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EXPLORING CONSCIOUSNESS THROUGH THE QUALITATIVE CONTENT OF EQUATIONS

Ashok Narasimhan and Menas C. Kafatos

ABSTRACT: The majority of the focus on equations in physics has been on the mathematical and computational aspects. Here we focus on the qualitative content of what the relationships expressed in equations imply. In some sense, we are asking foundational questions about the ontology of equations.

KEYWORDS: Mathematical formulae; Consciousness; Qualitative content; Ontology

INTRODUCTION

In science in general and physics in particular, there has been inadequate exploration of the qualitative content of equations. The inspiration for this discussion is what Richard Feynman¹ said: “The next great era of awakening of human intellect may well produce a method of understanding *the qualitative content* of equations”. Equations are about relationships between things and the mathematics of the equations define exactly how those relationships work and express themselves. However, it might be useful to think about *why* do those particular properties appear, in that qualitative form, in those relationships? We explore *why* and *what does it mean*, rather than ‘what is the mathematical output’.

We do this through *thought experiments* in three areas, two of them related to ‘complementarities’ in modern physics (special and general relativity) and in quantum mechanics. The third is a hypothesis that ties them together with Consciousness

¹ R. P. Feynman (2011). *The Feynman Lectures on Physics, Vol II* (Basic Books; New Millennium edition), ISBN-10: 0465024947

COMPLEMENTARITIES

Complementarities in physics refer to properties that are logically separate constructs, which displace one another in any single physical situation, yet both are required for a complete understanding of the situation².

Complementarities in Relativity

Let us start by looking at normally understood complementarities in relativity:
 Mass and Energy in special relativity (SR) and
 Space and Time in general relativity (GR).

These complementarities in special and general relativity are typically considered to be separate complementarities, but we will see if in fact they are inextricably linked. In fact, the usual complementarities as envisioned by Niels Bohr², refer to incompatible variables, and these, for example, would be position and momentum; and time and energy. Here we see that we can generalize and have these mixed in the two sets of relationships above.

The starting point in our thought experiment is the famous relationship/equation³

$$E = mc^2$$

where, of course, E = energy, m = mass and c is the speed of light.

Now, for the purposes of our thought experiment on the qualitative meaning of this equation, we will focus only on the obvious: mass and energy are equivalent (but complementary) entities, and the transformation from one to the other is mediated by the speed of light. For this initial thought experiment, we will not address the qualitative implications of the *square* of the speed of light – that is the subject of a separate discussion.

What does this tell us *qualitatively*? It says that energy, mass and the speed of light are linked. Let us take this a little further. Speed is time taken to travel distance and distance is nothing other than separation in space. So now we qualitatively have space and time in this equation.

Qualitative Insight 1: Energy, mass and space-time are related.

² See e.g. N. Bohr (1937). Causality and Complementarity. *Philos Sci.* 4: 289–298. N.D. Theise, and M.C. Kafatos (2013). Complementarity in biological systems: a complexity view. *Complexity*, 18(6):11–20.

³ A. Einstein (1975), Aether und Relativitätstheorie, trans. W. Perret and G.B. Jeffrey, in *Physical Thought from the Pre-Socratics to the Quantum Physicists*, ed. S. Sambursky (New York, Pica Press).

Qualitative Insight 2: Energy and mass are complementarities particularly relevant in special relativity and space and time are complementarities in general relativity. Both of those are traditionally not considered to be linked – but this seems to indicate that these are all interrelated and directly linked qualitatively. As a separate exercise in a different paper, we will explore the formal mathematical consequences of these relationships, but for now, let us stay with the qualitative meaning of this equation.

By substituting time t and space s to the equation, we see that $= \frac{ms}{t}$. Again, we ignore the square function of $\frac{s}{t}$ for the purpose of this immediate thought experiment and keep it for later mathematical exploration.

So we can qualitatively say that if $= \frac{ms}{t}$, then mass and space-time are much more closely linked, since they are on the same side of the equation, compared to energy.

Qualitative Insight 3: Mass and space-time are closely interlinked.

Let us now consider, in our qualitative thought experiment, that gravity is the curvature of space-time caused by mass⁴.

Qualitative Insight 4: Gravity has also now appeared in the equation.

Let's now take another qualitative look at $E = \frac{ms}{t}$. Energy seems to be the primal reality, since it subsumes and contains mass, space-time and gravity.

Qualitative Insight 5: Energy, rather than being just a complementary dual to mass, is in fact the primal entity that contains the others: mass, space-time and gravity.

Now let's take another qualitative look at the equation $E = \frac{ms}{t}$. With a simple transposition, we can obtain $T = \frac{ms}{e}$.

Let's look at some qualitative scenarios:

Energy E cannot be zero - the equation would then become meaningless and would have no value.

If mass m is zero but space s and energy E have a positive value, then time t becomes zero.

Qualitative Insight 6: If there is space and energy but no mass, then time = 0

If time t is zero, then space s is zero. So this would imply that the realm is now *outside* space-time, with no mass/particles, but only energy.

⁴J.A. Wheeler (1980). In *Some Strangeness in the Proportion*, ed. H. Woolf (London, Addison-Wesley).

Qualitative Insight 7: If we have conditions of energy but no mass, then space-time collapses.

Now let us continue our thought experiment by trying to see under what circumstances these conditions can be met. In order to do this, we will have to move to the quantum scale.

Mass is a function of scale. In our thought experiment, let's imagine that we drop down to the quantum or sub-atomic scale. What would we see? At a sub-atomic scale, it is 99.9999999999996% empty space, with no material (mass) in this space. Therefore, the above conditions are met.

Qualitative Insight 8: At this sub-atomic or quantum level, space-time does not exist.

Let's continue further with our thought experiment. At the quantum scale, there are no hard 'boundaries' to the atoms, where one stops and the other starts, so this 'empty space' threads and snakes its way through every atom in the universe

As the atoms, molecules and higher aggregates of matter move in regular space-time, some mass may appear at a specific location of this empty space, but this is replaced by locations that earlier had mass now becoming 'empty'. *So, at any point, there is always a flexible, dynamic, interconnected 'pathway' or 'web', connecting every atom in the universe, within which there is no mass.*

Note that this is a true vacuum, unlike the interstellar 'vacuum', where there is always residual mass, through quantum foam and other phenomena.

In interstellar vacuum, the speed of light is a finite number, determined by the very small, but always present, mass density of interstellar space. The conventional definition of the speed of light is 'in a vacuum' – but no true vacuum exists in interstellar space. So the speed of light has a finite and fixed number, represented by the speed of light in the mass density of the 'near vacuum'.

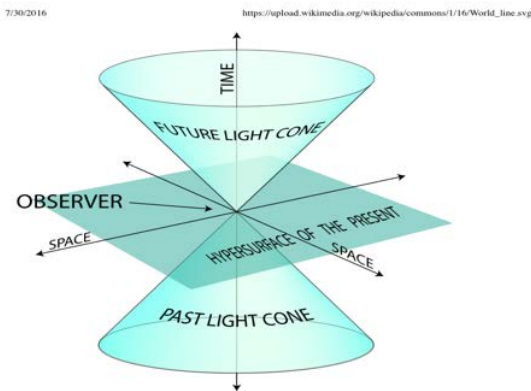
In this sub-atomic or quantum vacuum (NOT to be confused with the conventional definitions in QFT, with QED⁵ and QCD components), there is a true vacuum, so the speed of light is infinite. In other words, as we have seen before in our thought experiment, space-time collapses.

Insight 9: There is, at quantum scales, a 'web' that connects every atom in the universe and within this 'web', space-time does not exist.

There is another major implication of this view of a 'quantum web' within which space-time does not exist. And that is – this 'outside' space time is not 'outside' (which

⁵ See for example R.P. Feynman (1985). *QED: The Strange Theory of Light and Matter* (Princeton, Princeton Univ. Press).

itself is a pure space-time word) but is *intricately intertwined with space-time*. The traditional light-cone⁶ diagram is depicted as:



Insight 10: This quantum web ‘outside’ of space time is not ‘outside’, but *is embedded in, and embeds, space-time*.

So where does this lead us in our thought experiment? If the ‘outside space-time’ is not in some distant unknown ‘location’, ‘far away’ (all these conventional but limiting space-time words of everyday life!) from space-time, but is embedded in and embeds, space-time, then we have the conditions that allow for ‘leakage’ and interaction between the two domains.

Qualitative Insight 11: This complete interpenetration between the ‘outside space-time’ web at quantum scales and classical space-time at macroscopic scales, provides the mechanism for ‘leakage’ and interaction between these two domains.

⁶ The diagram shown is for flat space-time (from *Wikipedia*).

As a separate subsequent exercise, we will also explore the mathematical consequences of no space-time in the quantum domain and the interrelationship with the macroscopic domain in ordinary space-time.

Quantum Complementarities

Now let us switch gears and look at the complementarities in quantum mechanics. This discussion is broadly based on the Copenhagen Interpretation of quantum mechanics.

The complementarities we are considering are wave and particle. These are best illustrated by the double-slit experiment and its many variations⁷. In very simplified terms, the complementarities indicate that:

Light behaves as a wave or a particle depending on whether the path that it takes is ‘observed’. If it is not observed, it is a wave. If it is observed, it is a particle.

The wave function is ψ , a complex function that includes an imaginary part. Qualitatively, the presence of an imaginary part tells us that it cannot be directly observed or represented in space-time, but is a representation of an implicit order with degrees of probability.

Qualitative Insight 12: ψ ‘exists’ outside space-time.

It is the ‘act of observation’ that causes the collapse of the wave-function and collapses the probabilities inherent in the wave-function to the specific manifestation of the particle in space-time, represented by $|\psi|^2$, or ψ ‘squared’ by its complex conjugate. This quantity is a real number that represents the existence of particle in specific space-time region.

Qualitative Insight 13: $|\psi|^2$ exists in ordinary space-time.

In our thought experiment, let us consider that the Mind or Consciousness or Universal Awareness cannot be represented in space-time. As such, it is ‘outside’ space-time. Let us call this the *Observer* (note: the caps used in the Observer is meant to imply an Observer that is beyond our personal physical-psychological domain). The Observer has to ‘reside’ outside space-time, in order to ‘observe’ ψ , which also ‘exists’ outside space-time.

Qualitative Insight 14: The Observer exists outside space-time.

⁷ M. Kafatos, and R. Nadeau (2000). *The Conscious Universe: Parts and Wholes in Physical Reality* (New York, Springer-Verlag), ISBN: 978-0387988658.

However, once the Observer ‘observes’ ψ , the wave-function collapses and the particle manifests in ordinary space-time as $|\psi|^2$ – and this is observed and measured in space-time by the mind and consciousness of the individual physical observer (note: no caps used in ‘mind’, ‘consciousness’ or ‘observer’, indicating localization in space-time).

This local physical individual mind and consciousness of the observer registers his/her perception by neural synapses firing in the brain in ordinary space-time.

In order for this to happen, there has to be an integration, or at least a direct connection, between the *Observer outside* space-time and the *observer in* ordinary space-time.

Qualitative Insight 15: The Observer ‘exists’ in the quantum web, which is outside space time, but is deeply embedded in and embeds, ordinary space-time, where the observer exists. This deep interpenetration is what allows interaction between these two domains and between the Observer and the observer, with the Observer causing the collapse of the wave function and the observer recording and experiencing the results of the collapse.

MATHEMATICAL COMPLEMENTARITIES

Mathematical systems which in totality form the language with which we communicate with nature, must also reveal complementary relationships. These complementarities reside ‘outside’ space-time, in the realm of the Observer. They are transcendent entities as proposed by the ancient Pythagoreans and Plato. Not only they link the ‘quantum vacuum’ with space-time, they also link the Observer with the observer. As such, mathematics links the transcendent with the psycho-physical levels of existence. Even though appearing to be the products of observer-minds, they are in fact ‘eternal’ entities, the mathematical forms of Plato.

Examples of complementary mathematical systems include: Geometry and algebra; real numbers and complex numbers; synthesis and analysis; integration and differentiation, etc. These complementary constructs merge into higher and more powerful systems such as algebraic topology; category theory, etc. in a similar way as in physics we have quantum field theory that emerged from the complementary matrix mechanics and wave mechanics; string theory that emerged from quantum field theories, etc.

We obtain a new insight that is usually not considered: Mathematics, rather than being in some abstract level of existence, is actually the very language that allows the quantum vacuum to communicate with space-time; and most crucially, the Observer

with the observer. Mathematics is not an abstract level of existence, disconnected from everyday existence. Rather, it is the very connection of different levels of existence and as such, of paramount importance to make sense of the physical and mental universe.

SUMMARY AND CONCLUSIONS

In conclusion, we would like to thank the readers for joining us in these thought experiments⁸. We started with the simple equation governing the relationship between energy and matter in relativity, explored the inclusion of space, time and gravity in that same relationship, then explored how that implied the existence of a ‘web’, at quantum scales, that connects every atom in the universe. This quantum web is outside space-time and indeed it embeds and is embedded in, space-time. We then proceeded to develop the thought experiment some more and explored how the implicit order of the wave function ψ exists outside space-time. Consciousness is primal and exists both outside space time and as consciousness within our bodies, in space-time. When Consciousness Observes the implicit wave function ψ outside space-time, it causes the collapse of the wave function to $|\psi|^2$ that is observed by our local consciousness in ordinary space-time.

Finally, mathematics as the language which gives meaning to physical theories, is itself exhibiting complementarities that ultimately lead to the primary relationships between the Observer and the observed, wherein consciousness manifests reality⁹.

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⁸ We would appreciate thoughts, comments and most importantly, an opportunity to work together to explore both the formal mathematical implications as well as the deeper qualitative aspects of where this approach can take us.

⁹ M. Kafatos (2015). Fundamental Mathematics of Consciousness. *Cosmos and History: The Journal of Natural and Social Philosophy*, 11(2):175-188 <http://www.cosmosandhistory.org/index.php/journal>