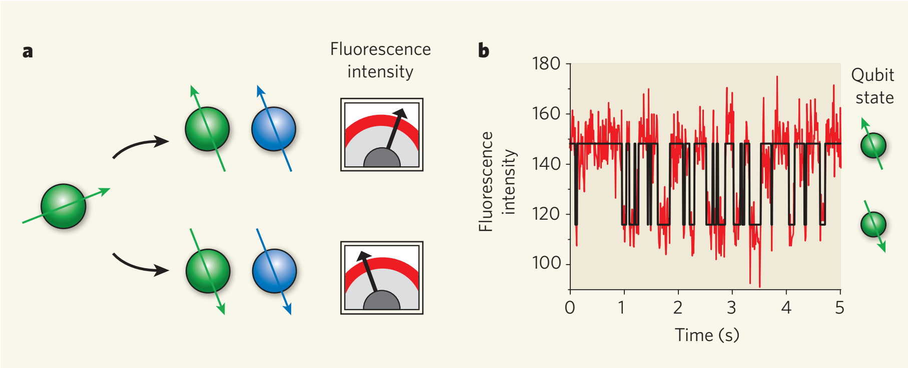

Figure 1 | Quantum jumps. **a,** The principle of the non-demolition measurement technique used by Neumann *et al.*[1] and Vamivakas *et al.*[2] to detect quantum jumps between two spin-qubit states. The qubit under investigation (green) is correlated with an auxiliary system (blue), such that their spin orientations are parallel to one another. The auxiliary system is measured by monitoring its fluorescence intensity, and the procedure is repeated several times to reveal the state of the qubit under study with high accuracy. **b,** The quantum jumps observed by Neumann *et al.*[1] for a single nuclear spin in diamond. Fluorescence intensity is given in number of photons per 5 milliseconds. The red curve shows experimental data; the black curve shows inferred spin state. (Figure courtesy of J. Wrachtrup, University of Stuttgart.)

fluorescence intensity, the centre looks brighter or darker depending on its spin orientation. Typically, however, electronic spin orientation cannot be determined in a single measurement, because the laser also changes the spin orientation before the different fluorescence levels can be distinguished.

To get around this problem, Neumann *et al.* used an electronic spin as the auxiliary system to measure the nuclear spin of the nitrogen–vacancy centre. They applied microwave pulses to the composite system to correlate the nuclear spin with the electronic spin, such that the spins are oriented along the same, albeit unknown, direction. Next, they measured the orientation of the electronic spin and repeated the procedure many times to boost the signal that results from changes in the orientation of the nuclear spin[8]. The key innovation of Neumann *et al.* lies in the use of a strong magnetic field to preserve the orientation of the nuclear spin during the measurement process. This allowed them to precisely distinguish the nuclear-spin states. The transitions between these states were then seen as sudden jumps in fluorescence (Fig. 1).

Meanwhile, Vamivakas *et al.*[2] report the observation of quantum jumps in a different artificial atom: a quantum dot in a semiconducting composite structure[7]. Such quantum dots can be manipulated optically, but they do not have the properties required for direct spin-state detection in a single measurement. Therefore, the researchers grew a pair of quantum dots on top of each other. One of the dots hosts the electronic spin qubit to be investigated, whereas the other dot is the auxiliary system for readout. The dots have different state-transition frequencies, and thus can be excited independently of each other by lasers of slightly different colour. However, the two dots are weakly coupled via the phenomenon of quantum tunnelling, implying that the transition frequency of the readout dot depends on the spin orientation of the qubit-hosting dot. This coupling can be used for non-demolition spin detection[9]. By repeatedly exciting the readout dot, Vamivakas *et al.* were able to detect the quantum jumps in the electronic spin qubit.

Taken together, these two results[1,2] represent major advances in the manipulation of solid-state quantum systems: they extend the family of solid-state quantum systems that can be measured with quantum-limited precision. Even though much work remains to be done to improve and to use such measurements in quantum information science, some near-term applications of these techniques can be envisaged. For example, the ability to reliably detect the state of spin qubits in diamond is instrumental in developing quantum-limited, nanoscale magnetic sensors, which can potentially operate in biological environments[10,11]. Beyond such applications, the observation of quantum jumps in two novel physical systems is a remarkable manifestation of the fundamental principles of quantum theory. ■

Mikhail D. Lukin is in the Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA. Jacob Taylor is in the Joint Quantum Institute and the National Institute of Standards and Technology, Gaithersburg, Maryland 20899, USA.
e-mails: lukin@physics.harvard.edu; jacob.taylor@nist.gov

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50 & 100 YEARS AGO

50 YEARS AGO

Nature and Man. By John Hillaby— Any series of books designed to help young people to keep up with the progress of science deserves encouragement. In one of this new series, John Hillaby ... has attempted to show the perpetual struggle between man, animals and plants and how the balance of Nature often becomes greatly disturbed from what seem trivial beginnings ... Among the topics described are the blocking of the Congo River by the devil's lilac and the expenditure of £3 million on chemicals to clear it for traffic; the fearsome effect of too many lemmings, musk-rats and rabbits and other animals; soil-erosion ... and the consequences of over-shooting big game ... Whether the author is right to pitch a book with this approach to young people of "12 and upwards" is very questionable.

From *Nature* 17 September 1960.

100 YEARS AGO

The fifteenth number ... of the Italian review *Scientia*, now in its fourth year, is largely occupied with philosophy. The ideas of Poincaré, Bergson, Einstein, and the Pragmatists naturally form the text of discussions, such as that by F. Severi on "Hypothesis and Reality in Geometrical Science," or Chwolson's "Can we apply Physical Laws to the whole Universe?" or F. Enriques's criticism of Pragmatism. The theory of two star-streams interpenetrating one another is described by Mr. A. S. Eddington, of the Royal Observatory, Greenwich. M. Guignebert sketches the rise of Christianity in accordance with the sifted conclusions of recent research. Mr. Abegg's article on "Chemical Affinity" has a pathetic interest, from the fact that while it was in the press the author met his death in an aëronautic accident ... Reviews of scientific periodicals, notes of scientific meetings, and critical notices of books, make up an issue that is very level in quality.

From *Nature* 15 September 1910.