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STRUCTURE-PRESERVING ISOGEOMETRIC DISCRETIZATIONS FOR INCOMPRESSIBLE MAGNETOHYDRODYNAMICS

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The incompressible magnetohydrodynamics (MHD) equations describe the behavior of an electrically conducting incompressible fluid in the presence of an external electromagnetic field. These highly coupled nonlinear equations are infused with important structure, evidenced by a wide array of balance laws for mass, momentum, magnetic flux, total energy, cross helicity, and magnetic helicity. These balance laws are considered to be of prime importance in the evolution of laminar and turbulent flow structures, and they are largely a result of the divergence-free nature of magnetic and velocity fields in an incompressible MHD flow. However, most numerical methods yield discrete magnetic and velocity fields which are only divergence-free in an approximate sense and consequently do not obey many fundamental laws of physics.

In this talk, I will present a new class of spline-based discretizations which exactly satisfy the velocity incompressibility constraint and magnetic solenoidal involution and hence replicate the balance law structure of the incompressible MHD equations. This class of methods extends recently developed isogeometric divergence-conforming B-spline discretizations for the incompressible Navier-Stokes equations [1, 2] to the MHD regime. In the limit of vanishing kinematic viscosity and magnetic resistivity, these discretizations exactly conserve total energy and cross helicity, two quantities of fundamental importance for flows at high magnetic Reynolds numbers including turbulent dynamos. I will give a brief overview on how to construct such discretizations, discuss their mathematical properties with a focus on discrete balance laws, and present numerical results illustrating the promise of this new technology.

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