Towards A New Philosophical Foundation for Physics – Speculations on the Nature of Space, Gravity,Inertia and Mass

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Abstract
Recognizing that physics is now at an important turning point, the authors put forward ideas relating to the nature of space and its role in the emergence of gravity, inertia, mass and, ultimately, the 'reality' that derives from (scientific) observation and measurement. The essay cites relatively recent experiments and observations relating to phenomena such as the Casimir Effect,Unruh Effect, Zitterbewegung and the results from the 'moving mirror' experiment. It argues that, when combined with older problems such as quantum entanglement,these phenomena provide new evidence that might inform a better understanding of the role of space in its interaction with particle/field entities. Furthermore, it suggests that space may have a significant role in the creation of these entities. The authors suggest that fresh creative insight will be needed for physics to address the scale of the challenge implicit in this new, and exciting, territory. However, this is unlikely to emerge without revising the philosophical framework that underpins physics. This would need to reconcile quantum ontologies with non-quantum ontologies that may be scale dependent. In order to meet the many emerging challenges a more open, participatory and permissive physics is envisioned.
Keywords Entropy, gravity, inclusionality, inertia, mass, quantum vacuum, reality, space.

1 Introduction

Recent theoretical work and experimental findings each refute the idea that space is a benign nothingness, or void. Our essay on the significance of space moots a philosophy that we see as a first step in enhancing current theoretical frames leading to a more comprehensive and compatible system of exploration and understanding.

While all sciences represent their observations in domains that are, at least, implicitly 3-dimensional, the philosophical framework underpinning the more intensely theoretical sciences, such as physics, make it necessary to theorize in higher dimensions[1] in order to 'explain', or to account for, the results of the new

[1]For example time as a 4^{th} dimension in General Relativity theory.

experiments and observations. As experiments become more sophisticated and sensitive the resultant observations lead to ever more intense debate and speculation as to the 'real' nature of reality. While some see this as evidence of a perplexing universe, we are more inclined to see it as an epistemological overhead that stems from continuing to observe and to measure in only 3-dimensions when physics is increasingly multi-dimensional. This would explain why current approaches seem to offer only partial, or illusory, glimpses of what we are exploring. It accounts for the growing and, possibly, unparalleled sense of mystery and 'weirdness' that many scientists experience.

In the past, science has usefully drawn upon a vital source of ideas and valuable insights from the 'philosophical spring' in order to make advancements. Today, a similar process is no less important. This paper therefore advances a number of ideas as a way to initiate a conversation about how physics might refocus its philosophical base, in order to invite and encourage creative and informed debate, and research, on the above topics.

We believe that the present interest in the nature of space and, in particular, quantum vacuum activity is an early indicator as to the future direction of physics. A successful continuation of this new trajectory in physics will require a (not unprecedented) process of reinvention, or possible revolution, that includes developing a new philosophical foundation. To that end we acknowledge the significant role Natural Inclusionality [1] has played in influencing our thinking during the development of this paper. According to Natural Inclusionality the classical description of space requires a reinterpretation:

Space is regarded merely as the distance over which mass, force and energy are stretched (or stretch themselves), such that they have variable density or frequency, and has no other influence beyond their limits. In this default condition, matter is inert and space passive. The very possibility of motion is therefore made ultimately dependent on some inscrutable external forceful agency or 'unmoved mover' to get it going. But if such agency can only be contained or applied locally, where is it? There is clearly something, or rather somewhere, missing from this classical description, which leads energy in the guise of mass and force paradoxically to be mentally confined within and excluded from the boundaries of discrete, completely quantifiable units-i.e. as atomic particles in material bodies, photons in electromagnetic radiation and phonons in heat. That missing somewhere, according to natural inclusionality, is everywhere, without limit-the intangible receptive presence of space. With the dynamic inclusion of this non-local omnipresence within, throughout and beyond local form, movement and change become understood in terms of processes of flow as a continuous energetic reconfiguration of space, not as the travel of independent particles or waves through space. By the same token, massy bodies and electromagnetic radiation are un-

derstood as distinctive energetic configurations of space, neither solely 'particles' nor 'waves', but 'flow-forms'[1].

2 Inertia, Mass and Gravity

The relatively recent discoveries of a physical manifestation in 'empty space' have shown space to be a sea of virtual[2] activity[3]. The Casimir and Davies-Unruh Effects [2], the results of the 'moving mirror' experiments [3], fermion chirality and Zitterbewegung [4-5] all suggest that space plays an active role in the manifestation of certain physical phenomena. We venture to suggest that the virtual sea of activity resident in space may well be the domain of so called 'hidden variables' that mediate and, perhaps, cause the emergence of 'phenomena' including non-locality, mass conference, inertia and, perhaps, plays a pivotal role in the emergence of 'gravitational' influence.

Rueda and Haisch [5-6] have suggested that inertial and gravitational mass each arise from interactions of the electric charges and quarks of matter with the quantum vacuum. They suggest that matter distorts or polarizes the quantum vacuum, leading to an attraction of virtual particles with opposite charges and repulsion of those with like charges (cited by Chown [5]). This idea resonates with the idea of matter interacting with 'space', as has been proposed elsewhere [1,7-8].

Whilst offering a different interpretation of the nature of space itself, we agree that the quantum vacuum somehow interacts with mass and this is what causes the emergent properties of gravity and inertia; hence our proposed mechanism is somewhat similar to that proposed by Rueda and Haisch [6].

As matter is mostly 'empty space', and as space is considered to be a sea of quantum vacuum activity, it would seem that matter itself is permeated with quantum vacuum activity. It follows that the quantum vacuum interactions within matter may play a significant role in the emergence of mass and inertia.

When energetic bodies are in uniform motion, the quantum vacuum permeates as laminar flow throughout them, whereas under acceleration we suggest there is a disturbance[4] of the quantum vacuum activity, which is manifest as a Davies-Unruh Effect [9-10]. As has been suggested [2,6], the result is an increase in inertia, which we term virtual mass. By way of analogy this could, perhaps,be understood as some kind of induction phenomena whereby quantum vacuum energy becomes stored within the body during acceleration[5]. Radiation emission

[2]Virtual in the sense that such activity is not easily measurable, is barely observable and does not have extension in 3 dimensional 'space'.

[3]Also termed quantum vacuum noise.

[4]The quantum vacuum when moving through mass under acceleration induces radiation effects.

[5]Under acceleration there is a kind of 'induction effect' (with photon emission) in which the quantum vacuum interacts with fundamental matter fields [6] causing the affected body to

during acceleration suggests virtual particle conversion[11], which in our view is not unlike the Hawking black hole radiation effect[6][2]. It is only at the large accelerations in the vicinity of black holes that we see effects that are barely detectable in our everyday experiences (e.g. at low accelerations, photon numbers are small and their wavelengths are very large [11]).

Davies sums up the present paradoxes in the following way:

A further set of unsolved problems concerns the deeper significance of the relationship between acceleration and quantum vacuum noise. Does the existence of "acceleration radiation" suggest a link between the quantum vacuum and inertia? Haisch et al.[41] *claim that the very existence of inertia can be traced to the activity of vacuum noise on an accelerating particle. Although this claim has not received widespread support, it is tempting to believe that the distinction between inertial and accelerated motion provided by acceleration radiation is telling us something fundamentally new about the principles of dynamics*[2].

Davies is suggesting that there is something new, maybe at a deeper level, that has been missed or perhaps misunderstood. In any case, researchers still find themselves having to make sense in the 3 dimensional domain of reality.

Verlinde [12], in making a conclusion on the origin of gravity, touches on the dynamic role of space in the creation of inertia and gravity. He posits that differences in entropy is the primary cause of gravity:

Other authors have proposed that gravity has an entropic or thermodynamic origin, see for instance [14]. But we have added an important element that is new. Instead of only focussing on the equations that govern the gravitational field, we uncovered what is the origin of force and inertia in a context in which space is emerging. We identified a cause, a mechanism, for gravity. It is driven by differences in entropy, in whatever way defined, and a consequence of the statistical averaged random dynamics at the microscopic level. The reason why gravity has to keep track of energies as well as entropy differences is now clear. It has to, because this is what causes motion! The presented arguments have admittedly been rather heuristic.

While we agree that entropic considerations are important and, indeed, relevant we view entropic effects as emergent and, therefore, only indicators of 'causes' resident at a deeper level, that is, beyond 3-dimensions. In what follows we attempt to explore these ideas further.

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become progressively 'saturated' with a form of quantum vacuum activity, thus progressively retarding the movement of quantum vacuum through it. This causes a progressive resistance to increasing acceleration.

[6]See also New Scientist. "Hawking Radiation Glimpsed in Artificial Black Hole". Accessed December 21, 2012. http://www.newscientist.com/article/dn19508-hawking-radiation-glimpsed-in-artificial-black-hole.html?full=true&print=true for parallels with the Unruh Effect.

3 The Role of Entropy in the Quantum Vacuum

It has been suggested that gravity, rather than a 'physical field', emerges from quantum field theory (Sakharov cited in [13]). Entropy has been suggested to be an element of a similar 'gravitational' induction effect, emergent from the energy flux of unobservable degrees of freedom (Jacobson cited in [13-14]).

Whilst entropy is not directly measureable [15] in the 3-dimensional domain it is nonetheless produced there. It is not a physical element of the thermodynamic equilibrium itself (as conceptualized in 3-dimensions); rather it is a virtual effect or flux produced during a reaction, which remains hidden. We propose that entropy, as understood by thermodynamic theory, and when emitted by bond resonances at equilibrium, is a disturbance or flux in quantum vacuum activity caused by the local presence of energetic flux and mass. Entropy viewed in this way would be analogous to the Casimir Effect and is a part of the underlying mechanism for the induction of mass, gravity and inertia, as described later in this paper, and as explored in previous work [7].

We propose that the quantum vacuum of space, rather than being the source of gravitational influence via a polarisation mechanism in itself, also includes 'hidden variables', 'dark' forms of energetic flux. These 'hidden variables' would exist in states that, whilst not being accessible to direct detection or measurement in 3 dimensions when 'entropic', none-the-less play a role in the energetic interactions of mass when 'gravitational' or 'inertial'.

We suspect that what are currently theorized as Dark Energy, or Dark Matter,are varieties of these virtual manifestations permeating the quantum vacuum of space. It is possible that they will provide a route for the investigation of further dimensions and provide evidence of the so-called 'hidden' variables that would explain quantum phenomena, such as non-locality.

In the case of non-locality, its apparent manifestation in 3 dimensions might suggest that, at a deeper level, 'distance' as such, may not exist; furthermore, that the notion of definitive 'locality' (as distinct from dynamic locality) is purely a manifestation of 3-dimensional 'reality'.

3.1 Some Ideas on the Phenomenon of Gravity

We contend that, in the vicinity of a body, there exists a disturbance in the quantum vacuum proportional to its mass[7]. In our view, in its interaction with matter, the quantum vacuum induces the emergence of gravity (see Sakharov cited in [13]). This disturbance results from a Casimir-like effect such that, in the vicinity of mass, there is an imbalance of quantum vacuum activity[8]. This in turn causes bodies in close proximity to move together, but not necessarily via

[7]Mass is an extension in 3-D of interactions from within the quantum vacuum. Mass 'soaks' up quantum vacuum activity.

[8]This is similar to the Active Gravitational Mass idea of Haisch and Rueda (see [6]).

the same mechanism as that proposed by Le Sage or Brush cited in Edwards [16].

When two bodies approach each other in 'free space', the strength of apparent 'attraction' is directly proportional to the magnitude of disturbance of the quantum vacuum activity in the intervening space, caused by the presence of the bodies. Within this disturbance, the vacuum bodies induce a 'suction-like' reaction that causes them to move together. It is almost as though two bodies that appear to undergo gravitational attraction are pushed together by the higher vacuum activity in the surrounding space. Although mass is mostly space there are still residual field, or energy centres observable at any particular scale (we loosely term these 'horizons' or 'points of diminution' or 'diminished mass'). This explains why gravitational affect is related to size and mass.

It also follows that the interaction of mass and the quantum vacuum can provide an explanation for the equivalence of inertial and gravitational mass. Thus, two bodies of unequal mass will fall at the same acceleration in a 'gravitational field' because the Casimir Effect is proportionally influenced by an opposing Davies-Unruh effect. A comparatively large mass will experience a higher Casimir effect, compared with a less massive body, but its 'fall' will also be proportionally retarded by an increase in its virtual mass (inertia) due to the Davies-Unruh Effect. On the other hand while the less massive of the two bodies will experience a lower Casimir 'push', it will also experience a proportionally lower inertial increase or retardation.

4 Suggestions for Physics – Some Tentative Conclusions

The observations and theorising that led to the idea of a quantum vacuum have now taken physics to an important new horizon and we are beginning to glimpse a 'reality' far stranger than the one we have become used to. This poses new challenges, because theorizing is tending to take the place of experiments and observations due to the constraints of working in 3 dimensions. On the other hand, certain empirical observations, such as those from the moving mirror experiment, Casimir, Unruh, the double slit experiment and from non-locality experiments in general are providing tantalizing glimpses of what appears to be a deeper world.

However, while these sophisticated experiments are being used to explain the many new and exciting ideas, such as the Many World Theory, String Theory, and so on, their conclusions are limited by being interpreted in only 3 dimensions. In order to explain their strangeness, physicists are forced into making their theorizing processes more elaborate, thus creating a new virtual reality as a surrogate. In the meantime the search continues for the ground-breaking observations and or experiments that might tell us how it all works and what it all means. The excitement over the work on the Higgs boson is a recent example.

The experiments and observations employed by physics are cosmic in scale, now

that we can take excursions, via our telescopes or interstellar vehicles, into black holes, neutron stars and far-off galaxies. Despite some wonderful observations and measurements made from these 'natural', massively powerful laboratories, we still try to explicate the data using only 3 dimensions. Thus, the problem remains.

While we are getting tantalizing glimpses of a mysterious, 'hidden world', how can we 'explain' them without having to devise increasingly complex experiments and ever more complex theories? In this essay, our missions not to offer a clear solution but, rather, to invite a philosophical conversation about the nature of space. This, we argue,is needed in order to invite the much-needed creative input and ideas that will be needed to define the new order. Such a platform is already being suggested by many researchers and distinguished commentators including Davies [2], Rueda and Haisch [6], Johnson & Walker[17], Wuthrich [13] and David Tong [18]. For instance, Tong's recent article in Scientific American has already initiated an important debate that is at the heart of physics. Moreover, its proposition, namely, that reality is a non-quantized continuum is germane to this essay. In our view, this is an exciting and much-needed first step, as we continue to move into a new era of physics.

The paper by Rafelski et al [19] demonstrates the depth of interest in the problem of the quantum vacuum and in our view straddles an important physics-philosophy coupling. In their discussion of the 'three riddles' at the nexus of quantum theory, particle physics and cosmology the authors bring to the fore not only plausible arguments, but as important suggest new directions for inquiry into the nature of space. The authors argue:

Contemporary physics faces three great riddles that lie at the intersection of quantum theory, particle physics and cosmology, they are

1. The expansion of the universe is accelerating - the extra factor of two appears in the size.

2. Zero-point fluctuations do not gravitate - a matter of 120 orders of magnitude.

3. The "True" quantum state does not gravitate.

The latter two are explicitly problems related to the interpretation and physical role and relation of the quantum vacuum with and in general relativity. Their resolution may require a major advance in our formulation and understanding of a common unified approach to quantum physics and gravity. To achieve this goal we must develop an experimental basis.

So not only is more research needed, but moreover a new perspective from which to formulate ideas and problems is also needed. We suggest that new and perhaps alternative ontologies are required that encourage new, innovative and creative insights.

The maturing philosophy of Natural Inclusion (NI) offers one such perspective. Alan Rayner [8] the founder, describes NI in these words:

A term introduced by Alan Rayner and Ted Lumley, in conversation with others, intended to distinguish a form of reasoning that includes intangible presence and so is more comprehensive, comprehensible and realistic than abstract rationality. Eventually it became necessary for Alan Rayner to distinguish his understanding of inclusionality as 'natural inclusionality', which takes account of local influence and identity, from Ted Lumley's understanding, which considers only nonlocal influence and regards locality as illusory.

Space in the context of NI is described as [8]:

According to the logic of natural inclusionality, ... space cannot be pluralized into discrete particularities; it can only be distinguished into distinct, dynamically and permeably bounded regions. This is because a presence that has no resistance can neither be cut nor resisted by a tangible frame. It is inescapably present throughout and beyond the boundaries of tangible figures. A tangible frame is an inclusion of and is included in space but the frame is not the space. The tangible frame can move (or be moved) and be cut, but not the space. When the frame moves the space stays where it is: in relative terms by remaining still space permeates freely through the frame, the frame does not cut through the space. Moreover, if the frame is to move without being forced to do so by a force situated somewhere outside of it, it must have the capacity for movement within itself, i.e. the frame is itself a manifestation of energy, not inert structure-it is a variably fluid 'framing', not a permanent, absolutely rigid 'framework'. This tangible 'framing', or 'dynamic interfacing', has to be present for form to be distinguishable in a feature-full cosmos, but it can neither 'occupy' nor 'exclude' the space that it includes and is included in.

NI accommodates continuousness and therefore perhaps at certain scales posits that reality is in fact non-quantum in nature, as suggested by David Tong [18].

The introduction of such philosophical innovations would, in our view, invite new and perhaps very productive conversations leading to ideas and maybe new insights that might create conditions for thinking about old and current problems in new ways. After all that is what has happened many times before as 'breakthroughs' have arisen in the most unexpected of ways.

In this essay metaphor and analogy have been employed as they help to invite new ideas and imaginings. Our approach is therefore very much in keeping with the inquiry trajectory proposed by Bohm [20] who suggested that future scientists would be less dependent on mathematics and modelling as they begin to draw upon new approaches that in the end would lead to a merging of art and science.

Acknowledgements

The authors acknowledge the support of Emeritus Professor John Wood who offered several very helpful suggestions and recommendations during the final stages of manuscript preparation. Also our thanks to Dr. Alan Rayner who offered useful suggestions during the early drafting of this paper.

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