Gauge-Free Hamiltonian Structure of the Spin Maxwell-Vlasov Equations

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High energy density plasma physics has become a popular subject (see, e.g., [7] and references therein). In such systems, quantum mechanical effects, such as wave function dispersion and/or statistical effects, can become important (for a recent experimental example, see [8]), and much of these plasmas can be rightly termed quantum plasmas. Much of the early literature on quantum plasmas has focused on condensed matter systems, with a background lattice structure, and the linear effects that follows (see, e.g., [21]). However, recent developments shows a different direction, where the nonlinear aspects of such systems are in focus [10, 23]. Examples of recent results include quantum ion-acoustic waves [2], trapping effects [22], and relativistic effects [14, 15]. A method for treating such systems that closely resembles the classical case is to use kinetic equations as a starting point. In particular, incorporating the dynamics of the intrinsic spin of the consistuents [4–6, 9, 11], yields a rich and enlarged phase space structure. Kinetic theory with spin will be our main objective here, in particular its Hamiltonian structure.

For the kinetic theory of interest here we show it has a Hamiltonian structure that is a generalization of that given in [13, 16, 17] (see also [3]). We present the noncanonical Poisson bracket, prove directly that it satisfies the Jacobi identity, find Casimir distributions are stable [12].