Ion-scale transition of plasma turbulence: Pressure-strain effect

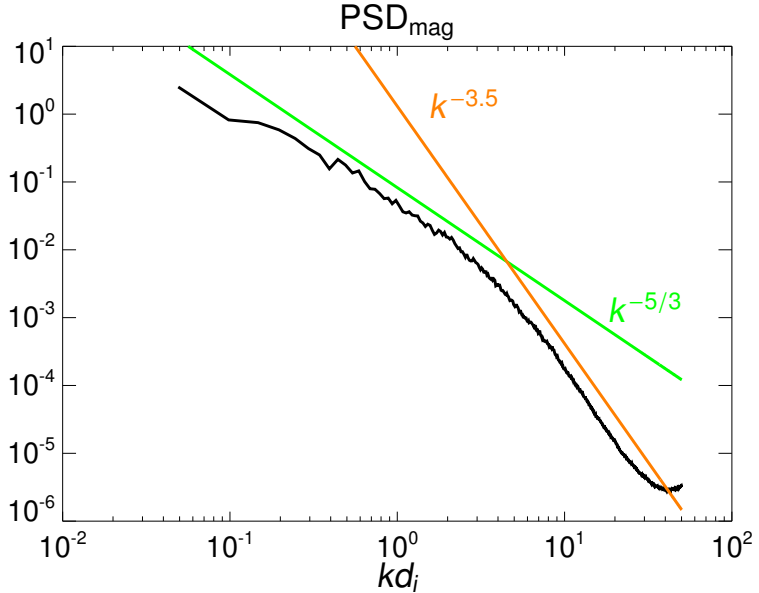
Petr Hellinger[1], Andrea Verdini[2], Simone Landi[2], Luca Franci[3], Emanuele Papini[2], Lorenzo Matteini[4], and Victor Montagud-Champs[1]

[1]Astronomical Institute, CAS, Prague, Czech Republic
[2] Università di Firenze, Italy
[3] Queen Mary University of London, UK
[4] Imperial College, London, UK

EGU 2022, Vienna, Austria

Ion-scale transion (break) in a 2-D hybrid simulation

- $\boldsymbol{B}_0$ along z
- x-y grid 2048^2
- $\Delta x = \Delta y = d_i/16$
- size $128^2 d_i^2$
- Alfvénic fluctuations $\delta B_{rms}/B_0 = 0.25$ for $kd_i < 0.22$
- zero cross-helicity
- $\beta_i = 0.1$
- $\eta = 4 \times 10^{-4}$
- 8192 ppc



KHM equation – extended compressible Hall MHD

Energy budget

$$\frac{\partial}{\partial t}\left\langle \frac{1}{2}\left(\rho|\boldsymbol{u}|^2+|\boldsymbol{B}|^2\right)\right\rangle = -Q = -\overbrace{\eta\langle J^2\rangle}^{Q_\eta} + \overbrace{\langle \mathbf{P}:\boldsymbol{\nabla u}\rangle}^{-Q_\Sigma}$$

KHM equation:

$$Q = -\frac{1}{4}\frac{\partial S}{\partial t} + K_{\mathrm{MHD}} + K_{\mathrm{Hall}} + \Psi + \frac{\eta}{2}\Delta S_B.$$

where $\boldsymbol{w} = \sqrt{\rho}\boldsymbol{u}$,

$$S_w = \left\langle|\delta\boldsymbol{w}|^2\right\rangle,\quad S_B = \left\langle|\delta\boldsymbol{B}|^2\right\rangle,\quad S = S_w + S_B,\quad \Psi = -\frac{1}{2}\left\langle\delta\boldsymbol{w}\cdot\delta\left(\frac{\boldsymbol{\nabla}\cdot\mathbf{P}}{\sqrt{\rho}}\right)\right\rangle + Q_\Sigma$$

$$K_{\mathrm{MHD}} = -\frac{1}{4}\boldsymbol{\nabla}\cdot\boldsymbol{Y} - \frac{1}{4}R + \frac{1}{2}C_1,\quad \boldsymbol{Y} = \left\langle\delta\boldsymbol{u}\left(|\delta\boldsymbol{w}|^2+|\delta\boldsymbol{B}|^2\right) - 2\delta\boldsymbol{B}\left(\delta\boldsymbol{u}\cdot\delta\boldsymbol{B}\right)\right\rangle$$

$$R = \langle\delta\boldsymbol{w}\cdot(\theta'\boldsymbol{w} - \theta\boldsymbol{w}')\rangle,\quad K_{\mathrm{Hall}} = -\frac{1}{4}\boldsymbol{\nabla}\cdot\boldsymbol{H} + \frac{1}{4}C_2,\quad \boldsymbol{H} = \left\langle\delta\boldsymbol{B}\left(\delta\boldsymbol{j}\cdot\delta\boldsymbol{B}\right) - \frac{1}{2}\delta\boldsymbol{j}|\delta\boldsymbol{B}|^2\right\rangle$$

KHM equation in the 2D hybrid simulation

$-\partial S/\partial t/4$

decay

K_{MHD}

MHD cascade rate

K_{Hall}

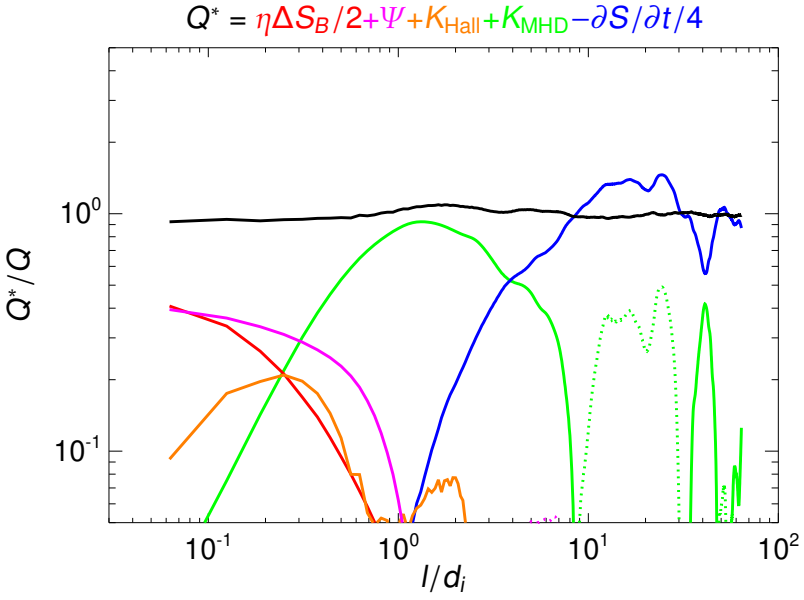
Hall cascade rate

Ψ

pressure-strain term

$2\eta\Delta S_b^{(i)}$

dissipation term



Summary

Ion-scale transion/break: a combination of

- onset of Hall physics
- onset of “dissipation”
- pressure-strain coupling can play a role of an effective dissipation channel

iopscience.iop.org/article/10.3847/1538-4357/ac5fad