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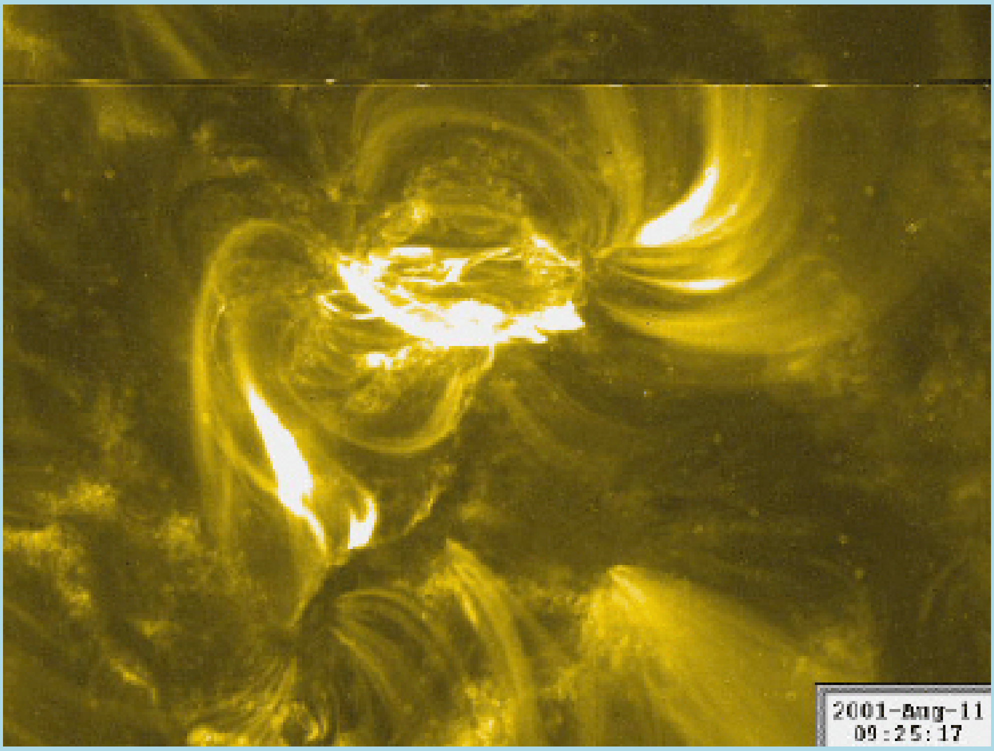
Magnetic flux emergence and its 3D reconnection with an existing coronal field

K. Galsgaard, Niels Bohr Institute, Denmark

F. Moreno-Insertis, V. Archontis, IAC, Tenerife, Spain

A. Hood, University of St Andrews, Scotland



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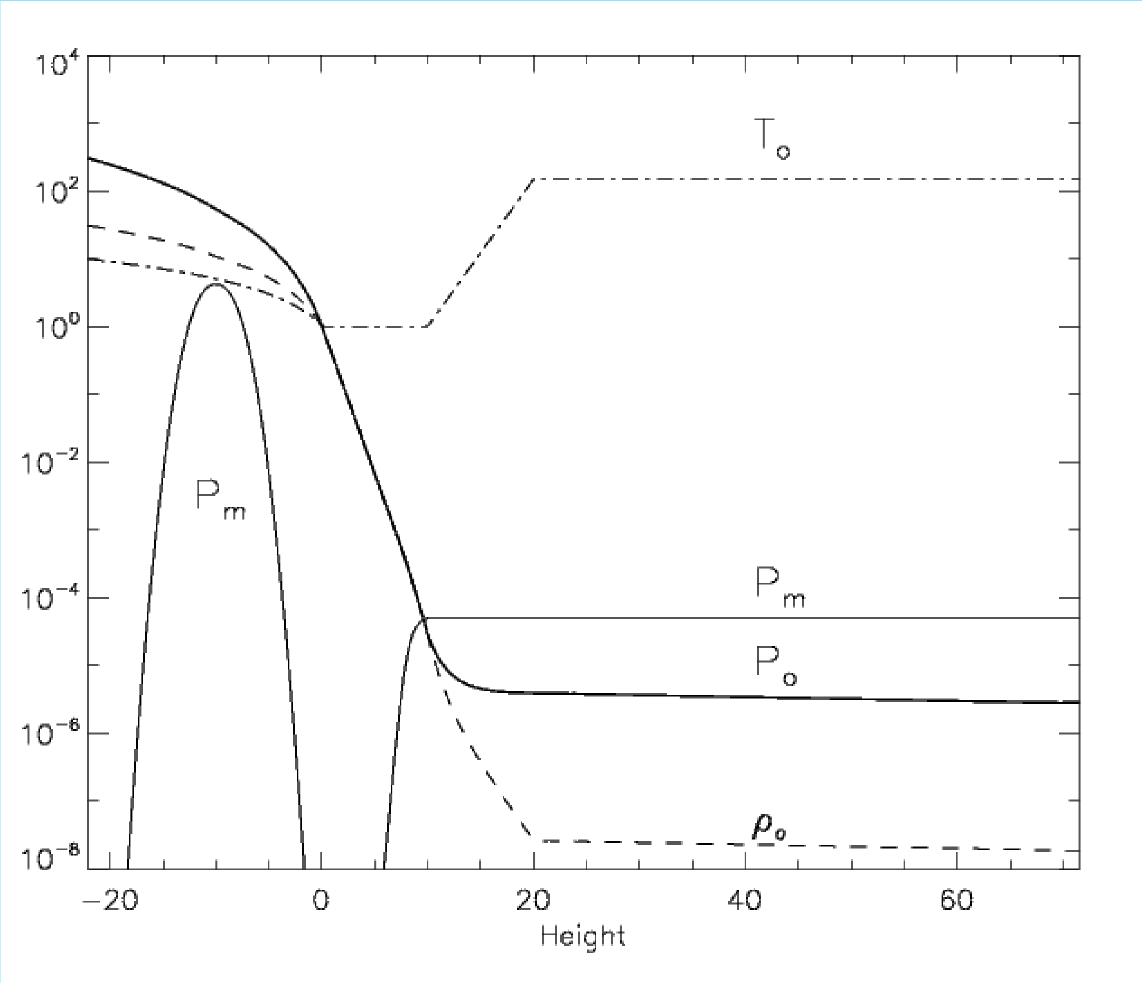
Model

- **Stratified atmosphere**
  - Upper part of the conevection zone to the lower corona
- **Twisted loop embedded in the convection zone**
  - Emergence driven by a density decrease in the central part of the tube
- **Setup is similar to Fan's**
- **Horizontal magnetic field above the photosphere**
  - Runs with a number of different orientations



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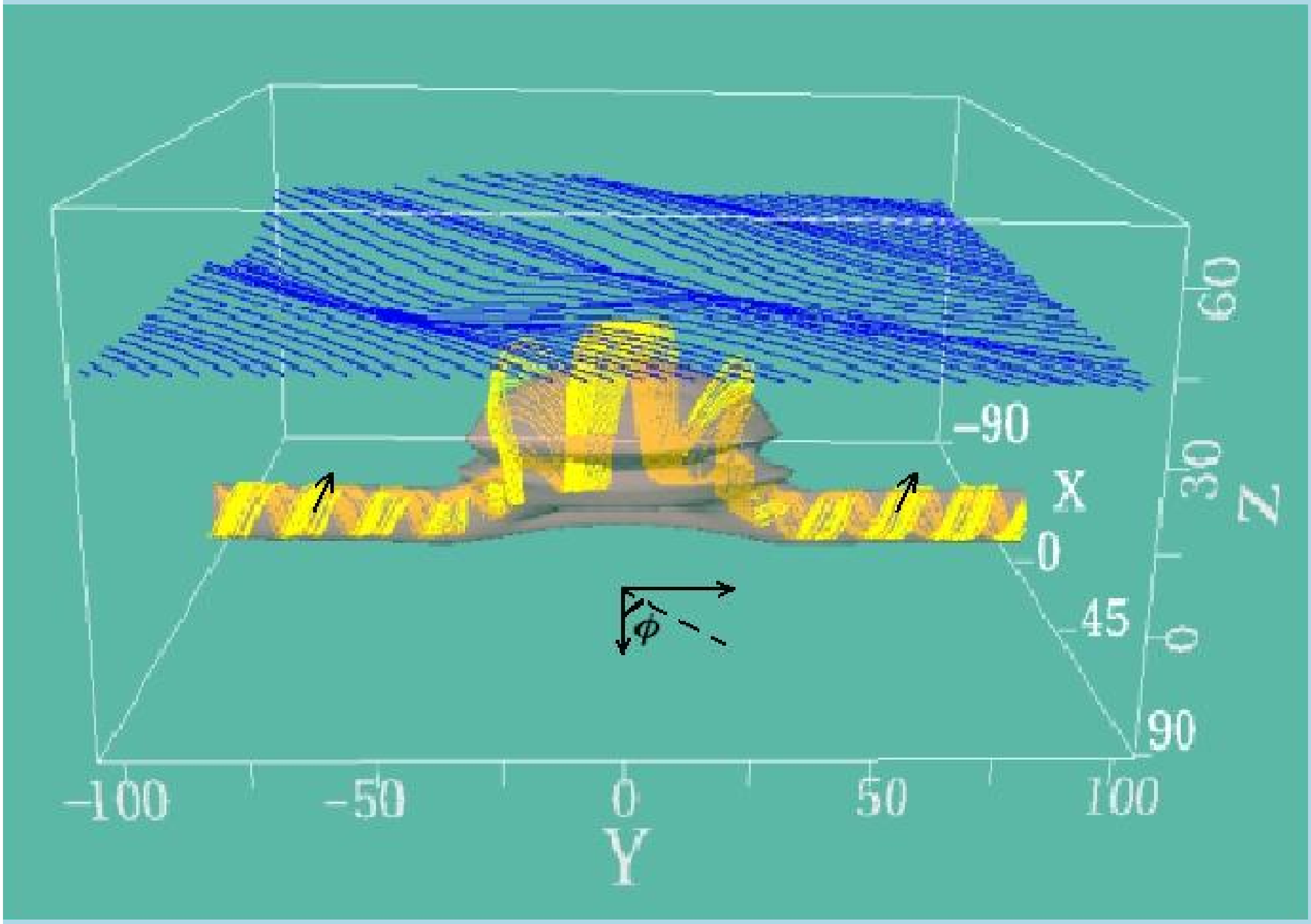
General structure



- **Yellow: emerging tube**
- **Blue: coronal field**
- **Isosurface: Constant magnetic energy (relative small value)**
- **Runs with different orientations of the coronal field**

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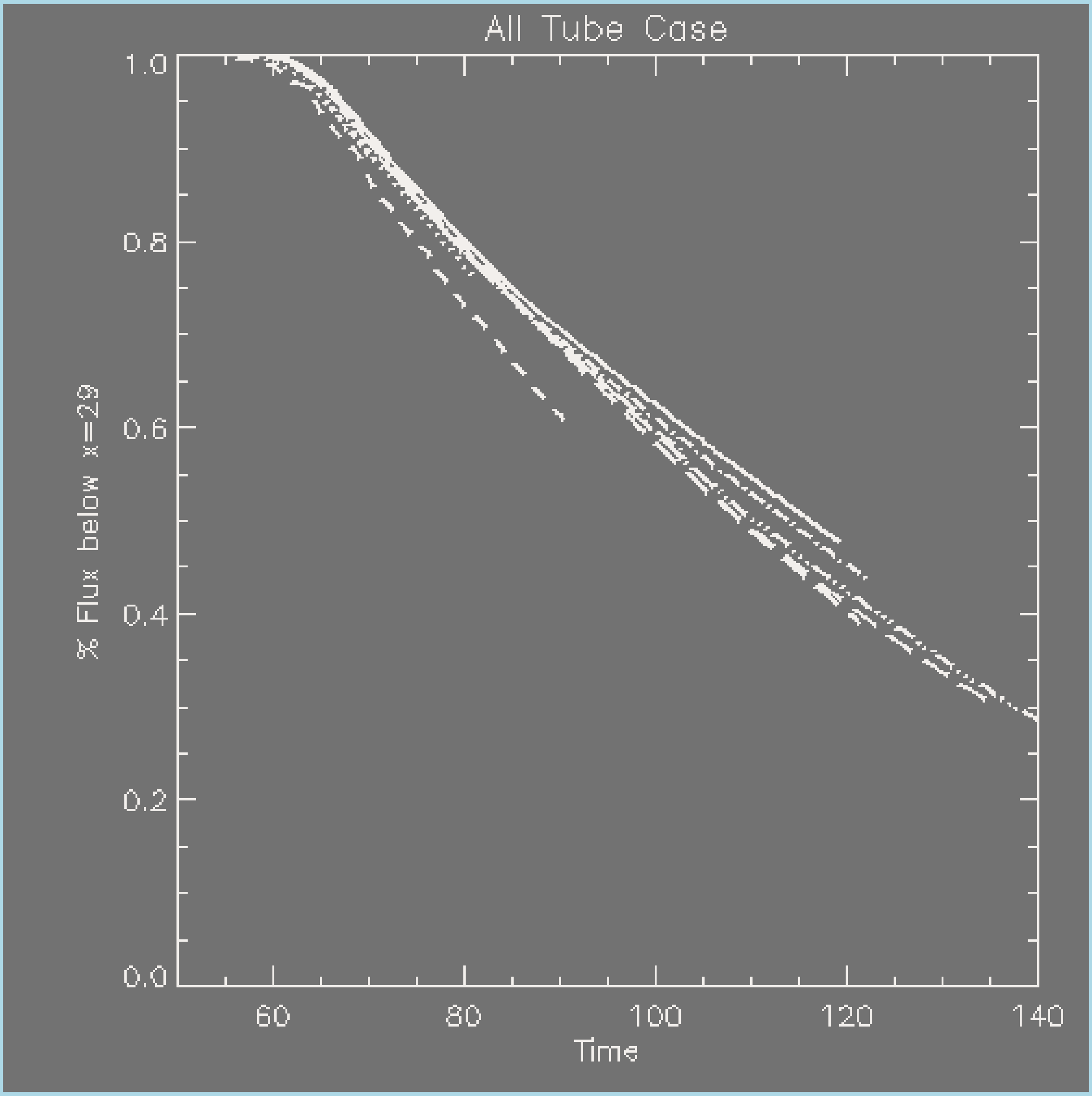
Fraction of Emerged flux

- **Measurer the flux below a given height as a function of time**



- **Agree with observations**
  - Reports of constant emerge rates from observations - different between events

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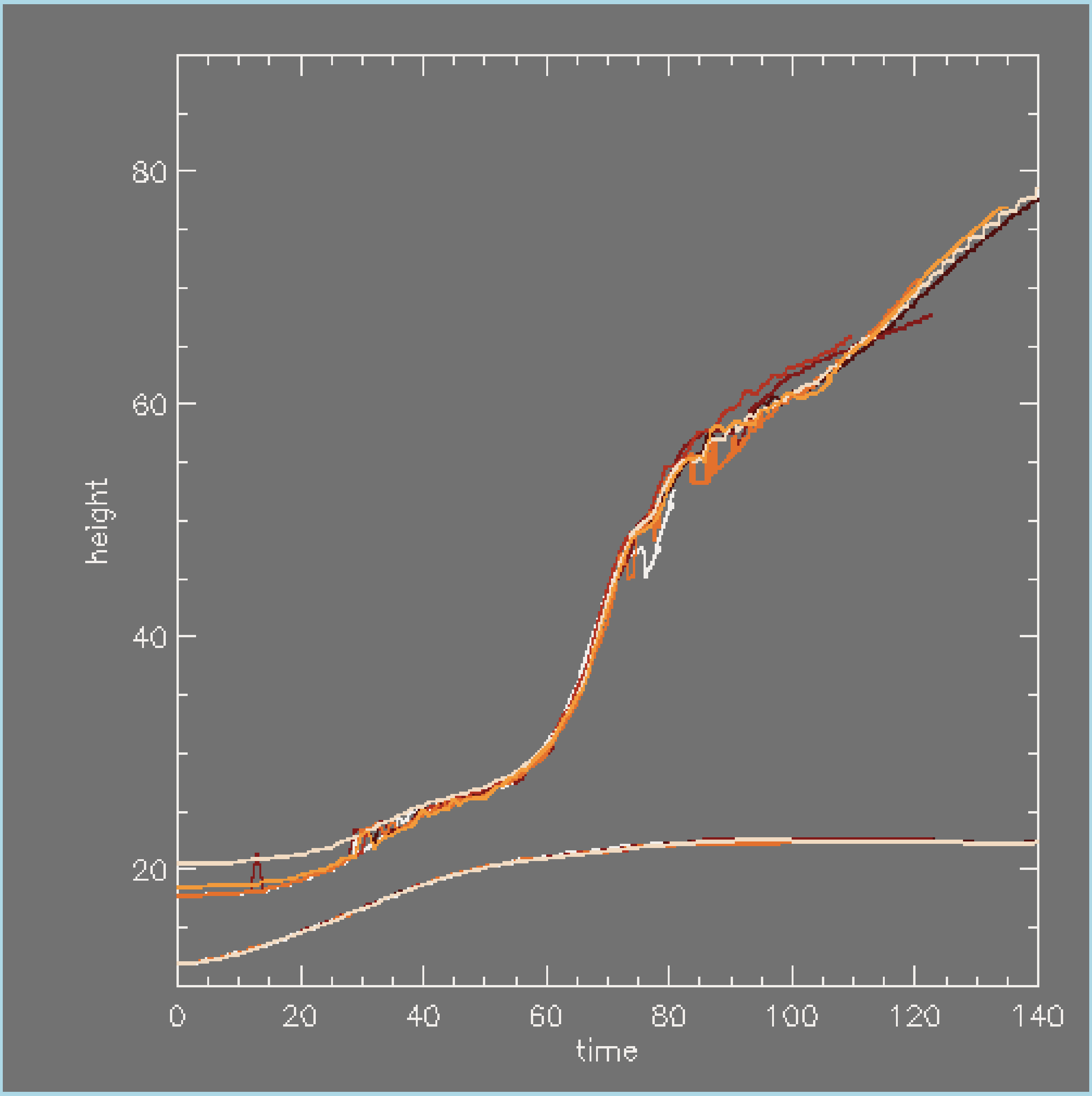
Loop height

- Determines the loop height as a function of time
- Center of the loop stays below the transition region
- All experiments expands upwards with similar speed



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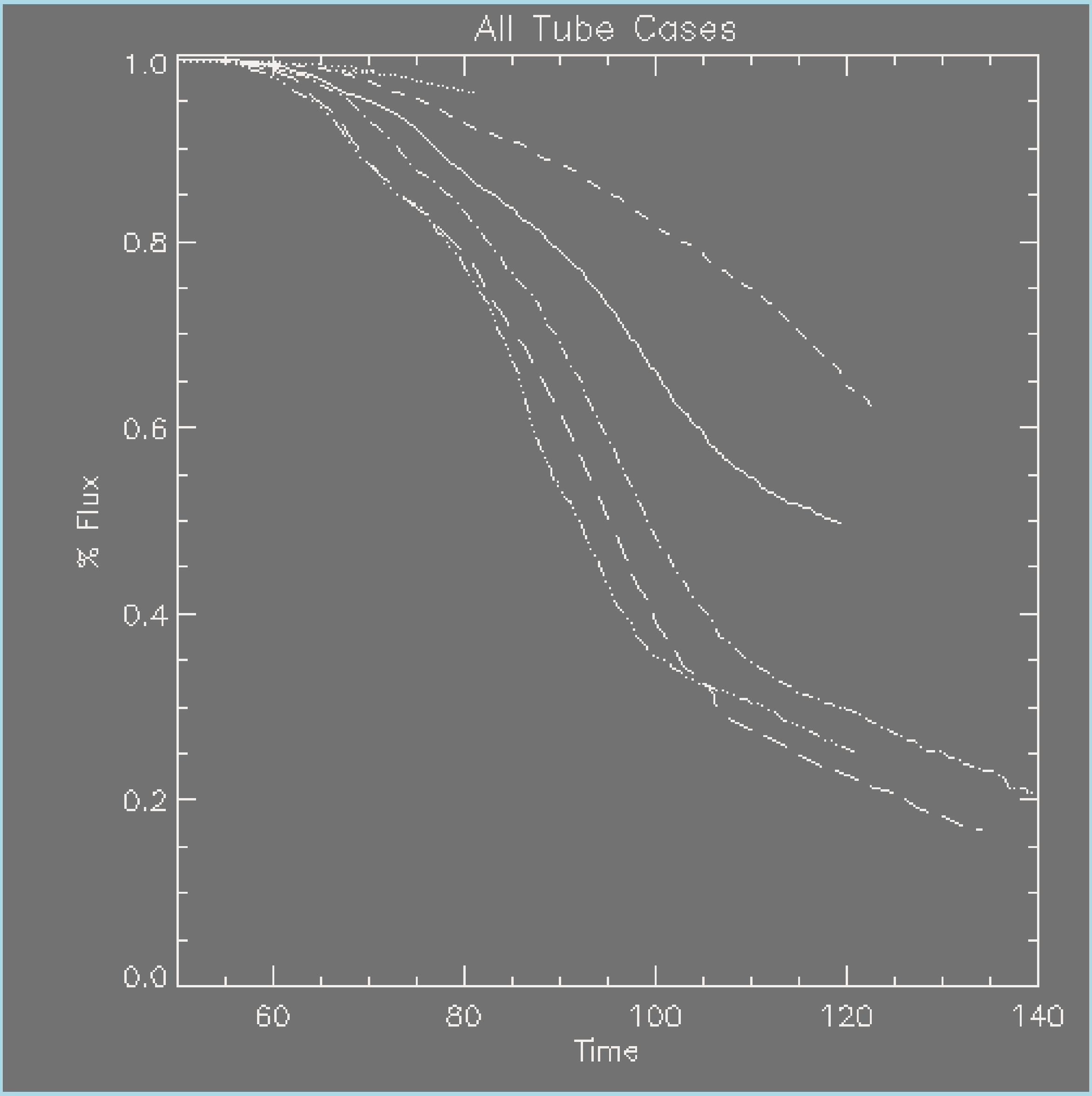
Connectivity changes

- **Determine the connectivity of the loop flux as a function of time**
- **Up to 80% of the tube flux reconnects with the coronal field**
- **Relative orientation is very important for the speed of reconnection**



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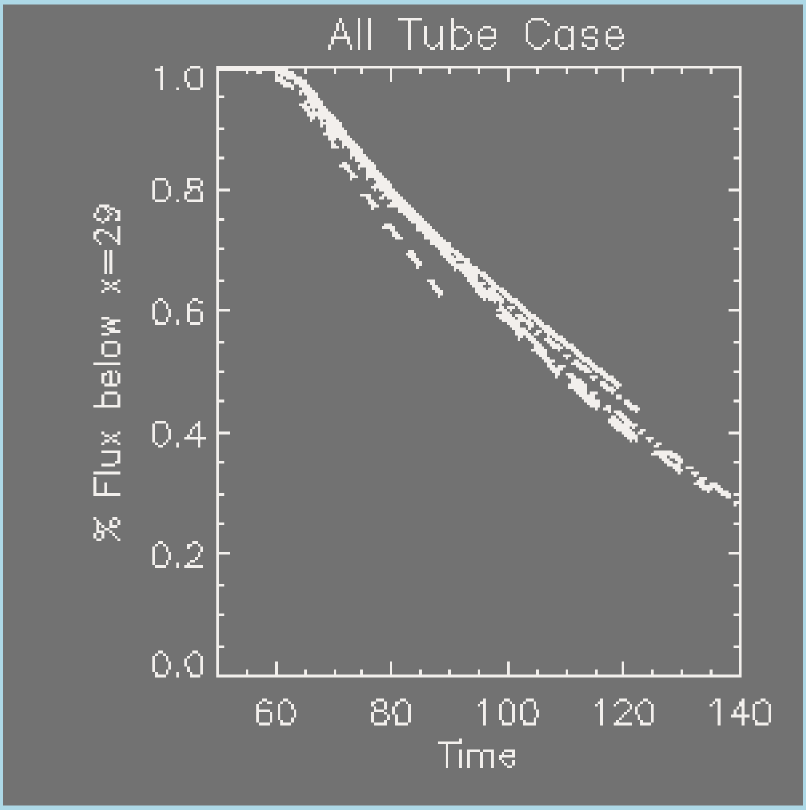
Puzzle

- **Why are the two first results nearly independent on the orientation of the overlaying field, and the last one strongly dependent on it?**
- **How can more than 50% of the flux emerge when the center of the tube is still below the transition region?**



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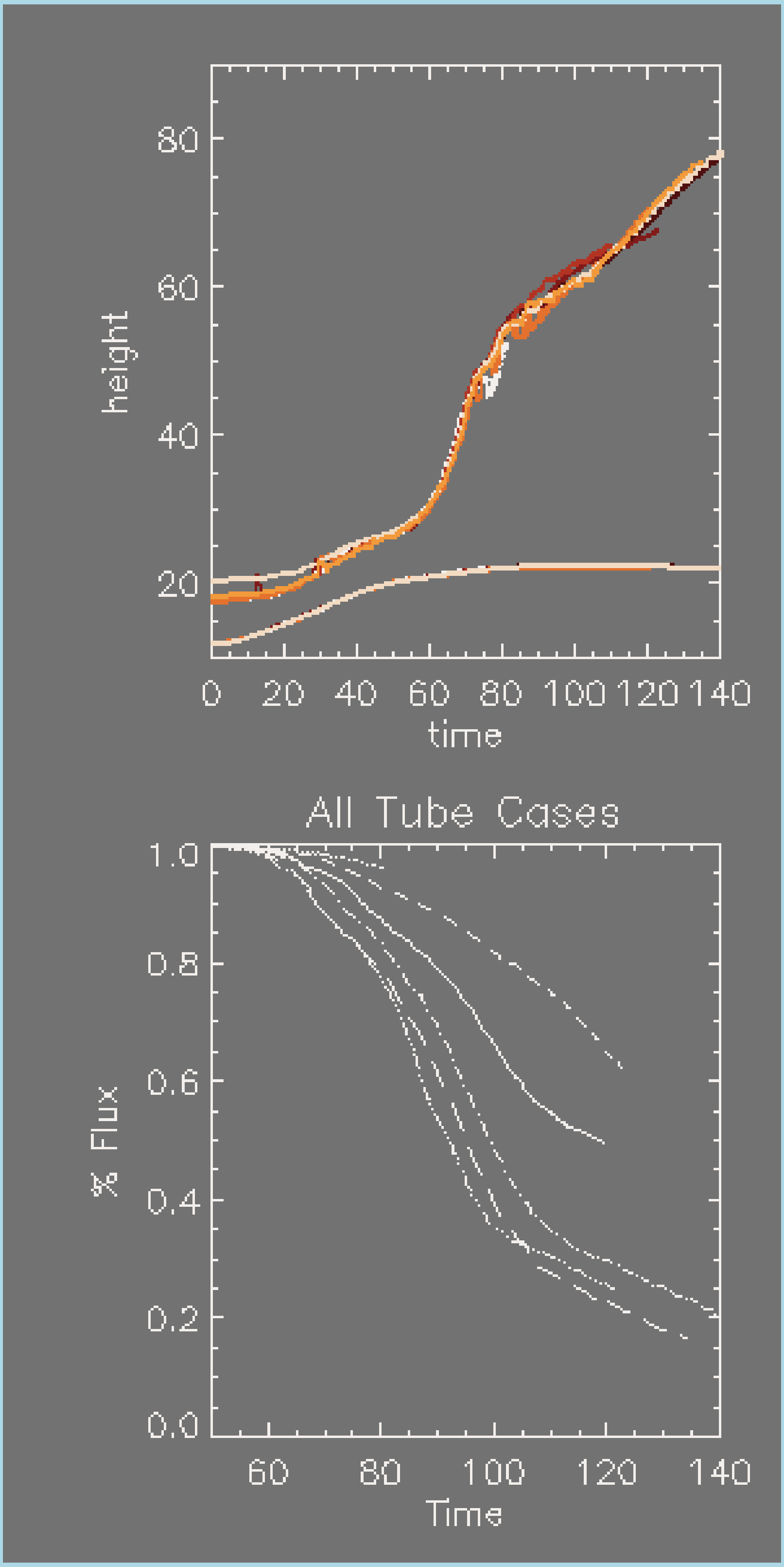

height
80
60
40
20
0
20
40
60
80
100
120
140
time
All Tube Cases
1.0
0.8
0.6
0.4
0.2
0.0
% Flux
60
80
100
120
140
Time

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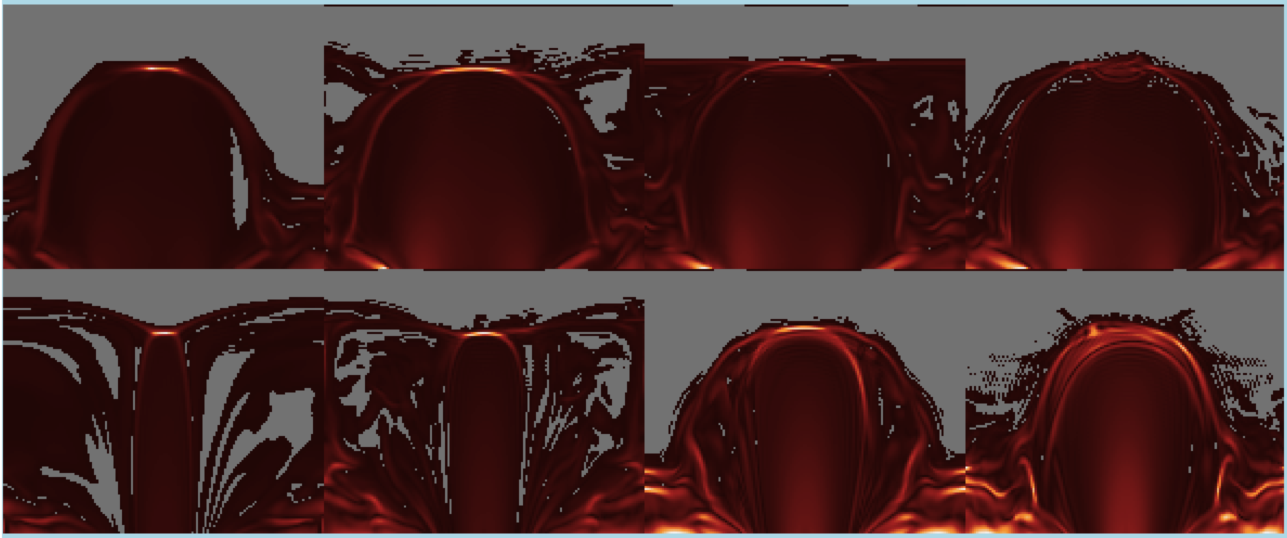
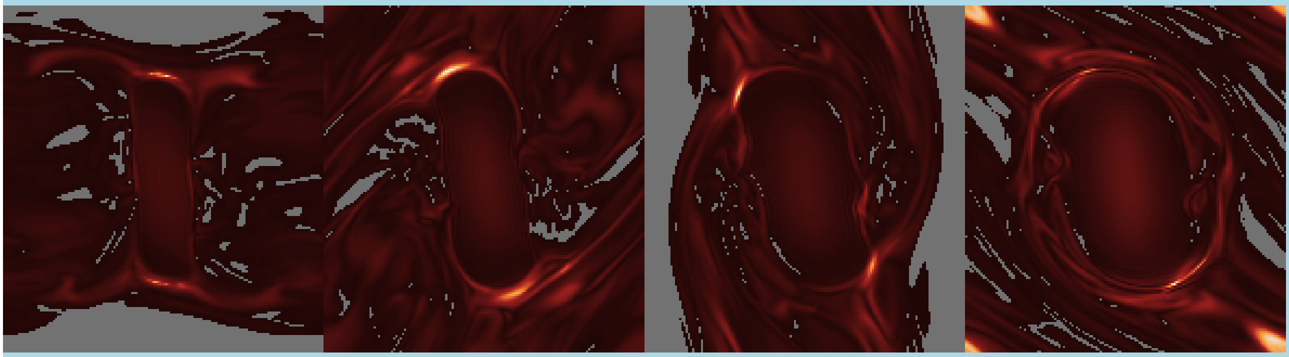
Volume of emerged structure

- **Images showing the location of high current**
- **5 different orientations of coronal field**
  - From antiparallel to 45 degreed from parallel
- **Time = 100**

Along and Across loop



Constant height



- **Flux volume of tube increases as the fields become increasingly parallel...**

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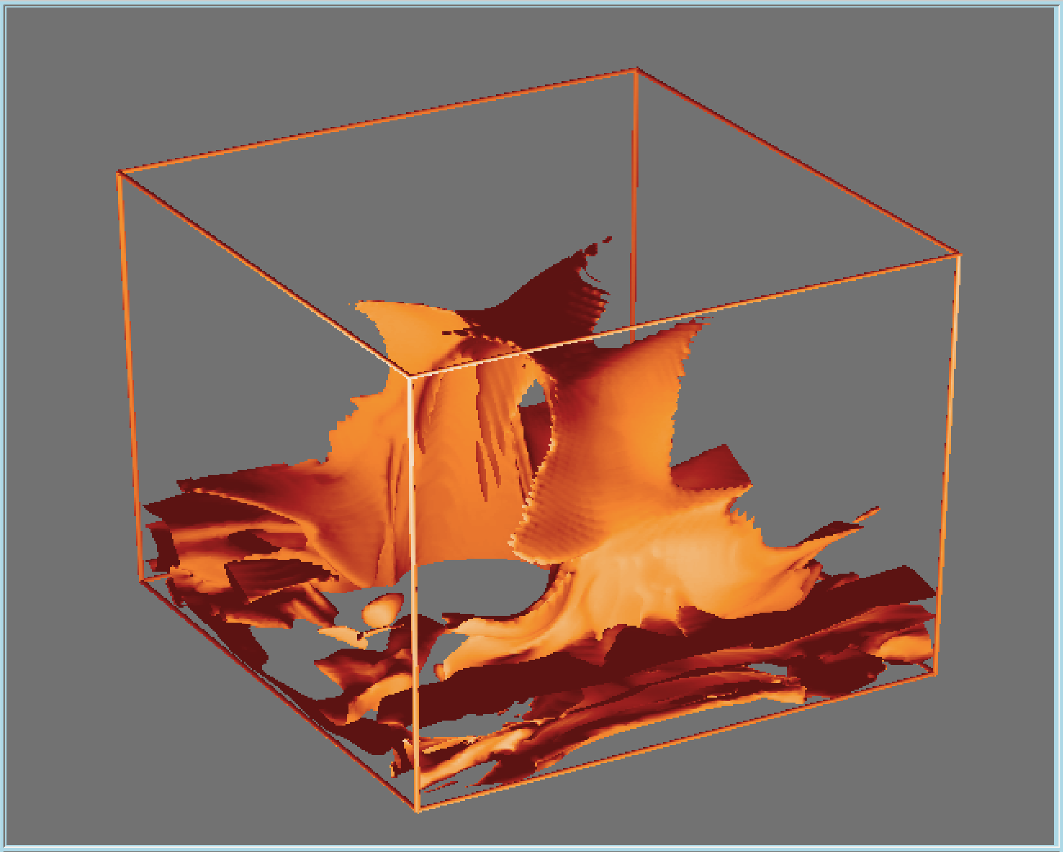
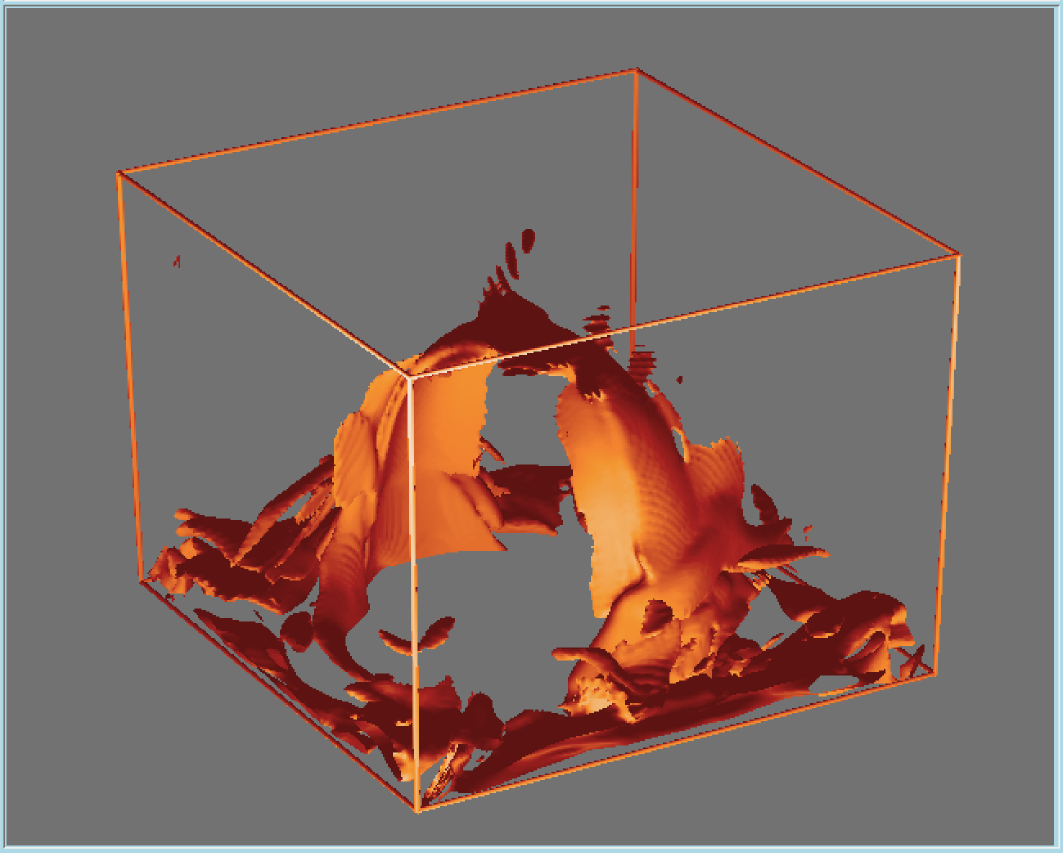
Current sheet orientation

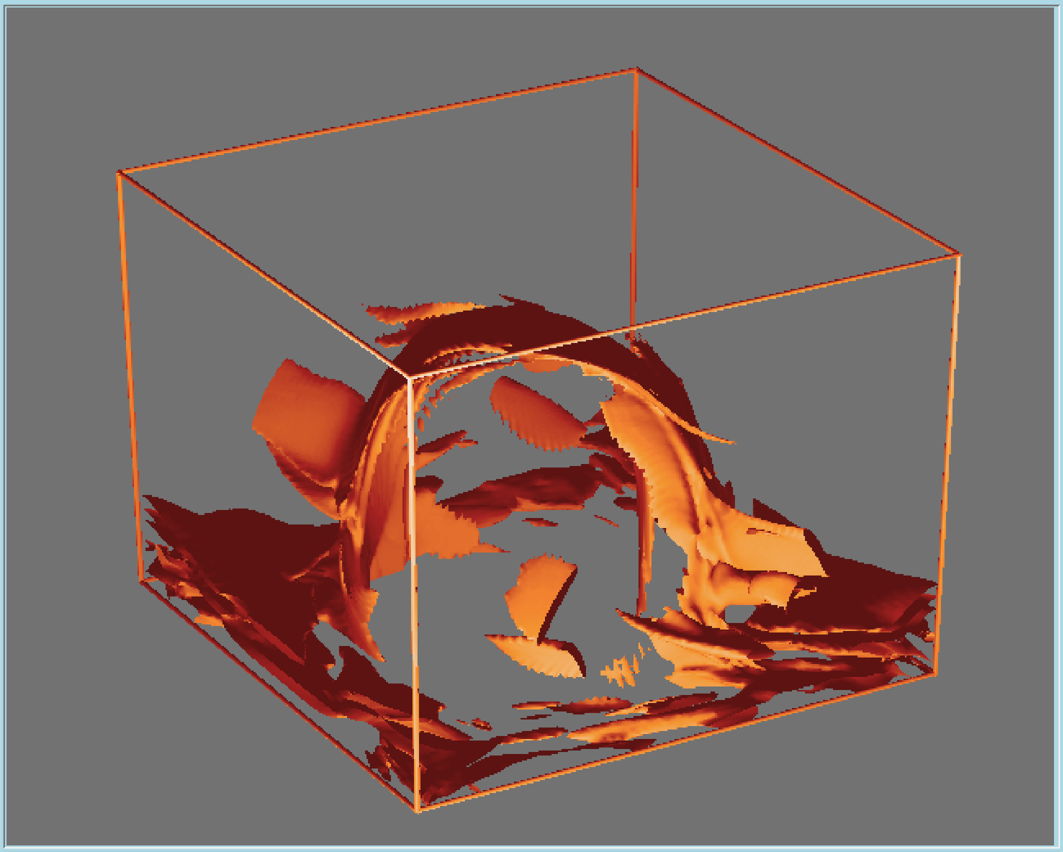
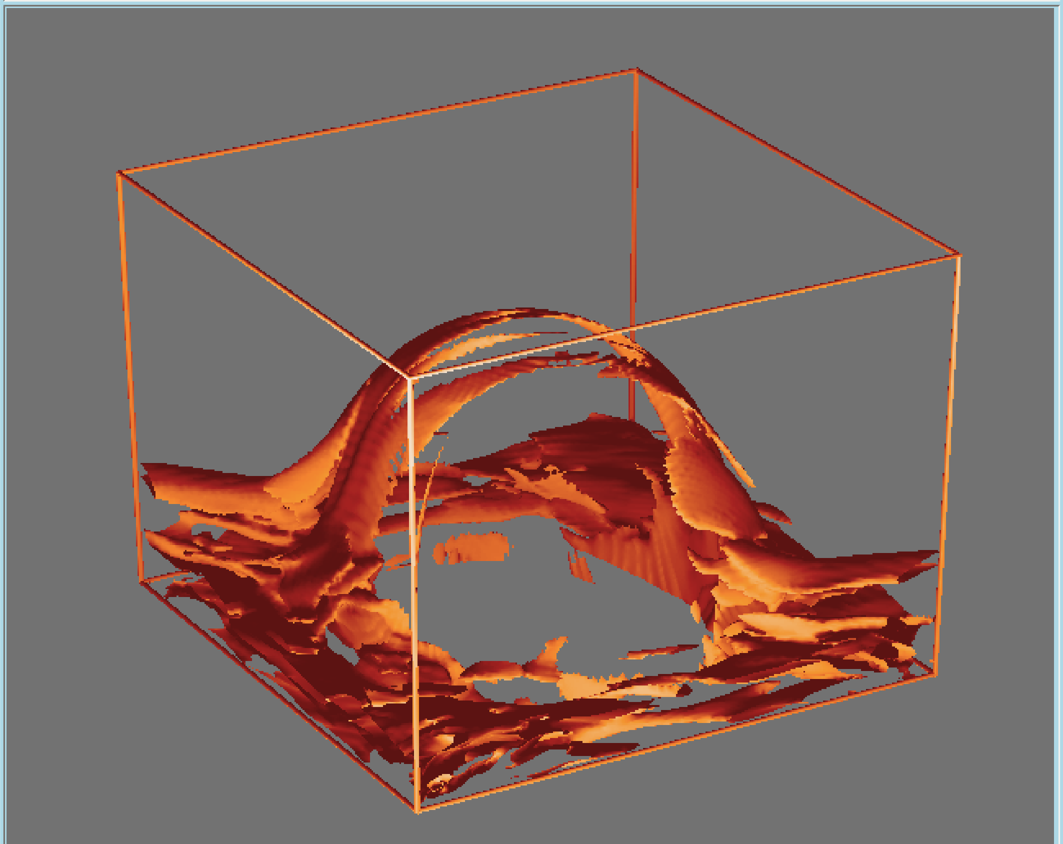
- **Isosurfaces of scaled current**
  - antiparallel followed by jumps in 45 degrees.

180 degree



135 degree



90 degree	
45 degree	

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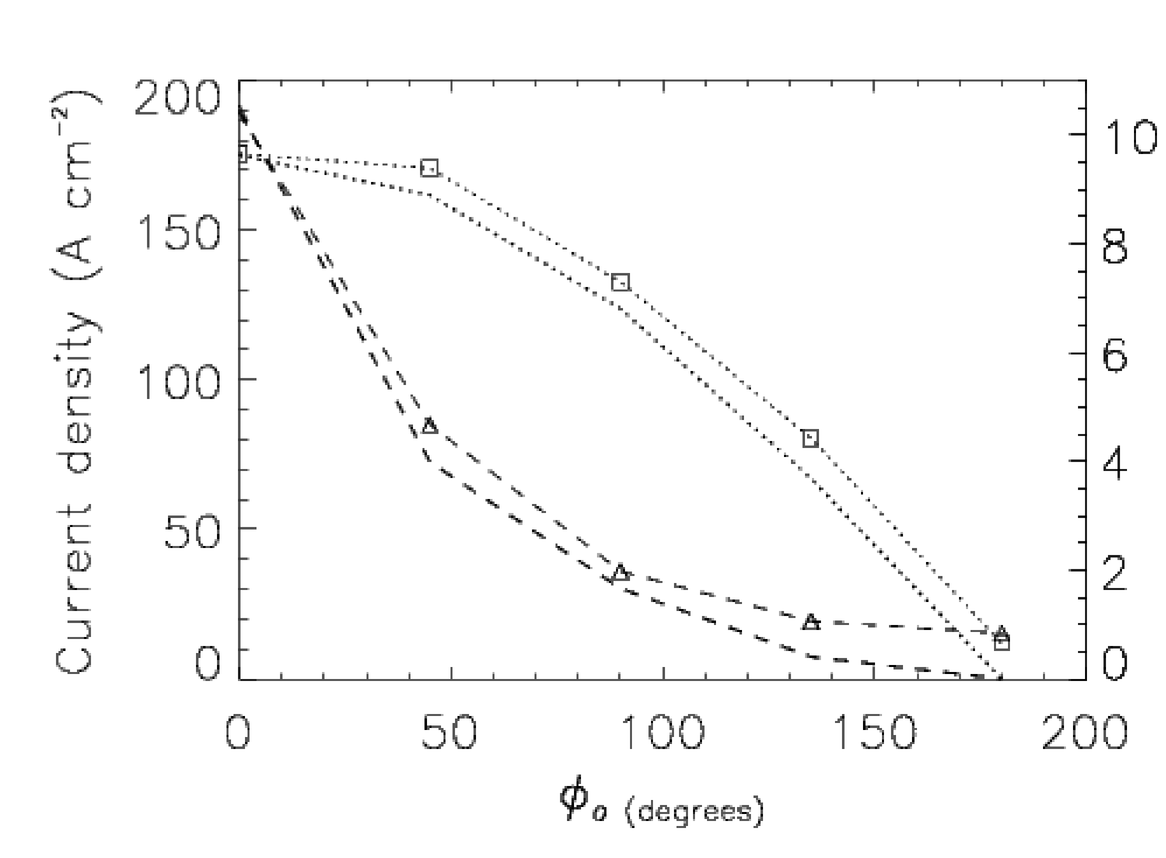
Variations of Current and Temperature

- Peak current and temperature decreases with angle



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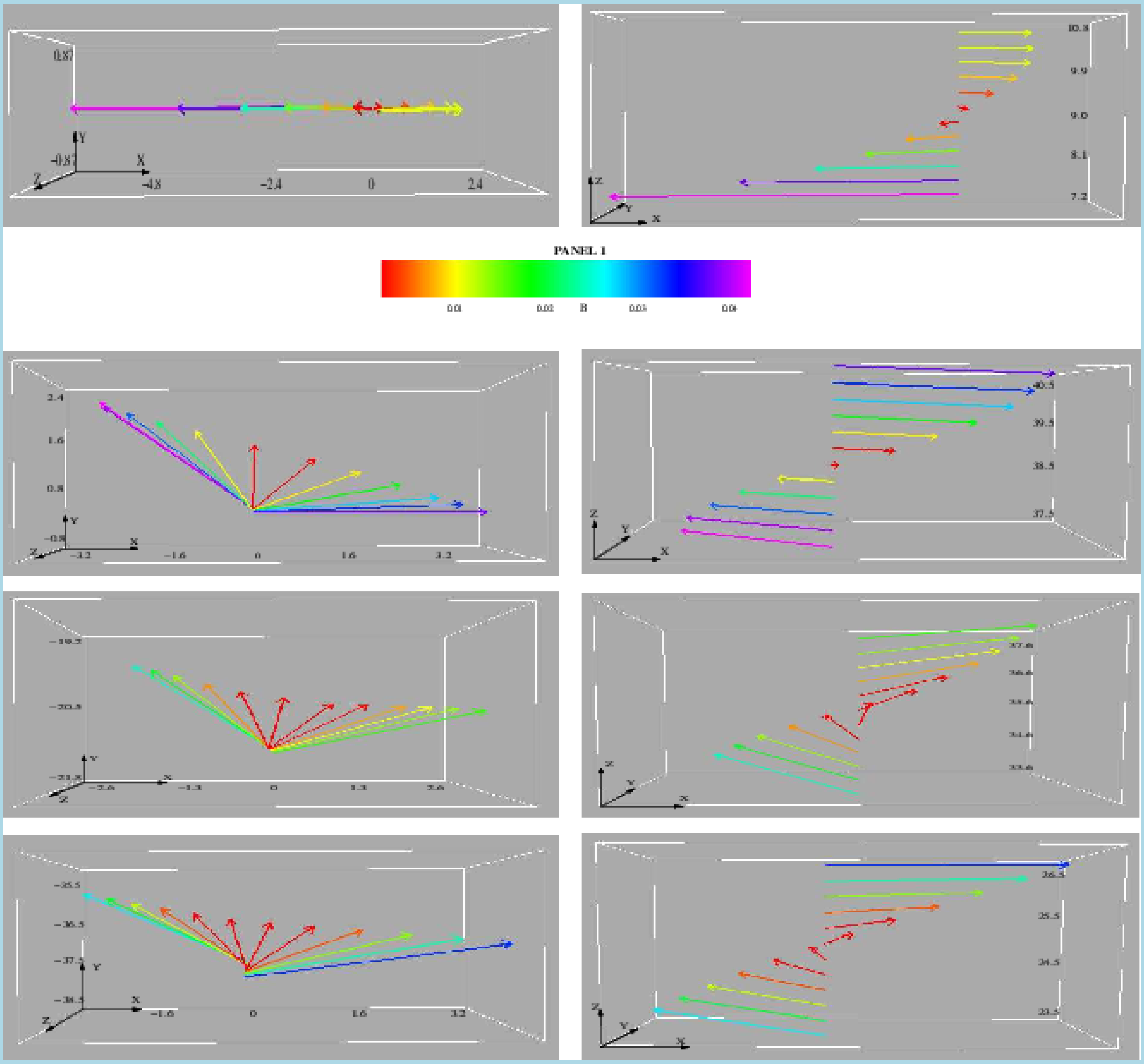
Rotational discontinuity

- Anti parallel case
- Top row: Initial situation
- Lower panels: later time, three different locations along the current sheet



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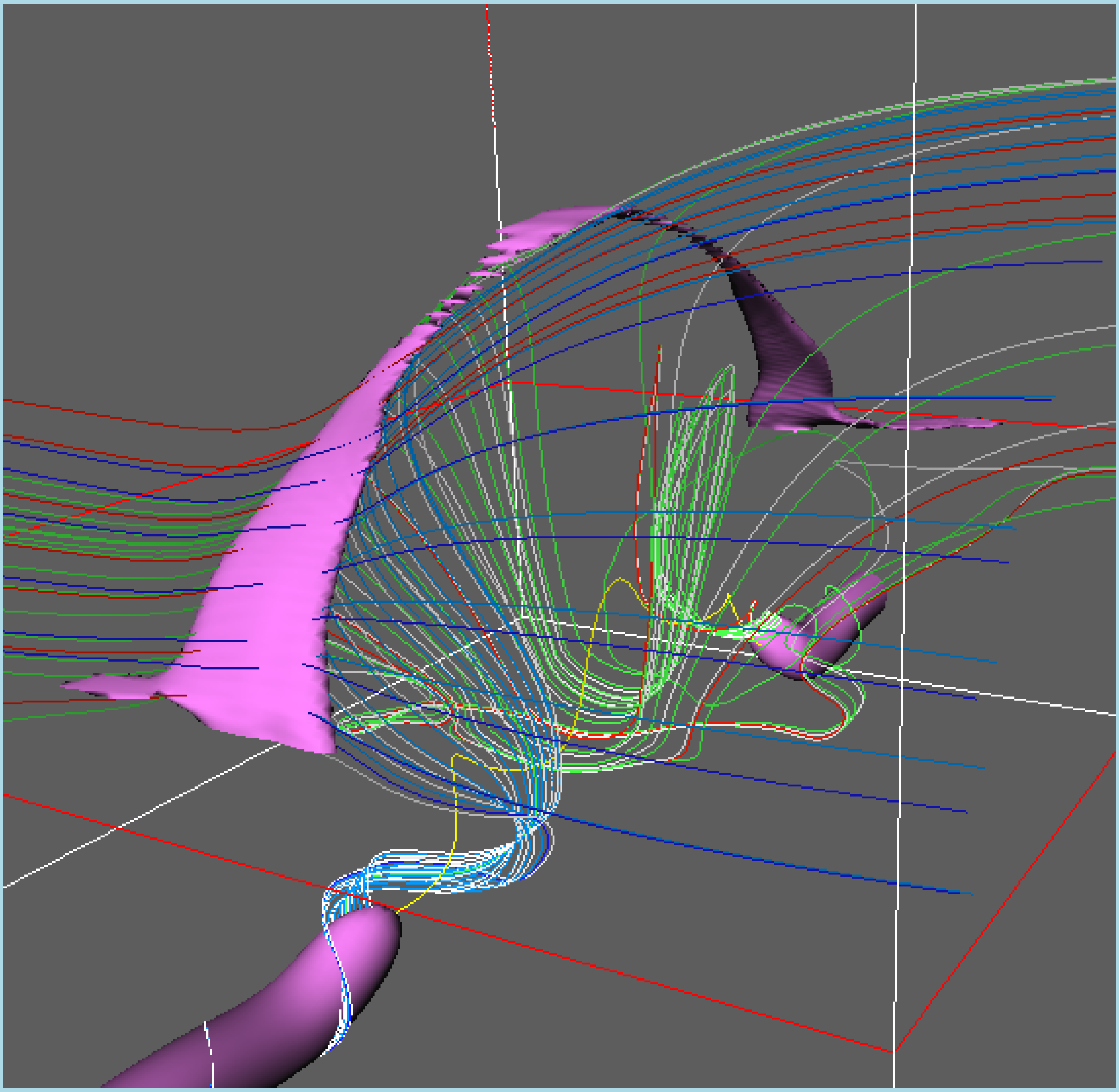
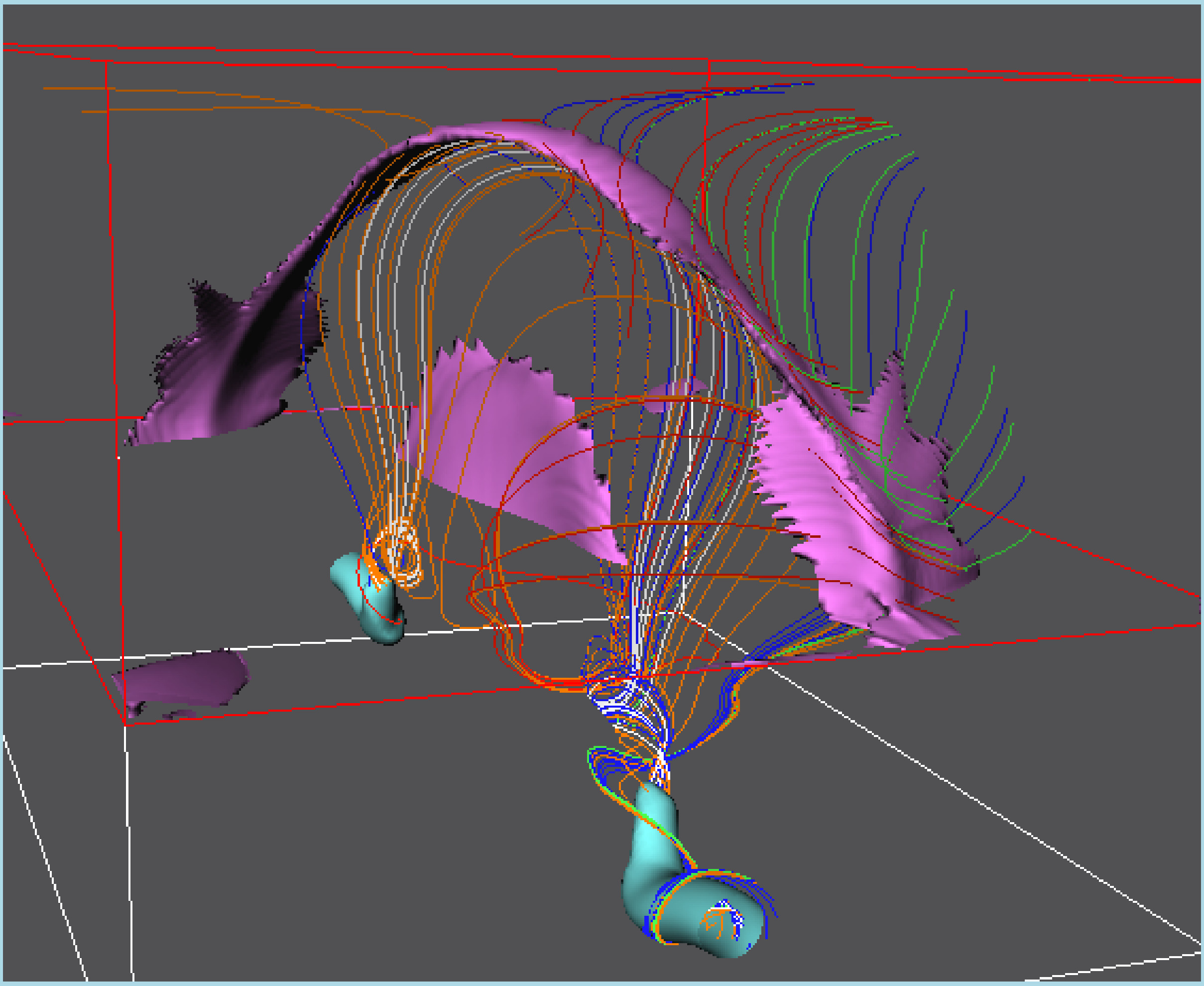
Field line structures

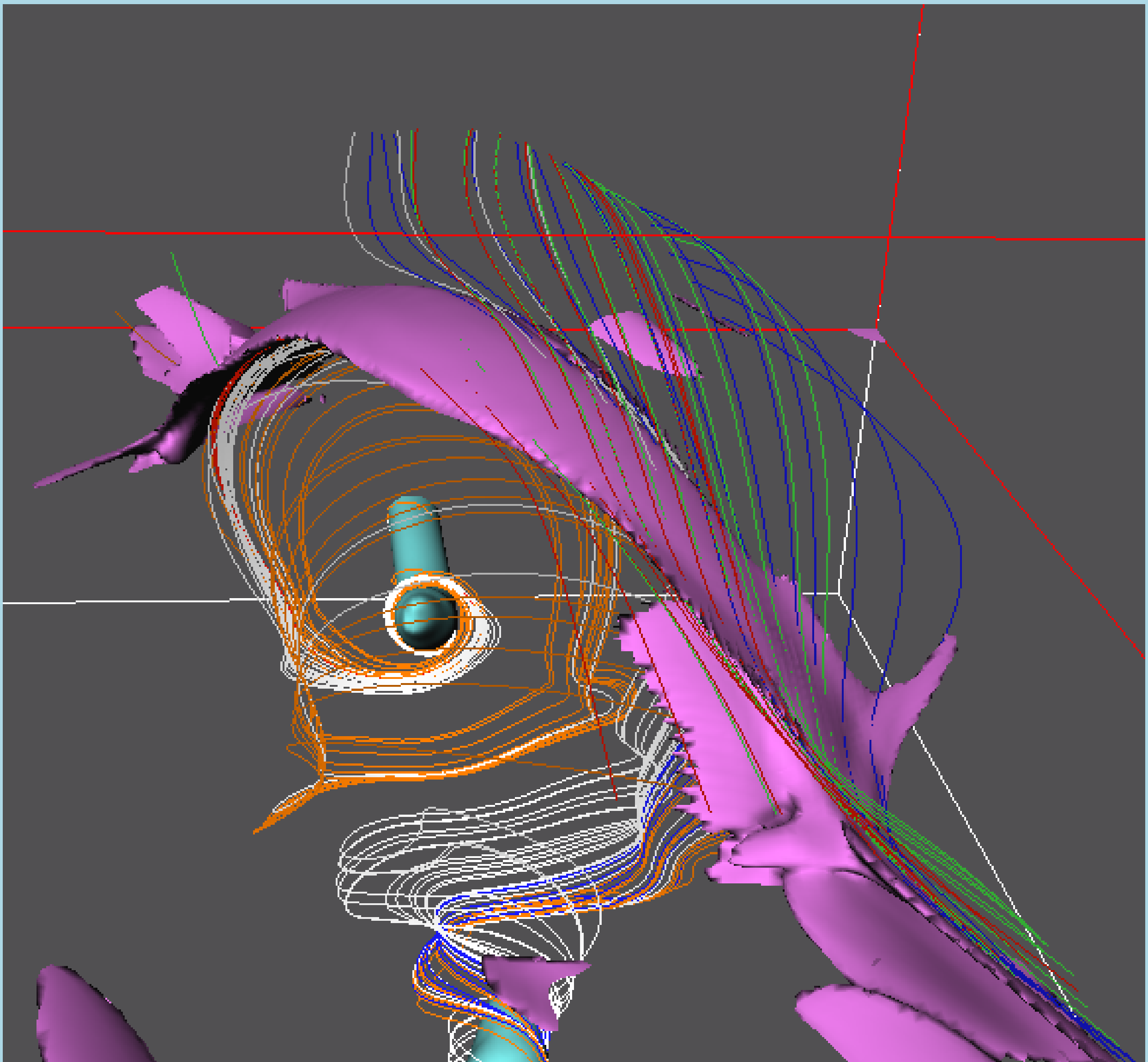
- 180 degrees

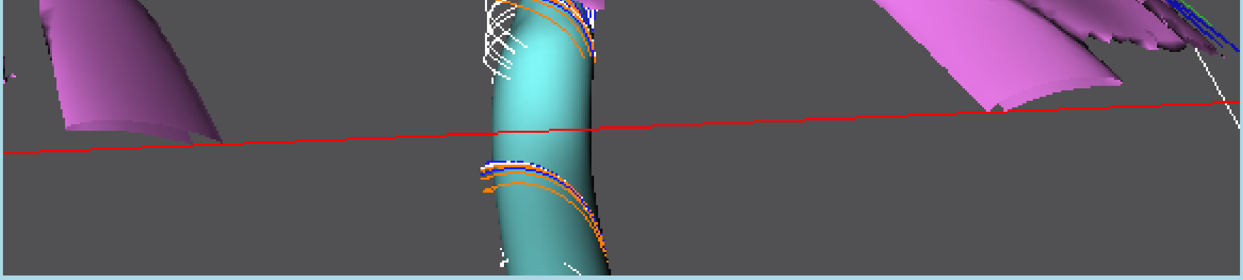


- 135 degrees

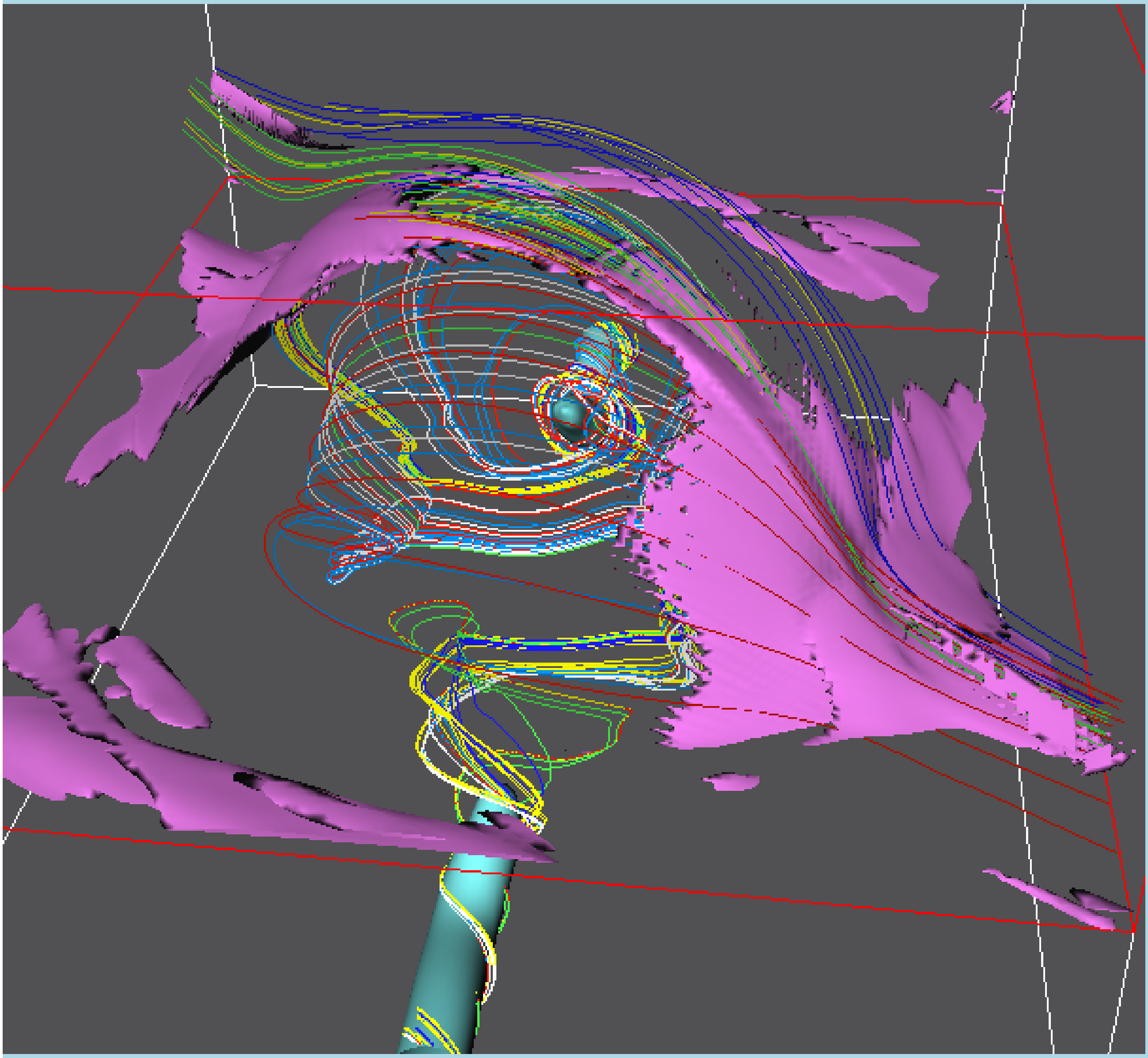


- **90 degrees**

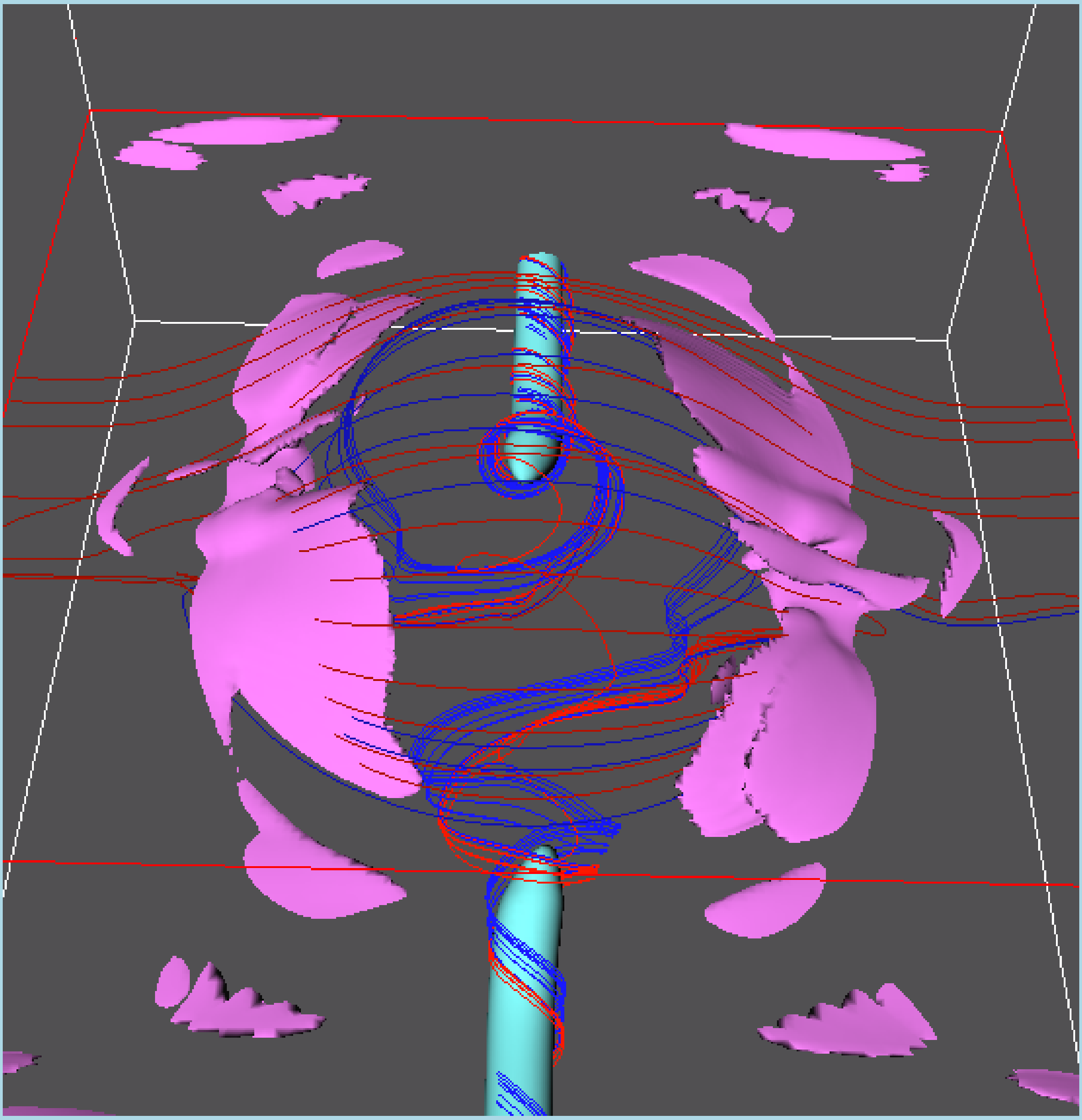




- **45 degrees**



- **0 degrees**



Coronal field across tube axis.Anti parallel to emerging flux
Coronal field 45 degree across tube axis.
Coronal field along tube axis.Perpendicular to emerging flux
Coronal field 45 degree across tube axis.

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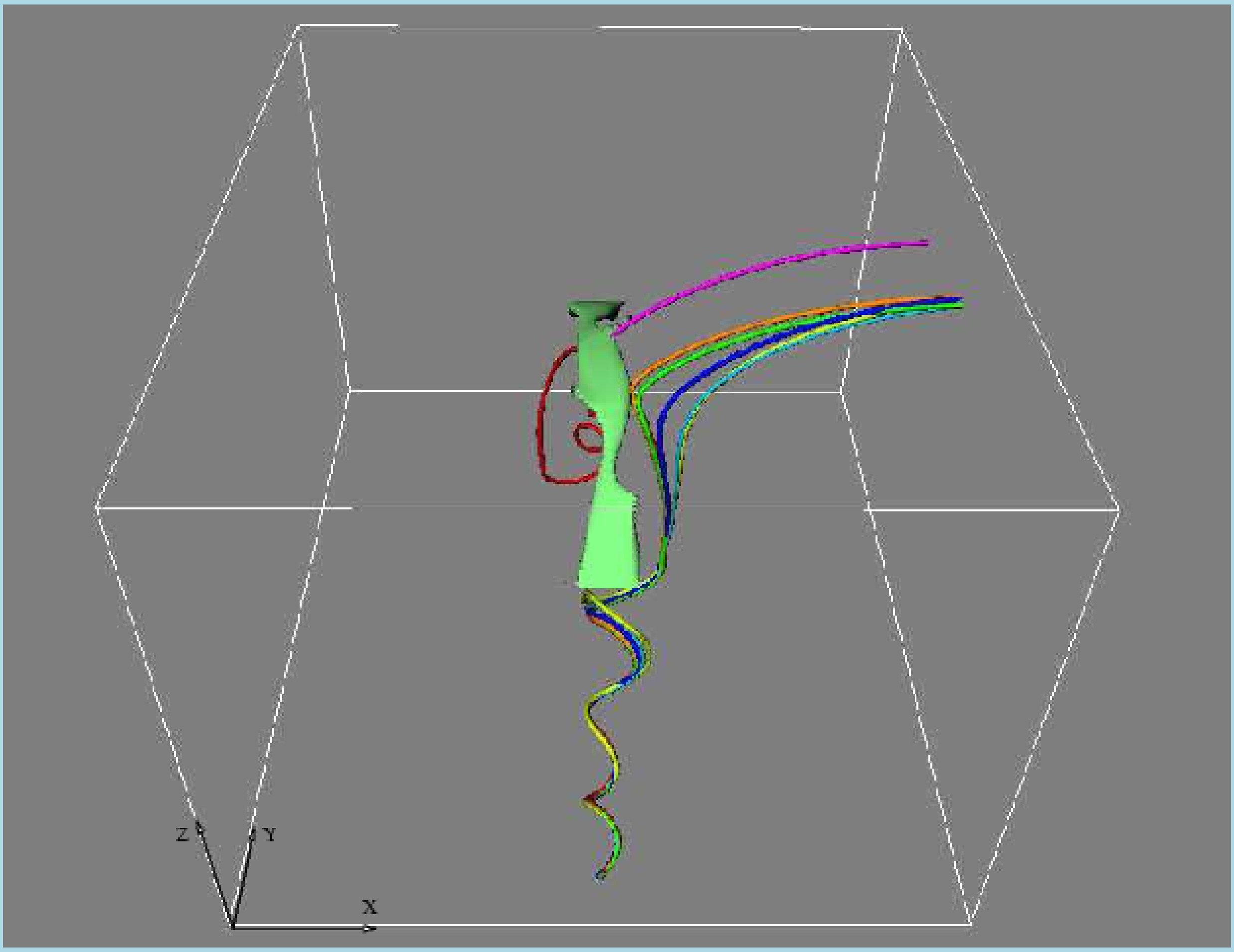
Slippage

- **Field lines are slipping through the plasma**



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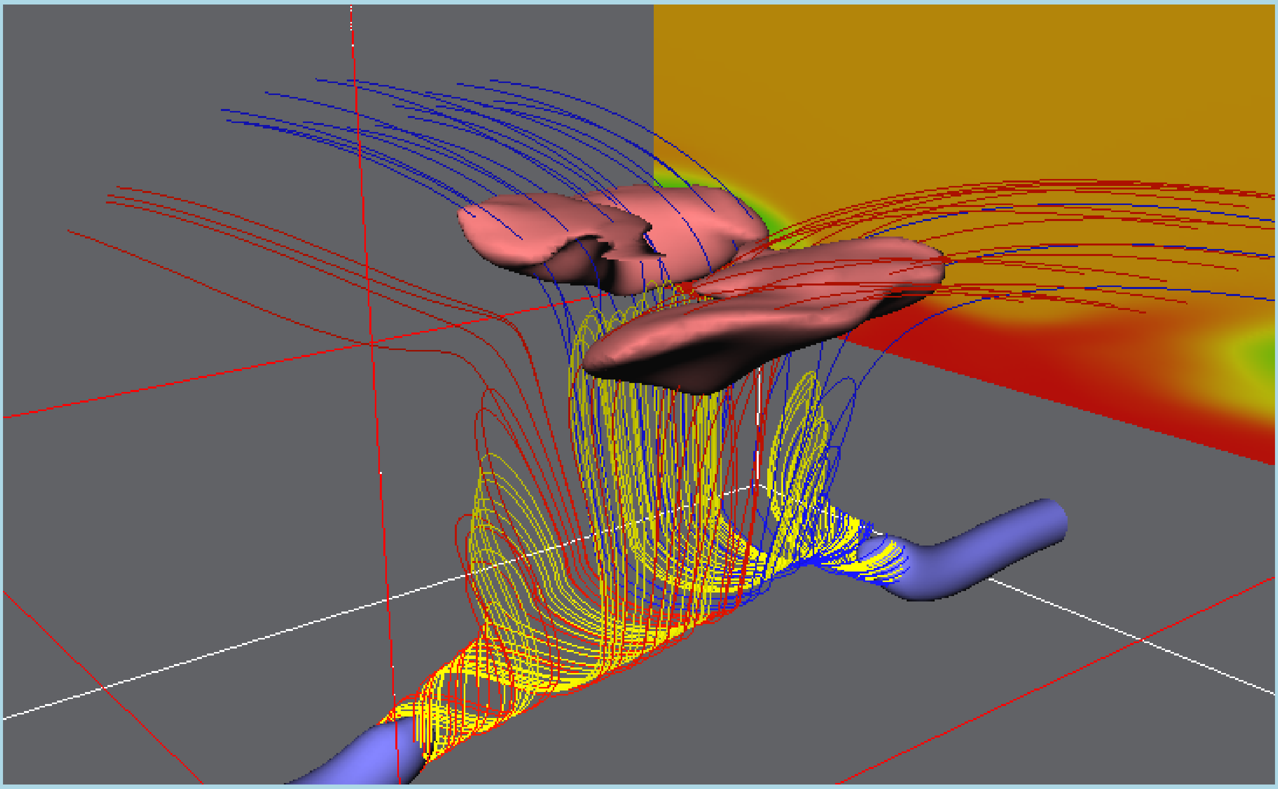
High temperature regions: 1

- Time = 102
- 180 degrees



- Isosurfaces of hot plasma
- Field lines from hot plasma
- Field lines from hot plasma
- Tube lines
- Red and blue are open field lines

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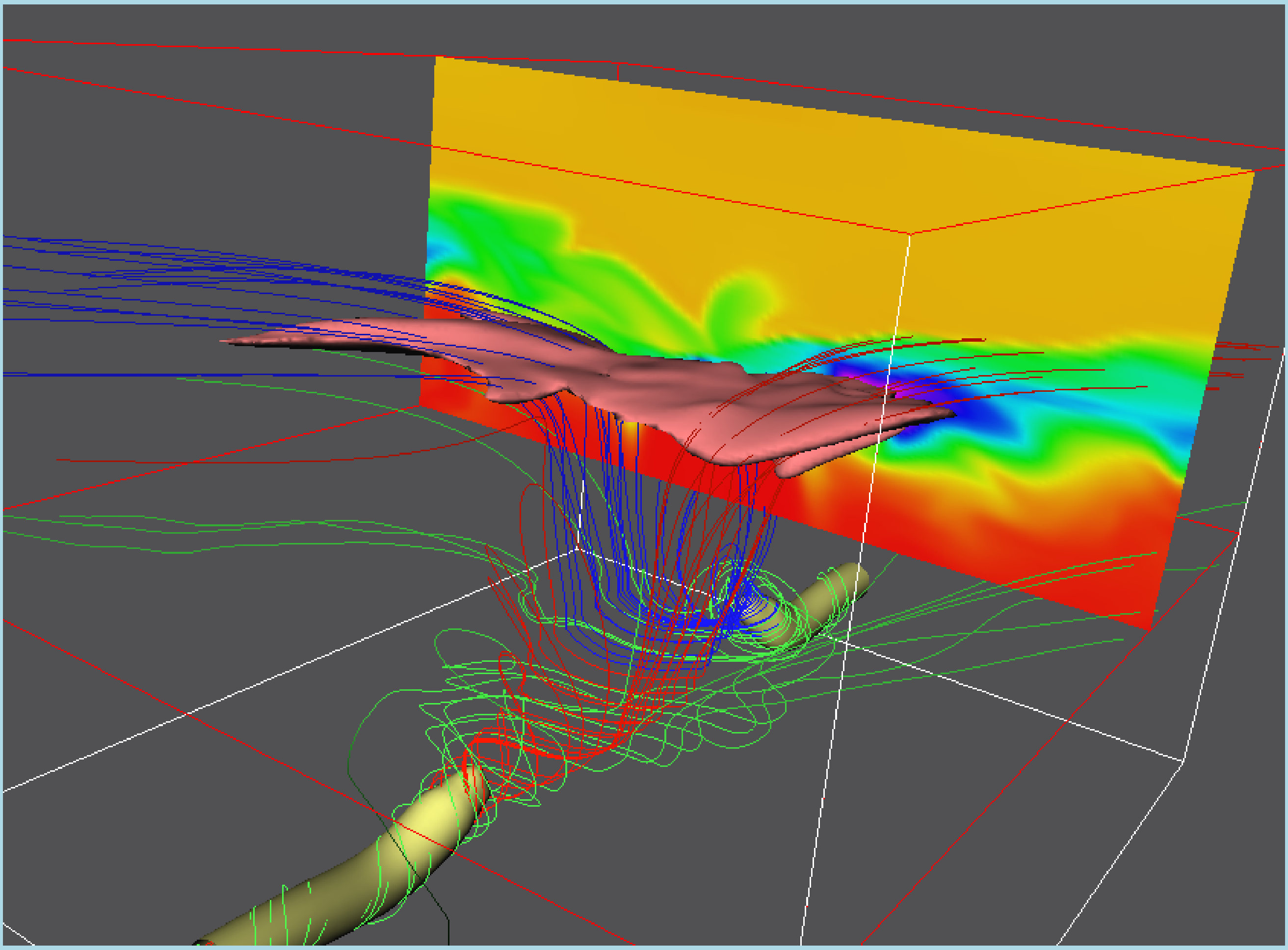
High temperature regions: 2

- Time = 103
- 135 degrees



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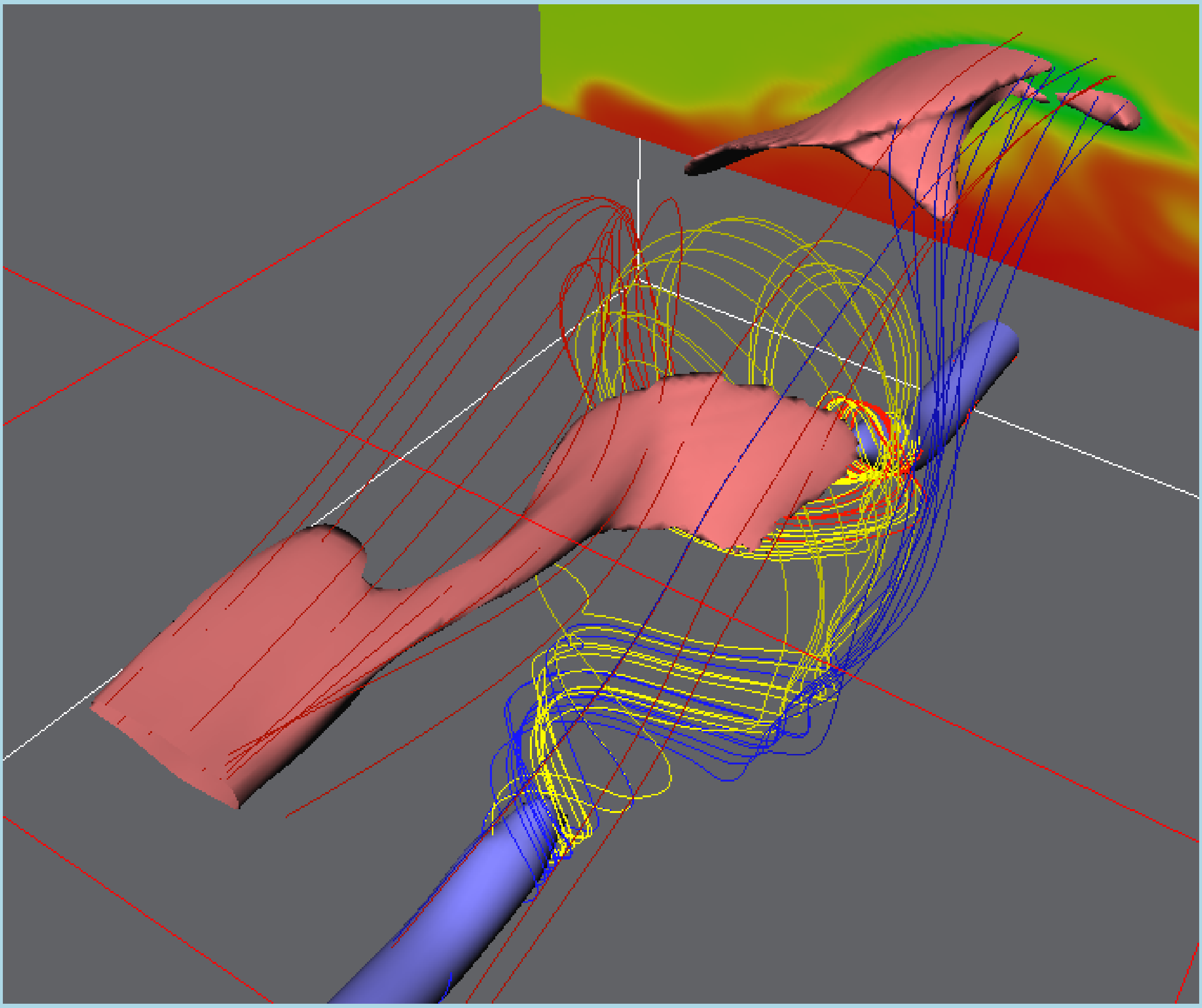
High temperature regions: 3

- Time = 102
- 90 degrees



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- **The problem is very complex**
- **Many things depend on the relative orientation between emerging and coronal magnetic field.**
  - Current strength - orientation
  - Plasma temperature
  - jet velocities
  - Location of most efficient reconnection location
  - Location of characteristic observables

- **Open questions (we are working on!)**
  - Plasmoid phase
  - More realistic energy equation
    - Anisotrope heat conduction
      - Significant impact on the temperature peak and space distribution
  - Structure of the coronal field
    - Coronal field orientation rotates with height
    - Resonance layers
  - Structure of the initial loop
- **More realistic setup**
  - Embedded flux tube

Summary

- Coronal magnetic field
- Convection
- Energy equation

- **Your favorite issue!**