Poster Presenters (in alphabetical order)

1. **Takahiro Arai** (Japan Agency for Marine-Earth Science and Technology)

Title: Analyzing interleg coordination in human walking using the Bayesian inference of phase oscillator model.

Abstract: In human walking, the left and right legs move alternately, half a stride out of phase with each other. The antiphase condition between the legs remains unchanged although stride frequency and length vary with walking speed. From the viewpoint of previous studies for walking analysis, we may expect that interleg coordination is strictly controlled to maintain the antiphase condition for adaptive walking. However, the control mechanism remains unclear.

In this study, we model the control of interleg coordination during walking as coupled phase oscillators using Bayesian inference. The Advantage of using the data-driven approach based on the phase description theory is that the multi-dimensional system is described as one-dimensional in a way that the control of interleg coordination can be interpreted as a function of modulation of the rhythms of gait motion of each leg.

As a result, we found that the control of the relative phase between the legs has neutral stability around the antiphase condition; This stability indicates that the relative phase is not actively controlled unless the deviation from the antiphase condition becomes large. In other words, the control of interleg coordination has a dead zone. Such a forgoing of control presumably reduces energy consumption during human walking.

2. **Francesco Avanzini** (University of Luxembourd)

Title: Circuit Theory for Chemical Reaction Networks

We lay the foundation of a circuit theory for chemical reaction networks. Chemical reactions are grouped into chemical modules solely characterized by their current-concentration characteristic, as electrical devices by their current-voltage (I-V) curve in electronic circuit theory. This, combined with the chemical analog of Kirchhoff's current and voltage laws, provides a powerful tool to predict reaction currents and dissipation across complex chemical networks. The theory can serve to build accurate reduced models of complex networks as well as to design networks performing desired tasks.

3. **Arvind Ayyer** (Indian Institute of Science)
Title: An exactly solvable two-dimensional exclusion process
Abstract: We define a new disordered asymmetric simple exclusion process (ASEP) with two species of particles, first-class and second-class, on a two-dimensional toroidal lattice. The dynamics is controlled by first-class particles, which only move horizontally, with forward and backward hopping rates p_i and q_i respectively if the particle is on row i. The motion of second-class particles depends on the relative position of these with respect to the first-class ones, and can be both horizontal and vertical. We show that the stationary weight of any configuration is proportional to a monomial in the p_i's and q_i's. Our process projects to the disordered ASEP on a ring, and so explains combinatorially the stationary distribution of the latter first derived by Evans (Europhysics Letters, 1996). We compute the partition function, as well as densities and currents of all particles in the steady state. We observe a novel mechanism we call the Scott Russell phenomenon: the current of second class particles in the vertical direction is the same as that of first-class particles in the horizontal direction. This is joint work with P. Nadeau (European Journal of Combinatorics, 2022).

4. **Luca Casagrande** (University of Pisa)
Title: Role of anisotropy in pulsating active matter
Abstract: Contraction waves have been observed in different biological systems where contractile tissues are present [1]. Some examples can be found in embryonic development, cardiac arrhythmogenesis and uterine contraction [2]. Recently, a particle-based model reproducing the spontaneous emergence of contraction waves has been proposed [3]. In this model, a dense system of active particles is considered, where each particle features isotropic repulsion with neighbors, and has an internal drive that periodically changes its size.
However, it is well know that cells in tissues are not isotropic. Therefore, we consider additional degree of freedom which embody by the ability of particles to change their

eccentricity. It enables us to investigate the role of particle anisotropy in pulsating collective dynamics. The resulting dynamics are studied through numerical simulations, and also an analytical hydrodynamics approach is possible using coarse-graining methods. We present the full phase diagram that illustrates the stationary regime as a function of the control parameters of the model. Our model elucidates the interplay between ne- matic order and phase synchronization in pulsating active matter, and it paves the way towards study- ing how to control the emergence of contractile waves in biological tissues.

5. **Abhijit Chakraborty** (Kyoto University)
Title: Aggregation of self-propelled particles with sensitivity to local order
Abstract: We study a system of self-propelled particles (SPPs) in which individual particles are allowed to switch between a fast aligning and a slow nonaligning state depending upon the degree of the alignment in the neighborhood. The switching is modeled using a threshold for the local order parameter. This additional attribute gives rise to a mixed phase, in contrast to the ordered phases found in clean SPP systems. As the threshold is increased from zero, we find the sudden appearance of clusters of nonaligners. Clusters of nonaligners coexist with moving clusters of aligners with continual coalescence and fragmentation. The behavior of the system with respect to the clustering of nonaligners appears to be very different for values of low and high global densities. In the low density regime, for an optimal value of the threshold, the largest cluster of nonaligners grows in size up to a maximum that varies logarithmically with the total number of particles. However, on further increasing the threshold the size decreases. In contrast, for the high density regime, an initial abrupt rise is followed by the appearance of a giant cluster of nonaligners. The latter growth can be characterized as a continuous percolation transition. In addition, we find that the speed differences between aligners and nonaligners is necessary for the segregation of aligners and nonaligners.

6. **Jinfu Chen** (Peking University)
Title: Optimizing Brownian heat engine with shortcut strategy

Abstract: Shortcuts to isothermality provide a powerful method to speed up quasistatic thermodynamic processes within finite-time manipulation. We employ the shortcut strategy to design and optimize Brownian heat engines, and formulate a geometric description of the energetics with the thermodynamic length. We obtain a tight and reachable bound of the output power for shortcut-driven heat engines. The bound is reached by the optimal shortcut protocol to vary the control parameters with a proper constant velocity of the thermodynamic length. With the shortcut strategy, we optimize the control of Brownian heat engines to achieve the maximum power in the general-damped situation. We also derive the efficiency at the maximum power and the maximum power at given efficiency for shortcut-driven heat engines.

7. **Yahia Chergui** (Mhamed Bougara University IGEE Institute Boumerdes Algeria)
Title: Chemical bonds of ZnO Rocksalt structure under extended pressure and temperature a molecular dynamics prediction
The challenge of studying the chemical bonds of ZnO is due to; they are between covalent and ionic types. In this work we are investigated the technique of molecular dynamics and the DL_POLY code to analyze the behavior of the chemical bonds of ZnO rocksalt type of 5832 atoms (2916 atoms of Zinc and 2916 of oxygen), under the range of pressure 0-100 GPa and the range of temperature 300-3000 K; the calculations are run on the RAVEN Supercomputer of Cardiff University in UK. Our results are in the vicinity of the available data, this information are very important in many industrial fields especially in nanoscale of medecine, pharmacetics and cosmetics.

8. **Kensaku Chida** (NTT Basic Research Laboratories)
Title: Negative cross-correlation of thermal noise in capacitively-coupled nanometer-scale dots
Abstract: We observed single electron (SE) motion in capacitively-coupled nanometer scale dots. The thermal motion of SEs in the two dots are negatively correlated due to the Coulomb interaction. This study indicates that electron counting statistics provides us with information on heat transport in the nanometer scale.

9. BISWAJIT DAS (IISER KOLKATA)

Title: Inferring entropy production in anharmonic Brownian gyrators

Abstract: A non-vanishing entropy production rate is one of the defining characteristics of any non-equilibrium system, and several techniques exist to determine this quantity directly from experimental data. The short-time inference scheme, derived from the thermodynamic uncertainty relation, is a recent addition to the list of these techniques. Here we apply this scheme to quantify the entropy production rate in a class of microscopic heat engine models called Brownian gyrators. In particular, we consider models with anharmonic confining potentials. In these cases, the dynamical equations are indelibly non-linear, and the exact dependences of the entropy production rate on the model parameters are unknown. Our results demonstrate that the short-time inference scheme can efficiently determine these dependencies from a moderate amount of trajectory data. Furthermore, the results show that the non-equilibrium properties of the gyrator model with anharmonic confining potentials are considerably different from its harmonic counterpart - especially in set-ups leading to a non-equilibrium dynamics and the resulting gyration patterns.

10. Alberto Dinelli (Laboratoire MSC, Université Paris Cité)

Title: Non-reciprocity across scales in active mixtures

Abstract: In active matter, the lack of momentum conservation makes non-reciprocal interactions the rule rather than the exception. Non-reciprocity is responsible for a wealth of emerging behaviors that are hard to predict starting from the microscopic scale, due to the absence of a generic theoretical framework out of equilibrium. In this talk, we consider bacterial mixtures that interact via mediated, non-reciprocal interactions like quorum-sensing and chemotaxis. By explicitly relating microscopic and macroscopic dynamics, we show that non-reciprocity may fade as coarse-graining proceeds, leading to large-scale bona fide equilibrium descriptions. In turns, this allows us to account quantitatively, and without fitting parameters, for the rich behaviors observed in microscopic simulations including phase separation, demixing or multi-phase coexistence. We also derive the condition under which non-reciprocity is strong enough to survive coarse-graining, leading to a wealth of dynamical patterns. Again, the

explicit coarse-graining of the dynamics allows us to predict the phase diagram of the system starting from its microscopic description. All in all, we show that the fate of non-reciprocity across scales is a subtle and important question.

11. **Igors Dubanevics** (OIST)

Title: Population Genetics of E. coli in Microchannels: Theory, Experiment, and Numerical Simulation

Abstract: Spatial barriers significantly impact the evolution of cell populations. This research examines the population genetics of Escherichia coli within rectangular microchannels with open ends, employing a comprehensive approach encompassing theory, experiments, and numerical simulations. The microchannels' shape gives rise to distinct stripe patterns of co-specific cells along rigid boundaries, with random mutations in the middle of the channel displaying a higher fixation likelihood. We observe that natural selection exerts weaker influence compared to well-mixed populations. Theoretical predictions are validated through experimental observations of proliferating Escherichia coli in a microfluidic device. By developing numerical simulations based on the discrete element method, we aim to gain deeper insights into the physical interactions between cells and their microchannel surroundings.
This study enhances our understanding of the evolutionary effects resulting from shifting dynamics in confined populations, offering implications for microbial ecology and providing insights into tissue dynamics in higher organisms.

12. **Andres Ducuara** (YITP)

Title: Maxwell's Demon walks into Wall Street: Stochastic Thermodynamics meets Expected Utility Theory

Abstract: The interplay between thermodynamics and information theory has a long history, but its quantitative manifestations are still being explored. We import tools from expected utility theory from economics into stochastic thermodynamics. We prove that, in a process obeying Crooks' fluctuation relations, every α Rényi divergence between the forward process and its reverse has the operational meaning of the ``certainty equivalent'' of dissipated work (or, more generally, of entropy production) for a player with risk aversion $r=\alpha-1$. The two known cases $\alpha=1$ and $\alpha=\infty$ are recovered and receive the new interpretation of being associated to a risk-neutral and an extreme risk-averse player respectively. Among the new results, the condition for $\alpha=0$ describes the behavior of a risk-seeking player willing to bet on the transient violations of the second law. Our approach further leads to a generalized Jarzynski equality, and generalizes to a broader class of statistical divergences.

This talk is based on: https://arxiv.org/abs/2306.00449

13. Etienne Fodor (University of Luxembourg)

Title: Pulsating active matter

Abstract: Cells in tissues consume fuel to sustain periodic mechanical deformation [1]. The combination of individual deformation and local interactions yields contraction waves, propagating throughout tissues with only negligible cell displacement [2]. We consider a model of dense repulsive particles whose activity drives periodic change in size of each individual [3]. It reveals that, in dense environments, pulsation of synchronised particles is a generic route to contraction waves. The competition between repulsion and synchronisation triggers an instability which promotes a wealth of dynamical patterns, ranging from spiral waves to defect turbulence. We identify the mechanisms underlying the emergence of patterns, and characterize the corresponding transitions. We derive the hydrodynamics of our model, and propose an analogy with that of reaction-diffusion systems.

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14. Remi Goerlich (Tel Aviv University)
Title: Experimental test of Landauer's principle for stochastic resetting in a potential
Abstract: We probe experimentally the thermodynamic and ergodic properties of Brownian diffusion in a potential under stochastic resetting. The non-equilibrium free energy is probed on the recorded trajectories, allowing to verify the first and second law of thermodynamics for diffusion with resetting. Remarkably, heat is being extracted from the single temperature heat bath, unveiling the Maxwell demon nature of the non-equilibrium steady-state. Since every time the particle is reset to the origin, a finite quantity of information is erased, Landauer principle sets a lower bound on the energy needed to implement resetting in a physical system. By measuring the work needed to maintain the system out of equilibrium for different resetting protocols as well as the associated non-equilibrium free energy, we are able to probe this bound for the minimal energetic cost. The bound is independent of the physical process implementing the resetting and is approached in the quasistatic limit of a real process. This information thermodynamic result is complemented by a verification of the non- ergodic nature of the trajectory, underlying the deep connection between information process and ergodicity.

15. Trevor GrandPre (Princeton University)
Title: Mapping single cell lineages to the population growth rate with finite data
Abstract: In populations of rapidly growing microbes, individual cell variations slow the rate of population doubling below that of a single cell's average doubling time. Determining the growth rate of a population from the generation times of a single lineage is challenging. However, our research reveals that averaging over isolated lineages calculate the growth rate, which is related to a large deviation principle in exponentially growing populations. Precisely estimating the growth rate requires numerous lineages that exponentially rely on the lineage duration. However, limited data may result in estimation errors. To account for these effects, we developed a novel method that is unbiased by finite lineage length. Our research also shows that convergence to the population growth rate is achievable with a few lineages, but it may

converge from above or below the infinite time population growth rate, depending on the growth parameters chosen in a cell size control model.

16. Iyyappan Iyyasamy (The Institute of Mathematical Sciences)
Title: Brownian yet Non-Gaussian Heat Pump
Abstract: We investigated the performance of a Brownian heat pump working in a heterogeneous thermal bath. The diffusion coefficient of the heterogeneous bath is fluctuating and it is modeled as an Ornstein–Uhlenbeck process. We trap the Brownian particle with time-dependent harmonic potential and by changing the stiffness coefficient and bath temperature, we perform a Stirling heat cycle. We numerically calculate the average absorbed work, ejected heat to the hot bath and the performance of heat pump. For shorter cycle times, we find that the performance of a Brownian yet non-Gaussian heat pump is significantly higher than the normal (Gaussian) heat pump.

17. Kotaro Kasuga (Department of Physics, Niigata University)
Title: Reciprocal relation associated with the violation of the fluctuation response
Abstract: relation in non-equilibrium Langevin systems including a two-state model
In this study, we extend Onsager's reciprocal relation to nonequilibrium Langevin systems. In the systems, we derive the reciprocal relations associated with the violation of the fluctuation response relation (FRR). Our reciprocal relations hold for the violation of the FRR in contrast with Onsager's reciprocal relation holding for kinetic coefficients. Some previous studies have derived nonequilibrium relations in the system applied to mechanical perturbations. This study differs from the previous nonequilibrium studies in that thermal and mechanical perturbations are applied.

We study two nonequilibrium Langevin systems subjected to a mechanical force and a time-varying temperature. One is a single overdamped Brownian particle subjected to a constant mechanical force. The other is a system in which the potential is stochastically switched. We derive the reciprocal relation in these two systems. In particular, the reciprocal relation holds for all time in the case of the single overdamped Brownian particle. The property is in contrast to the previous nonequilibrium relations, such as Harada-Sasa equality, holding only at time zero. These reciprocal relations are also valid

far from equilibrium. Because the FRR violation can be experimentally observed, one can also confirm these reciprocal relations through experiments with systems such as colloidal suspensions.

18. Jitendra Kethepalli (International Centre for Theoretical Science)
Title: Unusual chaos and thermalization properties of confined hard rods
Abstract: In this work, we present a comprehensive analysis of the dynamical properties and equilibration behavior of hard rods confined to integrability-breaking confining traps. Specifically, we will explore the behavior of hard rods in both harmonic and quartic traps and discuss how the harmonically trapped system shows non-chaotic to chaotic behavior with increasing system size. We further investigate the underlying non-ergodic nature of the hard rod in harmonic trap and contrast it with the ergodic and thermalizing behavior observed in the quartic trap. Based on this we provide a heuristic understanding of equilibration of harmonically trapped rods, highlighting the significant differences observed between the two types of confinement. Our findings shed new light on the complex dynamics of confined hard rod systems, with implications for the Generalized hydrodynamics in the presence of confinement.

19. Henrik Kiefer (Institute of Theoretical Physics, Freie Universität Berlin)
Title: Modeling and Forecasting of Non-Equilibrium Time Series Data with the Generalized Langevin Equation
Abstract: We apply the generalized Langevin equation (GLE) to model and forecast general time series data. For this, we combine numerical methods to extract the parameters of the GLE from the observed data and to predict future correlated data. For the time series analysis and prediction, we introduce a filter formalism and remove transient effects, such as seasonality or trends, from the data. We compare our forecasting results with predictions from conventional methods such as long-short term memory (LSTM), geometric Brownian motion (GBM), and Facebook's Prophet. Here, we focus on two fields of application: financial and meteorological data. Our results suggest that the GLE delivers highly accurate predictions in both cases and is significantly less

computationally demanding than machine learning methods such as LSTM. Our results are supported by studies on synthetic data from model systems.

20. **Anton Klimek** (Free University Berlin)
Title: Classification of organisms by their Non-Markovian motion
Abstract: The motion of organisms is well known to be a non-equilibrium process, which exhibits drastically different features for different types of organisms. From an evolutionary perspective one can interpret organisms' patterns of motion as adaptions to search efficiently for resources [Klimek & Netz EPL 2022] and it is known that cell motion can be described by the generalized Langevin equation (GLE) [Mitterwallner et al. PRE 2020].
Here, we present a method to differentiate cells solely by their non-Markovian trajectories based on the GLE in a non-equilibrium framework and apply it to distinguish two different swimming types of strongly confined microalgae Chlamydomonas reinhardtii cells with an accuracy of 100%.
The model we use is suggested by the data and succeeds to describe the motion on the single cell level. By a simple fit we can extract model parameters for individual cells and subsequently perform an unbiased cluster analysis to determine the number of different cell types in the population and obtain an assignment of every cell to one of the types. Additionally, the model suggested by the data includes information on the underlying processes leading to the observed patterns of motion, which in the case of our Chlamydomonas reinhardtii data hints towards a harmonic coupling inside of the cell. As it still remains a challenge to classify cells on the single cell level, the presented method to distinguish cells with as little information as their trajectories might have important implications in biology and medicine.

21. **Anzhelika Koldaeva** (Okinawa Institute of Science and Technology)
Title: Population Genetics of E. coli in Microchannels: Theory, Experiment, and Numerical Simulation (shared with Igors Dubanevics)
Abstract: Spatial barriers significantly impact the evolution of cell populations. This research examines the population genetics of Escherichia coli within rectangular

microchannels with open ends, employing a comprehensive approach encompassing theory, experiments, and numerical simulations. The microchannels' shape gives rise to distinct stripe patterns of co-specific cells along rigid boundaries, with random mutations in the middle of the channel displaying a higher fixation likelihood. We observe that natural selection exerts weaker influence compared to well-mixed populations. Theoretical predictions are validated through experimental observations of proliferating Escherichia coli in a microfluidic device, while numerical simulations employing the discrete element method (DEM) elucidate the physical interactions between cells and the microchannel surroundings. This study enhances our understanding of the evolutionary effects resulting from shifting dynamics in confined populations, offering implications for microbial ecology and providing insights into tissue dynamics in higher organisms.

22. **Shoki Koyanagi** (Kyoto University)

Title: Numerically "exact" simulation of quantum Carnot cycle: Work diagram approach

Abstract: Though there are many studies regarding quantum thermodynamics, there are only a few studies in which strong system-bath (SB) interaction is considered. In our study, we introduce quasi-static Helmholtz energy [1], and define thermodynamical quantities, such as magnetic susceptibility, by differentiating the free energy [2]. To study the quantities' behavior, we employ spin-boson model, and conduct numerical calculations of quantum Carnot cycle in quasi-static, non-Markovian and strong system-bath interaction regime [3]. We show work diagram, as the pressure – volume (P-V) diagram in classical Carnot cycle, for not only the system but also the SB interation.

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23. **Euijoon Kwon** (Seoul National University)

Title: Unified Hierarchical relationship between thermodynamic tradeoff relations

Abstract: In recent years, researchers have introduced various inequalities to establish bounds on thermodynamic quantities. Thermodynamic uncertainty relations (TURs) and

entropic bounds (EB) provide a tradeoff relation between stochastic currents and total entropy production (EP). The classical speed limit (CSL) governs the rate of state transformation, taking into account EP and the statistical distance between two states. Additionally, the power-efficiency (P-E) tradeoff prevents finite power when efficiency reaches Carnot efficiency. However, the hierarchical structure and interconnections among these inequalities have remained largely unexplored. In this study, we propose a unified hierarchical relationship that encompasses these bounds. We extend the TUR to incorporate a broader range of observables, including current-like and state-dependent observables, and establish its applicability across various types of systems. Furthermore, we demonstrate that the extended TUR implies the EB when an appropriate state-dependent observable is selected. We also derive CSL and P-E tradeoff from the EB, for both Langevin and Markov jump systems. To illustrate the practical significance of our newly discovered thermodynamic bounds, we provide specific examples.

24. Pik-Yin Lai (Dept. of Physics, National Central University)
Title: Reconstructing connection weights and topology of Directed Networks from Noisy node Dynamics using Stochastic Force Inference
Abstract: We consider coupled network dynamics under uncorrelated noises that fluctuate about the noise-free long-time asymptotic state. Our goal is to reconstruct the directed network only from the time-series data of the dynamics of the nodes. By using the stochastic Force Inference method[1] with a simple natural choice of linear polynomial basis, we derive a reconstruction scheme of the connection weights and the noise strength of each node. Explicit simulations for directed and undirected random networks with various node dynamics are carried out to demonstrate the good accuracy and high efficiency of the reconstruction scheme[2]. We further consider the case when only a subset of the network and their node dynamics can be observed[3], and it is demonstrated that the directed weighted connections among the observed nodes can be easily and faithfully reconstructed. In addition, we propose a scheme to infer the number of hidden nodes and their effects on each observed node. The accuracy of these results are illustrated by simulations.

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[3] B. Gemao and Pik-Yin Lai, Effects of hidden nodes on noisy network dynamics, Phys. Rev. E 103, 062302 (2021).

25. **Zhen Li** (Department of Complexity Science and Engineering, Graduate School of Frontier Sciences, The University of Tokyo)
Title: The thermodynamic efficiency and entropy generation rate of the Lorenz system
Abstract: Lorenz system, which is an early finding of chaotic solution, is originally derived from a simplified model of atmospheric convection. This model is developed from the Oberbeck-Boussinesq approximation of 2-dimension NS equations in gravitational field. As the convection can be regarded as a heat engine driven by temperature difference, its thermodynamic efficiency and entropy generation rate can be calculated. There are three major findings. Generally, the efficiency increases as the temperature difference increases no matter whether the dynamics are stable or chaotic. An upper bound, which is less than 1, appears for the efficiency. And an abrupt drop of the efficiency, as well as the entropy generation rate, happens at the point where the system starts to be chaotic. The first finding is commonly observed in heat engines operating between two different heat reservoirs, while the third one is due to an abrupt drop of the average of one variable in Lorenz equations at the same point. These results are expected to contribute to the understanding of atmospheric motion from a thermodynamic point of view.

26. **Joël Mabillard** (Université Libre de Bruxelles (U.L.B.))
Title: Transport processes in crystals
Abstract: At the macroscale, transport processes in crystalline solids generate irreversibility. These dissipative effects must be included in the set of hydrodynamic equations and a key question is to derive them from the underlying dynamics of the particles. Contrary to fluids, crystals manifest long-range order by the spatial periodicity

of their atomic structure. The breaking of the three-dimensional continuous group of spatial translations implies the existence of three slow modes in addition to the five slow modes arising from the fundamental conservation laws of mass, energy, and linear momentum. Using a systematic approach based on the local-equilibrium and originally developed for normal fluids, a statistical-mechanical derivation of the hydrodynamic equations, which includes the Goldstone modes, will be presented. The set of dissipative hydrodynamic equations is obtained as well as microscopic expressions for the transport coefficients, in terms of Green-Kubo and Einstein-Helfand formulas. The entropy production rate is shown to be non-negative, in agreement with the second law of thermodynamics. The dispersion relations of the eight hydrodynamic modes are investigated for a cubic crystal, and the transport coefficients are computed numerically from the Einstein-Helfand formula using a molecular dynamics simulation.

27. **Alessandro Manacorda** (University of Luxembourg)
Title: Pulsating with discrete symmetry: Lattice dynamics of deformable active particles
Abstract: Cells in epithelial tissues can drastically deform their shapes and volume giving rise to collective behavior such as size oscillation and wave propagatio. These phenomena have a strong impact in many biological contexts such as embryonic development, cardiac arrhythmias and uterine contraction.
Following the recent formulation of active deformable particles, we introduce a lattice model of pulsating particles whose activity is given by the ability to change an internal degree of freedom at the single-particle level. The system then corresponds to a spatially-extended version of the periodically driven Potts model, exhibiting complex behavior already at fully-connected level; we show how the interplay between pulsation and synchronization gives rise to emergent behavior such as wave propagation.
Fluctuating hydrodynamic
equations are derived from microscopic dynamics and highlight the role of symmetry breaking. The latter proves to be a fundamental ingredient for wave propagation because of the competition between pulsating and arrested phases and its relation with reaction-diffusion systems.
The model introduced thus stands as a suitable candidate to understand the targeted

phenomenology and paves the way to the analysis of symmetry breaking in nonequilibrium field theories and many-body energetics, two of the main future directions in the growing field of pulsating active matter.

28. **Jose Daniel Muñoz Castaño** (Department of Physics, Universidad Nacional de Colombia, Bogota)

Title: Thermalizing a harmonic oscillator from a micro-canonical ensemble: A fluctuation relation for the heat

Abstract: Autors: Leonel F. Ardila (1), Nicolas Torres(2), Jose D. Munoz(1, presenting author) and Carlos Viviescas(2), Simulation of Physical Systems Group (1) and Chaos and Complexity Group (2), Center of Excellence in Scientific Computing: CoE-SciCo, Department of Physics, Universidad Nacional de Colombia. In this work we investigate the thermalization of a classical harmonic oscillator starting from a micro-canonical ensemble at energy Eo and finishing in a canonical one at temperature T. We derived analytically that the probabilities P(Q) and P(－Q) of gaining or losing a certain amount of heat Q are related as P(Q)=exp(-2Q/kT) P(-Q), a result we also verified through molecular dynamics simulations with an overdamping Langevin equation algorithm. Our results give insight into the thermalization process and contributes to extend fluctuation relations to micro-canonical initial states.

29. **Jihui Pei** (Peking University)

Title: On the validity of Margenau-Hill quasiprobability of quantum work

Abstract: In quantum thermodynamics, the two-projective-measurement (TPM) scheme provides a successful description of stochastic work only in the absence of initial quantum coherence. Extending the quantum work distribution to quasiprobability is a general approach to characterize work fluctuation with initial coherence. However, among a large number of different definitions, there is no consensus on the most reasonable work quasiprobability so far. We synthesize several physically reasonable requirements including the first law of thermodynamics, time-reversal symmetry, positivity of second-order moment, and a support condition for the distribution function. We prove that the only definition that satisfies all these requirements is the

Margenau-Hill (MH) quasiprobability of work. In this sense, the MH quasiprobability of work shows its advantages as a valid description.

30. Samuel Poincloux (The University of Tokyo)
Title: Flow and deformation of a sponge-like granular media
Abstract: Highly compressible media such as porous soils and snow can undergo sudden and catastrophic flowing instabilities under shear. To investigate the potential role of large compressibility in the development of instabilities, we explore experimentally the mechanical response of an assembly of ring-shaped grains. The rings can rearrange like grains in the sand, but also sustain massive elastic compression like a typical sponge. By imposing oscillatory shear to a 2D assembly of these rings and recording their position and shape, we question the role of shape fluctuations in the collective irreversible flow observed.

31. Guenter Radons (Institute of Physics, Chemnitz University of Technology)
Title: From normal to anomalous deterministic diffusion in delay systems
Abstract: Already since many decades deterministic chaotic diffusion continues to be a research topic of utmost interest. Most efforts concentrated on low-dimensional systems such as one-dimensional iterated maps or Hamiltonian systems with a few degrees of freedom. In recent years renewed interest in such systems sparked due to new developments related to weak ergodicity breaking and the existence of infinite measures, especially in the context of anomalous diffusion. It was only very recently that diffusion in infinite-dimensional systems, namely in simple scalar time-delay systems, was investigated in detail, leading to very surprising results [1,2]. An important aspect there is the influence of a variation of the delay time, the role of which was recognized only in the last few years [3-5]. We will review some of these results, especially those which are important for the understanding of our most recent findings, which show that a transition from normal to anomalous diffusion can be induced by a time-delay modulation. This transition is accompanied by the manifestation of ergodicity breaking, which provides a considerable theoretical challenge due to the dynamics in infinite dimensional state space and the appearance of hitherto unknown complex scenarios.

We identify various phases, some of which have surprising duration statistics, where for instance a power law distribution is seemingly cut-off by an exponential decay, only to lead eventually again to an asymptotic power law. Corresponding to this, also the mean square displacements show cross-over phenomena from anomalous to normal and asymptotically back to anomalous diffusion. To capture the essence of these processes, new stochastic models will be we introduced and analyzed.

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32. **Mukhayo Rasulova** (Institute of Nuclear Physics Academy of Sciences of Uzbekistan)
Title: EVOLUTION OF A QUANTUM SYSTEM OF MANY PARTICLES INTERACTING VIA THE GENERALIZED YUKAWA POTENTIAL
Abstract: We study the evolution of a system of N particles that have identical masses and charges and interact via the generalized Yukawa potential. The system is placed in a bounded region. The evolution of such a system is described by the Bogoliubov–Born–Green–Kirkwood–Yvon (BBGKY) chain of quantum kinetic equations. Using semigroup theory, we prove the existence of a unique solution of the BBGKY chain of quantum kinetic equations with the generalized Yukawa potential.

33. **Mukhayo/Tohir Rasulova/Akramov** (Institute of Nuclear Physics Academy of Sciences of Uzbekistan and National University of Uzbekistan)
Title: Generalizationtion of the non-linear Schrödinger equation for multi-particle cases

Abstract: The nonlinear Schrödinger equation is a key ingredient in many quantum simulation and
quantum computing schemes, where it is used to describe the time evolution of the quantum state of a system. Therefore, understanding the derivation of this equation is crucial for developing and optimizing these technologies. In that sense, a new method is proposed to obtain the non-linear Schrödinger equation by the chain of Bogoliubov-Born-Green-Kirkwood-Yvon (BBGKY) quantum kinetic equations.

34. **Sunghan Ro** (Massachusetts Institute of Technology)
Title: Metastability of Discrete-Symmetry Flocks
Abstract: We study the stability of the ordered phase in flocking models with a scalar order parameter. In particular, we consider the active Ising model, an active flocking model with Ising-like alignment rules. Using numerical simulations and the hydrodynamic description of the model, we demonstrate that droplets of particles moving in the direction opposite to that of the ordered phase can spontaneously nucleate and grow. We have analytically characterized this self-similar growth, showing that droplets grow ballistically in all directions. Our results suggest that discrete-symmetry flocks are metastable in all dimensions.

35. **Mitsusada M. Sano** (Department of Materials Science, Graduate School of Human and Environmental Studies, Kyoto Univesity)
Title: Two quantum fluctuation theorems for the McLennan-Zubarev Ensembles
Abstract: I will present the derivation of the quantum fluctuation theorems for entropy production and currents

36. **Saikat Santra** (International Centre for Theoretical Sciences (Tata Institute of Fundamental Research), India)
Title: Extremal statistics of a one dimensional run and tumble particle with an absorbing wall
Abstract: In this talk I will discuss about our study on the extreme value statistics of a run and tumble particle (RTP) in one dimension till its first passage to the origin starting

from the position $x_0 (> 0)$. This model has recently drawn a lot of interest due to its biological application in modelling the motion of certain species of bacteria. Herein, we analytically study the exact time-dependent propagators for a single RTP in a finite interval with absorbing conditions at its two ends. By exploiting a path decomposition technique, we use these propagators appropriately to compute the joint distribution $P(M, t_m)$ of the maximum displacement M till first-passage and the time t m at which this maximum is achieved exactly. The corresponding marginal distributions $P_M(M)$ and $P_M(t_m)$ are studied separately and verified numerically. In particular, we find that the marginal distribution $P_M(t_m)$ has interesting asymptotic forms for large and small t_m. While for small t_m, the distribution $P_M(t_m)$ depends sensitively on the initial velocity direction σ_i and is completely different from the Brownian motion, the large t_m decay of $P_M(t_m)$ is same as that of the Brownian motion although the amplitude crucially depends on the initial conditions x_0 and σ_i.

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37. Yasuji Sawada (Frontier Research Institute for Interdisciplinary Sciences, Tohoku University)

Title: On the transition from a material world to a pre-RNA world in an assembly of polynucleotides

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Abstract: It has been suggested that the present DNA and proteins world was preceded by RNA world in which genetic information of RNA molecules was replicated by the mutual catalytic function of RNA molecules (e.g. Johnston et.al 2001). However, the important question how the transition from a material world to the beginning of RNA world occurred remains unsolved experimentally nor theoretically (Zhou et.al. 2019). We believe that the transition is sharp based on the fact that the a gradual shift between these two worlds does not warrant the quality of information carried by the molecules (Eigen 1971). Accurate copy of information would be guaranteed only by self-replication. Self-replicability is the unique attribute observed in all the living organisms and not shared in material world.

Based on this viewpoint we present a nonlinear dynamical model for the transition from a material world of randomly assembled polynucleotide molecules to a pre-RNA world of self-replication of informative molecules (Sawada et al. 2023, PRE in press, arXiv:2304.04989). The model dynamical system is expressed by a coupled equations of the doublet and singlet densities of the length and information of interacting polynucleotide polymers with natural decay constants. It has a lowest order nonlinearity, as it would provide us with a transition at the earliest time in the ever-increasing density parameters. The dynamical equations were applied for various possible networks of the interacting polymers. A quantitative expression of the critical conditions for the onset of growing fluctuation towards self-replication in this model were obtained by analytical and numerical calculations.

The obtained results of the research would be helpful for designing future experiments for the self-replication of RNA molecules. Although some values of chemical reaction rates and natural decay constants have been reported for some chemical and thermodynamic conditions (Joyce 2002), they might be far different from those in different prebiotic conditions. And one cannot at present claim the critical condition (3) was satisfied or not at prebiotic time. On the other hand, the existing autocatalytic model which is based on the assumption that the ligases had existed from the beginning of the material world (e.g. Hordijk & Steel 2018). It has not been clarified how the ligase happened to appear in the early material world. The future research will clarify which model is closer to the reality of the mechanism to start pre-RNA world.

Finally, the present research implies that the self-replication system belongs to dissipative structures which are known to exist in a system far from thermodynamic equilibrium, and, therefore, that the initiation of life would be deeply connected to the second law of thermodynamics.

38. **Sahil Kumar Singh** (International Centre for Theoretical Sciences, Bengaluru)
Title: Blast waves in the zero temperature hard sphere gas: double scaling structure
Abstract: The non-equilibrium state of a fluid is usually described by hydrodynamics. However, on a microscopic level, the individual particles follow Newton's laws of motion. How does hydrodynamics emerge from microscopic Newtonian dynamics? A rigorous derivation of hydrodynamics starting from microscopic Newtonian dynamics is lacking. Phenomenological textbook derivations involve applying conservation of mass, momentum and energy to a parcel of fluid, and there are also derivations based on the Boltzmann equation. In this talk, we will verify the predictions of hydrodynamics from those of direct simulation of Newton's equation of motion for a hard disc gas in 2-dimensions for a blast wave initial condition. We will find two scaling regions: the core region advancing as t^{2/5} and the bulk region advancing as t^{1/2}. We will show that the two regions are connected by the rules of asymptotic matching. In the bulk region, we will show that the prediction of hydrodynamics agrees well with that of Newtonian dynamics. In the core region, there are some discrepancies, possibly due to the failure to reach local equilibrium. My talk will be based on [1].
References: Sahil Kumar Singh, Subhadip Chakraborti, Abhishek Dhar and P. L. Krapivsky, Blast waves in the zero temperature hard sphere gas: double scaling structure, arxiv:2211.10315

39. **Varinder Singh** (Center for Theoretical Physics of Complex Systems (PCS), Institute for Basic Science, South Korea)
Title: Thermodynamic uncertainty relation in nondegenerate and degenerate maser heat engines
Abstract: We investigate the thermodynamic uncertainty relation (TUR), i.e., a trade-off between entropy production rate and relative power fluctuations, for nondegenerate

three-level and degenerate four-level maser heat engines ¥cite{VS_TUR}. In the nondegenerate case, we consider two slightly different configurations of three-level maser heat engine and contrast their degree of violation of standard TUR. We associate their different violating properties of TUR to the phenomenon of spontaneous emission which gives rise to an asymmetry between them. Furthermore, in the high-temperature limit, we show that standard TUR relation is always violated for both configurations. For the degenerate four-level engine, we study the effects of noise-induced coherence on TUR. We show that depending on the parametric regime of operation, noise-induced coherence can either suppress or amplify the relative power fluctuations. Moreover, we show that noise-induced coherence can be used to suppress relative power fluctuations along with amplifying the power of the engine at the same time, which makes noise-induced coherence a free quantum resource in enhancing the performance of quantum heat engines.

40. **Gianmarco Spera** (Laboratoire Matière et Systèmes Complexes)

Title: Nematic Torques in Scalar Active Matter

Abstract: Active matter describes systems comprising elementary units able to exert non-conservative forces on their environment. Activity leads to a fascinating variety of collective behaviours unmatched in passive systems, such as the transition to collective motion. The latter is arguably the most studied phase transition in active matter and the ordered phases emerging from the interplay between self-propulsion and aligning interactions have naturally attracted a lot of attention. In this talk, I will instead focus on the role of aligning interactions in the disordered phase. In particular, I will show that nematic alignment plays an unexpected role in the 'high-temperature' phase: it can induce or suppress phase separation, increase particle accumulation at boundaries, and suppress demixing in systems comprising active and passive particles. I will then show how all these phenomena can be understood by introducing a field-theoretical framework to go beyond the mean-field description of the system. In the presence of nematic torques, fluctuations are then shown to enhance polar order, leading to an increase in the particle persistence length. In turn, the latter accounts quantitatively for all the phenomena reported above. To show this, I will briefly describe a new theory for motility-induced phase separation in the presence of aligning torques.

41. Pragya Shukla (IIT Kharagpur, India)
Title: Universality in non-equilibrium regime of non-Hermitian Complex systems
A statistical description of part of a many body system, especially the one in non-equilibrium regime, often requires a non-Hermitian random matrix ensemble with nature and strength of randomness sensitive to underlying system conditions. This in turn makes its necessary to analyze a wide range of multi-parametric ensembles with different kinds of matrix elements distributions. The spectral statistics of such ensembles is not only system-dependent but also non-ergodic as well as non-''stationary''. This motivates us to theoretically analyze the evolution of the ensemble averaged spectral density on the complex plane as well as its local fluctuations with changing system conditions. Our analysis, based on the complexity parameter formulation [1,2], reveals the existence of a critical statistics as well as hidden universality in non-ergodic regime of spectral fluctuations.
Another important insight given by our analysis [1] is about the similarity of the evolution equation for the spectral angles correlations to that of a circular Brownian ensemble; the detailed existing information about the latter can then be applied to determine those of the former.
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42. Kazuaki Takasan (University of Tokyo)
Title: Activity-induced quantum phase transitions: A proposal for quantum active matter
Abstract: Active matter is an ensemble of self-propelled entities, such as flocks of birds and schools of fish, that has attracted significant attention for its various phase transitions and pattern formations that are not present in equilibrium systems [1]. The physics of active matter has been studied mainly in classical systems. In particular, its application to biophysics has been successful, helping to understand the nature of

biological systems [2]. In contrast, the study of active matter in quantum systems has been limited due to the lack of open quantum many-body systems in experiments. Recently, however, such systems have become accessible through advances in atomic-molecular-optical experiments [3]. Thus, it is now reasonable to consider the quantum versions of active matter physics.

Recently, we proposed a quantum many-body model that resembles active matter and exhibits several activity-induced quantum phase transitions [4]. The model consists of two-component hard-core bosons on a lattice with a non-Hermitian hopping term, mimicking the activity in classical systems. Through exact diagonalization and quantum Monte Carlo simulation, we obtained a phase diagram that includes several nonequilibrium phases, including motility-induced phase separation and polar flocking. Furthermore, we proposed an experimental setup to realize this model using ultracold atoms in optical lattices. In addition, we present more recent studies on another quantum active matter model containing spin-spin interaction [5]. In this recent work, our numerical and analytical calculation shows that the interplay between activity and hard-core interaction induces a ferromagnetic (polar) order. These works bridge two research fields, quantum many-body physics and active matter physics, which have not had much interaction with each other, and open a new way to explore novel quantum phases of matter.

This talk is based on the collaboration works [4, 5] with Kyosuke Adachi (RIKEN) and Kyogo Kawaguchi (RIKEN).

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43. Ofir Tal-Friedman (Tel Aviv University)
Title: BRINGING RESETTING OF STOCHASTIC PROCESSES CLOSER TO REALITY

Abstract: Inspired by many examples in nature, stochastic resetting of random processes has been studied extensively in the past decade. In particular, various models of stochastic particle motion were considered where, upon resetting, the particle is returned to its initial position. My presentation will be separated into two parts:
1. While Diffusion with stochastic resetting serves as a paradigmatic model to study resetting phenomena in general, the lack of a well-controlled platform by which this process can be studied experimentally has been a major impediment to research in the field. I will present our experimental realization of colloidal particle diffusion and resetting via holographic optical tweezers. We provide the first experimental corroboration of central theoretical results and go on to measure the energetic cost of resetting in steady state and first-passage scenarios. In both cases, we show that this cost cannot be made arbitrarily small because of fundamental constraints on realistic resetting protocols.
2. I will present our generalization of diffusion with resetting to account for situations where a particle is returned only a fraction of its distance to the origin, e.g., halfway. This model always attains a steady-state distribution, and as we change the fraction of resetting, the steady-state transitions from the known Laplace form obtained in the limit of full resetting to a Gaussian form, which is obtained close to the limit of no resetting. A similar transition is shown to be displayed by drift-diffusion. Finally, I will show the extension of our analysis to capture the temporal evolution of drift-diffusion with partial resetting, providing a bottom-up probabilistic construction that yields a closed-form solution for the time-dependent distribution of this process in Fourier-Laplace space.

44. Hiromu Ushihara (Depertment of Physics, the University of Tokyo)
Title: Analysis of energy currents based on quantum master equations applicable to many-body systems
Abstract: An open quantum system, a system coupled to external baths, can be a platform for interesting non-equilibrium phenomena. To study open quantum systems, the Gorini–Kossakowski–Sudarshan–Lindblad (GKSL) equation is widely used, but the systematic derivation of the GKSL equation for small systems is not directly applicable to many-body systems. In this study, the energy currents in the one-dimensional

Heisenberg model and Hubbard model coupled to baths at both ends are studied based on alternative quantum master equations applicable to many-body systems.

45. Yuxin Wu (Peking University)
Title: Heat statistics in the relaxation process of the Edwards-Wilkinson elastic manifold
Abstract: The stochastic thermodynamics of systems with a few degrees of freedom has been studied extensively so far. We would like to extend the study to systems with more degrees of freedom and even further–continuous fields with infinite degrees of freedom. The simplest case for a continuous stochastic field is the Edwards-Wilkinson elastic manifold. It is an exactly solvable model of which the heat statistics in the relaxation process can be calculated analytically. The cumulants require a cutoff spacing to avoid ultra-violet divergence. The scaling behavior of the heat cumulants with time and the system size as well as the large deviation rate function of the heat statistics in the large size limit is obtained.

46. Mizuki Yamaguchi (The University of Tokyo)
Title: Proof of avoidability of the quantum first-order transition in transverse magnetization in quantum annealing of finite-dimensional spin-glasses
Abstract: Quantum annealing (QA) has attracted attention as a method for solving combinatorial optimization problems. In QA we start with a quantum system whose ground state is easily prepared, and change the Hamiltonian slowly to a classical Hamiltonian whose ground state represents the solution of the combinatorial optimization problem. However, QA is known to fail for hard optimization problems. Some studies [1] reveal that the failure of QA frequently accompanies the quantum first-order transition in transverse magnetization, and therefore claim that this transition is the origin of the failure of QA. On the other hand, some other studies [2] ascribe the failure of QA to other mechanisms. The reason why QA fails is controversial, and no decisive answer has been obtained.

In this presentation, we rigorously prove that QA-AFF (a variant of QA with the antiferromagnetic fluctuations term) [3] for finite-dimensional spin-glass systems does

not have a quantum first-order transition in transverse magnetization. Our result applies to any finite-dimensional spin-glass system as long as the interaction is short-range and the quenched random variables follow shift-invariant probability distributions. We remark that the ground state search of finite-dimensional spin-glass systems is known to be a hard optimization problem (i.e., NP-hard problem), which is considered to be intractable by any quantum computation including QA. In the light of the above fact, our result suggests that the quantum first-order transition in transverse magnetization is not a fatal factor for the failure of QA for hard optimization problems.

The proof of our main result is inspired by the Legendre transformation of the ground energy with respect to the strength of transverse magnetic field. Although our system has quenched randomness, we can show that its ground state energy and transverse magnetization as functions of transverse magnetic field are self-averaging, which allows us to treat only averaged systems, not each random instance. We then add the AFF term, which smooths singularities corresponding to the quantum first-order transition in transverse magnetization.

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47. Kyo Yoshida (University of Tsukuba)

Title: An attempt to construct an ensemble model for turbulence

Abstract: We introduce an ensemble model of turbulence recently proposed in Ref. 1. The ensemble consists of flow fields in which the flux of an invisid conserved quantity, such as energy, is constant in the wavenumber space. A numerical sampling of a typical state from the ensemble was attempted. [1] Yoshida, Phys. Rev. E 106, 045106(2022)