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Exact spherical vortex solutions in fluid and plasma dynamics

We revisit Hill's solution, which characterizes a self-propelling spherical vortex within nested toroidal pressure surfaces, confined by a spherical boundary in an ideal Eulerian fluid. The re-derivation employs Galilei symmetry alongside the Bragg-Hawthorne equation in spherical coordinates. Using the equivalence between the equilibrium Euler equations in fluid dynamics and the static magnetohydrodynamic equations, we derive a generalized type of vortex solution applicable to both dynamic fluid equilibria and static plasma equilibria with a nonzero azimuthal vector field component, while satisfying physical boundary conditions. By applying the separation of variables to the Bragg-Hawthorne equation in spherical coordinates, we develop new fluid and plasma equilibria characterized by nested toroidal flux surfaces and boundary vorticity sheets and current sheets, respectively. Additionally, we analytically demonstrate and numerically illustrate the instability of the original Hill's vortex when subjected to certain radial perturbations of the spherical flux surface.