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Non-linear electrodynamics for astrophysical plasmas

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In this work we study the initial value problem of a non-linear extension of classical Electromagnetism, known as "Force-Free Electrodynamics" (FFE). The FFE equations describe the dynamics of a diluted plasma near the event horizon of a rotating black hole. In these astrophysical regions, magnetic fields dominate the dynamics when compared with the matter that constitutes those plasmas, giving rise to an decoupled description for Electromagnetism.
As a starting point, we consider a covariant formulation of the FFE theory in terms of two scalar potentials, known as "Euler potentials", which allow a very elegant and precise geometric interpretation of it. The ease of formulating FFE in terms of two potentials lies in the fact that, being the only dynamical variables, it provides an optimal scenario for its numerical implementation. In this work we show that this formulation is weakly hyperbolic, which means that the system does not have a well posed initial value problem in the usual sense. In this way, it is not possible to guarantee uniqueness or continuity during the dynamic evolution, which implies that this formulation is not convenient for numerical simulations.

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