MHD simulations of solar supra-arcade downflows including thermal conduction

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Brief:

- We study some dark structures known as ‘Supra-arcades downflows’ (SADs) which have been detected descending through the solar corona to the photosphere.
- One of the major challenges is to understand how it is possible that SADs can survive in hot plasmas.
- In oder to give an explanation we already performed 3D simulations considering ideal MHD where we could reproduce SADs well. But now we explore a new scenario that includes thermal conduction, so for this we perform 2D simulations considering non-ideal MHD.
- The numerical tool we use is the FLASH code.

Flash code

“The software used in this work was in part developed by the DOE NNSA-ASC OASCR Flash Center at the University of Chicago”.

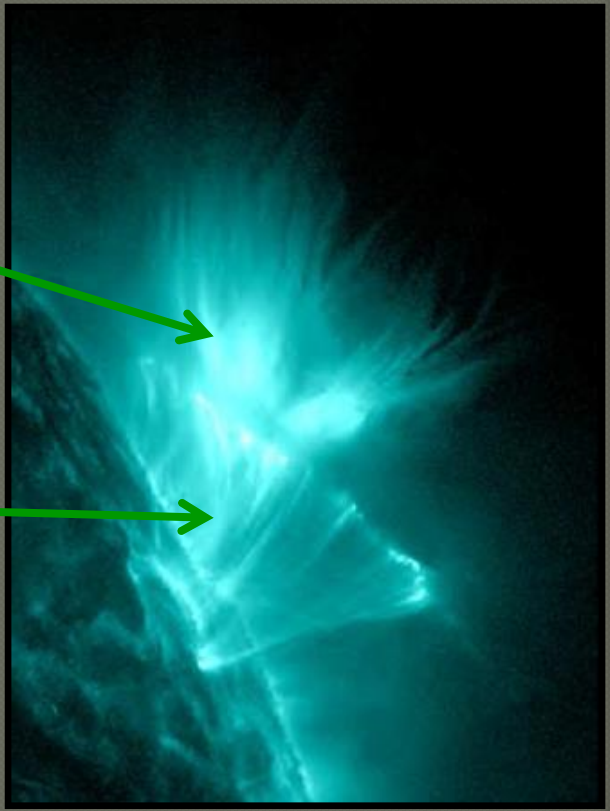
What are SADs?

- ❖ SADs have been always detected during solar flares, and are associated to coronal mass ejections (CME).
- ❖ There is a consesus that due to the lack of X-ray and EUV emission in images and spectra, SADs are dark voided flows descending through the hot plasma.

Fan Temperature (8-13) 10^6 K

video

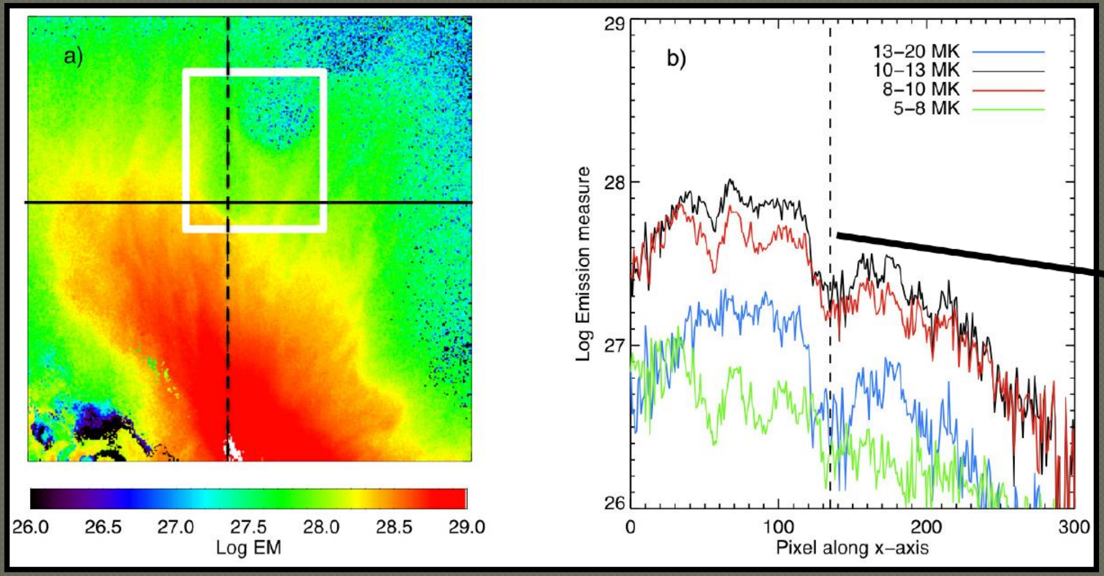
Coronal arcade



Filter of 131 Å
Image taken with SDO/AIA.

McKenzie (2013) reported that the plasma flow is turbulent in the fan region instead of laminar, also reported vortices and shear flows.

SAD detection



Emission measure is lower by a factor of [2-4]

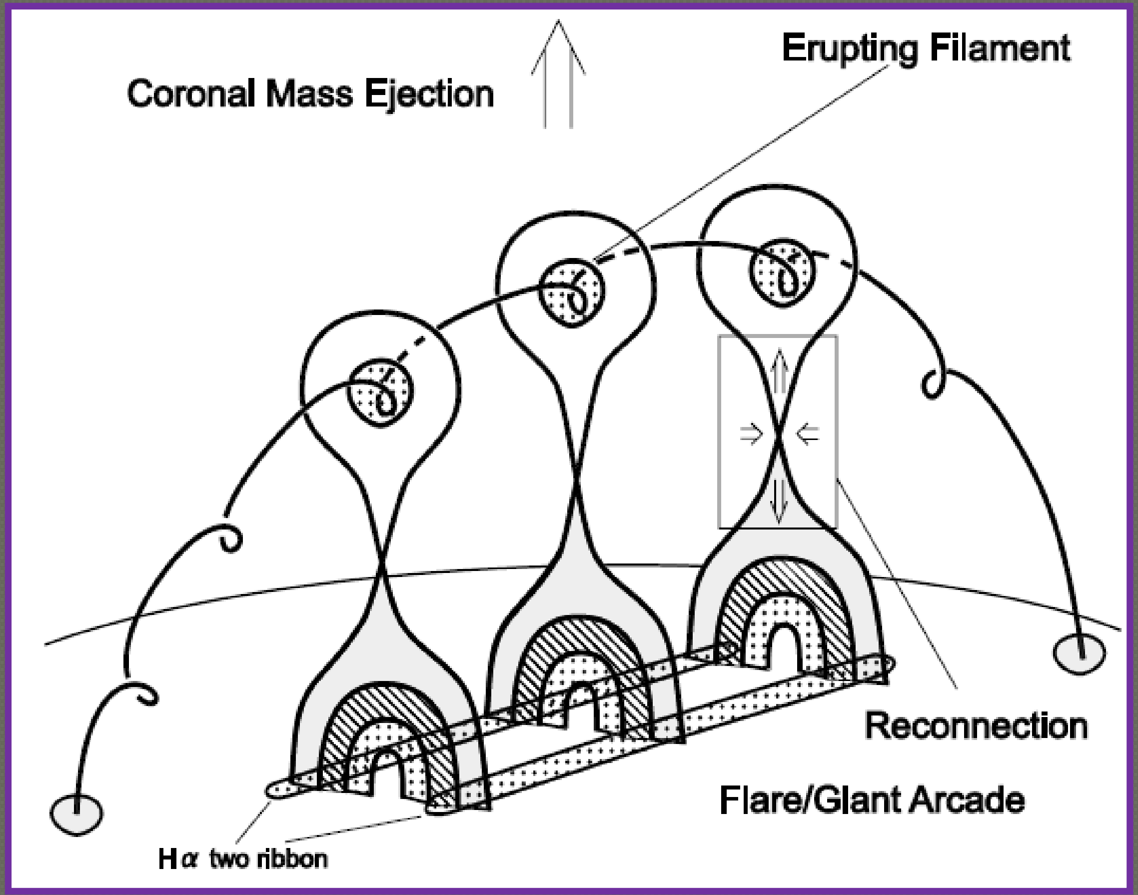
Savage et al. (2012)

Emission measure for several temperatures bands (SDO/AIA)

Long duration solar flares

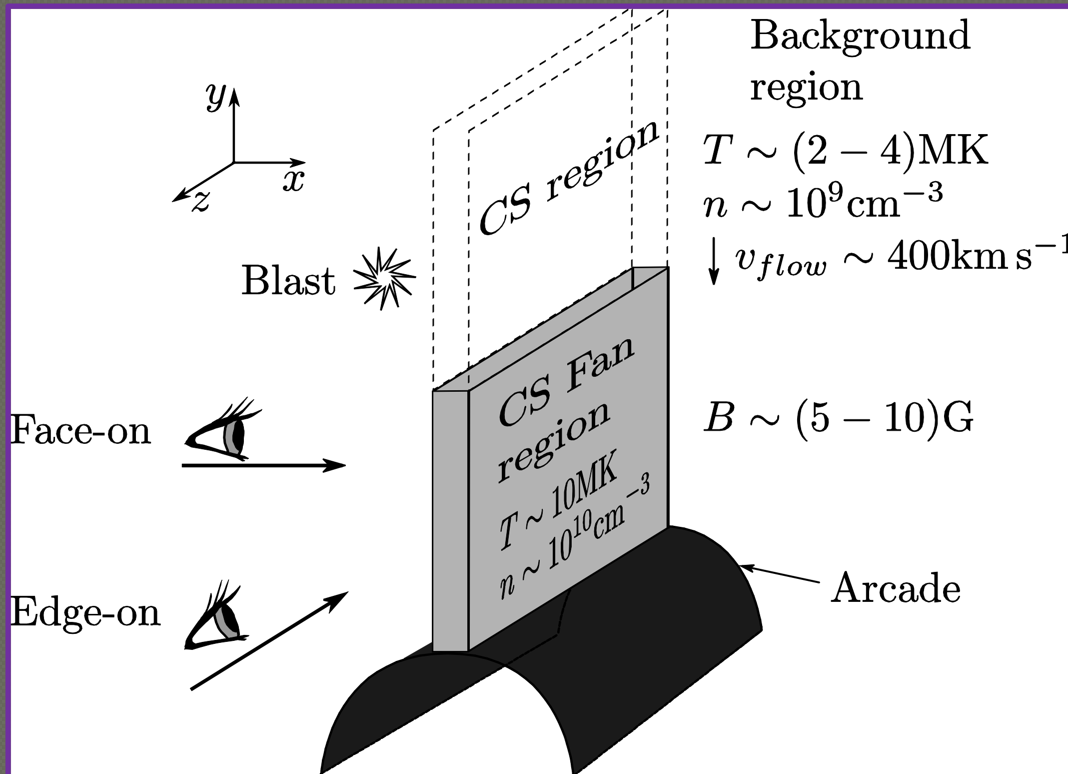
❖ Magnetic reconnection is a fundamental process associated with SAD formation.

video



Shiota et al. (2005)

Setting up the turbulen fan: in part motivated by the description provided by McKenzie (2013)



Cécere, Zurbriggen, Costa & Schneiter (2015, ApJ)

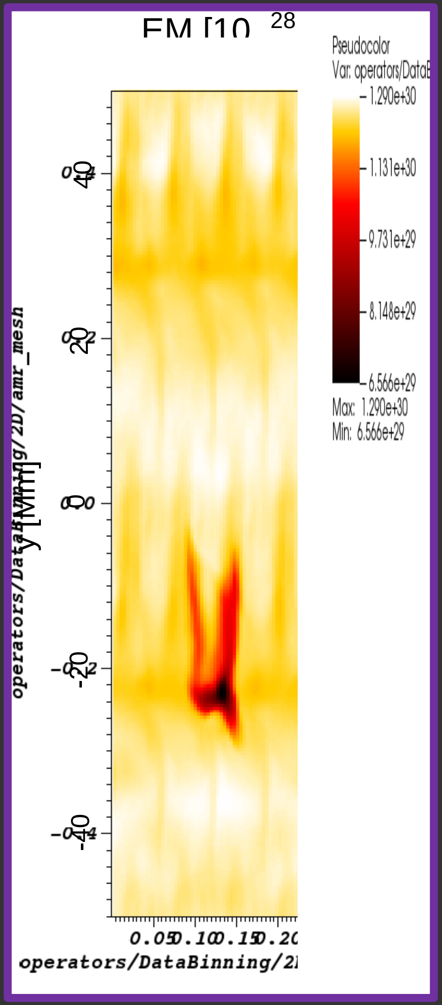
Let's enumerate the minimum requirements to be able to say we reproduced a dark void consistent with a SAD:

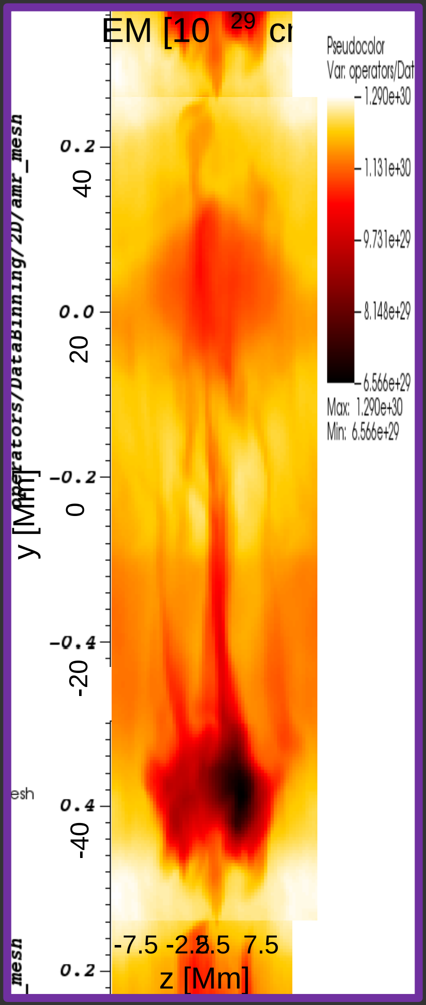
- To obtain a sub-dense cavity with a density contrast with its surroundings of a factor of ≈ 2 (or greater). I.e. an emission contrast of a factor of ≈ 4 (or greater).
- To live for at least 1 minute before being crushed by the hot fan.
- To have a descending velocity between [50-200] km/seg.

Bursty reconnection size of 4 Mm and fan width of 4 Mm

Bursty reconnection size of 12 Mm and fan width of 22 Mm

Emission measure contrast ~ 2.1





Emission measure contrast ~ 4

video

Figures: face-on fan view of the Emission Measure.

Is thermal conduction negligible?

- Thermal conduction effects are rarely considered in numerical simulations of coronal fan where SADs dynamically develop.
- To the best of our knowledge, none of the numerical scenarios proposed to explain SAD's origin and dynamics consider the heat conduction term.
- For completely ionized plasmas as we consider, thermal conduction increases non-linearly with temperature and is highly anisotropic:

$$\vec{F}_{\mathbf{cond}} = -\kappa_{\parallel}\nabla T_{\parallel} - \kappa_{\perp}\nabla T_{\perp}$$

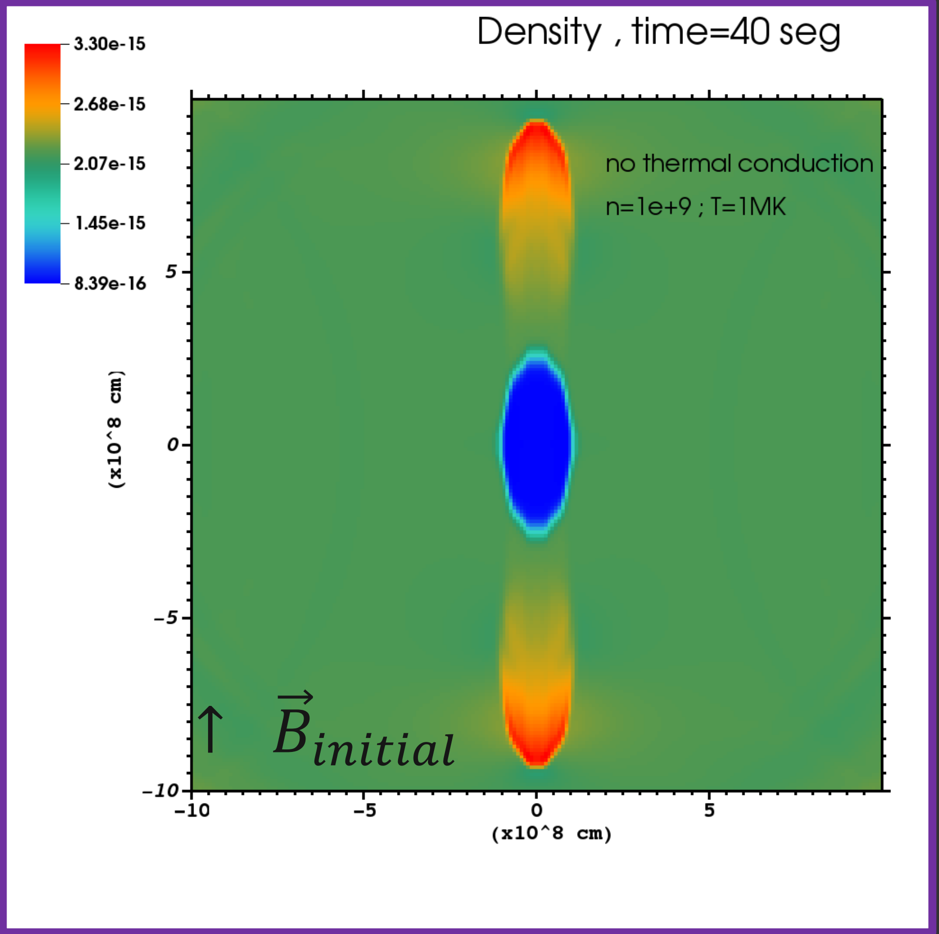
- Timescales of conductive and radiative cooling are:

$$\tau_{\mathbf{cond}} \propto \frac{\rho L^2}{\kappa_{\parallel} T^{2.5}} \sim 20 \text{ seg.}$$

$$\tau_{\mathbf{rad}} \propto \frac{T^{1.5}}{n_e} \sim 10^3 \text{ seg.}$$

Test including thermal conduction

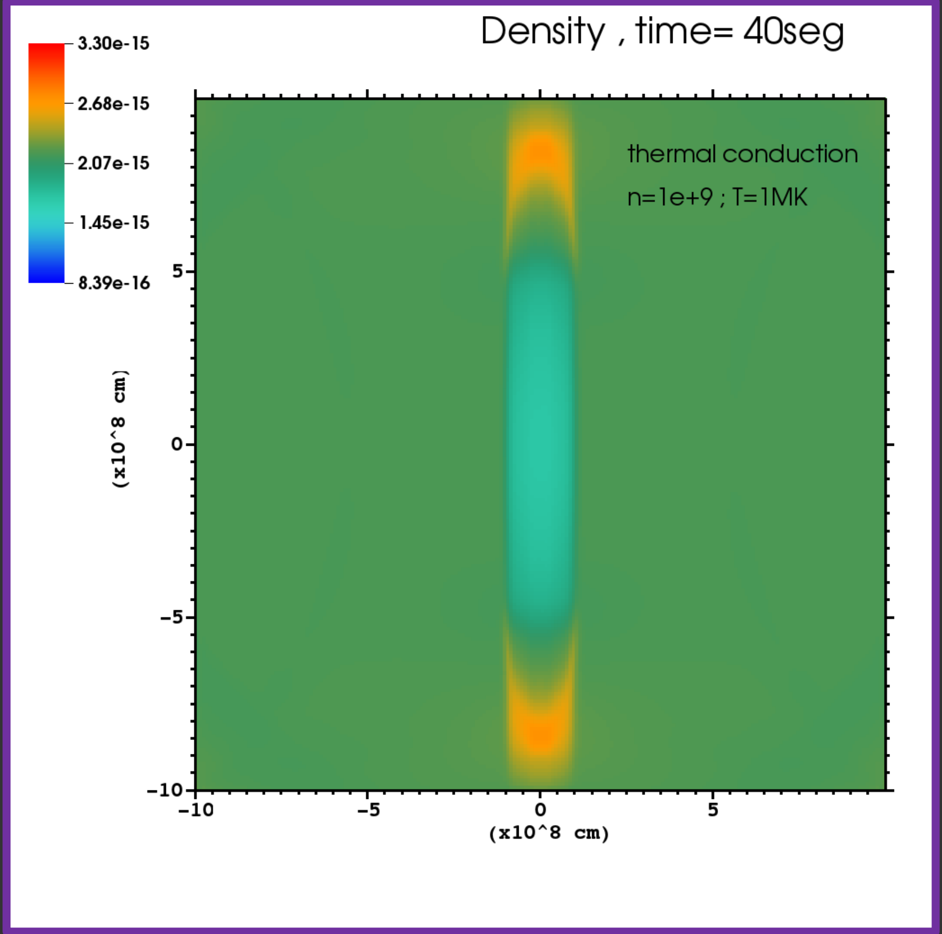
Neglecting heat conduction



Density contrast ~ 2.5

✓ SAD?, yes!

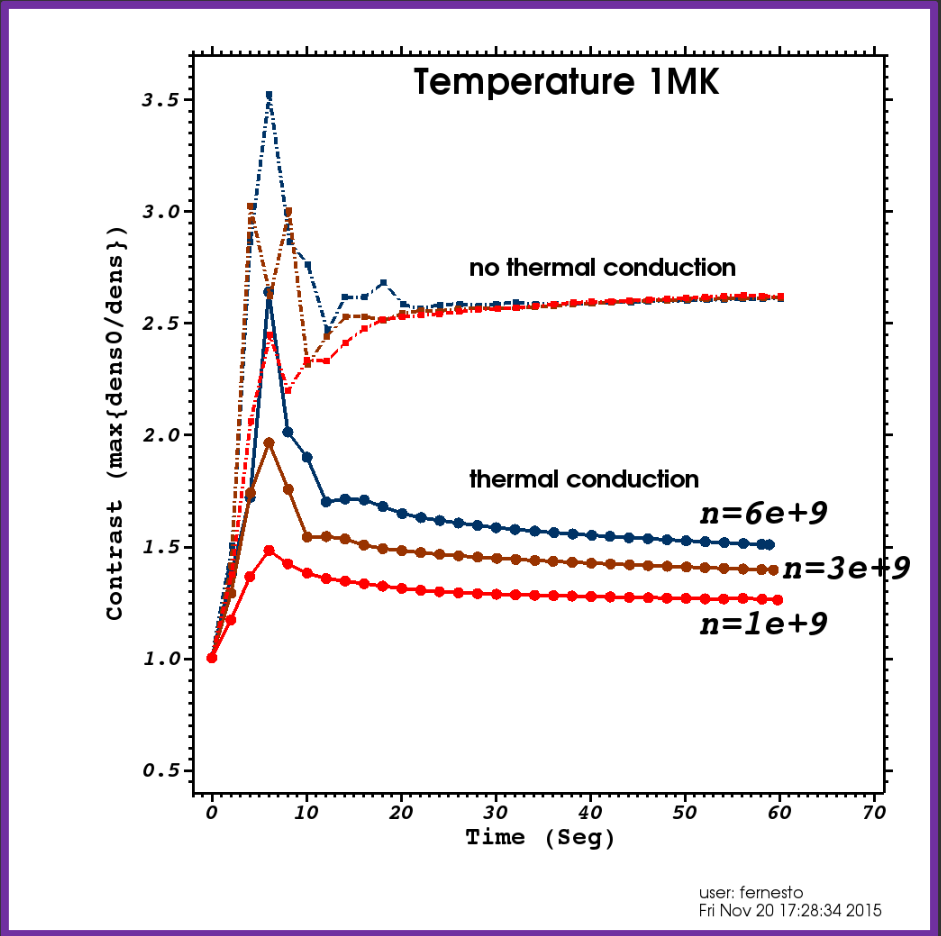
Considering heat conduction

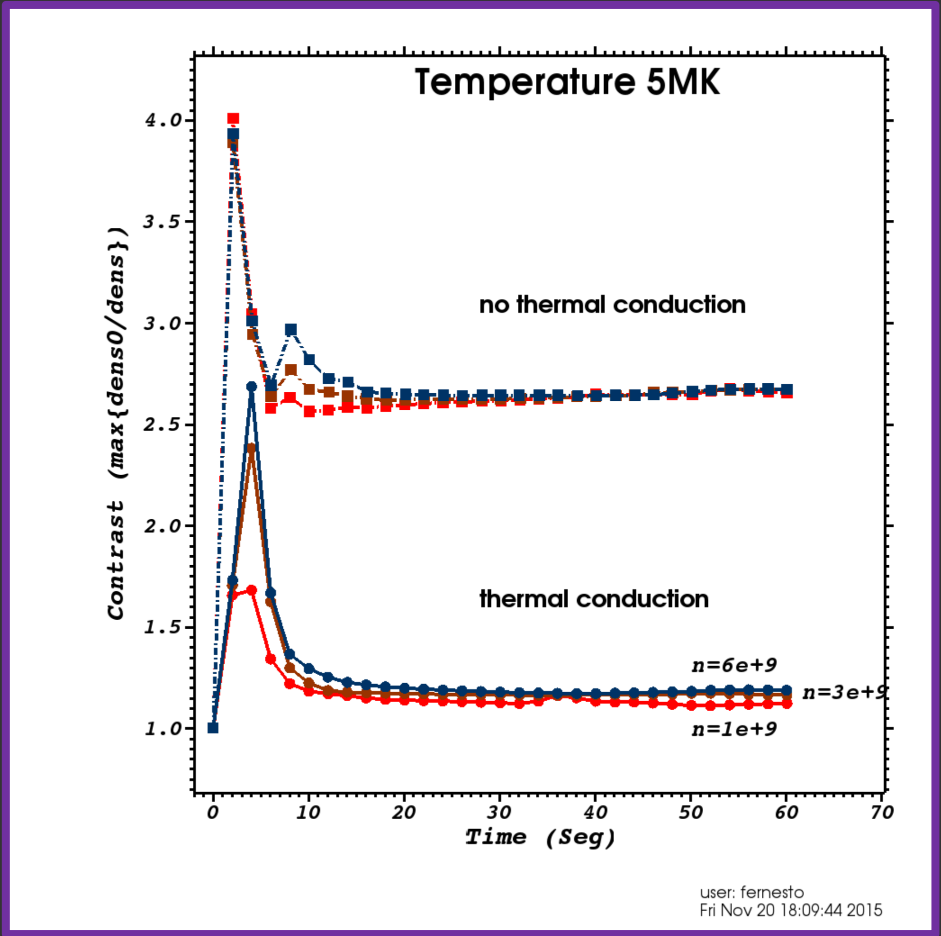


Density contrast ~ 1.4

✓ SAD?, not!

Test including thermal conduction

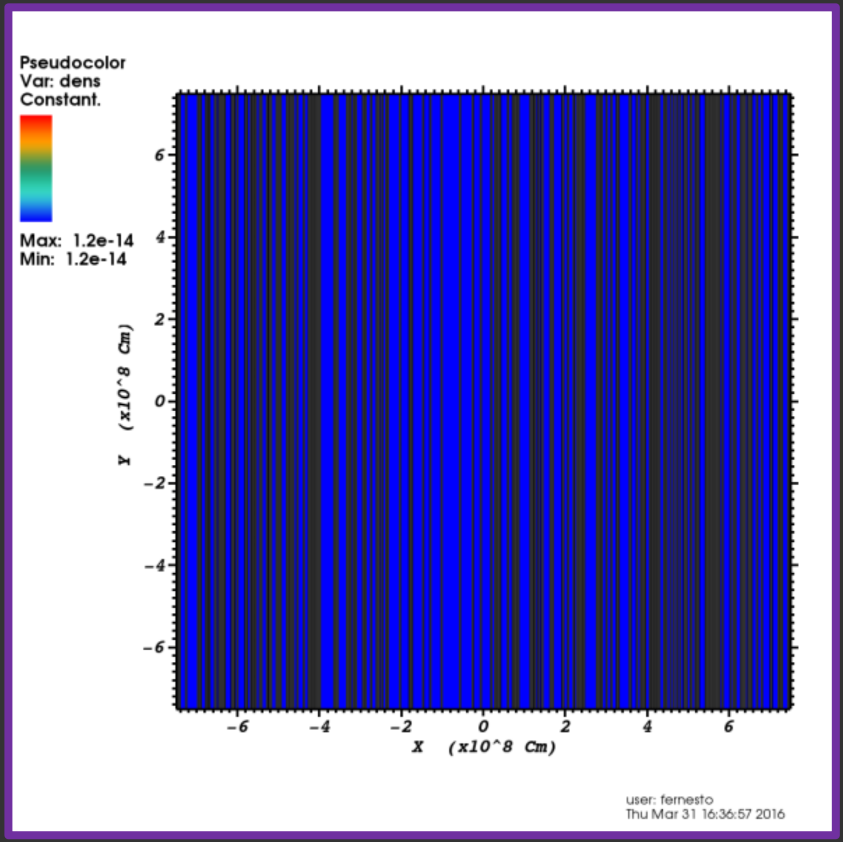




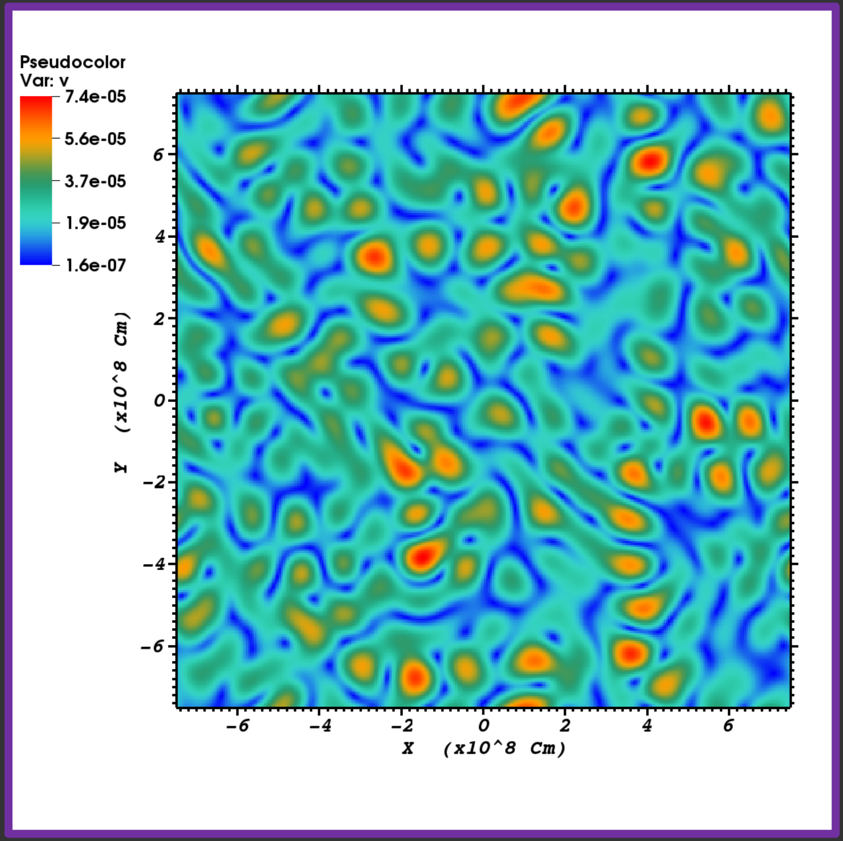
$$\tau_{\text{cond}} \propto \frac{\rho L^2}{\kappa_{\parallel} T^{2.5}}$$

Initial conditions

$$Temp_{init} = 1\ MK$$

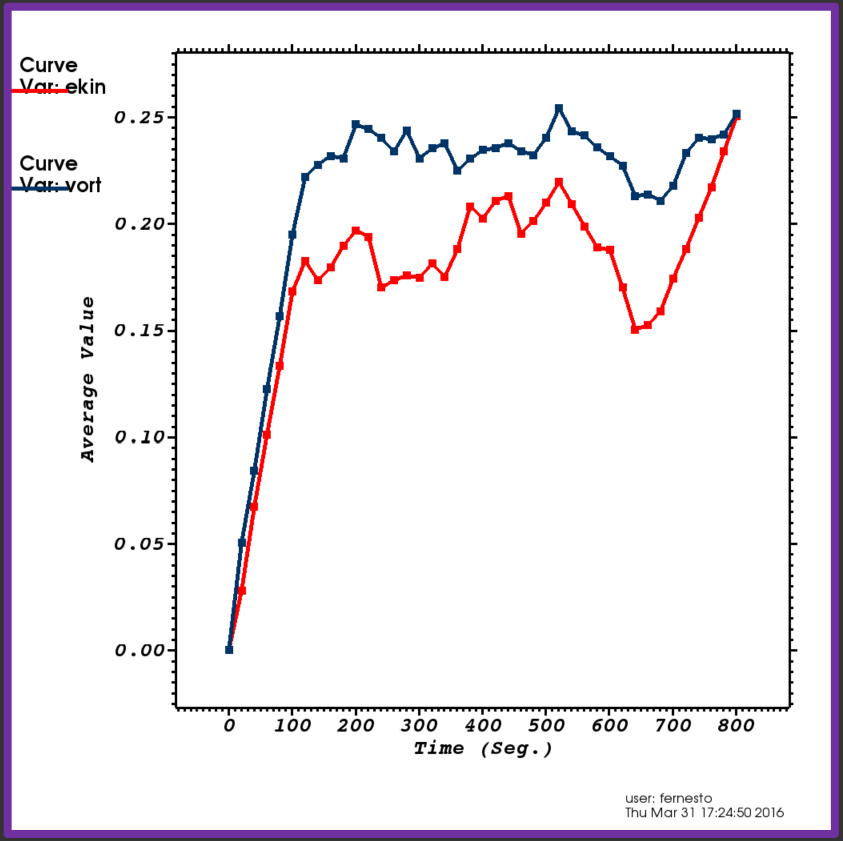


Module of velocity at first time step

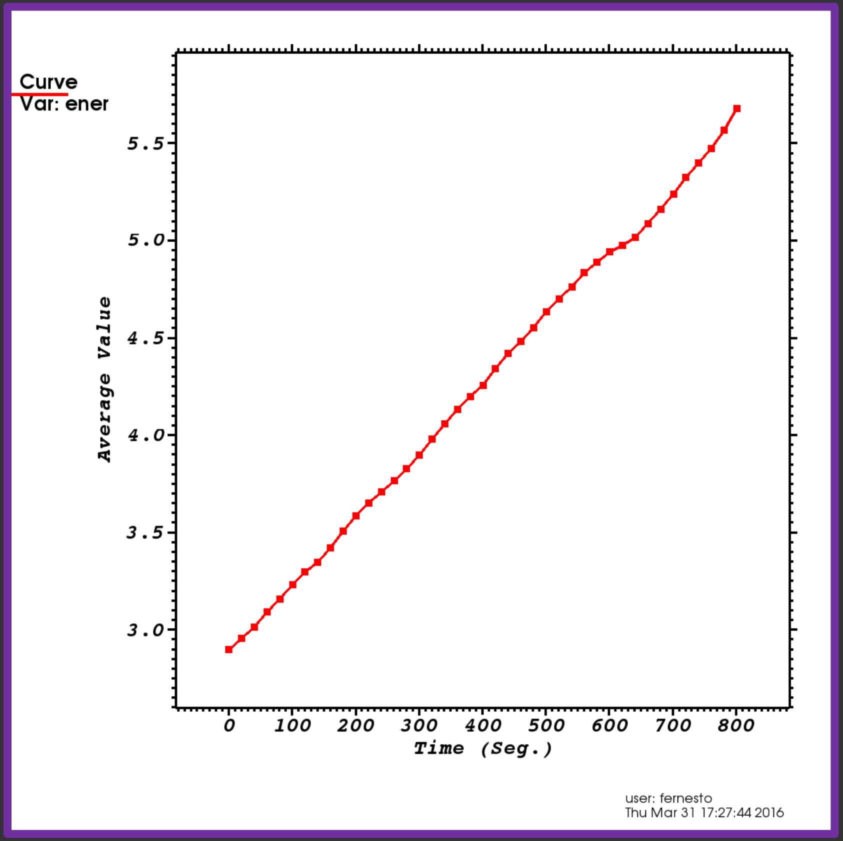


Average of some quantities of interest

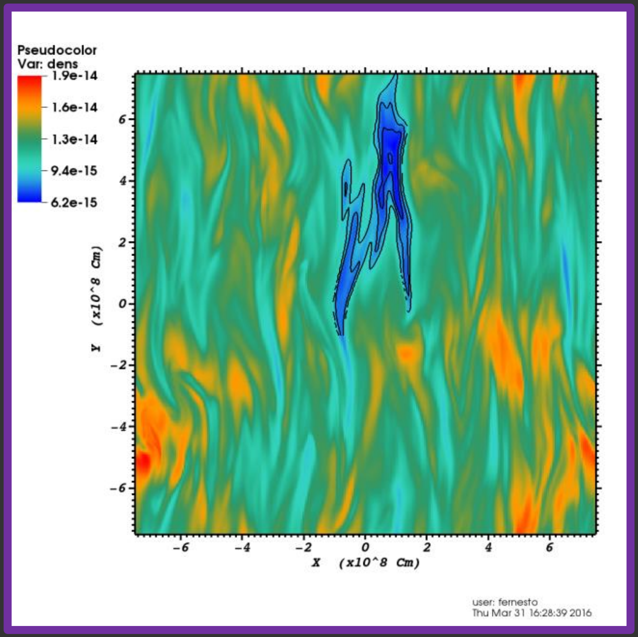
Kinetic energy and vorticity

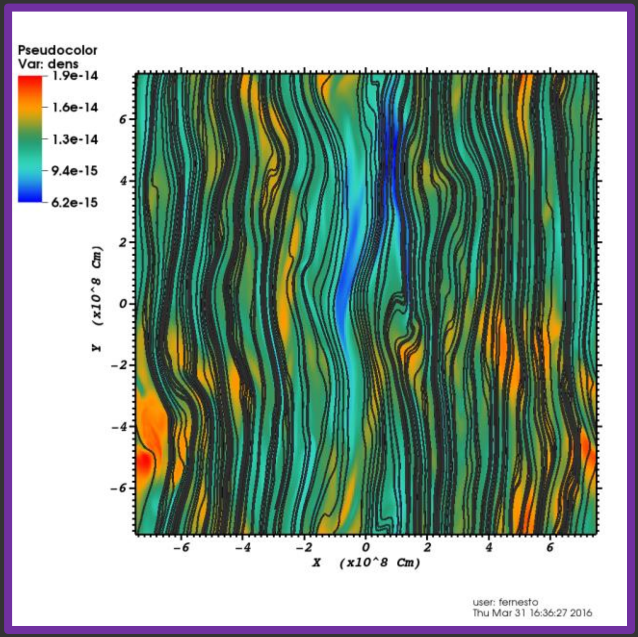


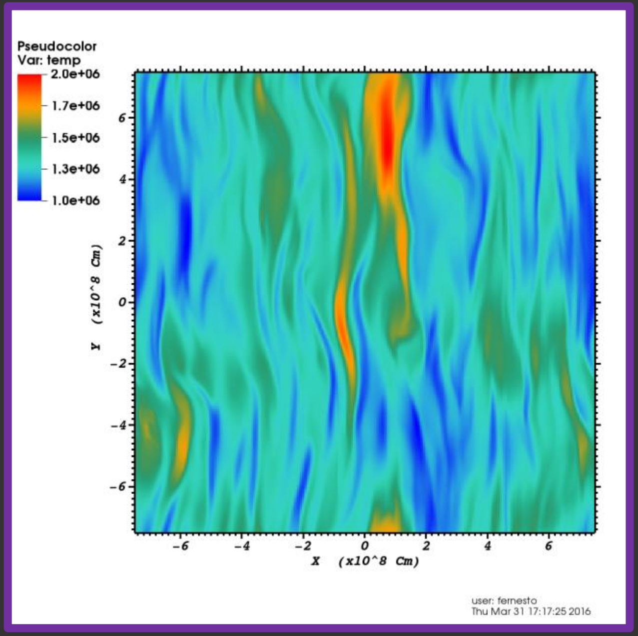
Total energy



Turbulent regimen + bursty reconnection pulse







Conclusions

- In Cecere et al. (2015) we obtained results comparable with the observations imposing a bursty reconnection pulse at a perturbed fan. However, this scenario requires a particular fan properties where thermal conduction is negligible.

- Is Cecere et al. (2015) the only possible scenario? Up to know considering different turbulent fan properties and thermal conduction we have not been able to satisfy the mininum requiriments to reproduced SADs features.

Thank you!

Questions…?