this channel. It is also possible that training increases health-worker effort, instills higher ethical standards, or gives health providers more confidence to trust their own judgment. Finally, understanding how training improves quality may help to explain why the program was unable to address the important problem of overprescribing antibiotics.

The government of India has endorsed the goal of providing “universal access to good quality health care services without anyone having to face financial hardship” (*9*). The informal health care sector has no role in this vision; that implies that directly funding the public sector to strengthen primary health care will crowd out unqualified providers from the market. Indeed, this has been the experience of countries such as Sri Lanka and Thailand (*10*). Government health expenditure in India is low by international standards (*11*), and it is plausible that this underlies the poor performance of the public sector. But most policy experts agree it is not just about resources (*12*). In many states of India, governance problems are pervasive, health workers are poorly motivated, and absenteeism is high. The informal sector is thus likely to persist, at least in the short term.

Better evidence on the effectiveness of approaches to improve health service delivery in India’s public sector is needed before more money is poured into the system. The dearth of evidence in part reflects the inherent challenge of conducting this type of research, as well as the neglect of health systems research relative to clinical and epidemiological research (*13*). In the absence of such evidence, Das *et al.*’s findings provide a compelling case for training informal providers as a pragmatic way forward in the short term. Before scaling up this approach, however, it would be prudent to understand how high rates of attendance were achieved and why many providers did not improve clinical practices despite numerous hours of training. ■

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PHYSICS

Cold atoms twisting spin and momentum

Ultracold atoms can simulate complex quantum systems

By **Monika Aidelsburger**

Inspired by the intriguing topological phenomena recently observed in condensed-matter systems (*1*), a variety of different research areas, from optical to mechanical systems, have devoted their studies to topological physics. Owing to their high level of experimental controllability, cold atomic gases offer a promising platform to simulate condensed-matter models. Their charge neutrality, however, is an apparent limitation. To overcome these constraints, new experimental techniques are currently being developed that mimic the physics of charged particles. On page 83 of this issue, Wu *et al.* (*2*) report on such a new experimental technique to simulate two-dimensional (2D) spin-orbit coupling (SOC) for neutral atoms in an optical lattice—an important ingredient to explore topological quantum states.

SOC is a relativistic effect that links the spin degree of freedom of a particle to its momentum. Intuitively, this can be understood if we consider a moving particle in a static electric field. In the rest frame of the particle, the electric field gives rise to a magnetic field that interacts with the spin of the particle. This leads to a momentum-dependent Zeeman or spin-orbit interaction. A well-known example is the atomic fine-structure splitting that arises as a result of the motion of the electron in the electric field of the nucleus. In solids, the SO interaction emerges owing to the motion of the electrons in the intrinsic electric field of the material. It can occur in materials with broken interfacial or bulk inversion symmetry, known as Rashba (*3*) and Dresselhaus (*4*) contributions, respectively.

After the discovery of quantum Hall insulators, it was believed that topological quantum states can only exist in 2D and only if time-reversal (TR) symmetry is broken by applying a magnetic field. SOC was essential in understanding that there is a new class of topological materials that exists without TR symmetry breaking (*5*). The observation of 2D and even 3D topological insulators soon followed (*1*). More recently, there has been increasing interest in topological superconductors, in particu-

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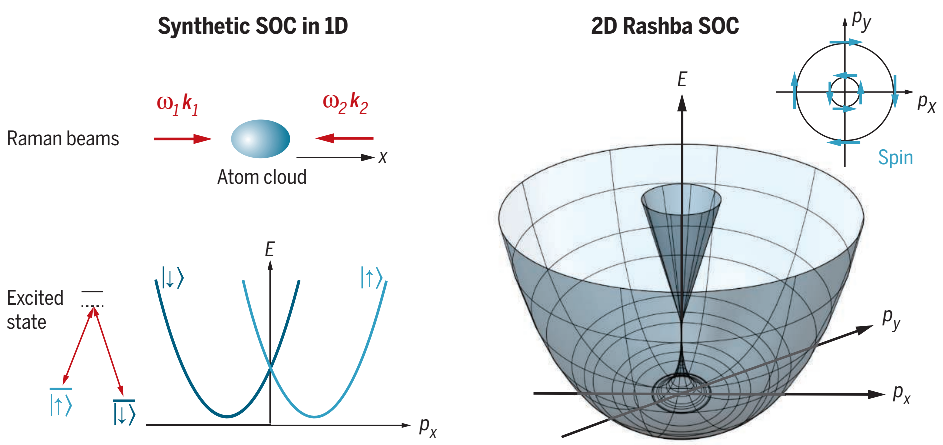
Synthetic 1D-SOC with cold atoms

A pair of Raman beams couples two hyperfine levels labeled |↑⟩ and |↓⟩, using a two-photon transition (energy-level diagram). The resulting 1D-SOC leads to a band splitting and shifts the dispersion relation in a spin-dependent way, resulting in a twofold-degenerate ground state. (Right) Rotating the two parabolas around the vertical axis results in a ring of degenerate states at the bottom, the spin polarized with the opposite sign between the inner and outer surface.



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lar because they host exotic quasi-particle excitations known as Majorana fermions with fascinating properties. They are predicted to exhibit unusual exchange statistics that go beyond bosonic or fermionic ones and could find application in topological quantum computation (*6*). Again, the SO interaction was part of the breakthrough when it was realized that topological superconductivity could be induced in a material with strong SOC by making use of the proximity effect with a conventional superconductor.

Ultracold atoms provide a promising alternative to studying exotic quantum states that emerge as a result of SOC. But, because this type of interaction does not naturally arise in cold-atom experiments, it needs to be artificially synthesized by other means. Typically, the role of the spin is played by different internal states of the atom, and the coupling to its motional degrees of freedom is engineered with laser light (*7*). The technique of choice (*8*), now widely used in many laboratories, uses a pair of laser beams to couple two hyperfine levels via a Raman transition (see the figure, left panel). The atoms absorb a photon from one of the two laser beams and re-emit it into the second one. The atoms thereby experience a momentum kick given by the difference between the two photon recoil momenta. This couples spin and momentum and generates a 1D SOC. A first step toward higher-dimensional SOC was reported earlier this year (*9*), in which the authors demonstrated 2D-SOC with tunable anisotropy and magnitude. The experimental flexibility of cold atoms systems allows for the engineering of a variety of different forms of SOC even without solid-state analog, and combining them with optical lattice potentials may lead to even richer band structures (*10*).

> ***"...SO-coupled quantum gases...[have]... potential for investigating exotic phenomena...beyond traditional condensed-matter physics...[extending]...to exotic forms of SOC that involve larger spin states."***

Wu *et al.* demonstrate a new technique to simulate 2D-SOC in a square optical lattice using Raman transitions. The dimensionality is tunable between 1D and 2D, and the lowest-energy band can be made topologically nontrivial by changing the strength of an effective out-of-plane magnetic field. The setup is particularly appealing because it involves only a single laser source and does not require phase-locking between several optical beams. Instead, a single laser beam is split into two parts to produce a spin-independent optical lattice and a frequency-shifted Raman beam.

The latter, together with some of the optical lattice beams, creates a double Raman transition in the 2D plane to induce spin-flips. The engineered Hamiltonian has no analog in solid-state systems, but expanding it around zero quasimomentum reveals a term reminiscent of Rashba-type SOC (see the figure, right panel). In addition, there is a kinetic energy term that couples to the out-of-plane component of the spin that makes the system different from the normal Rashba Hamiltonian. It will be interesting to study in future theoretical and experimental works to what extent this Hamiltonian gives rise to Rashba-type physics or leads to novel exotic quantum states.

The study of SO-coupled quantum gases is a fascinating research area that is evolving rapidly and has a great potential for investigating exotic phenomena that go beyond traditional condensed-matter physics. As an example, the above ideas could be extended to 3D-SOC (*11*) or to exotic forms of SOC that involve larger spin states (*12*).

Currently, one limitation lies in heating of the quantum gas due to spontaneous emission of photons, and an important research direction consists of developing new schemes or identifying different atomic species, where such effects are mitigated. One of the major goals in the field is to study strongly interacting SO-coupled quantum gases, where many exciting questions remain to be addressed, both experimentally and theoretically. ■

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CELL DEATH

The MIFstep in parthanatos

Preventing cells from killing themselves may save tissues from damage during disease

By **Elizabeth Jonas**

If we knew how cells die, we might be able to prevent cell death, thereby saving vital tissues and organs in diseases as diverse as heart attack, stroke, diabetes, liver and kidney failure, and neurodegenerative diseases of the brain. Indeed, it has become clear from recent studies on anastasis, or reversal of apoptotic cell death (*1*), that cells can survive many severe insults and recover completely. On page 82 of this issue, Wang *et al.* (*2*) show that cell death can be prevented by blocking the breakdown of DNA that is a hallmark of a set of related cell death subtypes, grouped under the name of parthanatos (*3*).

Cells can die in several ways, such as loss of membrane integrity, loss of organelle function, loss of metabolites such as adenosine triphosphate (ATP), or damage and/or loss of genomic DNA. Investigators have focused on either preventing the cell from starting down the road toward death (e.g., opening a blocked artery in the brain during stroke) or finding the "commitment" step in the cell death pathway and thwarting death at that point, turning the cell back onto a road to recovery (*4*).

The phenomenon studied by Wang *et al.*, parthanatos, occurs when the prominent feature of injury is DNA damage, in the setting of imminent risk of cell death such as during stroke. When a cell's DNA repair pathways (*5*) are rendered ineffective or are simply missing, cells must decide either to live with damaged DNA or to die, as mutations may favor cancer or other disease states. Fragile mutant cells face difficulties surviving, and one decision point toward death occurs when DNA damage is too extensive for a given setting. Indeed, mutant cancer cells with defective DNA repair are vulnerable to treatments designed to disable the remaining DNA repair machinery (*6*). In injury, some repair enzymes become overwhelmed while others become overactivated, leading to the destruction of a cell's

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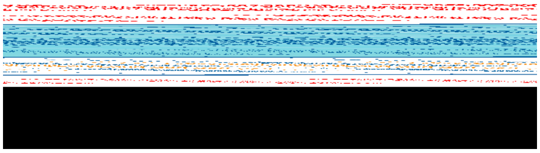

Cold atoms twisting spin and momentum

Monika Aidelsburger (October 6, 2016)

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