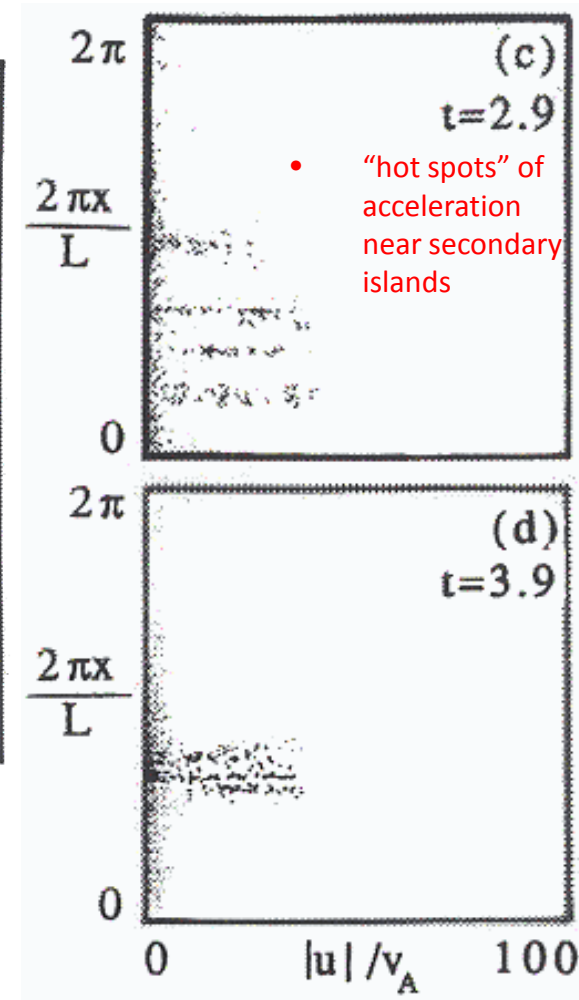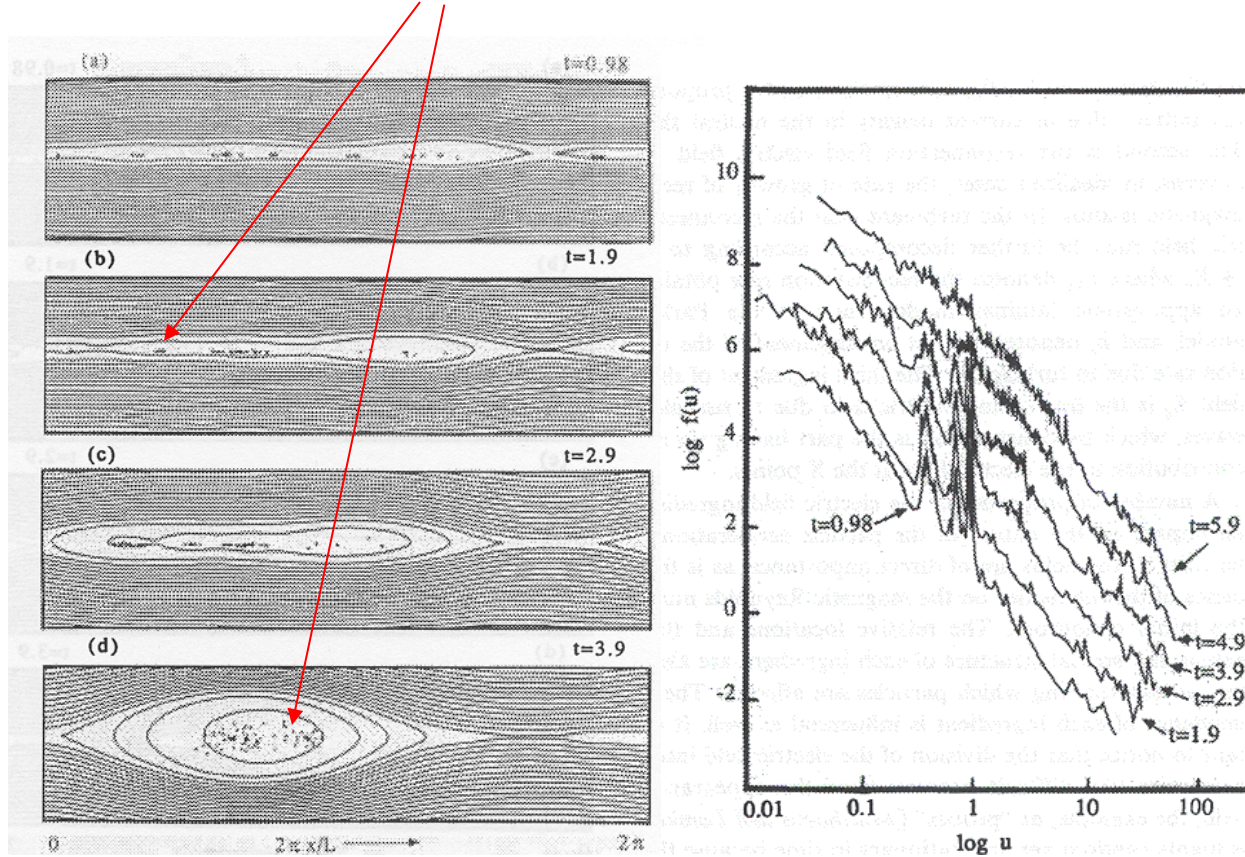# Multiple islands and acceleration in a turbulent environment

W H Matthaeus

Test particle acceleration by turbulent reconnection

**High energy particles**

- "hot spots" of acceleration near secondary islands

Particles are accelerated (direct & velocity diffusion) in region between X- and O-points. Powerlaw/exponential distributions.

Profileration of Xpoints in MHD:
spatial picture and space-time evolution

- A small region of a 16Kx16K Fourier spectral simulation with threefold oversampling of Kolmogorov scale, analyzed on 32Kx32K grid; Rm = 50000, total of 5649 X-points at peak time

Magnetic field lines, electric current density, and X points
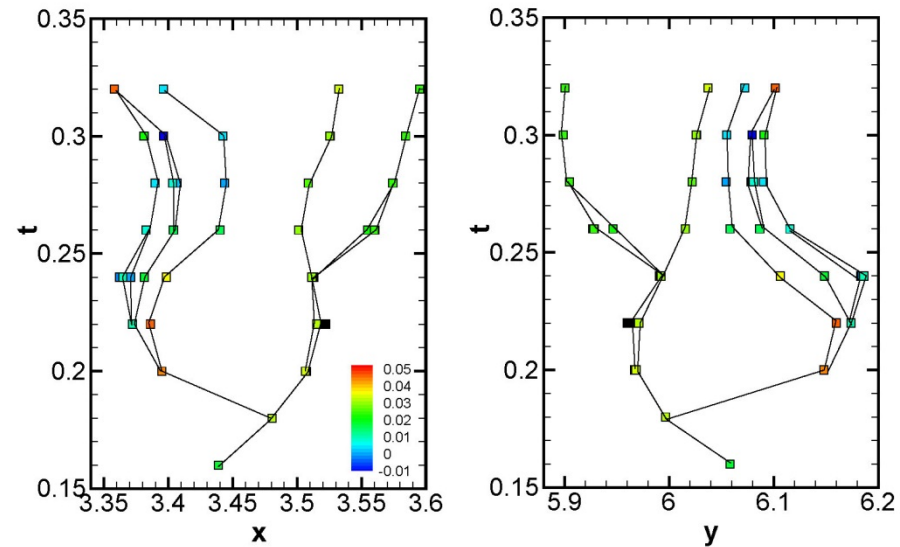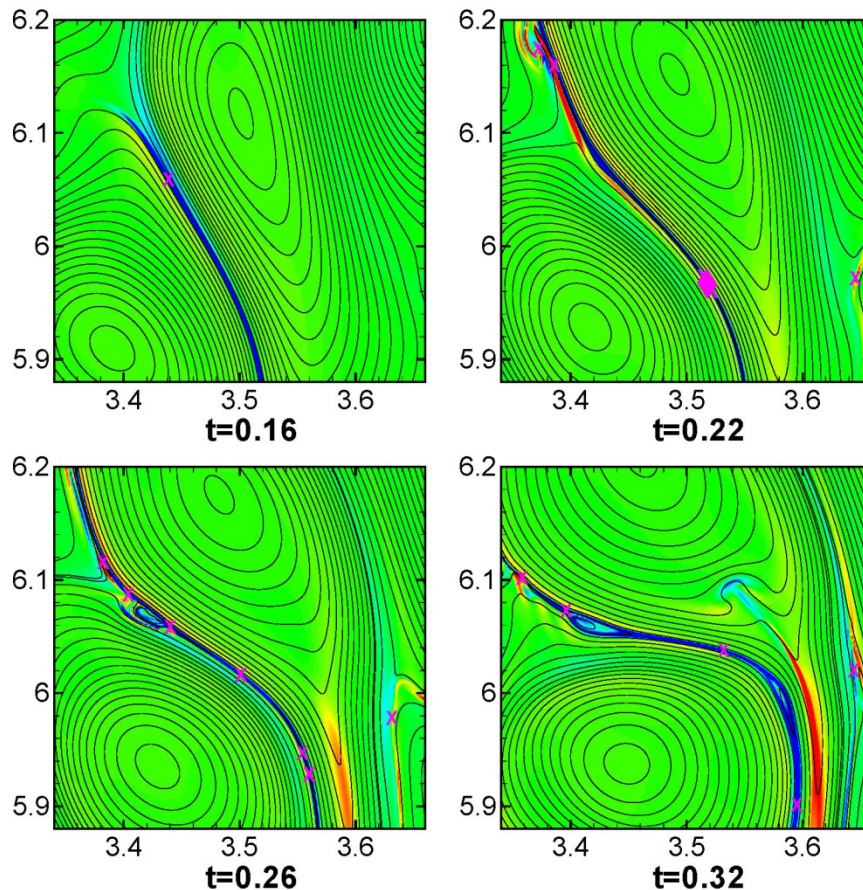
Space-time development
of X-points and reconnection rates
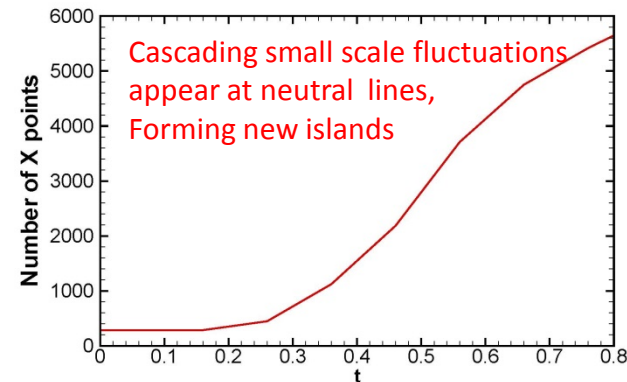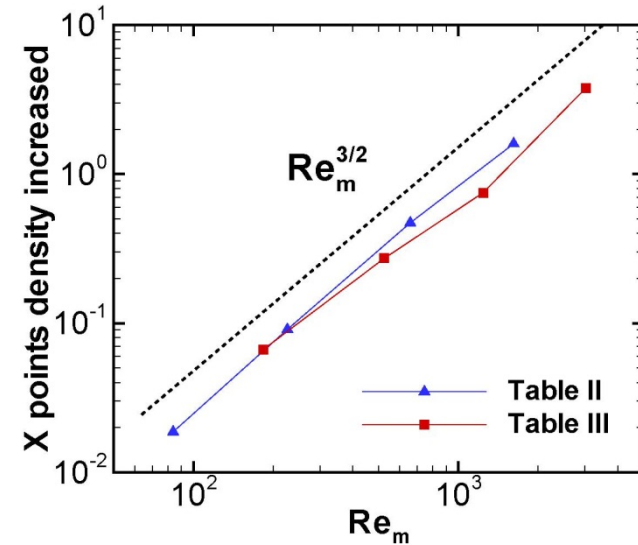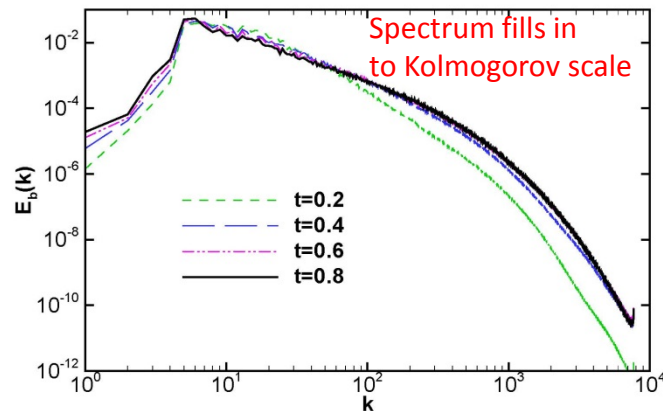in this small region

Plasmoid scaling properties in MHD

Examine many runs at varying resolution, initial data and Reynolds numbers

- Number of Xpoints/flux tubes

  - Vs Rm (at peak dissipation)

  Can be understood in terms of basic cascade physics
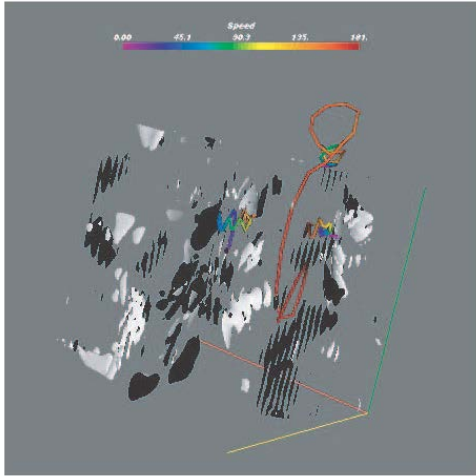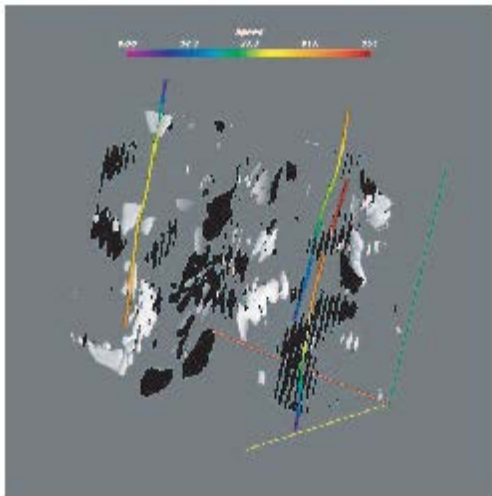
  - vs time

$Re_m^{3/2}$

X points density increased vs Re_m

Table II
Table III

Spectrum fills in to Kolmogorov scale

$E_b(k)$ vs k

t=0.2
t=0.4
t=0.6
t=0.8

Cascading small scale fluctuations appear at neutral lines, Forming new islands

Number of X points vs t

- Resolution 16384^2
- Rm=50000
- Kmax/Kdiss = 3.4
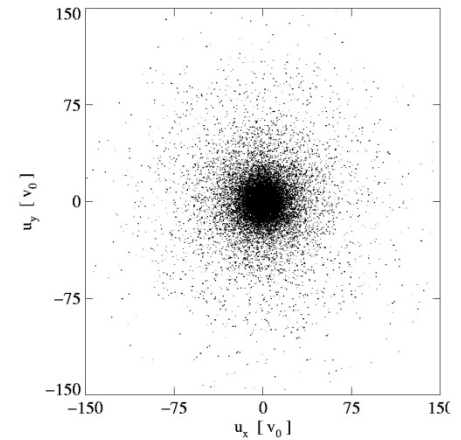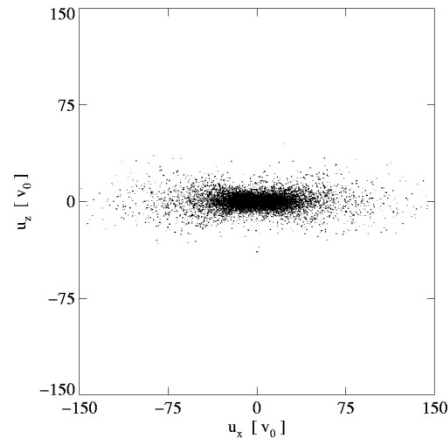
3D MHD/test particles with strong B_0:   distributions at short times <crossing time of Lc
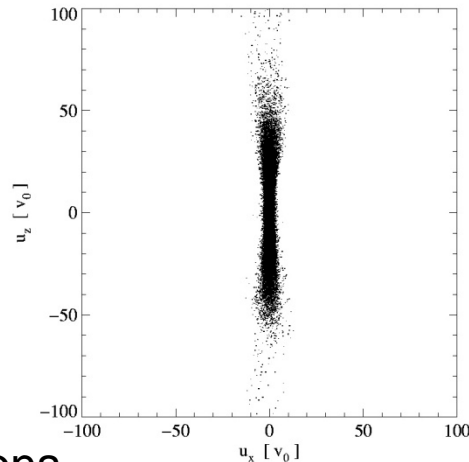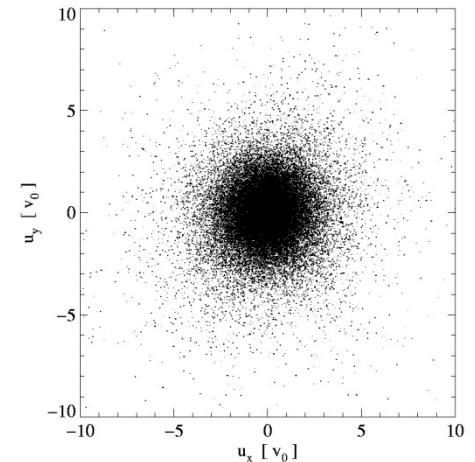

protons

Trajectories and current structures

B_0 direction

perp plane
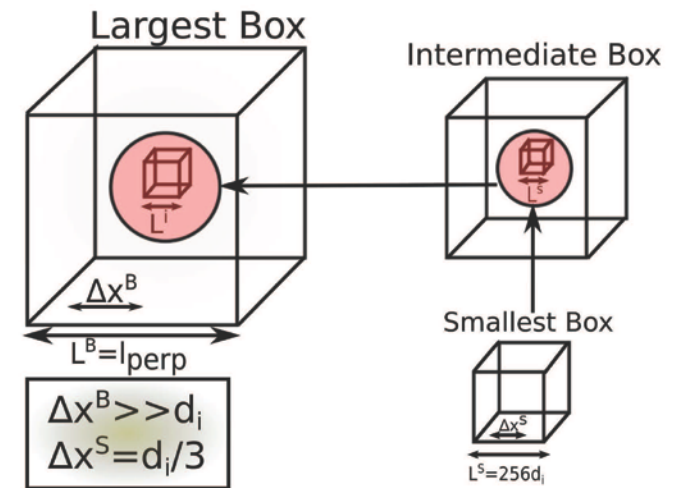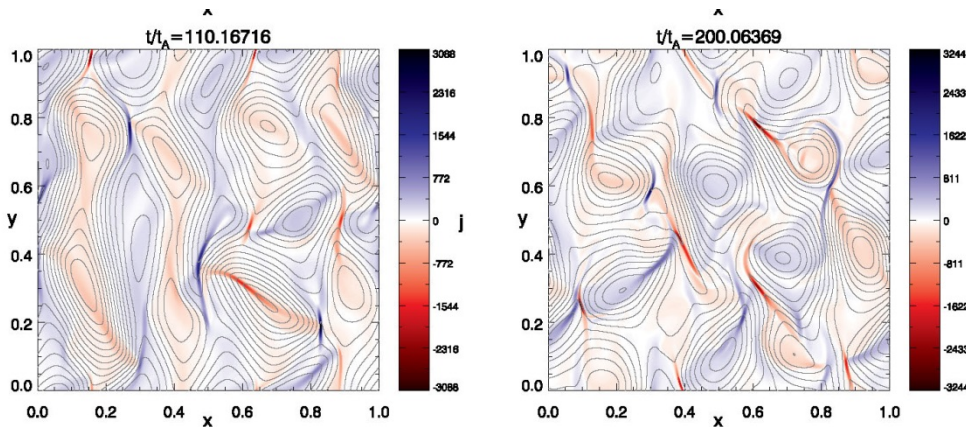
electrons

Dmitruk et al, 2004
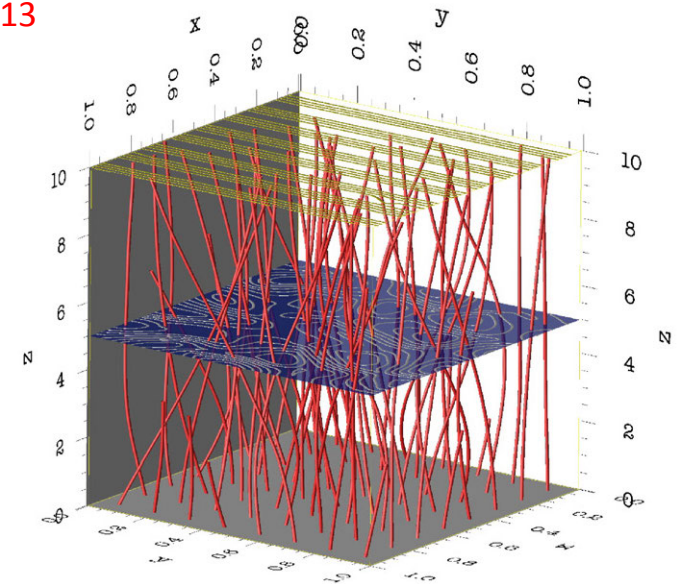
Test particles in RMHD coronal loop model
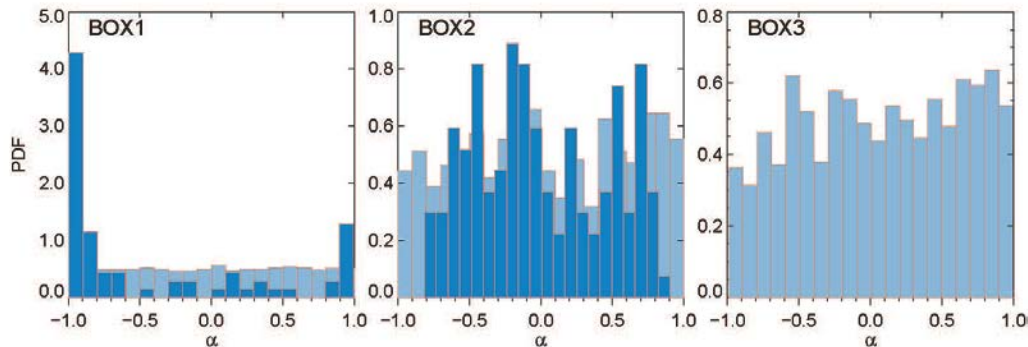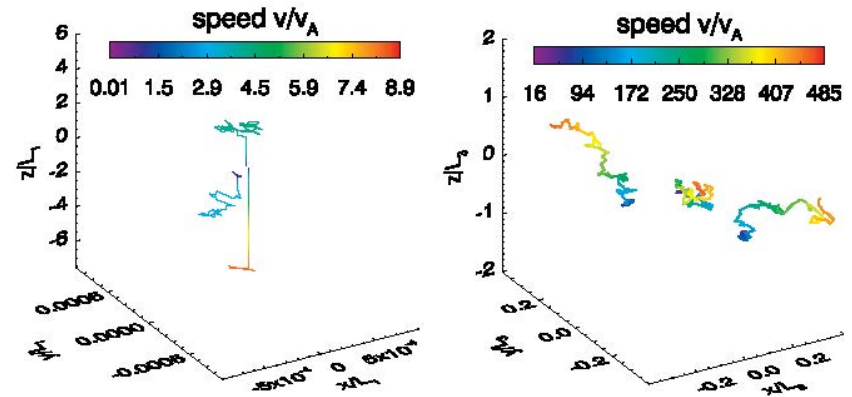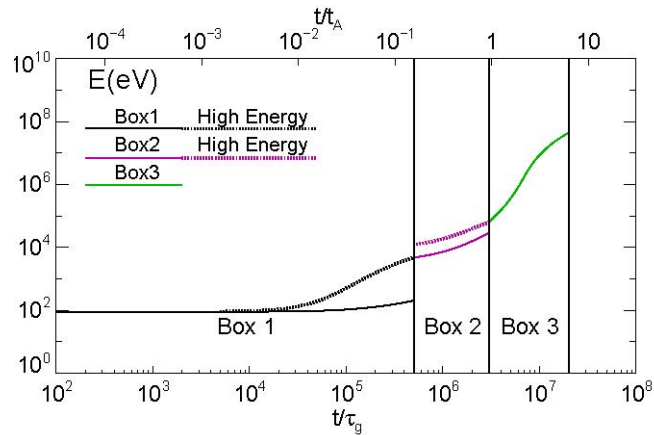
Dalena, Rappazzo, Matthaeus 2013

- MHD data from driven (weakly) 3D spectral method simulation
- Multibox model – maintains possibility of *resonant pitch angle scattering* at all times

Rappazzo et al, ApJ 2008, 2010

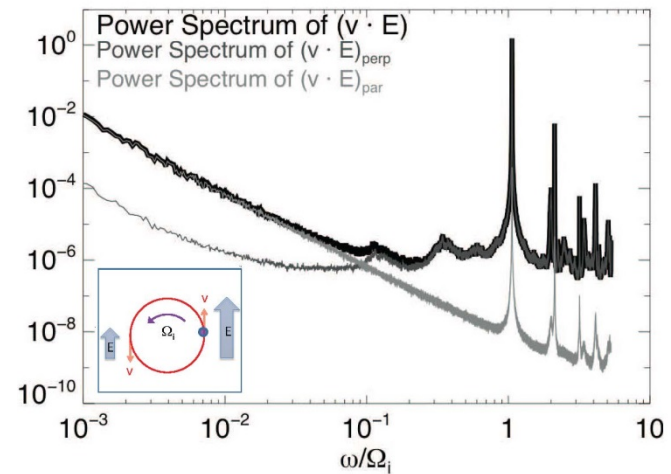$\Delta x^B >> d_i$
$\Delta x^S = d_i/3$

hierarchy of boxes

RMHD-multibox: two stage acceleration

Stage !: small gyroradii
→Direct parallel acc.
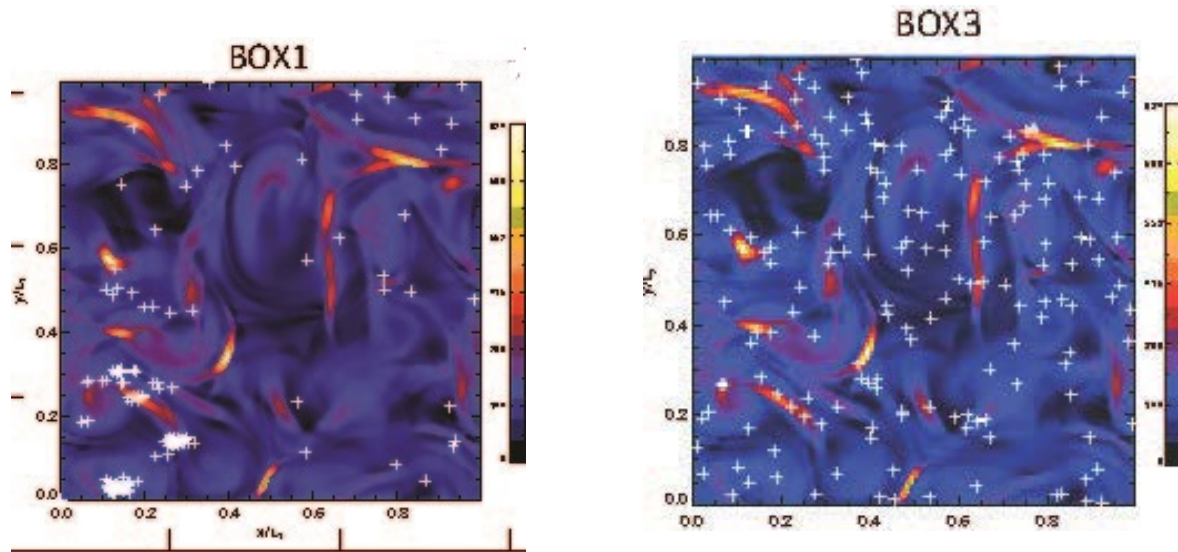
Stage 2: larger gyroradii
→ Perp. Betatron acc.

Later: betatron +
strong scattering

pitch angle distributions: dark=highest energy
light = all

Large **resonant** contribution:
Not parallel wavenumbers!

RMHD multibox

Stage 1 – parallel acceleration dominates, highly associated with current sheets

Stage 2, larger gyroradii, perpendicular acceleration dominates;
        resonant (as in betatron);
        associated with electric field inhomogenities,
        and therefore more loosely with current structures

Discussion points

- When are these "the same" and when ate they different?
  - Reconnection
  - Particle acceleration
  - Dissipation

- Is the 2D reconnection paradigm viable?

- Topology become pretty fuzzy when there are so many small islands

- How are reconnection rates defined in 3D?

- 3D effect: two stage acceleration

- Is particle acceleration closely related to dissipation when collisions are weak?

- Implications for LES/SGS ?