Analog models of gravity: quantum simulating fundamental theories in condensed matter and optical systems

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In this introductory talk I will review the basic concepts underlying the physics of the so-called analog models of gravity and, more in general, the recent developments in the use of condensed matter and optical systems to quantum simulate problems of high energy and gravitational physics [1,2].

After a brief historical review of the general concept of analog model, I will summarize the most promising systems that are presently under experimental investigation in this context, among which surface waves on classical fluids, sonic excitations in superfluids of ultracold atoms and of photons, and nonlinear optical systems. For each of these systems, I will illustrate my view on the main recent achievements and the most challenging open questions.

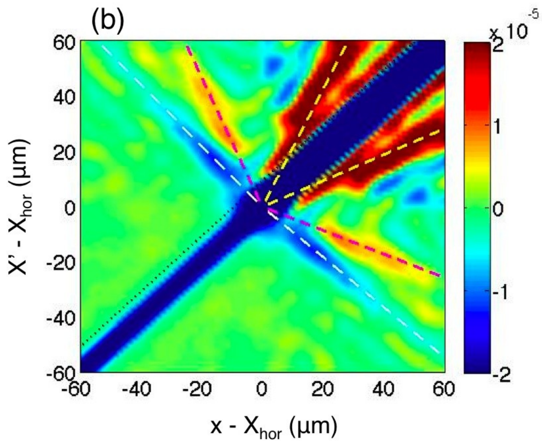

Illustration 1: Light intensity correlations in the emission from a quantum fluid of light displaying an analog black hole horizon. Signatures of analog Hawking radiation are highlighted. Figure from Gerace and Carusotto, PRB 86, 144505 (2012)

A special attention will be paid to the analog Hawking radiation, that is the emission of correlated pairs of quanta by the horizon of an analog black hole out of the zero-point quantum fluctuations. The mathematical analogy with quantum field theory of curved space-times will be highlighted, as well as the rich new features that are characteristic of condensed matter and optical systems.

I will conclude with a sketch of the most exciting new perspectives of the field. On one hand, I will show how analog models are suggesting new configurations where quantum hydrodynamics effects can be experimentally investigated and entanglement of macroscopic hydrodynamic degrees of freedom generated and manipulated. On the other hand, I will illustrate the latest advances in the investigation of the back-reaction effects of quantum fluctuations onto the underlying space-time metric and I will present simple toy-models of this physics that may provide some new insight into very challenging black hole evaporation phenomena.

[1] C. Barceló, S. Liberati, M. Visser, Liv. Rev. Relativity **14**, 3 (2011)
[2] I. Carusotto and R. Balbinot, Nat. Phys. News & Views, Aug. 2016