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Quasi-local masses and cosmological coupling of astrophysical compact objects

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The possibility of a non-zero coupling between local astrophysical objects, such as black holes (BHs), and the large-scale cosmological dynamics, has a quite long history. Recently, there have been interesting developments on the issue, from both theoretical and observational points of view.
In this talk, I will discuss a General Relativity framework allowing the embedding of local objects into the cosmological background, giving rise to a general description of the coupling between local inhomogeneities and the large-scale homogeneous background. In this framework, if BHs are singularity-free objects, they must couple to the large-scale cosmological dynamics.
I will show that the coupling is associated to a curvature term in Einstein's equations, yielding to the precise prediction $M(a) \propto a$, where $M(a)$ is the Misner-Sharp (MS) mass of the object, and a is the scale factor. I will show that the cosmological coupling occurs whenever the energy of the central object is quantified by the quasi-local MS mass, whereas the decoupling occurs whenever the MS mass is fully equivalent to the nonlocal Arnowitt-Deser-Misner (ADM) mass, i.e. in the case of singular BHs.
Finally, aiming at determining whether we will be able to assess if BHs are singular or not, I will discuss observational prospects to distinguish between the two scenarios, by means of gravitational wave signals from binary BH mergers from both 2G and 3G detectors.

Primary author: MURGIA, Riccardo (GSSI (Gran Sasso Science Institute))

Presenter: MURGIA, Riccardo (GSSI (Gran Sasso Science Institute))

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