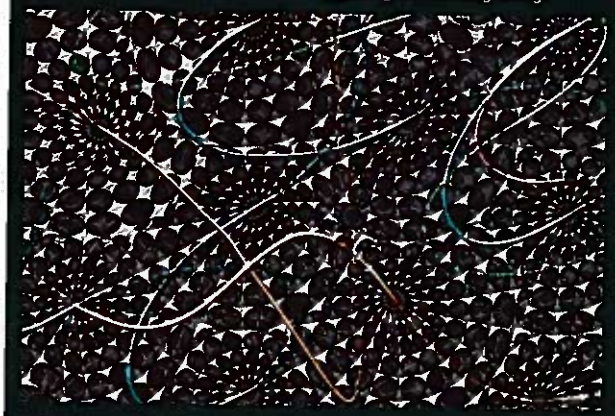
THE THEORIES

Two rival ideas could explain cyclic universes

M-THEORY

Attempts to create a single, unified explanation for all forces and particles in the cosmos have led to the possibility that our four-dimensional Universe is part of an infinite, multi-dimensional 'membrane' (hence the 'M') – or 'brane' for short. According to this, the Big Bang is no longer the moment when the entire cosmos is crammed into a single point, known as a 'singularity' when conditions achieve infinite values, and standard theories break down. Instead, this moment is envisaged as being the result of a collision between two branes, releasing the colossal amount of energy we call the Big Bang. As well as avoiding the problematic singularity, M-theory implies that the question of what happened before the Big Bang amounts to asking what happened before the collision of the branes. And one possibility is that there were an infinite number of previous collisions, each one triggering a fresh Big Bang.



LOOP QUANTUM GRAVITY (LQG)

Another result of trying to unify Einstein's conception of space, time and gravity with quantum theory, Loop Quantum Gravity leads to the view of space-time as being a kind of fabric made up of subatomic loops acting together to create what we call the 'force' of gravity. As with M-theory, when applied to the Big Bang, LQG no longer has the troublesome singularity which causes conventional views of gravity to break down. In contrast to M-theory, however, LQG appears to give a much clearer account of what happened before the Big Bang, with little need for extra speculation to bring about the rebirth of a previous universe. According to LQG, the Big Bang was actually just one half of a 'Big Bounce', in which a previous universe collapsed down on itself before re-expanding to form a new universe. Instead of collapsing down to a point of infinite density and temperature – as in a singularity – it just reaches a small but finite size, and a high but finite temperature and density.

universe in their accounts of creation. Only now is it being taken seriously by scientists, even though it was shown to be a possibility almost a century ago. When Albert Einstein applied his theory of gravity – called General Relativity (GR) – to the Universe, he expected it to predict that space was infinite, static and everlasting. But his equations revealed a host of possible universes – including ones that go through endless cycles.

Such universes offered a solution to the mystery of what happened before the Big Bang. But the idea was dealt an apparently fatal blow in the 1930s by the US physicist Richard Tolman. He claimed the amount of radiation within the Universe would grow with every cycle, making each last longer. But if our Universe is just the latest in an infinite number, it should by now contain an infinite amount of energy – which it clearly doesn't.

Tolman's argument, however, contains a crucial flaw. It assumes Einstein's equations can be trusted at the moment when one universe emerges from another – and they can't. Instead, they go haywire at the precise moment of the Big Bang, predicting a state of infinitely high temperatures in zero volume called a 'singularity' – conditions which are extremely improbable. No-one can therefore be certain what happened to the radiation between each cosmic cycle.

A tale of two theories

But now theorists think they have solved the singularity problem, and breathed new life into the cyclic universe idea. It's all due to breakthroughs in research aimed at fixing the problems with Einstein's theory by combining it with quantum theory – the laws of the sub-atomic world. Devising such a 'unified theory' has proved to be far from simple, but to date, two candidates have emerged – M-theory and Loop Quantum Gravity (see 'The theories', left).

The resurrection of the cyclic model began in 1999, when theorists Professor Paul Steinhardt of Princeton University and Professor Neil Turok, then at the University of Cambridge, suggested that the Big Bang is just one of an endless series of collisions between multi-dimensional objects predicted by M-theory called 'branes'. Steinhardt and Turok calculated that each 'Big Bounce' avoids the singularity state and also the build-up of radiation which wrecked previous theories of a cyclic universe.

They dubbed their theory the Ekpyrotic Universe – from the Greek for 'born from fire'. Yet despite its apparent attractions, theorists pointed out that the Ekpyrotic Universe theory's reliance on M-theory, which is itself still in its infancy, makes it highly speculative. "There are some open questions that need to be addressed, such as a better understanding of the conditions when the branes collide," says Dr Parampreet Singh of Canada's Perimeter Institute.

Singh is one of the leaders in probing the mysteries of the Big Bang with the principal rival to M-theory,

TESTING THE THEORIES

Planck's detectors measure microwave radiation in space