Contemplations on Our Physical Links to the Universe: Searching for and Finding the Hidden Harmony

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ABSTRACT

The author discusses the evidence and consequences of our indissoluble physical links to the entire universe. He finds that the apparent conflicts in fundamental physical theories regarding issues of causality and locality are not real conflicts based in the physical world. He presents an emergent worldview interpreted in the context of a cultural, philosophical and linguistic background in which a strong tension between inseparability of the whole and the local causal flow of events seems not to exist. The existence of the whole can be felt in the parts, as something real, measurable and undeniable. Its simplicity and harmony are spiritually enriching and emotionally moving.

This discussion concerns my individual efforts as a physicist to formulate a consistent and satisfactory worldview. This worldview must be consistent with a variety of facts of the observable physical world and even the imaginable physical world. It is also desirable that it be spiritually satisfying. There is no requirement that such a worldview be correct and final, since the history of physics teaches that at no time in history has such an understanding of the physical world been achieved, and there is no reason to think that we have now achieved such a view. There has, of course, been a progressive sharpening of our understanding, and this will continue.

The single most important motivation for my reconsiderations of fundamental physical theories, especially the theory of relativity, is the new awareness in physics of the existence of the massive and vast universe and the ever-present and all-encompassing gravitational link of everything in this universe to everything else [1]. Contemporary theories of motion in space and time do not incorporate the presence of the universe, but it is an essential presence to be acknowledged. Apart from the theoretical and philosophical need for reconsideration, there is also experimental evidence that supports a new point of view. What I want to stress in the present context is the inseparability of all entities in the universe, even if it is only a physical, gravitational inseparability.

At this point in time, the physicist's worldview is formed by two fundamental theories of motion. One, Einstein's general theory of relativity, deals with the inter-relations of matter, space and time as they are linked through gravitational interaction. The other theory, that of quantum mechanics, deals with observables of the microscopic, quantum world. Underlying all physical theories is the theory of modifications of space and time resulting from motion in empty space, called the theory of special relativity. The theory of the constituents of matter and their interactions, called the Standard Model of particle physics, is based on quantum theory and special relativity. We also have a mature theory of cosmology, based on general relativity and observations. This standard model of the cosmos, the big-bang theory, describes an evolving, "expanding" universe that originated about 14 billion years ago. This model is based on the *guess* that the universe is the same at all points of space, which is supported approximately by observation and also influenced by the observation that distant galaxies are moving away from us at speeds proportional to their distance from the solar system.

The success of these theories can be measured by how well their predictions agree with the observations we are able to make. It is indeed remarkable that physicists and cosmologists are able to draw precise correspondences between what they observe and what is contained in the theoretical representation of the physical world. Yet all physicists who have studied the foundations of these theories are well aware that they are either shaky or mutually incompatible. For example, all attempts to harmonize the quantum theory with the general theory of relativity have been unsuccessful. Thus, the standard model of particles and interactions cannot incorporate the most fundamental interaction—gravity—into its successful scheme. The highly successful theory of quantum electrodynamics, which describes the motion of charged particles such as the electron and their interactions with light and other charged particles, also posits an absolute vacuum—empty space without real particles or light— that contains *infinite* energy density. This conflicts with generally accepted cosmology: Our standard model of the evolution of the universe states that the universe as a whole is expanding and that the rate of expansion is proportional to the average density of matter and energy in the universe. An infinite or even a large amount of energy density implies a rate of expansion far exceeding the observed rate of expansion.

Therefore, natural philosophers of today are not at peace. Their worldviews are confused and they are desperate, more so than ever in the history of physics, to understand these interconnections in their lifetimes. So much is known as fact and observation, and various theories seem remarkably successful in their own domains. Yet there is no harmony, and in fact there are clashes of dissonance.

This situation is particularly disturbing for those who are interested in origins and interconnections. My research in the past few years has been guided by a determined effort to understand the foundations of quantum physics and of the theory of space, time and motion. This determination comes from a very personal belief, underlying which is a definite philosophy, formed by various influences, in the fundamental har-

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mony and unity of the material world. Above all I believe that the entire universe originated in accordance with well-defined, simple natural principles, and its various constituents—both living and nonliving—are constrained in their motion and evolution by these simple principles. My research has convinced me that each constituent of this universe is part of an indissoluble link, but also subject to the simple progression of cause and effect, without instantaneous influences. Although this link is purely physical, acting through the long-range and irresistible gravitational interaction, it is a link that can be felt and experienced by every individual. This realization then affects one's attitude toward everything living and nonliving, as they are all linked to oneself.

At this point let me briefly mention the intellectual and cultural background relevant to my research. It includes direct and indirect influences and teachings, as well as the cultural and philosophical background specific to my formative years.

While mysticism is familiar and even influential in our lives in India, our philosophies are strongly rooted in rational enquiry, causality and unified existence. Science in the modern sense, especially physical science, is hardly 100 years old in India. India's rich traditions in astronomy and mathematics have not found continuity into modern times. Most Indian science today is not original. This is a very unsatisfactory situation intellectually, especially for anyone with even the slightest familiarity with the intense perseverance and spirit of inquiry highlighted in Indian philosophical systems [2]. These teachings underscore the importance of going to sources and foundations, and encourage asking the most fundamental questions. They encourage seeking knowledge even from "Death." They repeatedly remind us that the entire perceptible universe, including the living and the nonliving, is a single whole, and material realizations are transformations of a fundamental indestructible and indescribable entity.

Culturally, there was a strong materialist influence on my thinking, as I grew up in a place that received considerable communist influence politically and intellectually [3], but this was mixed with an innate intuition that acknowledged clues and revelations originating in nonmaterial sources, including art and life. Aesthetic consonance in the perceptible, observable and imaginable worlds has been a criterion of mine for deciding preferences of inquiry. I have maintained a certain confidence in first-person inner experiences while contemplating the physical world and its interconnections.

All higher education in India, especially science, is carried out in English, which is not the native language of most of those opting to study science. The original sources of all ancient Indian knowledge are in Sanskrit, which is also not part of contemporary native language abilities. Thus, acquiring authentic knowledge of science and philosophy often means acquiring new language skills. While this might not be a problem in the long run, it cannot be concluded that this factor is irrelevant.

It is difficult to trace philosophical influences in a direct manner, since one is only vaguely aware of them during one's formative years, or even later. The idea of the axiomatic approach was familiar to me from an early stage, as was the feeling that everything we see happen in the world around us must have a cause behind it and that the result of any action cannot be erased away. The principle of causality was a strong influence; so also was a leaning toward determinism in the inanimate world. I was also consciously influenced by the ancient Indian method of reaching pristine truths by eliminating what is not truth, saying, "It is *not* this." Thus our notions of physical reality can never be final. We must be prepared to change our theories as we perceive and comprehend more of the world.

I will discuss the possibility of modification of our fundamental theories in order to make them consistent with the presence of our "once given" Universe [4]. Theories are representations of the physical world and not the physical world itself. In fact, our physical theories employ several unobservable factors for a successful description of the physical world. The uncertain objective reality of the unobservables creates an open territory, the exploration of which can lead to new physical theories, perhaps based on new unobservables.

Unobservables in Physical Theories

Observable phenomena, and what is considered measurable reality, are described in physical theories in terms of certain *unobservables*, things beyond perception, the objective reality of which is debatable or indefinite [5]. This seems to be an inevitable structure in all our physical theories. Observables—tangible reality—are usually derivatives of these unobservables. Familiar examples of unobservables in our physical theories are the field, potential, phase, vacuum, etc. If we go deeper we see that *even space and time are unobservables*.

An Example from Cosmology

I will now discuss an important example from cosmology. The big-bang model of cosmology describes an evolving and expanding universe. Estimation of the amount of matter in the universe is an old problem. It is an important issue because the fate of the universe crucially depends on its matter content. If the density of matter exceeds a particular value called the critical density, then the universe will re-collapse. This special density value signifies that the total energy in the universe—the sum of the positive energy of motion and matter and the negative energy of gravitational binding—is zero, as perhaps it should be if everything started from nothingness (matter and energy are equivalent and both influence the evolution of the universe). All observations show that the matter that constitutes us and our environment and all that is visible in the universe—made of electrons, protons, neutrons and light—amounts to hardly 3% of the critical density. There are, however, other dependable observations that can measure even nonluminous and unseen matter using their gravitational properties, and these observations indicate that in fact the density of matter in the universe is close to the critical density [6]. Of what, then, does the other 97% of the matter in the universe consist? What are its properties? We do not know yet. Currently prevailing speculation is that about 30%—provisionally called "dark matter"—consists of yet-to-be discovered particles that interact with matter only very weakly and are therefore very difficult to detect. The rest of the unseen matter seems to be even stranger. One important observation that studies very distant supernovae (bright stellar explosions) and measures their distance and speed of recession seems to show that the rate of expansion of the universe is increasing [7]. To understand the strangeness of this observation, imagine watching a stone thrown upward and seeing it speed up as it rises. This can happen only if there is repulsive gravity, but we have no experimental evidence in the whole history of physics for repulsive gravity. Yet we confront a situation in cosmology that requires a form of matter that can generate the equivalent of repulsive gravity. The inferred properties of this dominant form of matter are so close to that of vacuum or empty space that *it could only be the vacuum itself*—an unobservable! The physical vacuum familiar to us, however, contains nothing and should not influence anything. This is the point at which peculiarities of the quantum microscopic world come into the picture.

The vacuum in quantum physics is not just emptiness. It is postulated to be a reservoir containing an infinite amount of energy residing in quantum oscillations of various fields including the electromagnetic field, and it is generally asserted by quantum physicists that this infinity is not observable directly. What are really observable are some very small residues in very special physical situations. The structure of present quantum theory demands such a strange, perhaps absurd, construction. By paying this price, theoretical physicists are able to calculate and predict several microscopic physical effects with amazing accuracy. When the dynamics of the universe is considered, however, every bit of energy contributes, and the concept of a quantum vacuum with infinite or even merely large energy density becomes discordant for reasons mentioned above. However, the new cosmological observations that indicate accelerated expansion require a very small amount of "dark energy," just about the equivalent of a hydrogen atom per cubic meter, with properties similar to that of the quantum vacuum [8]. So sophisticated observations have led us to a form of matter that is almost mystical, and certainly the most mysterious we have ever come across. Not only does it dominate, it will eventually become the only form of matter in the universe because of this strange property: It does not diminish as the Universe expands!

This is the Copernican principle at its extreme. In its original form it held that man and Earth had no privileged position in this solar system. The generalized Copernican principle applied to the universe, asserting that even the solar system is just one of the infinite equivalent positions in the universe. Now it turns out that even the matter that we are made of is only an insignificant fraction of all matter. This worldview implies a strange alienation. Most of the universe is "not of our kind."

The matter we are made of is rare. We, our environment, our cosmic neighborhood and so on may not be unique, but they are certainly rare. Our integrated worldview should not ignore this, and in fact should incorporate this realization not only in our science, as we are forced to, but also in our philosophy and ethics.

An Example from Quantum Physics

My next example is related to an unobservable that has given rise to numerous debates, speculations and even philosophies—the *wavefunction* in quantum mechanics. It is one of two basic entities, along with time, employed in describing the dynamics of the microscopic world, just as position and time are the basic entities used in the classical description of motion. The wavefunction represents the wave-particle duality manifest in the quantum world. As far as we know, no objective reality can be ascribed to the wavefunction, but all observational results in physics are supposed to be potentially associated with it.

One of the basic issues involved in this question is that of nonlocal influence. One can discuss and experiment with situations in which there are two particles described together by one wavefunction and no objective property can be ascribed to either particle *separately*. Making an observation of just one of the particles yields some result and therefore a definite property for that particle. The other particle then simultaneously, spontaneously and nonlocally assumes a definite property, however far this second particle is from the first! That is what standard quantum theory and related experiments together imply. This of course violates the basic notion of locality inspired by special relativity (in Einstein's words, "On one supposition we should, in my opinion, absolutely hold fast: the real factual situation of a system is independent of what is done with another system, which is spatially separated from the former" [9]).

This is the situation in our most successful theory, all arising from the need to deal with a mysterious unobservable. This problem and its tension with the spirit of relativity are perhaps the most-discussed fundamental issues in physics. See for example the famous discussion by Einstein and his collaborators Podolsky and Rosen (EPR) [10]. This situation created an intense emotional problem for me with the process of rational inquiry, mainly due to the clash of quantum nonlocality with everything else one knows about the physical world, especially causality. Even the philosophies that are familiar to me, which advocate wholeness and oneness, do not deny the cause-effect link [11].

Any satisfactory understanding of motion and events in space and time will have to address the relation between cause and effect in quantum physics. The reason is simple. If physical influences can propagate instantaneously, then there is no meaning in the cause-and-effect order of events. What is "before" for one observer can become "after" for another one moving relative to the first.

I have ventured into probing the consequences of the unobservables in quantum theory, especially the process of the realization of observable results from the unobservable ones, and the issue of the cause-effect link. I will briefly mention these aspects after a discussion of a new view of space, time, motion and matter.

Space, Time and Matter: The Need for a New Theory

Space and time are the fundamental metaphysical concepts on which kinematics and dynamics, and thus every description of the physical world, are built. Our theories use these concepts as priors. They are, however, *unobservables*. They have no physical existence separated from matter. All the same, descriptions of matter—of its states and changes—require these concepts.

The accepted theory of motion deals with space and time as one unified four-dimensional entity despite the qualitative and perceptive difference between space and time. Called the special theory of relativity, it is basic to every other description of physical phenomena and has immensely influenced human thought. This theory confers equal status to all observers and reference frames in uniform motion relative to one another. All physical laws have the same form in these inertial systems, and every such observer has the right to claim the state of rest. Spatial and temporal intervals are modified based on relative motion, and clocks in relative motion age at different rates. There is no absolute time or invariant concept of simultaneity, and there are no preferred reference frames relative to which one can discuss motion in an absolute sense.

We now know, however, that there is a preferred frame relative to which we can measure our motion precisely—this is the average rest frame of the matter in the universe [12]. Operationally the absolute velocity of motion can be measured by measuring the Doppler shift of the all-pervading cosmic microwave background radiation (CMBR). This radiation is supposed to be isotropic—with no preferred direction. Its properties, especially the spectrum, are expected to be the same when measured in any direction. Observationally, however, there is excess energy in one direction and correspondingly less from the opposite direction, exactly like the Doppler effect changes in the frequency of sound as the listener moves away or toward the source. From these measurements we can determine precisely how fast Earth is moving through the radiation background as well as through the average absolute frame of the universe. So *no observer really has the right to claim a state of rest without being at absolute rest relative to this frame*. In addition, there is absolute time available. The temperature of the microwave background decreases uniformly as the universe expands and can serve as the absolute time, at least in principle. These facts were not known when special relativity was formulated and certainly not recognized even in later times. This is why a reconsideration is needed.

This is not the occasion to discuss the technical details of the reconsideration of the theory of relativity [13], but some facts do need to be mentioned. If we start with the obvious assumption that every physical entity is gravitationally linked to every other physical entity in this universe, then it turns out that all physical effects hitherto thought to be due to kinematics of relative motion are in fact due to gravitational interaction with the matter in the universe. The velocity of light and of all communications, including quantum communication, is restricted to a maximum value by this gravity. The rates of moving clocks are affected by the gravity of the universe. Certain peculiar behaviors of elementary particles and atoms, including the Pauli exclusion responsible for the stability of atoms and life, seem to be related to gravitational interaction with the universe. There is a precursor to these ideas in Mach's well-known but largely ignored principle advocating a connection between inertial forces and the matter in the universe [14].

If the universe were empty, none of the effects thought to be the results of the theory of relativity would be seen. Therefore, special relativity will have to be replaced by another theory that describes modifications of space and time due to motion as resulting from gravitational interaction with the universe. I call this theory *cosmic relativity*.

It is not difficult to verify by direct calculations that the influence of the universe on every local action is in fact large and cannot be ignored. For example, if we calculate the gravitational potential of the Earth at its surface, it is a very small number. The gravitational potential of the sun is 10 times larger, and that due to the Milky Way galaxy is 1,000 times larger. Even this number is small, being only one millionth of the gravitation potential due to all the matter in the universe. If we calculate the integrated gravitational potential of all the distant galaxies, however, we get a number that is a billion times larger than Earth's gravitational potential. Although most of the galaxies are far away, there are so many of them that in the end they dominate the gravitational influence.

I will mention one crucial difference between the new theory and special relativity, and also mention the relevant experimental evidence that supports the new theory. It is well known from the early explorations of relativity that a clock in motion slows down in comparison to a stationary clock. As stated in Einstein's original 1905 paper,

> if one of two synchronous clocks at A is moved in a closed curve with constant velocity until it returns to A, the journey lasting t seconds, then by the clock that has remained at rest the travelled clock on its arrival at A will be $(\frac{1}{2})tv^2/c^2$ second slow [15].

If applied to a clock that takes off in a flight at typical flight speeds, goes around the earth and comes back in about 40 hours, this prediction gives a tiny retardation of about 0.04 microsecond compared to a clock stationary in the laboratory. Because Einstein's theory deals only with relative velocities, the fact that the earth's surface is moving relative to the cosmos is of no consequence to the theory. For example, clocks that are transported westward and eastward at equal speeds will both suffer the same time dilation; but what is it that really happens?

In cosmic relativity, what matters is the true velocity relative to the preferred frame of the cosmos. A clock that is "stationary" on the earth's surface is in fact moving eastward at a speed of 220 meters per second because of the eastward rotational velocity of the earth. A clock that goes westward at 200 m/s has a true speed eastward of only 20 m/s. Thus we arrive at the amazing prediction that the clock traveling westward can age more than a stationary clock, directly contradicting Einstein's 1905 prediction.

It turns out that the clock comparison experiments performed by Hafele and Keating in 1972, as well as some subsequent tests, have demonstrated exactly this effect [16]. There is experimental evidence that a traveling clock can run faster than a stationary clock, an effect that can be understood only by taking into account the preferred frame and the gravitational effect of the universe. Thus there is unambiguous evidence that the 100-year-old theory of relativity must be replaced with a theory based on cosmic gravitational effects. Of course one expects that this change will take time, because science is one of the most conservative disciplines and accepts change only slowly.

Determinism and Causality in Microscopic Physics

Quantum physics is supposed to have brought the deterministic phase of physical descriptions to an end. Events in microscopic physics are not predictable, even when there is full knowledge of the initial conditions, as described by the present quantum theory. Only the probabilities of elementary events are predictable. Related to this point is the issue of nonlocality and instantaneous influences mentioned above.

A detailed consideration of quantum correlations has allowed me to conclude that there is in fact no nonlocal influence in quantum mechanics [17]. Arguments based on some earlier work by Einstein and Karl Popper show that there is no nonlocality and that therefore the standard quantum theory is incomplete as it stands [18]. This view is supported by the finding from cosmic relativity that no physical influence whatsoever can propagate faster than the limit specified by the gravitational interaction of the entire universe.

This insight prompted me to ask whether quantum phenomena could be understood without their inherent indeterminism. In the standard quantum theory, cause-effect uniqueness is violated in the sense that the same initial cause described by a particular wavefunction can give rise to a multitude of final results occurring at random in different observations. This is what is meant by indeterminism in quantum mechanics. There are empirical and theoretical reasons not to depend on a gambling dice model—called hidden variable theories—of quantum phenomena. I have a proposal that is related to the properties of the unobservable wavefunction [19]. The randomness is encoded in a wave property called a *phase;* by its very nature this initial phase is an unobservable. If we include this random phase in a new description, it is conceivable, but by no means definite, that the uniqueness of the cause-effect relation can be restored in quantum mechanics. Such a change in quantum theory can lead to a tremendous change in our worldview and philosophy, given that the indeterminism of quantum theory has profoundly affected modern philosophy of science.

Conclusions: Discovering Harmony

I have attempted to present some explorations into the foundations of our physical theories that are affected by mutual tensions and contradictions. Taken one by one, these successful theories have practically consistent foundations. When the physical world is seen as a whole, however, obvious and serious discrepancies and conflicts arise. I have been personally disturbed by these problems, but not bewildered by their magnitude, because the systems of inquiry with which I am familiar within my culture have asked more difficult questions and have explored larger interconnections. Finally, the result of my contemplations so far has been positively encouraging, revealing several aspects of harmony between our fundamental theories. Most importantly, the research has highlighted the causal inseparability of the massive and vast universe and its role in determining properties of local physical phenomena, such as modifications of intervals of space and time due to motion through the universe, and an intricate balancing of the atomic world. The realization of the strong inseparability of everything in this universe will have lasting influences upon my future scientific studies as well as in my worldview, philosophy and even personal life.

This search for harmony seems to take the explorer to new notions of space and time, material and causal, and yet inseparable from the local. The existence of the whole can be felt in the part, as real, measurable and undeniable. Its simplicity and harmony are spiritually enriching and emotionally moving, and its scale and intimacy make one feel secure in some strange way.

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References and Notes

1. C.S. Unnikrishnan, “Cosmic Relativity: The Fundamental Theory of Relativity, Its Implications and Experimental Tests,” electronic preprint (2004) available at <http://arxiv.org/abs/gr-qc/0406023>.

2. The variety of “Indian philosophical systems” does not allow me to make any general statements on them. What I have in mind here is the philosophy highlighted in the *Upanishads*. What one generally imbibes as philosophy while growing up in India is a mixture of these and thoughts from Buddhism and Jainism, along with ethical and moral lessons from Hindu mythology.

3. Kerala, India’s southernmost state, has elected communist governments since 1957. It boasts a strong popular science movement that is predominantly leftist. In terms of the multi-religious coexistence, it has some similarity to Melilla.

4. The phrase “once given universe” was used by E. Mach in *The Science of Mechanics* (London: Open Court, 1942) to stress the importance of taking into account its presence with its real properties in the formulation of mechanics.

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10. A. Einstein, B. Podolsky and N. Rosen, “Can Quantum Mechanical Description of Physical Reality Be Considered Complete?,” *Physical Review* **47** (1935) pp. 777–780.

11. The arguments against “causality” (sometimes called refutations of it) highlighted in Buddhist interpretations are not a denial of the causal chain, but an argument against the separable identification of cause and effect.

12. See, for example, G.F. Smoot and D. Scott, “The Cosmic Background Radiation” (1996), available at <http://arxiv.org/abs/astro-ph/9603157>.

13. Unnikrishnan [1].

14. Mach [4] pp. 277–306.

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