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Canonical vs. Phenomenological Formulations of the Spin Hydrodynamics

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Recent observations of the spin polarization of weakly decaying Lambda hyperons have opened up a new direction to explore non-trivial vortical structures of strongly interacting matter produced in the heavy-ion experiments. A consistent framework of relativistic hydrodynamics with spin degrees of freedom (spin hydrodynamics) is under construction now to allow for future dynamic simulations of the spin polarization. This type of hydrodynamic description is based on the conservation of the total energy and linear momentum as well as the total angular momentum which includes both the orbital and spin parts.

The phenomenological approach used to construct the framework of spin hydrodynamics commonly uses a simplified form of the spin tensor [1,2]. This form does not posses an expected symmetry, namely, it is not totally anti-symmetric (which is a direct consequence of Noether's Theorem applied to the Dirac Lagrangian). Consequently, in this approach the connection between the spin hydrodynamics and the underlying field-theoretic arguments is obscured.

In our recent work [3] we demonstrate how one can connect the spin hydrodynamics constructed with a totally antisymmetric (canonical) spin tensor with the phenomenological approach used by other authors. We show that the two frameworks are not connected only by a pseudo-gauge transformation (what most people implicitly assume) but an additional subtraction of a specific divergence-free term to the canonical energy-momentum tensor should be done.

Our results help us to find and clarify connections between different formulations of spin hydrodynamics, which is important for the construction of a final, fully consistent formalism.

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