THE PROBLEM OF KALUZA AND KLEIN

The Kaluza-Klein idea of extra spacetime dimensions continues to pervade current attempts to unify the fundamental forces.

Michael Duff (1994)

In 1921 Einstein presented to the Prussian Academy a paper by Theodor Kaluza … in which the gravitational and electro-magnetic field are geometrically unified in five dimensions.

Jeroen van Dongen (2000)

[**The**] **extra spatial dimensions are put on an essentially equal footing with those of ordinary space and time.**

Roger Penrose (2004)

Ask any physicist. There *is* no problem of Kaluza and Klein. Well, not unless you think there is. I think he should. But who am I to say?

In the 1920s Theodor Kaluza and Oskar Klein, a Pole and Swede respectively, both do mathematics. What they also have in common is an idea which, 85 years later, Penrose will call 'cute.' The idea is this: What if there is an extra space dimension?

Why would they want one? Well, they want to solve a pressing problem: How to unify the fundamental forces—two are known in their time—of electromagnetism and gravity? They think that a fourth dimension ought to do the trick. It almost does.

Kaluza publishes the theory in 1921. Einstein presents it for him. Of course the question's asked: Where *is* this fourth dimension? Klein comes to his rescue. He says it has collapsed. That ugly word again: Compactified. Klein invents it.

Frank looks incredulous. I tell him how to do it: Take a rubber band. Cut it. Stretch it and imagine it goes on forever. It's an infinite dimension. Cut off all but a small piece and glue its ends together. Now he has his own Compactified dimension. Shrink it further till he cannot see it. It is tiny but it's really there. The hard part comes last. He must spread it round all over: There are little loops he can't see at each point in 3-D space he can.

I take him through it step by step without the rubber band: Pick a point anywhere. Imagine a little loop. Shrink it down until it's much too small to see. Now imagine that this loopiness is everywhere. Welcome to 4-D Kaluza-Klein space.

What you see in it is less than what you get.

K-K space looks just like 3-D space. So what is their K-Kzy point? Well, Kaluza makes amazing math with his extra dimension. It does gravity like Einstein. And electromagnetism just like Maxwell, *both*! Even Einstein is impressed. All this from a fourth dimension?

K-K comes with one condition: The size of the extra dimension *must* be fixed. This turns out to be terminal. GR says the size, the very shape, of space can change. That's what GR's gravity is all about. How can K-K's fourth dimension be exempt? The verdict's swift: It can't. K-K space bites the dust. It falls victim to GR and its recently observed light-bending success.

So, what's the K-K Problem? Well, dumping it no longer looks as good as it did then. It gets dumped because, as Penrose says, its extra dimension is 'put on an essentially equal footing with those of ordinary space and time.' At the time there seems to be no reason why it should be on some other footing.

But Frank has a reason: His perspective is he's seeking the Beginning. So he assumes it did exist. He's hearing from all sides—by which I mean me mostly—that initially there was no space and time. So the Beginning, to exist at all, would need to have *its own* dimensions. What if K-K's fourth dimension's one of those? Why would it *ever* be put on an equal footing with ordinary space dimensions? Could it be K-K got a bad rap?

That fourth dimension worked so well. It was a key step to string theory. Was it dumped for the wrong reason? Was it on the right track?