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New analysis of magnetic tornadoes

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The recent work[1] showed how the equations of ideal, compressible magnetohydrodynamics (MHD) may be elegantly formulated in terms of Lie derivatives, building on the work of Helmholtz, Walen and Arnold. The “linear" fields approach reduces ideal MHD to a low order set of non-linear ordinary differential equations capable of further simplification, so has the potential to enrich understanding of this difficult subject, which has application both to laboratory and geophysical/astrophysical plasmas.

The just published work [2] extends the linear fields’ solution of compressible nonlinear MHD to the case where the magnetic field depends on superlinear powers of position vector, usually but not always, expressed in Cartesian components. Implications of the resulting Lie-Taylor series expansion for physical applicability of the Dolzhansky-Kirchhoff (D-K) “linear field" equations are found to be positive. It is demonstrated how resistivity may be included in the D-K model. Arguments are put forward that the D-K equations may be regarded as illustrating properties of nonlinear MHD in the same sense that the Lorenz equations inform about the onset of convective turbulence. It is thereby suggested that the Lie-Taylor series approach may lead to valuable insights into MHD turbulence, especially fast timescale transients and the role of plasmoids.

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1. Arter, W. 2013 “Potential vorticity formulation of compressible magnetohydrodynamics. Phys. Rev. Lett. 110, 015004." (doi:10.1103/PhysRevLett.110.015004)
2. Arter, W. 2017 “Beyond linear fields: the Lie–Taylor expansion",
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