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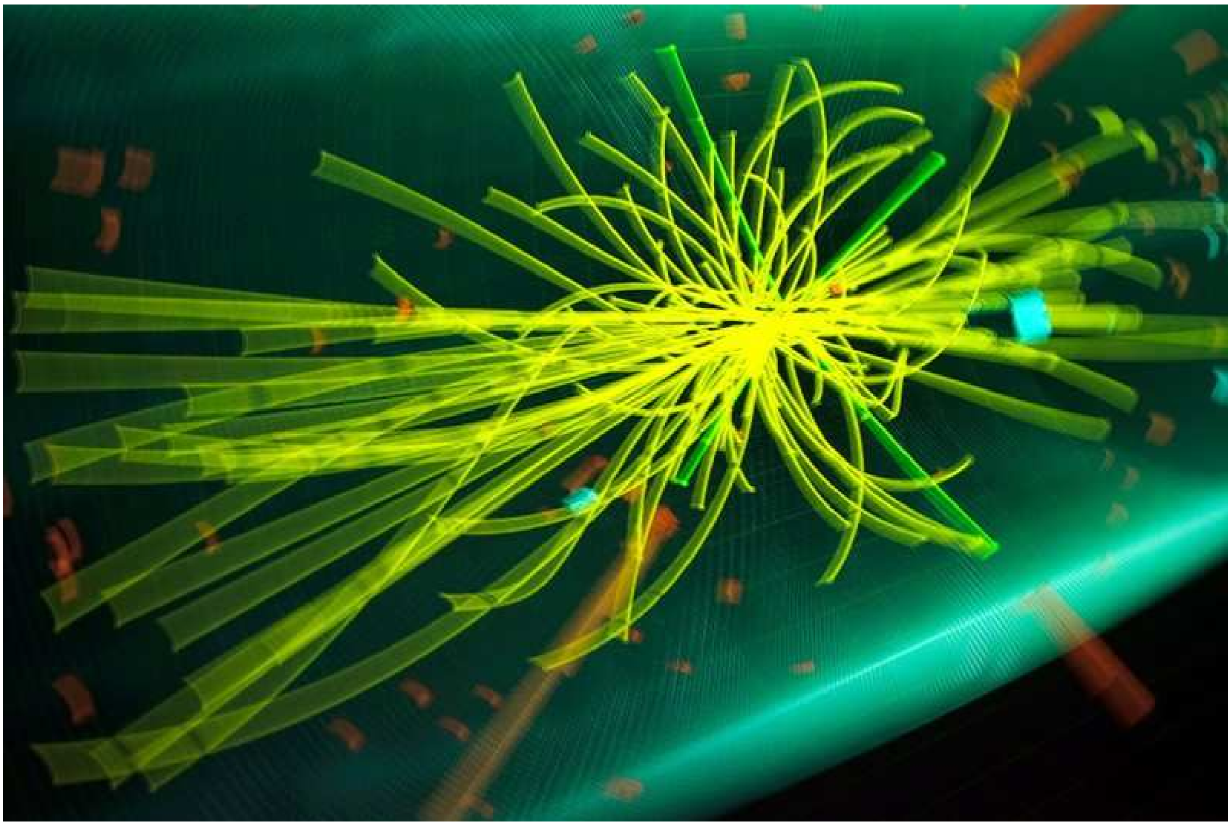
Five particles that don't exist – yet could change our world



Fabrice Coffrini/AFP/Getty Images

By **Andrea Taroni**

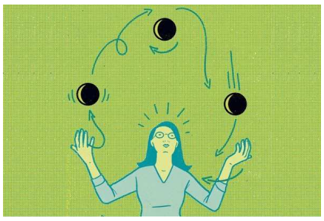
Move over, electron. Step aside, Higgs boson. The fundamental particles that make up physics' standard model get a lot of air time. But there is another breed of particle, just as important, that is often overlooked. That's understandable, for in a sense "quasiparticles" do not exist at all, though they have a lot in common with regular particles and are essential for understanding the world (see "Lessons in reality from particles that don't exist"). They only pop up within the confines of solid materials, but their unique properties could revolutionise modern technology…

Phonons: Electric cowboys

Smashing protons in CERN's Large Hadron Collider led to the discovery of the Higgs boson. It couldn't have happened without phonons.

At normal temperatures, phonons are collective oscillations of atoms that shuttle heat around solids. But at very low temperatures, these quasiparticles act as cowboys that corral electrons into herds that move as one with almost zero resistance. This is how low-temperature superconductivity arises, and the huge electromagnetic fields superconducting magnets create are what curves protons round the LHC's circular racetrack. Such magnets are also used in MRI scanners, where they force oxygen atoms in tissues into a dance that emits traceable radio signals.

Phonons are also key to the workings of fledgling thermoelectric materials. These convert heat into electricity, with the long-held dream of allowing a car's waste engine heat to power its electrics.



Read more: Lessons in reality from particles that don't exist

A breed of subatomic particle made from nothing has huge implications for technology – and shows how tenuous reality itself is

Magnons: Sultans of spin

Imagine a computer that, when you flipped the on switch, came on at exactly the point you'd left it. That's the promise of magnons, quasiparticles that emerge from waves of flipping spin, a quantum-mechanical property of atoms that is the origin of magnetism.

In standard PCs and smartphones, working memory is stored as units of charge, which dissipates when the device is switched off. With magnons, stored information would not dissipate until the magnetic field was changed, regardless of power supply.

Spintronics, as this idea is called, would have other advantages. It uses less power, so chips can be pushed closer together without overheating — a problem that is plaguing further miniaturisation of transistor chips. Magnons can also be prompted to organise by electromagnetic waves, so computers could become entirely wireless.

Excitons: Plants' secret weapon

Earth receives more energy from the sun in an hour than the entire human population uses in a year. Plants have perfected the art of capturing that juice – thanks to excitons.

Inside a plant's leaves are light-harvesting proteins. Their electrons absorb photons, and the energy kick pings them out of position, creating a "hole". The electron and hole then link up to form an exciton, which can be transported around the plant's photosynthetic machinery. When they get to where they're needed, the electron and hole recombine, releasing energy that is used to split water into hydrogen and oxygen, a key stage in making sugars from sunlight.

This reaction ultimately supports all life on Earth, and we'd love to mimic it in solar cells. In 2013, researchers at the Massachusetts Institute of Technology found a way to directly image excitons, a significant step to making that happen.

Majoranas: Quantum heroes

If you ever want a true multi-tasker, go for a quantum computer. These as-yet imperfectly realised machines use delicate, indeterminate quantum states to weigh up lots of solutions to a problem all at once, as long as no disturbance from the environment breaks the quantum spell.

Majorana quasiparticles could make quantum computing more robust, supplying “qubits” for quantum number-crunching. A sort of massless electron, Majoranas come in pairs, with each particle acting as a half of the whole. That means you have two copies of all the information they contain, so in theory Majorana qubits should be far less vulnerable to external noise. But these qubits exist in the midst of a huge background of other electronic effects, and isolating the Majorana information is tricky, says Attila Geresdi, who studies these systems at QuTech in Delft, the Netherlands.

Weyl fermions: Ambidextrous electrons

Weyl fermions are like a shy cousin of the electron. Predicted mathematically almost 80 years ago, they have two key properties: they have no mass, which means they can move very fast, and they come in mirror images of each other, like right and left hands.

This handedness, or chirality, means Weyls are resistant to interference from sources that don’t match their handedness. This in turn means they are difficult to scatter, and streams of the two types of Weyl fermion can potentially flow close to each other without interfering. Some think these properties could make them the basis for highly sophisticated computer processing well beyond spintronics (see “Sultans of spin”, above). But since materials that host Weyl fermions were only created recently, it is early days in the field of “Weyltronics”.
