Can gravity mediate the transmission of quantum information?

Andrea Mari[1], **Stefano Zippilli**[1], **David Vitali**[1]

1. *Physics Division, School of Science and Technology, University of Camerino, 62032 Camerino, Italy*

Abstract: We propose an experiment, inspired by quantum communication theory, to test the non-classicality of the gravitational interaction.

We consider two optomechanical systems that are perfectly isolated, except for a weak gravitational coupling. If a suitable resonance condition is satisfied, an optical signal can be transmitted from one system to the other over a narrow frequency band, a phenomenon that we call *gravitationally induced transparency*.

In this framework, the challenging problem of testing the quantum nature of gravity is mapped to the easier task of determining the non-classicality of the gravitationally-induced optical channel: **If the optical channel is not *entanglement-breaking*, then gravity must have a quantum nature.** This approach is applicable without making any assumption on the, currently unknown, correct model of gravity in the quantum regime.

In the second part of this work, we model gravity as a quadratic Hamiltonian interaction (e.g. a weak Newtonian force), resulting in a Gaussian thermal attenuator channel between the two systems. Depending on the strength of thermal noise, the system presents a sharp transition from an entanglement-breaking to a non-classical channel capable not only of entanglement preservation but also of asymptotically perfect quantum communication.

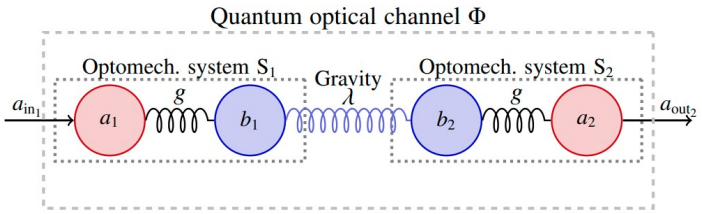

Fig. 1 The apparatus required to observe the gravitationally induced transparency phenomenon is based on two optomechanical systems, S_1 and S_2. Each system is composed of an optical cavity mode a_j that is coupled with a mechanical resonator b_j , where j = 1, 2. By tuning the mode frequencies and the optomechanical coupling g, gravity can induce an effective quantum channel Φ from the optical input of S_1 to the optical output of S_2. Any quantum optics experiment demonstrating that Φ is not entanglementbreaking would imply that gravity is a non-classical phenomenon.

References

[1] Andrea Mari, Stefano Zippilli, David Vitali, *Can gravity mediate the transmission of quantum information?*, Physical Review D **113**, L021905 (2026). [arXiv:2504.05998]

[2] Code related to [1]: https://github.com/andreamari/optomechanics/

[3] Sougato Bose, Ivette Fuentes, Andrew A Geraci, Saba Mehsar Khan, Sofia Qvarfort, Markus Rademacher, Muddassar Rashid, Marko Toroš, Hendrik Ulbricht, and Clara C Wanjura. *Massive quantum systems as interfaces of quantum mechanics and gravity*. Reviews of Modern Physics, **97**(1): 015003, 2025. [arXiv:2311.09218]

[4] Chiara Marletto and Vlatko Vedral. *Quantum-information methods for quantum gravity laboratory-based tests.* Reviews of Modern Physics, **97**(1): 015006, 2025. [arXiv:2410.07262]