General Relativity and Quantum Cosmology

The matter Lagrangian and the energy-momentum tensor in modified gravity with non-minimal coupling between matter and geometry

T. Harko

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We show that in modified $f(R)$ type gravity models with non-minimal coupling between matter and geometry, both the matter Lagrangian, and the energy-momentum tensor, are completely and uniquely determined by the form of the coupling. This result is obtained by using the variational formulation for the derivation of the equations of motion in the modified gravity models with geometry-matter coupling, and the Newtonian limit for a fluid obeying a barotropic equation of state. The corresponding energy-momentum tensor of the matter in modified gravity models with non-minimal coupling is more general than the usual general-relativistic energy-momentum tensor for perfect fluids, and it contains a supplementary, equation of state dependent term, which could be related to the elastic stresses in the body, or to other forms of internal energy. Therefore, the extra-force induced by the coupling between matter and geometry never vanishes as a consequence of the thermodynamic properties of the system, or for a specific choice of the matter Lagrangian, and it is non-zero in the case of a fluid of dust particles.

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