THE BOUNDARY PROBLEM

It will be seen that I have not succeeded in formulating boundary conditions for spatial infinity. Nevertheless, there is still a possible way out.... For if it were possible to regard the universe as a continuum which is *finite (closed) with respect to its spatial dimensions*, we should have no need at all of any such boundary conditions.

Albert Einstein (1917)

The surface of the Earth as a whole has no boundary; why should it not be the same for the whole of space?

Georges Lemaître (1950)

A space boundary? It's another brain bender. What does the edge of the universe look like? Where is it? What is to be found there and what lies beyond? These questions are about what physicists call boundary conditions. As he has already seen, present-day cosmology sweeps questions about boundary conditions under the religion rug. Or tries.

In 1917, two years after GR bursts upon the scene, Einstein knows better. He publishes the paper that converts cosmology into a science. It's concerned with boundary conditions. He asks himself about the universe's edge. He finds a fundamental truth: Everything depends upon the edge—if there *is* an edge. And it all depends upon its absence if there isn't.

Another fundamental truth is: When I'm mean about someone behind their back, the next day they are nice. So, today, he's early. He sits on his chair. He pays attention. Just down the way the Black Eyed Peas are singing: What's going down?

I want to show him how a simple edge can change our thinking. Let's think, I say, about the way the world is viewed some six or seven hundred years ago. People think the world is flat. If you sail too far you will fall off. Of course you'd think they'd think: We should see right here a drastic drop in sea level. In this way one can say, without going to the edge, that it ain't so. Those stuck on the eastern shore don't know what *is* there, six weeks' sailing to the west, but if they think clearly they will know what's not: There is no edge that ships fall off. Of course bold sailors go to see this for themselves. They come back. They report: No edge. It's soon seen that if one keeps on going on Earth's 2-D surface one comes back to where one left.

Einstein knows about this. It helps him to think about the edge of space. First he takes a look at Newton's universe. Newton says the universe holds all the matter in a large but finite zone. This hangs in an infinite and empty space. Einstein shows that, if there is no matter at infinity, there is no matter anywhere. In other words, he shows that Newton's version of the universe is wrong. This confronts him with the question of the edge. He shows that if there is an edge this too leads to contradiction. But how can there be no edge?

He finds a way. He abandons the idea that the universe is infinite. To make sense the universe must have a finite size and it must have no edge. He sees it as a 3-D analogue of the Earth's 2-D surface. His universe is finite; it's closed in on itself. He needs no spatial boundary conditions to plug into his equations; there is no boundary in space. It's a fundamental insight that some physicists don't get; even Feynman, who says, 'The earth's gravitational field never ends, but peters out very slowly in a precise and careful law, probably to the edges of the Universe.'

Einstein gave little thought to whether there's a boundary—an edge of sorts—in time. But GR's equations say there must be one—in the beginning. This is as close as Einstein gets to where Frank's booked to go. Much later, Hartle and Hawking come up with a way to tweak the math to get rid of the GR edge in time. They do it by assuming time is then the same as space, whatever that is. It's a neat trick but for Frank it explains nothing.

I'm left feeling Einstein's bold boundary excursion holds a clue. Its signposts seem to say: No boundary in space and one (or two) in time. But how does no boundary begin?