PASSION FOR PHYSICS

International School of Physics Enrico Fermi

60th Anniversary

15 June 2013
Villa Monastero
Varenna (Lake Como)

UNDER THE HIGH PATRONAGE OF THE PRESIDENT OF THE ITALIAN REPUBLIC

Extreme Events and Rogue Waves in Nature: New Insights from Nonlinear Science

John Dudley
Université de Franche-Comté, Besançon, France

The study of extreme events in nature encompasses many and diverse phenomena that are unexpected and severe. This talk will provide an introduction to recent advances studying the physics of extreme events that are using the methods and tools of nonlinear science. Particular examples of rogue waves in oceanography and the generation of giant high intensity laser pulses will be discussed in detail because they illustrate how multidisciplinary approaches to research are proving especially fruitful. A particular focus will be the notion of nonlinear soliton emergence, which appears as a universal feature in many different classes of extreme localization. We will describe both the physics and the history of this particular concept, which is intimately linked to the very first numerical studies of nonlinear problems that were stimulated by Enrico Fermi in 1953.

Supersymmetry in Nuclei

Francesco Iachello
Yale University, USA

Supersymmetry is a far-reaching concept that provides a unified description of mixed systems of bosons and fermions. Originally introduced for applications in elementary particle physics, it has been subsequently applied to other fields of physics. One of the most useful applications so far has been to problems in nuclear physics, where experimental evidence for dynamic supersymmetry has been found. In this presentation, after a brief historical introduction, the mathematical framework, graded Lie algebras or superalgebras, needed for the description of supersymmetry will be introduced and applied to the study of supersymmetry in nuclei where the graded algebra is U(n/m).

Preliminary evidence for the occurrence of supersymmetry in nuclei was found in the 1980's. More recently, in a series of experiments performed at various laboratories, the preliminary evidence has been confirmed and further expanded to the even more complex situation of mixed systems of bosons and fermions with internal symmetry, described by the graded algebra $U(n/m)_{\pi} \otimes U(n/m)_{\nu}$. Both the preliminary evidence and the recent evidence leading to the discovery and confirmation of supersymmetry in nuclei will be presented. Finally, the implications of this discovery to other fields of physics will be briefly mentioned.

Fascination for the Weirdness of Quantum Mechanics: from Fundamental Questions to Applications

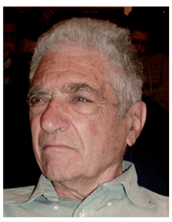
Alain Aspect
Institut d'Optique, Palaiseau, France

My life as an experimentalist in AMO physics has been punctuated with fascinating quantum phenomena, such as Anderson localization, or coherent population trapping, discovered by Adriano Gozzini, in Pisa, almost forty years ago. But in parallel with these sophisticated phenomena, I have always been fascinated by elementary questions about quantum mechanical weirdness, even when the general wisdom was that «this question was raised by Einstein and given a satisfactorily answer by Bohr». As an experimentalist, I had the opportunity to revisit some of these basic questions, such as wave-particle duality for a single particle, including in the Wheeler's delayed choice scheme, or non-classical correlations of entangled particles. Careful reading of Bohr reveals that his answers to Einstein are definitely elaborated, but not always crystal clear, in accordance with his statement that «Clarity and Truth are Complementary».

I will take the example of the experimental realizations of the Einstein-Podolsky-Rosen GedankenExperiment, to illustrate the fact that although the weirdest properties of entanglement have been experimentally demonstrated, not all discussions about interpretation are settled. I will argue that it is precisely such discussions that have prompted, and continue to stimulate the discovery of unexpected applications in quantum information.

The Marvellous Neutrino

Carlo Rubbia
CERN, Geneva, Switzerland



Personal Recollections of Varenna: Physics, Fermi, Mountains

Jack Steinberger
CERN, Geneva, Switzerland

3D Structure of the Nucleon

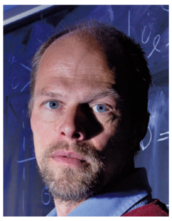
Harut Avakian
Thomas Jefferson National Accelerator Facility, Newport News, USA

In recent years, the hadronic physics community has extended its investigation of partonic structure of hadrons beyond the standard parton distribution functions (PDFs), by exploring the parton's motion and its spatial distribution in the direction perpendicular to the parent hadron's momentum. Two sets of non-perturbative functions have been introduced to investigate and describe the structure of hadrons at the quark-gluon level: Transverse Momentum Dependent (TMD) parton distributions and Generalized Parton Distributions (GPDs). Much of the interest in TMDs and GPDs has been triggered by their potential to help unravel the spin structure of the nucleon, as they carry information not only on the longitudinal but also on the transverse momentum and position of partons, providing rich and direct information on the orbital motion of quarks. Studies of the 3D PDFs are currently driving the upgrades of several existing facilities (JLab and RHIC), and the design and construction of new facilities worldwide (EIC, GSI, and JPARC).
In this talk, we present an overview of the latest developments in studies of the orbital structure of nucleons and nuclei as well as some future measurements at various facilities worldwide.

Quantum Networks

Uzy Smilansky
The Weizmann Institute of Science, Rehovot, Israel

Quantum networks (graphs) have been used to model and explain a plethora of physical systems and phenomena, such as e.g., magnetic susceptibility of organic molecules, spectral bands in periodic solids, Anderson localisation and Quantum Chaos, to count only a few prominent examples. Graphs, which are built of simple components - vertices and connecting edges - display a large variety of complex behaviour patterns due to their non-trivial connectivity, and hence their importance as paradigms in so many fields of physics. The main advantages of studying graphs is in the simple dynamics on their building blocks (propagation on edges and transmission through vertices) which renders them amenable for theoretical or computational analysis. In this talk I shall present several examples which shed light on the way the network topology brings about complex dynamics, and how they help in addressing practical physical issues.



Disordered Photonics

Diederik Wiersma
LENS and INO-CNR, Firenze, Italy

Disordered photonics is a field that receives growing interest from the optics community, and in which fundamental physics concepts are combined with practical applications. Light transport in disordered systems has interesting analogies with solid state and atomic physics, mainly due to interference in multiple scattering. At the same time, it is now understood that disorder can have very practical applications like that of enhancing the efficiency of solar cells and creating novel light sources. Nature provides also a fascinating inspiration in this field as it was recently discovered that some animals - like the white beetle - use a complex amorphous photonic pattern to create strong scattering, its structure having been optimized by millions of years of natural selection.

The Complex Physics of Climate Change and Climate Sensitivity: a Grand Unification

Michael Ghil
Ecole Normale Supérieure, Paris, France and University of California, Los Angeles, USA

Recent estimates of climate evolution over the coming century still differ by several degrees. This uncertainty motivates the research presented herein.
The complex physics of climate change arises from the large number of components of the climate system, as well as from the wealth of processes occurring in each of the components and across them. This highly heterogeneous complexity has given rise to countless attempts to model each component and process. Two overarching approaches have attempted to apprehend the complexity as a whole: deterministically nonlinear and stochastically linear. Call them the Ed Lorenz and the Klaus Hasselmann approach, respectively, for short.
We propose a “grand unification” of these two approaches that relies on the theory of random dynamical systems. In particular, we apply this theory to the problem of climate sensitivity, and study the random attractors of nonlinear, stochastically perturbed systems, as well as the time-dependent invariant measures supported by these attractors.
Results are presented for several simple climate models, from the classical Lorenz convection model to El Nino-Southern Oscillation models. Their attractors support random Sinai-Ruelle-Bowen measures with nice physical properties. Applications to climate sensitivity and predictability are discussed.
This talk presents joint work with M. D. Chekroun, D. Kondrashov, J. C. McWilliams, J. D. Neelin, E. Simonnet, S. Wang and I. Zaliapin.

Higgs found. What next?

Fernando Ferroni
Sapienza Università di Roma, Italy

The Large Hadron Collider has completed its first cycle of measurement leaving us with a spectacular gift: the discovery of the Higgs boson. And now what? What is the impact of such a fundamental achievement on the HEP field? What shall we go after now in priority? The almost incredible success of the Standard Model poses delicate questions. There is however a contradiction between the 4% of Universe that t we know even too well with respect to the lack of understanding of the remaining vast majority. Even amongst the particles we play with daily there are unsolved questions, neutrinos being the top of the iceberg. I will try to point to the main lines of research for the field in the near future.