Sumanta Kundu

Postdoctoral Research Fellow
Department of Physics and Astronomy "G. Galilei"
University of Padova, Padova, Italy
Homepage: https://sumantakundu.weebly.com/

Personal Data

Date of Birth: 24.01.1991 | Gender: Male | Nationality: Indian
Email: sumanta492@gmail.com, sumanta.kundu@unipd.it | Skype: sumanta.kundu91

Research Interests

Phase transitions and critical phenomena in-and-out of equilibrium systems, percolation, polymer dynamics, complexity in protein structures, fracture and breakdown phenomena, machine learning.

Education

2019: Ph.D. in Physics (Theoretical), S. N. Bose National Centre for Basic Sciences, University of Calcutta, India.
2013: Master of Science in Physics, S. N. Bose National Centre for Basic Sciences, University of Calcutta, India.
2011: Bachelor of Science in Physics (Honors), University of Calcutta, India.

Research Experiences

April 2021 – Present
Postdoctoral Research Fellow, Department of Physics and Astronomy, University of Padova, Padova, Italy. | **Adviser:** Prof. Enzo Orlandini.
Research topic: Statistical mechanics approaches to Machine Learning and protein structure generation.

June 2019 – March 2021
Postdoctoral Research Fellow, Department of Earth and Space Science, Osaka University, Toyonaka, Osaka, Japan. | **Adviser:** Prof. Takahiro Hatano.
Research topic: Unified Understanding of Slow Earthquakes and Ordinary Earthquakes based on Non-equilibrium Physics.

February 2019 – May 2019:
Visiting Research Fellow, Theoretical Physics, The Institute of Mathematical Sciences, Chennai, India. | **Adviser:** Prof. R. Rajesh.
Research topic: Entropy Driven Phase Transitions.

November 2013– February 2019
PhD Student, Department of Theoretical Sciences, S. N. Bose National Centre for Basic Sciences, Salt Lake, Kolkata, India.
Thesis title: *Some Studies of Percolation Phenomena in Disordered Systems*.
Supervisor: Prof. S. S. Manna.

Short-term Academic Visits

July 2022 (10 days)
Institute of Physics & Astronomy, University of Potsdam, Potsdam, Germany.
Host professor: Prof. Ralf Metzler.

July 2017 (7 days)
Department of Physics, University of Lisbon, Lisbon, Portugal.
Host professor: Prof. Nuno A. M. Araújo.

June 2014– July 2014:
Department of Physics, NTNU, Trondheim, Norway.
Host professor: Prof. Alex Hansen.

Academic Skills

Monte-Carlo simulation | Large-scale molecular dynamics simulation | Finite-size scaling analysis | Regression analysis | Machine learning algorithms: DNN, CNN, and LSTM | Tools of complex network theory.

Programming Skills

Programming languages: Python, Fortran, Bash shell scripting, and C (basic)
Parallel computing: OpenMp (fortran platform)
Tools: LAMMPS, Matplotlib, Xmgrace, Gnuplot, Gimp, LaTeX, and OpenGl.

Supervision, Organized events, and Review service

2022:	**Galilean Diploma Thesis supervision**, Department of Physics and Astronomy, University of Padova, Padova, Italy. | Master's student: Leonardo Zampieri.
September 2018:	Organized "National Essay Competition 2018"- NEC 2018, for school students at S. N. Bose National Centre for Basic Sciences, Kolkata, India.
Refereed in journals: (6 Reviews contributed)	Phys. Rev. E (1), Physica A (2), Frontiers in Physics (2), Journal of Physics: Complexity (1).

Fundings, Awards and Recognition

June 2022:	Travel grant for EUTOPIA summer school from COST Action CA17139, France (**1100 Euros**).
August 2020:	Review Editor for Frontiers in Physics, and Statistical and Computational Physics.
March 2015:	Best poster award for presenting *Network Topology of a Desert Rose* at the **BOSEFEST 2015** held at S. N. Bose National Centre for Basic Sciences, Kolkata, India.
December 2014:	Best poster award for presenting *Network Topology of a Desert Rose* at the **STATPHYS-KOLKATA VIII** held at S. N. Bose National Centre for Basic Sciences , Kolkata, India.

Publications

1. "Jamming and percolation in the random sequential adsorption of a binary mixture on the square lattice".
   S. Kundu, H. C. Prates, and Nuno A. M. Araújo, J. Phys. A: Math. Theor. **55**, 204005 (2022).
2. "Breaking universality in random sequential adsorption on a square lattice with long-range correlated defects".
   S. Kundu, and D. Mandal, Physical Review E **103**, 042134 (2021).
3. "Extracting correlations in earthquake time series using complex network analysis".
   S. Kundu, A. Opris, Y. Yukutake and T. Hatano, Frontiers in Physics **9**, 656310 (2021).
4. "Jamming and percolation properties of random sequential adsorption with relaxation".
   S. Kundu, N. A. M. Araújo and S. S. Manna, Phys. Rev. E **98**, 062118 (2018).
5. "Double transition in a model of oscillating percolation".
   S. Kundu, A. Datta and S. S. Manna, Phys. Rev. E **96** 032126 (2017).
6. "Colored percolation".
   S. Kundu and S. S. Manna, Phys. Rev. E **95**, 052124 (2017).
7. "Percolation model with an additional source of disorder".
   S. Kundu and S. S. Manna, Phys. Rev. E **93**, 062133 (2016).
8. "A simple discrete-element-model of Brazilian test".
   S. Kundu, A. Stroisz and S. Pradhan, Eur. Phys. J. B **89**, 130 (2016).

9. "Network topology of the desert rose".
   S. M. Hope, **S. Kundu**, C. Roy, S. S. Manna and A. Hansen, Front. Phys. **3**, 72 (2015).
10. "Fiber bundle model with highly disordered breaking thresholds".
    C. Roy, **S. Kundu** and S. S. Manna, Phys. Rev. E **91**, 032103 (2015).
11. "Scaling forms for relaxation times of the fiber bundle model".
    C. Roy, **S. Kundu** and S. S. Manna, Phys. Rev. E **87**, 062137 (2013).

Overview of Research Work

1 **Unified understanding of slow earthquakes and ordinary earthquakes based on non-equilibrium physics**. (Status: Completed).

The fundamental difference between ordinary and slow earthquakes lies in their time scale of released energy. The duration of slow earthquakes spans from days, months to years while, ordinary earthquakes last only for few seconds. The properties and mechanics of recently discovered slow earthquakes are largely unknown. It is observed that the empirical statistical laws, for example, Gutenberg-Richter law and Omori's law do not hold for the slow earthquakes. We have investigated the non-triviality in the time series of slow earthquakes and compare the results with that of the ordinary earthquakes. We made use of the tools of complex network to answer two basic but fundamentally important questions: (i) whether the magnitudes of the earthquakes are correlated, and (ii) whether correlation exists in the inter-event times between the consecutive earthquakes. Our findings based on the visibility graph analysis, which transform a time series into a complex network, indicate that the magnitude series are not statistically equivalent to a random time series, but the apparent form of correlation is unknown. In contrast, the inter-event time series exhibit long-range correlations similar to fractional Brownian motion. Moreover, based on a number of network theoretical measures, we found that the statistical properties of the slow earthquakes are distinctly different than that of the ordinary earthquakes.

2 **Some studies of percolation phenomena in disordered systems**. (Status: Completed).

The emergence of large-scale connectivity from the small-scale connectedness is the signature of a percolation transition and therefore, the system always exhibits a global connectivity beyond this transition point. The small-scale connectivity is significantly influenced by the disorder present in the system. We introduce four different lattice percolation models which has real practical relevance and study how the percolation properties of a system are affected by different sources of disorder. Using extensive numerical simulations we conclude that although the percolation threshold is dependent on the specific source of disorder, all four variants of the percolation models belong to the percolation universality class.

3 **Failure properties of heterogeneous materials**. (Status: Completed).

Failure properties of materials subject to external load is a topic of immense interest due to its practical relevance, as precise determination of strength of a material can minimize the losses in terms of economy as well as human lives. We investigate the failure properties of such materials by means of the Fiber Bundle model and also address the role played by the heterogeneity on the dynamics of failure process. The relaxation dynamics, avalanche statistics and the brittle to quasi-brittle phase transition have been explored in this study. A universal power law divergence of the relaxation time has been observed as the external load approaches the critical point of failure. Depending on the width of the heterogeneity we also observe brittle to quasi-brittle transition characterized by the distinctly different scale-invariant behavior of the avalanche sizes.

4 **Properties of fracture networks in three dimensions**. (Status: Completed).

Fracture networks are of great importance in geophysical transport properties. In reservoirs, they provide highways for fluid and gas transport. As a proxy for fracture networks produced through hydraulic fracturing, we analyze Desert roses which are gypsum crystals consisting of intersecting disks.

We determine their geometrical structure using computer assisted tomography. Then, by mapping the geometrical structure onto a graph, the topology of the desert rose is analyzed. Further, based on what is known about the geological processes that lead to the formation of desert roses, we have constructed a model based on diffusion limited aggregation. By comparing the topology, we find that the model gets a number of the features of the real desert rose right in the narrow range of model parameter.

Research Presentations

(Total: 28 | Plenary talk: 1 | Invited talks: 4 | Contributed talks: 9 | Posters: 14)

1. Presented seminar talk on *'Non-universality in the random sequential adsorption criticality in the presence of spatially long-range correlated defects'* at the Institute of Physics & Astronomy, University of Potsdam, Potsdam, **Germany** (July 2022).
2. **Plenary speaker** at the International Conference on Condensed Matter & Statistical Physics (ICCMSP 2022) (online), held at Presidency University, Kolkata, **India** (May 2022).
3. Presented **invited talk** on *'Jamming and percolation in the random sequential adsorption in the presence of spatially correlated defects'* at the departmental seminar (Online), University of Warwick, Coventry, **United Kingdom** (March 2022).
4. Presented **invited talk** on *'Jamming and percolation in the random sequential adsorption in the presence of spatially correlated obstacles'* at the International Conference on Statistical and Computational Physics (Online), University of Gour Banga, Malda, **India** (March 2022).
5. Presented poster on *'Nonuniversal features in the random sequential adsorption in the presence of spatially long-range correlated disorder'* at the Venice meeting on fluctuations in small complex systems V, Venice, **Italy** (October 2021).
6. Presented talk on *'Breakdown of universality in random sequential adsorption in the presence of spatially long-range correlated disorder'* at the Conference of the Italian Society of Statistical Physics - SIFS (Online), **Italy** (June 2021).
7. Presented talk on *'Uncovering complex characteristics of earthquake time series using complex network analysis '* at the NETSCI 2020 Conference (Online), Rome, **Italy** (September 2020).
8. Presented talk on *'Correlations in earthquake time series as revealed by the visibility graph'* at the Slow Earthquakes workshop 2020 (Virtual), **Japan**, (September 2020).
9. Presented poster on *'Uncovering complex characteristics of earthquake time series using complex network analysis'* at the JpGU-AGU joint meeting (Virtual), **Japan**, (July 2020).
10. Presented talk on *'Quantifying statistical characteristics of earthquakes using complex network analysis'* at the Slow to Fast: SEQ Cafe, held at Osaka University, Osaka, **Japan**, (September 2019).
11. Presented poster on *'Quantifying characteristics of slow and fast earthquakes using complex network analysis'* at the International Joint Workshop on Slow Earthquakes, held at Tohoku University, Sendai, **Japan**, (September 2019).
12. Presented poster on *'Double Transition in a Model of Oscillating Percolation'* at the **NSS2018**- National Summer School on Statistical Physics, held at S. N. Bose National Centre for Basic Sciences, Kolkata, **India**, (June 2018).
13. Presented talk on *'Double Transition in a Model of Oscillating Percolation'* at the EPCQS- Emergent Phenomena in Classical and Quantum Systems held at S. N. Bose National Centre for Basic Sciences, Kolkata, **India**, (February 2018).
14. Presented poster on *'Oscillating Percolation'* at the FPSP XIV- Fundamental Problems in Statistical Physics XIV, Bruneck, **Italy**, (July 2017).
15. Presented talk on *'Colored Percolation'* at the Department of Physics, University of Lisbon, Lisbon, **Portugal**, (July 2017).
16. Presented **invited talk** on *'Percolation: A Simple Model of Phase Transition'* at the Department of Physics Jadavpur University, Kolkata, **India**, (May 2017).

17. Presented talk on *'Colored Percolation'* at the BOSEFEST 2017, held at S. N. Bose National Centre for Basic Sciences, Kolkata, **India**, (February 2017).
18. Presented talk on *'Colored Percolation'* at the Discussion meeting on the occasion of 60 years of Broadbent and Hammersley (1957) paper on percolation phenomena, held at S. N. Bose National Centre for Basic Sciences, Kolkata, **India**, (January 2017).
19. Presented poster on *'Colored Percolation'* at the FRACMEET 2017, held at Institute of Mathematical Sciences, Chennai, **India**, (January 2017).
20. Presented poster on *'Retarded Percolation Transition with the Second Source of Disorder'* at the STATPHYS-KOLKATA IX, held at Saha Institute of Nuclear Physics, Kolkata, **India** (December 2016).
21. Presented poster on *'Retarded Percolation Transition with the Second Source of Disorder'* at the STATPHYS 26- 26th IUPAP International Conference on Statistical Physics, held at PALAIS DES CONGRES, Lyon, **France** (July 2016).
22. Presented poster on *'Retarded Percolation Transition with the Second Source of Disorder'* at the BOSEFEST 2016, held at S. N. Bose National Centre for Basic Sciences, Kolkata, **India**, (March 2016).
23. Presented poster on *'Network Topology of the Desert Rose'* at the CCP2015- XXVII IUPAP Conference on Computational Physics held at Indian Institute of Technology Guwahati, Assam, **India**, (December 2015).
24. Presented poster on *'Network Topology of a Desert Rose'* at the BOSEFEST 2015, held at S. N. Bose National Centre for Basic Sciences, Kolkata, **India**, (March 2015).
25. Presented **invited talk** on *'Network Topology of a Desert Rose'* at the FRACMEET 2015, held at Institute of Mathematical Sciences, Chennai, **India**, (January 2015).
26. Presented poster and talk on *'Network Topology of a Desert Rose'* at the STATPHYS-KOLKATA VIII, held at S. N. Bose National Centre for Basic Sciences, Kolkata, **India**, (December 2014).
27. Presented poster on *'Scaling forms for relaxation times of the fiber bundle model'* at CONDENSED MATTER DAY-2013, held at Indian Institute of Science Education and Research, Kolkata, **India**, (December 2013).
28. Presented poster on *'Scaling forms for relaxation times of the fiber bundle model'* at BOSEFEST 2013, held at S. N. Bose National Centre for Basic Sciences, Kolkata, **India**, (January 2013).

Other Attended Schools/Conferences

1. EUTOPIA Summer School on topology in the context of soft matter and biological molecules, organized by Physics Department, Université Paris Cité, Paris, **France** (June 2022).
2. Workshop on Understanding Complexity (online), organized by the Italian chapter of the Complex Systems Society, **Italy** (May 2022).
3. Virtual LAMMPS workshop and symposium, hosted by Temple University, Philadelphia, **USA**, (August 2021).
4. Workshop on Rock Friction, Non-linear Physics and Slow Earthquakes, Kyushu University, Fukuoka, **Japan**, (June 2019).
5. Science Academies' Refresher Course on Statistical Physics and its Application, Tripura University, Tripura, **India**, (May 2017).
6. Statistical Physics School, Raman Research Institute, Bangalore, **India**, (April 2014).
7. International School and Conference on *'Networks in Biology, Social Science and Engineering'*, Indian Institute of Science, Bangalore, **India**, (July 2012).

References

Prof. Subhrangshu Sekhar Manna
Emeritus Professor
Department of Theoretical Sciences
S. N. Bose National Centre for Basic Sciences
Block-JD, Sector-III, Salt Lake, Kolkata-700106, India.
Email: subhrangshu.manna@gmail.com

Prof. Takahiro Hatano
Professor
Department of Earth and Space Science
Osaka University
560-0043 Osaka, Japan
Email: hatano@ess.sci.osaka-u.ac.jp

Prof. Nuno A. M. Araújo
Assistant Professor
Departamento de Física, Faculdade de Ciências,
Universidade de Lisboa, 1749-016 Lisboa, Portugal
Email: nmaraujo@fc.ul.pt

Prof. Amitava Datta
Professor
School of Computer Science & Software Engineering
The University of Western Australia
35 Stirling Highway, Perth, WA 6009, Australia.
Email: amitava.datta@uwa.edu.au

Last updated: August 3, 2022