Article

On the Causal Structure of the Universe

Blazej Kot*

Abstract

I suggest we treat causality, not matter, as the fundamental constituent of reality. I introduce a unit of causality named *toma* and outline how the resulting framework leads naturally to general relativity, quantum electrodynamics and quantum chromodynamics. This novel framework is the first to show how to derive GR, QED and QCD from first principles and as such holds promise for being a Grand Unified Theory.

Key words: causal structure, Universe, toma, unit of causality, GR, QED, QCD.

Introduction

The theory of atomism - that the universe is made up of fundamental units of matter - is considered well supported experimentally. However, the stage we have reached in physics by following this model seems not to lead naturally to a unification of the forces of the nature into one coherent theory.

I am therefore presenting an alternative model based not on atoms - units of matter - but on tomas - units of causality. Instead of focusing on what is interacting at a fundamental scale, I focus on the pattern of interactions at all scales.

I first introduce a mathematical model of interacting tomas and then argue that the general relativity, QED and QCD all naturally follow from it.

Tomas

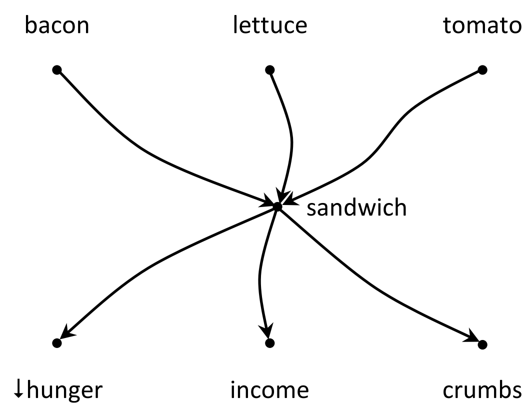
I consider the fundamental nature of the universe to be causality - the ability of things to cause other things to happen.

By "things" I am not referring merely to physical objects, but to anything at all. For example, my being cold may cause me to turn on the heater. Or two cars crashing may cause a wreck. This definition of "thing" may seem unusual, so I use the special word toma instead. The implications of treating an idea on the same basis as a material object are philosophical and I will not discuss them here. However, if for now we ignore these philosophical aspects, we can still look at the interaction of tomas from a purely mathematical viewpoint.

*Correspondence: Blazej Kot, Independent Researcher. E-mail: blazejkot@xnet.co.nz

It is natural to consider that multiple tomas may come together to cause any particular toma - just as bacon, lettuce and tomato come together to cause (create) a sandwich. Likewise, a toma may cause multiple tomas - as a sandwich may cause a decrease in one's hunger, income for the cafe at which it was purchased, and crumbs on the floor.

We can model a toma as the set of all tomas caused by it. We can then represent a toma in a diagram by a point connected to the tomas it causes with an arrow. For example:



Each toma in this example can be written as a set, as follows:

bacon = {sandwich}

lettuce = {sandwich}

tomato = {sandwich}

sandwich = {↓hunger, income, crumbs}

↓hunger = ∅

income = ∅

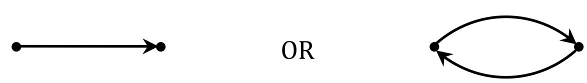
crumbs = ∅

Obviously, not all tomas relevant to the example are shown. As the structure of tomas even for a simple event are complex, we often will only draw a subset, or *view*, of all the tomas actually at work.

This type of structure is known in computer science as a *multitree* - each node (toma) has multiple parent tomas (ones that it is caused by) and children nodes (ones it causes). By studying the properties of multitrees we can therefore understand how causality works in general. This I turn to in the next section.

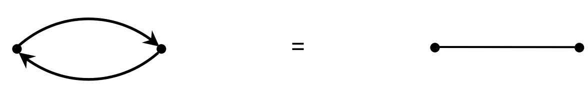
Spacetime

Two tomas can be directly connected within a multitree in one of two ways:

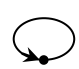


On the left, one toma causes the other toma - an *asynchronous* connection. On the right, two tomas mutually cause each other - a *synchronous* connection.

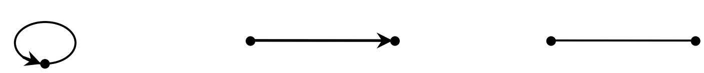
For clarity of diagrams, the latter case may be drawn in a simplified fashion:



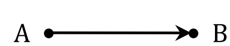
There is nothing preventing a toma from being able to cause itself:



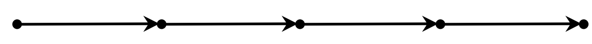
Any multitree, and hence any causality structure, can be built using just these three elements:



Let us first consider the element:

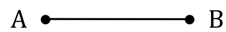


This means *B* is caused by *A* and *A* is not caused by *B*. Hence, *B* comes *after A* - hence the term asynchronous for such a connection. If we link a number of these elements together:



we obtain an axis of time dimension - each toma to the right of the first happens successively later.

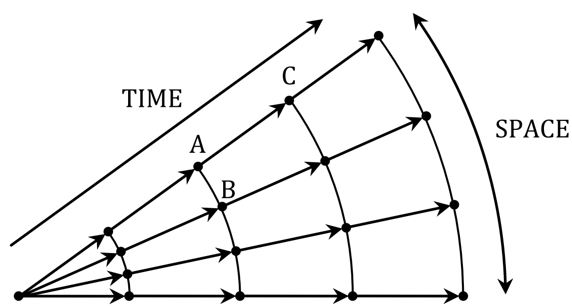
The element:



corresponds to when A and B mutually cause each other, meaning they happen simultaneously. As they happen at the same time, but are different, they can be thought of as happening in different places.

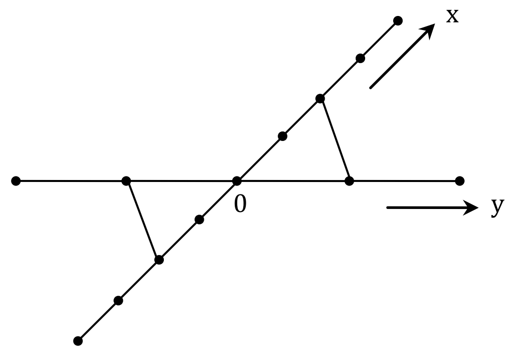
We can combine a series of these elements to create an axis of space dimension:

We can then combine the two axes as follows:



Tomas A and B occur simultaneously, at different locations. Toma C happens after A in the same spatial location as A. So we have constructed a spacetime of one time and one spatial dimension.

Two spatial axes are not orthogonal if they have a direct connection between them:



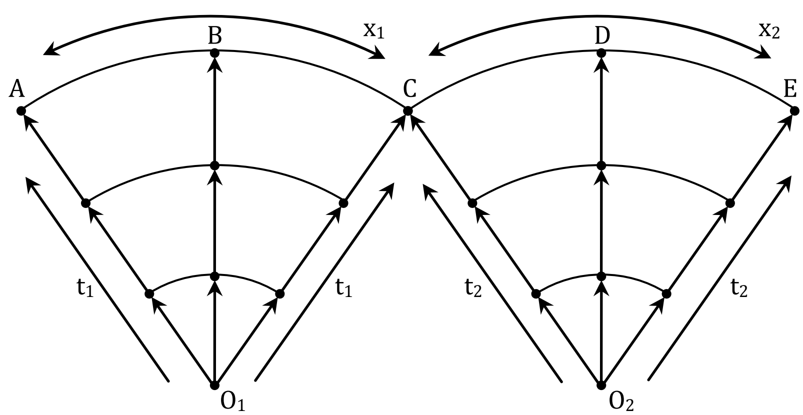
In this case, two steps along *x* from *0* are equivalent to one step along *y* and one along the connection. When axes are orthogonal, steps along one are under no circumstances equivalent to steps along the other. This supports the common sense notion that measurements along orthogonal axes should be independent.

How many orthogonal spatial dimensions does a multitree in general have? As we are only looking at spatial dimensions, we can ignore all asynchronous connections. The result is what is known in computer science as a *graph* - a set of nodes with undirected links between them. We know that there are nonplanar graphs - ones that cannot be embedded in two dimensional space - but all graphs can be embedded in three dimensions. It follows that in general a multitree has exactly one time dimension and three orthogonal spatial dimensions.

Therefore, any causality structure can be interpreted as a four dimensional spacetime. Next I turn to studying the properties of this spacetime.

General Relativity

Consider the following diagram:



This diagram shows two sets of spacetime axes, sourced at points (observers) O_1 and O_2. From each observer's origin time axes radiate outwards and spatial axes connect them. O_1 sees events A, B and C as simultaneous, as all three are two time steps from the observer's origin, while O_2 sees C, D and E as being simultaneous. However, O_1 does not in general agree with O_2 that C, D and E are simultaneous. We also see that in general the time axes and spatial axes of the two observers will not be parallel, so the observers will not in general agree on spacetime coordinates of events.

Let us say, however, that we wish to create a new system of coordinates shared by both observers such that they can meaningfully compare their measurements. In this system, the observers should agree that A, B, C, D and E are all simultaneous. In O_1 events are simultaneous if

$$x_1^2 + y_1^2 + z_1^2 = (ct_1)^2 \tag{1}$$

That is, all simultaneous events - those occurring at time t - lie on a sphere of radius ct, where c is a constant. Rearranging, we obtain:

$$x_1^2 + y_1^2 + z_1^2 - c^2t_1^2 = 0 \tag{2}$$

Likewise, for simultaneous events in O_2:

$$x_2^2 + y_2^2 + z_2^2 - c^2t_2^2 = 0 \tag{3}$$

Combining the last two equations, we obtain:

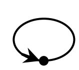
$$x_1^2 + y_1^2 + z_1^2 - c^2t_1^2 = x_2^2 + y_2^2 + z_2^2 - c^2t_2^2 \tag{4}$$

which is the generalized Lorentz transformation upon which general relativity is built [1].

Hence, the curved spacetime of general relativity is simply a framework of absolute coordinates built upon reality which consists only of relative coordinates.

Quantum Electrodynamics

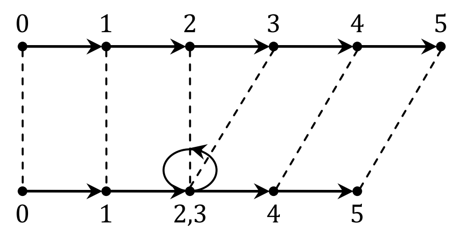
Thus far we have ignored the self-loop element:



Consider the following scenarios:

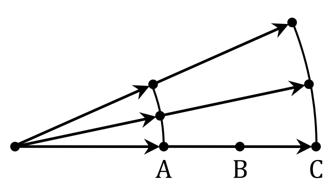
On the left is a standard axis of time. Each step along it increases the time coordinate by *1*. On the right, the axis loops back on itself so that the point at $t = 2$ is the same point as at $t = 3$.

Comparing the two scenarios, we can see a self-loop acts to shift the time coordinates after it:



The dashed line connects corresponding time coordinates. After the self-loop, the bottom axis has been shifted by *1* unit. We can refer to this shift as $\phi(t)$, which is *0* for $t = 0,1,2$ and *1* for t greater than *2* in this case.

The following illustrates a part of spacetime:



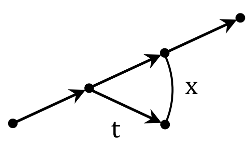
Since time is a continuum, between two points *A* and *C* there is at least one point *B*. In fact, there is an infinity of points between *A* and *C*. If we consider *AC* to be an infinitesimal unit of time *dt*, so that both *A* and *C* have valid space coordinates, it follows that in the interval $dt = AC$ we can find *n*, for any *n*, points with time coordinates but no space coordinates.

We have established a unit of time *dt* may enclose *n* points with no space coordinates. If one of these *n* points has a self-loop, the overall shift will not be an integer: $\phi = 1/n$ in this case. This provides a mechanism for interpreting fractional shifts.

Note that for any integer shift ϕ = *1,2,3..,n* the points after the shift line up with, indeed are the same points as, those before the shift. An integer shift leaves the points within the same spatial continuum. However, a noninteger shift does not. If the shift is not an integer, the subsequent points *disappear* from the spatial dimension, and exist *in between* the original space's points.

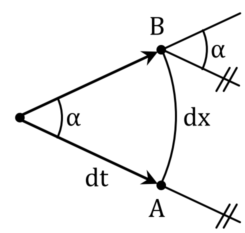
The cyclical nature of ϕ allows us to think of a phase angle $2\pi\phi$ as an additional dimension for each axis or path. Indeed, it is obvious that the result of two phase shifts in sequence is equivalent to one phase shift of angle equal to the sum of the two original phase angles.

Consider a path in spacetime. This is just a sequence of tomas linked asynchronously:



The fundamental unit of a path is two tomas linked by an arrow as above. Each path element has an associated duration in time *t* and a distance in space *x*.

Consider an infinitesimal path *dx, dt*:



The path from *A* to *B* is associated with a phase shift $\alpha = dx/dt$. Travelling along this path shifts the phase angle by *dx/dt* as the phase is measured relative to the element *dt* which itself rotates by -α:

$$\alpha = \frac{dx}{dt} = \frac{x}{t} = v \tag{5}$$

Where v is the velocity, constant over the path element.

The path from *A* to *B* may also contain self-loops itself. This may be interpreted as a *spinning* of whatever is travelling along the path. If the rate of spin is *M*, such that the phase velocity is *M*, the total phase gained over a path of distance *x*, duration *t* is:

$$\Delta\phi(x,t) = \int_{x'=0}^{x'=x} M d\phi \tag{6}$$

Now, as $d\phi = v\,dx'$,

$$\Delta\phi(x,t) = \int_{x'=0}^{x'=x} Mvdx' = [Mvx']_{x'=0}^{x'=x} = Mvx = \frac{Mx^2}{t} \tag{7}$$

Let $P(X)$, where $X = e^{i\phi}$, be a uniform probability distribution of phase angle such that:

$$\int_0^{2\pi} P\left(e^{i\phi}\right)d\phi = 1 \tag{8}$$

Let us say we observe a particle or toma at spacetime point *A*. We do not know what its phase is, only that it certainly has a phase. Therefore, its phase angle is described completely by $P(X)$.

Let us say we are interested in following the particle to point *B*, a distance *x*, time *t*, away. We know the phase is shifted by $\Delta\phi(x,t)$ so that the angular probability distribution is now:

$$P\left(e^{i\phi+i\Delta\phi(x,t)}\right) = P(wX) \tag{9}$$

where:

$$w = e^{i\Delta\phi(x,t)} \tag{10}$$

is the *winding factor*. Let us now say the particle may have arrived at point *B* from either point *A*, or a new point *Z*, corresponding to paths (x_1, t_1) and (x_2, t_2) to *B*. The angular probability distribution is now:

$$P(w_1X) + P(w_2X) \tag{11}$$

where:

$$w_1 = e^{i\Delta\phi(x_1,t_1)} \tag{12}$$

$$w_2 = e^{i\Delta\phi(x_2,t_2)} \tag{13}$$

And it follows, from the fact that $P(x)$ is a uniform angular distribution, that:

$$P(w_1X) + P(w_2X) = \mathrm{P(wX)} \tag{14}$$

where:

$$w = w_1 + w_2 \tag{15}$$

Now, the probability distribution of finding the particle at point B with any phase is:

$$P(B) = \int_{\phi=0}^{\phi=2\pi} P(wX)dwX$$

$$= \int_{\phi=0}^{\phi=2\pi} P\left(|w|e^{i\phi+iARG(w)}\right)|w|de^{i\phi+iARG(w)}$$

$$= |w| \int_{\phi=0}^{\phi=2\pi} P\left(|w|e^{i\phi+iARG(w)}\right)de^{i\phi+iARG(w)}$$

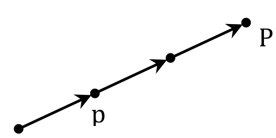
$$= |\mathrm{w}|^2 = |\mathrm{w}_1 + \mathrm{w}_2|^2 \qquad (16)$$

So, if there are multiple paths for reaching a point with associated winding factors $w_1 .. w_n$, the probability of observing a particle or toma at that point is proportional to $|w|^2 = |w_1 + .. + w_n|^2$. This mechanism is identical to Feynman's formulation of QED [2].

Quantum Chromodynamics

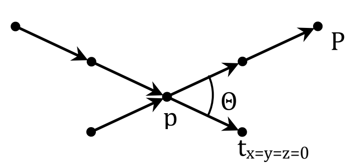
QCD and the Standard Model follow from creating a quantum field theory with the symmetry group U(1) × SU(2) × SU(3) [3]. The previous section outlined how QED and thus QFT arose naturally in the tomatic approach by considering phase shift. This section explains the origin of the symmetry group thus yielding QCD.

Consider a point *p* on a path *P*:



We know that the point *p* has a complex coordinate *r* such that *r* = distance along *P* from origin and *arg(r)* = phase shift. As phase is relative, it can be measured with an arbitrary reference at *p*, yielding the U(1) symmetry.

Consider the local coordinate system at *p*, especially the time axis for which *x = y = z = 0*.



Clearly, the physics is independent of the choice of Θ, and as P and t are both complex, this yields SU(2).

Lastly, consider the three orthogonal space axes at p. They may be rotated in any direction while remaining mutually orthogonal, thus yielding SU(3).

Therefore, the combined local symmetry of a tomaticmultitree is that of the group U(1) × SU(2) × SU(3), corresponding to the foundation of the Standard Model.

Conclusion

I have presented a novel non-atomic model of physics which allows one to derive GR, QED and QCD together from first principles. This is the first approach that allows one to do so successfully, and as such is a candidate for being a Grand Unified Theory of physics.

The tomatic model has applications to other fields of study, such as philosophy, cognitive science and computer science.

The world has no substance of its own. It is simply a vast concordance of causes and conditions that have had their origin, solely and exclusively, in the activities of the mind that has been stimulated by ignorance, false imagination, desires and infatuation.

Buddha [4]

References

1 Einstein, A., Die Grundlage der allgemeinen Relativitätstheorie. (The Foundation of the Generalised Theory of Relativity.), Annalen der Physik 49, 769-822 (1916)
2 Feynman, R. P., Space-Time Approach to Quantum Electrodynamics, Phys. Rev. 76, 769–789 (1949)
3 Ellis S. D., Physics 557-8 (Particle Physics) Lectures, Autumn 2012, Winter 2013. University of Washington, Department of Physics.
4 Mahamaya Sutra, The Teaching of Buddha. Bukkyo Dendo Kyokai (Society for the Promotion of Buddhism), 751st Revised edition (1993).