Advances in Mathematics and Theoretical Physics

Roma, Accademia Nazionale dei Lincei, September 19-22, 2017

Program

	Tuesday 19	Wednesday 20	Thursday 21	Friday 22
9:00 - 9:30	Registration			
9:30 - 10:20	Welcome address	I. Giardina	C. Procesi	C. Liverani
10:25 - 10:55	coffee break	coffee break	coffee break	coffee break
10:55 - 11:45	G. Gallavotti	T. Damour	Y. Kawahigashi	G. Parisi
11:50 - 12:40	R. Brunetti	G. Lechner	A. Guionnet	M. Bischoff
	lunch break	lunch break	lunch break	lunch break
14:30 - 15:20	D. Bahns	S. Hollands	free afternoon	S. Rychkov
15:25 - 15:55	coffee break	coffee break	free afternoon	coffee break
15:55 - 16:45	A. Okounkov	A. Kupiainen	free afternoon	J. Fröhlich
16:50 - 17:40	D. Evans		free afternoon	
18:30 - 20:00		L. Maiani Public lecture Auditorium Ara Pacis		G. Vallortigara Public lecture Auditorium Ara Pacis
20:00 -23:00			Work dinner LINCEI - Palazzo Corsini	

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Talks: Title and Abstract

Dorothea Bahns

University of Göttingen

Constructive QFT with Minkowski signature - The Sine Gordon model in pAQFT

After recalling the formalism of perturbative Algebraic Quantum Field Theory (pAQFT), I will explain how it allows to prove finiteness of the S-matrix of the Sine Gordon model in different representations and how the net of local observables can be constructed.

Marcel Bischoff

Ohio University, Athens

Symmetries in Quantum Field Theory beyond Groups

I will report on some recent progress in understanding generalized symmetries in quantum field theory, in particular, rational conformal field theory in low dimensions.

Romeo Brunetti

University of Trento

Positive, self-adjoint and additive Wick's polynomials of scalar fields

I wish to present a possible solution to the old problem of self-adjointness of Wick's polynomials by enlarging the Wightman framework as to include additive non linear maps (work done in collaboration with Fredenhagen and Hollands)

Thibault Damour

IHES

Gravitational Waves and Binary Black Holes

The recent discovery of several gravitational wave events by the two Laser Interferometer Gravitational-Wave Observatory (LIGO) interferometers has brought the first direct evidence for the existence of black holes, and has also been the first observation of gravitational waves in the wave-zone. The talk will review the theoretical developments on the motion and gravitational radiation of binary black holes that have been crucial in interpreting the LIGO events as being emitted by the coalescence of two black holes. In particular, we shall present the Effective One-Body (EOB) formalism which led to the first prediction for the gravitational-wave signal emitted by coalescing black holes. After a suitable Numerical-Relativity completion, the (analytical) EOB formalism has allowed one to compute the bank of 200 000 accurate templates that has been used to search coalescence signals, and to measure the masses and spins of the coalescing black holes.

David Evans

Cardiff University

K-theory and Conformal Field Theory

I will discuss the programme to understand conformal field theory via twisted equivariant K-theory. In particular, studying module categories and modular invariants for the twisted doubles of finite groups through correspondences as bivariant Kasparov KK elements, and realising the twisted doubles of finite groups as conformal field theories. This has also resulted in a better understanding of the double of the Haagerup subfactor, which was originally thought to be exotic and un-related to known models.

Jürg Fröhlich

ETH Zürich

The Statistical Mechanics of the Universe

A dilettante's view of some of the central enigmas of cosmology is presented. A proposal for the description of the state of the Early Universe is brought forward. A mechanism possibly explaining the generation of primordial magnetic fields is described and analyzed. The axion model of "Fuzzy Dark Matter" is described and criticized for its instabilities. A model of Dark Energy is introduced and discussed, and a conjectural application of this model to an explanation of the observed matter-antimatter asymmetry is sketched.

Giovanni Gallavotti

INFN - Roma 1

Friction, reversibility and nonequilibrium ensembles

The Navier-Stokes equations are "irreversible" (are they?). I shall use them as an example of a general proposal for a theory of statistical ensembles, and their equivalence, describing the statistical properties of nonequilibrium stationary states.

Irene Giardina

University of Roma Sapienza

Dynamic scaling in natural swarms

Collective behavior is widespread in biological systems across many different scales and organisms. As physicists, our hope is that the (complex) details of the individuals are not important when looking at collective properties, and that large scale behavior can be characterized in terms of general laws, much as we do in condensed matter. However, this assumption cannot be given for granted and must be experimentally justified.

In an attempt to improve on this situation, we present here experimental evidence of the emergence of dynamic scaling laws in natural swarms. We find that spatio-temporal correlation functions in different swarms can be rescaled by using a single characteristic time, which grows with the correlation length with a dynamical critical exponent z~1. We run simulations of a model of self-propelled particles in its swarming phase and find z~2, suggesting that natural swarms belong to a novel dynamic universality class. This conclusion is strengthened by experimental evidence of non-exponential relaxation and paramagnetic spin-wave remnants, indicating that previously overlooked inertial effects are needed to describe swarm dynamics. The absence of a purely relaxational regime suggests that natural swarms are subject to a near-critical censorship of hydrodynamics.

Authors: A. Cavagna, D. Conti, C. Creato, L. Del Castello, I. Giardina, T.S. Grigera, S. Melillo, L. Parisi, M. Viale

Alice Guionnet

ENS de Lyon

Fluctuations of Discrete Beta Ensembles and Random tilings

We consider random lozenge tilings of some fixed large domain. It is well known that for relatively simple domains, the general shape of these tilings converge almost surely when the mesh of the domain goes to zero and local and global fluctuations are well known. We consider more complicated domains where holes are allowed and study their fluctuations. To do so, we remark that the distribution of horizontal tiles are given by discrete Beta-ensembles, analogues of the distributions of eigenvalues of large random Gaussian matrices for discrete variables. We analyze these distributions thanks to certain equations that Nekrasov derived, analogue to the Dyson-Schwinger equations for random matrices. Our results also include other models such as Jack deformations of the Plancherel measure. This talk is based on joint works with Borodin, Borot, Gorin, Huang.

Stefan Hollands

University of Leipzig

Entanglement Measures in Quantum Field Theory

In quantum theory, there can exist correlations between subsystems of a new kind that are absent in classical systems. These correlations are nowadays called "entanglement".
An entanglement measure is a functional on states quantifying the amount of entanglement across two subsystems (i.e. causally disjoint regions in the context of quantum field theory).
A reasonable measure should satisfy certain general properties: for example, it should assign zero entanglement to separable states, and be monotonic under separable, completely positive maps ("LOCC-operations"). The v. Neumann entropy of the "reduced state" (to one of the subsystems) is one such measure if the state for the total system is pure. But for mixed states, it is not, and one has to consider other measures. In particular, one has to consider other measures if the subsystems have a finite non-zero distance.
In this talk I will present several good measures, and in particular analyze the "relative entanglement entropy", E_R, defined as the "distance" of the given state to the set of separable states, where "distance" is defined using Araki's relative entropy. I will show several features of this measure for instance: (i) charged states, where the relative entanglement entropy is related to the quantum dimension of the charge, (ii) vacuum states in 1+1 dimensional integrable models, (iii) general upper bounds for certain special regions in general CFTs in d dimensions, (iv) area law type bounds. I will also explain the relationship between E_R and other entanglement measures, such as distillable entropy.
[Based on joint work with Jacobus Sanders.]

Yasuyuki Kawahigashi

Tokyo University

Conformal field theory, operator algebras and vertex operator algebras

We compare two mathematical axiomatizations of chiral conformal field theory. One is a conformal net based on operator algebras and the other is a vertex operator algebra which grew out from the Moonshine conjecture. We present various results on conformal nets and compare them with those on vertex operator algebras with emphasis on comparison of the representation theories. In particular, we show that we can pass from a vertex operator algebra to a conformal net and come back under a mild technical assumption.

Antti Kupiainen

University of Helsinki

Proof of the DOZZ Formula

In 1994 Dorn and Otto and in 1996 independently Zamolodchikov and Zamolodchikov proposed a remarkable explicit expression, the so called DOZZ formula for the 3 point structure constants of the Liouville Conformal Field Theory (LCFT) which is expected to describe the scaling limit of large planar maps properly embedded in the sphere. I will review a rigorous construction of LCFT and sketch a recent proof of the DOZZ formula obtained together with R. Rhodes and V. Vargas.

Gandalf Lechner

Cardiff University

Yang-Baxter representations of the infinite symmetric group

The Yang-Baxter equation (YBE) lies at the heart of many subjects, including quantum statistical mechanics, QFT, knot theory, braid groups, subfactors, quantum groups, quantum information ... . In this talk, I will consider mainly involutive solutions of the YBE ("R-matrices"). Any such R-matrix defines a representation and an extremal character of the infinite symmetric group as well as a corresponding tower of subfactors. Using these structures, I will describe how to find all R-matrices up to a natural notion of equivalence inherited from applications in QFT (given by the character and the dimension), how to completely parameterize the set of solutions, and how to decide efficiently whether two given R-matrices are equivalent. Examples include diagonal R-matrices as they appear in DHR theory, or Temperley-Lieb type R-matrices at parameter q=2.

Carlangelo Liverani

University of Roma Tor Vergata

Energy transport in Hamiltonian systems

I will review some results on energy transport in weakly coupled classical Hamiltonian systems and discuss ongoing attempts to go beyond the weak coupling limit.

Andrei Okounkov

Columbia University

Gauge theories and Bethe eigenfunctions

The talk will be based on a joint paper https://arxiv.org/abs/1704.08746 with Mina Aganagic. In this paper, we essentially complete the program of Nekrasov and Shatashvili who explained the meaning of Bethe roots, Bethe equations, etc. of quantum integrable systems via their correspondence with supersymmetric gauge theories. We explain the meaning of off-shell Bethe eigenfunctions (which also give solutions of the quantum Knizhnik-Zamolodchikov equations and related difference equations). Our formulas may be seen from a geometric, representation–theoretic, combinatorial, and other angles.

Giorgio Parisi

University of Roma Sapienza

On the replica approach for statistical mechanics of random systems

Claudio Procesi

Sapienza University of Roma

On the non linear Schroedinger equation on an n—dimensional torus

The non linear Schroedinger equation. NLS for short, in its simplest *resonant* form is
$i\, u_t + \Delta u = k\, |u|^{2q}\, u$, $q \leq 1 \in \mathbb{N}$. Δ is the Laplace operator.
We study this on an n-dimensional torus. It is well known that the NLS can be treated as infinite dimensional Hamiltonian system, perturbation of the linear one.
We show the existence of a strong reducible *normal form* and by applying a suitable KAM algorithm, the existence of large families of quasi-periodic solutions with various properties of stability.
Joint work with Michela Procesi.

Slava Rychkov

CERN and ENS Paris

Constructing Quantum Field Theories Non-perturbatively with Hamiltonian Methods

While path integral approach to quantum field theories has come to dominate the field, the Hamiltonian methods have been unjustly neglected. I will discuss some work, inspired by the Rayleigh-Ritz method in quantum mechanics, which uses the Hamiltonian approach to do approximate but precise non-perturbative computations in strongly coupled quantum field theory in 1+1 dimensions.

Public Lectures: Title and Abstract

Luciano Maiani

Università di Roma La Sapienza, Roma CERN, Ginevra

Elementary particles: the search for simplicity

The search of the last constituents of matter, the “Elementary Particles”, has fascinated mankind since the beginning of scientific thinking. Modern science has made impressive progresses, discovering a new level of reality beyond atoms and atomic nuclei: quarks, which make now part of our everyday language and of the collective imaginary. The discovery of the “Higgs boson” has marked the success of a description of physical reality based on elements of simplicity, unthinkable only fifty years ago. Along the way, we have discovered fascinating connections between the physics of Microcosm and the large scale structures, galaxies and clusters of galaxies, that have been formed in the Universe since primordial Big-Bang.

There are still mysteries. Among them, the possible existence of new particles, to explain the non-luminous, dark matter gravitating around galaxies, that accounts for more than 90% of the matter present in the Universe. To clarify this and other mysteries, powerful particle accelerators are planned, to reach energies of one order of magnitude larger than the energy of the Large Hadron Collider now working at CERN.

Title and abstract in Italian

Particelle Elementari: la ricerca della semplicità

La ricerca dei costituenti ultimi della materia, le “Particelle Elementari”, ha affascinato l’uomo fin dai primi passi del pensiero scientifico. La scienza moderna, nel Novecento, ha compiuto progressi straordinari scoprendo un nuovo livello del mondo reale, oltre l’atomo e il nucleo atomico: i quark, entrati ormai nel linguaggio di ogni giorno e nell’immaginario collettivo. La scoperta del “bosone di Higgs” ha sancito il successo di una descrizione della realtà fisica basata su elementi di semplicità impensabili solo cinquant’anni fa. Lungo questo percorso, si scoprono affascinanti relazioni tra la fisica del Microcosmo e le strutture su grande scala che si sono formate, nell'Universo, a partire dal Big Bang iniziale.

Ci sono ancora importanti misteri. Tra questi, la possibile esistenza di nuove particelle che potrebbero essere la chiave della materia non luminosa che gravita intorno alle Galassie e rende conto di più del 90% della materia esistente nell’Universo. Per chiarire i misteri, sono allo studio nuove macchine con energie superiori di un ordine di grandezza all’energia della macchina del CERN.

Giorgio Vallortigara

Centre for Mind/Brain Science, University of Trento

The Sense of Number

Evolutionary origins and neurobiology

The abilities to deal with non-verbal and non-symbolic aspects of numerousness by an approximate number system (or "number sense") are evolutionarily ancient, and they can be investigated from a comparative perspective. I shall discuss here evidence in non-human animals and human infants showing precocious abilities to represent the cardinal and ordinal aspects of numerical cognition, as well as arithmetic operations. Furthermore, non-human animals and human infants appear to associate smaller numbers with the left space and larger numbers with the right space, mapping numbers to space in a way that resembles adult human mental number line. These abilities are observed very early in development and in the absence (or with very reduced) experience, thus supporting a nativistic foundation of non-symbolic numerical cognition.

Title and abstract in Italian

Il Senso del Numero

Origini evolutive e basi neurobiologiche

Quali sono le basi neurobiologiche della nostra conoscenza del numero? Sottostanti le capacità matematiche simboliche e discrete che si sono sviluppate in alcune società umane, giacciono, incarnate nell'attività dei sistemi nervosi, le radici non-simboliche della rappresentazione della numerosità. Basate sulla stima della quantità e sul continuo, esse sono osservabili anche nelle creature prive di linguaggio simbolico, i bambini più piccoli e gli animali non umani.