117th STATISTICAL MECHANICS CONFERENCE

SHORT TALK SCHEDULE

SESSION A

A1: Sungchul Ji, Rutgers University
Information is not Entropy

Abstract: The Planckian information (I_P) is defined as the information produced by the so-called Planckian processes which are in turn defined as any physicochemical or formal processes that generate long-tailed histograms fitting the Planckian Distribution Equation (PDE),
y = (A/(x + B^5)/(Exp(C/(x + B)) – 1) (1)
where A, B and C are free parameters, x is the class or the bin to which objects or entities belong, and y is the frequency. The PDE was derived in 2008 [1] from the blackbody radiation equation, by replacing the universal constants and temperature with free parameters, A, B and C. PDE has been found to fit not only the blackbody radiation spectra itself (as it should) but also other long-tailed histograms generated in a wide range of fields including atomic physics, protein folding, cell metabolism, brain physiology, psychology, linguistics, econophysics, and cosmology [2].
One possible explanation for the universality of PDE is that many long-tailed histograms are generated by some selection mechanism acting on randomly/thermally accessible processes. Since random processes obey the Gaussian distribution, the ratio of the area under the curve (AUC) of PDE to that of Gaussian-like symmetric curves can be used as a measure of the order generated by the Planckian processes. The 'Gaussian-like' curves were generated by Eq. (2), which was derived from the Gaussian equation by replacing its pre-exponential factor with free parameter A:
y = Ae– (x – μ)^2/(2σ^2) (2)
The degree of mis-match between the area under the curve (AUC) of PDE and that of GLE is postulated to be a measure of non-randomness (and hence order). This measure of order is referred to as the Planckian Information (IP) defined quantitatively as shown in Eq. (3) or Eq. (4):
I_P = log2 (AUC(PDE)/AUC(GLE)) bits (3)
It is generally accepted that there are at least three basic aspects to information – amount, meaning, and value. Planckian information is primarily concerned with the amount (and hence the quantitative aspect) of information. There are numerous ways that have been suggested in the literature for quantifying information besides the Hartley information, Shannon entropy, algorithmic information, etc.
The Planckian information represents the degree of organization of physical (or nonphysical) systems in contrast to the Boltzmann or the Boltzmann-Gibbs entropy which represents the disorder/disorganization of a physical system. The organization represented by I_P results from symmetry-breaking selection processes applied to some randomly accessible (and hence symmetrically distributed) processes.
There is a great confusion in science and philosophy concerning the relation between the concepts of information and entropy as pointed out by Wicken. A large part of this confusion may be traced back to the suggestions made by Schrödinger in 1944 and others subsequently (e.g., von Neumann, Brillouin, etc.) that order can be measured as the inverse of disorder (D) and hence that information can be measured as negative entropy.
The concept of "negative entropy" violates the Third Law of Thermodynamics and hence cannot be used to define "order" nor "information". However, Planckian information, I_P can be positive, zero, or negative, depending on whether AUC(PDE) is greater than, equal to, or less than AUC (GLE), respectively, leading to the conclusion that
"Information can but entropy cannot be negative." (4)
Hence that
"Information is not entropy." (5)
Another way of supporting the thesis that information and entropy are not equivalent is to invoke the

notion of irreducible triadic relations (ITR) of Peirce (1839-1914), according to whom the sign (i.e., anything that stands for something other than itself) is irreducible triad of object, representamen (also called sign) and interpretant. The irreducible triadic relation (ITR) can be represented as a 3-node network:

f g
A --------> B --------> C
(object) (sign) (interpretant)
| ^
| |
|____________________|
h

where f = sign production; g = sign interpretation; and h = information flow.
The arrows constitute a commutative triangle, i.e., f x g = h.

The communication system of Shannon is also irreducibly triadic, since it can be mapped to the sign triad: A = sender; B = message; and C = receiver. Entropy (in the sense of Shannon's communication theory) is one of the three nodes and Information (in the sense of Peircean semiotics) is one of the three edges. Clearly, nodes and edges are two different classes of entities, consistent with Statement (5).
The calculation of the Shannon entropy (H) and the Planckian information from the fMRI (functional Magnetic Resonance Imaging) data measured from the human brain by Carhart-Harris et al. before and after infusing the hallucinogen, psilocybin, clearly indicates that both the Shannon entropy and the Planckian information increased [3] which contradicts the notion of information as a negative entropy.

References:

[1] Ji, S. (2012). Molecular Theory of the Living Cell: Concepts, Molecular Mechanisms and Biomedical Applications. Springer, New York. Chapters 11 and 12. PDF at http:/www.conformon.net under Publications > Book Chapters.

[2] Ji, S. (2017). Waves as the Symmetry Principle Underlying Cosmic, Cell, and Human Languages. Information 2017, 8, 24; doi:10.3390/info8010024.
PDF at file:///C:/Users/sji/Downloads/information-08-00024-v2%20(2).pdf

[3] Ji, S. (2017) Planckian Information calculated from fMRI Signals indicates that Psilocybin Increases Neurodynamic Organizations in the Human Brains. A poster presented at The Brain Berlin 2017 Conference, Free University of Berlin, April 1-4, 2017.

A2: Duyu Chen, Princeton University
Coauthors: Salvatore Torquato

Transport and Elastic Properties of Hyperuniform Networks: Optimality, Anisotropy and Disorder

Abstract: Physical and biological examples of transport phenomena through a network of narrow channels are ubiquitous. In this work, we focus on the determination of the effective conductivity and elastic moduli of various two-dimensional ordered and disordered hyperuniform and nonhyperuniform cellular networks. Specifically, we employ simulation techniques and rigorous bounds to determine the effective conductivity of the networks, and cross-property bounds to determine their elastic moduli. We investigate how hyperuniformity affects the effective conductivity and elastic moduli of the networks, and how close disordered hyperuniform networks can come to being optimal, i.e., maximal with respect to these physical properties. We find that generally when short-range and long-range order of the network increases, the effective conductivity and elastic moduli of the network increase. Moreover, we find that certain disordered networks derived from disordered stealthy hyperuniform point patterns possess nearly optimal values of effective conductivity and elastic moduli
while maintaining isotropy.

A3: Ge Zhang, Princeton University

PCoauthors: Frank H. Stillinger and Salvatore Torquato
A classical many-particle system with unique disordered ground state

Abstract: We already know a few classical many-particle systems with disordered ground states, for example, equilibrium hard-sphere systems below jamming density. All previously known disordered ground states of many-particle systems are uncountably infinitely degenerate. However, numerical studies on our recently-suggested perfect-glass model suggest that they have unique disordered classical ground state. This model constrains the structure factor to a finite value, and therefore prohibits crystallization at any finite temperature [1]. We tried to enumerate the local energy minima of this model by performing energy minimizations, starting from 10^7 to 10^9 different random initial conditions, for relatively small systems (10-70 particles). In doing so, a lowest energy is achieved 10 to 10^6 times. Presumably, this is the ground state energy. For all system sizes, numerically found ground states are always related to each other through translations, rotations, and inversions. This numerical result suggests that the disordered ground state of this model is unique except for trivial symmetric operations.
[1] G. Zhang, F. Stillinger, and S. Torquato, Scientific Reports, 6, 36963 (2016).

A4: Jaeuk Kim, Princeton University
Coauthors: Salvatore Torquato
Heavy-tailed Probability Density Functions for Randomly Perturbed Lattices

Abstract: Hyperuniformity is a state of matters where the long-wavelength density fluctuations are significantly suppressed, and disordered hyperuniform systems are gathering attentions due to their exotic properties and potential applications. Among many proposed numerical methods to generate disordered hyperuniform point systems, the simplest one would be generating randomly perturbed lattices, or shuffled lattices, which are lattices whose particles move from their original positions by random displacements following a certain probability density function. In a series of works by Gabrielli and his colleagues, they proposed that a perturbed lattice with variance-less random displacements will have the structure factor vanishing for small wavenumber k as S(k)~k^\alpha, where 0<\alpha<2, but without mentioning specific examples. Here, we present a family of probability density functions, whose second moments do not exist, to implement for randomly perturbed lattices. We provide with the proper system sizes to observe the expected small-wavenumber behavior of the structure factors.

A5. Zheng Ma, Princeton University
Coauthors: Salvatore Torquato

Abstract: In the last decade, hyperuniform systems have attracted attention because they offer many theoretical challenges and are endowed with novel transport and optical properties. Recently, the hyperuniformity concept has been generalized to theoretically characterize scalar fields, two-phase media and random vector fields. We devised methods to explicitly construct hyperuniform scalar fields and, by thresholding them, to ascertain whether the resulting two-phase random media are hyperuniform. We investigated spatial patterns generated from Gaussian random fields, the Cahn-Hilliard equation for spinodal decomposition, and Swift-Hohenberg equations that have been used to model pattern formation. We showed that the Gaussian random scalar fields can be constructed to be hyperuniform. It is also demonstrated that spinodal decomposition patterns modeled by the Cahn-Hilliard equation are hyperuniform in the scaling regime and labyrinth-like patterns generated by the Swift-Hohenberg equation are effectively hyperuniform. Moreover, we showed that thresholding a hyperuniform Gaussian random field to produce a two-phase random medium tends to destroy the hyperuniformity. Our work paves the way for new research directions to characterize the large-structure spatial patterns that arise in physics, chemistry, biology and ecology and can guide experimentalists to synthesize new classes of hyperuniform materials with novel physical properties.

A6: Subhro Ghosh, Princeton University

Coauthors: Joel L. Lebowitz
Generalized stealthy hyperuniform processes

Abstract: We undertake a rigorous mathematical study of stealthy hyperuniform point processes, that have been of considerable interest in the recent statistical physics literature. A stealthy point process is one whose structure function has a gap around the origin. More generally, we study translation invariant stochastic processes on Rd or Zd whose structure function vanishes on an open set. We show that such processes exhibit the following remarkable "maximal rigidity" : namely, the configuration outside a bounded region determines, with probability 1, the exact value (or the exact locations of the points) of the process inside the region. In particular, such processes are completely determined by their tail. In the 1D discrete setting (i.e. Z-valued processes on Z), this can also be seen as a consequence of a recent theorem of Borichev, Sodin and Weiss; in higher dimensions or in the continuum, this phenomenon seem to be surprising even at the level of physical heuristics. For stealthy hyperuniform point processes, we prove Torquato's conjecture which entails that such processes have bounded gaps (or holes), with a universal bound that depends only on the size of the gap in the spectrum of the correlation function.

A7: Ian Jauslin, Institute for Advanced Study
Coauthors: Joel L. Lebowitz
High-fugacity expansion and crystalline order in hard-core particle lattice systems

Abstract: Using an extension of Pirogov-Sinai theory we prove phase transitions, corresponding to sublattice orderings, for a general class of hard core lattice particle systems with a finite number of close packed configurations. The proof also shows that for these systems the frequently used Gaunt-Fisher expansion of the pressure in powers of the inverse fugacity has (aside from an explicit logarithmic term) a nonzero radius of convergence.

A8: Nikolay Gulitskiy, Saint Petersburg State University
Coauthors: N. V. Antonov, M. M. Kostenko, and T. Lucivjansky
Renormalization group approach to the turbulent compressible fluid: scaling regimes and anomalous scaling of passively advected fields.

Abstract: We study a model of fully developed turbulence of a compressible fluid, based on the stochastic Navier-Stokes equation, by means of the field theoretic renormalization group. In this approach, scaling properties are related to the fixed points of the renormalization group equations. In contrast to the direct analysis near the real-world space dimension 3 [Theor. Math. Phys.,110, 3 (1997)], an existence of additional regime is observed in the framework of double (y, ε)--expansion scheme, where y is an exponent, describing scaling behaviour of a random force, and $\varepsilon=4-d$ is a deviation from the space dimension $d=4$. The aim of the present work is to explore the existence of additional regimes and to analyze the crossover between them.
Turbulent advection of passive scalar (density and tracer) and vector fields by this velocity ensemble is considered as well. It is shown that various correlation functions of the scalar field demonstrate anomalous scaling behavior in the inertial-convective range. The corresponding anomalous exponents, identified with scaling dimensions of certain composite fields, can be systematically calculated as a series in y and ε. All calculations are performed in the leading one-loop approximation.

A9: Tolga Caglar, Sabanci University
Coauthors: A. Nihat Berker, Kadir Has
Phase Transitions between Spin-Glass Phases in Random Chiral Systems

Abstract: The q-state clock model, for quenched random right/left chiral and ferromagnetic/antiferromagnetic interactions, has been studied in d=3 for even q, using renormalization-

group theory. In contrast to the previously studied [1] odd-q model, even q has a robust, conventionally ordered antiferromagnetic phase (i.e., as distinct from an algebraically ordered phase). The upshot is four different spin-glass phases, with phase transition between the spin-glass phases. The spin-glass phases and all of their phase boundaries are differentiated by chaos with different values of Lyapunov exponent, which we calculate.
[1] T. Çaglar and A.N. Berker, Phys. Rev. E 95, 042125 (2017).

A10: Stefan Boettcher, Emory University
Coauthors: Shanshan Li, Renato Portugal
Real-Space Renormalization Group for Discrete-Time Quantum Walks and Grover Search Algorithms

Abstract: We explore discrete-time quantum search on fractal networks with the renormalization group (RG) and determine the asymptotic complexity of the Grover search algorithm in terms of the quantum walk exponent d_w^Q (that, we have shown, equals $\frac{1}{2} d_w^R$ of the random walk dimension) and the spatial (fractal) dimension d_f. We obtain exact – and likely general – results for the complexity (or computational cost with system size) to grow as N^α with $\alpha=3d_w^Q/d_f-1$, which the Tulsi method can optimize to $\alpha=1/\min\left\{ d_{s},2\right\}$, referring to the spectral dimension $d_s=d_f/d_w^Q$ of the network. To this end, we develop the real-space RG analysis of the quantum walk obeying a unitary master equation and analyze the probability to overlap with the sought-after site asymptotically in time and system size. We establish a large universality class of search algorithms by considering entire families of quantum coin and search operators. This universality class could be broken for non-reflective (non-Grover) and/or non-real coins.

A11: Dominic Robe, Emory University
Coauthors: Stefan Boettcher
Record Breaking and Dynamic Heterogeneity in Colloidal Glasses

Abstract: In a sequence of random values, one can determine the largest value that has been generated, the record. As more values are generated, new records appear at an ever slower rate. We study the dynamics of an aging colloidal glass system, bearing in mind the statistics of record-breaking events. We have found that the aging of dynamical observables collapse well when the intermittent, irreversible particle rearrangements are compared to record-breaking fluctuations of a stochastic variable.

A12: Per Moosavi, KTH Royal Institute of Technology
Coauthors: Edwin Langmann, Joel L. Lebowitz, and Vieri Mastropietro
A non-equilibrium linear-response approach to heat transport

Abstract: I will present a linear-response approach to heat transport and time evolution in interacting 1D many-body systems starting from an non-equilibrium initial state defined by a non-uniform temperature profile. The validity is motivated by comparison with exact results for the Luttinger model with local interaction.

A13: Colin Rylands, Rutgers University
Coauthors: Natan Andrei
Quantum impurities in Luttinger Liquids: Exact solutions via Bethe Ansatz

Abstract: Quantum impurities coupled to interacting, one dimensional environments have many interesting and remarkable features not seen in their higher dimensional counter parts. We consider such models when the environment is a Luttinger liquid and show they can be solved using Bethe Ansatz.

A14: Sherry Chu, MIT

Coauthors: Daniel A. Beller, David R. Nelson, and Mehran Kardar
Coalescence of directed paths in random media

Abstract: We study the coalescence of directed paths in random media (DPRM) as a model for biological lineages in population dynamics. This is motivated by (stepping stone) models for bacterial range expansions, which exhibit a rough growing front with Kardar-Parisi-Zhang (KPZ) statistics. With open boundary conditions, the rate of coalescence (disappearance of a species) at long times decays as a power law (with exponent $\alpha = 1.7$), and can be fitted very well to a Gamma function. Given periodic boundary conditions (border of an island), coalescence rates decay exponentially, and the limiting probability distribution of uncoalesced DPRM differs from that of diffusive random walkers.

A15: Rajinder Mavi, Michigan State University
Coauthors: Jeffrey Schenker
Effects of degenerate spectrum in Anderson Localization

Abstract: We discuss a model in an Anderson localized regime which exhibits near degeneracy of eigenvalues, such models rescaled eigenvalue processes will be clustering Poisson processes. We discuss the dynamics induced among the degenerate states.

A16: Hanrong Chen, Massachusetts Institute of Technology
Coauthors: David R Nelson, Arup K Chakraborty, Mehran Kardar
HIV dynamics with number fluctuations

Abstract: We present a simple model of intra-host HIV dynamics that exhibits an oscillatory approach to a fixed point with nontrivial populations of target and infected cells, that could represent the chronic phase of HIV infection. Such models that ignore spatial effects perhaps more appropriately describe the dynamics of infection in localized tissues in the host, such as within a lymph node, where now number fluctuations become important. We perform kinetic Monte Carlo simulations of this model, and find that the infection can now go extinct early on, or after arrival at the fixed point. Early extinction may represent failed transmission of an infection from another host. Because of oscillatory behavior towards the fixed point, we anticipate a non-monotonic behavior of the probability of extinction as a function of time.

A17: Eugene Kolomeisky, University of Virginia
Coauthors: J. P. Straley
Fermionization in dilute Bose systems with synthetic dispersion laws

Abstract: Experimental advances in synthesizing spin-orbit couplings in cold atomic Bose gases hold a promise to create single-particle dispersion laws featuring degenerate energy minima along a ring or a sphere in momentum space. We show that for arbitrary space dimensionality ground-state properties of a dilute system of Bose particles with such dispersion and short-range repulsive interactions are universal with the chemical potential exhibiting quadratic dependence on particle density as found in a one-dimensional free Fermi gas. The same effect is predicted for a repulsive two-dimensional Bose gas with quartic in momentum dispersion law which is also within experimental reach.

A18: Michael Kiessling, Rutgers University
A heuristic relative entropy principle with complex measures

Abstract: I propose a heuristic extension to signed and to complex measures of the familiar relative entropy functional for probability measures. I report on empirical computer-generated evidence for the conjecture that the critical points of such functionals capture the asymptotics of a large class of sign-changing expectation value functionals in the thermodynamic limit.