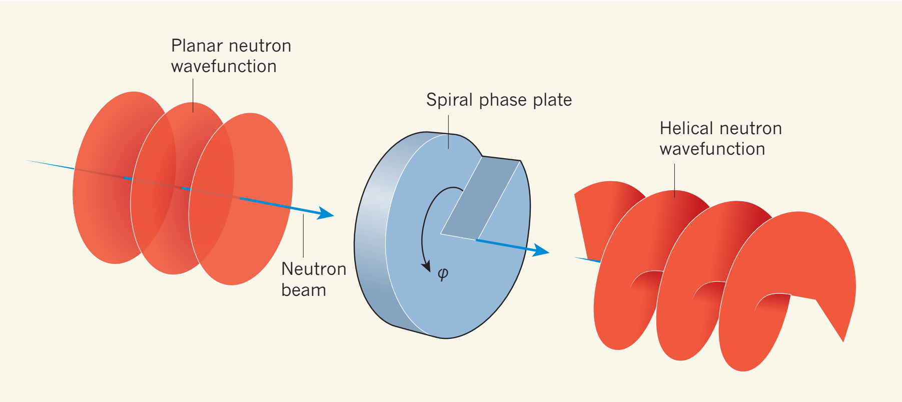

Figure 1 | Orbital angular momentum of neutrons. Clark *et al.*[1] channelled a beam of neutrons through a device known as a spiral phase plate, which modified the neutrons' original, planar wavefunctions and imparted orbital angular momentum to the particles. The wavefunction of the neutrons that emerge from the device has acquired an azimuthal phase distribution of the form $e^{iL\varphi}$ (where i is the imaginary unit, L is any integer and φ is the azimuthal angle of the plate). This phase variation causes the helical structure seen in the emergent wavefunction, which is associated with the acquired orbital angular momentum.

ref. 9 for a review). The fact that photons are not the only particles that can have OAM has opened up possibilities for fundamental studies of electromagnetic interactions and for applications such as improved electron microscopes.

Clark and colleagues' work adds neutrons to the list of particles that can have OAM. The authors generate OAM-carrying neutrons by guiding a beam of the particles through a device known as a spiral phase plate (Fig. 1). The thickness of this device varies uniformly as a function of the plate's azimuthal angle, φ (the angle measured around the circumference of the plate). The wavefunction of a neutron passing through this device acquires a phase shift that is proportional to the plate's local thickness. For appropriate values of the variation of thickness with φ, the wavefunction acquires an azimuthal phase distribution given by $e^{iL\varphi}$, where L is any positive or negative integer and i is the 'imaginary unit' (the square root of −1).

The authors fabricated several plates whose thickness distributions corresponded to various values of L, and thus generated neutron beams carrying OAM of different $L\hbar$ values. Like its spin, a neutron's OAM is a quantum-mechanical attribute. It occurs as a consequence of the helical structure of the particle's 'twisted' wavefunction when it emerges from the plate. To verify that the neutron beam had acquired OAM as it passed through the plate, Clark *et al.* used a technique known as neutron interferometry. In this approach, the neutron wavefunction was split into two paths and a spiral phase plate was placed in one of them. The two paths were subsequently combined coherently to form an output beam whose interference pattern showed the azimuthal phase distribution that the wavefunction had acquired.

Although Clark and colleagues' results are impressive, they represent only the first step in an emerging field of research. For example, in the present experiment, the neutron beam falling on the spiral phase plate is a statistical mixture of several OAM quantum states. Before applications can be developed, neutrons must be generated that have quantum states with definitive OAM values (eigenstates). In addition, holographic methods have been developed for creating optical[10,11] and electron[12] OAM states, and these are more precise and versatile than the use of spiral phase plates. It will thus be interesting to explore the use of holographic techniques for neutrons too. The potential use of neutron OAM states for quantum-information studies is another exciting prospect.

Finally, Clark and colleagues' study opens up a further avenue for future work: the use of neutron beams with OAM for imaging. Because neutrons are penetrating particles, they could offer practical advantages compared with optical and electron microscopy in deep-imaging studies of materials. One might therefore conclude that OAM-carrying neutron beams may boldly go where no quantum particle has gone before. ■

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NATURE

50 Years Ago

A Biological Retrospect. By Sir Peter Medawar — The title of my presidential address, as you will have discerned, is "A Biological Retrospect", and on the whole it has not been well received. 'Why a biological *retrospect*?', I have been asked; would it not be more in keeping with the spirit of the occasion if I were to speak of the future of biology rather than of its past? Unfortunately, it is impossible to predict new ideas … and we are caught in a logical paradox the moment we try to do so. For to predict an idea is to have an idea, and if we have an idea it can no longer be the subject of a prediction. Try completing the sentence 'I predict that at the next meeting of the British Association someone will propound the following new theory of the relationships of elementary particles, *namely*…'. If I complete the sentence, the theory will not be new next year; if I fail, then I am not making a prediction.
From *Nature* 25 September 1965

100 Years Ago

We have still … very much to learn about causes in action; and the mystery of the earth, and of our connection with it, grows upon us as we learn. Can we at all realise the greatest change that ever came upon the globe, the moment when living matter appeared upon its surface … And here was living matter, a product of the slime, if you will, but of a slime more glorious than the stars. Was this thing, life, a surface-concentration, a specialisation, of something that had previously permeated all matter, but had remained powerless because it was infinitely diffuse? Here you will perceive that the mere geologist is very much beyond his depth.
From *Nature* 23 September 1915