Making a Quantum Universe: Symmetry and Gravity

Houri Ziaeepour[1,2]
Email: houriziaeepour@gmail.com

[1] Institut UTINAM, CNRS UMR 6213, Observatoire de Besançon, Université de Franche Compté, France;
[2] Mullard Space Science Laboratory, University College London, UK.

We outline a quantum model for the Universe [1] and show that an interaction similar to gravity emerges when it is partitioned to subsystems. The model is based on three well motivated assumptions with compelling observational and theoretical evidence: 1) Quantum mechanics is valid at all scales and applies to every entity, including the Universe as a whole; 2) Any quantum system is described by its symmetries and its Hilbert space is a representation of these symmetries [2]; 3) The Universe has infinite degrees of freedom corresponding to commuting observables. The Hilbert space of this model represents $SU(N \rightarrow \infty) \cong$ surface preserving Diff.(S^2) [3]. Thus, its algebra depends on 2 angular parameters of the sphere. Generators of the algebra can be expanded with respect to spherical harmonic functions and a Lagrangian analogous to Yang-Mills (YM) models can be constructed on the 2D sphere. We normalize generators of $su(\infty)$ algebra such that its structure coefficients become proportional to $\hbar/M_P$, where $\hbar$ is the Planck constant and M_P the Planck mass. We notice that when $\hbar \rightarrow 0$ or $M_P \rightarrow \infty$, the symmetry becomes homomorphic to abelian group $U(1) \times U(1) \ldots$ in classical systems. Moreover, the appearance of $\hbar/M_P$ in the construction of the model solves a puzzle raised in [4], namely why the scale of quantumness $\hbar$ is universal. At this stage the Lagrangian of the model is static and trivial. But, when the Universe is divided to subsystems by symmetry breaking [5] or more generally by partitioning of the Hilbert space by a subalgebra associated to a finite dimensional group G [6], the model acquires two additional parameters, which can be interpreted as *distance* and *time*. More precisely, subsystems represents $SU(\infty) \times G \cong SU(\infty) \cong$ Diff. (S^2). The radius of the sphere in Diff.(S^2), which in the case of full system is irrelevant, becomes an observable when subsystems are compared and is measured in unit of $\hbar/M_P$. Moreover, a clock à la Page & Wootters provides a reference by which variation of the state of a subsystem by application of a member of $SU(\infty) \times G$ can be compared with the variation of the clock. In addition to explaining the origin of spacetime dimension, this model shows that spacetime is the parameter space of the Hilbert space of Universe content and Einstein equation presents the projection of the dynamics in its Hilbert/Fock space into its classical parameter space. Signature of spacetime metric is induced by maximum speed of variation of coherent states [7], and Lagrangian of Einstein gravity depends linearly on the Riemann curvature because of quadratic form of the YM Lagrangian. We briefly discuss common points of this model with string theory and loop quantum gravity and their differences.

References

[1] H. Ziaeepour,in preparation; will be submitted as feature article to the special issue of MDPI journal Universe "80 Years of Professor Wigner's Seminal Work *"On Unitary Representations of the Inhomogeneous Lorentz Group"*" (2020).

[2] H. Ziaeepour,"Symmetry as a foundational concept in Quantum Mechanics", *J. Phys.: Conf. Series* **626**, (2015) 012074 [arXiv:1502.05339].

[3] J. Hoppe,"Quantum theory of a massless relativistic surface and a 2D bound state problem" , MIT Ph.D. Thesis, (1982).

[4] H. Ziaeepour,"And what if gravity is intrinsically quantic ?", *J. Phys.: Conf. Series* **174**, (2009) 012027 [arXiv:0901.4634].

[5] P. Zanardi,D. Lidar,S. Lloyd,"Quantum tensor product structures are observable-induced", *Phys. Rev. Lett.* **92**, (2004) 060402 [arXiv:quant-ph/0308043].

[6] E.A. Mazenc,D. Ranard,"Target Space Entanglement Entropy", [arXiv:1910.07449].

[7] P. Pfeifer,J. Fröhlich,"Generalized time-energy uncertainty relations and bounds on lifetimes of resonances", *Rep. Mod. Phys.* **67**, (1995) 759.