DIAGNOSTICS AND FINE STRUCTURING OF CORONAL HEATING FROM 3D MHD MODELING OF TWISTED/BRAIDED CORONAL LOOPS

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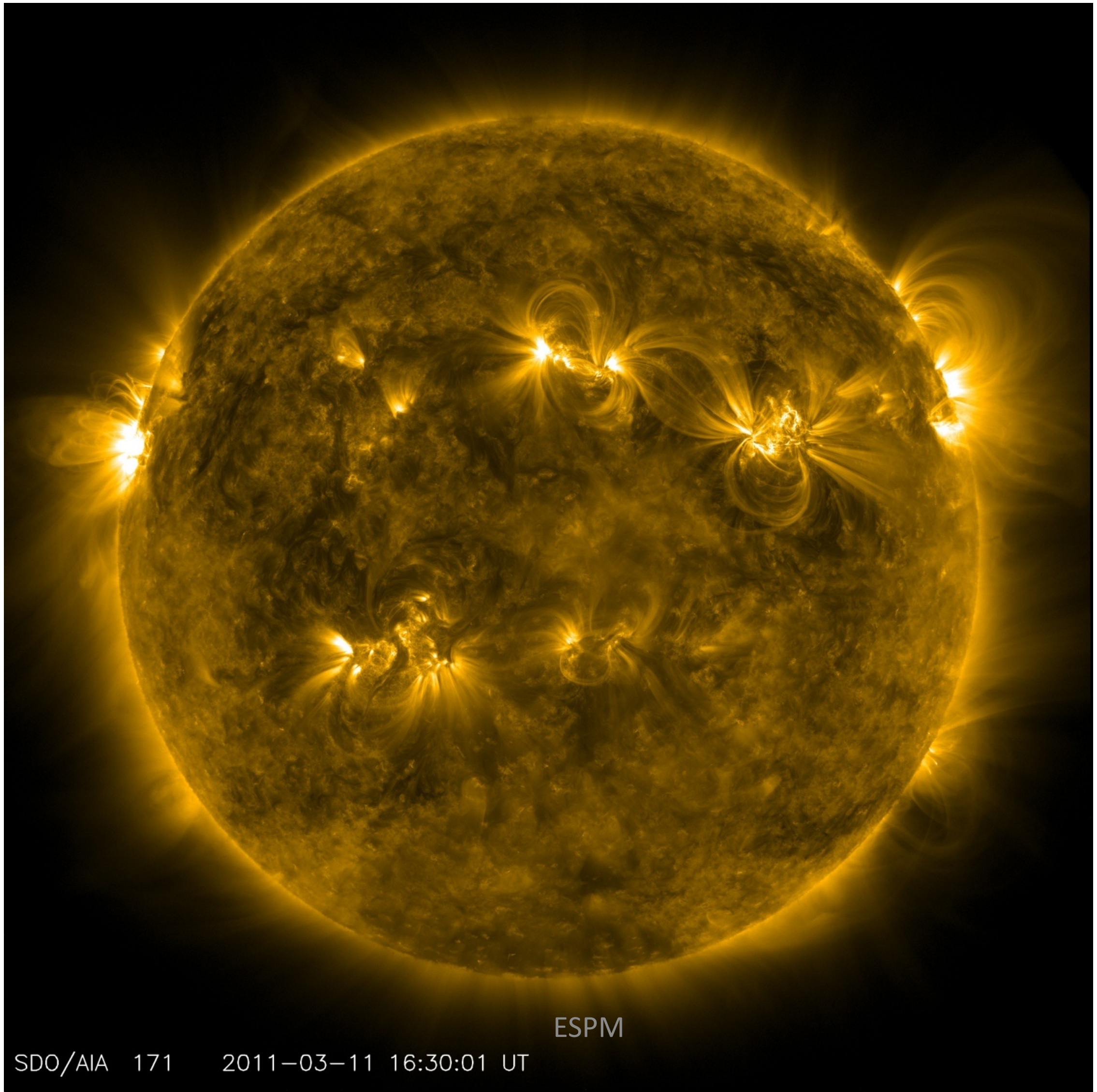
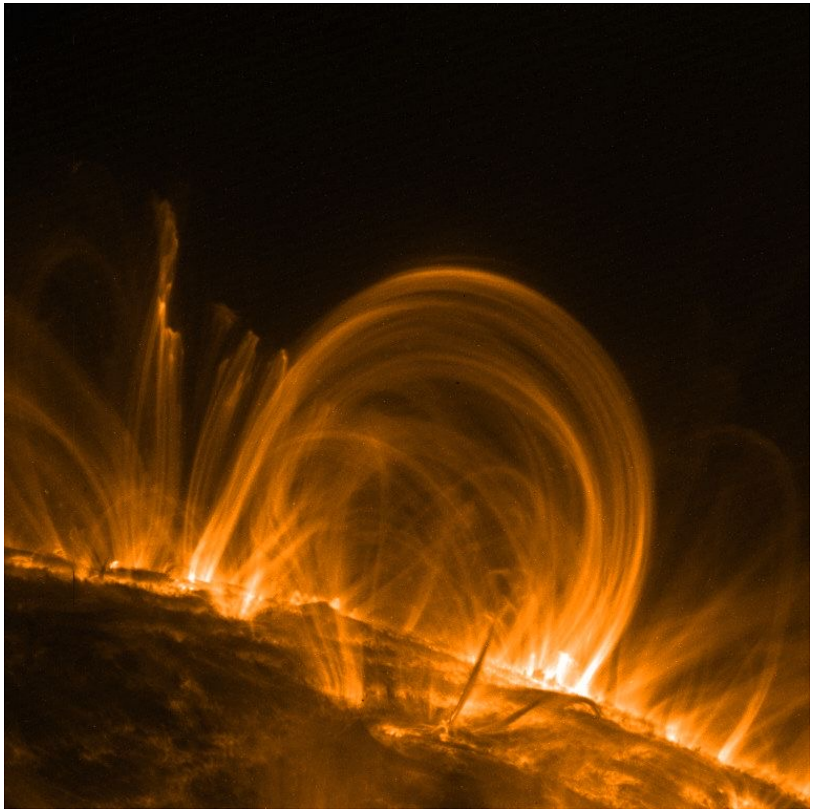
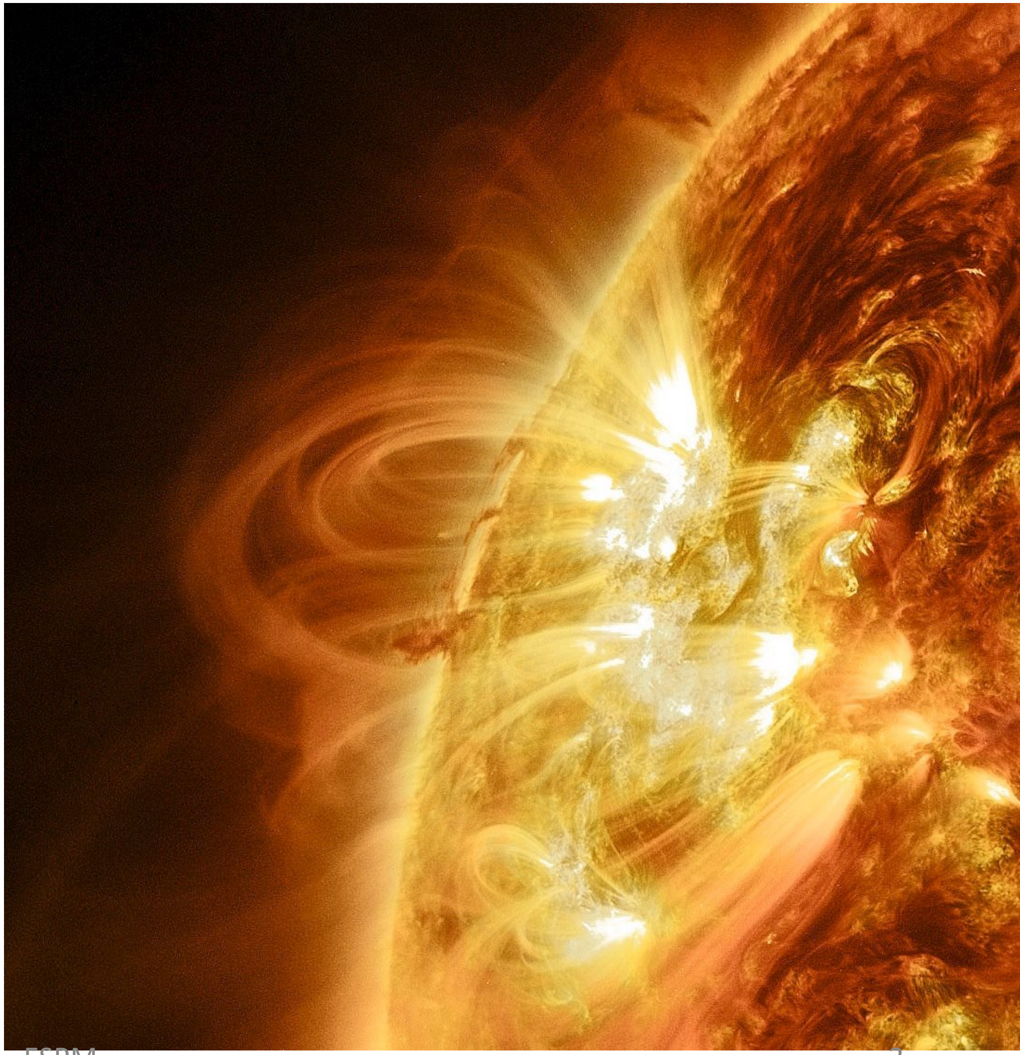
The corona

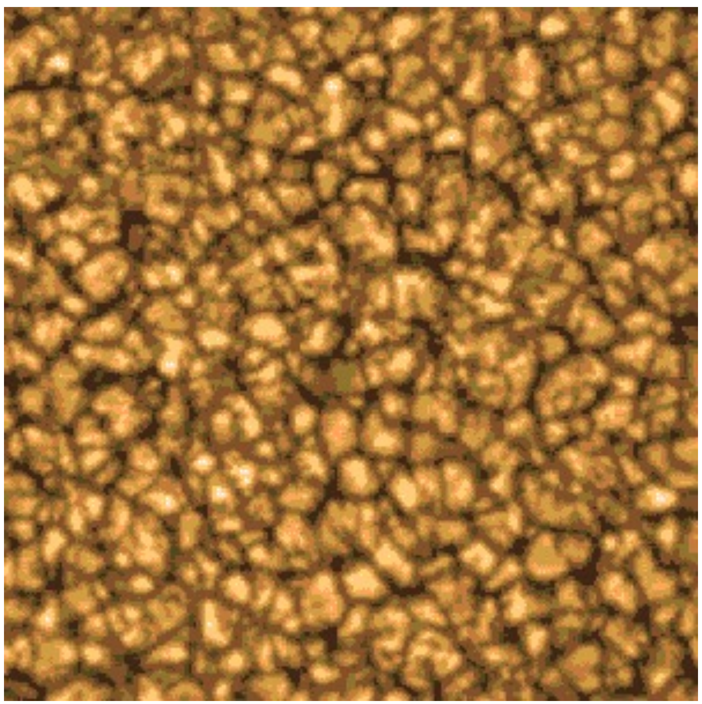


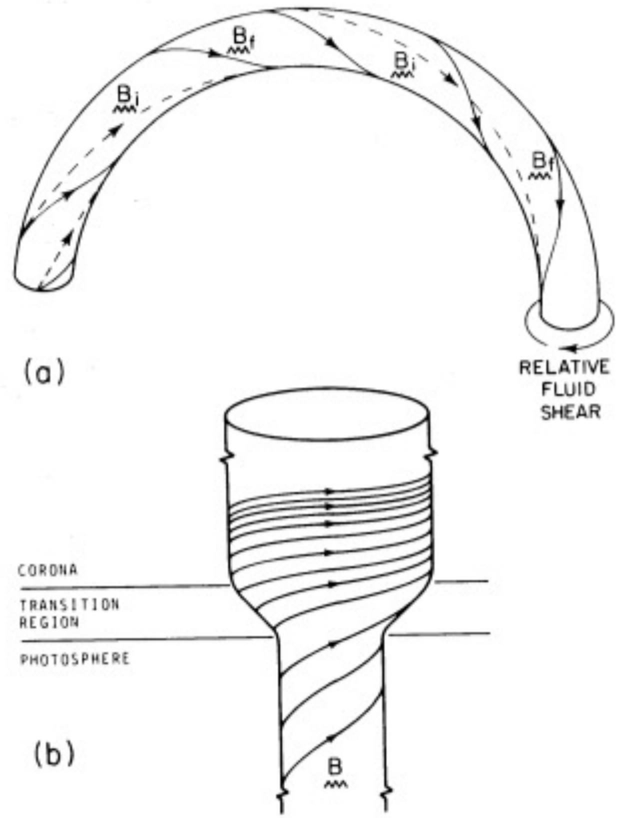
The confined corona: coronal loops





MHD modeling of twisted coronal loops





Rosner, Golub, Coppi, Vaiana 1978

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3D MHD MODELING OF TWISTED CORONAL LOOPS

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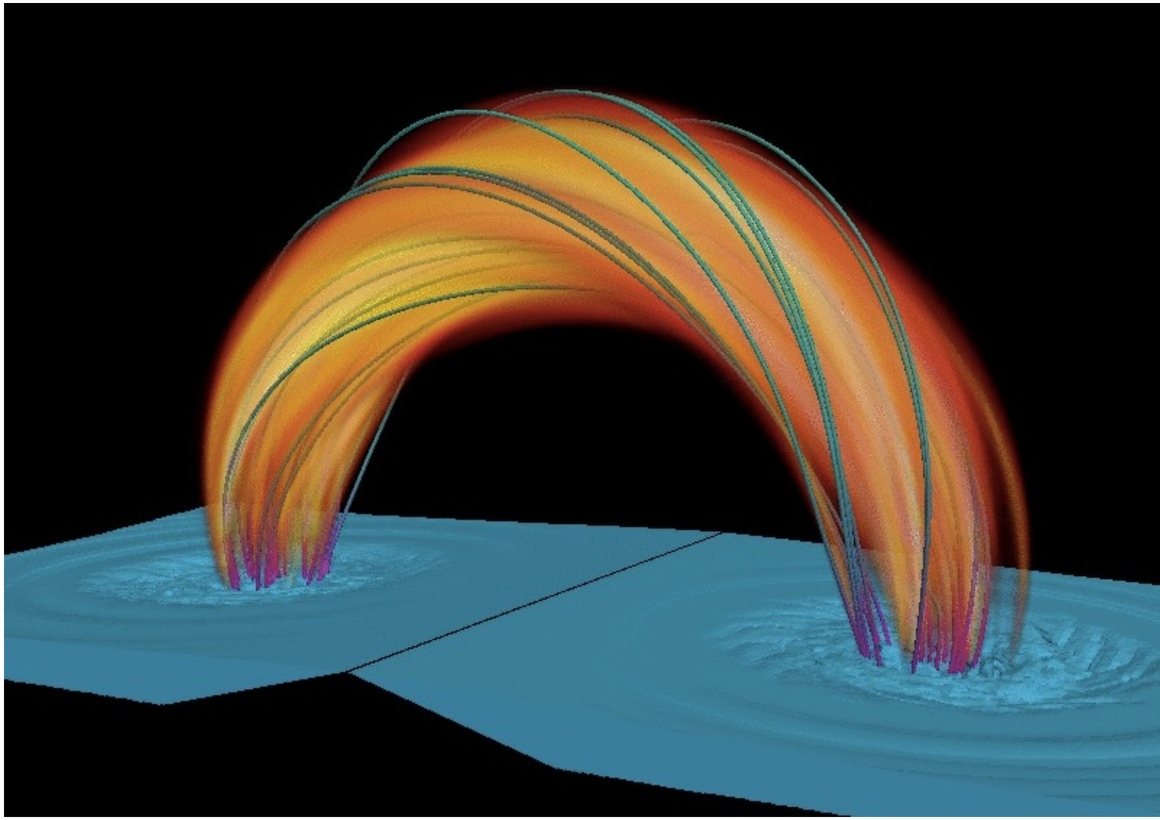
The 3D MHD model

(Reale et al. 2016)

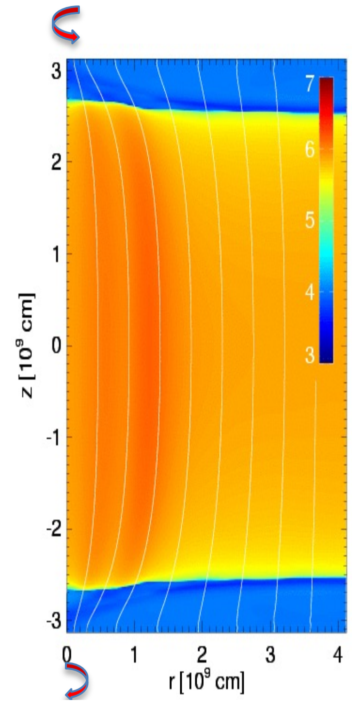
- Twisting is driven by rotation of the footpoints rooted in the photosphere
- We assume Joule heating above a current threshold (Hood+ 2009)

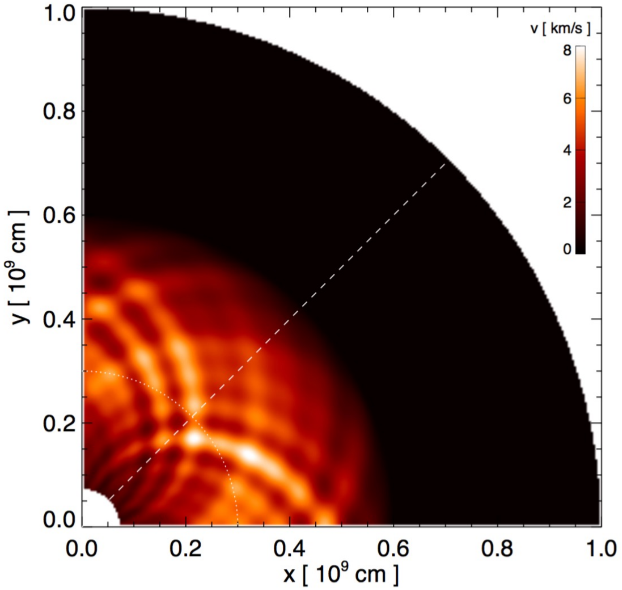


The basic loop model

- <u>The loop field: tapering down to the chromosphere</u>

- <u>The twisting/braiding</u>
  - Footpoint rotation
    - Basic constant angular speed ω
    - Maximum: 5 km/s (both footpoints)
    - Radius: r = 3000 km
  - **Braiding:** RANDOM COMPONENT ADDED TO ROTATION VELOCITY AT THE FOOTPOINTS (see pattern aside)





The 3D MHD model

(PLUTO 4 - Mignone+ 2007)

Three-dimensional cylindrical coordinates: r, φ, z

One quarter domain: $0 < \varphi < \pi/2$, $r_0 = 0.07\ 10^9$ cm

The equations:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \boldsymbol{u}) = 0 \ ,$$

$$\frac{\partial \rho \boldsymbol{u}}{\partial t} + \nabla \cdot (\rho \boldsymbol{u}\boldsymbol{u} - \boldsymbol{B}\boldsymbol{B} + \boldsymbol{I} P_t) = \rho \boldsymbol{g} \ ,$$

$$\frac{\partial \rho E}{\partial t} + \nabla \cdot [\boldsymbol{u}(\rho E + P_t) - \boldsymbol{B}(\boldsymbol{u} \cdot \boldsymbol{B})] =$$

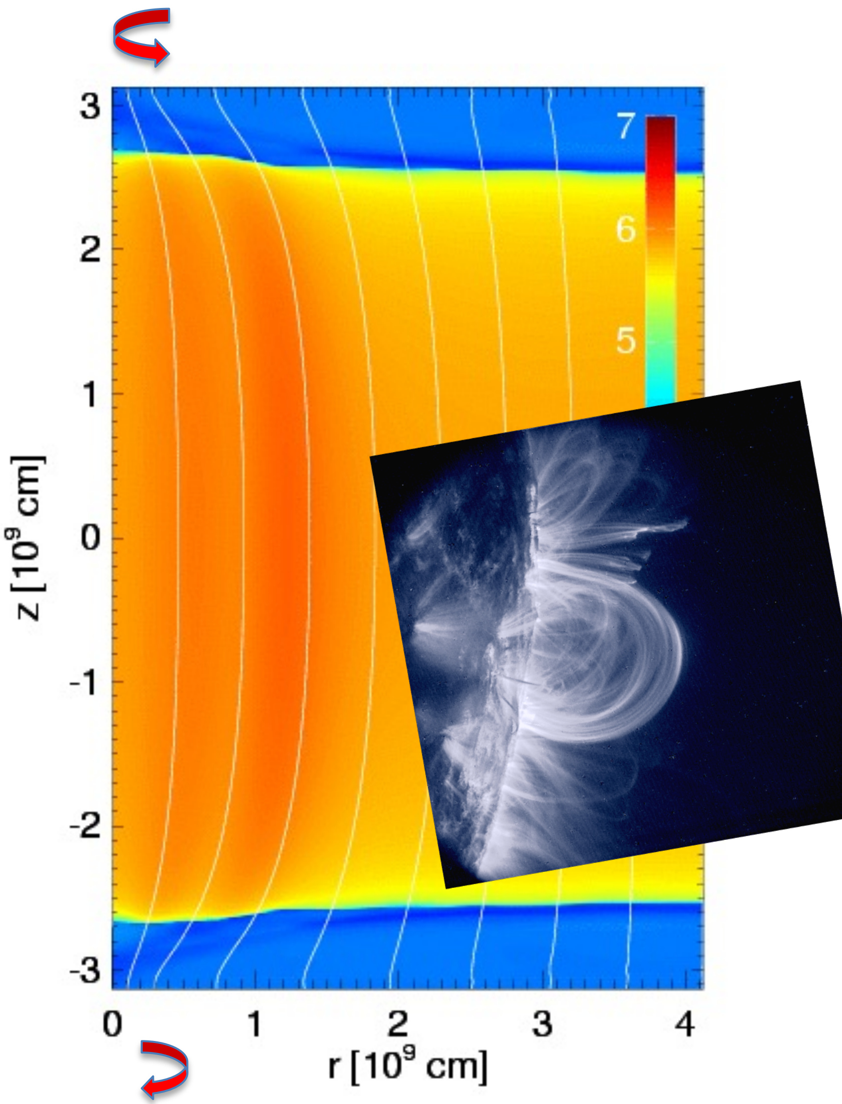
$$- \nabla \cdot [(\eta \cdot \boldsymbol{J}) \times \boldsymbol{B}] + \rho \boldsymbol{u} \cdot \boldsymbol{g} - \nabla \cdot \boldsymbol{F}_c - n_e n_H \Lambda(T)$$

$$\frac{\partial \boldsymbol{B}}{\partial t} + \nabla \cdot (\boldsymbol{u}\boldsymbol{B} - \boldsymbol{B}\boldsymbol{u}) = -\nabla \times (\eta \cdot \boldsymbol{J}) \ ,$$

where

$$P_t = P + \frac{\boldsymbol{B} \cdot \boldsymbol{B}}{2} \ , \qquad E = \epsilon + \frac{\boldsymbol{u} \cdot \boldsymbol{u}}{2} + \frac{\boldsymbol{B} \cdot \boldsymbol{B}}{2\rho} \ ,$$

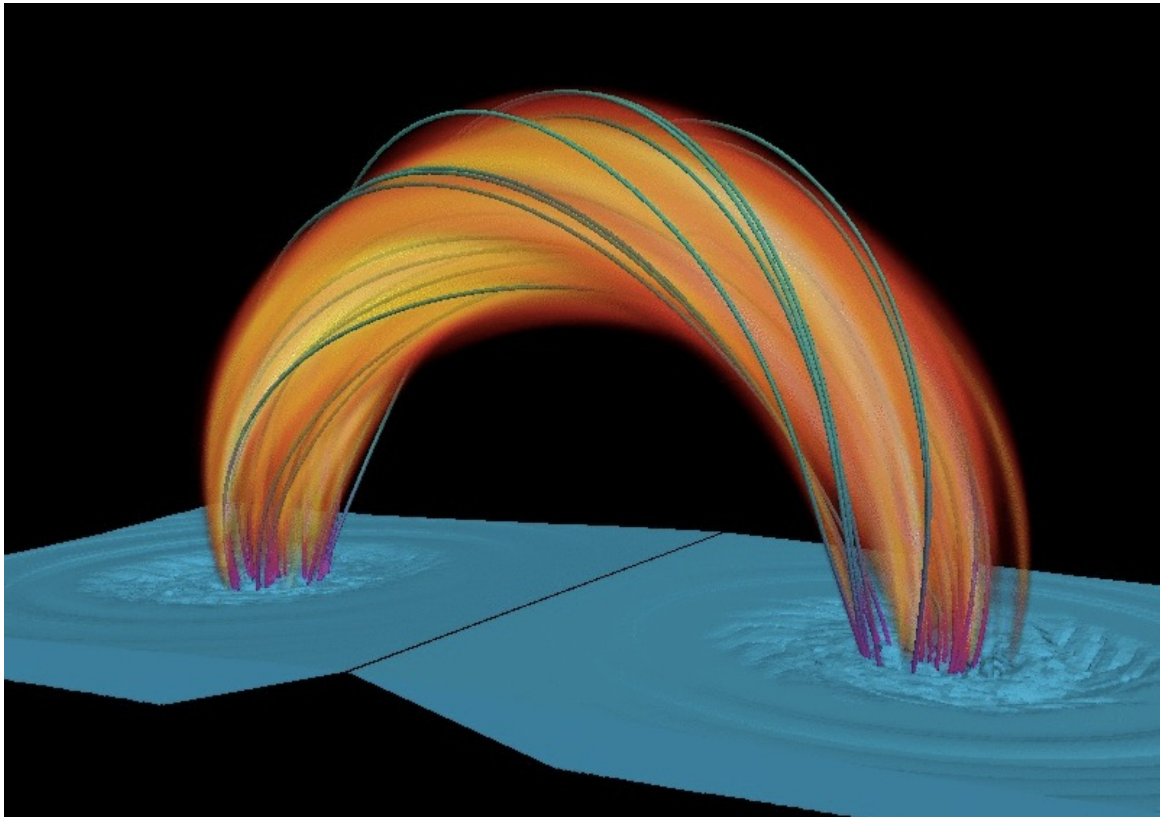
$$\mathbf{F}_c = \frac{F_{sat}}{F_{sat} + |\mathbf{F}_{class}|} \mathbf{F}_{class}$$



The 3D MHD model

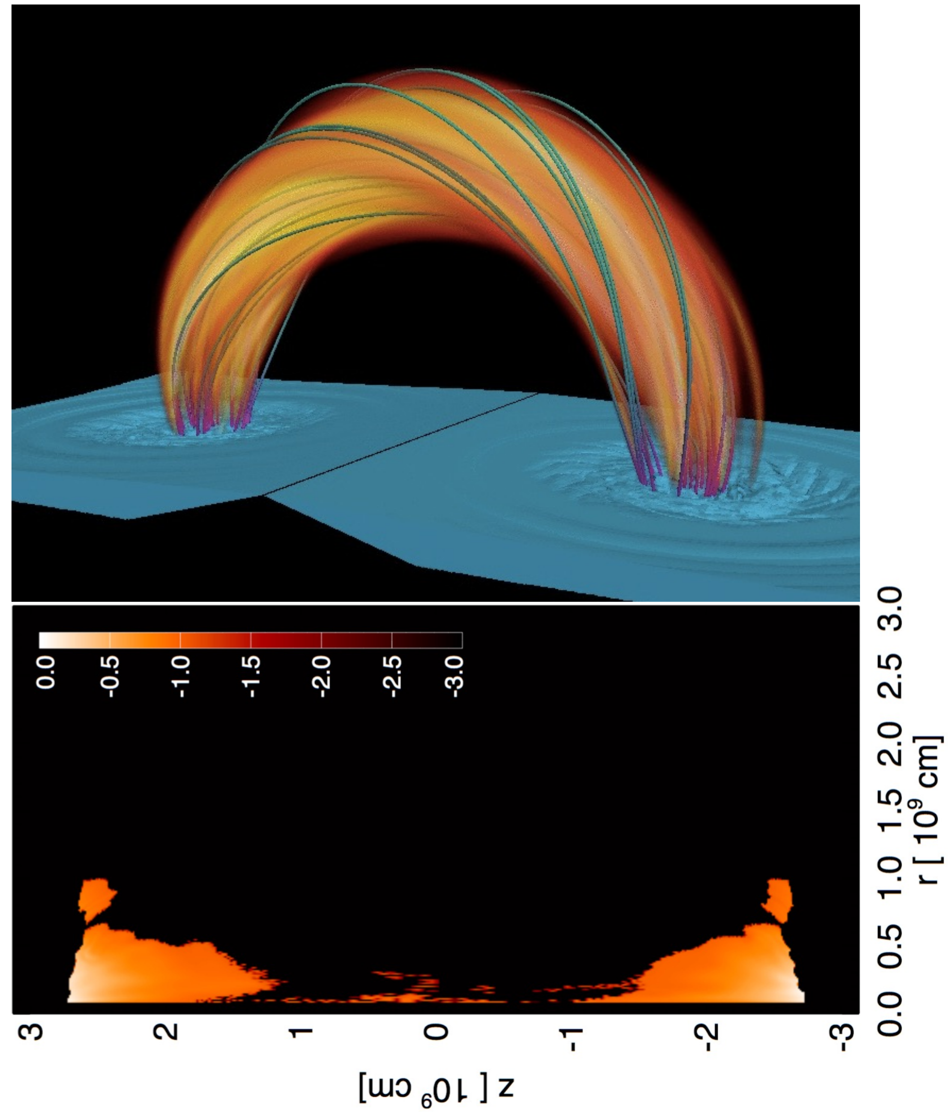
(Reale et al. 2016)

- HPC:
  - [384x256x768] cells
  - 16000/32000cores
  - ~10 Mhrs on CINECA/FERMI, Italy

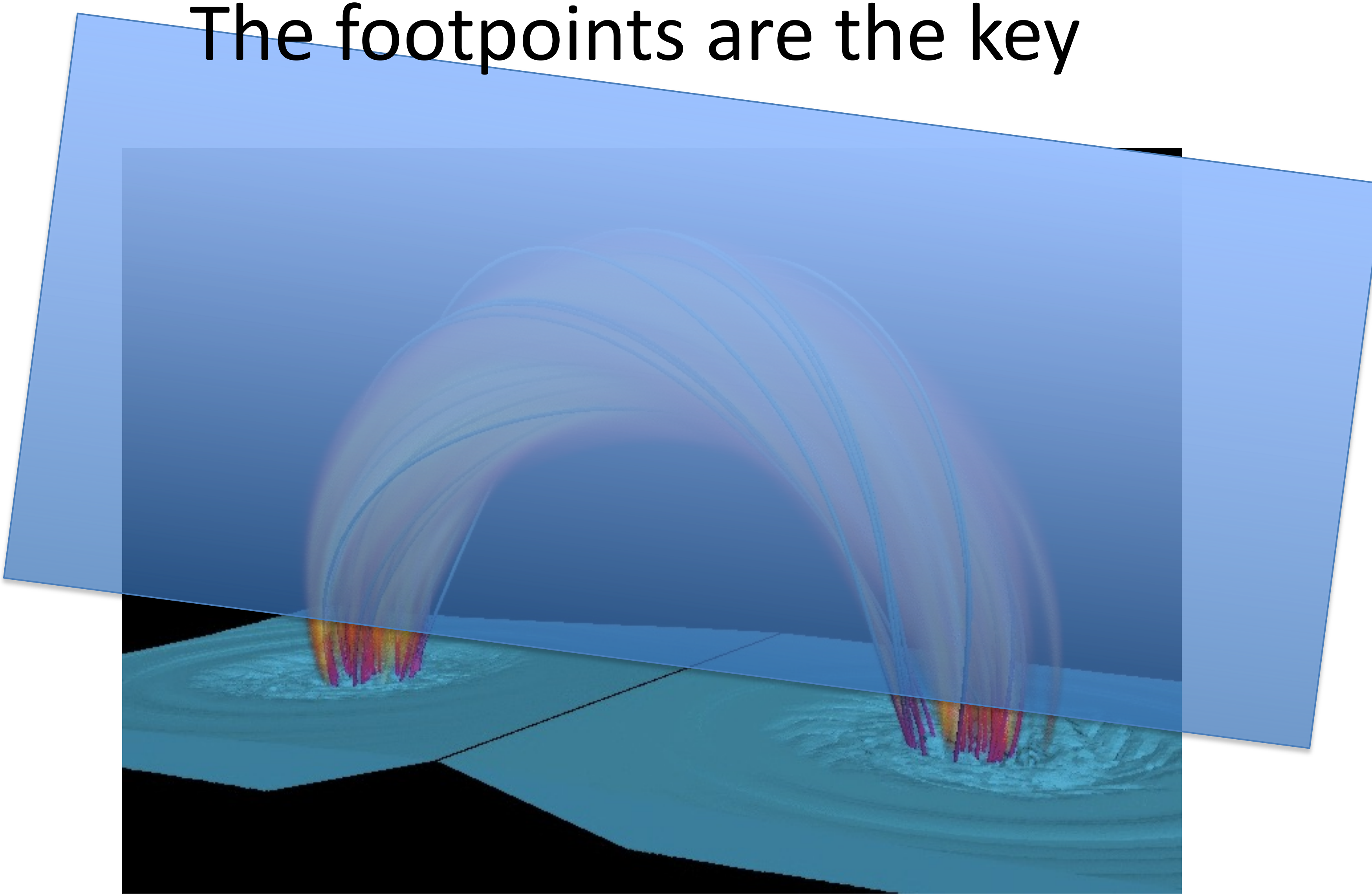


Final heating distribution

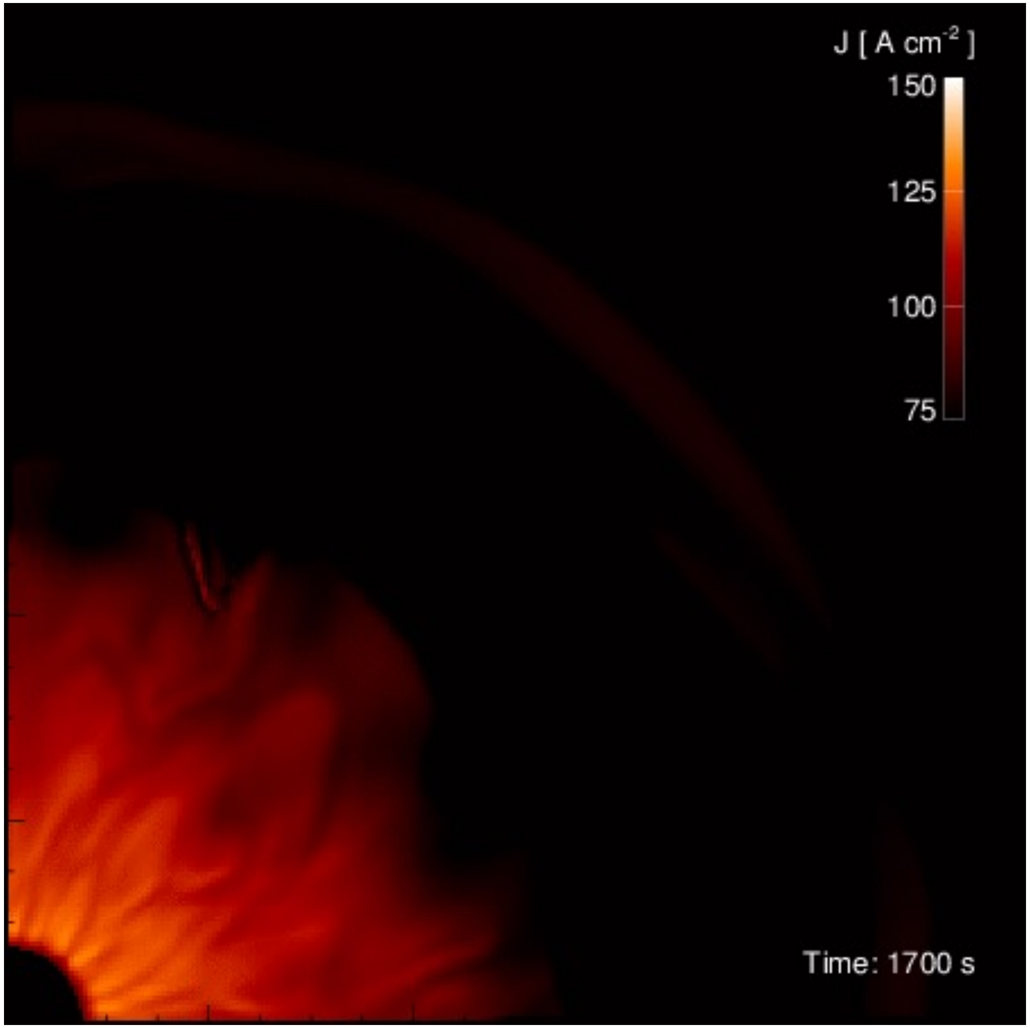
- Larger currents and heating released mostly at the footpoints *(where the magnetic field is more intense because of TAPERING)*



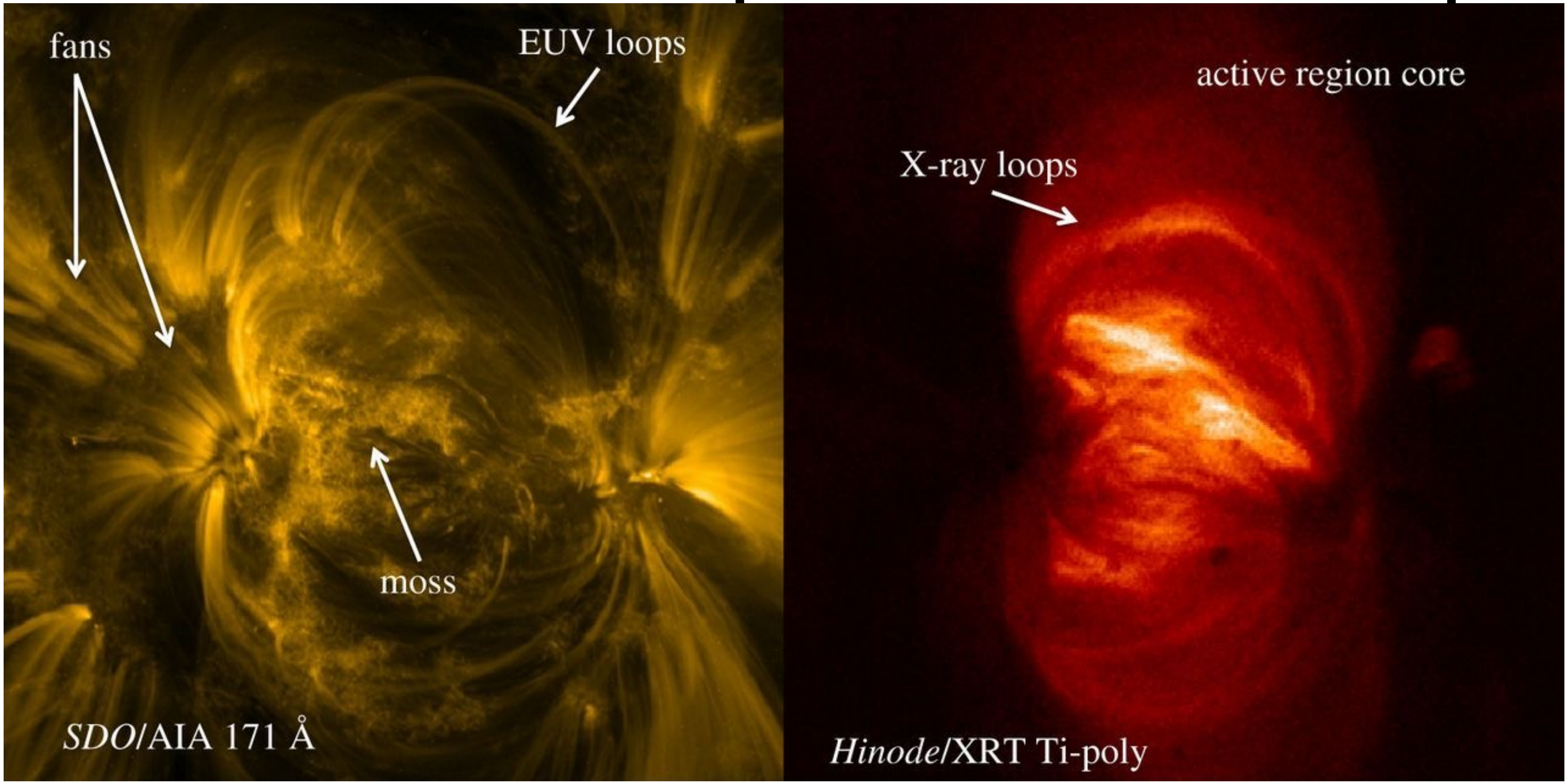
The footpoints are the key



Dissipation of currents



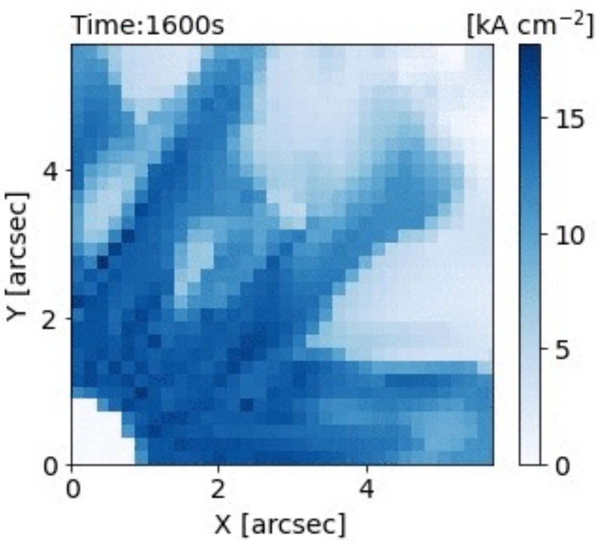
In some EUV lines (e.g., *FeIX 171A*) we observe footpoints of hot loops



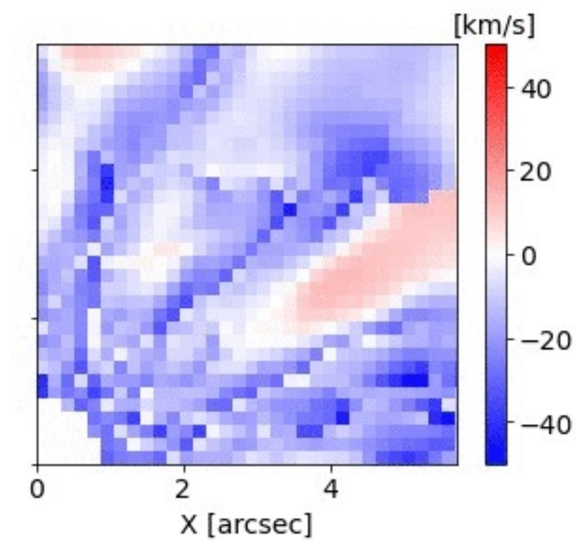
Schmelz & Winebarger 2015

High resolution spectroscopy can monitor the fine structure of currents!

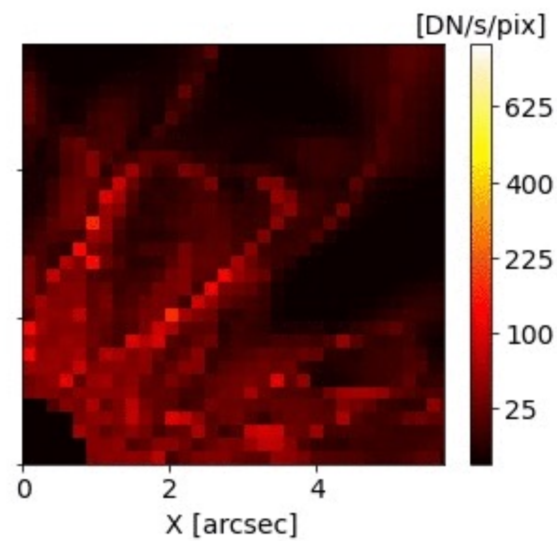
Current density



FeIX 171a: Doppler shift



FeIX 171a: Intensity



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Conclusions

- Field stressing by braiding/twisting can provide loop heating
- Higher current dissipation at the footpoints because of loop tapering
- We show that EUV high resolution spectroscopy (FeIX 171A) can track the fine structure of currents and dissipation