ABSTRACTS - DARIO MARTELLI

Quantum Gravity and Black Holes

1. What is quantum gravity (and why it is important)

In this lecture, we will discuss the fundamental theories of physics that underpin our current understanding of the Universe and the laws that govern it. In particular, we will highlight the challenge of formulating a theory capable of describing Nature at both extremely small and extremely large scales -- a theory of quantum gravity. Such a theory could unveil some of the remaining mysteries of human knowledge and open up new, unexpected possibilities.

2. Theories of quantum gravity: supergravity, string theory, holography (and more)

In this lecture, we will provide an overview of various proposals for theories of quantum gravity. We will offer a heuristic discussion of supergravity, string theory, and other related approaches. In particular, we will argue that the so-called holographic principle has introduced a new paradigm in theoretical physics, fundamentally transforming our understanding of gravity and the other fundamental forces of nature.

3. Black holes: theoretical foundations, observations and open problems

For a long time, black holes were considered little more than a theoretical possibility and were frequently portrayed in science fiction. However, recent astrophysical observations have confirmed their existence in nature, sparking renewed interest within the scientific community in understanding the features that continue to make them so mysterious. In this lecture, we will begin by outlining the mathematical foundations of black holes, then examine their remarkable properties, the theoretical challenges they pose, and some of the leading proposals aimed at addressing these puzzles.

ABSTRACTS - ERIC LAENEN

Present and future of particle physics

Abstract:

In the first lecture I will introduce the key theoretical ideas and principles behind the Standard Model of particle physics, such as fields and symmetries. This will be interspersed with descriptions of how experiments pointed us in certain directions, and likewise when theorists foretold nature's properties, using these principles.

In the second lecture I will touch upon how particle physics organizes itself, in particular how CERN works and operates, and how the LHC works. This is the year that the European particle physics community, including CERN, updates its strategy. I will discuss how the process works and what a range of outcomes might be.

In the third lecture I will review the present state of affairs in various branches of particle physics, and how we are trying to push the envelop of our knowledge. Here the theme is "precision", and I will sketch how the drive for precision has lead to impressive innovations in our theoretical methods. At the end of these lectures you should then have a good impression of the present state and possible future of particle physics.

ABSTRACTS - RICCARDO ZECCHINA

Artificial Intelligence

Lecture 1 (Broad Audience): How does AI really work. Where We Stand and What's Next.

Abstract:
This lecture introduces the basic ideas behind machine learning and modern artificial intelligence (AI). We'll explain the key reasons behind AI's current success and outline what developments we can expect in the next decade as we move toward Artificial General Intelligence.

Lecture 2 (Scientists): How AI is Changing Scientific Research

Abstract:
Artificial intelligence is reshaping the way scientific research is done, speeding up discoveries and providing new methods for investigation. We'll discuss the principles that make AI a powerful scientific tool and present clear examples of its direct and indirect impacts on research. The potential risks involved in misusing AI tools will also be briefly covered.

Lecture 3 (Physicists): The Physics Behind AI

Abstract:
Artificial intelligence is built on artificial neural networks (ANNs) with billions of connections. Understanding how these networks behave after training is similar to studying complex physical systems far from equilibrium, and it requires insights from both physics and algorithmic theory. We'll focus on two key aspects:

1. Geometry of Learning Landscapes:
   We'll describe the complex geometric structure of ANN training landscapes, linking them to computational performance and physical properties.

2. Physically Realistic AI Models:
   We'll discuss the challenge of designing AI models that are physically or biologically realistic yet remain competitive. Current AI relies heavily on gradient descent, a method very different from the distributed computations found in biological brains.

ABSTRACTS - LEONARDO CASTELLANI

Quantum Computing

1. Why quantum and why computing

In the first lecture I will briefly retrace the steps leading to the use of quantum mechanical systems as computational tools, providing examples and a simplified account of the basic rules of Quantum Mechanics, the theory that describes the microscopic world and that celebrates this year its 100-th birthday. Some basic notions of computational complexity will be recalled, and the transition from bits to quantum bits, with some of its counterintuitive consequences, will be discussed on a non-technical level. Brief considerations on the status of hardware development for quantum computers will close the lecture.

2. Quantum gates and quantum circuits

The second lecture deals with some applications of quantum bit manipulation and transmission. After introducing a few elementary linear algebra notations, I will treat some examples of quantum gates and quantum circuits, followed by a discussion on quantum teleportation and quantum cryptography.

3. The power of quantum algorithms

The third lecture will at first focus on measurement and quantum mixtures. Then some considerations on simultaneity of collapse, and quantum histories, will be presented with examples. Finally, Shor's algorithm for factorization, and Grover's algorithm for searching solutions in a data base will be discussed.

GIORGIO PARISI - REGGE LECTURE 2025

"**Dalla complessità alle radici della moderna intelligenza artificiale**"

Abstract:

In questa conferenza viene riassunta brevemente la storia delle grandi scoperte in fisica, ma anche in biologia, che hanno portato alle basi della moderna intelligenza artificiale.