Lightning Talk at CCS 2025

# *Noise-Induced Traffic Instabilities: Modelling and Experimental Insights*

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# Motivation: Stop-and-go Waves in Traffic

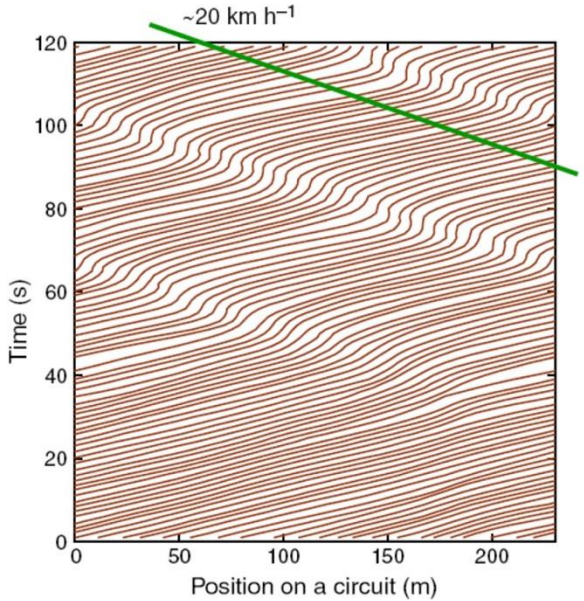




Fig 1: Sugiyama et al.: Traffic jams without bottlenecks. New J Phys, 10:033001, 2008

# Motivation: Stop-and-go Waves in Traffic

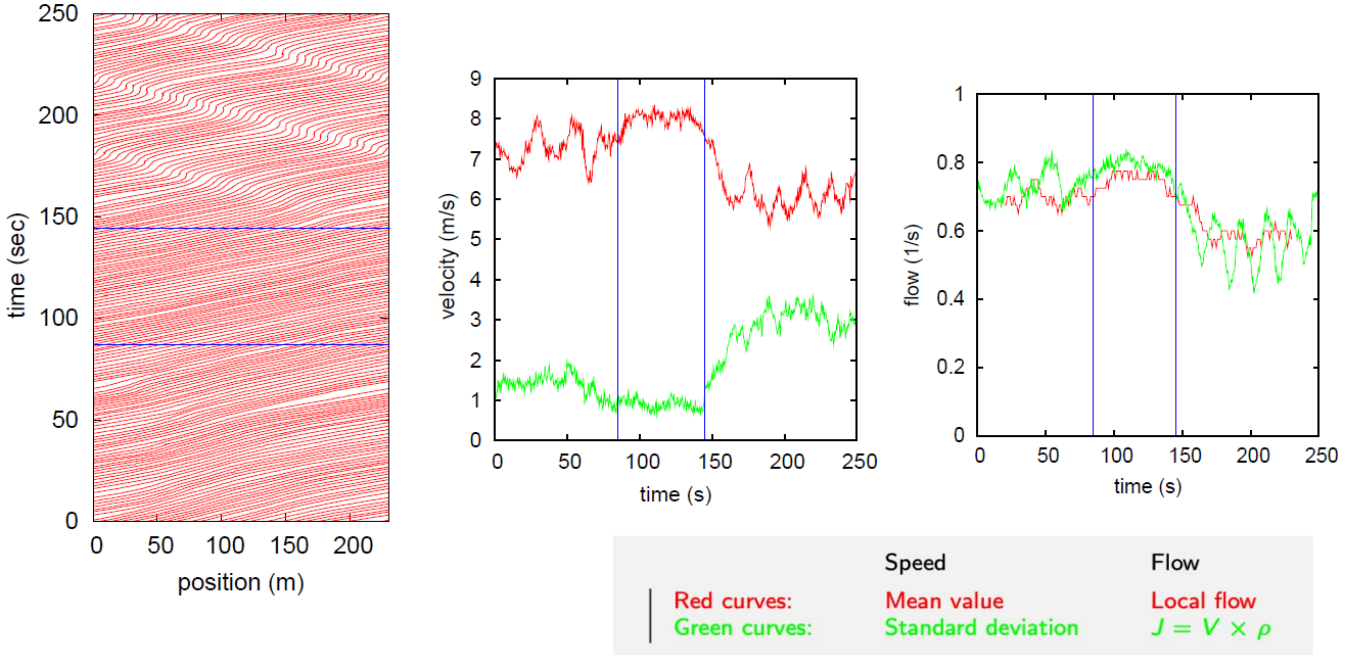



Fig 2: Phase transition in the Sugiyama Experiment. Speed drops, standard deviation rises

# Deterministic Car-Following Model

Optimal Velocity Vodel (OVM)

$$\dot{v} = \frac{v_{opt}(s) - v}{\tau}$$

is linearly stable if

$$0 < \frac{2}{\tau} < T$$

$\tau$: Reaction time
T: Timegap

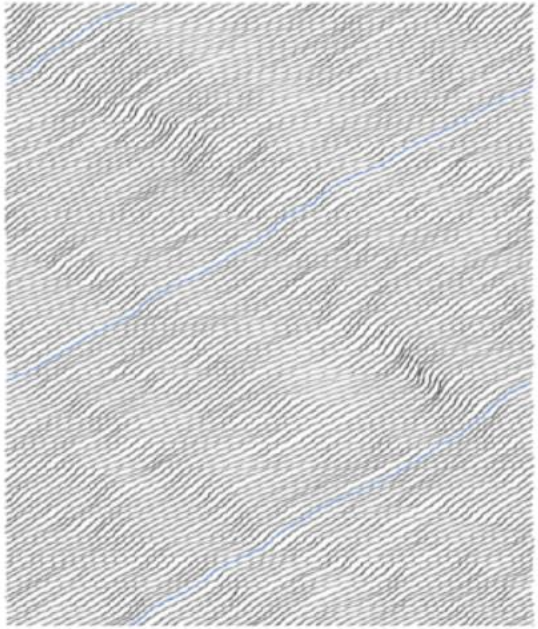
# Stochastic Car-Following Model

$$dv_n(t) = A\big(x_{n+1}(t) - x_n(t), v_n(t), v_{n+1}(t)\big)dt + \boldsymbol{\sigma dW_n(t)}$$

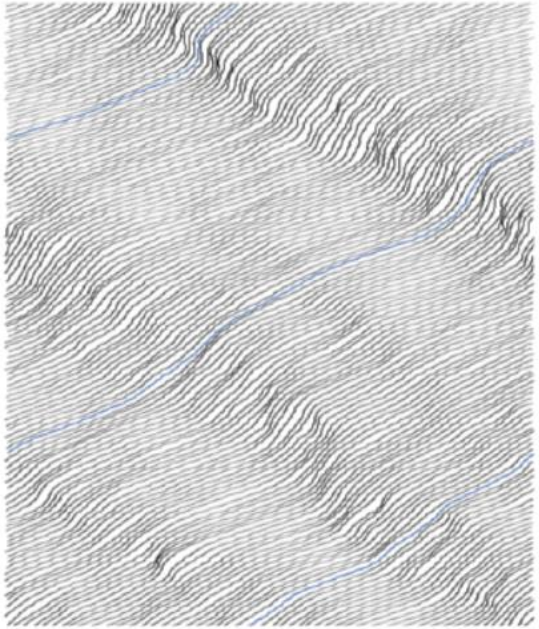
- With $\boldsymbol{\sigma dW_n(t)}$ *independent Wiener processes*
- *Can lead to unstable traffic with stop-and-go waves even if A is linearly stable.*

# Stochastic Car-Following Model

$A$ linear
(unconditional stability)



Critical settings for $A$
(subcritical instability)



# The Adaptive Time-Gap Model

No phase transition in linearly stable models-> white noise can not influence stability properties

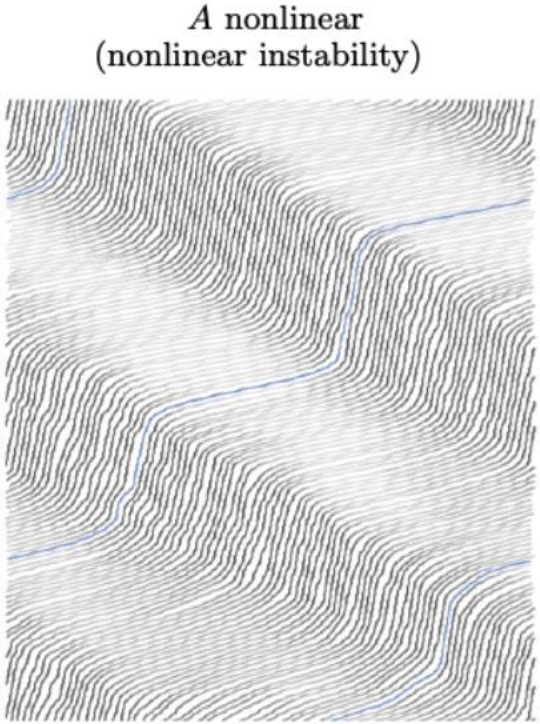
What about the Adaptive Time-Gap Model [1]

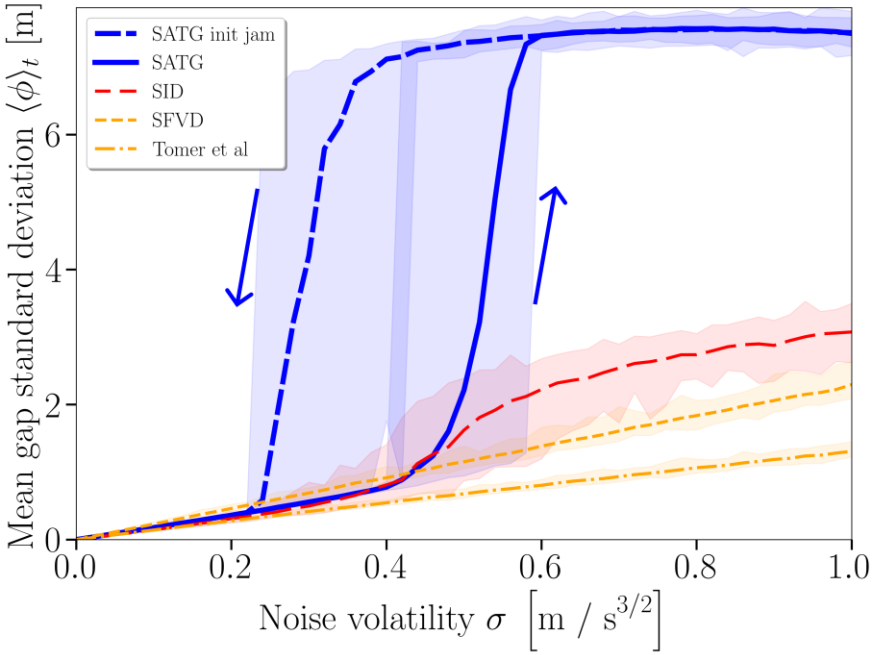
- non-linear
- Linearly stable for all parameter if $\tau, T > 2$

$$\dot{v} = \frac{1}{T_k}\left[\frac{g_k - T\, v_k}{\tau} + \Delta v_k\right] dt + \boldsymbol{\sigma d W_n}$$

[1] Tordeux, Antoine, Sylvain Lassarre, and Michel Roussignol. "An adaptive time gap car-following model." *Transportation research part B: methodological* 44.8-9 (2010): 1115-1131.

# The stochastic Adaptive Time-Gap Model (ATG)




Dufour, Oscar, et al. "Noise-induced transition to stop-and-go waves in single-file traffic rationalized by an analogy with Kapitza's inverted pendulum." *arXiv preprint arXiv:2503.23594*(2025).

# Results and Future Steps

**Linear stability not sufficient to control stop-and-go dynamics in stochastic systems**

Future Actions:

- Conduct testing on simulation platforms CARLA with driver Seat.
- Perform robotic experiments.

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