An efficient spectral Poisson solver for the nirvana-III code: the shearing-box case with vertical vacuum boundary conditions

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April 2, 2026

Self-gravity (SG) is essential in astrophysical processes like molecular cloud collapse, FU Orionis outbursts, and protoplanetary disc accretion. While iterative multigrid methods on Cartesian grids require accurate boundary potential estimates, spectral methods solve the Poisson equation in Fourier space with $N \log(N)$ efficiency but assume full periodicity, causing unphysical domain repetitions.

The Vico-Greengard-Ferrando (VGF) method overcomes these issues by modifying the Green's function in Fourier space to account for unbound potentials, enabling FFT-based solutions with machine accuracy at modest resolutions. However, it has not been adapted to the shearing box approximation, which demands two periodic and one vacuum boundary condition. We present VGF-HybridBC, a novel full spectral method, based on the VGF method, designed to preserve both accuracy and efficiency while handling mixed periodic and vacuum boundary conditions in shearing boxes (Rendon Restrepo & Gressel, A&A, 2025, https://doi.org/10.1051/0004-6361/202557659)