

Gravitoelectromagnetism: applications to gravitational lensing and Komar integrals

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Abstract.

Stationary spacetimes are 4D Lorentzian manifolds admitting a time-like Killing vector field T . There is a 3D Riemannian manifold canonically associated with the quotient of the spacetime by the integral lines of T — the “space manifold” — which mathematically describes our everyday notion of 3-dimensional space. The projection of time-like geodesics (describing the worldlines of test particles) onto the space manifold results in a curve whose 3-acceleration is formally analogous to the Lorentz force of electromagnetism — an analogy called “gravitoelectromagnetism” (GEM). This allows for an enlightening description of the motion of test particles in a gravitational field, as well as of part of the Einstein field equations, in terms of “gravitoelectric” and “gravitomagnetic” fields analogous to their electromagnetic counterparts.

We present two further applications of the formalism: (1) extending it to null geodesics, we show that gravitational lensing can also be described in terms of GEM fields, and deflection angles computed by applying the Gauss-Bonnet theorem to 2-surfaces on the space manifold. This is used to address a debate in the literature concerning the impact of relativistic effects in galactic dynamics. (2) We obtain new expressions for the Komar mass, shedding light on its physical significance in non-static spacetimes.