Flux Emergence of a Non-Twisted Magnetic Flux Tube

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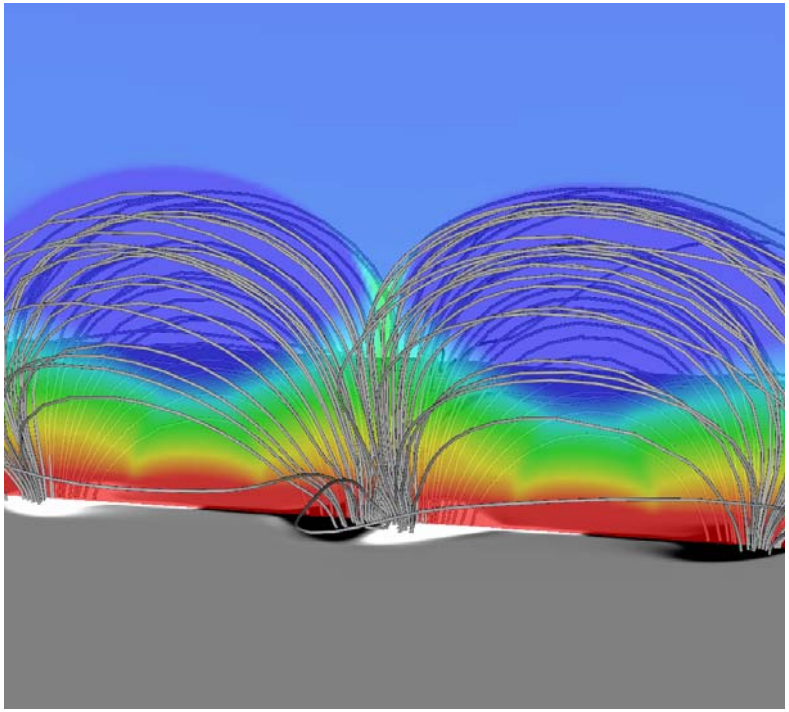


11th HEL.A.S Conference, Athens, Greece, 9-12 September 2013

Overview

Introduction
1.Flux Emergence and observations
2.Numerical Model and Initial Conditions

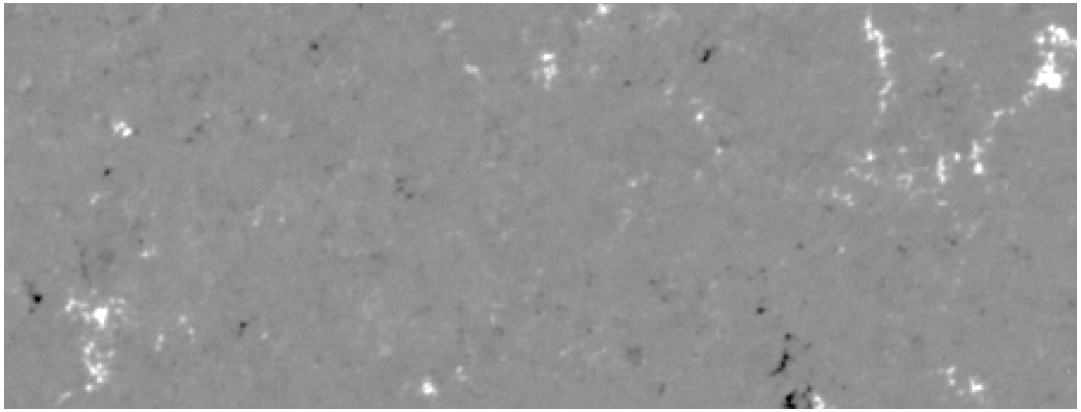
The effect of twist
1.Highly twisted flux tube
2.Weakly twisted flux tube
3.Non twisted flux tube

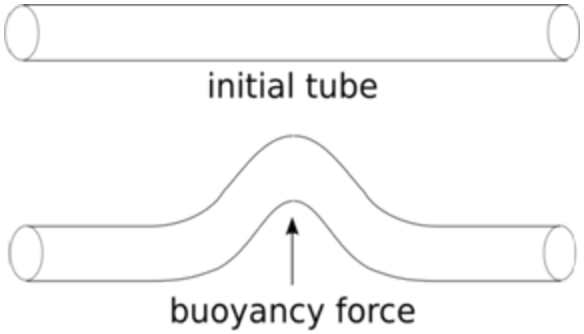
Summary

Flux Emergence – Observations and Physics

Flux emergence is the process where magnetic fields emerge from the solar interior into the solar atmosphere and create dynamical phenomena.

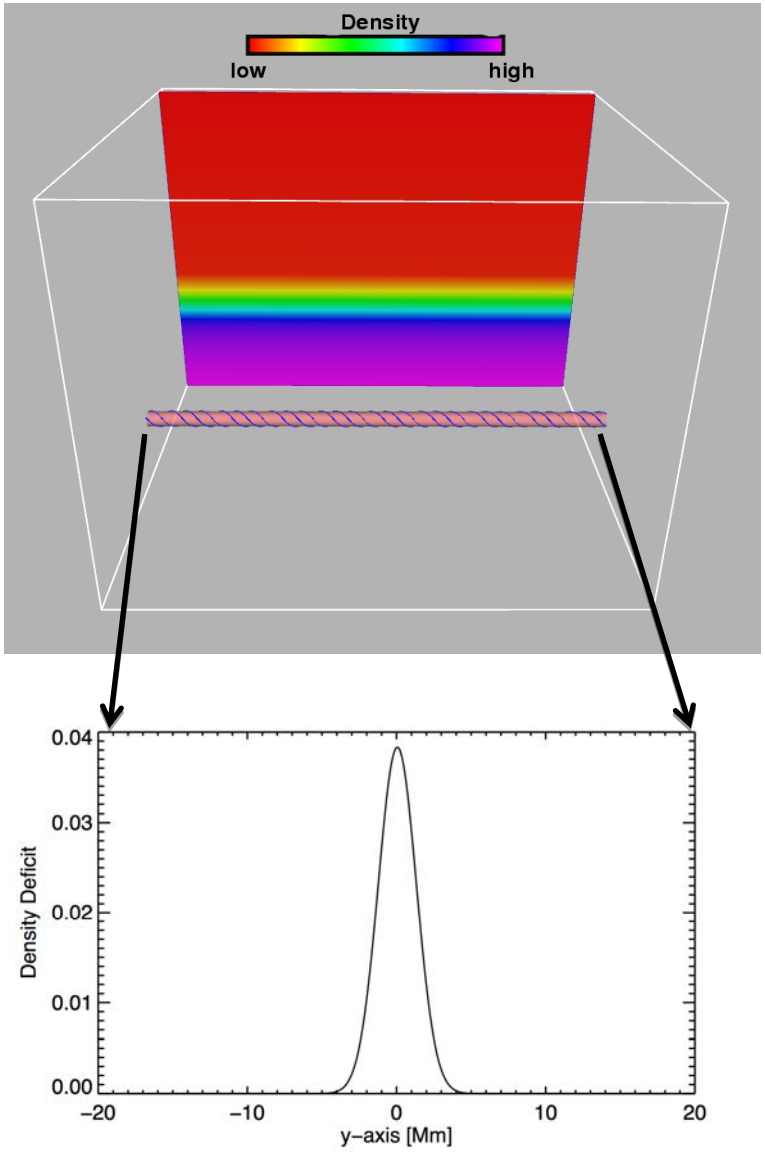
2013-02-15 01:00 – 2013-02-16 01:00 SDO/HMI





1. Total pressure continuous $P_i + \frac{B_i^2}{8\pi} = P_e$
2. Thermal equilibrium $T_i = T_e$
3. To rise, $P_i < P_g \rightarrow \rho_i < \rho_e$
4. B tube becomes lighter and rises (Parker 1955)

Initial Conditions I – Twist



Emergence in a non magnetised atmosphere

$$B_y = B_0 e^{-\frac{r^2}{R^2}},\ R = 450km$$

$$B_\phi = \alpha r B_y$$

$$\Delta\rho = \frac{p_t(r)}{p_{st}(z)}\rho_{st}(z)e^{-\frac{y^2}{\lambda^2}},\ \lambda = 10$$

$$B_0 = 2.8kG,\ \beta = 25$$

Parameter α: measure of twist per unit of length.

For a tube of radius $R = 450km$:

Highly twisted case:

$\alpha = 22 \times 10^{-4} km^{-1} \rightarrow 45°\ between\ B_\phi, B_y$

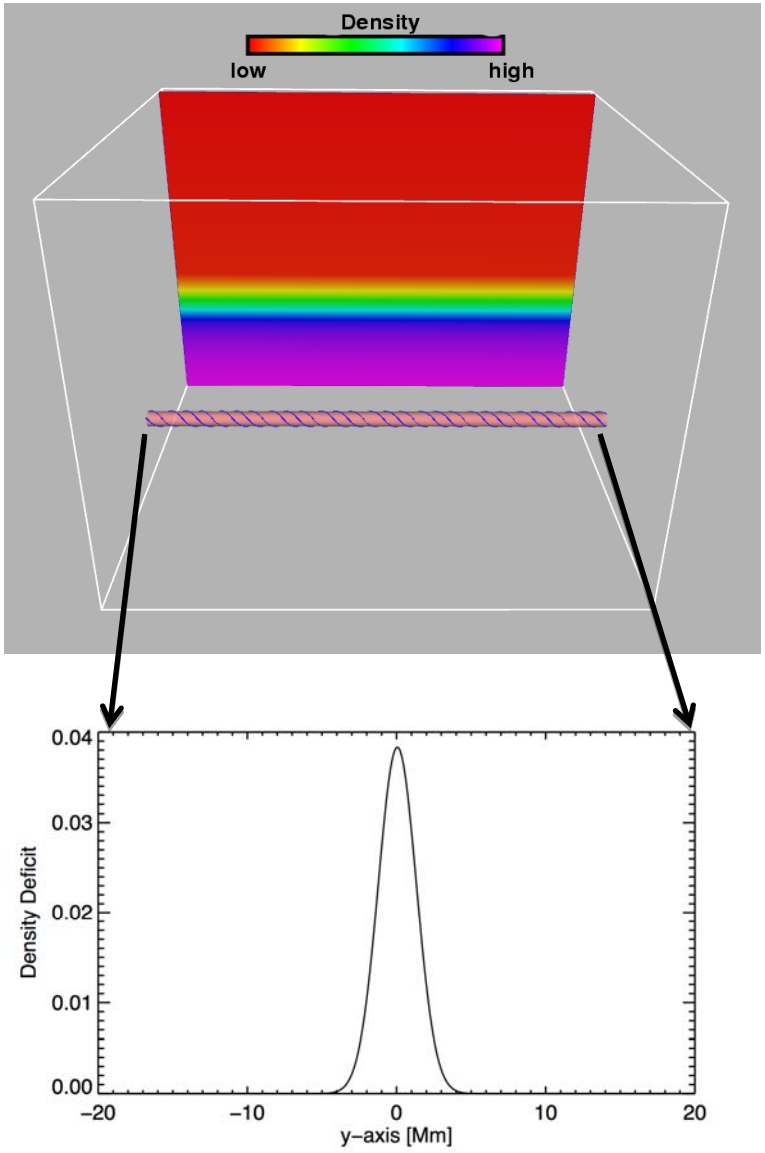
Weakly twisted case:

$\alpha = 55 \times 10^{-5} km^{-1} \rightarrow 14°\ between\ B_\phi, B_y$

Non twisted case:

$\alpha = 0$

Initial Conditions II - Stratification



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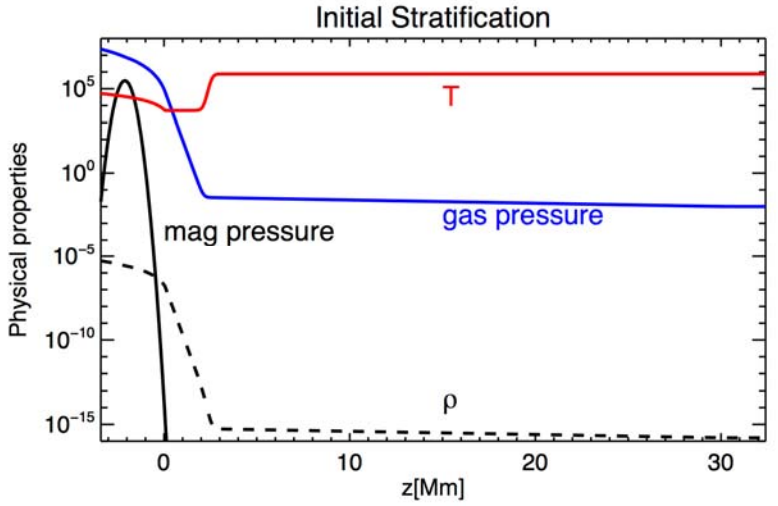


LARE3D code: time dependent, resistive, compressible MHD with constant resistivity, joule and viscous heating.

Highly Twisted Flux Tubes – Basic Characteristics

The key characteristics of the emergence of a highly twisted flux tube are:

1.Formation of a bipolar region.

2.Shearing motions along the Polarity Inversion Line (PIL)

Interactions and eruptive phenomena:

1.Reconnection along the PIL due to sharing (van Balleggooijen and Martens 1989)

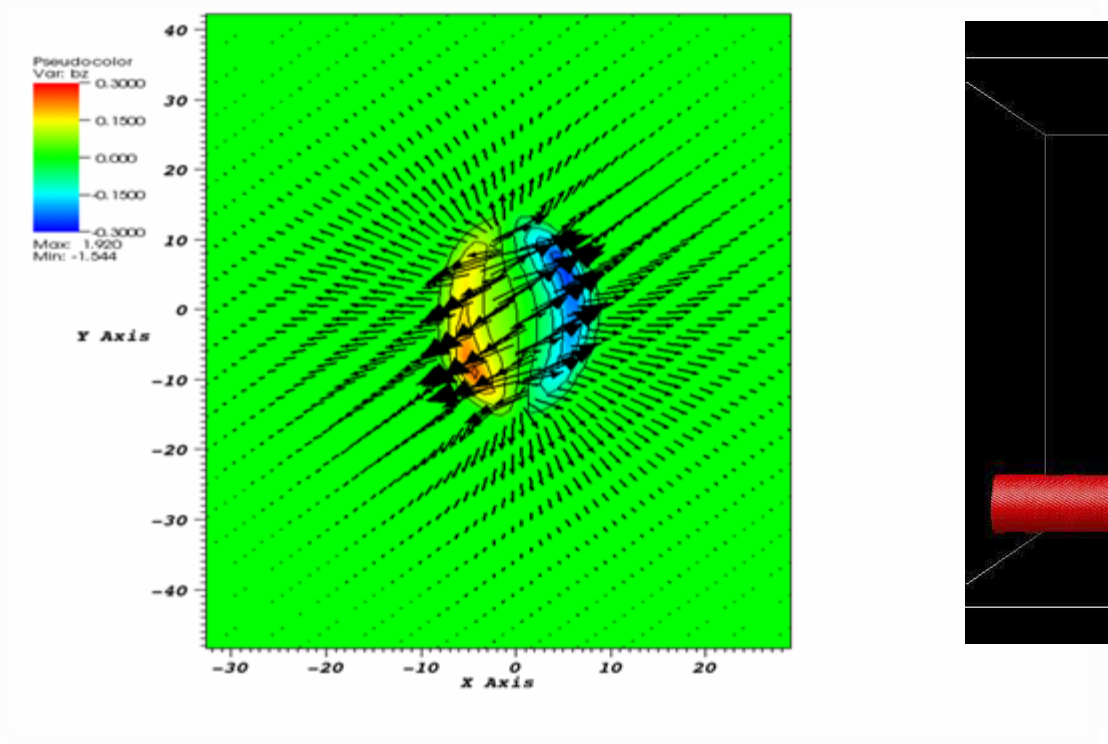
2.Formation of post-emergence flux rope (PEFR) (Manchester et al. 2004, Archontis et al 2009)

3.Eruption of the PEFR depending on initial field magnitude, external field etc. (Torok & Kliem 2005, Archontis and Hood 2012)

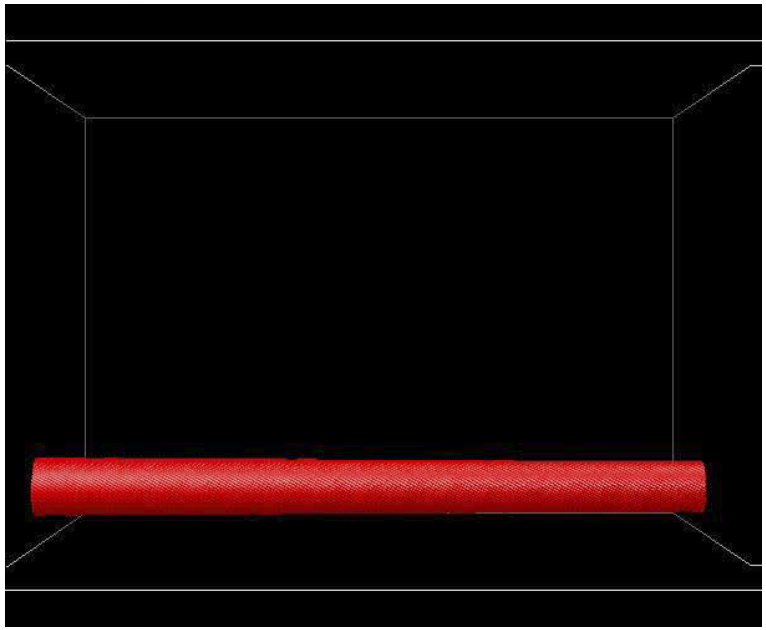
4.Formation of jets and eruptive phenomena (Gontikakis et al 2009, Moreno-Insertis et al 2008)

Highly Twisted Flux Tubes – Basic Characteristics

Bipolar Region –Shearing Motions

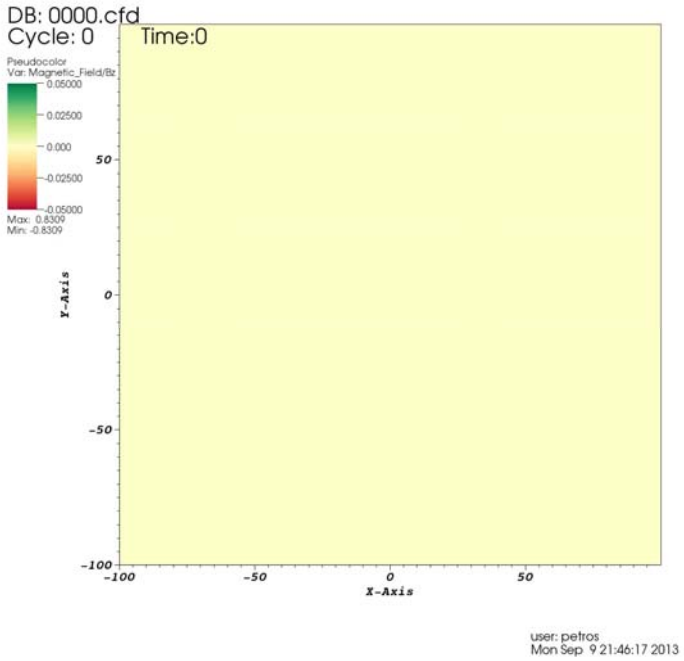


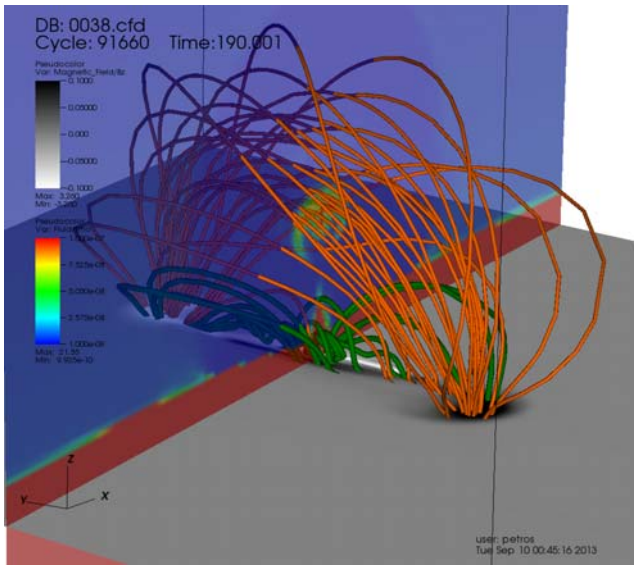
Flux Emergence



Weakly Twisted Flux Tubes – Basic Characteristics

Highly Twisted	Weakly Twisted
Bipolar Region	2 Bipolar Regions with Shearing

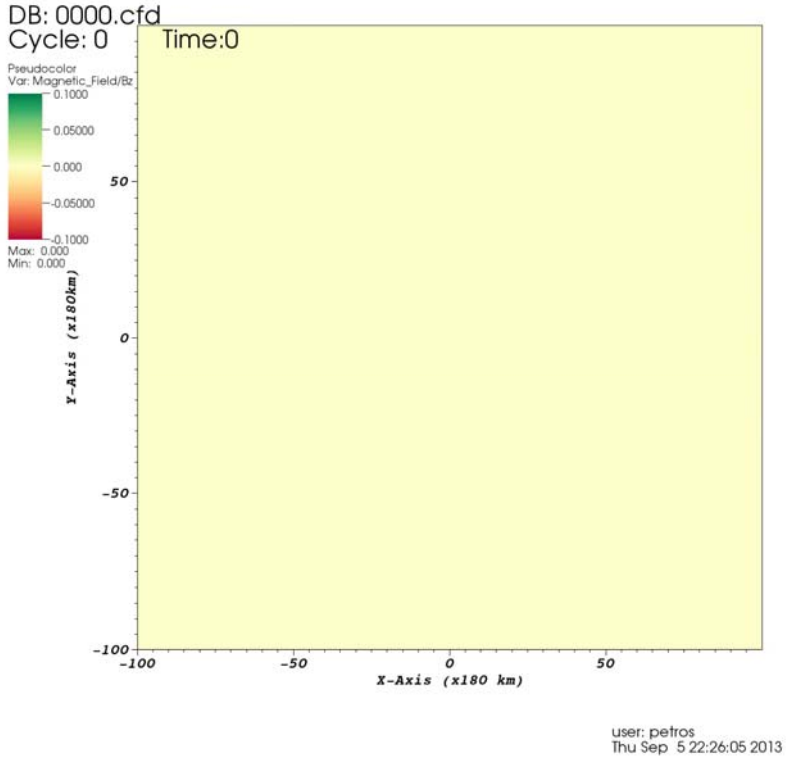




Archontis, Hood, Tsinganos 2013, accepted

Non Twisted Flux Tubes – Differences with Highly Twisted

Highly Twisted	Non Twisted
Bipolar Region	2 Bipolar Regions without Shearing

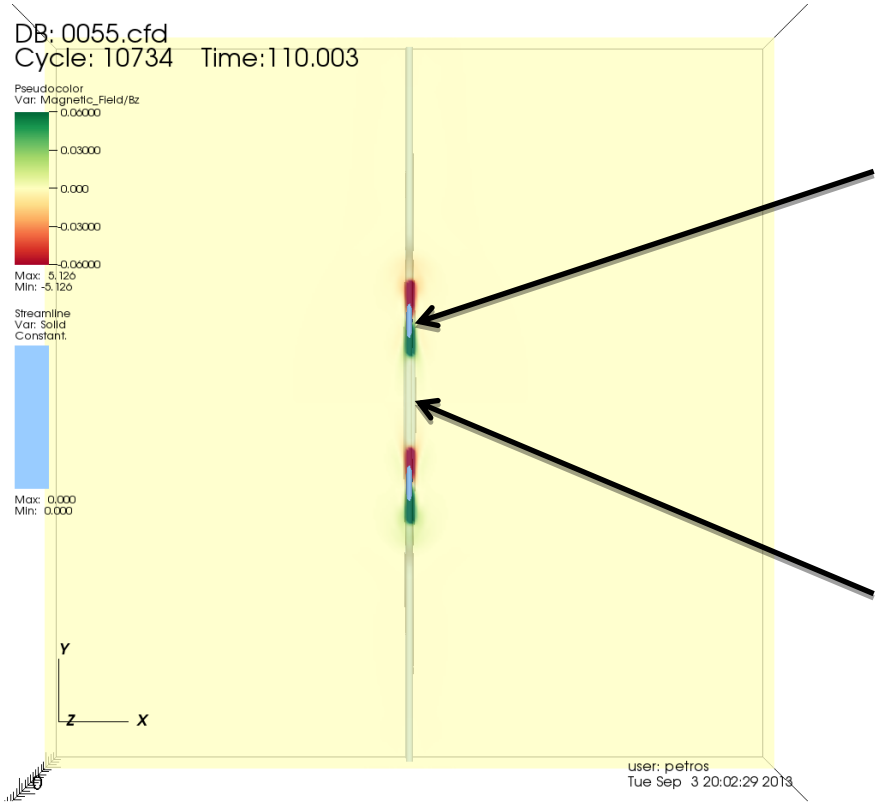


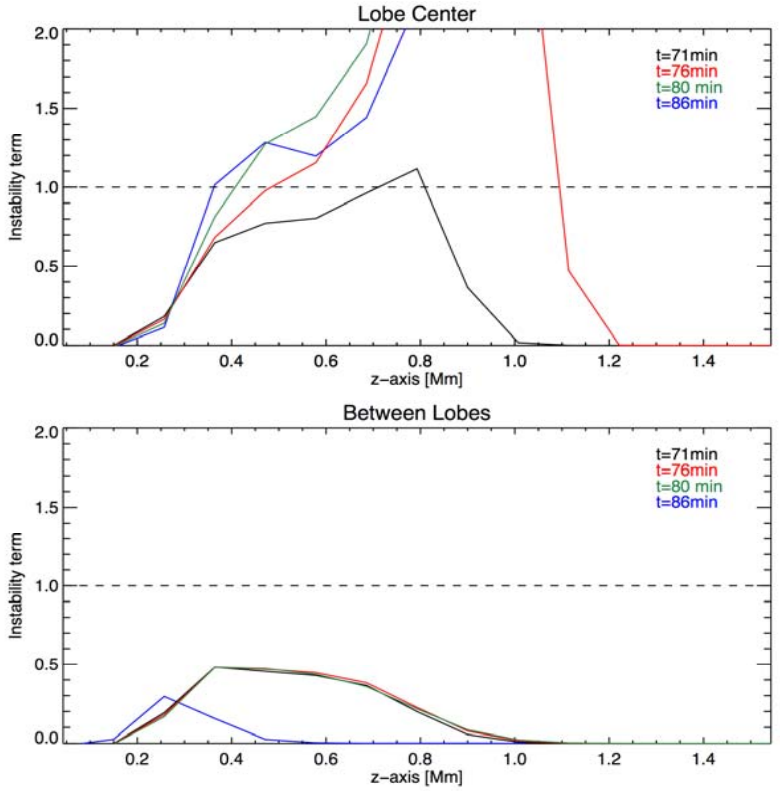
Similarities with weakly twisted emerging flux tube

Non Twisted Flux Tubes – Buoyancy Instability

Buoyancy Instability Critical Condition (Acheson, 1979):

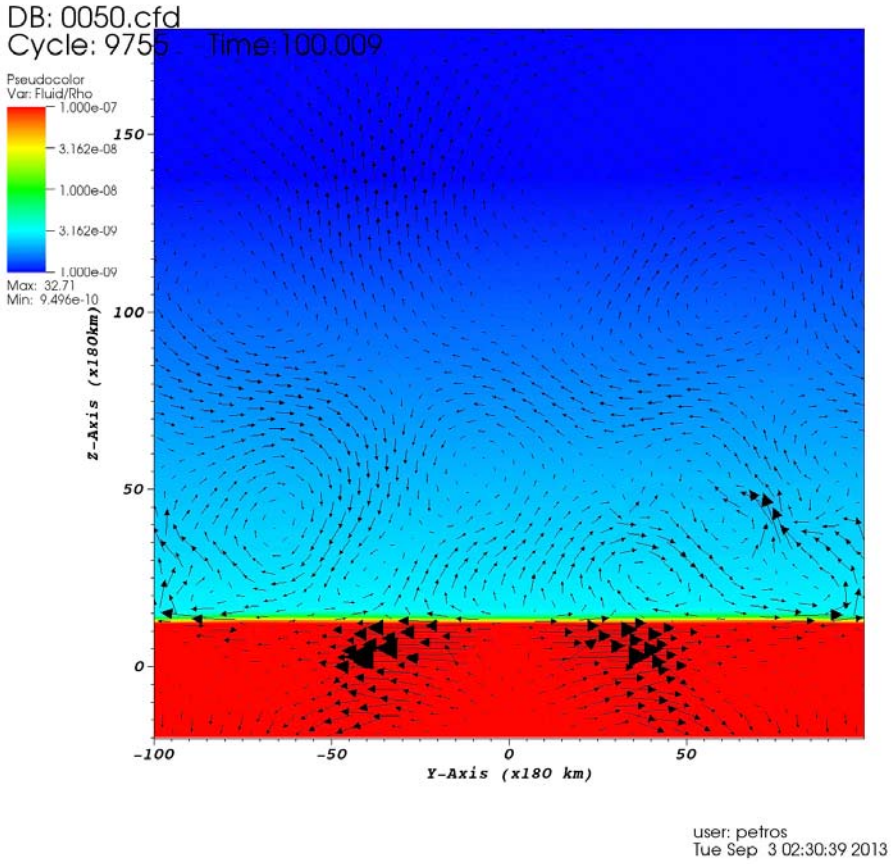
$$-H_p \frac{\partial}{\partial z}(\log B) > -\frac{\gamma}{2}\beta\delta + k_\parallel^2 \left(1 + \frac{k_\perp^2}{k_z^2}\right)$$





Non Twisted Flux Tubes – Emergence and Jets

The two emerging lobes come in contact and reconnect, forming jets, and an envelope magnetic field, which confines the jets.



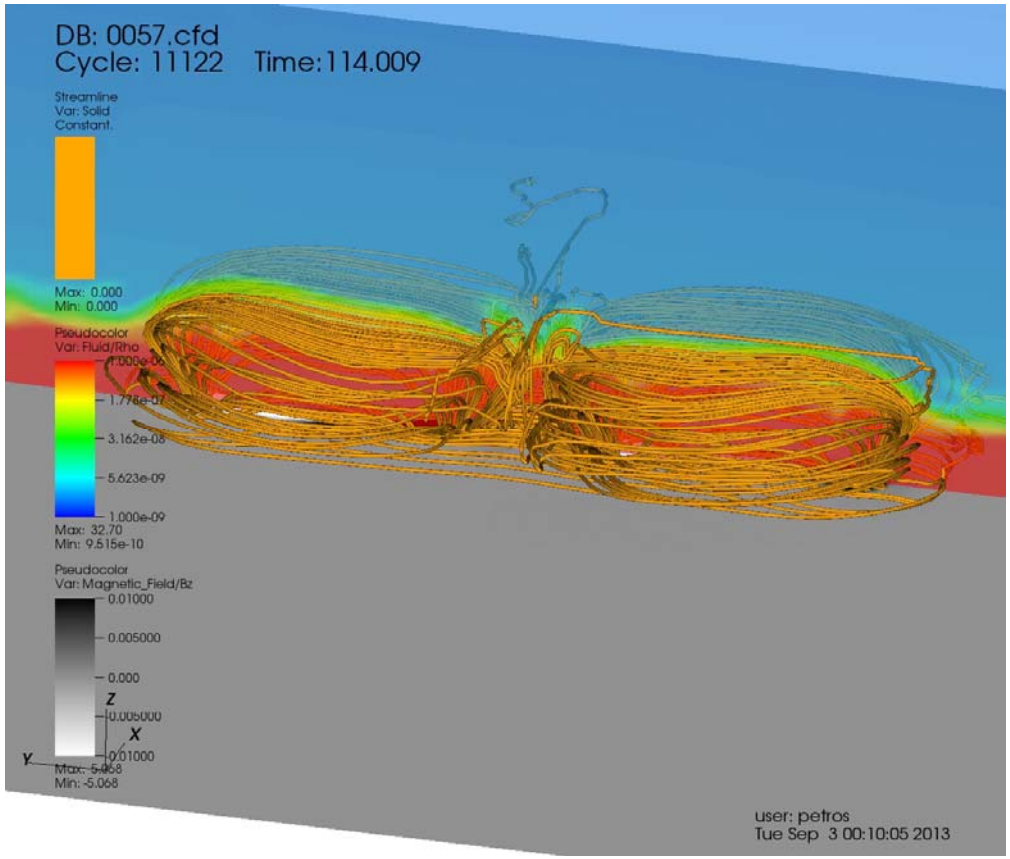
Simulation duration:
2h 51min (video: 1h 40min)

Ejection Velocities:
30-220 km/s

Ejection temperatures:
30.000K (compression ejections)
up to
5.2MK (reconnection jets)

Non Twisted Flux Tubes – Formation of a Twisted Flux Tube

Through reconnection, a twisted flux tube is formed in the place where the inner opposite polarities collide.

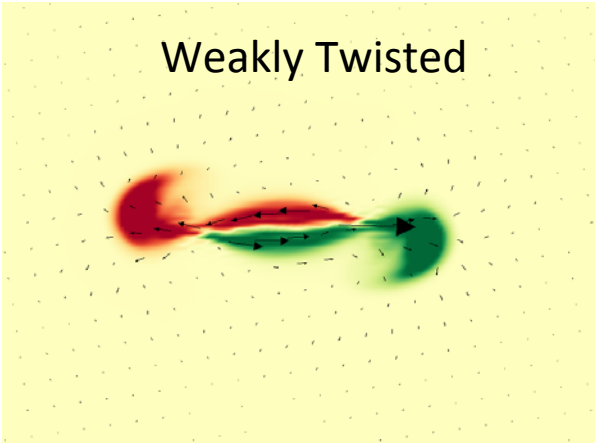


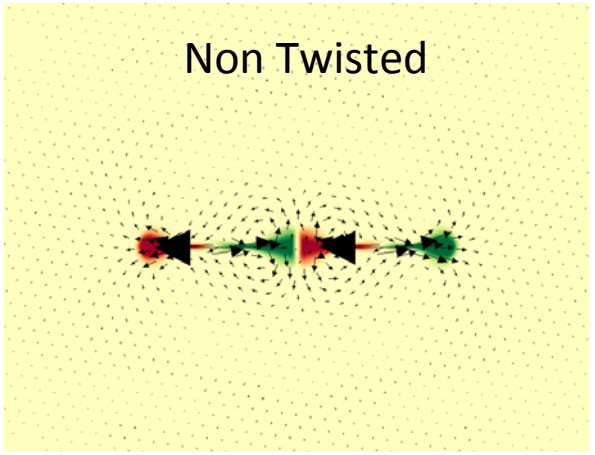
B_x Component:
a)3D topology of the reconnection site.
b)Motions around the PIL

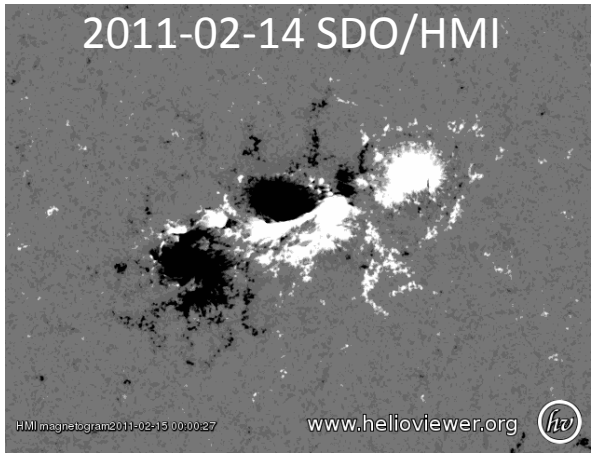
Observe flux cancelation at different height per time

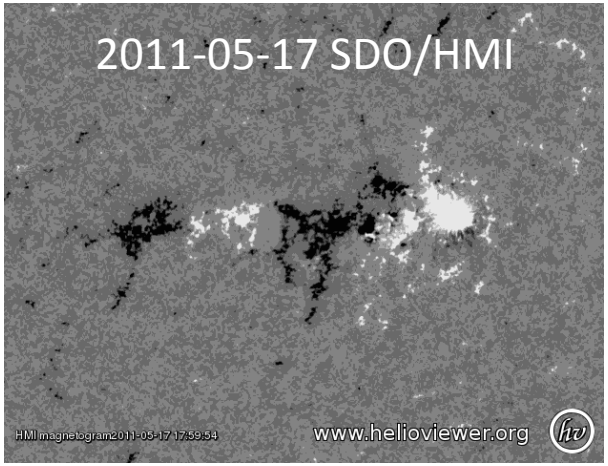
Observations ?

Maybe?









Thanks to Georgios Chintzoglou

Summary

In the non-twisted flux tube emergence we identify:

1)A double bipolar region emergence that leads to the formation of two interacting lobes.
2)Reconnection jets of temperature up to 5.2MK and velocity up to 200km/s
3)Formation of a magnetic envelope through reconnection
4)Formation of a twisted flux tube along the PIL

Future work:

1)Case of NTFT with $\lambda=5$ (smaller buoyant part of the tube)
2)Cases of weakly twisted and non twisted flux tubes with an ambient field
3)Observations (in progress)

Thank you!