THE NEW DIVIDE

We seem to be making for a real clash between the relativity and the quantum concepts.

General Jan Smuts (1931)

No one has been able to construct a theory which is completely satisfactory as a unification of quantum mechanics and relativity. It is still not even clear whether this can be accomplished without a radical change in the basic principles of either, or both, theories.

Lee Smolin (1997)

General relativity and quantum mechanics appear to be fully inconsistent with one another.

Carlo Rovelli (1997)

[General relativity] recognizes that spacetime is curved but neglects the uncertainty principle, while [quantum mechanics] takes the uncertainty principle into account but pretends that spacetime is flat. Both theories have been spectacularly successful in their own domain, but neither can be anything more than an approximation to the truth.

John Baez (2001)

She walks in near noon. After a few inconsequential words about the weather and the furniture she holds out her hand.

By the way, call me Birgit Kapelhoff, she says, looking straight at me.

She spells it out and has me write it down. I need it for her cards. Her title, she says, should be principal. Everything, she says again, to be in lower case.

It is an awkward moment. It's not just that of course she is tacitly acknowledging she didn't give me her name in that interview at her hotel suite a few weeks ago. It's more the feeling that her manner gives me, an odd feeling that it's *not* her name.

As it happens Kapelhoff's a name I know. It's what is known as a location name; it means church square. It's an uncommon name. The way she spells it is now little used. How do I know? Well, I recall it as the name that Doris Day was born with. Way back when, I was a fan. Her real name *is* Doris von Kapelhoff and it is really rare, or so I think the cognoscenti said. As she likes to say and I like to do I do as soon as she is gone: I check it out. Just for a change I swing with Bing. Bing goes bingo!—my recollection checks.

Why would she lie about her name? It leaves me with second thoughts

about this work. I haven't given it a lot of worry up to now. In most respects it looks like easy street. But maybe it's too easy. As the saying goes, if it *seems* to be too good to be true…. My spidey sense is all atingle. It's warning that this may be Barney Rubble. It fails the sniff test—nothing I can quite pin down. What to do? My best bet is: Take to the beach again before I find I'm in a jam. But on the other hand my motto's always been what I don't know can't hurt me so the easy way would be to let it slide. I've always had a soft spot for the easy way. And it's not just the money. Something about this work has got me on the hook. It's like self-study on the Net; if what I read were less confusing I'd be having fun. And so I do, I let it slide.

And I too slide—into a chasm that splits physics to its roots. On the surface it seems simple: quantum theory versus relativity. Even before I figure out what they are it is clear that their divergence isn't simple. It infiltrates the fabric, ideas, structure, mathematics, practice, teaching, organization, politics and financing of fundamental physics. In a vague way I already knew about it. But nothing has prepared me for the depth, the breadth, the mind-bending bewilderment I find.

The two compete for money, students and prestige. Relativity takes an early lead it loses soon after the race begins. It runs for a hundred years. It is still running. God knows how I'll get this mess across to him.

Meanwhile he haunts the office. His work ethic's pretty ordinary, seems to me. He pretends to read. He paces. Mostly though he chatters up a storm. He makes it hard to concentrate. He tells a dirty joke or two. I gather I'm supposed to fake that this is fine. Maybe I could even like him someplace else. Or not. But certainly not here. My desk is piled with books and sundry paper stuff already. It's stacked to keep his fat butt off my desk without quite cutting off my freeway view.

So I sit him on his chair and say he needs to know the rift. He needs to follow how it comes to be. Which means I need to understand it too. Which means lots of digging, lots of physics, lots of history from lots of websites. There's lots of info out there. But teasing out its meaning turns out to be tough.

It begins in the early 1900s. For the first time physics enters realms that are outside our experience. One is far too large; the other is too small. Relativity is about space and time. It's tied up with the speed of light, far faster than the fastest rocket. Quantum mechanics is about the way things work—or seem to—at scales smaller than an atom. Einstein plays creative roles in both. Indeed Einstein more than any other drives the rift in physics. It persists to this day. Most people think his thing is relativity. But his Nobel is for his role in starting quantum theory.

It's soon clear that these two theories are at odds. They are two solitudes. When MacLennan uses these two words as the title of his book he speaks of cul-

tures—English and French. Rilke, speaking of relations between the sexes, calls them *zwei Einsamkeiten*. It's much the same idea; but *zweimalig* Rilke's better.

When next he sits I tell him that it seems a civil discourse on the surface, but he shouldn't be deceived. In a sense it is a battle to the bitter end. When the outcome is decided we may witness a reprise, a revolution no less sweeping than a century ago. Hoping he won't catch the catachresis, I say it will be an earthquake that will reshape physics. Once more, say the auguries and I, the world will change.

In his heyday Einstein comes up with two theories that define the field of relativity: special relativity in 1905; and general relativity a decade later. Both deal with how things move in space and time. Someday soon, I warn him, we will take a look at both. Meantime I'm doing lesson planning, surfing, sussing out who has the story right, who tells it well, and generally getting bearings of my own. He may as well stay home, I say. To my surprise he doesn't go.

SR deals with things moving steadily. It is spelled out in equations; real physics is invariably written up as math. It shows how measurements of time and space depend on how the one who does the measuring moves relative to what he measures. Einstein ties his new equations to the speed of light; they work even when things move very fast. It's out of these equations about space and time and motion that he pulls the emm-cee-squared one. There's no way that Frank will understand this. Surely she can see he doesn't have a clue. She still has, or says she has, this foolish notion—though she doesn't say it's foolish—that he can pull a cosmogonic rabbit from my 'research' hat.

What he needs to know is *this* equation isn't only an equation. It's an insight into how the world is made. It says that mass and energy are two forms of the same thing. Like, I plan to tell him, ice and steam. Though they don't look the same they are both water by another name. So how can I get this across? 'Mass-energy' might keep the SR concept in his face. Whatever term I use I doubt he'll get it. *GR's* next and GR gets much worse.

Einstein's passion drives him to it. GR too's about how objects and observers move through space. With GR they move any which way. Finding its equations takes him years of work. He's pursuing an idea to its logical conclusion: Laws of nature can't depend upon the dipsy-doodles of observers. So, as Eisenstaedt explains, Einstein sets off with 'an inspired imagination [to] reach some unknown and improbable land.' Eight years later he arrives. His great revelation is that gravity is *not* a pull exerted at a distance between bodies like the Earth and Moon. He shows that a mass like Earth affects the curvature of space. A second mass—such as the Moon or, say, a showman shooting from a circus cannon—just goes with the curve; it takes the shortest path that it can find. So does

the Sun. So does a galaxy. This path is called a geodesic. It may look curved depending on one's point of view. Headwinds and alternate landing strips aside, a flight from New York to Hong Kong will take the shortest path. It won't head west. It heads near-north to eastern Hudson Bay, the Arctic Ocean and Siberia. Its course makes a wide loop on almost any map. But seen from overhead this line looks straight. It's the line a piece of string makes on a globe when stretched from New York to Hong Kong.

Actually GR starts out being about motion but in the end it's about gravity. Not just the gravity all know and love—like astronauts soon sick if they're deprived. GR embraces gravity from faintest traces between galaxies to fiercest tempests in black holes. Newton treats gravity as action at a distance—a concept that he never likes. GR gets rid of his problem. It shows that gravity is *local*. This is a deep idea. What we like to think of as Earth's pull on, let's say, a four-seam fastball several feet above the ground is in fact the curve of space between the batter and the mound.

An equation is a way to ask a question. Solving the equation gives an answer. After Einstein comes up with GR's equations, he and others search for answerable questions. In the 1920s Friedmann finds an answer for a version of the universe. It ruins Einstein's day. It leads to rafts of problems. Though the best minds on the planet try to fix them they don't go away. So Einstein's fingerprints and Friedmann's are on many of the clues.

He'll find Einstein's prints on quantum theory too. Quantum theory's a loose term. Its meaning has evolved. It begins a hundred years ago as the idea of energy that comes in tiny pieces known as quanta. Quanta do strange things. One might say *QT* calculates the ways small things are strange.

Actually, having started small, these days QT applies at least in principle to things of almost any size. Of course given all the talk of how the early universe was tiny even he can see the question: Can QT calculate the universe? Well, I plan to tell him, that's the question. Many toil as we speak to find the answer. But to ask the question they must first define that universe exactly. They can't. It's called GIGO: putting Garbage In, it says, gets Garbage Out.

Quantum mechanics is a term he'll need to know. It too is not precise. It means one or all of several different quantum theories. At first he may think it sounds mysterious. And it is. But I bet that he will soon detest it. These days QT usually means *QM*. Not that this will make it any simpler or less detested.

Unlike GR, QM's not concerned with curving space. It works with geometry kids learn in school. While it deals with things that are very small it also deals with bigger things. Big things are made of atoms. So QM deals with everything; though for big things its equations can get messy.

Reading further I discover QM doesn't really deal with things at all. It just gives the *odds* of finding this or that. Well, that's not quite right either. Turns out it's difficult to say anything quite right about it using words. For now I'll just tell him QM is a term for strange things happening with particles of light and atoms. He doesn't know it yet but soon he will eat QM three meals a day.

First I must break the news to him about *Complementarity*. It's an idea I am slowly getting used to. Some see it as the bedrock of quantum theory. Like many others, I see it as strange. Most science sets out what we know—or think we know. QM starts with what we *don't* know. Not as in we don't know yet; but as in we can't know ever. Why not? Well, that's just the way it is. I'm thinking this is not a friendly message for your average detective when, having gone for lunch, he walks in bearing Starbucks coffee. Two Guatemala blacks for him and me and a cup marked C for cappuccino. Does he expect her? I don't ask and he doesn't say. He just puts the cappuccino on her desk.

Maybe it's time to try him out. I tell him to take a look at something, any kind of thing that's moving. He looks out the window. It could use a wash. A steady stream of cars is heading north to the I-5. Okay, I say, pick one and watch it closely. I ask: At any given instant do you know precisely where it is? He nods in a skeptical, not-buying-this-shit kind of way. And, I ask him: Radar gun in hand, could you at that instant know its exact speed? Another nod. Actually, I tell him, QM says it can't be done. This earns me a look of pure disdain.

Okay, it is a lousy demonstration. But the concept that it *can't* be done is basic to QM. The more we know about where something is the less we know about how fast it's moving. With something big—a car—the wiggle room's so tiny no one gives a damn. But with something small—an atom—the wiggle room is big. If he could measure where an atom is exactly he'd know nothing about where it's going—or if it moves at all. And he'd have no way to find out without letting go of what he knows of where it is. Science seems to be a search for certainty. But uncertainty is what QM is all about. And, I tell him, this is just a taste, a teaser, of its weird ways.

I'm careful not to say that they are right but GR and QM are both incredibly successful. Each in its own domain predicts things more precisely than experiments can check them out. Each says something too about what went on in the early universe but neither gives a credible description of how it all began. Between them they split physics into two broad streams no one can reconcile. For his benefit I label this the New Divide. It derails the nascent scientific revolution. Physics reels in disarray.

For some reason he's still punching keys on his computer. I try a dozen different searches, combing through the differences between the theories. They

stem from different philosophic roots. Relativity is kin to a philosophy called scientific realism. It says reality exists even if it's not observed. Nineteenth-century philosopher George Berkeley asks, 'If there are trees, and no one to perceive them, do they exist?' Well, actually, he is said to say it but he didn't. Confronted with this question, a realist will answer simply: Yes. It's the philosophy that Einstein will embrace.

QM, on the other hand, seems to say that only probabilities are real. All else—if there *is* an else—depends on if and how we choose to observe. In this QM tends to *Positivism*. It's a philosophy that Comte composes in the 1800s. It springs to life three generations later in the Café Central in Vienna. It deeply influences physics.

The positivist says to Berkeley: If there's no observer then the question has no meaning. To me this sounds like a sloppy way of saying: No. Worse; it's like saying that no crime has been committed if no witness can attest the facts. But then I realize: Is this not in practice if not principle the law?

After founding quantum theory Einstein soon abandons it. He says that it does not describe the real world. To his friend Max Born he writes:

> Quantum mechanics is very impressive. But an inner voice tells me that it is not yet the real thing. The theory produces a good deal but hardly brings us closer to the secret of the Old One. I am at all events convinced that He does not play dice.

The quantum anti-realists reject Einstein's ideas as not just wrong but meaningless. The rift deepens. Its final plunge begins with money. Yet another Belgian, Ernest Solvay, funds physics meetings. Attendance is by invitation. In October 1927, the invitees include proponents of QM and critics. The topic is electrons and photons, QM in thin disguise. Proponents arrive well prepared, critics maybe less so. There is—as they would say in a press conference today—a vigorous discussion. When it's over the consensus is that Einstein lost the battle. And perhaps the war.

In 1935 Einstein and some colleagues try to launch a comeback. By now they don't need a hit; they need a homer. They assail the standard version of QM. It says: Until it's measured, the state of any quantum system is a mix of all the states it *might* be in. It's called *Superposition*.

Schrödinger's a physicist who preaches his own version of QM. In support of Einstein he dreams up a zany problem. He means it to lampoon the standard version. He creates a cat that is *both* dead and alive—until someone checks it. He sets out how to craft this quantum mess:

> A cat is penned up in a steel chamber, along with the following device (which must be secured against direct interference by the cat): in a Geiger counter

> there is a tiny bit of radioactive substance, so small, that perhaps in the course of the hour one of the atoms decays, but also, with equal probability, perhaps none; if it happens, the counter tube discharges and through a relay releases a hammer which shatters a small flask of hydrocyanic acid. If one has left this entire system to itself for an hour, one would say that the cat still lives if meanwhile no atom has decayed. The wave [or probability] function of the entire system would express this by having in it the living and dead cat (pardon the expression) mixed or smeared out in equal parts.

He calls it quite ridiculous. It seems like good fun. But the cat debate continues to this day. Hoping to avoid a dirty look, I sic Frank onto Wikipedia. Soon he's watching an alive-and-dead-cat video on YouTube.

That cat may make QM look ridiculous. But quantum mechanists aren't worried. QM's living high. It is the fashionable side of the Divide. I know he'll never get it. I don't get it either. Getting QM without math, I read, is swimming without water. Getting it with math one finds the math is all there is to get.

In this also, relativity is different. Einstein puts it in plain language. He writes a slim text which, he says, 'presumes a standard of education corresponding to' high school graduation. In other words it got a bum rap. Relativity is really not so hard.

But even this he doesn't need to get. A brief outline and key aspects—especially the politics—should be enough. Tomorrow, I imagine, is the day to pitch it. This is an optimistic thought that doesn't become action. I no sooner think it than she bursts into the room. Well, not bursts exactly but it's unexpected and she seems more in a hurry than she usually is.

Her cappuccino's cold. I zap it in the microwave as she explains she needs to be in Berlin. Potsdam actually. At the Einsteinturm, she says. When she says its name her accent is high German. For some reason I don't mention that I'm fairly fluent. Nor do I feel a need to tell her that I've seen the Einsteinturm. The outside of it, that is. It's next to the lab where, in the 1880s, Michelson and Morley found no variation in the speed of light. These days it's just a funky building with a fancy solar telescope. Strictly private. An appointment would require months of notice. Without one she won't even get inside. Does she know this?

I play travel agent for the balance of the day. She leaves me details of her passport, which is in, she says, her married name. So is the credit card. Whatever. I book it all except the Potsdam train, no reservation needed, and the Einsteinturm of which she says no more.

So I'm left with Frank to mind the store. Turns out for two days it is all mine. He's off to parts unknown. His training is in limbo. Trying to discount this latest letdown I digest documents, pore over books, draft up outlines till she returns.

Israel asked Einstein to be its president, she announces apropos of nothing

as she walks in at eleven with her carry-on, looking like she flew from Sacramento, not Berlin. She is back too early. Does she catch my startled look? I'm staring at her suitcase—stupidly, because it has no baggage tag—as if it has an answer for my silent question: Why? I hide surprise by starting the caffeine machine. She rattles on: Citizen of five countries but *never* an Israeli. Overnight, physics is a Jewish conspiracy, she tells me, meaning long ago it seems. Check it out she tells me for the umpteenth time.

What is this about? From her, it's not just a lecture, it's a dissertation. Well, whatever. Not my problem. Me, I do googling and listing. I do hunt and peck. I do CliffsNotes. When moved I do eloquence. And I keep my hot head down. Or so I tell myself as I lug mugs back to my desk.

She took the early flight, she tells me. Is she watching my reaction? It's a momentary struggle to look bored, to turn back to the keyboard with no hint it *is* a struggle. I succeed, or so it seems. She looks through some stuff and soon enough she's gone.

The reason for the struggle is there is no early flight. There is no flight from Europe that will get you into LAX at any morning hour. She should know that. She should know too that I know. It is a stupid story. *If* she flew a sched from overseas this morning then she flew in from the west; she came from Asia. Or she caught a costly charter. I was sort of sure before but now I *know* she's up to something and she wants to keep it under wraps. I wonder what to do. And then I think, again, I do the CliffsNotes.

I turn back to relativity. I'm finding that SR is not about the universe. Not on the intergalactic scale. It deals with what happens in the 'hood. It's based on two ideas. One is that the laws of physics can't depend upon the speed of an observer. The other's that the speed of light's the same for all observers too.

My first thought when I read this is it's simple. Even he should get it. My next thought is this isn't fair to him. A further search turns up this from Eisenstaedt: 'Relativity deals with some tricky concepts that the ordinary physicist finds difficult to understand.' If the ordinary physicist has trouble with it he may be excused. And I'm no physicist; each day all day and half the night I bend my brain into a pretzel to absorb these strange ideas.

It helps when I go back to how we got here. For centuries physics is obsessed about two things. One is matter. Stuff that *is*. As in lead and gold. As in what *is* this stuff? And the other thing is stuff that *moves*. At first physics focuses on moving stuff even more than on what it is. By chance or by design this fits with practical reality. Turning lead into gold may make an alchemist rich. In his dreams. Moving stuff makes many rich in real life. The camel. The horse. The wheel. The ship. The steam engine. The eighteen wheeler. The 747. In back of

my mind a ship's captain—he's a character of Simenon's—is saying, 'There's good money in carrying onions to England.' Wherever it may be, most stuff is worth more somewhere else. Trade is the lifeblood of civilizations. Moving stuff. Would it be cynical to think that physics follows fashion, that it goes where the money is?

Anyway, come 1680 Newton turns his mind to moving stuff. Not that he thinks of it that way, but he does think of it. He doesn't get it all exactly right. It doesn't have to be exactly right. He gets it right enough that what he thinks gives moving stuff a boost. He lays a foundation for a scientific revolution and the first course of bricks for a science-based economy. Nothing, I think—thinking of a line to say to Frank—nothing is more practical than that.

When relativity arrives it changes almost nothing practical. The equations of SR matter if stuff moves very fast. For example, they apply to driving down the road. But they have no practical significance for drivers, as the rules we take for granted give them almost perfect answers. I tell Frank that they are so close he can't tell the difference. Which gives me a bright idea. I write up a couple of cop kind of reports.

> Incident Report No. 1
>
> We drive north, doing 70. It's a 60 zone. A vehicle approaches, going south. Our radar reflects back. The radar unit checks the frequency of the reflected signal. It shows its speed, relative to us, as 130 mph. A chip in the unit subtracts 70 to allow for our speed and shows its speed as 60. It uses Newton's math. The subtraction, 130 - 70 = 60, says no ticket. But Einstein says that Newton's math is wrong. It underestimates the speed by about 0.000000000001 mph. Of course that's far too small to matter; it's maybe half the thickness of a hair per year.

So who cares about the difference? Not the cops. Not Frank. Not even Einstein. On the other hand, at higher speeds the difference might matter.

> Incident Report No. 2
>
> We're in the police rocket. It's a routine run to Io at 70 kmps. Relative, of course, to Earth. A hot rocket whizzes by the other way. As its pilot should know, the limit in the Solar-System's 60. The radar registers 130. Subtraction says 130 - 70 = 60. Looks like she's okay. But is she? The computer uses Einstein's math. It shows that subtraction underestimates the hotshot's speed by 25%. Her relative-to-Earth speed is just over 80 kmps! A light-speed call will issue her a ticket.

How can this be? Well, like I say it is the math of relativity. In other words, real speeds don't work the way that grade-school math might lead one to believe. And for speeds close to the speed of light the math may make a ticketable difference.

Here's something else for him to chew on. What if cop and hotshot were

both doing 186,000 m.p.s.—the speed of light? Newton's math computes the radar reading as 372,000. Einstein's says this is impossible. The radar reads just 186,000 m.p.s. This is a limit of a different kind: No matter how the hotshot burns she can't exceed this speed.

Some physicists make particles like protons move as fast as they can push them. They find that they too can't push past this limit. This sort of thing leads physicists to buy the SR package. Buy it? One might rather say they fall in love! But for the rest of us SR remains removed from real life.

Later when I show this to him he surprises me. He seems to catch on quickly. I watch him read it carefully, not once but twice. The cop-car caper seems to work for him. Of course there's much more to SR but I don't push too hard; the rest of it can wait. Now I need to introduce him to its better half.

GR also starts out simple. Think of this, I tell him. He's in a big sealed crate. How can he tell if it is here on Earth or in his spaceship that's accelerating at one gee in outer space? A peek outside might help him guess, but peeks and guesses aren't allowed. No matter what he has inside the crate, he can't find out which reality is real. Either way, his weight will be the same. Einstein thinks of this and takes a mental leap: Gravity's the same thing as acceleration! So he sets up a theory that treats them as the same. It starts out as a theory of how things move in space when one includes acceleration. But it becomes a theory of the shape (or, more precisely, the geometry) of space. That's right: He says space has a shape. *This* is the essence of the general theory.

It predicts some small but strange effects. They are soon found. For example it predicts that gravity bends light and by how much. In 1919 Eddington, secretary of the Royal Astronomical Society, narrowly escapes jail as a draft-dodger by travelling to Principe to watch stars near the sun in an eclipse. And lo, the stars appear to move. They move as far as GR says they should. The news is flashed across the world. For the first time in history a scientist is a celebrity. He soon finds he has lost control of his own message. The media take charge.

I've been thinking of her message off and on all day. What's her point? So they've been good at it. Lots of them. Jews, I mean. And physics. In the end I can't resist. I have to check it out. Knowing it's silly, I search israel+einstein+president+jewish+conspiracy+physics. Whoa! Multi-thousand hits! One of them's billed as Cranks, crackpots, kooks and loons on the Net. Lots of sites confirm that he was asked. I look him up on Wikipedia. It says she's right, five countries, never Israel. Strange but true. But so? What's it to her? True to form I'm not about to ask; I just tuck it in my mental pocket.

Then there is another pocket thing. It darkens my horizon. It's clear to me Frank has no notion about how he should proceed. How *can* he? Einstein died in

1955. Fellow physicist Wolfgang Pauli in 1958. Schrödinger in 1961. Niels Bohr in 1962. Four architects of the 20th-century scientific revolution gone in seven years. The last of the greats of that great era, Born, died in 1970. It's not that no great physicists are left alive. It's not even that those who are seem stuck in the tracks of those who aren't. It's that his witnesses are dead.

When she stops by around five I say so. She says with a straight face, solemn even, that this is where he may need some help. Help? He needs hand-holding. Meanwhile she's bopping round the world. She brings back nothing useful. Or nothing that she tells me. Not a single expert contact who could help us on our way.

Next day when he comes in I tell him we will have to work from records. Which mostly means my Web stuff. Bowing to necessity he says he doesn't care. Witnesses, he says, are over-rated. What they say is often spin. He'd rather work from records any day. We have a tacit, though not friendly, understanding of the way we'll work together. But 'work' is, for him I've found, a word in which one should not put great store.

After he has gone something still bugs me. Israel? Einstein? How does her outburst tie in with the Einsteinturm? If she went I bet that she did not get in but she says not a word about it. Is there some other place in Potsdam where she might have gone? Well, as she's always saying, check it out. In two hundred milliseconds good old Google finds a million hits (or so it says) for Potsdam+physics. Top of page one is a map for finding Max Planck Institute for Gravitational Physics. Aka the Albert-Einstein-Institut. At Golm, just a few klicks down the road the other way. Quantum Gravity and Unified Theories Division, I read. Black holes and stuff like that. A good place for her to visit. Totally legit. But if that's where she went, why not tell the truth?

They say one swallow does not make a summer. But three should make one think of spring.