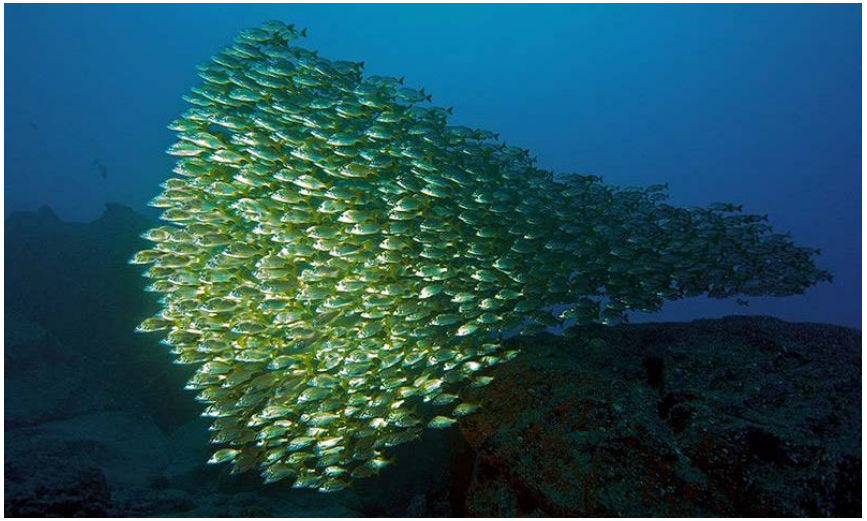
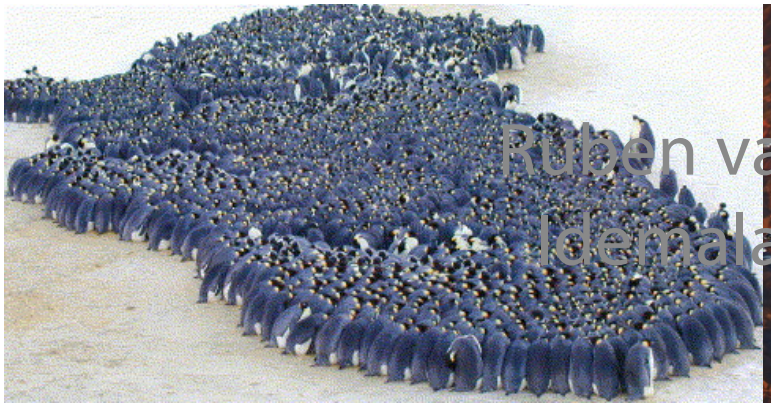
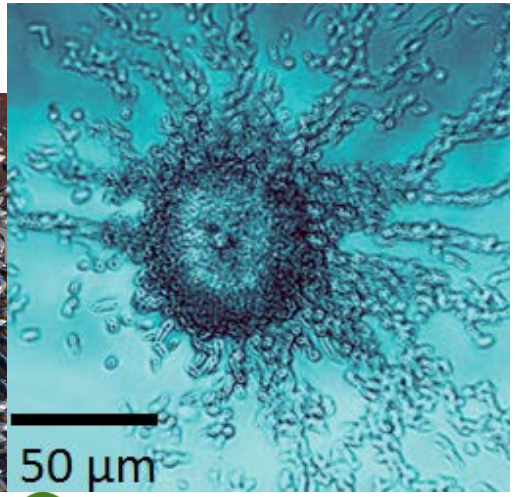
Moving without a leader







Kessin et al
Nature 2003

Population models

Flocking behaviour:

Vicsek model

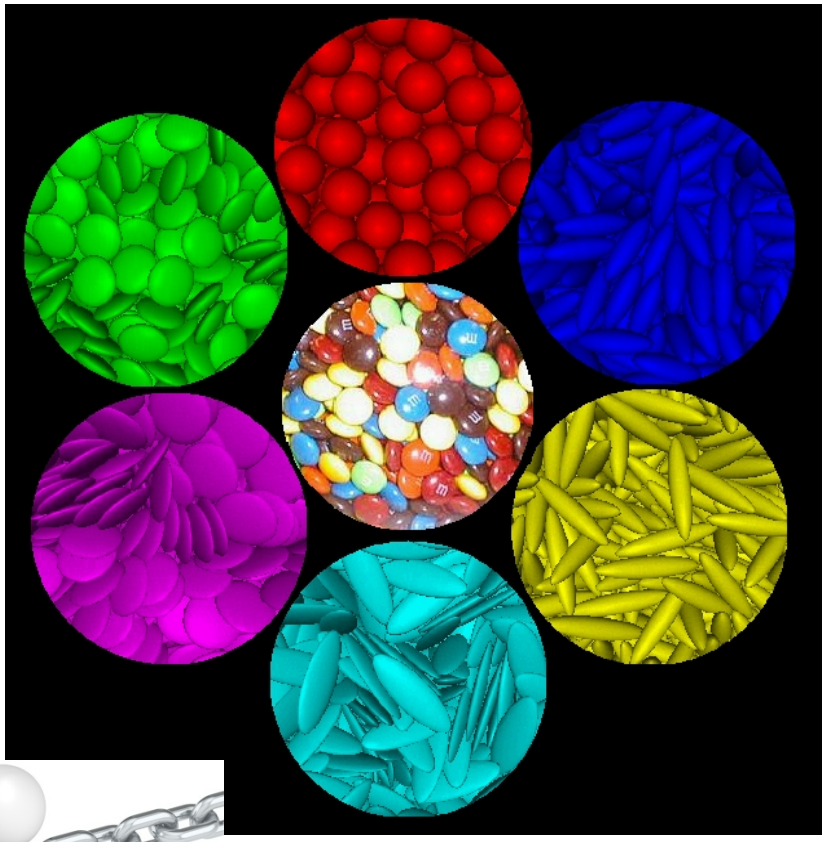
- Vicsek Model (1995)
  - Point-particles with velocity $\vec{v}_0$
  - Align with velocity of local environment
  - Noise on direction

Population models

Active (overdamped) soft matter

Flocking behaviour:

Vicsek model

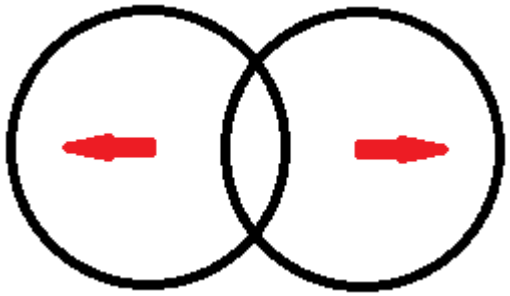


High density:

Jamming

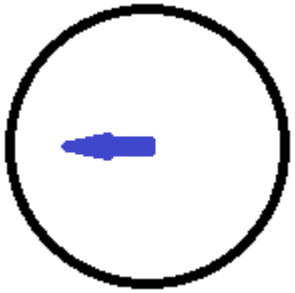
Interaction rules

- Forces
  - Repulsive when overlapping
  - Self-propulsion
- Torques
  - Alignment with neighbours
  - Noise



Interaction rules

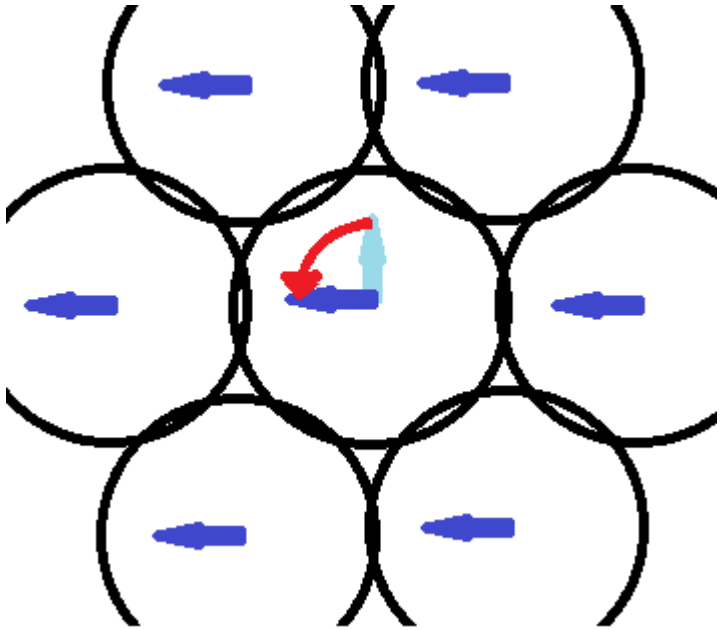
- Forces
  - Repulsive when overlapping
  - Self-propulsion



- Torques
  - Alignment with neighbours
  - Noise

Interaction rules

- Forces
  - Repulsive when overlapping
  - Self-propulsion
- Torques
  - Alignment with neighbours
  - Noise



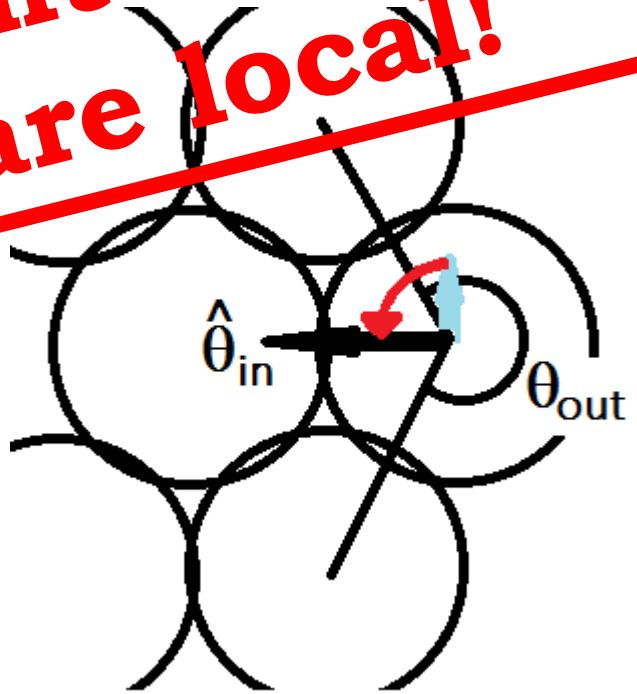
Interaction rules

- Forces
  - Repulsive when overlapping
  - Self-propulsion
- Torques
  - Alignment with neighbours
  - Noise

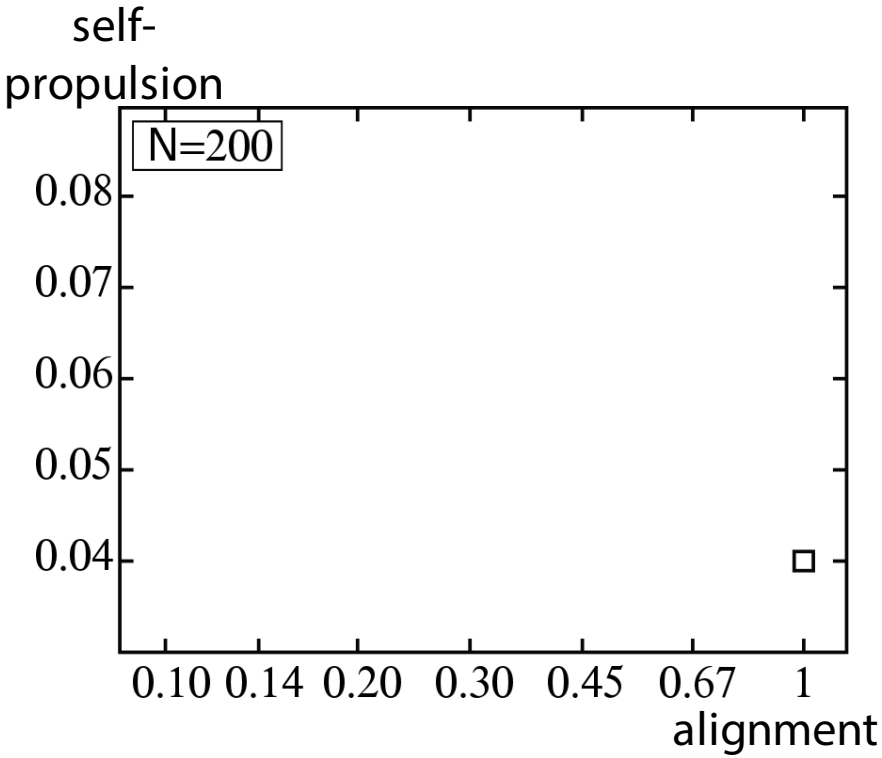
Interaction rules

- Forces
  - Repulsive when overlapping
  - Self-propulsion
  - Outsiders want in
- Torques
  - Alignment with neighbours
  - Noise
  - Outsiders want in

All interactions are local!

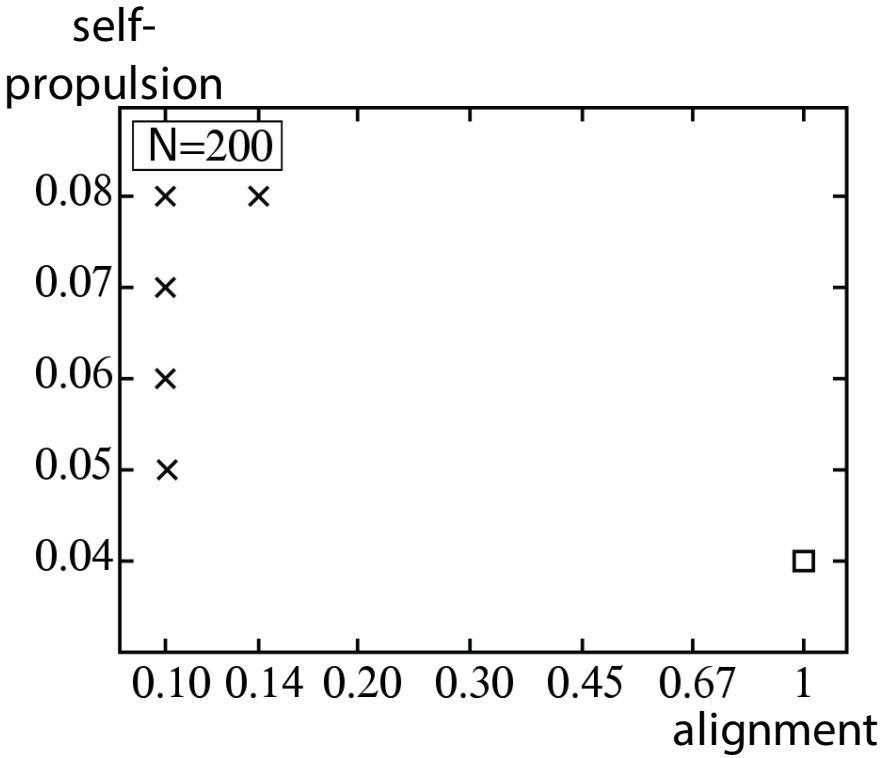


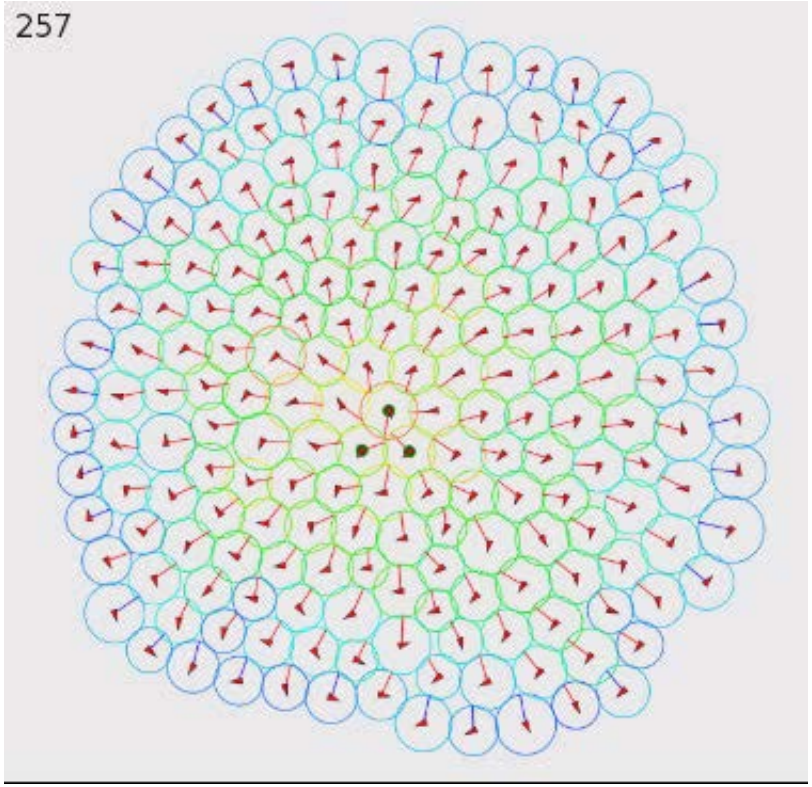
State diagram



jammed

State diagram



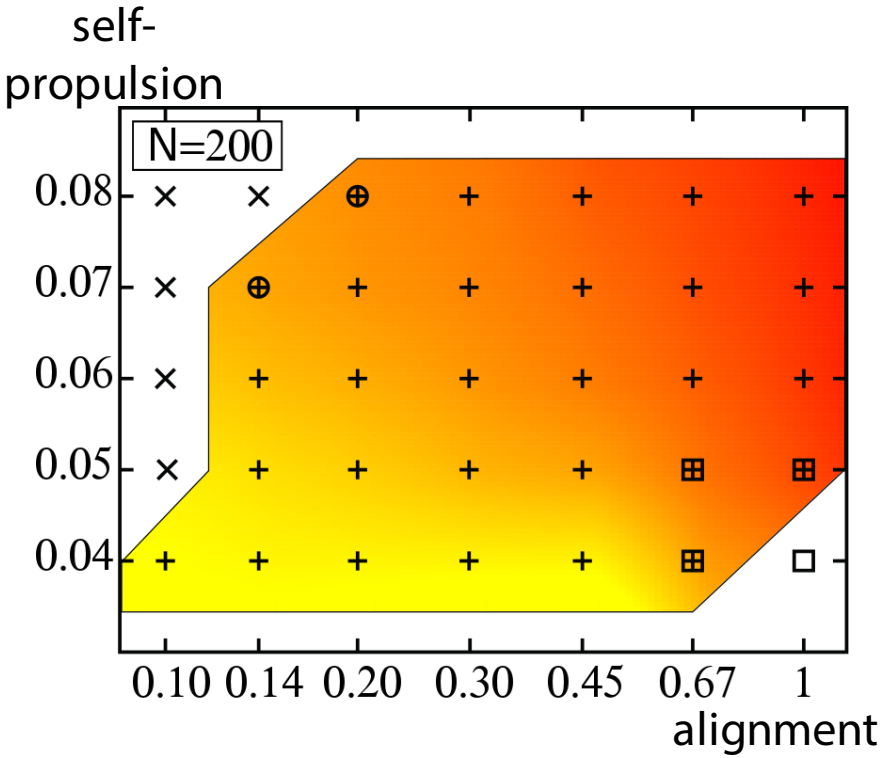


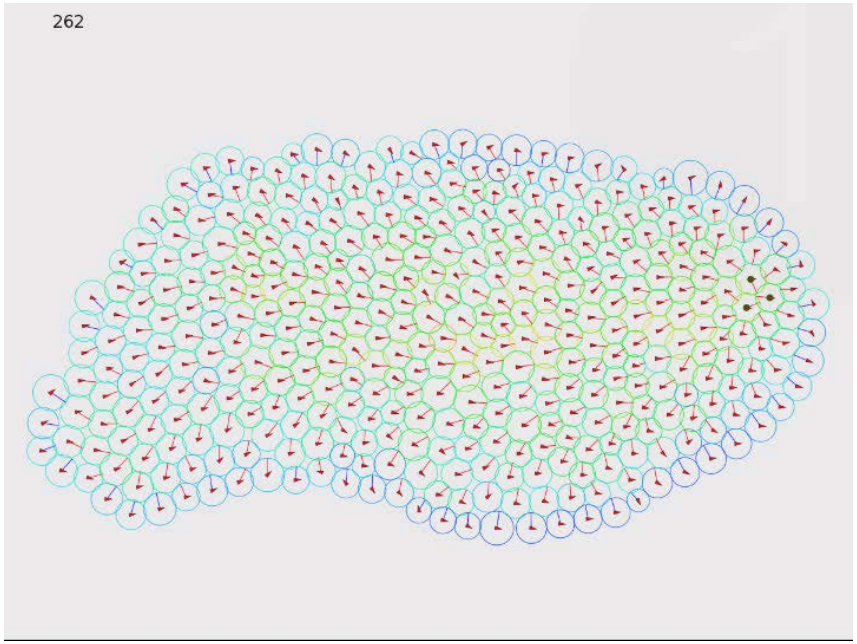
× break up

□ jammed

RvD et al. PRE **91**, 032706/arXiv: 1411.4821

State diagram





× break up

\+ migration

□ jammed

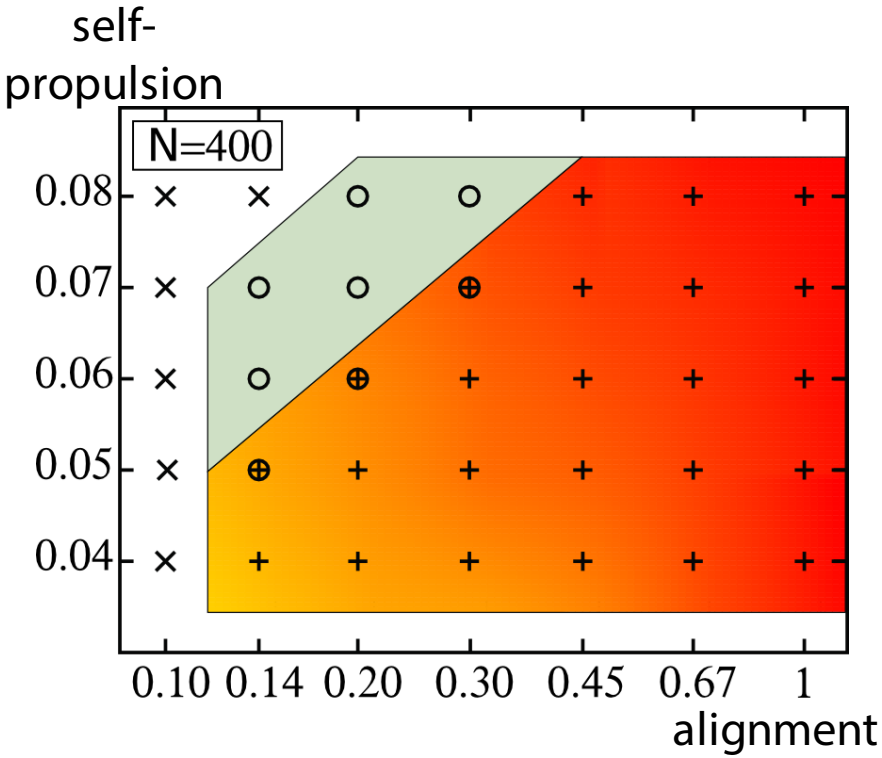
Φ=0.29 Φ=0.56

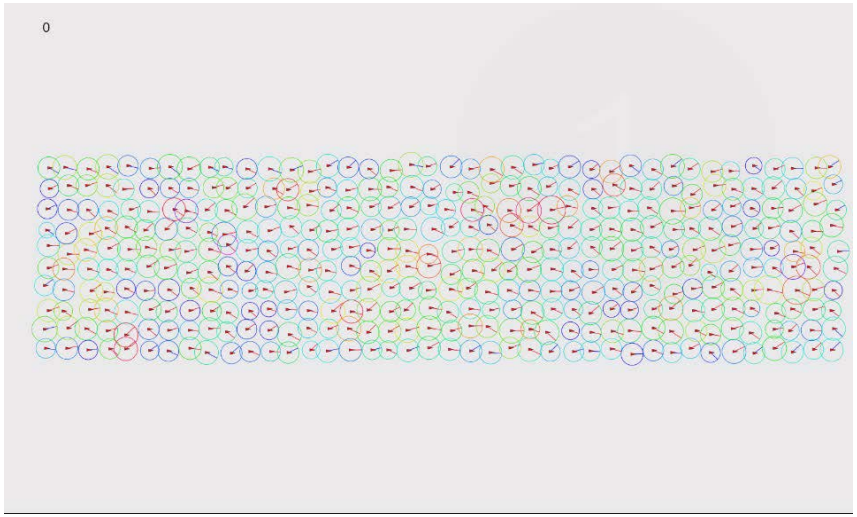
Order parameter:

$$\phi \equiv \frac{1}{N}\left|\sum_i \hat{\psi}_i\right|$$

RvD et al. PRE **91**, 032706/arXiv: 1411.4821

State diagram





× break up
○ rotation
\+ migration
□ jammed

φ=0.38 φ=0.59

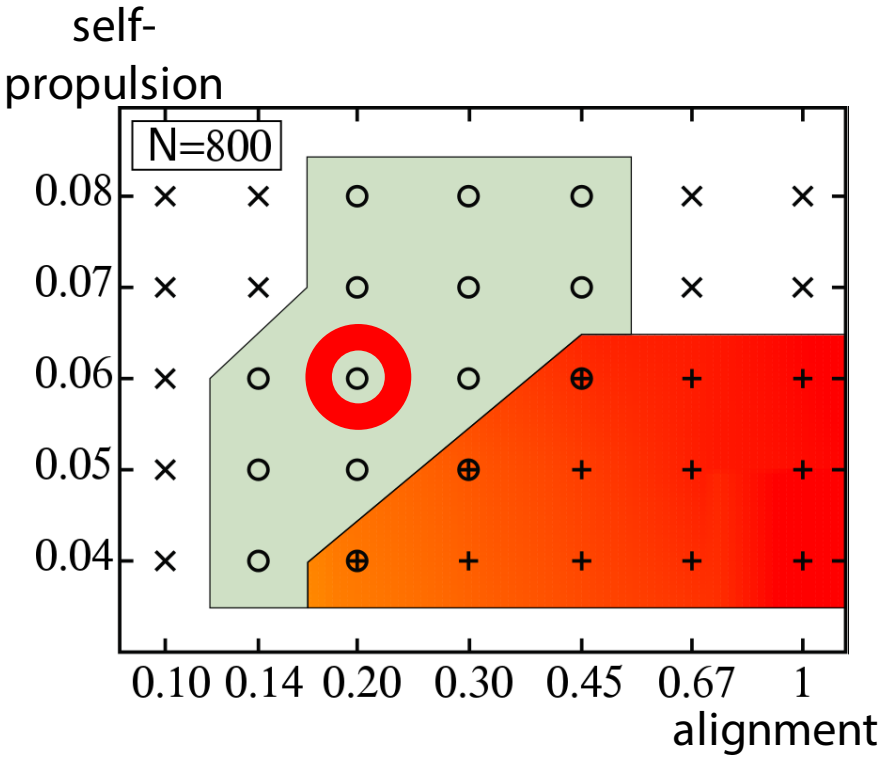
φ=0.0

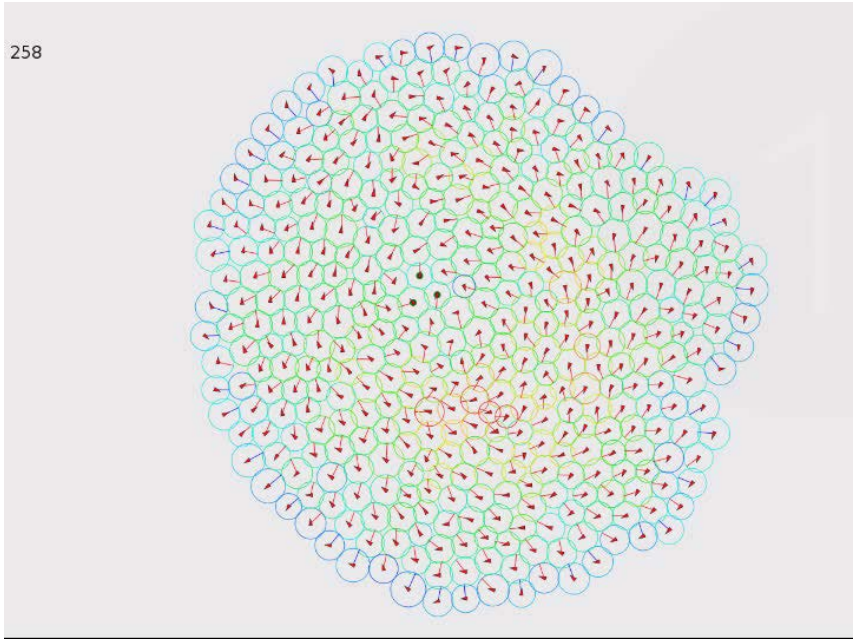
Order parameter:

$$\phi \equiv \frac{1}{N}\left|\sum_i \hat{\psi}_i\right|$$

RvD et al. PRE **91**, 032706/arXiv: 1411.4821

State diagram





× break up
○ rotation
\+ migration
□ jammed

φ=0.49 φ=0.61

φ=0.0

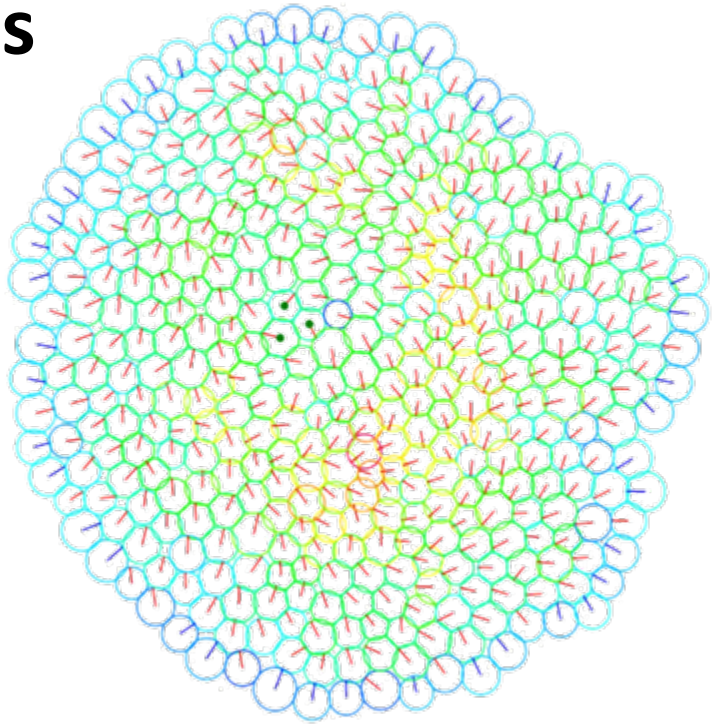
Order parameter:

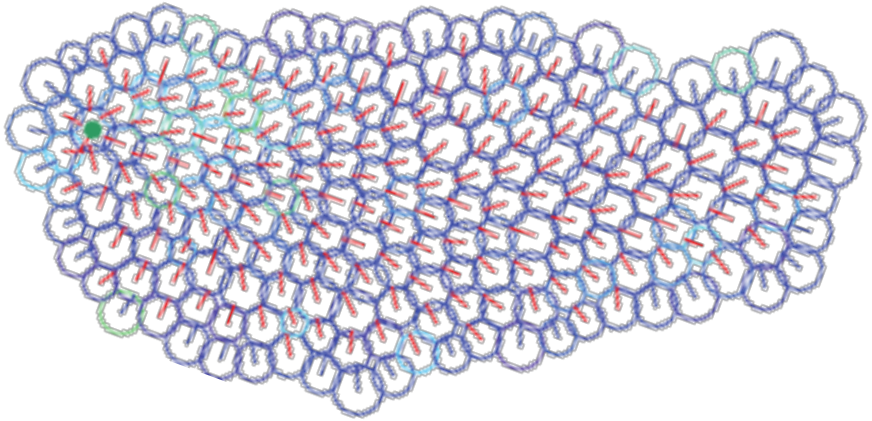
$$\phi \equiv \frac{1}{N}\left|\sum_i \hat{\psi}_i\right|$$

RvD et al. PRE **91**, 032706/arXiv: 1411.4821

Moving without a leader

- **Collective global dynamics** from **local** interactions:
  - Migration
  - Rotation
  - ‘Run-and-tumble’





RvD et al. PRE **91**, 032706/arXiv: 1411.4821

Social / geometric alignment

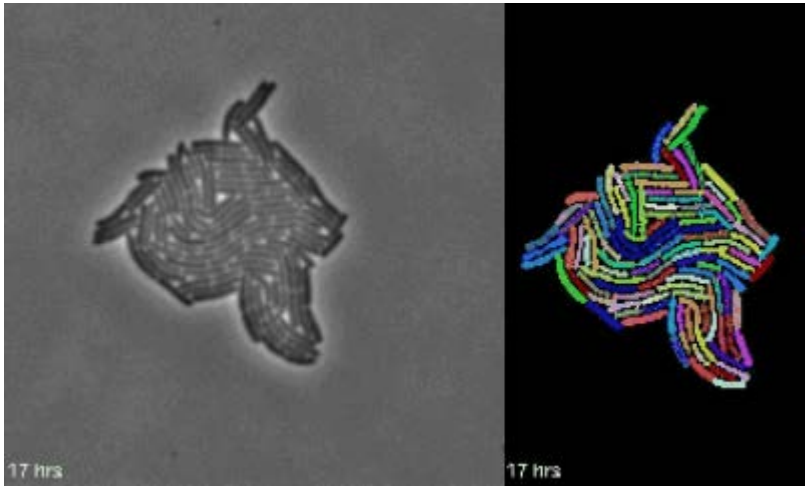
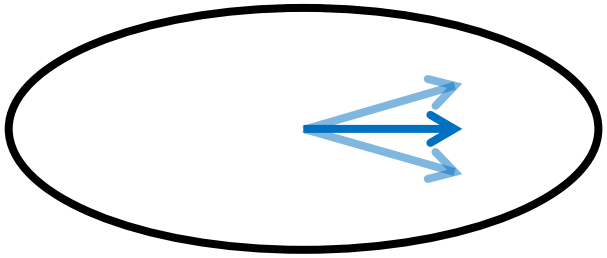


Image from TansLab (AMOLF)

How can cells align without eyes?

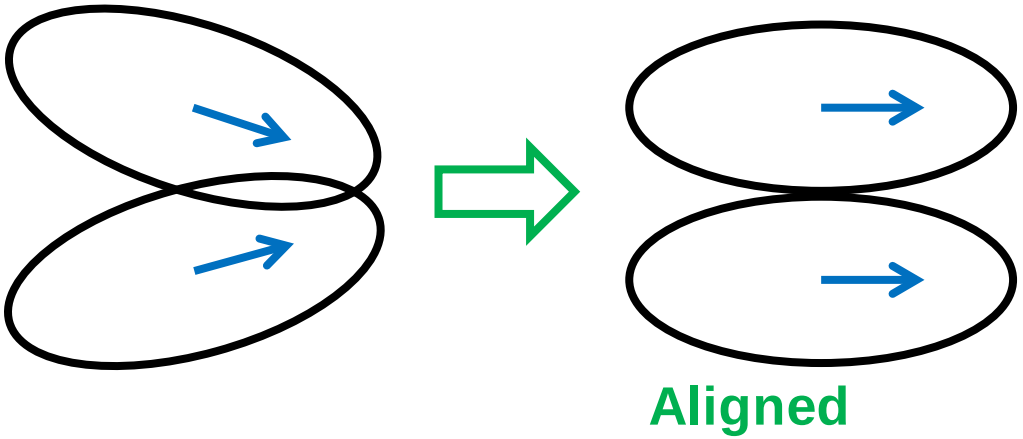
Anisotropic interaction rules

- Forces
  - Self-propulsion
  - Repulsive when overlapping
- Torques
  - Noise
  - Steric repulsion

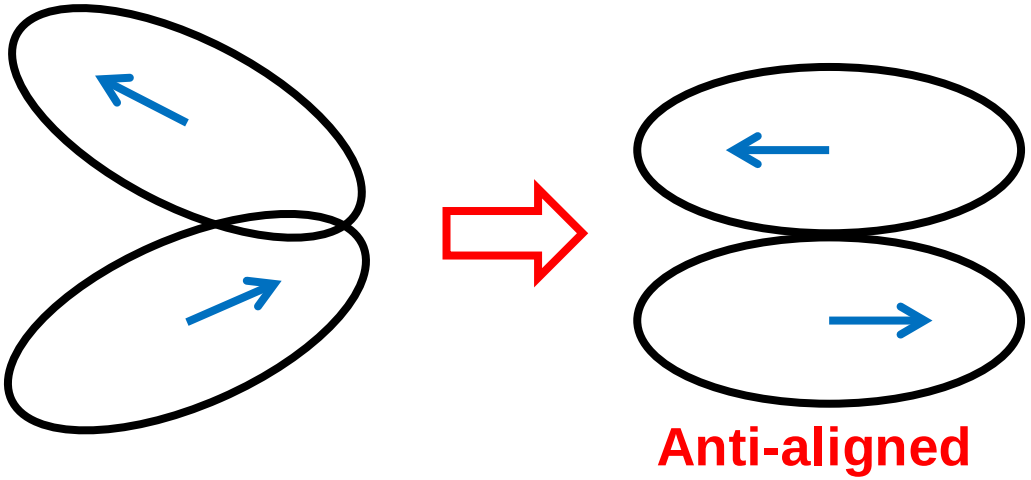


Anisotropic interaction rules

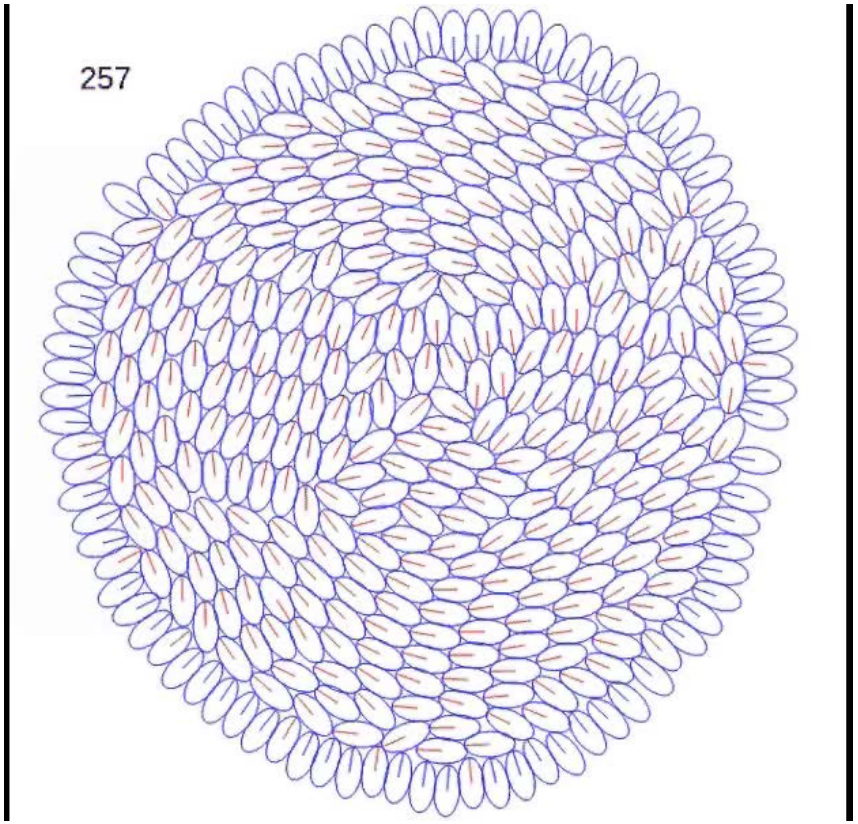
- Forces
  - Self-propulsion
  - Repulsive when overlapping

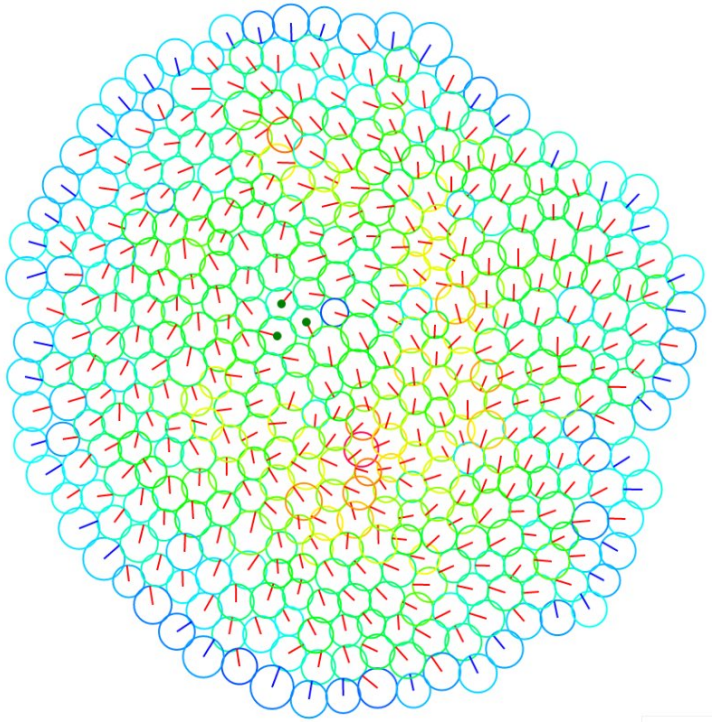


- Torques
  - Noise
  - Steric repulsion



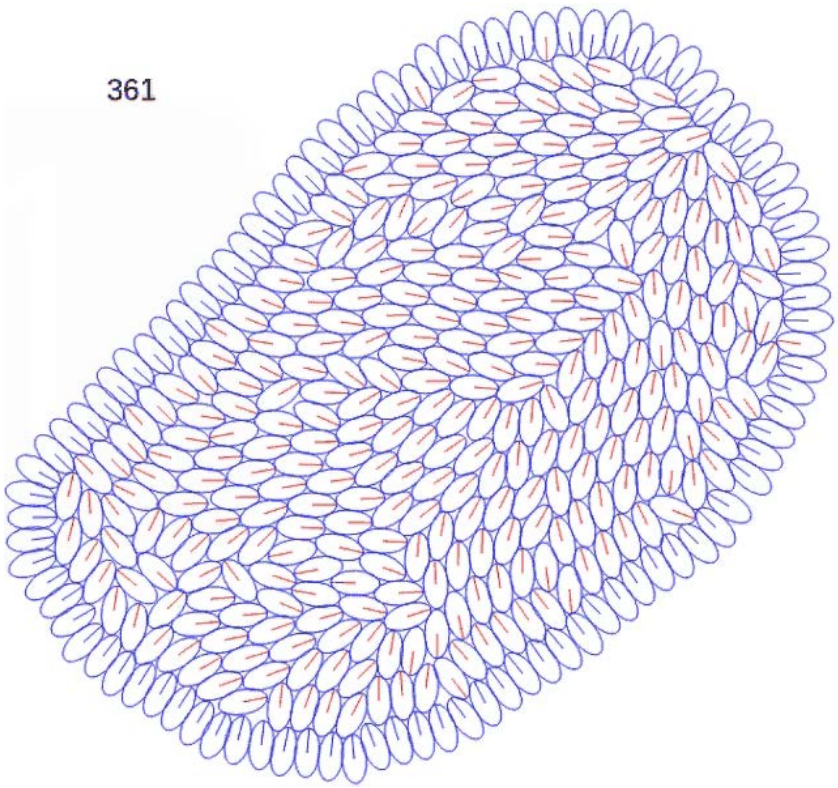
Rotating state?



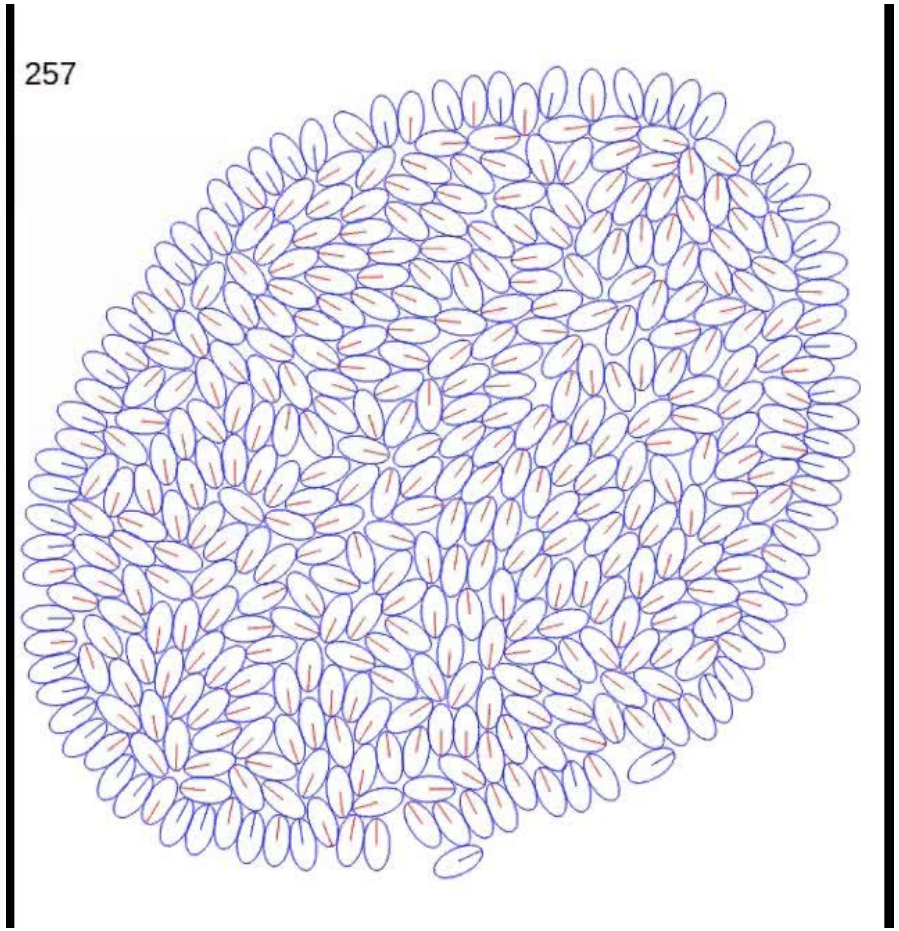


But, unstable

States of eliptical particles

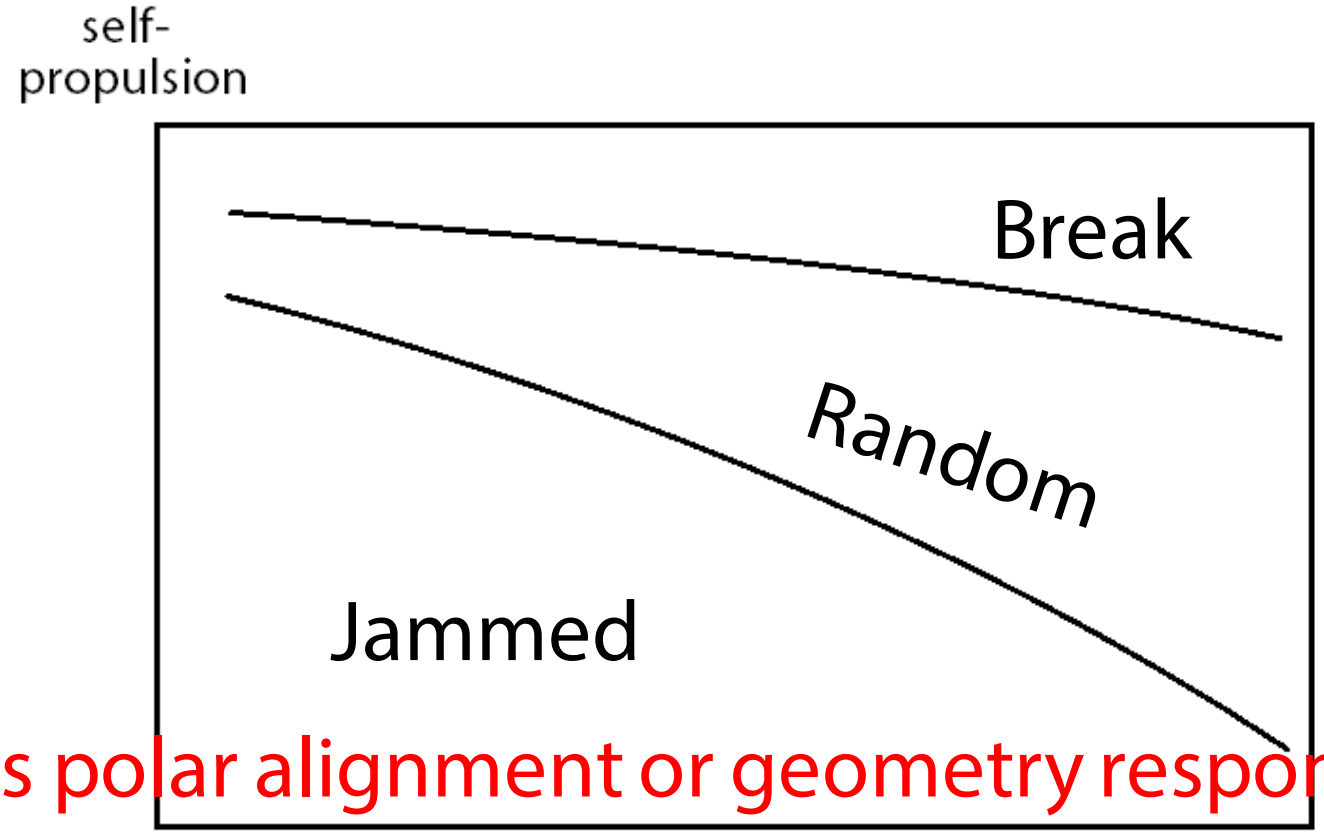


Jammed “Slug”



Random

Preliminary state diagram



Is polar alignment or geometry responsible for collective dynamics?

Thanks

- Timon Idema (Delft)
- Carl Goodrich (UPenn)
- Anshuman Pal (UPenn)

- Brian Tighe (Delft)
- Doris Heinrich (Leiden)
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- Shashi Thutupalli (Princeton)