The Principle of Relativity and Process Cosmology

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1. The Difference between Einstein's and Whitehead's Principles 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 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

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[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.

[3] Whitehead, A. N., *Process and Reality (PAR),* The Free Press Corrected Edition, 1978, p. 22.

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 is the reversal of Aristotelian ontology. The concept of matter as "hypokeimenon" (substratum) of nature, the cornerstone of scientific materialism, presupposes the Aristotelian 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 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

[4] Whitehead, A. N., *The Principle of Relativity(POR)*, Cambridge University Press, 1922, p.21.

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 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

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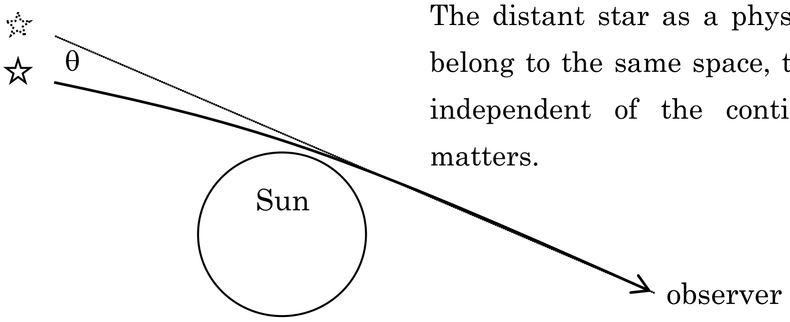
[5] Whitehead, A. N., *The Concept Of Nature*, Cambridge University Press, 1920, p.165.
[6] *POR*, p. 83.

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 (i.e. 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]



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

[7] POR p.110

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: $\frac{d}{du_4}\frac{\partial}{\partial \dot{u}_\mu}\frac{dI}{du_4} - \frac{\partial}{\partial u_\mu}\frac{dI}{du_4} = 0$ $[\mu = 1,2,3]$ 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 $\left\| J^{(x)}_{\mu\nu} \right\|$ 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 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]

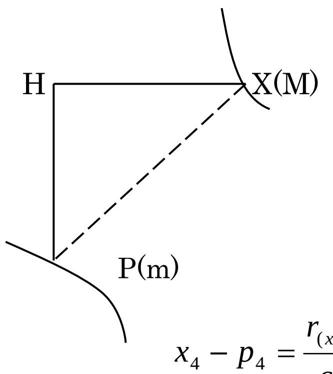
> If the above formula gives results which are discrepant with observation, it would be quite possible with my general theory of nature adopt Einstein's formula, based upon his differential equations, for the determination of the gravitational field. They have however, as initial assumptions, the disadvantage 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: $P(p_1,p_2,p_3,p_4)$



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

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

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

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

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

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

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[8] *POR.* p. 80.

[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 γ is the gravitational constant, and w_m is a Lorentz-invariant quantity $w_m = \Omega_m\{c(x_4 - p_4) - \xi_m\} = \Omega_m\{r_{(x)} - \xi_m\}$

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

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

2 Critical Examinations of Whitehead's physical theory of gravitation in the history of 20th century physics

Eddington first took notice of Whitehead's theory. He proved in his 1924 paper that Whitehead's equation has the same solution (the Schwartzchild solution) as Einstein's in the special case of the stationary gravitational field due to a single mass-point.[10] The implication of this equivalence was that Whitehead's theory can pass the standard tests such as periherion precession of Mercury and the bending of light-rays close to the sun. The similar result was obtained by Temple, who also gave a generalized version of Whitehead's theory which holds in the space-time with constant curvature.[11] In the 1920s, the comparison of two theories was mainly on the level of conceptual analysis, for both gave the same results under the limited conditions, and it was difficult to choose between them on experimental grounds then available. The question at issue was the justifiability of Whitehead's theory which, presupposing Minkowski's space globally, rejected the general principle of relativity. For example, Band criticized Whitehead by pointing out that the acceptance of a uniform or "fiat" space was untenable on account of the illegitimate assumption of a standard of absolutely uniform motion.[12] But the problem of finding the exact solutions of both theory other than Schwartzchild's was so difficult that the crucial experiment between them was not yet contrived.

In the 1930s and 1940s the main interests of physicists shifted to the realm of

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[10] Eddington, A. S. ,"A Comparison of Whitehead's and Einstein's Formulae", Nature, 113, 1924, p.192

[11] Temple, G., "Central Orbit in Relativistic Dynamics Treated by the Hamilton-Jacobi Method," Philosophical Magazine, Ser. 6, 48, I 924, pp. 277-292.

[12] Band, W. ,"Dr. Whitehead's Theory of Absolute Acceleration," Philosophical magazine, 7, 1929, pp. 434-40.

quantum mechanics and nuclear physics which developed without relying on any gravitational theory. Here physicists were satisfied only with the special theory of relativity, and kept away from Einstein's later project of relativistic cosmology and the unified theory of fields. Whitehead was regarded as a metaphysician, and his theory of relativity seemed to be virtually ignored during this period.

The re-evaluation of Whitehead's theory began in the 1950s, which was due to an Irish physicist, Synge, who esteemed Whitehead's theory for its elegance and originality, and located it between Newton's theory of action-at-a-distance, and Einstein's theory of local action. Setting aside Whitehead's philosophical background, Synge reconstructed mathematical formulae of Whitehead's theory in Einstein's terminology to make them accessible to contemporary physicists.[13] Synge also treated the problem of a continuous static model, and calculated the gravitational field of a finite sphere of uniform density at rest on the basis of Whitehead's theory.[14]

Two years later, this result was extended by Rayner to the case of non-static continuous distributions of matter. Calculating the gravitational field of a finite, uniformly rotating, homogeneous sphere, Rayner examined the perturbing effects of the rotation of the central sphere on the orbits of planetary motion, and got similar results to those obtained by Lens and Thirring applying Einstein's theory to the same problem. Rayner also constructed a cosmological model uniformly expanding with homogeneity and isotropy on the basis of Whitehead's theory. [15]

Whereas Synge and Rayner proved that Whitehead's theory, in spite of the paradigm-difference, had the same conclusions as Einstein's in various applications, Clark for the first time took up the problem of establishing a crucial experiment between the two. Having discussed on the two-body problem, Clark proved that Whitehead's theory of gravitation involves a secular acceleration of the center of mass, and suggested that Whitehead's theory might be refutable by observing the motions of the centers of mass of double stars.[16] The same problem was also discussed by Schild, who showed that Whitehead's theory can be modified in such a way that linear and angular

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[13] Synge, J., Relativity Theory of A. N. Whitehead, Baltimore: University of Maryland, 1951.

[14] Synge, J. L., "Orbits and Rays m the gravitational Field of a Finite Sphere according to the Theory of A N Whitehead " Proceedings of the Royal Society of London Ser. A 211 1952, pp. 303-319.

[15] Rayner, C. B. ,"The Application of the Whitehead Theory of Relativity to Non-static Spherically Symmetrical Systems," Proceedings of the Royal Society of London, 222, I 954, pp. 509-526.

"The Effects of Rotation in the Central Body on its Planetary Orbits after the Whitehead Theory of Gravitation," Proceeding of the Royal Society of London, 232, 1955, pp. 135-148.

[16] Clark, G A, "The Problem of Two Bodies m Whitehead s Theory," Proceedings of the Royal Society of Edinburgh, Ser. A, 64, 1954, pp. 49-56.

momentum are rigorously conserved, and the center of mass of any isolated system has no secular acceleration. Schild added an interesting remark that Levi-Civita, using Einstein's theory of general relativity, obtained a similar secular acceleration, but that this was later proved to be in an erroneous calculation.[17]

In the 1960s, the confrontation between gravitational theories and experiments again became a matter of concern for physicists. The rapid progress of technology and astronomy made it possible to test various gravitational theories at an unprecedented levels of accuracy. The number of theories in need of testing having increased, the desire to sift them out systematically was intensified. Pioneered by Dicke and Nordtvedt, the various meta-theoretical frameworks of gravitational theories were propounded. Concerning the principle of equivalence on which Einstein founded the general theory of relativity, we must mention the results of redshift experiments in 1965 on the earth by the use of the Mösbauer effect (recoilless emission and absorption of photons). The accuracy of that observation was about twenty times higher than those previously obtained by astronomical observations. This proved to be a strong support for Einstein who had considered the gravitational redshift one of the most important tests of general relativity. Moreover, it is thought by many physicists today that the result of the gravitational redshift proves the so-called Schiff's conjecture that any theory of gravitation must necessarily be a metric theory.

Inspired by Dicke's ideas, Will energetically grappled with the problem of testing in the 1970s, and presented five criteria by which we can eliminate those theories that disagree with experiment. He laid out the "Parametrized Post-Newtonian" framework (PPN) as a meta-theory in which nine metric parameters. varying from theory to theory, made it possible for him to render the various theories of gravitation commensurable. As for Whitehead's theory, Will admitted it was an elegant theory that had been "a thorn in Einstein's side", but claimed that he had now succeeded in refuting it by geophysical effects, the fifth criterion which he had invented.[18]

According to Will, Whitehead's theory involves a small anisotropy in the gravitational constant G measured by Cavendish experiments on the earth. As the earth rotates, the anisotropy in G produces "Earth tides", i.e. variations in the acceleration g measured by the gravimeter, which are completely analogous to the tides produced by the moon and the sun. Making use of a simplified model of the galaxy, Will calculated the amplitude of the earth tides on the basis of Whitehead's theory, and got the value,

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[17] Dyer, J. L. and Schild, A. ,"The Center of Mass Motion in a Conservative Gravitational Theory of Whitehead's Type," Journal of Mathematical Analysis and Application, 4, 1962, pp. 328-340.

[18] Will, C. M. ,"Einstein on the Firing Line," Physics Today, 25, 1972, pp. 23-29.

"Relativistic Gravity in the Solar System. II: Anisotropy in the Newtonian Gravitational Studies Constant ", 4, 1974, pp. 288-290. Astrophysical Journal 169 1971, pp. 141-156.

$\frac{\Delta g}{g} = 2 \times 10^{-7}$ which proved to be 200 times larger than the experimental limit. So he concluded that "Whitehead's theory, after 50 years of life. was "killed" by the geophysical data. Will's argument, though accepted by many physicists today as valid, was not without objections concerning the process he used to calculate and estimate the predicted value of earth tides. Fowler claimed that he could reduce the value by a factor of 100 under a different model of the galaxy, and thereby diminish the discrepancy between Whitehead's theory and the geophysical data. Remembering that Whitehead was prepared to adjust his own formulae to take account of new data, Fowler concluded that: [19]

> "The real issues between Einstein and Whitehead are not physical but philosophical. No empirical test can decide the issue of the adequacy of Whitehead's basic theory of relativity. This issue must be settled on other grounds."

3 The paradigm difference between Whitehead's and Einstein's theories of relativity reflected in the interpretation of coordinate singularities of the Black-hole or the White-hole.

It is a well-known fact since Eddington(1924) that Whitehead's gravitational theory gives the equivalent results to Einstein's concerning the one-body problem. As the corresponding solution of general relativity is given as Schwartzschild'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 mathematical equivalence does not mean the physical equivalence, and the equivalence itself does not hold in the case of the 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 $a = \frac{2\gamma m}{c^2}$. 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,

[19] Fowler, D, "Disconfirmation of Whitehead s Relativity Theory-A Critical Reply " Process Studies, 4, 1974, pp.288-290

$r > 7 \times 10^5\ km$.)

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

$$ds^2 = \sum_\mu \sum_\nu g_{\mu\nu} dx_\mu dx_\nu$$

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$$

$$h_{mn} = -\beta(1-\beta)^{-1} r^{-2} x_m x_n$$

$$h_{m4} = 0 \qquad h_{44} = -\beta$$

Whitehead's formula dJ for the potential mass impetus

$$dJ^2 = \sum_\mu \sum_\nu J_{\mu\nu} dx_\mu dx_\nu$$

$$J_{\mu\nu} = \eta_{\mu\nu} + k_{\mu\nu}$$

$$k_{mn} = -\beta\, r^{-2} x_m x_n$$

$$k_{m4} = \beta\, r^{-1} x_m \qquad k_{44} = -\beta$$

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 make a time coordinates t in dJ 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 physical 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 temporal non-symmetrical character of Whitehead's theory will be made symmetrical through the transformation $t = t' - a\log|(r-a)| + const.$ $(dt = dt' - a(r-a)^{-1}dr)$ 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 β > 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-system 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 Eddington-Finkelstein coordinates which is used for the purpose of resolving singularity of Schwarzschild metric. In Einstein's formula, this singularity appears on the surface of Black-hole and White-hole. Whitehead's dJ corresponds to the formula with no-singularity only for White-hole. A variant for Whitehead's gravitational theory, which uses "advanced potentials"(i.e. the future-state of another particle influence the present-state of one particle) corresponds to the space-time formula with no-singularity for Black-hole.

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 in order* to resolve the surface singularity of White-hole

↔ Whitehead's dJ adopting retarded potentials.

The coordinates system which represents Schwarzschild space-time metric *ds in order* to resolve the surface singularity of Black-hole

↔ Whitehead's dJ adopting advanced potentials.

The above shows that Whitehead's theory neither predict Black-hole nor White-hole, but contains formula corresponds to Schwarzschild metric without surface singularities, i.e. the event horizon of spatio-temporal "holes".

4 The creative advance of the world in Process Cosmology and the Principle of Relativity

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.

Relativity principle in Whitehead's metaphysics 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 the universe as the totality of spatio-temporal occasions are "in unison of becoming" in the common history as a unity of contrasted opposites.

On the other hand, Einstein's 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 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 Newton and Einstein? What is the nature of the relation between process cosmology and the relativistic concept of time which Einstein systematized in his theory? I would like to investigate the significance of process cosmology with a special reference to relativity theory, and reconsider the meaning of the concept of extensive continuum, the place of real potentiality in which the world constitutes itself as a four-dimensional space-time.

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 origin of process cosmology was the theory of relativity and the epochal theory of becoming whose inspiration came from quantum mechanics. Whitehead’s speculative philosophy can be viewed as the metaphysical generalization both of the principle of universal relativity and the individuality of a quantum event. This historical 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 themes 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 arised 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, i.e.,

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

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.