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Toward the implementation of the full-f nonlinear Coulomb collision operator with the gyromoment approach

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The gyromoment (GM) approach was developed by B. J. Frei et al. [1] to address the challenges associated with the gyrokinetic (GK) modeling of turbulent dynamics in the boundary region of fusion devices. Based on expanding distribution functions onto a Hermite-Laguerre polynomial basis and evolving in space and time the expansion coefficients, the GM approach has the potential to efficiently simulate plasmas across a wide range of collisionalities. The GM approach was shown to be effective in delta-f simulations [2,3,4].
The present work is part of the broader effort to extend the GM method to full-f simulations. In particular, it addresses the challenge related to implementing numerically the nonlinear Coulomb collision operator, emphasizing the potential of the GM method for comprehensive and efficient simulations in fusion devices, especially in high collisionality scenarios.
The expansion of the full-f nonlinear Coulomb collision operator within the GM approach has been derived analytically [5,6] and has been numerically implemented in the delta-f regime [7]. However, the numerical evaluation of the full-f Coulomb collision operator requires the computation of traceless and symmetric parts of spherical harmonic basis tensor contractions at arbitrary ranks. Here, we introduce an innovative mathematical approach to evaluate spherical harmonic basis tensors and the trace removal of their contractions. This technique leverages the inherent symmetries of basis tensors to reduce the computational burden from factorial to polynomial complexity. This allows for the numerical evaluation of the GM expansion of the nonlinear Coulomb collision operator, thus enabling GM simulations with proper collisions.

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