each other or to the cores from which they were chipped, so flake production might have occurred elsewhere. However, because the steepness of the slopes at the site rarely permitted the team to open large excavations, this prospect remains to be examined thoroughly.

What were the stone tools used for? Zhu *et al.* note the discovery of animal remains near the oldest tools, including bones belonging to bovids (a family that includes antelopes and cattle), cervids (comprises deer) and suids (pigs). The authors did not address whether this association provides evidence of tool use for carcass processing. To evaluate the possibility, it would be necessary to identify signs such as: cut marks on the bones that point to flesh removal with tools; breakage marks on the bones, suggesting that they had been hammered to extract bone marrow; tool wear; or the presence of trace biological residues on the tools. If this question is investigated in the future, the degree of post-recovery cleaning of the stone tools might have compromised the use of approaches[11] such as residue studies.

Hominins originated in Africa possibly more than 6 million years ago[12]. The absence in Eurasia of both any hominin sites dating to the early portion of this interval and any fossils that can be attributed to hominin genera such as *Australopithecus* and *Paranthropus*, found in Africa until about 1 million years ago, points instead to a species of *Homo* as the most likely candidate for the first hominin to have left Africa. The oldest known African fossil attributed to *Homo* is a 2.8-million-year-old jawbone from Ethiopia[13], which provides a time estimate for the earliest possible exit of the genus from Africa. Of course, the actual date of departure might have been later.

The hominin dispersal probably occurred under the variable climates of the Pleistocene ice age. Does a migration to higher latitudes suggest the evolution of behavioural adaptations to colder climates? Perhaps. The conventional interpretation that the palaeosols of the Loess Plateau formed during favourable warm and wet conditions, and its loess under harsher cold and dry conditions, is probably an oversimplification[14], but at the Shangchen site, palaeosol layers containing stone tools outnumber loess layers containing such tools by a ratio of about 2 : 1. Rather than maintaining a continuous occupation of the Loess Plateau, the hominin population might have increased or dwindled, depending on the climate[15].

The roughly 14,000-kilometre trek from eastern Africa to eastern Asia represents a range expansion of dramatic proportions. The dispersal of hominins was probably facilitated by population increases as they moved into new territories and filled empty niches, and could also have been driven by the phenomenon of resource depletion that underlies the high mobility of today's hunter-gatherers[16]. Yet even with a dispersal rate of only 5–15 kilometres per year, a value well inside the daily foraging range of modern hunter-gatherers[17], the distance between Africa and Asia could have been covered in just 1,000–3,000 years. The present record of hominin sites and the dating techniques that are currently available to researchers are not sufficient to resolve a dispersal event of such potential speed, or to determine its exact form, but we can surely look forward to more finds that will help to solve this migration mystery. ■

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QUANTUM PHYSICS

Quantum optics without photons

Atoms can exhibit wave-like behaviour to form matter waves. Such waves have been used to model the basic processes that underpin how light interacts with matter, providing an experimental platform for future research. SEE LETTER P.589

ALEJANDRO GONZÁLEZ TUDELA
& J. IGNACIO CIRAC

The fundamental theory that describes the interaction between light and matter at microscopic scales is known as quantum optics. One of the most striking and tangible consequences of this theory is that excited atoms in the quantum electrodynamic vacuum — a state that contains no photons, often referred to simply as the vacuum — can decay to their ground state by emitting a photon, a process called spontaneous emission. In 1946, physicist Edward Mills Purcell proposed that this process can be tailored by structures that alter the photonic environment[1], such as photonic crystals[2], engineered dielectrics (insulators) in which light cannot propagate at certain frequency ranges. In the 1990s, it was predicted[3] that spontaneous emission in photonic crystals leads to exotic decays, in which photons

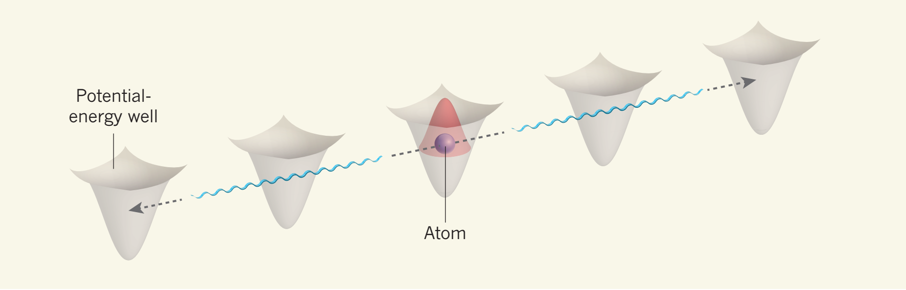

Figure 1 | Matter-wave emitters. Krinner *et al.*[4] trapped rubidium atoms in a one-dimensional optical lattice formed by the interference of laser fields — the interference generates a periodic pattern of light intensity that corresponds to a series of potential-energy wells, in which atoms can be confined. Each atom has two internal states, one of which (red) is confined to the atom and the other (blue) which is unconfined and overlaps with adjacent empty wells. By tuning the parameters of the system, the authors could make occupied lattice sites emit atoms as waves (dotted arrows) that travel along the lattice. The emission mimics that of photons from atoms confined in photonic crystals (materials engineered so that light cannot propagate at certain frequency ranges).

adopt a 'superposition' state in which they are simultaneously emitted into the surrounding environment but also localized around the emitting atoms. On page 589, Krinner *et al.*[4] report the first observation of the dynamics of these exotic decays, not using photons, but using a system of trapped, ultracold atoms.

The atoms in Krinner and colleagues' experiments are trapped in optical lattices[5], which are formed by the interference of counter-propagating laser fields — the interference generates a periodic pattern of light intensity in which the atoms are confined. Given their quantum-mechanical nature, the atoms can tunnel between neighbouring sites in the lattice at a rate that can be adjusted by altering the lasers' intensities. Because such systems are highly controllable and exhibit low decoherence (the atoms are well isolated from their environment and thus behave ideally), they are an almost perfect platform for simulating complex quantum problems found in fields such as condensed-matter and high-energy physics (see go.nature.com/2uied19). Krinner *et al.* now demonstrate that trapped-atom systems can also be used to simulate quantum optical problems.

The authors' experiments are based on a proposal[6] published in 2008. The idea is to use atoms — in this case, rubidium atoms — that have two internal states, which respond to a one-dimensional optical lattice in different ways (Fig. 1). One state (let's call it the *f* state) 'sees' regions of high light intensity as deep optical potential-energy wells from which it cannot move, whereas the other (the *a* state) hardly notices the wells, so that atoms in that state can propagate through the optical lattice as a matter wave. An atom in state *f* thus represents a matter-wave emitter in an excited state, whereas an atom in state *a* behaves like a photon that can be emitted through spontaneous emission. To complete the analogy with atomic decay phenomena in a structured photonic environment, the two internal states are coupled to each other using external fields, so that an initial excitation can be transformed into a propagating matter wave.

In their experiments, Krinner *et al.* model the simplest scenario of spontaneous emission in a photonic crystal, but one that potentially offers the most insight into such processes: the spontaneous emission of a single photon into the vacuum. By tuning the experimental parameters of their system, they observed a phenomenon known as fractional decay[5], in which the emitter ends up in a quantum superposition of being both excited and having decayed to the ground state. The authors also report direct evidence that the probability of the emitter remaining in the excited state does not decrease exponentially over time. Both the non-exponential behaviour and the fractional decay are some of the most peculiar effects that photonic crystals induce in quantum emitters. The new measurements are analogous to previously reported measurements of the spontaneous emission of photons in the visible-light[7,8] and microwave[9] regions of the electromagnetic spectrum, but in those studies, it was not possible to measure the dynamics of the decay.

The authors' experimental platform offers several useful features in addition to its excellent controllability and low decoherence. First, it is flexible enough to emulate photonic crystals that have different geometries, and to model 3D environments in which further unusual features of spontaneous emission emerge[10,11]. It also allows access to parameter regimes that are out of reach of optical implementations, such as situations in which the coupling between emitters and the environment is very strong. Moreover, it might enable spontaneous emission to be studied in environments that are even more exotic than photonic crystals, such as in materials known as topological insulators — although the experimental set-up would need to be adapted so that the atoms move in the way that simulates the movement of excitations in such materials, and the efficiency with which decays can be detected would need to be improved.

Together with photonic platforms in the optical and microwave regimes, Krinner and colleagues' system opens the way to studies of the physics that emerges in unconventional quantum optical set-ups. If the experiments are extended to include many emitters, it might be possible to observe collective spontaneous-emission phenomena that cannot be predicted using current computational methods, or even to engineer interactions among the emitters that cannot be produced using other platforms. ■

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MICROBIOLOGY

Viruses cooperate to defeat bacteria

It emerges that viruses called phages, which infect bacteria, can suppress the bacterial immune system during an initial wave of unsuccessful infection, enabling subsequent viral infection to succeed.

AUDE BERNHEIM & ROTEM SOREK

Bacteria and the viruses that infect them, known as phages, are engaged in a constant arms race. Bacteria continually evolve new mechanisms of resistance against viruses, while phages evolve countermeasures to overcome these defence mechanisms. Writing in *Cell*, Borges *et al.*[1] and Landsberger *et al.*[2] reveal how phages can 'collaborate' to shut down the bacterial immune system and achieve a successful infection. Although an initial viral attempt at infection fails, this enables a subsequent phage infection to be successful. This example of 'cooperation' between genetically identical individuals of a viral population illuminates a previously unknown group strategy of phages, and provides an interesting example of viral 'altruism'.

The bacterial anti-phage defence system called CRISPR–Cas recognizes and targets foreign nucleic acids in a sequence-specific manner[3]. To block CRISPR–Cas defences, phages express genes that encode proteins that inhibit the function of the CRISPR–Cas machinery[4,5]. Because these anti-CRISPR proteins are encoded in the phage genome (Fig. 1), a phage must enter a bacterial host cell and begin to express them to mount a counter-attack. Yet this raises a conundrum. CRISPR–Cas defences can attack phage DNA as soon as it enters a bacterial cell[6], before the phage gets a chance to express and use its anti-CRISPR proteins. So what purpose do anti-CRISPR proteins serve if the help they provide is likely to arrive too late for the individual virus that expresses them?

To investigate this, Borges, Landsberger and their respective colleagues studied the bacterium *Pseudomonas aeruginosa* and examined viral anti-CRISPR proteins that target a version of the bacterial CRISPR–Cas system called type I-F. Both groups observed that the initial ratio between the number of phages and the