University of Calcutta

Senate House, Kolkata - 700073

Date of Enrollment : **16th August 2019**
Registration Number : **04016/Ph.D.(Sc.)Proceed/2021**
Date of Registration : **19th August 2021** Date of Letter : **7th September 2021**
(Please quote the above Number and Date in all future Correspondence)

From:
Deputy Registrar (Acting)
University of Calcutta

To:
Smt Kathakali Biswas
N-120, Maharani Indira Devi Road,
Behala, Kolkata-700060.

Madam,

I am desired to inform you that you have been granted registration for the Ph.D. programme under this University in **Physics (Theoretical)** in terms of **6.6** of the Regulations for the Degree of Doctor of Philosophy (Ph.D.), C.U., framed under UGC Guidelines, **2016.**

This registration shall remain valid for next six years with effect from the date of enrolment as indicated above.

You are to comply with the usual rules of migration in case you have passed the qualifying examinations for the Ph.D. programme from a University/Institute other than the University of Calcutta.

Title of Thesis

"Exploring The Role Of Spatial Correlation In Dynamics Of Complex Systems."

Name of the Supervisor : **Prof. Dr. Parongama Sen**
Name of the Joint Supervisor : **X**
Name of the Associate Supervisor : **X**

Yours faithfully,

Deputy Registrar (Acting)
Deputy Registrar (Acting)
University of Calcutta

N.B. Please see the instructions overleaf.

Opinion formation models with extreme switches and disorder: Critical behavior and dynamics

Kathakali Biswas [1,2] and Parongama Sen [2]

[1]Department of Physics, Victoria Institution (College), 78B Acharya Prafulla Chandra Road, Kolkata 700009, India
[2]Department of Physics, University of Calcutta, 92 Acharya Prafulla Chandra Road, Kolkata 700009, India

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In a three-state kinetic exchange opinion formation model, the effect of extreme switches was considered in a recent paper. In the present work, we study the same model with disorder. Here disorder implies that negative interactions may occur with a probability p. In the absence of extreme switches, the known critical point is at $p_c = 1/4$ in the mean-field model. With a nonzero value of q that denotes the probability of such switches, the critical point is found to occur at $p = \frac{1-q}{4}$ where the order parameter vanishes with a universal value of the exponent $\beta = 1/2$. Stability analysis of initially ordered states near the phase boundary reveals the exponential growth (decay) of the order parameter in the ordered (disordered) phase with a timescale diverging with exponent 1. The fully ordered state also relaxes exponentially to its equilibrium value with a similar behavior of the associated timescale. Exactly at the critical points, the order parameter shows a power-law decay with time with exponent 1/2. Although the critical behavior remains mean-field-like, the system behaves more like a two-state model as $q \to 1$. At $q = 1$ the model behaves like a binary voter model with random flipping occurring with probability p.

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I. INTRODUCTION

To address the problem of opinion formation in a society [1–3], several models with three opinion states have been considered recently [4–20]. Typically these opinions are taken as ± 1 and 0, where ± 1 may represent extreme ideologies. In a recent paper [17], using a mean-field kinetic exchange model, the present authors studied the effect of extreme switches of opinion, which is not usually considered in such models. Several interesting results were obtained; in particular, for the maximum probability of such a switch, the model was shown to effectively reduce to a mean-field voter model beyond a transient time. In this paper we extend the previous work by including negative interaction between the agents which acts as a disorder. Such negative interactions have been incorporated in three-state kinetic exchange models previously [10–14] and several properties have been studied in different dimensions. However, the effect of extreme switches and negative interaction both occurring together has not been studied earlier. Since these two features can occur simultaneously in reality, the dynamics of a model incorporating both is worth studying. In the absence of the extreme switches the critical point as well as the critical behavior is known [10–12]. The interest is primarily to see how the critical behavior is affected in the presence of the extreme switches.

In the present two-parameter model, representing the probabilities of negative interaction and extreme switches, in addition to obtaining the phase boundary and behavior of the order parameter, we have studied the dynamical behavior close to the fixed point. The relaxation of the order parameter from a fully ordered state is also studied at and away from criticality. The static critical behavior as well as the dynamical behavior are found to be similar to the mean-field model without extreme switches. However, we find that the nature of the phases in terms of the densities of the three types of opinions is quite different. Especially, the case with maximum extreme switches in the presence of the negative interaction leads to an interesting mapping to a disordered binary model. As a starting point, the mean-field model has been studied where the majority of the results can be obtained analytically. We derive the time derivatives of the three densities of population in terms of the transition rates which are then either solved analytically or numerically. A small-scale simulation is also made particularly to study the finite size scaling behavior of the order parameter.

In Sec. II, the model is described. Results are presented in Sec. III and some further analyses are made in the last section which also includes the concluding remarks.

II. THE MODEL

We have considered a kinetic exchange model for opinion formation with three opinion values $0, \pm 1$. Such states may represent the support for two candidates or parties and a neutral opinion [17,21,22] or three different ideologies where ± 1 represent radically different ones. The opinion of an individual is updated by taking into account her present opinion and an interaction with a randomly chosen individual in the fully connected model. The time evolution of the opinion of the ith individual opinion denoted by $o_i(t)$, when she interacts with the kth individual, chosen randomly, is given by

$$o_i(t+1) = o_i(t) + \mu o_k(t), \tag{1}$$

where μ is interpreted as an interaction parameter, chosen randomly. The opinions are bounded in the sense $|o_i| \leqslant 1$ at all times and therefore o_i is taken as 1 (-1) if it is more (less) than 1 (-1). There is no self-interaction so $i \neq k$ in general. The values of the interaction parameter are taken

Nonequilibrium dynamics in a three-state opinion-formation model with stochastic extreme switches

Kathakali Biswas [1,2] and Parongama Sen [2]

[1]*Department of Physics, Victoria Institution (College), 78B Acharya Prafulla Chandra Road, Kolkata 700009, India*
[2]*Department of Physics, University of Calcutta, 92 Acharya Prafulla Chandra Road, Kolkata 700009, India*

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We investigate the nonequilibrium dynamics of a three-state kinetic exchange model of opinion formation, where switches between extreme states are possible, depending on the value of a parameter q. The mean field dynamical equations are derived and analyzed for any q. The fate of the system under the evolutionary rules used in S. Biswas *et al.* [Physica A **391**, 3257 (2012)] shows that it is dependent on the value of q and the initial state in general. For $q = 1$, which allows the extreme switches maximally, a quasiconservation in the dynamics is obtained which renders it equivalent to the voter model. For general q values, a "frozen" disordered fixed point is obtained which acts as an attractor for all initially disordered states. For other initial states, the order parameter grows with time t as $\exp[\alpha(q)t]$ where $\alpha = \frac{1-q}{3-q}$ for $q \neq 1$ and follows a power law behavior for $q = 1$. Numerical simulations using a fully connected agent-based model provide additional results like the system size dependence of the exit probability and consensus times that further accentuate the different behavior of the model for $q = 1$ and $q \neq 1$. The results are compared with the nonequilibrium phenomena in other well-known dynamical systems.

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I. INTRODUCTION

One of the main motivations in studying nonequilibrium phenomena is to check what kind of steady states can be reached using different initial conditions. In the well-known Ising-Glauber model at zero temperature, on lattices or networks, several studies have been made to show that the steady states may not be the equilibrium steady states [1–14]. Exit probability, a quantity related to the type of final state reached from an initially biased state, has also been studied extensively in recent times in spin and opinion-formation models [15–26]. In systems with more than two states, several other interesting features, like the two-stage ordering process, have been noted [26]. In addition, how a system evolves to a stable state starting from an unstable fixed point is also a matter of interest [27].

Opinion dynamics models relevant to social phenomena have received extensive attention recently [28–31]. These models typically show a rich nonequilibrium behavior. Usually, the opinion of an agent is updated following the interaction with other individuals; sometimes the influence of media is also incorporated. In the numerous models studied so far, the interaction and the choice of the interacting agent(s) play crucial roles. The simplest models involve binary opinions typically represented by 0,1 or ± 1. The voter model [32,33], in which an agent just copies the opinion of another randomly picked up agent, is one of the simplest and earliest opinion dynamics models. Later, models involving more complexities have been constructed [29,30]. The binary models obviously cannot capture all the intricacies of the real world. Hence, models with three or more opinion states as well as continuous values of opinions have been considered in the recent past. The voter model can be generalized with a larger number of states easily [34] while other multistate models which involve the effect of more neighbors have also been considered [35,36]. In comparison to the simple binary-state models, here the opinions are not merely flipped but can change in more than one possible way. We focus our attention on the so-called kinetic exchange models where pairwise interactions are considered at each step [37]. However, these models generally have some restrictions. In particular, in the kinetic exchange models most recently studied with three discrete opinion states quantified by -1, 0, and 1 (assumed to represent e.g., left, central, and right ideologies), a transition from 1 to -1 or vice versa (i.e., an extreme switch of opinion) is not allowed to the best of our knowledge [38–42]. Also, in many other similar three-state models such a restriction is imposed [43–49]. However, human behavior being complex and unpredictable, such switches cannot be completely ruled out. In fact, there are real-world examples where even political cadres or leaders shift their allegiance to parties with totally opposite principles [50,51]. The reasons may be associated with immediate gains and selfish interests, lack of strong ideological beliefs, etc. We consider a model for opinion dynamics where extreme switches are allowed to happen and see how the dynamics are affected by this. It may be added here that for the multistate voter model or Potts-type models, such extreme switches can take place; however, in the relevant studies, the effect of such switches has not been the issue of interest specifically [34–36].

In this article, we have considered a kinetic exchange model of opinion dynamics with three states, with the possibility of switching between extreme opinions. In the mean field approach, the equations for the time derivatives are set

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Highlights

Block size dependence of coarse graining in discrete opinion dynamics model: Application to the US presidential elections

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Kathakali Biswas, Soumyajyoti Biswas*, Parongama Sen

- Considering Ising model and Kinetic exchange model as opinion dynamics model.
- Simulating electoral collage system by applying coarse graining(CG) procedure.
- Non-monotonic variation of popular candidate losing probability(ϵ) with coarse graining block sizes.
- Observable dependence of ϵ with involved noise factors.
- Analyzing the effects of two-step CG on the models.

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