7th Annual Meeting of the Cycling Research Board
Break-Out Session BM4: Microscopic Simulation
25-27th, October 2023 — Bergische Universität Wuppertal

Lane and band formation in mixed traffic flow

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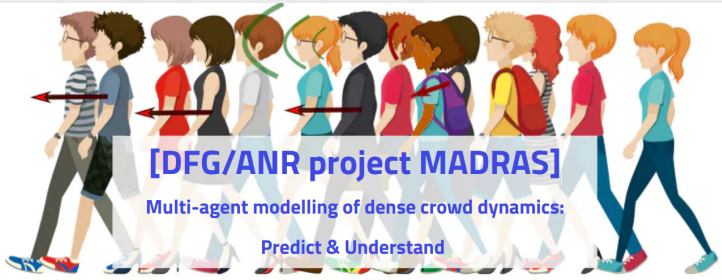
MADRAS ANR/DFG Project

madras-crowds.eu



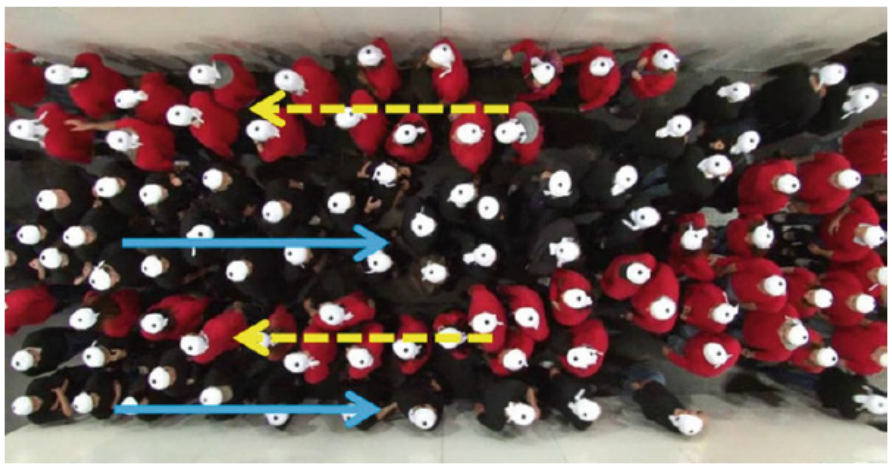
- **Forschungszentrum Jülich — Institute for Advanced Simulation (IAS7)**
  Mohcine CHRAIBI, Jakob CORDES
- **University of Wuppertal — School for Mechanical Engineering and Safety Engineering**
  Antoine TORDEUX, Raphael KORBMACHER
- **University Toulouse Capitole — Institut de Recherche en Informatique de Toulouse**
  Benoit GAUDOU, Nicolas VERSTAEVEL, Frédéric AMBLARD, Huu-Tu DANG
- **University Lyon 1 — Institut Lumière Matière**
  Alexandre NICOLAS, David RODNEY, Oscar DUFOUR

- Modelling of dense crowd dynamics (from 2 to 8 ped/m^2)
- Experiment-based modelling
- Development and validation of multi-agent simulation tools

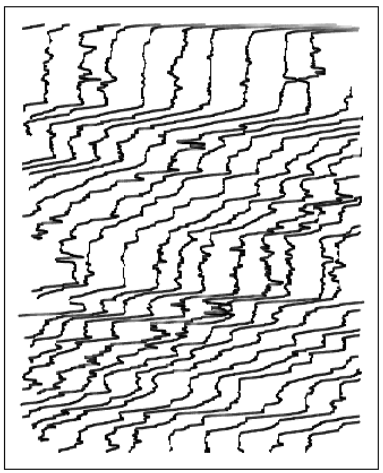
Collective behaviors in pedestrian dynamics

- Many examples of collective behaviors in pedestrian dynamics: lane, band and stripe formation, stop-and-go waves, intermittent flow, etc.
- Phase transition, metastability, non-linear effect
- Collective dynamics induced by interaction model features: relaxation and delay, noise, heterogeneity in agent behaviors and characteristics, etc.

Lane formation



Stop-and-go waves



Microscopic modelling

- Motion model F depending on state variables $\mathbf{X}_n$ (e.g. distances to neighbours) and parameters $\mathbf{p}$ (e.g. maximum speed, size)
- Two types $k = 1, 2$ of agents and two different settings $\mathbf{p}_1$ and $\mathbf{p}_2$ for the model parameters

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Model 1 *Heterogeneity of the agents*: Static attribution of the two parameter setting $\mathbf{p}_1$ and $\mathbf{p}_2$ to the two types of agents

$$M_1(n, k) = F(\mathbf{X}_n, \mathbf{p}_k) \tag{1}$$

Model 2 *Heterogeneity of the interactions*: Dynamic attribution of the parameter setting $\mathbf{p}_1$ and $\mathbf{p}_2$ according to the type of interaction:

$$M_2(n, k) = \begin{cases} F(\mathbf{X}_n, \mathbf{p}_1), & \text{if } \tilde{k}(\mathbf{X}_n) = k \\ F(\mathbf{X}_n, \mathbf{p}_2), & \text{otherwise} \end{cases} \tag{2}$$

with $\tilde{k}(\mathbf{X}_n)$ the type of the closest agent in front

Illustration in 1D

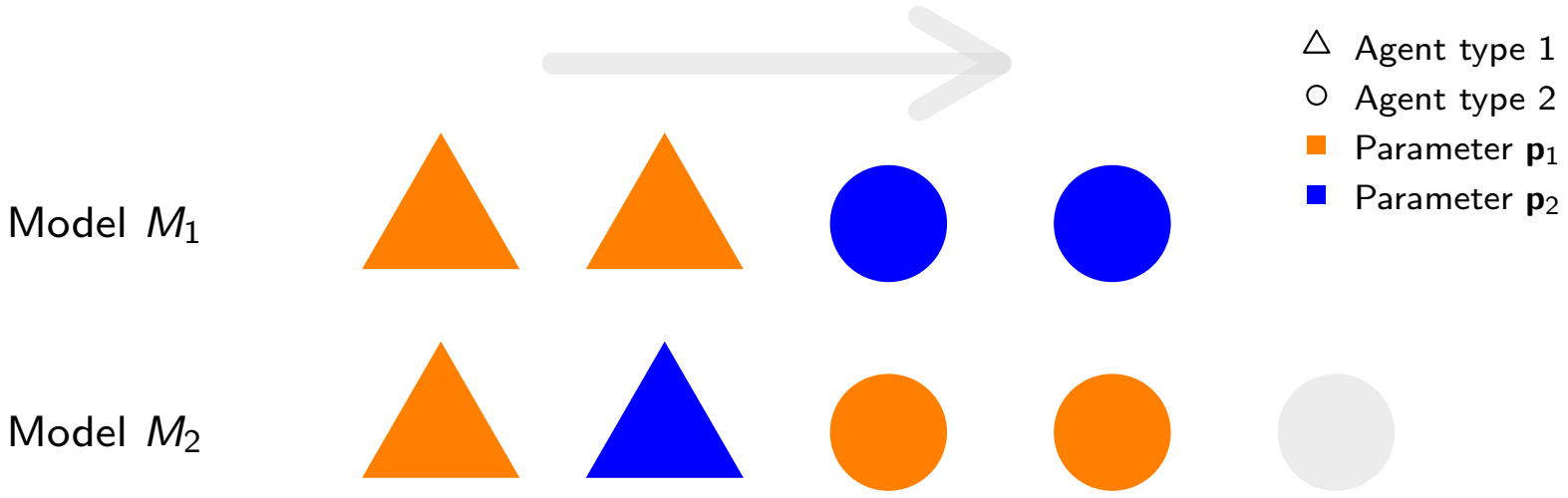


Figure: Illustrative example in 1D for the two heterogeneity models. The heterogeneity relies on the agent type for M_1, while it depends on the type of the agent in front for M_2.

Online simulation platform

- **NetLogo online simulation platform available at:**

  vzu.uni-wuppertal.de/en/online-simulation

Order parameter for lane and band formation

- Models M_1 and M_2 tend to describe lane and band formation, respectively

- Order parameter for lane formation: Rex and Löwen, *Phys Rev E* 75 (2007)

$$\left| \begin{array}{l} N = \text{card}(m, |y - y_m| < \Delta, k = k_m) \\ \bar{N} = \text{card}(m, |y - y_m| < \Delta, k \neq k_m) \end{array} \right. \qquad \phi_L = \left[\frac{N - \bar{N}}{N + \bar{N}} \right]^2$$

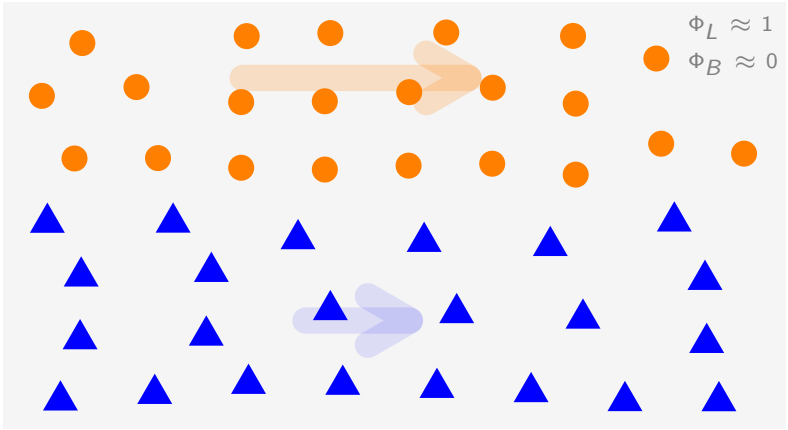
- Order parameter for band formation:

$$\left| \begin{array}{l} M = \text{card}(m, |x - x_m| < \Delta', k = k_m) \\ \bar{M} = \text{card}(m, |x - x_m| < \Delta', k \neq k_m) \end{array} \right. \qquad \phi_B = \left[\frac{M - \bar{M}}{M + \bar{M}} \right]^2$$

Lane and band formation

Self-organisation in lanes

Model M_1: *Heterogeneity of the agents*



Self-organisation in bands

Model M_2: *Heterogeneity of the interactions*

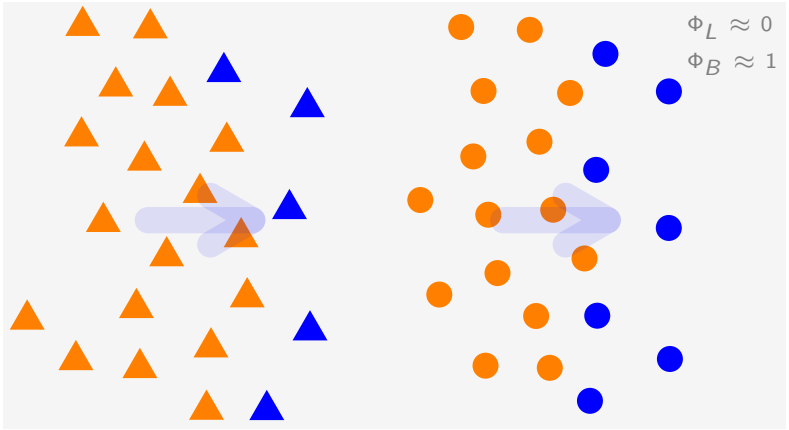


Figure: Typical screenshots for the model M_1 with heterogeneity in the agent characteristics, for which lanes emerge (left panel), and for the model M_2 with heterogeneity in the interactions, for which bands emerge (right panel).

Simulation setup

- Simulation on a torus with dimensions $w = 9$ and $h = 5$ m — 45 agents (density of 1 agent/m^2)
- Collision-free (CFM) and social force (SFM) pedestrian models
- Monte Carlo simulation from random initial position — Measurement of agent mean speed and average lane and band order parameters after a simulation time of $t_0 = 10$ min
- Variation of the model parameters $\mathbf{p}_1$ and $\mathbf{p}_2$ according to
  1. Agent's desired speed (maximum speed and time gap or repulsion rate parameters)
  2. Agent's size (agent's radius)

Simulation setup

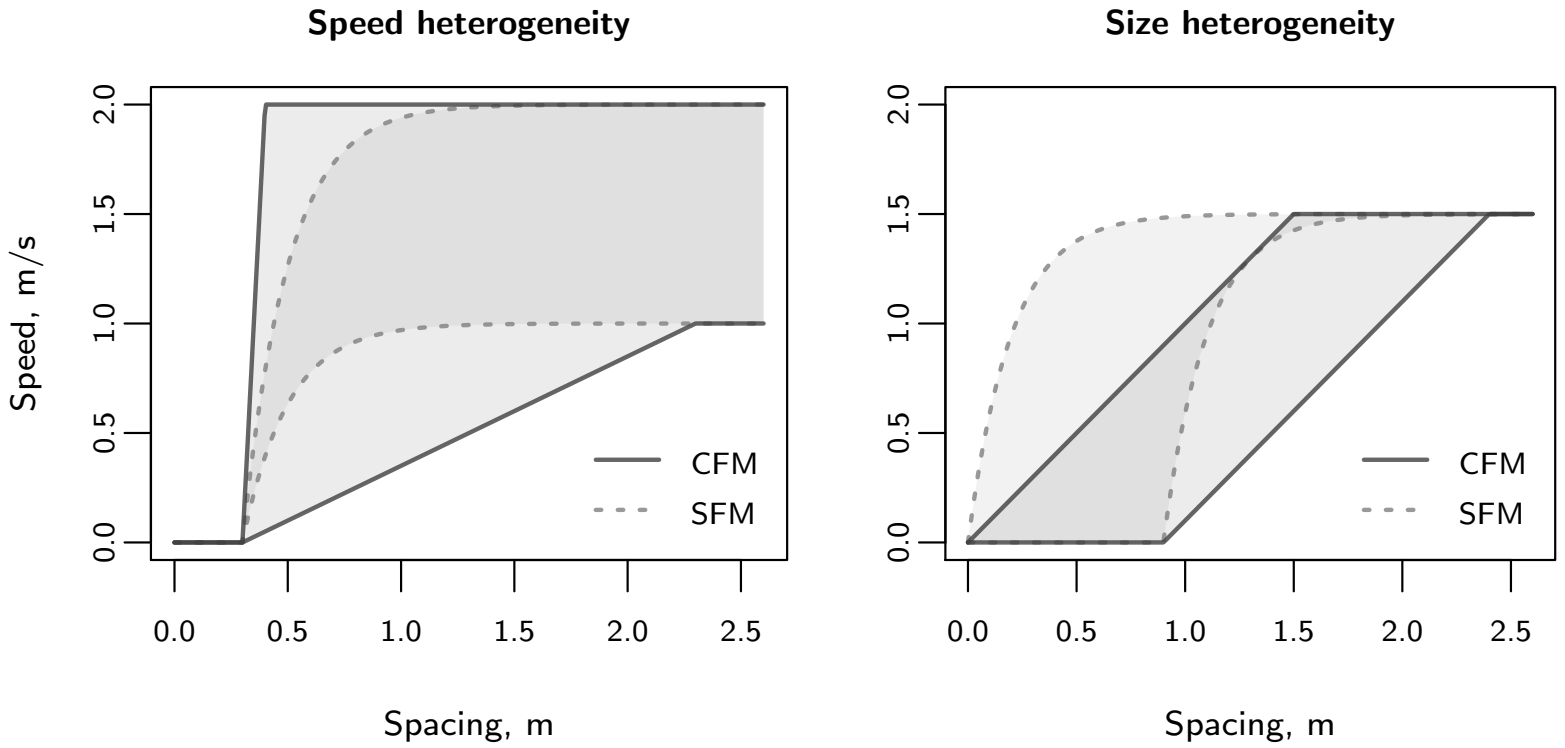


Figure: Range of variation of the CFM and SFM parameters for heterogeneity relying on agent speed (left panel) and on agent size (right panel).

Heterogeneity of the agent' speed

CFM

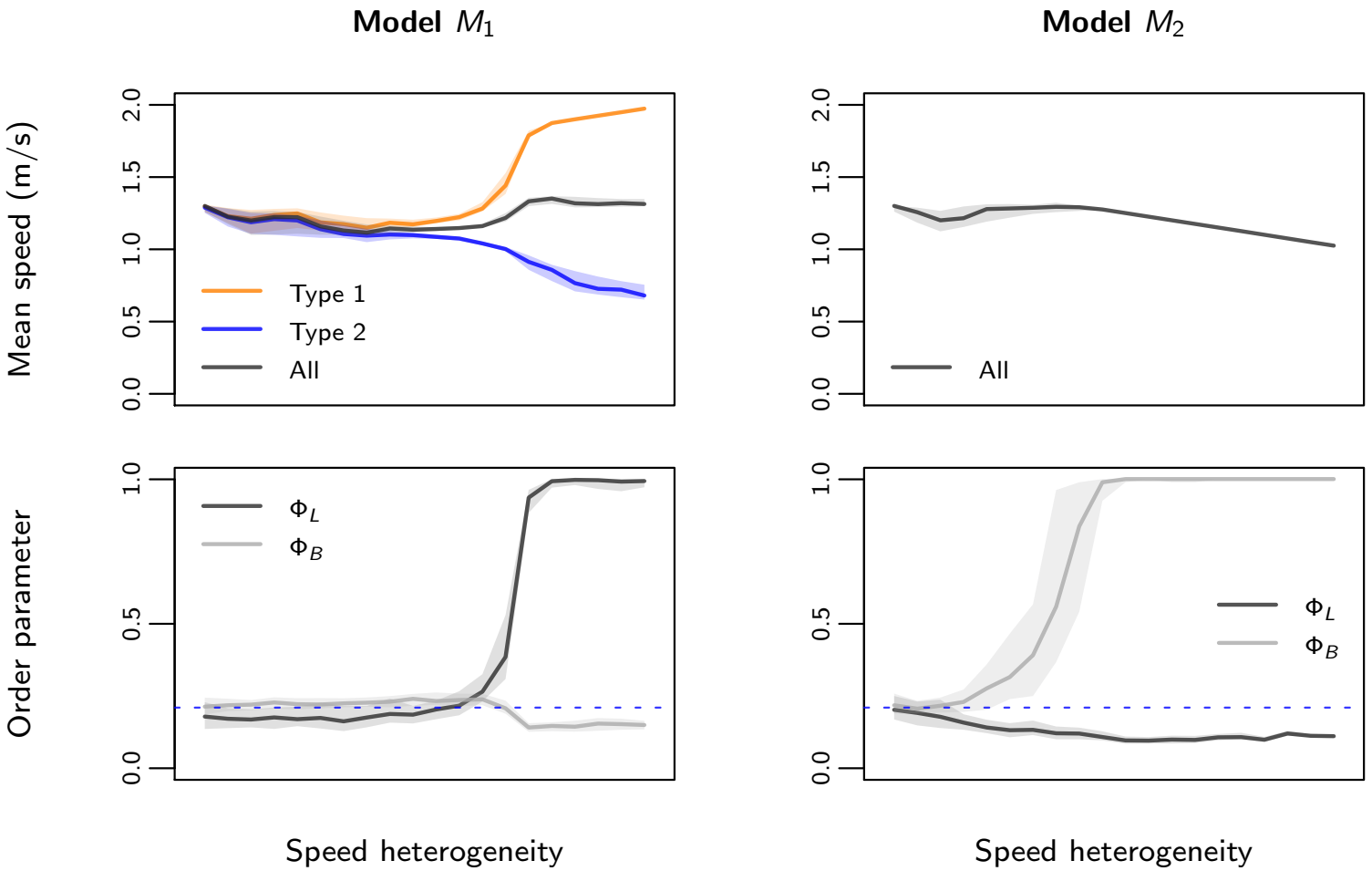


Figure: Mean speed (top panels) and order parameter for lane and band formation (bottom panels) according to the heterogeneity of the agent speed for the collision-free model.

Heterogeneity of the agent' speed

SFM

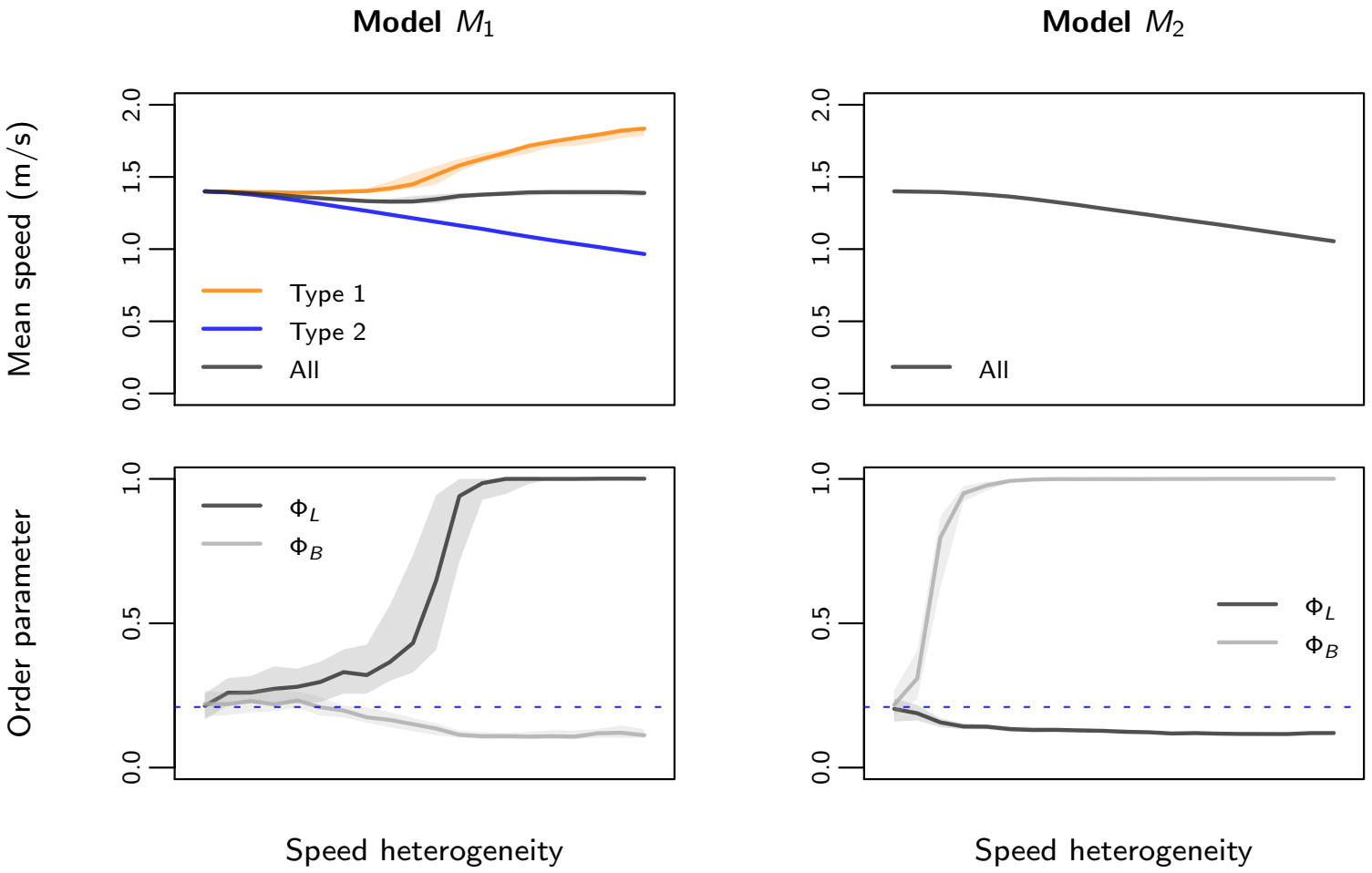


Figure: Mean speed (top panels) and order parameter for lane and band formation (bottom panels) according to the heterogeneity of the agent speed for the social force model.

Heterogeneity of the agent' size

CFM

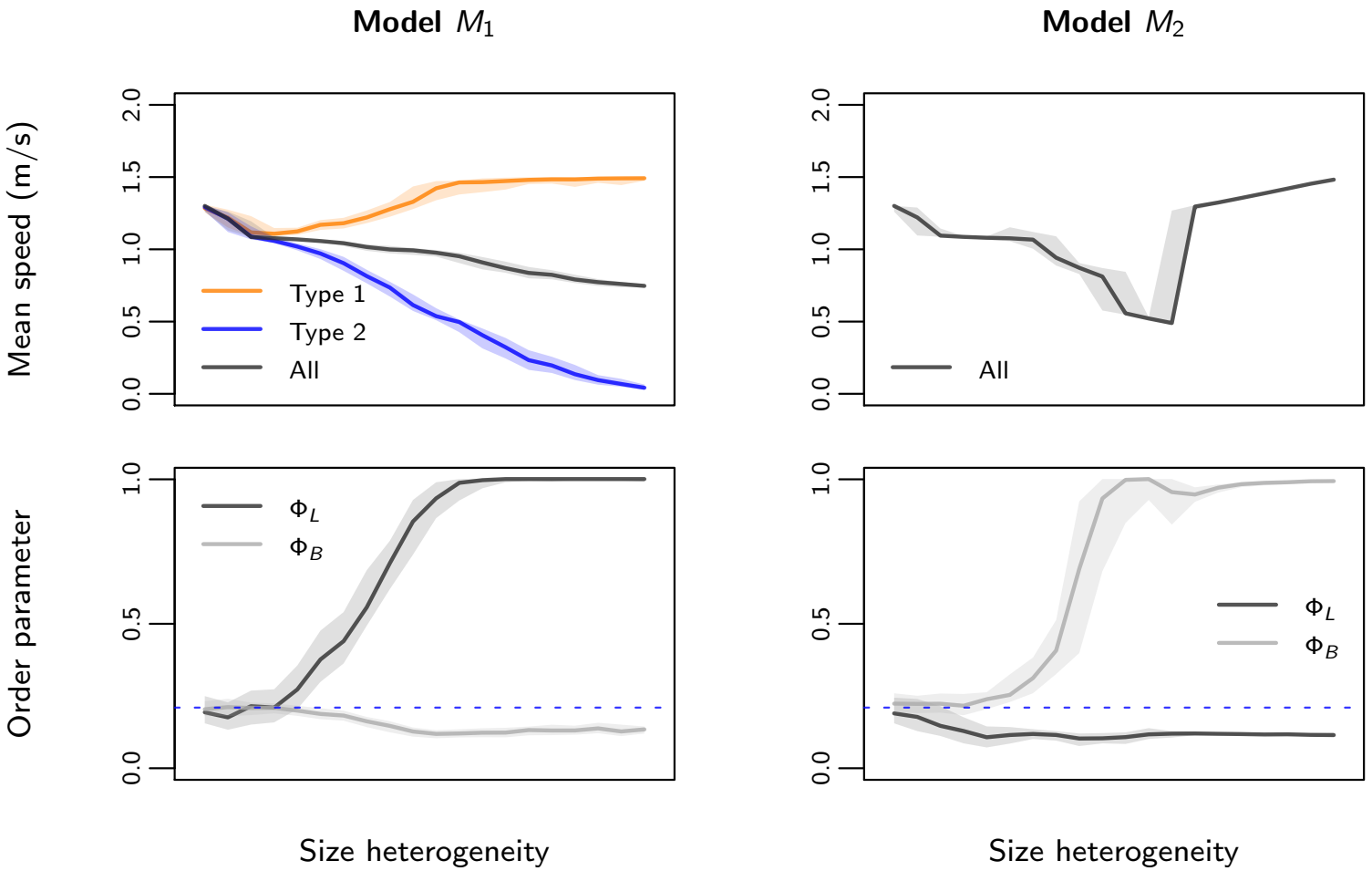


Figure: Mean speed (top panels) and order parameter for lane and band formation (bottom panels) according to the heterogeneity of the agent size for the collision-free model.

Heterogeneity of the agent' size

SFM

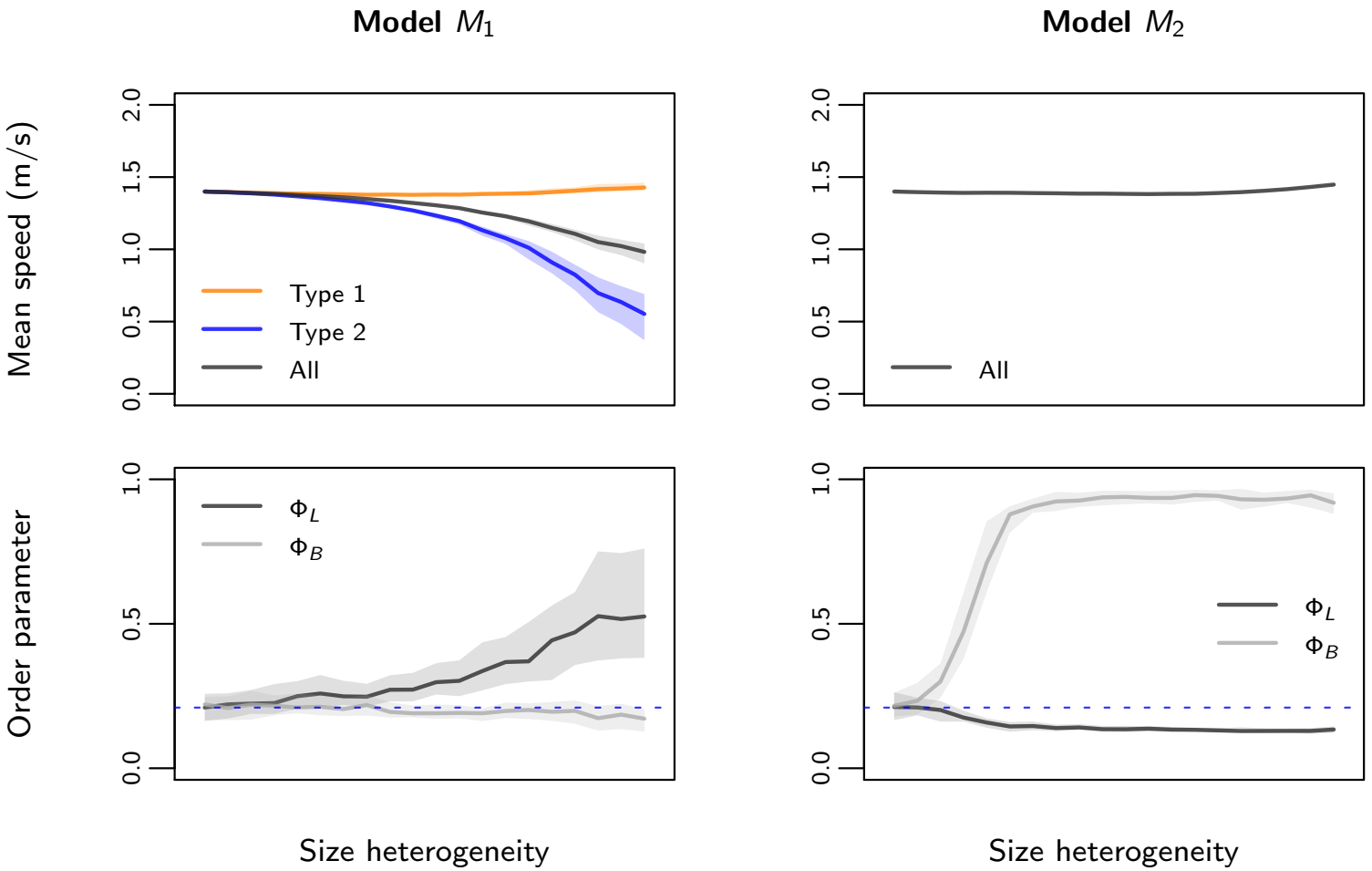


Figure: Mean speed (top panels) and order parameter for lane and band formation (bottom panels) according to the heterogeneity of the agent size for the social force model.

Summary and work perspectives

Summary

- Identification of two mixed traffic modelling approaches
  - **M1** Heterogeneity of the agent characteristics
  - **M2** Heterogeneity of the type of interactions
- Universal mechanisms for the formation of lanes (M1) or bands (M2)

  $\rightarrow$ Features observed regardless of the model used and agent characteristics (desired speed or size of the agents)

Working perspectives

- Influence of the density, system size, transient time t_0
- Robustness to stochastic noise
- Corridor and bottleneck: segregation effects for slower/bigger agents

Thank you for your attention !

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