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Hearts of Darkness: the inside-out probing of black holes

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The standard paradigm of black holes, rooted in Einstein's General Relativity, predicts the existence of singularities. However, the emergence of quantum gravity candidates and new observational technologies have opened the door to exploring regular black holes and black hole mimickers as viable alternatives. These non-singular solutions, which replace the central singularity with a finite-core structure, challenge traditional concepts and offer a path towards understanding gravitational collapse beyond Einstein's framework. In this talk, I will discuss the theoretical foundations of regular black holes and black hole mimickers, and their possible instabilities and phenomenology. I will further explore their observational signatures, ranging from gravitational wave echoes to modifications in black hole images, as a means to distinguish them from classical black holes. In the end I will argue that by leveraging recent advancements in observational astrophysics, we might be at the dawn of a new era for quantum gravity phenomenology.

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