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 soft state, Dotera et al. 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.

Second, how airtight is the identification of spin degrees of freedom as the driving mechanism for nematicity? In the Lee–Rice–Anderson approach 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, Tomomari Dotera and colleagues address this problem by searching for a generic mechanism for quasicrystal formation in soft matter. Unlike in alloys, whereicosahedral and 10-fold quasicrystals are abundant, nearly all reported soft-matter quasicrystals have 12-fold symmetry. 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: (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 \( \varepsilon \) 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 and a hexagonal crystal phase — all stabilized by entropy. In the opposite limit, when \( \lambda < 2 \), the system exhibits re-entrant melting, 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.

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
Following these guidelines, Dotera and colleagues focus precisely on this region to search for new types of order. In a first step, they observe that particles predominantly arrange into equilateral and isosceles triangles with side lengths \( \sigma \) and \( \lambda \sigma \). These triangles act as tiles that cover the simulation box. The formation of quasicrystals then requires the simultaneous re-entrant melting suggests the possibility of multiple structures, a phenomenon known as structural polymorphism. Deliberate choices for the three parameters in the HCSS system are necessary to target \( n \)-fold symmetry: \( \lambda \) controls the interior angle of triangles, the density sets the triangle composition and the temperature must be low but not too low — just below the stability limit. Following these guidelines, Dotera et al., reproduced two known quasicrystals (LD10 and HD12) and discovered four new ones (LD12, HD18, LD18 and LD24). The notation specifies the symmetry (the number gives the symmetry of the structure factor) and whether the quasicrystal has comparably low density (LD) or high density (HD).

In all cases, quasiperiodic order develops spontaneously from the fluid. With the exception of LD18 (which did not fully equilibrate on the timescale of the simulations), the assemblies seem to be thermodynamically stable. A comparison with previous discoveries of quasicrystals in simulations reveals key differences. LD18, HD18 and LD24 consist of tiny domains that have periodic order individually, but are limited in size and obey a discrete, incommensurate, orientational relationship. As a result, quasiperiodic order is not present locally, but rather in a mosaic-like fashion — only on a length scale larger than the domains (Fig. 1). More work is required to elucidate the role of dimensionality on the degree of randomness in the triangle phases and their relation to hexatic order.

The work by Dotera et al. confirms the earlier observation that the cooperation between two length scales plays an important role in the stabilization of soft-matter quasicrystals. In practice, the ratio of the two length scales can be controlled either directly by an appropriate interaction potential in real space (as done here) or in reciprocal space, or indirectly by particle functionalization and shape. The present results demonstrate that it is worthwhile to continue with systematic investigations of the HCSS and related models as they promise a plethora of new structures and hidden phenomena, many of which might be unknown or unexpected.

**Figure 1 |** Artistic depiction of the 18-fold mosaic quasicrystal obtained in soft-matter simulations by Dotera and colleagues. The structure consists of equilateral triangles (yellow), 80° rhombi (two isosceles triangles joined together; blue) and scattered defects (white). Although rhombi and triangles cluster together locally, they do not fully phase-separate. The thick black lines have been added by the artist to evoke the image of a stained glass window.