WHERE ALL THE PHOTONS GO

Where be your gibes now, your gambols, your songs, your flashes of merriment, that were wont to set the table on a roar?

William Shakespeare (ca. 1600)

There is no other course left but with better assistance to begin the work anew, and raise or rebuild the sciences, arts, and all human knowledge, from a firm and solid basis.

Francis Bacon (1620)

'A slow sort of country!' said the Queen. 'Now, HERE, you see, it takes all the running YOU can do, to keep in the same place.

Lewis Carroll (1871)

All science is cosmology, I believe, and for me the interest of philosophy, no less than of science, lies solely in the contributions which it has made to it.

Karl Popper (1959)

In their pretty paintings [Monet and Renoir and Degas] wanted to describe the fleeting photons absorbed by the eye, to describe nature entirely in terms of its illumination.

Jonah Lehrer (2007)

Most days these days I walk up Lankershim near dawn. When skies are clear Will's canopy—most excellent, his roof with frets of golden fire—soon fades. The glow above the hills brings photons into mind. It gets me thinking of the cosmic luminosities. A solar photon scattered from an atom in the air beyond the hills was born maybe eight minutes sooner than it meets my eye. The photons in my mind are old. Far older than the universe today, they may not yet exist. The picture in my head is space, stars eaten, every one, the last black holes all self-consumed, their space all made, their mass tanks emptied in their final fizzles. In all this future cosmos there is nothing like an azure sky. Only photons, mostly stretched to deepest red as restlessly they roam, each heading for the place where it will die. It is, let's say, ten trillion years from now but while they wend their way the end has not yet come. From him I now know how it all begins. Before I'm done I want to know the end. So next I need to see: Where *do* the photons go?

He said too little of them; I must piece together what I can. I start with Infeld, in the 1950s, newly asking an old question: What is light? Is it a shower of photons, or waves in the ether? Then comes Feynman and his *QED*. He shows

how it all comes down to arrows, little arrows lined up heads to tails that even I can understand, if this is understanding. What he shows is that a photon gets from A to B by going every way it can. He works in the continuum so there are infinitely many ways. Frank's ways would have a large but finite number. This would complicate the QED. But Feynman's key point is he says that photons are not particles. He gives short shrift too to QM's sacred cow, Complementarity, and he dismisses its handmaid uncertainty summarily:

> I would like to put the uncertainty principle in its historic place: When the revolutionary ideas of quantum physics were first coming out, people still tried to understand them in terms of old-fashioned ideas (such as, light goes in straight lines). … If you get rid of all the old-fashioned ideas and instead use … *arrows* for all the ways an event can happen there is no need for an uncertainty principle!

Feynman would have liked the thought that there *are* no straight lines. A Tweedle seeking a straight line through Flecks swings like a jitterbug. A photon of six Tweedles is six jitterbugs. Unlike Planck's and Einstein's quanta, which can come in many sizes, Tweedles are true quanta and they come in just one size. I think the photons' energies must lie in how their Tweedles hang together. He'd be proud of me. But how—each time I think of him I wonder—can he not hang together? Where's he gone? The question he would ask if he was here is: How do photons move?

Well, this must be where twists come into play. It's hard to do this in my head but even worse on paper. B-T has three kinds of helon: full twist clockwise, full twist anti, and no twist at all. The third kind is dum-dee, or it's dee-dum, its mirror image; either way they cancel out each other's twist so he calls this H_0. I call it a *Nolon*. B-T's photon is three Nolons in the simplest braid—no braid at all.

Three Nolons look like nothing much to me. But any twist in ribbon's like a knot in string; I can move it up or down but it won't disappear unless it finds an end or runs into its mirror image. Untangling twist to a topologist is simply solitaire. That is to say, it's in the cards, it is conserved. The twist exists, but does a photon?

Feynman's photons are not anywhere. This seems to mean the same as everywhere except where they *can't* go. Why don't they go there too? Because they get to an electron sooner. Feynman's photons are not particles, they're waves, like ripples in a field of wheat. In the world of particles these photons don't exist. Not really. Oh yes, I know they fill a slot that seems to lie in wait for them according to the Standard Model. But photons we imagine as the chat between electrons have a problem being real. The fact is they are fictions: Physicists invented them to suit their purpose. In the end there's nothing *there* to stick around.

It seems to me that B-T's photons too aren't really real. When he cuts to where the universe is working we see why. A dum is half a twist in two dimensions between Flecks, a dee is half a twist the other way, so Nolons are no-twists. Their no-braids, photons, if one thinks of them as being any *place*, are just a fancy term for boundless space. Lacking spatial definition, each one *is* in some sense everywhere. So it's true as Bohr insists: There *is* no path that's followed by a photon. I think of it this way: A photon is three Nolons or six Tweedles. Each Tweedle must be perfectly conserved until it's canceled. So one might imagine that each Tweedle in a photon has a path. But if it does there is no way to know it. Even if one called upon a Tweedley Maxwell's demon he'd be searching for a needle in a needle-stack that shuffles all the needles every Move.

The fact is that the photon consists not in the location but in the *relation* of its Tweedles. Though my money says a photon's hotter if its Tweedles hang together closer. And how close is closer? Deep space sometimes serves up an extremely energetic gamma photon. It's the smallest photon known. At any given Move, if you could look, you'd find its Tweedles mostly in a volume of some hundred billion billion Flecks—if *they* could be defined. The Tweedles of an ordinary photon—of the kind we see—roam in a larger volume. Any given Move all six might be among some trillion trillion trillion trillion trillion trillion trillion Flecks.

What little he did say of photons tells a different tale. I remember him some weeks ago observing from a photon's point of view: There *is* no universe. A photon, he said to me, always has its end in view. Travel for a photon's easy. It perceives no distance to its end, however far away. It takes no time to get there. When it leaves its home electron it's *instanter* at another in the place where it's destined to cease to be. He says a photon is a bit of mass that's not allowed to be out on its own.

What's coming to me now is this: My problem about photons, where they go, is *not* a problem. He is right. A photon *never* leaves home with no destination. Photon is our name for two electrons doing what some rule—much broken—says cannot be done, like an off-market trade, a share sold under-counter in a less-than-standard lot. Where's the counter that it's under? Now I see, in Photonworld, there isn't one. Energy that's lost from one electron shows up in another. It's not ever any place between. It's another tunneling transaction. That's why every photon has its end in hand before it can begin. As far as *it's* concerned it doesn't dally on the way.

All evening these daydreams stay with me. After two the bar has hushed. Fewer photons end their short lives in my eyes than did when I was looking at the dawn. Behind my eyes the universe appears like Durrell's city—half-imagined, wholly real. I hear the hypnotic murmur of the sea upon the shore. Its sounds, it

seems, should never end. And yet there was a day, about four billion years ago, when they began.

There is, I see, a melancholy almost like nostalgia here at the end of all things. Long before The Number Twelve Looks Like You this was Tolkien. The nostalgia comes from thinking of a simpler age and the enthusiasms of the scientific revolution as it's born. Its first fuss is the photon. Then too one question was: Where do the photons go? Copenhagen answers: Well, they do exist but where they travel can't be found. His answer, that they don't exist but that they do go somewhere, may be similar in practice. But the question seems to me to be: Why did it take so long?

Physics was seduced by photons, by sweet nothings that go nowhere so we find no way they go. Richard Panek says that when our children look out at the universe they will embrace the dark. My Frank would find in this, I think, a reassuring answer. Though fictional like him the photons all know where to go. *ET*—a fiction too, I think with pleasure—got it right. They all go home.