Magnetorotational Turbulence and Dynamo in a Collisionless Plasma

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Objectives

- Many black-hole accretion flows, including that at the center of our Galaxy, are so hot and diffuse that the collisional mean free path is larger than the system size.
  - Collisionless kinetic physics dictates the efficacy of momentum and heat transport and affects magnetic-field amplification
- Current models are couched with a fluid (MHD) framework
  - The assumptions upon which these models rest must be tested using a more fundamental kinetic approach.

Accomplishments

- We have conducted the first 3D kinetic numerical simulation of magnetorotational turbulence and dynamo in a collisionless accretion disk, using the local shearing-box framework
- Magnetorotational instability is shown to amplify a su-thermal zero-net-flux magnetic field and generate self-sustained turbulence and outward angular-momentum transport. Significant Maxwell and Reynolds stresses are accompanied by comparable viscous stressed produced by field-aligned pressure anisotropy.
- This pressure anisotropy is regulated primarily by mirror and ion-cyclotron instabilities through particle trapping and pitch-angle scattering. The latter endow the plasma with an effective viscosity, which is biased with respect to the field direction.
- Field energy spectra indicate Alfvén-wave and kinetic-Alfvén-wave cascades from large (MHD) to small (kinetic) scales. Particle energy spectra indicate nonthermal particle acceleration.

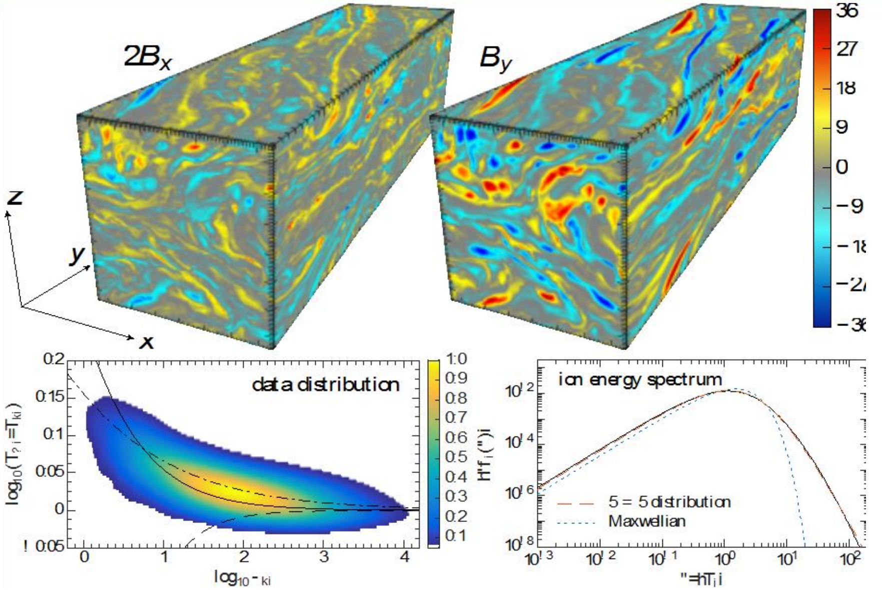

Fig. 1. (top) Turbulent magnetic-field fluctuations; (bottom-left) temperature anisotropy is regulated along the mirror, ion-cyclotron, and firehose instability thresholds; (bottom-right) ion energy spectrum exhibits power-law tail

Impacts

- Black-hole accretion powers some of the phenomeno-logically richest electromagnetic sources in the Universe. Accurate modeling is required for interpretation of observed X-ray, infrared, and sub-mm/mm emission.
- Insight into how magnetized plasmas behave in extreme environments & how free energy of differential rotation is converted into kinetic, magnetic, and non-thermal energy.

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