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Geometry and Horizons in Gravitation

Nastassja Cipriani José María Martín Senovilla

1) UPV/EHU 2) KU Leuven

The recent discovery of the existence of the gravitational waves, predicted by General Relativity more than one hundred years ago, has opened a new scenario for the physics of the XXI century and, at the same time, has reminded us of the importance of the role played by black holes in the understanding of our universe. Black holes are studied in many fields such as astrophysics, numerical relativity and cosmology. During the past decades researchers have progressed a lot: they can now simulate the dynamics of a binary system made of a black hole and a companion star or of two black holes, as well as describe the evolution of galaxies with respect to their central black holes. From a theoretical point of view, however, we still lack of a geometrical-mathematical framework for an exhaustive theory describing dynamical black holes. The key object in order to geometrically characterize black holes is the black hole horizon. It represents a sort of boundary, the region that separates the black hole from the rest of the spacetime. This concept was firstly introduced to describe the boundary of stationary black holes, and it was called the event horizon. Unfortunately, this originally definition is no longer appropriate if we want to describe black holes interacting with their exterior regions. Several new definitions have been tried, to capture the very nature of an evolving-in-time horizon, but none of them seem to suit perfectly. Our research is focused on the geometry of horizons. We study a particular class of surfaces, namely spacelike surfaces which are at the same time marginally trapped and umbilical. Our goal would be proving that such surfaces can foliate isolated as well as dynamical horizons.