electronic states — is large, continuous and robust to changes in temperature[5]. At lower carrier concentrations, however, the Fermi surface is seen to be carved up into segments or disconnected 'Fermi arcs' centred along the Brillouin zone diagonals as the temperature is reduced[6]. This reduction in the volume of occupied states violates a fundamental sum rule, and as such is regarded as a further indication of violation of Fermi-liquid theory.

The observation by Louis Taillefer and co-workers, reported for the first time at this conference, of quantum oscillations in a high-purity, low-carrier-density copper oxide superconductor[7] therefore came as a big surprise to the community. Quantum oscillations are a manifestation of quantized orbits of quasiparticles at or near the Fermi surface induced by a strong magnetic field. Although the paradigm of quantum oscillations as proof of the existence of fermionic quasiparticles was challenged later in the conference, their observation in a low-doped high-temperature superconductor seemed to signal the end of a twenty-year quest and the beginning of a new chapter in the field. It has also brought the two sides (underdoped and overdoped) of the phase diagram together, almost for the first time, and demonstrated that some vestige of quasiparticle physics survives deep into the underdoped region of the phase diagram. The key question now of course is how these small Fermi pockets evolve with carrier number into the large Fermi surface seen on the opposite side.

Coupled with the continuing, fruitful search for non-Fermi-liquid physics in quasi-one-dimensional conductors (which also featured at the conference), these are exciting times for the correlated-electron community. As fate would have it, there was a jewellery shop in the foyer of the conference hotel called 'Landau'. The jewels could have been Landau's metaphorical quasiparticles. Rather appropriately, the shop was advertising most of its stock at half price, as though the spirit of Lev Landau was on the verge of moving out, just as strongly correlated electrons were moving in. Despite the sense of foreboding, there were certain exclusions to the sale. Perhaps these were the faint rays of optimism emanating from the auditorium, most notably in that most notorious of non-Fermi-liquids, the high-temperature superconductors. Don't pack up just yet, Landau. All is not lost.

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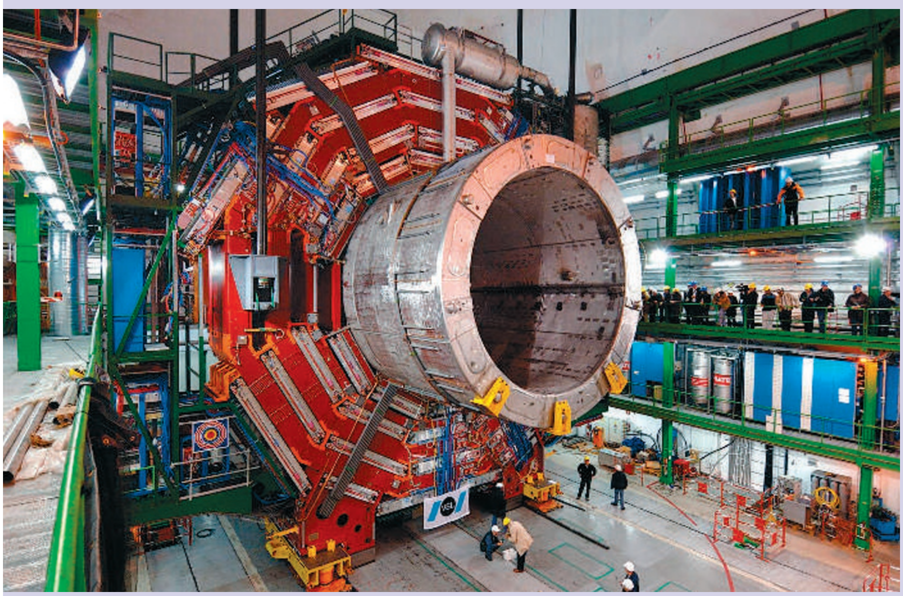
PARTICLE PHYSICS

Search for the 'unparticles'

Particle physicists are now invited to study 'unparticle physics'. In *Physical Review Letters*, Howard Georgi explores the notion that there exists "stuff", as he puts it, that cannot be thought of as particles (*Phys. Rev. Lett.* **98,** 221601; 2007).

At the root of his analysis is the principle of scale invariance. Scale invariance means that the physics of a system remains the same regardless of a change of length or energy scale (through multiplication by a common factor). It applies, for example, in quantum field theory — which is the basis of current particle-physics theory — in the situation where the electromagnetic field is quantized, but there are no charged particles: as the photon has zero mass and as, without charge, there is no electromagnetic coupling, this (rather boring) theory looks the same whatever the scale. In quantum electrodynamics, however — the hugely successful, quantum-field-theory description of electromagnetic interactions — there are charged particles and electromagnetic coupling, the strength of which changes with the energy scale. Hence quantum electrodynamics is not scale-invariant.



CERN

Unlike the photon, most other particles aren't massless, and in general mass creates a problem for scale invariance: the standard model of particle physics is not scale-invariant. But what if, muses Georgi, there were another sector of the theory that interacts so weakly with the standard model that it hasn't been noticed yet, and what if it were exactly scale-invariant?

For four dimensions of spacetime, such a scale-invariant sector could not hold particles of definite non-zero mass — it could only contain 'unparticles'. Georgi concedes that it's difficult to talk about the physics of something that is so different from our familiar notion of particulate matter. But using low-energy 'effective' field theory, some phenomenological exploration, at a simple level, is possible.

Georgi finds that unparticle stuff would have a distinctive experimental signature, appearing as a non-integral number of invisible particles. Seeing the invisible isn't impossible — the detectors due to turn on at CERN's Large Hadron Collider next year (such as CMS, pictured partway through its installation) could register amounts of missing energy and momentum in the debris of high-energy proton–proton collisions that might indeed signal the existence of something, beyond the standard model, as subtle as unparticle stuff.

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