

Joy Das Bairagya



Ph.D. Research Scholar in Complex Systems, Physics, IIT Kanpur

Personal Information

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About Me

I am a physics researcher with five years of experience in **theoretical** and two years' experience on **experimental** studies on **complex systems**, including **collective behaviour**, **game theory**, **nonlinear dynamics**, **evolution**, **nonequilibrium statistical physics** and **adaptation**. My PhD focuses on **collective decision-making** and **self-organization** in *Diacamma indicum* ants during nest relocation, combining **behavioural experiments** with **agent-based** and **mathematical modelling**.

I am interested in applying game theory to ecological and social dilemmas, investigating cooperation and strategic interactions in **ants** and **human societies**. My research spans bounded rationality in humans, biological coordination, and optimal transport. I specialize in:

- **Collective Behaviour & Self-Organization** in decentralized biological systems
- **Behavioural Experiments & Data Analysis** in ant colony decision-making
- **Statistical hypothesis testing and mathematical modelling** in ant decision-making
- **Agent-Based & Evolutionary Game Theoretic Models** for cooperation and transport efficiency
- **Complex Systems & Nonlinear Dynamics** in biological and social contexts
- **Nonequilibrium Statistical Mechanics and Network theory** in cooperative game theory

My interdisciplinary approach enables me to address challenges across biology, ecology, and socio-economic systems.

Education

No.	Degree(s)	Institute/University/Board	Country	Subject(s)	Year
1.	Doctor of Philosophy (PhD)	Indian Institute of Technology Kanpur (IITK)	India	Physics	Ongoing
2.	Master of Science (M.Sc.)	Indian Institute of Technology Kanpur (IITK)	India	Physics	2020
3.	Bachelor of Science (B.Sc.)	University of Burdwan	India	Physics (Hons.) Chemistry, Mathematics	2017
4.	Higher Secondary Examination (12th Standard)	West Bengal Council of Higher Secondary Education	India	Physics, Chemistry, Mathematics, Biology, English and Bengali	2014
5.	Secondary Examination (10th Standard)	West Bengal Board of Secondary Education	India	Bengali, English, Physical Science, Life Science, Mathematics, History, Geography	2012

Research Experience

Doctor of Philosophy (PhD)

[Start Date: 01/08/2020 – Ongoing]

Department of Physics, Indian Institute of Technology Kanpur, Kanpur | Supervisor: Prof. Sagar Chakraborty

Thesis Topics: Decisions in queen-less ants

- I. Empirical evidence on **Japanese queen-less ants** (*Pristomyrmex punctatus*) suggests **coexistence** of small body sized **cooperator** ants and large body sized **defector** ants. The presence of defectors leads to the overexploitation of the **common good**—i.e., the **workforce** produced by cooperators. Owing to **overexploitation**, every isolated colony should inevitably **collapse**. To scrutinize the reason behind prevention of such **tragedy of commons**, I build an **evolutionary game** theoretic model. My study highlights the paramount role of **asymmetric migration** and **hostility** in **preventing extinction**.

- II. **Trail laying ants** are known for efficient **traffic management** collectively, however it is largely unexplored how **tandem running** ants maintain their transport through **decentralized decision making**. *Diacamma indicum* is an ant species **relocates** their nest members to an optimal nest from suboptimal one using tandem running. By creating **nature inspired path constrained** during the relocation in controlled laboratory setup confirmed, despite being **stuck in jams**, their **decentralized** but efficient **adaptive decision-making** capabilities **emerges** as a **collective solution** to the hindrance during relocation. **Modelling** the situation through **agent-based simulation** (in python) helps to pinpoint and comprehends the impact of **individual behavior** on **mitigating jams** and overall transport phase. (Collaboration with Ant Lab, Department Biological Sciences, IISER Kolkata).
- III. Investigate whether **ants' self-organized decision** for managing traffic at a path constriction in the middle of the path is optimal by modeling it using **classical game theory**. Additionally, **experimentally test** whether changing the position of the path constriction results in the emergence of different solutions, as predicted by game theory. (Collaboration with Ant Lab, Department of Biological Sciences, IISER Kolkata)
- IV. From **experimental observation** of relocations in a path which creates **dilemma** between **Nash equilibrium** and **Pareto optimal solution**, I try to comprehend the ability, beyond decision making, of taking **strategic decisions** during **bidirectional** journey while relocating their nestmates. To fully understand the experimental observation, I try to build a **theoretical** as well as **agent-based model**. (Collaboration with Ant Lab, Department Biological Sciences, IISER Kolkata)

Other Topics:

1. Eco-evolutionary game theoretic model
 - I. To understand theoretically, feasible ways for **emergence of cooperation** to prevent catastrophic **tragedy of the commons** in a population with **finite carrying capacities** while sharing a **common resource**, I build an **evolutionary game** theoretic model.
 - II. To scrutinize, how a **finite population** could prevent tragedy of the commons while harvesting a **growing common resource**, I build an evolutionary game theoretic model from **microscopic** scenarios using **non-equilibrium statistical physics**.
 - III. By modelling a **Bayesian evolutionary game** theoretic model, I try to comprehend the paramount role of agent's **erroneous information channel** for perceiving **information** about common resource.
2. Emergence of **bounded rational behavior** in **hunter-gatherer**
 - I. Theoretical model to comprehend feasible evolutionary reason behind the **bounded rationality in humans**. Through **emergence of coordination** in a **stag-hunt** strategic situation, **procedurally rationality** happens to **evolutionary stable strategy (ESS)** against the invasion of **VNM rationality**.
3. Emergence of **Cooperation** in a sparse network due to **collaboration**. (Collaboration with prof. Jonathon Newton of **Institute of Economic Research at Kyoto University**)

M.Sc. Project

[Start Date: 01/08/2019 – 30/07/2020]

Department of Physics, Indian Institute of Technology Kanpur, Kanpur | Supervisor: Prof. Tapobrata Sarkar

Work Topics: Black hole thermodynamics

- I. The geometry of RN-AdS fluids
- II. Investigated the Geometry of AdS black hole thermodynamics in extended phase space

Fellowship and Scholarships

- I. [Prime Minister's Research Fellowship and Grants \(2021-ongoing\)](#)
- II. Institute Research Fellowship of IIT Kanpur (2020-2021)
- III. [Department of Science & Technology, Innovation in Science Pursuit for Inspired Research \(INSPIRE\) \(2014-2017\)](#)
- IV. [Swami Vivekananda Merit-cum-Means Scholarship \(2012, 2014\)](#)

Academic Achievements

Secured top ranks in national entrance examinations:

- I. TIFR GS-2018 (AIR-13)
- II. JEST-2018 (AIR-96), JEST-2020 (AIR-157)
- III. JAM-2018 (AIR-48)
- IV. NET-2019 (AIR-47, LS)
- V. GATE-2020 (AIR-1610)

Research Skills

- * Developing and executing research both analytical and experimental.
- * Experienced in designing and executing in orgasmic level research, particularly with ants.
- * Experienced in different observational data collection procedures concerning ants' behavior.
- * Experienced in handling and interpreting a broad spectrum of data set by using different statistical methods.
- * Experienced in building and analyzing a mathematical model to comprehend empirical observation using non-linear dynamics and non-equilibrium statistical mechanics.
- * Experienced in building agent-based model to comprehend experimental observation.
- * Experienced in building analyzing mathematical model to scrutinize an analytical question.
- * Experienced in using non-linear dynamics, nonequilibrium statistical physics to analyze different aspect of a research problem.
- * Experienced in classical game theory to model strategic decision making.
- * Experienced in evolutionary game theory to model feasible evolutionary reason behind any strategy.

- * Assisted in supervising Doctorate, Master's, Research project student, particularly in the realm of designing the research, data analysis, building mathematical and agent-based model, python programming, LaTeX and presentation skills.
- * **Programming Language:** Python, Mathematica, Linux
- * **Technical Software:** Origin, LaTeX, Inkscape
- * **Agent-based model:** Python

Publication

Manuscript under preparation

1. **J. D. Bairagya**, U. Chakraborty, S. Annagiri, S. Chakraborty, "A game played by tandem-running ants: Hint of procedural rationality". (arXived)
2. Manish K. Pathak, **J. D. Bairagya**, S. Chakraborty, S. Annagiri, "Traffic jams and its resolution through adaptive decisions in tandem-running ants". ([bioRxived](#))

Publications

1. A. Patra, **J. D. Bairagya***, S. Chakraborty, "Bayesian eco-evolutionary game dynamics", Physical Review E 111 (4), 044401 (2025). (* Corresponding other)
2. **J. D. Bairagya**, S. Chakraborty, "Catalyzing coordination in stag-hunt game: Emergence of evolutionary stable procedural rationality", Journal of Physics: Complexity 6 (3), 035004 (2025).
3. **J. D. Bairagya**, S. Chakraborty, "Hostility prevents the tragedy of the commons in metapopulation with asymmetric migration: A lesson from queenless ants", Physical Review E 108 (6), 064401 (2023).
4. **J. D. Bairagya**, S. S. Mondal, D. Chowdhury, S. Chakraborty, "Eco-evolutionary games for harvesting self-renewing common resource: effect of growing harvester population", Journal of Physics: Complexity 4 (2), 025002 (2023).
5. **J. D. Bairagya**, S. S. Mondal, D. Chowdhury, S. Chakraborty, "Game-environment feedback dynamics in growing population: Effect of finite carrying capacity", Physical Review E 104 (4), 044407 (2021).
6. **J. D. Bairagya**, K. Pal, K. Pal, T. Sarkar, "Geometry of AdS black hole thermodynamics in extended phase space", Physics Letters B 819, 136424 (2021).
7. **J. D. Bairagya**, K. Pal, K. Pal, T. Sarkar, "The geometry of RN-AdS fluids", Physics Letters B 805, 135416 (2020).

(Please refer to my [Google Scholar](#) profile)

Teaching Experience as PMRF Fellow

As a **Prime Minister's Research Fellow (PMRF)**, I am required to complete **50 hours of teaching** per year outside my home institute. To fulfill this obligation, I have served as an **instructor** for the following course:

- I. Solving textbook problem of Quantum Mechanics (Online)
- II. Short introduction to Statistical Hypothesis Testing (at [Institute of Smart Structures and Systems](#))
- III. Mathematical introduction to Chaos and Fractals (at [Institute of Smart Structures and Systems](#))
- IV. Introduction to LaTeX ([Department of Information Technology, Chhatrapati Shahu Ji Maharaj University, Kanpur](#))
- V. Evolutionary Game Theory (at [Institute of Smart Structures and Systems](#))
- VI. Equilibrium concepts in game theory (at [Institute of Smart Structures and Systems](#))

Teaching Assistance Experience

In addition to role as an instructor, I have also worked as a teaching assistant for the following courses

- I. Statistical Mechanics [Instructor: Prof. Sagar Chakraborty, IIT Kanpur]
- II. Non-equilibrium Statistical Mechanics [Instructor: Debashish Chowdhury, IIT Kanpur]
- III. Statistical Mechanics [Instructor: Prof. Girish S. Setlur, NPTEL]
- IV. Probability and Statistics [Instructor: Prof. Andrew Thangaraj, NPTEL]

Conference and Schools

- I. Presented “A game played by tandem-running ants: Hint of procedural rationality” at XXXVIII International Ethological congress **Behaviour 2025, in Kolkata, India** (August 2025)
- II. Presented “Catalysing coordination in stag-hunt game: Emergence of evolutionary stable procedural rationality” at Decision, Games, and Evolution at **ICTS Bangaluru, India** (March 2025)
- III. Presented “Hostility prevents the tragedy of the commons in metapopulation with asymmetric migration: A lesson from queenless ants” at **Statphys28, University of Tokyo, Japan** (August 2023).
- IV. Presented at Conference on Nonlinear Systems and Dynamics, **IISER Pune, India** (December 2022).
- V. Participated in **Bangalore School on Statistical Physics XII** (June - July 2021).

Academic Referee

Referee:

Name: Prof. Sagar Chakraborty

Designation: Professor

Department: Department of Physics

Institute: Indian Institute of Technology Kanpur (IIT Kanpur)

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Referee:

Name: Prof. Sumana Annagiri

Designation: Professor

Department: Department of Biological Sciences

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