Plasmoid jets in 3D flux emergence simulations

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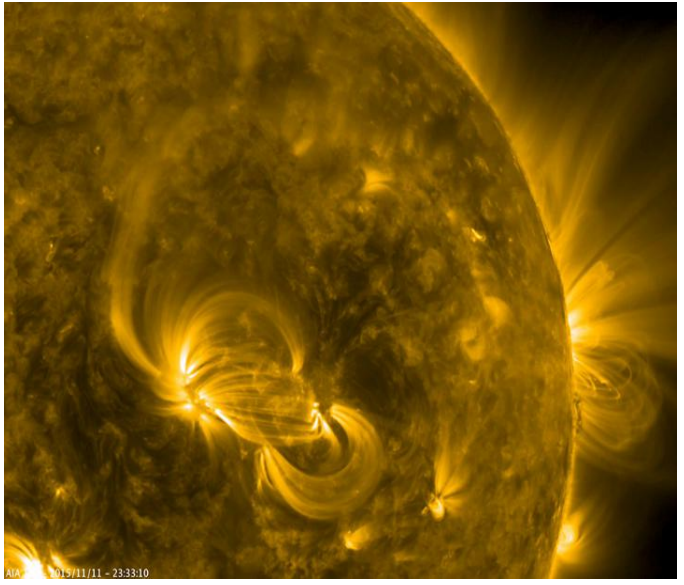
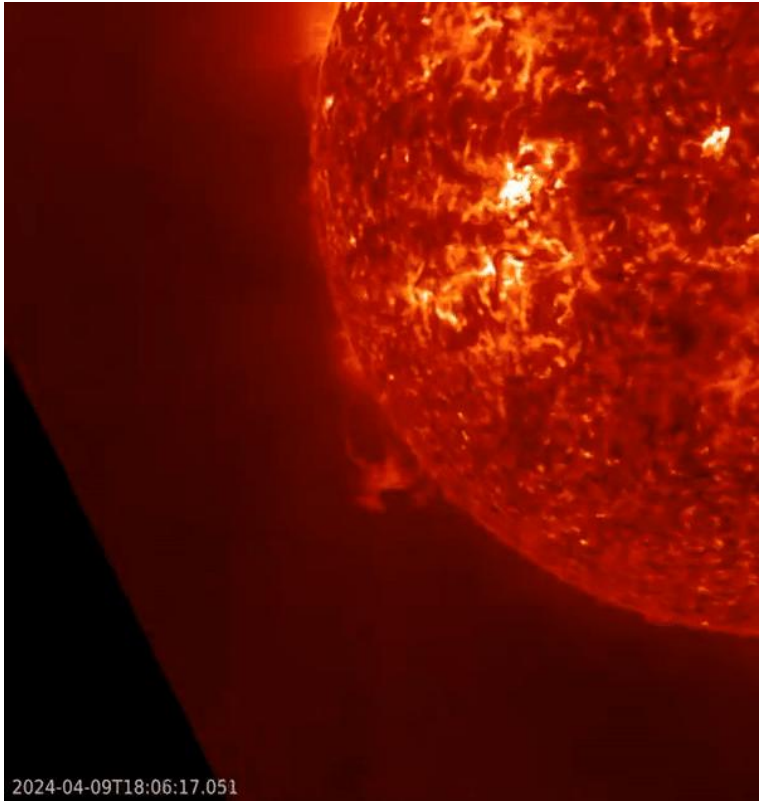
Why Magnetohydrodynamics?

- **Magnetohydrodynamics (MHD):** the simplest self-consistent plasma model. It describes the plasma as a ***single***, ***magnetised***, ***electrically conducting*** fluid.
- Assumptions:
    1) Large length scales (quasi-neutrality)
    2) Low frequencies (electrons + ions coupled)
    3) Relativistic effects are neglected ($v_A \ll c$)
- Astrophysical plasmas usually meet these criteria
- MHD elegantly captures the dynamics of many solar transients (viz. CMEs, flares, jets, …).



Solar coronal jets

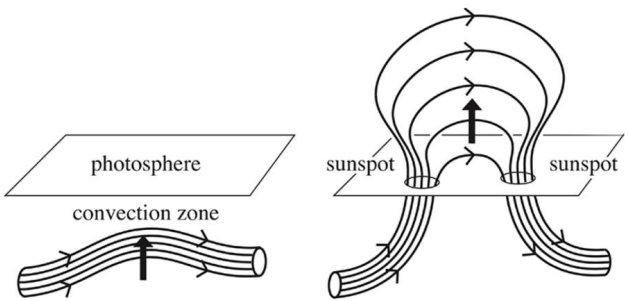
- Collimated plasma ejections originating from the solar corona
- Usually hot ($\mathrm{T} \simeq 1\text{–}10\ \mathrm{MK}$)
- Magnetic reconnection plays a key role.
- Typically encountered in active regions / coronal holes
- Can manifest as a result of:
  1) ***Magnetic flux emergence***
  2) Magnetic flux cancellation
  3) Onset of instabilities (?)
- Flux emergence → very important process!



- Let’s try to simulate the emergence of magnetic flux from the solar interior up to the solar corona!

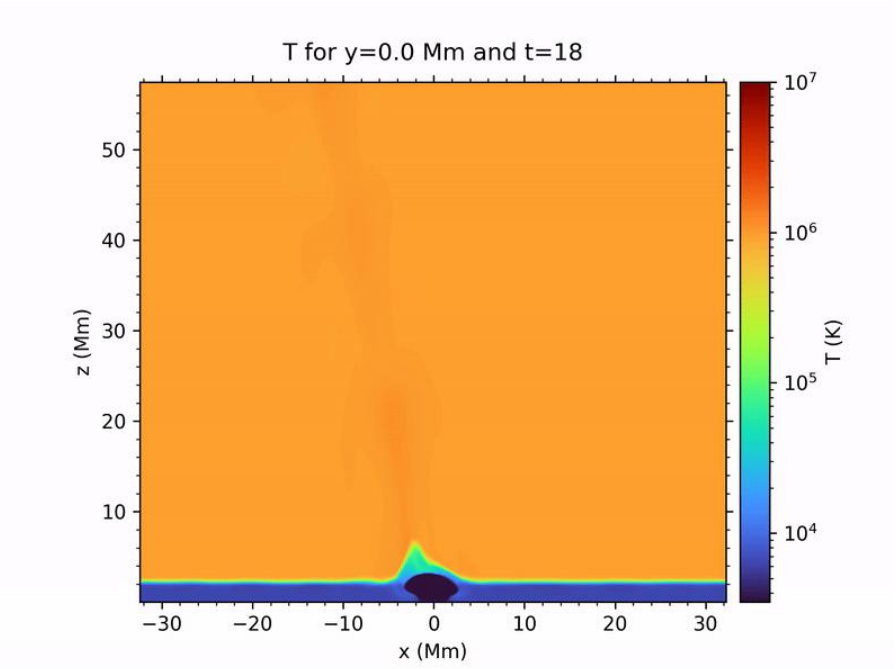
Lare3D code

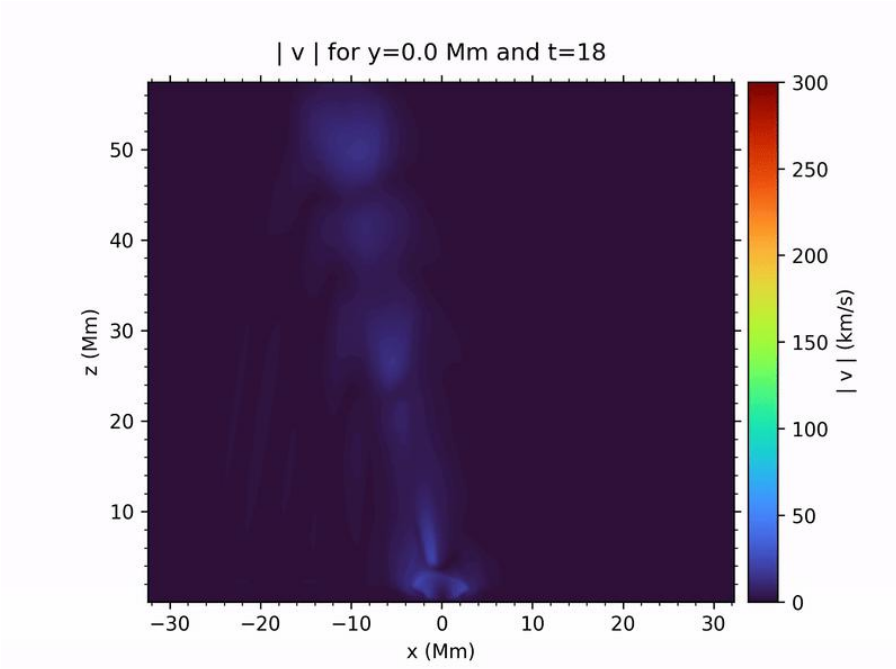
- Numerical code which solves the time dependent, compressible, resistive MHD equations with a finite difference scheme.
- Energy dissipation is permitted: user-controlled **Ohmic resistivity** and **shock viscosity.**
- 3D Cartesian staggered grid.
- First solves the Lagrangian fluid equations and then remaps the physical quantities in the original, Eulerian grid.
- Inclusion of ambient magnetic field (like coronal holes!)
- Stratified atmosphere



Solar Physics: Overview, E. E. Priest , 2020,

Simulation results

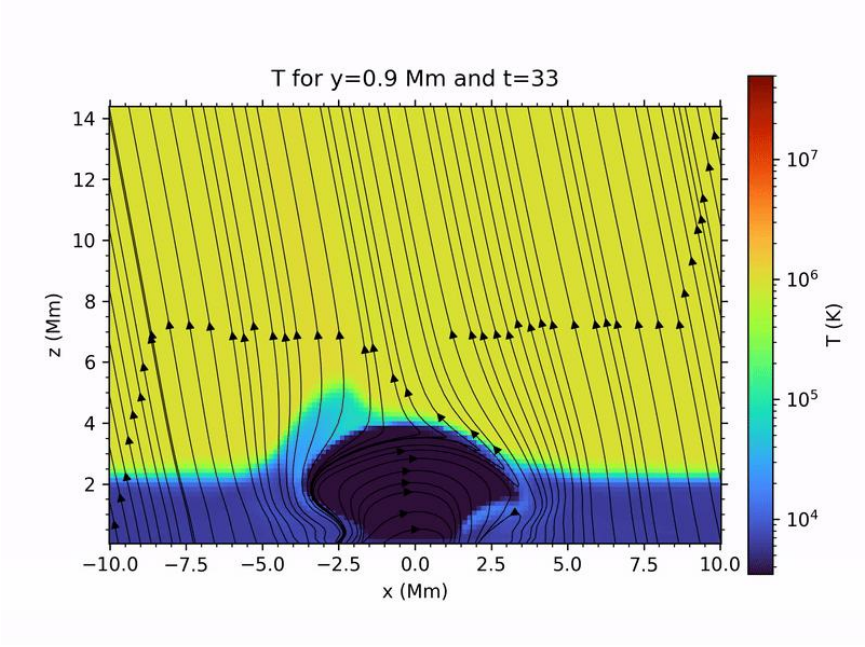




- Standard jet after t=23. But before?
- Another very transient eruption takes place, not predicted by standard jet models!

What did we just witness?

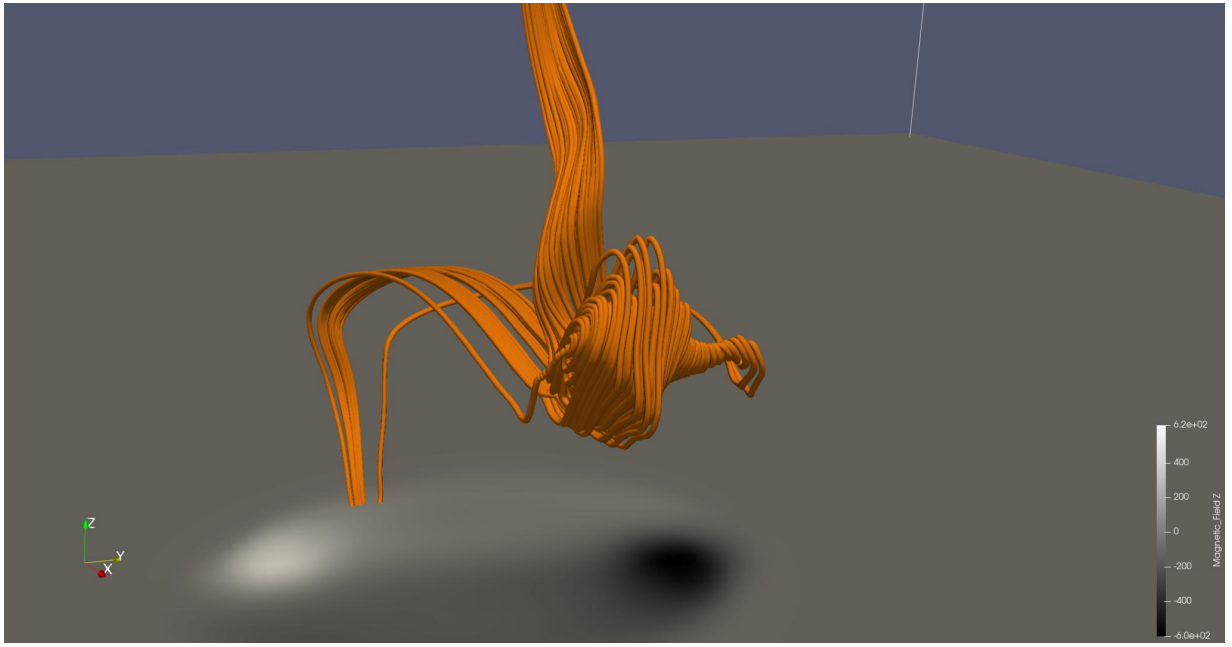
- Let’s have a closer look at the first eruption with higher temporal cadence:



- Magnetic field is twisted + many neutral O-points → Plasmoids!
- Probably formed inside the current sheet during emergence process.
- They also produce a multi-thermal coronal jet
- How?

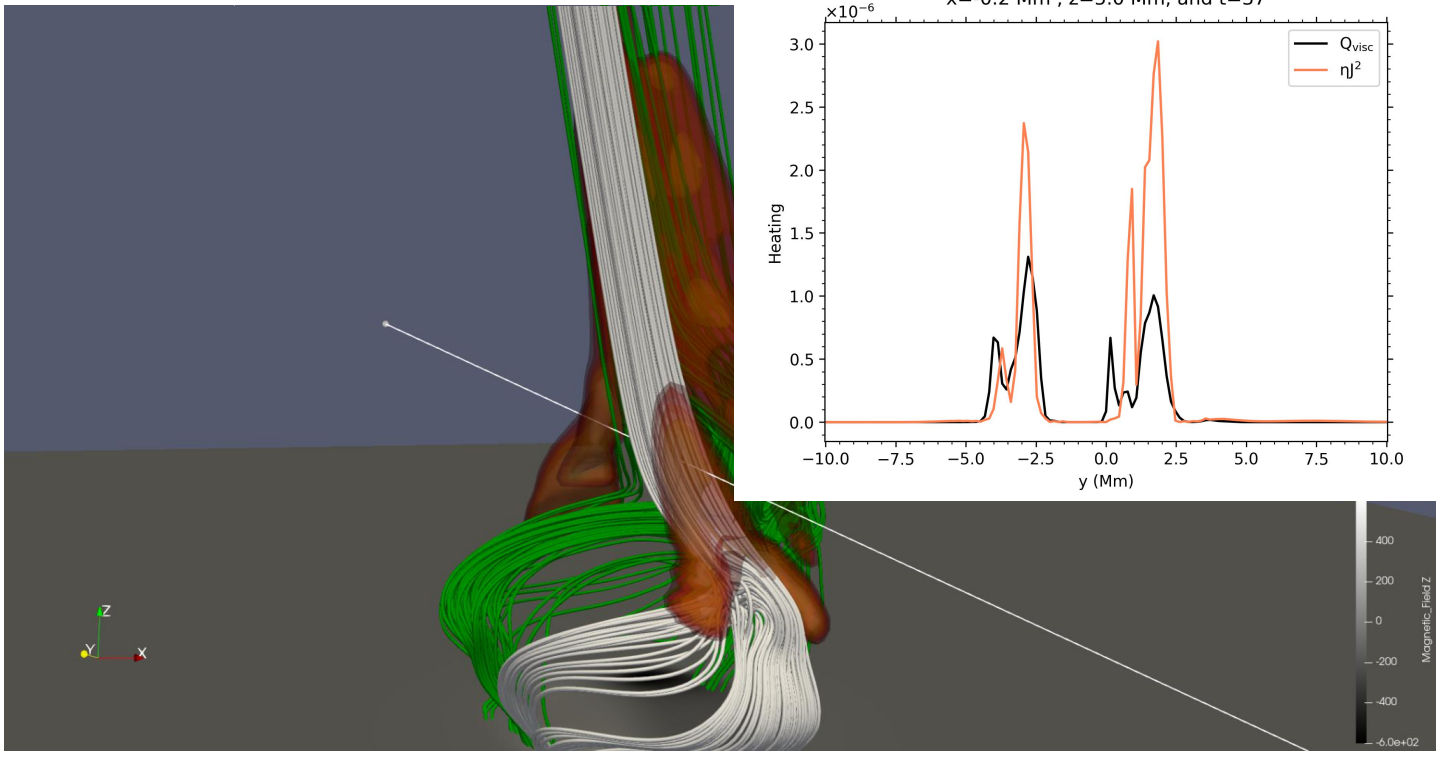
3D Plasmoid jets

- Let’s see what happens in 3D.
- Plasmoids are **flux ropes:**
- They are usually cool + dense.
- Hence, the cool jet component stems from the plasmoids per se.
- But where do the hot components come from?



3D Plasmoid jets (cont.)

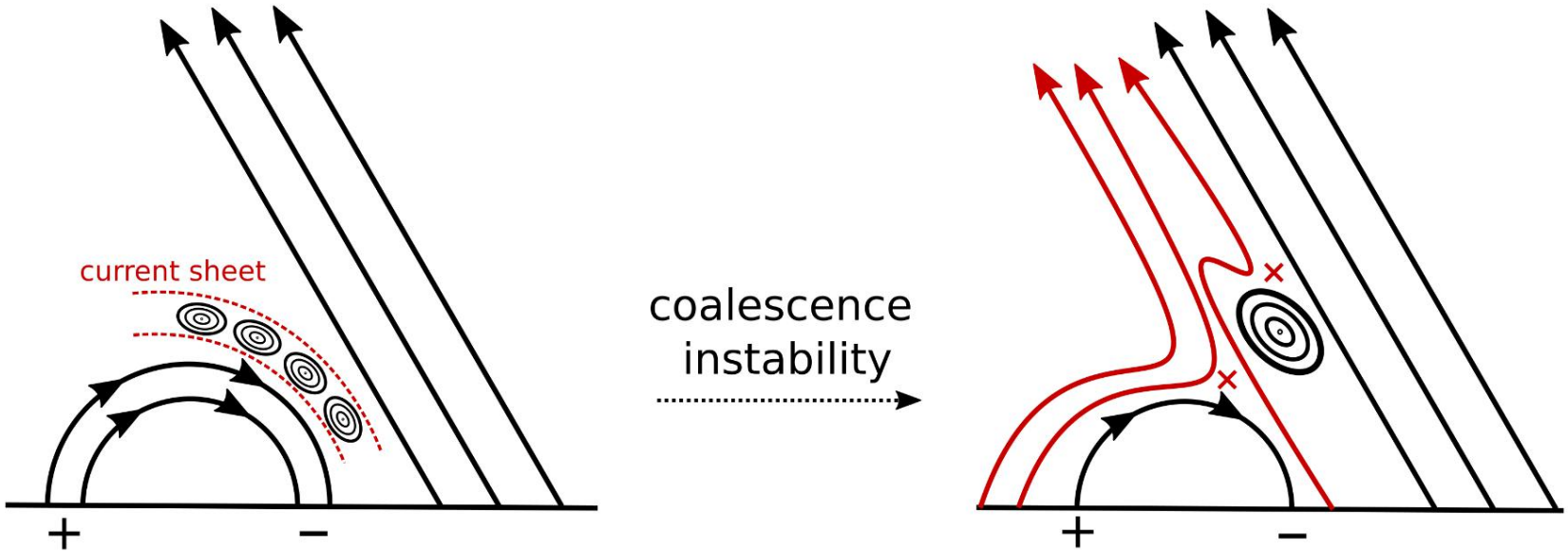
- Origin of hot lanes in jet
- Temperature isosurfaces in 3D
- Heating around the plasmoids!
- Which mechanism heats the plasma there?
- Possible mechanisms:
    1) Joule heating
    2) Viscous heating



Joule heating → Reconnection!

But which fields reconnect exactly?

A model for the plasmoid jets



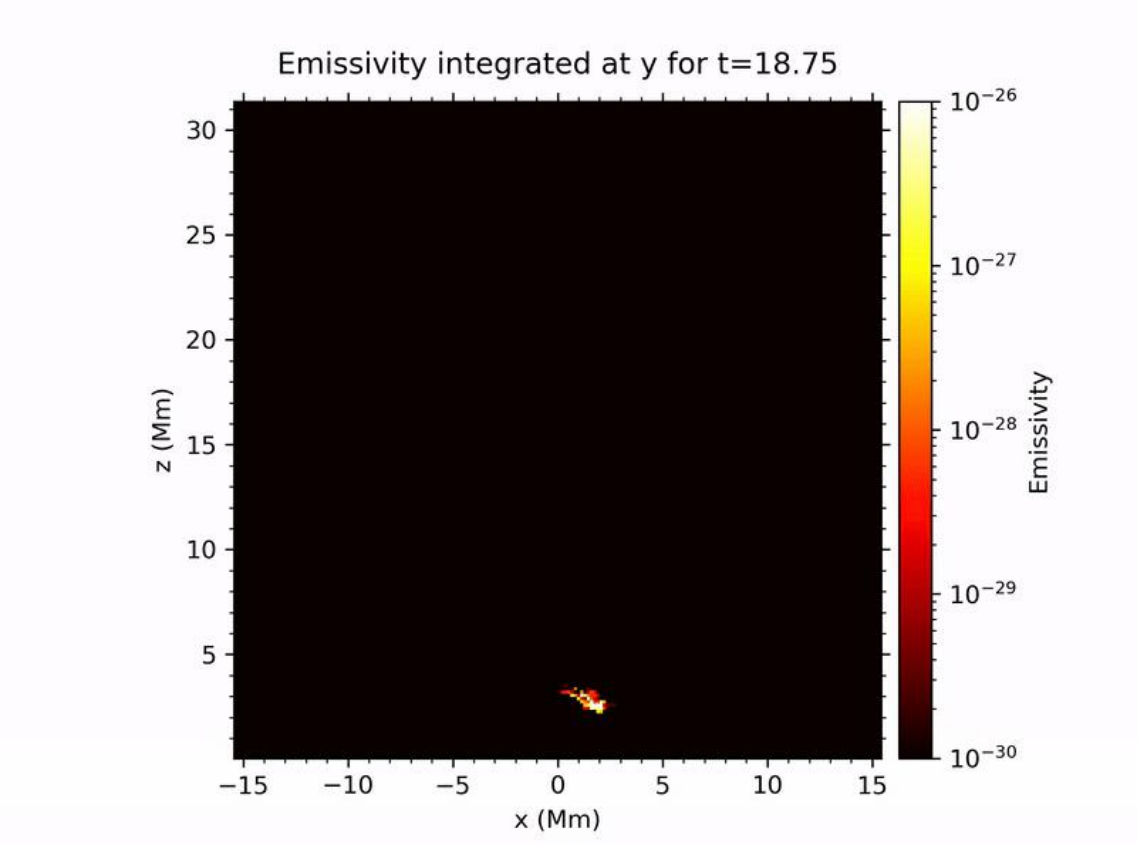
- *Internal* reconnection between plasmoid and emergent/ambient field!
- Unlike standard jet, the 2 flux systems have not yet interacted.

Poor man’s Synthetic images

- Let’s try to see how these jets may appear in realistic scenarios!
- We will calculate:

$$I = \int \rho^2 d\ell$$

- Intend to create AIA synthetic images in the future by employing temperature response functions, DEM analysis etc.



Discussion

- Plasmoids have been well-studied by observational means.
- Yet even so, no coronal jet model predicts such jets!
- Fully 3D phenomenon. Twist is needed!
- Reminiscent of mini-filament [1] eruptions.
- Such jets are multithermal, and apparently take place prior to standard jets.
- In-depth study of the dynamics is hard due to 3D nature of reconnection. But:
- Employ parametric studies to further assess the conditions under which they form.
- The role of thermal conductivity needs to be investigated...

[1] Sterling, A., Moore, R., Falconer, D. et al. Small-scale filament eruptions as the driver of X-ray jets in solar coronal holes. Nature 523, 437–440 (2015).

Thank you for your attention!!