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Iron-based superconductors

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the spin density wave (SDW) gap — the typical splitting of the metallic bands in the magnetic state observed in the tunnelling spectrum at low temperatures. Based on this concurrence, they propose that the fluctuations must have spin character, and occur on a scale typical of magnetic energies.

Although the results of Rosenthal et al. are definitely exciting, several questions remain. First, what is the basic mechanism for the creation of these highly anisotropic electronic states that form around simple defects in NaFeAs? It was recently shown that, theoretically, similar magnetic states can form and grow surprisingly large in the SDW state, and tend to have a dimer-like structure similar to that observed in CaFe$_2$As$_2$ (ref. 8). It remains to be seen, however, whether such states can survive in the nematic phase and at higher temperatures. In particular, it would be very interesting to find out whether such dimer-like electronic structures could do a better job of reproducing the NaFeAs QPI data than the impurity potentials considered by Rosenthal and colleagues and rejected as an explanation of their data.

Second, how airtight is the identification of spin degrees of freedom as the driving mechanism for nematicity? In the Lee–Rice–Anderson approach$^{11}$ used by Rosenthal and colleagues, the low-temperature SDW gap does not appear explicitly, so the only connection with the energy of the nematic response to impurity atoms occurs through its coincidence with the typical energy scale of a spin fluctuation. Because orbital ordering occurs at very similar temperatures, could it be that the energy peak of the nematic signal lying within the SDW energy gap is fortuitous? A resolution of this question requires a thorough theoretical calculation of the QPI signal in the fluctuating regime, including both spin and orbital degrees of freedom.

Finally, what ultimately drives the large nematic susceptibility responsible for the various remarkable phenomena (magnetism, orthorhombic-to-tetragonal structural transition and enhanced nematic fluctuations) observed for NaFeAs, but absent in LiFeAs, a structurally similar superconductor? As is now commonplace in the field of iron-based superconductors, the answer seems to depend on details, but an understanding of these details could prove crucial for uncovering the origin of superconductivity and finding a recipe to increase the critical temperature.

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SOFT MATTER

A triangular affair

Disks interacting via particular potentials self-organize into triangles that stabilize mosaics with 10-, 12-, 18- and 24-fold symmetry, as revealed by computer simulations. Discoveries of further novel quasicrystals may now be within reach.

Michael Engel and Sharon C. Glotzer

Thirty years after their discovery, and after being celebrated by the 2011 Nobel Prize in Chemistry, quasicrystals are well recognized as thermodynamic equilibrium states of matter. We now know that long-range order does not require spatial periodicity. However, despite significant progress, why and how quasicrystals arise is still not fully resolved. Writing in Nature, Tomonari Dotera and colleagues address this problem by searching for a generic mechanism for quasicrystal formation in soft matter$^1$. Unlike in alloys, whereicosahedral and 10-fold quasicrystals are abundant, nearly all reported soft-matter quasicrystals$^2$ have 12-fold symmetry$^3$. Working with a surprisingly simple model system, Dotera et al. now report old and new tilings, and discuss their relation to quasicrystals found in macromolecular and nanoparticle systems.

The team performed Monte Carlo computer simulations of identical disks in two dimensions that interact through hard-core/square-shoulder (HCSS) potentials. The simulations use three rules of interaction$^4$: (1) particles may not approach closer than a distance $\sigma$, (2) particles do not interact at distances greater than $\lambda\sigma$ and (3) there is a modest energy penalty $\epsilon$ for each pair at distances between $\sigma$ and $\lambda\sigma$. The behaviour of the system is determined by the ratio $\lambda$ of the shoulder radius to the hard-core radius, the density and the temperature.

It is illustrative to discuss previous findings concerning the HCSS model. Two limits of the parameter $\lambda$ have been studied extensively. For $\lambda = 1$, the hard-disk model is recovered. Hard disks exhibit a fluid phase, a long-debated hexatic phase$^5$ and a hexagonal crystal phase — all stabilized by entropy. In the opposite limit, when $\lambda$ is large, the hard core disappears. Particles then resemble ultrasoft colloids$^6$ and form stripes$^7$ and micellar cluster crystals$^8$ — both are mesophases typical for block copolymers and other systems with competing interactions. In between these limits, when $1 < \lambda < 2$, the system exhibits re-entrant melting$^9$, which means that compression of the solid induces melting. Re-entrant melting is an example of anomalous thermodynamic behaviour observed for water and other network-forming liquids. The observation of re-entrant melting explains why the HCSS system and related soft-core systems are test beds for the study of liquid–liquid phase transitions$^9$.

Despite intensive previous work, and the simplicity of the HCSS model, little is known about the ordered phases occurring in the intermediate $\lambda$ regime. This is surprising, because the existence of