Physical Mechanism for the Occurrence of Wide-Scattering in Traffic Cellular Automata (TCA) Models

Presented by

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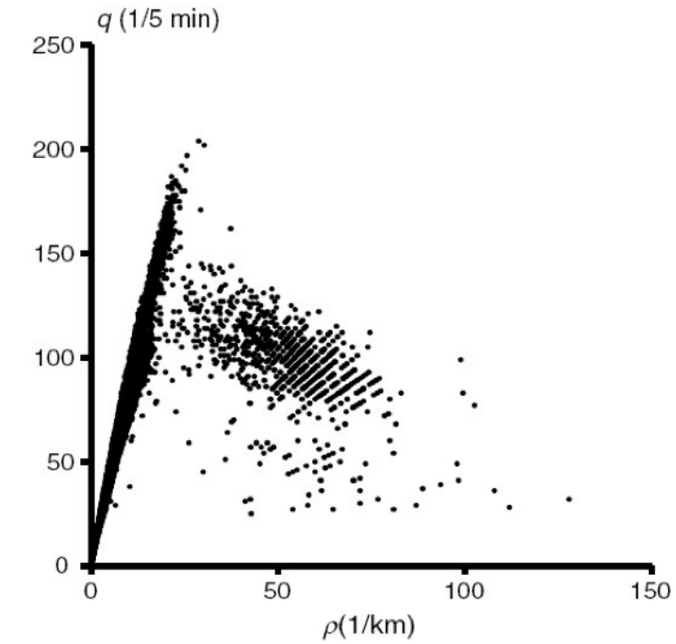
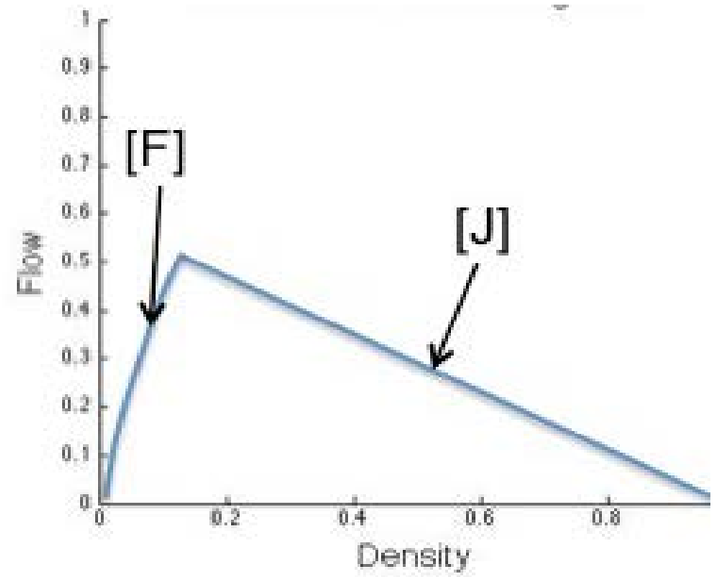
Background

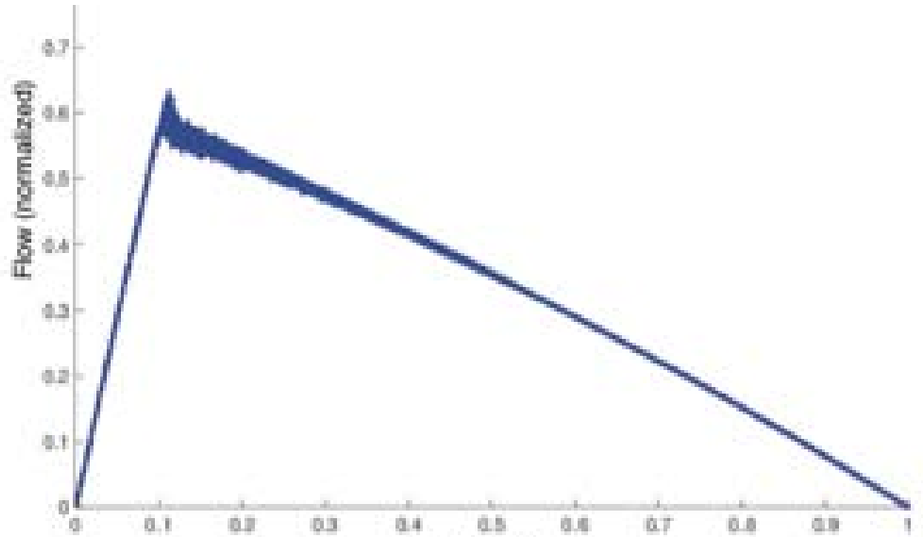
- Flow-density relation (Fundamental Diagram)
  - Nagel-Schneckenberg CA model (1992)
- Wide-scattering of flow-density states
  - Three-phase theory (Boris Kerner, 2000s)
    - KKS Model (2012)
  - Average Space Gap Model - JF Tian (2012)
  - Defensive Driving Model - JPL Neto (2012)

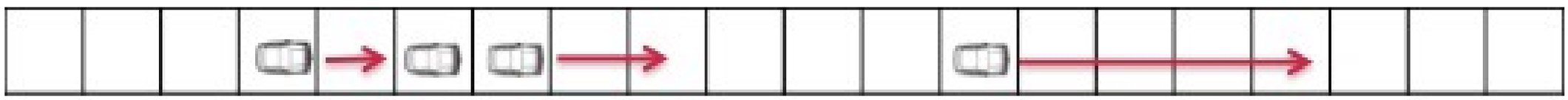




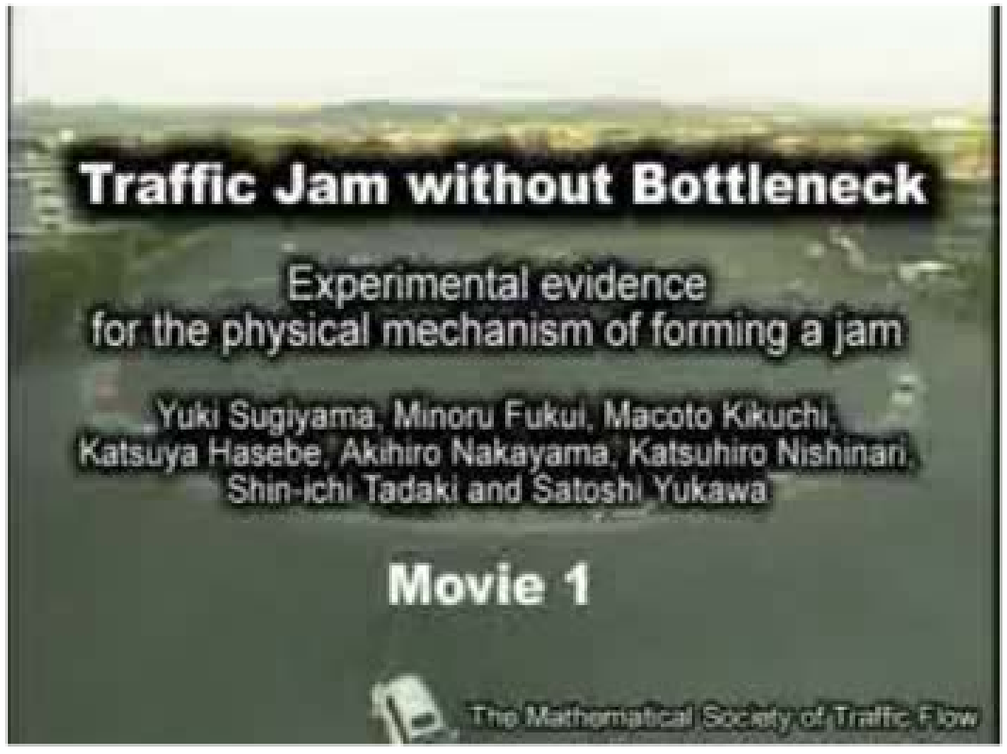
Conceptualisation

- Lack of understanding of wide-scattering
  - Study using Nagel-Schreckenberg Cellular Automata (1991)





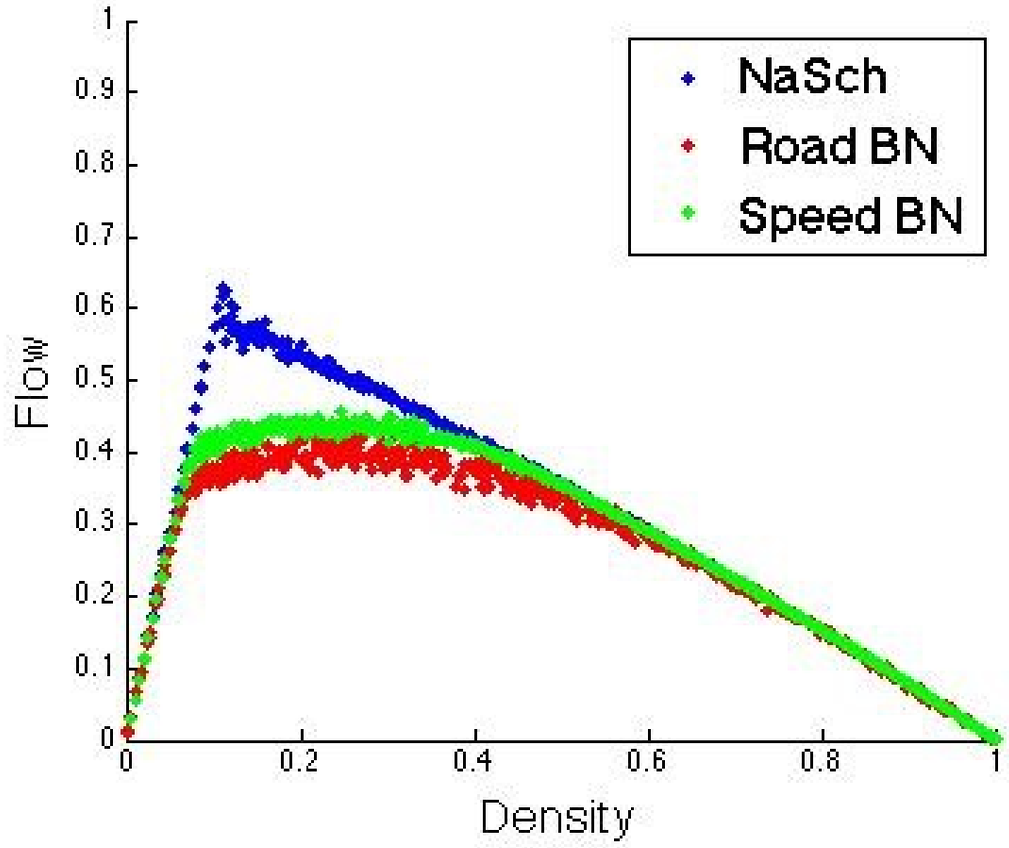
1. Success in describing mechanism of jam formation
   - Corresponds to Sugiyama (2008)



Proposing an elementary mechanism which captures wide-scattering

2. Preliminary studies:

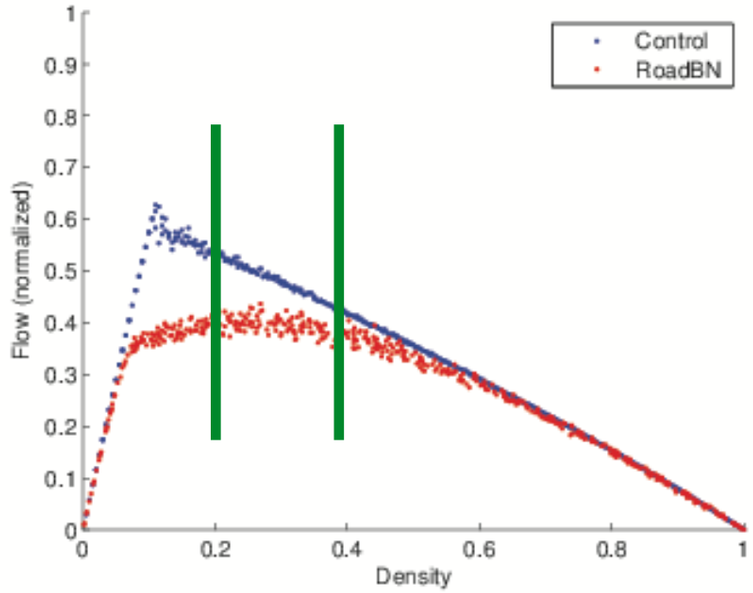
- Congestion under bottlenecks



Verify using wide-scattering captured by NaSch model under bottlenecks

Numerical Model

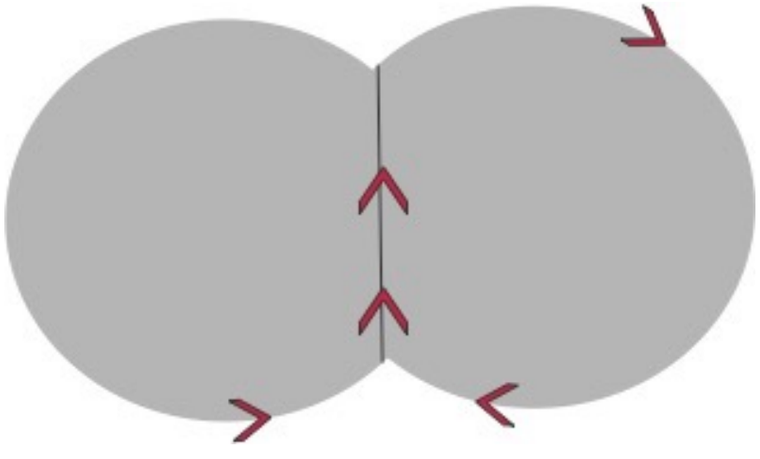
- Quantifying width of scattering

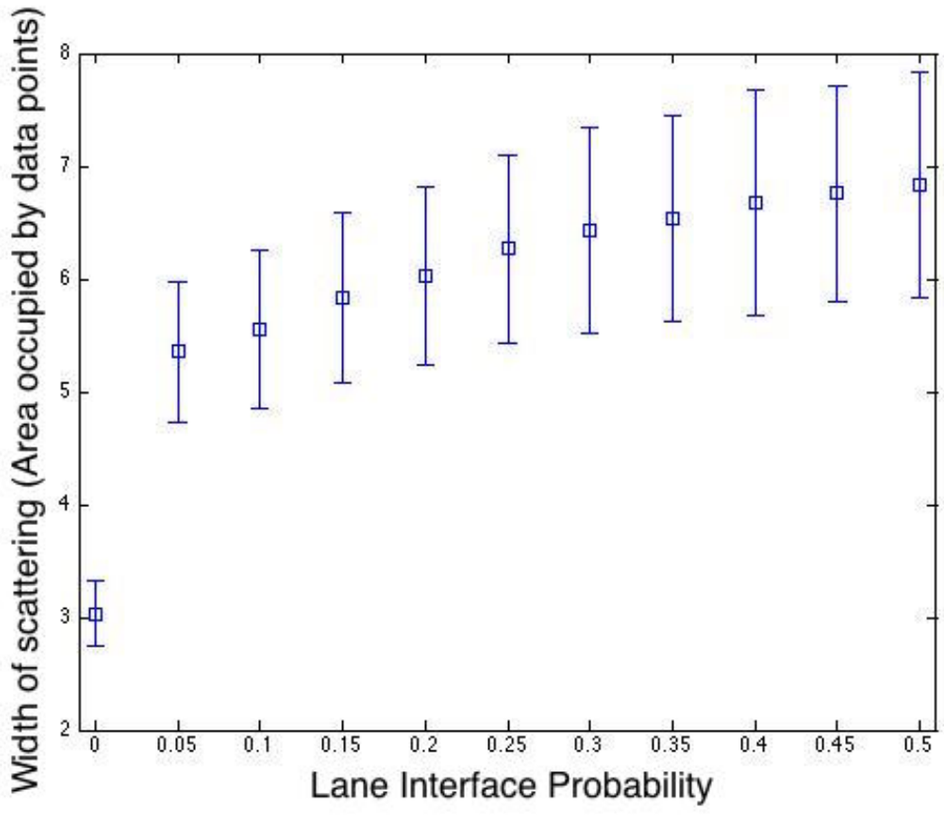


  - Average number of flow data point per density

- Propose methodology which varies the width of scattering systematically in the NaSch model using bottlenecks

- Lane probability = [0 , 0.5]



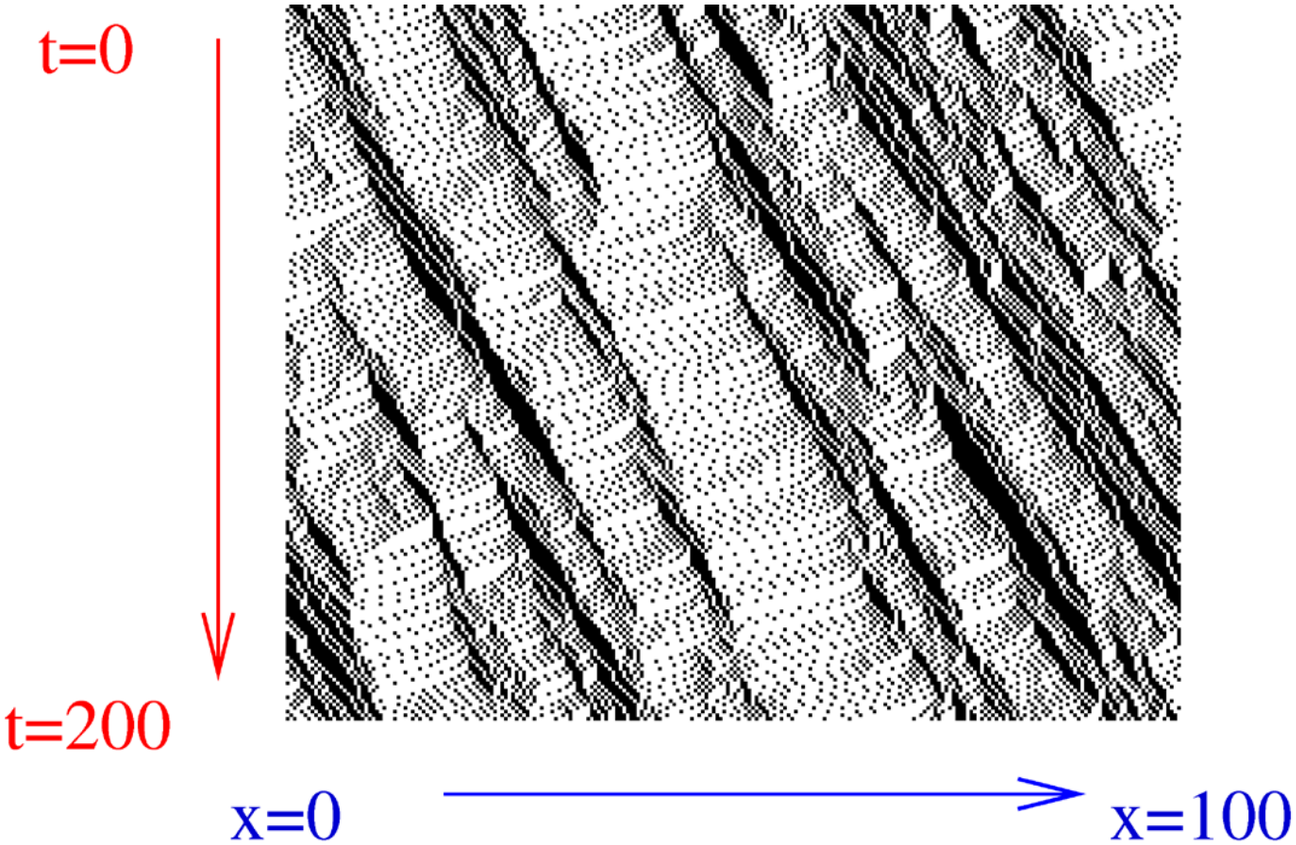


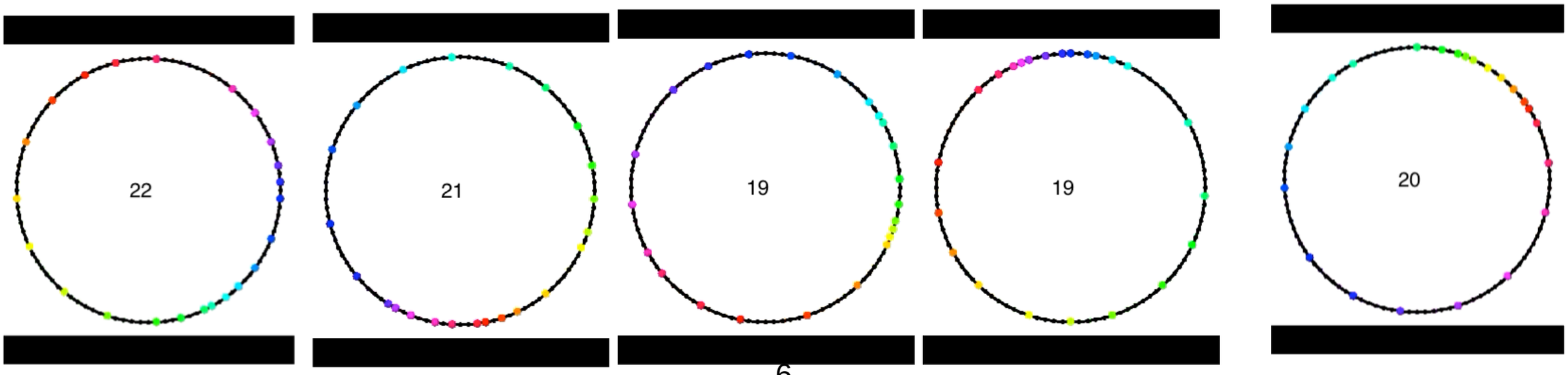
Hypothesis

- Wide-scattering is due to the variability of cluster formation in congested traffic state

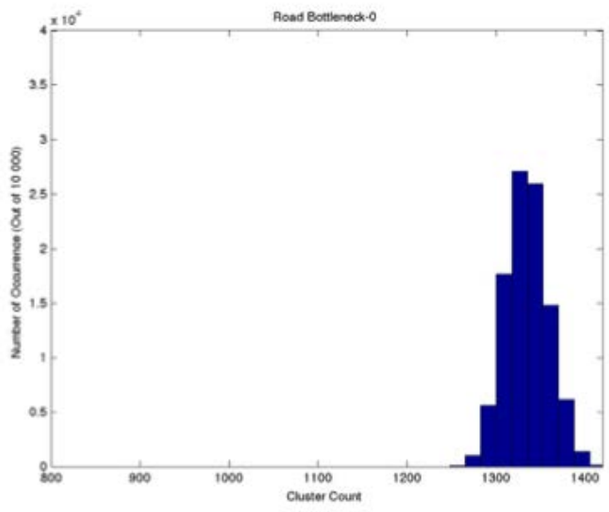
- Congested traffic - clustering of random sizes

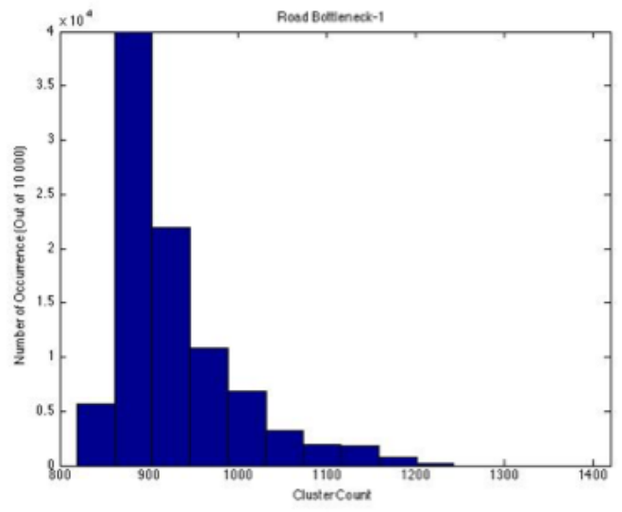
- Quantifier: Time series of cluster count



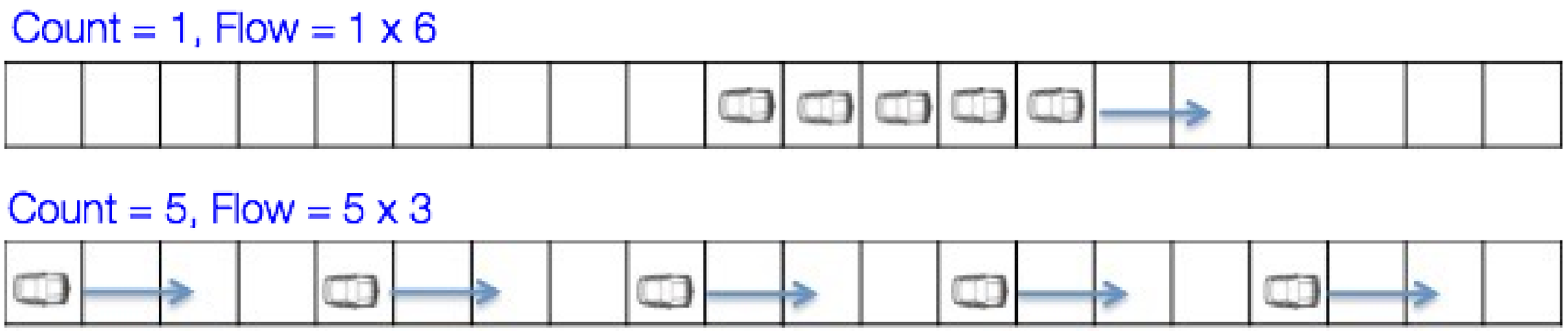


- Variability = Std deviation of cluster count fluctuation



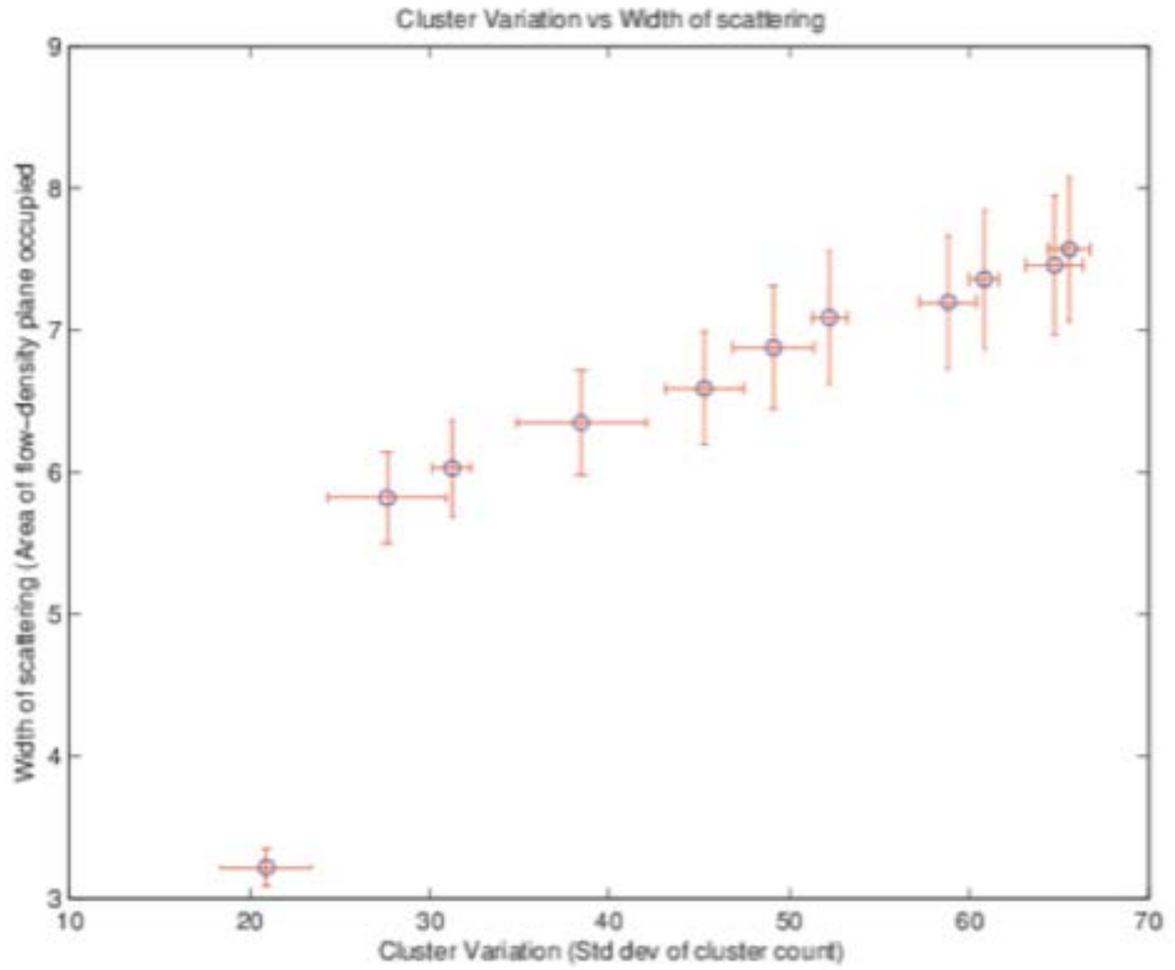


- Underlying Physics



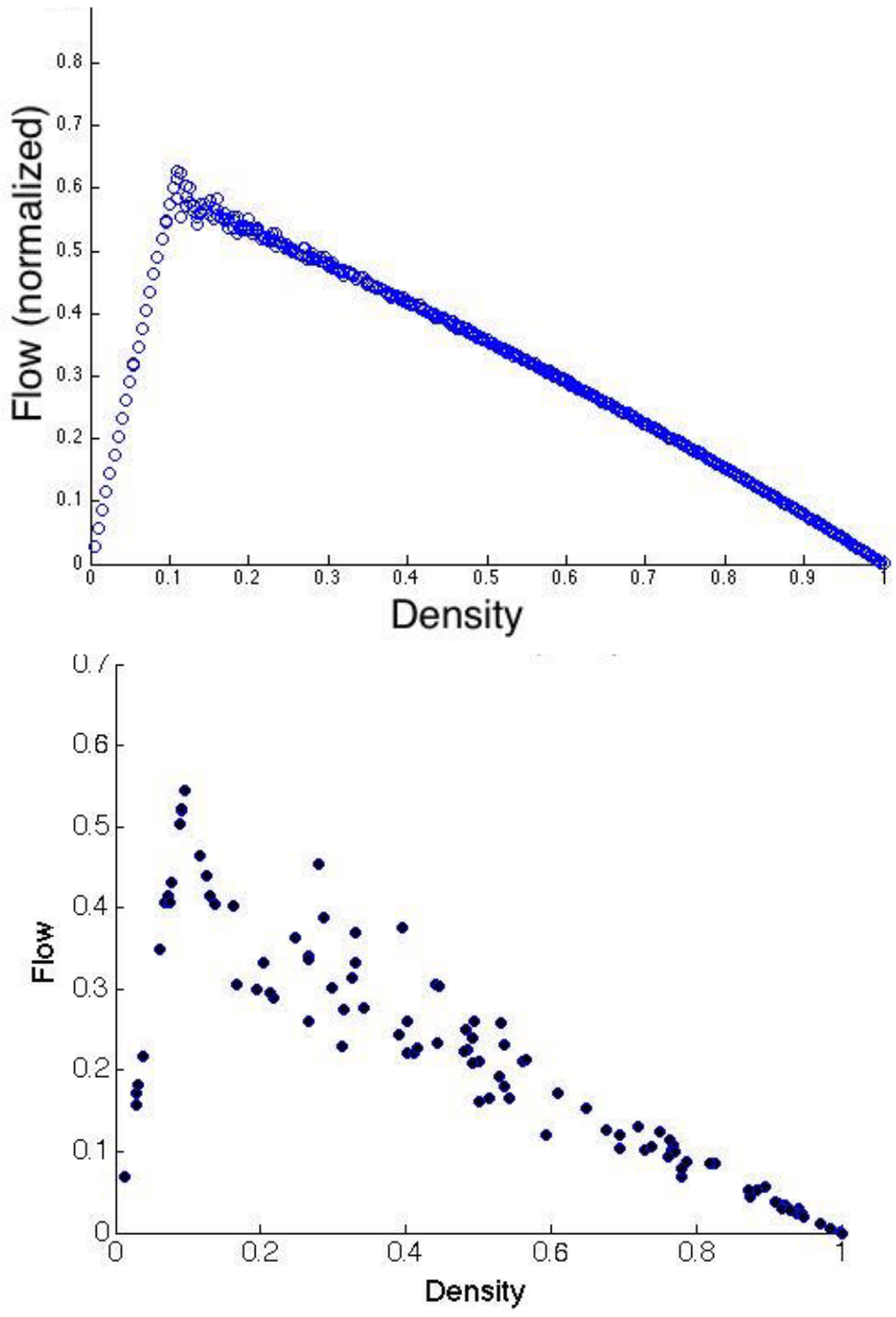
Numerical Results

- Objective function: Std dev of cluster count
- Tuning parameter: Lane probability in roadBN
- Relationship between scattering width and standard deviation of cluster count
- **Numerically: Variability of cluster formation**



Analysis on Existing TCA Models (I)

- Wide-scattering in TCA models
  - JF Tian (2011) average space gap model
- Three phase traffic
  - Competition due to Slow-to-start rules
  - Anticipation due to Velocity synchronisation

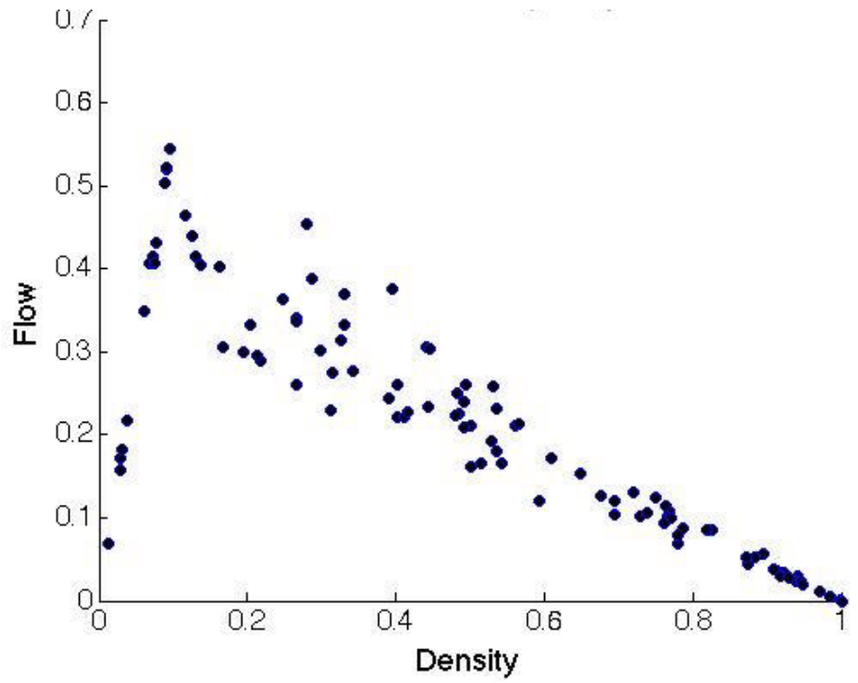


Analysis on Existing TCA Models (II)

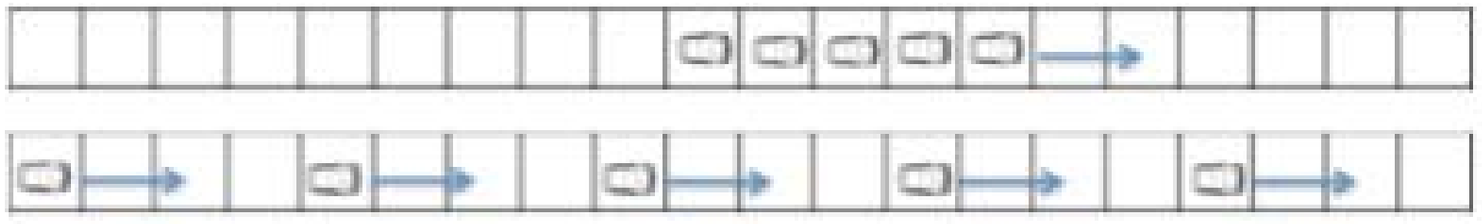
Table 1 Width of scattering and cluster variation between ASGM and NaSch Model. Data obtained for density = 0.16, sampled over 10 sets of 100 readings

	Width of Scattering	Cluster Variation
Control	49.5 ± 3.3	18.3 ± 0.4 (Mean = 136.2)
ASGM	76.7 ± 1.9	32.3 ± 0.7 (Mean = 64.9)

- Width increases with cluster variation ~50%
- Normalised standard deviation: 0.13 vs 0.50



Qualitative Analysis



- Speed adaptation
  - Assessing speed of preceding vehicles
  - Synchronises vehicle speeds
    - Many single vehicle clusters
- Slow-to-start rule
  - Favours large cluster -> slow speed
- Additional ASGM mechanism
  - Favouring statically unfavourable cluster configurations

Summary & Future Works

- Elementary mechanism which leads to wide-scattering in TCA models

- Variability of cluster formation in congested traffic
  - Described physical mechanism
  - Checked with tuneable scattering using road bottlenecks
  - Check for theoretical coherence with three-phase models (AGSM)

- Further numerical analysis can be done with TCA models

Thank you!

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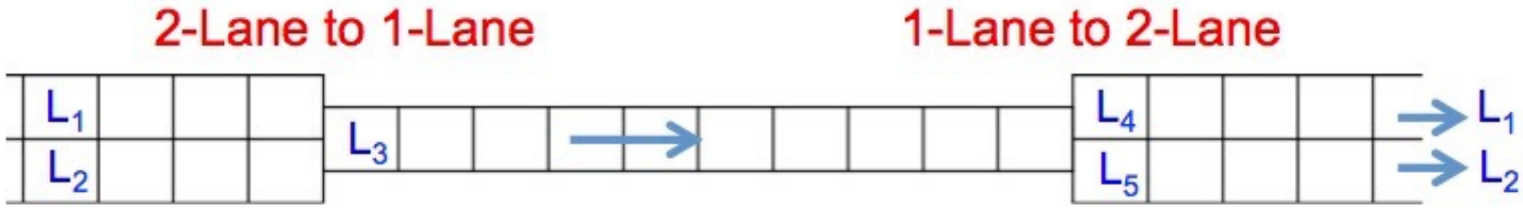
Model (I)



- NaSch CA model - Discrete and stochastic
  - 4 evolution rules: Acceleration, Systematic deceleration, Random deceleration, Movement
  - Periodic boundary condition
- Modification: Road bottlenecks