Title: Quantum materials.
Lecturer: Dr. Enrico Da Como
Department of Physics, University of Bath, BA2 7AY. United Kingdom
Dates and location: Fridays 3rd, 10th, 17th, 24th May 2024, 14h30-17h. Room L1.5, MO17 Dpt Physics.

Introduction.
I will present an overview of quantum materials introducing the fundamental electron-electron, electron-phonon and spin-orbit interactions that identify material classes such as superconductors and Mott insulators, charge density wave materials and topological insulators. I will start with an historical perspective on the discovery of these solid state systems and also present some of the most recent real world applications and future opportunities.

Graphene and 2D TMD materials
In this lecture I will present the electronic structure of graphene and briefly touch on the structure of bi-layer and tri-layer graphene. I will explain what makes it so unique and review some of the milestone papers about its electrical and optical properties. In the second part I will introduce the transition-metal-dichalcogenides (TMDs) illustrating the metallic and semiconducting compounds. I will explain why semiconductors such as MoS_2 and WS_2 change their properties when thinned down to the monolayer limit. In addition, I will start to introduce how the 2D physics of these materials was the seed for more recent discoveries such as topological insulators

Charge density wave and excitonic insulators
I will present fundamentals of charge density waves starting from 1D systems and extending to 2D. I will introduce the Peierls instability and present some of the mean-field models used to describe the behaviour of charge density wave materials. In the second part I will present the concept of the excitonic insulator as first described by Kohn and report some recent discoveries and experimental evidence for such electronic phases.

Experimental techniques to probe the electronic structure of quantum materials
The exotic properties of quantum materials require advanced experimental methods in order to confirm theoretical predictions or discover new phenomena. As far as concerns the band structure of quantum materials, angle resolved photoemission spectroscopy (ARPES) has played a central role and in combination with spin detection (spin-ARPES) has provided experimental evidence for the peculiar structure of topological insulators and topologically protected spin states. I will give a general introduction to ARPES and also review some of its more recent evolutions such as time resolved ARPES and spin resolved ARPES. I will show some milestone examples of how these techniques advanced the field. In addition, I will compare this surface sensitive technique with bulk methods such as quantum oscillations from transport experiments.