MODERN PHYSICS AND EASTERN MYSTICISM

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Twentieth-century physics has had a profound influence on general philosophical thought, because it has revealed an unsuspected limitation of classical ideas and has necessitated a radical revision of many of our basic concepts. The concept of matter in subatomic physics, for example, is totally different from the traditional material substance of classical physics, and the same is true for concepts like space, time, or causality. These concepts, however, are fundamental to our outlook on the world around us, and with their radical transformation our whole world view has begun to change.

similarities of world views

These changes brought about by modern physics all seem to lead towards a view of the world which is very similar to that of Eastern mysticism, for the concepts of modern physics often show surprising parallels to the ideas expressed in the religious philosophies of Hinduism, Buddhism, and Taoism. Although these comprise a vast number of subtly interwoven spiritual disciplines and philosophical systems, the basic features of their world view are the same. This view is not limited to the East, but can be found to some extent in all mystically oriented philosophies. I could therefore phrase my argument more generally by saying that modern physics seems to lead us to a view of the world which is similar to the views held by mystics of all ages and traditions.

A detailed analysis of the parallels between the principal theories of modern physics and the mystical traditions of the Far East can be found in *The Tao of Physics* (Capra, 1975). In this paper, I want to concentrate on two ideas which are emphasized throughout Eastern mysticism and which are recurring themes in the world view of modern physics: the unity and mutual interrelation of all things and events, and the intrinsically dynamic nature of the universe.

After presenting a brief juxtaposition of the mechanistic world view of classical physics and the 'organic' view of Eastern mysticism, I shall show how the notion of a fundamental interconnectedness of nature arises in quantum theory and how it acquires an essential dynamic character in relativity theory, implying a new conception of particles which is closely related to the Eastern conception of the material world. Finally, I shall discuss the philosophical ideas underlying S-matrix theory, one of the principal theories to combine both quantum theory and relativity theory, and the striking parallels between the models of particles formulated in the S-matrix framework and certain ideas in Indian and Chinese mysticism.

MECHANISTIC AND ORGANIC WORLD VIEWS

a mechanistic worldview

The traditional world view of classical physics is a mechanistic view of the world. It has its roots in the philosophy of the Greek atomists, Democritus, Leucippus, and others, who saw matter as being made of several 'basic building blocks" the atoms, which are purely passive and intrinsically dead. The atoms were thought to be moved by some external force which was often assumed to be of spiritual origin, and thus fundamentally different from matter. This image became an essential part of the Western way of thinking. It gave rise to the dualism between spirit and matter, between the mind and the body, which is characteristic of Western thought This dualism was formulated in its sharpest form in the philosophy of Descartes who based his view of nature on a fundamental division into two separate and independent realms, that of mind *(res cogitans),* and that of matter *(res extensa).* The Cartesian division allowed scientists to treat matter as dead and completely separate from themselves, and to see the material world as a multitude of different objects assembled into a huge machine. Such a mechanistic world view was held by Newton who constructed his mechanics on its basis and made it the foundation of classical physics.

an organic world view

Opposed to the mechanistic conception of the world is the view of the Eastern mystics which may be characterized by the word 'organic', as it regards all phenomena in the universe as integral parts of an inseparable harmonious whole. For the Eastern mystic, all things and events perceived by the senses are interrelated, connected, and are but different aspects or manifestations of the same ultimate reality. OUf tendency to divide the world we perceive into individual and separate 'things' and to experience ourselves in this world as isolated egos is seen as an 'illusion' which comes from our measuring and categorizing mentality. The division of nature into separate objects is, of course, useful and necessary to cope with our everyday environment, but it is not a fundamental feature of reality. For the Eastern mystic, any such objects have therefore a fluid and ever-changing character. The Eastern world view is thus intrinsically dynamic, and contains time and change as essential features. The cosmos is seen as one inseparable reality-forever in motion, alive, organic-spiritual and material at the same time. Motion and change being essential properties of things, the forces causing motion are not outside the objects, as in the classical Greek view, *but* are an intrinsic property of matter. I shall now show how the main features of this picture appear in modern physics.

QUANTUM THEORY

uncertainties and tendencies

One of the main insights of quantum theory has been the recognition that probability is a fundamental feature of the atomic reality which governs all processes, and even the existence of matter. Subatomic particles do not exist with certainty at definite places, but rather show-as Heisenberg (1963) has put it-"tendencies to exist." Atomic events do not occur with certainty at definite times and in definite ways, but rather show "tendencies to occur." Henry Stapp (1971) has emphasized that these tendencies, or probabilities, are not probabilities of 'things', but rather probabilities of interconnections. Any observed atomic 'object' constitutes an intermediate system connecting the preparation of the experiment and the subsequent measurement. It exists and has meaning only in this context-not as an isolated entity, but as an interconnection between the processes of preparation and measurement. The properties of the object cannot be defined independently of these processes.Jf'the preparation or the measurement is modified, the properties of the object will also change.

observing and measuring

On the other hand, the fact that we speak about an 'Object'-an atom, an electron, or any other observed system-shows that we have some independent physical entity in mind which is first prepared and then measured. The basic problem, then, with observation in atomic physics is-in the words of Stapp (1971) -that "the observed system is required to be isolated in order to be defined, yet interacting in order to be observed." This problem is resolved in quantum theory in a pragmatic way by requiring that the preparing and measuring devices be separated by a large distance so that the observed object be free from their influence while travelling from the area of preparation to the area of measurement.

In principle, this distance must be infinite. In the framework of quantum theory, the concept of a distinct physical entity can be defined precisely only if this entity is infinitely far away from the agencies of observation. In practice, this is of course not possible, nor is it necessary. We have to remember, here, the basic attitude of modern science that all its concepts and theories are approximate. In the present case, this means that the concept of a distinct physical entity need not have a precise definition, but can be defined approximately. For large distances between the preparing and measuring devices, their disturbing effects on the observed object are small and can be neglected, and one can speak of a distinct physical entity being observed. Such a concept, therefore, is merely an idealization. When the measuring devices are not placed far enough apart, their influence can no longer be neglected, and the whole macroscopic system forms a unified whole and the notion of an observed object breaks down.

the effect of distance

Quantum theory thus reveals an essential interconnectedness of the universe. It shows that we cannot decompose the world into independently existing smallest units. As we penetrate into matter, we find it is made of particles, but these are not the 'basic building blocks' in the sense of Democritus and Newton. They are merely idealizations which are useful from a practical point of view, but have no fundamental significance. In the words of Niels Bohr (1934, p. 57):

essential interconnectedness

> Isolated material particles are abstractions, their properties being definable and observable only through their interaction with other systems.

THE COSMIC WEB

At the atomic level, then, the solid material objects of classical physics dissolve into patterns of probabilities, and these patterns do not represent probabilities of things, but probabilities of interconnections. Quantum theory forces us to see the universe not as a collection of physical objects, but rather as a complicated web of relations between the various parts of a unified whole. In the words of Werner Heisenberg (1963, p.96):

a web of relations

> The world thus appears as a complicated tissue of events, in which connections of different kinds alternate or overlap or combine and thereby determine the texture of the whole.

This however, is the way in which the Eastern mystics experience the world, and they often express their experience in words which are almost identical to those used by atomic physicists. Take, for example, the following quotation from a Tibetan Buddhist, Lama Govinda (1973, p. 93):

> The external world and his inner world are for (the Buddhist) only two sides of the same fabric, in which the threads of all forces and of all events, of all forms of consciousness and of their objects, are woven into an inseparable net of endless, mutually conditioned relations.

These words by Govinda bring out another feature which is of fundamental importance both in modern physics and in Eastern mysticism. The universal interconnectedness of nature always includes the human observer and his or her consciousness in an essential way. In quantum theory, the observed 'objects' can only be understood in terms of the interaction between the processes of preparation and measurement, and the end of this chain of processes lies always in the consciousness of the human observer. The crucial feature of quantum theory is that the human observer is not only necessary to observe the properties of an object, but is necessary even to define these properties. In atomic physics, we can never speak about nature without, at the same time, speaking about ourselves. As Heisenberg has put it (1963, p. 75):

the human observer

> Natural science does not simply describe and explain nature; it is a part of the interplay between nature and ourselves,

In modern physics, then, the scientist cannot *play* the role of a detached observer, but becomes involved in the world he or she observes. John Wheeler (1974) sees this involvement of the observer as the most important feature of quantum theory, and he has therefore suggested replacing the word 'observer' by the word 'participator'. But this, again, is an idea which is well known to any student of a mystical tradition. Mystical knowledge can never be obtained just by observation, but only by full participation with one's *whole* being. The notion of the participator is thus basic to the mystical traditions of the East.

replacing 'observer' with 'participator'

THEORY

The second basic theory of modern physics, relativity theory, has forced us to change our concepts of space and time in a drastic way. It has shown that space is not three-dimensional and that time is not a separate entity. Both are intimately connected and form a four-dimensional continuum called 'space-time'. In relativity theory, therefore, we can never talk about space without talking about time and vice versa. We have now been living with the theory of relativity for a long time and have become thoroughly familiar with *its* mathetical formalism. But this has not helped our intuition very much. We have no direct sensory experience of the four-dimensional space-time continuum, and whenever this 'relativistic' reality manifests itself we find it very hard to deal with it at the level of intuition and ordinary language.

A similar situation seems to exist in Eastern mysticism. The mystics seem to be able to attain non-ordinary states of consciousness in which they transcend the three-dimensional world of everyday life to experience a higher, multidimensional reality, a reality which, like that of relativistic physics, is impossible to describe in ordinary language. Govinda (1973, p. 136) talks about this experience when he writes:

> An experience of higher dimensionality is achieved by integration of experiences of different centres and levels of consciousness. Hence the indescribability of certain experiences of meditation on the plane of three-dimensional consciousness.

space-time in mysticism and physics

The dimensions of these states of consciousness may not be the same as the ones we are dealing with in relativistic physics, but it is striking that they have led the mystics towards notions of space and time which are very similar to those implied by relativity theory. Throughout Eastern mysticism, there seems to be a strong intuition for the 'space-time' character of reality. The fact that space and time are inseparably linked, which is so characteristic of relativistic physics, is stressed again and again. Thus the Buddhist scholar D. T. Suzuki writes (1959, p. 33):

> As a fact of pure experience, there is no space without time, no time without space.

In physics, the concepts of space and time are so basic for the description of natural phenomena that their modification entails a modification of the whole framework we use to describe nature. The most important consequence of this modification is the realization that mass is nothing but a form of energy, that every object has energy stored in its mass.

These developments-the unification of space and time and the equivalence of mass and energy-have had a profound influence on our picture of matter and have forced us to modify our concept of a particle in an essential way. In modern physics, mass is no longer associated with a material substance, and hence particles are not seen as consisting of any basic 'stuff', but as bundles of energy. Energy, however, is associated with activity, with processes, and this implies that the nature of subatomic particles is intrinsically dynamic. In a relativistic theory, where space and time are fused into a four-dim ensional continuum, these particles can no longer be pictured as static three-dimensional objects, like billiard balls or grains of sand, but must be conceived as four-dimensional entities in space-time. Their forms have to be understood dynamically, as forms in space and time. Subatomic particles are dynamic patterns which have a space aspect and a time aspect. Their space aspect makes them appear as objects with a certain mass, their time aspect as processes involving the equivalent energy. Relativity theory thus gives the constituents of matter an intrinsically dynamic aspect. It shows that the existence of matter and its activity cannot be separated. They are but different aspects of the four-dimensional space-time reality.

movement, flow, change

The Eastern mystics seem to be aware of the intimate connection of space and time, and consequently their view of the world, like that of modern physicists, is intrinsically dynamic. Most of their *concepts*, images, and myths contain time and change as essential elements (see Capra, 1975, chap. 13). The more one studies the religious and philosophical texts of the Hindus, Buddhists, and Taoists, the more it becomes apparent that in all of them the world is conceived in terms of movement, flow and change. More than that, the Eastern mystics also have a strong intuition for the 'space-time' character of material objects which is so typical of relativistic physics. Physicists have to take into account the unification of space and time when they study the subatomic world, and consequently they view the objects of this world-the particles-in terms of activity and processes. The Eastern mystics, in their non-ordinary states of consciousness, seem to be aware of the unity of space and time at a macroscopic level, and thus they see the macroscopic objects in a way which is very similar to the physicists' conception of subatomic particles. Suzuki (1968a, p. 33), for example, writes in one of his books on Buddhism:

> Buddhists have conceived an object as an event and not as a thing or substance.

The two basic theories of modern physics thus exhibit all the main features of the Eastern world view. Quantum theory has abolished the notion of fundamentally separated objects, has introduced the concept of the participator to replace that ofthe observer, and has come to see the universe as an interconnected web of relations whose parts are only defined through their connections to the whole. Relativity theory, so to speak, has made the cosmic web come alive by revealing its intrinsically dynamic character, and by showing that its activity is the very essence of its being.

Current research in physics aims at unifying quantum theory and relativity theory into a complete theory of the subatomic world. We have not yet been able to formulate such a complete theory, but we do have several partial theories which describe certain aspects of subatomic phenomena very well. All of these theories express, in different ways, the fundamental interrelatedness and the intrinsically dynamic character of the universe, and they all involve philosophical conceptions which are strikingly similar to those used in Eastern mysticism. To illustrate some of these similarities, 1 shall now discuss the view of matter implied by Svmatrix theory, one of the most useful frameworks for the description of particles and their interactions.

towarda complete subatomic theory

S-MATRIX THEORY

S-matrix theory is used in particle physics to describe the phenomena involving hadrons, or strongly interacting particles, which constitute the overwhelming majority of the subatomic particles discovered so far. The S-matrix framework seems to be most appropriate for the description ofhadrons, as it provides a mathematical formalism which is able to give a dynamic account of the great variety of phenomena associated with the strong interactions and usually given the name 'particle reactions': the transformation of hadrons into one another, their mutual interaction through the exchange of other hadrons, the formation of bound states, and their decay into various particle combinations.

'particle reactions'

The key concept of the theory is that of the S matrix which was originally proposed by Heisenberg in 1943 and has been developed, over the past two decades, into a complex mathematical structure which seems to be ideally suited to describe hadron phenomena (Chew, 1966). The S matrix is the collection of probabilities for all possible reactions involving hadrons, In practice, of course, one is never interested in the entire collection of hadron processes, and thus one never deals with the whole S matrix, but only with those of its elements which refer to the processes under consideration. These are represented symbolically by diagrams like the one shown in Figure 1 which pictures one of the simplest and most general particle reactions: two particles, A and B, undergo a collision to emerge as two different particles, C and D. S-matrix diagrams do not picture the detailed mechanism of a particle reaction, but merely specify the initial and final particles in terms of their momenta, spins, and other characteristic properties.

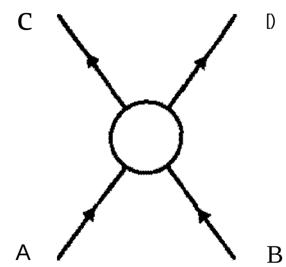

Figure1. S-matrixdiagramfor a reaction involvingfour different particles.

a shift from objects to events

The important new concept in S-matrix theory is the shift of emphasis from objects to events. Its basic concern is not with the particles, but with their reactions. Such *a* shift from objects to events is required both by quantum theory and by relativity theory. On the one hand, quantum theory has made it clear that a subatomic particle can only be understood as a manifestation of the interaction between various processes of measurement. It is not an isolated object, but rather an occurrence, or event, which interconnects other events in a particular way. Relativity theory, on the other hand, has forced us to conceive of particles in terms of space-time, as four-dimensional patterns, processes rather than objects. The Ssmatrix approach combines both of these viewpoints. Using the four-dimensional mathematical formalism of relativity theory, it describes all properties of hadrons in terms of reaction probabilities, and thus establishes an intimate link between particles and processes. Each reaction involves particles which link it to other reactions and thus build up a whole network of processes.

Figure 2 shows an example of such a network of interactions, a 'tissue of events', all described by the S matrix. The interconnections in this diagram cannot be determined with certainty, but are associated with probabilities. Each reaction occurs with some probability, which depends on the available energy and on the characteristics of the reaction, and these probabilities are given by the various elements of the S matrix.

adynamic structure

This approach allows one to define the structure of a hadron in a thoroughly dynamic way (Chew, 1974). The neutron (n) in our network, for example, can be seen as a bound state of the proton (p) and the π^- from which it arises, and also as a bound state of the Σ^- and the K+ into which it decays. Either of these hadron combinations, and many others, may form a neutron, and consequently they can be said to be components of the neutron's 'structure'. The structure of a hadron, therefore, is not understood as a definite arrangement of constituent parts,

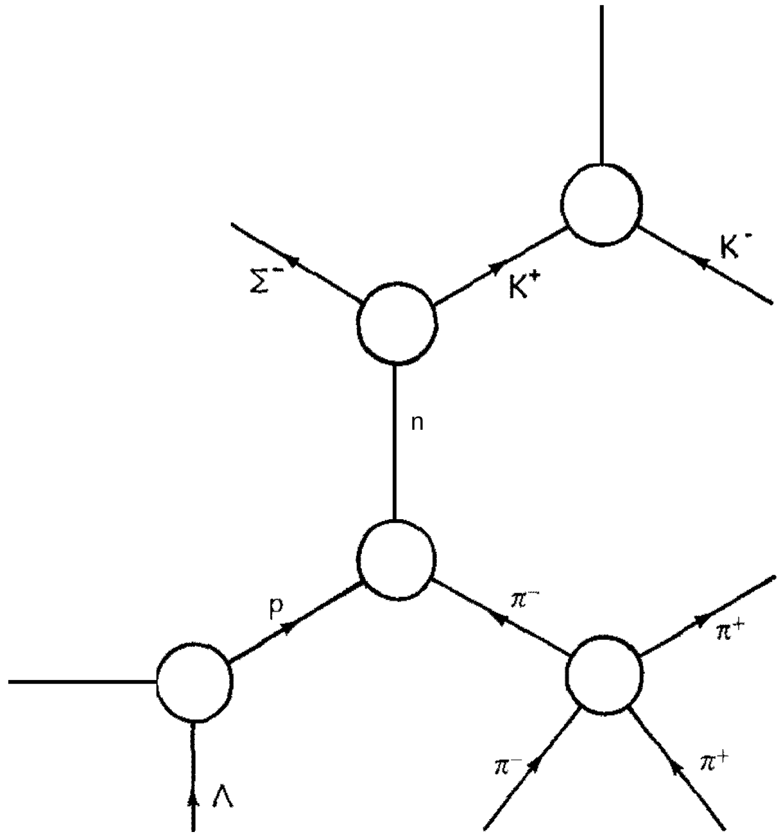

figure 2. S·matrix diagram picturing a network of reactions.

but is determined by all sets of particles which may interact with one another to form the hadron under consideration. Thus a proton exists potentially as a neutron-pion pair, a kaon-Iambda pair, and so on. The tendencies of a hadron to exist in various manifestations are expressed by the probabilities for the corresponding reactions, all of which may be regarded as aspects of the hadron's internal structure.

By defining the structure of a hadron as its tendency to undergo various reactions, S-matrix theory gives the concept of structure an essentially dynamic connotation. At the same time, this notion of structure is in perfect agreement with the experimental facts. Whenever hadrons are broken up in high-energy scattering experiments, they disintegrate into corn-binations of other hadrons; thus they can be said to 'consist' potentially of these hadron combinations. Each of the particles emerging from such a collision will, in turn, undergo various reactions, thus building up a whole network of events.

Although it is a matter of chance which network will arise in a particular experiment, each network is nevertheless structured according to definite rules. These rules are the conservation laws observed by the strong interactions; only those reactions can occur in which a well-defined set of 'quantum numbers' (charge, isospin, parity, etc.) is conserved (Chew et al., 1964).

concept of a reaction channel

The hadron reactions, then, represent a flow of energy in which particles are created and dissolved. but the energy can only flow through certain 'channels' characterized by the quantum numbers conserved in the strong interactions. In S-matrix theory, the concept of a reaction channel is more fundamental than that of a particle. **It** is defined as a set of quantum numbers which can be carried by various hadron combinations and often also by a single hadron. Which combinations of hadrons flow through a particular channel is a matter of probability and depends, above all, on the available energy.

In order to describe all hadrons as intermediate states in a network of reactions, one has to be able to account for the forces through which they mutually interact. These are the strong-interaction forces which scatter colliding hadrons, dissolve and rearrange them in different patterns, and bind groups of them together to form intermediate bound states. In Svmarrix theory, the interaction forces are associated with particles and the relation between forces and particles is based

the 'crossing' reaction

on a special property of the S matrix known as 'crossing'. To illustrate this property, consider the diagram shown in Figure 3. This diagram can be read in two directions: in the 'direct channel' (read from bottom to top) it represents the reaction $p + \pi^- \rightarrow P + n$: in the 'cross channel' (read from left to right) it pictures the reaction $\bar{p} + p \rightarrow \pi^- + \pi^+$. (The rule *for* obtaining the 'crossed' reaction is that particles have to be replaced by their antiparticles whenever the corresponding arrows in

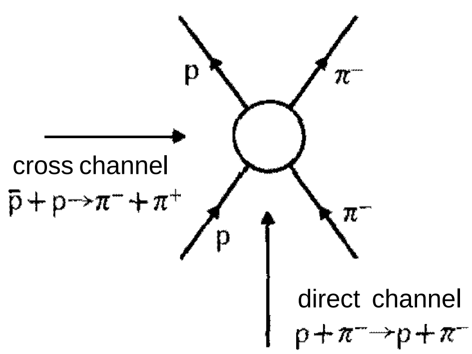

Figure 3. A diagram representing the reaction $P + \pi^- \rightarrow P + \pi^-$ in the direct channel and $\bar{p} + P \quad \pi^- + \pi^+$ in the cross channel.

the diagram point against the direction of the channel. **In** our example, the outgoing proton is replaced by an incoming antiproton ($\bar{p}$), the incoming π^- by an outgoing π^+.) The crossing property of the S matrix, now, refers to the fact that both these processes are described by the same S-matrix element. This means that the two processes represent merely different aspects, or channels, of the same reaction. (There are four more processes which are still described by the same S-matrix.element, but only the two mentioned here are relevant for our discussion of interaction forces.)

The connection between forces and particles is established through the intermediate states in the two channels. In the direct channel of our example, the proton and the π^- can form an intermediate neutron, whereas the cross channel can be made up by an intermediate neutral pion *(see* Figure 4). This pion-the intermediate state in the cross channel-is interpreted as the manifestation of the force which acts in the direct channel binding the proton and the π^- together to form the neutron. Thus both channels are needed to associate the forces with particles; what appears as a force in one channel is manifest as an intermediate particle in the other.

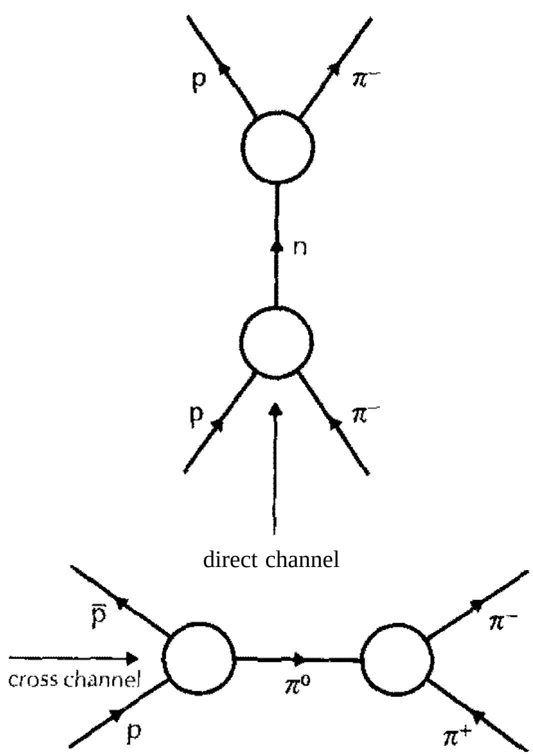

Figure 4. Intermediate states in the direct and cross channels of the reaction pictured in Figure 3.

difficulties of intuitive visualization

Although it is relatively easy to switch from one channel to the other mathematically, it is extremely difficult-if at all possible-to have an intuitive picture of the situation. This is because crossing is an essentially relativistic concept, arising in the context of the four-dimensional formalism of Svmatrixtheory, and thus very difficult to visualize. Loosely speaking, one might say that the proton and the *sr:* interact 'through the exchange of a π^0'. Such words are often used in particle physics, but they do not fully describe the situation. An adequate description can only be given in terms of direct and cross channels, that is, in abstract concepts which are almost impossible to visualize.

THE CHANGES

The framework of the S matrix, then, is able to describe the structure of hadrons and the forces through which they mutually interact in a thoroughly dynamic way in which each hadron is understood as an integral part of an inseparable network of reactions. The emphasis is not on static fundamental structures or entities, but on change and transformation, and because ofthat emphasis the philosophy of S-matrix theory comes very close to Eastern thought, where all 'things' are seen as dynamic, impermanent, and illusory.

Like modern physicists, Eastern mystics have realized that all phenomena in this ever-changing world arc dynamically interrelated. Hindus and Buddhists see this interrelation as a cosmic law, the law of *karma,* but they are generally not concerned with any specific patterns in the universal network of events. Chinese philosophy, on the other hand, has developed the notion of dynamic patterns which are continually formed and dissolved in an ongoing cosmic process called the *Tao.* In the *I Ching,* or *Book of Changes,* one of the foundations of ancient Chinese thought, these patterns have been elaborated into a system of archetypal symbols, the so-called hexagrams.

yin *and* yang

The basic ordering principle of the patterns in the *I Ching* is the interplay of the polar opposites *yin* and *yang,* the primordial pair which is the grand leitmotiv that permeates ancient Chinese thought and culture. In the 1 *Ching.* the *yang* is represented by a solid line (-), the *yin* by a broken line (--), and these two kinds of lines are used to construct 64 six-line figures, the hexagrams, which display all possible combinations of solid and broken lines *(see* Figure 5).

These hexagrams represent the patterns of the *Tao* which are generated by the dynamic interplay of *yin* and *yang,* and are

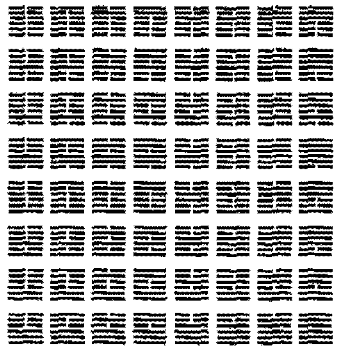

Figure 5. The 64 hexagrams of the *I Ching.*

reflected in all cosmic and human situations. These situations, therefore, are not seen as static, but rather as phases in a continuous flow and change. Accordingly, the things in the physical world are not independent objects, but merely transitional stages in the cosmic process which is the *Tao:*

> The *Tao* has changes and movements. Therefore the lines are called changing lines. The lines have gradations, therefore they represent things. [Wilhelm, 1968, p. 352]

I Ching and Simatrix theory

Because of its notion of dynamic patterns, generated by change and transformation, the *I Ching* is perhaps the closest analogy to S-matrix theory in Eastern thought. In both systems, the emphasis is on processes rather than objects. In Svmatrix theory, the processes are the particle reactions that give rise to the phenomena in the world of hadrons, In the *I Ching,* the basic processes are called 'the changes' and are seen as essential for an understanding of all natural phenomena:

> The changes are what has enabled the holy sages to reach all depths and to grasp the seeds of all things. [Wilhelm, 1968, p. 315]

These changes are not regarded as fundamental laws imposed on the physical world, but rather-in the words of Hellmut Wilhelm (1964, p. 19)-as "an inner tendency according to which development takes place naturally and spontaneously." The same can be said of the 'changes' in the particle world. They, too, reflect the inner tendencies of the particles which are expressed, in S-matrix theory, in terms of reaction probabilities.

The changes in the world of hadrons give rise to structures which are represented symbolically by the reaction channels. The structures are not regarded as fundamental features of the hadron world, but are seen as consequences of the particles' dynamic nature, that is, of their tendencies for change and transformation. In the *I Ching*, too, the changes give rise to structures-the hexagrams-and, like the channels of particle reactions, these structures are symbolic representations of patterns of change. As the energy flows through the reaction channels, the 'changes' flow through the lines of the hexagrams:

patterns of change

> Alteration, movement without rest,
> Flowing through the six empty places,
> Rising and sinking without fixed law, ...
> It is only change that is at work here.
>
> [Wilhelm, 1968, p. 348J

HADRON SYMMETRIES

Both in ancient Chinese thought and in the S-matrix theory of modern physics, change and transformation are considered to be the primary aspects of nature; the structures and patterns generated by the changes arc seen as secondary. Yet, in particle physics, these patterns are an essential feature of the strong interactions and any successful theory of hadrons will have to explain them. The quantum numbers characterizing the particles do not take arbitrary values, but are restricted to a limited number and thus make it possible to arrange hadrons into a few distinct groups, or 'families'i-Sl.l, multiplets, Regge trajectories, etc.s-whieh exhibit striking symmetries. So far, these regularities in the hadron spectrum have been determined and classified in a purely empirical way and cannot yet be derived from the details of the particles' interactions. The main challenge for S-matrix theory is, therefore, to derive the hadron symmetries from the dynamics of the strong interactions. In such a theory, the quantum numbers and the symmetric patterns implied by them would be reflected in the mathematical structure of the S matrix and thus be a consequence of the particles' dynamic nature.

aim of S-matrix theory

At present, physicists are trying to achieve this ambitious aim by postulating several general principles which restrict the mathematical possibilities of constructing S-matrix elements and thus give the S matrix a definite structure. So far, three general principles have been established which are related to our methods of observation and measurement and are known as Poincare invariance, unitarity, and analyticity (Chew, 1966). The central aim of theory is to derive the structure of the S matrix from these principles. Up to now, it has not been possible to construct a mathematical model which satisfies all three principles, and the idea has therefore arisen that they may be sufficient to determine all the properties of the S matrix-and thus all the properties of hadrons-suniquely. This idea is known as the 'bootstrap hypothesis'. Its originator and main advocate is Geoffrey Chew who, on the one hand, has developed the idea into a general 'bootstrap' philosophy of nature (1968, 1970) and, on the other, has used it (in collaboration with other physicists) to construct specific models of particles formulated in Svmatrixlanguage (1966).

the bootstrap' hypothesis

THE BOOTSTRAP

The basis of the bootstrap philosophy is the idea that nature cannot be reduced to fundamental entities, like fundamental building blocks of matter, but has to be understood entirely through self-consistency. All of physics has to follow uniquely from the requirement that its components be consistent with one another and with themselves.

nature as self-consistent

This idea constitutes a radical departure from the traditional spirit of basic research in physics which had always been bent on finding the fundamental constituents of matter. At the same time, it is the culmination of the conception of particles as an interconnected web of relations. The bootstrap philosophy abandons not only the idea of fundamental building blocks of matter, but accepts no fundamental entities. whatsoever-no fundamental laws, equations, or principles. The universe is seen as a dynamic web of interrelated events. None of the properties of any part of this web is fundamental; they all follow from the properties of the other parts, and the overall consistency of their mutual interrelations determines the structure of the entire web.

a web of interrelated events

It is evident that this idea is very much in the spirit of Eastern thought. An indivisible universe, in which things and events are interrelated, would hardly make sense unless it were self-consistent. In a way, the requirement of self-consistency, which forms the basis of the bootstrap hypothesis, and the unity and interrelation of all phenomena, which are so strongly emphasized in Eastern mysticism, are just different aspects of the same idea. This becomes particularly clear in Chinese philosophy. Joseph Needham, in his thorough study of Chinese science and civilization, discusses at great length how the Western concept of fundamental laws of nature has no counterpart in Chinese thought (Needham, 1956, pp. 528ff). According to Needham, the Chinese did not even have a word corresponding to the classical Western idea of a 'law of nature'. The term which comes closest to it is *li*, which Needham translates as 'dynamic pattern'. He says that, in the Chinese View,

"dynamic pattern' rather than ,natural laws'

> The cosmic organisation ... is, in fact, a Great Pattern in which all lesserpatterns are included, and the 'laws' which are involved in it are intrinsic to these patterns. (Needham, 1956, p. 567}

This is exactly the idea of the bootstrap philosophy: everything in the universe is connected to everything else and no part of it is fundamental. The.properties of any part are determined, not by some fundamental law, but by the properties of all the other parts.

limits of bootstrap

When the bootstrap idea is formulated in a scientific context, it has to be limited and approximate, and its main approximation consists in neglecting all but the strong interactions. Since these interaction forces are about a hundred times stronger than the electromagnetic ones, and many more orders of magnitude stronger than weak and gravitational interactions, such an approximation seems reasonable. The scientific bootstrap, then, deals exclusively with strongly interacting particles, or hadrons, and is therefore often called the 'hadron bootstrap'. It is formulated in the framework of
theory and its aim is to derive all properties of hadrons and their interactions uniquely from the requirement of self-consistency. The only 'fundamental laws' accepted are the general Sonatrix principles mentioned above, which are required by our methods of observation and are thus essential parts. of our scientific framework (Chew, 1968). Other properties of the S matrix may have to be postulated temporarily as 'fundamental principles', but will be expected to emerge as a necessary consequence of self-consistency in the complete theory.

mosaic of interlocking models

The phenomena involving hadrons are so complex that it is by no means certain whether the complete self-consistent S matrix will ever be constructed, but one can envisage a series of partially successful models of smaller scope (Chew, 1970). Each of them would be intended to cover only a part of hadron physics and would therefore contain some unexplained parameters representing its limitations, but the parameters of one model may be explained by another. Thus more and more hadron phenomena may gradually be covered with ever-increasing accuracy by a mosaic of interlocking models whose net number of unexplained parameters will keep decreasing. The term 'bootstrap' is thus never appropriate for any individual model, but can only be applied to a combination of mutually consistent models, none of which is any more fundamental than the others.

The picture of hadrons which emerges from these bootstrap models is often summed up in the provocative phrase: "Every particle consists of all other particles." It must not be imagined, however, that each hadron contains all the others in a classical, static sense. Rather than 'containing' one another, hadrons 'involve' one another in the dynamic and probabilistic sense of S-matrix theory, each hadron being a potential bound state of all sets of particles which may interact with one another to form the hadron under consideration. In that sense, all hadrons are composite structures whose components are again hadrons, and none of them is any more elementary than the others. The binding forces holding the structures together manifest themselves through the exchange of particles, and these exchanged particles are again hadrons, Each hadron, therefore, plays three roles: it is a composite structure, it may be a constituent of another hadron, and it may be exchanged between constituents and thus constitute part of the forces holding a structure together.

binding forces

The concept of crossing is crucial for this picture. Each hadron is held together by forces associated with the exchange of other hadrons in the cross channel, each of which is, in turn, held together by forces to which the first hadron makes a contribution. Thus, as Chew (et al., 1964) has put it, "each particle helps to generate other particles which, in turn, generate it." The idea, then, is that this extremely complex bootstrap mechanism is self-determining, that is, there is only one way in which it can be achieved. In other words, there is only one possible self-consistent set of hadrons-the one found in nature.

,interpenetration' and Indra's net

As I have mentioned above, the concept of crossing is extremely hard to visualize, and thus the bootstrap conception of particles presents great difficulties for our imagination. Given these difficulties, it is fascinating to see that the idea of each particle containing all the others has also arisen in Eastern thought. It is to be found in Mahayana Buddhism where it is known as 'interpenetration' and is illustrated by many parables. Here is one of them, taken from the *Avatamsaka Sutra,* * which uses the image of a network of pearls to illustrate the idea of the interconnected web:

> In the heaven of Indra, there is said to be a network of pearls, so arranged that if you look at one you see all the others reflected in it. In the same way each object in the world is not merely itself but involves every other object and in fact *is* everything else, In every

*This scripture is the basis of one of the main schools of Mahayana Buddhism, known as the Avatamsaka school in India, the Hua-yen school in China, and the Kegon school in Japan; *see* Suzuki, 1968b, pp. 147ft·,

> particle of dust, there are present Buddhas without number. [Eliot, 1959, p. 109J

The similarity of this image with that of the hadron bootstrap is indeed striking. The metaphor of Indra's net may justly be called the first bootstrap model, created by the Eastern sages some 2,500 years before the beginning of particle physics.

intellectual incompre-hensibility

Buddhists insist that the concept of interpenetration is not comprehensible intellectually, but is to be experienced by an enlightened mind which transcends the ordinary world of space and time. It can only be experienced, they say, when it is realized that space and time, too, are interpenetrating (Suzuki, 1959). In modern physics, the situation is quite similar. The hadron bootstrap depends crucially on the concept of crossing which can only be understood in terms of relativistic space-time, that is, in terms of a four-dimensional continuum for which the Buddhist 'interpenetration of space and time' seems to be a perfect description. Since most of us have no direct experience of such a four-dimensional continuum, we find it extremely difficult to imagine how a single particle can contain aUother particles and at the same time be part of each of them. This, however, is exactly the view OI the Mahayana:

> When the one is set against all the others, the one *is* seen as pervading them all and at the same time embracing them all in itself. [Suzuki, 1968, p. 52)

CONCLUSION

In conclusion, I want to make a few remarks concerning the question: what can we learn from these parallels? Is modern science, with all its sophisticated machinery, merely rediscovering ancient wisdom, known to the Eastern sages for thousands of years? Should physicists, therefore, abandon the scientific method and begin to meditate? Or can there be a mutual influence between science and mysticism-perhaps even a synthesis?

the question for science

I think that all these questions have to be answered in the negative. 1 see science and mysticism as two complementary manifestations or the human mind, of its rational and intuitive faculties. The modern physicist experiences the world through an extreme specialization of the rational mind; the mystic through an extreme specialization of the intuitive mind. The two approaches are entirely different and involve far more than a certain view of the physical world. However, they are 'complementary', as we have learned to say in physics. Neither is comprehended in the other, nor can either of them be reduced to the other, but both of them are necessary, supplementing one another for a fuller understanding of the world. To paraphrase an old Chinese saying, mystics understand the roots of the *Tao* but not its branches; scientists understand its branches but not its roots. Science does not need mysticism and mysticism does not need science; but man needs both. Mystical experience is necessary to understand the deepest nature of things, and science is essential for modern life. What we need, therefore, is not a synthesis but a dynamic interplay between mystical intuition and scientific analysis.

a dynamic interplay

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The Tao of Physics: An Exploration of the Parallels Between Modern Physics and Eastern Mysticism is a 1975 book by physicist Fritjof Capra. A bestseller in the United States, it has been translated into 23 languages. Capra summarized his motivation for writing the book: â€œScience does not need mysticism and mysticism does not need science. But man needs both.â€ The Tao of Physics: An Exploration of Parallels between Modern Physics and Eastern Mysticism - Fritjof Capra. The Tao of the West: Western Transformations of Taoist Thought - J.J. Clarke. Tracing the Contours of Daoism in North America - Louis Komjathy.Â Alan Watts - The Taoist Way - Alan Watts, lecturer on Eastern philosophy, explains Daoism and its relation to other philosophies. Alan Watts - Lao Tzu's Tao Te Ching - Alan Watts explains and gives commentary on the Daoist classic Daodejing. Alan Watts - The I Ching - Alan Watts expounds on the I Ching, its significance to Chinese culture and the related concepts of Yin and Yang. Modern Physics and Eastern Mysticism, therefore, demonstrate that rhythm and motion are essential aspects of the phenomenal universe. Another parallel is the understanding that all matter, whether here on Earth or in outer space, is participating in a continual cosmic dance (Capra: 1975, 256-259). Moreover, both of them agree on the idea of the emergent and convergent universe. According to Eastern Mysticism, the world of Maya (illusion) changes perpetually, since the cosmic dance of Shiva is a rhythmic, dynamic dance.Â In conclusion, I have examined some fundamental ideas inherent in Modern Physics and Eastern Mysticism. Interestingly, the emerging views in each of the two systems of thought parallel to each other. by Deborah Morrison.