A QUANTUM FOR GRAVITY

The reconciliation of gravitation and quantization is still one of the most intractable problems in contemporary theoretical physics.

John Stachel (1986)

To Einstein, terms like 'the gravitational field', 'the structure of space-time', and 'the ether' were all synonymous.

Basil Hiley (1991)

Philosophers must take what physicists say about quantum gravity with a grain of salt.

John Baez (2001)

The search for quantum gravity is a true quest.

Lee Smolin (2006)

Particle physicists tell us that there are five forces…. But is gravity a force like the others? *Is it a force at all?*

Dennis Lehmkuhl (2008)

The key difficulty of quantum gravity may therefore be to find a way to understand the physical world in the absence of the familiar stage of space and time.

Carlo Rovelli (2009)

Simply put, we do not know what a quantum spacetime means.

Steven Carlip (2012)

It's a cooler day—well, not so hot and muggy—with no sign of her again. This brings some measure of relief from practicing dissimulation. Nothing's easy for me when she is around. But even when she's not she can and does walk in at any time. I can't tell her about my Frank. She'd think I'm crazy. And whatever she might do about it I am sure it wouldn't be my book.

"There is more to do."

He sounds bright and chirpy like he often seems to when I'm not.

I'm thinking of her secret scam, whatever it may be. Then for no reason I remember Poe, lying dying in a gutter, maybe rabies, it is said. My thoughts roam over others who set out to wrestle a beginning out of nowhere into view, Lemaître of course among them. It's incredible that Frank could suss out the Beginning when so many experts failed.

"They knew too much."

It comes out brutal like a line from *The Sopranos*, as if knowledge made them an unnecessary risk. Or maybe—I'm aware my mind meanders—he is thinking of the twice-shot Hitchcock film.

I ponder what he really means. They couldn't see the forest for the trees? Perhaps that could be part of it. But somehow I don't think it was the most of it. Why do I think of Frost:

> He thought he kept the universe alone;
> For all the answer he could wake
> Was but the mocking echo of his own

But I digress. Or maybe not. It seems to me that it was more about them seeing so much of what are not even the right trees. Most all of physics (and philosophy) has been devised by people pondering the *stuff* that they can *see*; the nothingness between that stuff becomes defined by lack of it. They bear two burdens. Stuff they think about in marvelous detail turns out to be a modicum of what is actually there. And vacuum that they think about as being there turns out to not be there at all. Entire books and countless papers written on an empty subject matter about which they surely knew too much.

There's irony in vacuum being non-existent. Philosophers—from Parmenides who says Nature will not tolerate a vacuum to Descartes who builds a reputation out of repetition—wrestle mightily with nothing. Descartes is the *cogito-ergo-sum*, I-think-therefore-I-am guy. But *vacuo ergo non* might have become him better. For philosophy and physics nothing is a detour to distraction. Parmenides was righter than he knew. Frank says nothing *is* impossible. By which he doesn't mean what those words usually mean. He means what I mean when I say there *is* no nothing. There is always something, even if it's only space. *Only* space? What am I saying? Space is *only* seven tenths of all there is. By mass fraction, that is. And by volume it's ten out of ten.

So Frank has even more advantages. He starts out knowing that the stuff we see is but a twentieth of what exists; this keeps his eye on the main chance. And too, he never gets caught up in nothing.

I can guess what more he thinks there is to do. Rovelli says, 'Quantum gravity is therefore the study of the structure of spacetime at the quantum scale.' Well, Spacetime at the quantum scale is right before him. Rovelli also says, 'The search for a quantum theory of gravity raises once more old questions such as: What is space? What is time? What is the meaning of "moving"?' These are the very questions he's been asking and he finds that the Beginning brings him answers. Rovelli goes on, 'I think it is fair to say that there isn't even a single complete and consistent *candidate* for a quantum theory of gravity.'

So there is more to do. For me it isn't about physics though. It's not about

my failure in philosophy. And it's not about her money; she's been gone a week and, putting two and two and two together, we won't see another check. Whatever. What it *is* about is less easy to say. Somehow once he spoke, her quest—what she *says* her quest is—became mine. And it isn't just the joy of writing. It is just the two of us and what Greene calls 'touching the true texture of reality.' So here I am. Here we are. Tying up loose ends.

The big loose end is quantum gravity. That pot of gold at the end of the universe's rainbow. Some smooth amalgam of GR and QM if you buy the pitch. What is it really? One can read a lot of books on it and still not know. I can't speak for him. He has his take on it. My bet's on Rovelli. QG will be quantum space. And that's his business.

Of course the real role of the fictional detective's not detecting; it is entertaining. It was Frankly Real's role to find how the universe began. What a laugh! And now to my amaze my *fictive* flic seems to have done just that. In a few hectic days he has glommed onto the Beginning and has tracked its metamorphosis to space and time. Now he is showing how this simple start-up makes sense of a raft of contradictions, some of which have puzzled thinkers for two thousand years. What a tale to tell! My money says she has no plan to tell it. Maybe I should take off with my notes and find another place. Would she try to stop me? Could she? I don't know and I would rather not find out. So back to work. In 1835, a syphilitic colonist, John Batman, steps from his canoe into a swamp beside the muddy Yarra next to what is now the heart of downtown Melbourne—the one in Oz, that is, a city of four million—and says, 'This will be the place for a village.' Famous first words—Gil Grand. In vein similar, Frank's saying the Beginning is the basis for a theory of quantum gravity.

"There are no points!"

Why is he going back to this? He should feel confident that his conclusion is on solid ground. This universe is pointless. Its space is made of Flecks and there is nothing smaller. The Beginning *is* a Fleck. It is entire. Even physicists who slice and dice it with imagined numbers will, if pressed, agree. And, once entire, always entire. As space and time unfold Flecks multiply, but no Fleck is divisible. This is a fine but elementary distinction: One Fleck begets two Flecks but it cannot be two half Flecks. Nothing smaller means no size-less points.

"So now," he says, so far as I can tell still thinking of the non-existent points, "how can we check?"

I think the place to look for one might be the bottom of a big black hole. Well, it might be the place to look if he had any chance of looking. Of course that's something nobody can do.

"Penrose showed how one can look."

Well, yes, it's true. He and Hawking looked into their heads instead. But Frank's no Penrose, nor is my head Hawking's.

"Let's look anyway."

Sometimes he knows exactly what I'm thinking.

"So write."

When Penrose and Hawking go to work on them, black holes are barely hypothetical. They are still theoretical today since nobody has ever seen one. Nobody ever will see one and send news back to us. But their effects are visible and even from afar they are bizarre. Big black holes engender violent events that show them up, like stars that whip around in orbits that reveal they're in the clutches of a compact but colossal central mass. The speed of anything in orbit depends only on the mass it's orbiting. Such observations lead to wide consensus that black holes exist.

It seems certain there's a black hole at the center of the Milky Way. Maybe it's the definition of a galaxy, a big black hole like pharaoh with adjacent masses—dust and gases, stars, Dark Matter—orbiting as captive minions. 'Big' here means a hole that holds the mass of maybe billions of stars. Is all that mass compressed to Fleck size? His Beginning seems to say even a single particle cannot be smaller than a Fleck. There's something in this picture I don't get. But then no place is more remote from personal experience than is the center of a big black hole. With math and wheelchair and voice synthesizer Hawking blazes an amazing trail through this abyss. Can the Beginning give Frank his own look at the most bizarre place there is? My doubts aside, all he would have to do is *think* his way into the bottom Fleck.

"Create a black hole," he says offhandedly as if he is not following my thoughts.

I try it in steps. Start with space as we now know it: Flecks close-packed like froth.

"Put a *Pooharticle* in one of them," he says.

I gather it's a Something he's inventing for the purpose and he's giving it a silly name. I get it. It's a particle that thinks.

"It's modeled on a bear of little brain."

A quick check tells me he's not kidding. How does he know something that I don't know?

"Bear with me and you will see."

His stress on the first word says the bad pun is intended.

"It is in a particular Fleck."

So he has a sense of humor. But he's serious.

"Next Move it's in a next-door Fleck. How does the Pooharticle know that it

moved?"

He asks this in an odd triumphant way as if he thinks he's proving something but I don't know what to think.

"It can't."

Maybe I'm being dense.

"There *is* no way that it can tell."

I guess this must be right. It's in a Fleck before the Move; and now it's in a Fleck. One looks exactly like another. But I'm still not sure where we are going.

"Put a new Pooharticle in the same Fleck. Then, after the next Move, they find they're in adjacent Flecks. How do they know who moved?"

I think I get it now. One must have moved. They can't tell which. Maybe they *both* moved. When he next speaks he sounds pleased.

"Now gravity. Suppose that each Pooharticle has mass like an electron's but no charge."

I don't think there is such a thing but then there's no Pooharticle so I just let it go.

"Do they attract each other?"

Well, I suppose they must. Fortunately, before I can think so, he answers himself.

"Not unless each has curved the space around itself."

Again the note of triumph in his voice.

"But what does *that* mean?"

And again he's lost me.

"The volume of a Fleck can't change and so the only way for space to curve is that its Flecks squish out of shape."

Whatever that means. And I *still* can't see where he is going.

"Squished means skinny, so the only way for a Pooharticle to create gravity is for the Fleck it's in to get an extra neighbor. Look, I'll show you." And he tries to make a picture in my head.

It doesn't work, but now I get it. I don't tell him shape is meaningless for Flecks because he's right: There's a difference between a Fleck with four Windows and one with five. I check it on the Web. In a foam or froth or crystal or an aggregate like sand it's called coordination number. I think he's thinking of it as a quantum thing.

"And," he goes on while I'm checking, "vice versa."

I flash an image of an extra Fleck squished in between.

"Now, *here* is gravity. It's all in rolling cosmic dice. There are more Flecks in the skinnier direction. So the odds are better for Pooharticles to Move that way."

There is no doubt about the triumph now. He's giving off vibrations.

"So do you see it?"

I *do* now and I try to tell him that I do.

"You don't!" He laughs.

The second time in days he's laughed at me.

"You *don't* get it. The Pooharticles don't have the mass to do that. They can't squish a next-door Fleck, not all the time. Their gravity's just not that strong."

Now I'm deflated. At a loss. I think he's wrong. Somewhere someone said, at Planck scale, gravity is strong. He is oblivious.

"No. Don't you see? It's *quantum* gravity." In elation his voice almost shrieks the quantum. "Any given Move, either a Pooharticle's Fleck has an extra neighbor or it doesn't."

And now I think I do see. It is quantum gravity. Well, more precisely it's a quantum *for* gravity. And it's simple. It's a Tock-long increase in the Fleck-connectedness of space. It's so simple it seems unbelievable. Actually, it's so simple it just may be real. It's like what Lehmkuhl calls the egalitarian interpretation of GR. When you get right down to it, as in the Beginning, gravity *is* the geometry of space played out in time.

"So now," he says, now sober-sounding, "it's all in absolute space, right?"

Yes, we've had that discussion already.

"But look at it through the Pooharticle's eyes. What does it see?"

I didn't know it had eyes but I try not to think of this. I try to think of something useful. Nothing comes.

He fills the mental silence. "It sees nothing."

I feel foolish and half clever and, still thinking nothing, think maybe I got it right.

"Nothing to see. It's in a Fleck like any other Fleck."

For no clear reason, I think *déjà vu* all over again. Yogi Berra.

"But say a fat Pooharticle is sitting in a nearby Fleck and *does* create a lot of gravity?"

At last a question I can answer. It would see an extra Fleck in that direction. A skinny Fleck. Or maybe two.

"Not quite," he says, "but close. It might see an *extra* Window."

Of course. It can't see into another Fleck. It only knows the Windows in its own. Maybe it might see more extras near the bottom of a big black hole. Slowly the whole notion comes together: A Fleck's quantum number is its Windows count—its coordination number. *That's* quantum gravity.

I sort of see it and I want to burst out that I see it now but if I do maybe he'll say again I don't and so I squelch it.

"So Einstein was right."

It takes a moment to connect, but yes, his view of gravity and space was right, *is* right. Space and gravity are the same thing.

"Think of a big empty space."

I close my eyes and think myself into the middle of a billion-light-year void between galactic superclusters.

"Add two neutrons one ångstrom apart."

That's a ten-billionth of a meter—smaller than a single atom. I'm not sure how to imagine neutrons but I try.

"How much pull does gravity of one have on the other?"

Well of course I don't know, but the Web has all the answers. I am looking at a page and trying to remember what a Newton is when he asks me:

"How long will it take them to reach each other?"

For this I need yet another calculator. And the answer, it turns out, is half an hour. That's five times longer than it takes to work it out.

"Now separate them by a millimeter."

He means gravity will take a longer time to bring them back together. But I'm startled by how *much* longer: Two million years!

"Now set one here and plant the other in the Metro station."

That's a mile or more apart. Call it two kilometers. He means in empty space. The answer is . . . they'd take some six quadrillion years—four hundred thousand times the time since the Beginning. Like forever.

"What's the quantum theory picture?"

QM says the Wave Function of each neutron extends instantly all the way to the other. But QM can't do gravity.

"And general relativity?"

GR says each neutron curves space to and from the station and so each is rolling down the other's curved-space hill. But *very* slowly.

"So what's really going on inside the station?"

I try to think of how the mass of my neutron must make an extra Window sometimes so there is an extra Fleck next to it—for some Moves. And that extra Fleck would sometimes do something to the Flecks next to it and so ad infinitum. Well not quite *infinitum*. But eventually all the way across the universe, with the disturbance spreading one Fleck per Tock at the speed of light.

"Right."

It's silly. I get this warm feeling from his cold approval. He is flimsy fiction but in this moment he's more real than the room. So I press on.

It won't take long for the disturbance to spread to the Metro station neutron. Simple calculation shows six microseconds. But, I think, it's Moves that matter. I convert it. More than 10^{38} Moves before the Metro neutron could know that the

other one is out there. If you call that 'knowing.' Will its Windows rattle as the wave goes by? Like floating mid-Pacific, watching the tsunami from the impact of a surfer hitting Kawailoa water. Its wave's submicroscopic but it's spreading at the speed of sound. Does it move a molecule nearby?

It's less than that, I realize. The answer to my molecule is yes; the ocean's movement's much too small to measure, yet it must exist. But the Windows of the Flecks next to the Metro neutron will not blink, not for perhaps some years, and then for maybe only one Move, after which they'll face another wait. And so I see it now; I understand where he's been leading. QM and GR explain the reach of gravity by fantasizing that each mass makes something happen all the time—QM instantly in the whole universe, GR inside a light-speed-spreading circle. The something is absurdly tiny to explain the feeble force. Each has its something; neither one is real.

The real something—tiny it is true but not absurdly—flickers like Will-o'-the-wisp. It happens here, it happens there, it never happens everywhere; it doesn't happen often, and it doesn't stay for long. Seen at Fleck scale, gravity has got no Problems. No wonder it is feeble. A mind-numbing numbering of far-flung nearly-nothings add up to an inexorable tendency, a drift that is consistent with the world we see. And so a check.

"And so the moral is . . . ?"

He is provoking me yet foolishly I still feel I should hang my head. I don't know what he has in mind and so I do.

I'm trying to digest it. And, a bit slow maybe, I suppose I see. Space may be absolute. No, it *is* absolute. But to a particle, a measurement, it's relative. That's the point of his ridiculous Pooharticles. They don't see space, they don't even see the Flecks next door; they only see the Windows in their Fleck. They know nothing of their neighbors but their number. They know nothing about where they are and after each Move they don't know if they have moved. Why? Because there *is* no way to know. It's absolute space but it has no labels and no signposts; it only has relationships and when the UC rolls the dice each Move they change. A particle that wins the movement lottery pops through a Window with each Window having the same chance. Up close it looks like Windows doing all the work. It also looks like chaos.

But there's order that emerges from the chaos. The chaos has no metric. It is digital. The order has a metric. It's statistical. The trick to it is that we only see the order. We track its patterns and we think we see what's going on. So we make up a story to explain it. And—surprise!—we find we've got it wrong. Is this what Herbert has in mind when he says, 'Looked at one way, the universe is Brownian movement, nothing predictable at the elemental level.'?

The universe is messier than physics has imagined. Yet it's also simpler. Like money, matter follows the connections. Out of this my Frank is saying gravity is born. A new thought shakes me. Gravity is not a force! No wonder it's a stubborn holdout facing down that five-force merger. Galileo, Newton and unnumbered others assume gravity's a force. Then Einstein shows it is the other face of space, not quite a force. Yet he doesn't see it as emergent; doesn't say it's not a force; and—strangely—tries to unify it with the other forces.

Even stranger, it is Einstein who shows how a property can be emergent—that property is pressure. It's 1905 and most physicists are from Missouri when it comes to atoms. At this point atoms have been science fiction for two thousand years. In April Einstein finishes his thesis. It's all about a way to calculate how big—or small—a molecule of, say, sugar is in water. In May he publishes a paper on how atoms in a liquid jiggle particles of pollen. Pollen jiggles can be seen under a microscope. Physicists can now observe not atoms but *effects* of atoms. Soon the atom is the highlight of the physics fashion show. The pressure of a gas is caused by atoms we can't see that bump into some thing—a bike tire maybe—that we can. Pressure, physics says, is an *emergent* property. Emergent means no atom *has* the property of pressure. Each atom does its random atom thing. Thus pressure is a property that physicists invent to label something they can measure but, because they are so big and atoms are so small, they can't explain. It's obvious when looked at from the atom's point of view: Pressure as a property emerges at the scale of physicists from the way that atoms, by their nature, must behave.

So now it's up to me to say how Frank sees space emerge from Fleck scale, which he cannot see, as physicists could then not see the atom. Nowadays Missouri is a more sophisticated state so 'show me' doesn't need a microscope. As a detective should, he gathers all the evidence and weighs it as a whole. He says that gravity's a property that physicists invent to label something they can measure but, because they are so big and Flecks so small, they can't explain. Explaining it seems easy when he sees it from the UC's point of view. Gravity emerges at the scale of physicists from the way he knows space quanta, by their nature, must behave.

Society emerges at the scale of peoples from the way that people, by their very nature, must behave.

And in this moment, as this thought occurs to me, I know that I will try to stop whatever she is up to. What exactly will I do? That thought can wait.

As space emerges so does gravity and vice versa. Overlooking atom-distances—vast vistas in the Fleckish landscape—Flecks become invisible and space looks smooth. A physicist can measure distance to a fraction of an ångstrom—a ten-billionth of a meter—rather smaller than an atom. Light moves

this far in a trillion trillion Tocks. Its particle—a photon—moves erratically, Fleck by Fleck and Tock by Tock, and nothing anchors Flecks themselves in place. I can think about the path of any particle—it actually has one—but to *specify* its path needs points of reference that I don't have. Bohr would insist its path does not exist. Frank says only that no one can measure where it went.

Bohr's sense that all is senseless at atomic scale makes sense at the far smaller scale where all the action is. New concepts and new stories at new scales should come as no surprise. This is what happens after Bohr explores the atom. Now Markopoulou, comparing Planckish micro-scale with what becomes the sub-atomic *macro*-scale, says that it is 'unlikely that micro and macrolocality will coincide.' My guy can follow the path of a particle; he sees its herky jerks. He can pull back to a Bohr's-eye view and watch it cross an atom width, its deviation from smooth movement maybe one part in a trillion. That's a deviation no one can detect. Even at the smallest scales that anyone will ever measure, Fleck jerks are subliminal. There will never be a pollen demonstration here. But he says that, as Einstein guessed, its motion's not continuous, it's digital.

So space has structure physics can't examine. For physicists its isolation from examination tends to mean it isn't really there. But they can tell it's there because it is the key to its statistical expression. Statistical is all they'll ever get to see. Physics needs a theory of what's behind their sub-atomic structures, a theory that predicts statistical expressions, a theory that enables them to test it.

"Pauli would dismiss this as naive visualization."

Did my thinking or my writing bring him out to strike this sour note? His point about Pauli may be well taken; he'd dismiss it. He'd be right. It needs new math.

There's no elation in response to this concession. Instead I feel him shrink back like a disappointed conger in its coral hole.

I slide into a troubled contemplation. GR says that matter dances a gavotte with space and time in combination. Each set of dancers, one might say, informs the other as the mind evokes emotion while emotion strokes the mind. Now he's at the Fleck scale, can he really climb back to the scale that GR sees? Markopoulou says, 'Taking the idea that General Relativity is an effective theory seriously involves rethinking physics without spacetime.' By 'effective theory' she's not saying that it works. She means GR is about effects, not causes. By 're-thinking physics' she's implying GR should emerge from physics that is truly background-free. Could it emerge from his Beginning? Like she says, that needs new physics.

I'm exhausted, sweaty, limp as the proverbial, but can't stop thinking. I know that much is missing from the naive picture he has seen. What bothers me most

is what bothered Mach. Mass moving—aka inertia. Is it, too, emergent? At Fleck level can there be momentum? Could it have only a tendency to be conserved?

My fog thins. I suddenly see further. After each Move nothing moves. What I mean is, until next Move, everything just *is*. Information about what keeps on moving must be frozen in that 3-D state. It's like the universe at any instant is a 3-D hologram encoding 4-D information. How does it survive the dice? How does one's mind subsist—how do I stay this person and yet learn—amid a blizzard of a thousand trillion synapse blips per second? Surely it subsists because the blizzard *is* the mind.

The elevator is on service and the stairwell light's not working so I stumble down the stairs. My thoughts keep going with their own momentum. Mach is right, if Einstein is with what he says Mach said: The universe provides the Frame of Reference for inertia. He gets a check for that. Likewise for rotation. What Mach couldn't know for sure, and nor could Einstein, is its mass is mostly space. But even as I think of this he takes a different tack.

"Where does this new space come from?"

His tone is unfriendly and demanding.