General Relativity and Quantum Cosmology

Hamiltonian Dynamics of Spatially-Homogeneous Vlasov-Einstein Systems

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We introduce a new matter action principle, with a wide range of applicability, for the Vlasov equation in terms of a conjugate pair of functions. Here we apply this action principle to the study of matter in Bianchi cosmological models in general relativity. The Bianchi models are spatially-homogeneous solutions to the Einstein field equations, classified by the three-dimensional Lie algebra that describes the symmetry group of the model. The Einstein equations for these models reduce to a set of coupled ordinary differential equations. The class A Bianchi models admit a Hamiltonian formulation in which the components of the metric tensor and their time derivatives yield the canonical coordinates. The evolution of anisotropy in the vacuum Bianchi models is determined by a potential due to the curvature of the model, according to its symmetry. For illustrative purposes, we examine the evolution of anisotropy in models with Vlasov matter. The Vlasov content is further simplified by the assumption of cold, counter-streaming matter, a kind of matter that is far from thermal equilibrium and is not describable by an ordinary fluid model nor other more simplistic matter models. Qualitative differences and similarities are found in the dynamics of certain vacuum class A Bianchi models and Bianchi Type I models with cold, counter-streaming Vlasov matter potentials analogous to the curvature potentials of corresponding vacuum models.

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