Collective Motion of Humans in Mosh and Circle Pits at Heavy Metal Concerts[1]

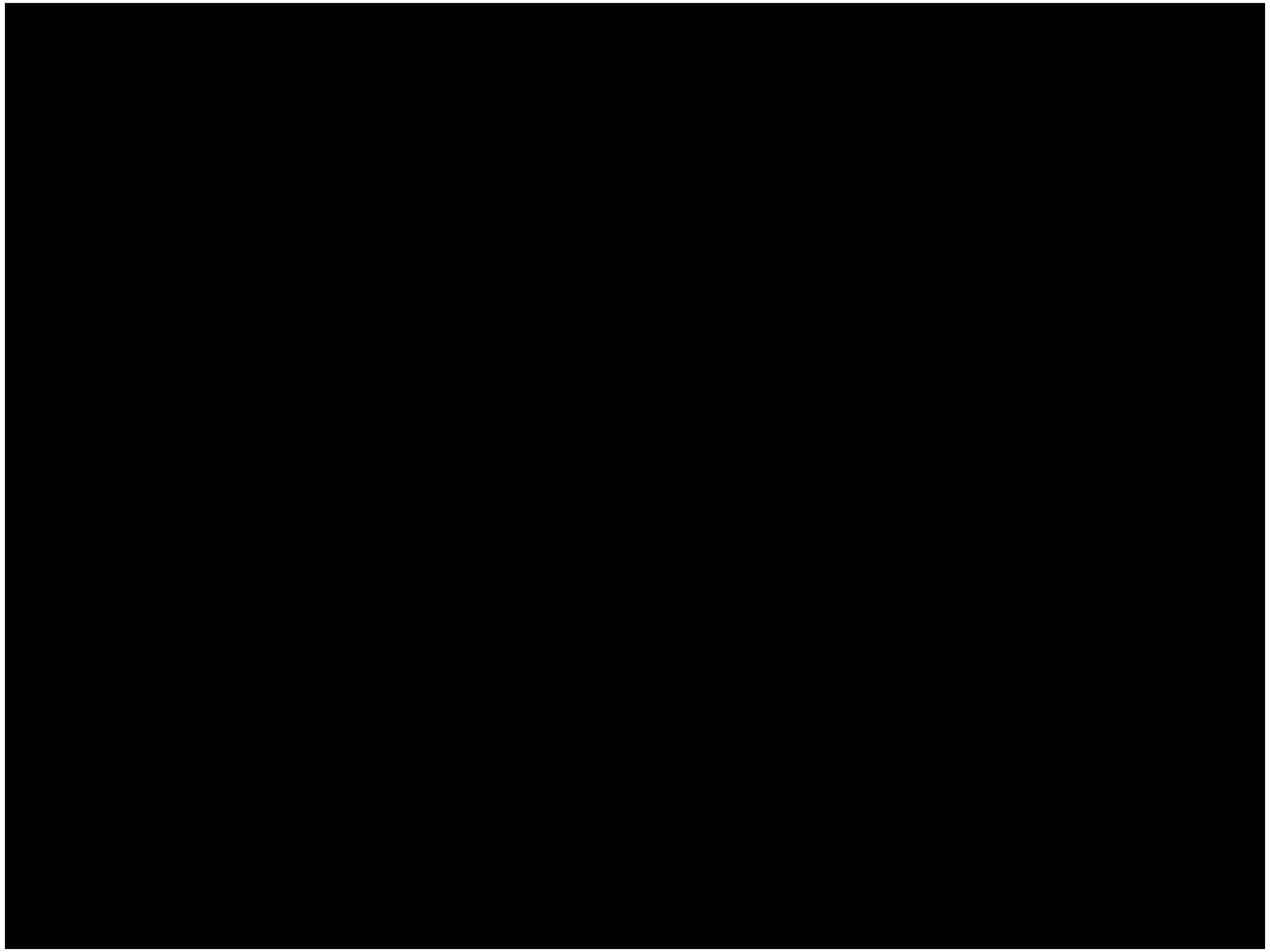
Silverberg, J. L., Bierbaum, M., Sethna, J. P., & Cohen, I. (2013). Collective motion of humans in mosh and circle pits at heavy metal concerts. Physical Review Letters, 110(22) doi:10.1103/PhysRevLett.110.228701.

Modeling Human Collective Behaviors

- Studying emergent behaviors in crowds not regulated by social norms
  - High-volume pedestrian traffic
  - Panicked escapes from crowded environment

- Better understanding can lead to better social engineering

What exactly is a mosh pit?



Modeling a Mosh Pit

- Analyzed six YouTube videos of sufficient video quality
- Conducted a particle image velocimetry (PIV) analysis
- Matched data to models of interacting gaseous particles
- Conducted simulations to explore parameter space

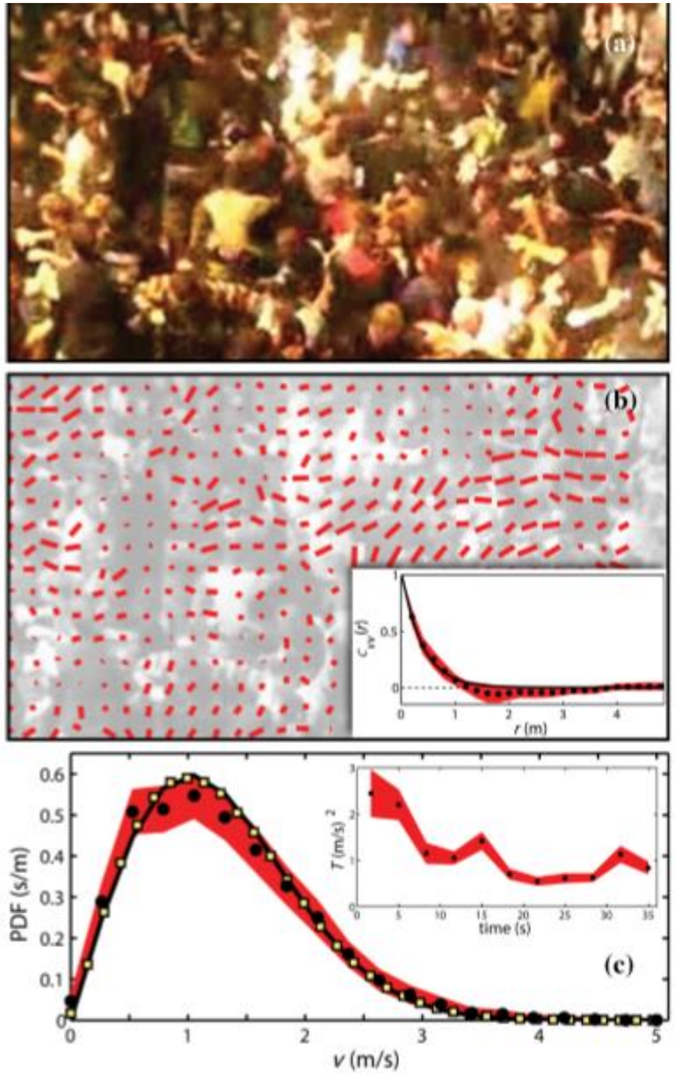


Illustration of PIV analysis

Mosh Pit Simulation

Forces considered include:

MASH: mobile active simulated humanoid

A repulsive force between MASHers:

$$\vec{F}_i^{\text{repulsion}} = \begin{cases} \epsilon\left(1 - \frac{r_{ij}}{2r_0}\right)^{3/2} \hat{r}_{ij} & r_{ij} < 2r_0 \\ 0 & \text{otherwise,} \end{cases}$$

A propulsion force that propels MASHers:

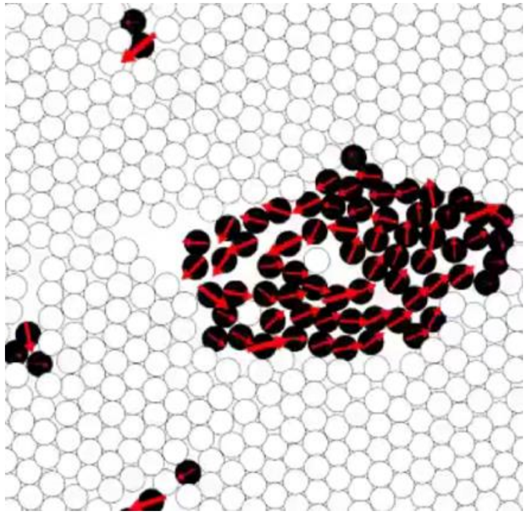
$$\vec{F}_i^{\text{propulsion}} = \mu(v_0 - v_i)\hat{v}_i,$$

A flocking term that causes MASHer clustering:

$$\vec{F}_i^{\text{flocking}} = \alpha \sum_{j=0}^{N_i} \vec{v}_j \Big/ \left| \sum_{j=1}^{N_i} \vec{v}_j \right|$$

A noise term:

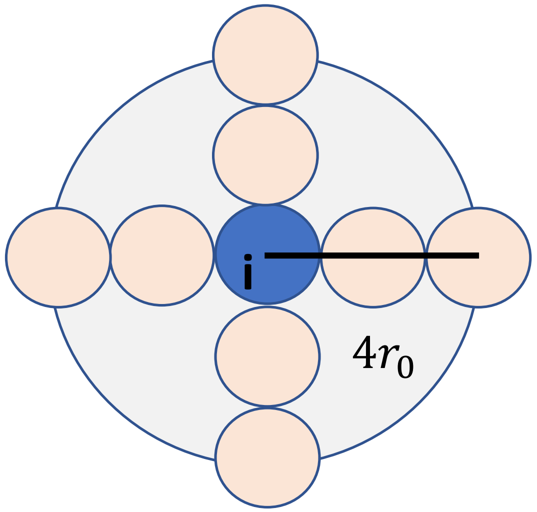
$$\vec{F}_i^{\text{noise}} = \vec{\eta}_i.$$



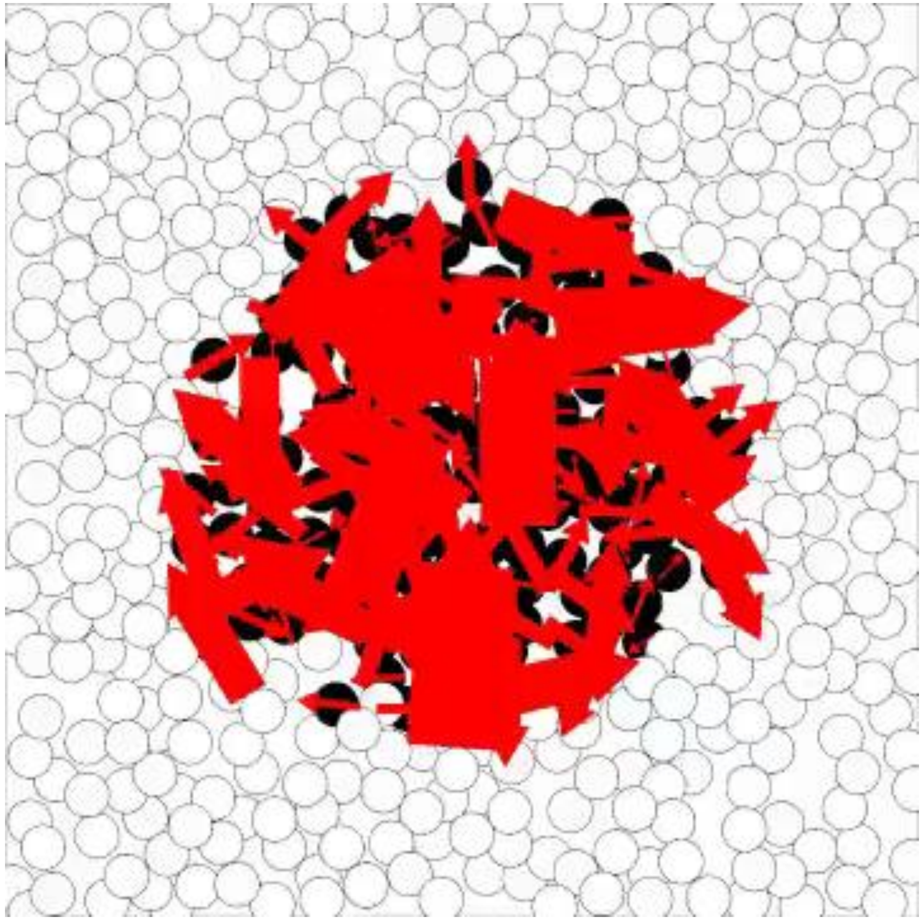
$$\vec{F}_i^{total} = \vec{F}_i^{repulsion} + \vec{F}_i^{propulsion} + \vec{F}_i^{flocking} + \vec{F}_i^{noise}$$

Simulation parameters for different MASHer types

- For **passive** MASHers
  - Prefer to be stationary ($v_0 = 0$); no coupling to neighbors ($\alpha = 0$) ; no randomness ($\overrightarrow{\eta_i} = 0$)
- For **active** MASHers
  - Prefer to be in constant motion ($v_0 = 1$); variable coupling to neighbors ($0 \leq \alpha \leq 1$); variable level of randomness ($0 \leq \sigma \leq 3$)
- For **all** MASHers
  - Repulsion force dominates during contact ($\varepsilon = 25$);
  - Flocking force calculated from MASHers within a circle of radius “two-MASHers” ($r_{flock} = 4r_0$)

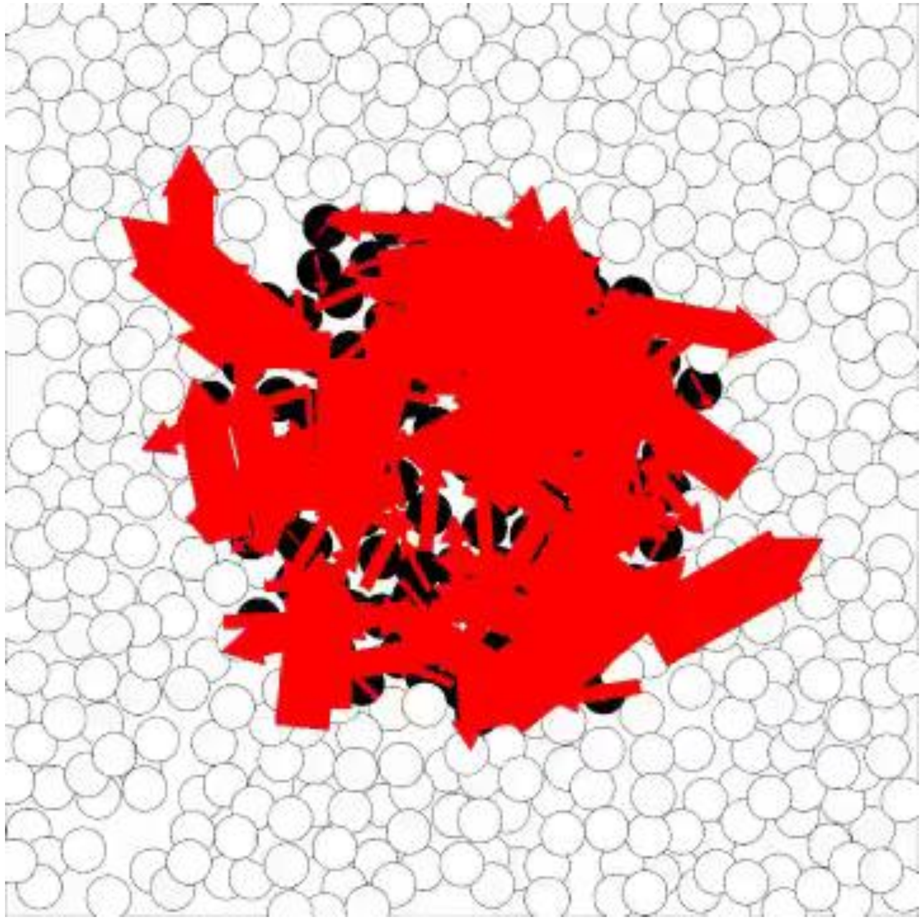


Emergent behavior #1: Mosh pit



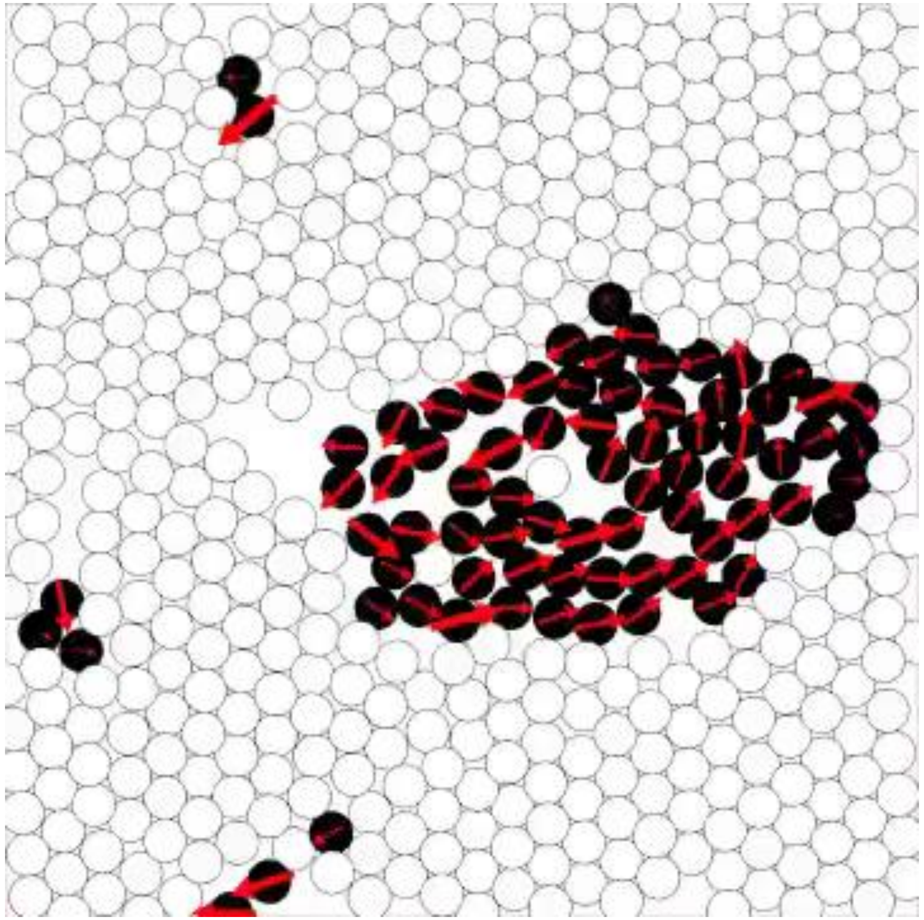
Mosh pit – localized random motion resembling an ideal gas (low coupling, high randomness)

Emergent behavior #2: Circle pit



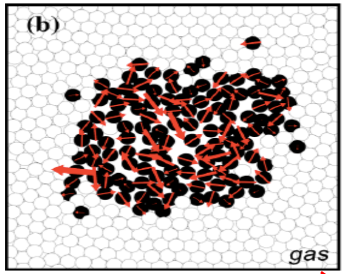
Circle pit – localized organized motion with circular geometry (moderate coupling, moderate randomness)

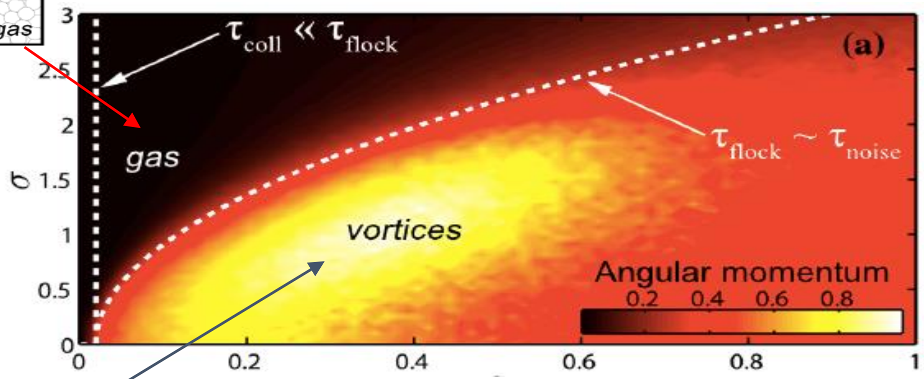
Emergent behavior #3: Lanes

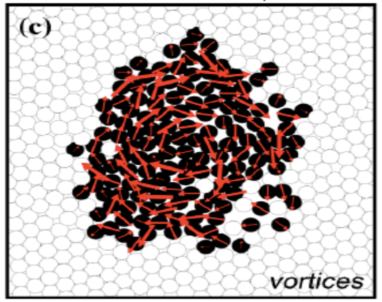


Lanes – localized organized motion with linear predominance (strong coupling, low randomness)

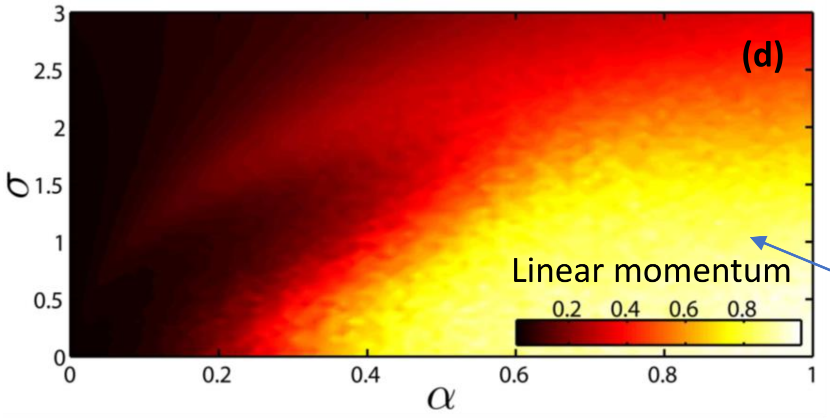
Emergent behavior changes with flocking force and randomness

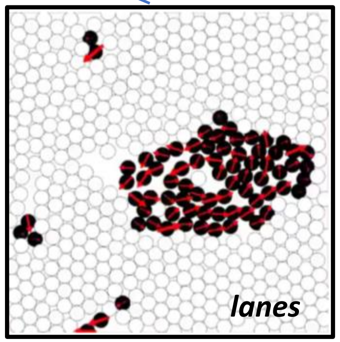






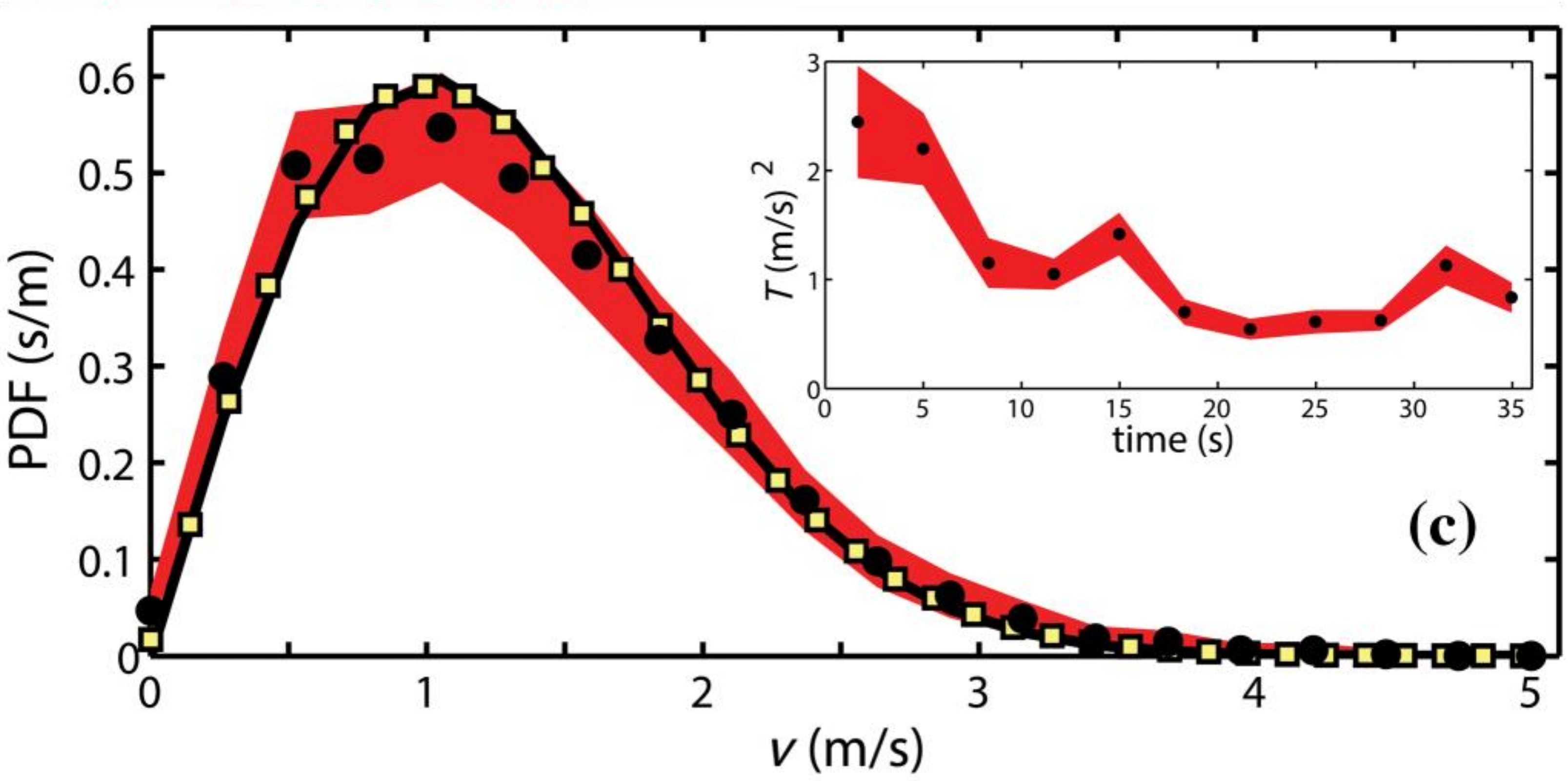
The RMS angular momentum of active MASHers illustrating gas-like behavior and vortex formation.





RMS of active MASHer linear momentum illustrating a region of lane formation at high flocking and low noise.

Mosh pits behave like an ideal gas



Inset shows that mosh pits “cool down" with time.

- Measured speed PDF from a video (**solid black circles**)
- Best fit to a 2D Maxwell-Boltzmann distribution (**black line**),
- Speed distribution from simulations (**yellow squares**).

Comparison with Previous Studies

Compare Flow Behavior

Previous Model: Pedestrian flow is usually well approximated by a laminar flow.
(L. F. Henderson, Nature (London) 229, 381 (1971).)

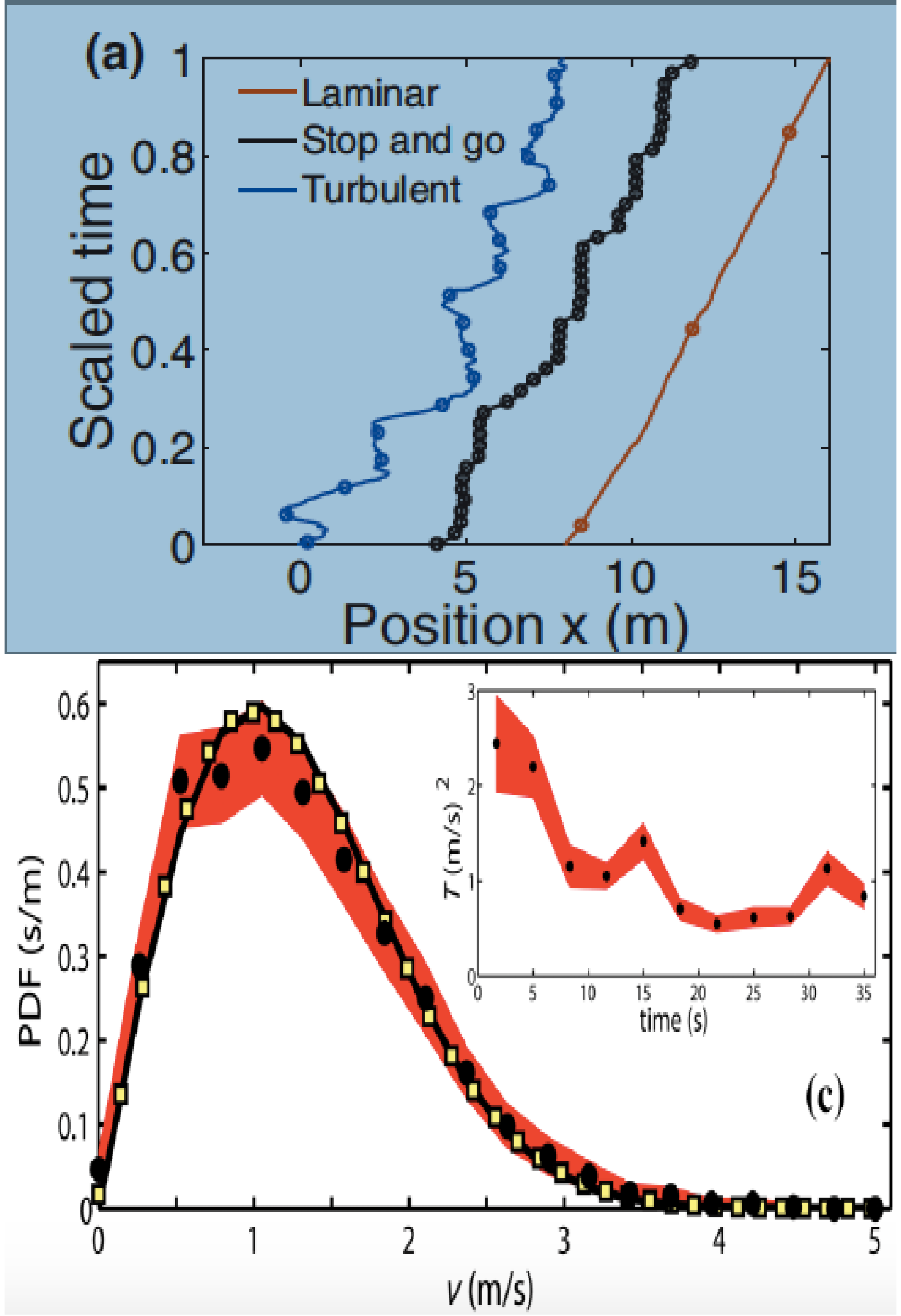
Current Model: Studies a more general crowd; therefore expect more complex behavior.

Different Velocity Distribution

Previous Studies: Studies on panic stampede shows that, under high density, human flow exhibits phase transition from laminar flow, to stop-go flow,to turbulent flow.

(D. Helbing, A. Johansson, and H. Z. Al-Abideen, Phys. Rev. E 75, 046109 (2007))

Current Study: In a rock concert the human flow cannot be approximated by a laminar flow, yet it obeys Maxwell velocity distribution.



Emergent Vortex Phenomenon

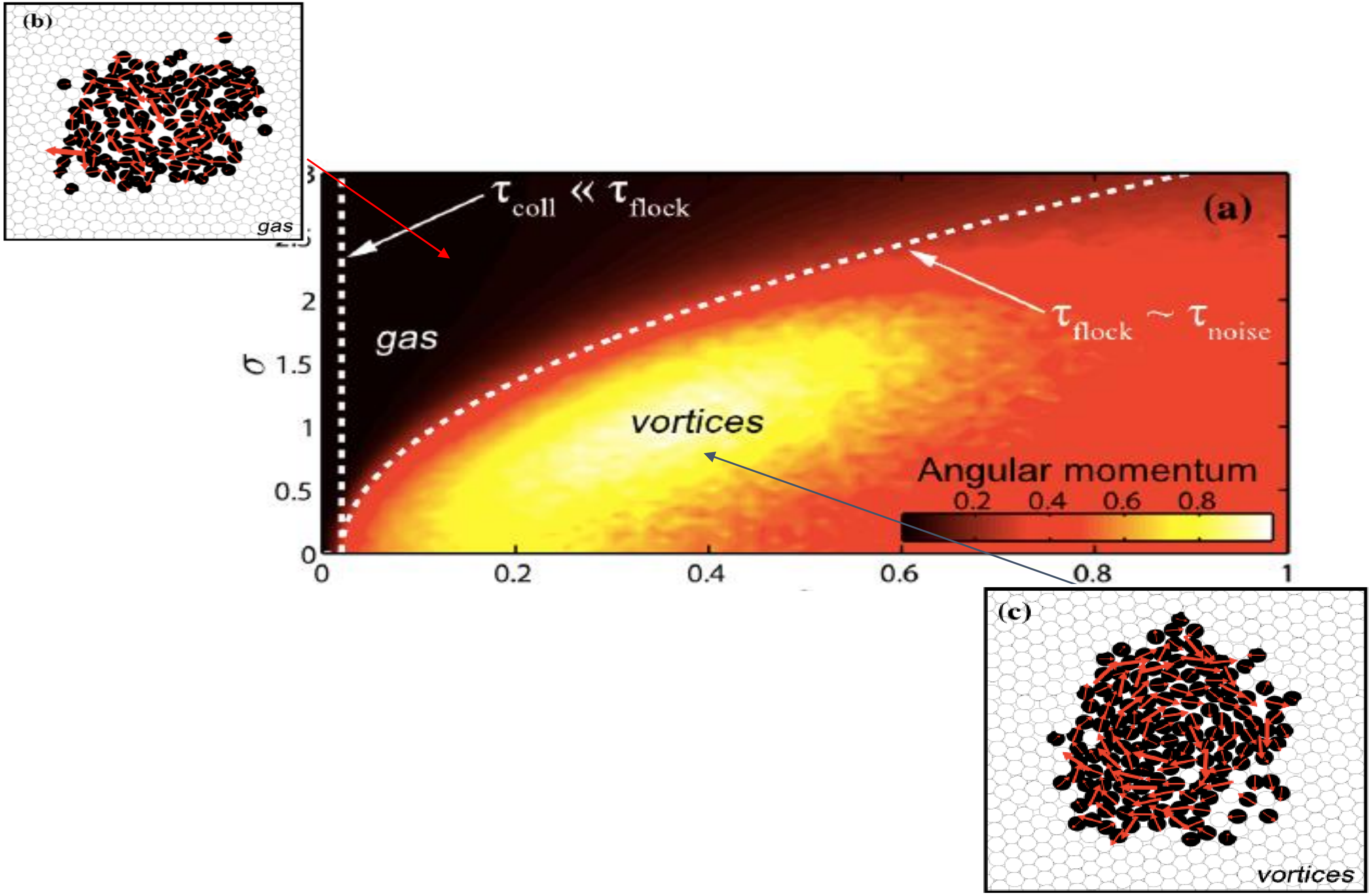
Previous Studies: Under low noise level, vortex formation has been observed in a number of previous studies under different conditions.

(S. Bazazi, K. S. Pfennig, N. O. Handegard, and I. D. Couzin, Behav. Ecol. Sociobiol. 66, 879 (2012).)

(J. Toner, Y. Tu, and S. Ramaswamy, Ann. Phys. (Amsterdam) 318, 170 (2005).)

Current Study: There exists a phase where vortices exist. However, there is a phase transition from gaseous phase to vortex phase, which has not been observed before.

A Distinct Phase Transition



Conclusions

- Repulsion + propulsion + flocking + noise $\Rightarrow$ Different Patterns

- Random forces dominates $(\tau_{flock} \gg \tau_{noise} \,\&\, \tau_{coll})$ $\Rightarrow$ gas like

  Flocking term dominates $(\tau_{flock} \ll \tau_{noise} \,\&\, \tau_{coll})$ $\Rightarrow$ vortex like

  $(\tau_{flock} \lll \tau_{noise} \,\&\, \tau_{coll}) \Rightarrow$ lane like

- Understand collective motion (protest, panicked crowds etc.)

  Architectural safety design

  Crowd management strategies

Critiques

agreed by authors

- 50%CW in simulation, 5% CW in observation
- Not based on staged experiments
- Limited access to effective videos
- Some further variations not described well (ninja pits, push pits etc.)

Citation Report

- 40 citations (SCOPUS, November 28 2017)

- Highlights include:
  - Developing model to explain different observed group behavior in fish[2]
  - Modeling “active matter” via inspiration from human flocking behavior[3]
  - Simulating interaction between social robot and pedestrian crowd[4]
  - Modeling crowd behavior with simple power law based on an “interaction energy” determined by time to collision[5]
  - Describing the motions of self-propelled “partially catalytic spherical colloids”[6]

References

1. Silverberg, J. L., Bierbaum, M., Sethna, J. P., & Cohen, I. (2013). Collective motion of humans in mosh and circle pits at heavy metal concerts. Physical Review Letters, 110(22) doi:10.1103/PhysRevLett.110.228701.
2. Demšar, J., & Bajec, I. L. (2017). Evolution of collective behaviour in an artificial world using linguistic fuzzy rule-based systems. PLoS ONE, 12(1) doi:10.1371/journal.pone.0168876
3. Bottinelli, A., Sumpter, D. T. J., & Silverberg, J. L. (2016). Emergent structural mechanisms for high-density collective motion inspired by human crowds. Physical Review Letters, 117(22) doi:10.1103/PhysRevLett.117.228301
4. Butail, S. (2015). Simulating the effect of a social robot on moving pedestrian crowds. Paper presented at the IEEE International Conference on Intelligent Robots and Systems, , 2015-December 2413-2418. doi:10.1109/IROS.2015.7353704
5. Karamouzas, I., Skinner, B., & Guy, S. J. (2014). Universal power law governing pedestrian interactions. Physical Review Letters, 113(23) doi:10.1103/PhysRevLett.113.238701
6. De Graaf, J., Rempfer, G., & Holm, C. (2015). Diffusiophoretic self-propulsion for partially catalytic spherical colloids. IEEE Transactions on Nanobioscience, 14(3), 272-288. doi:10.1109/TNB.2015.2403255