Gravity from Quantum Mechanics via Large-N limit

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The main purpose of this research project is describing how certain known facts about gravity can naturally emerge from the standard quantum mechanical description of composite systems. Indeed, one of the most intriguing conundrum in modern physics is that of understanding how it is that its two most successful theories, namely Quantum Mechanics (QM) and General Relativity (GR), do not talk to each other. Building a dialogue between them seems very difficult, in particular because of the following intrinsic issues. First of all, the two theories evidently speak different languages: the formalism of linear algebra and Hilbert spaces for QM, versus that of differential geometry and smooth manifolds for GR. Secondly, they talk about very different subjects, such as elementary particles and microscopic systems on the QM side, and macroscopic objects and cosmological systems on the GR one. Finally, they give a completely different meaning to the most fundamental notion in our interpretation of nature, namely “time”. In this project we elaborate upon the three discrepancies above by specific formal tools that we believe can help find a way towards a reconciliation. In particular, as for the first point, we use General Coherent States [1]: they are normalized elements of Hilbert spaces in one-to-one correspondence with the points of a smooth manifold, recognizable as a classical phase-space. Coming to the second point, we consider the formal procedure introduced by L. Yaffe [2] to represent the route from micro-to-macro as a quantum-to-classical crossover. Yaffe describes how a globally symmetric Large-N quantum theory can naturally flow into a classical one when the limit $N \to \infty$ is performed. As for the concept of time, we consider the "PaW mechanism" introduced in [3]. This is based on the a priori assumption that the Universe is timeless, and the usual perception of time emerges only when the measurement process enters the scene. A timelessness hypothesis from the QM viewpoint seems exactly what is needed in order to go towards the notion of time entering GR. The tools mentioned above, i.e. [1] [2] [3], have been successfully used in Ref. [4] to identify a Schwarzschild Black Hole, i.e. one of the most known prediction of GR, as an actually macroscopic quantum system playing the role of environment for a possible test particle. Thus, it is tempting to wonder: "Is possible to find a formal connection with the Hawking radiation? Might results of Ref. [4] be obtained also in the case of other predictions of GR?" Such questions lead towards the famous open problem dubbed "quantum gravity". In this regard it should be noted that the aim of this project is different from the usual ones: the plan is not to perform a "quantization" of gravity, but rather make gravity to emerge as a proper classical limit of specific Large-N quantum theories. However, there are aspects in the results of Ref.[4] that may be of interest to the two most celebrated proposals of "quantum gravity", that is "String Theory" and "Loop Quantum Gravity".

[1] Gilmore R. Geometry of symmetrized states. *Ann. Phys.*, **74**, 391-463 (1972).

[2] Yaffe L. Large-N limits as classical mechanics. *Rev. Mod. Phys.*, **54**, 407-435 (1982).

[3] Page D. and Wootters W. Evolution without evolution: dynamics described by stationary observables. *Phys. Rev. D*, **27**, 2885-2892 (1983).

[4] Coppo A. *Schwarzschild Black Holes as Macroscopic Quantum Systems*. Tesi di Laurea Magistrale in Scienze Fisiche e Astrofisiche. Universita’ degli studi di Firenze (2019).