Principle of Causality and Inertial Frames of Reference

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Annotation

A generalization of the causality principle is proposed. The hypothesis assumes that the principle of causality is applied separately and independently for each different inertial frame of reference (IFR). It was found that the observer has only the information that the IFR has, relative to which he is stationary. Further analysis led to the conclusion that from the observer's point of view, any event exists in all IFR, even if it exists only in part of IFRs.

The hypothesis predicts that there are two types of transformations during the transition between inertial frames of reference. The first are transformations from the observer's point of view. The second type of transformations are direct transformations of the space-time and fields. It has been shown that the hypothesis does not contradict modern widely-accepted theories of physics. If the hypothesis is correct, then all modern theories of physics satisfy only the first type of transformations. The hypothesis allows us to create a new class of theories that takes into account the second type of transformations. These theories can lead to new predictions. Therefore, it can be argued that the hypothesis is, in principle, falsifiable. The hypothesis indicates the possible existence of something more fundamental than spacetime.

Introduction

The principle of causality is one of the most general principles of physics.

As the study of the literature shows, there were no attempts to generalize this principle.

Let's look for opportunities for such generalization. We consider the formulation of the causality principle to be correct, we do not try to modify it. Then there remains only the search for some implicit postulate of the principle of causality, which is accepted a priori, without experimental confirmation. After that, one will need to find a way to modify it. At the same time, since the formulation of the principle of causality does not change, the new generalized principle will transform into the existing one as it approaches zero the difference between the implicit postulate of the principle of causality and its modification.

Obviously, this can only be some very fundamental postulate, which is perceived as obvious without evidence and without experimental verification, and which has never been questioned before.

We consider only inertial frames of reference. For spacetime with curvature, we consider local inertial frames of reference.

1. The principle of causality

Consider the principle of causality. The principle of causality says that any event is caused by something, it has a cause. In classical physics, by the previous state of the system, it is possible to uniquely find the state of the system at any subsequent time. In quantum physics, the state of a system is usually described in terms of wave functions, and one can only find the probability that the system is in a certain state when measured. The principle of causality allows, knowing the state of the system at some point in time, to find the state of the system, or the probability of the system being in some state during the measurement, at any subsequent point in time. It can be written like this:

$$\varphi(t + dt) = A\varphi(t) \quad (1)$$

Here φ– the state of the system or its wave function when using a quantum description, t– time, A– some operator. The state of the system φ includes the set of values that are necessary to describe the system. For example, to describe a system of objects based on Newton's law of universal gravitation, if we consider objects as material points, the masses, velocities and coordinates of objects are sufficient to describe the state. Accordingly, the value should consist of mass, velocity vector and object coordinates.

According to the principle of causality, events without a cause do not exist. Someone might think that, for example, the radioactive decay of the nucleus of an atom has no cause. Let's look at equation 1. The radioactive decay of a nucleus is obviously described by this equation. Therefore, it also corresponds to the principle of causality. The principle of causality does not mean determinism. There are many discussions on this issue. Note that if there were at least one phenomenon that violates the principle of causality, then this would mean a refutation of this principle.

Equation 1 describes causality both when using the description of classical physics and for when using quantum physics. It is clear that having a wave function, you can get the probability of finding the system in some state. We want to describe the transformations both for the classical case and for the quantum one, therefore, further, for brevity, when we talk about state transformations between the IFRs and, at the same time, the quantum system, we are talking about the transformation of the wave function from which the state can be obtained.

Some events cannot affect other events, since they are separated by a space-like interval. In quantum physics, this is expressed as the absence of correlation of measurement results at points separated by a space-like interval. There are other limitations for other formulations, for example, the Bogolyubov micro-causality condition [1]. Such restrictions can be considered as additional restrictions on the operator A. For the purposes of this hypothesis, both these constraints and some detailed properties of the operator A are not important and will not be considered. The only important thing is that there is some operator A with some properties that transfer the system from a state at a time t to a state at a time $t + dt$.

It can be noted that equation 1 alone is not enough for the causality principle. Let's say we know the state of the system in some inertial frame of reference (IFR). Let's denote this IFR L. Is it possible on the basis of this to find the state of the system in another IFR, L', moving at a non-zero speed relative to L? If this is not possible, then events in different IFR cannot be linked to each other. However, the practice of applying the principle of causality in modern theories of physics implies that, knowing the state of a system in one IFR, it is possible to obtain the state of a system in another IFR. Thus, in order to fulfill the principle of causality, the following equation must also be fulfilled, for each φ_i' and t_i', for an arbitrary L':

$$\begin{cases} \varphi_i'(L') = B_{\varphi i}\varphi(L) \\ t_i'(L') = B_t t_i(L) \end{cases} \quad (2)$$

Here φ_i' is one of the set of states in IFR L', t_i– time in L for φ_i, the i-th element of the set φ, t_i'- the corresponding time in L', $B_{\varphi i}$– some operator that translates the state of the system from one IFR L to another IFR L' for φ_i, B_t– an operator that translates time from IFR L to IFR L'. We are not considering the properties of these operators here yet.

The transformation above is usually written a little differently. To find a state at some point in space-time in one IFR, usually take a state in another IFR at some point in space-time. Equation 2 includes such a description as a special case when it does φ_i' not depend on all states in L, but only on the state at some point.

If two IFR have zero relative velocity and differ in the origin or orientation of the axes, then a simple transformation can translate one IFR into another. To exclude such transformations from consideration, we will further consider only different IFR. For our purposes, we will determine that two IFR differ if they have a non-zero relative velocity.

Now let's look at equation 1 again. We want to separate the state transformation between the IFR from the state change over time. Let's change the equation to the following:

$$\varphi(t+dt, L) = A\varphi(t, L) \tag{3}$$

Now it $\varphi(t, L)$ denotes the state of the system not just at a moment in time t, but also in some IFR L. The operator A, accordingly, translates the state of the system between different time points in the same IFR.

Then, in order to fulfill the principle of causality, it is necessary to perform two equations simultaneously, 2 and 3, which leads to a system of equations:

$$\begin{cases} \varphi(t+dt, L) = A\varphi(t, L) \\ \varphi_i'(L') = B_{\varphi i}\varphi(L) \\ t_i'(L') = B_t t_i(L) \end{cases} \tag{4}$$

Equation 1 allows us to describe the principle of causality when we do not consider in detail the properties of transformations between IFR. Equation 4 is needed for a more detailed analysis of how the causality principle and transformations between IFR are related.

2. The principle of causality and inertial frames of reference

Consider a spacetime, with some fields, containing an observer. An observer can be either a certain device or an intelligent being. We assume that the principle of causality is fulfilled in this space-time.

Further, event will mean an event that is described by the principle of causality.

Consider the following question: can the considered space-time contain cause-and-effect relationships starting from an event that did not occur in this space-time?

An example of such an event could be the collision of two objects. It does not matter whether these are elementary particles described by quantum physics or some large objects. It is important that, according to the views established in physics, if an event, a collision of two objects for example, occurred in one IFR, then it occurs in all IFRs. This means that equation 2, the state transformation between IFRs, must preserve events. After the transformation, some properties of the event may change, spatio-temporal distances with other events may change, but the event itself occurs in all IFRs.

Causal relationships starting from an event that did not occur in this space-time can be described as a set of states at some point in time t in some IFR that do not follow from a set of states at a time t_0. That is, the set of states $\varphi'(t)$ contains states that are not included in the set $\varphi(t)$, where they $\varphi(t)$ satisfy equation 3 and are obtained from the state at a time t_0. Obviously, this contradicts equation 3, and is therefore impossible. The expected result, because otherwise it would violate the principle of causality.

Let's consider the question of how information about an event can be described from the point of view of the causality principle. Some event occurs, after which there are cause-and-effect relationships starting from this event. Then the information about the event is a set of cause–and-effect relationships starting from this event.

Suppose equation 2 does not conserve events during the transition between IFRs or does not hold at all, equation 3 holds. Then, an event may exist in some set of IFRs and not exist in another set of IFRs. This assumption means that the causality principle is applied separately and independently for each different inertial frame of reference. This is the basic assumption of the hypothesis.

For the case of wave function transformation, non- conservation of events during the transition between IFRs means a change in the probability of the system being in some state, including the appearance of new possible states after the transition and the disappearance of some states that existed in the previous IFR before the transition.

Let's define what the application of the causality principle independently and separately for each different IFR is. We assume that the causality principle is applied separately and independently for each different IFR, if equation 3 is fulfilled, and equation 2 does not conserve events during the transition between IFRs. Note that a special case of non-conservation of events during the transition between IFRs is the case when equations 2 are not fulfilled at all, that is, based on the state of the system in one IFR, it is impossible to determine the state of the system in another IFR.

If the principle of causality is applied independently for each IFR, then there may be differences in causal relationships in different IFR. Differences in cause-and-effect relationships mean that some events could occur in one IFR and not occur in some other IFR. A difference in events also means a difference in objects. As an example, as a result of the collision event of two electrons, several new particles were generated in one IFR, and there was no collision in the other IFR, so no new particles could appear. We do not assume that the difference in events is limited to the micro level. With a sufficiently large difference in events, the Moon may exist in one IFR and not exist in another IFR.

Separately, we note that the situation when some events occur simultaneously in one IFR and, according to the theory of relativity, at different times in other IFR, does not lead to a difference in cause-and-effect relationships.

If there are differences in cause-and-effect relationships in different IFR, then this leads to the fundamental impossibility of transferring information between IFR about those events that are not in another IFR. To transmit such information, it is necessary that an event that is not in IFR has an impact on events that are in IFR, which contradicts the principle of causality if applied independently for different IFRs.

Now let's consider how the independent application of the causality principle affects an observer and the information available to an observer.

3. The principle of causality and an observer

In what frame of reference does the observer observe? The answer to this question is pretty obvious. The observer observes in the frame of reference relative to which he is stationary. If this were not the case, then, for example, when receiving a signal from a satellite about its observations, it would be impossible to say that the signal from the satellite carries information about what is happening in the reference frame relative to which the satellite is stationary.

The conclusion that immediately follows from this: An observer cannot have information about an event that did not occur in his IFR, the IFR with respect to which he is motionless.

This is one of the most important conclusions of the hypothesis.

One can try to build various schemes for how to get information from more than one IFR, but they all rest on one unresolvable problem. The problem is that to get information from some other IFR, one need to eliminate the transition transformation between IFRs, equation 2, which is impossible.

Suppose equation 2 does not conserve events during the transition between IFRs or does not hold at all, equation 3 holds. Then, an event may exist in some IFR set and not exist in another IFR set. Let's consider how the observer will perceive it, whether the events between the IFRs will differ from the observer's point of view. For our purposes, we assume that if an event exists in all the considered IFRs, then this event does not differ between IFRs, even if some properties of the event change.

An observer can get information about what is happening in other IFRs in two ways. The first method is to receive a signal with information from an observer who is at rest relative to another IFR moving at a non-zero speed relative to the first observer. The second way, the observer can change his speed and switch to another IFR. Let's consider, for each of the options, how the events will look from the observer's point of view.

Let's consider the first method. Let there be an IFR L and an IFR $L^{'}$ moving at a non-zero speed relative to each other. In the IFR, L let there be an observer 1, stationary relative to it. In $L^{'}$ there is an observer 2, stationary relative to this IFR. Observers 1 and 2 exchange information about what they are observing. Let the signal sent by each of the observers contain information about an event that is in the IFR of the observer that sends the signal, but there is no in the IFR of receiving observer. Can the receiving observer receive information about an event that he does not have in the IFR? This information can be described as a set of cause-and-effect relationships starting from an event that was not in this IFR. Or, otherwise, as a set of states of the system that does not satisfy equation 3. As discussed above, this is not possible. Therefore, no matter what the other observer sends, for the receiving observer, the received signal cannot contradict the principle of causality and equation 3.

Now consider the second method. The observer observed something, saved the results of his observations on numerous instruments. After that, the observer changes its speed and begins to have zero speed relative to the other IFR. Can an observer detect that there are no events in the new IFR that were in the previous IFR? Again, this information can be described as a set of cause-and-effect relationships starting from an event that was not in this IFR. Or, otherwise, as a set of states of the system that does not satisfy equation 3. As discussed above, this is not possible. Now let's consider whether an observer can detect that there are some events in his new IFR that were not in the previous IFR. To do this, the observer somehow needs to be able to find out if there was such an event in the previous IFR. That is, it is necessary to find cause-and-effect relationships that are absent in the previous IFR and are present in the new IFR. Or, in other words, find the set of states from equations 3 that are present in the new IFR and are absent in the previous one. There is no such information in the new IFR. It is impossible to get it from another IFR, as specified above. Receiving such information would mean that such information appeared in the IFR, while it cannot be there. Therefore, we conclude that the observer cannot detect that in his new IFR there are no events that were in his previous IFR.

By the sameness of events, we mean that if an event occurred in one IFR, then it occurred in all IFRs. Here we do not claim that the properties of any event are the same in all IFRs.

We come to the conclusion that from the point of view of the observer, the events are the same in all IFRs, even if they actually differ due to the fact that equation 2 does not conserve events during the transition between IFRs or is not performed at all. Or, otherwise, from the observer's point of view, any event exists in all IFRs, even if in fact the event exists only in part of IFRs.

This is the key result for the hypothesis.

Note that this result is true both for the case when equation 2 conserve events, and for the case when events are not conserved.

A key result has been obtained for generalizing the causality principle: it does not matter whether the events in different IFRs differ or not, but for an observer it will always look like the events in all IFRs are the same.

4. Application of the principle of causality and human existence

Suppose that the fields in different inertial reference frames having nonzero velocity relative to each other are completely independent. With acceleration or deceleration, we would move to another frame of reference, the fields in which would be completely independent of the previous one. In this case, if there is a person in one of the IFRs, then there is no reason for him to be in any other IFR. Thus, a person could exist only in one IFR, and would disappear when his speed changed. But this obviously contradicts everyday experience - when the speed changes, our consciousness remains continuous, the body continues to exist. Based on this, there should be a limit to how different the fields and, accordingly, the events in different reference frames are.

Suppose that when the relative velocity of inertial reference frames tends to zero relative to each other, the difference between applying the causality principle simultaneously to both IFRs and separately for each IFR should tend to zero. In this case, there is some dependence of the fields located in different IFRs on each other. With a sufficiently small difference in speed between the IFRs, a change in speed by a person will not lead to his disappearance in the IFR that has become his new reference system with zero relative speed. This condition is necessary for human existence.

This can be formulated as follows: when the relative velocity of two inertial reference frames tends to zero, the difference between applying the causality principle separately for each of these IFRs with the application of the causality principle simultaneously to both IFRs should tend to zero. This is another postulate of the hypothesis, additional to the main assumption.

5. Types of space-time transformations and fields

Let us consider the transformations of space-time and fields arising on the basis of the main assumption of the hypothesis

It can be noted that from the point of view of the observer, every event exists in all IFR, the principle of causality connects events in all IFRs. At the same time, in fact, events may differ, some events may exist in one IFR and be absent in another. Therefore, two types of transformations can be distinguished here.

The first type is transformation of space-time and fields based on fields observed in different IFRs by observers stationary relative to the corresponding IFRs.

The second type of transformation is the transformation of space-time and fields from the point of view of the observer. The observer can be stationary relative to one of the inertial reference frames, he can change his speed, but, according to the results above, for him any event looks like it exists in all IFRs.

Let's look at these types of transformation and their differences from each other in more detail.

First, let's consider the transformations of space-time and events from the observer's point of view. An observer can observe only in the IFR relative to which he is stationary. All information about events in other IFRs is indirect, and is restored based on observations in the observer's reference frame. The observer observes, and based on the results of observations, makes assumptions about what the transformations of space-time should be. The observer sees that the events that he observes in one frame of reference occur in other reference frames. From this, the observer can conclude that if an event occurs in one frame of reference, it occurs in any other IFR. On the basis of such observations and conclusions based on them, it is possible to construct transformations of space-time, fields and the corresponding theory. Let's call this type of transformations observable transformations of space-time and fields.

The second type of transformation of space-time and fields is the transformation of space-time and fields based on fields observed in different inertial frames of reference by observers stationary relative to the corresponding inertial frame of reference. As discussed above, it is impossible for observers to obtain information about events in IFRs moving relative to them and directly compare them. Let's call this type of transformation direct transformations of space-time fields.

From the basic assumption of the hypothesis, we have obtained that there should be two types of transformations of spacetime and fields.

The presence of two different types of transformations makes it impossible to use a single continuum of space-time, where the transition between the IFRs corresponds to a change of coordinates. In a single continuum of space-time, it is impossible to obtain different events in different IFRs. Therefore, if the hypothesis is correct, then it indicates the existence of something more fundamental than spacetime.

6. Postulates of the hypothesis

Now we can describe all the postulates of the hypothesis.

Postulate 1: The principle of causality is applied separately and independently for each different inertial frame of reference.

This postulate is the main assumption of the hypothesis.

This postulate is less restrictive than the usual principle of causality, which acts on events in all reference systems. Therefore, the addition of this postulate does not limit, but expands the hypothesis, in comparison with the existing principle of causality.

Postulate 2: When the relative velocity of two inertial frames of reference tends to zero, the difference between applying the causality principle separately for each of these IFR with the application of the causality principle simultaneously to both IFRs should tend to zero.

Whether this postulate can be considered as a separate postulate or it is simply a consequence of the previous postulate is not entirely clear. It has already been shown above how this requirement arises. Therefore, we can say that this statement is a consequence of the fact of human existence.

7. Hypothesis testing capabilities

The conclusion obtained above that, from the observer's point of view, events in all IFRs are the same, excludes the possibility of direct testing of the hypothesis by comparing events in different IFRs.

There are theories of physics that expect the same events in all IFRs. If a pair of particles collided in some IFR, then all modern theories of physics expect that such a collision will occur in all reference frames. It turns out that all modern theories of physics agree with this hypothesis, although they satisfy only transformations from the observer's point of view.

One can try to find other ways to test the hypothesis. One way is to build a theory based on a hypothesis. And then it would be possible to test the predictions of such a theory.

We can see a way to indirectly test the hypothesis, try to find restrictions from above and below on how much events can differ in different IFRs. Exactly how to do this is not entirely clear, but some considerations can be made. A person changes his speed in a fairly wide range. At the same time, a person exists in all these IFRs. Using this fact, and based on various models about how events change between IFRs, by chance or otherwise, it is possible to get a restriction from above on how different events are between IFRs. This idea of indirect verification is quite simple. This may mean that one can find a number of indirect ways to test the hypothesis.

Perhaps a detailed analysis will allow us to find ways to also find opportunities to check the restriction from below.

8. An example where there is a difference in events in different IFRs

It is usually believed that the IFR is a certain coordinate system in space-time. Accordingly, the transition between IFRs is just a change in the coordinate system. It is obvious that when changing the coordinate system in any space-time, any event that exists in one IFR will also exist in other IFRs. This means that the principle of causality applies simultaneously to all IFRs, which is not consistent with the hypothesis. Therefore, if the hypothesis is correct, then the transition between IFRs cannot be just a change in the coordinate system in space-time. Here, either space-time has some more complex properties, or there is something that is more fundamental than space-time.

When reading the hypothesis, someone may have the opinion that everything seems to be formally correct, the hypothesis really does not contradict modern theories, but this formal logical correctness has nothing to do with real physics. Note that such an opinion rather means that the metaphysical picture of the world of such a reader contradicts this hypothesis. Therefore, this is a philosophical argument that should not be considered in science.

However, it will still be useful to show how this hypothesis can be used to build theories based on it. First, let us give an example of a certain hypothetical universe where the postulates of the hypothesis are realized. Let us show how it turns out that events in different IFRs may differ. Then we will consider how to build a theory based on a hypothesis, in general.

Let's consider what properties the initial model should have and what we expect to get.

The initial model must be integral and allow a mathematical description. We expect to get a set with infinite number of spacetimes. For each different IFR, there must be its own space-time belonging to this set. In each space-time belonging to this set, the principle of causality must be satisfied. In this case, the principle of causality must be satisfied independently for each space-time. Postulate 2 must be satisfied; when the relative speed of two inertial reference systems tends to zero, the difference between applying the principle of causality separately for each of these IFRs and applying the principle of causality simultaneously to both IFRs must tend to zero.

The requirement for the integrity of the original model here arises from the fact that as a result we must obtain an infinite number of space-times, instead of the usual space-time continuum. Therefore, it is necessary to have something fundamental from which all space-times with fields on them are derived.

In each of the space-times, some laws of physics must be fulfilled. We demand that the laws of physics be the same in all space-times. At the same time, for our purposes, it does not matter whether these laws of physics are similar to those known to us or not. The goal here is to show that it is possible to find a model in which the postulates of the hypothesis are satisfied. Finding such an example will mean that it is possible to build other models. And that, perhaps, in one of these models it is possible to obtain the same laws of physics that are known to us.

So, we are looking for a hypothetical universe in which the postulates of the hypothesis would be fulfilled.

Let's start with a simplified example. Let's consider the plane (x, y), with the field $f(x, y) = x + y$ given on it. Obviously, nothing is changing here, there is no time and no dynamics.

Let's look for how to transform the space (x, y) into a set S consisting of space-times $((z, t), L)$, where z is the spatial coordinate, t is time, L is the inertial reference system of which the space-time corresponds (z, t), and where equation 3 is satisfied.

To do this, take some transformation from (x, y) to (z, t) and check that equation 3 is satisfied there.

Consider the following transformation:

$$t = ky$$

$$z = x$$

Here t is a candidate for time, z is a candidate for space. We will find the inertial reference system corresponding to such a system of equations later. k is a certain coefficient, the meaning of which will become clear later.

Let's find out how to calculate the field values at the point (z, t), knowing the values at the point (z, t_0), where $t_0 = ky_0$. We find: $f(z,t) = f(x, ky) = x + ky = x + ky + ky_0 - ky_0 = (x + ky_0) + k(y - y_0) = f(z, t_0) + (t - t_0)$

Time in the equations of physics is a parameter of change. We have obtained an equation where there is a change parameter. This parameter can be called emergent time, since equation 3 is satisfied. The space z can be considered an emergent space because when t changes, changes occur in this space.

Thus, from a two-dimensional plane without time and dynamics, we moved to a one-dimensional space with time and dynamics, and found a candidate for emergent space-time for some IFR. The parameter k can now be interpreted as a unit of time.

Now let’s look at how to add transitions between IFRs to such a model. Let's rotate the previous space-time (z, t) by an angle a in space (x, y), move on to (z', t'). We rotate both axes at the same time. We assume that the time axis should always be perpendicular to the space axis. The equation after rotation changes slightly, but equation 3 is still satisfied, there is a change parameter. It is obvious that the distance between any two points belonging to z and z', respectively, changes uniformly and proportionally to the time interval t or t', and the rate of its change depends on the angle a. Therefore, we can say that a candidate for an inertial reference frame has been found. Accordingly, space-times (z, t) and (z', t') correspond to different inertial reference systems if their axes have a non-zero angle relative to each other.

Inertial reference systems must have some other properties that we are not considering yet. For now, the goal is only to show the idea of how, without time and dynamics, to deduce time.

In the resulting equation, the state at a previous point in time affects the state at subsequent points in time. Therefore, we can talk about the emergence of the principle of causality. As a result, from the space (x, y) we moved to the set $((z, t), L)$,, where for each IFR L there is its own space-time, for each of which Equation 3 is independently satisfied.

It is clear that the considered example with the field $f(x, y) = x + y$ is as simple as possible and is given to demonstrate the ideas.

If the field $f(x, y)$ is more complex, it is possible to expand the field into some complete system of orthonormal functions, a functional basis, so that the field at each point is equal to the sum of functions with certain coefficients. For example, when expanding in a Fourier series, the function $f(x)$ can be represented as $f(x) = \sum_{k=-\infty}^{+\infty} \widehat{f}_k e^{ik\frac{2\pi}{\tau}x}$. Then check whether it is possible, with parallel translation of the line to a certain distance l, to construct an equation for changing the expansion coefficients of the form

$$\Phi(\mathrm{l}) = A\Phi(0) \tag{5}$$

Here $\Phi(0)$ is the set of expansion coefficients on some functional basis, for each point for some selected line, l is the distance at which the line was transferred, $\Phi(\mathrm{l})$ is the set of expansion coefficients for each point for the selected line after its parallel transfer over a distance l. If such an equation can be constructed, then we can say that a candidate for space-time has been found. If it doesn't work, we go back and try another functional basis. At the same time, it is not possible to find the required functional basis for every field. If the required functional basis is found, then you need to check that the same equations will work when the line is rotated by an arbitrary angle, so that we can talk about the existence of speed. The transition to an IFR moving at a certain speed relative to the previous one corresponds to a rotation of the line by a certain angle. The smaller the angle between the IFRs, the smaller the difference in speed.

It can be noted that if, after turning the line, the equations describing the evolution of the field expansion in the space-time under consideration are unchanged and identical in all IFRs, then this will mean the same laws of nature in all IFRs and the absence of a dedicated reference frame. This sameness can be obtained if the field equation does not have preferred directions. For the purposes of the example, the absence of a dedicated frame is not required, since there is no goal to construct a picture of the universe that is consistent with known physical theories.

From a space without time, where nothing changes due to the absence of time, we have moved to a set of space-times. We can say that in each of them we have obtained some effective fields that describe the state and evolution of the system.

It is obvious that when a line of space is rotated, the field expansion coefficients, in the general case, cannot but change. Moreover, the smaller the rotation angle, the smaller the change. As already discussed, the angle of rotation between the lines corresponds to a certain relative speed. Therefore, we find that the lower the relative IFRs speed, the smaller the changes in the expansion coefficients. It can be argued that in the general case, knowing the expansion coefficient before the rotation, it is impossible to calculate the coefficient after the rotation. This means that, knowing the state of effective fields in one IFR, it is impossible to calculate the state of effective fields in another IFR

In order for an intelligent observer to exist in such a universe, we postulate that an intelligent observer can exist in space-time constructed in the manner described. It is clear that for the existence of an observer, a number of other conditions must be met, which we will not consider here. For the purposes of constructing an example, the fundamental possibility of the existence of an observer in such an emergent space-time is sufficient for us.

It is obvious that in the hypothetical universe under consideration, consisting of a plane (x, y) with some smooth field $f(x, y)$, and where it is possible to construct space-time using the described method, the principle of causality is applied independently for each IFR. Obviously, the smaller the angle between the lines corresponding to different IFRs, the smaller the difference in the field expansion coefficients. Any events in such a universe must be described on the basis of the coefficients of the field expansion according to the functional basis. This means that in such a universe, the smaller the difference in speeds between two IFRs, the smaller the difference in applying the principle of causality independently for each IFR and simultaneously to both IFRs.

So, we have found some hypothetical universe in which the principle of causality is fulfilled and the postulates of the hypothesis are fulfilled.

Looking at this example, we can show how to build theories based on the hypothesis in question, in general, if we are looking for something more fundamental than spacetime.

1. Let us postulate the existence of something more fundamental than space-time

2. We determine how we will obtain space-time and fields from what was postulated in the first step. In this case, it will be necessary to somehow either obtain or postulate the principle of causality. The principle of causality must be applied in accordance with the postulates of the hypothesis.
3. Next, it will be necessary to show that the resulting fields and properties of space-time correspond to those observed, including those consistent with quantum physics.

We have completed the first two points for a universe without time and dynamics. What other options there are for something more fundamental is unclear. It might be possible to get something similar based on a universe with more than one time. Perhaps something else can be found that is still unknown.

Perhaps some properties can be added to space-time so that the postulates of the hypothesis are fulfilled. But it is not yet clear how this can be done. So perhaps theories based on the hypothesis can only be built using something more fundamental than spacetime.

Conclusion

The application of the causality principle to IFRs and the hypothesis that the causality principle is applied separately and independently for each individual IFR are considered.

It was found that the observer has only the information that the IFR has, relative to which he is stationary. Further analysis led to the conclusion that from the observer's point of view, any event exists in all IFR, even if in fact the event exists only in part of IFRs.

This hypothesis leads to the conclusion that there are two types of transformations during the transition between IFRs. The first is transformations from the observer's point of view. The second type of transformation is a new type of transformation, these are direct transformations of the space-time and fields.

Since all modern widely-accepted physical theories believe that if an event occurred in one IFR, then it occurred in all IFRs, this means that these theories satisfy only transformations from the observer's point of view. This also means that the hypothesis does not contradict any widely accepted physical theory, but at the same time such theories describe only a specific case.

Since the hypothesis predicts the second type of transformations, which is absent in all widely-accepted theories, this means the possibility of constructing a new class of theories that would take into account an additional type of transformation. If for transformations of the first type, transformations from the observer's point of view, we can say that they correspond to transformations of STR and GTR, for flat spacetime and for spacetime with a curvature, then there is no theory that would describe transformations of the second type.

It is impossible to obtain the exact form of direct transformations of space-time fields within the framework of this hypothesis. This requires a deeper theory. Such a theory may lead to the prediction of new effects that can be experimentally verified. Therefore, it can be argued that this hypothesis is, in principle, falsifiable.

Let's consider possible objections to the hypothesis:

1. It can't be, because it can never be
2. It's not science, it's philosophy
3. In any space-time, an event, if it occurs, occurs in all IFRs. It is impossible to find such a space-time that the event occurs only in the part of IFRs. Therefore, the hypothesis is incorrect.
4. The special theory of relativity leads to the Minkowski space. In the Minkowski space, an event, if it occurs, occurs in all IFRs. Therefore, this hypothesis contradicts STR.
5. Where is the theory that will describe all of this? Maybe such a theory is impossible to build?

The answer to the first possible objection is pretty obvious. Yes, it may seem that the hypothesis contradicts common sense. However, in science, this should not be an argument.

On objection #2. Above, the possible options for testing the hypothesis were considered and it was shown that the hypothesis is, in principle, falsifiable. Therefore, it can be argued that it refers specifically to science, and not to philosophy.

On objection #3. As already mentioned, the hypothesis indicates the existence of something that is more fundamental than spacetime, precisely because it is impossible to obtain different events in different IFRs in spacetime.

On objection #4. The answer to it has already been given, but we will write again, in more detail. STR is dependent on the principle of causality. So, in the first postulate of STR, the laws of nature are mentioned. The laws of nature connect the initial state, which can be considered as a cause, and the state at some subsequent point in time, which can be considered as consequences. The second postulate of STR mentions the motion of light in a vacuum. That is, there is something that moves in some conditions at some point in time, and it is claimed that it will behave this way from now on. Here, too, the cause and effect are visible. There are no ways to formulate the postulates of STR without relying on the principle of causality. The hypothesis generalizes the principle of causality, and leads to two types of transformations. One of the transformations, transformations from the observer's point of view, conserves events during the transition between IFRs. According to the STR, the event, if it has occurred, occurs in all IFRs. Therefore, STR is consistent with transformations from the observer's point of view. STR, if the hypothesis is correct, describes only transformations of the first type, transformations from the point of view of the observer. The hypothesis, indeed, does not agree with Minkowski space, as with any other space-time, but this does not mean that it contradicts STR. The Minkowski space remains here as a useful tool describing only what the STR describes. STR does not describe transformations of the second type.

A similar possible objection can be formulated for the general theory of relativity, the answer is the same.

On objection #5. In order to create a theory, one need to understand that it is possible in principle. The hypothesis shows the existence of such a possibility. It adds new possibilities for building theories. The future will show whether these possibilities will be used in the construction of theories.

There are a number of open questions in the hypothesis. For example, it is necessary to consider in detail whether the principle of causality and its application to different IFRs can somehow be verified. Perhaps it is possible to obtain experimental estimates on how much the application of the causality principle separately to different IFR can lead to a difference in events between IFRs.

Another open question, closely related to the previous one, is the search for opportunities for experimental verification of the hypothesis. This will probably require the development of a deeper theory that would take into account the new type of transformations that arise in this hypothesis. But perhaps a more detailed analysis of the consequences of the hypothesis will lead to the fact that ways will be found to test the hypothesis without the need to build a deeper theory.

References

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