DEPARTMENT OF PHYSICS

Physics Pulse

IIT (ISM) DHANBAD

VOL.II No.5 MAY 25, 2025 PHYSICS NEWSLETTER*

One for All and All for One : Simulating Flocks and Swarms

By VHASKAR CHAKRABORTY

When we look up at the sky, it's captivating to see birds moving in perfect harmony, as if sharing one mind. In Western Europe, starling flocks twist in evershifting, mesmerizing pattern. This collective behavior isn't unique to birds—schooling fish and swarming locusts follow similar patterns. The 2019-2022 locust infestation in India, driven by swarms from Pakistan and Iran, devastated crops and darkened skies like a sandstorm.

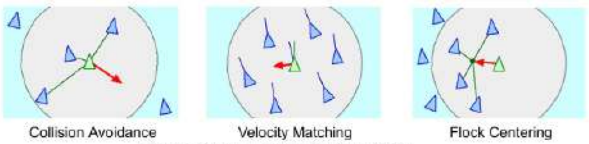


Fig 1: Behavioral rules in the Boids model

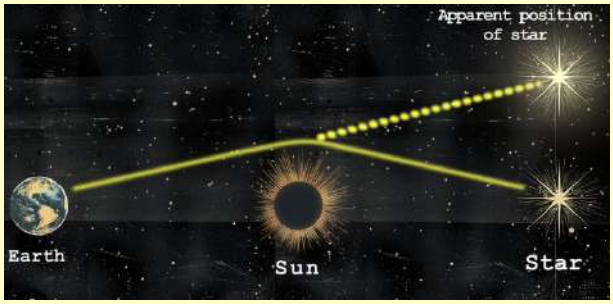
Fig 2: Self-organized flocking in the Vicsek model.

Fig 3 : starling murmuration

Likewise, the annual sardine run in KwaZulu-Natal, South Africa, sees billions of sardines migrate northward. While flocking aids survival, its underlying physics is complex. To simplify this, we turn to models like the Boids model by C. Reynolds and the Vicsek model by T. Vicsek. Though simple, these models show how basic rules can lead to complex collective behavior and reveal how scientists began studying such phenomena. Flocks consist of discrete birds, yet their movement appears fluid. Each bird acts on its own perception, yet all together they move as one.

Physics in History

- May 7, 1952: Geoffrey Dummer first published the concept for the integrated circuit.
- May 15, 1963: Mercury-Atlas 9, the final crewed mission of NASA's Mercury program was launched.
- May 16, 1960: Theodore Maiman demonstrated the first working laser using a ruby crystal.
- May 18, 1974: India conducted its first nuclear test, "***Smiling Buddha***," at Pokhran, Rajasthan.
- May 29, 1919: Arthur Eddington's solar eclipse observations confirmed Einstein's GTR by proving that starlight bends around the Sun.



The Boids Model

In 1987, computer graphics scientist Craig W. Reynolds published his groundbreaking paper on Flocks, Herds, and Schools, where he introduced a model that treats a flock as the collective result of interactions between individual birds, or boids, each governed by its own behavior. The term "Boid" comes from "bird-oid object," where "-oid" signifies resemblance, indicating a bird-like computational agent. The boids interact to coordinate their movement, balancing two opposing behaviors: staying close to the group and avoiding collisions. Reynolds' model follows three rules: collision avoidance (avoiding nearby flockmates), velocity matching (aligning speed with others), and flock centering (staying close to the group)(see Fig 1). Flock centering also lets simulated flocks bifurcate near obstacles, just like real flocks. Nearby flock-mates are defined

*Send your feedback to: physicspulse@iitism.ac.in

as a spherical zone of interaction centered at the boid's local origin. The flocking model keeps boids aligned, cohesive, and collision-free, mirroring the fluid motion of real-world swarms. But while the Boid model captured the beauty of flocking, it left open a deeper question—could collective motion be studied through the lens of Physics?

The Vicsek Model

In 1995, Tamás Vicsek et al. published a celebrated paper introducing a model with novel dynamics to study clustering, transport, and phase transitions in non-equilibrium systems. The model, based on simple rules and random fluctuations, investigates the behavior of particles with a constant absolute velocity. The central rule is: "*at each time step, a given particle driven with a constant absolute velocity assumes the average direction of motion of the particles in its neighborhood of radius r with some random perturbation added* ." Despite its simplicity, the model exhibits rich dynamics and a kinetic phase transition from no transport to finite net transport. Unlike the boid model, the Vicsek model applies not only to schools of fish and bird flocks but also to bacterial colonies. Their system had many particles, each moving at a fixed speed but in a random direction within a periodic box, interacting within a radius r.

At each step, particles update their position while maintaining speed, adjusting direction based on neighbors and random noise. With many particles and low noise, they align and move together, but high noise keeps them disorganized. To study this transition, they measured the absolute value of the average normalized velocity. By tuning noise and density, they uncovered key insights into kinetic phase transitions. This work was also one of the earliest contributions to the study of self-driven particles in physics.

The study of flocking and swarming has fascinated researchers across disciplines, uncovering insights into emergent behaviors, biological systems, and even traffic control. It reveals how seemingly simple everyday phenomena often stem from complex underlying science, deepening our appreciation of the world's intricacies.

References :

1. Reynolds, C.W., 1987, August. Flocks, herds and schools: A distributed behavioral model. In Proceedings of the 14th annual conference on Computer graphics and interactive techniques (pp. 25-34).

2. Vicsek, T., Czirók, A., Ben-Jacob, E., Cohen, I. and Shochet, O., 1995. Novel type of phase transition in a system of self-driven particles. Physical review letters, 75(6), p.1226.

Chronos Saga 2025

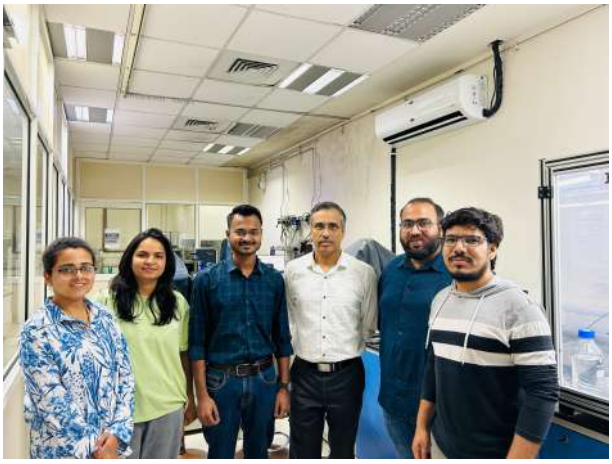
On April 5th, 2025, the department bid a warm and memorable farewell to the outgoing M.Sc. 2nd year students through a vibrant celebration — CHRONOS SAGA — held at the GJLT. The event was thoughtfully organized by the M.Sc. 1st year students.

National Visits

Prof. Ritwik Mondal visited S N Bose National Centre for Basic Sciences, Kolkata as Invited Speaker for a talk. Dr. Mondal talked about "***Inertial Magnons: A new Frontier in THz Spin Dynamics***". Magnons, the quanta of spin waves in magnetically ordered materials, have long been a cornerstone in understanding the dynamics of magnetism at the quantum level. These collective excitations play a pivotal role in fields ranging from spintronics to quantum computing. However, a recent discovery of inertial spin dynamics and inertial spin waves have challenged conventional theories of magnetization dynamics and opens the door to a deeper understanding of ultrafast magnetic phenomena. These excitations are particularly significant in the context of high-frequency regimes e.g. THz, where their unique properties could enable faster and more energy-efficient devices. In this talk, Dr. Mondal has given a brief overview of the THz inertial magnons and their properties in ferro, antiferro, ferrimagnets, and conical spin spiral. Using the description of the linear spin wave theory of ordered magnetic systems and he has shown that the hybridization of the standard magnons and inertial magnons can lead to rich physics at THz regime. The work was carried out by Mr. Subhadip Ghosh at Ultrafast Terahertz Spintronics Group (UTSG).

Preyash Kumar Bal visited the Soft Matter Physics Lab led by Prof. Sajal Kumar Ghosh at Shiv Nadar Institute of Eminence

to perform collaborative research experiments from 28th April to 5th May 2025.



Higher Studies

Mr. Darpa Narayan Basu (final year M.Sc. Physics) was awarded a Ph.D. fellowship by Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau (RPTU), Kaiserlautern, Germany.

Ms. Somasree Bhattacharjee (final year M.Sc. Physics) was awarded a Ph.D. fellowship by the Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany.

Ms. D. Hyandavi Anand (final year B.Tech. Engineering Physics) has been selected for the Master's program in Quantum Technology at Uppsala University, Sweden.

Ms. Mythili Balachandran (final year B.Tech. Engineering Physics) has been selected for the Master of Science in Computer Science program at Purdue University, USA.

Conference Organized

The Department of Physics at IIT(ISM) Dhanbad, in collaboration with BIT Mesra, celebrated World Quantum Day 2025 with a one-day conference on ""Quantum Information Meets Quantum Many-Body Physics and Quantum Optics""(4th April, 2025). The event was inaugurated by Prof. Bobby Antony, Head of the Department of Physics, IIT(ISM), and featured 7 invited talks (4 in-person, 3 online) from leading experts.

Esteemed speakers included Prof. Amit Kumar Pal (IIT Palakkad), Prof. Debraj Rakshit (HRI), Prof. Titas Chanda (IIT Madras), Prof. Bijay Agarwalla (IISER Pune), Prof. Victor Mukherjee (IISER Berhampur), Prof. Utkarsh Mishra (University of Delhi), and Prof. Mauro Paternostro (University of Palermo Queen's University Belfast).

Covering topics from quantum sensing and thermodynamics to non-equilibrium physics, the conference attracted over 60 participants and fostered engaging scientific discussion. It was part of a year-long initiative celebrating the centenary of modern quantum mechanics and coincides with the centenary celebration of IIT(ISM).

Visitors at Department

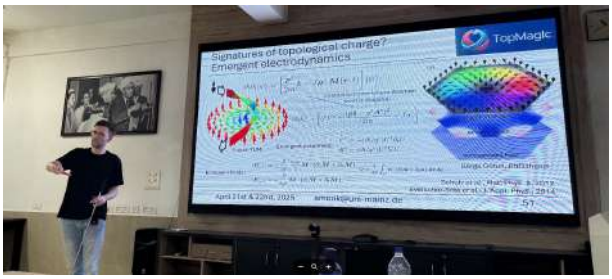
Prof. Bijay Kumar Agarwalla from IISER Pune visited the group of Prof. Sudeshna Sen from 3 to 10 April, 2025, during which he interacted with several students of the department. He is an expert in non-equilibrium statistical mechanics, quantum transport in low dimensions, and quantum information and processing. He also delivered a talk at the one-day conference on **Quantum Information Meets Quantum Many-Body Physics and Quantum Optics** held at the Department on 4 April, 2025. He also presented a seminar titled **Anomalous quantum transport in low-dimensional lattice systems** on 9th April, 2025. We hope to see him in the future as well.

Dr. Alexander Mook from Johannes Gutenberg University, Mainz visited the department and delivered a lecture series on "***Topology in Ordered Magnets: Textures and Dynamics***" during 21-22 April at Raman Hall. His visit was sponsored by Paired Early Career Fellowships in Applied Research (PECFAR) by IGSTC.

In Part I, he discussed several magnetic interactions, symmetries, homotopy groups, and the origin of different magnetic textures (e.g., skyrmions, hopfions, etc.).

In Part II, he places a strong emphasis on exploring the dynamic behavior of various magnetic textures, such as domain walls, skyrmions, and spin spirals. He investigated how these textures respond to external stimuli, including magnetic fields, electric currents, and thermal gradients, and examined their motion, stability, and interactions over time. The lecture series was attended by the UG, PG students of the department with engaging discussions.

On 23rd April, Dr. Mook delivered an interesting research talk titled "**A tale of demons and decay in altermagnets**".



Research Talk

Prof. R. P. Giri delivered an online talk in a conference, with the theme "***Interdisciplinary Science for Better Perspective***". He presented their recent experimental data, which offers deeper insights into the subject. He also highlighted recent advances in the use of graphene-based nanoparticles as therapeutic agents for cardiovascular diseases.

Research Publications

1. Meghana N, Vishakha Zimba, and J Nayak, Enhancing the room temperature formaldehyde gas sensing properties of tungsten trioxide nanorods by compositing with graphitic carbon nitride, Journal of Alloys and Compounds

2. Pritam Chattopadhyay, **Avijit Misra**, Saikat Sur, David Petrosyan, and Gershon Kurizki, Sensing multiatom networks in cavities via photon-induced excitation resonance, Quantum Sci. Technol.

3. Moshahid Raza, **Ritwik Mondal**, Zafar Alam, Arun Dayal Udai, and Zafar Alam, Modeling and experimental validation of transient surface roughness in magnetorheological finishing using 3-D magnetic flux density, Journal of Magnetism and Magnetic Materials

4. Soubhik Bhattacharyya, **R. Thangavel**, and, **P. M. Sarun**, Effect of hydrostatic pressure on the electronic and superconducting properties of bismuthate superconductor: An ab initio study, Journal of Applied Physics.

5. Sheetal Sharma, Manoj Kumar Gupta, and **V.K. Singh**, Enhanced photoluminescence emission and pH sensitivity in oxygen-dominated functional group of highly stable $Ti_3C_2T_x$ MXene, Mater. Chem. Phys.

Book Published

Prof. Umakanta Tripathy has recently edited a book titled **Biochemical and Biophysical Methods in Molecular and Cellular Biology**, now published by Springer Singapore. This book delves into the fundamental principles and applications of advanced biochemical and biophysical techniques used in molecular and cellular biology. It covers cutting-edge methods for studying single molecules, biomolecules, subcellular structures, and cells—making it an invaluable resource for researchers and students in the field.

Editorial Board: **Chief Editor:** Prof. Bobby Antony (HOD), **Editors:** Prof. P. M. Sarun, Prof. Tusharkanti Dey, **Assistant-Editor:** Mr. Mithilesh Mishra,
Student Editors: Mohana Priya. T, Rishit Raj, Surajit Das, Alwin S. S., Deep Karmakar, Vishnu Nayak, Divya Bhengra, Gaurav, Himanshu, Sanchari Biswas, Aminul Hussain, Prashant Singh Lohiya

Article Submission: CLICK HERE
Previous issues of Physics Pulse: CLICK HERE
Send your feedback to: physicspulse@iitism.ac.in