Dragon-king-like extreme events in bursting neurons under excitatory and inhibitory synaptic coupling

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Extreme events such as tsunami, earthquake, flood, power blackout have devastating effect on life and society. Prediction of extreme events is thus a necessity to take *a priori* measures to mitigate disasters. It is basically defined as a large size event that deviates largely from the events of nominal size. Statistically more accurate criterion for detecting extreme events from a measured time series is available in the literature. For prediction of extreme events, its dynamic origin has to be understood. For this purpose, extreme events have been studied in simple dynamical systems including experiments in lasers and electronic circuits.

Most of the extreme events are rare and reflected as long-tail non-Gaussian distribution of event sizes, small to very large and, thus become difficult to predict. On the other hand, a class of extreme events exists that are not so rare, more frequent, as examples, the bubbling of share market before a crash, population size of Paris [1]. The population size of Paris differs largely from the other cities in France. It showed a dragon-king behavior when the population size of all cities in France were plotted according to their rank size. It revealed a large departure of the population size of Paris from a power-law distribution followed by the small to intermediate size cities. Such an abnormal dragon-king like event, if occurs in any system, help distinguish small to intermediate size events from a large size event which has a significantly different dynamic origin. This enhances predictability of large size events or extreme events of such kind. Recently, the dragon-king behavior was observed in a simple model of two unidirectionally coupled oscillators [2, 3]. It showed bubbling of a trajectory as a large excursion from the synchronization manifold near the critical coupling when a small mismatch or noise was introduced. The large excursions of trajectories emerge as large size events that differ from the trajectories which remain confined to the synchronization manifold. The probability distribution of large size events depart largely from a power-law that is followed by small to intermediate size events mainly confined to the synchronization manifold. This work also indicates that a prediction and control of such extreme events is a possibility. Further investigations of such dragon-king-like events in simple dynamical models are necessary for deeper insights of such events that is still lacking.

We report here a simple of model of Hindmarsh-Rose bursting neurons under a combination of excitatory and inhibitory synaptic coupling that shows presence of extreme events [4]. Two coupled bursting neurons establish antiphase (out-of-phase) synchronization when the inhibitory coupling specially plays a role in the occasional departure of the trajectory of the coupled system from the antiphase synchronization manifold. This large excursion of the trajectory from the antiphase synchronization manifold follows the dragon-king statistics with a large departure from a power law followed by the other trajectories which remained bounded to the antiphase synchronization manifold. Most importantly, we find a precursor to each large event that is encouraging for further investigation if we can derive a predictability measure. We extend this to a large ensemble to bursting neuron under the same coupling configuration. We attempt an experimental verification of dragon-king event in electronic analog of two Hindmarsh-Rose neuron systems.

References

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