Theoretical models for electronic properties of quasicrystals

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In this lecture I will discuss some simplified theoretical approaches to understanding electronic properties of quasicrystals. As is well-known, quasicrystals pose a major theoretical challenge: standard techniques used for periodic crystals cannot be used because the Bloch theorem does not hold for these materials. There remains the possibility of ab initio numerical methods which, however, cannot be extended to very large systems. Studying simplified models is thus very useful and as I will show, there has been progress on several fronts in recent years. I will start by giving a brief look at quantum magnetism and some of the predictions that one can make for the Heisenberg spin model in 2D tilings. Possible extensions and implications for 3D systems will be discussed. Then, I will introduce a class of tight-binding models for electrons propagating in a quasiperiodic tiling. Some interesting results for the non-interacting cases will be discussed, with illustrations for 1D, 2D and (less frequently) 3D systems. We will then consider the effects of adding interactions between electrons, by including Hubbard terms. Attractive interactions in tilings, can in particular, lead to an unconventional type of superconductivity whose properties will be outlined. Other interacting models leading to Kondo effects, and valence fluctuation phenomena will also be briefly presented. Examples of experimental measurements and results will be given where possible.

References:

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[3] Review article "The Fibonacci quasicrystal: case study of hidden dimensions and multifractality », A. Jagannathan (submitted to Rev. Mod. Phy.) available at : arXiv:2012.14744