Modern Cosmology and Process Philosophy

Yutaka Tanaka,
Sophia University, Japan

Contents

1. Whitehead's Principle of Relativity

Einstein's principle of relativity has two components: one is the special principle, and the other is the general one. The former states that all inertial systems are equivalent for the description of natural phenomena, while the other claims that the same equivalence should hold generally in any chosen frame of reference.[1] Whitehead did not rely on either of them. First, he pointed out in *The Principles of' Natural Knowledge* that the physical content of Einstein's theory can be deduced without relying on Einstein's principles. The special theory of relativity correlates space to time through the Lorentz Transformation, which Einstein deduced from the combination of the special principle and the principle of the constant velocity of light.

Whitehead, on the other hand, deduced the same transformation from the weaker principles of kinematics and geometry, i.e.

(1) the uniformity and symmetry of space-time,

(2) the symmetry and transitiveness of transformation, etc.[2]

Secondly, Whitehead repeatedly laid stress on the inequality between inertial and rotating systems in his book, *The Principle of Relativity*, the title of which was certainly ambiguous and therefore misleading.

The principle of relativity in Whitehead's sense must be understood in the context in his philosophical thought. This principle plays the central role not only in his physics, but also in his metaphysics. The physical principle of relativity is generalized to the metaphysical

---

[1] Einstein, A., *The Meaning of Relativity*, Princeton University Press, 1974, p. 58.

[2] Whitehead, A. N., *The Principles of Natural Knowledge* (*PNK*), Cambridge University Press, 1925, pp. 171-181.

one. The more we understand his metaphysics, the more we comprehend his physics. So we may well begin with the definition of this principle in *Process and Reality*:

> "It belongs to the nature of a 'being' that is a potential for every 'becoming'. This is the 'principle of relativity'.[3]

As the above formulation of the principle is the most general characterization on the metaphysical level, it needs some explanation as to how it is embodied within the realm of physics. What we must bear in mind is that two lines of Whitehead's criticism of classical physics are closely connected with the above principle: i.e. his criticism of scientific materialism, and his rejection of Cartesian dualism involving the "bifurcation of nature."

In Whitehead's metaphysics, "*Becoming*" is more fundamental than "*Being*", which means the reversal of Aristotle's ontology. The concept of matter as "*hypokeimenon*" (*substratum*) of nature, the cornerstone of scientific materialism, presupposes Aristotle's concept of substance: matter is conceived as the true Being which exists independently of perceivers: the description of the configuration of matter in space-time through the deterministic laws is thought to be the only task of physicists: there remains no place for the perceiving subjects. Nature, as it is perceived by us, is separated from nature as the object of physics. This bifurcation cannot be easily overcome: if we try to bridge them by considering the one as a cause and the other an effect, then we soon find that such a kind of causality is unintelligible on account of the "fallacy of misplaced concreteness". Whitehead pointed out this fallacy by grasping the most concrete aspect of nature as *creative becoming* rather than as static, substantial *Being*. According to Aristotelian ontology, *Being* precedes *Becoming* because the former is the actuality of the latter. The opposite is the case with Whitehead. *Becoming* is the actuality of *Being*: what has been thought to be substantial *Being* must be re-interpreted as derivative from *Becoming*. Therefore the most fundamental category of nature should be found in "events", and not in "substance". Concerning the concept of event, Whitehead wrote: [4]

> "I give the name 'event' to a spatio-temporal happening. An event does not in any way imply rapid change: the endurance of a block of marble is an event Nature presents itself to us as essentially a becoming, and any limited portion of nature which preserves most completely such concreteness as attaches to nature itself is also a becoming and what I call an event. By this I do not mean a bare portion of space-time. Such a concept is a further abstraction. I mean a part of the

[3] Whitehead, A. N., *Process and Reality (PAR),* The Free Press Corrected Edition, 1978, p. 22.
[4] Whitehead, A. N., *The Principle of Relativity(POR)*, Cambridge University Press, 1922, p.21.

becomingness of nature, coloured with all the hues of its content. Thus nature is a becomingness of events in terms of space and time. Thus space and time are abstractions from this structure."

Whitehead tried to reduce physical entities which were previously considered as substantial *Being* to the *Becomingness* of interrelated events. What he means by "event" must not be interpreted as something cut off from the pre-existing continuity of space-time, but the space-time itself is an abstraction from the concrete relatedness of events. What must be noticed here is that the concept of events as four dimensional structures plays the role of mediation between space and time. Both matter as a self-identical substance and space-time as a fixed framework of physics are to be deconstructed to the interrelation of becoming events.

Whitehead executed such deconstruction by what may be called the reversal of subject-predicate logic. In classical physics matter is treated grammatically as subject, and its spatio-temporal determinations as adjectives. Whitehead, on the contrary, treats matter as an "adjective" of four-dimensional events with specific characters. Material beings are considered by him, not to be causes of perceived qualities, but treated merely as one of many adjectives uniformly modifying events. This does not mean that events occupy the place of substance, for the essence of an event consists in its relatedness.

The reason why classical physics had to fix separately the framework of space and that of time was that it lacked necessary means of representation for four-dimensional events. Whitehead, adopting Minkowski's idea that four-dimensional manifold should give the framework of relativity theory, tried to deduce that framework itself from the interrelated structures of events. This procedure was called by him "the method of extensive abstraction", according to which the elements of Minkowski's manifold, event-particles without extension, were mathematically re-constructed from becoming events with spatio-temporal extension.

Thus Whitehead endeavoured to reconstruct the fundamental categories of physics after having deconstructed classical physics through the relativistic reduction of *Being* to *Becoming*. Einstein's theory was to be assimilated to his own paradigm, and at the same time to be criticized in certain points, especially the relation of matter to space-time.

Whitehead was not satisfied with the view of matter presupposed by Einstein, according to which spatio-temporal determinations, depending on the configuration of matter, had to be separated from our perceptual experiences. Whitehead claimed that the condition of perceptual situation, which makes the measurement of spatio-temporal magnitudes possible, should be given independently of matter.

According to Einstein's theory of general relativity, the metric properties are decided completely by matter. Space-time is said to be "warped" by matter: The "curvature" of space-time is variable, and it may be said "fiat" only when the gravitational field caused by matter is negligible.

Whitehead rejected the very idea of the priority of matter over space-time. As was stated before, matter was considered by him as an "adjective" of events, and it can not exert any influence on the essential characteristic of space-time, which should be determined only on the level of events. The existence of matter only concerns accidental qualities of space-time.

On this point the problem arises whether the metric properties are considered to be essential or accidental. Considering the contingency involved in the configuration of matter, Whitehead rejected the effect of matter on space-time metric: the very idea that the curvature of space-time is variable should be irrelevant in Whitehead's theory. In The Concept of Nature he wrote: [5]

> “Space caught bending” appeared on the news-sheet of a well-known evening paper. This rendering is a terse but not inapt translation of Einstein's own way of, interpreting his results. I should say at once that I am a heretic as to this explanation and that I shall expound to you another explanation based upon some work of my own, an explanation which seems to me to be more in accordance with our whole scientific ideas and with the whole body of facts which have to be explained.

The "bending of space" was and is a favorite phrase used by many physicists to explain the meaning of the verification of Einstein's gravitational theory at the time of eclipse. It can be paraphrased more exactly by saying that non-Euclidian geometry holds in the neighborhood of the sun. It was this thesis that Whitehead wanted to replace by his own theory of measurement.

Whitehead was convinced that geometry should be distinguished from physics. Geometry represents the uniform relatedness of nature, especially of spatio-temporal relations. Physics treats the contingent properties of nature. These convictions were related to his rejection of scientific materialism and of the bifurcation of nature. The theme of physics, according to him, is not the material things themselves cut off from the perceptual data but the perceived phenomena which show themselves "contingently" in the uniform framework of space-time.

The space-time in which material bodies are located, in his view of unified nature, is

---

[5] Whitehead, A. N., *The Concept Of Nature*, Cambridge University Press, 1920, p.165.

nothing other than that in which the visual images of them are situated. Concerning the reason why the uniformity of space-time should be a necessary condition of measurement, Whitehead wrote: [6]

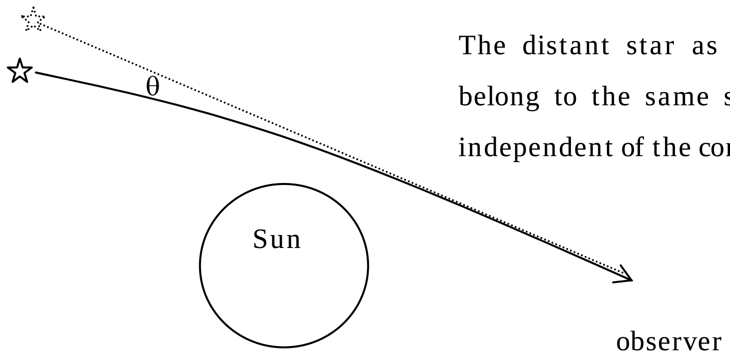
> "By identifying the potential mass impetus of a kinematic element with a spatio-temporal measurement Einstein, in my view, leaves the whole antecedent theory of measurement in confusion, when it is confronted with the actual conditions of our perceptual knowledge. The potential impetus shares in the contingency of appearance. It therefore follows that measurement on his theory lacks systematic uniformity and requires a knowledge of the actual contingent physical field before it is possible. For example, we could not say how far the image of a luminous object lies behind a looking-glass without knowing what is actually behind that looking-glass."

If we are to locate a material body and the visual image of it in the same space, it is necessary that the space should have a uniform structure independent of matter. For example, we can interpret the result of Eddington's experiment in such a way that we need not say, "Space caught bending". The experimental evidence for the idea that rays of light are bent in the neighborhood of the sun is that the visual image of a distant star is shifted on account of the intervening sun. But how can we talk about the shift unless we locate two visual images in the same space? As one is observed in the presence of the intervening sun and the other during its absence, the same space is required to have a uniform character independent of matter.

Thus Whitehead set about constructing a gravitational theory according to which rays of light are bent through the physical (contingent) effects of the gravitational field. Whereas Einstein's theory states that rays of light pass straightly (along a geodesic line) in the "warped' space, Whitehead's theory states that they pass literally along a crooked curve in the "flat" space. The speed of light cannot have the constant value c in the gravitational field, but varies as if the space is filled of the medium whose refractive index is changeable with gravitational potential such that $1+\frac{2\gamma m}{c^2 R}$ where γ is Newton's gravitational constant, m is the mass of the sun, and R is the polar coordinate from the sun. This leads to the same result as Einstein's theory concerning the angle of the bending of light from distant stars around the sun. [7]

[6] *POR*, p. 83.

[7] POR p.110



The distant star as a physical object and its visual image belong to the same space, the structure of which should be independent of the contingent presence of gravitating matters.

Whitehead points out what may be called the problem of measurement in the theory of general relativity. Though the general theory of relativity uses non-Euclidean space with variable curvatures, astronomers and experimental physicist must first presuppose Euclidian space (or at least the space with uniform curvature) in order to test the relativistic effects through sensible phenomena. The uniformity of space-time is one of the a priori conditions which make measurement itself possible in Whitehead's theory.

We must remember that Whitehead deduced the constant *c* of Lorenz-transformation from the purely formal postulates representing uniformity of nature independently of the light signals in his *Principles of Natural Knowledge.* That the speed of light always equals with c is a contingent fact of nature, and strictly speaking, it does not hold in the presence of matter.

The mathematical formulation of Whitehead's theory is, as in Einstein's case, supplied with tensor-analysis. But it is to the physical structure of gravitational field that the Riemannian theory of differentiable manifold with variable curvature is applied in Whitehead's theory.

Adopting a different interpretation from Einstein's theory which identifies the gravitational with space-time metric, Whitehead introduces the concept of *impetus* as a *physical* quantity in order to determine the path of light or of a moving particle in the physical field. There are two kinds of impetus: the potential mass impetus and the potential electro-magnetic impetus.

Writing the potential mass impetus as $\sqrt{(dJ)^2}$ and the potential electro-magnetic impetus as dF, we can integrate the total impetus realised along the time-like world-line

AB as follows: $\int_A^B dI = \int_A^B \{M\sqrt{(dJ)^2} + c^{-1}EdF\}$ where M is the proper mass as an "adjective" uniformly qualifying the world-line AB, E is the charge of the mass, c is the velocity of light.[8]

The two kinds of impetus can be expressed in covariant tensors respectively with first and with second orders, as follows:

$$dJ^2 = \sum_\mu \sum_\nu J_{\mu\nu}^{(u)} du_\mu du_\nu \qquad dF = \sum_\mu F_\mu^{(u)} du_\mu$$

In order to derive the equations of motion Whitehead applies the variation principle to the above impetus $\delta\int_A^B dI = 0$ and gets a set of differential equations of the Euler-Lagrange type: $\frac{d}{du_4}\frac{\partial}{\partial \dot{u}_\mu}\frac{dI}{du_4} - \frac{\partial}{\partial u_\mu}\frac{dI}{du_4} = 0 \qquad [\mu = 1,2,3]$ where $\dot{u}_\mu = \frac{du_\mu}{du_4}$ for differentiation along the route M, $\frac{dI}{du_4}$ is a function of $\dot{u}_1, \dot{u}_2, \dot{u}_3$ and of u_1, u_2, u_3, u_4.

Whitehead treats the gravitational field on a par with other physical fields, as independent of the metric structure of Mincowski's space-time. Therefore, it is required in Whitehead's theory that the system of n mass particles with gravitational interactions should be mathematically similar to the system of n charges moving under their mutual electro-magnetic interaction.

It must be noticed that Whitehead put forward four alternative laws of gravitation which satisfy the following requirements: (i) to have no arbitrary reference to any one particular time-system, (ii) to give the Newtonian term of the inverse square law, and (iii) to yield the small corrections which explain various residual results which cannot be deduced as effects of the main Newtonian law.

The first is Einstein's law of general relativity. The other three alternatives use two tensors, i.e. Galilean tensor $\left\| G_{\mu\nu}^{(x)} \right\|$ which represents "the uniform significance of events", and $\left\| J_{\mu\nu}^{(x)} \right\|$ as the tensor of gravitational field. Among them, the fourth alternative is usually referred as Whitehead's theory of gravitation in the narrow sense.

Concerning these alternatives, Whitehead stresses the importance of experimental tests

---

8 *POR.* p. 80.

to determine the fittest. Admitting the possibility of falsification of his own version of gravitational theory, he points out that the fourth alternative, i.e. his own gravitational theory can also pass the classical tests of Einstein's theory. He writes:[9]

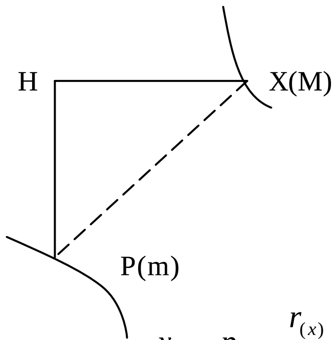
> If the above formula gives results which are discrepant with observation, it would be quite possible with my general theory of nature adopt Einstein's formula, based upon his differential equations, for the determination of the gravitational field. They have however, as initial assumptions, the disadvantage of being difficult to solve and not linear. But it is purely a matter for experiment to decide which formula gives the small corrections which are observed in nature.

Whitehead's theory of gravitation in the narrow sense is sometimes referred as "a theory involving action at a distance with the critical velocity c". This characterization of Whitehead's theory is due to Synge, who located Whitehead's theory between the two extremes of Newtonian theory on the one hand and the general theory of relativity on the other. Such a middle-way character comes from the peculiar definition of the physical field in Whitehead's theory.

The physical field of an event P modified with mass m is defined as the domain of P's causal future, i.e. the set of world-lines along which the physical signals propagate from P with the critical velocity c. The distance between P and any event X which is under the causal influence of this physical field vanishes into zero in the Mincowski metric. Thus the causal efficacy may be characterized by an action at a distance propagating with c.

Kinematic routes of M: $X(x_1,x_2,x_3,x_4)$

m: $P(p_1,p_2,p_3,p_4)$



$$x_4 - p_4 = \frac{r_{(x)}}{c}$$

$$dG_M^2 = -dx_1^2 - dx_2^2 - dx_3^2 + c^2 dx_4^2$$

$$dG_m^2 = -dp_1^2 - dp_2^2 - dp_3^2 + c^2 dp_4^2$$

are infinitesimal invariants respectively expressing a spatio-temporal property of the kinematic element X(M) and P(m)

$$\Omega_M = \frac{1}{\sqrt{1-(\frac{v_M}{c})^2}} \qquad \Omega_m = \frac{1}{\sqrt{1-(\frac{v_m}{c})^2}}$$

To recast Newton's formula of gravitational potential into a Lorentz-invariant form, Whitehead uses the formula

---

9 POR p.84.

$$dJ^2 = dG_M^2 - \frac{2}{c^2}\sum_m \Psi_m dG_m^2 = dG_M^2 - \frac{2}{c^2}\sum_m \frac{\gamma\, m}{\Omega_m (r_{(x)} - \xi_m)} dG_m^2$$

$\Psi_m = \dfrac{\gamma\, m}{w_m}$ where g is the gravitational constant, and w_m is a Lorentz-invariant quantity $w_m = \Omega_m \{c(x_4 - p_4) - \xi_m\} = \Omega_m \{r_{(x)} - \xi_m\}$

$$\text{where } \xi_m = \frac{1}{c}\{(x_1 - p_1)\dot{p}_1 + (x_2 - p_2)\dot{p}_2 + (x_3 - p_3)\dot{p}_3\}$$

If the mass is at rest, then w_m becomes identical with the spatial distance r, we get the Newtonian formula of gravitational potential. Thus Whitehead's theory can give Newton's formula under the special condition.

2 Whitehead’s theory of Gravitation and Black-and-White Holes

It is a well-known fact since Eddington(1924) that Whitehead’s gravitational theory gives equivalent results to Einstein’s concerning the one-body problem. As the corresponding solution of general relativity is given as Schwarzschild’s space-time, Whitehead’s theory of gravitation can pass all classical tests of general relativity.

Considering that whereas Einstein’s theory identifies gravitation with space-time curvature, Whitehead’s background space-time is the “flat” Minkowski space-time, it needs explanation why both theories give mathematically equivalent solutions with each other in the case of the one-body problem. In the following I will show that the equivalence between both theories does not hold in the case of an extremely strong gravitational field, i.e. black-hole or white-hole singularities.

First we compare the *ds* formula as pace-time metric in Einstein’s theory with *dJ* formula as potential mass impetus in Whitehead’s theory concerning the one-body problem. Let the mass of a central body be *m*, the gravitational constant γ, the gravitational radius $a = \dfrac{2\gamma\, m}{c^2}$. For simplicity, let c=1, 2γ=1 in the suitable measure of units. Let the ratio of *a* to the distance r from the central body be *β*, *β* is extremely smaller than 1. (Whereas the gravitational radius of the sun is about 3 km, $r > 7\times 10^5\ km$.) Let the uniform and isotropic metric be $\eta_{\mu\nu}$ in Minkowski space-time. Then,

Einstein's metric formula *ds* representing the warped space-time	Whitehead's formula *dJ* for the potential mass impetus
$ds^2 = \sum_\mu \sum_\nu g_{\mu\nu} dx_\mu dx_\nu$ $g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$ $h_{mn} = -\beta(1-\beta)^{-1} r^{-2} x_m x_n$ $h_{m4} = 0 \qquad h_{44} = -\beta$	$dJ^2 = \sum_\mu \sum_\nu J_{\mu\nu} dx_\mu dx_\nu$ $J_{\mu\nu} = \eta_{\mu\nu} + k_{\mu\nu}$ $k_{mn} = -\beta\, r^{-2} x_m x_n$ $k_{m4} = \beta\, r^{-1} x_m \qquad k_{44} = -\beta$

If we use the polar coordinate, then Einstein's theory gives the infinitesimal space-time distance

$$ds^2 = -(1-\beta)^{-1} dr^2 - r^2(d\theta^2 + \sin^2\theta\, d\varphi^2) + (1-\beta)dt^2$$

Whitehead's theory, gives the infinitesimal potential mass impetus

$$dJ^2 = -(1+\beta)dr^2 - r^2(d\theta^2 + \sin^2\theta\, d\phi^2) + (1-\beta)dt^2 + 2\beta dr dt$$

If we bracket the physical interpretation of respective theories off and compare *dJ* and *ds* as purely mathematical formula, then we find that there is a transformation from one to the other. When we let a time coordinates *t* in *dJ* be transformed to *t'*

$$t = t' - a\log|(r-a)| + const. \qquad (dt = dt' - a(r-a)^{-1} dr)$$

we get

$$dJ^2 = -(1-\beta)^{-1} dr^2 - r^2(d\theta^2 + \sin^2\theta\, d\varphi^2) + (1-\beta)dt'^2$$

which is equivalent to Einstein's *ds*.

Can we also maintain the physical or semantic equivalence between Whitehead's *dJ* and Einstein's *ds* on the above mathematical or syntactical equivalence?

Those physicists who have so far compared both theories seemed to take the physical equivalence for granted at least concerning the one-body problem, and search for the difference in the many-body problem. I would like to stress that both theories cannot be semantically equivalent even for the one-body problem.

Let us note the difference between *ds* and *dJ* concerning temporal symmetry.

Einstein's formula is <u>symmetrical</u> for the temporal coordinate, whereas Whitehead's formula for potential mass impetus is <u>non-symmetrical</u>. The semantic reason which causes this syntactical difference is that Whitehead adopts the retarded potential (the past of *m* determines the present gravitational potential around *M*) when he calculates the gravitational influence from *m* to *M* separated from each other at a distance. In other words, causal influence is always transmitted from the past to the future and *not vice versa* in Whitehead's theory.

In the case of Einstein's *ds*, not only the spatial coordinates are symmetrical, but also with respect to time coordinates; *ds* does not say the temporal directionality of gravitational influences. The distinction between the future and the past in the general theory of relativity does not appear in the formula itself, but only when we consider the initial condition which we can choose.

The temporally non-symmetrical character of Whitehead's theory will be forced to be symmetrical through the transformation:

$$t = t' - a\log|(r-a)| + const. \quad (dt = dt' - a(r-a)^{-1}dr \ )$$

which is meaningful only in the framework of general relativity where the temporal coordinate does not have any objective meaning independent of spatial coordinates. There is a distinction between space-like and time-like (four-dimensional) distances *ds as a whole* but there is no guarantee that the temporal coordinate t always represent time in the Schwarzschild metric *ds.* When $\beta > 1$, the role of temporal coordinate *dt* and that of spatial coordinate *dr* are *formally* exchanged with each other, and, therefore, the condition t=const. does not always represent the temporal cut of the four-dimensional world.

On the other hand, Whitehead theory presupposes the multiple time-systems in which the condition t=constant must always represent real time in a suitable inertial system. Therefore, t' does not represent real time (i.e. time as measured in a inertial system) in Whitehead's theory. Further, if β=1, Einstein's metric represents singularity, i.e. the so-called event horizon, whereas Whitehead's *dJ* does not represent any singularity at all.

In fact, Whitehead's formula *dJ* (the potential mass impetus) corresponds to the coordinate system which Eddington-Finkelstein used for the purpose of resolving a singularity of the Schwarzschild metric. In Einstein's formula, this singularity appears on the surface of a black-hole and a white-hole. Whitehead's *dJ* corresponds to the suitable coordinate system which contains no-singularity for a white-hole. A Variant of Whiteheadian gravitational theory, which uses "advanced potentials" (i.e. the future-state of one particle influence the present-state of another particle) corresponds to the space-time coordination containing no singularity for a black-hole.

Whitehead insists that space-time geometry should be distinguished from contingent influences of gravitational field. Gravitation would cause physical singularities but not space-time singularities in Whitehead's theory. On the other hand, Einstein's theory does not distinguish between space-time metric and gravitation. The paradigm difference between both theories becomes evident when we consider the so-called "event horizon" of the surface of a black-hole in the Schwarzschild solution.

If we substitute $d\theta$=0, $d\varphi$= 0, and ds = 0

In $ds^2 = -(1-\beta)^{-1}dr^2 - r^2(d\theta^2 + \sin^2\theta\, d\varphi^2) + (1-\beta)dt^2$, then we can get the velocity of light v along the direction of a radius in the rest frame with a strong gravitational field such that

$|v|=|\frac{dr}{dt}|=|1-\beta|=|1-\frac{a}{r}|<1$.

When $r \to \infty$. then $v \to 1$(= c), i.e. the absolute value of the speed of light in the vacuum without any matter. The nearer the light approaches the event horizon, the smaller the speed of light becomes, and if r=a, the speed of light would becomes zero.

If we adopt Einstein's interpretation of gravity, we must say that the above velocity of light which *seems* less than 1 is only *apparent* and the speed of light *is* always constant (absolute) if we adopt a locally-chosen inertial frame around every 4-dimensional point of space-time. The contraction of a measuring rod along the direction of a radius and the delay of a clock cancel each other so that the speed of light will be constant (i.e. absolute) in every locally-chosen frame.

On the other hand, if we adopt Whitehead's interpretation of gravity, the his formula dJ simply tells that the velocity of light cannot be constant in the presence of the gravitational field. There would be no distinction between real and apparent speeds of light.

If we substitute $d\theta$=0, $d\varphi$= 0, and dJ=0,

in $dJ^2 = -(1+\beta)dr^2 - r^2(d\theta^2 + \sin^2\theta\, d\phi^2) + (1-\beta)dt^2 + 2\beta dr dt$, then we get the velocity of light v along the direction of a radius in the rest frame with a strong gravitational field such that

v= 1 or $-\frac{1-\beta}{1+\beta} = -\frac{1-\frac{a}{r}}{1+\frac{a}{r}}$, which means that the speed of a out-going light is always constant whereas the speed of a in-going light becomes smaller and smaller until it becomes zero when r=a. We may sum up the correspondence between Whitehead's dJ and Einstein's ds concerning the one-body problem as follows.

The coordinates system which represents Schwarzschild space-time metric ds resolving the surface singularity of a White-hole

↔ Whitehead's dJ adopting retarded potentials.

The coordinates system which represents Schwarzschild space-time metric ds resolving the surface singularity of a Black-hole

↔ Whitehead's dJ adopting advanced potentials.

The above shows that Whitehead's theory contains formula corresponds to the Schwarzschild metric without surface singularities, i.e. the so-called event horizon of spatio-temporal "holes".

3 The Creative Advance of the World in Process Philosophy

The theory of relativity and quantum mechanics, as they both contain revolutionary principles of physics to be generalized as a unified cosmology, exerted a great influence in the making of Whitehead metaphysics. One of the main characteristics of Whitehead's cosmology is "the creative advance of the world". Time is an essential dimension in which the history of the whole universe is dynamically related with an individual "actual occasion" which prehends and transcends its "actual world" as a "subject-superject", or as a "self-creating creature". Subjectivity and objectivity are, thus, dynamically related with each other, and the otherwise contradictory qualifications, such as relationality versus individuality, interdependence and *causa-sui*, become the unity of opposites through creative process. The principle of universal relativity does not remain a physical principle , but it is generalized as the most universal metaphysical principle in the philosophy of organism. The principle of relativity in Whitehead's metaphysics is not, as Einsteins', a physical principle concerning the choice of apatio-temporal coordinates system, but the ontological principle of metaphysics which stipulates essential relatedness of actual entities with the distinction between actuality and potentiality, subjectivity and objectivity: actuality as subjectivity implies becoming, and being as objectivity implies mere potentiality.

The principle of relativity in Whitehead's *metaphysics* is so thoroughgoing that it does not only apply to the inner-world occasions, but also applies to the God-world relation itself. God as an actual, infinite, and eternal entity and spatio-temporal occasions are "in unison of becoming" in the common history as a unity of contrasted opposites.

On the other hand, Einstein's *physical* principle of relativity, seems to be in sharp contrast with Whitehead's metaphysical principle. The background philosophy of Einstein's physical theory is incompatible with the very idea of "creative advance" of the world in Whitehead's sense. Every thing seems to be eternally fixed in the framework of the four-dimensional manifold of space-time *sub specie aeternitatis*. Einstein's theory of relativity "spatializes" time, not to mention the essential directionality of time, the "becoming" of an actual occasion in process metaphysics. Strict determinism seems to hold sway there as well as the Newtonian world-system.

Some process theologians, unsatisfied with the locality of “now-here”, postulate “now-everywhere” ,i.e. something like “the temporal front” of the creative advance of the world. The idea of “now-everywhere”, however, presupposes the old-fashioned idea of absolute time, and so “there is the rub”: Is process cosmology capable of talking about the “creative advance of the whole universe” without relying on the Newtonian idea of absolute time? If possible, then how is it possible for us to talk of the creative history of the universe in a non-deterministic sense without relying on the concept of “absolute” time? What is the nature of the relation between process cosmology and the relativistic concept of time which Einstein systematized in his theory?

Question: Is the idea of “the creative advance of the world” in process cosmology compatible with the theory of relativity?

It seems that the idea of “the creative advance of the world” is incompatible with the theory of relativity.

(Objection-1) The theory of relativity is fundamentally a deterministic theory: all events are described there from the standpoint of eternity (*sub specie aeternitatis)*. Time in relativity physics is so completely “spatialized” that nothing novel appears in space-time, and the contrast between the indeterminate future and the determinate past disappears in this theory.

(Objection-2) Process cosmology needs some kind of “temporal front” of the universe, i.e. the cosmological “now” has an objective absolute meaning without any reference to spatial positions. As the special theory of relativity excludes the notion of “absolute simultaneity”, we cannot say “now” globally, but only say “here-now” locally in the truly objective sense.

(objection-3) The general theory of relativity does not guarantee the existence of the cosmological time which can locate all events of the universe in the unique well-ordered sequence of temporal coordinates. Whether such a cosmological time exists or not depends on the contingent distribution of matter in the universe. As some cosmological solutions of Einstein’s equations (e.g., Gödel’s model with closed time-like world lines) excludes the possibility of cosmological time, the distinction between past and future along the time-like world lines loses its global meaning. There is no a priori necessary reason why there should be a history of the whole universe.

On the contrary, we must remember that the historical origin of process cosmology was Whitehead's encounter with the theory of relativity and quantum physics. Whitehead's speculative philosophy must be evaluated as a metaphysical generalization both of the principle of universal relativity and the individuality of a quantum event. This fact shows that "the creative advance of the world" is a necessary conceptual apparatus in Whitehead's metaphysics in order to unify the background ideas of relativity theory and quantum physics.

I will answer and respond to above objections in the following way:

When we consider the theory of time in process cosmology, we must distinguish between Whitehead's tripartite work for philosophy of science and his later metaphysics. *The principles of natural knowledge* treats only with an objective aspect of nature as perceived whereas *Process and Reality* treats both with subjectivity and objectivity, and also with a dynamical transition from objectivity to subjectivity as well as from subjectivity to objectivity. The main theme of the philosophy of organism is the internal genetic analysis of actual occasions and the coordinate analysis of their extensive interrelations.

The philosophical theory of time must first discuss time as lived by us, that is, the internal time-experience in our memory, our direct perception of ourselves and the external world, our anticipation of the indeterminate future, and then the external time measured by clocks in physics. Both discussions are necessary in order to avoid the "fallacy" of misplaced concreteness.

That actual occasions do not happen in space-time is the fundamental stand-point of process metaphysics. Space-time is an abstraction from the interrelations of actual occasions, and not the absolute framework in which actual occasions happen. Process in the primary sense as "concrescence" does not mean a temporal passage measurable by clocks: it means an actualization of potentiality, a self-creating process of the unity of subject appropriating and housing the actual world. An actual occasion having arisen from its actual world always transcends it as a novel self-creating creature, and gives itself to its future actual occasions. The creative advance of the world in process metaphysics means that every actual occasion arises as a unity of subject in its actual world and also transcends this world as s self creating creature. We can represent the dialectic reciprocal movement of an individual actual occasion and its world in the following schema:

Let us denote actual occasions with a,b,c….., and their actual worlds with w(a),w(b),….. The actual world of an actual occasion is always finite because actuality must be finite and determinate in every possible ways. But actuality also means "decision among alternative potentialities", always involves the increase of information in the universe. An actual occasion prehends the universe from its own perspective, creates a new world with contrasts.

As an actual occasion x is a novel entity diverse from any entity in the "many" which it unifies(PR21), x cannot be a member of its own actual world.

$$\forall x(\neg (x \in W(x)))$$

In other words an actual entity housing its actual world always transcends that world. This is a fundamental aspect of the creative advance of the world. As "becoming" is a creative advance into novelty, the meaning of the phrase "the actual world" is relative to the becoming of a definite actual occasion. Further, no two actual occasions originate from an identical world, though the difference between the two worlds only consists in some actual occasions in one and not in the other, and in the subordinate entities which each actual occasion introduces in to the world (PR23):

$$\forall x \forall y((W(x) = W(y)) \to (x = y))$$

The asymmetry between the past and the future is represented as the asymmetrical relation between an actual occasion and the actual world of another actual occasion such that

$$\forall x \forall y((x \in W(y) \to \neg (y \in W(x)))$$

The creative advance of the world is a cumulative process in the following sense:

$$\forall x \forall y \forall z(((x \in W(y) \wedge (y \in W(z)) \to (x \in W(z)))$$

The creative advance of the world in the primary sense is said about one actual occasion and its actual world, and the creativity is an individual occasion's self-creating creativity. The advance itself does not presuppose the well-ordered temporal sequence of actual occasions. Only the partial order is sufficient to express the cumulative character of the creative advance of the actual world.

4 Process Philosophy and Big-Bang Cosmology

Relativistic quantum cosmology is one of the most controversial frontiers of modern physics. The discovery of astronomical vestiges of the Big-Bang in the 1960s has made it possible for physicists to tackle metaphysical problems concerning the origin and the destiny of our universe.[10] In the Western Middle Ages, God's creation of heaven and earth in seven days was a topic of great importance amongst Christian theologians. Today, it is

[10] X. Fustero & E.Verdauer, "Standard Big-Bang Cosmology", in *Foundations of Big-Bang Cosmology*, ed. by F.W. Meyerstein, World Scientific, 1987, pp.29-140.

the physicist Steven Weinberg's story of "the First Three Minutes" after the Big-Bang about fourteen billion years ago which engages the minds of those concerned with the origin of the universe.[11] Some physicists, unsatisfied with merely describing the universe *after* the Big-Bang, boldly set about resolving the Big-Bang-singularity itself. The dogma of *creatio ex nihilo*, which was considered as one of the incomprehensible mysteries in Christianity, is now discussed by physicists as a genuine theoretical possibility.[12]

Leibniz summed up the fundamental problems of metaphysics in the question: "Why are there beings rather than nothing at all?" His answer was based on the principle of sufficient reason, which ultimately appealed to God as the First Cause.[13]

Heidegger restated the above question with capitalized *Nichts*, and criticized onto-theology for its explication of *Being*.[14] Metaphysics is not sufficient for the solution of the *Problematik* of *Being* because the "root" of beings is not a being at all. We will find an analogous situation in the realm of natural science today in the search of the ultimate ground of being.

As quantum physics does not permit the unlimited use of the principle of sufficient reason, the creation of the universe from nothingness, which has been formulated as a fluctuation of the vacuum, might well be considered as a mere *contingency* in the sense suggested by Heisenberg's principle of uncertainty. Such a conception of *nothingness* seems necessarily to result in a kind of paradox because it explicitly contradicts one of the most fundamental principles of ontology: that nothing comes out of nothing, or everything comes out of something. I would like to discuss two interrelated problems which have some bearings on the transcendental dialectics of Kant's *First Critique*, and then to put forward the paradox of Big-Bang cosmology; Why are there beings rather than nothing at all?

The first problem to be considered concerns the "decidability" of the cosmological problems;

Is it possible for us to determine, empirically or speculatively, whether the whole universe is finite or infinite in space and in time?

As the universe qua the spatio-temporal totality of beings necessarily includes ourselves who ask the cosmological question, we cannot observe it from the outside in relation to

---

[11] S. Weinberg, *The First Three Minutes*, Basic Books, Inc. Publishers, 1987.

[12] *300 Years of Gravitation*, ed. by S. W. Hawking & W. Israel, Cambridge University Press, 1987.

[13] G. W. Leipniz, “Principles of Nature and of Grace, founded on Reason” in *Leipniz: Philosophical Writings*, translated by Mary Morris, Everyman's Library, p.26.

[14] M. Heidegger , *An Introduction to Metaphysics*, translated by Ralph Manheim, Yale University Press, 1959, pp. 1-51.

space and time. Only able to inquire into the universe from the inside, we cannot in principle stipulate the spatio-temporal boundary conditions of the universe. How, then, can we apply the fundamental laws of physics to the whole universe without knowing its boundary conditions? And even if we can do without necessary boundary conditions on the purely theoretical level, how can the Big-Bang cosmology claim empirical certainty concerning the origin of the universe when, according to the accepted theory, we human beings, are only the latest products of the expanding universe?

The second problem to be considered concerns the modern version of the cosmological arguments for a God who imposes order on the universe;

How has the universe achieved its organization in its history since the Big-Bang?

The second law of thermodynamics tells us that any closed system cannot evolve from chaos to order. If there is any system evolving from chaos to order, it must be open, and therefore capable of admitting new "information" through its interaction with the outside environment.

Therefore, if we admit the creative evolution from the simple to the complex material structures of the universe, we would have to characterize the whole universe as an open system. But *what is it to which the universe open?*

If it is something, then it must be included in the universe. On the other hand, if the universe is a self-sufficient closed system, how can we explain the creative evolution from the Big-Bang to the present universe — a process which includes the creation of human beings who can ask the being of the universe?

One may think that the impossibility of resolving the above cosmological problems had been established by Kant's *First Critique*. Certainly, Kant's stated intention was to prove that the *a priori* use of pure reason cannot determine whether the universe is finite or infinite because of the antinomy which it necessarily involved. I would like to stress that the problem is more complex for us than it was for Kant. Due to the scientific revolution caused by the theory of relativity and quantum physics, Kant's cosmological arguments can no longer be acceptable without suitable modifications. Kant was able to assume the universal validity of Euclidean geometry and Newtonian physics as *quid facti*, and to ask the *quid juris* question concerning the possibility of such knowledge a priori.

Thanks to Einstein we have come to believe that both Newtonian physics and Euclidean geometry are not universally valid, and that their validity should therefore be claimed only as a posteriori knowledge. Moreover, the status of the fundamental laws of physics which Kant considered as synthetic *a priori* has been drastically changed; for example, the conservative law of matter has been unified with that of energy, and the law of causal change has been reformulated in terms of probability theories. Kant's arguments of transcendental analytics proved to be insufficient for the explanation of the problems of modern physics. This means that while Kant's laying of the foundation of empirical science in judgments synthetic a priori has become dubious, physicists today are beginning to consider cosmological problems that Kant rejected as unanswerable on purely rational grounds a priori in his arguments dealing with transcendental dialectics.

The finite-versus-infinite antinomy of the universe was resolved by Einstein in his 1917 paper, "Cosmological Considerations on the General Theory of Relativity".[15] In this celebrated paper, Einstein set out to resolve the paradoxical problem of how to describe the whole universe including ourselves from the inside — that is, how to apply the differential laws of relativity physics to the whole universe, and how to integrate them without the arbitrary specification of its boundary conditions. Einstein has shown that this paradox of impossible boundary conditions can be resolved if our universe proves to be a non-Euclidean, Riemannian space with a positive curvature on empirical grounds a posteriori. In this case, our universe is t o be described as a spatially finite universe with no boundaries, and the condition of having no boundaries would serve as a boundary condition for the application of the universal laws of physics to the universe. Einstein's predilection with the eternity of the universe led him to introduce the "cosmological constant" in order to make his model of the universe temporally stable. In 1922 Einstein's static cosmology was modified by Freedmann in such a way that it could describe the unstable evolving universe; and this was verified by astronomical observations of Hubble's law.[16]

The problem of the eternity of the universe was empirically decided by Penzias and Wilson, whose 1964 discovery of background radiation as the remnant of the Big-Bang earned them a Nobel Prize in 1978. The standard theory of the Big-Bang is theologically important, for it tells us on empirical grounds that the universe is spatially finite though it has no boundaries; that the universe has a history spanning about fourteen billion years; and that the material structure of the universe has been formed in the process of its expansion.[17] It is noteworthy that the method of relativistic cosmology is characterized by the idea that the topology of space-time is inseparable from the gravitational field. The universe as a whole must be taken into consideration because of the gravitational field

---

[15] Einstein, "Kosmologische Betrachtung zur Allgemeine Relativitäts Theorie", S.B. Preuss. Akad. Wiss.,1917, pp. 142-152

[16] Freedmann, "Über die Krummung des Raumes", Zeitschr.Phys. ,10, l922, pp. 377-86.

[17] P. Davies, God and the New Physics, Penguin Books, 1984, pp.25-44.

which makes the idea of an isolated physical system untenable.

Moreover, topological thinking of relativity physics demands that the concepts of spatial distance and temporal duration be modified in such a way that they become frame-independent measurable quantities; it should be reconsidered within the framework of four-dimensional space-time. There is a sense in which we can say that Big-Bang which occurred fourteen billion years ago is nearer to us than the events we read about in yesterday's newspaper — if, that is, we can define "nearness" in terms of the four-dimensional distances of relativistic cosmology. The fact that we can now observe the evidence of the Big-Bang in Penzias and Wilson's background radiation means that the beginning of the universe can be located on the backward light cone at a zero distance from the here-present event. We may say that the relativistic cosmology, through combining Riemann's idea of the non-Euclidean manifold of space-time with empirical evidences, has answered the first antinomy of Kant's transcendental dialectics in such away that the universe has a temporal beginning, that it is spatially finite in spite of having no boundaries, and that it is now expanding itself in the cosmological history. Although we have evidences of the past singularity of the Big-Bang, we cannot have such a direct evidence of the future singularity of the Big-Crunch as the global "death" of the universe. Concerning the future of the universe, we have not empirical evidences enough to predict whether the universe has a temporal end or not.

The "birth" problem of the universe, however, seems inseparable from the "death" problem because we can have empirical evidences of the black hole which can be considered as a local "death" of the universe. The existence of a black hole which relativistic cosmology predicts would theoretically give us essential information concerning the life-death problem of the universe. Rejecting the idea of the eternal universe, modern physics has solved another paradox concerning the "heat death" of the universe.

In 1865 Clausius predicted on the basis of the cosmological formulation of the two laws of thermodynamics; the entropy as the measure of disorder of the universe will increase to the maximum-thermodynamic equilibrium, whereas its energy always remains constant. This prediction was paradoxical. If the universe is eternal in the sense of the conservation law of mass and energy, why did it not reach to the state of maximum entropy long ago? And if the universe has a beginning in time, what or who "wound up the clock" of cosmic maximum complexity and order in the beginning? Such a concept of *deus ex machina* would be formidable both to scientists and theologians.

After the discovery of the Big-Bang, physicists began to reconsider Clausius' cosmological formulation of thermodynamics. According to our best scientific understanding of the primeval universe, it does seem as though it began in the simplest state of all and that the currently observed complex structures and elaborate activity only appeared subsequently. Clausius thought that the evolution of the universe from simplicity to complexity would be impossible and the "heat death" would be an inevitable result.[18] Certainly, the second law of thermodynamics requires that the order of any closed system should give way to disorder, so that complex structures tend to decay to a final state of disorganized simplicity. Therefore, if the universe as a whole is a closed system, the evolution of the universe from simplicity to complexity would be impossible and the "heat death" would be an inevitable result. The fact of creative evolution means that the universe cannot be a closed system. As there is nothing outside of the universe, we must say that the universe as the totality of beings is open to nothingness. This paradox of "open wholeness", the apparent conflict of the creative evolution of the universe with the second law has only recently been solved.

According to Paul Davies, Fan Li Zhi, and other physicists, the coupling of thermodynamics and the cumulative effects of universal gravity opens the way to the injection of order into cosmic material by the cosmological gravitational field.[19] The expanding universe can generate order in the cosmic material itself, thus preventing thermodynamic equilibrium. Moreover, the expansion of the universe should be considered as a continuous creation of space rather than as scattering of material beings into empty space as the ready-made framework. The universe as a whole can be an open system through its spontaneous generation of order in cosmic material during its dynamic expanding process.

Tanabe argued from philosophical reasons in *Dialectics of Relativity Physics* that relativity physics contains contradictions which cannot be solved in its own terms unless it is integrated with quantum physics.[20] Both relativity and quantum theories can provide only partial descriptions of the universe; the former deals with the extremely macroscopic whereas the latter with the extremely microscopic aspects of the same universe.

In 1970 Penrose and Hawking mathematically proved that the Big-Bang as well as black

---

[18] R. Clausius, Ann. Phys. Vol.125, 1865, p.353., cited in Order our of Chaos, by Ilya Prigogine and Isabelle Stengers, A Bantam Book, 1984, p.119.

[19] P. Davies,op.cit.,pp.44-57. Fan Li Zhi and Ll Shu Xian, *Creation of the Universe*, World Scientific Publishing Co. Pte. Ltd. , 1989, Chap.6.

[20] *The Complete Works of Hajime Tanabe, 12*, pp.371-402., Chikuma Shobo , Tokyo, 1964

holes are inevitable results of Einstein's theory of general relativity. Relativistic cosmology is considered by them to be incomplete for the explanation of the life-death problem of the universe; it must be complemented by quantum physics because there seems to have been "the coincidence between maximum and minimum" both in the beginning and end of the universe. By a simple application of quantum mechanical principles, it is estimated that, at scales of 10^{-33} cm and durations shorter than 10-43 second, general relativity will have to be supplemented by a theory that correctly handles the quantum effects of the very early universe. It is in this domain of quantum cosmology that we seem to confront what may be called the ultimate paradox of physics: why are there beings rather than nothing at all?

In 1982 the Russian physicist Alex Vilenkin launched a relativistic quantum theory of *cosmogenitum ex nihilum* in his paper, titled "Creation of Universes from Nothing".[21] The American physicist Heinz Pagel commented on Vilenkin's idea of Nothingness as the earliest state of the universe:[22]

> The Nothingness "before" the creation of the universe is the most complete void that we can imagine --- no space, time, or matter existed. It is a world without place, without duration or eternity. . . .Yet this unthinkable void converts itself in the plenum of existence ---a necessary consequence of physical laws. Where are these laws written into the void? It would seem that even the void is subject to law, a logic that existed prior time and space.

Vilenkin's answer to the fundamental paradox of physics might well be characterized as saying that there is something rather than nothingness because nothingness is creative. He used an analogy of nothingness between the creation of the universe from nothingness before its inflationary expanding stage on the one hand and the pair-creation of a particle and its anti-particle from nothingness on the other, the latter of which we can confirm as a "quantum tunneling effect" in experiments. Instead of "Nature abhors a vacuum", the view of the new physics suggests, "The vacuum is all of physics; everything that ever existed or can exist is already potentially there in the vacuum as the place of nothingness. Physicists came to this remarkable view of the nothingness by way of a deeper understanding of Heisenberg's uncertainty principle and the existence of anti-matter. [23]

---

[21] Vilenkin, "Creation of Universes from Nothing", Physics' Letters, 1982, pp. 25-28.

[22] H.R. Pagels, *Perfect Symmetry*: *The Search for the Beginning of Time*, New York, Simon and Schuster, 1985, p.347.

[23] H. R. Pagels , The Cosmic Code : Quantum Physics as the Language of Nature, Penguin

The *cosmogenitum ex nihilum* in relativistic quantum physics does not imply that there is any concept of time in which the universe did not exist before a certain instant and then came into being. Real time is defined only within the universe, and does not exist outside it. The creation of the universe from nothingness as a tunneling quantum effect at the minimum radius was described through an imaginary time, which the "no boundary proposal" for the quantum state postulates. As Stephen Hawking has emphasized, to ask what happened before the universe began is like asking for a point on the Earth at 91^0; it just is not defined. In what way should we realize the creative nothingness of quantum relativistic cosmology? We cannot consider it as *absolute nothingness* because we must still grant the existence of a body of pre-existing laws of nature in order to explain the *cosmogenitum ex nihilum* in scientific terms. *The topos of nothingness* from which the universe is created, in which the expanding universe is open, must be more primordial than space-time. This *topos* cannot be space-time without matter because space-time itself has been created in the beginning. The Whiteheadian concept of the extensive continuum as the receptacle of creativity would give an important philosophical suggestion concerning how to realize this primordial place of nothingness. Whitehead characterizes the extensive continuum as below:[24]

> The extensive continuum expresses the solidarity of all possible standpoints throughout the whole process of the world. It is not a fact prior to the world; it is the first determination of the order---that is, real potentiality---arising out of the general character of the world. In its full generality beyond the present epoch, it does not involve shapes, dimensions, or measurability; these are additional determinations of real potentiality arising from our cosmic epoch.

The Big-Bang cosmology which has recovered the solidarity of the whole universe needs the concept of nothingness both as the receptacle which is more fundamental than the four dimensional space-time manifold on the one hand, and as creative activity which makes the universe evolve in this receptacle on the other. Creativity in the topos of nothingness is the principle which makes it possible for the universe to exist as an "open wholeness."

Books, 1986, pp.252-256.

[24] Whitehead, Process and Reality, corrected edition, p.66, Free Press, 1979