Magnetic Flux Emergence and eruptive activity in the Sun

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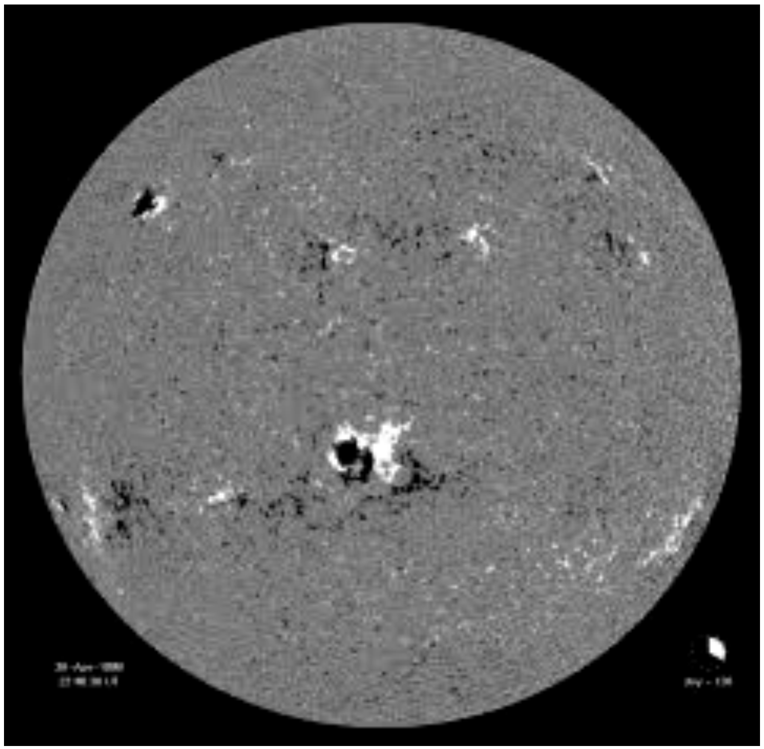
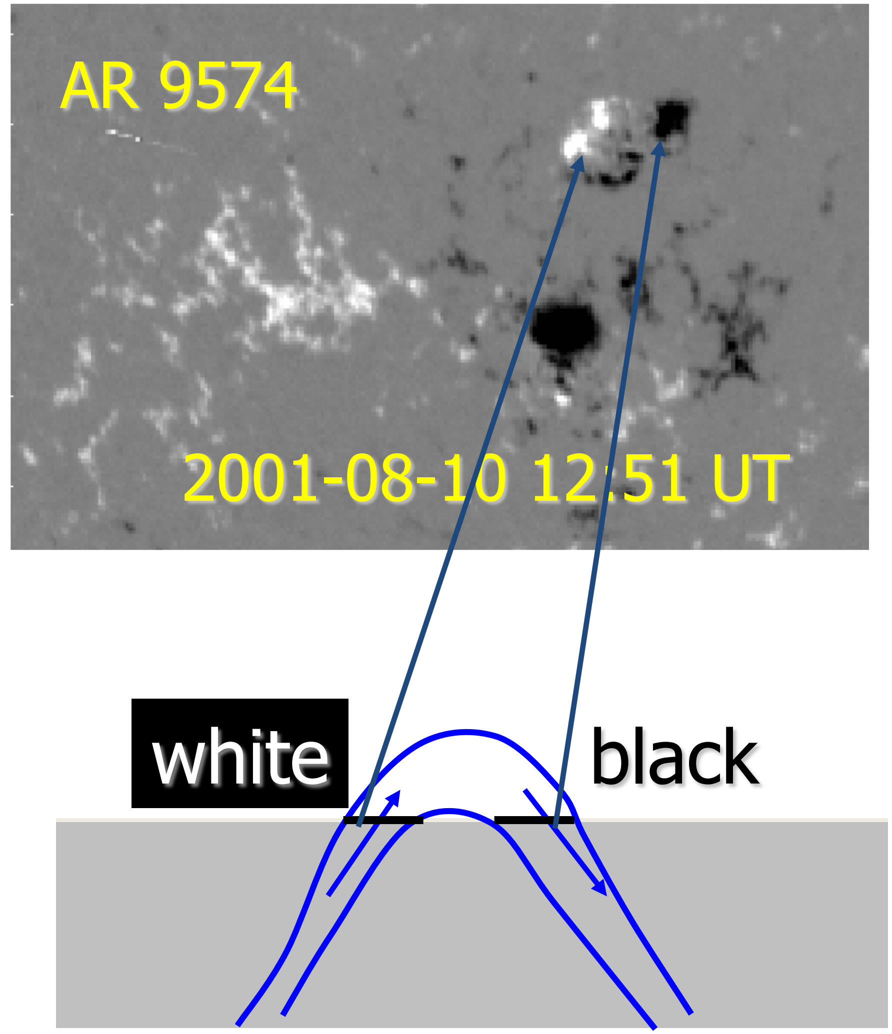
Magnetic Flux Emergence in the Sun: Observations & Theory.

MFE in a full disk magnetogram.

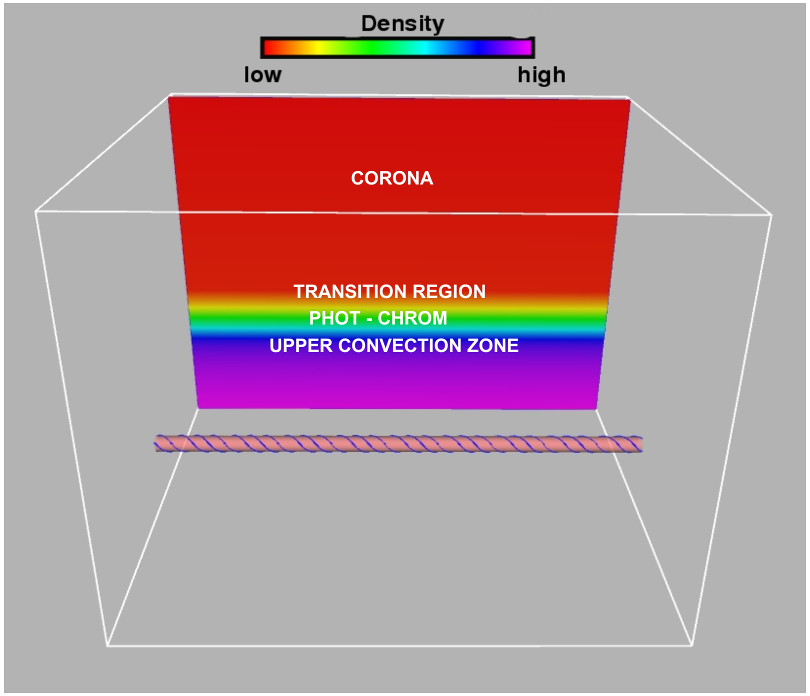


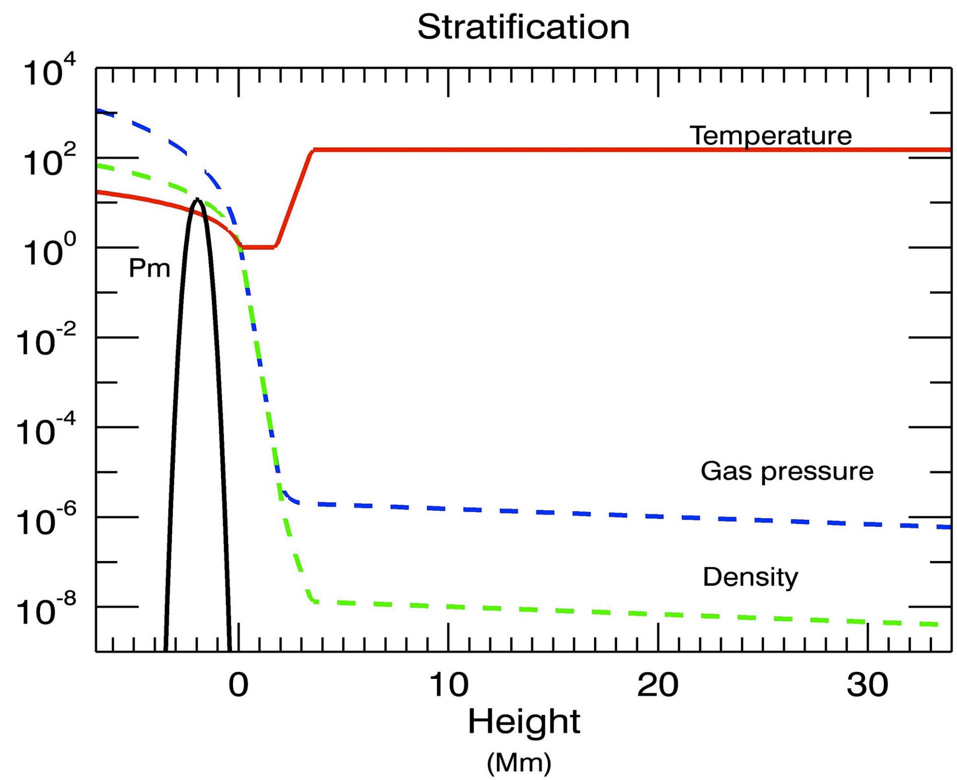
MDI magnetogram around an Active Region.



Emerging magnetic field forms sunspots

Magnetic Flux Emergence: Simulations

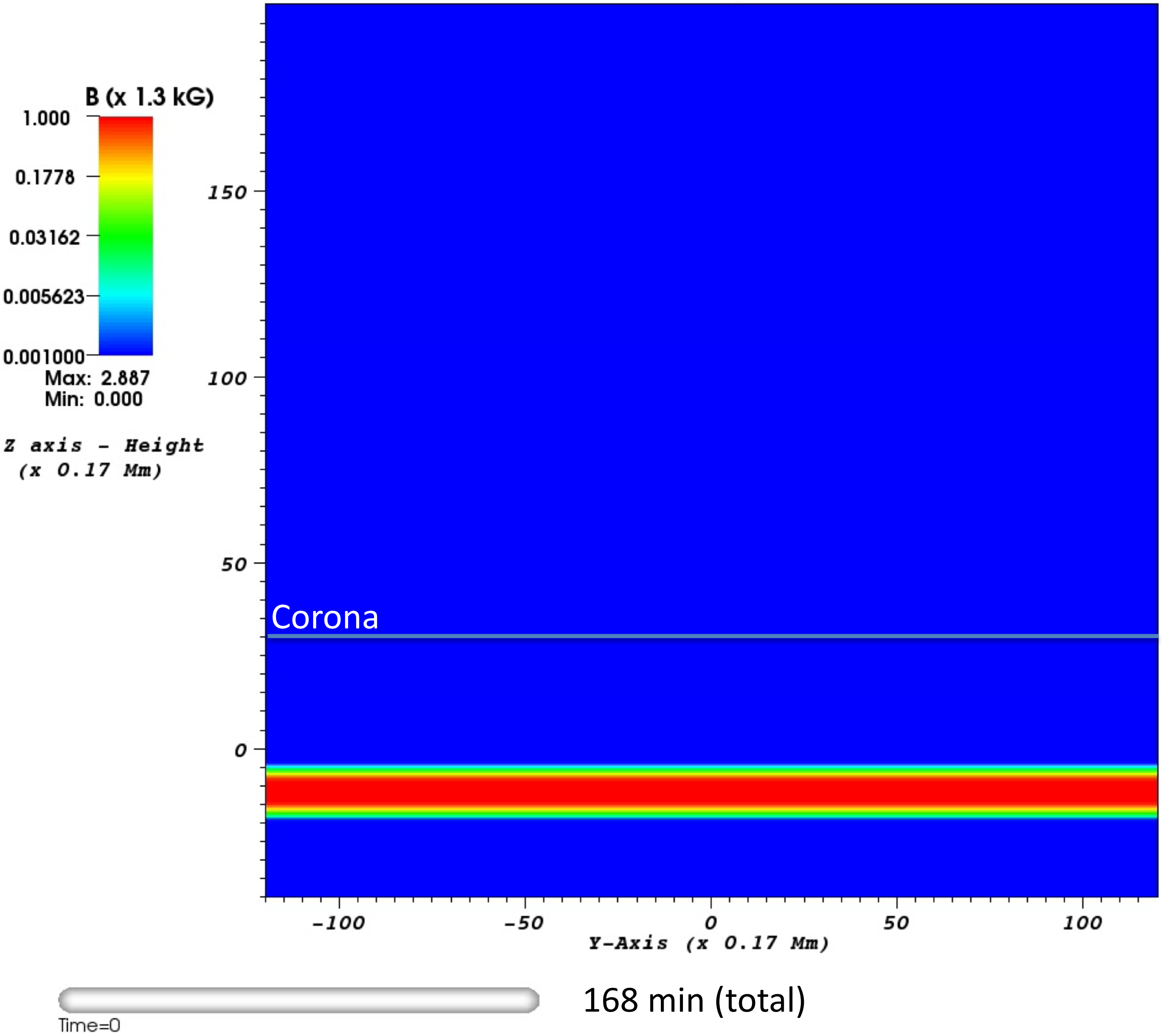




- Stratified (plane-parallel) atmosphere.
- Magnetic flux tube (twisted).
- Density deficit → buoyancy.
- Ambient magnetic field.

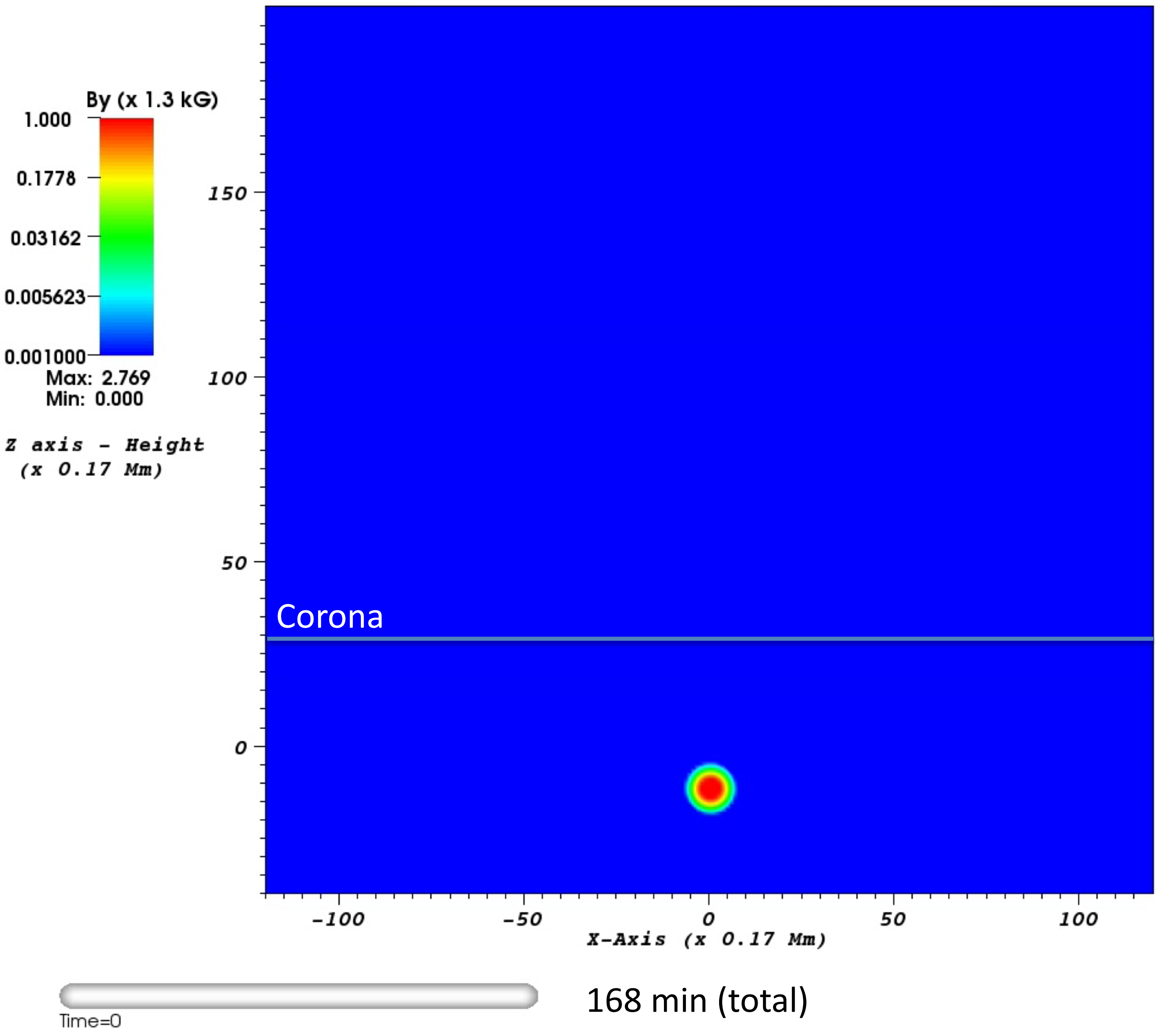
- Atmosphere, magnetic field(s).
- Large density and pressure contrast.
- Hydrostatic equilibrium.
- 3D resistive MHD (Lare3d code).

B_y (along the tube)



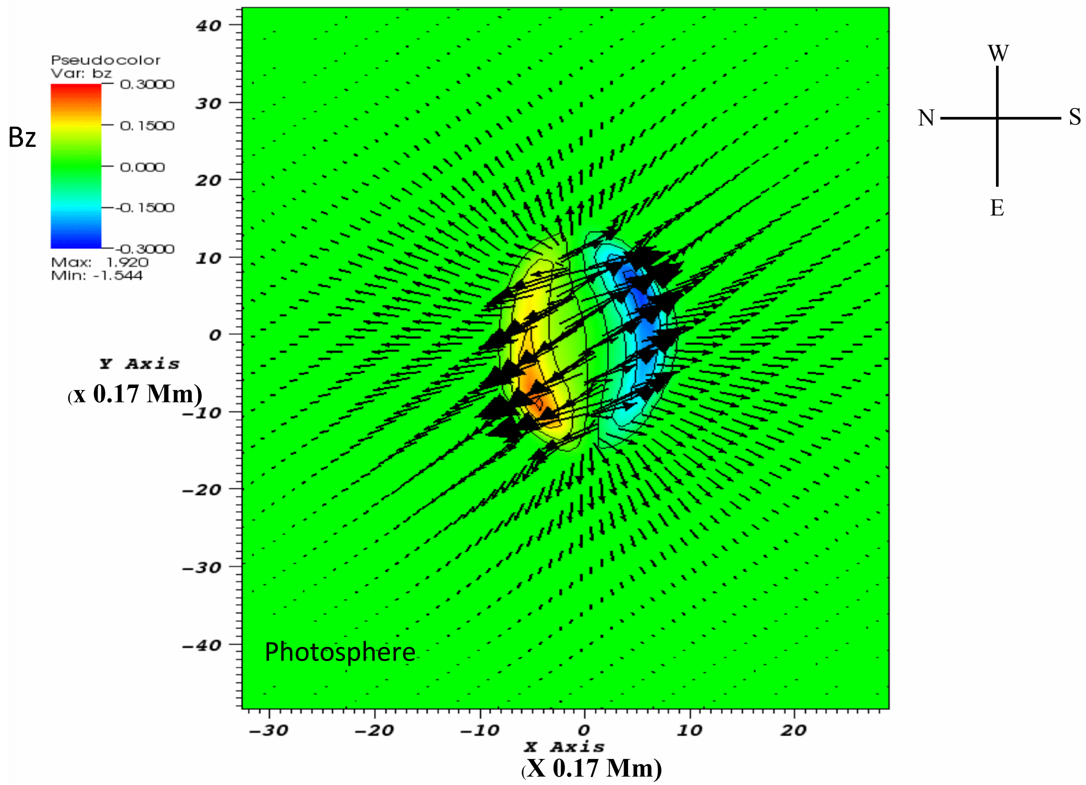
168 min (total)

B_y (cross section / mid-plane)



168 min (total)

Photosphere: Emerging Active Region and magnetic "tails"

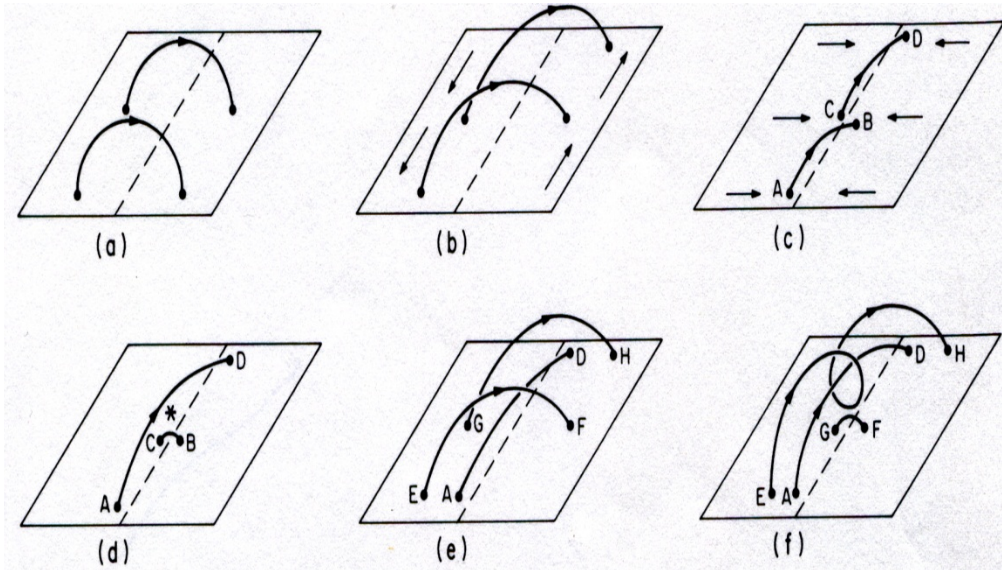


- V_{rise}=1.7 km/sec, t=12.5 min.
- Formation of a bipolar region.
- B ~ 600G at the photosphere.

- Formation of **'tails'** on both sides of PIL.
- Organized **shear** velocity flow along the PIL.
- **Inflow** in the transverse direction.

Archontis, et.al. ApJ (2005)

Theory: Formation of (erupting) filaments

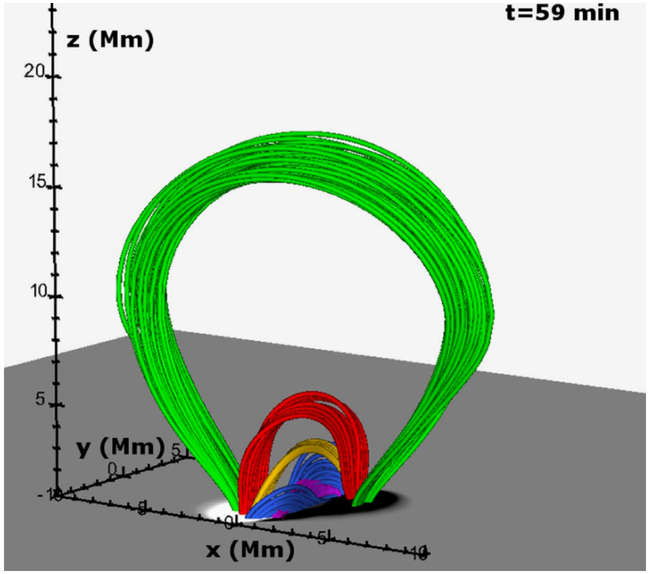


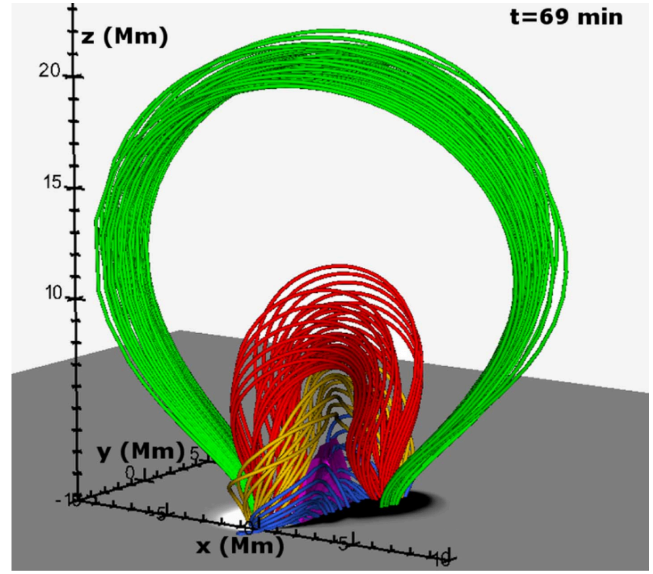
A. van Ballegooijen and P. Martens (1989)

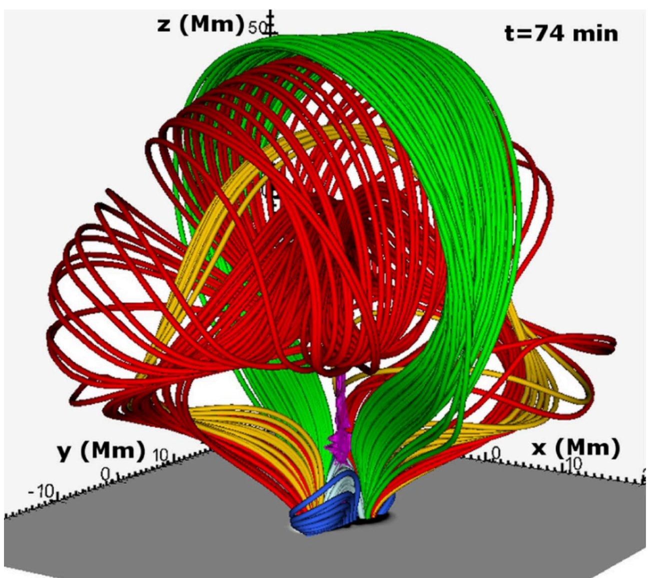
Shearing motion + Convergence + Reconnection

Current sheets, longer loops and helical magnetic field structures, which might erupt.

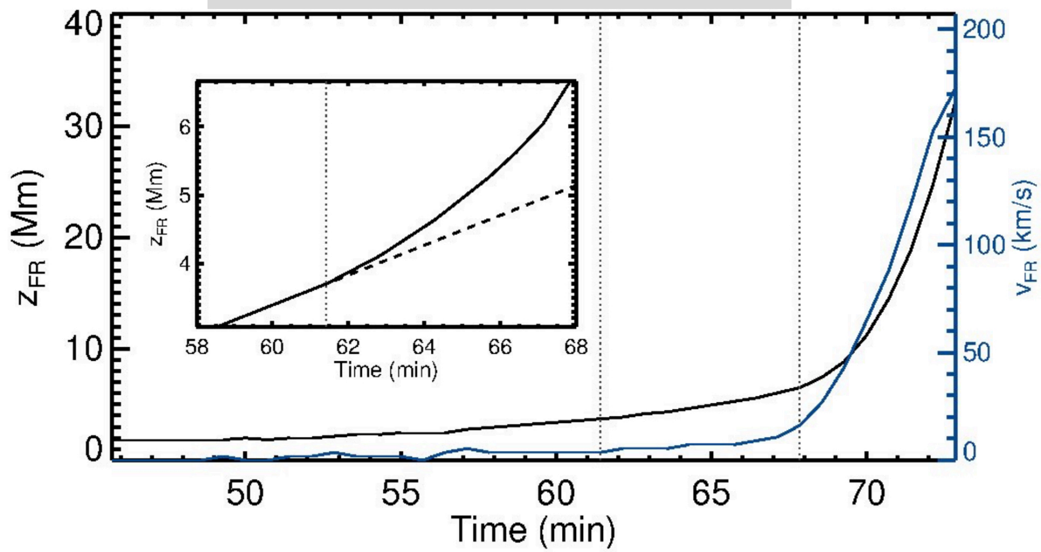
Simulations: Formation of (erupting) flux-ropes

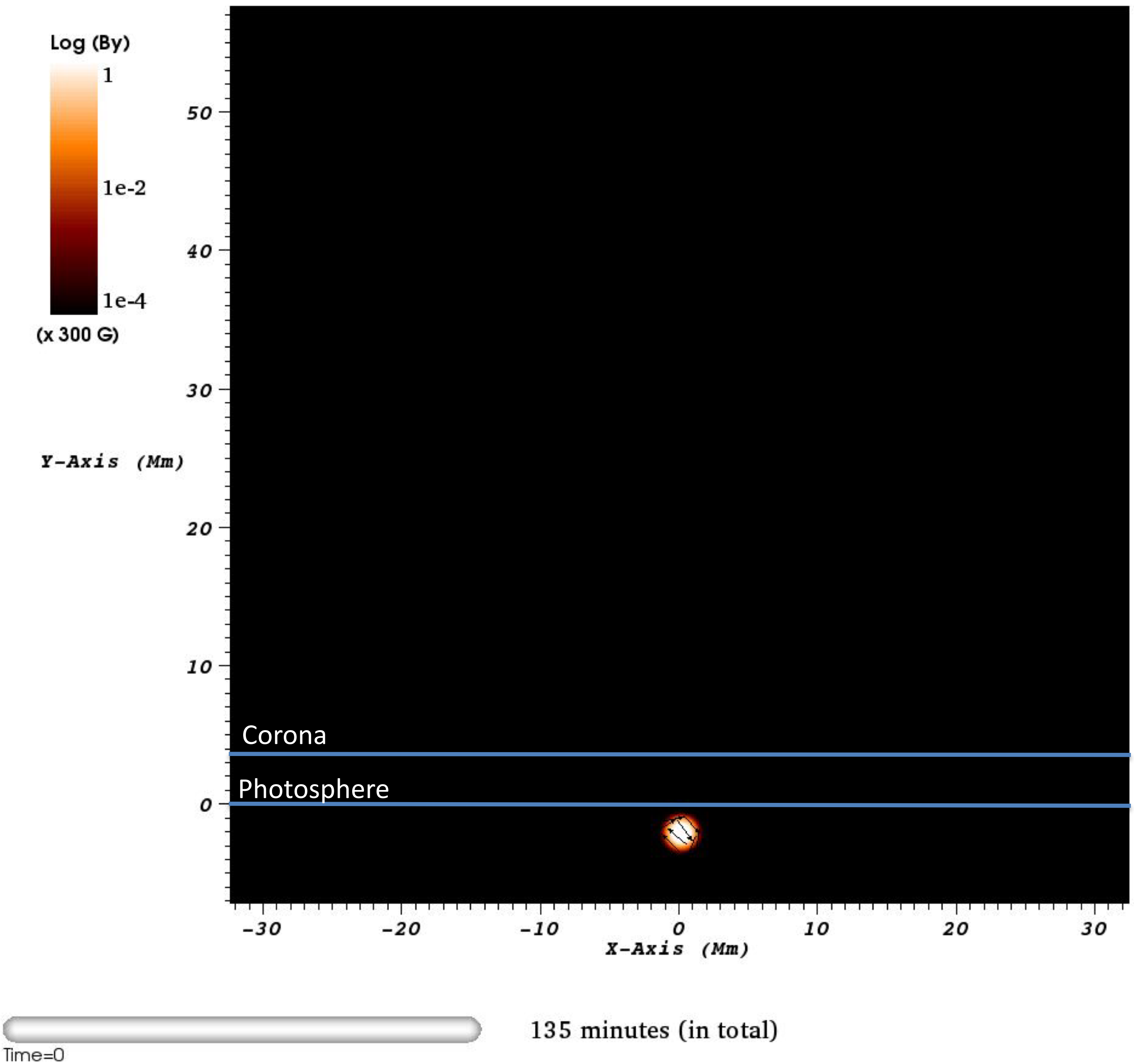




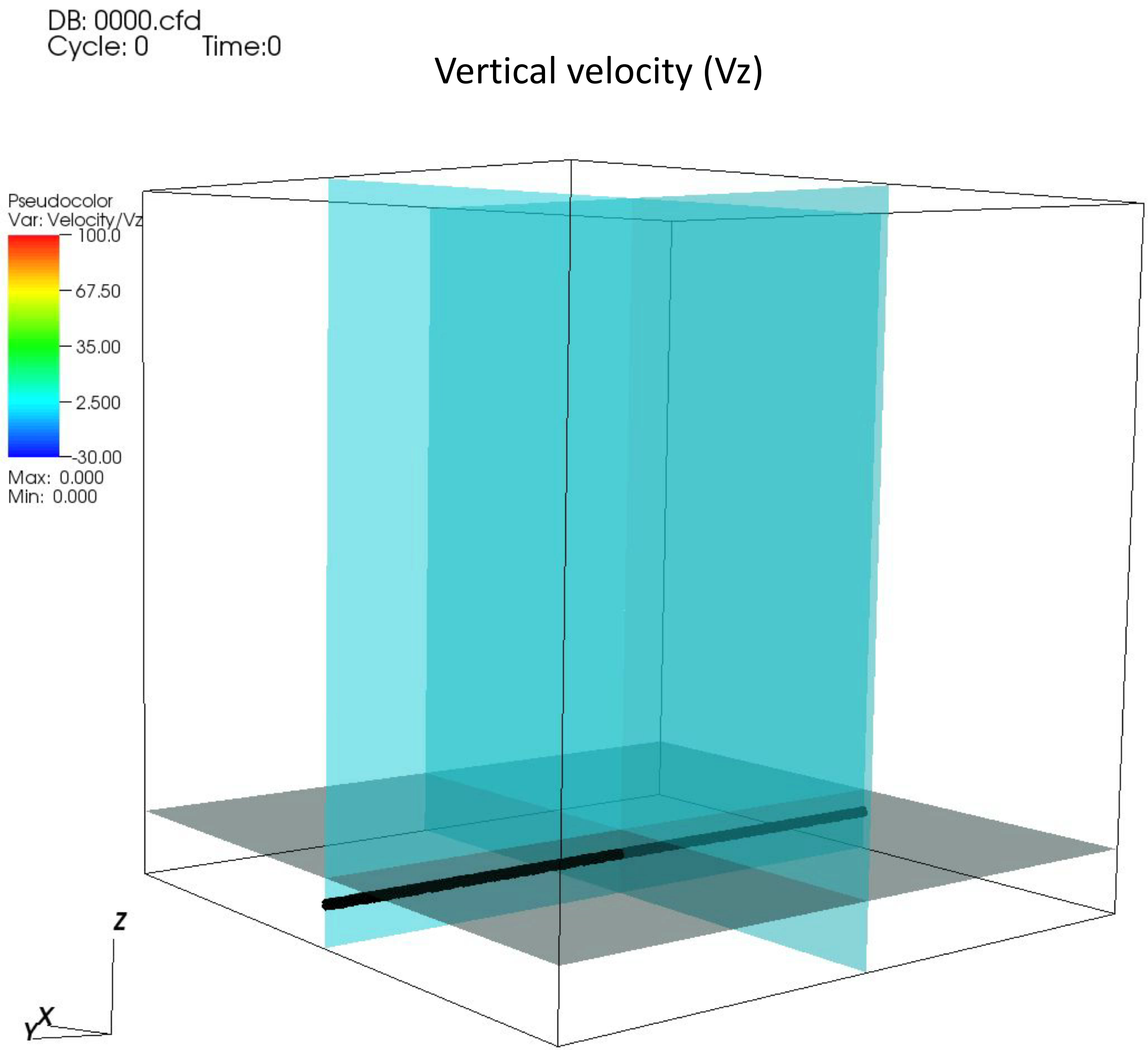


Syntelis, Archontis, Tsinganos, ApJ, (2017)



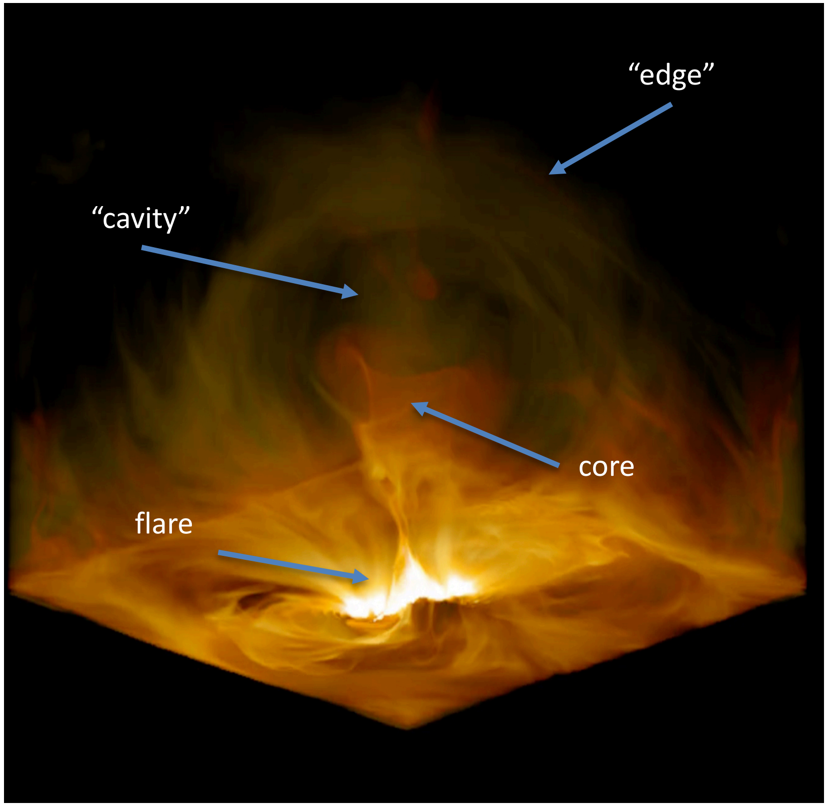

Log (By)
1
1e-2
1e-4
(x 300 G)
Y-Axis (Mm)
50
40
30
20
10
0
Corona
Photosphere
-30
-20
-10
0
10
20
30
X-Axis (Mm)
135 minutes (in total)
Time=0

Vertical velocity (Vz)

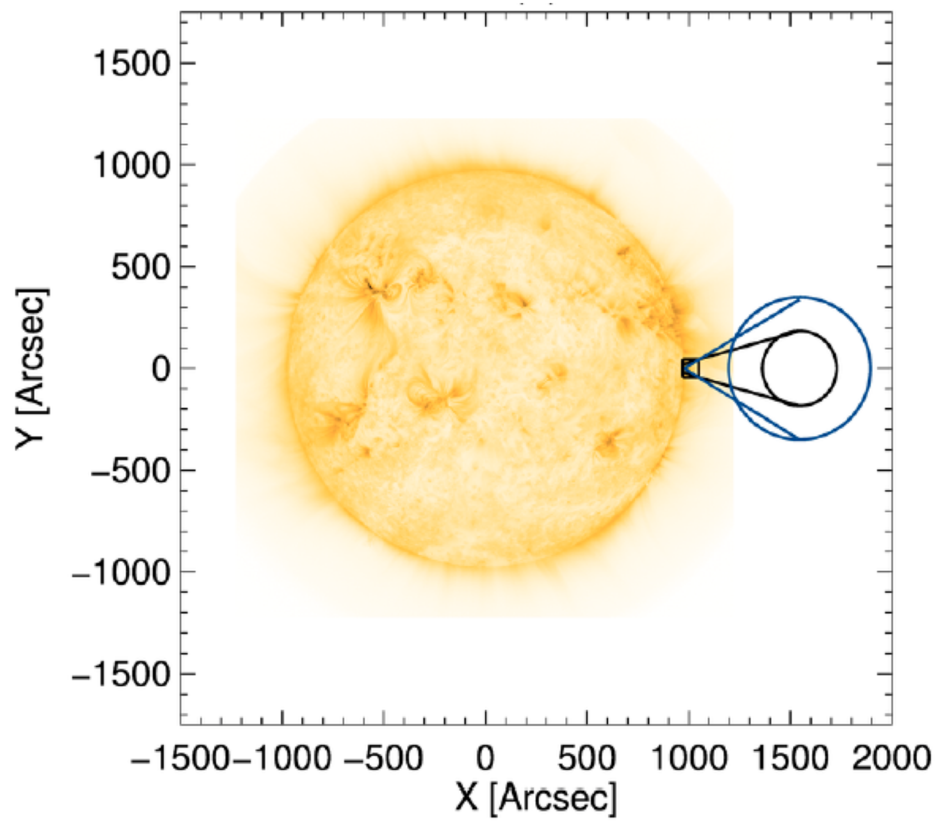


Simulations:Eruptions of CME-like structures

Simulations: synthetic images of eruptions



Simulations: extrapolated size of the eruptions

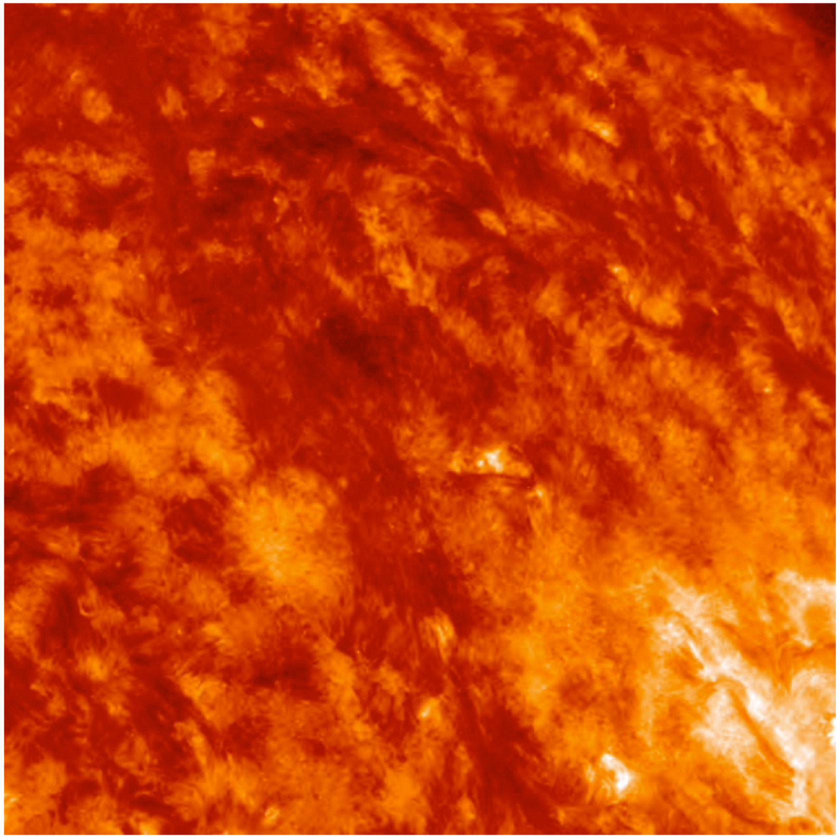


- AIA 170A + AIA 304A
- Dense plasma in the core.
- Hot and cool erupting plasma.
- Flare ($5x10^6$ K).

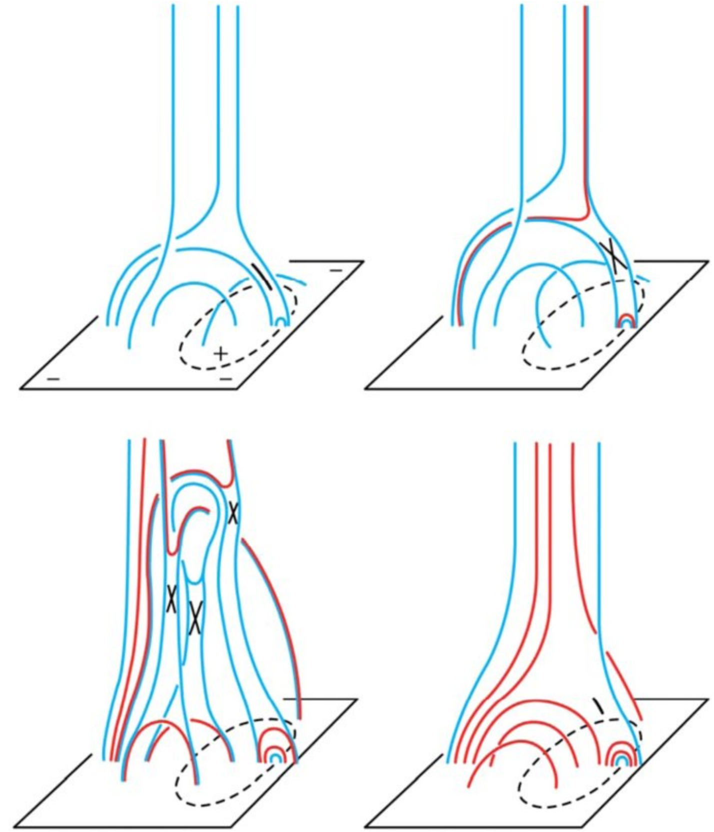
- Extrapolation at 0.6 $R_\odot$.
- Length of the flux rope ~ 100 Mm
- Energy ~ 10^{28} erg
- Small CMEs.

Syntelis, Archontis, Tsinganos, ApJ, (2017)

Observations: small-scale (mini) filaments drive jets?



SDO/AIA 304 A (4/4/2013)



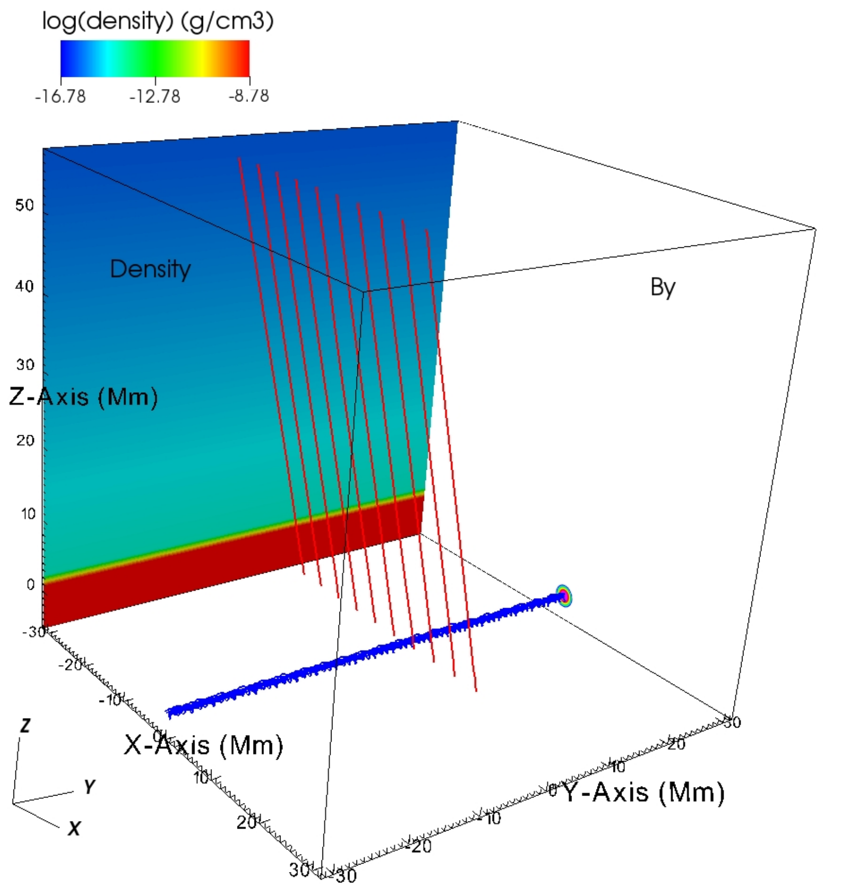
Moore et.al., ApJ, (2010).

‘Blowout’ jets.

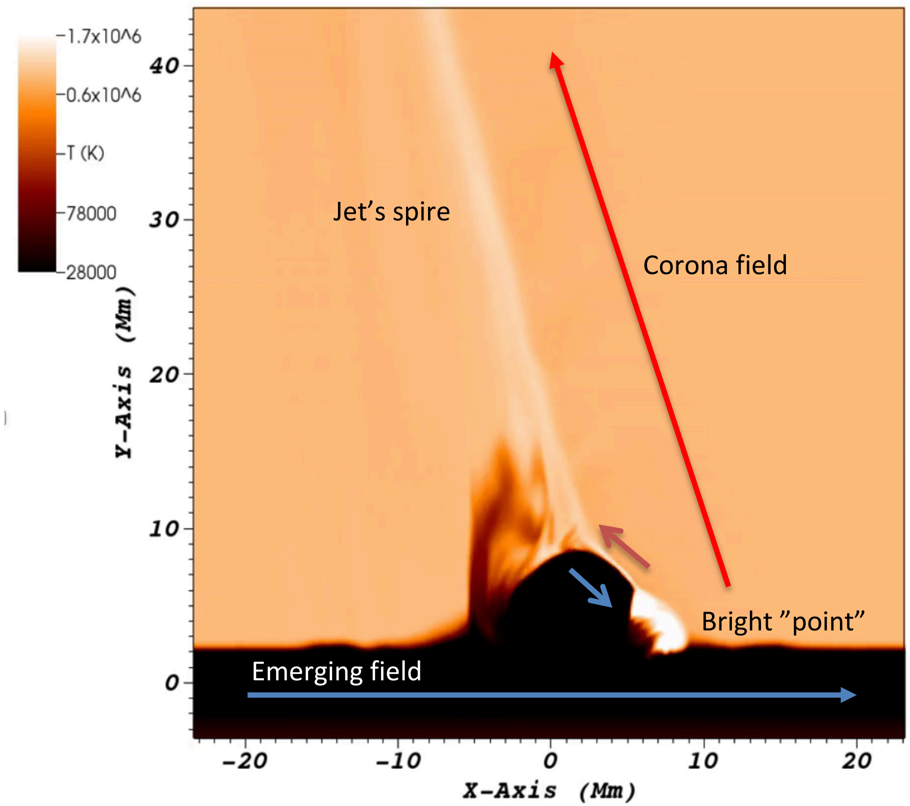
- Eruption of the field.
- ‘External’ & ‘Internal’ reconnection.
- Wider jet channel.
- Hot and cool emission.
- Brightening on arcades.

Simulations: Jets via flux emergence

3D Simulations: flux emergence into magnetized corona



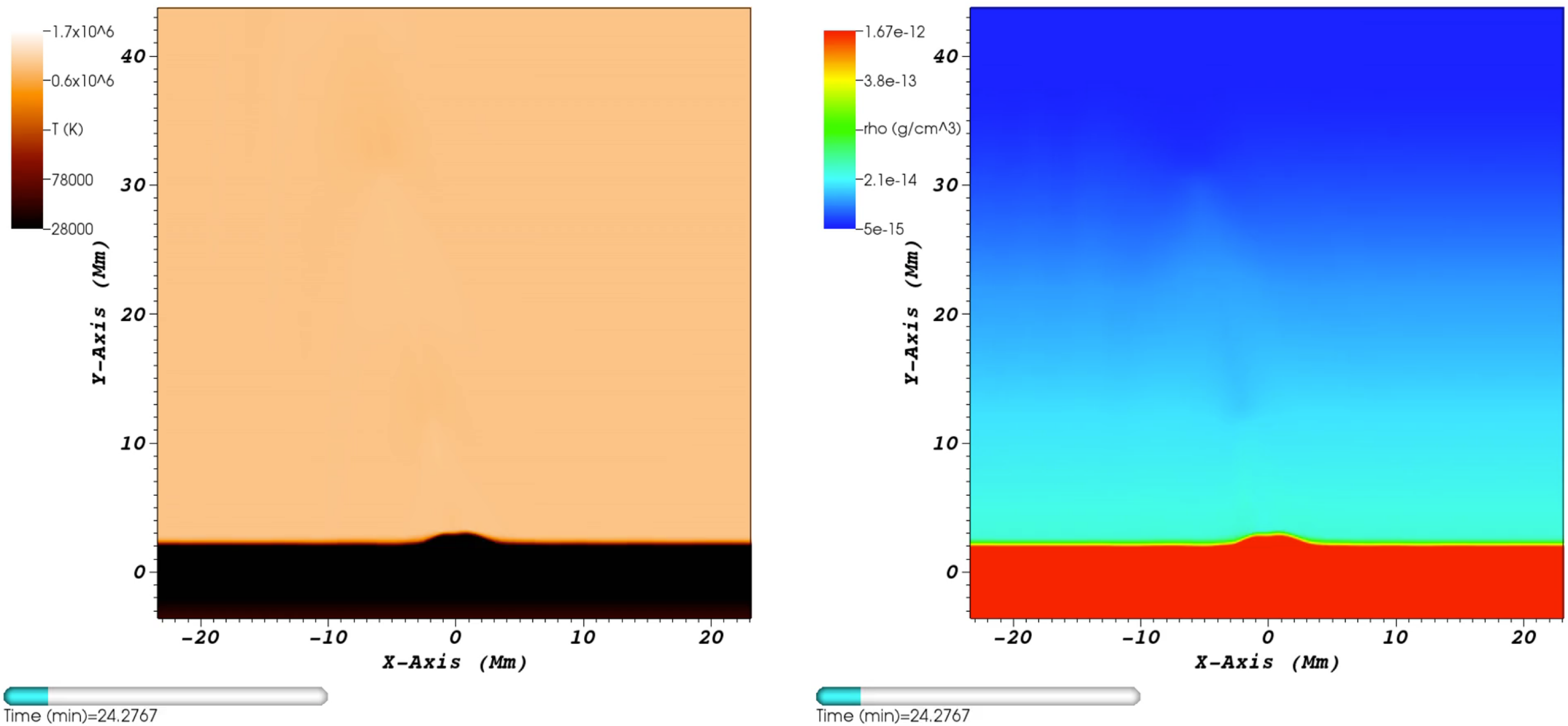
3D Simulations: comparison to observations



Temperature

Archontis et.al., ApJ, (2013).

Simulations: First model to explain eruption-driven jets.

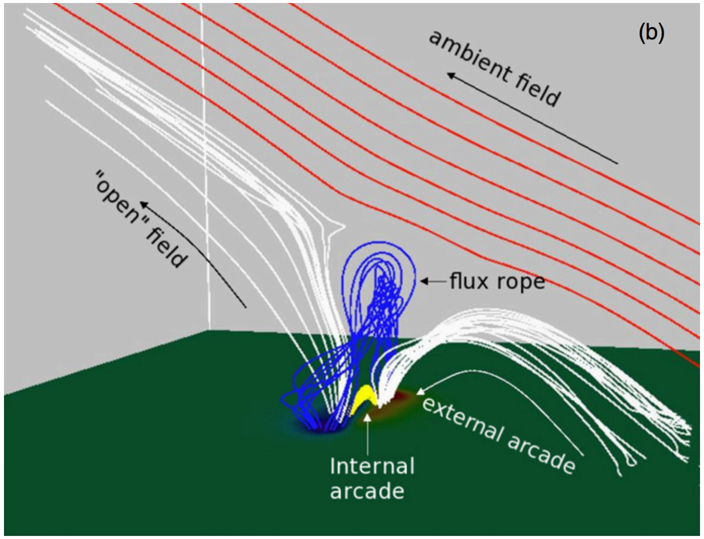


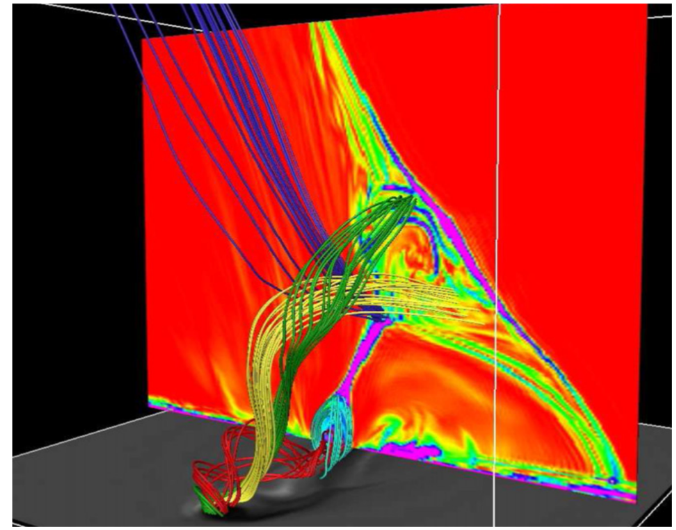
Model explains the key observed features:

- Hot and cool emission along the jet.
- Spire of the jet is much wider.
- Bright point underneath the jet.

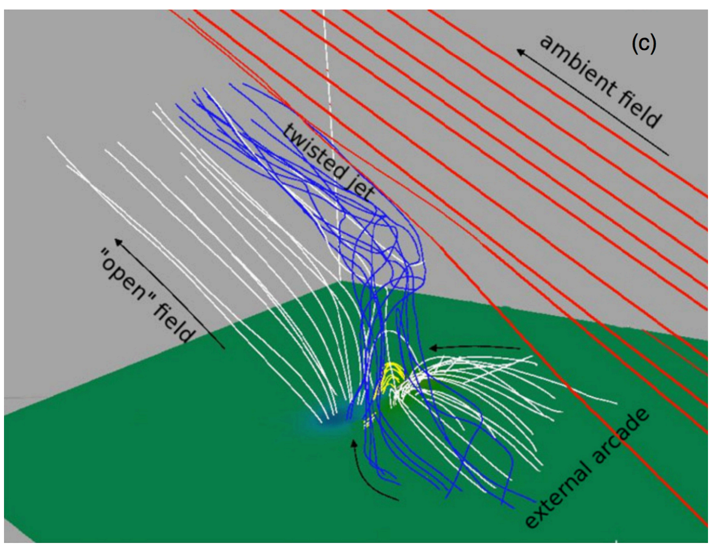
Archontis, V. & Hood, A., ApJL, (2013).

Simulations: Eruption-driven jets in 2D and 3D.

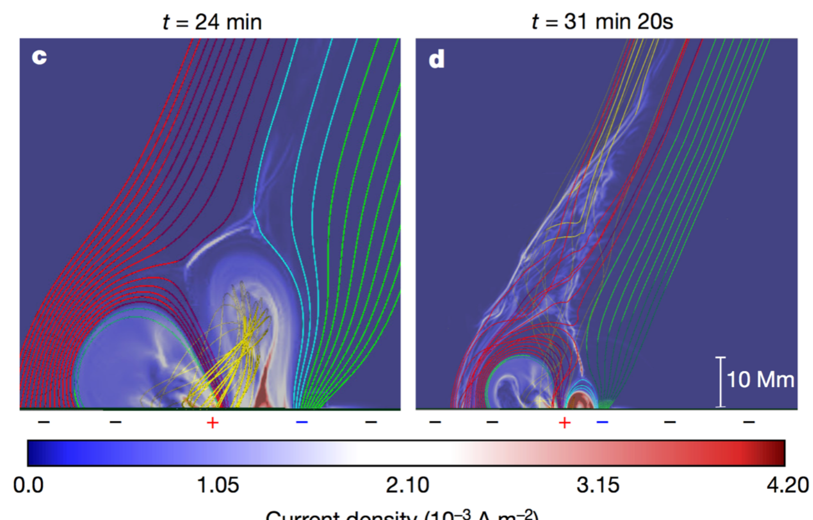




Moreno-Insertis, F., V. & Kalsgaard, K., ApJ, (2013).



Archontis, V. & Hood, A., ApJL, (2013).



Wyper, Antiochos & DeVore, Nature, (2017).

Conclusions and work in progress

Conclusions

- Nature of flux emergence is well understood. Formation of bipolar regions, strong PILs, magnetic tails, sigmoidal emerging regions in a self-consistent manner has been achieved.

- The formation of unstable flux ropes via strong shearing along PILs leads to eruptions on various scales. On small-scales, blow-out jets are triggered. On large-scales, CME-like structures erupt. A unified model for jets-CMEs.

- The mechanism of eruptions is mainly related to external (break-out) reconnection, internal reconnection (e.g. tether cutting) and or instabilities (e.g. torus instability).

Work in progress

- Study the role of convection on flux emergence and the formation of pores/sunspots and Active Regions.

- Coupling of global dynamo with near-surface convection simulations to investigate the emergence and eruptivity of magnetic fields.

- Can eruptions drive phenomena on even smaller scales (e.g. spicules) ?

THANK YOU !