Flux Emergence

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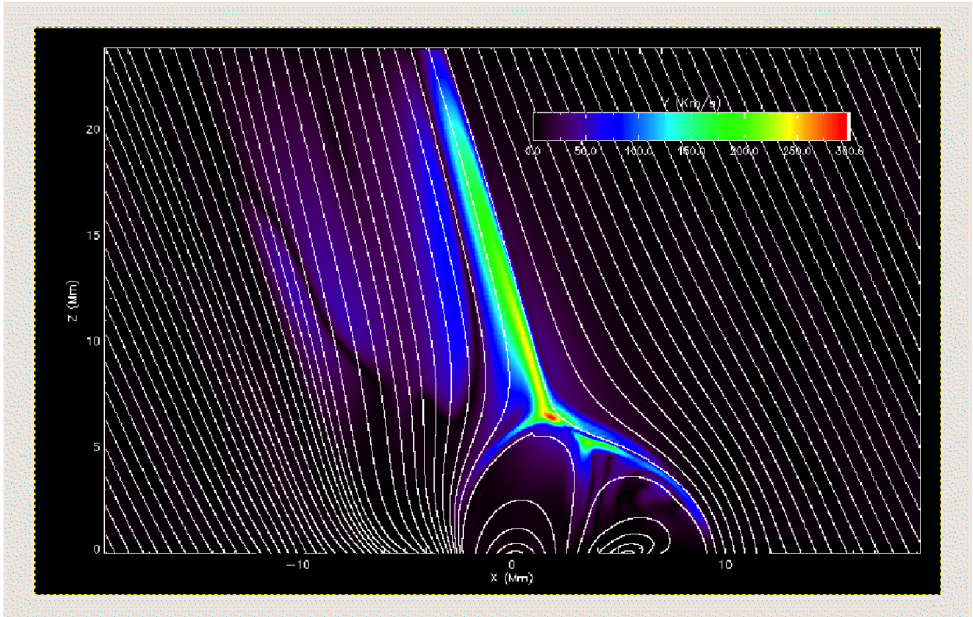
University of St Andrews

14 September 2010



Thanks to :
Vasilis Archontis, Michelle Murray, David MacTaggart, Klaus Galsgaard, Fernando Moreno-Insertis.

Outline

- 1. Basic set up.
- 2. General field at photosphere (magnetograms)
- 3. Sigmoids
- 4. Flux Rope Formation
- 5. CMEs and Eruptions

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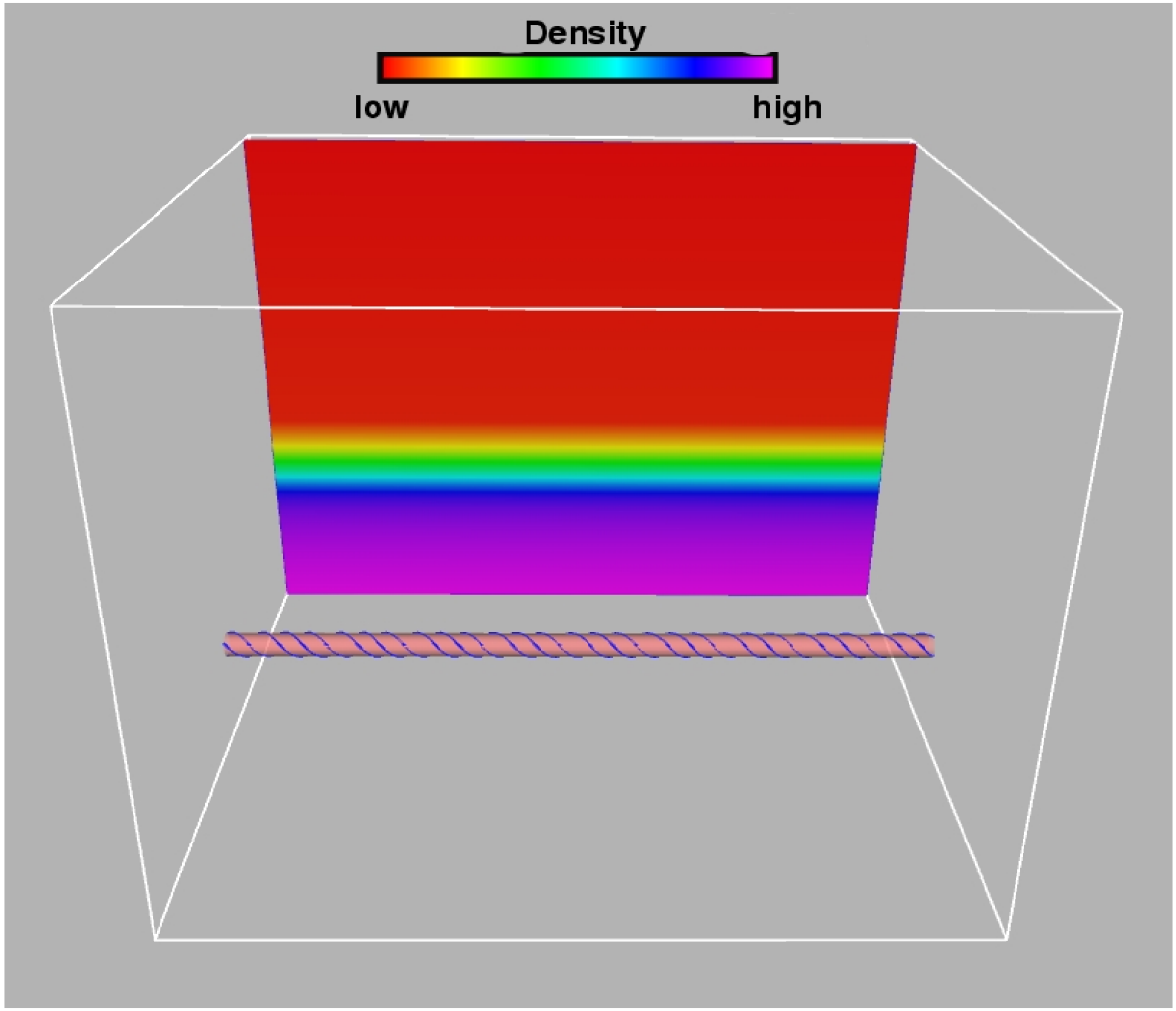
- 6. Need to use CHIANTI (lots and lots)

Initial Conditions



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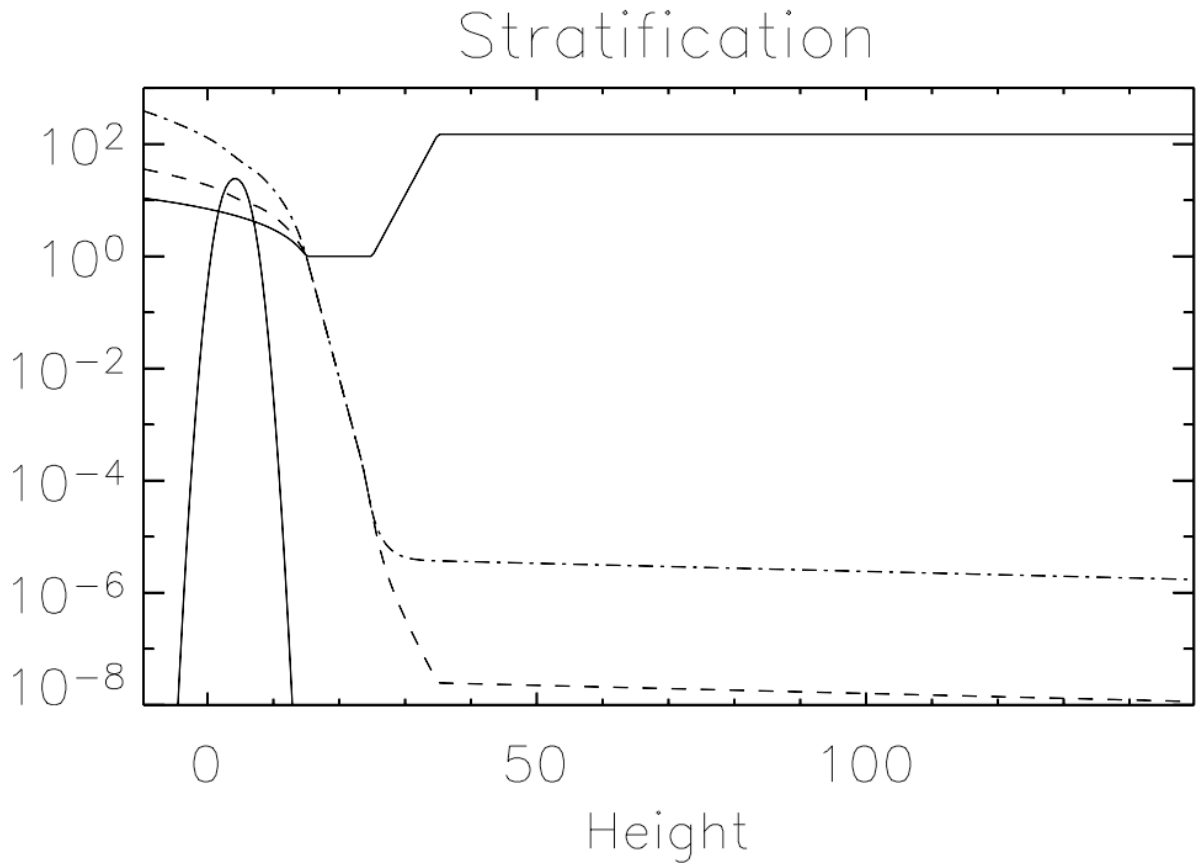

Tube buoyant in the middle.

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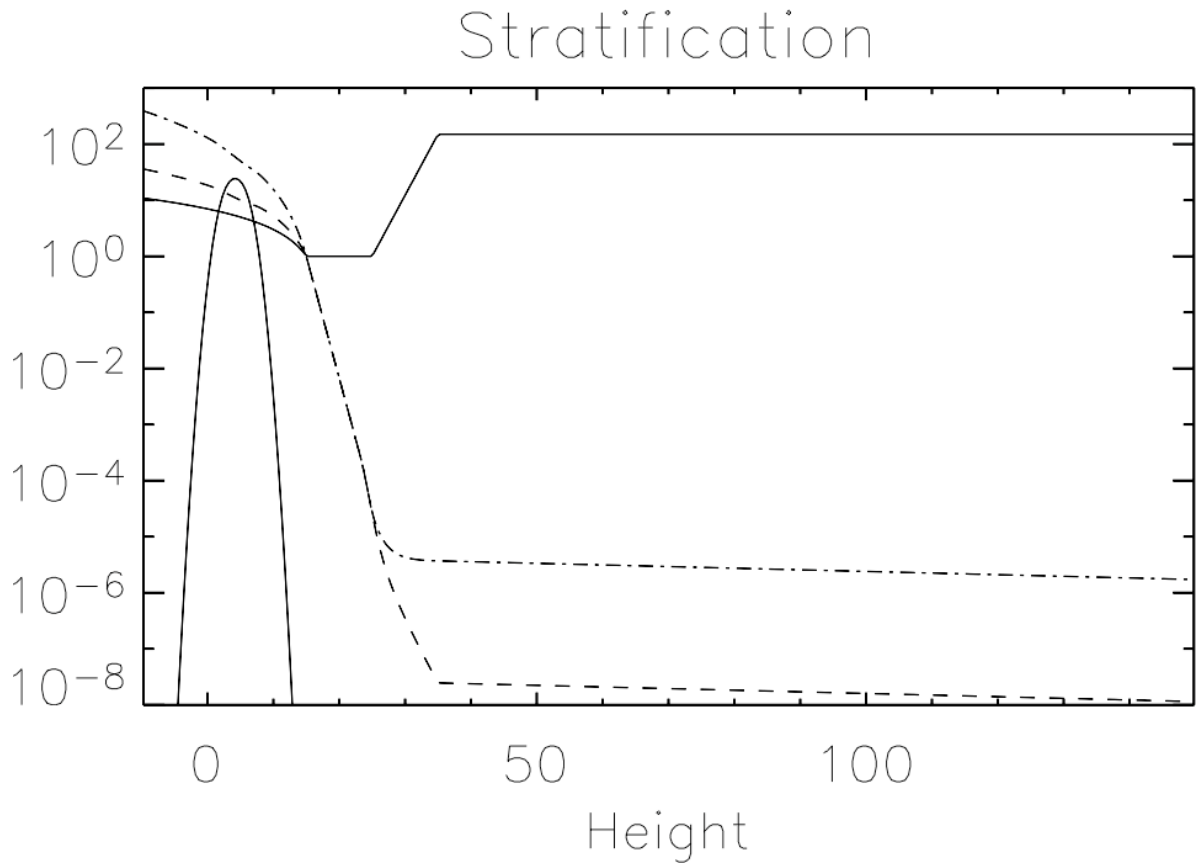


Tube buoyant in the middle. But first some observations.

Pre-existing Twisted Flux Rope?

AR 5617 emergence and twist

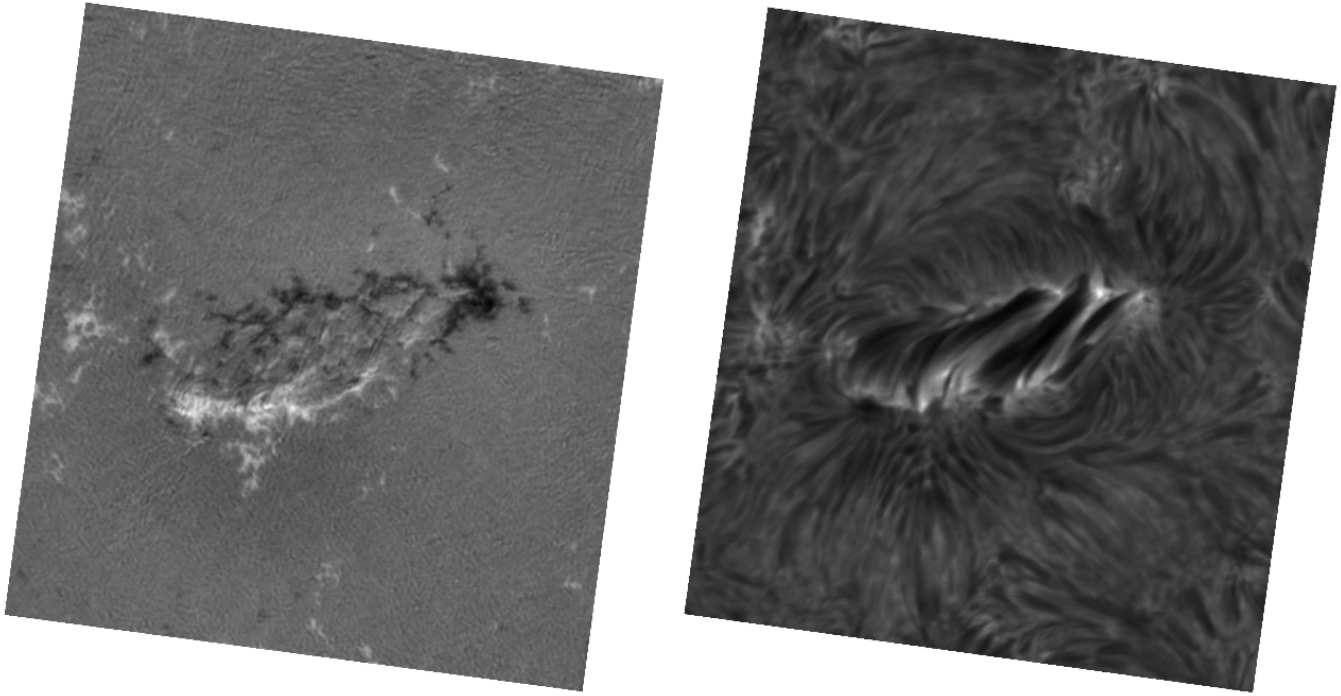


Figure: MDI and H_α 7.5 hours after the emergence began.

Observations show many ARs have (at least) modest level of twist (Pevtsov, Canfield & Metcalf, 1995; Longope, Fisher & Pevtsov 1998; Zhang & Bao, 1999; Lites et al., 1995; Strous, 1994; Strous et.al., 1996; Strous & Zwaan, 1999, etc.)

AR10808 - Magnetogram - MDI - 12/09/2005 - 15/09/2005

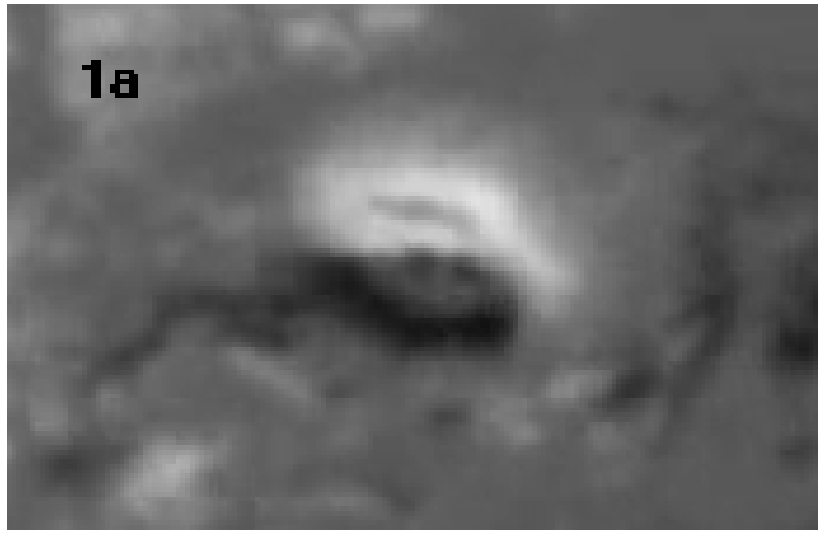
Emergence and magnetic 'tails'. (Canou et al, 2009)

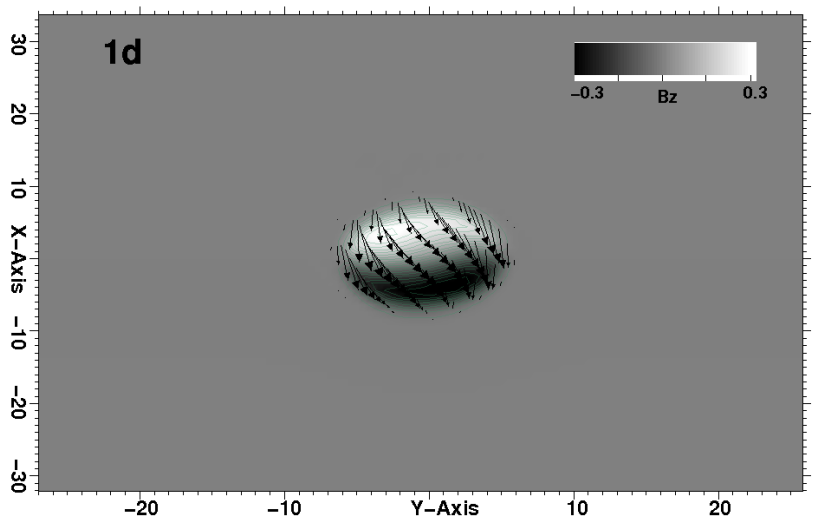
(Movies/mdi-mag200509.mpg)

Canou *et al*, 2009

- AR10808 MDI and THEMIS magnetograms
- δ-spot and many eruptions.
- Horizontal magnetic fields shows change of direction across neutral line.
- Twisted Flux Rope emerging?
- NLFFF extrapolation indicates TFR emerging.
- Pre-existing TFR before eruption.

Magnetic Tails Observation and Simulation





Photospheric base.

Initial phase: emergence into the photosphere.

(Movies/movie-long.mov)

- Density deficit & buoyancy: tube rises to the photosphere. Vrise=1.7 Km/sec, t=12.5 min.
- Formation of a bipolar region.
- $B \approx 600G$ at the photosphere.

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(Movies/movie-long.mov)

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- Organized shear velocity flow in the photospheric layer.

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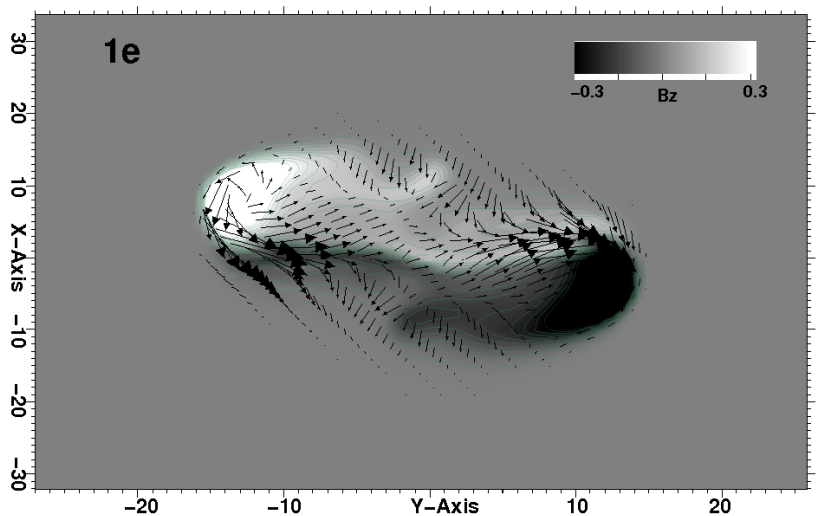
- Formation of a bipolar region.
- $B \approx 600G$ at the photosphere.
- Formation of tails on both sides of PIL.
- Organized shear velocity flow in the photospheric layer. Inflow in the transverse direction.
- See also: Fan (2001), Manchester (2004), etc.

Magnetic Tails Observation and Simulation

SOHO/MDI/Mag 2005/09/15 14:27:03 UT



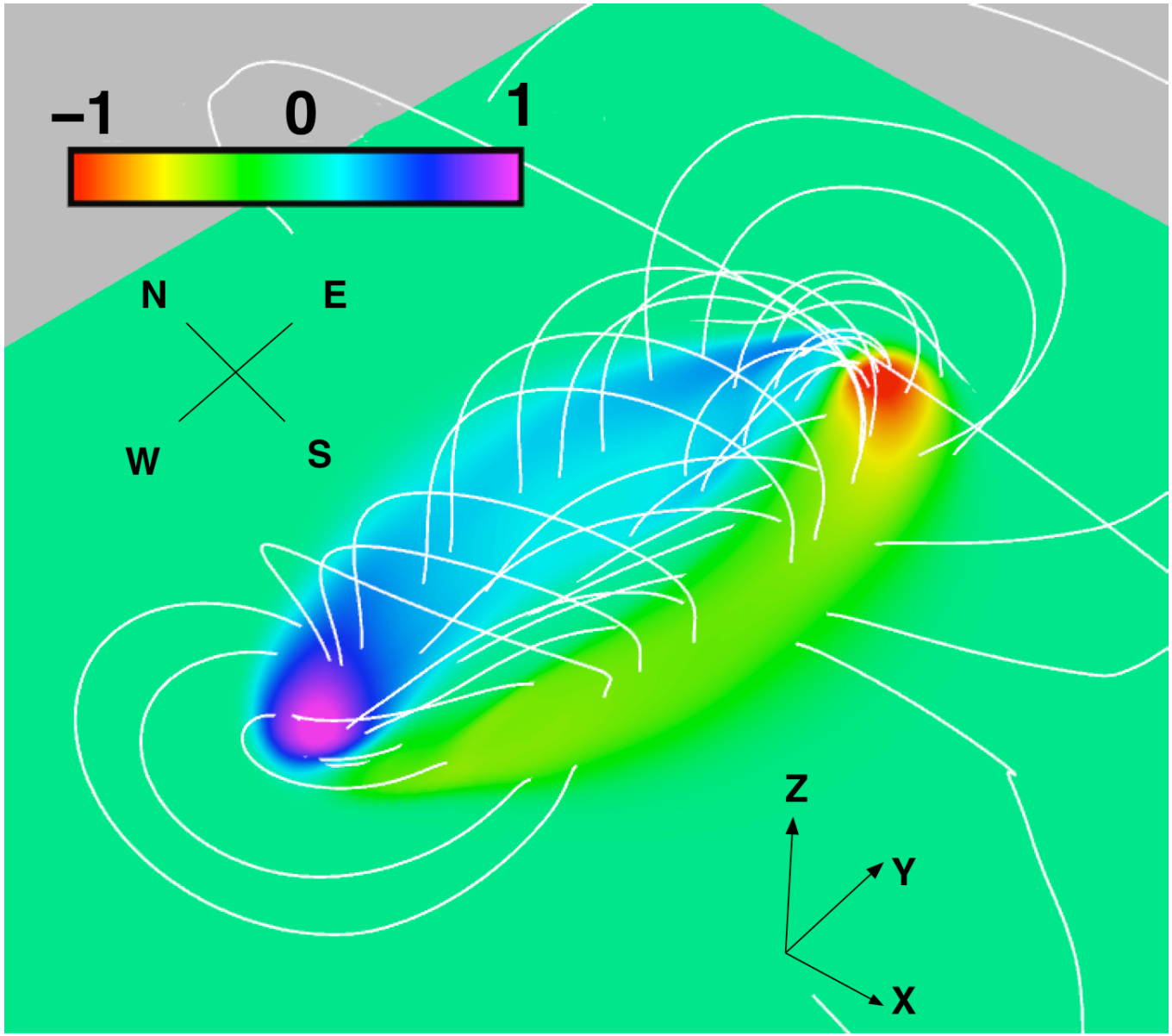
Magnetic tails and field rotation

Photosphere

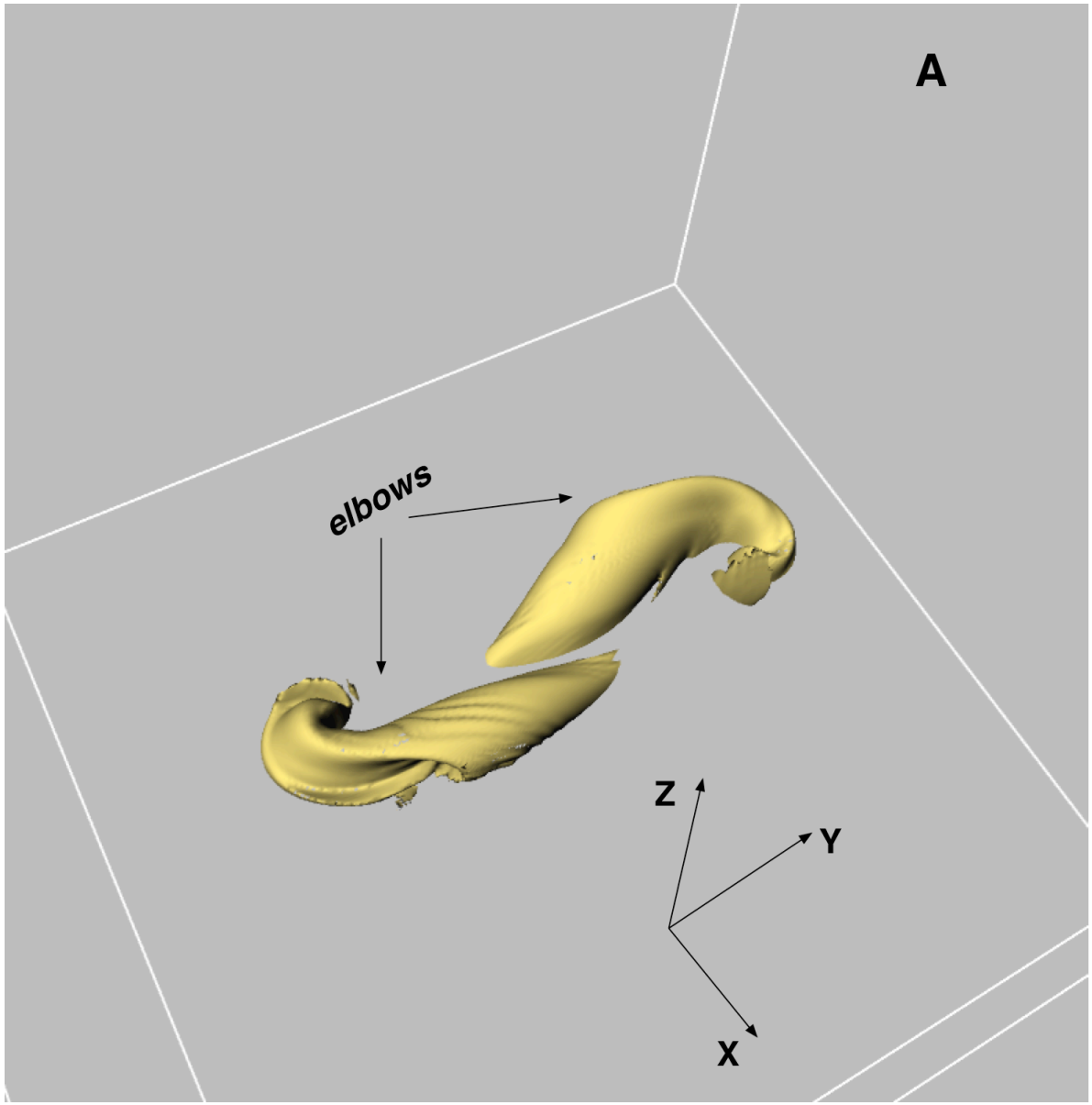
Bipole formation. Shape of magnetic tails depends on twist.

(Movies/B50bzvxy.mpeg)

Sigmoids: Line of sight $\mathbf{B}$.



Sigmoids: Current Sheets



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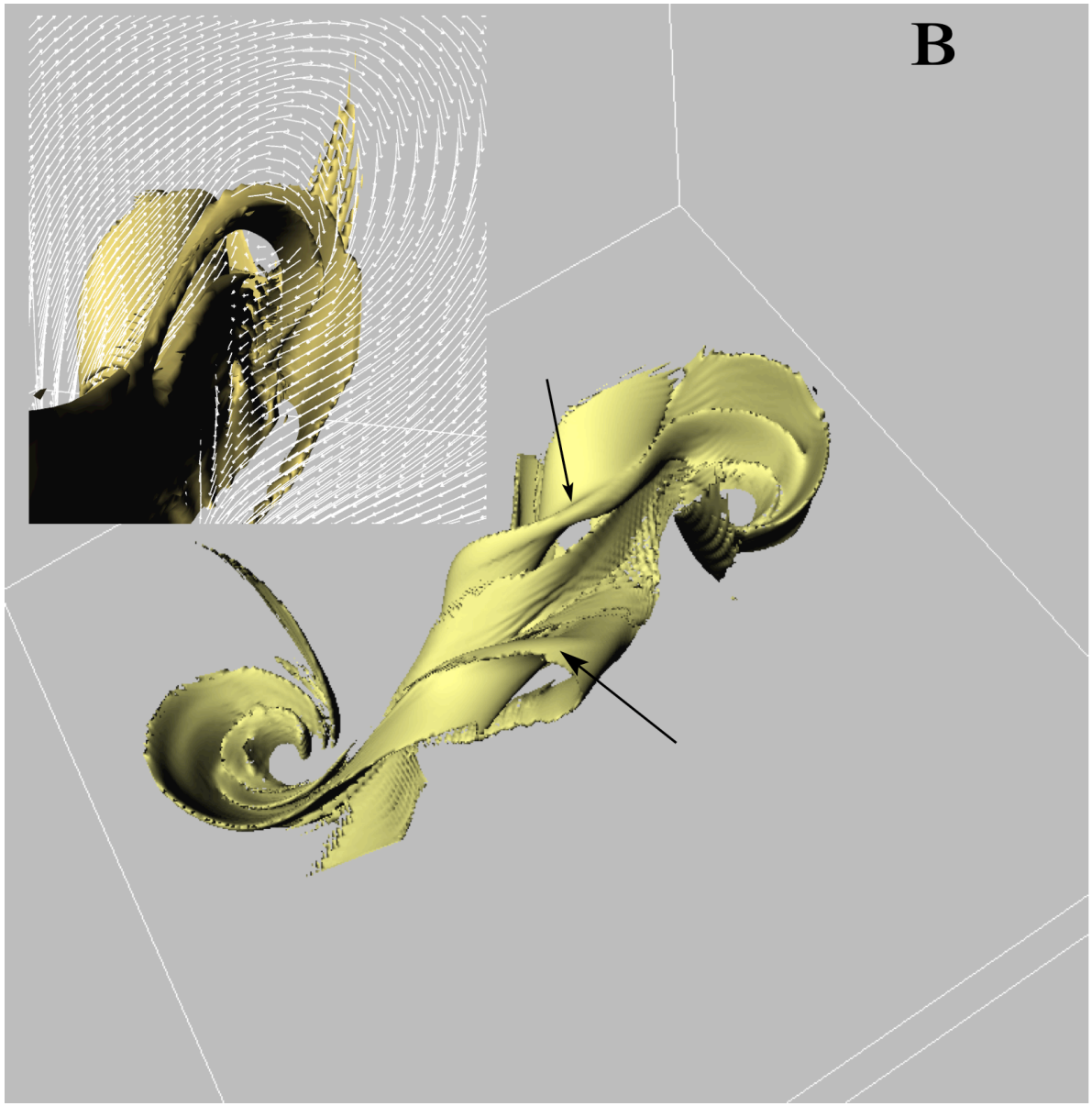
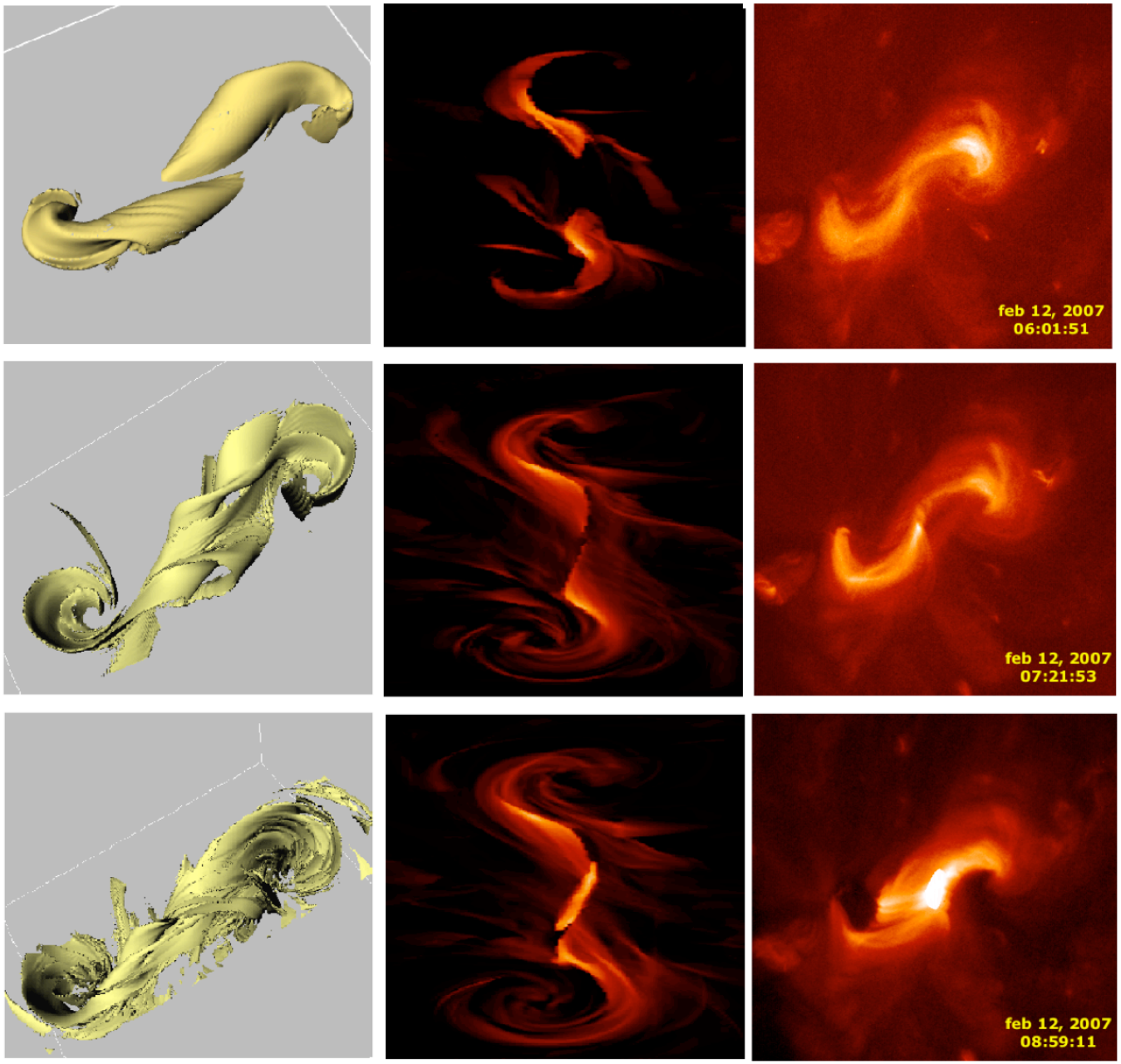
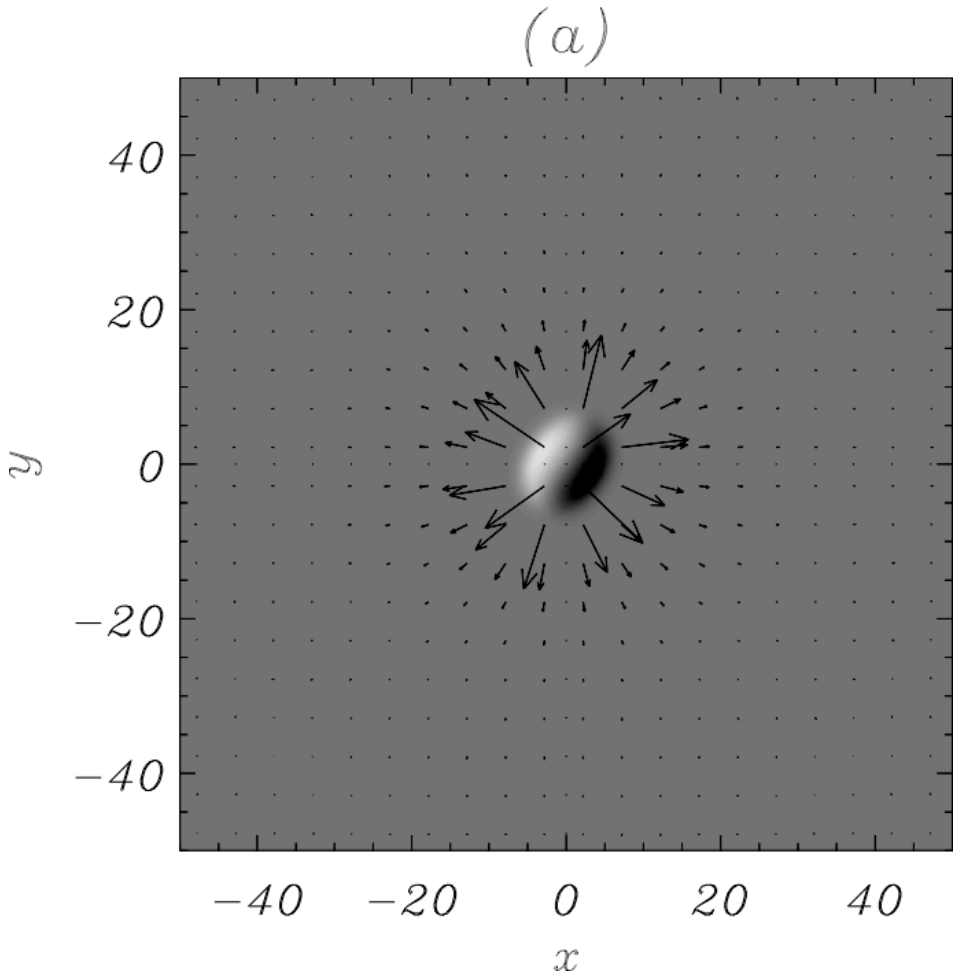


Sigmoids: Comparison with Observations

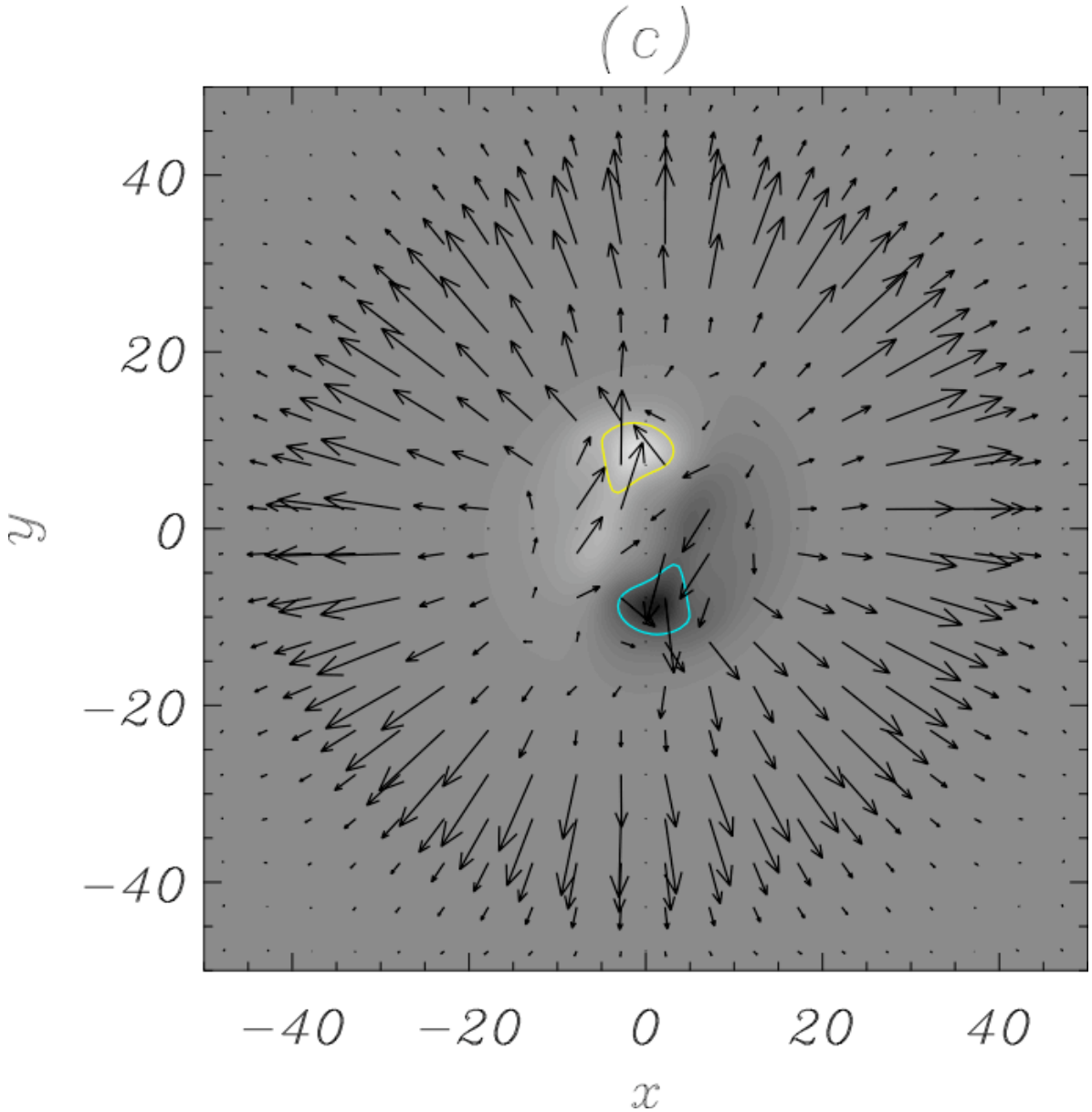


Flux Rope Formation

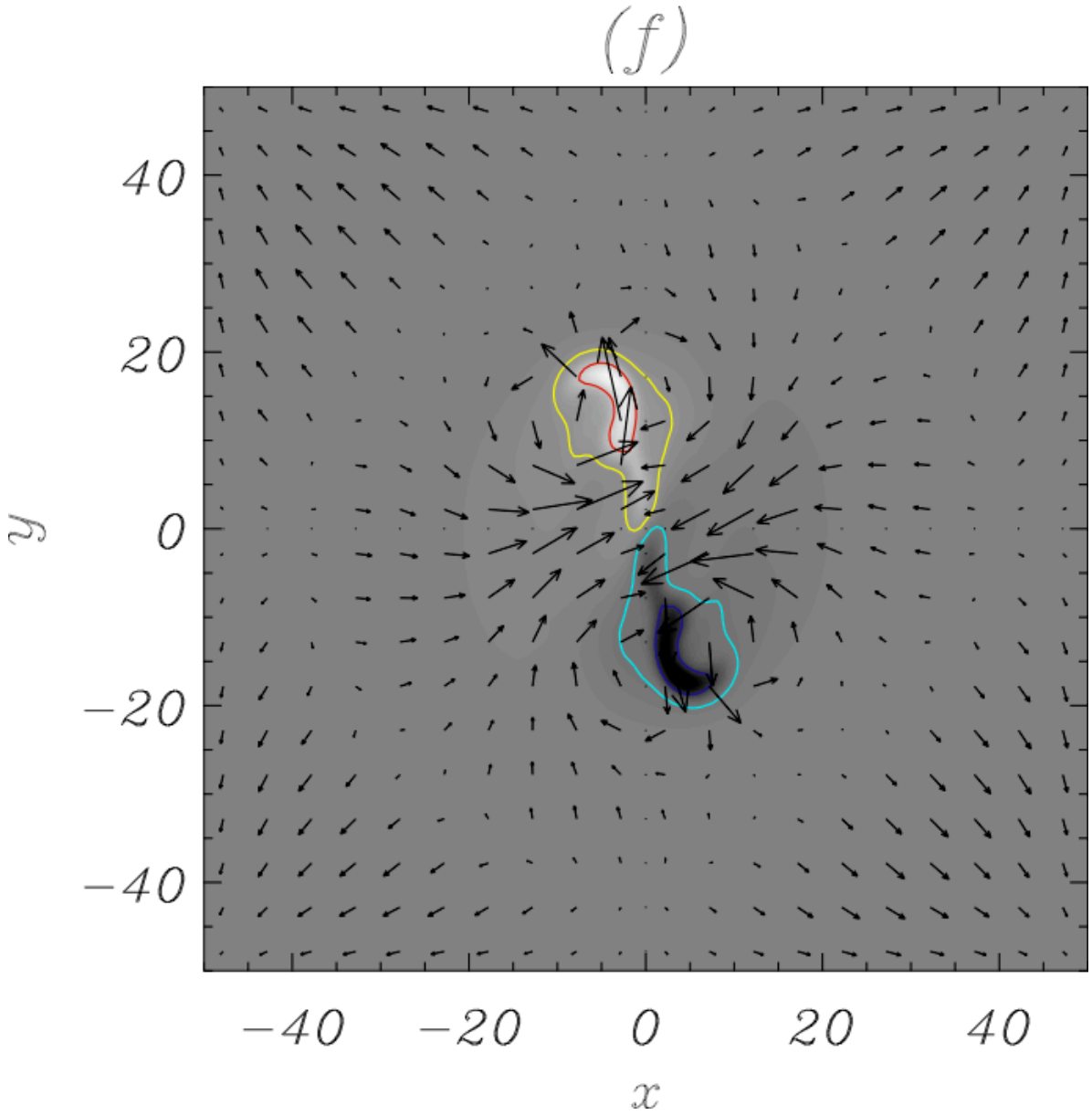


Magnetogram (white positive, black negative) ($z = 2$).
Arrows are horizontal velocity (length indicates magnitude).

Flux Rope Formation: Shear Flow

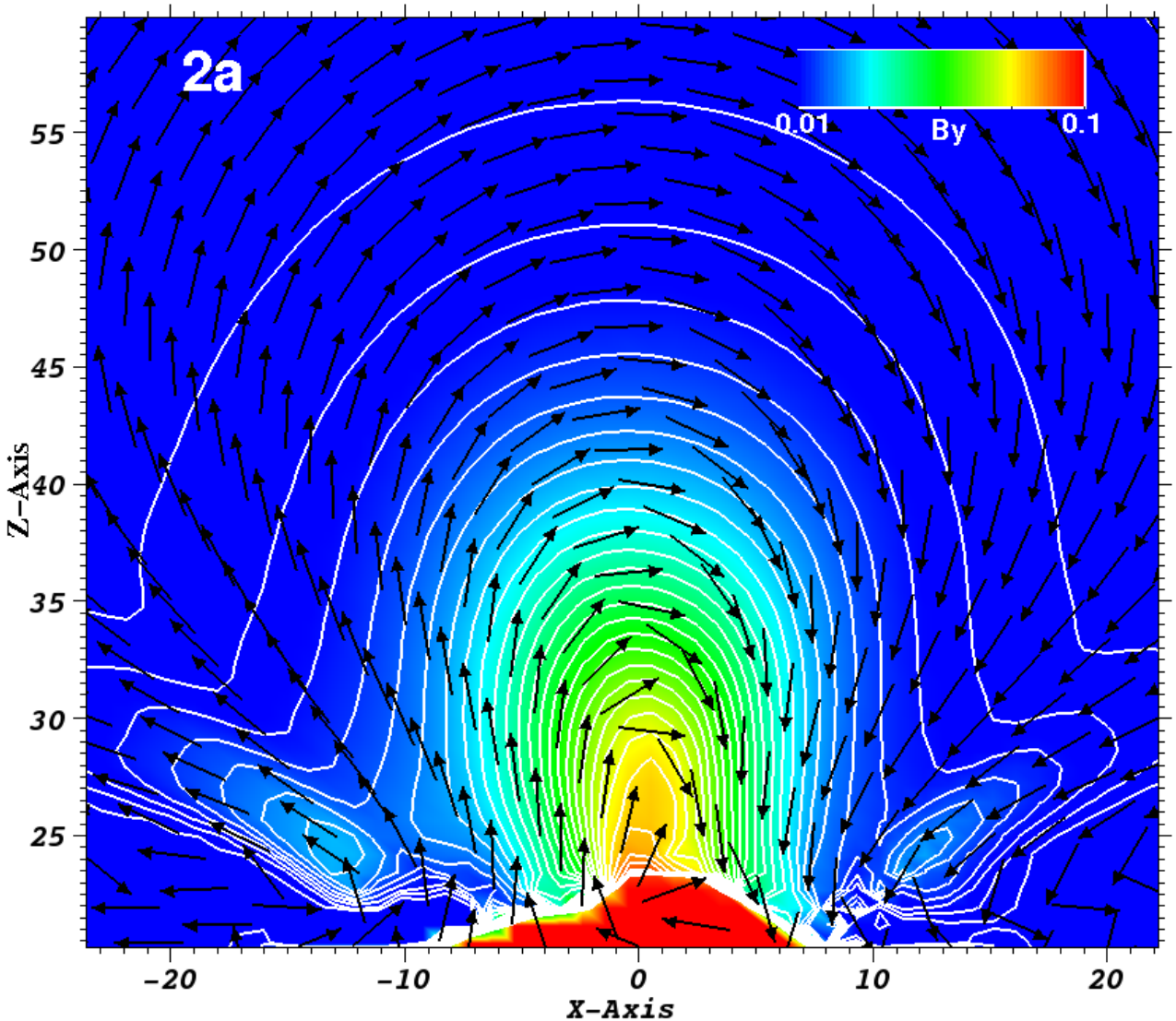


Flux Rope Formation: Converging Flow



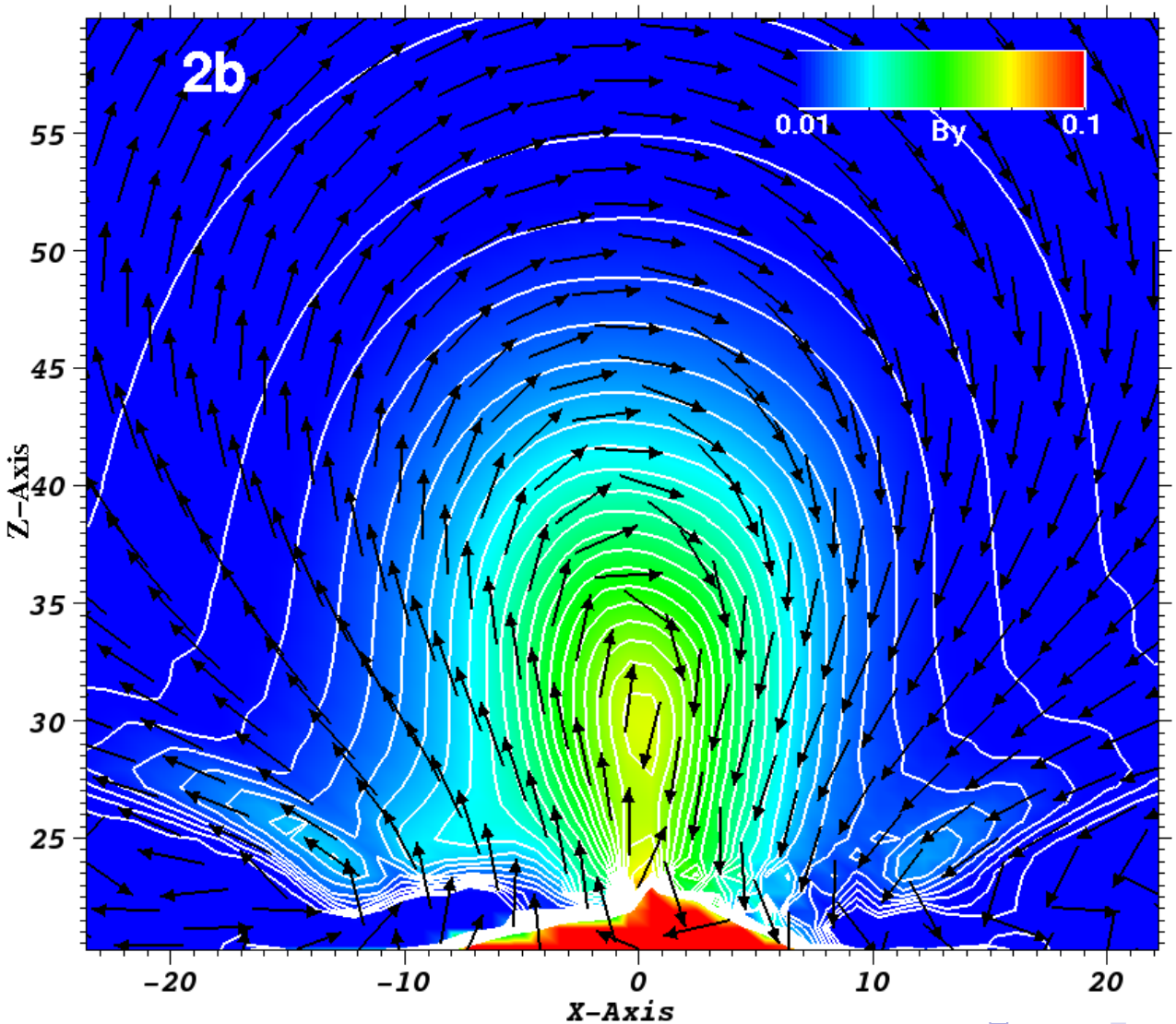
New Flux rope Formation

Contours of B_y and arrows show full magnetic field vector at $t = 90$. Rapid expansion creates pressure deficit - inflow.



New Flux rope Formation

Contours of B_y and arrows show full magnetic field vector at $t = 100$. New rope forms if inflow above original axis.



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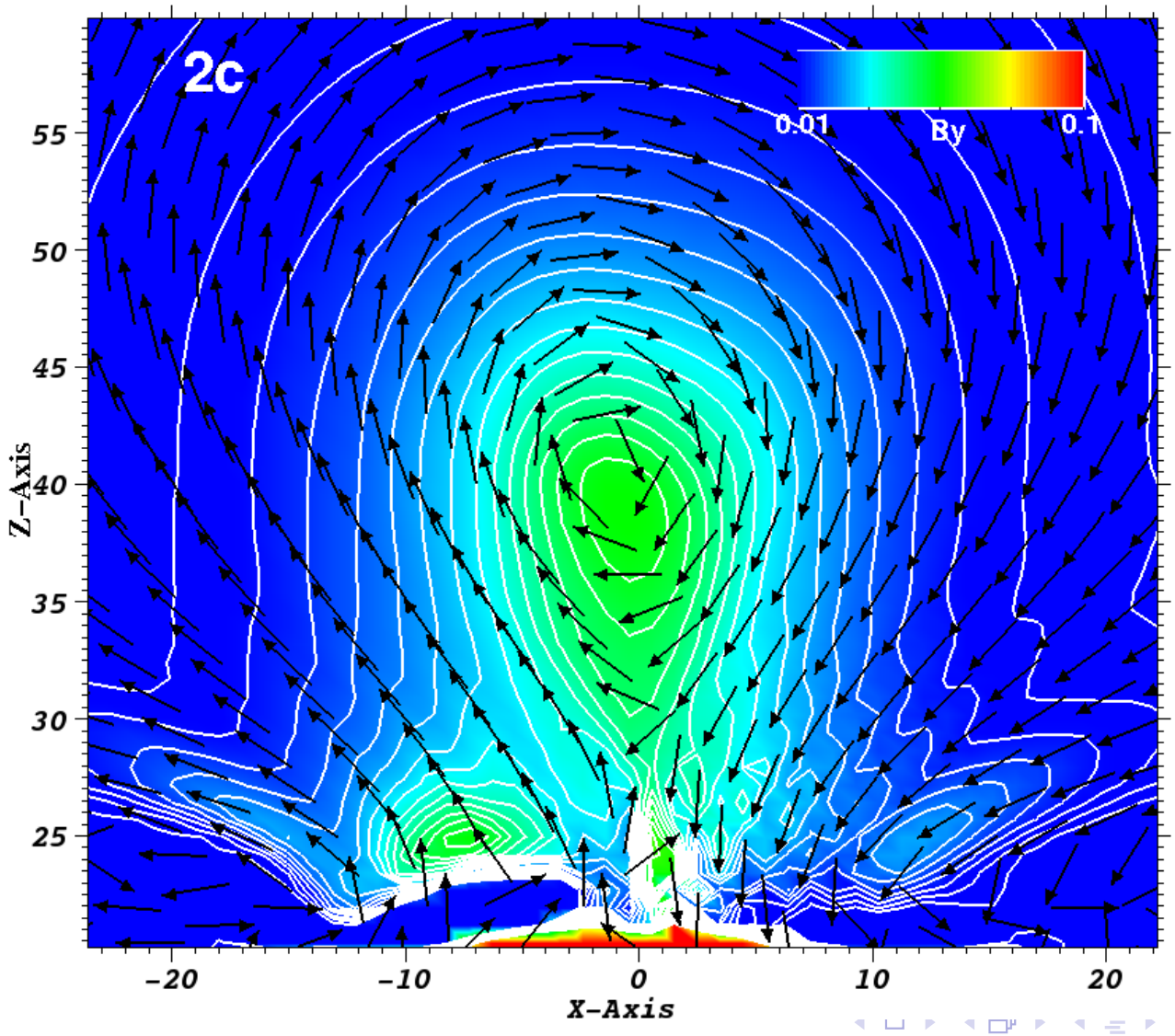
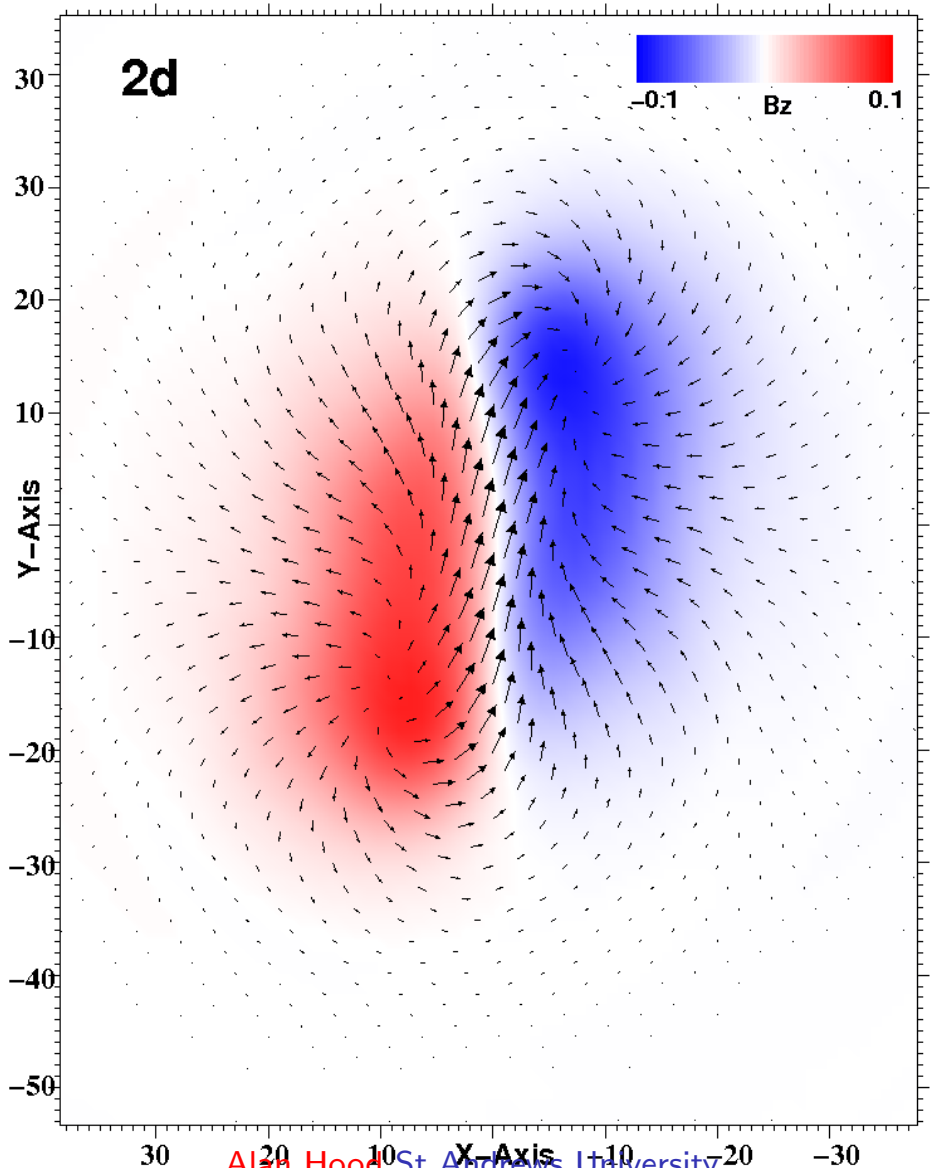
Contours of B_y and arrows show full magnetic field vector at $t = 120$.



New Flux Rope Emergence

Magnetogram of B_z at $z = 30$ (bottom of transition region).
Arrows indicate horizontal field at $t = 90$.



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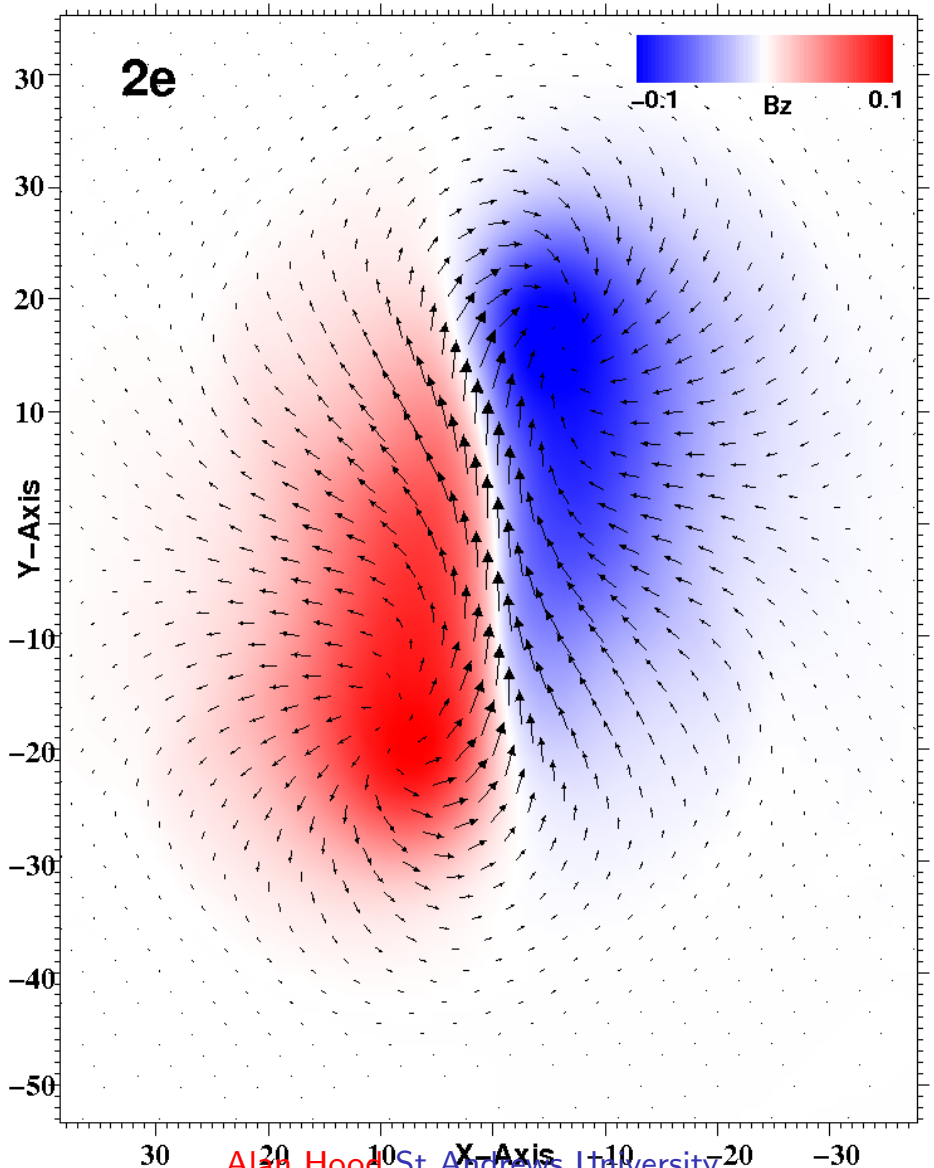

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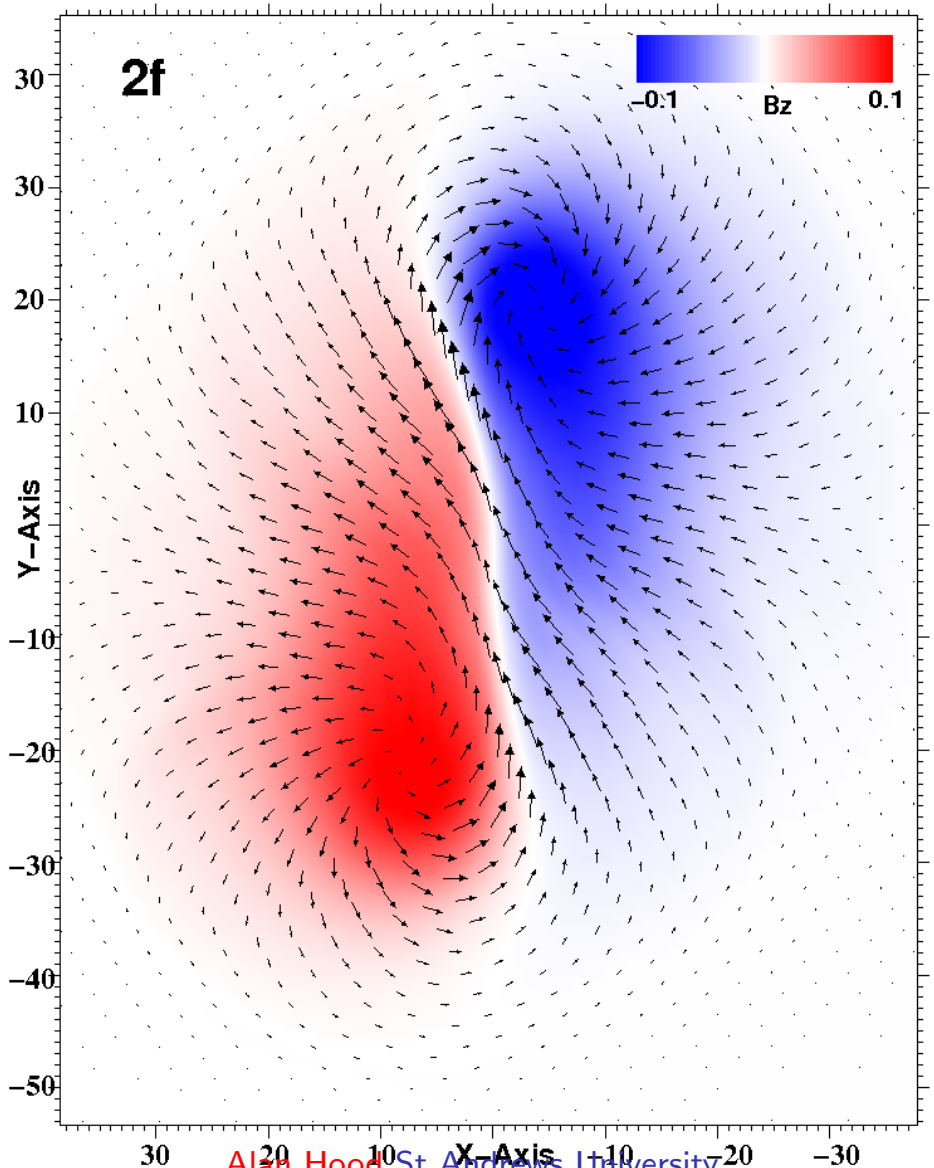
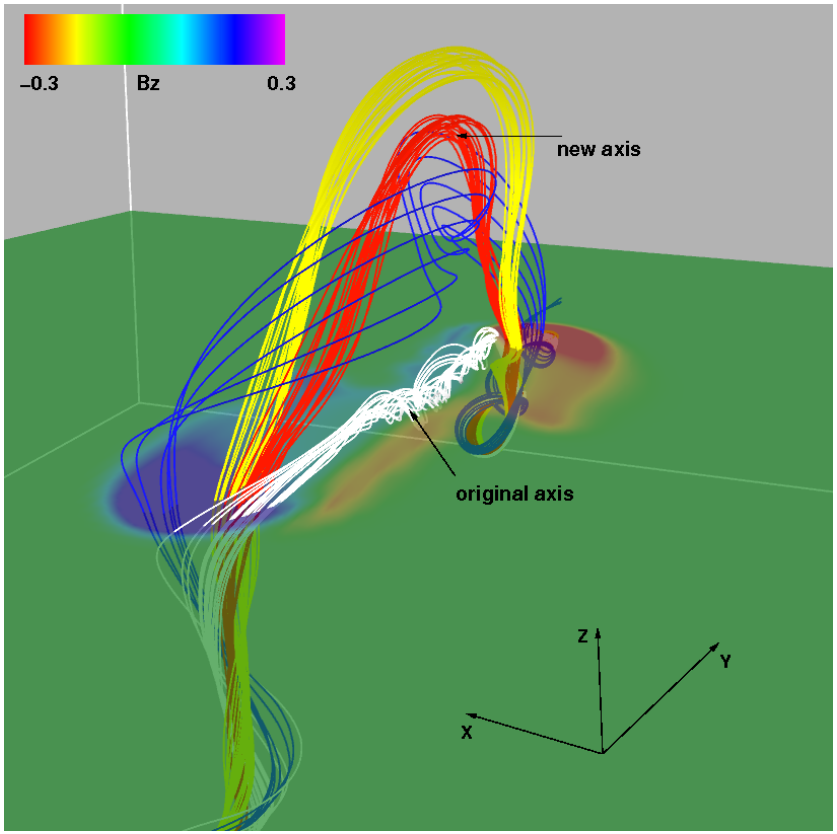


Final Field Description



Red - axis of new rope (carries dense plasma). Blue - one rotation around red. White - original axis.

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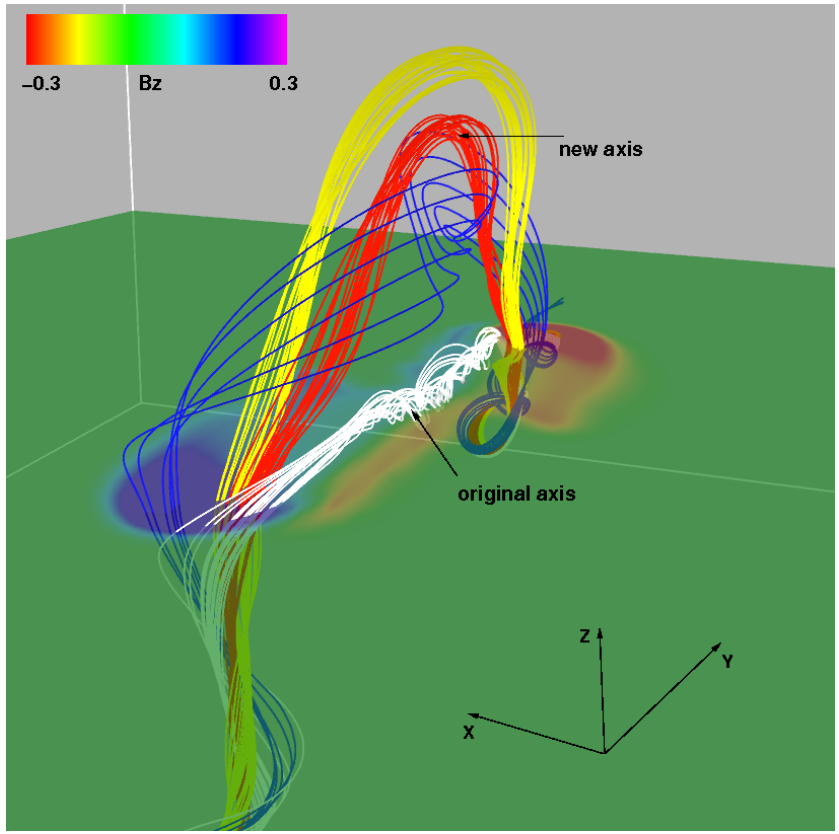

Red - axis of new rope (carries dense plasma). Blue - one rotation around red. White - original axis. Eruption of rope depends on overlying field. Held in place by yellow lines - need to remove them.

Eruptions and CMEs: Needs reconnection with coronal $\mathbf{B}$.

(Movies/movie2.mov)

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- Full emergence depends on overlying coronal $\mathbf{B}$.