singlets, the individual diquarks that make up the tetraquark could not exist as free particles. But there's abundant empirical evidence from the spectrum of hadron masses and from scattering phenomena that certain kinds of diquarks are strongly coupled. These favored diquarks are the ones that are antisymmetric under exchange of any of the three quark labels: color, flavor, or spin orientation.

The mesonic-molecule hypothesis is particularly plausible when the mass of the meson in question is very close to the kinematic threshold for decay to a pair of daughters that might be its molecular constituents. And indeed, theorist Jonathan Rosner at the University of Chicago has pointed out that the Z$^\pm$ mass is close to the sum of the masses of a particular pair of D mesons that might be forming a mesonic molecule.[3] Every D meson carries a single c (or $\bar{c}$) quark.

University of Rome theorist Luciano Maiani favors the idea that Z$^\pm$(4430) and the other problematic charmonium states are tetraquarks. On that basis, he and coworkers have assigned to each of them a specific diquark–antidiquark bound state and predicted the existence of additional charmonium tetraquarks yet unseen.[4] In particular, they predict that experimenters will find two different neutral siblings of the Z$^\pm$ with masses within a few MeV of 4430. That prediction follows from the strict adherence to isotopic-spin symmetry expected of tetraquarks. Mesonic molecules, by contrast, could exhibit significant violation of that approximate symmetry, which is an elaboration of the charge independence of the strong interactions. Maiani and company also predict more distant tetraquark relatives of the Z$^\pm$(4430), with masses up to 4.6 GeV. Some of those, they argue, should have an unusual affinity for decaying into baryon–antibaryon pairs.

Fooled again?

The tetraquark quantum states adduced to account for the observed and predicted charmonium exotics all have the diquark and antidiquark in an *s*-wave state of zero relative orbital angular momentum. Higher orbital states would weaken the already precarious binding. When evidence of the Θ^+(1530) pentaquark baryon was reported in 2003, Wilczek and MIT colleague Robert Jaffe considered that it might be a bound state of two diquarks plus a

physics update

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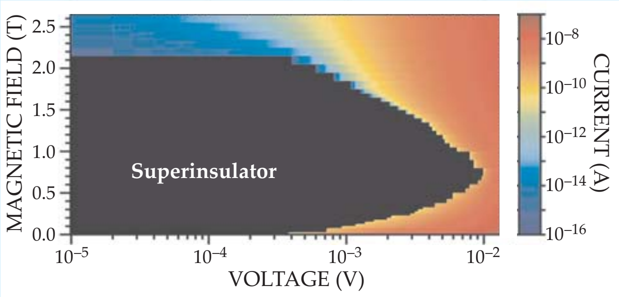
Giant piezoresistance. A new experiment, conducted by scientists from France, Switzerland, and the UK, has recorded the largest-ever change brought about in a bulk material's electrical resistance by straining the material at room temperature. Called piezoresistance, the phenomenon is often exploited in sensors. In simple metal-foil piezoresistors, the kind used to examine the integrity of a concrete wall or to monitor a prosthetic limb, the change in resistance per unit of strain (a ratio referred to as the gage factor) has a typical value of about 2. For silicon-based piezoresistors, the kind used in cell phones and airbag accelerometers, the gage factor is usually about 100. The new experiment uses a silicon–aluminum hybrid material in which the arrangement of the components, not their composition, is of paramount importance. The metal—in this case aluminum—is effectively a current shunt; applying a mechanical stress to the device deflects current toward or away from the shunt and thereby alters the device's resistance. For appropriate geometric configurations, the researchers, led by Alistair Rowe of the École Polytechnique in Palaiseau, France, measured a gage factor of nearly 900, the largest ever seen at room temperature in a bulk material. Giant piezoresistive structures could be good news for the designers of microelectromechanical devices in which the measurement of ultra-small accelerations or atomic-scale deflections is important. Alternatively, higher sensitivity to movement can be translated into lower power requirements when battery energy is at a premium, as in cell phones. (A. C. H. Rowe et al., *Phys. Rev. Lett.* **100**, 145501, 2008.) —PFS



A superinsulating state. In conventional superconductivity, electrons combine into Cooper pairs, and those pairs collectively enter into a single quantum state in which current can flow with zero electrical resistivity; there is no current dissipation and no Joule heating of the material. A multinational collaboration led by Valerii Vinokur of Argonne National Laboratory in the US and Tatyana Baturina of the Institute of Semiconductor Physics in Russia recently reported on an analogous but opposite situation in which electrical current is vanishingly small, effectively zero. The group studied a thin film of superconducting titanium nitride. Below critical values of temperature and applied voltage, the system went through an abrupt transition from an insulator with normal, linear resistivity to one with apparently infinite resistivity. What's more, the transition could be crossed by tuning a magnetic field for a given threshold voltage, as shown in the figure. As with a superconductor, the superinsulator has zero Joule loss—but now because there is no current rather than no resistance. The experimental system was successfully modeled and analyzed as an array of superconducting islands or droplets connected by Josephson weak links. The researchers conjecture that such a network is also essential to the superconductor-to-insulator transition in thin films. (V. M. Vinokur et al., *Nature* **452**, 613, 2008.) —PFS

Guiding light. In the pursuit of a quantum computer, the photon is a leading candidate for the quantum bit, or qubit. Working models of photonic circuits, however, have been unscalable arrangements of bulky mirrors and beamsplitters sitting atop a square-meter-sized table. Now scientists at the Center for Quantum Photonics at the University of Bristol in the UK have printed several dozen photonic circuits onto a silicon wafer. The research team created waveguides by first depositing a doped layer of silica onto the wafer, then patterning 3.5-micron-wide ridges into the silica. Two waveguides are coupled when they approach each other and then diverge, as shown in the figure, allowing evanescent waves to overlap. Using such directional couplers, the researchers not only fabricated on-chip beamlone strange antiquark.[5] In that case, however, Bose statistics forbids an *s*-wave between the two diquarks. "But because the experimental evidence for the pentaquark at first seemed so compelling," recalls Jaffe, "we speculated that maybe forming the favored antisymmetric diquark pays so well that a pair of them can bear the insult of being in a *p*-wave."

The supposed pentaquark was first sighted in collisions between photons and nuclei at a synchrotron light source and at a nuclear-physics accelerator. When follow-up searches were carried out with higher statistics at particle-physics accelerators, the pentaquark signal was gone. Old particle-physics hands had wondered why, if the Θ^+(1530) really did exist, they had not found it decades ago when they were searching in the same energy regime for positively charged baryons with positive strangeness.[6]

The B factories, by contrast, allow experimenters to find hadronic states they probably couldn't have unearthed earlier. The 5.3-GeV B mesons created there in great profusion are just about as heavy as mesons ever get. They decay (by flavor-changing weak interactions) preferentially into mesons that carry charmed quarks. It's among such decays that theorists expect exotic mesons to be found—if they exist.

PEPII and KEKB were built primarily to study the tiny asymmetry between particles and antiparticles (see PHYSICS TODAY, May 2001, page 17). As a byproduct of that effort, Belle and BaBar have accumulated enormous reserves of B-decay data that could reveal many more new states. "That's a fantastic resource we're just beginning to explore," says Jaffe. "QCD is a beautiful and complete theory, but nobody has been able to solve it for hadronic states. We need all the help we can get to understand the confinement of quarks inside hadrons."

Bertram Schwarzschild

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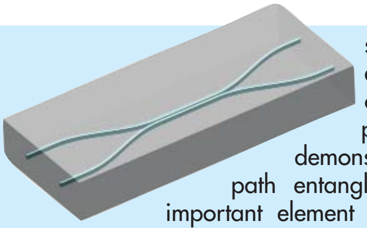

splitters, interferometers, and even a controlled-NOT gate, but combined those devices into photonic circuits. Among their demonstrated results is a high-fidelity, path entangled state of two photons, an important element for quantum computation. The silica-on-silicon photonic circuits may also be applied to quantum metrology and communication technologies. (A. Politi et al., *Science* **320**, 646, 2008.) —JNAM

Collisions between carbon dioxide molecules can affect greenhouse warming. Visible light coming from the Sun pours down daily and is reflected back from Earth's surface as IR radiation. Extra warming occurs when some of that IR is absorbed and retained in the atmosphere. Only a trace gas in the atmosphere, CO_2 is far outnumbered by O_2 and N_2 molecules, but its growing presence (mostly due to human activity) and its ability to absorb and trap IR radiation are thought to be instrumental in producing greenhouse effects. The interactions between atoms in a single molecule generate the molecule's dipole moment and polarizability, two properties that greatly affect how the molecule absorbs or scatters radiation. Going to the next level of complexity, a new study shows in detail how a large class of molecules, including CO_2, absorbs and sometimes scatters light energy during intermolecular collisions. Michael Chrysos and his colleagues at the University of Angers (France) and Saint Petersburg State University (Russia) have derived exact mathematical formulas that can be used to calculate how collisions between so-called linear-rotor molecules modify the molecules' absorption spectra. During a molecular interaction, a transient supermolecular complex arises with its own degrees of freedom—distinct from those of the constituent molecules—and its own dipole moment or polarizability. The net result is that a broad band of frequencies, including many that are unavailable to single molecules, can be absorbed or scattered. The new study is important for several reasons: It allows exact calculations of how the intercepted IR photon energy is converted to kinetic energy and shared among neighboring gas molecules; it allows for the inclusion of higher-order effects, such as the simultaneous collision of three molecules; and it provides evidence that long-range intermolecular interactions are far more important than short-range ones for absorption, a conclusion in conflict with mainstream assumptions. (M. Chrysos et al., *Phys. Rev. Lett.* **100**, 133007, 2008.) —PFS

Peaks and labyrinths in a magnetic fluid. A ferrofluid is a colloidal suspension of nanometer-sized magnetic particles in a nonmagnetic carrier fluid. As you might expect, it can be easily manipulated with external magnetic fields and often exhibits different patterns and instabilities. For example, when a sufficiently strong magnetic field is applied perpendicular to the flat surface of a ferrofluid, the Rosensweig instability produces a stationary array of peaks protruding above the surface. When a similar field is applied to a ferrofluid droplet immersed in a confined immiscible liquid, the labyrinthine instability produces horizontal fingering as the two fluids interpenetrate. A new experiment reveals a hybrid situation in which those two normally distinct instabilities occur simultaneously. Scientists from Taiwan and Brazil immersed a ferrofluid droplet in a thin layer of a miscible nonmagnetic fluid. The images of the experiment, with a side view in the upper panels and a top view in the lower ones, show what the researchers found after switching on the field. The Rosensweig instability grows rapidly to its greatest amplitude in 0.43 s (left panels), at which time diffusion is already affecting the base of the droplet, decreasing the magnetic body force that sustains the peak against gravity and surface tension. At 1.2 s (middle panels), the peak is clearly decaying as the fingering progresses and after 5 s (right panels) the surface is again flat and radial diffusion dominates. (C.-Y. Chen, W.-K. Tsai, J. A. Miranda, *Phys. Rev. E* **77**, 056306, 2008.) —SGB ■