the quantum foam with topology-changing wormholes fluctuating on all length scales. As a consequence of scale invariance, quantum critical states show characteristic power-law correlations. For a quasi-one-dimensional version of their model, Gils *et al.*[1] have managed, by analytical and numerical means, to identify the quantum field theory describing the critical quantum foam state, thus providing a full catalogue of all scaling dimensions. The related problem for the full 2D system, however, remains unsolved.

Why are these results important? Topological phases with time-reversal symmetry are expected to describe certain frustrated quantum magnets. But meaningful applications will require a better understanding of the viability of such phases in microscopic models that are much simpler than the Levin–Wen model[2] (see ref. 3 for recent progress). Further strong motivation for the continued study of topological phases comes from the perspective of topological quantum computation. As first pointed out by Alexei Kitaev[4], a controlled collection of defects in suitable topological phases has all the right properties to act as a quantum register, where quantum information can be stored and processed. The very fact that topological phases lack any form of local order then guarantees that the quantum information can be protected from intruding environmental noise.

But in the end it is the fascinating mix of progress in mathematical characterization, in physical realization and in the potential use in quantum information technology that lends a particular charm and dynamic to the study of topological phases of quantum matter. ❐

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QUANTUM MECHANICS

Bad news for time travellers

It is a tricky problem that Marty McFly has to solve in the first film of the *Back to the Future* trilogy. Sent back 30 years, on board a time machine built by the slightly mad scientist Doc Brown (pictured), he accidentally interrupts the first meeting of his future parents, then has to pull all kinds of strings to make their love affair happen — and thereby secure his own existence.

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The possibility of time travel inspires physicists too. In the dawning age of quantum computation, one question in particular is keeping them busy: could closed timelike curves (CTCs) — where the path of a particle through spacetime returns to its starting point — help a computer to solve (computationally) hard problems more efficiently? In recent work it has been suggested that, at least in certain circumstances, this should be the case. But Charles Bennett and colleagues now argue that, in practically relevant settings, it isn't (*Phys. Rev. Lett.* in the press; preprint at http://arxiv.org/abs/0908.3023v1; 2009).

The predicted advantages of CTC-assisted quantum-state evolution include more than computational benefits. It has been conjectured that CTCs also help to perfectly distinguish quantum states, even if these are non-orthogonal — something that is impossible in standard quantum mechanics. But Bennett *et al.* claim there was a problem with these earlier works: the conclusions drawn were based on considering only fixed pure input states, but the results thus obtained do not hold for the general case in which the input consists of a distribution of several states.

This is so because, unlike in standard quantum mechanics, in models including nonlinearities such as CTCs, the evolution of a mixture of states is not equal to the mixture of the evolutions of the individual states. These findings suggest that CTCs not only fail to help computations (or quantum state discrimination), but also affect conclusions reached about other nonlinear extensions of quantum mechanics. However, quantum mechanics doesn't have to be, by necessity, linear — Bennett *et al.* expect that, after all, a 'well behaved' nonlinear theory may be possible.

As far as we know, CTCs exist only in fiction. But still, thinking about a world with CTCs has already led to consistent physical models that, for example, avoid the 'grandfather paradox' (the consequences of which Marty McFly tried so hard to escape otherwise — successfully, of course). And for the future, the study of CTC-assisted computation should lead to a fuller understanding of the foundations of quantum information. Or perhaps it already has?

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