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PLENARY LECTURE

Multivariate control, diffraction and imaging of crystalline matter

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One of the *leittmotifs* of contemporary condensed-matter physics is the presence in the same material of competing forms of order, often (but not always) linked to competing microscopic interactions. Classic examples of this behaviour are the competition between magnetism and superconductivity in most unconventional superconductors, and between itineracy and localisation, the latter often associated with complex forms of multi-tensorial order. In many cases, the competition and coupling between different order parameters can be 'tuned' by a variety of parameters over complex, multivariate phase diagrams. Tuning with 'clean' variables such as temperature, pressure, magnetic field and uniaxial/biaxial strain is often preferred by physicists because it does not introduce chemical disorder, but chemistry usually produces more powerful 'handles' such as doping and chemical pressure. From the late forties onwards, 'classic' techniques such as neutron and X-ray diffraction and spectroscopy on large single crystals and polycrystalline samples have produced the lion's share of the results, especially the highly reliable kind that theorists like to talk about. In particular, in spite of being one of the oldest techniques, powder diffraction continues to remain central to this physics discourse, thanks in part to the development of exquisite instrumentation. For the past twenty years or so, the focus in condensed-matter physics has been slowly shifting toward phenomena that are intrinsic to high-aspect-ratio crystalline matter, such as 2D materials and interfaces. I will show that 'traditional' techniques such as neutron diffraction can continue to remain highly relevant in these new scenarios, provided that instrumentation development continues apace. Perhaps more importantly, I will also show that, having honed their skills with 'conventional' diffraction, physical crystallographers can be perfectly at ease with 'exotic' techniques such as, for example, coherent dichroic imaging. These techniques have their roots in the same physical principles that underpin powder diffraction, and are perfectly adapted to address the challenges of 21st century structural science.