Phase (like) Transitions in Active Driven Systems.
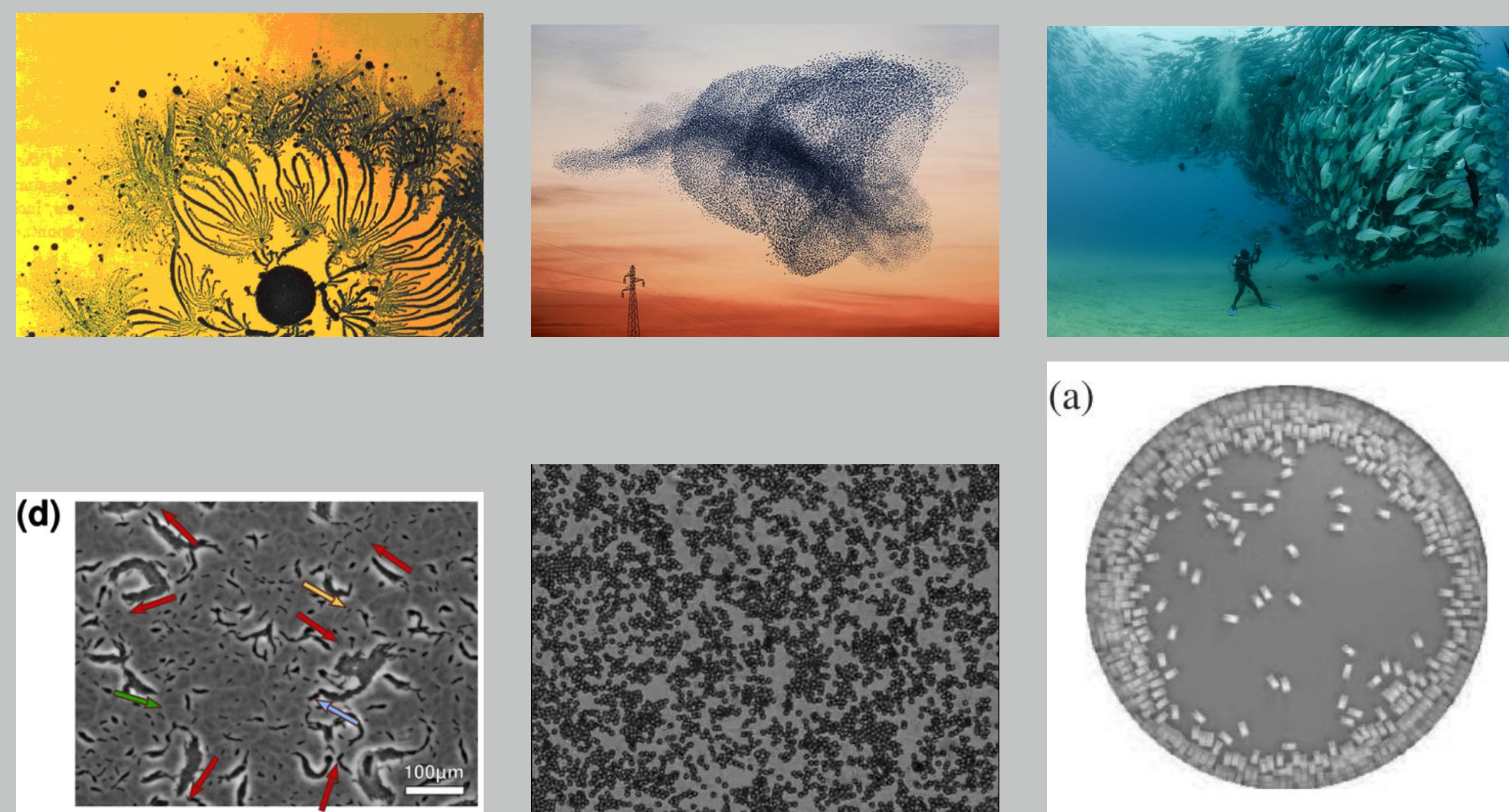
Quantitative Life Sciences Group

The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy

Example of Active Driven Systems.

- ▶ Living Systems
  - ▷ Flock of Birds
  - ▷ School of Fish
  - ▷ Bacterial Colonies
- ▶ Non-Living systems
  - ▷ Janus Particles
  - ▷ Rods on a vibrating table.

Features of Active Driven Systems

- ▶ Collective behavior
  - ▷ Forging.
  - ▷ Self-defense.
  - ▷ Social behavior.
- ▶ Far from Equilibrium.
  - ▷ No momentum conservation.
  - ▷ Self-Propelled
- ▶ Spontaneous symmetry breaking

Study of Active Driven Systems

- ▶ Mean field approximations.
- ▶ Hydrodynamic description.
- ▶ Simulation study.

Vicsek Model

- ▶ 'N' particles are placed randomly and uniformly in a box of $L \times L$.
- ▶ All the particles initially have random velocity.
- ▶ All the particles move with a constant speed v_0
- ▶ Neighborhood of interaction is a circle centered on the particle.
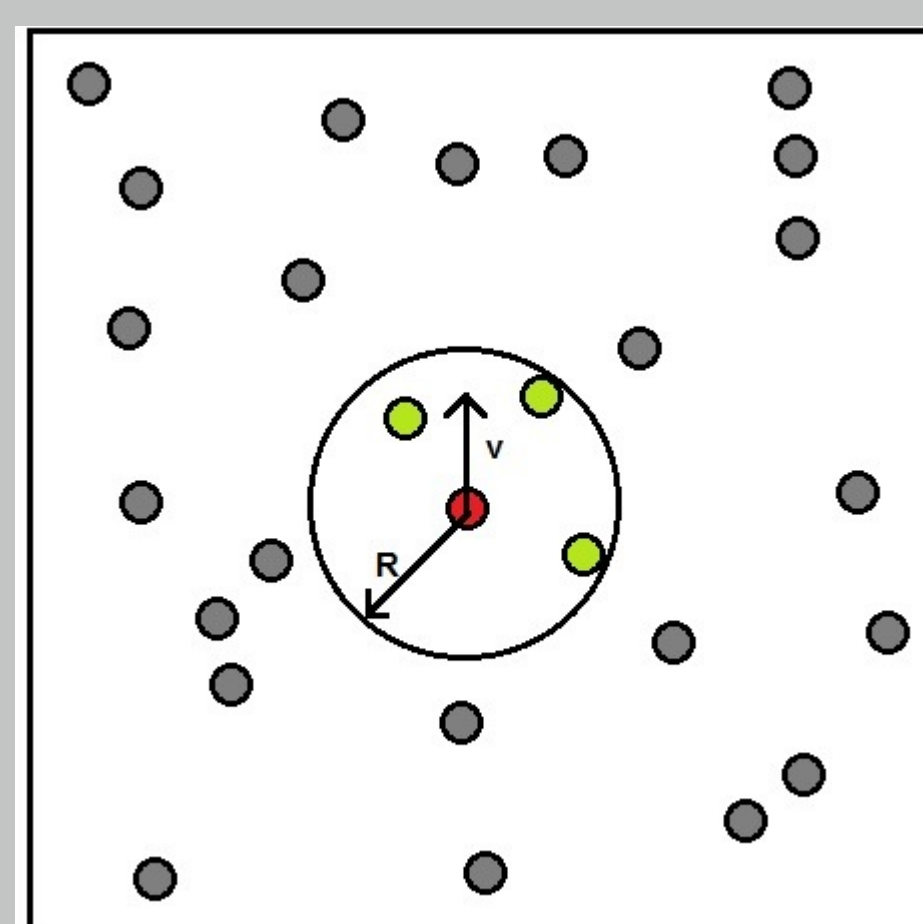
- ▶ After every time interval all the particles adjust their direction to the average velocity of the particles in their neighborhood of interaction.
- ▶ This adjustment is imperfect due to presence of noise.

Features of Vicsek Model

- ▶ System undergoes second order phase transition with the noise.
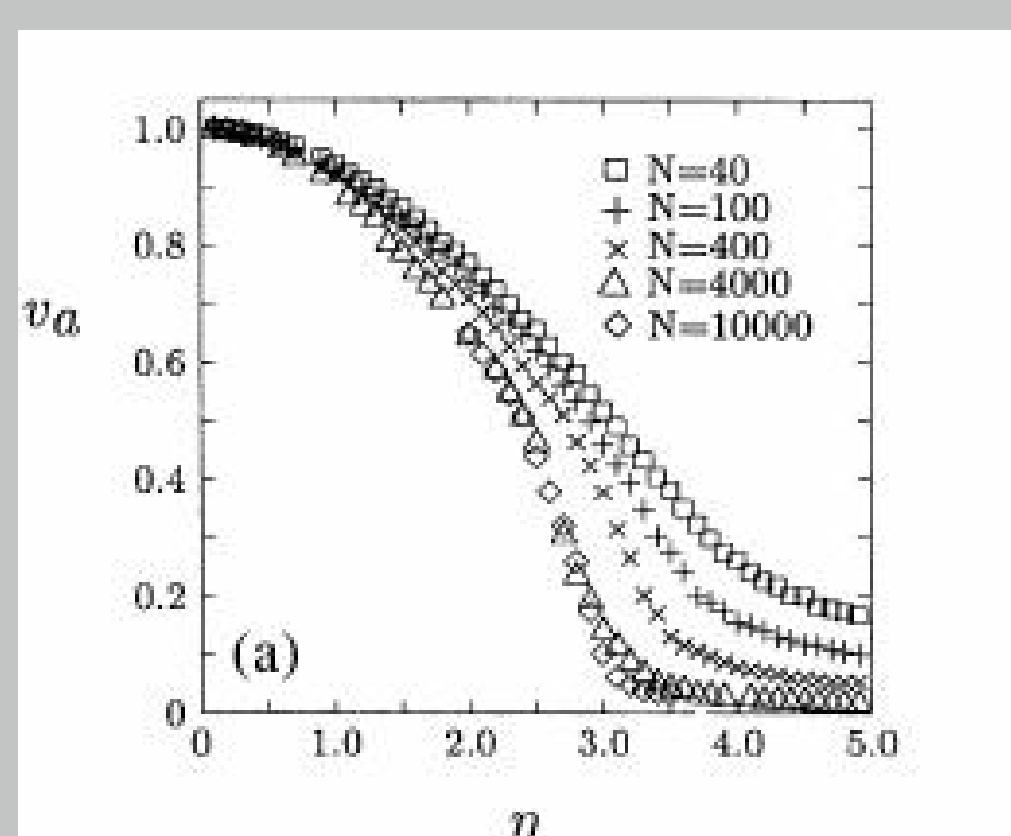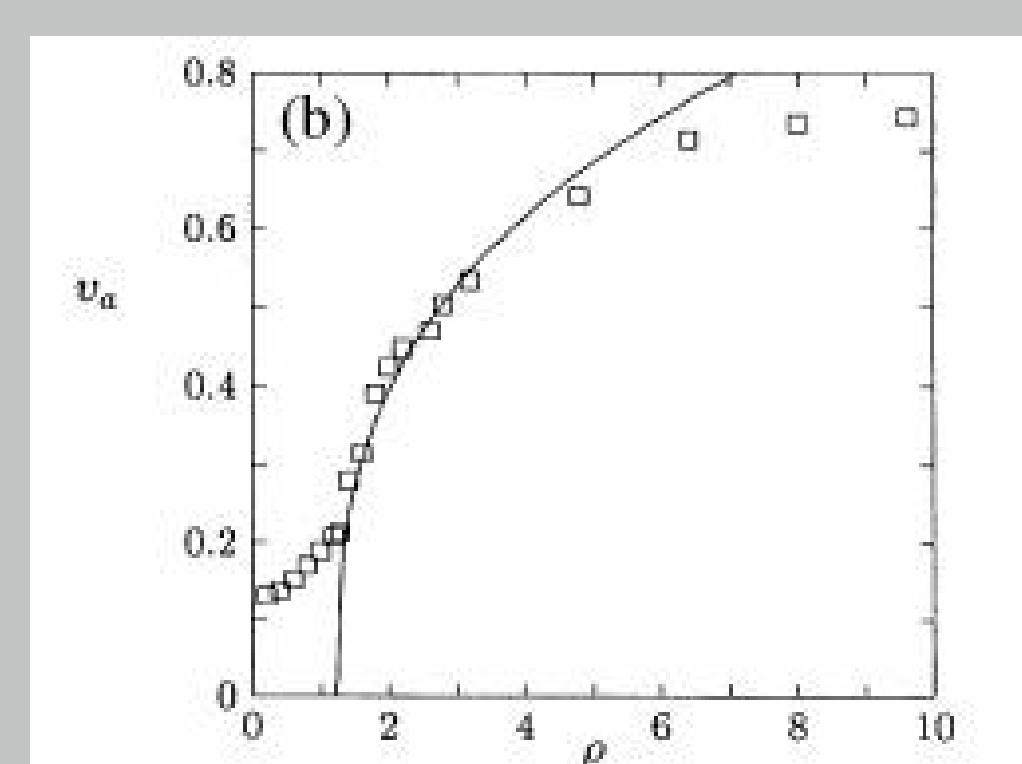- ▶ Second order phase transition with density.

Figure : v_a Vs η

Figure : v_a Vs ρ

Modification to Vicsek Model

- ▶ Usually agents in biological systems do not have full $360°$ view. For example;
  - ▷ Cyclopean View of grey-headed Albatross $\approx 270°$ in horizontal plane.
  - ▷ Cyclopean View of humans is $180°$ in horizontal plane.
  - ▷ Cyclopean View of Dasyatis sabina fish is $\approx 327°$ in horizontal plane.

Modification to the Vicsek Algorithm.

- ▶ Interaction neighborhood is a sector of a circle of radius R enclosing an angle (2ϕ). We call angle ϕ as 'view-angle'
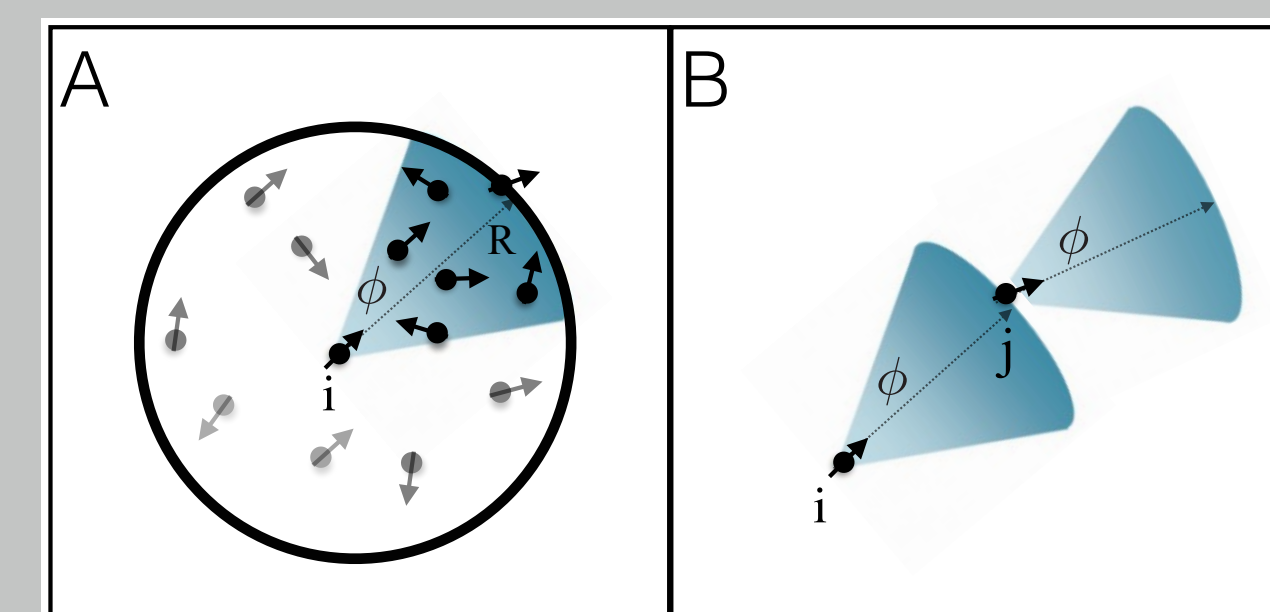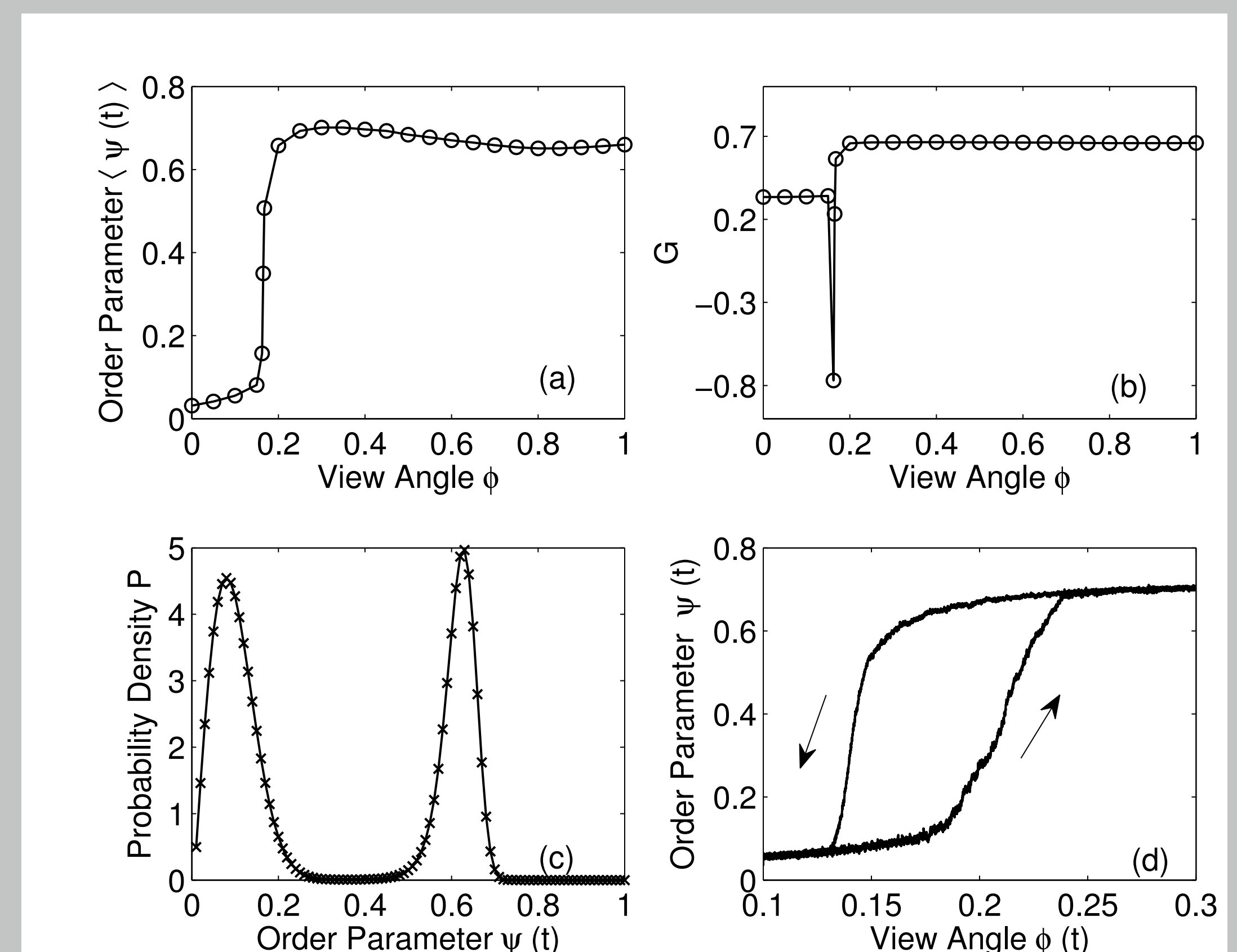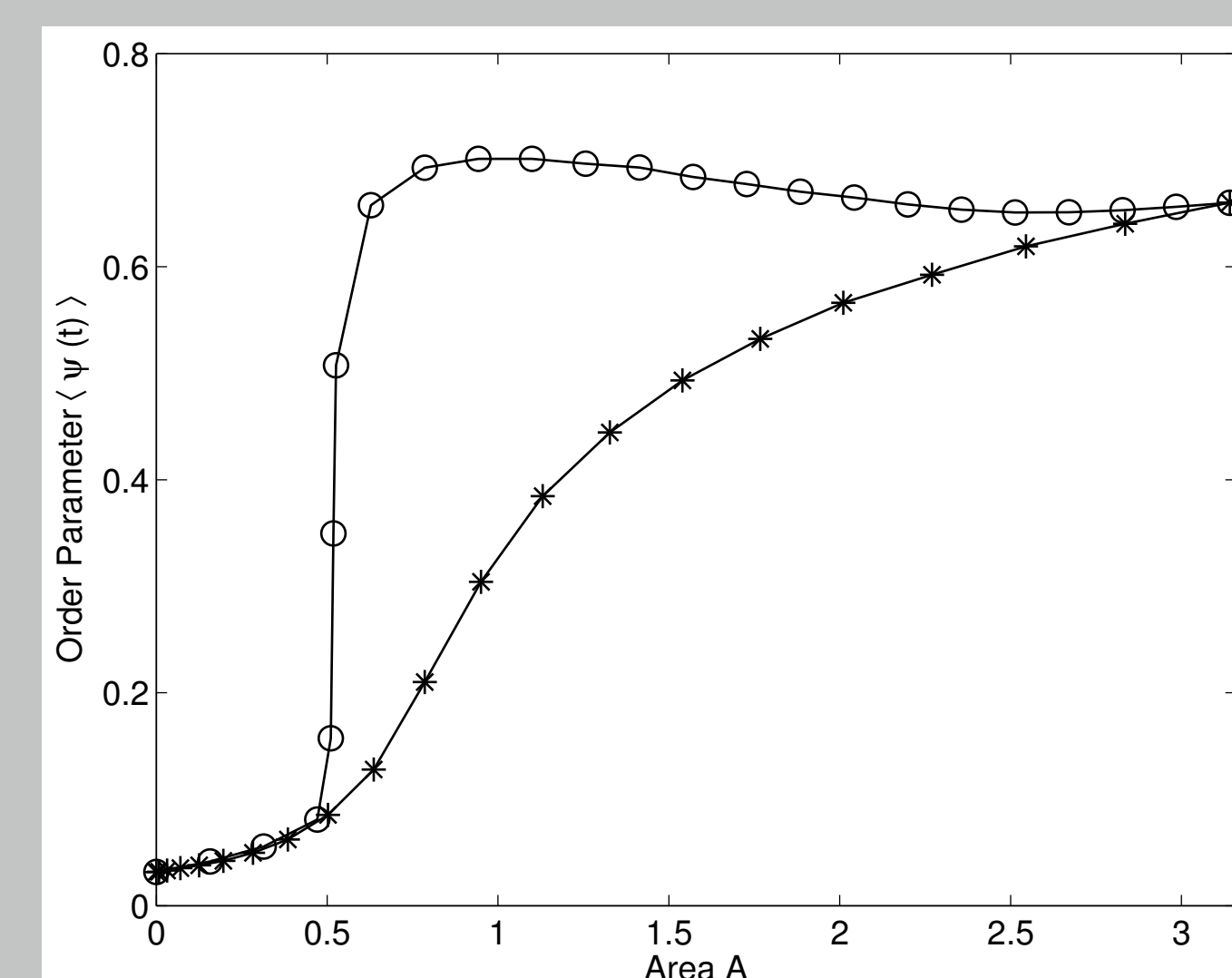
Figure : The neighborhood S_i of the red particle.

Results

Role of anisotropy

Conclusions

- ▶ We find that, for this modified model and for the given parameter set, system undergoes a phase transition as the view-angle(ϕ) is varied and we establish that its of first syorder.
- ▶ As we reduce the view-angle(ϕ), order parameter(ψ) varies non-monotonically and it can have highest value for $\phi < 2\pi$.
- ▶ We find that ordered motion, even in the presence of the noise (i.e. $\eta > 0$), can persists down to remarkably small view-angle, up to ($\phi \approx 0.2\pi$).
- ▶ The exists directional anisotropy in the modified model and that plays a role in determining the nature of the phase transition.

References

- ▶ T. Vicsek et al. Phys. Rev. Lett. 75, 1226 (1995).
- ▶ T. Vicsek and A. Zafeiris, Phys. Rep. 517, 71 (2012)
- ▶ M. Durve and A. Sayeed Phys Rev E 93, 052115 (2016)