

# LOOP QUANTUM GRAVITY

And all my days are trances,  
And all my nightly dreams  
Are where thy dark eye glances,  
And where thy footstep gleams—  
In what ethereal dances, By what eternal streams.

Edgar Allan Poe (1834)

Poe's physical science was generally sound for the day.

Richard Hodgens (1985)

We need a form of [quantum theory] that does not assume the existence of any classical background geometry for space. Loop quantum gravity is an example of such a theory.

Lee Smolin (2001)

[In the Loop Quantum Gravity picture] these "quanta of gravity" do not live immersed in a spacetime. They *are* space. The idea of space as the inert "container" of the physical world has disappeared.

Carlo Rovelli (2004)

Unlike Frank she *does* show an interest in Poe. Poems is a list she listed in the early days when she liked listing lists. But Poe's the only poet on my poet list I've seen her really read. She's reading the last stanza of *To One in Paradise* for the third time. An ache of desolation for his cousin-bride, Virginia, taken by consumption at the age of twenty-four. Why would she be so keen to read his verse? That his meter is quadrameter I do not tell her. Nor reveal his scheme as rhymed sestina. Nor mention that in this he follows Byron's lead. But Byron brings a mind at peace; not Poe. His wound's too deep, his threnody too soon. And yet, I write, he writes.

Will he show his face today? If so, a loopy picture's waiting for him. According to a version of QG the universe is made of loops. Loops of what? would be a likely question. Froot is what I plan to say. The straight answer is: Spin. That's the word from leading authors. Space, they say, is a *Spin Network*. By which they mean a network made of spin. Whaddaya mean, spin, he'll say, aggressive, pissed off by the Froot. Hey, I'm on your side, I'll say to him.

Turns out that the spin bit is red herring. It's Penrose's fault. Many years ago he's playing round with quantum networks. They look like a floor made of triangle tiles. Each side has a number: ones and twos and threes, etcetera. He calls the numbers spins for reasons that are mainly whimsy. It takes Rovelli to, much later,

say what spin is in a way that I can understand. It's like tiny ripples in the field of gravity. They make loops. So I have news for him. If the world is loopy now then the Beginning must have loops. How do I break the news?

Maybe I should take a tip from Rees. He distils the universe in *Just Six Numbers*. In it Ouraborus, a mythical Egyptian creature, depicts a conundrum of physical cosmology. Ouraborus (aka *The Worm Ouroboros*) is a snake that eats its tail. This antic makes a loop. Rees marks off the scales of sizes in the universe around the loop from  $10^{25}$  m, the scale of the visible universe, near the head end to  $10^{-25}$  m, the scale of sub-sub-atomic quarks, near the tail. He uses the tail-eating snake image to convey 'the ultimate synthesis that still eludes us—between the cosmos and the quantum.' Or, one might say, between the entire universe and its fundamental bits. It illustrates an insight that, at largest scale, the universe partakes of its own smallest structure; we don't know how. Maybe the worm could ease Frank into loop quantum gravity. Or maybe I should think about it.

String theory and loop quantum gravity are kinds of quantum gravity. The difference between them is: String theory begins with space and time and builds its strings, from which GR may emerge; LQG begins with GR and builds loops of gravity, from which space and time emerge.

GR expresses a large-scale relationship among matter, gravity and space. But what does that relationship look like at the smallest scale conceivable? Well, this is what QG is all about. It kicks off in the '60s. Wheeler and DeWitt come up with an equation meant to merge GR with quantum theory. It describes the contents and geometry of the whole universe. It's a sensation. It looks this simple:

$$\hat{H}\psi = 0$$

It's not as simple as it seems. For a while nobody does much with it. But two decades later Smolin and Rovelli make a shocking discovery. Two shocks: They find exact solutions. Not one, not two, but infinitely many. And they lead to quantum loops. LQG is born.

In physics anything so clean and simple-looking as this equation is definitely beautiful if it says something about the universe. But the sensation turns out to be what it doesn't say. What's missing? Well, there is no  $t$  in it! It describes the universe but doesn't mention time. How can I explain the impact to him? It sets a timeless fox among the physics chickens. They flap and fluster, do their chicken thing. Even chicken things, I fear, are far beyond him.

So now some physicists are chasing the idea that there is no time. Not only in the early universe; no time now! In this view time's an illusion. This is the outlandish landscape that she set him up to wander in. From his point of view—if he could see it—LQG has a more fundamental flaw. It has no way to interface with the Beginning. It says how space is but has no place for how it gets to be that way.

In this it mirrors the first failing of GR. For the guy who's got the job of finding the Beginning, it's no happy hunting ground.