Formation of solar coronal loops through magnetic reconnection in an emerging active region

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Outline

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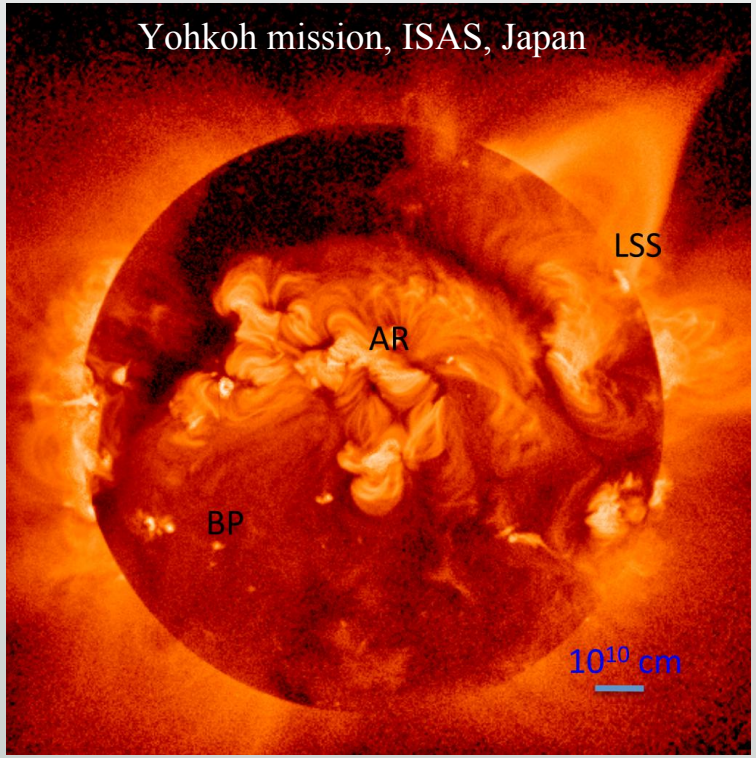
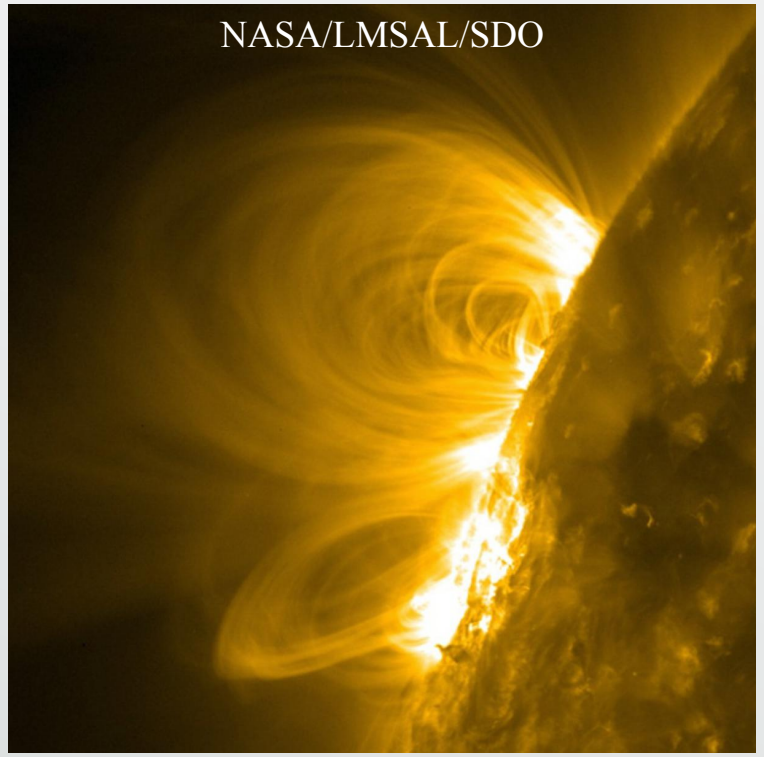
- Observations and Results
- Summary

Background



Hot loops: ≥ 2 MK, typically observed at the wavelengths of soft X-ray and EUV (e.g., Winebarger et al. 2011).

Warm loops: 1–2 MK, observed by EUV images and spectrographs (e.g., Lenz et al.1999; Xie et al. 2017);



Coronal loops are building blocks of solar active regions (Reale 2014).

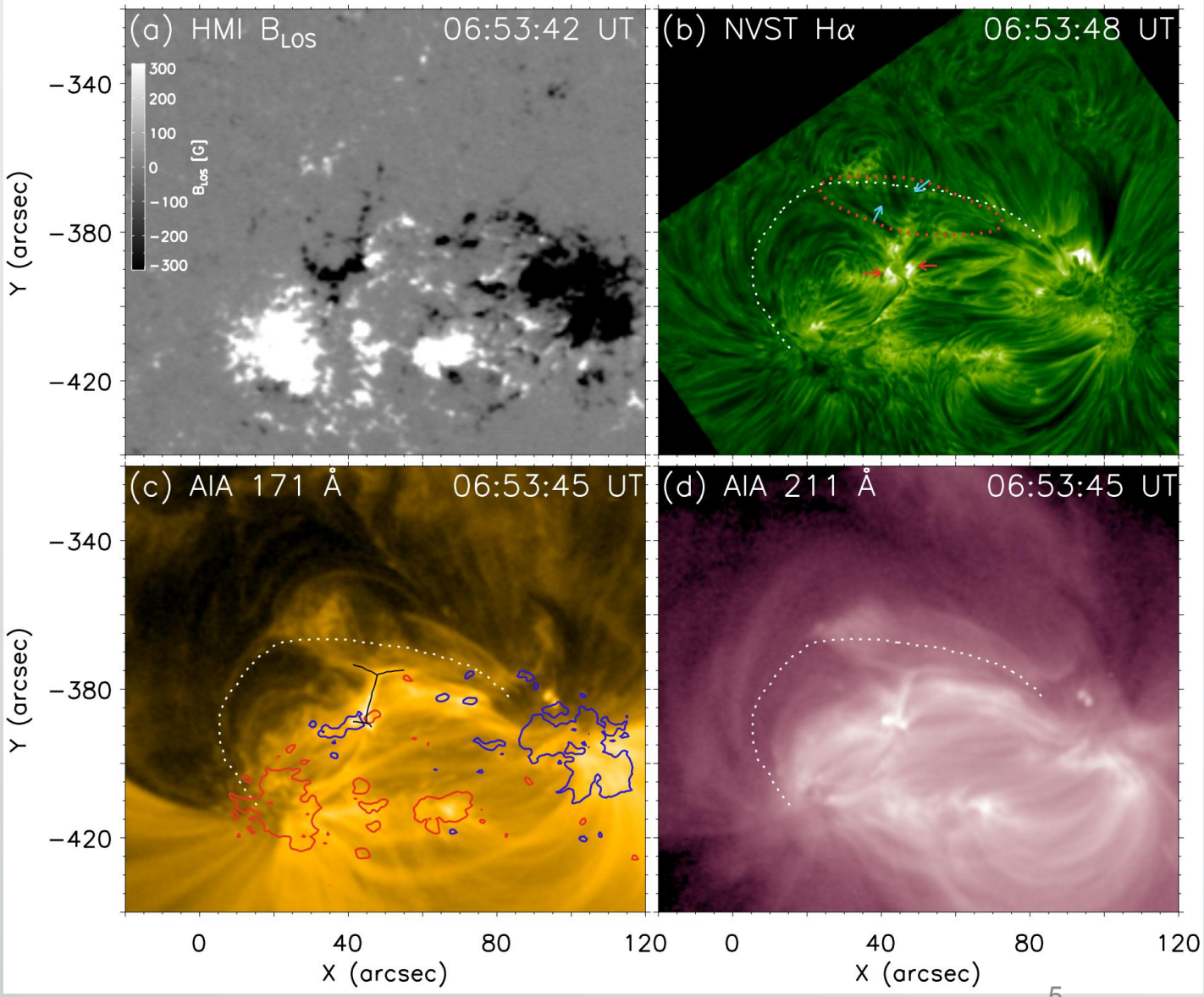
Background

- **Thermal instability** (Mok et al. 2008);
- **Coronal nanoflares model** (e.g. Testa et al. 2014, 2020, Polito et al. 2018);
- The energy released **in the lower solar atmowphere** (Chitta et al. 2018, 2020);
- **Magnetic reconnection between different loop-sets** (He te al. 2010, Tripathi 2021);
- Emerging ARs:
- 1. Coronal loops could result **from the rise of undulatory flux tubes** whose dipped lower parts emerge to the corona after magnetic reconnection (Pariat et al. 2004);
- 2. The coroanl loop formation is triggered by an increase in the upward-directed Poynting flux at the loop foot-points as a result of **the advection of the photospheric magnetic field** (Chen et al. 2014).

Observations: overview

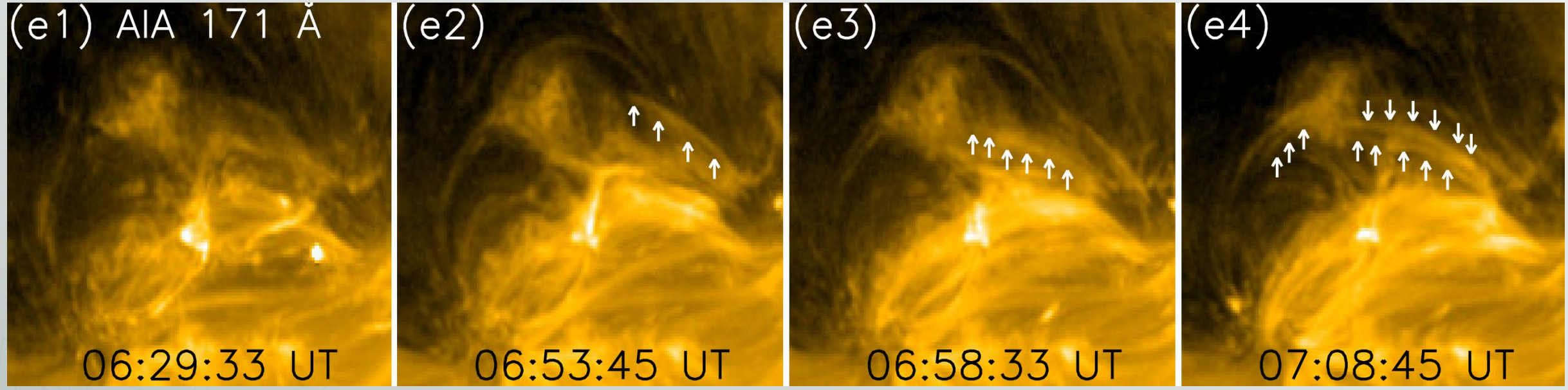
- AIA EUV images (171, 211 Å)
- NVST Hα line-core images
- AIA EUV images (1600 Å)
- HMI: LOS magnetograms and Vector mangetic field

- Target: AR 12778
- Time: 2020-10-26 05:00 -- 08:00 UT



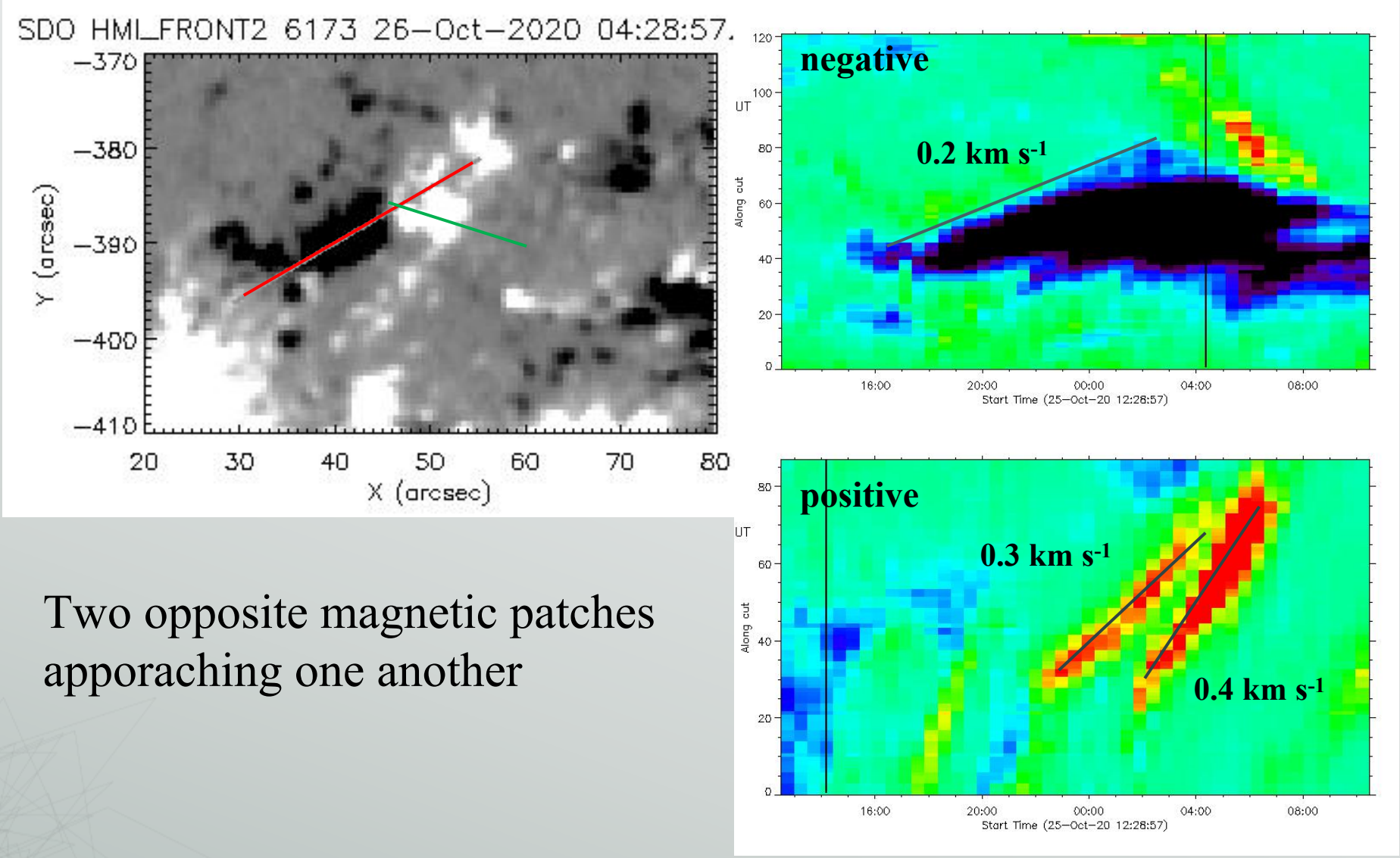
Formation of coronal loops

Two episodes:
First: 06:00–06:19 UT,
Second: 06:41–07:10 UT.



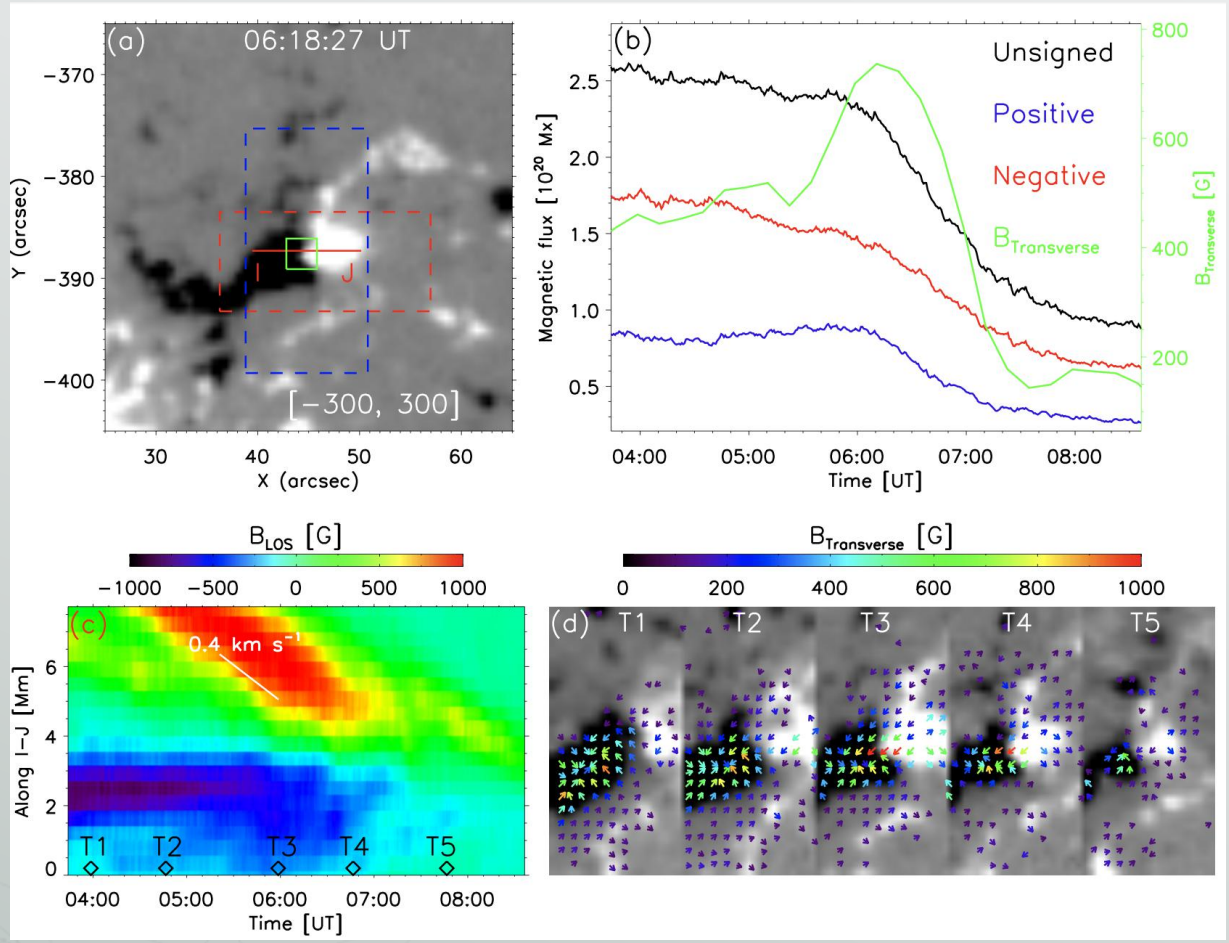
Second episode of loop formation, the arrows mark several newly formed coronal loops.

Results: Magnetic field evolution and geometry of magnetic reconnection



Two opposite magnetic patches apporaching one another

Magnetic field evolution and geometry of magnetic reconnection

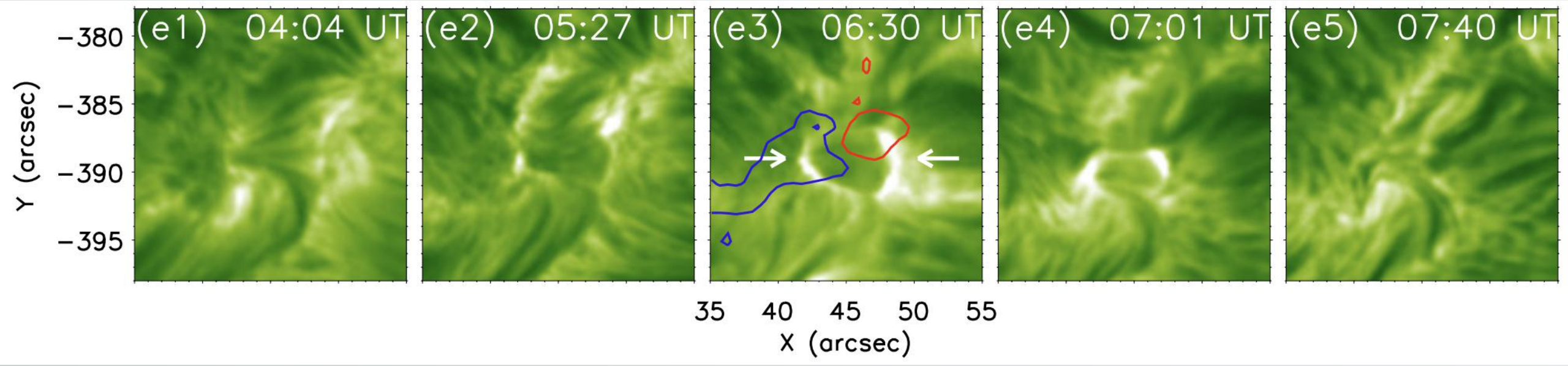


Decreasing unsigned magnetic fluxes with an average cancellation rate of ~10^{20} Mx hr^{-1};

The positive flux moves towards the negative one with a speed of ~0.4 km s^{-1};

The transverse field between the two polarities is enhanced by ~260G;

Magnetic field evolution and geometry of magnetic reconnection

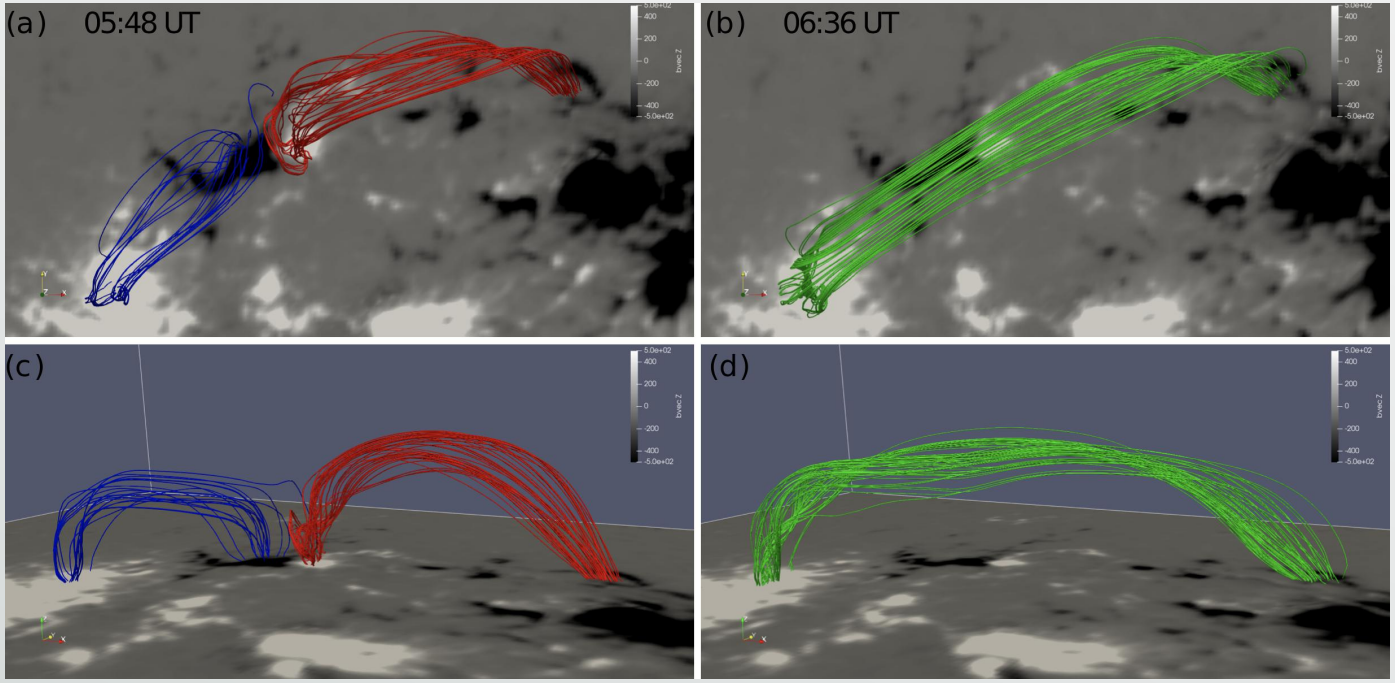


The appearance and disappearance of dark fibrils.

Magnetic field evolution and geometry of magnetic reconnection

Observational evidence:

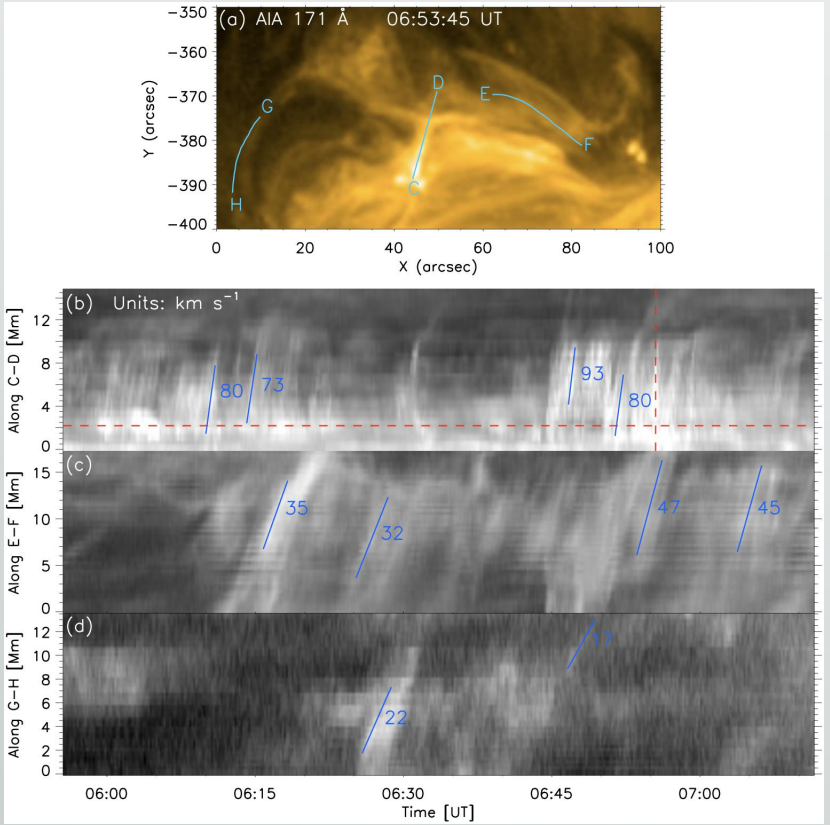
1. approaching opposite-polarity magnetic fluxes,
2. subsequent flux cancellation,
3. plasme sheet
4. formation of overlying coronal loops,
5. enhancement of the transverse magnetic field,
6. small low-lying loops/fibrils.

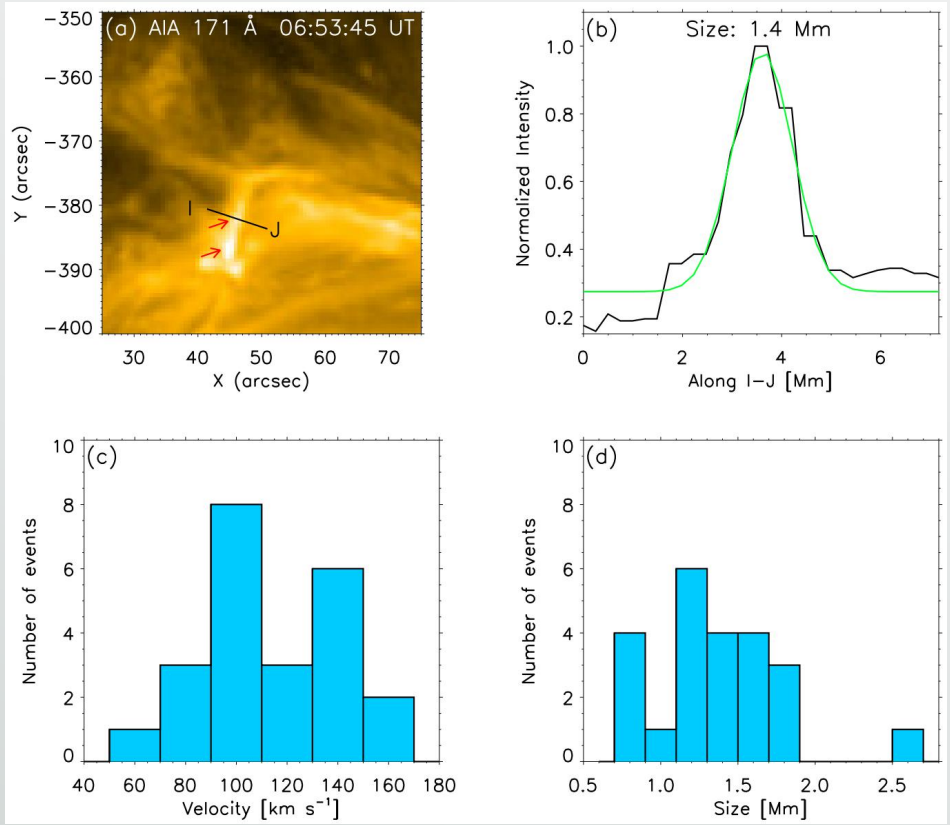


Magnetic field lines in the MHS model (Zhu & Wiegelmann 2018, 2019).

The coronal loops are formed through magnetic reconnection.

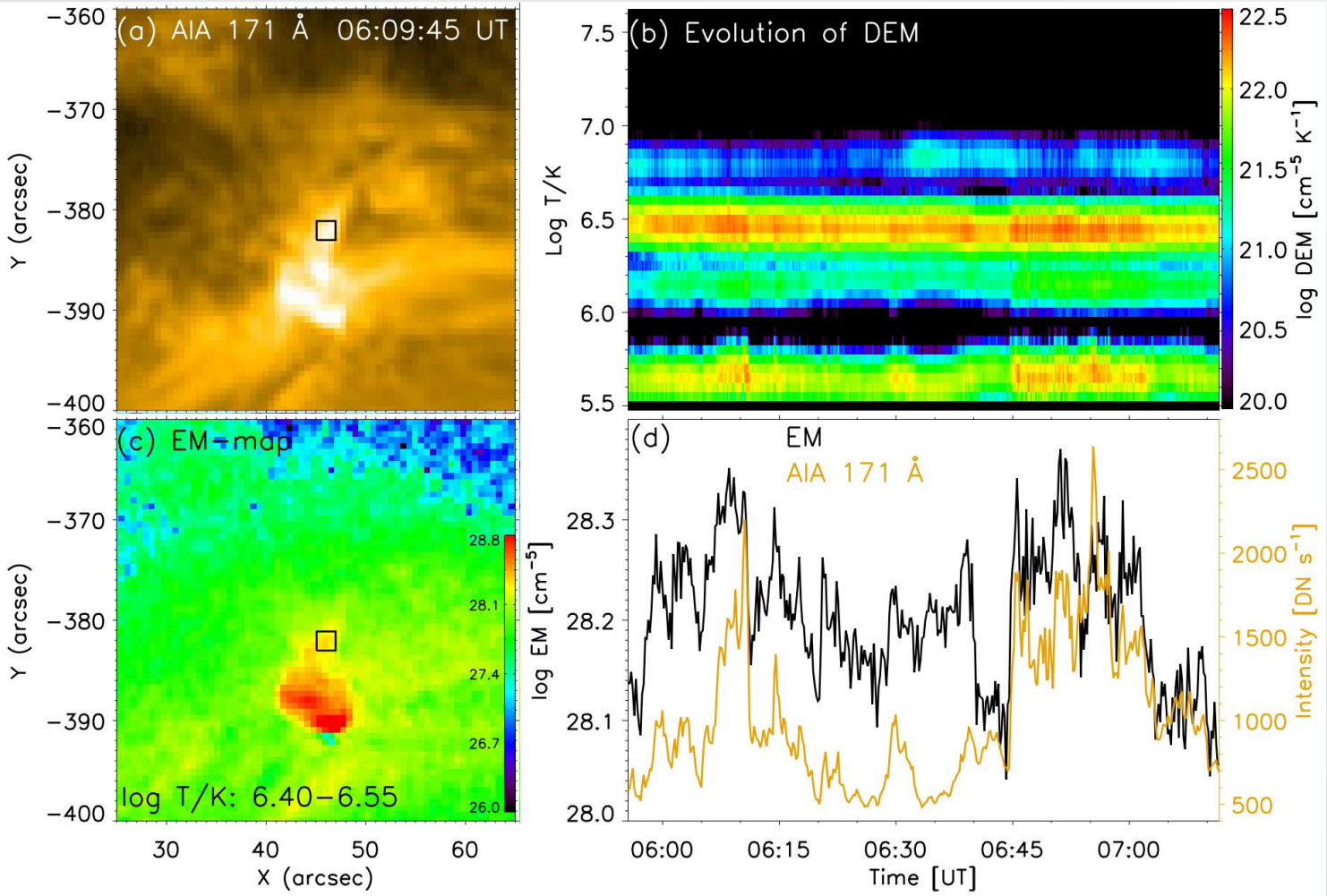
Plasma flows resulting from the magnetic reconnection





Numerous bright blobs: width ~ 1.37 Mm, projected velocity ~114 km s^{-1}.
Downward flows with a velocity ~ 20 to 50 km s^{-1}.

DEM analysis for the reconnection region



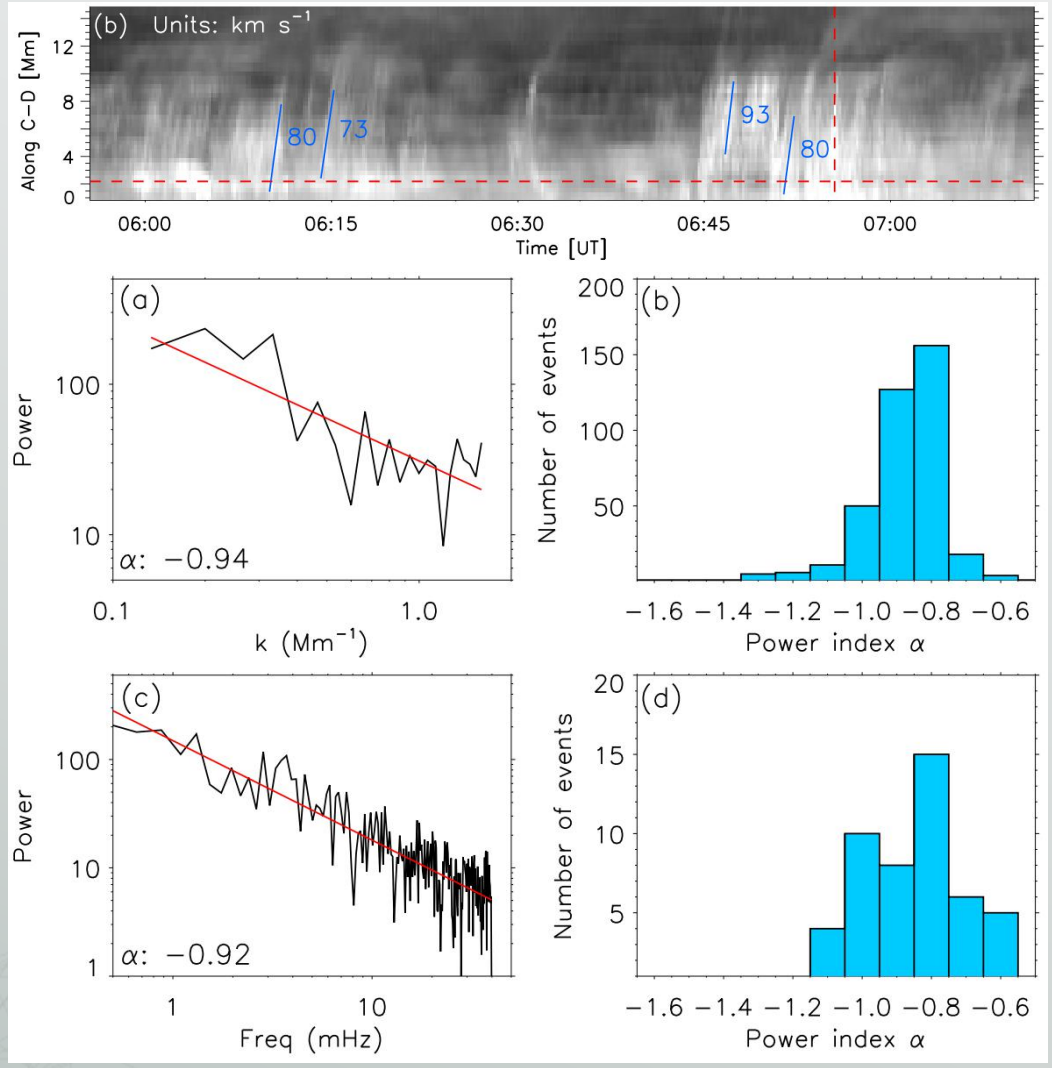
DEM (Cheung et al. 2015; Su et al. 2018; Xue et al. 2020)

Temperature:
logT/K = 6.4-6.55 (3MK),

Emission measure (EM):
2.0×10^{28} cm^{-5},

Density:1.2×10^{10} cm^{-3}.

Power spectral analysis for the plasma sheet



The spectra index α are mostly larger than -1.1 and distinctly different from -1.67, a spectral index expected in the scenario of turbulent magnetic reconnection (Barta et al. 2011, Shen et al. 2011)

Summary

- We have identified direct observational evidence for the formation of coronal loops through magnetic reconnection as new magnetic fluxes rise into the upper atmosphere: two pre-existing loop-sets, newly formed coronal loops and small loops (Hα dark fibrils), plasma sheet, flux cancellation, enhanced transverse field.

- Numerous bright plasma blobs appear intermittently in the plasma sheet with an average width of 1.37 Mm, and move upward with projected velocities of ~114 km s^{-1}.
- The spectral index from power spectral anaysis for these blobs is distinctly different from the expected one in a turbulent reconnection scenario.


Thank you!
湖光塔影