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# Dispersion and scaling of fluctuating vehicles through a sequence of traffic lights

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**Abstract**

We study the dynamical behavior of vehicles moving with fluctuating speed through a sequence of traffic lights which are controlled by the synchronized strategy. The dynamics of fluctuating vehicular traffic controlled by traffic lights is described in terms of the stochastic nonlinear map. We study two kinds of traffic: case (A) in which vehicles are allowed to pass other vehicles freely and case (B) in which vehicles are inhibited to pass other vehicles. Vehicles move together (without dispersion) for specific values of cycle time, while vehicles extend over the road for other values of cycle time. Then, vehicular traffic exhibits the dispersion. When the dispersion of vehicles occurs, the variance of arrival time shows the scaling behavior. The scaling properties are derived. The scaling form and exponents are discussed by comparing with those of dynamic scaling of rough surface.
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## 1. Introduction

Recently, transportation problems have attracted much attention in the fields of physics [1–5]. The traffic flow has been studied from a point of view of statistical

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mechanics and nonlinear dynamics [6–25]. Mobility is nowadays one of the most significant ingredients of a modern society. Vehicular traffic is optimized by traffic control strategy. For security, high-speed vehicles are controlled by traffic lights to move together with normal-speed vehicles. Also, vehicular traffic is controlled by traffic lights to give priority for a road because the city traffic networks often exceed the capacity.

The dynamical state of traffic changes by varying both cycle time and strategy. The flow throughout depends highly on the cycle time and strategy of traffic light. Optimizing traffic lights has been investigated for city traffic by using the cellular automaton model [26] and the car following model [27]. Relationship between the road capacity and jamming transition has been clarified.

Until now, one has studied the periodic traffic controlled by a few traffic lights. Very recently, the vehicle traffic moving through an infinite series of traffic lights has been investigated by using the nonlinear map model [28,29]. It has been shown that the vehicle displays the self-similar behavior and deterministic chaos. Their works have been done for the vehicular traffic moving with constant velocity through a sequence of traffic lights. However, the velocity of vehicles fluctuates irregularly from traffic light to traffic light in real city. The effect of fluctuating velocity on the traffic control has little been investigated. For security and road capacity, one must control vehicular traffic in such way that all vehicles move together. However, the tour time of vehicles is the same for specific values of cycle time, while the tour time changes from vehicle to vehicle for other values of cycle time. There are open questions. When vehicles move with fluctuating velocity, can one control the vehicular traffic by the traffic lights? If vehicles cannot move together with other vehicles, how do they extend over the road? We address the dispersion of vehicular traffic through a sequence of traffic lights.

In this paper, we study the control, dispersion and scaling of fluctuating vehicles moving through an infinite series of traffic lights, which are controlled by the synchronized strategy. We extend the deterministic model of vehicular traffic to the stochastic one to take into account fluctuation of vehicular speed. We present a stochastic nonlinear-map model to describe the dynamics of fluctuating vehicular traffic controlled by a sequence of traffic lights. We investigate the dynamical behavior of vehicular traffic by iterating the stochastic map. We clarify the dynamical behavior and the scaling properties of fluctuating vehicular traffic.

## 2. Stochastic nonlinear-map model

We consider $M$ vehicles moving through a sequence of traffic lights on the highway. Each vehicle moves at a fluctuating velocity. We consider two kinds of vehicular traffic: case (A) in which vehicles pass freely over other vehicles and case (B) in which vehicles are inhibited to pass other vehicles. In case (A), each vehicle does not depend on the other and is uncorrelated with the other vehicles. Therefore, the dynamical behavior in case (A) is consistent with that of a single vehicle. In case (B), a vehicle correlates highly to vehicles ahead if the speed is higher than that of

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