A MINIMALIST APPROACH TO QUANTUM TIME: TOWARDS “QUANTUM INDIVIDUATION”

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Abstract:

A sketch of the arguments for non-fundamental character of the standard “universal” physical time and the novel concept of Local Time (LT) will be briefly presented. Then “quantum individuation” stemming from the LT Scheme will be crossed with the favorite subject of prof. Valerije (Valja) Bocvarski – of Morphology of Physics in the sense of ‘every instant of time a new universe’ – the latter being my understanding of Valja’s arguments presented in our numerous “quarrels” about the meaning of quantum theory.

$p = -i\frac{\partial}{\partial x}.$

$$\left\|\left(\frac{x}{t_m} - \frac{p}{\mu}\right) e^{-it_m H}\psi\right\| \to 0, \quad m \to \infty, \qquad (1)$$

The time-less operators x, p; and $e^{-it_m H}$ -- the one-parameter unitary group generated by the system's Hamiltonian H (depending on x, not on p - can be introduced also for the relativistic quantum fields). ψ is (without loss of generality) a *scattering state* for the continuous spectrum of H.

Eq.(1) is an orthodox quantum-mechanical result describing the fundamental mechanisms of quantum interactions.

An alternative reading of eq.(1) [due to Hitoshi Kitada of the University of Tokyo]. Eq.(1) is a mathematical result that does not necessarily call for our classical intuition about Time. **Consider (1) without prejudice**. Then we can read from (1): (i) [the universal statement] if for some $t = t_0$, the support of ψ is around some $x = x_0$, then the support of $e^{-it_m H}\psi$ is around $x = x_0 + \frac{p}{\mu} t_m$--classical-like; (ii) There is no time in (1), except our prejudice on t_m: x, $p = -i\partial/\partial x$ and H do not depend on t_m; (iii) The meaning of the parameter t_m is fixed by eq.(1): the unitary transformation generated by H dynamically establishes:

$$t_m \sim \frac{\mu\, x}{p} \qquad (2);$$

(iv) Classically, eq.(2) emphasizes t_m as an instant of time, i.e. a kind of definition of time (and is often used for "time quantization") due to the time dependent, classical p; (v) For every ψ, different Hamiltonians give rise to numerically different approaches to the limit in eq.(1); (vi) Without in-advance-established physical interpretation of t_m, the Hamiltonian "generates" eq.(2), i.e. "dynamics", which may be regarded as a primitive of QM formalism.

Then, dynamics, $e^{-it_m H}$, "produces" Time independently for every H. I.e., different Hs – different systems –give rise to different (local*) system's times:

One Hamiltonian (one system) ↔ One Time. (LT)

***Local means: "isolated" i.e. [at least approximately] subjected to the "Schrodinger law" . $e^{-it_m H}$**

Realistic systems can never meet the exact criterion $m \to \infty$. Hence the fundamental uncertainty for local time of every, single, local (isolated) system: Now, (local) Time is "a private thing" of a single, individual system. It dynamically appears as a classical parameter and dynamically "gets ripe" [in the sense of approximate validity of eq.(2)]. The "clock" of a single system is formally $e^{-it_m H}$, which may serve for gauging dynamics of all other systems.

Dynamics $e^{-it_m H}$, i.e. the local clock, now "produces time" for every single local system, *leaving the Universe (as we perceive it) without the notion of time*.

Every single local system "gets ripe" with its own, unique local time—a quantum-mechanical notion of individuality. "Maturation" of the local system's time is dynamical emergence of individuality—i.e. quantum individuation.

I suppose that Valja would find all this interesting. WHY so?

The Universe [consisting of more than one “local system”] is a dynamical thing—interactions dynamically rearrange the LT-distribution in the Universe i.e. distribution of local systems, their subsystems, correlations… and ultimately [loosely speaking] dynamically “create” and “recreate” the Universe. This kind of “(re)creating the Universe” is dynamical, not based on the standard concept of “universal Time”, and I really miss Valja’s opinion on this matter.

What is LTS useful for?

For an ensemble of local systems with their respective local times:

1) The standard Schrodinger law is exchanged with an alternative fundamental dynamical law that describes a "proper mixture";

A) Local Time is non-trivial only for "macroscopic" (many-particle) systems, which exhibit behavior that is characteristic for open systems;

B) There is unique "pointer basis" even for a bipartition of a local system (measurement problem "solved" on the statistical-ensemble level). No need for "collapse", many-worlds, HVs and other interpretations etc.;

C) Straightforward for application (simple situations though!), e.g. tripartite models of quantum measurement;

D) [macroscopic] Local systems "get ripe" in the "decoherence time" intervals—i.e. very short intervals;

What is LTS useful for?

For an ensemble of local systems with their respective local times:

E. Dynamics implied by LT is "strange": (a) non-differentiable dynamical map, (b) dynamically obtains Markovian character for a closed [macro] system in the context of a specific [non-quantum-information-like] "coarse graining" description, (c) The point "(b)" universally valid for an open system (after tracing out), (d) There are energy-dependent-domains for such Markovianity (low and very high energies provide dynamical appearance of Markovianity), (e) Derives the Luders-von Neumann formula for quantum measurement, (f) If there is a stationary state, then smaller systems are faster in attaining the ST than the larger systems, (g) New readings of some results in the standard theory of open quantum systems (notably: "derivation" of the "Born approximation", naturally implied the "ergodic average" etc.).