Theoretical physics

Looping the loop

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A new "theory of everything" is gaining ground

PHYSICISTS like everything neat and tidy. They assume that the universe must be governed by a single set of rules and are thus disturbed that, at the moment, they have to rely on two sets. One, called quantum mechanics, describes the small, fundamental particles of which matter consists and the forces by which those particles interact. The other, called general relativity, describes the force of gravity, which holds big objects together.

Reconciling these two universal descriptions has exercised some of physics' most brilliant minds, but has yet to provide an uncontested result. Until recently, the widespread expectation was that some version of an idea called string theory would prevail. But string theory has been around for decades without delivering the goods, and that failure has encouraged the protagonists of an alternative explanation to push themselves forward.

Getting knotted

Loop quantum gravity, as this rival is known, was dreamed up in 1986 by Abhay Ashtekar, of Pennsylvania State University. He rewrote the equations of general relativity to make them compatible with quantum mechanics. It really took off as an alternative to string theory, though, when it was picked up by Lee Smolin, now of the Perimeter Institute in Waterloo, Ontario, and Carlo Rovelli, of the Université de la Méditerranée in France. Together, they developed Dr Ashtekar's idea to show that it implies that space and time are not smooth, as general relativity requires, but come in tiny, distinct chunks.

This granularity emerges from what is the most important difference between the two theories. String theorists think that the world is made of matter that exists independently of space and time. The matter in question consists of particles that are formed from different vibrations of “strings”. (Strings are so called because they vibrate in a way that is similar, mathematically at least, to the vibrations of the strings of a musical instrument.) According to string theory, space and time are a fixed background that has a geometric structure—an unchanging stage on which nature's play takes place.

Loop quantum gravity is, in the jargon, background independent. This means that theorists working on it believe the laws of nature can be stated without making any prior assumptions about the geometry of space and time. Space and time are mere consequences of these laws. Loop quantum gravity can be visualised, as its name suggests, as a mesh of loops. According to its rules, it is meaningless to ask where in space and time this mesh exists, because the mesh is the stuff of which space and time are composed.

That is significant because it radically alters physicists' understanding of reality. Space is no longer the stage on which the pageant of existence is played out; it becomes part of the drama. Indeed, theorists working on loop quantum gravity think that matter itself is merely the result of twisting and braiding ribbons of space-time. A fundamental particle is created when three ribbons are joined in a plait. If one of the ribbons in the plait is twisted, it gives the resulting particle an electric charge. If it is twisted in the opposite direction, the particle has the opposite charge. And if it is twisted twice, the particle gains double the charge. So far, the theorists have described how three of the 16 particles in the Standard Model of particle physics may be created in this way.

String theory is the more established of the two; some 90% of theoretical physicists are engaged in developing it. But both it and loop quantum gravity harbour unresolved problems. Most important, neither has been tested experimentally. Nor, despite hopeful talk to the contrary, is there much prospect of an experiment being devised. While particle-physics colliders and space-based observatories could rule out some of the more exotic versions of each, no one has been able to suggest a way to decide between them in general.

Having two candidates for a theory of everything is almost as upsetting to physicists as their inability to reconcile quantum mechanics and general relativity in the first place. They would far rather have just one. This could be achieved by finding which one is right and which one is wrong, by finding that both string theory and loop quantum gravity are wrong and a third theory is right, or by finding that the two theories can be unified. Unfortunately, 20 years down the line, exactly how this may be done remains elusive.