Title: An Invitation into Eventum Mechanics of Quantum Information

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Abstract: Quantum states are not observables like in any wave mechanics but co-observables describing the reality as a possible knowledge about the statistics of all quantum events, like quantum jumps, quantum decays, quantum diffusions, quantum trajectories, etc.
However, as we show, the probabilistic interpretation of the traditional quantum mechanics is inconsistent with the probbilistic causality and leads to the infamous quantum measurement problem. Moreover, we prove that all attempts to solve this problem as suggested by Bohr are doomed in the traditional framework of the reversible interactions.

We explore the only possibility left to resolve the quantum causality problem while keeping the reversibility of Schroedinger mechanics. This is to break the time symmetry of the Heisenberg mechanics using the nonequivalence of the Schroedinger and Heisenberg quantum mechanics on nonsimple operator algebras in infinite dimensional Hilbert spaces. This is the main idea of Eventum Mechanics, which enhances the quantum world of the future by classical events of the past and constructs the reversible Schroedinger evolutions compatible with observable quantm trajectories by irreversible quantum to classicl interfaces in terms of the reversible unitary scatterings. It puts the idea of hidden variables upside down by declaring that what is visible (in the past by now) is not quantum but classical and what is visible (by now in the future) is quantum but not classical. More on the philosophy of Eventum Mechanics can be found in [1].

We demonstrate these ideas on the toy model of the nontrivial quantum - classical bit interface. The application of these ideas in the continuous time leads to derivation of the quantum stochastic master equations reviewed in [1] and of my research pages [3].
V. P. Belavkin: Quantum Causality, Stochastics, Trajectories and Information. Reports on Progress in Physics 65 (3): 353-420 (2002). quant-ph/0208087, PDF.
http://www.maths.nott.ac.uk/personal/vpb/vpb_research.html
http://www.maths.nott.ac.uk/personal/vpb/research/cau_idy.html

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Perimeter Institute, August 2010

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- Reconstruction of randomness and measurement.
- Quantum computation of emerging chaos.
- Quantum stochastics and eventum mechanics.
- Conclusion: Quantum hidden and visible variables.

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- In fact it is the only fundamental operational causal theory containing QM with a consistent probabilistic interpretation.

Quantum Mechanics

'The whole is more than the sum of its parts' - ARISTOTLE.

- The entropy on $\mathcal{A}$ decreases to zero by a standard extension $\mathcal{A} \vee \mathcal{A}' = \mathcal{B}(\mathcal{H})$ composing the quantum system $\mathcal{A}$ with its antipode (transposition) $\mathcal{A}'$.

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Quantum causality and interpretation

- *Quantum causality* requires all future quantum properties $\mathtt{Q} \in \mathcal{A}$ to be *predicates* in any state at a time t, i.e. to be *statistically predictable* with respect to every observable *event* $\mathtt{E} = \mathtt{E}^{\dagger}\mathtt{E}$ measured up to t.

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- Here $\mathtt{E}^{\perp} = \mathtt{I} - \mathtt{E}$ and $\mathsf{P}(\mathtt{Q}|\mathtt{E}) = \|\mathtt{QE}h\|^2 / \mathsf{P}(\mathtt{E})$ is *a posteriori* probability of $\mathtt{Q}$ w.r.t. $\mathtt{E}$. Unlike in the classical case, not every orthoprojector $\mathtt{Q}$ is a predicate with respect to a given $\mathtt{E} \in \mathcal{A}$.

- The classical-quantum interface is a function of the brain continuously increasing the entropy of the memory as a potential information from the quantum pure states.
- The wave packet "collapse" is simply the work of the consciousness postselecting the state of the classical memory due to awareness of the measurement data.
- In the state of a sleep the brain can spontaneously release the unconsciously stored past information not trigged by missing data, producing our dreams.
- The posterior dynamics is described by stochastic quantum state jumps and diffusions driven by the short and white noise as innovation processes in the brain memory.
- The stochastic Master equations of EM were derived in full generality on the QS model in the product Fock-Hilbert space by QSC method in 1980 – 1988.
- It dismisses the EPR paradox by explaining it as a the decoherence of atom (as invisible microworld) resulting from interacting with a 'cat' (as a visible macroworld) during the observation.

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- Thus, the deterministic interpretation is incompatible with the data, but the probabilistic one is causally inconsistent: No *system property* $\mathtt{Q} \in \mathcal{A}$ except the trivial one $\mathtt{Q} = \mathtt{I}$ can be tested without *demoliting*.

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Quantum nondemolitiong observation

- Consider as a model a free quantum particle of unit mass $[\mathrm{q}, \mathrm{p}] = \mathrm{i}\hbar\mathrm{I}$:

$$\mathrm{X}(t) = \mathrm{q} + \mathrm{p}t, \quad \mathrm{P}(t) = \mathrm{p}.$$

$\mathrm{X}(t)$ is unobservable since $[\mathrm{X}(r), \mathrm{X}(t)] = \mathrm{i}\hbar t\mathrm{I} \neq 0$.

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- However $\mathrm{Y}(t) = \mathrm{X}(t) + \mathrm{e}(t)$ is observable up to an idependent error $\mathrm{e}(t)$ if the the dynamics is perturbed as

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{X}(t) = \mathrm{P}(t), \quad \frac{\mathrm{d}}{\mathrm{d}t}\mathrm{P}(t) = \mathrm{f}(t)$$

  by an independent 'Langevin' force $\mathrm{f}(t)$ satisfyng the error-perturbation CCR

$$[\mathrm{e}(r), \mathrm{f}(t)] = \hbar\mathrm{i}\mathrm{I}\delta(r, t) \quad \forall r, t.$$

- Moreover, $\mathrm{Y}(t)$ is *causally nondemolition process* in the sense that

$$[\mathrm{Y}(r), \mathrm{X}(t)] = 0, \quad [\mathrm{Y}(r), \mathrm{P}(t)] = 0 \ \ \forall t \geq r,$$

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- Note tat we have also derived for free the exact formulation of the Heisenberg error-perturbation uncertainty principle $\sigma_{\mathrm{e}}\sigma_{\mathrm{f}} \geq \hbar/2$ for variations

$$\langle \mathrm{e}(r)\,\mathrm{e}(t)\rangle = \sigma_{\mathrm{e}}^2 \delta(t-r), \quad \langle \mathrm{f}(r)\,\mathrm{f}(t)\rangle = \sigma_{\mathrm{f}}^2 \delta(t-r).$$

Eventum mechanics

'Everything in the future is a wave, everything in the past is a particle.' - LAWRENCE BRAGG.

- The universe is described by the commutant $\mathcal{C}' \subseteq \mathcal{B}(\mathcal{H})$ of an abelian algebra $\mathcal{C}$ generated by all compatible (observable) events $\mathtt{E}$ commutative on a Hilbert space $\mathcal{H}$ in an initially pure state ω.

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- The universe is described by the commutant $\mathcal{C}' \subseteq \mathcal{B}(\mathcal{H})$ of an abelian algebra $\mathcal{C}$ generated by all compatible (observable) events $\mathtt{E}$ commutative on a Hilbert space $\mathcal{H}$ in an initially pure state ω.
- The entropy on any eventum subsystem $\mathcal{A} \in [\mathcal{C}, \mathcal{C}']$ decreases to the entropy induced on $\mathcal{C}_{\mathcal{A}} = \mathcal{A} \wedge \mathcal{A}'$ under the extension $\mathcal{A} \vee \mathcal{A}' = \mathcal{C}'_{\mathcal{A}}$.

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- The unitary dynamics $\mathtt{U} : \mathcal{H} \to \mathcal{H}$ on any autonomous subsystem must be stable: $\gamma(\mathcal{C}'_{\mathcal{A}}) \subseteq \mathcal{C}'_{\mathcal{A}}$, otherwise the universe is not closed (no universe).

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- The probabilistic interpretation is consistent on $\mathcal{A}$ if only $\gamma(\mathcal{C}_{\mathcal{A}}) \supseteq \mathcal{C}_{\mathcal{A}}$ and the evolution can pass any information about the quantum properties to the classical events increasing the entropy on $\mathcal{C}_{\mathcal{A}}$.

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- **Theorem** Let $\mathfrak{a} = \mathcal{B}(\mathfrak{f})$ be algebra of bounded operators on a Hilbert space $\mathfrak{f}$, $\check{C}(X)$ be diagonal subalgebra $\mathfrak{c} \subset \mathcal{B}(\mathfrak{h})$ on $\mathfrak{h} = \mathrm{L}^2_{\mathfrak{A}}(X)$ and U be a unitary operator in $H = \mathfrak{h} \otimes \mathfrak{f}$ s.t. $\theta(\mathrm{B}) := \mathrm{UBU}^\dagger \in \mathcal{B} = \mathfrak{c} \otimes \mathfrak{a}$ for any $\mathrm{B} = \mathrm{c} \otimes \mathrm{a} \in \mathcal{B}$. If θ is reversible, then $\mathfrak{c}$ is autonomous, $\theta(1 \otimes \mathrm{c}) = 1 \otimes \upsilon(\mathrm{c})$, where $\upsilon(\mathrm{c}) = \mathrm{ucu}^\dagger$ with a unitary operator u in $\mathfrak{h}$ implemented by an automorphism of X.

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- **Proof** Since $\theta(\mathcal{B}) \in \theta(\mathcal{C})'$, the surjectivity $\mathcal{B} = \theta(\mathcal{B})$ of the reversible θ on $\mathcal{B} = \mathcal{C}'$ implies $\mathcal{C}' = \theta(\mathcal{B}) \subseteq \theta(\mathcal{C})'$ for $\mathcal{C} = 1 \otimes \mathfrak{c}$, i.e. $\theta(\mathcal{C}) \subseteq \theta(\mathcal{B})' = \mathcal{C}$. Due to the same argument $\theta^{-1}(\mathcal{C}) \subseteq \theta^{-1}(\mathcal{B})' = \mathcal{C}$, and therefore $\theta(\mathcal{C}) = \mathcal{C}$. Hence θ is an authomorphism on $\mathcal{C}$. It is obvious at least in the case of finite X that it can be implemented by the unitary operator $\mathrm{u} : \eta \mapsto \eta \circ g$ acting

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Reconstruction of the Chaos

- **Problem 1.** Given a mixed state $\mathbb{E}(c) = \sum c(x) p_x \equiv (c, P)$ on the algebra $C(X) \sim \mathfrak{c} = \{\check{c} : c \in C(X)\}$ of measurable functions $c : X \to \mathbb{C}$ by a probability law $P = (p_x)$ on the data space X, find an auxiliary system $\mathcal{B}_0$ with a pure state $\varpi = \varepsilon_0 \otimes \mathrm{P}$ and endomorphism θ of the algebra $\mathfrak{c} \otimes \mathcal{B}_0$ such that $\langle \varpi, \theta(\mathrm{I} \otimes \check{c}) \rangle = (c, P)$, where $\langle \varepsilon_0, \check{c} \rangle = c(0) = (c, P_0)$ is given by δ-distribution $P_0 = \delta_0$ corresponding to an initial point-state $x_0 = 0$.

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- One can embed $C(X)$ into the matrix algebra $\mathbb{A} = \mathbb{M}(X)$ as the diagonal subalgebra $\mathfrak{c} = \check{C}(X)$ and find $\mathtt{s}^\dagger = \mathtt{s}^{-1}$ s.t. $\langle 0 | \sigma(\check{c}) | 0 \rangle = (c, P)$ for $\sigma(\mathrm{a}) = \mathtt{sas}^\dagger$ and a pure vector state $\langle 0 | \check{c} | 0 \rangle = c(0)$ for an atomic $x = 0$.

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- **Example**: $X = \{0, 1\}$, $P = (p_0, p_1)$, $\langle 0 | = (1, 0)$,

$$\check{c} = \begin{pmatrix} c_0 & 0 \\ 0 & c_1 \end{pmatrix}, \quad \mathrm{s} = \begin{pmatrix} p_0^{1/2} & p_1^{1/2} \\ p_1^{1/2} & -p_0^{1/2} \end{pmatrix}, \quad |0\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}.$$

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- However $\sigma(\mathfrak{c}) \nsubseteq \mathfrak{c}$. There is no solution with an Abelian or finite-dimensional $\mathcal{B}_0$ unless $\mathbb{E}$ is a pure state, $P = \delta_x$.

Chaos as a boudary valueinterface problem

- Take $\mathbb{E}(\mathtt{B}) = \langle 0,0|\mathtt{B}|0,0\rangle$ on $\mathcal{C}_- \otimes \mathcal{A}_+$ where $\mathcal{C}_- = \check{C}(\mathbb{Z}_-) \equiv \mathcal{M}(\mathbb{Z}_-)$, $\mathcal{A}_+ = \mathcal{B}(\ell^2_+) \equiv \mathcal{N}(\mathbb{Z}_+)$, $\mathbb{Z}_\mp = \{0, \mp 1, \mp 2, \ldots\}$ and $|n_-, n_+\rangle = |n_-\rangle \otimes |n_+\rangle$, $n_\mp \in \mathbb{Z}_\mp$.

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- On the H-span $\ell^2_- \otimes \mathbb{C}^2 \otimes \ell^2_+$ of $|m,x,n\rangle = |m\rangle \otimes |x\rangle \otimes |n\rangle$, $x \in \{0,1\}$ define the operator $\mathrm{U} = p_0^{1/2}\mathrm{U}_0 + p_1^{1/2}\mathrm{U}_1$ by

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where $x(n) = (1-(-1)^n)/2 \in \{0,1\}$ is the evenness of n.

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- **Theorem** Thus defined operator U is unitary and $\mathrm{UBU}^\dagger \subset \mathrm{B}$, where $\mathrm{B} = \mathcal{M} \otimes \mathbb{A} \otimes \mathcal{N}$. Moreover, if ϵ is the pure state $\varphi_0 \otimes \varphi_0 \otimes \varphi_0$ defined by $\varphi_0(\cdot) = \langle 0| \cdot |0\rangle$ on $\mathcal{M}$, $\mathcal{N}$ and $\mathbb{A}$ respectively by the ground vector $|0\rangle$ in ℓ^2 and in $\mathbb{C}^2$, then $\epsilon\left(\mathrm{U}(\mathrm{I} \otimes \check{\mathrm{c}} \otimes \mathrm{I})\mathrm{U}^\dagger\right) = c_0 p_0 + c_1 p_1$.

Proof Use the isomorphism of $\ell^2 \otimes \mathbb{C}^2 \otimes \ell^2$ and two-sided infinite vacuum-product $\ldots \mathfrak{h} \otimes \mathfrak{h} \otimes \mathfrak{h} \ldots$ of $\mathfrak{h} = \mathbb{C}^2$ by

$$|m, x, n\rangle \simeq |\ldots, 0, x_k^-, \ldots, x_2^-, x_1^-, x, x_1^+, x_2^+ \ldots, x_l^+, 0, \ldots\rangle$$

given by the bit representations $(x_k^-, \ldots, x_2^-, x_1^-)$ of
$m = 2^{k-1}x_k^- + \ldots + 2x_2^- + x_1^-$ and $(x_1^+, x_2^+, \ldots, x_l^+)$ of
$n = x_1^+ + 2x_2^+ + \ldots + 2^{l-1}x_l^+$. Then $\mathrm{U} = \mathrm{TS}$, where $\mathrm{S} = \mathrm{I}^- \otimes \mathrm{s} \otimes \mathrm{I}^+$ is the scattering and T is left shift

$$\langle \ldots, x_1^- | \langle x | \langle x_1^+, x_2^+, \ldots | \mathrm{T} = \langle \ldots, x_1^-, x | \langle x_1^+ | \langle x_2^+, \ldots |$$

with $\langle 0^-, 0, 0^+ | \mathrm{T} = \langle 0^-, 0, 0^+ |$ and $\epsilon_0 \left(\mathrm{U} \check{c} \mathrm{U}^\dagger \right) = \langle 0 | \mathrm{s} \check{c} \mathrm{s}^\dagger | 0 \rangle$.
The stability of B such that $\mathrm{U}^\dagger \mathrm{B} \mathrm{U} \not\subseteq \mathrm{B}$ follows from

$$\mathrm{TBT}^\dagger \subset \mathcal{M} \otimes \mathbb{B} \otimes \mathcal{N}, \; \mathrm{s}(\mathcal{M} \otimes \mathbb{B} \otimes \mathcal{N})\,\mathrm{s}^\dagger = \mathrm{B}.$$

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