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The Physics of Traffic

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Congestion in freeway traffic is an example of self-organization in the language of complexity theory. Nonequilibrium, first-order phase transitions from free flow cause complex spatiotemporal patterns. Two distinct phases of congestion are observed in empirical traffic data–wide moving jams and synchronous flow. Wide moving jams are characterized by stopped or slowly moving vehicles within the jammed region, which widens and moves upstream at 15-20 km/h. Above a critical density of vehicles, a sudden decrease in the velocity of a lead vehicle can initiate a transition from metastable states to this phase. Human behaviors, especially delayed reactions, are implicated in the formation of jams. The synchronous flow phase results from a bottleneck such as an on-ramp. Thus, in contrast to a jam, the downstream front is pinned at a fixed location. The name of the phase comes from the equilibration (or synchronization) of speed and flow rate across all lanes caused by frequent vehicle lane changes. Synchronous flow occurs when the mainline flow and the rate of merging from an on-ramp are sufficiently large. Large-scale simulations using car-following models reproduce the physical phenomena occurring in traffic and suggest methods to improve flow and mediate congestion.