

PHILOSOPHY, ONTOLOGY, AND PHYSICAL EXPLANATION

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1. Philosophy in an Old-Fashioned Sense

The centerpiece of this paper is to be a proposal for a physical-causal account of certain famously puzzling experiments involving light beamed into closed boxes through narrow apertures. By a “physical-causal” account I mean that I will attempt to explain how these intriguing phenomena arise out of background processes of a particular description. Here we have something that people might justifiably find peculiar on its face: a philosopher mucking around in physics. How can it be that scientific explanations come out of philosophical thinking? The modern compartmentalization of the disciplines speaks against this, as do the major movements of twentieth-century philosophy away from any constructive inquiry into the nature of things. But there was a time not so long ago when “philosophy” and “science” were not cleanly distinguished in their meanings. Insofar as the causal explanations proposed herein succeed, this will constitute a defense of the idea of philosophy and physical science coinciding, or in other words, the revival of a seemingly antique scientific tradition that called itself “natural philosophy.”

This earlier tradition of physical science is epitomized in the person of Michael Faraday. Untrained in higher mathematics, he was nevertheless accomplished not only as an experimenter but also in physical theory. As to the latter he was, for one thing, an astute critic of the many causal theories being proffered in his time regarding electricity, magnetism, and so on. On the constructive side, that is, regarding his stated eventual goal of a physical understanding of why and how the various forces of nature take place, he came up with some ideas that have considerable merit. The concept of a line of force was widely taken up, while much less well-known is an intriguing speculation about the nature of matter (along with a corresponding speculation about light). He proposed that perhaps what is called an atom is really not an impenetrable space-occupying object at all but a “center of force” such that the gravitational “force” or field energy (as we would say today) spreading out from the atom is actually the underlying physical reality that is constitutive of that atom. The suggestion here is that there is no present thing (in the usual sense) occupying a discrete site but only a central point or region of maximum concentration, as it were, upon which an extended field as a whole converges and thereby exerts the specific causal powers we misleadingly attribute to an “atom.” Faraday is usually celebrated primarily as an experimenter rather than as a theorist—despite the fact that, as I discuss further below, this supposition about the field-constitution of matter is strikingly well borne out in

twentieth-century scientific experience. I argued several years ago in *Process Studies* that Whitehead diverged philosophically from mainstream physics by carrying forward the “natural philosophy” outlook of Faraday (which, by the way, Maxwell had promoted forcefully and consistently) into the twentieth century. Whitehead’s physical ideas built on Faraday’s in a way that responded to more advanced physical knowledge. A few other notable thinkers can also be regarded as carrying forward the natural philosophy point of view, though as far as I know none have so thoroughly worked it out both philosophically and mathematically.

The upshot is that natural philosophy actually did continue into the twentieth century, though in isolation and obscurity. In addition to having reputable supporters in the recent and not so recent past, I believe that natural philosophy has actually had its prospects considerably enhanced, not deterred, by twentieth-century findings of physics, despite seemingly puzzling and baffling aspects of today’s physical knowledge. This, I propose, is because modern discoveries point in the direction of a revolution in ontology, and it is in the course of this revolution that fundamental explanation first becomes a genuine prospect.

2. The Contemporary Situation

When I first started thinking along this line in my youth, my belief in the prospects of natural philosophy amounted partly to a kind of faith, a rationalistic faith that one should be able to make sense of things that go on in the physical world.

Early on I had vague intuitions that certain very basic questions about the understanding of nature not only persisted unanswered but were not being addressed by existing physics. They seemed to be literally off the agenda, left out and forgotten. For example, it is pretty clear that the theoretical apparatus of quantum physics, with all its predictive power, technological utility, and consequent prestige, does not contain or imply any causal and physical account of what actually happens at the microcosmic level when light interacts with matter. We are assured of this by Richard Feynman, who stated forthrightly that quantum theorists have long ago “given up on” the quest for such a physically descriptive understanding of light in interaction with matter, and his statement is, I think, fairly easily corroborated. In one passage that has been quoted widely, Feynman warns that anyone who seeks to inquire in the direction of understanding what actually goes on in the quantum experiment is heading down a “blind alley from which nobody has yet escaped.” Not everyone has followed his advice and stayed away from these questions. Indeed, it is often remarked that quantum theory stands in need of a physical interpretation, as if to invite questioning along this

very line. The effort at a “physical interpretation” is often guided by the assumption that the object of interpretation, the thing to be interpreted, is quantum theory, that is, the well-confirmed quantum-mechanical formalism. It is assumed that the question to be asked is, What does the mathematical device (or the form of same) represent, physically? Whitehead viewed this procedure as misguided, comparing it to medieval Scholasticism in “looking first to” formalistic constructs. We avoid the issue here, by conceiving “physical interpretation” in a different way, namely, as seeking to understand how the basic qualitative phenomena of “quantum” experiments are physically produced. There is plenty to mull over here; one can ask why there is (apparently) intrinsic indeterminism, why there are (apparent) nonlocal connections, how there could be ontological (as opposed to epistemological) indefiniteness of certain quantitative properties, why everything seems to consist of something like waves, why they also seem to act like particles, and so on. All of this is at present open territory when it comes to explanation.

We can understand the persistent need for a physical interpretation, then, as meaning not that the formalism needs to be interpreted but rather that the undeniable successes of established “theory” are in service to aims and values other than that of an actual (qualitative) understanding of what goes on physically. Indeed, the physical phenomena in the “quantum” domain have seemingly quite perplexing aspects to them, which are often held up as offering an opening for religious points of view, for example, Eastern mysticism. But I have persisted in wanting to resolve all perplexities in an underlying causal account, and thus felt a kinship with David Bohm. However, the Bohm approach as I understand it appears to regard the classical ontology, or certain elements thereof, as indispensable, whereas I have tended to agree with the thrust of mainstream physics that this ontology is ultimately inadequate. Indeed, I would argue that the classical ontology falls short at a philosophical level before we ever get to specific problems of physical explanation.

I hasten to add that if one is really bent on rehabilitating purely explanatory questions in physics, the field of problems is in no way limited to quantum physics. Take relativity theory. Does the special theory of relativity, which places light transmission at the center of its model of space, time, and velocity, explicate the physical nature of light propagation, that is, does it answer the basic question, What happens when light propagates? What is light? In no way. In fact, it deliberately leaves out of account all goings-on in or of empty space through the procedural doctrine that came to be known as operationalism. Nor is this question answered at the microcosmic level by quantum physics, as we have just seen. For another example consider putative descriptions used by particle physics: Do standard verbal adaptations such as “particle exchange” convey what actually goes on in the causal connectivity of subatomic structure? As far as I can

tell, not at all. In all these and similar cases, it is not a question of certain remaining gaps in the theoretical picture; rather, *all questions of this class have dropped out of consideration*. Thus it might be said that in the twentieth century a whole *dimension* of physical science, a dimension concerned not immediately with any kind of utility (i.e., mathematical modeling, “unification,” and prediction) but simply with physical and causal understanding or explanation, is officially abandoned and largely disappears from sight. But it has long seemed to me that there is really scant reason to think that this dimension of physics cannot still legitimately and fruitfully be pursued. Reasonable people might balk at allowing the term “physics” for such a prosaic quest, considering how the word is ordinarily used today, in which case they should feel free to call it natural philosophy, philosophy of nature, or theory of nature. However, it cannot, I believe, be called non-science.

The question that has persistently animated me is this: *Is natural philosophy, in this sense of causal and physical explanation in physics, really defunct and dead, irretrievably archaic? Or has it merely gone dormant, awaiting some radical revision of physical ontology, that is, of the basic operating conception of physical reality and physical entities?* The classical materialist ontology that physics operated with for centuries is clearly inadequate to fully account for facts uncovered in the twentieth century, even though this ontology has continued to supply the images, concepts, and models that science is constrained, purely by default, to make use of. Would not an obvious remedy for this situation be to replace this ontology, this fundamental conception of physical being, with a different one?

Philosophers and other non-physicist inquirers mostly steer quite wide of the left-out “commonsense” physical questions about such things as what really goes on in a “particle exchange,” a light “wave,” and so on, opting to defer wholly to the discourse of scientists on these matters. Deference is carried to the extent of not inquiring in a particular direction at all simply because the experts themselves do not venture there. It has been standard to assume that the default of physical/causal explanation in fundamental physics indicates an ineluctable limitation on human knowledge. This position has been very much bolstered by traditions of epistemological philosophy, particularly the traditions derived from Hume and Kant. But to resolve on natural philosophy is to hold at arms length this allied outlook of pragmatic science and certain nihilistic traditions of philosophy. Rather than accept permanent, drastic limitations on human understanding, I believe there is another option, namely, to suppose that the problem lay with the limitations of one particular way of thinking about physical explanations, the adoption of which is always an essentially philosophical and conceptual move, though it may be all but automatic in many cases.

But a recurring question for many is going to be, What about the highly celebrated and successful physical theories of today? Are their successes not evidence that they represent in themselves some kind of direct insight into the physical phenomena? Again, whatever their powers, these theories are in essence formal-mathematical solutions and thus clearly the wrong kind of thing to turn to if what one wants is causal and physical explanation, that is, a descriptive account of events and processes outside the sphere of direct observation that explain why the qualitative and quantitative phenomena are as they are. The latter is quite a different sort of inquiry, really an *approach to science* currently lying outside the considerations of mainstream physics. While quantitative models may certainly be effective and useful in many ways, broadly “confirmed,” and so on, they do not actually do any physical explaining because they amount to a different mode of knowledge altogether, namely, empirical models valued on the basis of predictive power. A certain confusion can easily muddy the waters here. The fact that a particular mathematical theory “works” (in whatever sense) can easily be a piece of evidence for, or even serve to suggest, as Herbert Dingle said, a new and deeper understanding of nature. But it is important not to confuse this particular *utility* of theories in furthering knowledge with the case of a theory itself embodying or directly providing an understanding of what is going on in nature. What I am saying here is much the same as what Nietzsche expressed when he said that the formal and quantitative treatments of the world, whatever they might tell us, could never in principle add up to an understanding of the world; he compared this to the formal analysis of music, known as music theory, which no matter how exhaustive has “nothing whatever of what is really music in it.”

In summary, I have clung to the possibility that a genuinely explanatory dimension of physical science could be restored, though science has long been disengaged from such a pursuit. Perhaps natural philosophy has not actually been refuted or outdated at all, as everyone seems to think, but has simply been left out and ignored as a prospect and project in favor of purely utilitarian scientific values.

3. Post-Classical Physics as an Ontological Problem

In thinking about these matters I have always gravitated toward the question, What is electromagnetic radiation? This has seemed a useful focal-point for long-unanswered questions of physical science. Knowledgeable people seem to assume that this question in the raw and commonsense form I want to ask it is irretrievably outdated; indeed they might scarcely recognize this old question of nineteenth-century natural philosophy. But why should we accept this? Suppose we do accept that the “aether”-*substance* that was once invoked as a medium for

the propagation of light is defunct in all of its possible forms; does this necessarily mean throwing out all prospect of a causal and physical explanation of light-related phenomena? Can we be so sure that it is not possible to supersede the materialistic kind of physically explanatory context by replacing it with some fundamentally different kind of physically explanatory context? One might have immediately in hand no constructive ideas about what such an alternative explanatory context would look like, but does this warrant the conclusion that the demise of the substance-ether is also the end of physical-causal explanation itself? I had few companions in this unrestrained rationalistic approach to such problems; Whitehead is one, as I gradually came to realize, and there are one or two others, as I eventually discovered. One thing I have liked about reviving the old question about the actual causal or physical explanation of light is that it is not only a question of physics but is also about a literally ubiquitous fact of nature that pervades ordinary life. At the same time it has seemed a kind of universal hinge question for today's physics in that if a truly complete answer were ever given to it, this would most likely render newly intelligible a wide array of facts reaching from quantum to relativity physics and beyond.

So what are the basic facts that have to be accounted for in any understanding of light propagation, which is to say, of "field" or empty-space physical processes generally? For the sake of brevity I will avoid a history of experimentation and simply attempt to summarize what is known in certain important features. First, there is definitely something wavelike about light, that is, a property analogous to a wave, though in view of what is known today we can safely assume that it is not actually an oscillation in some omnipresent material, but something distinctly different from this. Here I propose acknowledging and accepting that any mental picture of an ordinary wave propagating in and through matter is not going to be applicable, but not going on to presume that the phenomenon is outside any possible semantics of physical description. So far I am simply saying that there is a definite *wavelike* feature, while denying that it conforms specifically to the mental picture that ordinarily goes with the term "wave." "Wavelike" then means only that there is some kind of cyclic and reiterative structure. This wavelike feature, by the way, applies not only to light, but characterizes all aspects of physical reality including atoms of matter. Second, there are some intriguing phenomena that are revealed when you create a beam of monochromatic or single-frequency light, reduce the intensity or brightness to an extreme degree, and shine it into sensitive detection devices. In the simplest case, a screen coated with light-sensitive material is placed at the back of an enclosed box, so that all light can be blocked from impinging on the screen except as controlled by the experimenter in two ways: by modifying the apertures on the front of the box and by adjusting the output of the emitter. As to the latter, the amount of light reaching the screen in a given time can be turned down so low that the effect of an individual

incoming unit of the transmission—usually called a “photon” but to avoid the pitfall of materialistic pictures we will call it a “pulse”—can be observed by itself. One thing that happens is that each incoming pulse of light imparts a discrete bit of energy input to the detection material. The next thing observed is that if you turn up the intensity or brightness, the incoming pulses will follow upon each other more rapidly, but the amount of energy they each carry will remain the same. Adjusting the frequency or color, however, does change the energy level, so that a higher frequency turns out to mean a higher energy packed by the individual pulse. Frequency is in effect another name for energy level. Intensity or brightness, for its part, means numbers of individual propagative events (to stay with deliberately vague language) impinging in a given time. This is roughly the opposite of what would be expected if we were relying on the picture of a wave propagating in some continuous material such as water or air.

The next intriguing observation is that when you allow only one individual propagating pulse or “photon” to make its mark on the detection material, it does so at some pinpoint site in the material that cannot be predicted beforehand except as a distribution of probabilities over the area of the screen. This is one of several findings that led to the resurrection of the old particle model of light, at least as far as a usefully suggestive language is concerned, as against the wave model that became dominant in the nineteenth century. Another factor behind the language of “particles” and “photons” was the work of Max Planck and Einstein which demonstrated that the energy levels of the individual pulses were always whole-number multiples of an exceedingly tiny quantity called Planck’s constant. The unit parts of light came in bundles of indivisible units of energy, or more precisely, of causal action. The mental picture of a traveling packet of energy units may well be misleadingly materialistic and localistic; nevertheless the term “Planck’s constant” identifies an important truth about physical reality, namely the fact of a fundamental and irreducible constitutive unit in which all physical processes or “energy exchanges” take place.

The natural next phase of this discussion of optical experiments concerns the aperture control, specifically the two-slit aperture combined with the ultra-low-intensity emitter. This crucial phase of the discussion calls for several preparatory remarks.

First, the intriguing micro-aspects of radiation should not lead us to forget that the macro-structure, consisting of *wavelike* propagative and cyclic sequences of some kind, is every bit as devoid of an explanation in the post-classical, post-materialistic era of physics. Even though the notion of electromagnetic “waves” remains virtually indispensable in certain contexts as a matter of sheer discursive utility, and though the conception of perpendicular oscillations in something

called electric and magnetic fields yielding propagation along the third rectilinear axis is a compelling abstract model that in some sense works, nevertheless such mental pictures, ontologically speaking, are misleading. To be on safe and solid ground as far as really describing what goes on it is necessary to speak more vaguely (or so it seems at first) of “events” in some sense arising out of and passing on into other such “events,” and of these relationships adding up to a propagative or reiterative “process.”

Second, speaking in nonspecific terms about “events” provides a certain flexibility for understanding in that it allows as a logical possibility the nonexistence of continuously enduring facts, such as “aether” or continuous vibration, in terms of which the “events” are understood. It allows for the possibility of a kind of reiterative process in which one event arises out of an antecedent event from which it is fully differentiated and individuated, unlike a continuously oscillating wave in which the starting and finishing points of a cycle can be chosen arbitrarily. Such a notion is highly compatible with early quantum discoveries which gave rise to talk of light coming in discrete packets of energy, and so on, as explained briefly below. This conceptual strategy furthers the supposition that events and processes can be discussed without reference to enduring material stuff or objects undergoing the events, fostering the idea of “pure activity,” or “pure transition” as Maurice Merleau-Ponty once said, that is, events and processes in a matter-independent sense.

Lastly, thinking along this line leads in the direction of Whitehead’s early work on physics, in view of his suggestion of an “event ontology”: that events, rather than material presences or things, are the ultimate, irreducible constituents of physical reality. His analysis of events as wholes and parts in relation to other events, for instance, lends itself to the composition of the so-called “photon” by Planck units of causal action. That is, it seems likely that a traveling “packet of energy” composed of irreducible energy units can readily be built out of Whitehead’s account of the composition of events by other events in terms of a hierarchy of inclusion. After all, a “unit of causal action” is nothing if not an “event.” Following this logic, it would seem that if such physical Planck units are fundamental and irreducible, this establishes all by itself the correctness of the “event”-ontological interpretation of physics as proposed by Whitehead and Milic Capek! The event-ontological account of Planck’s constant succeeds in avoiding materialistic pictures by proceeding on different ontological assumptions. In any case, “events” combining and reiterating in “processes” is only too obvious as a basic account of light transmission that could hardly be wrong as far as it goes. That it avoids sharp mental pictures is probably a definite plus in preserving accuracy. But there is a successful rendering of truth and intelligibility through this language only if it can be shown to identify distinctive physical processes

without any imposition of materialistic pictures, thus amounting to a *constructive* repudiation of the classical ontology, which is essentially what Whitehead proposed or at least hoped for. The processes so identified must also, of course, be shown to be causally efficacious in the ways required by specific phenomena.

The preparatory remarks are almost over. I am about to get to my core argument, an account of what is observed in the double-slit experiment and a proposal for explaining some of its more intriguing features. I am going to try to explain the observed facts not by thinking up a novel theory, but rather by simply applying a few simple tenets of event-ontological physics as conceived by Whitehead in the period of the early 1920's and before. You will note that I do not bring in any elements of explanation that emerged only in Whitehead's later metaphysical thought. I do leave an obvious opening here for panexperientialists in the fact that I skip over the question of quantum indeterminism, which the panexperientialist wants to account for through an element of self-determination in fundamental entities. Concerning my relationship to the Whiteheadian metaphysics, it might be good at this point to lay what few cards I have on the table. There is a view out there that says that the work of Whitehead's philosophy of nature period fell short of its aims because it was insufficiently radical or general in its approach, meaning that it failed to rise to the level of metaphysics and/or ontology which is where real explanation is achieved—in short, that it was all something of a wandering in the wilderness until the breakthrough ideas that led to *Process and Reality*, wherein his mature positions are to be found. After all, his alternative to Einstein's general theory of relativity was never adopted by physics, and because of this one assumes that it must be wrong and Einstein's theory must be right. But I have become over time more and more firmly convinced that whatever the fate of his quantitative physical theory, Whitehead's interpretive commentary on modern physics developed from around 1905 to around 1922 was (a) implicitly ontological in the radical sense, meaning it was a theory about the nature of physical reality as such, though perhaps unwittingly, and (b) right. Relating to both these points, there is a book recently translated into English that should warm the hearts of Whiteheadians. It is a compilation of class notes to unpublished lectures by the philosopher Maurice Merleau-Ponty. Titled "La Nature," the material complements some brief published work of his on problems in the fundamental conception of nature or ontology of nature, as he termed it. This book contains a whole chapter on Whitehead, the upshot of which is a highly favorable review of Whitehead's middle-period work. (Also recommending this chapter is the fact that retranslations of Whitehead back into English produce some entertaining results.)

4. The Two-Slit Experiment

So what are the basic tenets of Whiteheadian physical ontology that I propose to apply in specific physical explanations? For the present purpose, they come down to three interrelated claims:

- (1) the fundamental character of physical reality is not presence in space, that is, the givenness of space and the occupation of space by objects, but rather the “passage of nature” in which events arise out of and pass into other events;
- (2) each event arises out of and passes back into *a contextual whole* of physical reality; and
- (3) space, measurable or serial time, and material presences are emergent, derivative, or foreground facts whose reality traces to that primordial flux of events which occurs independently of the existence of these secondary facts; in other words, being (of space, time, and matter) is traced to an origin in what amounts to genuine nonbeing in the sense of absolute formlessness devoid of enduring particulars but which is nonetheless fully real as physical activity or “energy,” as the physicists say. Tracing “being” to in some sense “nonbeing”—or “nothing,” as some physicists are wont to call it—clarifies the meaning of fundamental explanation (which is to say ultimate, or radically complete, explanation) and affirms its possibility. If successful, this is a triumph for rationalism, here meaning the view that every physical phenomenon ultimately makes sense and can be fully explained in terms of causal processes.

In summary form, the three basic tenets are: reality as passage or process in distinction from presence or locality; internal connectedness of individual reality-constitutive events with a total contemporaneous activity; and space, time (in some sense), and matter as emergent rather than pre-given realities. For my purpose here the scholarly matter of whether any or all of this is what Whitehead really thought is largely academic; think of these three tenets as an elaboration of the general idea of an event ontology which has a particular emphasis due to the explanatory purpose to which it is being applied.

In the two-slit interferometer, monochromatic light passes into an otherwise dark chamber through two narrow, parallel slits and falls upon a detection screen at the back. The interaction within the chamber between the light coming from one opening and that coming from the other opening produces a pattern on the screen consisting of a series of parallel light and dark bands grading into one another. Only the two-slit aperture produces this particular pattern of illumination. So-called interference or (more properly) superposition effects of this kind demonstrate the wavelike or cyclic structure of the propagation. Now, when you turn down the intensity of the light to an extreme degree, so that the unit stages or pulses of the propagation (usually called photons, though it is confusing to suggest

a particle model at this point) enter the chamber one at a time, it is observed that each ends up acting at a pointlike site on the screen, a site seemingly selected at random. If this experiment is allowed to run long enough, and the light-absorption events are recorded in photographic material, eventually these individual sites of absorption will build up into—guess what—the two-slit interference pattern. From this one can conclude that the individual pulse of light energy has the character of an expanding wave-front that passes through both slits and thereby divides into two parts, in order for there to be the particular two-slit-generated interaction that produces this pattern. This would seem to be strong evidence that the composite part of light is not a particle, since otherwise a single particle would somehow be passing through both slits at the same time. If you really had to have light particles to explain some other evidence, you could imagine a particle traveling along with a wave in such a way that the wave, carrying the effects of passing through both slits, steers or guides it to one or another site of interaction. This is often called a “pilot wave” theory. But in my view there is nothing in phenomena that requires an actual particle and everything makes much more sense if we simply get rid of it. As I see it the language of “particles” is merely a convenient modeling discourse that should not be construed as physically descriptive. Every piece of evidence for particles can be plausibly accounted for, I believe, in another way.

Now, this experiment is supposed to have something famously perplexing about it. What was that? If we are going to drop the insistence on a particle, then there is nothing troubling about the individual interactions building up into the two-slit interference display. The composite unit-event of light (whatever it is) is wavelike, spreads through space as an expanding front and thus passes through both openings, then the two emerging portions of the process interact to influence the probabilities for distribution of individual detection sites manifested in the statistical aggregate as a series of light and dark bands. It was the particle that caused the whole puzzlement; it could not go through both slits. This should inspire a strategy of at least trying to see if we can get along wholly without it. That localized matter is not an ultimate or fundamental form of reality is in keeping with tenets number (1) and (3) of the event-ontological interpretation.

There do, however, remain some real problems for explanation here which are not unique to the double-slit apparatus. Prime among them is the question of how the spread-out, wavelike propagation, which presumably pervades in some sense the space of the chamber prior to the hitting the screen, is absorbed at a particular localized site. It is somewhat as if a wave washed onto a beach and disturbed only a single pebble. Does this not at least show that the propagation “arrives as” a particle, as David Bohm remarked? My answer is, there is no logical need for something to be a localized traveling particle or to turn into such a particle

immediately prior to or upon interaction. It is equally possible, indeed more economical in terms of assumptions, to simply talk about a localized point in matter at which the wavelike activity (whatever it is) is absorbed or has its effect. If our minds do not immediately furnish us with an explanatory context for how such a thing can happen, that is, what kind of sense-making transition connects the spread-out “wave” to an effect at a particular discrete site, this may only be yet another indication that a revolution in background assumptions is necessary. In the meantime I propose simply saying that in its propagative phase the “wave”-event is indefinitely spread out, but when it interacts with matter, it does so, for reasons yet to be identified, at a discrete atomic site.

I will now attempt to frame a solution to the problem of identifying that physical process by which the abrupt localizing transition takes place. I indicated that any problems of physical explanation would be handled using the three tenets of a Whiteheadian event-ontology as I read it. To that end I want to first recall and expand on principle number (2), that each elemental “event” of nature is an instance of arising out of and passing back into a contextual whole. The “passage of nature” as fundamental structure of reality means that an event constitutive of physical reality (both matter and empty space) arises and passes as a transition connecting its causal past with its causal future. Simply through “happening” as thus embedded in the causal nexus, it is “internally related” to a contextual whole, meaning that there are aspects or phases of the elemental constitutive event itself that reach throughout a total environment. (Whether internal relatedness requires that the events be occasions of experience is a question on which I take no position. I propose that for the purpose of causal-physical explanations “internal relatedness” can be construed simply as expressing a genuine causal embeddedness as opposed to a discrete seriality of events along a causal chain.) Those more inclusive events made up of these elemental events (along a hierarchy of levels, one supposes) will likewise possess “internally,” that is, within their own constitution, an aspect of dispersedness (in a certain sense) throughout a whole. This notion of an inherent togetherness of the minutest constitutive structure with a total environment might be a difficult one for some to accept, but it should, I would think, feel agreeable not only to Whiteheadians but also to physicists, knowing as they do that an entity such as an electron or an atom is only artificially conceived as occupying a discrete, bounded locality, and in reality possesses an aspect reaching outward into surrounding nature to an indefinite extent. That is, it is an essentially contextual or “field”-constituted entity in addition to being persistently effective at a particular microcosmic site. In other words, Faraday’s humble speculation was on the right track. An account of how quantum theorists have been drawn toward the idea of an ineliminable influence of the physical surrounding as a whole on a quantum system is provided in Michael Epperson’s book *Quantum Mechanics and the Philosophy of Alfred North Whitehead*.

Let us consider next tenet number (3), that space, time, and matter are emergent realities. This is the same thought that Whitehead voiced in *Process and Reality* as the “principle of process”: “*how an actual entity becomes constitutes what that actual entity is*” (PR 23). We apply this principle here in a purely physical rather than metaphysical context. An “atom” of detection material, say, is essentially a process, which means at a minimum that it is the continual reiteration of a site of activity. It is not a persistently present thing at all but a *localization event* which continually occurs or reiterates. This implies oscillation between a phase of pre-locality or radical dispersal (hence the “field” specific to each “atom”) and a phase of localized effectiveness as an elemental constituent of matter. This reinforces principle (2): that the “site in space” or instance of primitive event-locality as such, not to mention the effective physical activity we call “atom,” bears internal connection to a contextual whole causally conditioning it. But the main point here is that since space itself is emergent, this contextual totality is not a given three-dimensional spread of space extending throughout the universe, but instead amounts to a *prelocal dimension of physical reality*. Integral to the reality of the atom itself, as well as to its constituent elements, is connecting transition between locality and prelocal or contextual totality. In other words, what is called an atom or particle is not a localized object vibrating in place at a microcosmic site, but a locally efficacious activity that physically pervades its own causally conditioning environment.

Now, finally, I will attempt to put a physical explanation together.

Each atom of detection material is characterized in one of its aspects by a physical connectedness, linkage, or transition into its environment as a totality from its particular site of localized action. The empty space “field” or contextual surrounding of the aggregate material is thus a dense matrix of staggering numbers of connecting transitions between the contextual (or prelocal) and the local aspects of physical reality, each specific to one particular atomic site. Now, the background of physical relations in which this activity takes place, namely the field, is known to be also the arena of electromagnetic propagations. Indeed, Faraday speculated that it was the fields of force radiating from objects, *rather than* the “ether”-substance, that formed the medium of propagation. In any case, upon approaching the detection material the propagation, as a process in and of the physical field, encounters and mingles with this profusion of localizing-dispersing activity. Interaction with matter might then be initiated when the propagative energy “selects”—and we will not here speculate more about this—a particular one of these active linking transitions and contributes itself (i.e., its energy) to it. Since the outwardly connecting linkage is actually an integral aspect of the atom itself, this “selection” and contribution occurrence is one and the same

event as the absorption of the propagative energy by a particular atom. In this account *no particle collides in any sense with an atom*; instead, a spread-out, pervasive process is absorbed at discrete localities by virtue of pre-existing active linking transitions between the localized aspect of physical reality and a purely contextual or prelocal aspect. (I should add that not only atoms and other so-called particles, but unoccupied space as well, must on this view consist of events linked intrinsically into prelocal background process.) All this might sound a bit complex and contrived at first, but it is really a direct effect of two simple proposals: that the atom is event-constituted and that events bear “internal relatedness” to a total causal context in which they are embedded. The catch, again, is that we have to accept the idea of a literally prematerial and prelocal (that is, essentially contextual and pervasive) aspect of physical reality characterized essentially by activity or transition. The whole idea is derived directly from the assumption that causal transition—i.e., the “event”—is the fundamental and irreducible structure of physical reality. (Some very good philosophers appear to believe that a post-materialist theory of physical reality requires panexperientialism. While I am open to the possibility that the elemental “event” can only really be understood as an occasion of experience, I have yet to be fully convinced.)

To summarize the preceding, it seems to me that the event-ontology, conceived as a radical alternative to the classical conception of physical reality, contains and implies a quite natural solution to the notorious problem of how the quantum measurement takes place.

As to the question of the macro-nature of the propagation, that is, the exact nature of the wavelike empty-space processes, I have here only given a basic foothold of an idea, namely that light propagates as a gap-inclusive reiteration of pulses of energy embedded in a dense background flux of activity which is only to be understood ontologically, that is, as an inherent character of physical reality. A detailed elaboration of this can be found in a recent article of mine in *Process Studies*.

In my published works so far I have explored how the same explanatory success as we just saw with the double-slit experiment might be repeated across other domains and aspects of physics using the same background proposal.

5. The Relationist Solution from Other Quarters

Whiteheadians are not the only ones to have noted that “internal relatedness,” if such a thing could be made sense of, would solve quantum mysteries. Consider this quotation from a background essay by James T. Cushing which occurs at the

beginning of an anthology he edited with Ernan McMullin titled *Philosophical Implications of Quantum Theory*:

One of the most interesting philosophical questions, perhaps, concerns the relations among empirical adequacy, explanation, and understanding for quantum phenomena. Are explanation and understanding really possible when a detailed causal explanation is in principle impossible? In Bas van Fraassen's (1985) terms, are the EPR correlations a mystery? Paul Teller has suggested that relational properties of physical objects may not simply supervene wholly upon nonrelational properties of localizable individuals, but that a type of "*relational holism*" [emphasis in original] is essential in which the objects have inherent relations among themselves. He claims that this is "a holism we can understand" (Teller 1986, 73). But is it? A central issue is whether or not we can truly *understand* such descriptions of our world.

It seems safe to say that "relational holism" here says pretty much the same thing as the "internal (or inherent) relatedness" that Whiteheadians talk about. Paul Teller sees relational holism as the overcoming of "particularism," which seems to be very much the same thing as the metaphysical position, criticized by Whiteheadians, that recognizes only external relations. From this standpoint, Cushing is questioning whether there really is understandability beyond "particularism." But by focussing on Teller's suggestion at this point, he appears to be tacitly acknowledging that *if* the general idea of relational holism could be shown to be or made to be fully understandable in application to physical realities, this *would* be a breakthrough in making sense of one of the most notorious mysteries of quantum physics. The next question is obvious: Does the physical ontology of "events" as fundamental entities, of nature as fundamentally "passage," and so on, succeed in giving relational holism a detailed intelligible content that shows it to be a fully understandable possibility? If so, the implication of this, going by Cushing, would be that a major quantum perplexity (here called the EPR correlations) is, if not wholly resolved, at least some way toward being resolved. This would apply, of course, to anyone's effort to frame an interpretation of physics according to Whiteheadian principles, not just mine. And one more thing: Common reason suggests that the constituents of the causal relation are "events." Suppose that what has unique success in explaining phenomena is an ontology developed in terms of "events" and their internal connectedness. What could this be other than a furthering of the prospects for causal explanation, in which events beget other events, and so on, quite contrary to Cushing's statement that "a detailed causal explanation is in principle impossible"? As I see it, a fundamental ontology based on "event" or "process"

thinking, which overcomes the limitations of materialistic and localistic mental pictures, comes with the pervasive possibility of causal explanation. This is because genuine causal connectedness—which is to say transition, process, becoming, difference constituting identity (of a process or event), and so on—is built into the ontological position, the account of “being.” Clearly, if locality is an emergent rather than a fundamental aspect of reality, then nonlocal connection ceases to be a “hard” mystery, intractable to causal thinking, and becomes at least potentially intelligible in causal terms.

6. Dawn of a New Physics?

Having spent considerable time thinking along these lines, and feeling rather isolated in my positions, I was naturally excited to discover the work of Reginald Cahill on “process physics.” He pursues this project from a more technical and mathematical angle, but also with a philosophical dimension. I am not equipped to comment on crucial aspects of it, but I can comment on its nontechnical aspects. Both his and my writings have talked about the rehabilitation of a Heraclitean as against a Parmenidean ontology. My sense is that his proposal might well fill out the broader philosophical-ontological project by supplying a formal-mathematical and technical side of the picture. My own focus has been on reestablishing a broader role for non-mathematical reasoning in physical science, more like the kind of balance that exists in other sciences. For the sake of restoring this balance, my emphasis has been deliberately and decisively away from technical and mathematical approaches. The event-ontology as I draw it out and apply it seems to me amenable to Cahill’s account of absolute space in terms of “quantum foam,” which fills the role of the old “aether” but is continually forming itself. One thing that makes me particularly optimistic about Cahill’s work is his critical perspective toward Einsteinian relativity physics. Though this would appear to break radically with current mainstream physics, there are a variety of reasons to believe nevertheless that here Cahill gets it right on a crucial issue. This critical perspective on relativity theory is shared by Whitehead in *Principle of Relativity* and other works, as well as by the later work of philosopher of science Herbert Dingle, who studied relativity theory under Whitehead. I am interested to know what Professor Cahill thinks about the controversy over Whitehead’s alternative theory of relativity.

7. Conclusion: Philosophy and Science

In summary, I believe that the current gulf of specialization between physics and philosophy is merely due to the particular historical trends in both fields that have drawn them along mutually isolating trajectories. One certainly should not assume that because the science of physics itself has apparently abandoned natural

philosophy in its historical meaning, this settles the question, since this act of abandonment might have purely pragmatic grounds and may well be temporary in the larger picture, especially considering the abrupt transitions from one era of science to the next as brought out by Thomas Kuhn.

A genuine coinciding of physical science with philosophy occurs, I argue, in the form of fundamental ontology. The scientific significance of ontology as a procedure of inquiry is best indicated by its sheer explanatory power. A single proposal of fundamental ontology—namely that physical reality or being is characterized by process (or becoming, activity, transition, etc.)—is evidenced in such a large and diverse range of phenomena across the whole of physics that the probability of its not being true is extremely small. Moreover, it seems clear that both the encompassing general explanation, that is, the "process" fundamental ontology, and the explanations of particular phenomena, are going to be essentially conceptual and semantical rather than mathematical in content. In short, the whole undertaking takes place in the common language. Its discourse is never technical; for example, the convenient language of "particles" is repudiated as falling back on materialistic concepts. Naturally there is likely to be another aspect to any revision of basic physical concepts, which will be mathematical and technical with a view to experimental testing and prediction. But in my view it is a mistake not to accord the purely explanatory and "natural reasoning" dimension of inquiry an autonomous status and value as a legitimate aspect of advancing scientific knowledge.