THE FLATNESS PROBLEM

One of the most puzzling properties of our universe is that it is now expanding at a rate very close to the critical divide separating the ever-expanding universes from the recollapsing ones. … In order that we be as close to the divide as is observed today, the universe must have begun expanding extraordinarily close to the divide originally.

John Barrow (1991)

The hot big bang model suffered from extreme dependence on initial conditions. Finding the present universe in this model would be as unlikely as finding a pencil balanced on its point after an earthquake.

Jonathan Halliwell (1991)

GR says Spacetime is curved. He should know this by now. But when I say it he looks at me like: What the expletive-deleted does that mean? He doesn't say it; he just looks that look.

It is similar to saying that the surface of the Earth is curved. The curve's so slight the curvature is easy to forget. Some places, such as mountain ranges, are much curvier. Their curves move slowly if at all. Others, such as tidal waters, curve a bit this way or that as hours go by. But overall the 2-D surface of the Earth is curved more or less like a sphere.

Spacetime could be curved like a sphere too. A sphere curves the same way fore-and-aft and side-to-side. A curvature that curves the same way both ways is called positive. A bigger sphere has smaller curvature. Makes sense: It's more flat.

There's another kind of surface curve. It's like a saddle. It curves up fore-and-aft and down side-to-side or vice versa. This curvature's called negative. If it's flatter then the curvature is less. In between the two kinds there is zero curvature. This is called flat. The question is then: What's the universe's curvature? Is it positive or negative; or is it flat?

His look is less than patient. Hang in, I advise. These are basics that he'll need if he's to grasp this clue, which is so strange and so sensational a Holmes might have the whole thing solved by now.

Spacetime being 4-D means the universe is curved in four dimensions and that's harder to imagine—I find it impossible—but the idea is the same. For now all he needs to know is that the curvature depends upon the average density of matter in the universe. If the density is high enough, the curvature is positive. If it's low enough, the curvature is negative. And if it is *exactly* a certain density, the universe is flat.

Why does it matter how flat it may be? Well, in the end its curvature determines what it does. If its curvature is even slightly positive, it is heading for a crunch, a Big Crunch. Gravity will bring the matter back together at some future date. The only question is how soon. How soon depends on curvature. The more the curvature the sooner comes the crunch. But if its curvature is negative it's heading for the wide blue yonder. It will expand forever, shrugging off the pull of gravity, slowing down but not succumbing, never coming to a stop.

So what's the problem? If the Big Crunch is coming it won't happen for more than ten billion years. Who cares? It's a disaster that's of no concern to politicians. But it bothers physicists. They have a problem: What they measure says the universe is flat. Flat to a degree that seems to make no sense.

It's like Halliwell sets up his pencil on its point and then lets go. It stays upright. How long before it falls? If it stays up for a second everyone is looking for the trick. Superglue? Well, the universe has balanced more than 13 billion years without a wobble. Something, one might think, must hold it up.

Among experts the consensus is there is no trick. Nothing holds it up. It seems the universe must have precisely the right density of matter to be flat. How precise? Well, a single extra atom in each Earth-sized volume would have tipped it way off balance long ago.

How came the universe to be so close to flat? Something must have made it flat way back. For anyone who's after the beginning this could be a clue.