Two-point momentless: Space and time in the context of quantum entanglement.

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Abstract

In this paper, a cause for the lack of unification between quantum field theory and general relativity is identified. It is shown that the description of spacetime in current theoretical models assumes energy to be unchanging at small units of time on the quantum scale. As a means of counteraction, a condition is established for quantum gravity theories and the concept of 'two-point momentless' is presented.

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1 Introduction

General relativity unfolded upon questioning the absolute notions of Newtonian space and time. Ever since, the most accepted view of spacetime is a structure whose geometry depends on matter.
The numerous predictions and consistency that the theory has demonstrated over a century, has only been challenged by the discovery of quantum phenomena, e.g., if matter curves spacetime, since quantum superposition tell us that a particle can be in two positions at the same time, where does the particle affect the curvature?

In this paper, we determine one root cause for the lack of unification between general relativity and quantum physics by identifying a so far overlooked assumption on the notion of space which necessarily contradicts the quantum properties of matter in Chapter two. The analysis is extended to the variable of time in Chapter three. As a result, an unprecedented requirement is defined for future theories of quantum gravity. In Chapter four, the concept of 'two-point momentless' is proposed as an alternative basis consistent with this new requirement.

2 Space

Research on newborn babies provides evidence that humans acquire a notion of space soon after birth, possibly even before [1],[2].

We now know that this innate concept, which is normally closer to the idea of a Newtonian space, is an incorrect representation of physical space and yet, there are still aspects of the process in which information received through sensory perception is interpreted as a mental construct which remain unchallenged and have a direct influence on our mathematical interpretation of space.

To show this, we consider a Gedankenexperiment at a scientific gathering where neuroscientists who have been investigating brain dynamics in spatial navigation, run the following experiment on the first day of the meeting: they request a set of participants to walk from their accommodation to the conference hall. Only one of the members knows the way and is guiding the rest of the group. As they walk, they are focused on various discussions and are mostly inattentive to their surroundings. Once the group reaches the

hall, they are asked to draw a map of their route as accurately as possible. To draw a map, the mind recalls information from the memories of the walk in a relatively fast process. The final mental representation of the path does not necessarily contain all the details that can be remembered, often it is a simplification.
The answers given by the participants differ and are more or less accurate when compared to an official road map, however they all have in common the fact that their minds construct a map by putting together information perceived at different moments in time. This disparity in time is usually not something mind is aware of, instead all points are taken to exist simultaneously and exactly as they were perceived. This premise is the fundament upon which mind formulates space.

To understand spacetime at a quantum level, one might first investigate if it is possible to define a quantum distance operator.
Insights can be gained from studying the specific case of two entangled particles, α and β. The non-separability of the quantum state necessarily implies that the positions of α and β cannot be individually assigned.
To give an intuitive understanding of such state, authors often use analogies and explanations which if not interpreted accurately, can become contradictory. One example is the definition of entanglement which describes it as a state for which "everything can be known about the system and yet nothing can be said/known about its parts". This statement is often presented in the form of a paradox, and yet could only be paradoxical from the classical point of view that holds the parts α and β as independent entities. Implicit to the formulation of such definition, is the ingrained notion that α and β must exist at two distinct locations x_α and x_β, explicitly contradicting and neglecting the conclusions gained from our understandings on entanglement.

Entanglement gives us in fact very valuable information about the parts of a system: it tells us that they are not findable as separate entities when entangled; 'α' and 'β' understood in the classical sense are mere labels. Entanglement is not negating the existence of parts, but it provides a new frame upon which their relation must be understood.

A quantum distance operator could only be asserted based on the separation between the two parts α and β, and yet here it has been clearly exemplified that it is not possible to determine the positions of the two par-

ticles when they are entangled.
Quantum physics negates the 'two points' and the line between the points that characterize any classical distance $d_{\alpha\beta}$.

One might argue that, at least classically, space cannot be a mere theoretical concept since it is also a measurable variable. One way to quantify the classical distance between two points α and β with a high degree of precision is by measuring the time it takes for a light pulse to make a round trip between two mirrors placed at x_α and x_β. A scientist at x_α records this time and infers the distance the light had travelled.
This inference assumes that α and β remained static throughout the experiment, an assumption that is necessary to define the separation between the fix points x_α and x_β. Despite this being a valid approximation at a classical level, when energy is considered at a quantum level the fact of its impermanence cannot be ignored. Particles are not static elements: for example, in the context of quantum field theory an electron spends time as a combination of virtual electrons and virtual photons.

When the light reaches the scientist at x_α after its round trip, the energy of a quantum system at x_β has necessarily changed; α and β do not necessarily need to be entangled for this to be the case.
We conclude that the existence of space in our current description as a spatial construct has never been demonstrated experimentally and that it is a concept that necessarily assumes energy to have a degree of permanence, which is in fact the same premise mind uses to depict spatial mental images.

3 Time

Our notion of space is intricately correlated to our understanding of time. Classically, time was defined by Newton in [3] as "absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration."

Here, we will consider 'duration', 'interval' and 'moment' as synonyms, δt_{AB}. Newton saw time as an absolute and independent entity, a position no longer accepted in general relativity. Nevertheless, the 'momentary' nature of time is present in most mathematical and physical models today.
A more recent definition of time was proposed by Gerard 't Hooft in [4]:

"Time is the order in which our models for nature predict, prescribe or explain events", where "events are characterised first of all by their locations in space, and moments in time". According to this view, there is always a causal relationship between the quantum states of a given system at two different moments t_A and t_B.
When analysing the evolution at this subtle level of energy, small scales of time become relevant. Based on the premise that energy is never static, the following question arises: if the initial quantum state of a system is defined at t_A as $\phi(t_A)$, and if t_A is an interval of time and therefore divisible, is this definition necessarily assuming that there is no change within that interval? Each moment is necessarily divisible into smaller intervals. Consequently, if energy is impermanent, a description of any initial state needs to reflect such changes throughout the moment t_A. A resolution to this quest cannot be found if using the same concept of time. Attempting to do so results in an infinite regression that is not physically meaningful: as one divides moments into smaller and smaller ones.

This reasoning offers an incredible insight into our notion of time: namely, that our understanding of time 'in moments' assumes a degree of permanence. Regardless of how small the intervals of time of consideration are $\delta t_{AB} \to 0$, the addition of static moments of energy cannot ultimately describe impermanence and therefore this concept of time presupposes a limitation to our understanding of matter, particularly at the quantum level.

The conclusions of Chapters two and three evidence the need to research a subtler level of impermanence that has not been investigated before. Moreover, we propose that for a modern theory to be valid at a quantum level, it has to reflect the impermanent nature of energy or what we will name 'condition of impermanence':

Condition of impermanence = energy is never static or permanent.

4 Two-point momentless

Based upon the conclusions of Chapter three, if time cannot be described as moments, one may ponder if there is an alternative formulation or if otherwise physical laws should prescind of its notion as proposed in [5].

This question is closely related to our understanding of causality, a subject which has been intensively discussed in relation to the arrow of time [6]. ‘Why time has a direction’ is an unresolved question in general physics. Whereas physics laws are predominantly time reversal invariant, more precisely CPT symmetric, our observation of time is one-directional: for example, given the right conditions, a seed turns into a sprout, but the reverse process is not observed.
Here, we propose that the inefficacy from present models to elucidate the arrow of time, is due to the fact that sequential events are understood independent from each other: for example, the description of a system at time t_A, $\Phi(t_A)$, does not contain ‘in itself’ any information of any subsequent moment t_B.
Our current description of time ’in moments’ stops time (or the evolution of a system) within an interval t_A, permitting a static and independent description, and simultaneously giving rise to the possibility of choice of direction, steaming from the disjunction between two now disconnected instances.

To provide an alternative that can characterize the transition point between events at a subtle level, we take the viewpoint of energy as ‘continuously arising’, where this arising adheres to a principle of causality.
In contrast to block-time models, here ‘past’ and ‘future’ are not a reality of the arising, neither can the arising be subject to the boundary of a present ‘moment’.

An alternative mathematic formulation is needed that considers the fact that there is no unit of time without disintegration, and therefore dismisses boundaries, yet not in the context of infinite smaller intervals. Such formulation should allow for an arising that is complete disintegration, by affirming the negation of moments being necessarily bound by time.

To clarify, this view is not negating time, it is instead negating moments. The arising can therefore be described as ‘momentless’. Energy is continuously arising, this arising adheres to the principle of causality and is momentless

The meaning of ‘momentless arising’ can be better understood regarding the causality laws from which it emerges. It is here, in the arising, where the relationship between cause and effect must be understood.
Two possibilities that can be negated based on the discussion presented in

Chapter three are: a) sequential arising, where the cause at t_A is followed by the effect at t_B: energy does not exist in one moment and then suddenly in another moment without the two having a connection and b) simultaneous arising: if cause and effect are considered as independent entities, this proposition would be equivalent to a view where past and present exist simultaneously, contradicting the hypothesis of continuous arising.

Consequently, one must conclude that at this subtle level, the decay of the cause and the arising of the effect cannot be described independent of each other, for they can only be independent within static moments of time. If they are not independent, their arising is interdependent. This inseparability is by definition an entangled state.

Next we would like to know how this principle changes our understanding of the Universe, in particular its quantum aspects. Consider for example a single atom confined by means of an ion trap in a vacuum chamber. What are the cause and effect relevant to the evolution of this single atom in time and what is entangled in its arising?
The non-static nature of the confined atom should not be understood as ‘it’ completely disintegrating into the vacuum and reappearing from the void. Instead, its arising is based on specific conditions, such as its constituent subatomic particles, the vacuum quality achieved by the vacuum chamber or the stability of the magnetic field. All these factors influence the potentiality of the effect and are interdependent elements to its arising. In the model the authors proposed in [7], the diversity of quantum field states is determined by the Universe vacuum structure which in turn is linked to black hole formation and constitutes the main condition for the arising of all matter. The model also showed that there is an interdependent relationship between the quantum vacuum structure and matter itself, where the stability of one depends on the other. Here, the single atom does not exist as an independent unit outside of its ‘parts’, the virtual excitations. The relationship between the state of the atom at a given stage (effect) and its direct cause (the atom at a previous instance) can be understood as follows: the moment the cause ceases, the effect stems upon the conditionality of the quantum field excitations, which is dependent on the local vacuum structure and external influences such as strong magnetic fields, none of which are static at any time. The authors will present further examples on the significance of ’two-point momentless’ in papers to come.

Summarizing, this Chapter focused on understanding energy as interdependently arising. This arising can be designated as 'two-point momentless', where 'two-point' refers to the two points of negation: in our example we are negating an independent or isolated mode of existence of a cause and its immediate effect.

5 Conclusion

In this paper, we have shown that our current understanding of spacetime implicitly assumes a subtle degree of permanence which cannot be compatible with quantum physics. We propose a novel requirement for future theoretical models and propose the alternative description of 'two-point momentless' to describe a causal interdependent arising which is not bound by moments.

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