RELATIVELY SPEAKING

There are no landmarks in space; one portion of space is like every other portion, so that we cannot tell where we are.

James Maxwell (1878)

Does Oxford stop at this train?

Albert Einstein (apocryphal)

To find another work … with the same range of scientific, philosophical and general intellectual implications [as relativity], one would have to go back to Newton's PRINCIPIA.

Gerald Holton (1960)

Any deviation from special relativity could point physicists toward an elusive goal, a quantum theory of gravity.

Adrian Cho (2005)

[Special relativity] was the beginning of a fundamental shift of philosophy in science, from asking questions of what *is* to asking what *can be known*.

Robert Oerter (2006)

I've been dreading this day. The big-three theories loom large. They are impossible to duck. But I'm sweating them myself. Even going easy there's no chance that he can handle them, no way that I can swot him up. Sometimes his driveway doesn't reach the road. I can see him walking out in sheer frustration. The end. I can't do that. It's not about the money. It's just I've come to like this job. To write? Too right! I get paid to play with words. It grows on you as the trite saying goes. And, yes, this writing thing is growing on me.

I'm late, the which I never am. I even walk up the back stairs to postpone the day's pain. He too must be flinching. He is even later.

When he gets here he is like: Let's get it done.

But as he pulls his chair up to my screen—a welcome innovation in itself—suddenly it all shifts in my head.

My inspiration of the day is that he doesn't need the physics; he needs *history*. He's not going to do physics so he doesn't need to know it. The scientific literature, the institutes, the books, the Internet, the *arXiv* site—they're full of physics. She doesn't need him to do that. Anyway, it's his needs that I should attend, not hers. He'll need a grasp of where the ideas come from and what role they play. If he was *fictional*, as he would be in a perfect world, he'd be haunting metaphysics'

metaphoric neighborhood, strolling in its streets, browsing in its stores, imbibing in its inns. Not living in them; certainly not *working* on them. The whole idea is that he is an outsider. If, that is, there is a whole idea. Anyway, it seems my trauma has been all for naught.

So here I am. I scrap my script. Of course I didn't really have one. I take another tack, ad lib. What's in my mind is that he's barely on the job, reading up on what she likes to call the background, and relativity is popping up all over. He's been a gumshoe all his working life. He likely never knew what relativity's about though I assume he must have heard of it before he took this job. But where is it *from*? What *is* it? What does it *do*? What is *wrong* with it? Maybe he could handle some of that.

What he needs to know first is, as Einstein himself explains, it's not as difficult as advertised. The math of SR is no challenge to a college grad. But its ideas are deep.

Relativity is not Einstein's idea. In the early 1900s when he starts his work on it, it has been round for several hundred years. It's what he does with it that takes the world by storm. In fact, Poincaré has similar ideas but Einstein takes them further.

How does he do it? Well, he does a *Gedankenexperiment*. It translates as 'thought-experiment'. The great advantage of a *Gedankenexperiment* is one doesn't have to *do* it. Rather, one *imagines* it and figures how it has to go. So what does *he* imagine? It's this simple: Two things moving. Any two that don't accelerate and don't rotate. Einstein calls it 'inertial' motion. He calls the things 'bodies' or 'frames' but they are just things. In his mind's eye he has each one carry an observer. The observers watch what happens. It sounds boring but he uses this to see how things must move in space and time.

I've been rereading Reichenbach, another great Berliner, not a jelly donut. Einstein's bulldog, someone called him, I remember from college days. There is no way to get a grip on space. The first concept of relativity is that to measure something about one thing—where it is or how it's moving—it must be measured *relative* to something else. A position or a speed in space itself is meaningless. Hence 'relativity'.

Boring, but this stuff, I say to him, is basic. If something is, where is it? If it moves, how far? How fast? It's called kinematics. Eisenstaedt says of it: 'It is clearly the first of the physical sciences because the whole of physics makes use of it; it is the science of the foundations of physics.'

Just as I get into stride he stages a diversion. What's so special about special relativity? he says in an antagonistic tone.

Well, at least he's asking something, and the answer's easy. Special's just a

bad translation that won't go away. Einstein's term in German, '*spezielle*', would translate better as 'specific'. It's *spezielle* because it's not *allgemeine*—or all-encompassing, aka general—the *other* kind. It's specific because it deals with a specific circumstance. The circumstance is: It deals with things that move steadily. No rotation, no acceleration. End of lesson one.

That, he says, was almost painless. He sounds surprised. So I get going while the going's good.

When she walks into the office there's Frank looking at my screen and talking relativity. Does she see this as the miracle it is?

SR as it is called among the cognoscenti is said to rest on two assumptions. Einstein bases *them* on his experience. Frank says he can live with that.

The first assumption is the laws of physics are the same for all observers, which is a fancy way to say that steady motion doesn't change the rules. It looks like a good bet: No one has ever seen them change. Einstein gives it a confusing label that—translated—turns into 'the principle of relativity (in the restricted sense)'. Leave off the label and the principle is simple.

The second thing he assumes is: The speed of light's the same regardless of the source's or observer's motion. No matter where light comes from or who measures it, its speed must be the same. This is why it can be simply called the speed of light. *This* is the surprise! Einstein bases this one on experience too; it isn't new. But he takes it seriously. He says it's not just what's observed; it is a fundamental law. Of this law he says a decade later, or a translator later says it for him, 'Who would imagine that this simple law has plunged the conscientiously thoughtful physicist into the greatest intellectual difficulties?'

In 1905 Einstein launches SR in a paper titled: On the electrodynamics of moving bodies. Actually, it's in German so its title is *Zur Elektrodynamik bewegter Körper*. It is simple. It is also nothing short of revolutionary. It plunges physics into intellectual difficulties from which it will not fully emerge in a hundred years. Nearly a half-century later Polish physicist Leopold Infeld, himself a notable contributor to the theory, writes of it:

> The title sounds modest, yet as we read it we notice almost immediately that it is different from other papers. There are no references; no authorities are quoted, and the few footnotes are of an explanatory character. The style is simple, and a great part of this article can be followed without advanced technical knowledge. But its full understanding requires a maturity of mind and taste that is more rare and precious than pedantic knowledge, for Einstein's paper deals with the most basic problems; it analyzes the meaning of concepts that might seem too simple to be scrutinized.

So of course he won't understand relativity, not even in the restricted sense.

But he does need to understand the *Frame of Reference*. It is relativity's key concept. I think of it as a platform from which an observer can observe the world. The key assertion of relativity is that there *is* no *Special Frame*. That is, there is no Frame of Reference that can be claimed to be at rest in some special way. There is, therefore, no frame that *should* be used for measurement of motion. This notion's known but rarely noted before 1900. More often cited is the notion of an aether that pervades the universe. It is thought to be the medium through which light moves. The thing is, if this medium exists, it *is* a Special Frame. After 1900 aether fails. Einstein leads the relativity revival.

He shows his assumptions lead to curious conclusions. For example, the length of any object depends upon the Frame of Reference of the observer. So does the rate of ticking of a clock. Hop on a bus and see clocks beside the road slow down and nearby racetracks become shorter. If it is an express bus. He shows too that we have no way to say events at different places are or are not simultaneous. Observers moving differently will disagree about their timing. They may disagree about which one was first. Experiments confirm all his conclusions. This is taken as support for his assumptions. But the *interpretation* of his theory—what it means—is still disputed to this day.

As a mere afterthought he shows that mass *is* energy—they're two forms of a single thing. This is the famous formula. The only one that everybody knows. It says $E = mc^2$ though that's not the way that Einstein puts it. This means that an observer (one who doesn't take the ride) sees an accelerating object's mass increase. Why? Well, because it is taking on kinetic energy. If one could get anything, no matter how small—say a single atom—up to the speed of light its mass would be infinite. And so could not go any faster: An infinite mass is an immovable object.

This phenomenon is routinely seen in particle accelerators—ponderous machines that propel particles to near the speed of light. A few that are as big as little cities propel protons fast enough to make their masses increase by a factor of a million. The high mass makes it hard to push them up to even higher speeds. This is the practical side of the cosmic speed limit—the idea that trying to go faster is just futile.

It also explains why smashing particles together near the speed of light can make hot, dense matter like that of the Big Bang. A noted physicist is reported as saying that a new high-energy benchmark set by the *LHC* 'is a huge step toward unraveling Genesis Chapter 1, Verse 1, what happened in the beginning.' What is not reported? Well, stepping toward chapter one doesn't mean that they can make it back to *verse* one. SR gives the reason why they can't.

SR phenomena seem strange because they are not seen in daily life. The rea-

son they aren't seen isn't they aren't there; they are. But they're extremely tiny at the speeds a person can experience. He's seen this with my Incident Report. This time I tell him that to set an airspeed record the *SR-71* burns about ten tons of fuel. At top speed SR says the *SR-71* (no relative; aka the Blackbird) gains mass due to its motion. The increase is less than an extra grain of sand stuck to its pilot's boot. Of course this makes no noticeable difference to the flight. The flight crew plans for loss of fuel-mass and ignores the increase in mass-energy. However, increase in mass-energy gets large as speeds approach the speed of light. The flight crew for a particle accelerator *must* plan for this increase or their particle will crash.

For a few years SR rules the Spacetime roost. But soon its space and its time too turn out to be at best approximate. Ten years after SR hits the spotlights GR puts it in the shade. How do I tell him this? And it gets worse: The assumptions that SR is based on seem to be disintegrating. Craig and Smith sum up its problems: 'Unfortunately for Einstein's Special Theory, however, its … assumptions are now seen to be questionable, unjustified, false, perhaps even illogical.'

Maybe he doesn't need to know this. Not yet. What he does need is to feel dissatisfaction in the air, a longing to tear down the temple and to build anew. He needs to know new building is in order or *in Ordnung* as the master himself might have said.

In any case he's noted—or he should have, since I told him twice already with a *mea culpa* for the double negative—that SR does *not* show that absolute time and space do not exist. Einstein says he doesn't *need* them. He says he doesn't like them. He doesn't say that they're not real. Kennedy says, 'Einstein's *theory*, on the other hand, does not mention reality; it merely describes relations between measurements, that is, between appearances.' So SR is not *about* reality. It says how things *appear* to be when an observer measures them. Why should I mention this to Frank? Well, for at least two reasons. One is he'll find that relativity's archrival, quantum theory, comes under heavy fire for being about measurement and saying nothing of reality. The other and more pressing reason is that he won't be making measurements. His efforts *must* be grounded in reality.

One more thing he'll need to note: Ten years after SR demolishes the Special Frame, general relativity makes such a splash few notice that it brings a whole new Special Frame in the back door. The few who do include another famous physicist: Lorentz. But I don't tell him this. Not yet. It wouldn't do to disillusion him too soon.