Logical Causality in Quantum Mechanics

Relational Realism and the Evolution of Ontology to Praxiology in the Philosophy of Nature

Workshop #2

June 26-27, 2009

Brussels, Belgium - Vrije Universiteit Brussel
Centrum voor Logica en Wetenschapsfilosofie
(Center for Logic and Philosophy of Science)

Participants include: Jean Paul Van Bendegem, Dean, Math Faculty, VUB; Director of CLWF

Paul Gochet, Emeritus Professor of Philosophy, University of Liège (http://en.wikipedia.org/wiki/Paul_Gochet)

Michael Epperson, Director of CPNS, Dept. of Philosophy, CSUS

Ronny Desmet, Senior Research Fellow, CLWF

Michel Weber, Director, Le Centre de Philosophie Pratique Chromatiques Whiteheadiennes, L'Université catholique de Louvain (http://fr.wikipedia.org/wiki/Michel_Weber)

Timothy Eastman, NASA-Goddard

Meeting overview:

This is the second in a series of focused workshops exploring the phenomenon of logical causality in quantum mechanics and the interpretation of this phenomenon within the framework of Whiteheadian metaphysics. We will be attending to a number of specific questions (listed below) derived from recent conversations among Ronny Desmet, Michel Weber, Gary Herstein, Michael Epperson, David Finkelstein, George Shields, and others.

Although the explorations undertaken at this workshop will fall within the general context of our "Logical Causality in Quantum Mechanics" research project (www.csus.edu/cpns/research.html), they will not be limited to the concerns of the latter; our goal, rather, is to gain new insights, via the expertise of the workshop's participants, into the questions with which our project is concerned. To that end, it will be helpful if participants familiarized themselves with the project and the questions it explores. An overview of the project can be read online via the link above.

Topics to be explored:

1. **Logical models in Quantum Mechanics**
(see the paper by David Finkelstein, "Quantum Systems Have No Models" attached).
Issues include, but are not limited to, the following:

• predicate and propositional logic in quantum mechanics

• non-commutative predication

2. **State reduction, probability valuation, and actualization of potentiality (Phase III of concrescence) best characterized via propositional logic?** (See correspondence between Epperson and Finkelstein, attached).

Issues include, but are not limited to, the following:

• 'and' conjunctions in the pure state become 'xor' conjunctions in the mixed state (PEM)

• first order predicate logic applicable to the pure state only (Phase I and II of concrescence) while propositional logic conditions state reduction and actualization (Phase III and IV of concrescence)

3. **Logical models in Whitehead's metaphysics: General Issues**

Issues include, but are not limited to, the following:

• predication as relational vs. merely adjectival (See Ronny Desmet remarks, attached)

• Question related to #2 above: 'Relations' are understood as 'facts in process of becoming' *internally related*, via prehension, to antecedent facts. Therefore the predicate logic by which Phase I of concrescence is understood is wholly dependent upon the propositional logic by which the antecedent facts were actualized/satisfied.

• What does it mean that logic is an a priori desideratum (i.e., not derivative) for Whitehead (PR, 3-7)?

> (Ronny Desmet to Michel Weber): "If you want to derive logic (to be defined) from some fundamental process principles, then we should avoid calling those principles logical principles, for else, logic is not derivative and contingent, but a priori and necessary. On the other hand, we should be clear that we cannot list any process principle without relying on the logic of our ways of listing, our ways of talking (in other words, we have to clearly distinguish the ontological and the methodological status of logic). E.g. when Whitehead says that a proposition need not be true or false, but interesting, luring, etc. (and hence, stresses the what you call 'shared relevance,' which violates the PEM), this is an ontological claim. E.g., when Whitehead demands consistency (and hence, adherence to the PNC), this is a methodological requirement.

4. **Logical models in Whitehead's metaphysics: Technical Issues**

• Logic in *Principia Mathematica*: Shifting from algebraic logic to mathematical logic

• Logic in Whiteheadian metaphysics and quantum mechanics requires classes and relations (cf. Topic #1 above and Finkelstein essay, attached)

• "Indication" Whitehead's "Indication, Classes, Numbers, Validation" *Mind*, New Series, Vol. 43, No. 171 (Jul., 1934), pp. 281-297 (Attached)

• (Ronny Desmet to Michel Weber): A logic that cannot accommodate the notions of "any" and "some," as well as classes and -- above all -- relations, cannot be a Whiteheadian logic. The key to my current understanding is contained in the first lecture of his CN. Let me give a relevant quote and add a kind of PR-translation in between brackets:

"Thought places before itself bare ... entities ... which the thinking clothes by expressing their mutual relations. Sense-awareness discloses fact with factors which are the entities for thought."

(Thought places before itself logical subjects which are clothed by patterns. Sense-awareness discloses the whole of nature with actual entities which become the logical subjects of indicative and higher-level feelings.)

The following 4 attachments were included in the email containing this overview:

Attachment 1: Paper by David Finkelstein, "Quantum Systems Have No Models"

Attachment 2: Whitehead's "Indication, Classes, Numbers, Validation"
Mind, Vol. 43, No. 171 (Jul., 1934), pp. 281-297
Also includes corrections printed in *Mind*, Vol. 43, No. 172 (Oct., 1934), p. 543
and review by Max Black, *Journal of Symbolic Logic*, Vol. 12, No. 4 (Dec., 1947), p. 144

Attachment 3: Paper by Michael Epperson, "Relational Realism: The Evolution of Ontology to Praxiology in the Philosophy of Nature"

Attachment 4: Paper by Michael Epperson, "Quantum Mechanics and Relational Realism: Logical Causality and Wave Function Collapse" *Process Studies*, Vol. 38, No. 1 (2009)

In addition, please see the following appendices, A-C:

Appendix A

From Ronny Desmet:

Dagobert D. Runes' Dictionary of Philosophy of 1942:

Logic, traditional: the name given to those parts and that method of treatment of formal logic which have come down substantially unchanged from classical and medieval times. Traditional logic emphasizes the analysis of propositions into subject and predicate and the associated classification into the four forms, A, E, I, O; and it is concerned chiefly with topics immediately related to these, including opposition, immediate inference, and the syllogism (see *logic, formal*). Associated with traditional logic are also the three so-called laws of thought -- the laws of *identity* (q. v.), *contradiction* (q. v.) -- and *excluded middle* (q. v.) -- and the doctrine that these laws are in a special sense fundamental presuppositions of reasoning, or even (by some) that all other principles of logic can be derived from them or are mere elaborations of them. *Induction* (q. v.) has been added in comparatively modern times (dating from Bacon's *Novum Organum*) to the subject matter of traditional logic. -- A. C.

A. Arnauld and others,
La Logique ou l'Art de Penser, better known as the Port-Royal Logic, 1st edn., Paris, 1662 ; reprinted, Paris, 1878; English translation by T. S. Baynes, 2nd edn., London, 1851.
F. Ueberweg,
System der Logik und Geschichte der logischen Lehren, 1st edn., Bonn, 1857; 4th edn., Bonn, 1874.
C. Prantl,
Gescbichte der Logik im Abendlande, 4 vols., Leipzig, 1855-1870; reprinted, Leipzig, 1927.
H. W. B. Joseph,
An Introduction to Logic, 2nd edn., Oxford, 1916.
F. Enriques,
Per la Storia della Logica, Bologna, 1922 ; English translation by J. Rosenthal, New York, 1929.
H. Scholz,
Geschichte der Logik, Berlin, 1931.

Appendix B

From Ronny Desmet (in conversation with Michel Weber):

Leibniz's Proof Method:

1. the law of identity

2. the law of non-contradiction (PNC)

3. the law of excluded middle (PEM)

4. and a law of salva veritate substitution

This scheme is the closest I could find, corresponding with your substance principles of ontology.

Whereas one can trace back 2. 3. and 4. to Aristotle, 1. is typically associated with Leibniz.

Jean Paul van Bendegem (in *Inleiding tot de moderne logica en wetenschapsfilosofie)* makes clear that whereas 2. and 3. belong to propositional logic, Leibniz's principium identitatis indiscernibilium can only be expressed in second or higher order predicate logic.

Now, my question was, whether we can (a) or should (b) look for a logical scheme corresponding with your process principles of ontology (society, contrast, shaded relevance).

. I think we should look at Whitehead's 1934 article "Indication, Classes, Numbers, Validation," because this is the only logic-related article published after PR

But should we look for a process logic? Maybe Whitehead's view is that logic is only at play at the level of our intellectual feelings with the subjective form of judgments, and that the logical principles only emerge at that higher level, and hence do not need to correspond with the fundamental process principles? Even in this case, however, the above mentioned 1934 article of Whitehead should be studied.

If one chooses the language of propositional logic, the four principles I highlighted in my earlier mail can be written as three axioms and one rule:

(A1) $p \equiv p$

(A2) $\sim(p \,\&\, \sim p)$

(A3) $p \vee \sim p$

(R1) $A(p) / A(p/B)$

(R1) says that when we have a proposition A which includes proposition p, then p can be replaced by an arbitrary proposition B.

If one chooses the algebraic logic of Boole, the three axioms, corresponding with your three principles of substance logic can be written as

(A1) x=x
(A2) x(1-x)=0
(A3) x + (1-x)=1

The problem is that this logic (A1, A2, A3, R1) is too weak to necessarily determine a classical propositional logic, and to guarantee, e.g., that the double negation of p entails p. So in order to have a sufficiently rich classical starting point, we should take e.g. the logic of Principia Mathematica instead of this weak logic consisting of only four principles. And then we should check, e.g., whether Whitehead's 1934 article defines a logic that is deviant from the logic of PM or not, and if so, where it deviates, and what its relation is to, e.g., an appropiate logic of QM.

Anyway, I agree with your view that for mesocosmic purposes, a classical logic will do, and Jean Paul will read Whitehead's 1934 article to help me with the question of whether or not the logic implied by this article goes beyond a classical logic. The latter question is what interests me most.

Regarding your question on how to conceive of the principle of non-contradiction (PNC), the principle of the excluded middle (PEM), and the principle of identity (PI) in the context of Principia Mathematica (PM), the following is a rough sketch of an appropriate answer:

In PM Whitehead and Russell start with the notion of proposition, and three "primitive ideas" : assertion, negation, and disjunction. In terms of these, they define conjunction, implication, and equivalence. Then they list their "primitive propositions employed in the calculus of propositions," in other words, the axioms of their propositional logic:

(*1.1) Anything implied by a true proposition is true.
(*1.2) The principle of tautology.
(*1.3) The principle of addition.
(*1.4) The principle of permutation.
(*1.5) The associative principle.
(*1.6) The principle of summation.
(*1.7) If p and q are propositions, then the negation and the disjunction are also propositions, etc.

As you will have notice, PNC, PEM, and PI are not yet mentioned. In fact, PNC and PEM are both simple propositions in Whitehead and Russell's propositional logic (resp. *3.24 and *2.11).

On the other hand, in order to discuss PI, they first introduce the notion of propositional functions, additional primitive ideas (such as universal and existential quantification), etc. So, only at the level of their (second order) predicate logic (not at the level of their propositional logic) Whitehead and Russell discuss "identity." In fact, it is a definition:
(*13.01) x and y are to be called identical when every predicative function satisfied by x is also satisfied by y
Notice that Leibniz' law of identity then follows as a proposition:
(*13.101) x and y are identical when any property of x is a property of y

Of course, the interest of PM for philosophers and mathematicians goes beyond this above reconstruction of PNC, PEM, and PI. In fact, for philosophers (and for Whitehead in particular) the key point is that predication is not only about adjectives, but also about relations; and for mathematicians, that the approach is sufficiently rich to define classes, membership, relations, and ultimately, to

encompass all of mathematics (cf. logicism), while prohibiting the occurence of paradoxes (cf. the theory of types).

That Whitehead often opposes the Aristotelian logic and the logic of relations means that he opposes the view that predication is only adjectival, and not relational. Understanding this is key to understanding Whitehead in general. E.g., the difference between adjectival and relational predication can be linked to his early distinction between cognisance by adjective and cognition by relatedness. E.g. Whitehead's remark that physical properties such as charge and mass are true Aristotelian properties, can only be understood if one is clear that they are adjectival, and not relational, properties. E.g. Whitehead's definition in PR of propositional feelings as the merger of indicative feelings and predicative feelings, and hence of the proposition as the merger of logical subject and predicative pattern, might be misunderstood as a regress to the notion of a narrow subject-predicate logic, unless one understands that predicative also means relational!!!

Even though it remains to be seen in what respect Whitehead's 1934 article deviates from PM, I have the feeling that we do not need a non-PM logic in the context of Whitehead's philosophy, and only have to make clear what the ontological status of the PM logic is.

Meanwhile I have been browsing both Book II of Whitehead's *Universal Algebra* (as it deals with Boole's algebra of symbolic logic), and Whitehead's 1934 article (in search for a non-PM logic).

All this is very interesting, but it does not add to our discussion. Book II comes closest to the laws of thought in Chapters IV (application to logic) and V (propositional interpretation), without however singling out the three laws you list. The 1934 article deviates from PM without becoming non-cassical, e.g., in trying to base "arithmetic upon constructions which are purely logical, abstracted from the notion ... of types," and by keeping "the notion of truth value ... in the background."

In fact, I also read Quine's contribution on "Whitehead and Modern Logic" in the Schilpp volume on Whitehead, and if I were to integrate what I learned from browsing, UA, PM, and the 1934 article, and if I were a lot smarter than I actually am, then Quine's text would result. Of course, Quine does not go far enough, for he does not delve into what interests me most, the philosophical links. So, e.g., when he writes about the 1934 article that it "is costly, for it turns essentially on the use of statements in non-truth-functional contexts," then I wonder: "what was the philosophical benefit (next to a partial abstraction from the notion of types) justifying that cost?"

Appendix C:

From conversation among Michael Epperson, David Finkelstein, Gary Herstein, and George Shields, in reference to David's paper, "Quantum Systems Have No Models." attached.

From: Gary L. Herstein [mailto:gherstein@netzero.net]
Sent: Sunday, May 24, 2009 4:12 PM
To: david.finkelstein@physics.gatech.edu
Cc: epperson@csus.edu; Kallfelz@cwu.EDU; george.shields@kysu.edu; hpstapp@lbl.gov; mshirigarakani@pace.edu; plasmas@starpower.net; jorge.nobo@washburn.edu

With reference to David's essay, I confess that right from the start I found the phrasing of the initial paragraph a bit off. In standard logical parlance, it is not the *predicates* that commute around conjunction, but *entire sentences* since it is *only* at the level of sentences that orthodox logical conjunction operates.

However, standard logic does not deal with all the different kinds of conjunction that are out there, nor need one travel into the arcana of QM to discover these "peculiarities" which really aren't all that peculiar. There are at least three independent kinds of conjunction: of sentences, of subjects and of predicates. Standard logic only recognizes the first, but linguistics is aware of the other two. Thus, when Donald Davidson attempted to reduce "Jack and Jill went up the hill" to "Jack went up the hill *AND* Jill went up the hill", he erroneously conflated sentential conjunction with subject conjunction. Davidson's analysis is false because it loses the essential fact that Jack and Jill went up the hill *together*. Subjects in this form of conjunction still appear to commute, since the nature of their conjunction is precisely one that takes no account of order, only of togetherness.

Predicate conjunction is different. "Susan got married and had a baby" says one thing that is quite different from "Susan had a baby and got married." Predicate conjunction does not merely say "and", it asserts "*and then*;" as such, the order is irreducibly a part of the meaning. But it is also less clearly conjunction *simpliciter* as much as a kind of operator application.

In the realms of mathematics and physics it is unclear to me what it means to speak of the "conjunction of predicates," their commutation or their lack thereof. I'm sorry, but, "The predicates of mathematical objects commute, of course" (first page, first paragraph) makes no sense to me, and seems to be conflating a number of ideas that probably need to be kept separate. This seems to be an example of the application of operators, and such application carries no necessity (logical, mathematical or otherwise) of commutativity. Non-commutative operators are hardly rare in mathematics, and to suggest that they have no model is certainly not correct. For instance, this would appear to imply that non-abelian groups have no models, which is demonstrably false.

Even within predicate logic, unless one is dealing with absolutely uniform types then the order of application becomes an essential component of whether or not one is even making a meaningful sentence, much less a true one. If "Q" is a predicate of sentences, "P" a predicate of objects, and "a" an object, then Q(P(a)) is meaningful, but P(Q(a)) is not. Even when one is dealing with predicates of a common type, commutativity is hardly guaranteed. Such predicates can be viewed as elements of a non-abelian group operating on an underlying set of objects (assuming the predicates pick out objects in the underlying set when they operate on such objects). Once again, one can readily find situations where PQ(a) <> QP(a). The "and then" order preserving form of operator application seems much closer to this than to that of sentential conjunction.

WRT "ontic" vs. "ontological" I would encourage caution with "ontic". This is a term that is loaded with connotations from Heideggerian phenomenology. Unless you are intimately familiar with such usages, I would avoid them assiduously. Even if it is galactically improbable that you'll ever find yourself in dialog with a Heideggerian, I think it is genuinely worthwhile to avoid any gratuitous misunderstandings.

Along similar lines, I find "praxic" the better term, since it is the adjectival form of "praxis." "Praxiology," as David notes, carries an awful lot of additional connotative weight which it seems to me is unlikely to do more than confuse.

Gary L. Herstein
http://www.brightfuse.com/gary-herstein

From: Michael Epperson [mailto:epperson@csus.edu]
Sent: Sunday, May 24, 2009 6:33 PM
To: 'Gary L. Herstein'; 'david.finkelstein@physics.gatech.edu'
Cc: 'Kallfelz@cwu.EDU'; 'george.shields@kysu.edu'; 'hpstapp@lbl.gov'; 'mshirigarakani@pace.edu'; 'plasmas@starpower.net'; 'jorge.nobo@washburn.edu'

Dear Gary,

Thanks very much for your comments on David's article. On my reading, it was implied that we're talking about propositional logic and not predicate logic, simply because that is the nature of QM. Every eigenstate is always part of the wavefunction, so in logical terms, the 'conclusions' (outcome state specification and its truth value) are always 'contained' within the 'premises,' and therefore the logic we're chiefly concerned with re: the problems of measurement and state reduction, etc, is necessarily *sentential/propositional*, not predicate logic. In a spin ½ system, e.g.:

1. Either the electron is spin up or the electron is spin down
2. The electron is not spin up

---

3. The electron is spin down

So when David speaks of predicates, for me, it was always within this context and not within the context of predicate logic as a category. That is, when he writes, "The predicates of mathematical objects commute, of course" I read that in the context of mathematical objects *as representative of features of physical systems*. Classical mechanics allows for the simultaneous observation of physical quantities, therefore their operators must commute. That is the context in which I read the quoted sentence. For example, slice a quarter in half through its edge, splitting into the heads face and the tails face. Seal each face in an envelope and put them at opposite ends of a room—Station A and B. Open one envelope and you have the state of the 'entire' quarter-system, thanks to commutativity. It doesn't matter which is opened first.

But in a QM version of that scenario, say an EPR experiment testing a spin ½ system, PSI is not merely State A + State B as it was in the classical example. The composite system A + B does not allow commutativity of operators, and entanglement (even non-local) is understood to be a physical exemplification of the otherwise purely mathematical/conceptual qualification of non-commutativity, and whatever logical order undergirds that qualification.

So if taken within the context of commutativity in classical vs. quantum mechanics (which I think is simply a tacit stipulation in the paper), I don't think the problems you raise re: predicate vs. propositional logic are really so bad as to make the quoted sentence *nonsensical* as you evaluated it. But I think you're right that erring on the side of caution is always best, and it might be better to stipulate as little as possible in these papers (I think it lead to the same kind of problem William had with my paper.) Perhaps some preliminary discussion of propositional vs. predicate logic as applied to QM would be useful as a precaution. And in that regard, I think your note on the use of 'ontic' is right on target since it is a banner term in Heidegger.

Re: 'praxic', 'praxis,' and 'praxiology' I'm not as concerned because the use of 'praxis' as shorthand for 'human praxis' pertains to a very restricted sphere of philosophical ethics and psychology—clearly not what we're doing. Furthermore, I look at our usage as a novel rehabilitation of the original introduction of the term 'praxiology' to philosophy, which was from Louis Bourdeau in application to the science of functions in nature, NOT von Mises and his application of the term to economics, sociology, etc. Bourdeau did some really interesting work there that has gone largely unnoticed, and whose rehabilitation in modern physics might be quite interesting to many scholars.

From: Gary L. Herstein [mailto:gherstein@netzero.net]
Sent: Friday, May 29, 2009 7:34 PM
To: epperson@csus.edu
Cc: david.finkelstein@physics.gatech.edu; Kallfelz@cwu.EDU; george.shields@kysu.edu; hpstapp@lbl.gov; mshirigarakani@pace.edu; plasmas@starpower.net; jorge.nobo@washburn.edu; wkallfelz@gmail.com

One statement of Michael's that still has me a bit puzzled (and I throw this out now so that I can spend the next few days landing somewhere else): "On my reading, it was implied that we're talking about propositional logic and not predicate logic, simply because that is the nature of QM."

If that were the case, then any discussion of predicates would be entirely inappropriate. The minimally robust universe of discourse in which predicates can even be mentioned is the meta-theory of First Order Predicate Logic (FOPL). If that (or something even "thicker") is not the universe of discourse we are operating in, then any discussion of predicates is out of order. If we are in propositional logic, then propositions are what we are working with. I really don't see any way around this.

Your own discussion moves from "predicates" to "operators." This may or may not be significant. But forming models of non-commutating mathematical operators poses no substantive difficulty. If these are the same as the predicates that David is dicussing, then his claim that they do not commute runs up against the same problems (at least as far as I can understand the claims) I previously noted.

Maybe I shouldn't be posting this when I am tired and frantic, but I did not want to wait too much longer to float this set of concerns. Thanks!

Gary L. Herstein
http://www.brightfuse.com/gary-herstein

From: Michael Epperson [mailto:epperson@csus.edu]
Sent: Friday, May 29, 2009 9:53 PM
To: 'Gary L. Herstein'
Cc: 'david.finkelstein@physics.gatech.edu'; 'Kallfelz@cwu.EDU'; 'george.shields@kysu.edu'; 'hpstapp@lbl.gov';

'mshirigarakani@pace.edu'; 'plasmas@starpower.net'; 'jorge.nobo@washburn.edu'; 'wkallfelz@gmail.com'

Hi Gary,

"One statement of Michael's that still has me a bit puzzled (and I throw this out now so that I can spend the next few days landing somewhere else): "On my reading, it was implied that we're talking about propositional logic and not predicate logic, simply because that is the nature of QM."

If that were the case, then any discussion of predicates would be entirely inappropriate."

My point was that all the predication and quantification in the pure state—all the non-commuting 'and' statements –BECOME propositional 'or' statements in the mixed state, by virtue of the fact that the probability valuations sum to unity. The reduction of all the 'and' statements to 'or' statements—i.e., the problem of state reduction--is, for me, the signature issue re: the function of logic in QM, not the fact of predication and quantification in the pure state.

Here's how I understand the non-commutative predication in the pure state: System A and System B are associated with vector spaces *V*^a and *V*^b, and the composite system A + B is associated with the tensor product space *V*^a ⊗ *V*^b. If u _1 and u_2 are non-null vectors in V^a, and v_1 and v_2 are non-null vectors in V^b, then you CANNOT say that the state of A + B can be specified simply by adding the states of A and B separately. This is because u_1 and u_2 are orthogonal, as are v1 and v2, and PSI is a vector of unit length, where

PSI = 1/sqrt2 (u_1 ⊗ v_1) + (u_2 ⊗ v_2)

Thus you cannot characterize State A 'by itself' and State B 'by itself' when A + B are in the state PSI. That kind of predication doesn't work in PSI, because neither A nor B is in a definite state in PSI. However, both (u_1 ⊗ v_1) and (u_2 ⊗ v_2) are individually completely sensible. But they are each unrelated to the other in the sense that each is a quantification **over a unique domain of discourse**. (Each term can be thought of as an alternative history of the 2 systems, or if you like the Everett model, parallel co-actual universes). FOL / predicate logic (at least as I understand it) applies only to individuals within a given domain of discourse, not across diverse domains.

And indeed, when PSI is reduced, the 'and' becomes an 'or' because of the probability amplitudes qualifying (u_1 ⊗ v_1) and (u_2 ⊗ v_2); PEM (via the orthogonality of the vectors u_1 and u_2 in V^a, and v_1 and v_2 in V^b) combined with the probability amplitudes guarantees that one of the terms will be actualized. So in that sense, it is propositional logic that best characterizes the heart of QM—the actualization of potentia--at least for me. The fact that superposition and entanglement evince non-commutativity in the pure state is definitely central to the phenomena of superposition and entanglement; but these alone do not define QM—and indeed, neither phenomenon has any significance whatsoever apart from the BIG problem of state reduction and the propositional logic by which it is described. QM is more about 'either or' than it is 'both and', I would argue, because every QM evolution is always borne of an antecedent 'either or' proposition, and always ends in one.

"The minimally robust universe of discourse in which predicates can even be mentioned is the meta-theory of First Order Predicate Logic (FOPL). If that (or something even "thicker") is not the universe of discourse we are operating in, then any discussion of predicates is out of order. If we are in propositional logic, then propositions are what we are working with. I really don't see any way around this."

I guess what I'm saying is that while non-commutativity and predicate logic can be sensibly used to describe superposition and entanglement, state reduction is best described in the language of propositional logic. Though one can sensibly apply FOL / predicate logic within alternative domains of discourse in the pure state (alternative histories / alternative equivalence classes / alternative universes, etc), it is difficult to see how it could apply *across* alternative domains/histories/universes in the mixed state.

Anyway, yours and David's expertise in predicate calculus, etc, far exceeds mine, so please keep that in mind. But I hope what I am *trying* to say in the above is clear, (even if incorrect!)

Thanks again for your correspondence and contributions. They are MUCH appreciated!

Best,

Mike

From: Michael Epperson [mailto:epperson@csus.edu]
Sent: Saturday, May 30, 2009 3:19 AM
To: 'Gary L. Herstein'
Cc: 'david.finkelstein@physics.gatech.edu'; 'Kallfelz@cwu.EDU'; 'george.shields@kysu.edu'; 'hpstapp@lbl.gov'; 'mshirigarakani@pace.edu'; 'plasmas@starpower.net'; 'jorge.nobo@washburn.edu'; 'wkallfelz@gmail.com'

Just a couple more thoughts before I hit the sack:

Re: the whole predicate vs. propositional logic issue, the point of my last email is that each applies to different aspects of a QM measurement interaction. But if the issue is, "how do we fundamentally characterize 'quantum logic'" it seems to me re: our discussion so far, there have been 2 general approaches based upon the work done so far, from Birkhoff/von Neumann to the present day (and by 'general' I mean to the extent that *I* am able to discern the details—an extent that is admittedly not great):

a) as some kind of non-commutative MV logic where PEM isn't necessarily satisfied; or

b) as some kind of quasi-classical propositional logic where PEM is always satisfied, but the distributive law isn't (per the uncertainty relations).

As to the former, I can't comment since I don't really comprehend the ways in which MV or fuzzy logic might apply to QM in a useful way. I just don't know how to understand QM with truth values greater than 2. And if one can formulate a quantum logic as modified classical propositional logic, you don't need more than 2 truth values. All you need is PEM (the presupposition of which is no less reasonable than the presuppositions of MV logic) and the understanding that certain AND statements are actually XOR statements. Certain classically understood logical conjunctions are actually quantum

logical disjunctions / 'exclusive or' statements. You gave a few examples of this in your first email. Here's another one--in lieu of 'position' and 'momentum' which isn't as interesting as:

'I want the chocolate and vanilla ice cream.'

Classical logic: Depending upon the predication, there are 2 different possible logical conjunctions there. 'I want the ice cream that is both chocolate and vanilla' and 'I want the chocolate ice cream and the vanilla ice cream.'

Modified propositional quantum logic with PEM presupposed: There is no 'actualized' ice cream that is both chocolate and vanilla. It's not enough to say 'The choices are chocolate and vanilla'; one must say the *alternatives* are chocolate and vanilla. Chocolate and vanilla is really Chocolate XOR vanilla. In terms of potentia vs. probability as discussed in my last email, the potentia constitutive of the pure state may indeed be chocolate and vanilla in superposition; but the probabilities constitutive of the mixed state are chocolate or vanilla.

I know that quantum logic derived from propositional logic has been explored rigorously over the years, and I know one of the supposed deficiencies compared to MV approaches was that it didn't adequately apply to open systems—no one-way temporal arrow for irreversible processes. But Griffiths' consistent histories approach has solved that problem as I understand it. I'm certain there are other inadequacies in the modified propositional logic approach that I am not aware of. I'm re-reading Putnam's 'Is Logic Empirical?' and some things by Omnes. Trying to get a grip…

--Mike

From: david.finkelstein@physics.gatech.edu [mailto:david.finkelstein@physics.gatech.edu]
Sent: Saturday, May 30, 2009 10:11 AM
To: Gary L. Herstein
Cc: Kallfelz@cwu.EDU; george shields; hpstapp@lbl.gov; mshirigarakani@pace.edu; plasmas@starpower.net; jorge nobo; wkallfelz@gmail.com; epperson@csus.edu

About propositions. Maybe terminology changed since 1935 but I think Birkhoff-von Neumann simply nodded.

As I recall, propositions are definitely true or false, though we may not know which, while predicates are true or false depending on the individual to which they are applied. Predicates are proposition-valued functions of a random variable, sometimes called propositional functions. "The sky is blue" is a proposition, assuming it refers to the moment and place of its utterance; "is blue" is a predicate waiting for its argument.

A photon polarization filter passes some photons and block others. So it determines a predicate about the generic photon, not a proposition. If you plug a photon in, the result is a proposition.

Correspondingly a projector representing the filter obeys PP=P and has both eigenvalues 0 and 1. The only exceptions are the trivial operators 0 and 1, which indeed represent the False and the True proposition.

Do these things need to be spelled out in the paper? Or are they wrong and need to be corrected? Or are they not even wrong?

Regards,

David

From: Michael Epperson [mailto:epperson@csus.edu]
Sent: Sat 5/30/2009 14:42
To: david.finkelstein@physics.gatech.edu; 'Gary L. Herstein'
Cc: Kallfelz@cwu.EDU; Shields, George; hpstapp@lbl.gov; mshirigarakani@pace.edu; plasmas@starpower.net; 'jorge nobo'; wkallfelz@gmail.com
Subject: RE: Epperrson, Stapp, and the status of my contributions (to the Fetze r-Franklin Group)

Hi David,

"As I recall, propositions are definitely true or false, though we may not know which, while predicates are true or false depending on the individual to which they are applied... A photon polarization filter passes some photons and block others. So it determines a predicate about the generic photon, not a proposition. If you plug a photon in, the result is a proposition."

I guess the point of my last 2 emails was that QM doesn't seem to coherently accommodate the idea of "determining a predicate about the 'generic' anything." In the case of the photon and polarizer, the classical idea of the photon being an enduring object—an 'individual' whose physical qualifications/predicates are 'changed by' the filter causes all the infamous conceptual difficulties of QM. The Whiteheadian / consistent histories view would be that the photon before the filter is *not* the 'same photon' after the filter, only now with new predication. This is because the actual occasions (facts) constitutive of the photon-society prior to relations with the polarizer are not the same facts subsequent to (and consequent of) those relations. The interaction produces alternative histories, not alternative qualifications of the same history. Therefore there is no 'generic' domain of discourse for the predicate logic; there are alternative domains, which is problematic for simple T/F predication. It is not a problem for propositional logic, though.

Quoting from my previous email, re: PSI = 1/sqrt2 (u_1 $\otimes$ v_1) + (u_2 $\otimes$ v_2) for System A and System B, associated with vector spaces *V*^a and *V*^b:

"both (u_1 $\otimes$ v_1) and (u_2 $\otimes$ v_2) are individually completely sensible as *propositions*. But as predications of some 'generic individual' they are each unrelated to the other in the sense that each is a quantification over a unique domain of discourse. (Each term can be thought of as an alternative history of the 2 systems, or if you like the Everett model, parallel co-actual universes). FOL / predicate logic (at least as I understand it) applies only to individuals within a given domain of discourse, not across diverse domains.

And indeed, when PSI is reduced, the 'and' becomes an 'xor' because of the probability amplitudes

qualifying (u_1 $\otimes$ v_1) and (u_2 $\otimes$ v_2); PEM (via the orthogonality of the vectors u_1 and u_2 in *V*^a, and v_1 and v_2 in *V*^b) combined with the probability amplitudes amounts to a presupposition that one of the terms will be actualized. So in that sense, it is propositional logic that best characterizes the heart of QM—the actualization of potentia--at least for me."

When you write "A photon polarization filter passes some photons and block others. So it determines a predicate about the generic photon, not a proposition. If you plug a photon in, the result is a

proposition" I like the first and third sentences taken together. I don't know why you need the second sentence. (By that, I don't mean 'you don't need it'; I mean, literally, 'I don't know why'!) As always, I'm constantly struggling to try to understand these things, and am grateful for yours and William's and Gary's expertise.

Best,
Mike

From: Shields, George [mailto:george.shields@kysu.edu]
Sent: Monday, June 01, 2009 11:30 AM
To: epperson@csus.edu; david.finkelstein@physics.gatech.edu; Gary L. Herstein
Cc: Kallfelz@cwu.EDU; hpstapp@lbl.gov; mshirigarakani@pace.edu; plasmas@starpower.net; jorge nobo; wkallfelz@gmail.com

Mike, David, Gary et al:

I have taken several weeks off after the academic term in order to spend time with family and do house improvement things, so I have not been responsive. I am now back on-line. I find the recent e-mail discussions on logic and QM to be extremely interesting, and I have a couple of quick comments.

1. Mike's statement -- "The Whiteheadian / consistent histories view would be that the photon before the filter is *not* the 'same photon' after the filter, only now with new predication. This is because the actual occasions (facts) constitutive of the photon-society prior to relations with the polarizer are not the same facts subsequent to (and consequent of) those relations."

I think this is an important and well-stated point about how Whiteheadian thinking can be helpful and relevant to our understanding of quantum phenomena. In a different context, note how this way of thinking causes Young's two-slit photon experiment to become re-conteuxtualized and far less paradoxical; indeed, just what Mike is suggesting is applied by Robert Valenza and Granville Henry to Young's two-slit problem in their interesting article entitled, "The Preprojective and Postprojective" published in *Process Studies 2*6 (Spring-Summer 1997) -- which I refereed for PS. By contrast to Whiteheadian occasions, substance ontologies which view photons as self-identical substantial entities persisting over the time of the experiment are completely perplexing when applied to two-slit phenomena as they imply what exactly? -- the photon approaching the slit is subsequently "split in two," or somehow two substantial photons suddenly appear where previously there was one substance? The theoretical capacity of Whitehead's approach here is surely an argument in its favor, and one not enough noticed in philosophy of science circles (in my view).

2. Mike's assertion that simple T/F predication in not a problem for propositional logic has, of course, been challenged by discussions within the topic of "naval logic" -- referring to Aristotle's question of a future sea battle and related questions about T/F bivalence in application to propostions which are future tensed (see *De Interpretatione* 9 and 12). Even here, however, I think it correct to say that many-valued logics are unnecessary and the principle of bivalence prevails -- in the final analysis, there are no genuine counter-examples to it in the domain of propositional logic. To show this, in my opinion, is Hartshorne's great achievement in his important *Mind* essay entitled, "The Meaning of 'Is going to be'." Arguments for logico-fatalism such as the Master Argument of Diodorus Chronus (a Stoic logician) create a problem for anyone who wants to hold that the future is always (at least partly) open, as do Whiteheadians, since they argue that the future must always be closed on pain of giving up PEM. On the other hand, some logicians such as Lukaiseiwicz have suggested that the solution to

Aristotle's sea battle problem resides in positing an I-value (I= indefinite as regards truth or falsity) along with T and F, so that we get three-valued truth-tableaux with I-values attaching to any tableaux constructed for future tensed propositions. So, the situation has appeared to a number of philosophers that we should either embrace fatalism or give up bivalence or PEM with respect to propositional logic. Hartshorne shows a way out of this dilemma. As he argues, the Taylor-Montague argument for logico-fatalism that "X will occur" is *contradicted* by "X will not occur," and thus the "future" with respect to any arbitrary event X is definitely one way or another no matter what one's temporal standpoint or state of knowledge, collapses once it is noticed that these propositions are not true contradictories: "X will occur" is the logical *contrary*, not the *contradictory* of, "X will not occur," since its genuine contradictory is in fact "X *may not* occur." The future is propositionally triadic: either X will occur, will not occur, or may-or-may-not occur (and it is question begging for the last alternative not to be admitted as content for a proposition, since formal logic should itself be neutral to metaphysical considerations, a fortiori if formal logical considerations are being employed to *decide* a metaphysical questions). Such propositions ("X will occur," "X will not occur," "X may occur," and "X may not occur") can be arranged in a kind of modalized square of opposition that is isomorphic with the standard non-modalized square with the result that each proposition is either T or F. If this is correct, then, Mike's assertion about propositional logic is correct, at least in so far as objections from naval logicians are concerned.

The discussion here is extremely terse and condensed and the issues involved with naval logic are much more complicated than what I have indicated, but this is the essential gist of the argument. For more on this topic, including consideration of many other objections and concerns, see my essay "The Logic of Future Contingents," co-authored with Donald Viney, in my my book *Process and Analysis.*

Thanks,

George