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Restructuring Physics From Its Foundation in Light of Maharishi Vedic Science

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Abstract

In this article, we present a new understanding and language of physics based directly on the unified field. This understanding is made possible through the latest developments in our understanding of the unified field provided by the superstring and the understanding and experience of the unified field provided by Maharishi Vedic Science and its experiential technologies. Our discussion begins with a consideration of the unified field itself viewed from its own level and in terms of its own intrinsic properties and behavior. We subsequently extend this analysis to include a systematic investigation of its fundamental modes—the elementary particles and forces of nature, in which we explicitly identify all known particles with specific vibrational states of the field. We propose a new language and terminology of physics in which the elementary particles are named for the specific vibrational states of the field they correspond to. The special significance of the Vedic terminology in this context is explained and discussed. We conclude with a consideration of the implications for society of a fully developed science and technology of the unified field made possible through the subjective approach of Vedic Science and its applied, experiential technologies.

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I. Introduction

It was Einstein's deep conviction that the laws of nature had a simple, geometric, unified foundation, and that this unification could be understood by the human intellect. Within the past two decades, a number of important breakthroughs in this area have led to a progressively more unified understanding of the laws of nature, culminating in the recent discovery of completely unified field theories. These theories afford, for the first time, a self-consistent and completely unified description of the elementary particles and forces in terms of a single, self-interacting field. The heterotic superstring with an internal $E_8 \times E_8$ gauge symmetry, in particular, unifies all known forces in a consistent quantum theory of gravity. Recent formulations of the heterotic string, including manifold compactifications [1], orbifold compactifications [2], and especially string formulations directly in four dimensions [3], have produced impressive derivations of the observed low-energy $SU(3) \times SU(2) \times U(1)$ gauge group and all known matter fields directly from the underlying, unified superstring field.

These achievements mark the beginning of a new era in physics—one in which the unified source and foundation of the entire discipline is fully in view. This unprecedented situation calls for a new understanding and language of physics—one in which the elementary particles and forces, and indeed the entire discipline, are clearly understood and expressed in relation to their unified source in the unified field. Until now, the understanding and associated terminology of physics has been dominated by historical and/or random influences. An example of the former is the term "lepton" (meaning "light") which is used today to denote the electron, muon, and tauon and their associated neutrinos. In fact, the tau lepton is actually heavier than most baryons—a term that means "heavy." The term "quark," which is used to denote the elementary subconstituents of baryons and mesons, is a prime example of the randomness of the nomenclature. Originally taken from Joyce's *Finnegans Wake*, the term commonly refers to a breakfast cheese found in Germany and Switzerland.

The term "lepto-quark" is used in physics to denote the proposed unification of leptons and quarks at the level of grand unification. It illustrates the historical tendency to base the understanding and interpretation of deeper, more unified levels of nature's dynamics (i.e., grand unification) in terms of more superficial, incomplete and fragmented levels (i.e., electroweak unification). It also illustrates the proliferation of terminology that was already inappropriate (i.e., historical, as in lepton, or random, as in quark) to increasingly fundamental scales.

A more illuminating perspective would be one in which the more superficial and diversified levels of the discipline were based upon more fundamental levels, and where these more fundamental levels were in turn connected to their unified source in the unified field. All aspects of the discipline would then be seen in terms of their sequential unfoldment from the unified field, providing a natural logic and organization to the entire discipline. Provided the terms were chosen accordingly, each aspect of the discipline would indicate its position and purpose with respect to the whole. The vision of the whole would, in turn, give significance to each part.

This foundational approach to knowledge has been applied at Maharishi International University by faculty from numerous different disciplines through their development of "Unified Field Charts." These charts provide a conceptual map of an entire discipline. They illustrate the interrelation of all the different parts of the discipline, from the most abstract foundational levels to the most superficial and applied levels, and show how the whole discipline sequentially emerges from a unified source (e.g., the universe of sets in mathematics, the transition state in chemistry, or the superstring in physics). By relating the parts of knowledge to the wholeness of knowledge, these charts bestow knowledge at a glance. They also provide a powerful research perspective: any gaps in the current understanding of the discipline tend to be starkly exposed as areas requiring further study.

Some shift towards this new, unified field-based perspective is already occurring in the context of the string. The low-energy effective field theory governing physics at observable scales (i.e., the known particles and forces) are now being described as the "massless modes" of the string. These massless string modes, and thus the elementary particles and forces they represent, can be classified according to their purely stringy characteristics—their periodicity conditions on the string world sheet. For example, the graviton, the dilaton, and the two-index antisymmetric tensor belong to the Neveu-Schwarz (antiperiodic) sector of the string, and so forth. However, the choice of language (e.g., "Neveu-Schwarz" sector) is more historical than descriptive, and remains the exclusive province of string theorists.

Many students and lay physicists with a sincere desire to understand the most fundamental knowledge of natural law now available through modern science have expressed frustration at the inappropriate and often confusing language of fundamental particle physics. In the following sections, we will begin to develop a new perspective and terminology of physics based directly on the unified field, and not primarily upon historically prior levels of physics. We will begin this analysis with a consideration of the unified field itself, viewed from its own level and in terms of its own intrinsic properties and behavior.

In this analysis, in addition to the latest developments in our understanding of the

unified field provided by the superstring, we make use of the very complete description of the unified field and its self-interacting dynamics provided by Vedic Science as recently formulated by Maharishi Mahesh Yogi [4]. Maharishi Vedic Science is based upon the ancient Vedic tradition of gaining knowledge through the exploration of consciousness. Many thousands of years ago, the seers of the Himalayas discovered, through the exploration of the silent levels of their own awareness, a unified field where all the laws of nature are found together in a state of wholeness. This unity of nature was directly experienced to be a self-interacting field of consciousness which is unbounded, all-pervading, unchanging, and the self-sufficient source of all existing things. They experienced and gave expression to the self-interacting dynamics through which this unified field sequentially gives rise to the diversity of all the laws of nature. The expression of this knowledge, and the techniques by which it is gained, has been passed on over thousands of years in what is now the oldest continuous tradition of knowledge in existence [5]. In the past three decades, Maharishi has reformulated this knowledge in a scientific framework that is both accessible and empirically testable, placing the Vedic knowledge in the intellectual mainstream of the West and reviving it in the East as well. This revival of the Vedic knowledge has given rise to a new, quantitative science of consciousness with practical applications and proven technologies in every major area of human concern, including health, education, rehabilitation, and world peace [4-7].

Vedic Science, like modern science, seeks to identify and explore the most fundamental and universal principles of intelligence at the basis of nature's functioning. In addition, Vedic Science (unlike modern science) provides systematic experiential technologies which allow the direct exploration of these most fundamental and universal principles of intelligence in consciousness [8-10]. These subjective technologies allow the mind to experience deeper, more fundamental and unified states of awareness. These fundamental states of awareness have been found to possess a close structural correspondence to the physical structure of natural law at fundamental scales [11]. This deep parallel between the structure of human intelligence and the intelligence of nature is well known to physicists. Wigner referred to this connection as "the unreasonable effectiveness of mathematics in the physical sciences," i.e., the subtle structures of human intelligence codified in mathematical formulas correspond precisely to the subtle structures of intelligence displayed in nature. For Einstein, this connection between human intelligence and the intelligence of nature also had deep significance. For him "the eternal mystery of the universe [was] its comprehensibility" by the human mind. This deep parallel between human intelligence and the intelligence of nature makes it possible to gain profound physical insight into the mechanics of nature through the understanding and experience of the most fundamental mechanics of human intelligence.

This important realization fulfills a principal need of modern physics. It is commonly stated that there is no common-sense basis for the understanding and teaching of modern physics. The understanding of advanced concepts in physics has historically been based on the classical intuitions gained from the experience of simple mechanical systems and wave tanks encountered in more elementary courses. However, these concrete classical concepts no longer provide an adequate basis for understanding physics at the

quantum-mechanical or quantum field-theoretic levels, and are often more confusing than illuminating. If one's outer, sensory experience fails to provide a viable common-sense basis for physics, then the only obvious alternative is the inner experience of the dynamics of consciousness itself. From the arguments presented above, it is already clear that such an approach can indeed provide an effective intuitive foundation for physics which extends to the dynamics of fundamental scales. (As our analysis proceeds, this point will become increasingly clear.) Using this consciousness-based approach, the MIU faculty have developed a twenty-lesson introduction to the conceptual foundations of unified field theories which is taken by all first-year students, in which we have found that even the most abstract principles of the discipline are easily grasped by students with no prior scientific background.

The experiential technologies of Maharishi Vedic Science—which include the Transcendental Meditation and TM-Sidhi programs—have revealed a single, unified field of intelligence at the foundation of conscious experience. In this fundamental state of awareness, the knower, the known, and the process of knowing are united in a state of pure, self-interacting consciousness, in which consciousness knows itself alone. This inner subjective experience is marked by the onset of a unique constellation of physiological [12], neurophysiological [13], and biochemical changes [14], consistent with the proposal [15] that the experience of pure consciousness corresponds to a fourth major state of consciousness distinct from waking, dreaming and deep sleep states of consciousness. From this experience, we conclude that human consciousness, like material creation, has at its basis a unified field of intelligence. The most parsimonious explanation, provided by Maharishi Vedic Science [4], is that these two fundamental fields of intelligence are not independent, but one and the same, providing a profound and previously unexpected unification of subjective and objective realms of experience. Indeed, such a framework appears to be required [11] to account for experimentally observed field effects of consciousness* and other phenomenological aspects of higher states of consciousness. It also explains the otherwise "unreasonable" parallel between human intelligence and the intelligence of nature.

When first proposed, such a framework seemed to require a radical rethinking of physics and/or the relationship of consciousness to the physical world. In retrospect, it seems rather natural that the most fundamental level of human experience—the unified field of pure self-interacting consciousness—would be the same unified field found at the basis of all other forms and phenomena in nature. According to this perspective, the unified field is the unified source of both subjective and objective realms of existence. As such, the unified field is fundamentally as much a field of subjectivity as it is a field of objectivity. From this perspective, the use of a subjective approach to knowledge appears both justified and natural.

Indeed, one might worry that the purely objective approach of modern science would fail to apply at the level of super-unification, both in principle and in practice. In principle, since by assumption there is only one dynamical degree of freedom at the scale of super-unification (the unified field), a subject-object relationship might be difficult to

See Appendix A on field effects of consciousness.

sustain. In practice, the time and distance scales characteristic of super-unification are far beyond the range of any conceivable accelerator technology. As the principal focus of theoretical physics has shifted to the experimentally inaccessible domains of grand unification and super-unification, already theorists have had to rely increasingly on their analytic and intuitive abilities—subjective competencies of their own consciousness. Thus the development and application of a subjective approach seems not only natural, but increasingly necessary.

The viability of the subjective approach is amply demonstrated by the precision and depth of insight into the most fundamental mechanics of nature's intelligence—the structure and dynamics of the unified field and the mechanics of symmetry breaking—which is available in the Vedic texts. In the following sections, we will therefore incorporate insights from both the objective approach of modern theoretical physics and the predominantly subjective approach of Maharishi Vedic Science to unfold a more complete and appropriate understanding and terminology of physics based upon the unified field.

II. The Essential Characteristics of the Unified Field

We will begin our analysis of the discipline of physics with a consideration of the unified field itself. In the interest of generality, we will resist the temptation to place undue emphasis on the model-dependent features of the E_8 , heterotic string. Instead, we will focus on universal properties which are characteristic of any unified quantum field. Such an analysis, in principle, is rather difficult to contain: a complete description of the unified field would probably entail a full analysis of the entire, diversified structure of manifest creation, since the totality of natural law is ultimately contained within the structure and dynamics of the unified field. The discriminating intellect will therefore discern, within the structure of the unified field, the potential for the entire universe, as a tree is contained within the seed. (Indeed, we will argue in a later section that the process of creation can be viewed as nothing more than a sequentially more elaborated commentary on the structure of the unified field itself.) We will, nonetheless, attempt to limit our discussion to the most basic and fundamental properties of the field and reserve, until a later section, the subsequent unfoldment of further details concerning the structure of the universe.

We will begin our discussion with a concise review of the essential characteristics of the unified field as described by Maharishi Vedic Science, which will provide a useful direction and framework for our subsequent physical analysis. According to Maharishi Vedic Science, the unified field is fundamentally a field of consciousness [4]. The field is known as *atman*, meaning "pure consciousness," or "self," since the unified field constitutes the deepest reality and hence the true identity of everything in nature. The term "consciousness" is clearly distinguished from the highly individualized and anthropocentric sense of the term common to everyday experience: it is used to denote a completely universal field of "pure, self-interacting" consciousness—consciousness aware of itself alone, devoid of any individualizing influence or external objects of experience [4,5]. Due to its essential nature as consciousness, Maharishi explains, the unified field has the dual characteristics of *existence* and *intelligence* [6,16]. Consciousness

exists—all forms and phenomena in the universe, which constitute its various expressions, can be said to exist by virtue of its existence. The existence of consciousness is an empirical reality which is self-evident in higher states of consciousness [10], if not necessarily in the waking state, in which consciousness, being outwardly directed, is never the object of experience. The *intelligence* property of consciousness is associated with its self-interacting nature: due to its essential nature as consciousness, consciousness is aware of its own existence—i.e., consciousness "witnesses" itself [6,9]. This highly non-linear property of awareness sets up within the field of consciousness a three-in-one structure of knower, known, and process of knowing: consciousness (the knower) is aware of consciousness (the known) through the agency of consciousness (the process of knowing). This self-interacting dynamics of consciousness knowing itself and its associated three-in-one structure of knower, known, and process of knowing is called the *Ved* [4]. This self-interacting dynamics is responsible for the spontaneous and sequential emergence of the diversified structure of the laws of nature from the field of pure consciousness: one (consciousness) becomes three (knower, known, and process of knowing), and these in turn become many through a precise and spontaneous sequence of expression described in Maharishi Vedic Science and open to direct experience through its applied, experiential technologies, the Transcendental Meditation and TM-Sidhi programs. This inherent capacity for consciousness to know itself, or "witnessing" property of the field, is known as *buddhi* (meaning "intelligence" or "intellect") in the language of Maharishi Vedic Science [9]. It refers to the highly *dynamic, discriminative* (consciousness discriminates between itself as knower, known, and process of knowing) and *creative* (it creates three from the state of unity) property of the field responsible for the spontaneous and sequential emergence of the diversified structure of the laws of nature. A more complete discussion of this self-interacting dynamics and its associated three-in-one structure will be presented in the following section. For the moment, we will focus on the two essential characteristics of *existence* and *intelligence*, and their seemingly fundamental role in the unified quantum field theories of modern theoretical physics.

In any unified quantum field theory, the most obvious and essential property of the unified field is that it *exists*. As in Maharishi Vedic Science, everything else may be said to exist by virtue of its existence. For this existence to be substantial, it must be permanent, i.e., the field should exist eternally. This property is expressed in physics as the time-translational invariance of the Lagrangian density—an essential characteristic of any realistic unified field theory.

The second major property of the unified field which one is led to expect on the basis of our previous analysis is *intelligence*. By assumption, the unified field is the unified source of all the laws of nature governing physics at every scale. These laws of nature formally express the order and intelligence inherent in natural phenomena. If there were no laws of nature, there would be no consistent patterns of natural behavior, and nature would be unintelligible. If, as particle physicists believe, all the laws of nature have their dynamical origin in the unified field, then the unified field must itself embody the total intelligence of nature's functioning.

To some extent, we can trace this property of intelligence to the fact that the unified field, beyond its mere existence, has a very precise and definite mathematical structure.

This structure is typically defined in terms of symmetries of the field—invariance with respect to a set of internal and external transformations, such as Lorentz invariance, supersymmetry, modular invariance and gauge invariance. External symmetries, such as Lorentz invariance, describe the behavior of the field under transformations of space and time—translations, rotations and boosts. Internal symmetries, such as gauge invariance, refer to transformations among the various internal degrees of freedom of the unified field—bosonic and/or fermionic. The precise mathematical structure of the unified field serves as an unmanifest blueprint for the entire creation: all the laws of nature governing physics at every scale are just partial reflections or derivatives of this basic mathematical structure. However, this view of intelligence in terms of the classical symmetries of the unified field is a rather passive and inert one. The term “intelligence” achieves its full significance only at the quantum-mechanical level of description, in which the field acquires a degree of *dynamism*, *discrimination* and *creativity* not present at the classical level.

The transition from the classical to the quantum-mechanical description formally begins with the imposition of the canonical commutation relation

$$[\Phi, \Pi] = i\hbar \quad (1)$$

between the field Φ and its canonically conjugate momentum Π . (In the simplest cases, the canonical momentum Π is equal to the time derivative or rate-of-change of the field, which we will denote by $\dot{\Phi}$.) The constant $\hbar = 10^{-27}$ erg-sec appearing in Equation (1) is known as Planck’s constant (also called the quantum of action), and sets the scale for all quantum-mechanical phenomena. The canonical commutation relation (1) introduces an element of *discrimination* not present at the classical level: the field (Φ) is clearly distinguished from its own motion ($\dot{\Phi}$). The latter is given an entirely separate symbol (Π), and the two (Φ and Π) acquire the status of incompatible operators in Hilbert space. (This clear distinction between the field Φ and its activity Π also supports the concept of a “witnessing” quality of the field found in our previous discussion of Maharishi’s Vedic Science.)

The discrimination between the field Φ and its conjugate momentum Π imposed by the canonical commutation relation (1) applies to their sequence as well: the commutator or “Lie bracket” (1) is antisymmetric in Φ and Π . The two operators (Φ and Π) become the generators of an infinite-dimensional Lie algebra of operators composed of all polynomials in Φ and Π . This algebra of operators includes the Hamiltonian in addition to all other quantum-mechanical observables. The fundamental importance of sequence in this quantum-mechanical algebra again reveals a degree of discrimination not present in the classical description, in which the field Φ and its conjugate momentum Π commute. The non-commuting nature of this algebra is fundamental to the dynamical structure of the quantum theory, in which the evolution of all observables is given by their commutator with the Hamiltonian. If the commutator (1) were to vanish, e.g., in the classical limit as $\hbar \rightarrow 0$, all dynamical evolution would cease. Thus the entire dynamics of the quantum theory has its ultimate origin in the dynamical relationship between Φ and Π imposed by the relation (1).

The dynamical relation (1) between Φ and Π has more than algebraic significance; it has deep physical significance as well. It leads directly to the Heisenberg uncertainty principle

$$\delta\Phi \delta\Pi \geq \hbar/2 \quad (2)$$

which states that the field Φ and its conjugate momentum Π cannot be simultaneously specified with arbitrary precision. Any classically well-determined state of the field $\Phi(x)$ necessarily implies a large indeterminacy in the rate-of-change of the field $\Pi(x)$, or a state of dynamic motion. Any classically well-determined state of motion of the field $\Pi(x)$ implies a large uncertainty in the amplitude of the field $\Phi(x)$, implying large displacements from the origin and hence a large potential energy $V(\Phi)$. Either situation implies a state of high energy—kinetic and/or potential. Thus the canonical commutation relation (1), and the resulting uncertainty principle (2), imply a level of *dynamism* not found at the classical level. This introduces a new form of quantum-mechanical activity which extends even to the state of least excitation or “ground state” of any quantum-mechanical system. This irremovable level of activity present in the ground state of a system is known as “zero-point motion,” and has no classical analogue. It has immediate implications for the ground state of the unified field.

Classically, the state of least excitation of a field is a state in which the field is zero everywhere, and thus a state of complete classical inertia. However, the uncertainty principle (2) implies that such a state of precisely determined field amplitude ($\Phi = \delta\Phi = 0$) corresponds to a completely indefinite rate-of-change of the field ($\delta\Pi = \infty$) and hence a state of infinite energy density. Such a state cannot possibly correspond to the ground state of the system. The ground state of a field (also called the “vacuum state” since it represents the absence of physical particles and forces) cannot correspond to any definite field shape. It must therefore correspond to a quantum-mechanical coexistence of many shapes. Direct calculations confirm this general argument: the vacuum state of a field is a quantum-mechanical “superposition,” or simultaneous coexistence, of all possible shapes (see Appendix B on the vacuum wave functional). This result has profound implications for quantum cosmology. It implies that the vacuum state of the unified field contains, within its unmanifest structure, the potential for the entire universe—and indeed for all possible universes. This all-possibilities nature of the vacuum will be further explored in a subsequent section on quantum cosmology.

The dynamism (2) implied by the quantum principle increases at more fundamental spacetime scales. This accounts for the fact that nuclear transformations at distance scales $\sim 10^{-13}$ cm are far more powerful than chemical transformations occurring at $\sim 10^{-8}$ cm. At scales characteristic of the unified field, the Planck scale of 10^{-33} cm or 10^{-43} sec, the intrinsic dynamism of the field is nearly infinite—on the order of 10^{100} ergs per cubic centimeter—much greater than the mass-energy of the known universe.* Thus

* Here one must draw a distinction between energy and dynamism. Since gravity couples to the energy-momentum tensor, any energy of the vacuum significantly different from zero would lead to a strong gravitational self-attraction, placing the universe into a deSitter phase of exponential expansion or contraction. The experimental constraints on the vacuum energy are thus very stringent: somehow, the energy density associated with such vacuum fluctuations must be cancelled. A partial solution to this problem is afforded by

it is clear that the quantum principle adds tremendous dynamism to the rather abstract and inert characteristic of intelligence available in the classical description.

Besides adding a degree of discrimination and dynamism to the abstract property of intelligence available at the classical level, the quantum principle also endows the field with a *creative* capacity which is far beyond that of any classical field theory. For example, the dynamical self-interaction of the gluon field induced by quantum effects leads to strong coupling and hence to the highly nonlinear process of color confinement. Thus the entire spectrum of bound-state hadrons results from the quantum-induced self-interaction of the gluon field. The dynamical breaking of supersymmetry and the resulting masses for sparticles and higgs bosons probably results from a similar, quantum-induced strong coupling phase in the hidden sector gauge group. The spontaneous breaking of gauge symmetries like the electroweak symmetry is also due to a quantum-mechanical mechanism. In this case, radiative corrections to the higgs mass at renormalization-group scales $M_* \ll M_{\text{Pl}}$ trigger spontaneous symmetry breaking, giving masses to quarks and leptons and to the intermediate vector bosons. More generally, the emergence of — discrete quanta from the continuous dynamics of a field is impossible in the context of classical field theory [17]. Quantum mechanics is needed to generate quanta (i.e., particles) from the field, and thus to create the material universe as we know it.

Thus we conclude that the quantum principle introduces qualitatively new behavior which is not found at the level of classical field theory. In particular, it introduces a degree of *discrimination*, *dynamism*, and *creativity* not present at the classical level. These characteristics make the rather abstract and inert quality of intelligence present in the classical description *dynamic*, *discriminative*, and *creative*, which corresponds precisely to the dynamic, discriminative, and creative quality of intelligence, or *buddhi*, found in our previous discussion of Maharishi Vedic Science. For this reason, we will associate the quantum principle with the intelligence (or buddhi) characteristic of the unified field—that property of the unified field which, combined with its classical symmetries and structure, is responsible for the creative dynamics of nature—the spontaneous and sequential emergence of the diversified structure of the laws of nature governing life on all levels of the physical universe.

In this section, we have identified two essential properties of the unified field—*existence* and *intelligence*. Concerning existence, very little can be, or need be, said. Its reality can be inferred from the existence of the universe. The intelligence property is abundantly displayed in the innumerable laws of nature governing natural phenomena at every scale of the physical universe. We have traced this property of intelligence to the unified field itself—to its classical symmetries and structure, and especially to the quantum principle, which endows the field with a degree of intelligence—of discrimination, dynamism and creativity—not present at the classical level.

supersymmetry. In the limit of exact supersymmetry, the positive vacuum energy contributed by the vacuum fluctuations of bose fields is cancelled by the negative energy associated with the vacuum fluctuations of fermi fields. Since supersymmetry is necessarily broken at some level, this cancellation cannot be exact, and some additional cancellation mechanism is needed. There is some evidence to suggest that this mechanism could be provided by wormhole interactions.

It is interesting to note that in Maharishi Vedic Science, because the unified field is fundamentally a field of consciousness, it automatically incorporates both characteristics of existence and intelligence [6,16]. In the unified field theories of modern theoretical physics, the quantum principle is always introduced as an extra, *ad hoc* assumption. There is no understanding in physics concerning the origin of the quantum principle, and there is little hope that quantum mechanics will be derivable from string theory. One can therefore appreciate the elegance and economy of Vedic Science, in which one fundamental postulate (consciousness) automatically incorporates both characteristics of existence and intelligence—both the field and the quantum principle.

In the language of Vedic Science, these two are known as *atman* and *buddhi* (see Figure 1). The term *Samhita*, meaning "collectedness" or "unity," is also used to describe the unified field [4]. Whereas *atman* brings out the essential nature of the unified field as consciousness, *Samhita* emphasizes its fundamentally unified nature. The special significance of these Vedic terms will be discussed in Section IV.

In this section, we have identified the essential characteristics of the unified field based on an elementary analysis of the algebraic form of the canonical commutation relation (1). In the next section, we will present a more complete, geometric formulation of quantum mechanics in Hilbert space. We will find that the Hilbert space formulation provides a far more explicit and comprehensive view of the self-interacting dynamics of nature's intelligence governing the mechanics of creation from the unified field. It thereby also affords a more complete and satisfactory framework for making precise, quantitative connections between the unified quantum field theories of modern theoretical physics and the Vedic Science of Maharishi Mahesh Yogi.

III. The Hilbert Space Formulation of Quantum Mechanics and the Three-in-One Dynamics of Intelligence

In the previous section, we traced the dynamical origin of nature's intelligence to the structure and dynamics of the unified field. At the classical level of description, this intelligence is contained in the precise mathematical form of the unified field—its classical symmetries and structure—which provides the unmanifest "blueprint" of the laws of nature governing physics at every scale. With the introduction of the quantum principle, this passive, classical view of intelligence acquires a level of dynamism, discrimination and creativity not present at the classical level. This dynamic and creative view of intelligence afforded by the quantum principle is sufficient to explain the spontaneous and sequential emergence of the entire, diversified structure of the laws of nature from the unified field, as has been explicitly demonstrated by the latest unified quantum field theories, particularly the superstring.

We have also noted that the clear discrimination between the field Φ and its canonically conjugate momentum Π introduced by the quantum principle (1) suggests a witnessing quality of the field, in which the field stands clearly divorced from its own activity. The term "witnessing" tends to imply a degree of alertness not generally ascribed to a classical field theory, but it is precisely this quality of dynamic intelligence that the quantum principle provides. This dynamism has its roots in the algebraic form of the canonical commutation relation (1) and in the resulting infinite-dimensional Lie

Structure of a Unified Quantum Field

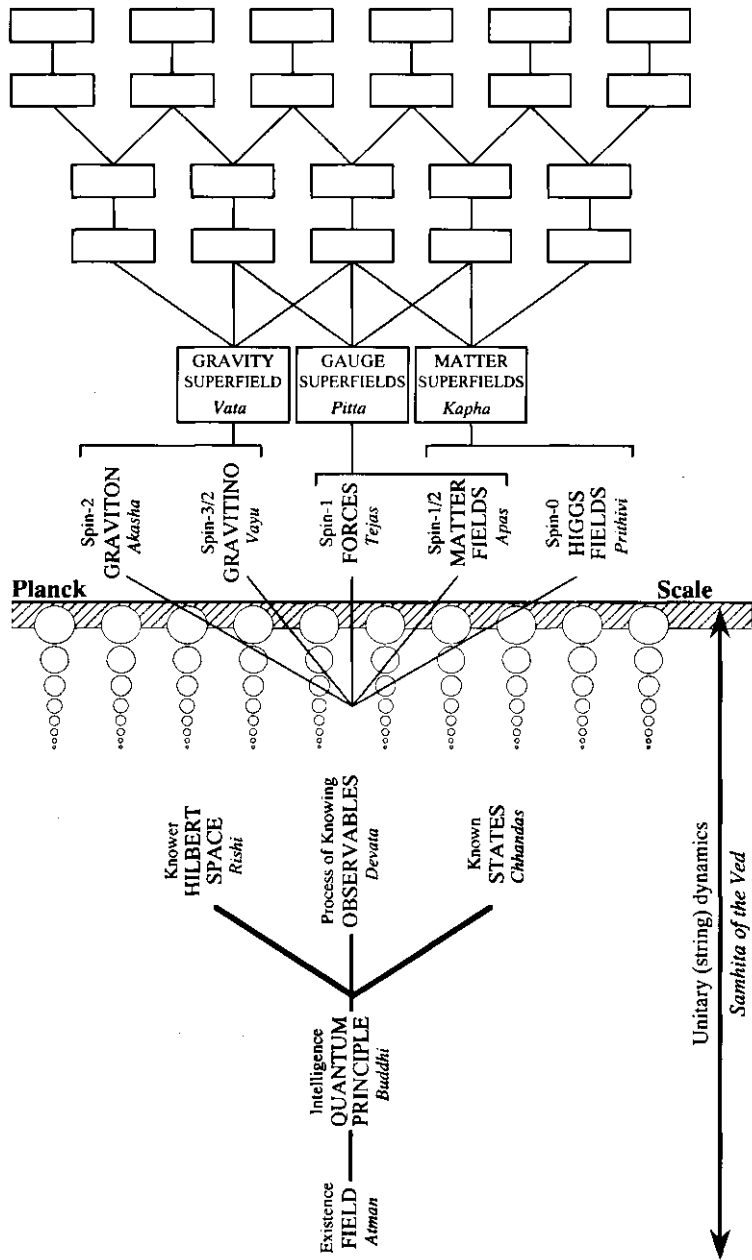


Figure 1.

algebra of quantum-mechanical observables, and achieves its full physical significance in the Heisenberg uncertainty principle (2), which endows the field with tremendous dynamism at fundamental spacetime scales.

In the fundamental approach of Maharishi Vedic Science, this highly dynamic and alert quality of the field is present *ab initio*—the unified field is *defined* as a field of dynamic intelligence, or *consciousness* [4]. Here, as we have previously noted, the term consciousness is clearly distinguished from the highly individualized and anthropocentric sense of the term common to everyday experience. It is used to denote a completely universal field of "pure, self-interacting" consciousness—consciousness aware of itself alone, devoid of any individualizing influence or external objects of experience [4,5]. This, however, does not imply that this most fundamental and universal value of consciousness is beyond the range of human experience. The experiential technologies of Vedic Science are precisely formulated to bring this fundamental state of awareness within the realm of human experience [4].

In this most fundamental and universal structure of experience, known as "transcendental consciousness" or "pure consciousness," consciousness is isolated in its pure form, devoid of thought or any concrete object of experience. However, due to its intrinsic nature as consciousness, consciousness is aware of its own existence—i.e., consciousness "witnesses" itself [6,9]. This highly nonlinear, self-interacting property of awareness sets up within the field of consciousness a three-in-one structure of knower, known, and process of knowing: consciousness (the knower) is aware of consciousness (the known) through the agency of consciousness (the process of knowing). This self-interacting dynamics of consciousness, or witnessing quality of the field, is termed the *intelligence* aspect of the unified field, or *buddhi* in the language of Vedic Science [4,9]. It is dynamic, discriminative (consciousness discriminates between itself as knower, known, and process of knowing) and creative (it creates three from a state of unity), and corresponds precisely to the dynamic, discriminative, and creative quality of intelligence found in our earlier discussion of the quantum principle.

This highly nonlinear, self-interacting quality of consciousness is a familiar property of any unified non-Abelian gauge field. A non-Abelian (i.e., nonlinear) field possesses a degree of self-interaction not present in an Abelian field, such as electromagnetism. Because the electromagnetic field equations are linear in the field strength, two beams of light pass through each other with no interaction and hence no awareness of each other's presence. A non-Abelian field, such as the gluon field of quantum chromodynamics, the unified electroweak field, or a superunified gauge field, possesses the nonlinear property of self-interaction which is lacking in an Abelian field. As a consequence of its own self-coupling, a non-Abelian field responds dynamically to its own presence—the field interacts with the field through the agency of the field. It is this highly nonlinear, self-interacting or "self-referral" property of the field, which achieves its full significance in the presence of the quantum principle, that makes the unified field a field of consciousness, according to Maharishi Vedic Science.*

In fact, it is essential for this argument that the field be purely self-interacting, as in the case of a unified quantum field, and thus the self-sufficient source of all created things. —Maharishi Mahesh Yogi, private communication.

This self-interacting dynamics of the unified field described by Vedic Science, with its three-in-one structure of knower, known, and process of knowing, is most clearly reflected in the full, geometric formulation of quantum mechanics in Hilbert space. The Hilbert space formulation of quantum mechanics and its interpretation in the light of Maharishi's Vedic Science will form the principal subject of this section.

Quantum mechanics emerged in the beginning of the twentieth century as a totally new framework and language of nature appropriate to the physics of fundamental scales. Quantum mechanics studies the dynamics of fundamental physical systems like atoms in the case of nonrelativistic quantum mechanics, the fundamental particles and forces of nature in the relativistic formulation of quantum field theory, or the universe as a whole in the context of quantum cosmology (see Section V). All of these radically different systems share the same formal structure of knowledge within the framework provided by the quantum principle.

Quantum mechanics treats the state of the system as a vector in a linear space. That is, the state of the system is represented by a single point in an infinite space of points representing all possible states of the system.* The evolution of a quantum-mechanical system corresponds to a motion within this space of states—a movement or transformation from one point to the next. The mathematical equation controlling this motion (and thus the evolution of the quantum-mechanical system) is called the time-dependent Schrodinger equation:

$$H|\Psi\rangle = i\hbar |\dot{\Psi}\rangle \quad (3)$$

The motion or rate-of-change $|\dot{\Psi}\rangle$ of the quantum-mechanical state $|\Psi\rangle$ is obtained by acting on the state with the Hamiltonian H .

This abstract, quantum-mechanical space of all possibilities is called a Hilbert space. A Hilbert space has specific, geometric properties, which are ultimately responsible for most of the characteristic features of the quantum theory. Firstly, it is a linear space or *vector space*. This means that points in space ("vectors") can be meaningfully added and subtracted. This property of Hilbert space leads to one of the most remarkable features of the quantum theory—the principle of *superposition*. It means that a system can be in a state which is a linear combination, or vector sum, of two or more physically inequivalent states. This implies, for example, that a quantum-mechanical system can display a simultaneous coexistence of classically incompatible properties (e.g., both alive and dead in the case of Schrodinger's quantum-mechanical cat).

Hilbert space is an *infinite dimensional, complex* vector space, comprised of all linear combinations of an infinite set of orthonormal basis vectors with complex coefficients. The infinite size of the space stems from the fact that all physically interesting systems can occupy an infinite number of physically inequivalent states. The fundamental role played by complex numbers in quantum mechanics is more surprising; it has no obvious classical analog. It is a striking example of the need to introduce more abstract and holistic

* In fact, the state of the system is usually represented by a "ray"—a vector with unit norm. This is because the length of the vector is associated with the total probability that the system exists, which is assumed to be one in most quantum-mechanical applications. This distinction is not relevant to the present discussion.

numerical and conceptual frameworks in order to adequately describe more abstract, holistic and fundamental levels of nature's functioning.

The structure of Hilbert space also includes an *inner product*, which introduces the concept of length. The inner product measures the size of any vector in Hilbert space as well as the magnitude of all its components along any orthonormal set of basis vectors.* Herein lies the seat of all quantum-mechanical knowledge: by allowing the decomposition of any quantum-mechanical state vector $|\Psi\rangle$ in terms of a set of physically meaningful basis vectors, the inner product determines all the physical properties of a quantum-mechanical system—its energy, its momentum, its angular momentum, etc.

The geometric properties of Hilbert space, i.e., the properties of additive closure, completeness, the inner product, etc., give the space a wholeness which is far greater than the infinite collection of points it represents. That is, the space of all quantum-mechanical possibilities has an existence and integrity of its own that transcends and exceeds the individual points that comprise it. For example, one can rearrange all of the points in Hilbert space while preserving the structure of the space itself. In other words, one can define a set of transformations of the space onto itself which leave the structure of the space unchanged.† These transformations map points in Hilbert space onto other points, "transforming" one point into another, in such a way that the space itself remains invariant. Despite this dynamic transformation of all its component parts, that wholeness which we call the Hilbert space is completely unchanged.

Among these transformations there exists a class of transformations of special geometric and physical significance. These transformations, known as unitary transformations, map points onto points in such a way that all geometric relationships among the initial set of points are preserved by the transformation. Such transformations are generated by the exponentiation (e^{i0}) of self-adjoint operators (0), which are associated with quantum-mechanical observables such as energy, momentum, angular momentum, etc. The time-dependent Schrodinger equation (3) governing the time evolution of the quantum-mechanical system is an example of such a transformation. It takes a quantum-mechanical system, which is represented by a specific vector $|\Psi\rangle$ in Hilbert space, and transforms this state into a new state

$$|\Psi'\rangle = |\Psi\rangle + dt |\dot{\Psi}\rangle = (1 - i dt/\hbar H)|\Psi\rangle \quad (4)$$

The integrated effect of the continuous action of the Hamiltonian on the system (4) is a unitary transformation

$$|\Psi(t')\rangle = U(t',t)|\Psi(t)\rangle; U(t',t) = e^{-iH(t'-t)/\hbar} \quad (5)$$

Because the evolution (5) is unitary, it is invertible and hence information preserving. This contrasts with the most common form of macroscopic, thermodynamic evolution, in which entropy is produced, information destroyed, and which is therefore irreversible.

* See footnote on previous page.

† Or possibly some subset of that structure, depending on whether the transformation is differentiable, linear, or unitary.

So far our discussion of Hilbert space and its properties has been rather formal and abstract. We will now adopt a more concrete perspective by placing this formal discussion of Hilbert space in the specific physical context of a unified quantum field. We will see what new physical insights into the unified field and its self-interacting dynamics are afforded by the Hilbert space formulation of quantum mechanics, and examine these insights in the light of the fundamental description of the self-interacting dynamics of nature's intelligence provided by Maharishi's Vedic Science and its applied, experiential technologies.

From a physical standpoint, the Hilbert space of states represents all possible states of a quantum-mechanical system. Since at any time a quantum-mechanical system is represented by a single vector $|\Psi\rangle$ within this infinite dimensional space of states, the Hilbert space is essentially unmanifest—an unmanifest field of all possibilities for the quantum-mechanical system. Since the evolution of a quantum-mechanical system is described by a motion (5) of the state vector $|\Psi\rangle$ within this space of states, the Hilbert space also provides the abstract arena in which quantum mechanics unfolds. And because the space itself is completely unchanged by the unitary transformation (5) which controls the evolution of the system, the Hilbert space can be described as a silent, unmanifest "witness" to the entire dynamics of quantum-mechanical evolution. Here again, the term "witness" tends to suggest a degree of alertness not necessarily implied by the aforementioned properties of unmanifest, unboundedness (or infinity), silence and non-change. This property of alertness is supplied by the inner product defined on the space. At every moment in the evolution of the quantum-mechanical system, this geometric property of the space determines, through a comparative process, every characteristic of the physical system. This lively, discriminative but unmanifest basis of knowledge provided by the Hilbert space corresponds to what we have previously termed the "knower" or *Rishi* (meaning "knower," "seer," or "silent witness") quality of the unified field in our discussion of Maharishi's Vedic Science [4]. In the structure of knowledge, *Rishi* is the knower—the lively, discriminative but unmanifest basis of knowledge, which stands as a witness to the known and the process of knowing.*

There is another attribute of *Rishi* described by Maharishi's Vedic Science which is also clearly reflected in the structure of a Hilbert space. Specifically, there is not one but many different possible varieties of *Rishi* or perspectives within the unified field. These different qualities of *Rishi* provide different, but complementary, viewpoints about the unified field and its self-interacting dynamics. This plurality of perspectives is seen in the structure of the Hilbert space as the freedom to choose among various possible basis vectors. For every quantum-mechanical observable, there exists a complete set of orthogonal basis vectors. These are given by the eigenvectors (states possessing definite classical values) of the associated observable.† Any complete set of orthonormal basis

*The need to consider states of infinite norm in quantum mechanics introduces a further degree of liveliness not present in the classical structure of a Hilbert space. It changes the structure of the space to what is called a "rigged" Hilbert space, which involves a highly dynamic interplay between several different function spaces. For a detailed discussion, see ref. [18].

† In general, more than one observable may be needed to completely specify a set of basis vectors. In this case, the set of observables needed to define the basis vectors is called a maximal commuting set.

vectors spans the Hilbert space and thereby provides a complete characterization of quantum-mechanical knowledge. Although each, in itself, is entirely self-sufficient, the availability of several different bases presents a variety of distinct but complementary perspectives. For example, in one basis, energy serves as the defining characteristic of the system; in a second, its position in space, and so on. This "complementarity" of different viewpoints is one of the more striking characteristics of the quantum theory, and has its clear correspondence in the different qualities of the knower or Rishi in Mahari-shi Vedic Science.

If the property of "knower" in the structure of quantum-mechanical knowledge is provided by the Hilbert space of states, then the "process of knowing" is provided by the quantum-mechanical observables. These quantum-mechanical observables represent all the properties of a quantum-mechanical system that can be known—its energy, momentum, angular momentum, etc., depending on the details of the quantum-mechanical system. These quantum-mechanical observables correspond to operators in Hilbert space, and can therefore be viewed as infinite-dimensional matrices. These operators, it must be emphasized, are distinct from the classical quantities they represent. The latter depend intimately upon the state of the system, whereas the quantum-mechanical observables do not. They have a more universal status, and are associated with the process of *gaining knowledge*, i.e., of extracting information about the quantum-mechanical system. The value of some classical observable (represented by a lower case *o*) in a quantum-mechanical system is computed by taking the inner product of the state vector $|\Psi\rangle$ with the state vector acted upon by the corresponding quantum-mechanical observable (represented by a capital *O*):

$$\langle o \rangle = \langle \Psi | O | \Psi \rangle \quad (6)$$

The value of the quantity (*o*) is well defined only if the system is in an eigenstate of the corresponding observable (*O*); i.e., if

$$O | \Psi \rangle = o | \Psi \rangle \quad (7)$$

Otherwise, the quantum-mechanical system does not generally possess a definite value of the observable, and a sequence of measurements performed with identically prepared systems will yield different values. The average or expected value of *o*, averaged over many trials, is given by the expectation value (6).^{*} Thus the quantum-mechanical observable (*O*) is clearly distinct from its classically measured quantity (*o*); the latter depends intimately upon the state of the system, whereas the former is an operator in Hilbert space associated with the process of gaining knowledge.

The quantum-mechanical notion of an observable (*O*) is a far more dynamic concept than the classical quantity (*o*) it represents. Due to their status as operators, these quantum-mechanical observables are the dynamical generators of transformations in Hilbert space. They actively transform one quantum-mechanical state into another and, more

^{*} A more detailed discussion of the quantum measurement process will be presented in Section V.

generally, map the entire Hilbert space onto itself. Because they correspond to self-adjoint operators, their continuous action generates a unitary transformation. Thus, for instance, the Hamiltonian H , the quantum-mechanical observable that corresponds classically to the energy of the system, becomes the dynamical generator of time translations. The momentum operator P actively translates the system in space. The angular momentum operator L accomplishes a rotation of the physical system. The field operator Φ creates and destroys particles from the field, etc. Indeed, all transformations are induced by quantum-mechanical observables. They are the dynamical generators of all change, governing all activity and transformation in nature.

Of all the quantum-mechanical observables, the Hamiltonian enjoys the most privileged position. It is the operator of nature's choice: of all the quantum-mechanical observables, it is the Hamiltonian which acts continuously upon the system, and which is thereby responsible for the time evolution of the system. This is the meaning of the time-dependent Schrodinger equation (3). The evolution of the quantum-mechanical system $|\Psi\rangle$ is generated by the continuous action of the Hamiltonian on the system. Thus the Hamiltonian plays the role of the force of evolution: that specific impulse of natural law which controls the time evolution of everything. It is interesting to note that despite its fundamental physical role, the Hamiltonian is itself composed of other more fundamental operators. Like all quantum-mechanical observables, it can be expressed as a polynomial in the field Φ and its canonically conjugate momentum Π .

Because of their principal role in extracting knowledge about the physical system (6), the quantum-mechanical observables clearly fall within the category of "process of knowing." But their role as such can also be seen in another, more fundamental geometric sense. Without the quantum-mechanical observables and the transformations they generate, the Hilbert space would be completely inert. These transformations map the space onto itself, relating points in Hilbert space to other points. The set of all such transformations that leave the space invariant serves to define the space—its symmetries and its structure. They provide the dynamical means through which the Hilbert space knows itself—through which the quantum-mechanical space of all possibilities becomes aware of its infinite structure. This dynamics of knowing, the dynamics of transformation within the field, is known as *Devata* in Maharishi's Vedic Science [4]. In the structure of knowledge, *Devata* is the process of knowing—that dynamical element in the structure of knowledge which links the knower with the object of knowledge. As for the case of Rishi, there is not one but many different qualities of *Devata*, collectively known as *Devatas*. They are described as the dynamical impulses of natural law governing all transformations in the field of consciousness, in exact correspondence with the quantum-mechanical observables in the Hilbert space formulation of the quantum theory.

Last in the structure of quantum-mechanical knowledge is the "known" or "object of knowledge." These are provided by the quantum-mechanical states themselves—the individual points in Hilbert space. These points, which collectively comprise the space, represent individual, isolated possibilities within the quantum mechanical field of all possibilities. One, and only one, such point represents the actual state of the physical system at any given time (although this state might correspond to a superposition of classically

distinct or even incompatible properties). The labeling of these quantum-mechanical states requires a choice of basis vectors in Hilbert space. These basis vectors are, in general, the eigenvectors of some self-adjoint operators—a maximal commuting set of quantum-mechanical observables. From a dynamical standpoint, the most natural choice of basis vectors are the eigenstates of the Hamiltonian—the so-called energy eigenvectors. These states possess a definite, well defined energy and a degree of stability which is not shared by any other states. From the time-dependent Schrodinger equation (4,5) it is clear that these energy eigenstates undergo a particularly simple time evolution:

$$|E_n(t')\rangle = e^{iE_n(t'-t)/\hbar} |E_n(t)\rangle \quad (8)$$

They oscillate in time with a frequency $\omega_n = E_n/\hbar$ proportional to their energy, and thus correspond to the stable vibrational modes of the system.

In the context of a unified quantum field theory, these stable vibrational states of the field play an especially fundamental role: they comprise the elementary particles and forces of nature. For example, in the framework provided by the superstring, all the elementary particles and forces governing physics below the Planck scale correspond to massless vibrational states of the string, or string “fundamentals.” The higher-energy modes, or string “harmonics,” correspond to heavier particles with masses $O(M_{Pl})$. These stable vibrational states of the string thereby provide the stable foundation on which the entire material universe is constructed—the elementary particles and forces of nature. They ultimately underlie the behavior of macroscopic, bulk matter, which has a tendency to hide the essential, abstract nature of the field from which it arises.

Here we find a very deep connection between modern theoretical physics and the Vedic Science of Maharishi Mahesh Yogi. In Vedic Science, the “known” or *Chhandas* quality of the unified field, represented by individual points in an infinite space of all possibilities, also corresponds to natural, stable modes of the field. Indeed, the term *Chhandas* is often translated as “rhythm” or “frequency,” although Maharishi gives primary significance to its role as the “known” in the structure of knowledge [4]. Hence *Chhandas*, the known, corresponds to the natural resonant modes of consciousness—the fundamentals and harmonics of the unified field which provide the stable foundation on which the entire subjective and objective universe is constructed. As in the case of modern physics, *Chhandas* also has the property of “hiding” the essentially abstract quality of the field within layers upon layers of increasingly inert structure.

In the previous paragraphs, we have analyzed the structure of quantum-mechanical knowledge provided by the Hilbert space formulation of the quantum theory. We have observed a close correspondence between the quantum-mechanical description of the unified field and the self-interacting dynamics of nature’s intelligence described by Vedic Science. This correspondence is summarized graphically in Figure 1. Both formulations describe a fundamental three-in-one structure of knowledge. From the point of view of quantum mechanics, these three are represented by the Hilbert space, the quantum-mechanical observables, and the individual states in Hilbert space. From the point of view of Vedic Science, the self-interacting dynamics of the unified field also gives rise to three distinct values, known as Rishi, Devata and *Chhandas*. We have presented one particularly simple interpretation of these three as

the knower, the known, and the process of knowing, although Maharishi has at times introduced other translations. Knower, known, and process of knowing, however, are particularly interesting since they highlight the difference between the objective approach of modern science and the predominantly subjective approach of Vedic Science, in which the unified field is directly experienced as a field of consciousness. The essential knowledge provided by both approaches, and even the technical details, appears to be the same. The shift in terminology (e.g., “quantum-mechanical observables” versus “process of knowing”) is a natural consequence of the different approaches. Both approaches offer powerful advantages. The objective approach, with its associated mathematical formalism, provides a precise, quantitative framework that has led to the development of important technological applications which have had a major impact on many areas of human concern. The subjective approach of Maharishi’s Vedic Science, through its applied, experiential technologies, allows the direct exploration of the most fundamental aspects of natural law in consciousness, developing higher states of consciousness and the growing ability to utilize natural law spontaneously to enrich all aspects of life in a completely balanced and holistic way [4–10]. These two complementary approaches to knowledge will be further explored, together with their relative merits, in Sections IV–VI.

Having established the fundamental three-in-one structure of knowledge in the Hilbert space formulation of quantum mechanics, we will indicate briefly how the same basic structure appears in different forms when we consider the operator-algebra and path-integral formulations of the quantum theory.

The path-integral approach is a formulation of quantum mechanics based almost exclusively on the use of classical concepts. In this formulation, the evolution of a quantum-mechanical system is described entirely in terms of classical objects moving along classical trajectories. This gross intrusion of classical ideas into the sacred domain of the quantum theory has its inevitable repercussions. Specifically, one is forced to postulate that the quantum-mechanical system (e.g., a point particle) simultaneously moves along many distinct classical trajectories—a classical absurdity. The fundamental postulate of the path-integral formulation is that all possible paths (known as “classical histories”) contribute to the particle’s evolution. Each classical history (P) is weighted by a phase factor $e^{iS[P]}$ which depends upon the classical action $S[P]$ associated with that history. The quantum-mechanical amplitude for a particle to move from an initial point A to a final point B is given by the sum over all histories weighted by their classical action:

$$\langle B|A \rangle = \int [dP] e^{iS[P]/\hbar} \quad (9)$$

The emergence of classical behavior occurs in the following way. In the limit as $\hbar \rightarrow 0$, or in the case of large S , the various contributions to the quantum-mechanical evolution associated with different classical trajectories P are accompanied by widely different and uncorrelated phases. As a consequence, the contribution to the quantum-mechanical evolution (9) from all of these histories cancels through a process of destructive interference. An exception to this rule occurs at, and immediately surrounding, the classical path of least action. Since the action S achieves a minimum along the path of least action, the action will be nearly constant for all paths in the neighborhood of this path. These histories

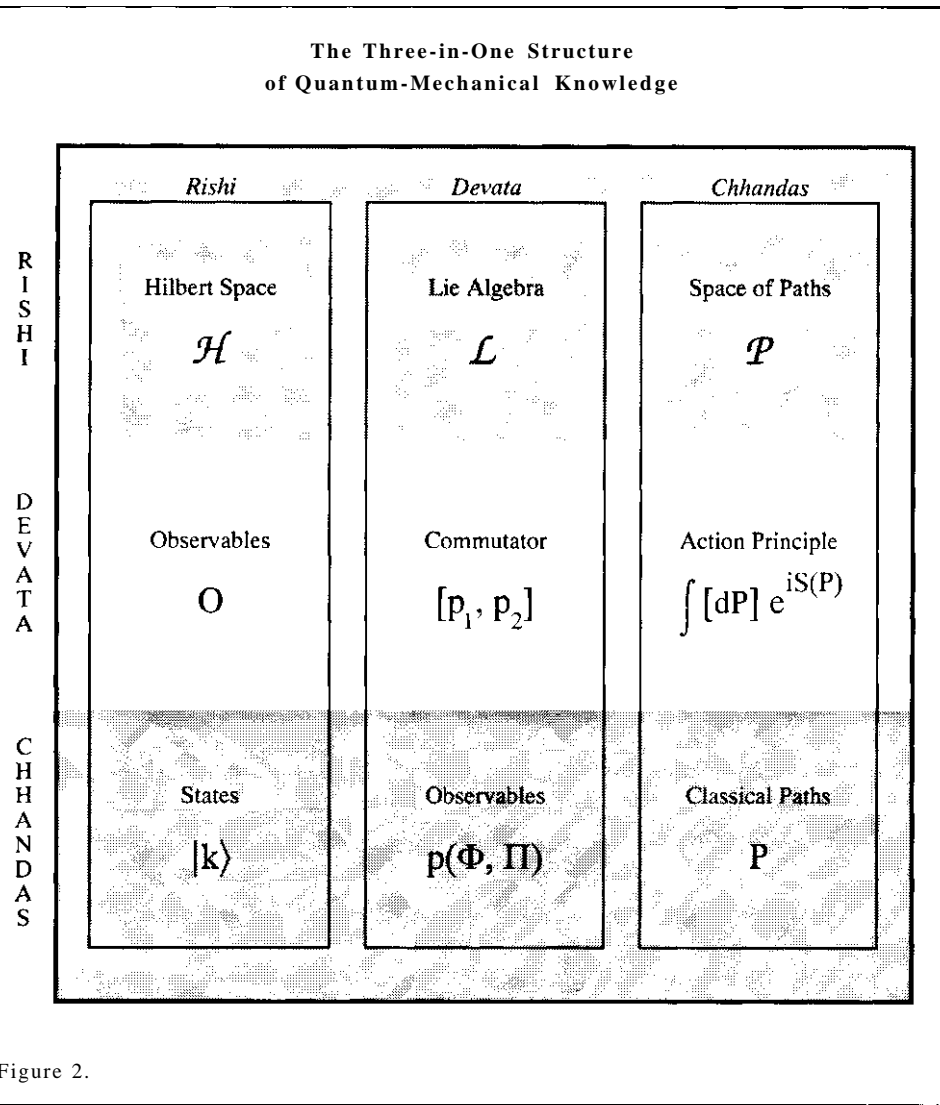
interfere constructively and therefore dominate the quantum-mechanical evolution of the system. Everywhere else, the phase is varying so rapidly that there is no appreciable contribution to the quantum-mechanical evolution. In the extreme classical limit, only those paths which are infinitesimally close to the path of least action contribute to the evolution of the system; this means that effectively only the classical path of least action survives.

In this alternative formulation of quantum mechanics due to Feynman, we can still identify a dynamical interplay between three distinct elements. First is the space of all possible histories, which exist simultaneously at the quantum-mechanical level. Second are the individual paths themselves, including the classical path of least action, which dominates in the classical limit. Third is the dynamical principle (9) or “action” principle, which computes the contribution of each classical history and thereby governs the evolution of the quantum-mechanical system. This three-in-one structure is actually quite similar to the structure of quantum-mechanical knowledge presented by the Hilbert space formulation. In the latter, we have the quantum-mechanical space of all possibilities (the Hilbert space), the individual states that comprise this space, and the quantum-mechanical observables, including the Hamiltonian, which governs the evolution of the system through the time-dependent Schrodinger equation. Indeed, the two formulations are physically equivalent: the dynamical evolution derived from the action principle (9) is, in fact, identical to the time-dependent Schrodinger equation (3). They merely provide two different but complementary perspectives on the same, underlying dynamics of nature.

Even the most rudimentary formulation of the quantum principle provided by the algebraic form of the canonical commutation relation (1) and the associated Lie algebra of observables exhibits a fundamental three-in-one structure. From this algebraic perspective, we have the infinite set of quantum-mechanical observables (comprising all polynomials in Φ and Π), the individual elements that comprise this set, and the binary operation or Lie bracket, which transforms the set into itself and governs, through the Heisenberg equations of motion, the dynamical evolution of the quantum-mechanical system.

This analysis of the Hilbert space, the operator-algebra and path-integral formulations of quantum theory illustrates a universal principle of Maharishi’s Vedic Science that knowledge has a three-in-one structure. In all three formulations we observed an infinite space to be identified with Rishi, the individual elements that comprise this space which we identified with Chhandas, and a dynamical principle relating the elements to the space which we identified with Devata. Having considered these viewpoints separately, we can also comment on their qualities relative to each other. We observe that the Hilbert space sets the tone for the Hilbert space formulation of quantum mechanics, the commutator sets the tone for the operator algebra, and the classical paths for the path-integral formulation. This suggests that, in the total structure of quantum-mechanical knowledge available to a physicist, the Hilbert space formulation provides the predominantly Rishi viewpoint, the operator algebra offers a predominantly Devata viewpoint, and the path-integral formulation a predominantly Chhandas viewpoint (see Figure 2). In a similar way, Maharishi has explained [4] that the entire Vedic literature can be divided into three classes, which respectively present the mechanics of creation from the Rishi, Devata and Chhandas perspectives.

In this section, we have analyzed the structure of quantum-mechanical knowledge



provided by the Hilbert space formulation of the quantum theory and examined this fundamental knowledge in the light of Maharishi Vedic Science. We observed a close correspondence between the three-in-one structure of quantum-mechanical knowledge and the self-interacting dynamics of nature's intelligence (Rishi, Devata, and Chhandas) described by Vedic Science. We have previously shown that the highly nonlinear dynamics of self-interaction introduced by the quantum principle endows the field with a degree of dynamism, discrimination, and a creative capacity which is essential for the emergence of creation as we know it. We have therefore identified the quantum principle with the "intelligence" aspect of the unified field—that property of the unified field which, along with its classical symmetries and structure, is responsible

for the spontaneous and sequential emergence of the diversified structure of the laws of nature. In Maharishi Vedic Science, this intelligence aspect of the unified field, or *buddhi*, is considered equally fundamental: it is this dynamic, discriminative, and creative property of the field which allows the field to know itself, i.e., to interact with itself in a highly dynamic and nonlinear way. This self-interacting dynamics of the unified field has, in fact, been called by Maharishi the "first principle of nature's functioning" [4]. It sets up within the unmanifest field the three-in-one structure of knower, known, and process of knowing, whose dynamical interactions sequentially unfold the diversified structure of the laws of nature governing life at all levels of the physical universe.

In the following section, we will present a systematic analysis of the fundamental modes of the unified field—the elementary particles and forces of nature. Through the combined understanding provided by Maharishi Vedic Science and the latest four-dimensional string formulations, we will develop a more natural understanding of, and terminology for, the elementary particles based directly on the unified field.

IV. The Elementary Particles and Forces of Nature as Modes of the Unified Field

In the previous sections, we presented a detailed analysis of the essential characteristics of the unified field and its self-interacting dynamics. In this section, we will expand this analysis to include a systematic investigation of its fundamental modes—the elementary particles and forces of nature. We have already seen that unified quantum field theories provide a natural understanding of the elementary particles and forces as the stable vibrational states of the field. These natural resonant frequencies, known as energy eigenstates, possess certain properties of stability and discreteness that lend themselves naturally to an interpretation in terms of particles, and which are indeed responsible for the classical understanding of the universe as composed of particles.* Due to their physical interpretation as particles, these energy eigenstates are also known as "physical particle states" of the field. We have previously identified these particle states with the "known" or *Chhandas* quality of the field in Section III.

In the simplest theories, these physical particle states exist in simple, one-to-one correspondence with the fundamental dynamical degrees of freedom of the underlying field. For example, in quantum electrodynamics, electrons and photons respectively correspond to excited states of the electron and photon field. In more complicated, nonlinear field theories, this is generally not the case. In quantum chromodynamics, for instance, the complex spectrum of physical particles (the baryons and mesons) bears no simple resemblance to the fundamental degrees of freedom of the underlying fields—the quark and gluon fields. There may be many layers of quantum dynamics separating the fundamental degrees of freedom of the underlying field and its emergent, physical spectrum of stable vibrational states.

*The discreteness of the energy levels of a quantum field results from the fact that the amplitude of vibration associated with each of these resonant modes is constrained by the quantum principle to be in discrete multiples of Planck's constant. For a more complete introduction, see ref. [11].

Until recently, there was no known field theory with a physical spectrum rich enough to accommodate the great diversity of elementary particles and forces observed in nature. Previous unified field theories based on extended supergravity had a physical spectrum rich enough to include some, but not all, of the known forces—the strong, electromagnetic and gravitational forces, but not the weak force. It was once hoped that the remaining forces and particles could be explained through a more complicated dynamics involving bound states of the fundamental components of the underlying theory (bilinears in the $N=8$ supergravity multiplet), but these efforts met with severe technical difficulties. It is only with the recent discovery of the superstring that a completely unified field theory of all the elementary particles and forces has become possible.

Now, for the first time in history, all known particles and forces of nature can be explicitly identified with modes of the unified field. A detailed investigation into the structure and dynamics of the superstring field reveals a rich spectrum of vibrational states in direct correspondence with the observed elementary particles and forces: the graviton, the spin-1 force fields, chiral matter fields, and all their supersymmetric partners. Within the framework provided by the superstring, all the necessary building blocks of creation can be clearly understood as the natural resonant modes of the unified field.

In our effort to connect all aspects of physics to their unified source in the unified field, we will briefly explain how all the known forces and particles of nature arise from the superstring, clearly identifying each of these particles with specific vibrational states of the field. This identification has been considerably simplified by the recent derivation [3] of supersymmetric Flipped $SU(5) \times U(1)$ from the superstring using the free-fermionic formulation in four dimensions [19]. This derivation provides the most direct link between the heterotic string and the observed elementary particles and forces of nature, while naturally avoiding the problems of cosmological baryogenesis, rapid proton decay, tree-level flavor-changing neutral currents, and Cabibbo universality generally associated with manifold and/or orbifold constructions in ten spacetime dimensions.

Indeed, the discovery of a fully realistic grand unified theory, which is what supersymmetric Flipped $SU(5) \times U(1)$ represents, can be counted as one of the major achievements of this current project to restructure all aspects of physics in light of the unified field. Prior to the knowledge provided by the superstring, it was impossible to know, based on the partial and fragmented understanding of physics available at the electroweak scale, exactly what new forces and new gauge symmetries were relevant to the physics of fundamental scales. As a consequence, grand unified model building was largely a matter of guesswork, and in the historical development of these theories, Flipped $SU(5) \times U(1)$ was essentially overlooked.* Now, based on the knowledge of the unified field provided by the superstring, one can easily show that Flipped $SU(5) \times U(1)$ is the only viable grand unified theory that can arise from the unified field in the context of string theory. The canonical grand unified theories, based on conventional $SU(5)$, $SO(10)$, or E_6 , all require adjoint or larger self-conjugate Higgs representations to break them, and these are not available in string theories (see Appendix C). In contrast, Flipped $SU(5) \times U(1)$ breaks uniquely to the Standard Model using just antisymmetric

* See, however, ref. [C3].

representations of $SU(5)$ [a $\underline{10}$ and a $\underline{5}$], which are abundantly available in string theories. Motivated by the superstring, we first examined Flipped $SU(5) \times U(1)$ in the spring of 1987 [3], and immediately found that this simple theory automatically solved the phenomenological problems (e.g., monopoles, fermion mass relations, mixing angles, proton decay) and technical problems (i.e., the gauge hierarchy problem) of previous grand unified field theories. Hence the discovery of the first viable grand unified theory was a direct result of connecting the area of grand unification to the underlying structure of the unified field provided by the superstring. This provides a rather striking example of the type of results which can be expected from clearly and explicitly connecting all aspects of physics to their source in the unified field.

A string is, by definition, a one-dimensional extended object. One must bear in mind, however, that this one-dimensional object is just the classical tip of a vast, quantum-mechanical iceberg. It is a localized, classical expression—a stable vibrational mode—of an unbounded, underlying superstring field. The string stands in relation to the field as a point particle stands in relation to the field in a conventional relativistic quantum field theory of elementary particles: both the string and the particle represent excited states of their respective, underlying quantum fields. Nevertheless, the concrete perspective afforded by this classical description provides a useful starting point for our subsequent analysis and discussion of the complex physical spectrum of a superstring theory.

The *heterotic* string is essentially a quantum field theory of closed, elastic, relativistic strings. These one-dimensional strings are endowed with the freedom to vibrate in a number of transverse dimensions perpendicular to the string. These dimensions can be viewed as forming an external space in which the string is embedded. Some of these dimensions are bosonic and some are fermionic. If these bosonic and fermionic dimensions happen to exist in one-to-one correspondence, as in the case of the superstring, then one can say that the embedding space takes the form of a superspace. An even more fundamental vantage point results if we discard the concept of the embedding space and consider the string entirely from its own, internal perspective. In this second approach, one defines on the string a set of bosonic and fermionic fields $\phi(\sigma)$, $\psi(\sigma)$ where σ is a parameter between 0 and 2π which specifies the location on the string. Then, instead of an external embedding space in which the string lives and vibrates, we have a one-dimensional field theory of bosons and fermions defined on the string itself.

In the free-fermionic formulation of Antoniadis et al. [19], all but two of these string degrees of freedom are assumed to be fermionic. (One always has the freedom to adopt such a perspective, since at this very fundamental level of string field theory, the difference between a bose field and a fermi field is a formal distinction only.) The two remaining bose fields play a rather special role. Because they are bosonic, these fields can sustain arbitrarily large amplitudes. (Fermi fields $\psi(\sigma)$ are characterized by Grassman-valued amplitudes which have the property $\psi^2 = 0$ and therefore behave formally like infinitesimals.) The macroscopic excursions of these bosonic string modes behave, from a mathematical standpoint, like motion in a non-compact space. Physically and psychologically, we associate with these excursions the notion of an external, physical space. From this profound perspective afforded by the superstring, the emergence of physical space, in addition to all the particles and forces that inhabit it, is a consequence of the

string itself. Space and particles, respectively, result from bosonic and fermionic degrees of freedom intrinsic to the string.

The number of string degrees of freedom is completely determined by mathematical and quantum-mechanical consistency. In particular, conformal invariance (invariance of the string dynamics with respect to scale) is needed to ensure the cancellation of quantum-mechanical anomalies and, in the free-fermionic formulation in four dimensions, fixes the number of string degrees of freedom to be 20 counter-clockwise (or “left-moving”) fermions and 44 clockwise (or “right-moving”) fermions. These fundamental fermionic degrees of freedom defined on the one-dimensional string are not trivially related to the rich spectrum of vibrational states appearing in four dimensions. The complete enumeration of the physical, four-dimensional spectrum requires first a specification of periodicity conditions for the string degrees of freedom, followed by a counting of all vibrational states of the string consistent with these conditions.

The specification of periodicity conditions means the following. Since the energy eigenstates of a system correspond to stationary states—states whose time evolution involves at most multiplication by a periodic phase—these states must correspond to standing waves on the string. For any bosonic string degree of freedom $\phi(\sigma)$, such standing waves are necessarily periodic in the string parameter σ : $\phi(\sigma + 2\pi) = \phi(\sigma)$ since σ and $\sigma + 2\pi$ correspond to the same position on the string. However, for a fermionic string degree of freedom $\psi(\sigma)$, this is not necessarily true. A fermion can also be antiperiodic in σ : $\psi(\sigma + 2\pi) = -\psi(\sigma)$, or can even satisfy a more general, rational periodicity condition: $\psi(\sigma + 2\pi) = e^{i2\pi n} \psi(\sigma)$; $n = 1, 2, 3 \dots$. The antiperiodic case is roughly analogous to the peculiar behavior of fermions in four spacetime dimensions: one must rotate a fermion by two full turns before it returns to its original status. It means that the fermionic fields are not single-valued functions on the string, but have two sheets, or even n sheets in the more general case of rational periodicity conditions. The specification of periodicity conditions for all fermionic string degrees of freedom is necessary (but not sufficient) to completely define the vibrational states of the string.*

Once the fermion periodicity conditions have been specified, there are still a large number of vibrational states consistent with these conditions. The lowest-frequency vibrations consistent with these periodicity conditions can be called the “fundamental” modes of the string. In addition to these string fundamentals, there will also be an infinite series of string “harmonics” possessing integer multiples of these fundamental frequencies which satisfy the same periodicity conditions. Crudely speaking, the fundamentals correspond to massless modes of the string. These are identified with the known elementary particles and forces of nature, which have masses much less than M_{Pl} . The higher frequency harmonics give rise to an ascending tower of massive modes with energies greater than M_{Pl} which have little to do with physics below the Planck scale.

Due to the number of string degrees of freedom, the many possible choices of

* In the interest of technical completeness, we note that the specification of these periodicity conditions is performed not on the string *per se*, but on the string world sheet. The world sheet is the $1 + 1 = 2$ dimensional spacetime surface that describes the classical history of a string as it evolves through time. At the one-loop (quantum) level of the string dynamics, these world sheets have the topological structure of a torus. The periodicity conditions described above actually refer to the behavior of these world-sheet fermions under parallel transport around this one-loop string world torus.

periodicity conditions, and the richness of the resulting spectrum, the complete derivation of all known particles from the string is a somewhat lengthy procedure, which we reserve for the Appendix. It must also be viewed as somewhat model-dependent, since at the present time there are several different string formulations, including manifold compactifications and orbifold compactifications of ten-dimensional string theories in addition to the more direct approach we have outlined. The equivalence of all these approaches is by no means clear: the underlying string theory is certainly the same, but the identification of known elementary particles and forces with specific string modes may be different, and at the present time appears far from unique. In the following discussion, we will therefore emphasize the most general, model-independent features of the massless string modes which have a clear interpretation in terms of the known elementary particles and forces of nature.

These massless modes of the string give rise to an effective low-energy theory governing physics below the Planck scale. On the most general grounds of Lorentz invariance and quantum-mechanical consistency, we know such a theory must take the form of a renormalizable quantum field theory of elementary particles. Quantum-mechanical consistency restricts the range of possible particles and forces to five fundamental categories distinguished by their quantum-mechanical "spins." From a classical standpoint, spin simply refers to the angular momentum intrinsic to the elementary particles. This spin is constrained by the quantum principle to take half-integer values: 0, 1/2, 1, 3/2 or 2 in units of \hbar . From a field-theoretic perspective, spin has even deeper significance. It determines the spacetime transformation properties, the form of the couplings, and thus most of the physical characteristics of the underlying field. Spins greater than 2, for example, do not lead to quantum-mechanically consistent field theories. We will briefly introduce these quantum-mechanical spin types, which collectively constitute the five fundamental categories of matter and energy in nature, together with a brief summary of the relevant portions of Appendix C which identify these spin types with specific vibrational states of the string.

- 1) The spin-2 graviton, responsible for the force of gravity and the field of curved spacetime geometry.
[The graviton belongs to the "Neveu-Schwarz" or antiperiodic sector, which corresponds to massless vibrational states of the string in which all 20 left-moving and 44 right-moving world-sheet fermions are antiperiodic under parallel transport around the one-loop string world torus.]
- 2) The spin-3/2 gravitino, the supersymmetric partner of the graviton field.
[The gravitino corresponds to a massless vibrational state of the string in which all fermions are antiperiodic except for ψ^μ (the supersymmetric partners of the two transverse bosonic string coordinates) and $\chi^{1\dots 6}$, which are periodic under parallel transport around the one-loop string world torus.]

(10)

(Equation continues on next page.)

- 3) The spin-1 force fields, responsible for the strong, weak and electromagnetic forces in addition to other, superheavy grand unified force fields.

[Same as 1].

- 4) The spin-1/2 gauginos, the supersymmetric partners of the spin-1 force fields.

[Same as 2.]

- 4b) The spin-1/2 matter fields—the quarks and leptons.

[The three generations $N_{i=1,2,3}$ of the Standard Model correspond to massless string modes with the following periodicity conditions:

N_1 : $\psi^\mu, \chi^{1,2}, y^{3,4,5,6}, \bar{y}^{3,4,5,6}, \bar{\psi}^{1,\dots,5}, \bar{\eta}^1$ antiperiodic;

N_2 : $\psi^\mu, \chi^{3,4}, y^{1,2}, \bar{y}^{1,2}, \omega^{4,5}, \bar{\omega}^{4,5}, \bar{\psi}^{1,\dots,5}, \bar{\eta}^2$ antiperiodic;

N_3 : $\psi^\mu, \chi^{5,6}, \omega^{1,2,3,4}, \bar{\omega}^{1,2,3,4}, \bar{\psi}^{1,\dots,5}, \bar{\eta}^3$ antiperiodic;

and the rest periodic under parallel transport around the one-loop string world torus.]

- 5) The spin-0 matter fields, including the supersymmetric partners of the quarks and leptons in addition to certain neutral scalars (higgs bosons) responsible for the spontaneous breaking of gauge symmetries.

[The squarks and sleptons are similar to 4b, with opposite periodicity conditions for $\psi^\mu, \chi^{1,\dots,6}$. The higgs bosons arise from the same antiperiodic sector described in 1.]

(10)

From this analysis, we conclude that within the framework provided by the superstring, all the elementary particles and forces of nature can be clearly understood in terms of the unified field. We have explicitly identified all known particles with specific vibrational states of the string (10). Thus, the elementary particles and forces of nature, which provide the stable building blocks for the whole material universe, stand clearly revealed for what they are—the natural resonant modes of the unified field. This clear understanding provided by the superstring lays the foundation for a new interpretation and language of physics, in which the elementary particles and forces of nature, and indeed the entire discipline, are clearly connected to their unified source. In the light of this new understanding, many of the historical perspectives and language of physics will give way to a more natural understanding and terminology based directly on the unified field. Instead of their currently random and/or historical names, the elementary particles will be named for the specific vibrational states they correspond to: periodic, antiperiodic, etc., revealing their rightful place in the internal structure and dynamics of the unified field. This natural labeling of all aspects of the discipline in terms of the unified field provides a natural order and organization to the entire discipline which was not possible as long as its unified foundation was hidden from view.

At the present time, we have also seen that the labeling of modes provided by the free-fermionic string formulation is rather awkward. Due to the number of string degrees

of freedom, the many possible choices of periodicity conditions, and the richness of the resulting spectrum, the labeling of these string modes (10) is necessarily somewhat cumbersome. Vedic Science, in comparison, provides a very natural and compact language of nature which is also based directly on the unified field. In the language of Maharishi Vedic Science, the five fundamental categories of matter and energy (10) responsible for material existence are called *tanmatras* (meaning elementary in the sense of non-composite) [6,9]. Respectively they are known as *akasha*, *vayu*, *tejas*, *apas*, and *prithivi*. There is a striking correspondence between these five tanmatras and the five quantum-mechanical spin types of a unified quantum field theory: between the akasha or "space" tanmatra and the gravitational field; between the vayu or "air" tanmatra, which stands as a link between space and the other tanmatras, and the gravitino field; between the tejas or "fire" tanmatra, responsible for chemical transformations and the sense of sight, and the spin-1 force fields; and between the apas and prithivi ("water" and "earth") tanmatras and the spin-1/2 and spin-0 matter fields, respectively.

This correspondence is even more striking in the context of a supersymmetric unified field theory, such as the superstring. In a supersymmetric theory, there is a natural pairing of the five spin types into three types of $N=1$ superfields (see Figure 3). The spin-2 graviton and the spin-3/2 gravitino become unified in the context of the *gravity superfield*, the spin-1 force fields and spin-1/2 gauginos combine to form *gauge superfields*, and the spin-1/2 matter fields and their spin-0 supersymmetric partners give rise to *matter superfields*. These same pairings are also considered fundamental in Vedic Science, wherein akasha and vayu appear unified in the structure of *vata prakriti*, tejas and apas become united in the structure of *pitta prakriti*, and apas and prithivi combine to form *kapha prakriti* [20]. Like the $N=1$ superfields, the prakritis pertain to the structure of natural law at fundamental spacetime scales—at or near the scale of super-unification. This striking correspondence, which has been discussed in greater detail elsewhere in the literature [11], adds further weight to the fundamental identity between the unified field of pure, self-interacting consciousness and the unified field of modern theoretical physics: not only do they possess identical properties and characteristics (see Sections II and III) but they share the same spectrum of excitations.

It is very interesting in this context that the unified field or *atman* (self) is also known as *sutratma* (literally, string-self) [21]:

मम चैव शरीरं वै सूत्रमित्यभिधीयते ।

mama chaiva shariram vai sutram ity abhidiyate

My body is called a string.

(or)

This my body having the nature of a string.

Like the heterotic string, this string (sutratma) has the topology of a circle, or *mandala* [4]. The self-interacting dynamics of consciousness described in the Ved gives rise to several distinct categories of mandala, which include the five tanmatras or spin types introduced above (10) in addition to others (*manas*, etc.) which correspond to subjective realities that have little to do with physics below the Planck scale. Here again we observe a close correspondence between the structure and dynamics of the unified field described

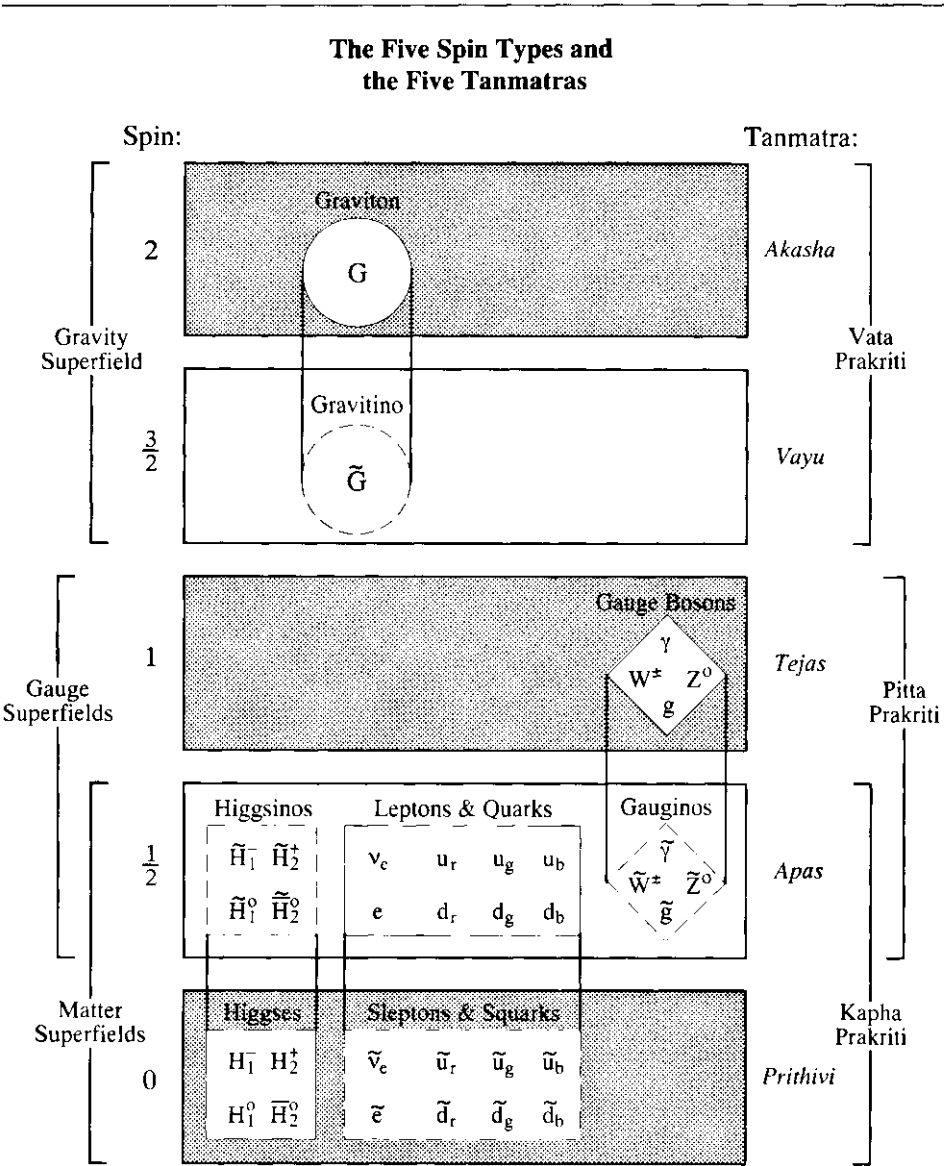


Figure 3.

by Maharishi Vedic Science and the unified quantum field theory of modern theoretical physics. The essential knowledge, and even the technical details, appear to be the same. The difference in terminology can be naturally understood as a consequence of the different approaches.

To understand the significance of the Vedic names *akasha*, etc., in relation to the unified field, we first recall what the five fundamental categories of matter and energy

actually represent in the context of a unified field theory. They represent the stable vibrational states, or natural resonant frequencies, of the unified field. We have explicitly identified the five quantum-mechanical spin types with specific vibrational states of the field—periodic and/or antiperiodic, fundamentals and/or harmonics of the string (10). We have therefore discovered a level of nature's dynamics where all matter and energy—the elementary particles and forces—correspond to specific "sounds" or vibrational patterns of the unified field.

This same understanding is considered fundamental in Maharishi Vedic Science. Vedic Science posits an intimate relationship between sound and meaning, or name and form, at the unified level of nature's functioning: *nama* (name) becomes identified with *rupa* (form) at the level of the unified field [10]. This intimate relationship between sound and meaning, which we have also seen in the context of the superstring, suggests a profound system of nomenclature which is both novel and natural: to name every object or expression of the unified field with the actual sound or vibration of the field which that object corresponds to. According to Maharishi, this is precisely what the Vedic names *akasha*, *vayu*, etc., represent. They are the actual "sounds" or vibrational patterns of the unified field associated with those fundamental objects. The spoken words (*akasha*, etc.) directly reflect these fundamental sounds, amplified, translated in frequency, and articulated on the level of speech.

Due to this intimate connection between sound and meaning, Vedic Science has been aptly described as a highly refined and sophisticated science of sound. This is perhaps most profoundly illustrated in the case of the Rig-Ved, the most fundamental aspect of the Vedic Samhita and, according to Maharishi, the foundation of the entire Vedic literature [4]. According to Maharishi Vedic Science, the Rig-Ved presents a complete record of the structure and dynamics of the unified field in the form of sound. Indeed, the syllables of the Rig-Ved are the actual sounds generated by the self-interacting dynamics of the unified field and the mechanics of symmetry breaking through which the unified field sequentially gives rise to the diversified structure of natural law seen in nature [10]. For this reason, this fundamental aspect of the Vedic literature is also known as *shruti*, which means "heard." This term refers to the manner in which the Ved was cognized. These primordial sounds, or mechanics of nature's functioning, were heard by the sages in the most silent, settled state of their own awareness—the unified field of pure, self-interacting consciousness.* These sounds were subsequently recorded and preserved in the form of speech. Thus the Rig-Ved, according to Maharishi, is not an intellectual commentary on the fundamental mechanics of nature's functioning. It is an actual acoustic record of the total structure of the unified field and its self-interacting dynamics. This explains why the Ved is primarily an oral tradition, a tradition of sound painstakingly preserved and passed down from generation to generation. Transcription, translation and interpretation of the Ved is given very little importance in the Vedic tradition. The true meaning and significance of the Ved is vested in the Ved itself. This understanding is aptly summarized in a verse from the Rig-Ved [6].

*At this fundamental level of awareness, it is more correct to say that the Ved hears itself, since in this unified state of consciousness the knower, the known, and the process of knowing are one and the same. This is why the Ved is called *Samhita*, meaning unity of knower, known, and process of knowing [4].

**ऋचो अक्षरे परमे व्योमन् ।
यस्मिन्देवा अधि विश्वे निषेदुः ।**

*Richo akshare parame vyoman
yasmin deva adhivishve nisheduh*

The sounds of the Ved are generated by the collapse of unity within itself, in which reside all the dynamical impulses of natural law responsible for the whole manifest universe.

This is the specialty of the Vedic language, the intimate connection between sound and meaning whereby the name corresponds precisely to the form of the object. Such a language, in which every expression of the unified field is named with the actual sound of the unified field which that object corresponds to, is unified field-based in the fullest possible sense. Such names possess a level of authenticity that is not shared by the historical and/or random nomenclature currently in vogue.

Maharishi explains that the Vedic names are especially significant for an individual possessing the requisite level of consciousness. Due to the intimate connection between sound and meaning at the unified level of nature's functioning, an impulse of sound automatically carries with it the associated form, with all its various properties and characteristics. If the awareness is lively at this fundamental level, the sound automatically structures the corresponding experience, with all its associated properties and characteristics. This level of awareness in which the name automatically invokes the form of the object is known as *ritam bhara pragya*, meaning "that level of the intellect that comprehends only truth" [4]. Given access to this fundamental level of awareness, the Vedic terminology provides a powerful research methodology. All the fundamental modes of the unified field can be systematically stimulated on the level of consciousness through the introduction of these Vedic terms [4]. Without this ritam level of awareness, the Vedic names lose their special significance, much as a hologram loses its special significance in the absence of coherent light. Maharishi explains that it was the lack of widespread availability of this fundamental level of consciousness in recent history that had placed the Vedic knowledge in a state of decline [9]. This situation is also described by the previous verse from the Rig-Ved, which continues [6]

**यस्तन्न वेद किमुचा करिष्यति ।
य इत्तद्विदुस्त इमे समासते ॥**

*Yastanna veda kimricha karishyati
ya ittadvidus ta ime samasate*

He whose awareness is not open to this field,
what can the sounds of the Ved accomplish for him?
Those who know this level of consciousness are
established in unity, wholeness of life.

The current revival of the Vedic knowledge by Maharishi has largely been possible through his rediscovery of the specific subjective technologies, the Transcendental Meditation and TM-Sidhi programs, needed to restore this basic experience. The Transcendental

Meditation technique naturally produces this fundamental level of awareness, in which consciousness is identified with the unified field. The TM-Sidhi program then stimulates sequentially all the fundamental modes of the unified field using specific mental formulas or impulses of sound prescribed by Maharishi Patanjali thousands of years ago [4]. The resulting experience of all the fundamental aspects of natural law as modes of one's own awareness indeed provides the most striking experiential confirmation of the proposed identity between the unified field of pure, self-interacting consciousness and the unified field now being glimpsed by modern theoretical physics [11]. This direct experience is as repeatable, as striking and unambiguous for the experiencer as any data obtained through the use of particle accelerators. It can be replicated at any time by anyone possessing the requisite apparatus and training. This apparatus and training, respectively, consist of a human nervous system and instruction in the experiential technologies of Maharishi Vedic Science—the Transcendental Meditation and TM-Sidhi programs. Indeed, the direct experience of the unified field of pure, self-interacting consciousness as the unified field of all the laws of nature is self-evidently more real than any experience in the domain of ordinary waking consciousness, for the same reason that waking experience is self-evidently more real than dreaming—it represents a more integrated, holistic and logically self-consistent state of functioning of the brain physiology.

The knowledge of the Vedic sounds and their classification by Maharishi has had profound application in many different areas. This knowledge presents a complete science of transformation based on the unified field. Through the introduction of specific impulses of sound (specific frequencies or patterns of vibration of the unified field), one can induce a transformation from one frequency or pattern to another, in a manner familiar to experimentalists and theorists working with scattering experiments or Feynman graphs. The introduction of a new frequency or "particle" into the initial-state configuration leads to a whole new range of final-state possibilities, in accordance with a set of selection rules and conservation laws appropriate to physics at that level. This has opened up an entire field of "Vedic engineering" or Maharishi Yagya [9], which applies the knowledge of the Vedic sounds to effect transformations at any and all levels of the physical universe. Although Vedic engineering is not a new science, it had fallen into a state of relative disuse because its application must be from the level of the unified field. Without the corresponding level of consciousness, the Vedic sounds are just gross expressions on the level of speech, and have a correspondingly limited effect.

One interesting and widespread application of the Vedic terminology is known as Maharishi Vedic Vigation Technology, which addresses specific imbalances in the physiology through the application of certain sounds. This represents just one small aspect of a complete science of health known as Maharishi Ayur-Ved, which is based directly on the fundamental knowledge contained in the Rig-Ved [4]. The principal focus of Maharishi Ayur-Ved is on the level of the unified field, i.e., the restoration of balance in the physiology through direct experience of the unified field of pure, self-interacting consciousness. However, Maharishi Ayur-Ved also includes numerous approaches based on more expressed levels of natural law if and when necessary,

including the restoration of physiological balance at the level of the three prakritis or superfields through the application of primordial sounds, herbs or minerals with the appropriate balance of these prakritis. As in modern science, there are many different levels of structure on which any organ or tissue can be described and treated: the gross structural level, the molecular or biochemical level and, in the case of Maharishi Ayur-Ved, increasingly fundamental levels including the five spin types, the three superfields, and the unified field itself.

A complete discussion of the numerous applications and approaches of Maharishi Vedic Science is beyond the scope of this work. However, the spectacular achievements and proven effectiveness of the Vedic language and approach in the field of health alone [22] clearly demonstrate the practical value of a unified field-based approach and terminology in which all objects are named with the actual sounds or vibrations of the field that they correspond to.

Such a level of perfection of nomenclature is what we would like to achieve for physics. Such a system will necessarily include the use of Vedic terms, since these are the actual sounds corresponding to the fundamental objects studied by physics. We have therefore included these Vedic Science expressions in our graphical presentation of the structure of a unified quantum field shown in Figure 1.

In this section, we have understood all the elementary particles and forces of nature in terms of the unified field. We have explicitly identified all the elementary particles and forces, along with the origin of space itself, with specific vibrational states of the field using the free-fermionic string formulation. These elementary particles and forces, which comprise the five quantum-mechanical spin types, are shown in relation to the unified field in Figure 1, together with their corresponding Vedic Science expressions. The addition of these Vedic Science names should provide the student of physics, as well as the advanced researcher, with a powerful research methodology when these names are applied via the TM-Sidhi program at the appropriate, unified level of awareness, where the correspondence between name and form is lively. In addition to the abstract knowledge such experience provides, the applied, practical value of these fundamental fields is obvious and automatic at that unified level of awareness.* The implications of a complete science and technology of the unified field will be further considered in Section VI.

V. Quantum Cosmology and Vedic Cosmology

The most obvious practical expression of the unified field is the universe itself. The study of the origin and evolution of the universe is the science of cosmology. In this section, we will review the mechanics of creation from the unified field and their implications for a unified field-based cosmological theory, using the combined perspectives of modern science and the Vedic Science of Maharishi Mahesh Yogi.

*The practical application of the five tanmatras is described in Patanjali ref. [23]. Research has shown a restoration of physiological balance and efficiency [24], improved health and resistance to disease [25], growth of intelligence [26] and creativity [27], improved moral reasoning [28], and many other benefits [29] from the regular practice of the TM-Sidhi program.

We will begin this analysis with a concise summary and overview of the structure of a unified quantum field developed in Sections II–IV and presented in Figure 1. In Section II, we identified the essential characteristics of the unified field as existence and intelligence. We saw that the intelligence aspect of the field, which we identified with the quantum principle, endowed the field with a degree of dynamism, discrimination, and a creative capacity not present at the classical level of description. This was essential for the spontaneous breaking of gauge symmetries, the breaking of supersymmetry, and for the emergence of discrete quanta (i.e., particles) from the continuous dynamics of the field. In Section III, we saw that this intelligence aspect of the field introduced by the quantum principle automatically implies a fundamental three-in-one structure of knowledge, comprised of the Hilbert space, quantum-mechanical observables, and states in the Hilbert space formulation of the quantum theory. The highly nonlinear, self-interacting dynamics of the field afforded by the quantum principle ultimately gives rise to a rich spectrum of vibrational modes or energy eigenstates of the field, which form the stable building blocks of the entire material universe—the elementary particles and forces of nature. Within the framework provided by the superstring, it is the massless modes, or string “harmonics,” which constitute the known elementary particles and forces governing physics below the Planck scale. At these scales, the Lorentz-invariant structure of classical spacetime, together with quantum-mechanical consistency, restricts the range of quantum fields to five fundamental spin types, which combine to form three superfields in the context of a supersymmetric unified quantum field theory, such as the superstring. The resulting supersymmetric grand-unified structure is, in general, followed by a further sequential process of spontaneous symmetry breaking: $SU(5) \times U(1) \rightarrow SU(3)_c \times SU(2)_w \times U(1)_Y \rightarrow SU(3)_c \times U(1)_{em}$, leading to the separate strong, weak and electromagnetic forces at observable energies far below the Planck scale (see Figure 1).

The identical structure and sequential dynamics is described by Maharishi’s Vedic Science. The unified field or *atman*, being consciousness, has as its essential characteristics both existence and intelligence. The intelligence aspect, or “witnessing” quality, of the field is known as *buddhi*. Due to its essential nature as consciousness, the unified field is aware of its own existence. This self-interacting property of awareness sets up, within the field of consciousness, a three-in-one structure of knower, known, and process of knowing: consciousness (the knower) is aware of consciousness (the known) through the agency of consciousness (the process of knowing). This three-in-one dynamics of consciousness knowing itself (known as the Ved) generates a rich spectrum of vibrational modes, which appear as all forms and phenomena in the universe. Among the resonant modes of consciousness are the five fundamental categories of matter and energy, or *tanmatras*, responsible for the material universe. As in a supersymmetric unified quantum field theory, these five combine to form three more holistic entities, known as *prakritis* in the language of Vedic Science.

Maharishi points out that this entire dynamics and sequence of expression, from unity to diversity, can be seen as a sequentially more elaborated commentary on the nature of *atman* itself [10]. Every stage in the sequential unfoldment of the laws of nature from the unified field is a spontaneous and inevitable consequence of the nature of

consciousness and its self-interacting dynamics; it results from the discriminative (*budhi*) nature of consciousness to know itself more and more completely. From this fundamental perspective, put forth by the Vedanta aspect of the Vedic literature, the mechanics of creation do not begin with the field of consciousness and proceed towards matter; the entire sequence of expression is understood to occur within the field of consciousness [4]. The process of creation simply represents a sequentially more elaborated self-commentary on the nature of consciousness itself.

Similarly in physics, the entire dynamics and sequence of expression shown in Figure 1 can be viewed as a sequentially more expanded commentary on the unified field itself. Every stage in the sequential unfoldment of the laws of nature from the unified field is an automatic consequence of the detailed structure of the unified field and its self-interacting dynamics. At no stage in this sequential unfoldment is it necessary to introduce additional *ad hoc* postulates and assumptions: the creative process occurs entirely by itself in a self-sufficient manner as a spontaneous and inevitable consequence of the unified field itself. Herein lies the predictive power of a unified quantum field theory—the entire diversified structure of the laws of nature can be derived from the highly compact and unified structure of the unified field—provided one possesses the analytic tools needed to unfold its detailed dynamics.

This spontaneous and sequential mechanics of creation is summarized in a verse from the Vedic literature describing the mechanics of speech. Because the individual and the cosmos are unified at their basis, the individual awareness (*atman*) and its self-expression through speech is directly parallel to the mechanics of creation in nature. This mechanics is analyzed in *shiksha* [30], on which Maharishi has offered the following commentary:

Atman buddhi arthan manas vivarta kayagni vayu akasha

Speech is an expression of *atman*, the self. Its development begins when the intelligence aspect of *atman*, or *buddhi*, discriminates the self into the knower, the known, and the process of knowing. These three are represented by *arthan*, which means the "objects of *buddhi*." All possible relationships among these three, and their associated shades of meaning, constitute the domain of *manas*, or "mind." The four (*atman*, *buddhi*, *arthan*, *manas*) are traditionally associated with the subjective aspect of existence. These are followed by *vivarta*, which means "transformation in appearance." It describes the transition from subjectivity to objectivity which occurs, according to Maharishi, when the subjective impulse of thought gets translated, through the DNA, into neuropeptides and other complex proteins which comprise the biochemistry of thought [4]. This transition also represents the junction point between the quantum-mechanical and the classical in the structure of the human physiology. It is called a "transformation in appearance" because, according to Maharishi Vedic Science, the transition from quantum-mechanical to classical, or from consciousness to matter, never really occurs. Nature is never separate from consciousness, and the emergence of classical behavior is a matter of appearance only. The classical viewpoint merely affords a natural and convenient perspective once the system achieves a certain degree of complexity, or once matter becomes sufficiently precipitated. On the level of the "cosmic physiology," this apparent transition from quantum-mechanical to classical

begins at the Planck scale, where the field of gravity decouples from the rest of physics and spacetime begins to display its classical $3 + 1$ dimensional structure. At the same time, the dynamics of the superstring begins to be replaced by an approximate, effective low-energy field theory of elementary particles. Neither of these transformations are genuine: the transition from quantum gravity to classical gravity and from string dynamics to field theory are "transformations in appearance" only. Next comes *kayagni*, or "fire of intelligence." Once the impulse of thought enters the biochemistry, it creates (along with other physiological changes) a spur to exhale, leading to a movement of air (*vayu*) and to the production of sound through the vocal chords which then propagates through space (*akasha*). Hence the emergence of the physical elements (*vayu*, etc.) follows the transformation (*vivarta*) from quantum-mechanical to classical, just as the five spin types follow the transition to classical spacetime in the structure of a unified quantum field theory (see Figure 1).

Here again, the key point which emerges from Maharishi Vedic Science description is that the transition from *atman* to *buddhi*, to *arhan*, etc., never really occurs. *Buddhi*, *arhan*, *manas*, etc., all exist within the nature of *atman* itself. Intelligence is not outside of consciousness: it is the very nature of consciousness. Discrimination between the knower, the known, and the process of knowing is not outside of intelligence, but is the very nature of intelligence. The entire sequential mechanics of creation exists within the field of consciousness. It is just a sequentially more elaborated commentary on the nature of consciousness, as intellectually conceived by its own discriminative aspect, or *buddhi*. Hence the notion of diversity disconnected from unity is a fundamental misconception. This misconception is known as *pragya-aparadh* or "mistake of the intellect" [4]. Because it plays an important role in our subsequent cosmological discussion and is considered so fundamental in Maharishi Vedic Science, we will take a moment to elaborate on this concept here.

Pragya-aparadh results when, in the mechanics of creation from the field of consciousness, the intellect loses sight of the essential unity which is the true nature of the self. Due to an inflexibility in the neurophysiology, somewhere in the sequential progression of unity to diversity the experience of unity is lost. The intellect gets caught up in its own creation, i.e., gets overshadowed by the perception of diversity to the exclusion of the unity which is the actual nature of the self being discriminated. According to Maharishi, this mistake of the intellect is so fundamental to the nature of human experience that it is responsible for all problems and suffering in life.

Psychologically, this experience of a fragmented and disconnected existence causes disorientation. Uncertainty, instability, isolation and limitations automatically result when the unified source and basis of existence is hidden from view. Neurophysiologically, this fragmented structure of experience gives rise to the highly unintegrated style of brain functioning known as waking consciousness, which is considered normal throughout the world. Physiologically, this fragmented state of psychology leads, through imbalanced thinking and its associated neurochemistry, to imbalance in the physiology, leading to a degradation of the immune system and a resulting susceptibility to numerous diseases and disorders, and to an acceleration of biological aging. Sociologically, the lack of understanding and clear experience of the holistic

and unified basis of existence results in behavior which is less than harmonious and universal in its scope.

This fragmented structure of knowledge and experience is reflected in the current systems of education, as well as in the structure of the individual academic disciplines themselves. Of all the disciplines, only physics has achieved some partial understanding of its unified source in the unified field, and this relatively recent understanding has had little impact on the manner in which physics is understood and taught. The primary purpose of Maharishi Vedic Science and its applied, experiential technologies is to restore a more integrated state of neurophysiological functioning in which all aspects of experience are clearly connected to their unified source in the unified field of pure, self-interacting consciousness. The Transcendental Meditation technique, for example, by taking the awareness repeatedly from the localized channels of thought and perception to the silent, unmanifest source of thought, cultures within the brain physiology a flexibility which simultaneously comprehends both silence and dynamism—unbounded awareness together with the localized boundaries of waking, dreaming and deep sleep states of consciousness. The TM-Sidhi program, by taking the awareness repeatedly through the fine mechanics of creation from the unified field, clearly reveals all the diverse aspects of natural law as various modes of the unified field. This experience, in particular, develops an integrated state of neurophysiological functioning in which all aspects of experience are directly perceived as modes of one's own intelligence. In this expanded state of awareness, the psychology, physiology, and social behavior are restored to a natural state of integration, harmony and balance [24-29]. This quality of experience is summarized in a verse from the Bhagavad Gita [9], which Maharishi has described as the encapsulated essence of the Vedic wisdom:

He whose self is established in unity, whose vision everywhere is even, sees the Self in all beings, and all beings in the Self.

This Vedic conception of the entire universe residing within the unified field, as opposed to emerging from it, has its corresponding understanding and expression in a relatively recent area of physics known as quantum cosmology. Quantum cosmology applies the principles of quantum mechanics to the universe as a whole. Because the universe incorporates gravity in addition to the other fundamental forces and particles, a proper treatment of this subject necessarily requires a unified field theory such as the superstring, since without unification the force of gravity is not quantum-mechanically consistent. The first papers on superstring cosmology are now beginning to appear.

We have previously seen, based on general principles, that the vacuum state of a field, or indeed any state characterized by a finite energy density, must represent a simultaneous coexistence of many classical field shapes. Indeed, in Appendix B we show that the vacuum state of a scalar field is given by a quantum-mechanical superposition of all possible shapes. The vacuum state represents the natural starting point for any cosmological study, since it is the only stable, unbounded, Lorentz-invariant state of the field. Let us now consider what would happen if the unified field, through

some dynamical means of self-observation, were to perform a measurement of its own amplitude.

According to a fundamental postulate of quantum measurement theory, the field would collapse to an eigenstate $|\phi\rangle$ of the field operator Φ , i.e., to a definite classical field shape:

$$\Phi(x, t_0) |\phi\rangle = \phi(x) |\phi\rangle \quad (11)$$

This result is rather intuitive: if the field were to remain in a state which was a superposition of all classical shape states, the field would not possess any definite amplitude and the measurement could not yield a definite result. Hence the effect of a measurement is to collapse the initial quantum-mechanical superposition of all classical field shapes to some definite, well-defined classical shape. However, this localized classical state of the field is highly unnatural from the standpoint of quantum mechanics, since it represents a state of infinite energy density. From the Heisenberg uncertainty principle (2), the fact that the uncertainty in the field $\delta\Phi$ is zero in a definite classical shape state implies an infinite uncertainty in its canonically conjugate momentum. Such a field shape will therefore immediately explode from its classically definite value to assume, once again, a quantum-mechanical superposition of all possible shapes (see Figure 4). However, the resulting superposition of classical field shapes will no longer possess the precise and definite balance of shapes which characterizes the vacuum state. (The vacuum state is the unique superposition of field shapes which is stable in time, unbounded in space—i.e., Lorentz invariant.) The initially perfect balance of the vacuum state, once disturbed by the quantum measurement process, becomes unstable: the field continues to reverberate forever in a highly nontrivial time evolution.

According to Maharishi's Vedic Science, the most fundamental and authoritative expression of the mechanics of creation is contained in the Ved itself—in the phonetic

Collapse of the Vacuum Wave Functional and the Mechanics of AGNIM

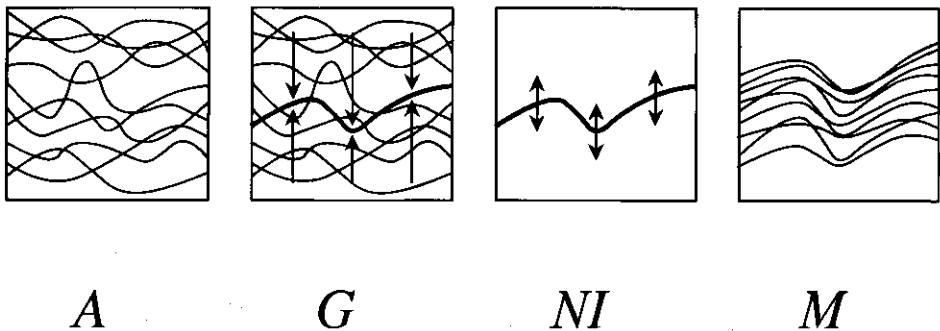


Figure 4.

structure of the Rig-Ved Samhita, whose sequential progression of sound and silence* perfectly reflects the mechanics of creation itself [4]. Unfortunately, the available translations of the Ved do not mean much, since there are no corresponding English words that capture all the information stored in the Vedic phonemes. Maharishi has, however, placed considerable emphasis on the phonetic analysis of the Rig-Ved [10], and we will therefore briefly summarize the mechanics of creation as revealed through a phonetic analysis of the first word of the Rig-Ved: **AGNIM**.

According to Maharishi, the letter **A** represents fullness—the field of all possibilities. Phonetically, it corresponds to the most wide open and least obstructed position in the physiognomy of speech. It is the first letter in every major phonetic (or alphabetic) system and is said to include all other sounds, in the sense that its modulation by the tongue and lips produces all other sounds. The letter **G** represents its extreme opposite—complete emptiness or "point value" of speech. Phonetically it corresponds to the most closed or fully obstructed value of speech. The combination **AG**, according to Maharishi, represents the collapse of fullness to a point, which occurs when consciousness, the field of all possibilities, becomes aware of its own point value. It is precisely analogous to the collapse of the vacuum wave functional which would occur if the field were to observe its own amplitude (see Figure 4). The letter **N** represents negation, while the letter **I** indicates a leading out. The combination **NI** represents a negation of the point value followed by a leading out from the point back in the direction of infinity. In the words of Maharishi, "consciousness recoils from its own point value, which represents a highly restricted and hence unnatural state of the awareness." This is, again, closely analogous to the situation in quantum mechanics, where the field rebounds dynamically from the highly unnatural classical shape state (11) which results from quantum measurement to again become a quantum-mechanical superposition of shapes. Finally the **M** in **AGNIM** represents continuance, and implies that the mechanics of creation, once set into motion by the collapse of infinity, continues indefinitely, in direct analogy to the situation described by quantum mechanics.

There are several aspects of this cosmological model based on the collapse of the vacuum wave functional that require refinement. First, the collapse of the vacuum wave functional, were it really to happen, would require an enormous expenditure of energy, since it takes the field from the vacuum state to a highly excited state of the field, and it is not clear where this energy would come from. This, by itself, is not sufficient to invalidate the model, since it is not clear how to interpret or enforce energy conservation at the superunified scale, given the presence of wormholes and other nonperturbative quantum-gravitational effects. Second, there is no evidence in physics for the reduction of the wave function in closed, quantum-mechanical systems with no external, classical observer. In particular, highly sensitive experimental tests of nonlinear corrections to the Shrodinger equation of the form that could lead to a reduction of the wave packet have found no evidence for such nonlinear behavior. Both arguments indicate that an

* Maharishi explains that much of the creative dynamics of nature is contained in the gaps between the Vedic phonemes, i.e., in the sequential mechanics of transformation from one syllable to the next. The mechanics of collapse of sound to silence, the mechanics of transformation within the silence, and the sequential emergence of sound from silence are all essential components of the Vedic Samhita [4].

actual collapse of the vacuum wave functional based on any intrinsic field-theoretic mechanism appears unlikely.

It seems much more plausible, from the standpoints of both modern science and Vedic Science, that the "collapse of infinity" does not constitute an actual collapse of the vacuum wave functional, but merely represents a shift in attention—from the quantum-mechanical superposition of all possible field shapes, which represents the true structure of the quantum vacuum, to one of the infinite number of field shapes which comprise this state. Once the awareness has become localized on a particular value, the subsequent evolution of that state would appear to follow in precisely the same dynamical manner described above. However, due to the simultaneous coexistence of all such states, each of which undergoes a highly nontrivial time evolution, the overall structure of the vacuum remains completely unchanged and retains its perfectly balanced and symmetrical structure.

This basic notion of a shift in attention may provide a more useful interpretation of quantum measurement generally. Besides the fact that there is no physical evidence for wave function reduction in closed quantum-mechanical systems, there are other arguments and experiments which suggest that the reduction of the wave function may be more a matter of perspective than an actual physical event. First, the reduction of the wave packet has been experimentally shown to violate strong causality: i.e., the collapse extends to space-like separated components of a quantum-mechanical system. This makes any physical interpretation of the collapse of the wave function as an actual, causal event extremely difficult. Second, the collapse of the wave function has been shown to obey weak causality, which means that it cannot be used to communicate any information. Thus there is no indication whatsoever for a second observer that a collapse has occurred as a result of a measurement performed by the first observer, which also suggests that the collapse of the wave function is a phenomenon in consciousness and not a physical event *per se*. It appears to be intimately associated with a fragmented perspective, in which the quantum-mechanical system is assumed to possess an objective existence independent from the system that measures it.*

According to this expanded cosmological framework, the true quantum vacuum is seen as a simultaneous coexistence, or quantum-mechanical superposition, of all possible universes. Some of these universes correspond to deSitter manifolds in a state of exponential inflation, while others are in a state of contraction. We are the inhabitants of one such inflationary universe. As long as our awareness remains permanently confined within the localized boundaries of thought, speech and action, this will be the extent of the reality we know. If, through proper education, our comprehension is expanded to include the wave function of the universe, we become identified with a much greater wholeness in which time and evolution cease, and the eternal, Lorentz-invariant reality becomes the dominant perception.

This is the knowledge and experience provided by Maharishi Vedic Science. The localization of the awareness within boundaries becomes a matter of conscious choice—a shift of the attention from infinity to a point. There is no harm in experiencing the

*This view has also been expressed recently by J.S. Bell. [31]

point—of enjoying isolated possibilities in the field of all possibilities—provided the experience of the whole is maintained. In this highly flexible state of awareness, in which the parts are enjoyed while the whole is maintained, there is no collapse and no associated loss of wholeness. It is the loss of wholeness, not the enjoyment of the parts, which is known as *pragya-aparadh*. It makes one a captive of one's isolated experiences and a victim of circumstances in the endless field of change. The capacity for localized experience through the machinery of the nervous system is a precious gift, provided such experience is not at the expense of the understanding and experience of the unbounded wholeness which is the true nature of the self. The juxtaposition of dynamism and silence, of change and nonchange, within the integrated structure of human experience, is the natural state of life in enlightenment [9]. Silence without dynamism, or *atman* without *buddhi*, is existence without intelligence—flat and inert. Dynamism without silence, or *buddhi* without *atman*, is intelligence with no stable existence, localized and unstable. Both, together, constitute the true nature of consciousness—eternally existing, eternally creating.

The availability of this integrated structure of knowledge and experience will have a profound impact on quantum measurement and quantum cosmology, for which a consistent interpretation has not been available within the fragmented structure of ordinary waking experience.

VI. Unified Field Based Civilization

In this article, we have presented a new understanding and language of physics based directly on the unified field. We have based this analysis on the most recent developments in our understanding of the unified field provided by the superstring and on the very complete understanding and experience of the unified field provided by Maharishi Vedic Science and its applied experiential technologies. Our analysis began with a consideration of the unified field itself, viewed from its own level and in terms of its own intrinsic properties and behavior. In Section IV, we extended this analysis to include a systematic investigation of its fundamental modes—the elementary particles and forces of nature. Using the latest, four-dimensional string formulation, we explicitly identified all known particles and forces with specific vibrational states of the field. We proposed a new, unified field-based language and terminology in which the particles are named for the specific vibrational states they correspond to: periodic, antiperiodic, etc., revealing their rightful place in the internal structure and dynamics of the unified field. By connecting all aspects of physics to their unified source in the unified field, the whole of physics can be clearly seen in terms of its sequential unfoldment from the unified field, providing a natural logic and organization to the entire discipline.

Although the labeling of these string modes was somewhat cumbersome in the framework provided by the free-fermionic string formulation, we found that Maharishi Vedic Science provides a very natural and compact system of nomenclature in which every expression of the unified field is named with the actual sound or vibration of the field which that object corresponds to. These Vedic names also provide a powerful research methodology when applied, via the TM-Sidhi program, at the appropriate,

unified level of awareness where the correspondence between name and form is lively. The experiential technologies of Vedic Science thereby provide knowledge through direct experience of the most fundamental mechanics of nature's functioning.

Many physicists will, at first, view the use of a subjective methodology and approach to knowledge with skepticism. This is because, historically, there has been no stable, reliable basis for subjective knowledge. However the shift away from the purely objective methodologies of elementary particle physics to incorporate more subjective approaches is inevitable. Already particle theorists are forced to rely increasingly on their analytic and intuitive abilities as the principal focus of theoretical physics has shifted to the experimentally inaccessible domains of grand unification and super-unification. According to some well-placed estimates, the practical life span of conceivable accelerator technologies is at most one or two decades.

The historical basis for rejecting a subjective approach is that there has been no stable foundation to conscious experience that could serve as a basis for reliable knowledge. However the rediscovery, through Vedic Science, of a stable ground state of consciousness which is non-variable and completely universal provides a common, stable basis for subjective experience. Knowledge gained on this basis has been found to be reliable, repeatable, and open to verification at any time by anyone with appropriate training in the relevant experiential procedures [32,33]. The rediscovery of this stable foundation to conscious experience thereby eliminates the historical grounds for rejecting a subjective approach to knowledge. During the past twenty years, a large body of published scientific evidence has grown to support the efficacy and effectiveness of this subjective approach [12-14,22,24-29,A1-A15]. To continue to resist this approach in the face of this evidence simply because it stretches the prevailing world-view must be regarded as highly unscientific.

Science is meant to be beneficial to life. Every step of progress in our scientific understanding of natural law has found its practical application in a corresponding level of technology: chemical, electronic, nuclear, etc. These practical technologies have brought great comfort and convenience to many areas of life in society. However, the technological application of specific, isolated laws of nature based on a partial and fragmented understanding of natural law has resulted in psychological, sociological, and ecological imbalance, and has even threatened mankind with annihilation. The continued progress of society now demands the practical utilization of a level of nature's functioning which is at once more powerful and more holistic—a technology based on the total potential of natural law available in the unified field. The practical application of this most fundamental and profound knowledge of natural law has already demonstrated its capacity to create a quality of life [22,24-29] and civilization [A1-A15] which was not possible based upon prior levels of scientific knowledge.

Through the knowledge and technologies of Maharishi Vedic Science, every aspect of life becomes profoundly unified field-based: the mind, body and behavior remain profoundly connected to their unified source in the unified field of pure, self-interacting consciousness. With the elimination of *pragya-aparadh*, the physiological and neuro-physiological functioning becomes integrated and balanced [24]. The immune system and other homeostatic mechanisms become spontaneously capable of resisting any

physiological imbalance or disorder, creating a natural state of health and well-being [22]. In contrast, modern medicine, which relies on increasingly exotic and expensive cures, has led to a crisis in health care, with spiraling medical expenditures in the U.S. of over \$500 billion annually, of which an estimated \$125 billion is wasted on unproven and/or ineffective treatments [34]. Many of these expensive and highly intrusive treatments, such as coronary bypass surgery, have no statistical effect on the future history of the disease [35]. In addition, the poisonous side effects of allopathic drugs are often more dangerous and far-reaching than the diseases they are intended to cure [36]. The widespread use of some of these medicines, such as antibiotics, has led to the emergence of a whole new generation of drug-resistant diseases, which thrive in highly sanitized hospital environments. Up to 36% of hospitalized patients contract iatrogenic diseases (diseases caused by the side effects of modern medicine), which have been shown to contribute to many more deaths than AIDS and other diseases at the forefront of public concern [37]. Maharishi Ayur-Ved, which is based primarily on prevention and, when necessary, natural and effective cures that are completely free of negative side effects [22], provides a more humane and effective health care system, which is also affordable for the many countries for which allopathic medicine is completely inaccessible.

In the field of education, Maharishi Vedic Science has given birth to a highly innovative, integrated, and successful approach in which every aspect of every discipline is profoundly linked to its unified source in the unified field. All academic disciplines have their ultimate origin in the dynamics of human consciousness, and the systematic understanding of the dynamics of intelligence provided by Vedic Science thereby provides a natural and much-needed interdisciplinary foundation for education [38]. Through the introduction of unified field charts described in Section I, every aspect of each academic discipline is clearly located within the structure of the whole discipline, and the entire discipline is shown sequentially emerging from its unified source in the unified field—i.e., the pure consciousness of the artist, the pure intelligence of the mathematician, or the heterotic superstring in the language of physics. This method of presentation achieves its full significance with the introduction of the Transcendental Meditation and TM-Sidhi programs, in which all streams of knowledge are directly experienced as modes of one's own consciousness. In this way, as students gain knowledge of the different disciplines, they automatically awaken more and more to the reality of the creative potential of their own intelligence, realizing that all fields of knowledge are just different expressions of their own intelligence [38]. In addition, while the students are gaining intellectual knowledge of the laws of nature they are simultaneously growing in the ability to act spontaneously in accordance with the laws of nature: i.e., to not make mistakes that create the ground for problems and suffering in their own lives or in the life of society. This quality of spontaneous right action [8] is the automatic result of a properly functioning brain physiology, in which the unified field of all the laws of nature is fully lively in the conscious awareness [28]. This integrated system of education, which combines intellectual understanding of natural law with the direct experience of the most fundamental dynamics of natural law in consciousness, has been shown to develop the intelligence [26] and creativity [27] of the student, whereas conventional education has no impact on basic tests of intelligence or creativity.

In the field of behavior, Maharishi explains [8,9] that the development through Vedic Science of a completely unified and universal state of awareness spontaneously results in a quality of activity which is nourishing and life-supporting for the whole environment. When, through the elimination of *pragya-aparadh*, "all beings are seen in the Self and the Self in all beings," one behaves towards oneself and one's environment in a completely harmonious and evolutionary way. Short-sighted and harmful behavior towards others or one's environment is highly unnatural in that expanded state of comprehension. In a sociological setting, extensive research has shown that the collective practice of the advanced TM-Sidhi program produces an influence of harmony and coherence that extends to society as a whole [A1-A15]. These extended, field effects of consciousness, known as the *Maharishi Effect*, have been shown to reduce crime, violence, hostility, and war in recalcitrant areas where political and negotiated settlements have historically demonstrated their inability to do so.* These effects result from collective functioning at more fundamental and universal levels of awareness, and thus far provide the most spectacular experimental confirmation of the fundamental identity between pure consciousness and the unified field, and of the knowledge and applied technologies of Maharishi Vedic Science.

It is a fortunate fact that the utilization of natural law is often easier than the intellectual understanding of natural law. The profound practical benefits to the individual and society of the knowledge and technologies of Vedic Science are not gained on the basis of intellectual understanding. It is the direct experience of more unified and holistic levels of natural law in consciousness which produces the desired physiological, psychological and sociological changes. These practical benefits arise long before a detailed intellectual understanding of the structure and dynamics of the unified field is gained through such experience. Very quickly, the brain physiology becomes accustomed to maintaining pure consciousness, and a more integrated and balanced state of neurophysiological functioning is permanently sustained [24]. The restoration of physiological balance and efficiency, improved health and resistance to disease, and harmonious and life-supporting social behavior are the spontaneous results of this direct experience and its associated physiological correlates [24-29].

Thus, the intellectual understanding of natural law is quite distinct from the spontaneous utilization of natural law in daily living. In particular, the former is not a prerequisite for the latter. In the spontaneous mechanics of desiring, for example, a simple mental impulse automatically activates dozens, if not hundreds, of laws of nature. Through the desire to open a window, for example, the muscles move and the body rises and walks toward the window, guided by the sense of sight and touch. Even a child with no intellectual understanding of the laws of nature knows how to rise and move through this simple and spontaneous mechanics of desiring. This natural ability to utilize natural law spontaneously is built into the hardware of the human brain physiology. The thinking process has therefore been compared to an automated switchboard, spontaneously activating and organizing the laws of nature in a coordinated way for the fulfillment of any specific desire.

Maharishi explains that the range of natural law which is spontaneously utilized by

* See Appendix A on field effects of consciousness.

the mind depends on the natural range of one's comprehension—the degree of alertness at more fundamental levels of nature's functioning [8]. Desiring from the transcendental level, the level of the unified field, spontaneously makes use of the entire range of natural law [9]. During the TM-Sidhi program, for example, an impulse of thought projected from the unified field of pure, self-interacting consciousness mobilizes the total potential of natural law, accomplishing the desired result with maximum efficiency and the least expenditure of energy [4]. When individual awareness functions from the same, unified and holistic level from which nature conducts the evolution of the entire universe, the fulfillment of desire becomes a spontaneous and inevitable phenomenon [9]. This spontaneous ability to use natural law in a coordinated manner is already programmed into the hardware of the human brain physiology. Its utilization simply depends on the range of natural law that is lively in the awareness.

The spontaneous use of natural law to enrich all aspects of life in society is therefore easier, as well as more important, than intellectual understanding of natural law. It is not, after all, the intellectual understanding of natural law that makes natural law a living reality in daily life. It is the expansion of the conscious awareness to incorporate more profound and unified levels of natural law by taking the awareness repeatedly to more fundamental and universal levels of consciousness that makes natural law a living reality. There will continue to evolve innumerable theories of natural law and the unified field put forth by all the academic disciplines as they gain an understanding and appreciation of their unified source in the unified field, which forms the ultimate origin and foundation of every discipline. Even within the discipline of physics, there will be many different formulations of the unified field, e.g., vibrating strings in 26, 10 or fewer spacetime dimensions, $1 + 1$ dimensional conformal field theories, piadic numbers, etc. All of these different viewpoints are correct, and merely provide different, complementary viewpoints of the same, basic underlying reality. There is no harm in this intellectual inquiry, provided it does not preclude the direct utilization and practical application of the unified field now, while the fully developed, applied technologies of the unified field are available through Maharishi Vedic Science. Without this simple, practical technology to utilize the unified field spontaneously on the level of one's conscious awareness, this most complete and profound knowledge of natural law would remain divorced from practical life and living, and even the scientists would remain intellectual witnesses to the reality of the unified field. It is this spontaneous and direct utilization of the unified field to enrich all aspects of life which will make civilization unified field-based.

This spontaneous and direct practical application of the unified field to enrich all aspects of life contrasts with the previous application, through technology, of specific, isolated laws of nature based on the intellectual understanding of those laws. It was this scientific understanding of specific laws of nature and their technological application which laid the foundation for the industrial revolution, in which more and more rapid development became possible through the use of increasingly sophisticated machines and technologies. The industrial revolution has, however, led to a highly machine-dependent civilization, to a degree that has robbed life of some of its natural self-sufficiency and dignity. In contrast, the very complete science and practical technologies of the unified field made possible through the subjective approach of Maharishi

Vedic Science allows the spontaneous utilization of the total potential of natural law to enrich all aspects of life in a completely balanced and holistic way, and provides the means to accomplish anything through the simple and spontaneous mechanics of desiring [7,8]. This supreme level of fulfillment and self-sufficiency based on the spontaneous utilization of the total potential of natural law, as opposed to the technological application of specific, isolated laws of nature, lays the foundation for a post-industrial revolution to a unified field-based civilization—a civilization based on the complete knowledge and practical application of the unified field of all the laws of nature. The practical applications of this complete science and technology of the unified field to health [22], education [26-29], rehabilitation [39] and world peace [A1-A15] have already demonstrated their capacity to produce a quality of life and civilization which is far beyond that which is attainable through the objective approach of modern science alone. To resist such an approach due to its subjective methodology is therefore not only unscientific, but inhumane.

Fortunately, the empirical approach of modern science is well equipped to distinguish between fact and fancy, and to evaluate objectively the effectiveness of any approach through its own empirical means of investigation. One is therefore optimistic that, in time, more and more scientists will be drawn to investigate this subjective approach of Vedic Science and the profound knowledge and practical technologies it provides. With the complete knowledge of the unified field and its self-interacting dynamics provided by Maharishi Vedic Science, modern physics will achieve a level of fulfillment that is unattainable through its present, limited objective methodologies. In the process it will raise the quality of life in society to a level of dignity and supreme fulfillment that is unparalleled in the annals of recorded history—a unified field-based civilization enjoying Heaven on Earth.

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Appendix A: Field Effects of Consciousness

At present, the most striking empirical evidence in support of a unified field-theoretic description of consciousness is the Maharishi Effect, which refers to extended field effects of consciousness produced by the collective practice of the TM-Sidhi program. Over thirty consecutive studies provide powerful evidence that the group practice of the TM-Sidhi program by as few as the square root of one percent of a population can reduce

political violence, crime, and other manifestations of societal incoherence. These studies employ standard sociological measures to assess the influence of groups of experts collectively practicing the TM-Sidhi program on a surrounding population.

Historical Development

In 1960, Maharishi predicted that one percent of a population practicing the TM technique would produce measurable improvements in the quality of life for the whole population. The first study designed to test this prediction [A1] analyzed crime rate change in 22 U.S. cities (population > 25,000) from 1972-1973. Crime rates decreased in the 11 cities with one percent of the population practicing the TM technique, while crime rates in the matched control cities continued to rise. A more extensive study [A2] analyzed crime rate trends in 48 U.S. cities (population > 10,000) over the eleven-year period from 1967-1977. This included all independent cities in this population range with one percent of the population instructed in the TM program. Crime rates decreased significantly in the 24 "one percent" cities compared with their own previous trends and compared with 24 matched control cities over the same period. Subsequent replications have analyzed crime rate trends in 160 cities and 80 metropolitan areas in the U.S. using increasingly powerful design and analysis techniques [A2], and have further demonstrated Maharishi's prediction that participation in the TM program would lead to a reduction in crime rate trends.

With the introduction of the more advanced TM-Sidhi program in 1976, Maharishi anticipated a more powerful influence of coherence in the collective consciousness of society. He subsequently predicted that the group practice of the TM-Sidhi program by as few as the square root of one percent of a population would have a demonstrable effect on standard sociological measures.*

The relatively small number of participants practicing the TM-Sidhi program predicted to generate this effect of societal coherence has made it possible for many direct experimental studies to be performed, in which the necessary number of participants come together on courses in various locations for periods of time ranging from one week to several months. Most of these studies, including research at the metropolitan, state, national and international scales, have used time series analysis to reliably estimate experimental effects independent of cycles and trends in time series data. This type of research design, called an experimental intervention study, constitutes a unique and rigorous approach for the social sciences.

Time Series Analysis

The effects of the TM and TM-Sidhi programs on quality of life indices are usually assessed with time series analysis using the autoregressive integrated moving average (ARIMA) approach of Box and Jenkins [A3]. (A time series is a sequence of equally-spaced measures on some variable, e.g., monthly crime rate.) This methodology has become the standard for rigorously estimating the effects of an outside intervention on a time series or for empirically determining the form of causal relationship between two

* This prediction is based on a field-theoretic model which assumes a coherent superposition of amplitudes, such that the intensity of the effect generated is proportional to the square of the number of participants.

continuous time series [A4]. Time series "intervention analysis" is used to assess effects of hypothesized influences during specific time periods (e.g., when the number of TM-Sidhi participants exceeds a certain critical threshold). Time series "transfer function analysis" is used to model the input-output relationship between a continuous independent exogenous variable (e.g., the daily number of TM-Sidhi participants) and the dependent or endogenous variable (a social indicator such as crime rate).

With both methods, the time series approach controls for any serial dependence of observations, trends, or seasonal cycles in the data over time by including these influences in a "noise model" of the series [A4]. That is, as part of the time series analysis a mathematical model of the time-dependent regularities in the endogenous series is constructed, and this model will account for, and therefore control for, patterns in the endogenous time series that can be predicted from its own past history. The noise model thus serves essentially as a "null hypothesis" for effects of the exogenous variable.* Any intervention effects or transfer function effects on the endogenous variable indicate effects of the independent variable that cannot be predicted either from the previous history of the series or from any unmeasured continuous variables that may be partially determining the endogenous variable. These time series methods have proven to be ideal for assessing the effects of the group practice of the TM-Sidhi program upon sociological indicators.

Recent Intervention Studies

Within the past few years, there have been an increasing number of experimental studies using time series intervention and transfer function analysis to assess the effects of the group practice of the TM-Sidhi program at the metropolitan, state, national and international scales.

At the metropolitan and state levels, time series intervention studies found reduced crime in Metro Manila, Philippines, in New Delhi, India, and in Puerto Rico during periods in which large groups had assembled for conferences involving twice daily practice of the TM-Sidhi program [A5]. Time series transfer function analysis similarly found a reduction in violent crime in Washington, D.C., in weeks following an increase in the size of a permanent group of TM-Sidhi participants [A6]. Other intervention studies in Metro Manila and in Rhode Island found improvements in holistic indices of the quality

* The noise model N_t has the form $N_t = [\theta(B)/\phi(B)]a_t$, where $\phi(B)$ and $\theta(B)$ specify autoregressive and moving average parameters, respectively, at various time lags, and where a_t is a series of independent and normally distributed random disturbances. The term (B) indicates a backshift operator that is used to model lagged influences in a time series. The noise model effectively removes the serial dependence of the data by modeling it, and the residuals to the noise model (a_t) form independent data points.

Transfer function analysis models the endogenous time series Y_t as $Y_t = C + V(B)X_t + N_t$, where X_t is the continuous exogenous series, $V(B)$ is the transfer function connecting the two series, C is a possible constant, and N_t is the stochastic noise model that specifies the combined nonrandom (time-dependent) influences other than the exogenous series [A3]. Intervention analysis employs an identical model, except that the exogenous variable is a binary intervention series I_t , specifying the time periods during which an intervention occurred.

The transfer function or intervention effect $V(B)$ is approximated by $\Omega(B)/\delta(B)$, where $\Omega(B)$ contains parameters indicating the time delay of influence of the exogenous variable and the magnitude of its effect at various time lags, and where $\delta(B)$ contains parameters specifying the rate at which this influence decays (for an abrupt temporary effect) or grows (for a gradual permanent effect) [A3]. The time series methodology can thus be used to model both linear and nonlinear influences of one series on another.

of life composed of available monthly social indicators during periods of assemblies of large groups of TM-Sidhi participants [A5].

The most well-documented analyses at the national level have been in the U.S., where a permanent large group of participants in the TM-Sidhi program has been established at Maharishi International University (MIU). The size of this group has exceeded the square root of one percent of the U.S. population on a regular basis since 1982. An analysis of annual changes in a quality of life index comprising 11 major variables showed a significant improvement correlated with the size of the group of TM-Sidhi participants [A7]. More detailed analyses of the U.S. quality of life using time series intervention and transfer function analysis during 1979-1985 found reduced weekly fatalities due to violence (homicides, suicides, and motor vehicle accidents) on weeks immediately after the size of the MIU TM-Sidhi group exceeded the square root of one percent of the U.S. population [A8]. This analysis showed that two-thirds of the observed decrease in U.S. violent fatalities from 1979 to 1985 could be directly attributed to the group practice of the TM-Sidhi program. Reduced violent deaths were also found in Canada when the size of the MIU group exceeded the square root of one percent of the combined populations of the U.S. and Canada [A9]. In addition, time series intervention analysis of monthly U.S. and Canadian economic trends (a "misery" index combining inflation and unemployment) showed improved economic conditions in months immediately after the number of participants exceeded the required number (1600) for the population of the U.S. and Canada [A10].

There have been three assemblies in which the number of TM-Sidhi participants approached or exceeded the square root of one percent of the world's population—about 7000 individuals. During each of these assemblies, there was a significant reduction of international conflict, as indicated by time series intervention analysis of news events [A11]. The time series of news events was created from content analysis (rating of news items) of major newspapers by raters who were unaware of the dates of the news items being rated. Time series analysis also indicated a significant reduction in fatalities and injuries due to terrorism during and immediately after the period of these assemblies; data on terrorism was collected by an independent agency [A11].

Reduction of Violence in the Middle East through the Maharishi Effect

One especially critical experimental test of the hypothesis that the group practice of the TM-Sidhi program by the square root of one percent of a population would positively affect sociological measures was conducted in Israel in August and September of 1983 [A12]. Based on the results of previous experiments, the research hypotheses and the specific measures to be used in the study were lodged in advance of the experiment with an independent review board of scientists in the U.S. and Israel.

It was predicted that group practice of the TM-Sidhi program in Jerusalem would reduce stress in the collective consciousness of Israel and Lebanon. Box-Jenkins ARIMA intervention, cross correlation, and transfer function analyses were used to study the effects of changes in the size of the group on several variables and composite indices reflecting the quality of life in Jerusalem and Israel, and also the war in Lebanon.

Figure 5 shows a striking covariation between the size of the group of TM-Sidhi participants (dotted line) and a composite index of quality of life that was the arithmetic

Maharishi Effect: Reduced Conflict in Lebanon and Improved Quality of Life in Israel

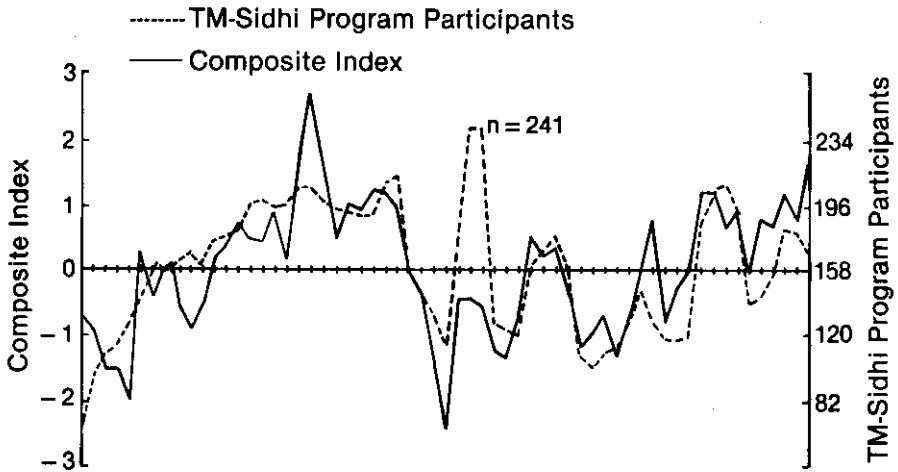


Figure 5. This figure illustrates the covariation between the number of TM-Sidhi participants (dashes) and a composite index of quality of life in a study conducted in Israel during August and September of 1983. The composite index was the arithmetic average of standardized scores for crime rate, traffic accidents, fires, stock market, national mood, and the number of war deaths as a measure of war intensity in Lebanon. The sociological parameters employed in this study were lodged in advance of the experiment with an independent review board of scientists in the United States and Israel. (Figure courtesy of D. Orme-Johnson.)

average of standardized scores for crime rate, traffic accidents, fires, stock market, national mood, and the number of war deaths as a measure of war intensity in Lebanon.

Increases in the size of the group had a statistically significant effect on the individual variables and on the composite quality-of-life index. Cross correlations and transfer functions indicated that the group had a leading relationship to change on the quality-of-life indicators, supporting a causal interpretation. There was a 34% reduction in war intensity and a 76% reduction in war deaths during periods of high numbers of TM-Sidhi participants. Time series analysis demonstrated that the effect could not be attributed to seasonality (such as weekend effects or holidays) or to changes in temperature.

The hypothesis that the influence occurs on a fundamental and holistic level of nature is supported by the fact that the arithmetic average of the different measures produced the clearest results and by the observation that the different sociological measures tended to change independently of each other when the group size was small, but all changed coherently in a positive direction as the group size was increased.

A subsequent study (Figure 6) assessed the impact on the Lebanon war of three successive assemblies in which large groups practiced the TM-Sidhi program during a six-month period from November 13, 1983 to May 18, 1984 [A13]. The assemblies were

Maharishi Effect: Progress Towards Peace in Lebanon

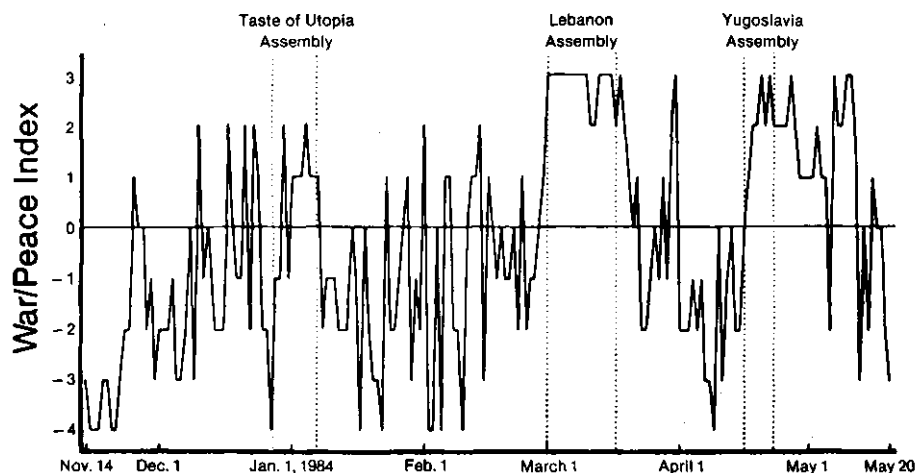


Figure 6. During the six-month period from November 13, 1983 to May 18, 1984 a measure of war intensity in Lebanon was most positive during three assemblies in which the number of TM-Sidhi participants exceeded the predicted thresholds required for an influence on the war. Time series analysis indicates significantly greater progress towards peaceful resolution of the conflict during these assemblies than would have been predicted from the prior history of the Lebanon war ($p < .00005$). The particularly large effect coincident with the Lebanon assembly held in the immediate vicinity of the conflict suggests the importance of proximity in the generation of societal coherence. (Figure courtesy of C.N. Alexander.)

held in the United States, Lebanon and Yugoslavia, and were approximately two weeks long.

The authors used a time series intervention analysis of the Lebanon war to compare levels of conflict during the days on which the assemblies occurred compared to the baseline period which consisted of all other days during the six-month period of the study. The level of the conflict was measured by three indices: daily levels of a Peace/War Index [A14] of events reported in major Lebanon newspapers, daily reported war deaths, and daily injuries due to the war. The scoring was performed by representatives of the different factions involved in the conflict, and inter-rater reliability was high.

As predicted in advance, the Peace/War Index showed that prevailing negative conditions were abruptly reversed, and greater progress towards peaceful resolution of the Lebanon conflict was observed than would have been expected based on the prior six-month history of the war ($p < .00005$). War deaths fell by 55%, from a mean of 6.5 per day during the baseline to a mean of 2.9 per day during the three assemblies ($p < .0005$). War injuries fell by 38%, from a mean of 20.6 per day during the baseline to a mean of 12.7 per day during the assemblies.

The study of the Lebanon conflict was subsequently expanded to include a daily time series intervention analysis of a 27-month period during which there were seven assemblies of TM-Sidhi participants of sufficient size to influence the Lebanon conflict according to the square root of one percent formula [A15]. These assemblies, which ranged from a small group in the central area of fighting within Lebanon, to larger groups in Israel, Yugoslavia and the Netherlands, to three groups of up to 7,800 in the U.S., are the only ones in the last decade of sufficient size in relation to their proximity to Lebanon to exceed the threshold for a predicted impact there. For each assembly lasting between one and eight weeks, improvements in quality of life (including reduction of political violence and progress toward peace) were predicted publicly and in advance for the surrounding population equal to $\sim 100 n^2$, where n is the number collectively practicing the TM-Sidhi program. For a total of 93 days, or 11.33% of the period of the study, this population included all or most of Lebanon, or at least the primary region of conflict within Lebanon.

The 821-day data base, which included daily levels of cooperation and conflict and the number of reported war fatalities and injuries, was generated using independently developed 16-point scales of cooperation and conflict [A16]. Events were coded by an experienced Lebanese coder, blind to the experimental hypotheses and unaware of the assemblies and the technology employed, from eight international news sources, including the *New York Times*, and news broadcasts from radio stations in and near Lebanon representing all major parties to the conflict, as reported by the *Foreign Broadcast Information Service*.

Box-Jenkins intervention analyses indicated (Figure 7) that in contrast to nonexperimental days, during the 93 days when assemblies were sufficiently large for a predicted impact in Lebanon there was an estimated:

- a) 66% mean increase in level of cooperation among antagonists ($t = 4.96$, $p = 4 \times 10^{-7}$);
- b) 48% reduction in level of conflict ($t = -5.81$, $p = 3 \times 10^{-9}$);
- c) 71% reduction in war fatalities ($t = -6.45$, $p = 1 \times 10^{-10}$); and
- d) 68% reduction in war injuries ($t = -4.91$, $p = 5 \times 10^{-7}$).

A composite Peace/War Index combining these variables indicated (Figure 8) that the seven assemblies each had independently significant positive effects on the war ($t = 9.03$, $p = 9 \times 10^{-20}$).

The study employs an interrupted time-series design with multiple replications, which offers a "very powerful" basis for addressing the issue of causality [A17]. Changes in temperature or holidays did not account for any of the improvements during each assembly. The mean temperature on experimental days (which were spread across all four seasons) was slightly higher than on other days, yet despite an overall tendency for higher levels of violence to occur on hotter days, violence still diminished sharply on experimental days. The possible impact of religious and national holidays was separately assessed, and in the one case where these had a significant impact on the war (cooperation was higher on Moslem holidays) this was also included as part of the null model when assessing the impact of the assemblies.

* The value of $|t|$ coincides approximately with the number of standard deviations when the number of degrees of freedom is ≥ 30 as in the case of the present study.

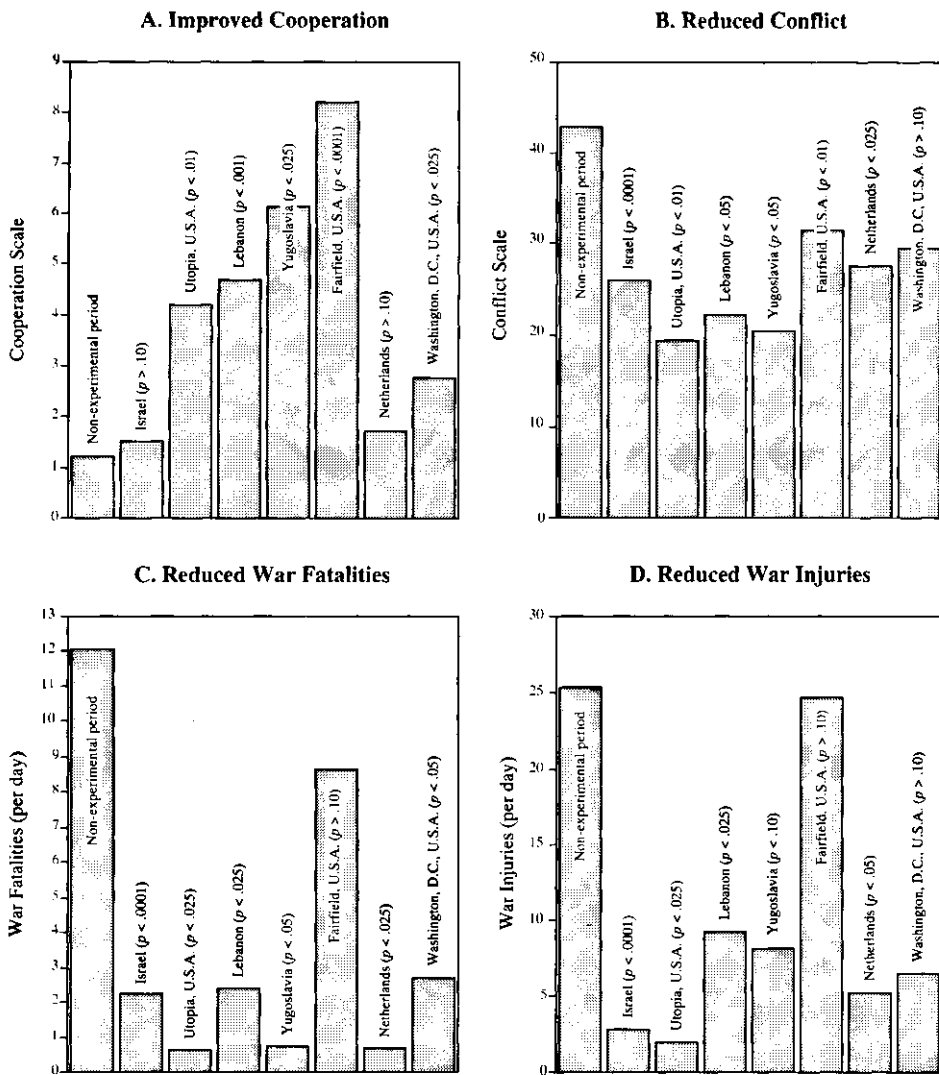


Figure 7. Mean daily level of cooperation (A), levels of conflict (B), number of war fatalities (C), and number of war injuries (D) in the Lebanon War during the non-experimental and each of seven experimental periods from June 1983 to August 1985. Time series intervention analysis indicates: (A) significant improvements in the level of cooperation during five of the experimental periods, and during all seven combined ($p = 4 \times 10^{-7}$); (B) significant reductions in the level of conflict during six of the experimental periods, and during all seven combined ($p = 3 \times 10^{-9}$); (C) significant reductions in the number of war fatalities during six of the experimental periods, and during all seven combined ($p = 1 \times 10^{-10}$); (D) significant reductions in the number of war injuries during four of the experimental periods, and during all seven combined ($p = 5 \times 10^{-7}$). (Figures courtesy of J. Davies.)

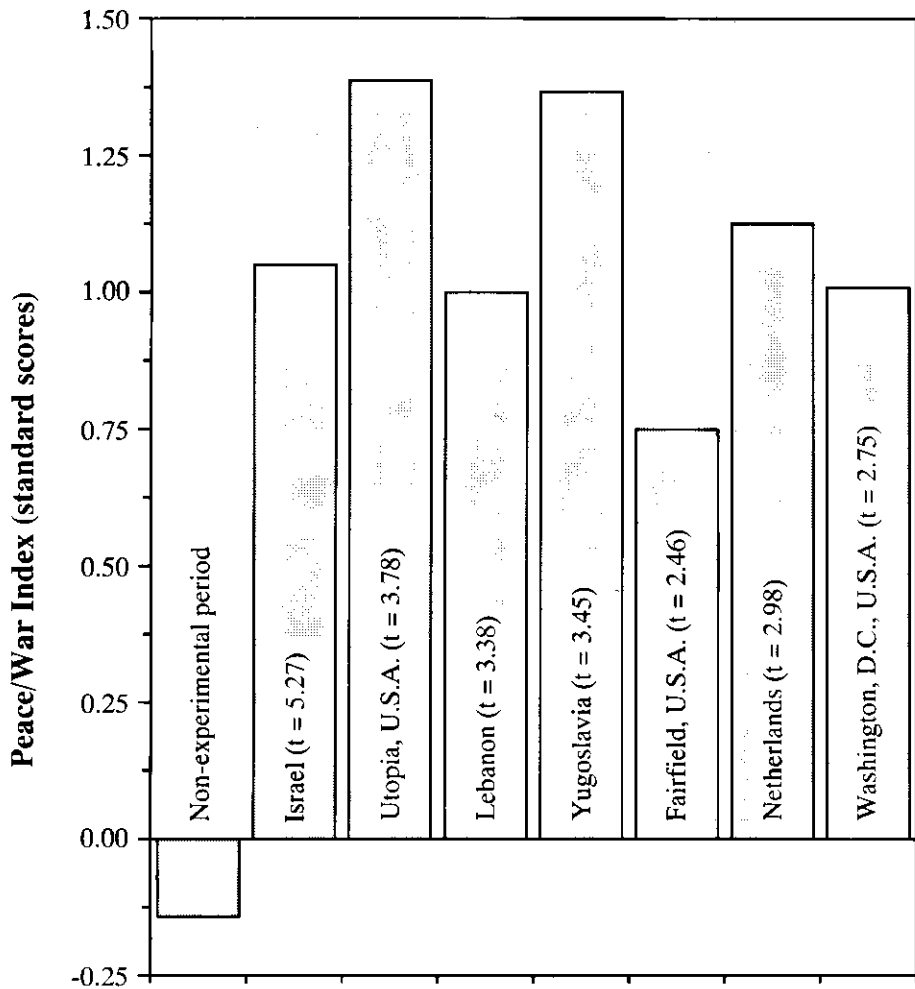


Figure 8. Estimated mean daily level of a composite Peace/War Index for the Lebanon War for each of seven experimental periods between June 1983 and August 1985. Time series intervention analysis indicates significant progress towards peace during each experimental period, and for all seven combined ($p = 9 \times 10^{-20}$). (Figure courtesy of J.Davies.)

The possibility that improvements were due to the assemblies being initiated in response to worsening conditions in the war, and thus being held when the conflict was improving anyway (through regression toward the mean), may be discounted for several reasons. First, all assemblies except that in Lebanon were announced several weeks or months in advance, and dates set without reference to the situation in Lebanon, which was no more a concern than other trouble spots within the range of impact of each assembly. Second, the statistical independence of the occurrence of the assemblies from

patterns of behavior in the war (dependent series) in the weeks and days immediately preceding and following the assemblies was explicitly tested and confirmed. Finally, it is clear from the results that the observed impact on each variable represents improvement substantially away from the mean, not regression toward it. For the same reasons, the improvements could not be due to convening assemblies at the first sign of improvement in the war. Also, positive changes were found to occur with zero time-delay, from the first day of each experimental period: that is, the periods began before the improved events could be reported in the press, and ended before renewed violence could be reported.

The design of the experiment also precluded explanation in terms of coincidence, *post hoc* selection of data, or measurement artifact. Coincidence may be ruled out on the basis of extremely low probability values (9×10^{-20} on the Peace/War Index), and the high level of consistency across all indices and replications (assemblies). *Post hoc* selection of assemblies, variables or data sources was precluded through announcement to the media (and in some cases to independent review boards) of dates and predicted effects prior to each assembly (again excepting that held in Lebanon). Any possibility of measurement artifact or bias was severely limited through use of independently developed scales, multiple news sources representing all parties, and a highly experienced coder, familiar with the political and cultural context of the war, but blind as to the nature of the hypotheses, the independent variable, and the theory and technology on which the hypotheses were based.

Explanation of observed improvements as a consequence of publicity or other behavioral interactions between assembly organizers or participants and the people fighting in Lebanon can also be excluded. Only in the Lebanon assembly was there any possibility of direct personal interaction, and that was minimized in that participants and organizers remained isolated in their facility in a small village except for such activities as purchase of food and travel when first joining or leaving the assembly. In no case did the media in Lebanon carry any prior or concurrent news items concerning any of the assemblies, nor was there any attempt during any assembly to create any expectation of change, or otherwise influence the behavior of parties to the conflict other than through practice of the TM and TM-Sidhi program (which involves an inward focus of attention, to maximize coherence and normalize stress principally for the purpose of personal development).

These findings strongly support the hypothesis that societal coherence can be enhanced, and even protracted violence alleviated, across any population size as a spontaneous and non-intrusive field effect generated by the group practice of the TM-Sidhi program.

Interpretation

Besides their obvious practical implications for eliminating war and improving the quality of life in society, these research findings clearly have profound implications concerning our understanding of consciousness and its relation to the physical world. Indeed, they appear to invalidate completely the prevailing psychological and

sociological paradigm. In such circumstances, it is vital that leading physicists, psychologists and other scholars carefully assess the impact of these findings on our understanding of the natural universe. One such analysis is presented in ref. [11], where it is argued that these results are consistent with the current framework of unified quantum field theories, but require an expanded physical framework for our understanding of consciousness. For completeness, we will briefly review the main elements of that analysis here.

Although it would be more accurate to say that the Maharishi Effect data constitutes evidence for an "action at a distance" with respect to consciousness rather than a "field effect" *per se*, physics has historically come to associate action at a distance with field phenomena. The observed attenuation of the effect with distance (i.e., the fact that a relatively small group in Lebanon produced an effect comparable to a group of over 7000 halfway around the globe) would support such a field-theoretic interpretation. The quadratic dependence of the intensity of the effect upon the size of the coherence-creating group is also characteristic of a field phenomenon in which the radiators are operating coherently. More specifically, the coherent superposition of amplitudes required to produce such an intense constructive interference suggests the behavior of a bose field.

However, there are certain features of the Maharishi Effect that are not easily understood on the basis of a conventional field. The main difficulty with a simple field-theoretic model is in understanding the observed data on the basis of any of the known fields. The only known candidates for such long-range interactions are electromagnetism and gravity. Any conventional gravitational interaction between individuals is presumably orders of magnitude too weak.* Moreover, it is generally agreed that the electromagnetic interaction between individuals would also be too weak to give rise to any significant effects. This conclusion is probably reasonable despite new evidence that the physiology may be sensitive to environmental AC electric fields six to seven orders of magnitude weaker than had been previously considered possible [A18]. In fact, the brain appears to be particularly sensitive to EEG-modulated microwave radiation in the 0.5-10 gigahertz range, offering a potential mechanism for EEG communication and entrainment. It has been shown by Tourenne [A19] that certain cellular structures within the cortex that support the propagation of electromagnetic solitons could provide highly efficient radiators of microwave radiation, which would presumably be modulated in the EEG band.

While we therefore feel it is essential to pursue possible electromagnetic mechanisms for the Maharishi Effect, these mechanisms at present appear unable to account for the observed phenomenology. (Moreover, there was no evidence of attenuation in an instance where the coherence creating group was electromagnetically shielded by a metallic enclosure [A11].)

* This also holds true for possible spin-1 forces that interact with gravitational strength, such as a proposed "fifth force" or the gauge bosons associated with a hidden sector. (The latter would probably operate only at short distances anyway due to confinement effects.) The same is presumably true of other weakly-interacting bosons that have escaped detection in particle physics experiments.

If conventional mechanisms are unable to account for the observed data, then some unconventional mechanism involving new physics is obviously needed. Since there are no other long-range forces of electromagnetic or comparable strength, one is led to consider alternative theoretical frameworks that could serve to bridge the substantial distance factors involved. One such framework is suggested by the structure of spacetime geometry at the scale of super-unification—the proposed domain of pure consciousness.

Although we do not currently possess the calculational tools needed to unfold the full dynamics of quantum gravity, there are several indications that the local $3 + 1$ dimensional structure of classical spacetime geometry observed at energies far below the Planck scale may provide a totally inappropriate framework for physics at the scale of super-unification. In particular, topological effects in quantum gravity could lead to inherently non-local phenomena. For instance Ellis et al. [A20] have shown that worm holes may cause initially pure quantum states to evolve into mixed states. Such effects cannot be accommodated within a local framework, or even a framework that is approximately local on scales much larger than the Planck length, for this would necessarily lead to large and phenomenologically unacceptable violations of energy and momentum conservation [A21].

Moreover, these non-local effects have been derived in a perturbative context in which the non-local effects of gravity are expected to be relatively benign. The full, non-perturbative theory of quantum gravity can be expected to contain even more profoundly non-local effects. Indeed, there are strong indications that the Planck scale is associated with a fundamental phase transition in the dynamics of quantum gravity and/or the structure of spacetime geometry (e.g., a transition from four dimensions to ten dimensions). Such a phase transition would be expected to produce long-range correlations that could enhance the non-local structure of the theory. Hence the local structure of a relativistic field theory may provide a totally inappropriate framework for physics at the super-unified scale. Therefore, one might expect that if the domain of consciousness is fundamentally the super-unified scale, then phenomena of consciousness would include influences that are inherently non-local. The Maharishi Effect data can thus be viewed as evidence that individual consciousness can access the scale of super-unification, consistent with the proposed identity between pure consciousness and the unified field.

The question most often raised by physicists is how human consciousness could possibly interact with physics at such fundamental scales. This question stems from a recent but widespread understanding that consciousness is purely a product of complex biochemical and electrophysiological processes in the brain. Such a viewpoint may seem compatible with the restricted range of experience available in waking consciousness (in which consciousness itself is not directly perceived), but it is clearly incompatible with experience in higher states of consciousness. For example, in the state of pure consciousness, consciousness experiences itself as the unified source and fountainhead of all the laws of nature: all forms and phenomena in the universe are experienced to emerge from there, and can be generated at will through the application of the TM-Sidhi program. Hence according to the understanding and direct experience provided by Maharishi

Vedic Science, the natural range of human experience is from point to infinity: it extends from the localized boundaries of sensory experience, through subtler levels of thought and feeling, to the unbounded field of pure, self-interacting consciousness. Maharishi explains that the range of one's conscious influence is determined by one's range of comprehension—localized or unbounded, and that the Maharishi Effect is a direct result of collective functioning at more fundamental and universal levels of consciousness. The empirical research presented above provides a striking confirmation of this profound perspective, and of its immense practical value for the individual and society.

Appendix B: The Vacuum Wave Functional of a Scalar Field

One is always free to expand the vacuum state of a quantum field in a basis of classical shape states. Consider a free, hermitian, scalar field $\Phi(x,t)$. One can define eigenstates of the field operator with the property that

$$\Phi(x, t_0) |\phi, t_0\rangle = \phi(x) |\phi, t_0\rangle \quad (\text{B1})$$

where the eigenstates $|\phi, t_0\rangle$ correspond to definite shapes $\phi(x)$ of the Heisenberg field $\Phi(x,t)$ at some fixed time $t=t_0$. Since these classical shape states form a complete (continuum normalized) basis, one can expand the vacuum state $|0\rangle$ as a superposition of these states:

$$|0\rangle = \int [d\phi] \Omega[\phi] |\phi, t_0\rangle \quad (\text{B2})$$

By requiring that all particle lowering operators $a(k)$ annihilate the vacuum, it is easy to verify that the vacuum wave functional $\Omega[\phi]$ is given by

$$\Omega[\phi] = e^{-\frac{1}{4\pi} \int dx dy dk \phi(x) \phi(y) e^{ik \cdot (x-y)} \sqrt{k^2 + m^2}} \quad (\text{B3})$$

Because this vacuum wave functional $\Omega[\phi]$ is non-vanishing for all $\phi(x)$, we observe that the quantum vacuum actually corresponds to a superposition of all classical field shapes.

Appendix C: Deriving Flipped SU(5)xU(1) from String

Two essential ingredients in formulating a consistent string theory are conformal invariance and modular invariance. The former condition fixes the number of degrees of freedom on the world-sheet. It can be satisfied in any number of dimensions $d \leq 26$ (10 for a supersymmetric left- or right-moving sector) if the space time coordinates $X_\mu : \mu = 0, 1, \dots, d-1$ are supplemented by internal degrees of freedom contributing $26-d$ ($15-3d/2$) to the central charge of the Virasoro algebra. Modular invariance then imposes nontrivial constraints on the boundary conditions for these internal degrees of freedom which ensure that counting

errors are not made when higher-genus string topologies are summed. It is known that the number of solutions to these modular invariance conditions is restricted, particularly if the number of spacetime dimensions d is close to the critical number 26 (or 10). In particular, in $d=10$ there are only two modular invariant heterotic string theories with $N=1$ spacetime supersymmetry, based on the gauge groups $SO(32)$ and $E_8 \times E'_8$ [C1].

The choice of gauge group for string theories formulated directly in $d=4$ dimensions is much more extensive, and no systematic enumeration of models has yet emerged. The strategy followed here is to start from the bottom up, looking for models which contain phenomenologically favored ingredients such as the Standard Model or a plausible grand unified theory. Although it may be that the Standard Model can be derived directly from string without invoking any field-theoretic intermediate scale of gauge symmetry breaking, so far all phenomenological string models [1–3] have had four-dimensional groups larger than $SU(3) \times SU(2) \times U(1)$. We feel [3] that if one is to extend the Standard Model gauge group, it is both interesting and desirable to embed it in a grand unified theory (GUT), i.e., a simple non-Abelian group containing the $SU(3)$, $SU(2)$ and (maybe) $U(1)$ factors of the Standard Model. Such a framework combines the physical advantages of GUTs (e.g., slow baryon decay, cosmological baryosynthesis, small neutrino masses, etc.) with the well-known benefits of the string. However, there is an obstacle to such a program that we have emphasized previously [3]: in general, GUTs require higgs fields in adjoint representations to break the gauge symmetry down to the Standard Model, and these do not exist in string theories with $N=1$ supersymmetry and/or chiral fermions [C2, 18] that have level $K=1$ Kac-Moody algebras.

The only viable GUT that does not require adjoint higgses is Flipped $SU(5) \times U(1)$ [C3,3]. This model also possesses [C4] other advantages, such as natural higgs doublet-triplet splitting, a seesaw neutrino mass matrix, no problematic fermion mass relations, and no troublesome $d=5$ proton decay operators. The minimal Flipped $SU(5) \times U(1)$ model [3] contains $N_g=3$ generations of matter fields $F_i = (\underline{10}, 1/2)$, $\bar{F}_i = (\bar{\underline{5}}, -3/2)$, $l_i^c = (\underline{1}, 5/2)$; two pairs of chiral higgs fields $H = (\underline{10}, 1/2)$, $\bar{H} = (\bar{\underline{10}}, -1/2)$ and $h = (\underline{5}, -1)$, $\bar{h} = (\bar{\underline{5}}, 1)$ which respectively break $SU(5) \times U(1)$ down to $SU(3) \times SU(2) \times U(1)$ and $SU(3) \times SU(2) \times U(1)$ down to $SU(3)_c \times U(1)_{em}$; and four $SU(5) \times U(1)$ singlets $\phi_{0,i}$. The superpotential of the model is [3]

$$\begin{aligned}
 W = & \lambda_1^{ij} F_i F_j h + \lambda_2^{ij} F_i \bar{F}_j \bar{h} + \lambda_3^{ij} \bar{F}_i l_j^c h \\
 & + \lambda_4 H H h + \lambda_5 \bar{H} \bar{H} \bar{h} \\
 & + \lambda_6^m F_i \bar{H} \phi_m + \lambda_7^m h \bar{h} \phi_m + \lambda_8^{mnp} \phi_m \phi_n \phi_p
 \end{aligned} \tag{C1}$$

which is the most general set of trilinear interactions invariant under the discrete symmetry $H \rightarrow -H$. The couplings $\lambda_{1,2,3}$ give masses to charge $-1/3$ quarks, charge $+2/3$ quarks and charged leptons, respectively; λ_4 and λ_5 combine the uneaten higgs color triplets in the H and \bar{H} with the triplets in the h and \bar{h} to form supermassive Dirac eigenstates, leaving only the Weinberg-Salam higgs doublets naturally light; λ_6 provides a seesaw neutrino mass matrix yielding light left-handed neutrinos with masses $0(m_w^3/m_{GUT}^2)$; λ_7 insures acceptable electroweak symmetry breaking and prevents a light axion; and λ_8 stabilizes the potential against a large ϕ v.e.v. [3].

We start with a brief review of the main characteristics of four-dimensional heterotic string theories in the free fermionic formulation [18]. In the light-cone gauge, in addition to the two transverse bosonic coordinates X^μ and their left-moving superpartners $\psi^\mu(z)$, the fermionic content is 44 right-moving and 18 left-moving fermions $\bar{\psi}^A(\bar{z})$: $A = 1, 2, \dots, 44$ and $\chi^i(z), y^i(z), w^i(z)$: $i = 1, 2, \dots, 6$, respectively. World-sheet supersymmetry is nonlinearly realized among the latter via the supercurrent

$$T_F(z) = \psi^\mu \partial_z X_\mu + \sum_{i=1}^6 \chi^i y^i \omega^i \quad (C2)$$

A four-dimensional string model is defined by specifying a set Ξ of boundary conditions for all the world-sheet fermions, constrained by making the world-sheet supercurrent (C2) periodic (spacetime fermions) or antiperiodic (spacetime bosons). When all the boundary conditions are diagonalized simultaneously in some general complex basis $\{f\}$, the elements of Ξ are vectors α such that every complex fermion f picks up a phase

$$f \rightarrow -e^{i\pi\alpha(f)} f : \alpha(f) \in (-1, 1] \quad (C3)$$

when parallel transported around the string. In this case, Ξ forms a group under addition (mod 2), and can therefore be generated by some basis $B = \{b_1, b_2, \dots, b_N\}$. It has been shown [18] that to every element α of Ξ there corresponds a sector H_α in the string Hilbert space H , and to every basis element b_i of B a fermion number projection:

$$H = \bigoplus_{\alpha \in \Xi} \prod_{i=1}^N \left[e^{i\pi b_i \cdot F} = \delta_\alpha c^* \left(\frac{\alpha}{b_i} \right) \right] H_\alpha \quad (C4)$$

where F is the vector of all fermion numbers defined: $F(f) = 1 = -F(f^*)$, the dot product is Lorentzian (left minus right), δ_α is the spacetime fermion parity and the phases $c \left(\frac{\alpha}{b_i} \right)$ are constrained by multiloop modular invariance.

In order for this Appendix to be self-contained, we now give the explicit form of the constraints on the basis B and on the phases c for generic rational boundary conditions.

Basis B

- a1) We choose B to be canonical, i.e., any linear combination $\sum m_i b_i = 0$ iff $m_i = 0 \pmod{N_i}$ for some integers N_i (for example, $N_i = 2$ when the fermions are periodic or antiperiodic), and the vector $1 \in B$.
- a2) For any pair b_i, b_j of basis elements, one has* $N_{ij} b_i \cdot b_j = 0 \pmod{4}$ where N_{ij} is the least common multiple of N_i and N_j , and $N_i b_i^2 = 0 \pmod{8}$ if N_i is even.
- a3) The number of real fermions which are simultaneously periodic under four boundary conditions b_1, b_2, b_3, b_4 is even.

* The Lorentzian dot product counts each real fermion with a factor 1/2.

Phases C

- b1) We choose the $c(b_i)$ for $i < j$ such that they are simultaneously $\delta_{b_j} x(N_j^{\text{th}} \text{ root of unity})$ and $\delta_{b_j} x \exp\{i \frac{\pi}{2} b_i \cdot b_j\} x(N_i^{\text{th}} \text{ root of unity})$.
 b2) The remaining phases are calculated using the properties

$$\begin{aligned} c\left(\begin{smallmatrix} \alpha \\ \alpha \end{smallmatrix}\right) &= -\exp(i \frac{\pi}{4} \alpha^2) c\left(\begin{smallmatrix} \alpha \\ 1 \end{smallmatrix}\right) \\ c\left(\begin{smallmatrix} \alpha \\ \beta \end{smallmatrix}\right) &= \exp(i \frac{\pi}{2} \alpha \cdot \beta) c^*\left(\begin{smallmatrix} \beta \\ \alpha \end{smallmatrix}\right) \\ c\left(\begin{smallmatrix} \alpha \\ \beta + \gamma \end{smallmatrix}\right) &= \delta_\alpha c\left(\begin{smallmatrix} \alpha \\ \beta \end{smallmatrix}\right) c\left(\begin{smallmatrix} \alpha \\ \gamma \end{smallmatrix}\right) \end{aligned} \quad (\text{C5})$$

Physical states from the sector H_α are obtained by acting on the vacuum $|0\rangle_\alpha$ with bosonic or fermionic oscillators with frequencies $[1 + \alpha(f)]/2$ ($[1 - \alpha(f)]/2$ for f^*) and applying the fermion number projections, eq. (C4). The mass formula is

$$\begin{aligned} M^2 &= -\frac{1}{2} + \frac{1}{8} \alpha_L^2 + \sum_L \nu_L \\ &= -1 + \frac{1}{8} \alpha_R^2 + \sum_R \nu_R \end{aligned} \quad (\text{C6})$$

where $\alpha_L(\alpha_R)$ is the left (right) part of the vector α and the $\nu_L(\nu_R)$ are frequencies. When some fermions are periodic, the vacuum is a spinor in order to represent the Clifford algebra of the corresponding zero modes. For each periodic complex fermion f there are two degenerate vacua $|+\rangle$, $|-\rangle$, annihilated by the zero mode f_0 and f_0^* , and with fermion numbers $F(f) = 0, -1$, respectively.

Before we start to construct our model, we note a simple but very crucial relation between the world-sheet fermion numbers $F(f)$ and the $U(1)$ charges $Q(f)$ with respect to the unbroken Cartan generators of the four-dimensional gauge group, which are in one-to-one correspondence with the $U(1)$ currents $F^* f$ for each complex fermion f :

$$Q(f) = \frac{\alpha(f)}{2} + F(f) \quad (\text{C7})$$

The charges $Q(f)$ can be shown to be identical with the momenta of the corresponding compactified scalars in the bosonic formulation. The representation (C7) shows that Q is identical with the world-sheet fermion numbers F for states in a Neveu-Schwarz sector ($\alpha = 0$), and $(F + 1/2)$ for states in a Ramond sector ($\alpha = 1$); note that the charges of the $|\pm\rangle$ spinor vacua are $\pm 1/2$.

* The Lorentzian dot product counts each real fermion with a factor 1/2.

Our Flipped SU(5)xU(1) string model [3] is generated by the following basis of eight vectors of boundary conditions for all the world-sheet fermions:

$$S = (\underbrace{1, \dots, 1}_{\chi^\mu, \chi^{1, \dots, 6}}, 0, \dots, 0; 0, \dots, 0) \quad (C8a)$$

$$b_1 = (\underbrace{1, \dots, 1}_{\chi^\mu, \chi^{1,2}, y^{3, \dots, 6}, \bar{y}^{3, \dots, 6}}, 0, \dots, 0; \underbrace{1, \dots, 1}_{\bar{\psi}^{1, \dots, 5}, \bar{\eta}^1}, 0, \dots, 0) \quad (C8b)$$

$$b_2 = (\underbrace{1, \dots, 1}_{\chi^\mu, \chi^{3,4}, y^{1,2}, \bar{y}^{1,2}, \omega^{5,6}, \bar{\omega}^{5,6}}, 0, \dots, 0; \underbrace{1, \dots, 1}_{\bar{\psi}^{1, \dots, 5}, \bar{\eta}^2}, 0, \dots, 0) \quad (C8c)$$

$$b_3 = (\underbrace{1, \dots, 1}_{\chi^\mu, \chi^{5,6}, \omega^{1, \dots, 4}, \bar{\omega}^{1, \dots, 4}}, 0, \dots, 0; \underbrace{1, \dots, 1}_{\bar{\psi}^{1, \dots, 5}, \bar{\eta}^3}, 0, \dots, 0) \quad (C8d)$$

$$b_4 = (\underbrace{1, \dots, 1}_{\chi^\mu, \chi^{1,2}, y^{3,6}, \bar{y}^{3,6}, \omega^{4,5}, \bar{\omega}^{4,5}}, 0, \dots, 0; \underbrace{1, \dots, 1}_{\bar{\psi}^{1, \dots, 5}, \bar{\eta}^1}, 0, \dots, 0) \quad (C8e)$$

$$b_5 = (\underbrace{1, \dots, 1}_{\chi^\mu, \chi^{3,4}, y^{2,6}, \bar{y}^{2,6}, \omega^{1,5}, \bar{\omega}^{1,5}}, 0, \dots, 0; \underbrace{1, \dots, 1}_{\bar{\psi}^{1, \dots, 5}, \bar{\eta}^2}, 0, \dots, 0) \quad (C8f)$$

$$\zeta = (0, \dots, 0; 0, \dots, 0, \underbrace{1, \dots, 1}_{\bar{\phi}^{1, \dots, 8}}) \quad (C8g)$$

$$\alpha = (\underbrace{1, \dots, 1}_{y^{4,6}, \bar{y}^{4,6}, \omega^{4,6}, \bar{\omega}^{2,3,4,6}}, 0, \dots, 0; \underbrace{\frac{1}{2}, \dots, \frac{1}{2}, \underline{A}}_{\bar{\psi}^{1, \dots, 5}, \bar{\eta}^{1,2,3}}) \quad (C8h)$$

where

$$\underline{A} = (\underbrace{\frac{1}{2}, \dots, \frac{1}{2}}_{\bar{\phi}^{1, \dots, 4}}, \underbrace{1, 1}_{\bar{\phi}^{5,6}}, \underbrace{0, 0}_{\bar{\phi}^{7,8}}) \quad (C8i)$$

where 1 stands for periodic fermions, 0 for antiperiodic, and 1/2 for those twisted by a phase $-i$. The semicolon separates left- from right-movers: we have chosen a basis in which all left-movers ($\bar{\chi}^i, \chi^i, y^i, \omega^i : i = 1, 2, \dots, 6$) are real, among which supersymmetry is realized non-linearly, 12 right-movers ($\bar{y}^i, \bar{\omega}^i$) are real, and 16 ($\bar{\psi}^{1,2, \dots, 5}, \bar{\eta}^{1,2,3}, \bar{\phi}^{1,2, \dots, 8}$) are complex. We make the following choice of generalized GSO projection coefficients:

$$\begin{aligned} c \begin{pmatrix} b_i \\ S \end{pmatrix} &= c \begin{pmatrix} b_i \\ b_j \end{pmatrix} = c \begin{pmatrix} \alpha \\ b_i \end{pmatrix}_{i \neq 5} \\ &= c \begin{pmatrix} \alpha \\ \zeta \end{pmatrix} = -c \begin{pmatrix} \alpha \\ b_5 \end{pmatrix} = -1 \end{aligned} \quad (C9)$$

with the others specified by modular invariance and spacetime supersymmetry.

The basis vectors $\{S, \zeta, 1 = b_1 + b_2 + b_3 + \zeta\}$ define an N=4 spacetime supersymmetric model with an SO(28)xE₈ gauge group: S plays the role of the supersymmetry

generator, since when added to a sector it gives its superpartner. The vectors b_1 and b_2 reduce to $N=1$ supersymmetry, break $SO(28) \rightarrow SO(10) \times SO(6)^3$ and give six chiral families $(\underline{16}+\underline{4}) + (\underline{16}+\underline{4})$, two from each of the sectors b_1, b_2 and b_3 . The vectors b_4, b_5 and 2α break $SO(6)^3 \rightarrow U(1)^6$, $E_8 \rightarrow SO(16)$ and lead to six chiral $SO(10)$ families. In addition, in the observable sector there are two extra $\underline{16} + \underline{16}$ pairs from b_4 and b_5 , and two $\underline{10}$'s from b_4+b_5 . Finally, the vector α breaks $SO(10) \rightarrow$ Flipped $SU(5) \times U(1)$, $U(1)^6 \rightarrow U(1)^4$ and the "hidden" group $SO(16) \rightarrow SO(10) \times SO(6)$, and projects out half the chiral families. The four remaining $U(1)$'s correspond to the right-moving world-sheet currents $\eta_1 \eta^*_{-1}, \eta_2 \eta^*_{-2}, \eta_3 \eta^*_{-3}$, and $\bar{\omega}_2 \bar{\omega}_3$.

Thus the following massless matter particles are produced by the sectors $b_{1,2,\dots,5}$, $S+b_4+b_5$, 0 and their superpartners in the observable $SU(5) \times U(1) \times U(1)^4$ sector.

(a) The $b_{1,2,3}$ sectors produce three $SO(10)$ chiral families $M_\alpha = F_\alpha + \bar{F}_\alpha + l_\alpha^c$ ($\alpha = 1, 2, 3$) with $F \equiv (\underline{10}, 1/2)$, $\bar{F} \equiv (\bar{\underline{5}}, -3/2)$ and $l^c \equiv (\underline{1}, 5/2)$ of $SU(5) \times U(1)$ and the following extra $U(1)$ charges:

$$\begin{aligned} (M_1)_{(-\frac{1}{2}, 0, 0, 0);} \quad (M_2)_{(0, -\frac{1}{2}, 0, 0);} \\ \text{and } (F_3)_{(0, 0, \frac{1}{2}, -\frac{1}{2})} + (\bar{F}_3 + l_3^c)_{(0, 0, \frac{1}{2}, \frac{1}{2})} \end{aligned} \quad (C10)$$

(b) The $b_{4,5}$ sectors give

$$\begin{aligned} (F_4)_{(-\frac{1}{2}, 0, 0, 0);} \quad (f_4)_{(\frac{1}{2}, 0, 0, 0);} \quad (\bar{l}_4^c)_{(\frac{1}{2}, 0, 0, 0);} \\ (\bar{F}_5)_{(0, \frac{1}{2}, 0, 0);} \quad (\bar{f}_5)_{(0, -\frac{1}{2}, 0, 0);} \quad (l_5^c)_{(0, -\frac{1}{2}, 0, 0)} \end{aligned} \quad (C11)$$

respectively, where $f \equiv (\underline{5}, 3/2)$, $\bar{l}^c \equiv (\underline{1}, -5/2)$ and $\bar{F} \equiv (\bar{\underline{10}}, -1/2)$.

(c) The $S + b_4 + b_5$ sector gives

$$\begin{aligned} h_{45} &\equiv (\underline{5}, -1)_{(-\frac{1}{2}, -\frac{1}{2}, 0, 0);} \\ \phi_{45} &\equiv (\underline{1}, 0)_{(\frac{1}{2}, \frac{1}{2}, 1, 0);} \\ \phi_i &\equiv (\underline{1}, 0)_{(\frac{1}{2}, -\frac{1}{2}, 0, 0)} \quad \text{for } i = 1, \dots, 4; \\ \phi^+ &\equiv (\underline{1}, 0)_{(\frac{1}{2}, -\frac{1}{2}, 0, 1);} \\ \phi^- &\equiv (\underline{1}, 0)_{(\frac{1}{2}, -\frac{1}{2}, 0, -1)} \end{aligned} \quad (C12)$$

(and their conjugates \bar{h}_{45} , etc.) obtained by acting on its vacuum with the $\bar{\psi}^{a*}, \bar{\eta}^3, \bar{\omega}^2 \pm \bar{\omega}^3$ fermionic oscillators for the first four states respectively, and by those of $\bar{y}^{5,6}, \bar{\omega}^{5,6}$ for the ϕ_i : $i = 1$ to 4 (and their complex conjugates for \bar{h}_{45} , etc.)

(d) Finally, the Neveu-Schwarz 0 sector gives

$$\begin{aligned}
 h_1 &\equiv (\underline{5}, -1)_{(1,0,0,0)}; \quad \Phi_{23} \equiv (\underline{1}, 0)_{(0,-1,1,0)}; \\
 h_2 &\equiv (\underline{5}, -1)_{(0,1,0,0)}; \quad \Phi_{31} \equiv (\underline{1}, 0)_{(1,0,-1,0)}; \\
 h_3 &\equiv (\underline{5}, -1)_{(0,0,1,0)}; \quad \Phi_{12} \equiv (\underline{1}, 0)_{(-1,1,0,0)}
 \end{aligned} \tag{C13a}$$

their complex conjugates;

$$\Phi_I \equiv (\underline{1}, 0)_{(0,0,0,0)} \quad \text{for } I = 1, \dots, 5 \tag{C13b}$$

obtained by acting on the vacuum with the fermionic oscillators of $\chi^1 + i\chi^2$ with $\bar{\psi}^{a*}\bar{\eta}^1$, $\bar{\eta}^{2*}\bar{\eta}^3$, $\bar{y}^1\bar{\omega}^1$ (for h_1, Φ_{23}, Φ_1), $\chi^3 + i\chi^4$ with $\bar{\psi}^{a*}\bar{\eta}^2$, $\bar{\eta}^1\bar{\eta}^{3*}$, $\bar{y}^4\bar{\omega}^4$ (for h_2, Φ_{31}, Φ_2) and $\chi^5 + i\chi^6$ with $\bar{\psi}^{a*}\bar{\eta}^3$, $\bar{\eta}^{1*}\bar{\eta}^2$, $\bar{y}^2\bar{y}^3$, $\bar{y}^5\bar{\omega}^5$ and $\bar{y}^6\bar{\omega}^5$ (for $h_3, \Phi_{12}, \Phi_{3,4,5}$).

For completeness, we also list the massless matter fields transforming under the hidden $\text{SO}(10) \times \text{SO}(6)$ gauge group.

(e) The sectors $b_i + 2\alpha$ and $b_i + 2\alpha + \zeta$ for $i=1$ to 5 give the following vector representations:

$$\begin{aligned}
 &((\underline{1}, \underline{6}) + (\underline{10}, \underline{1}))_{(0, -\frac{1}{2}, \frac{1}{2}, 0)}; \\
 &((\underline{1}, \underline{6}) + (\underline{10}, \underline{1}))_{(-\frac{1}{2}, 0, \frac{1}{2}, 0)}; \\
 &(\underline{1}, \underline{6})_{(-\frac{1}{2}, -\frac{1}{2}, 0, \frac{1}{2})} + (\underline{10}, \underline{1})_{(-\frac{1}{2}, -\frac{1}{2}, 0, -\frac{1}{2})}; \\
 &(\underline{1}, \underline{6})_{(0, -\frac{1}{2}, \frac{1}{2}, 0)} + (\underline{10}, \underline{1})_{(0, \frac{1}{2}, -\frac{1}{2}, 0)}; \\
 &(\underline{1}, \underline{6})_{(\frac{1}{2}, 0, -\frac{1}{2}, 0)} + (\underline{10}, \underline{1})_{(-\frac{1}{2}, 0, \frac{1}{2}, 0)}
 \end{aligned} \tag{C14}$$

which are $\text{SU}(5) \times \text{U}(1)$ singlets.

(f) The following sectors give spinorial representations of $\text{SO}(6)$:

$$\begin{aligned}
 b_1 \pm \alpha(+\zeta): & \quad (\underline{1}, \underline{4})_{(-\frac{1}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{2})}^{-\frac{5}{4}} + (\underline{1}, \underline{4})_{(-\frac{1}{4}, \frac{1}{4}, \frac{1}{4}, -\frac{1}{2})}^{-\frac{5}{4}} \\
 b_1 + b_4 + b_5 \pm \alpha(+\zeta): & \quad (\underline{1}, \underline{4})_{(-\frac{1}{4}, \frac{1}{4}, -\frac{1}{4}, \frac{1}{2})}^{\frac{5}{4}} + (\underline{1}, \underline{4})_{(-\frac{1}{4}, \frac{1}{4}, -\frac{1}{4}, -\frac{1}{2})}^{\frac{5}{4}} \\
 b_1 + b_2 + b_4 \pm \alpha(+\zeta): & \quad (\underline{1}, \underline{4})_{(-\frac{1}{4}, \frac{1}{4}, -\frac{1}{4}, -\frac{1}{2})}^{\frac{5}{4}} + (\underline{1}, \underline{4})_{(\frac{1}{4}, -\frac{1}{4}, \frac{1}{4}, -\frac{1}{2})}^{-\frac{5}{4}} \\
 S + b_2 + b_4 \pm \alpha(+\zeta): & \quad (\underline{1}, \underline{4})_{(\frac{1}{4}, \frac{1}{4}, -\frac{1}{4}, \frac{1}{2})}^{-\frac{5}{4}} + (\underline{1}, \underline{4})_{(-\frac{1}{4}, -\frac{1}{4}, \frac{1}{4}, -\frac{1}{2})}^{\frac{5}{4}} \\
 b_4 \pm \alpha(+\zeta): & \quad (\underline{1}, \underline{4})_{(\frac{1}{4}, -\frac{1}{4}, -\frac{1}{4}, -\frac{1}{2})}^{\frac{5}{4}} + (\underline{1}, \underline{4})_{(-\frac{1}{4}, \frac{1}{4}, \frac{1}{4}, -\frac{1}{2})}^{-\frac{5}{4}} \\
 b_2 + b_3 + b_5 \pm \alpha(+\zeta): & \quad (\underline{1}, \underline{4})_{(-\frac{3}{4}, \frac{1}{4}, -\frac{1}{4}, 0)}^{-\frac{5}{4}} + (\underline{1}, \underline{4})_{(-\frac{1}{4}, \frac{3}{4}, \frac{1}{4}, 0)}^{\frac{5}{4}}
 \end{aligned} \tag{C15}$$

which are $\text{SU}(5)$ singlets, but carry the non-zero $\text{U}(1)$ charges indicated by the upper right index, corresponding to fractional electric charges $\pm 1/2$.

We observe that the above string spectrum (C10-C15) corresponds to a three-generation Flipped $SU(5) \times U(1) \times U(1)^4$ model, with all the required higgs representations needed to break $SU(5) \times U(1) \times U(1)^4$ down to the Standard Model. Among the four surplus $U(1)$ generators, there is one anomalous linear combination

$$U(1)_A \equiv -3U(1)_1 - U(1)_2 + 2U(1)_3 - U(1)_4 \quad (C16)$$

while the three orthogonal combinations are completely free of both gauge and mixed gravitational anomalies. In ref. [3] we show that the anomalous combination is broken by the Dine-Seiberg-Witten mechanism [C5]. These extra $U(1)$ factors forbid renormalizable superpotential couplings giving masses to all but the third generation of quarks and leptons t, b, τ . Non-renormalizable couplings induced by the exchange of massive string modes then provide a viable mechanism for generating the remaining fermion masses with $m_{c, u, s, d, \mu, e} \ll m_{t, b, \tau}$. A detailed analysis of Yukawa couplings, nonrenormalizable couplings, gauge symmetry breaking, the top-quark mass, proton decay, and flavor-changing neutral currents is provided in ref. [3], where it is explicitly shown that the choice of boundary conditions (C8) provides a phenomenologically realistic derivation of low-energy physics from the superstring.

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