Co-existence of Turbulence and Discrete Modes in the Solar Wind

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The *p*- and *g*-mode in the SW controversy

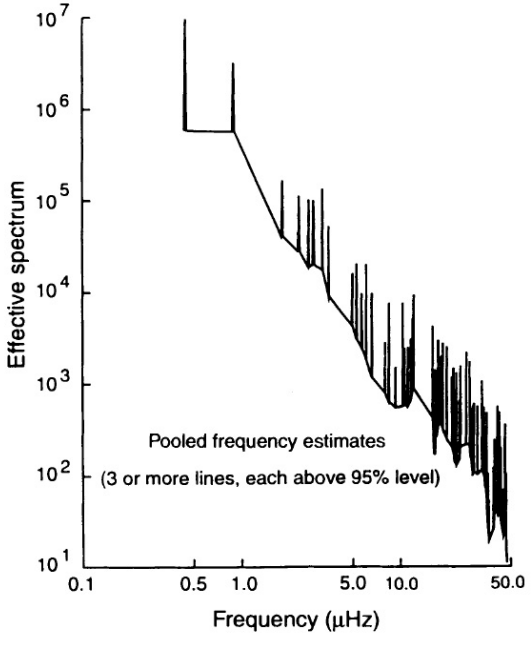
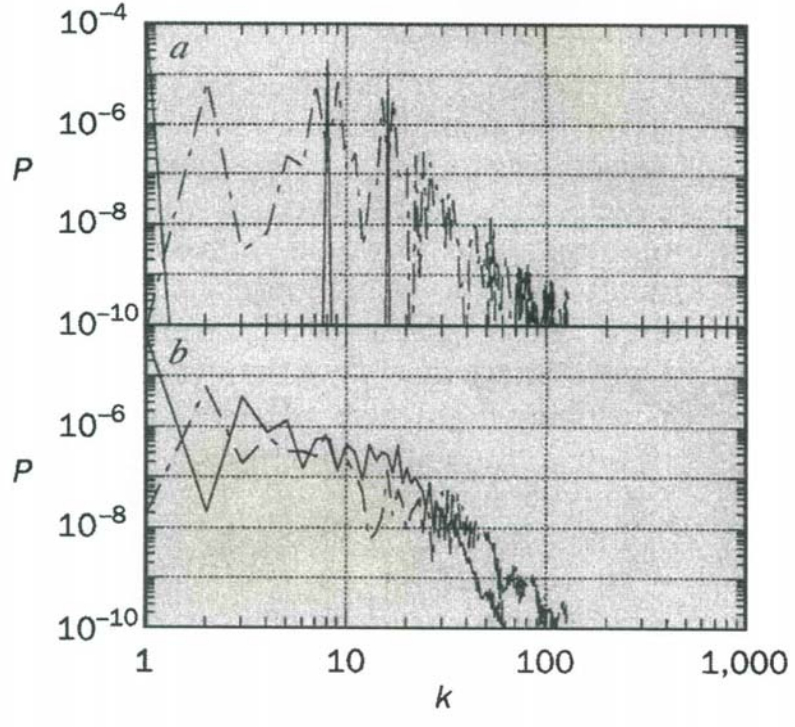


FIG. 3 Line spectrum in the *g*-mode frequency range derived from three or more frequency coincidences in the spectra of interplanetary particle fluxes.

Thomson et al, Nature, **376**, 139 (1995)



a, Power spectrum of the initial magnetic field (solid) and field magnitude (dot-dash) for a compressible MHD simulation. *b*, Same as *a* but at a later time.

Roberts et al, Nature, **381**, 31 (1996)

Discrete modes & turbulence in a coronal geometry

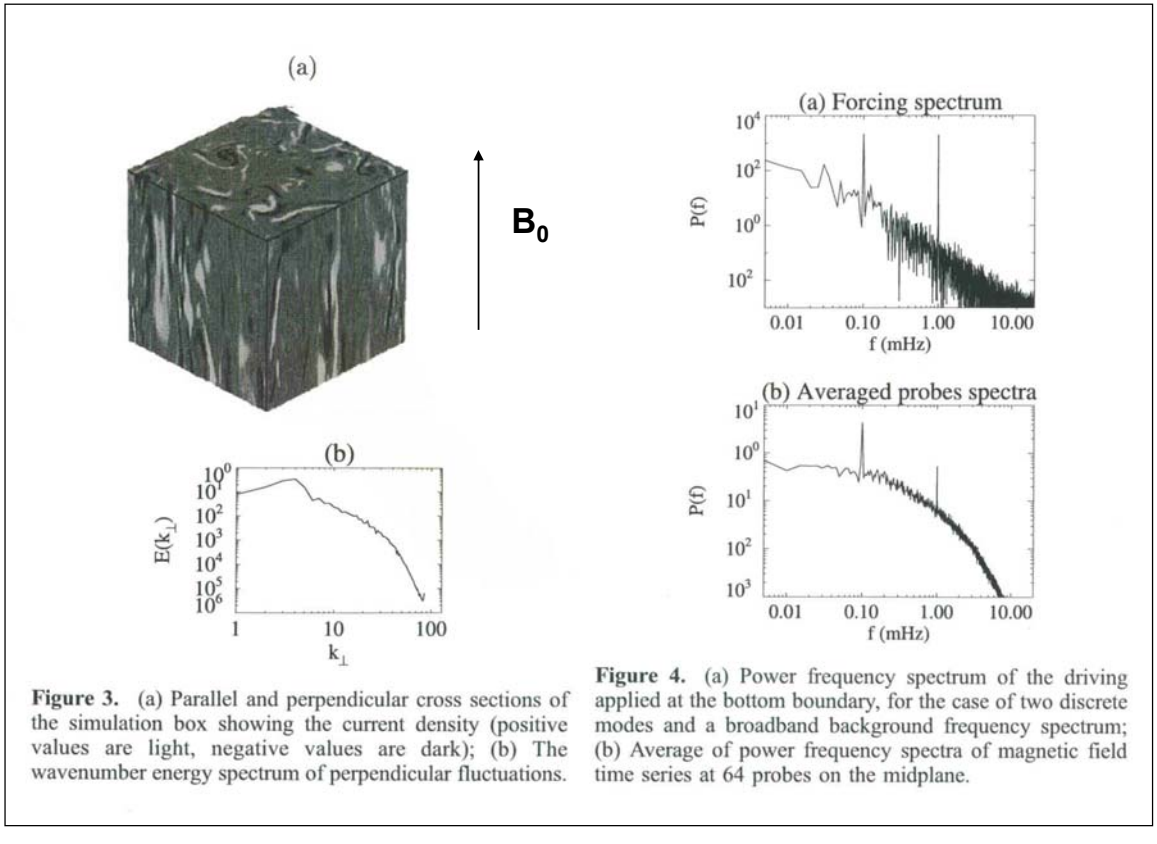


Figure 3. (a) Parallel and perpendicular cross sections of the simulation box showing the current density (positive values are light, negative values are dark); (b) The wavenumber energy spectrum of perpendicular fluctuations.

Figure 4. (a) Power frequency spectrum of the driving applied at the bottom boundary, for the case of two discrete modes and a broadband background frequency spectrum; (b) Average of power frequency spectra of magnetic field time series at 64 probes on the midplane.

Dmitruk et al, GRL, **31**, 21,805 (2004)

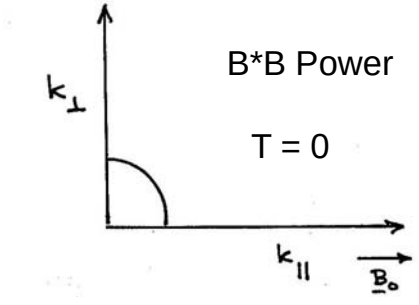
3-D Reduced MHD simulations by Dmitruk, Matthaeus & Lanzerotti.

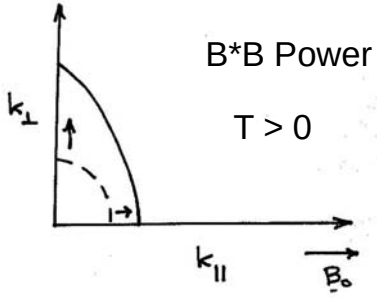
Reduce MHD: Appropriate for weakly compressible plasma in the presence of a strong magnetic field.

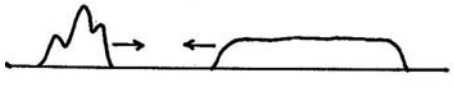
Simulations:
Mean B-field in z-direction;
No plasma flow in z-direction;
Velocity (*p*-mode) time-dependent stirring at z=0;
Frequency analysis at z=0 and $z=z_{max}$;

Anisotropy in MHD turbulence due to a mean magnetic field

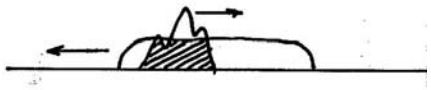
Shebalin et al, J. Plasma Phys., **29**, 525 (1983)

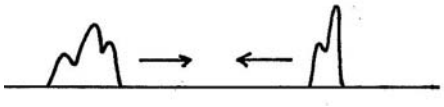






Interactions with low k-modes





Interactions with high k-modes

3D MHD System

1) $$\frac{\partial}{\partial t}\rho + \nabla \bullet (\rho \underline{u}) = 0$$

2) $$\frac{\partial}{\partial t}\underline{u} + \underline{u} \bullet \nabla \underline{u} = -\frac{1}{\rho}\nabla P + \frac{\underline{J} \times \underline{B}}{\rho} + D_u$$

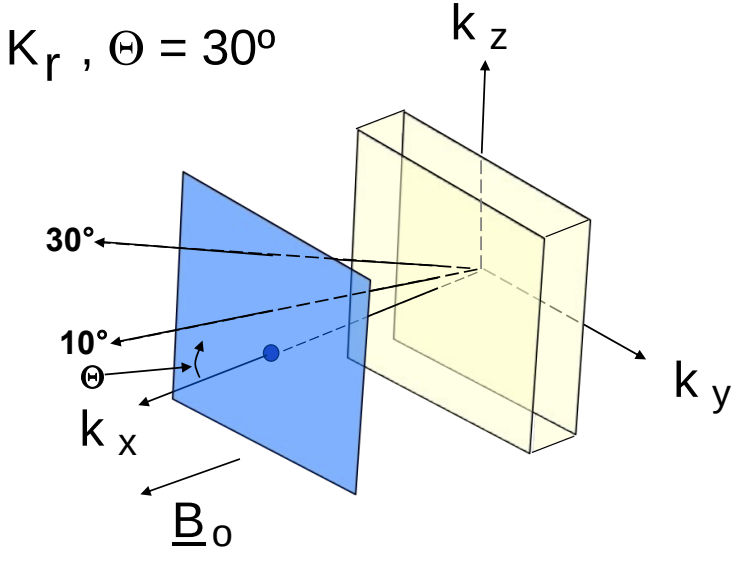
3) $$\frac{\partial}{\partial t}\underline{A} = \underline{u} \times \underline{B} + D_a$$

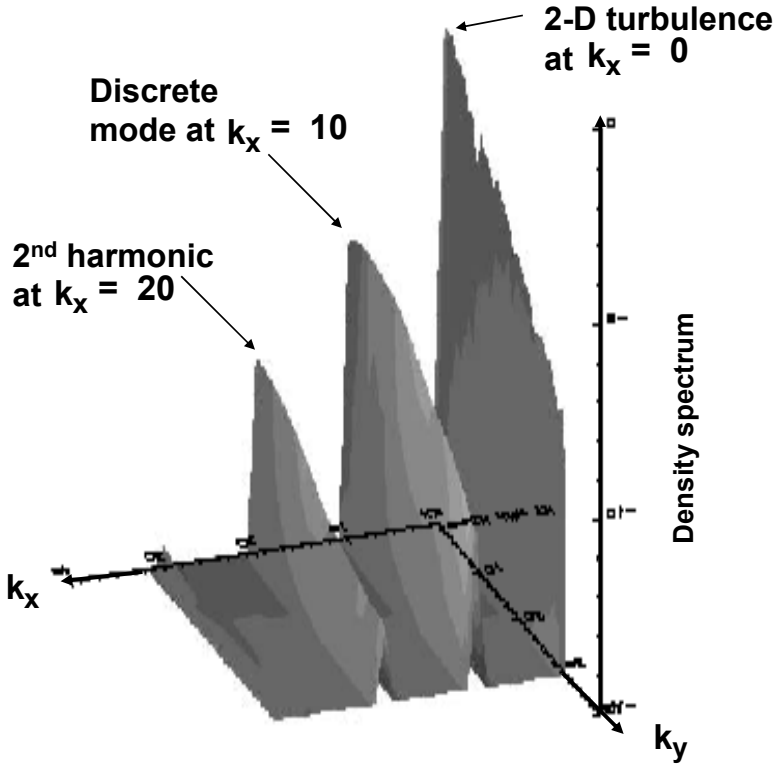
where $P \sim \rho^{\gamma}$ $\gamma = 5/3$

Dissipation: $D_u \sim k^4 \underline{u}_k$ $D_a \sim k^4 \underline{a}_k$

Grid sizes = 64 x 64 x 64 and 128 x 128 x 128

Simulation Geometry

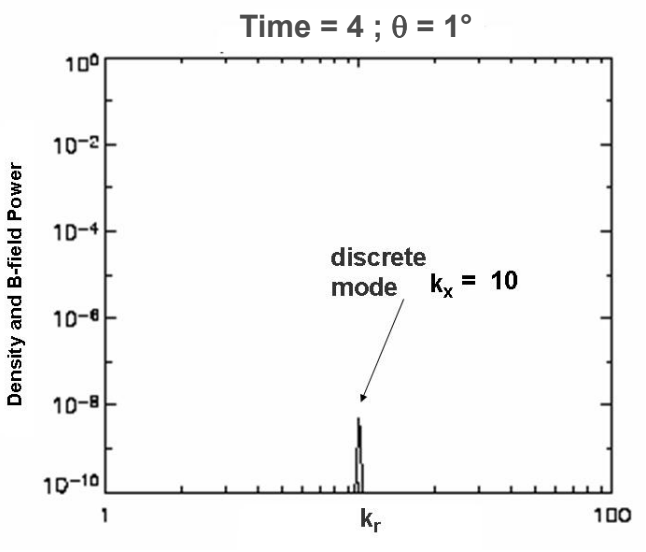


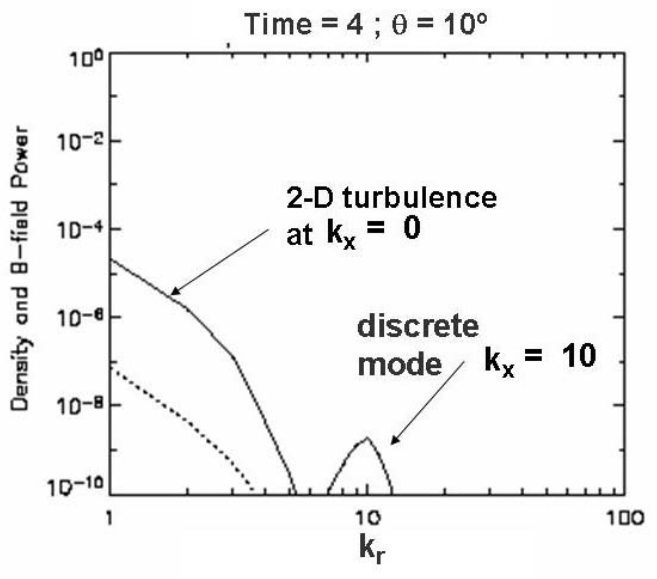


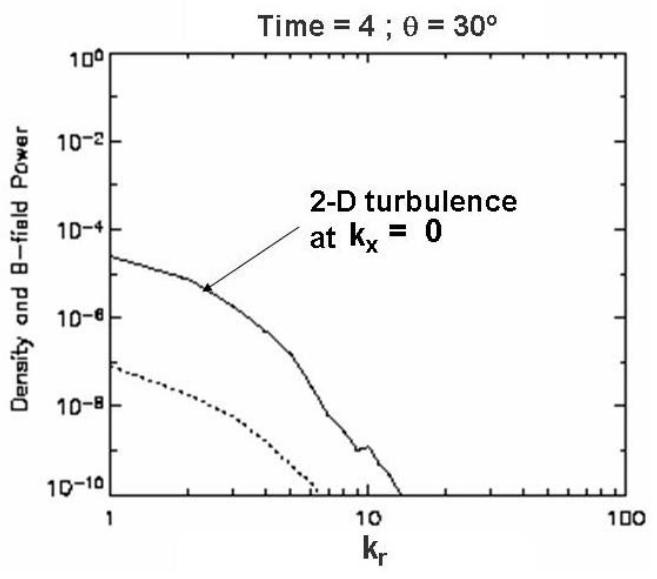
- Reduced spectra k_r : $\tan\theta = \frac{k_r}{k_x}$

- Driven 2-D turbulence at $k_x = 0$
- Decaying discrete mode at $k_x = 10$

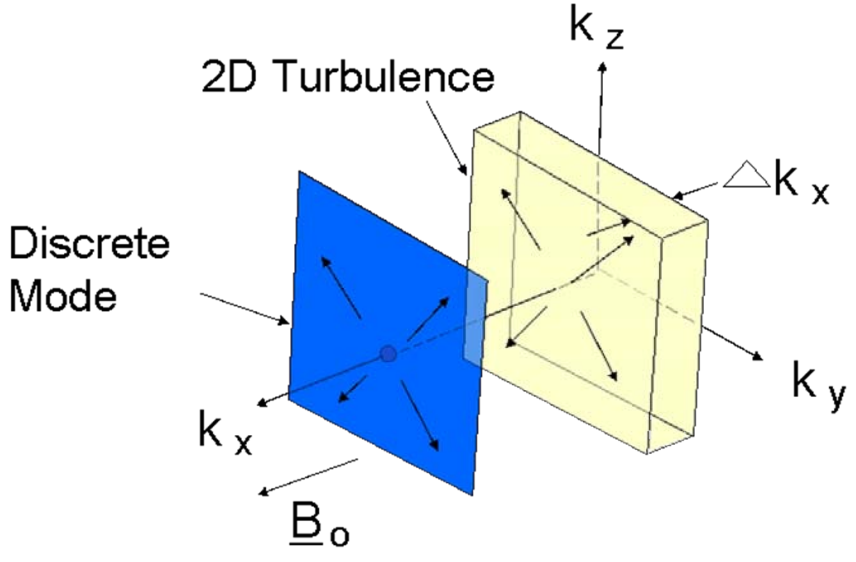
Reduced Spectra of the same plasma state measured at different Θ angles to the mean magnetic field







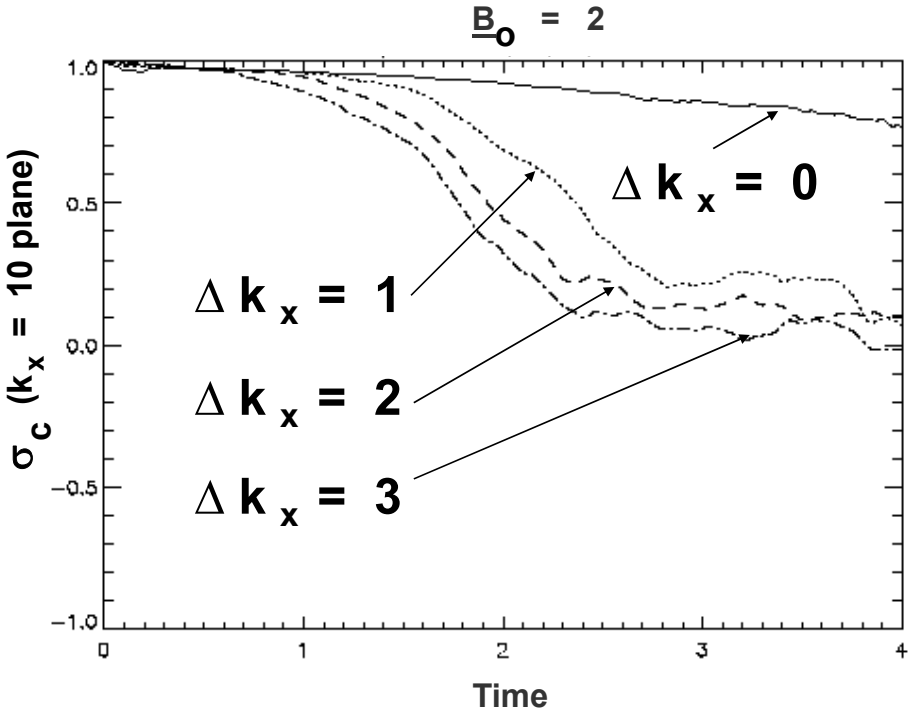
The effect of turbulence with non-zero $\Delta k_{||}$ bandwidth

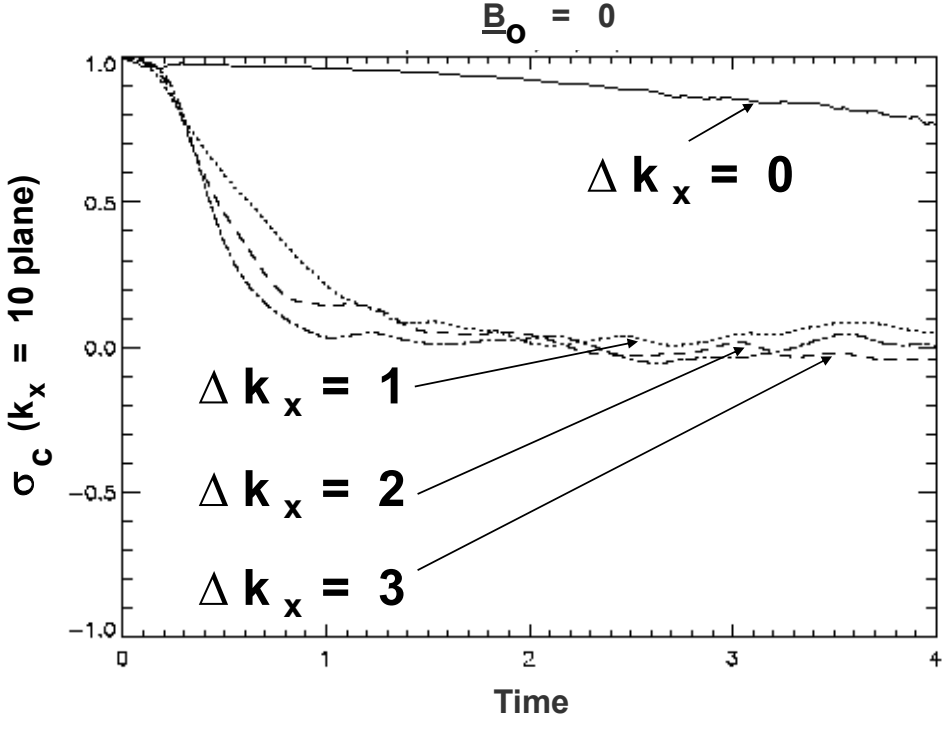


Time > 0

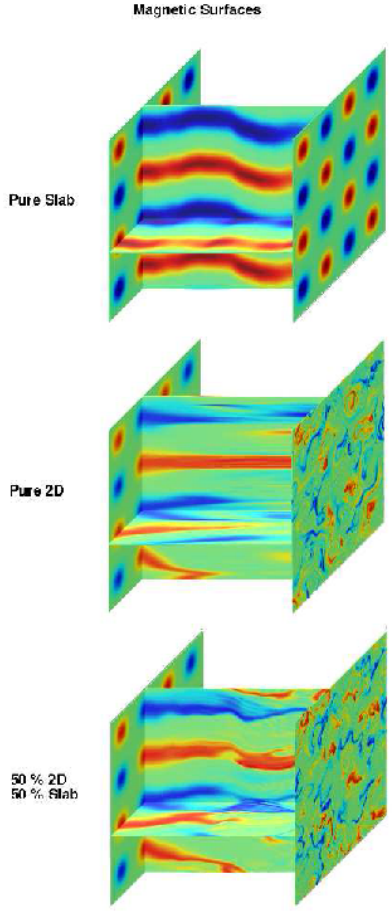
Survivability of Monochromatic Alfvénic (high cross-helicity) Mode

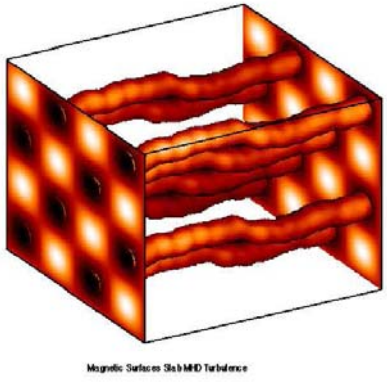
- Initial discrete mode $\sigma_c = \dfrac{2\,\underline{u} \bullet \underline{B}}{\underline{u} \bullet \underline{u} + B \bullet B} = +1$ at $k_x = 0$
- Driven 2-D turbulence with k_x bandwidths: $\Delta k_x = 0, 1, 2, 3$

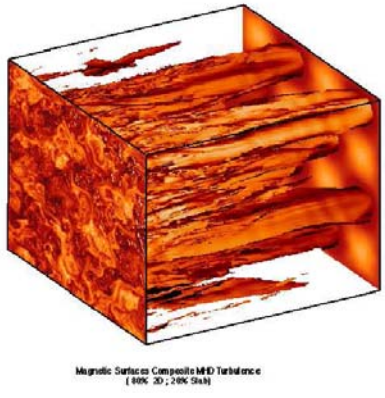




Magnetic Surfaces & Field-Line Renditions







Conclusions

- Discrete modes and turbulence can co-exist for several nonlinear times;

- Persistence of the discrete mode depends on
  - Presence of a background B_0 field
  - Large separation between the $k_{||}$ bandwidth of turbulence and the discrete mode's $k_{||}$ wavenumber;

- Direction of reduced spectrum (k_r) wrt B_0 influences observability.