

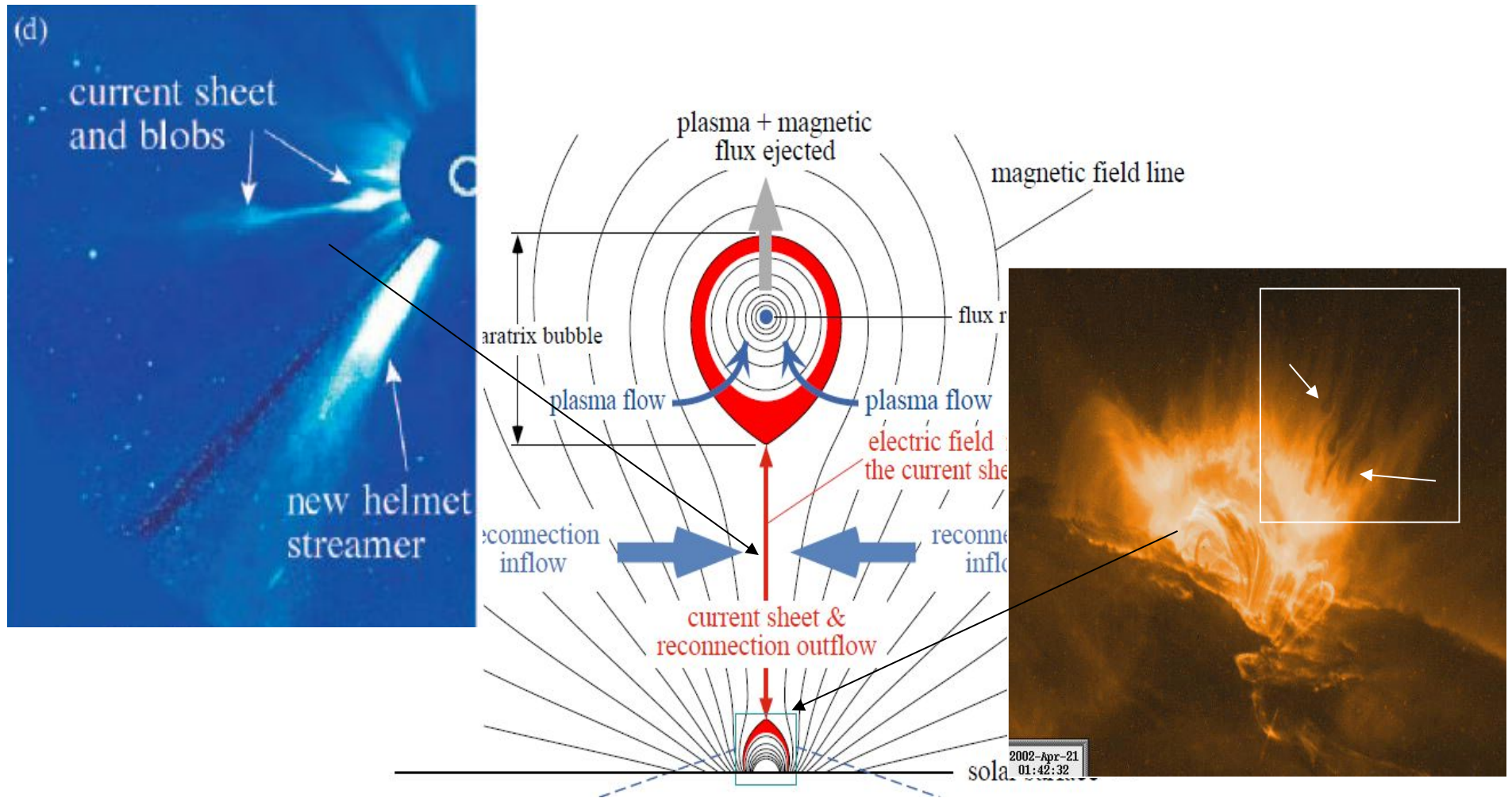
# Plasma Instabilities in Large Scale Magnetic Reconnection Associated with CMEs

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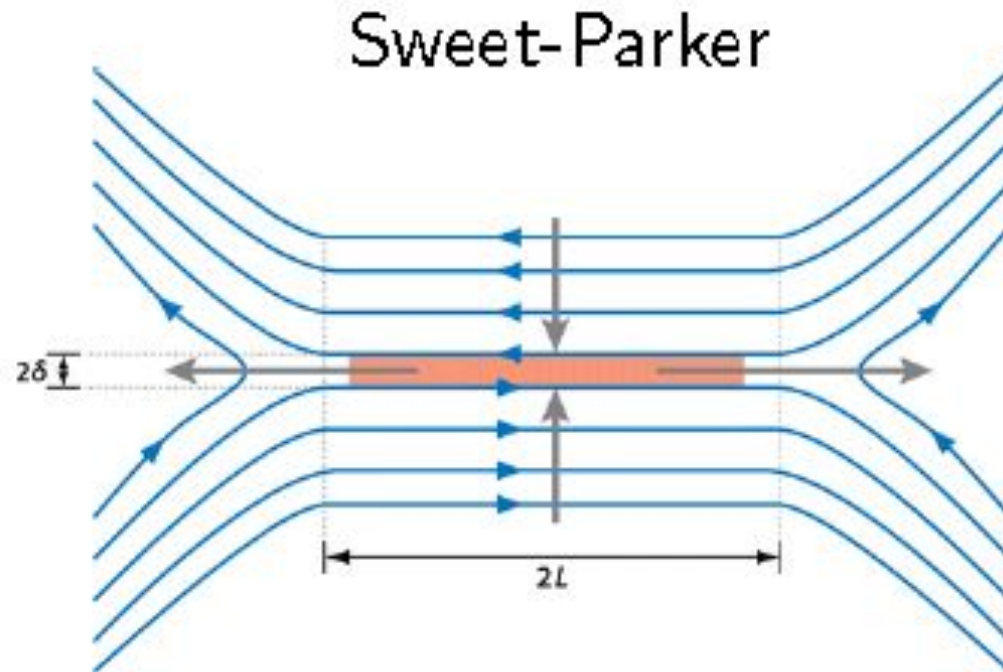
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# The CMEs/eruptive flares model



# Sweet-Parker reconnection



$$\frac{v_{in}}{\delta} \sim \frac{v_{out}}{L},$$

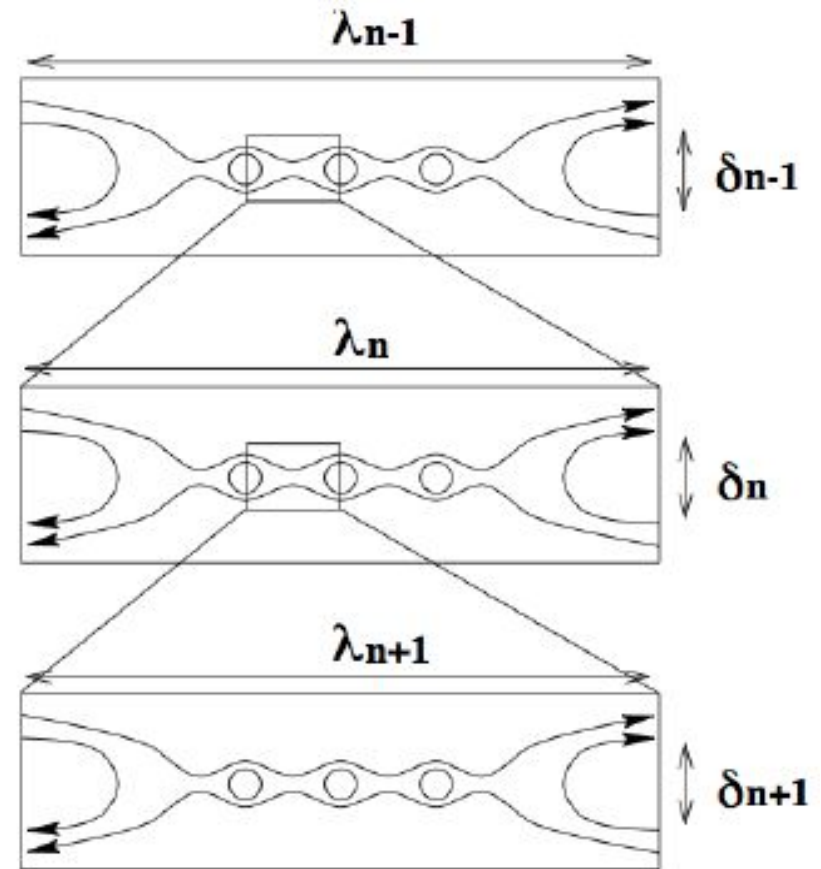
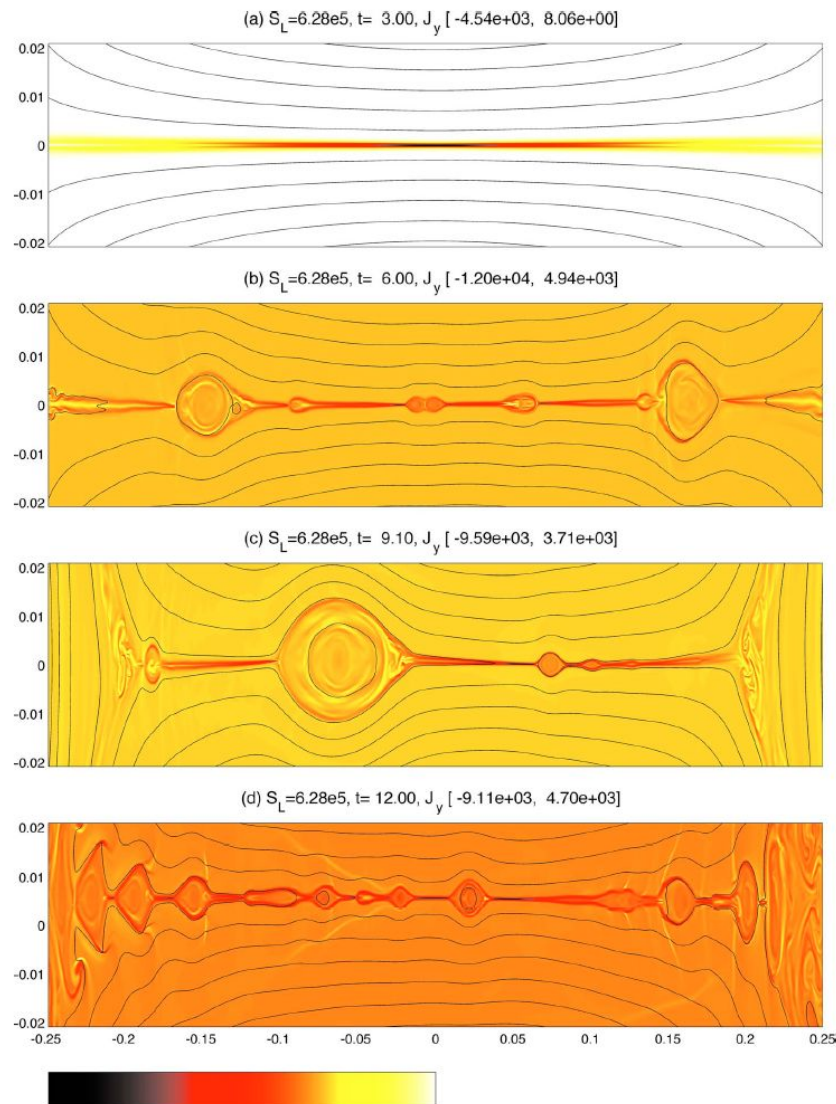
$$v_{out} = \frac{B}{\sqrt{\rho}} = V_A.$$

$$v_{in} \sim \frac{\eta}{\delta}$$

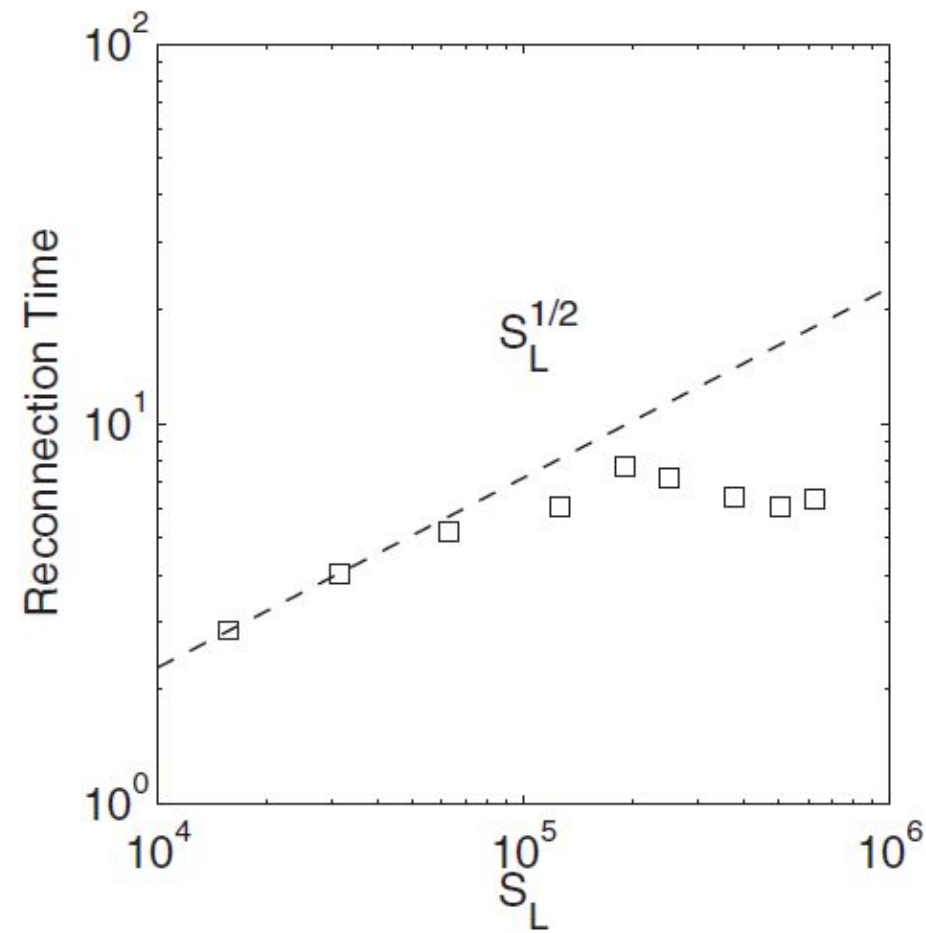
$$\gamma \sim \frac{v_{in}}{V_A} \sim \sqrt{\frac{\eta}{V_A L}} \sim S^{-1/2}.$$

Where  $S = LV_A/\eta,$

# The plasmoid instability

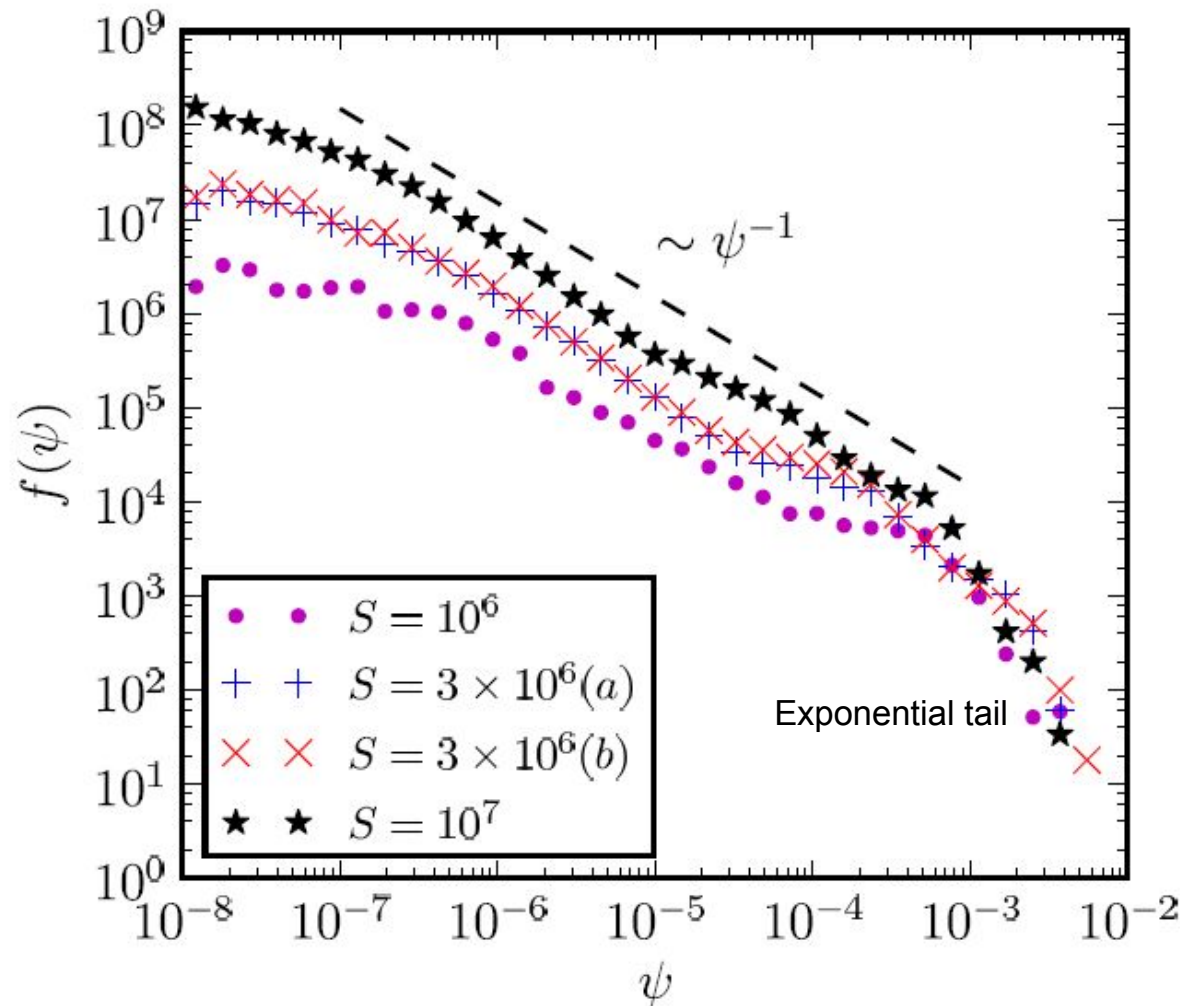


# Reconnection rate



Bhattacharjee and Huang 2009

# Distribution of magnetic fluxes of plasmoid



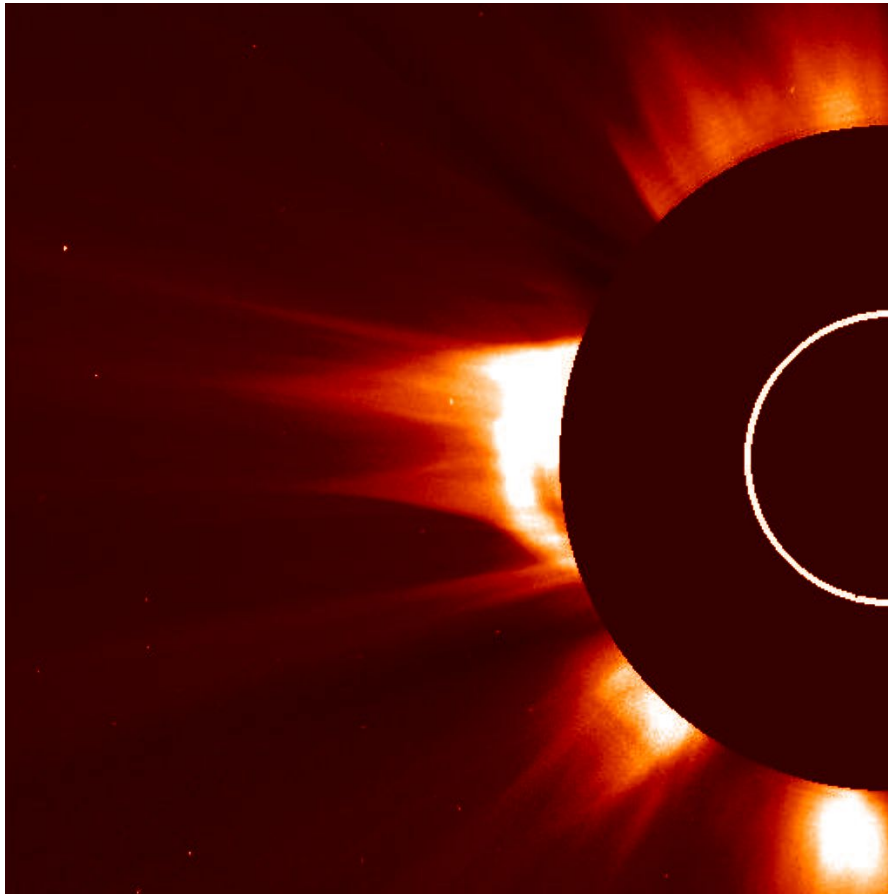
Huang & Bhattacharjee 2012

This figure shows distributions of magnetic fluxes of plasmoids from four simulations with different Lundquist number.

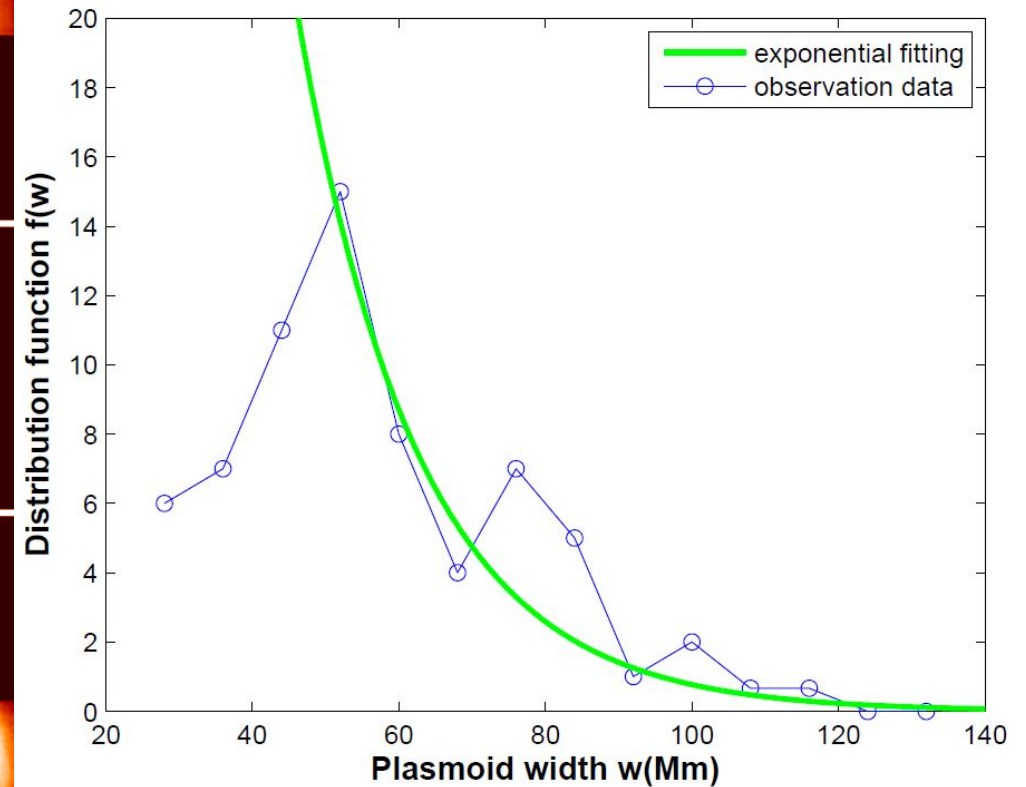
The results of four runs show a power-law distribution with an exponential tail in the large-scale regime

The simulation results are in agreement with theoretical prediction by solving a governing equation of plasmoid formation.

# Observations of plasmoid distribution

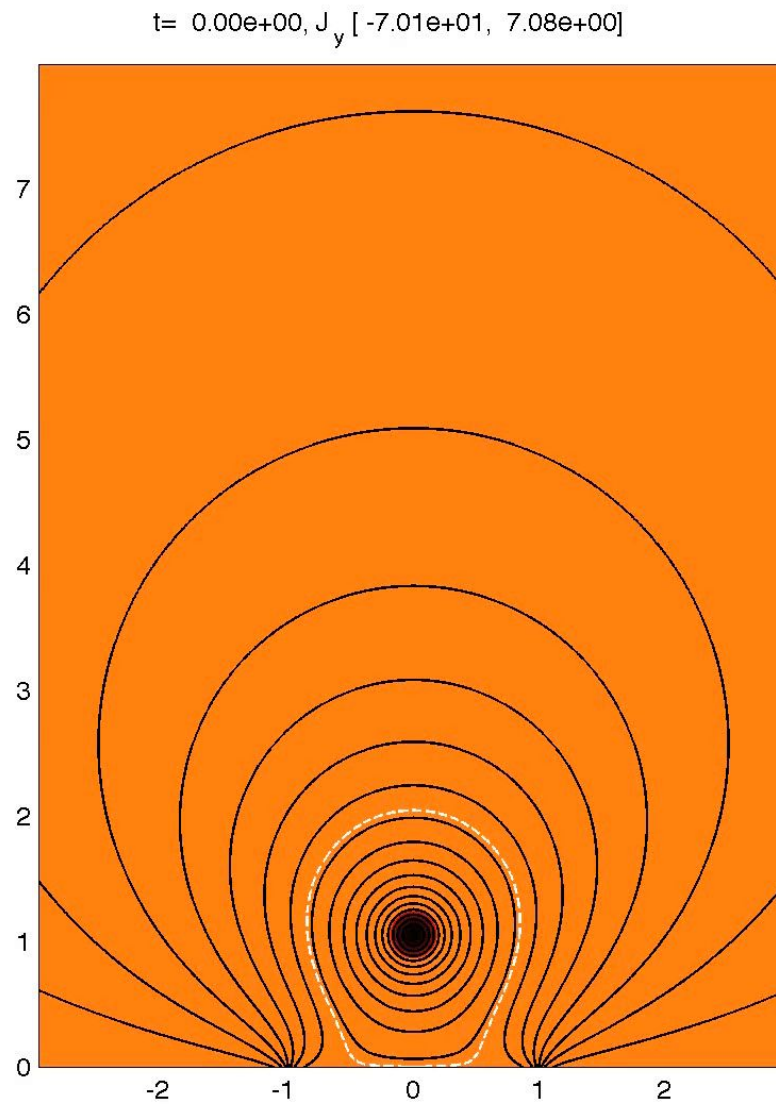


A ray structure and plasmoids observed in a CME event in 2002/01/08 by LASCO C2 white light coronagraph

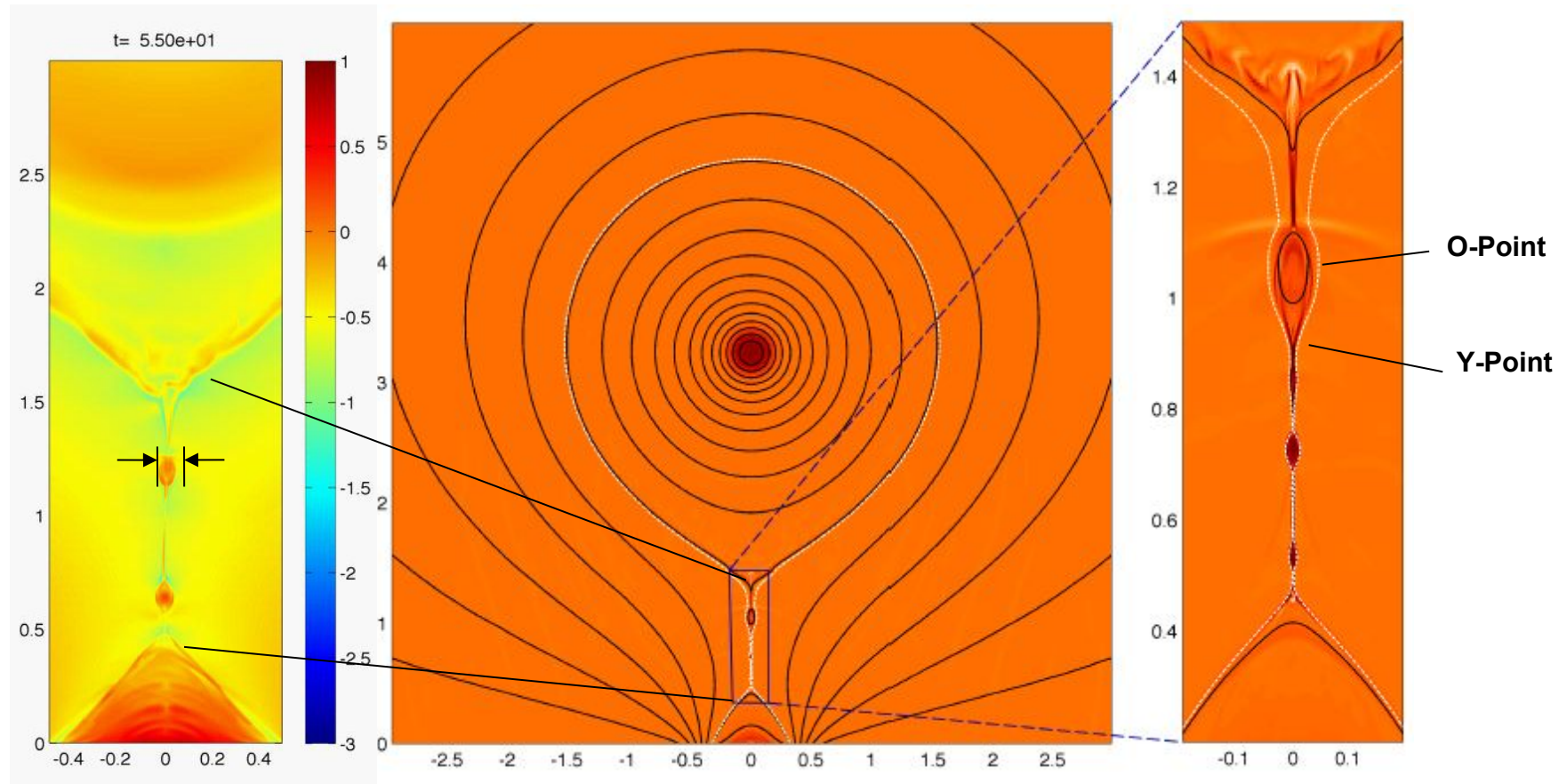


We observe 72 plasmoids from this event, their scale distribution plot is shown in the right panel.

# A numerical model for CME eruption

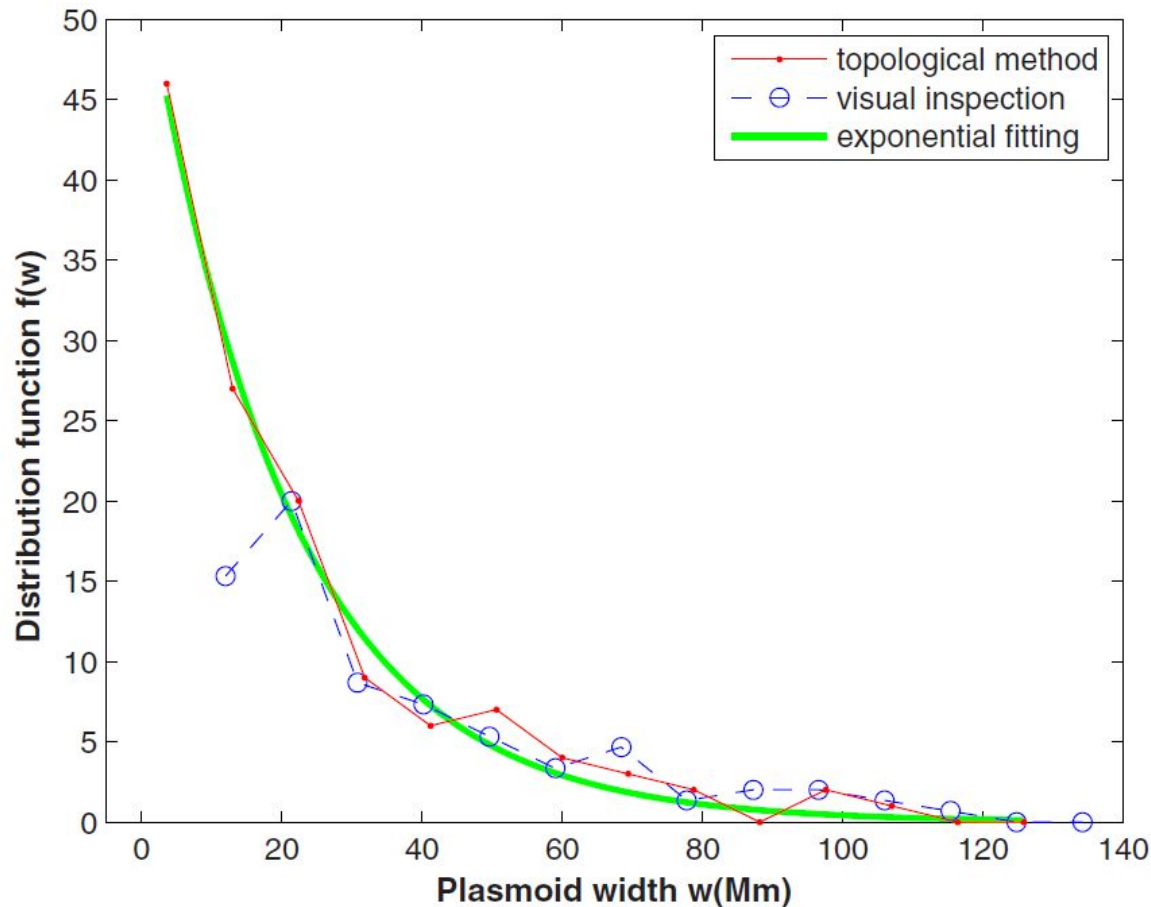


# Plasmoid distribution derived by two methods



We use two methods to determine scales of plasmoids. The first one uses computer code to resolve and record plasmoid size through recognizing Y- and O- points along current sheet, the second one measures plasmoids scale by their emission measure.

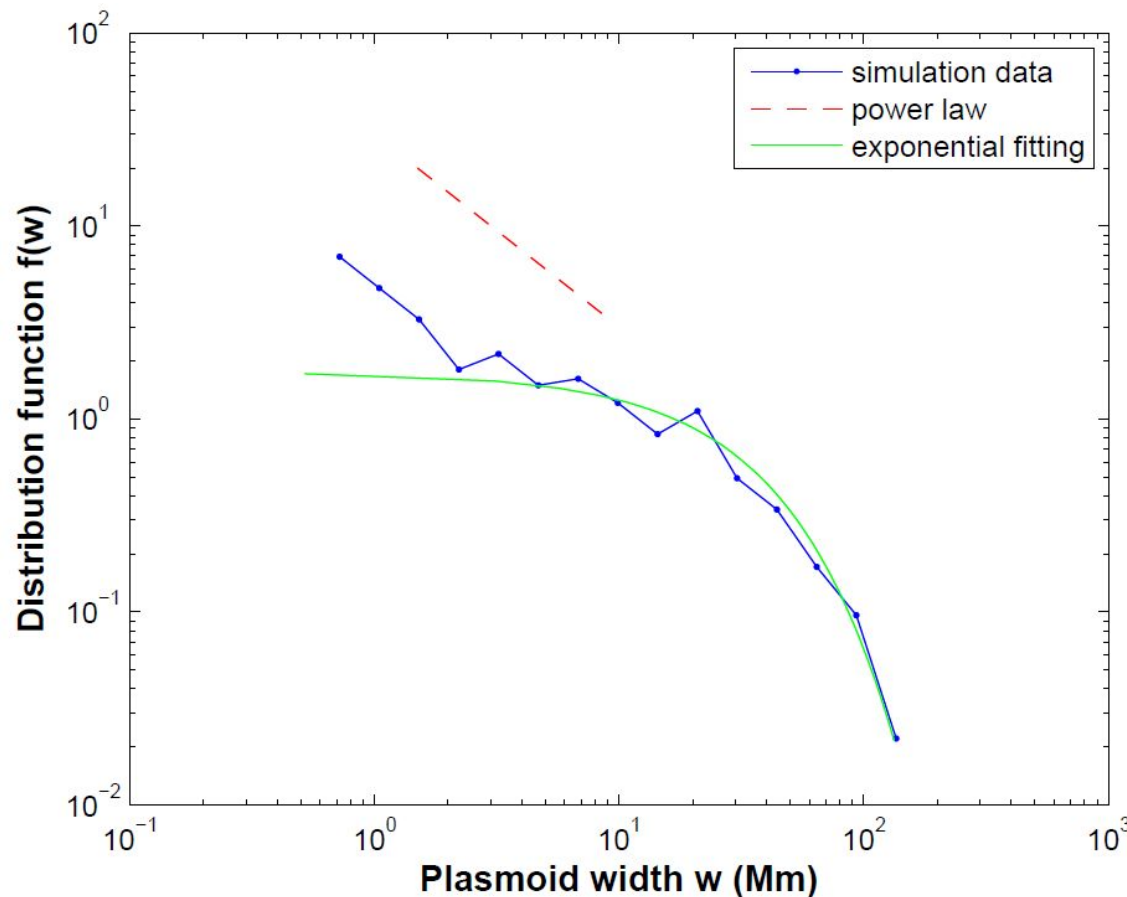
# Comparison between two distribution plots



The distribution derived from visual inspection method qualitatively agree with the observation.

Distributions from two methods agree with each other in large scale regime, but have different trends in small scale regime.

# Log plot of plasmoid distribution shows trend of power-law distribution in the small scale regime



Log plot of plasmoid distribution (simulation results derived by the second method) shows that:

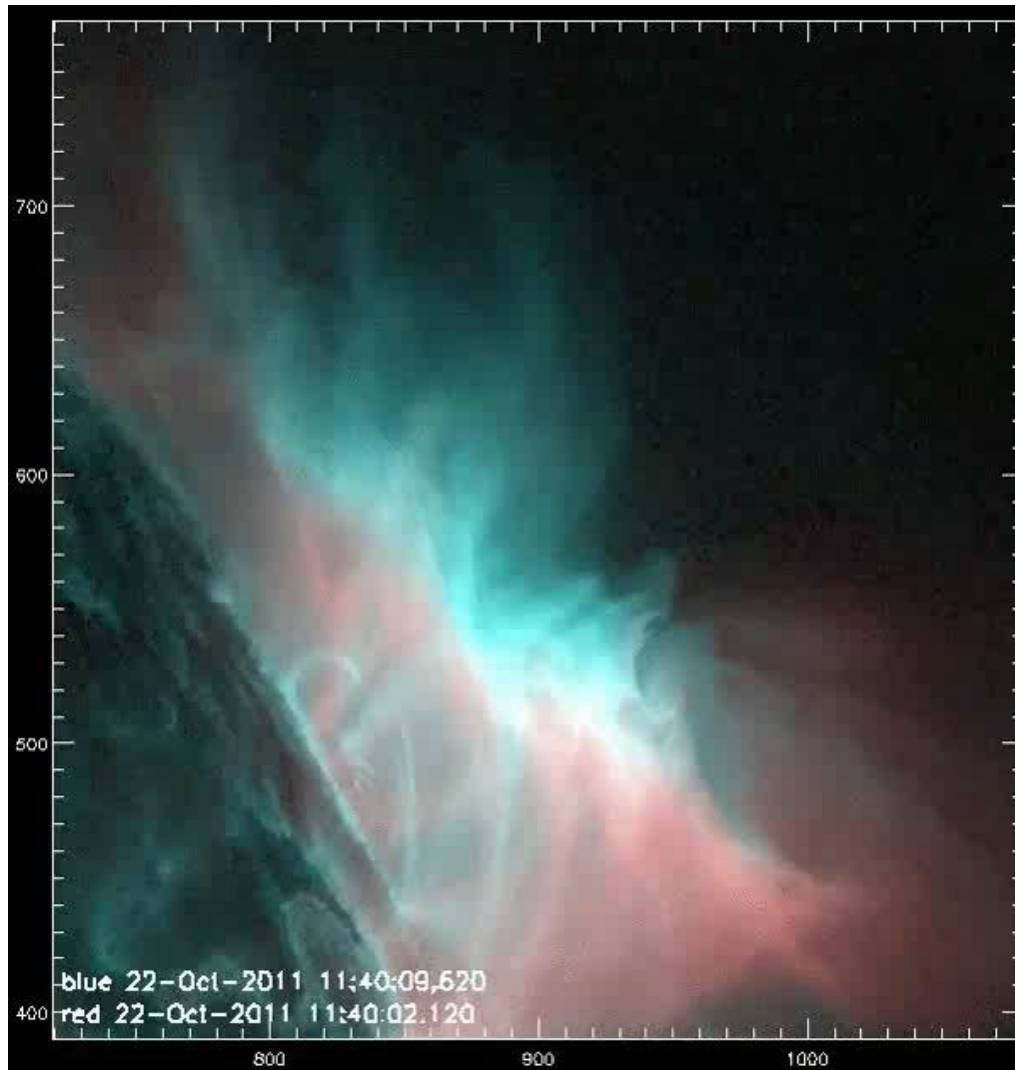
In the large-scale regime it can be fitted by exponential function

In the small-scale regime, it shows trend of power-law distribution

# Main results

1. The plasmoid distribution from observations and simulations are in qualitative agreement when data from both sources are processed by visual inspection. This fact suggests that plasmoid instability is a possible mechanism for CME current sheet reconnection.
2. Predictions of log-normal distribution of plasmoids are thus questionable. Our work suggests that the plasmoid distribution follows a power-law with an exponential tail. Similar conclusions might also apply to the dayside magnetopause in the Earth's magnetosphere.

# Supra-arcade downflows



Also know as tadpoles

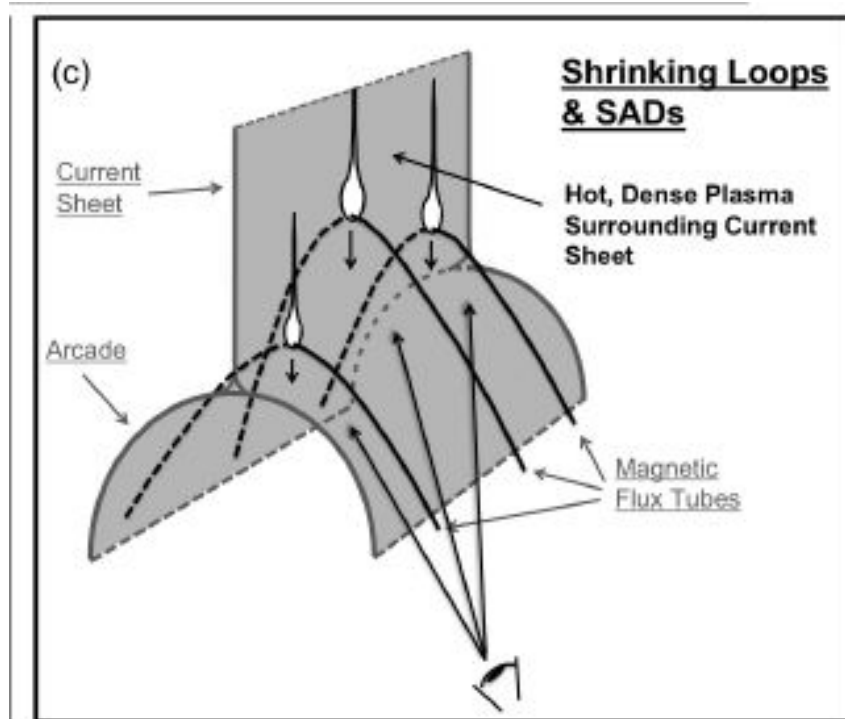
Low emission, low density

Long, wiggling structures

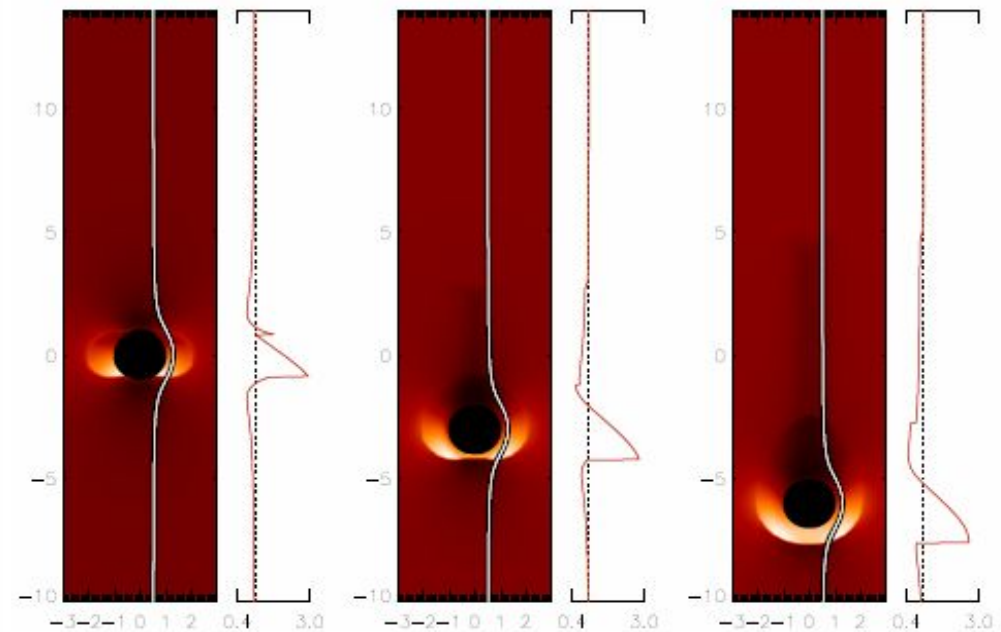
Average life time 10-20 minutes

Happen in a repeated manner

# Existing simulations/models of supra-arcade downflows

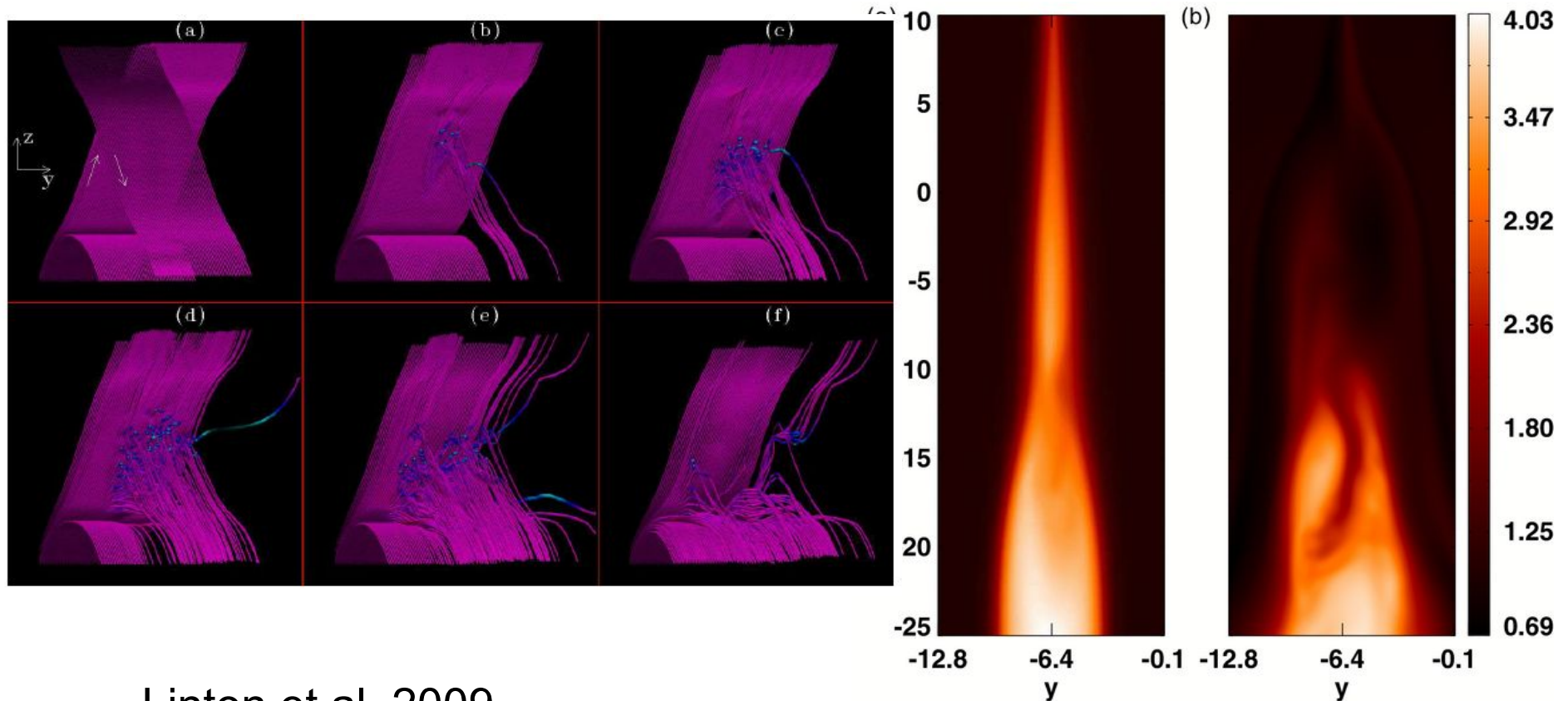


Savage et al. 2012



Scott et al. 2013

# Existing simulations/models of supra-arcade downflows

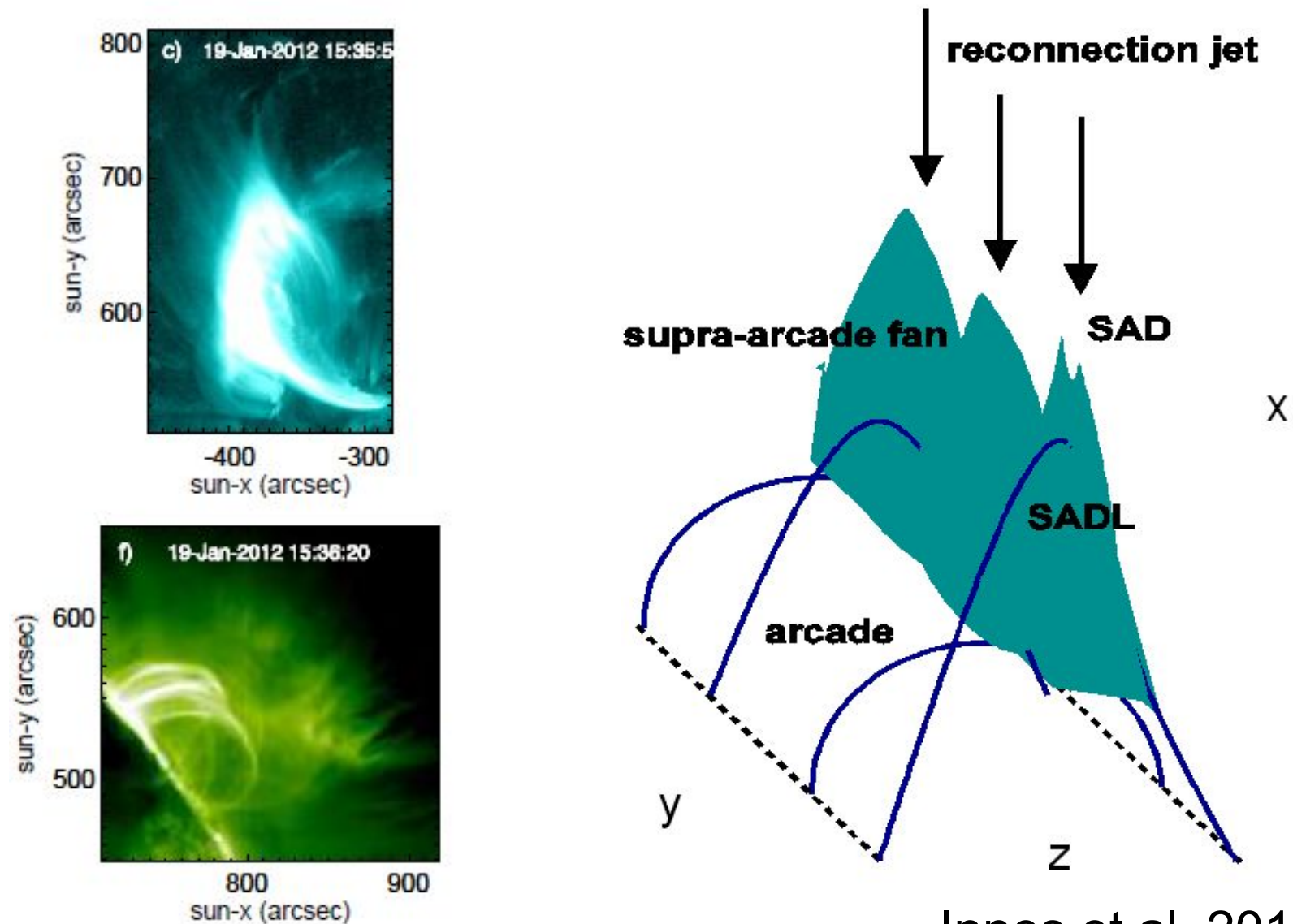


Linton et al. 2009

Cassak et al. 2013

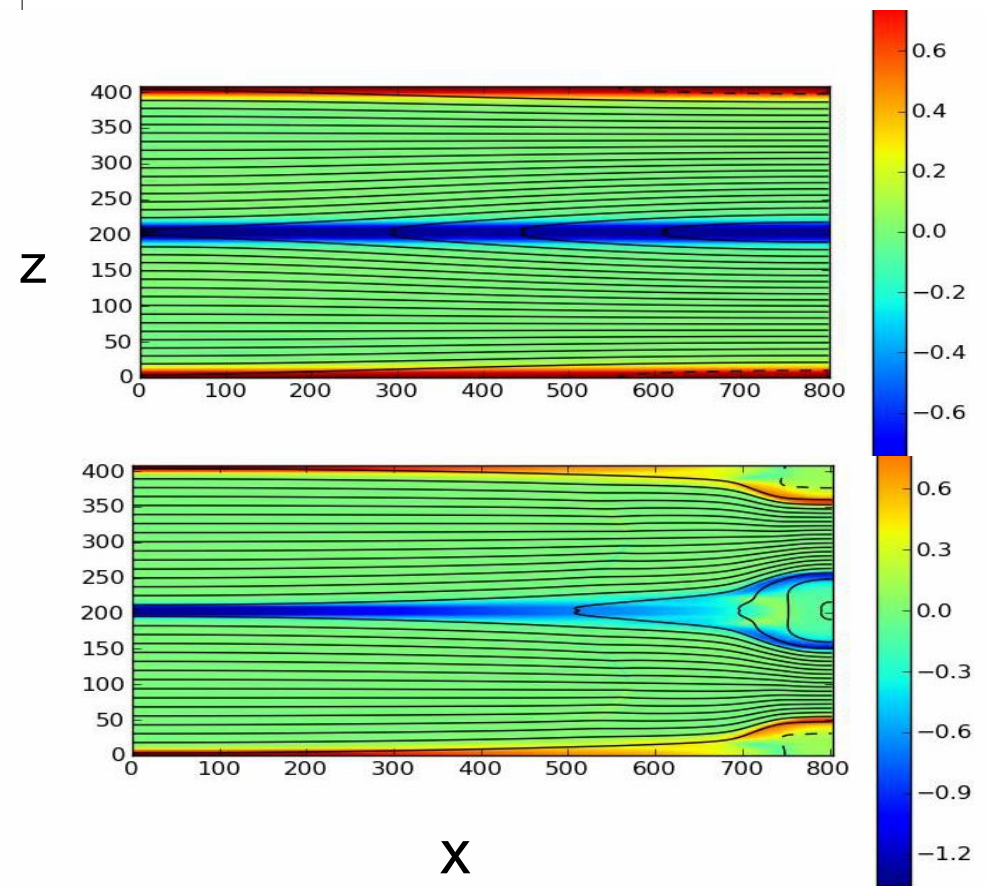
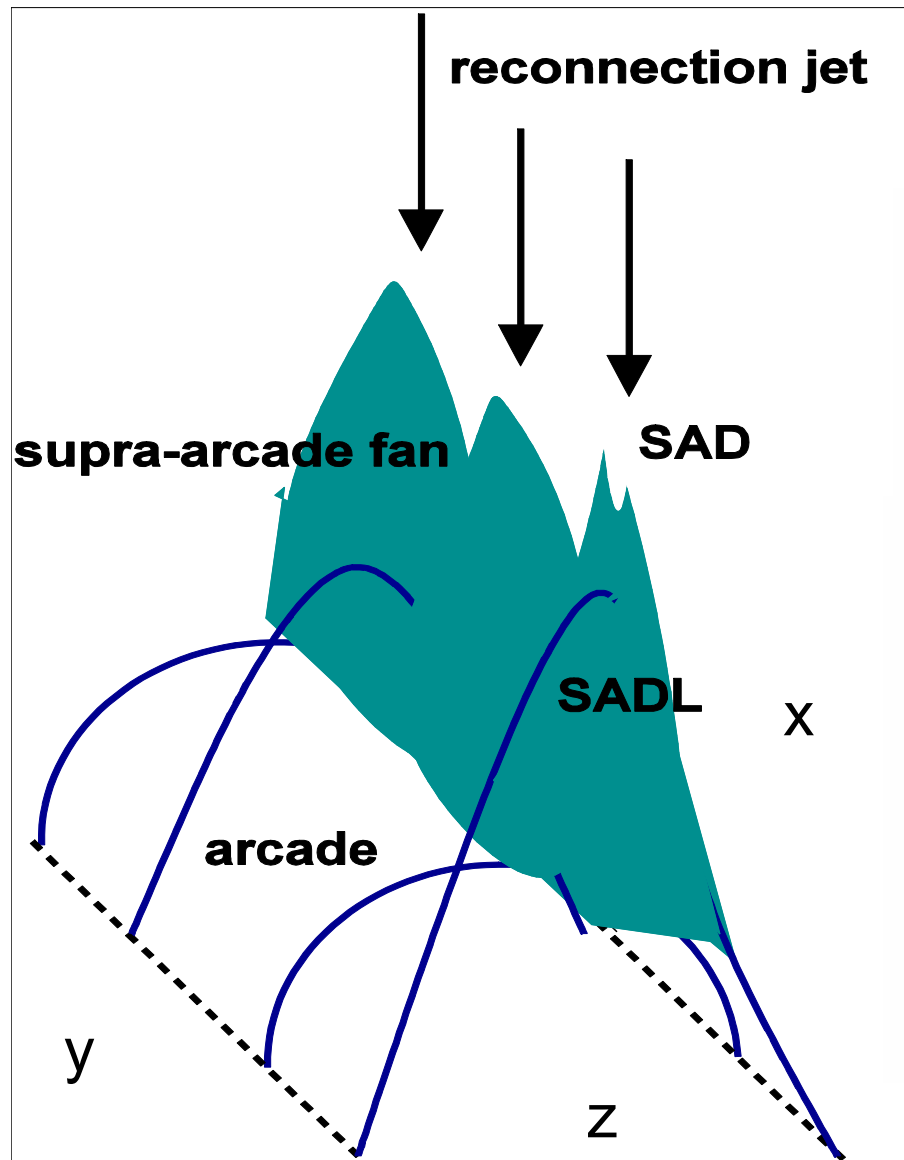
limitations: (1) rely on anomalous resistivity  
(2) have not been able to reproduce observations of SADs

# Geometry of supra-arcade downflows

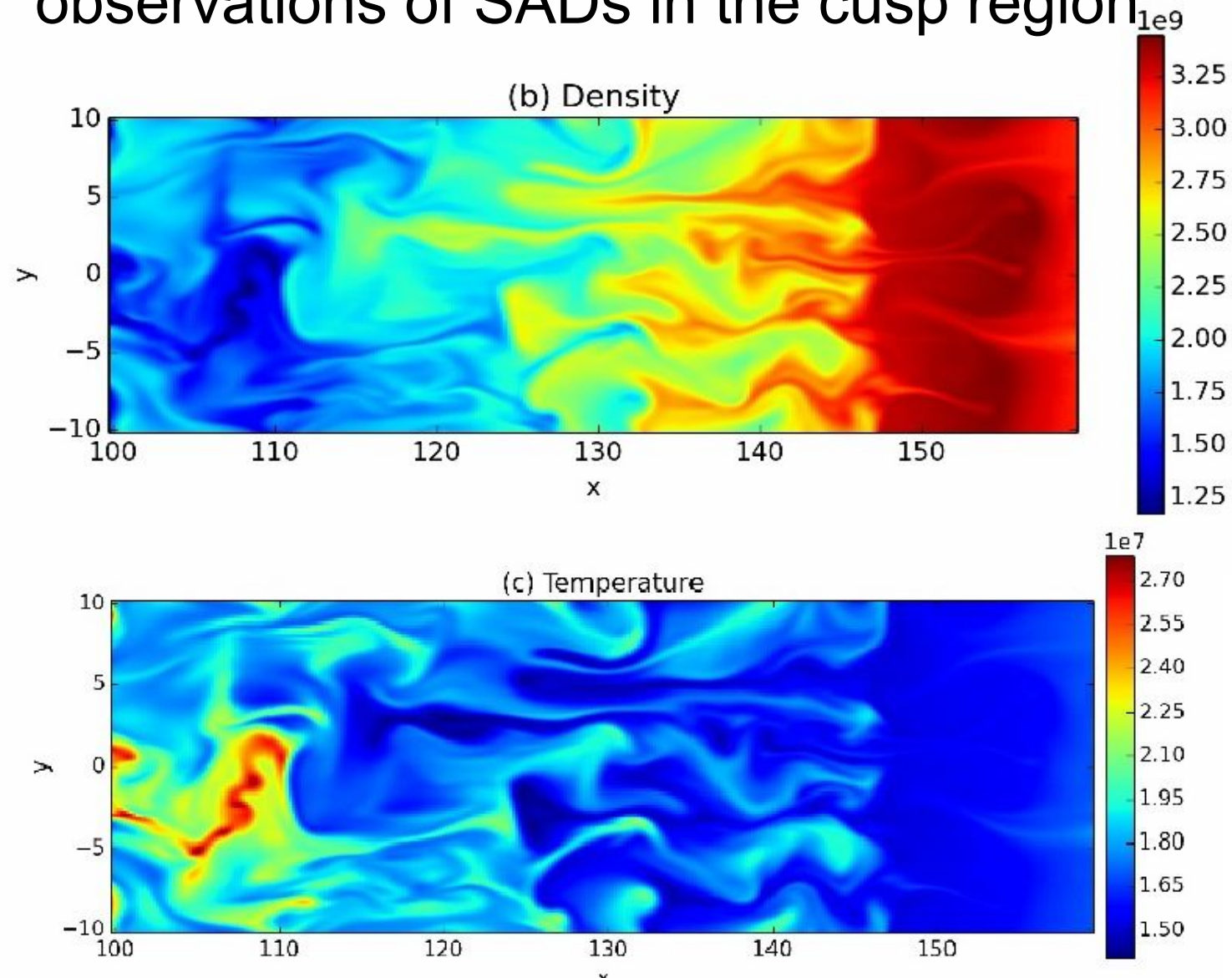


Innes et al. 2014

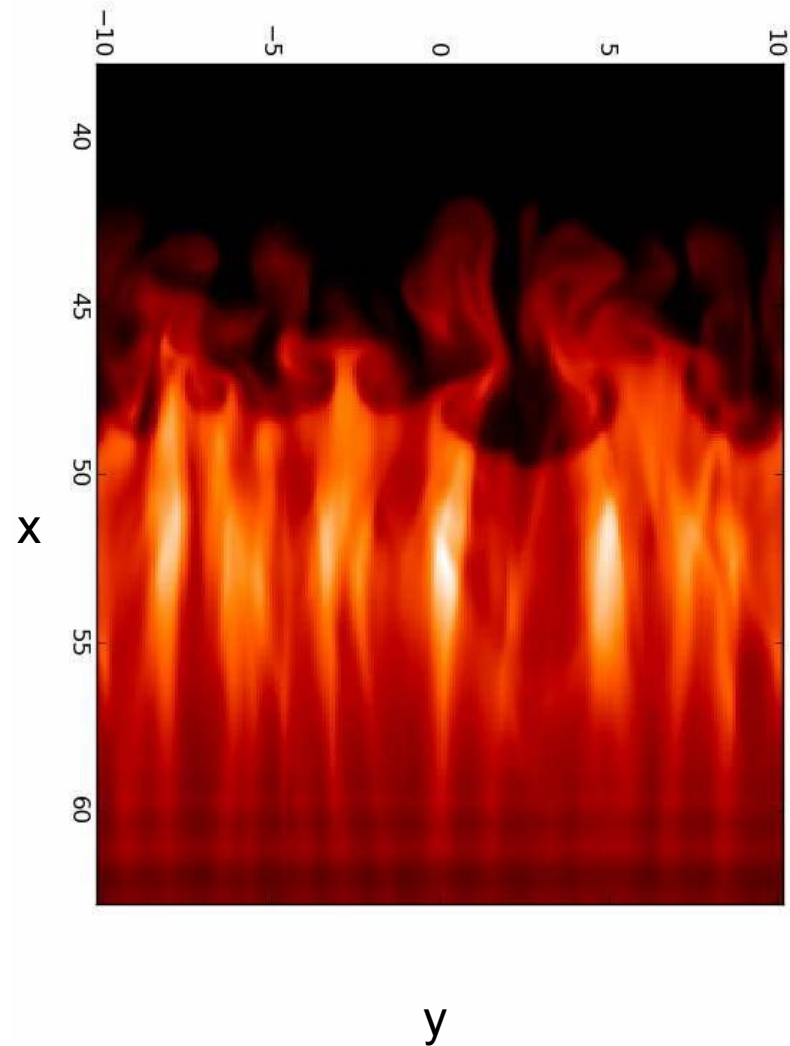
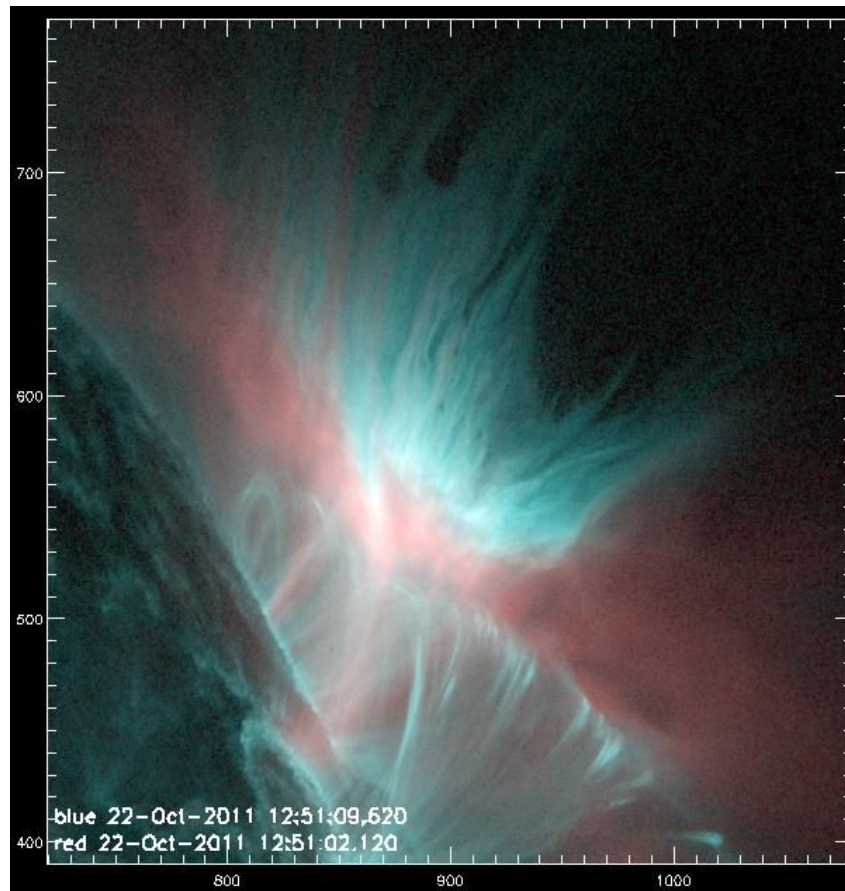
# Three-dimensional numerical model setup



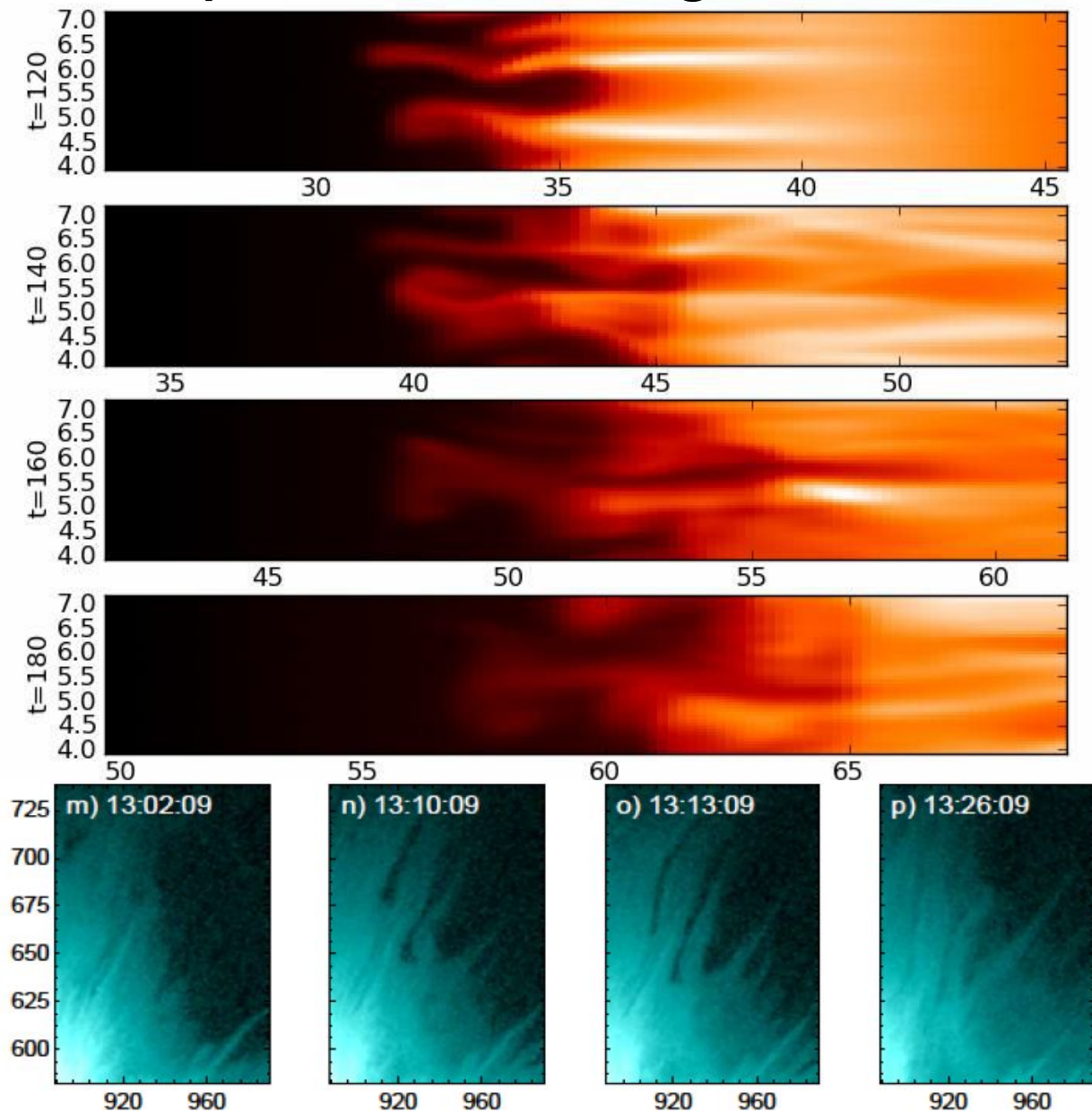
# Rayleigh-Taylor-type instabilities reproduce observations of SADs in the cusp region



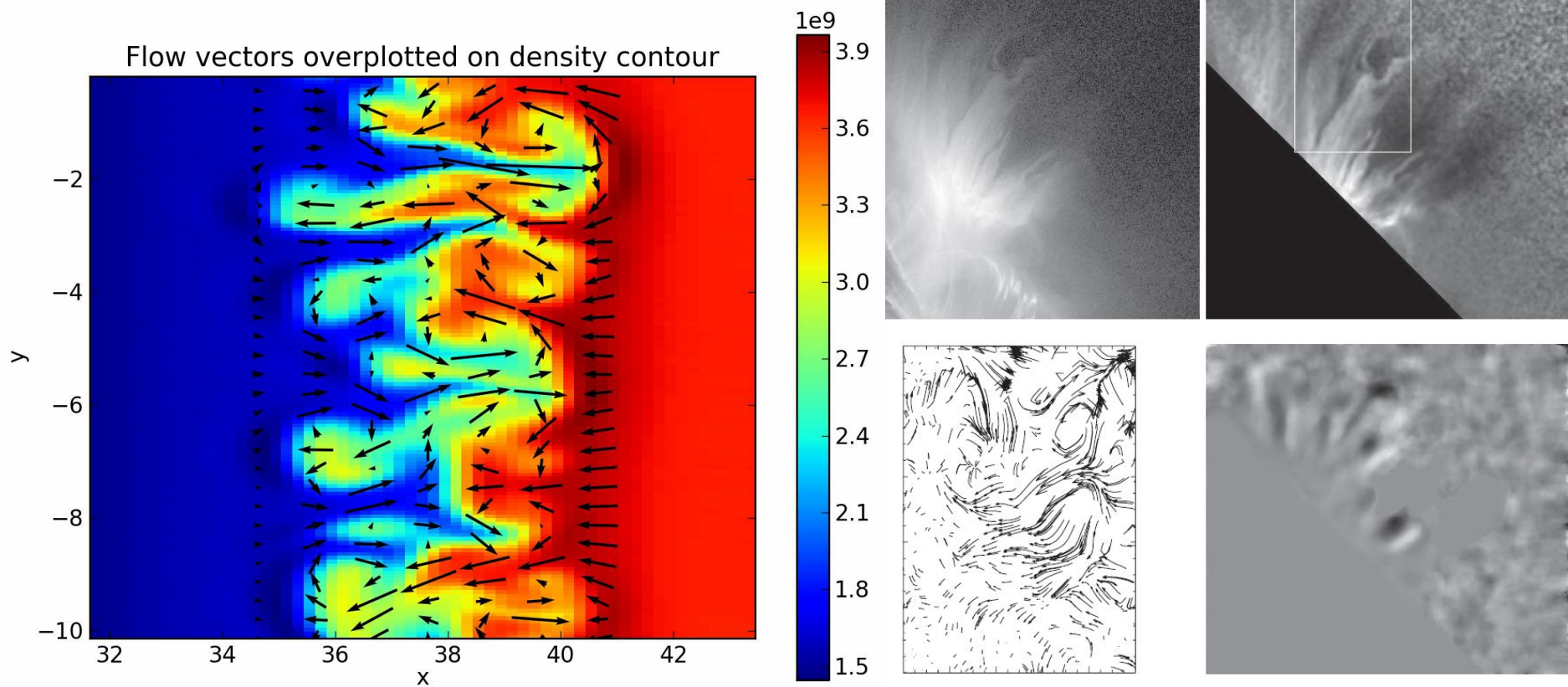
Synthetic emission count rates of AIA 131 Å from simulation data agrees well with observations



# SADs eventually fade into the surrounding plasmas of bright fans

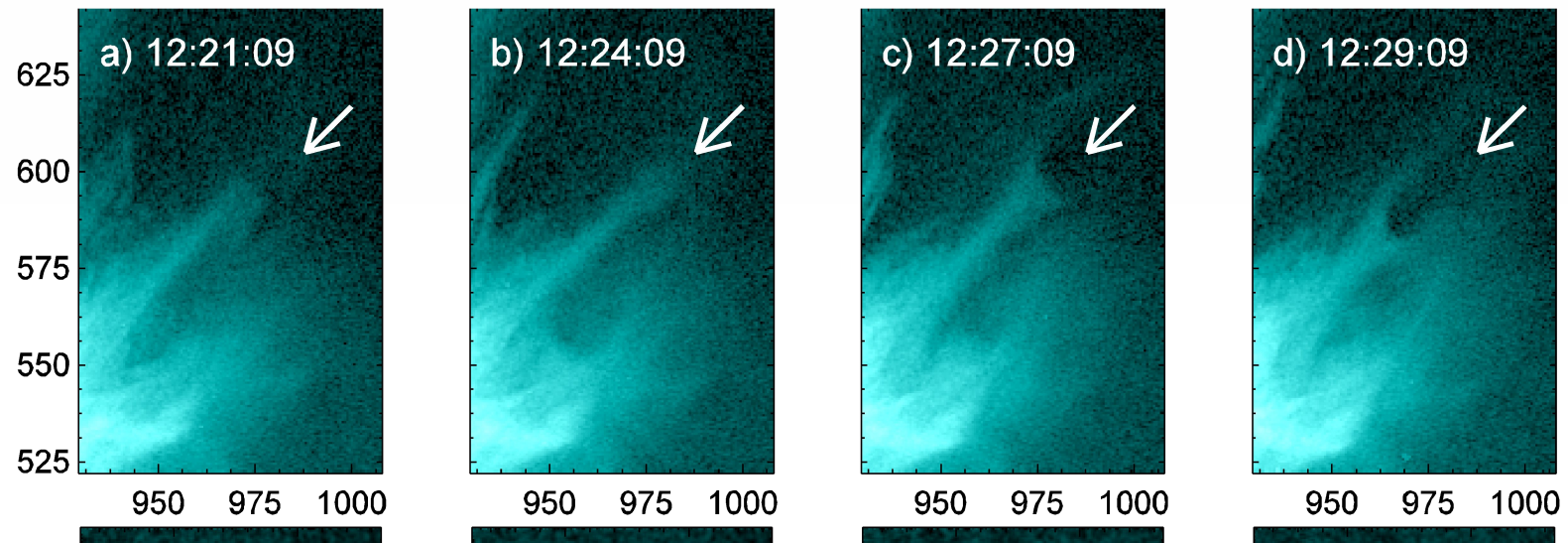
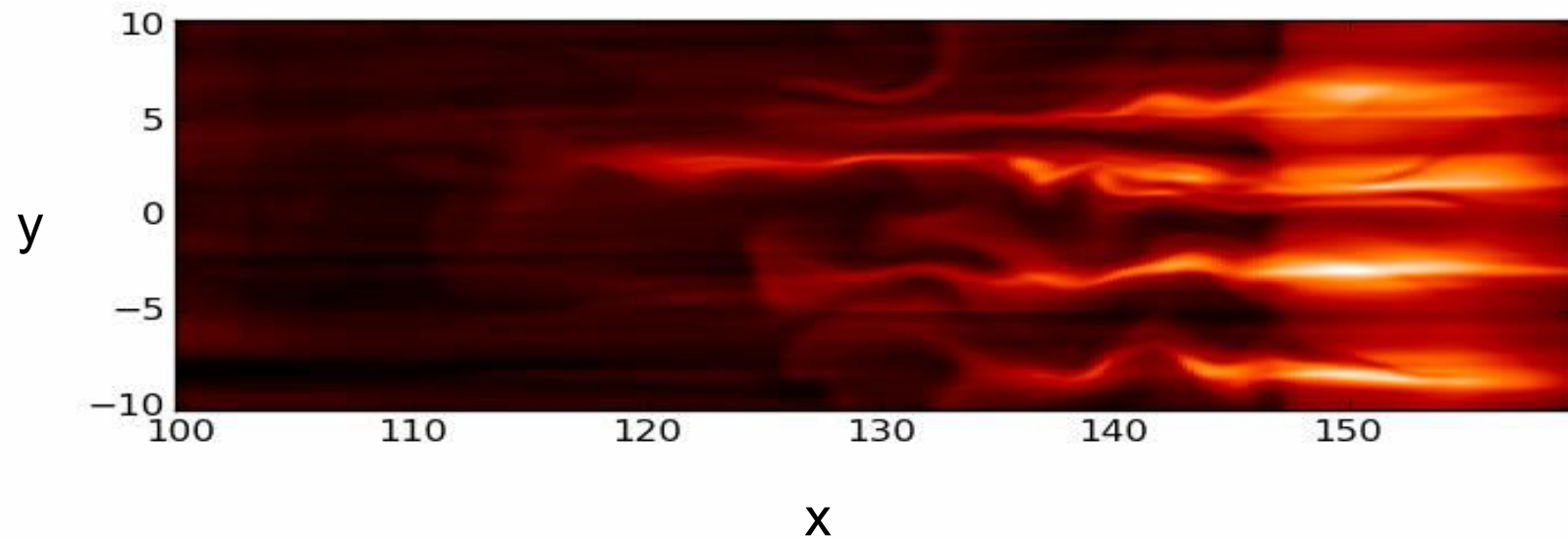


# The cusp region is quite turbulent



McKenzie et al. 2013

# SADs prefer to form at the tip of spikes



- 1. Rayleigh-Taylor-type instabilities arise at the exhaust region of a current sheet
- 2. The instabilities do not depend on reconnection mechanism
- 3. What drive the instabilities?

# Open questions and future works

- Three-dimensional plasmoid instability
- Other solar applications of plasmoid instability
- The driving mechanisms of SADs
- The high-speed flows observed by SUMER in the cusp region

- Thank you for your attention!
- Questions?