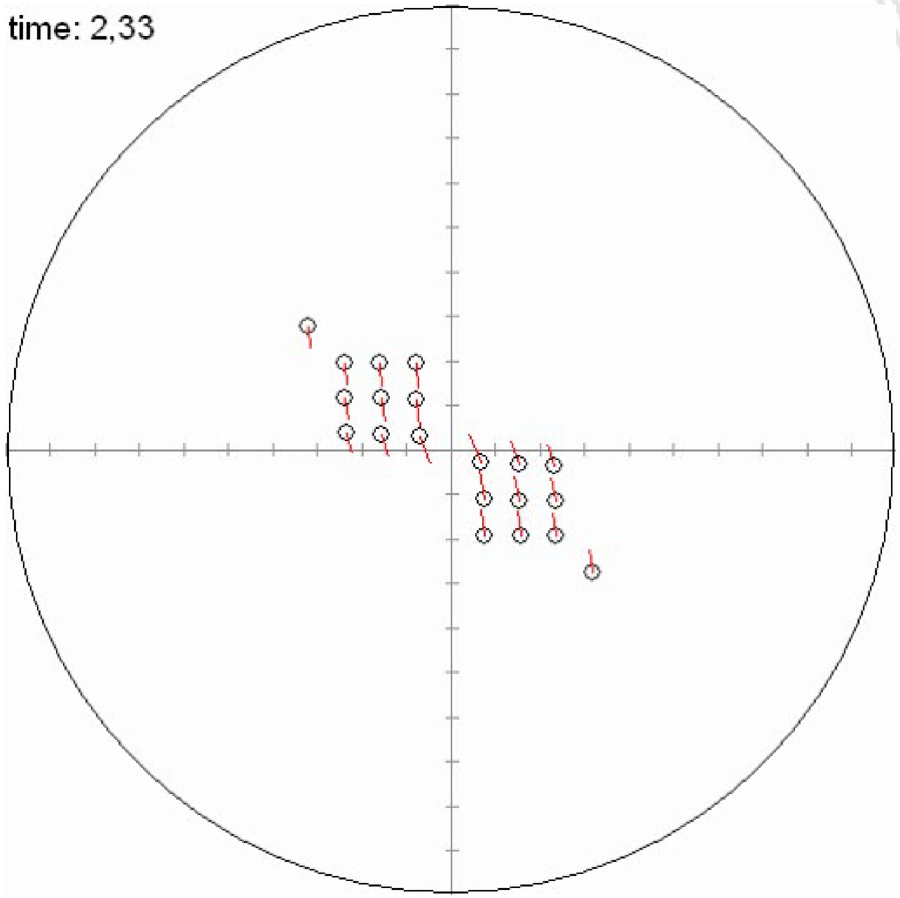
Harmonic potential

Logarithmic potential

Only one stable circle

ALL circular motions neutrally stable

20 Daphnia in a container



Transition to ordered motion

„Angular momentum“

$$L_v = \frac{(\vec{x} \times \vec{v})_z}{|\vec{x}|} = v \sin \theta$$

Significance of self propulsion

- Without self propulsion one has a classical gas in a potential: no circulation develops
- What is the critical parameter?
- Phasediagram?

Phasediagram

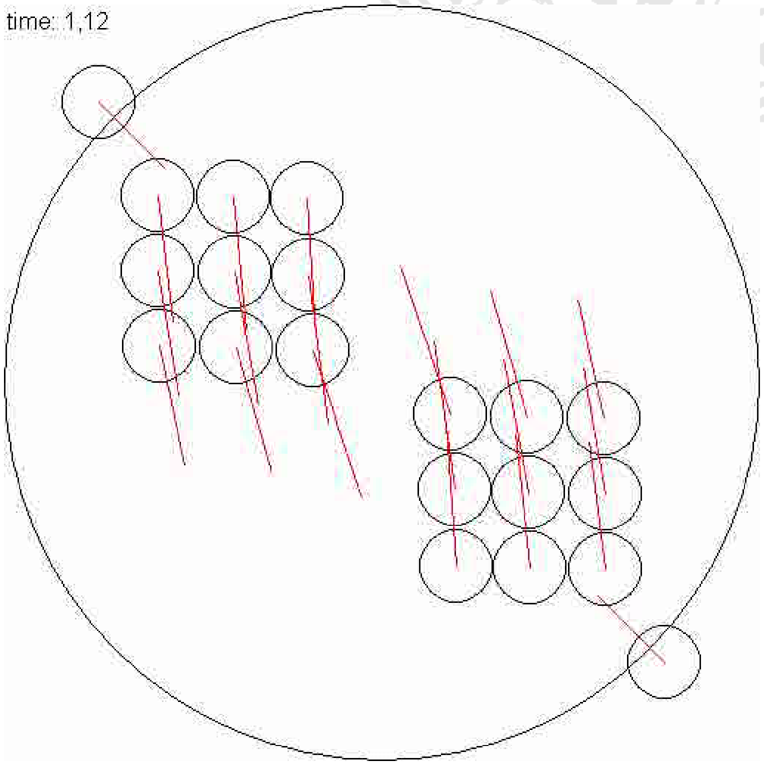
No Vortex

Vortex

No Vortex

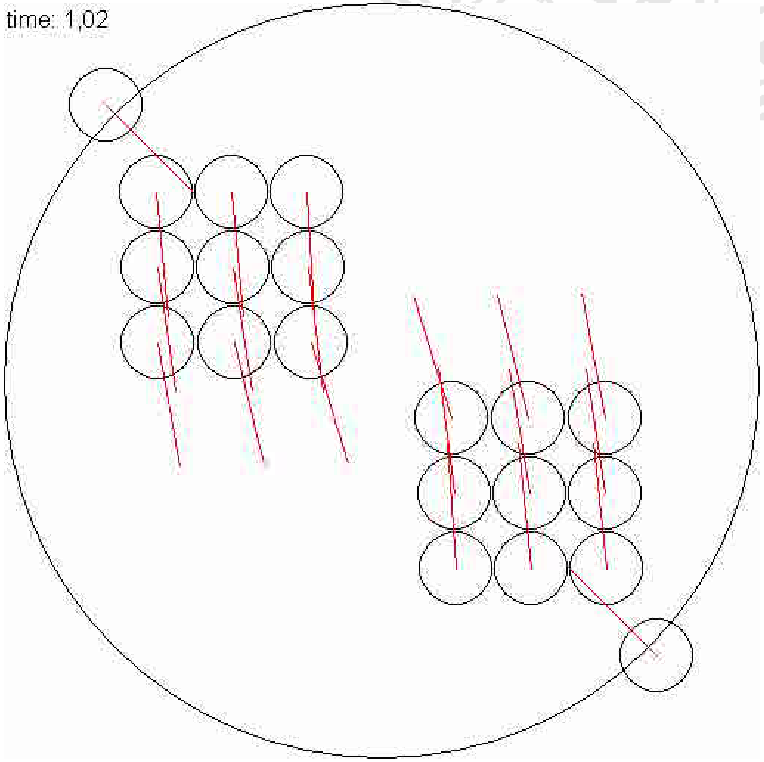
$$\dot{\vec{v}} = \gamma(1-\vec{v}^{\,2})\vec{v} - \nabla V(\vec{x})$$

Weak self propulsion, no vortex



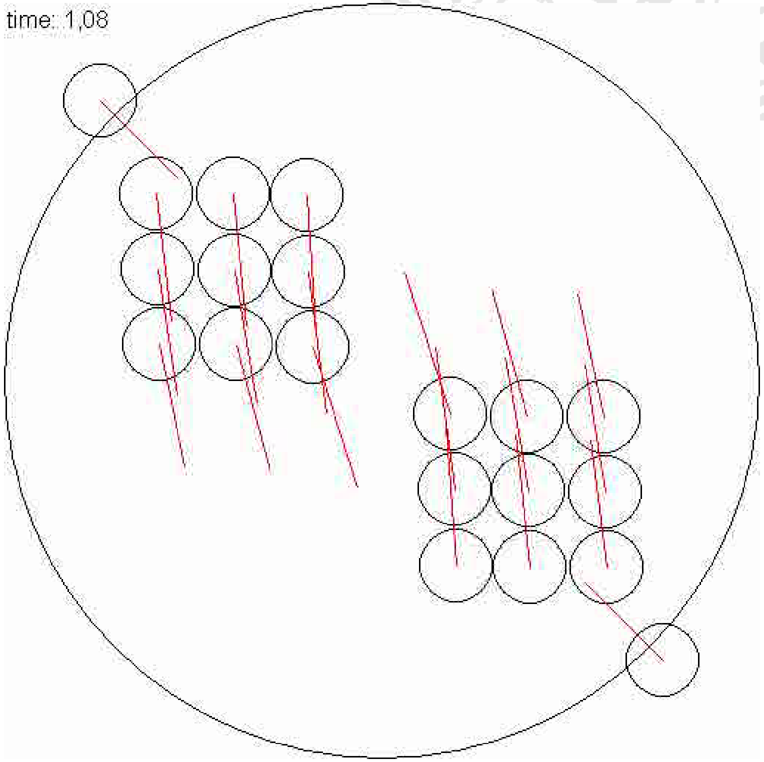
$\gamma = 0.01$

Strong self propulsion, no vortex



$\gamma = 20$

Vortex formation



$\gamma = 0.4$

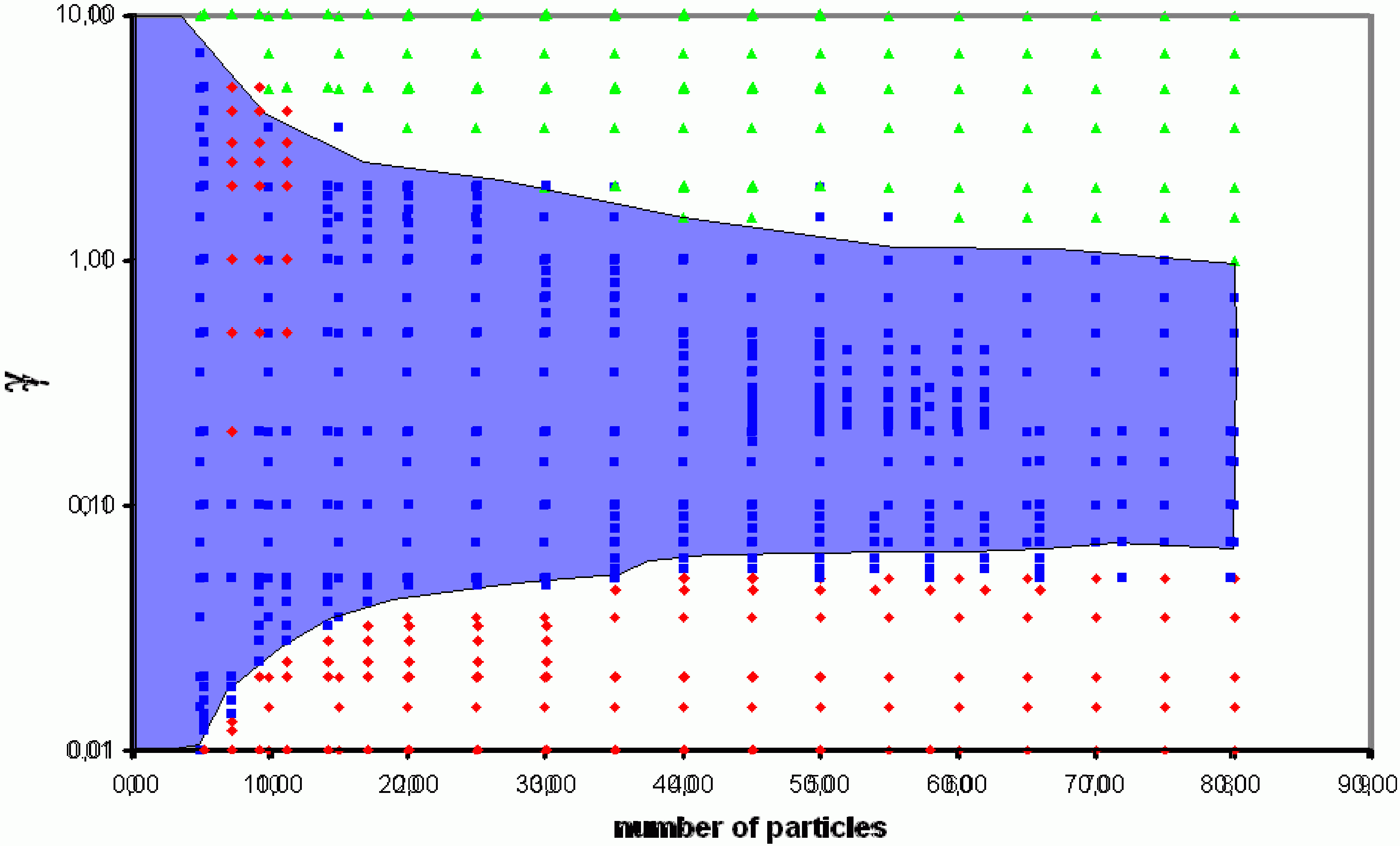
Phasediagram

No Vortex

Vortex

No Vortex

Phase Diagram , *R=14 and 10*



Angular velocities vs. γ and N

0.001 0.1 10

γ

60 120

N

Hydrodynamic Interactions

Frequently
used:
Steady flow
around sphere:
‚Stokeslet‘

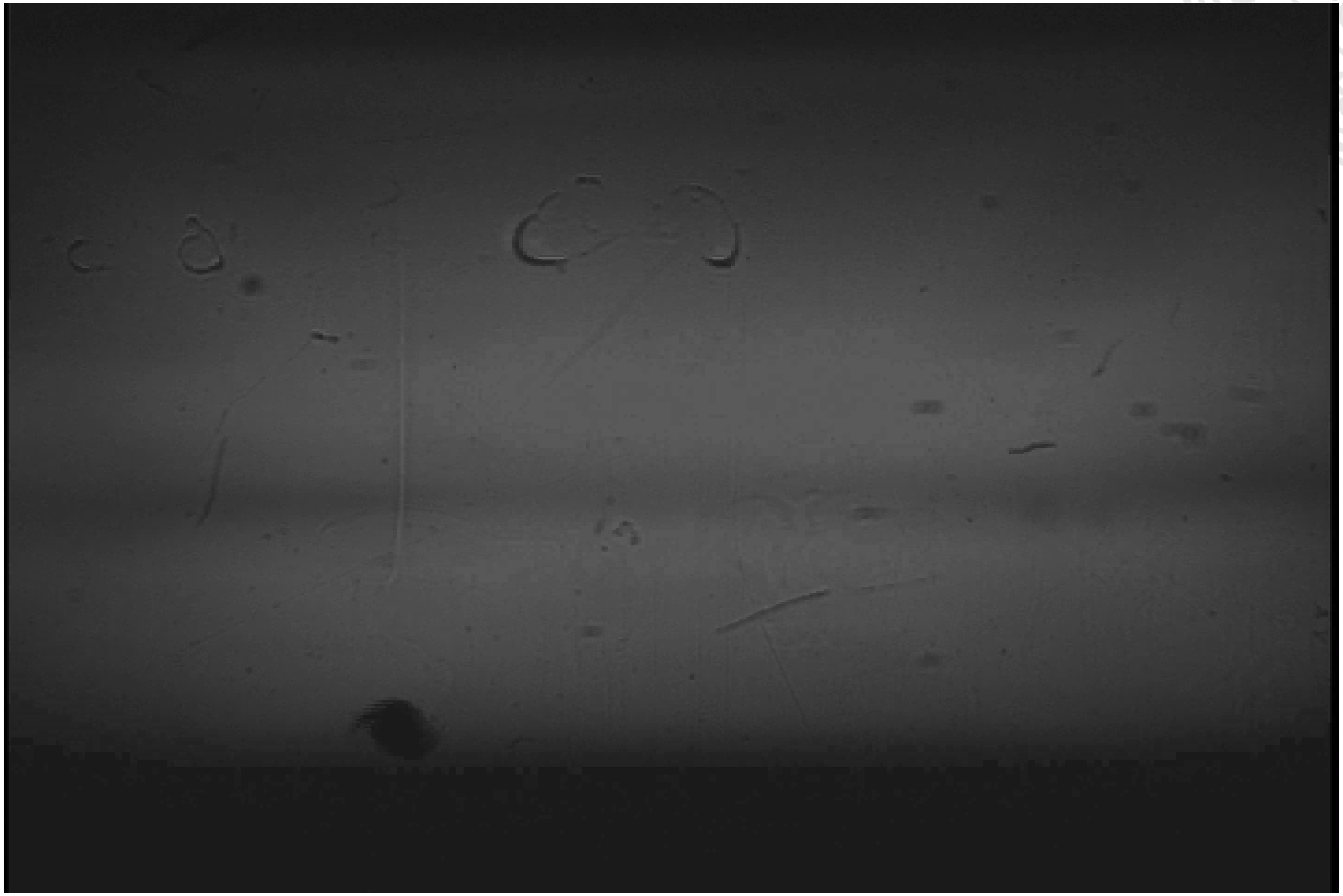
Hydrodynamic interactions

- Model each agent by a Stokeslet (flow around a sphere)
- Single agent approximation

Shorter transients

Faster rotation
Stronger fluctuations

Trail tracking:



Summary

A weak self propulsion will not give a vortex,

... neither will a strong one

As the number of agents increases
escape is more likely,
the vortex will dissolve

Hydrodynamic interactions increase the vorticity

... but Stokeslets or force dipoles may not be
enough