An examination of measurement relevant to entanglement and ontology: Answers to some long standing questions.

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Abstract:

This paper is about how measurement has been misunderstood and that has led onto further misunderstanding. It has given the impression of 'spooky action at a distance' and made it seem that Bell's inequalities argument supporting that must be correct. An argument is presented here, considering whether some measurements are not informing about the pre-existing properties of particles; but rather provoking responses that are providing the measurement outcomes. The mathematically impossible predictions for quantum experiments when pre-existing properties are assumed is looked at, while provocations are considered. That is, with regard to different orientations of response being of non-equivalent type and therefore not justifiably, added and subtracted; calling into question the applicability of Bell's inequalities. Different categories of measurement are given. Entanglement is discussed in the light of the previous measurement arguments. Concluding that entanglement is due to symmetry, shown in *same* first measurement outcomes fitting predictions. There is refutation of faster than light communication, as a measurement is a response to the provocation supplied by the apparatus, not a preexisting property that has come into being upon first partner measurement. An ontological background for QM, relativity and perception is mentioned and reference made to the RICP explanatory framework. The Harry Beck London underground 'Tube' map is used in an argument that high predictive power does not necessarily equate to complete correspondence with underlying reality, only an aspect or some aspects of it.

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An examination of measurement:

'MIT 8.04 Quantum Physics I, Spring 2013 First lecture on Superposition' given by Allan Adams [1]: Allan Adams is asked by a student, using words to the effect: *How do we know that the measurement apparatus is giving a correct answer*? Allan Adams says something like: *How do you know my name is Allan? You ask; "what's your name" and I say "Allan" and so that's my name*. (The precise words used below.) Fair point, but use of the electron spin detector is more like asking; "How do you behave under these particular circumstances?": Allan is put into a box with a lion. Now he cannot run away, so there are two just two remaining lifesaving behaviors possible. Freeze, inhibiting the prey response of the lion. Or rage, intimidating the predator. On finding the result Allan can be categorized as a 'Freezer' or a 'Rager', neither of which are usual 'Allan-ness' properties. The Lion box is not simply a measurement device but a provocation device.

'Introduction to Superposition MIT 8.04 Quantum Physics I' [1] Quotes. Student questions: "How do you know the boxes work?" and later: "You can't (inaudible) you know which one is White." Allan Adams: "It's like how do you know my name is Allan? You say 'Allan' and I say 'What?' - right? But you're like 'that's not a test of whether I'm Allan'. But that's what it means to say the electron is White. It's like well 'what's the test?', 'What's your name?' 'I'm Allan'. 'Oh great that's your name'."

[Allan Adams is using White to represent one of the binary outputs of x axis spin detection] First quoting him and then considering putting him in a Lion box may seem a bit cruel to Allan. No disrespect is intended. He is a marvelous teacher. During his lecture simplifications are used to help understanding of the subject and it seems in some instances illustrate the current state of understanding of it within physics. Such as the way in which names are assigned (and then assumed to be properties) as shown in the quote, and mention that it really doesn't matter how a 'colour box' works (as he says in the referenced video, it could be a hyper-intelligent monkey inside, it doesn't matter). It isn't that physicists don't know the workings of the apparatus. They do and the precise way the apparatus functions is not needed to consider the outputs. Other mechanisms/means could hypothetically do the same. So the monkey suggestion is not wrong. Moreover, what is interesting and significant is that by dismissing how the apparatus functions there isn't philosophical consideration of what is happening when a particle interacts with the machine. Is it sorting pre-existent differences or creating them? That gets sidestepped but will be discussed here. It will be shown that experimental results are indicating that the provocation device is not a device measuring existing reality, an inherent property, but measure-er of the created response it provoked. A kind of untrustworthy reality interface. (Reality interface: An interface between the underlying (source) reality and perception. Imposing orientation and relative reference frame. It gives a limited fixed state output, that pertains to the information input from the environment. That information having been changed in type, or in some other way).

Evidence for provocation is given in the descriptions of experiments in 'Introduction to Superposition MIT 8.04 Quantum Physics I' [1] If y axis spin is produced then x axis spin is potentially lost. Fitting the evidence from experiments where x axis spin is tested first and then one output (let's say up) is y axis tested, and then x axis tested again. Former x axis spin 'supposed identity' has been lost by half of the particles undergoing the test (the spin measurement outcome has become 50:50 chance). But, if only half have changed, it would be necessary to explain why only half the particles lose their x axis spin; and why them in particular, rather than all being affected the same way? A better proposition is: If y axis spin is produced then x axis spin is probably lost, as the particles re-tested along the x axis behave as if they have never been previously tested in that way. This means spin isn't an identity or inherent property but a response to what a particle has 'experienced'. Therefore, the output of a provocation of one partner particle, not carried out on the other, cannot be used to know about the one not tested in that way. If the apparatus is a provocation device, like the Lion box mentioned previously, it isn't possible to know for example both x and y spin for one member of a pair of entangled particles; y from 'measurement' and x from knowing the spin of the entangled partner. The possibility of an x measurement does not come into existence until the necessary provocation is applied.

Investigating spins with Stern-Gerlach type apparatus: The response to a provocation not carried out does not exist. Each different test with the apparatus is a different provocation producing a new response and there is no correlation between the responses for each axis.

The above premise suggests that the Bell's inequalities argument is a red herring, as Bell's argument requires the assumption that all measurements are of pre-existing intrinsic properties. Also the explanatory framework providing the necessary ontology for dispelling the paradoxes or relativity and allowing QM and relativity to exist without contradiction is not the space-time continuum. The argument that the quantum experiment results must be pre-existent in the space-time continuum is incompatible with the necessary (as will be explained) alternative ontological framework. Description of the explanatory framework including the underlying ontology can be found at the end of this article.

“What Bell did- Tim Maudlin” (Video) [2] very clearly sets out the EPR argument for which Bell’s inequalities argument was developed. When Tim Maudlin is explaining the problem of spins near the end of the video (53:58) he says that the spins are measured either along the x or y axis. Then he says the expectations and goes on to say ‘U’s and ‘D’s must be assigned. Both x and y could be vertical and so up and down are possible descriptions for both; Importantly though, having the same designations for both orientations is inadequate as they are not the same (responses) but perpendicular. If x axis spin is measured giving up and down results, y axis measurement should be some other designation differing from the names for the x spin axis outcomes; an indication that it is ‘perpendicular to’ *not ‘same as’* the x measurements.) ‘T’s and ‘B’s for the v axis measurements (for top and bottom) could be placed instead of ‘U’s and ‘D’s (up and down). The conclusion Tim Maudlin gives is that it must be mathematically impossible to do what he has described. But is that mathematically impossible thing actually correctly representing the measurements made? As shown, it can be argued that it is not. The mathematical representation is based upon some prior assumptions, including that the measurements are of pre-determined ‘elements of physical reality’ and that reality is ERP local (in keeping with Einstein’s space time continuum model). In the light of the preceding (and following) discussion the assumptions need to be reconsidered.

It was already known when Bell developed his inequalities argument that second measurements of a particle do not show the entanglement. Measurement along a different spin axis after first measurement negates the value of the first axis spin that was measured. As at repeat testing of the first the outcome is 50:50 and not 100% as it would be without the second different spin axis measurement in-between. There is no correlation between x axis spin and y axis spin.

If x and y are uncorrelated the y measurement of one of the particles shouldn't alter the x measurements of the other particles. The number of 'U's is only different, when the y values are also considered, if the y ups are considered as the same thing a x ups designated 'U'. They should be differentiated by calling the responses something different.

When a provocation is altered the meaning of the measurement outcome has to alter, even if without careful consideration of what is occurring, it may seem to be the same measurement outcome. E.g., Up and Down. The new responses cannot be the same as the previous ones. They are not correlated to the preceding responses, to different the provocations, either. When the orientation the magnetic field of the Stern-Gerlach device is altered so must the orientation of the response in space.

<u>Allan's bad day;</u> The second box could be another different provocation such as a Water box. Now the freeze / rage lion responses must be lost or Allan drowns. Now he can tread water or swim around the walls. Going from Lion box to another Lion box there is no change, as he is already exhibiting an appropriate and possible response. However, Lion box to Water box there is certainly and necessarily change and the new response has no correlation to the previous response, to the different provocation. The earlier lion response is lost. He can't be *frozen and* treading water or swimming, and he can't be raging uncontrolled while doing controlled swimming or treading water. Alluding to the idea that there can't be both x and y spin of the same particle at the same time. Putting him back into a Lion box, after a Water box, *a new choice of response must be made* as the former lion response was lost while in the Water box. So it appears just as if the first Lion box measurement was never conducted. Though clearly showing change is unavoidable when a provocation is altered and former responses are not retained as properties in those circumstances, it may not be a convincing analogy because of the different rather than similar kinds of provocation imagined.

Here is another analogy; the provocations are less severe, making up for the ill treatment of Allan with the Lion and Water boxes. <u>Allan's Invitations</u>: He is going to be invited to a number of social events. There are 3 different changing rooms, called X, Y and Z. In each room he will receive an invitation and must dress appropriately for the occasion. If he goes into X he will find an invitation to a formal dinner and the dress code. He has the choice of a dinner jacket and cravat or a smoking jacket and bow tie. He makes a choice. If after leaving he re-enters the same room X, or another room X, he does not have to choose how to dress because he is already wearing appropriate attire. Though if he goes into Y he will find an invitation to a causal house party. He is given the choice of track pants and hoodie or blue jeans and sweater. Now he will have to get changed because he can't attend in formal wear. Likewise, if he enters Z, where he gets an invitation to a pool party. Here he must choose between board shorts and multi-coloured beach towel or swimming trunks and plain bath towel. Any changing room of the same letter, entered directly after a room of that letter, will give the same outcome. However, for any different letter room for the following test there is an even chance of either outcome. A 50:50 result if a different letter retest is done many times. The analogy works with the assumption that Allan has no inherent preference for any particular clothing type. Because of that he can be imagined tossing a coin inside the changing rooms to choose.

To clearly demonstrate the change from certain outcome for same rooms, one after another, to probabilistic 50:50 outcomes, for rooms that are different (and when the same one is entered once again after a different one in between), it would be necessary to send many Allan clones through (or at least people similar enough to be considered as equivalent to an Allan). Another group can watch the outcomes from the sequence of changing rooms entered and marvel at the similarity of their apparel choices to electron spin measurement outcomes, for different orientations of measurement.

There are at several different kinds of interaction with elements of physical reality that are thought of as measurements or observations. Relevant to Question 1 posed in the FQXi blog: Physics of the Observer call for proposals and program launch, 1. "What does being an observer mean? …" [7]

1. With Measuring instruments: (that do not provoke responses) between what is unseen / unknown and what is seen or known. Using a device or measuring instrument that merely gives a limited fixed state output that pertains to the intrinsic state of the object at measurement. (Though may still cause the observer effect by disturbing what is observed in the act of measurement.) The information within the material reality is used to form a related intermediate output reality. That measurement can then be used to form knowledge about the object or be used in calculations. E.g. measurement of a position by direct contact with a sensor, or detector such as a screen, or photographic film.

2. With Reality interfaces: An interface between aspects of the underlying (source) reality and perception, that gives a limited fixed state output that pertains to the information input but is not that information. The information is changed in some way such as change of distribution by a lens and/or change of type such as digital output of a camera from photon information input) Organisms sensory systems that take information from the environment (could be thought of as sampling) and generate a related representation. A computer obtaining input from a sensor or sensors might also fall into that category. These measurements are of objective information but not the material sources of the information. An observer is able to comprehend the output of the receipt and processing of information. Observers and reality interfaces are going beyond mere measurement that

fixes (what might be varying values in the underlying reality) they are generating a new output reality from input information with definite differences from the source external reality. An example would be measurement of the frequency of received sound with an oscilloscope, that tells something about the source.

3.With Provocation devices: The instruments that provoke responses that can then be mistaken for pre-existing intrinsic properties.

The 3 categories have in common imposing of orientation and reference frame. That is the first step in going from an underlying reality without orientation or reference frame to a relative (output) reality. In no way can the 3 categories be considered equivalent and so ought to be differentiated with different names. The first kind is a Direct inquiry measurement (measurement of the property or characteristic of the object in question itself), the second is an Indirect inquiry measurement (measurement of information produced by the object in question, or produced because of an effect of the object in question upon something else rather than interaction with the object in question, allowing a property or characteristic to be deduced), and the third Provocation (measurement of an induced response not an inherent characteristic or property), as described in this paper.

There is a 4th kind of measurement / observation that can be considered here, 'Selection pressure': With devices that impose a (not pre-existent) 'selection pressure' upon a population when interaction with them occurs. The device causes a differentiation of a population and selection of a differentiated sub set from the population. This will be discussed further below.

There is an assumption in the mathematical puzzle regarding polarization, shown in the previously mentioned Tim Maudlin video [2], that the results of the challenges presented by the different polarizer orientations are all equivalent and can be added and subtracted. Giving something mathematically impossible like puzzle shown in table form in the video. Whereas each result might better be considered a unique subset produced by a different 'selection pressure' that is not correlated to other results. The photons that have passed through had certain characteristics upon meeting the polarizers and hence particular relations that were not the same as for those passing different relative orientation of polarizer challenges. The selection is not of a pre-existent property of the particle held by itself alone but is a *relation* between polarizers and particle that came to be only upon their meeting, a contextual co-incidence.

1. Polarizers aligned so all light passes: Photons will be called *Oranges*

2. Polarizers at 30-degrees to full alignment:

Photons that are stopped will be called *Red apples;* Photons that pass Green apples

3. Polarizers at 30-degrees and 60-degrees orientation:

Photons that are stopped will be called *Black bananas;* Photons that pass *Yellow bananas*

4. Polarizers at 0 and 60-degrees orientation:

Photons stopped will be called *Brown raisins*; Photons that pass *Green grapes*

The impossible sum is therefore:

Oranges – (Black bananas + red apples) = Green grapes

100%   25%   25%   25%

The above is a mathematically incorrect formula

It is incorrect to assume that those photons that were able to pass the 60-degrees difference in orientation of the polarizers were in all aspects of behavior, such as orientation of motion at the moment the relation with the polarizer occurred, identical to those that have passed the two different 30 degree differences; and that the 30-degrees difference results can be added to find the result for the 60-degrees difference in orientation measurement.

Brown raisins ≠ Black bananas + Red apples

75%   25%   25%

The 60-degrees difference challenge is different, providing a 'selection pressure' that is not present at the 30 degree challenges, providing their own selection pressures.

Tim Maudlin concludes in the video [2] (2014), after this puzzle has been discussed, "If the predictions of quantum formalism are accurate then the physical world itself cannot be ERP local." In his paper "What Bell Did" he says that more fully: "What Bell's theorem, together with the experimental results, proves to be impossible (subject to a few caveats we will attend to) is not determinism or hidden variables or realism but locality, in a perfectly clear sense. What Bell proved, and what theoretical physics has not yet properly absorbed, is that the physical world itself is non-local" [3] Tim Maudlin (2014). This paper shows that that is not necessarily so.

In the EPR argument it is assumed that the measurements are predetermined and the same kind, and so they can be added and subtracted, and assumptions can be made about the unmeasured on the basis of their presumed pre measurement existence. Here that assumption is called into question by means of the analogies given and discussion of the puzzles presented by Tim Maudlin, using the insight from those analogies. *It is important to stop thinking that it is always inherent properties, that are pre-existent elements of physical reality, that are being measured. Instead measurements can sometimes be regarded as the unique responses to particular challenges, provocations, or selection pressures as they happen*. Consequently 'spooky action at a distance' is found unlikely to be an actual physical phenomenon, as the evidence in favour of it has been called into question and found wanting.

Re. entanglement:

Particles A and B are prepared in such a way that they are anti-correlated. If that is regarded as a response to the preparation procedure it can then be thought of as persisting in the same way that a spin axis detection response is retained; so that a repeat testing produces the same outcome. If the anti-correlated pair undergo the same spin axis test they are undergoing the same provocation and the responses are anti-correlated as expected. It does not matter which same test. Anti-correlation can only be found if the test is the same. If instead A has an x axis spin test and B has a y axis spin test, the response has no relevance to the formerly anti-correlated partner. A does not have a y spin axis spin inherent property and nor has it been provoked into responding with y spin axis spin, B does not have x axis spin as an inherent property and has not been provoked into a x axis spin response. It has been shown that there is no correlation between the different kinds of spin axis spins, which seems to imply they are not inherent properties held concurrently. So having two different spin axis outcomes provides no extra information than two same spins. As the non-matched spins are only relevant to the particle tested in each particular way. To be clear: If the test is a provocation causing a response: Test of the first partner of an entangled pair does not immediately cause the anti-correlated state of the distant partner because a test has to be carried out on that partner too to provoke the anti-correlated response. So there isn't faster than light communication happening.

The 'connection between' the entangled particles is symmetry established at preparation and is a relation between the two particles rather than something that can be possessed by just one of the partners, or both individually without regard to the other. The symmetry requires both in a relation. It can be sustained over large spatial separations and shows up when same measurements are performed on the separated partners. Giving results that meet with expectation being either correlated or anti correlated according to how the particles were prepared. There is no need for each particle to carry a complete set of outcomes for every test that could be carried out so that the partners can co-ordinate their results. That just happens because of the symmetry, whichever same test. There is no faster than light communication. When a measurement is carried out on one, the result, from the same test (measurement), that will be obtained from the other can be known. Nevertheless, that result does not already exist, it hasn't come into being with the first measurement. Only when the second test is carried out on the partner does the expected measured state happen, as it is a response to the measurement. Different tests do not provide more information about the particles. If a test hasn't been carried out on a particle the (would be) result of that test has no relevance. It isn't a property of the particle and it is not a behaviour expressed because of the test (measurement) because the test hasn't happened. "Spooky action at a distance", as Einstein called it, isn't faster than light communication going on or hidden variables but responses to 'provocations', wrongly identified and treated as inherent properties.

Re. Ontology:

The 2013 conference on Quantum physics without observers is available as a series of YouTube videos. Watching the summary [4], the problem the participants have been wrestling with, namely lack of an ontology, a background in which QM fits with classical physics and experience is made strikingly clear. Richard Feynman [5] too puzzles over why QM works so well. He explains very well, that the mathematics works as a tool for getting the right answer and the procedures can be simply explained, like bean counting getting the same results as abstract arithmetic rules. He makes clear that in whatever way it is done it doesn't explain why it works. Putting how the mathematics is calculated into English leads to weird descriptions. Interestingly Tim Maudlin says, in regard to *his* conclusion of non-locality of the physical world. "Acceptance is just the beginning. The next question should be: how is this non-locality implemented in a precisely defined physical theory? The problem of "standard quantum mechanics" not being a precisely defined theory, not up to "professional standards" for mathematical physics (which Bell also eloquently lamented), immediately takes center stage." [3] Tim Maudlin 2014.

The lack of a realistic 'background' and the need for it counters dismissal of the RICP explanatory framework [8] on the grounds that it gives the same outcomes as relativity, and the explanations of why there are paradoxes of relativity that it provides are not the only possible ones- so "what is the use of it?" If the background is not un-involved it is possible to give explanations that do not require actual superposition or involve splitting worlds.

Consider here interaction of environmental vibrations emanating from atoms with the motion of a particle giving the impression of wave particle duality. Also interaction with the environment of a glass block as the relation of amplitudes at top and bottom surfaces is correlated with the relation of wavelength and the number of them that will fit the depth of the glass. Which does not require communication between photons at top and bottom surfaces to explain changes in amounts of reflection but only interaction of the photons with the dynamic environment. Full number of wavelengths depth maximizing reflection and a half number minimizing it. Re. the double slit experiment: Seeing that there is a wave phenomenon does not necessarily mean the wave motion is inherent to the particle by itself. An object is not isolated from the environment that surrounds it. It is reasonable to propose that it is the influence of the environment that causes the wave motion to be adopted. The particle is needed for the wave motion to be manifest (through the interference pattern) on the detector; built up even with single particles. The production of that pattern implying a wave has gone through both slits *could* be indicating that the waves are not an inherent property but an external influence.

Thought has been given to the possibility of conducting double slit experiments at extremely cold temperatures to minimizing vibrations. It might be difficult though, to make practical use of that environment, to demonstrate the effect of environmental influence. The idea for why there appears to be wave particle duality was put forward in the FQXi contest November 2010 - February 2011: Is Reality Digital or Analog? Entry called "What Is Reality in the Context of Physics?" by Georgina Parry [9]. The glass block behaviour /particle interaction is a related extension of that idea. That behaviour is not just the expression of intrinsic properties. Taking the idea that not all measurements are of intrinsic properties but some are actually provocation of a response (Considering the Stern Gerlach apparatus to 'measure' electron spin here), such measurements are not in the same category as measurements of pre-existing properties.

Both quantum physics (excluding Bohmian mechanics) and relativity do not take account of an underlying material reality, a reality consisting of Beables, (called Object reality in the RICP explanatory framework). They are both models that are formed from information. As relativity is generally understood the output from received electromagnetic radiation is taken to be the external reality. This has happened because of a category error. Measurements of seen images are muddled with measurements of material objects. The 'information' derived space-time universe is taken to be THE reality, while the beable universe is not considered. The category error is also the cause of the paradoxes associated with relativity [8]. QM produces very good predictions. Not sufficient to consider the ‘picture of quantum reality’ produced from descriptions of what is being done mathematically, to be complete reality. That mistake would be a bit like taking the Harry Beck London underground map to be complete reality for accurately predicting the order of stations and line exchanges only occurring at marked junctions. Even though the spatial journey of a passenger on the material train does not correspond to the spatial changes shown on the map. Harry Beck’s ‘Tube’ map [10].

The map is designed for ease of use of the network. The map represents some aspects of reality accurately; ordering of stations, and correctly indicated line junctions where passengers can switch lines. The spatial distribution of the network, that is its correspondence to spatial geography has though, been forfeited. It is spatially / geographically highly inaccurate in order to give simplicity of function, that is ease of use. The layout of the map has no doubt caused some traveler’s confusion in regard to actual distances travelled between marked stations. Research on this is published in a paper called ‘Mind the Map’: “Results show that the elasticity of the map distance is twice that of the travel time, which suggests that passengers often trust the tube map more than their own travel experience on deciding the “best” travel path. This is true even for the most experienced passengers using the system” [11] Zhan Guo, (2011). It can be used for easy navigation of the network but not for planning a journey outside of it, meaning the locations of the stations in relation to each other on the map do not correspond to the geographical distribution of the stations in material reality or on ordinance survey maps. The map is constructed from information about the network and conveys that information accurately, but it does not fully correspond to the reality that is its raison d’etre, the material ‘tube train’ rail network with a particular spatial distribution in material reality. The relevance to physics is this provides a refutation of the argument that a model with impressive predictive power must be accurately modeling reality because of that high predictive power. The map analogy shows that high predictive power can only be taken as an indication of some correspondence to reality not entire correspondence.

Bohmian mechanics is an attempt to incorporate beables, to make something more ‘realistic’, reconnecting with the material world and not relying only on structures formed from information. The well intentioned attempt to combine beables and the informational model creates a chimera of dubious nature. It may be prudent to keep them separate, taking care to acknowledge what they are and are not. The informational ‘domain’ can be populated by what is knowable (including appropriate mathematical manipulation of that) and what is known from measurements and outputs from received information. The beables domain consists of what is real but not directly knowable and is the source of what is knowable and known. The beables are the sources of information, the material apparatus and the observers. So the informational models; QM, relativity and perception absolutely require beables within the ontic background to also exist, appended to those models to make sense of them and complete them.

Summary:

An argument has been set out: that measurement in quantum experiments is not merely asking for an introduction i.e. asking for a pre-existent inherent property but is provoking a response, that is, a behaviour that is not there without the provocation. This is a departure from the idea of strict determinism of pre-existent properties of the measured particles.

With this approach entanglement can be reconsidered and it is found to be explicable as kinds of symmetry in the relation between particles. Symmetry that is detected in expected results when a first ‘test’ that is the same is performed. But cannot be used to assume outcomes of different tests not performed.

Several different kinds of measurement interactions have been differentiated: Direct, Indirect, Provocation and Selection pressure. Provocation and Selection pressure discussed with Quantum physics measurements and Bell's argument in mind.

The Harry Beck map analogy shows that high predictive power can only be taken as an indication of some correspondence to reality not entire correspondence. Worth bearing in mind in relation to QM and its impressive predictive power.

Does anyone want to argue that the Stern Gerlach apparatus is merely asking for an introduction and not provoking a novel response?

References / Resources:

[1] MIT 8.04 Quantum Physics I, Spring 2013 First lecture on Superposition presented by Allan Adams. Published on Jun 18, 2014 https://www.youtube.com/watch?v=lZ3bPUKo5zc

[2] Tim Maudlin - What Bell Did This talk was held during the "Summer School on the Foundations of Quantum Mechanics dedicated to John Bell" in Sesto, Italy (28.07.2014 - 30.07.2014). Published on Aug 4, 2014 https://www.youtube.com/watch?v=Vg5z_zeZP60

[3] Tim Maudlin, http://arxiv.org/ftp/arxiv/papers/1408/1408.1826.pdf, 2014

[4] Sheldon Goldstein - Retrospective and perspective in quantum theory without observers https://www.youtube.com/watch?v=jO81pBEac8E This is

a talk held at the conference "Quantum Theory without Observers III" (ZiF, Bielefeld, 22.04.26.04.2013). There are also interviews with several of the participants available. Published on Jun 25, 2013

[5] QED: Fits of Reflection and Transmission -- Quantum Behaviour -- Richard Feynman (2/4) Published on Mar 14, 2012

[6] The Sir Douglas Robb Lectures, University of Auckland, 1979Interview with David Bohm Uploaded on Dec 24, 2011 Interview with David Bohm at the Nils Bohr Institute in Copenhagen, 1989. Introduction shown below video on YouTube page "I would say that in my scientific and philosophical work, my main concern has been with understanding the nature of reality in general and of consciousness in particular as a coherent whole, which is never static or complete but which is an unending process of movement and unfoldment...." (David Bohm: Wholeness and the Implicate Order)

[7] Physics of the Observer call for proposals and program launch

[8] Georgina Woodward. Reality in the Context of Physics (RICP): An Explanatory Framework: Bridging the Pitfalls of Category Error, Dispelling Paradox and Excluding Magic from Physics 2016 viXra submission 1608.0049v1

[9] Entry called "What Is Reality in the Context of Physics?" by Georgina Parry. Is Reality Digital or Analog? FQXi.org contest November 2010 - February 2011:

[10] Harry Beck's Tube map - Transport for London. https://tfl.gov.uk/corporate/about-tfl/cultureand-heritage/art-and-design/harry-becks-tube-map

[11] Guo, Z. (2011). Mind the map! The impact of transit maps on path choice in public transit. Transportation Research Part A: Policy and Practice. Vol. 45, (7), pp. 625-639.

[11] Entry called “What Is Reality in the Context of Physics?” by Georgina Parry. Is Reality Digital or Analog? FQXi.org contest November 2010 - February 2011:

Further argument for explanatory framework including the ontological background is provided elsewhere, in other articles, diagrams and essays posted on the FQXi.org site and FQXi community online discussion)

The term ‘beable’ comes from “The theory of local beables” by J. S. Bell and Alain Aspect. Beables are those things that are ‘be-able’ rather than merely ‘know-able’. It includes; the sources of information, material apparatus and observers. It also includes things that are formed from configurations of beables such as the position of dials on the material apparatus. (This is discussed in the 1979 Interview with David Bohm [6]) So they are the actual constituents of the material world itself, rather than he constructs formed from information.

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