Unitarity and information in quantum gravity: a simple example

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In approaches to quantum gravity, where smooth spacetime is an emergent approximation of a discrete Planckian fundamental structure, any effective smooth field theoretical description on a smooth spacetime is bounded to miss a part of fundamental degrees of freedom and thus break unitarity. This is applicable also to trivial gravitational field (low energy) idealizations realized by the use of the Minkowski background geometry which, as any other spacetime geometry, corresponds, in the fundamental description, to infinitely many different and closely degenerate discrete microstates. These microstates provide an infinite reservoir for information at the end of black hole evaporation and their consideration has been argued to lead to a natural resolution of the black hole evaporation puzzle. In this paper we show that all these expectations can be made precise in a simple quantum gravity model for cosmology derived from loop quantum gravity. Concretely, even when the model is fundamentally unitary, pure states of our cosmological model evolve into mixed states due to decoherence with the Planckian microscopic structure when degrees of freedom irrelevant to coarse-grained low-energy cosmological observers are traced out. Moreover, in the suitable situations of physical relevance these hidden degrees freedom do not carry any 'energy' and thus realizes in a fully quantum gravitational context the idea (emphasized before by Unruh) that decoherence can take place without dissipation.

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