General Relativity and Quantum Cosmology

Mass and Angular Momentum in General Relativity

J.L. Jaramillo, E. Gourgoulhon

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We present an introduction to mass and angular momentum in General Relativity. After briefly reviewing energy-momentum for matter fields, first in the flat Minkowski case (Special Relativity) and then in curved spacetimes with or without symmetries, we focus on the discussion of energy-momentum for the gravitational field. We illustrate the difficulties rooted in the Equivalence Principle for defining a local energy-momentum density for the gravitational field. This leads to the understanding of gravitational energy-momentum and angular momentum as non-local observables that make sense, at best, for extended domains of spacetime. After introducing Komar quantities associated with spacetime symmetries, it is shown how total energy-momentum can be unambiguously defined for isolated systems, providing fundamental tests for the internal consistency of General Relativity as well as setting the conceptual basis for the understanding of energy loss by gravitational radiation. Finally, several attempts to formulate quasi-local notions of mass and angular momentum associated with extended but finite spacetime domains are presented, together with some illustrations of the relations between total and quasi-local quantities in the particular context of black hole spacetimes. This article is not intended to be a rigorous and exhaustive review of the subject, but rather an invitation to the topic for non-experts. In this sense we follow essentially the expositions in Szabados 2004, Gourgoulhon 2007, Poisson 2004 and Wald 84, and refer the reader interested in further developments to the existing literature, in particular to the excellent and comprehensive review by Szabados (2004).

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