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Gauge-Invariant Localization of Infinitely Many Gravitational Energies from All Possible Auxiliary Structures

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The problem of finding a covariant expression for the distribution and conservation of gravitational energy-momentum dates to the 1910s. A suitably covariant infinite-component localization is displayed, reflecting Bergmann's realization that there are infinitely many gravitational energy-momenta. Initially use is made of a flat background metric (or rather, all of them) or connection, because the desired gauge invariance properties are obvious. Partial gauge-fixing then yields an appropriate covariant quantity without any background metric or connection; one version is the collection of pseudotensors of a given type, such as the Einstein pseudotensor, in *every* coordinate system. This solution to the gauge covariance problem is easily adapted to any pseudotensorial expression (Landau-Lifshitz, Goldberg, Papapetrou or the like) or to any tensorial expression built with a background metric or connection. Thus the specific functional form can be chosen on technical grounds such as relating to Noether's theorem and yielding expected values of conserved quantities in certain contexts and then rendered covariant using the procedure described here. The application to angular momentum localization is straightforward. Traditional objections to pseudotensors are based largely on the false assumption that there is only one gravitational energy rather than infinitely many.

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