KRISHNENDU PAL

Assistant Professor
Department of Chemistry
National Institute of Technology Durgapur
From: June, 2022-present

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Education

Jan, 2022- June,2022

National Postdoctoral Fellow(NPDF).
Physics and Applied Mathematics Unit
Indian Statistical Institute, Kolkata(www.isical.ac.in)

Feb, 2021 – Nov, 2021

Postdoctoral Fellow.
Department of Mathematics,
Indian Institute of Technology, Ropar (IIT Ropar)(www.iitrpr.ac.in),
Rupnagar, Punjab-140001, India

July, 2018 – Dec, 2020

DBT Postdoctoral Research Associate.
Postdoctoral fellowship holder of Department of Biotechnology-Research-Associate Program(DBTRA), Govt. of India,
School of Chemical Science,
Indian Association for the Cultivation of Science(www.iacs.res.in),
Jadavpur, Kolkata-700032, WB, India.

Aug, 2017 – July, 2018

Extended Senior Research Fellow.
Department of Chemical, Biological and Macro-Molecular Sciences,
S. N. Bose National Centre for Basic Sciences(www.bose.res.in),
Salt Lake City, Sector-3, JD Block, Kolkata-700106, WB, India.

Aug, 2012 – July, 2017

Ph.D. (Awarded degree on 2nd August, 2018).
Department of Chemical, Biological and Macro-Molecular Sciences,
S. N. Bose National Centre for Basic Sciences,
Degree awarded by The University of Calcutta(www.caluniv.ac.in),
87/1, College Street, Kolkata-700073, WB, India.

July, 2010 – June, 2012

Master of Science (M. Sc.).
Chemistry (Physical Chemistry Special),
The University of Burdwan(www.buruniv.ac.in),
Burdwan-713104, WB, India,
Percentage: 80.5%, First Division.

July,2007 – June, 2010

Bachelor of Science (B. Sc.).
Chemistry (Honours),
St. Xavier's College Kolkata Autonomous (www.sxccal.edu) Under The University of Calcutta, Kolkata, WB, India,
Percentage: 60.0%, First Division.

Research Experience

Ph.D

5 years of regular Ph.D. as Junior(2012-2014) and Senior(2014-2017) Research Fellow at S. N. Bose National Centre for Basic Sciences(SNBNCBS), Kolkata.

Thesis title : "**Nonequilibrium Features of Voltage Gated Sodium Ion Channel**"
Supervisor : Prof. Gautam Gangopadhyay. S. N. Bose National Centre for Basic Sciences.
Subject : Chemistry (Physical)

Thesis Summary

The research on the voltage-gated sodium ion channel draws immense attention in neuroscience as a target for anesthesia and treatments for genetic diseases in brain, muscle and heart. The sodium ion channel, coupled with the potassium channel initiates the action potential, the most essential requirement for communication between cells. Sodium channel is mostly investigated experimentally using the patch clamp and voltage clamp techniques where the channel kinetics is studied during the relaxation of channel protein. Here we have investigated the **nonequilibrium kinetic and thermodynamic responses** of sodium ion channel under **stochastic, oscillating and pulsed voltage protocols** along with various **drug binding situations**. The works done in the thesis is briefly summarized as: **(1)** We have shown that **open state drug blocking is a free energy driven process while closed state blocking is an entropy driven process**. Comparing all voltage protocols we have shown that the **inactive state blockers/Local Anaesthetics are more potent channel blockers than open state blockers. (2)** Comparing **closed-state-inactivation and open-state-inactivation path** we have explored **the energetically optimum processes or the favouring path of inactivation using reaction path contribution towards total entropy production**. **(3)** Using **oscillating external** voltage protocol we have studied the **dynamic hysteresis at nonequilibrium steady** state and its parametric dependence upon frequency, amplitude, mean voltage of the external voltage protocol. The **utilization of energy and associated dissipative work done** at nonequilibrium steady state is also investigated. A master equation description of the dynamical behaviour has been provided. **(4)** Considering **sodium and potassium channel blockers in single channel model a more realistic and extended picture of drug affected Ionic currents, Spiking frequency, Action Potential Duration(APD), Gating dynamics** etc have been studied using **Gillespie's Kinetic Monte-Carlo simulation technique. (5)** Finally we have **extended our study from one neuron to two neurons, unidirectionally coupled via electrical synapses**. We have shown that the **size of patch or channel number fluctuations** in individual neurons have very **important role in unidirectional synchronization and metabolic energy consumption** and these properties has been studied in presence of sodium, potassium drug blockers using **Langevin description.**

ESRF

After thesis submission on 26th July, 2017, I was upgraded to Extended Senior Research Fellow from 1st Aug, 2017 to 6th July, 2018.

POSTDOC-I/ RESEARCH ASSOCIATE

2.5 years of regular Department of Biotechnology Postdoctoral Research Associate(RA) as RA-I (9th July, 2018 - 30th June, 2019) and RA-II (1st July, 2019 - 31st Dec, 2020) at Indian Association for the Cultivation of Science, Kolkata.

Supervisor : Prof. Deb Shankar Ray. School of Chemical Sciences, Indian Association for the Cultivation of Science.

Subject : Nonlinear Dynamics, Reaction-Diffusion System.

Postdoctoral Work Summary

During my postdoctoral research I have switched to **Nonlinear dynamics**. I have worked on the following fields of Reaction-Diffusion Systems: **(6)** We have studied **Antiresonance** phenomenon in two component **two coupled layer chemical oscillator problem** where we have shown that t**he oscillator which is directly being driven by external periodic forcing shows deep suppression of response at an antiresonance frequency** where undriven coupled oscillator shows usual oscillation. This **happens due to the destructive interference between the coupling and the external periodic forcing**. Thus the oscillator directly being driven goes to an homogeneous steady state while the other oscillator showsusual spatiotemporal patterns. This **antiresonance phenomenon has never been studied earlier in reaction-diffusion system** which makes our study a first citation of antiresonance being occurred in reaction diffusion system. **(7)** Next we have shown a special kind of antiresonance phenonmemon occuring in **single chemical oscillator problem** which is **parametrically being driven**. Here the antiresonance occurs because of the drive excites the system through a direct transition and a parametric transition. The **destructive interference of two simultaneous transitions gives rise to an antiresonance dip in the response function-frequency spectrum**. This is manifested in the stabilization of the dynamics in an intermediate frequency range centered at the dip, outside which one observes spatio-temporal patterns due to instability. **(8)** Next we consider a model reaction-diffusion system with **two coupled layers** in which one of **the components in a layer is parametrically driven by a periodic force**. On perturbation of a homogeneous stable steady state, the system exhibits **parametric instability inducing synchronization in temporal oscillation at half the forcing frequency** in absence of diffusion and **spatio-temporal patterns in presence of diffusion**, when strength of parametric forcing and the strength of coupling are kept above their critical thresholds. Our objective in this work is **to demonstrate how the diffusive coupling between two layers can induce temporal or spatio-temporal synchronization in oscillatory chemical reaction or reaction-diffusion systems through parametric instability.**

POSTDOC-II

9 months of regular Institute Postdoctoral Fellow (9th Feb, 2021- 12th Nov, 2021,) at Indian Institute of Technology Ropar (IIT Ropar), Punjab.

Supervisor : Prof. Partha Sharathi Dutta, Department of Mathematics, IIT Ropar.

Subject : Nonlinear Dynamics, Ecology, Critical Transitions, Spatial Early Warning Signals.

Postdoctoral Work Summary

(9) In my 2nd postdoctoral research I have worked on **Catastrophic Critical Transitions** on **Spatial Ecological systems**. Catastrophic Critical Transition is **sudden irreversible change in population density** of an ecosystem **from a stable state to alternating degraded state** which occurs due to variation of the bifurcation parameter (such as rainfall, grazing, harvesting, Temperature etc) via mostly **Saddle node bifurcation**. Non-catastrophic Transition also occurs via Transcritical, Pitchfork, Hopf Bifurcations etc where the transition is mostly gradual or smooth. Critical Transitions are associated with **Critical Slowing Down(CSD)**. CSD can be identified by certain **Temporal Indicators** such as **increasing Variance, increasing Autocorrelation, Increasing Skewness** near bifurcation point or **Tipping point**. These Indicators can predict a forthcoming Critical Transition from the available time series data. Also similar Spatial Indicators are available which can predict approaching transition form spatial data/ spatial pattern. These Indicators are called **Spatial Early Warning Signals**(EWS). In this work I have shown using various ecological models that **with increasing environmental noise correlation the critical transition can be delayed in contrast to the literature that environmental color noise correlation can only cause early critical transition.** I have used Ornstein-Uhlenbeck Noise and Spatially extended systems and shown the spatial patters of critical transition.(Manuscript to be submitted). Recently I am trying to apply Non-equilibrium Statistical Mechanics (Fokker-Planck, Master Equation description, Landscape-Flux theory etc) to explore the fate of ecological systems.

List of Publications

Research Article
(International, Peer Reviewed)

1 "Probing kinetic drug binding mechanism in voltage-gated sodium ion channel: open state versus inactive state blockers", **K. Pal** and G. Gangopadhyay. **Channels(Austin, Tex.)**, **9, 307-316 (2015).** (Taylor & Francis Publishing Company). ISSN:19336969(web), 19336950(print). Impact Factor: **2.123** (2020).

2 "Dynamical characterization of inactivation path in voltage-gated Na + ion channel by nonequilibrium response spectroscopy", **K. Pal** and G. Gangopadhyay. **Channels(Austin, Tex.), 10, 478-497(2016).** (Taylor & Francis Publishing Company). ISSN:19336969(web), 19336950(print). Impact Factor: **2.123** (2020).

3 "Nonequilibrium response of a voltage gated sodium ion channel and biophysical characterization of dynamic hysteresis", **K. Pal**, B. Das and G. Gangopadhyay. **J. Theoretical Biology, 415, 113-124 (2017).** (Elsevier Publishing Company). ISSN: 00225193. Impact Factor: **2.691** (2020).

4 "Termination of Action Potential Due to Site Selective Ion Channel Blockers", **K. Pal** and G. Gangopadhyay. **Fluctuation and Noise Letters**, **19(2), 2050015 (2019).** (World Scientific Publishing Company). ISSN: 02194775(print), 17936780(web). Impact Factor: **1.136** (2019).

5 "Spatiotemporal antiresonance in coupled reaction-diffusion systems", **K. Pal**, S. Paul, and D. S. Ray, **Physical Review E**, **101, 052203 (2020)**. (American Physical Society). ISSN: 24700045 (print), 24700053(web) .Impact Factor: **2.529** (2020).

6 "Antiresonance and stabilization of spatio-temporal dynamics of parametrically driven Gray-Scott reaction-diffusion system" by **K. Pal** and D. S. Ray, **ChemistrySelect**, **5(34), 10787-10794 (2020).** (Wiley-VCH). ISSN: 23656549(web). Impact Factor: **2.109** (2020).

7 "Synchronization and metabolic energy consumption in stochastic Hodgkin-Huxley neurons: Patch size and drug blockers", **K. Pal,** D. Ghosh and G. Gangopadhyay. **Neurocomputing, 422, 222-234 (2021)**. (Elsevier Publishing Company). ISSN: 09252312. Impact Factor: **5.719** (2020).

8 "Parametric instability-induced synchronization in chemical oscillations and spatio-temporal patterns", S. Paul, **K. Pal** and D. S. Ray. **Physical Review E, 102, 052209 (2020)**. ISSN: 24700045 (print), 24700053(web) (American Physical Society). Impact Factor: **2.529** (2020).

9 "Environmental color noise induced early critical transition in spatio-temporal ecological systems", **K. Pal** and P. S. Dutta.**(2022).** Manuscript to be submitted.

Conference Series
(International, Peer Reviewed)

"Nonequilibrium thermodynamics and a fluctuation theorem for individual reaction steps in a chemical reaction network"**, K. Pal,** B. Das, K. Banerjee and G. Gangopadhyay, Journal of Physics: Conference Series, 638, 012002 (2015), STATPHYS-KOLKATA-VIII.

Skills

- **Non-equilibrium Thermodynamics:** Recent developments: Entropy production rates, Free energy, Dissipative work done etc and response dynamics.
- **Nonequilibrium Statistical Mechanics: Kinetic Monte-Carlo simulation(Gillespie simulation), Langevin Dynamics simulation** using self written Fortran code. Analytical techniques to solve **Master Equation.** Knowledge of **Langevin and Fokker Planck solution techniques.**
- **Nonlinear Dynamics(NLD): Phase plane analysis, Linear stability analysis, Bifurcations, Limit cycles** etc in various nonlinear systems. Mathematical Techniques of NLD such as: Perturbation techniques such as **Lindstedt-Pöincaré technique, the Method of Averaging, the Method of Multiple Scales, Blekhman perturbation scheme. Renormalization Group Theory** etc.
- **Theoretical Ecology:** Catastrophic, Non-catastrophic Critical Transitions, Temporal and Spatial **indicators** of **Early Warning Signals(skewness, correlation, standard deviation etc)** of **Critical Transitions**.
- **Reaction Diffusion Systems: Turing instability, Hopf instability, Spatio-Temporal Antiresonance, Pattern formation.**
- **Numerics:** Solving **coupled ODE using Euler, Huen, Runge-Kutta Method. Partial Differential Equation using FTCS** (Forward in Time Central in Space Method), **Box-Muller Algorithm** for **Gaussian Random Number** generations, Differential and Integral method for Ornstein-Uhlenbeck **Color Noise generation**, Solving **Stochastic Differential Equations**(SDE). Expert in **Fortran Programing**.
- Worked on **Coherence resonance, Stochastic Resonance,** between external signal and internal noise in Hodgkin-Huxley neuron. Developed self written Fortran code to analyze CV(coefficient of variation), ISIH(Inter Spike Interval Histogram), SNR (Signal to Noise Ratio) of spike trains. Knowledge of biological neuron models such as Hodgkin-Huxley, FitzHugh–Nagumo, Morris-Lecar, Hindmarsh-Rose etc and their mathematical extension to coupled linear or complex networks. Theoretical and Computational knowledge of Electrophysiology: conductance of Ion Channels, Ionic current measurements. Theoretical knowledge of Voltage clamp, Patch clamp techniques. Markovian modeling of Ion channels (NA^+, K^+, Ca^{2+} channels), Effect of Local anesthetics, Single channel simulation using **Gillespie simulation**. Knowledge of **Dynamic Hysteresis**, Memristor properties of neural circuits.

Technical Skills

- FORTRAN programing (Expert)
- MATLAB (Advanced)
- C programing (Beginner).
- MATHEMATICA (Advanced).
- Plotting softwares : GNUPLOT(Expert), XMGRACE(Expert), ORIGIN(Expert), R(Novice).
- Libre Office (Expert), Microsoft Office (Expert), TEXMAKER(Expert).
- Operating system: Linux (Expert) and Windows (Expert).

Teaching Assistantship

Taken regular classes of B. Tech students for the IIT Ropar UG Mathematics Course **MA201: Differential Equations.**

Syllabus:

Ordinary Differential Equations: First-order Equation, Exact equations, integrating factors and Bernoulii equations. Lipschitz condition, Picard's existence and uniqueness theory. Second order differential equations with constant coefficients: homogeneous and non-homogeneous differential equations, Wronskian and linear independence of solutions, method of variation of parameters, Cauchy-Euler equations, method to solve second order equations with variable coefficients, some applications. Solution of IVP using Laplace Transform and Euler's method. Series solutions, Frobenius method, Legender and Bessel equations, orthogonal properties of Legender polynomials

Partial Differential Equations: Linear second order partial differential equations and their classification, heat equation, vibrating string, Laplace equation, method of separation of variables.

Subjects Taught at NIT Durgapur

ODD SEM:

1. **States of Matter(Gas, Solid, Liquid):** NIT Durgapur 3rd Sem Intigrated MSC Students.[CYC301]
2. **Advanced Quantum Mechanics**: NIT Durgapur 9th Sem Intg. MSC+ 3rd Sem MSC Special Students. [CYE911/CYC9111]
3. **Irreversible Thermodynamics**: NIT Durgapur 9th Sem Intg. MSC+ 3rd Sem MSC Special Students.[CYE912/ CYC9112]
4. **Engineering Chemistry-1,** BTech, 1st Sem.[CYC01]
5. **Engineering Chemistry-2,** B.Tech Chemical Engineering, 3rd Sem.[CYC331]

EVEN SEM:

1. **Phase Equilibrium and Colligative propertes**, NIT Durgapur 4th Sem Intigrated MSC Students.[CYC402]
2. **Data Analysis/Statistics**: NIT Durgapur 6th Sem Intigrated MSC Students.[CYC601]
3. **Statistical Thermodynamics/Statistical Mechanics**, NIT Durgapur 8th Sem Intg. MSC+ 2nd Sem MSC Special Students.[CYC2101/CYC801]
4. **Engineering Chemistry-1,** BTech, 2nd Sem.[CYC01]

Physical Chemistry Lab

1. 9th Sem Intg. MSC+ 3rd sem Msc
2. 7th sem Intg. Msc/1st sem Msc
3. 6th Sem Intg. MSC
4. 4th Sem Intg. MSC
5. B.Tech 1st Sem

Journal Reviewer

Review Editor of **Frontiers in Computational Neuroscience**
Journal Link: https://www.frontiersin.org/journals/computational-neuroscience#

Conference Attended

1 Current Trends in Biochemical & Biophysical Modeling (CTBBM), 7-8 th October 2013, S.N. Bose National Centre for Basic Sciences, Kolkata [Poster presentation].

2 National Symposium on Nonequilibrium Statistical Physics and Nonlinear Dynamics , 2-4th January, 2014, Indian Association for the Cultivation of Science, Kolkata [Poster presentation].

3 Theoretical Chemistry Symposium(TCS), 18-21st December, 2014, National Chemical Laboratory, Pune [Poster presentation].

4 Perspective in Teaching and Research in Physical Chemistry , 21-22nd August, 2015, Indian Association for the Cultivation of Science, Kolkata [Poster presentation].

5 The Annual Symposium of the Indian Biophysical Society, Indian Institute of Science and Educational Research, Mohali, 22nd - 25th March 2017[Poster presentation].

6 Nonlinear Dynamics in Chemistry & Biology, 08-09 April, 2019, S.N. Bose National Centre for Basic Sciences, Kolkata [Poster presentation].

Scholarship & Fellowship

1 **Inspire Scholarship** (2008-2012) of Govt. of India.

2 **Junior, Senior, Extended Research Fellowship** of S. N. Bose National Centre For Basic Sciences (2012-2018).

3 **DBT RA National Postdoctoral Fellowship** of Department of Biotechnology, Govt. of India (2018-2020).

4 **Postdoctoral Fellowship** of Indian Institute of Technology, Ropar(Feb 2021- Nov,2021).

5 **Dr. D. S . Kothari National Postdoctoral Fellowship**, UGC, Govt. of India(9th September, 2021).

6 **National Postdoctoral Fellowship(NPDF)**, SERB, Govt. of India(16th December, 2021).

Personal Profile

I love teaching. Calculus, Programming, Geoscience and Neuroscience are my favourite science subjects. On the other hand I love English literature and History. I do photography in pass times. I love and play Football and Badminton regularly(Intra-Institute Badminton champion, 2018). I love trekking mountains. Learning guitar and tabla(Indian classical drum). I frequently also take part in various social works like teaching children of slum dwellers(been an active member of Literacy Camp, SNBNCBS) and blood donation. I had been a former board member of SNBose Club(Muktangan) and coordinator of Visual Arts section of Muktangan where I actively contributed in cultural programs.

Marital Status : Married
Nationality : Indian
LinkedIn profile : https://www.linkedin.com/in/krishnendu-pal-0380126a/
Google Scholar : https://scholar.google.com/citations?user=8ZlmxHAAAAAJ&hl=en&oi=ao

I declare that the information stated above are true.

Krishnendu Pal

31-08-2023