SISSA meets ENS
27-28 September 2018

PROGRAMME

Tuesday

09:00–9:20 Opening

9:20–10:20 Saint-Raymond: *Internal waves in domains with topography*

10:20–10:50 **Coffee Break**

10:50–11:50 Serone: *Perturbation theory and beyond in Quantum Mechanics and Quantum Field Theory*

11:50–12:50 Berti: *Dynamics of Water Waves*

12:40–14:30 **Lunch**

14:30–15:30 Bouchet: *Large deviation theory applied to climate dynamics and astronomy: two new frontiers of statistical mechanics*

15:30–16:00 **Coffee Break**

16:00–17:00 Dabrowski: *The weak Hilbert-Smith conjecture from the Borsuk-Ulam type conjecture*

17:00–18:00 Everaers: *Physics of (or inspired by) the folding of chromosomes*

20.00 **Social Dinner**

Friday

9:20–10:20 de la Salle: **Banach space representations of SL(n,Z) and applications**

10:20–10:50 **Coffee Break**

10:50–11:50 Lapi: *Recent developments in galaxy formation and evolution*

11:50–12:50 Kassel: *Determinantal probability measures on linear subspaces*

12:40–14:30 **Lunch**

14:30–15:30 De Simone: *Machine Learning for High-Energy Physics*

15:30–16:00 **Coffee Break**

16:00–17:00 Stoppa: *The constant scalar curvature Kaehler equation with a Higgs term*

17:00–18:00 Savary: *Quantum physics of rocks*

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ABSTRACTS

Speaker: **Massimiliano Berti** (SISSA)
Title: *Dynamics of Water Waves.*
Abstract: I shall present recent results about the complex dynamics of the water waves equations of a bi-dimensional fluid under the action of gravity and eventually capillary forces, with space periodic boundary conditions. This is an infinite dimensional Hamiltonian system. We shall discuss both long time existence results as well as bifurcation of small amplitude time quasi-periodic solutions. Major difficulties are the quasi-linear nature of the water waves equations and complex resonance phenomena.

Speaker: **Freddy Bouchet** (ENS)
Title: *Large deviation theory applied to climate dynamics and astronomy: two new frontiers of statistical mechanics.*
Abstract: I will discuss a set of recent developments in non-equilibrium statistical mechanics applied to climate and the solar system dynamics. Those two complex dynamical systems are wonderful new playgrounds for statistical mechanics. Their understanding involves large deviation theory, stochastic partial differential equations, and diffusion Monte-Carlo algorithms. The first application will be extreme heat waves as an example of rare events with huge impacts. The second one will be the study of rare trajectories that suddenly drive a turbulent flow from one attractor to a completely different one, related to abrupt climate changes on Jupiter troposphere. The third application will be the study of rare trajectories that change the structure of a planetary system.

Speaker: **Ludwik Dabrowski** (SISSA)
Title: *The weak Hilbert-Smith conjecture from the Borsuk-Ulam type conjecture.*
Abstract: We show that a conjecture of Ageev follows from the Borsuk-Ulam-type conjecture of Baum, Dabrowski and Hajac. Then we explain how the Ageev conjecture implies the weak version of the Hilbert-Smith conjecture which states that a locally compact topological group acting continuously and freely on a connected finite-dimensional manifold so that the orbit space is finite dimensional is isomorphic to a Lie group. The Hilbert-Smith conjecture originates from the already settled Hilbert's fifth problem concerning a characterization of Lie groups.

Speaker: **Andrea De Simone** (SISSA)
Title: *Machine Learning for High-Energy Physics.*
Abstract: I will briefly introduce the main concepts of Machine Learning, and discuss its recent successes and some applications to science. I will describe the importance of the two-sample statistical test as a discovery tool, and provide details of my current research activity on developing Machine Learning algorithms for it. In addition to enable one to check the statistical compatibility between two observed data and expectations the proposed technique allows to identify the parameter regions where discrepancies are significant. An overview of the main open problems in high-energy physics and an explicit application of the proposed method to them will also be provided.

Speaker: **Mikael de la Salle** (ENS)
Title: **Banach space representations of SL(n,Z) and applications**.
Abstract: A group is what encodes the symmetries of a mathematical object. The problem I will discuss in my talk will be to understand for what kind of mathematical objects a given group of arithmetic origin (for example SL(n,Z)) can appear as a group of symmetries. More specifically I will be interested in the symmetries of compact manifolds. In that context a whole research program was initiated by Zimmer in the early 80's in order to classify these actions. I will explain how rigidity results on representations on infinite dimensional normed spaces, that were obtained in a series of works by different authors including Lafforgue de Laat and myself, have been recently used by Brown, Fisher and Hurtado to solve the main cases of these conjectures.

Speaker: **Ralf Everaers** (ENS)
Title: *Physics of (or inspired by) the folding of chromosomes.*
Abstract: Eukaryotic genomes are organized in sets of chromosomes. Each chromosome consists of a single continuous DNA double-helix and associated proteins that organize locally in the form of a chromatin fiber. During cell division (mitosis) chromosomes adopt a compact form that is suitable for transport. During periods of normal cell activity (interphase), chromosomes decondense inside the cell nucleus. Being long chain molecules (in the case of human chromosomes the contour length of the chromatin fiber is on the order of 1 mm), the random thermal motion of interphase chromatin fibers is hindered by topological constraints, similar to those restricting the manipulation of a knotted ball of wool.

In the first part of the talk, I will recall some results from a simulation study of de-condensing model chromosomes [1], where we have explored the consequences of this effect. Not only did the model reproduce the sequence-averaged experimental behavior, but it also suggested a quantitative equilibrium model for the territory formation and the crumpled chain statistics: dense solutions of non-concatenated ring polymers. In the second part of the talk, I will illustrate how to extend our approach to modeling specific biological systems, notably the large scale chromosome folding in Drosophila nuclei during the course of development [2]. In the third part of the talk, I will try to provide a deeper understanding of the nature of the crumpled state, where chains occupy distinct territories and where the relation between the spatial and genomic or contour distance is of the form $R^2(L) \sim L^{2\nu}$ with $\nu = 1/3$, which is markedly different from the strong mutual interpenetration of Gaussian chains with $\nu = 1/2$ characterizing equilibrated linear polymer melts or solutions. I will discuss the relation to the statistics of lattice animals or trees, the understanding of the average tree behavior with the help of Flory arguments as well as scaling arguments allowing to rationalize the distribution functions of the corresponding observables with the help of a small number of additional exponents [3-8].

[1] A Rosa & R Everaers, PLoS computational biology 4 (8), e1000153 (2008)

[2] P. Carrivain, Y. Ogiyama, C. Vaillant, D. Jost, G. Cavalli & R. Everaers, in preparation

[3] A Rosa & R Everaers, Physical review letters 112 (11), 118302 (2014)

[4] A Rosa & R Everaers, Journal of Physics A: Mathematical and Theoretical 49 (34), 345001 (2016)

[5] A Rosa & R Everaers, The Journal of Chemical Physics 145 (16), 164906 (2016)

[6] R Everaers, AY Grosberg, M Rubinstein & A Rosa, Soft matter 13 (6), 1223-1234 (2017)

[7] A Rosa & R Everaers, Physical Review E 95 (1), 012117 (2017)

[8] A Rosa & R Everaers, arXiv preprint arXiv:1808.06861 (2018)

Speaker: **Andrea Lapi** (SISSA)
Title: *Recent developments in galaxy formation and evolution .*
Abstract: I will present the recent research of the SISSA group in galaxy formation and evolution (especially Ph.D. students), with particular focus on: formation of primeval galaxies and the reionization history of the Universe; co-evolution of massive spheroidal galaxies and hosted supermassive black holes; properties of spiral/disc galaxies in the local Universe. I will stress the connections of this research lines to the quests for the nature of dark matter and dark energy, to large-scale cosmology, and to the recent gravitational wave detections from merging compact binaries. Finally, I will highlight how in recent years our understanding of galaxy formation and evolution has been appreciably enhanced by the analysis and interpretation of multi-wavelength (and now multi-messenger) observations via the joint exploitation of numerical simulations, (semi-)analytic modeling and data-science statistical techniques.

Speaker: **Adrien Kassel** (ENS)
Title: *Determinantal probability measures on linear subspaces.*
Abstract: Determinantal point processes (DPP) are a well-studied class of random collections of points with some form of repulsion. Examples include: statistics of fermions, eigenvalues of some random matrices, zeros of Gaussian analytic functions, uniform spanning trees of graphs, and maybe the positions of a flock of birds on a wire too.

When the underlying space is a finite or countable set, a DPP is simply a probability measure on subsets of that set. It is called determinantal because of its algebraic structure involving determinants.

In this talk, I will describe an extension of this class, by defining determinantal probability measures on linear subspaces of a vector space. I will explain how this indeed is a generalization of DPPs and I will present a concrete situation (coming from discrete geometry on graphs, and inspired by lattice gauge theory too) where such a measure appears naturally. This example consists in a tower of combinatorial stochastic processes on graphs encoded by a certain Laplacian, the bottom case of which is the uniform spanning tree measure.

This is a report on joint work in progress with Thierry Lvy (Paris 6).

Speaker: **Laure Saint-Raymond** (ENS)
Title: *Internal waves in domains with topography.*
Abstract: TBA

Speaker: **Lucile Savary** (ENS)
Title: *Quantum physics of rocks.*
Abstract: Rocks are not only for construction, paving, and mosaics. They are also a playground to explore quantum many body physics. Crystalline materials host highly quantum electrons that can exhibit amazing emergent properties with technological promise and which possess fundamental beauty. To study them theoretically requires a synergy of materials chemistry, physics, and mathematics, borrowing from quantum field theory, statistical mechanics, topology and more. I'll discuss examples involving gauge fields, topological edge modes, and Weyl fermions.

Speaker: **Marco Serone** (SISSA)
Title: *Perturbation Theory and Beyond in Quantum Mechanics and Quantum Field Theory.*
Abstract: Perturbative series in quantum mechanics and quantum field theory are generally only asymptotic. In specific theories the series are known to be Borel resummable to the exact result. We show how to reproduce the known results on Borel resummable theories and how to extend these results to more

general theories. In addition, we explain how to define a modified perturbative series which is Borel resummable in a class of quantum mechanical systems where the ordinary perturbative series is not, due to non-perturbative effects.

Speaker: **Jacopo Stoppa** (SISSA)

Title: *The constant scalar curvature Kaehler equation with a Higgs term.*

Abstract: The equation of constant scalar curvature for metrics of Kaehler type is intensively studied in complex differential geometry. We show that it is possible to deform with a Higgs term in a natural way (very similarly to the case of the Hermite-Yang-Mills equation). This extends a result of Donaldson for Riemann surfaces. We describe the first example of a manifold without constant scalar curvature Kaehler metrics but for which the equation with a Higgs term becomes solvable. Joint work with Carlo Scarpa (SISSA).