Hardcore run and tumble particles with time-periodic drive

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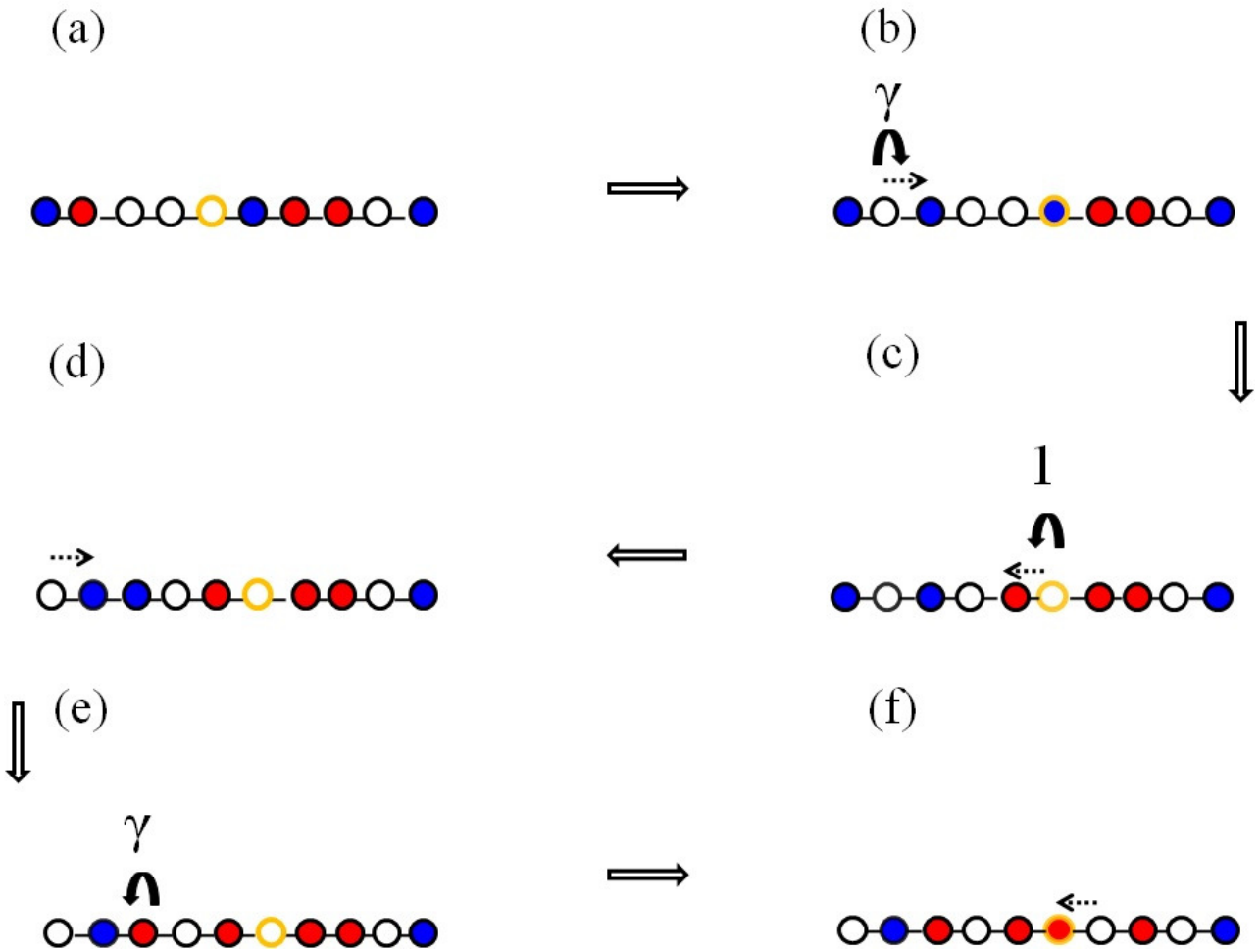
April 23, 2025

Introduction

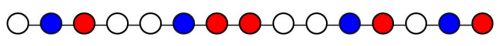
- Interaction among active particles can give rise to collective phenomena
- What happens when a set of interacting run-and-tumble particles is subjected to external potential?
- Hardcore exclusion simplest form of interaction
- Active motion of hard-core particles on a $1d$ lattice with tumbling probability $\gamma \ll 1$
- External potential modeled as a 'defect site' where tumbling probability is high
- Defect site moves through the ring lattice with speed $u > 0$

Persistent Exclusion Process with Defect

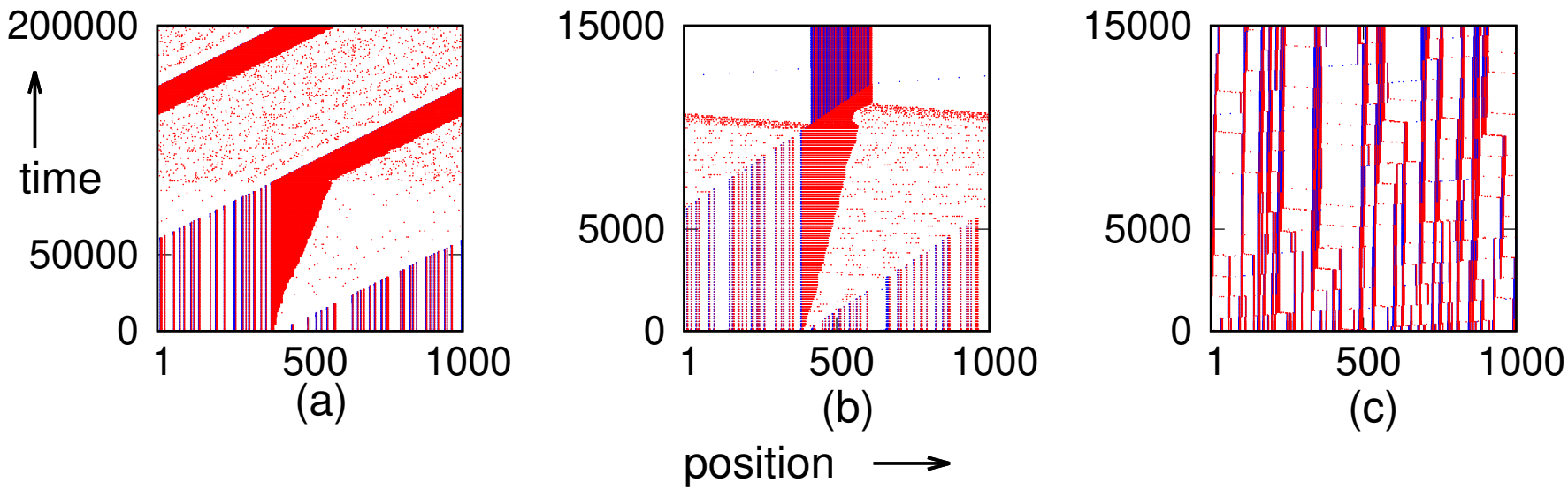
- Soto, Golestanian, PRE (2014); Dandekar, Chakraborti, Rajesh, PRE (2020)



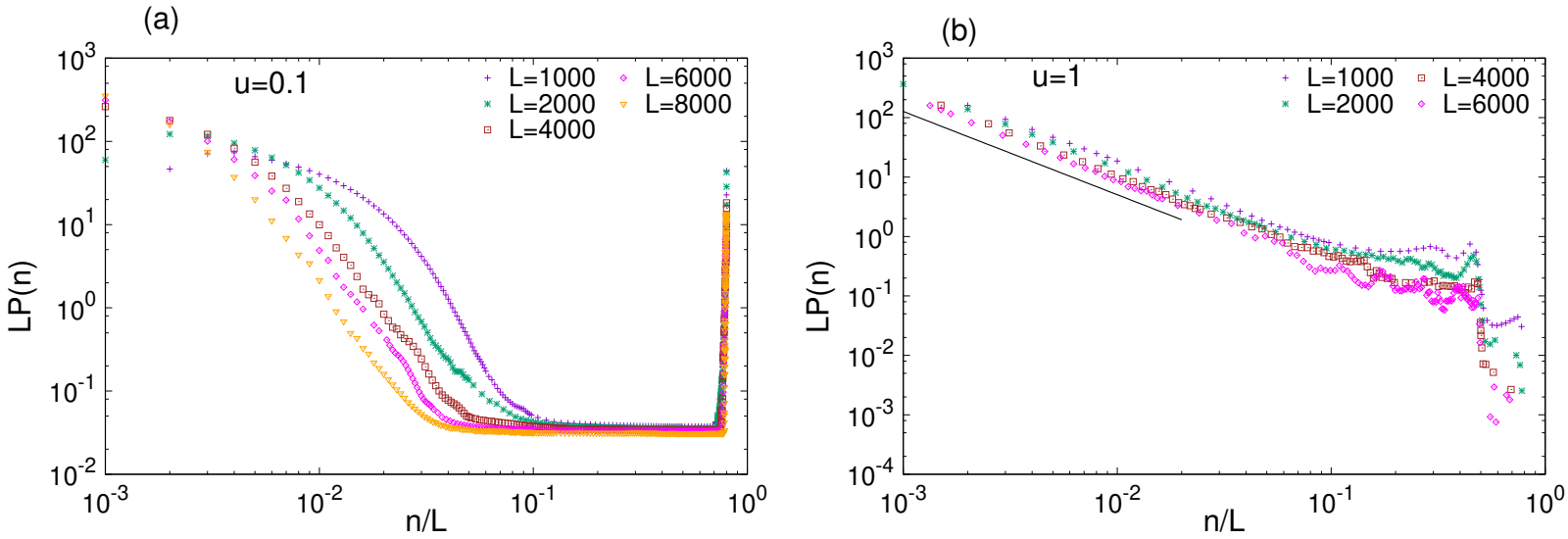
No tumbling in the bulk: $\gamma = 0$

- Jammed state without defect 
- A right-mover switches to a left-mover and moves behind the defect
- A left-mover switches to a right-mover and moves ahead of the defect and gets stuck again
- The defect then catches up with it, turns it to a left-mover which finally moves behind the defect
- The moving defect thus creates a trail of left-movers behind it
- When the leftmost particle gets stuck, all others pile up behind it
- A large particle cluster is formed

Defect velocity $u = 0.01, 0.1, 1$



Cluster size distributions

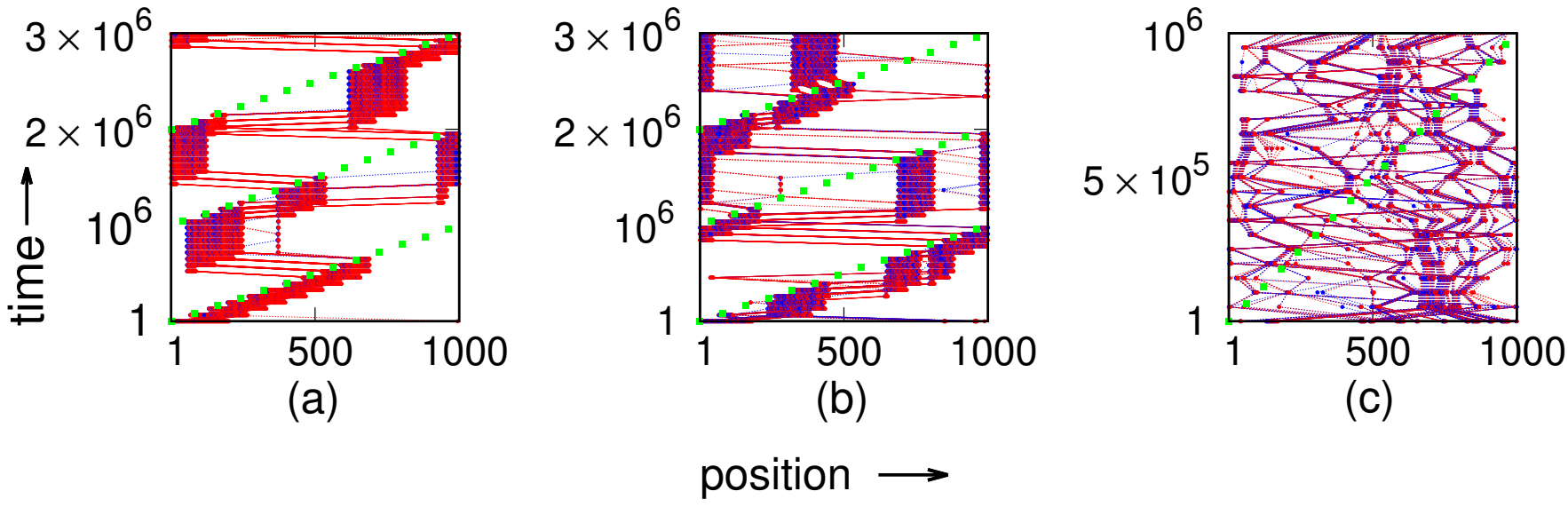


- For large u probability to find a single large cluster is significantly less
- When the defect moves fast it is possible that a right-mover stays behind
- Imperfect velocity alignment makes complete phase separation difficult

Non-zero bulk tumbling rate

- Large persistence time helps the defect restore long-range order
- Non-zero γ allows the particles to switch their velocities independently
- Long range velocity order created by the moving defect is thus disrupted
- For $\gamma \lesssim u/L$ small number of tumbles take place during one sweep of the defect
- Loss of order at the bulk happens slowly such that there is enough time for the moving defect to fix it
- As γ increases further, ordering is gradually lost

$\gamma = u/L, 10u/L, 1000u/L$



- $u = 0.001$

Possible experimental verification

- E.coli bacteria show run-tumble motion
- Narrow microfluidic channel of width $\sim$ mean run length
- Certain mutant strains were isolated whose tumbling ability was impaired
- Defect can be a hard wall which reflects the cells back
- Defect movement can be mimicked by removing the partition at the end of its residence time and immediately reinserting it at a small distance away
- A narrow microfluidic channel in the shape of a ring, with removable partitions and motile E.coli bacteria inside it
- Possible generalization to other active matter systems
- Ref: Phys Rev E 111, 034122 (2025)