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Unsupervised machine learning of muons experiments –why?

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Zero-field muon spin relaxation experiments probe directly the intrinsic magnetic fields that arise spontaneously in a given material. The full understanding of such experiments requires a microscopic description of the material under investigation, including its electronic state and the complex interactions between the muon and the material's electronic and structural degrees of freedom. However, paradoxically, such experiments can also yield crucial information about poorly-understood systems, well before we know enough about them for such detailed modelling. In this talk I will ask two questions: "How is this possible?"and "Can we do it better?"To address the first question I will review the particular cases of $LaNiC_2$ and $LaNiGa_2$, two closely related superconductors where the case for an exotic, time-reversal symmetry breaking pairing state is now well established, with muons experiments having played the key role. I will describe how we got to this point, emphasising the prudent use of phenomenological fitting functions and group-theoretical analyses. I will argue that while such approach cannot substitute detailed microscopic modelling (which has to have the final word) it can be crucial to get us to the point where the latter becomes feasible. I will then address the second question, specifically asking whether there is room for improvement in the way we tackle muons data phenomenologically. I will introduce the concept of unsupervised machine learning, using Principal Component Analysis and Auto-encoders as paradigmatic examples. I will propose that unsupervised machine learning can be used to find compact descriptions of muons data, helping with detection of phase transitions and material classification, without requiring either a microscopic theory or phenomenological fitting functions. I will illustrate this with muons data on real magnetic and superconducting materials and introduce simple software tools that can be used to carry out similar analyses.

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