on the equator was not sufficient to establish the superposition nature of the quantum state[2]. To do this, the authors also performed experiments in which, after detecting the rotated photon, they then rotated the total atomic arrow about the x direction by various amounts. They then made the precise north–south measurement. As predicted for a simultaneous north and south state, they observed a much lower probability that the arrow would be found on the equator than is possible for a classical arrow that is either just north or just south of the equator.

By measuring at different rotation angles, McConnell *et al.* determined the Wigner function — a quantum probability distribution of the direction in which the total atomic arrow points. The Wigner function looked like a two-dimensional doughnut centred on the x axis (Fig. 1b), but rather than simply having an empty hole of zero probability at its centre, the centre of this doughnut had negative probability. This negative probability was a clear sign that the measurement of a single rotated photon collapsed the atoms into an entangled state. This is the first time that a negative Wigner function has been observed for such a large collection of atoms.

Several experiments have created entanglement between atoms using many photons to measure the north–south orientation of the total atomic arrow[3], producing large amounts of 'quantum squeezing'[4] — enhancement in the sharpness of the atomic arrow needed for realizing better quantum sensors. McConnell *et al.* observed no improvement in the total sharpness of their atomic arrow.

However, the squeezing experiments carried out so far can be viewed semi-classically: quantum mechanics produces a certain magnitude of 'noise', after which the noise can be treated as arising from a fictitious classical source. In McConnell and colleagues' work, the observation of a negative Wigner function demonstrates that any semi-classical description fails to capture their flavour of entanglement.

The authors also demonstrate that nearly all of the roughly 3,000 atoms must be involved in the generated entanglement, by using a multipartite entanglement measure known as the entanglement depth, which has been applied in related work[5]. It is unclear exactly how to interpret this particular measure because it does not provide information about the magnitude of the shared entanglement[6,7]. However, showing that entanglement can be simultaneously shared among so many atoms continues to push the progression of the observation of quantum mechanics from the microscopic to the mesoscopic regime. It may one day help us to understand the transition from the quantum to the classical world of our everyday experience, in which we would never see arrows pointing both slightly north and slightly south at the same time.

In future work, the detection of two or more rotated photons[8] may open the door to even larger amounts of entanglement, and to states that might be useful for quantum sensors

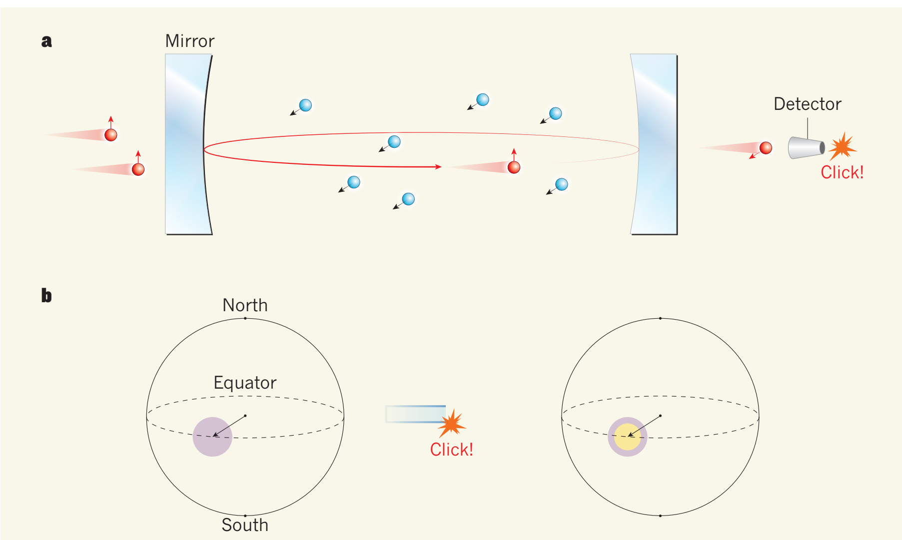

Figure 1 | Creating highly shared entanglement. **a**, Vertically polarized photons (red) pass many times through atoms (blue) as the photons bounce back and forth between highly reflecting, weakly transmitting mirrors. The polarization of a photon is only very occasionally rotated to horizontal owing to quantum noise (uncertainty) in the quantum-spin orientation of the atomic arrows. Only horizontally polarized photons generate a click on a detector. **b**, The quantum probability distribution of the orientation of the total atomic arrow is represented by a region (purple disk) at the tip of an arrow on the equator of a sphere. McConnell *et al.*[1] show that detecting just one horizontal photon (click!) changes this distribution to a 'two-dimensional doughnut', which has a positive outer region (purple) and a negative inner region (yellow) — a hallmark of quantum entanglement between the atoms. The negative-probability filling means that, no matter how the doughnut is rotated about its axis, the probability of measuring the arrow on the equator is zero.

NATURE

50 Years Ago

'Detection in Denmark of the Sinkiang nuclear detonation' — Measurements of fission products in air at ground level are made regularly in Copenhagen using a high-volume air sampler and a 100-channel γ-spectrometer. A filter exposed during the period October 23–26, 1964, gave the first reliable indication of new fission-products by the appearance of the 1,596-keV line of lanthanum-140. The sample was a compressed filter containing dust from about 150,000 m^3 air ... The concentration of lanthanum-140 was estimated as 5×10^{-5} pc./m^3. Filters sampled on October 28 and October 30 show concentrations which are approximately 10 and 100 times greater ... This seems to prove that debris from the Sinkiang explosion reached Copenhagen by transportation in the upper troposphere in less than 10 days. Later measurements on a rain sample from October 23 finally proved that the transportation time did not exceed 7 days.

From *Nature* 27 March 1965

100 Years Ago

An allusion to musical sands may be found in one of the tales from the "Arabian Nights"—"The Story of the Two Sisters who were jealous of their Younger Sister." Prince Bahman, who was journeying in search of rarities and treasures, reaches the foot of a mountain, and while ascending "was assailed with the most hideous sounds," while others who followed him heard "groans, shouts, and all sorts of insulting epithets." One of the wonders they were in search of was the "Singing Tree," which "commenced to issue a series of exquisite strains of music" as soon as the Princess Parizadé saw it.

From *Nature* 25 March 1915