Traffic and Granular Flow '15

October 28th, 2015

Statistical Structures of Low Density Pedestrian Dynamics

Alessandro Corbetta

Eindhoven University of Technology, NL

with:

Chung-Min Lee (CSULB), Roberto Benzi (Rome 2),

Adrian Muntean (TU/e), Federico Toschi (TU/e)

TU/e Technische Universiteit Eindhoven University of Technology

Where innovation starts

CASA Centre for Analysis, Scientific computing and Applications

Introduction & Motivation

- Walking pedestrians: *rich & complex dynamics*
  - Reliable models: relevant in science & technology

- Stochastic, nearly unpredictable motion
  - *Quantitative*-(statistical) *assessment of fluctuations?*
    - Measurements?
    - Rare behaviors?
    - Modeling?

Introduction & Motivation

- This presentation:
  - "low density" pedestrian dynamics in a corridor
    - Quantitative-(statistical) models?
- Content:

Introduction & Motivation

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- Content:

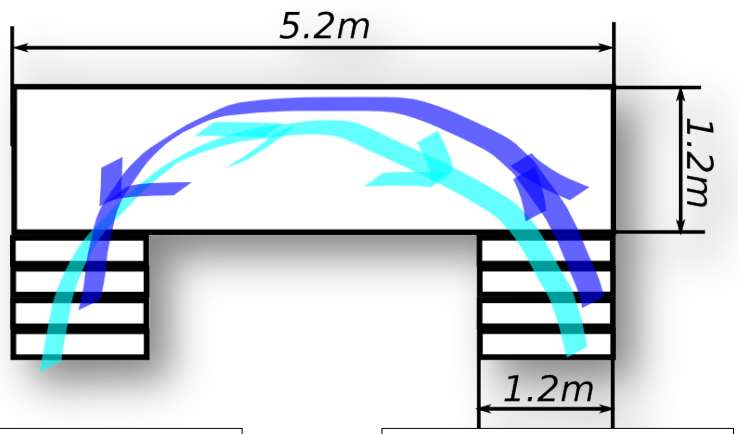
  1. High statistic resolution measurements
  2. Analysis of stochastic fluctuations

     Quantitative model up to rare events

High statistics measurements approach

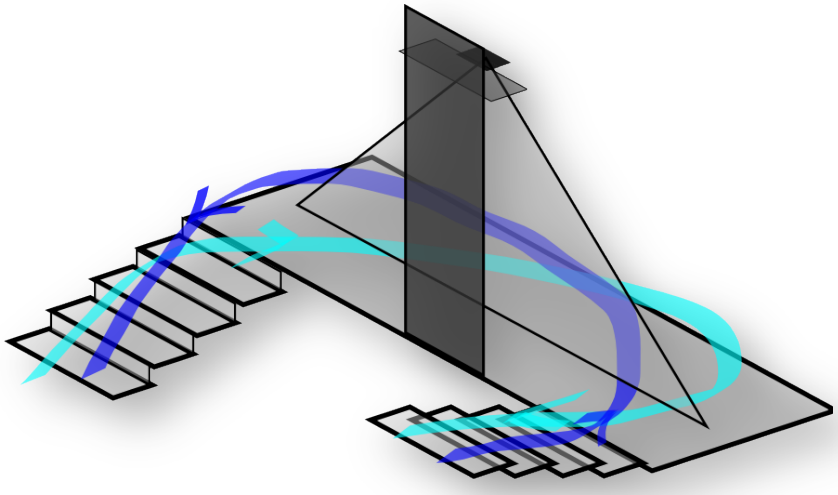
Metaforum building, TU/e

- Real-life setting
- 1y recording ~h24,
- ~2.2K people every weekday
- **~230K tracks** dataset



0th floor, *canteen*

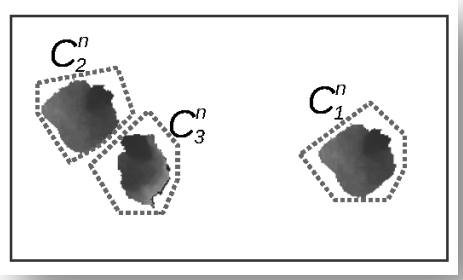
1st floor, *dining area*

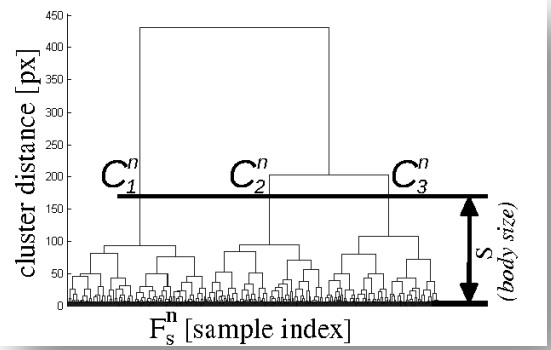


[Seer *et al.* 2014, Corbetta *et al.* 2014, Corbetta *et al.* 2015]

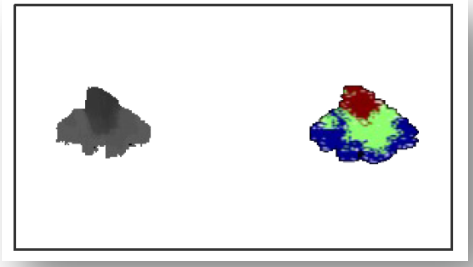
Pedestrian tracking technique

- **1. Heads detection**
  - Overhead, 3d view
    - Depthmap-based, Via Microsoft Kinect
    - (Complete) clustering of “depth-cloud”
    - 15Hz sampling





Clusterization tree cut at “body scale”



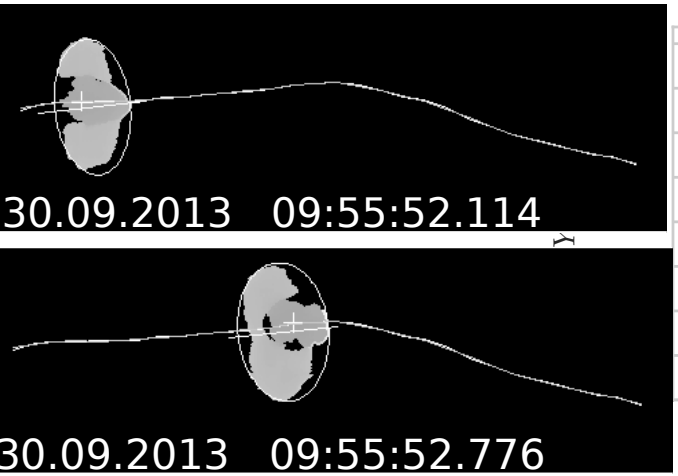
Heads marked as low depth (closest) percentiles

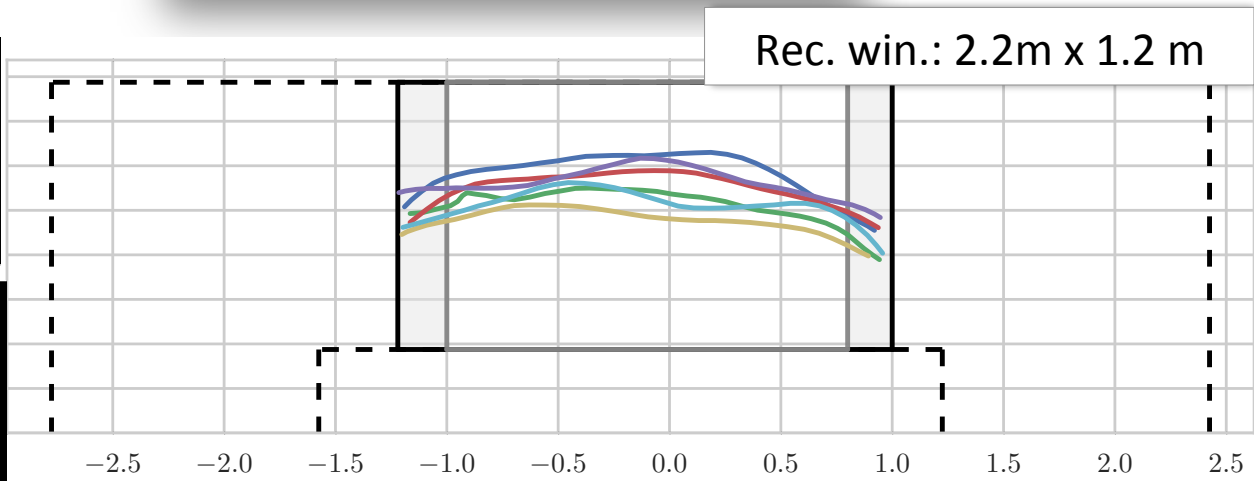
(Seer et Al., 2014)

Pedestrian tracking technique

- **2. Head tracking**
  - Head Spatio-Temporal matching via 3DPTV
    - from experimental fluid mechanics
      (Willneff et Al. 2002, Willneff 2003)
    - Nearest search with velocity prediction
  - Implementation:

OpenPTV
open source particle tracking velocimetry

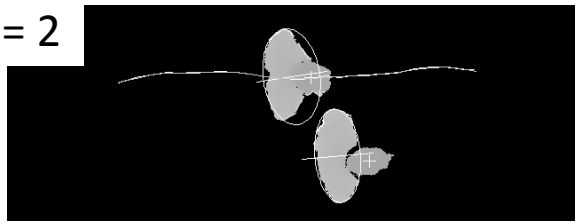




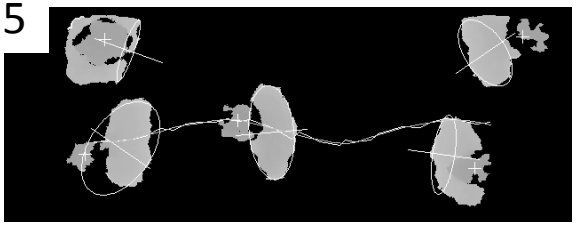
Acknowledgment: A. Liberzon (TAU)

Traffic - local occupancy

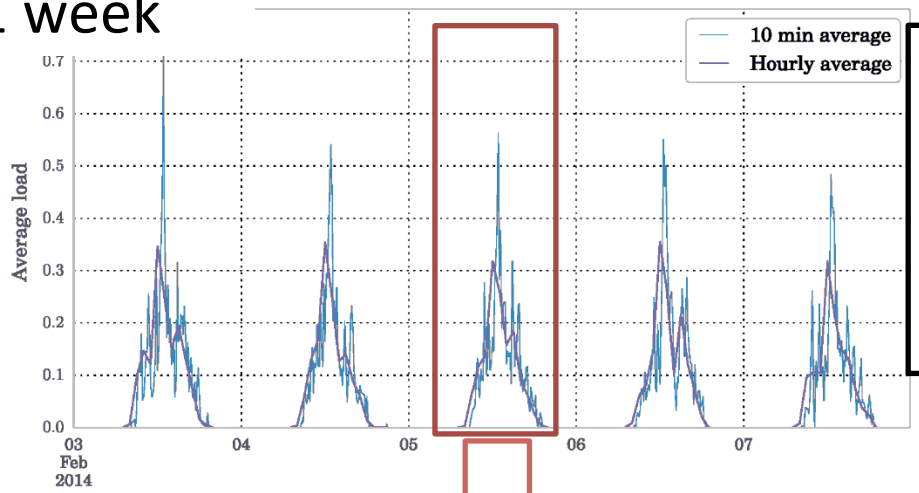
Occupancy = 2



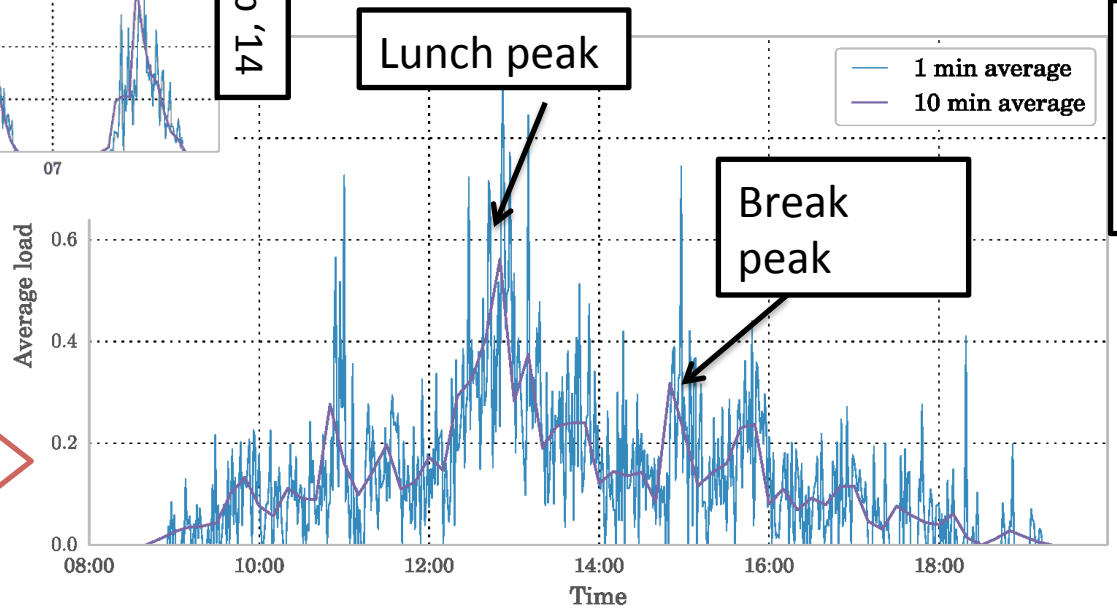
Occupancy = 5



1 week

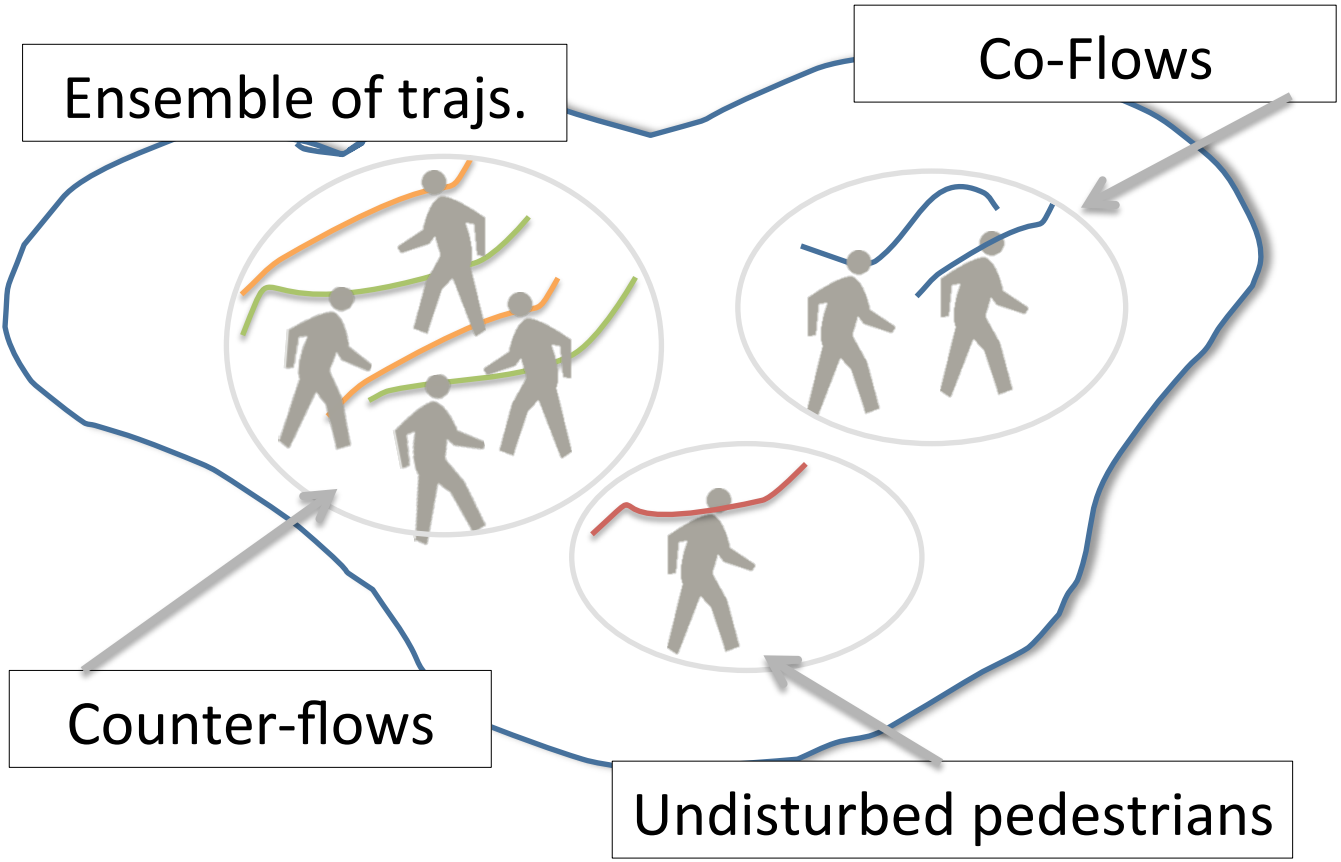


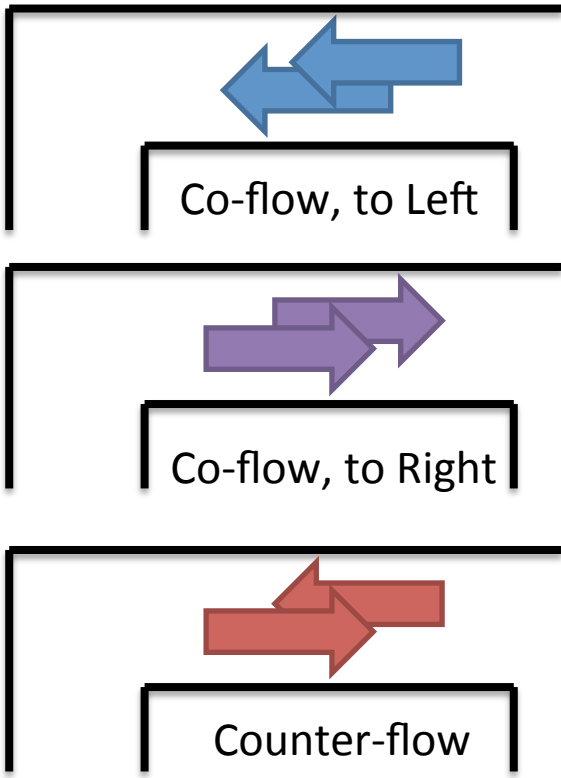
week 3rd Feb '14



5th Feb '14

Many flow conditions



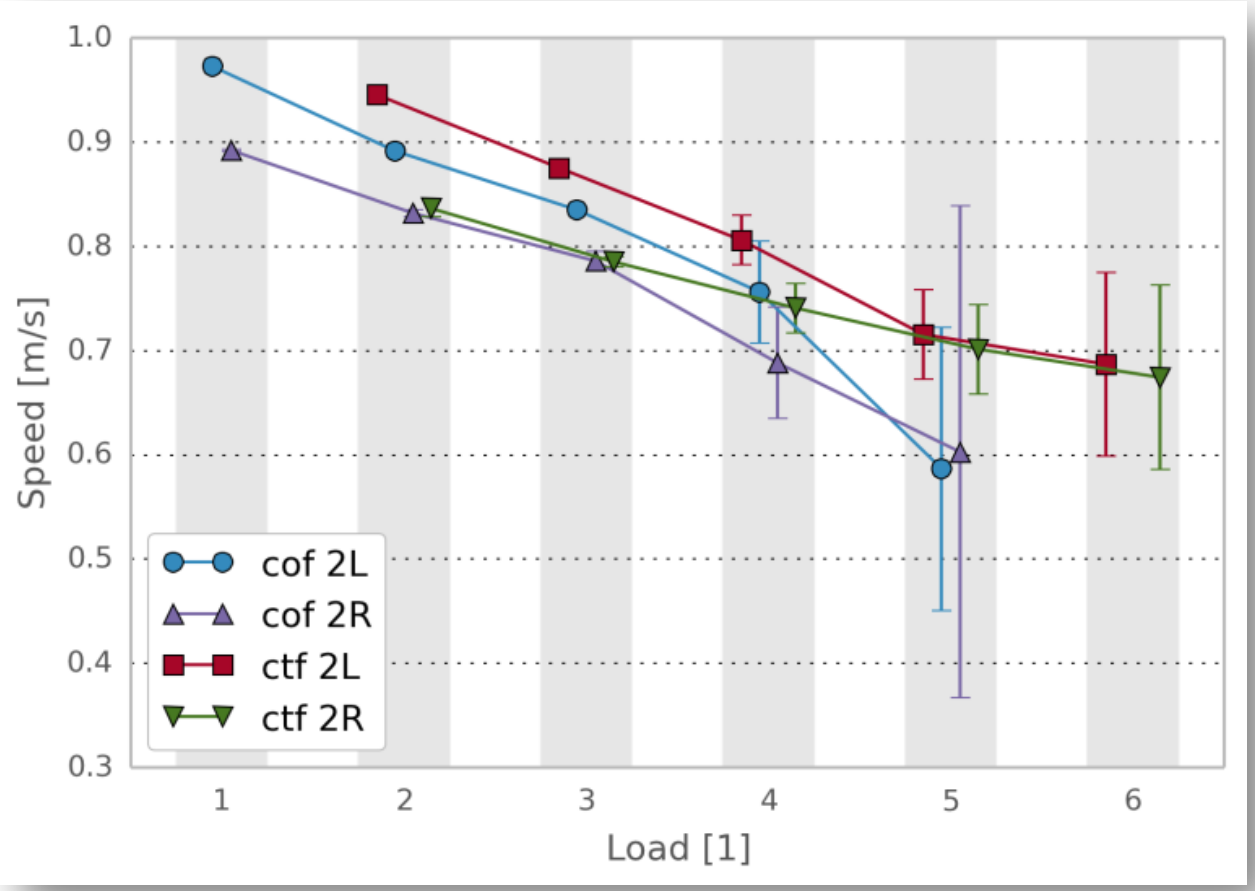


Partitioning ensemble trajectories in flow classes

=> statistics *per*-class

Fundamental diagrams

Simple *per*-class statistics on velocities



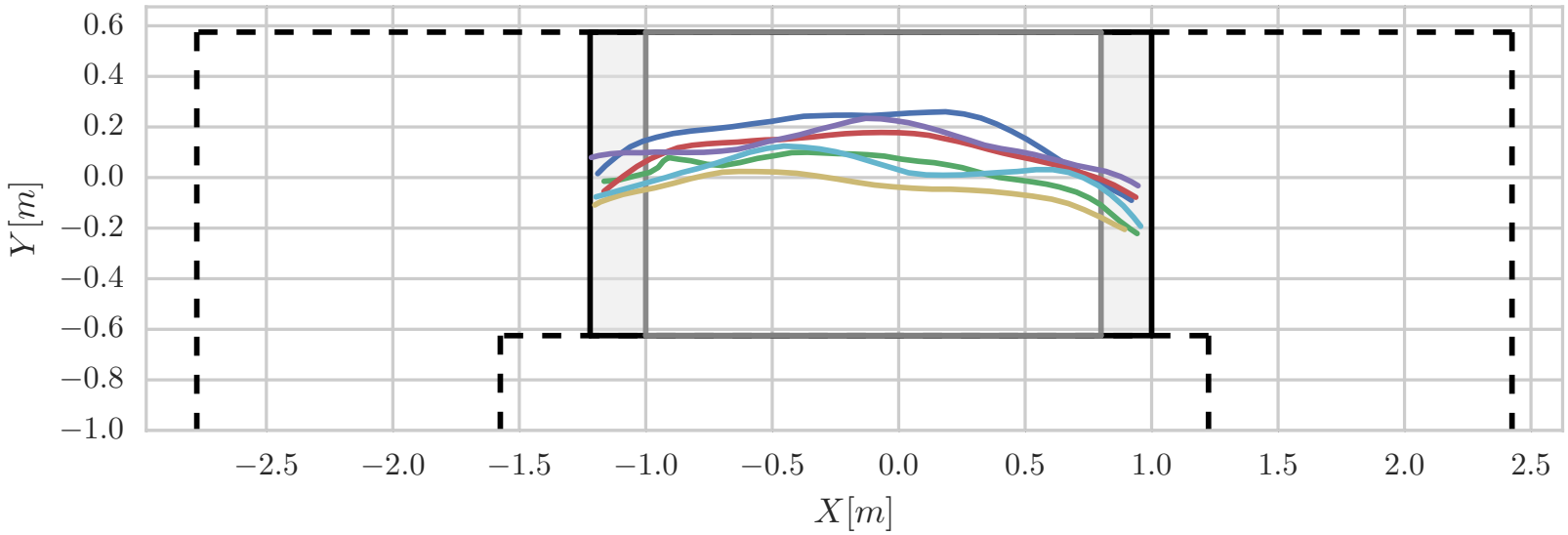
- L-R symmetry broken
- Descending direction faster
- Counter-flow > Co-flow (at same load)
  - Ped. ascending might have trays

[Corbetta *et. al* 2014]

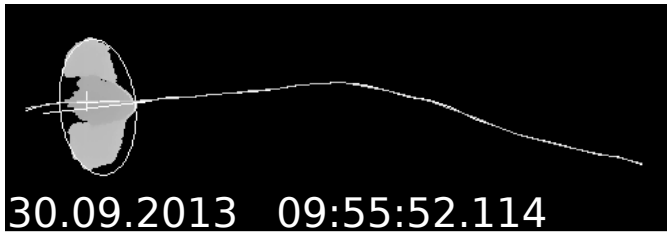
Beyond average values…

- Full probability distribution functions
  - Analyze stochasticity
  - Mathematical models
- Now: **undisturbed pedestrians**

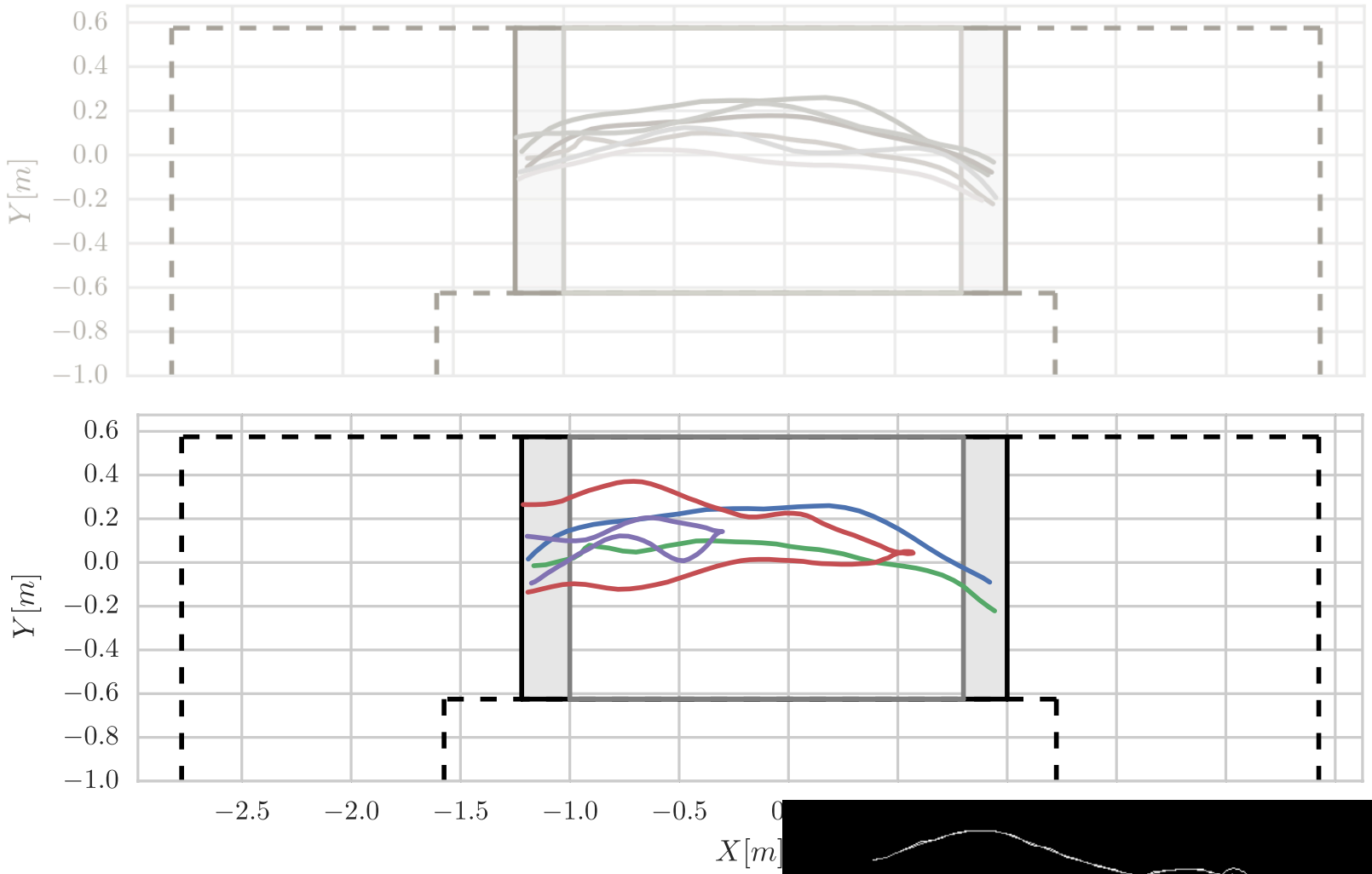
Undisturbed pedestrian dynamics

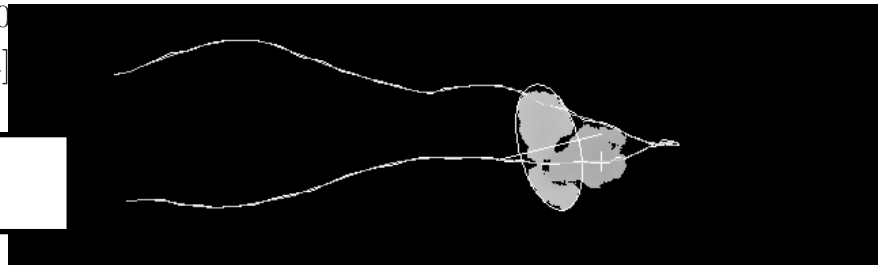


- Simple scenario
  - Pedestrians **cross** the corridor (L -> R)
  - No reasons to stop



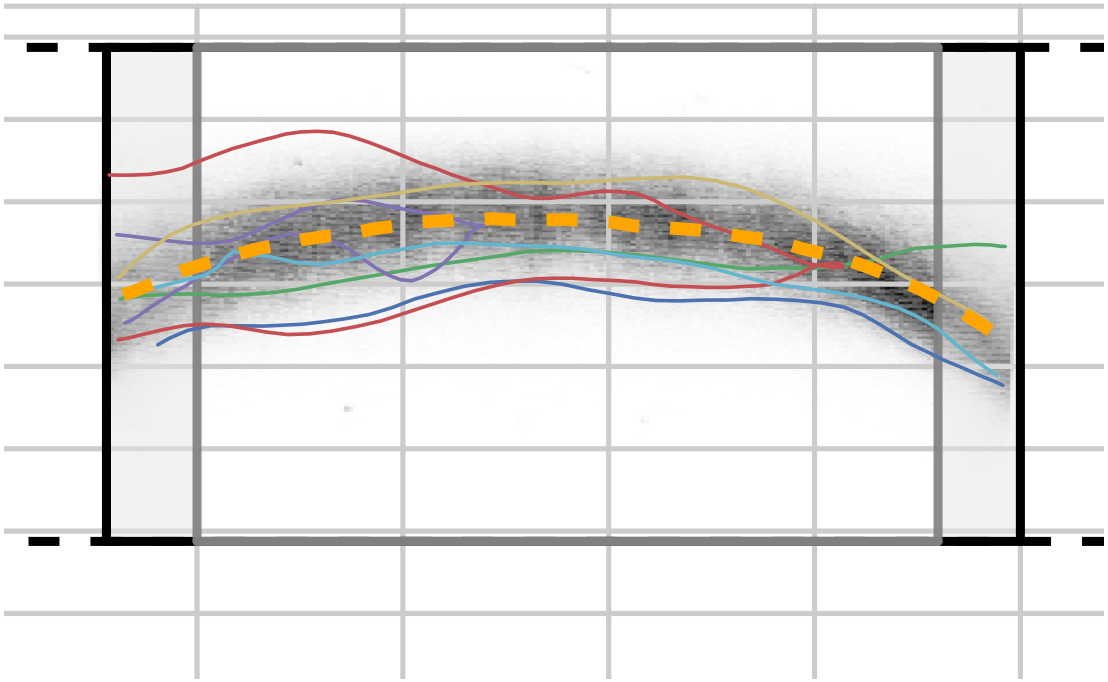
Undisturbed pedestrian dynamics





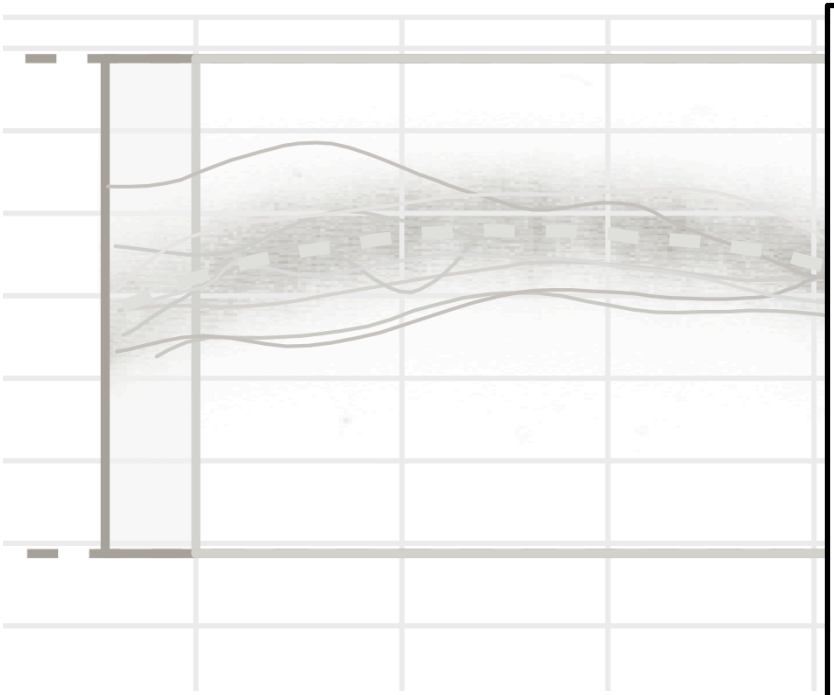
- **Rare events:** trajectory inversions

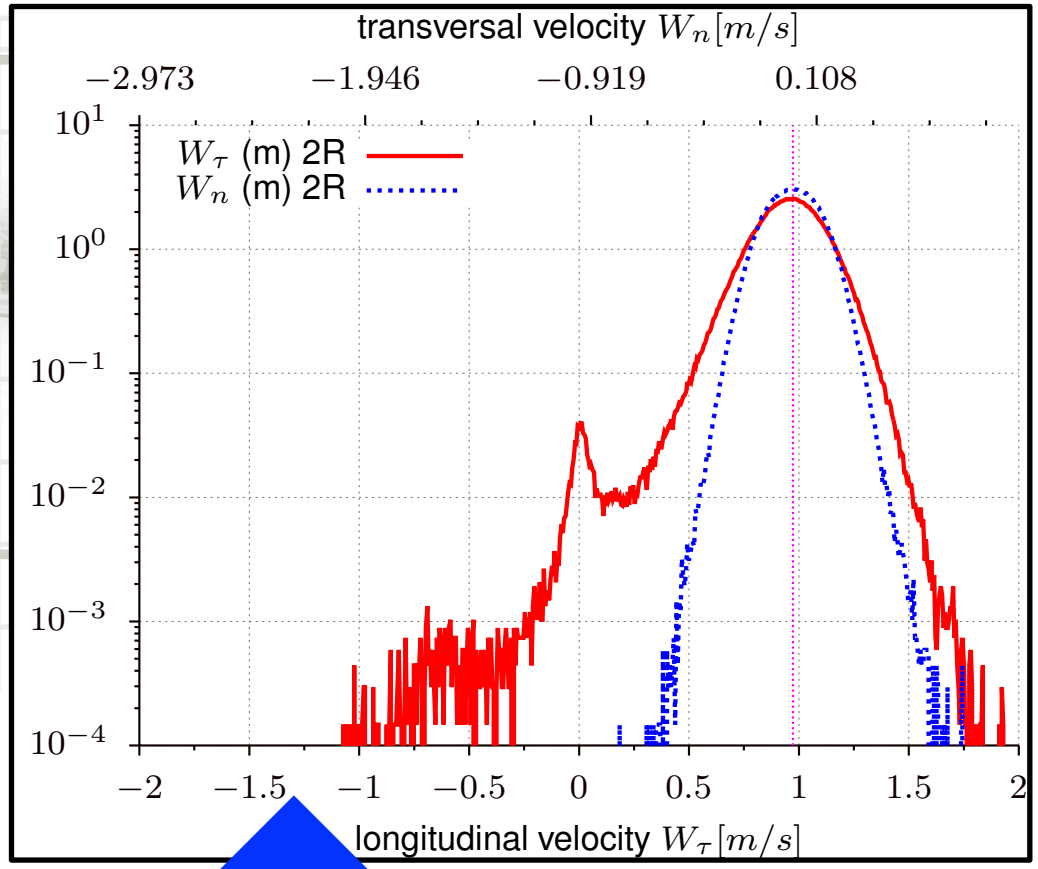
High-statistics perspective



1. Preferred walking path
2. “Confined” transversal motion
3. longit. & transv. fluctuations

High-statistics perspective





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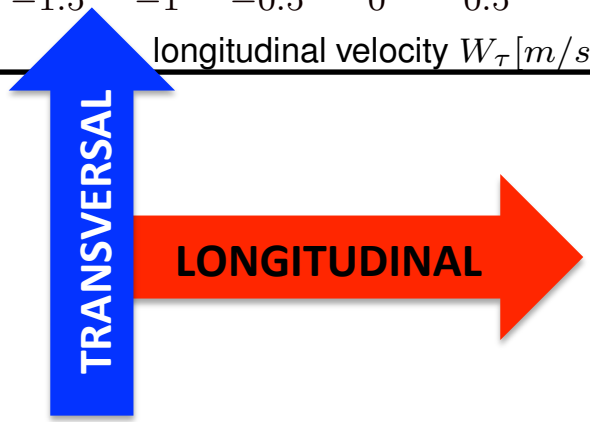


Can we reproduce this behavior in statistical sense?

Langevin-like equation

Second order stochastic dynamics:

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

$$\dot{\mathbf{v}} = -\nabla_{\mathbf{v}} K(\mathbf{v}) - \nabla_{\mathbf{x}} V(\mathbf{x}) + \dot{\mathbf{W}}$$

Activity
(active friction for propulsion)

Spatial confinement

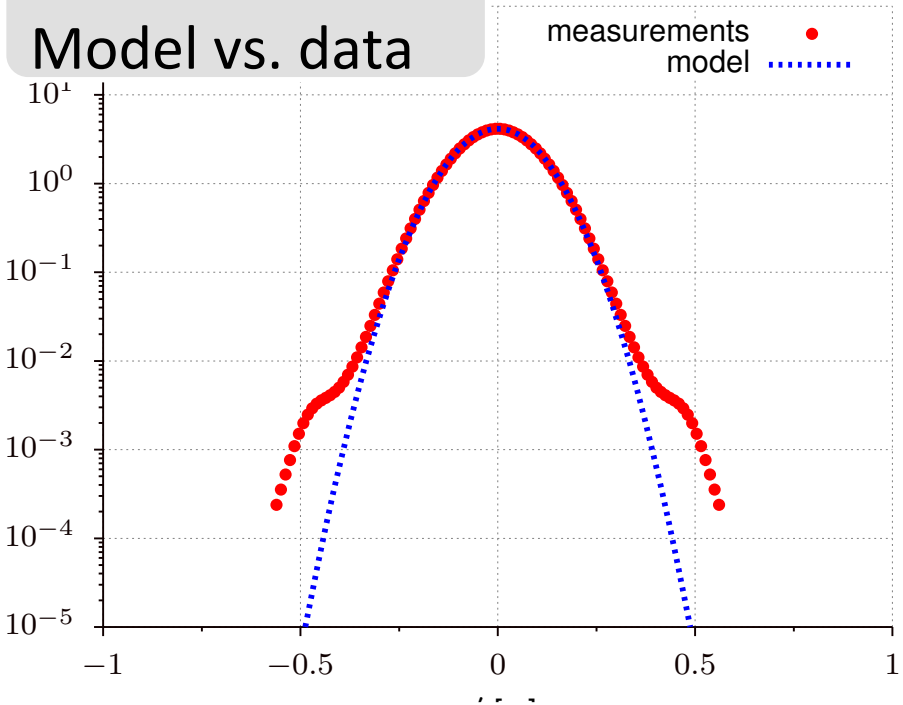
Random external factors

Transversal fluctuations

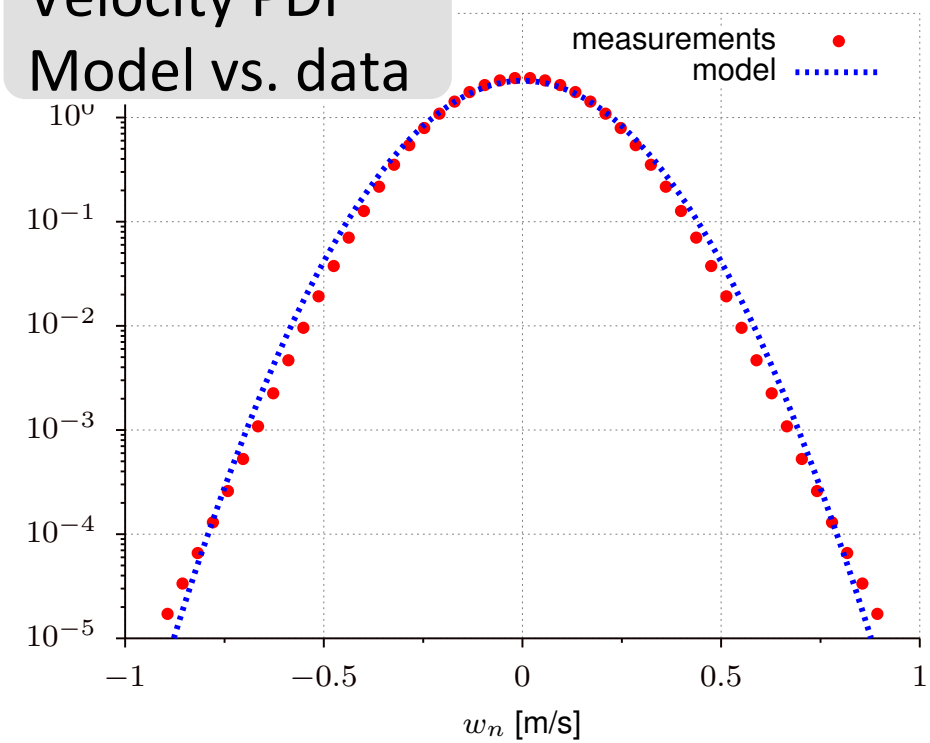
Stochastic motion around preferred path:

Quadratic potential for position (V) and velocity (K)

Position PDF
Model vs. data



Velocity PDF
Model vs. data

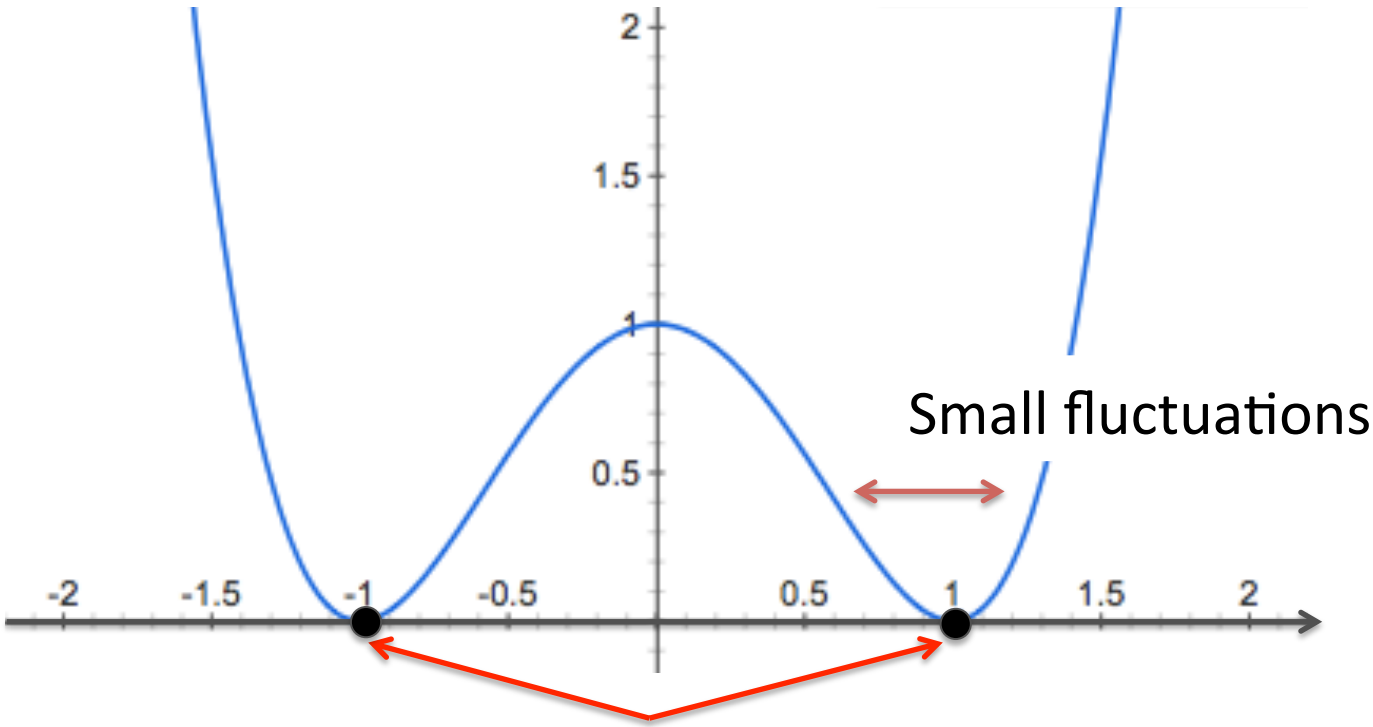


Confined Gaussian fluctuation: $\dot{v} = -2\gamma v - 2\beta y + \sigma_y \dot{w}$

Bi-stable longitudinal motion

4th order velocity potential velocity (K)

Simplest bi-stable stochastic velocity dynamics

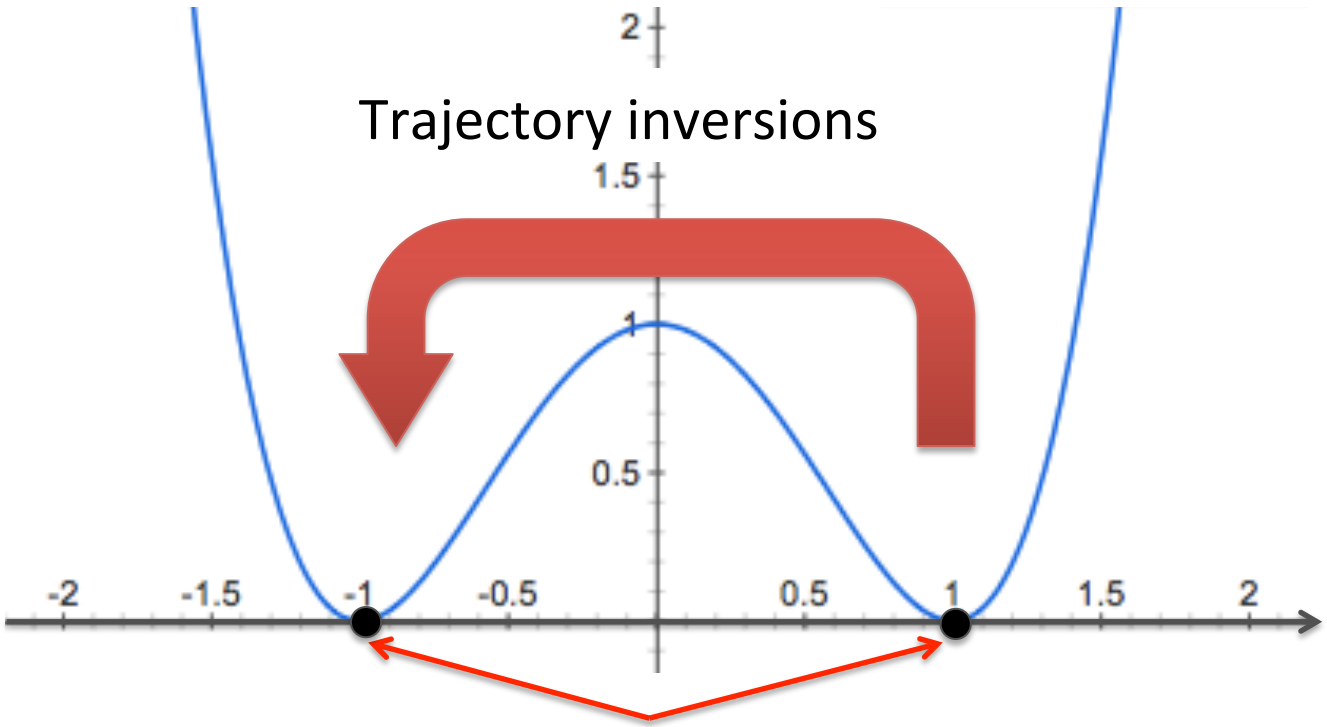


Stable velocity states

Bi-stable longitudinal motion

4th order velocity potential velocity (K)

Simplest bi-stable stochastic velocity dynamics



Stable velocity states

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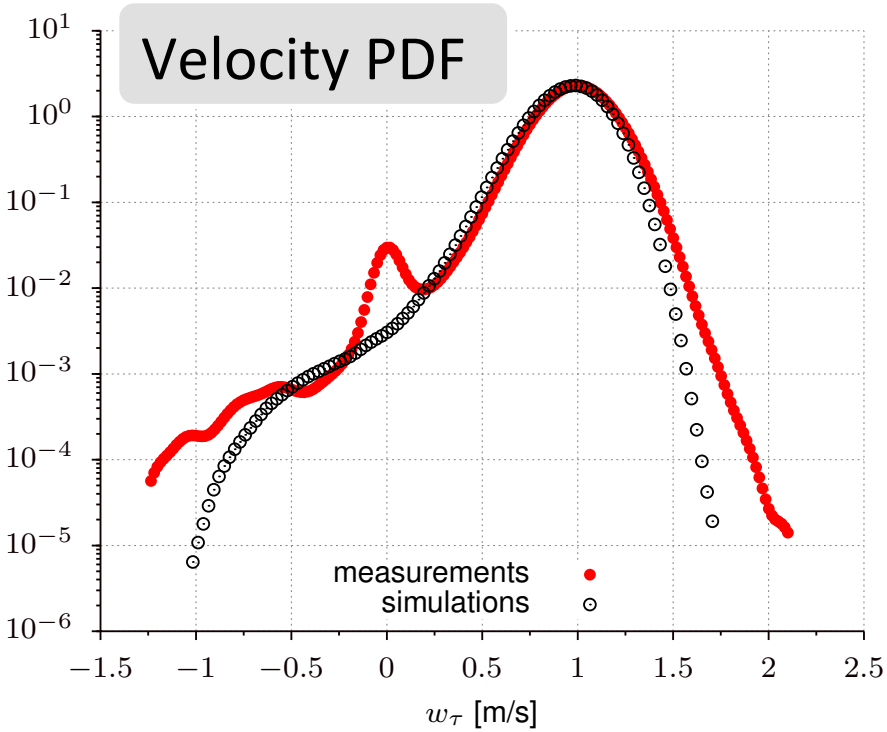

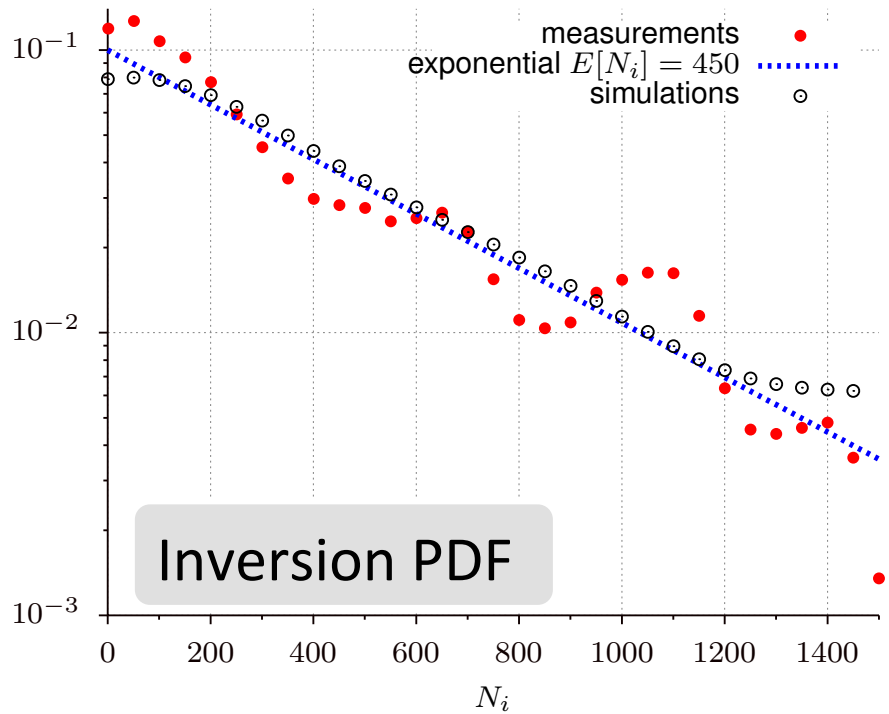

- Inversion dynamics captured in velocity pdf
- Rare and uncorrelated => **Poisson statistics**

$$\dot{u} = 4\alpha u(u^2 - u_p^2) + \sigma_x \dot{w}$$

[A. Corbetta *et. al*, to be submitted]

Conclusion

- Analyzed pedestrian dynamics via large experimental datasets
  - Statistic insights possible
  - Analogous features expected in low density crowds

- Simple Langevin-like model to reproduce stochastic features of undisturbed pedestrians motion
  - Quantitative
  - Small fluctuations and rare inversions captured within same model

- Next:
  - Avoidance dynamics in pairs & higher order interactions
    [A. Corbetta, Phd Thesis, 2015 – soon online]
  - Statisticity investigation at high density regimes?

References

1. A. Corbetta, L. Bruno, A. Muntean, F. Toschi, High Statistic Measurements of Pedestrian Dynamics, 2014, Transportation Research Procedia, 2.
2. S. Seer, N. Brandle and C. Ratti, *Kinects and human kinetics: a new approach for studying pedestrian behavior*, Transportation Research Part C: Emerging Technologies, 2014, 48 : 212-228.
3. A. Corbetta, A. Muntean, K. Vafayi, F. Toschi, Parameter Estimation of Social Forces in Pedestrian Dynamics models via a Probabilistic Method, 2015, Mathematical Biosciences and Engineering, 12 (2), 337-356
4. The OpenPTV initiative, 2012 -, www.openptv.net
5. J. Willneff, A. Gruen, A new Spatio-Temporal Matching Algorithm for 3D-Particle Tracking Velocimetry, The 9th of International Symposium on Transport Phenomena and Rotating Machinery, Honolulu, Hawaii, 2002
6. J. Willneff, A Spatio-Temporal Matching Algorithm for 3D Particle Tracking Velocimetry, PhD Thesis, ETH-Zurich, 2003
7. A. Corbetta, Multiscale crowd dynamics: physical analysis, modeling and applications, PhD Thesis, 2015
8. A. Corbetta, C. Lee, R. Benzi, A. Muntean, F. Toschi, Fluctuations and mean behaviours in diluted pedestrian flows, to be submitted

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