TEILHARD'S VISION OF THE WORLD AND MODERN COSMOLOGY

by Michael Heller

Abstract. Some physical aspects of Teilhard's synthesis are focused upon and confronted with the recent achievements of physics and cosmology. The stuff of the universe, according to modern physical theories, has become something more similar to a structure or form than to inert pieces of material substratum. Directedness of time and history no longer seems to be an ontological *a priori* of any existence, but rather an outcome of finely tuned initial conditions. And the growth of complexity is now regarded as a process emerging out of physical laws rather than a foreign element in the body of physics. The question is considered of how these results affect Teilhard de Chardin's vision of the world.

Keywords: complexification; cosmology; evolution; matter; Pierre Teilhard de Chardin; time.

In Teilhard de Chardin's vision of the world one can distinguish two layers. Although closely interwoven with each other, they are clearly visible. The first layer consists of a very specific interpretation of scientific data, the second layer, of a certain mysticism which gives a peculiar atmosphere to Teilhard's work. He was a biologist, and there is no doubt that his vision of the world borrowed its main features from biology. However, no global vision of the world claiming to be based on or oriented toward the sciences, can avoid taking information from physics in general and from cosmology in particular. "To push anything back into the past"—this is the opening sentence of *The Phenomenon of Man*—"is equivalent to reducing it to its simplest elements. Traced as far as possible in the

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direction of their origins, the last fibers of the human aggregate are lost to view and are merged in our eyes with the very stuff of the universe" (PM[b], 43). To deal with "the stuff of the universe" is, in Teilhard's opinion, the task of physics and cosmology.

The importance of the physical ingredient of Teilhard de Chardin's vision of the world is obvious. In fact, the entire first part of *The Phenomenon of Man* is devoted to contemplating the past of the universe "as it must appear to an observer standing on the advanced peak where evolution has placed us" (PM[b], 39). Since Teilhard's time, this peak has grown higher, and today we better see the details of the world's history. It would be of great interest to critically compare our present understanding of the physical world with that which entered Teilhard's way of seeing. That is precisely the aim of this essay. To make this goal practicable, I shall focus on *The Phenomenon of Man*, only occasionally referring to other Teilhard writings.

When reading *The Phenomenon of Man*, one can relatively easily trace Teilhard's information source concerning current cosmological ideas. The manuscript of *Le Phénomène humain* was ready in 1938 (and first published in 1955); at that time the most elaborated cosmological theory was that of Georges Lemaître. By 1955 the steady-state cosmology was also on the market. Since, however, it presented the stationary rather than evolutionary universe, it did not fit Teilhard's scheme. No wonder, therefore, that Teilhard's knowledge of cosmology was mainly based on Lemaître's writings. In a footnote at the end of the first chapter of *The Phenomenon of Man*, one reads: "Nowadays, for various convergent reasons, notably Relativity combined with the centrifugal retreat of the galaxies, physicists prefer to turn to the idea of an *explosion* pulverizing a primitive quasi-atom within which space-time would be strangulated (in a sort of natural absolute zero) at only some millions of years behind us (PM[b], 52).[1] This is a clear echo of Lemaître's views on the primeval atom and its subsequent decay ("pulverization") which gave origin to the universe and its present variety of forms. Teilhard also mentions an "unresolved simplicity" that is "at the very bottom" of things—typical elements of Lemaître's cosmology.[2] Lemaître's idea that the primeval atom—the simplest possible state of matter—initiated the evolution and complexification of the universe certainly pleased Teilhard's aesthetic taste for dualism, and also supported his key concept of the maximum complexification state fulfilling the history of the universe. If Teilhard de Chardin calls the latter Omega, the former is sometimes referred to as Alpha (see, for instance, PM[b], 283).

In the present study, I do not intend to trace vestiges of cosmological ideas spread in Teilhard's writings; my goal, I think, is more ambitious. Teilhard's vision of the world is doubtless based on three views which he arrived at by reflecting on contemporary physics and cosmology. They are: the view on matter as the stuff of the universe; the view on evolution in time as a fundamental feature of the universe; and the view on a special type of energy which is responsible for the complexification of the universe. Approximately half a century has elapsed since Teilhard de Chardin formulated his vision of the world, and it seems reasonable to confront these three tenets of Teilhard with the recent developments in physics and cosmology.

STUFF OF THE UNIVERSE

Teilhard's vision of the world starts with matter and ends with spirit as two poles of the same reality. At the Alpha point, matter originates and through the growth of multiplicity and gradual complexification attains its final state at the point of Omega, where Spirit dominates and completes the evolution of the universe. Teilhard de Chardin underwent a similar line of development in his personal life: from the early fascination with matter (iron, crystals, rocks), through the "cosmic sense" which apprehends separate things as elements of a wider whole, up to the experience of a single all-embracing Form or Spirit, the final goal of the evolution (King 1981, chap. 1).

In the vision of the world presented in *The Phenomenon of Man*, "the stuff of tangible things reveals itself with increasing insistence as radially particulate yet essentially related, and lastly, prodigiously active" (PM[b], 44). In the physicist's analysis, matter "tends to reduce itself into something yet more granulated" and is "in an unending state of disintegration as it goes downward" (PM[b], 44–55). In this process, "beyond a certain degree of depth and dilution," we lose the familiar properties of our macroscopic world: light, color, warmth, impenetrability, etc., and "indeed, our sensory experience turns out to be a floating condensation on a swarm of the indefinable" (PM[b], 45). Although matter itself, at its fundamental level, certainly is not a tangible thing, it is "the substratum of the tangible universe" (PM[b], 45).

In spite of its "radically particulate" character, matter reveals its holistic aspects. "Considered in its physical, concrete reality, the stuff of the universe cannot divide itself but, as a kind of gigantic 'atom', it forms in its totality . . . [the] only real indivisible" (PM[b], 47).

Precisely because of its holistic aspects, matter, as it appears to Teilhard's visionary intuition, is far from being an inert stuff of the mechanistic philosophy. "Matter reveals itself to us *in a state of genesis* or becoming" (PM[b], 53; italics in original). The process of *granulation* "gave birth to the constituents of the atom and perhaps to the atom itself" (PM[b], 53). The holistic aspect of matter does not consist in a repetition of the same pattern; different pieces of matter become a whole by the structural interaction of everything with everything. This interaction is at the basis of the creative process of complexification, the key concept to understanding Teilhard's system. In this sense, matter is "prodigiously active."

When reading Teilhard's writing, one has a strong impression that the entire system was constructed by him to overcome the "temptation of matter." One should not forget that in Teilhard's time positivistic and materialistic tendencies were much more alive in the sciences than nowadays (in the biological sciences they are still quite strong). The strategy chosen by Teilhard (the choice certainly being conditioned by his personal experience) consisted of affirming matter rather than "fighting it," however not as an independent absolute but as the other pole of Spirit. "The difficulties we still encounter," writes Teilhard, "in trying to hold together spirit and matter in a reasonable perspective are nowhere more harshly revealed. Nowhere is the need more urgent of building a bridge between the two banks of our existence—the physical and the moral—if we wish the material and spiritual sides of our activities to be mutually enlivened" (PM[b], 67–68). This perspective should be kept in mind if we try to understand why Teilhard so strongly insisted on the "tangible" character of matter in spite of its "disappearance" on deeper levels of "granulation." Even if matter in itself is not a tangible thing, it is "the substratum of the tangible universe."

To contemporary theoretical physicist, Teilhard's "temptation of matter" or his "involvement in matter" is difficult to understand. The "stuff of the universe" as seen through the eyes of modern physical theories has very little in common with the traditional concept of matter; it has become so abstract and so far away from the sensory perception that to many philosophizing physicists it looks more like a "pure form" than a substratum of what can be seen and touched. To elucidate this intuition I shall not comment on the host of enunciations by outstanding physicists similar to that of John Barrow: "We must recognize that 'things' like photons and neutrons cannot be 'real' in the same way that we think that chairs and tables are real. They are more like shadows: arising from a combination of light and the observer's situation" (1988, 150). Neither shall I develop Misner's idea that "the world's hardware is its software."[4] Instead, I shall briefly present some results of the modern quantum field theory relevant to our understanding of the concept of the "stuff of the universe."

Quantum field theory is not only the most successful physical theory (its predictions concerning electron-photon interactions are correct to within one part in 10^8), it is also the most adequate theory explaining three of the four fundamental physical interactions, namely, electromagnetic, nuclear weak, and nuclear strong interactions (it does not refer to gravity). It is more fundamental than the ordinary quantum mechanics since it is relativistic, and the ordinary quantum mechanics is to be recovered from it by a suitable limiting process (quantum field theory is essentially quantum mechanics with an infinite number of degrees of freedom). There are strong reasons to believe that, in the present state of the development of physics, one cannot understand the "stuff of the universe" without referring to quantum field theory.

Quantum field theory is a relativistic theory, that is, its laws are the same in all inertial reference frames. This means that the empirically testable predictions of quantum field theory cannot change if we make a transition from one inertial frame of reference to another inertial frame of reference. Mathematically, such a transition is performed with the help of the so-called Poincaré transformation. Here we have reached the key point of my argument.

From the point of view of the majority of physics textbooks, the Poincaré transformation is merely a set of equations allowing one to change from one inertial reference frame to another inertial reference frame. For a mathematical physicist, however, Poincaré transformations should be looked upon from a much wider perspective. First, one defines an abstract mathematical structure, called a Poincaré group. It is an abstract structure since it embodies certain purely formal symmetries implemented in the concept of the group operation. At this stage, there are no equations which would "describe" these symmetries. The equations appear only when the abstract Poincaré group is *represented* in a concrete mathematical space. We deal with a group representation when transformations between points of this space, called *representation space*, are given (now in the form of equations), and if these equations reflect (in the precisely defined meaning of this term) the abstract symmetries of the group.

In the theoretical structure of quantum field theory, an important role is played by the space of states. Elements of this space, the state vectors, model possible states of the considered quantum system (from the mathematical point of view, it is a Hilbert space), and it is this space which is treated as a representation space for the abstract Poincaré group.

In general, any abstract group admits an infinite number of possible representations (even in the same representation space, many different representations of the same group can be defined). From among many possible representations of the Poincaré group (in the Hilbert space), only the so-called unitary representations have physical meaning. Here we meet the miracle of quantum field theory. Every group representation can be decomposed into the so-called *irreducible representations*, in a sense, the smallest representations of the given group. It turns out that irreducible unitary representations of the Poincaré group describe properties of the physical fields, namely, of what in modern physics best corresponds to the everyday concept of matter.

We remember Saint Anselm of Canterbury's ontological proof of God's existence: God is the most perfect being. What exists is more perfect than what does not exist. Therefore God exists. It is commonly believed among philosophers that this "proof" is not valid since there is in it a jump from the purely logical or formal order (what can exist) to the ontological order (what actually exists). Something similar seems to intervene in our case. Purely formal, abstract symmetries of the Poincaré group, when unitarily represented in the Hilbert space, become measurable physical fields. What is an inadmissable jump in Saint Anselm's proof seems to be the essence of the physical method.

Of course, we could neutralize the above reasoning by stressing that irreducible unitary representations of the Poincaré group are not physical fields themselves, but they *model* physical fields. This is certainly true; however, the concept itself of modeling is, in these circumstances, a very peculiar concept. There is no "thing," given to us independently, which we could model with the help of some mathematical structures. The only access we have to physical fields is through their mathematical models. What is inherent in the unitary representations of the Poincaré group that distinguishes it from all other symmetries (and their representations) and makes them apt to model the existing things?

Teilhard de Chardin wanted to overcome the "temptation of matter" with the help of his concept of the bipolar stuff of the universe (matter and spirit as two aspects of the same reality). Contemporary philosophizing physicists seem to have just the opposite problem: how to save matter against idealistic or Platonic interpretations of modern physical theories.

I do not want to say that Teilhard's intuitions in this respect were totally wrong. I only suggest that the progress of physics has disclosed horizons that go beyond the field of possibilities Teilhard had at his disposal.[5]

TIME AND EVOLUTION

If we had to choose a single word to characterize Teilhard's vision of the world, our choice would certainly go to the word *evolution*. His way of seeing the reality is evolutionary from the beginning to the very end. "Is evolution a theory, a system or a hypothesis?" asks Teilhard de Chardin. And he immediately answers: "It is much more: it is a general condition to which all theories, all hypotheses, all systems must bow and which they must satisfy henceforward if they are to be thinkable and true. Evolution is a light illuminating all facts, a curve that all lines must follow" (PM[b], 241). Strangely enough, exactly at this point Teilhard's thinking meets serious difficulties when confronted with the perspectives opened by the achievement of contemporary cosmology.

One of the most far-reaching discoveries of the present science of the universe is that not everything has to have a single history. Three concepts are strongly interrelated: time, history, and evolution. History presupposes time. A linear course of events measured by time is history. And if one can find a parameter or criterion which would indicate an increase of a certain quantity along this course of events, one is entitled to speak about evolution. The point is that in the theory of relativity, in general, there is no unique time and no unique history. There might be two sources of this phenomenon.

The first source is very well known from special relativity; general relativity adds to this phenomenon its own peculiarities. Time, and consequently history, is not an invariant concept. It depends on the choice of a reference system. Two different observers, remaining in two different states of motion, can contemplate two different histories of the same process. A typical example is the process of gravitational collapse. When viewed by an observer taking part in the process, it ends up catastrophically with the final crunch in the infinitely great tidal forces. However, when regarded by an "external" observer, the history of the collapsing object is infinitely long, only asymptotically approaching the "no-return" surface.

The second source of the nonuniqueness of time is even more striking (and it is typically generally relativistic). It can happen that the entire space-time manifold cannot be covered by a single coordinate system, and local time coordinates cannot be combined to form a universal (global) history. This happens notoriously if closed timelike curves occur in a given space-time manifold. Moreover, such situations are generic, in the sense that if we wanted to choose a world model (being a solution to Einstein's equations) at random, the chances to pick up a model with the global history would be negligibly small.

It follows that evolution is not an "ontological a priori," it is not "a general condition to which . . . all systems must bow and which they must satisfy . . . if they are to be thinkable and true." For a global time to exist, and consequently for an evolution to occur, certain preconditions must be satisfied. The present theory of relativity knows a beautiful mathematical theorem which precisely specifies these preconditions (Hawking and Ellis 1973, 198–201).[6] It is not a surprise that they require a certain degree of causality (excluding the existence of temporal loops) together with a stability of this property (in the sense that small perturbations should not destroy it).

What is surprising is that these preconditions are satisfied in the actual universe. The initial conditions from which our world took off had to be very finely tuned to produce the world with a global history on the background of which the evolution could proceed. A tiny deviation from these initial conditions would have destroyed the possibility of global time and evolution. This should be considered as another instance of "anthropic coincidences" to which we owe our own existence (see Barrow and Tipler 1986; Leslie 1989).

This is not yet the end of the story. According to the present paradigm, the initial conditions of the actual universe were established as the consequences of the quantum gravity era of the very young universe. So far, there is no final theory of quantum gravity, but a few existing models quite clearly suggest that in the primordial state of the universe there was no time (at least in the present meaning of this term). In the widely popularized Hartle-Hawking world model,[7] time emerged from purely spatial dimensions of the quantum era; in other models of quantum cosmology (Isham 1993, 49–89), there were quantum correlations that gave origin to a temporal ordering of events.

Let us employ Teilhard's metaphoric language to express our conclusions. Evolution is not "a curve that all lines must follow." Contemporary theoretical physics suggests just the opposite: all lines must be organized into a very special pattern to give rise to the evolutionary processes. Teilhard always took science seriously. There are strong reasons to believe that if he lived today and knew the recent developments in cosmology, he would modify his views. Instead of the aprioristic inevitability of time, he would contemplate the fine tuning which enabled the evolution to start and develop.

BY REASON OF COMPLEXITY

A driving force of the Teilhardian evolution is a growth of complexity. It is not an abstract evolution that leads the universe through the process of transmutations. It is the increase in complexity that makes evolution a decisive factor of the cosmic process. However, we should not forget that in Teilhard's time thermodynamics was concerned mainly with equilibrium structures, with the second law (entropy growth in irreversible phenomena) completely dominating the scene. To a structure with growing complexity, there corresponds a negligibly small number of configurations in the space of all possible outcomes. It is, therefore, an "extremely improbable" state. From the point of view of equilibrium thermodynamics, complexification processes should be regarded as miracles. This "miraculous" aspect of biological evolution was emphatically expressed by Prigogine and Stengers: "Thus any attempt at extrapolation from thermodynamic descriptions was to define as rare and unpredictable the kind of evolution described by biology and the social sciences. How, for example, could Darwinian evolution—the statistical *selection* of rare events—be reconciled with the statistical disappearance of all peculiarities, of all rare configurations, described by Boltzmann? As Roger Caillois asks, 'Can Carnot and Darwin both be right?' " (1984, 128).

To proceed with his vision of the world, Teilhard de Chardin had to overcome this discrepancy between Carnot and Darwin. To this end he developed the following strategy. Things have their external aspect as well as their internal aspect. Ordinary physics deals with the external aspect of things, but "a kind of phenomenology or generalized physics" has to be created which would be able to deal with both aspects of things. Teilhard de Chardin argues: "It is impossible to deny that, deep within ourselves, an 'interior' appears at the heart of beings, as if it were seen through a rent. This is enough to ensure that, in one degree or another, this 'interior' should obtrude itself as existing everywhere in nature from all time. Since the stuff of the universe has an inner aspect at one point of itself, there is necessarily a *double aspect to its structure*, that is to say in every region of space and time—in the same way for instance, as it is granular: *co-extensive with their Without, there is a Within to things*" (PM[b], 61; italics in original).

To the *without* and *within* of things there correspond two types of energy: a tangential energy which "represents 'energy' as such, as generally understood by science" (PM[b], 71) and a radial energy that draws the universe "towards even greater complexity and centricity"—in other words forwards (PM[b], 70).[8]

From the point of view of physics, the idea of "two energies" is completely arbitrary. Moreover, it turned out to be unnecessary in order to explain the origin and growth of structures in the universe. One should admire Teilhard's intuition, which directed his thinking to the problem of complexity. In his day, however, any speculation to solve this problem had to be premature. In contemporary nonlinear thermodynamics, there is no longer any contradiction between Carnot and Darwin, and we should turn to the scientific explanation of the growth of complexity.

The space of an essay does not allow me to go into details of the contemporary theory of the growth of complexity.[9] I shall focus only on its mathematical foundation. It was changing from linear dynamics to nonlinear dynamics that enabled physicists and mathematicians to cope with the problem of complexity. A typical property of linear equations (which model linear dynamical systems) is that the sum of their two solutions gives us the new solution.

Consequently, a totality modeled by a linear equation can be nothing more than the sum of its parts. A typical example is wave motion. A particular wave is described by a solution of the very well-known *linear* differential equation called the wave equation. This equation has many other solutions. Each of them describes waves with different characteristics (length, amplitude, velocity of propagation . . .). If we add two such solutions, we obtain a new wave which is a composition of the original two waves (such a "superposition" of solutions is responsible for the phenomenon of interference of two waves) . If the universe were only a linear system, nothing really new could emerge out of its dynamics.

Nonlinear equations are totally different in this respect. Two of their solutions do not lead to a new solution. If we "superimpose" two solutions of a nonlinear equation, they can produce an extra effect that was not present in any of the original solutions. Consequently, even a simple nonlinear equation can exhibit a very complex and unexpected behavior. For instance, Einstein's equations of gravitational field are strongly nonlinear. Each of their solutions corresponds to a particular gravitational field (for example, coming from the sun, or a planet, or a star). If we combine two such gravitational fields, we do not obtain a simple sum of them. The two original fields interact with each other, and the interaction itself acts as a source of a new gravitational field. This new gravitational field enters into an interaction with all already-existing fields and is itself a source of a new field. And so on, and so on. We must solve the equations to see the final outcome of this nonlinear net of interactions.

Nonlinear equations very often exhibit another interesting property. To select a particular solution of a given equation, one must choose the initial conditions of the solution. If I throw a stone, its trajectory depends on the position of my hand and on the direction I am aiming at. The trajectory of the stone is a solution of the equation of motion, a concrete position of my hand and the chosen direction determine the initial conditions of this solution. It can happen that a slight deviation from the original initial conditions selects a solution that is only slightly different from the original solution. In such a case, nothing interesting happens. However, if slightly modified initial conditions lead to drastically different solutions, the predictability breaks down (although the motion remains fundamentally deterministic), and the solution can produce a highly structured pattern. We never have absolute control over initial conditions. We can select physical magnitudes only within a certain "box of errors," and if the initial conditions taken from this box lead to drastically different solutions, we cannot guess in advance what will develop from the selected initial conditions. This phenomenon is called deterministic chaos. The name is not particularly well chosen since the processes denoted by it form the basis of the origin and evolution of highly organized structures, which in and of themselves are not chaotic at all. Still, the name is not entirely bad since these highly organized structures often present "chaotic shapes": there are no two identical cells in the same organism, there are no two identical trees in the same species.

We cannot claim that we already have understood all mechanisms underlying the growth of complexity in the universe, but we can claim that the old contradictions between Carnot and Darwin have disappeared. Prigogine and Darwin go smoothly together.[10] Nonlinear thermodynamics, that is, thermodynamics making use of nonlinear equations, provides physical principles of the growth of complexity, including biological evolution. There is no need for any type of nonphysical energy.

CONCLUDING REMARKS

Erwin Schrödinger once wrote: "A scientist is supposed to have a complete and thorough knowledge, at first hand, of *some* subjects and, therefore, is usually expected not to write on any topic of which he is not a master. This is regarded as a matter of *noblesse oblige*" (Schrödinger 1969, preface). In this sense, any synthesis based on the sciences is always, and always will be, premature. On the other hand, there is inscribed in our cultural genes a sort of instinct for an all-embracing, unified vision of the world and our place in it. "I can see no other escape from this dilemma" continues Schrödinger, "(lest our true aim be lost forever) than that some of us should venture to embark on a synthesis of facts and theories, albeit with second-hand and incomplete knowledge of some of them . . ." (Schrödinger 1969, preface). This is why, although any synthesis is always premature, it is indispensable.

Moreover, science of the last decade of the twentieth century contains in itself, if not germs of a synthetic vision, then at least some elements of a large-scale perspective. In the present essay I have touched upon three such elements: the nature of the stuff of the universe, the roots of time and evolution, the nonlinear strategies of the origin and growth of structures. The stuff of the universe, in the eyes of contemporary physics, has decidedly become something more similar to a structure or form than to inert pieces of material substratum. Directness of time and history no longer seems to be an ontological *a priori* of any existence, but rather an outcome of finely tuned initial conditions. And the growth of complexity is now regarded as a process emerging out of physical laws rather than a foreign element in the body of physics. Contemporary physics tends toward a Grand Unification—not only, in the technical meaning of this term, to combine all fundamental forces into one theoretical structure, but also in the sense of elaborating general concepts so that we may ask more far-reaching and more overall questions.

This essay has focused on some *physical aspects* of Teilhard's synthesis. I do not claim that physics is enough to create a synthetic vision of reality. Teilhard had his own ways of going beyond the realm of physics. He attempted "to see and to make others see." This is why I like to call his synthesis a vision of the world. Some people have better eyes than others.

NOTES

1. Initials refer to abbreviations used throughout this issue of *Zygon,* as shown in the key on pp. 7-8.

2. See also p. 328: "The astronomers have lately been making us familiar with the idea of a universe which for the last few thousand million years has been expanding in galaxies from a sort of primordial atom."

3. Lemaître writes, ". . . the best we can do is to call it [the initial state of the universe] an Atom, rather in the Greek sense of the word than of this very complicated thing which is a modern atomic nucleus. . . . The beginning of cosmology is therefore expanding space starting from zero and filled up with the pieces of the Primeval Atom, presumably small, more or less stable, atoms, such as these which are observed today in actual physics" (1958, 8).

4. This is the main thesis of Charles Misner's paper, "The Immaterial Constituents of Physical Objects," delivered at the UNESCO Symposium in Munich, September 1978.

5. In some cases, the new horizons have substantiated Teilhard's rather vague intuitions. For instance, in the view of nonlocality of quantum phenomena (revealed in Aspect's experiments), Teilhard's claim that the "total" character of matter "is something quite other than a mere entanglement of articulated inter-connections" (PM[b], 48-49) seems today to be fully justified.

6. For a more accessible review with some philosophical comments, see Heller (1990, 203-7).

7. See the original paper (Hartle and Hawking 1983, 2960-75) and its popularization (Hawking 1988).

8. In fact, Teilhard assumes that there is only one energy which "is physic in nature," but it can be divided into two components—tangential and radial.

9. I refer the reader to recent popular and semipopular literature, for instance: Prigogine and Stengers (1984), Davies (1988), and Stewart (1990).

10. The problem of the relationship between Prigogine's theory of structure formation and Teilhard's thought was analyzed by J. F. Salmon (1986).

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