Reconnection in the Solar Corona

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MHD Reconnection

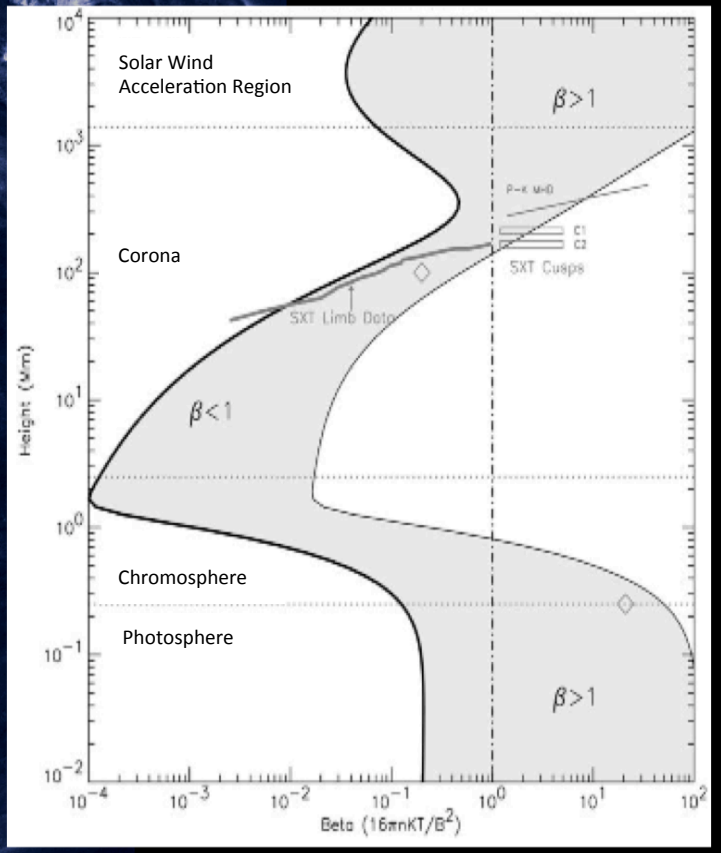
- Requires a current sheet discontinuity to form in the magnetic field
- Discontinuous magnetic field connectivity (topology) give rise to discontinuous stresses
- Favorable locations for CS formation
  - Along magnetic field separatricies between nested (mulipolar) flux structures
  - Along discontinuities in the boundary flow

Basic Types of Reconnection

- Reconnection across separatricies in a complex magnetic field structure:
  - Nested (multipolar) topologies
  - Null-points (embedded bipolar structures)
  - Relaxation of field line braiding (Parker heating)
  - Ideal instabilities (e.g., kink)
- Heliospheric current sheet Y-point:
  - Pinch disconnection
  - Interchange

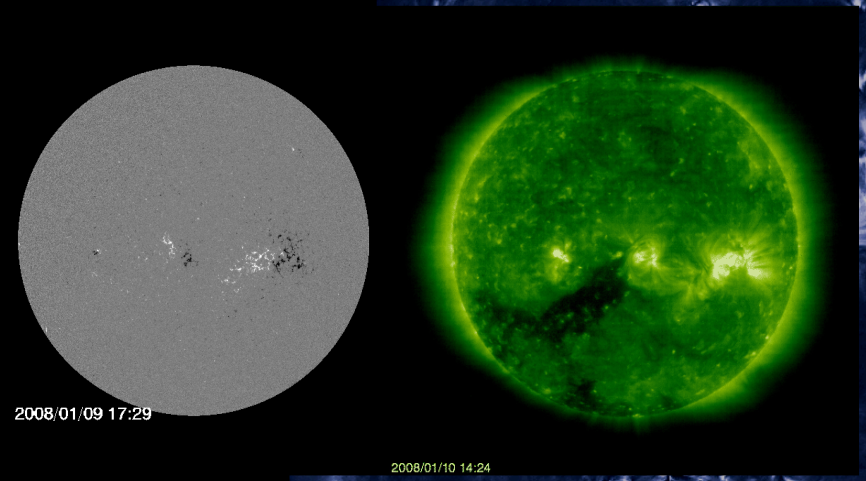
Coronal Environment

- Magnetically Dominated:
  - $\beta << 1$
- Quasi-steady Evolution:
  - $V_{Alfven} >> V_{Drivers}$
- Highly Non-Dissipative:
  - $R_m > 10^{10}$
- Ideal MHD (mostly) valid
  - $\lambda << L$

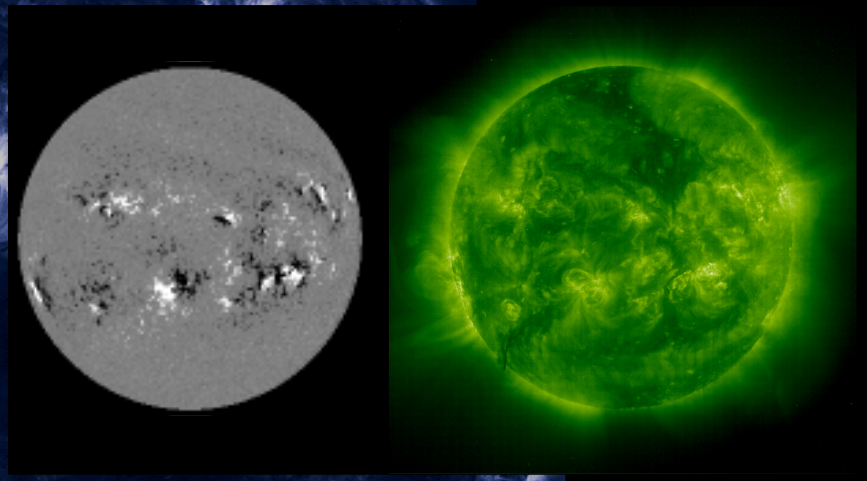


Gary, 2001

Coronal Magnetic Field Structure



SOHO: MDI, EIT 195. 09 Jan 2008

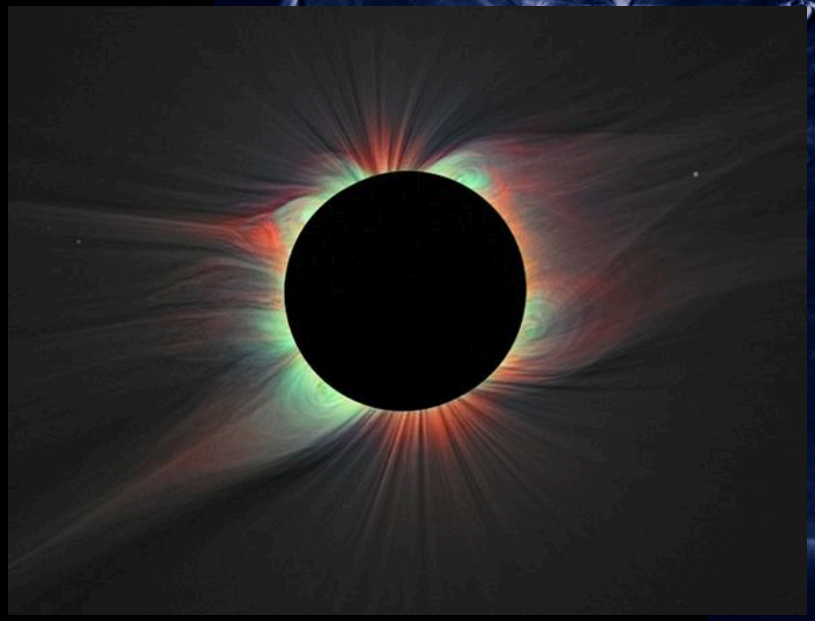


SOHO: MDI, EIT 195. 09 Nov 2002

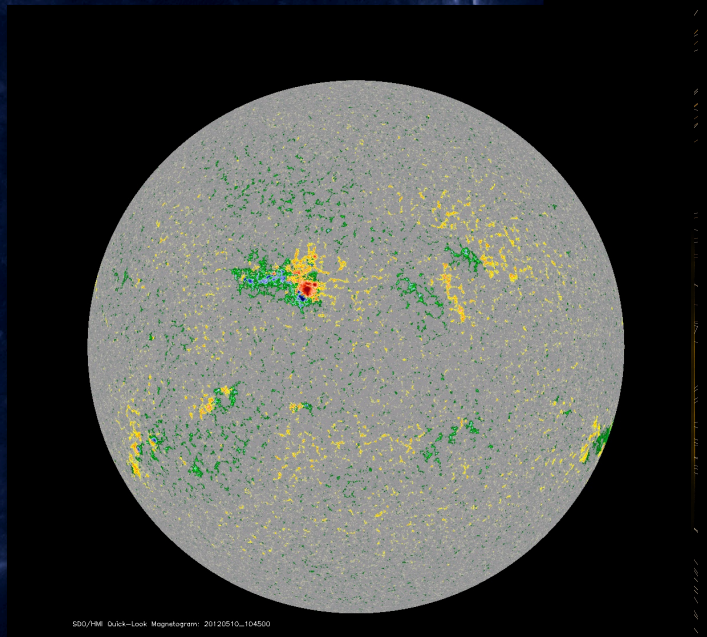
- Photospheric flux distribution governs coronal hole pattern
- Highly complex, nested, multipolar structure

Magnetic Separatrices

- Boundaries between magnetic domains of different connectivity (topology)
- Intrinsic property of magnetic field geometry



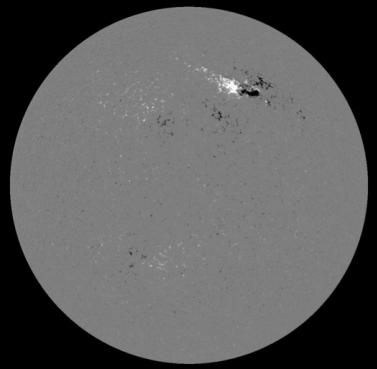
Habbal, et al.



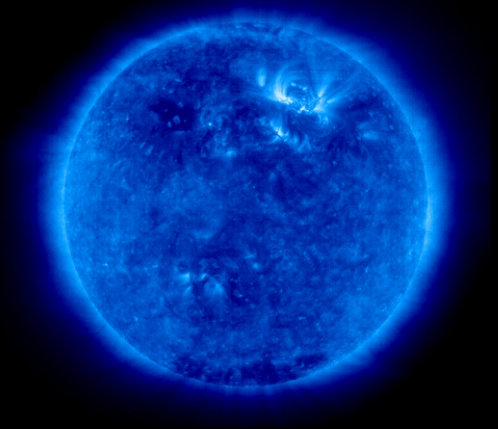
NASA SDO: HMI, AIA 171. 10 May 2012

Embedded Bipole

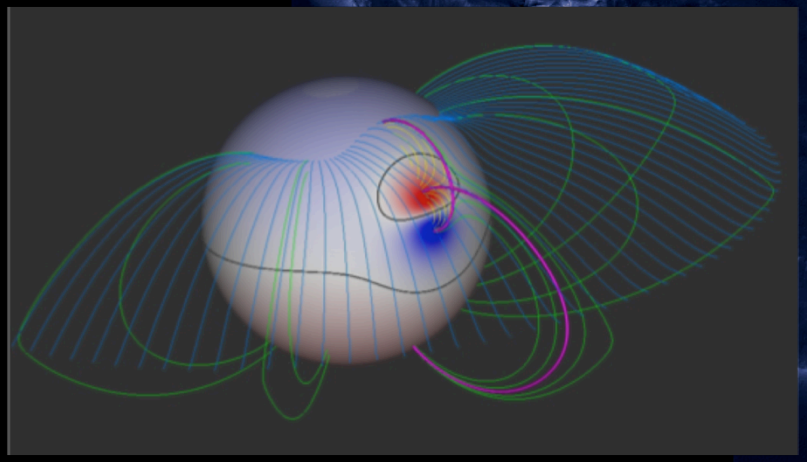
- Simplest, non-trivial structure
- Ubiquitous throughout the corona
- Occurs with all local PIL's, over large range of scales

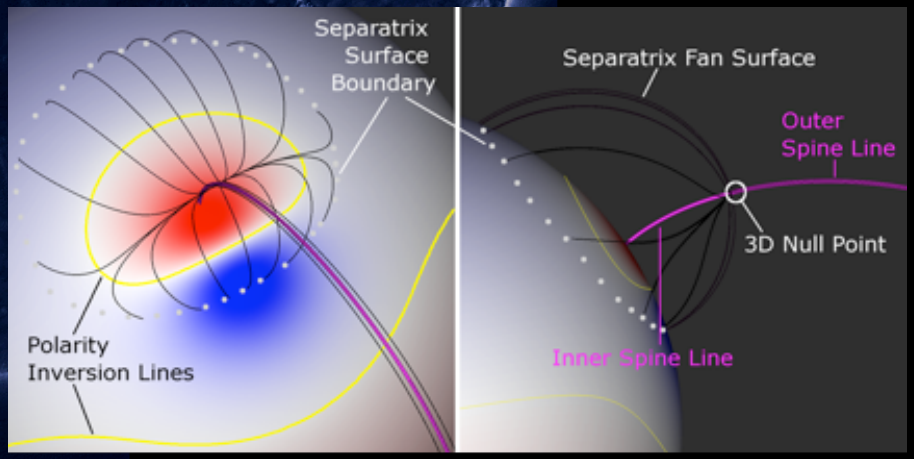


MDI 14 Jan 2010



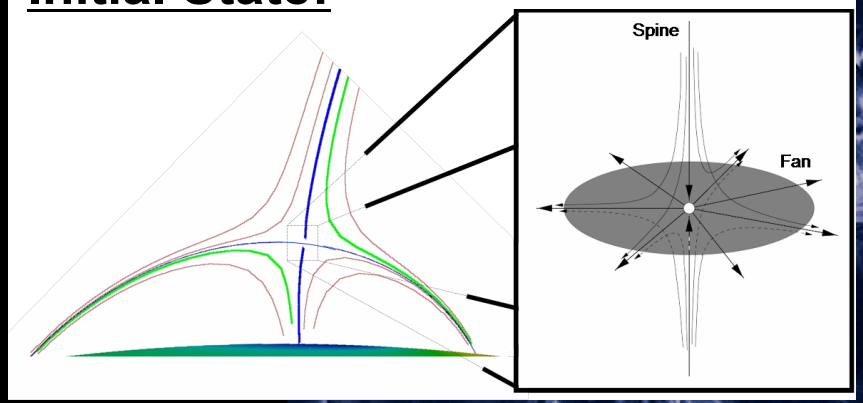
EIT 171A 14 Jan 2010





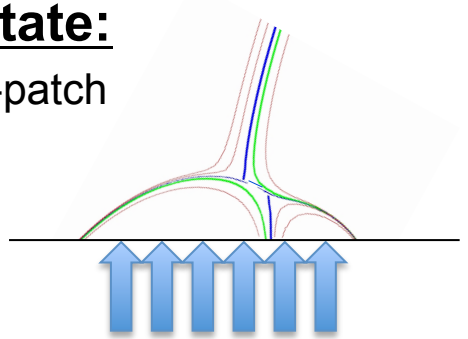
Reconnection: Null-Point / Separatrix

Initial State:



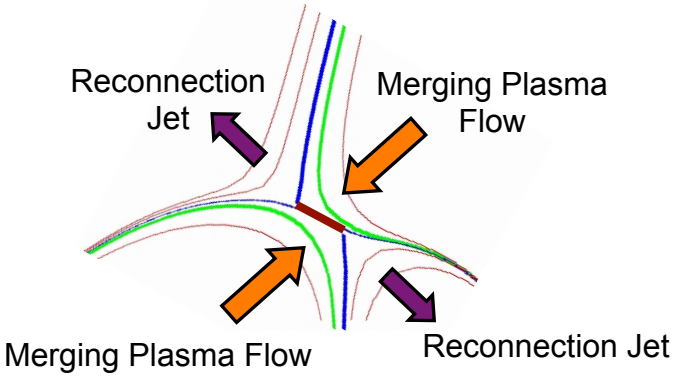
Stressed State:

Deformed null-patch



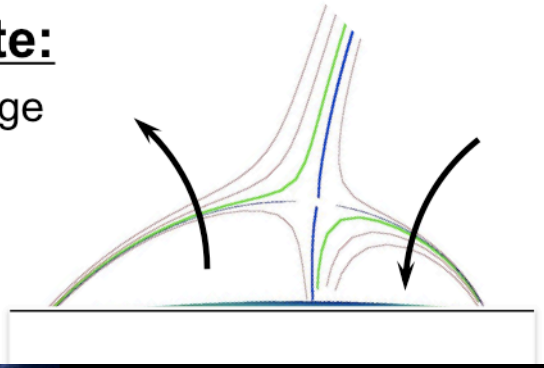
General Energy Injection
(flux/helicity injection, boundary flow)

Reconnection:



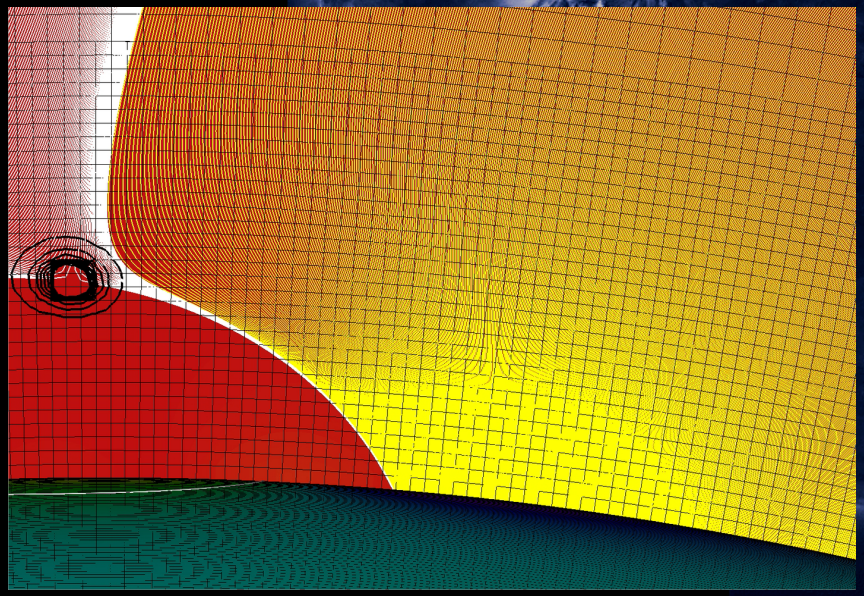
Final State:

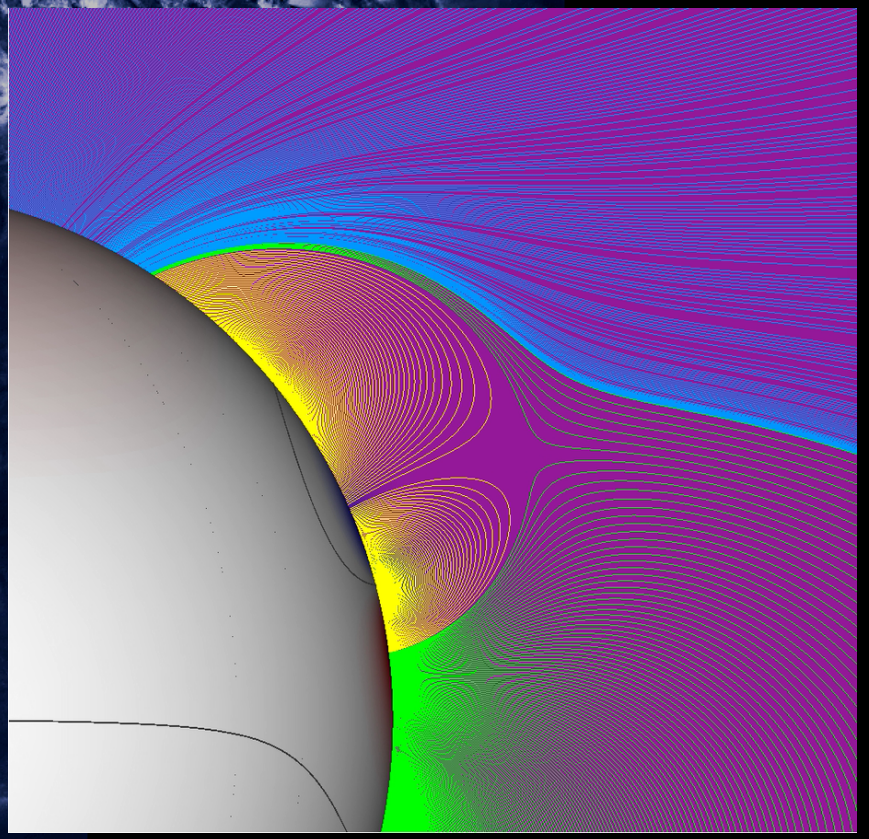
Flux exchange



Current Sheet Formation

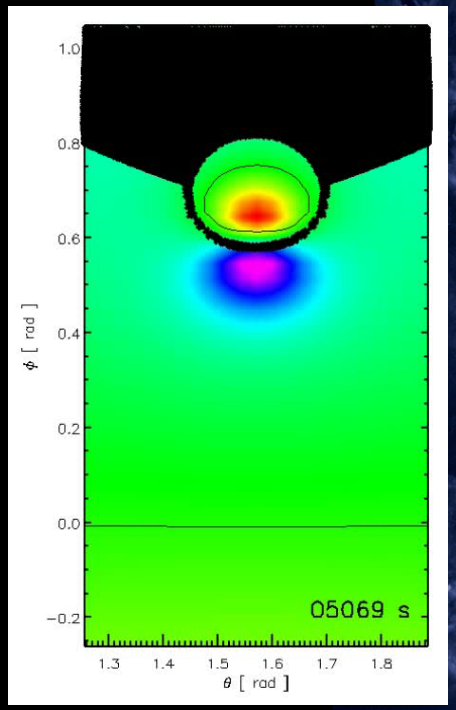
- Reconnection current sheet along separatrix around deformed null



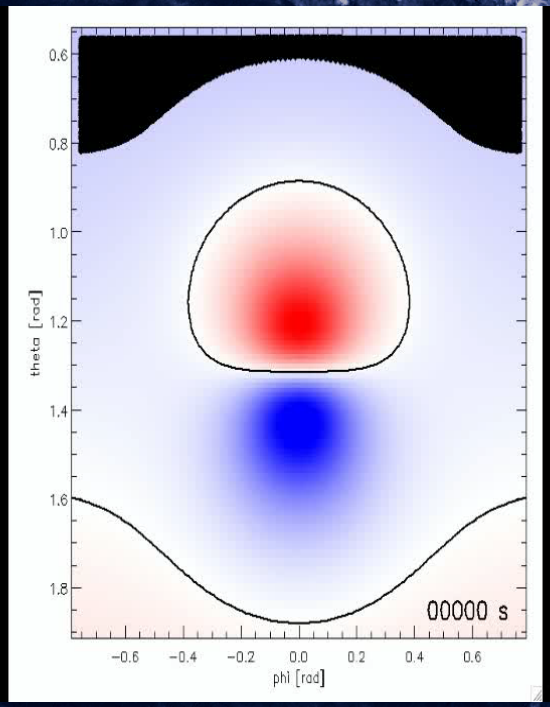


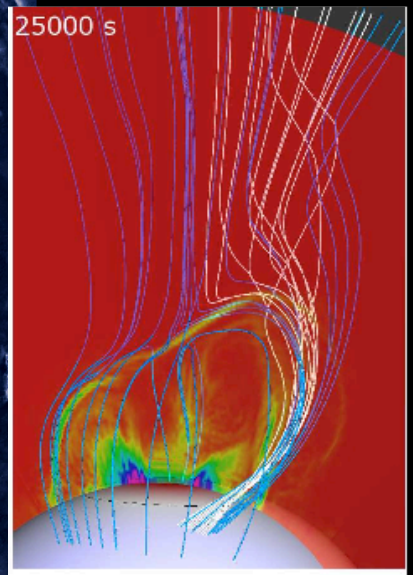
Topology Remains Smooth

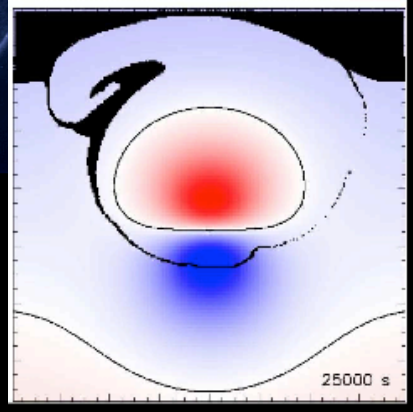
Rigid Body Convection



Pure Helicity Injection

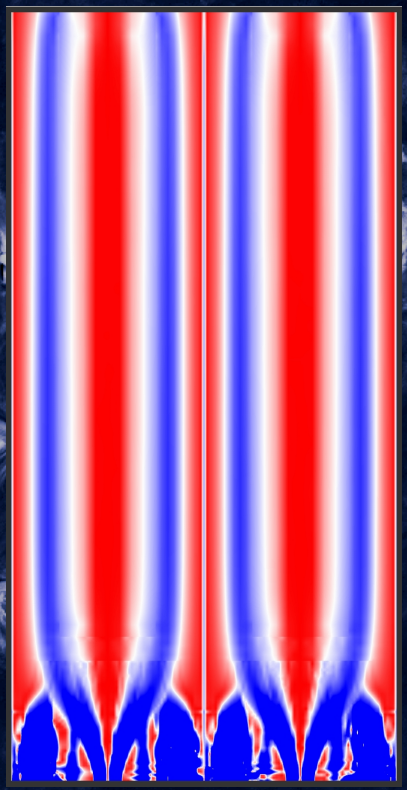
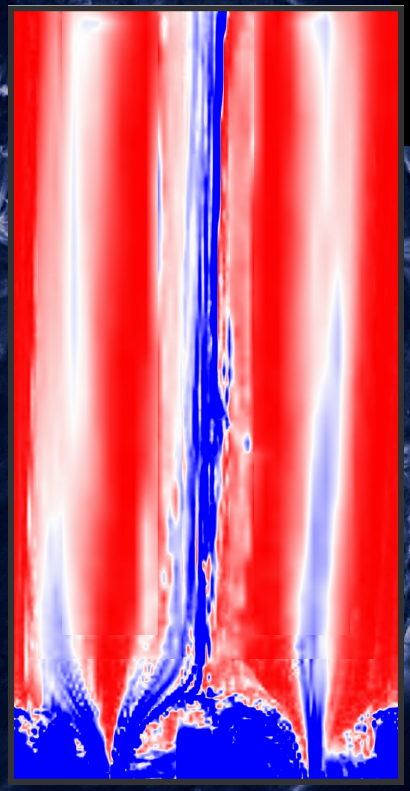


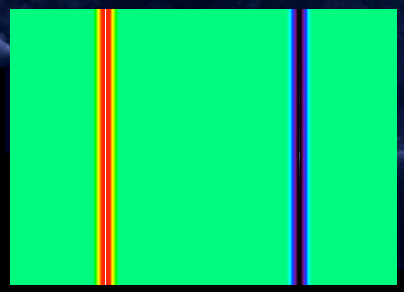
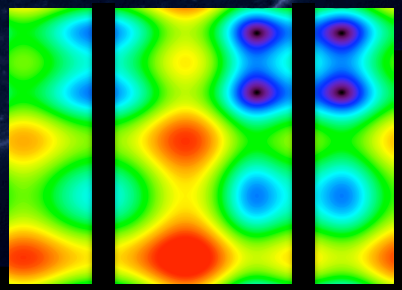
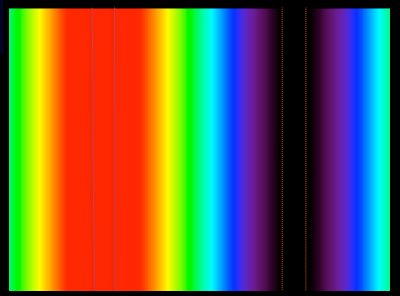




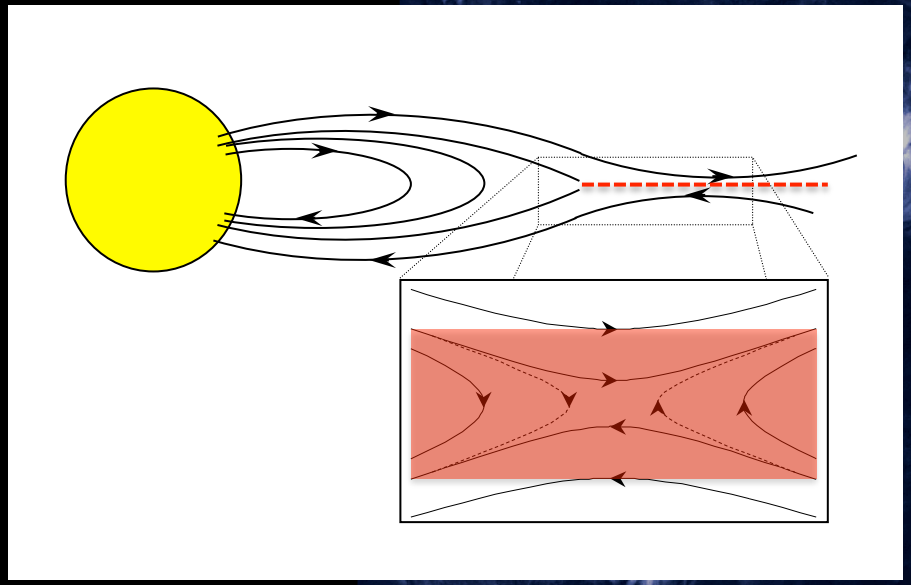
- Coronal holes remain connected via open field corridors

Current Discontinuities

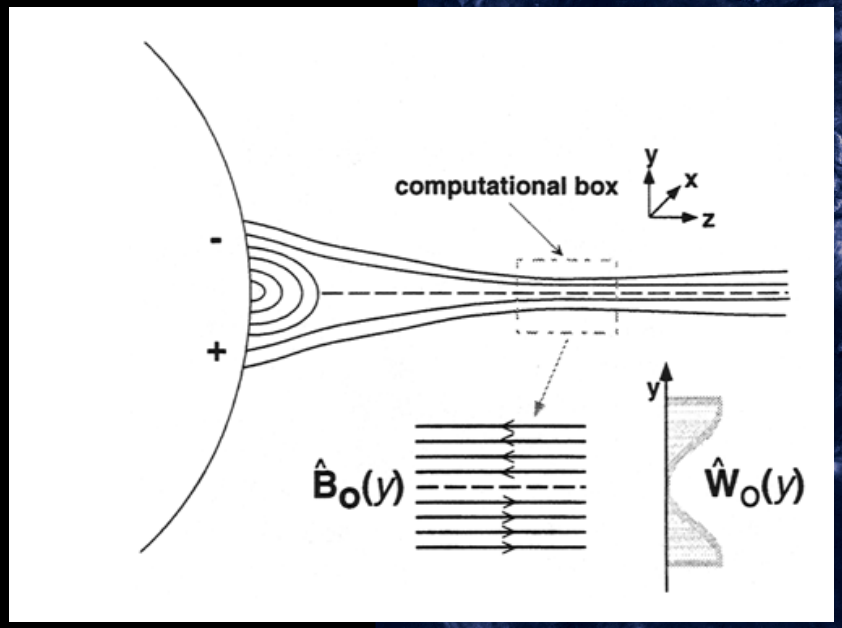
HCS Y-Point Region



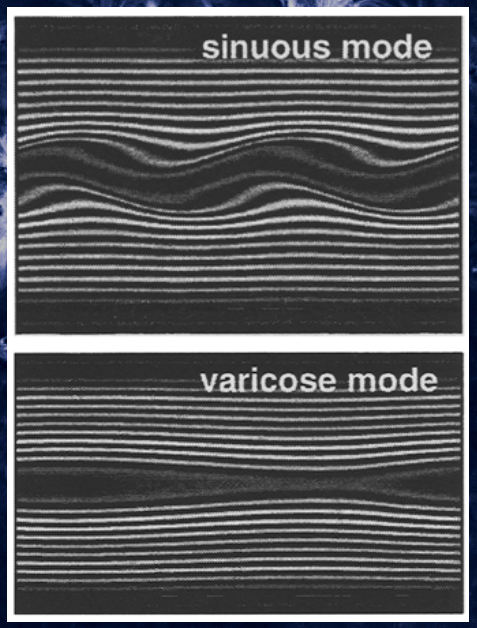
- Continuous wind → HCS Y-point unstable
  - Tearing mode
  - Fluid instabilities

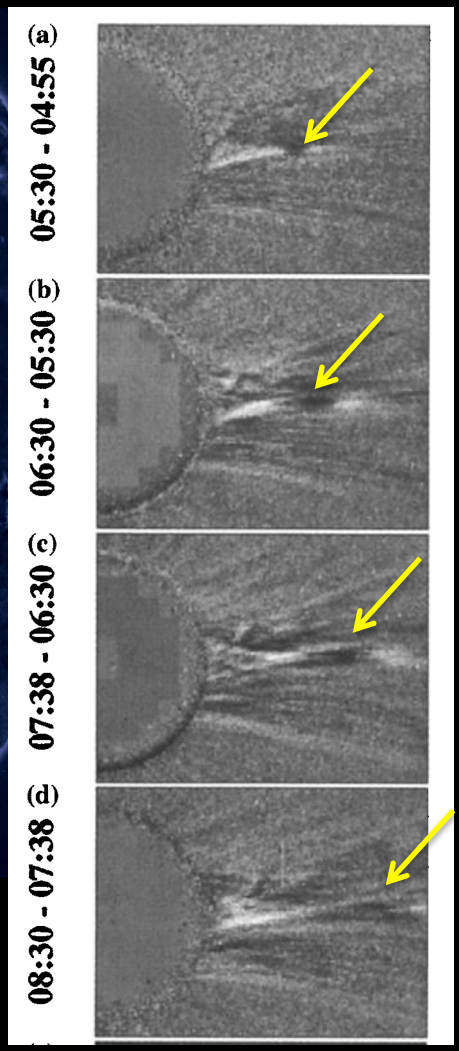
- Quasi-rigid coronal hole rotation implies continuous opening/closing field
- "Streamer blob" plasmoid release

Unstable Streamer Stalk



Karpen et al., 1999





Wang et al., 2000

- Tearing instability leads to fluid instability

Summary

- Two favorable regions for CS formation:
  - Separatricies bounding nested structures
  - Heliospheric Current Sheet Y-point region
- Stress discontinuities across separatrices give rise to reconnecting current sheets
- HCS Y-point region unstable to tearing, which leads to plasmoid acceleration by fluid instability

Quasi-Steady Evolution