Miller *et al.* monolithically fabricate a series of 2D electron device microstructures that enable them to determine the effects of constriction of the 5/2 FQH fluid. They find that constriction by a 0.5-μm-wide quantum point contact does indeed destroy the 5/2 FQH state. But, they also find that confinement by slightly larger constrictions, of just 0.8 and 1.2 μm wide, doesn't. This more encouraging result has two important implications for our ability to investigate non-abelian statistics experimentally.

First, the survival of the fragile 5/2 state within a single constriction could enable the fractional charge of the quasiparticles that populate it to be determined, and compared to the value of e/4 predicted for the Moore–Read state. In previous studies, the charge of the quasiparticles of the abelian 1/3 FQH state has been measured either by monitoring the one-by-one addition of quasiparticles into an anti-dot placed within a constriction[5], or by analysing the power spectrum of the shot noise that arises from tunnelling of quasiparticles through the constriction[6,7]. In principle, the same approaches should be applicable to the authors' 5/2 FQH system. Yet, the very non-abelian nature of the quasiparticles of this system might yet throw up some surprises that would complicate the answer to the question of whether the Moore–Read formalism paints an accurate picture of the 5/2 FQH state.

But perhaps a more ambitious, and certainly more exciting, possibility offered by the present work is to build complex device structures with multiple constrictions. This would enable the construction of a quasiparticle Aharonov–Bohm interferometer (see Fig. 1), similar to that used to probe the abelian anyon statistics of the 1/3 FQH fluid[8]. Theoretical analysis[9,10] of such an interferometer operating in a non-abelian 5/2 FQH regime predicts the emergence of unusual, history-dependent interference phenomena. One of the key challenges to building such a device will be to engineer constrictions that are narrow enough to transmit measurable quasiparticle tunnelling currents while maintaining a sufficiently small electron depletion to ensure that the 5/2 FQH fluid remains dominant. For the strong 1/3 FQH state it was adequate to limit the constriction electron density depletion to 7%, relative to the centre of island within the Aharonov–Bohm ring, to maintain the 1/3 fluid throughout the island[8]. But, in the case of the 5/2 state, because of the proximity and strength of competing nearby correlated electron states, it is likely that a much weaker depletion of around 1% would be needed to avoid the complications that a contribution by such states would cause. In the widest constrictions demonstrated by Miller *et al.*[1] the depletion is estimated to be around 16%, far short of this target. But if future work can bring this down to the level needed to study a pure non-abelian FQH fluid, the rewards in terms of new physics is likely to be great indeed.

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STATISTICAL MECHANICS

Crackling crossover

Magnetic domains in a thin film grow in a jerky manner as avalanches of spins flip their directions. At low temperatures, the measured distribution of avalanche sizes agrees with one theory; at high temperatures, with another.

James P. Sethna

is in the Laboratory of Atomic and Solid State Physics, Clark Hall, Cornell University, Ithaca, New York 14853-2501, USA.

e-mail: sethna@lassp.cornell.edu

We are rapidly learning how to understand crackling noise. Many things crackle: paper when it is crumpled, faults when tectonic plates rub together and magnets as they change magnetization — the subject of the article by Ryu, Akinaga and Shin on page 547 of this issue[1]. The response to a smooth, slow external force is a series of abrupt avalanches with a broad range of sizes. Thus earthquakes are the crackling response of the Earth as the continents drift.

Why do things crackle? The first hint comes from the simple power-law distribution of avalanche sizes. Most earthquakes are small; there are many more magnitude-six earthquakes than magnitude seven, and very few of magnitude eight. Indeed, the probability $P(s)$ of an earthquake (or magnetic spin avalanche) of size s falls off as a power law, $s^{-\tau}$. The exponent τ is universal — meaning that it will be shared among a large family of materials and systems. It will typically differ between systems that are fundamentally different; for example, crumpled paper and earthquake faults respond in basically different ways to their external forces. The exponent will also depend on the dimensionality of the system; for example, thin two-dimensional films will be different from bulk three-dimensional magnets. But τ usually will be independent of the microscopic details of the materials (which enables theoretical models to describe real experiments accurately). Sometimes τ will be shared between strikingly different systems — for example, magnets and fluids invading porous rock — that are in the same universality class.

Power laws provide a hint to understanding crackling noise because they suggest the existence of an emergent symmetry of the system: scale invariance. Scale invariance means that the system looks (statistically) the same when put under a magnifying glass. Figure 1 shows some of the avalanches in a simple model of a magnet. The wide variety of avalanche sizes and their characteristic fractal shapes are typical of scale-invariant systems. When magnified the small avalanches become medium sized, the medium sized become large, and one of the large ones might become the background 'infinite' avalanche — riddled with holes of all sizes formed by interior sub-avalanches. The domain walls observed by Ryu *et al.*[1] have this fractal scale-invariant symmetry too.

Symmetries are a powerful tool for understanding materials. Because solids (on long length-scales) have translational symmetry, we know that motion through them must obey certain laws; heat, vacancies, impurities and neutrons in solids all obey the same laws of motion because the diffusion equation is the translation-invariant macroscopic law that dominates on long length- and timescales. Liquids are all described by the same Navier–Stokes equations because they have a galilean symmetry — invariance to translations and shifts in velocity. Quantum field theories (quantum electrodynamics, governing light and atoms; quantum chromodynamics, governing quarks and the nucleus; and the unification theories governing higher energies) are strongly constrained by the need to be Lorentz-invariant such that they obey Einstein's prescription that light's speed is the same to all moving observers.

Why are magnets and other crackling systems symmetric under change of scale? This emergent symmetry isn't a property of the original system — it emerges from the way avalanches trigger one another. A big avalanche is composed of smaller components, which trigger one another in the same way that big avalanches combine into enormous ones. Imagine 'demagnifying' the system, stepping back and ignoring the smallest avalanches. The material now behaves like a new system with slightly different 'coarse-grained' rules, a new point in system space (Fig. 2). Tracking the so-called 'renormalization-group flows' as we coarse-grain the system[2], both universality and the emergence of scale invariance are found to be due to attracting fixed points in system space. If two different materials coarse-grain into the same fixed point, they will be self-similar — they look the same when demagnified — in precisely the same way (with the same exponent τ).

But why do Ryu *et al.*[1] measure two different values for τ? Our understanding of two-dimensional (thin-film) magnets remains incomplete. In three dimensions, though, we understand that there are two different fixed points, depending on the importance of long-range dipolar interactions between spins[3]. If dipolar forces are not important, front propagation (originally studied by those using water to push oil out of porous rock) occurs; if they are strong, the behaviour is mean-field-like. If they are weak but non-zero, then small avalanches will be described by front propagation exponents and large avalanches by mean-field. Figure 2 shows the renormalization-group flows corresponding to this crossover. A system with weak dipolar forces will initially coarse-grain towards the front propagation fixed point U; however, the dipolar forces grow under coarse graining, eventually leading to a crossover to mean-field behaviour described by S. The scaling function estimated experimentally by Ryu *et al.*[1] is universal because it is determined by the green unstable line flowing from U to S. A quantitative theory of the crossover, and indeed for the two-dimensional phase diagram, remains a theoretical challenge for the future.

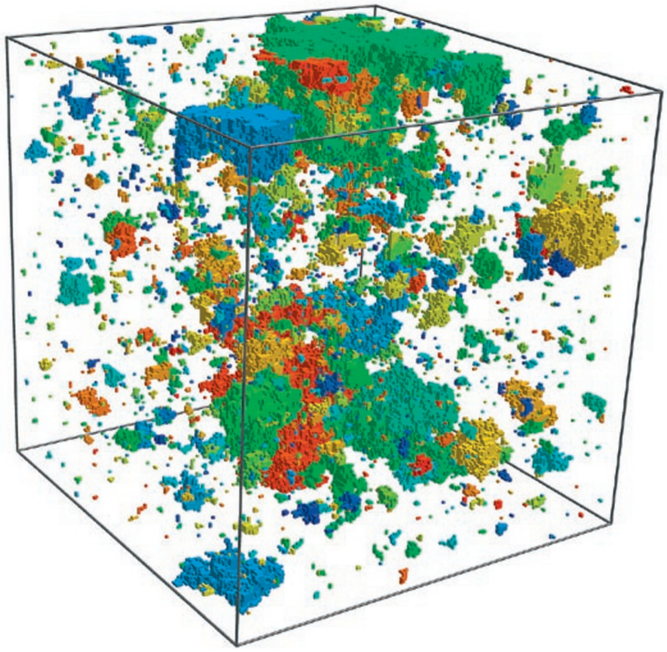

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Figure 1 Avalanches, here in the jerky magnetic-domain growth of a simulated three-dimensional magnet, often have a fractal structure and a wide distribution of sizes.

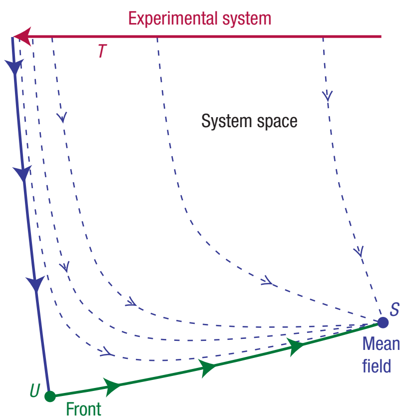

Figure 2 System flows under 'coarse-graining'[2]. System space has one axis for each parameter: temperature, dipolar interaction and so forth. Fixed points such as U and S are self-similar; systems that flow to fixed points become self-similar on long length scales.

It's natural to ask whether the 'fundamental' symmetries of nature (translation, rotation and Lorentz invariance) might be emergent too. The translation-invariant diffusion equation describes transport in crystals where the atomic lattice is microscopically not invariant under translations (except translations by integer numbers of lattice constants). In principle, Einstein's relativity and Lorentz invariance could emerge from a universe made up from a crystalline lattice too — indeed, lattice simulations of quantum chromodynamics and other field theories rely on this emergent symmetry[4]. So far exactly the reverse has been the case. Just as a magnet at high temperature loses its magnetization and becomes symmetric under the exchange of north and south poles, so the vacuum becomes more symmetric at short distances (high energies). Our universe started with high symmetry and broke it to form quantum mechanics and atoms; these atoms combine to form crackling materials in which new fractal symmetries emerge.

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