Bhaktivedanta Science
Lecture Series No. 1

The End of Physics

by

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(An illustrated lecture paralleling
the ITV video script, "The End of Physics",
by the same author)

1: Title slide

2: Scene of rolling countryside from the air. [The World We Live In, p. 61]

While looking down from an airplane, the Nobel Prize winning physicist Steven Weinberg once reflected that the earth below looked very familiar and comforting, and that it is almost irresistible for humans to believe that we have some special relation to the universe. Yet he concluded that this is actually an illusion.

3: Picture of the Crab nebula.

This earth is simply a tiny part of an overwhelmingly hostile and alien universe which has evolved from an unspeakably unfamiliar early condition by blind physical processes. These processes made no prevision for man, and indeed, human life is simply a more-or-less farcical outcome of a chain of accidents reaching back to the first few minutes of the big bang. To Weinberg, "The more the universe seems comprehensible, the more it also seems pointless." [Weinberg, pp. 143-144.]

4: Very Large Array radio telescopes, Socorro, New Mexico. [Sagan, 1980, p. 261]

The alienation of modern man from a world which once seemed full of meaning and purpose has been thought by many to be the unavoidable price we pay for advancement in scientific knowledge.

5: Picture of Carlo Rubia watching particle track display. @

We live in a great age of scientific exploration. With instruments such as telescopes, microscopes, and particle accelerators, we have extended the range of our senses from the realm of the stars and galaxies down to the realm of the atoms and subatomic particles.

6: Stars and nebulae. [World We Live In, p. 28]

In recent years our understanding of these two domains has seemed to converge, as theories of subatomic particle physics began to dovetail neatly with theories of the universe as a whole. Physicists were making great strides in creating a unified theory of all forces and material elements--a theory that promised to describe the genesis of the universe from a single, unified principle of great simplicity and beauty.

7: Quantum chaos.

According to this developing theory, the origin of the universe begins with a state of quantum chaos. This state of affairs can be thought of as the closest approximation imaginable to literally nothing. The laws of physics exist, but there is neither space, nor time, nor matter. There is only the quantum

mechanical potentiality for the creation of matter.

8: Quantum chaos with Guth's inflating universes.

In this quantum chaos, bubbles of space-time appear spontaneously by quantum mechanical transitions similar to the quantum jumps of atomic physics. In each bubble time begins, along with an exceedingly tiny region of space. Most of these bubbles disappear as quickly as they form, but some survive to enter a phase of rapid cosmic expansion.

9: Computer graphics showing evolution of the universe according to current ideas. [Based on whimsical poster in Discover, June, 1983, p. 92]

This chart summarizes some of the main stages of development that a given universal bubble is thought to pursue. In the "quantum gravity epoch" the universe obeys a unified force law which ties together gravity and the strong, weak, and electromagnetic forces of subatomic physics. It is under this not-yet-formulated law that space-time itself is thought to emerge from timeless chaos.

The "age of unity" begins after the universe has existed for some 10^-43 seconds. The strong, and electro-weak forces remain unified, but gravity has become a separate force. The universe expands violently from subatomic to grapefruit size, and fills with a swarm of superheated subatomic particles.

As the universe cools, the strong and electro-weak forces become distinct, and the electro-weak force differentiates into the weak and electromagnetic forces. Quarks combine to form protons and neutrons, and after about three minutes of universal history, these particles begin to form helium nuclei.

Later, after some 100,000 years of expansion and cooling, electrons and nuclei combine to form atoms. Galaxies, stars and planets begin to form, and finally life emerges on the earth. According to this scenario, the entire pageant of universal history from quarks to man unfolds strictly according to the laws of physics.

10: Cornell electron storage ring. [Close, 1987, p. 164] --or SLAC particle detector? Particle detector at SLAC. [Close, 1987, p. 127]

Some physicists have anticipated that the development of this all encompassing theoretical picture heralds the end of physics--a time when the secrets of nature will be fully known and no really fundamental discoveries remain to be made.

But there is an ironic twist to this idea. It seems that the new theories cannot be tested experimentally. The key phenomena described by these theories occur at unimaginable energy levels far too high to be reproduced in the laboratory. Physicists seem to be confronted with two unpalatable choices: either give up their quest for an ultimate understanding of nature, or convert physics from the paradigm of empirical science into what Howard Georgi, one of the architects of the new

theoretical picture, calls "recreational mathematical theology." [Crease & Mann, 414.]

11: Picture of telescopes in Hawaii.

We are faced with two rather unsatisfying outcomes of modern scientific research. One is that science has seemed to strip away all the humanly relevant aspects of reality, revealing an underlying chaos of pointless contending forces. The second is that in spite of all our endeavors, the ultimate truths of nature may lie permanently outside the grasp of scientific knowledge, and may simply be a matter of metaphysical speculation.

12: Picture of Fermilab office building. [Omni, Feb., 1984, p. 40]

How have we gotten into this situation? To try to get some insight into this, let us look back over the history leading up to this modern scientific age. We begin by leaving the citadels of modern physics, such as the Fermi National Accelerator Laboratory shown here, and going back thousands of years to an early conception of matter and the material cosmos. This is the ancient Indian (or Vedic) account of the creation of the universe.

13: South Indian temple. [CC, Madhya-lila 3, plate 4]

In making a historical study of this kind, it is important to realize that people of different cultures and periods of history may have ideas that both differ fundamentally from our own, and also have fundamental underlying similarities. To properly appreciate these similarities and differences, it is necessary to momentarily suspend our customary outlook, and to try to enter as much as possible into the worldview of the culture we are studying. Only then will we be able to profitably compare it with our own worldview.

As we shall see, our discussion of the ancient Vedic worldview will first cover some ideas that are completely alien to modern scientific thinking. However, we will also see the gradual emergence of some significant points of similarity.

14: Lord Krishna in Vrindavana [BTG, vol. 15, no. 10, cover]

The central theme of the Vedic worldview is that the absolute cause of all causes is a supreme personality, known by many names such as Krsna and Govinda. The body of Krsna is understood to be completely transcendental. It possesses the materially contradictory attributes of perfect unity and variegated structure. Krsna is thus understood to exist beyond material time and space as we know them.

15: Spiritual world. [S.B., canto 2, part 1, plate 15]

According to the Vedic conception, the totality of all that exists emanates from the personal form of the Supreme Lord. This totality consists of a spiritual realm, having the same materially contradictory properties of oneness and variety, and a

material realm, in which the physical laws of our experience are manifest.

The spiritual realm exists eternally, and indeed it is characterized by the complete absence of material time. In contrast, the material realm is subject to time, which in Vedic terms is regarded as a continuous process of creation and annihilation.

16: Pradhana.

The material manifestation is based on the transformation of a fundamental energy known as pradhana. This energy is comparable in many ways with the quantum chaos envisioned by modern physicists. It is potentially capable of producing all material manifestations, but in its natural, undisturbed state it is devoid of all familiar physical attributes, including the geometrical properties of space.

17: Maha-Visnu [BTG, vol. 13, no. 7, p.3]

According to the Vedic conception, the material creation is initiated by an expansion of the Supreme Lord known as Maha-Visnu. The process of creation results in the formation of innumerable universes, which are maintained for some time, and then merged back into the pradhana prior to another cycle of creation.

18: Brahmandas.

Here we see how these countless universal globes might appear from a vantage point within the pradhana. We should emphasize that it would not be possible to see this scene with our present material senses, since our sense organs are composed of elements that become manifest only within the material universes. According to the Vedic conception, however, we ourselves are non-material in essence, and it is actually possible to see a scene such as this (or the preceding scene) by the development of higher consciousness.

19: Labeled universal shells.

This picture shows a schematic cross section through one of the universal globes, or brahmandas. We see that this globe consists of a series of concentric shells composed of material elements in various stages of development. The brahmanda is said to begin as atomic in size, and then expand. As it develops, the pradhana making up the globe is first transformed into a state known as mahat-tatva. Within the globe of mahat-tatva a smaller globe of false ego becomes manifest. Within this a globe of ether becomes manifest, followed by successively smaller globes of air, light, water, and earth. Finally, the observable cosmos of our experience becomes manifest within the globe of earth.

The elements of mahat-tatva, false ego, ether, and so on are successive transformations of the pradhana, rather than independent substances. They are stages in the generation of

gross matter from subtle material energy, and each successive stage is characterized by the introduction of new material properties.

20: Universal shells, shown with proportion of 1/2.

For convenience, we have shown the successive shells of elements as being of equal thickness, but actually each successive shell is 1/10th the thickness of the one preceding it, and the observable cosmos has a diameter of 1 ten-millionth of the brahmanda as a whole. Here we show the effect of this by using a ratio of 1/2 rather than 1/10.

21: False ego.

To understand the Vedic conception of the universe, it is important to realize that according to Vedic thought, the conscious self or atma is not a product of the material energy; rather, it is a tiny particle of the superior potency of the spiritual realm.

Within the material universes, conscious selves are subject to the illusion of having a false self (or false ego) composed of material energy. The manifestation of the material energy that is responsible for generating this illusion is thus known as false ego (or ahankara). Here we represent the atma as an effulgent spark surrounded by an insentient false persona generated by false ego.

22: Ether = material space.

The element of false ego generates all further material elements that go into the manufacture of the false material selves. The first of these elements is ether, which in Vedic terms is equivalent to space itself. We can thus compare ether with the space-time continuum which is manifested from quantum chaos in the latest cosmological scenarios. Outside the region of ether, material space as we know it does not exist.

From ether, the element air is generated, which is characterized by the property of touch, or tangibility. Air in this sense should be distinguished from the idea of atmospheric air as one substance among other substances.

23: Light (tejas) = form and electromagnetism.

From air the element of light (or fire) is generated. According to the Vedic conception, this element is responsible for all manifestations of light, fire, heat, and electricity. As such it seems to correspond with the modern scientific idea of electromagnetism. It is interesting to note that the element of light is responsible for the generation of material form. One possible parallel to this is that in modern physics, the electromagnetic force is held to be responsible for complex forms, which are all based on the electromagnetic interactions of atoms.

24: Inner sphere = the observable universe.

From light the elements of water and earth are successively generated. Within the globe of earth, the properties of matter are fully developed, and it is within a small part of this region that the observable cosmic manifestation takes place.

25: Renaissance diagram of the structure of the universe [Heninger, 1977, p. 28]

In our historical survey we now turn to the European renaissance, a period which lies on the watershed between ancient and modern ways of thinking. Here we see a renaissance diagram depicting contemporary ideas concerning the structure of the universe.

At this time Europe was awash in the flotsam and jetsam of the ancient world. Of course, most Europeans in this period were Christians. However, Christianity had incorporated many of the teachings of ancient Greek philosophers such as Plato and especially Aristotle, whose system of physics formed a standard part of the academic curriculum. The works of later Greek scientists such as the astronomer Ptolomy also formed an important part of this curriculum.

Finally, mystical and alchemical teachings coming from various ancient sources were widely studied during the renaissance period. These included the Jewish Cabala and the writings of Hermes Trismegistus, an ancient sage who was reputed to have been a contemporary of Moses.

26: Computer generated diagram showing the medieval and renaissance cosmos.

The renaissance conception of the universe was based largely on Aristotle and Ptolomy. Here we see a simplified diagram showing the main features of this conception. The earth is at the center, and surrounding it are the orbits of the planets.

The universe has concentric shells of water, air, fire, and ether which surround the earth, and are surrounded in turn by heaven (empyreum) and the abode of God. This arrangement is reminiscent of Vedic cosmology, but there is one striking difference. In the Aristotelian system followed in Europe, the shell of ether begins beneath the orbit of the moon, and thus the sun, moon, and planets were regarded as being ethereal in nature. In contrast, the Vedic system places the entire visible cosmos within a small part of the sphere of earth.

A second key difference is that in the Aristotelian system the four elements, earth, water, fire, and air were regarded as more-or-less independent substances that sort themselves into layers around the earth on the basis of their relative degree of lightness (levity) or heaviness (gravity). Some thinkers, however, also proposed that these elements were successive condensations of the more subtle element of ether.

27: Portrait of Robert Fludd (1574-1637). [Debus, 1979, frontispiece]

Just to convey some of the flavor of the thinking of that period, we shall briefly consider the ideas of Robert Fludd, an Englishman who was a contemporary of Francis Bacon. Fludd was a physician and the author of a number of philosophical and cosmological works. Whereas Bacon is generally regarded as a forerunner of the modern, empirical outlook on nature, Fludd was one of the last persons to elaborately present the old, medieval view.

Fludd maintained that the material cosmos was generated from an original substrate, which he calls materia prima (first matter). This substrate has the potential to produce all material manifestations, but there are no actual manifestations within it, and thus it can be called "nothing". The materia prima is thus similar to the Vedic pradhana and to the "quantum nothing" of modern cosmology. In agreement with the Vedic system, Fludd maintains that the materia prima was activated by God to produce the material creation. This is his understanding of "creation ex nihilo".

28: Computer graphics rendition of Fludd's diagram of the material world as a reflection of the spiritual world. [Heninger, 1977, p. 83]

This diagram depicts Fludd's conception of the relation between the material and spiritual worlds. According to Fludd the material world is a reflection, or shadow likeness of the spiritual realm, and both the forms and substances of this world have their counterparts in the spiritual world. In the diagram, the blue circles in the lower, material half represent the successive spheres of empyreum, ether, and the four gross elements. In the Bhagavad-gita and other texts of the Vedic tradition, a very similar conception is presented.

29: Human body divided into elemental, mental, and spiritual layers. [Debus, 1979, p. 41]

Here Fludd alludes to another Vedic theme. This is that the soul, by a process of self purification, can travel to the spiritual world by passing from the gross state of existence to progressively subtler states, until finally it is completely free from any connection with the material energy. As we have already pointed out, the Vedic tradition maintains that the atma or conscious self is a spiritual entity which has become entangled in a body of gross and subtle material elements. Since all levels of subtlety, from earth up to the original spiritual level, are present right here on earth, it is possible for the soul to travel to the spiritual realm by a process of gradually disentangling itself from false material identification.

In this illustration Fludd represents self purification symbolically, by dividing the human body into levels ranging from earth in the genital region, up to ether in the chest, and pure spirit above the head. This should be compared with traditional diagrams used to illustrate the yoga process.

30: Early 16th century clock (by Jacob Zech). [Goudsmit, 1980, p. 94]

Such was the worldview of Robert Fludd, a man steeped in the ancient traditions that still persisted in Europe in the 16th and early 17th centuries. But during this same time, another way of looking at the world was being rapidly developed. Instead of seeing the world as a manifestation of subtle elements, emanating from a spiritual source and intimately connected with that source, others were seeing it as--a clockwork.

With the development of clocks in the 13th century, Europe had become fascinated with the idea of a machine that can operate entirely by itself. This led quickly to the creation of many mechanical inventions, both practical and impractical, ranging from the mechanically propelled carriages and flying machines of Roger Bacon to the many mechanical schemes of Leonardo da Vinci.

And a hundred years before Leonardo, Oresme had already likened the universe to "a man making a clock and letting it go to be moved by itself." [Jaki, p. 53]

31: Two meshing gears.

The comparison between the universe and a clock was only a metaphor. However, it did suggest an intriguing idea. If so many things that we can directly see and analyze can be understood in terms of mechanical cause and effect, then perhaps the ultimate constituents of nature are tiny mechanical parts.

32: Gears and surroundings made of "ultimate gear wheels".

With the revival of knowledge of the Greek atomic theory of Democritus, people began to envision a concrete, mechanical model of the universe, and they elaborated a new mechanical philosophy to go along with it. They began to regard matter as a system of tiny particles, or atoms, that interact with one another mechanically according to fixed mathematical laws and thereby produce all the phenomena of the universe.

33: Picture of alchemist.

The new mechanical approach to nature had some very attractive features. First of all, it was clearly intelligible. If all matter was made of tiny particles that mechanically interact, then in principle it should be possible for the human mind to fully understand nature. Mechanical explanations were much easier to understand than the explanations of most contemporary scholars, who simply speculated about mysterious qualities and principles that neither they nor anyone else could clearly define.

34: Alchemical symbol for the "essence of mercury". [Lapp, 1963, p. 17]

And, of course, the mechanical picture was much clearer than the mystical treatises of the alchemists, who described matter using arcane allegories and symbols that could be understood, if

at all, only by initiates.

35: Portrait of Galileo Galilei [Utet, 1969, op. p. 32]

Also, the mechanical approach made it possible to immediately obtain interesting experimental results. If nature is a machine, then it must be made of parts (like the gears of a machine) that relate to one another in a simple, quantitative way. The early Italian scientist, Galileo Galilei, was one of the first persons to use experiments to discern mathematical laws operating in nature.

36: Galileo's inclined plane experiment.

One example is the law that the vertical distance traveled by a freely falling body is proportional to the time since the start of its fall. Galileo is said to have demonstrated this by rolling metal balls down an inclined plane, and adjusting movable wires in their path so that the resulting clicks made by the balls followed a steady musical beat.

37: Boyle's law demonstration.

Here is another simple example. This apparatus was used by Robert Boyle, a 17th century English scientist who helped found the Royal Society, one of the worlds first scientific organizations. By adding mercury to one end of the tube and measuring the volume of trapped air in the other end, Boyle showed that air pressure is inversely proportional to volume, a finding that has a simple mechanistic explanation.

Early scientists such as Boyle and Galileo were quite emphatic about their belief in God. However, once the mechanistic view of nature was adopted, a sharp dichotomy was created between the spiritual and the material. If matter shades off through a hierarchy of levels from gross to subtle, then one can readily imagine how God, acting on the most subtle level, can control the behavior of gross matter. But if matter is mechanical from top to bottom, then a transcendental God can direct nature only by interfering with the machinery and causing a "miraculous" violation of mechanical cause and effect.

This problem was discussed extensively by Boyle, but it attained severe proportions with the work of Isaac Newton.

38: Portrait of Isaac Newton [Manuel, 1968, op. p. 334]

Sir Isaac Newton was an enigmatic figure, a mathematical genius who revolutionized the newly developing mechanistic science, but who also wrote many books on theology and devoted nearly 30 years of his life to the study of alchemy. In a brief period in the 1660's Newton wrote his famous Principia mathematica, which introduced precise mathematical laws of motion that applied equally to the planets and to objects on the earth.

39: Computer graphics reproduction of a page from Newton's Principia (in Latin).

Using Newton's methods it became possible to establish a new standard of mathematical explanation. A theory was considered to be correct if it provided mathematical rules precisely defining the motion of the material particles making up the physical system. For over two hundred years Newton's laws of motion were regarded as the basis for all scientific explanations of natural phenomena. Physical science became a series of footnotes to Newton.

40: Newtonian force diagram.

One feature of Newton's laws of motion is that they are deterministic. This means that the physical conditions at one time rigidly determine what will happen at all future times. For example, the future motion of the masses shown here is completely determined by their positions and their velocities (the blue arrows) at one moment in time. Similarly, to consistent Newtonians, everything that happens in nature, including your decision to watch this slide show right now, is rigidly determined by the way matter was set in motion at the beginning of the universe.

41: Portrait of Gottfried Wilhelm von Leibniz [Manuel, 1968, op. p. 335]

Of course Newton himself was not a Newtonian. He thought that God would interfere with the motion of matter from time to time in such a way as to exert direct personal control of the world.

But many of his contemporaries disagreed, including the philosopher Gottfried Wilhelm von Leibniz. To Leibniz it seemed like bad craftsmanship if God had created a machine that needed continual personal attention. After all, couldn't mere humans build clocks that would run for days automatically? It seemed much more consistent with God's glory and perfection to suppose that God had ordained the physical laws, wound up the universal clockwork in the beginning, and simply let it run automatically with undeviating Newtonian precision.

42: Diagram of Atma perceiving different colors.

As the mechanistic outlook became established, it also became more and more difficult to see how a nonphysical mind or soul could interact with matter, and thereby direct the operation of the brain. This diagram illustrates the Vedic understanding of visual perception: Physical light of different wavelengths gives rise to the conscious perception of colors in the atma. The sensory connections, indicated by the red lines, involve the transfer of sense data from gross matter to the atma through a series of stages of increasing subtlety. By eliminating the intermediate stages, the mechanistic philosophy created a nearly unbridgeable gap between matter and spirit. Newton's predecessor, Rene Descartes tried to explain how this gap might be bridged, but his explanations did not prove convincing, and

gradually the very idea of a nonphysical self was dropped from the worldview of science.

43: Picture of Lavoisier. [Sci. Amer., Jan. 84, v 250, n 1, p. 136]

At the same time that it was revolutionizing man's concepts of God and the soul, the new mechanistic outlook was also bringing about profound changes in people's understanding of the elements making up matter. In the emerging science of chemistry an element came to mean a subunit of matter that could not be broken down into smaller subunits. On this basis, scientists such as Joseph Priestley and Antoine Lavoisier showed experimentally that earth, water, and air are not elements, but rather chemical compounds or mixtures. Here Lavoisier is demonstrating how water can be formed by igniting a mixture of hydrogen and oxygen.

44: Rumford's heat experiment.

Fire retained its elemental status for a while longer. In the early 19th century it was widely accepted that heat is a substance. Scientists called this substance caloric, and they thought that the warming of a cool object by a hot object is due to the flow of caloric. This idea was torpedoed by Count Rumford, a rather colorful American scientist who, while not performing experiments, managed to become a Count in the Electorate of Bavaria.

In the experiment shown here, one brass rod turns continuously against another in a container of water. As long as the rod is rotated, enough heat can be generated by friction to continuously boil the water. Rumford reasoned that this heat could not be flowing into the apparatus like a fluid, since the water still boils even if the rods are attached to insulated supports. He arrived at the modern conclusion that the heat must be due to mechanical vibrations generated by the scraping together of the rods.

45: Portrait of Michael Faraday [Crowther, 4rd plate after p. 100]

This brings us to the subject of ether. In 1830 the British scientist Michael Faraday was performing experiments in an attempt to understand the mysterious phenomenon called electricity. Using simple arrangements of iron rods and coils of wire, he was able to show that by changing the flow of electrical current in one coil, he could induce a flow of current in another coil.

46: Magnetic field.

To explain such observations Faraday proposed a radical theory: He suggested that magnets and electric currents produce something called force fields that extend through space, and have a definite structure. He thought that the pattern of iron filings produced by a magnet trace out such a field.

47: Picture of James Clerk Maxwell [Crowther, 10th plate after p. 100]

The idea of a force field turned out to be highly useful, but also extremely difficult to assimilate into the existing framework of thought. The physicist James Clerk Maxwell used Faraday's field concept to create a complete mathematical theory of electrical and magnetic phenomena, and in the course of this he showed that light could be interpreted as an electro-magnetic disturbance that travels like a wave through space.

48: Maxwell's mechanical model of electro-magnetism.

If electric and magnetic disturbances can propagate through empty space, it would seem that space must not be empty. At first, Maxwell created mechanical models of electromagnetism, such as this one, which featured arrays of rotating vortices (shown in red) and movable balls (shown in blue). If these vortices and balls existed everywhere in space, their movements could account for all known electromagnetic phenomena.

Later, Maxwell described electromagnetic fields in a more abstract way by assigning electric and magnetic "forces" to all points in space. Nonetheless, he and his contemporaries believed that these forces must be strains or deformations in a mechanical substrate that pervades space. This substance came to be known as the luminiferous ether.

49: Waves propagating in a stationary medium.

For years physicists tried to formulate consistent models of this ether. Their basic idea was that the ether is an elastic medium that propagates waves in much the same way that ripples are propagated across the surface of a body of water.

If light is indeed a wave moving through ether, then light should move at different speeds, depending how fast the ether is moving past us. We can see this by considering the water example. If the water is still, as shown here, then the waves move out with equal speed in all directions.

50: Waves propagating in a moving medium.

But if the water is flowing past the vibrating source, then the ripples move more slowly upstream than downstream. Scientists assumed that the ether surely could not be stationary with respect to the earth, and thus they thought that the speed of light should be greater in some directions than in others.

51: Portrait of Michelson.

In 1887 the American physicist Albert Michelson and his partner Edward Morley made an attempt to detect this directional difference in the speed of light. For this purpose they had to make very delicate measurements involving the interference of beams of light that have traveled in perpendicular directions.

52: The Michelson-Morley Interferometer of 1887 [Swenson, 1972, 5th illustration after p. 106]

Here we see an old photograph of their original apparatus, in which mirrors guiding the beams of light are mounted for stability on a block of sandstone floating in an annular trough of mercury.

To their surprise, Michelson and Morley found no detectable effect. Either the ether was stationary relative to the earth, or the whole ether theory was wrong.

53: Portrait of Albert Einstein [Science 84, Nov., p. 61]

This finding resulted in a series of fundamental theoretical developments culminating in 1905 with Einstein's theory of relativity. It is often said that this theory banished the idea of an ether from physics. But to Einstein himself, relativity simply required an ether that is not a physical substance.

According to Einstein, "More careful reflection teaches us... that the special theory of relativity does not compel us to deny ether. We may assume the existence of an ether; only we must give up ascribing a definite state of motion to it...

According to the general theory of relativity, space without ether is unthinkable; for in such space there would not only be no propagation of light, but also no possibility of existence for standards of space and time..." [Cantor and Hodge, pp. 53-54.]

The moral of the story is that some very fundamental things in nature simply cannot be understood in terms of the mechanical interaction of parts like the visible, understandable parts of man-made machines.

54: Bohr, Heisenberg, and Pauli. [Rozental, 1967, op. p. 97]

And this was only the beginning. In the 20th century the bottom fell out of the secure, intelligible world of classical, mechanistic physics.

In the years following World War I physicists such as Niels Bohr (on the left) and Werner Heisenberg (in the center) developed a new, fundamental physical theory in order to explain the mysterious properties of atoms.

55: Hydrogen atom.

Initially Bohr had created a model of the hydrogen atom, in which the lightweight electron orbits about the massive nucleus, as shown on the left. Later, however, it turned out that the electron could not be understood simply as a particle following a definite orbit. It had to be described by a standing wave pattern that at any one time extends throughout space in the vicinity of the nucleus. This is shown on the right, where the density of the yellow stippling indicates the strength of the electron wave.

56: Double slit experiment.

The wavelike behavior of an electron is not limited to phenomena on the scale of an atom. It also shows up in the double slit experiment, which was first used in the 19th century to demonstrate the wave nature of light. In this experiment, a wave coming from the left passes first through the single slit on the left of the apparatus, then through the two slits in the middle, and finally it reaches the screen on the right.

57: Double slit interference pattern.

Here the behavior of such a wave is indicated. As the wave, moving to the right, passes through the two slits in the center of the picture, it forms two waves which interfere with one another. If one observes the screen one will see an interference pattern consisting alternating bands of high and low wave intensity.

58: Wave-particle duality.

Electrons be can sent through this apparatus instead of light. In that case we use a phosphorescent screen, so that each electron will make a visible flash as it hits the screen. The top rectangle shows the cumulative pattern of flashes after 10 electrons have gone through the apparatus. It appears that electrons are behaving as small particles.

The bottom rectangle, however, shows the cumulative pattern of 300 electrons. We see that the flashes concentrate in bands exactly corresponding to the kind of interference pattern made by waves. This suggests that a real wave must be passing through the apparatus to create this pattern. But actually, all that has happened is that 300 electrons have passed through, one after another, and each one behaved just like a small particle, producing a localized flash where it hit the screen. Where then is the wave?

At present physicists describe phenomena such as these with a mathematical formalism called quantum mechanics, which we can think of here as involving an arbitrary shift from wave to particle. One first analyzes the two slit experiment using a wave model. Then one uses the wave to determine where the particles are allowed to show up. Only the statistical behavior of many particles is determined by the wave, and so an element of chance is brought into the theory to explain what an individual particle does.

59: Wheeler diagram. [Discover, Oct. 1982, p. 76]

Heisenberg, who was schooled in Greek philosophy, likened this transition from wave to particle to the conversion of potentiality into actuality. This of course is reminiscent of Fludd's materia prima, and the Vedic pradhana.

If we apply quantum theory to the universe, as physicists are wont to do, we encounter the same problem of wave and particle on a universal scale. The "potential wave" of the universe encompasses many possible universal histories, but

somehow we live in an actual universe in which one particular history has taken place. Physicists have made many attempts to make sense out of this, and this picture illustrates one by the physicist John Wheeler, who proposes that the universe brings itself into actual being by its own observation of its potential self.

60: Computer graphics showing particle interactions recorded by the UA1 detector at CERN. [Close, 1987, p. 194]

This discussion gives us a hint of some of the puzzling problems that lie at the foundations of the quantum theory. But physicists in general have not let these problems impede their work. They have forged ahead, discovering many new subatomic phenomena, and devising new theories to explain them. Since World War II, the main line of advance has been made using high energy particle accelerators. By smashing together subatomic particles at higher and higher energies, and observing the tracks made by particles emerging from the collisions, physicists have learned more and more about how they interact.

61: Picture of the first cyclotron. [Van Nostrand's Scientific Encyclopedia, 5th ed., 1976, p. 17]

At first, this research could be carried out with fairly simple equipment. The first atom smasher made by Ernest Lawrence in the 1920's was only a few inches in diameter.

62: The Large Electron-Positron Collider (LEP) at CERN, near Geneva. [Close, 1987]

As particle accelerators grew more and more powerful, the theories explaining the phenomena they produced predicted more and more energetic phenomena. Gradually, particle accelerators became so large that aerial photography is necessary to indicate their size.

Here at CERN near Geneva, Switzerland, we see the circular path of accelerated particles in the projected Large Electron Positron machine, which is some 27 kilometers in circumference.

63: Photo of Manhattan showing size of proposed "Superconducting Supercollider" [Science 85, Nov., p. 70]

There are plans for even bigger accelerators. Here the ring of the proposed 5-billion dollar Superconducting Supercollider is shown as it would appear if built around New York City. This machine is planned to accelerate particles around a ring 94 kilometers in circumference, and bring them up to energies of 20 trillion electron volts.

But to adequately test the latest Grand Unified Theories, much higher energies are needed--energies of up to 100,000 billion billion electron volts, which would require an accelerator some 10 light years in length. It looks as though this particular line of research is rapidly reaching limits beyond which it cannot go.

64: Exploding watch

High energy particle physics has been compared to the process of studying a watch by firing a bullet at it and observing the tracks made by the pieces that come flying out. By such methods we might learn something about the structure of the watch. But one thing that we would be sure to miss would be information concerning the complex details of that structure.

To get an idea about what we may be missing in the search for an ultimate theory of nature, let us take a brief look at the latest physical theories. These theories are based on what are called quantum fields--mysterious, insubstantial patterns of energy that extend through space like Faraday's force fields, but which also have the strange, paradoxical qualities we find in quantum mechanics.

65: Quantum field.

The quantum fields are the new elements of modern physics. According to current theories, all material objects are made from them, even though their properties are quite different from the properties of matter as we normally experience it. Thus the solid material foundation of the mechanical universe has been stripped away, to be replaced by abstract webs of quantum mechanical potentiality. In these fields virtual particles--patterns of energy that do not quite exist--are continually appearing and disappearing. The rigid determinism of Newtonian physics is gone, and events appear to take place with unpredictable spontaneity.

66: Wave field as illustration of quantum field.

In this picture we use a very pedestrian example to illustrate the nature of a quantum field. We show a simple wave field, a flexible continuum that can oscillate up and down and transmit waves, just like the surface of a pool of water. We have shown the field in a state of motion that appears chaotic. To understand an actual quantum field, one should imagine infinitely many similar wave patterns, all co-existing in a potential state, and giving rise to large scale phenomena that are definite and actual.

67: Weight and spring model of the field.

Our pedestrian wave field can be represented by the mechanical model shown here, in which weights connected together by elastic bands are free to oscillate up and down. Given the positions and velocities of these weights at one time, it is easy to calculate with a computer what the wave field will do as time passes.

68: The wave field in color coded form.

Here we see the original wave field in color coded form.

The so-called "strength" of the field is indicated by the colors shown on the left, with blue and black indicating positive strength, yellow indicating zero, and red indicating negative strength.

We will now follow the changing wave field, starting with our original chaotic state, and taking a look at the field at 5 second intervals.

69-78: Sequence of 10 steps at 5 sec intervals, showing appearance of A and Aum. Pause at last frame.

We see that a letter A appeared and disappeared, followed by the symbol for Aum. Let us replay the appearance of the Aum in greater detail, observing the field at 1 second intervals.

79-86: Sequence of 8 steps at 1 sec intervals showing appearance of Aum in greater detail. Pause at last frame.

We see that the symbol quickly materializes from an apparently chaotic pattern and then quickly dissipates. Actually, both the A and the Aum were deliberately coded into the initial wave pattern, and it only looked chaotic. The coding method is based on the well known principles governing the making of holograms.

The point of this example, is that the noise which is continuously manifesting from quantum potentiality on a subatomic level may actually contain subtle information, and it is possible for that information to manifest in the production of organized form on the visible, tangible level. (We note, parenthetically, that this phenomenon can be even more strikingly exhibited in so-called nonlinear systems than in the simple, linear system used here.)

87: Supersoul [BTG, vol. 21, no. 11, p. 2]

To thinkers in the Vedic tradition, as well as to renaissance Europeans like Fludd, the transformation from potential to actual was directed by the will of God, who was regarded as omnipresent and all powerful. Modern physics still follows the mechanistic tradition, which long ago banished God from any direct role in the universe. But the new physical theories actually provide a natural way for God to exert control over nature. According to the Vedic philosophy, the Supreme Lord directs the action of the material elements by evoking subtle sound vibrations in the pradhana. We can likewise imagine how God could influence material actions and reactions by injecting delicate, orderly vibrations into the virtual chaos of the quantum field.

88: Atma above the layers of elements.

If there is any truth to such ideas, how could we go about obtaining practical verification of it? It would indeed be difficult to try to trace out the emergence of order from subatomic chaos, and this certainly cannot be done using the

current methods of experimental physics. However, the ancient traditions describing a transcendental, spiritual nature also describe how we can obtain direct knowledge of that nature.

The key idea here is that the atma, or innermost self, actually belongs to the transcendental nature.

89: Free and embedded atmas, with labels for the elements.

We are actually spiritual, and we interact with the elements of matter, starting with the most subtle element of false ego. Here this is depicted by surrounding the atmas in the material world by successive layers of elements, which indicate the order of transmission of information between transcendental and gross material levels. The inner layers constitute what is traditionally known as the subtle body, and the outer layer constitutes the gross physical body of our ordinary experience.

According to this idea, the transmission of sense information between the self and the physical brain will involve vibrations in the element of ether, or space, which links the gross and subtle elements.

This diagram uses circles and bands of color to indicate how different subtle and gross elements interact, but actually all elements, from transcendental to gross, are present everywhere in the material realm. The atma under the influence of false ego directly interacts only with the material elements, but it is also possible for the atma to operate entirely on a transcendental level, as shown at the top of the picture.

90: Yogi. [BTG, vol. 10, no. 4, cover]

We began this presentation by pointing out the frustrating meaninglessness that characterizes the universal worldview of the modern physicists. According to the Vedic perspective, it would indeed be futile to try to storm transcendence through calculation and the manipulation of material machines. However, by a process of spiritual purification, the self can directly realize its own spiritual nature, and return to its original transcendental source. Here may be the real key to understanding the mysteries of the universe.

91: Credits.

92: Address for more information.

93: The End.

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