

Vector magnetic field in Emerging flux

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1. What are the observed signatures of the EMF in the photosphere?

Are ephemeral brightenings due to reconnection of magnetic flux tubes?

2. What is the topology of emerging flux?
Constraints for simulations.

Vector magnetic field in Emerging flux

- ASP (Kubo et al 2003)
- • Flare Genesis experiment (Bernasconi 2002, Pariat et al 2004)
- Hinode/SOT (Otsuji et al 2007, Ichimoto et al 2008)
- • THEMIS/MTR (Pariat et al 2007)
- • Hida VMG (Watanabe et al 2008)

Spectropolarimetry

Stokes parameters IQUV

Inversion of the Stokes parameter

(MELANIE, INVTOOLS, UNNOFIT...)

Resolution of the 180 degree of ambiguity

FLARE GENESIS EXPERIMENT 2000

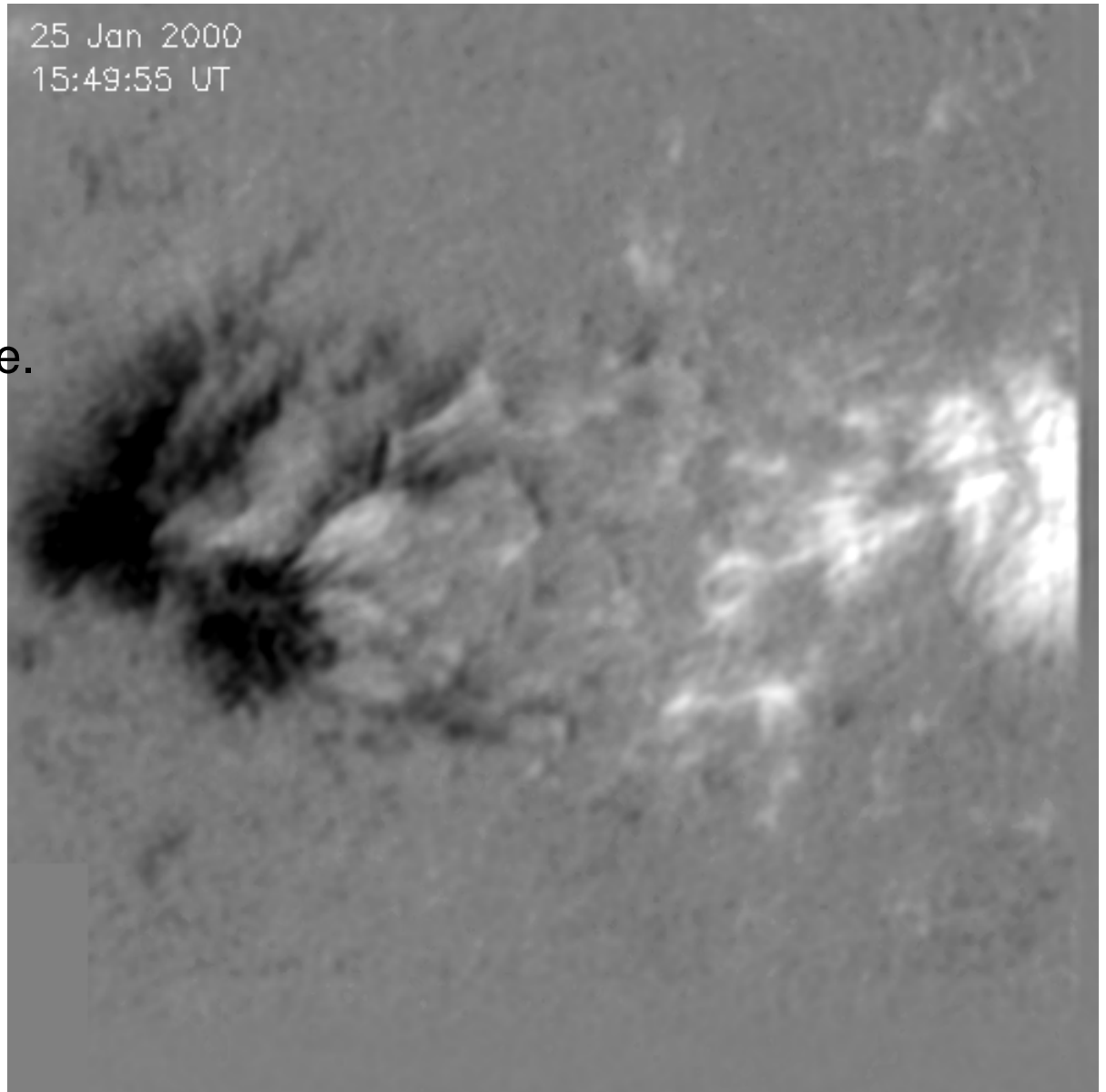


- ❑ **Balloon** ~ 35 km altitude during 17 days.
- ❑ **Main telescope:** Cassegrain, **80 cm Ø**, F/1.5
Spatial resolution: theoretical 0.2" in flight 0.5"
- ❑ **Gondola pointing accuracy:** ~ 10"
- ❑ **Image Motion Compensation** system (IMC):
fast tip-tilt mirror (about 1".)

Imaging Vector Magnetograph

- Polarization analyzer: 2 liquid-crystal polarization modulators + 1 linear polarizer.
- 0.16 Å lithium-niobate **Fabry-Perot** etalon filter coated for 6000 - 6600 Å operation.
- Field of view: **100" x 100"**

Magnetic field



Magnetic field measures from:

- * Stokes using Ca I 6122.2 Å line.
(I, V, Q, U)
. Cadence 6min

- * Calibration with IVM vector magnetograms

- Longitudinal and Transversal
• Field Components

- * Solution of the 180° ambiguity

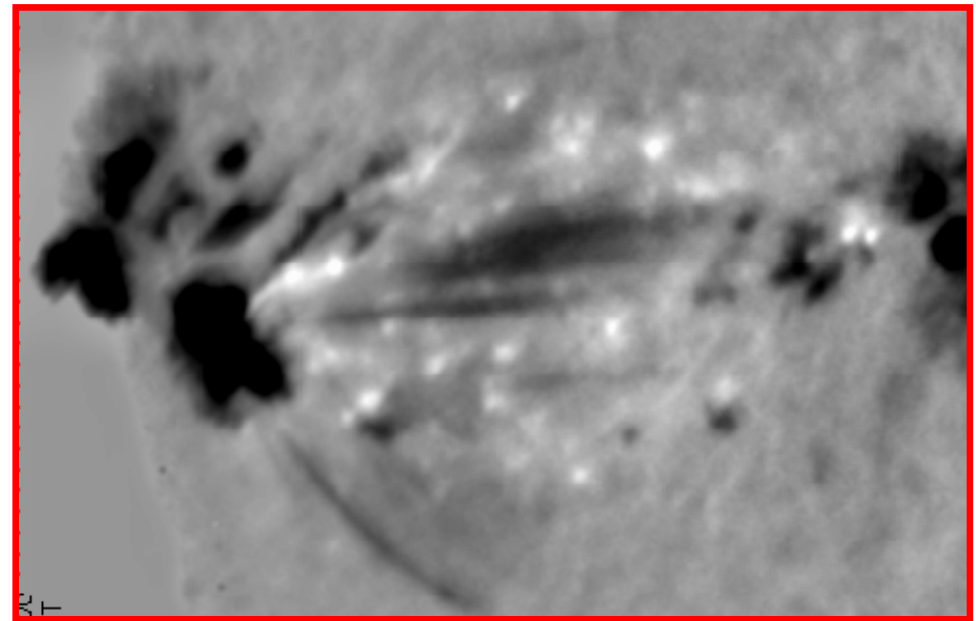
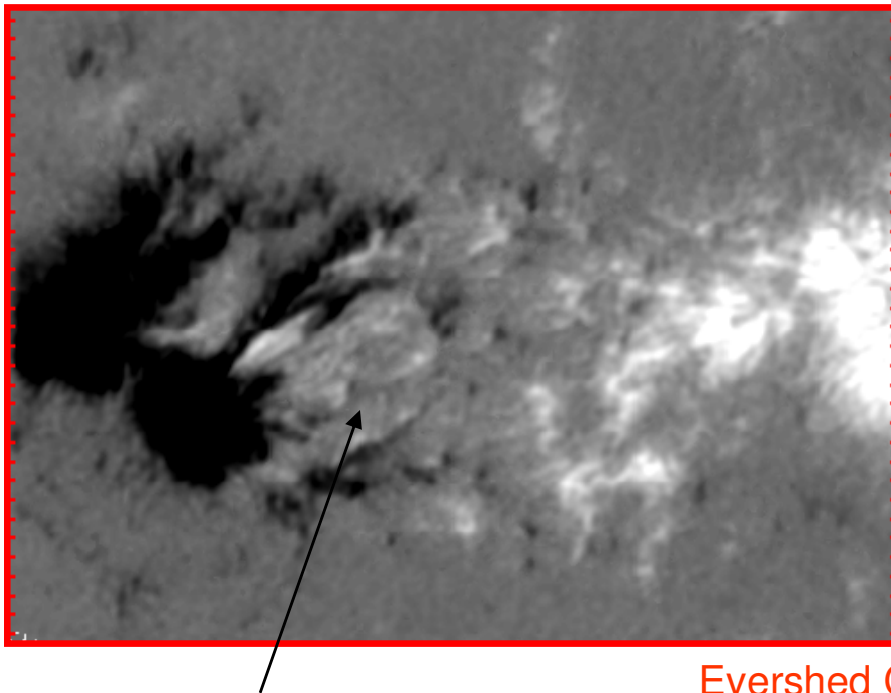
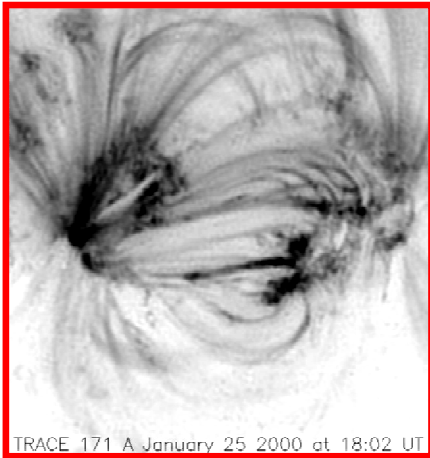
(Rust 1999)

Evershed Conference India 08

4 hours

Ellerman bombs (EB)

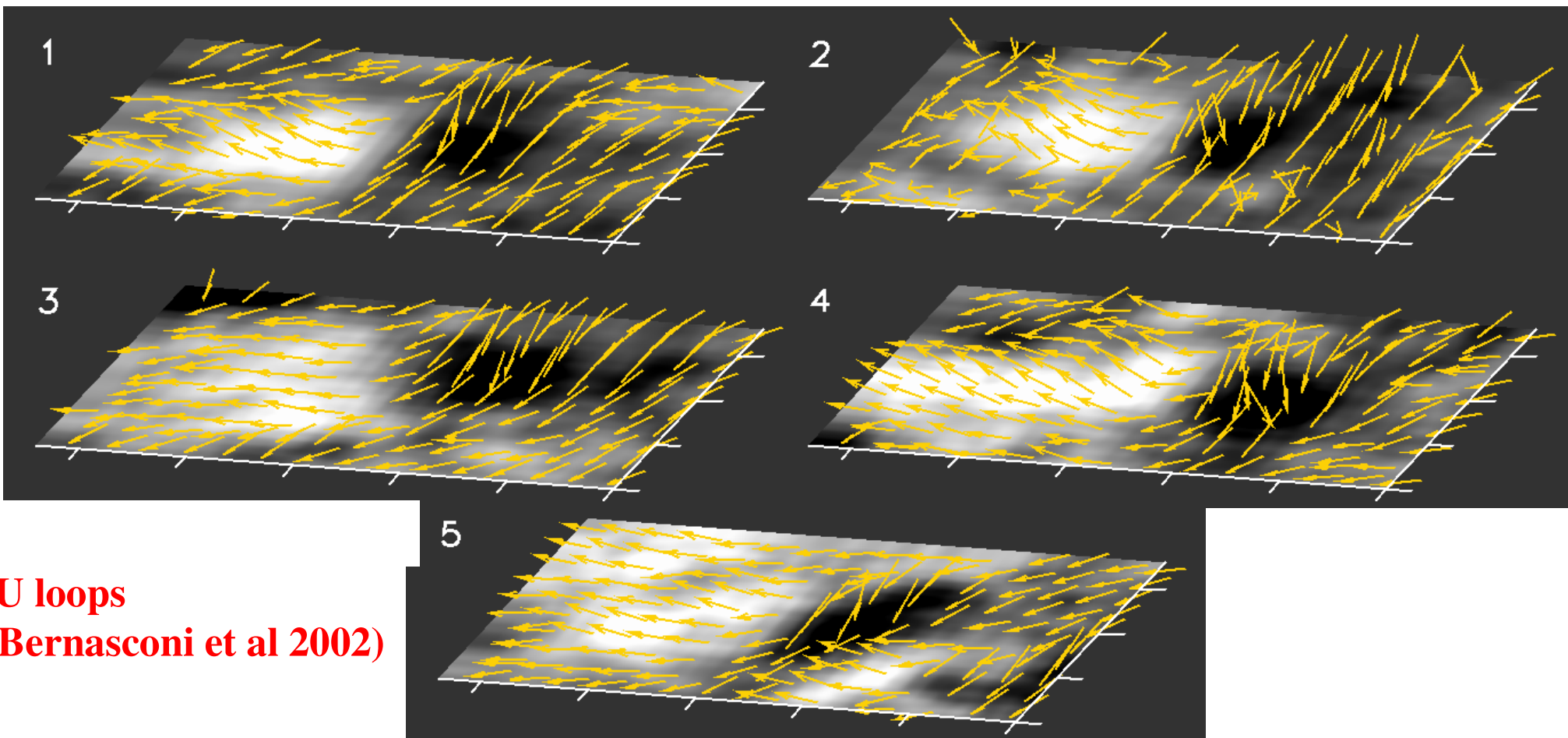
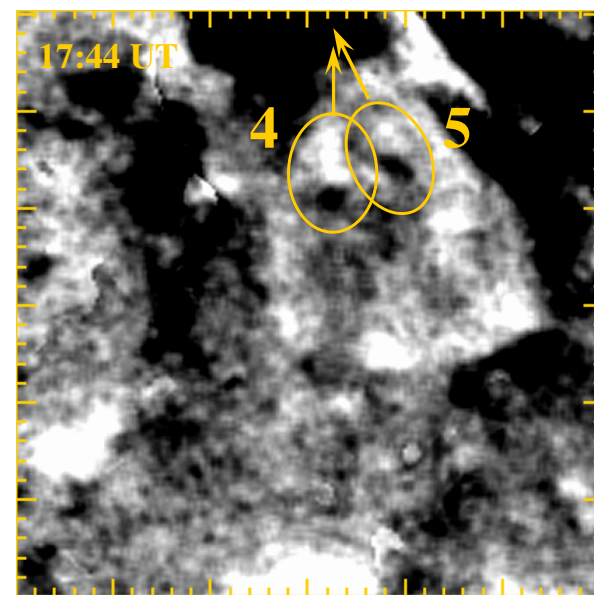
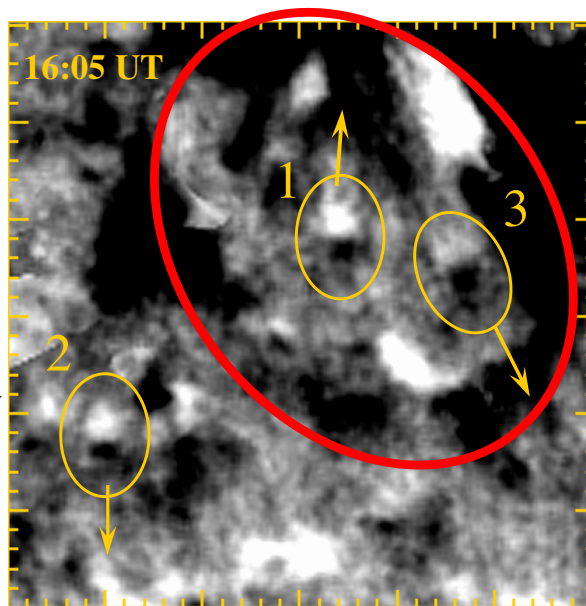
- Ellerman bombs visible in the wings of $H\alpha$, Ca lines, in 1600Å
- Life times 20 min
- Elongated structures
- Downflows (Georgoulis et al 2002)



Vector Magnetic field

Emergence of bipoles inside
the supergranule

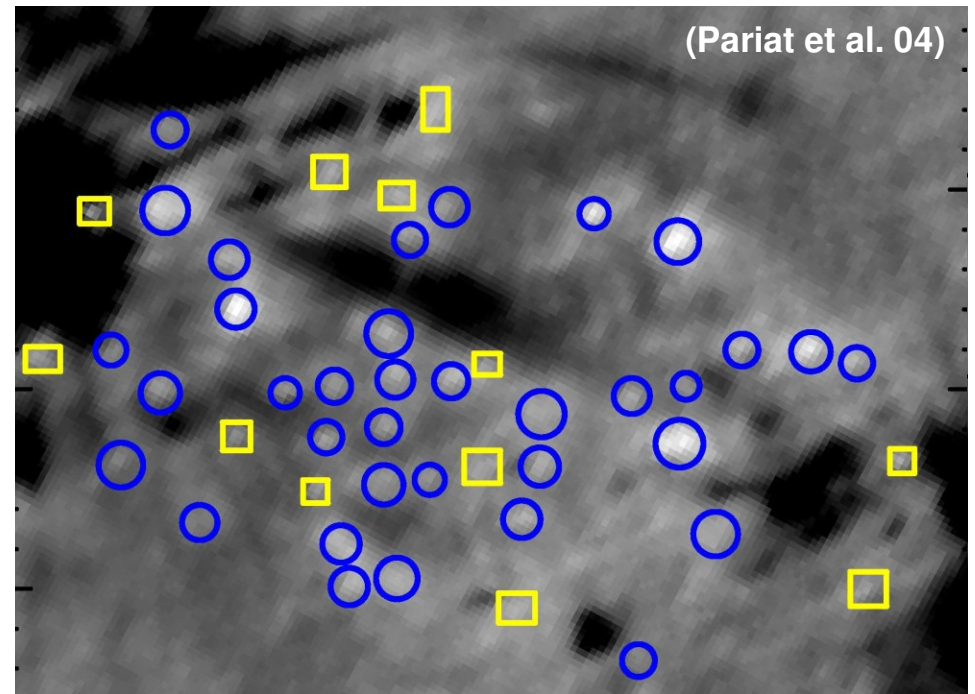
Tick marks separation is 1".



U loops
(Bernasconi et al 2002)

Link with magnetic topology

- EBs are extremely well related to Bald Patches and separatrices
- Bald Patches : $\frac{B_z}{B} \bar{\bar{\nu}} \approx 0$
 $B \cdot \nabla B_z > 0$
- BPs and separatrices are preferential sites for reconnections



- Strong argument for reconnection
- EBs : signature of magnetic reconnection, allowing the emergence of flux tubes through the photosphere.

Magnetic field extrapolation

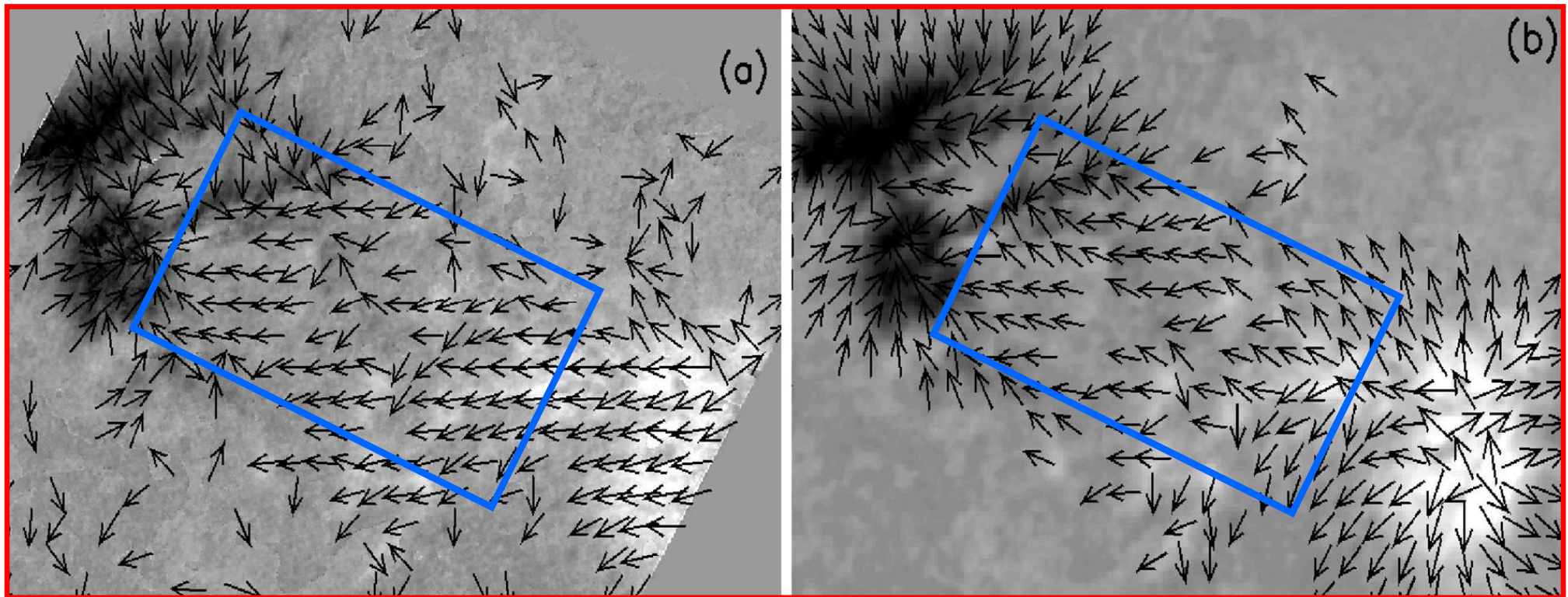
- Linear Force free field extrapolation:**

Observations used to set the free parameter α

$$\nabla^2 \mathbf{B} + \alpha^2 \mathbf{B} = 0$$

Comparison of the observed photospheric horizontal field (a)
with the extrapolated one (b).

(minimum residual method, Leka et Skumanich SoPh 99)



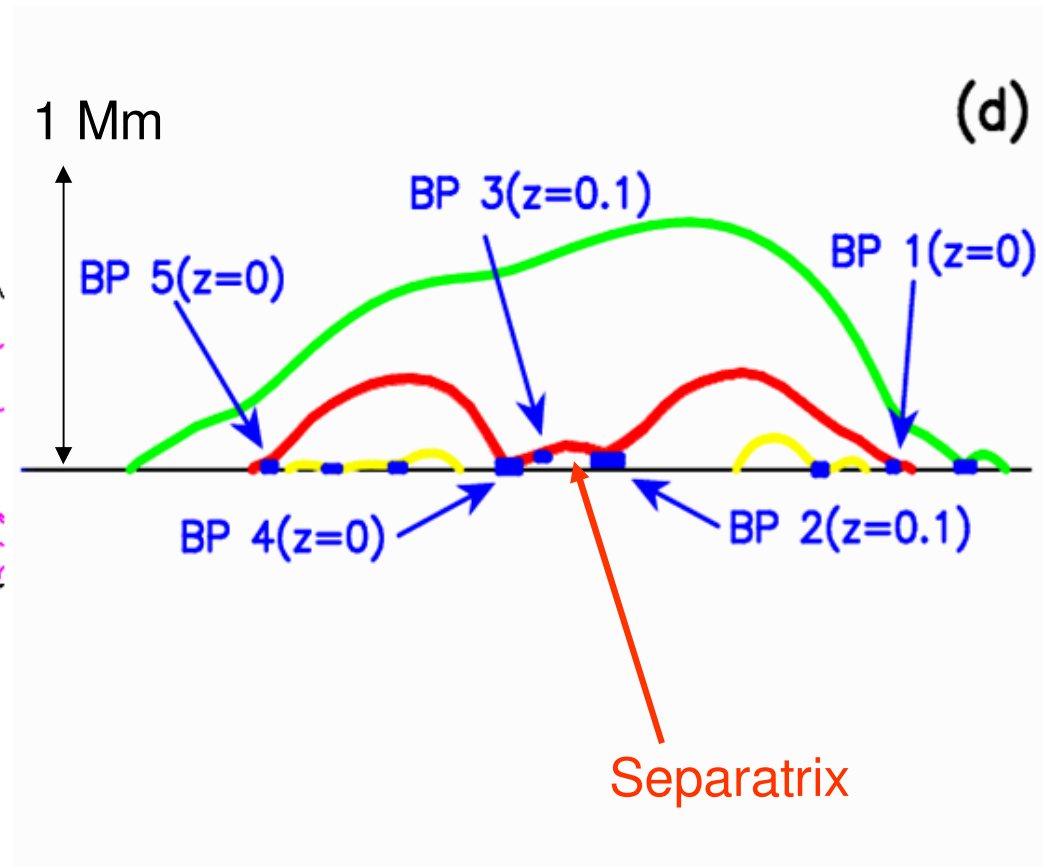
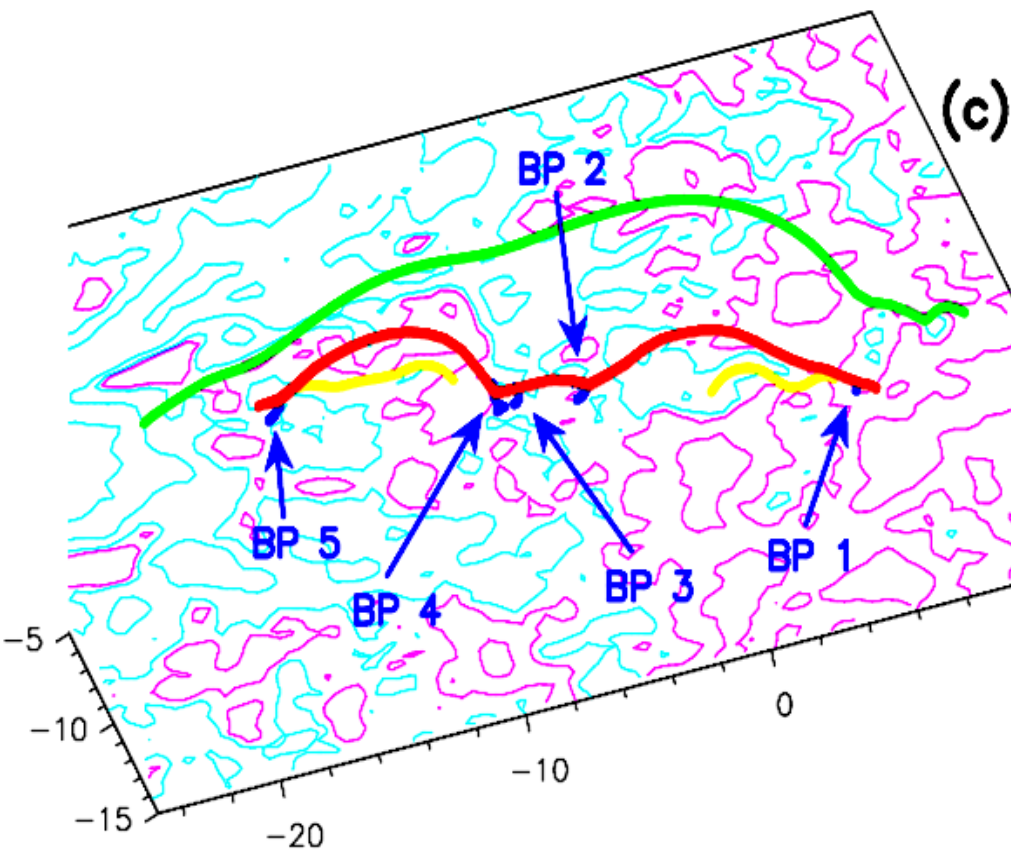
Observations

$$\alpha = 2.2 \cdot 10^{-2} \text{ Mm}^{-1}$$

Reconstructions

(Pariat et al 2004)

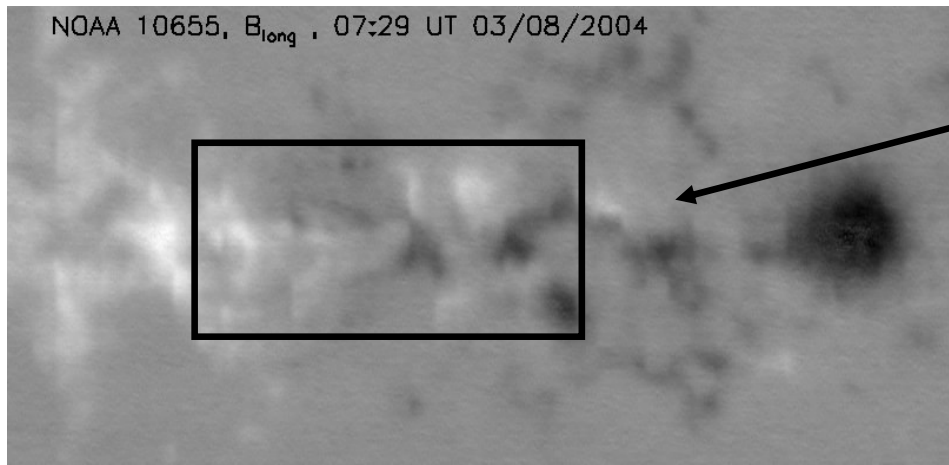
Low chromosphere magnetic topology: serpentine field lines



Flux tubes are undulated and connected to the photosphere by several Bald Patches (BPs)

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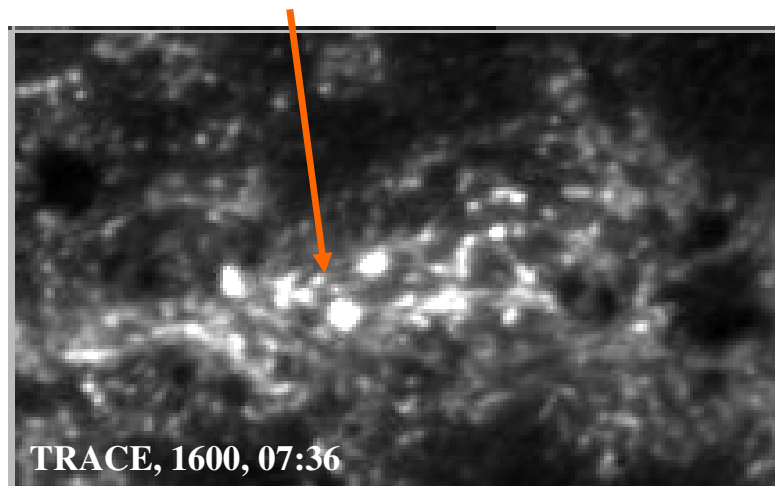
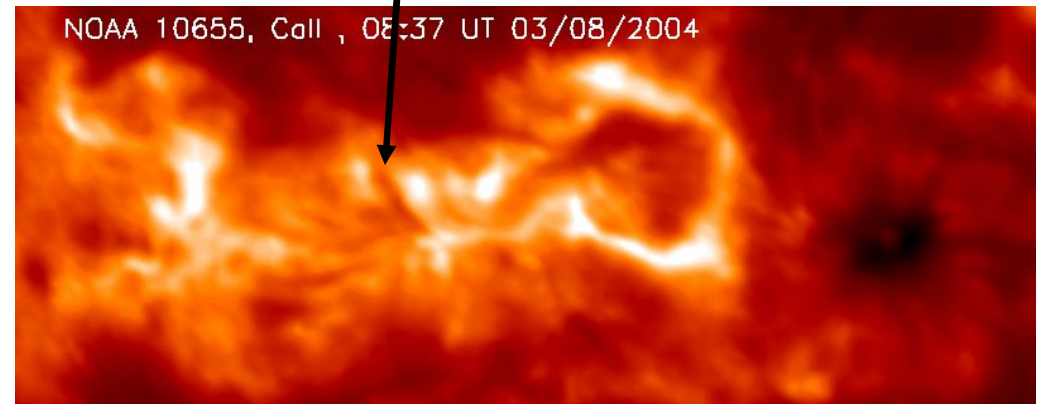
Campaign THEMIS 04



Mixed polarities

Arch Filament System (AFS)

Ellerman Bombs seen as bright points in 1600 Å (Schmieder et al. 2004).

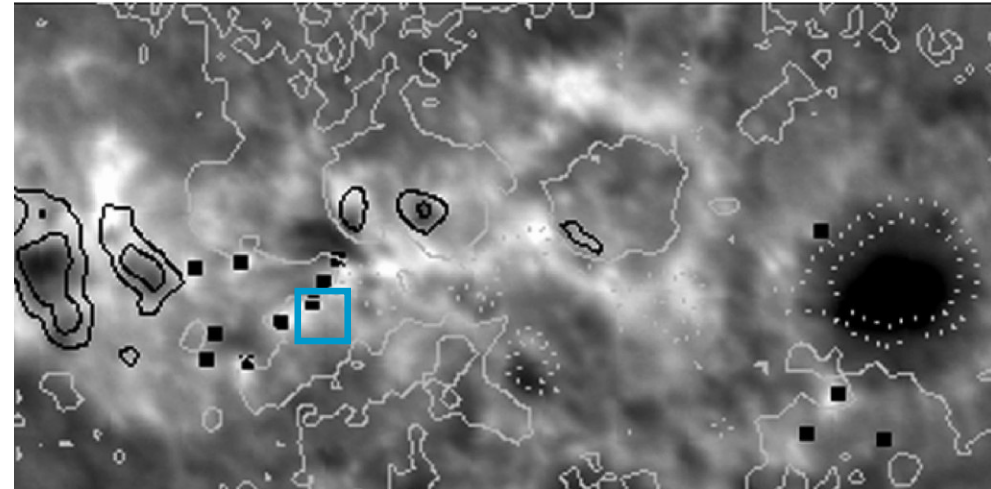


Correlation between emergence of magnetic flux and reconnection events

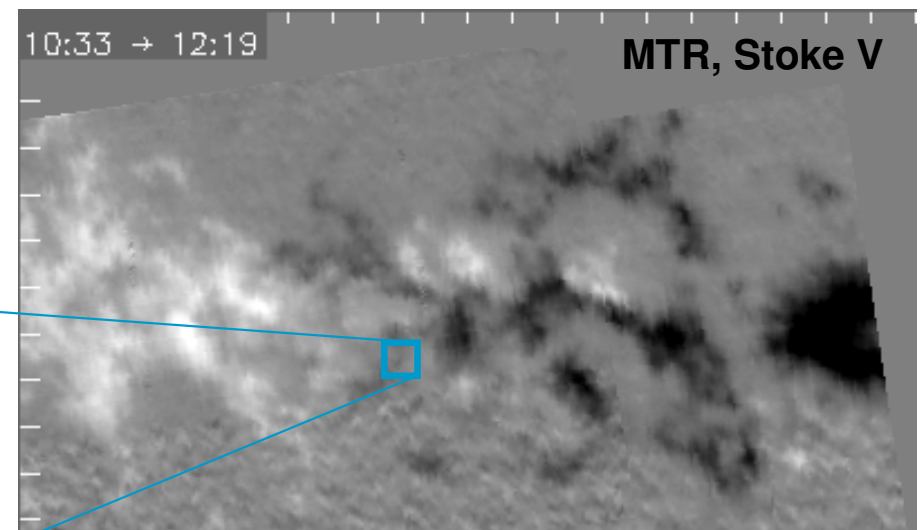
(Pariat, Schmieder, Mein, Deng, Berlicki, 2007)

Link with magnetic topology

- THEMIS observations :
- scans between 10:30 and 12:19 UT
 - H α and Ca II observations :
 - Several EBs are present roughly in the same area than before (EBs tend to reoccur)
 - Vector Magnetic field measurements
 - EBs located on horizontal fields linking magnetic polarities: Bald Patch topology
- Most EBs (9/13) are located along an inversion line.

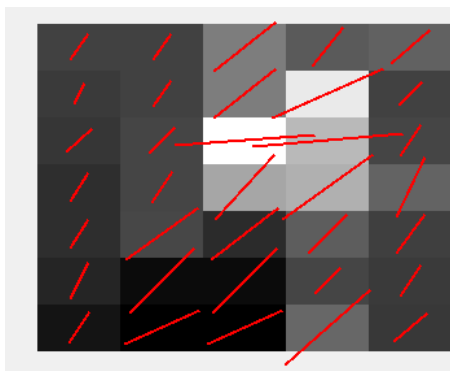


MSDP Ca II



MTR, Stoke V

Blong
& Btrans



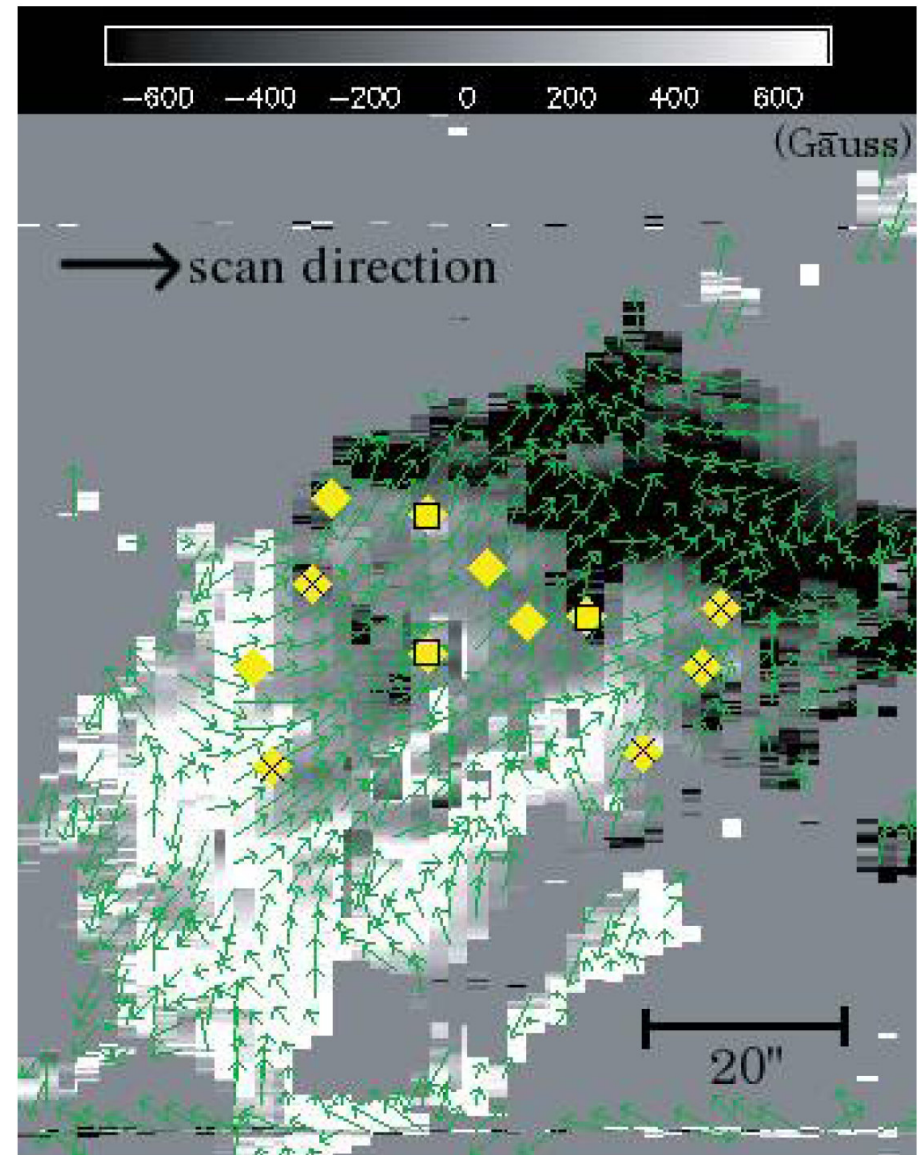
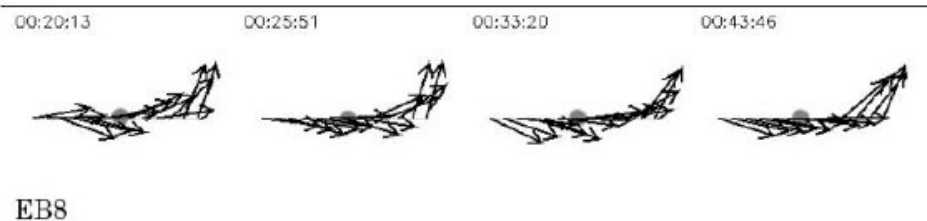
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Evolution versus time of the vectors

Hida observations

Ellerman bombs

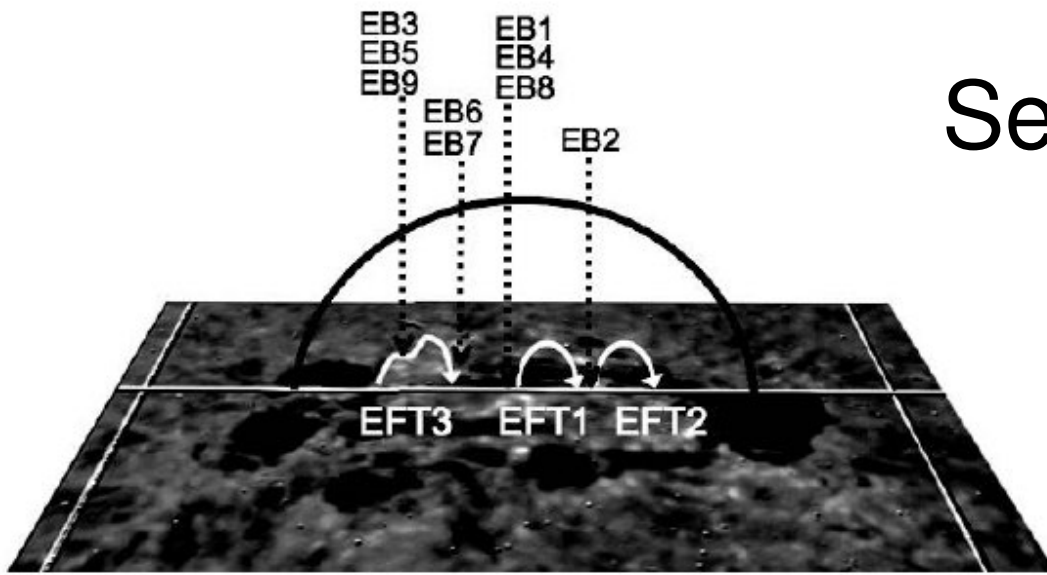
Magnetograms



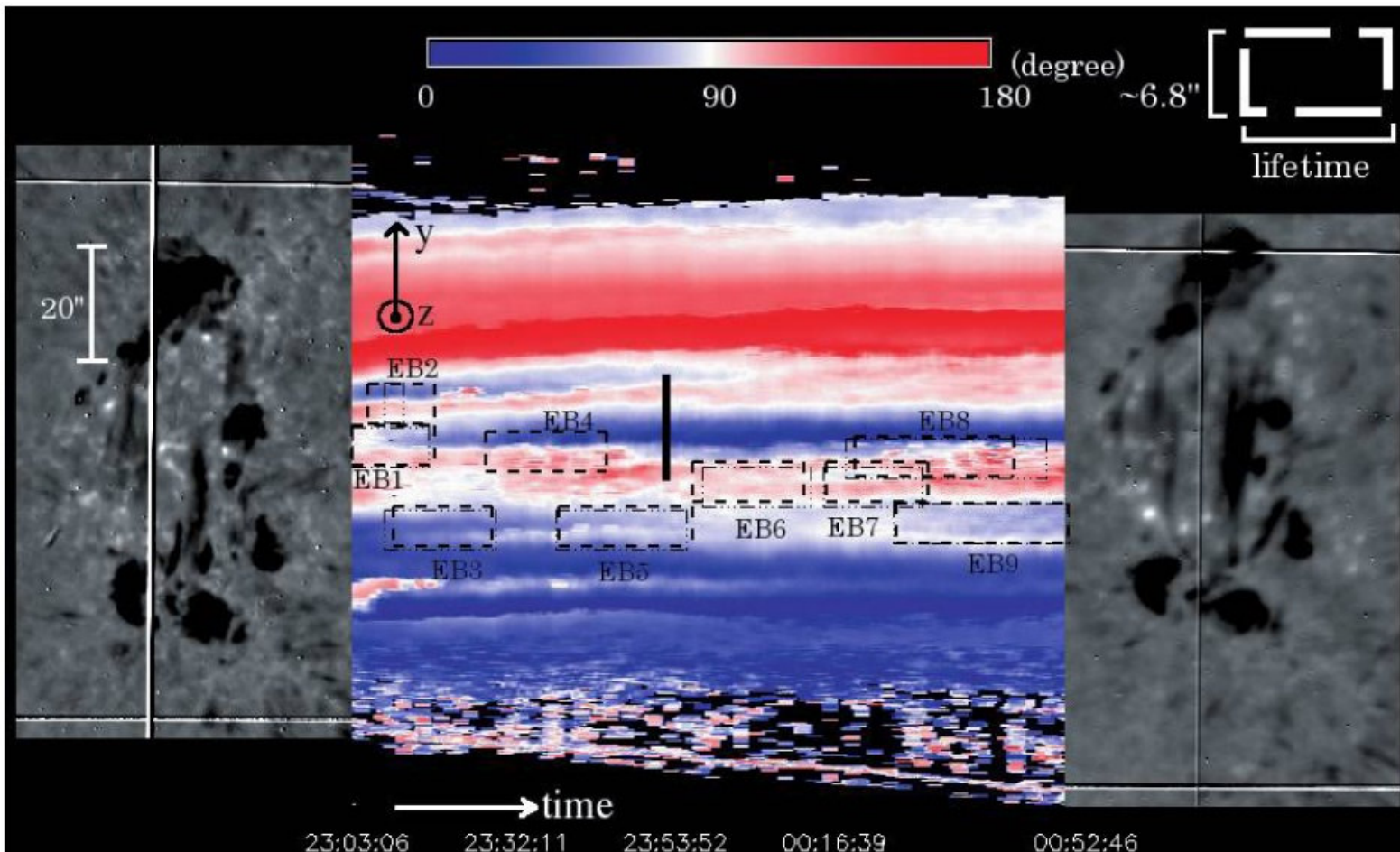
Watanabe et al 2008

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Sea Serpentine structure

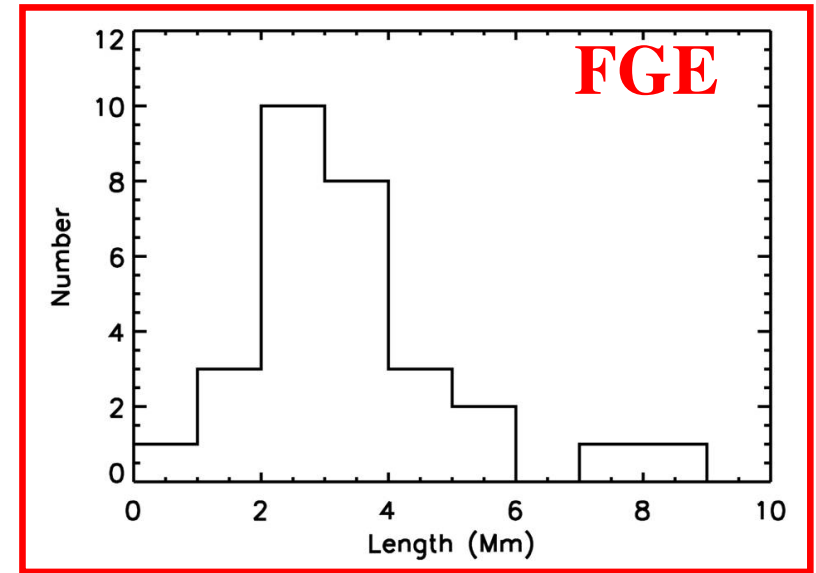
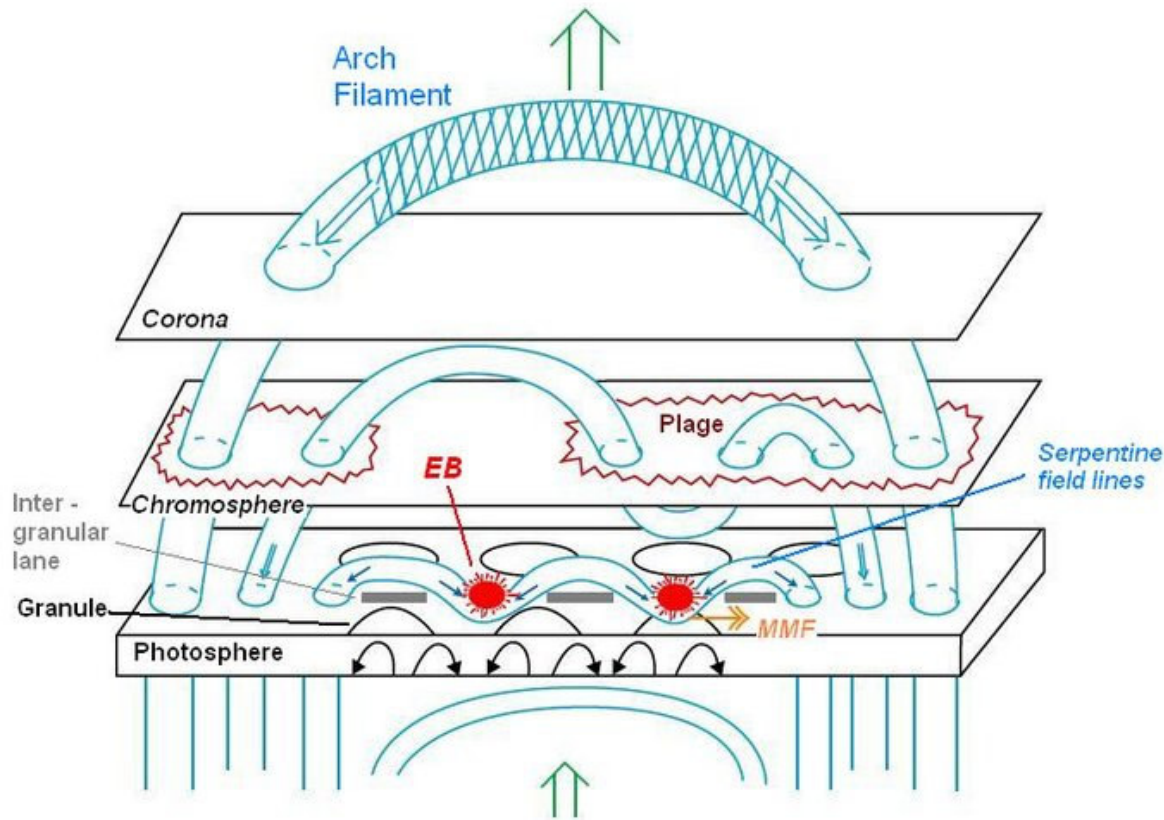


Watanabe et al 2008



Inclinaison
diagram

Serpentine tubes passing through the photosphere

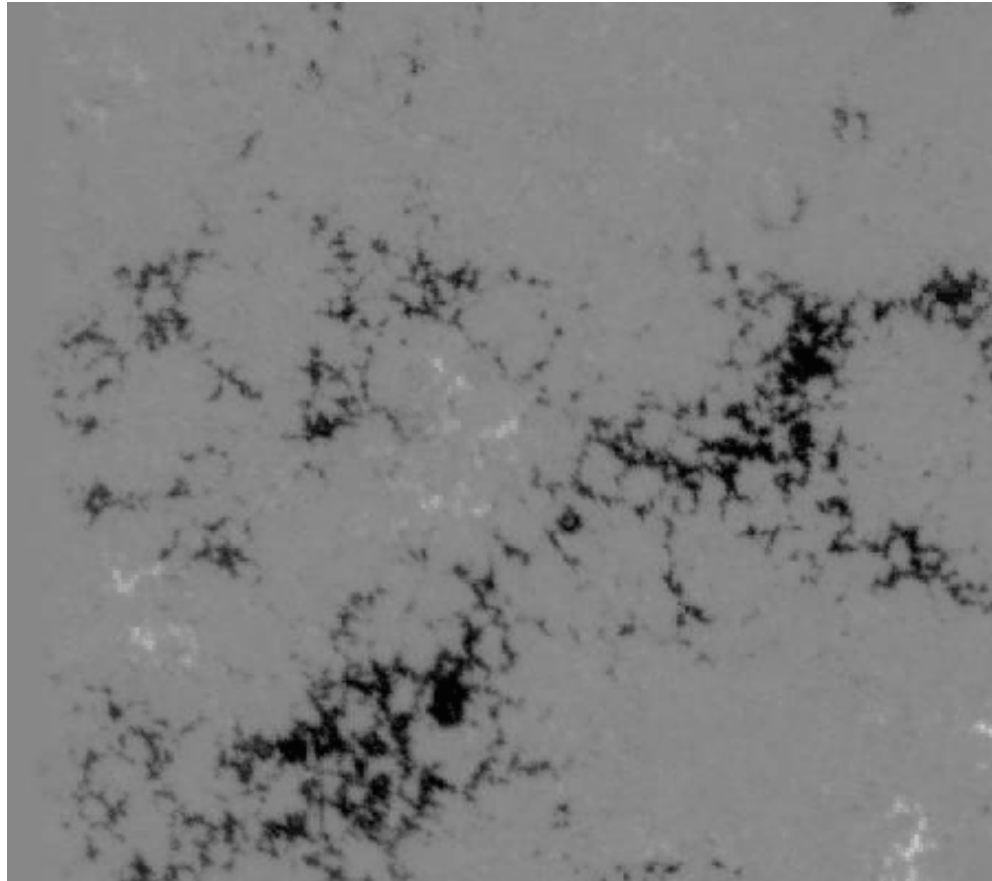


Distribution of the distance between two consecutive BPs within serpentine field lines:
 Cutoff below $\sim 2\text{-}3$ Mm consistent with the **Parker instability**:
 (Shibata ApJ 89, Magara ApJ 01, Isobe 2007...)

Conclusion

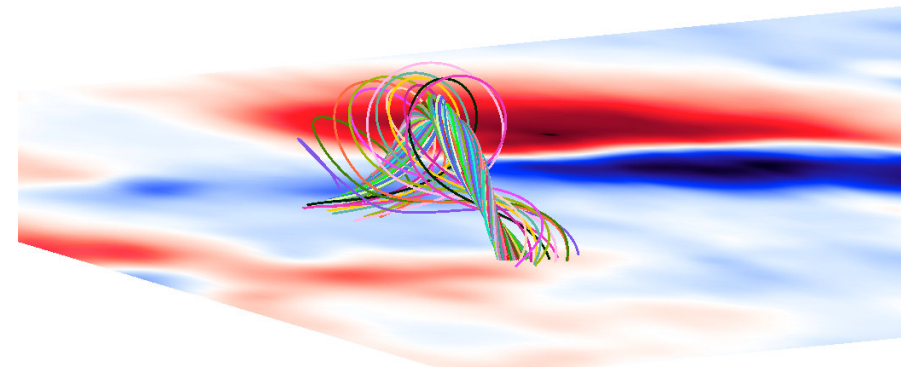
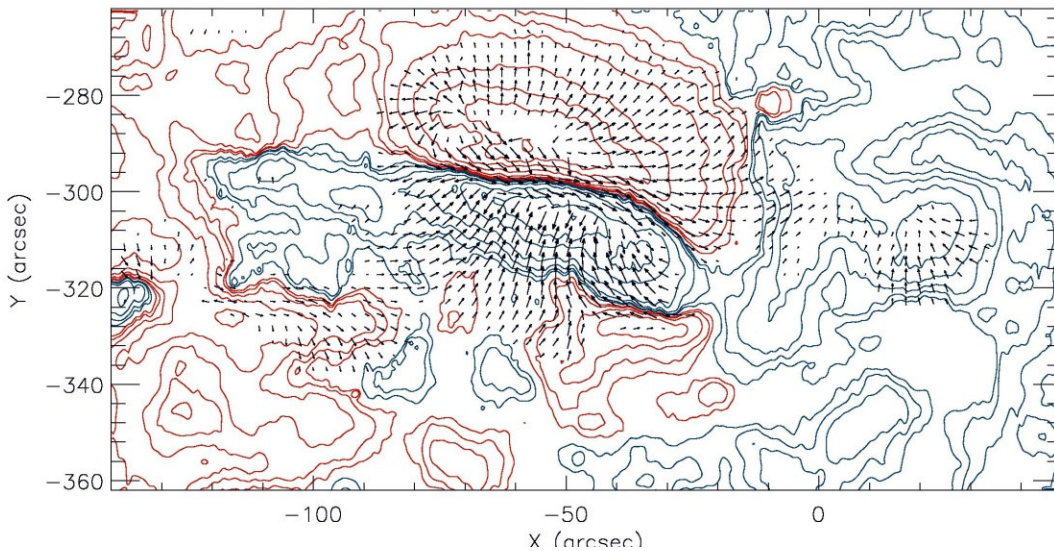
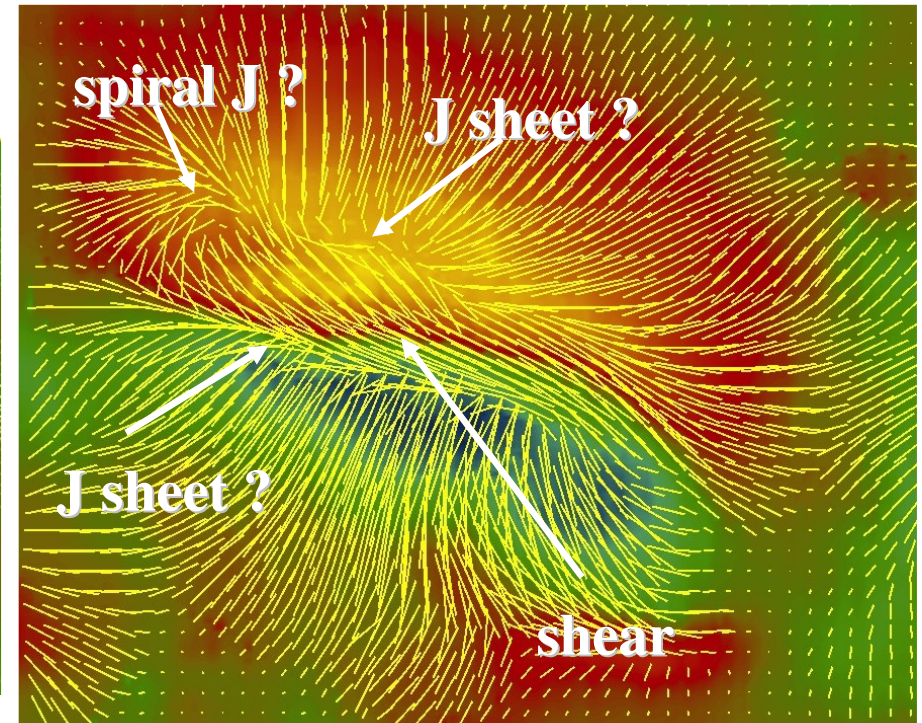
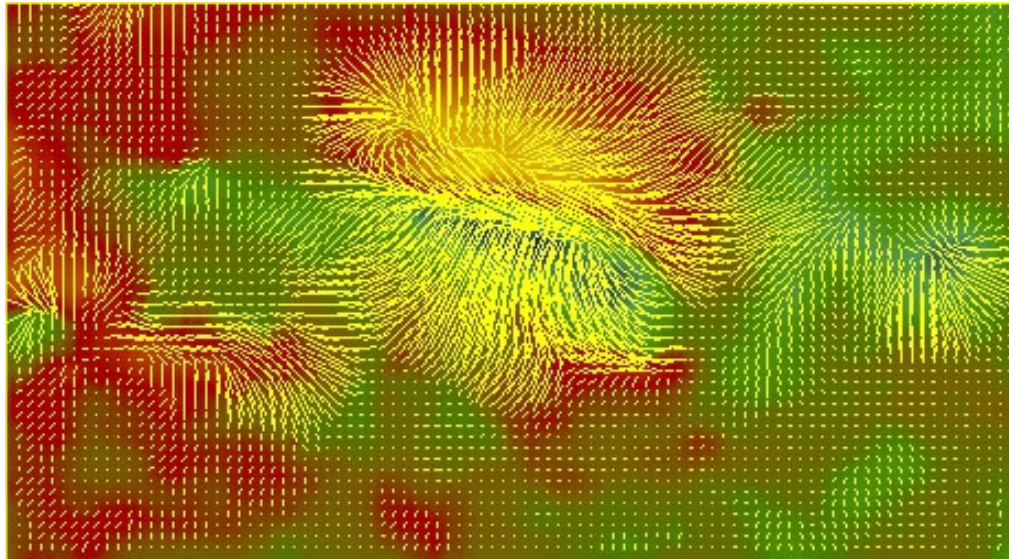
- Horizontal magnetic vectors or shallow dips above EMF
- confirmed by ASP, FGE, SOT, THEMIS, VGM
Downflows (FGE, SOT)
- Confirmation of the “Bald Patch” topology and serpentine nature of the emerging flux tube
- EB signature of magnetic reconnections
- Convection (many theoretical papers: i.e. Cheung et al 2008) Rayleigh instability (Parker) ???

Hinode emerging flux



48 hours
(1-2 dec 2006)

Large emerging twisted flux tube



Canou, Amari, Bommier, Aulanier,
Schmieder, Li 2008