**Website Information**

**Department of Physics**
**Dayananda Sagar University**

**Faculty details:**

| **Item** | **Details** |
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| Facult Name: | Dr. Sudharsan S |
| Room No: | A-318 |
| Designation: | Assistant Professor |
| E-Mail | sudharsan-phy@dsu.edu.in |
| Research area: | Extreme Events, Nonlinear Dynamics and Complex Networks |
| Publications (Past 5 years) | 1. **S. Sudharsan,** *Origin and dynamical analysis of extreme events in the oscillator model of microcantilevers in a tapping mode Atomic Force Microscopy* Phys. Scr. **101** 145206 (2026).<br>2. R. Shashangan, **S. Sudharsan**, Dibakar Ghosh, and M. Senthilvelan, *Controlling extreme events in neuronal networks: A single driving signal approach* Chaos **36**, 023131 (2026).<br>3. C. M. Baxter, **S. Sudharsan**, S. Ramakrishnan, *Emergence of extreme event librations and rotations and synchronization in a network of three coupled Josephson junction oscillators,* IFAC-PapersOnLine **59**, 455 (2025).<br>4. R. Shashangan, **S. Sudharsan**, Dibakar Ghosh, and M. Senthilvelan, *Propagation of extreme events in multiplex neuronal networks* Phys. Rev. E **112**, 014310 (2025).<br>5. **S. Sudharsan**, Tapas Kumar Pal, Dibakar Ghosh and Jürgen Kurths, *Extreme events in a coupled chaotic non-identical oscillators* Phys. Rev. E **111**, 034214 (2025).<br>6. R. Sree Ardhanareeswaran, **S. Sudharsan**, M. Senthilvelan and Dibakar Ghosh, *Intermittent cluster synchronization in a unidirectional ring of bursting neurons* Phys. Rev. E **111**, 014215 (2025).<br>7. R. Shashangan, **S. Sudharsan**, A. Venkatesan and M. Senthilvelan, *Mitigation of extreme events in excitable systems*, Eur. Phys. J. Plus **139,** 203 (2024).<br>8. **S. Sudharsan**, A. Venkatesan, P. Muruganandam, M. Senthilvelan, *Suppression of extreme events and chaos in a velocity-dependent potential system with time-delay feedback,* Chaos, Solitons & Fractals **161**, 112321 (2022). |

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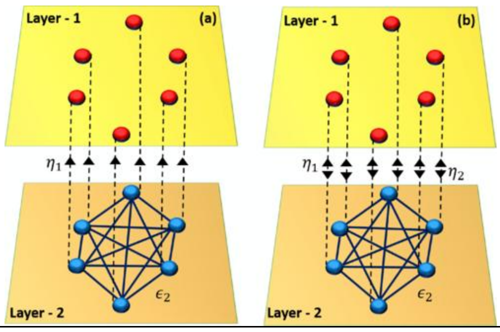
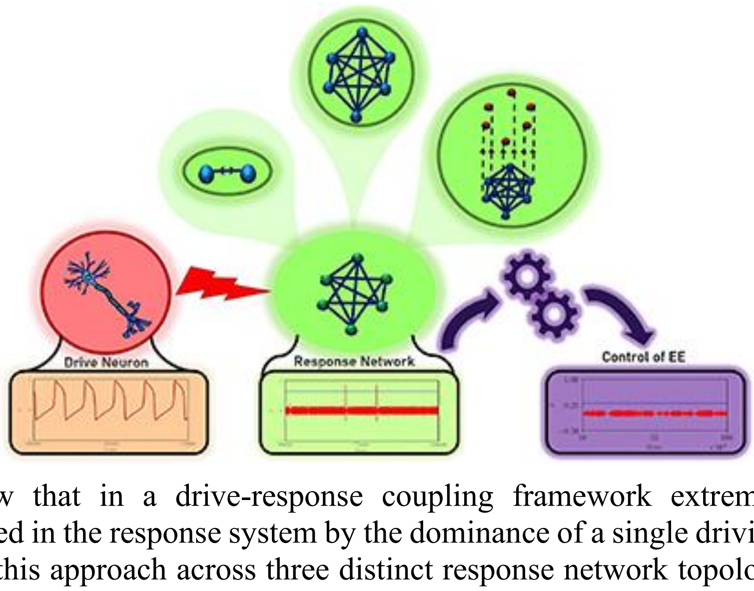
| | 9. J. Meiyazhagan, **S. Sudharsan**, A. Venkatesan and M. Senthilvelan, *Prediction of Occurrence of Extreme Events using Machine Learning* Eur. Phys. J. Plus **137**, 16 (2022). |
| Sponsored Projects (Past) | Dynamical origin of extreme events in complex networks - 2023-2025 – NPDF Project – Cost - Rs. 27.26 Lakhs |
| Profile Links: | **Google Scholar: https://scholar.google.com/citations?hl=en&tzom=-330&user=v-nqvtAAAAAJ**<br>**Scopus ID:** 57221679285<br>**Orcid:** 0000-0002-2535-4556<br>**Web of Science Researcher ID:** GMX-3804-2022 |
| Research Activities (Write about your best research results max of 2-3 pages including diagrams) | My primary research interests encompass the investigation of the dynamical origin of extreme events in complex networks. Extreme events are rare and recurrent, disastrous events whose study is of utmost importance to avert the consequences. Rogue waves, earthquakes, tsunamis, tornadoes, share market crashes, and epilepsy are some well-known examples of extreme events. Understanding fundamentally "how these events originate?" is of paramount importance for all further analysis and thereby to prevent the disasters. Difficulty in answering this question arises due to the absence of exact dynamical models to track these events and the lack of sufficient number of real time data (owing to its rarity). My research interests and experience attempt to fill this gap by studying the extreme events in simple dynamical systems and systematically extending it to the complex systems by increasing the complexity.<br>In this direction, I am intrigued to further understand profoundly the properties of extreme events in complex networks. In particular, (i) the mechanism behind its origin, (ii) the role of the degree and the coupling strength in producing extreme events in various kinds of other networks, (iii) the interrelation between several collective dynamical states and extreme events, (iv) how extreme events propagate in a network, (v) how the propagation can be mitigated and so on. Understanding, these properties, may give us a clue on several phenomena in several contexts such as (i) role of gap junctions, synaptic plasticity and neuroplasticity in promoting epileptic seizures, (ii) controlling the outbreak and spread of epidemics to prevent unprecedented death, (iii) crucial factors responsible for share market crashes, (iv) important nodes and hubs for networked power failure and so on.<br>The following are some of the properties that me and my collaborators have explored.<br>**<u>Propagation of extreme events in multiplex neuronal networks:</u>**<br>**(https://doi.org/10.1103/jy8r-7gfh )**<br> |

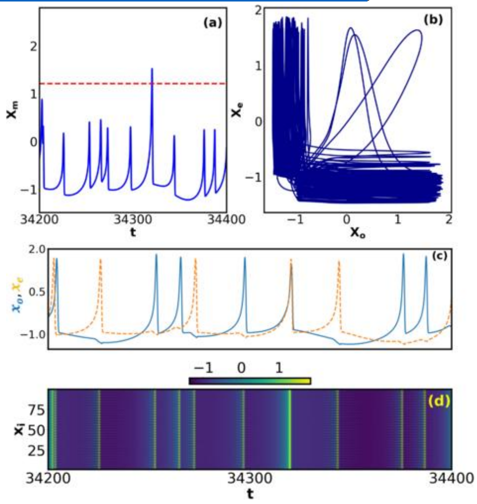
In previous studies, the propagation of extreme events across nodes in monolayer networks was studied extensively. In this work, we extend this investigation to explore the propagation of extreme events between two distinct layers in a multiplex network. We consider a two-layer network, where one layer is globally coupled and exhibits extreme events, while the second layer remains uncoupled. The interlayer connections between the layers are either unidirectional or bidirectional. We find that unidirectional coupling between the layers can induce extreme events in the uncoupled layer, whereas bidirectional coupling tends to mitigate extreme events in the globally coupled layer. To characterize extreme and nonextreme states, we use probability plots to identify distinct regions in the parameter space. Additionally, we study the robustness of extreme events emergence by examining various network topologies in the uncoupled layer. The mechanism behind the occurrence of extreme events is explored, with a particular focus on the transition from asynchronous state to a fully synchronized excitable state. For numerical simulations, we use nonidentical FitzHugh-Nagumo neurons at each node, which captures the dynamical behavior of both coupled and uncoupled layers. Our findings suggest that extreme events in the uncoupled layer emerge through the gradual disappearance of disordered state, accompanied by occasional bursts of synchronized activity. Results obtained in this work will serve as a starting point in understanding the dynamics behind the propagation of extreme events in real-world networks.

**<u>Controlling extreme events in neuronal networks: A single driving signal approach</u>**
**(https://doi.org/10.1063/5.0318162)**




We show that in a drive-response coupling framework extreme events are suppressed in the response system by the dominance of a single driving signal. We validate this approach across three distinct response network topologies, namely, (i) a pair of coupled neurons, (ii) a monolayer network of N coupled neurons, and (iii) a two-layer multiplex network each composed of FitzHugh–Nagumo neuronal units. The response networks inherently exhibit extreme events. Our results demonstrate that influencing just one neuron in the response network with an appropriately tuned driving signal is sufficient to control extreme events across all three configurations. In the two-neuron case, suppression of extreme events occurs due to the breaking of phase-locking between the driving neuron and the targeted response neuron. In the case of monolayer and multiplex networks, suppression of extreme events results from the disruption of protoevent frequency dynamics and a subsequent frequency decoupling of the driven neuron from the rest of the network. We also observe that when the size of the neurons in the response network connected to the drive increases, the onset of control occurs earlier, indicating a scaling advantage of the method.

**Intermittent cluster synchronization in a unidirectional ring of bursting neurons**
**(https://doi.org/10.1103/PhysRevE.111.014215)**




We report a new mechanism through which extreme events with a dragon-king-like distribution emerge in a network of unidirectional ring of Hindmarsh-Rose bursting neurons interacting through chemical synapses. We establish and substantiate the fact that depending on the choice of initial conditions, the neurons are divided into different clusters. These clusters transit from a phase-locked state (antiphase) to phase synchronized regime with increasing value of the coupling strength. Before attaining phase synchronization, there exist some regions of the coupling strength where these clusters are phase synchronized intermittently. During such intermittent phase synchronization, extreme events originate in the mean field of the membrane potential. This mechanism, which we name as intermittent cluster synchronization, is proposed as the new precursor for the generation of emergent extreme events in this system. These results are also true for diffusive coupling (gap junctions). The distribution of the local maxima of the collective observable shows a long-tailed non-Gaussian while the interevent interval follows the Weibull distribution. The goodness of fit is corroborated using probability-probability plot and quantile-quantile plot. This intermittent phase synchronization becomes rarer and rarer with an increase in the number of clusters of initial conditions.

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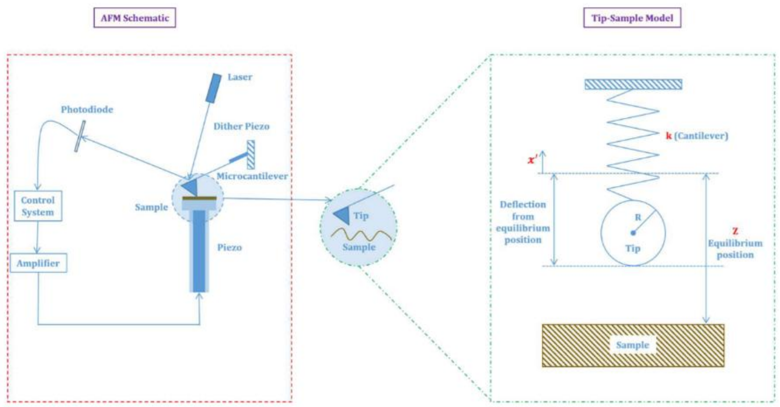
| | **<u>Origin and dynamical analysis of extreme events in the oscillator model of microcantilevers in a tapping mode Atomic Force Microscopy</u>**<br>(**https://iopscience.iop.org/article/10.1088/1402-4896/ae542c**)<br><br>In this work, we identify the emergence of extreme events in an oscillator model representing the dynamics of a microcantilever in the tapping mode of Atomic Force Microscopy. We confirm the emergence of extreme events using the peak-over-threshold method, which identifies time series trajectories that cross a pre-calculated threshold. Appropriate bifurcation diagrams, time series, phase portraits, and frequency histogram of the peaks are used to depict and identify the region and nature of emergence of extreme events. Further, the qualified extreme events are verified statistically using the Generalized Extreme Value distribution, and its interevent interval is found to follow the Exponential Distribution, confirming the rarity of the emergence. The dynamics of the extreme events are deciphered, and it is found that increasingly large amplitude oscillations precede the extreme events. Otherwise, the nature of oscillations is bound to a limit. Such a phenomenon occurs as a result of a crisis induced metamorphosis of the chaotic attractor at the critical value of the bifurcation parameter. It is also found that the interplay between the potential form and the external forcing gives rise to extreme events in the considered system. |
| Collaborations | Prof. Dibakar Ghosh, PAMU, Indian Statistical Institute, Kolkata<br>Prof. Jürgen Kurths, Postdam Institute of Climate Research, Germany<br>Prof. M. Senthilvelan, CSIR Emeritus Scientist, Bharathidasan University<br>Prof. M. Lakshmanan, DST National Science Chair, Bharathidasan University<br>Prof. P. Muruganandam, Physics, Bharathidasan University<br>Dr. P. Venkatesan, Associate Professor & Principal, Nehru Memorial College, Trichy |
| Invited Talks | Served as a Resource Person and delivered a special lecture titled **“Understanding Computation – The Third Pillar of Science”** at the **State Level Seminar** held on 18th February 2026, organized by the PG & Research Department of Physics, Government Arts College (Autonomous), Salem – 636 007, Tamil Nadu, India. |

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| Awards and Recognitions | 1. ANRF (Erstwhile SERB) National Postdoctoral Fellowship Awardee<br>2. DST INSPIRE Fellowship Awardee<br>3. University Gold Medalist in Post Graduate |