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Fallacious Notion of Spacetime Continuum

8.1 The Notions of Space and Time

Introduction. Most followers of Relativity theories consider the spacetime continuum to be a physical entity which can even be deformed and curved. This misconception is quite deep rooted in the metaphysical eternalist viewpoint of existence in contrast to the logical presentist viewpoint. As per the eternalist viewpoint, a so-called material object in a spacetime world is a continuous series of spacetime events, each of which exists eternally as a distinct part of the world. There is no distinction between the past, present and future. We may refer to it as a block view of spacetime. As per the presentist viewpoint, the present moment is different from the past and future and that physical entities exist only in the present. The physical phenomenon does not exist in the past and the future regions of time. The foundations of General Theory of Relativity (GR) are critically dependent on the integrity of the notion of spacetime continuum. Actually, spacetime is just a mathematical notion which has no physical existence.

The Coordinate Space. The association of the set of points P on coordinate line X with the set of real numbers x, constitutes a coordinate system of the one-dimensional space, once the notion of certain unit length has been defined. The one-to-one correspondence of ordered pairs of numbers with the set of points in the plane X^1X^2 is the coordinate system of the 2D space consisting of points in the plane. Similarly, with a predefined notion of unit length, an essential feature of 3D space is the concept of one-to-one correspondence of points in space with the ordered sets of real numbers. The predefined notion of unit length or scale for different coordinate axes constitutes the metric of space for quantifying the notion of distance and the position measurements of the sets of points in this coordinate space.

We define a space (or manifold) of N dimensions as any set of objects that can be placed in a one-to-one correspondence with the ordered sets of N numbers x^1, x^2,..., x^N. Any particular one-to-one association of the points with the ordered sets of numbers is called a coordinate system and the numbers x^1, x^2, ..., x^N are termed the coordinates of points. In all coordinate spaces that are metricized, we associate the notion of unit length along all coordinate axes and a metric tensor g_{ij} with each coordinate system. All essential metric properties of a metricized space are completely determined by this tensor.

The Physical Space. The notion of physical space implies the spatial extension of the universe wherein all material particles and all fields are embedded or contained. The true void between material points is in essence the physical space, or empty space, or free space. It is important to note here that the coordinate space, along with its scale or metric, is our 'human' creation intended to facilitate the quantification of relative positions of material particles and fields. The existence of physical space does not depend in any way on the existence or non-existence of coordinate systems and coordinate spaces. Of course, for the study and analysis of physical space and the material particles and fields embedded in it, we do need the structure of coordinate systems and coordinate spaces as a quantification tool. The most significant point to be highlighted here is that whereas the metric scaling property is only associated with coordinate space, the physical properties of permittivity, permeability and intrinsic impedance are associated with physical space.

Notion of Time. In Nature, there are a large number of physical processes, which undergo cyclic changes. Depending on the consistency of such cyclic changes and the convenience of their measurement, we may select any one of them as our reference scale for relative measurement of change. The angular position of a planet in orbit, the position of a pendulum oscillating about a mean and the vibrations of many electro-mechanical systems are all examples of physical processes that undergo cyclic changes. Any such process could be adopted as a reference scale for relative measurement of change or the reference scale for time. In general, the study of natural phenomenon invariably involves the comparative study of various changes. For this comparative study, we need to use a reference scale, or more correctly a reference time scale, for relative measurement of change or for measurement of time. Hence Time, as a relative measure of change, is an important parameter in the study of an essentially dynamic physical Universe.

8.2 Particle Traces

Consider a very simple example of a particle motion along the X-coordinate. This motion can be represented through a distance-time curve or trace on an X-T coordinate plane. The velocity and acceleration of the particle at any point along the X-axis will be represented by the slope and curvature of the trace at that point. Let us now consider a particle moving in a circular orbit in XY plane. The motion of this particle can be represented as a helical trace in a XY-T coordinate space or manifold. The velocity and acceleration characteristics of this particle will be represented by the geometry of helical trace in the XY-T manifold. An important point to be noted here is that the helical trace does not physically exist anywhere at any time; it is just a mathematical or graphical representation of the motion of a particle over a period of time.

Space-time manifold XYZ-T Similarly the motion of various particles in three-dimensional physical space can be represented through suitable traces in a four-dimensional XYZ-T space-time manifold. An important point to be noted here too is that four-dimensional traces of particles do not physically exist anywhere at any time; these are just mathematical representations of the motion of particles in three dimensional space over a period of time. The 4-D geometry of particle traces is just a mathematical representation. In the same way, a four-dimensional space-time manifold XYZ-T does not physically exist anywhere at any time; it is just a mathematical notion. However, due to some logical fallacy, the mathematical notion of space-time manifold got assigned a more sophisticated name of spacetime continuum which is generally implied to be a physical entity in Relativity Theories. This notion of 'spacetime continuum' is fallacious.

The 4-D spacetime manifold can be regarded as a mathematical continuum of points (x, y, z, t). But a mathematical continuum of points cannot be said to get curved. Neither can the geometry of a 4-D mathematical continuum of points get influenced by the matter-energy content embedded in 3-D physical space. For the operation of GR, spacetime continuum of physical nature is definitely required. But for the existence of physical spacetime continuum, the physical space is required to exist at each and every point t of the time-axis. However, it can be shown that physical space can exist only at the present instant $t=t_p$ on the time-axis.

8.3 Physical Entity

The dictionary meaning of a physical entity is an entity that has physical existence. Here physical implies 'having substance or material, perceptible to the senses'. It includes quantities that can be physically measured. In essence, it implies a distinction between abstract and physical entities. If we have complete information about certain entity and can mentally visualize it, then that entity must be a physical entity (e.g. Solar System, Sound Waves etc.). If we have complete information about certain entity and still cannot mentally visualize it, then that entity must be an abstract entity (e.g. 4-D spacetime). However, if we know certain entity to be physical and still cannot visualize it then it will imply that we do not possess complete information about that entity (e.g. electron, proton etc.). The dynamic motion of particles embedded in 3-D physical space could be represented as traces in the 4-D spacetime manifold. The fact that the geometrical shape of such traces could be adjusted by manipulating the metric of this manifold, has been misconstrued to imply that the physical phenomenon of gravitation could somehow adjust the metric of the 4-D spacetime manifold. This misconception created the popular impression as if the spacetime continuum is a physical entity.

8.4 Space-time: 4-D Block or a Trace of 3-D Space?

Let us examine another crucial aspect of the notion of spacetime. That is, whether the abstract notion of spacetime manifold is a useful construct to represent a trace of 3-D physical space along the time coordinate or does it represent a 4-D block of the continuum of space and time points (x,y,z,t). In the block view of the spacetime continuum there are two crucial implications which probably have never been highlighted or critically examined:

(a) Firstly, the time coordinate is treated at par with space coordinates. That is, just as there is no a-priori bar on any two mutually interacting particles from occupying different positions on any spatial coordinate, similarly there is no a-priori bar on any two *mutually interacting particles* from occupying different positions on time coordinate (including positions in past and future time zones).

(b) Secondly, in the mathematical handling of the time coordinate, no distinction is made between the present time and the past time or the future time. That is, any material particle located at (x_1, y_1, z_1, t_1) of the spacetime continuum can influence the geometry (topography) of spacetime at locations (x_2, y_2, z_2, t_2) and (x_1, y_1, z_1, t_3) regardless of whether t_2 and t_3 represent the past time zone or the future time zone with respect to t_1.

To illustrate these points, let us consider a 2-D (thin) metal sheet located in the XY plane of a rectangular 3-D (XYZ) manifold. Let this plane 2-D sheet be positioned at $Z=z_0$ at time $T=t_0$. Let us examine the following three cases:

Case I : Traces in XYZ manifold. Let us further assume that this 2-D sheet is moving along Z-axis at a uniform velocity v with its plane surface constrained in the XY plane. Let the position of this sheet move to z_1 at time t_1, z_2 at time t_2 ... and z_n at time t_n. Suppose we wish to study the motion of free electrons constrained on the surface of this sheet and want to obtain detailed representation for their trajectories or traces of their paths over a finite period of time. For this purpose, we may find it convenient to use 3-D XYZ manifold to represent the curved traces of the particles under study. Here it can be easily appreciated that while the particles under study are constrained to move in the 2-D plane of the metal sheet, their curved traces can be represented in the 3-D XYZ manifold. It is also true that the study of the geometry of curved traces can provide us valuable information on the velocities and accelerations of the corresponding particles. A significant point to be noted here is that while an abstract XY plane can be considered as located at every point z of the Z-axis, the 2-D metal sheet (a physical entity) constrained in the XY plane can exist only at one point z_n at time t_n. That is, even though the 2-D metal sheet constrained in the XY plane does steadily traverse the Z-axis, the particles of the metal sheet cannot be said to constitute a 3-D continuum in the 3-D XYZ manifold. Further, the geometry of the 3D XYZ manifold cannot influence the velocities and accelerations of free electrons constrained on the plane surface of the metal sheet under any circumstances.

Case II : Traces in XYT manifold. Let us now assume that the 2-D plane sheet under consideration is fixed at $Z= z_0$ and does not move in any direction. Suppose, we wish to study the motion of free electrons constrained on the surface of this sheet and want to obtain detailed representation for their trajectories or traces of their paths over a finite period of time. For this purpose, we may find it convenient to use 3D XYT manifold to represent the curved traces of the particles under study. While the particles under study are constrained to move in the 2D plane of the metal sheet, their curved traces can be represented in the 3D XYT manifold. It is also true that the study of the geometry of curved traces can provide us valuable information on the velocities and accelerations of the corresponding particles. Further, the geometry of the XYT manifold cannot influence the free electrons constrained on the plane surface of the metal sheet but may influence the representation of their traces.

Let us focus on the position of the metal sheet under consideration on the time axis. Let the time axis extend from zero to infinity. Further let t_p depict the present time on the time axis. Obviously, the t_p marker is continuously moving away from the origin of the time axis. The time zone $t< t_p$ represent the past and the time zone $t> t_p$ represent the future. Now let us take a mental snapshot of the whole range of time axis. We find that the physical body of the metal sheet is only located at $t= t_p$ and is not located anywhere in the past or the future time zones. The traces of free electrons constrained to move on the surface of this sheet (physically located at $t=t_p$) can only be represented in the past time zone. However, the computed or projected trajectories of these particles can be represented in the future time zone. The most significant point to be noted from our mental snapshot of the whole range of time axis is that the physical phenomenon is occurring only in the metal sheet constrained in the XY plane and located at $t=t_p$. There is no physical phenomenon in the past or the future time zones of the XYT manifold. These past and future time zones of the XYT manifold can only be used for representing the traces or computed trajectories of the particles constrained in the present zone ($t=t_p$). Hence we can logically conclude that the past and future time zones of the XYT manifold cannot be regarded as physical entities since these are only abstract mathematical constructs. It may be emphasized here that while an abstract XY plane can be considered as located at every point t of the Time-axis, the 2-D metal sheet (a physical entity) constrained in the XY plane can exist only at one point $t= t_p$ on the Time-axis. That is, even though the 2-D metal sheet constrained in the XY plane does steadily traverse the T-axis, the particles of the metal sheet cannot be said to constitute a '3-D continuum' in the 3-D XYT manifold.

Case III : Traces in XYZT or the spacetime manifold. Let us now replace the 2-D plane sheet of case II above with 3-D physical space (e.g., the physical space associated with our solar system). Suppose we wish to study the motion of particles contained within this space and want to obtain detailed representation for their trajectories or traces of their paths over a finite period of time. For this purpose, we may find it convenient to use 4-D XYZT manifold to represent the curved traces of the particles under study. While the particles under study are constrained to move in the 3-D physical space, their curved traces can be represented in the 4-D XYZT manifold. It is also true that the study of the geometry of curved traces can provide us valuable information on the dynamics of the corresponding particles. Further, the geometry of the 4-D XYZT manifold cannot influence the dynamics of particles contained in the 3-D physical space of our solar system but may influence the representation of their traces.

To appreciate this point, we need to focus on the position of the physical space on the time axis. Let us take a mental snapshot of the whole range of time axis. We find that the physical space is only located at $t= t_p$ and is not located anywhere in the past or the future time zones. The traces of particles, constrained to move in the physical space (located at $t=t_p$), can only be represented in the past time zone. However, the computed or projected trajectories of these particles can be represented in the future time zone. The most significant point to be noted from our mental snapshot of the whole range of time axis is that the physical phenomenon is occurring only in the 3-D physical space located at $t=t_p$.

There is no physical phenomenon in the past or the future time zones of the XYZT manifold. These past and future time zones of the XYZT manifold can only be used for representing the traces or computed trajectories of the particles contained in the physical space located at the present zone ($t=t_p$). Hence, we can logically conclude that the past and future time zones of the XYZT or spacetime manifold cannot be regarded as physical entities; these are only abstract mathematical constructs. It may be emphasized here that while an abstract XYZ manifold can be considered as located at every point t of the Time-axis, the 3-D physical space constrained in the XYZ manifold can exist only at one point $t= t_p$ on the Time-axis. That is, even though the 3-D physical space constrained in the XYZ manifold does steadily traverse the T-axis, the points of the physical space cannot be said to constitute a 4-D continuum in the 4-D XYZT manifold.

Hence, the spacetime continuum is not a physical entity but just an abstract mathematical notion which can neither influence any physical phenomenon nor can its geometry be influenced by any physical phenomenon. But GR is based on the fallacious notion of a physical 4-D spacetime continuum, where the mass-energy content within a finite region of 3-D physical space (say our solar system) is required to govern the metric of 4-D spacetime manifold in the vicinity, in accordance with Einstein's Field Equations. It is unbelievable that the matter-energy content of the solar system located on the present time zone on the Time-axis, can physically influence the geometry of 4-D spacetime in its past and future time zones. Thus the ‘Castle in the Air’ of Relativity, founded on the fallacious notion of ‘spacetime continuum’ collapses as a conceptual mistake. Even if the spacetime continuum is regarded as a physical entity as per the metaphysically eternalist viewpoint, the GR can still be shown to be invalid on the grounds of discontinuous deformations induced under the GR postulate.

8.5 Basic Objectives of the Spacetime Model

The spacetime structure has been exploited for two major objectives in Relativity. The first objective is to ensure a constant speed of light propagation in all inertial reference frames moving at uniform relative velocity with respect to one another, by adopting Minkowski spacetime manifold. The second, and more prominent objective, is to employ the 4D spacetime manifold as a graphical template to facilitate the plotting of trajectories of objects moving in a gravitational field.

Spacetime Minkowski Manifold. In SR it has been assumed that speed of light in vacuum will be constant c in all inertial frames K_1, K_2, etc. in relative uniform motion. This assumption has been built into the invariance of spacetime interval as:

$$dS^2 = (dx)^2 + (dy)^2 + (dz)^2 - (ct)^2$$
$$= (dx')^2 + (dy')^2 + (dz')^2 - (ct')^2$$
$$= (dx'')^2 + (dy'')^2 + (dz'')^2 - (ct'')^2 \qquad (8.1)$$

This distinguishes Special Relativity from Galilean relativity and is the origin of the special concept of spacetime due to the special linkage between space and time coordinates through equation (8.1).

As a consequence of this assumption the measure of time and distance becomes relative and different in each of the frames K_1, K_2, etc. in accordance with Lorentz transformations, and this is important. All notions of length contraction or time dilation or clock synchronization originate from the operation of equation (8.1) for different inertial frames K_1, K_2, etc. in relative uniform motion. However, within our solar system, BCRF is the unique reference system K_0 in which the speed of light c is a constant and the measure of time and distance is absolute not relative. Within the solar system, there may be an infinitely large number of particles or objects in relative motion (e.g. trains, aircraft, satellites, planets etc.) with which we could attach reference frames K_1, K_2, etc. But the measure of time is still required to be the same absolute measure UTC or TAI. Here, it is not important which coordinate frame you actually use for convenience. It is important to note that for all such convenient coordinate frames you actually use a common time measure say UTC, the usage of which has been rendered extremely convenient through GPS receivers. Usage of this common measure of time in all frames K_1, K_2, etc. has effectively rendered the notions of spacetime and relative time t' or t'' as obsolete in real life.

8.6 Spacetime manifold as a Graphical Template

For plotting certain data on ordinary graph paper with rectangular Cartesian X-Y axes, we generally use uniform scales on each axis. As is well known, by using a logarithmic scale, one can convert an exponential curve to a straight line. A log-log plot is a two-dimensional graph of numerical data that uses logarithmic scales on both the horizontal and vertical axes. Due to the nonlinear or differential scaling of the axes, a function of the form $y = a.x^b$ will appear as a straight line on a log-log graph, in which b will be the slope of the line.

Let us now consider the trajectory of an object, falling vertically on a gravitating body of mass M. We can plot this trajectory on a Y-T graph such that Y-axis represents the height and T-axis represents time.

We find this trajectory to be a parabolic curve. Now taking a cue from the log-log graph, we can choose a suitable log-log or differential scale along Y and T axes such that the parabolic trajectory on normal graph transforms into a straight line on the differential scale graph. This makes the trajectory of an object, moving in a gravitational field, look very simple. Let us use this differential scale graph as a template. For obtaining the trajectory of any other object falling vertically on a gravitating body of mass M, we only need to locate the initial starting position of this object on the template graph and then draw a straight line of the required slope.

Let us now consider the trajectory of an object, falling in 2D X-Y plane on a gravitating body of mass M. We can plot this trajectory on a 3D XY-T linear scale graph. We find this trajectory to be a complex spiraling curve. Now we can choose a suitable log-log or differential scale along X,Y and T axes such that the spiraling trajectory on linear scale graph transforms into a straight line equivalent geodesic on the differential scale graph. Once again, this makes the trajectory of an object, moving in a gravitational field, look very simple. Let us make a template of this differential scale graph. The differential scale or the magnitude of the unit vectors along any particular axis of an orthogonal coordinate system is given by the square-root of the corresponding metric coefficient for that axis. For obtaining the trajectory of any other object falling in X-Y plane on a gravitating body of mass M, we just need to locate the initial starting position of this object on the XY-T template graph and draw a geodesic of the required slope. However, it must be understood that for plotting trajectories of objects moving in the gravitational field of a body of different mass M', the differential scaling factor or the corresponding metric coefficients must be adjusted accordingly. If we find that drawing a 3D XY-T differential scale graph is physically difficult, we can just compute the data points for the required trajectory from the given template and that will serve the purpose. The required graphic trajectories can then be obtained with the aid of appropriate computer application programs.

We can extend this methodology for obtaining trajectories of objects moving in 3D physical space, in the gravitational field of a gravitating body of mass M. For this we can first obtain a differential scale 4D manifold XYZ-T as a template such that the Newtonian trajectories in the given gravitational field appear as geodesic curves in this template manifold. Of course, the differential scale or the metric of this template manifold will have to be correlated with the mass M of the gravitating body. Now, to obtain the trajectory of any other object in the given gravitational field, we can mark the initial starting position of the object in the template manifold and then compute the trajectory as a geodesic through that position. Isn't it wonderful to use the 4D XYZ-T manifold, with a suitable differential scale, as a template for obtaining trajectories of objects as geodesic curves? However, we will have to adjust the differential scale or the metric coefficients of this template manifold according to the mass M of the gravitating body. And this is precisely what is being done through EFE in the GR model. Further, to ensure a constant speed of light propagation in all coordinates, we can choose the 4D XYZ-T manifold as a Minkowski manifold with a differential metric!

What needs to be highlighted here is that in GR, the Riemannian 4D space-time manifold is being used precisely as a differential scale template for getting the trajectories of objects as geodesic curves. There is no doubt, what so ever, that GR is just a mathematical model used for obtaining the trajectories of objects as geodesic curves! However, the founders of GR did attempt to elevate this mathematical model to the status of a physical theory by assuming the 4D space-time manifold to be a physical spacetime continuum and also assuming that the mass-energy content of a gravitating body somehow controls the metric of this physical entity. Once we realize that 4D spacetime manifold is just an abstract mathematical construct and not a physical entity, then it is quite a simple matter to understand that GR is just a mathematical model and not a physical theory.

