THE HORIZON PROBLEM

The impossibility of the causal communication that would be required for thermalization, in the standard model, is referred to as the *horizon problem.*

Roger Penrose (2004)

The problem arises when we try to explain how the universe became so uniform.

Brian Greene (2004)

Today the coffee's barely brewed when he shows up. Is his behavior changing? It throws me off my pace. The problem of the day or maybe week looks difficult because it is conceptual. Carroll calls it 'the most insistent and perplexing issue' in Big Bang cosmology. Right away he sits down with his mug. I'm not ready so I take him to the Big Flash picture once again. On Wikipedia I get the hi-res image. Sounding like a hypnotist, I say: This is the infant universe; it's very hot. About 3,000°C, 5,000°F, it's like the surface of the Sun. It is soon after atoms form so there is nothing bigger than a single atom anywhere.

The picture shows the remnant radiation of the CMB. At first glance it shows no surprises. It shows large-scale structure in the early universe. It has hotter, denser zones and colder, less dense zones. But there is a stunning message coded in the colors. The difference between the red and blue, between the coldest and the hottest places in the universe, is no more than ten parts in a million, or 0.0001%. If 3,000°C is average, the hot spot is 3,000.02°C and the coldest is 2,999.98°C when the Big Flash flashes. GR says this happens less than 400,000 years after the universe began.

As he now knows, the colors are synthetic. They magnify small differences. The Big Flash light has long since cooled. Like a switched-off light bulb it's still radiating but its color is below the range of human vision.

So, I say as he slurps not-hot coffee not quite hanging on my every word, here is the clue: The picture shows that temperatures in the early universe are far too uniform. The technical description is: Close to *Thermal Equilibrium*. This condition happens in small systems over time. But in the early universe it is impossible! Vilenkin says it's like getting a message 'Elvis lives' from all these places that have never spoken to each other. I wait for his reaction. A detective is supposed to get excited when anything impossible appears upon the scene. When he doesn't bite I give him a comparison from close to home. The human body has a heat control. It *actively* maintains an even temperature of 37°C. Nonetheless it often varies a de-

gree or so between adjacent freckles.

So how does heat spread out so uniformly through the universe? That it *is* spread out is certain. The data in the picture can't be doubted. For four decades better pictures using different equipment say the same.

The easy question is: Was it that way from the beginning? Two things say the answer's no. If it was uniform from the beginning how did it get to be a bit *non*-uniform, as the Big Flash picture says in a few hundred thousand years it is? And GR says the universe was very small in its first instants. Quantum theory says that random fluctuations in those instants would have made it far from uniform. One thing most everyone agrees on is that quantum theory governed in the very early universe.

So I say: Let's just treat the picture as best evidence. What does it say? Well, it says the temperature is almost uniform after four hundred thousand years. But looking east and looking west—or any two directions—we see two places that are as far from us as light can travel since the Big Bang. So each must be beyond the other one's horizon, using that term in its cosmologic sense. This is the Horizon Problem: How could Thermal Equilibrium have spread throughout the universe far faster than the speed of light? Looking at the universe as far as we can see, we find a contradiction. This is a deep and fundamental problem. Physics says it can't be so. Is there something wrong with physics?

Of course this would be *pas probléme* if we could just shrug off GR. Maybe we could say it doesn't work in the conditions at that time. But there is reason to believe it *does* work. The conditions in the picture are conditions that GR assumes: The universe is much the same in all directions. And GR predicts production of light elements just minutes after the beginning. It says, since then they shouldn't change. Measurements confirm GR's predictions. It is too successful to discard. Today it is *the* model of the universe. The Big Flash picture leaves cosmology (and maybe physics) in a mess. So physics finds a fix . . . of sorts.

The fix is: Something happened on the way to the Big Flash, a mathematical device that makes the universe expand right after it begins. This device is called *Inflation*.

This stuff is standard fare in tragic plays two thousand years ago. Having tangled players in a web that mortal powers can't resolve, the play brings in a godlike creature. It's the *deus ex machina*; it descends from stage machinery to sort the tangle. Today its namesake is an unlikely contrivance that provides an unexpected answer to a messy problem. Physicists' four-letter word for this is: Ugly.

Flatfoot doesn't care. He's not changing his behavior; he is leaving early.

"Why *does* de Sitter keep his particule?"

It sounds like someone! But there's no one in the room. It's a silly question for

me to imagine; its insinuation's true but totally obscure. Willem de Sitter *should* be Sitter when his Willem is left off. Keep the 'de' if the last name's a single syllable; that is the rule. De Gaulle thus keeps his particule. I shake my head to clear it of distraction. Inflation? Would my fictional detective be impressed? Once more I read Penrose to confirm *he* doesn't buy it. I like this because I don't buy it too.

On the street the acid in the air is bad today but I'm distracted. I think about the difference that fiction makes. It's paradoxical: If Frank would turn his mind to it I bet he'd buy the fiction of Inflation. But a fictional detective would fixate upon the Big Flash fact. To me it's like Inflation generates a whole new problem: *Why* would the universe inflate? When I get home I'll add it to my Problem list.

Without Inflation the horizon is a problem. It's a problem he can see with his own eyes. Inflation is a way to hide this problem with a bigger problem. Like all good clues it is impossible. The more I think of it the crazier it gets.