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Editorial: Nematicity in iron-based superconductors

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Editorial on the Research Topic
Nematicity in iron-based superconductors

In iron-based materials, nematicity is a commonly observed symmetry-breaking state that exists in proximity to superconductivity. The nematic instability is associated with a structural transition that lowers the symmetry of the lattice and characterized by both the development of anisotropy in transport and electronic properties as well as orbital-dependent splitting in the electronic bands. The variety of experimental signatures characterizing the nematic state allowed investigations with diverse experimental probes that throughout the past decade uncovered multiple surprising results. Yet, key questions regarding the origin of nematicity remain unsettled as the spin, orbital, and lattice degrees of freedom are intimately coupled [1].

The current Research Topic compiles the latest works that tackle both the origin and characterization of the nematic phase in iron-based materials. The contributions mainly focus on the analysis of doped compounds of the “122” group (e.g., $BaFe_2As_2$) including the heavily hole-doped ones, in which a new type of nematic instability has been recently reported [2], and on FeSe, that provides the unique opportunity to study the nematic phase within a wide range of temperature in the absence of long-range magnetic ordering [3]. In this way, we highlight the forefront of the research on nematicity in iron-based superconductors.

The Research Topic presents three review papers and six experimental and theoretical contributions collected from the front of original research.

Degiorgi reviews optical studies of FeSe and $Ba_{0.6}K_{0.4}Fe_2As_2$. The study of the broadband optical anisotropy in FeSe suggests that spin fluctuations together with the high-energy orbital ordering assume a dominant role in the onset of nematicity. For optimally doped $Ba_{0.6}K_{0.4}Fe_2As_2$, it is shown that the stress-induced optical anisotropy occurs only below the superconducting transition temperature. These findings demonstrate an intimate relation between spin fluctuations, orbital nematicity, and superconductivity.

Rana and Furukawa present a mini-review of their ^{77}Se nuclear magnetic resonance (NMR) studies on FeSe, when the compound is tuned by application of physical pressure, chemical pressure, or a combination of both. Indeed, FeSe exhibits a complex *T*-*x*-*p* phase diagram as physical pressure, *p*, is applied or sulfur is substituted for selenium in $FeSe_{1-x}S_x$ (chemical pressure), including magnetic order and abundant magnetic fluctuations. Rana and Furukawa find that, while antiferromagnetic fluctuations appear to enhance T_c in general, the effect is stronger in the absence of nematicity.

Rhodes et al. present a detailed review of the evolution of the Fermi surface of FeSe in the nematic phase, addressing the problematic issue of the "missing electron pocket." It is still unclear how the experimentally determined Fermi surface near the M point of the Brillouin zone evolves from having two electron pockets in the tetragonal state, to exhibiting just a single electron pocket in the nematic state [4]. In this review, Rhodes et al. collect recent angle-resolved photoemission spectroscopy (ARPES) and scanning tunneling microscopy works to analyze the orbital dependent band-shifts in the nematic phase, as well as theoretical modeling based on the inclusion of an additional nematic order parameter having "*xy*" orbital character.

Bötzel and Eremin analyze the magnetic anisotropy of FeSe using the same phenomenological model reviewed in Rhodes et al. The model combines the usual nematic order parameter based on the differentiation of the *xz* and *yz* orbitals with a non-local *xy* nematic order parameter. The interesting result is that the inclusion of the latter successfully describes not only the absence of the Y-electron pocket, but also the temperature dependence of the anisotropy on the spin susceptibility.

Onari and Kontani discuss a unified picture of nematicity for iron-based superconductors presenting a theoretical description based on a self-consistent diagrammatic approximation. The model allows for the description of several experimental signatures of nematicity both in FeSe-based superconductors and in heavily hole-doped "122"-type materials, which derive from $BaFe_2As_2$ by doping towards the end-members K/Rb/ $CsFe_2As_2$.

The controversial issue of nematicity in heavily hole-doped "122" materials is also the focus of Hong et al. that discuss the Research Topic from the experimental point of view. Whereas nematic orders far from a magnetic instability have been claimed in $(Ba,Rb)Fe_2As_2$, it is still debated whether the elastoresistance of these compounds is a signature of a new nematic instability. Hong et al. present elastoresistance data for a multitude of heavily hole-doped 122-systems, which show a divergence of elastoresistance. However, they present a new interpretation based on the well-known Lifshitz transition in the system unrelated to nematicity. This work adds a new element to the interpretation of elastoresistance, an experimental quantity that has impacted heavily in the investigation of nematicity.

Curro et al. present an NMR work, on the distribution of spin fluctuations in doped pnictides and the effect of uniaxial strain and strain hysteresis. They find that the spin lattice relaxation rate is inhomogeneous, and the spatial distribution of local spin fluctuations correlates with the nematic susceptibility. Their results suggest that a nematic glass behavior is induced by quenched strain fields associated with doping atoms.

Gong et al. present a systematic study of nematic fluctuations in the non-superconducting $BaFe_{1.9-x}Ni_{0.1}Cr_xAs_2$ system combining electronic transport, ARPES, and inelastic neutron scattering measurements. By monitoring the evolution of the nematic fluctuations as a function of Cr doping, a strong correlation between the resistivity- and spin nematicity is revealed, while the orbital anisotropy behaves differently. Their results suggest the importance of the interplay between local moments and itinerant electrons for understanding the nematic fluctuations.

Kreisel et al. theoretically analyze the anisotropy of the spin excitations in FeSe, focusing on the high-energy range as the one detected by resonant inelastic x-ray scattering (RIXS) experiments. They consider an itinerant model previously used to describe the spin-excitation anisotropy as measured by neutron scattering measurements, with magnetic fluctuations included within the random phase approximation. The calculated cross section exhibits overall agreement with the data of recent RIXS experiments on FeSe [5], where a theoretical interpretation in terms of local moments was discussed. The work by Kreisel et al. proves again that nematic phenomenology presents some aspects that can be described either via an itinerant or a local spin scenario, suggesting a non-trivial role of electronic correlations in affecting the metallic state of iron-based superconductors [6].

This editorial conveys the objectives of the above nine articles that represent the latest progress in the research of nematicity in iron-based superconductors. We wish to thank all the authors and referees for their contributions and hope for more future studies on this Research Topic.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

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