Plenary Talks

• ***Wednesday 28***

09:00. **Andrea Cavagna** (ISC-CNR Roma): *Superfluid transport of information in turning flocks of starling.*

Collective decision-making in biological systems requires all individuals in the group to go through a behavioural change of state. During this transition, the efficiency of information transport is a key factor to prevent cohesion loss and preserve robustness. The precise mechanism by which natural groups achieve such efficiency, though, is currently not fully understood. I will present an experimental study of starling flocks performing collective turns in the field. We find that the information to change direction propagates across the flock linearly in time with negligible attenuation, hence keeping group decoherence to a minimum. This result contrasts with current theories of collective motion, which predict a slower and dissipative transport of directional information. We have proposed a novel theory whose cornerstone is the existence of a conserved spin current generated by the gauge symmetry of the system. The theory turns out to be mathematically identical to that of superfluid transport in liquid helium and it explains the dissipationless propagating mode observed in turning flocks. Superfluidity also provides a quantitative expression for the speed of propagation of the information, according to which transport must be swifter the stronger the group's orientational order. This prediction is verified by the data. We argue that the link between strong order and efficient decision-making required by superfluidity may be the adaptive drive for the high degree of behavioural polarization observed in many living groups. The mathematical equivalence between superfluid liquids and turning flocks is a compelling demonstration of the far-reaching consequences of symmetry and conservation laws across different natural systems.

09:45. **Gerald Dunne** (Connecticut U.): *Resurgence and non-perturbative physics.*

"Resurgent" semiclassical analysis, a systematic unification of perturbative and non-perturbative sectors, can be applied to resolve fundamental problems in quantum theories with degenerate minima. Expansions about different saddle points are quantitatively related to one another in a precise manner. Illustrations include double-well and periodic potentials in QM, and asymptotically free QFTs such as CPN and Yang-Mills, where this resurgent approach yields a new semiclassical interpretation of IR renormalons.

14:30. **Claudio Castelnovo** (Cambridge)**:** *Monopole physics in spin ice materials.*

Spin ice materials such as Dy2Ti2O7 and Ho2Ti2O7 provide a rare instance of emergent gauge symmetry and fractionalisation in three dimensions. Their elementary excitations carry a fraction of the magnetic moment of the microscopic spin degrees of freedom, and they can be thought of as magnetic monopoles. This talk aims at introducing spin ice models and materials, and reviewing some of their unusual properties. The peculiar nature of the excitations affects both equilibrium and response properties of spin ice materials. These include unusual neutron scattering structure factors, dynamical arrest and long lived non-equilibrium metastable states, as well as a response to external magnetic fields that promotes spin ice as a magnetic analogue of an electrolyte. The formulation of the low-temperature phase in terms of an emergent gauge field permits an unusual degree of analytical progress in the modelling of these materials.

15:15. **Leonardo Fallani** (LENS, Firenze U.): *Multi-component one-dimensional liquids of fermions.*

Quantum gases of neutral atoms cooled down to the nanokelvin scale provide a powerful technological platform for the “quantum simulation” of fundamental physics in interacting many-body systems. By using atomic physics techniques to trap and control the state of ultracold atoms, we can engineer clean tabletop realizations of paradigmatic theoretical models, often introduced in the context of condensed-matter physics, to describe e.g. strongly-correlated electrons interacting on a lattice or in low dimensions.
In this talk we report on a recent experimental investigation of multi-component one-dimensional liquids of ultracold 173Yb fermions [1]. These atoms are characterized by a large nuclear spin and highly-symmetric atom-atom interactions, which result in the possibility of performing quantum simulations of systems with intrinsic and tunable SU(N) symmetry, with N up to 6. By controlling the number of spin components N, we have studied how static and dynamic properties of strongly-correlated 1D fermions change with N, evidencing for the first time intriguing effects caused by the interplay between interactions and quantum statistics. These experiments provide a test bench for 1D theories and open new directions in experimental quantum simulation, connected e.g. to large-spin SU(N) magnetism or to the investigation of quantum field theories with extended SU(N) symmetries.
[1] G. Pagano et al., Nature Physics 10, 198 (2014).

• *Thursday 29*

09:00. **Simone Giombi** (Princeton U.): *Higher spin theories and holography.*

Higher spin gravity theories in Anti-de Sitter space have been conjectured to be holographically dual to conformal field theories with vector-like matter fields: these include the free CFT's of N-component massless scalars or fermions., but also interacting CFT's such as the Wilson-Fisher fixed point in 3 dimensions and certain Chern-Simons matter theories. I will give an overview of these conjectures and their status, and discuss in particular some recent tests of the dualities based on comparing bulk and boundary partition functions.

09:45. **Erik Tonni** (SISSA): *Aspects of Entanglement in QFT.*

Entanglement of quantum states and its measures play an important role in different areas of theoretical physics like condensed matter, quantum gravity and quantum information. During the last decade many results have been obtained to quantify entanglement in quantum field theories and to get insights from its general properties. Some of these achievements will be discussed, focussing on the entanglement in conformal field theories, which can be studied also through holographic techniques.

14:30. **Fawad Hassan** (Stockholm U.): *Bimetric theories.*

Bimetric theories can describe gravity in the presence of an extra spin-2 field. From a theoretical perspective, these models are intriguing since generically they can contain a ghost instability and ghost-free versions of them have been constructed only over the past few years. This talk will review the ghost-free bimetric theory and discuss some recent results in the field.

15:15. **Martin Kunz** (Geneve U.): *Planck, BICEP2 and implications for inflation and dark energy.*

Last year ESA’s Planck space telescope released the most detailed map ever created of the cosmic microwave background – the relic radiation from the Big Bang. The map shows the Universe at a time when it was just 380 000 years old, and the tiny fluctuations that it contains represent the seeds of all future structure: the stars and galaxies of today. I will discuss the Planck

CMB results and some of their implications for inflation and dark energy. I will also spend some time on newer measurements, especially on the claimed detection of primordial B-modes by the BICEP2 collaboration.

• ***Friday 30***

09:00. **Owe Philipsen** (ITP, Frankfurt): *Heavy dense QCD and nuclear matter on the lattice.*

At finite baryon density the fermion determinant of the QCD partition function is complex-valued. This so-called sign problem prohibits simulations of lattice QCD by Monte Carlo methods and is the reason that the QCD phase diagram remains largely unknown. Here I present a new method to deal with finite densities in two steps. First, an effective lattice theory of Polyakov loops is derived by means of combined strong coupling and hopping expansions. The theory is so far valid for heavy quarks only, but has a milder sign problem that can be dealt with by various algorithmic methods. As an application, the QCD deconfinement transition at fnite temperature has been calculated for all baryon densities. Moreover, for the first time it is possible to describe the onset transition to cold nuclear matter at zero temperature as well as the nuclear equation of state and the nuclear binding energy directly from QCD.

09:45. **Discussion Session: Sarkar, Kunz, Maggiore.**

14:30. **Marco Incagli** (Pisa U.): *AMS02, Fermi and Planck: verifying the Cosmological Standard Model with Space Experiments, an experimentalist perspective.*

In recent years, the Cosmological Standard Model has been successfully tested with space experiments, based on satellites or on the International Space Station. Though suffering from limited dimensions, with respect to ground based ones, and therefore limited geometrical acceptance, these experiments allow to probe the sky both in the GHz domain (meV) and in the GeV-TeV domain in a much more clear way, thus providing strong constraints on the so-called LambdaCDM model and on the Dark Matter search. I will review the experimental techniques and the results of three recent experiments operating in different energy and particle domains: AMS02, probing charged cosmic rays in the GeV-TeV energy range, Fermi, mostly, but not only, devoted to study photons in a similar energy range, and Planck, which recently published maps of the sky in the frequency range between 25 and 1000 GHz.

15:45**. Subir Sarkar** (Oxford U.): *Seeing the high energy universe with IceCube.*

Recent results from the IceCube experiment at the South Pole will be presented, in particular the discovery of extraterrestrial high energy neutrinos, as well as the detection of atmospheric neutrino oscillations. Ongoing activities and proposed future plans will be discussed.

• *Saturday 31*

09:00. **Davide Gaiotto** (Perimeter Institute)**:** *Protected quantities in supersymmetric gauge theories.*

Supersymmetric quantum field theories with four or more supercharges can be associated to a large variety of protected quantities, which can be computed exactly through methods such as localization and provide rather non-trivial information about their dynamics, dualities and defects. Often, these protected quantities are a key tool to establish unexpected relations to other physical and mathematical structures. I will provide a general overview of the subject and some recent new results.

09:45. **Alessandro Strumia** (Pisa U.): *Theoretical implications of present LHC unobservations.*

We discuss the Higgs mass naturalness problem at the light of recent LHC results. The main focus of the talk is presenting an alternative to the usual interpretations: natural new physics at the weak scale (such as supersymmetry) and anthropic selection. Basic ideas of Agravity will be outlined.

11:05. **Maurizio Pierini** (CERN): *Results from the LHC run I and perspectives for run II.*

We review the main physics results of the 7 TeV and 8 TeV proton-proton data by ATLAS and CMS, including the Higgs boson discovery and characterisation and the search for new physics. In view of the energy upgrade and a target luminosity of 200 fb-1, we discuss the lesson learned, the expected and unexpected developments, the challenges ahead of us, and the physics goals for Run II.