Demystifying the Paranormal – Can Ghosts be Explained?

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Abstract.

It is commonly assumed that "ghosts" have no place within physics and that the anecdotal reports we have of them are nonsense and nothing more. I consider the possibility that this assumption may be both incorrect and unnecessary. This article poses the question: "What must we change about the way in which we construe reality in order that ghosts might become physically possible?" The answer turns out to be interesting and surprisingly simple. What must be changed is the assumption that there is only *one* reality for physics to consider when dealing with any particular region of spacetime. In this article I present a theory which allows for the possibility that two similar realities could overlap in a common region. It also provides a mathematically consistent mechanism by which these disparate realities could interact resulting in something very much like a "haunting." I couch this theory in terms derived from the Virtual World Simulation Hypothesis. This is more a matter of convenience than a matter of metaphysics as it will turn out that we do not have to take this particular interpretation literally. Rather, we can use it as a helpful device to explain an unfamiliar idea. I will focus on the electromagnetic interactions between the ghost's hypothesized world and our own since ghosts seem to be observed mostly by way of these. I will attempt to generalize quantum electrodynamics to a situation where two independent, but very similar, worlds occupy the same spacetime volume. The result is a theory that goes some way towards explaining a phenomenon that has been reported from time immemorial and which, until now, has seemed to be physically impossible. I will also argue that this theory is renormalizable and that it gives rise to no results that contradict everyday physics under circumstances where the two proposed realities do not interact.

Introduction.

Ghosts have been reported throughout human history, and all languages seem to contain at least one word for the concept. While different cultures explain it differently, they seem to be documenting a phenomenon whose essential characteristics vary little. Ghosts, when seen, are often observed to resemble persons that have died. This has led to the belief that they are the souls or non-corporeal essences of those deceased persons. Ghosts are also described as being able to interact with the living world. They can sometimes speak. They can, apparently, move objects and even touch people.

Science has tended to discount the ghost phenomenon. This is, in part, because it is difficult to demonstrate in any reproducible way. Most of the evidence is, therefore, anecdotal in nature. Also, it has been a subject rife with hoaxing and downright lunacy (the Spiritualist Movement being a case in point). More importantly, there has been a tendency to dismiss the phenomenon because it does not comport with our notions of physics and Scientific Materialism. If an ashtray flies across a room, 4-momentum is not being conserved. This shouldn't be possible. If a ghost is seen, photons must be emanating from it. Where could these come from? Given the success of modern science and the pertinence of these objections, it is little wonder that the subject has acquired a bad reputation and is generally ignored within intellectually respectable circles. But it is for these very reasons that the subject does commend itself to our serious attention. If ghosts are real they are, almost certainly, telling us something quite important about how reality actually works; if they are real, reality cannot work the way we think it does.

It is not my purpose, in this article, to argue for or against the objective existence of ghosts. The reader is welcome to come to his own conclusions regarding this matter. Instead, I will simply ask the reader to suspend his disbelief and assume, for the moment, that ghosts *are* real and that they are more-or-less like the phenomenon that has been described to us by the majority of people who claim to have encountered it. I will go on to investigate what this "fact" may be trying to tell us about reality and to construct a theory, however incomplete and tentative, that explains many of the peculiar characteristics of ghosts.

What are We Trying to Explain?

When theorizing about a strange subject, and one that has been a frequent victim of fraud and innocent misinterpretation, it is imperative that we delineate the boundaries of what we are theorizing about. I begin by asking that we forget about most of the (silly) things that Hollywood and fictional stories tell us about ghosts. Ghosts do not wear white bedsheets. They do not rattle chains. They rarely talk to us in more than fragmentary sentences. Also, they are rather seldom actually seen. And, when they are seen, they usually appear to us as indistinct figures or darkish shadows through which we cannot see clearly. On rare occasions they may be seen clear as day, appearing just like normal people. But such occasions are rare indeed. If the documented research is to be believed, ghosts are more usually evidenced by their tangible manifestations; they bang on walls, cause us to hear footsteps, push us, pull on our clothing, give rise to disembodied voices and EVPs. Sometimes they even attack us. But they are not too often seen. A proper theory needs to explain this. Also, very importantly, when one person in a room experiences a ghost the other people in the room experience it too. (If only one person sees it it doesn't usually take the rest a long time to diagnose the problem!) Ghosts are an intersubjective phenomenon.

I think we should put to the side some of the more dodgy claims connected with ghosts. So-called "orbs" are almost certainly just dust, bugs, and photographic anomalies. Most "demonic possessions" are probably just the result of mentally questionable people letting their imaginations work overtime. Mediums, séances, and dowsing rods are probably just bunk. So let's not try to explain everything. Instead, let's try to explain the bare bones of the phenomenon – the things that almost every culture and investigator can, sort of, agree upon. I have already mentioned a few of these things. Other things would include the fact that ghosts often seem to be attached to particular "haunted" locations. Another would be the fact that they don't seem to grow old and die. Ghosts have been reported that would have died of old age long ago if they were who we think they are. These are a few of the things I will try to explain.

Now I must say that the theory I am about to set forth will strike most readers as bizarre. But this is only to have been anticipated. Any theory that would attempt to explain a phenomenon such as ghosts, one which blatantly contravenes almost everything we think we know about reality, is going to have to be pretty strange. I begin by calling the reader's attention to another set of ideas – one almost equally strange.

The Simulation Hypothesis.

The Simulation Hypothesis gained philosophical currency with the publication of several articles by Hans Moravec and, separately, Nick Bostrom (1,2). Since then it has taken on a number of different forms. The one I am interested in here goes by the name 'The Virtual World Simulation Hypothesis.' In simple terms, this idea holds that our world can be thought of as a kind of computer simulation. We are, in effect, like those "Sims" in the computer game of the same name. Bostrom and others believe that a computer program of sufficient sophistication could instantiate and simulate us – our brains, our thoughts, our sensations – in such a way that "we" would perceive them consciously. Essentially, we are conscious Sims in someone, or something's, computer program or game.

The philosophical implications of this idea are far-reaching, and I will comment upon some of these in the last section of this article. For the moment, let us just assume that this version of the Simulation Hypothesis is on the right track. For the purpose of this discussion let us assume that our reality consists, basically, of 1s and 0s being processed by a computer, hypercomputer, or Universal Turing Machine (UTM) of some kind existing in a higher-order reality of which we can have no direct knowledge. It runs our universe somewhat like one of our computers runs the Sims' universe. Of course, its program is vastly more complex than that of the Sims and can do things much more realistically. But, still, this is the kind of picture I'm painting. It depicts and places us within a simulated "World" that obeys the laws of physics (as we somewhat understand them). It would be consistent and complete from our point of view. In this sense, we would not notice or be able to deduce the fact that we were Sims. I will return to the notion of 'completeness' presently. It should be understood that the Virtual World Simulation Hypothesis is an altogether different idea from the one underlying the popular Matrix Trilogy. (Interestingly, the possibility that ghosts are related to programming errors on the part of the Matrix was alluded to in one of these movies.)

A Theory of Ghosts.

Suppose that a person dies suddenly in his house. Suppose further that, at a point in time somewhat previous to his death, the UTM creates a secondary simulation of that person's house and places the last viable file of that person in it. We have just assembled the raw materials for a ghost. Why the UTM would do such a thing, I cannot hope to say. Presumably, this is just a thing it sometimes does based on the nature of the algorithms it runs. In any case, I refer to this newly-created, independent simulation as a *sub-simulation*. This is a concept that will feature centrally in everything that follows. Whereas it used to be running one simulation only, now the UTM runs two in parallel – one for us, one for the potential ghost. This potential ghost would not necessarily notice too much amiss right away. He'd experience himself continuing to live in his accustomed abode.

For all I know things like this, the branching off of sub-simulations, might be occurring all the time within the UTM and the tape it reads and prints on. Maybe it always happens when people die suddenly. Maybe it happens every time a leaf falls off a particular tree. Since the primary simulation (the one we live in and call "reality") would go on without interruption, we'd never be any the wiser. In order for what are reported as hauntings to occur something else is required. I propose the following: If a sufficient degree of similarity exists between our simulation and a particular sub-simulation the UTM may, on occasion, make "mistakes" or, perhaps to optimize computational efficiency, allow one simulation to be confused with, and thereby bleed into another. In effect, I'm proposing that two sufficiently similar simulations, simulations having a great many 1s and 0s in common, may be able to communicate, one to the other, such that events in one may be mirrored in the other and vice-versa. Whether this is a result of accidental "laziness" on the part of the UTM or a clever attempt to save CPU time, I can't speculate. Whatever the cause, it might very well present us with something like a ghost. If we live in the house where the unfortunate person died, we might expect never to notice a thing. Even if there exists a sub-simulation of the dead person, we could well hope never to encounter evidence of it. But if, once in a while, the UTM makes a mistake and mixes, however briefly, the 1s and 0s of our respective simulations, we might experience a "ghost" which would be nothing more than traces of something going on in a different simulation, a simulation not our own but one so closely related to ours by virtue of its similarity to the "real" world that the UTM's algorithms may fail, if even for a moment, to make the necessary distinctions. When this condition exists we would say that we were experiencing a haunting.

The Ghost's Sub-Simulation.

Lacking direct access to the ghost's world we can only speculate as to its nature. If we are indeed living in a simulation, a sub-simulation is to be regarded as something similar and semi-autonomous. It would instantiate a reality very much like our own for its inhabitant(s) but be run off to the side as a separate virtual reality. In it would live the potential ghost who corresponds to a previous file that encoded the information that was necessary to simulate him. In the circumstances I will consider, it will have been derived from the mainline simulation we regard as "reality" by duplicating a part of that simulation and running it in a different way – a way which includes a person that has died in our world, and, perhaps, nobody else.

I begin by distinguishing between what we will call 'complete' simulations and 'incomplete' simulations. A 'complete' simulation is one like that we call "reality." It does not appear to be bounded in any spatiotemporal way. We can land on the moon and the moon's surface is simulated for us to walk on. We can look at the Sombrero Galaxy and we'll see it and even be able to measure its light's spectrum. The past seems always to have existed. (We can find dinosaur fossils.) Its future, for all we know, will go on indefinitely. In short, it is fully complete and logically self-consistent. It shows us the workings of its laws of physics in a way that would never make us mistake it for anything other than the "real" universe we think we live in.

Now, an 'incomplete' sub-simulation is to be thought of more like a duplicate of part of a complete simulation. I propose it to be just a set of alternate 1s and 0s, run using the same laws of physics as our 'complete' simulation, but instantiating only a little bit of information. It's derived from – budded-off, as it were, from – our complete simulation and may instantiate only a haunted house. Perhaps it gets generous and instantiates the front lawn of the house. But, maybe, not a whole lot more. No moon, no Sombrero Galaxy, just a little, incomplete, part. That's where the ghost "lives." To do its necessary calculations, this sub-simulation builds itself out of a part of our complete simulation and runs forward from there. It is not always going to be logically self-consistent. Maybe the ghost can turn on his electric light. But there's no power station in his reality to make it glow. Certainly, he feels gravity. But there isn't really an Earth there to generate it for him. Maybe the ghost can go into his yard. But there's no street in front of it anymore. Insofar as it works, this sub-simulation is just a *derived thing* – something borrowed originally as 1s and 0s from our "real" simulation but now running as an independent, 'incomplete,' thing. (The "Sims" computer game I alluded to earlier would also be an example of an 'incomplete' simulation.)

We always see ourselves as having a past and a future. In the ghost's reality things seem to be a little different. His reality may run for only a few days or minutes. Maybe this is the best the UTM can do for him. In short, an 'incomplete sub-simulation' is envisioned to be a spatiotemporally restricted thing – a semi-independent thing derived from, but separate from, the "Real World." It encompasses just a little space. It simulates just a little time. Moreover, I must propose another strange idea regarding the ghost's incomplete sub-simulation. I have to propose that, relative to what we perceive as the flow of our time, the ghost's sub-simulation turns on and off at intervals. Its time doesn't always have to run in lock-step with our own. (Of course, since the ghost always starts up with whatever memories he starts up with, he will never notice anything abnormal going on with his time.)

Why would I propose such implausible things? Only because they agree well with the anecdotal reports of what ghosts are. And the anecdotal evidence is all I really have to build off of here. Anne Boleyn's ghost is sometimes seen in the Tower of London. It is never seen in Yankee Stadium; it seems to be spatially restricted to its own "haunted" location. It can't seem to move away from that place. Also, it never appears to grow old. If Anne Boleyn's sub-simulation always ran concurrently with ours she'd have died of old age hundreds of years ago. Yet people still report seeing her. It seems to be the case that the ghost's sub-simulation is a just a very restricted little representation of a possible reality that runs for a time, then shuts off, runs some more, shuts off again, and so on. In most cases of hauntings it seems to rewind itself at intervals and start again from its beginning. There are, however, some cases, such as those of so-called 'crisis apparitions' and 'post-mortem apparitions,' where the sub-simulation seems to run only once. After this the ghost is not seen again. If a sub-simulation can run for only a short time, and runs (relative to our "time") over and over, we experience what is called a 'residual haunting.' This is a very common type of haunting. In rarer cases, the sub-simulation may be more long-lived. The ghost then has time to interact with us at length, figure out that he is a ghost, and, on occasion, even do things to us. These situations are referred to as 'intelligent hauntings.'

Lastly, I introduce the notion of a *common coordinate system* for our world and that of the ghost. It seems likely that the UTM employs something like a spacetime coordinate system to define the locations of the things it is simulating in the "real" world and likewise for the ghost's world. If it places the doorknob of the haunted house at spatial coordinates (0,1,4) in our world then it seems reasonable to think it would use (0,1,4) for the doorknob of the ghost's haunted house and similarly for the toaster and the sofa – after all, the ghost's house was copied from the real house to begin with. In a sense, that house occupies the same volume of spacetime as the real house during those periods when the sub-simulation is running.

The Ghost.

I envision the ghost as a simulated person, in no particular way different from ourselves save for his unusual dwelling place. Generally, he seems derived from the last viable file, the 1s and 0s, corresponding to the last moments of his former self. I say this because dead old people give rise to old ghosts and not child ghosts, and so on. The UTM may have little choice in this matter since it, perhaps, does not save earlier copies of peoples' files for very long. What use would it have for the 1s and 0s that represented you 10 years ago? It's probably just interested in simulating you right now. Also, that file must describe a person that is alive and capable of doing things. If a person shoots himself I expect the computer to simulate him as he was before the bullet killed him. A "dead" ghost wouldn't make for much of a haunting.

Indeed, this may explain the fact that ghosts frequently seem to arise from sudden deaths – suicides, murders, and battlefield deaths are all prolific generators of ghosts. A person who gets sick, lingers in a coma for years, then dies, would be a poor candidate for becoming a ghost. If he did he would probably end up a comatose ghost incapable of doing anything more than making a impression on a bed. Such impressions are sometimes noticed and attributed to ghosts. Maybe they are due to comatose ghosts. But a ghost like that wouldn't make for much of a haunting, any more than a dead one would.

Why the ghost ends up haunting one location as opposed to another is difficult to understand. Often it is the place he has died that is chosen. But, on other occasions, a person dies in one place yet their ghost appears somewhere else. The only requirement seems to be that the place have some relevance to the ghost's former life. The ghost does not appear to have much choice when it comes to determining his haunting location. I say this because haunted prisons and insane asylums are so common as to be almost cliché. If ghosts could pick and choose, one thinks they would opt for less unpleasant venues.

Let me also comment on the subject of multiple hauntings. Many locations seem to contain two or more ghosts. Some EVPs apparently record one ghost talking to another. Since real ghosts seem to be very rare, this is a surprising observation. If ghosts were scattered at random over the Earth's surface the likelihood of finding two or more in the same place would have to be remote. One explanation might be the following: The hard part of making a ghost is creating the sub-simulation. Once created, it may be relatively easy for the UTM to download more ghosts into it resulting in a multiple haunting situation.

I would expect to be asked "Why must a person die in order to become a ghost?" The answer is that he doesn't. There is the so-called Doppelgänger phenomenon, in which a still-living person is seen as a ghostly double of himself. In English such ghosts are called 'fetches,' 'fyes,' or 'wafts.' In Norway they are referred to as 'vardøgrs.' This phenomenon suggests that living people can occasionally give rise to sub-simulations and ghosts. Buddhists would, I think, describe this as a person's unconciously projecting a 'Tulpa' of himself. (A brain-in-a-vat or Matrix-like version of the Simulation Hypothesis would not allow for such a phenomenon.)

The Haunting.

If that was all there was to it, there wouldn't be any hauntings. A ghost might go about his business, isolated within his sub-simulation, for years. We wouldn't notice a thing unless he could interact with us in some way. I mentioned earlier that I think this interaction happens when the UTM temporarily mixes up some of the 1s and 0s of our simulation with that of the ghost. Again, I cannot say exactly why it does this. One thing that appears to be necessary is a high degree of overlap, similarity, congruence, or call it what you like, between the ghost's simulated locale and the corresponding locale in our world. This seems to be a necessary, but not sufficient, condition for an active haunting. I say this because the similarity between two locations isn't likely to change very quickly, most of the time. Yet hauntings, typically, turn on and off over and over again. In many cases this may result from the sub-simulation running and then stopping relative to our simulated time. But it certainly seems as if cross-communication between two simulations is only a sometime affair. I will introduce a new 'paraphysical' quantity, $c(\boldsymbol{x}, t)$, that describes the strength of this cross-communication as a function of the common spacetime coordinate system shared by ourselves and the ghost. $c(\boldsymbol{x}, t)$ is to be regarded as a dimensionless, positive, real-valued, scalar field. When it is zero, no haunting is taking place. When it differs from zero, we experience a haunting. We assume that it always remains rather small. Hauntings tend to be subtle experiences. Also, we assume that it does not usually vary much over microscopic or atomic time/distance scales. (As far as we have any reason to suspect, hauntings are fairly large-scale phenomena.) We expect $c(\boldsymbol{x}, t)$ to be related to the degree of similarity (in terms of 1s and 0s) between our reality and the one inhabited by the ghost. But it also appears to be influenced by other factors as yet not understood.

The Electrodynamics of Ghosts.

We will now begin the mathematical development of this theory. While we know nothing about the details of the process, it seems safe to assume that the UTM, when it simulates our reality, or that of the ghost, is simulating the quantum mechanical states appropriate to that world and then deriving our conscious experience from these in some manner. Therefore our world will, at any given point in the simulation, be described by a quantum state $|R\rangle$ and that of the ghost by $|G\rangle$ (where R and G refer, of course, to 'real' and 'ghost'). $|R\rangle$ and $|G\rangle$ are to be understood as multiparticle states in Fock space (3) and should not be confused with simple one-particle Schrodinger wave functions. Such states are constructed from the vacuum by acting upon it with creation operators corresponding to the various electrons, quarks, photons, and so forth that make up our world and that of the ghost. Essentially, they specify the information regarding how many of each type of particle there are and what those particles are doing.

These quantum states evolve according to equations derived from a Lagrangian that describes the interactions between their various particles. If we focus our attention on charged material particles and their electromagnetic interactions, which is a reasonable thing to do here since ghosts are usually experienced through effects that are primarily electromagnetic in origin, we must point out that observing a ghost particle entails having it interact electromagnetically with our world and vice-versa for the ghost observing our particles. To keep things simple let us just look at the electromagnetic interaction between electrons. In the absence of any haunting the relevant Lagrangian is easy to write down:

1) $$L_{\text{em}} = \overline{\psi_R}\,[\gamma^\mu[\text{i}\,\partial_\mu - e\,A_{R\,\mu}] - \text{m}]\psi_R - \tfrac{1}{4}F_R{}^{\mu\nu}F_{R\,\mu\nu} + \overline{\psi_G}\,[\gamma^\mu[\text{i}\,\partial_\mu - e\,A_{G\,\mu}] - \text{m}]\psi_G - \tfrac{1}{4}F_G{}^{\mu\nu}F_{G\,\mu\nu}.$$

The objects ψ_R, A_R, etc., are understood to be operator-valued functions of the common spacetime coordinate system shared by ourselves and the ghost. $F_R{}^{\mu\nu}$ is the electromagnetic field strength tensor appropriate to our world. $F_G{}^{\mu\nu}$ pertains to the ghost's reality. I propose that a haunting occurs when we experience a *mixing* of A_R and A_G in their interaction with the electron fields according to:

2) $$A_{\text{R}\mu} \longrightarrow \left(1 + c(\boldsymbol{x}, t)^2\right)^{-1/2}[A_{\text{R}\mu} + c(\boldsymbol{x}, t)\; A_{\text{G}\mu}] \text{ and}$$
$$A_{\text{G}\mu} \longrightarrow \left(1 + c(\boldsymbol{x}, t)^2\right)^{-1/2}[A_{\text{G}\mu} + c(\boldsymbol{x}, t)\; A_{\text{R}\mu}]\,.$$

Note that this mixing of quantum fields is confined to the photon fields. I do not apply it to the electron fields. Nor do I apply it within the electromagnetic field strength tensors. When $c(\boldsymbol{x}, t) = 0$ there is no haunting. As $c(\boldsymbol{x}, t)$ becomes larger we begin to experience some of the ghost and his simulation. In the same way, he experiences us. $\left(1 + c(\boldsymbol{x}, t)^2\right)^{-1/2}$ functions simply as a normalization factor. Under the influence of this transformation the Lagrangian becomes:

3) $$L_{\text{em}} = \overline{\psi_R}\,[\gamma^\mu[\text{i}\,\partial_\mu - e\left(1 + c(\boldsymbol{x}, t)^2\right)^{-1/2}\left[A_{\text{R}\mu} + c(\boldsymbol{x}, t)\; A_{\text{G}\mu}\right]] - \text{m}]\psi_R - \tfrac{1}{4}F_R{}^{\mu\nu}F_{R\,\mu\nu} + \overline{\psi_G}\,[\gamma^\mu[\text{i}\,\partial_\mu - e\left(1 + c(\boldsymbol{x}, t)^2\right)^{-1/2}\left[A_{\text{G}\mu} + c(\boldsymbol{x}, t)\; A_{\text{R}\mu}\right]] - \text{m}]\psi_G - \tfrac{1}{4}F_G{}^{\mu\nu}F_{G\,\mu\nu}.$$

We will assume, for the moment, that $c(\boldsymbol{x}, t)$ is roughly constant over the spacetime volume of interest. Also note that $c(\boldsymbol{x}, t)$ is in no way a dynamical variable of this theory. It is like a physical "constant" that changes with time and space. While this new Lagrangian maintains gauge invariance only under circumstances where $c(\boldsymbol{x}, t)$ is constant, it has the advantage of resulting, under these circumstances, in simple Feynman rules and a physics which, in many respects, corresponds with that we would like to see for ghosts. These new Feynman rules are similar to the familiar ones but with two important differences: Firstly, the vertices connecting an incoming and outgoing "real" electron (or positron) line with a "real" photon contribute with a coupling constant $e\left(1 + c(\boldsymbol{x}, t)^2\right)^{-1/2}$. It is likewise for the "ghost" particles. Secondly, new vertices appear which connect incoming and outgoing "real" electron (or positron) lines with a "ghost" photon and incoming and outgoing "ghost" electron (or positron) lines with a "real" photon. These contribute with a coupling constant which is $e\,c(\boldsymbol{x}, t)\left(1 + c(\boldsymbol{x}, t)^2\right)^{-1/2}$. Consider the scattering of one "real" electron off another in the presence of a haunting. To find the probability amplitude for this process (to second order in the coupling constant) we will sum the amplitudes corresponding to the usual Feynman diagrams and new diagrams in which it is a "ghost" virtual photon that is being exchanged. Straightforward arithmetic shows that the overall coupling constant is still e. Thus the resulting amplitude is unchanged by the presence of the haunting. The contribution from the "ghost" virtual photon compensates exactly for the reduction in the coupling strength of the normal interaction. This is encouraging – as long as we are dealing with interactions between "real" particles and other "real" particles electromagnetism should continue to work normally in our world even if $c(\boldsymbol{x}, t)$ became different from zero. The same situation would obtain for the ghost. Suppose, instead, that we try to scatter "real" electrons off of "ghost" electrons. Now things are a little different. In each of the two relevant Feynman diagrams would be a vertex connecting either "ghost" fermions with a virtual "real" photon or "real" fermions with a "ghost" virtual photon. Arithmetic again yields a simple result. Looking at the behavior of our electrons, we would have to conclude that the "ghost" electrons had a charge that was reduced by a factor of $2\,c(\boldsymbol{x}, t)\left(1+\,c(\boldsymbol{x}, t)^2\right)^{-1}$ from its normal value. Also, since there are no vertices connecting an incoming "real" electron with an outgoing "ghost" electron, the scattering would be the same as that produced by two non-identical particles; this makes sense as we would not want to say that "ghost" and "real" particles are indistinguishable (4).

The Haunted Physics Laboratory.

Suppose that two physicists decide to study hauntings. They equip a laboratory with measuring devices and an, initially empty, observation box where they can conduct research. One of them commits suicide in the laboratory, hoping to become a ghost. Let's say that he succeeds and becomes re-simulated into an identical virtual laboratory. His friend stays alive and conducts tests in the now-haunted "real" laboratory. According to a prearranged plan the ghost physicist places some electrons into his observation box. If Equation 3) is to be believed, the living physicist will see, partially, the electromagnetic influence of these particles should a haunting take place. He will detect this influence by the effect it has on his electrons or other charged objects (here we're using electrons as an example). Let us look at Equation 3) from a semi-classical point of view. We must recall that, according to Dirac theory, the 4-current density in the 'real' world is given by by $e\,\overline{\psi_R}\,\gamma^\mu \psi_R$, and by $e\,\overline{\psi_G}\,\gamma^\mu \psi_G$, in that of the ghost. Varying Equation 3) by $A_{\mathrm{R}\mu}$ we find:

$$4)\qquad {F_R}^{\mu\nu}{}_{,\nu} = J^\mu \Big/ \left(1 + c(\boldsymbol{x}, t)^2\right)^{1/2} + \tilde{J}^\mu\, c(\boldsymbol{x}, t) \Big/ \left(1 + c(\boldsymbol{x}, t)^2\right)^{1/2}$$

where J^μ denotes the 4-current density in our world, and $\tilde{J}^\mu$ that in the ghost's world. Varying by $A_{\mathrm{G}\mu}$, we find a corresponding equation for things the ghost's world. Let us now vary Equation 3) by $\overline{\psi_R}$ so as to get the Dirac equation for the behavior of 'real' electrons. We find:

$$5)\qquad [\gamma^\mu[\mathrm{i}\,\partial_\mu - e\left(1+\,c(\boldsymbol{x}, t)^2\right)^{-1/2}\left[A_{\mathrm{R}\mu} + \,c(\boldsymbol{x}, t)\;A_{\mathrm{G}\mu}\right]] - m]\psi_R = 0.$$

This tells us what effective "4-potential" the 'real' electron is responding to. We can perform the same excerise for the ghost's Dirac equation. We obtain, as a practical matter, a Lorentz force law for 'real' electrons which reads:

6) $$m\,\ddot{x}_R{}^{\mu} = e\Big(F_R{}^{\mu}{}_{\nu}\Big/\left(1+c(\boldsymbol{x},t)^2\right)^{1/2} + F_G{}^{\mu}{}_{\nu}\,c(\boldsymbol{x},t)\Big/\left(1+c(\boldsymbol{x},t)^2\right)^{1/2} - \left(1+c(\boldsymbol{x},t)^2\right)^{-3/2}\Big[c(\boldsymbol{x},t)\,\left(c\,(\boldsymbol{x},t)^{,\mu}\,A_{R\nu} - c(\boldsymbol{x},t)_{,\nu}\,A_R{}^{\mu}\right) - \left(c\,(\boldsymbol{x},t)^{,\mu}\,A_{G\nu} - c(\boldsymbol{x},t)_{,\nu}\,A_G{}^{\mu}\right)\Big]\Big)\,\dot{x}_R{}^{\nu}.$$

And we'll obtain a reversed version for the ghost and his electrons. It will be observed that this equation of motion does not respect gauge invariance, nor should it. As has been mentioned, strict gauge invariance requires the constancy of $c(\boldsymbol{x}, t)$. We are, therefore, both free, and obliged, to choose a gauge for our 4-potentials. We choose Feynman gauge as the most natural. (Recall that, if the photon has even the smallest imaginable mass, Proca's equation forces us directly into this gauge.)

No assumptions regarding the constancy of $c(\boldsymbol{x}, t)$ have been made in deriving Equations 4) and 6) (and their two ghostly counterparts). These can be used under any circumstances. It seems likely that, under many circumstances, $c(\boldsymbol{x}, t)$ can be treated as, more-or-less, a constant. This allows us to make some simplifications to the mathematics. Since all we are interested in is the effective field that real (or ghost) electrons respond to, let us simplify matters by writing:

7) $$F^{\mu\nu} = F_R{}^{\mu\nu}\Big/\left(1+c(\boldsymbol{x},t)^2\right)^{1/2} + F_G{}^{\mu\nu}\,c(\boldsymbol{x},t)\Big/\left(1+c(\boldsymbol{x},t)^2\right)^{1/2}$$ and

8) $$\tilde{F}^{\mu\nu} = F_G{}^{\mu\nu}\Big/\left(1+c(\boldsymbol{x},t)^2\right)^{1/2} + F_R{}^{\mu\nu}\,c(\boldsymbol{x},t)\Big/\left(1+c(\boldsymbol{x},t)^2\right)^{1/2}.$$

It now becomes possible to write Maxwell's equations and the Lorentz force law, in the presence of a haunting, in a much more simple and compact form:

9) $$F^{\mu\nu}{}_{,\nu} = J^{\mu} + 2\,\tilde{J}^{\mu}\,c(\boldsymbol{x},t)\Big/\left(1+c(\boldsymbol{x},t)^2\right)$$

10) $$F_{\alpha\beta,\gamma} + F_{\beta\gamma,,\alpha} + F_{\gamma\alpha,\beta} = 0$$

11) $$\tilde{F}^{\mu\nu}{}_{,\nu} = \tilde{J}^{\mu} + 2\,J^{\mu}\,c(\boldsymbol{x},t)\Big/\left(1+c(\boldsymbol{x},t)^2\right)$$

12) $$\tilde{F}_{\alpha\beta,\gamma} + \tilde{F}_{\beta\gamma,,\alpha} + \tilde{F}_{\gamma\alpha,\beta} = 0$$

13) $$m\,\ddot{x}_R{}^{\mu} = e\,F^{\mu}{}_{\nu}\,\dot{x}_R{}^{\nu}$$

14) $$m\,\ddot{x}_G{}^{\mu} = e\,\tilde{F}^{\mu}{}_{\nu}\,\dot{x}_G{}^{\nu}$$

where $F^{\mu\nu}$denotes the classical electromagnetic field strength tensor, as measured by the living physicist, and $\tilde{F}^{\mu\nu}$ that measured similarly by the ghost. In cases where $c(\boldsymbol{x}, t)$ does vary markedly over the spacetime volume of interest, things become more complicated. I will examine a few such cases in the section dealing with the visibility of ghosts. While we need make very few assumptions regarding the ways in which $c(\boldsymbol{x}, t)$ can vary with space and time, we are forced to say that it must be constant over atomic time and distance scales. We don't find that our atoms change much in the presence of a haunting. (If they did, we would surely die.) That places some restrictions on the variability of $c(\boldsymbol{x}, t)$.

Looking at the above equations, we notice an interesting thing. There is a limit to how pronounced a haunting can become. This occurs when $c(\boldsymbol{x}, t) = 1$. As the haunting becomes "stronger" its practical effects actually diminish to zero. As $c(\boldsymbol{x}, t) \to \infty$ everything returns to normal. This is because A_G has now taken over the role once played by A_R and vice-versa. Really, it doesn't matter what name we give the gauge fields. They still perform their function.

The quantity $2\,c(\boldsymbol{x}, t) \big/ \left(1 + c(\boldsymbol{x}, t)^2\right)$ appears so often in what follows that I will designate it $V(\boldsymbol{x}, t)$. $V(\boldsymbol{x}, t)$ is a real scalar field with a value between 0 and 1 inclusive. Essentially, it measures the "strength" of the haunting as a function of space and time. Thus Equation 9) would be written:

9') $$F^{\mu\nu}{}_{,\nu} = J^{\mu} + V(\boldsymbol{x}, t)\, \tilde{J}^{\mu}.$$

It would be vice-versa for $\tilde{F}^{\mu\nu}{}_{,\nu}$.

Suppose that the real physicist and his ghostly counterpart each place a bar magnet in their boxes. Suppose that a haunting now develops such that $V(\boldsymbol{x}, t)$ becomes greater than 0 inside their boxes. Each magnet will feel a (partial) magnetic field from the other and therefore move. It will appear to both physicists as if 4-momentum is not being conserved which, indeed, it isn't. Conservation of 4-momentum derives, by way of Noether's Theorem, from the independence of physical law on location in spacetime (i.e. the fact that physics works the same way everywhere). By introducing $c(\boldsymbol{x}, t)$ into the picture I have destroyed this invariance. And it is necessary to do this. (Poltergeists will not be able to make ashtrays fly across rooms otherwise.) The futility of trying to maintain any sort of 4-momentum conservation within a theory such as this can be underscored by considering the following scenario: Suppose a haunting develops and that a ghost throws an ashtray at you. Energy will transfer from the ghost's world (his arm muscles lose some ATP) and pass into our world (the ashtray hits you). Suppose that the haunting then subsides and never occurs again. Our world will have gained some energy, and will keep it forever. The ghost's "world" is, simply, gone. We could formulate a different example in which the ghost's reality gained some energy and never lost it. That, too, is entirely possible. We need to forget about any concepts of conserved energy and momentum when dealing with a theory like this.

Now the 4-divergences of the left-hand sides of Equation 4), and the ghost's version thereof, both vanish identically owing to the antisymmetry of $F_R{}^{\mu\nu}$ and $F_G{}^{\mu\nu}$. The current densities should also have vanishing 4-divergences. This implies that:

15) $$c(\boldsymbol{x}, t)_{,\mu}\, J^{\mu} = 0 \text{ and}$$
$$c(\boldsymbol{x}, t)_{,\mu}\, \tilde{J}^{\mu} = 0.$$

Equations 15) put some definite constraints on what $c(\boldsymbol{x}, t)$ can do. Suppose, for instance, that the living physicist fills his box with charged particles (basically converting it into a volume where $J^{\mu} = (\rho, 0,0,0)$ with ρ being the charge density). Let the ghost leave his box empty. As long as this situation remains in effect the value of $c(\boldsymbol{x}, t)$ within the box must hold constant. It can vary any way it wants to in space but must remain fixed in time. If, instead of charges, the living physicist puts a wire carrying a current into his box $c(\boldsymbol{x}, t)$ will have to be the same throughout that wire. It can change in time and space in other ways. But its value within the wire must always be everywhere the same.

The Importance of Congruence Between the Simulations.

Referring back to Equations 15) we notice some interesting things. The 4-gradient of $c(\boldsymbol{x}, t)$ is constrained only when J^μ or $\tilde{J}^\mu$ differs from 0. Where these quantities are, for all intents and purposes, zero, $c(\boldsymbol{x}, t)$ is free to do as it wishes subject to the dictates of the UTM. Suppose that both J^μ and $\tilde{J}^\mu$ differ from zero in some area. This places two constraints on the 4-gradient of $c(\boldsymbol{x}, t)$ and would restrict more stringently the forms a haunting could take. Of course, if $J^\mu = \tilde{J}^\mu$ the number of constraint equations drops back to one. It should then be easier for a haunting to take place. I am assuming that the ghost's simulation has been borrowed from that of "reality." So, throughout many parts of it, J^μ and $\tilde{J}^\mu$ are equal, at least more-or-less. This may go a long way towards explaining the fact that many "haunted" locations are old, abandoned, places, little changed since the ghost first formed. Had they been much changed, areas where J^μ and $\tilde{J}^\mu$ differ from each other would be very common and the freedom of $V(\boldsymbol{x}, t)$ to change would be restricted correspondingly. This may also explain why hauntings often seem to die out with the passage of time. We seldom encounter ghosts of Ancient Egyptians. This may be because the similarities that once existed between their sub-simulations and our world have been obliterated over the centuries. I should also mention another factor that seems to constrain the behavior of $c(\boldsymbol{x}, t)$ – physical consistency. Were $c(\boldsymbol{x}, t)$ to become large in an area where a "real" object and a "ghost" object, overlapped both might well explode. The one couldn't get out of the way of the other's tangible influence. Since this does not usually happen in connection with hauntings, we must assume that the UTM "knows better" than to try to do such a thing!

While it is not my intention to turn this article into a recitation of ghost stories, there is one which is so relevant to our discussion that I will have to mention it briefly. It concerns the 'Ghost of Flight 401.' (5) This well-documented case involved an Eastern Airlines L-1011 that crashed in Florida due to cockpit error. Many persons were killed. For months thereafter witnesses reported seeing two members of that flight's crew on board *several other Eastern Airlines L-1011s*. This caused such a stir that the airline threatened to fire employees for spreading these reports. Apparently the publicity was scaring passengers away. Now, what is remarkable about this haunting is that it took place in locations that had nothing to do with the deaths of the ghosts – that was a different airplane altogether. Or was it? I suspect that what happened went something like this: The two crewman died in the crash and recent viable files of them were downloaded into a sub-simulation of their still-intact airplane. Now that airplane no longer existed in our reality, of course, and could hardly become the location for a haunting. But one Eastern Airlines L-1011 is very much like any other. Their files would share most of the same 1s and 0s in common. As far as the UTM was concerned, it seems, one Eastern Airlines L-1011 could barely be distinguished from another. So it made a "mistake" and mixed the ghosts' sub-simulation with the "real" simulations of virtually identical airplanes. In this way the haunting came about.

The Interaction of Ghosts with Real Matter.

Ghosts are often described as being able to touch things in our world. They are reported to shove people. Poltergeists throw objects around and bang on walls. Ghosts can sometimes produce disembodied voices so it appears that their vocal cords can interact with our air. EVPs (those that cannot be dismissed easily as pareidolia) should probably be looked at as just very quiet disembodied voices that require a sensitive recorder to pick up. In fact, ghosts interact with us through their tangibility more often then they are seen.

A ghost is tangible to the extent that it cannot put its hand through objects in our simulation and I cannot put my hand through it. It is tangible to the extent that it interacts as a real material object in our world and we in its. I cannot put my hand through my desk. Why not? This is due to interatomic repulsions that develop as the atoms in my hand come too close to the atoms in the desk. The interaction energy that develops as atoms get close to one another is a complicated product of electrostatic, dispersion, and exchange forces. It is by no means obvious how go about calculating this energy when real atoms are interacting with ghost atoms. Since we don't think ghost particles function as identical particles to our own, we would not expect to encounter the exchange forces. What remains is largely electromagnetic in origin so we will guess that the strength of these repulsive interactions is roughly proportional to $V(\boldsymbol{x}, t)$. Unless our guess is terribly wrong, we can already explain an important thing – the fact that ghosts are more often felt and heard than they are seen. Anyone who has tried to put his hand through his desk knows that the energies involved are enormous. $V(\boldsymbol{x}, t)$ does not have to get very big for the ghost to become tangible to us. It has to become quite a bit larger before we can see the ghost. I will present some calculations that try to ballpark this in the next two sections.

The Visibility of Ghosts.

I chose $V(\boldsymbol{x}, t)$ to denote the quantity in question because it relates very directly to the *visibility* of ghosts (and, equally, to our visibility in their respective worlds). According to everything set forth thus far, there is an uncanny symmetry between our situation and that of the ghost. Really, we would appear as "ghosts" to the ghost whenever a haunting takes place. Now the nature of a ghost's appearance is going to be a complicated function of illumination conditions and $V(\boldsymbol{x}, t)$. I will only go over a few examples. The reader can, of course, investigate other possibilities for himself.

If a ghost is well-illuminated by "ghost" light that exists in *his* haunted house the "ghost" electrons in his surface will vibrate and give off "ghost" light. If he moves into an area where $V(\boldsymbol{x}, t)$ is large some of this light (remember, the ghost is now a *source* of light) will filter into our world and we may be able to see him. The intensity of the light we would see (in Watts/meter^2) will be reduced by a factor of $V(\boldsymbol{x}, t)^2$ if we are also in the high $V(\boldsymbol{x}, t)$ area. If we are in a low $V(\boldsymbol{x}, t)$ area we would see him less well since our eyes could only interact with the "real" photons he produced. In a low $V(\boldsymbol{x}, t)$ area the "ghost" photons would not be visible to us. Depending on the illumination conditions in our simulation of the haunted house we might see him or not. If our house was well-illuminated we might just see something if $V(\boldsymbol{x}, t)$ was large – our eyes would not be very sensitive. If it was dark in our house we would see the ghost more easily. He would appear to us as a faintly glowing apparition. Such sightings are reported and would seem mostly to correspond with what we would expect if $V(\boldsymbol{x}, t)$ were in the neighborhood of 0.1 or a little bigger. A full-blown, plainly visible ghost, such as one might see if $V(\boldsymbol{x}, t) = 1$, is seldom encountered. So, as an empirical matter, we guess that $V(\boldsymbol{x}, t)$ rarely gets much bigger than 0.1 or maybe a little more.

Suppose that the ghost's simulated house isn't well-illuminated but that ours is. Suppose, again, that the ghost moves into an area where $V(\boldsymbol{x}, t)$ is large. If our "real" light sources aren't in that area then no light will shine into the ghost's simulation. We won't see a thing and neither will the ghost. But, if our light sources are also in the high $V(\boldsymbol{x}, t)$ area, they will shine light into the ghost's reality (which light he will be able to see). This light will shake the electrons in his surface and he will, therefore, reflect light. The intensity of this light will be reduced by a factor of $V(\boldsymbol{x}, t)^4$ since the light now has to make two trips – one into the ghost's reality and another back into ours. Under these circumstances the question becomes how large must $V(\boldsymbol{x}, t)$ be in order for us to see the ghost? How thinly must you slice a human body before it becomes transparent or invisible? (This is a sort of 'optical thickness' problem.) I think that a slice of a typical human that was 10^{-4} m thick would be nearly transparent. The imaginary part of the ghost's refractive index will be $V(\mathbf{x}, t)^2$ times that of a normal person. A normal ghost (or person) is about 0.3 m thick. So we need $V(\mathbf{x}, t)$ to be in the range of 0.02 or more to see the ghost somewhat clearly. If our light sources, assumed to be within the area of large $V(\mathbf{x}, t)$, were behind the ghost, how large would $V(\mathbf{x}, t)$ have to be for us to detect him? The answer follows from what has already been said. $V(\mathbf{x}, t)$ would have to be, at least, about 0.02. If detected he would appear as a shadow that blocked out the light coming from behind him. Such apparitions are among the most common kinds reported.

Suppose that the ghost is in an area where $V(\mathbf{x}, t)$ is large. Let's say he sets off a ghost flashbulb. It will produce both 'real' and 'ghost' photons. If we happen to be in the high $V(\mathbf{x}, t)$ area our retinas will respond (partially) to both kinds of photons. If we are in an area where $V(\mathbf{x}, t) = 0$, we'll (according to Equation 6)) only see the 'real' photons. So the light will appear even dimmer to us than it would otherwise.

The Tangibility of Ghosts.

I now give a simple calculation pertaining to this matter. Human bodies are composed mostly of water so I will use water as a substitute for ourselves and the ghost. Suppose I try to determine how tangible a ghost is by pushing a disk of ice having a cross section of 18 cm^2 into him. By 'pushing into' I mean a very specific thing – I need it to *co-occupy* the same space as the ghost's water molecules. I am not trying to stab him, which would simply push his molecules out of the way. Fortunately, there are many good semi-empirical models that describe the behavior of water. Most of these employ the Lennard-Jones potential to describe the intermolecular interaction energy (6,7):

16) $$U(r) = \frac{A}{r^{12}} - \frac{B}{r^6},$$

where A is usually taken to be about 6×10^5 kcal $Å^{12}$/ mol and B about 6×10^2 kcal $Å^6$/ mol. r is the average distance between a water molecule and its nearest neighbors. Minimizing U(r) gives r = 3.55 Å as a good average distance between the molecules. If I push the disk 1 cm into the ghost we are dealing with 2 moles of water, 36 g, half coming from the disk and half coming from the ghost. r will therefore be decreased by a factor of $2^{1/3}$. If the ghost were fully tangible, just like a real person, pushing the disk into him in this way would require an enormous 1.1×10^4 J of energy. This corresponds to a pressure of roughly 6×10^4 N/cm^2 that would have to be overcome as the disk was pushed in and came to overlap with the ghost. (It is no wonder that I cannot put my hand through my desk!)

I will take a much smaller pressure, around 6×10^{-2} N/cm^2, to be something that would be required if we want to interpenetrate the ghost fairly easily and not generate enough excess energy in the process to do significant harm to him or ourselves. Since the pressure, will be roughly proportional to $V(\mathbf{x}, t)$, the ghost will begin to become more-or-less intangible at around $V(\mathbf{x}, t) \leq 10^{-6}$. Thus $c(\mathbf{x}, t) \approx 10^{-6}$ marks a rough dividing line between a tangible and an intangible ghost. Since I have already shown that $c(\mathbf{x}, t)$ must be on the order of 10^{-2} for the ghost to be visible, it is immediately obvious why ghosts are more often heard and felt than they are seen; $c(\mathbf{x}, t)$ must be roughly four orders of magnitude greater for the ghost to be visible than it has to be for the ghost to be tangible.

The Phenomenology of Ghosts.

Having completed the construction of this theory, I will take a little time to examine whether it can actually explain some of the curious things ghosts are reported to do. Ghosts are often reported in association with so-called cold-spots or hot-spots. What could be going on here? If the air in the ghost's haunted house is cold (maybe he died in the winter) and the air in our "real" house is warm a transfer of energy would take place in any area where $V(\mathbf{x}, t)$ became large enough. Cold "ghost air molecules" would collide with warm "real air molecules." We would see the temperature in that area fall. The ghost would see it rise.

EMF detectors are often used to check for hauntings. Why should these work? If the ghost, or objects in his simulated environment, were at a different electrostatic potential than things in our environment (perhaps the ghost shuffled his shoes over his carpet, or he may have died during a thunderstorm), and if $V(\mathbf{x}, t)$ were suddenly to become large, we would see the effects of this difference in potential as a change in our own electromagnetic field. Such a thing could, conceivably, register on an EMF detector. This analysis may go some way towards explaining the "static electricity" feelings many people report during ghostly encounters.

Ghosts are sometimes reported as walking through walls. Often, when this is observed, a bit of background investigation reveals that the wall in question was constructed after the ghost first formed. So, in his simulated reality, there is no wall. Now, the new wall must represent a discontinuity, a break in congruence, between the ghost's version of the haunted house and our version of it. It is therefore an area where $c(\mathbf{x}, t)$ may find itself constrained to be close to 0; perhaps no haunting can occur within this area. So the ghost just cannot be visible or tangible in the area of this new wall. So he walks on through it since, in his simulated reality, there is nothing to stop him. And we stop seeing him as he enters this area since, as he enters it, he ceases to function as a source of light or tangible influence in our world.

Strangely enough, ghosts are sometimes detected through the smells they produce – cigar smoke, perfume, body odor, have all been reported. In an area where $V(\mathbf{x}, t)$ was sufficiently large "ghost smell molecules" could interact with our smell receptors. The energy of their binding to those receptors would be reduced by a factor of $V(\mathbf{x}, t)$, of course. But many smell molecules bind to their corresponding receptors with a great deal of ΔG. Even if $V(\mathbf{x}, t)$ weren't particularly large we might still be able to discern their effects and "smell" the ghost. The ghost could smell us too, under these circumstances.

The Simulation Hypothesis Reconsidered.

Returning to examine the Virtual World Simulation Hypothesis, I will consider two cases. In the first case the higher-order reality contains sentient observers. Maybe they are the creatures that built the UTM. Anyway, if it is inhabited by conscious beings, that reality has a perfectly legitimate claim to existence. After all, those observers will consciously experience it. Now, it could exist in two different ways. That higher-order reality could be, as Bostrom suggests, a simulated virtual world running on an even bigger UTM in a higher-higher order reality. There could even be an infinite regress of such realities, as Bostrom has also suggested. This isn't a particularly "economical" idea. But it might be right nonetheless. If it isn't right, there must be a "highest-order" reality that terminates the chain. This would, presumably, be the "Real" World, real in same sense that Science and Materialism consider our world to be real. I will be the first to admit that this notion of "Reality" is problematic in its own right. But it is, at least, familiar to everyone and might make for a reasonable way of thinking. That is if there are sentient observers in the higher-order reality or realities.

On the other hand, suppose that there are no conscious beings associated in any way whatsoever with the higher-order reality where the UTM exists and simulates us. (Actually, this is the view I favor.) Some people will object : "If there are no conscious beings there, who built and programmed the UTM?" I don' t know. Maybe it just took shape spontaneously. That' s beside the point. If there are no sentient observers that could look at or touch the UTM then its existence, and that of the world where it is imagined to exist, become, as far as I am concerned, ontologically moot points. The UTM neither exists nor fails to do so. Its "existence" becomes, under these circumstances, a vacuous idea, an idea about nothing. It is an idea that feels as if it means something but doesn't. In effect, there is no "real" UTM! The whole idea is just shorthand for a different take on the ways the Laws of Physics work. (Having climbed up the ladder, we have no further use for it and can now push it away.)

I have used the Simulation Hypothesis to *illustrate* a theory of ghosts. Readers who like the Simulation Hypothesis and my ghost theory can go on thinking in exactly the way we have been thinking throughout this article. The ghosts won' t appear any differently, regardless of how one construes the Simulation Hypothesis. But for me the UTM is, in effect, an as-if way of thinking, a heuristic device for explaining a complicated idea. If my guess is right, Science and Materialism are on somewhat the right track in their efforts to account for reality – and I suspect that there is only one reality to account for (at least, only one that we'll ever get to experience). But they fall short in assuming that there is only *one* conventional reality to explain. If I am right reality is a multifaceted thing containing not only our commonly perceived, public world, but also many "smaller" worlds that have, for various reasons and in various ways, budded off from it and which can, under favorable circumstances, communicate with it in the manner I have described. If this view is correct, the things I have invoked the UTM to explain are simply the Laws of Physics expanded to take account of the fact that reality is more intricate than we think it is.

References and Footnotes.

1) Bostrom, Nick. *Philosophical Quarterly*, 2003, Vol. 53 No.211, 243.

2) See Wikipedia: Simulated Reality and Simulation Hypothesis.

3) For a good, and not very mathematical, introduction to Fock space and related matters see: Teller, P. An Interpretive Introduction to Quantum Field Theory, Princeton University Press, 1995. For a more complete treatment see: Hatfield, B. Quantum Field Theory of Point Particles and Strings, Addison-Wesley, 1992

4) The renormalization of this theory raises some interesting questions and should be discussed briefly. The "real" and "ghost" photon loops that figure in calculating the vertex correction and electron self-mass terms give rise to results that differ in no essential way from those encountered in normal QED. Of course, there are twice as many particles to keep in mind. But, otherwise, nothing important is changed. The fermion loops that renormalize the photon propagators – the vacuum polarization terms – require a more delicate treatment. These loops can and do link incoming "real" photon lines to outgoing "ghost" photon lines and vice-versa. There is, accordingly, some amplitude for a "real" photon to be created at one vertex only to be absorbed as a "ghost" photon somewhere else. In other words, there is some amplitude for a "real" photon to "turn into" a "ghost" photon and vice-versa. These vacuum polarization graphs also contribute additional amplitudes for a "real" or "ghost" photon to turn back into itself. This is an undesirable situation. For one thing, it makes it hard to see how to renormalize the theory. For another, the ability of "ghost" photons to turn into "real" photons (and vice-

versa) would complicate our efforts to understand the phenomenology of hauntings. This ability of one state to turn into another presents us with a classical two-state situation of a kind encountered frequently in quantum mechanics. The most famous case in point is, perhaps, that of K_S and K_L (Gell-Mann, M., Pais, A., Phys. Rev. **97,** 1387 (1955)). We will solve our problem in a similar way. Instead of expressing things in terms of A_R and A_G let us rotate into a different basis according to $A_R \to (A_1 + A_2)/\sqrt{2}$ and $A_G \to (A_1 - A_2)/\sqrt{2}$. The vacuum polarization graphs that would allow A_1 and A_2 to interconvert now cancel out leaving behind something that resembles much more closely ordinary QED. One could renomalize this theory by the usual methods – basically absorbing the (formally divergent) contributions of *all* the closed loops into new values for the physically measured quantities e and m – those that, presumably, appear in equation 3). One could then rotate back into the original $\{A_R, A_G\}$ basis giving a renormalzed theory in which only Feynman diagrams giving finite amplitudes need be considered and in which "real" and "ghost" photon lines do not turn into one another.

5) Fuller, J. G. <u>The Ghost of Flight 401</u>, Berkley, 1976.

6) For example: Jorgensen, W. L.; Chandrasekhar, J.; Madura, J. D.; Impey, R. W.; Klein, M. C. *J. Chem. Phys*., 1983, Vol. 79, 926.

7) "The calculated interaction energy is a sort of upper bound in that it does not allow readjustment of the orbitals within each monomer after orthogonalization, which is considered polarization because it can't easily be separated from polarization of each monomer in response to the electrostatic potential of the other. The repulsive effect from this orthogonalization is the primary repulsive interaction – e.g., in water dimer the electrostatics are attractive and the net binding of ~5kcal/mol is a combination of (depending on how one partitions) roughly 10kcal of electrostatic binding, 7 kcal of repulsion due to orthogonalization and a couple of kcal of other effects of reorganization and dispersion. For a system like Ne2, where there is only the weak dispersion for an attractive interaction, the equilibrium geometry is at long distance, where the small attractive force from dispersion (which varies as 1/R^6) balances the Pauli repulsion (which is big at short distances but varies as Exp(-R)); at the equilibrium distance the attractive energy is roughly -2 times the repulsive term." (M. Frisch, personal communication). We may be encouraged to think that our approximations are somewhat reasonable in the sense that the exchange term contributes energies that are of the same general order of magnitude as the electrostic term.