Slow particles and weak collisions in gyrokinetics

MANTIS DISCOVERY

MANTIS · MIT CSAIL

OCTOBER 2026

01

The question

Gyrokinetic models describe small-scale turbulence in magnetized plasmas. In a linear electrostatic gyrokinetic model, can collisionless transport, or weak collisions at a rate ν, make the states a computation does not resolve decay at one uniform rate?

02

How we are approaching it

- Look for states the electric field hardly sees. Slow particles give whole infinite-dimensional subspaces whose field response vanishes uniformly.
- Build approximate eigenvectors on the imaginary axis from differentiated wave packets. Under a nondegeneracy condition they concentrate near the passing boundary.
- Bound their residuals for two collision models: Maxwellian velocity diffusion and a one-species linearized Coulomb operator.

03

What we have so far

Quasineutral coupling does not remove the obstruction created by slow particles when the quadratic energy is coercive.

If one species also has the right low-energy drift parity and an even gyroaverage, field feedback and finitely many bounded observations cannot give a decay rate uniform in ν.

04

Spectrum of the undriven model

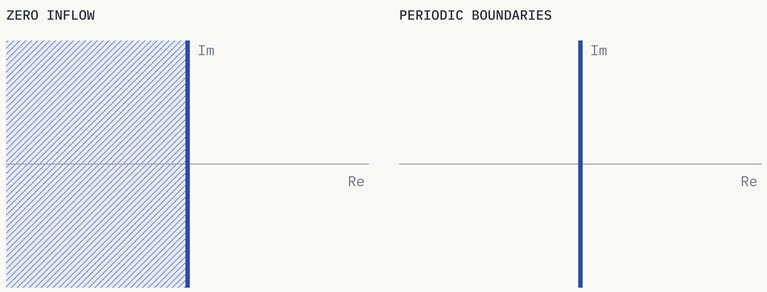


FIGURE 1. With zero inflow at the boundary the undriven spectrum is the closed left half-plane; with periodic boundaries it is the imaginary axis.

05

Residual bound

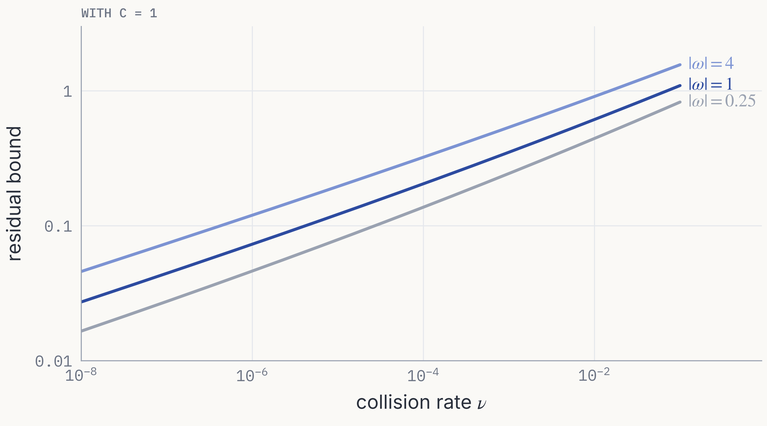
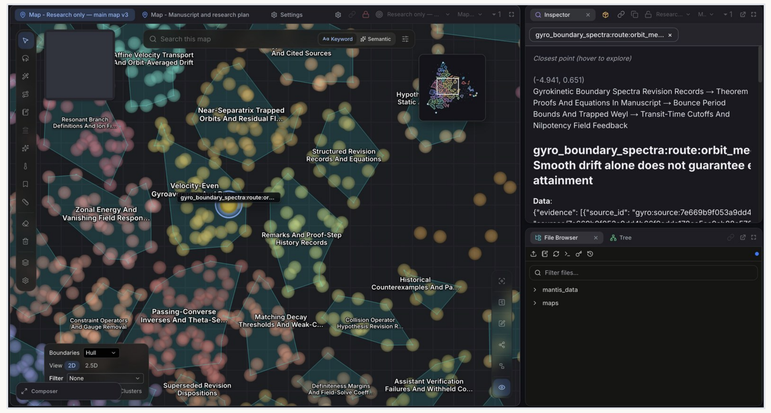


FIGURE 2. The curves show the residual bound stated below as the collision rate falls, with $C = 1$, at three frequencies.

At bounded frequencies the wave-packet residuals are at most $C\left(\nu^{1/3} + \nu^{1/5}|\omega|^{2/5}\right)$, so they vanish as $\nu \to 0$.

06

In Mantis



1,575 RECORDS · THE OPEN RECORD

Smooth drift alone does not guarantee exact zero attainment.

The record is a rejected inference: a smooth-drift example comes arbitrarily close to zero frequency without reaching it.

ALSO ON RECORD

A revision rejected fixed-excess surjectivity, because nonzero frequencies stay bounded below by $2\pi/T^*(c^*)$.

07

Open questions

- These results are for the linear models shown and the full distribution norm. Which of them survive in weaker norms?
- Concentration near the passing boundary needs a nondegeneracy condition. Can it be dropped?