Chapter 7. The Metaphysics of Possibility in PTI

"All the world's a stage,
And all the men and women merely players:
They have their exits and their entrances;
And one man in his time plays many parts..."

Shakespeare, *As You Like It*

PTI is a realist interpretation which, its strong form, takes the physical referent for quantum states[1] to be ontologically real possibilities existing in a pre-spacetime realm, where the latter is described by Hilbert Space (or--more accurately--Fock Space, accommodating the relativistic domain). These possibilities are taken as real because they are physically efficacious, leading indeterministically to transactions which give rise to the empirical events of the spacetime theatre. PTI can also be considered in a weaker, agnostic, 'structural realist' version, in which the Hilbert Space structure of the theory is taken as referring to some structure in the real world without specifying what that structure is. (I specifically address the structural realism aspect in section 7.6.) PTI in its strong form is very different from the traditional 'possibilist realism' or 'modal realism' pioneered by David Lewis. In order to make this distinction clear, I first briefly review the traditional account.

7.1 Traditional formulations of the notion of possibility

As noted in Chapter 1, David Lewis pioneered realism about possibilities in a comprehensive and sustained philosophical examination of entities he termed "possible worlds" Lewis (1986). In Lewis' formulation, possible worlds are the same sorts of entities as our own world. They are states of affairs that could conceivably occur, but

[1] The term 'semantic realism' is often used to denote the idea that theoretical terms refer to specific physical entities, the position I advocate herein concerning quantum theory. In contrast, 'epistemic realism' denotes the idea that we have good reason to believe a theory's claims. I consider a stance of epistemic realism about quantum theory as relatively uncontroversial, so I do not address it here.

which differ from the set of events in the actual (experienced) world. According to Lewis, these worlds are every bit as real as the actual world; the only difference is that the actual world is the one we happen to inhabit. Thus, in this theory, 'actual' is *indexical*, meaning that it is a matter of perspective, not of kind or nature. Figure 7.1 schematically illustrates this relationship between Lewisian possible worlds and the actual world.

(a) (b) (c) (d)

Figure 7.1: A set of "possible worlds" in traditional Lewisian possibilist realism.[2] Worlds (a), (b), and (d) are possible worlds; the 'actual world' (c) (in shaded rectangle) is defined only relative to an observer. Each world is considered to be a complete, universal set of events.

The Lewisian formulation is readily applicable to 'many-worlds'—type interpretations, in which each measurement event[3] causes a 'branching' or copying of a particular world or collection of objects. However, PTI's proposed dynamic possibilities

[2] Image: Pixomar / FreeDigitalPhotos.net

[3] Recall that, as discussed in Fields (2010), the notion of a 'measurement event' is ill-defined in Everettian interpretations because it requires dividing the physical objects under study into those which constitute the 'measured system' and the 'measuring apparatus'. Such a specification is non-unique and therefore requires reference to an external observer or arbitrary choice.

are fundamentally different from those of the Lewisian picture, as will be discussed in the next section.

7.2 The PTI formulation: possibility as physically real potentiality

As noted above, Lewisian possible worlds are just alternative universal states of affairs, and are no different in their basic nature from the actual world. In contrast, the dynamical possibilities referred to by state vectors in PTI are Heisenbergian 'potentia,' which are less real than events in the actual world, yet more real than mere thoughts or imaginings or conceivable events. This relationship is illustrated in Figure 7.2.[4]

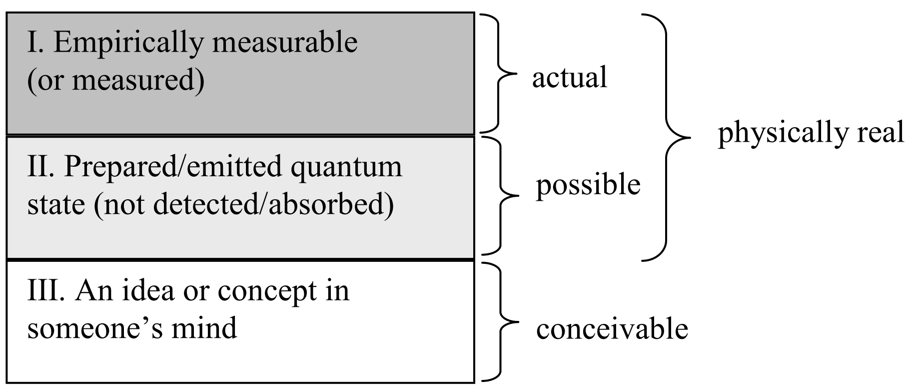


Figure 7.2
Quantum entities are less real than empirically measurable events, but more real than thoughts or merely conceivable situations.

Under PTI, the realist use of the term 'possible' or 'potential' refers to physical possibilities; that is, entities which can directly give rise to specific observable physical

[4] Actually, mental activity *could* be considered real as well in that it could be based on quantum possibilities; this remains an interesting metaphysical question, but it is not crucial for PTI.

phenomena based on a realized transaction.[5] This is distinct from the common usage of the term 'possible' or 'possibility' to denote a situation or state of affairs which is merely conceivable or consistent with physical law. So, in general, 'possibilities' in PTI are entities underlying specific *individual* events rather than collective, universal sets of events such as the worlds in Figure 7.2. In more technical terms, the possibilities underlying, for example, the detection of a photon at point X on a photographic plate are the offer wave components constituting the path integral in Feynman's 'sum over paths' (recall Chapter 4).

Specific examples of each metaphysical category illustrated in Figure 7.2 are:

I. A detector click
II. A spin ½ atom prepared in a state of 'up along x'
III. "That possible fat man in the doorway"[6]

As noted in Chapter 1, traditional approaches to measurement in quantum theory inevitably end up needing to invoke an 'observing consciousness' in order to 'collapse' the wave function (or state vector) and bring about a determinate outcome, necessitating speculative forays into psycho-physical parallelism. Thus, PTI is actually *less radical* that these much more common approaches because it does not need to invoke mental substance in order to address what certainly started out as a purely physical, scientific question about material objects.

7.3 Offer waves, as potentia, are not individuals.

[5] This is very similar, indeed perhaps the same as, Teller's proposal (Teller 1995, 2002) that (however negatively stated in the words of Frigg 2005, 512), the quantum field "has only something like structural efficacy, meaning that it does no more than [specify] the structure of physically possible occurrences."

[6] This is a reference to a famous 1948 paper by Quine, "On What There Is," in which he criticizes traditional possibilist realism because of the apparent proliferation of any conceivable entity in a 'slum of possibles' that is a 'breeding ground for disorderly elements'. (Reprinted in Quine, 1953).

A significant component of the literature in philosophy of quantum theory is addressed to understanding the metaphysical nature of quantum systems such as electrons in the following sense: are they individuals, i.e., do they have some 'essence' above and beyond the usual dynamical attributes such as momentum, spin, and (in traditional approaches) spacetime location, etc.? In the PTI picture, the answer to this question is an unequivocal "No."[7] This is because the PTI (as well as original TI) ontology has no 'particles' to whom one could even begin to attribute individualized 'essences' or identities. In 7.3.1 we will see that a direct consequence of the nonexistence of particles is that quantum states are restricted in their mathematical form to be either symmetric (meaning unchanged under an exchange of subsystem labels) or antisymmetric (meaning changing only by a sign under an exchange of subsystem labels), and must therefore be either bosons or fermions. (The latter feature of the quantum mechanics of multi-particle systems is sometimes viewed as a curious fact in need of explanation).[8] In 7.3.2 I will discuss the apparent dependence of particle number on an observer's state of motion,which also suggests that the notion of particle is not fundamental.

7.3.1 Wave function symmetry related to nonexistence of particles

First, recall that standard quantum mechanics assigns to a quantum emitted from a specific location in the laboratory, at some time $t=0$, a Gaussian wave function[9] depending on the amount of time elapsed since its emission. Such a wave function is illustrated schematically in Figure 7.3 (a). Now, suppose two quanta of the same type are emitted at $t=0$ (say, both electrons). If sufficient time has elapsed, the wave function for the two quanta looks like Figure 7.3 (b): that is, there is significant overlap (cross-hatched region). The usual way of discussing this is to say that there is no way to know which particle is described by which wave function, and therefore one has to assume that the

[7] Thus I agree with Teller's view (1997) that quanta lack "primitive thisness."

[8] In particular, O. W. Greenberg has explored the idea of 'parastatistics' in which the quanta are neither bosons nor fermions.

[9] Again, offer waves are not restricted to being wave functions, which are committed to a particular basis (namely the position basis); but this is probably the most familiar and intuitively easy way to conceptualize the issue under study.

particles are indistinguishable, where their indistinguishability is contingent on the fact that wave functions can overlap. However, in the TI/PTI ontology, there are no 'particles' associated with either wave function, independently of whether or not the wave functions overlap. This leads to a different, but arguably stronger, demonstration of the fact that quantum states must be either symmetric or antisymmetric.

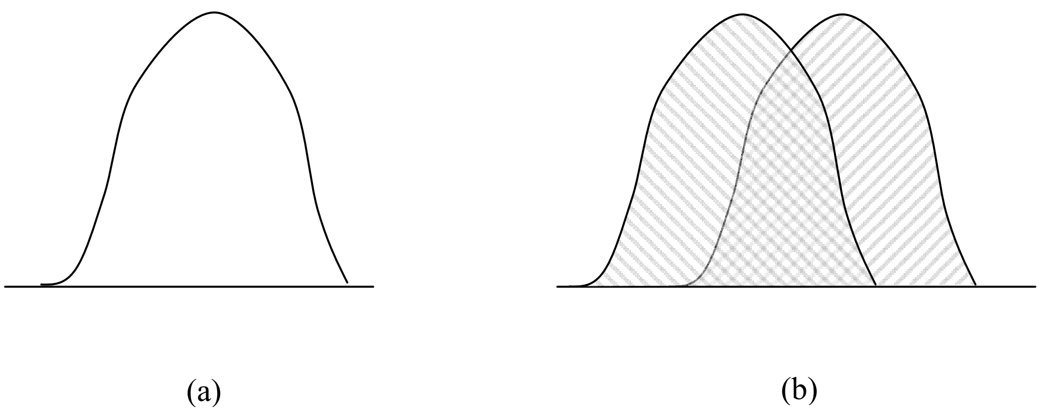


Figure 7.3. (a): The gaussian wave function of a free quantum.
(b): Overlapping wave functions of two free quanta.

The usual way of arguing that quantum states must be either symmetric or antisymmetric is by demanding that observable quantities (such as probabilities of detection) be invariant under a change of particle labels. For example, consider (as in Eisberg and Resnick 1974) two particles in a one-dimensional box of side length a, one of them occupying the ground state $G(x_1)$ and the other occupying the first excited state $F(x_2)$ where x_1 and x_2 denote the location of each of the particles. (The two functions G and F have very different dependences on spatial location x.[10]) Now consider a non-

---

[10] For this example, they are $G(x) \sim \cos\frac{\pi x}{a}$ and $F(x) \sim \sin\frac{2\pi x}{a}$

symmetrised two-particle wavefunction such as $\Psi(x_1, x_2) = G(x_1)\, F(x_2)$. The probability density will be

$$P(x_1, x_2) = \Psi^*(x_1, x_2)\, \Psi\, (x_1, x_2) = G^*(x_1)\, F^*(x_2)\, G(x_1)\, F(x_2). \qquad (7.1)$$

But if we transpose the particle labels, then we get

$$P\, (x_2, x_1) = \Psi^*(x_2, x_1)\, \Psi\, (x_2, x_1) = G^*(x_2)\, F^*(x_1)\, G(x_2\,)\, F(x_1); \qquad (7.2)$$

In equations (7.1) and (7.2) we have the functions G and F and their complex conjugates evaluated at different points x_i , so the probability densities $P(x_1, x_2)$ and $P(x_2, x_1)$ are not necessarily equal. In order to make them equal, we have to construct either the symmetric wave function Ψ_S or the antisymmetric wave function Ψ_A, viz.:

$$\Psi_S(x_1, x_2) = \frac{1}{\sqrt{2}}\, [G(x_1)\, F(x_2) + G(x_2)\, F(x_1)]$$

$$\Psi_A(x_1, x_2) = \frac{1}{\sqrt{2}}\, [G(x_1)\, F(x_2) - G(x_2)\, F(x_1)]$$

Thus, to review, the usual argument demands that empirically observable quantities such as the probability density be invariant under a transposing of particle labels based on the premise that quantum objects are ‘indistinguishable.’ The latter premise is arrived at because of an argument such as “wave function overlap makes it impossible to tell which particle is associated with which wave function.”

Now suppose there are no particles at all. Then there is no auxiliary entity to associate with a wave function which could be ‘labeled,’ and which therefore could be addressed by the above sort of argument. But we can arrive at the need for symmetrization more directly as follows. Consider eqs. (7.1) and (7.2). If there are no particles whose labels could be transposed, the only way to make these two expressions equal is to demand that $x_1 = x_2$. But if we do that, the resulting wave function only refers to *one* quantum. In the absence of auxiliary (labelable) quantum entities, the only way we can enforce the fact that there are two quanta is to provide two distinct arguments x_1 and x_2. Then the arguments *don't label anything*, but they are required in order to distinguish between a wave function for only one quantum and a wave function for two quanta. If they don't label anything, then there can be no physically appropriate meaning in an expression like $G(x_1)\ F(x_2)$ which implies a difference between the two arguments of the functions G and F. The mathematical expression of the fact that *there is no physical difference between the two arguments* is precisely the set of symmetric and antisymmetric wave functions above. Thus, *the observed fact that Nature has only bosons (represented by symmetric states) and fermions (represented by antisymmetric states) can be arrived at simply by assuming that there are actually no 'particles' (or individuals) meriting labels of any kind*. Again, we return to the idea that the fundamental ontological reality is that of nonlocalized fields and their excitations. The new feature proposed in PTI is that these fields represent possibilities for transactions, the latter corresponding to specific observable events.

7.3.2 The puzzle of 'Rindler quanta'

An ongoing discussion in the literature concerns so-called "Rindler quanta." These are excited states of the field which are only seen by an observer in a state of constant acceleration with respect to an inertial observer who (in contrast) sees a vacuum (unexcited) state of the field. The field excitations have the form of a "thermal bath," which is similar to the coherent state discussed in Chapter 6 in the sense that it contains an indefinite number of quanta. An accelerating detector registers quanta from this 'thermal bath' which does not seem to be present to the inertial observer. The phenomenon of Rindler quanta has serious implications for the question of the 'reality' of quanta, since it seems to tell us that not only the properties of quanta but even *whether or* *not there are any quanta* is a purely 'contextual' matter—i.e., dependent on the observer and what types of measurements he/she chooses to make.[11]

From the PTI standpoint, the problem evaporates. There are no independently existing 'quanta' in either case; there are simply possible transactions. Rindler phenomena tell us that an accelerating observer (modeled by a simple accelerating detector in the literature on this topic) simply has a different perspective on the relevant transactional opportunities than does an inertial observer. In particular, to an inertial observer, the accelerating detector *emits* quanta, which are simply related to the energy of its acceleration. Thus, a transaction appearing to an inertial observer as a quantum emitted by the accelerating detector and received by an inertial detector is seen by the accelerating observer as a quantum emitted by the field and received by the accelerating detector. In both cases, a transaction occurs; it is simply interpreted differently by the different observers. The two observers define their 'field vacuum state' differently;[12] they experience the very same transaction, but seen from different perspectives based on their differing reference vacuum states. Since transactions, and the possibilities leading to them, are the fundamental ontological entities in TI—rather than quanta---TI has no trouble accounting for the phenomenon of Rindler quanta.

7.4 The macrosopic world in PTI

In this section, I consider macroscopic objects and the everyday level of experience in the transactional picture.

---

[11] Cf., "Are Rindler Quanta Real?", Clifton and Halvorsen 2000. http://philsci-archive.pitt.edu/73/1/rindler.pdf

[12] The Rindler vacuum state actually has *negative* stress-energy density in an amount exactly balanced by the stress-energy density in the 'thermal bath' of Rindler quanta. Cf. DeWitt (2003, 608-618). Thus the Rindler vacuum and the thermal bath together are equivalent to the Minkowski (inertial) vacuum in terms of energy.

7.4.1 Macroscopic objects are based on networks of transactions

I said in the previous section that there are no individual ‘particles,’ just field excitations-- Heisenbergian ‘potentia’-- that can lead to observable events via actualized transactions. Here I wish to address the question: what is it about transactions that make events ‘observable’?

First, recall that it is only through actualized transactions that conserved physical quantities (such as energy, momentum, and angular momentum) can be transferred. Such transfers occur between emitters and absorbers which are also field currents (recall Chapter 6). Thus the supporting entities and structures for actualized transactions are generally only potentia themselves. The realizing of phenomena is a kind of ‘bootstrapping’ process in which actualized events are rooted in unactualized possibilities.

For a specific illustration, consider a baseball, depicted in Figure 7.4 as we ‘zoom in’ to view it on smaller and smaller scales. The third square represents molecular constituents; the fourth square, a Feynman diagram, represents interactions among subatomic constituents both within molecules (intramolecular forces) and between molecules (intermolecular forces). Bound systems such as atoms are only offer waves, but they can (and do) continually emit and absorb photons and other subatomic quanta. Those emitted quanta are absorbed by, for example, our sense organs, setting up enormous numbers of transactions transferring energy between ourselves and the atomic constituents of the baseball. The energy transfers effect changes in our brain, providing for our perception of the baseball.

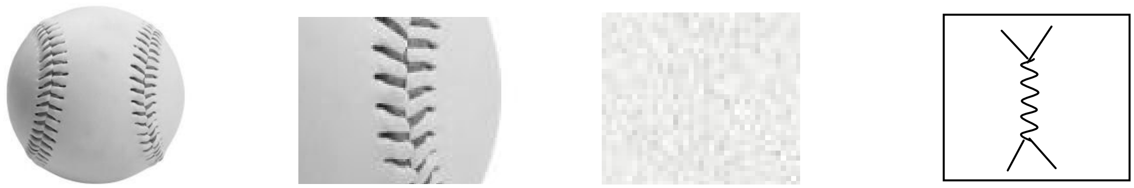


Figure 7.4: Zooming in on a baseball.[13]

Thus, in the TI (and PTI) picture, a necessary feature and key component of any observation of a system is absorption of offer waves and corresponding generation of confirmation waves. We can go further and make a general interpretational identification of absorption with observation in a way not available to traditional interpretations of quantum theory: absorption is the way the universe "observes itself" and makes things happen. This identification is possible because under TI, absorption plays an equal role with emission in the dynamics of an event. In contrast, traditional interpretations take emission as the entire dynamical story and then cannot account for why observations seem to have such a special role in the theory. As Feynman tells us, we should sum the amplitudes over 'unobserved' intermediate stages of an event to get a total amplitude for a final 'observed' event, and then take the square of that. Why should we square that amplitude, and why should Nature care whether we 'observe' or not in this algorithm? *The only way that Nature could know or care would be because something physical really happens in such 'observations,' and the only possible physical process accompanying an 'observation' is absorption*. Under traditional interpretations which

[13] Baseball image: Nutdanai Apikhomboonwaroot / FreeDigitalPhotos.net

neglect absorption, the above apparently inexplicable procedure leads us into an impenetrable thicket of anthropomorphic considerations of the supposed affect of a mental substance -- “consciousness” --- on a physical substance, namely a quantum system. In Feynman’s words: “*Do not keep saying to yourself, if you can possible avoid it, "But how can it be like that?" because you will get 'down the drain', into a blind alley from which nobody has escaped. Nobody knows how it can be like that.”*[14] I suggest that an escape route from the ‘blind alley’ is available; the price (or dividend, depending on one’s point of view) is taking absorption into account as a real dynamical process and embracing the implications for our world view which are explored in this and the next chapter.

7.4.2 Macrosopic observation as primarily intersubjective.

Next, let’s consider a prototypical observation: once again, the two-slit experiment. Let’s assume that the quanta under study are monochromatic (single frequency) photons originating from a laser. In setting up the laser and the two screens, we handle macroscopic materials such as photographic plates. All of these actions consist of molecular level transactions between enormous numbers of atoms and between some of the surface atoms and our hands. Energy is transferred via these transactions from those emitters to absorbers on our bodies; that energy serves as input for additional emissions between our sense organs and absorbers in our nerves, and so on, culminating in transfers of energy to our brains.[15] Brain changes make possible our perception that ‘something happened’ (recall, from Chapter 2, Descartes’ argument that it is not possible to observe anything that does not produce a perceptible change). But exactly *what happened* can vary considerably, depending on the specific transactions being actualized. A transaction between the photographic plate and my retina will not be the same as the transaction between another part of the plate and someone else’s retina, but the laws of physics[16]

---

[14]The Messenger Lectures, 1964, MIT

[15] This description is not meant to be physiologically rigorous; it is merely an indication of how energy transfers via transactions ultimately result in brain changes.

[16] E.g., conservation of physical quantities corresponding to the symmetries of the system and compliance with such laws as the principle of least action.

ensure that all those many transactions are coordinated such that a coherent set of phenomena are created.

The point is that a macrosopic 'observed event' is generally the product of an enormous number of transactions, even for only one observer. If one wishes to have one's observation corroborated, more transactions are required as another set of eyes, hands, etc. are introduced. These comprise a different set of absorbers, and the emitters may well be different as well. The transactions occurring for the second observer are not the same as those occurring for the first observer. For there to be corroboration, the two observers have to agree on macroscopic facts such as "There is a dark spot at position x=50" which can be instantiated by a large number of different sets of microscopic transactions. The process of corroboration is thus one of comparing the transaction-based perceptions of two (or more) different observers and deciding whether they represent the same macroscopic event. *But the event itself can be no more than the sets of transactions taken as constituting it.* It is always definable only in terms of the subjective or intersubjective experiences of an observer or observers.

The above should not be taken as a reversion to mere subjectivism,[17] since for any individual transaction between emitter and absorber, there *is* an objective matter of fact concerning which transaction was actualized. Furthermore, there are certainly experiments in which an individual actualized transaction can be amplified to the macroscopic level, as in detection by a photomultiplier. But even in the case of amplification of a single transaction to the observable level, the type of event observed depends on what absorbers are present for the emitted quantum. In general, ordinary events are collections of enormous numbers of transactions, with different sets of transactions for different observers.

7.4.3 Implications for the Realism/Antirealism debate

[17] Subjectivism is the view that knowledge can only be about experiences of a perceiving subject and not about any genuine object external to the subject.

The PTI account of observation provides for a synthesis of the longstanding 'realism/antirealism' dichotomy in that both doctrines can be seen as conveying a partial truth. Let us first briefly review these doctrines.

The doctrine of realism spans many forms, from the 'naive realism' most of us grow up believing, to much more sophisticated forms, including 'scientific realism,' that have evolved in philosophical debate. For our purposes, we can make do with a definition from the Stanford Encyclopedia of Philosophy: "Metaphysically, [scientific] realism is committed to the mind-independent existence of the world investigated by the sciences."[18] The world and the entities in it are assumed by the scientific realist to exist independently of our minds, perceptions, and knowledge. The objects in our world are considered as possessing definite properties, which we can come to know without fundamentally disturbing or changing those basic properties.

Antirealism denies this view; it asserts that objects of knowledge are dependent on (or constituted by) some form of subjectivity or mental substance. For example, the philosopher and Irish Cleric George Berkeley famously asserted -- and ably defended -- the doctrine '*esse est percipi'* (to be is to be perceived) , and concluded that all objects are ultimately ideas in the mind of God.[19] The work of Immanuel Kant (discussed previously in Chapter 2) is relevant to the realism/antirealism dichotomy because Kant asserted that the only world we can ever come to know is that which depends on the concepts and functions of the human mind: the world of appearance, or what he termed the 'phenomenal' realm. Kant did assert that there was 'something else out there'; in his terms, the 'noumenal' realm, but it was a basic principle of his philosophy that we can never come to know this elusive realm, that which he called the 'thing-in-itself.' Devitt (1991) refers to Kant as a 'weak realist' because Kant did hold that there was *something* that existed independently of our knowledge, even if we could (according to Kant) never obtain knowledge about it.

---

[18] From Chakravartty, Anjan, "Scientific Realism", *The Stanford Encyclopedia of Philosophy (Summer 2011 Edition)*, Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/sum2011/entries/scientific-realism/>. I consider only the physical world, not social or political 'worlds' for the purposes of this work.

[19] This antirealist doctrine was primarily explicated in Berkeley's *Treatise Concerning the Principles of Human Knowledge* (1710).

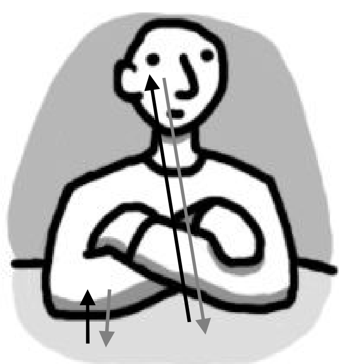
In the latter 20th century, Kant's basic approach evolved into a version of antirealism generally known as 'constructivism.' In Devitt's terms, constructivism asserts that 'we make the known world" (Devitt 1991, 236). He correctly (in my view) points out that much of the constructivist argument rests on a conflation of epistemological (knowledge-based), semantic (meaning-based), and ontological (metaphysical) issues. But despite these weaknesses in the usual sorts of arguments for constructivism, it is in quantum theory where this form of antirealism begins to gain traction because of the notorious dependence of property detection on what we choose to measure (recall Section 1.1). In contrast, realism demands that the object of knowledge is *not* fundamentally changed by observation.[20]

We can formulate this dispute in terms of the *subject-object distinction* presupposed by any discussion about knowledge on the part of an observer (subject) and the aspect of the world he wishes to know about (object). In these terms, the realist believes that knowledge is *object-driven*, while the antirealist believes that knowledge is *subject-driven*. We can now make contact with PTI by identifying the 'object' with the offer wave and the 'subject' with the set of confirmations taking place upon absorption of the offer wave components. The latter can be thought of in terms of a particular experimental setup or just in terms of the sense organs of an observer.

With the above identification, PTI can resolve the realism/antirealism conflict by declaring a measured form of 'victory' for both sides. Realism correctly asserts that there truly is "something out there" that is independent of observation. In PTI terms, this is the object represented by a quantum state or offer wave $|\Psi\rangle$. But Antirealism correctly asserts that the form that the 'something' takes is at least partly dependent on how it is

[20] The Bohmian theory provides a way to retain realism about quantum objects because it asserts that there really are quantum particles with definite positions, independently of our knowledge or concepts. (Bohmians acknowledge that we disturb those positions in an uncontrollable way when we measure certain contrasting (noncommuting) properties, but that if we choose to measure position, what we find is a particle position that existed independent of our observation. However, I do not favor the Bohmian theory because the 'guided particle' ontology is incompatible with the relativistic domain (e.g., recall that the classical electromagnetic field must be described by an indefinite number of quanta), there is no account of how guiding waves living in 3N-dimensional configuration space 'guide' particles in 3-space, and its account of the Born Rule can be only statistical in nature.

observed (in physical terms, detected in an actualized transaction), which takes into account the types of confirmations $\langle \Phi |$ generated by absorbers. Recall from Chapter 4 the man observing the table, reproduced here as Figure 7.5. It's not the 'categories' or 'concepts' in his mind that do the primary work here, but simply the absorbers in his sense organs. Thus, the 'subject-object' dichotomy becomes the 'confirmation-offer' complementary relationship in PTI.



Object $\Leftrightarrow$ Offer Wave
Subject $\Leftrightarrow$ Confirmation Wave
Phenomenon $\Leftrightarrow$ Transaction

Figure 7.5 . Subject and object.

The foregoing "defangs" anti-realism in the following sense: it need not be anthropocentric, since in PTI, one can have an actual phenomenon/event in the absence of a 'conscious observer.' All one needs is emitters and absorbers, which are physical (if pre-spacetime) entities.

This formulation also provides a solution to a long-standing puzzle faced by Kant scholars. The problem is this: Kant insisted that knowledge of the phenomenal world was obtained by way of an interaction of human perceptual activity and concepts with the noumenal world. But the nature of this interaction was deeply obscure. If the noumenal object or 'thing-in-itself' was truly 'unknowable,' what sort of causal power could it have to produce knowledge, even if through human-centered concepts and perceptions? PTI provides at least a partial answer: the noumenal realm is the realm of offer waves; the phenomenal realm begins with their absorptions, which generate confirmations and ultimately specific actualized events. The nature of the interaction between the noumenal realm and the phenomenal realm is just the transactional process.

Thus, in Kantian terms, one can say that the knowable phenomenon is rooted in the unknowable noumenon (quantum entity or offer wave) which is answered by confirmations from absorbers in the sensory organs. Actualized transactions result in transfers of energy, which are processed by the senses and their attendant cognitive structures. There are two components to the latter process: (1) physical/ontological (the quantum transaction arising from absorption by the sense organs) and (2) epistemic (the subjective/theoretical concepts used to identify and understand the phenomenon arising from the transaction). The current work deals only with aspect (1) because that is all that is necessary to account for the basic phenomena (the 'raw sense data' as described in a Russellian or foundationalist account)[21]. As has been noted by other researchers (e.g., Kent 2010), having to bring in philosophies of mind or explicit psycho-physical dualism weakens the scientific account because there is no account of 'mental substance' in the exact science of physics. Traditional 'collapse' approaches inevitably must engage in forays into psychologism of this kind because there is no consistent way to break the linearity of the theory and thereby provide for a determinate result on the physical level without taking absorption into account.

Thus, the transactional model denies the strongest form of realism, namely the view that objects in their independent entirety are 'directly given' to the senses; but it provides support for what is termed 'representational realism'. The latter assumes that what is directly present to the knower is not the object itself, but 'sense data' that make

[21] In this regard, I do not deal in this work with the deep and subtle questions concerning the relationship of subjective perception to sense data, although I do assert that perception properly needs an object, even if not 'physical' in the usual sense: perception is transitive and presupposes the fundamental subject-object distinction. (In contrast, one might refer to a perception-free account of experience as *awareness*, which is the ability to perceive.) I assume that *whatever* it is that is subjectively perceived can be attributed to physical transfers of energy via actualized transactions. In cases of non-veridical or hallucinatory perception, an account may be possible in terms of atypical biological processes in the hallucinating subject which ultimately can be traced to transactions among the microscopic constituents of biological components (e.g., neurons).

contact with the objectively existing external object and therefore provide authentic knowledge about it. In PTI, sense data are the product of the object, as a source of offer waves -- and the subject, as a set of absorbers. Together, the subject and object produce transactions that provide information about the object *conditioned on the manner and circumstances under which it is perceived*. The latter sentence is important: such knowledge is always only partial, since transactions vary depending on what types of absorbers are available to the offer waves comprising the object.

7.5 An example: phenomenon vs. noumenon.

This section makes contact with Shakespeare's famous verse that opened this chapter. Let us consider an example of the way in which a *phenomenal* world of appearance, thought of as occurring in 'spacetime,' arises from a transcendent *noumenal* level in terms of an aspect of popular culture: internet-based 'massive multiplayer online role playing games' or MMORPGs, such as "World of Warcraft" or "Second Life".

In the game Second Life, a player can access an online game environment by loading a software package on his local computer. The player uses the software to create for himself a character, or "avatar", which represents him in the online game environment. Let's call the human player 'Jonathan' and his game avatar 'Jon.' Once Jon is established in a game environment, he carries with him a point of view (POV) through which Jonathan can perceive what Jon perceives as the latter pursues his in-game career. Now, suppose Jonathan decides to have Jon create something—a table, for example. Jonathan can input certain commands through Jon into the game environment, and a 'table' will appear at the desired 'location' in Jon's vicinity.

Now, consider another human player, Maria, whose game avatar is 'Mia.' Maria might be sitting at her computer in Sydney, Australia while Jonathan is in Montreal, Canada. Nevertheless, their avatars may be in the same game environment 'room', say the 'Philosophy Library,' where Jonathan/Jon has just created his 'table'. Now, suppose Jon and Mia don't know that they are only avatars, but assume themselves to be autonomous beings. We might imagine Jon and Mia discussing the table in front of them along the same lines as the discussion in Bertrand Russell's *The Problems of Philosophy*, Chapter 1. For readers unfamiliar with this material, Russell's discussion involves noting that the appearance of the table depends, to a great extent, on the different conditions under which it is viewed (or, more generally, perceived). These appearances may be mutually contradictory: for example, the table may appear smooth and shiny to the eye, but rough and textured under a microscope. Following this line of argument, Russell famously concludes that the only knowledge we can have of the table is of various aspects of its *appearance,* which must always be contingent on the conditions under which it is perceived; and that the 'real' table underneath the appearances -- whatever that might be -- is a deeply mysterious object. In his words: "Thus it becomes evident that the real table, if there is one, is not the same as what we immediately experience by sight or touch or hearing. The real table, if there is one, is not immediately known to us at all, but must be an inference from what is immediately known. Hence, two very difficult questions at once arise; namely, (1) Is there a real table at all? (2) If so, what sort of object can it be?" (Russell 1959 , 11). Russell's presentation is an account of the deep divide between, in Kant's terms, the world of appearance (phenomenon) and the thing-in-itself (noumenon). (Notice how he repeats the phrase 'if there is one," to emphasize how little we really know about it.)

If Jon and Mia pursue this analysis, they, too, find that the only knowledge they have of the table is based on its appearance (which their human players can monitor on their computer screens showing their avatars' POVs). Suppose the side of the table first facing Jon is black and other side, facing Mia, is white. Jon and Mia can talk to each other and discuss what they see, and they can agree to compare their perceptions by, say, changing places. Then Mia can confirm that the other side of the table is black, and vice versa. By performing this sorts of comparative observations, Mia and Jon can convince themselves that there 'really is' a table there because they can *corroborate* their different perceptions in a consistent way: their intersubjective observations form a coherent set. This suggests to them that there is 'something out there' that is the direct cause of their perceptions. In common-sense realist fashion, they might conclude that there is a 'real' table behind or underneath the appearances –a 'table-in-itself' -- that 'causes and resembles' their perceptions of it.[22]

But what about Jonathan and Maria? They both know that, while the 'table-in-itself' could be said to be the cause of Jon and Mia's perceptions of the game table, the 'table-in-itself' *does not 'resemble' the game table at all*. What is the 'table-in-itself'? It is nothing more than *information* in the form of binary data, manipulated by the people who created the game and by the human users (Jonathan and Maria). Compared to the game table perceived by Jon and Mia, it is insubstantial, abstract. And yet clearly, it *is the direct cause of the avatars' perceptions of an ordinary table* (the 'table-of-appearance') which, to them, is *not* just an 'illusion': the avatars cannot ignore it (for example, they will bump into it and may even incur physical damage if they try to run through it as if it isn't really there). If a human user were to somehow speak to an avatar like Mia and tell her that the objects in her world are nothing but information, she would scoff at the suggestion, and might ask why she suffers damage if she falls off a cliff in her 'only information' world. To the avatars, their world is perfectly concrete and consequential.

What does this little parable tell us about our world of 'ordinary' objects-of-appearance; that is, our empirical world? It tells us that it is conceivable and even quite possible that the 'table-in-itself' of *our* world is a very different entity from what the table-of-appearance might suggest. Because we, and the objects around us, are governed by the laws of physics (the 'rules of the game,' if you will), we interact with them and are affected by them, and in that sense they are certainly real, just as the game-environment objects are real for Jon and Mia. But the 'object-in-itself' is precisely *that aspect of the real object which is not perceived*. If such an aspect exists at all, we can reasonably expect it to be on an entirely different level from our perceived world of experience. Indeed, in terms of PTI, the 'object-in-itself' can be considered to be the offer wave(s) giving rise to possible transactions establishing the appearances of the object. Just as the 'table-in-itself' behind the avatars' table does not really live in their game world and is a

[22] The naive realist notion that independently existing objects outside the mind are the causes of ideas (perceptions) that resemble them is extensively critiqued in Descartes' *Meditations*.

kind of abstract information, so the offer waves giving rise to our real empirical objects do not live in spacetime and can be considered a kind of abstract but physically potent information – i.e., the physical possibilities first introduced in Chapter 4.

Now, recall from Chapter 2 that Kant asserted that the 'thing-in-itself' is *unknowable*. I wish to contest this, based on two main (disparate) points: (1) the fact that Kant has already been shown to have been mistaken in assuming that Euclidean (flat) space is one of the 'categories of experience,'[23]; and (2) the fact that *perceiving* (i.e., sensory perception) is not equivalent to *knowing*, since knowledge can also be obtained by intellectual (rational) means.[24] Concerning (2), recall the arguments in Chapter 2 that an empirically successful principle-type theory can be taken as providing new theoretical referents to previously unknown structural properties of the world. Such an approach to new knowledge is an *intellectual* or rational one rather than an empirical one, the latter being dependent on observation through sensory perception (including the use of sense-enhancing technologies such as microscopes or telescopes), and therefore being subject to the limitations of appearance. In contrast, unexpected but fruitful theoretical development can be considered as pointing to an abstract (non-observable) level of reality inaccessible to observation, as in the postulation of atoms. The latter was an intellectual step forward in knowledge, not an empirical one.

Recall also that Bohr asserted that the quantum object is something "transcending the frame of space and time" – suggesting (albeit despite himself) an altogether metaphysically new type of entity. The Hilbert Space structure of quantum theory greatly exceeds the structure of the empirical world in that it precludes our ability to attribute always-determinate classical properties to objects (recall Chapter 1). Therefore, it's natural to suppose that the structure of the theory describes something "transcending the

[23] This could be considered the 'Kant's credibility is already suspect' argument.
[24] This this is the case is demonstrated by the great empirical success of physical theories arrived at through rational analysis and mathematical invention. In Einstein's words: "How can it be that mathematics, being after all a product of human thought independent of experience, is so admirably adapted to the objects of reality?" Einstein, A. (2010). Nature seems to be inherently mathematical and logical; were that not the case, theoretical science could not provide any useful knowledge.

frame of space and time" but which is nevertheless real because objects described by those Hilbert Space states can be created and manipulated in the laboratory.[25]

Let us review the argument so far: players in an online game such as Second Life (SL) can intersubjectively confirm the existence of an object in the SL environment, just as people in our world can intersubjectively confirm the existence of a table. But the object-in- itself remains elusive, in that each observer who perceives the object perceives a different version of it. That's because the object-in-itself exists in domain II (recall Figure 7.2) ; it is not observable because it is not actualized and therefore does not exist in the world of appearance (i.e, 'spacetime'). At the game level, the object's observation by a particular avatar Mia is contingent on a transaction between the avatar and an aspect of the object, that aspect being determined by the manner and circumstances under which the object-in-itself (OW) is received—i.e., the confirmation wave (CW) generated by the avatar. The CW consists in the user Maria turning on her computer, loading the game, accessing a particular location in the game world, and orienting her avatar Mia's POV in the appropriate direction (all these being dictated by the *information* of domain II which is the data manipulated by the human players Jonathan and Maria). The 'actualized transaction' consists in Mia's POV registering the appearance of the table by specifying which pixels on the screen should be colored red, green, etc. This is only possible because of two things: (1) Jon/Jonathan created the table 'offer wave' with specific properties and (2) Mia/Maria accessed the appropriate properties in order to receive the 'offer wave' and actualize its appearance in her POV.[26]

We can use this model to immediately gain insight into the phenomenon of 'nonlocality.' While the avatars and their objects have a maximum speed *c*, Jonathan and Maria transcend the game environment and can freely communicate instantaneously (with respect to the game environment), so that information can be transmitted from one

[25] Here I endorse Hacking's dictum that "if you can spray them then they are real" (Hacking 1983, p.23), referring to an experimentalist's comment that he could 'spray' a piece of equipment with positrons.

[26] At a higher meta-level are the game designers who decide what types of OW can be created and how—the Gods of the Game, if you will.

region in the game environment to any other at infinite speed. This is precisely because that information is *not actually contained in* the game environment. So, for example, Mia might shoot an arrow at game-speed *c* in Jon's direction while Maria tells Jonathan (over the phone) that she is doing so. Instantly, Jon can step aside and miss the arrow, even though he should not be able to do so according to the rules of the game environment (which would preclude Jon from seeing the arrow coming at him). 'Faster-than-light' or 'nonlocal' influences are evidence of physically efficacious information existing on a level other than that of the usual local processes (i.e., the game environment or 'spacetime').

7. 6 Causality

In this section, I consider the vexed notion of "causality" and discuss how transactions can illuminate this longstanding conundrum.

7.6.1 Hume's elimination of causality

The reader may recall that the Scottish philosopher David Hume first cast enormous doubt on this commonplace notion of everyday life. As a strict empiricist, he looked for specific evidence of causality in the empirical (observable) world and could not find it. For example, consider a billiard game. The player strikes the cue ball; the cue ball moves and strikes another stationary ball. Subsequently, the second ball moves with the same momentum as the cue ball, which comes to a halt. It is perfect common sense that the cue ball *caused* the second ball to begin moving. However, we never actually *see* the cause; all we see is the pattern of events, which is repeated every time we perform these actions. The reader may object: but surely, we saw the cue ball strike the second ball. How could the second ball *not* move, since it was hit by the cue ball, which we clearly observed? But notice again that we did not actually see the cause; the cue ball striking the second ball is not *observably* a 'cause.' It is simply an event. Our expectation that the second ball must move is based on the fact that we have always seen this happen. It is certainly conceivable that the second ball could just sit there, despite having been hit.

The motion of the second ball is predicted by physical law; but again, physical law simply describes patterns of events; it does not say *why* they happen. For this reason, Hume concluded that causation is not really in the world, but is something we *infer* from what he termed the “constant conjunction of events.”

Another aspect of the “common sense” of causality (despite the fact that we never actually see it) is that the cause always precedes the effect: in terms of the above example, the cue ball striking the second ball *precedes* the motion of the second ball. The contingent, empirical time-asymmetry of causation is addressed further in Chapter 8. For now, I note that this feature of causation is simply a feature of the types of patterns that we see in the empirical world, and should not be thought of as necessarily extendable to the unobservable entities of the micro-world (e.g., electrons), as is customarily assumed (see footnote 5 in this connection).

7.6.2 Russell, Salmon, et al

As might be expected due to its unobservable nature, the concept of causality is a very slippery and elusive notion. Many distinguished philosophers have attempted to chase it down and capture it in definitive terms, without conclusive success. Bertrand Russell initially expressed great skepticism about causality in this famous quip:

“The law of causality, I believe, like much that passes muster among philosophers, is a relic of a bygone age, surviving, like the monarchy, only because it is erroneously supposed to do no harm”. (1913, 1).

Russell nevertheless felt that causality needed to be well-defined in order to support the development of physical laws which seemed to imply causal processes (even if physical laws do not explain them). He developed a theory of causality in terms of “causal lines” (Russell, 1948). This theory was based on several reasonable postulates, such as the idea that there is a kind of ‘quasi-permanence’ in the world: we do not see utter chaos, with objects suddenly and randomly changing their properties. However, Russell's theory was far from bullet-proof, and came under sustained and cogent criticism from Wesley Salmon (1984), who proposed his own theory of causation. Salmon sought to distinguish genuine causal processes from 'pseudo-processes' consisting of effects which are not causal in the usual sense. An example is a moving spot of light on a wall which can exceed the speed of light (see Figure 7.6). In that case, no material object actually exceeds the speed of light, but an observable artifact does.

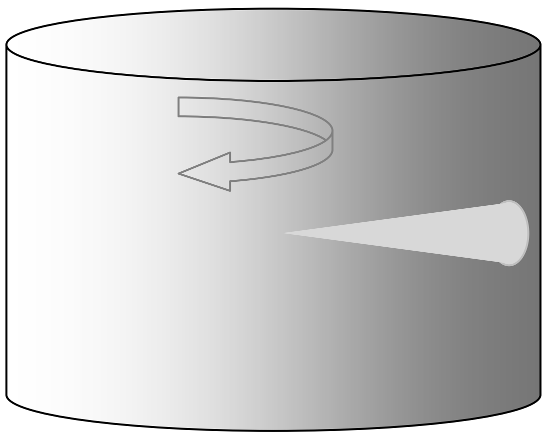


Figure 7.6 The moving spot that 'exceeds the speed of light'.[27]

Salmon endeavored to capture the essence of causality in terms of the ability of a causing event to transfer a 'mark' to the affected event (some persistent change in the second event which is the effect). However, this theory, too, has been found to have loopholes that hinder its ability to distinguish between what we consider to be genuine causal process and pseudo-processes, such as the moving spot of light or the changing portions of a charged metal plate in shadow (Salmon, 1997, 472). Another weakness, according to critics, is that it does not take into account processes such as trajectories of bodies, in which an earlier state seems to serve as the 'cause' of a later state. This issue is

[27] Lighthouse Image: digitalart / FreeDigitalPhotos.net

related to the notorious philosophical riddle of identity and persistence of particular objects. The story of the philosophical pursuit of 'causality' as an ontological entity is thus one of attempts to construct theories of causality which exclude all situations that we regard as non-causal and include only those which we regard as causal.

There has been no conclusive resolution to this puzzle, and I suggest that this is because Hume and Russell (1913) were right: causality is *not* an ontological feature of the world. In TI terms, it is an inference we make based on situations involving very probable transactions (i.e. transactions with weight close to unity). It can be seen as a supporting feature of physical law because overwhelmingly probable transactions underlie the empirical expression of such fundamental physical principles as the Principle of Least Action (recall Section 4.4.1).

7.6.3 Transactions to the rescue

Note that we can also understand the distinction between 'causal processes' and pseudo-processes in terms of transactions. A transaction constitutes a transfer of energy from the emitter to the absorber. The spot in Figure 7.5 is the location of an emitter (it is a point of reflection of photons, and in microscopic terms[28] this means that a photon is absorbed and a new one of exactly the same state (offer wave) emitted at that point). Thus the *location* of photon emission is moving at a speed greater than *c*, but no energy is actually being transferred faster than *c*. We can also account for the apparent persistence of macroscopic physical objects in terms of transactions; recall the baseball of section 7.4.1, whose apparent persistence depends on transfers of energy via transactions among its constituents and between those and our sense organs. If 'earlier states cause later ones,' it is in terms of such energy transfers.

Other pseudo-causal processes can similarly be ruled out by reference to transactions. For example, transactions allow us to unambiguously demarcate genuine persistent objects from pseudo-persistent 'non-objects,' such as the parts of a charged

[28] That is, in terms of quantum electrodynamics in which reflection is a type of scattering event: the incoming photon of momentum *p* is distinct from the outgoing photon of momentum *p*'. See also Feynman (1985, 101).

metal plate in shadow, only when they are in shadow (Salmon, 1997, 472). Dowe's reply (2000, 98-9) is that this is not a causal process because the above is not a genuine object—it does not possess identify over time. The burden is then on Dowe to define what constitutes identity over time—which he takes as primitive and thereby, according to Psillos, (2003, 124) makes his account circular. We can define the persistence of an object through time as attributable to ongoing transactions among its constituents as discussed above in connection with the baseball example. The charged metal plate is a network of transactions whose macroscopic cohesiveness is supported by those transactions; the changing set of portions of the charged plate in shadow is not. The latter consists of the changing set of transactions between an observer and emitter(s) outside the plate; i.e,, between a light source, an observer, and some object making certain portions of the plate inaccessible to the light source (hence resulting in the appearance, to the observer, of shadowed regions where the emitted OW cannot be reflected from the plate).

7.7 Concerns about Structural Realism

I conclude this chapter by considering a higher-level issue of interpretive methodology. I noted earlier that PTI can be considered in a weaker, structural realist (SR) form which remains agnostic about what these sub-empirical offer and confirmation waves 'really are' in ontological terms. In that regard, I should address some objections to SR, which was first developed by Worrall (1989) in an attempt to circumvent the so-called 'pessimistic induction' concerning the ability of scientific theories to refer to ontological entities. The 'pessimistic induction' consists in pointing out that many of those supposed entities (e.g., 'phlogiston') were later found not to exist; thus, based on past experience, it seems likely that the putative entities referred to by a currently successful theory might also be repudiated. Worrall proposed instead that successful theories refer to *structural* aspects of the world, even if it could not be known what the specific nature of those structures were.

Psillos (1999) has objected that Worrall's distinction between structure and nature (i.e., substance/properties) cannot be maintained when applied to specific entities described by a theory:

"To say what an entity is is to show how this entity is structured: what are its properties, in what relations it stands to other objects, etc. An exhaustive specification of this set of properties and relations leaves nothing left out. Any talk of something else remaining uncaptured when this specification is made is, I think, obscure. I conclude, then, that the 'nature' of an entity forms a continuum with its 'structure', and that knowing the one involves and entails knowing the other" (Psillos 1999, 156-157).

The above characterization applies to empirical phenomena, perhaps, but not necessarily to sub-empirical entities. That is, one can consistently propose that the structure of quantum theory dictates that the entities described by the theory cannot be considered to exist within the confines of a spacetime manifold (since the relevant mathematical space for N quanta is 3N-dimensional and therefore not mathematically commensurate with spacetime). Therefore we can remain agnostic about the precise nature of those entities but still insist, based on empirical success of the theory, that their dynamical *structure* is accurately captured by the form of the theory. The theory says how the entities are structured but not what they are: in Aristotelian terms, it provides their 'formal cause' but not their 'material cause' (if any!).[29]

Thus the key difference between the current proposal and typical structural realist proposals is that it denies the usual unexamined identification of 'real' with 'empirical'. For example, Barnum (1990) offers the following comment concerning a formulation by Dieks:

> "In Dieks' view, his semantical rule is the sort of thing which is necessary in any attempt to interpret a physical theory: 'certain parts of the models [of the theories] are to be identified as empirical substructures; i.e., part of the theoretical models have to correspond to observable phenomena.' I agree with this general

[29] The ancient Greek philosopher Aristotle proposed that all objects have four types of cause: material (relating to its substance); formal (relating to its structure); efficient (relating to its creator); and final (relating to its purpose).

> characterization of the interpretation of theories: the "internal meaning" of the terms of the theory, given by the mathematical structures which are models of the theory, needs to be supplemented by "empirical meaning." This is done by showing how the theory relates to our experience" "

This characterisation certainly has had its merits in connection with classical theory, in which all physical entities can be considered as existing in spacetime. However, the above approach would seem too restrictive for quantum theory, whose structure is incommensurable with the empirical arena of spacetime . We already know what parts of quantum theory relate to our experience—i.e., the probabilities given by the Born Rule---but the point of a realist interpretation of the theory is to go *beyond* that, to find a physical referent for those parts of the theoretical model that cannot be identified as empirical substructures. Thus I agree with Ernan McMullin (1984), who notes that part of the interpretational task is to discover to what the theoretical quantities refer, without assuming that they must refer to something in the macroscopic (empirical) world:

> "[I]maginability must not be made the test for ontology. The realist claim is that the scientist is discovering the structures of the world; it is not required in addition that these structures be imaginable in the categories of the macroworld." (1984, 14)

McMullin's point above is a subtle but crucial one, which cannot be overemphasized in connection with the present work. Specifically, our claim is that quantum states refer to something sub-empirical, yet real. As noted previously, this is a new category which is not part of the macroworld, and it is not legitimate to reject it based merely on perceptions that it might seem 'implausible' or 'unimaginable' when compared to the categories of the macroworld. So it is bound to be counterintuitive. Yet one can still show "how the theory relates to our experience" by positing the conditions (i.e., the actualizing of transactions) under which the sub-empirical entities give rise to empirical events.

Psillos' objection thus begins with a premise with which I would disagree; namely, "To say what an entity is..." : a structural realist is not committed to the claim that a theory always says what an entity *is*—that it gives an "exhaustive specification" in usual spacetime or substance/property terms. In fact, this was exactly Newton's interpretive stance when asked to what 'gravity' refers.[30] Newton clearly regarded his theory as *about* gravity and as *referring to* gravity; thus he was realist about his theory. But his theory did not spell out the specific ontological nature of gravity. [31]

PTI in its strong form does go beyond the original TI by proposing a specific ontological referent in the form of physical possibilities. Nevertheless, if one is reluctant to embrace this new metaphysical category, one can still allow that TI captures an essential *structural* element of quantum systems (advanced solutions arising from absorption) missing in the usual account, and thereby provides a more complete interpretation than its competitors.

In the next chapter, I consider the nature of spacetime in PTI.

---

[30] Concerning the ontology of gravity, Newton famously stated "*Hypotheses non fingo*" (I feign no hypotheses); from his *General Scholium* appended to the *Principia* of (1713).

[31] A similar argument is presented in Dorato and Felline (2011): "...we propose, therefore, the properties of *the explanandum* are constrained by the general properties of the Hilbert model [of quantum theory]. In this sense the *explanandum* [e.g., how or why quantum systems obey Heisenberg's uncertainty principle] is made intelligible *via* its *structural similarities* with its formal representative, the explanans [e.g., representability of such systems by Fourier expansions]. Given the typical axioms of quantum mechanics ... any quantum system exemplifies, or is an instance of, the formal structure of the Hilbert space of square summable functions." (2010, 6; preprint version)