# Magnetic Topology of Quiescent Prominence Bubbles

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# Outline

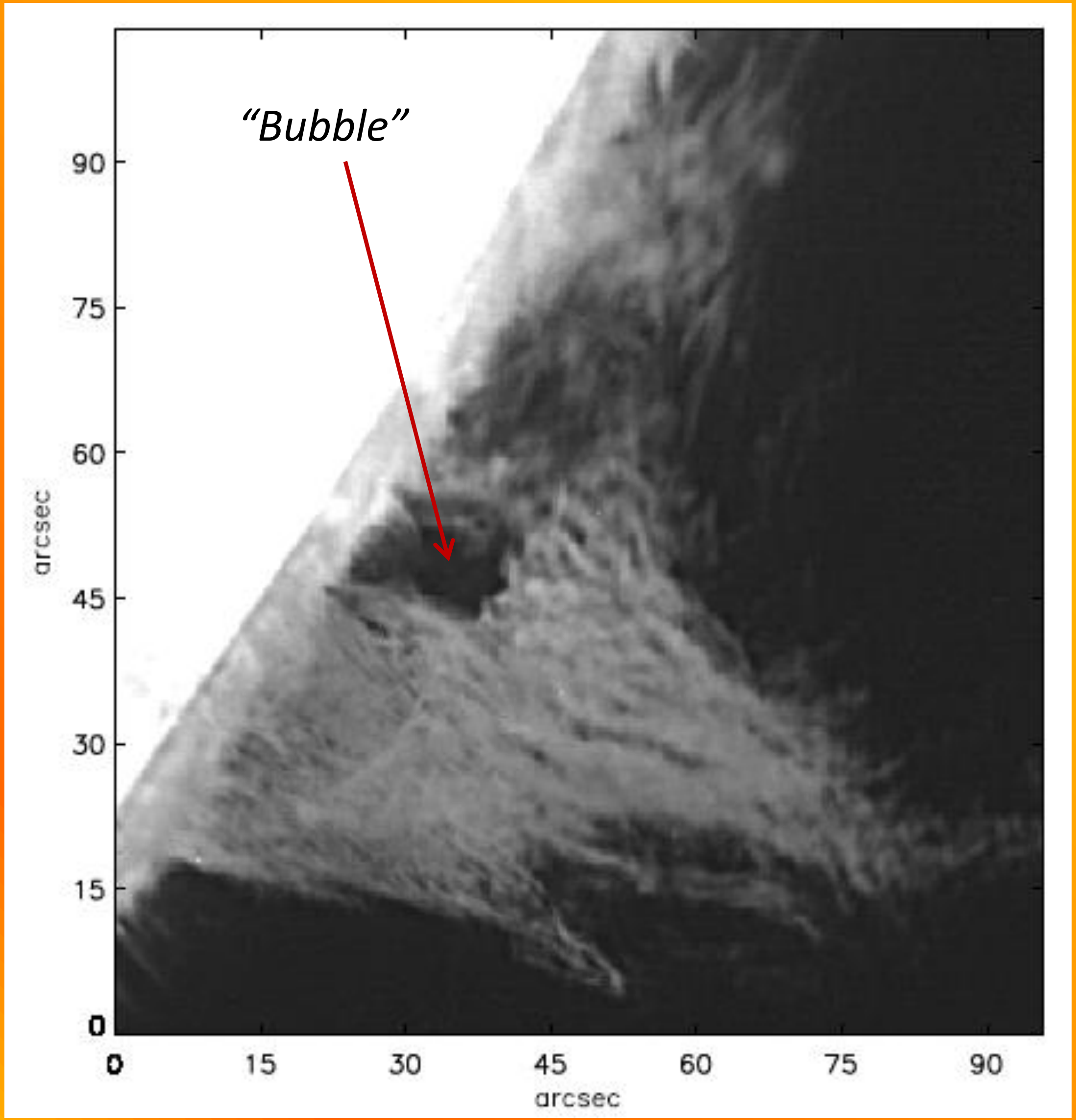
I. **Motivation: Bubbles and Plumes in Prominences**
*Observations:* Quiescent Prominences from SOT and AIA
*Models:* Rayleigh-Taylor instability in dipped geometry

II. **LFFF Models of Prominence Magnetic Field**
2.5D topologies: OX/OF topology

III. **The Polar Crown Prominence of April 20th, 2011**
Observations: Hα, SDO/AIA 304Å, 193Å
Connection to magnetic field and emerging flux
Toy models of quiescent prominences
Magnetic topology: Bubbles, bright arches and separators

IV. **The Polar Crown Prominence of June 22nd, 2010**
Observations: SDO/AIA 304Å, 193Å
Symmetric and Asymmetric models
“Large” and “Small” bubbles: Within body and within feet

# Hinode/SOT Observations



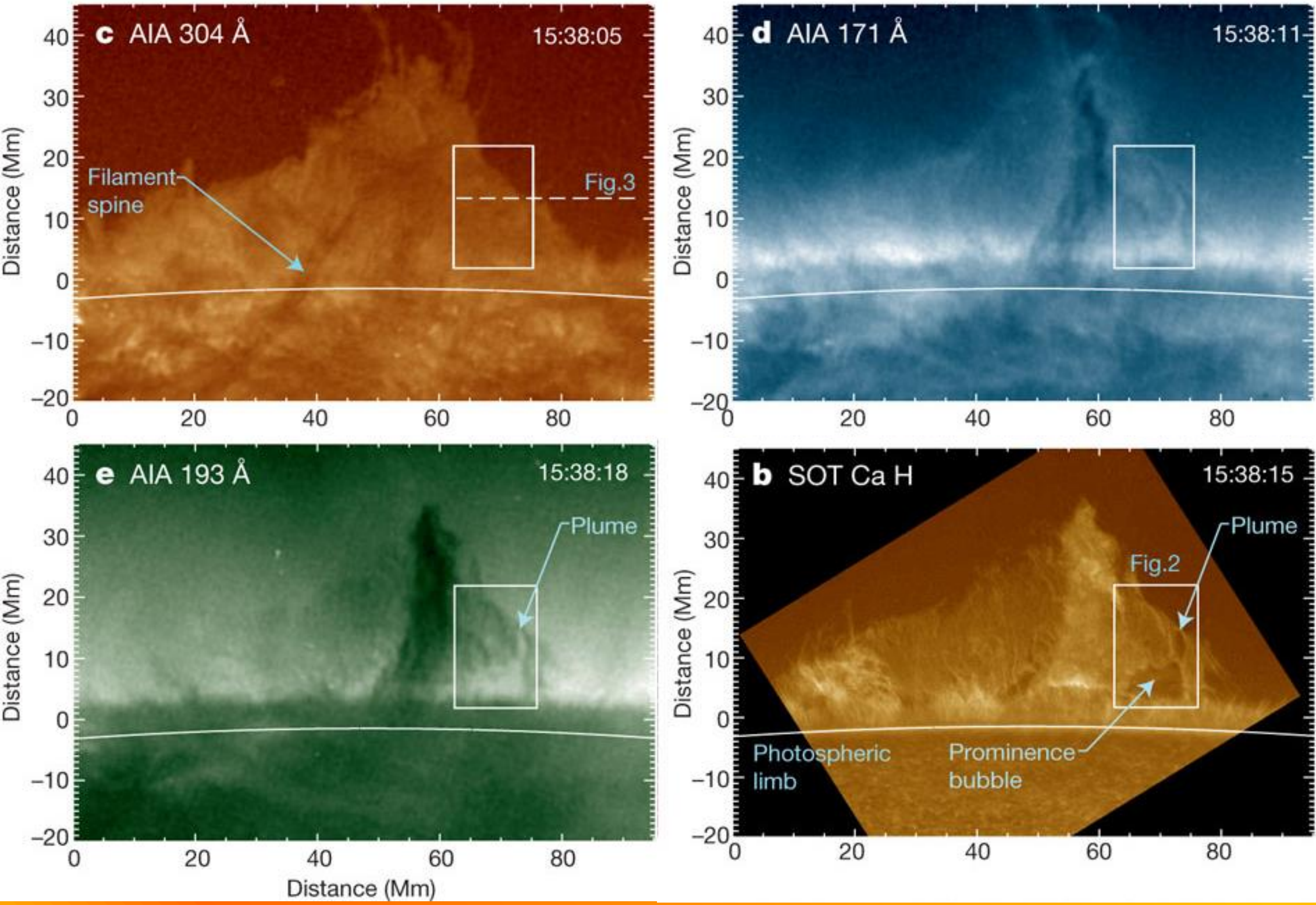

**Many "vertical" threads**

- plane-of-sky velocities, i.e., "vertical motions" up to 2 – 15 km $s^{-1}$ (time-slice technique)

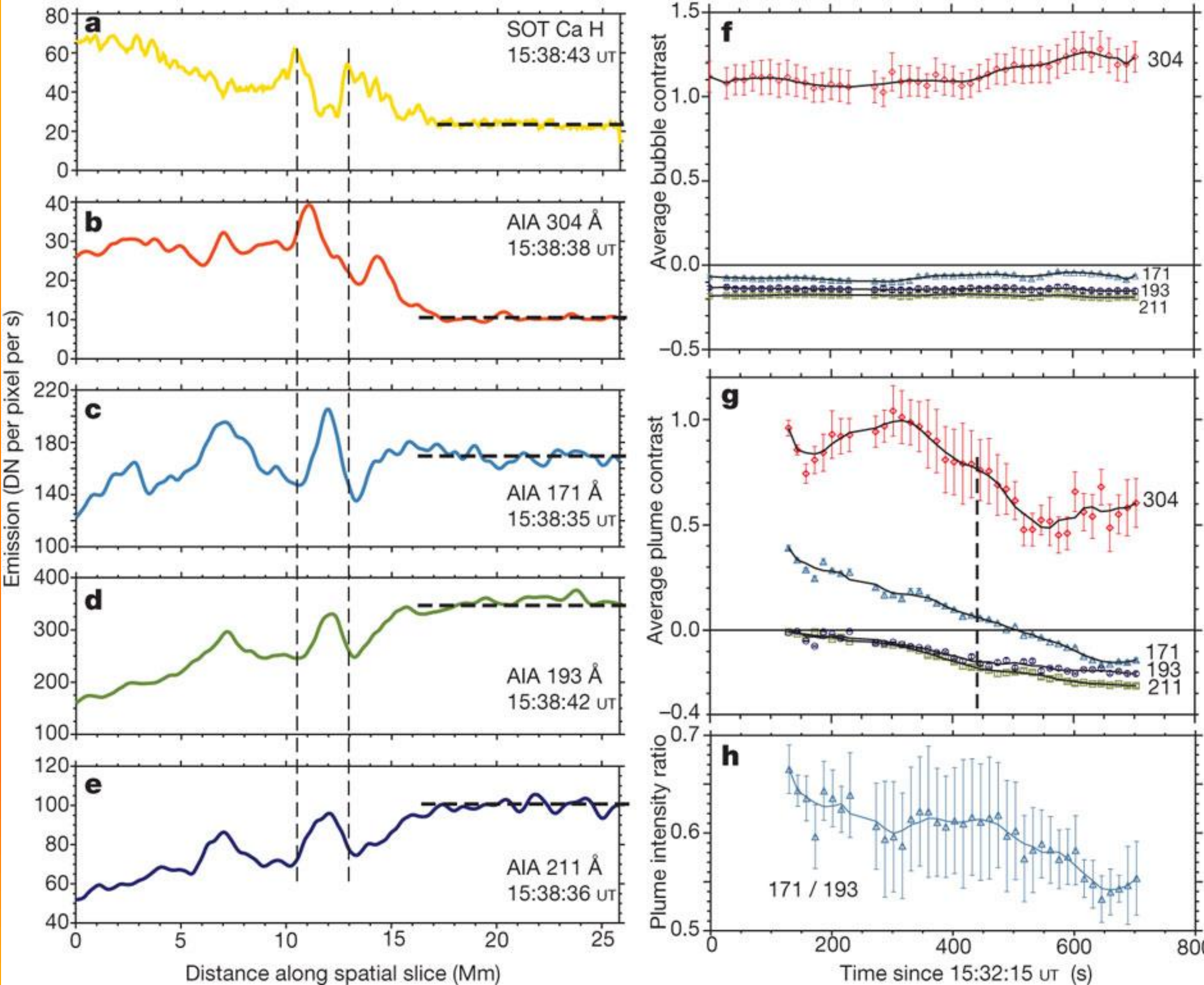
- Hα Doppler-shifts:
  - counter-streaming
  - velocities up to 15 km $s^{-1}$

**=> Threads are NOT vertical, but highly inclined to LOS**

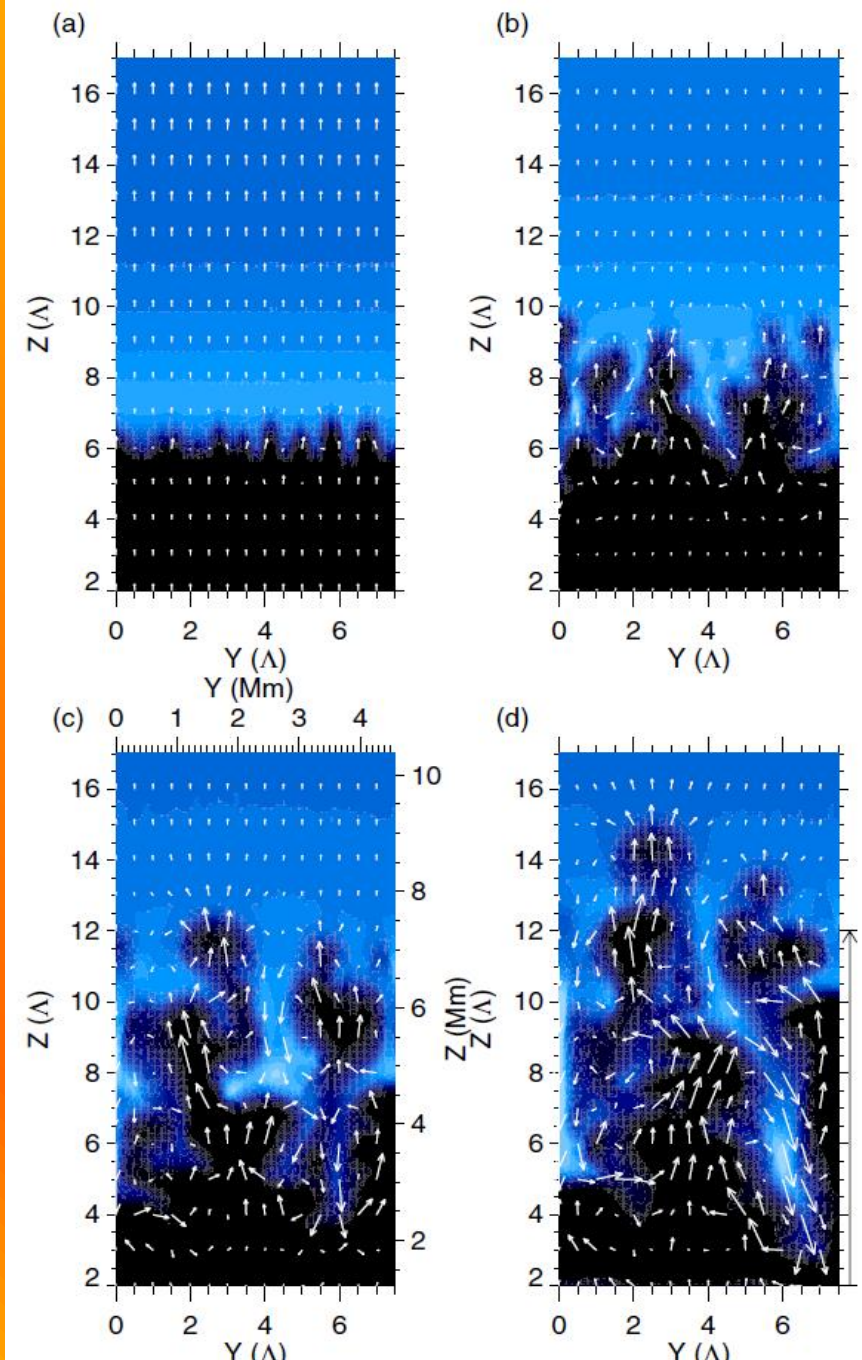
*Schmieder et al. (2010), A&A 514, A68*



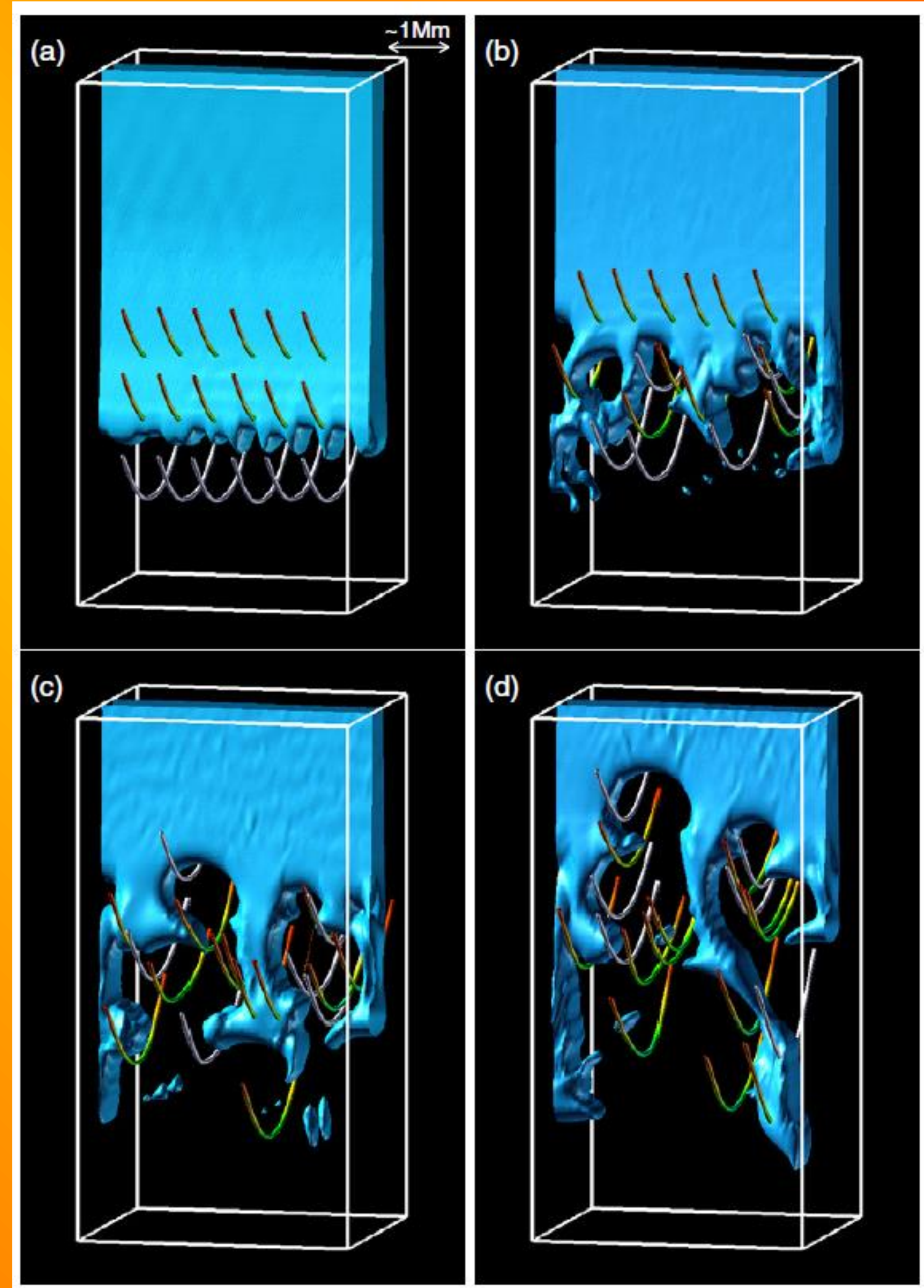

***Berger et al. (2011), Nature 472, 197***



a
SOT Ca H
15:38:43 UT
b
AIA 304 Å
15:38:38 UT
c
AIA 171 Å
15:38:35 UT
d
AIA 193 Å
15:38:42 UT
e
AIA 211 Å
15:38:36 UT
Emission (DN per pixel per s)
Distance along spatial slice (Mm)
f
Average bubble contrast
304
171
193
211
g
Average plume contrast
304
171
193
211
h
Plume intensity ratio
171 / 193
Time since 15:32:15 UT (s)




*Hillier et al. (2011), Astrophys. J. 736, L1;*



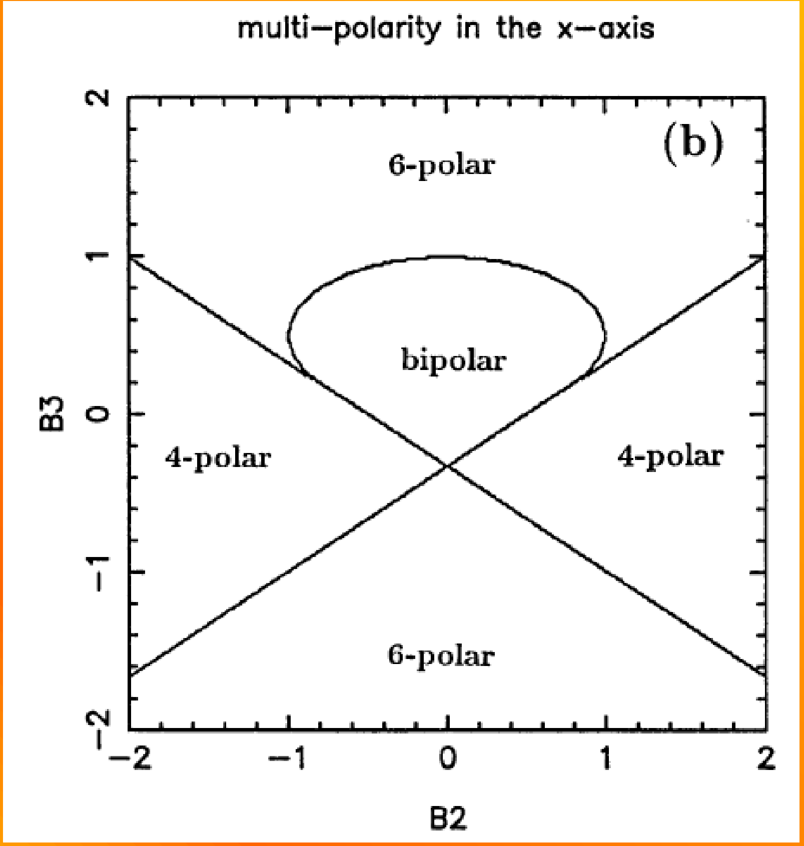

*Hillier et al. (2012), Astrophys. J. 746, 120*

# II. Prominences: LFFF Models

**Force-free fields:**

$$\nabla \times B = \alpha B \,,$$

$$\nabla . B = 0 \,,$$




$$B_x = \frac{\widetilde{B}_{(n_x;n_y)}}{k_x^2 + k_y^2} \left(- \alpha k_y sin(k_x x) sin(k_y y) - l k_x cos(k_x x) cos(k_y y)\right) e^{-lz} \,, \quad (4)$$

$$B_y = \frac{\widetilde{B}_{(n_x;n_y)}}{k_x^2 + k_y^2} \left( l k_y sin(k_x x) sin(k_y y) - \alpha k_x cos(k_x x) cos(k_y y)\right) e^{-lz} \,, \quad (5)$$

$$B_z = \widetilde{B}_{(n_x;n_y)} sin(k_x x) cos(k_y y) e^{-lz} \,. \quad (6)$$

with $\widetilde{B}_{(n_x;n_y)}$ is the amplitude of the harmonic $(n_x; n_y)$, and

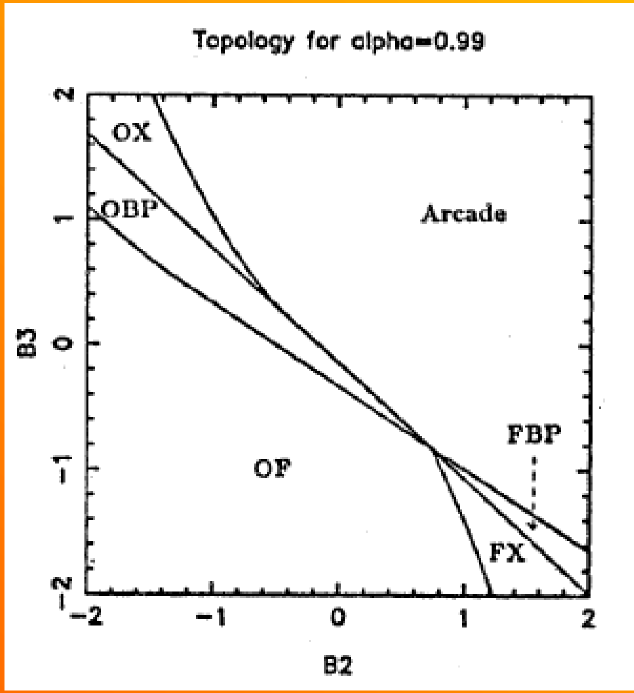
$$k_x = n_x . 2\pi / L_x \,, \quad (7)$$

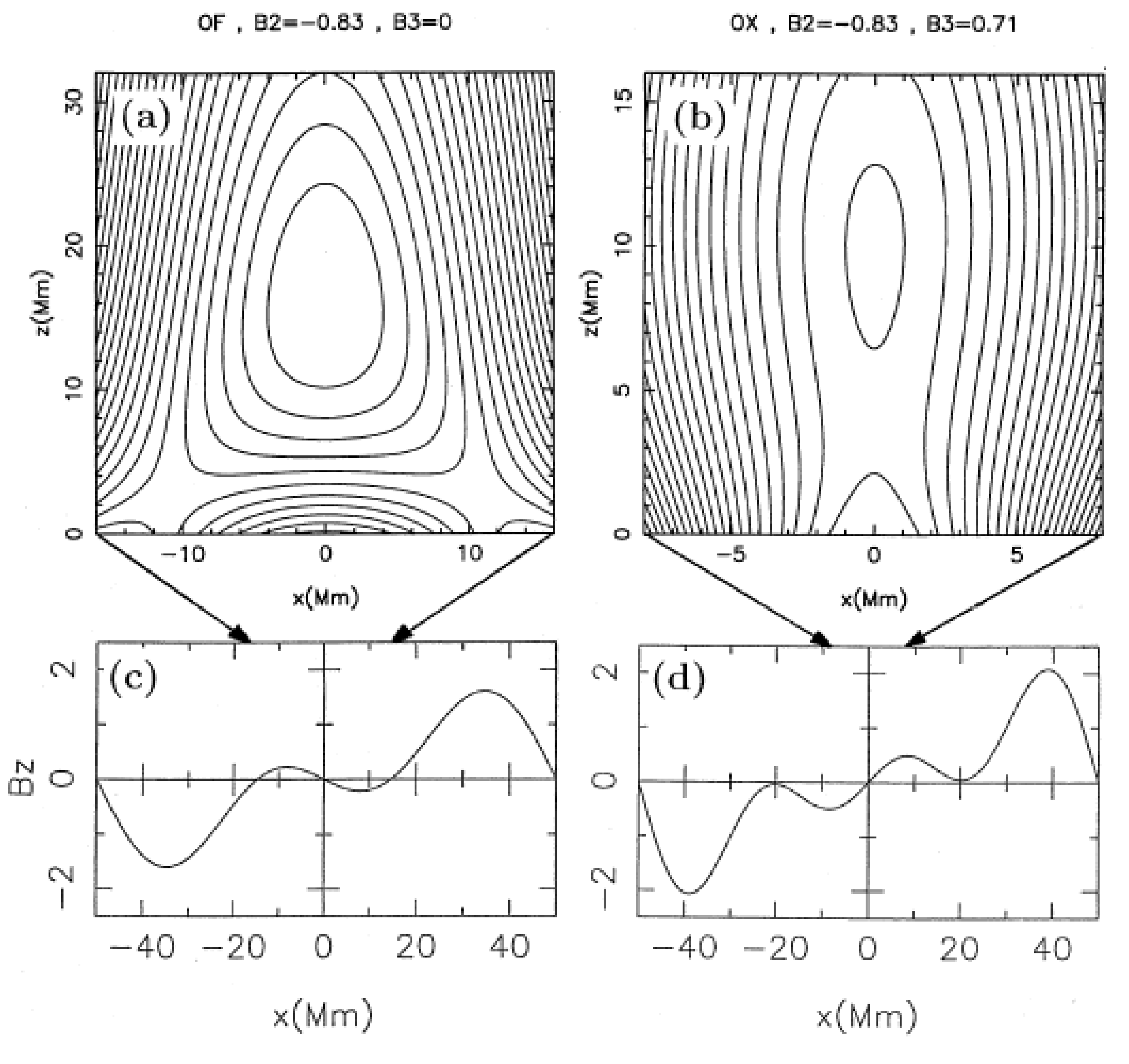
$$k_y = n_y . 2\pi / L_y \quad (8)$$

$$l = \sqrt{k_x^2 + k_y^2 - \alpha^2} \,. \quad (9)$$

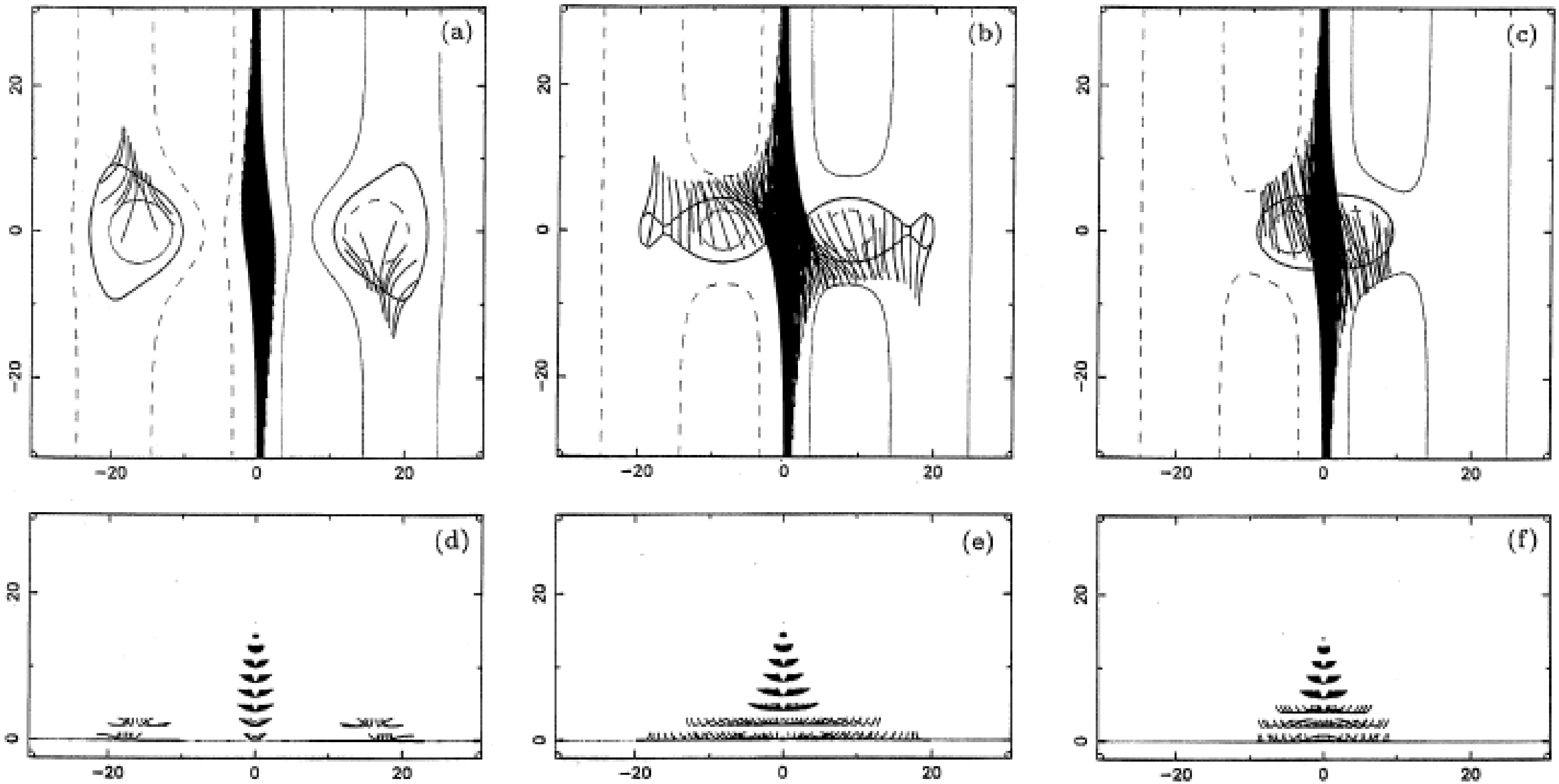
***Aulanier & Démoulin (1998), Astron. Astrophys. 329, 1125***

# Prominences: 2.5D Topologies

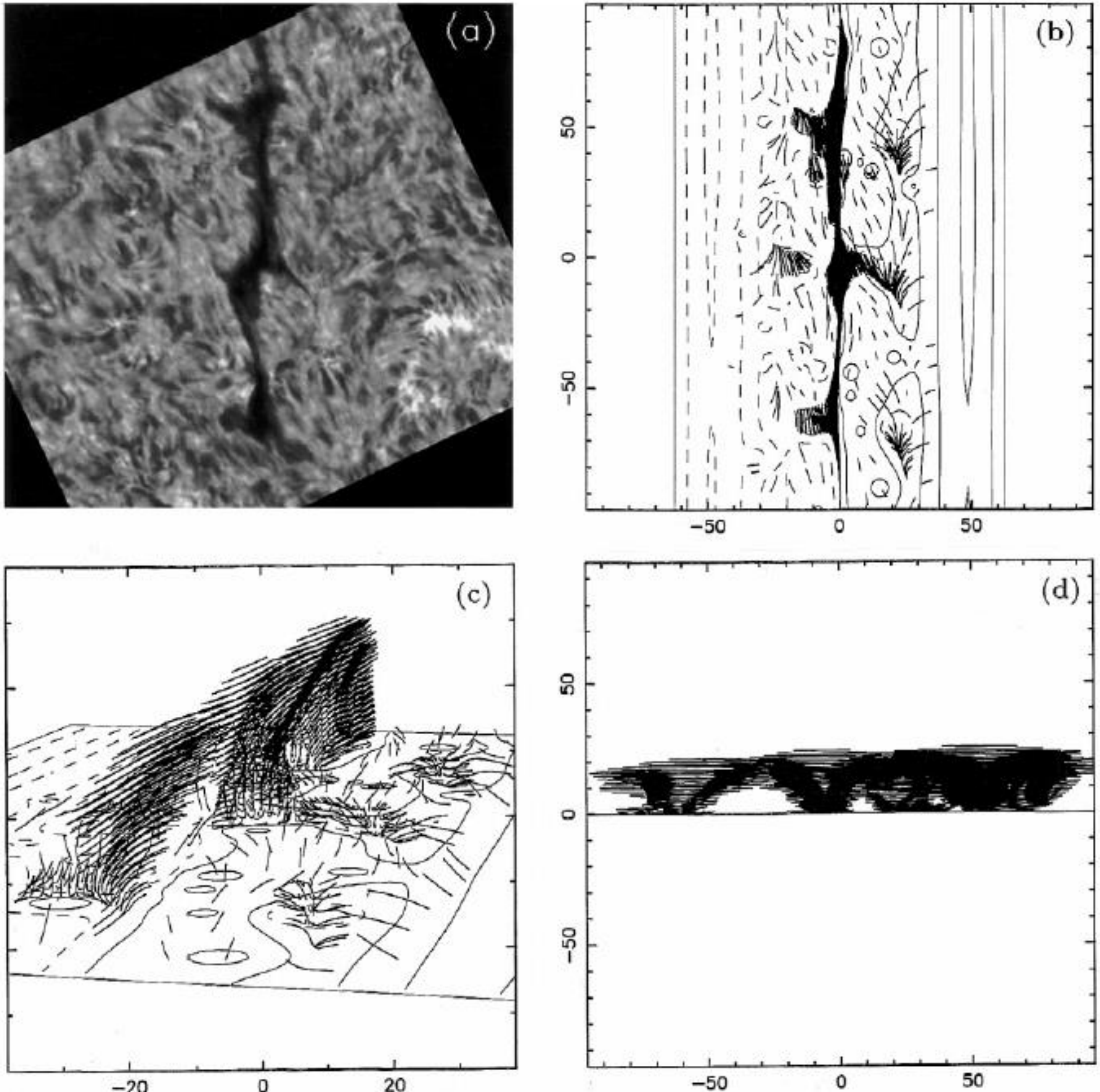


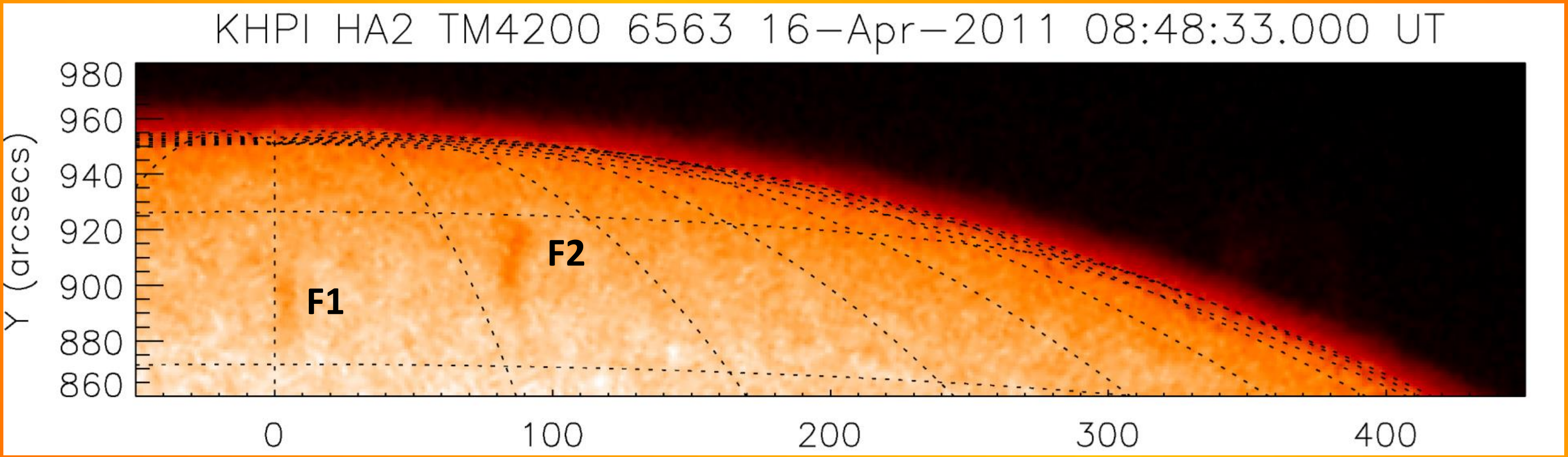
# Prominences: 3D OX Flux Ropes

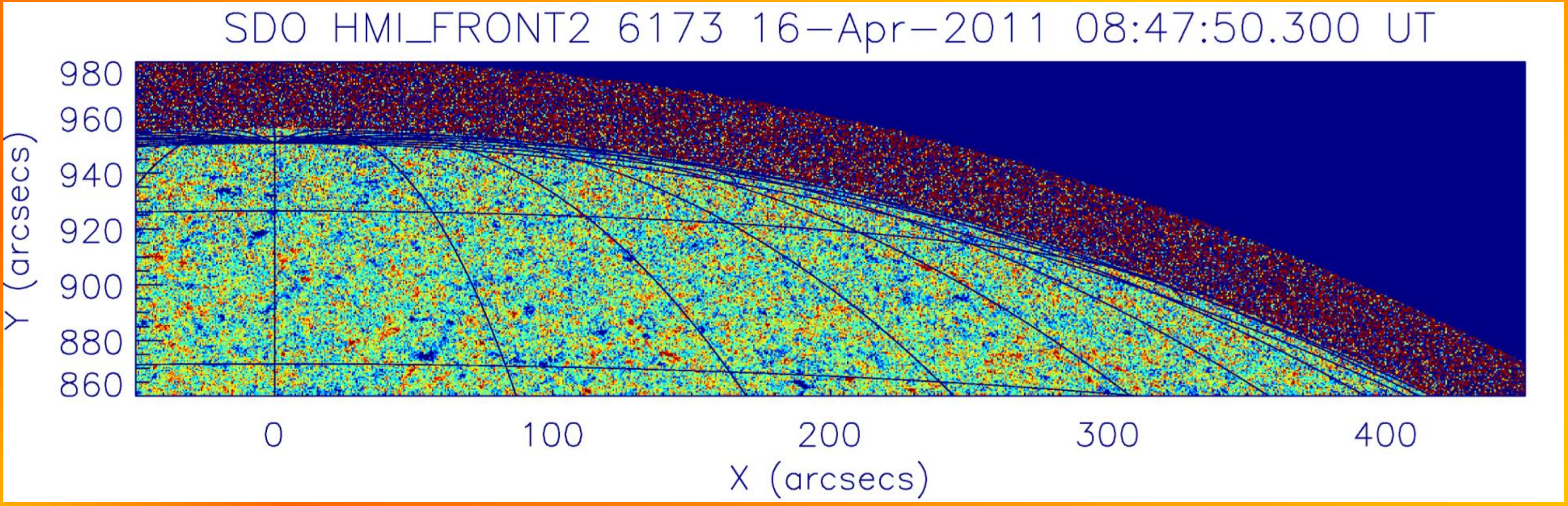



*Aulanier et al. (1999), Astron. Astrophys. 335, 309*

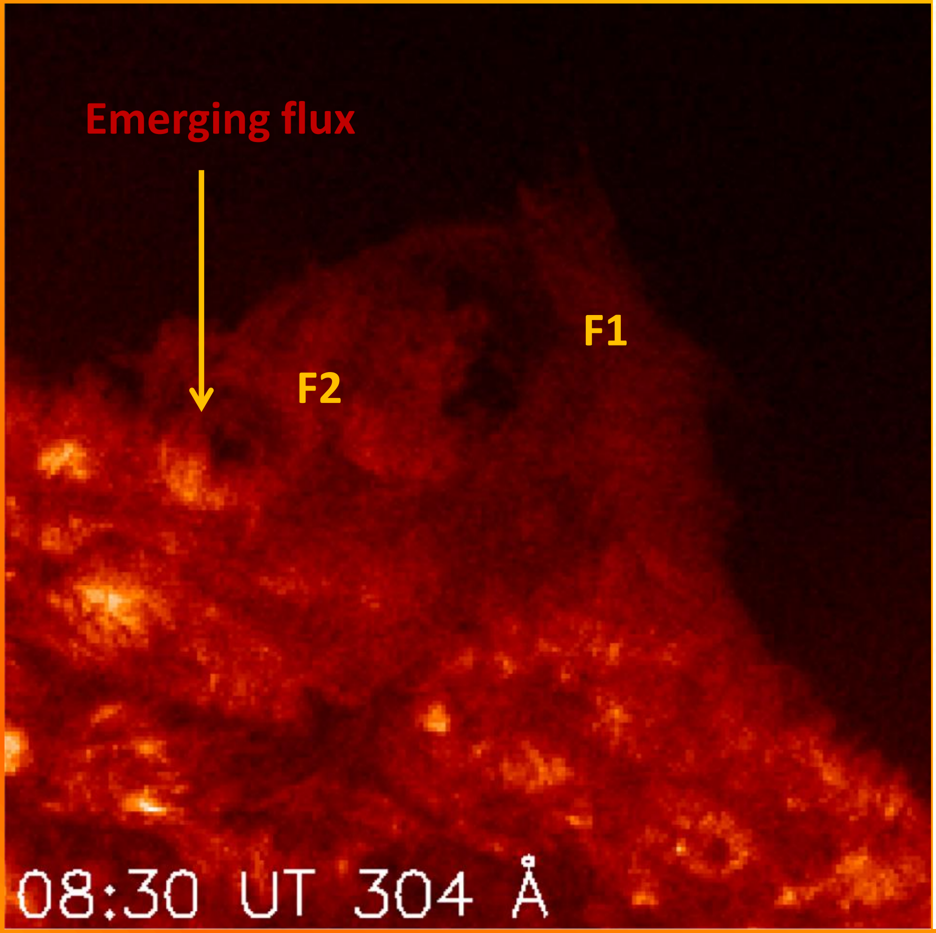

(a)
(b)
(c)
(d)
50
0
-50
-50
0
50
20
0
-20
-20
0
20
50
0
-50
-50
0
50

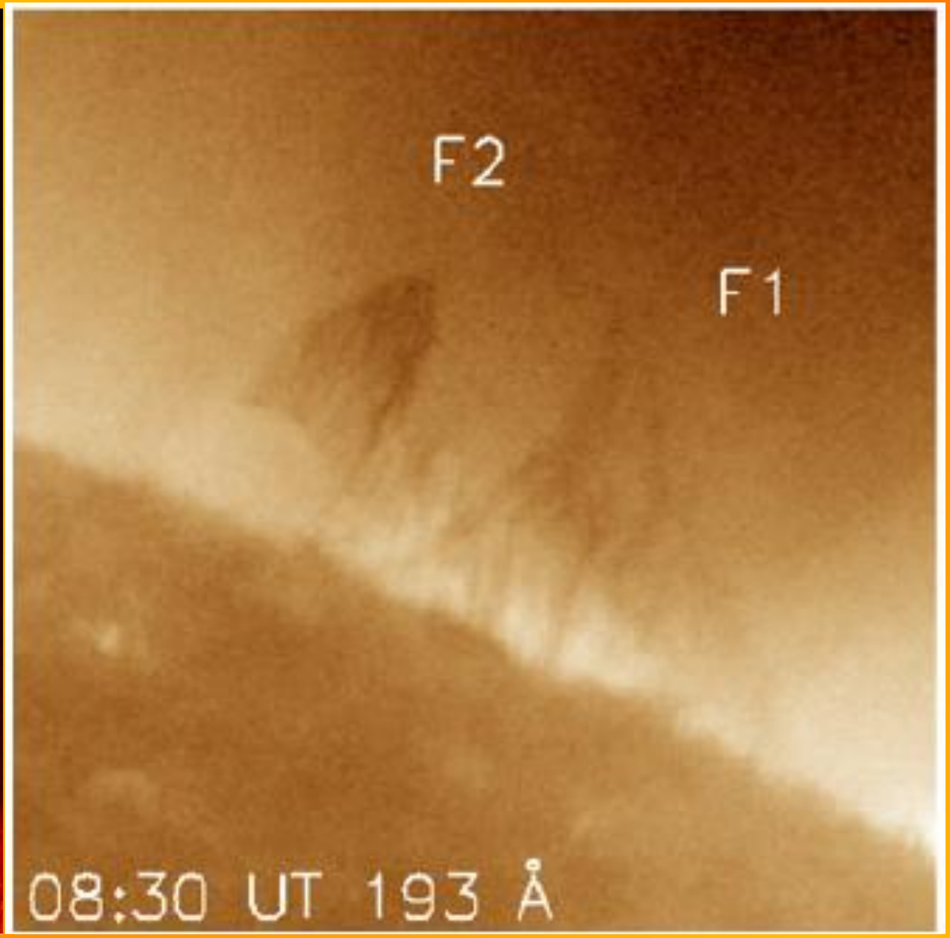
# III. Prominence of April 22nd, 2011



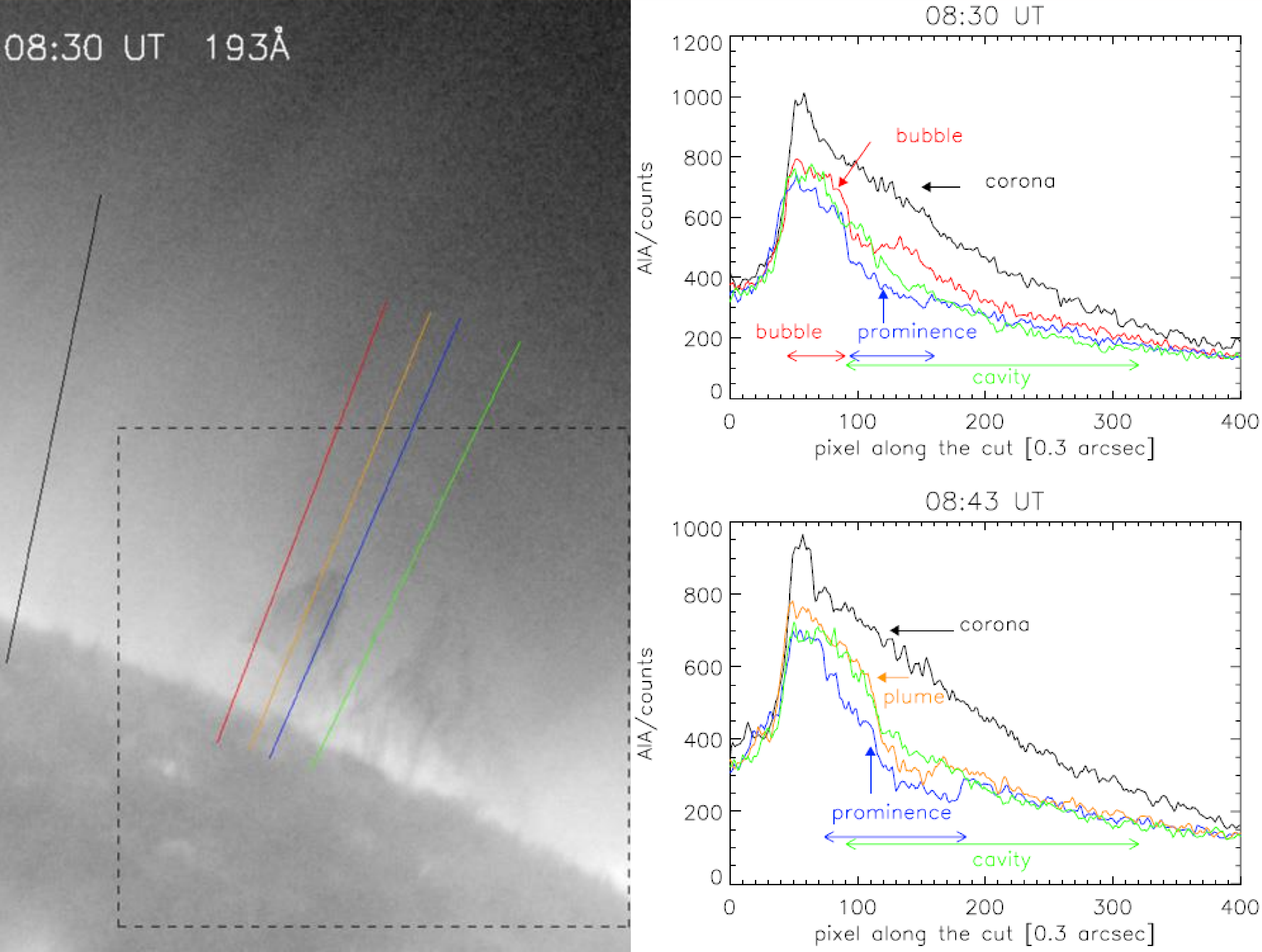



# Prominence of April 22$^{nd}$, 2011



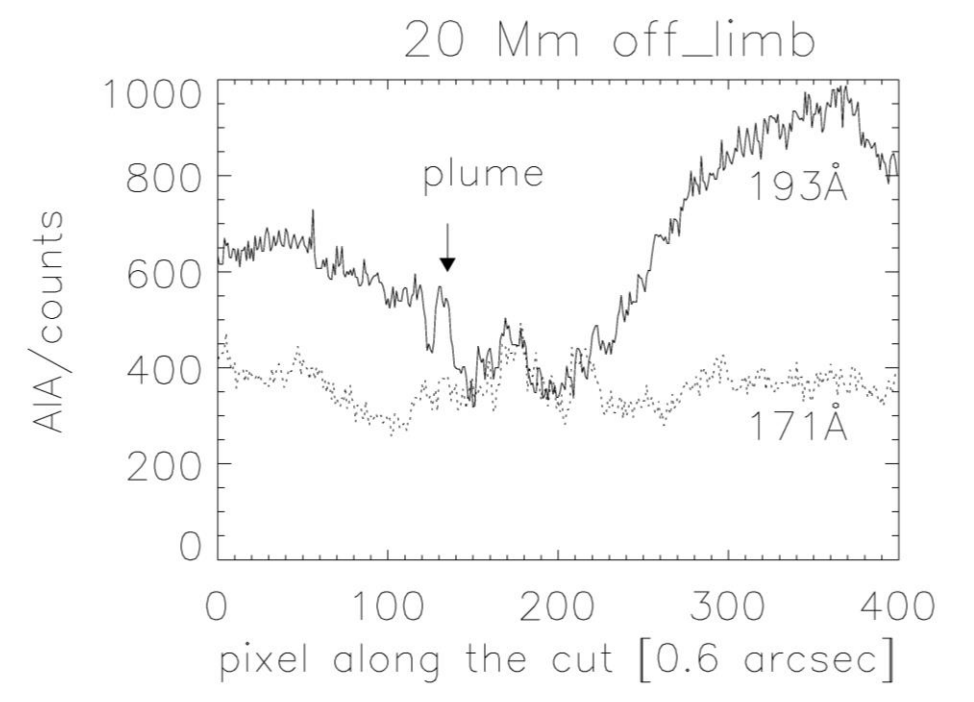



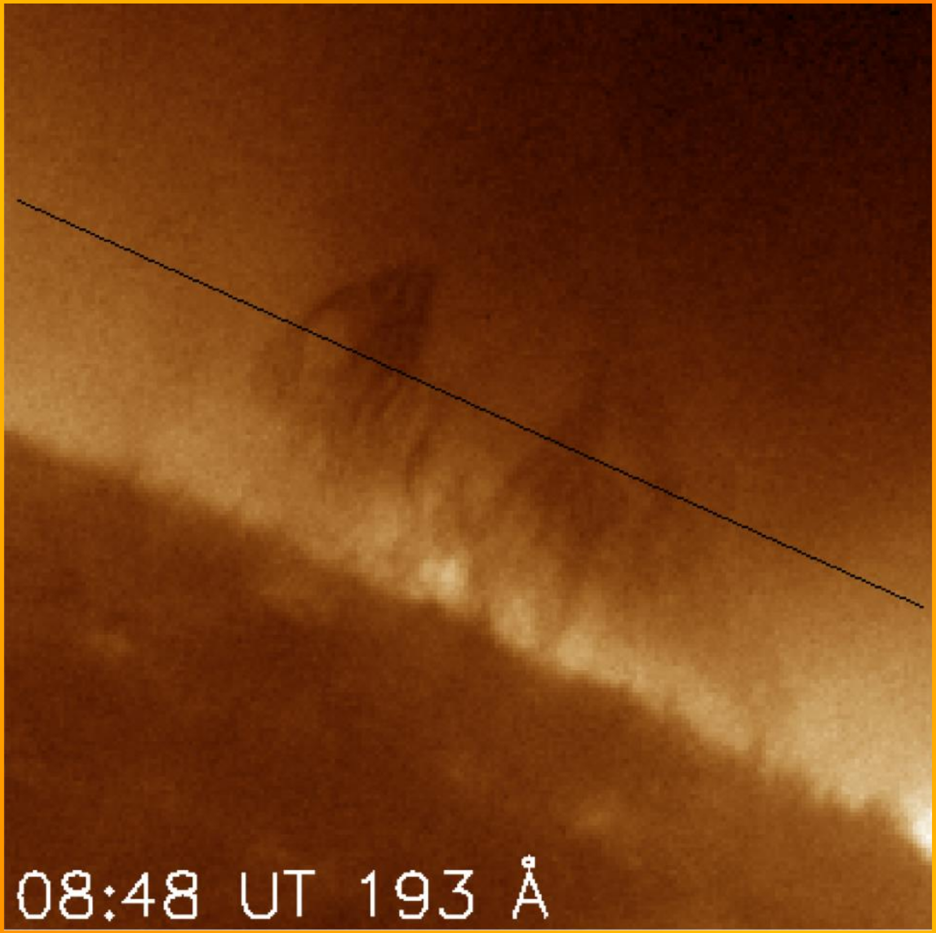

*Dudík et al. (2012), Astrophys. J., 761, 9*



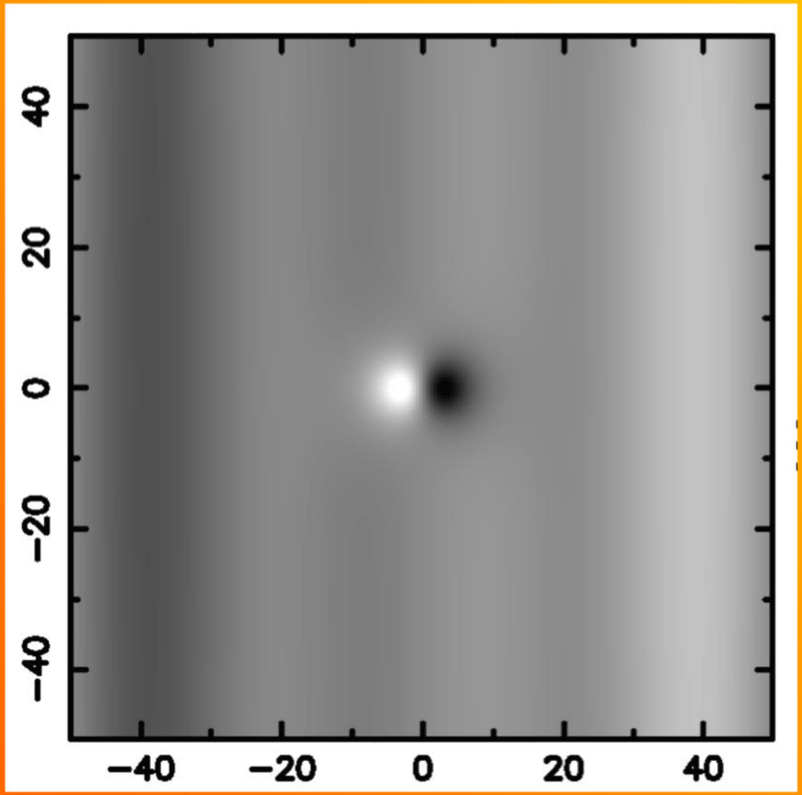
08:30 UT 193Å
08:30 UT
AIA/counts
bubble
corona
bubble
prominence
cavity
pixel along the cut [0.3 arcsec]
08:43 UT
AIA/counts
corona
plume
prominence
cavity
pixel along the cut [0.3 arcsec]

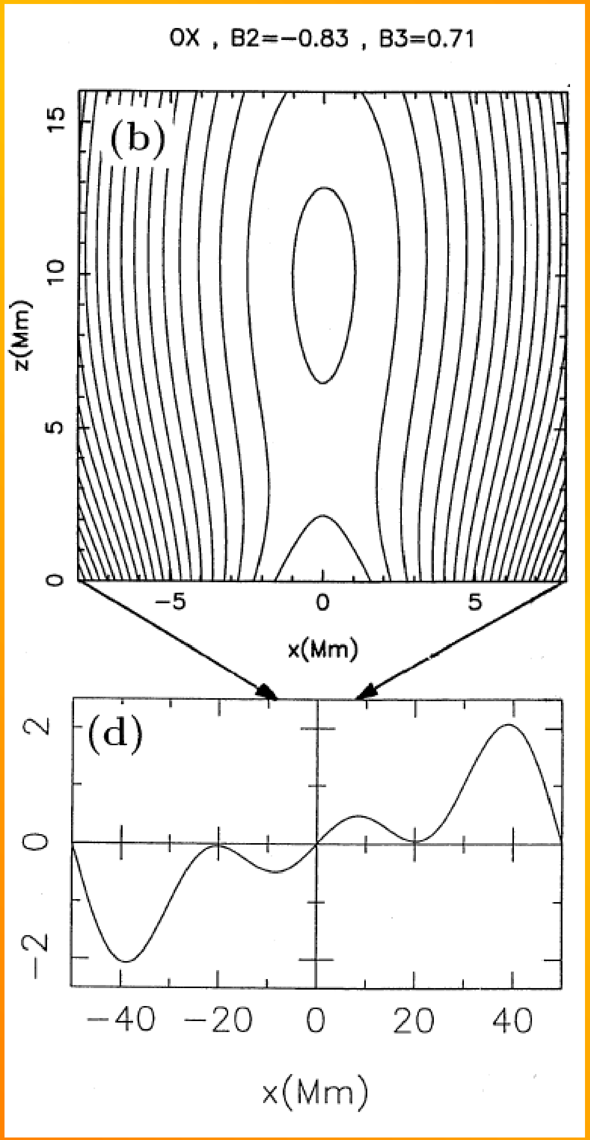
# 18 Minutes Later – a Plume



# How to Create a Bubble…

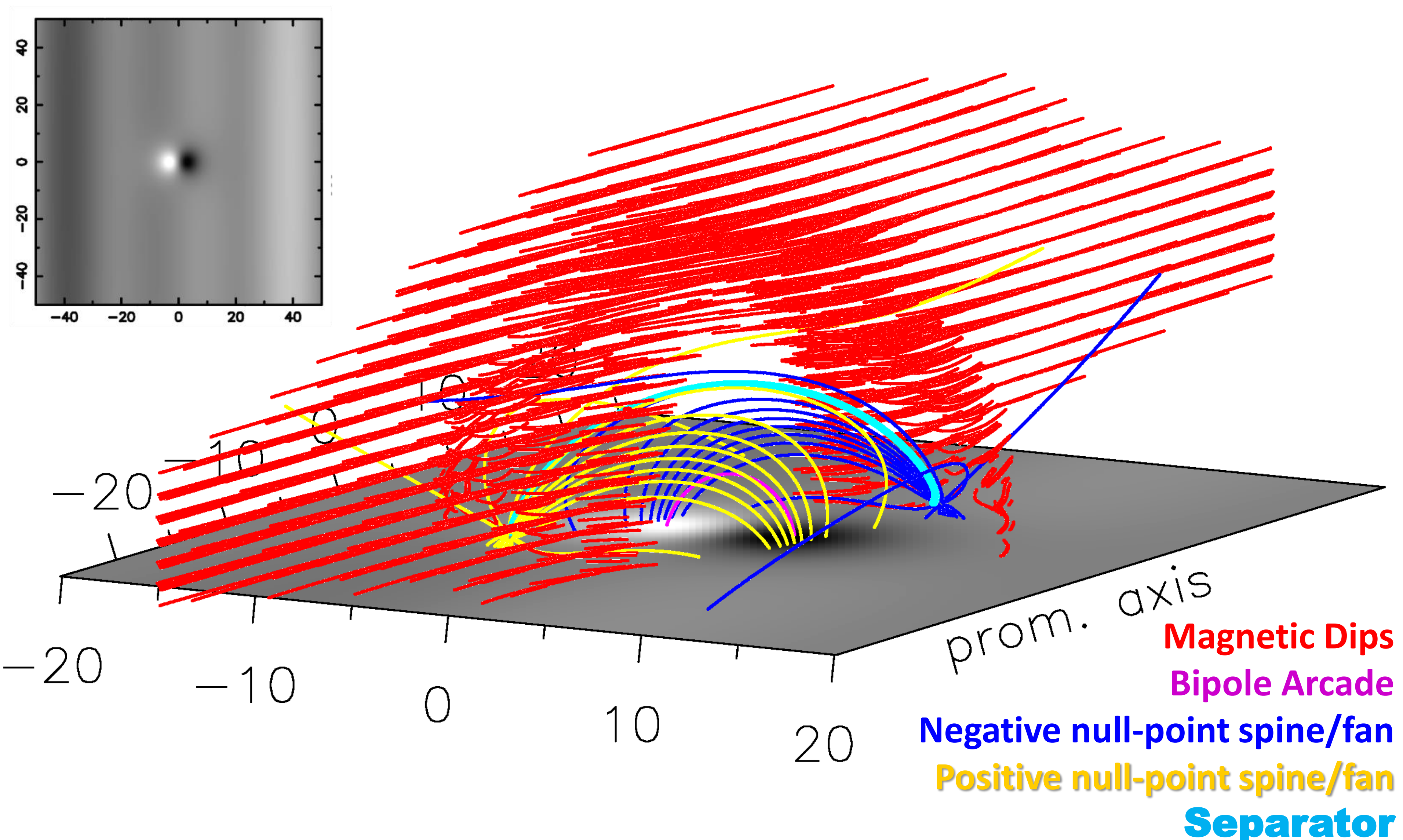


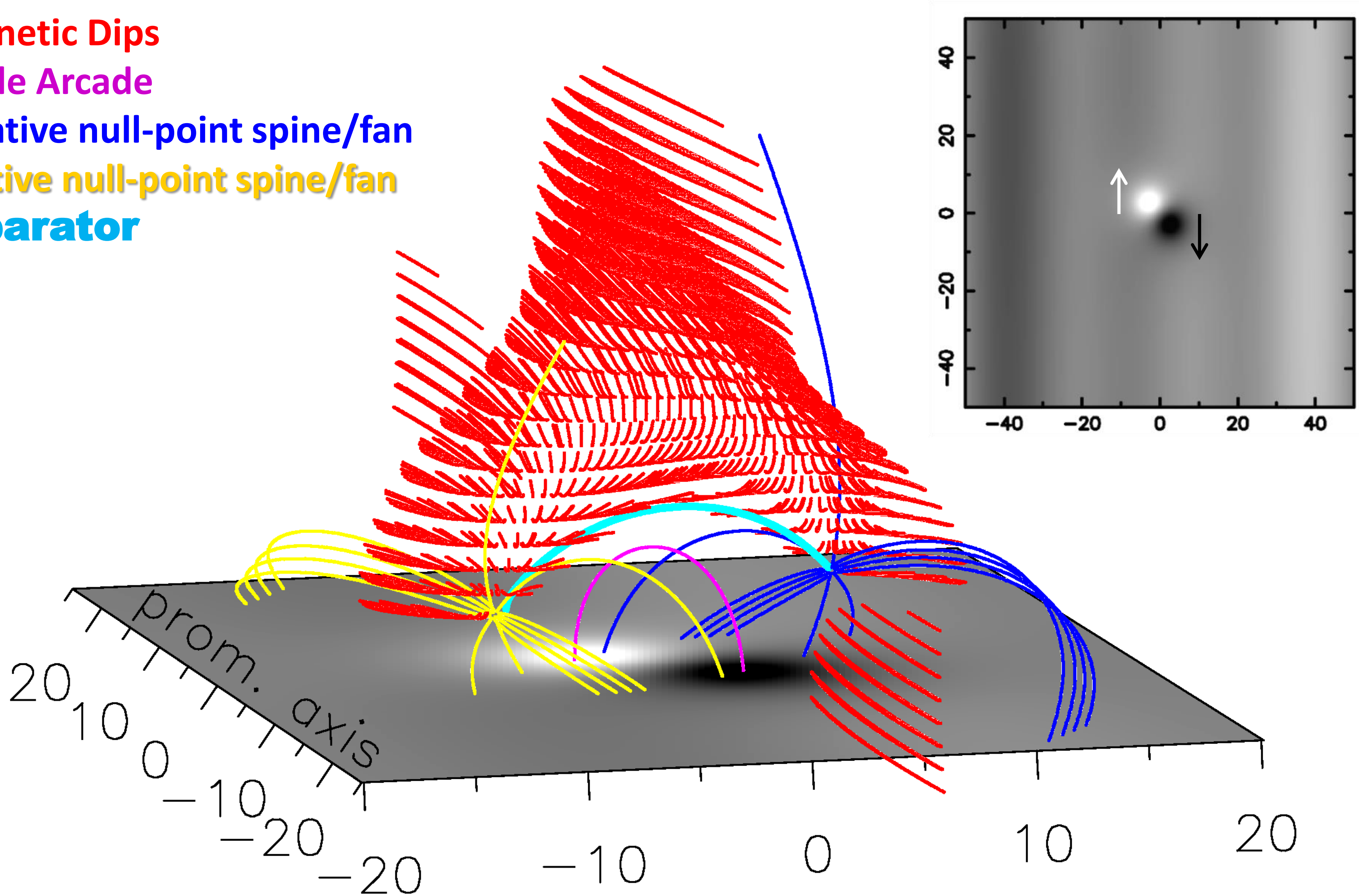

**Synthetic magnetogram**

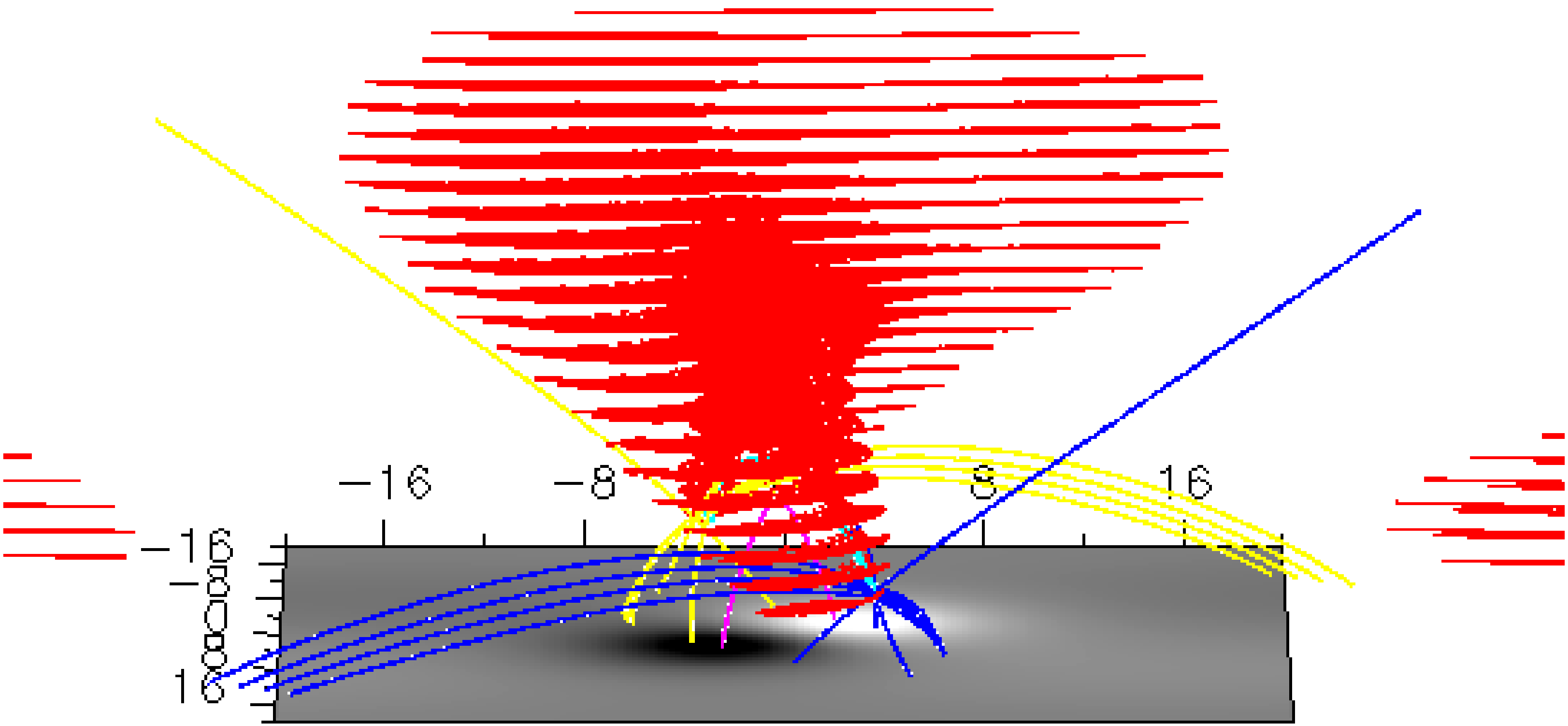
- creates the OX flux rope
- strong parasitic bipole
- no magnetic shear

# Generic Bubble: Magnetic Topology



# Sheared Bipole: Cusp-Shape

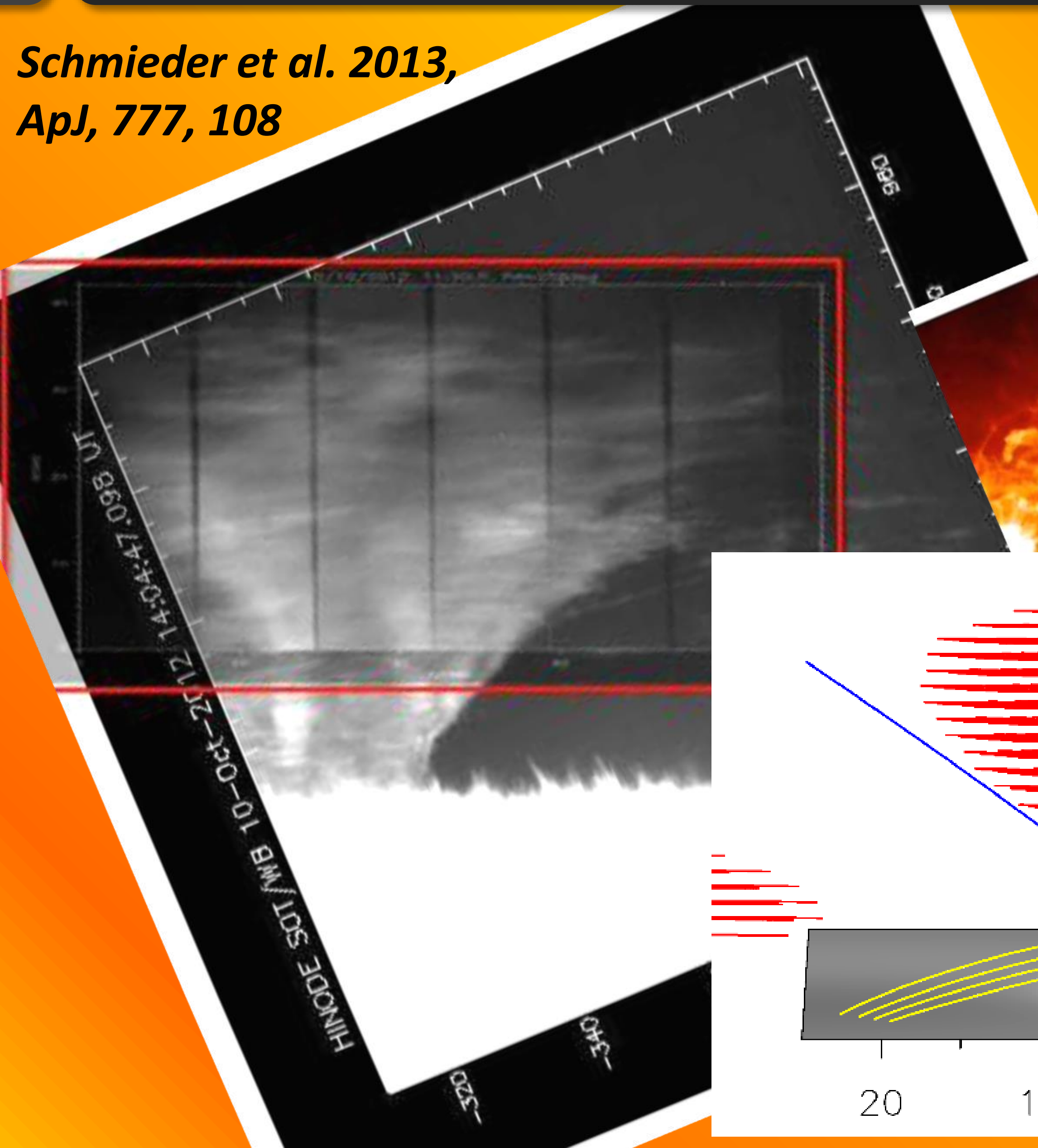


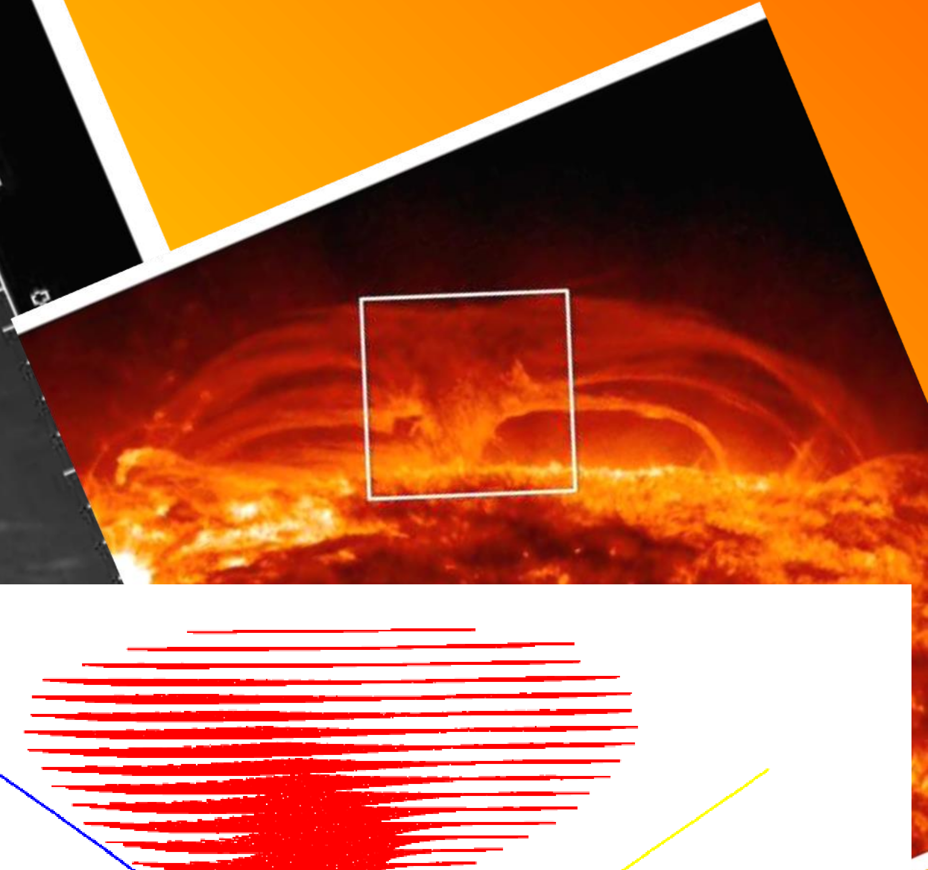


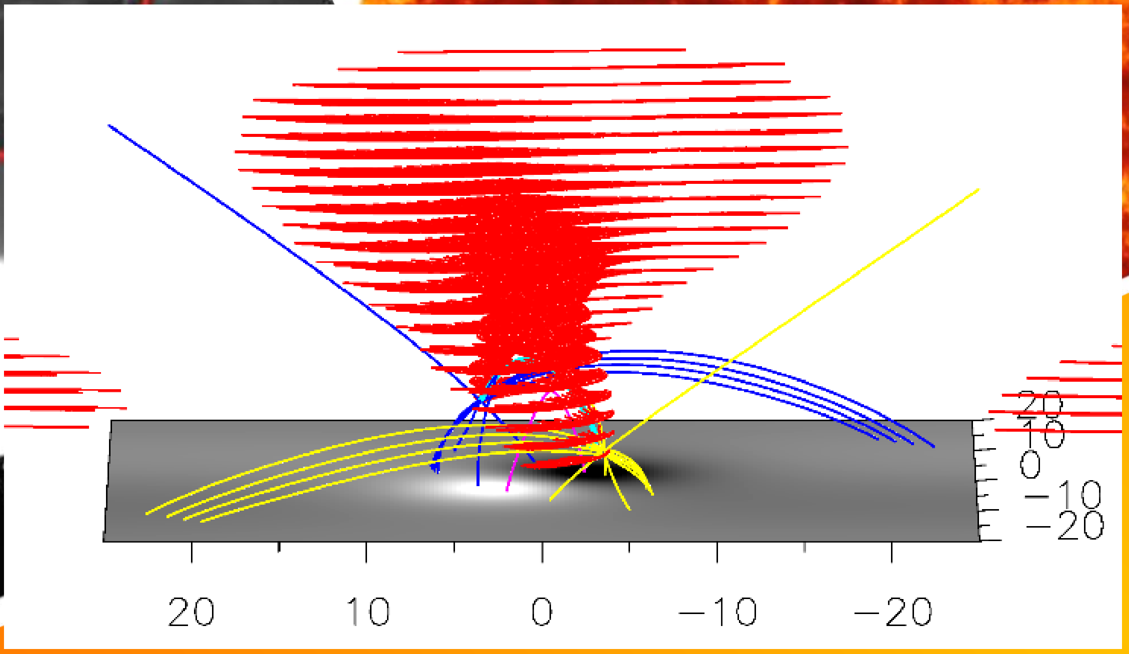
−16
−8
8
16
−16
−8
0
8
16

# Tree-shaped Prominences

***Schmieder et al. 2013, ApJ, 777, 108***





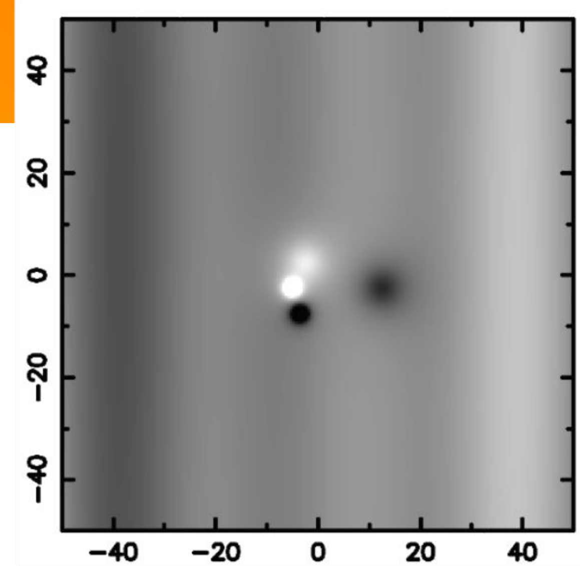
Magnetic Dips

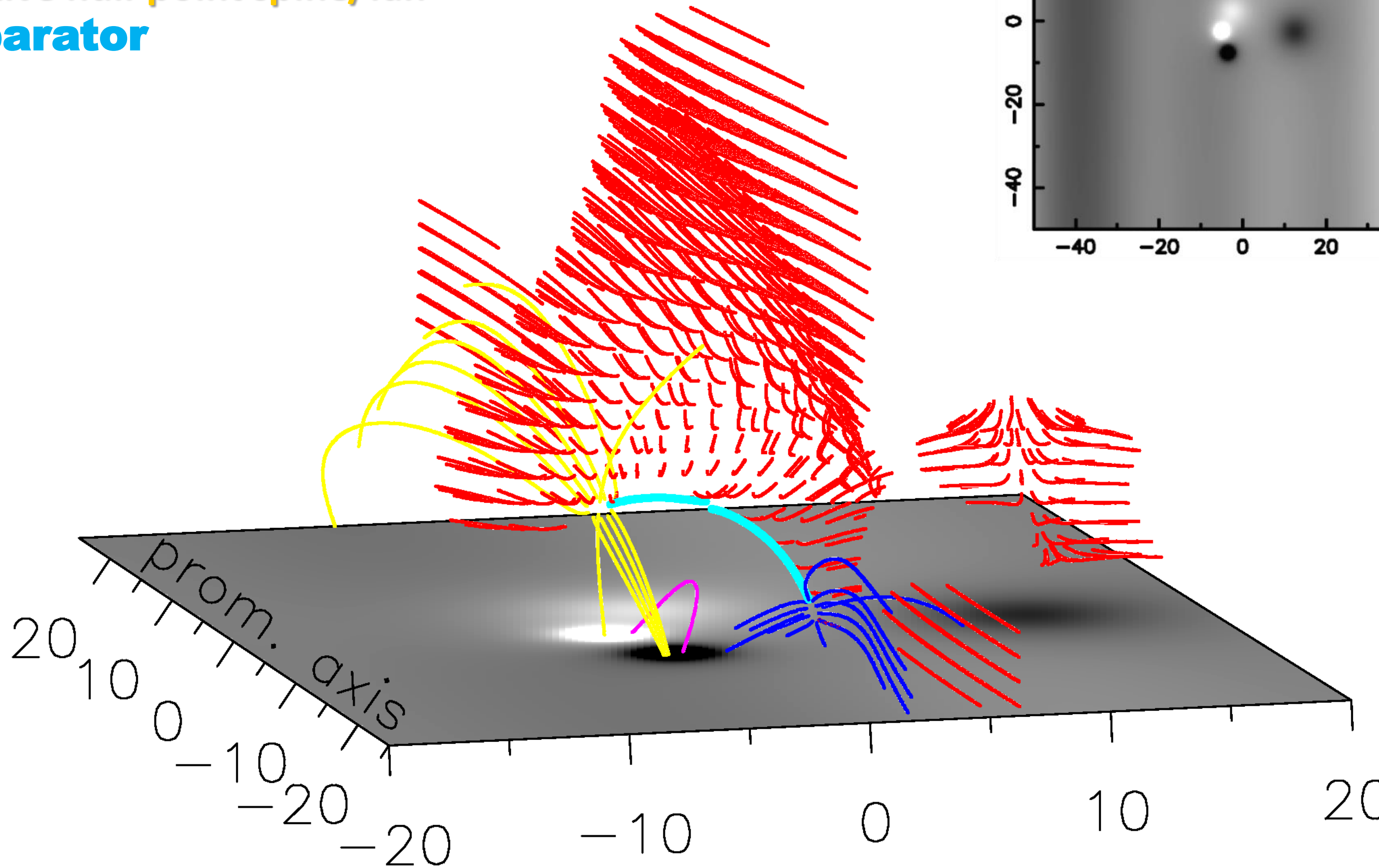
Bipole Arcade

Negative null-point spine/fan

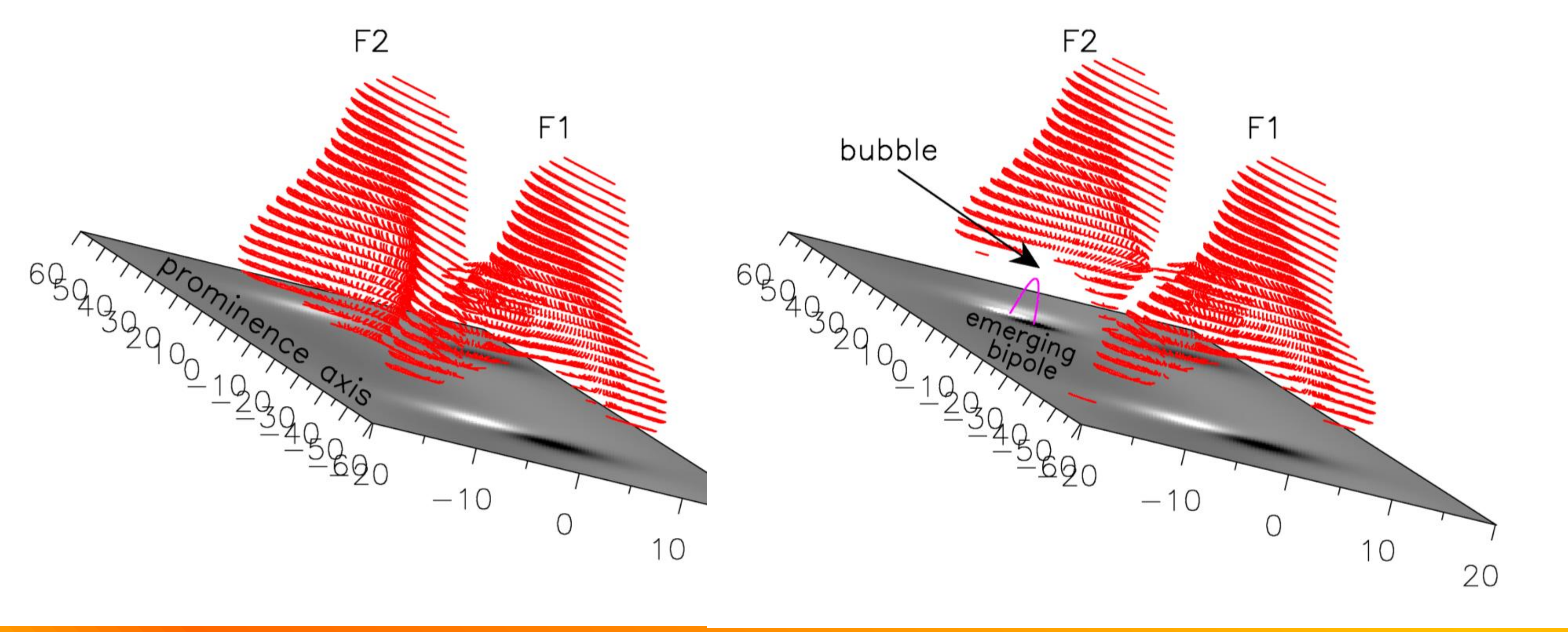
Positive null-point spine/fan

**Separator**

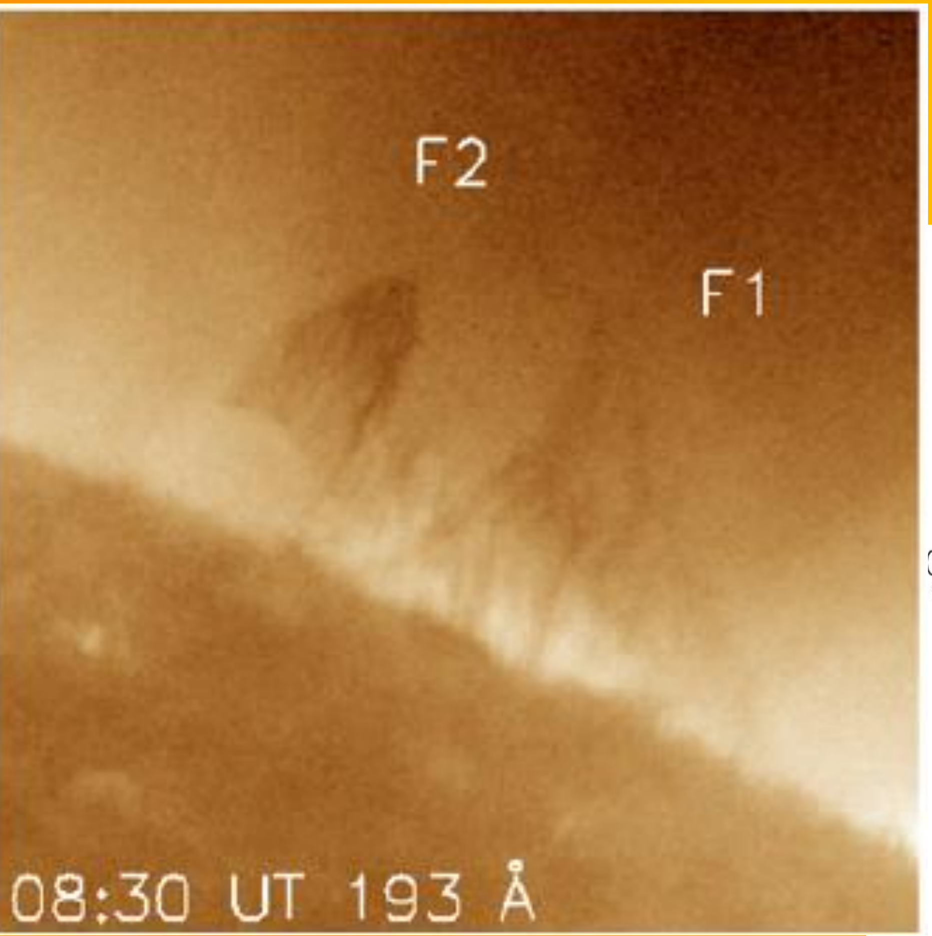


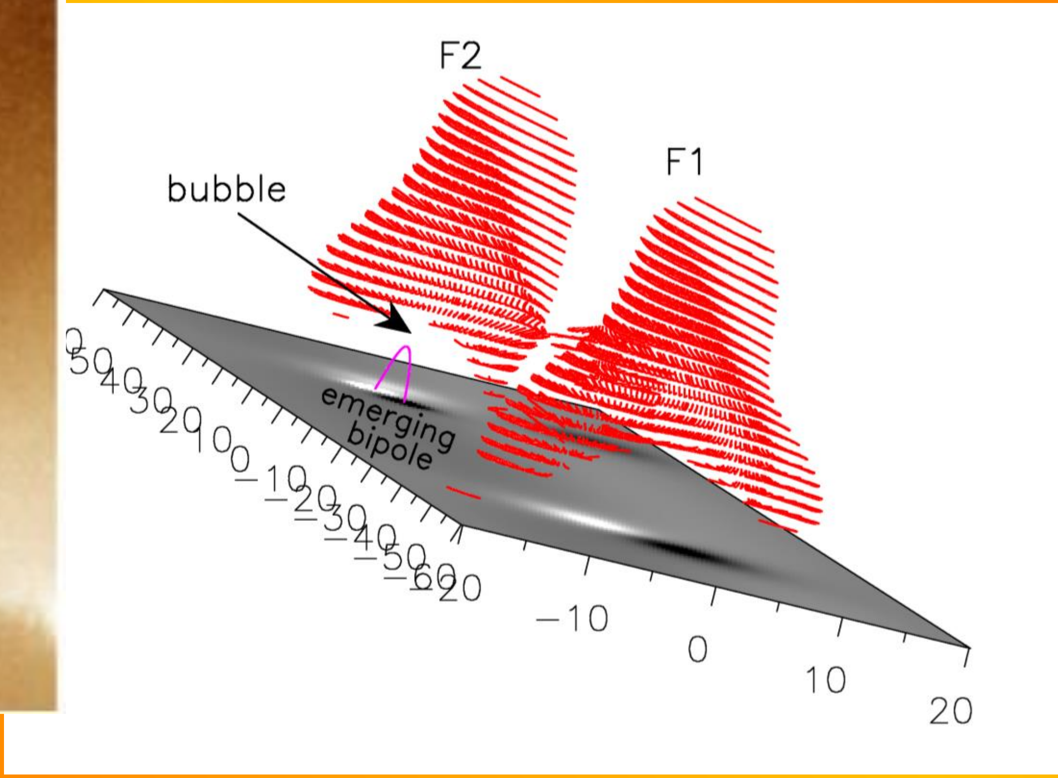



# Emerging bipole: The Bubble



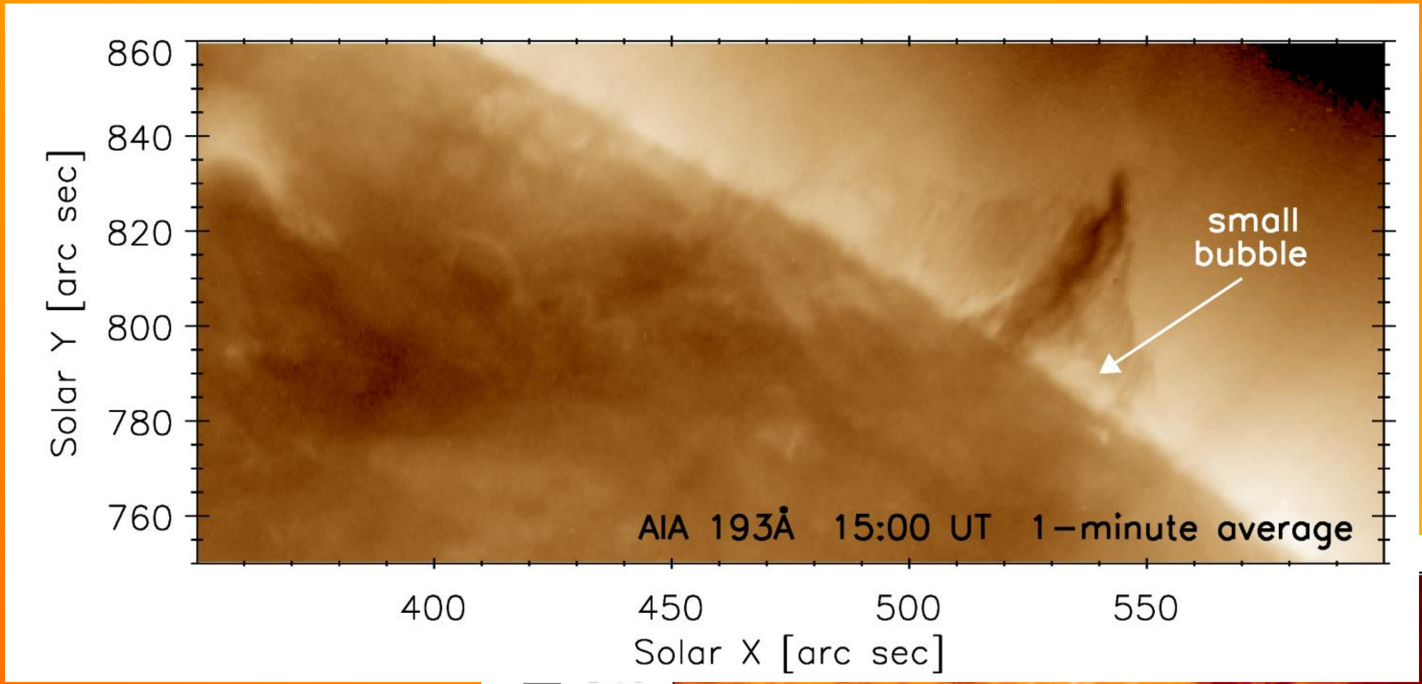
# Emerging bipole: The Bubble

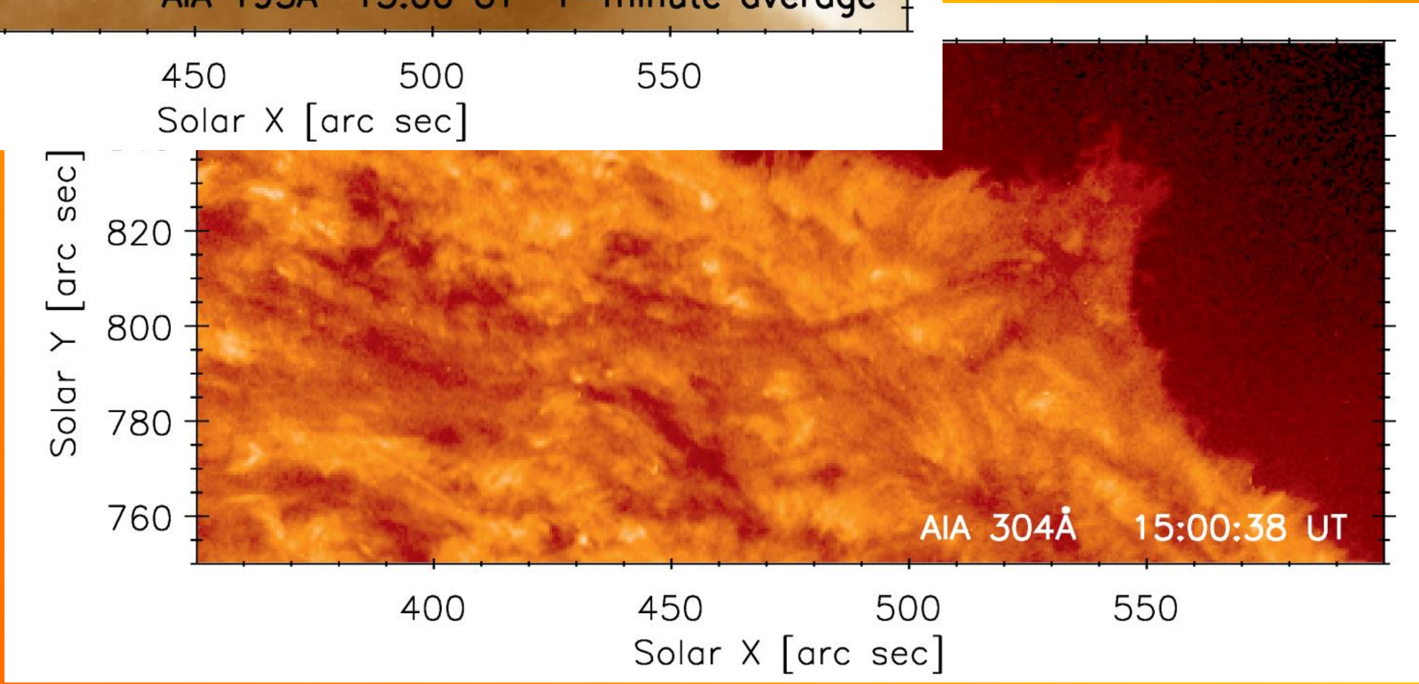



*Dudík et al. (2012), Astrophys. J., 761, 9*

# IV. Prominence of June 22nd, 2010

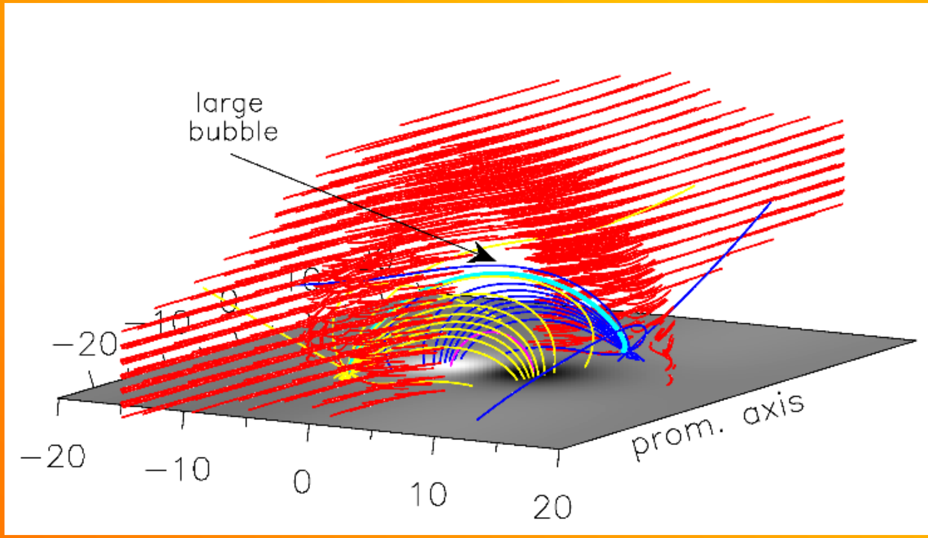


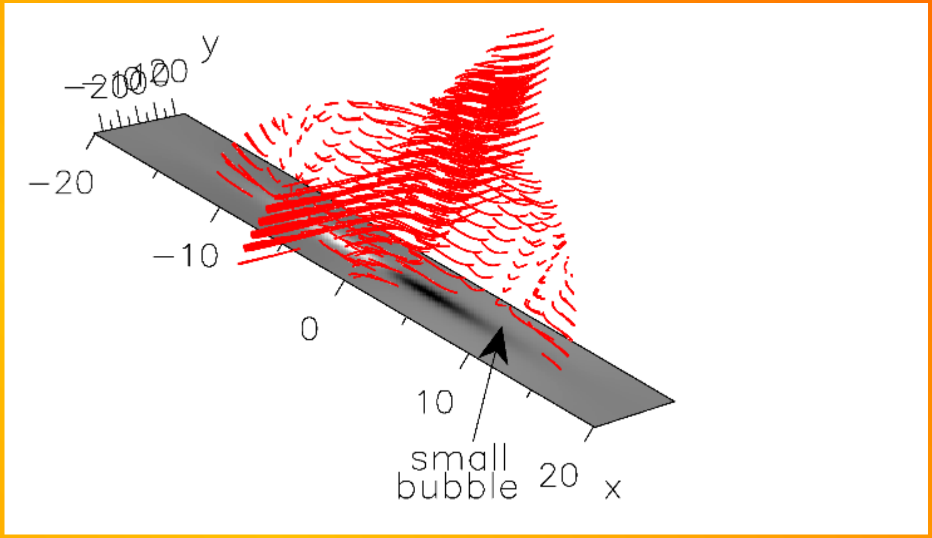



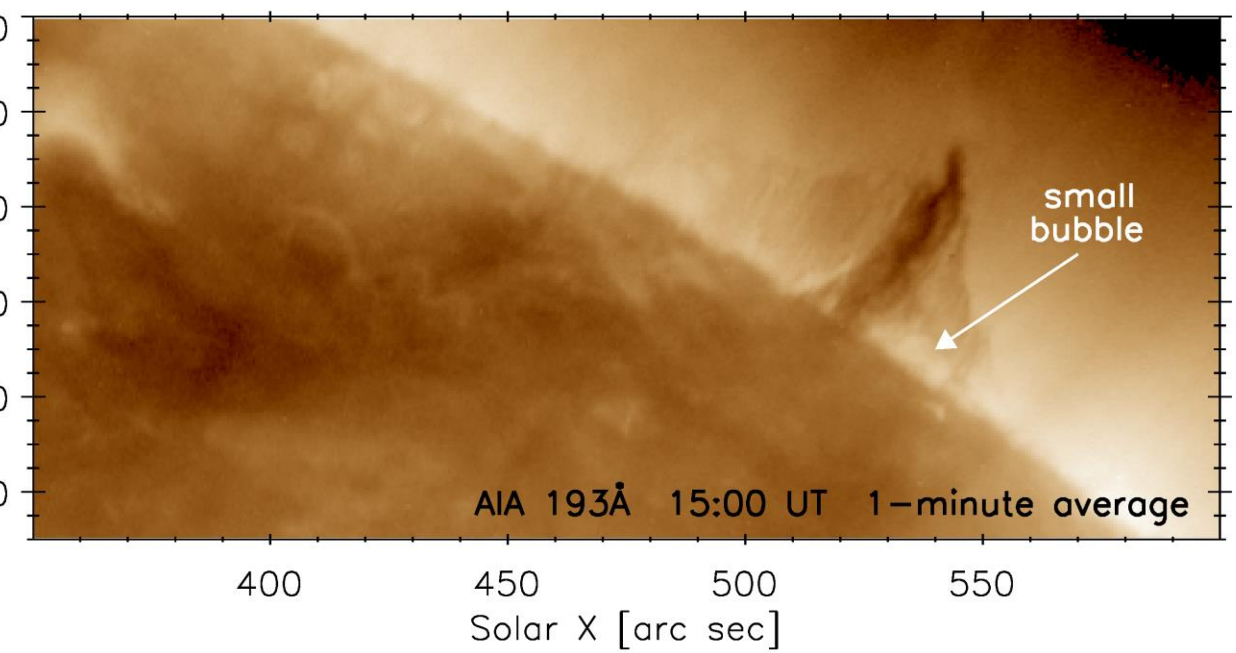

***Berger et al. (2011), Nature 472, 197***

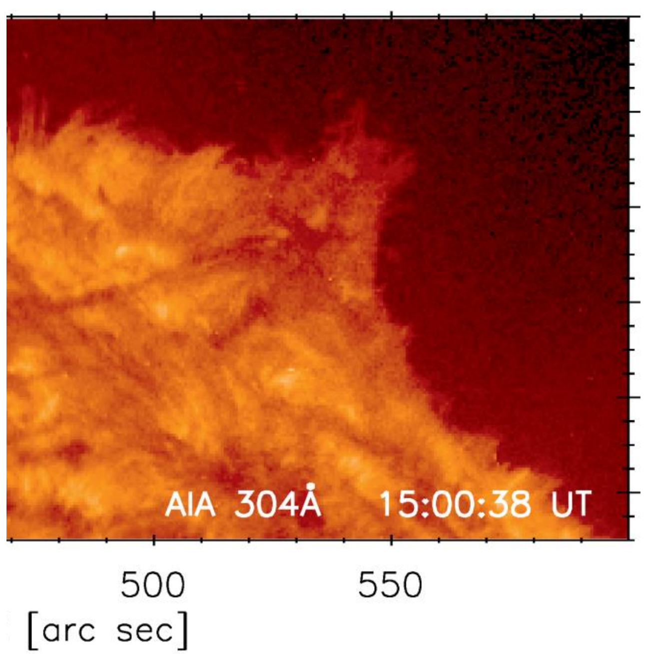
***Gunár et al. 2014, A&A, submitted***

# The Unsheared Model: Off-Limb

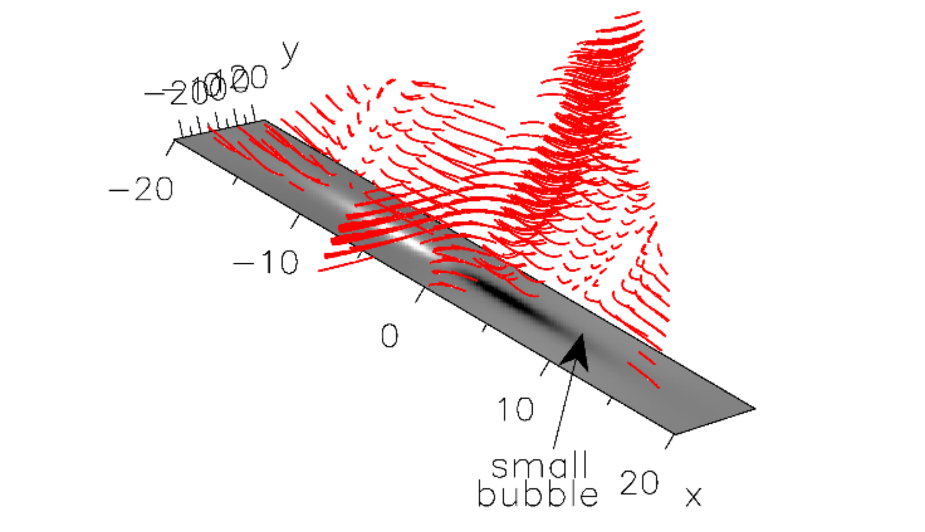


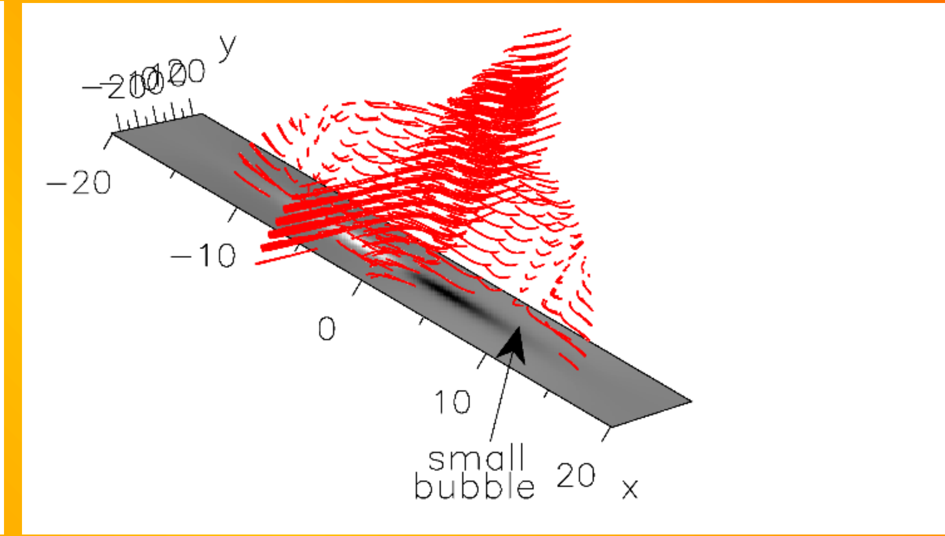



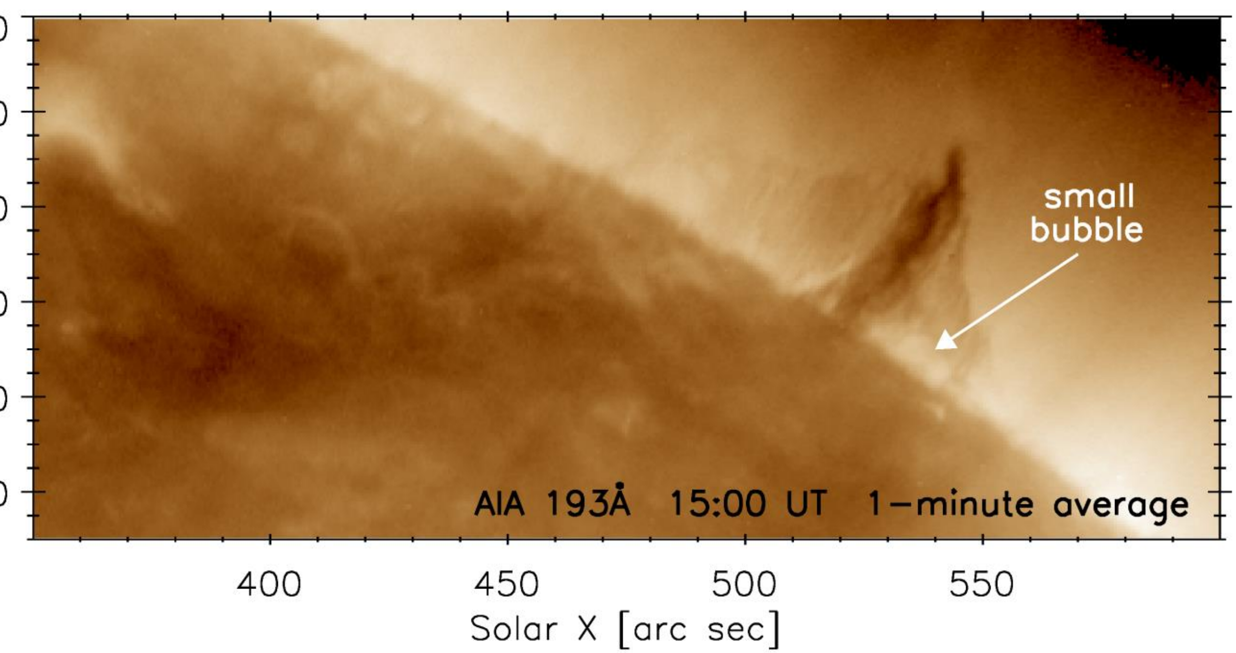



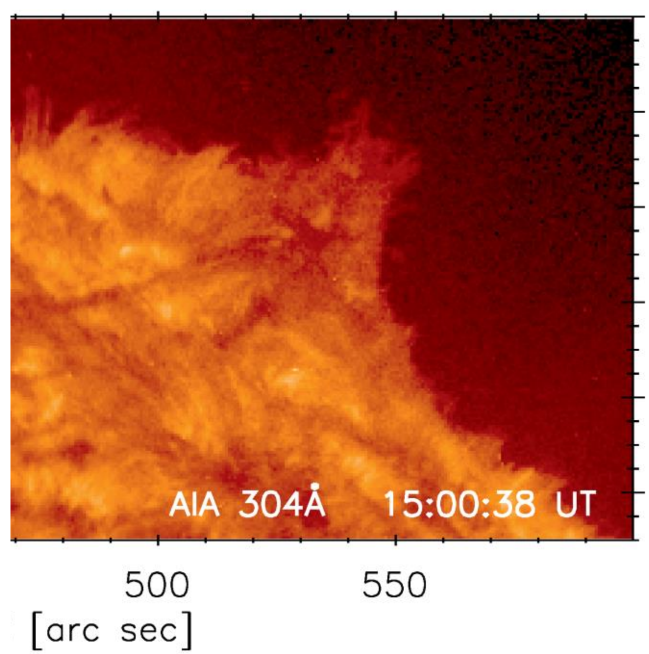



# Symmetric and Asymmetric



# Summary

- **Bubbles and plumes are not brighter than the surrounding corona**

- **Bubbles are topologically complex structures**
  - **magnetic arcades, not dips**
  - **null points and separators**
  - **plumes due to reconnection at the separator?**

- **The magnetic field of the quiescent prominences can be modeled with minimum of physics**
  - **OX topology and 1 – 2 sheared bipoles**

- **The configurations approximate well the observed prominences**


Thank you for your attention