

Slipping reconnection in a solar flare observed with GREGOR

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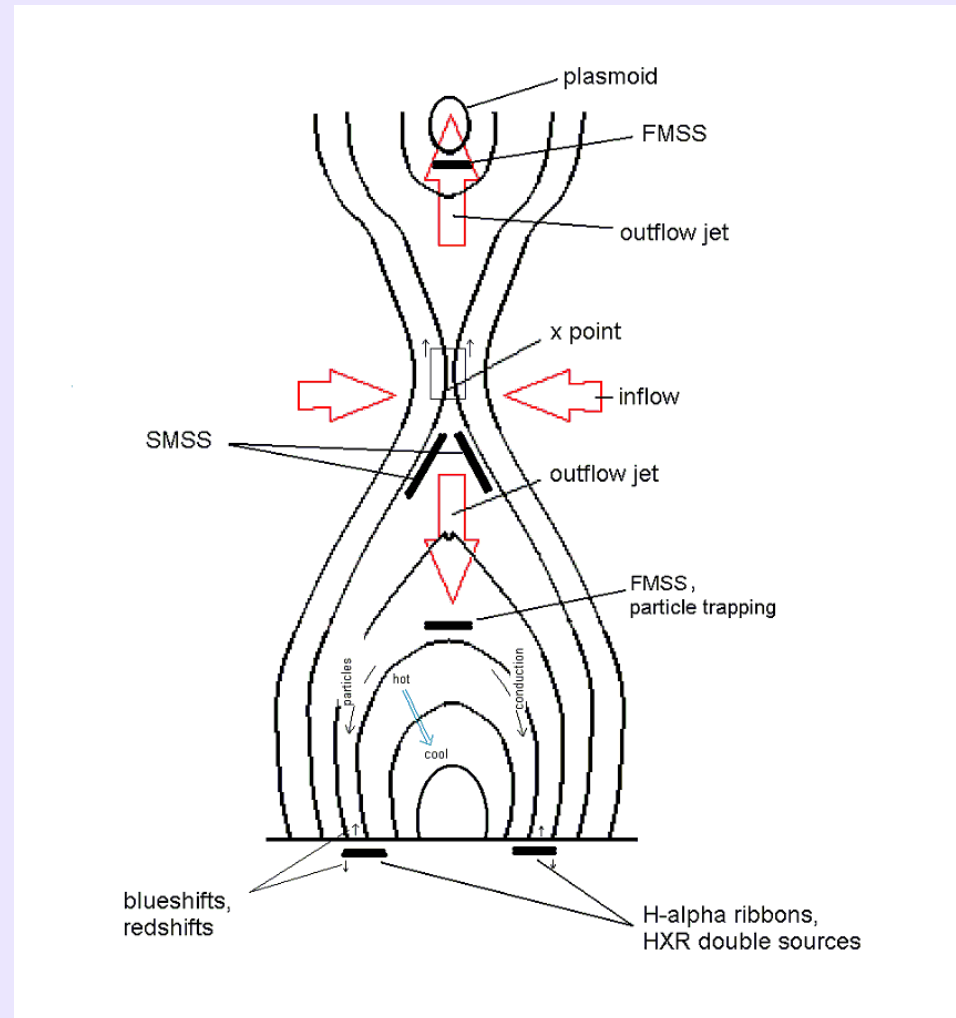


Introduction

A standard 2D reconnection model of solar flares: CSHKP

(Carmichael 1964, Sturrock 1966, Hirayama 1974, Kopp & Pneuman 1976)

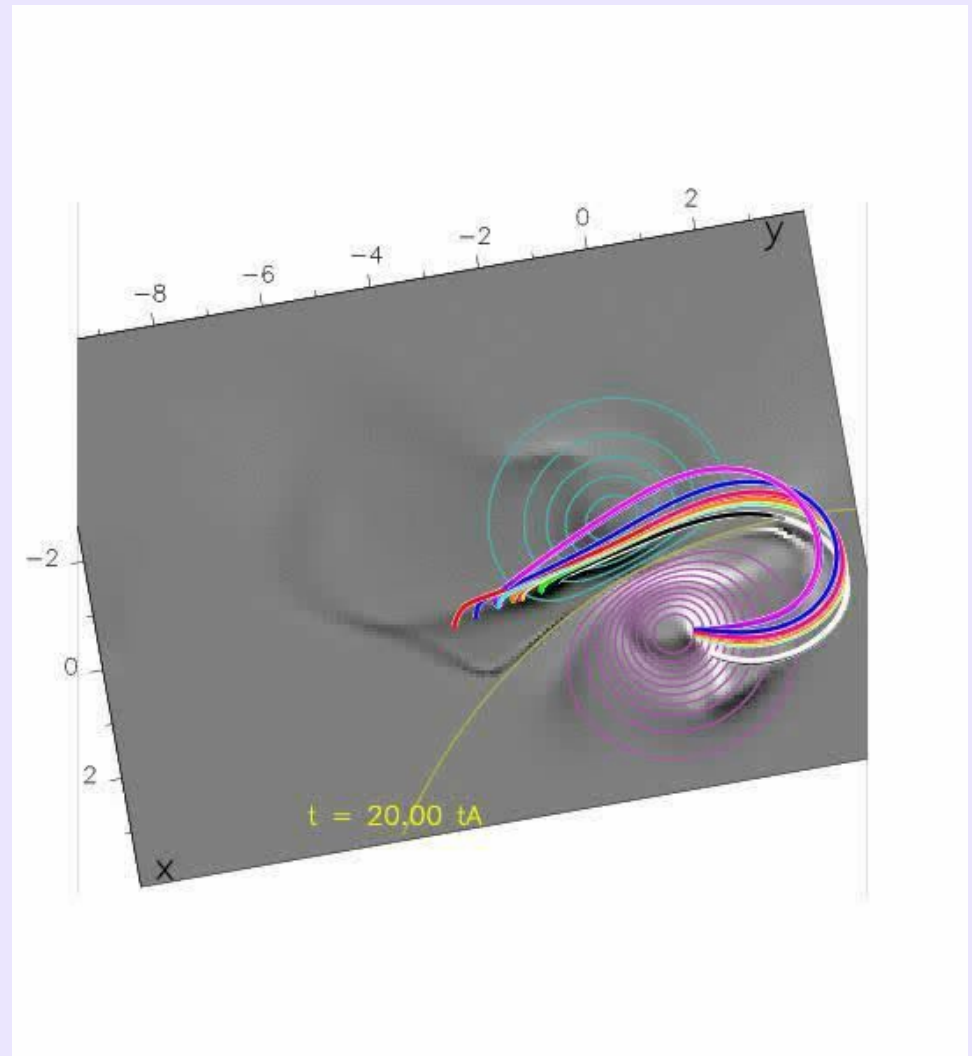
The complete 3D model contains inherent 3D features (such as hooked or J-shaped flare ribbons) not present in the standard 2D model.



3D model:

(Aulanier et al. 2006,
Masson et al. 2012,
Dudík et al. 2014)

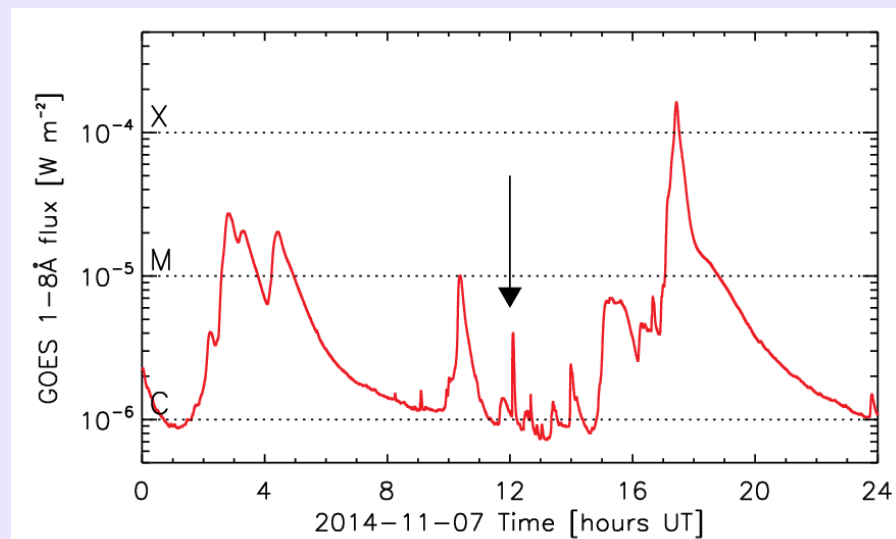
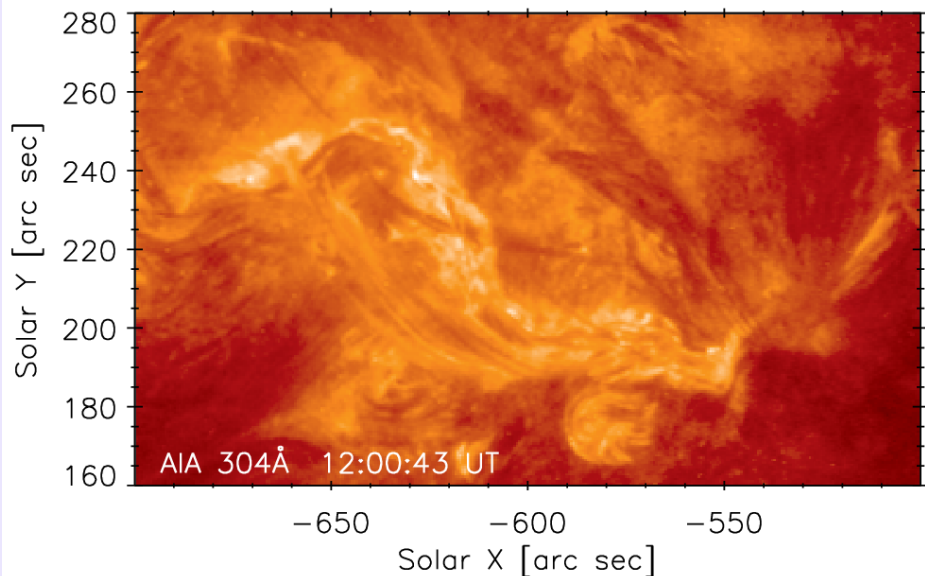
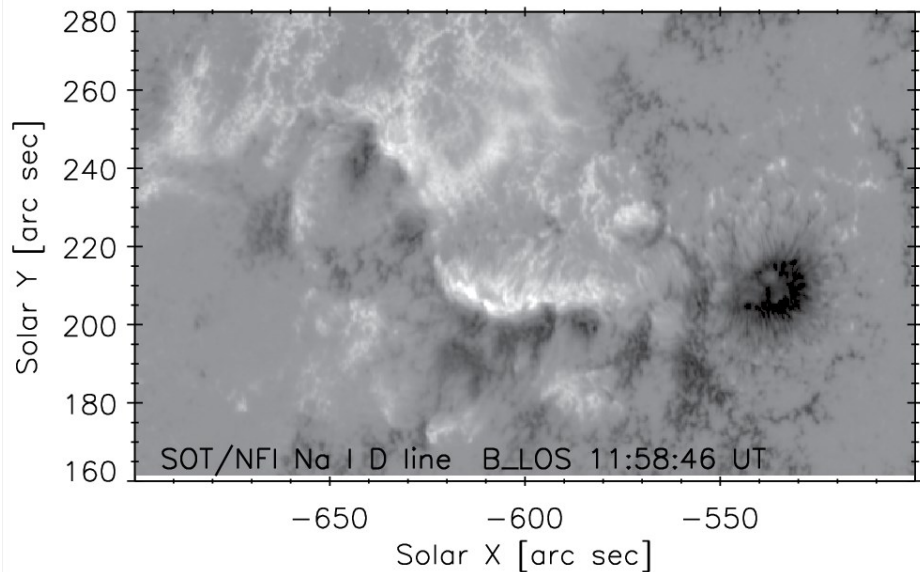
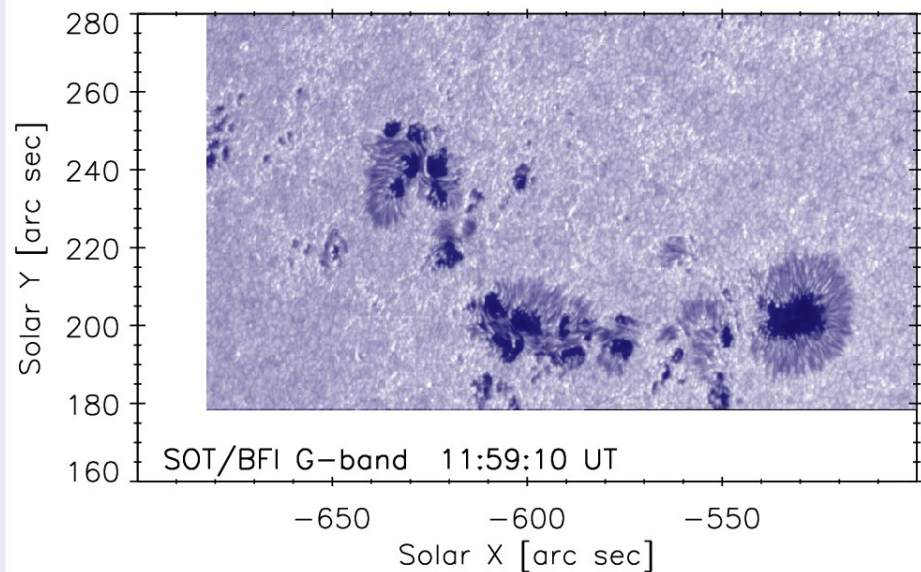
No X-point is present but the reconnection proceeds continuously in quasi-separatrix layers marked by color lines in the movie. The apparent motion is caused by many subsequent reconnection events. The observational consequence is a motion of bright kernels along the flare ribbon. They move in both directions because magnetic field lines move against each other when exchanging connectivity.



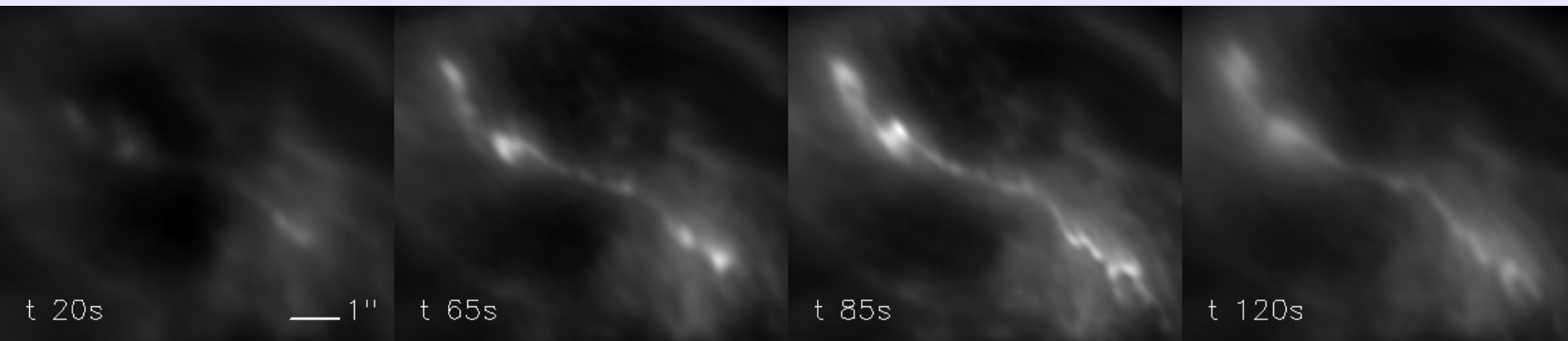
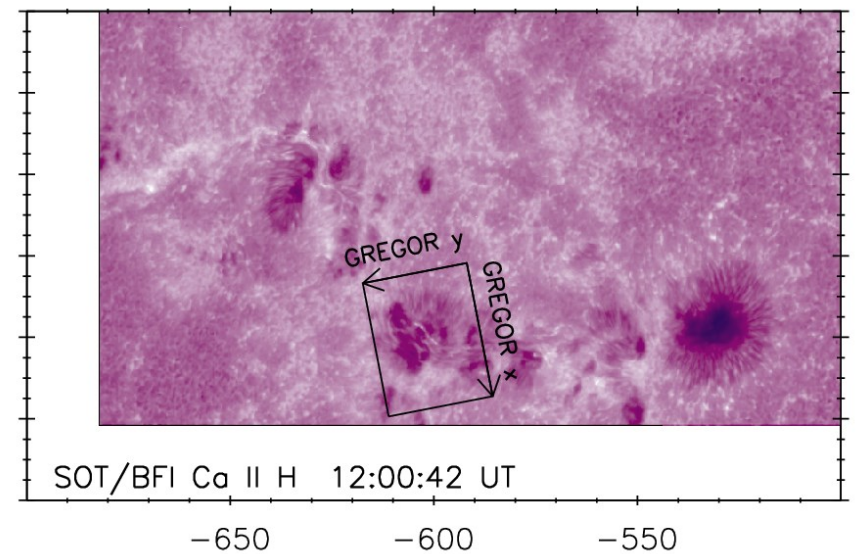
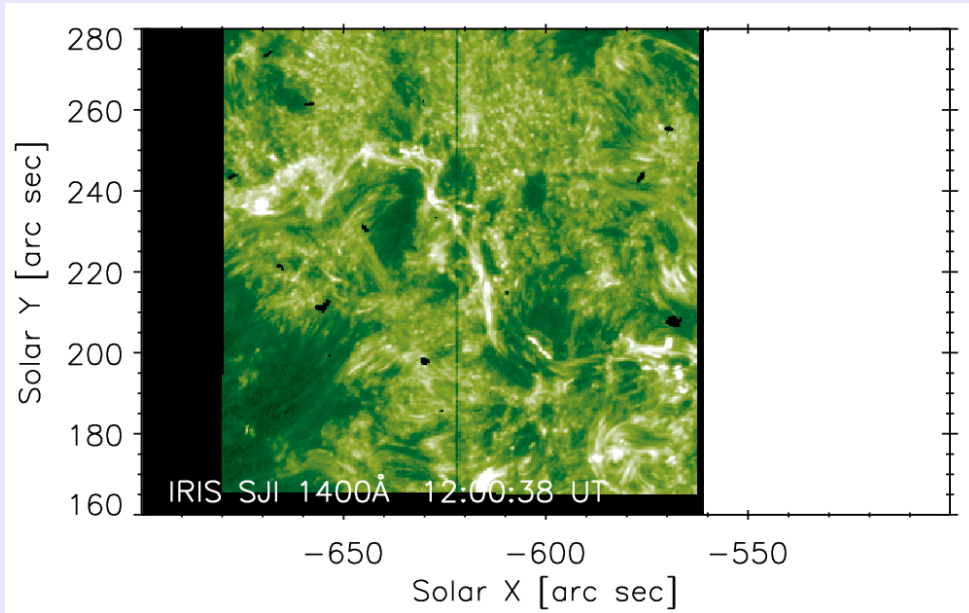
Observations

- Complex sunspot group NOAA 12205, at 13 N 37 E, 7 November 2014, 11:59:08–12:01:31 UT
- A C3.9 flare developed later (start 12:04, peak 12:06 UT)
- GREGOR (D=1.5 m, AO), blue imaging channel, Ca II H 3968 Å, interference filter with FWHM 1 Å
- Image scale 0.026"/pixel, exposure 30 ms, frame rate 7.68 Hz (130 ms per frame)
- MFBD reconstruction: 32 frames (~ 4 s) used to reconstruct 1 image, sliding mode with a lag of 8 frames => 134 reconstructed images with a time step of 1 s. Resulting spatial resolution ~ 0.1"
- Context data used from SDO/AIA, HINODE/SOT, IRIS

NOAA 12205

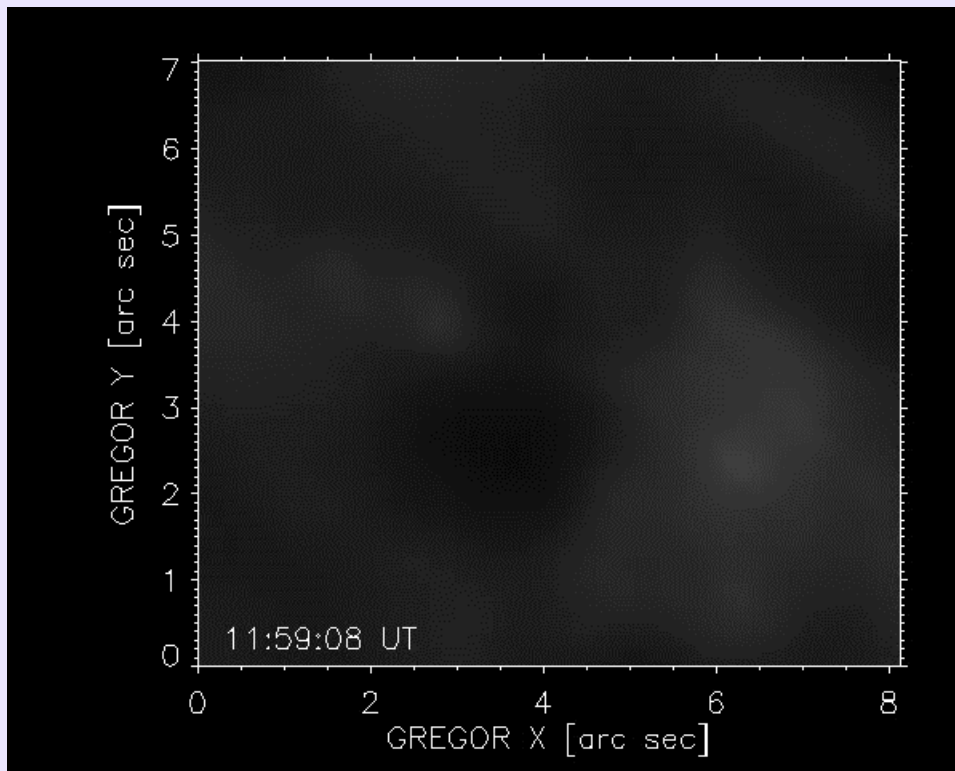


The flare (a pre-flare, in fact)

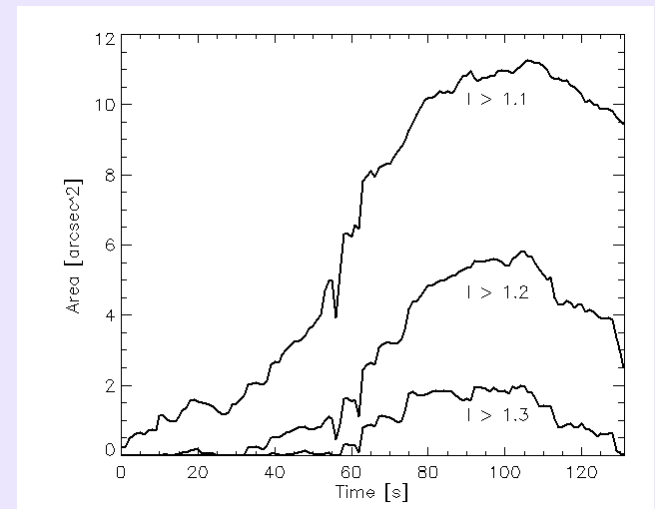


GREGOR Ca II H, $t_0 = 11:59:08$ UT

The flare ribbon, observed above an umbra (crossed by a complex light bridge) shows small-scale brightenings. Some of them move along the ribbon. The movie consists of 132 frames with a cadence of 1 frame/s.



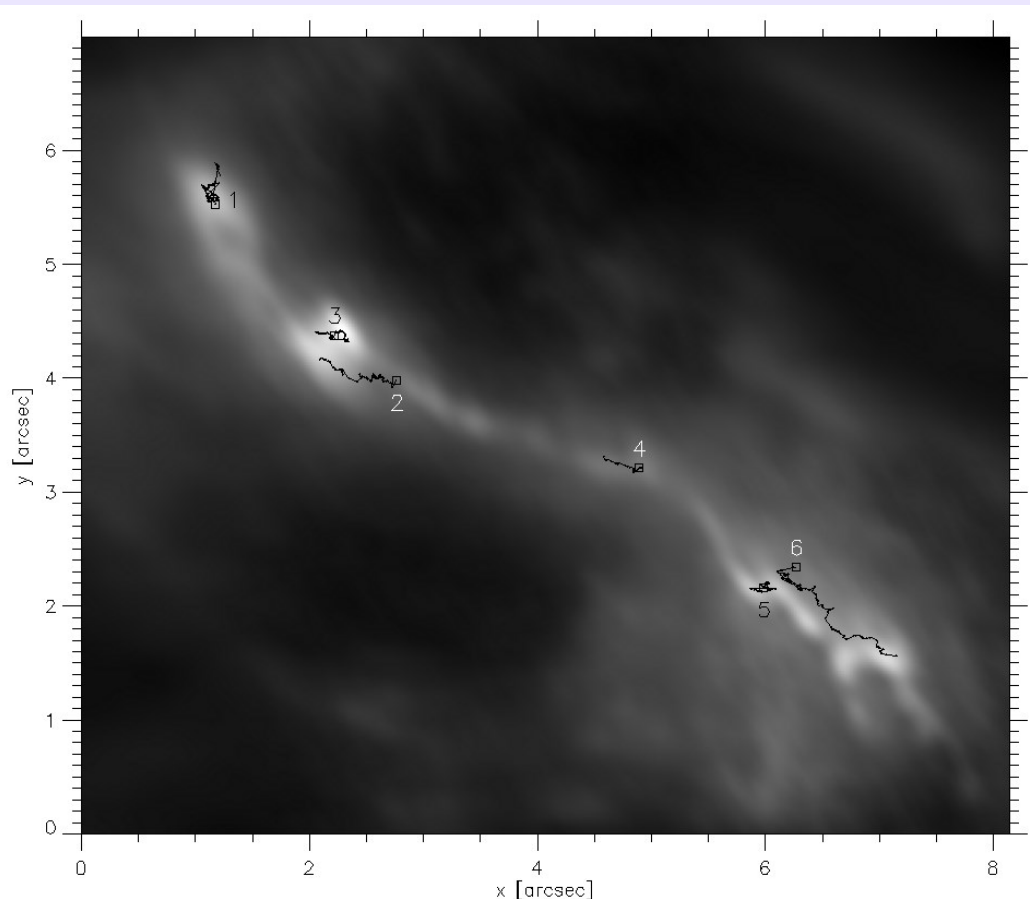
Evolution of the flare-ribbon area defined by three different intensity thresholds.



Light curves and velocities of bright knots

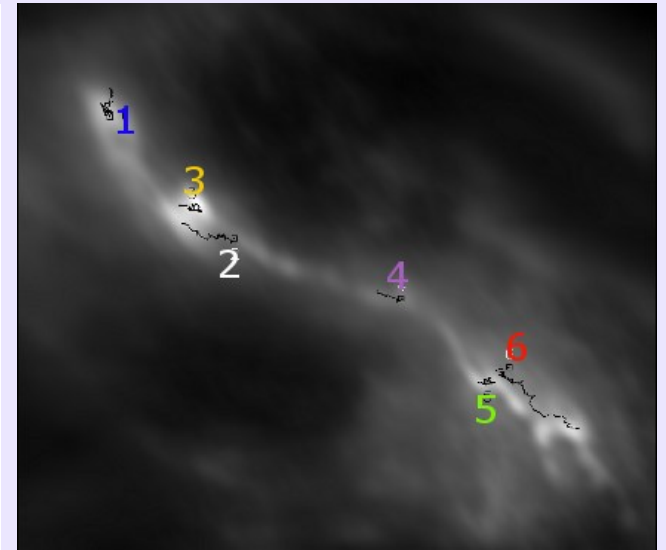
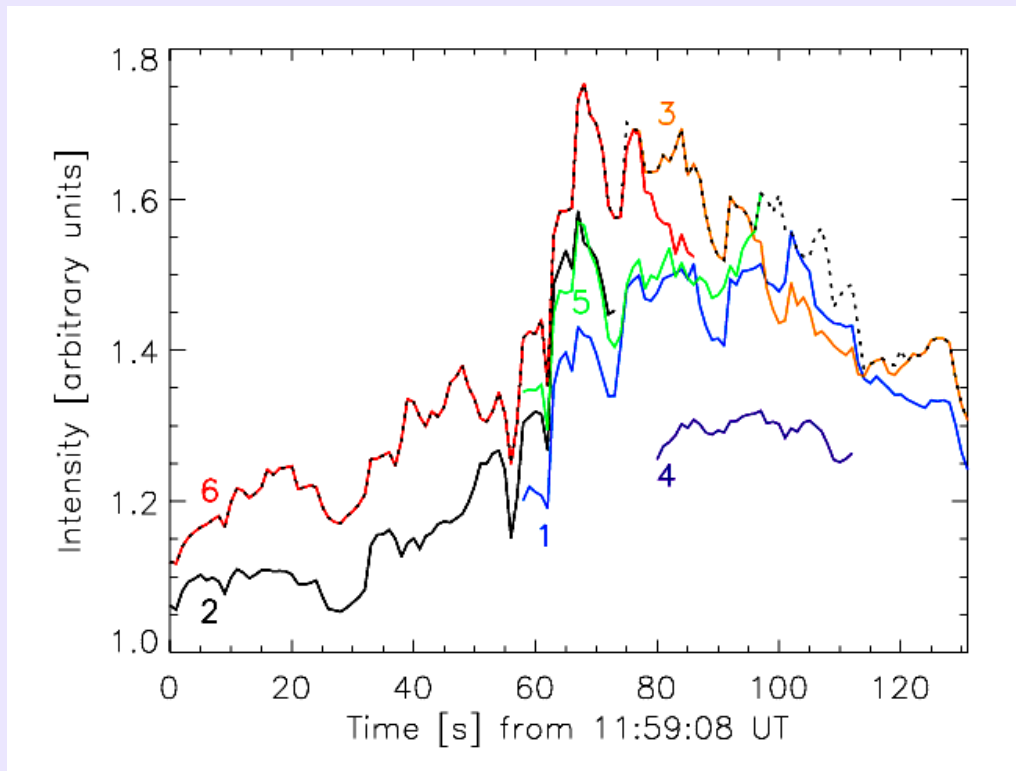
Feature tracking: Correlation of intensities between two frames in a small window ($1''.24 \times 1''.24$) surrounding the tracked feature.

Output: position and value of intensity maximum inside the feature.

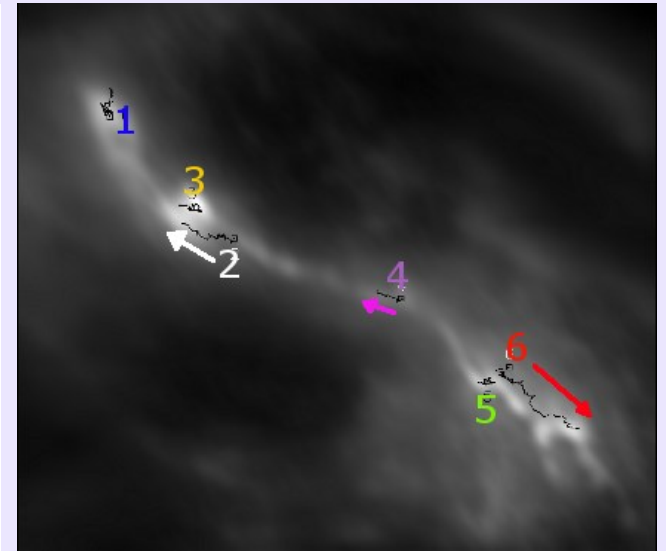
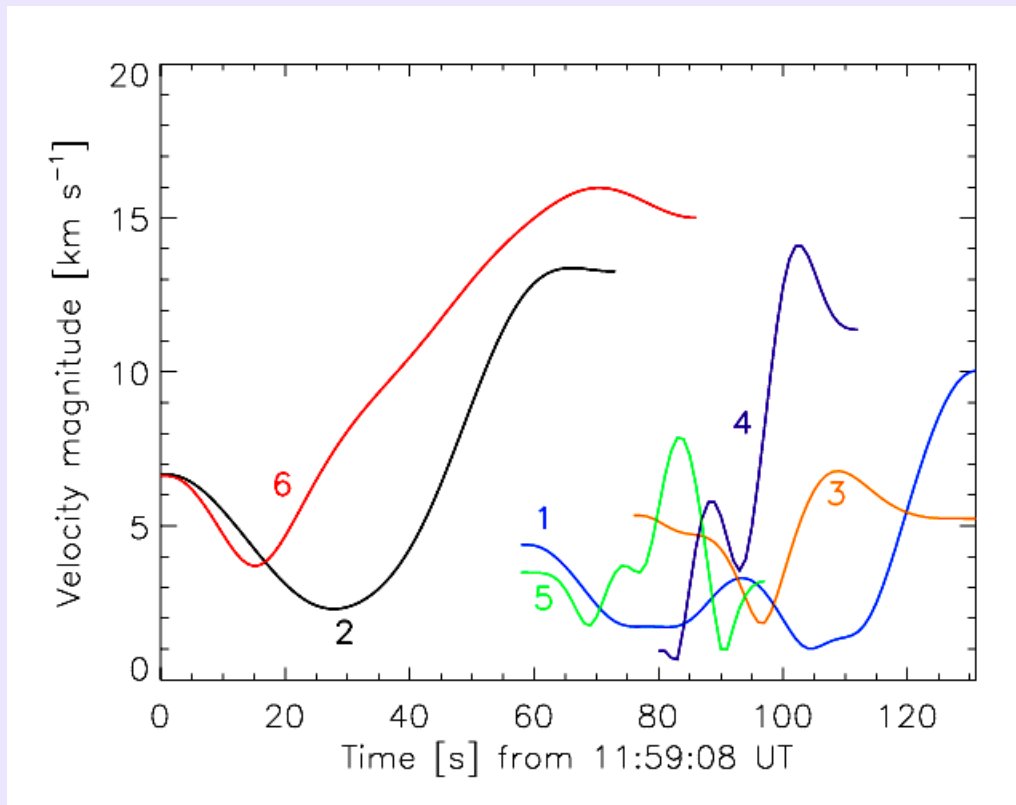


Successful tracking of
6 bright kernels:

	t_{start}	t_{end} [s]
1	58	131
2	0	73
3	76	131
4	80	112
5	58	97
6	0	86



Light curves of the six tracked bright kernels. The black dotted line shows the maximum intensity in the flare ribbon. Intensities are in units of average intensity in the area before the flare onset. Light curves 2 and 6 are highly correlated (0.97), suggesting a common process.



Instantaneous velocities of the six tracked bright kernels, calculated of their positions and filtered by a low-pass Fourier filter. The error is approximately ± 4 km/s. An acceleration is typical for kernels 2, 4 and 6. The kernel 6 is moving in opposite direction to the motion of 2 and 4.

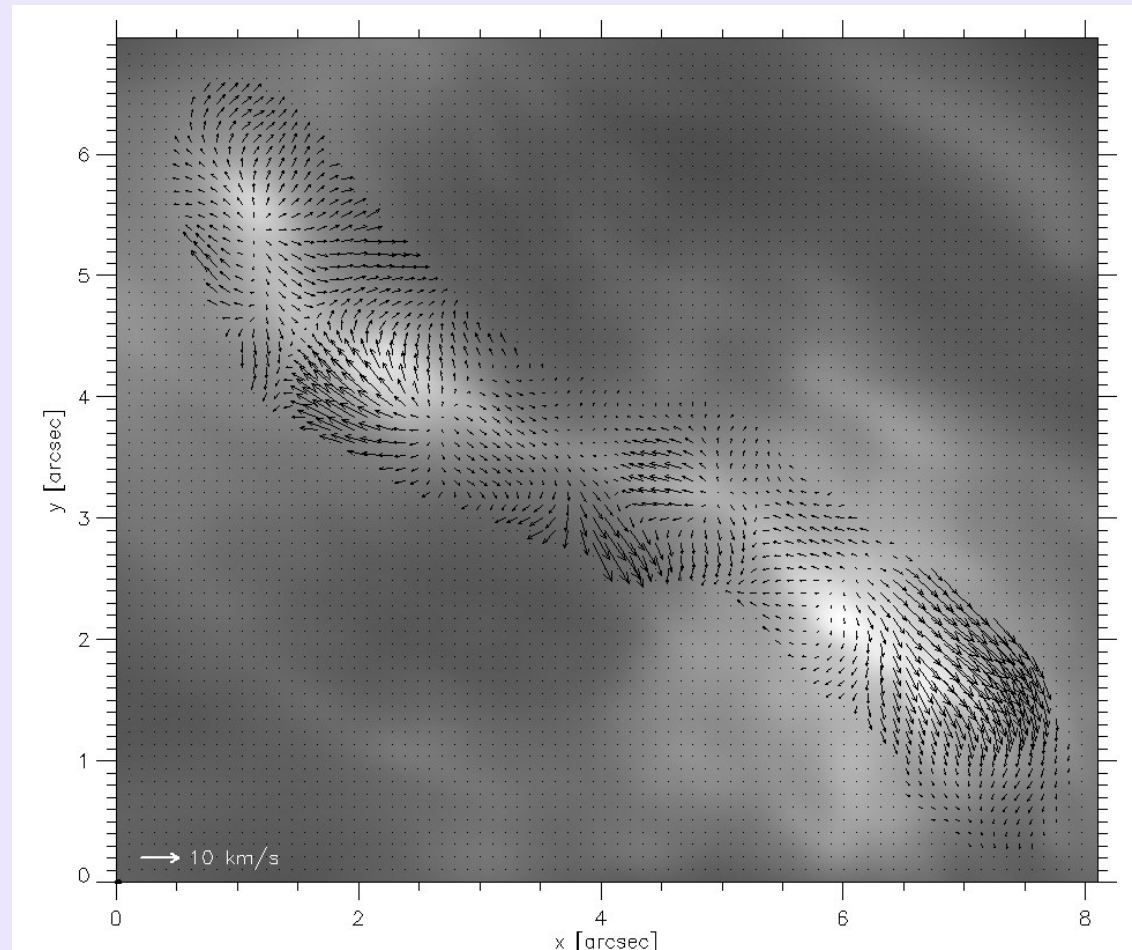
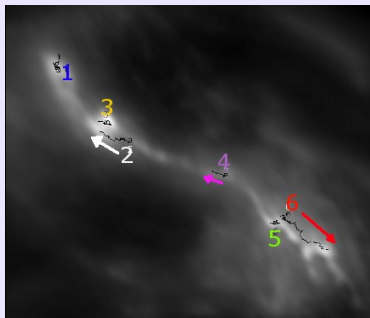
Average velocity magnitudes of the moving bright kernels 2, 4 and 6, obtained from feature tracking

2 : 7 ± 1 km/s; 4 : 8 ± 2 km/s; 6 : 11 ± 2 km/s

LCT flow map
of the flare ribbon.

Tracking window $0''.5$,
integrated over the
whole 132 s series.

Motion of kernels 2, 4,
6 can be seen as well
as the expansion of
the ribbon area.



Conclusions

- A small pre-flare ribbon above a sunspot umbra was observed with extremely high spatial ($0''.1$) and temporal (1 s) resolution. The observed ribbon was a small part of a much larger structure that was involved in a C3.9 flare occurring three minutes later.
- The observed motion of bright kernels in both directions (velocity magnitude of 10 km/s) is consistent with the idea of slipping reconnection.
- First instance of bright kernel motions observed in visible light at small scales and in a small pre-flare.
- The slipping reconnection is occurring also outside of major flaring events and at small spatial scales.



Thank you for attention