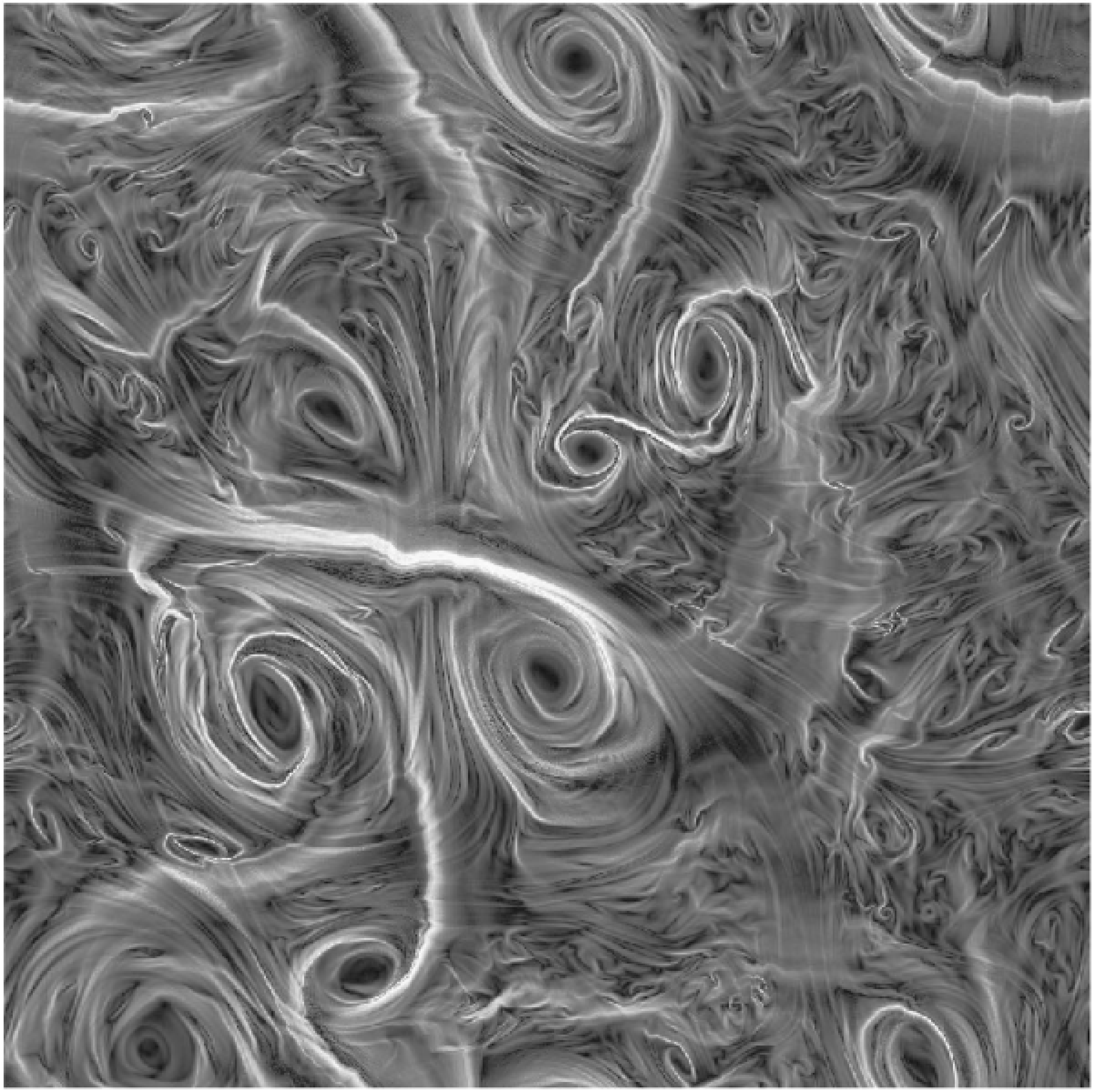
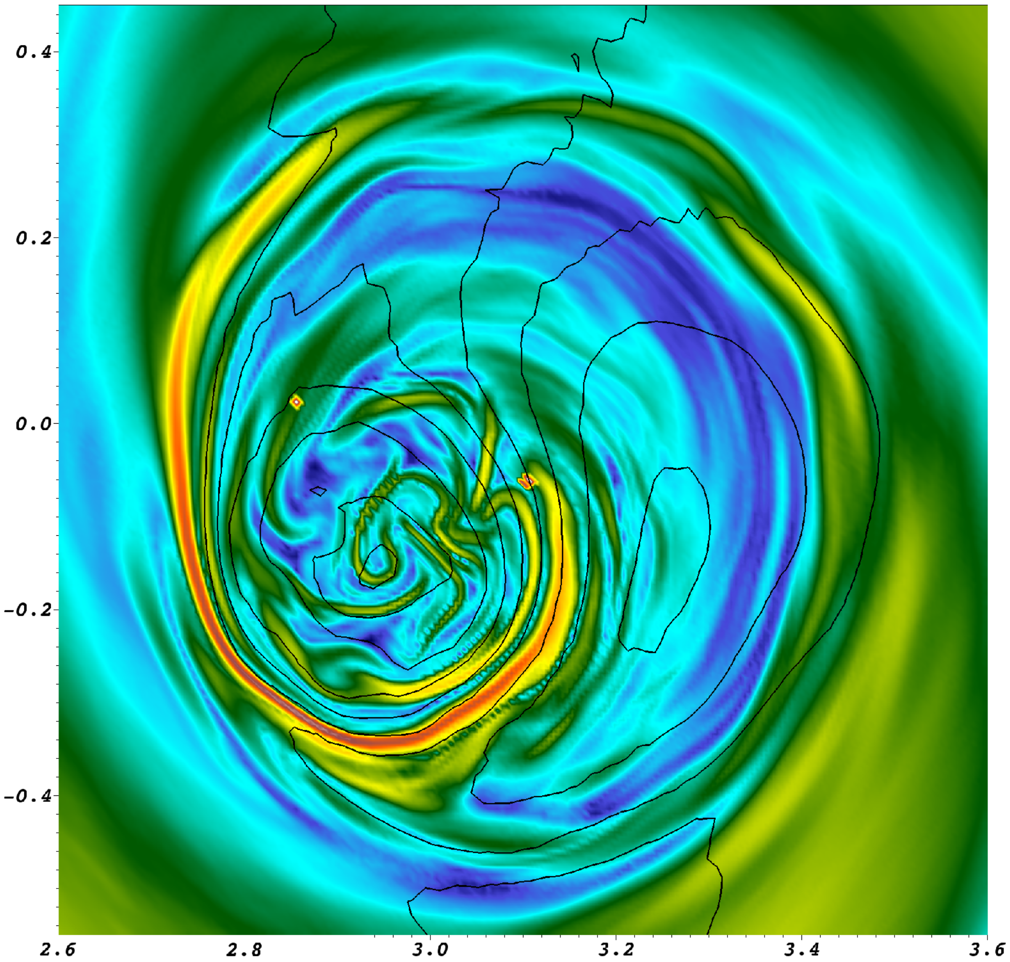


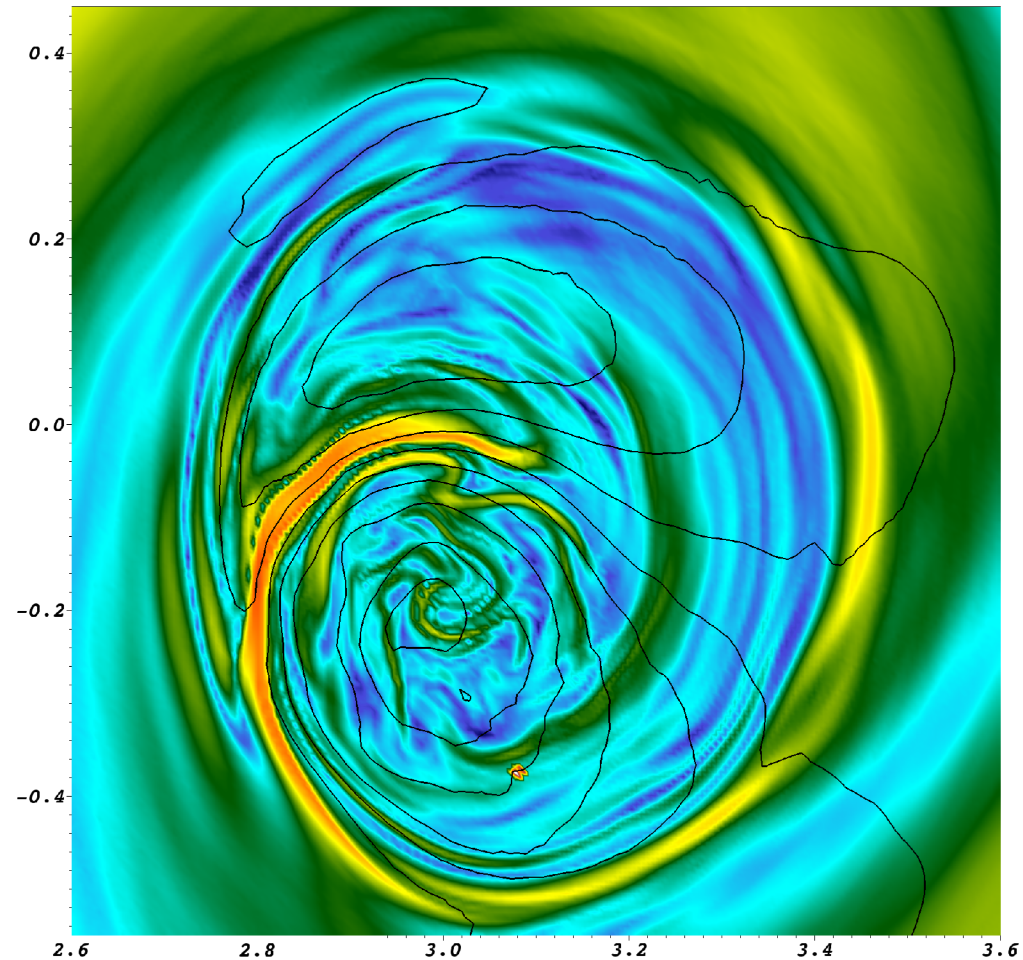
Plasma FTLE(±**V**) resembles FTLE of decaying 2D fluid turbulence, with multiple vortices and fine scale structure (e.g., G. Lapeyre, Chaos, 2002)

Finite Time Lyapunov Exponent: **V** ± **B**

FTLE(**V**+**B**) with U+$\tilde{\psi}/R_o$ lines



FTLE(**V**-**B**) with U-$\tilde{\psi}/R_o$



- Kink also has a **V**±**B** structure! Elsässer variables => incompressible MHD. but not RMHD!
- Approximated by simplest combination of poloidal stream functions U-ψ/R_o
- **V**±**B** structure has X-points, like **B**, but different locations

φ=0 (HFS), t=467.2

Summary

- Modern version of Finite time Lyapunov Exponent is a powerful and increasingly powerful tool for studying for 3D, time-dependent vector fields - numerical
  - Diagnostic for evolving underlying structure of vector fields and time-dependent Lagrangian Coherent Structures in the presence of turbulence; originally developed for fluids
  - Rapidly improving methods, interpretation, applications
- First application to plasmas
  - Plasma has multiple vector fields: MHD **B**, **V**
  - High accuracy FTLE computation developed in VisIt visualization package
  - Sawtooth crash in M3D, single time – new insights
- Next step: time-dependent LCS for plasma
- Applies to general vector fields; many possible uses
  - Next generation simulation codes – compute simultaneously?