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Are Chronons the Elementary Particles in Space and Time?

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ABSTRACT

In the search for a physical theory of time, I proposed that chronons are elementary particles of time (Hsü, 1992); natural phenomena which seem to be spontaneous changes are interpreted in terms of chronon-captures. Natural radioactivity is considered the result of chronon-bombardment: the chronon-capture by uranium-238, for example, causes its decay into thorium-234 and alpha particle. Catalysis in chemistry is explained by assuming a larger cross-section for chronon-capture by a catalyst. Life is defined as the acquisition by a cell the ability to capture chronons, and death is the loss of that ability. Since then, I have developed the idea that chronon can be a quantum action or quanton Lévy-Leblond and Balibar, 1990), an energy/time product. Such a chronon/quanton could be the elementary particle in space and time.

Chronons have variable energy, mass, and lifetime. Photons are chronons travelling at the speed of light in wave motion. Neutrinos are chronons travelling at the speed of light, but not in wave motion. A third kind of elementary particles has been called WIMPs. Those are particles which neither travel at the speed of light, nor in wave-motion. Photons and neutrinos have vanishingly small mass, but aggregates of chronons can have a finite mass. Chronons, as energy carriers, could serve the function of being carriers of information. Energy transfer in biologic growth could be effected through such information carriers. An input of orderly sequenced chronons could explain the phenomena of biologic clocks.

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[2] **Editorial Board Note:**

This paper has been reviewed by four referees and three of them do not recommend to publish it as a scientific paper. However most members of the editorial committee consider that the idea expressed in this article is originated from earth science research and might shed new inspiration on the related field. So we decide to accept it as a "non-refereed" article in this journal. This doesn't mean we endorse the idea expressed in this article. It is left to the readers to make their own judgement.

The chronon theory explains natural phenomena in terms of particle-interactions. The postulate of light transmission by particle collisions could be tested by mathematical modelling. The postulate that radioactive decays are activated by neutrino captures could be tested by experiments. The theory has an relevance to earth sciernce, as it points to a new approach to study problems of earthquakes, energy production, and disposal of radioactive wastes. Identification of chronons as information-carriers could have implications to problems in life sciences.

(Key words: Chronons, Quantons, Time, Particles)

1. INTRODUCTION

Chronon is a word expressing an idea. No ideas under the sun are completely new, the word is a synonym or near-synonym to such ideas as atom (Greek), apeiron (Greek), ether, phlogiston, Dirac's oscillator in vacuum, quantum time, time as discrete dynamic variable, qi (Chinese), entropy, negentropy, information bit, etc. I was not the first to invent the word: chronon had been used by various authors to designate their various concepts of elementary particle of time.

Friederich Dürrenmatt (1980), a Swiss writer, equated chronon to the seed that gave us The Big Bang and the expanding universe. The word was used by Margenau (1977) as the smallest measurable physical duration. Martin Gardner (1992) referred to chronon as the fundamental unit of quantized time, and suggested that "between chronons one can imagine one or more parallel universes operating within our space, but totally unknown to us." Gardner's science-fiction vision seems, however, to have been derived from Hugh Everett's (1957) idea of parallel universes. T. D. Lee (1983) had indeed proposed to treat units of time as discrete dynamic variable.

In an introduction of the chronon concept, I referred to the action of chronon-capture (Hsü, 1992), which causes radioactive elements to decay, cells to grow by photosynthesis, or to divide. Such an action of capturing was envisioned as an elementary particle of time. The concept that time is particulate contradicts the basic postulate since Rene Descartes on the duality of mind and matter. Time in relativistic physics has been "shifted out of the superstructure of the universe into the minds of human beings, where it belongs, (Davies, 1990)." Time is immaterial and bodies are material, The elementary particles of bodies are material, and they are timeless.

The unity of mind and matter, or everything in the cosmos, has been a traditional Chinese assumption, as developed by Chu Hsi's as neo-confucianism in the 12th century. A similar postulate of a world of dynamic actions is the essence of Spinoza's metaphysics of the 17th century. The Descartian concept of the materiality of of the inanimate world has, however, prevailed in natural philosophy. Elementary particles are considered the basic constituent of matter., ever since the time of Newton, who wrote in his *Opticks*:

"Now the smallest particles of matter cohere by the strongest attractors, and compose bigger particles of weaker virtue: and many of these may cohere and compose bigger particles whose virtue is still weaker, and so on for diverse successions, until the progression ends in the biggest particles on which the operations in chemistry, and the colours of natural bodies depend, and which by cohering compose bodies of a sensible magnitude. There are therefore agents in nature able to make the particles of bodies of a sensible magnitude. These are

therefore agents in nature able to make the particles of bodies stick together by very strong attractions. And it is the business of experimental philosophy to find them out."

Despite of the successes of the Newtonian physics, the Newtonian concept of elementary particles of matter, being held together by gravity, seems to be heading toward a dead end (Weinberg, 1994). The purpose of this article is to question the fundamental assumption of the pure materiality of the Newtonian "smallest particles of matter." Could the elementary particles be assumed a dynamic entity, an action, which is defined in physics as the product of mass, acceleration, distance, and time? Could such actions be the chronons which I had proposed to be the elementary particles of time? In other words, could chronons be the actions of the elementary particles in modern physics such as photons,. neutrinos, quarks?

In my original definition, I thought that chronons do not have spatial attributes such as mass, charge, or spin (Hsü, 1992). In this article, however, I shall define chronon χ as the quantum action ($h = 6.55 \times 10^{-27}$ erg. second). With such a definition, chronons are not only elementary particles of time, but also elementary particles in time and in space. Chronons have energy E and duration t. They are thus neither static or timeless: chronons are dynamic actions. A close approximation to my concept was independently expressed by Lévy-Leblond and Balibar (1990), who proposed the term quanton:

"We must abandon the idea that every physical object is either a wave of or a particle. Neither is it possible to say, as is sometimes done that particles "become" waves in the quantum domain and conversely, that waves are "transformed" into particles. Nor should it be said that quantum objects have a dual nature, which is simultaneously wavelike and corpuscular (something which is logically absurd, since the two concepts are mutually exclusive).

It is, therefore, necessary to acknowledge that we have here a different kind of an entity, one that is specifically quantum. For this reason we name them quantons."

Quantons are thus quantum actions, no more nor less. The theory of chronons, as presented in this article, postulates the following:

(1) Chronons are quantons, or quantum actions, and the action is conserved in particle collision, such as photoelectricity.
(2) Chronons are particles of variable mass, energy, and duration; they are carriers of energy and thus of information, while time is registered by duration of actions.
(3) Chronons travelling at speed of light and in wave-motion are photons and those not in wave motion are neutrinos.
(4) Chronons travelling at less than the speed of light are"WIMPs," or of other "elementary particles."
(5) Chronons have non-vanishing restmass, and they are aggregated to form particles with a detectable mass.
(6) Chronons are aggregated and frozen as neutrons in a "black hole".
(7) Chronons were released from a "black hole" by the Big Bang.

2. CHRONONS AS CARRIERS OF ENERGY

In classical mechanics, a fundamental attribute of matter is its mass, and the dynamics of a moving object is described by three fundamental units: mass, length, and time. In a dynamic cosmos where all things are in motion or in change, elementary particles cannot be not stationary entities. I propose that elementary particles are actions. Action is defined in terms of all the three fundamental units, of physics, mass, length and time. The smallest

measure of action is the quantum action, expressed by Planck's constant h = 6.55 × 10^{-27} erg-sec. I choose, therefore, to define chronon χ as the quantum action: a dynamic particle with a mass; it carries a quantum energy E during a finite duration t, or

$$\chi = h = E\,t \tag{1}$$

Photons are chronons moving in wave motion and travelling with the speed of light c, their action is defined by the relations :

$$\chi = h = E/\nu = E\,\tau \tag{2}$$

$$h = (m\,c^2).\tau = (m\,c).\lambda \tag{3}$$

where τ, λ and ν the period, wave-length and frequency of the photon wave-motion and m its mass. The values for h and c are constant, but E, m, λ and ν are variables for photons in different states of motion.

In modern physics, photons are assumed to be annihilated by the photoelectricity effect. If, however, photon is a chronon, the particle may have just lost its acceleration, but not its mass, to the electron. The linear momentum is drastically reduced, but there is no need to postulate that the particle of a zero restmass has been changed into nothingness. Photon may have just become a "ghost" of itself, moving at a much lower energy state or being stopped altogether. Photon can be said to have been reverted to a common chronon, but it has not been annihilated.

If photons cannot be annihilated, we could state that photons are not only carriers of energy but they are also material. Their restmass may be zero, namely it is not directly or indirectly measurable, but their restmass is not nothing. There is no reason not to suppose that the mass of photons are not conserved when they collide.

Photons, gluons, and gravitons can be considered free chronons in various states of motion. Since the mass of the individual chronons is not nil, the chronons can be combined to form aggregates with verifiable mass, such as electrons, neutrons, and protons. Thus defined, chronons are the Newtonian elementary particles, and the postulated basic constituent of all things in the universe. Chronons are indivisible and are thus the atoms in the Greek sense.

3. TRANSMISSION OF LIGHT BY CHRONONS

The mathematical formulation of the particle/wave duality of light is a triumph in quantum mechanics. Physicists predict mathematically and monitor experimentally the movement of photons, but the duality seems to defy comprehension in everyday language. Light was once assumed to travel through ether, but the classic theory is proved incorrect by the experimental observations that the speed of light propagation is constant. Einstein's space-time concept finds verification in various observations, but Hendrick Lorenz's idea of space-shortening can be invoked to explain the same phenomenon. Lorenz is forgotten, because his hypothesis was "useless" in the sense defined by Lakatos: it did not explain anything except the observational data which led to its formulation. Ether is, however, not exactly "dead", and a modification of the idea is embedded in Dirac's extension of Maxwell's theory of electromagnetic field. Dirac pictured a collection of vast number of oscillators in a vacuum, each

of whose energy levels is quantized. Vacuum is thus seething with virtual activity, and there are endless fluctuations in the energy of the field at all points within the space (Coveney and Highfield, 1990). I am now substituting the word chronons in place of Dirac's "oscillators". Moreover, chronons are not only dynamic constituents of electromagnetic waves, they are uniquitous. They could oscillate, they could move as photons, or they could be frozen in a Black Hole.

Exothermic reactions in the interior of the Sun are the source of energy reaching the earth. Some 97% of the energy is in the form of charged particles and photons. In adopting a cosmological model that the interstellar space of the universe is filled by dispersions of chronons, I propose that the photons do not travel directly from a source to a monitor, but they transfer their energy by collisions and relays.

The relay model assumes that the energy of a source photon is transmitted by collision to a chronon at rest (or nearly at rest), causing the latter to be changed into the state of photon motion. The latter serves an energy carrier and transfers the energy, like the baton of relay racers, to the next chronon. The photon that is relieved of its energy would become again a chronon such as a WIMP, but that could become a photon again when it is hit by another photon from behind. A series of equi-distant collisions causes each of the subsequent chronons to become a photon; the distance between successive collisions is the de Broglie wave-length of the photon-motion (Coveney and Highfield, 1990). After N number of collisions, the last chronon at rest is converted into a photon which can be detected by a monitor. Light , i.e., a very small fraction of the photons, from the sun is thus transmitted like laser beams, and solar light is a combination of beams of different wave lengths.

Chronons, being the elementary particles, should have a very high density, certainly not less than the density of neutron stars, 10^{14} g/cm^3. Although the mass of a light photon is very small (10^{-32} g or less), the gravitional attraction becomes appreciable just before and after the collision when chronons come very, very close together. The driving forces of the movement of photons in a relay of collisions are impact but also gravitation plays a role, especially when chronons are very close. Driven alternately by the kinetic and the gravitational energy, the movement of photons ($\tau = \lambda / c$), is analogous to pendulum ($T = 2\pi\sqrt{L}/\sqrt{g}$). The wave-period τ is a function of λ and the pendulum-period T a function of arm-length L.

Photons move in an E -τ "timescape" like roller-coasters, but they do not have a free path: A photon driven by impact energy climbs over the crest of an energy barrier and falls under the gravitional pull into a trough where it collides and sends the next chronon into photon-motion. The particle which lost its energy is now left behind in the trough, before it is compelled to move forward again by the impact of the photon following. The "timescape" may have high peaks and deep valleys or they are rolling hills. The conservation of action states that E dt=h: the action is the same to cross from one valley to another, despite the different time and energy requirements.

4. NEUTRINOS, AXIONS, WIMPS, AND MAGNETIC MONOPOLES

Some 3% of solar energy is released is in the form of the kinetic energy of neutrinos. Neutrinos move with the speed of light, as verified by the neutrinos from the 1987 supernova, which reached the earth at about the same time as the optical signal. Neutrinos differ, however, from photons in their non-periodic motion. A neutrino flux from the sun has been verified,

but is found to be 3 times lower than predicted (Boehm and Vogel, 1992). Is it possible that two-third of the solar neutrinos never reached us?

In discussing the dark matter of the universe, the four candidates are light neutrinos, axions, WIMPs, and magnetic monopoles. The electron neutrinos were the obvious choice, but the knowledge that the universe is "matter-" rather than radiation-dominated suggests that the dominant particles are not moving at or near the speed of light. Astrophysicists preferred, therefore, the candidacy of those not moving relativistically (Krauss, 1990).

If WIMPs, or weakly interacting massive particles, were to make up the dark matter in the galactic halo, their expected mean velocity would be about 300 km per second.12 Could we not consider WIMPs one kind of chronons which do not move with the speed of light?

When a WIMP is involved in a head-on collision with a nucleus of mass equal to its mass, the WIMP can transfer all of its energy of motion to the nucleus, which will recoil with the same velocity as the WIMP initially had, just as for billiard balls of equal mass.11 What would happen if a photon or electron neutrino is involved in a head-on collision with a WIMP?

5. THE CONSERVATION OF ACTION

The distribution of chronons in vacuum cannot be anisotropic, because speed of light transmission is the same in all directions. Chronons in vacuum cannot be regularly spaced, like atoms in crystals with unit-cell length, because light of different wave lengths are transmitted through the same medium. Nevertheless source photons, characterized by given λ and τ, retain their identity while their energy is transmitted, thus the distance λ and duration τ between each collision should be the same. Randomly distributed chronons commonly do not satisfy this requirement, light transmission by photons requires a rare coincidence of regularly spaced collisions. Randomly distributed particles, such as gas molecules in air, move in brownian motion, because the molecules have such a large size that they collide at irregular intervals and are scatterred in various directions. The probability that photons move in a relay as postulated must be very, very small. On the other, a series of periodic collisions could occur by chance if there are very, very many chronons of small enough diameter. With the help of mathematical modelling, one might obtain a solution as to the maximum diameter of the particles and the maximum density of particle-dispersion to permit collisions in the form of wave motion. The very small probability to transmit photons over large distances is the reason why distant stars are almost invisible.

Photons at source emit at regular intervals initiate a laser of photons, and their regular motion pave the way for the transmission of a light beam of photons which follow. The conservation of action states:

$$\chi = \mathrm{h} = (\mathrm{m}_1.\mathrm{c})\lambda_1 = (\mathrm{m}_2.\mathrm{c})\lambda_2 \qquad (3)$$

Eq. (3) states the de Broglie relationship between the momentum of moving photon and its associated wave: the wave length of the particle is inversely proportional to its momentum, the constant of proportionality is the Planck's constant. Not all energetic chronons emitted from the sun or stars could transmit their energy as laser beams; chronons commonly collide at random distance without periodicity, or

$$\chi = \mathrm{h} = \mathrm{E}_1.\tau_1 = \mathrm{E}_2.\mathrm{t}_2 \qquad (4a)$$

$$\chi = h = (m_1\ c).\lambda_1 = (m_2\ v).s_2 \qquad (4b)$$

Each delay in collision ($s > \lambda$) results in: $E_2 < E_1$ and $m_2.v = m_1.\ c$. The quantum of energy being transferred by, or the momentum of, the energy-carrier is thus dissipated if the motion cannot be periodic. One can conclude, therefore, that much of the solar energy cannot reach us, because it has been dissipated as heat in the interstellar space. Conversely chronons such as WIMPs could also be activated by photon-bombardment to a higher energy state.

The conservation of action explains the theoretical and experimental observation in quantum mechanics that "small amounts of energy (ΔE) can be 'borrowed' for a time (Δt) when $h = (\Delta E)(\Delta t)$ (Close, 1983)." A corollary is that the translational kinetic energy of a chronon is dissipated by time. Time seems to have a function analogous to friction (which reduces force F), as a comparison of the following relations suggests:

$$h = t\ .\ E \qquad (5)$$

$$F = \mu;\ N \qquad (6)$$

where μ is coefficient of friction and N normal force. Perpetual motion of light depends upon t inifinite number of regular collisions of chronons, and is thus for all practical purpose impossible. There is a limit how far a chronon can travel. We can thus state that the universe is finite: its age and its boundary are defined by the chronons at the farthest outpost.

6. CHRONON CONCEPT AND TIME DILATATION

Time-dilatation in the special theory of relativity states that time, as measured in seconds, is velocity-dependent. The theory contradicts common sense, and contributes to the increasing gap between real-life experiences and fundamental laws in physics. An application of the chronon-concept could provide an explanation of this strange phenomenon. Assume that the distance s and travel time t between the source and the receiver of light propagation across a "timescape" with characterized l and t is measured by the number of colliding chronons N:

$$s = N(\lambda), \qquad t = N(\tau) \qquad (8)$$

Equation (8) states that the distance s, measured by the same number of colliding chronons (N) is different if s is expressed in centimeters (for photons of different wave length λ). Likewise the time t, measured by the same number of colliding chronons is also different if it is expressed in seconds (for photons of different period τ). The speed of light travel remains, however, constant, for photons of various wave-lengths and periods:

$$c = s/t = \lambda/\tau = \lambda\nu \qquad (9)$$

The chronons in vacuum are assumed to be a compressible medium so that the number of colliding chronons between the moving source and receiver remains constant, or $N_1 = N_2$. For the same velocity, the distance or time of light travel between moving objects can be said to remain unchanged if it is measured by a dimensionles number N. The values of λ in

cm and τ in seconds are, however, different, depending if the receiver is moving toward or away from the source. The values are smaller in the former case, and such pheonomenon has been called blue shift, space-shortening or time-retardation. The values are larger in the latter case, and such pheonomenon has been called redshift, space-shortening or time-retardation.

7. BIG BANG FROM BLACK HOLE

Scientists and philosophers from the Occident are fascinated by I-Ching, and I too acquired a respect for the ancient after I realized that truth could be perceived by pattern-recognition. While knowledge is accumulative in helping us to find truth by the technique of digitized sequencing, I see no reason not to accept the essence of Zen-Buddhism that truth can be suddenly and intuitively perceived through the acquisition of zen (禪), a form of pattern- recognition, which is often expressed as metaphors or parables.

The symbol for the metaphor ying-yang is a circle divided into halves by an s-shaped curve, the black ying and the white yang. The ying and yang make up the yuzhou (宇宙). The two Chinese characters yu and zhou were antique words no longer in use except in the combined form yuzhou, which means the cosmos. The Greek word for the universe is derived from kosmos, which signifies order. It is thus not surprising that occidental philosophers studying the cosmos have always looked for the order, the cause, the logical sequencing of things and events. Only recently did I realize that the Chinese word yu signifies directions, which are spatial attributes and the word zhou signifies past, present, and future, which are attributes of time. The making of the compound word reflects the ancient Chinese pattern-recognition that the universe consists of space and of time (Li, et al., 1990). The elementary particles are not only spatial but also temporal, being the quantum actions.

The ying-yang sign symbolizes a universe with a polarity of light and darkness. The idea is also deeply rooted in the Juda-Christian ideology. The first sentences of the Bible read:

"In the beginning the God created the heaven and the earth. And the earth was without form, and void: and darkness was upon the face of the deep. And God said, Let there be light."

It is not surprising that the Catholic Church is pleased with the Big Bang Theory, which has been considered a verification of the Biblical account of genesis: In the beginning there was the Big Bang, then there were the photons. Afterwards there has been a continuous expansion of light, so that photons and chronons have been pushed to the outer limit of the universe; the universe expands while it ages.

Photons are not created out of nothing. Where did the chronons come from? I found again a metaphor from the I-Ching. An observant person may notice that there is a small white dot in the black half and black hole in the white half of the ying-yang symbol, expressing a parable in the Tao-Teh Ching of Lao-tzu: the light is inevitably turned into darkness, and the darkness into light. Ancient Chinese sages seem to tell us that a Black Hole is the origin of the universe, and the universe is eventually going to fall back into a Black Hole. This is, of course, the modern paradigm of cosmogeny: The gravitational attraction from a Black Hole is so strong that everything passing near the hole will fall into it, including the photons (Hawking, 1988), which are chronons that move with the speed of light. Movement requires space. When all the elementary particles lose their dynamics, they are no longer what they were outside. Photons that are forced to remain stationary become chronons. Fermions, being

densely packed aggregates of chronons in the first place, would become even more densely packed. A Black Hole consists thus of chronons at rest (or nearly at rest) held together by gravitational energy. The Hole will grow in size with the entrapment of more light and matter. With the accumulation of an ever increasing number of chronons, continued bombardment by light and matter, and adiabatic heating of the nucleated chronons, a critical point could be eventually reached when a straw breaks the camel's back: the last influx of energy into the Black Hole ignites a Big Bang.

Halton Arp (1987) proposed numerous Small Bangs instead of one Big Bang; he interpreted the high-redshift quasars as having been "created in our universe at a later time than the Big Bang." I see no reason why there should not have been more than one Black Holes, exploding at different times.

8. NEUTRINO CAPTURES AND RADIOACTIVE DECAYS

The three kinds of radioactive decays are alpha, beta, and gamma decays, describing respectively the phenomena when a nucleus emits an alpha particle (helium nucleus), an electron, or a gamm-ray. The emitted particles have an energy lower than that of the barrier which should have prevented their escape from the radioactive nuclei. Their escape during decay has been explained in terms of the tunnelling effect Lévy-Leblond and Balibar, 1990). The nomenclature is derived from the picture of a particle bumping into a mountain. Finding itself at a lower altitude than the height of the mountain, the particle has to tunnel itself through the barrier to come out on the other side. Tunnelling is one way of looking at the situation, an alternative is leap-frogging: the particle got enough energy and jumped across the barrier.

In the absence of adequate knowledge, we tend to assume a spontaneity to natural phenomena. A fundamental aim of science is, however, to postulate causes other than divine. The tunnelling (or leap-frogging) effects are processes leading to the effect of decays. What is the cause of the decays? Why should an alpha or beta particle start to "tunnel." When should it "tunnel" its way out? Is it spontaneous, or has there been an accomplice?

The current theory for the alpha decay of ^{238}U assumes that an alpha particle will have to make many collisions with the "wall of the barrier," but the probability of getting out is very small. The average half-life of the nucleus is thus is very large, or 10^{10} years, because of the extremely small probability of getting out. The explanation is a form of circular reasoning. The probability is extremely small because our experiments have found very long halflife for the decay. We turn around then and tell our students that the long halflife is the result of the very little chance of an alpha-particle to dig a tunnel through (or leap across) the barrier!

Is there an alternative to this explanation? Is it possible that a particle does not decay arbitrarily. The observation of a predictable halflife suggests that the decay of radioactive atoms obeys a rule, and the relation is pertaining to time: there is the waiting time, and there is the duration of a collision when extra energy is transmitted from one to another particle to enable the latter to leap across the energy-barrier. I have, therefore, approached the problem from a consideration of the meaning of time, and suggested that natural radioactivity results from chronon-capture (Hsü, 1992). The decay of uranium atom has been described as:

$$U^{238} + \chi \rightarrow Th^{234} + \text{alpha-particle} \qquad (10)$$

Likewise, I have describved beta-decay as the consequence of a collision between a atomic nucleus and a chronon. The beta and the electron-capture decays of the ^{40}K nucleus have been expressed by the relations:

$$^{40}K + \chi \rightarrow ^{40}Ca + e^{-} \tag{11}$$

$$^{40}K + e^{-} + \chi \rightarrow ^{40}A \tag{12}$$

In particle-physics literature beta-decay is described as the decay of neutron n^{o} into proton p^{+} , electron e^{-} and an antineutrino no:

$$n^{o} - p^{+} \rightarrow e^{-} + \bar{\nu}^{o} \tag{13a}$$

The last term in Eq. (13) is a "book-keeping device." When the beta decay was first discovered a serious problem threatened to undermine the fabric of physics. The charges are conserved during the decay, but the momentum was apparently not conserved. Faced with the observation, physicists had to make a choice: "Either momentum conservation for elementary particles had to be abandoned, or something was being emitted that could not be observed, but which carried off just the right of momentum to make everything to work out right. One of the "czars" of theoretical physics in the 1930s, Wolfgang Pauli, declared that that the second alternative was the only acceptable one. Later, Fermi coinced the name *neutrino* - Italian for "little neutron" - for the unobserved that must have been emitted in the reaction (Krauss, 1990)."

Keeping the books on the conservation of the energy balanced, physicist could calculate the energy of the neutrino by rearranging the terms of Eq. (13):

$$\nu^{o} \rightarrow p^{+} + e^{-} - n^{o} \tag{13b}$$

$$E_{neutrino} = (E_{electron} + E_{proton} - E_{neutron})$$

Rearranging terms in Eq. (13a), the beta-decay could be phrased in terms of neutrino capture, or

$$n^{o} + \nu^{o} \rightarrow p^{+} + e^{-} \tag{14}$$

This is, in fact, the third solution to the problem that "threatened to undermine the fabric of physics." The beta-decay of potassium nucleus could be considered an activation through the capture of a neutrino:

$$^{40}K + \nu^{\bullet} \rightarrow ^{40}Ca + e^{-} \tag{15}$$

Now we can play a mathematical game of comparing Eqs. (11) and (15) and conclude

$$\chi = \nu^{o} \tag{16}$$

Translated into plain spoken words, Eq. (16) states that the chronon captured in the beta-decay is a neutrino.

That the emission of an electron, as in beta-decay, could be induced by the capture of a neutrino is the basis for experiments to detect solar neutrinos. In experiments to measure the solar flux in the Homestake gold mine, South Dakota, the neutrino target consists of C_2Cl_4. Solar neutrinos interact with ^{37}Cl to create an electron and ^{37}A. The latter has a halflife of 35 days and its creation has been detected before it decays by electron-capture to form ^{37}Cl again (Boehm and Vogel, 1992). The Brookhaven experiment is a sufficient demonstration that radioactive decays are not a spontaneous "tunnelling effects;" they could be induced by particle-interactions or chronon-captures, and in the case of beta-decay the chronon capture is a neutrino.

Are electron-captures spontaneous decaying processes or are they also externally induced? This radioactive process is effected through a capture of an electron by a proton in a nucleus, or

$$p^+ + e^- \rightarrow n^o + \nu^o \qquad (17)$$

One could envision a preprogrammed decay of an electron orbit until an innermost electron is absorbed by a nucleus, like an overaged artificial satellite is destined to fall back to the earth. Or one could envision that the fall has been induced by collisions: the electron falls into the neucleus because it has interacted with a neutrino, or

$$p^+ + e^- + \nu^o \rightarrow n^o + 2\nu^o \qquad (17)$$

Actions on electrons by neutrinos have also been verified by experiments (Bohem and Vogel, 1992).

9. CHRONONS AS TIMERS TO ACTIVATE BIOLOGIC CLOCKS

The expression biologic clock refers to physiologic phenomena, ranging from the germination of a seed, migration of birds, to the vital decay of an aging organism. Biologic rhythms in us such as the daily sleep-and-wake habit and the monthly menstruation period are well known. Those who have had malaria could marvel at the regularity of its 48-hour or 72-hour rhythm. Even more common are the circadian, lunar or seasonal rhythms in animals and plants (Coveney and Highfield, 1990; Fraser, 1988). There seem to be internal pace-makers in all living organisms.

Biologic time is manifested by aging. An amazing fact was discovered that embryonic human cells which kept their normal and constant set of choromosomes could not be cultivated in culture for more than 50 doublings (Hayflick, 1956). The time needed for cell-division is different for various species: the duration of a cycle of cell-division for bacteria asexual reproduction is of the order of 10^3 seconds, for grass-hopper is 10^4 seconds, for high plants is 10^5 seconds, and even slower for human beings (Fraser, 1988; Anonymous, 1975). There is furthermore the waiting time. The division, the wait, and the limitation of divisibility seem to be the reason why the maximum life-expectation of Homo sapiens is less than 120 years. The waiting time is not the same for different individuals. The persons who suffer from progeria, one of whom is born after every 80 million births, have a very high rate of cell division so that the aging is accelerated (Mills and Weiss, 1990); a child 10 years of age looks like a 90-year old (Brown, 1992). The waiting time could also be retarded by environmental factors, and the lifespan of some insects is artificially prolonged 2 or 3 times through such interferences.

An even more mysterious aspect of biologic time is the efficacy of genetic clocks. A few years back, the already dwindling population of panda-bears in southwest China suffered a crisis when the arrow-bamboo plants of the region all flowered and died at about the same time. Bamboo is a grass and commonly reproduces by sprouting of new roots every spring. After a regular interval of numerous years, however, bamboo will bloom when a new generation is seeded. The parent bamboo dies after the bloom, and the daughter continues to produce offsprings every year by sprouting new roots until the time of the next periodic bloom. Species of bambus have waiting intervals ranging from several years to more than a hundred years between successive flowering. The species Phyllostachys bambusoids, for example, was first recorded to flower in China 999 B.C., and plants of that species have bloomed regularly once every 120 years ever since. The remarkable fact is the regularity of the periodicity (Gould, 1977). Some animals could count too: the periodical cicadas have a 17- or 13-year cycle (Fraser, 1988; Gould, 1977). Their nymphs live underground, feeding from tree roots. Then, suddenly, when the period comes, millions of mature nymphs emerge from the ground, they mate, reproduce and die. There is a biologic clock in each nymph to count the number of passing years.

While the waiting time for the germination of bambus has a periodicity of 3×10^{9} seconds, the fastest clocks are timed by the vibrations of the atoms and molecules in the skin of human body at 10^{-16} second in response to ultraviolet radiation. Photosynthetic reactions seem to be regulated by pico-second (10^{-12} s) clocks (Fraser, 1988). Movement of micro-molecular solutes in cells have period of 10^{-7} to 10^{-4} second, while cell-division or metabolic turnover rates vary from minutes, to hours or days (Fraser, 1988; Margineanu, 1992). What is the carrier of the information that activates the biologic clocks?

While the skin molecules vibrating at the frequency of ultraviolet light (10^{-16} s) apparently result from the actions by singular chronons of photons, the information-transfer to activate biologic rhythms requires pace-makers with longer periodicity. Cybernetics is the science that investigates information-transfer and data-processing by living organisms. We are told the amazing facts that a human body has 10^{14} cells and the information content of a single cell has been estimated to be about 10^{12} bits. The super-computers seem necessary, because living cell is a marvel of complex structure and life processes are complicated. Even photosynthesis is not simply a capture of photon at regular intervals: the process involves a whole series of electron-transfers to effect complex biochemical reactions. For cell-divisions, proteins have to be synthesized and many other biochemical reactions will have to take place, a whole series of single or aggregated chronons will have to be captured in a pre-determined order. The information bits in cells have to be structured into software programs to process information input.

Enzymes are catalysts in living cells and they cause and direct numerous chemical reactions that occur in living organisms. I suggested that catalystic reactions are activated by chronon-captures (Hsü, 1992). The law of conservation of action suggests that chronons "at rest" could be agitated into motion by incident photons or other high-energy chronons. The theory of chemical resonance suggests that coevalent bonds in organic molecules are stabilized by the resonant energy of harmonic oscillators. The term "chronon-captures" can be interpreted to signify that the absorption of light, or capture of chronons caused the oscillators to reach an excited state of higher resonant energy, sufficient to break the chemical bonds and thus activate biochemical reactions.

Biologic rhythms suggest periodic activation, or periodic arrival of "trains" of energetic chronons to effect a series of chronon-resonance for cell division. The long periodic interval could signify the long waiting time of an unusually energetic event.

10. RELEVANCE OF THE CHRONON CONCEPT TO EARTH SCIENCE

10.1 Application of the Chronon Concept to Stuidies of Earthquakes

A most difficult task for the earth scientists during the 20th century is an assignment to predict earthquake occurrences. It is commonly assumed that a quake is the consequence of accumulation of stress and strain, but we seem to have reached a limit on what we can do withi this approach of earthquake prediction. Perhaps we should try some outlandish ideas.

It is, in fact, not unreasonable to postulate that an earthquake occurs when the steady weakening of the strength of material in a seismically active region reaches a critical degree, while stress and strain accumulated steadily along earthquake faults. It is not the additional gravitational stress of the straw which breaks the camel's back, but the weakening by aging of the camel's bones! If so, we need not only to study the stress and strain induced by movements of lithospheric plates, but also the factors causing gradual reduction of the strength of material in seismic regions (Hsü, 1994).

One puzzling aspect in seismology is the unusually small stress-drop after earthquakes, often one or two orders of magnitude less than the strength of rocks measured by experiments. This observation could be invoked to supports the postulate that strength-reduction, rather than excessive stress, is the critical factor in the timing of the earthquake-trigger: rocks are weakening regionally, while stress is accumulating along faults, until a fracture is formed at the epicenter where the strength falls below the critical shear stress. Sudden occurrences of earthquakes could be the catastrophic consequence of a steady state decay of strength, if they could have been induced by anomalous factors of strength-weakening.

A special feature of earthquaking is the tremendous rate of energy release. In fact, the inability to distinguish seismic waves generated by atomic bombs and those generated by earthquakes hindered for years the agreement on the moratorium of underground bomb tests. The rapid release of energy by a fission-bomb is a consequence of a chain reaction. Could there be a chain reaction that is triggered to release the earthquake energy?

This line of thought led me to think of electron-capture reactions, such as the decay of ^{40}K into ^{40}A. Assuming neutrino interaction for electron-capture decay while keeping the books balanced, we have from Eq. (18), two neutrinos could be released by the capture of one neutrino. Equation (18) is book-keeping; it has been not experimentally verified. If there is such a process, the implications could be dramatic: the geometrical progression that each neutrino interaction breeds two neutrinos points to the possibility of a chain-reaction of neutrino-captures, in the manner of neutron chain-reaction.

My colleagues in neutrino physics have discouraged my speculation: the capture cross-section of neutrinos is so extremely small and the reaction postulated in Eq. (18) has not been experimentally verified. There is no scientific evidence that the very slow electron-capture decay of ^{40}K could have any effect on the strength of potassium-bearing rocks. On the other hand, beta decays with short halflife could be considered neutrino-captures by neutrons with a large cross-sections. Could such processes have a fatal effect in weakening the rocks of a seismicallz active region? One more lesson learned from the studies of neutrino captures

is the difficulty of its detection. The neutrino-capture by ^{37}Cl could be detected because the daughter product ^{37}A has a halflife of 35 days. If an neutron of an element capturing a neutrino will produce a daughter product of very short halflife, the neutrino capture cannot be detected by experiment. Nevertheless, the ionic bonding in the solid could be broken to cause the weakening of strength of the crystal.

I have experienced in my professional career that some good postulates were first formulated on the basis of wrong reasons. My fanciful idea on neutrino chain-reaction could be utterly wrong. On the other hand, the possibility that rocks in seismic regions have been weaked by some unknown nuclear reactions deserves a serious consideration, in view of the report of radon anomalies as precussors of earthquakes.

The radon anomaly is commonly considered an anomalous *release*. The conventional explanation is to assume an unusual escape of radon prior to an earthquake because of micro-facturing of the host rock (Deng, *et al.*, 1981). Two arguments could be advanced against this interpretation: First of all the radon-anomaly is not restricted to the zone of earthquake faulting where micro-facturing is expected before the quake. Secondly, the radon anomaly is commonly a decrease for weeks, or months before the quake, before a sudden rise just before the main shock.

If the radon-anomaly precussor is not an anomalous release because of accelerated micro-fracturing, could the anomaly be an indication of an anomalous rate production of radiogenic radon? Could there be a very slight variation in the rate of alpha-decay of uranium? Experimental studies of beta decay of relatively short duration has revealed significant variations of decay rates (Alburgh and Harbottle, 1990). Furthermore, the inconsistent results of ^{14}C dates have commonly been attributed to variations in the of the production rate of ^{14}C, but such an anomalous rate of production is not manifested by the ^{10}Be record. An alternative is to assume constant production, but a variable rate of the ^{14}C decay-rate during the last 15,000 years.

10.2 Applications of the Chronon Concept to Studies of Natural Radioactivity

One of the greatest mysteries in science during the recent years was a claim of having successfully accomplished cold fusion. After the dust has settled down, and the emotion has run its course, the claim has been dismissed, but it is difficult to deny that some form of energy has been produced in the cold-fusion apparatus. when "reports of energy-releasing nuclear reactions at toom temperature pour in from labs around the world (Holden, 1994)." Could the appreciable production of energy a result of "neutrino chain reactions"?

If the rate of radioactive decays could be accelerated appreciably by laboratory techniques, the principle is applicable not only to produce energy, but also deactivate radioactive wastes. From what we know now, the capturing cross-section for neutrinos is extremely small, and no reactors of the world are producing strong enough neutrino beams for any practical application. Recalling the history of investigating neutron-capturing, one could ask if there are slow neutrinos, or WIMPs? One could also ask if neutrinos could be slowed down enough for easier capturing. Furthermore, who are we to underestimate the inventive power of the scientists and technicians of the next century? Faraday and Maxwell never could dream of all the things which our contemporaries are making.

11. FALSIFIABILITY OF THE CHRONON CONCEPT

Physicists communicate the results of their experiments and observations in a mathematical language which becomes less and less comprehensible to a lay person. Paul Feyerabend (1987) provoked with an unorthodox view that scienctists invent postulates to contradict common sense. In fact, modern physics is a collection of paradoxes, starting with Planck's recognition of quantum energy. De Broglie gave us the wave/particle duality of light and Schrdinger his cat; the physics of light has become "totally unpicturable." Heisenberg discovered the uncertain principle, with the same Planck's constant to connect two uncertainties such as momentum/position or energy/time. Dirac invented positron the antimatter, and it became Feynman's electron moving backward in time! Einstein told a story of the twin paradox, and his space-time concept rendered meaningless the concept of simultaneity. There could be no past, present or future, and time has become "just a coordinate." It was considered as silly to think about the time before the Big Bang as to ask "for a point on the earth at 91°N latitude (Hawking, 1988)."

The word chronon was originally introduced in an effort to understand modern science in terms of classical physics, using the everyday language and referring to daily-life experiences. The chronon theory was formulated on the basis of a postulate that chronon is the quantum action. In defining chronons as the elementary particles of the universe, the theory had to assume that chronon has mass. The corollary is the recognition of the conservation of action, as well as that of matter, energy, and momentum in the quantum world. The concept permits a different perspective of the universe. The elementary particles are actions so that space and time should not be considered empty stages; space and time are the actions which have been conserved in various forms since the First Actions of the Big Bang. The universe expands and it ages, and its a history is a continuance of actions.

Lord Kelvin once said that our knowledge is a most unsatisfactory kind, if it cannot be expressed in numbers. I might add that our knowledge is a most unsatisfactory kind, if it cannot be expressed in written words. The introduction of the chronon theory eliminates the need to invent mathematical codes to avoid explanations for things which we do not understand. A basic postulate of the theory is the conservation of action, and its predictions are falsifiable. Theoretical physicists could verify if the chronon-theory of light propagation and for the origin of natural radioactivity. Experimental physicists could decide whether the conservation of action makes more sense than their usual mode of "book-keeping" to account for energy balance in nuclear reactions. Biologists could explore if the chronons as information-carriers have given us the biologic clocks.

This article is an abstract of the main conclusions to be presented in a forthcoming book on time and chaos, and I have profited from discussions during the last 4 years with many colleagues in physics, astrophysics, mathematics, chemistry, biophysics, and geophysics. The idea on the conservation of action was inspired by Yuk L. Yong who first suggested to me the importance of understanding Planck's Constant in formulating a physical theory of time. John Schellnhuber helped clarify my thoughts on the role of chronons as the universal elementary particles. Don Anderson, Halton Arp, Paul Feyerabend, Erwin Engeler, Dieter Imboden, Kurt Dressler, Herb Shaw, Wolfgang Berger, Jon Dobson, David Olgaard, Christine and Peter Hsü read a part or the whole of the various drafts of the manuscript and of the book; their suggestions and comments are much appreciated.

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