Quantum kung fu

If someone puts you in an armlock, what should you do? If you happen to be a martial artist well-practised in the art of joint manipulation, or *chin na*, you will know the answer already: there is one simple move that will allow you to turn the tables on your aggressor, leaving them on the wrong end of a throw. However, if your skill set tends more toward manipulating mathematical symbols, there is still hope, for the answer is also closely tied to theoretical physics.

Before I describe the move, let's consider some martial arts history. Many styles of kung fu are based on observations of the natural world – specifically, the behaviour of animals. For example, the legendary founder of the Northern Praying Mantis style, Wong Long, supposedly learned his art by testing that insect's reactions to being prodded with a twig – a method one might be tempted to call proto-scientific (and probably unethical). Other styles have allegedly been inspired by the crane, monkey, snake, tiger and dragon, to name just a few (the person who observed the dragon was presumably a proto-theorist).

To understand how to escape from the armlock, however, we are going to take our inspiration from an altogether different species – this time one from the "particle zoo". Imagine we have two electrons in a plane. Because all electrons are identical, if we borrow Wong Long's twig and prod our two electrons into switching places, everything will be just as it was, right? Not quite. Electrons are fermions, so the combined two-electron wavefunction picks up a minus sign when the electrons swap places – it is antisymmetric under exchange. That's all well and good, but we also have to account for the spin-statistics theorem, which says that swapping two particles is equivalent to rotating one of them through 360°. Hence, rotating an electron's spin one full turn doesn't bring it back to its original state. We have to rotate it twice.

The mathematical objects that share this property – needing to be "turned" through two full rotations to return to their original orientation – are called spinors. They were introduced to physics by Paul Dirac in his study of the electron, which won him the 1933 Nobel Prize for Physics. They remain very strange things, though, and in Graham Farmelo's biography of Dirac, *The Strangest Man*, the mathematical physicist Michael Atiyah had this to say about them: "No-one fully understands spinors. Their algebra is formally understood but their general significance is mysterious. In some sense they describe the 'square root' of geometry and, just as understanding the square root of –1 took centuries, the same might be true of spinors."

Taking the square root of geometry is fine in the weird world of quantum physics, but how does it help us get out of an armlock? Surely any object in everyday life requires at most one full turn to return to its original position? Not so. We now arrive at the solution to our problem: the "plate trick" or, as it's known in martial arts, coiling.

Stand with your feet shoulder width apart and your right hand held out in front of you as if you were holding a plate of soup in your palm. Now rotate your hand to the left, towards your body, so that the plate passes under your right armpit. You don't want to spill the

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soup, so your palm had better stay face up throughout. Continue moving the plate round in a circle until it is back in front of your body. The plate is now in its original position, but the system of you-plus-plate is certainly not – you're all coiled up!

One full rotation didn't bring you back. How about a second? Continue round in the circle, this time allowing the plate to pass over (rather than under) your right shoulder on its way round. Upon completing the second full rotation you'll find yourself back in your starting position, plate and all, with not a drop of imaginary soup spilt. In so doing you have provided a simple demonstration of a spinor – albeit one that you should perhaps not take too seriously when being quizzed on the niceties of the SU(2) Lie algebra in exams.

And to escape the armlock? Just apply the same manoeuvre. Wherever your aggressor's hand is gripping your arm, there will be a gap in their grip where their thumb meets their fingers. They can withstand at most a 360° rotation of your arm before you slip through this gap, but as we have just demonstrated, you can go all the way to 720° and be right back where you started. At that point, I recommend you apply another consequence of the antisymmetry of electrons under exchange: the Pauli exclusion principle. This can be done by demonstrating that the electrons in your aggressor's leg cannot simultaneously occupy the same position as those in your foot. A similar demonstration regarding the electrons in the ground and those in your (former) aggressor's body will follow presently.

As with any physical theory, there is a caveat: this move will only work if your aggressor is not skilled in the art of topology. If they are, they will choose a lock that forms a closed loop around your body – a *kimura* is one example – knowing that the linking number is topologically protected, so you can't get out without breaking the loop. Which is an option. Aside from that, though, the answer to the question of what to do if someone puts you in an armlock is simple: you take the square root of geometry.

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