MAKING SPACE

It is indeed an exacting requirement to have to ascribe physical reality to space in general, and especially to empty space.

Albert Einstein (1920)

Although there have been suggestions that spacetime may have a discrete structure, I see no reason to abandon the continuum theories that have been so successful.

Stephen Hawking (1996)

What we really want is some principle that tells us why the organization of the Universe changes in the way that it does: why it now expands so uniformly and isotropically.

John Barrow (2007)

The fact that every cubic metre of space is filled with dark energy in amounts that are incredibly tiny, and yet not quite zero, is a profound puzzle about the nature of the vacuum, the 'cost' of free space.

Frank Close (2009)

Early traffic rumbles eastward on the I-10 as I step out facing westward in the pre-dawn air. The sound waves run right through me and then flee across the sea. It's at this very moment that, left in their wake as if discarded, insight comes to me. I should have seen it right away. I mean, space is expanding, so its volume grows. But the volume of each Fleck is fixed. New Flecks are flicking into being even as I think this. No surprise. But more and more of them? A big Fleck factory is growing somewhere. Question is, then: Where? Which is to say: What is it? And as I ask I see this answer's easy too. It's uniform expansion, so many growing factories are operating far and wide; maybe more factories are manufacturing more space.

A worry gnaws at me while I wait for the train. With Flatfoot Frank I was the teacher. Now it seems that I'm the pupil. Like that law professor in *The Paper Chase*, he asks me questions in that way that says he knows the answer.

Actually, the question he left dangling shouldn't even *be* a question. After all, our problem with this wasn't what was *making* space, it was what made it stop. Our answer was that Fizzion fizzles out, runs out of gas. Its gas is mass crammed into Flecks, fat Flecks, so I imagined, though of course they can't be really.

What did he say when I wanted to pursue the question? Wait? Why wait? For what? I bet he doesn't know the answer. Rad to get the jump on him. So what do I know? Well, in the Beginning it seems simple: Fat Flecks making space get

skinny. Space expansion should slow down. But now it is accelerating. Carroll says, 'We still require an explanation for why the acceleration began recently.' Carroll is a fan of Humpty Dumpty; *recently* means six or seven billion years ago. Can Frank's Flecks provide an explanation? I am swimming in a mental rip till I recall Paul Keating, who's an Ozzie politician truly gifted at inventing insults, flinging at a disappointed candidate for party leader, 'A soufflé doesn't rise twice.' It's a glass-house stone from one who took two tries himself but it's a useful thought about the universe. You wouldn't think a universe would have a second go. Not after a few billion years of slowing down. And, too, the standard story seems so messy: Some beginning, then Inflation, Big Bang, long expansion slows down, then accelerates again. Are there really all these stages in the universe's story? Why does each one stop; how does the next one start? All of this stop-and-starting must arise from the Beginning. Wouldn't it be simpler if fat Flecks were still Fleck factories? But the question then is: Why would they fire up again six billion years ago?

So I try it on, like jumping through the hoops with no ringmaster. Each Fleck gets a chance to Fizzion every Move. But fatter Flecks get better chances. Their mass-energy gets divvied up and spread around. Soon the universe has fewer fat Flecks. So expansion must slow down.

I bear down on it as I imagine he does. Space expands. It has a way to do this: Fizzion. Just because the Flecks get leaner doesn't mean it has to stop. What if it *didn't* stop? And suddenly it hits me: His version of Inflation is still going on! It slowed down, then started speeding up. It got more gas back in its tank. And with that thought the rest is obvious. Where would one look to find fat Flecks these days? In big black holes, that's where! I see it: Each black hole eats matter and it churns out space. Its gravity sucks mass that fattens Flecks; the fat Flecks Fizzion, churning space back out.

This explains why the expansion is accelerating. And why he doesn't know—I read it long ago. The early cosmos *has* no big black holes. It is a dark, thin, slightly-lumpy soup of mostly hydrogen. It stays dark for a hundred million years or so while gravity makes the lumps thicker. Some of them form stars and one by one their lights go on. But for the next few billion years there will be few black holes. Lots of really big black holes—known as supermassive—come much later. Astronomers are working on the story. Black holes grow with galaxies when almost-light-speed shockwaves sweep gas from vast volumes when the first stars self-destruct. There you have it, Dr. Carroll. As required, an explanation: Big black holes are giving this soufflé a second rise. It's like a teenage growth spurt. And I think it means that black holes are Dark Matter. Easy peasy lemon squeezy. But by now their buffet's been picked over. The expansion will slow down again.

He mumbles something incoherent. I go over what I've found. He seems to pick up what I'm thinking. I can tell that he's excited that so much might be explained without the need to add a single extra Rule. It is simplicity in spades.

"Do you see what this means?" His first clear words today.

What does he mean by do I see it? It means that there were new black-hole space factories a few billion years ago, that's what it means.

"What does it do to the black holes?"

I hadn't thought of that. One thing's for sure: It springs a bigger leak in them than Hawking and his radiation can.

"Is tunneling linear with energy?"

Sometimes he throws non sequiturs as fast as I can catch them. He seems to think they are sequiturs, if that's a word that stands alone. I recall that QM tunneling is linear for low volts and goes with the square of higher volts, where 'higher' means an AA battery or two. It's likely not on the same planet as a fat Fleck in a big black hole.

"So what if it goes with the square?"

Well it can't really, now I think about it. When the odds of Fizzioning are one, they have nowhere to go but down. He starts with certainty. Flecks Fizzion every Move until the odds come down.

"What happens to the matter?"

It divides between the daughter Flecks of course. We went through this with the Beginning.

"But what is different now?"

Well, there's a lot that's different. Space. And gravity. And so the daughter matter gets dragged back into the hole. Whatever that is.

"So what *does* it do to the black holes?"

I thought I ducked that question but he won't let go. It empties them, I think, and empties big ones faster. Maybe that would put a lid on big black holes. There would be fewer really big ones than there would be if their size was random. That would solve the Problem of the Missing Holes. I pull up my list and add a check. It's the Fiorina answer: Up-and-coming big black holes, the power brokers of the cosmos, bump into their own invisible glass ceilings!

"So do you see what this means?"

It seems I still don't see what *he* means.

"What does it mean to us?"

To us? The size of black holes? It means nothing.

"Will one Fleck make enough?"

Enough of what? What does that have to do with size? And once again I realize he has a point. If it's not packed into a point, is a black hole's mass packed into

a Fleck? Can a one-Fleck-sized black hole make enough space? My first thought is: How would I know? But my second is: Maybe I could.

The number known as Hubble's constant is a measure of how fast space is expanding. It is measured in odd units—kilometers per second per Megaparsec. It's much easier to grasp as the percentage increase of intergalactic distances: 2.5×10^{-16} percent per second or nearly one percent per hundred million years. I use Excel to do a calculation. With one black hole per galaxy and average distance between galaxies of . . . how many Flecks must Fizzion every Tock to make the extra space? On my screen the answer, 10^{123} fat Flecks, stares back accusingly.

But then, I think, what does this tell us? We already know black holes aren't bottomless; the notion that they are must disappear along with zero size. Given that they have a bottom, it makes sense that mass in a black hole, like water in a well, will rise inside its wall. The question is: How high? A real answer needs new theory. But, what the heck, I think, it's worth a simple-minded try. The simple-minded question is: How big is that? The simple-minded way to answer is to multiply that many Flecks by the Fleck volume. It's about a kilometer cube. I wonder, could it be? A kind of super neutron star inside a black hole? There is lots of room. Even small big black holes are kilometers across.

The stock dismissal is: If one can't disprove a theory then it isn't real. So, is there a way to measure where the mass is at the bottom of a black hole? Not that I can see. The mass, though, can be measured. Astronomers are finding new ways to weigh big black holes. If they weigh lots of them they may find out if the biggest ones are missing.

Anyway, I realize, making space makes sense of the Coincidence Problem. Which, recasting Carroll's into Frank's terms, is: Why are we here just as the mass of matter becomes roughly equal to the mass of space? Well, we and all we see are mostly made of waste. It took two generations of star making and destruction to make enough of that. By that time black-hole factories had made a lot of matter into space, a coincidence that has a reason so it gets a check.

"Will you write it?"

Once again he puts his finger on the question. It's the book. I've had it more than half in mind. And I've got lots of notes. I think she thinks that they are hers. And *she* is not about to write it, I am clear on that.

"You'll do it."

Sometimes he can see my thoughts before I think them. How I'll do it I don't know. But I know now that I'm about to try.

"Do you imagine the Establishment will greet it with glad cries?"

The way he says this brings to mind abruptly how she once said this same word. The way *he* says it sounds sarcastic and I think of Gregersen, who wrote the

book on innovation, saying experts tend to resist new ideas.

"Do you think that I will stick around?"

It gives me a jolt of almost-panic. How can he leave now? And *how* can he leave anyway? It's not as though he has a place to go.

"They'll fricassee your testicles for breakfast."

Dan Brown, I think, while realizing that his 'they' means physicists. Is that who he's afraid of? Physicists?

"Where does this leave general relativity?"

A non sequitur again. Or am I missing something? For a long time Einstein doesn't think of space as something real. But when he adds antigravity to his GR equation for the universe he bites this bullet. Ah! Is this what he is asking, where he's heading? The GR solution is a war of forces—gravity and antigravity, they pull and push. The Beginning's different. It says antigravity is not a force. It's space. It doesn't need to push, it simply is. In time there's more. By contrast Einstein's cosmos teeters on a brink between collapsing and expanding without limit; it's incomprehensible why it is taking so long making up its mind. This is the Flatness Problem and Inflation is supposed to solve it but just eases it a little down the road. Well, the Big Fizz solves it right from the Beginning. It says space just growed. It doesn't deviate, not by a Fleck, from its inexorable growing. Viewed through GR glass, it emulates a perfect balance. I pull up my list again and add a check.

In reality there is no balance, just a term in an equation that is not quite right. So why does Einstein blunder to and fro? The reason is, he never thinks of space the way it is, as made of Flecks possessing volume, since he has no reason to see space this way. His universe is a solution of equations for another space. What is the solution for a universe where mass turns *into* space? This might make a thesis topic for someone someday.

But now I see his question's not about the cosmos, it's about GR itself. Would he say that it needs to come in from the cold—a chip off le Carré, if he has heard of him? Or maybe not. I still don't know how mass can pack in Flecks.

Two more things worry me: His saying Einstein's wrong is tilting at a mighty windmill; and then does he really mean to say that he might disappear?

"Space is tougher stuff than we imagined."

This I take to be his way of saying that my worries are my own.