Particle trajectories & impacts as predicted by slip-running reconnection

G. Aulanier, S. Masson, E. Pariat

with contributions

from
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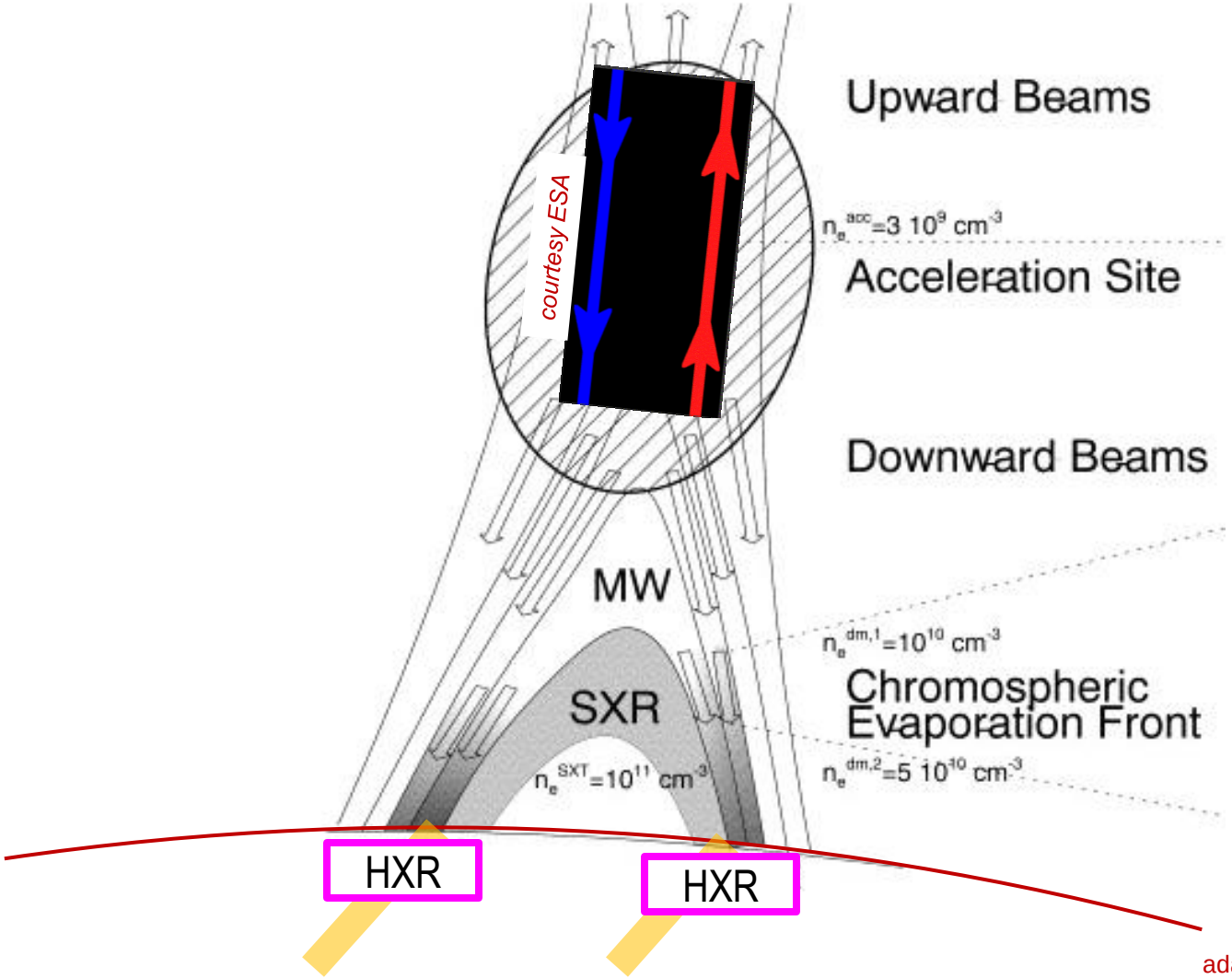
and
C.R. DeVore (NRL)

and
K. Schrijver (LMSAL)

The standard CSHKP flare 2D model

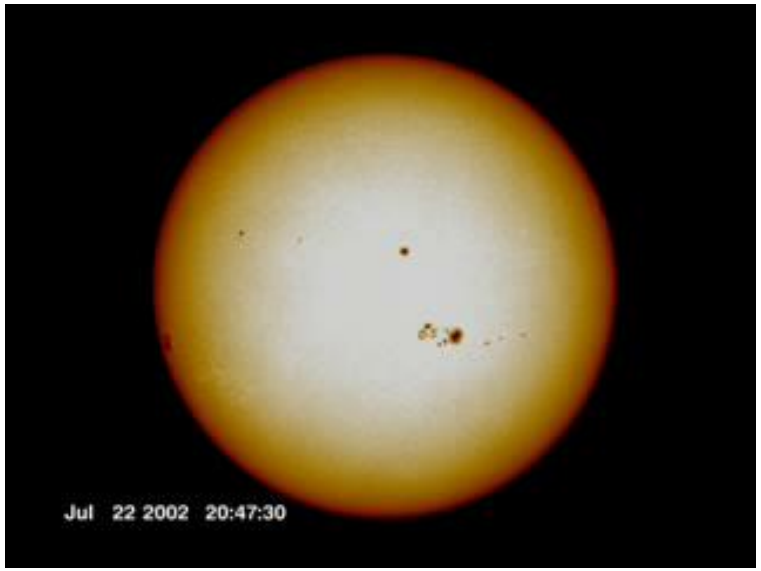


adapted from Aschwanden & Benz (1997)

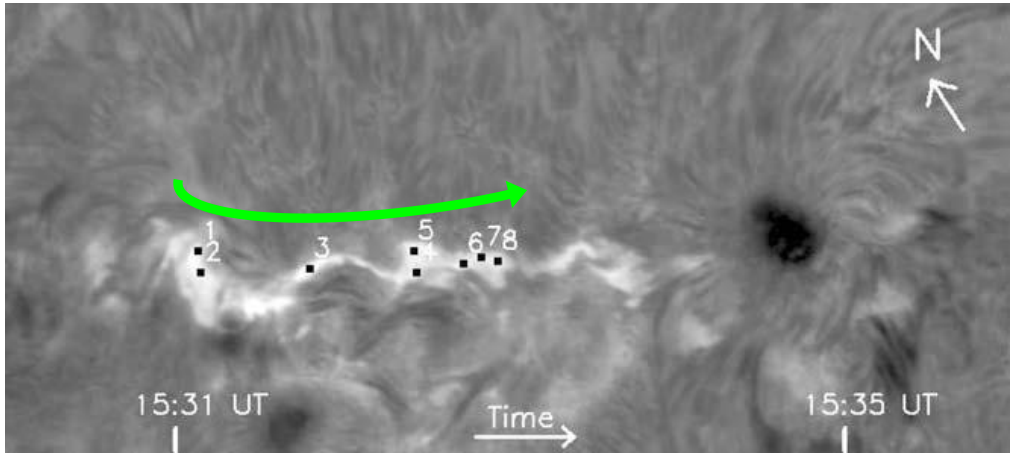
Ubiquituous moving multi-λ emissions along flare ribbons

HXR (RHESSI)
NASA / SVS
from Krucker et al. (2003)

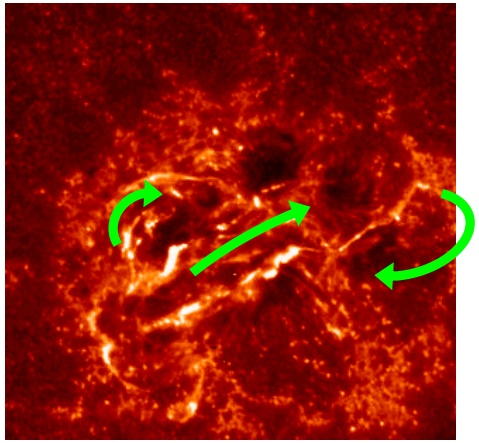
see also
Fletcher & Hudson (2002)
Bogachev et al. (2005)



Hα (VTT / MSDP)
Del Zanna, Berlicki, Schmieder & Mason (2006)



EUV (TRACE 1600A)
Chandra, Schmieder et al. (2009)

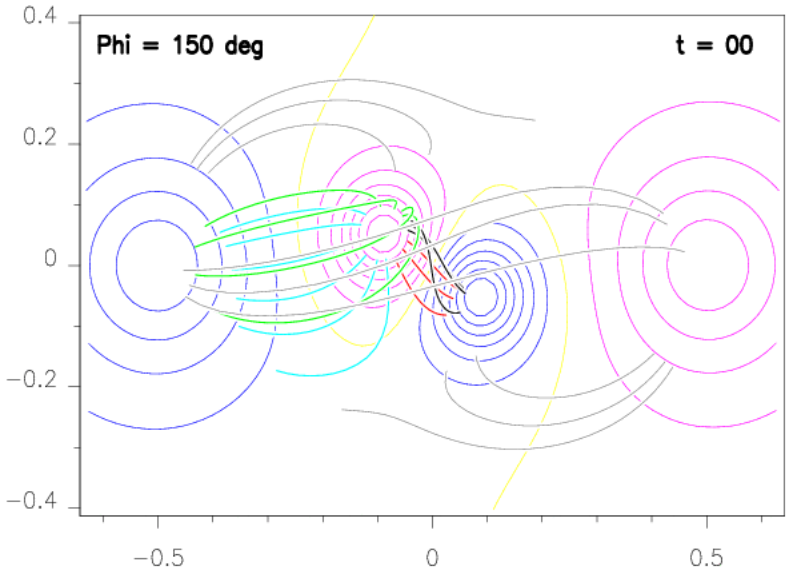


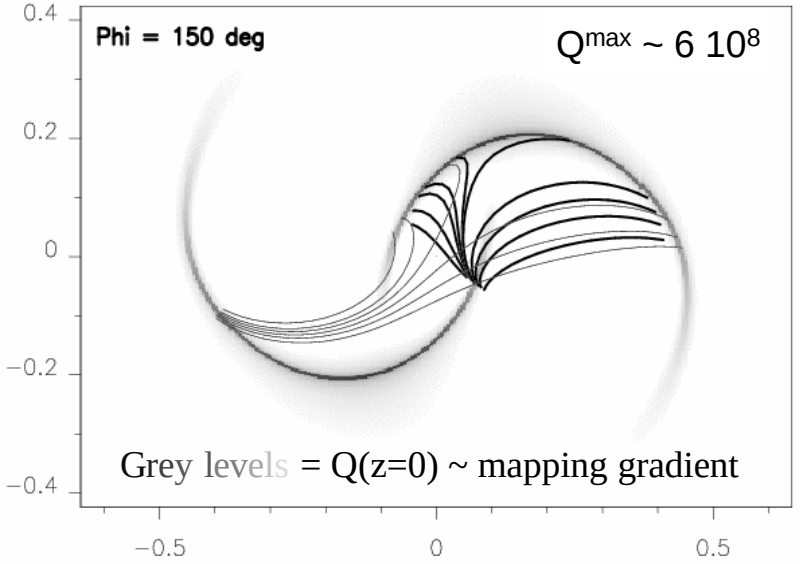
1. /5

Going from 2D to fully 3D

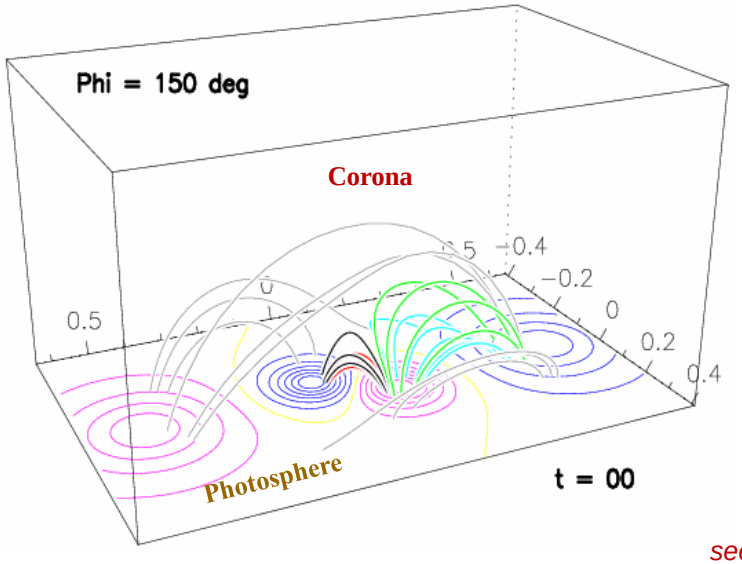
3D Quasi Separatrix Layers : *mapping gradients*

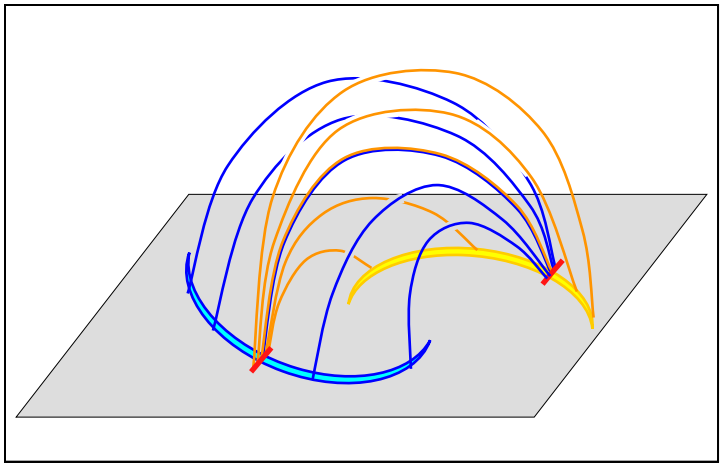
Top view





Projection view

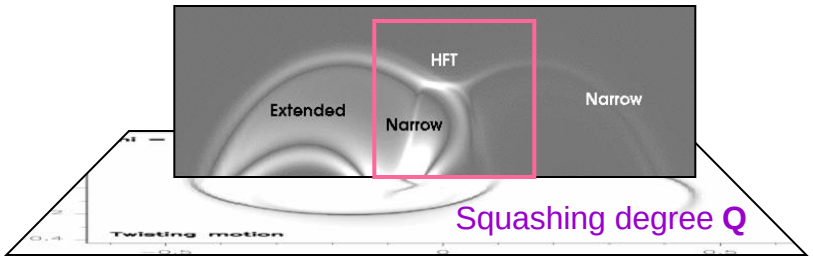


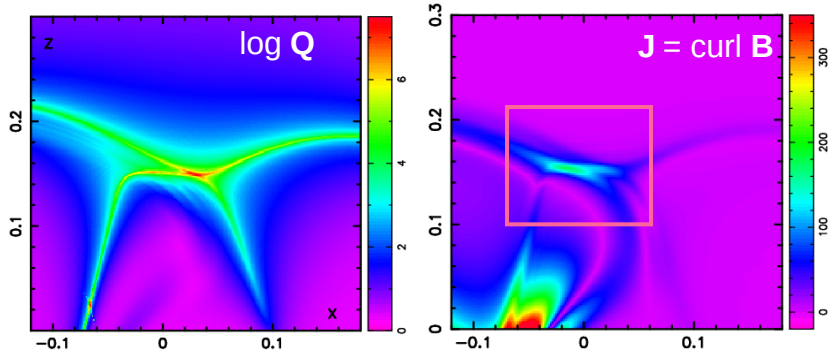


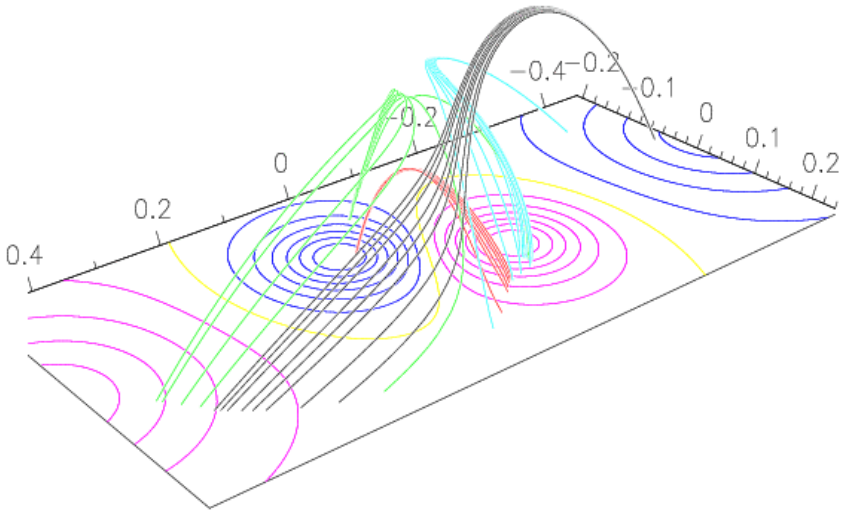
see Démoulin et al. (1996), Titov et al. (2002), Aulanier, Pariat & Démoulin (2005)

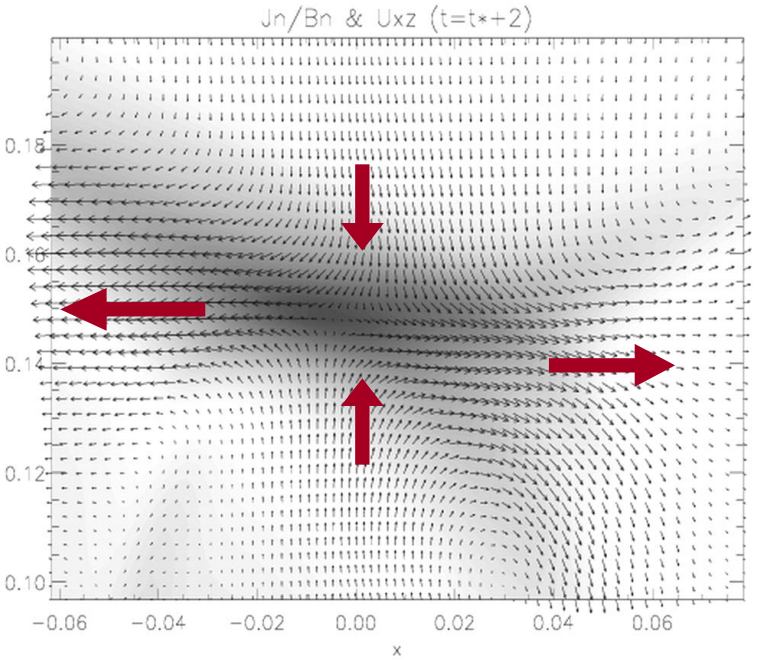
Reconnection jets & 3D fast field line slippage

Coronal currents









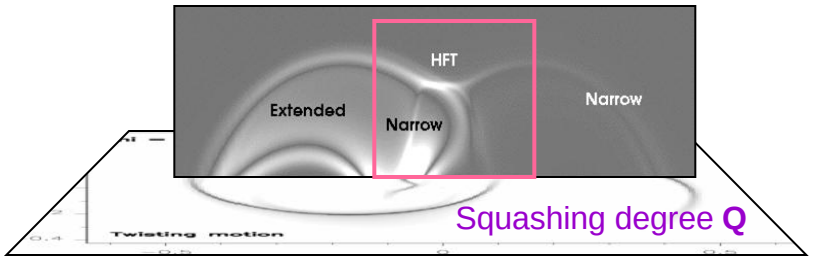
Aulanier, Pariat , Démoulin & DeVore (2006)

2. /5

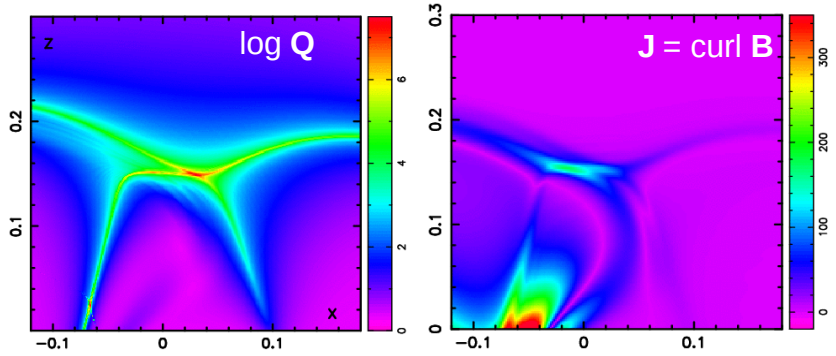
A direct observational example : slipping SXR loops

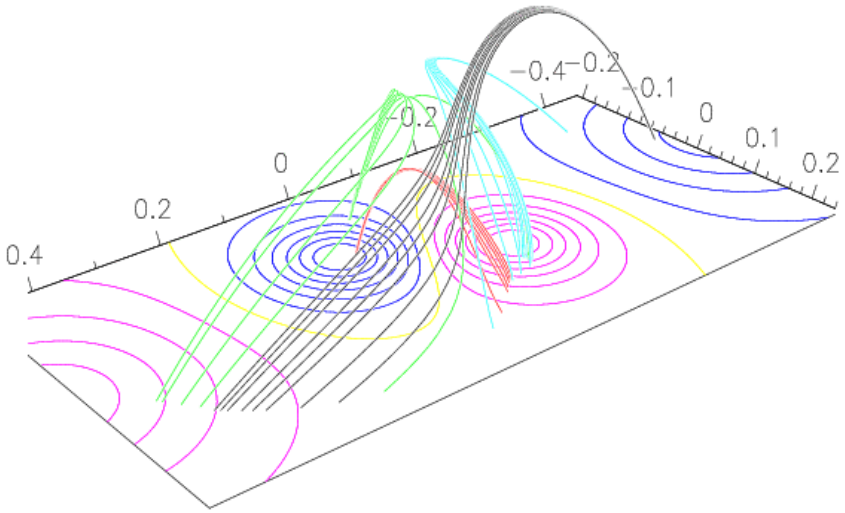
Reconnection jets & 3D fast field line slippage

Coronal currents

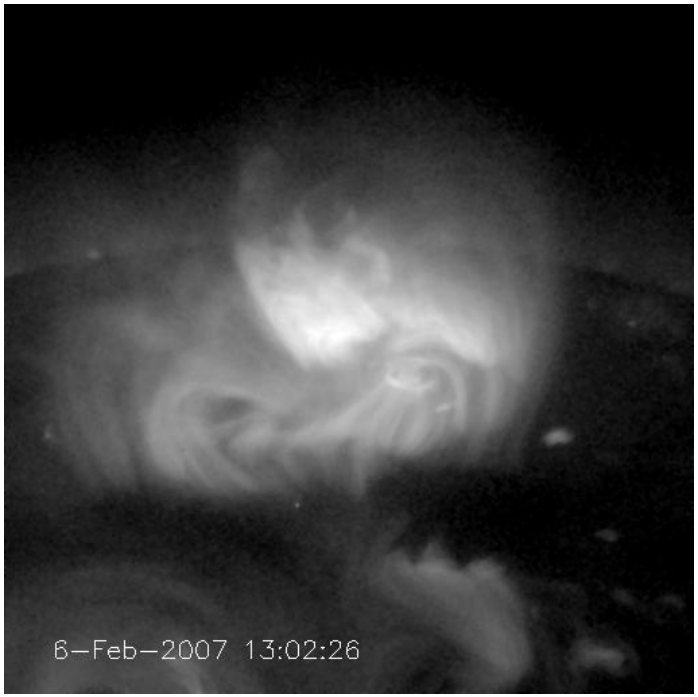


Squashing degree **Q**





Aulanier, Pariat , Démoulin & DeVore (2006)



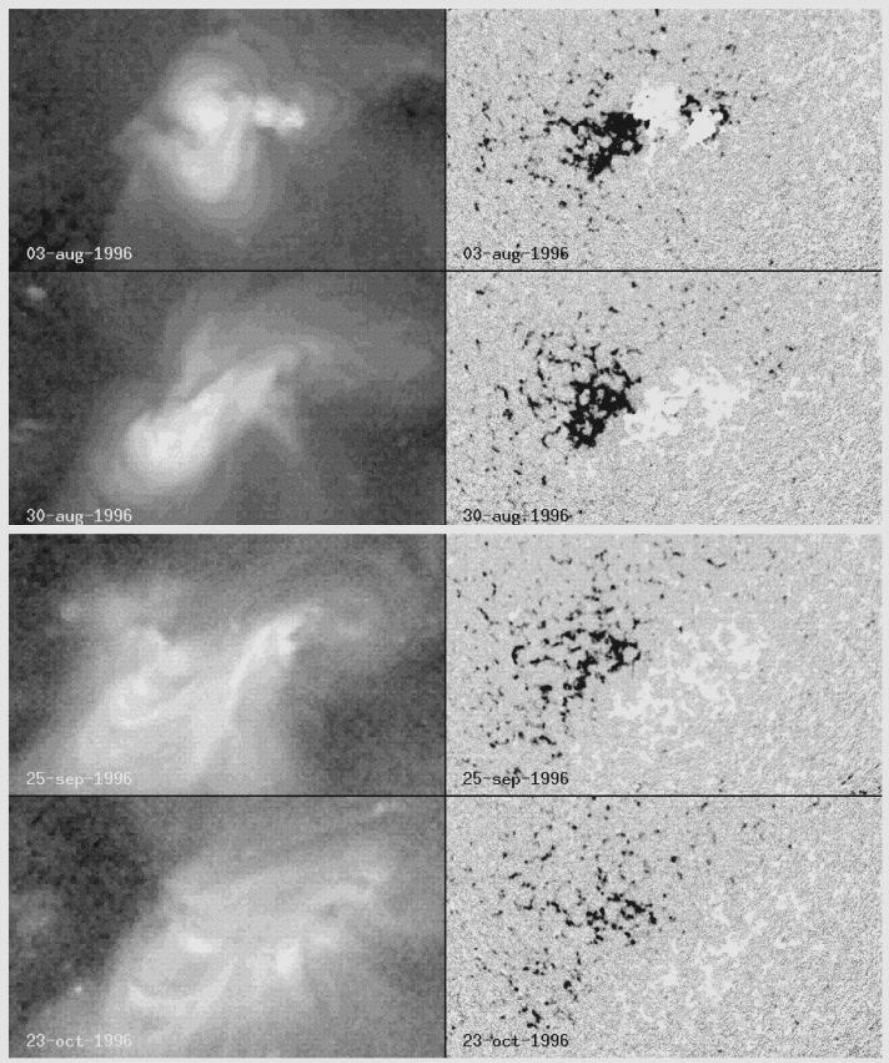
1-10MK slipping coronal loops
Hinode/XRT (Ti-poly)

Aulanier, Golub, DeLuca et al. (2007)

3. /5

Two-ribbon eruptive flares associated with CMEs

CMEs in sheared & decaying active regions

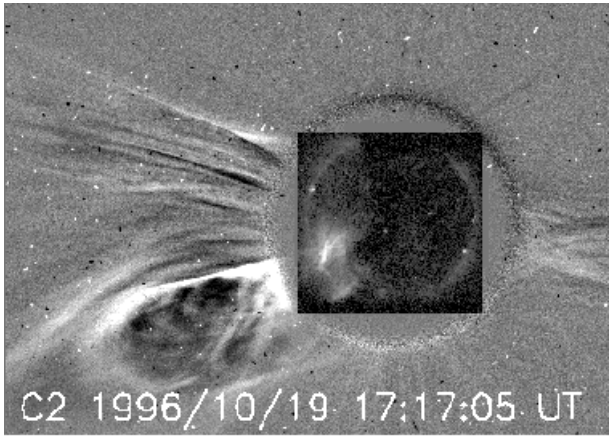


– **Flux = Σ Bz.dS** ↘

due to cancellation at PIL

– flare rate ↘

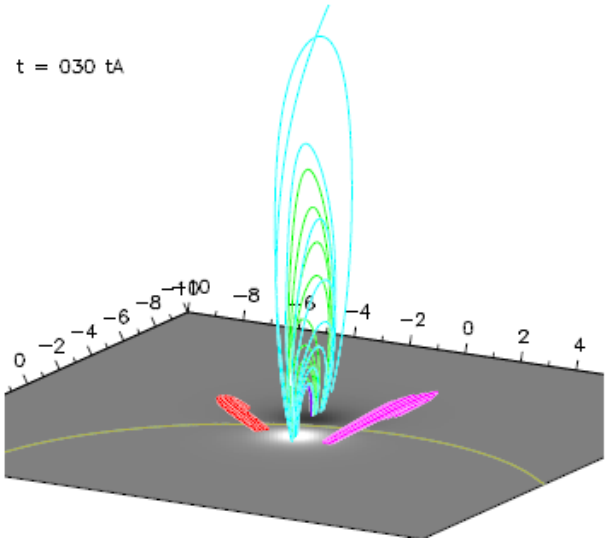
– **CME rate** **const**

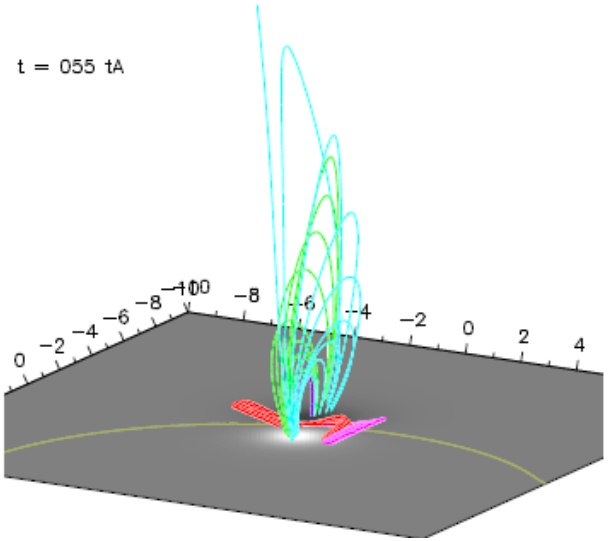


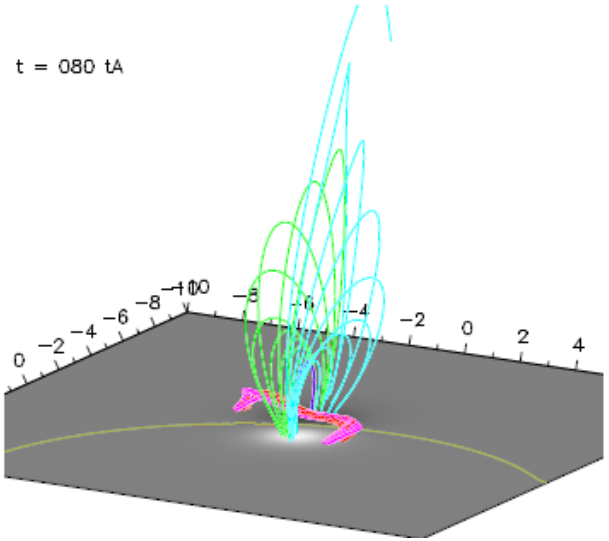
SoHO / LASCO
Yohkoh / SXT

Démoulin et al. (2002), van Driel Gesztelyi et al. (2003), Schmieder, Bommier et al. (2008)

Flux rope formation & growth

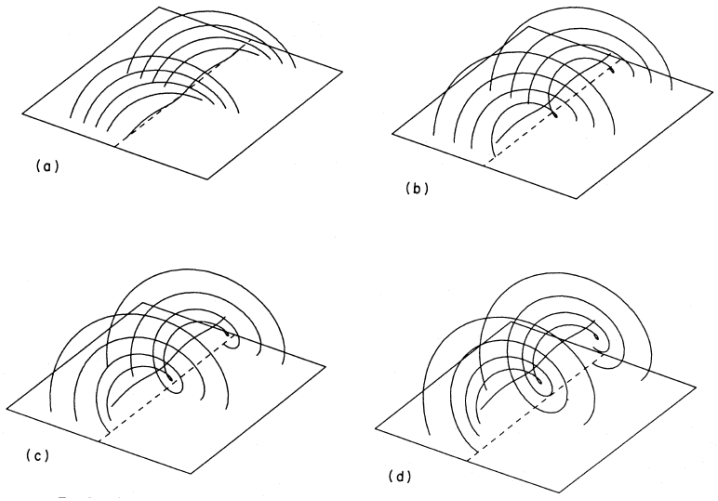




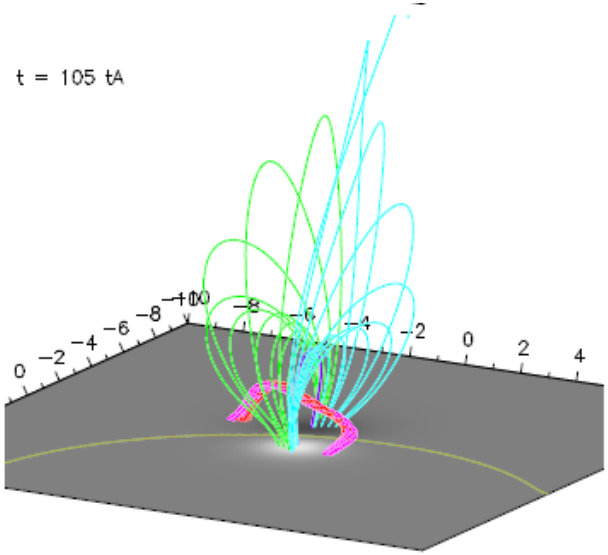


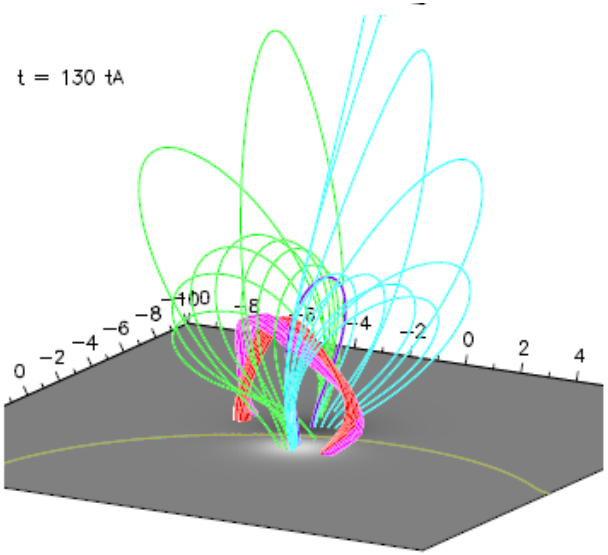
- Flux rope initially fed by photospheric flux cancellation, i.e. reconnection in U-loops at the PIL

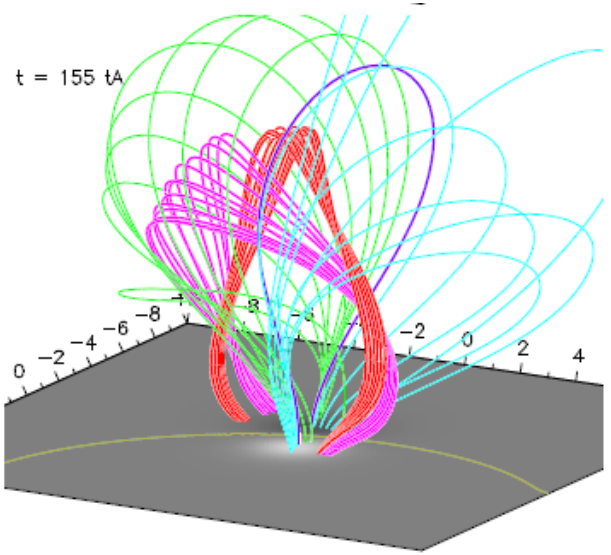
as in van Ballegooijen & Martens(1989), Forbes & Isenberg (1991)



Flux rope eruption & flare reconnection

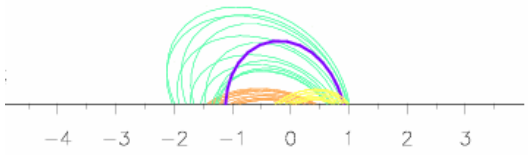




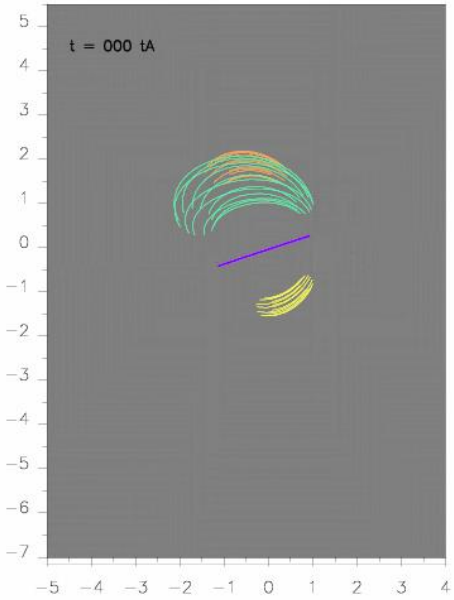


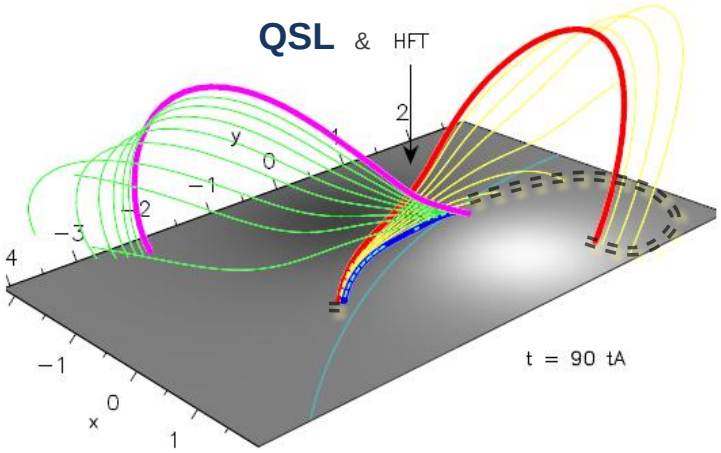
- Flux rope rapidly growths and accelerates
- Eruption continues freely only for t > 120 t_A (driven by the "torus Instability")
- Flare reconnection btwn orange and yellow lines

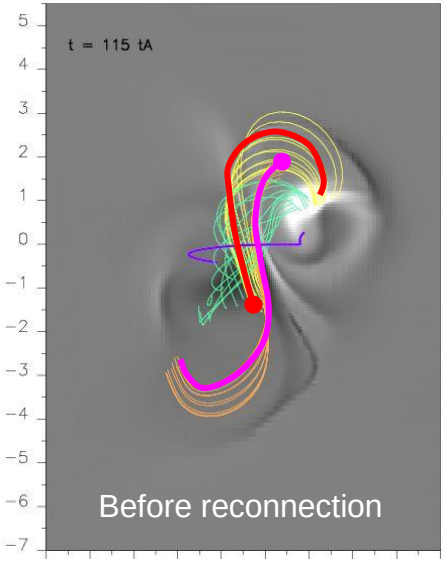
➔ does not drive the CME !

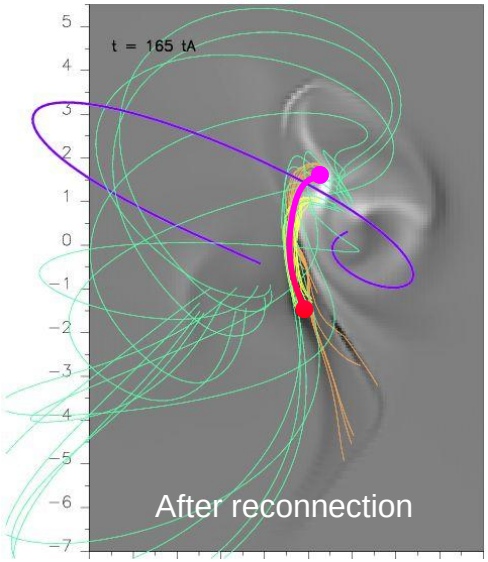


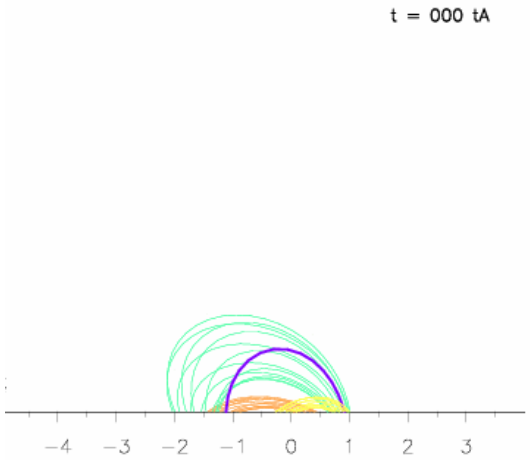
3D version of CSHKP model : slip-running reconnection







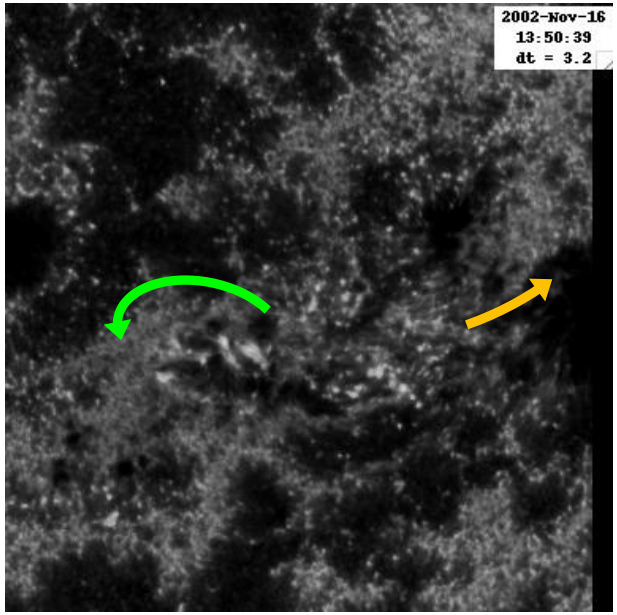


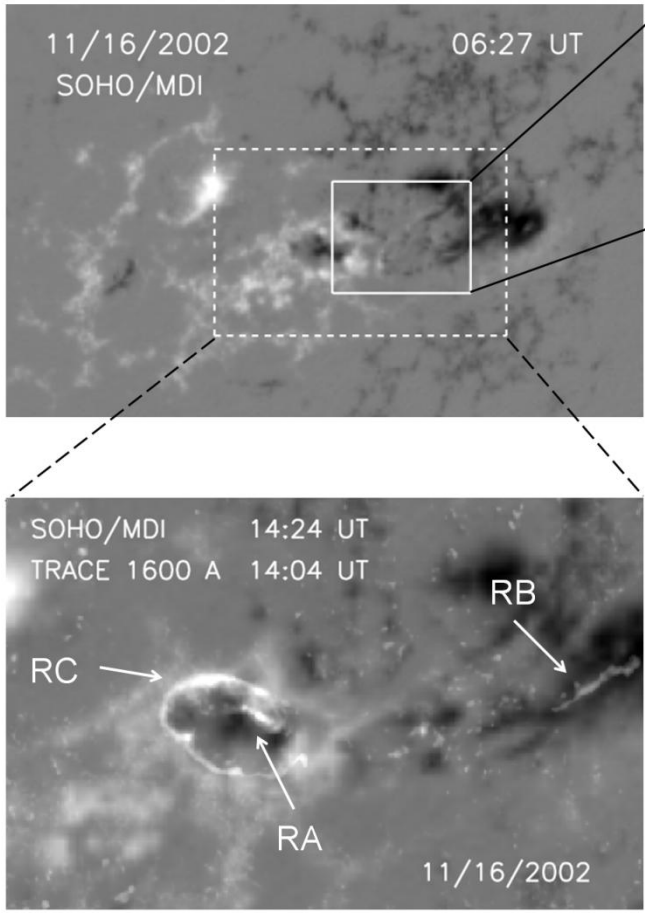


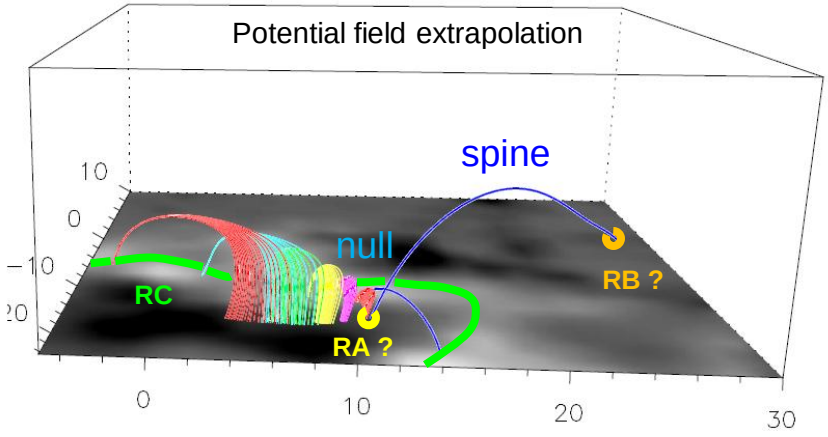
4. /5

Confined flares in null point topology

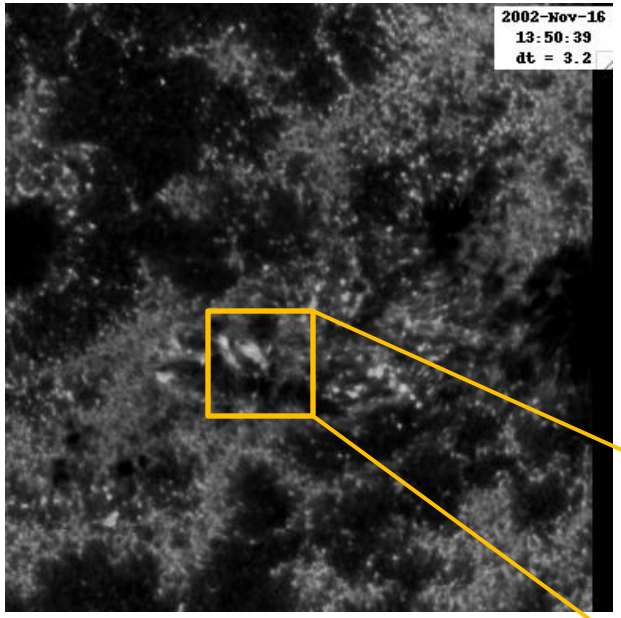
A confined flare related to a true 3D null-point

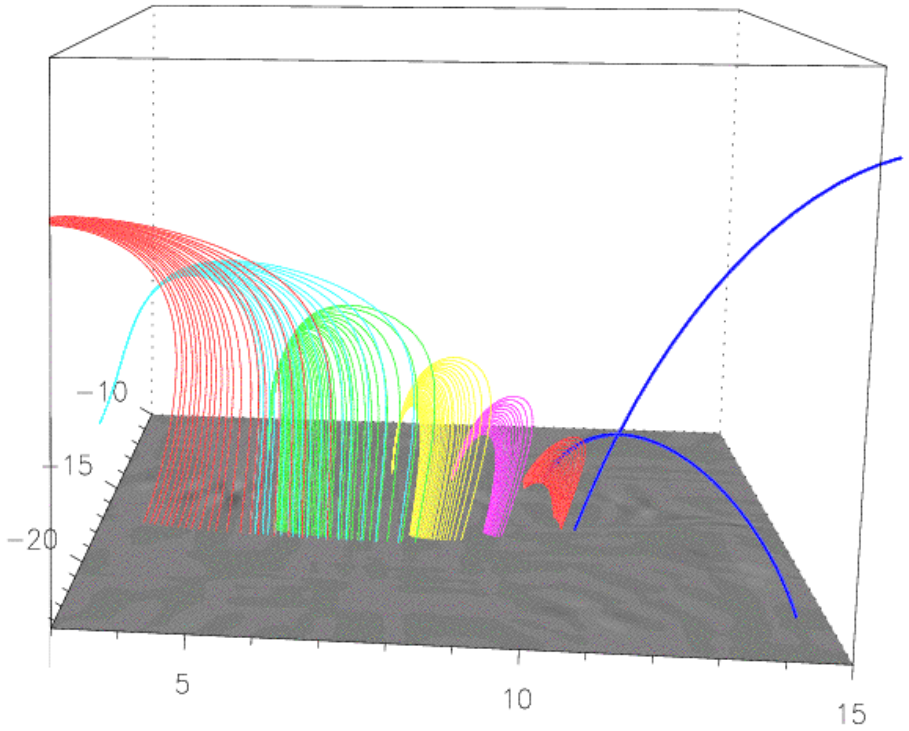


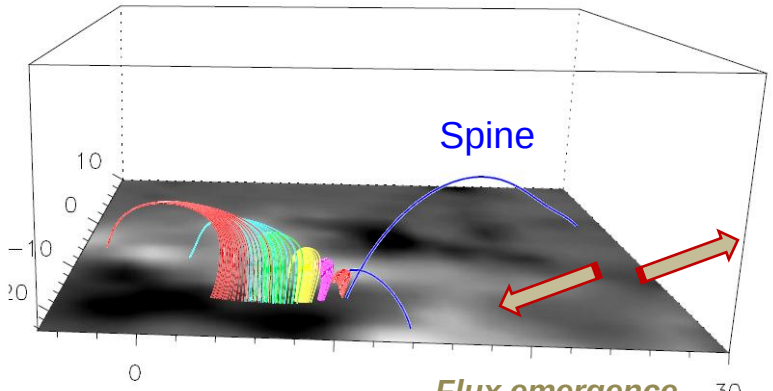




Slipping field lines before null-point reconnection



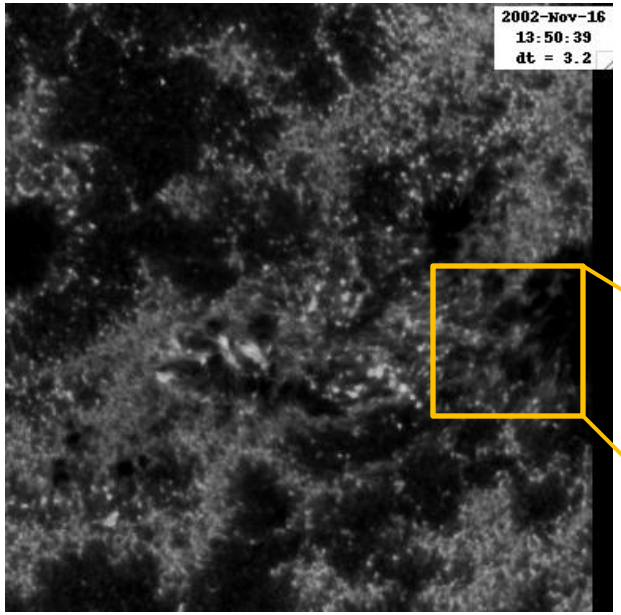


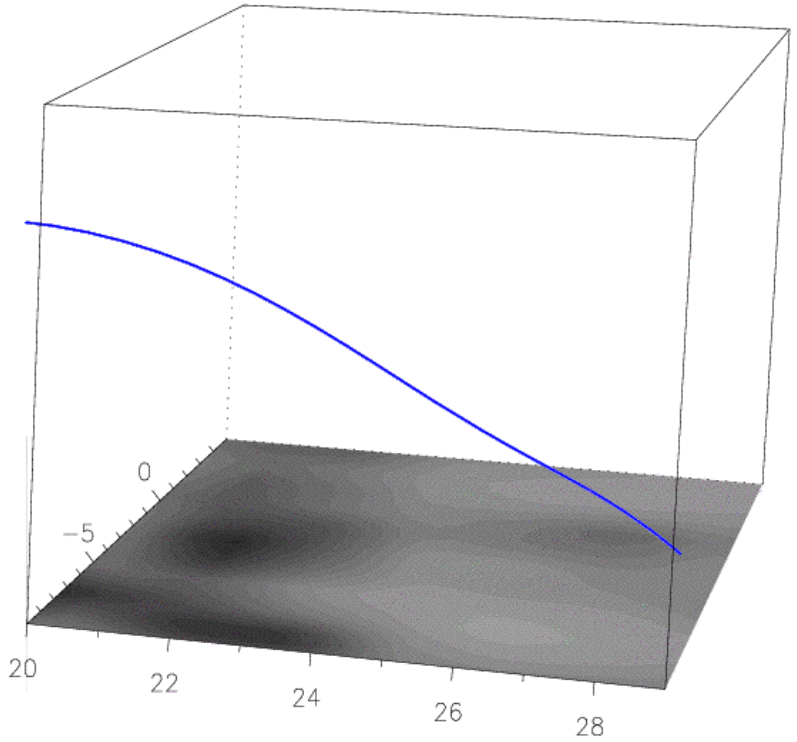


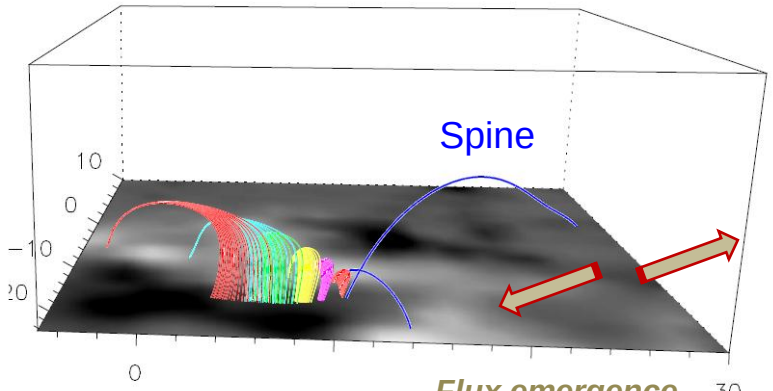
Flux emergence modeled by diverging flow motion

Masson, Pariat, Aulanier, Schrijver (2009)

Slipping field lines after null-point reconnection



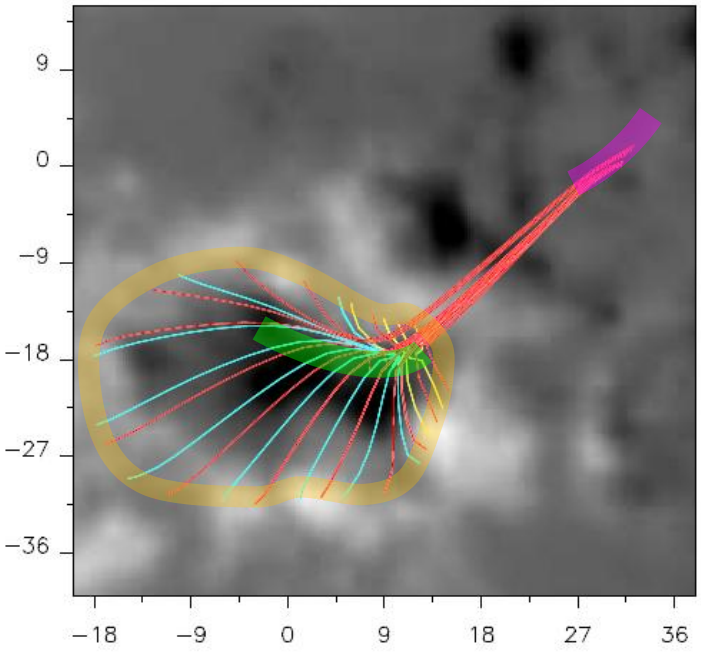


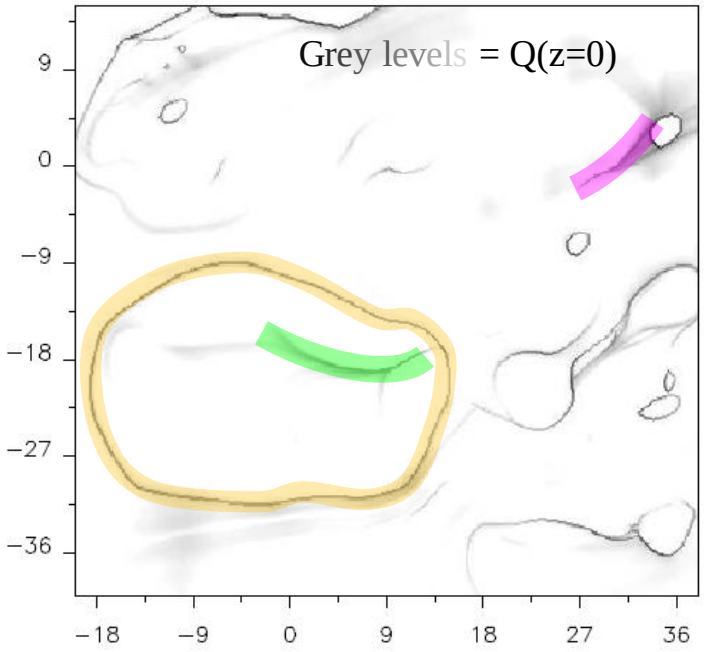


Flux emergence modeled by diverging flow motion

Masson, Pariat, Aulanier, Schrijver (2009)

Asymmetric null : separatrices + QSL halo

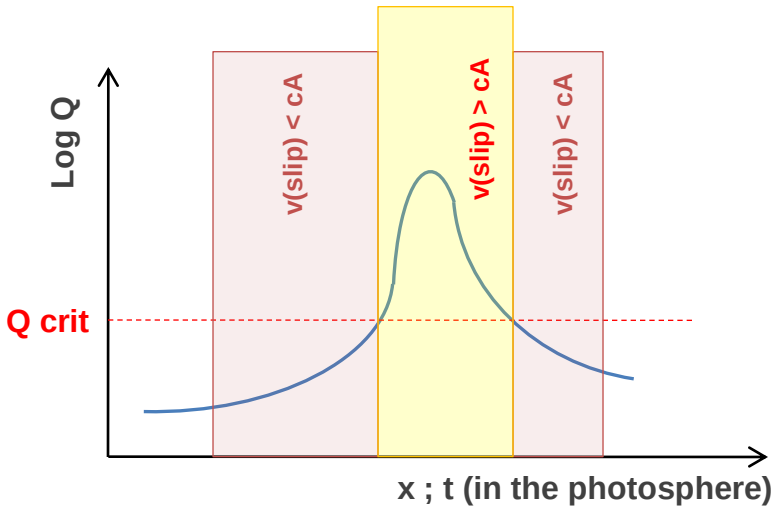




Field line slippage vs. topology of B

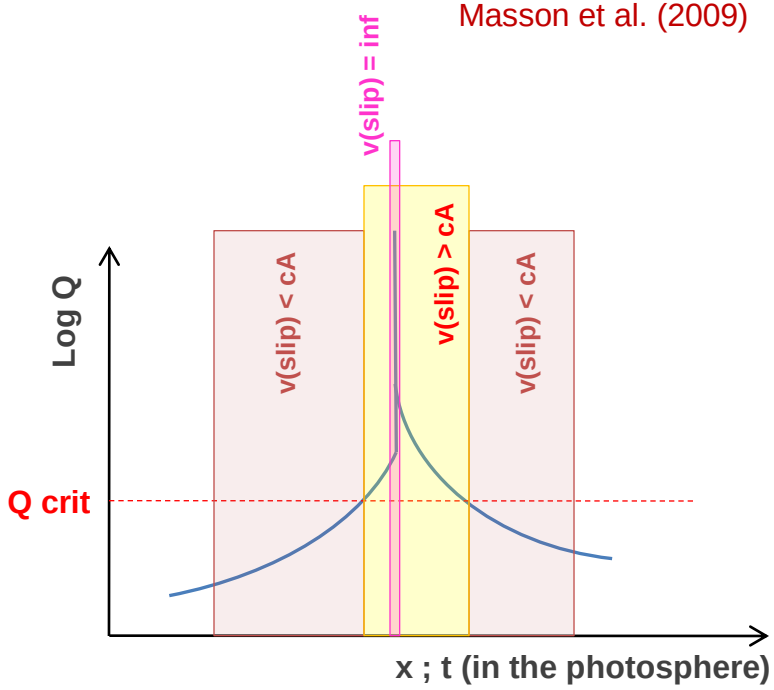
1) QSL case :

Aulanier et al. (2006)
Fletcher & Hudson (2002) ?



2) Null point case :

Masson et al. (2009)



Slipping reconnection ➔ **slow HXR footpoint motion**

Slip-running reconnection ➔ **fast HXR footpoint motion**

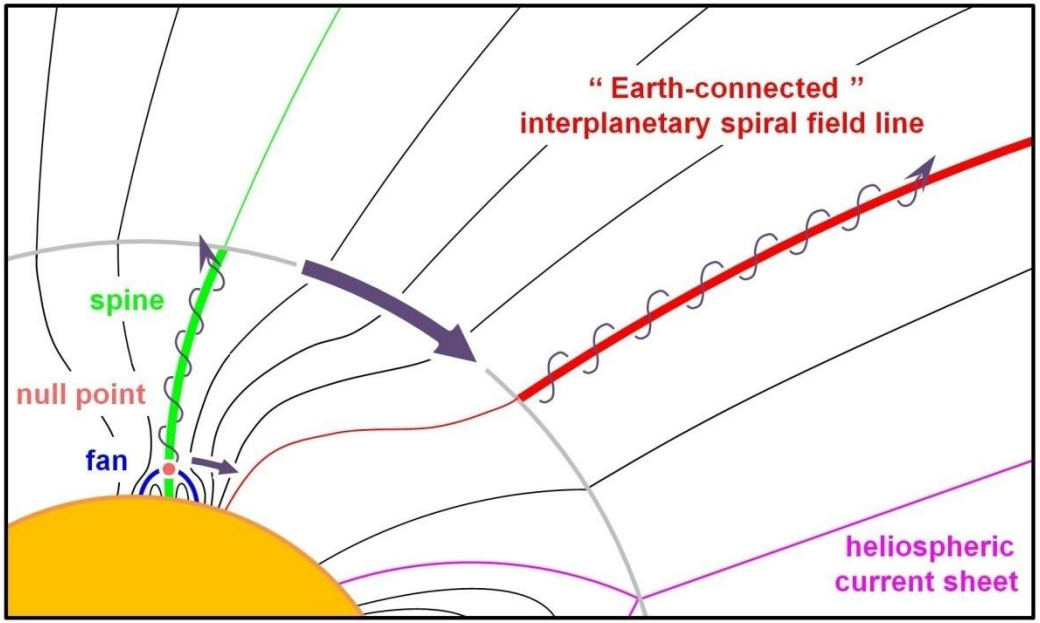
Null-point (or separator) reconnection ➔ **jump of HXR footpoint position**

Analogy with « torsional fan reconnection »
Priest & Pontin (2009), Al-Hachami & Pontin (2010) ?

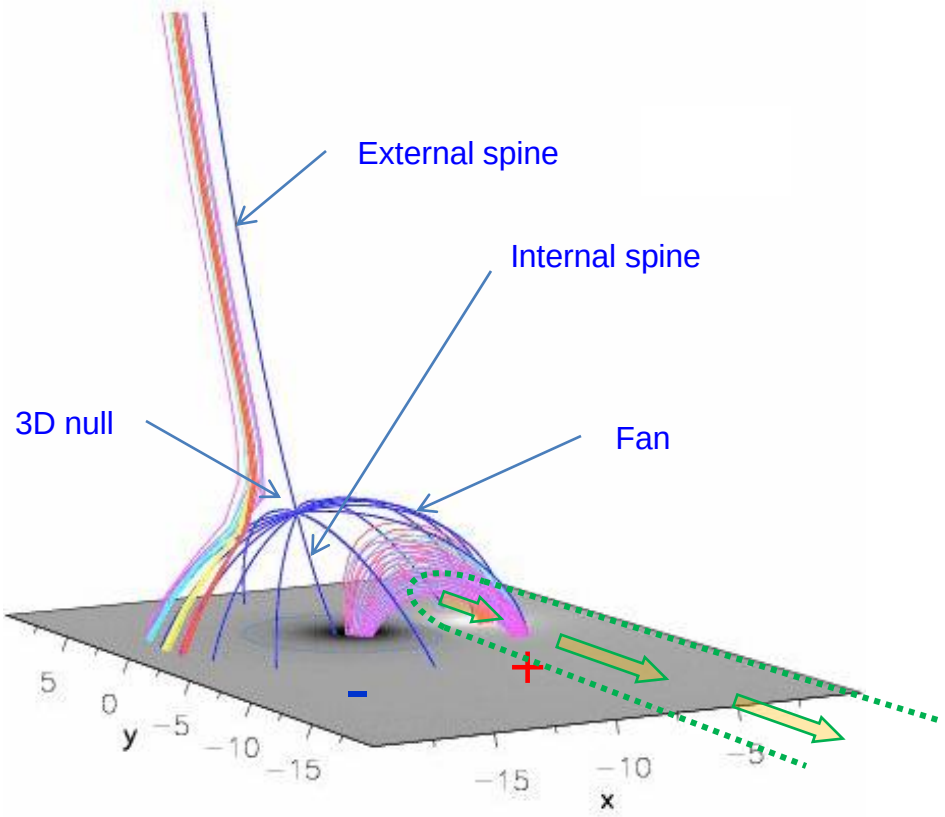
5. /5

Sweeping SEP beams

An often encountered problem …

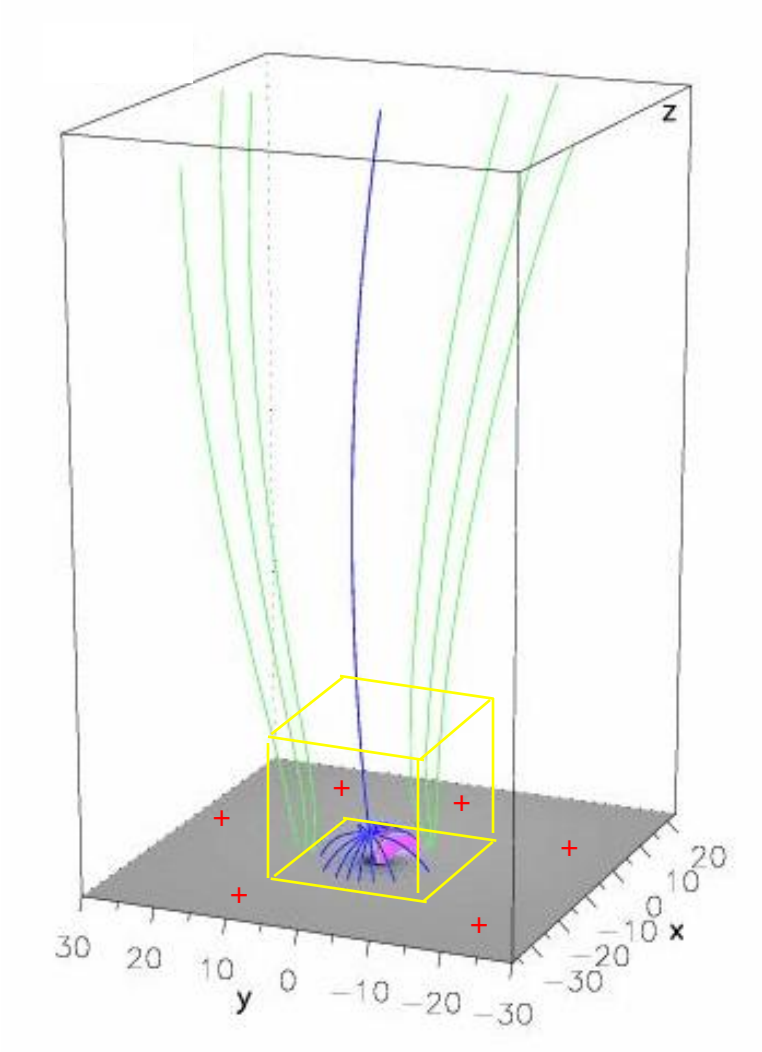


Initial configuration & photospheric driving



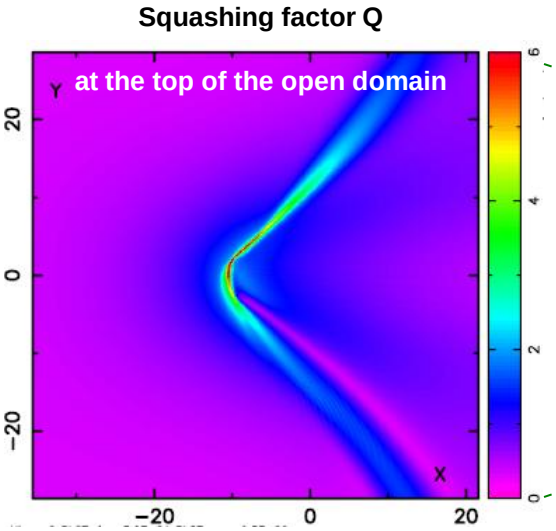
Photospheric motion

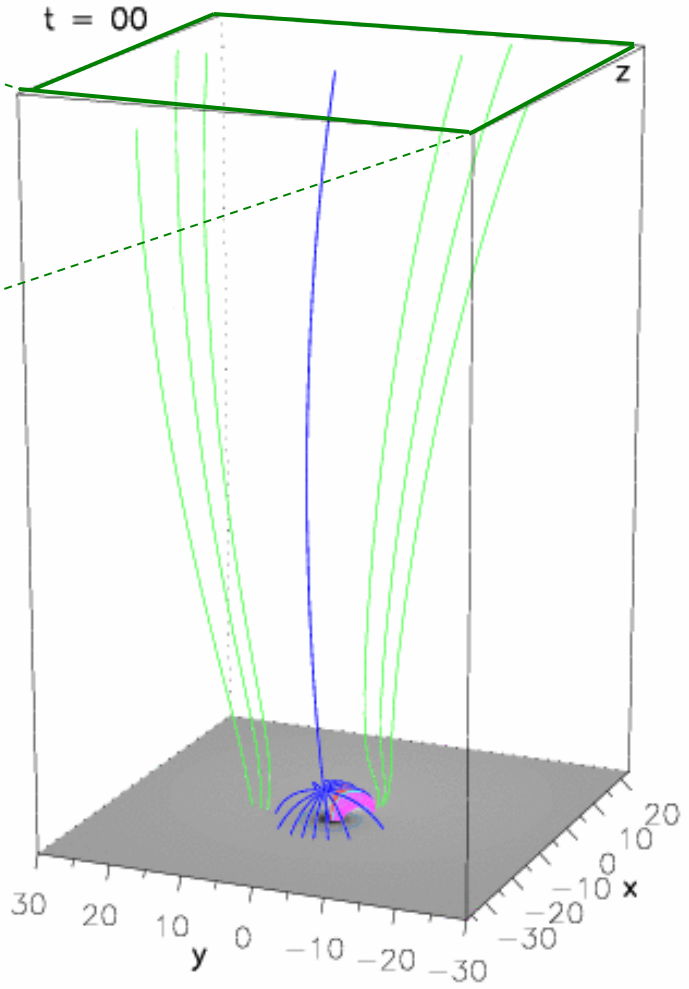
$U_{phot}^{max} = 0.35\ c_{Fast}^{coronal}$

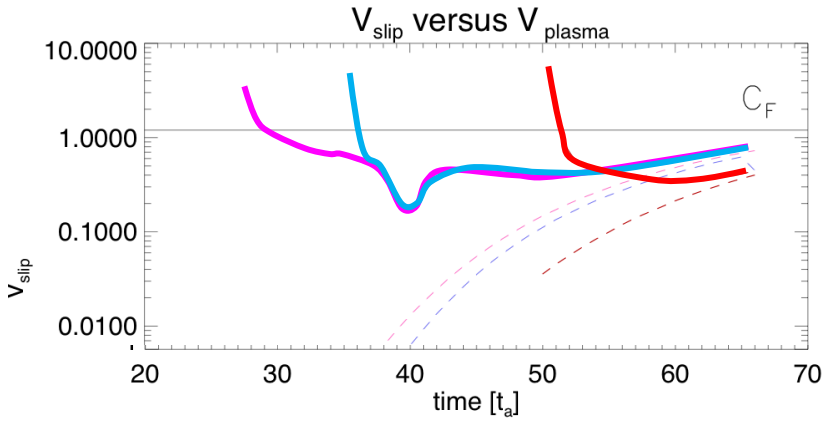


Masson, Aulanier, Klein & Pariat (in preparation)

Slip-running interchange reconnection

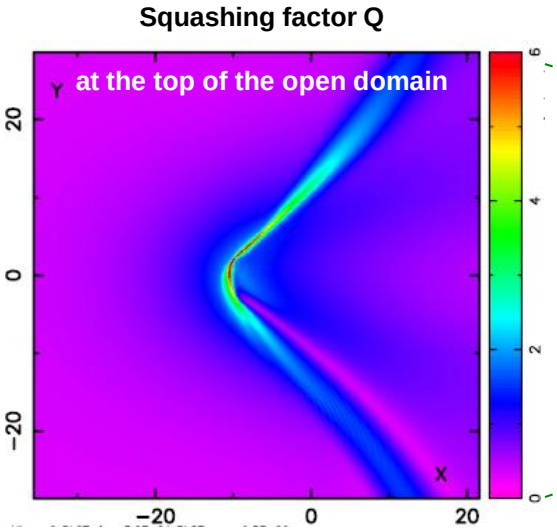


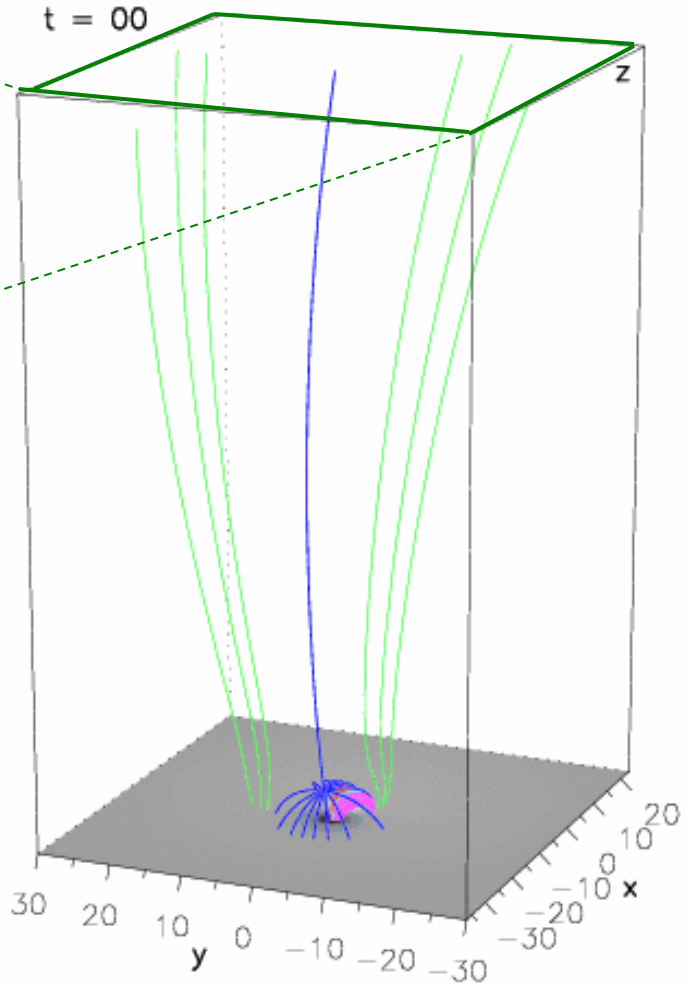


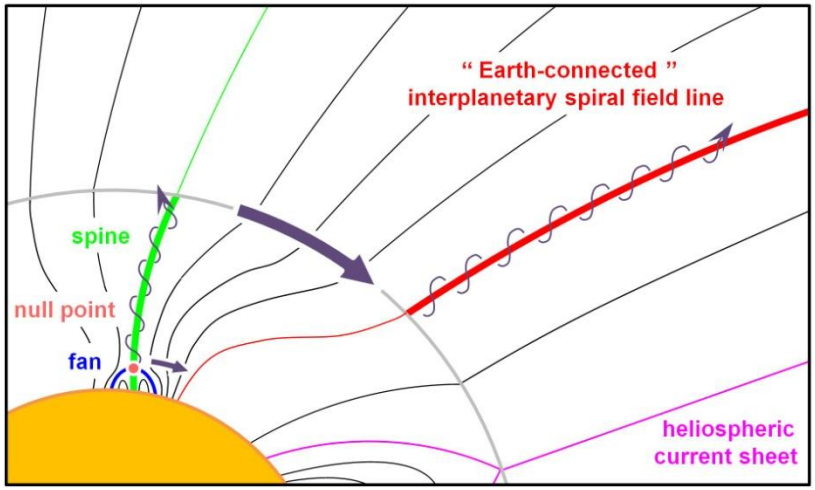


Masson, Aulanier, Klein & Pariat (in preparation)

Low-corona & MHD process (vs. IP & plasma effects)







Masson, Aulanier, Klein & Pariat (in preparation)

Slip-running reconnection in Quasi-Separatrix Layers

1) naturally occurs :

- in QSLs (regions of strong variations of field line mapping)

- around null points (because asymmetries associated with QSL halos)

1) naturally leads to :

- Slightly more extended acceleration regions

- Sweeping particle beams over large distances

- Moving impact sites of particles along flare ribbons (= QSL footprints)

- One peak in velocity of the impact sites (= field line moving footpoints)