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Title:	Flux ropes, current sheets, islands and turbulence
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Flux ropes, current sheets, islands and turbulence

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Abstract

We describe earth bound laboratory experiment investigations of patchy, unsteady, bursty, patchy magnetic field structures that are unifying features of magnetic reconnection and turbulence in helio, space and astro physics. Flux ropes are ubiquitous structures on the sun and the rest of the heliosphere. We use experimental probes inside the the flux ropes to macroscopic magnetic field lines, unsteady wandering characteristics, and dynamic objects with structure down to the dissipation scale length. can be traced from data sets in a 3D volume. Computational approaches are finally able to tackle simple 3D systems and we sketch some intriguing simulation results that are consistent with experimental data for magnetic reconnection and turbulence.

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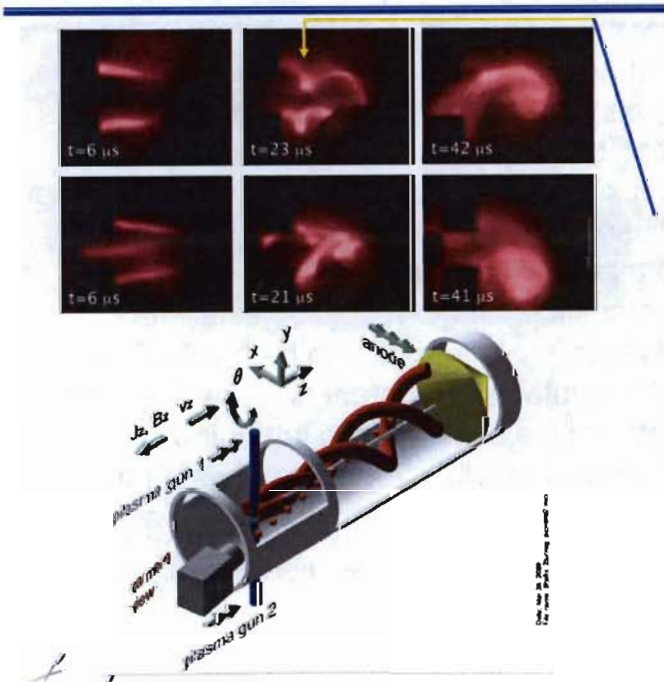
Outline

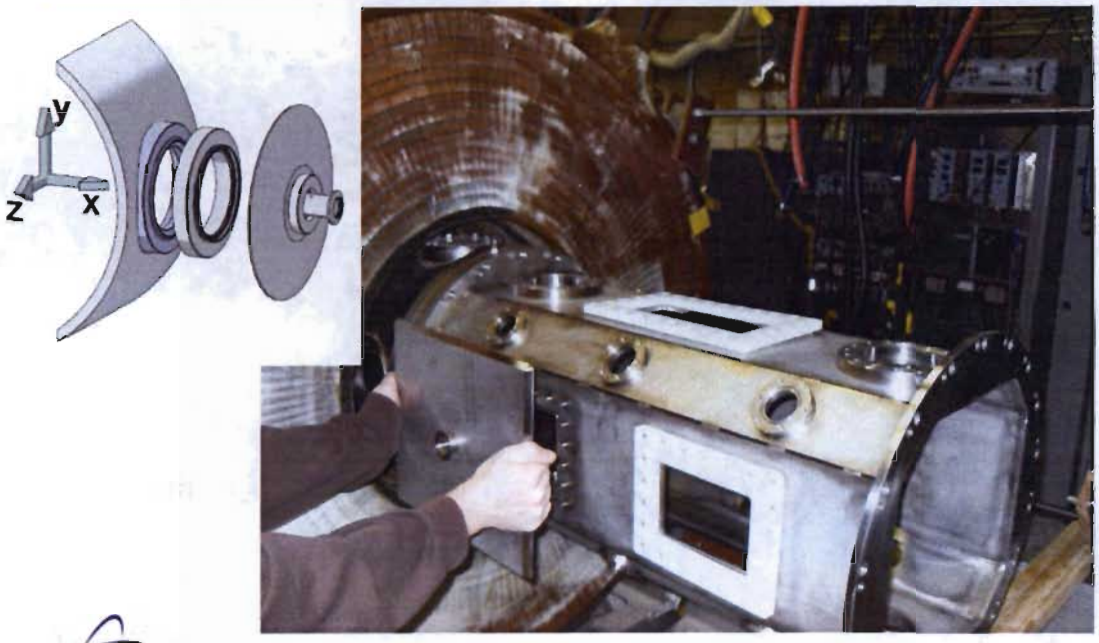
- MagnetoHydroDynamic (MHD) magnetic fields can have 3D micro structure that is quite different from external macro structure.
- RSX experimental model: 2 flux ropes = macroscopic B lines
  - Implications for turbulence
- FRC data in island-plasmoid-flux rope formation regimes

RSX experiment: flux ropes in 3D

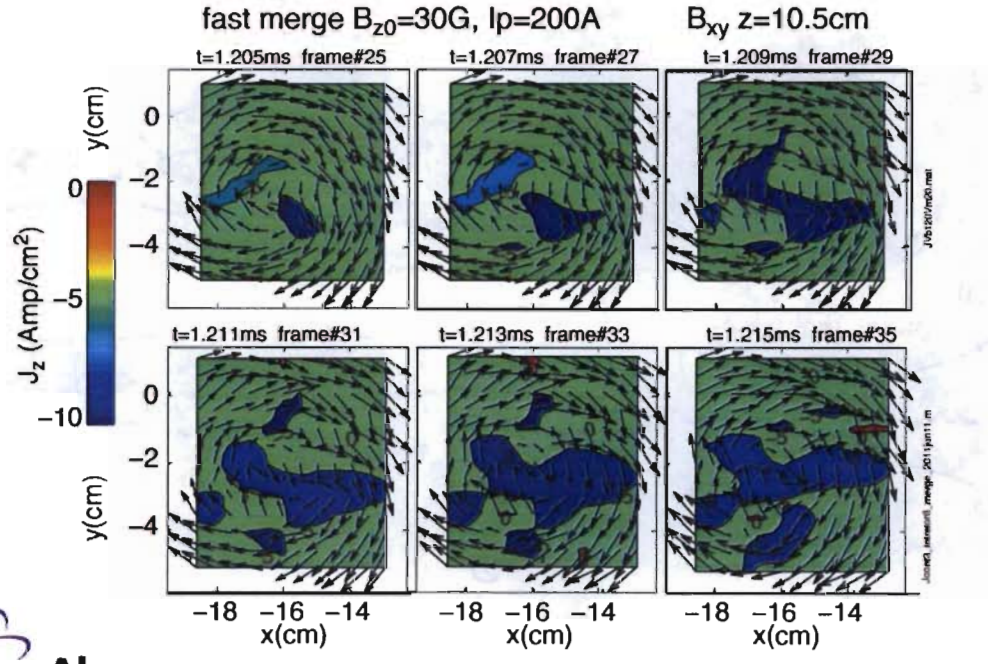


- Camera view is end-on & perspective
- Data shown here:
- Kinked flux ropes bump into each other at a 3D patch
- Note 3D localization of X-lines
- X-point-line "zippers" *upstream towards* gun
- Knob from 2D to 3D by reducing guide B field

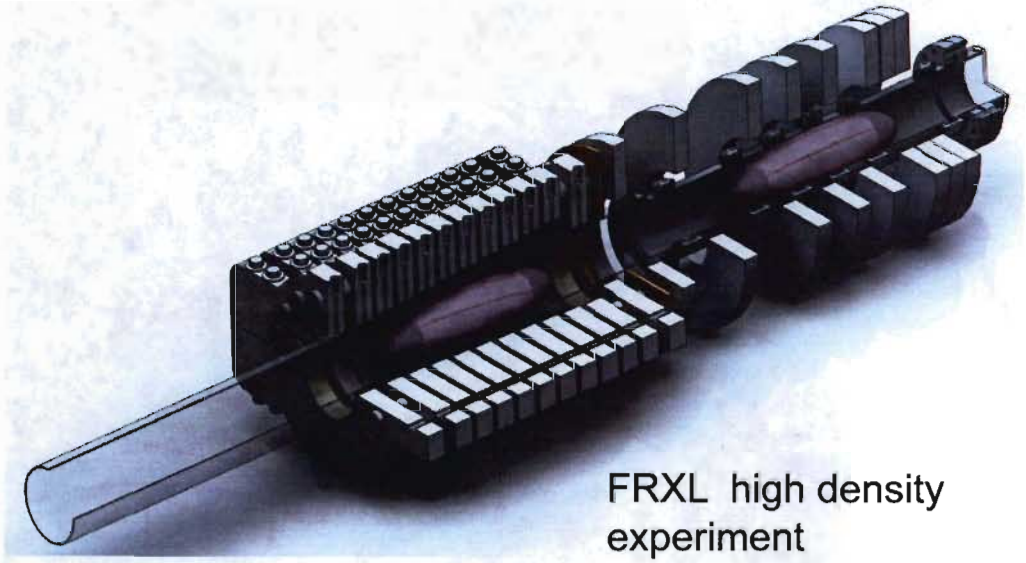
3D Scuff probe positioner



RSX: island-plasmoid subdivisions

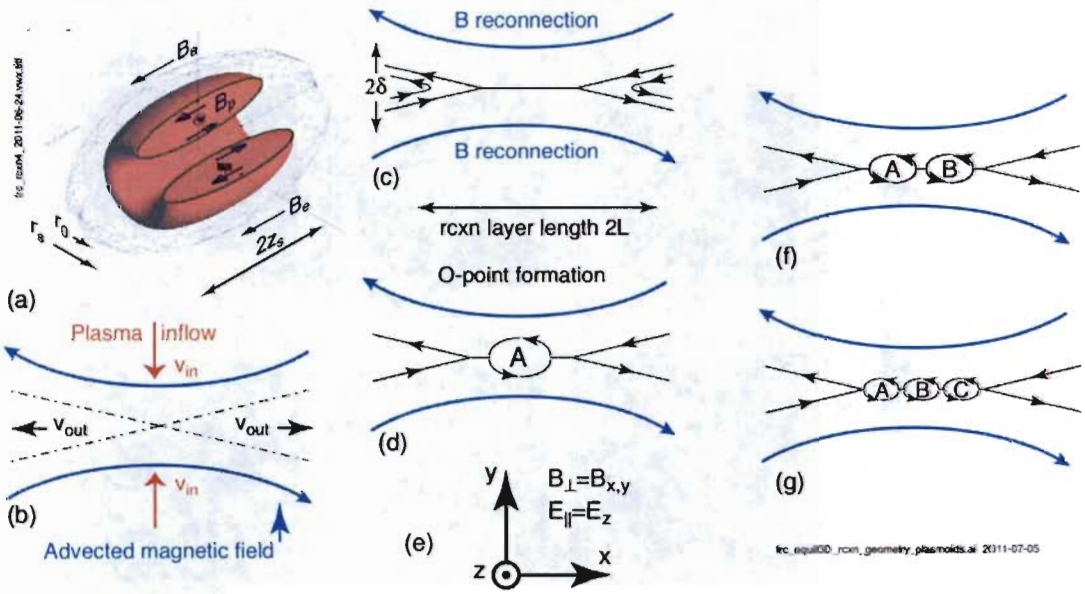


FRC data: island, plasmoid regimes?

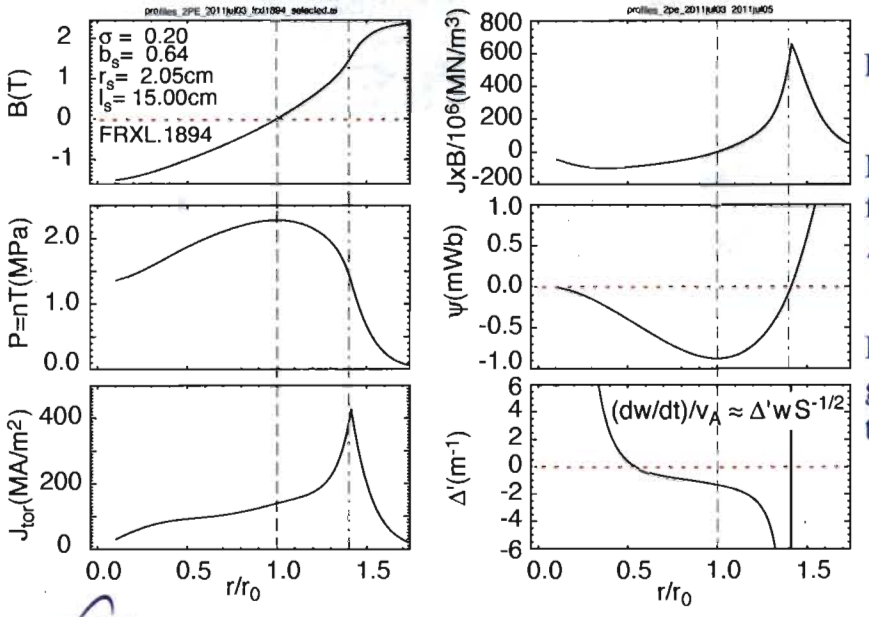


FRXL high density experiment

Sweet-Parker islands



New FRC equilibrium model + FRXL data

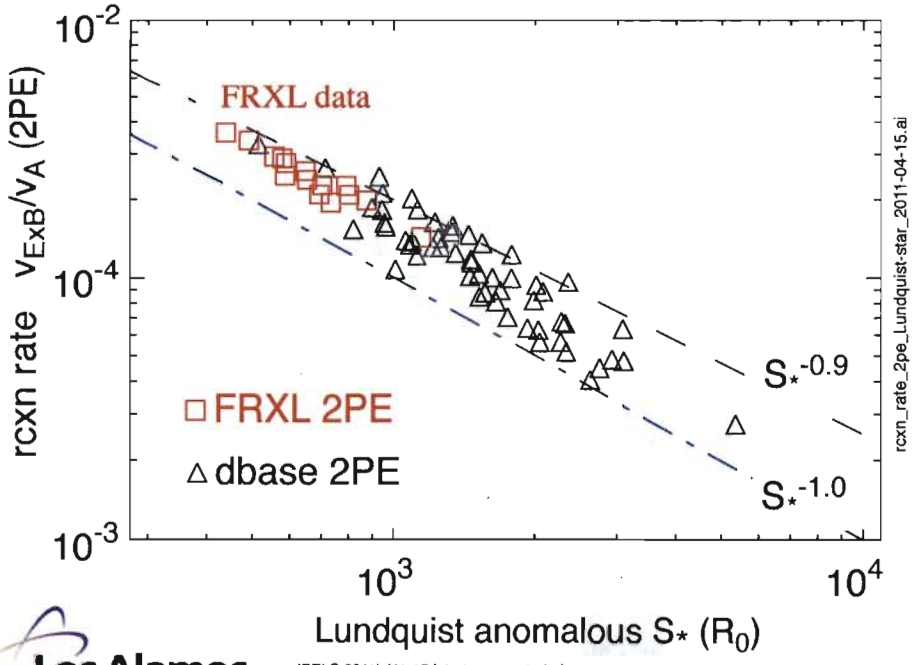


FRXL data

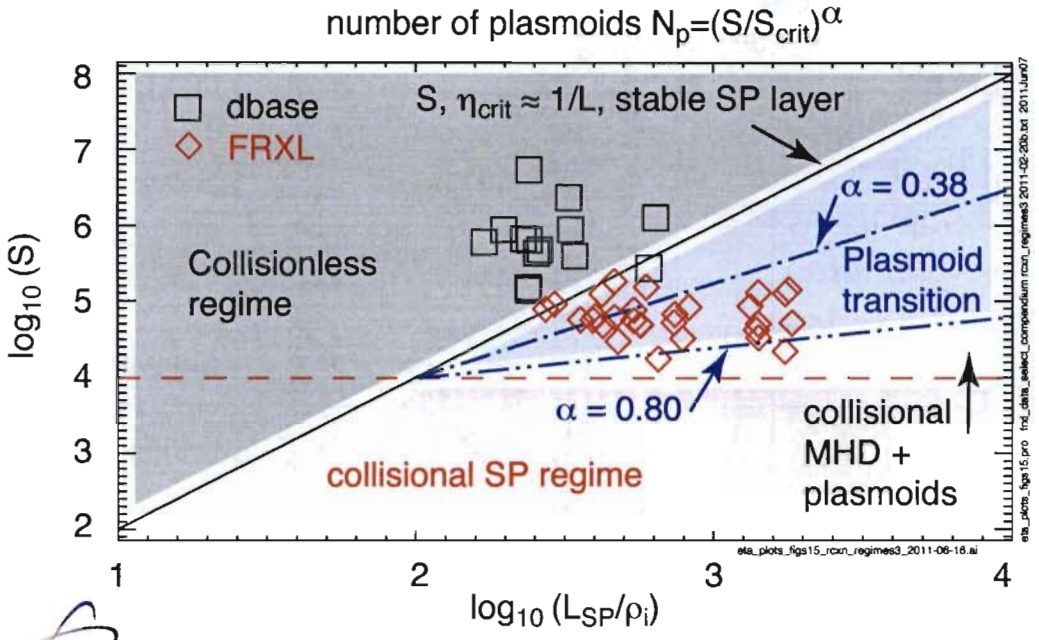
B·∇B restoring force vanishes at Δ' = 0

Instabilities can grow (including tearing modes)

Flux annihilation rate vs anomalous resistivity η^* & Lundquist number S*



Daughton plot of collisionality vs system size



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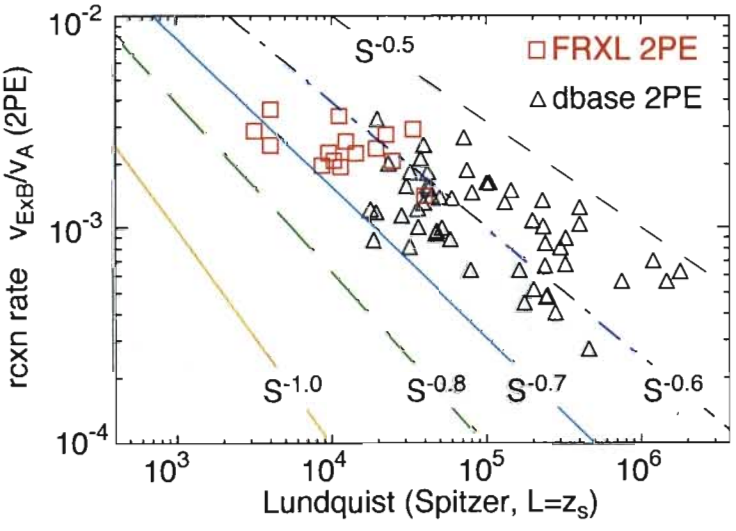
Reconnection rate vs Spitzer resistivity η & Lundquist number S



Field Reversed Configuration worldwide database extends up to $S > 3x10^6$!

regime change at $S>10^4$??

Intrator et al, in prep 2011

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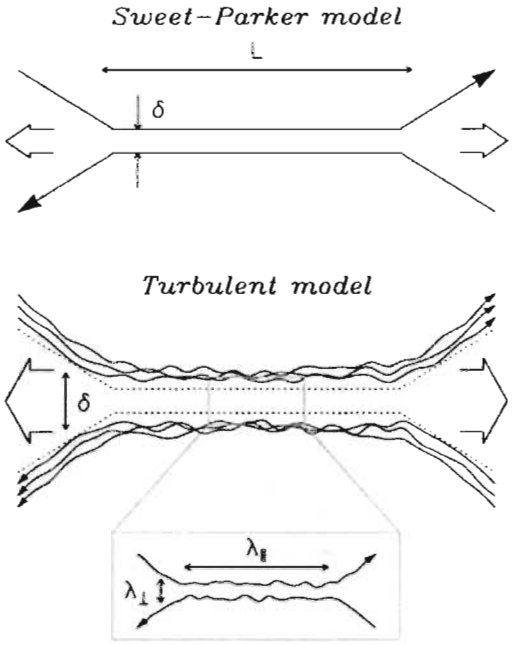
Implications for turbulence?



Regions of sheared, "bumpy", B field can be turbulent

- Lazarian, Vishniac ApJ 1999
- Kowal 1999

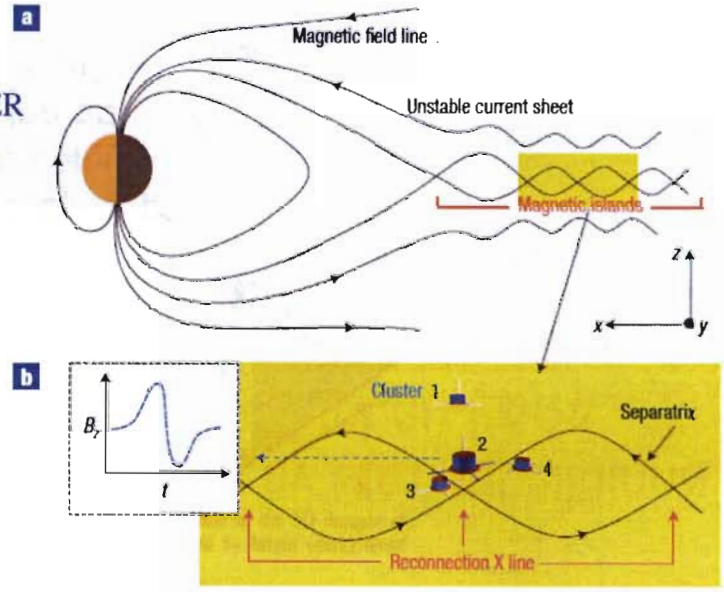
Secondary islands = multiple flux ropes

- 3D structure!
- Discontinuous X-lines in the out of plane direction
- Daughton et al, Nature-Physics 2011

For weaker guide fields, primary flux ropes are kink unstable !

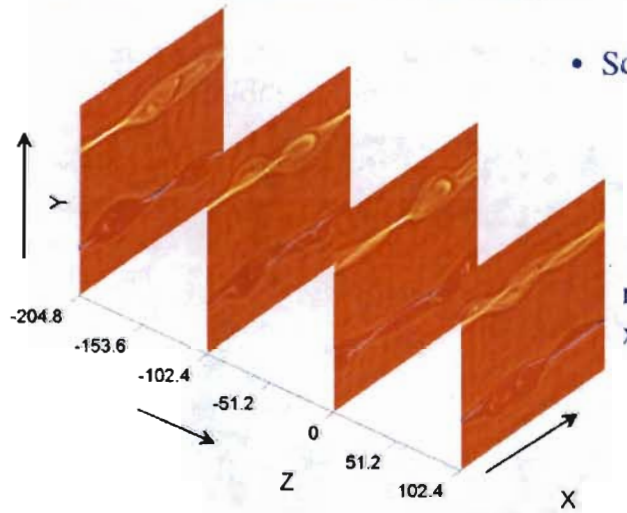
Spacecraft observation of secondary islands

Chen et al, CLUSTER data in magnetotail, Nature 2007



Reconnection current sheet simulations

- Schreier et al, PoP2010



Slices of J_z (out of plane reconnection current density) in x-y cutplanes

FIG. 3. (Color online) Slices of J_z in the x-y plane of the 3D domain at t=84. The upper (lower) current sheet is denoted by bright (dark) areas representing positive (negative) currents.

Reconnection current sheet simulations

- Schreier et al, PoP2010 (but look at RSX data slides 6,10!?)

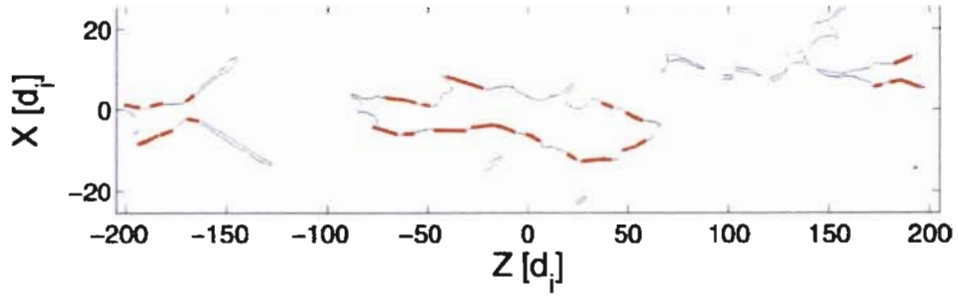


FIG. 5. (Color online) Edges of the projection of the strong current density at $t=201$ on the x-z plane and detected by the Canny method are shown in black. The thicker (red) lines are the result of the Hough transform.

- Projection onto x-z plane shows 3D structure!
- Discontinuous X-lines in the out of plane direction

Conclusion

- MagnetoHydroDynamic (MHD) magnetic fields can have 3D micro structure down to dissipation scales.
- Different external and internal structure
- RSX experimental data + flux rope shredding
- FRC data
  - Island-plasmoid-flux rope formation regimes
  - Tearing unstable turbulence?